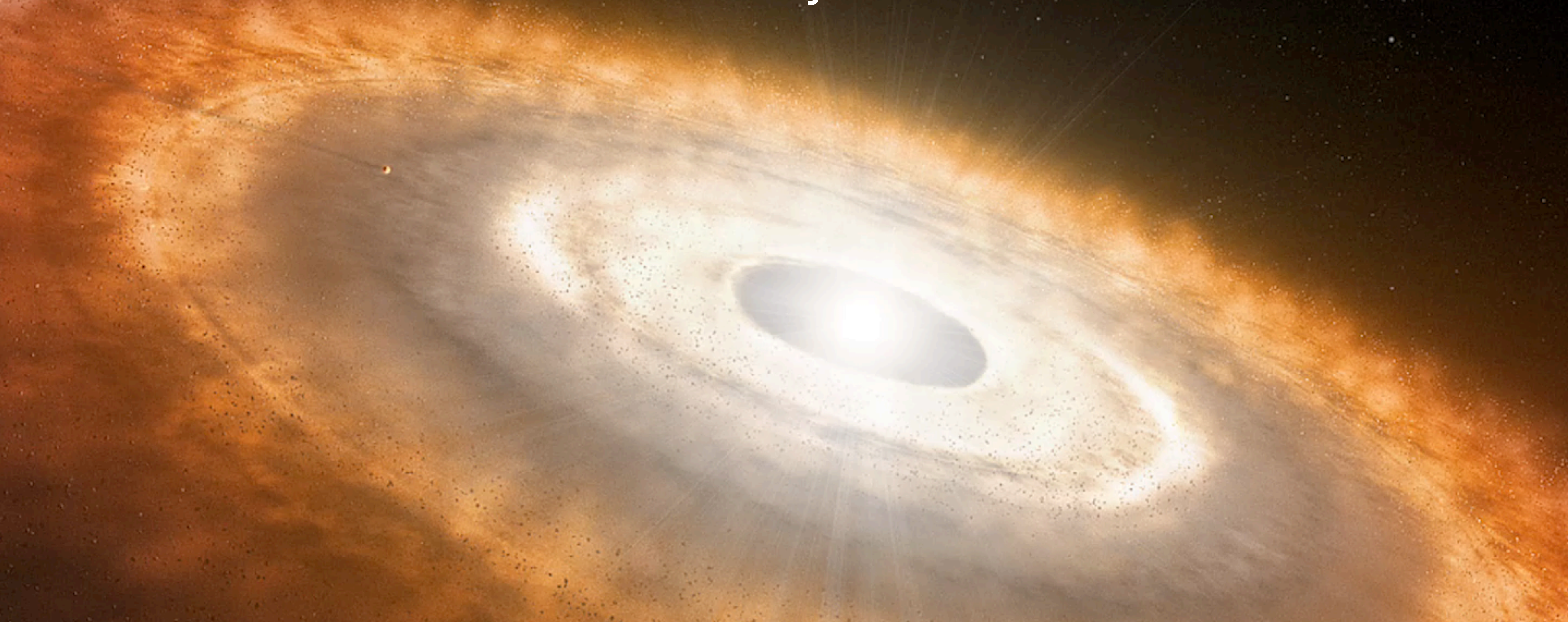
Modélisation de l’environnement des étoiles jeunes



Geoffroy Lesur

avec

Jérome Bouvier (IPAG)
Antoine Riols (Postdoc, IPAG)
Etienne Martel (PhD, IPAG)
George Pantolmos (Postdoc, IPAG)

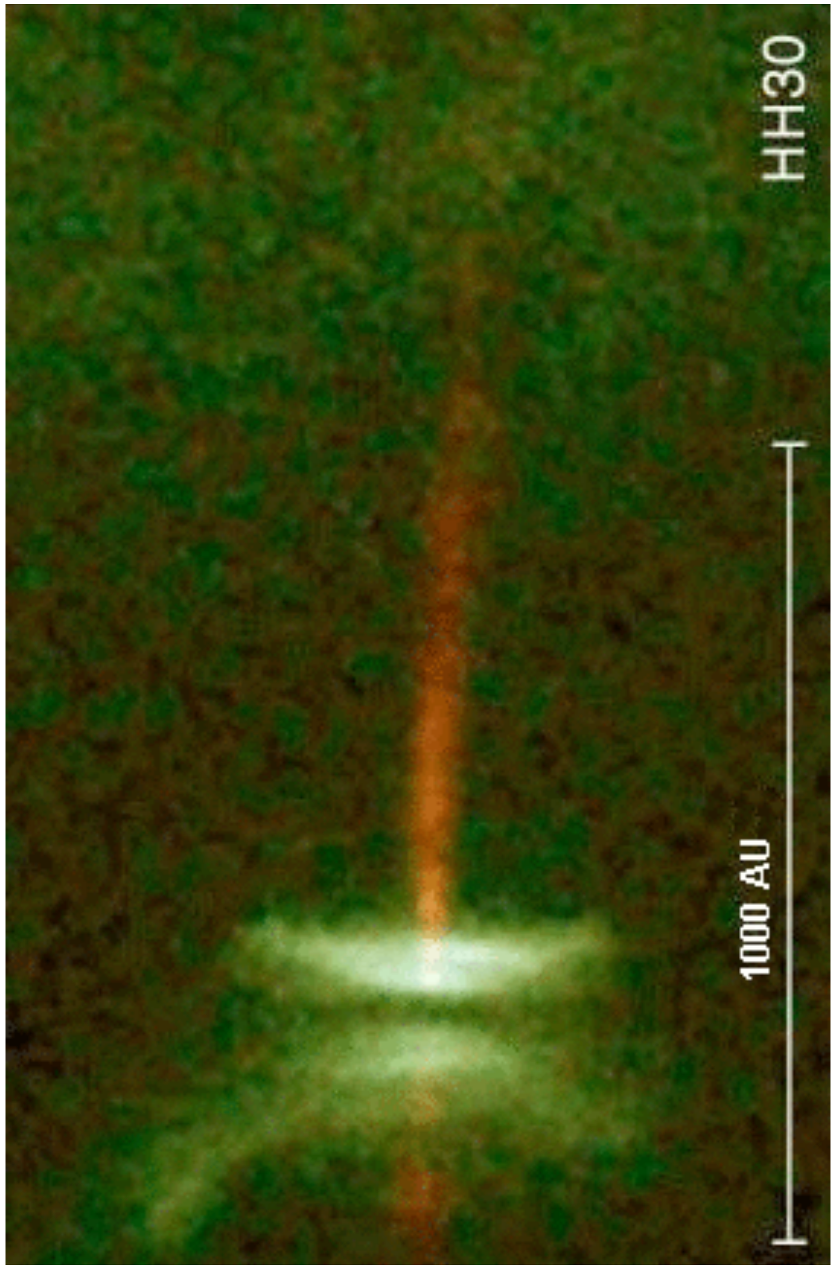
IPAG
Institut de Planétologie et d'Astrophysique de Grenoble

CNRS

Université Grenoble Alpes

erc
European Research Council
Established by the European Commission

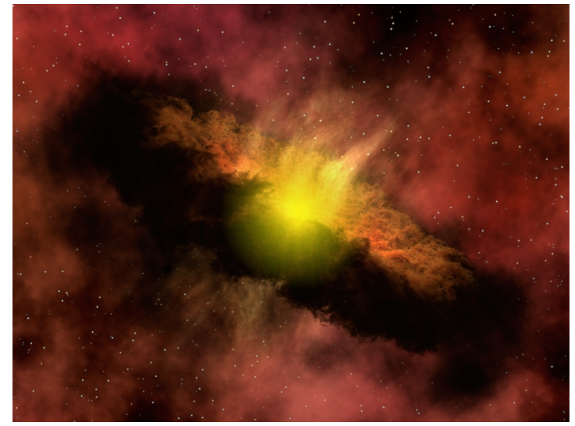
Protoplanetary discs

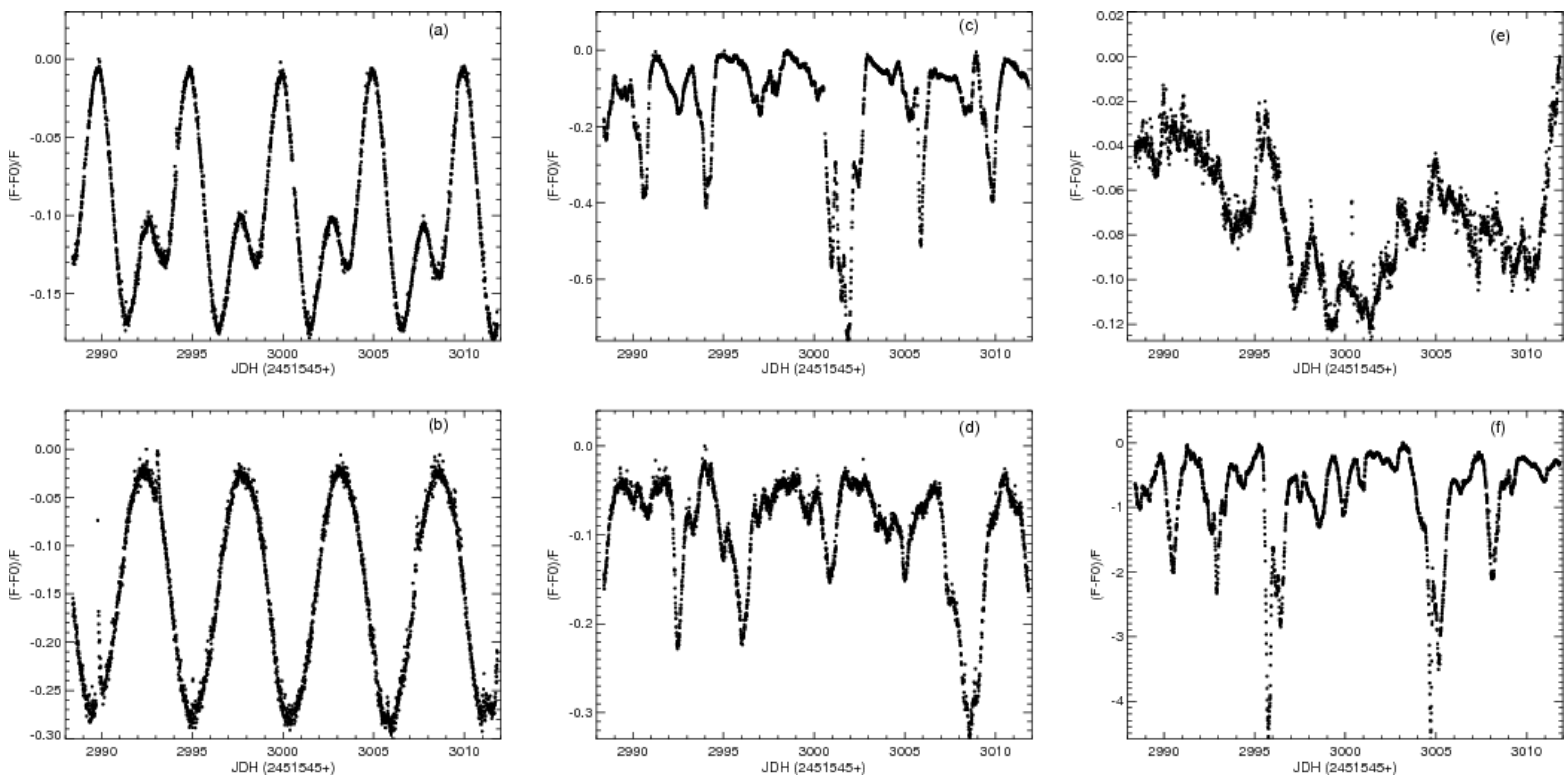


Credit: C. Burrows and J. Krist (STScl),
K. Stapelfeldt (JPL) and NASA

Artist view

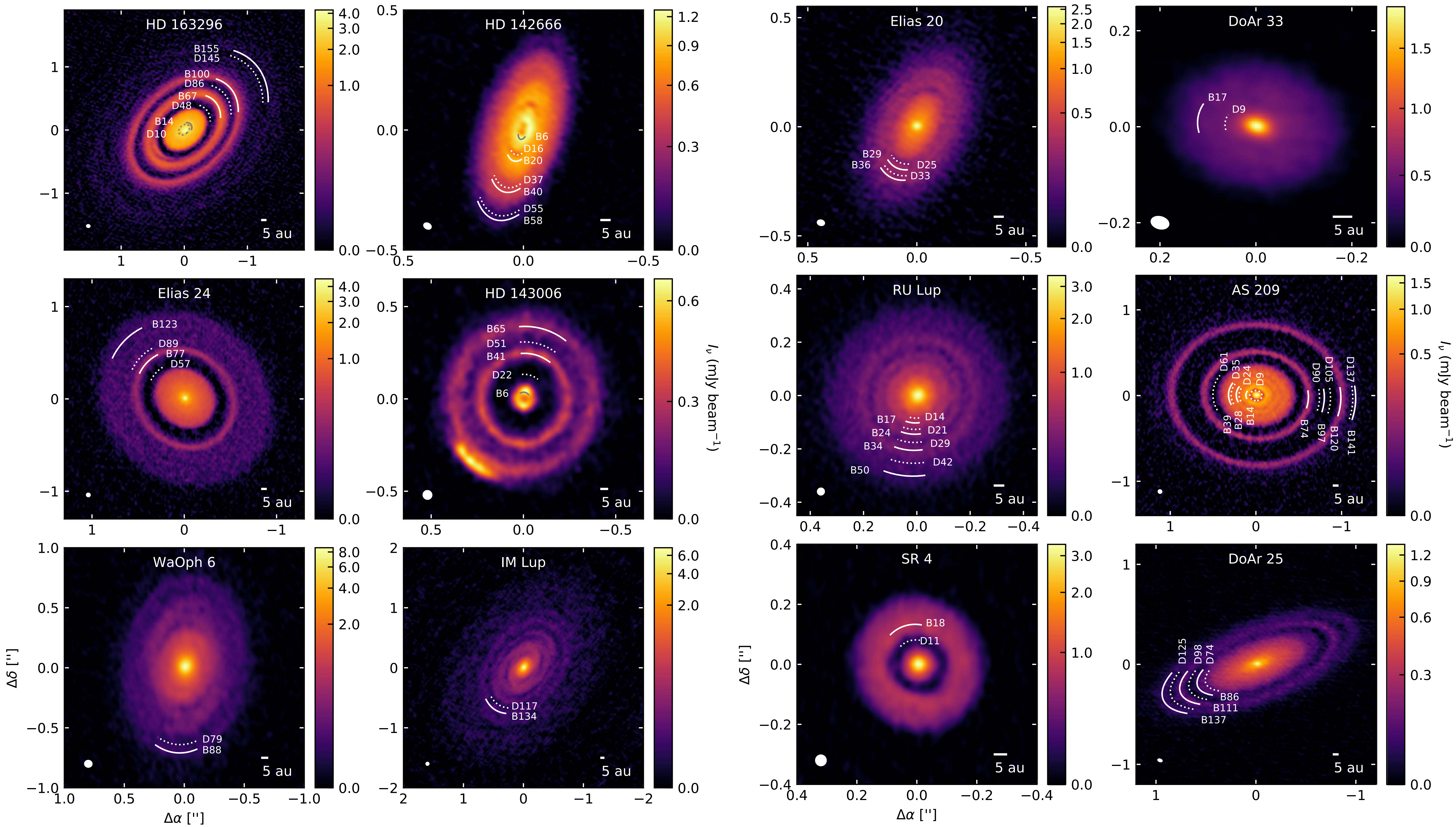
Young stars light curves





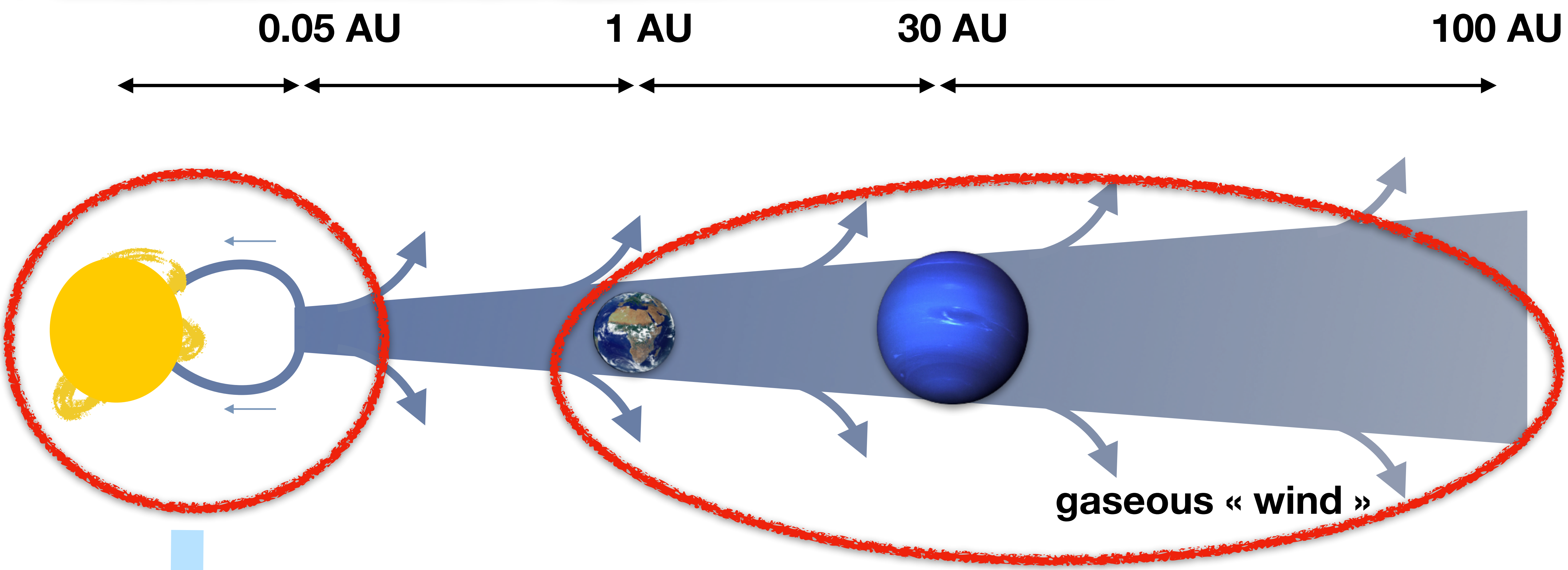
Structures are common

Example: 12 discs observed by the ALMA telescope (Chile)



[Huang+ 2018]

Disc structure



SPIDI ERC project
PI: Jérome Bouvier

Star-planet-disc interaction

MHDiscs
Revealing the dynamics of planet-forming discs

MHDiscs ERC project
PI: Geoffroy Lesur

Disc-wind interaction

Numerical method

I- PLUTO- a finite volume shock-capturing code

Equations of motion

$$\partial_t \rho + \boldsymbol{\nabla} \cdot \rho \boldsymbol{u} = 0,$$

$$\partial_t \rho \boldsymbol{u} + \boldsymbol{\nabla} \cdot \left[\rho \boldsymbol{u}\boldsymbol{u} + c_{\mathrm{s}}^2 \rho + \boldsymbol{B}^2/2 - \boldsymbol{B} \otimes \boldsymbol{B} \right] = -2\rho \boldsymbol{\Omega} \times \boldsymbol{u} + \rho \boldsymbol{g},$$

$$\partial_t \boldsymbol{B} + \boldsymbol{\nabla} \times \left[\boldsymbol{u} \times \boldsymbol{B} + \eta_{\mathrm{O}} \boldsymbol{J} + \eta_{\mathrm{H}} \boldsymbol{J} \times \hat{\boldsymbol{B}} - \eta_{\mathrm{A}} \boldsymbol{J} \times \hat{\boldsymbol{B}} \times \hat{\boldsymbol{B}} \right] = 0$$

$$\boldsymbol{\nabla} \cdot \boldsymbol{B} = 0$$

General conservative form

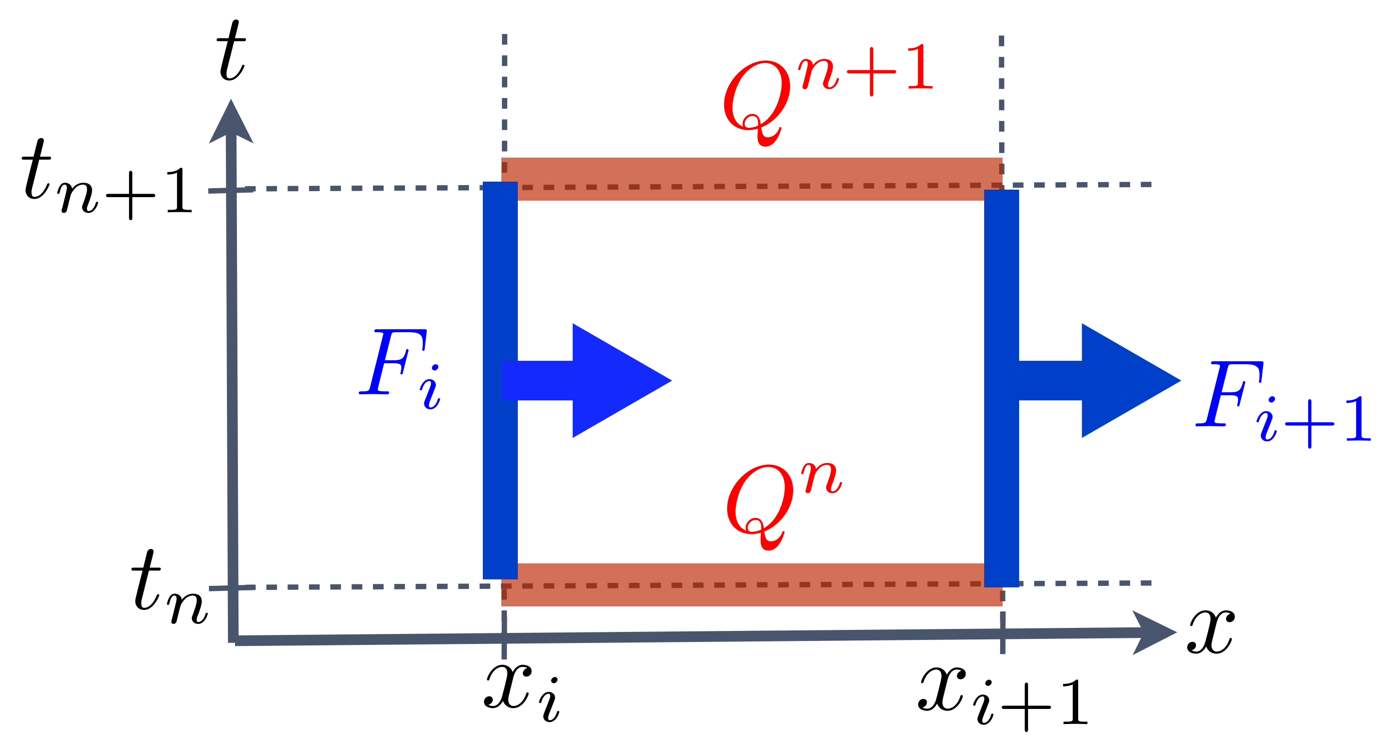
$$\partial_t Q + \boldsymbol{\nabla} \cdot \boldsymbol{F}(Q) = 0$$

Integrate in space and time:

$$Q_i^{n+1} = Q_i^n + dt(F_{i+1}^n - F_i^n)$$

Flux are computed solving a Riemann problem

[Mignone+ 2007, A&A 170:228]



Numerical method

II- PLUTO- features & scalability

- Code in ANSI C
- Checkpointing
- Open source (http://plutocode.ph.unito.it/)
- MPI parallelisation

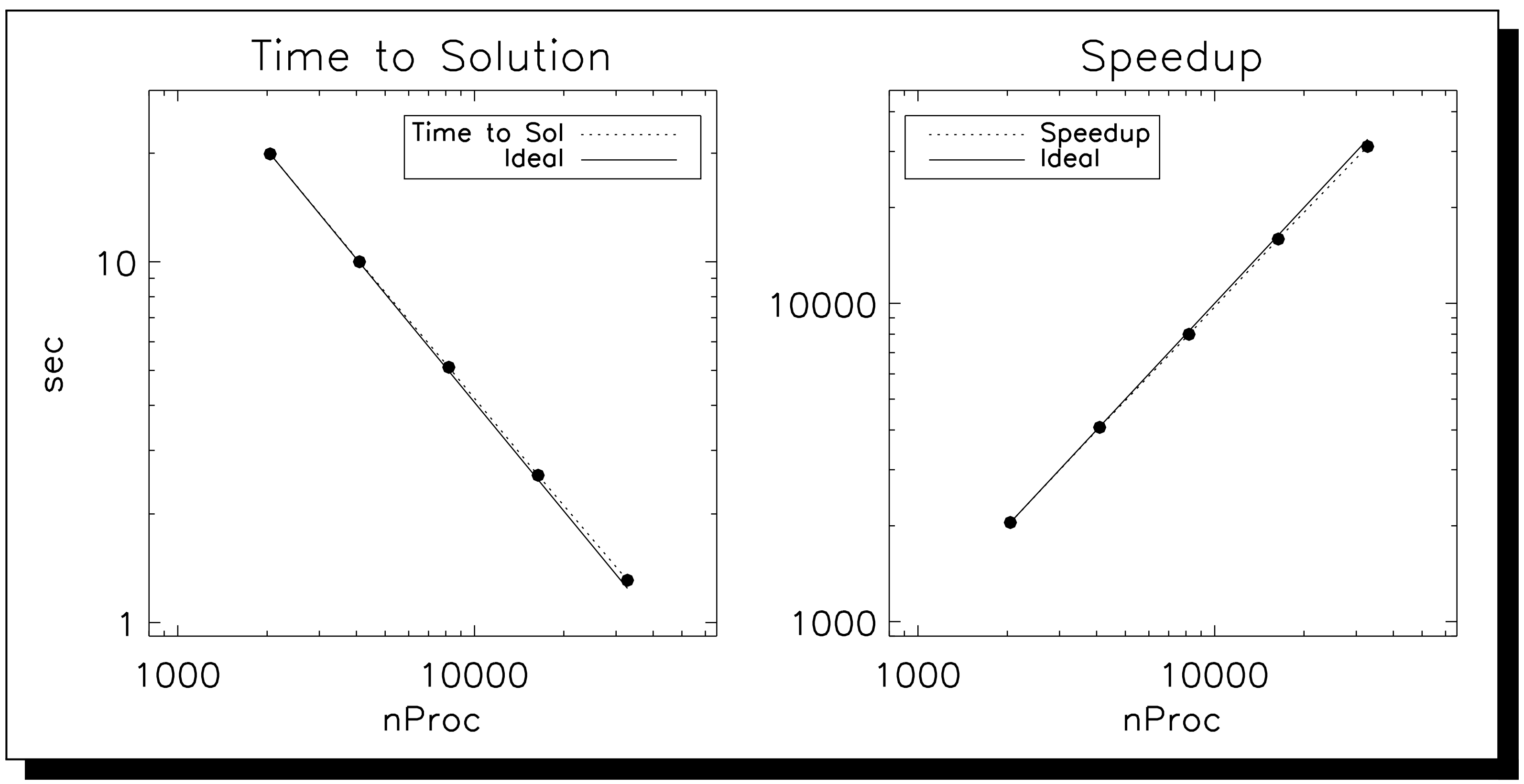


Figure 1.1: Strong scaling of PLUTO on a periodic domain problem with 512^3 grid zones. Left panel: average execution time (in seconds) per step vs. number of processors. Right panel: speedup factor computed as T_1/T_N where T_1 is the (inferred) execution time of the sequential algorithm and T_N is the execution time achieved with N processors. Code execution time is given by black circles (+ dotted line) while the solid line shows the ideal scaling.

[PLUTO user guide]

very good scalability up to 30 000 cores

Workflow

Pluto Job
2.5D (axisymmetric) on Dahu (~128cores)
3D on GENCI (~512-10 000 cores)

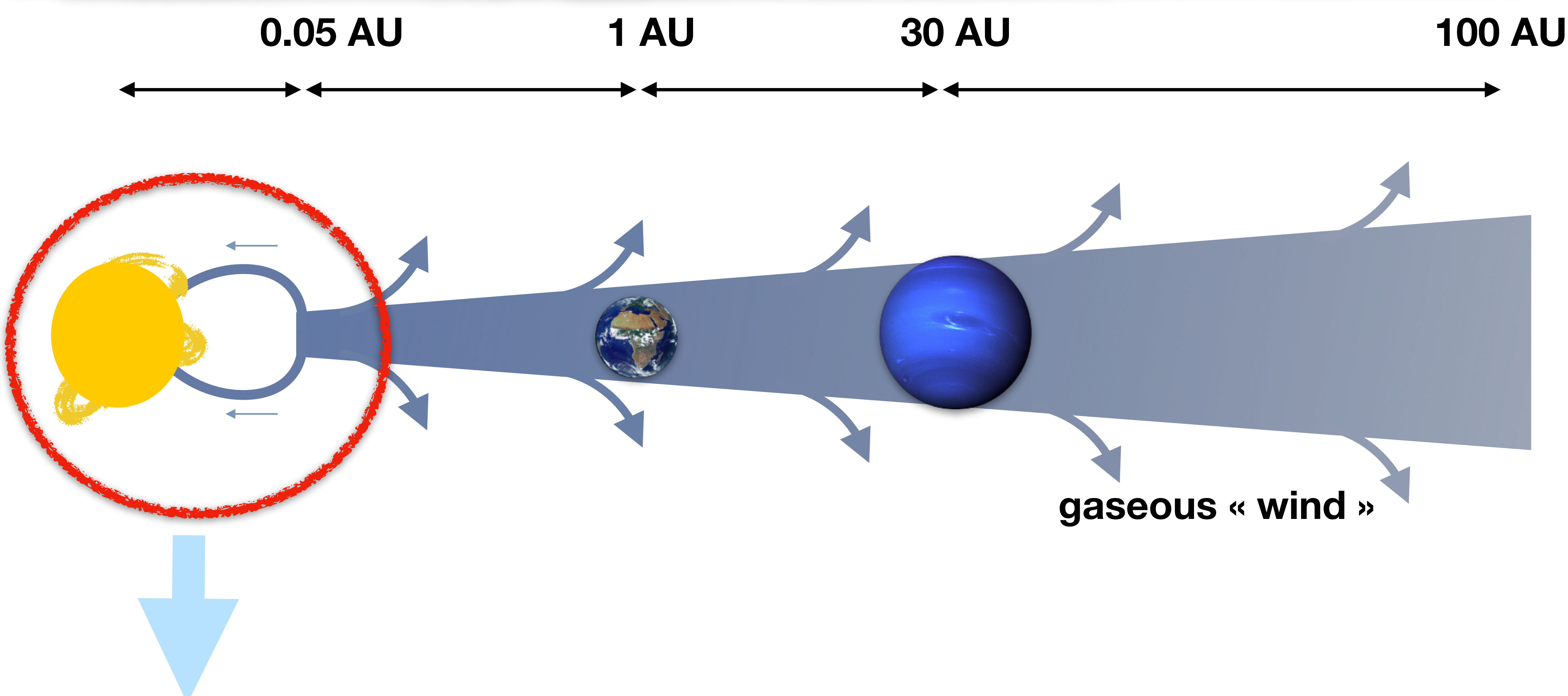
10 GB-2 TB of data per run

Python post-treatment on Luke
Storage on Summer (for data from GENCI)
or Bettik (for data from Dahu)

Radiative transfer with McFost (Pinte+2007)
Synthetic image

Paraview visualisation 3D data
Previously done on Froggy-visu
Future?

Disc structure



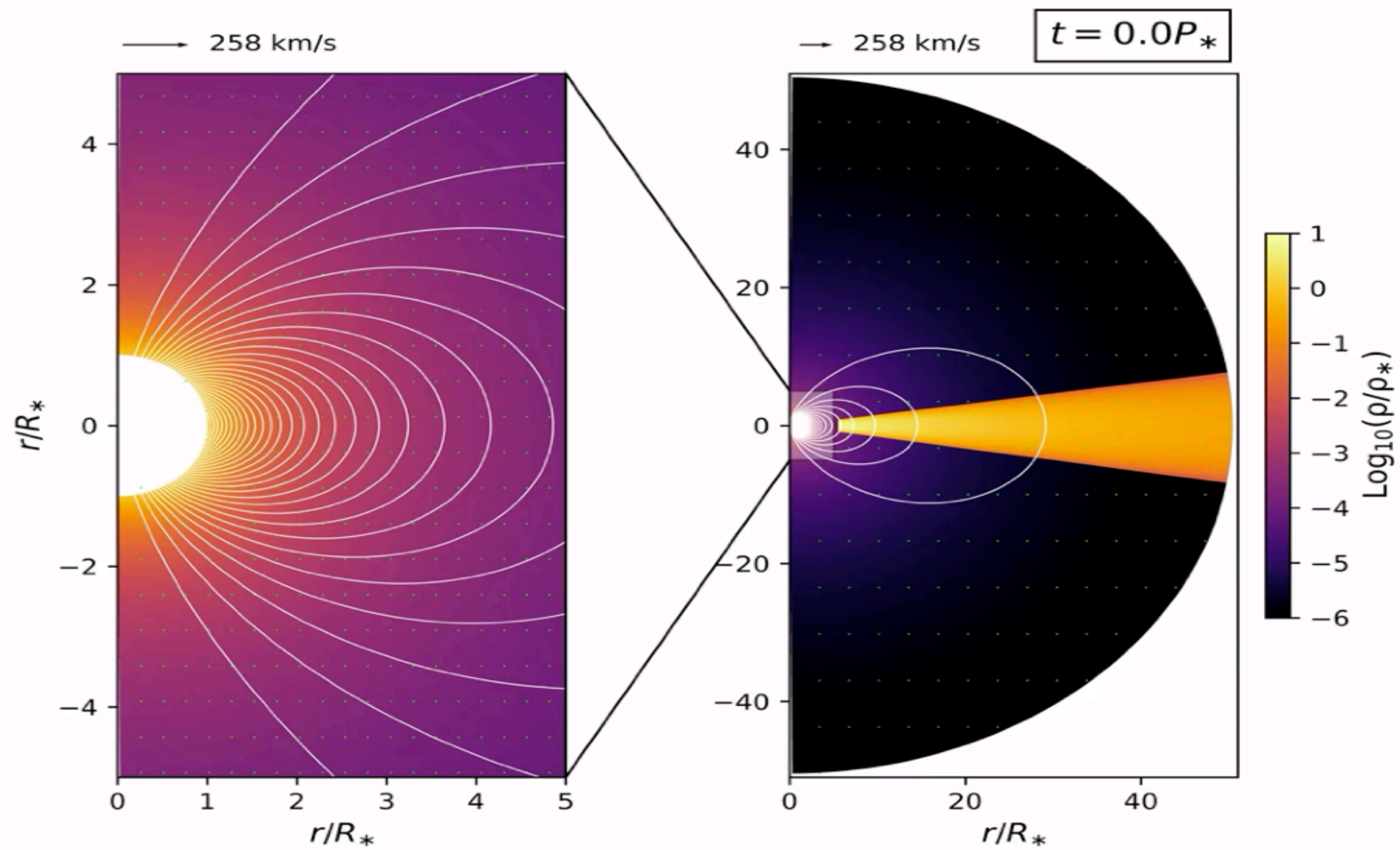
SPIDI ERC project
PI: Jérome Bouvier

Star-planet-disc interaction

SPIDI Simulations (MHD)

SPIDI webpage: spidi-eu.org

- MHD modeling of the environment around young Suns
- with Dahu supercomputer
- 1500 – 6000 hrs (60 – 250 days) on a single CPU

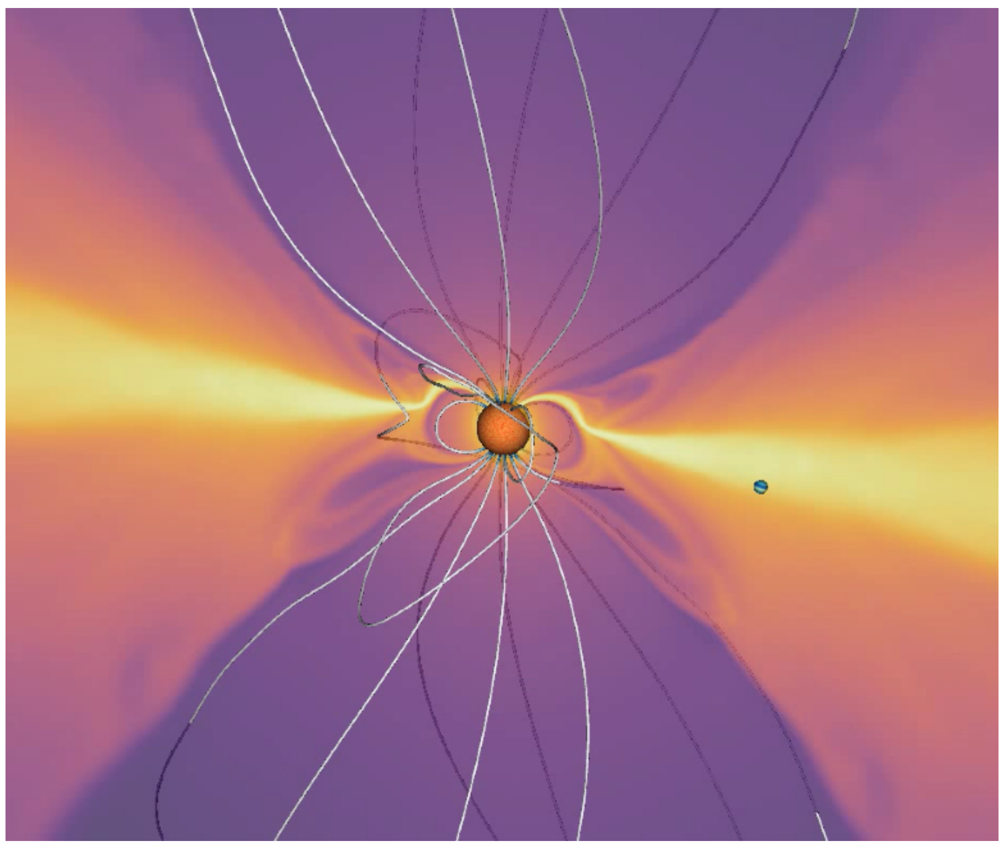


Courtesy G. Pantolmos

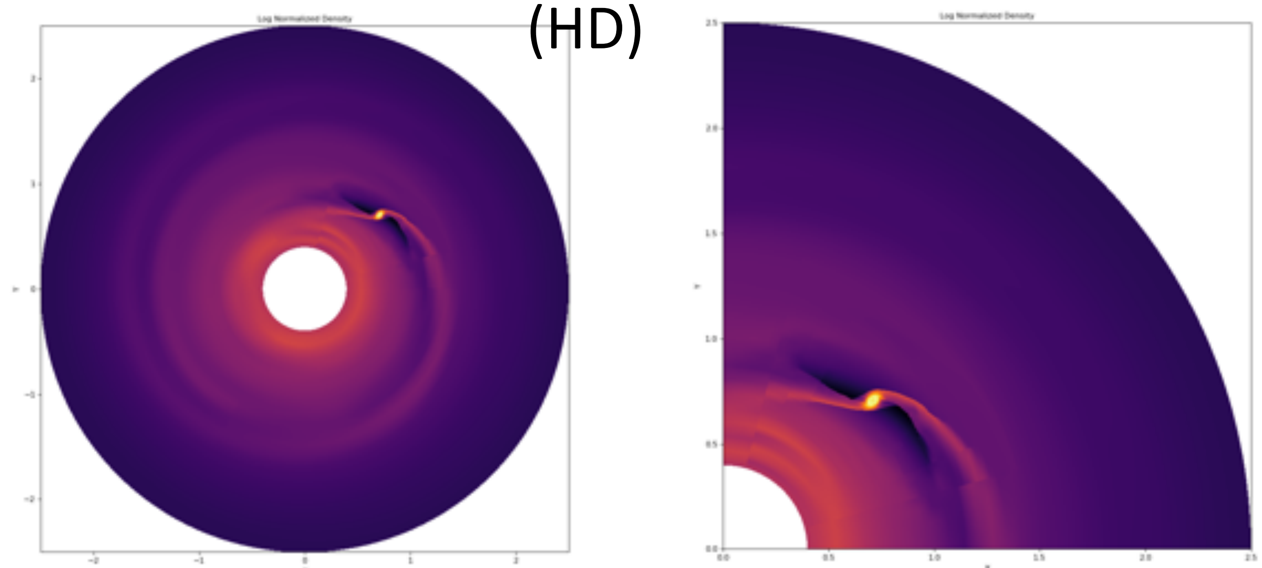
SPIDI Simulations (MHD)

SPIDI webpage: spidi-eu.org

3D example of **SPIDI** simulations (MHD)



disk-planet interaction (HD)

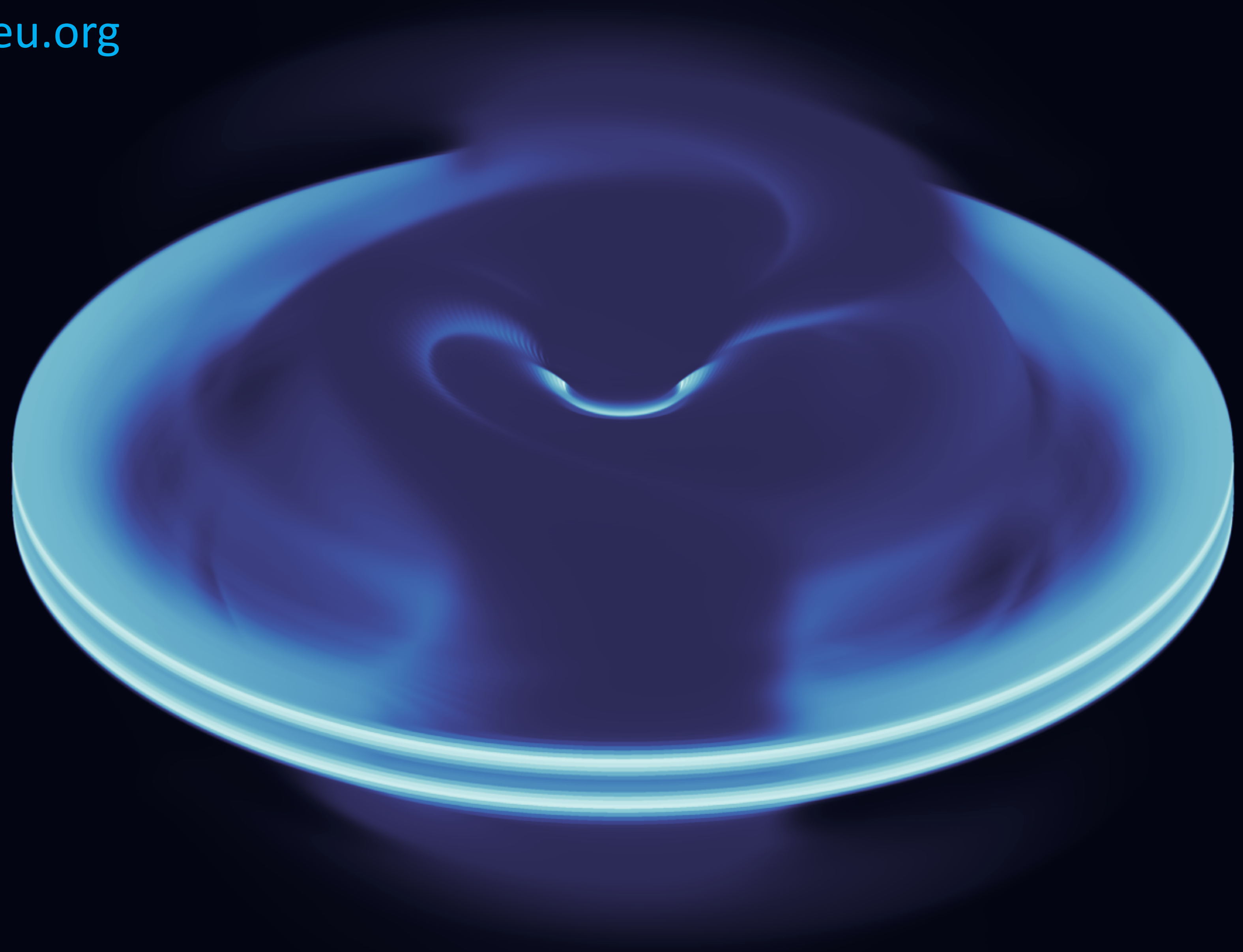


- 3D **S**tar – **P**lanet – **I**nner-**DI**sk simulations
- Understand observational signatures of young planets in the inner parts (< 0.1 au) of protoplanetary disks

Courtesy G. Pantolmos

SPIDI Simulations (RT)

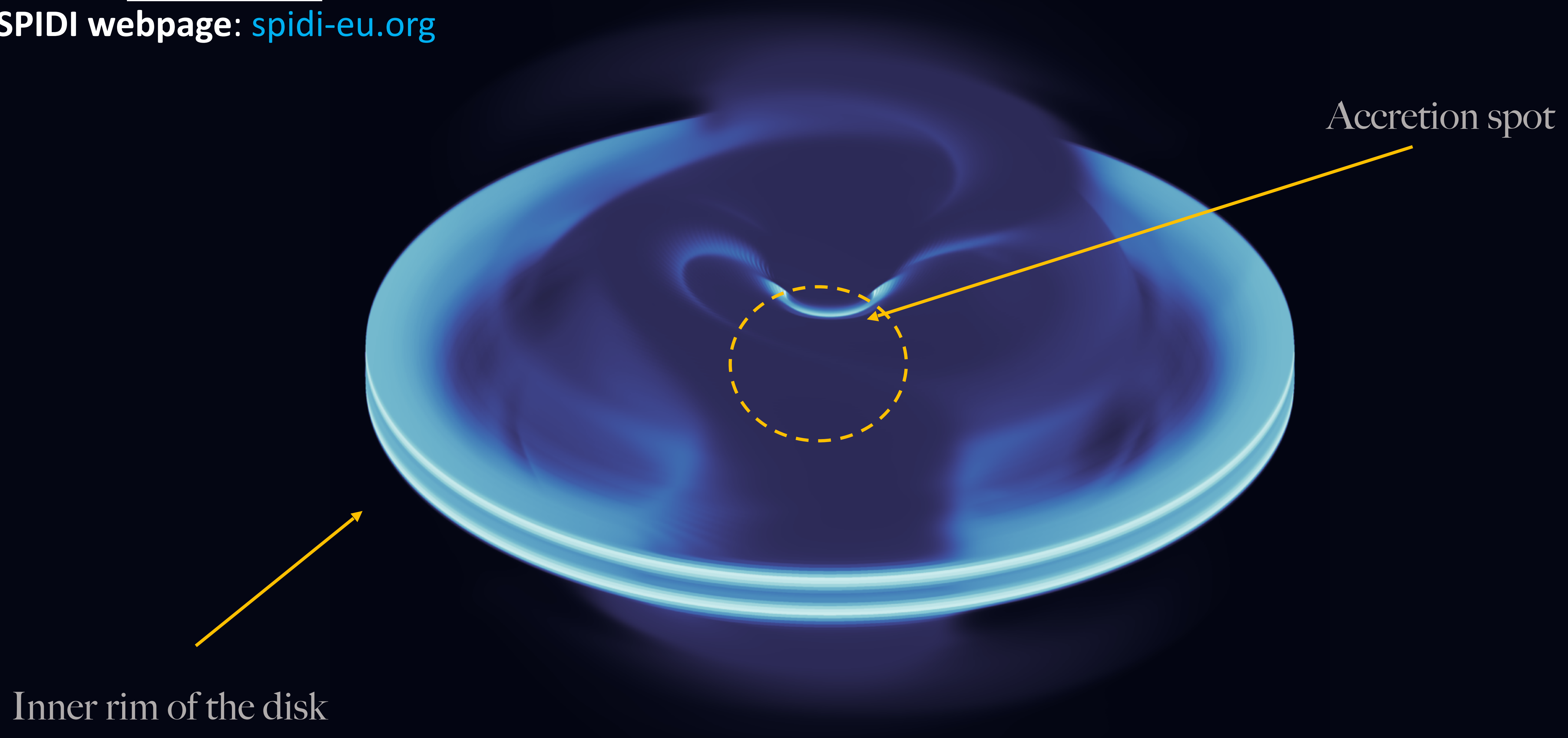
SPIDI webpage: spidi-eu.org



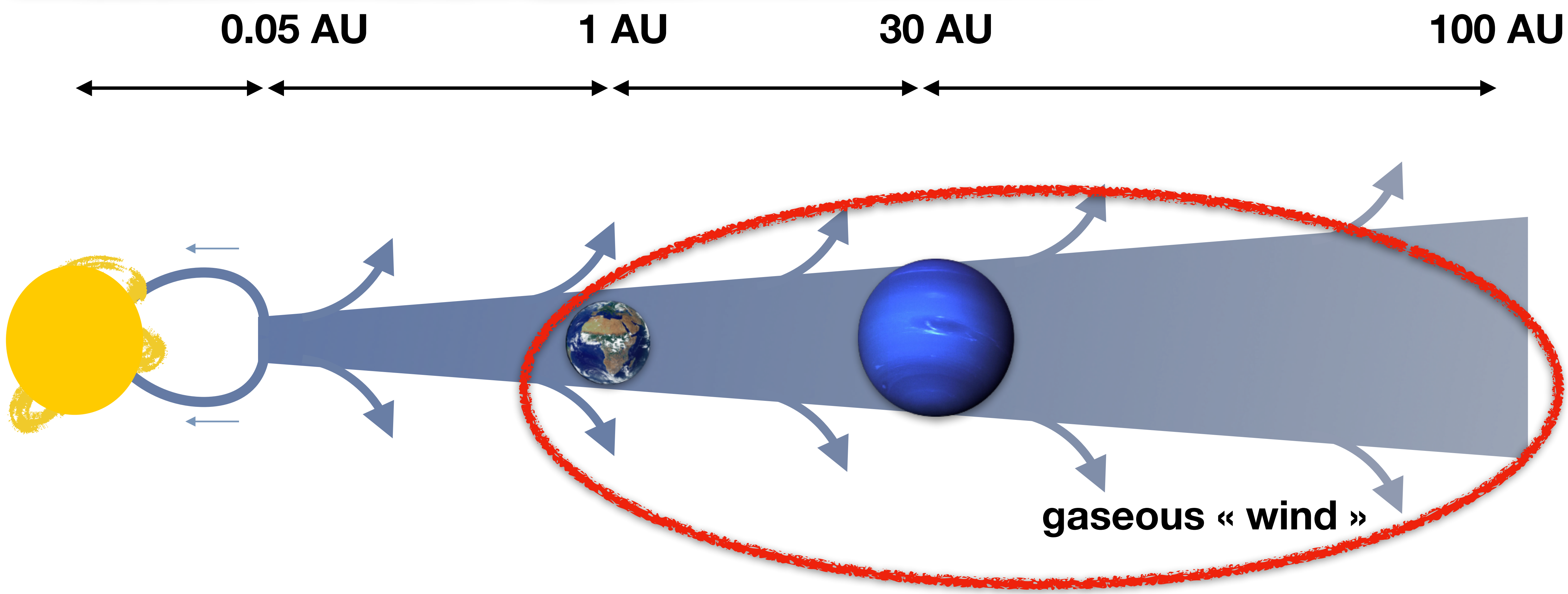
Gas falls from the disk to stellar surface, making a bright impact point

SPIDI Simulations (RT)

SPIDI webpage: spidi-eu.org



Disc structure



MHDiscs

Revealing the dynamics of planet-forming discs

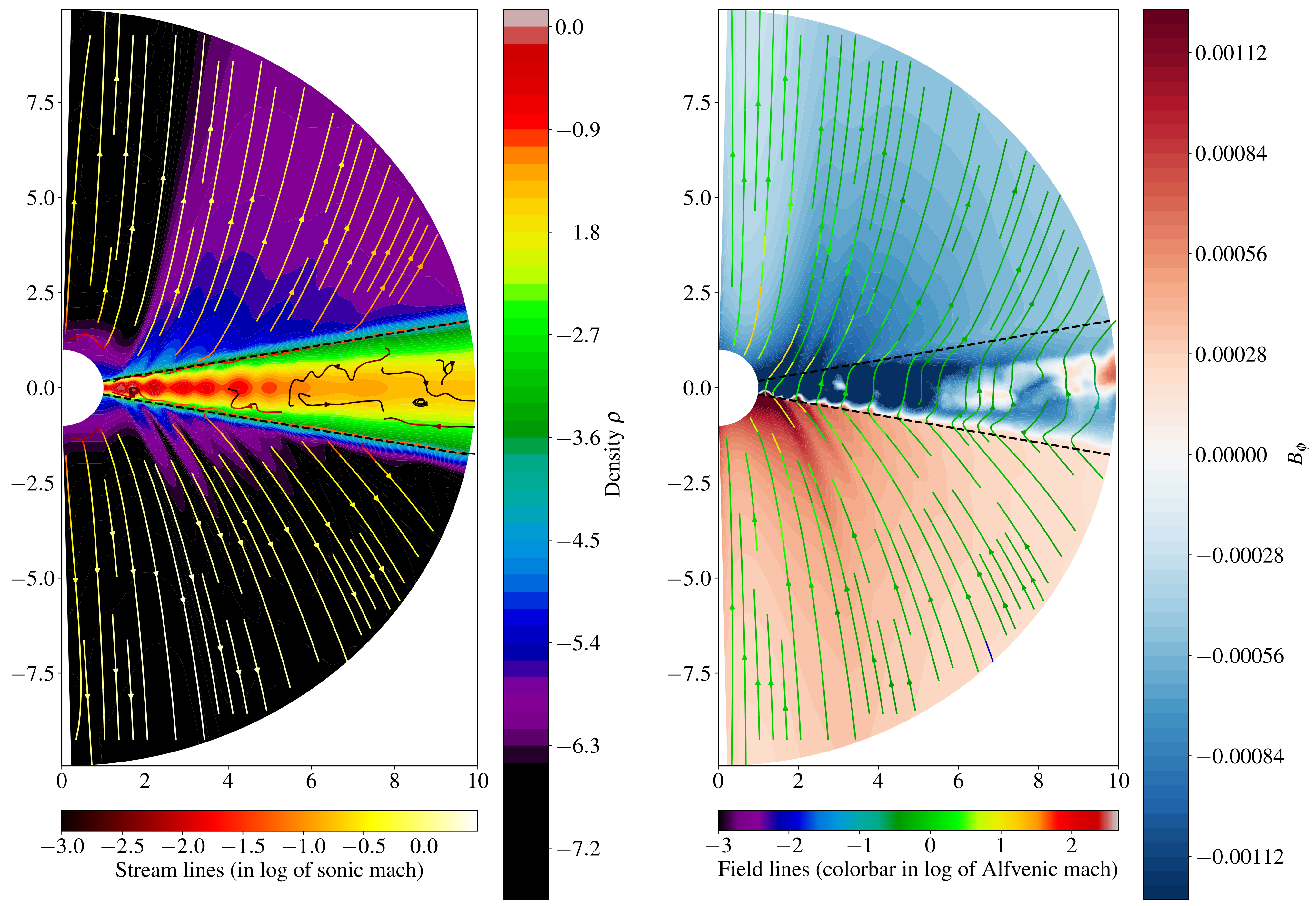
MHDiscs ERC project

PI: Geoffroy Lesur

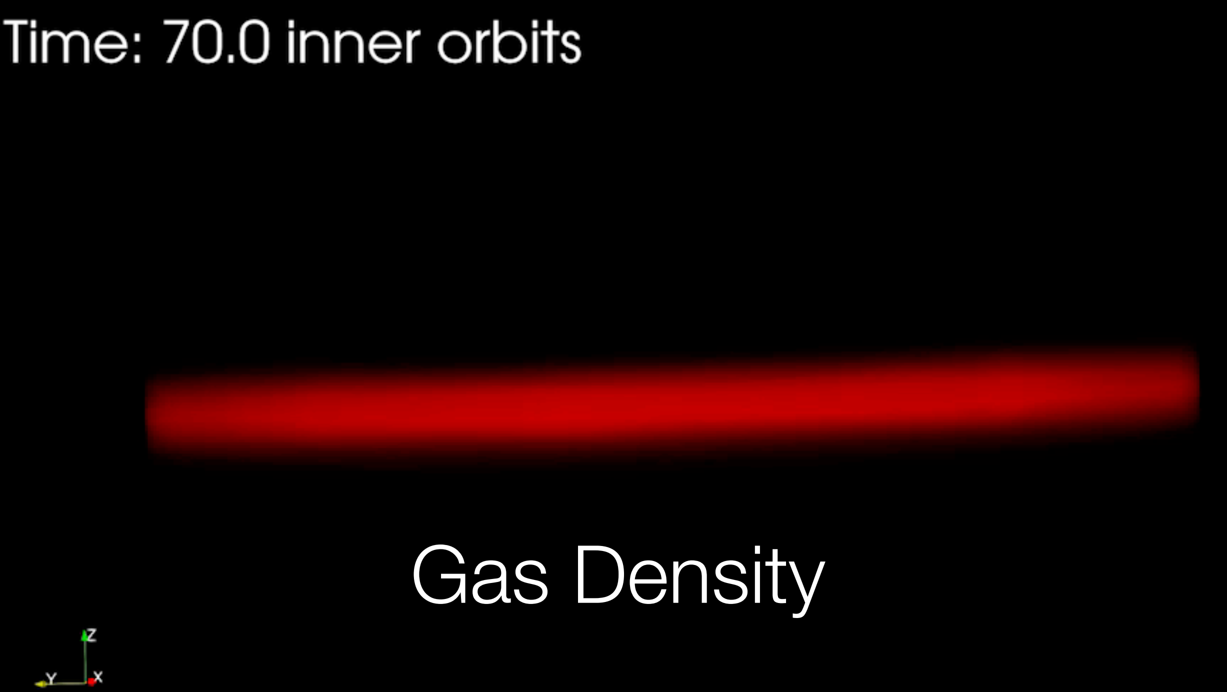
Disc-wind interaction

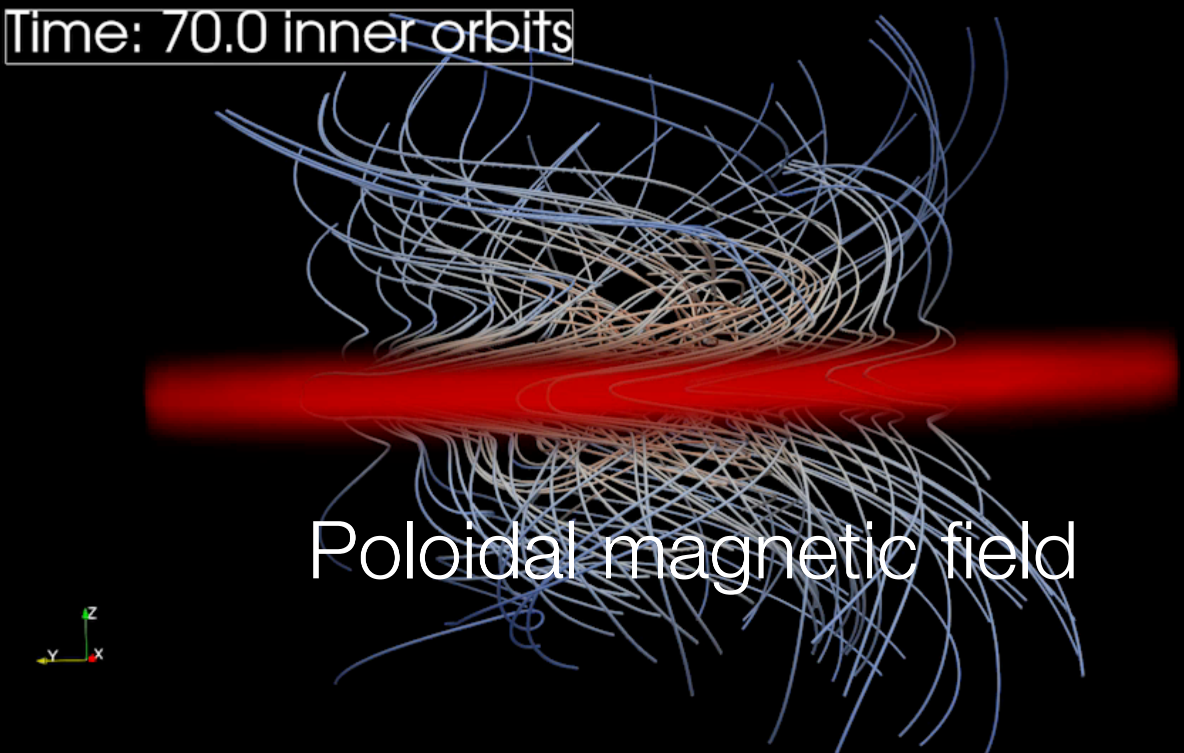
Disc+wind simulation on Dahu

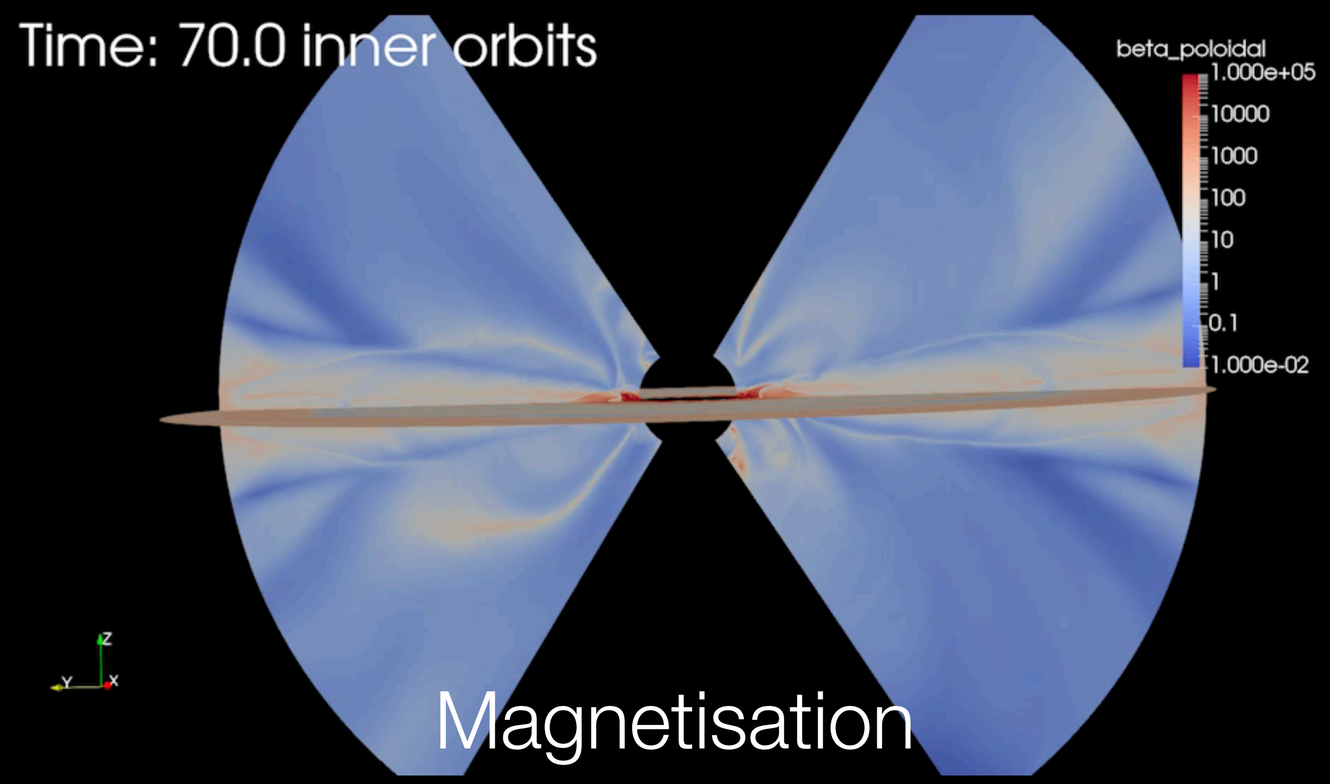
MHDiscs
Revealing the dynamics of planet-forming discs



Global 3D simulations



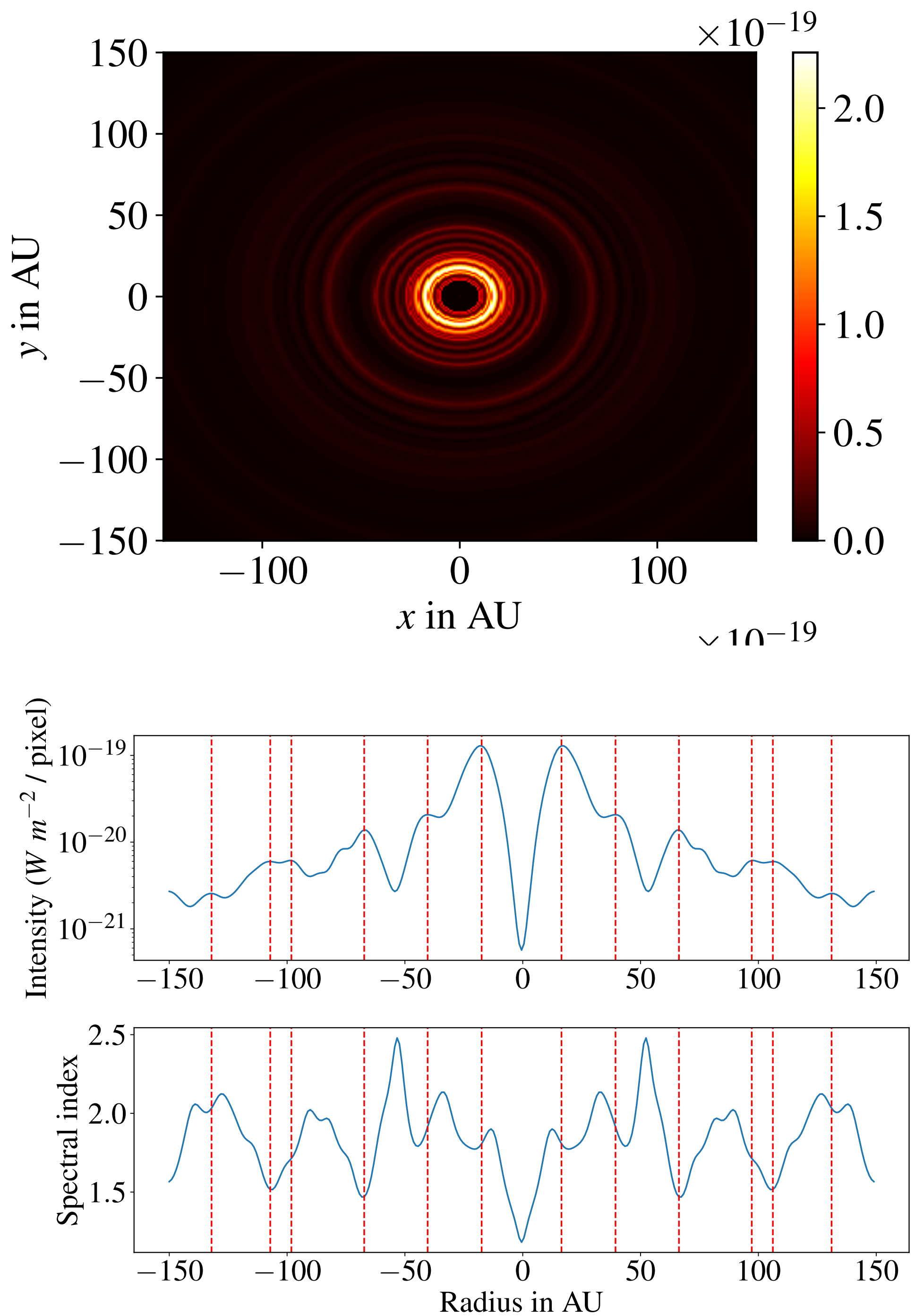




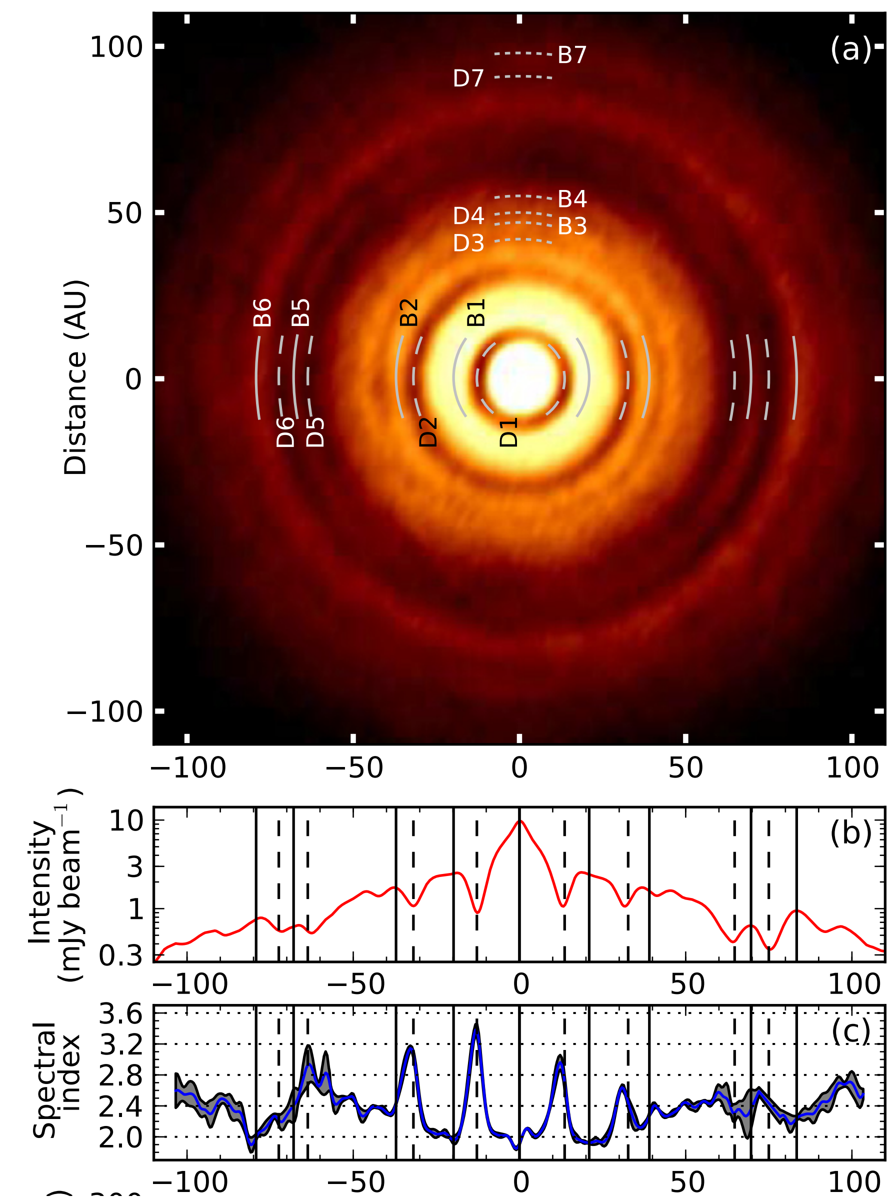
Testing ring formation against observations

MHDiscs
Revealing the dynamics of planet-forming discs

Numerical model



Observations



[Riols & Lesur in prep]

Contribution of ERC projects to Dahu

SPIDI
star planets
inner disk interactions

Origin: project overheads (~500 cores)

Pros:

- No justification required at the EU level
- No depreciation issues
- No need to mention it in the proposal

Cons:

- Represents a large fraction of the overhead budget (but depends on the size of your project)

MHDiscs
Revealing the dynamics of planet-forming discs

Origin: eligible costs (640 cores)

Pros:

- ERC covers the cost of the machine (in principle)+overheads

Cons:

- Depreciation makes your life difficult (need to have the machine bought, set up and running from day 1 of the project)
- Need for a detailed record of the usage of the machine
- *A priori* incompatible with best effort job (you are not allowed to share your machine)

Bottom line: buying clusters on European projects is a tricky business…

We’re hiring!

Need a code able to run on Exascale HPCs…

Looking for a dev. engineer to port PLUTO on heterogeneous architecture (CPU, GPU, XeonPhi, etc), using the Kokkos framework:

MHDiscs
Revealing the dynamics of planet-forming discs

mhdiscs.fr → **« news » section**

Thank you!