

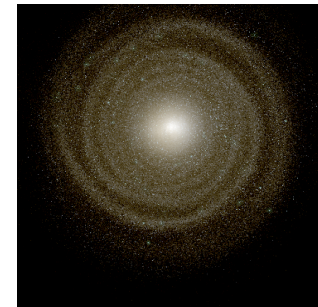
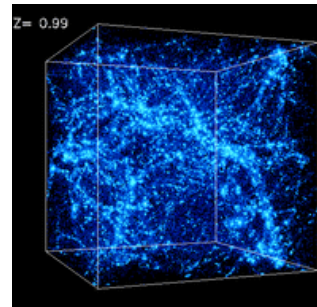
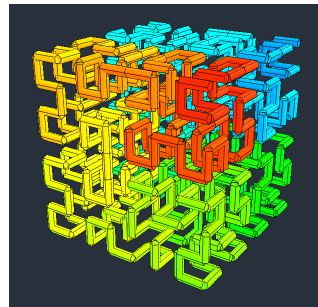
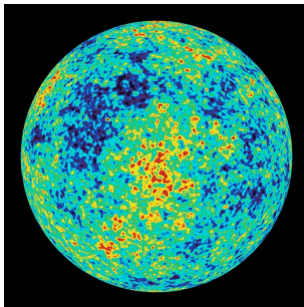
Open Source Simulation Tools in Astronomy and Astrophysics

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Zurich^{UZH}



Outline

- Open Source approach for computational astrophysics.
- Computational cosmology and astrophysical fluid dynamics.
- Open Software as a Scientific Methodology.
- Open Software and Scientific Careers
- Practical examples of implementations

Introduction

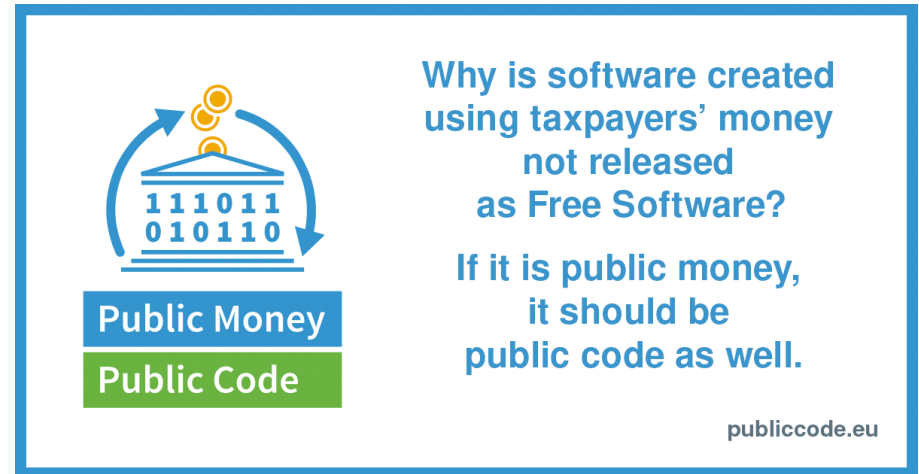
“Is your code public ?”

“No, because:”

- competition is fierce
- intellectual property
- scientific exploitation

“It should be, because:”

- more users, more bugs found
- developer’s community
- more scientific impact
- reproducibility
- code comparison
- code verification and validation



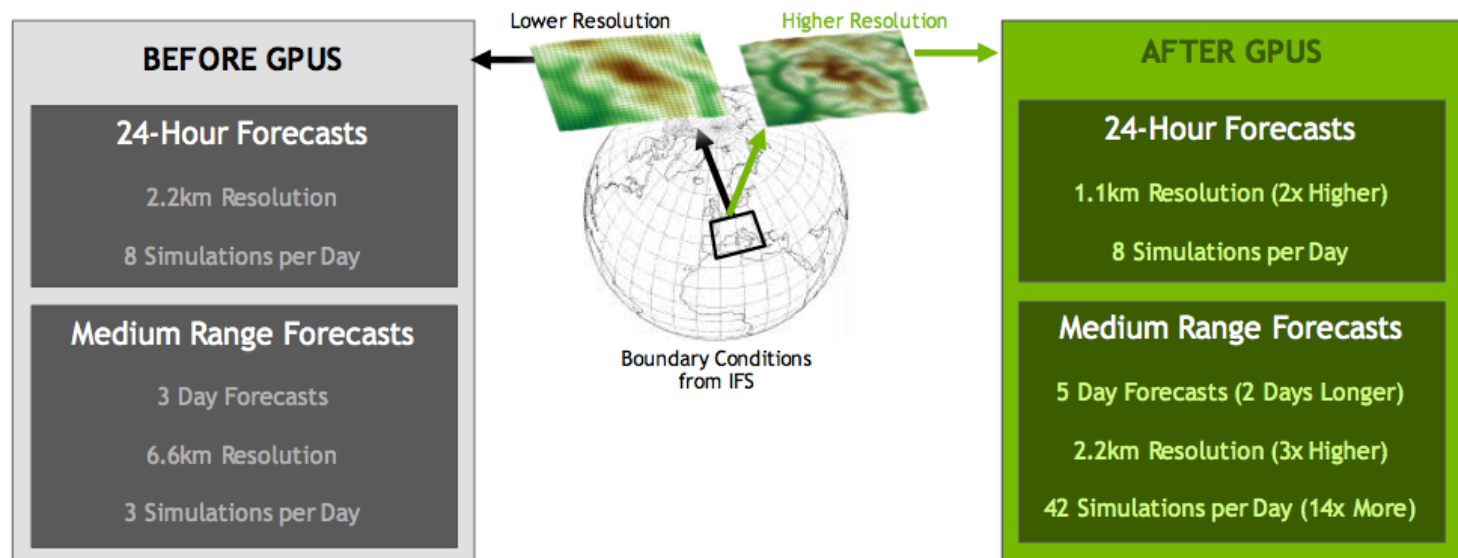
Free Software Free Society

Legal aspects: Open Source versus Free Software

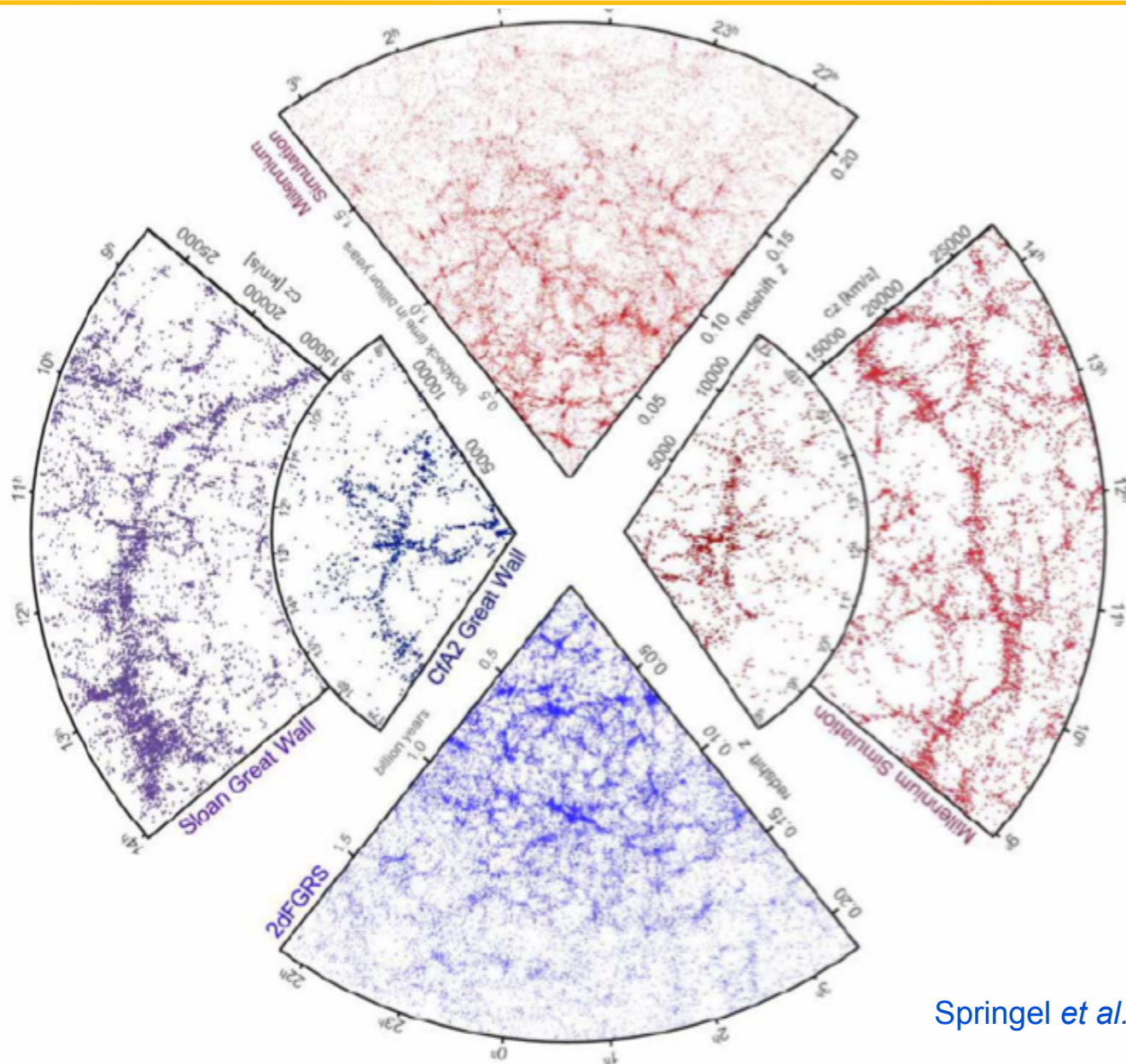
Computational Astrophysics in Precision Mode

Computer simulations to predict the complex behaviour of non-linear dynamical systems with high precision.

Breakthrough Advance in Swiss Weather Forecasting

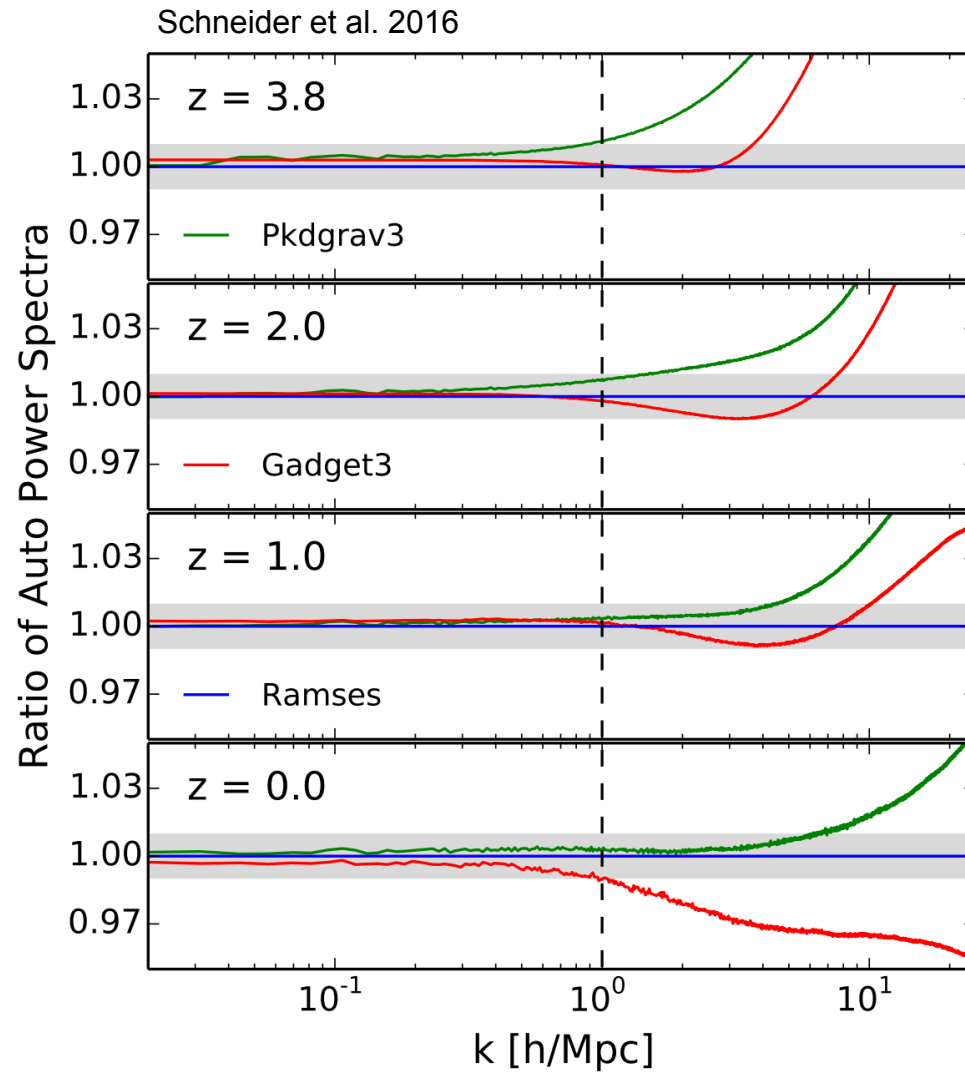


Cosmological simulations



Springel *et al.*, Nature, 2006

Accuracy of large scale structure simulations



The Euclid Flagship Simulation

2×10^{12} Particles

$L = 3780 \text{ h}^{-1} \text{ Mpc}$

Piz Daint: third fastest computer in the world now (www.top500.org) !



Computational Astrophysics in Discovery Mode

Computational Chemistry wins 2013 Nobel prize in Chemistry



Photo: A. Mahmoud
Martin Karplus
Prize share: 1/3



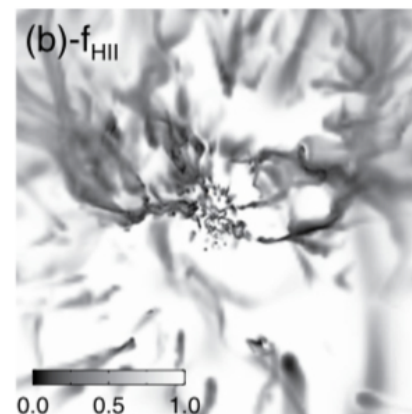
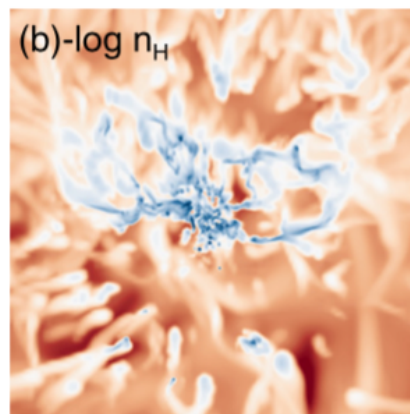
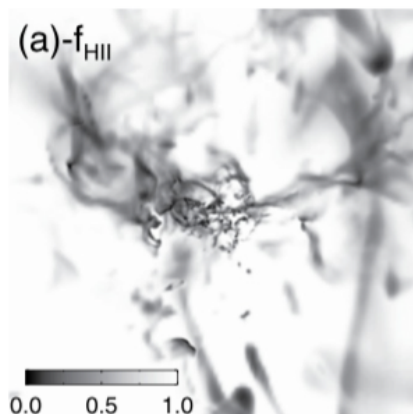
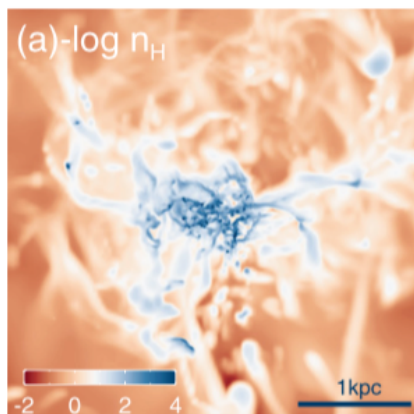
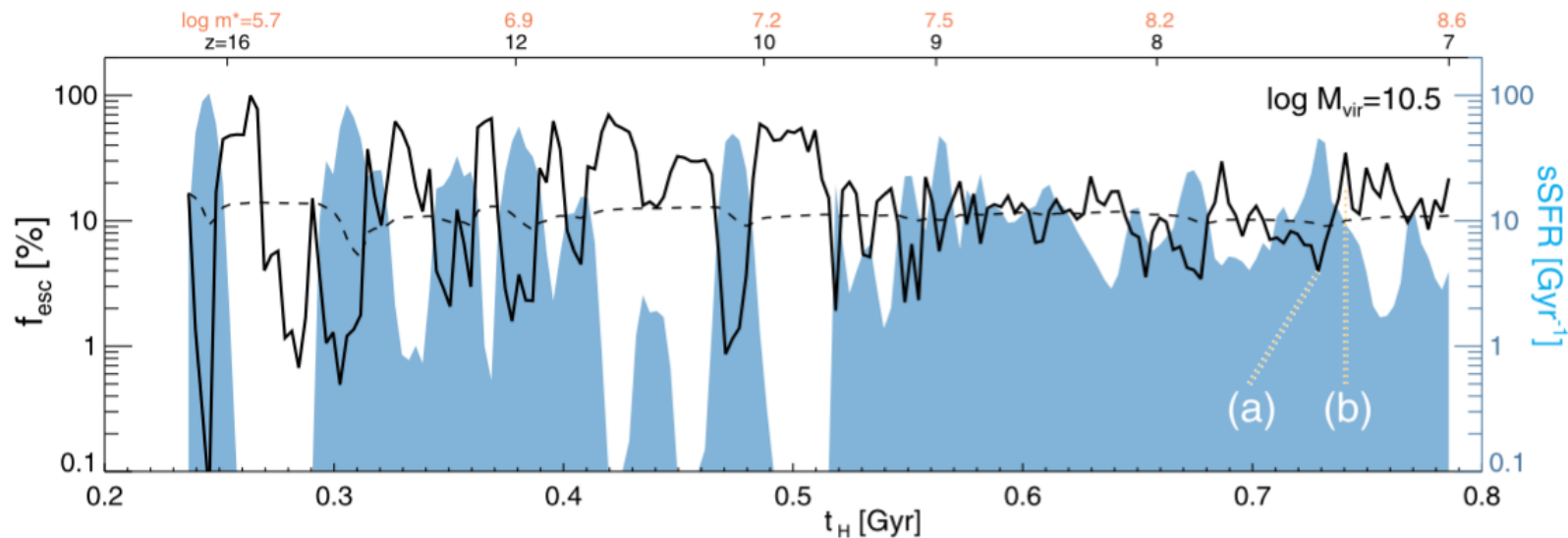
Photo: A. Mahmoud
Michael Levitt
Prize share: 1/3



Photo: A. Mahmoud
Arieh Warshel
Prize share: 1/3

The Nobel Prize in Chemistry 2013 was awarded jointly to Martin Karplus, Michael Levitt and Arieh Warshel *"for the development of multiscale models for complex chemical systems"*.

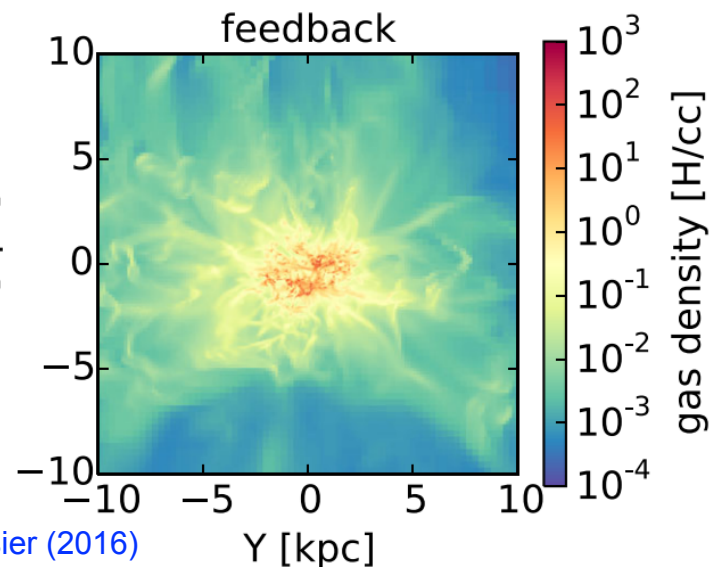
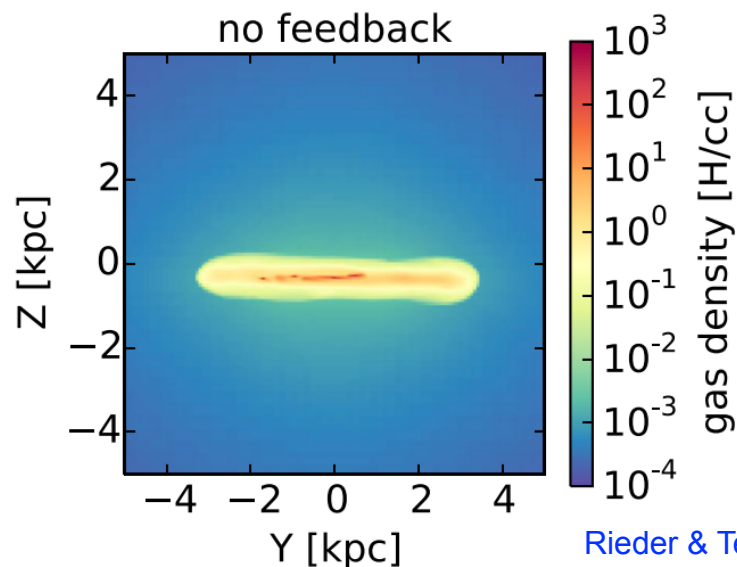
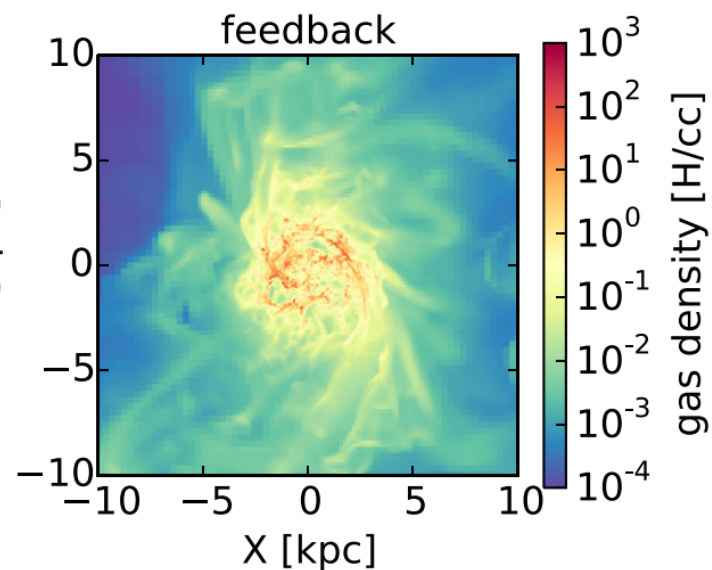
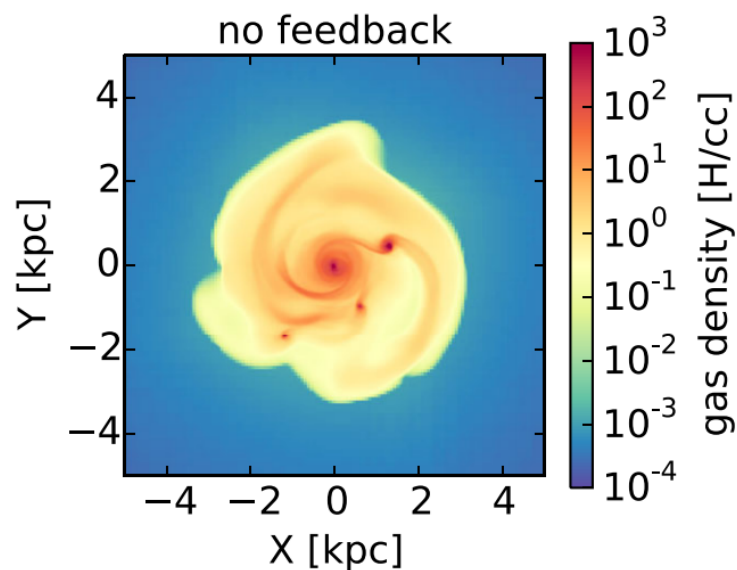
Cosmic reionization from high redshift galaxies



Kim & Cen (2014)

A turbulent dynamo as the origin of cosmic magnetic fields

Cooling halo simulations



Rieder & Teyssier (2016)

Open Source as a Science Methodology

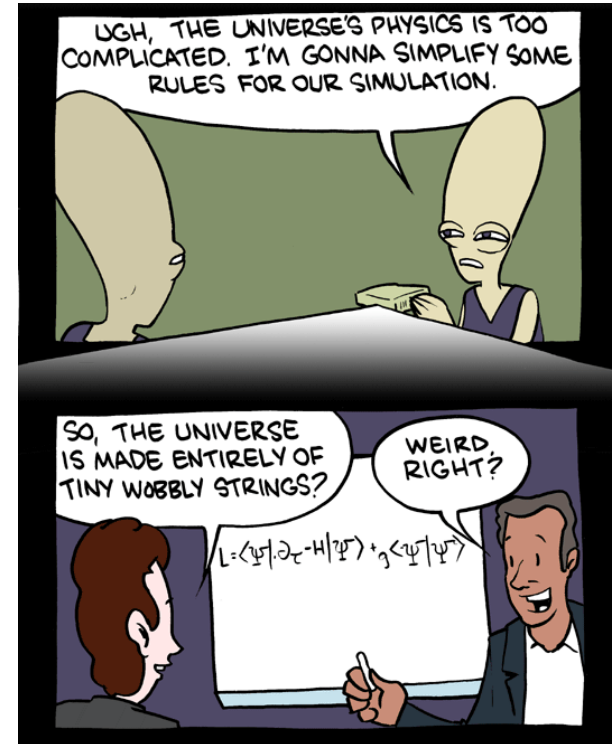
What is Physics ?

A mathematical theory of nature that can be tested using reproducible experiments.

- A mathematical theory that cannot be tested is not Physics.
- An experiment that cannot be reproduced by others is not Physics.

Computational Physics as the “third way”.

- Algorithms can be described as a set of logical expressions.
- Codes include many additional tricks or recipes that do not have any mathematical counterpart, as in a “black box”.
- Codes run “numerical experiments” that need to be reproduced.
- A simulation published without giving public access to the code is not Physics.



Science Code Manifesto

Manifesto Discussion Endorse Resources About

Software is a cornerstone of science. Without software, twenty-first century science would be impossible. Without better software, science cannot progress.

But the culture and institutions of science have not yet adjusted to this reality. We need to reform them to address this challenge, by adopting these five principles:

- | | |
|------------------|---|
| Code | All source code written specifically to process data for a published paper must be available to the reviewers and readers of the paper. |
| Copyright | The copyright ownership and license of any released source code must be clearly stated. |
| Citation | Researchers who use or adapt science source code in their research must credit the code's creators in resulting publications. |
| Credit | Software contributions must be included in systems of scientific assessment, credit, and recognition. |
| Curation | Source code must remain available, linked to related materials, for the useful lifetime of the publication. |

Open Software: Higher Scientific Impact

#	Bibcode Authors	Cites Title	Date	List of Links Access Control Help										
1	☐ 2005MNRAS.364.1105S Springel, Volker	3224.000 The cosmological simulation code GADGET-2	12/2005	A	E	F	G	X		R	C	S	O	U
2	☐ 2002A&A...385..337T Teyssier, R.	856.000 Cosmological hydrodynamics with adaptive mesh refinement. A new high resolution code called RAMSES	04/2002	A	E	F		X		R	C		O	U
3	☐ 1995ApJ...452..797C Couchman, H. M. P.; Thomas, P. A.; Pearce, F. R.	276.000 Hydra: an Adaptive-Mesh Implementation of P 3M-SPH	10/1995	A		F	G	X		R	C			U
4	☐ 2014ApJS..211...19B Bryan, Greg L.; Norman, Michael L.; O'Shea, Brian W.; Abel, Tom;	264.000 ENZO: An Adaptive Mesh Refinement Code for Astrophysics	04/2014	A	E	F		X		R	C		O	U

Practical Implementation of Open Software

Collaborative environments (bitbucket/github)

- Publications should refer to the bitbucket/github commit key
- Publications should have a link to the parameter files and initial conditions

Open Access database

- Simulation results in public database
- Code repository in public database (software can regenerate data)

Virtual Observatory Initiatives for both simulation data and software

Interested readers may want to try an extended version of the unified yt script at <http://bitbucket.org/mornkr/agora-analysis-script/> employed in the analyses of the proof-of-concept runs. For the analysis described in Section 5.3, the yt-3.0 changeset e018996fcb31 is used. For more information on the common analysis philosophy of the *AGORA* project and its toolkit yt (Turk et al. 2011), see Section 4.2 and the yt website <http://yt-project.org/>.

Virgo - Millennium Database

Documentation

CREDITS/Acknowledgments

Registration

News

FAQ

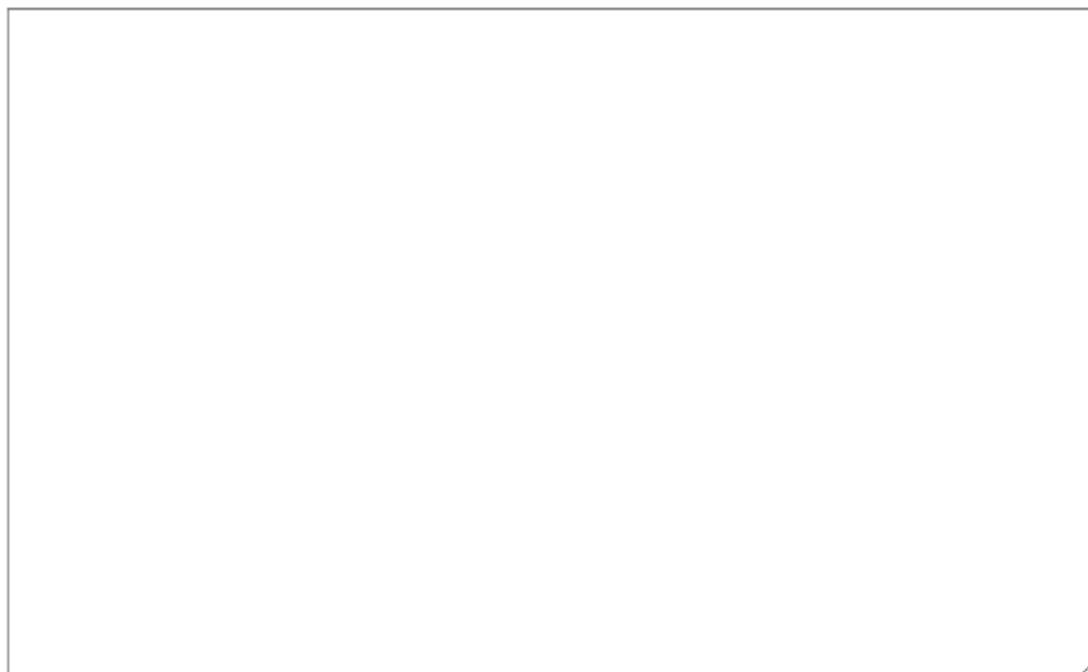
Databases

 **millimil (context)**



Streaming queries return unlimited number of rows in CSV format and are cancelled after 30 seconds.
Browser queries return maximum of 1000 rows in HTML format and are cancelled after 30 seconds.

There is a [partial mirror](http://galaxy-catalogue.dur.ac.uk:8080/Millennium/) of this database in Durham at <http://galaxy-catalogue.dur.ac.uk:8080/Millennium/>.
The Durham database does not contain all the latest L-Galaxies models but does contain more recent GALFORM models.



Query (stream)

Query (browser)

Help

Maximum number of rows to return to the query form:

Demo queries: click a button and the query will show in the query window.

Thank you !