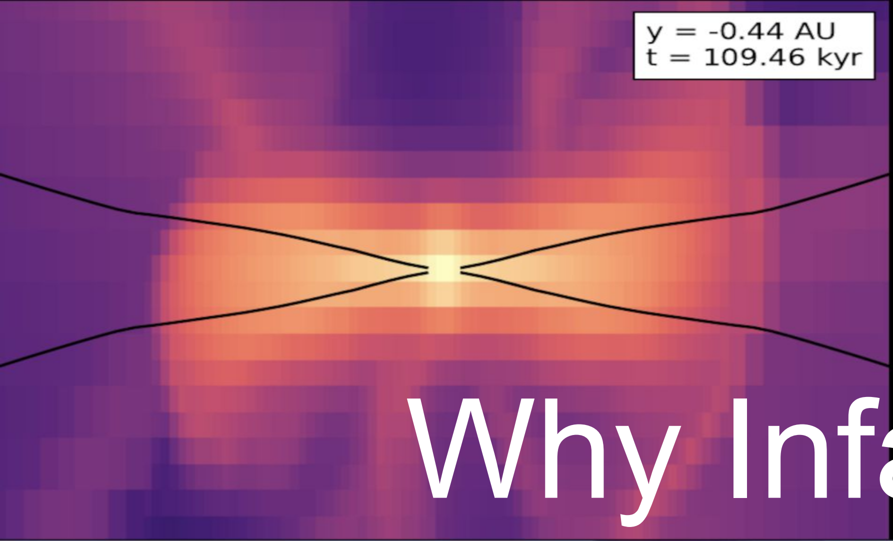
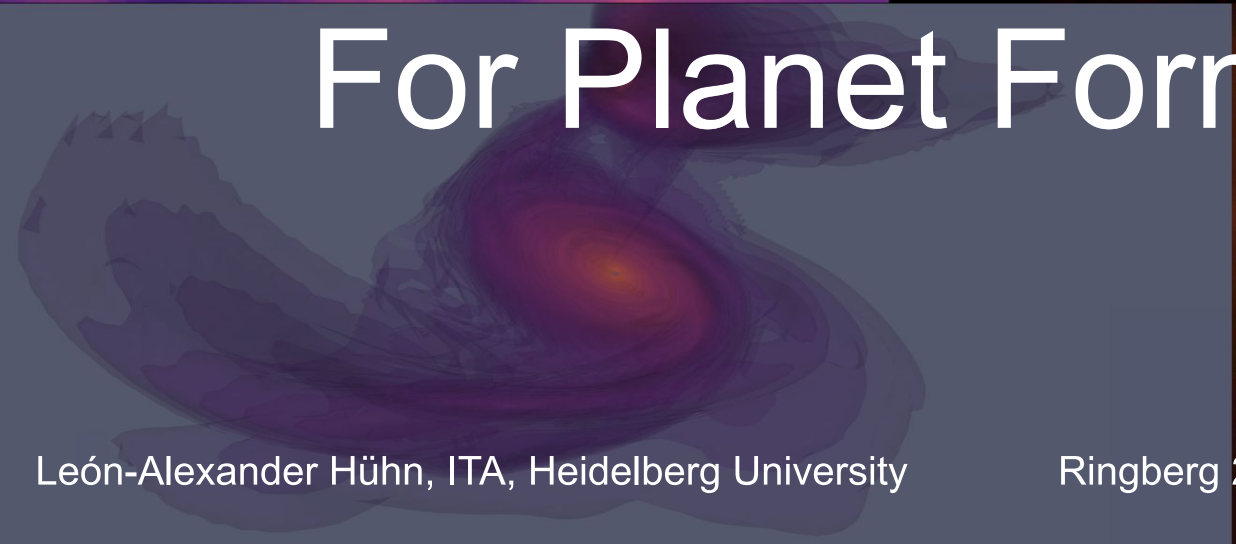


huehn@uni-heidelberg.de

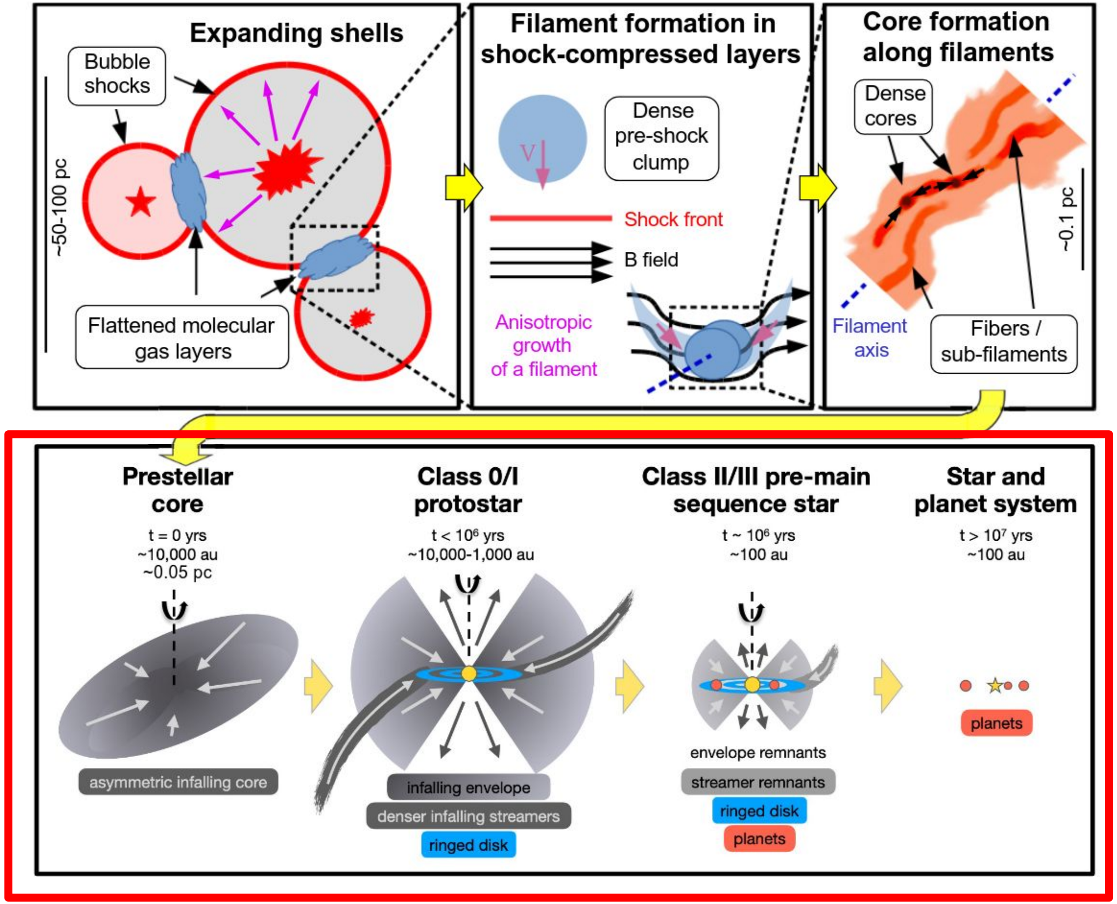
Why Infall Matters For Planet Formation



León-Alexander Hühn, ITA, Heidelberg University

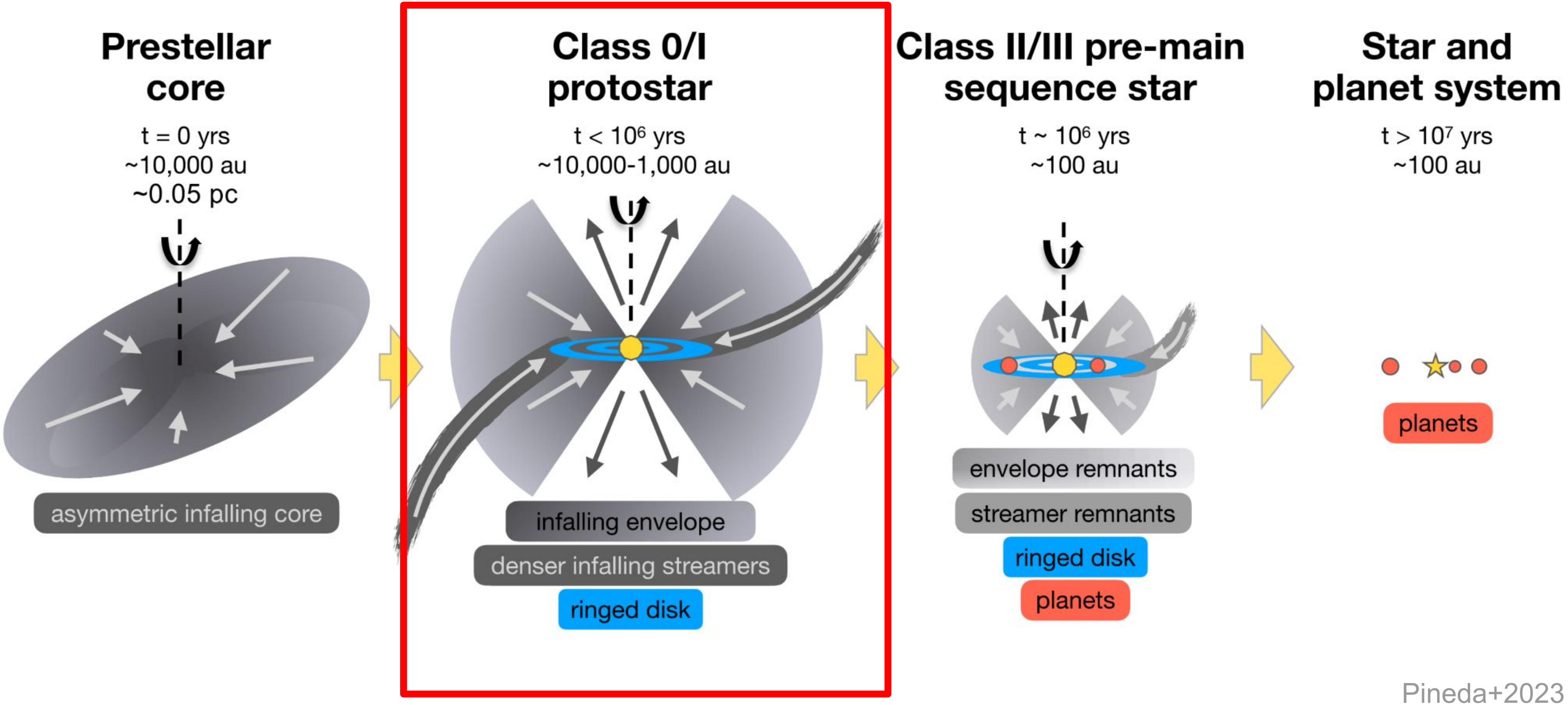
Ringberg 2026: Elements, February 13th 2026

From Galaxies to Planets…



Pineda+2023

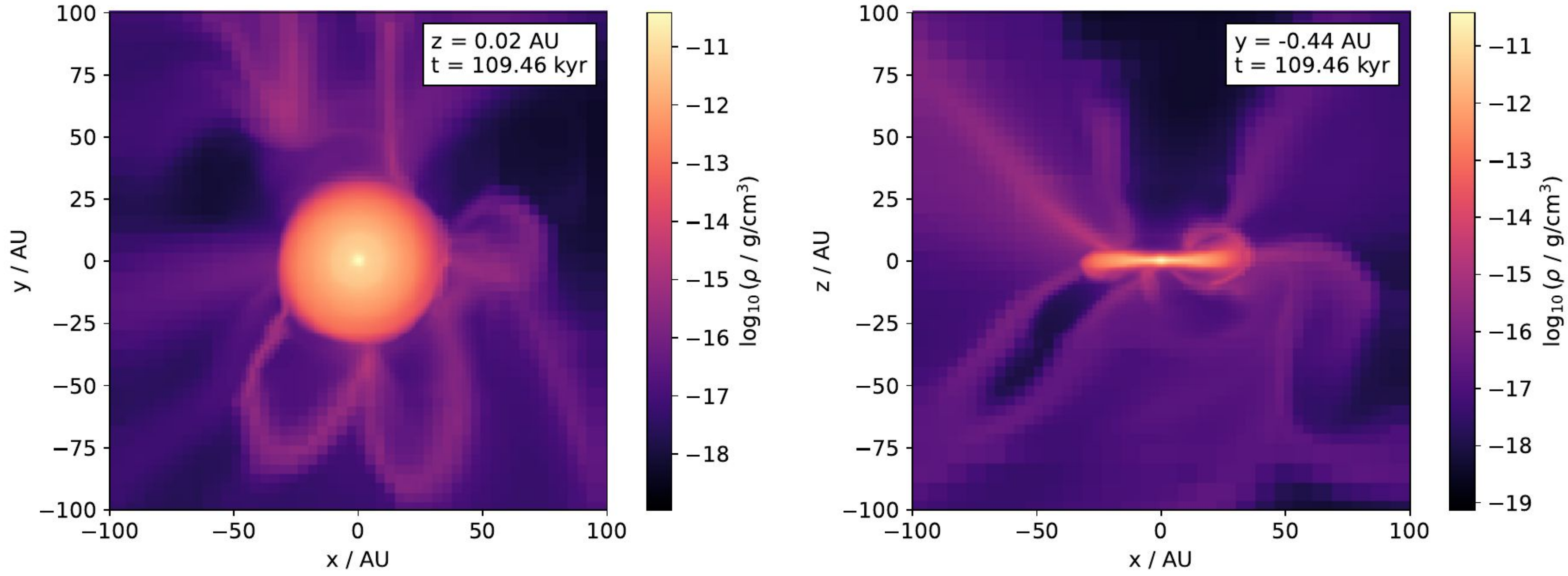
Evolutionary stages of protoplanetary disks



Pineda+2023

Environment of young disks

Hennebelle+2020; Hühn+2025a

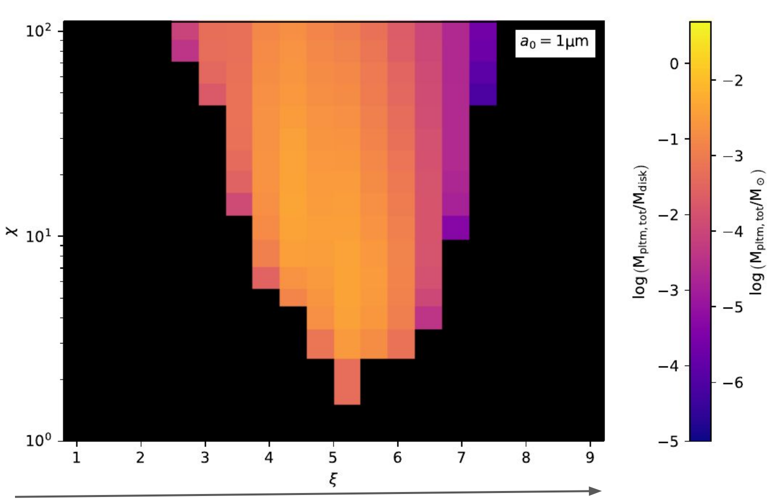


Young (Class 0/I) disks continuously accrete from their environment!

Early planetesimal formation?

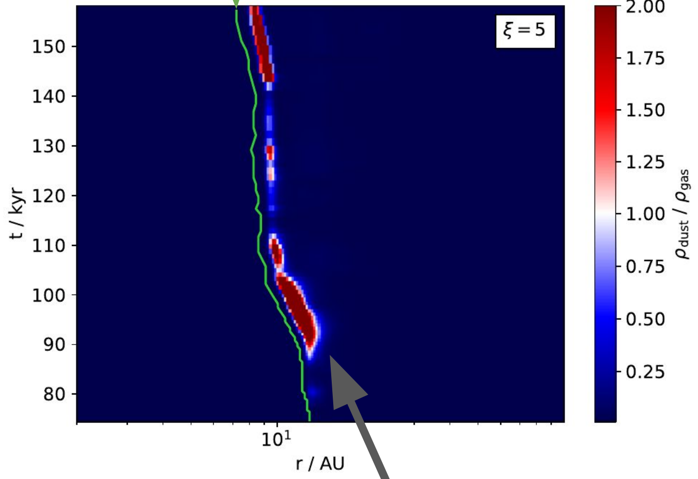
Water snow line

Lower turbulence



Higher temperature

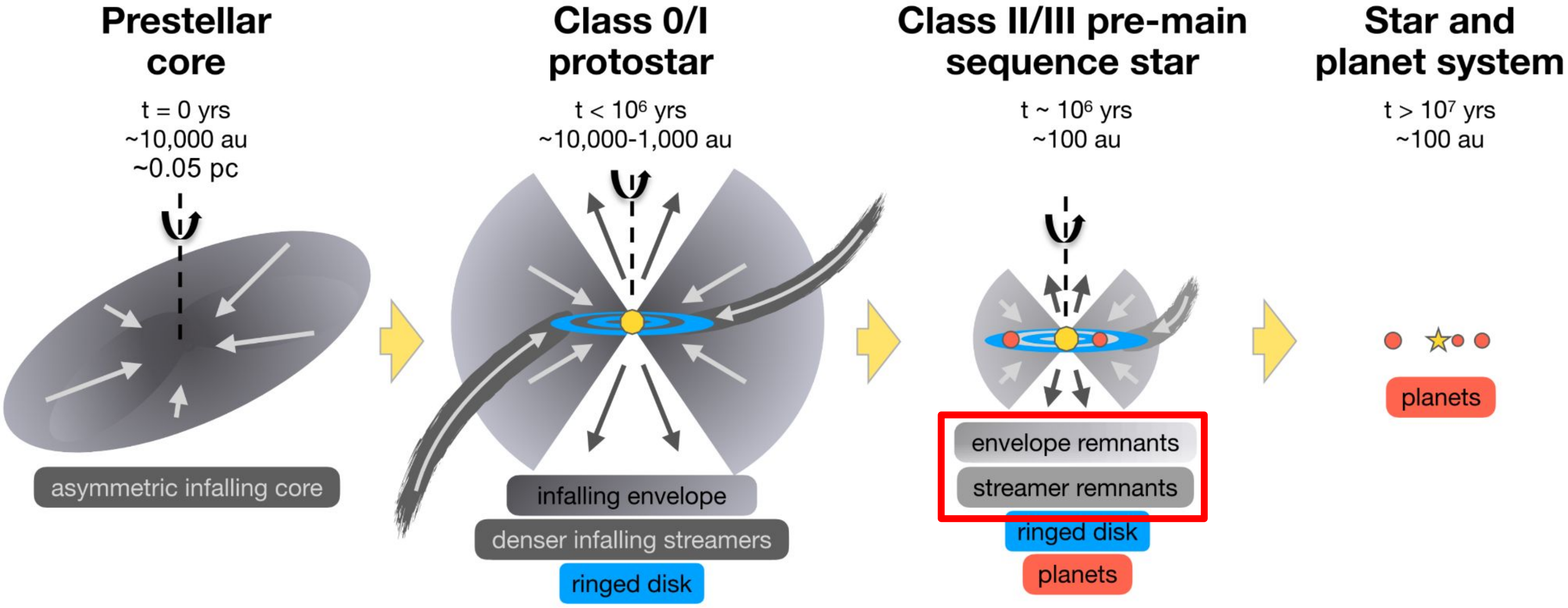
Hühn+2025a (inc. Lebreuilly, Rosotti)



Red = planetesimal formation

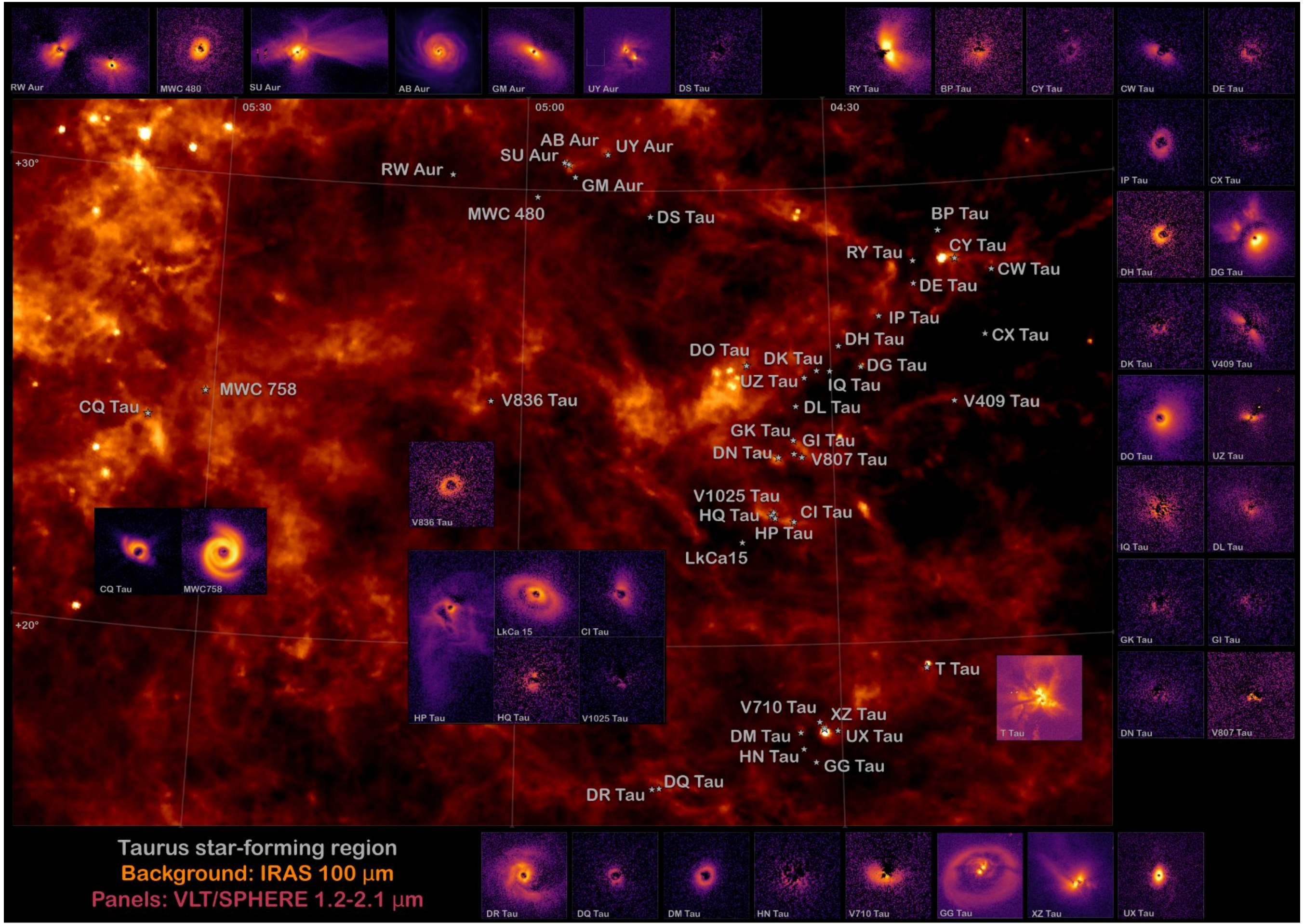
Retention of solids via **cold-finger effect**

The current picture of planet formation



Pineda+2023

How isolated are disks during the Class II stage?

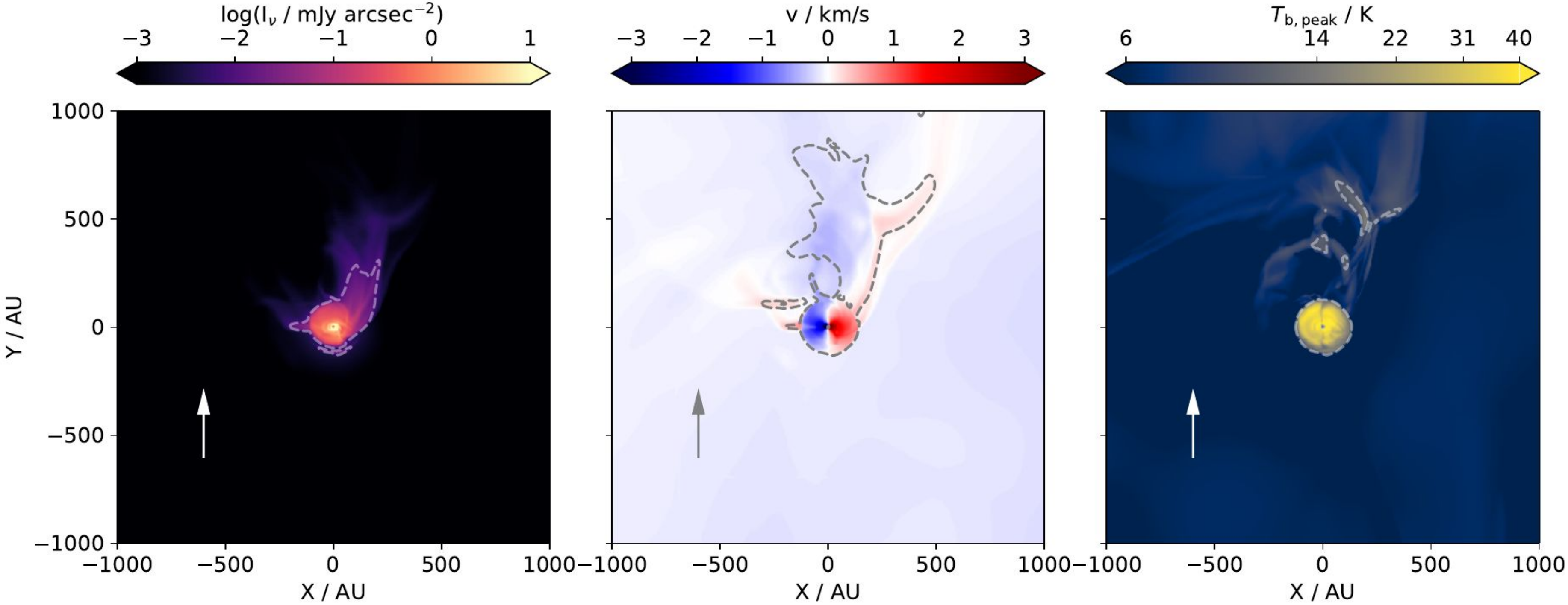


⅓ of sampled disks show ambient signal!

Garufi+2024

Bondi-Hoyle accretion: Streamer formation

$d/dt\, M$ = 1e-8 $M_\odot$ / yr
ρ_{ISM} = 3e-21 g/cm²

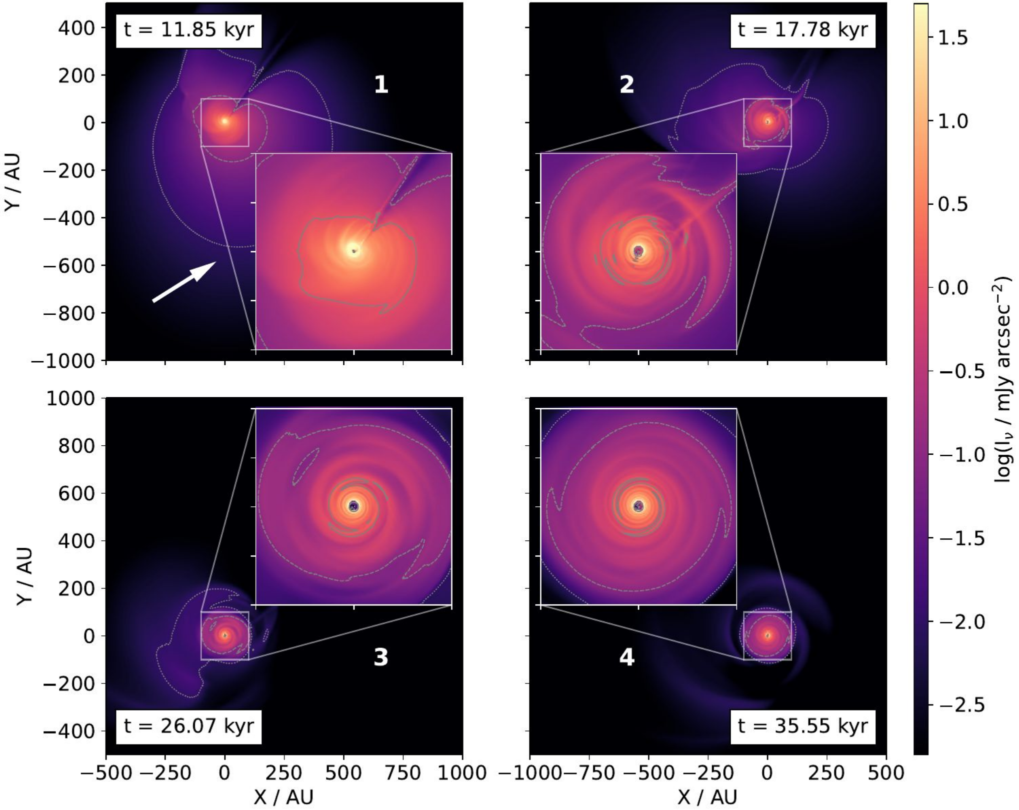


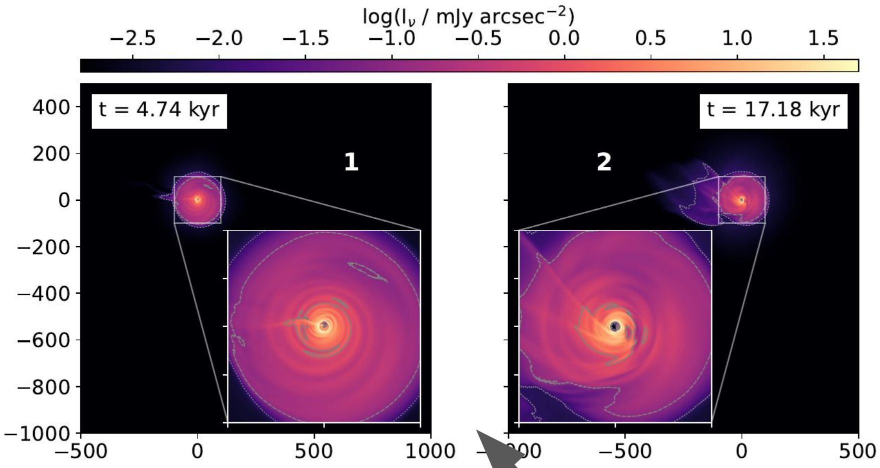
Infall in a turbulent medium naturally creates streamers…

Hühn & Dullemond 2025

Spiral formation

Hühn+ submitted





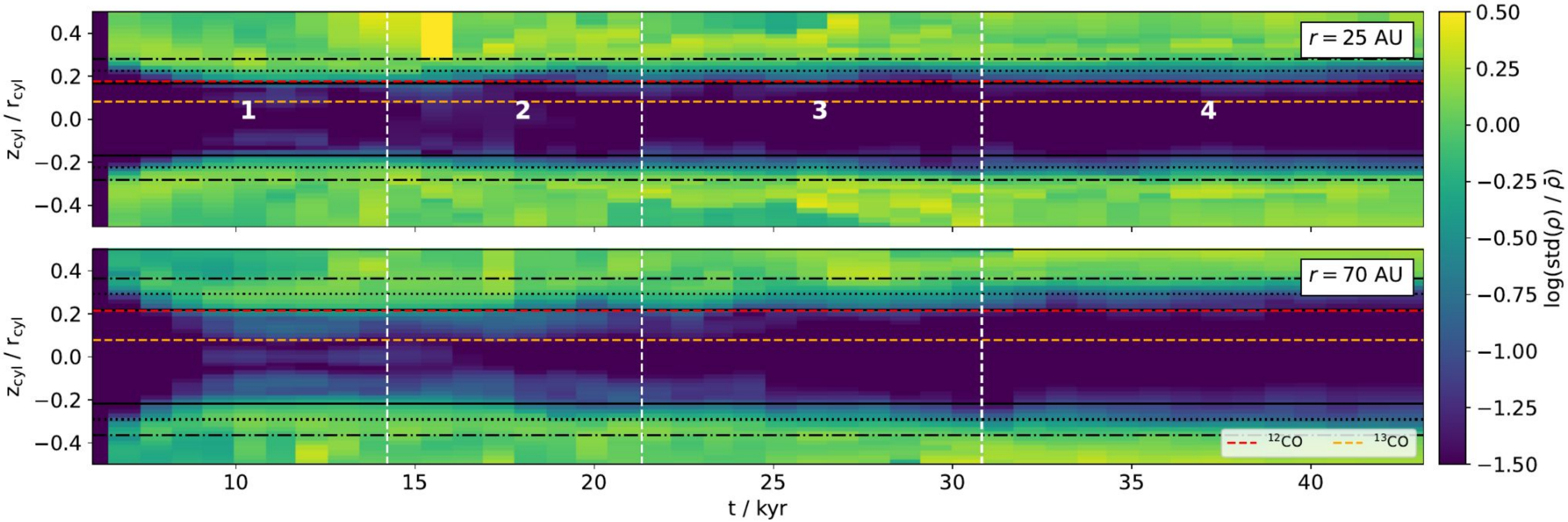
Single, impactful encounter with gas

Continuous, turbulent accretion

…that create visible substructures

What layers of the disk are affected?

$M_d = 0.05\ M_\odot$

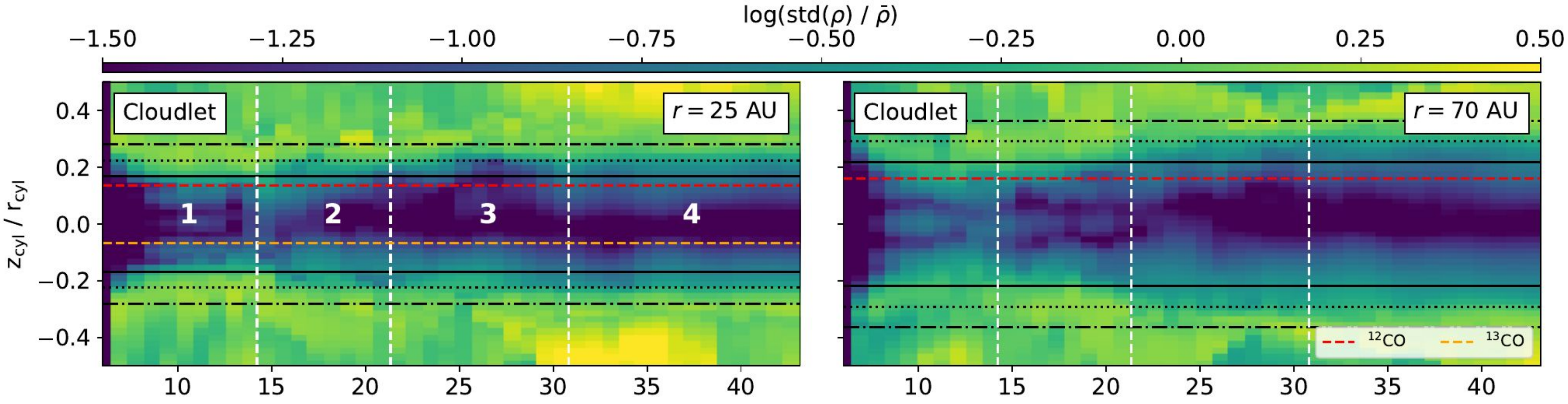


Hühn+ submitted

Even at the main impact, layers with z < 3H are unaffected
⇒ Spirals are only **on the surface** for **young disks**

What layers of the disk are affected?

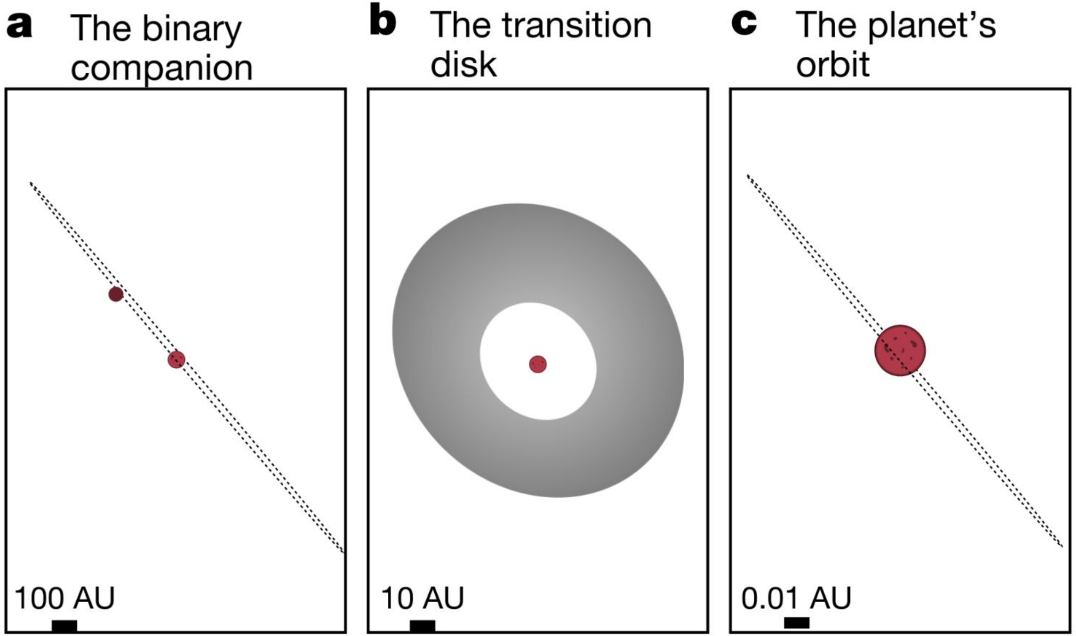
$M_d = 0.005\ M_\odot$



Hühn+ submitted

For lighter disks, **midplane layers** can be affected, especially in the outer disk
⇒ Late infall is more important for **older disks**
⇒ Different mechanisms for **planet formation here**? **Rejuvenation**?

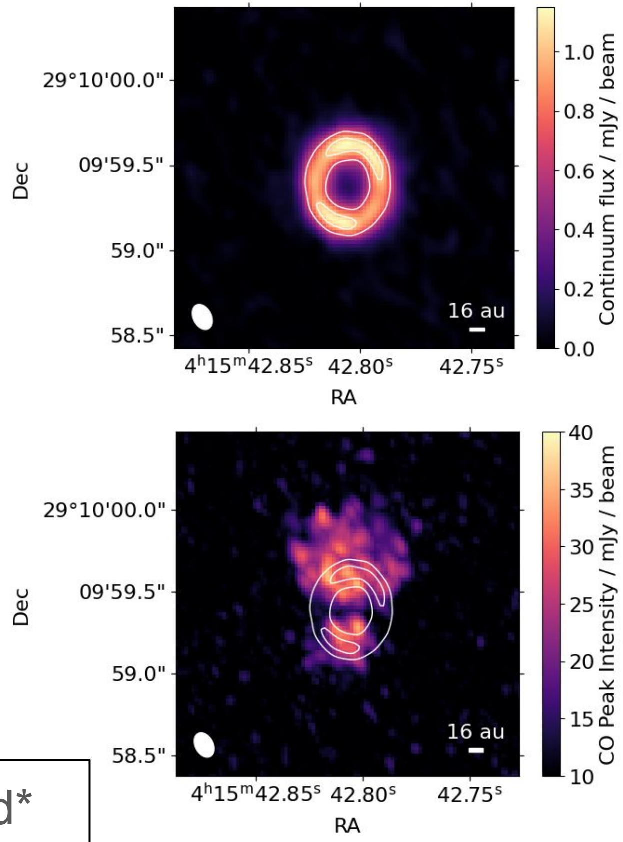
Late infall in IRAS 04125+2902?



Barber+2024

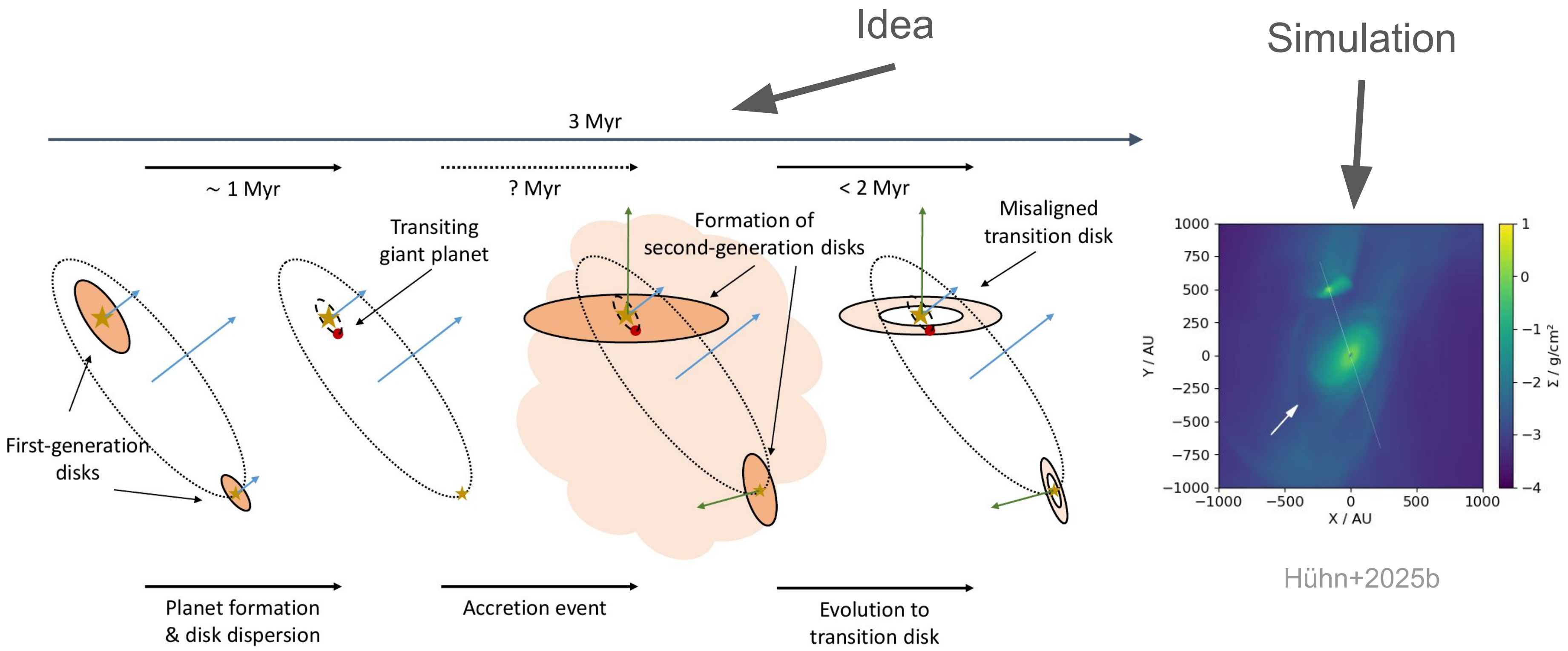
Binary and planet are aligned*
But: Protoplanetary disk is not!

Circum-primary disk



Bosschaart+2025
Shoshi+2025

Second generation disk?



Hühn+2025b

Why Infall Matters:

- (Early) infall influences planet formation **initial conditions**
- (Late) infall causes **streamers**, delivering new material

→ Enhance mass budget of first generation

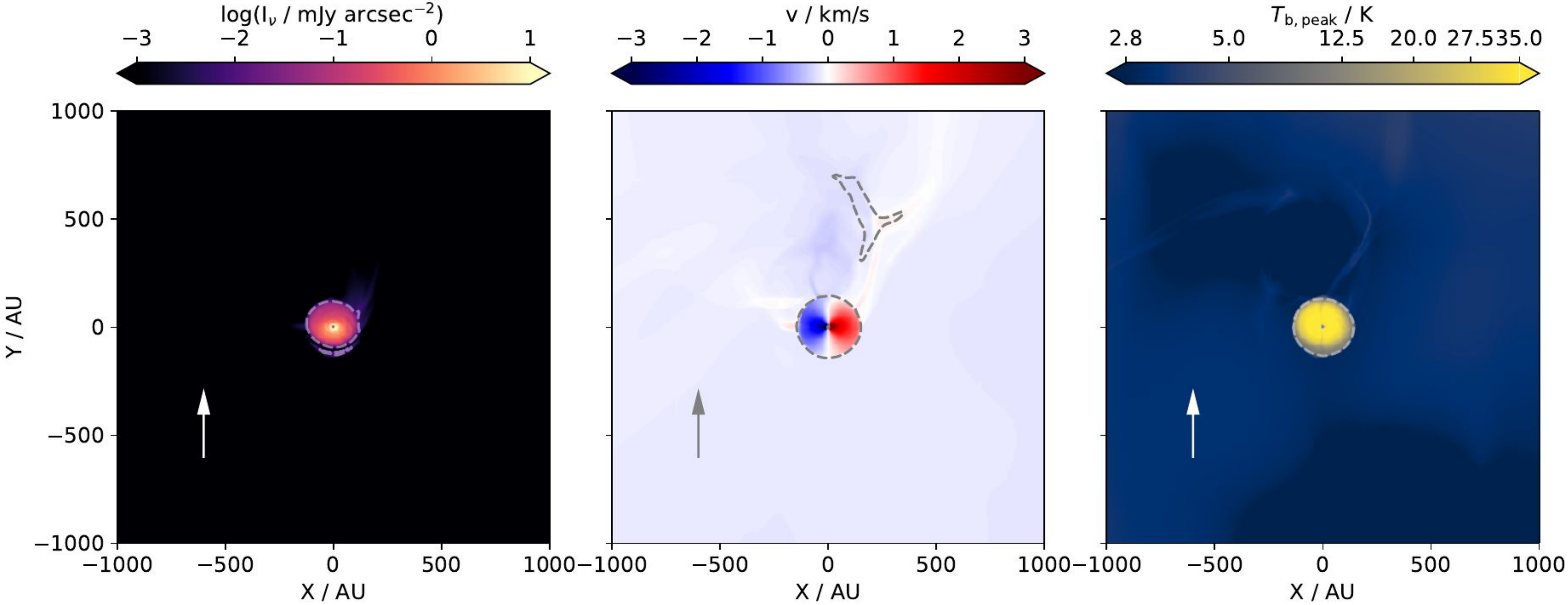
- (Late) infall causes **spirals** of many different shapes
- (Late) infall can create new **2nd generation** disks

→ Rejuvenating planet formation?

Additional slides

Invisible late infall?

$d/dt\, M = 1e\text{-}9\; M_\odot / yr$
$\rho_{ISM} = 3e\text{-}22\; g/cm^2$



Infall in “isolated” regions is likely undetectable…

Hühn & Dullemond 2025

A&A, 696, A162 (2025)
https://doi.org/10.1051/0004-6361/202452689

Astronomy & Astrophysics

Planetesimal formation via the streaming instability in simulations of infall-dominated young disks

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Astronomy & Astrophysics

Letter to the Editor

Late accretion offers pathway to misaligned disk around the planet-hosting IRAS 04125+2902

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ABSTRACT

We present a 3D hydrodynamical simulation of the accretion of a gas cloudlet onto the IRAS 04125+2902 binary system, where the 3-Myr-old primary hosts a transiting planet. We demonstrate that such an accretion event can naturally produce a circumstellar disk that is misaligned with respect to the rest of the system, consistent with the observed misaligned transition disk. In the model, the prescribed orbital plane of the cloudlet is largely retained by the resulting circumstellar disk after undergoing gravitational interactions with the secondary during the initial accretion. After ∼4.4 binary orbits, a disk with R_d = 300 AU has formed around the stellar primary made of ∼13% of the cloudlet mass, $M_{d,p} = 2.1 \times 10^{-3}\,M_\odot$. The companion also retains some of the cloudlet's mass and forms a disk with $M_{d,c} = 9.3 \times 10^{-5}\,M_\odot$, though only the transition disk around the primary has been observed. Our findings highlight the importance of considering mass inflow onto a protoplanetary disk for its evolution.

Key words. accretion, accretion disks – hydrodynamics – methods: numerical – protoplanetary disks – binaries: general – ISM: clouds

A&A, 704, A222 (2025)
https://doi.org/10.1051/0004-6361/202554335

Astronomy & Astrophysics

Emergence of streamers in simulations of late infall

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ABSTRACT

Growing observational evidence suggests that Class II protoplanetary disks may undergo substantial interactions with their environment in the form of late infall. This mass inflow predominantly manifests itself in the form of so-called streamers: filaments and arcs of gas connecting large-scale, extended gas structures to disk scales. Prevalent late infall has far-reaching consequences for planet formation theory, challenging the long-standing treatment of evolved disks in isolation. In this work, we investigate the emergence of late-infall streamers in different formation scenarios, their morphology and multiplicity, as well as their dependence on environmental conditions. We conducted this investigation by performing 3D hydrodynamical simulation using the grid-based code `FARGO3D`, which we post-process to obtain synthetic observations using the Monte Carlo radiative transfer code `RADMC3D`. We find that, while a late infall event in the form of a single encounter with a "cloudlet" of gas can produce a streamer via an interplay between the fallback of bound material and shocks, such features dissipate quickly, on a timescale of ~10 kyr. Furthermore, we find that streamers can also form naturally in a turbulent, dense environment without the need for such encounters, which could act to reconcile short-lived streamers with ubiquitous detection of these structures. Here, we find multiple co-existing streamers for a disk velocity relative to the interstellar medium of $v_{\rm sys} = 0.5\,{\rm km\,s^{-1}}$ and a turbulent velocity dispersion of $\sigma_{\rm turb} = 0.5\,{\rm km\,s^{-1}}$, in which case an angular momentum flux of $\dot{J} \sim 10^{38}\,{\rm g\,cm^2\,s^{-2}}$ arises. We find considerable dependence of the streamer morphology on the environment, which may act as a utility to constrain the physical conditions of the gas surrounding planet-forming disk, and therefore the conditions under which planets form.

Key words. accretion, accretion disks – hydrodynamics – radiative transfer – methods: numerical – protoplanetary disks – ISM: clouds