Code benchmark for planet-disk interaction

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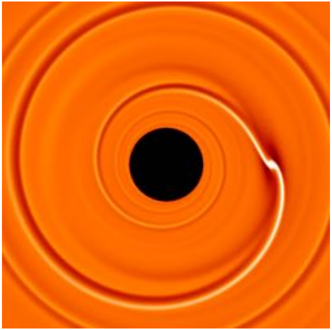
ASTROSIM - 10/10/2018

Planet-disk interaction

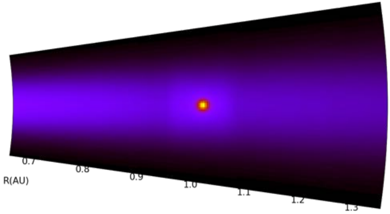
- Rotating gaseous protoplanetary disk
- Planet wake
- Planet migration
- Architecture of planetary system

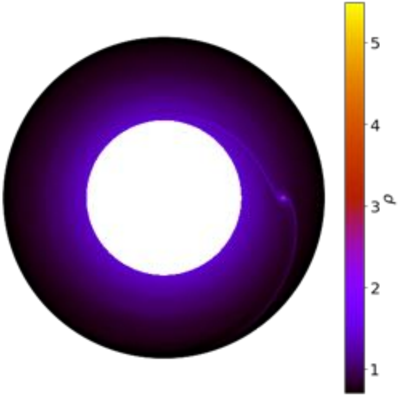


Credit : *F. Masset*

How to study numerically planet-disk interaction ?

- Grid geometry & resolution
- Equations
- Disk density profile
- Keplerian rotation→CFL
- Planet potential
- Boundary conditions





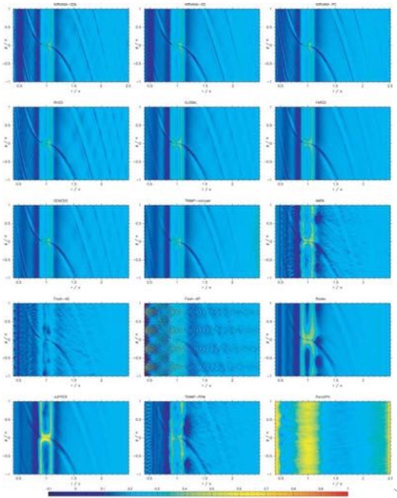
Code benchmark

Why ?

- Track bugs
- Test codes against more realistic problems
- Provide integration tests for codes

Some examples :

- Impact codes
- fluid mechanics codes
- *de Val-Boro et al. 2006*



Code benchmark

How ?

«*Anything left vague will be done in different ways by different groups*» (de Val-Boro et al. 2006)

- Choose the setup (meeting in UNAM/F.Masset) : initial condition, equations, resolution, boundary conditions, planet potential
  $\rightarrow$ shared document that can be modify by anyone
- Choose the output
  $\rightarrow$ give python/IDL script
- Open to any code

Code benchmark

The 4 setups

	Short run	Long run	Adiabatic	Moving planet
Resolution	$816 \times 80 \times 3136$	$192 \times 80 \times 1568$	368×3136	816×3136
Δr	1.72	0.7	1.72	1.72
Equations	Isothermal	Isothermal	Energy	Isothermal
Planet mass	9.10^{-6}	3.10^{-5}	9.10^{-6}	9.10^{-6}
Time	$10\,T_p$	$1000\,T_p$	$2000\,T_p$	$1340\,T_p$
Other	upper half disk		2D	2D

Adaptive Mesh Refinement Versatile Advection Code

Equations

General form

$$\partial_t \mathbf{U} + \nabla \cdot \mathbf{F}(\mathbf{U}) = \mathbf{S}_{phys}(\mathbf{U}, \partial_i \mathbf{U}, \partial_i \partial_j \mathbf{U}, \mathbf{x}, t),$$

$$\partial_t \rho + \nabla \cdot (\rho \mathbf{v}) = 0$$

$$\begin{aligned} \partial_t \rho + \nabla \cdot (\mathbf{v}\rho) &= 0 \\ \partial_t (\rho \mathbf{v}) + \nabla \cdot (\mathbf{v}\rho\mathbf{v}) + \nabla p &= 0 \end{aligned}$$

$$p = c_{adiab} \rho^{\gamma}$$

$$\begin{aligned} \partial_t \rho + \nabla \cdot (\mathbf{v}\rho) &= 0 \\ \partial_t (\rho \mathbf{v}) + \nabla \cdot (\mathbf{v}\rho\mathbf{v}) + \nabla p &= 0 \\ \partial_t e + \nabla \cdot (\mathbf{v}e + \mathbf{v}p) &= 0 \end{aligned}$$

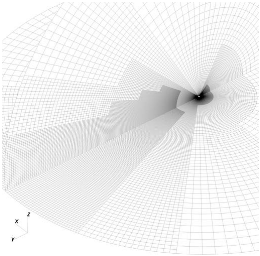
$$p = (\gamma - 1)(e - \rho \mathbf{v}^2/2)$$

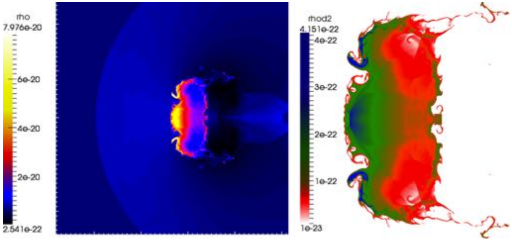
+non-linear,MHD,R-MHD,dust,. . .

Adaptive Mesh Refinement Versatile Advection Code

Some features (Xia et al. 2017, Porth et al. 2014)

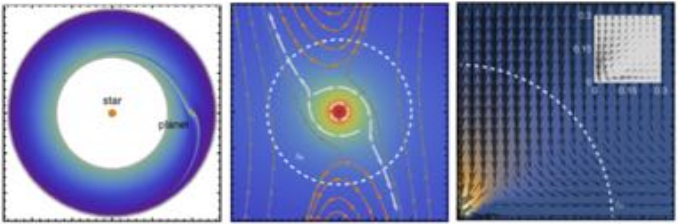
- AMR + stretched grid
- 1/2/3D, Cartesian, cylindrical, polar, spherical grids
- Spatial discretizations : central difference, finite difference, finite volume, Riemann solvers
- Temporal discretizations : Euler, predictor-corrector, RK4





Fast Advection in Rotating Gaseous Object
with Co-latitude Added at Observatoire de la Côte d'Azur

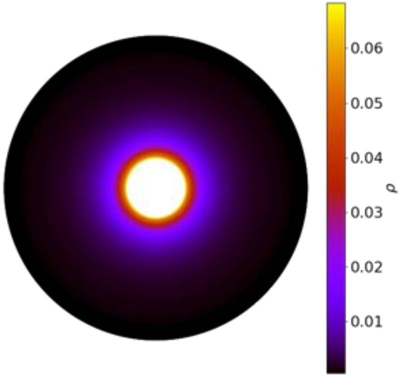
- Developed for planet-disc interaction problems
- 3D spherical stretched grid
- Finite difference scheme
- FARGO algorithm
- Hybrid OpenMP/MPI



Short run

Density

FARGOCA



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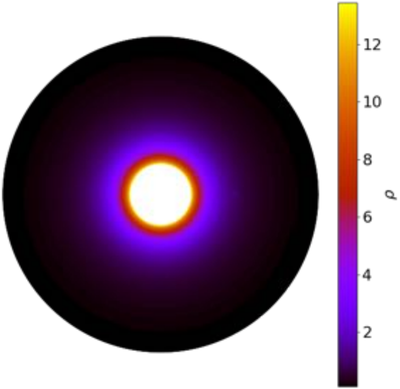

Short run
Density

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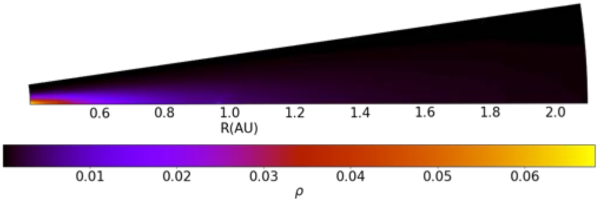

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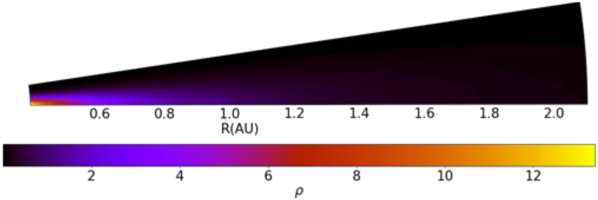

Short run

Radial velocity

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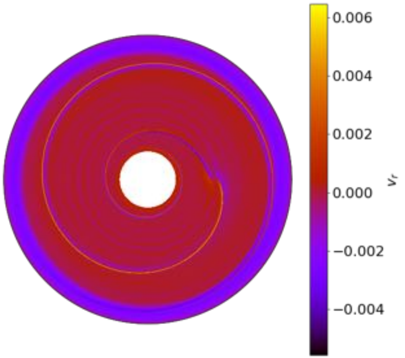

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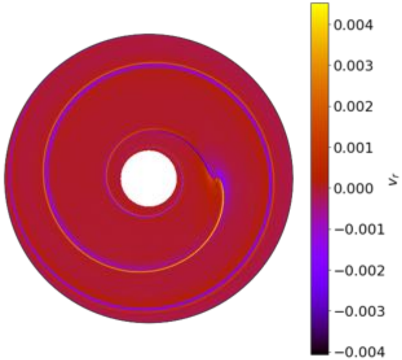

Short run

Radial velocity

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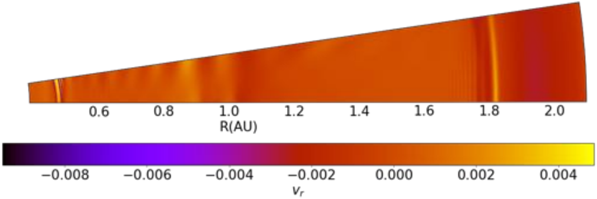

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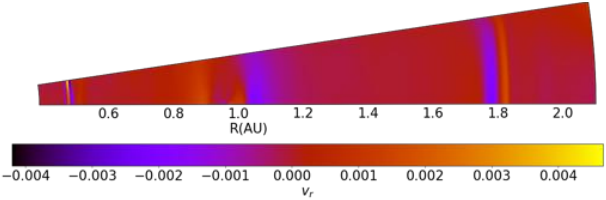

Short run
Latitudinal velocity

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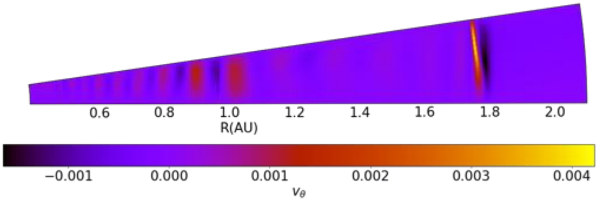

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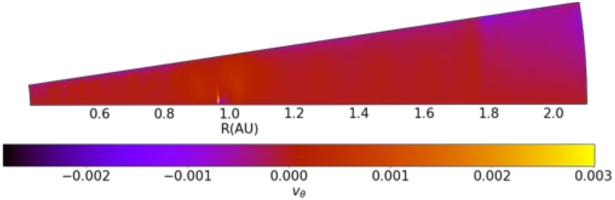

Long run
Density

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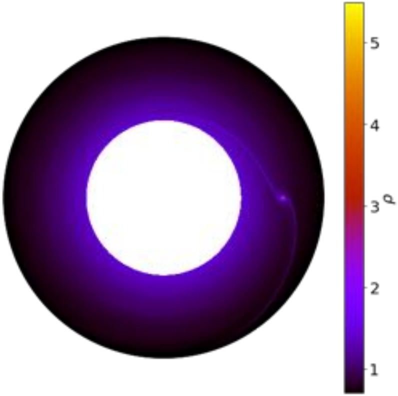

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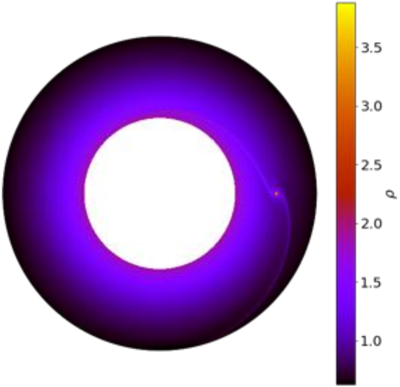

Long run
Density

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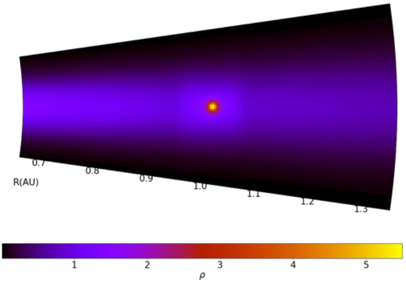

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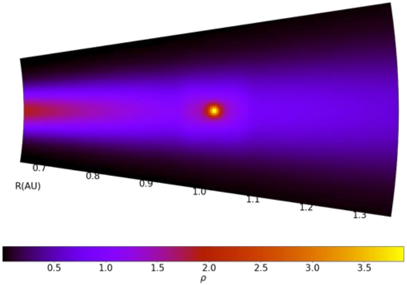

Long run
Radial velocity

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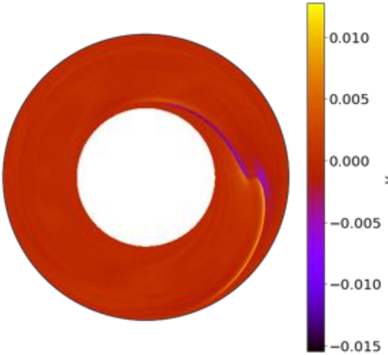

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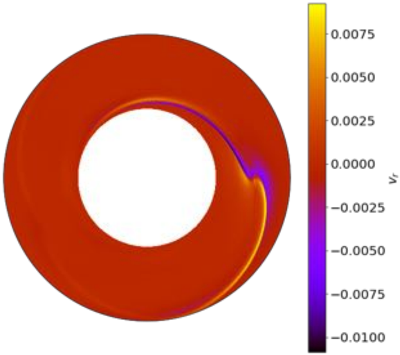

Long run
Radial velocity

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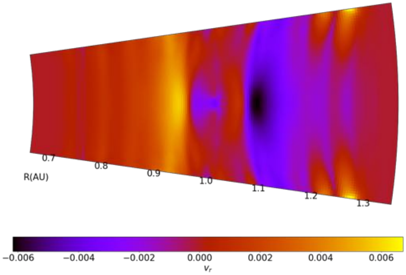

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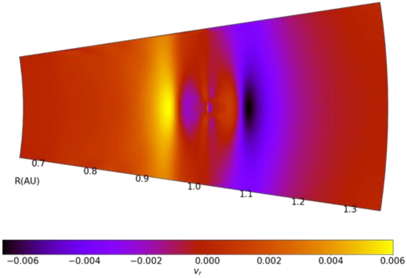

Long run
Latitudinal velocity

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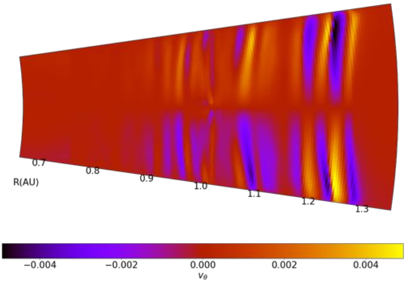

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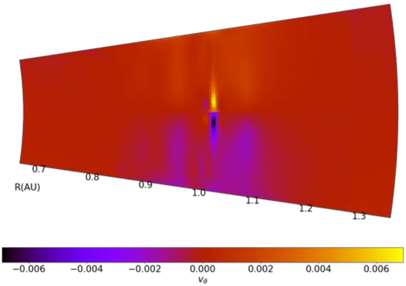

Discussion

- This benchmark is very useful to test new codes
- and to start in the domain
- BUT it is time consuming
- ALL THE PROBLEMS MUST BE VERY PRECISELY DEFINED