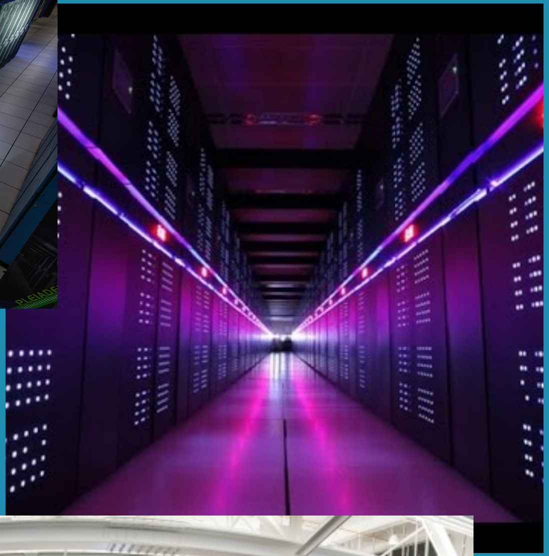
KU LEUVEN

Our Past Experience with Tier-0 at PRACE



Giovanni Lapenta, Francesco Pucci, Maria Elena Innocenti

PRACE

Past Experience – Tier 0

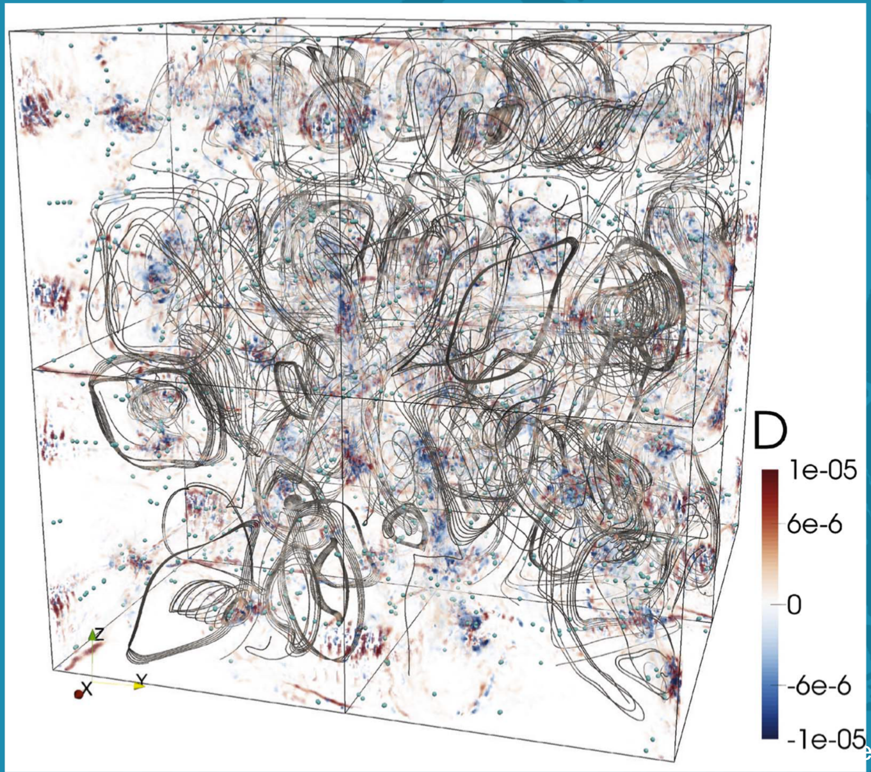
- **Fourth call**: The Life-cycle of Energy in Space Weather
    - Cineca and CEA
    - Technical: Recommended
    - Scientific: 6, 6, 5
- **Sixth call**: SWEET: Space Weather Effects on the Earth environmenT
    - Cineca and CEA
    - Technical: Strongly Recommended - we worked with them in preparation
    - Scientific: 6, 6, 5
- **Eight call**: Magnetic Reconnection in Three-dimensional Turbulent Configurations
    - Feedback from all centers, selected by LRZ
    - Technical: Strongly Recommended - we worked with them during preparation
    - Scientific: 6, 5, 5

Past Experience – Tier 0

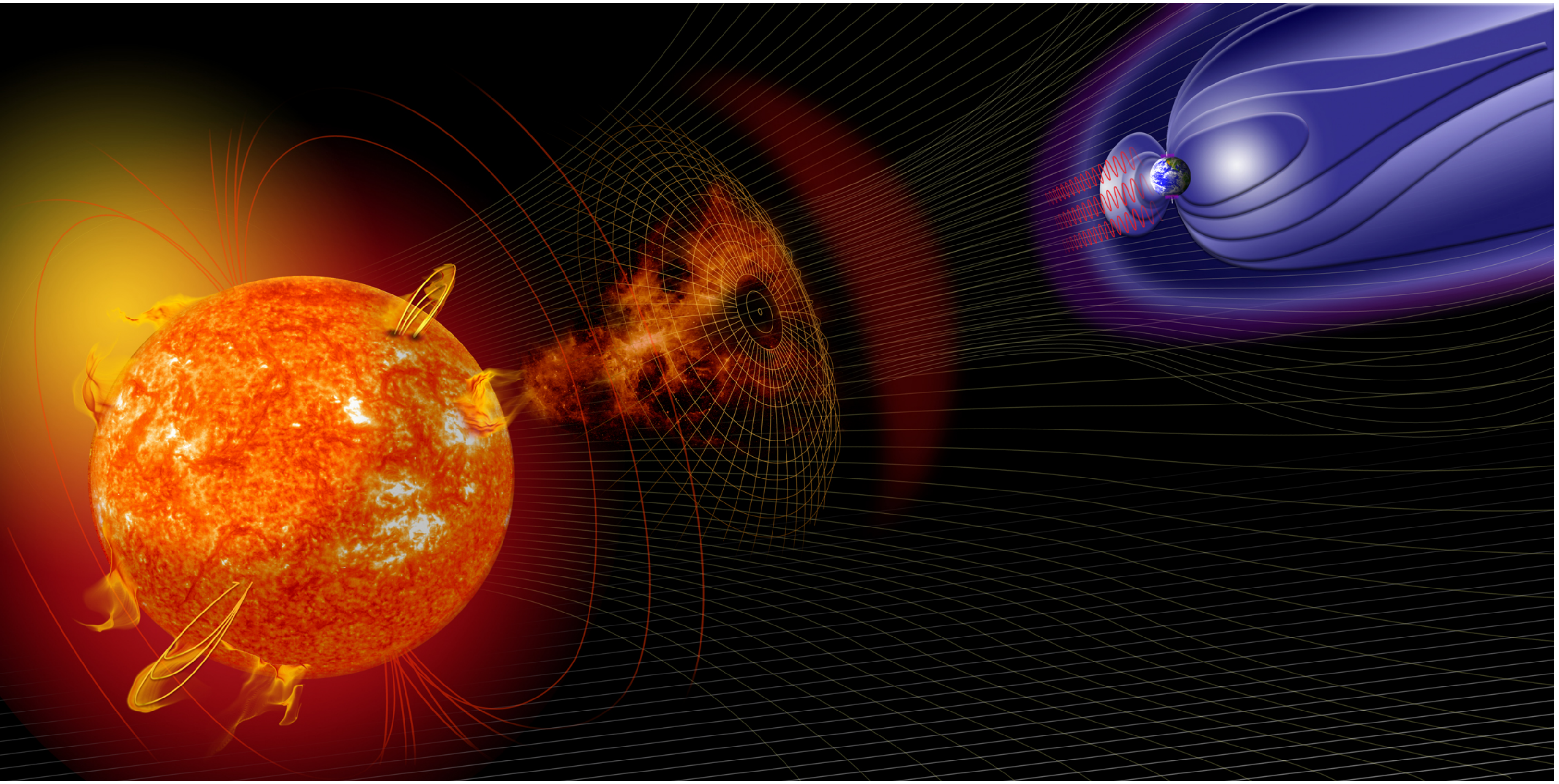
- **11th call and 12th**: Particle acceleration by magnetic reconnection in turbulence
  - BSC
  - Technical: Fully Complying with the system
  - Scientific: 6, 6, 5
- **14th call**: KARMA - Kinetic models of magnetic reconnection in pARtially ionised plasMAs
  - BSC
  - Technical: Fully Complying with the system
  - Scientific: 6, 6, 3
- **17th call**: TAPES - Turbulence in Astrophysical Plasmas from fluid to Electron Scales
  - LRZ
  - Technical: Suitable for the system
  - Scientific: 6, 6, 5

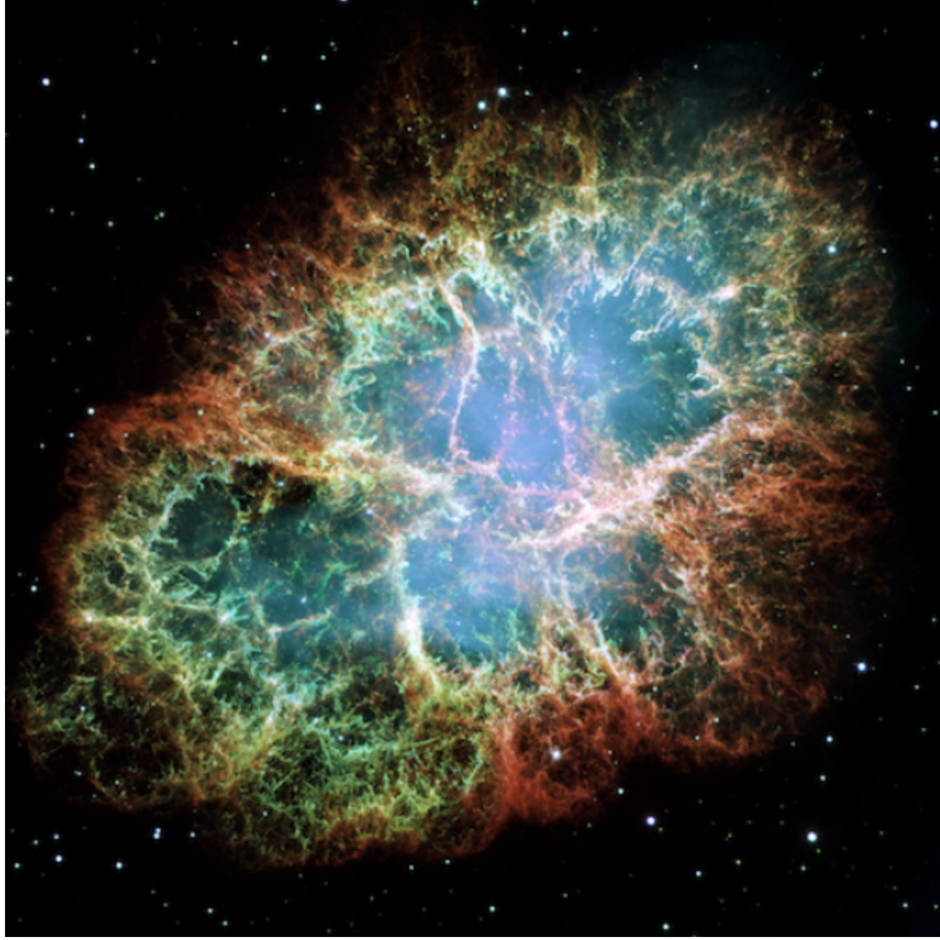
17th call: TAPES - Turbulence in Astrophysical Plasmas from fluid to Electron Scales

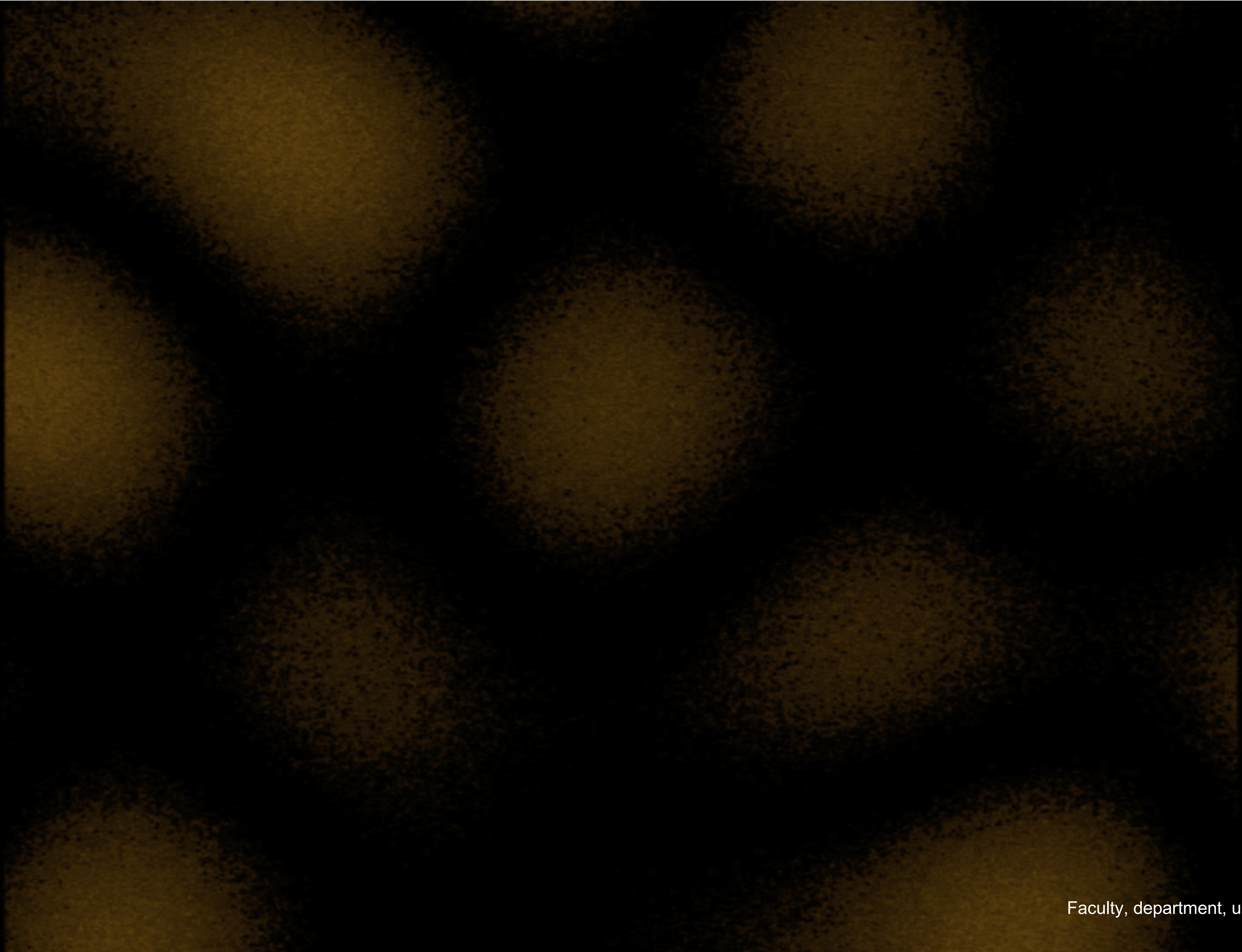
LRZ – 35 million hours



Plasma and Turbulence



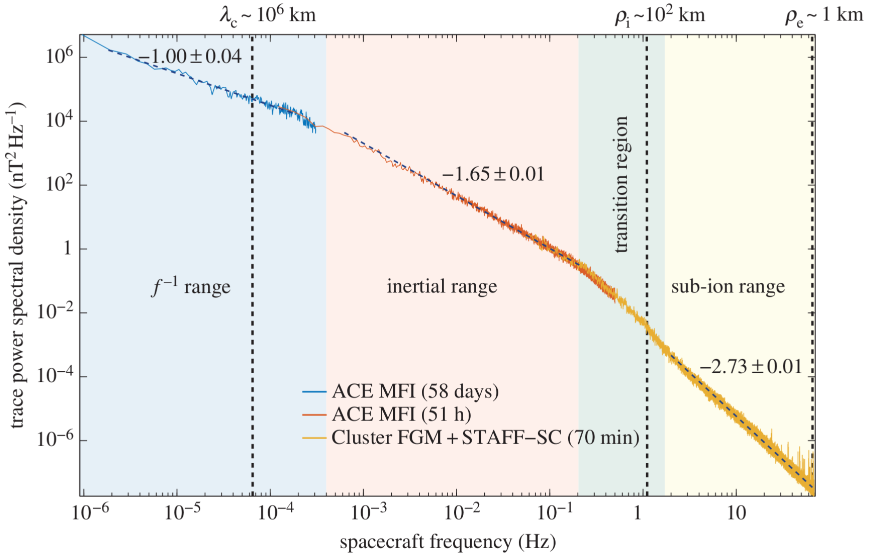




Turbulence in space plasmas

CONTEXT

- Turbulence is ubiquitous is space plasmas (heliosphere, galaxies, supernova remnants)
- Turbulence is studied by means of numerical simulation. The challenge consists in simulating a broad range of scales.



Several order of magnitude separate the injection and the dissipation range

SCIENTIFIC JUSTIFICATION

- Turbulence is relevant to understand key phenomena like particle energization and diffusion, and magnetic reconnection

COMMUNITY OUTCOME

- Turbulence is a key topic for several space missions (MMS, PSP and SO)

KU LEUVEN

European Commission

DEEP

NASA

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
UNITED STATES AIR FORCE

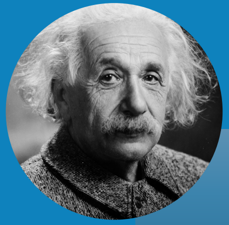
Hybrid computing

xPic

New Directions

- MLMD
- Exascale

Energy conservation



ECsim

ECSIM

Lapenta, JCP, 2017

Distributed computing

iPic3D

iPic

Markidis, Lapenta, MCS, 2010

Krylov methods

Celeste3D

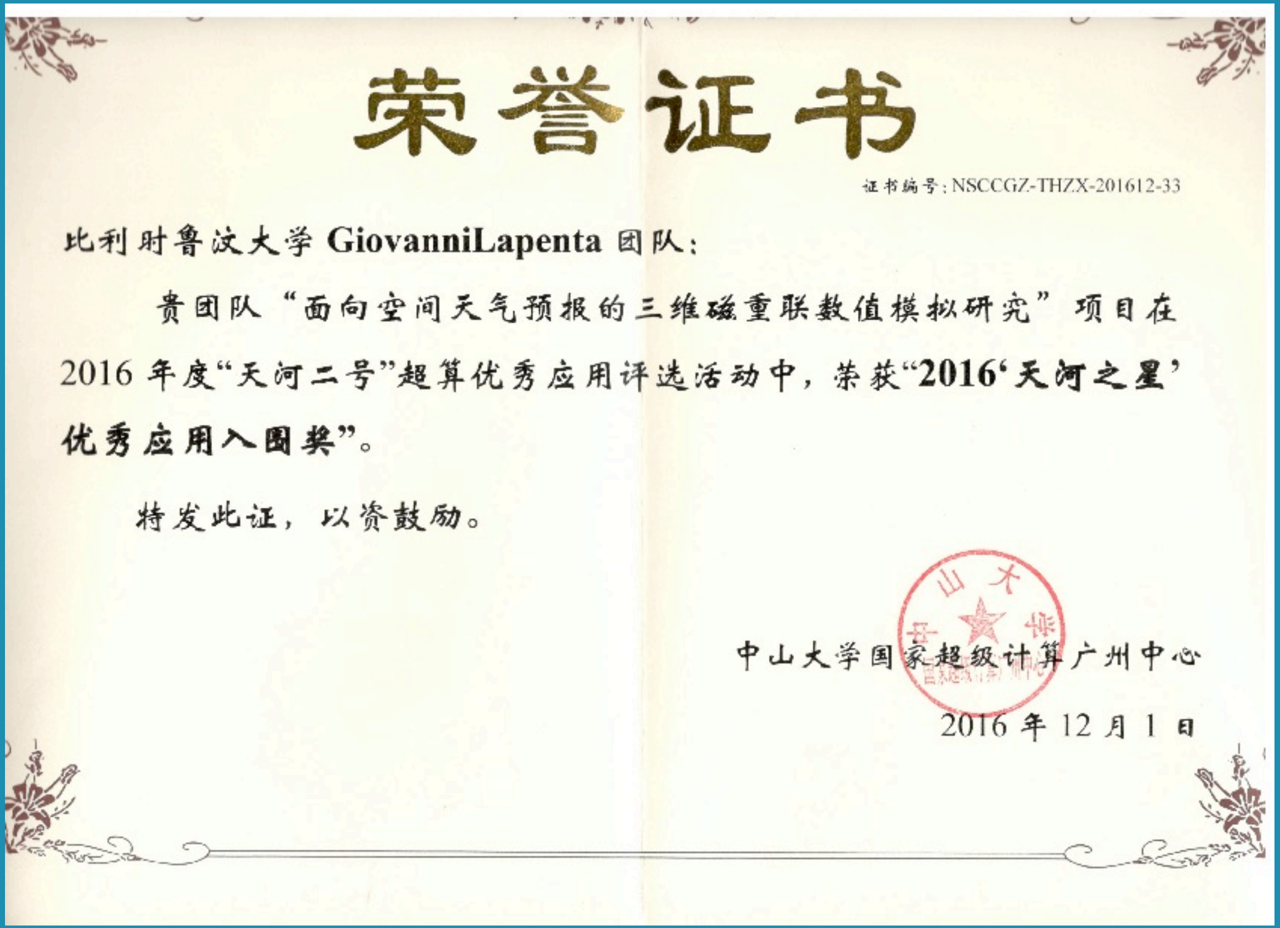
Celeste

Lapenta, Ricci, Brackbill, PoP, 2005

Vector computers

Venus

Brackbill, Forslund, JCP, 1985


荣誉证书

证书编号：NSCCGZ-THZX-201612-33

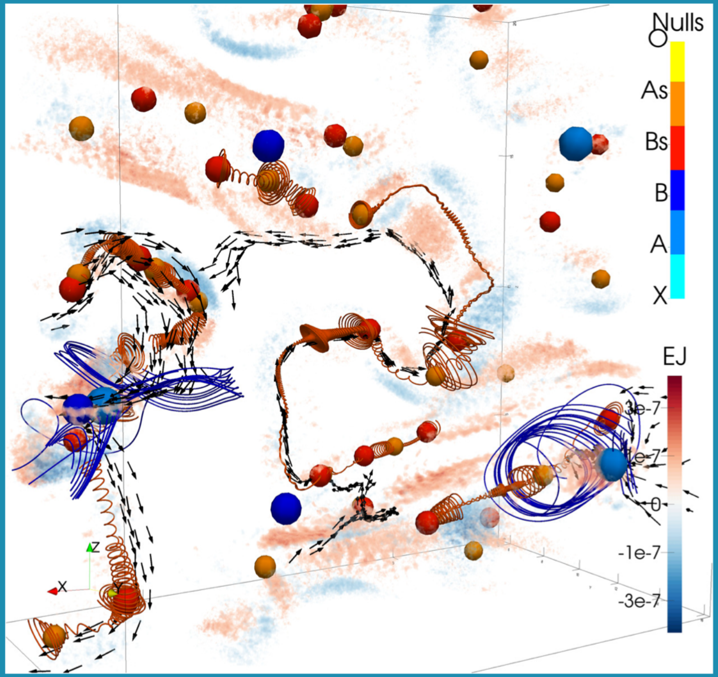
比利时鲁汶大学 GiovanniLapenta 团队：

贵团队"面向空间天气预报的三维磁重联数值模拟研究"项目在2016年度"天河二号"超算优秀应用评选活动中，荣获"2016'天河之星'优秀应用入围奖"。

特发此证，以资鼓励。

中山大学国家超级计算广州中心

2016年12月1日



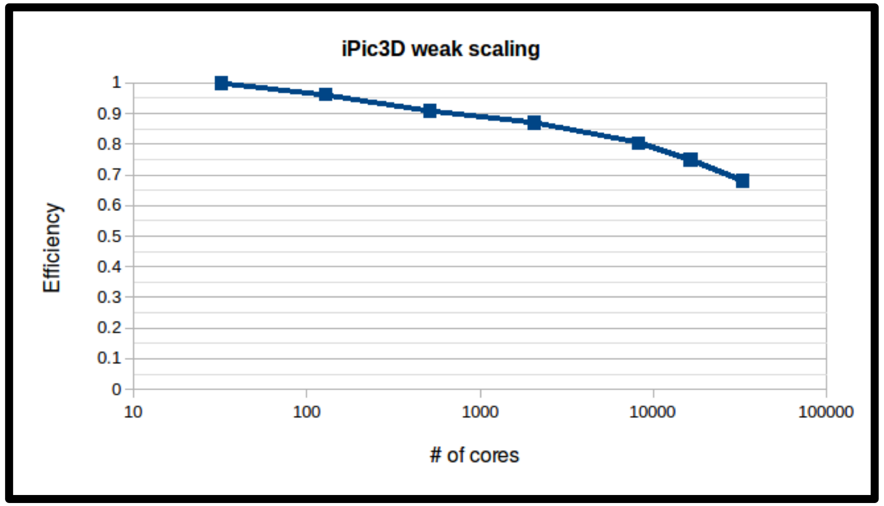

nature physics
ARTICLES
PUBLISHED ONLINE: 20 JULY 2015 | DOI: 10.1038/NPHYS3406

Secondary reconnection sites in reconnection-generated flux ropes and reconnection fronts

Giovanni Lapenta[1]*, Stefano Markidis[2], Martin V. Goldman[3] and David L. Newman[3]

KU LEUVEN

iPic3D weak scaling



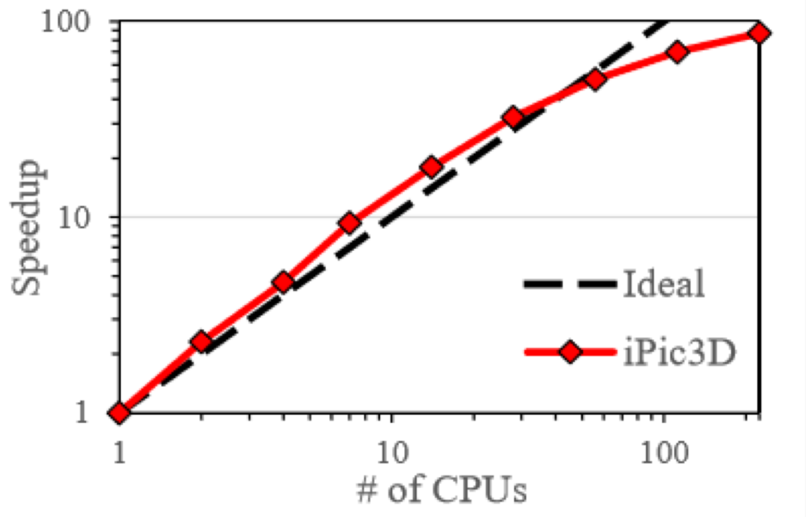
# of cores	Time [s]	Efficiency	Topology
32	53.34	1	4x4x2
128	55.45	0.96	8x4x4
512	58.64	0.90	8x8x8
2048	61.24	0.87	16x16x8
8192	66.35	0.80	32x16x16
16384	71.14	0.75	32x32x16
32768	78.42	0.68	32x32x32

- iPic3D weak scaling has been tested on SuperMUC
- Initial set-up: 3D Harris current sheet configuration with 4 species and 125 particles per species per cell was used. The code was run for 100 cycles with a fixed time step. The output was suppressed.
- 75% efficiency up to 16k cores, 68% efficiency for 32k cores.
- The efficiency increases with more particles per cell.

iPic3D strong scaling

iPic3D - Strong Scaling results

# of CPUs	# of nodes	Time [s]	Speedup
1	1	337.22	1
2	1	145.96	2.31
4	1	72.74	4.64
7	1	36.24	9.30
14	1	18.76	17.98
28	1	10.42	32.36
56	2	6.68	50.49
112	4	4.83	69.81
224	8	3.88	86.93



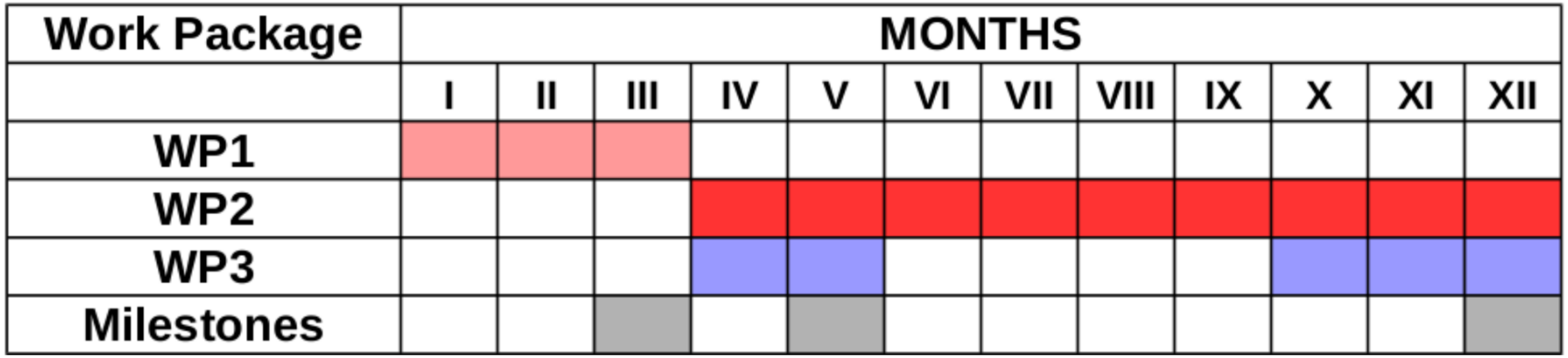
Our Proposal: Turbulence in Astrophysical Plasmas from fluid to Electron scale (TAPES)

- We have proposed a numerical method that allows to span a broad range of the turbulent cascade. The method is implemented in the code iPic3D. A simulation campaign will be conducted varying the range of scale resolved (varying the mass ratio)

Run Type	# Runs	# of cycles/ run	duration/ iteration/ cell (micro sec)	# cores (estimated)	Total core hours (10^6)/run	Total core hours (10^6)/ type run
MR64	10	9000	2	896	0.02	0.2
MR128	10	18000	2	3584	0.4	4.0
MR256	3	36000	2	14336	10.8	32.4
Total						36.6

- We start with small simulation to establish the best parameters. Then, we run three big simulations at the highest resolution allowed by present computational resources

TAPES: Gantt chart and collaboration



WP1: small simulations (MR64, MR128) for a total of 5mln hours, **WP2**: large simulations (MR256) for a total of 30mln hours, **WP3**: data analysis

Two groups are involved in the project:

- KU Leuven (7 members). Tasks: decide parameters, running simulation, fetching the data, post-processing and analysis of data.
- University of Calabria (2 members). Tasks: analysis of data, theoretical support to the study of turbulent phenomena.

Questions from the reviewers and answers

- The referees' reports were all very positive. The three scores were 5, 6, 6 on a scale of 1 to 6.
- A few (minor) comments were raised

Reviewer 1

Q: Not using realistic mass ratio

A: Simulations with realistic mass ratio are not currently feasible. The reduced mass ratio we will use will provide the necessary scale separation required to address the key topics in plasma turbulence described in the proposal. Also, as a by-product, as the reviewer recognizes, the present study will enable to clarify the role of using reduced mass ratio in simulations of plasma turbulence .

Reviewer 2

Q: Not clear the connection with the space missions and the role of each member of the team inside the project

A: We proved the involvement of team members with the space mission PSP and SO and clarified the role of each member assigning individual tasks

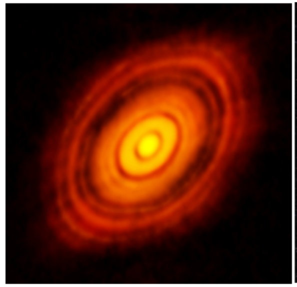
14th Call: KARMA: Kinetic models of magnetic reconnection in partially ionised plasmas

Project Description

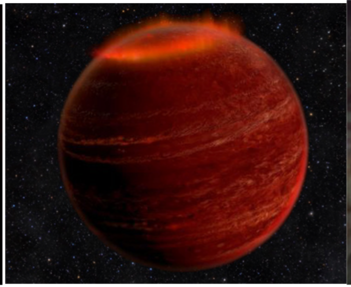
Magnetic reconnection is a process which converts magnetic energy into kinetic energy and heat in a variety of astrophysical and laboratory environments.

Many of these environments are partially ionised (i.e., not all the gas has been heated-up into plasma), but partial ionisation is rarely included as an ingredient in reconnection simulation.

We address kinetic reconnection in a partially ionised environment via a fully kinetic Particle In Cell approach which includes a Monte Carlo operator for collisions with background gas



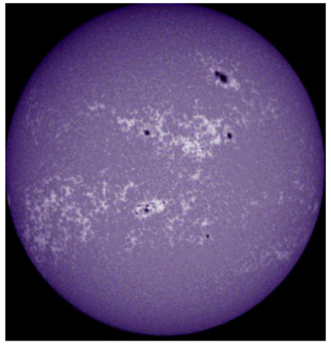
protostellar/planetary disks



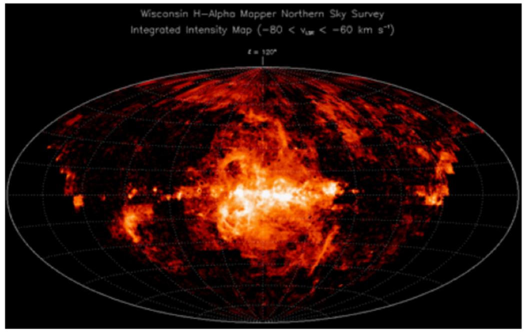
brown dwarf atmosphere

interstellar clouds

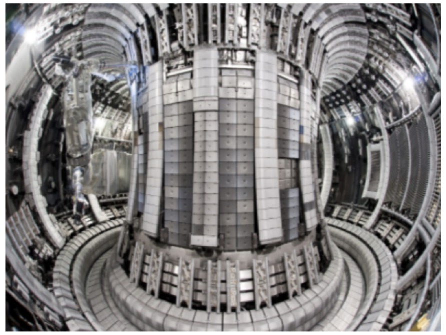
ionosphere



solar chromosphere



warm interstellar medium



tokamak breakdown phase

PRACE Project Preparation: review process

Main reviewers' concerns (6,6,3) and our replies:

"the proposal is quite novel, but I am not convinced that it will be a game changer"

we commented on the role of partial ionisation in affecting the transition between slow and fast reconnection, supported by independent literature

"The methodology is appropriate with the following caveat: the PIC algorithm is intrinsically noisy. This numerical noise has some similar effects to physics collisions, but it is, of course, completely artificial. Can the authors guarantee that the new physics that they expect their simulations to reveal will be unequivocally attributable to the "real" collisions between ions/electrons and the neutral background, rather than simply the effect of the numerical noise of the algorithm? "

we commented on the established techniques used in the code to control numerical noise and on our long experience with dealing with numerical noise in PIC simulations