Magnetized CMEs and solution adaptive mesh refinement in EUHFORIA

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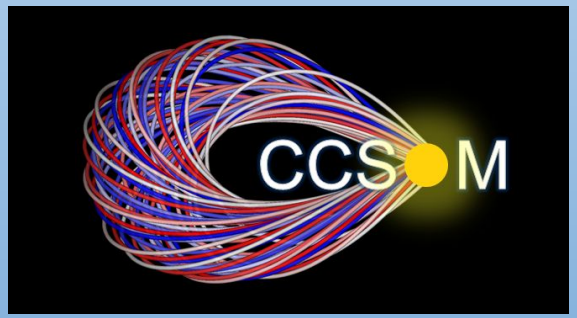

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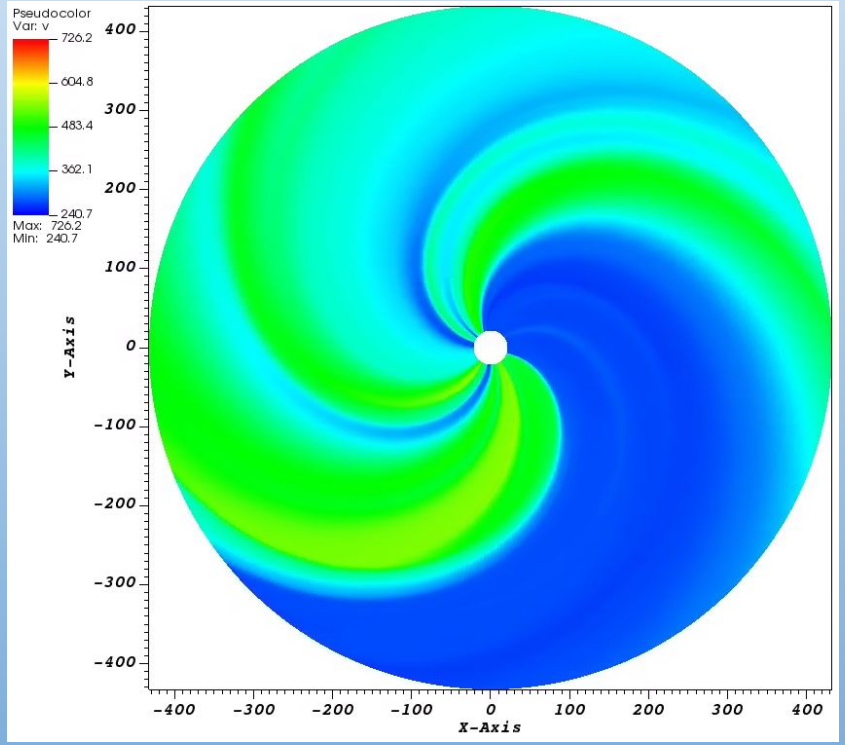
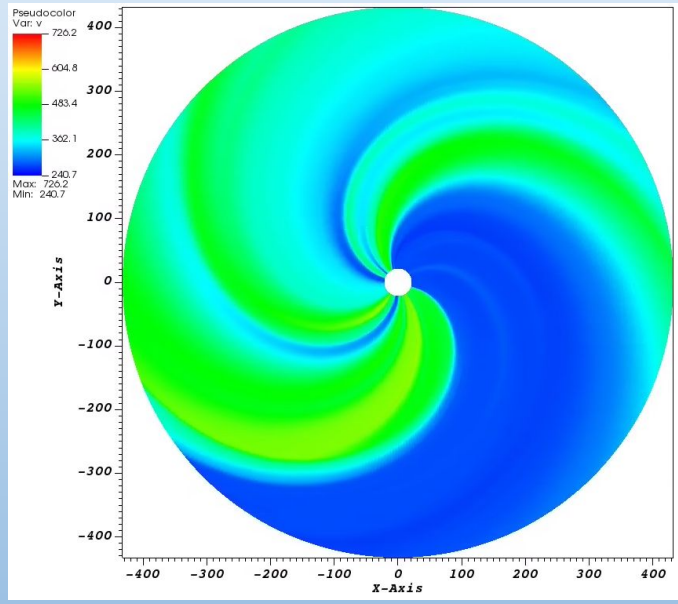
Spheromak model in Icarus

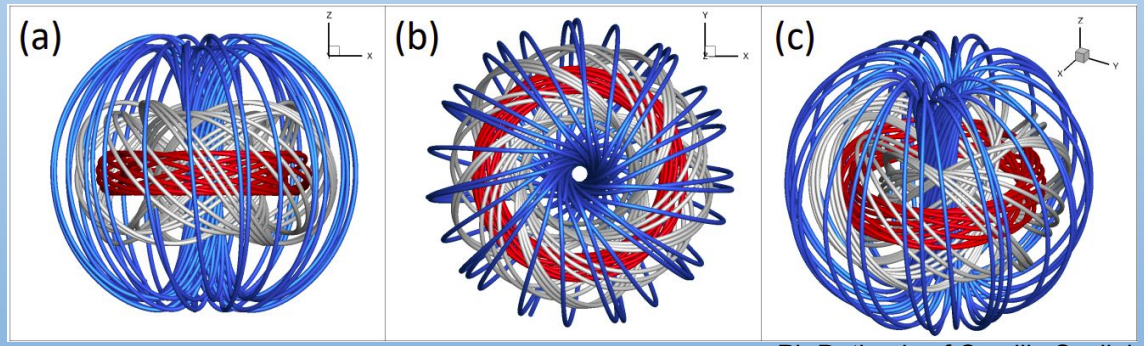
- Co-rotating solar wind in heliospheric model - **Icarus** in MPI-AMRVAC(Xia et al.,2018)
  - Solar wind is stationary after the relaxation
  - CMEs can be super-imposed on the wind



Spheromak model in Icarus

- Co-rotating solar in heliospheric model - Icarus
- EUHFORIA spheromak model(Verbeke et al., 2019) injected in the Icarus model
- Linear Force-Free spheromak model (LFFSpheromak)





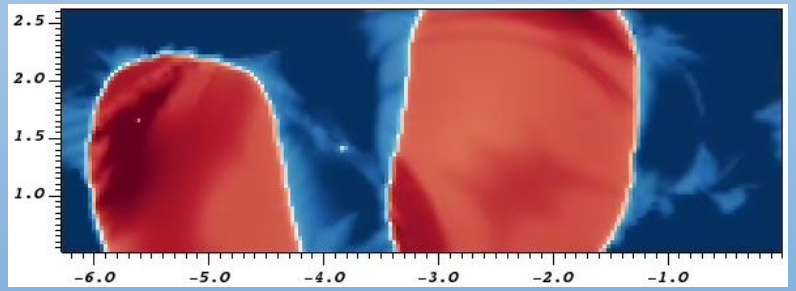
Ph.D. thesis of Camilla Scolini.

3D view of selected magnetic field lines of a linear force-free spheromak with tilt angle $\gamma_{CME} = 0^{\circ}$ and positive chirality. The magnetic field lines are confined within a sphere. Different colours mark field lines characterised by different morphologies. (a): side view. (b): top view. (c): angled view.

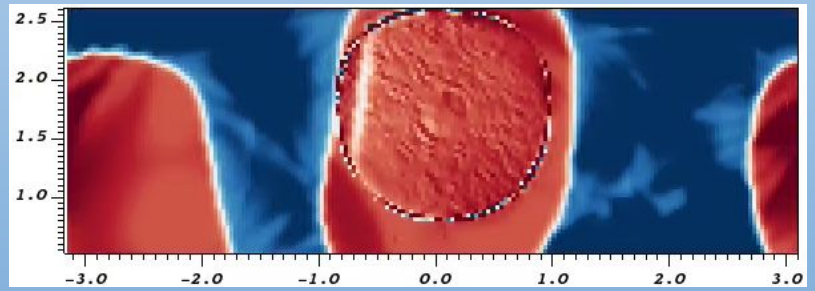
Motivation

- Operational point of view
  - Optimization (grid stretching & AMR) in Icarus ⇒ CPU time saved
- Physics point of view
  - Background wind reconstruction after CME insertion (solved)
  - Better capturing of CIRs or CIR shocks or CMEs or CME shocks (via AMR)

Icarus:

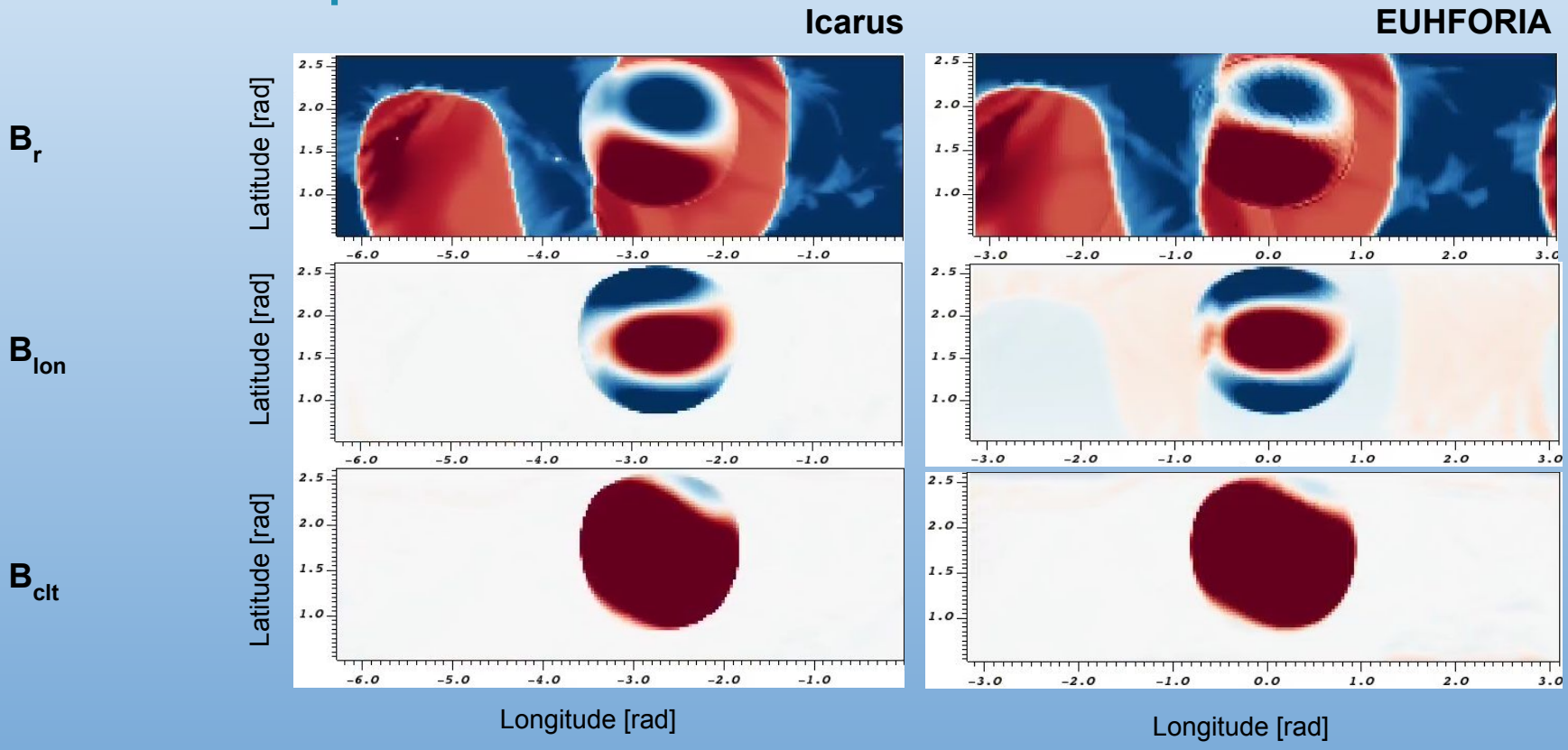


EUHFORIA:

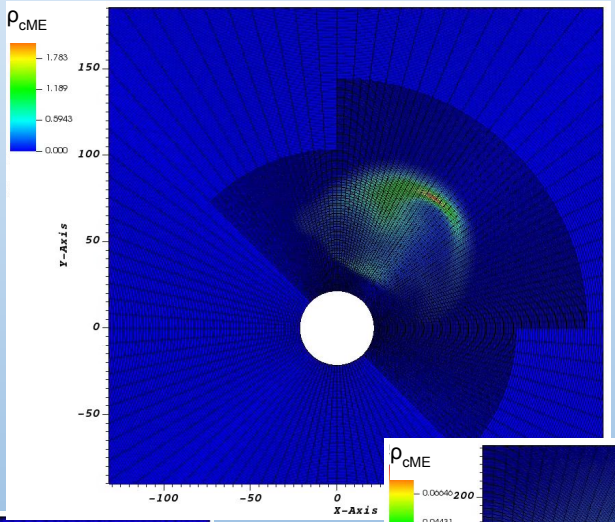


~24h after CME insertion

B field components at 0.1 AU

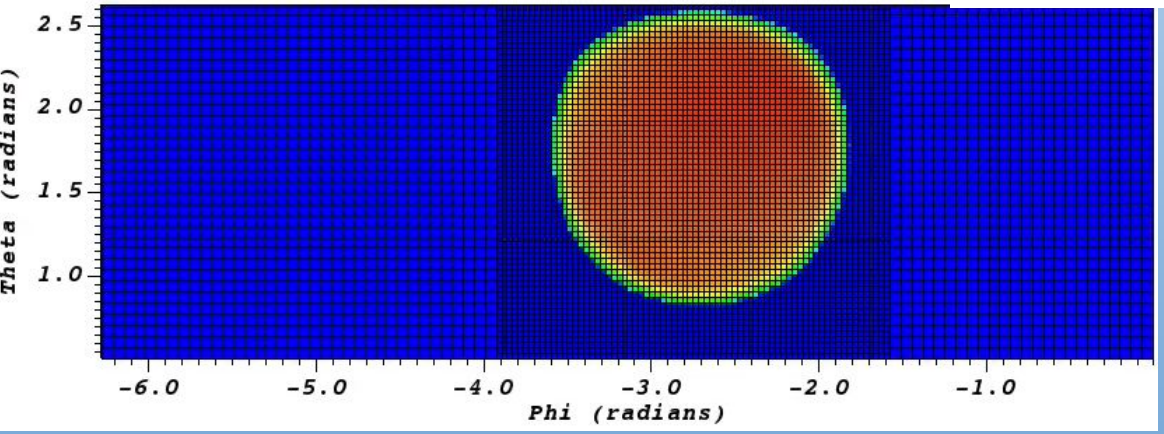


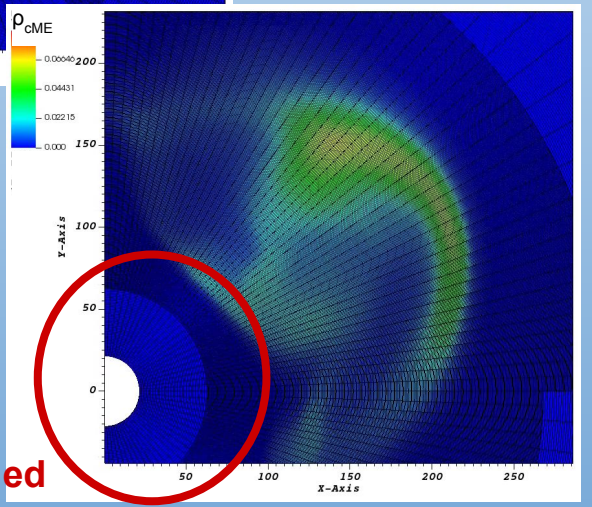
Adaptive Mesh Refinement (AMR)



Equatorial plane

Head on view: 0.1AU spherical slice





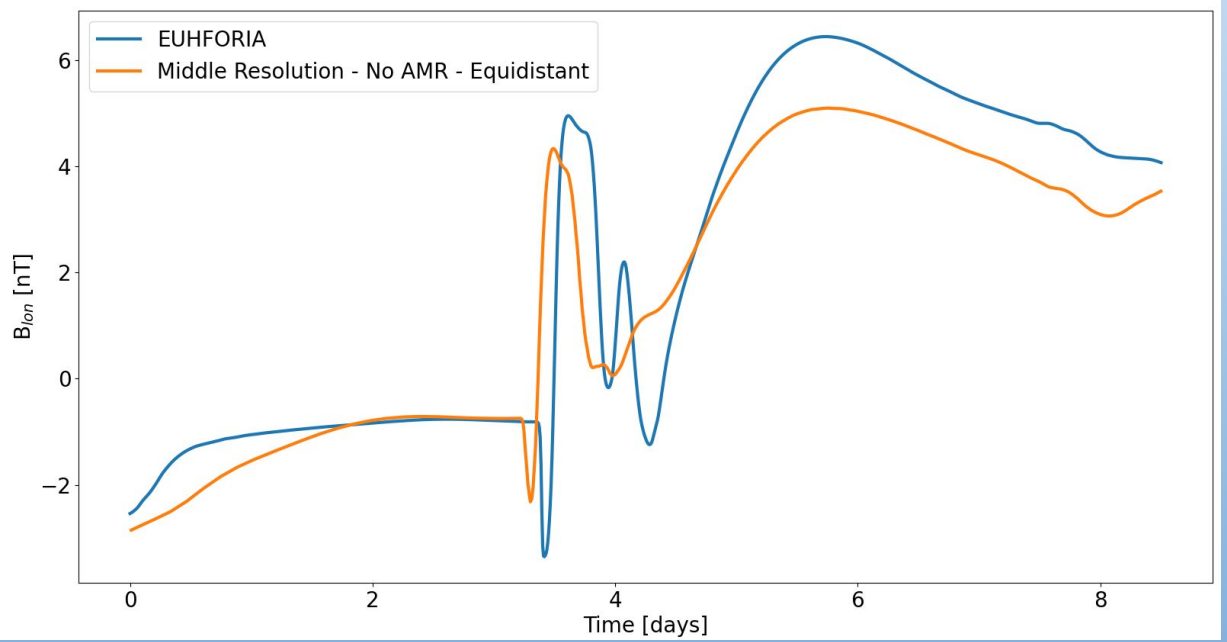
Coarsened

B_{lon} at Earth

Time-series at Earth for the B_{lon} component.

Blue - operational (middle) resolution in EUHFORIA.

Orange - middle resolution resolution in Icarus.



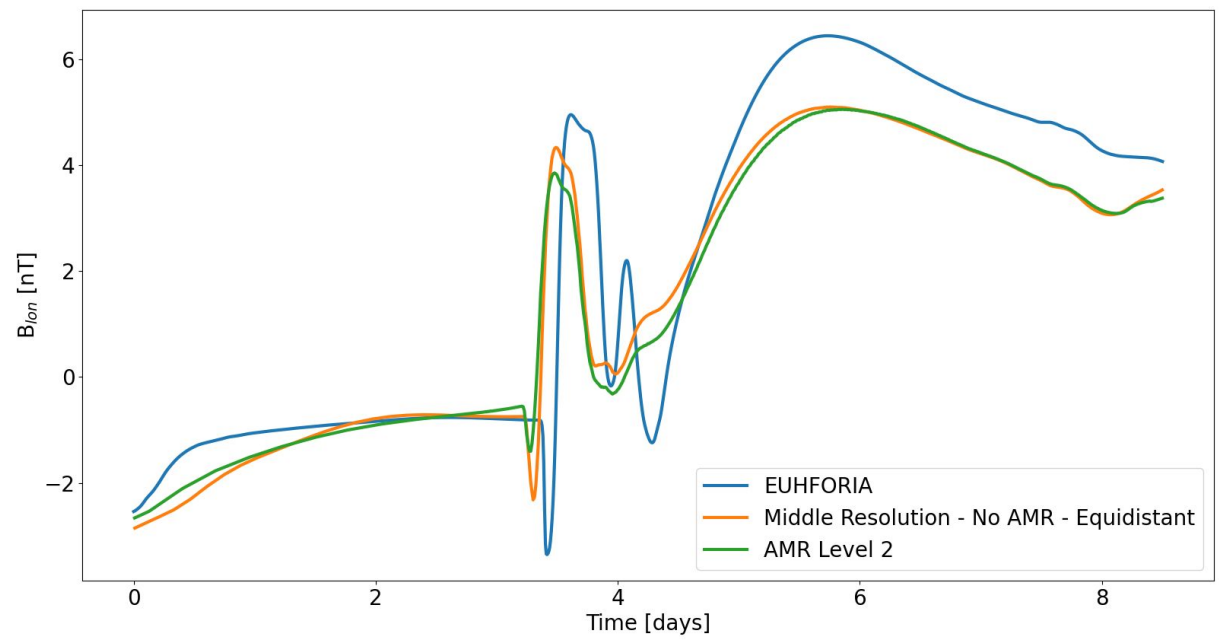
B_{lon} at Earth

Time-series at Earth for the B_{lon} component.

Blue - operational (middle) resolution in EUHFORIA.

Orange - middle resolution resolution in Icarus.

Green - Adaptive Mesh Refinement level 2.



B_{lon} at Earth

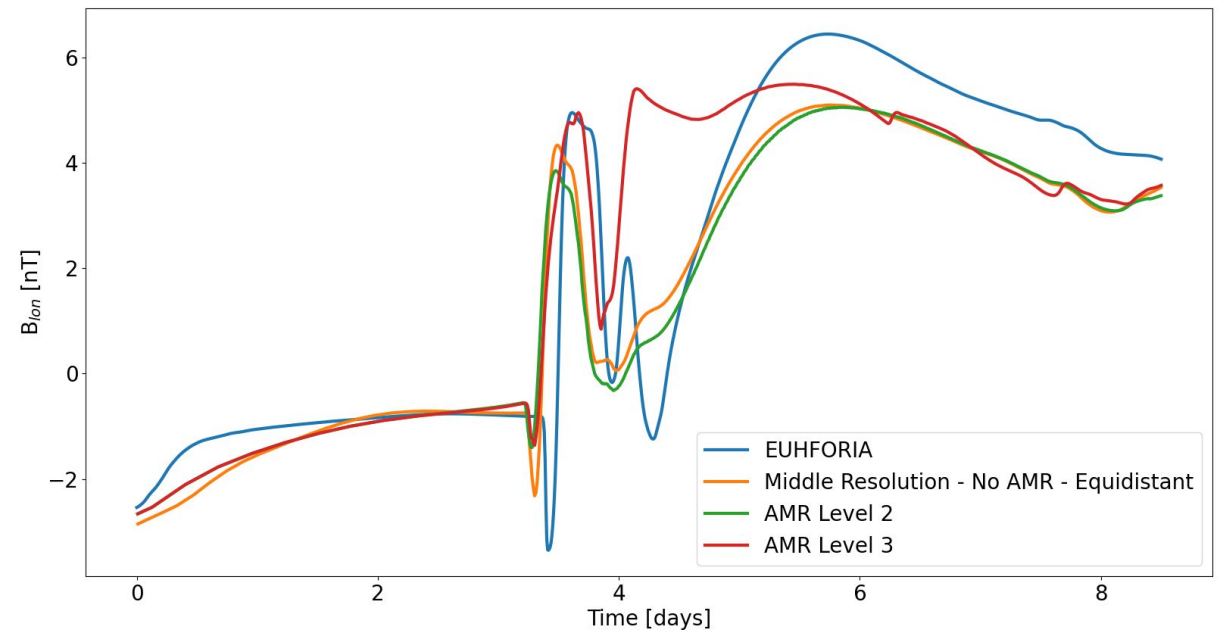
Time-series at Earth for the B_{lon} component.

Blue - operational (middle) resolution in EUHFORIA.

Orange - middle resolution resolution in Icarus.

Green - Adaptive Mesh Refinement level 2.

Red - Adaptive Mesh Refinement level 3.



Timings of the simulations

	EUHFORIA (Middle resolution)	Icarus (Middle resolution)	AMR 2	AMR 3
Wall-clock times	**18h 2m**	**6h 9m**	**0h 43m**	**4h 58m**

Simulations are performed on **1 node only (with 36 CPUs)** on the Genius cluster at the Vlaams Supercomputing Centre.

Speed up factors

	EUHFORIA (Middle)
AMR 2	**25.16**
AMR 3	**3.63**
Icarus (middle)	**2.93**

Summary

- No remnants left at the inner boundary
- Adaptive Mesh Refinement
  - Refined areas in the domain
  - More flexible resolution
- Improved computational time
- Saved computational resources
- Future work
  - Investigation of the different limiters
  - Event study
  - Analysis of the time-series

Thank you!