Space Research

2002 – 2003

in Switzerland

Artist's impression of INTEGRAL satellite

Schweizerische Akademie der Naturwissenschaften SANW
Académie suisse des sciences naturelles ASSN
Accademia svizzera di scienze naturali ASSN
Academia svizra da scienzas natüralas ASSN
Swiss Academy of Sciences SAS

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1 Foreword

The Committee for Space Research of the Swiss Academy for Natural Sciences coordinates and stimulates space research in Switzerland. It also maintains contacts with international organisations and in particular with ESA's science programme and COSPAR. It is thus responsible to produce every second year a report on space science activities in Switzerland for the COSPAR general assembly. This booklet is this report for the period 2002–2003.

Space reasearch in Switzerland is undertaken by many groups in the universities, federal institutes of technology and some private companies. The funding for this research comes mainly from these intitutions, the Swiss national science foundation and the federal governement. The research is not organised centrally. It is rather the sum of the efforts of the individual groups. It is hoped that the present report will give to the readers an idea of the richness of this research branch and help to identify the actors in Switzerland.

The Swiss organisation of space research in a large number of individual groups in many institutions makes it difficult to summarise in few lines the strengths of the programme. This is nonethless attempted in the next subsections. Our way of proceeding has the strength to allow groups to enter collaborations (mostly international) with a large variety of arrangements and a minimum in burocracy. It also makes it possible to develop unconventional ideas.

The bulk of the report is given by a number of contributions from individual research groups from many intitutions in Switzerland. Each has reported on their own research projects. These reports are expected to give the readers enough information to find the projects of interest to them and to locate the main institutes involved in Switzerland. Further information can be sought from the quoted literature or directly with the involved groups. The scattered nature of our space activities and the sometimes fuzzy boundaries of the subject also make it difficult to be complete in this report. Readers in Switzerland who may find that their activity was missed are invited to contact the commission for space research, c/o ISDC, 16,ch d'Écogia, CH-1290 VERSOIX.

Information on addresses of individuals and institutions may be obtained from the Swiss Space Office, Ms D. Bauman (tel: +41 (0)31 324 10 74) , Hallwylstrasse 4, CH-3003 BERNE.

Thierry Courvoisier
Chairman of the Space Research Commission

2 La recherche spatiale en Suisse — un aperçu —

2.1 Introduction

L'espace n'est une réalité pour l'humanité que depuis une quarantaine d'année et pourtant il fait partie intégrante de nos vies. Nous ne pouvons plus imaginer les télécommunications, la météorologie ou encore la navigation sans technologie spatiale.
L'espace c'est la surveillance de notre planète. Un satellite comme Envisat, par exemple, mesure la pollution, la déforestation ou encore la fonte des glaces. Les satellites comme Meteosat suivent les mouvements de l'atmosphère et permettent aux météorologues d'être chaque jour plus précis. La précision, et par conséquent la sécurité, de la navigation maritime ou aérienne a été améliorée et le sera encore grâce au projet européen « Galileo ». Notre soif d'information télévisuelle, radiophonique ou encore par internet ne peut être étanchée que grâce aux satellites de communication.
L'espace c'est aussi le domaine privilégié de l'astronomie, en 30 ans les connaissances sur notre univers ont fait un bond extraordinaire. Les images envoyées par les sondes qui sont parties explorer notre système solaire et celles transmises par le télescope spatial ont émerveillé les terriens et ont fortement contribué au développement et à la vulgarisation de l'astronomie.
Mais l'espace s'adresse avant tout à notre imaginaire sous deux aspects. Le premier en nous faisant rêver de voyage et de nouvelles conquêtes, le projet d'envoyer un homme sur Mars en est bien entendu l'exemple le plus révélateur. Et le deuxième, peut-être encore plus ancré en nous, en nous laissant l'espoir que la technologie spatiale pourra peut-être répondre à la question qui taraude l'humanité depuis qu'elle regarde le ciel : sommes nous seuls ?

FIG. 1 – La fusée Ariane 5.

En étant membre de l'Agence Spatiale Européenne (l'ESA), la Suisse a sa place dans l'espace et participe à des projets de recherche et de développement dans la plupart des domaines spatiaux (les italiques entre parenthèses renvoient aux projets décrits dans ce rapport). Notre pays contribue à hauteur de 3,1% au budget de l'agence ce qui représente 125 millions de francs pour l'année 2004. Cette contribution permet, d'une part, à des chercheurs des hautes écoles de participer aux activités scientifiques de l'ESA, et d'autre part de faire bénéficier à l'économie nationale de contrats de développement, contribuant ainsi à la compétitivité nationale, à la création d'emplois et à l'indépendance du pays.

2.2 L'observation de la terre

Menace sur le climat, ressources naturelles qui se raréfient, trou d'ozone, fonte des glaciers, pollutions, jamais les besoins d'observation n'ont été aussi cruciaux. En Suisse plusieurs instituts participent à cette activité spatiale fondamentale : la surveillance de notre planète.

Le Gamma Remote Sensing AG
Situé à Müri près de Berne, le GRS est une société fondée en 1995 et spécialisée dans l'analyse et l'interprétation d'image radar à ouverture synthétique (SAR). La société utilise les données des satellites Ers et Envisat pour évaluer les possibilités de la cartographie grâce à ces images. Le GRS est donc impliqué dans la recherche et le développement d'algorithmes et d'outils informatiques pour l'analyse d'image radar. Il est partie prenante du projet DUP (*data user programme*) de l'agence spatiale européenne qui doit permettre aux utilisateurs d'avoir une vision compréhensible des clichés.

Le GRS utilise les images radar pour cartographier les déformations de la surface du globe. Déformations qui peuvent être dues à l'exploitation d'une nappe phréatique, d'un gisement d'hydrocarbure, à un tremblement de terre ou encore à l'activité volcanique (*Earth Observation application to land surface displacement mapping*).

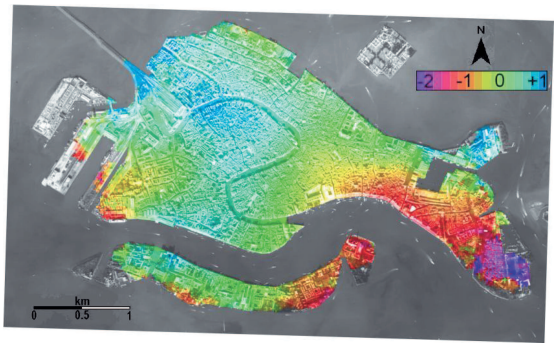

FIG. 2 – Déplacement vertical du sol à Venise entre 1992 et 1996 (données ESA analysées par GRS).

En partenariat avec la Finlande et l'institut européen de la forêt, le GRS évalue les possibilités offertes par les images radar pour suivre l'évolution de la forêt et pour faire un monitoring des concentrations de carbone. Ce projet fait partie des services permettant l'application du protocole de Kyoto (*EO application to environmental monitoring*). Toujours grâce aux images radar, le GRS, en collaboration avec les universités d'Innsbruck et Graz en Autriche, met au point un système permettant de mesurer les conséquences de catastrophes naturelles, comme les tempêtes (Lothar), avalanches, inondations ou glissements de terrain. Le système s'applique pour le moment uniquement à la chaîne des Alpes (*EO application to hazard mapping*).

Le Remote Sensing Laboratory

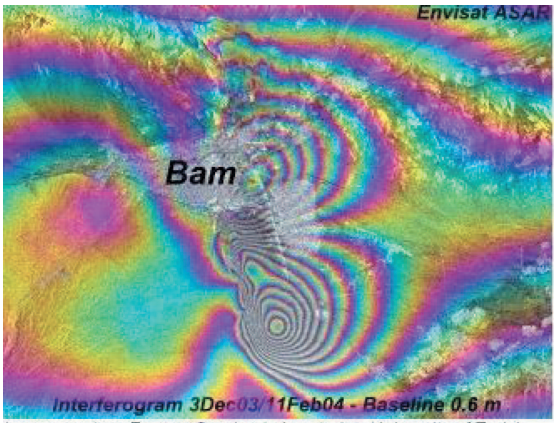

Image courtesy Remote Sensing Laboratories, University of Zurich

FIG. 3 – Les conséquences de tremblement de terre de Bam en Iran sur la croûte terrestre (ASAR).

Ce laboratoire qui fait partie de l'Université Hirschel de Zürich est particulièrement impliqué dans l'analyse d'image et de spectre radar. Le nombre toujours croissant d'utilisateurs tant dans le domaine de la recherche que dans celui des sociétés privées, assurances, chemins de fer, compagnies pétrolières etc. font de l'analyse d'images radar, un marché prometteur et plein d'avenir. Dans l'optique de la future mission SPECTRA, l'Agence spatiale européenne a confié au RSL le soin de développer un appareil qui doit simuler le processing des images (*Spectra End-to-end mission simulator*). SPECTRA sera un satellite à orbite polaire équipé entre autre d'un spectromètre radar dans le visible et l'infrarouge. Le but de la mission est d'étudier l'évolution de la végétation en fonction des variations climatiques et d'analyser le cycle du carbone sur terre. Toujours dans l'optique de l'étude du cycle du carbone, le RSL est engagé dans l'évaluation du potentiel des données spectrales issues d'un radar scrutant le sol depuis un avion (*Potential of imaging spectrometry for environmental analysis*)

Le RSL travaille aussi directement avec l'ESA pour calibrer et paramétrer les images prises par le radar ASAR du satellite Envisat (ASAR *Calibration*). Le but est de fournir aux utilisateurs de ASAR des erreurs des positions sur terre les plus petites possibles. Les marges d'erreurs sont de 8 mètres, respectant largement les spécifications exigées par le cahier des charges lié à l'instrument

En 2005, l'ESA a l'intention de développer une nouvelle génération d'imageur appelé APEX. Cet instrument équipé de 300 canaux spectraux sera embarqué dans un avion volant entre 4 et

10 km d'altitude. Le RSL est responsable de la direction scientifique du projet et de la collaboration avec l'industrie. APEX est un projet développé en collaboration avec l'ESA, PRODEX, et la Belgique.

En coopération avec le centre allemand aérospatial, le RSL conçoit des outils pour corriger les erreurs de position sur les images provenant du futur radar TerraSAR-X (*Goemetric error budget analysis*). Le satellite devrait être lancé en 2006 et la précision obtenue par le radar qui exploitera la bande X sera de 1 mètre. Les chercheurs ont construit un outil qui permet à l'utilisateur de l'instrument de corriger les erreurs sur les calculs d'orbite, sur les cartes, sur les modèles de surface, due à la réfraction atmosphérique ou due à la fréquence Doppler. Les deux équipes travaillent également sur un projet d'extraction de paramètres géophysiques et biophysiques d'après les données provenant du Pol-InSAR, instrument qui utilise l'interférométrie et la polarisation. Les performances de Pol-InSAR doivent permettre d'analyser les caractéristiques et l'évolution de la couverture végétale (*Pol-InSAR for extraction of geo and biophysical parameters*). La technique d'analyse a déjà été utilisée avec succès dans le cadre du projet « Swiss Alpine Airborne SAR Experiment », dans la région du glacier d'Aletsch, où quantité, qualité et déplacement de la neige, de la glace et de la végétation ont pu être mesurés avec précision.

L'École Polytechnique Fédérale de Zürich

Plusieurs départements et laboratoires de la haute école participent à la surveillance de la Terre. Par exemple, le laboratoire de la physique des hautes énergies a construit, pour être installé à bord de l'ISS, un détecteur de radiation synchrotron (*Synchrotron Radiation Detector* SRD) émise par les électrons et les positrons de haute énergie dans le champ magnétique de la Terre. L'échelle de sensibilité du SRD devait être assez large pour non seulement mesurer les interactions hautes énergies mais aussi le bruit de fond émis par les rayons X diffusés et par les particules chargées. L'expérience est maintenant terminée, l'analyse des résultats ayant montré que le bruit de fond n'était pas gênant sauf dans les régions polaires. Le SRD, toujours installé sur l'ISS, peut être utilisé pendant les années de basse activité solaire.

En 2002, l'EPFZ prend part avec 19 autres partenaires à une étude consistant à construire un modèle d'élévation digital du terrain (*DEM generation with SPOT5-HRS*) grâce aux images fournies par le satellite Spot-5. Les premiers résultats montrent que la différence entre modèle et observation est de l'ordre de 1 ou 2 pixels, les meilleurs résultats étant obtenus sur des terrains plats. Une fois l'outil opérationnel, l'institut est passé à l'application. À cause de la croissance de la population, le delta de l'Okavango au Botswana est soumis à une pression hydrique toujours plus forte. Pour évaluer les différents scénarios de gestion des ressources en eau, il faut pouvoir fournir un modèle hydrologique précis fondé sur un DEM, sur la couverture du delta (îles, marécages, etc.) et sur la dynamique de l'écoulement de l'eau. Afin de construire un modèle solide, l'institut se base sur les images stéréo des satellites Ikonos et Spot-5 pour palier le manque de données fiables de la région. Outre l'aspect utilitaire, cette recherche permet à partir d'images satellites facilement disponibles, de développer des méthode pour obtenir automatiquement des DEM utilisables.

2.3 Étude de l'atmosphère

La compréhension et l'étude de l'atmosphère font partie des préoccupations majeures des scientifiques et peu à peu des dirigeants. L'atmosphère nous protège des rayonnements nocifs du soleil (UV et X), contient l'air qui est vital, et l'atmosphère est le siège des échanges d'énergies qui régit notre climat. Or ces trois fonctions sont de plus en plus menacées, il est donc indispensable d'étudier et de surveiller l'atmosphère, ne serait-ce que pour une question de survie.

L'université de Berne

La distribution de la vapeur d'eau dans les hautes couches de l'atmosphère est un élément important pour évaluer l'influence du réchauffement climatique sur la circulation stratosphérique. Dans ce but, l'institut de physique appliquée a construit un appareil capable de mesurer les profils de distribution de la vapeur d'eau dans la stratosphère. L'instrument doit être capable, soit de mesurer l'évolution temporelle des profils en un point, dans ce cas il est installé au sol, soit de mesurer les profils sur de grandes régions en un moment donné et dans ce cas il est embarqué dans un avion (AMSOS *Airborne Millimeterwave Stratospheric Observing System*)

L'École Polytechnique Fédérale de Zürich

Pour suivre l'évolution de la pollution de l'air et du rayonnement l'agence spatiale européenne a lancé le projet TEMIS (*Tropospheric Emission Monitoring Internet Service*). Ce service qui fournit à l'utilisateur les concentrations de gaz de la troposphère en un lieu et une date donnée est conçu pour une bonne application des protocoles de Montréal (gaz destructeurs de la couche d'ozone) et de Kyoto (gaz à effet de serre). Ces informations sont dérivées des données du satellite Gome analysées entre autre par l'EMPA qui dépend de l'EPFZ. Les premiers tests effectués par l'EMPA sur les conditions qui règnent dans la plaine du Pô en Italie et dans les Alpes suisses (*DUP-POLPO*) ont été concluants et intégrés dans le projet TEMIS

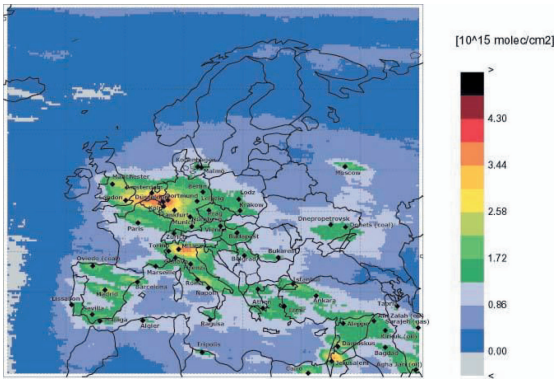

FIG. 4 – Exemple de colonnes troposphériques de NO_2 mesurée par Gome (photo EMPA).

Dans un futur proche, les satellites vont de plus en plus offrir des observations quasiment en temps réel. Les centres de données seront quant eux appelé à traiter des quantités de données considérables pour fournir des images 3D des couvertures nuageuses. Ces images en trois dimensions permettront d'améliorer les prévisions météorologiques grâce aux calculs des effets des nuages sur les échanges de chaleur de la Terre. L'EPFZ participe au projet *cloudmap2* en comparant les hauteurs et les vitesses estimées par les satellites avec celles estimées par une caméra au sol conçue par ses propres soins.

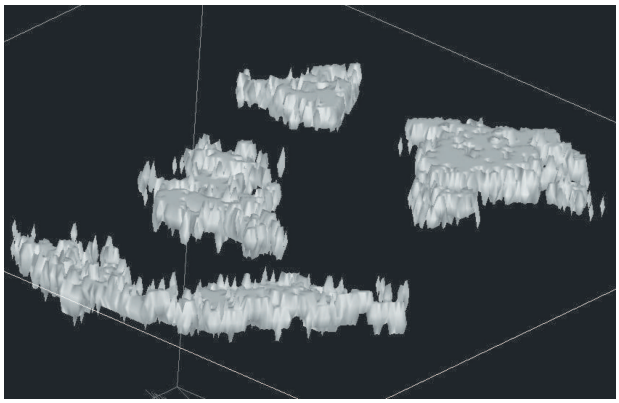

FIG. 5 – Visualisation 3D de la couverture nuageuse par la caméra au sol (projet *cloudmap2*).

Pour simuler correctement les processus atmosphériques entrant en jeu dans les modèles numériques de prévision du temps, il est important de modéliser les échanges d'énergies entre le sol et l'atmosphère. La couverture neigeuse est un paramètre important pour décrire le sol, or les données existantes ne sont pas précises. Avec le satellite Meteosat d'EUMETSAT de seconde génération (MSG) la précision des mesures permettent à Météosuisse et à l'EPFZ de développer un algorithme qui définit précisément les régions couvertes de neige (*snow cover map in the Alps*).

Les données des satellites Meteosat et Envisat sont utilisées par l'institut de géodésie et de photogrammétrie pour définir la distribution des pressions dans des atmosphères nuageuses en les comparant avec d'autres sources de mesures, à terre ou en orbite. Ce projet doit permettre de

mieux saisir la physique de l'atmosphère.

2.4 Astronomie

Si il y a un domaine où la recherche fondamentale est intimement liée à l'espace c'est bien celui de l'astronomie. En s'affranchissant, il y a une quarantaine d'année, de l'obstacle atmosphère, l'astronomie et l'astrophysique ont connu un développement spectaculaire. L'étendue du domaine spectral est tel, qu'à chaque fois qu'un nouvel instrument est lancé, un monde inconnu s'ouvre aux scientifiques. De plus, grâce aux images extraordinaires envoyées par des instruments comme le télescope spatial Hubble ou par des sondes interplanétaires comme Mars-Express, l'astronomie connaît un engouement populaire et médiatique que peu de sciences connaissent. Cet enthousiasme a permis de faire comprendre aux dirigeants la nécessité d'avoir une industrie et une recherche de pointe impliquée dans la recherche spatiale.

L'Université de Genève
L'astronomie à Genève, c'est surtout son observatoire extrêmement actif dans le domaine de l'espace, il abrite en effet le centre de données du satellite européen Integral, ses chercheurs participent à la définition et la mise au point de missions scientifiques, et ses ateliers mécaniques collaborent à la construction d'instruments scientifiques. L'astronomie à Genève c'est aussi un institut de physique qui travaille en étroite relation avec des institutions aussi prestigieuses que le CERN ou la NASA.
L'ISDC, le centre de données du satellite Integral (*Integral Science Data Center*) qui se trouve à Versoix près de Genève est certainement l'une des figures de proue de l'implication de la Suisse dans les programmes spatiaux de l'agence spatiale européenne. Cet institut qui compte une quarantaine de personnes a été fondé en 1994 suite à l'appel d'offre de l'ESA afin de créer un centre capable de servir d'interface entre le satellite Integral et la communauté scientifique. Les tâches de l'ISDC sont multiples, il doit recevoir en continu les données du satellite, analyser en temps réel les images pour jouer un rôle d'alarme, analyser et réduire les images pour les rendre compréhensibles par l'observateur, et enfin, concevoir un système d'archivage et de distribution des données.
Le rôle des membres de l'ISDC ne se cantonne toutefois pas seulement au traitement des données collectées par Integral dans le domaine du rayonnement X et Gamma, en effet, l'institut est également un pôle de recherche spécialisé dans l'étude des hautes énergies en astrophysique. Les principaux sujets sur lesquels travaillent les astronomes de l'ISDC sont les noyaux actifs des galaxies, les trous noirs, les étoiles à neutrons, et la formation des atomes au cours de l'histoire de l'univers qu'on nomme aussi nucléosynthèse.
L'observatoire de Genève participe également à la future mission GAIA. Ce satellite de l'ESA doit faire des mesures astrométriques (position, vitesse), photométriques et spectroscopiques de plus d'un milliard d'étoiles. La quantité de données à analyser et à réduire est telle, que ce ne sont pas moins de 19 groupes de travail qui ont été formé pour surmonter la tâche. Le responsable scientifique de GAIA a demandé à une équipe de l'Observatoire de Genève de diriger le groupe qui s'occupera des étoiles variables. L'équipe bénéficie ainsi de sa solide expérience grâce à son implication dans la précédente mission astrométrique Hipparcos. L'analyse des étoiles variables est une des clefs pour comprendre

FIG. 6 – La distribution des sources gamma dans la Galaxie («Integral wide survey», photo ISDC.)

l'évolution stellaire, les différentes populations galactiques ainsi que pour calculer les distances dans l'univers. GAIA doit être lancé en 2010.
Bien que basée sur des observations, la recherche peut aussi être théorique. Un groupe de physique théorique à Genève s'est attelé à essayer de mieux comprendre l'histoire et l'évolution de l'univers très jeune en utilisant la théorie des cordes, des premières ondes gravitationnelles, et de l'anisotropie et de la polarisation du bruit de fond cosmologique (*cosmology and particle physics*)
L'institut de physique, se penche aussi sur l'origine des rayons cosmiques en construisant un appareil qui doit être embarqué à bord de la station spatiale internationale. L'AMS (*Alpha Magnetic Spectrometer*) qui pourra analyser des rayons véhiculant des énergies de l'ordre du TeV, est conçu pour étudier la matière noire super symétrique, l'anti-hélium et la propagation des rayons cosmiques. Il devrait rejoindre l'ISS en 2007.

L'Université de Berne
Comment ne pas lier l'Université de Berne avec cette petite feuille d'aluminium flottant sur la Lune et qui est revenue sur Terre avec les astronautes d'Appolo 11 pour dévoiler une partie des mystères du vent solaire ? Depuis, l'Université n'a cessé d'être intimement liée avec l'exploration spatiale, que ça soit dans l'étude du soleil, des planètes ou encore du mouvement des astres.
Le concept et la fabrication d'instruments pour les sondes interplanétaires est un des points forts de l'Université de Berne. Son institut de physique a récemment fabriqué des spectromètres de masse de la taille d'une boîte de Coca-Cola voir d'une tasse de café, appareils qui doivent partir pour Mars, Mercure, Europe et Titan.

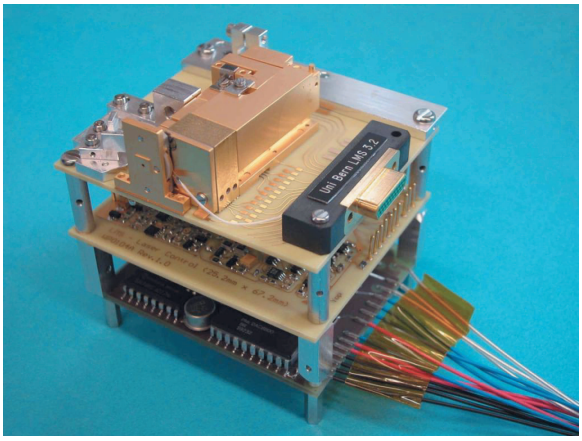

FIG. 7 – Spectromètre de masse miniature pour la recherche planétaire in-situ (photo institut de physique).

Elle participe notamment à la mission Mars-Express dans l'élaboration de l'instrument suédois ASPERA-3 qui doit mesurer les interactions entre le vent solaire et l'atmosphère martienne. ASPERA-3 sera suivi par ASPERA-4 qui doit aller faire le même genre d'expérience sur Venus. Autre instrument, autre planète, l'Université de Berne développe un appareil capable d'analyser la surface de Mercure, et qui doit partir avec la sonde Beppi-Colombo en 2012 (*Composition of crust and exosphere of Mercury*). Et enfin, l'université a proposé et fourni à l'agence spatiale européenne le spectromètre Rosina parti avec la sonde européenne Rosetta en route pour une rencontre prévue avec la comète Churyumov-Gerasimenko dans 10 ans.
L'université de Berne, très active dans le domaine de la mécanique céleste, développe des instruments capables de déterminer les orbites des objets artificiels qui tournent autour de la Terre, de même que l'étude de l'évolution à long terme des orbites d'une douzaine de satellites abandonnés (*CCD-Astrometry applied to fast moving objects*). Pour déterminer les paramètres astrométriques de ces corps, les instruments doivent mesurer leurs positions, la rotation de la Terre, le champ de gravité et les paramètres atmosphériques très précisément. Par exemple pour le futur satellite Goce dont la mission est de mesurer les variations de la gravité terrestre il faut connaître les orbites au centimètre près (*Precise orbiting determination*). L'université fait partie de CODE (*Center for Orbit Determination in Europe*) en collaboration avec les offices de topographie suisse, français et allemand.

Le Paul Scherrer Institut
Le Paul Scherrer Institut est un centre de recherche national sur les sciences naturelles et techniques, il collabore avec les universités, les autres instituts et l'industrie. L'astronomie fait donc partie de ses nombreux domaines d'activité.
Le PSI utilise les télescopes spatiaux XMM de l'ESA, Chandra et Spitzer de la NASA ainsi que les télescopes terrestres VLA et CHFT pour étudier la formation des étoiles et des planètes dans le nuage moléculaire du Taureau et dans la grande nébuleuse d'Orion (*star and planet formation in Taurus and Orion*)
BeppoSax et Euve s'ajoutent encore à la liste pour l'équipe qui étudie l'accélération des particules et l'échauffement de la couronne des étoiles magnétiques (*particle acceleration and coronal heating*)
Quant à XMM et Chandra ils sont également sollicités pour les mesures spectrales qu'ils peuvent fournir dans le domaine des rayons X. Ces spectres permettent ensuite aux chercheurs du PSI d'étudier les densités, les compositions chimiques, les températures et les opacités des atmosphères stellaires (*Xray spectroscopy with XMM and Chandra*).
Le PSI participe également à la construction d'appareils en collaboration avec l'ESA et la NASA. C'est le cas notamment de Miri un instrument qui doit permettre au futur télescope spatial James Webb de prendre des spectres et des images dans l'infrarouge. Les performances du télescope et de Miri devraient permettre d'observer des galaxies, des étoiles et même des planètes dans leurs phases de formation. Ce programme est un des programmes financés grâce à PRODEX (*Exploring origin and evolution of stars and planets*)

2.5 Le soleil

L'institut de Davos
L'institut de Davos, hôte du centre mondial de radiation, exploite les données du satellite Soho pour l'étude du Soleil. En collaboration avec l'IRMB Belge, l'institut a développé et construit un instrument (*SOVIM*) qui mesure la variation de l'irradiance (la constante solaire) ainsi que sa redistribution spectrale. Instrument dont les éléments matériels et logiciels ont été terminés à la fin 2003, il est actuellement en phase de test et devrait être expédié en 2006 à bord de l'ISS.
L'institut a également mis au point un appareil contenant trois filtres à quatre canaux pour le radiomètre du projet PICARD qui doit mesurer l'irradiance solaire dans l'UV. Ce projet conçu pour comprendre la relation entre irradiance UV et couche d'ozone est pour le moment stoppé faute de financement.
Toujours dans l'UV, l'institut, l'ESA, et la Belgique ont défini un appareil, Lyra, qui lui fera partie de la mission PROBA-2. Cet instrument doit assurer la surveillance de l'irradiance solaire dans quatre régions de l'UV, qui ont été choisies pour leur implication en aéronomie, météo spatiale et physique du Soleil.

L'Université de Berne
Le soleil est un champ privilégié de recherche à l'institut de physique de l'Université de Berne. En collaboration avec les Allemands du Max Planck Institut et deux universités américaines, les chercheurs suisses se penchent sur la composition chimique du vent solaire. Grâce au satellite Soho qui fonctionne parfaitement depuis 1995, ils étudient une vingtaine d'éléments et leurs isotopes ainsi que les éjections coronales (*SOHO/CELIAS*). Ils construisent également Plastic, un instrument d'analyse des particules solaires qui doit équiper le prochain satellite Stereo (*Solar wind and suprathermal particles*). Toujours dans le domaine solaire, les scientifiques bernois étudient le flux solaire dans l'ionosphère et la formation des aurores boréales à l'aide des données de l'instrument Lena placé sur le satellite Image lancé en 2000 (*Low-energy neutral atom mass spectrometer*)

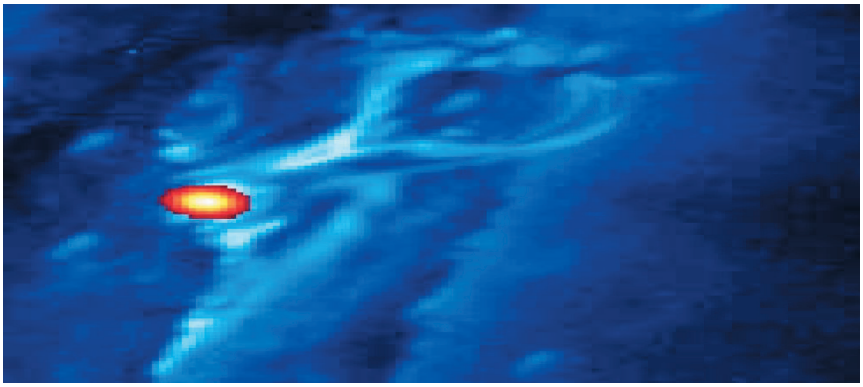

FIG. 8 – Pour la première fois l'instrument Hessi observe le point d'embrasement d'une éruption solaire caractérisé par le point rouge et jaune (photo EPFZ et PSI).

L'École Polytechnique fédérale de Zürich
La feuille d'aluminium de l'expérience Apollo a permis de se faire une idée de la composition isotopique des gaz nobles Hélium, Argon et Néon qui sont contenus dans le vent solaire. Ces données sont indispensables pour comparer les compositions des divers éléments du système solaire, planètes, météorites, etc. La NASA a lancé la mission GENESIS pour améliorer la précision des mesures de ces rapports, et pour définir les compositions du Krypton et du Xenon qui manquaient. L'expérience qui fonctionne sur le même principe que la feuille d'aluminium d'Apollo, contient des cibles spécifiques en fonction de la particule à recueillir et va durer 2 ans et demi. Le laboratoire de géologie isotope et ressource minérale de l'EPFZ a développé une technique (*Isotopic composition of noble gases*) pour extraire des cibles et des petits morceaux de Lune la composition de ces gaz nobles, le retour des échantillons de GENESIS est prévu pour septembre 2004.

Le Paul Scherrer Institut
Le soleil est bien présent dans les programmes de recherche du PSI. Toujours grâce aux télescopes de l'espace, las astronomes, en observant plusieurs étoiles de type solaire à différents stades de l'évolution, essaient de retracer la jeunesse du soleil pour expliquer la formation de la Terre et de son atmosphère (*Sun in time*).
Les données du satellite Rhessi et celles du radiomètre Phenix-2 sont utilisées pour valider les modèles qui essaient de simuler le comportement de la couronne solaire. En effet, les violentes bouffées émises dans les domaines X et radio lors d'éruptions solaires sont encore mal comprises (*solar flare with Rhessi*)

2.6 L'astrobiologie

L'amélioration spectaculaire des observations astronomiques aussi bien au sol que dans l'espace suggèrent de plus en plus que la vie a bel et bien pu se développer dans le système solaire ailleurs que sur la Terre. Ces observations ont petit à petit favorisé l'éclosion d'une nouvelle branche de l'astronomie: l'astrobiologie.

Le musée d'histoire naturelle de Berne
Le musée de Berne était impliqué dans l'analyse des images que devaient prendre les caméras de Beagle-2 sur la planète Mars (*Imaging of Mars materials*). Ces caméras, fabriquées par la société neuchâteloise Space-X, devaient permettre aux chercheurs du département des sciences de la terre du musée une analyse géologique et bactérienne de Mars. La perte de Beagle-2 n'a toutefois pas enterré les efforts consentis pour mener à bien les méthodes d'analyse, puisqu'elles seront sûrement utilisées pour de futures missions vers Mars.

L'École Polytechnique de Zürich

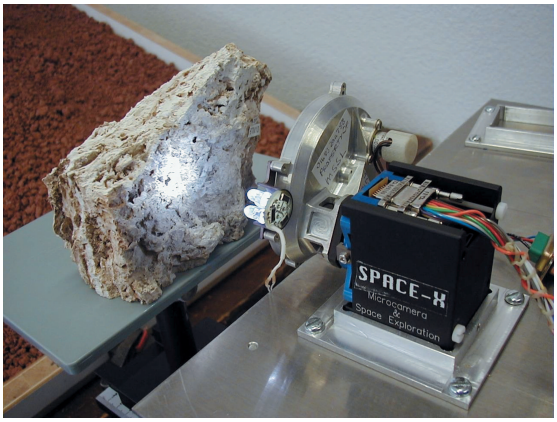

FIG. 9 – Caméra avec éclairage pour analyse géologique de Mars (photo musée de Berne).

Le groupe de biologie spatiale de l'EPFZ a monté une expérience pour la navette afin d'étudier la réaction des cellules soumises au stress lié à l'apesanteur (*Stress under microgravity*). Deux stress majeurs intéressent particulièrement les biologistes zurichois, le choc osmotique et le choc thermique. Une deuxième expérience liée à l'arrêt de l'activation des cellules T en apesanteur est également partie avec la navette (*Role of interleukin-2 receptor in signal transduction and gravi-sensing threshold of T lymphocytes*). Malheureusement, à cause de l'accident tragique de Columbia le 1er février 2003, les résultats des expériences ont été perdus.

2.7 La mesure du temps

L'observatoire de Neuchâtel

L'installation d'horloges de très haute précision à bord d'un satellite est cruciale pour le bon fonctionnement de celui-ci ainsi que pour l'interprétation des données. Les Suisses, et particulièrement l'observatoire de Neuchâtel, sont passé maîtres dans l'art de fabriquer de telles horloges. Cette maîtrise de la mesure du temps a permis à l'observatoire de décrocher le contrat pour équiper les satellites du futur système européen de navigation « Galileo ». Pour satisfaire les exigences de l'ESA qui imposait aux horloges une stabilité relative de 10 – 14 sur 10 000 secondes, l'observatoire a conçu, construit, assemblé et testé des horloges atomiques au rubidium (*Laser pump rubidium atomic frequency standard*)

L'observatoire de Neuchâtel, l'ESA et le CNES mettent au point l'expérience ACES (*Atomic Clock Ensemble in Space*) qui doit être installée à bord de l'ISS en 2008. ACES est formé de deux horloges de très haute précision qui, ensembles et profitant de l'apesanteur, doivent être 10 fois plus précises que la meilleure des horloges atomiques terrestres. Ces horloges doivent être capables de vérifier la stabilité de la constante physique alpha appelée également constante de structure fine. Pour relever un tel défi les horloges doivent assurer une stabilité relative de 10 – 16 sur une année.

Les scientifiques de l'observatoire ont également développé des lasers à fréquence variable pour la mission WALES qui doit mesurer, à l'aide d'instruments appelé Lidar, la distribution de vapeur d'eau et des aérosols dans l'atmosphère (*Tunable frequecy stabilisation for WALES*). En variant la fréquence du laser du Lidar, il est possible d'obtenir les concentrations de ces éléments, puis dans un deuxième temps, celles du CO, du CO_2 ou encore du CH_4.

2.8 Liens internationaux

L'Institut international de la science de l'espace

L'ISSI est un institut situé à Berne qui invite les scientifiques à travailler ensembles pour comparer et interpréter leurs données, afin de mieux cerner les besoins scientifiques en vue de l'élaboration de futures missions spatiales. Pour atteindre cet objectif l'ISSI organise des ateliers et des groupes de rencontre sur des thèmes précis. L'institut soutient également des projets conçus par des équipes internationales sélectionnés par un système d'évaluation basé sur le principe du «peer-

review». L'ISSI reçoit environ 250 visiteurs par année qui passent en moyenne une dizaine de jours à Berne.

2.9 Conclusion

L'abondance et la diversité des projets et des recherches liés à l'espace en Suisse ne permet pas de décrire minutieusement toutes les expériences (dont les titres sont spécifiés en italique) et leurs implications. Seuls certains domaines ont été mis en exergue, il ne s'agit en aucun cas d'un jugement de qualité ou d'intérêt. La Suisse est donc bien présente dans l'espace, son savoir-faire est reconnu mais la concurrence est tous les jours plus âpre et les contrats plus difficiles à obtenir. Pour l'année 2004, le bureau suisse de l'espace (`http://www.sso.admin.ch`) estime que la politique du «juste retour» appliquée par l'agence spatiale européenne, permettra à la Suisse de récupérer en contrats et collaborations entre 70 et 80% de sa participation financière à l'ESA. Ces contrats et collaborations sont fondamentaux, en effet ils permettent à notre pays de pouvoir contribuer à la prise de décision non seulement en ce qui concerne la recherche, mais aussi en ce qui concerne la surveillance et la protection de notre fragile planète bleue.

Pierre Bratschi

3 Space research in Switzerland — a synthetic view —

3.1 Introduction

Humanity's first venture into space was only about forty[1] years ago, yet space now occupies an important part of our lives. We can no longer imagine communications, meteorology, or even navigation without space technology.

Space is the watchtower of our planet. Satellites such as Envisat, for example, measure pollution, deforestation, or melting ice. Another satellite, Meteosat, tracks atmospheric currents and allows meteorologists to make more accurate weather forecasts. The precision, and hence the safety, of maritime and air travel have been improved and will continue to be thanks to Europe's "Galileo" project. Our thirst for information via television, radio or Internet can only be quenched with communication satellites.

Space is also the privileged domain of astronomy. In thirty years, our knowledge of the universe has advanced by leaps and bounds. Images sent by probes exploring our solar system, and pictures taken with space telescopes captivate humans and make astronomy more accessible.

Space beckons our imagination in two ways. First, it enables us to dream about visiting distant worlds: the quest to set foot on Mars is the most revealing example. Second, and perhaps more fundamentally, it allows us to hope that space technology can help answer a question that has perplexed us since our kind first gazed at the night sky: are we alone?

As a member of the European Space Agency (ESA), Switzerland has a role to play in space. It participates in numerous research and development projects involving various domains of space exploration (italics in the text correspond to projects described in this report). Our country finances roughly 3.1% of ESA's budget which represents 125 million CHF for 2004. This contribution allows university researchers to participate in ESA's scientific activities, and it benefits the national economy in the form of contracts to the private sector which stimulate job creation, and guarantees the financial independence of our country.

3.2 Observations of earth

Threats to the climate, natural resources, glaciers, the ozone layer, and air quality, make terrestrial observations more vital than ever. Several Swiss institutes participate in the surveillance of our planet.

Gamma Remote Sensing AG

Founded in 1995 in Muri near Berne, GRS specializes in the analysis and interpretation of the Synthetic Aperture Radar (SAR). This company uses data from the Ers and Envisat to determine the possibility of generating maps. Therefore, GRS is involved in the research and development of algorithms and software for the analysis of radar images. It is actively involved in ESA's DUP (*Data User Program*) project which should help users understand the images.

From radar images, GRS maps irregularities on the surface of the globe. These deformations can be due to the exploitation of water tables, a hydrocarbon leak, an earthquake or volcanic activity (*Earth Observation application to land surface displacement mapping* [2]).

As a partner with Finland and the European Forest Institute, GRS evaluates the possibility of

[1] See the Ariane launcher in figure 1 on page 5

[2] See figure 2 on page 6: *vertical displacement of the surface of Venice between 1992 and 1996 (ESA data analyzed by GRS.)*

using radar images to follow the evolution of forests and to monitor carbon concentrations. This project is part of the services used to apply the Kyoto Protocol (*EO application to environmental monitoring*). In collaboration with the Austrian universities in Innsbruck and Graz, GRS is developing a system that uses radar images to measure the consequences of natural catastrophes such as violent storms (Lothar), avalanches, floods, and landslides. So far, this system has only been applied to the Alps (*EO application to hazard mapping*).

Remote Sensing Laboratory

This laboratory, part of the Hirschel University in Zurich, is heavily involved in the study of radar images and spectra. What makes this field so promising is the rapidly growing user base from research institutions to the private sector (insurance, rail, industry, etc.).

With an eye on the upcoming SPECTRA mission, ESA selected RSL to create an instrument for the simulation of image processing (*Spectra end-to-end mission simulator*). Once launched into to its polar orbit, SPECTRA will deploy radar spectrometers in both visible and infrared bands. Its missions are to study how vegetation reacts to changes in the climate and to trace the carbon cycle. For the latter, RSL is assessing the potential of spectral data from a radar mounted on an airplane (*Potential of imaging spectrometry for environmental analysis*[3]).

The RSL is also working directly with ESA to parametrize and calibrate images taken with the ASAR radar aboard the Envisat satellite (ASAR *Calibration*). The aim is to provide ASAR users with the smallest possible errors in terrestrial position. An error box of 8 meters is completely within the specifications demanded by the instrument's configuration.

In 2005, ESA intends to develop a next-generation imager called APEX. Equipped with 300 spectral channels, this instrument will soar to an altitude of 4 to 10 km by plane. The RSL is responsible for the scientific direction of the project and industrial partnerships. APEX is a joint project of ESA, PRODEX, and Belgium.

With the German Aerospace Center, RSL conceives tools that will correct position errors of images from the upcoming TerraSAR-X radar (*Geometric error budget analysis*). Scheduled for launch in 2006, the satellite should deliver radar images in the X-band that have a precision of up to 1 meter. Researchers have built a tool that allows users to correct errors from orbital computations, maps, surface models, atmospheric refraction, and Doppler effects. Using data from Pol-InSAR, an instrument that employs interferometry and polarization, the two teams are trying to extract geophysical and biophysical parameters. This should help characterize the evolution of plant coverage (*Pol-InSAR for extraction of geo- and biophysical parameters*). This method has proven successful in the "Swiss Alpine Airborne SAR Experiment", which precisely measured the movement of snow, ice and vegetation around the Aletsch glacier.

Federal Institute of Technology Zurich (ETHZ)

Several departments of the university participate in terrestrial surveillance. For example, the laboratory of high-energy physics has constructed a detector (*Synchrotron Radiation Detector,* SRD) attached on the ISS, that measures synchrotron emission from electrons and positrons trapped in Earth's magnetic field. The sensitivity of SRD should be high enough to not only measure high-energy interactions, but also the X-ray background and the scattering of charged particles. Results show that the background noise is insignificant except in the polar regions. Still part of the ISS, the SRD can be used during years of low solar activity.

In 2002, the ETHZ joined 19 other partners for the numerical modelization of elevated terrain (*DEM generation with SPOT5-HRS*) from images obtained with Spot-5. Preliminary results indicate that the difference between model and observation is on the order of 1–2 pixels, with optimal results for flat surfaces. Once the instrument was operational, the institute sought to apply it. Because of demographic pressures, the Okavango Delta in Botswana sustains ever increasing demands for

[3]See figure 3 on page 6: *effects on the terrestrial crust after the earthquake in Bam, Iran (ASAR).*

water. Evaluating different scenarios for the distribution of water requires a precise hydrological model based on DEM (islands, swamps, etc.), and knowledge of the dynamics of water flow. In order to construct a working model, the institute used stereo images from Ikonos and Spot-5 to compensate for a lack of credible data on the region. Beyond its practical applications, this research permits the development of a usable DEM automatically from easily-accessible satellite images.

3.3 Atmospheric studies

Understanding the atmosphere preoccupies scientists and more and more leaders are listening. The atmosphere protects us from the Sun's harmful radiation (UV and X), its air is vital, and it provides the medium in which energy exchange dictates the climate. Yet these three functions are threatened, so studying the atmosphere is a question of survival.

University of Bern

The distribution of water vapor in the upper layers of the atmosphere is an important factor when evaluating the influence of global warming on circulation in the stratosphere. The Institute of Applied Physics built a device that measures the distribution profiles of water vapor in the stratosphere. From the ground, the instrument can measure the temporal evolution of profiles at a point. Once airborne, it can measure instantaneous profiles across a vast region (*AMSOS Airborne Millimeterwave Stratospheric Observing System*).

Federal Institute of Technology Zurich

To monitor air pollution and radiation, ESA launched TEMIS (*Tropospheric Emission Monitoring Internet Service*) which furnishes tropospheric gas concentrations for a given location and date. This service was conceived for application of the protocols of Montreal (ozone-depleting gases) and Kyoto (greenhouse gases). The data comes from the Gome satellite, and the EMPA (Federal Laboratories for Materials Testing and Research), which depends on the institute of technology, is among those charged with analyzing it. First experiments by EMPA on conditions at the Po plain in Italy and in the Swiss Alps (*DUP-POLPO*) were conclusive and integrated into the TEMIS project[4].

In the near future, satellites should provide even more observations and practically in real-time. Data centers will be asked to process volumes of information into 3-D images of cloud cover. By accounting for the effect of clouds on heat exchange in the atmosphere, these images will enable more reliable weather forecasts. The ETHZ participates in the CLOUDMAP2 project[5] by comparing the height and velocity of clouds as recorded by their ground-based camera against those estimated by satellites.

It is necessary to modelize the exchange of energy between the ground and atmosphere in numerical simulations of the weather in order to correctly mimic the atmospheric processes at play. Snow cover is an important parameter to describe the ground but existing data is imprecise. Thanks to the accuracy of second-generation Meteosat (MSG), MeteoSwiss and ETHZ can develop an algorithm that delimits regions covered in snow (snow cover map in the Alps).

Data from the Meteosat and Envisat satellites are used by the Institute of Geodesy and Photogrammetry to define pressure distributions in clouds in comparison with the other sources of measurement on the ground or in orbit. This project should help clarify the physics of the atmosphere.

[4]See figure 4 on page 8: *examples of tropospheric columns of NO_2 as measured by Gome (EMPA image).*

[5]See figure 5 on page 8: *3-D visualization of cloud cover from a ground-based camera (cloudmap2 image).*

3.4 Astronomy

If there is one domain that is intimately linked with space, it is assuredly astronomy. By breaking free of the atmosphere's veil around forty years ago, astronomy and astrophysics made spectacular progress. The spectrum is so broad that each new space telescope reveals novel horizons for scientists to explore. Thanks to the extraordinary images sent from the Hubble space telescope and from planetary missions such as Mars-Express, astronomy enjoys a level of popular success that few other sciences can rival. This enthusiasm has allowed political and business leaders to encourage the growth of industries and institutes that deal with space research.

University of Geneva
In Geneva, astronomy is synonymous with its observatory which is active in many domains. The observatory houses the data center for the European satellite Integral, its researchers participate in all levels of planning for international astronomy missions, and its workshop helps build scientific instruments. Astronomy in Geneva is also linked to the Department of Physics which works closely with prestigious institutes such as CERN and NASA.
The ISDC (*Integral Science Data Center*), an institute near Versoix that collects data from the INTEGRAL satellite, is certainly a prime example of Switzerland's contribution to ESA's space programs. This institute, which has around 40 collaborators, was founded in 1994 after its offer to create a center capable of serving as an interface between the Integral satellite and the scientific community was accepted by ESA. The ISDC's tasks are numerous; it must continuously receive data from the satellite, analyze images in real-time to react to alarms, reduce images into a user-friendly format, and conceive a system to archive and distribute data.
Scientists at the ISDC are not limited to processing data collected from Integral in X and gamma rays[6]. The center is a leading research pole specializing in high-energy astrophysics. Its astronomers study active galactic nuclei, black holes, neutron stars, and the formation of atoms during the universe's history (nucleosynthesis).
The Geneva Observatory also participates in the upcoming GAIA mission. This ESA satellite, is expected to make astrometric (position, velocity), photometric (intensity) and spectroscopic (wavelength) measurements for over 1 billion stars. There is so much information to treat that 19 groups were formed to meet the challenge. The scientist responsible for GAIA asked a team from the Geneva Observatory to lead the group handling variable stars. Prior experience with astrometry during the Hipparcos mission will benefit the team. Variable stars are a key to understanding stellar evolution, different galactic populations, and a way to determine distances in the universe. GAIA should launch in 2010.
Though based on observations, research can be theoretical. A group of theoretical physicists in Geneva is seeking to better comprehend the history and evolution of the early universe by using string theory, primordial gravitational waves, and the anisotropy and polarization of the cosmological background (cosmology and particle physics).
The Institute of Physics is also looking into the origins of cosmic rays. The AMS (*Alpha Magnetic Spectrometer*), built by the institute and joining the ISS in 2007, will examine rays with energy on the order of 1 TeV, their propagation, super-symmetrical dark matter, and anti-helium.

University of Bern
How can one not link the University of Bern with the strip of aluminum sent to the Moon and brought back by the Apollo 11 astronauts to help unravel the mysteries surrounding solar winds? Since then, the university is inseparable from space exploration whether it be in the study of the Sun, planets or stellar motion.

[6]See figure 6 on page 9: *galactic distribution of Gamma-ray sources (*INTEGRAL *Wide Survey,* ISDC *image).*

One of the university's specialties is the conception and fabrication of instruments used on interplanetary probes. The Physics Institute recently built a mass spectrometer[7] that is roughly the size of a can of soda or a coffee cup and should be sent to Mars, Mercury, Europa and Titan.

In the context of Mars-Express, the university helped design the Swedish instrument ASPERA-3 which will measure the interactions between the solar wind and the Martian atmosphere. Following ASPERA-3, ASPERA-4 will accomplish similar tasks on Venus. Moving on to Mercury, the university developed a device that is capable of analyzing the planet's surface and will depart with the Beppi-Colombo probe in 2012 (*Composition of crust and exosphere of Mercury*). Finally, the university proposed and provided ESA with the ROSINA spectrometer that left with the Rosetta probe for a close encounter with a comet called Churyumov-Gerasimenko 10 years from now.

Active in the domain of celestial mechanics, the university created instruments that are able to determine the orbits of objects around the Earth, as well as the long-term, orbital evolution of a dozen abandoned satellites (*CCD-Astrometry applied to fast-moving objects*). To calculate the astrometric parameters of these bodies, the instruments must carefully measure their positions, the Earth's rotation, the gravitational field, and atmospheric parameters. For example, the upcoming Goce satellite, whose mission is to measure variations in the Earth's gravity, requires orbits that are accurate to 1 centimeter (*Precise orbiting determination*). The university is a member of CODE (*Center for Orbit Determination in Europe*) and collaborates with the Swiss, French and German offices of topography.

Paul Scherrer Institute

The Paul Scherrer Institute (PSI) is a national research center that focuses on natural and technical sciences, and collaborates with universities, other institutes and industries. Astronomy is one of its many activities.

The PSI exploits space telescopes, such as ESA's XMM and NASA's Chandra and Spitzer, along with the grounded VLA and CHFT to study the formation of stars and planets in the molecular clouds of the Taurus and in the large Orion Nebula (*Star and planet formation in Taurus and Orion*).

BeppoSax and Euve join the list of telescopes used by the team studying particle acceleration and the coronal heating of magnetic stars (*Particle acceleration and coronal heating*).

Both XMM and CHANDRA furnish spectral results in X-rays. These spectra allow PSI researchers to explore the densities, chemical compositions, temperatures, and opacities of stellar atmospheres (*X-ray spectroscopy with XMM and Chandra*).

In addition, the PSI helps construct devices for ESA and NASA. This is the case for the MIRI instrument which should enable the anticipated James Webb space telescope to obtain spectra and images in the infrared. The formation of galaxies, stars, and even planets should be observable with MIRI. This program receives its funding from PRODEX (*Exploring origin and evolution of stars and planets*).

3.5 The sun

Institute of Davos

Host to the World Radiation Center, the Institute of Davos applies data from the Soho satellite to study the Sun. Together with the Royal Meteorological Institute of Belgium (IRMB), the institute planned and assembled an instrument (*SOVIM*) that measures the solar irradiance variation (solar constant) and the amount of spectral redistribution. Hardware and software for SOVIM

[7] See figure 7 on page 10: *miniature mass spectrometer for in-situ planetary research (Institute of Physics image).*

were completed in 2003 and the instrument is currently undergoing tests to prepare for its voyage to the ISS in 2006.
The institute also developed a device that features three filters with four channels which will record solar irradiance in the UV for the radiometry project called PICARD. This project, which sought to highlight the relation between UV irradiance and the ozone layer, is on hold due to a lack of funds.
Still in the UV, the institute, the ESA and Belgium fashioned a device called LYRA. Part of the PROBA-2 mission, the instrument will monitor solar irradiance in four UV bands specially chosen for their implication in astronomy, space weather, and solar physics.

University of Bern
The Sun is the focus of research at the Physics Institute of the University of Bern. In partnership with the Max Planck Institute and two American universities, Swiss researchers detail the composition of solar winds. Thanks to the Soho satellite, perfectly operational since 1995, researchers have been able to study about 20 elements and their isotopes as well as coronal ejections (*SOHO/CELIAS*). The research team is also building Plastic, a tool for the analysis of solar particles, that should be part of the equipment for the Stereo satellite (*Solar wind and suprathermal particles*). Scientists from Bern study the solar flux in the ionosphere and the formation of aurorae borealis with the help of data from the Lena instrument on board the Image satellite launched in 2000 (*Low-energy neutral atom mass spectrometer*).

Federal Institute of Technology Zurich
The strip of aluminum from the Apollo experiment provided an estimate of the abundances of the noble gases helium, argon and neon in the solar wind. This information is necessary for comparing the concentrations of various elements in the Solar System, planets, meteors, etc. To improve the accuracy of abundance ratios, and to establish the concentrations of krypton and xenon, NASA launched the GENESIS mission. The experiment is based on the same principle used for the Apollo aluminum strip, contains specific targets with respect to the element studied, and should last about two and a half years. The Institute of Isotope Geology and Mineral Resources of the ETHZ has developed a technique (*Isotopic composition of noble gases*) to extract the composition of noble gases from targets and Lunar fragments. Samples from GENESIS are expected to return to Earth in September, 2004.

Paul Scherrer Institute
Among the research topics underway at PSI, the Sun figures prominently. Using space telescopes, astronomers observe several Solar-type stars in different stages of evolution in order to recreate the Sun's early history and to explain the formation of the Earth and its atmosphere (*Sun in time*[8]).
Data from the Rhessi satellite and those of the Phenix-2 radiometer are used to validate models that attempt to simulate the behavior of the solar corona. In fact, the violent flares emitted in X-rays and radio waves during solar eruptions are still misunderstood (*Solar flare with Rhessi*).

3.6 Astrobiology

Museum of Natural History, Bern
The museum in Bern was supposed to help analyze images of Mars taken by cameras aboard Beagle-2 (*Imaging of Mars materials*). These cameras[9], created by a company from Neuchatel

[8]See figure 8 on page 12: *for the first time, the* HESSI *instrument observes the flashpoint of a solar eruption characterized by the red and yellow regions (*ETHZ *and* PSI *image).*
[9]See figure 9 on page 13: *camera with light for geological analysis on Mars (Museum of Bern image).*

called Space-X, would have allowed researchers from the museum's Department of Earth Sciences to perform a geological and microbial analysis of Mars. The loss of Beagle-2 did not signal the end of this project since the analytical methods that were developed can be used for future Mars missions.

Federal Institute of Technology Zurich
The Space Biology Group of the ETHZ planned an experiment for the Space Shuttle that would test the reaction of cells under gravitational stress (*Stress under microgravity*). Two forms of stress interest the biologists from Zurich; osmotic and thermal shocks. A second shuttle experiment tried to elucidate how a lack of gravity influences the disactivation of T-cells (*Role of interleukin-2 receptor in signal transduction and gravi-sensing threshold of T-lymphocytes*). Unfortunately, the results of these experiments were lost during the tragic accident of Columbia on February 1, 2003.

3.7 Measure of time

Observatory of Neuchatel
Placing high-precision clocks aboard a satellite is crucial for the satellite to function properly, and it helps when interpreting the data. The Swiss, especially those at the Observatory of Neuchatel, are reknowned for their fabrication of such timepieces. Their expertise in the measurement of time enabled the Observatory to win a contract to equip the satellites of Europe's navigation system of the future, "Galileo". To satisfy ESA's requirements, which demand that clocks be stable to within 10 – 14 seconds for every 10,000 seconds. The observatory conceived, assembled and tested rubidium atomic clocks (*Laser pump rubidium atomic frequency standard*).
The Observatory of Neuchatel, ESA and CNES are refining the ACES (*Atomic Clock Ensemble in Space*) experiment which will be installed on the ISS in 2008. Using two high-precision clocks in zero gravity, ACES should be 10 times more accurate than the best terrestrial atomic clocks. These clocks should be able to verify the stability of the physical quantity named the hyperfine structure constant. To meet this challenge, the clocks will have to be stable to within 10 – 16 seconds per year.
Scientists at the observatory also created variable-frequency lasers for the WALES mission which will use a tool called Lidar to measure the distribution of water vapor and aerosols in the atmosphere (*Tunable frequency stabilization for WALES*). By modifying the frequency of Lidar, it is possible to obtain the concentrations of water vapor and aerosols, as well as the abundances of carbon monoxide, carbon dioxide, and methane.

3.8 International links

International Space Science Institute
The ISSI in Bern invites scientists to compare and interpret their data in order to pinpoint the needs of scientists for future space missions. For this objective, the ISSI organizes theme-specific workshops and meetings. The institute also supports projects conceived by international teams that have been selected based on a system of peer-review. Around 250 visitors are welcomed by the ISSI every year. Guests spend an average of ten days in Bern.

3.9 Conclusion

The abundance and diversity of space-related projects in Switzerland does not permit a detailed description of all experiments (for which the titles are expressed in italics) and their implications. Only certain domains could be highlighted and the selection of these is not an indication of their quality or interest. Switzerland is well represented in space. Its knowledge base is respected

but the competition is becoming more aggressive and contracts are harder to obtain. For 2004, the Swiss Space Office (`http://www.sso.admin.ch`) estimates that the policy of a "just return" applied by the ESA will allow Switzerland to recover 70-80% of its financial contribution to the space agency in the form of contracts and collaborations. These deals are fundamental since they enable our country to participate in the decision-making process that governs research, and they permit Switzerland to help in the surveillance and protection of our fragile blue planet.

Pierre Bratschi
Translation: Arash Bodaghee (ISDC)

4 International institutes

4.1 International Space Science Institute (ISSI)

Directors: R.M. Bonnet (Executive Director since January 2003)
J. Geiss (Honorary Director since January 2003)
G. Paschmann
R. von Steiger

Staff: 3 scientific, 5 administrative
Board of Trustees: H.P. Schneiter, Industrial Ombudsman for ESA (President)
Science Committee: R. Pellinen, Finnish Meteorological Institute, Helsinki, Finland (Chairman)
Fields of research: From its inception in 1995, the scientific programme has focussed on Solar System Science, (Heliospheric and Solar-Terrestrial Physics, Solar Wind and Solar Processes, Planetary Science), but always included connections to Astrophysics and Cosmology, and to Earth Sciences from Space. In 2003, an expansion of the programme was agreed: Astrobiology, Earth Sciences, and the International Living With a Star (ILWS) Programme (Space Weather) will be taken in as new disciplines.

Introduction
The International Space Science Institute (ISSI) is an Institute of Advanced Studies at which scientists from all over the world are invited to work together to analyse, compare and interpret their data. It is ISSI's rationale to further interdisciplinary studies and interpretation.
Space scientists, theorists, modelers, ground-based observers and laboratory researchers meet at ISSI to formulate interdisciplinary interpretations of experimental data and observations. Therefore, the scientists are encouraged to pool their data and results. The conclusions of these activities are expected to help identifying the scientific requirements of future space science projects. ISSI's study projects on specific scientific themes are selected in consultation with the Science Committee members and other advisers.
The main tools in carrying out projects are Workshops and/or Working Groups on specific topics - participation is by invitation only. Furthermore, ISSI supports research projects of International Teams, proposed by the scientific community and selected through a peer-review system. Since 2003, ISSI issues a periodic open call for proposals on International Teams to the scientific community. ISSI also hosts Senior and Junior Visiting Scientists. In total, ISSI welcomes about 250 visitors annually, who spend some 360 work-weeks at ISSI.

Realisations in 2002 and 2003
All scientific activities result in some form of publication, e.g. in ISSI's hardcover book series Space Sciences Series of ISSI (SSSI), published by Kluwer Academic Publishers, Dordrecht, NL (reprinted from Space Science Reviews), in ISSI Scientific Report Series (SR), published by ESA's Publications Division, or individual papers in peer-reviewed international scientific journals. As of the end of 2003, 17 volumes of SSSI, and two volumes of SR have been published. Information about the complete collection can be found on ISSI's website `http://www.issi.unibe.ch` , in the section "`Publications` ".
In 2002 and 2003, the following volumes appeared:

The Astrophysics of Galactic Cosmic Rays , R. Diehl, E. Parizot, R. Kallenbach, and R. von Steiger (eds.), SSSI Vol. 13

Matter in the Universe , Ph. Jetzer, K. Pretzl, and R. von Steiger (eds.), SSSI Vol. 14

Auroral Plasma Physics , G. Paschmann, S. Haaland, and R. Treumann (eds.), SSSI Vol. 15

System History from Isotopic Signatures of Volatile Elements , R. Kallenbach, T. Encrenaz, J. Geiss, K. Mauersberger, T. Owen, and F. Robert (eds.), SSSI Vol. 16

Earth Gravity Field from Space - from Sensors to Earth Sciences , G. Beutler, R. Rummel, M.R. Drinkwater, and R. von Steiger (eds.), SSSI Vol. 17

The Radiometric Calibration of SOHO , A. Pauluhn, M.C.E. Huber, and R. von Steiger (eds.), SR no. 2

At the end of 2003, the following volume was being printed:

Magnetism of Mars and its Interaction with the Solar Wind , D. Winterhalter, M. Acuña, and A. Zakharov (eds.), SSSI Vol. 18, in press.

There are a number of upcoming publications, which result from ISSI activities in 2002 and 2003:

Planetary Systems and Planets in Systems , S. Udry, W. Benz, and R. von Steiger (eds.), Results of an ISSI-Workshop held in Saas-Fee in September 2002, to be published as SSSI Vol. 19. The aim of the workshop was to gather active researchers from various fields to assess the exciting new developments in the search for, and understanding of, systems with multiple planets (including our solar system) and planets in stellar systems: With improving detection methods and passing time, multiple planetary systems are being discovered in increasing numbers. The workshop addressed the observational and theoretical issues specific to planetary systems and to planets in multiple stellar systems. The focus was on the detection of planetary systems, of planets in binary or multiple stellar systems and on the understanding of the formation and the dynamical interactions in such systems including their observational consequences (stability, resonances, orbital evolution, etc.). This workshop was held in honour of Professor Michel Mayor's sixtieth birthday.

Magnetospheric Boundaries and Turbulence: Cluster Results G. Paschmann et al. (eds.), Results of two Workshops held at ISSI in March and November 2003. The focus was on the dayside magnetospheric boundaries (bow shock, magnetopause, and cusp), including their surroundings (foreshock, magnetosheath and magnetopause boundary layers). The goal of the workshop publication is to write a coherent book on the subject, which will appear as SSSI Vol. 20.

Calibration Techniques for In-Situ Plasma Instrumentation M. Wüest and R. von Steiger (eds.), Results of two Working Group Meetings held at ISSI in September 2002 and January 2003, which will be published as ISSI scientific report no. 3. This report will describe in detail the calibration process for plasma in-situ instruments, methods to intercalibrate between calibration labs and cross-calibrate between instruments on the same spacecraft or spacecraft cluster, describe methods to economize the calibration methods by using new techniques such as transfer calibration, artificial intelligence or statistical techniques for use in cluster missions.

It is impossible to list all individual or group papers published in international scientific journals, which are related to ISSI activities. The respective information can be found in ISSI's Annual

Reports 7 (2001–2002) and 8 (2002–2003), which are available online (`http://www.issi.unibe.ch`).

Outlook
In early 2004, two Workshops will take place. The first of them will aim at a comparative study of the outer planets before the exploration of Saturn by Cassini-Huygens, the second is dedicated to Coronal Mass Ejections (CME). Furthermore, ISSI will initiate its Forum series, i.e. invite experts for brainstorming sessions on innovative topics in the fields of science, policies, and society. The first Forum will be held on Astrobiology.

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4.2 The INTEGRAL Science Data Centre (ISDC)

The ISDC was formed as a response to a call for proposals issued by ESA in 1994 seeking from the community a team that would be capable of serving as the interface between ESA's gamma ray astronomy satellite INTEGRAL and the community. The tasks involved the reception of the satellite data, the processing the data in near real time and once consolidated and the development of an archive for the data as well as their distribution to the observes and the public.
A consortium was then formed that includes a dozen institutes in Europe and the United States under the leadership of T. Courvoisier of the Geneva Observatory. The tasks were better defined and the software that would be necessary to fulfill them was designed and implemented up to the launch of the satellite on October 17 2002. In parallel, the team that is necessary for the development and the operations of the ISDC was grown from 2 people at the time of the proposal to some 35 to 40 now.
The ISDC system has been switched on little by little starting at the time of launch, as the subsystems of the satellite have been put into operation. All the requirements that had been agreed on have been satisfied.
The INTEGRAL data are processed three times: once in real time, within seconds of the arrival of the data at ISDC. This very rapid processing is required to detect and localize gamma ray bursts in a very short time, as far as possible while these phenomena that last few seconds are ongoing. The bursts positions are then sent automatically to ground based observers that can turn telescopes within seconds to the position announced. The second processing of the data takes place within few hours of the reception of the data. This allows scientists at ISDC to detect new sources or to find those that have varied by large factors. These events can then be reported to the community to arrange for coordinated observations with other facilities. Finally the data are analyzed a third time, after a consolidation by ESA during which possible gaps in the real time telemetry are filled as much as at all possible. This allows ISDC staff to archive and distribute the best possible data and analysis results.
The scientists on the ISDC team not only operate and further develop the INTEGRAL analysis system and algorithms, they also contribute to the scientific exploitation of the INTEGRAL data.

They are involved in the study of active galactic nuclei, in that of X-ray binary systems and in nucleosynthesis problems. The interplay between the scientific research per say and the involvement in ISDC service tasks ensures that the ISDC really meets the needs of the community and does not become estranged, solving problems that are not perceived as important outside its walls. This also ensures that there is a close human and scientific interaction between people at the ISDC and outside.

In the coming years the ISDC will continue fulfilling its responsibilities as long as INTEGRAL is operated. In parallel, ISDC staff are looking at ways in which the unique expertise that has been collected in the development and operations can be put to the service of the community in the framework of different missions.

5 Astrophysics

5.1 High energy emission from active galactic nuclei (AGN).

Institute: ISDC

Principal Investigator: T. Courvoisier

Co-investigators:
M. Tuerler; M. Chernyakova
P. Favre; S. Deluit; R. Walter

Method: Research based on existing instuments: IUE, Beppo-SAX, Rossi-XTE, INTEGRAL.

Purpose of research: We use data from a large set of instruments on satellites to observe active galactic nuclei. This allows us to probe the emission in regions of the electro-magnetic spectrum that cannot be observed from the ground. Over the last years we have concentrated on UV, X-ray and gamma ray observations. Our aim is to understand the radiation processes and beyond this to understand how the energy that is liberated as matter falls in the central supermassive black holes is transformed in radiation.
For one part we use archival data and for the other we perform observations now. Our findings include a description of the events that make the observed ultraviolet variations in a sample of objects observed during 17 years, a comparative study of different types of AGN that allowed us to find differences that cannot be due solely to orientation effects and observations of the spectral region where most of the energy is radiated.

Status: This project has been going on for several years.
The basics elements of the physics of AGN has been understood shortly after their discovery in the 1960s and 70's. The next steps have proved very difficult and elusive. Although a large effort went over many years in trying to model the accretion processes with accretion disks, the models and observations have not yet been brought in agreement. We are therefore trying to explore some further avenues that do not rely on the existence of classical accretion disks. We are also exploring the parallels between the supermassive black holes at the centre of galaxies and those, much lighter, that are observed within our Galaxy.

Publications:

1. Tuerler M., Courvoisier T.J.-L., Chaty S., Fuchs Y., 2004, A+A 415, L35

2. Deluit S. and Courvoisier T.J.-L. 2003, A+A 399, 77

3. Favre et al. in preparation

Abbreviations:

AGN:	Active Galactic Nuclei
IUE:	International Ultraviolet Explorer
XTE:	X-ray Timing Explorer

5.2 INTEGRAL wide surveys

Institute: ISDC
In cooperation with:
IASF-Roma, IASF-Bologna, SAP/CEA Saclay,
Univ of Southampton, DSRI-Copenhagen

Principal Investigator: R. Walter; A. Bodaghee; J. Zurita; S. Soldi

Purpose of research: The purpose of this reasearch is to study the new high energy sources detected by INTEGRAL, their individual and statistical properties, to identify them and to analyse how their detection changes our understanding of our galaxy and of active galactic nuclei.

Status: About 30% of the sources detected by INTEGRAL are new or not identified. Up to now we have concentrated our effort on sources within the galactic plane. Those sources are most probably of galactic nature and most of them are expected to be accreting binaries in which matter falls from a low or high mass stellar companion to the surface of a neutron star or to a black hole.
A first result of that analysis is a catalogue of sources detected in the soft gamma-rays (Bird et al, 2004). This catalogue has been built from the first year of INTEGRAL core program data and revealled many new sources that were not detected by previous missions either because of their transcient nature or because those sources are faint or strongly absorbed in the X-ray domain.
The average image of our galaxy contains more soft gamma-ray sources than previously believed, increasing the contribution of the point sources to the soft gamma-ray emission of the galaxy. One important and new result is that the diffuse galactic emission contributes for less than 10% of the total galactic emission (Lebrun et al 2004). It was believed to be a much stronger component.
Statistical studies of the various populations of sources detected by INTEGRAL are on going through comparison with existing source catalogues (in particular X-rays) and by the distribution of the source brightness in the INTEGRAL energy domains.
30% of the sources detected are not identified. This identification work as started using observations with XMM and Chandra, existing infrared surveys and dedicated optical and infrared follow-up spectroscopic observations. One of the first result that came out is the detection by INTEGRAL of a new population of highly absorbed X-ray binaries, especially in the Norma arm of our galaxy (Walter et al, 2003).
In the extragalactic domain many Seyfert 2 type active galactic nuclei (AGN) are expected to be detected in the soft gamma-rays. Those absorbed sources should form 60% of the total AGN population are however mostly invisible in the X-rays. The high energy emission that is the main signature of the black-hole accretion paradigm has therefore been poorly studied. INTEGRAL will be very helpful to probe if 60% of the active galactic nuclei are indeed absorbed (which is an important constraint for the AGN unification models) and to further study the spectral shape of those objects at high energy.
Now that the INTEGRAL data are becomming public we plan to use the complete data sets to study the extragalactic soft gamma-ray sources and to obtain deeper surveys of our own galaxy.

Publications:

1. Walter et al, 2003, A&A 411,427
2. Lebrun et al, 2004, Nature 428, 293
3. Bird et al, 2004, ApJ in p

5.3 Monitoring Accreting X-ray Pulsars in the INTEGRAL Core Program

Institute: ISDC
In cooperation with:
IAA Tübingen (D); IASF Palermo (I)
IASF Milano (I); Univ. of Warwick (UK)

Principal Investigator: R. Staubert; S. Mereghetti; P. Kretschmar, I. Kreykenbohm
K. Pottschmidt; J. Wilms; A. Santangelo
A. La Barbera; L. Sidoli; M. Chernyakova

Purpose of research: Accreting X-ray pulsars are typically variable sources even in the case of the minority of persistent sources. Their long-term flux history and period evolution allows to derive information about accretion mechanisms and system properties, if they can be studied over longer time scales.
Since the end of CGRO-BATSE observations no regular flux measurements in the hard X-ray range and no regular pulse period measurements have been available.
There is an ongoing project to derive the flux and pulse period history of accreting X-ray pulsars observed during the Integral Core Program and to make this information available to the astronomical community via specific Web pages, which also contain background informatyion about the monitored sources. In addition, specific sources are studied in detail by different members of the collaboration, depending on the available data and the interest in these sources.

Status: The data from the Core Program scans is routinely analyzed and checked for sources at the ISDC and the associated institutes. This work is done in close collaboration with other monitoring efforts, especially the one for LMXB in the Core Program. The WWW pages with information for the community are about to be made public at the time of writing. Work is still ongoing both to validate the results and to streamline the analysis effort, especially in the time analysis.
Besides the global effort, specific analysis has been done and published for the sources Vela X-1, Cen X-3, GX 301-2 and SAX J2103.5+4545.

Publications:

1. Wilms et al.: Persistent Accreting Neutron Stars in the INTEGRAL Galactic Plane Survey Proc. American Astronomical Society, HEAD meeting #35, #08.06

2. Santangelo et al.: A global view of Accreting Pulsars during the first year of the Integral Core Programme Proc. 5th Integral Workshop

3. Staubert et al.: Integral Observations of Vela X-1 in a flaring state Proc. 5th Integral Workshop

5.4 Search for Al26 in the Gamma Velorum Wolf-Rayet star

Institute: Observatoire de Geneve / INTEGRAL Science Data Center
In cooperation with:
G. Meynet (Geneva); P. Dubath (Geneve)
J. Knoedelseder (Toulouse); R. Diehl (Garching)
G. Lichti (Garching); S. Schanne (Paris)

Principal Investigator: N. Mowlavi

Purpose of research: The study of radioactive nuclei in the Galaxy provides a unique tool to probe the nucleosynthesis that occured in the recent past. The case of the unstable aluminium isotope, Al26, is of special interest. It has been observed by its spectral signature at 1809 keV to be present in the Galaxy in diffuse emission, with a total inferred mass of three times the mass of the Sun. This raises the puzzle of its astrophysical origin. Several types of stars can potentially synthesize Al26 and eject it in the intersellar medium. The best fit to the galactic map of Al26 obtained by the previous gamma-ray satellite COMPTEL favors contributions from massive stars, both from Wolf-Rayet stars and supernovae. The relative contribution by each of these two types of objects is however still unclear.
INTEGRAL, with its high spectral sensitivity, is expected to provide a better insight into this puzzle. The current research focusses on the Al26 production by the closest Wolf-Rayet star to the Sun, WR 11 in the Gamma Velorum binary system. The research adresses both model predictions, in collaboration with the stellar evolution group at the Geneva Observatory, and the analysis of INTEGRAL data, in collaboration with other SPI groups in Europe. If the analysis results in a positive detection, it would be the first detection of Al26 in a single object, and a definite success for INTEGRAL.

Status: From a theoretical point of vue, Al26 yields have been computed for WR 11 based on recent models of Wolf-Rayet stars including rotation. We are currently investigating the implications of those new yields on the flux expected at 1809 keV on Earth, taking into account the most probable distance to WR 11 derived from the data recorded by the Hipparcos satellite.
The analysis of the INTEGRAL data accumulated during the first year of the mission, on the other hand, is progressing in collaboration with the other SPI groups in Europe, mainly the CESR in Toulouse and the MPE in Garching. The main difficulties of the work are the low number of photons at those high energies, about only 100 per hour, and the high background noise, more than 99% of the photons being produced inside the spacecraft. The extraction of the 1% signal of astrophysical origin is currently under way by making use of the presence of the coded mask and by modeling as adequately as possible the background noise.

Publications:

1. Vuissoz C., et al. 2004, NewAR 48, 7
2. Mowlavi N., et al. 2004, INTEGRAL V workshop, in press
3. Oberlack U., et al. 2000, A&A 353, 715 (relevant to the subject but not from the PI of this research)

5.5 INTEGRAL-RXTE observations of Cygnus X-1

Institute: Max-Planck-Institut fuer extraterrestrische Physik (MPE), Garching, Germany &
INTEGRAL Science Data Centre (ISDC), Versoix, Switzerland
In cooperation with:
See affiliations of co-investigators.

Principal Investigator: Katja Pottschmidt

Note, however, that the INTEGRAL data analysed for this project (performance verification phase) belong to the whole INTEGRAL consortium within the one year proprietary period.

Co-investigators:
J. Wilms (Univ. Warwick); M.A. Nowak (CSR-MIT, Boston); P. Dubath (ISDC, Versoix)

I. Kreykenbohm (IAAT, Univ. Tuebingen & ISDC, Versoix)
T. Gleissner (IAAT, Univ. Tuebingen)
M. Chernyakova (Lebedev Physical Institute, Moscow & ISDC, Versoix)
J. Rodriguez (CEA Saclay, Gif-sur-Yvette & ISDC, Versoix)
A.A. Zdziarski (Nicolaus Copernicus Astronomical Center, Warszawa)
V. Beckmann (NASA GSFC, Greenbelt & JCA, Univ. Maryland)
P. Kretschmar (MPE, Garching & ISDC, Versoix)
G.G. Pooley (Cavendish Laboratory, Cambridge)
S. Martinez-Nunez (GACE, Univ. Valencia)
T.J.-L. Courvoisier (ISDC, Versoix & Observatoire de Geneve)
V. Schoenfelder (MPE, Garching)
R. Staubert (IAAT, Univ. Tuebingen)

Method: Research based on existing instruments:
Data from ESA's International Gamma-Ray Astrophysics Laboratory (INTEGRAL) and NASA's Rossi X-ray Timing Explorer (RXTE) have been analysed.

Purpose of research: The canonical black hole binary Cygnus X-1 has been extensively observed during INTEGRAL's performance verification phase in 2002 November and December. About 50 ks of (quasi-)simultaneous RXTE observations have been obtained in order to support calibration efforts. Together these observations provide some of the highest quality broad-band energy spectra available for this source.
Broad band studies are of special importance for understanding the physical processes at work near galactic and extragalactic black holes which emit an appreciable fraction of their overall luminosity in this energy regime. It is generally believed that the observed high energy X-rays / gamma-rays are produced by Comptonization, i.e., by up-scattering of softer photons from the accretion disk in a hot electron plasma (corona).
Our data set provides a unique opportunity for testing the different physical Comptonization models which are currently available. Also a new alternative model to Comptonization, namely synchrotron emission from an outflow of material (jet) can be evaluated. In addition, a prominent feature of the hard radiation — namely its strong short term variability on time scales below 1 s — can be used to further constrain models.
This variability has been very well studied with RXTE, however an extension to the higher energies available with INTEGRAL promises interesting new insights into the accretion process of black holes.

Status:
Different Comptonization models have been fitted to all the (quasi-) simultaneous INTEGRAL-RXTE spectra. Results obtained with the earliest data extraction software and calibration of INTEGRAL (launched 2002 Oct. 17), have been presented in a 2003 issue of the Astronomy and Astrophysics journal which was specially dedicated to the presentation of first INTEGRAL results.
Re-analyses with updated INTEGRAL and/or RXTE calibrations as well as the inclusion of additional models have been presented at the "X-Ray Timing 2003: Rossi and Beyond" conference in Boston, 2003 November, and at the "5th INTEGRAL Science Workshop" in Munich, 2004 February. Work on the high time resolution data has started. The overall results from the spectral modelling which has been performed up to now can be summarized as follows:

> Consistent with earlier results, thermal Comptonization with reflection provides an adequate description of the 2–550 keV hard state spectrum of Cyg X-1 as measured

with RXTE and INTEGRAL. The Comptonizing plasma is of moderate optical depth and temperature.

The presence of a second and optically thick Comptonization cloud remains an interesting possibility, giving fits of comparable statistical quality as the single cloud model. However, these fits might alternatively indicate complexity of a different origin at low energies.

In order to distinguish between the different Comptonization models, the broad band calibration of the INTEGRAL instruments has to be further improved. Solving the question about the existence of a hard tail additionally requires to sum spectra over longer exposure times — after evaluation the variability on those time scales.

Also, no absolute flux measurement is possible with the current calibration of the INTEGRAL instruments. Solely considering the 10–200 keV spectrum in a first approach to the new jet model, we have found that synchrotron X-rays (when properly folded through the detector response) can provide a very good description of the data. Additional work is required to determine if such models can be extended to the whole 2–550 keV range.

Publications:

1. Pottschmidt, K., Wilms, J., Nowak, M.A., Dubath, P., Kreykenbohm, I., Chernyakova, M., Rodriguez, J., Zdziarski, A.A., Beckmann, V., Kretschmar, P., Gleissner, T., Pooley, G.G., Martinez-Nunez, S., Courvoisier, T.J.-L., Schoenfelder, V., Staubert, R., 2004, INTEGRAL-RXTE Observations of Cygnus X-1, in: Proc. 5th INTEGRAL Science Workshop, ESA SP–552, in press

2. IWilms, J., Pottschmidt, K., Nowak, M.A., Chernyakova, M., Rodriguez, J., Beckmann, V., Kretschmar, P., Gleissner, T., Pooley, G.G., Martinez-Nunez, S., Courvoisier, T.J.-L., Schoenfelder, V., Staubert, R., Zdziarski, A.A., 2004, INTEGRAL/RXTE Observations of Cygnus X-1, in: Proc. X-Ray Timing 2003: Rossi and Beyond (P. Kaaret, F.K. Lamb, and J.H. Swank eds.), AIP Conf. Proc.

3. Pottschmidt, K., Wilms, J., Chernyakova, M., Nowak, M.A., Rodriguez, J., Beckmann, V., Kretschmar, P., Gleissner, T., Pooley, G.G., Martinez-Nunez, S., Courvoisier, T.J.-L., Schoenfelder, V., Staubert, R., Zdziarski, A.A., 2003, INTEGRAL-RXTE Observations of Cygnus X-1, A&A Lett., 411, 383–388

Abbreviations:

MPE:	Max-Planck-Institut fuer extraterrestrische Physik
ISDC:	INTEGRAL Science Data Centre
INTEGRAL:	International Gamma-Ray Astrophysics Laboratory
RXTE:	Rossi X-ray Timing Explorer

5.6 New Facets of GRS 1915+105 as seen by INTEGRAL and RXTE

Institute: CEA Saclay service d'Astrophysique, France

In cooperation with:

INTEGRAL Science Data Center Versoix, Switzerland

Principal Investigator: J. Rodriguez

Co-investigators:

D.C. Hannikainen; O. Vilhu. S.E. Shaw; V. Beckmann

A. Paizis; S. Corbel; T. Belloni; G. Pooley
M. Ribo; Y. Fuchs et al

Method:

1. Research based on existing instuments:
   INTEGRAL, RXTE mainly, but multi-wavelength observations are also conducted (Ryle radio Telescope, VLA...)

2. Satellite

Purpose of research: The aim of this research is to monitor about once a month the famous microquasar GRS 1915+105, using the newly launched ESA's satellite INTEGRAL, in a (quasi) simultaneous multi wavelength campaign, from the radio, through IR/Optical, and soft X-ray (RXTE) observations. The goal of such a research is to

1. probe the connection between accretion (manifesting through X-ray and Gamma-ray emission), and ejection (through radio-IR) processes.

2. Study the physical origin of the high energy (soft X-ray and gamma ray) emission, the thermal emission from an accretion disc for the soft X-rays, and its influence on the source spectral variations, but also discriminate between several models for the origin of the so-called "hard tail" at higher energy:

   - thermal Comptonisation;
   - non-thermal Comptonisation;
   - hybrid thermal/non-thermal Comptonisation;
   - reflection component.
   - Synchrotron Self Compton + Synchrotron emission from a compact jet any mixture of the afore mentioned models other?

     This is done through spectroscopic studies and modeling of the spectra, but also through high resolution temporal studies, and characterisation of the Quasi Periodic Oscillations, related to the accretion flows.

3. Perform time resolve spectroscopy: GRS 1915+105 is one of the most intriguing object of our Galaxy, displaying variability at all time scales. Although it has been proved to spend most of its time in a steady state, 12 different classes of variability have been identified in the second to hour time range. I order to understand the origin of such variations, it is important to separate, when accumulating spectra) the time of high flux from those of low fluxes. Then by performing spectral fittings of those different "epochs" we will be able to understand the physical origin of the changes.

Status: Our first INTEGRAL AO campaign will be finished in May. So far the systematic study of this microquasar (and the field around the source), has allowed us to:

- discover a new source (IGR J19140+0951, Hannikainen, Rodriguez & Pottschmidt 2003, IAUC 8088)

- identify a 13th class of variability in GRS 1915+105 during the first observation (Hanni kainen, Vilhu, Rodriguez et al. 2003 A&A 411, L415)

- observe simultaneously, for the first time, a powerful compact jet in radio, a hard X-ray tail, and strong low frequency quasi periodic oscillations (Fuchs, Rodriguez, Mirabel et al. 2003, A&A, 409, L35)
- perform, for the first time, spectral fitting of the energy dependence of the QPO amplitude, and thus characterise very precisely the spectral properties of those features (Rodriguez, Corbel, Hannikainen et al. 2004, submitted to ApJ)

During this period, most of our observations were carried out when GRS 1915+105 was in the steady state. During all of them a strong (although variable in intensity) steady compact jet was observed. One of the first results of our campaign is to propose, as expected from theoretical models, that a part of the hard X-rays as its origin through synchrotron emission from the compact jet. The next step (work in progress) is to fit the high energy spectra with physical models such as eqpair (hybrid comptonisation), accretion disk models, jet model, and study the timing features up to higher energy. In the mean time we are working on the new class of variability, which contrary to what is usually observed (ie that flares are due to an increase of the accretion rate, and thus increase in the disc brightness) manifests hard spectra when the flux is increases, and is thermal dominated during the decrease.

Publications:

1. Fuchs, Rodriguez, Mirabel, et al. 2003, A&A 409, L35
2. Hannikainen, Vilhu, Rodriguez et al. 2003, A&A 411, L415
3. Rodriguez, Corbel, Hannikainen et al. 2004, submitted to ApJ

5.7 Study of accreting compact objects in binary systems

Institute: INTEGRAL Science Data Centre
In cooperation with:
The INTEGRAL LMXRB/HMXRB Core Program team

Principal Investigator: A. Paizis; T. Courvoisier

Purpose of research: This research is developed within the PhD thesis of A. Paizis under the direction of Prof. T. Courvoisier. It involves the study of compact objects in the galactic plane, mainly LMXRBs. This study is carried out exploiting INTEGRAL Core Program data coupled to multiwavelength observations (simultaneous approved RXTE, Radio and Optical observations).
The sample of sources studied includes LMXRBs hosting a black hole and a neutron star with very different variability, ranging from transient to peristent sources. The aim of this study is to have a comprehensive view of LMXRBs through their radio to gamma emission to understand the similarities and differences of those systems: transient versus persitent behaviour, black hole versus neutron star, Z sources versus Atolls. INTEGRAL, with its regular monitoring of the galactic plane in the currently less explored hard X and gamma Ray energy bands, plays a main role in studying the hard energy emission of those sources (change state, presence of hard tails etc).
To have a broader view of the influence of the accretion flow in binary system hard emission, the study has been enlarged to include also hard energy emission of some HMXRBs (where accretion via wind from the companion plays a big role instead of the Roche lobe overflow flow of LMXRBs) with special attention to CygX3 that has been regularly observed in INTEGRAL Galactic Plane Scans.

The extracted source light-curves and hardness intensity diagrams will be made publically avaible on the web, similarly to what the RXTE/All Sky Monitor has been doing in the softer X-ray band.
In this way, the high energy history of those sources will be easily accessible to anyone, enabling also the multiwavelength comparisons. In this respect, RXTE-INTEGRAL coordinated observations have been carried out in order to have a better coverage of the soft X-rays domain. Similarily, Radio (RATAN/MOST/VLA) and Optical (La Palma, La Silla) telescopes will be used.
All these obervations will give a very valuable data base for understanding the physics of X-ray binaries.
The X-ray binaries of the sample are strong emitters in the INTEGRAL energy range and are mostly Galactic. In order to study the other end of the population, i.e. faint and/or extra-Galactic sources that happen to be in the line of sight of the Galactic plane, a bright-source free region was studied using a deep field observation of Chandra (200ksecs).
274 point sources were detected as well as an evident diffuse emission. This study will continue in a systematic way along the galactic plane. Chandra and coordinated IR observations will allow to build a map of the population of the sources therein. This map will be compared with our knowledge of the evolution of our own Galaxy and the related expected distribution of sources.

Status: One year has passed since the beginning of the Core Program scans. All the currently available data have been analysed and the incoming data will be analysed on a regular basis. Multiwavelength observations (RXTE) have been triggered and are being studied as well. The first results of this project can be found in the special INTEGRAL A&A issue and in the 5th INTEGRAL Workshop proceedings (accepted for publication).

Publications:

1. A. Paizis, T. Courvoisier, O. Vilhu et al. 2004, Proc. of the The 5th INTEGRAL Workshop, The INTEGRAL Universe (astro-ph/0405376)

2. A. Paizis, V. Beckmann, T. Courvoisier, et al. 2003, A&A 411, 363

3. O. Vilhu, L. Hjalmarsdotter, A. A. Zdziarski, A. Paizis et al. 2003, A&A 411, 405

4. K. Ebisawa, A. Bamba, H. Kaneda, Y. Maeda et al., Proceedings of the New Visions of the X-Ray Universe in the XMM-Newton and Chandra Era “26–30” November 2001, The Netherlands.

5.8 GAIA Variable Source Analysis Architecture and Software Coordination and Development

Institute: Observatoire de Genève
In cooperation with:
19 Institutes across Europe and USA

Principal Investigator: Prof. Michel Grenon

Co-investigators: Dr Laurent Eyer, Prof. Gilbert Burki

Method:

1. Simulation.
2. Satellite.
3. Others: Coordination/Management/software development.

Purpose of research: The GAIA mission has been accepted in 2000 as one of the cornerstones of ESA program and confirmed in its revised version in 2002 for a launch in 2010. The complexity of softwares to reduce the huge data stream represents a challenge of the highest order. One billion stars will have multi-epoch astrometric, photometric and spectroscopic measurements which correspond to a several Peta Byte database size. In order to cope with this complexity, 18 working groups have been created and an iterative study, the GDAAS, has been initiated by the GAIA Science Team (GST).
Software is developed in the framework of GDAAS, as has to be tested in realistic simulations. This study will have implications from the payload definition to the scientific results at the end of the mission. Such a broad study, before launch, is mandatory to ensure a fully successful mission.
The GAIA project scientist Michael Perryman asked our group to lead the Variable Star Working Group (VSWG). Very conservative estimations by Eyer & Cuypers (2000) of the number of «classical » variable stars that will be detected by GAIA lead to 18 million (without including quasars, asteroids and exotic variable objects). The simple identification of those classical variable stars is yet a non-trivial task.
Time series analysis is very time consuming. If Fourier transforms were computed for 10% of the time series in one filter only, it would nowadays take 7000 years, just for computation time (GAIA has 16 photometric channels).
Multibands availability is a unique opportunity to identify the physical process responsible for the variability. Though the analysis can be highly parallelized, thereby reducing computation time, classification of the variable objects is of major difficulty. The analysis shall be tightly adjusted to the GAIA technical specificities.
Variable objects have a twofold nature for the GAIA scientists. On one side, they are the source of great scientific achievements (tests of stellar evolution, tracers of Galactic populations, distance estimators, expansion rate of the Universe tracers), on the other hand they can cause problems (for object matching, for photometric calibrations, for data compression or by introducing biases in astrometry). Therefore a complete treatment of variable stars shall be implemented to identify the benefits as well as the problems generated by variability.
After Hipparcos, ESA is unsurpassed in the domain of large scale astrometric and photometric surveys, two fundamental pillars of Astronomy. Our group has already been deeply involved in the Hipparcos mission. The VSWG task leader position demands knowledge of variability studies, management of large database and implication in management activities. Although, such study will have a large impact on science, our activities are at this step is limited to the identification of approaches, concepts and algorithms to treat the data flow and to envision possible difficulties.

Status:
The Working Group website (`http://obswww.unige.ch/~eyer/VSWG`) summarizes the activities and presents documents related to the tasks of the group.
More specifically:

- A working reference document has been issued.

- Descriptions of the satellite characteristics have been summarized.
- Forecasts about numbers of variable objects to be detected have been made, keeping track of recent works by others researchers.
- Lists of other surveys have been made (past, current, some future surveys will be added soon).
- The information on variable star characteristics is beeing gathered by members of the group.
- The correspondance between the variable type and its behaviour in photometric surveys (Hipparcos and OGLE) is investigated. This work is in progress.
- Data mining methods are listed and partially tested with Self-Organizing maps and Bayesian classifier on Hipparcos, AGAPE and ASAS data.
- Tools were identified, which help to fast investigate the time series (some of them are made available, either in Fortran or SuperMongo)

We have just completed a study with F. Mignard about the detection capability of periodic signals given the irregular sampling of the satellite.
Up to now two meetings have been organized: the kick-off meeting in Nice (December 2003), and the second in Cambridge (April 2004). In October 2004, an other meeting will take place in Paris, just after the GAIA Symposium.
We are now in the phase of writing software to deliver to GDAAS for September 2004.

Publications:

1. GAIA Variable Stars: Work Reference Document (Eyer & Figueras)
2. GAIA in 2003 (collective work)
3. Rate of correct detection of periodic signal with the GAIA satellite (Eyer & Mignard to be submitted to Astronomy and Astrophysics)

Abbreviations:

GDAAS: The Gaia Data Access and Analysis Study
GST: The Gaia Science Team

5.9 The Alpha Magnetic Spectrometer

Institute: DPNC, University of Geneva
In cooperation with: 36 institutions in Europe, USA and Asia

Principal Investigator: S.C.C Ting (MIT)

Co-investigators: M. Pohl (UniGe)

Method: Development and construction of own instruments:
AMS detector with five major instrument subsystems

Purpose of research: AMS will analyse cosmic radiation of galactic and extragalactic origin in Near Earth orbit. A precursor flight on NASA Space Shuttle mission STS-91 took place in June 1998, using the prototype detector AMS-01. The experiment took data during 10 days resulting in about 100 million triggers. This wealth of data already allowed a broad spectrum of physics results both concerning cosmic rays and the Earth's radiation belts. Based on experience gathered during this first mission, a more able detector, AMS-02, is being built. The detector is currently foreseen to be installed on the International Space Station (ISS) in April 2007. The new detector design aims to extend the energy range of the spectrometer into the TeV region and improve on its particle identification capabilities. It is built around a spectrometer with a superconducting magnet, supplemented with particle identification devices like a transition radiation detector, a time-of-flight system, a ring imaging Cerenkov detector, and an electromagnetic calorimeter. Its main physics goals are the search for supersymmetric dark matter, the search for anti-helium and heavy anti-nuclei, origin and propagation of cosmic rays as well as the observation of high energy photons from diffuse and point sources.

Status: The University of Geneva group is contributing to the silicon tracking detector, the core of the spectrometer. The new design of the tracking detector requires the production of a total of 192 ladders with about 2400 silicon sensors. About 75% of those are finished, the complete production including spares will end in the fall of 2004. The Geneva group is now concentrating on the integration of all silicon ladders onto planes, including those produced by INFN Perugia and their industrial partners. Two out of eight planes have already been fully equipped and tested. The remaining six planes will be finished by the end of 2004. The quality of the produced hardware is significantly better than what was available for the AMS-01 mission, due to improved noise characteristics of the silicon sensors and perfectioned handling procedures.
The overall schedule of the AMS project is dictated by the ISS construction schedule as foreseen by NASA. The major milestones of AMS-02 are at this time foreseen as follows:

- An AMS Critical Design Review took place in summer of 2003, and obtained NASA's consent to finish construction of AMS hardware.
- A second safety review is scheduled for the summer of 2004 to confirm NASA consent on mission safety issues.
- The AMS detector will be integrated at CERN during 2005. All subsystems have to be available for integration at that time. A Memorandum of Understanding with CERN concerning integration activities as well the accommodation of AMS science and operations centers at CERN has been signed in 2003.
- By the end of 2006, a thermal vacuum test of the full detector is foreseen at the European Space Agency space simulator facility at ESTEC. Afterwards, AMS hardware is to be delivered to NASA.
- The AMS Crew Operations Post, a small control center for astronaut interventions and a data buffer to cope with situations where the ground link is unavailable, will be launched in summer 2006. At this point, the AMS ground segment needs to be in place for testing.
- The AMS detector itself will be launched in April 2007 according to the current NASA manifest.

Publications:

1. The Alpha Magnetic Spectrometer (AMS) on the International Space Station: Part I - results from the test flight on the space shuttle. M. Aguilar et al., Phys. Rep. 366 (2002) 331–405.

2. The AMS Experiment: Results from AMS-01 and Propects for AMS-02. M. Pohl, Nucl. Phys. Proc. Suppl.122 (2003) 151–160.

3. The AMS Silicon Tracker. W.J. Burger, Nucl. Phys. Proc. Suppl. 113 (2002) 139–146.

5.10 Prototype Synchrotron Radiation Detector

Institute: ETH-Zurich, Laboratory for High Energy Physics [1]
In cooperation with:
RWTH Aachen (Germany) [2]
MIT Cambridge (USA) [3]
Academia Sinica Taipei (Taiwan) [4]
CSIST Lung-Tan (Taiwan) [5]
KNU Taegu (Korea) [6]

Principal Investigator: G. Viertel [1]

Co-investigators:
H. Anderhub [1]; D. Baetzner [1]; A. Biland [1]
C. Camps [2]; M. Capell [3]; V. Commichau [2]
G. Fluegge [2]; O. Grimm [1]; K. Hangarter [2]
H. Hofer [1]; G. N. Kim [6]; V. Koutsenko [3]
M. Kraeber [1]; A. Lebedev [3]; M.W. Lee [6]
S.C. Lee [4]; W. Lustermann [1]; D. Ren [1]
Z.L. Ren [4]; S.C.C. Ting [3]; A. Tiwari [1]
T.S. Wang [5]; B. Zimmermann [1]

Method:

1. Development and construction of own instruments: Detector to measure low energy X-rays and charged particles.

2. Others: NASA Space Shutt

Purpose of research: The Prototype Synchrotron Radiation Detector (PSRD) was designed to provide crucial data for the design of a Synchrotron Radiation Detector (SRD) to be operated on the International Space Station (ISS) during a multi-year mission. The SRD will detect the synchrotron radiation that is emitted by very high-energy electrons and positrons in the earth's magnetic field and thus extends the energy range accessible to tens of TeV. The SRD will detect X-rays in an energy range from 2.5 keV to about 1 MeV with a time resolution better than 10 nsec.
To determine the time resolution needed to overcome the background, the knowledge of the diffuse, low energy X-ray and charged particle background rate is necessary. Since available data is only very sparse and incomplete, the main goal of the PSRD mission is to determine these backgrounds. The PSRD was flown as a secondary payload on the Space Shuttle flight STS-108 in December 2001.

Status: The experiment is completed. The results from the PSRD data have shown that the background of the diffuse X-rays and charged particles is sufficiently low to measure the synchrotron radiation from multi-TeV electrons and positrons, except for the polar regions and the South Atlantic anomaly. The SRD design can be realized. For triggering purpose and to enhance the proton rejection,the SRD will be combined with an electromagnetic calorimeter. This system can be operated efficiently on the ISS during the years of low solar activity and provides a powerful tool to measure separately the electron and positron spectra in an energy range not accessible by any other detector.

Publications:

1. H. Hofer et al., Charge Determination of High Energy Electrons and Nuclei by Synchrotron Radiation with AMS, Nucl. Instr. Meth. A 416 (1998) 59.

2. H. Anderhub et al., Design and construction of the prototype synchrotron radiation detector, Nucl. Instr. Meth. A 491 (2002) 98.

3. B. Zimmermann, Analysis of the Prototype Synchrotron Radiation Detector Data from Shuttle Flight STS-108.

Abbreviations:

AMS:	ALPHA Magnetic Spectrometer
ISS:	International Space Station
PSRD:	Prototype Synchrotron Radiation Deector
SRD:	Synchrotron Radiation Detector
STS:	Space Transport System

5.11 Star and Planet Formation in Taurus and Orion

Institute: Paul Scherrer Institute, Laboratory for Astrophysics
In cooperation with:
Several institutes in Europe and the US

Principal Investigator: M. Güdel (PSI)

Co-investigators:
Taurus XMM-Newton project team (28 members);
associated with CFHT near-IR survey team (PI institute: Grenoble)
and Spitzer Taurus survey team (PI institute: Caltech)

Method:

1. Theory

2. Research based on existing instuments:
XMM-Newton, Chandra, Spitzer (proposed), coordinated with ground-based instruments (VLA, VLBA, CFHT)

Purpose of research: The Taurus Molecular Cloud (TMC) is the nearest galactic star-forming region and has become the standard testbed for star formation theory. Orion is the classic high-mass star formation region. We have started a comprehensive project to deeply study various facets of star and planet formation across all stages of evolution, in particular concentrating at the youngest stages that are accessible only by means of radio, millimeter, infrared, and X-ray

observations. A central point in our project is a closer understanding of high-energy mechanisms in protostars and T Tauri stars associated with large-scale magnetic fields. Feedback mechanisms between X-ray radiation, disk ionization, accretion, and stellar spin-down will be studied. The project also addresses the formation of jets and outflows and the role that magnetic fields may play.

Status: We have been awarded a large XMM-Newton project (630 ksec to observe 19 fields, complementary to several archival observations) designed to perform the first deep X-ray study of the TMC with X-ray detectors up to 10 keV in order to penetrate dense molecular clouds. The observations start in summer 2004.
This survey is complemented with the deepest optical and near-IR survey of the entire TMC, reaching sensitivity levels down to brown dwarf luminosities. These observations are under way and follow-up campaigns have been approved (project performed by the Grenoble team).
A large project (130 hrs in near- and mid-IR) has been submitted to observe TMC with the Spitzer infrared space observatory in a team effort related to the above two projects (decision pending).
Several Chandra observations of jet-driving protostars in TMC and Orion have been obtained. They show X-ray detections that will help understand the disk structure and composition.
Complementary radio and millimeter observations have been proposed or are being conducted.
A large field around the Orion Nebula Cluster has been obtained in X-rays with XMM-Newton. The data sets are being analyzed in the context of relations between activity and rotation in young stars.

Publications:

1. Briggs K., Güdel M., Audard M., Smith K., Mewe R., den Boggende, A.J.F. (2004): X-ray Emission from Young Stars in Suburban Orion. IAU Symposium 219: Stars as Suns: Activity, Evolution, Planets, eds. A.K. Dupree & A.O. Benz, (San Francisco: ASP) in press.

2. Smith K., Pestalozzi M., Güdel M., Conway J., Benz A.O. 2003, VLBI Observations of T Tauri South. Astron. Astrophys., 406, 957.

Abbreviations:

XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)
TMC: Taurus Molecular Cloud

5.12 Particle acceleration and coronal heating

Institute: Paul Scherrer Institut, Laboratory for Astrophysics
In cooperation with:
Columbia University, New York, USA
Integral Science Data Centre, Geneva
University of Colorado, Boulder, USA
SRON, Utrecht, The Netherlands
Center for Astrophysics, Cambridge, USA
California Institute of Technology, Pasadena, USA
Max-Planck-Institut für Radioastronomie, Bonn
Mullard Space Science Laboratory, UK

Principal Investigator: M. Güdel (PSI)

Co-investigators:

K. Arzner (PSI); M. Audard (Columbia); S. Skinner (Colorado)
R. Walter (ISDC); K. Smith (MPIfR Bonn); J. J. Drake (CfA)
V. Kashyap (CfA); R. Mewe (SRON); A. Raassen (SRON)
A. Beasley (Caltech); U. Mitra-Kraev (MSSL)

Method:

1. Theory;
2. Research based on existing instruments:
   XMM-Newton, Chandra, INTEGRAL, EUVE, BeppoSAX, Very Large Array (VLA), Very Large Baseline Array (VLBA);
3. Satellite.

Purpose of research: We study and simulate observational parameters that probe the role of particle acceleration and flare energy release in coronal heating of magnetically active stars. Differential emission measure distributions probe the distribution of plasma in temperature both during flares and during quiescence. Such distributions can be modeled by performing hydrodynamic computer simulations of flare-heated magnetic coronal loops. The accelerated electrons reveal themselves by their observable gyrosynchrotron emission at radio wavelengths. The correlation between radio and optical signatures and X-ray responses yields insight into the role of accelerated particles for coronal heating. Lastly, the statistical distribution of flares in energy as detected in long time series at EUV and X-ray wavelengths are key to our understanding of the importance of flare energy release for the coronal energy budget.

Status: Many data sets have been obtained with X-ray and EUV satellites and ground-based instruments. We have studied several cases of the Neupert effect in coordinated X-ray and radio/optical data of large flares on active stars (i.e., a delay of the X-rays with respect to optical and radio signals), giving strong support for the chromospheric evaporation scenario and impulsive heating by accelerated coronal electrons. A recent observation of Proxima Centauri has given evidence for continual chromospheric evaporation. The increased steady luminosity appears to be a consequence of increased densities due to chromospheric evaporation.
Modeling of the Neupert effect in larger data sets is under way using both combined X-ray/radio and combined X-ray/optical data sets.
INTEGRAL observing time has been approved to study the impact emission from high-energy particles in stellar flares.
In another approach, we have studied the statistical distribution of flares on active stars in EUV and X-ray energy in order to determine the role of small-scale flares ("microflares") in the coronal energy budget. We found that the flare energy distribution favors an important contribution of small flares to the overall coronal heating, to an extent that all of the coronal energy release could be due to flares. Analytic data inversion approaches are being studied.

Publications:

1. Güdel M., Audard M., Kashyap V.L., Drake J.J., Guinan E.F. (2003): Are Coronae of Magnetically Active Stars Heated by Flares? II. EUV and X-Ray Flare Statistics and the Differential Emission Measure Distribution Astrophys.
   J., 582, 423.
2. Güdel M., Audard M., Skinner S.L., Horvath M.I. (2002): X-Ray Evidence for Flare Density Variations and Continual Chromospheric Evaporation in Proxima Centauri Astrophys. J., 580, L73.

3. Güdel M., Audard M., Reale F., Skinner S.L., Linsky J.L. (2004): Flares from Small to Large: X-Ray Spectroscopy of Proxima Centauri with XMM-Newton Astron. Astrophys., in press.

Abbreviations:

BEPPOSAX: Satellite per Astronomia in Raggi X (X-ray satellite, Italy/Netherlands)
EUVE: Extreme Ultraviolet Explorer (NASA)
VLA: Very Large Array (radio; USA)
VLBA: Very Large Baseline Array (radio; USA)
XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)

5.13 The Sun in Time

Institute: Paul Scherrer Institute, Laboratory for Astrophysics
In cooperation with:
Columbia University, New York, USA
Villanova University, Villanova, PA, USA
SRON, Utrecht, The Netherlands

Principal Investigator: M. Güdel (PSI)

Co-investigators:
A. Telleschi (PSI); M. Audard (Columbia)
R. Mewe (SRON); E.F. Guinan (Villanova)

Method:

1. Theory
2. Research based on existing instuments:
   XMM-Newton, Chandra, ROSAT, ASCA, BeppoSAX, FUSE
3. Satellite

Purpose of research: By studying a sample of stars with masses and sizes like the Sun's, but with different rotation periods and thus ages, we can infer the role of declining rotation periods on the operation of the magnetic dynamo in a star like the Sun. By implication, we derive information about the young Sun which are of prime importance for the formation of planetary atmospheres and the prebiotic Earth. We are particularly interested in the much-enhanced high-energy emission (UV, FUV, X-rays) of the young Sun. Satellite observations are required to get access to the relevant data. The project will indicate to what extent the overall magnetic activity level reflects in the coronal heating efficiency, the coronal temperature structuring, and coronal abundances.

Status: From the analysis of a comprehensive sample of ROSAT, ASCA, and EUVE data, we previously derived the temperature stratification of the coronal plasma at different stages of a solar-mass star's evolution. New observations now obtained with XMM-Newton and Chandra complement this picture.
Characteristic temperature decay laws suggest that coronal heating works with an increasing efficiency for increasing activity levels. X-ray spectroscopic means are now providing insight into coronal densities and composition. The coronal composition shows a marked evolution from an iron-poor to an iron-rich state. A deeper investigation of the coronal composition as a function of magnetic activity in the young Sun is currently being conducted in the framework of a PhD project.

Publications:

1. Gaidos E.J., Güdel M., Blake G. A. (2000): The Faint Young Sun Paradox: An Observational Test of an Alternative Solar Model Geophys. Res. Lett. 27, 501.

2. Telleschi A., Güdel M., Arzner K., Briggs K., Audard M., Ness J.-U., Mewe R., Raassen A.J.J., Skinner S.L., Cuntz M., Saar S. (2004): Coronal X-Ray Spectroscopy of Solar Analogs. IAU Symposium 219: Stars as Suns: Activity, Evolution, Planets, eds. A.K. Dupree & A.O. Benz, (San Francisco: ASP) in press.

3. Güdel M., Audard M., Sres A., Wehrli R., Behar E., Mewe R., Raassen A.J.J., Magee H.R.M. (2001): XMM-Newton Probes the Solar Past: Observations of Solar Analogs at Different Ages. in 35th ESLAB Symposium, Stellar Coronae in the Chandra and XMM-Newton Era, eds. F. Favata & J.J. Drake (San Francisco: PASP), 65.

Abbreviations:

XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)

5.14 X-Ray Spectroscopy with XMM-Newton and Chandra

Institute: Paul Scherrer Institute, Laboratory for Astrophysics
In cooperation with:
Columbia University, New York, USA
SRON, Utrecht, The Netherlands
Hamburger Sternwarte, University of Hamburg, Ge
University of Colorado, Boulder, USA
PMOD/WRC, Davos

Principal Investigator: M. Güdel (PSI)

Co-investigators:
A. Telleschi (PSI); M. Audard (Columbia)
R. Mewe (SRON/Utrecht); A. J. Raassen (SRON/Utrecht)
J.-U. Ness (Hamburg); K. van der Hucht (SRON/Utrecht)
E. van den Besselaar (Utrecht); S. L. Skinner (Univ. of Colorado);
W. Schmutz (PMOD/WRC)

Method:

1. Theory

2. Research based on existing instuments:
XMM-Newton, Chandra, cordinated with ground-based instruments (VLA, VLBA)

Purpose of research: XMM-Newton and Chandra provide for the first time high-resolution X-ray spectroscopy of a large number of cosmic sources. X-ray spectra give unique access to the temperature statification of sources, their density, and their composition. We are systematically studying these properties from X-ray spectroscopy of about three dozens of stars, obtained either within the guaranteed time section of XMM-Newton, or within the guest observer programs of XMM-Newton and Chandra. X-ray spectroscopy of hot stars provides a new window to the composition and dynamics of stellar winds.

Status:

Using X-ray lines from various chemical elements, we study effects in the elemental composition of stellar atmospheres, their densities, temperature structure, and opacity. A large "guaranteed project" from XMM-Newton, obtained between 2000-2002, forms the basis of our comprehensive investigation, complemented by several Chandra observations.

Systematic effects in the coronal composition have been investigated with XMM-Newton both on giant stars and on solar analogs, finding various types of First-Ionization Potential Effects (some at variance with those known from the Sun).

A large study of optical depth effects due to line resonance scattering has shown that coronae are effectively optically thin.

We have studied coronal electron densities in a large sample of stars in order to find systematic trends. The results were used to infer general models on coronal structure.

Investigations of hot stars that shed winds show that the conventional picture of homogeneous mass loss with relatively mild heating in shocks does not apply in a number of sources. Very hard spectra point to the presence of extremely hot material. The origin of this plasma is uncertain.

An extended observing campaign of the hot-star binary gamma Velorum has for the first time shown a combination of a collisionally dominated spectrum with a photoionization component.

Publications:

1. Audard M., Güdel M., Raassen A.J.J., Mewe, R. (2003): A Study of Coronal Abundances in RS CVn Binaries. Astron. Astrophys., 398, 1137.

2. Güdel M., Arzner K., Audard M., Mewe R. (2003): Tomography of a Stellar X-Ray Corona: alpha Coronae Borealis. Astron. Astrophys., 403, 155.

3. Ness J.-U., Güdel M., Schmitt J.H.M.M., Audard M., Telleschi A. (2004): On the Sizes of Stellar X-Ray Coronae. Astron. Astrophys., submitted.

Abbreviations:

XMM-NEWTON: X-Ray Multi Mirror Mission (ESA Cornerstone)

5.15 MIRI - MidInfrared Instrument on the James Webb Space Telescope (JWST/NGST) Exploring Origins and Evolution of Stars, Planets, and Galaxies

Institute: Laboratory for Astrophysics at the Paul Scherrer Institut,
5232 Villigen-PSI
In cooperation with:
European Consortium ESA and NASA

Principal Investigator: Dr. Gillian Wright, UK Astronomy Technology Center at the Royal Observatory in Edinburgh

Co-investigators: Dr. A. Zehnder (PSI); PD Dr. M. Güdel (PSI)

Method:

1. Development and construction of own instruments:
   Cryogenic Harness and Contamination Control Cover Mechanism.

2. Satellite.

Purpose of research: The mid-infrared range is one of the astrophysically most interesting but least studied parts of the electromagnetic spectrum. The James Webb Space Telescope (JWST, formerly the "Next Generation Space Telescope") is designed to observe the Universe in the near- and mid-IR wavelength range at unprecedented sensitivity and spatial resolution. Its instruments are fed by a 6.5 m mirror. It will allow to penetrate deep clouds of dust to access objects in their formation phase, namely forming stars, planets, and galaxies. The instruments will obtain first-hand diagnostics of the chemical composition and the basic structure of these young objects. The three instruments on board obtain both imaging and spectroscopy. Our participation in the MIRI mid-IR instrument (performing both spectroscopy and imaging together) will hold promise for our long-term involvement in the area of star and planet formation studies.

Status: Under PRODEX program Phase B is financed. In this period a cryogenic test chamber and the STM harness will be built. PSI is as well responsible for the qualification at a temperature of 7K of the cryomechanics in collaboration with MPIA, Heidelberg
A PhD project has been started at PSI related to the development phase of MIRI and stellar infrared investigations using existing data.

Publications:
None yet (new project)

Abbreviations:

MIRI:	MidInfraRed Instrument
JWST:	James Webb Space Telescope, formerly NGST Next Generation Space Telescope
STM:	Structure and Thermal Model

5.16 Cosmology and Particle Physics

Institute: DPT Uni Geneve
In cooperation with:
GReCO, IAP, Paris, Astrophysics Oxford and others

Principal Investigator: Ruth Durrer

Co-investigators:
Christoph Ringeval; Cyril Cartier; Samuel Leach
Riccardo Sturani; Thierry Baertschiger; Markus Ruser

Method: Theory

Purpose of research: Our research spans from cosmology of the very early universe (where we are mainly interested in observational consequences of string theory and braneworlds) to the analysis and interpretation of cosmological data, especially the cosmic microwave background (CMB) but also the distribution of galaxies, large scale structure (LSS).
It is organized along the following main lines:

- Cosmological consequences of string theory (string cosmology, braneworlds).
- The production of primordial gravitational waves in cosmology.
- Anisotropies and polarization of the cosmic microwave background.
- Primordial magnetic fields and their cosmological implications.
- Non-linear Newtonian gravitational clustering.

Status: We have made some progress, among others in the papers mentioned below, but there are of course still many open questions.

Publications:

1. C. Cartier, R. Durrer and E. Copeland, "Cosmological perturbations and the transition from contraction to expansion", Phys. Rev. D67, 103517 (2003).
2. R. Trotta, A. Riazuelo and R. Durrer, "The Cosmological Constant and General Isocurvature Initial Conditions", Phys. Rev. D67, 063520 (2003).
3. F. Sylos Labini, T. Baertschiger, A. Gabrielli, M. Joyce, "Initial conditions, Discreteness and non-linear structure formation in cosmology", Europhys. Lett. 63, 633 (2003). e-Print archive: `astro-ph/0211058`.

6 Earth resources

6.1 APEX- Airborne Prism Experiment

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
European Space Agency / PRODEX
European Space Agency / EOEP
VITO (Belgium)

Principal Investigator: Prof. Dr. K.I. Itten

Co-investigators: Dr. J. Niek; Dr. W. Debruyn

Method: Development and construction of own instruments: APEX .

Purpose of research: Based on the present demand for airborne and spaceborne imaging spectroscopy data in remote sensing, the European Space Agency (ESA) has initiated a project to build a new generation airborne hyperspectral imager named APEX. APEX is a pushbroom imager with 300 spectral channels, operational in the spectral region from 380 to 2500 nm, and with 1000 pixels across track. It will be flown in an aircraft at operating altitudes between 4 and 10 km having a spatial resolution of 2–5 meters.
The mission objectives of APEX are mainly being a simulator, calibrator, and validator for spaceborne multispectral and hyperspectral instrument (such as SPECTRA). APEX further on shall foster the application development for hyperspectral imaging in Europe and worldwide. The project shall be an European answer to the scientific success of American hyperspectral instruments. Its specifications are state-of-the-art in resolution and overall radiometric performance.

Status: RSL is responsible for the scientific management of the project, for industrial consulting concerning the specialities of imaging spectrometer instrument, and for the construction of the Processing and Archiving Facility (PAF). The latter will be an universal, database driven system supporting the processing and distribution of all APEX data acquisitions. Sophisticated information technology tools are used for a versatile processing system, which will be persistent throughout the operational phase of the instrument.
ESA EOEP has taken the lead within APEX by providing the SWIR detector technology, the calibration home base, and the technical management.
The project is currently in Phase C/D, the first flight is expected for 2005.

Publications:

1. M.E. Schaepman, K.I. Itten, D. Schlaepfer, J.W. Kaiser, J. Brazile,W. Debruyn, A. Neukom, H. Feusi, P. Adolph, R. Moser, T. Schilliger, De Vos, L., G. Brandt, P. Kohler, M. Meng, J. Piesbergen, P. Strobl, J. Gavira, G. Ulbrich, and R. Meynart, APEX: Current status of the airborne dispersive pushbroom imaging spectrometer. Proc. SPIE, Vol. 5234, pp. 202–210. (2003)

2. Schlaepfer D., Kaiser J.W., Brazile J., Schaepman M.E. and Itten K.I., Calibration concept for potential optical aberrations of the APEX pushbroom imaging spectrometer, International Symposium on Remote Sensing. In: Sensors, Systems, and Next Generation Satellites VII. SPIE, Barcelona, Vol. 5234, pp. 221–231. (2003)

3. Schlaepfer D., and Schaepman M., Modelling the noise equivalent radiance requirements of imaging spectrometers based on scientific applications. Applied Optics, OSA41(27):5691–5701. (2002)

Abbreviations:

APEX:	Airborne Prism Experiment
EOEP:	Earth Observation Envelope Programme
PRODEX:	PROgramme de Dévelopement d'EXpériences Scientifiques
RSL:	Remote Sensing Laboratories
SPECTRA:	Surface Processes and Ecosystem Changes Through Response Analysis
VITO:	Vlaamse Instelling voor Technologisch Onderzoek

6.2 Investigation of the Potential of Imaging Spectrometry as an Earth Observation Method for Environmental Analysis

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich

Principal Investigator: Prof. Dr. K.I. Itten

Co-investigators: Dr. M. Kneubuehler; Dr. S. Dangel

Method:

1. Simulation.
2. Theory.
3. Research based on existing instruments:
   - airborne: HyMap, DAIS;
   - spaceborne: MODIS, MISR.
4. Aircraft.
5. Satellite.

Purpose of research: Within this project the potential of imaging spectroscopy as an Earth Observation method for Environmental Analysis is investigated. In the ongoing phase, special emphasis is being put on the quantification of the dynamic representation of the land surface in the framework of the Kyoto Protocol.

The primary goals of the study are the demonstration of the utility of spectro-directional remote sensing data and selected variable estimation algorithms for carbon cycle estimations on the one hand, and the use of field and laboratory goniometer measurements to assess the spectro-directional reflectance properties of ground surface targets on the other hand.

Status: As for the vegetation part, the definition of relevant parameters for carbon cycle estimations derivable from remote sensing data is addressed in an initial phase of the project. The proposed approach shall enable the vegetation product generation as well as the determination of the product uncertainty, a requirement for further use in regional to global ecological and climate change mapping and modelling.
The directional part presently deals with sophisticated methods for adequate preprocessing, measurement, correction and management of spectro-directional remote sensing data. Many applications, such as BRDF (bidirectional reflectance distribution function) correction of remote sensing data heavily depend on the accuracy of such data. The study of the relationship between field and laboratory measurements of spectro-directional effects includes also concepts to improve measurement and correction accuracy.

Publications:

1. Dangel, S., Kneubühler, M., Kohler, R., Schaepman, M., Schopfer, J., Schaepman-Strub, G. & K. Itten, (2003): Combined Field and Laboratory Goniometer System - FIGOS and LAGOS. Proc. IEEE - IGARSS, Toulouse, F.

2. Schaepman, M., Itten, K. & M. Rast (2003): Imaging Spectroscopy as a Quantitative Tool for the Retrieval of Biogeophysical Parameters. Geographica Helvetica, Vol. 58(2), 120–130.

3. Strub, G., Schaepman, M., Knyazikhin, Y. & K.I. Itten (2003): Evaluation of Spectrodirectional Alfalfa Canopy Data Acquired During DAISEX'99. IEEE Transactions on Geosci. and Remote Sensing, Vol. 41, No. 5, 1034–1042.

Abbreviations:

BRDF: Bidirectional Reflectance Distribution Function

6.3 SPECTRA End-to-end Mission Simulator

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
ESA/ESTEC; ALTERRA (NL)
ONERA (F)
ACRI (F)
Universitat de Valencia (E)

Principal Investigator: Prof. Dr. K. I. Itten

Co-investigators: Dr. S. Dangel; Dr. M. Kneubuehler

Method:

1. Simulation.

2. Satellite.

Purpose of research: The goal of the SPECTRA end-to-end mission simulator project is to define and architect a simulator for modelling currently proposed SPECTRA processing. The architecture includes hardware, software and proposals for integration of key modules. This

simulator study makes part of the accompanying scientific studies for SPECTRA, being one of ESA's Earth Explorer Core Missions Candidates presently in Phase A.
As far as the SPECTRA mission is concerned, the response of vegetation to climate variability is a major scientific question. Analyses of the global carbon cycle and of terrestrial ecosystems demonstrate strong links with the observed climatic trends. The monitoring of the carbon stock in terrestrial environments, as well as the improved understanding of the surface-atmosphere interactions controlling their exchanges of matter, energy and momentum, is of immediate interest for an improved assessment of the various components of the global carbon cycle. Studies of the Earth System processes at the global scale rely on models that require an advanced understanding and proper characterisation of processes at smaller scales. The objective of this mission is to improve the description of those processes by means of better constraints on and parameterisations of the associated models.
With SPECTRA a mission is proposed that shall focus on providing the critical information needed to improve biome specific parameterizations of canopy functioning models, for a range of scales from tens of meters to tens of kilometers, and help improve the description of carbon, energy, and water cycles in global models of Earth system processes. It will therefore aim at systematically observing a series of well identified globally distributed sites representing a large range of biomes and ecosystems. A combination of model up-scaling efforts and observations from a panoply of coarse spatial resolution sensors will link this local description of processes to global modeling of the Earth System.
Therefore, the mission must improve the consistency of the biome and ecosystem specific model parameterization when global models are assimilating remote sensing data provided by the series of coarse resolution sensors.
The SPECTRA mission would be characterised by a single satellite - single instrument solution composed of

- a platform anticipated to fly in a near-polar orbit, providing access to all land areas with the required spatial and temporal characteristics, and
- a sensor providing the required radiometric, spectral and directional performance in the visible to the thermal infrared domains.

Status: The first progress meeting of the SPECTRA mission end-to-end simulator Was successfully held in Zurich on January 20, 2004. The second progress Meeting is forseen for July 2004.
The SPECTRA mission has been selected at the "Earth Explorers Granada 2001 User Consultation Meeting" for industrial feasibility studies from 2002–2003.
Presently, SPECTRA is an Earth Explorer Core Mission Candidate to be possibly selected in April 2004 for a Design/Development Study (Phase B).

Publications:

1. ESA (M. Rast (ed.)), SPECTRA - Surface Processes and Ecosystem Changes Through Response Analysis, ESA-Publication SP-1257(5), September 2001.
2. Menenti, M., Rast, M., Baret, F., van den Hurk, B., Knorr, W., Mauser, W., Miller, J.R., Moreno, J.F., Schaepman, M.E., & Verstraete, M.M. (2003) Understanding vegetation response to climate variability from space: recent advances towards the SPECTRA Mission. In Sensors, Systems, and Next-Generation Satellites VII; (eds R. Meynart, S.P. Neeck, H. Shimoda, J.B. Lurie & M.L. Aten), Vol. 5234, pp. 76–85. SPIE, Barcelona.
3. Rast, M. (ed.) (2003): 2nd SPECTRA Workshop, ESA/ESTEC, 28–30. Oct. 2003, ESA SSP, CD-ROM, in print.

Abbreviations:

SPECTRA: Surface Processes and Ecosystem Changes Through Response Analysis

6.4 EO application to hazard mapping

Institute: Gamma Remote Sensing AG

Principal Investigator: A. Wiesmann

Co-investigators: U. Wegmüller; T. Strozzi; C. Werner

Method: Others: EO data processing and interpretation .

Purpose of research: Evaluate potential and develop applications of SAR data for the mapping of natural hazards (forest storm damage, flooding, avalanches, landslides). The main methods used are change detection techniques applied to multi-temporal and interferometric SAR. The research also includes signal processing and modeling aspects. In additions methods to combine the potential of optical and SAR EO data for mapping applications, in particular the mapping of natural hazards, are evaluated.

Status: The related KTI project Combined Remote Sensing Natural Monitoring, CIRSTEN, in co-operation between the Institute of Geodesy and Photogrammetry of the ETH Zürich and GAMMA to combine the potential of optical and SAR EO data for mapping applications, in particular the mapping of natural hazards, with GAMMA's main focus on SAR based applications was finalized in 2002.
The related ESA GSTP Study on Multi-Sensor and Interferometric Retrieval Techniques study (done in cooperation with Joanneum Research, Graz, and the University of Innsbruck) was a two years project (2000–2002) in which GAMMA investigated the potential of remote sensing, and in particular SAR, to map natural hazard events, including forest storm damage, flooding, and avalanches.
In 2002 a project was started to better develop the use of EO based information in the context of disaster management and humanitarian aid projects.
The related ESA DUP Projects ALPS and SLAM focus on the detection and mapping of creeping slopes using differential SAR interferometry. The main application area is the alpine zone.
So far the hazard types investigated included:

- forest storm damage (Lothar);
- avalanche mapping;
- flood mapping;
- and slide mapping.

Publications:

1. Wiesmann A., U. Wegmüller, M. Honikel, T. Strozzi T., and C. Werner, "Hazard mapping with multi-temporal SAR and InSAR", Proc. 3rd Int. Symp. on Retrieval of Bio- and Geophysical Parameters from SAR data for land applications, Sheffield, UK, 11–14 Sep. 2001, ESA SP-475, pp. 133–138, 2002.

2. Wegmüller U., A. Wiesmann, M. Honikel, T. Strozzi T., and C. Werner, "Potential roles for space-borne SAR in disaster management and humanitarian relief", Proc. 3rd Int. Symp. on Retrieval of Bio- and Geophysical Parameters from SAR data for land applications, Sheffield, UK, 11–14 Sep. 2001, ESA SP–475, pp. 307–311, 2002.

3. Strozzi T., U. Wegmüller, C. Werner, and A. Wiesmann, Alpine landslide periodical survey, Proc. IGARSS 2002, Toronto, Canada, pp. 3629–3631, 24–28 June 2002.

Abbreviations:

EO:	Earth Observation
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency
DUP:	Data User Program

6.5 EO application to environmental monitoring

Institute: Gamma Remote Sensing AG
In cooperation with:
VTT-Automation, Finland
European Forest Institute (EFI) Stora Enso, Finland
Univ. Jena, Germany

Principal Investigator: U. Wegmüller

Co-investigators:
C. Schmullius, (Univ. Jena); T. Häme (VTT)
A. Wiesmann; T. Strozziy; C. Werner

Method: Others: EO data processing and interpretation .

Purpose of research: Evaluate potential and develop applications of EO data in the context of environmental monitoring, with one main focus on forest and forest change mapping and the development of carbon monitoring services related to the implementation of the Kyoto protocol. Another focus is on the use of EO data based products as input to carbon cycle and green-house gas models.

Status: In the frame of ESA's programme TESEO (Treaty enforcement services using Earth Observation) a project for the development of carbon monitoring services related to the implementation of the Kyoto Treaty, was successfully proposed by a team lead by VTT-Automation, Finland, with the European Forest Institute (EFI), Stora Enso, Finland, and GAMMA as partners. A project duration of 16 months is planned. GAMMA's responsibilities are to review the potential of existing and near future SAR techniques and sensors and to propose, implement, and demonstrate Kyoto related services.
GAMMA participates in the EC Framework 5 project SIBERIA II (2002–2005), which concentrates on research related to the use of EO data based products as input to carbon cycle and green-house gas models.

Publications:

1. Strozzi T., P. B. G. Dammert, U. Wegmüller, J-M. Martinez, A. Beaudoin, J. Askne, and M. Hallikainen, Landuse mapping with ERS SAR interferometry, IEEE Trans. Geosci. Remote Sensing, Vol. 38, No. 2, pp. 766–775, 2000.

2. Wiesmann A., L. Demargne, F. Ribbes, M. Honikel, H. Yésou, and U. Wegmüller , "Forest storm damage assessment with ERS Tandem data", Proceedings of ERS-ENVISAT Symposium, Gothenburg, Sweden, 16–20 Oct. 2000.

3. Wiesmann A., Wegmüller U., T. Strozzi, and C. Werner, "The use of JERS SAR within the boreal forest mapping project SIBERIA", Proceedings of IGARSS 2000, Honolulu, USA, 24–28 July 2000.

Abbreviations:

EO:	Earth Observation
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency

6.6 EO application to land surface displacement mapping

Institute: Gamma Remote Sensing AG
In cooperation with:
CNR-ISDGM, Venice, Italy
Deutsch Steinkohle DSK
Deutsche Montan Technologie (DMT)

Principal Investigator: T. Strozzi

Co-investigators:
L. Tosi (CNR-ISDGM); V. Spreckels (DSK); N. Benecke (DMT)
U. Wegmüller; C. Werner; A. Wiesmann

Method: Others: EO data processing and interpretation .

Purpose of research: Land surface deformation mapping with differential SAR interferometry. Evaluate potential and develop applications for different types of land surface deformations (subsidence caused by ground-water extraction and natural compaction, mining induced subsidence, glacier motion, land slides, seismic deformation, volcanic deformation).

Status: In the frame of projects supported by the ESA Data User Programme (DUP) and Earth Observation Market Development Programme (EOMD) and GMES GAMMA developed and demonstrated SAR interferometric deformation mapping services. The applications included subsidence caused by ground-water extraction and natural compaction, as well as subsidence related to exploration of the underground resources coal, oil, and gas. The work was supported by contacts to authorities as well as the mining and oil industry. Between Nov. 2001 and Nov. 2003 a land subsidence monitoring service in the lagoon of Venice for regional and administrative authorities, will be developed in cooperation with CNR-ISDGM, Venice, Italy as project partner. Between 2003 and 2006 deformation mapping services for the mining sector will be developed in cooperation with DMT, Essen, Germany.
The interferometric techniques necessary for land slide monitoring are being developed and applied to the Swiss and Italian Alps. First promising results indicate a good potential.

Publications:

1. Wegmüller U., T. Strozzi, and L. Tosi, “Differential SAR interferometry for land subsidence monitoring: methodology and examples”, Proceedings of SISOLS 2000, Ravenna, Italy, 25–29 September 2000.

2. Strozzi T., U. Wegmüller, L. Tosi, G. Bitelli, and V. Spreckels, “Land subsidence monitoring with differential SAR interferometry”, Photogrammetric Engineering and Remote Sensing, Vol. 67, No. 11, pp. 1261–1270, Nov. 2001.

3. Spreckels V., J. Musiedlak, U. Wegmüller, T. Strozzi, and C. Wichlacz, “Detection of underground coal mining-induced surface deformation by differential InSAR data”, ISPRS WG I/2, I/5, IV/7 Workshop on High resolution mapping from space, Hannover, Germany, 19–21 Sep. 2001.

Abbreviations:

EO:	Earth Observation
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency
DUP:	Data User Programm
EOMD:	Earth Observation Market Development Program

6.7 ENVISAT ASAR Calibration and Validation

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
European Space Agency, DLR, Joanneum Research

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators: Dr. E. Meier; Dr. D. Small

Method: Research based on existing instruments: ENVISAT ASAR .

Purpose of research: In this project, RSL works directly with ESA and other partners to calibrate and validate parameters describing the imaging geometry of the advanced synthetic aperture radar (ASAR) instrument on the ENVISAT satellite.
In particular, accurate timing parameters are crucial in guaranteeing a precise geolocation in the processing step known as geocoding. The geocoding process transforms a radar image from its native grid aligned in the satellite along-track (path or azimuth) direction to a conventional map geometry (e.g. Swiss national map coordinates) by solution of range and Doppler equations in combination with cartographic and geodetic transformations.
Accurate geocoding requires acceptably low errors in the estimates of the satellite state vector locations, as well their timing annotations and the sampling window start time (SWST) used to specify the onset of the receive window for recording the reflected echoes of pulses sent previously. The project described here calibrates and validates these timing parameters to reduce geolocation errors for all ASAR users.

Status: Interfaces were constructed to the ENVISAT orbit state vector formats of variable timeliness and quality (predicted, restituted, preliminary, precise). Software for prediction of a ground or transponder position was developed and cross-validated. A semi-automated software process was implemented, whereby the predicted location is compared with a measurement of a strong target in a single-look-complex (SLC) image using a high oversampling factor to enable measurement resolution at a small fraction of the sample size.
The timing parameters associated with across-track (range) and along-track (azimuth) directions of the radar imagery were validated using measurements of the positions of corner reflectors and radar transponders in data sets acquired over the Netherlands, Switzerland, and Canada. Within the scope of this project, a data acquisition campaign was organised involving multiple ASAR passes over corner reflectors placed on the Duebendorf airfield outside of Zurich, Switzerland. Conventional ground control points (bridges, road intersections, etc.) were also measured in some cases for comparison.
These measurements were used to first refine the geometry parameters used in production of ASAR imagery by ESA and then validate the updated values using reprocessed campaign data. Preliminary results were presented at ESA's ENVISAT calibration review and validation

workshops, as well as IGARSS 2003 in Toulouse, France. A detailed final report was provided to ESA at the end of 2003.
For validation, a data set was procured processed with orbital state vectors of precise quality and refined SWST values, including corner reflector and transponder measurements from Switzerland, the Netherlands, and Canada. For all such available data, comparisons of predicted vs. measured image locations confirmed that the the prediction made on the basis of range, Doppler, state vector, and target position (and in the case of transponders, internal delay) was accurate to within the size of a single range sample. Such accuracy is striking (accuracy better than 8m for a satellite at a range of approximately 1x106 m, and is well within the original ENVISAT ASAR specifications. Accuracy in the along-track (azimuth) direction was generally comparable. Possible biases in the azimuth direction are the subject of continuing investigations.

Publications:

1. SMALL D., HOLZNER J., RAGGAM H., KOSMANN D., SCHUBERT A. [2003]: Geometric Performance of ENVISAT ASAR Products, Proc. of IGARSS'03, Toulouse, France, July 21–25, 2003, pp. 1121–1123.

2. SMALL D., SCHUBERT A., KRUTTLI U., MEIER E., NUESCH D. [2003]: Preliminary Validation of ASAR Geometric Accuracy, Proc. of ENVISAT Validation Workshop, Frascati, Italy, Dec. 9-13, 2002 (ESA SP–531, August 2003).

3. SMALL D., KOSMANN D., HOLZNER J., RAGGAM H., PIRRI M., SCHUBERT A., KRUTTLI U., HUMMELBRUNNER W., FRANKE M. [2002]: ASAR Level 1 Geolocation: Preliminary Results, Proc. of ENVISAT Calibration Review, Noordwijk, The Netherlands, Sept. 9–13, 2002.

Abbreviations:

ASA:	Advanced Synthetic Aperture Radar
DLR:	German Aerospace Research Centre
ESA:	European Space Agency
IGARSS:	International Geoscience and Remote Sensing Sypmposium
IM:	ENVISAT ASAR Image Mode
RSL:	Remote Sensing Laboratories
SLC:	Single Look Complex
SWST:	Sampling Window Start Time

6.8 Airborne Ultra-Wideband Low-Frequency SAR

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
armasuisse
Swedish Procurement Agency FOI

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators: Dr. E. Meier; A. Barmettler

Method: Research based on existing instuments:

- airborne;
- sensor: CARABAS (FOI, Sweden).

Purpose of research: In order to complete our research of the extraction of geo- and biophysical parameters from remotely sensed data in general, we are investigating ultra-wide-band SAR (UWB) with a high potential for low fequency imaging radar.
This research project focused on the use of data from the Swedish airborne SAR CARABAS, with transmits and receives radiowaves from 20–90 MHz (HF-/VHF-Band). The wavelength is in the order from 3 to 15 meters, and the electromagnetical waves interact only slightly with the canopy layer. Hence applications relating to the stem of trees (biomass) or to penetrate the canopy layer come to the fore and are being investigated.
Besides looking into the applications of UWB low frequency SAR, the project mainly addresses the processing of the radar raw data to radar maps. Since very long synthetic aperture integration angles (> 90 deg) are required for along track resolution, the motion compensation is one of the key problems.

Status: In late autumn 2003 a flight campaign was conducted with the Swedish low frequency sensor CARABAS. Several missions were flown over three test sites in Switzerland. Each test site had its own scientific goals under investigation. Those are foliage penetration and change detection, biomass estimation, effects of slight topography, rough topography in high alpine regions, imaging of glaciers, and first attempts of subsurface imaging of a cold ice glacier with this radar system. To bring low-frequency SAR in the context of currently better known sensors, the flight campaign took place concurrently along with the multifrequency sensors of DLR's ESAR- system.
Currently, the first data sets are being processed and examined. For that purpose, the processing chain developed at RSL was enhanced to process the image data directly on a high resolution DEM. Hence the image product is directly geocoded.

Publications:

1. BARMETTLER A., MEIER E., NUESCH D. [2001]: Development of an Ultra-Wideband SAR Processor, Proc. of CEOS SAR Workshop 2001, Tokyo, Japan, April 2–5, 2001.

Abbreviations:

DEM:	Digital Elevation Model
HF:	High Frequency
RSL:	Remote Sensing Laboratories, University of Zurich
UWB:	Ultra-Wideband
VHF:	Very High Frequency

6.9 Polarimetric synthetic aperture radar interferometry (Pol-InSAR) in L- and P-band for the extraction of geo- and biophysical parameters

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
German Aerospace Center (DLR)

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators: Dr. E. Meier; O. Stebler

Method:

1. Simulation.
2. Research based on existing instruments:
   - spaceborne;
   - airborne: Experimental SAR (E-SAR/DLR).

Purpose of research: The purpose of this project is to extract geo- and biophysical parameters from experimental airborne Pol-InSAR (polarimetric synthetic aperture radar interferometry) L- (1.3GHz) and P-band (350MHz) data. The Pol-InSAR method requires full polarimetric scattering matrix data at the end of an interferometric baseline. Pol-InSAR improves the performance of conventional (scalar) SAR interferometry (normally used for the generation of digital elevation models) by exploiting the wave polarisation, allowing a more sophisticated physical interpretation of SAR interferograms.
SAR interferometry enables the localisation of the distribution of scattering elements, while Pol-SAR allows to estimate their orientation. If interferometric scattering matrix data are available, complex interferograms of different polarisation states can be related to certain scattering mechanisms. It is the goal of this project to understand these scattering mechanisms of volume scatterers using low system frequencies (i.e. below 1.3GHz) and to describe the physical properties of the scattering media, especially for vegetation covers, characterised by a random volume over a multi-polarising ground.
The inversion problem of Pol-InSAR measurements has to be solved and geo- and biophysical parameters such as topographic heights beneath vegetation covers, vegetation heights/extinction and general geometric properties of vegetation volumes have to be retrieved. Since the airborne E-SAR data are acquired in a (multi-temporal) repeat-pass mode, different baselines (normal distances between flight tracks) are available, allowing a more accurate estimation of the required POL-InSAR parameters.

Status: So far, the Pol-InSAR technique has been successfully applied to the analysis of scattering mechanisms within vegetation volumes. For this reason, further multi-baseline/-frequency Pol-InSAR data sets had been acquired over forested areas in Switzerland. It is one aim of this study to investigate the feasibility of Pol-InSAR P-band (350MHz) measurements for vegetated surfaces.
In the frame of the SASARE project (Swiss Alpine Airborne SAR Experiment) this technique was flown for the first time over an alpine glacier to characterise and to analyse firn, snow, and ice surfaces using the aforementioned Pol-InSAR imaging technique. The multi-baseline and multitemporal SAR flights were carried out in September and October 2003 in the area of the Great Aletsch glacier using the E-SAR operated by the DLR and have been accompanied by several extensive ground truth campaigns. Corner reflectors of various types were mounted in different sub test sites on the glacier (Jungfraufirn, Konkordiaplatz, and Fieschersattel) for calibration and validation purposes of the SAR measurements. In order to perform a rigorous geometric, radiometric, and polarimetric calibration of the acquired data sets and — additionally — to account for displacement errors due to glacier movement the positions of the corner reflectors had been continuously determined by means of differential GPS measurements.
The interferometric acquisition mode of E-SAR will enable to perform change detection (C-band), to produce digital elevation models as a function of frequency (X-, L-, and P-band)

and polarisation (full scattering matrix), to measure surface displacements and/or deformation using differential InSAR, and to estimate penetration capabilities of low-frequent microwaves.
For the vegetation and the glacier test site also low-frequency ultra-wide band data of the Swedish CARABAS sensor had been acquired simultaneously. While using different SAR imaging techniques, the E-SAR and the CARABAS sensors make use of microwave frequencies between 20MHz and 9.6GHz and therefore provide a unique data set for the study of fundamental scattering mechanisms of microwaves interacting with natural surface and volume scatterers.

Publications:

1. STEBLER O., MEIER E., NUESCH D. [2002]: Multi-baseline polarimetric SAR interferometry - first experimental spaceborne and airborne results, ISPRS Journal of Photogrammetry and Remote Sensing (P&RS), 56(3):149–166.

2. STEBLER O., MEIER E., NUESCH D. [2002]: Forward and inverse modelling of multi-baseline L-band Pol-InSAR E- SAR data. Proceedings of the IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 24-28 June 2002, Toronto, Canada, vol. 2, pp. 823–825.

3. STEBLER O., BARMETTLER A., DIVIS L., MEIER E., NUESCH D., [2003]: Swiss Alpine Airborne SAR-Experiment. Activity Report 2003 of the International Foundation HFSJG (High Altitude Research Stations Jungfraujoch and Gornergrat Switzerland).

Abbreviations:

SAR:	Synthetic Aperture Radar
POLSAR:	Polarimetric SAR
INSAR:	Interferometric SAR
POL-INSAR:	Polarimetric InSAR
GPS:	Global Positioning System

6.10 SAR and SAR interferometric algorithms and software research and development

Institute: Gamma Remote Sensing AG

Principal Investigator: C. Werner

Co-investigators: U. Wegmüller; T. Strozzi; A. Wiesmann

Method: Others: EO data processing and interpretation .

Purpose of research: SAR and SAR interferometric algorithms and software research and development as technology push to the development of EO based applications. The activity strongly interacts with GAMMA's EO application development projects. Another objective is to keep GAMMA's high level commercial software package up-to-date.

Status: Recent SAR and SAR interferometric algorithms and software research and development included: the combination (stacking) of multiple interferograms to significantly reduce deformation estimation errors the investigation and development of alternative methods for surface deformation mapping such as intensity and coherence tracking phase unwrapping algorithm development using triangular network and minimum cost flow methods.
In 2001, research and development of a new technique for the interferometric interpretation of the SAR image phase of point targets was started. In 2003 a software package for interferometric point target analysis (IPTA) could be launched.
In 2002 adaptations to the ASAR sensor on ENVISAT, were realized including the development of tools to explore the additional functionality of this new sensor.
Preparations to adapt processing routines to the ALOS PALSAR a Japanese space-borne SAR to be launched in late 2004 have started.

Publications:

1. Werner C., U. Wegmüller, T. Strozzi, and A. Wiesmann, "Gamma SAR and Interferometric Processing Software", Proceedings of ERS-ENVISAT Symposium, Gothenburg, Sweden, 16–20 Oct. 2000.

2. Wegmüller U., C. Werner, T. Strozzi, A. Wiesmann, "Automated and precise image registration procedures", Proceedings of MultiTemp2001 Workshop, Trento, Italy, 13–14 Sep. 2001 (published by World Scientific).

3. Werner C., U. Wegmüller, T. Strozzi, and A. Wiesmann, "Interferometric point target analysis for deformation mapping", Proc. IGARSS 2003, Toulouse, France, 21–25 July 2003.

Abbreviations:

EO:	Earth Observation
SAR:	Synthetic Aperture Radar
ESA:	European Space Agency

6.11 Modelling Concepts and Remote Sensing Methods for Sustainable Water and Land Management of the Okavango Delta, Botswana

Institute: Institute of Geodesy and Photogrammetry (IGP), ETHZ *In cooperation with:*
Institute of Hydrology and Water Resources Management (IHW), ETHZ
Department of Water Affairs, Government of Botswana, Botswana

Principal Investigator: Prof. Dr. A. Grün (IGP), Prof. Dr. W. Kinzelbach (IHW)

Co-investigators:
K. Talukdar (IGP),
Dr. E.P. Baltsavias (IGP), P. Bauer (IHW)

Method: Research based on existing instruments: IKONOS, SPOT 5 HRG, Landsat 7 ETM+, Terra ASTER & MODIS, NOAA-AVHRR

Purpose of research: The Okavango delta in northwestern Botswana is an extremely complex and dynamic wetland ecosystem, facing increasing water demand from all Okavango River basin sharing countries (Angola, Namibia and Botswana). This demand puts the resource under growing pressure and pose intricate management problems. To provide different management scenarios, a hydrological modeling is envisaged under the project. Hydrological modeling requires a number of geophysical and biophysical parameters as input. Important geo- and

bio-physical parameters for the Okavango delta project are digital elevation models (DEM) and landcover features such as islands and spatial extent and dynamics of flooding. At present, however, there is no elevation model with dense grid spacing and high height accuracy available for the Okawango delta. In addition, the delta lacks accurate and reliable information on spatial distribution of islands and the extent and dynamics of flooding. These information can be derived from airborne and spaceborne remote sensing images using modern photogrammetric techniques.

The purpose of this research is to derive topographic surface elevation, i.e. DEM (geophysical parameter), landscape/cover features such as islands (geophysical parameter) and flooded regions (biophysical parameter) information from aerial and spaceborne remote sensing images. The research addresses the following questions:

1. How reliable and accurate can a DEM of a wetland ecosystem be derived from aerial or satellite images (IKONOS and SPOT 5 stereo images) ?

2. How can satellite imaging technology help to:

   (a) delineate different size classes of islands distributed all over the delta ?

   (b) extract multi-temporal information on flooding reliably and accurately ?

   (c) better identify the water-land boundary through fusion of multi- spectral/multi-sensor satellite data ?

The main scientific objective of the study is to investigate methods for automatic derivation of DEM from aerial images as well as IKONOS and SPOT5 stereo images, and for extraction of wetland landscape/cover features (islands and flooded regions) from satellite-based data.

Status: Aerial remote sensing images have been acquired and processed for DEM generation. A field campaign has been carried out to measure ground control points (GCPs) using differential global positioning systems (GPS) technique. A high resolution DEM (10 meter horizontal resolution and better than 1 meter height accuracy) has been derived from aerial images using digital and analytical photogrammetric techniques. The quality of the resulting DEM has been assessed through visual inspection, comparison with ground reference data measured using GPS and sample transects derived from ground-based levelling methods.

Satellite remote sensing images from SPOT5 HRG, Landsat 7 ETM+, Terra ASTER and MODIS, NOAA-AVHRR were acquired and processed. Geocoding of the satellite images has been carried out using GCPs collected by GPS measurements as well as using topographic maps. Different segmentation and classification algorithms are investigated to derive landscape/ landcover features of the delta. New approaches such as texture fusion and quadtree-based image segmentation will be investigated to improve the reliability of image segmentation and classification. The accuracy of the islands and flooded regions extracted from satellite data still needs to be assessed. For this task, existing information and field knowledge will be used. Geostatistical methods will also be investigated for validation of the results.

We are in the process of acquiring IKONOS and SPOT5 stereo images over a sample area of the delta to investigate their potential for generating a high accuracy DEM of a wetland environment. Satellite-based images are a cost-effective way of generating DEMs due to their large ground coverage.

Publications:

1. Bauer, P., Kinzelbach, W., Babusi, T., Talukdar, K., Baltsavias, E. (2002). Modelling Concepts and Remote Sensing Methods for Sustainable Water Management of the Okavango Delta, Botswana. Proc. ISPRS Commission VI Workshop "Developments and Technology Transfer in Geomatics for Environmental and Resource Management", Dar es Salaam, 25-28 March. In: IAPRS, Vol. 34, Part 6/W6, pp. 136-143.

2. Talukdar, K. (2004). Extraction and Classification of Wetland Features through Fusion of Remote Sensing Images in the Okavango Delta, Botswana. Submitted to the XXth International Society for Photogrammetry and Remote Sensing (ISPRS) Congress, Istanbul, Turkey, 12-23 July 2004.

Abbreviations:

ASTER:	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR:	Advanced Very High Resolution Radiometer
DEM:	Digital Elevation Model
ETM+:	Enhanced Thematic Mapper Plus
GCPS:	Ground Control Points
GPS:	Global Positioning Systems
HRG:	High Resolution Geometric
MODIS:	Moderate Resolution Imaging Spectroradiometer
NOAA:	National Oceanic and Atmospheric Administration

7 Atmosphere

7.1 DUP-POLPO ESA Data User Project: Pollution hot-spot monitoring from GOME applied to the Po-basin

Institute: EMPA
In cooperation with:
CNR-ISAO (Italy)

Principal Investigator: A.K. Weiss (EMPA)

Co-investigators:
D. Schaub (EMPA); A. Petritoli (CNR-ISAO)
P. Bonasoni (CNR-ISAO)

Method:

1. Application related method development.

2. Satellite.

Purpose of research: Within the project DUP-POLPO a prototype tool had been developed for monitoring large pollution plumes employing satellite data. It provides additional information to users who have to rely mostly on ground-based measurements, which lack a satisfactory geographical cover. The project combines ground measurements, ground-based remote sensing yielding column measurements, and satellite data, showing the advantages and drawbacks of the three systems and demonstrates the power of combined analysis for air pollution surveillance in several application examples. The usefulness of this combined data, together with meteorological data, is demonstrated by the example of nitrogen dioxide (NO2) plume monitoring, especially for Switzerland and the Po basin area. The work is based on tropospheric NO2 inferred from the satellite-borne GOME instrument, and two mountain stations (Jungfraujoch, Switzerland, and Mt Cimone, Italy).
The potential of the combined data to evaluate the severity, the spread and the origin of the pollution plume is tested. This is of interest for the end users, the Environmental Departments, because emission transport across country boundaries can be observed, which might become important for future emission trading.
The results of DUP-POLPO are example applications for users and an open-source IDL-program for users own applications. DUP-POLPO helps to infer air pollution information from satellite data ground measurements and meteorological wind fields.
Although the results could be similarly applied to other species and regions, this project is restricted to the NO2 pollution from Europe, with special focus on pollution hot spots, which influences air quality in Switzerland and in Italy. For the derivation of this regional information (Switzerland, Northern Italy) we will include data covering the whole of Europe (GOME data and meteorological forecast wind fields). We investigated data of the year 2000 and 2001. This prototype has been applied for tropospheric NO2 from GOME. Similar applications are expected with recently launched satellites, as SCIAMACHY on ENVISAT recording a wide range of species relevant for the Montreal and Kyoto protocols and emission restrictions.

Status: The project has been successfully finished in 11/2002. The results are published on a web-page `http://www.isac.cnr.it/t̃rasfene/POLPO_WEB/Users.html` where potential users can evaluate the potential of using GOME for air pollution purpose. A tool for data visualisation can be downloaded and is provided open source. A handbook and a case study collection guide the users. The project achievements are summarized as following:
Tropospheric GOME data have been demonstrated to be useful under favourable conditions to apply together with meteorological information for case studies. We suggest using GOME either as means of approximately 3 months of data, or to use GOME for selected episodes and processes relevant for tropospheric pollution. However, the conventional ground-based monitoring system, allowing continuous monitoring with higher resolution, cannot be substituted by GOME.
The most serious restriction for the application of GOME is the sparse overpass. Only a few seconds are recorded above Switzerland about every two days. As meteorological processes responsible for transport and spread of pollution have a time scale of a few hours to days, it would be highly desirable to have, e.g., a geostationary satellite providing air quality data. The second intrinsic difficulty is the resolution. The pollution is often inhomogeneously distributed on a small scale (depending on meteorological conditions and on the emission characteristics). GOME resolution is normally considerably coarser. It is sufficient to record the European pollution hot spots, and with summer means under calm conditions the pollution plumes of very large cities can be discerned. Ground measurements provide other information than satellite column measurements. Ground-based remote sensing records the column also, but have the same principal problem of unknown representativity. Because of lacking redundancy, these data can be interpreted t ogether under favourable circumstances (which is a comparable representativity) only. Stations situated in remote areas are suitable for comparison with satellite data, as their representativity is larger. Thirdly, cloud cover restricts the application of GOME. An automated cloud algorithm yielding cloud cover, height and even type (convective or stratus) would be highly desirable together with tropospheric satellite estimates. The POLPO tool lacks this.
Nevertheless, GOME has useful added value information to monitor NO2 transport on a European scale in either one of the conditions of

1. above low-level stratus,
2. during frontal activity and active conveyer belts,
3. when occlusions lift near-to-the ground pollution to the middle troposphere,
4. on cloud-free days.

A conclusion of the project is that modelling has to be extendet to facilitate the application of GOME data. Thus, work is continued in a subsequent project, embedded within the ESA project TEMIS.

Publications:

1. Weiss, A. K., Schaub, D. and Hofer, P. The use of space-borne measurements and the ground-based Swiss monitoring system for tracing atmospheric Pollution, pp 281–289 in: Borell, P, Borell, P.M., Burrows, J. P., Platt, U. (eds) Sounding the troposphere from space. TROPOSAT Final Report. ISBN 3–540–40873–8 Springer, Berlin, Heidelberg, 2004.

2. Petritoli, A., Bonasoni, P., Giovanelli, G., Ravegnani, F., Kostadinov, I., Bortoli, D., Weiss, A. K., Schaub, D., Richter, A., Fortezza, F. First comparison between ground-based and satellite borne measurements of tropospheric nitrogene dioxide in the Po basin. Submitted to JGR 2004.

3. Weiss, A., D. Schaub, A. Petritoli and P. Bonasoni, DUP–POLPO results part I–III, ESA report, Frascati, 2002.

Abbreviations:

CNR:	National Research Council
DOAS:	Differential Optical Absorption Spectroscopy
DUP:	Data User Program
EMPA:	Eidgenössische Materialprüfungs- und Forschungsanstalt (Swiss Federal Laboratories for Materials Testing and Research)
ESA:	European Space Agency
GOME:	Global Ozone Monitoring Experiment, instrument on the ERS-2 satellite
ISAC:	Institute for Atmosphere and Climate, (previous ISAO)

7.2 TEMIS...WP 2.3 Regional NO_2 product. (Tropospheric Emission Monitoring Internet Service)

Institute: EMPA

In cooperation with:

KNMI (TEMIS project leader) and TEMIS consortium

Principal Investigator: TEMIS: R. van der A (KNMI), WP2.3: A. K. Weiss (EMPA)

Co-investigators:

D. Schaub (EMPA); A. Petritoli (CNR-ISAO)

P. Bonasoni (CNR ISAO)

Method:

1. Application related method development.
2. Satellite.

Purpose of research: TEMIS is an ESA Data User Element. The project aims to compute and deliver global concentrations of tropospheric trace gases, and aerosol and UV products derived from observations of nadir-viewing satellite instruments such as GOME, SCIAMACHY and (A)ATSR. TEMIS is part of the Data User Programme (DUP) of the European Space Agency (ESA). The internet service of TEMIS is provided at `http://www.temis.nl/index.html` where users can download their data of interest.

A service is established to compute and deliver global concentrations of tropospheric trace gases. This delivered data base of trace gas concentrations will be important input for subsequent emission estimates of NOx, CH4, CO, aerosols, BrO and hydrocarbons. For the following trace gases potential users and user requirements have been identified: O3, NO2, CH2O, BrO, SO2, H2O, CO and CH4. In addition to these trace gases, users and user requirements of the products aerosols and the UV index have been identified. The implemented service aims at improving current practices of the users. The service consists of sub-services centred around four themes: Air pollution monitoring, UV radiation monitoring, Montreal & Kyoto protocol monitoring and Support to aviation control.

Our sub-service comprises modelling and validation activities (Workpackage 2.3). This provides added value to the satellite observations of hot spots. Trajectories are generated from numerical wind fields to facilitate analysis of the pollution identified by satellite measurements. The aim is the determination of the potential source region.

Status: The TEMIS project is in progress (see `http://www.temis.nl/index.html`). The service is partly already established.
Within our sub-service, images of GOME tropospheric NO2 covering the pollution hot spots are generated automatically. Images showing the SCIAMACHY results are delayed. Trajectories (depicting pathes of air masses) are calculated from numerical wind fields (from ECMWF). These will facilitate analysis of the pollution identified by satellite measurements with respect to the origin of pollution and prepare the determination of the potential source region. The development of the software is in large part finished. Access is granted for users via a wep-page which is in preparation now.

Publications:

1. D. Schaub, A. K. Weiss, J. Kaiser, A. Petritoli, A. Richter, B. Buchmann, and J. P. Burrows. A transboundary transport episode of nitrogen dioxide as observed from GOME and its impact in the Alpine region, submitted to ACP 2004.

Abbreviations:

CNR:	National Research Council
ECMWF:	European Centre for Medium-Range Weather Forecast
EMPA:	Eidgenössische Materialprüfungs- und Forschungsanstalt (Swiss Federal Laboratories for Materials Testing and Research)
GOME:	Global Ozone Monitoring Experiment, instrument on the ERS-2 satellite
ISAC:	Institute for Atmosphere and Climate, (previous ISAO)
SCIAMACHY:	SCanning Imaging Absorption spectroMeter for Atmospheric CartograpHY
TEMIS:	Tropospheric Emission Monitoring Internet Service

7.3 TerraSAR-X: Geometric Error Budget Analysis

Institute: Remote Sensing Laboratories (RSL)
University of Zurich-Irchel
Winterthurerstrasse 190
CH-8057 Zurich
In cooperation with:
German Aerospace Center (DLR)

Principal Investigator: Prof. Dr. D. Nuesch

Co-investigators: Dr. E. Meier; Dr. D. Small; O. Frey; M. Jehle

Method:

1. Simulation.
2. Theory.

Purpose of research:

- Geometric Error Budget Analysis

  This study is focused on geocoding of SAR data. On behalf of the German Aerospace Center (DLR) a geometric error budget analysis for the geocoding procedure of the future TerraSAR-X system has been carried out. We have analyzed the imaging model regarding the high spatial resolution and the ScanSAR mode and defined requirements for a high accuracy terrain geocoding of Spotlight mode data. In particular, we have investigated the

magnitude of potential errors originating from orbit position, datum shift parameters, cartography, geoid models, digital elevation and surface models, sampling window start time, atmospheric refraction and Doppler frequency, and their influence on the geometric accuracy of the geocoded image. In addition, the impact of terrain elevation differences within a SAR scene on the radiometric distortion has been examined in terms of an optimized antenna gain pattern correction.

- Atmospheric Path Delays

  As a result of the geometric error budget analysis study a further task was to estimate in detail the different contributions of path delay of electromagnetic waves traveling through the atmosphere and to develop a software which accounts for this delays.

  We have implemented state of the art models for calculating ionospheric and tropospheric path delays. Well-calibrated spaceborne ENVISAT-ASAR data are used to simulate atmospheric effects and to investigate improvements of the geometry of the scene.

Status: In order to perform the analysis efficiently an error budget analysis tool has been developed in MATLAB. The software comes with a graphical user interface. It features forward and backward geocoding simulation and calculation of error budgets for error sources like orbit position, datum shift parameters, cartography, geoid models, digital elevation and surface models, sampling window start time, atmospheric refraction and Doppler frequency. The geometric error budget analysis has been finished by end of March 2003. The results have been delivered to DLR in the form of a technical note.
The software tool calculating the different contributions of atmospheric path delay was developed in C++. At the current time software-tests are running and formal changes to adapt to the DLR - environment are in progress. First results have been presented and delivered to DLR.

Publications:

1. FREY, O., MEIER, E., NUESCH, D., ROTH A. [2004]: Geometric Error Budget Analysis for TerraSAR-X; Proc. of EUSAR 2004, Ulm, Germany, in print.

2. JEHLE, M., FREY, O., SMALL, D., MEIER, E., NUESCH, D. [2004]: Improved Knowledge of SAR Geometry through Atmospheric Modelling; Proc. of EUSAR 2004, Ulm, Germany, in print.

Abbreviations:

SAR:	Synthetic Aperture Radar
DLR:	German Aerospace Center

7.4 Airborne Millimeterwave Stratospheric Observing System (AMSOS)

Institute: Institute of Applied Physics University of Bern
Sidlerstrasse 5
3012 Bern
Switzerland

Principal Investigator: Dr. Dietrich G. Feist

Method: Research based on existing instuments:
Retrieval of vertical profiles of stratospheric water vapor from atmospheric microwave spectra. The instrument has been constructed at our institute and is used on a campaign basis about once per year.

Purpose of research: Water vapor is one of the most important trace gases is the middle atmosphere. It is involved in a large number of chemical as well as dynamical processes throughout the stratosphere and mesosphere. Water vapor molecules in the atmosphere emit microwave radiation at several distinct frequencies that can be detected with a microwave radiometer. From the shape of the detected lines, the vertical distribution of the water vapor molecules can be derived. This method allows remote sensing of stratospheric water vapor profiles above the instrument in a range of roughly 15–60 km altitude.
Our instrument can be used onboard an aircraft as well as on the ground from a high-altitude site. Operation from an aircraft allows measurements over a large geographical while ground-based operation allows continuous observations over extended periods of time. The observed water vapor profiles show patterns and changes in stratospheric circulation that could be related to global change.

Status: The instrument has been upgraded with a more sensitive receiver, new quasi-optics and new software. Therefore, it has not been in ground-based operation on the International Scientific Station Jungfraujoch as it has been during the previous years. The last flight campaign took place in November 2003 and covered only a small portion of the northern hemisphere. It was mainly a test flight for a much larger campaign in Finland that will take place in the spring of 2004.

Publications:

1. D. Gerber, I. Balin, D. Feist, N. Kämpfer, V. Simeonov, B. Calpin, and H. van den Bergh; Ground-based water vapour soundings by microwave radiometry and Raman lidar on Jungfraujoch (Swiss Alps); Atmos. Chem. Phys. Discuss., 3, pages 4833–4856, 2003.

2. A. Siegenthaler, O. Lezeaux, D. G. Feist, N. Kämpfer; First water vapor measurements at 183 GHz from the high alpine station Jungfraujoch; IEEE Trans. Geosci. Remote Sens., Vol. 39, No. 9, pages 2084–2086, 2001.

3. R. Peter; Stratospheric and mesospheric latitudinal water vapor distributions obtained by an airborne millimeter-wave spectrometer; J. Geophys. Res., Vol. 103, No. D13, pages 16275–16290, 1998.

Abbreviations:

AMSOS: : Airborne Millimeterwave Stratospheric Observing System

7.5 Tunable frequency stabilisation scheme for WALES (Water vapour Lidar Experiment in Space)

Institute: ON - Observatoire Cantonal de Neuchâtel (main contractor)
In cooperation with:
EPFL- NAM (Laboratory of Nanophotonics and Metrology)

Principal Investigator: V. Teodoridis (ON)

Co-investigators:
G. Mileti; R. Matthey; C. Affolderbach (ON)

S. Schilt; D. Werner (ON)
L. Thevenaz (resp. for NAM)

Method: Research based on existing instuments:

1. Development and spectral characterisation of tunable lasers.
2. Molecular, water vapour laser spectroscopy and metrology.
3. Development and construction of a four-wavelengths frequency stabilised laser seeder (TRP)

Purpose of research: The main objective of the ESA WALES (Water Vapour Lidar Experiment from Space) mission is to provide better insights into atmospheric water vapour and aerosol distribution in the upper troposphere and lower atmosphere. To achieve the measurement goals and to meet the scientific objectives a lidar (LIght Detection And Ranging) instrument has been envisaged that will operate following the DIAL (DIfferential Absorption Lidar) technique. Frequency stable and spectrally pure Injection Seed Lasers (ISL) are pivotal components for the implementation of a highly selective lidar instrument. They provide the narrowband signal that controls the wavelength setting precision and frequency drift of the transmitter source.
The goal of this ESA TRP project is to develop a four-wavelength frequency-stabilised laser system (the FDU, Frequency Detection Unit) that will injection seed the power oscillator of the WALES instrument transmitter laser. The properties of the output optical beams of the FDU have to be compatible with the specified DIAL operation in terms of spectral purity (bandwidth, sideband mode rejection, etc.) and frequency accuracy and stability. For this reason, narrow-band and tunable ISLs around 940 nm are being developed and frequency stabilised on a compact water vapour reference cell (the FRU, Frequency Reference Unit).
One of the main difficulties of the project consists to frequency-stabilise three ISLs on water vapour absorption lines of different strengths while the fourth ISLs has to be kept far from these lines, in a well-defined region of the optical spectrum. Innovative and high-performance laser frequency stabilisation techniques have therefore to be developed, implemented and evaluated.
In addition, spectroscopic and metrological studies will be necessary in order to ensure and demonstrate the final FDU performances.
Other issues in view of the later phases of the project have also to be addressed: optical beam geometrical properties, reliability and redundancy, automatic and unattended operation, etc.

Status: After a review on the main technological topics (tunable laser technology, laser frequency stabilisation techniques and water vapour spectroscopy) a preliminary design of the main subsystems (ISLs and FRU) and of the complete FDU has been compeleted. The detailed design is now under progress.
In parallel, a more prospective activity is being held on:

- the spectroscopy of water vapour around 940 nm;
- various laser diode technologies (FP, DBR, DFB, etc.);
- the possible extension of the WALES mission to other trace gas species and wavelengths (CO, CO2, methane, etc.).

Publications:

1. C. Affolderbach, G. Mileti, "Tunable, stabilised diode lasers for compact atomic frequency standards and precision wavelength references", accepted for publication in Optics and Lasers in Engineering, Special issue: Optics in Switzerland (2004)

2. C. Affolderbach, A. Vuillemin, R. Matthey G. Mileti, "Development of tunable, narrow-band, and frequency stabilised laser heads in Observatoire Cantonal de Neuchâtel", accepted for publication in the proceedings of the International Conference of Space Optics (ICSO), Toulouse, France, 2004, ESA Special Publication SP–554 (2004)

3. F. Guerin, Th. Pain, J.L. Palmade, E. Pailharey, D.Giraud, F.Jubineau, "WALES : WATER VAPOUR LIDAR EXPERIMENT IN SPACE", accepted for publication in the proceedings of the International Conference of Space Optics (ICSO), Toulouse, France, 2004, ESA Special Publication SP–554 (2004)

Abbreviations:

DBR:	Distributed Bragg Reflector
DFB:	Distributed Feedback
DIAL:	DIfferential Absorption Lidar
FDU:	Frequency Detection Unit
FP:	Fabry-Perot
FRU:	Frequency Reference Unit
ISL:	Injection Seed Laser
NAM:	Laboratory of Nanophotonics and Metrology (at EPFL)
ON:	Observatoire cantonal de Neuchâtel
WALES:	WAter vapour Lidar Experiment in Space

7.6 Cloudmap2

Institute: Institute of Geodesy and Photogrammetry, ETHZ *In cooperation with:*
UCL (UK) MeteoSwiss (CH)
DLR (D) SMHI (S)
FUB (D) RAL (UK)
KNMI (NL)

Principal Investigator: Prof. Dr. A. Grün

Co-investigators: Dr. G. Seiz, D. Poli, A. Roditakis

Method: Research based on existing instruments: ERS-2 ATSR2, MOMS, EOS-AM1 ASTER and MISR, Meteosat-6/-7; development and construction of own instruments: ground-based multi-camera system

Purpose of research: Current and near-future Earth Observation (EO) data, provided by ESA, EUMETSAT and NASA are used to derive geophysical value-added data products over Europe and the North Atlantic region, whenever possible in near real-time. Ground-based active (cloud radar, ceilometer) and passive (stereo imager system, IR camera) remote-sensing instruments are used to validate the EO-derived products as well as to be merged with the satellite- based results for a full 3D representation of the clouds. Numerical simulation experiments based on state-of-the-art radiative transfer methods are used to quantify the effect of broken clouds on the Earth's radiation budget and lead to a better representation of clouds within NWP models.

The role of ETH in Cloudmap2 is to estimate cloud-top height (CTH) and wind (CTW) from stereo images from satellites and cloud-bottom height (CBH) and wind (CBW) from stereo images acquired by their own ground-based multi-camera imager system, with stereo-photogrammetric techniques. A general sensor model has been developed for the orientation of unrectified images from CCD linear array sensors with along stereo viewing, to allow CTH estimation from unrectified images. The cloud-top and -bottom results are then combined and visualized in 3D.

Status: A sensor model for CCD linear array sensors with along-track stereo viewing has been developed. The model can provide direct or indirect georeferencing. The model was successfully tested on different CCD linear sensors carried on helicopter (Three-Line Sensor by Starlabo) and satellite (MOMS-02, SPOT5, ASTER, MISR).
In order to estimate CTH from satellite-based images, the along- and cross-track parallaxes of stereo pairs are automatically retrieved with the cloud-adapted multi-photo matching algorithm based on least-squares matching, developed at our Institute. The algorithm was applied on ASTER, MISR and ATSR2 images. For a non-moving object, the cross-track parallax is zero (assuming minimal rectification errors) and the CTH can be calculated from the along-track parallax. For a moving object like clouds, the motion within the time delay of acquisition between the two views can contribute significantly to the along-track parallax, depending on the cloud motion direction. A new method was developed in order to correct this motion error with Meteosat-6 Rapid Scan or Meteosat-7 images. Another approach for multi-line sensors like MISR is to use at least three non-symmetric views and estimate CTH and CTW simultaneously.
A ground-based sky imager system consisting of 3 digital cameras with wide-angle lenses has been established. The internal of the cameras has been precisely determinated with close-range calibration, while for the external orientation "sky" ground control points (stars, aircrafts) have been used. The CBH can be estimated from the stereo-images using photogrammetric methods and the cloud-adapted least-squares multi-photo matching.
The satellite- and ground-based stereo cloud height and wind products have been extensively validated with coincident satellite-based products (e.g. MODIS, GOES, Eumetsat SAF), as well as with in-situ (i.e. radiosonde) and ground-based (cloud radar, raman lidar, ceilometer, VIS and IR cameras) measurements.
The estimated CTH and CBH were finally visualized in 3D models. Commercial softwares and other tools available at our institute have been investigated and tested. For animation, particle systems have been used, while for static visualization volume rendering was applied.

Publications:

1. Seiz, G., Baltsavias, E.P., Gruen, A. (2002). Cloud mapping from the ground: use of photogrammetric methods. Photogrammetric Engineering & Remote Sensing (PERS), 68 (9), pp. 941-951.

2. Poli, D. (2003). Georeferencing of MOMS-02 and MISR stereo images with strict sensor model. Submitted paper for ISPRS Workshop "High resolution mapping from space 2003", Hannover, October 2003.

3. Seiz, G. (2003). Ground- and satellite-based multi-view photogrammetric determination of 3D cloud geometry. Ph.D. thesis, Institute of Geodesy and Photogrammetry, ETH Zuerich, Switzerland, Mitteilungen Nr. 80.

Abbreviations:

ASTER:	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ATSR:	Along-Track Scanning Radiometer
CBH:	Cloud-base height
CBW:	Cloud-base wind
CTH:	Cloud-top height
CTW:	Cloud-top wind
GOES:	Geostationary Observational Environmental Satellite
MISR:	Multi-angle Imaging SpectroRadiometer

7.7 Validation of Cloud Top Pressure derived from MSG-SEVIRI observations through a comparison with independent observations

Institute: Institute of Geodesy and Photogrammetry, ETHZ
In cooperation with:
FUB (D)
RAL (UK)
EUMETSAT

Principal Investigator: Prof. Dr. A. Grün

Co-investigators: Dr. G. Seiz, D. Poli

Method: Research based on existing instruments: Envisat AATSR, EOS-AM1 MISR, Meteosat-6/-7/MSG

Purpose of research: The objective of this project is to perform a comprehensive comparison of the MSG-SEVIRI intermediate Cloud-Top Pressure (CTP) product with a number of independent CTP estimations derived from different satellite- or ground- based observations. The spaceborne observations are provided by AATSR, MISR, MODIS and MERIS. Additional comparisons with CTP derived from SEVIRI observations but using different methods (e.g. stereo observations together with Meteosat-5) are helpful to foster the results from the different techniques. However, each observation and each retrieval method has its own characteristics and much can be learned from an inter-comparison of the results. A solid physical understanding of the radiative transfer processes in cloudy atmospheres is needed to interpret the different results and to draw the correct conclusions. The study duration has been divided into three Phases: a Preparatory Phase, an Intensive Analysis Period and the Evaluation and Recommendation part. The partners involved in the project are: Free University of Berlin - Institute for Space Science, ETH Zurich - Institute of Geodesy and Photogrammetry, Rutherford Appleton Laboratory (RAL) - Space Science and Technology Department. ETH will estimate Cloud-Top Height (CTH) from AATSR and MISR. The processing steps include:

1. Radiometric preprocessing of MISR and AATSR images;
2. Point extraction and matching in a suitable number of pyramid levels;
3. Preliminary CTH estimation;
4. CTW estimation with Meteosat-6 Rapid Scan;
5. CTH correction with Meteosat-6 CTW;
6. Final CTH estimation.

Status: During the initial phase of the project (November 2003-January 2004), the partners have performed all preparatory activities before the intensive observation period (phase 2). The satellite instruments used in the study (MODIS, AATSR, MISR and Meteosat6) and the processing tools have been identified and tested on a selected case study (26th December 2003 from 10:30 to 12:00 a.m. over Chilbolton (UK)) with simultaneous ground-based cloud radar measurements. ETH estimated CTH from rectified AATSR and MISR multi-images using algorithms developed at the Institute of Geodesy and Photogrammetry. The along- and cross-track parallaxes of stereo pairs were automatically retrieved with the cloud-adapted multi-photo matching algorithm based on least-squares matching. For a non-moving object, the cross-track parallax is zero (assuming minimal rectification errors) and the CTH can be calculated from the along-track parallax. For a moving object like clouds, the motion within the time delay of acquisition between the two views may contribute significantly to the along-track parallax, depending on the cloud motion direction. In order to correct this motion error, the cloud-top wind East-West and South-North components were estimated from Meteosat-6 Rapid Scan images in coincidence with the MISR and AATSR acquisitions. Another approach for multi-line sensors like MISR is to use at least three non- symmetric views and estimate simultaneously CTH and CTW. In the next phase, CTH will be estimated during an intensive observation period with the duration of one week. The results obtained by the single partners will be compared and used for the SEVIRI-MSG CTP product assessment.

Publications:

1. Fischer, J., Preusker, R., Seiz, G., Poli, D., Grün, A., Poulsen, C., Mutlow, C., Tjemkes, S. A., Borde, R., de Smet, A. (2004): Validation of cloud top pressure derived from MSG-SEVIRI observations through a comparison with independent observations. Eumetsat Users's Conference, Prague (to be published).

2. Seiz, G., Poli, D., Gruen, A. (2004): Stereo Cloud-Top Heights from MISR and AATSR for Validation of Eumetsat MSG Cloud-Top Height products. Eumetsat Users's Conference, Prague (to be published).

3. Seiz, G., Baltsavias, E., Gruen, A. (2003): High-resolution cloud motion analysis with Meteosat-6 Rapid Scans, MISR and ASTER. EUMETSAT Meteorological Satellite Conference, Weimar, 28 September - 3 October, Eumetsat Conference Proceedings (on CD).

Abbreviations:

AATSR:	Advanced Along-Track Scanning Radiometer
CTH:	Cloud-top height
CTP:	Cloud top pressure
CTW:	Cloud-top wind
MISR:	Multi-angle Imaging SpectroRadiometer
MSG:	Meteosat Second Generation
SEVIRI:	Spinning Enhanced Visible and Infrared Imager

7.8 A snow cover map in the Alps for assimilation in operational meso-scale numerical weather prediction and based on MSG data

Institute: Institute of Geodesy and Photogrammetry, ETHZ *In cooperation with:*
MeteoSwiss, Process Models
EUMETSAT

Principal Investigator: Prof. Dr. A. Grün, J. Quiby

Co-investigators:

Dr. M. de Ruyter de Wildt,
Dr. G. Seiz, Dr. E. Baltsavias

Method: Research based on existing instruments: MSG

Purpose of research: For the numerical simulation of atmospheric processes in Numerical Weather Prediction (NWP) Models it is important to correctly model the energy exchange between the ground and the atmosphere, as the energy exchange process impacts heavily on the vertical temperature and humidity structure of the lower troposphere. All the components of the process (short-wave (solar) radiation, long wave (thermal) radiation, momentum flux, latent heat flux and sensible heat flux) are significantly modified when the ground is covered with snow. However, the existing snow input data for meso-scale NWP models are not accurate enough: the data from conventional climate stations are too sparse to fulfil the requirements of the most recent operational high-resolution models. From satellites, it has not been possible so far to get good snow products at the model integration times as only polar-orbiting sensors possessed the necessary spectral channels for snow/cloud separation. EUMETSAT's Meteosat Second Generation (MSG) will help to close this gap; the aim of the project is to obtain the surface snow cover more frequently by using MSG data and to develop a snow product that is valid over alpine terrain.
The objectives of the project are:

- Development of new snow detection algorithms (multi-temporal, multi- spectral, texture-based) to improve the accuracy of snow cover mapping. The new methods will extend the classical pixel-based algorithms with the use of context information.
- Development / extension of MSG snow cover product for alpine terrain.
- Implementation of a processing chain for operational derivation of the MSG snow cover product at NWP initialisation times (00 and 12 UTC).
- Assimilation of MSG-derived snow cover fields in the operational meso- scale NWP model of MeteoSwiss, in co-operation with the model group at MeteoSwiss.

Status: At present, we are in the planning and preparation phase. We set up a preliminary processing scheme for the MSG data, which will be constructed during the next months. Existing methods for satellite-based snow mapping have been studied and screened for their applicability to MSG data.

Abbreviations:

MSG:	Meteosat Second Generation
NWP:	Numerical Weather Prediction

8 Planets

8.1 ASPERA-3/Mars Express: Remote particle sensing of ion populations in Mars' extended atmosphere

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Swedish Space Research Institute, Kiruna, Sweden (R. Lundin, S. Barabash)
Max-Planck-Institut für Aeronomie, Lindau, Germany (J. Woch)
Instituto di Fisica dello Spazio Interplanetari, Rome, Italy (S. Orsini)

Principal Investigator: R. Lundin, Swedish Space Research Institute, Kiruna, Sweden

Co-investigators: P. Wurz; A. Galli; P. Bochsler

Method:

1. Research based on existing instuments:
   The ASPERA-3 instrument on the Mars Express Spacecraft.

2. Satellite.

Purpose of research: The general scientific objective of the ASPERA-3 instrument is to study the solar wind Ð atmosphere interaction and characterize the plasma and neutral gas environment in the near-Mars space through energetic neutral atom (ENA) imaging. The main scientific objectives of the ASPERA-3 instrument are to

- Determine the instantaneous global distributions of plasma and neutral gas near the planet.

- Study the atmospheric escape induced by the highly variable solar wind and solar UV irradiation.

- Investigate the modification of the atmosphere through the solar wind on bombardment.

- Investigate the energy deposition from the solar wind to the ionosphere.

The Neutral Particle Detector (NPD) provides measurements of the ENA flux, resolving velocity and mass (H and O) of the coming particles with a co arse angular resolution.

Status: Mars Express (MEX) was successfully launched on June 2, 2003 and was sent on its journey to Mars. By the end of 2003 planet Mars was reached and successful insertion of the MEX spacecraft into a Mars orbit was accomplished. Since then the MEX orbit was tilted to a polar orbit and the apocentre was reduced to its operational extend of about 11'000 km. During early 2004 commissioning is going on. All sensors of the ASPERA-3 instrument have been turned on during commissioning and their performance appears to be nominal.

Publications:

1. S. Barabash, R. Lundin, H. Andersson, J. Gimholt, M. Holström, O. Norberg, M. Yamauchi, K. Asamura, A.J. Coates, D.R. Linder, D.O. Kataria, C.C. Curtis, K.C. Hsieh, B.R. Sandel, A. Fedorov, A. Grigoriev, E. Budnik, M. Grande, M. Carter, D.H. Reading, H. Koskinen, E. Kallio, P. Riihela, T. Sles, J. Kozyra, N. Krupp, S. Livi, J. Woch, J. Luhmann, S. McKenna-Lawlor, S. Orsini, R. Cewrulli-Irelli, A. Mura, A. Milillo, E. Roelof, D. Williams, J.-A. Sauvaud, J.-J. Thocaven, D. Winningham, R. Frahm, J. Scherer, J. Sharber, P. Wurz, and P. Bochsler, "The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) for the Mars Express Mission", ESA-SP (2004), in press.

2. J.A. Scheer, P. Wurz, and W. Heiland, "Scattering of slow ions from insulator surfaces at the example of molecular oxygen from LiF(100)", Nucl. Instr. Meth. B 212, (2003) 291–296.

3. P. Wurz, "Detection of Energetic Neutral Particles", The Outer Heliosphere: Beyond the Planets, (eds. K. Scherer, H. Fichtner, and E. Marsch), Copernicus Gesellschaft e.V., Katlenburg-Lindau, Germany, (2000), 251–288.

Abbreviations:

ASPERA-3:	Analyzer of Space Plasmas and Energetic Atoms
ENA:	Energetic Neutral Atoms
MEX:	Mars Express
NPD:	Neutral Particle Detector

8.2 ASPERA-4/Venus Express: Remote particle sensing of ion populations in Venus' extended atmosphere

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Swedish Space Research Institute, Kiruna, Sweden
(S. Barabash, R. Lundin, H. Anderson)
Max-Planck-Institut für Aeronomie, Lindau, Germany (J. Woch)
Instituto di Fisica dello Spazio Interplanetari, Rome, Italy (S. Orsini)

Principal Investigator: S. Barabash, Swedish Space Research Institute, Kiruna, Sweden

Co-investigators: P. Wurz; A. Galli; P. Bochsler

Method:

1. Development and construction of own instruments:
   NPD sensor for the ASPERA-4 instrument on the Venus Express mission.

2. Satellite.

Purpose of research: The general scientific objective of the ASPERA-4 instrument is to study the solar wind Ð atmosphere interaction and characterize the plasma and neutral gas environment in the near-Venus space through energetic neutral atom (ENA) imaging. ASPERA-4 is an almost identical copy of the ASPERA-3 instrument an Mars Express. The main scientific objectives of the ASPERA-4 instrument are to

- Determine the instantaneous global distributions of plasma and neutral gas near the planet.

- Study the atmospheric escape induced by the highly variable solar wind and solar UV irradiation.
- Investigate the modification of the atmosphere through the solar wind ion bombardment.
- Investigate the energy deposition from the solar wind to the ionosphere. The Neutral Particle Detector (NPD) provides measurements of the ENA flux, resolving velocity and mass (H and O) of the coming particles with a coarse angular resolution.

Status: The flight models of the sensors for the ASPERA-4 instrument are currently tested at the Swedish Space Research Institute. The hardware contribution from the University of Bern has already been delivered to Swedish Space Research Institute. Launch of the Venus Express spacecraft is foreseen for 9 Novemver 2005 and arrival at Venus will be 153 days later.

Publications:

1. S. Barabash, R. Lundin, H. Andersson, J. Gimholt, M. Holström, O. Norberg, M. Yamauchi, K. Asamura, A.J. Coates, D.R. Linder, D.O. Kataria, C.C. Curtis, K.C. Hsieh, B.R. Sandel, A. Fedorov, A. Grigoriev, E. Budnik, M. Grande, M. Carter, D.H. Reading, H. Koskinen, E. Kallio, P. Riihela, T. Sles, J. Kozyra, N. Krupp, S. Livi, J. Woch, J. Luhmann, S. McKenna-Lawlor, S. Orsini, R. Cewrulli-Irelli, A. Mura, A. Milillo, E. Roelof, D. Williams, J.-A. Sauvaud, J.-J. Thocaven, D. Winningham, R. Frahm, J. Scherer, J. Sharber, P. Wurz, and P. Bochsler, "The Analyzer of Space Plasmas and Energetic Atoms (ASPERA-3) for the Mars Express Mission", ESA-SP (2004), in press.

2. J.A. Scheer, P. Wurz, and W. Heiland, "Scattering of slow ions from insulator surfaces at the example of molecular oxygen from LiF(100)", Nucl. Instr. Meth. B 212, (2003) 291–296.

3. P. Wurz, "Detection of Energetic Neutral Particles", The Outer Heliosphere: Beyond the Planets, (eds. K. Scherer, H. Fichtner, and E. Marsch), Copernicus Gesellschaft e.V., Katlenburg-Lindau, Germany, (2000), 251–288.

Abbreviations:

ASPERA-4:	Analyzer of Space Plasmas and Energetic Atoms
ENA:	Energetic Neutral Atoms
NPD:	Neutral Particle Detector

8.3 Composition of crust, exosphere, surface evolution, formation and evolution of planet Mercury

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Instituto di Fisica dello Spazio Interplanetari, Rome, Italy (S. Orsini)
Swedish Space Research Institute, Kiruna, Sweden (S. Barabash, R. Lundin)

Principal Investigator: P. Wurz, Physikalisches Institut, University of Bern

Co-investigators: W. Benz; P. Bochsler; J. Scheer M. Wieser

Method:

1. Development and construction of own instruments:
   Two mass spectrometers are currently being developed, one for the Planetary Orbiter (MPO) and one for the Magnetospheric Orbiter (MMO) of the BepiColombo Mission for the measurement of the composition of the neutral particles in the planetary environment.

2. Satellite.

Purpose of research: The European Space Agency (ESA) has defined a new Cornerstone Mission, named BepiColombo, for the detailed exploration of planet Mercury. Because of observational difficulties Mercury is a largely unknown planet and therefore a high scientific return is expected from such an exploratory mission. Launch of BepiColombo is foreseen for May 2012 and the transfer to Mercury will take 4.5 years. Thus the dataphase will start beginning of 2017, approximately.
We intend to participate in the BepiColombo mission by developing two mass spectrometers. One mass spectrometer should be placed on BepiColombo/MMO spacecraft to perform Energetic Neutral Atom (ENA) imaging of the space around Mercury, the second instrument should be placed on the BepiColombo/MPO spacecraft to measure the elemental, chemical, and isotopic composition of Mercury's exosphere with a sensitive gas mass spectrometer. With these two instruments we would substantially contribute to three out of the six main scientific goals set for BepiColombo.

Status:
Currently, we perform detailed design studies of the two instruments. In addition, testing of components at the prototype level is also performed for both instruments.
We also created a set of computer models to simulate the Mercury exosphere, the magnetosphere and their interaction with the surface (the regolith) to enhance our understanding of the planet's composition and the processes connecting the exopshere, the magnetosphere and the surface with each other. These models will allow to establish realistic scientific requirements for the performance of the ENA and ion instruments to be developed for MPO and MMO.

Publications:

1. S. Massetti, S. Orsini, A. Milillo, A. Mura, E. De Angelis, H. Lammer, and P. Wurz, "Mapping of the cusp plasma precipitation on the surface of Mercury," Icarus, 166 (2003) 229–237.

2. H. Lammer, P. Wurz, M.R. Patel, R. Killen, C. Kolb, S. Massetti, S. Orsini, and A. Milillo, "The variability of Mercury's exosphere by particle and radiation induced surface release processes," Icarus, 166(2), (2003), 238–247.

3. P. Wurz and H. Lammer, "Monte-Carlo Simulation of Mercury's Exosphere," Icarus, 164(1), (2003), 1-13.

Abbreviations:

ENA:	Energetic Neutral Atom
MPO:	Mercury Planetary Orbiter
MMO:	Mercury Magnetospheric Orbiter

8.4 Miniature mass spectromters for in situ planetary research

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Swedish Space Research Institute, Kiruna, Sweden (S. Barabash, R. Lundin)
ESA Science and Technology Centre (ESTEC) Noordwijk, The Netherlands (R. Schulz)
Max-Planck-Institut für Aeronomie, Lindau, Germany (A. Korth)

Principal Investigator: P. Wurz, Physikalisches Institut, University of Bern

Co-investigators: J.A. Whitby; U. Rohner

Method:

1. Development and construction of own instruments: Laser Mass Spectrometer.

2. Satellite.

Purpose of research: To develop a versatile and highly miniaturised mass spectrometer to derive the elemental (and isotopic), chemical, and mineralogical composition of surface material from planetary bodies. The high miniaturisation will allow to accomodate this instrument even on small rovers (micro-rovers) forseen for in situ exploration of Mars, and possibly of Mercury, Europa, and Titan.

Status: Presently, two prototype mass spectrometer instruments have been realised at the University of Bern, one of the size of a soda can, the second even smaller, of the size of a small coffee cup. Current investigations are focussed on adapting these designs for inclusion of such a mass spectrometer in the scientific payload of the ExoMars mission of ESA and the of the Mars Science Laboratory mission of NASA.

Publications:

1. U. Rohner, J. Whitby, P. Wurz, and S. Barabash, "A highly miniaturised laser ablation time-of-flight mass spectrometer for planetary rover," Rev. Sci. Instr., (2004), in print.

2. U. Rohner, J. Whitby, and P. Wurz, "A miniature laser ablation time-of-flight mass spectrometer for in situ planetary exploration," Meas. Sci. Technol., 14 (2003), 2159-2164.

Abbreviations:

ESA:	European Space Agency
NASA:	National Aeronautics and Space Administration

8.5 Isotopic Abundances of Noble Gases in Lunar Rocks and Soils

Institute: Physikalisches Institut, University of Bern
In cooperation with:
US National Aeronautics and Space Administration

Principal Investigator: O. Eugster, University of Bern

Method: Research based on existing instruments.

Purpose of research: The abundances and isotopic composition of He, Ne, Ar, Kr, and Xe are measured mass spectrometrically in lunar rocks and soils. These investigations are supplemented by determinations of the concentrations of selected elements using neutron activation or ICP mass spectrometry. The purpose of this work is the study of the detailed history of rocks and soils based on cosmic ray effects, and the determination of the times, durations, and burial depths during exposure to cosmic irradiation. The elemental and isotopic composition of the noble gases trapped during rock formation or by implantation of solar wind particles are also measured.

Status: Several solar gas rich lunar soils and breccias have trapped 40Ar/36Ar ratios >10, although solar Ar is expected to yield a ratio of <0.01. Radiogenic 40Ar produced in the lunar crust from 40K decay was outgassed into the lunar atmosphere, ionized, accelerated in the electromagnetic field of the solar wind, and reimplanted into lunar surface material. The 40Ar loss rate depends on the decreasing abundance of 40K. In order to calibrate the time dependence of the 40Ar/36Ar ratio in lunar surface material, the period of reimplantation of lunar atmospheric ions and of solar wind Ar was determined using the 235U-136Xe dating method that relies on secondary cosmic-ray neutron induced fission of 235U. We identified the trapped, fissiogenic, and cosmogenic noble gases in lunar breccia 14307 and lunar soils 70001-8, 70181, 74261, and 75081. Uranium and Th concentrations were determined in the 74261 soil for which we obtain the 235U–136Xe time of implantation of 3.25 Ga ago. On the basis of several cosmogenic noble gas signatures we calculate the duration of this near surface exposure of 393 Ma and an average shielding depth below the lunar surface of 73 g/cm2. A second, recent exposure to solar and cosmic-ray particles occurred after this soil was excavated from the crater named Shorty 17 Ma ago. Using a compilation of all lunar data with reliable trapped Ar isotopi c ratios and pre-exposure times we infer a calibration curve of implantation times, based on the trapped 40Ar/36Ar ratio. A possible trend for the increase with time oft he solar 3He/4He and 20Ne/22Ne ratios of about 12 %/Ga and about 2%/Ga, respectively, is also discussed.

Publications:

1. Eugster O. (1999) : Chronology of dimict breccias and the age of South Ray crater at the Apollo 16 site. Meteorit. Planet. Sci. 34, 385–391.

2. Eugster O., Terribilini D., Polnau E., and Kramers J. (2001) The antiquity indicator 40Ar/36Ar for lunar surface samples calibrated by 235U–136Xe dating. Meteorit. Planet. Sci. 36, 1097–1116.

8.6 Imaging of Mars analogue Materials with the Mars Express Lander (Beagle 2) Camera system

Institute: Natural History Museum Bern (NMBE)
In cooperation with:
Spece-X Neuchâtel; Space Research Centre,
Physics and Astronomy Department, University of LEicester, UK

Principal Investigator: B. Hofmann

Co-investigators:
J.-L. Josset (Space-X), M. Josset (NMBE),
D. Pullan (Univ. Leicester)

Method: Research based on existing instuments (specify): Planetary microcamera identical to the ones on the Mars lander Beagle 2

Purpose of research: A stereo camera system identical to the one on Beagle 2 has been used for test imaging of various terrestrial rocks and minerals, including microbial fabrics from different types of palaeoenvironments: Surface environments (stromatolites) and filamentous fabrics from subsurface environments. Observation distances for rock samples were 60 and 120 cm for stereo images and 8 cm using a close-up lens (providing a resolution of 50 micron/pixel). Illumination is with a day-light lamp providing a light intensity simulating full solar illumination on Mars. At most landing sites on Mars, a variety of rocks may be encountered: active aeolian sediments, loose and indurated soil, sediments, and various igneous and impact-metamorphic rocks, possibly in situ but more likely as loose stones and boulders ejected from impact craters. Access to former subsurface environments is rather easy, therefore. Since the stereo camera system only allows for the discrimination of structures much larger than single microbes, we focus on macroscopic fabrics produced by large numbers of microbes, e.g. stromatolites in surface environments and streamer-like or pseudostalactitic fabrics from subsurface settings. Images taken with the Beagle 2 camera system demonstrate that important characteristics of microbial fabrics can be recognized using current equipment of Mars probes. The use of images with a resolution corresponding to a geologists hand-lens (the close-up lens), and close-up stereo imaging, proved particularly useful. This project was aimed to prepare for the interpretation of Beagle 2 images. After loss of this lander, the observation strategies developped in course of this project are still of use for application during future Mars landing missions.

Status: Test imaging is completed and in lack of immediate application in relation with Beagle 2 the result of this project are currently consolidated and a report is being written. Products will consist of a report, an image library and a Mars analogue reference sample collection. This project ends Sept. 04.

Publications:

1. B. A. Hofmann et al.: Imaging of Mars analogue materials using the Beagle 2 camera system. Proc. 2nd European Workshop on Exo/Astrobiology, Graz, Austria 16-19 Sept. 2002 (ESA SP-518, 387-389).

9 Magnetosphere

9.1 The Low-Energy Neutral Atom Mass Spectrometer for IMAGE

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Goddard Space Flight Center, NASA, Greenbelt, MD, USA (T.E. Moore, F. Herrero)
Lockheed Martin Palo Alto Research Laboratory, CA, USA (S.A. Fuselier)
University of New Hampshire, NH, USA (J. Quinn)

Principal Investigator: J. Burch, PI of IMAGE mission, Southwest Research Institute, TX, USA
Lead Investigator for LENA: T.E. Moore, GSFC/NASA

Co-investigators: P. Wurz, P. Bochsler, M. Wieser

Method:

1. Research based on existing instuments: LENA instrument on the IMAGE spacecraft.
2. Satellite.

Purpose of research: Investigation of the global ion outflow from the high-latitude ionosphere, its relationship to auroral features, and its consequences on magnetospheric processes will be investigated by the IMAGE mission. The investigations are performed via remote particle imaging of low-energy atoms emitted from the plasma volume of interest (LENA instrument). 2D mass- and energy-resolved images on time scales of minutes are the standard data product. The main research topic for the LENA instrument on the IMAGE spacecraft is magnetospheric/ionospheric research and its relationship to solar wind plasma conditions. In addition, the LENA instruments allows to study the neutral solar wind and the inflow of interstellar neutral gas.

Status: The IMAGE spacecraft was successfully launched on March 25, 2000. After reaching the final orbit, commissioning the spacecraft, and initial operations the Òfirst lightÓ image of LENA was recorded on May 5, 2000 demonstrating full functionality of the instrument. Since then LENA operated continously.

Publications:

1. P. Wurz, M.R. Collier, T.E. Moore, D. Simpson, S. Fuselier, and W. Lennartson, “Possible Origin of the Secondary Stream of Neutral Fluxes at 1 AU,” AIP Conference Proceedings (2004) submitted.
2. M.R. Collier, T.E. Moore, D. Simpson, A. Roberts, A. Szabo, S. Fuselier, P. Wurz, M.A. Lee, and B. Tsurutani, "An unexplained $10\frac{1}{4}$–$40\frac{1}{4}$ shift in the location of some diverse neutral atom data at 1 AU," Adv. Space Res. (2003), in press.
3. M.R. Collier, T.E. Moore, K. Ogilvie, D.J. Chornay, J. Keller, S. Fuselier, J. Quinn, P. Wurz, M. Wuest, and K.C. Hsieh, “Dust in the wind: The dust geometric cross section at 1 AU based on neutral solar wind observations,” Solar Wind X, American Institute Physics, 679 (2003), 790–793.

Abbreviations:

LENA:	Low Energy Neutral Atom
IMAGE:	Imager for Magnetopause-to-Aurora Global Exploration

10 Microgravity

10.1 Yeast cells: Stress under microgravity

Institute: Space Biology Group ETHZ
In cooperation with:
Inst. of Anatomy, Univ. Bern, Switzerland

Principal Investigator: Isabelle Walther

Co-investigators: Augusto Cogoli; Otfried Mueller

Method: Others: Shuttle

Purpose of research: This proposal has for first objective to investigate the capacity of the cells to correctly respond to stress factors in microgravity. Two different stress conditions will be investigated: osmotic and temperature shocks; the first involves a transmembrane protein sensor (osmosensing), the second implicates only intracellular reactions. The response will be analysed, when possible, at several levels: gene expression, ultrastructural changes and end point. Due to the importance of cytoskeleton proteins in the organisation of the cell structure and their possible role in the alteration of cells' reaction in space, the reorganisation of the actin protein after an osmotic shock will be especially investigated. To allow the experiments to be repeated after different cultivation times but with cells growing in a steady-state, a small automated chemostat will be developed. This bioreactor will fit in one or several Type I/E containers allowing it to be installed on the reference centrifuge on-board. A maximum of automatic functions will be integrated to reduce to the shortest the hand-on manipulation

Status: The manufacture of the last Bioreactor FM unit is completed, the other elements of the hardware are ready to use. Biological tests have been performed in our laboratory. The amelioration and adaptation of the analyses techniques are finalized. The hardware has been tested in a second EST (Experiment sequence test) in ESTEC, Noordwijk. The first EST could not be performed due to mismatch of the connectors between the multi-user facility Biopack and the ESA standard containers. The experiment was conducted in January 2003 on board of Columbia last flight.

Publications:

1. Walther, I., van der Schoot B. H., Jeanneret S., Arquint P., de Rooij N. F., Gass V. , Bechler B., Lorenzi G. and Cogoli A.: Development of a miniature bioreactor for continuous culture in a space laboratory. J. Biotechnol. 38, (1994), 21– 32.

2. Walther, I., Bechler, B., Müller, O., Hunzinger E., and Cogoli, A.: Cultivation of Saccharomyces cerevisiae in a bioreactor in microgravity. J. Biotechnol. 47, (1996) 113– 127.

3. Walther I., van der Schoot B., Boillat M. and Cogoli A.(2000): Performance of a miniaturized bioreactor in space flight: Microtechnology at the service of space biology. Enzyme Microb. Technol. 27, 778– 783.

Abbreviations:

FM:	Flight unit
EST:	Experiment Sequence Test

10.2 Role of the interleukin-2 receptor in signal transduction and gravi-sensing threshold of T lymphocytes

Institute: Space Biology Group, ETH Zurich
In cooperation with:
ESA/NASA

Principal Investigator: Augusto Cogoli

Co-investigators:
Otfried Müller; University of Bern
Millie Hughes-Fulford, University of California, San Francisco
Proto Pippia, University of Sassari

Method:

1. Development and construction of own instruments:

   Biopack developed and manufactured in collaboration with ESA, HTS and Bradford Engineering. Experiment specific hardware developed by ETHZ.

2. Others: Space Shuttle

Purpose of research: The expression of interleukin-2 receptor (IL-2R) is a key step of T lymphocyte activation. Nearly total loss of T cell activation in real microgravity was discovered in a Spacelab flight in 1983 and was confirmed later by several experiments in space. Thereby, cells appear to undergo apoptosis. Inhibition of IL-2R expression is probably one of the causes of such loss of activation. It is planned to analyse the pathway of mitogenic signal transduction in T cells in true microgravity as well as at variable g-levels between 0 and 1xg. The work will be supported by ground-based experiments with two new instruments, the "random positioning machine (RPM) and the centrifuge free-fall machine" (CFFM).
The objectives of this research project are:

- to investigate selected critical steps of T cell activation;
- to test the hypothesis that a failure in the expression of the IL-2 R is causing the loss of activity in microgravity;
- to identify "windows of sensitivity" to gravity during the activation process;
- to establish thresholds of gravi-sensing in T cells.

The main experimental approach will consist of the activation of cultures of purified peripheral blood lymphocytes with T cell mitogens in real and simulated microgravity. The specific IL-2R mRNA will be quantitatively determined with the reverse transcriptase-polymerase chain reaction (RT-PCR) technology, the insertion of IL-2R in the membrane will be visualised by immunofluorescence and its secretion in the supernatant will be measured by immunoassay. Apoptosis will determined by flow cytometry.
Signal transduction will be further analysed by determining the early expression of the oncogenes c-myc and c-fos. "Windows of sensitivity" to microgravity will be determined by interruptions of the incubation at 1xg with short incubations at 0xg. Finally, by using a variable-g centrifuge, if available, it is planned to identify a gravi-sensing threshold between 0 and 1xg.

Status:

- Biopack facility completed.
- Experiment specific hardware completed.
- Experimental protocol defined.
- Experiment Sequence Test, EST, September 2001.
- EST repetition March 2002.
- Flight preparation Nov-Dec. 2002.
- Flight January 2003.

Publications:

1. Walther I, Pippia P, Meloni MA, Turrini F, Mannu F, Cogoli A (1998) Simulated microgravity inhibits the genetic expression of interleukin–2 and its receptor in mitogen-activated T lymphocytes, FEBS letters, 436, 115–118. Schwarzenberg M, Pippia P, Meloni MA, G. Cossu, M. Cogoli-Greuter, A. Cogoli (1999) Signal transduction in T lymphocytes - A comparison of the data from space, the free fall machine and the random positioning machine. Adv. Space Res. 24, 793– 800.

2. Walther I, Cogoli A, Pippia P, Meloni MA, Cossu G, Cogoli M, Schwarzenberg M, Turrini F, Mannu F (1999) Human immune cells as space travelers. Eur. J. Med. Res. 4, 361– 363.

Abbreviations:

RT-PCR:	Reverse transcriptase - polymerase chain reaction
EST:	experiment sequence test

10.3 ACES: Atomic Clock Ensemble in Space

Institute: Observatoire de Neuchâtel
In cooperation with:
ESA, CNES, Observatoire and ENS-LKB, Paris.

Principal Investigator: Prof C. Salomon,ENS-LKB

Co-investigators: A. Clairon (BNM-SYRTE); A. Jornod, P.Thomann (ON)

Method:

1. Development and construction of own instruments:
   Development and construction of a space hydrogen maser (atomic clock).

2. Satellite (ISS).

Purpose of research: The experiment consists in flying two state-of-the-art atomic clocks on a terrestrial satellite (ISS). One clock, named PHARAO, built by CNES, is based on cold cesium atoms. Due to the the micro-gravity environment, this clock is expected to demonstrate an accuracy and a long-term stability up to ten times better than the best ground clocks, based on cold atom fountains. The other clock, named SHM, built by ON and CSAG, has gravity-independant performance and shows a better frequency stability than PHARAO in the short to medium-term range. It will serve as a flywheel oscillator for the metrological evaluation of the

cold-atom clock, and will complement it to create a tandem clock with unprecedented stability and accuracy. An on-board computer and a dedicated microwave link will allow scientists to perform time and frequency comparisons between the on-board ACES clock and the best available ground clocks worldwide.

The experiment will proceed in two main phases:

In a first, metrological, phase, an evaluation of the cold atom clock in the micro-gravity conditions will be conducted. In this part of the experiment, the hydrogen maser will serve as flywheel oscillator, to measure the dependence of the cold atom clock frequency on its operating parameters, and assess its accuracy and potential long-term stability(goal: 1e–16). Another goal of this evaluation is to improve the precision and accuracy of time comparisons between distant ground clocks, using the ACES clock with its microwave link to the ground as a transportable flywheel clock.

The second phase will be devoted to applications of the clock to fundamental physics: Several tests of postulates and predictions of the special and general theories of relativity will be performed by comparing the frequency of the combined ACES clock with that of ground clocks, via the dedicated microwave link established between the ACES platform and participating ground laboratories.

Using the large altitude difference (350–450km) between the ISS and ground clocks, it will be possible to measure the gravitational redshift, or “Einstein effect” which appears as a relative “slowing down” of time by about 1e–16/meter when nearing the earth surface. The expected precision of this measuement is at the level of a few parts in 1e6, 20 times better than the most precise verification so far, the Gravity Probe A experiment (1976).

In another test, time differences between ACES and ground clocks will be examined for possible correlations with the direction of the line joining the clocks with respect to distant stars. This will allow one to check for the isotropy of the speed of light, as postulated by the special theory of relativity, to a few parts in 1e10, a ten-fold improvement over previous tests.

A postulate of the general theory of relativity is the “constancy of fundamental constants”. As the resonant frequencies of different atomic species depend simultaneously on the fundamental constant alpha - also called the fine–structure constant – and the atomic number Z, any drift of alpha should result in a corresponding mutual drift of atomic clocks based on different atoms. The ACES clock, basically a Cesium clock, will be compared over the duration of the experiment with ground clocks based on e.g. Rubidium or Mercury, and even with optical clocks based on much lighter atoms such as Calcium. The long-term measurements (over 1 year) should provide an estimate of a possible drift of alpha at the level of 1e-16/year. While most estimates or upper bounds evaluated so far apply to a drift averaged over typically billions of years, the ACES experiment would provide an estimate of the “present-day” value.

Status: The instrument is composed of 2 entities: the Physics Package and the Electronics Package. An Elegant BreadBoard of the Electronics Package is presently under evaluation and verification. The validation of this Elegant BreadBoard will allow to release the manufacturing of the Engineering Model (EM) of the Electronics Package. The EM model of the Physics Package is under final manufacturing. Its integration will start by mid 2004. The final integration of the whole EM maser model (Electronics Package EM + Physics Package EM) will take place end of 2004, beginning of 2005.

Then will come the environmental tests (temperature, vibration, electro-magnetic compatibility,...) and the final performance validation of the EM Model. This validation will allow to release the manufacturing of the Proto-Flight Model which will be integrated in ACES experiment to be flown on the ISS.

Publications:

1. Ch. SALOMON et al.: Cold Atoms in Space and Atomic Clocks: ACES C.R. Acad. Sciences Paris, t.2, série IV, pp. 1313–1330, 2001.

2. A.JORNOD, D. GOUJON, D. GRITTI, L.-G. BERNIER*: The SHM-35 Space Qualified Maser: The 35 kg Space Active Hydrogen Maser(SHM–35)for ACES, proc. joint IEEE–FCS/EFTF, Tampa, Fl, May 2003, pp. 81–85.

3. Ph. LAURENT et al.:The Space Clock PHARAO: functioning and expected performances, proc. joint IEEE–FCS/EFTF, Tampa, Fl, May 2003, pp. 179–184.

Abbreviations:

ACES:	Atomic Clock Ensemble in Space
BNM:	Bureau National de Métrologie, France
CNES:	Centre National d'Etudes Spatiales, Toulouse, France
CSAG:	Contraves Space AG, Zürich
EM:	Engineering Model
LKB-ENS:	Laboratoire Kastler-Brossel, Ecole Normale Supérieure, Paris
ISS:	International Space Station
ON:	Observatoire de Neuchâtel
OP:	Observatoire de Paris
PHARAO:	Projet d'Horloge à Atomes Refroidis en Orbite
SHM:	Space Hydrogen Maser
SYRTE:	Système de Référence temps et Espace, BNM and OP, France

11 Solar physics

11.1 Solar flare research with RHESSI

Institute: Paul Scherrer Institut (PSI), Laboratory for Atsrophysics
In cooperation with:
Institut of Astronomy, ETHZ
Aristotle University (AUTH), Thessaloniki
Universite libre de Bruxelles (ULB)Y
University of California at Berkeley (UCLB)

Principal Investigator: Kaspar Arzner (PSI)

Co-investigators:
Arnold Benz (ETHZ); Loukas Vlahos (AUTH)
Bernard Knaepen (ULB), the RHESSI team (PSI, UCLB)

Method:

1. Simulation
2. Research based on existing instuments: RHESSI, Phoenix-2

Purpose of research: Solar flares show violent and sudden X-ray and radio emission. While there is general agreement on the photon emission processes (i.e., bremsstrahlung, gyrosynchrotron emission, or plasma waves which are converted into electromagnetic radiation), the origin of high-energy electrons is still controversial. Possible acceleration mechansims include scattering on MHD type waves, and DC electric fields in reconnection sites. Our investigations are based on two approaches: data analysis and numerical simulations. The latter are supported by theoretical estimates whenever possible. Comparing data from the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) and the frequency-agile Phoenix-2 radiometer at Bleien, Switzerland, we search for co-occurring temporal fine structures which indicate a common electron population responsible for both HXR and radio emissions. On the simulation side, ab-initio particle orbits in turbulent MHD fields with an Ohmic component provide theoretical predictions on acceleration times and energy spectra, and allow to switch on/off individual physical processes in order to investigate their influence, which is not possible for real data.

Status: Prior to the RHESSI launch in February 2002, the investigations were carried out on a purely theoretical and numerical basis. In particular, a percolation model of stochastic acceleration in dissipative MHD turbulence was proposed. As soon as RHESSI data became available, need for additional analysis software arose, which has in the sequel been developed at PSI. The purpose of this software is the identification of temporal fine structures in the RHESSI data, which, owing to the indirect RHESSI imaging principle, poses an inverse problem. Several approaches to solutions have been (and are) followed, with the goal of having different independent methods for benchmarking. The results are then compared to radio (Phoenix-2) data. Up to now, data from Fabruary 2002 to March 2003 have been analysed; later data (and those which are still expected from the current solar cycle) will be treated in the future. On the simulation side, plans for substantially extending the PSI computing facilities will open unprecedented possibilities with regard to real-time duration and size of the simulated systems. The simulations are performed in collaboration with ULB and AUTH.

Publications:

1. Arzner, K., Vlahos, L. (2004): Particle Acceleration in Multiple Dissipation Regions. Astrophys. J. Letters, 605, in press (April 10, 2004 issue).

2. Arzner, K. (2003): Time-Domain Demodulation of RHESSI Light Curves. Solar Phys., 210, 213.

3. K. Arzner (2002): A Percolation Model of Collisionless Runaway in Two-Dimensional Magnetic Turbulence. J. Phys. A: Math. Gen. 35, 3145.

Abbreviations:

MHD:	Magnetohydrodynamics
RHESSI:	Reuven Ramaty High-Energy Solar Spectroscopic Imager

11.2 SOHO/CELIAS: Solar Wind and Suprathermal Particles. Abundances of elements, charge states and isotopes and kinetic properties of heavy ions.

Institute: Physikalisches Institut, University of Bern
In cooperation with:
Max-Planck-Institut für Extraterrestrische
Physik, Garching, Germany
Max-Planck-Institut für Aeronomie, Lindau, Germany
University of Maryland, College Park, NH, USA
University of New Hampshire, Durham, NH, USA

Principal Investigator: Peter Bochsler, Physikalisches Institut, University of Bern

Co-investigators: H. Balsiger; X. Wang; P. Wurz

Method:

1. Research based on existing instuments:

   CELIAS instrument on the SOHO spacecraft.

2. Satellite.

Purpose of research: Investigation of the solar wind composition. Abundances of approximately 20 elements and their isotopes are studied in detail for different solar wind conditions. Diagnostics of coronal conditions with charge state distributions of heavy ions. Study of the temporal evolution of transient events (e.g. Coronal Mass Ejections) in the main energy range of the solar wind and for suprathermal particles.

Status: SOHO was launched on December 2nd, 1995. The CELIAS instrument is still operating nicely. Data anaylsis, interpretation, and modelling are in progress. In addition, post-launch calibration in the Mefisto calibration facility of the University of Bern using the flight spare instrument is under way.

Publications:

1. P. Wurz, P. Bochsler, J.A. Paquette, and F.M. Ipavich, "The Calcium Abundance in the Solar Wind," Astrophys. Jou, 583 (2003), 489–495.

2. M. Uzzo, Y.-K. Ko, J. C. Raymond, P. Wurz, and F. M. Ipavich, "Elemental abundances for the 1996 streamer belt," Astrophys. Jou., 585 (2003) 1062–1072.

3. P. Wurz, R. Wimmer-Schweingruber, P. Bochsler, A. Galvin, J.A. Paquette, and F. Ipavich "Composition of magnetic cloud plasmas during 1997 and 1998," Solar Wind X, American Institute Physics, 679 (2003), 685–690.

Abbreviations:

SOHO: Solar and Heliospheric Observatory
CELIAS: Charge, Element and Isotope Analysis System

11.3 STEREO/PLASTIC: Solar Wind and Suprathermal Particles. Abundances of elements, charge states and isotopes and kinetic properties of heavy ions.

Institute: Physikalisches Institut, University of Bern
In cooperation with:
University of New Hampshire, Durham, NH, USA
Max-Planck-Institut für Extraterrestrische
Physik, Garching, Germany

Principal Investigator: A. Galvin, University of New Hampshire, Durham, NH, USA

Co-investigators: Peter Bochsler; L. Blush; P. Wurz

Method:

1. Development and construction of own instruments: PLASTIC instrument on the two STEREO spacecraft.

2. Satellite.

Purpose of research: The STEREO mission consists of two spacecraft located at Earth orbit, with one spacecraft flying ahead of the Earth and one spacecraft flying behind the Earth, both with increasing distance to the Earth with time. STEREOs main focus is transient events in the solar wind, for example coronal mass ejections, which will be observed from two vantage points, perhaps a third if SOHO is still operating then. The PLASTIC instrument (one on each spacecraft) will perform measurements of the solar wind elemental and charge composition. Diagnostics of coronal conditions with charge state distributions of heavy ions. Study of the temporal evolution of transient events (e.g. Coronal Mass Ejections) in the main energy range of the solar wind and for suprathermal particles.

Status: The University of Bern is building a part of the PLASTIC instrument, namely the entrance system and electrostatic deflector, an ion-optical system to select the energy and arrival direction of the ions. Presently the two flight models and one flight spare unit have been completely manufactured and undergo calibration at the calibration facilities of the University of Bern. After final integration of the instruments these will also be calibrated in Bern before delivery to the spacecraft early 2005.

Publications:

1. L.M. Blush, F. Allegrini, P. Bochsler, A. Galvin, M. Hohl, R. Karrer, L. Kistler, B. Klecker, E. Möbius, M. Popecki, B. Thompson, X. Wang, R.F. Wimmer-Schweingruber, P. Wurz, "Tests and Calibrations of the PLASTIC Entrance System: Design Verification for Flight Models on the STEREO Spacecraft," proceedings of the European Physical Society meeting 2003, European Physical Journal C, (2003), in press.

2. A. Marti, R. Schletti, P. Wurz, and P. Bochsler, "Calibration Facility for Solar Wind Plasma Instruments," Rev. Sci. Instr. 72(2), (2001), 1354–1360.

Abbreviations:

PLASTIC: PLasma and SupraThermal Ion Composition
STEREO: Solar Terrestrial Relations Observatory

11.4 VIRGO Investigation on SOHO

Institute: PMOD/WRC, Davos
In cooperation with Multi-national H/W institutes:
IRMB, Brussels
IAC, Tenerife
SSD of ESA, Noordwjik

Principal Investigator: Claus Fröhlich, PMOD/WRC

Co-investigators:
Andersen B.; Pap J.M.; Appourchaux T.; Provost J.
Berthomieu G.; Roca Cortés T.; Crommelynck D.A.; Rüedi I.
Dewitte S.; Schmutz W.; Domingo V.; Sekii T.
Gough D.O.; Toutain T.; Jiménez A.; Wachter R.
Joukoff A.; Wehrli C.; Leifsen T.; Solanki S.K.

Method: Research based on existing instruments :
Satellite : VIRGO on SoHO

Purpose of research: Solar irradiance variability and Helioseismology with two type of absolute radiometers, sunphotmeters and a luminosity oscillation imager.

Status: Running Experiment on operating spacecraft.

Publications:

1. Appourchaux, T., Fröhlich, C., Andersen, B., Berthomieu, G., Chaplin, W., Elsworth, Y., Finsterle, W., Gough, D., Hoeksema, J., Isaak, G., Kosovichev, A., Provost, J., Scherrer, P., Sekii, T. and Toutain, T. :

   2000, Observational upper limits for low-l solar g modes. Astrophys. J., 538, 401–4.

2. Finsterle W., Fröhlich C.: 2001, Low-order p modes from VIRGO irradiance data Sol. Physics 200, 393–6.

3. Fröhlich, C.: 2003, Long-Term Behaviour of Space Radiometers Metrologia 40, S60–S65

Abbreviations:

VIRGO: Variability of Irradiance and Gravity Oscillations
SOHO: Solar and Heliospheric Observatory

11.5 SOVIM Investigation on the International Space Station

Institute: PMOD/WRC, Davos
In cooperation with H/W institutes
IRMB, Brussels
SSD of ESA, Noordwjik

Principal Investigator: Claus Fröhlich, PMOD/WRC

Co-investigators:
Appourchaux T.; Lean J.; Crommelynck D.A.; Rüedi I.
Dewitte S.; Schmidtke G.; Domingo V.; Schmutz W.
Fleck B.; Thuiller G.; Joukoff A.; Wehrli C.

Method:

1. Development and construction of own instruments :

   2 type of radiometers (PMO6-V, DIARAD), Sun Photometers SPM, Two Axis Sun Sensor TASS.

2. Satellite.

Purpose of research: Solar irradiance variability and spectral redistribution with two type of absolute radiometers and sunphotmeters. SOVIM (continuation of VIRGO, but no helioseismology).

Status: The launch of the Swiss-Belgian experiment SOVIM is scheduled for October 2006. The delivery of the experiment for integration into the Sun tracker built by Alenia is due in June 2004. End of 2003, the manufacturing of the hardware was finished and the instruments (three PMOD radiometers, two Sun photometers, the Two Axis Sun Sensor TASS, and the Belgian radiometer DIARAD) were integrated into the SOVIM package to verify their full functionality at different temperatures in air and vacuum in the context of the complete SOVIM package.

Publications:

1. Thuiller, G., Fröhlich, C. and Schmidtke, G. :

   1999, Spectral and total solar irradiance measurements on board the international space station. Proceedings of the 2nd European Symposium on the Utilisation of the International Space Station.

   ESA Publications Division, ESA SP 433, Noordwijk, The Netherlands, 605-611.

Abbreviations:

SOVIM:	Solar Variability and Irradiance Monitoring
ISS:	International Space Station

11.6 PREMOS - Investigation on the French Satellite PICARD

Institute: PMOD / WRC, Davos
In cooperation with H/W institutes:
Centre National d'Etudes Spatiales
Service d'Aéronomie du CNRS IRMB, Brussels

Principal Investigator: Werner Schmutz, PMODWRC

Co-investigators:

PMOD/WRC : Rozanov E., Rüedi I., Wehrli C.
PI PICARD : Gérard Thuillier

Method: Development and construction of own instruments : three 4-channel filter radiometers.

Purpose of research:

- PREMOS:

  UV irradiance at two selected wavelengths (215 and 265 nm); important for the ozone equilibrium of the terrestrial atmosphere. PREMOS measurements will be used (together with the TSI measurements of PICRAD/SOVAP and the images of PICARD/SODISM) as input for GCM simulations in order to investigate the response of the Earth's atmosphere to solar irradiance variations. In addition, there is a wavelength channels in the visible at 535 nm and the near IR, at 782 nm, to support the goals of PICRAD.

- PICARD aims:

  Confirm diameter variations (and validate ground measurements and their accuracy). Establish relation diameter/global irradiance/differential rotation. Study their variabilities and, if their amplitude allows, detect g-modes. Oblateness measure and solar shape to higher orders (dynamo and convection). Provide Space Weather - solar activity full Sun images with 1" resolution.

Status: The PICARD project is currently frozen by CNES due to financial problems. CNES is expected to decide in July 2004 when PICARD will be reactivated. This delay has forced the PMOD/WRC to reduce the development efforts on PREMOS. The only progress involved a new definition of the data interface between the central control unit and PREMOS and updates of the documentation.

Publications:

1. Thuillier, G., Joukoff, A., Schmutz, W.: 2003, The PICARD mission. Proceedings of the ISCS Symposium, 'Solar Variability as an Input to the Earth's Environment', A. Wilson (ed.), ESA SP-535, Noordwijk: ESA Publications Division, pp. 251–257.

Abbreviations:

PREMOS:	Precision Monitoring of Solar Variability (PMOD/WRC-experiment on the French satellite PICARD)
CNES:	French Space Agency, Centre National d'Etudes Spatiales

11.7 LYRA - Investigation on the ESA Technology Satellite PROBA2

Institute: PMOD / WRC, Davos

In cooperation with:
CSL, IMEC, MPAe<

Principal Investigator: Jean-Francois Hochedez, ROB

Co-investigators:

PMOD/WRC: Werner Schmutz; Eugene Rozanov;
Isabelle Rüedi; Christoph Wehrli

Method:

1. Satellite.
2. Development and construction of own instruments:
   three 4-channel filter radiometer.

Purpose of research: LYRA will monitor the solar irradiance in four UV ranges whose wavelengths were chosen for their relevance to aeronomy, space weather and solar physics:

- Channel 1: Lyman-alpha (121.6 nm).
- Channel 2: 200–220 nm Herzberg continuum range.
- Channel 3: Al filter (17–70 nm) including He II 30.4 nm.
- Channel 4: XUV Zr filter (1-20 nm).

The PMOD/WRC contribution to the experiment is the hardware for three identical instruments (without detectors), the cover mechanism, and the electronics. PROBA-2 is a technology-oriented mission and the innovative parts are newly-developed diamond detectors, which will be used for the first time in space. Diamond is a wide band gap material that renders the sensors "solar-blind". The advantage of solar-blind detectors is that they eliminate the need to block the unwanted visible light with filters if the UV is intended for observation.

Status: Construction of a prototype was started in 2003; it should be finished and ready for operation by the end of May 2004. All interface definitions have been prepared in cooperation with the ESA, the Belgian partners and Verhaert, t he spacecraft contractor. Procurement of the parts for the prototype and the flight model was initiated and the statement of work for several industry tasks to be outsourced to Contraves Space, Zurich was defined. Currently, first functional tests with the prototype parts are in progress. In spring 2004 the preliminary design review will be held and the experiment design fixed. LYRA is subject to a very tight schedule since delivery of the flight model is currently planned for October 2005.

Abbreviations:

CSL:	Centre Spatial de Liège, Belgium
IMEC:	Instituut voor Materiaal Onderzoek, Netherlands
LYRA:	Lyman-alpha Radiometer, experiment on PROBA 2
MPAE:	Max-Planck-Institut für Aeronomie, Lindau, Germany
ROB:	Royal Belgian Observatory

11.8 Isotopic composition of noble gases in the solar wind studied with GENESIS targets

Institute: ETH Zürich, Isotope Geology & Mineral Resources
In cooperation with:
Univ. Bern, Physics; NASA

Principal Investigator: Rainer Wieler

Co-investigators: Fritz Bühler (Univ. Bern); Ansgar Grimberg (ETH)

Method: Research based on existing instuments: noble gas mass spectrometry of returned samples

Purpose of research: The Apollo Solar Wind Composition experiment, collecting noble gas ions from the solar wind in aluminum foils exposed on the Moon, has yielded values on the isotopic composition of helium, neon, and argon which still form the baseline to compare other cosmochemically important reservoirs in the solar system with (meteorites, planetary atmospheres, planetary interiors, etc.). NASA's GENESIS mission is an extension of this experiment, collecting solar wind ions during about 2.5 years in a large variety of target materials. Among many other elements, this will also allow to study the isotopic composition of the heavy noble gases Kr and Xe in the solar wind, as well as to distinguish different solar wind regimes. Sample return is scheduled for September 2004.
One goal of our work on GENESIS targets is to obtain more precise values on the isotopic composition of all five noble gases than have been obtained by the Apollo foils and also by analyses of lunar dust samples. A further goal is to search for a higher-energy component which is indicated based on studies of lunar samples. This so-called SEP-component will be searched in a target material particularly selected for analyses by a noble gas extraction technique developed at ETH. Gas release is by stepwise etching with strong acids in vacuo, followed by on-line mass spectrometric noble gas analysis. The target is a metallic glass allowing a very uniform etching.

Status: We are currently studying the implantation efficiency of noble gas ions of typical solar wind energies in various target materials, as well as the isotopic fractionation upon implantation. We have carried out several artificial implantation experiments in a variety of target materials at the University of Bern. Targets of very low atomic mass (e. g. Al) expected to show negligible backscatter losses will be used for absolute calibrations of ion fluxes. The data will be compared with simulations with the TRIM code, to study the suitability of this code for the low energies relevant for the solar wind. First noble gas analyses of irradiated targets at ETH Z=FCrich show the basic feasibiltiy of this approach.

Publications:

1. Heber V. S., Baur H., and Wieler R. (2003) Helium in lunar samples analyzed by high-resolution stepwise etching: Implications for the temporal constancy of solar wind isotopic composition. Astrophysical Journal 597(1), 602-614.

Abbreviations:

SEP:	solar energetic particles
TRIM:	Transport of ions in matter (computer code)

12 Others

12.1 CCD-Astrometry applied to fast moving objects

Institute: Astronomical Institute University of Bern
In cooperation with:
European Space Agency

Principal Investigator: T. Schildknecht

Method: Research based on existing instruments:
Optical telescopes (1-meter telescope in Zimmerwald, 1-meter ESA telescope in Tenerife)

Purpose of research: The optical astronomy group of the AIUB is primarily conducting optical observations of artificial objects in the geostationary ring (GEO) and in the geostationary transfer (GTO) region. During the previous years a substantial set of observations of GEO objects has been acquired at the Zimmerwald Observatory. This data set consists of repeated astrometric measurements of about a dozen abandoned geostationary satellites. The data is used to investigate the long-term evolution of the orbits of these GEO objects. One particular goal of this work is an independent determination of the geopotential parameters C22 and S22 (Hugentobler et al., 1999).
The CCD-group is also involved in several search campaigns for "unknown" objects in the GEO and the GTO region (Schildknecht et al., 2001). By "unknown" objects in these regions we understand un-controlled, man-made objects, so-called space debris. The term space debris encompasses "dead" satellites, spent rocket upper stages, mission related objects like jettisoned instrument covers, as well as satellite or upper stage fragments from in-orbit explosions. The size of these objects ranges from tens of meters to micrometers. AIUB regularly performs space debris surveys using the 1 m ESA telescope at Izaña, Tenerife (in the context of collaborations with the European Space Agency ESA) and limited test surveys at Zimmerwald.
The results from the GEO space debris surveys revealed a hitherto unknown but significant population of small-sized GEO debris in the size range from one meter to one decimeter. The distribution of this population is steeply increasing towards smaller sizes. The apparent "cutoff" in the number of objects smaller than about 15 centimeters is entirely due to the sensitivity limit of the observation system. The real population of unknown objects smaller than about one decimeter could therefore still increase. The results have been confirmed to a certain extent by the NASA measurements for object sizes around one meter. Measurements for smaller objects in GEO were, however, not yet obtained by any other group. The several clusters of small objects sharing similar dynamical characteristics are the most remarkable result. The only rational explanation for the origin of these clusters are explosions.

Status: Optical observations played an essential role at the Astronomical Institute of the University of Bern (AIUB) since its establishment in 1922. Such observations were first performed at the Muesmatt observatory, then at the Zimmerwald observatory (built 1956 by Prof. Max Schürer). The Zimmerwald observatory was extensively used for astrometric purposes. More than 100 asteroids and a hand full of comets (among them the comet Wild-II, the target of the NASA stardust mission) were discovered in Zimmerwald and named by the discoverer.
The 1-m telescope of the Zimmerwald observatory, inaugurated in 1997, was also designed as an astrometric telescope using the CCD-technique (Charge-Coupled Device). AIUB's astrometry group made extensive use of this facility to develop, as a broad-band facility, the astrometric ob-

servation technique, in particular for observing fast moving objects like artificial Earth satellites, space debris, Near Earth Asteroids (NEAs), etc.
The astrometry group of the AIUB today has a world-leading position in the domain of CCD-Astrometry applied to fast moving objects. This is underlined by the fact that the group developed the software system for ESA's Space Debris Telescope on the island of Tenerife (1-m Zeiss-telescope at the Teide Astrophysical Observatory). Survey campaigns performed at Tenerife, planned jointly by ESA and AIUB, and processed at AIUB using its software, significantly improved the knowledge of the space debris population, in particular in the so-called geostationary belt.
In 2003 the Zimmerwald astrometry facility could be successfully used for the first time to perform a significant number of so-called NEO follow-up observations. In view of the attention this field of celestial mechanics attracts in the scientific community and in public, the observation of NEOs at Zimmerwald should be viewed as a remarkable success.

Publications:

1. Schildknecht, T., R. Musci, M. Ploner, W. Flury, J. Kuusela, J. de Leon Cruz, and L. de Fatima Dominguez Palmero, An Optical Search for Small-Size Debris in GEO and GTO, AMOS Technical Conference, September 9–12, Maui, Hawaii, 2003.

2. Schildknecht, T., Wiedergeburt der traditionellen Himmelsüberwachung und Astrometrie dank moderner Techniken. Orion, No 316, June 2/2003.

3. Hugentobler, U., M. Ploner, T. Schildknecht, G. Beutler, Determination of resonant geopotential terms using optical observations of geostationary satellites, Advances in Space Research, Vol. 23, No. 4, pp. 767–770, 1999.

Abbreviations:

CCD:	Charge-Coupled Device
ESA:	European Space Agency
GEO:	Geostationary Earth Orbit
GTO:	Geostationary Transfer Orbit

12.2 The Zimmerwald Geodynamics Observatory

Institute: Astronomical Institute University of Berne
In cooperation with:
Federal Office of Topography
Federal Institute of Technology
Federal Office of Metrology

Principal Investigator: Werner Gurtner

Co-investigators: Elmar Brockmann

Method: Research based on existing instuments:
Laser telemeter, GPS/GLONASS receivers, optical telescope, gravimeters

Purpose of research: Development, maintenance and operation of instruments for the collection of relevant data to be used in the determination of parameters like station position and velocities, earth rotation, the Earth's gravity field, atmospheric parameters (water vapor, free electron contents of the ionosphere), precise orbits of satellites (navigation/positioning systems, altimeter satellites, gravity missions), detection and tracking of near-earth objects, space debris. For this purpose some of the instruments are running permanently and fully automated

(GPS/GLONASS receivers, earth tide gravimeter), others whenever weather permits (satellite laser ranging telemeter, optical (CCD) observations.

Status: In 1976 a dome with a dedicated Satellite Laser Ranging (SLR) system consisting of a cassegrain telescope, a pulsed laser and the necessary electronic components a was built at the Zimmerwald observatory. In 1997 a 1-meter telescope designed for both SLR and optical observations, a very advanced dual-frequency Laser, new electronics and computers replaced the previous system. Today, the Zimmerwald observatory is one of the most accurate and productive SLR-facilities in the International Laser Ranging Service (ILRS). Currently it is the only facility capable of performing dual-frequency SLR observations on a routine basis. The productivity is mainly due to the advanced observation management, allowing for a quasi-simultaneous multi-satellite tracking and the high degree of automation.
Optical observations are performed using two different high-precision CCD cameras mounted on the same 1-meter telescope.
Depending on the scheduled laser satellites and optical targets the two operating modes are tightly interleaved.
The observatory is equipped with modern GPS (Global Positioning System) receivers, one of which is owned and operated by the Swiss Federal Office of Topography. It is one of the founding stations of the International GPS Service (IGS). Some of the receivers observe, in additon to GPS, also the Russian GLONASS satellite system.
The ETH Zurich owns a so called Earth tide gravimeter to monitor periodic changes of the Earth's gravity field in Zimmerwald.
The Federal Office of Metrology periodically determines the value of the Earth's gravity in Zimmerwald using an absolute (free-fall) gravimeter.

Publications:

1. W. Gurtner, E. Pop, J. Utzinger (2002). " Zimmerwald Dual-Wavelength Observations: First Experiences". Proceedings of the 13th International Workshop of Laser Ranging, Washington, DC, October 7–11, 2002.

2. W. Gurtner (2003). "Die Fundamentalstation Zimmerwald". Orion, No 316, June 2/2003.

3. T. Schildknecht, R. Musci, M. Ploner, J. de Leon Cruz, L. de Fatima Dominguez Palmero.(2001). "Optical Survey for Space Debris in GEO". 52nd International Astronautical Congress, 1–5 Oct 2001, Toulouse, France.

Abbreviations:

IGS:	International GPS Service
ILRS:	International Laser Ranging Service
SLR:	Satellite Laser Ranging
CCD:	Charge-Coupled Device
GPS:	Global Positioning System
GLONASS:	GLObal NAvigation Satellite System

12.3 Precise Orbit Determination for Low Earth Orbiters Using the Global Positioning System

Institute: Astronomical Institute, University of Bern

Principal Investigator: Urs Hugentobler

Co-investigators: Heike Bock; Adrian Jaeggi; Gerhard Beutler

Method: Research based on existing instruments:
Global Positioning System (GPS) tracking data from satellites CHAMP, SAC-C, and JASON-1.

Purpose of research: Low Earth Orbiters (LEOs) are orbiting the Earth at altitudes up to about 2000 km. Modern navigation satellite systems like the Global Positioning System (GPS) are at much higher altitudes, provide a global coverage and may, therefore, be used for determining orbits using spaceborne GPS receivers. In a few years already more than a dozen LEO satellites will be equipped with GPS receivers for precise orbit determination.
Depending on the observation type and the analysis method used, LEO orbits may be established with the accuracy of a few meters, a few decimeters or at the centimeter level. Different applications ask for different methods. Existing and planned missions for acquiring globally distributed atmospheric temperature profiles on a routine basis using the GPS occultation technique require an orbit accuracy of better than 0.1 mm/sec, an accuracy which can be provided by GPS with modern data analysis techniques. For the European GOCE (Gravity Field and Steady State Ocean Circulation Explorer) planned for launch in 2006 to an altitude of only 250 km and measuring the Earth's gravity field with an unprecedented accuracy, an orbit accuracy of 1–2 cm is required, a challenging goal which can only be met with the GPS.

Status: With a sound background in precise orbit determination and GPS data analysis the Astronomical Institute, University of Bern, started in 1999 with the analysis of GPS data from low Earth orbiters. A Ph.D. study (Heike Bock) focused on methods for efficient and robust algorithms for generating reduced-dynamic orbits and kinematic trajectories for low orbiting satellites. The developed methods were tested using data from the satellites CHAMP and SAC-C and allow to determine orbits with an accuracy of about 10 cm.
The Ph.D. candidate Adrian Jaeggi is currently investigating the procedures promising the highest possible orbit accuracies. Validation of reduced-dynamic orbits computed for CHAMP show an orbit accuracy of 3 cm. They show the best orbit quality among all CHAMP orbits contributed by more than a dozen institutions to the Comparison Campaign organized by the IGS (International GPS Service). Further improvements in stochastic orbit determination and inclusion of accelerometer measurements into the data analysis are current study topics.The work is supported by the Swiss National Science Foundation.
In a consortium of ten European institutions the AIUB will participate in the scientific data analysis for ESA's GOCE satellite mission striving for a mapping of the Earth's gravity field with unprecedented accuracy. The AIUB will be responsible for the computation of the precise orbits for the satellite.

Publications:

1. H. Bock (2003). "Efficient Methods for Determining Precise Orbits of LEOs using the GPS". Ph.-D. Thesis, University of Bern.

2. U. Hugentobler, G. Beutler (2003). "Strategies for Precise Orbit Determination for Low Earth Orbiters Using the GPS", in "Earth Gravity Field from Space - From Sensors to Earth Sciences", G. Beutler, M. Drinkwater, R. Rummel, R. von Steiger (Eds.), Space Science Reviews, Kluwer Academic Publishers, 108, 17–26.

3. A. Jaeggi, G. Beutler, U. Hugentobler (2003). "Efficient Stochastic Orbit Modeling Techniques Using Least Squares Estimators", XXIII General Assembly of the IUGG, Sapporo, Japan, June 30–July 11, 2003.

Abbreviations:

AIUB:	Astronomical Institute, University of Bern
GPS:	Global Positioning System
IGS:	International GPS Service
LEO:	Low Earth Orbiter
GOCE:	Gravity Field and Steady State Ocean Circulation Explorer

12.4 Center for Orbit Determination in Europe (CODE)

Institute: Asronomical Institute, University of Bern
In cooperation with:
Swiss Federal Office of Topography, Wabern
Bundesamt für Kartographie und Geodaesie, Frankfurt a.M., Germany
Institut Géographique National, Paris, France

Principal Investigator: Stefan Schaer

Co-investigators: Urs Hugentobler; Rolf Dach; Michael Meindl

Method: Research based on existing instruments:
GPS and GLONASS navigation satellites, IGS global tracking network.

Purpose of research: In the framework of "global change" precise continuous surveying of the Earth's geometrical shape and deformations as well as the realization of a global reference frame at the millimeter level are of crucial importance, e.g., for monitoring sea level changes. Loading processes causing crustal deformations provide independent information, e.g., on the hydrological cycle, studying the Earth's rotation provides insight in motions and mass redistributions in the atmosphere, the oceans, and the deep interior of our planet.
CODE is an Analysis Center of the International GPS Service (IGS). It determines for each day since 21 June 1992 the orbits of all active GPS (Global Positioning System) satellites and the clock corrections of all GPS satellites w.r.t. GPS time. The coordinates of a global network of about 150 tracking sites are computed on a daily basis for studying of vertical site displacements and plate motions, and to provide information for the realization of the International Terrestrial Reference Frame (ITRF). The daily position of the Earth's rotation axis with respect to the Earth's crust as well as the exact length-of-day is determined for each day and provided to the International Earth Rotation and Reference Systems Service (IERS). CODE also produces global map of the total free electron content in the atmosphere for each time interval of two hours.

Status: CODE is operating routinely since June 1992. The processing is currently based on the 30–seconds tracking data of about 150 globally distributed IGS (International GPS Service) tracking sites. The products are computed and made available with latencies between a few hours and one week. Since May 2003 CODE computes precise orbits for the GLONASS navigation satellites, the Russian counterpart of the GPS, as the only IGS analysis center applying a fully combined GPS/GLONASS data analysis. Concrete plans to include data from the future European navigation system GALILEO into the processing are already established. Current investigations include scale and origin of the realization of the ITRF and the influence of satellite antenna phase patterns on the results.
Products with various latencies (few hours to seven days) are available. The accuracy of the GPS orbits is at the 1–3 cm level per satellite coordinate, at the few picoseconds level for the clock corrections. GLONASS orbits have currently an accuracy of 5 cm as confirmed by independent SLR (Satellite Laser Ranging) observations. Station coordinates for about 150 tracking stations are determined with an accuracy of few millimeters in latitude, longitude, and height. The

daily position of the Earth's rotation axis with respect to the Earth's crust is determined with an accuracy of 0.1 mas, the exact length-of-day with an accuracy of 0.01 msec. Time series of Earth rotation parameters are available with high (2–hours) temporal resolution.
Time series of total electron content in the Earth's ionosphere as measured by GPS are available for an entire Solar cycle. The range of values span one order of magnitude between Solar minimum and maximum. Differential code biases for all satellites are monitored and made available for precise navigational applications. More information is available under `http://www.aiub.unibe.ch/igs.html`.

Publications:

1. G. Beutler (2003). "Satellite Navigation Systems for Earth and Space Sciences". Spatium, No 10, June 2003.

2. U. Hugentobler, S. Schaer, T. Springer, G. Beutler, H. Bock, R. Dach, D. Ineichen, L. Mervart, M. Rothacher, U. Wild, A. Wiget, E. Brockmann, G. Weber, H. Habrich, C. Boucher (2002). "CODE IGS Analysis Center Technical Report 2000", in "IGS 2000 Technical Reports", K. Gowey, R. Neilan, A. Moore (Eds.), IGS Central Bureau, JPL, CA, USA, pp. 73–82.

3. M. Meindl, S. Schaer, U. Hugentobler, G. Beutler (2003). "Tropospheric Gradient Estimation at CODE: Results from Global Solutions". Submitted to Journal of Meteorological Society of Japan.

Abbreviations:

CODE:	Center for Orbit Determination in Europe
GPS:	Global Positioning System
GLONASS:	Global Navigation Satellite System
IERS:	International Earth Rotation and Reference Systems Service
IGS:	International GPS Service
ITRF:	International Terrestrial Reference Frame
SLR:	Satellite Laser Ranging

12.5 Ultra Stable Atomic Beam Clock for Telecom Space Applications and Long-Term Space Missions

Institute: Observatoire de Neuchâtel, Switzerland

Method:

1. Development and construction of own instruments:
   Development of an optically-pumped cesium beam frequency standard.

2. Satellite.

Purpose of research: Atomic clocks play a major role in various space applications requiring a stable and/or accurate timing reference source, such as navigation system, telecommunication, long-term mission, and scientific experiments. To a large extent, the performance of the clock is the major limiting factor of the system capabilities.
In the scope of the European Global Navigation Satellite System Galileo, ON has already successfully developed, manufactured and tested the prototypes of the three actual or potential onboard clocks, namely the Lamped-pumped Rubidium Atomic Frequency Standard, the Space Passive

Hydrogen Maser (SPHM) and a Laser-pumped Rubidium Atomic Frequency Standard. While these standards have proven the expected performances, they still suffer from two major limiting factors due to their operation in vapor cell conditions, which are namely the long-term frequency drift and the frequency dependency over the outside temperature change.
The atomic beam frequency standard is an elegant alternative presently in wide use for GPS clocks. A laser-pumped rather than a magnetically deflected atomic beam can even compete with the SPHM in terms of frequency stability. Due to its inherent and simple design, the manufacturing and therefore the reliability of an atomic beam frequency standard can be strongly improved. This project constitutes a fundamental step in the general effort to reduce the mass of the on-board clocks, while keeping or even improving its performances. In particular it takes advantage of the latest progress in the field of tunable and narrow-band laser diodes.
The goal of this project is the frequency stability demonstration ($< 1^{-}12@1s$ and $< 1^{-}14@1d$) of a compact and simple optically pumped atomic beam frequency standard at the breadboard level.

Status: We have completed the initial task "Optical sub-system defintion" by a technical note “Review and Baseline”. This TN has led to a preliminary concept for the feasibility study, which has been accepted by ESA.
The second task “Optical sub-system validation” is under progress. Starting from a past development at ON, we are updating this atomic resonator. We also have procured various laser diodes and optics of the latest technology. The experimental study will consist first in demonstrating that the resonator frequency stability will no longer be limited by the laser frequency noise while using such a new diode. At that stage we forecast that the next performance limitation will arise from the insufficient fluorescence light detection efficiency. This will probably call for an improvement of the collection optics.

Publications:

1. Petit, P., V. Giordano, et al. (1994). “Performance of a 2dm3 optically pumped cesium beam tube: a progress report.” Proc. of the 8th European and Time Frequency Forum: pp. 517–522.

2. Dimarcq, N., V. Giordano, et al. (1991). “Comparison of pumping a cesium beam tube with D1 and D2 lines.” J. Appl. Phys. 69(3): pp. 1158–1162.

3. Thomann, P. and F. Hadorn (1989). “Short-term stability of a commercial optically pumped Cs tube.” Proc. of 1989 European Time and Frequency Forum: pp. 269–273.

Abbreviations:

ON:	Observatoire de Neuchâtel
SPHM:	Space Passive Hydrogen Maser
GPS:	Global Positioning System
ESA:	European Space Agency
TN:	Technical Note

12.6 Laser-pumped Rubidium atomic frequency standard

Institute: Observatoire Cantonal de Neuchâtel (ON)
In cooperation with:
Temex Neuchâtel Time (TNT: main contractor)

Principal Investigator: V. Teodoridis (ON); F. Droz (TNT)

Co-investigators: G. Mileti (ON); C. Affolderbach (ON)

Method: Research based on existing instuments:

1. Use of tunable laser diodes instead of discharge lamps in Rb clocks.
2. Basic research on microwave-optical double resonance spectroscopy.
3. Realisation of an Elegant-Breadboard (EBB) laser-pumped Rb clock

Purpose of research: The research aims at exploiting the superior spectral purity of tunable laser diodes as compared to spectral discharge lamps in order to develop a new generation of space atomic frequency standards for satellite navigation & positioning (GPS-GLONASS-GALILEO), telecommunication, and space science missions.
Based on the previously developed lamp-pumped Rb atomic frequency standard (RAFS), in ON from 1987 to 1997, in TNT from 1997, this ARTES-5 project has led to the realisation of an Elegant Breadboard (EBB) capable of reaching the GALILEO clocks specifications (relative frequency stability of a few 10–14 around 10'000 s) and beyond.
The signal-to-noise ratio of the atomic resonator could be increased by 1–2 orders of magnitude and its environmental sensitivity was significantly reduced by optimising the content of the Rubidium resonance vapour cell (buffer-gas) and the other relevant physical operating parameters: optical and microwave power, laser and quartz stabilisation loop, etc.
An extended-cavity diode laser was developed as a stand-alone device and implemented in the EBB, while other european integrated laser devices (DBR, DFB, VCSEL, etc.) are presently under evaluation and characterisation. In a future stage of the development, these new laser sources will allow further miniaturisation, power consumption reduction, and increased reliability by use of redundant approaches based on optical fibers and micro-actuators (MEMS and MOEMS).
This research has also allowed to develop basic knowledge and technology on narrow-band and tunable laser diodes and on simple and robust frequency stabilisation schemes. This activity has therefore several other implications: in other types of atomic clocks (laser-pumped atomic beams, laser cooled atomic fountains, optical frequency standards, etc.), telecommunication (WDM, free-space otpical communication, etc.), atmospheric sensing (Lidars, etc.), and fundamental research (example: the HYPER mission).

Status: The laser-pumped Rubdium gas-cell atomic frequency standard Elegant Breadboard has been designed, manufactured, assembled, optimised and successfully tested. It consists of two parts: (1) the TNT lamp-removed and modified RAFS; (2) the ON frequency stabilised extended cavity diode laser. It has reached the GALILEO RB clock specifications (< 5x10-12 at 1 s, < 5x10-14 at 20'000 s) and the final data analysis and reports are under progress. Several possibilities for further improving the performances, reducing the mass/volume/consuption and increasing the reliability are being reviewed in view of a contination of the project in the frame of the ARTES-5 program. The final presentation of the project in ESTEC is planned for June 2004.

Publications:

1. G. Mileti et al., "Laser-pumped Rubidium frequency standards: new analysis and progress", IEEE J. Quantum Electron. 34, pp. 233–237 (1998). (potential of the technique)
2. G. Mileti, C. Affolderbach, "A compact frequency stabilised laser head for space Rubidium clocks and wavelength references", ESA Special Publication SP–554, Proceedings of the 5th International Conference in Space Optics (ICSO), Toulouse, France, April 2004. (laser head)

3. C. Affolderbach, G. Mileti, F. Droz, “A compact, high-performance laser-pumped rubidium frequency standard”, Proceedings of the 18th European Frequency and Time Forum (EFTF), Guildford, UK, April 2004. (EBB)

Abbreviations:

DFB:	Distributed feed-back laser diode
DBR:	Distributed bragg reflector laser diode
EBB:	Elegant breadboard
GPS:	Global positioning system
HYPER:	Hyper-precision cold atom interferometry in space
MEMS:	Micro-electro-mechanical systems
MOEMS:	Micro-opto-electro-mechanical systems
ON:	Observatoire de Neuchatel
RAFS:	Rubidium atomic frequency standard
RB:	Rubidium
TNT:	Temex Neuchatel Time
VCSEL:	vertical-cavity surface-emitting laser
WDM:	wavelength-division multiplexing

12.7 DEM generation from SPOT5-HRS

Institute: Institute of Geodesy and Photogrammetry, ETHZ
In cooperation with:
CNES (F), ISPRS

Principal Investigator: Prof. Dr. A. Grün

Co-investigators: D. Poli, Z. Li

Method: Research based on existing instruments: SPOT5-HRS

Purpose of research: In Denver, USA, at the ISPRS Commission I Symposium in 2002, it was announced that ISPRS (International Society of Photogrammetry and Remote Sensing) and CNES (Centre National d’Etudes Spatiales) initiated a Study Team for assessing DEM production with HRS data. The HRS instrument carried on SPOT5 satellite can acquire instantaneous along-track stereoscopic pairs on large areas (i.e. swath width of 120 km) in panchromatic mode with a spatial resolution of 10 meters. HRS is designed to achieve relative elevation accuracy between 5 and 10 meters and absolute accuracy in the range 10 to 15 meters. Eleven worldwide distributed test areas provided by the same number of Principal Investigators (universities, national agencies, mapping companies) have been used for the investigations. For each test area, one or more reference DEMs and/or ground control information were available. The corresponding SPOT5-HRS scenes were supplied by CNES. In addition to the Principal Investigators, 19 Co-Investigators joined the Initiative. The results obtained by the single partners will be compared and used to assess the potential of HRS data. The Institute of Geodesy and Photogrammetry, ETH Zurich, is participating as Co-Investigator for the DEM production and assessment from a stereo pair acquired on 1st October 2002 over Germany. The data (ground control point locations and laser reference DEMs) were provided by DLR (German Aerospace Center).

Status: The data provided by CNES and DLR were processed for the DEM generation. The data consisted of: two stereo images from SPOT5-HRS sensor acquired on 1st October 2002 over an area of approximately 120x60 km2, the location of 81 object points and several reference DEMs created from Laser scanner data and by conventional photogrammetric and geodetic methods. For orienting HRS imagery, two alternative procedures have been applied: a rigorous sensor model for pushbroom sensors, which estimates the external and internal sensor orientation, according to the laws describing the physical imaging process, and with rational polynomial models, that use a general transformation to describe the relationship between image and ground coordinates. Both algorithms have been developed at the Institute of Geodesy and Photogrammetry.
In order to extract the DTM/DSMs from the linear array images (airborne or spaceborne), algorithms and software packages developed at our Institute have been applied. After the preprocessing of the imagery and production of the image pyramids, the matches of three kinds of features (i.e. the feature points, the grid points and the edges) are found on the original image, by progressively starting from the low-density features on the images with the low resolution. A triangular irregular network (TIN) based DSM is constructed from the matched features on each level of the pyramid, which in turn is used in the subsequent pyramid level for the approximations and adaptive computation of the matching parameters. Finally, the modified MPGC (Multi-Photo Geometrically Constrained) matching is used to achieve more precise matches for all the matched features and identify some inaccurate and false matches. The raster DTM/DSMs are then interpolated from the original matching results.
The final DTM/DSMs have been compared to the reference DEMs provided by DLR. The first results show differences of around 1.0-2.0 pixels, depending on the terrain type. The best results were achieved in smooth and flat areas, while, in mountain areas, some blunders up to 100m occurred.

Publications:

1. Poli, D., Zhang, L., Gruen, A. (2004). SPOT5-HRS stereo images orientation and automated DSM generation. International Archives of Photogrammetry and Remote Sensing Vol. 35, Istanbul (to be published).

2. Poli, D. (2003). Georeferencing of MOMS-02 and MISR stereoimages with strict sensor model. ISPRS Workshop “High resolution mapping from space 2003”, October 2003, Hannover, Germany (proceedings on CD).

3. Zhang L., Gruen, A. (2003). Automatic DSM Generation from StarImager (SI) Data. Optical 3-D Measurement Techniques VI, Gruen/Kahmen eds., Vol. I, pp. 93-105.

Abbreviations:

CNES:	Centre National d’Études Spatiales
DEM:	Digital Elevation Model
DLR:	German Aerospace Center
DSM:	Digital Surface Model
DTM:	Digital Terrain Model
MPGC:	Multi-Photo Geometrically Constrained Matching