COMPARISON OF KINETIC SIMULATION OF MAGNETIC RECONNECTION WITH IN-SITU OBSERVATIONS AND PLANNED SPIS BENCHMARKING

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OUTLINE

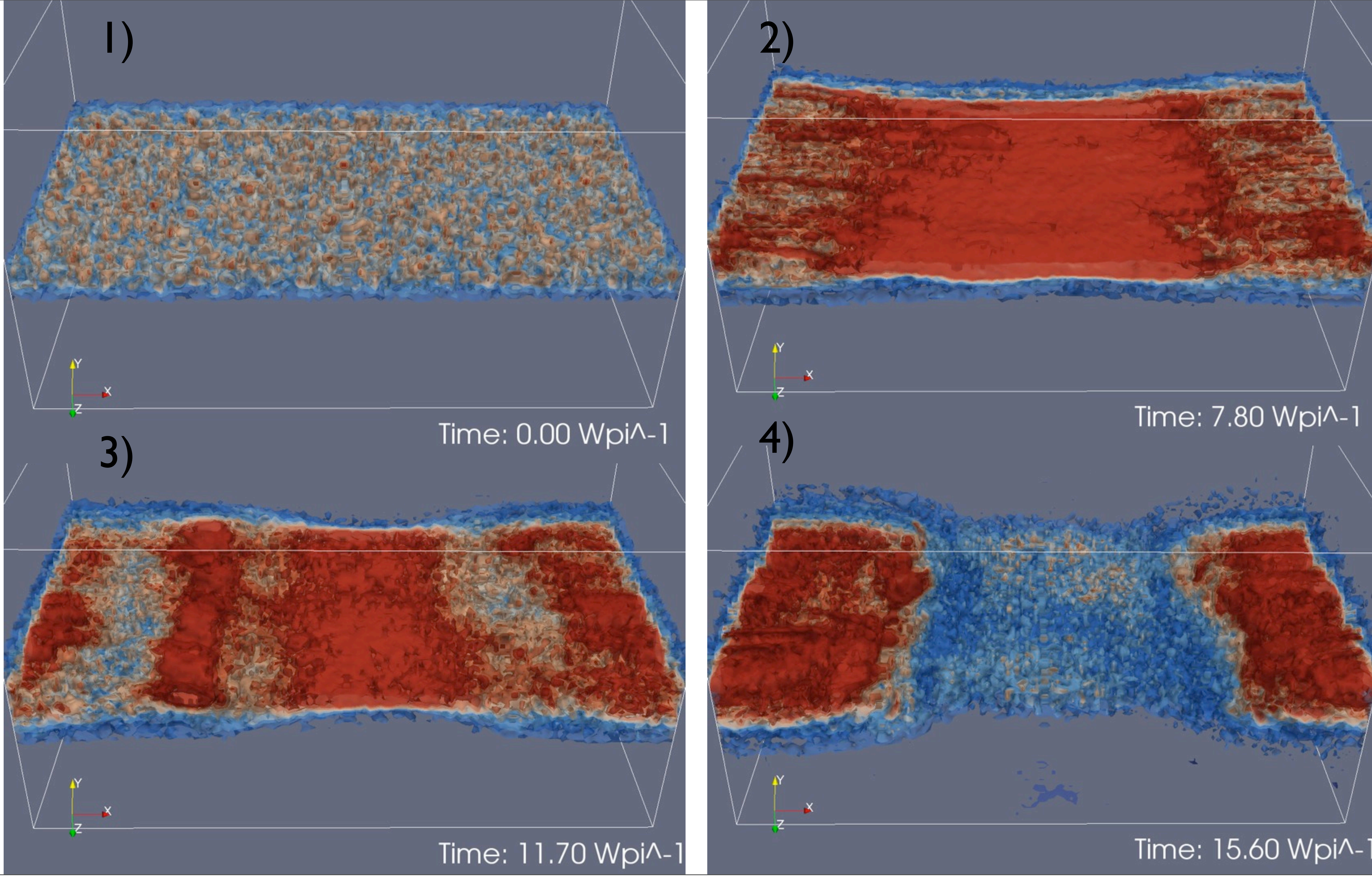
- PRESENTATION OF OUR GROUP ACTIVITIES AT KUL.
- PIC MODELING MAGNETIC RECONNECTION WITH USE OF VIRTUAL SATELLITES.
- SPACECRAFT CHARGING WITH EMPHASIS ON NUMERICS (effect of non uniform grid on PIC, effect of non total energy conservation, immersed boundary method)

OUR GROUP

- Theory and computational group at Centre for Plasma Astrophysics at Catholic University of Leuven (Belgium) working on:
  - space physics PIC simulations. In particular magnetic reconnection problems.
  - PIC methods developing. Focus on numerics.

COLLISIONLESS MAGNETIC RECONNECTION

- KINETIC SIMULATIONS OF MAGNETIC RECONNECTION. Output B, E, distribution functions, moment of the distribution functions.
- IMPLICIT PARALLEL Particle-in-Cell code, IPIC3D.
- LARGE SPACE SCALE (~100 ion skin depths) because implicit differentiation the PIC can be much larger than the Debye length.
- PHYSICAL MASS RATIO FOR PLASMA SPECIES.
- WORKING ON THEMIS DATA AND PREPARING MMS WITH CU AND LASP.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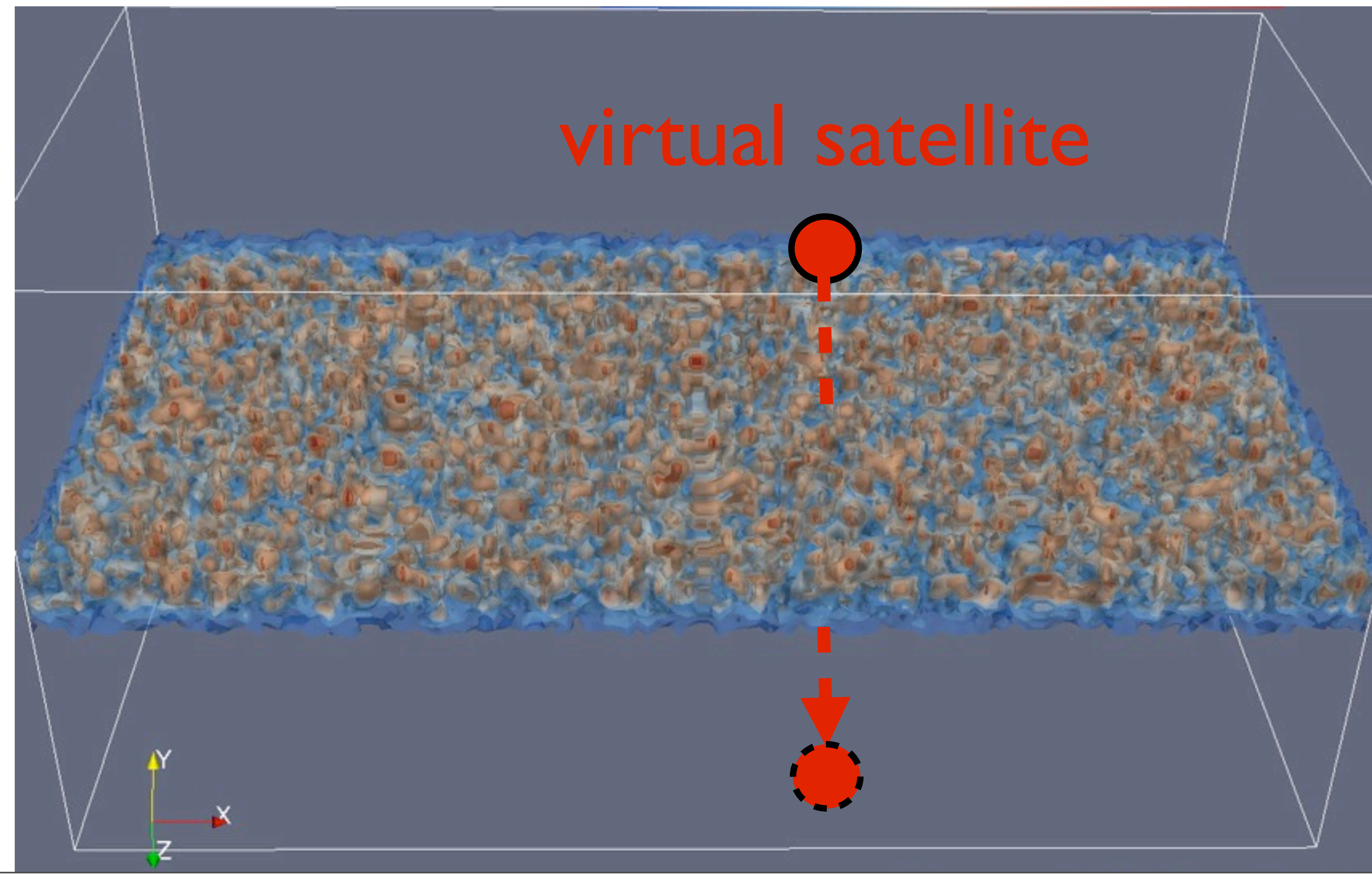
VIRTUAL SATELLITES

1. "Realistic" simulations.

2. Kinetic simulations provide output that can be directly compared with spacecraft probes data.

A virtual satellite can be added in the simulation to record quantities real spacecraft probes can detect. Virtual satellites can move an reproduce satellites crossings.



Observation-like data from simulations

B and E (three components) evolution from one of the virtual satellites

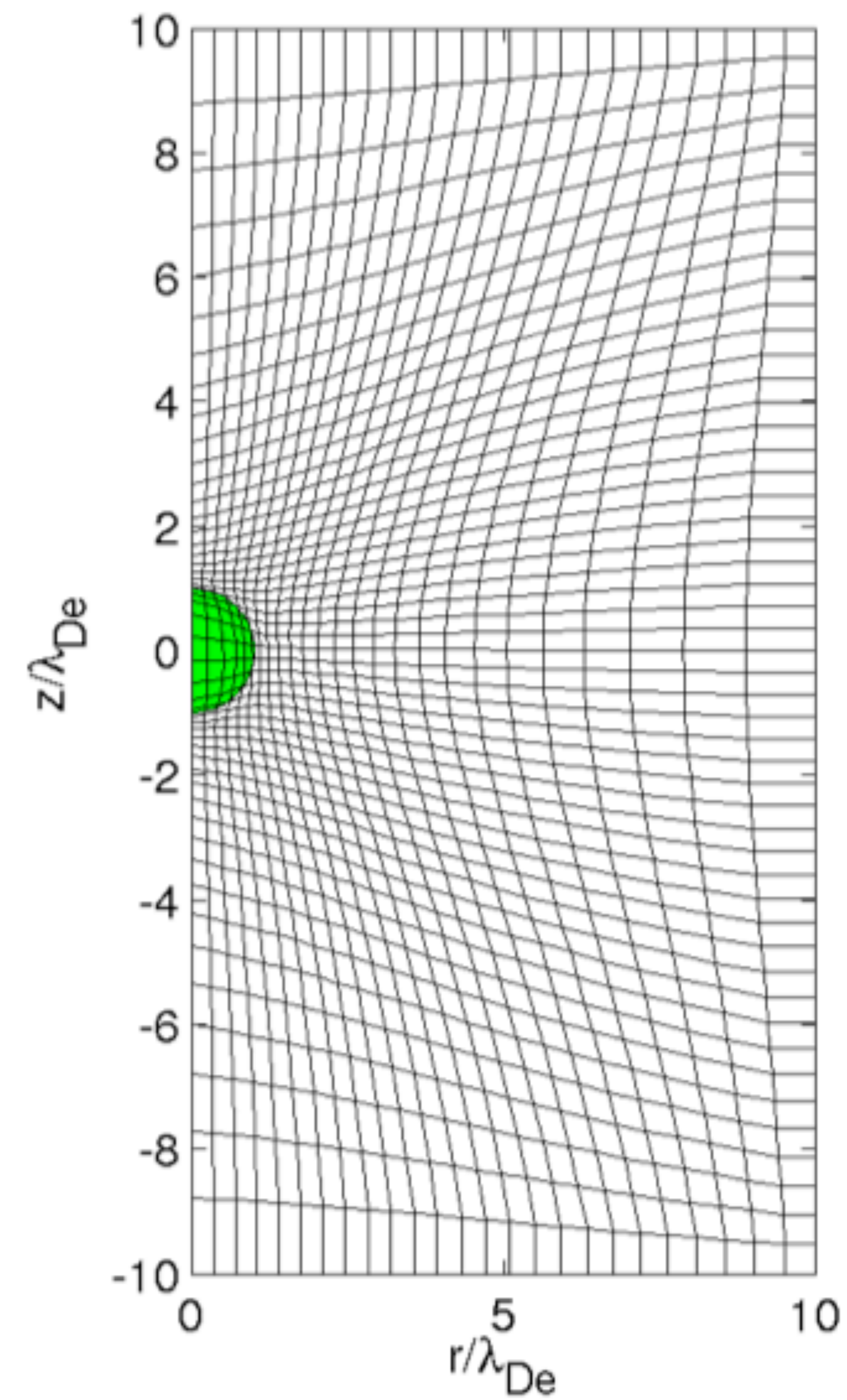
TOWARDS BETTER MODELING OF VIRTUAL SATELLITES

- Include the eventual spacecraft charging effects on virtual probes depending on the spacecraft plasma environment.
- Use of **SPIS** for modeling MMS spacecrafts and include realistic effects on virtual satellites.
- Planning to simulate with **SPIS** spacecraft charging with different values of B and densities retrieved by simulations.

SPACECRAFT CHARGING

Two KUL codes are used for studying the charging of a body immersed in a plasma:

- **Democritus**. 2D with non uniform grid. Serial.
- **iPIC3D**. 3D with uniform grid. Parallel.



We are doing PIC <u>numerical studies</u> that can be useful for **SPIS** PIC code.

SPACECRAFT CHARGING WITH EMPHASIS ON NUMERICS

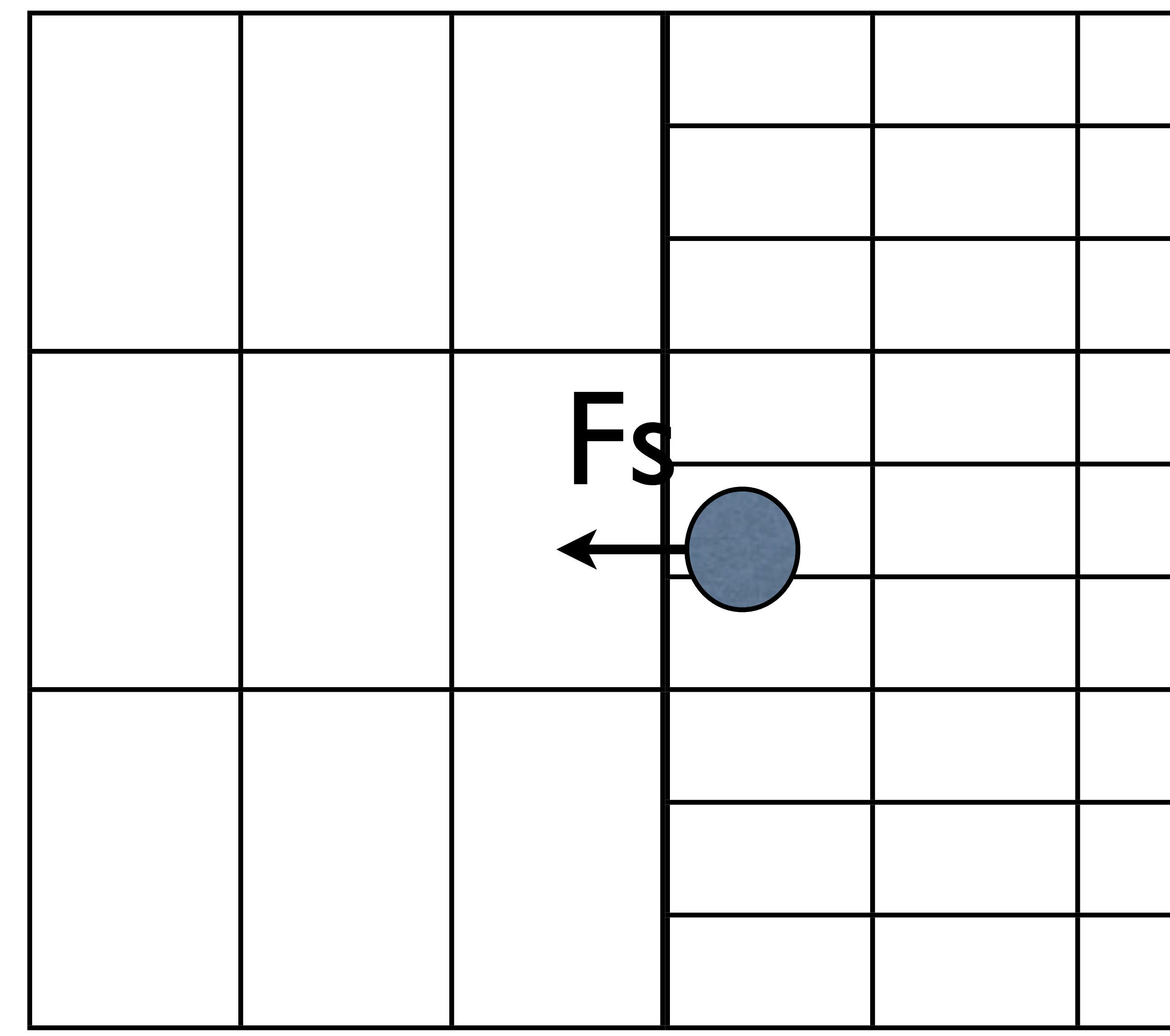
- **SPINE** community efforts focus mainly on requirements driven by physics models (see user requirements statement of work)
- We focus on numerical PIC issues that arise unphysical effects:
  - Self-forces on non uniform grids (non conservation of momentum) and their effect on sheath formation and spacecraft charging.
  - Effects of non energy conservation in PIC codes.
- Modeling deep charging via the Immersed Boundary method.

PIC METHODS WITH NON UNIFORM GRIDS

- Spurious forces arise in PIC codes when non uniform grids are used. These spurious forces affect the particle dynamics. The macroscopic effect is the non conservation of the total momentum.

- We are quantifying how much spurious forces affect particle dynamics in non-uniform grids in charging problems.

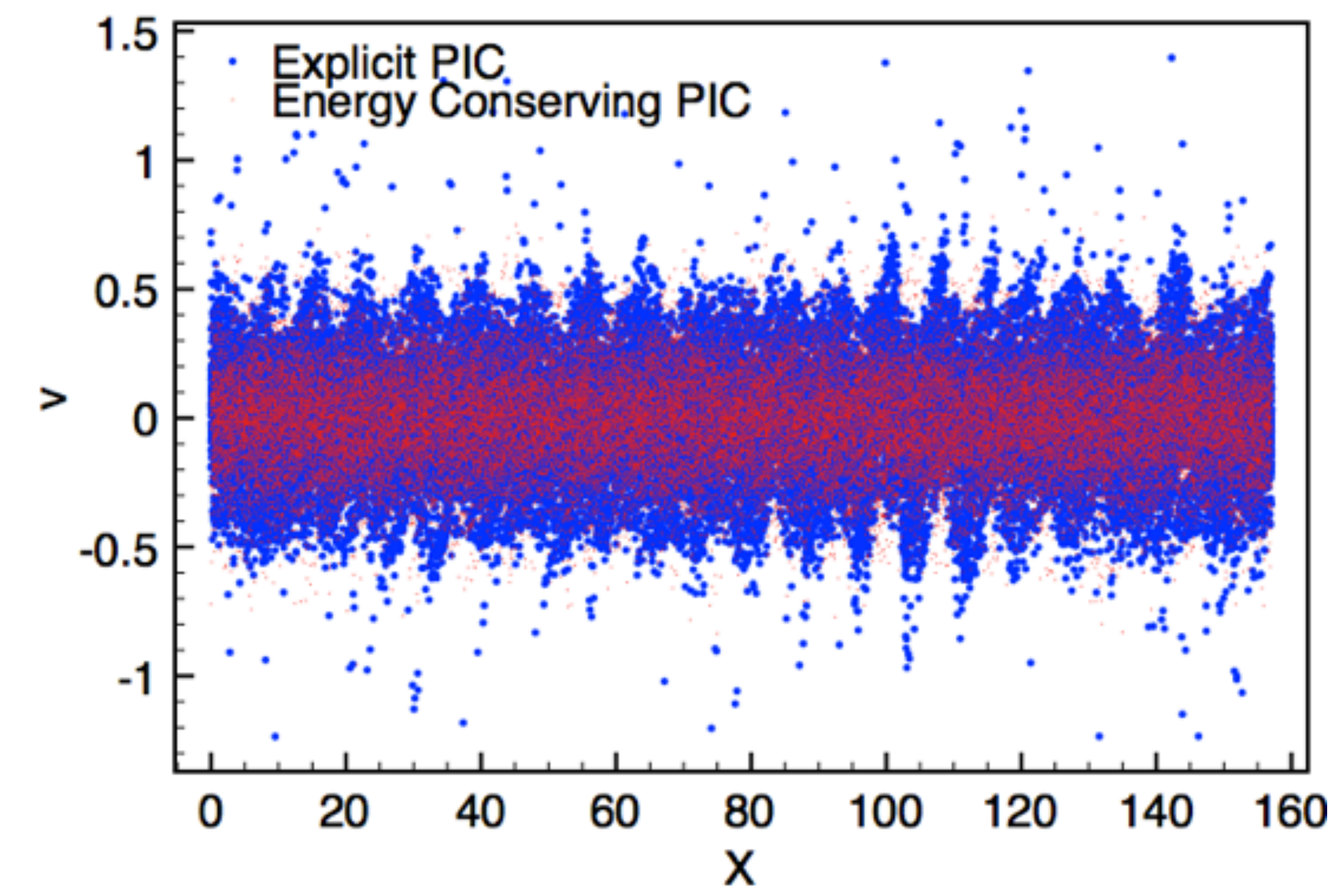
- We are developing a momentum conserving PIC for non uniform grids.

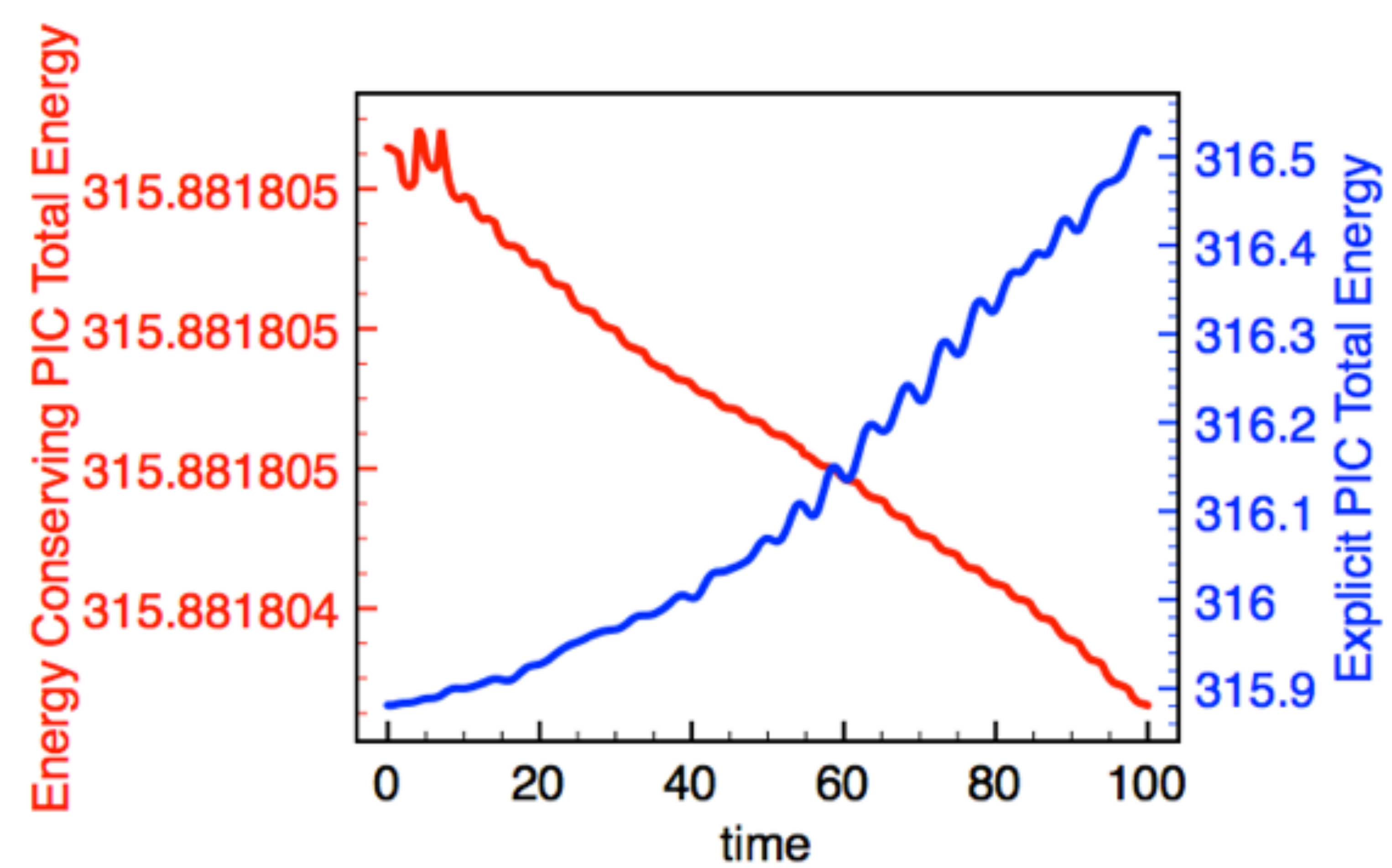


NON CONSERVATION OF ENERGY

- Developed the first ENERGY CONSERVING PIC METHOD (*The Energy Conserving Particle-in-Cell Method*, S.Markidis and G.Lapenta, submitted to JCP)

- Applying this new algorithm to the charging problem to determine the effects of the non conservation of energy on charging problem.





IMMERSED BOUNDARY METHOD

- In our codes, the spacecraft is not represented by a circuit coupled with ambient plasma. Spacecrafts are modeled as a group of motionless particles, characterized by a dielectric constant. This approach gives 2 main advantages:
  - We solve the Maxwell's equations (in a medium) in all the domain, included the spacecraft area.
  - We can model deep charging in a straightforward way.

DEEP CHARGING

A **particle stopping power** is introduced as a grid quantity at each cell g in the spacecraft region

$$\mu_g$$

A damping force is introduced in the equation motion of plasma particles entering the spacecraft region:

$$\frac{\mathbf{v}_p}{dt} = \frac{q}{m}\mathbf{E} - \mathbf{v}_p \sum_g W(\mathbf{x}_g - \mathbf{x}_p)\mu_g$$

Particle are stopped inside the spacecraft at different distances depending on μ_g

SUMMARY

- Planned use of **SPIS** for more realistic modeling of virtual satellites.
- Numerical studies of use of non uniform grid and non conservation of energy that can important for **SPIS** PIC code. Immersed boundary could be a straightforward method for modeling deep charging.