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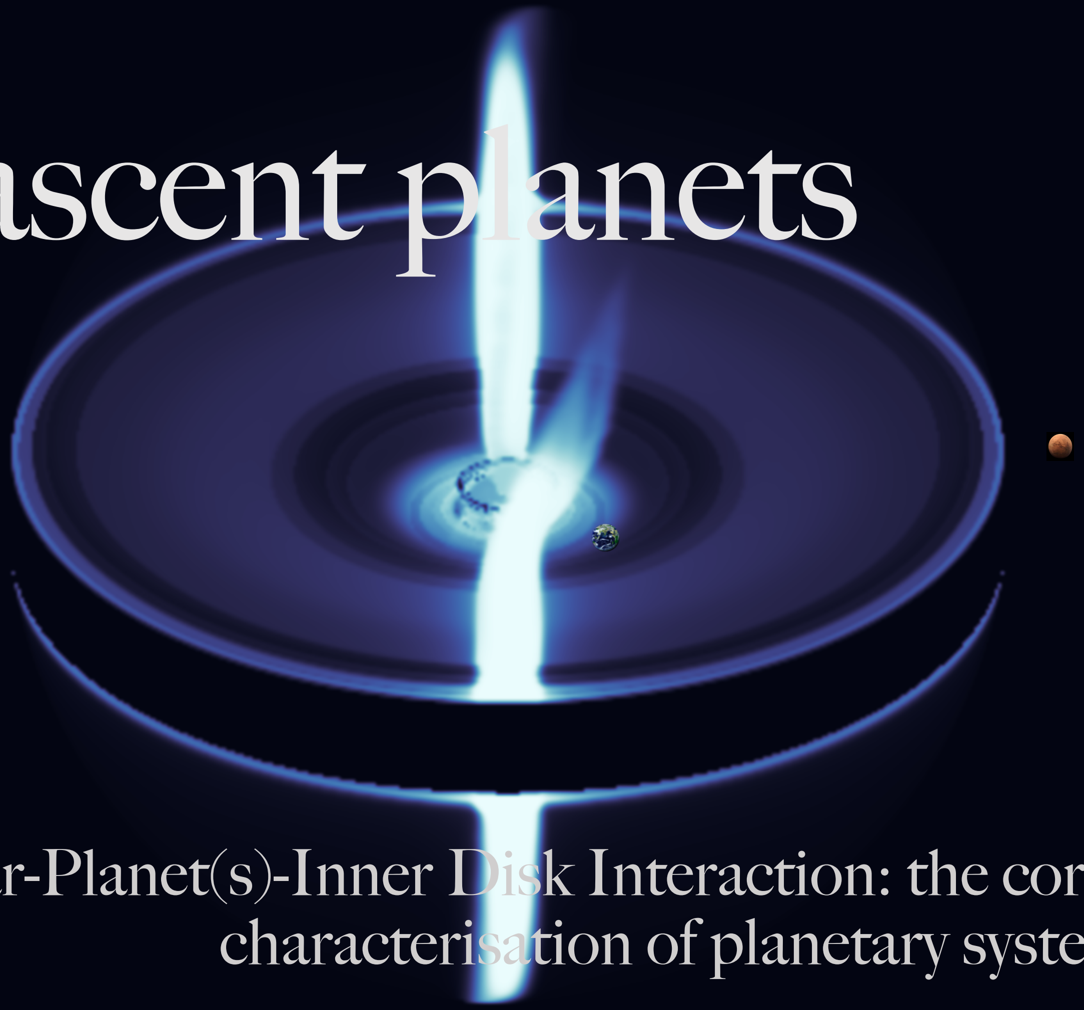
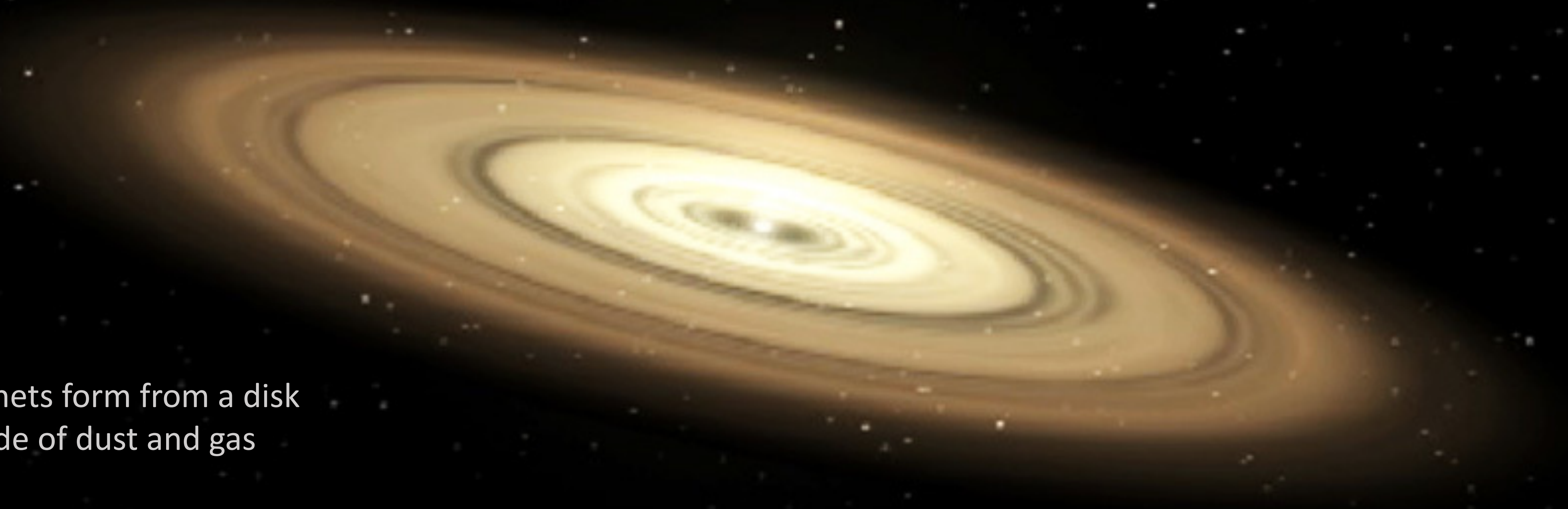
JCAD 2019

SPIDI
and the nascent planets



Star-Planet(s)-Inner Disk Interaction: the cornerstone of the characterisation of planetary systems

The birth of planets ...



Planets form from a disk
made of dust and gas

NASA's Goddard Space Flight Center
Video and images courtesy of NASA/JPL-Caltech

The birth of planets ...

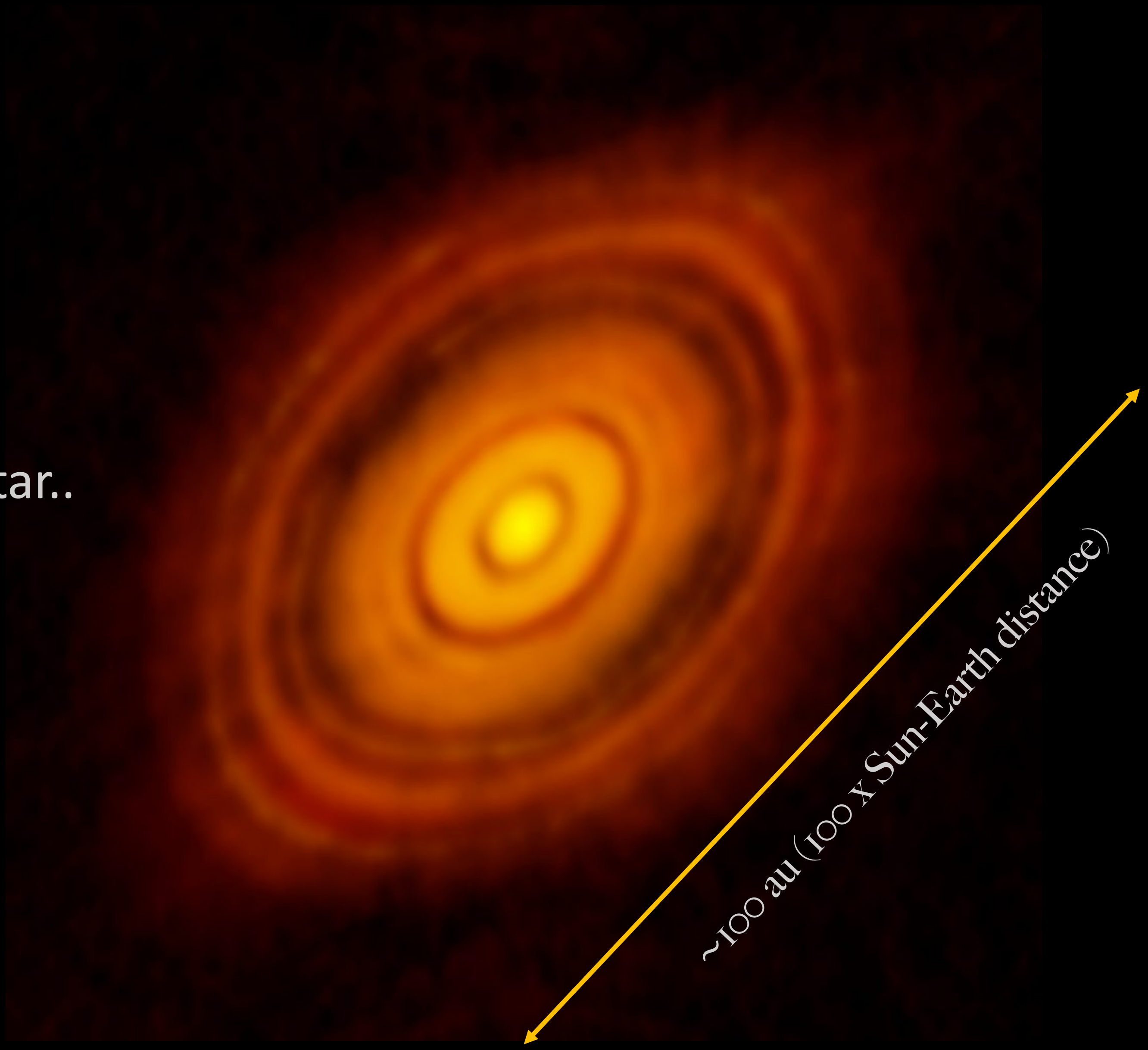
Gaps or density "holes" are most likely due to planets...

NASA's Goddard Space Flight Center
Video and images courtesy of NASA/JPL-Caltech

The birth of planets …

HL Tauri

Planets far from the star..



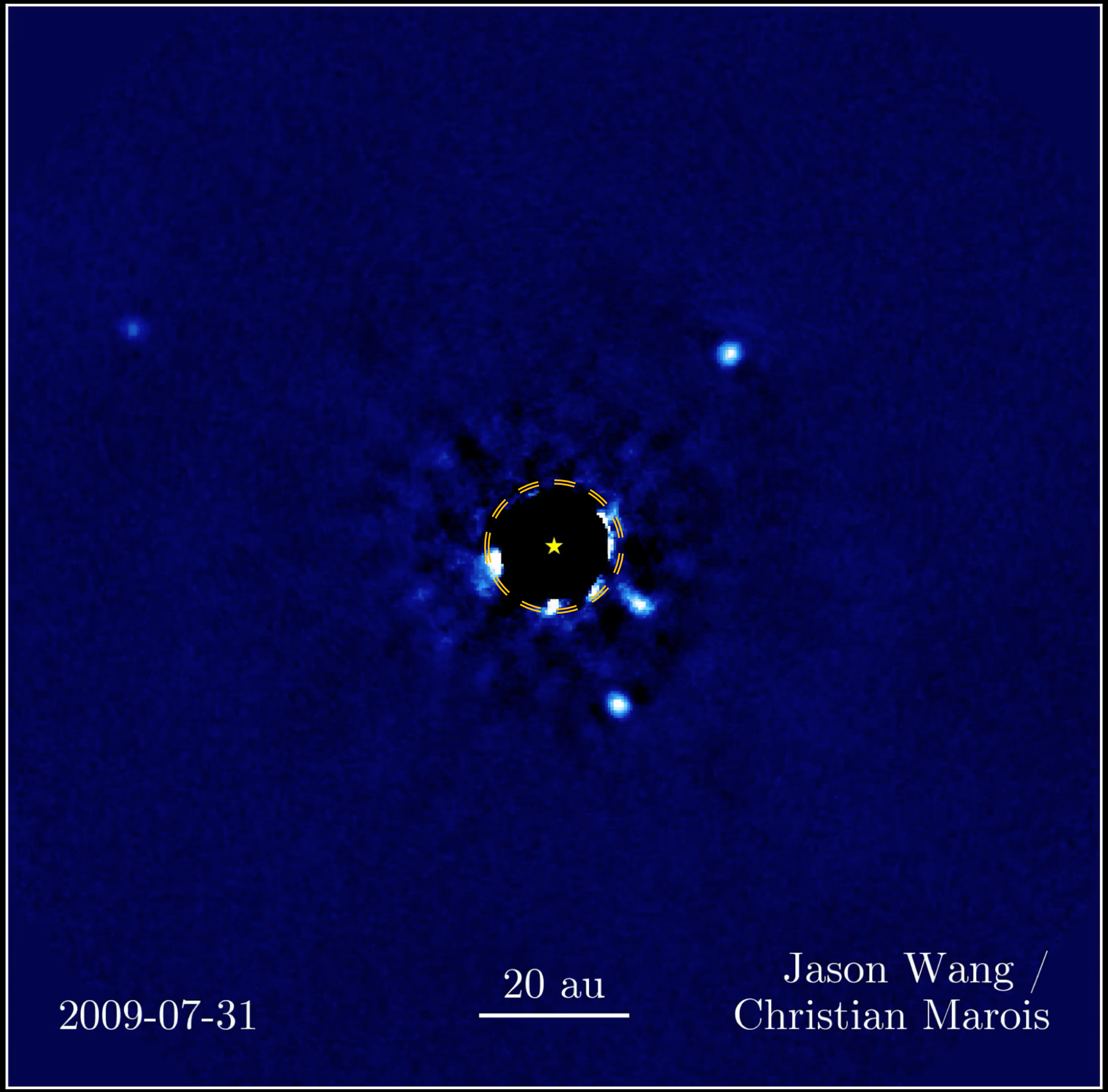
Gaps or density “holes” are
most likely due to planets…

Detecting planets outside the solar system...

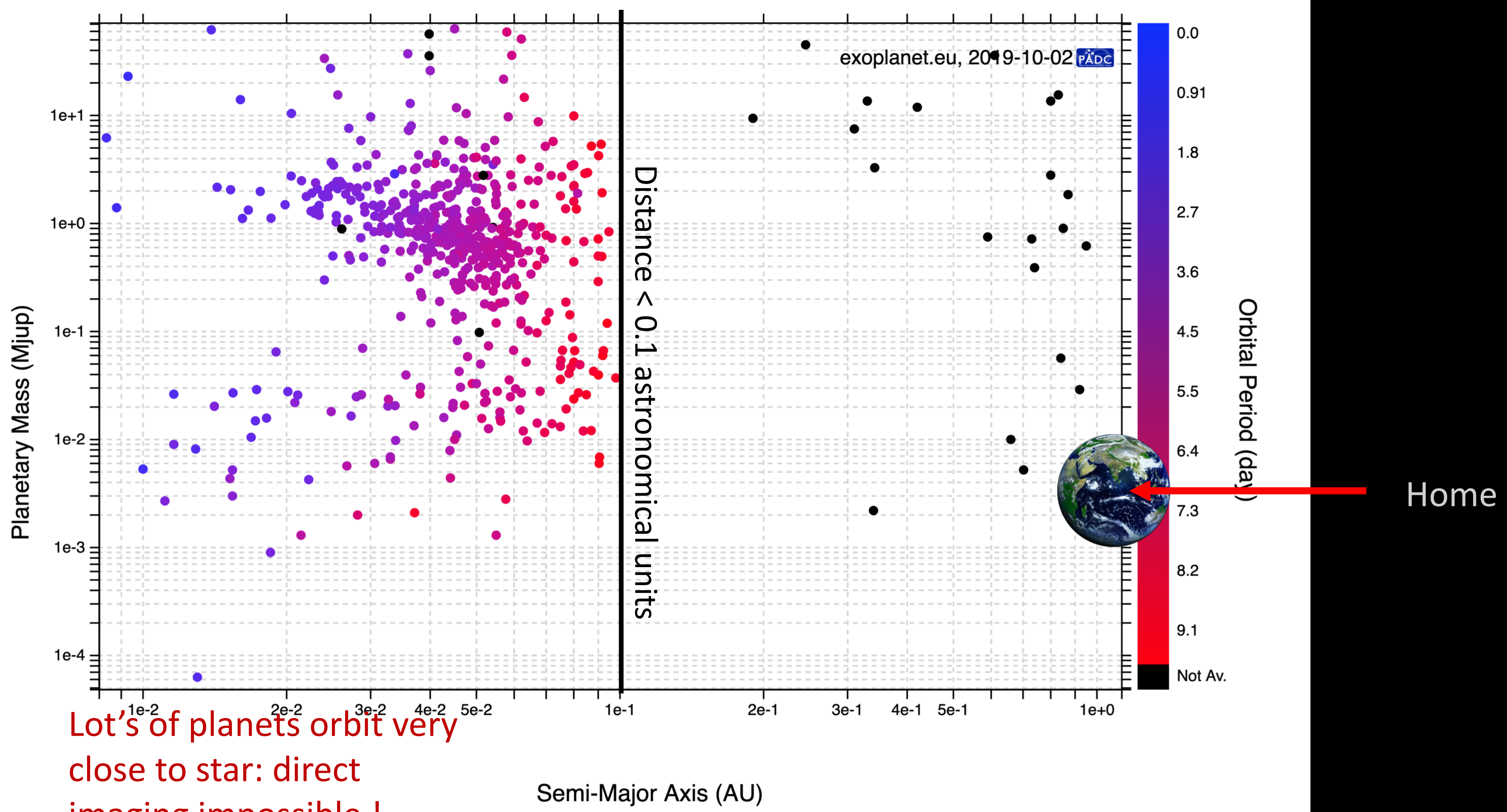
HR 8799

Planets orbiting around their star
from Saturn's orbit to Neptune's orbit

...The star and the first 10 au are hidden...



October 2nd 4118 exoplanets !



Lot's of planets orbit very close to star: direct imaging impossible !

Exoplanets.eu

S+PIDI

star planets
inner disk interactions

Studying planet formation ...

close to their star by characterising

the star, planet and disk interaction.

A numerical simulation approach...

European Research Council
Established by the European Commission
cnrs
GRICAD
Grenoble Alpes Recherche
Infrastructure de calcul intensif et de données

State-of-the-Art Simulations (1/2)

- Magneto-HydroDynamics modeling
- 3D simulations of the environment of young suns

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \boldsymbol{u}) = 0$$ → Mass conservation

$$\frac{\partial \rho \boldsymbol{u}}{\partial t} + \nabla \cdot \left[\rho \boldsymbol{u}\boldsymbol{u} + \left(P + \frac{\boldsymbol{B}\cdot\boldsymbol{B}}{8\pi}\right)\boldsymbol{I} - \frac{\boldsymbol{B}\boldsymbol{B}}{4\pi} - \boldsymbol{\tau}\right] = \rho \boldsymbol{g}$$ → Equation of Motion

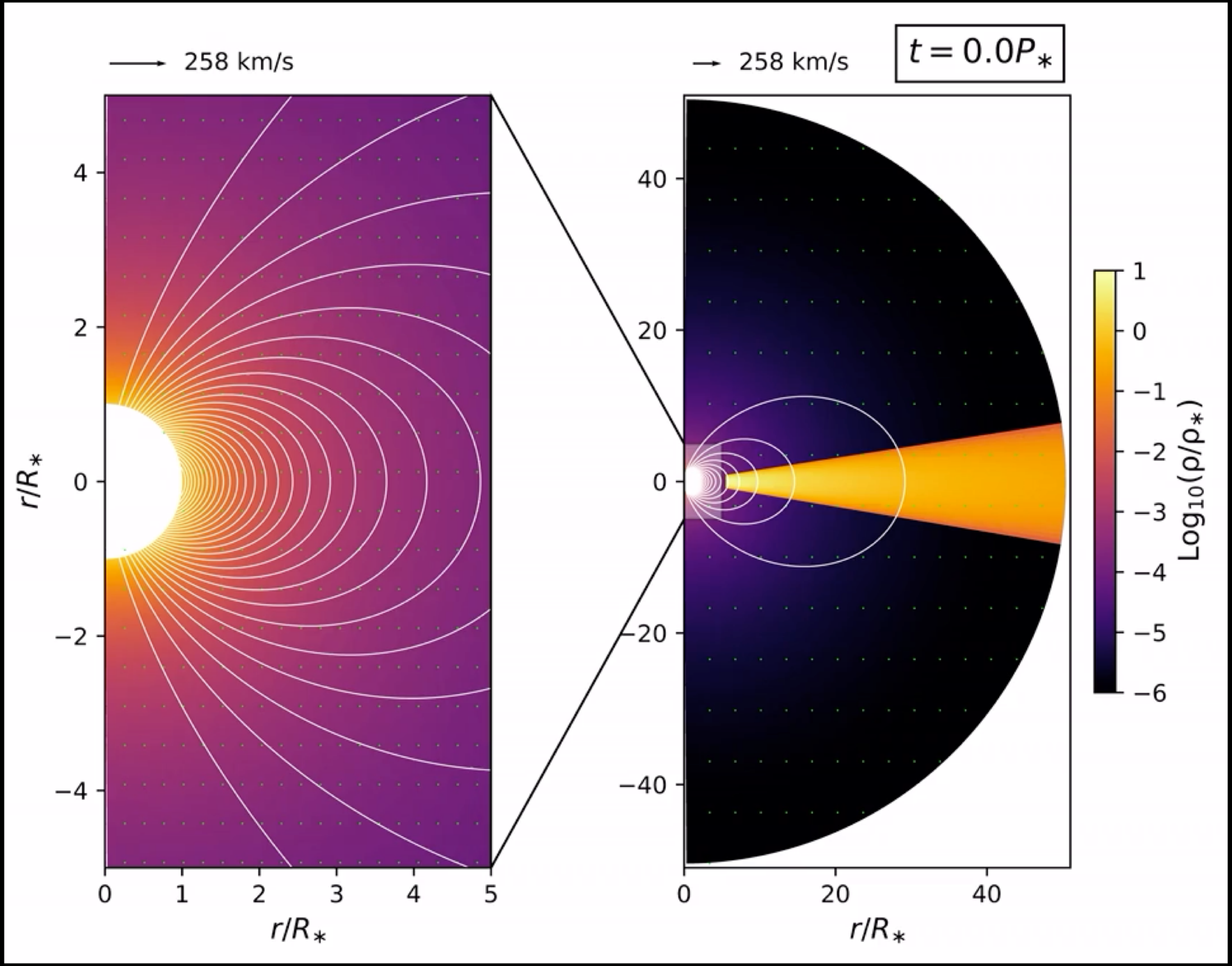
$$\frac{\partial E}{\partial t} + \nabla \cdot \left[\left(E + P + \frac{\boldsymbol{B}\cdot\boldsymbol{B}}{8\pi}\right)\boldsymbol{u} - \frac{(\boldsymbol{u}\cdot\boldsymbol{B})\boldsymbol{B}}{4\pi}\right] + \nabla \cdot \left[\eta_{\mathrm{m}}\boldsymbol{J}\times\boldsymbol{B}/4\pi - \boldsymbol{u}\cdot\boldsymbol{\tau}\right] = \rho\boldsymbol{g}\cdot\boldsymbol{u} - \Lambda_{\mathrm{cool}}$$ → Energy conservation

$$\frac{\partial \boldsymbol{B}}{\partial t} + \nabla \times (\boldsymbol{B}\times\boldsymbol{u} + \eta_{\mathrm{m}}\boldsymbol{J}) = 0.$$ → Induction equation

State-of-the-Art Simulations (2/2)

MHD modeling

- global MHD simulation
- with Dahu supercomputer
- 1500 – 6000 hrs (60 – 250 days) on a single CPU
- with free-source PLUTO code
  http://plutocode.ph.unito.it/



Connecting simulations to observations (1/2)

Light propagation equation : Radiative Transfer Equation (RTE)

Light variation = Emission (T, n, Light) − Absorption(T, n) x Light

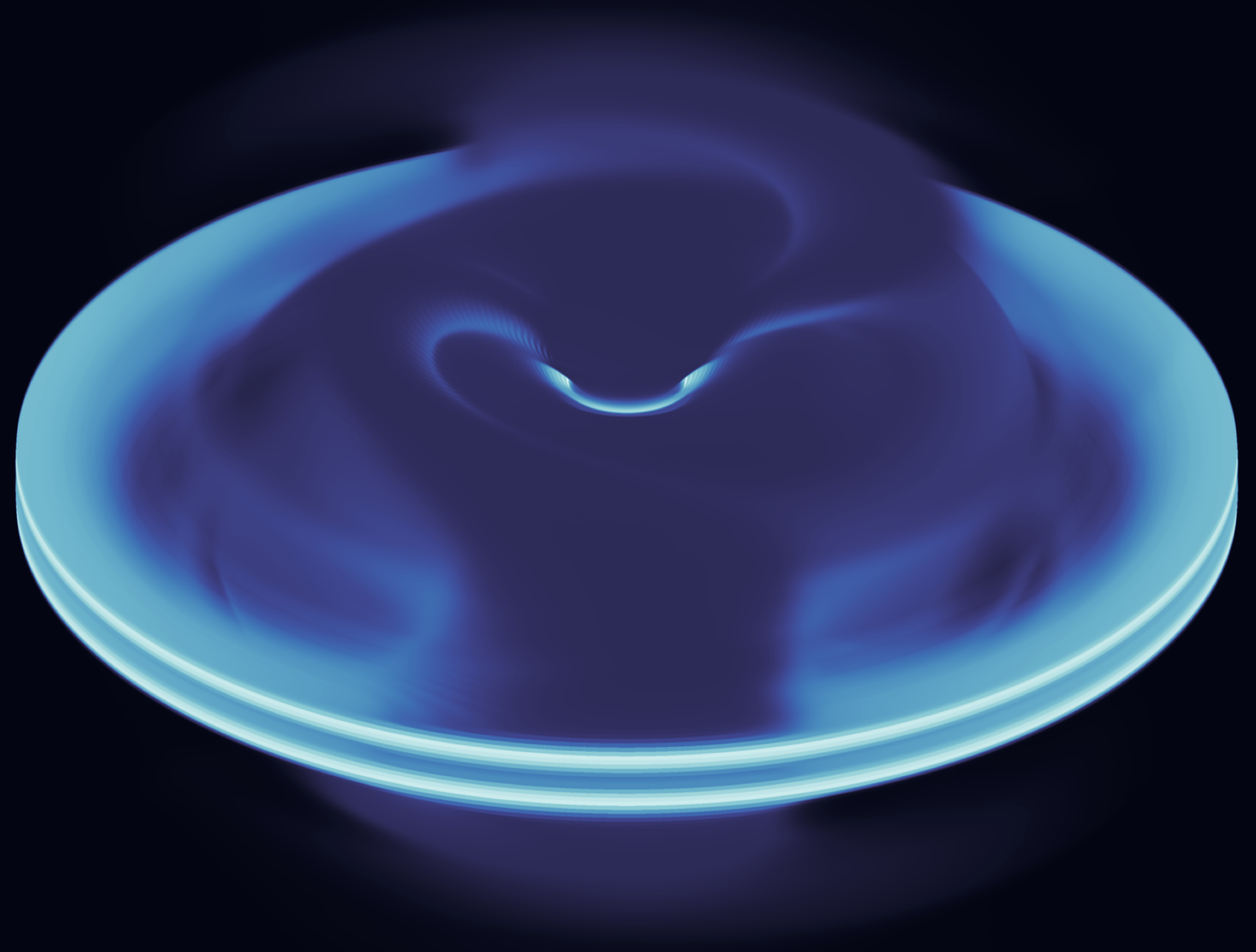
$$\frac{\mathrm{dI}}{\mathrm{ds}} = \eta(\mathrm{I}) - \chi \mathrm{I}$$

$$\sum_{l'} n_{l'}(C_{l'l} + R_{l'l}(I)) = n_l \sum_{l''} (C_{ll''} + R_{ll''}(I))$$

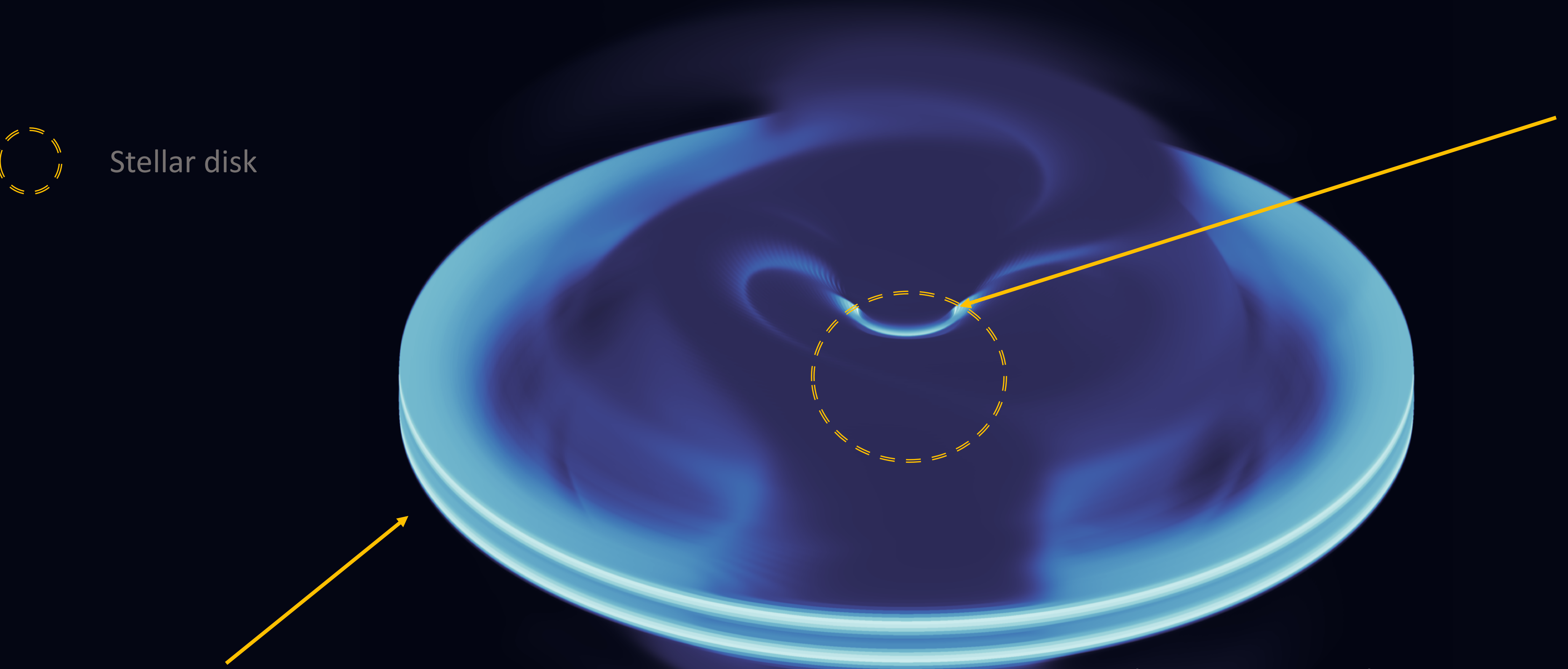
n = f(n, Light, T)

Particles density equations: Kinetic Equilibrium Equations

Connecting simulations to observations (2/2)



Connecting simulations to observations (2/2)



… Different particles (here Hydrogen), different frequencies (colors) probe different structures in the stellar environment: Here, the stellar magnetosphere

Take away messages...

- Star, planets disk interaction mould the stellar environment
- Observational signatures can be disentangled from numerical simulations
- Comparison of models with observations will open a new window for the characterisation of inner planetary systems

Stay in touch: spidi-eu.org

NASA/JPL-Caltech