Welcome to

Smilei)

3rd User & Training Workshop

Ecole Polytechnique | March 9-11, 2022

Smile:)

Status and Perspectives

Mickael Grech, LULI

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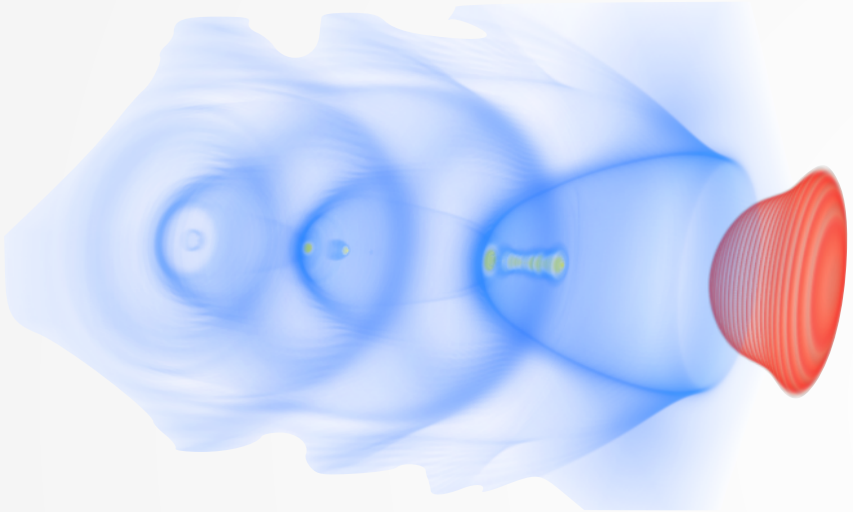
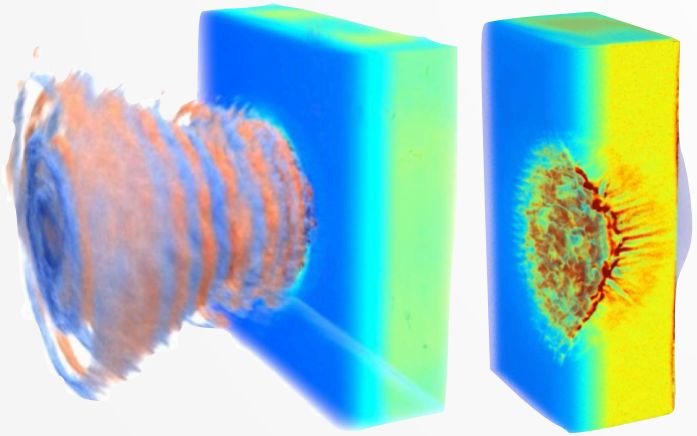
The Particle-In-Cell (PIC) simulation of plasmas

Laser Plasma Interaction



source: Massimo et al. (2020)



source: Smilei dev-team (2018)

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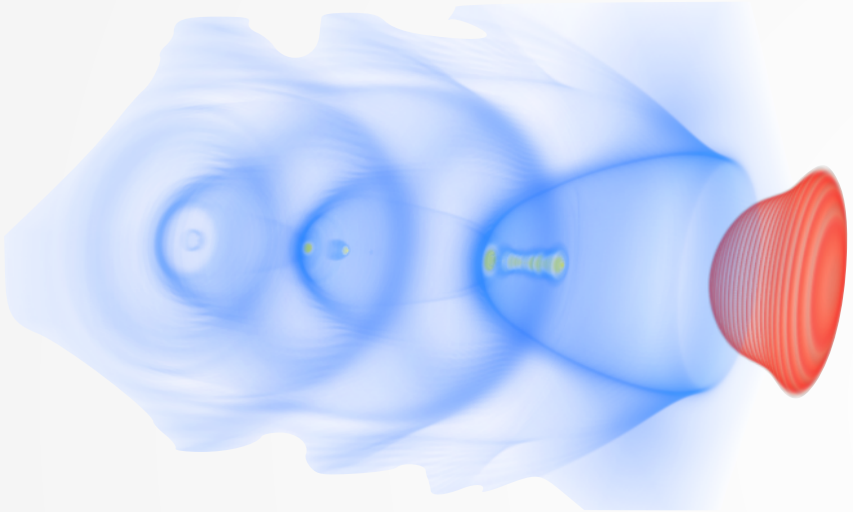

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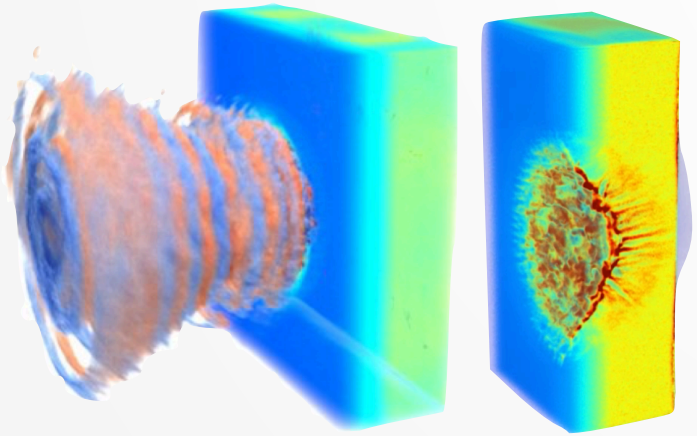

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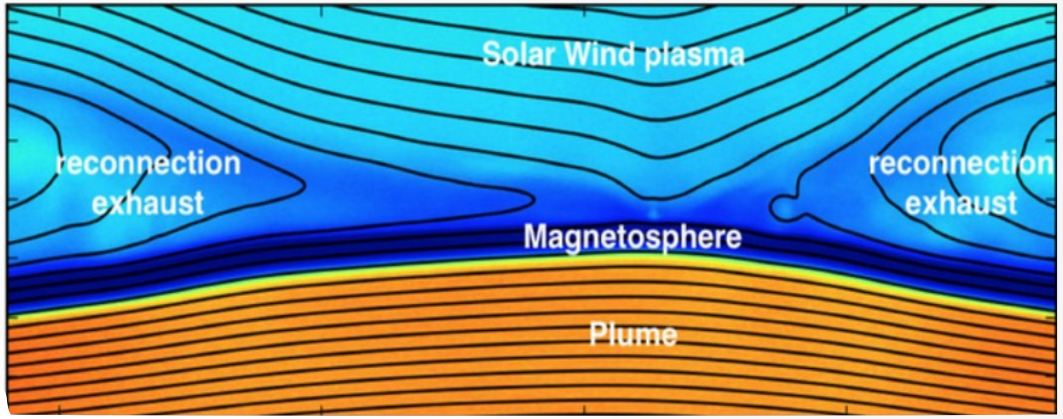
Space Plasmas



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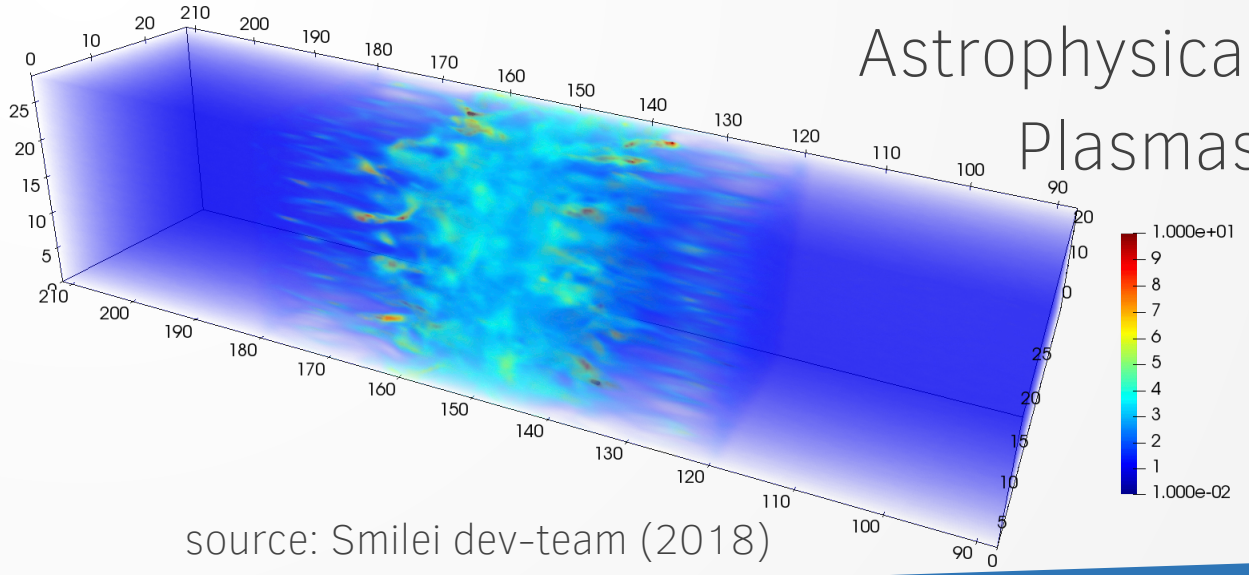
Astrophysical Plasmas



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Smilei is an electromagnetic Particle-In-Cell (PIC) code

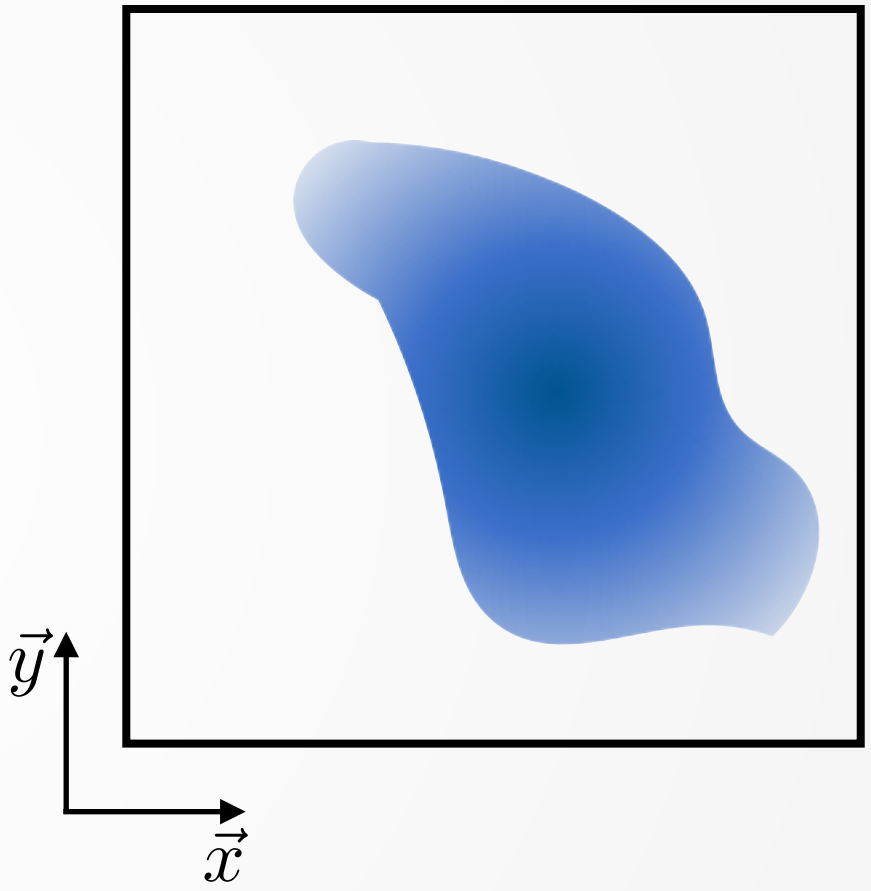
Electromagnetic Fields - Maxwell

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} \qquad \partial_t \mathbf{E} = -\frac{1}{\epsilon_0}\mathbf{J} + c^2 \nabla \times \mathbf{B}$$

$$\nabla \cdot \mathbf{B} = 0 \qquad \partial_t \mathbf{B} = -\nabla \times \mathbf{E}$$

Particles of the plasma - Vlasov

$$\partial_t f_s + \frac{\mathbf{p}}{m_s \gamma} \cdot \nabla f_s + \mathbf{F}_L \cdot \nabla_p f_s = 0$$



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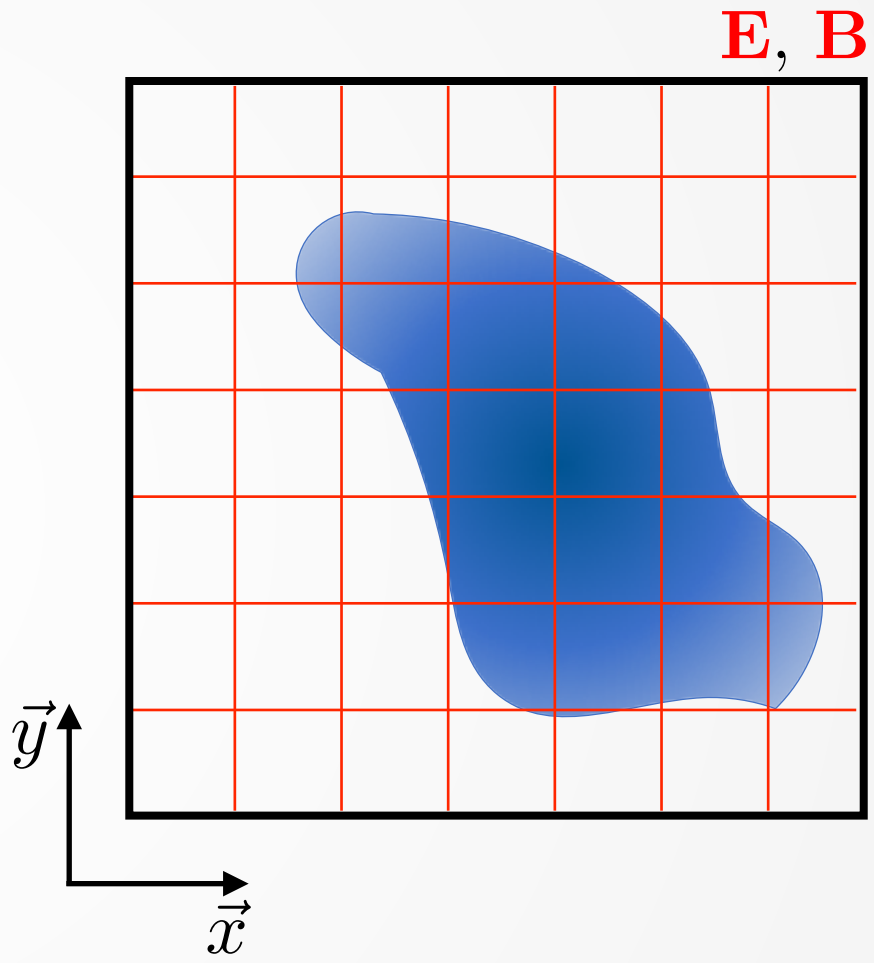

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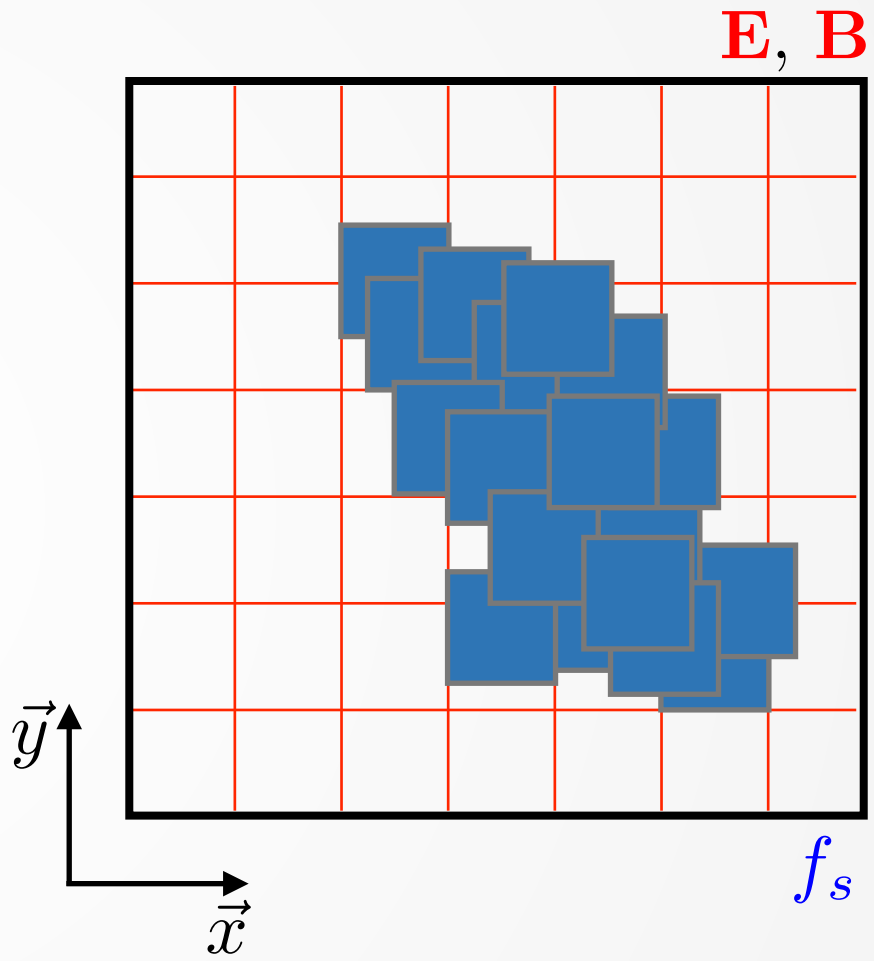

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$\rho, \mathbf{J}$ $\quad \Delta t \quad$ $\mathbf{F}_L$

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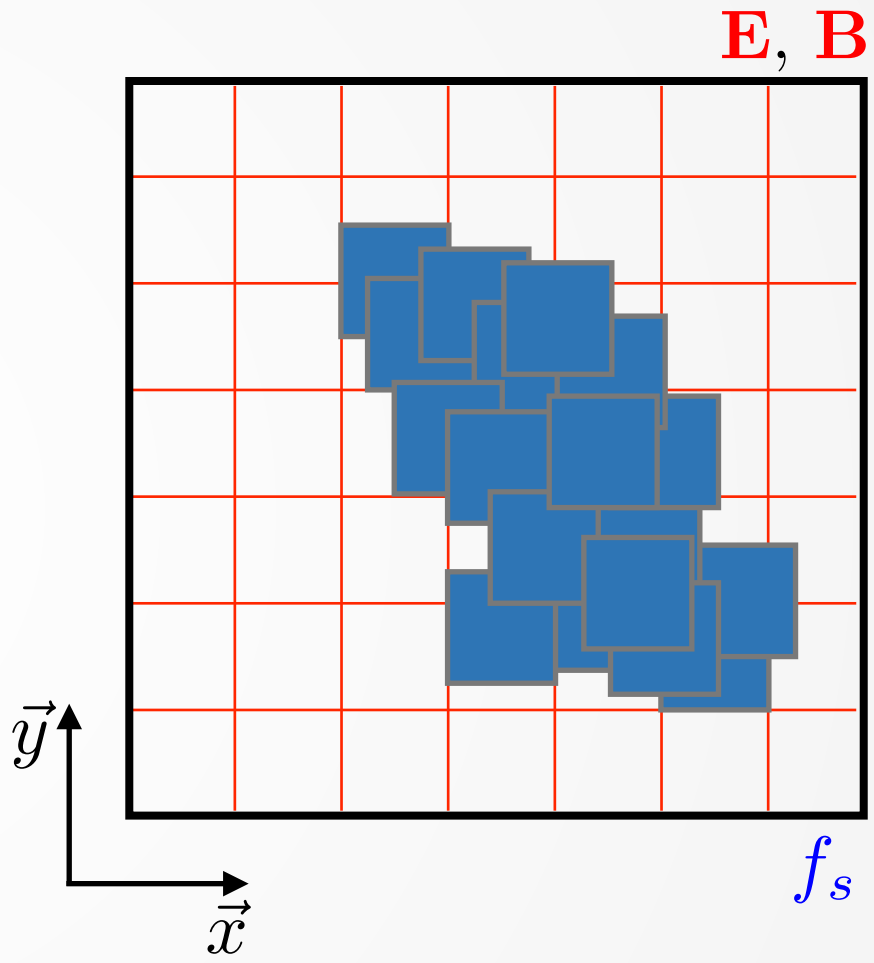

Guillaume's talk this afternoon

Smilei allows for advanced physics simulation

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Physics Modules

- collisions (Fokker-Planck)
- ionization (field & impact)
- fusion reaction (DD)
- inverse Compton scattering
- Breit-Wheeler pair production

Frédéric's talk on Friday morning

Advanced Models

- Azimuthal mode decomposition
- Laser envelop model

Francesco's talk on Friday morning

Smilei in a nutshell

Open-source & Community-Oriented

documentation • chat • online tutorials • post processing & visualization
training workshops • summer school & master trainings • issue reporting

High-performance

C++/Python • MPI/OpenMP • SIMD • HDF5/OpenPMD
a platform for Exascale (GPU porting under way)

Multi-Physics & Multi-Purpose

advanced physics modules: geometries, collisions, ionization, QED
broad range of applications: from laser-plasma interaction to astrophysics

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Frédéric & Francesco talks on Friday

The Smilei dev-team

Co-development between physicists & HPC specialists

Mickael Grech*
Frederic Perez*
Tommaso Vinci*

Arnaud Beck*
Guillaume Bouchard

Mathieu Lobet*
Francesco Massimo
Julien Derouillat, Res. Engineer**

*permanent staff **Res. Engineer position to be opened
(CNRS DDOR, w.s.f. INP, INSU, IN2P3)

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Haïthem Kallala

Marie Flé
Olga Abramkina (also at MdlS)

Asma Farjallah

Umesh Seth
Etienne Malboeuf

Nicolas Aunai
Jérémie Dargent

Clément Caizergues
Emmanuel d'Humières

Illya Plotnikov

Paula Kleij
Michèle Raynaud

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A project anchored in the HPC landscape

Integration in the French & European HPC landscapes

GENCI
Le calcul intensif au service de la connaissance

EuroHPC
Joint Undertaking

- running on all super-computers in France (and many in Europe)
- 10s millions computing hours every year via GENCI & PRACE
- GENCI technological survey
- French Exascale Project
- EuroHPC call for Exascale Centers of Excellence

Special/early access to various machines

2015 IDRIS/Turing BlueGene-Q
2016 CINES/Occigen
2018 TGCC/Irene-Joliot-Curie
2019 IDRIS/Jean Zay
2021 RIKEN/Fugaku

The Smilei project timeline

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High-Performance Physics-driven

Community-oriented

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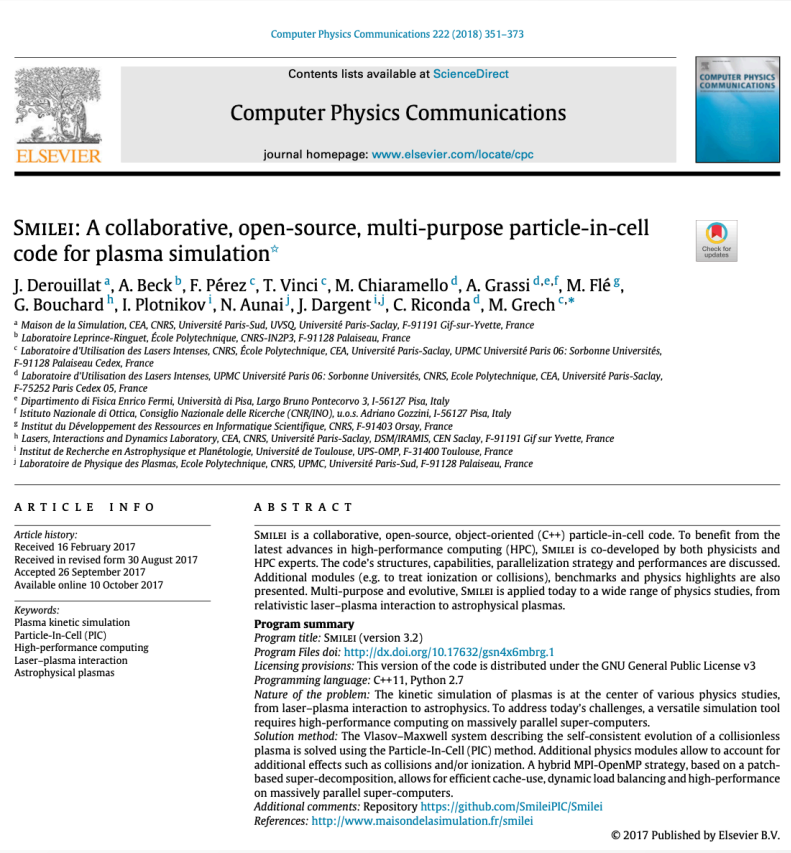

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journal homepage: www.elsevier.com/locate/cpc

SMILEI: A collaborative, open-source, multi-purpose particle-in-cell code for plasma simulation☆

J. Derouillat [a], A. Beck [b], F. Pérez [c], T. Vinci [c], M. Chiaramello [d], A. Grassi [d,e,f], M. Flé [g], G. Bouchard [h], I. Plotnikov [i], N. Aunai [j], J. Dargent [i,j], C. Riconda [d], M. Grech [c,*]

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[c] Laboratoire d'Utilisation des Lasers Intenses, CNRS, École Polytechnique, CEA, Université Paris-Saclay, UPMC Université Paris 06: Sorbonne Universités, F-91128 Palaiseau Cedex, France
[d] Laboratoire d'Utilisation des Lasers Intenses, UPMC Université Paris 06: Sorbonne Universités, CNRS, Ecole Polytechnique, CEA, Université Paris-Saclay, F-75252 Paris Cedex 05, France
[e] Dipartimento di Fisica Enrico Fermi, Università di Pisa, Largo Bruno Pontecorvo 3, I-56127 Pisa, Italy
[f] Istituto Nazionale di Ottica, Consiglio Nazionale delle Ricerche (CNR/INO), u.o.s. Adriano Gozzini, I-56127 Pisa, Italy
[g] Institut du Développement des Ressources en Informatique Scientifique, CNRS, F-91403 Orsay, France
[h] Lasers, Interactions and Dynamics Laboratory, CEA, CNRS, Université Paris-Saclay, DSM/IRAMIS, CEN Saclay, F-91191 Gif sur Yvette, France
[i] Institut de Recherche en Astrophysique et Planétologie, Université de Toulouse, UPS-OMP, F-31400 Toulouse, France
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Laser–plasma interaction
Astrophysical plasmas

ABSTRACT

SMILEI is a collaborative, open-source, object-oriented (C++) particle-in-cell code. To benefit from the latest advances in high-performance computing (HPC), SMILEI is co-developed by both physicists and HPC experts. The code's structures, capabilities, parallelization strategy and performances are discussed. Additional modules (e.g. to treat ionization or collisions), benchmarks and physics highlights are also presented. Multi-purpose and evolutive, SMILEI is applied today to a wide range of physics studies, from relativistic laser–plasma interaction to astrophysical plasmas.

Program summary
Program title: SMILEI (version 3.2)
Program Files doi: http://dx.doi.org/10.17632/gsn4x6mbrg.1
Licensing provisions: This version of the code is distributed under the GNU General Public License v3
Programming language: C++11, Python 2.7
Nature of the problem: The kinetic simulation of plasmas is at the center of various physics studies, from laser–plasma interaction to astrophysics. To address today's challenges, a versatile simulation tool requires high-performance computing on massively parallel super-computers.
Solution method: The Vlasov–Maxwell system describing the self-consistent evolution of a collisionless plasma is solved using the Particle-In-Cell (PIC) method. Additional physics modules allow to account for additional effects such as collisions and/or ionization. A hybrid MPI-OpenMP strategy, based on a patch-based super-decomposition, allows for efficient cache-use, dynamic load balancing and high-performance on massively parallel super-computers.
Additional comments: Repository https://github.com/SmileiPIC/Smilei
References: http://www.maisondelasimulation.fr/smilei

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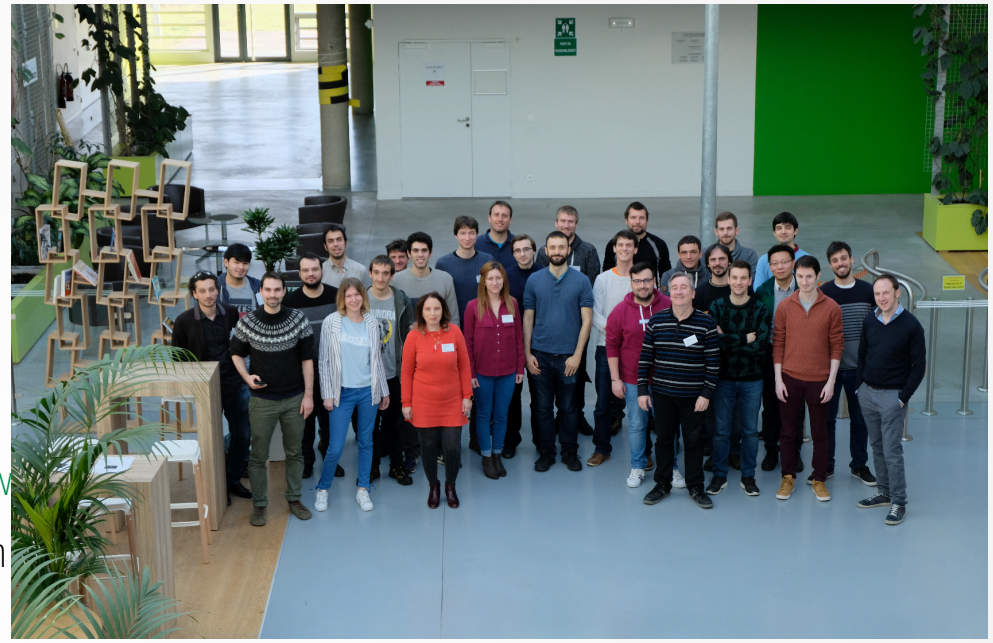
Version 4.3 Quasi-cylindrical geometry (azimuthal mode decomposition)
2nd training workshop (March. 7-8)



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Optimization on ARM architecture, Porting on GPU

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What you get with Smilei

A high-performance PIC code

running on various supercomputers worldwide

with dedicated **post-processing tools** (Happi) and an ensemble of **benchmarks** (Easi, for continuous integration)

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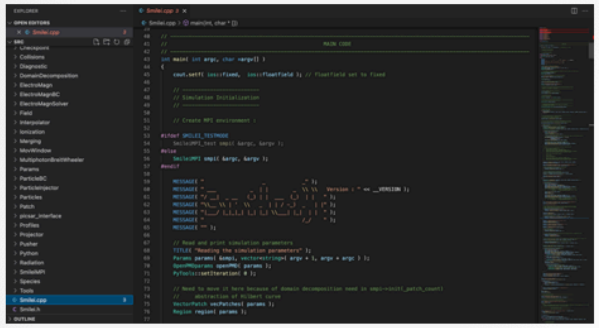

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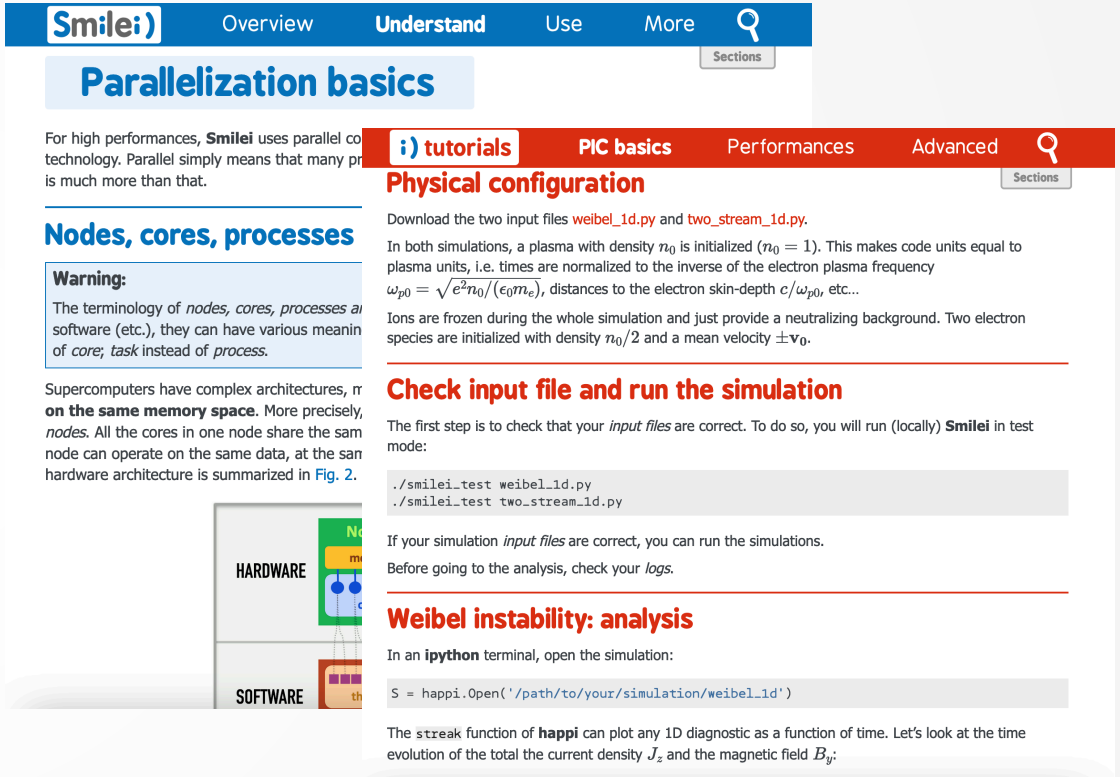

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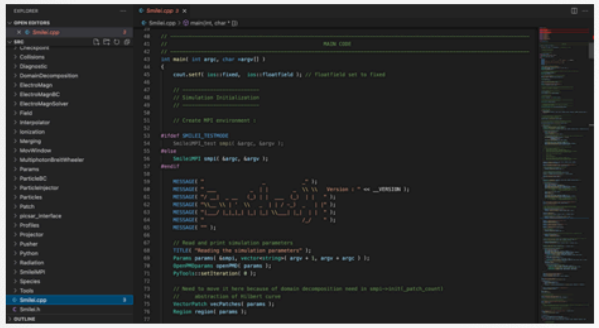

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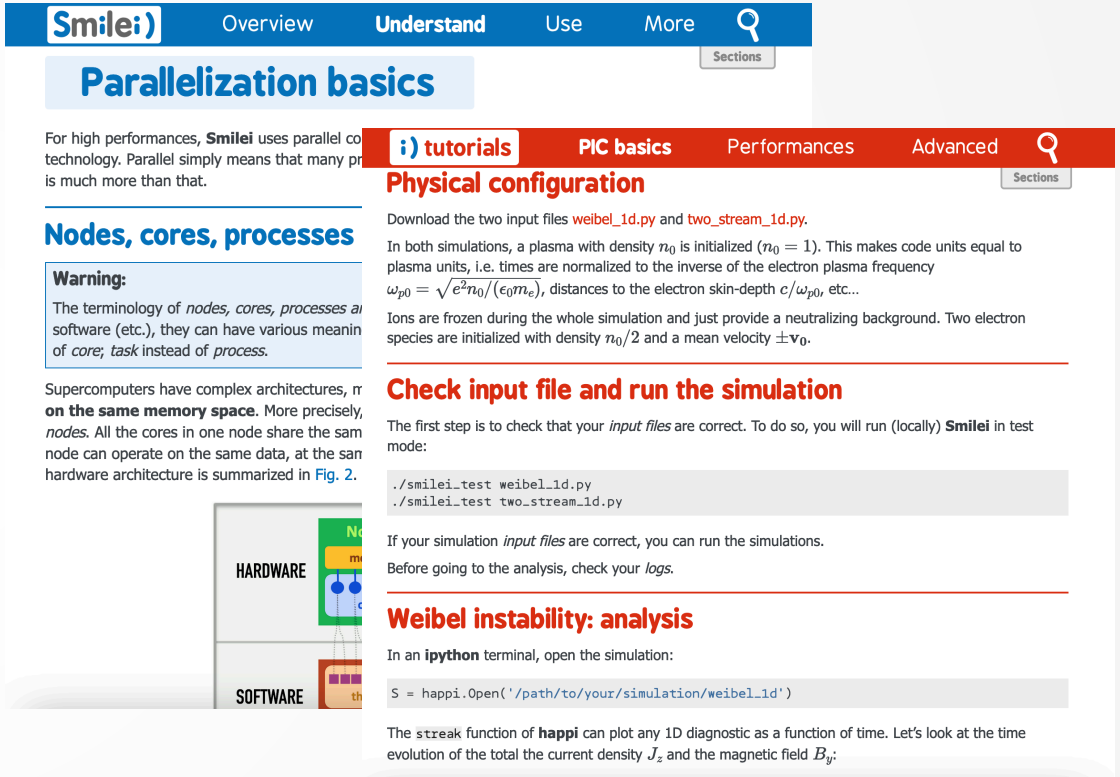
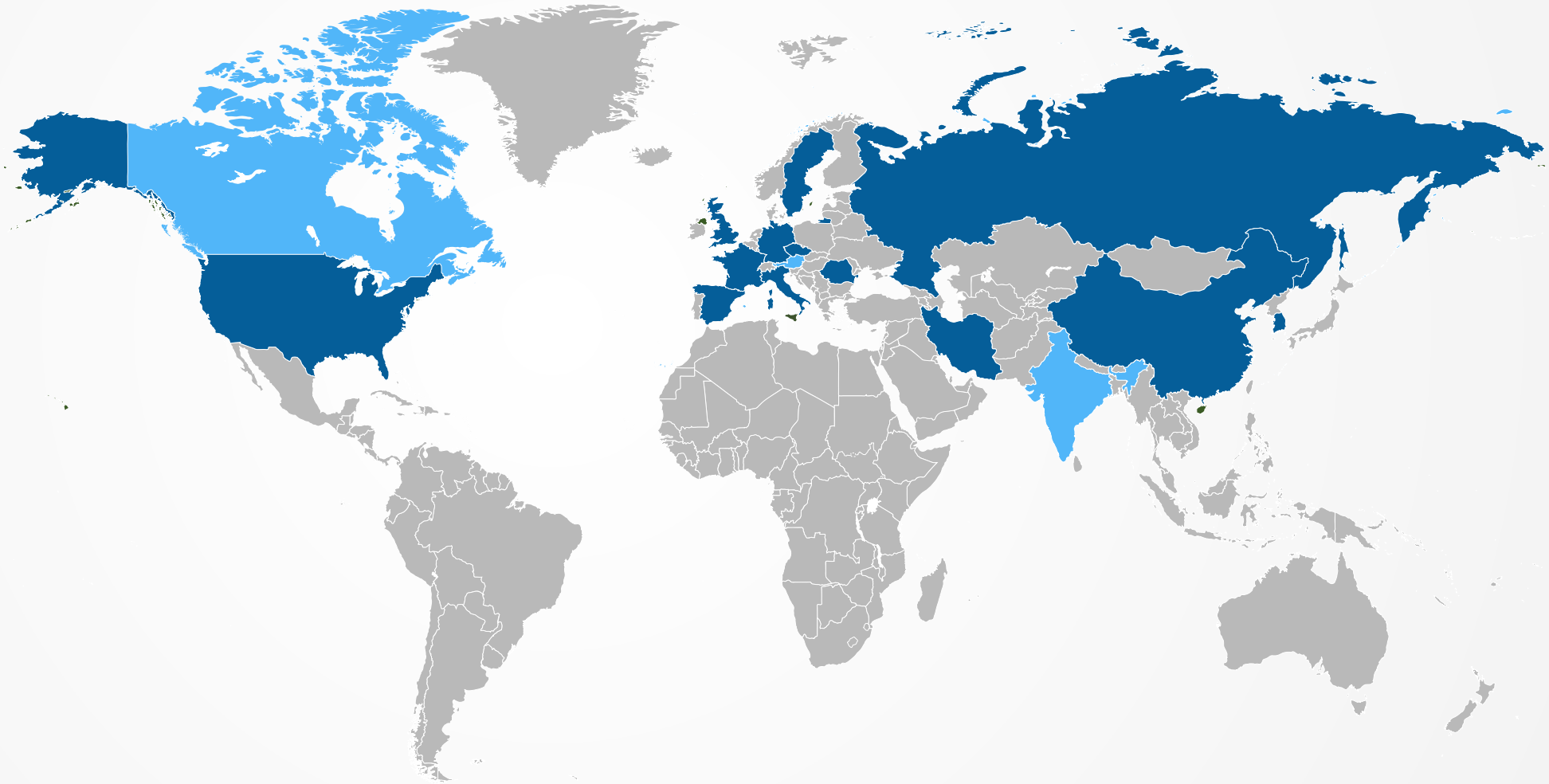


and a collaborative community

Github
sources, issues

Element
chat

Smilei's user community is international & steadily growing



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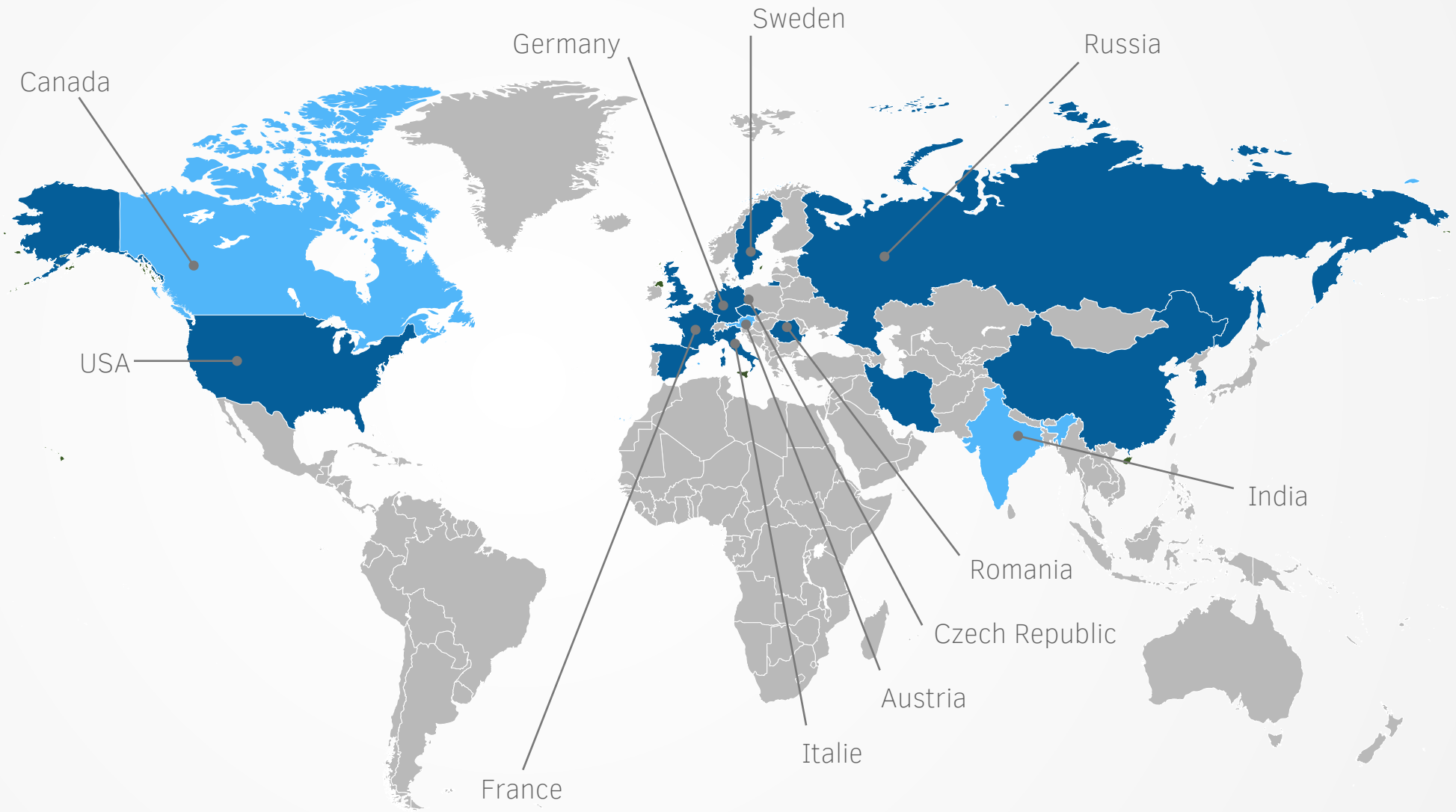

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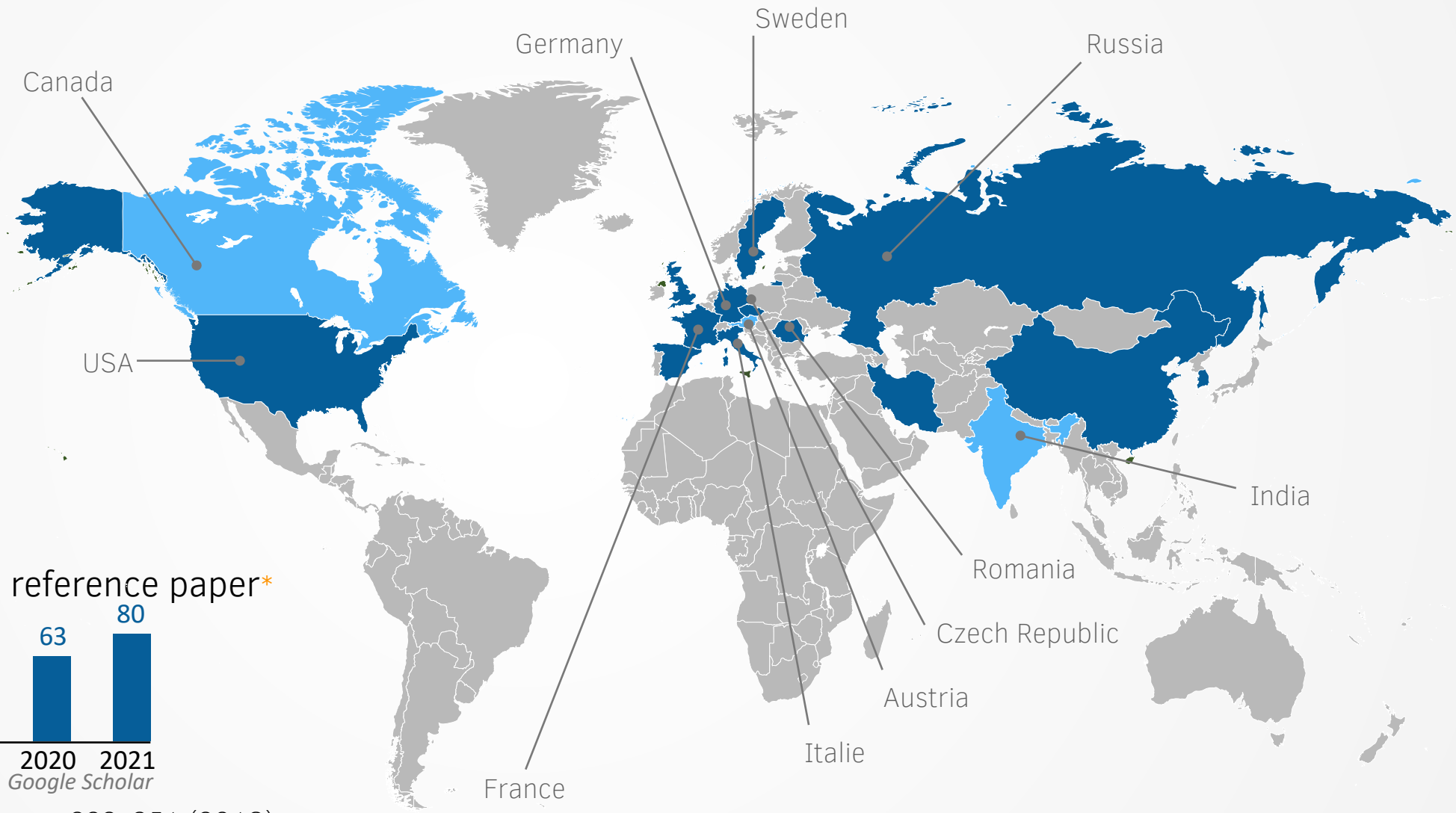
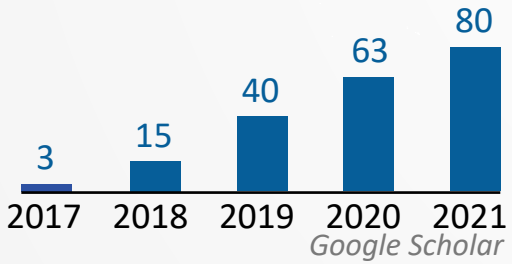


200+ citations for Smilei reference paper*



*Dérouillat et al., Comp. Phys. Comm. 222, 351 (2018)

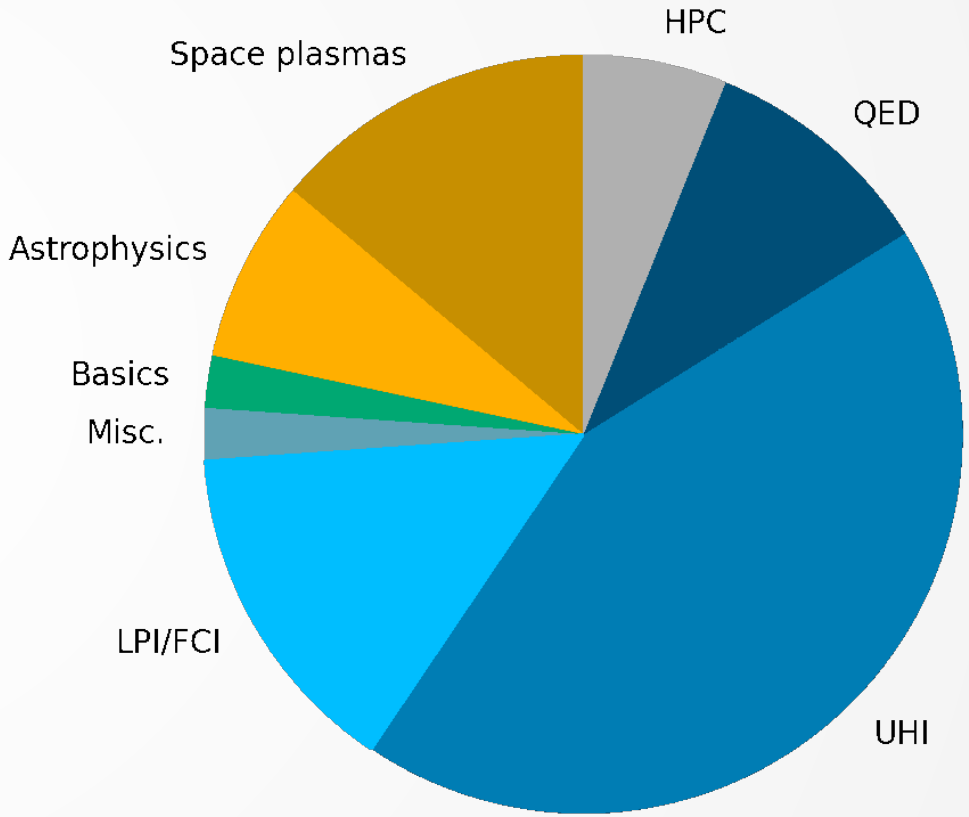
An international user community steadily growing

Scientific production is rich …

100 peer-reviewed papers have been published using Smilei
10+ PhD theses in France benefited from Smilei

… and focuses on various applications

LPI/FCI : laser-plasma interaction / inertial confinement fusion
UHI : Ultra-high intensity
QED : Quantum electrodynamics (extreme light)
HPC : high-performance computing
Space plasmas & astrophysics



Smilei is a research and teaching platform

10+ PhD theses benefit from Smilei

Marco Chiaramello, Université Pierre & Marie Curie (2016)
Laser amplification via stimulated Brillouin scattering (...)

Anna Grassi, Université Pierre & Marie Curie (2017)
Collisionless shocks in the context of laboratory astrophysics

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Teaching plasma physics

at the Master level (M1 at SU, M2 PPF & GI-PLATO)
in various winter/summer schools

Perspectives

Code & HPC aspects: meeting the Exascale challenge

Mathieu's talks (after this one & this afternoon)

- optimization on ARM/RISC architectures
- GPU porting
- parallelization by task
- research engineer position opening at MdlS

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- Bremsstrahlung high energy photon emission
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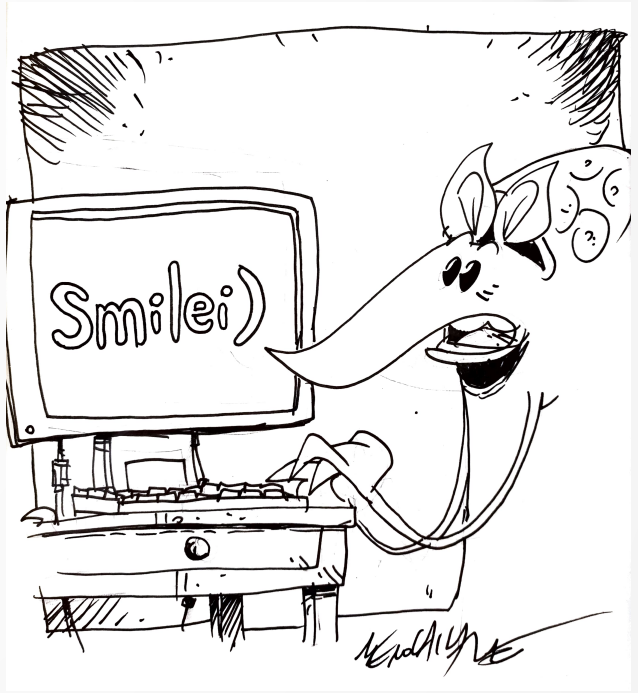
Keep on building & animating the user community

- encouraging new developers to join in (Table ronde, Friday 14h00)
- developing an online teaching platform (Arianna's talk this morning)
- preparing next user & training workshop !



Acknowledgements

Funding agencies

PLAS@PAR Plasmas à Paris

P2IO Physique des 2 Infinis et des Origines

PALM Laboratoire d'Excellence Physique : Atomes Lumière Matière

Physique des Infinis Une Initiative Sorbonne Université

AIDAS AI Data Analytics and Scalable Simulations

Contributing labs & institutions

MAISON DE LA SIMULATION

LMI

LPP

irap astrophysique & planétologie

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Thank you for your attention!