INAF-RSN2 Auditions

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Arxes: at the Origins of Planetary Systems

or

What We Do in the Shadows

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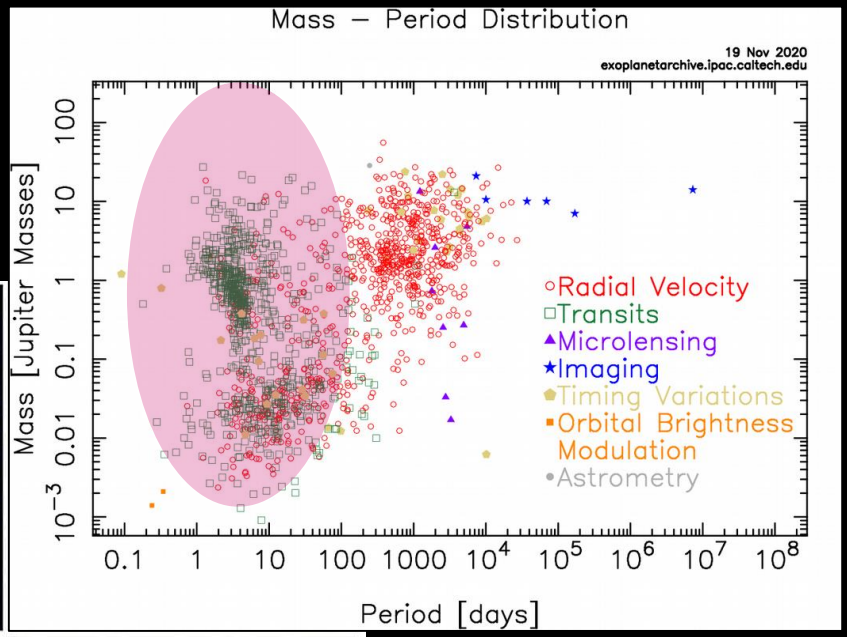
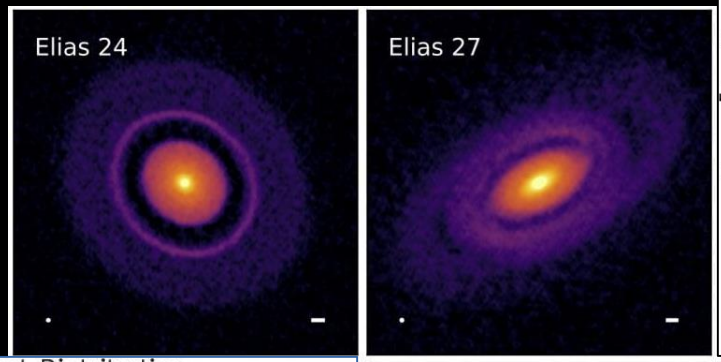
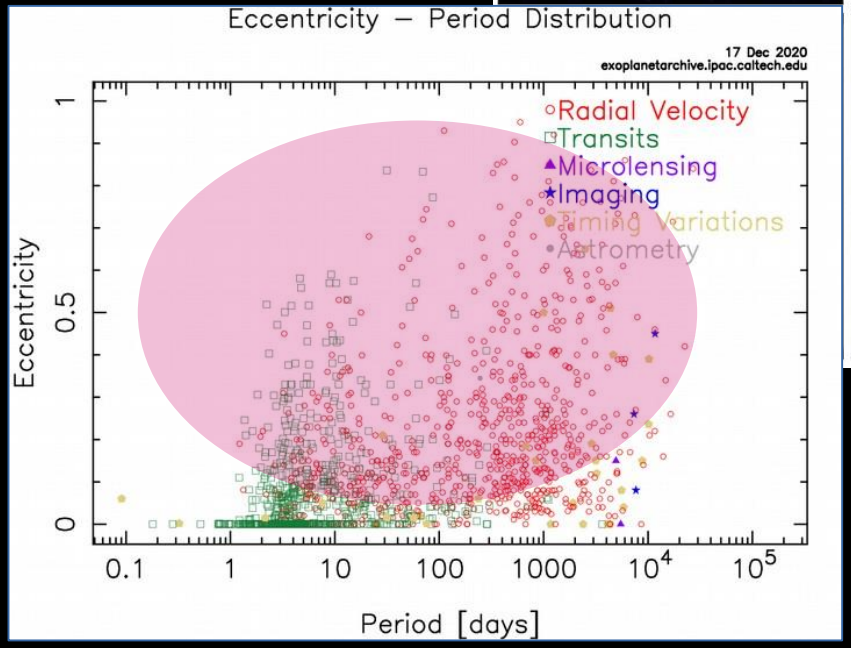
*On behalf of the **Arxes**, **AMS** and **DDyPSyPro** Teams*

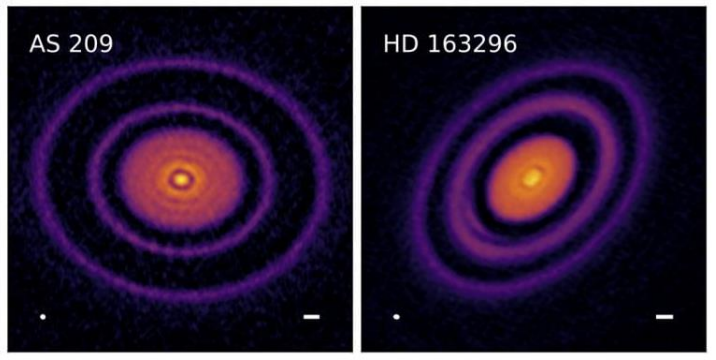
Modern Challenges in Planetary Formation

New observational data highlight our **limited understanding** of planetary formation.









Planets and their systems can form and evolve under a **wider range of conditions** than previously thought.

Programs, Projects & People at a Glance

Arxes
(P.I. Diego Turrini)

Arxes (pron. *arches*) is a program focused on **linking planetary architectures and composition to the formation and evolution history** of planetary bodies, their systems and their native protoplanetary disks.

AMS
(P.I. Diego Turrini)

AMS (Ariel Main Stream) is a project, born from Arxes and the Ariel mission, focused on studying the **compositional link between protoplanetary disks and exoplanetary atmospheres**.

DDyPSyPRO
(P.I. Stavro Ivanovski)

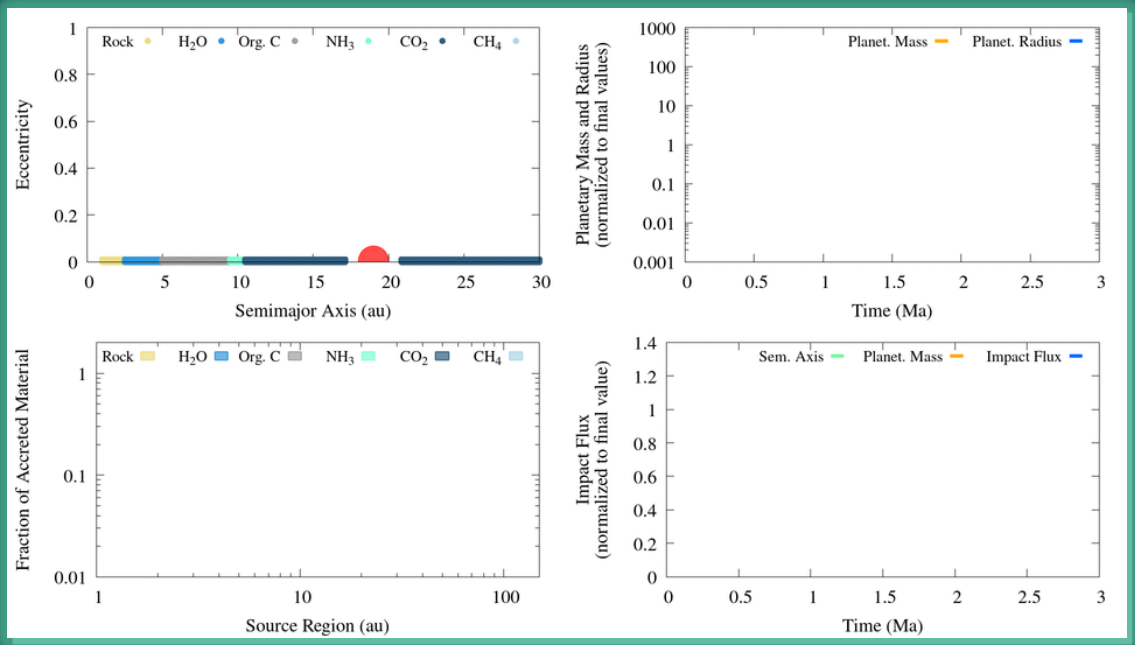
DDyPSyPRO is a program focused on understanding the **dust dynamical evolution and life cycle in protoplanetary disks** and their impact on disks characterization.

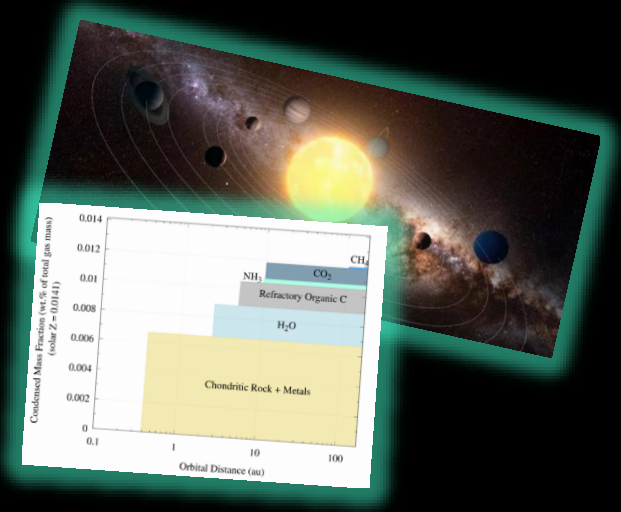
Teams

The **multidisciplinary teams** of Arxes, AMS and DDYPSyPRO include modelling, observational and computational skillsets merging expertises from Solar System, stellar astronomy and exoplanets.

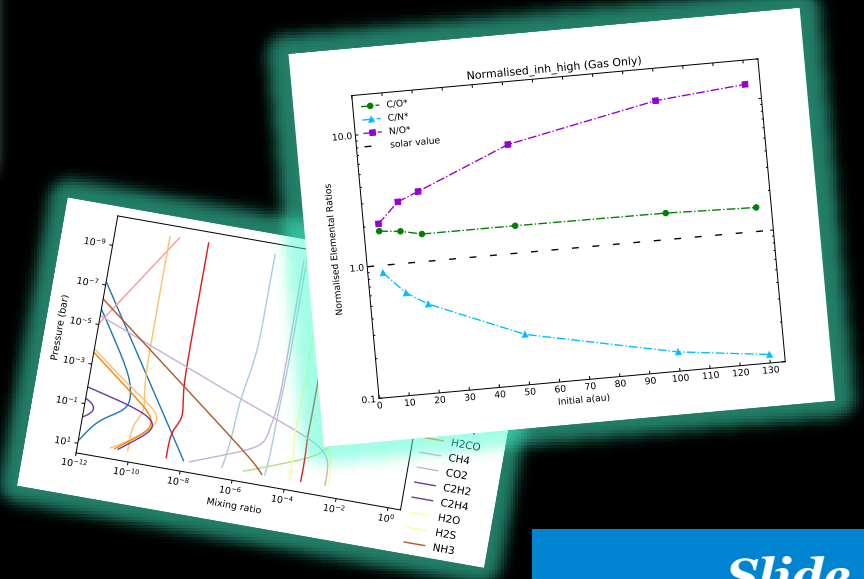
Arxes + AMS: Signatures of Planet Formation

Combining data from multiple astrophysical source, it is now possible to **compositionally characterize** the birth environment of planets with unprecedented details.





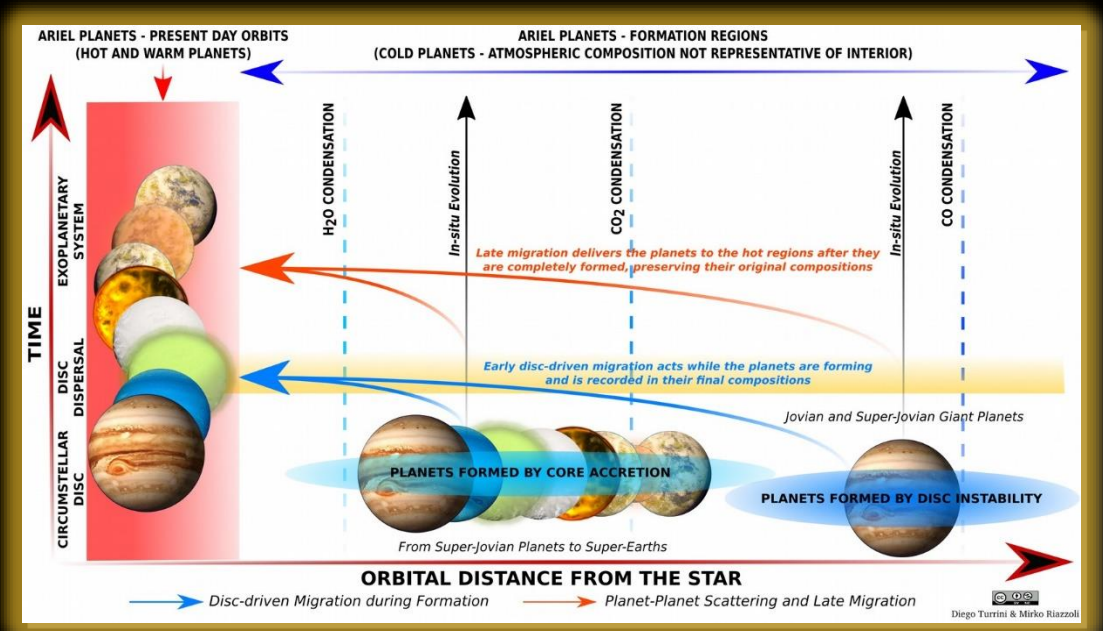
N-body simulations of protoplanetary disks allow to produce **physically-justified planetary compositions**.

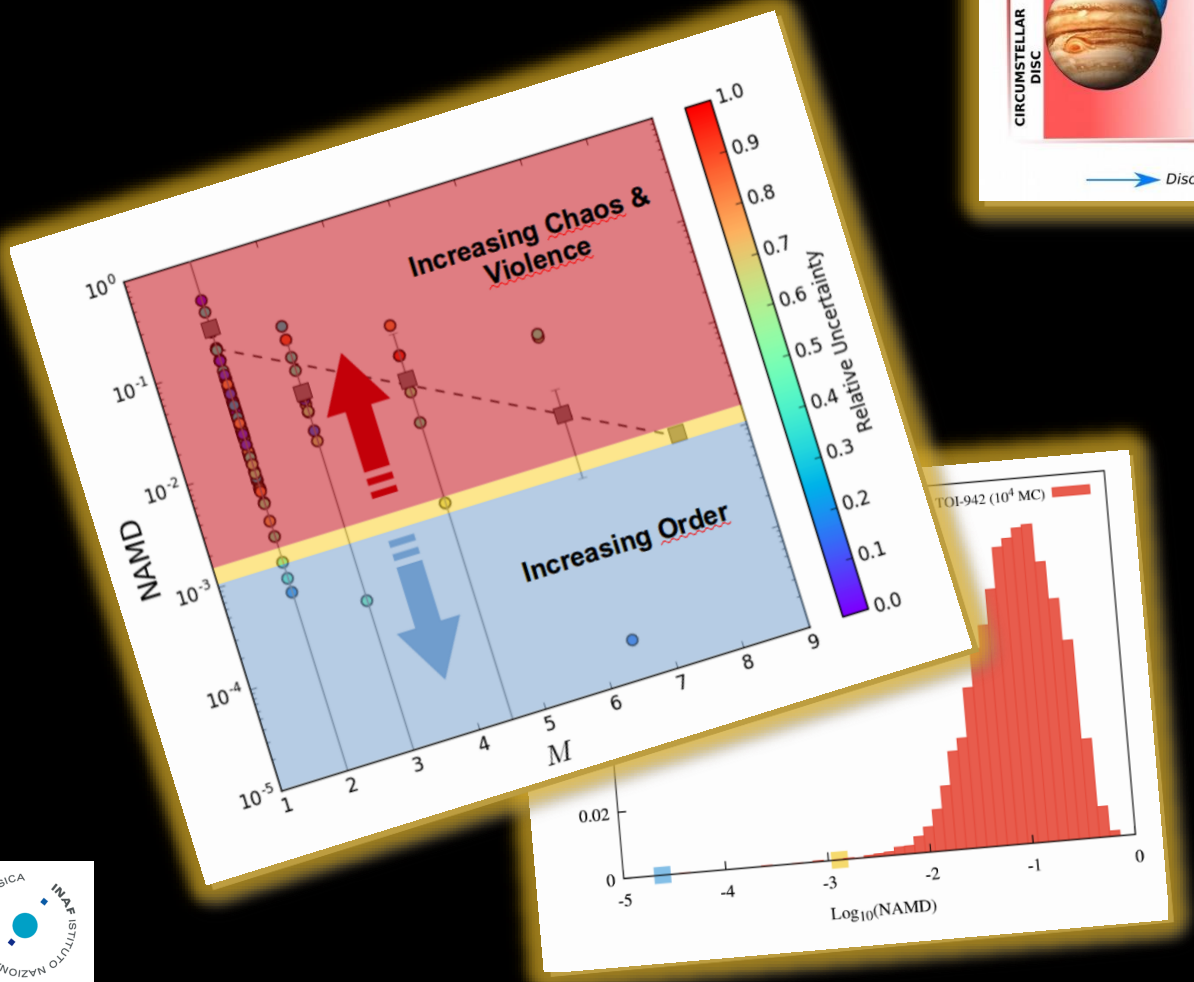


These models allows to reliably study the **compositional fingerprints** of planet formation and identify their **chemical tracers**.

Arxes: Signatures of Chaos and Order

Planetary systems possess a rich **diversity of orbital architectures**, making meaningful comparisons of their histories difficult without a **global metric of their dynamical states**.



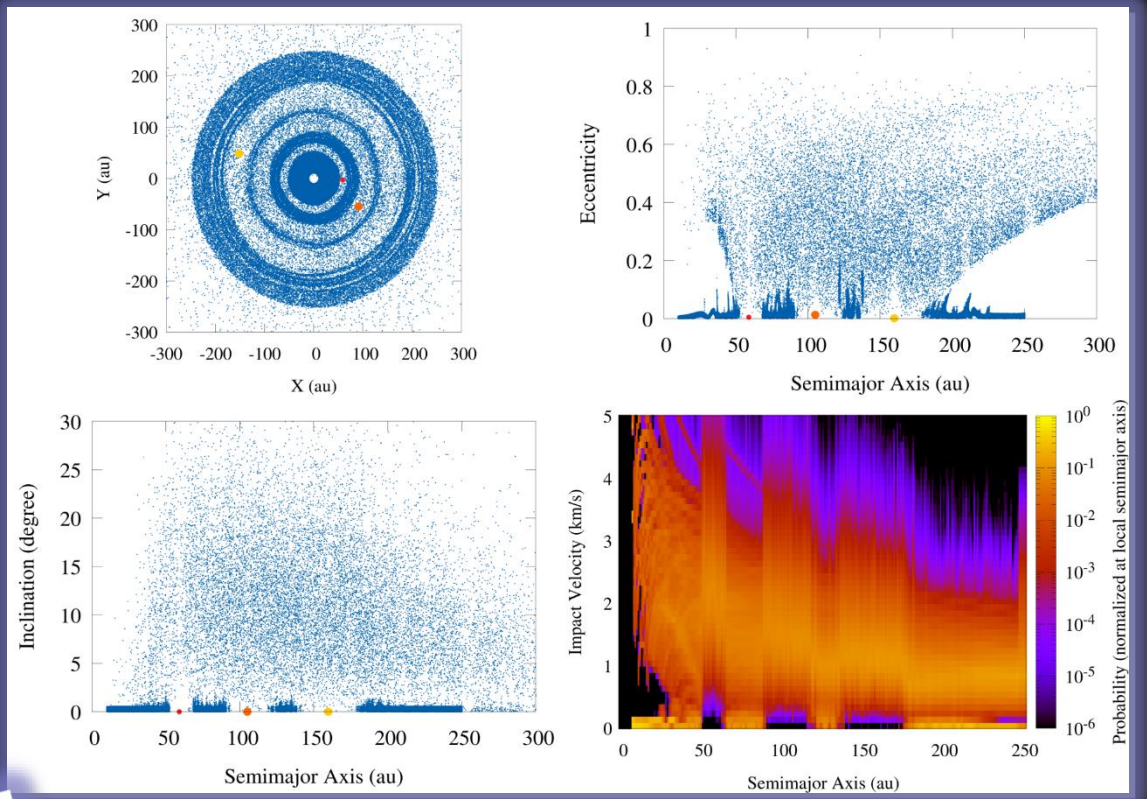


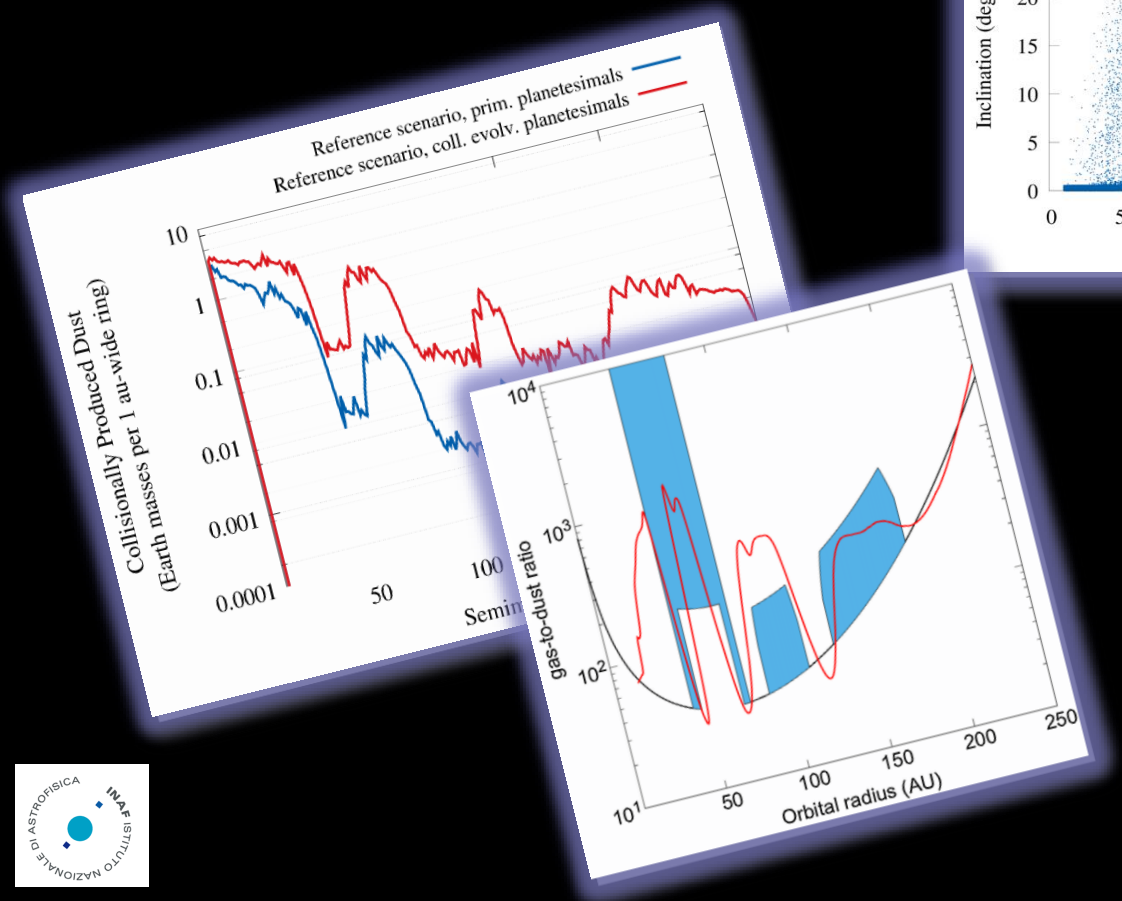
The NAMD is **fast** to compute, **architecture agnostic**, intuitively interpreted as **dynamical temperature**, and its uncertainty is easily computed by Monte Carlo techniques.

Arxes: Planet Formation's Feedback on Disks

Protoplanetary disks are not left unaltered by the planet formation process.

The interactions between planets and planetesimals have **feedback effects** on the dust and gas of disks.

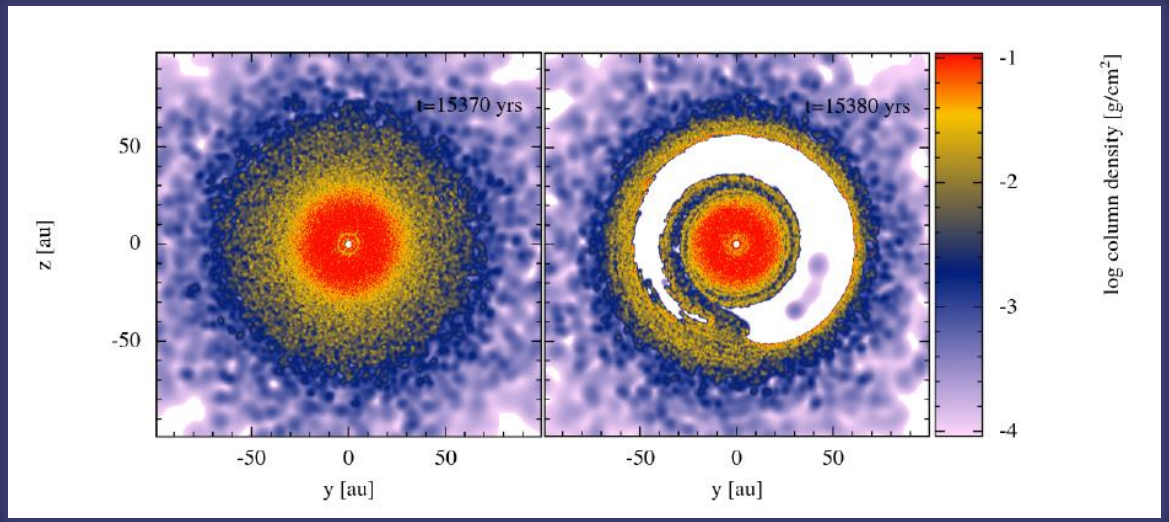




Combining n-body simulations and statistical collisional methods, we can quantify **dust regeneration in planet-hosting disks.**

DDyPSyPRO: Dust Life Cycle in Disks

The characterization of the planet-forming region in disks heavily depends on understanding the **dust dynamical evolution and lifecycle**.



Initial parameters: $R_0 = 50\ au$; $h = 2.5\ au$;
$\rho(y) = \rho_0 exp\left(\frac{-y^2}{2h^2}\right)$ con $\rho_0 = 6 \cdot 10^{-13} g/cm^3$;
$\rho_d/\rho = 0.01$; 32×110×24 particles;
volume $= 1mm^3$; density $= 3g/cm^3$; mass $= 3 \cdot 10^{-3} g$

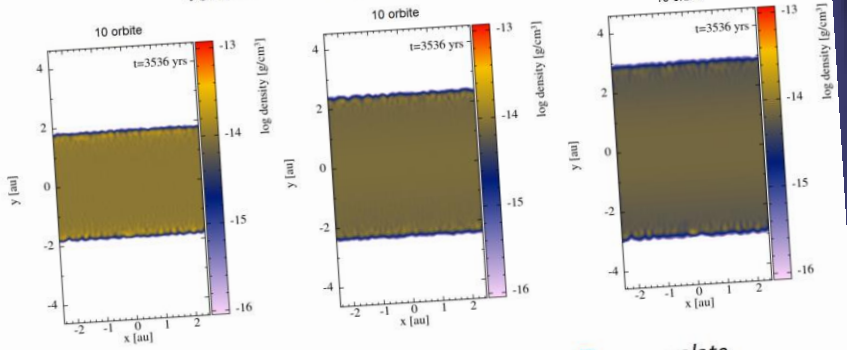
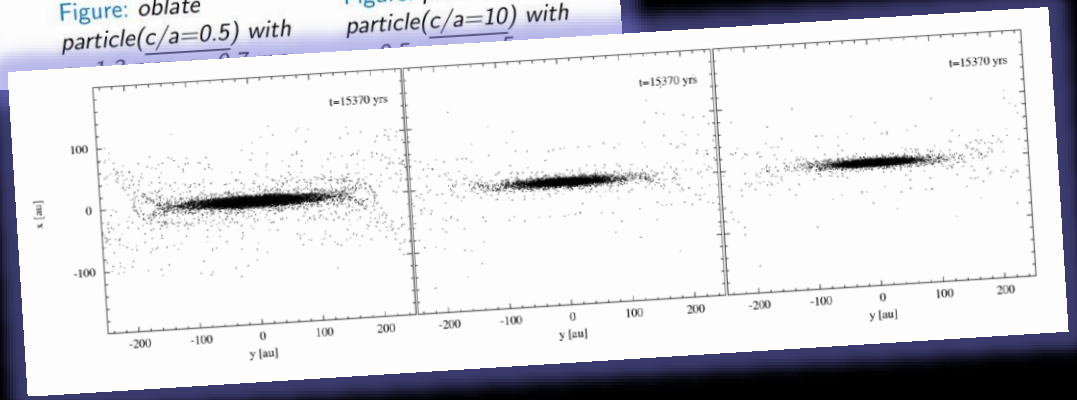


Figure: *spherical particle(c/a=1) with r=1 mm*

Figure: *oblate particle(c/a=0.5) with*

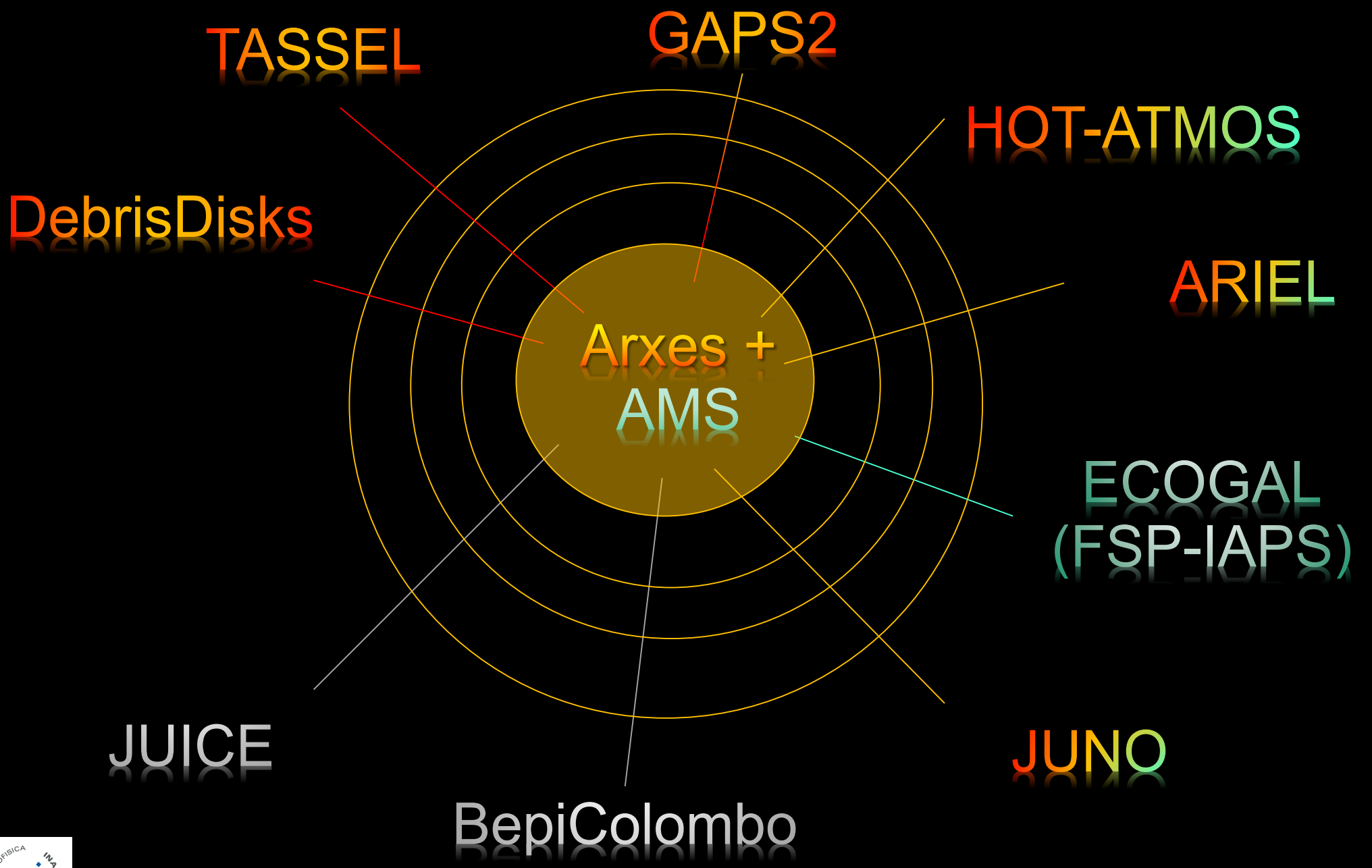
Figure: *prolate particle(c/a=10) with*

The know-how on dust evolution derived from Solar System studies allows for more **physically realistic models of dust-gas coupling** in disks.

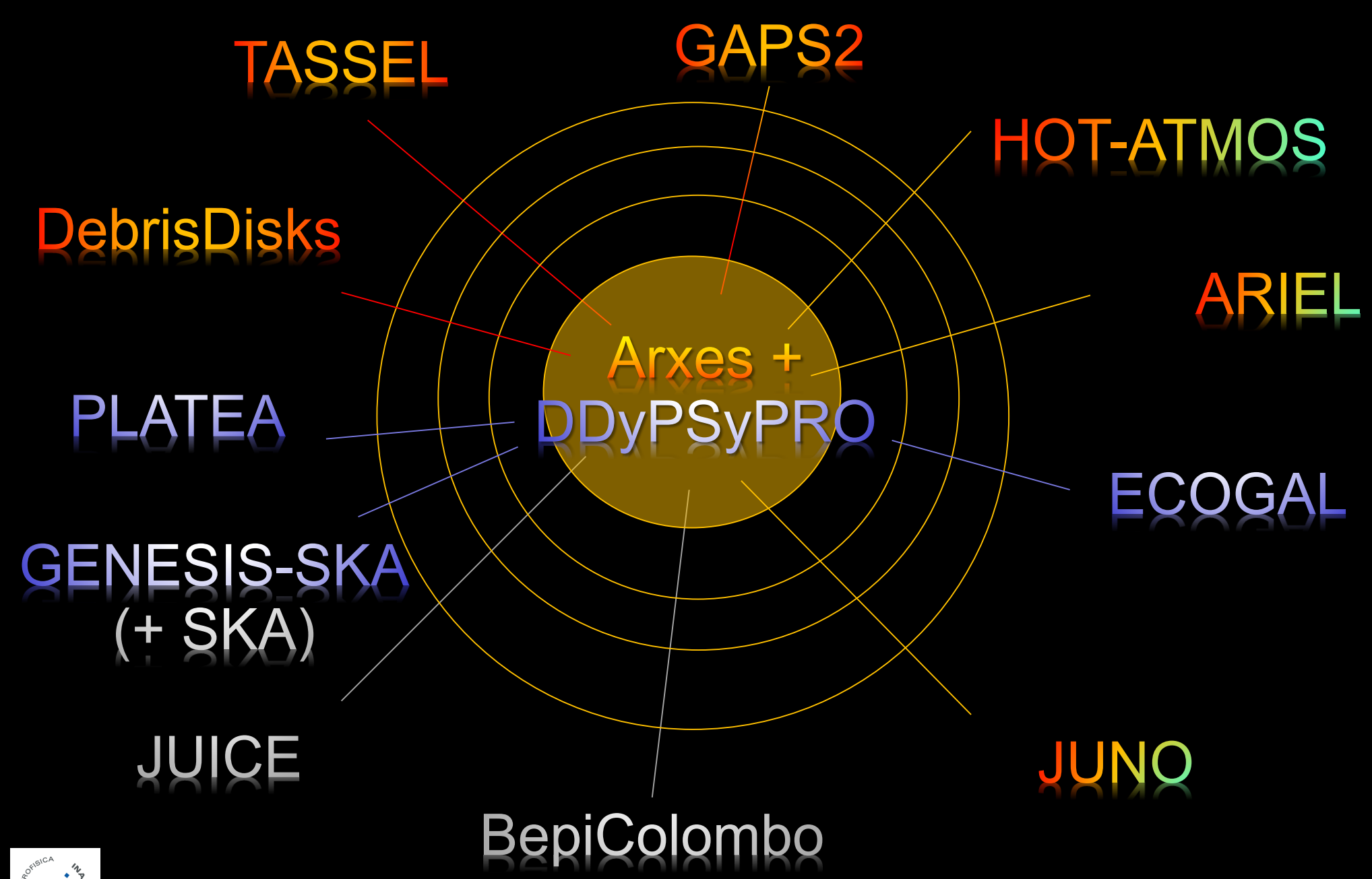


This, in turn, allows to **constrain and remove the biases** due to oversimplified assumptions.

A Network of Synergies in the study of Planets…



… and their Formation Environments



Technological Advancements and Facilities

Mercury-Arxes: parallel and GPU-accelerated n-body code to simulate forming planetary systems embedded in protoplanetary disks.

NAMDMC: Monte Carlo code to compute the dynamical excitation of planetary systems.

Debris: parallel statistical code to estimate the collisional dust production in planetesimal disks.

PHANTOM-NSP: first implementation of the SPH code PHANTOM capable of simulating non-spherical dust particles.

Genesis Cluster: develpment and scientific production platform for the activites of the teams, Genesis is a 144-cores cluster on a dedicated network and managed by LAPD and Arxes.

Scientific Leadership and Excellence

Coordination of the Planet Formation WG of Ariel's international consortium through the mission lifecycle (proposal + Phases A, B1, B2/C) + **contact node for Ariel-SPICA synergies** with SPICA's consortium.

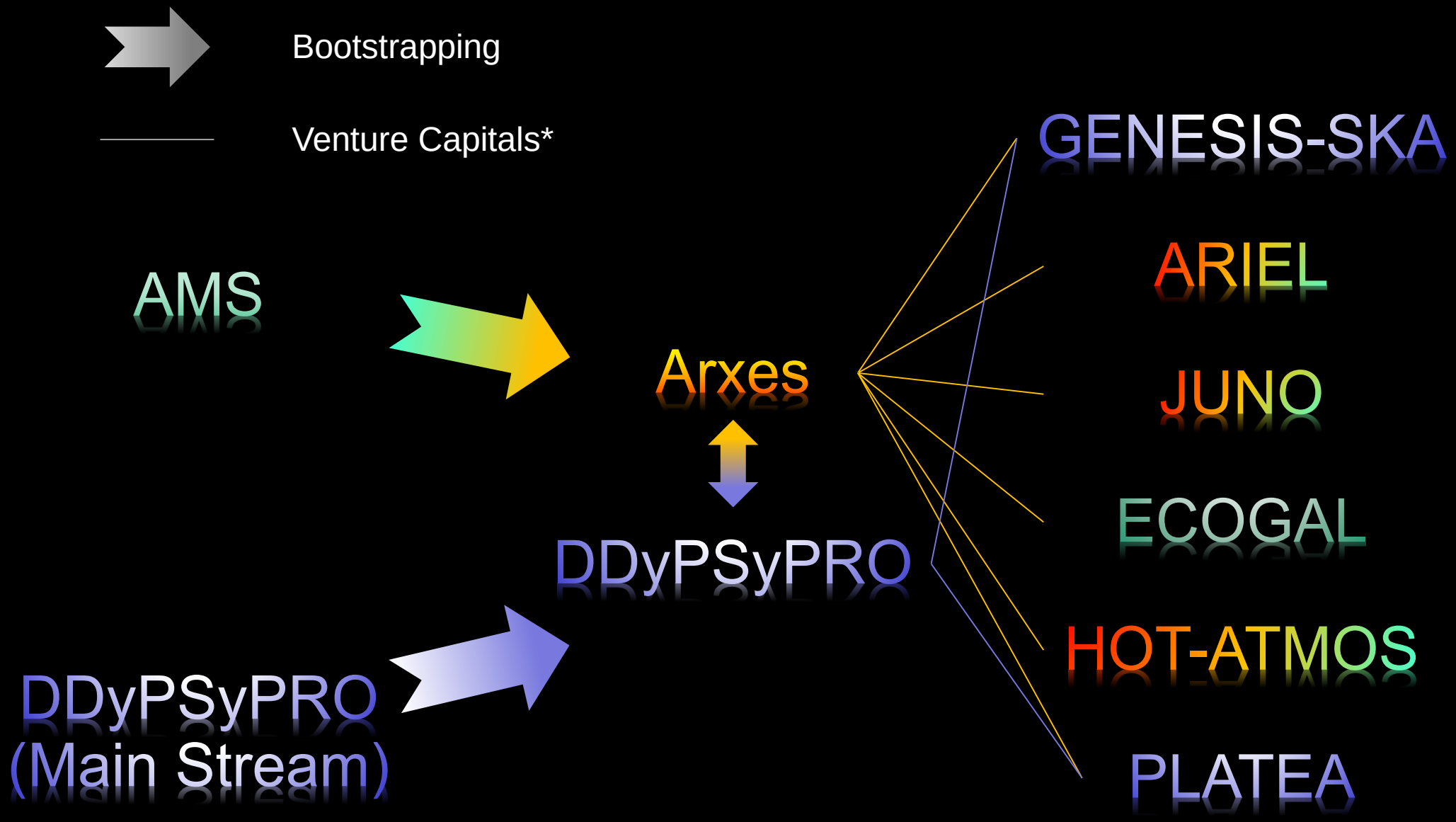
First identification of compositional tracers of planet formation and migration not relying on C and O.

First application of system-wide, architecture-agnostic metrics to study exoplanetary systems.

First identification of dust regeneration by collisional processes in protoplanetary disks.

First investigation of dust dynamics with non-spherical particles in protoplanetary disks.

Funding: Bootstrapping & Venture Capitals



* i.e. *What We Do in the Shadows*

Current Status, Goals & Criticalities

Current Status

New iteration of an INAF community that has long been an international excellence

Transitioning from the start-up stage to emerging community

Goals

Keep supporting INAF's major efforts in observational programs and space missions

Establish as an international, multidisciplinary excellence

Criticalities

Approaching the limits of what can be done leveraging on synergies and shared interests

Difficult to respond on-time to all the needs of the community

Due to limited size, difficult to reach critical mass to access major funding schemes