Code benchmark for planet-disk interaction

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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
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
  → shared document that can be modify by anyone
- Choose the output
  → give python/IDL script
- Open to any code
# Code benchmark

## The 4 setups

<table>
<thead>
<tr>
<th></th>
<th>Short run</th>
<th>Long run</th>
<th>Adiabatic</th>
<th>Moving planet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>$816 \times 80 \times 3136$</td>
<td>$192 \times 80 \times 1568$</td>
<td>$368 \times 3136$</td>
<td>$816 \times 3136$</td>
</tr>
<tr>
<td>$\Delta r$</td>
<td>1.72</td>
<td>0.7</td>
<td>1.72</td>
<td>1.72</td>
</tr>
<tr>
<td>Equations</td>
<td>Isothermal</td>
<td>Isothermal</td>
<td>Energy</td>
<td>Isothermal</td>
</tr>
<tr>
<td>Planet mass</td>
<td>$9.10^{-6}$</td>
<td>$3.10^{-5}$</td>
<td>$9.10^{-6}$</td>
<td>$9.10^{-6}$</td>
</tr>
<tr>
<td>Time</td>
<td>$10 , T_p$</td>
<td>$1000 , T_p$</td>
<td>$2000 , T_p$</td>
<td>$1340 , T_p$</td>
</tr>
<tr>
<td>Other</td>
<td>upper half disk</td>
<td></td>
<td>2D</td>
<td>2D</td>
</tr>
</tbody>
</table>
Adaptive Mesh Refinement Versatile Advection Code

Equations

**General form**

\[ \partial_t U + \nabla \cdot F(U) = S_{phys}(U, \partial_i U, \partial_i \partial_j U, x, t), \]

\[ \partial_t \rho + \nabla \cdot (\rho v) = 0 \]

\[ \partial_t (\rho v) + \nabla \cdot (\rho v v) + \nabla p = 0 \]

\[ \partial_t e + \nabla \cdot (e v + v p) = 0 \]

\[ p = (\gamma - 1)(e - \rho v^2 / 2) \]

\[ \partial_t \rho + \nabla \cdot (\rho v) = 0 \]

\[ \partial_t (\rho v) + \nabla \cdot (\rho v v) + \nabla p = 0 \]

\[ p = c_{adiab} \rho^\gamma \]

+ 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

AMRVAC
Short run
Density

FARGOCA

AMRVAC
Short run
Radial velocity

FARGOCA

AMRVAC

Code benchmark for planet-disk interaction
Short run
Radial velocity

FARGOCA

AMRVAC
Short run
Latitudinal velocity

FARGOCA

AMRVAC
Long run
Density

FARGOCA

AMRVAC

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**Long run**

**Density**

**FARGOCA**

**AMRVAC**

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AMRVAC

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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.