(CAS-) Perspective Talk:
The importance of the initial conditions

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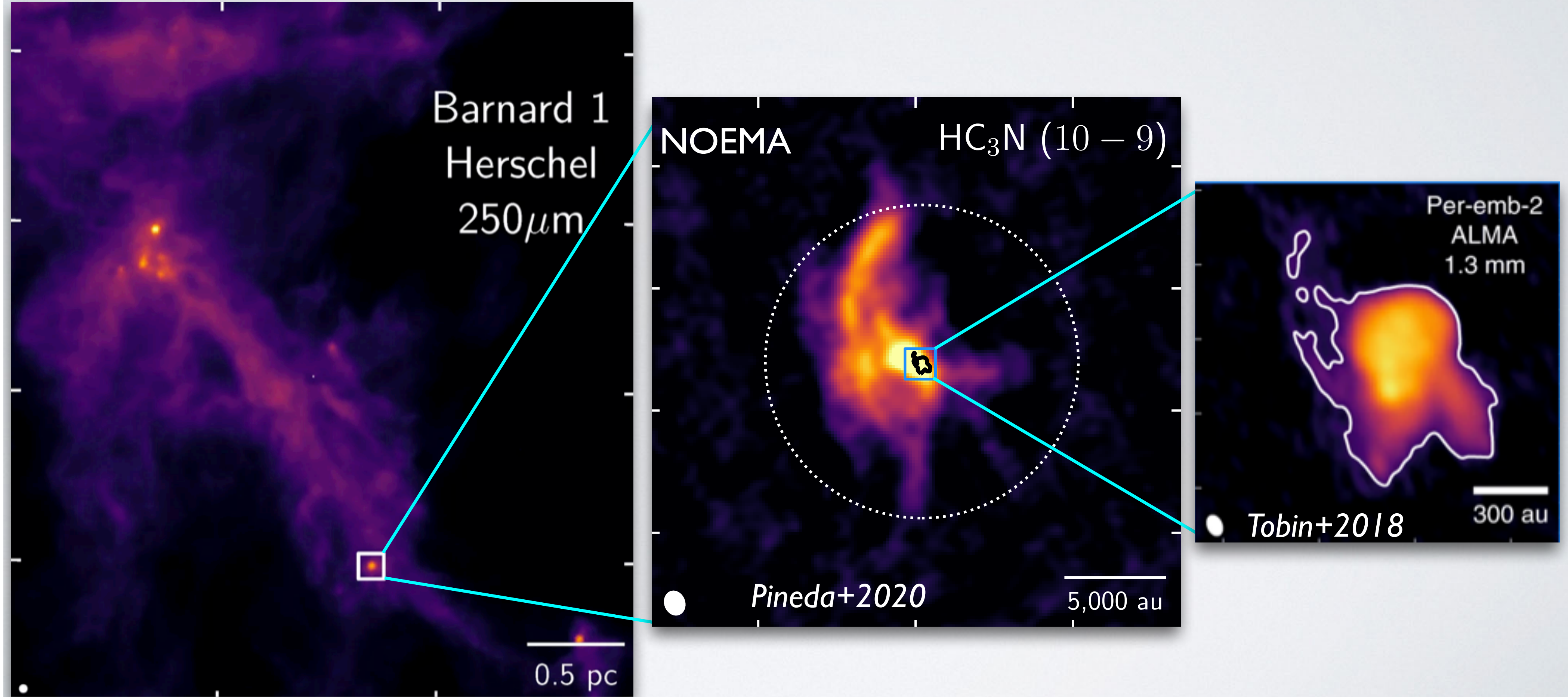
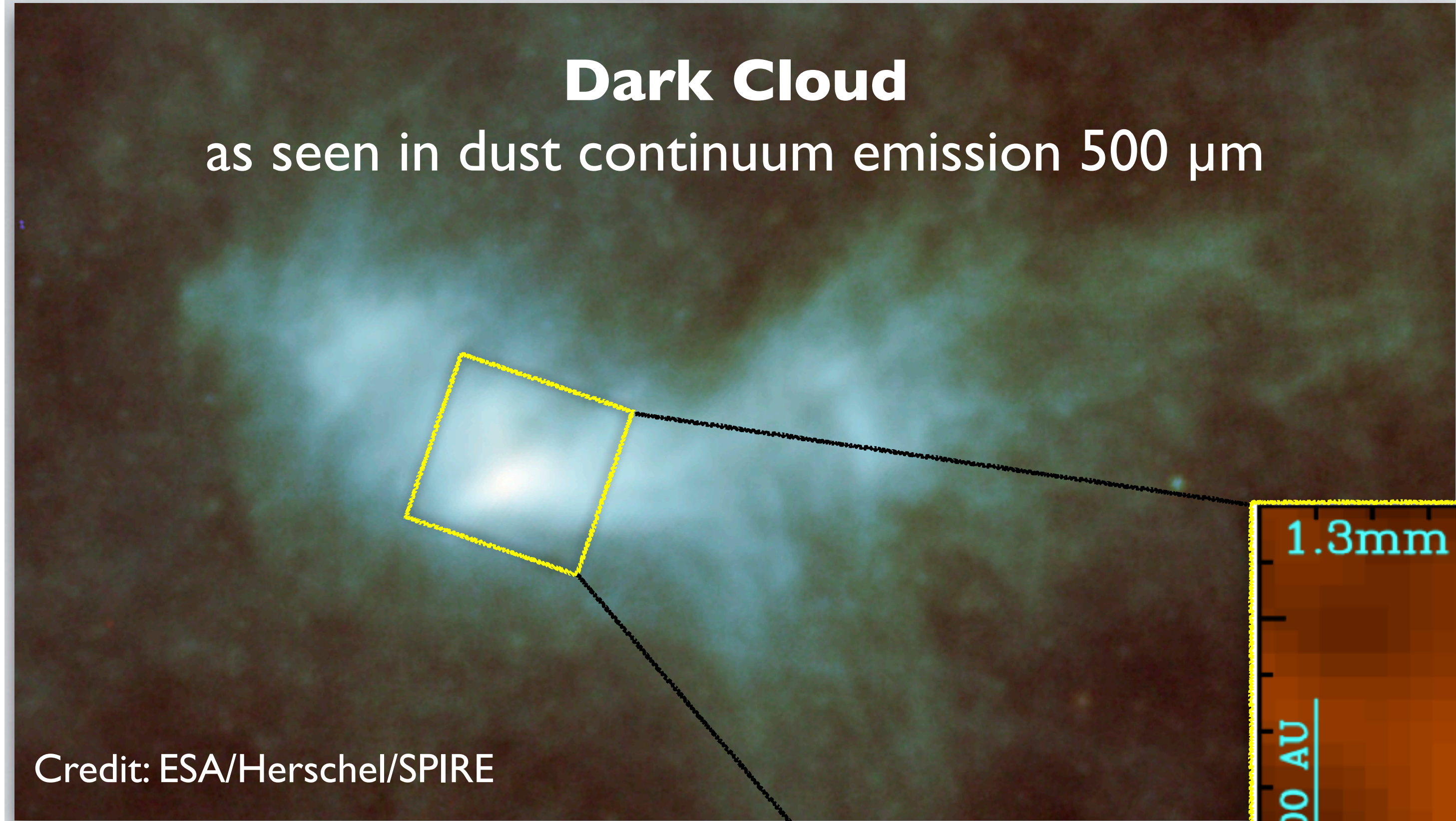
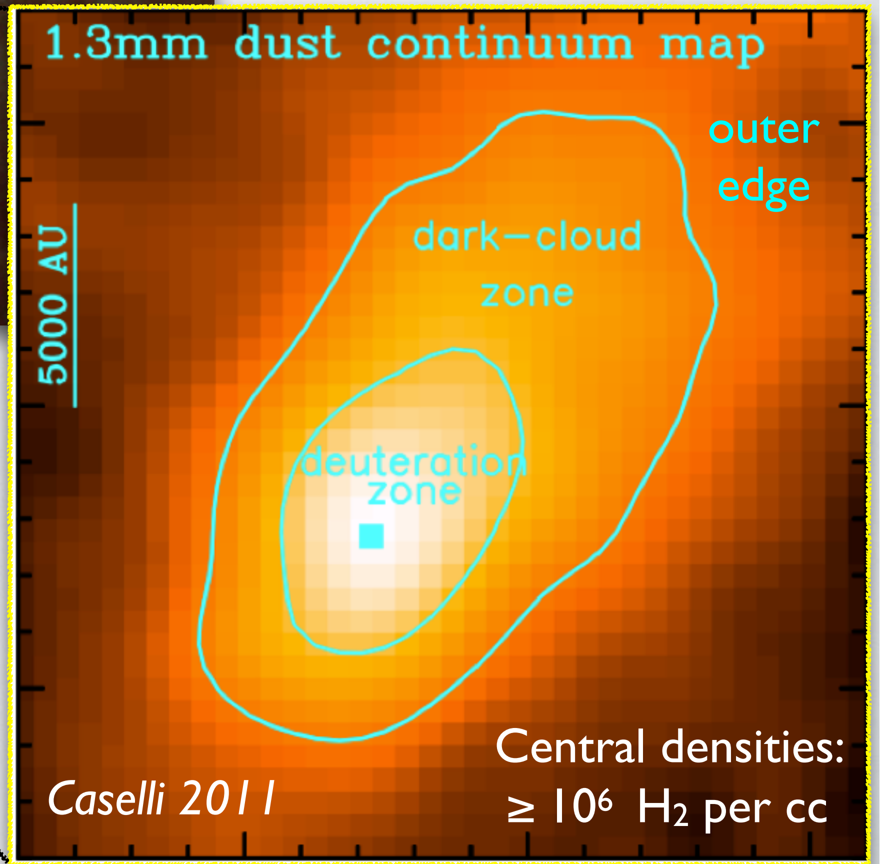


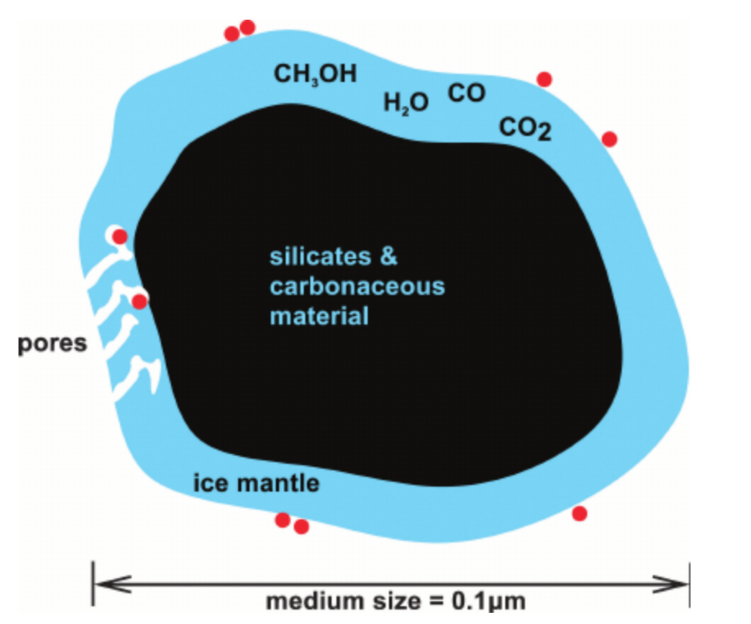
Zooming into a pre-stellar core (t = 0)



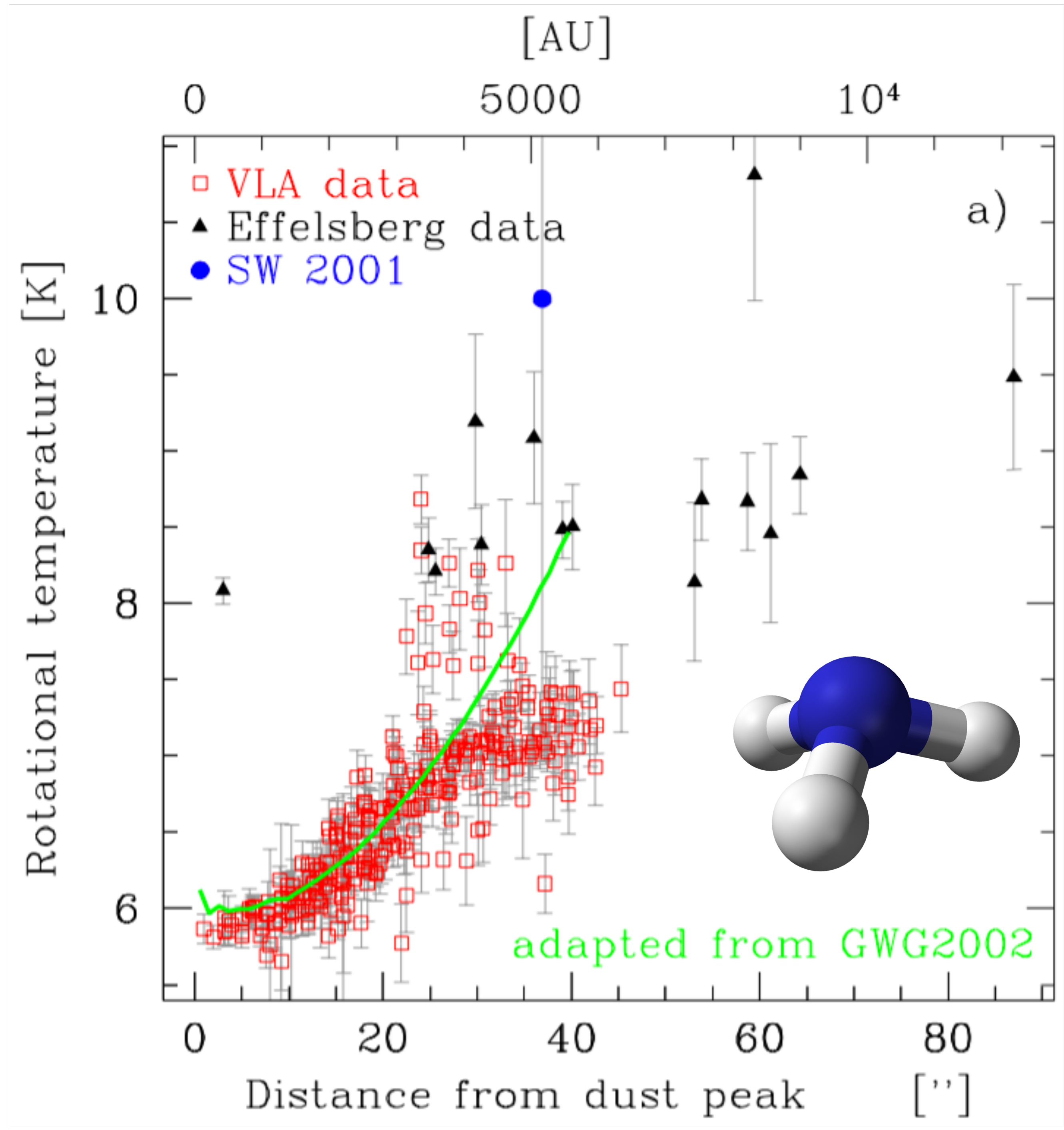
Pre-stellar core



In pre-stellar cores, the gas temperature drops to **~6 K** → molecular freeze-out (>90% CO in ice; *Caselli+1999*) and D-fractionation (D/H ≥ 20%; *Caselli+2002; Redaelli+2019*).

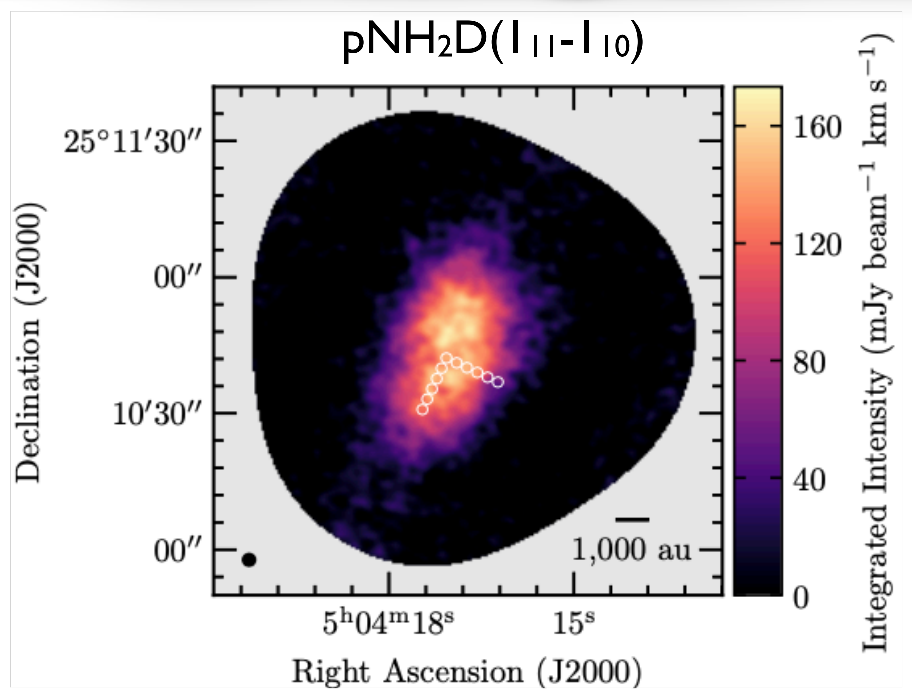


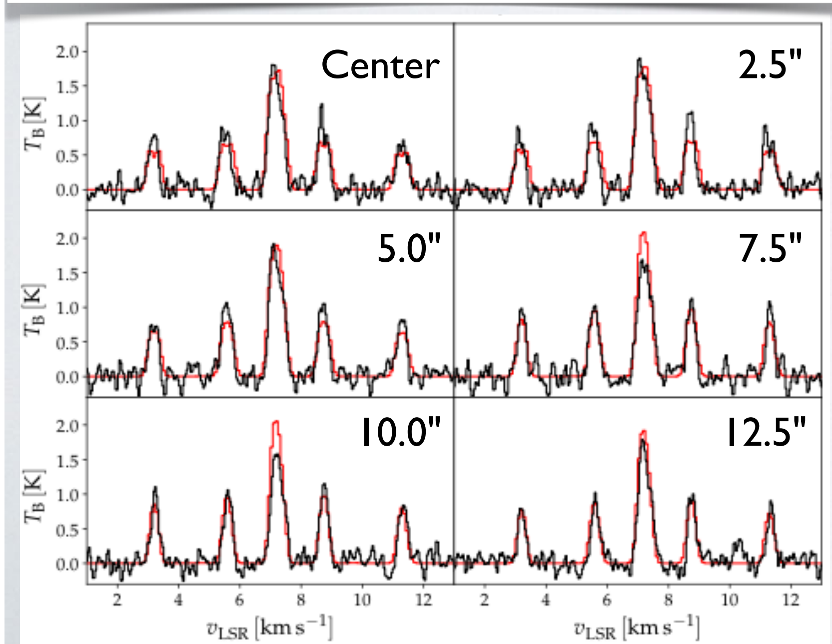
Karssemejer et al. 2012, PCCP



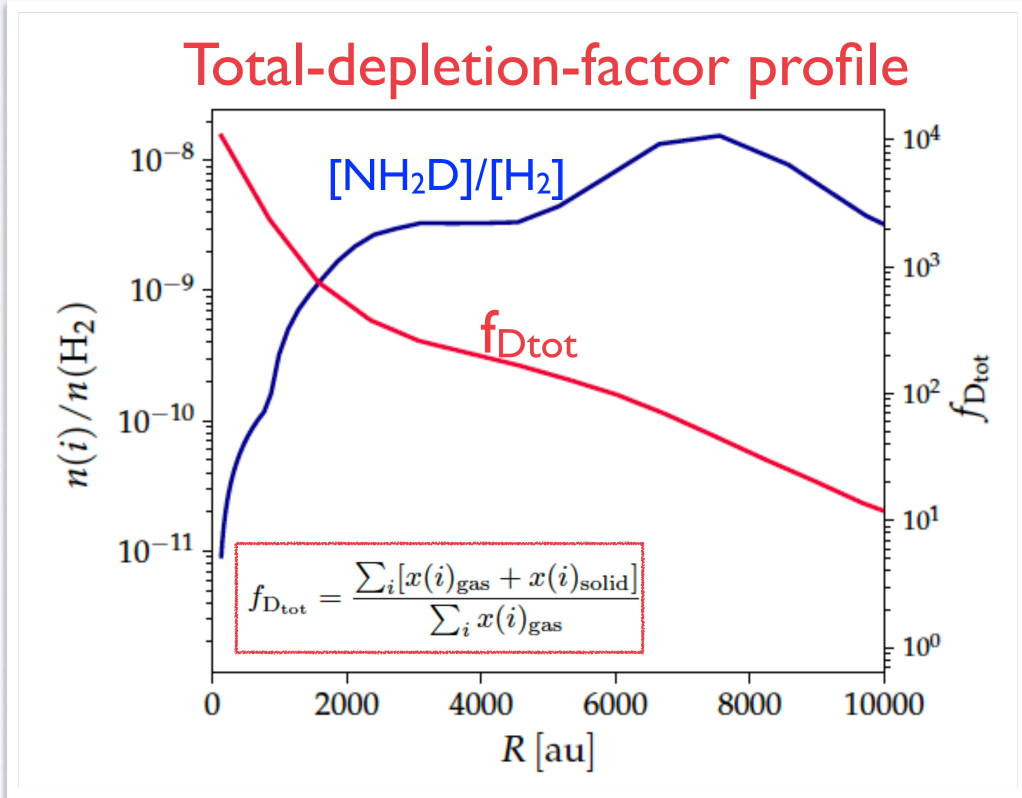
Crapsi, Caselli, Walmsley, Tafalla 2007

99.99% of all species heavier than He are frozen onto dust grains in the PSC central 2000 au



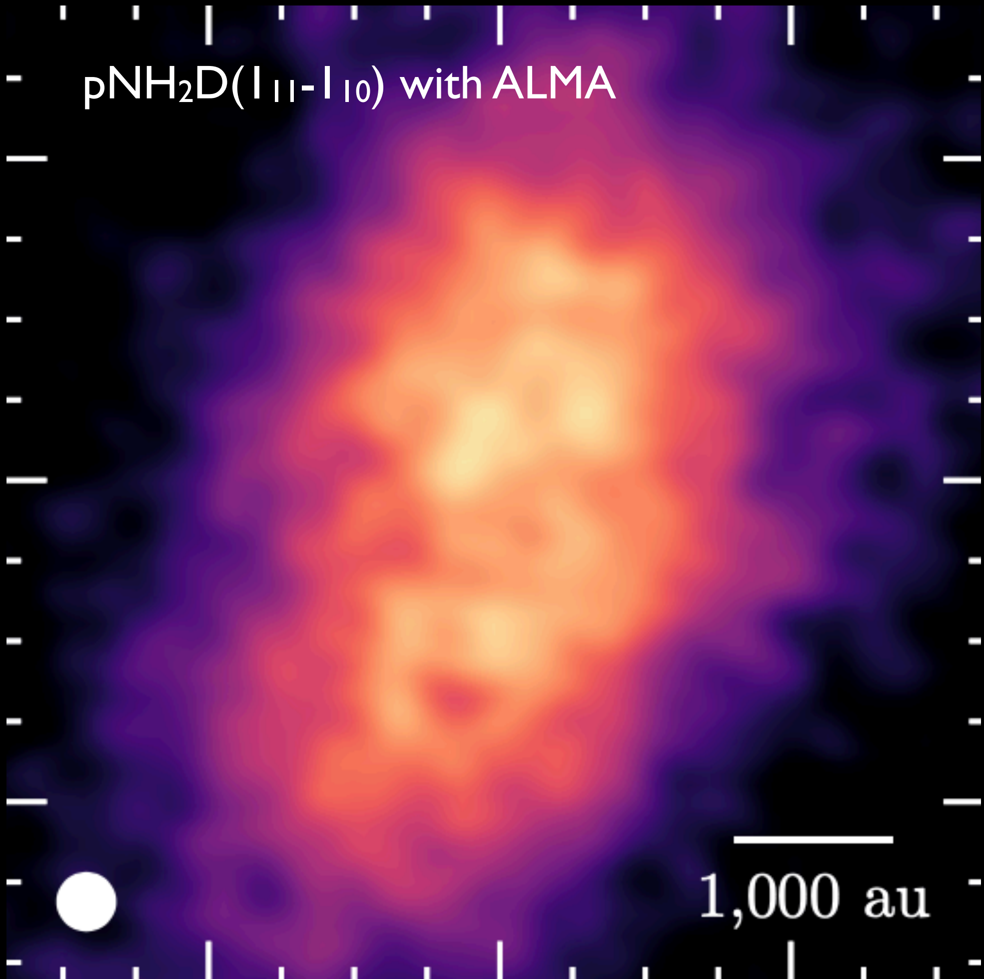


L1544 **ALMA**-Band 3 observations + comparison with gas-grain chemical/RT model: *NH_2D abundance sharply drops in the central 2000 au.*

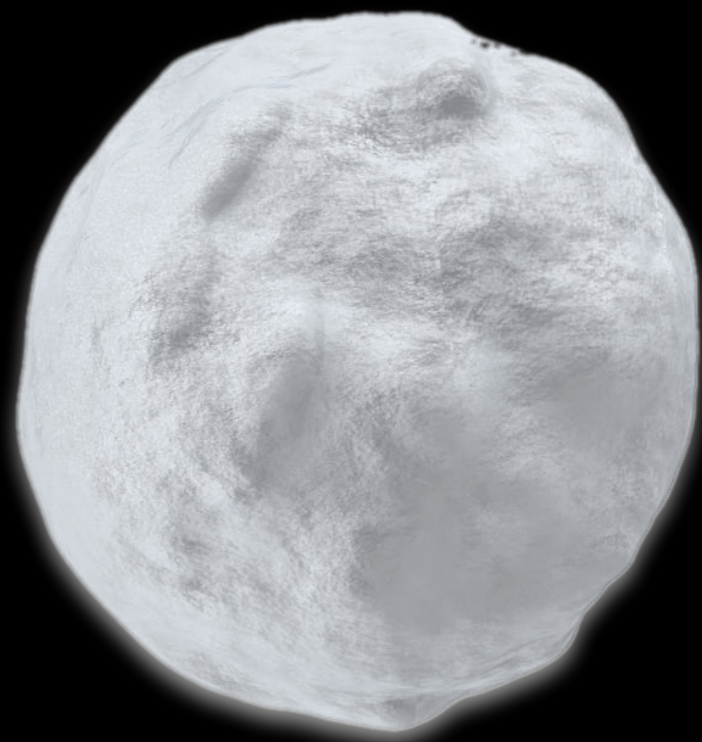


Caselli, Pineda, Sipilä+2021, sub.

Almost compete freeze-out before stellar birth



The sharpest view of a pre-stellar core centre



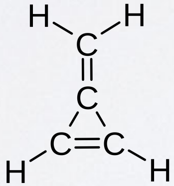
Artistic view of a typical dust grain in the centre of a pre-stellar core (ice thickness ~ 150 monolayers of ice on a 0.1 μm dust grain)

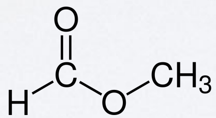
Gas-phase COMs surround pre-stellar cores and move on grain surfaces *within* PSCs

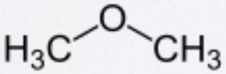
Harju+2020

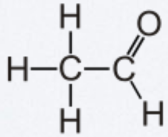
See also:

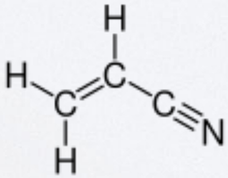
Marcelino+2007
Öberg+2010
Bacmann+2013
Bizzocchi+2014
Vastel+2014
Bacmann&Faure 2016
Jiménez-Serra+2016
Spezzano+2016, 2017, 2020
Scibelli & Shirley 2020
Ambrose+2021

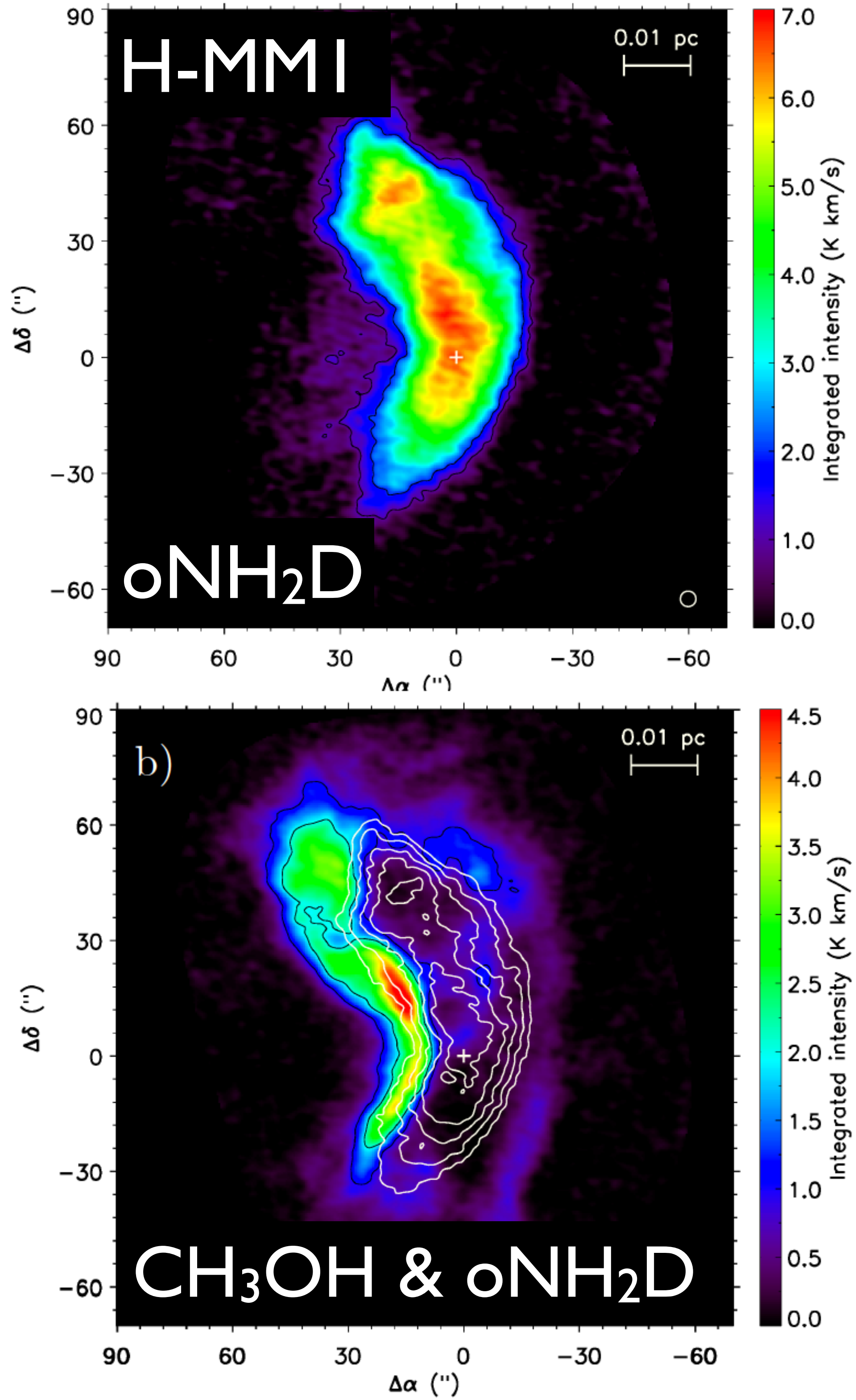




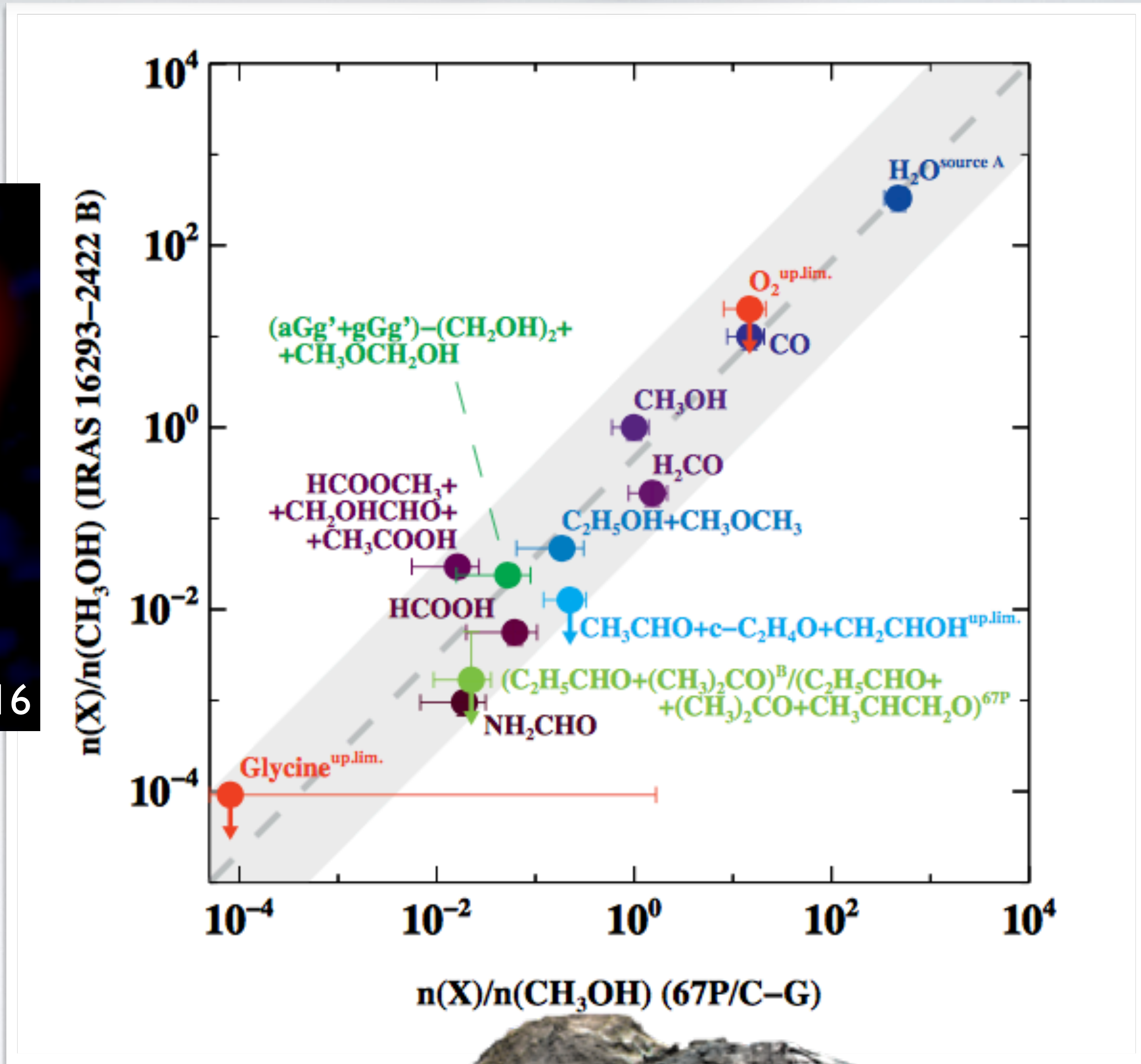








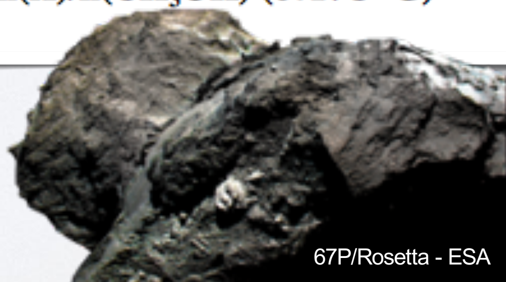
Similar COM abundances in comets and star forming regions



"The volatile composition of cometesimals and planetesimals is partially inherited from the pre- and protostellar phases of evolution."

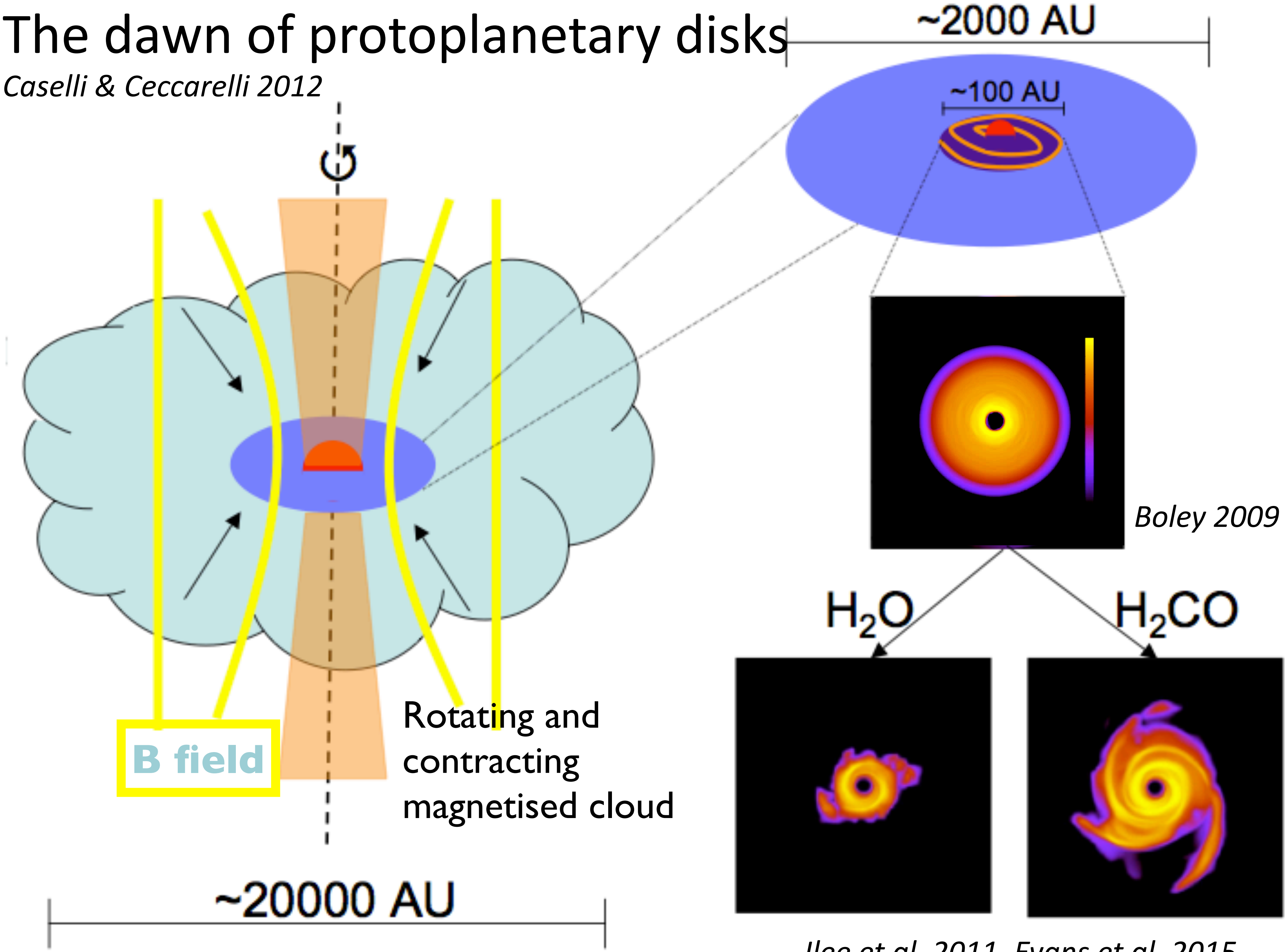
Drozdovskaya+2019

See also Biver+2015, Rivilla+2020



The dawn of protoplanetary disks

Caselli & Ceccarelli 2012

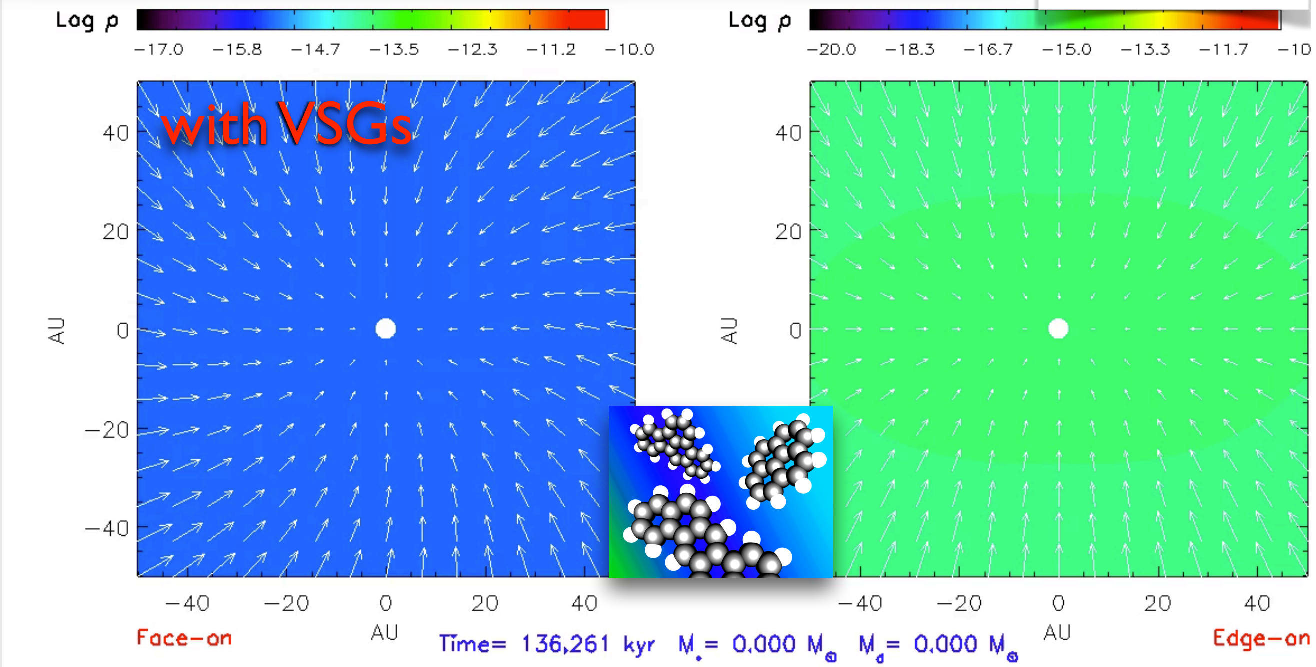


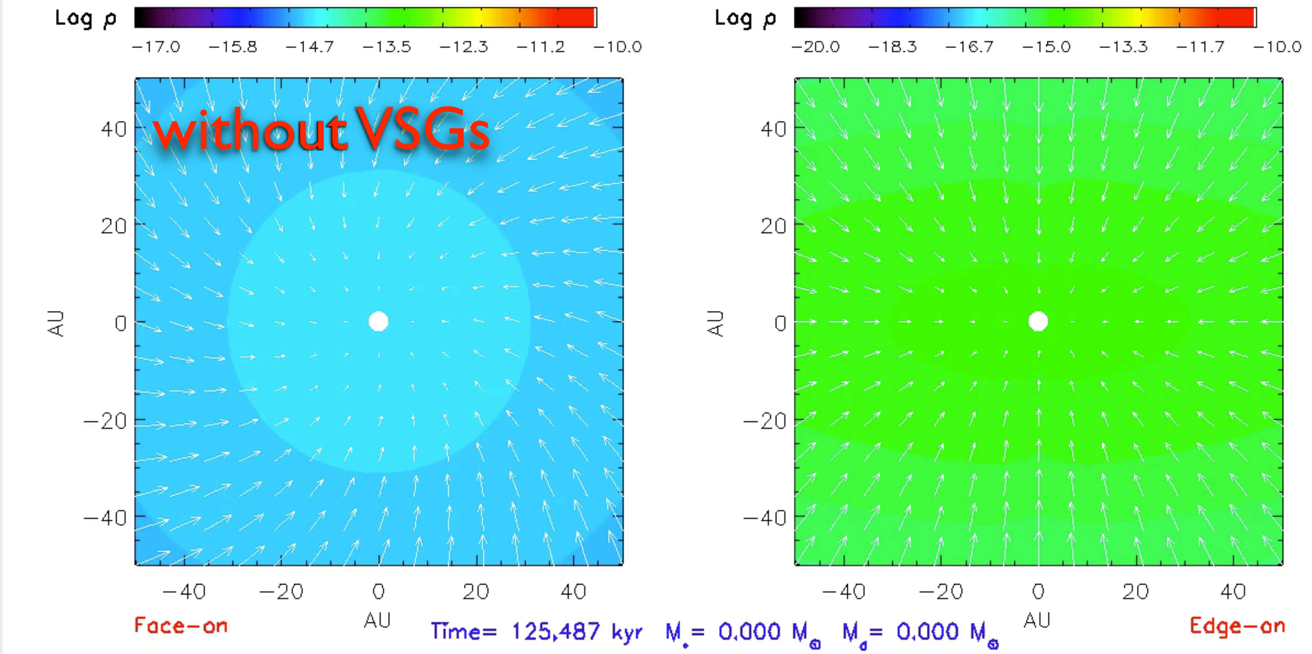
Ilee et al. 2011, Evans et al. 2015

Protostellar disk formation enabled by removal of very small dust grains (VSGs)

VSGs (10-100 Å) are well coupled with the magnetic field **B**; they "drag" B-flux, causing rotation to slow down during contraction.

Removal of VSGs (via adsorption onto larger dust particles; *Silsbee+ 2020*) reduces magnetic flux in the inner region, enabling disk to form.

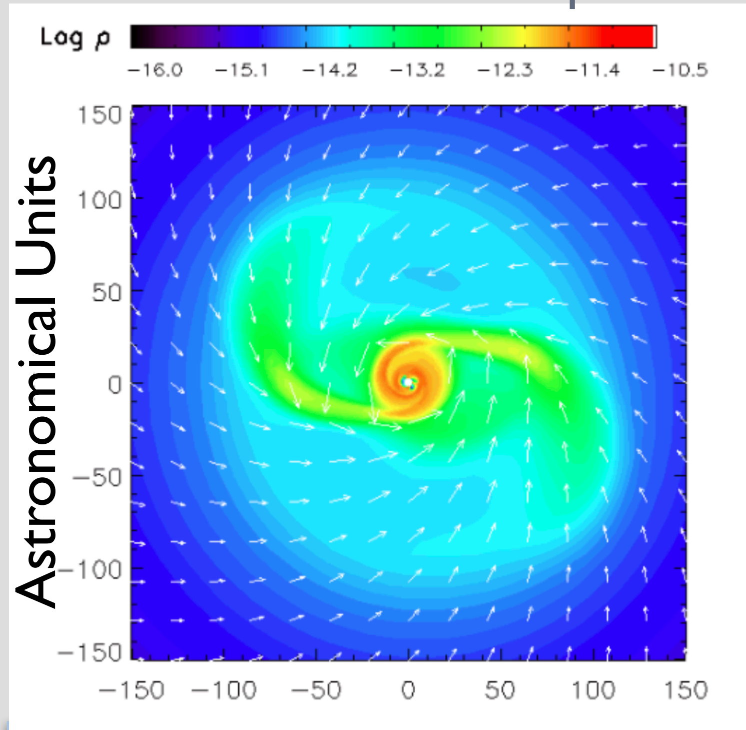




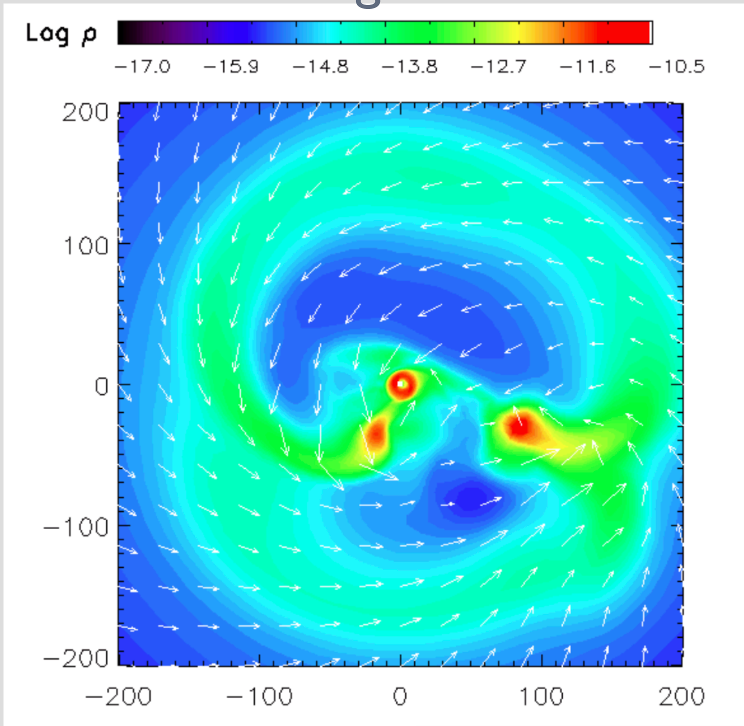
Zhao+2016, 2018, 2020

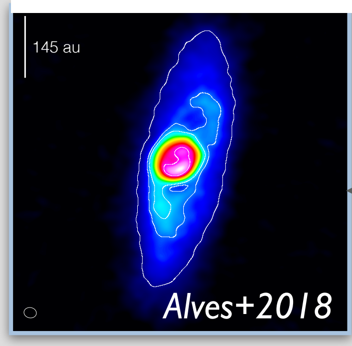
Simulated disks resemble observations

Simulated disk with spirals

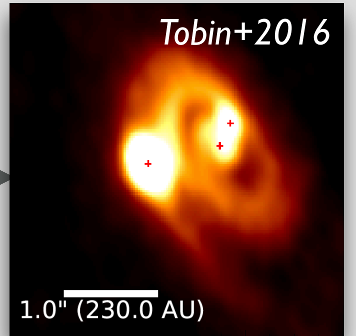


Simulated fragmented disk



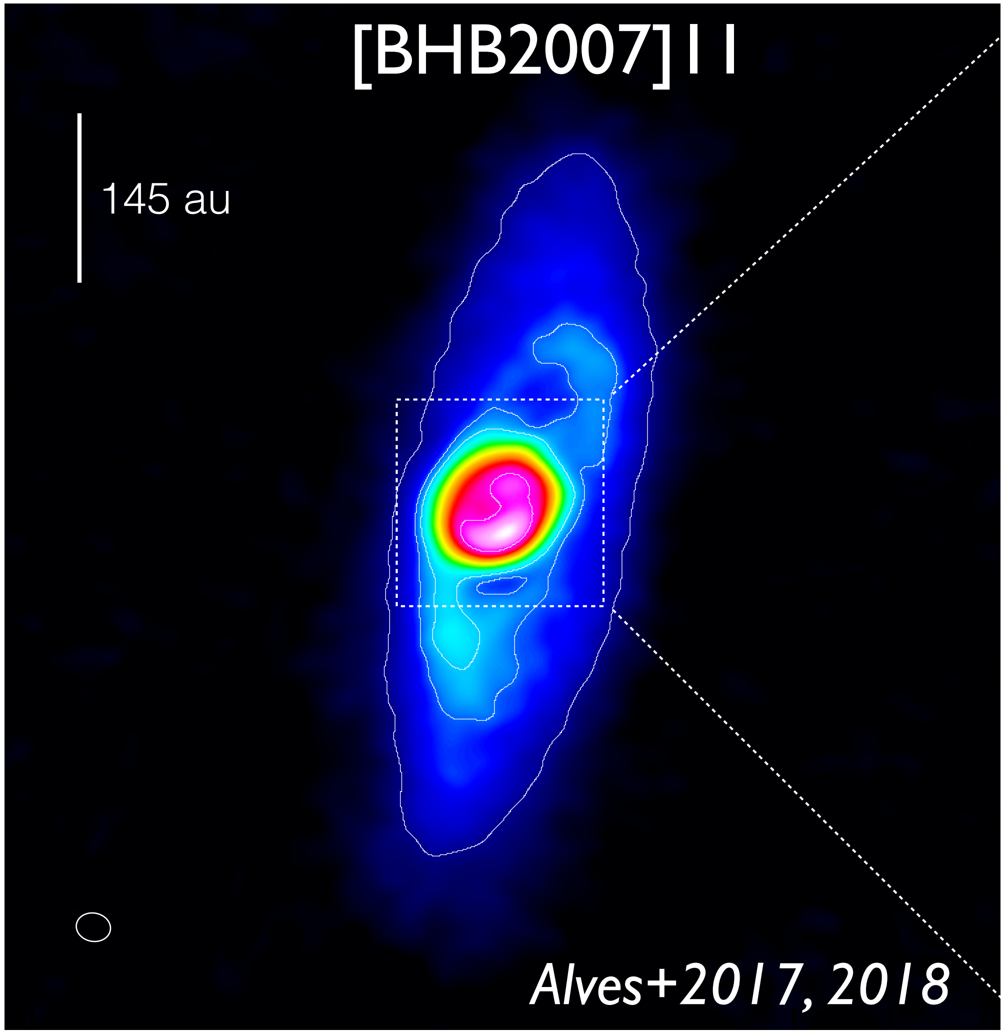


Observations

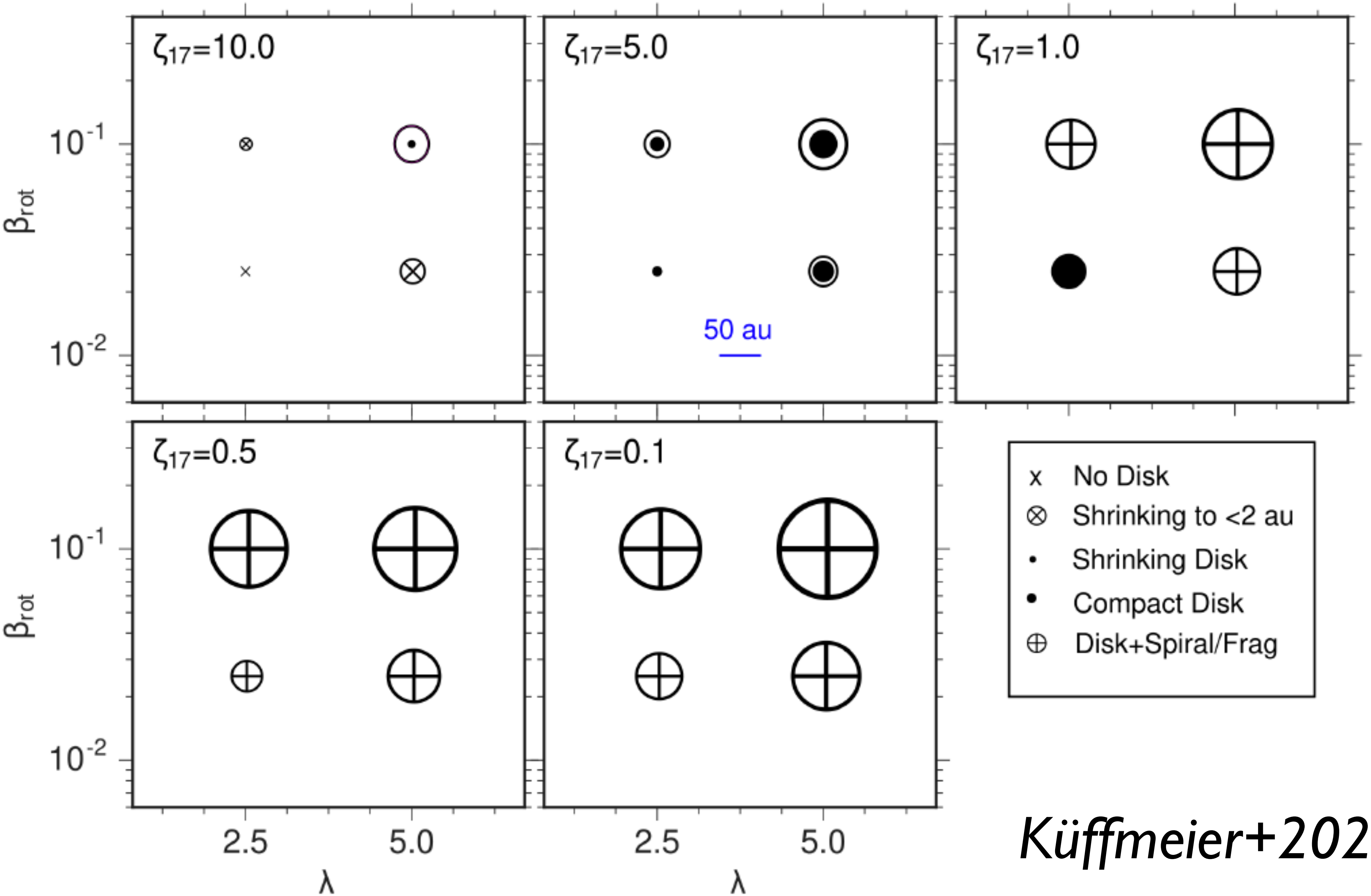


Zhao+2018, 2019, 2020

Zooming into a proto-binary system with ALMA: intricate feeding lanes connecting to the circumbinary disk

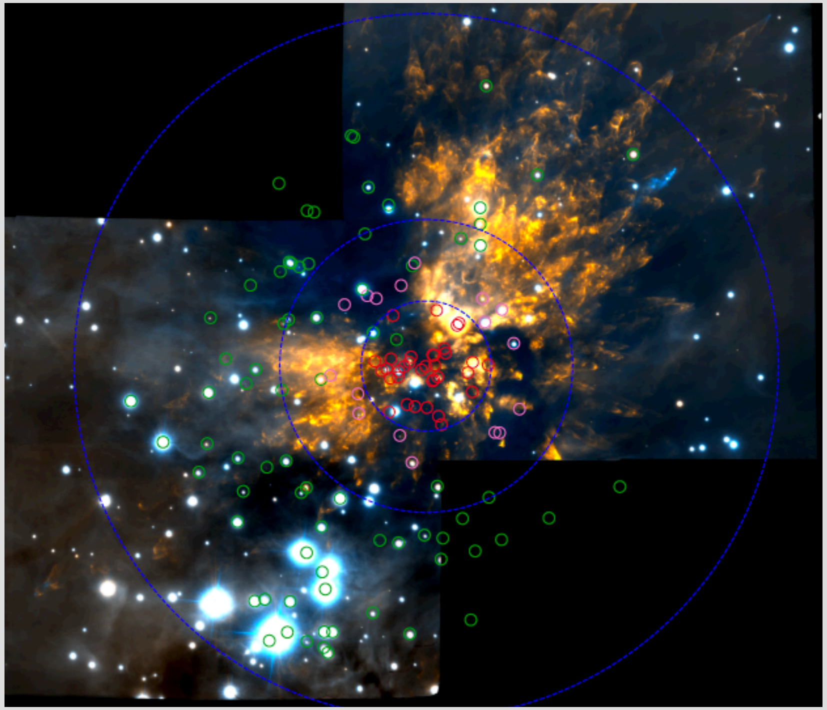


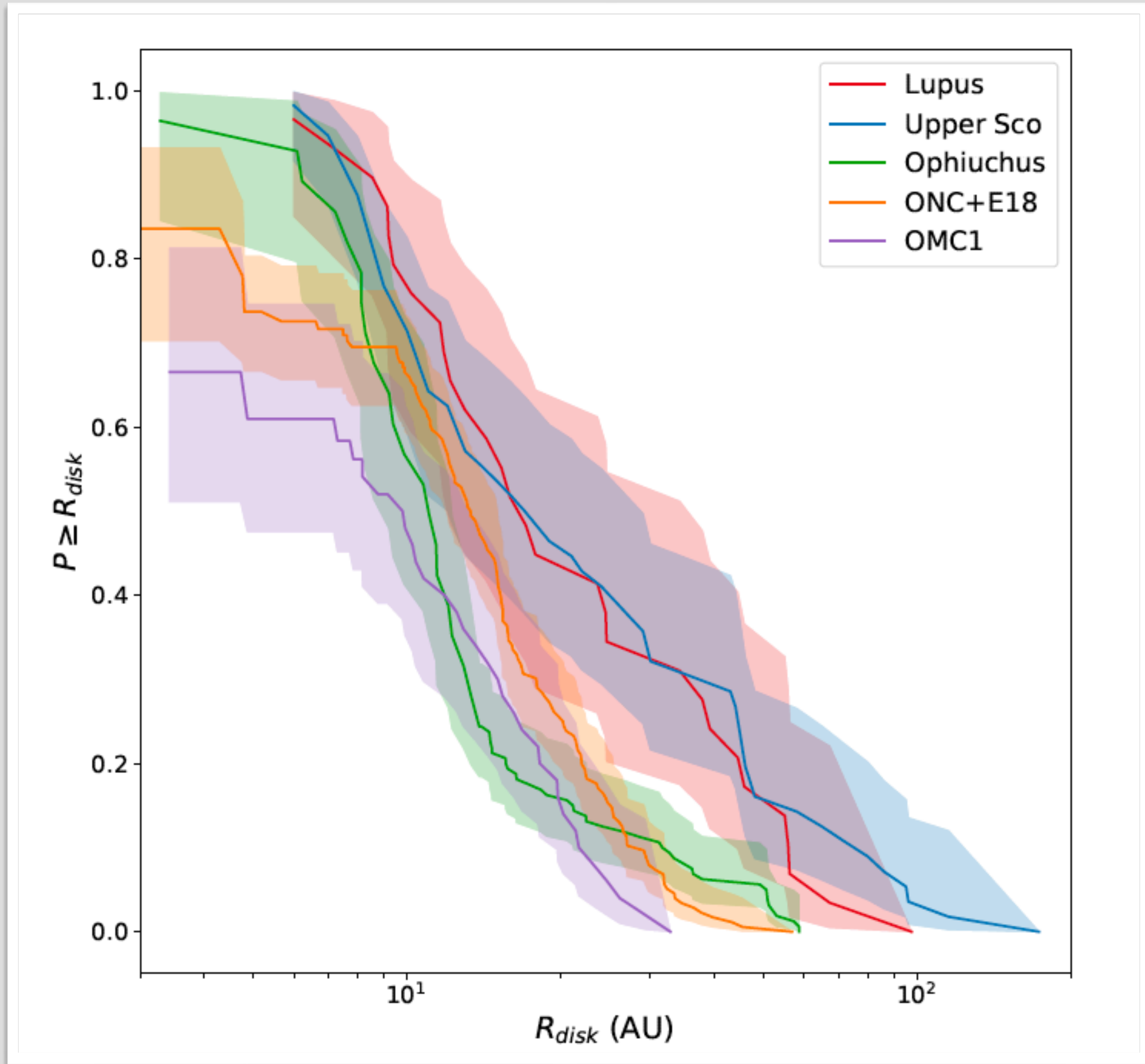
Disk size depends on the ionisation fraction



Küffmeier+2020

Large ionisation rate could explain disk observations in Orion



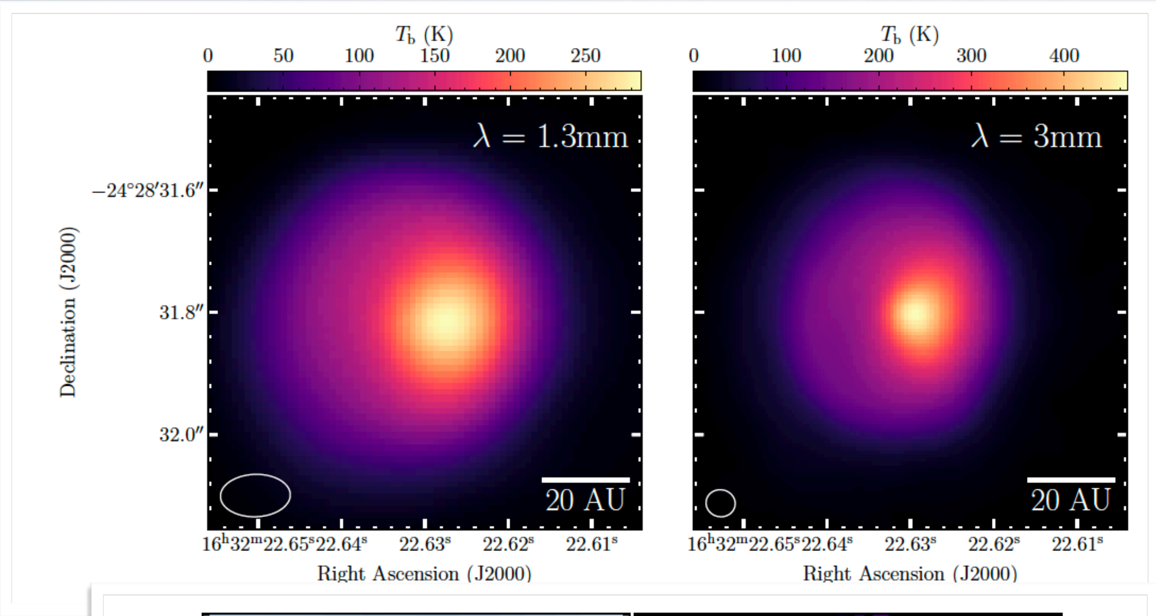


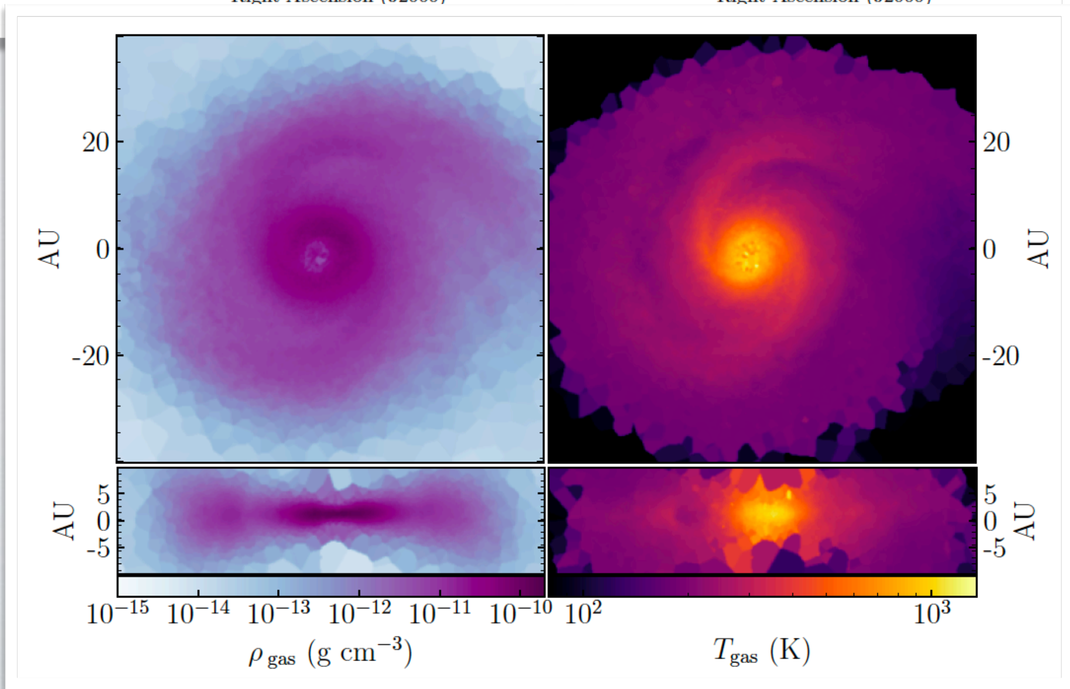
<<While photoevaporation from nearby massive Trapezium stars may account for the smaller disks in the ONC, the embedded sources in OMC1 are hidden from this radiation>>

Otter, Ginsburg+2021

Protostellar disks can be hot and gravitationally unstable

Joaquin



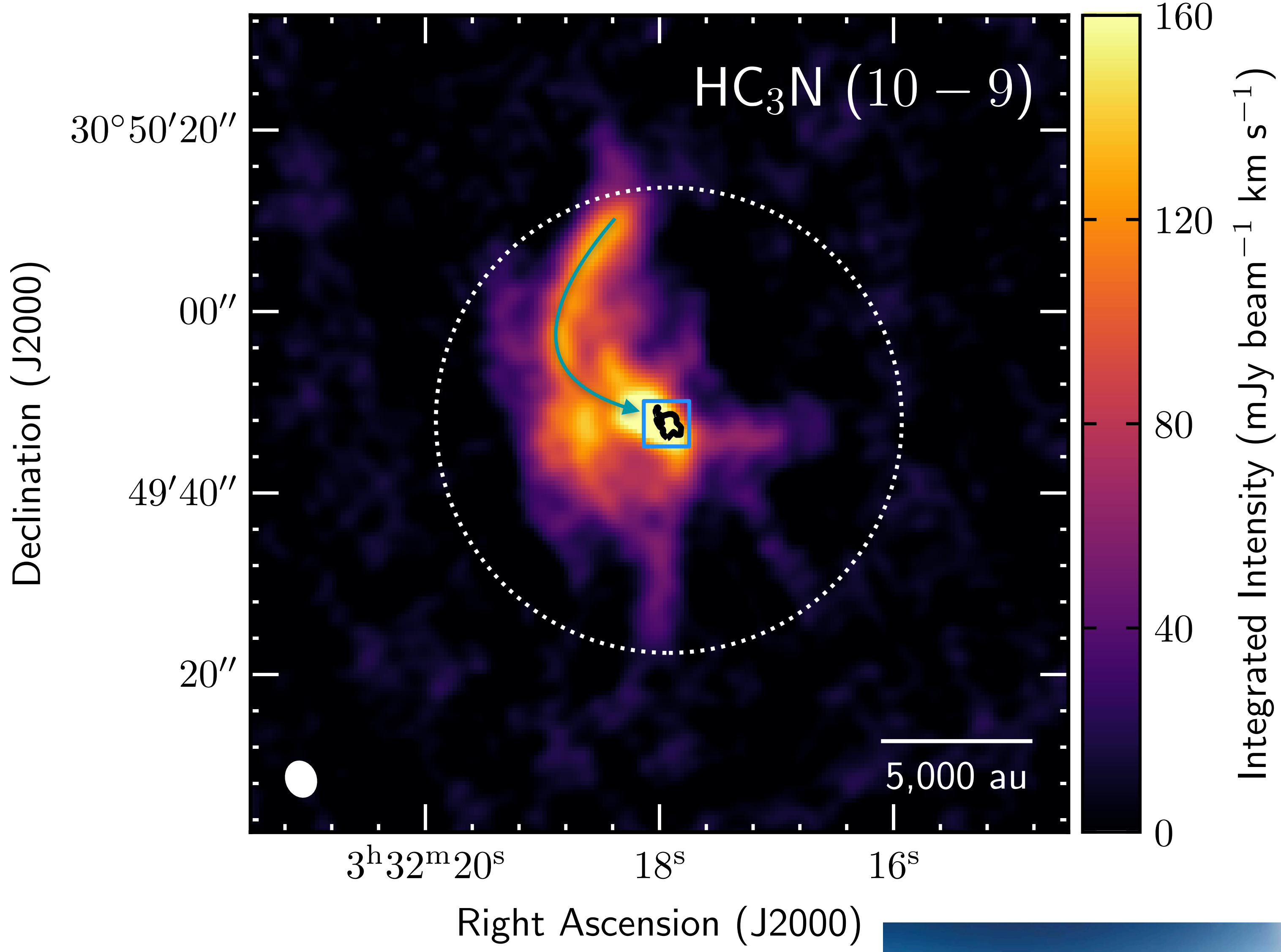


IRAS16293B ALMA observations: high brightness temperatures with T_b(3mm) > T_b(1mm), indicative of hot mid-plane.

RHD simulations of a gravitationally unstable disk reproducing ALMA observations: all icy mantles should evaporate here and create a "hot corino".

Zamponi+2021

Protostars accrete chemically young material directly from the surrounding cloud



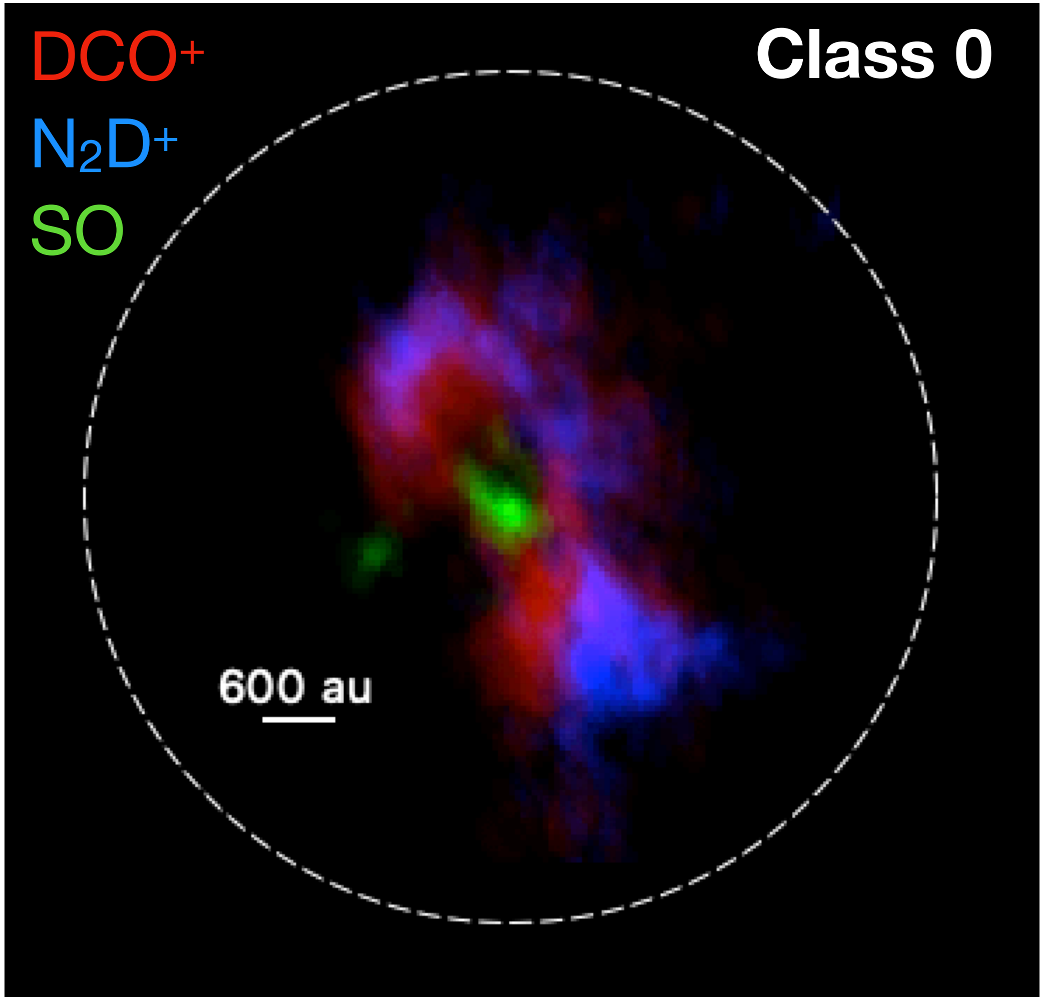
Pineda+2020, Nature Astronomy

NOEMA Large Survey

Envelope-Disk Connection

MIOP | NOEMA
PRODIGE

PIs: Caselli & Henning



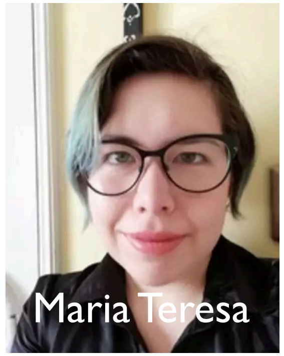
Finding more streamers

Follow material from envelope to disk scales

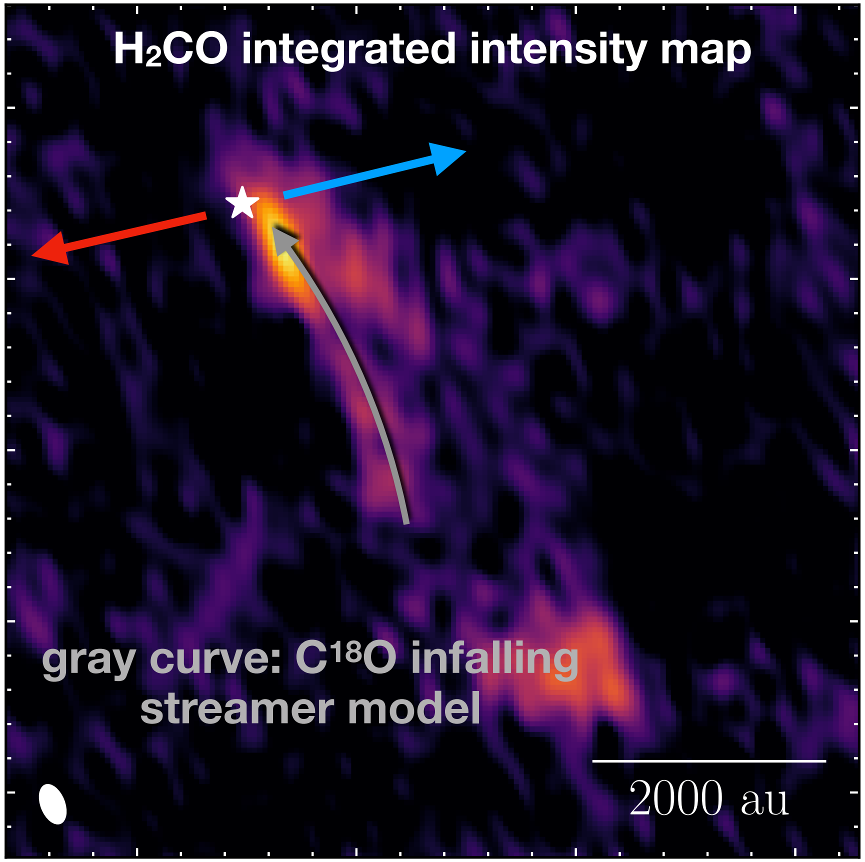
- Survey covers 32 Class 0/I and 8 Class II
- 520 hours over 4 years
- Resolution ~250 au, rms ~0.2 K
- Preliminary results, publications coming later this year

Segura-Cox, Pineda et al. in prep

Streamers Feed Older Embedded Disks



Per-emb-50 (Class I)



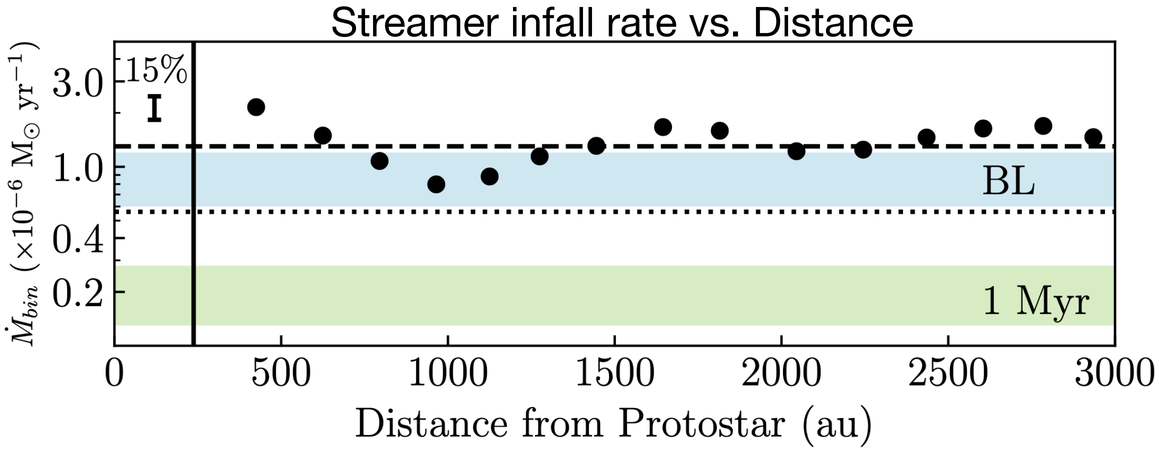
red & blue arrows: ^{12}CO outflow directions

NOEMA's wide bandwidth identifies H_2CO as a chemical tracer of streamers.

Kinematic modelling confirmed the streamer's infall onto the Class I disk.

The streamer infall rate is measured and compared with the protostellar accretion rate.

The streamer can sustain the protostellar accretion rate.

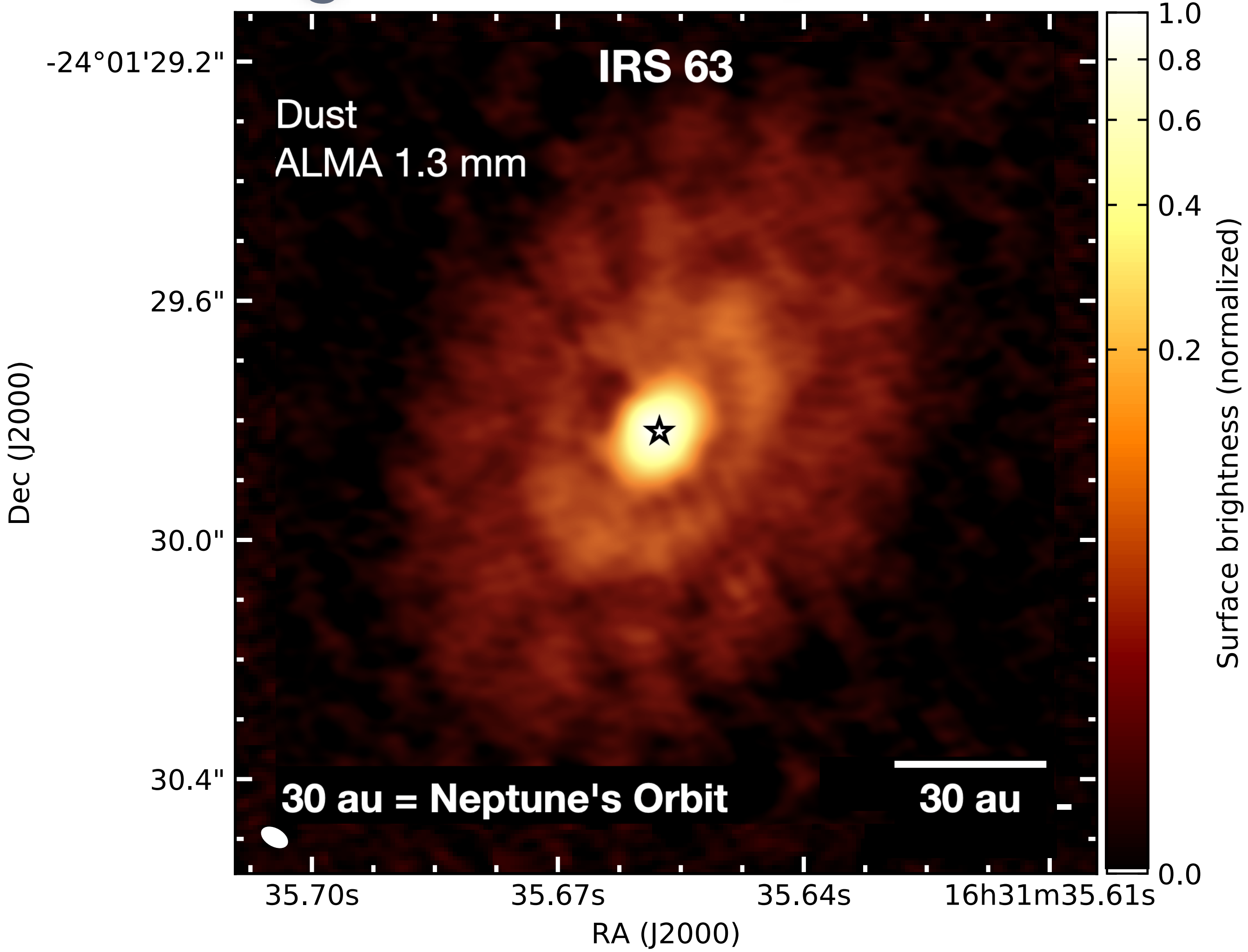


blue band: observed protostellar accretion rate (birthline age)
green band: observed protostellar accretion rate (1 Myr age)

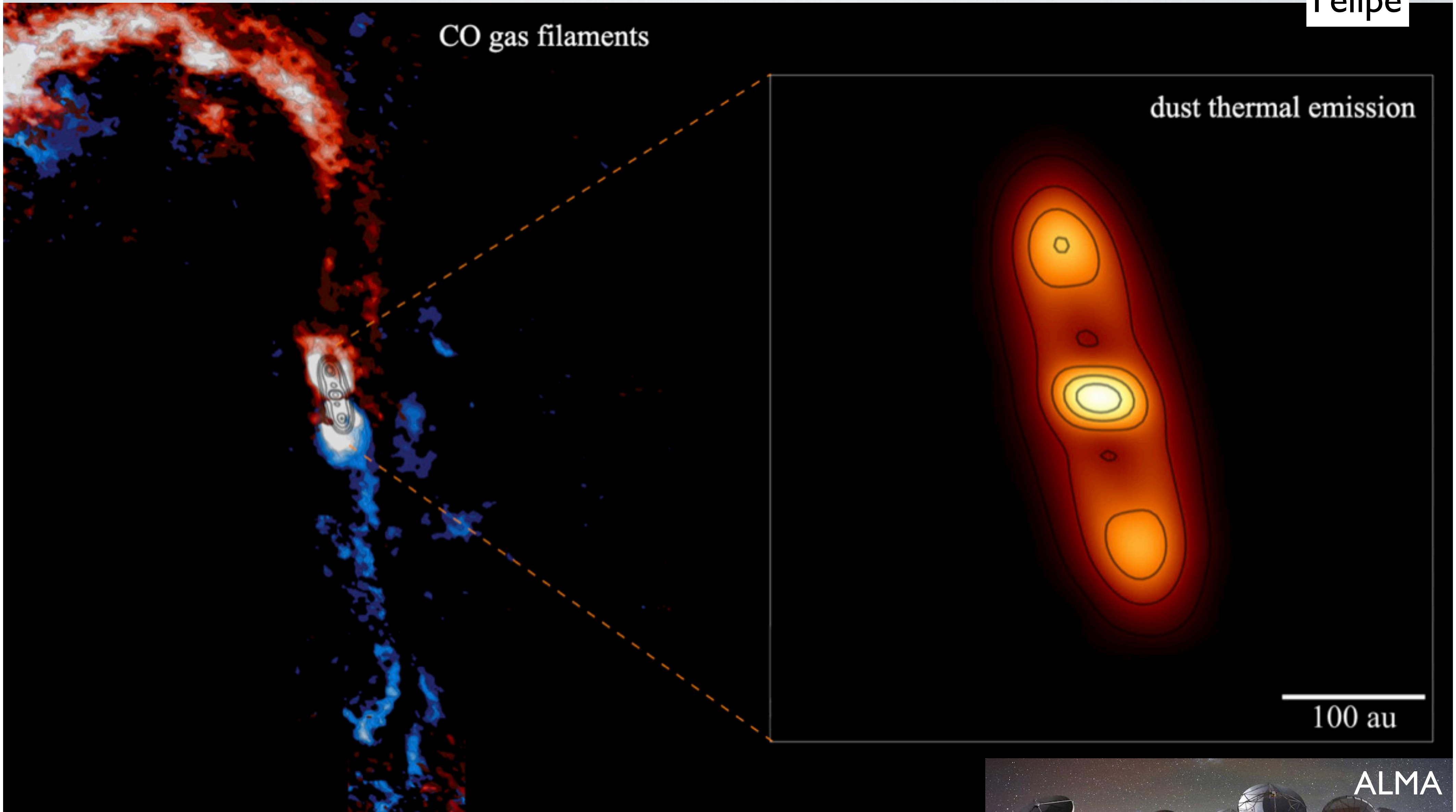
Valdiva-Mena, Pineda et al. in prep (Ph.D. Project)

The least-evolved disk with multiple dust rings: planet-formation starts early

Segura-Cox+2020, Nature



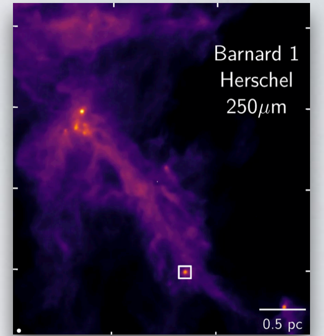
Also more evolved planet-forming disks are still fed by outer cloud



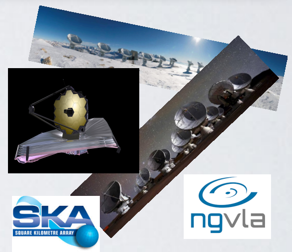
Alves+2020 (see also Ginski+2021; Küffmeier+2021)

SO WHAT ??

If you want to understand the physical/chemical structure of planet-forming disks, you need:

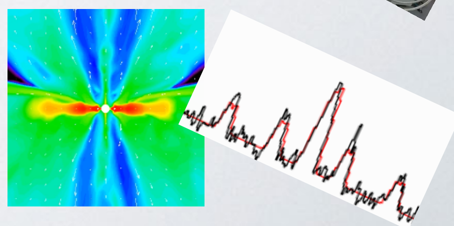


1. to take into account **initial conditions and the environment** during the formation/evolution;



2. **high-spectral/angular resolution and high-sensitivity** telescopes to unveil the dynamical, chemical and dust evolution from PSCs to PFDs;

3. **laboratory work** to measure (i) refractive indexes and opacities of ices and solids, (ii) ice spectroscopy and kinetics, (iii) accurate line frequencies;



4. **theory work** on chemical/dynamical evolution (ζ!) of early phases + detailed radiative transfer.