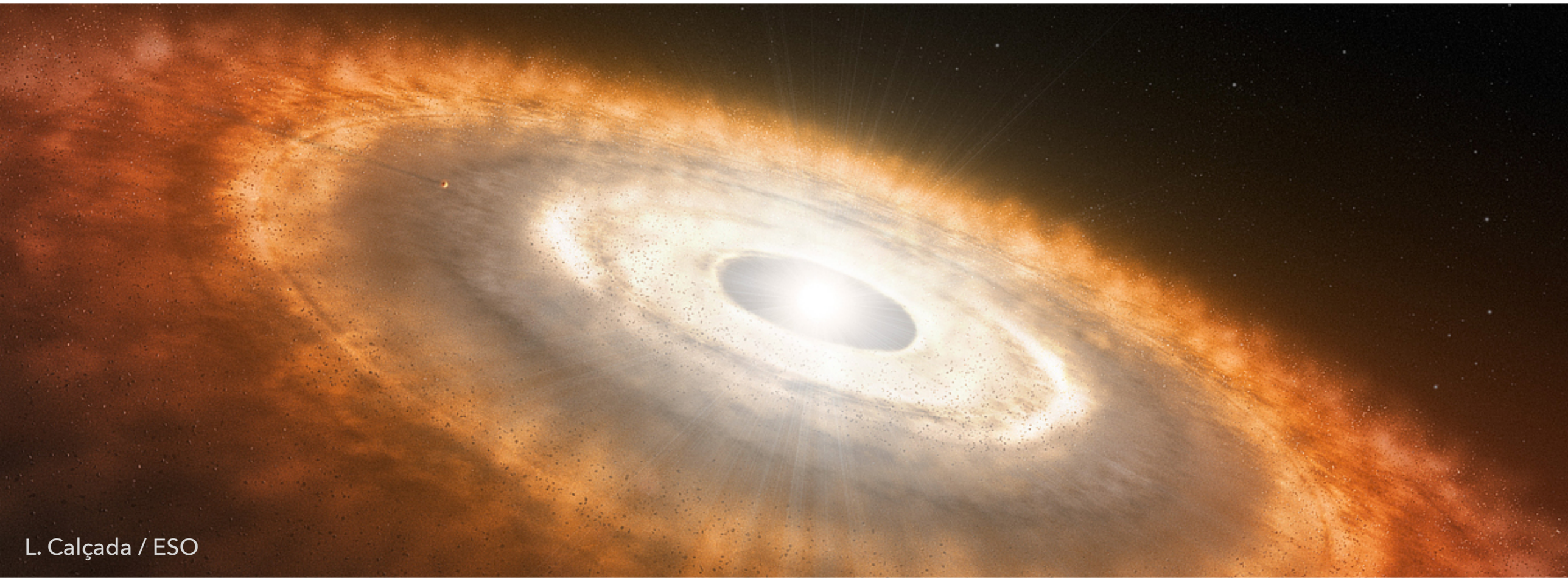
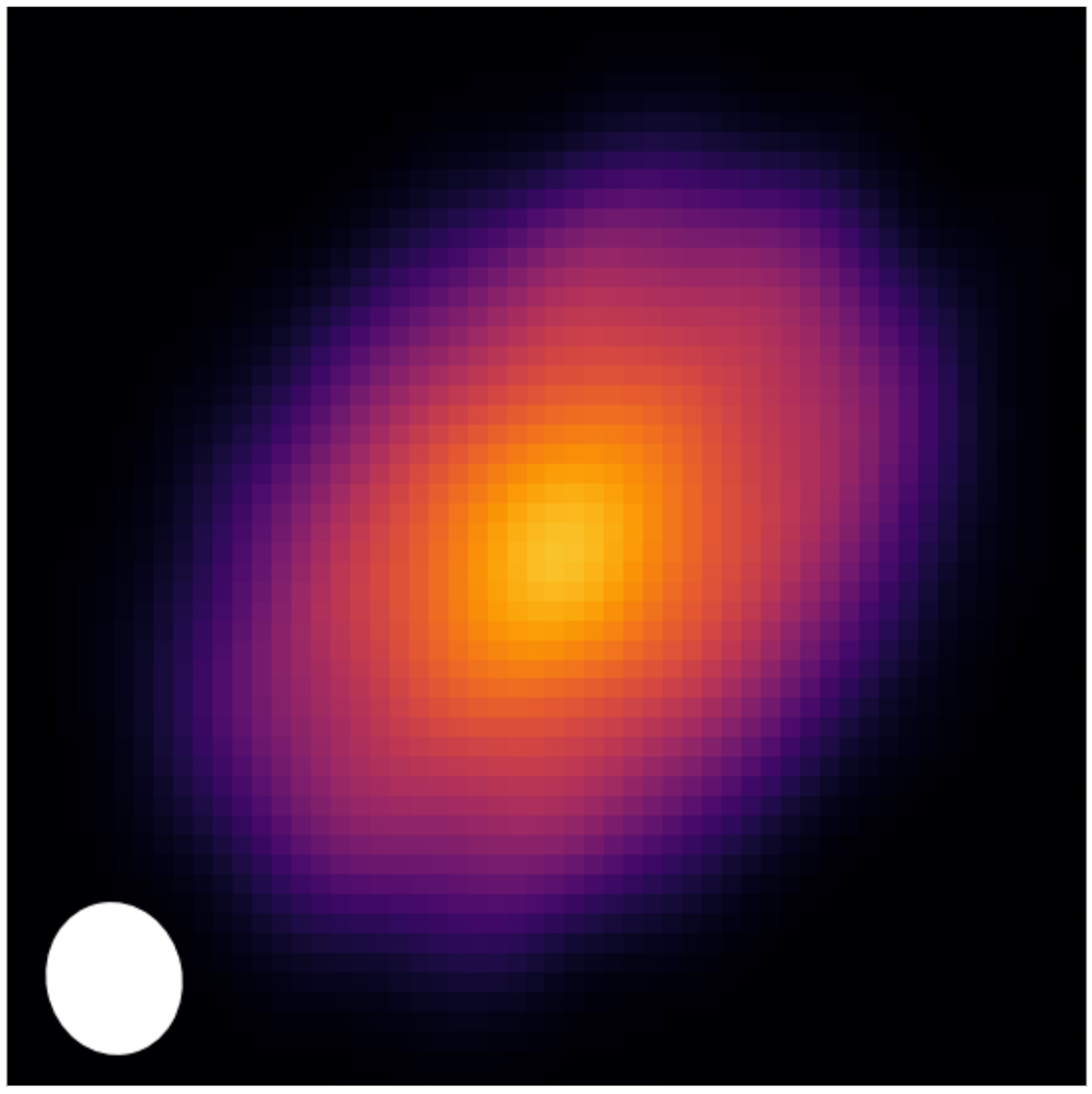


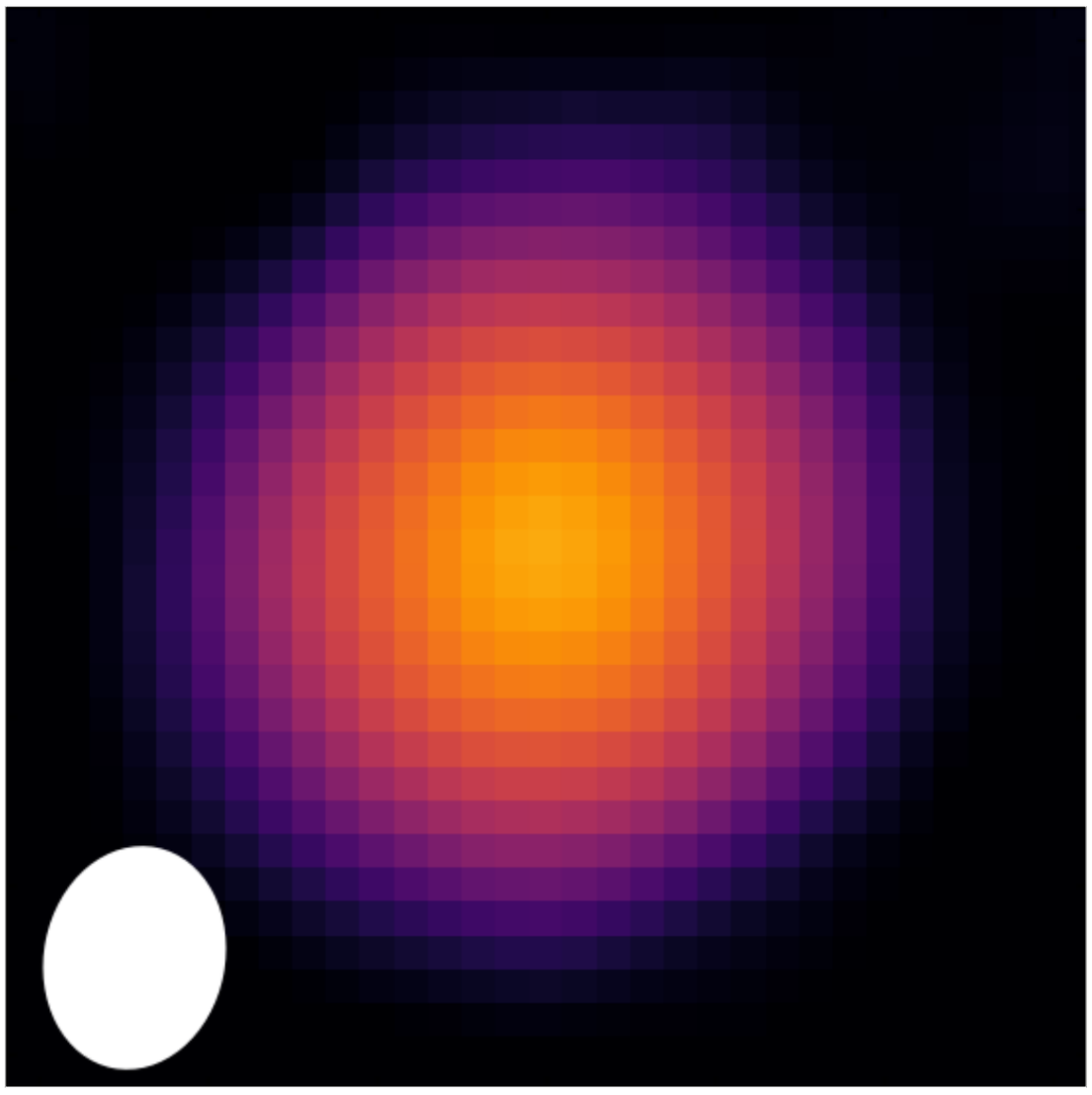

# Protoplanetary disks with ALMA

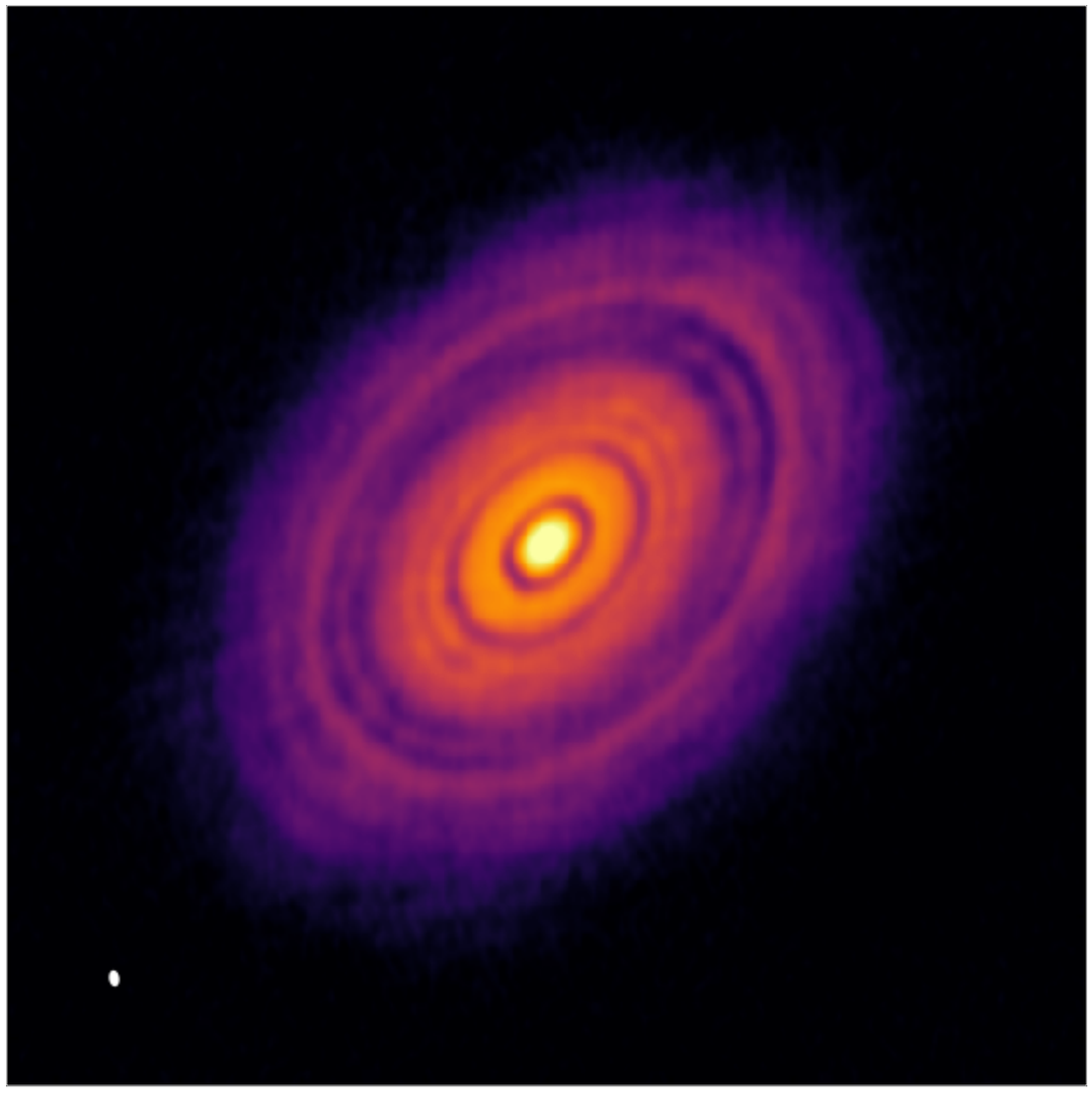
Álvaro Ribas - ESO/ALMA Fellow

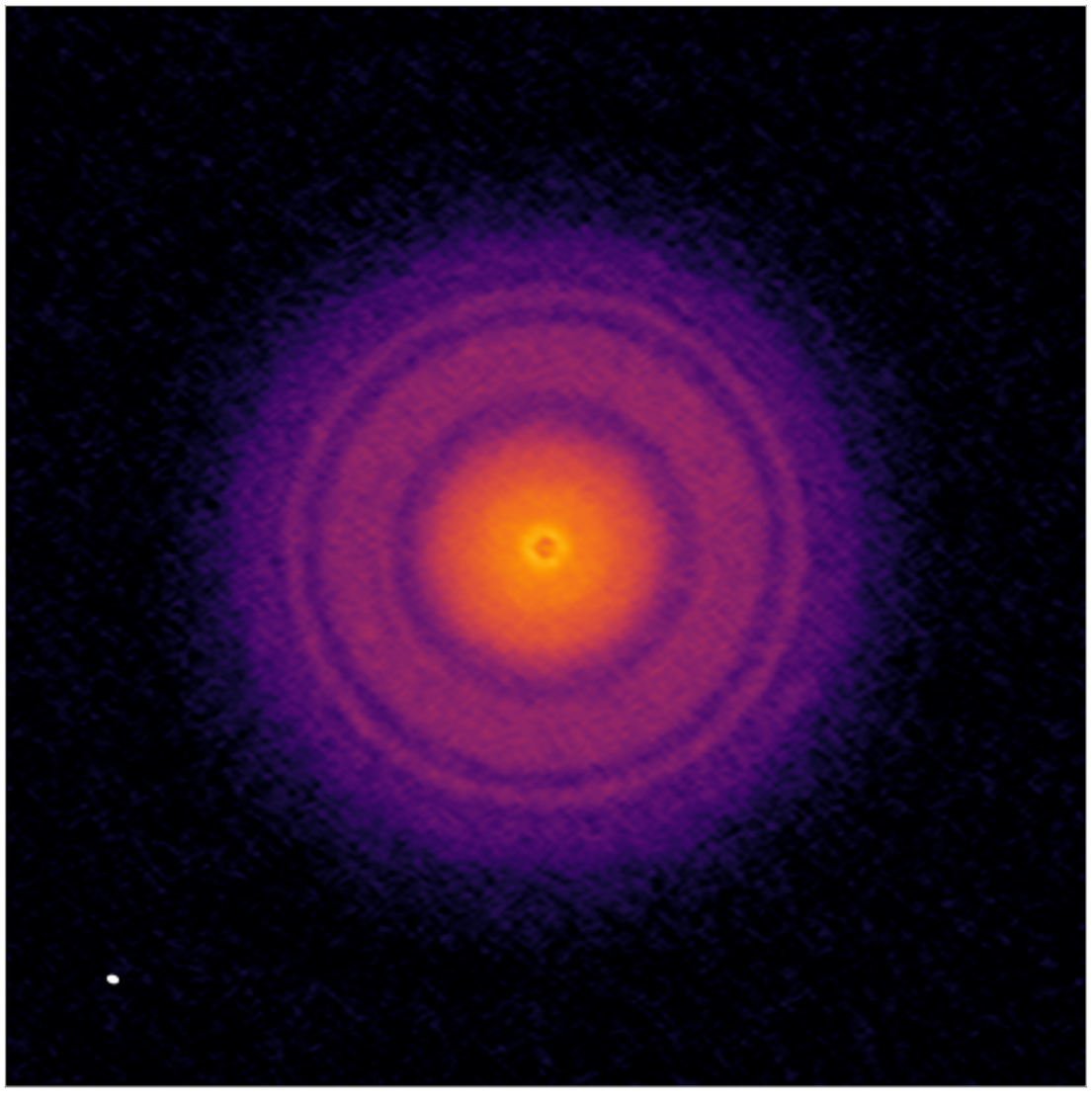
ALMA Community Day

Santiago, Chile, March 20th 2019

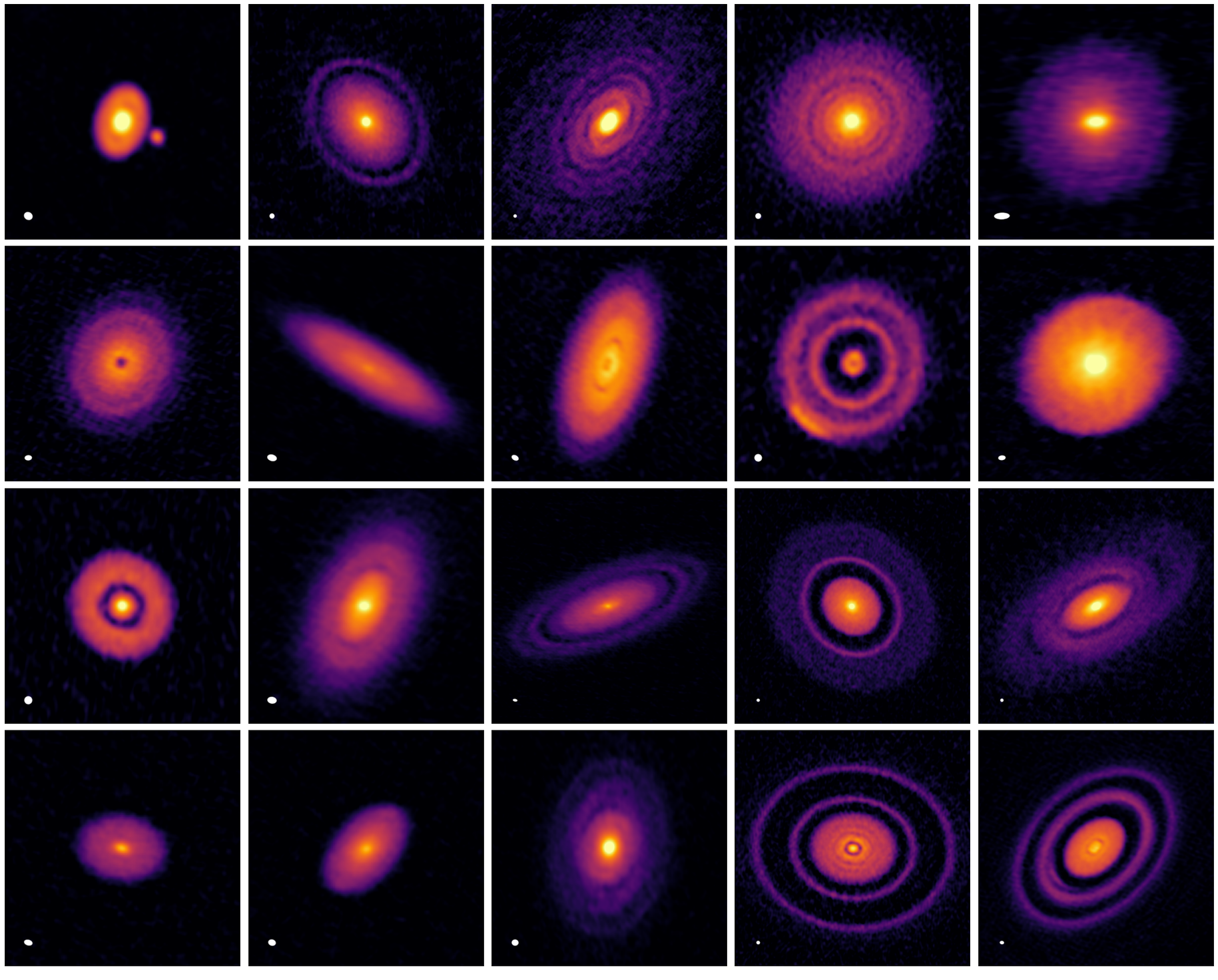








# ALMA is a revolution in planet formation studies



DSHARP collaboration

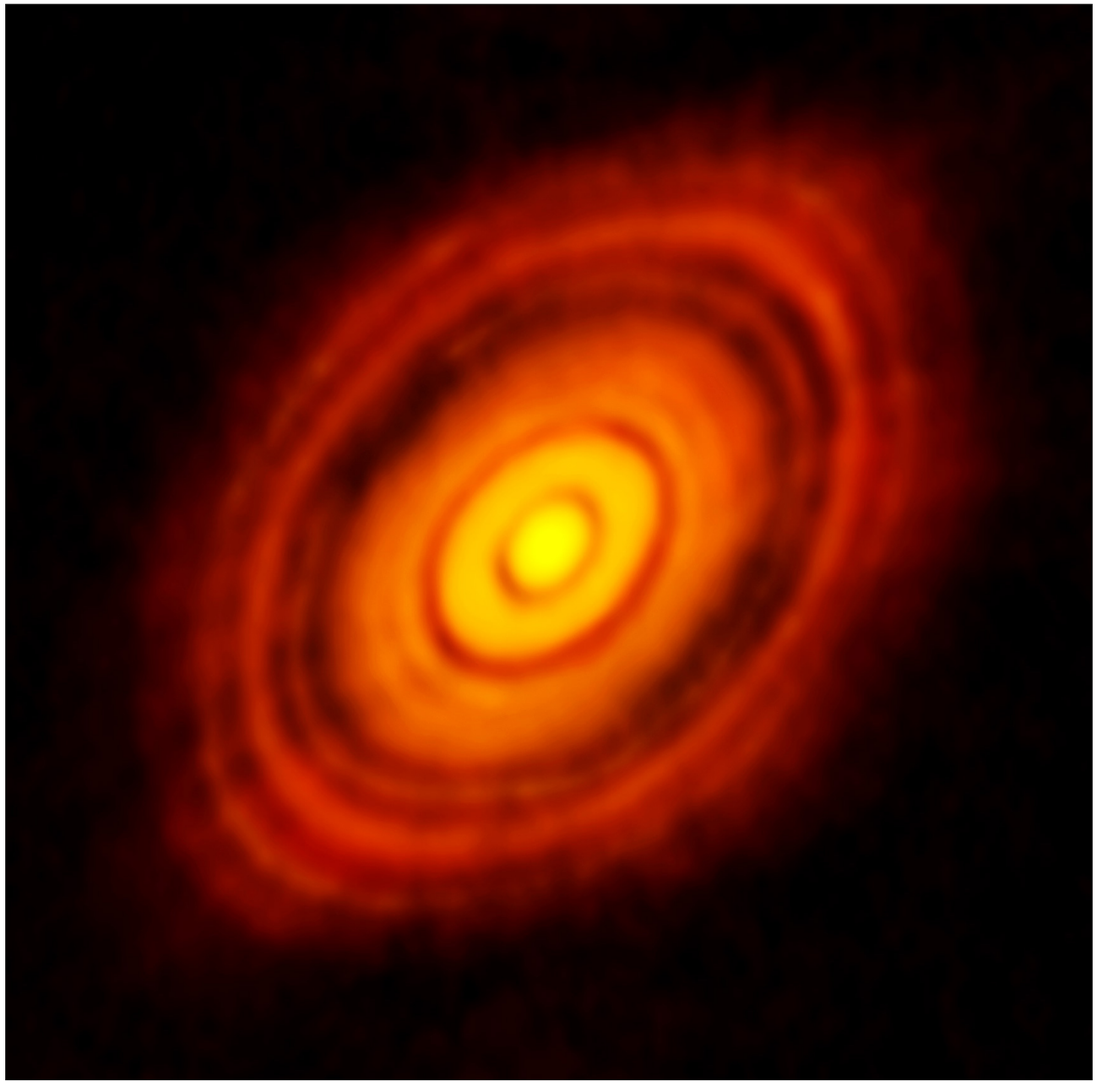
## Continuum:

- Dust mass, grain properties
- Dust grain growth, migration, traps
- Indirect detection of (proto)planets

## Gas lines:

- Gas and stellar masses
- Disk temperature and density structure
- Disk chemistry
- Location of snow-lines
- Indirect detection of (proto)planets

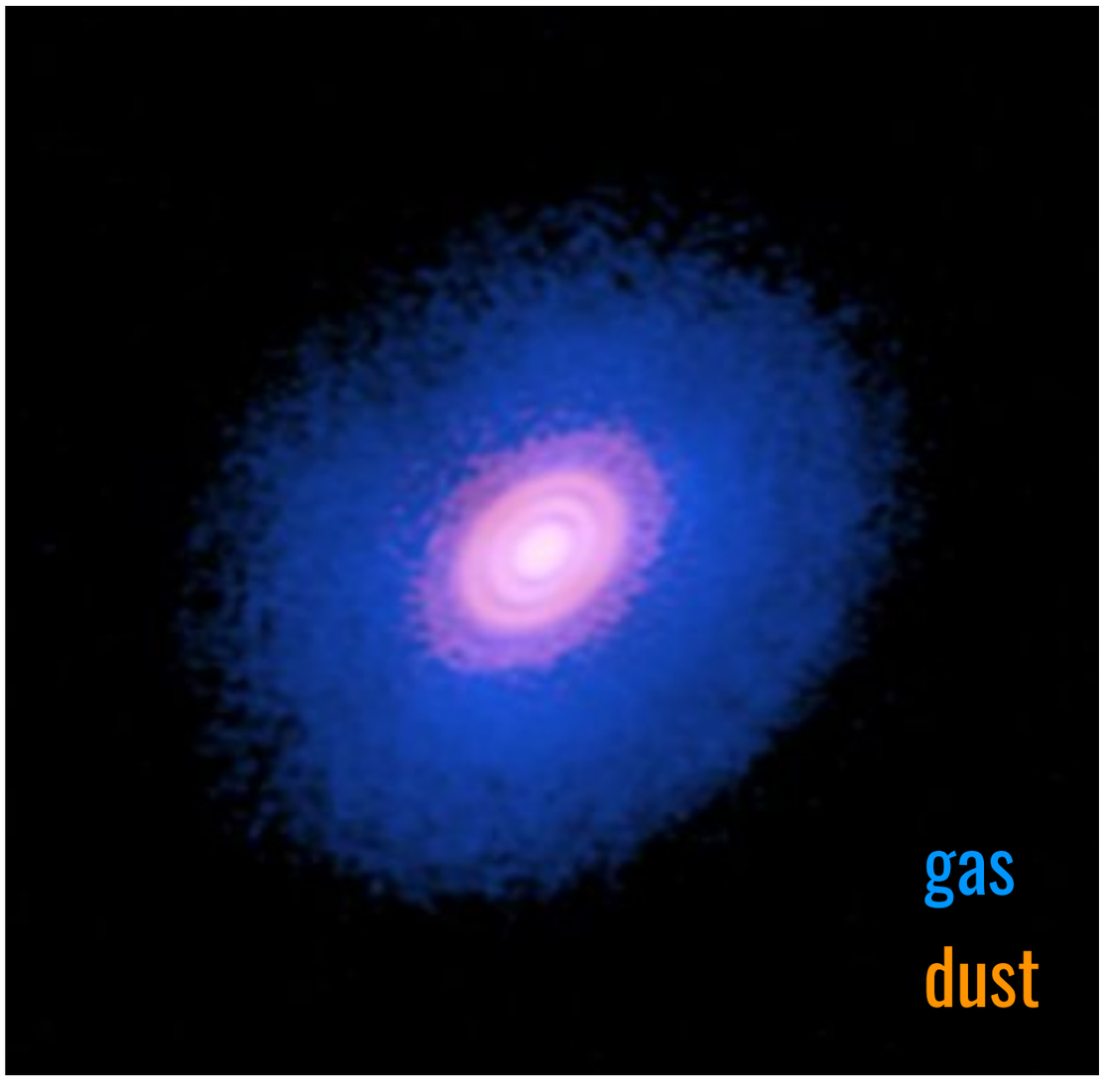
Continuum observations of protoplanetary disk trace **thermal emission** from **mm/cm-sized grains**



HL Tau

ALMA partnership et al. 2015

# Dust radial migration




HD 163296

A. Isella & B. Saxton

- Dust grains orbit at keplerian velocity
- Gas orbits at sub-keplerian velocity

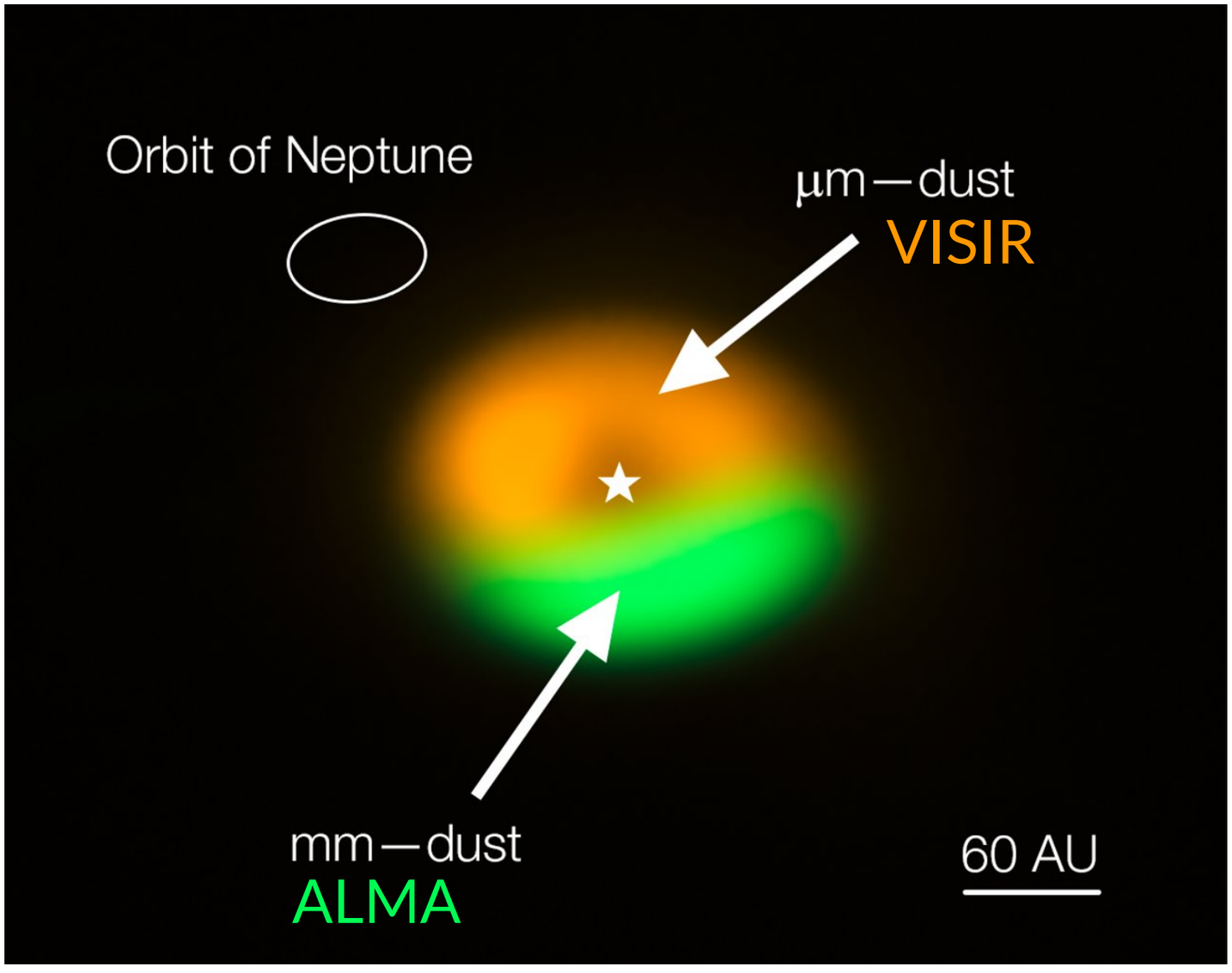
↓

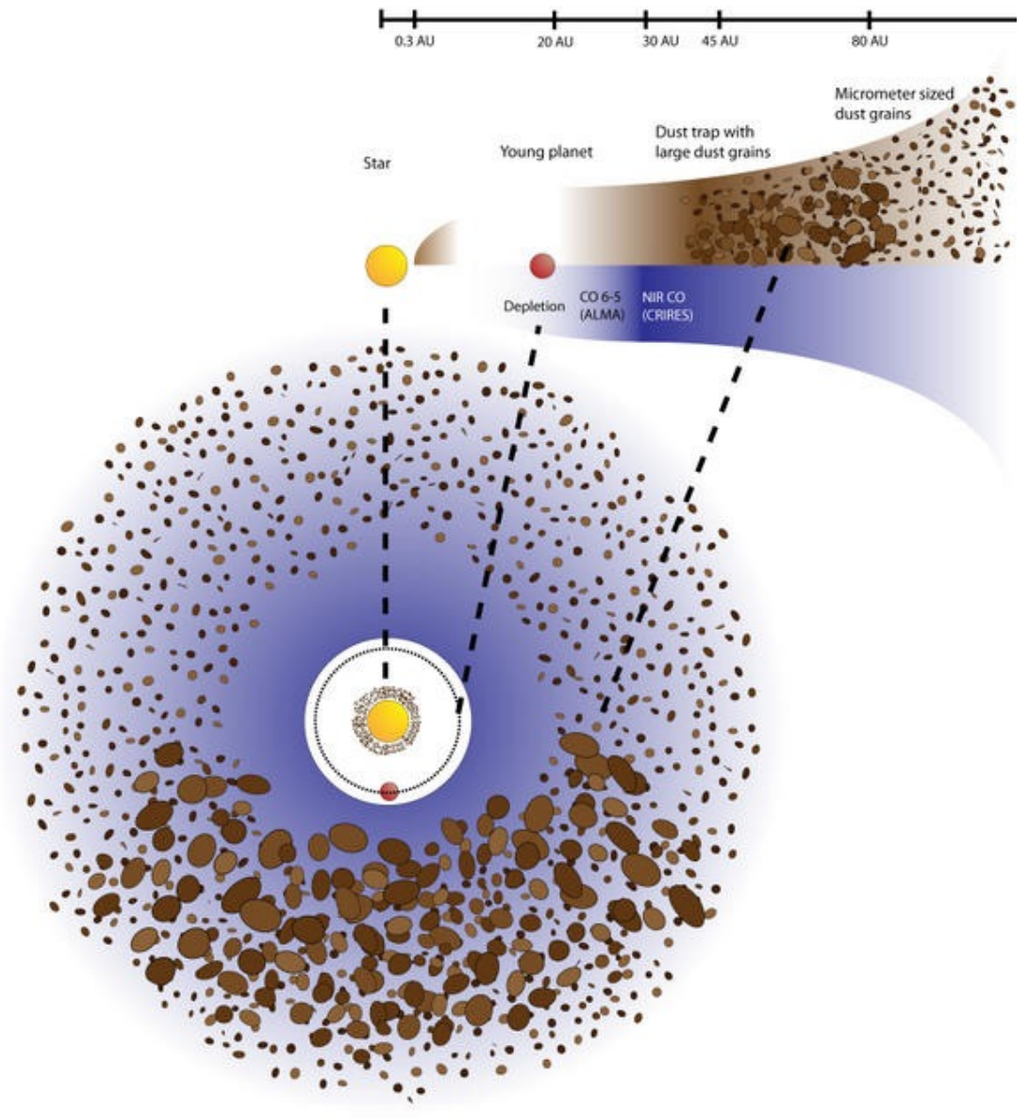
mm/cm grains slow down
and migrate inward

Disk radii depend on wavelength,
gas and dust radii are usually very
different.

# A solution to radial migration: dust traps

Dust particles move toward pressure maxima in the disk



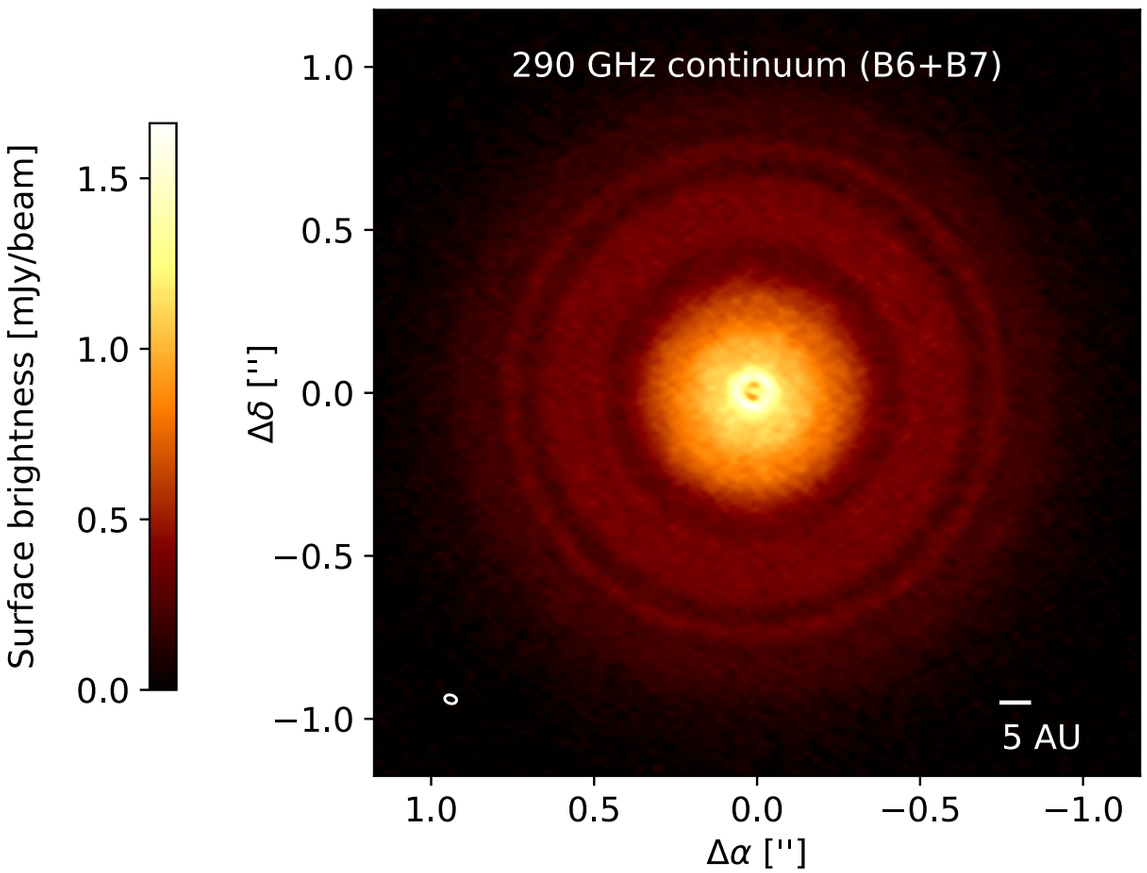



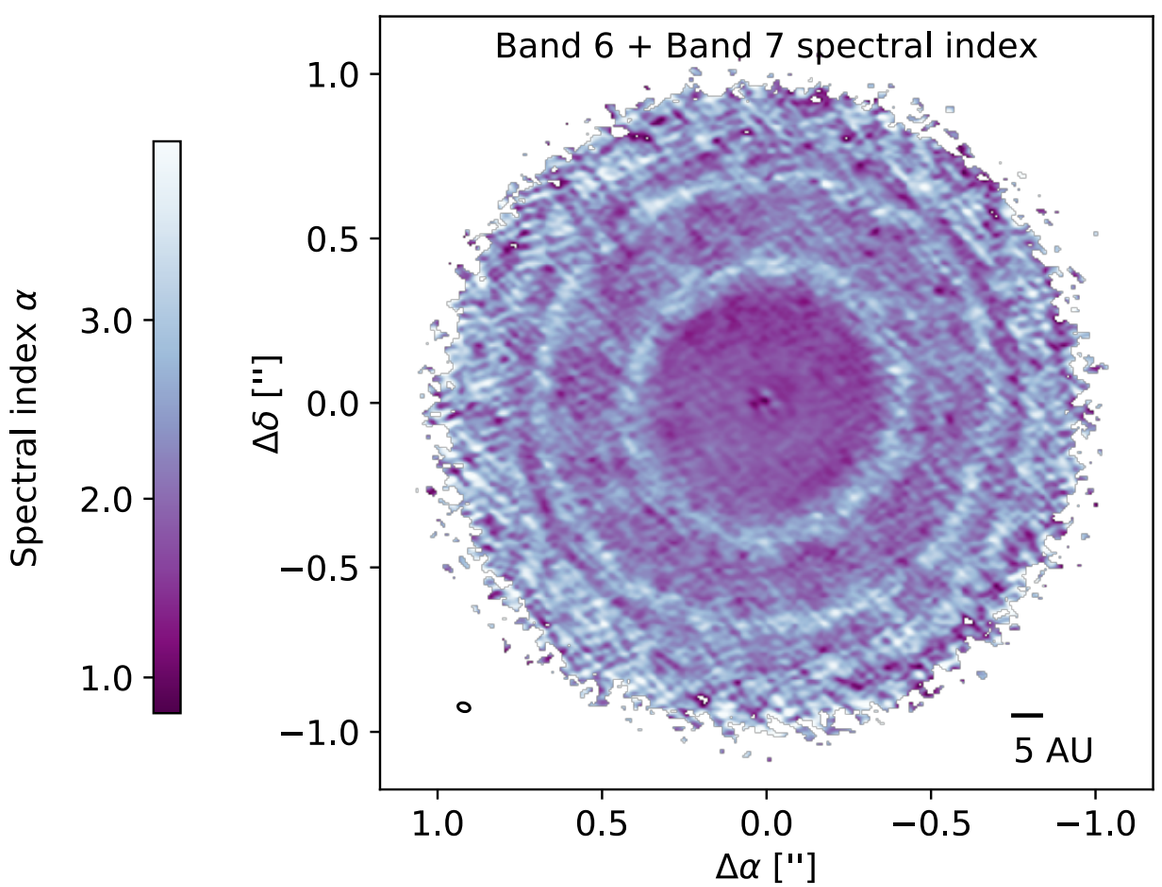

## Oph IRS-48

van der Marel et al. 2013

# A solution to radial migration: dust traps

## Rings and gaps can stop dust migration and aid grain growth



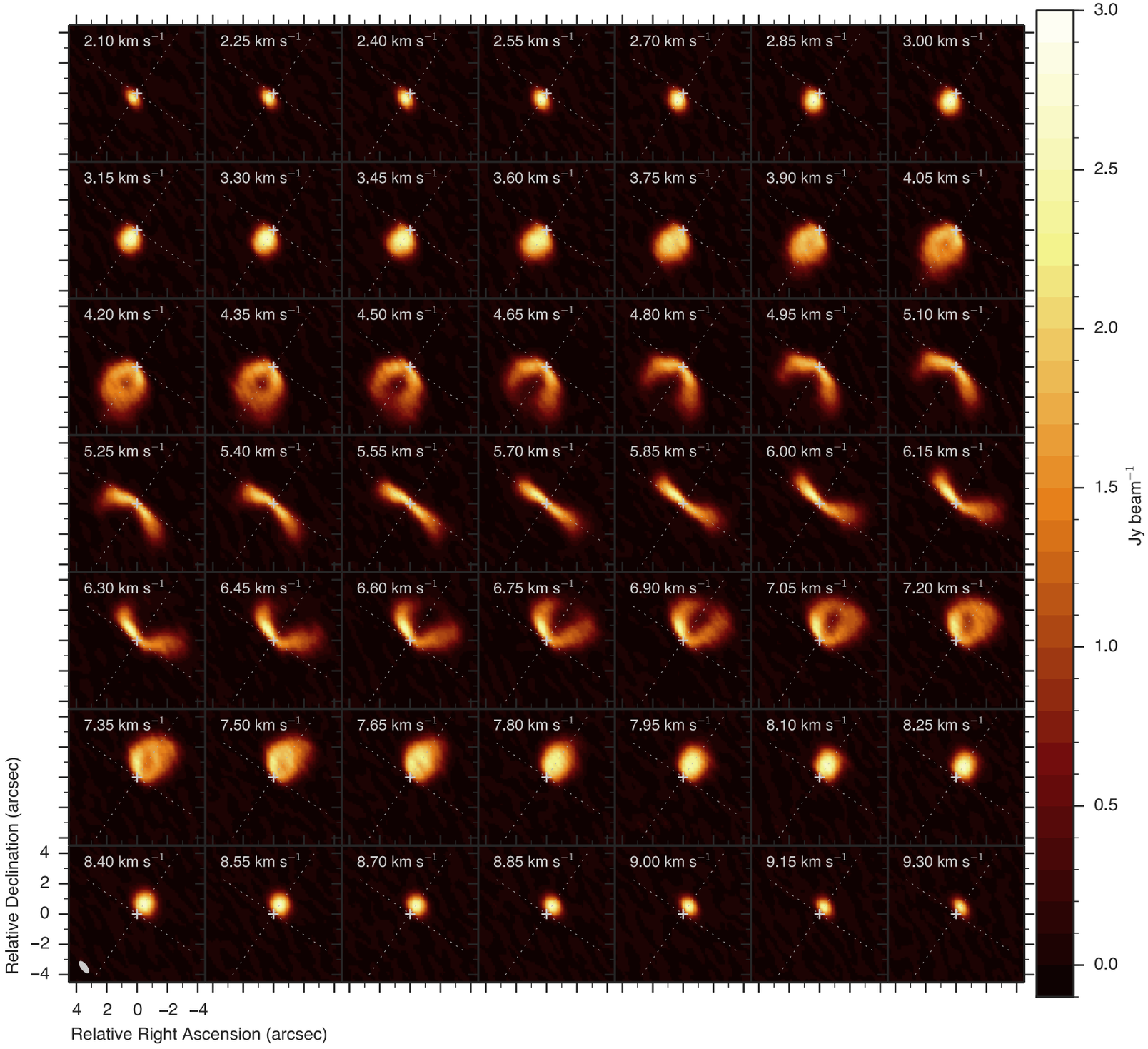




## TW Hya

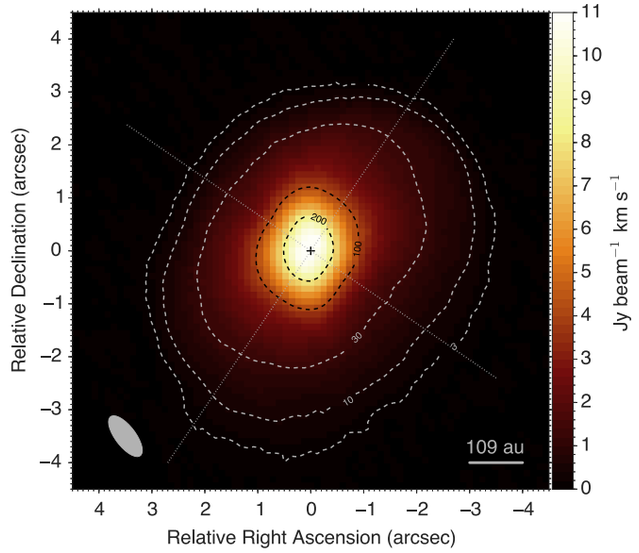
Huang et al. 2018

# Gas kinematics: disk rotation

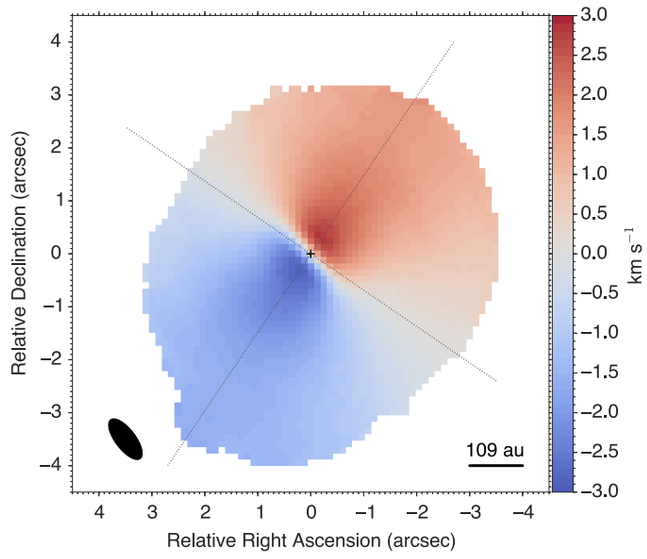
## $^{13}$CO(3-2) line




## 0th-moment: total intensity




## 1st-moment: velocity field




# HD 100546

Walsh et al. 2017

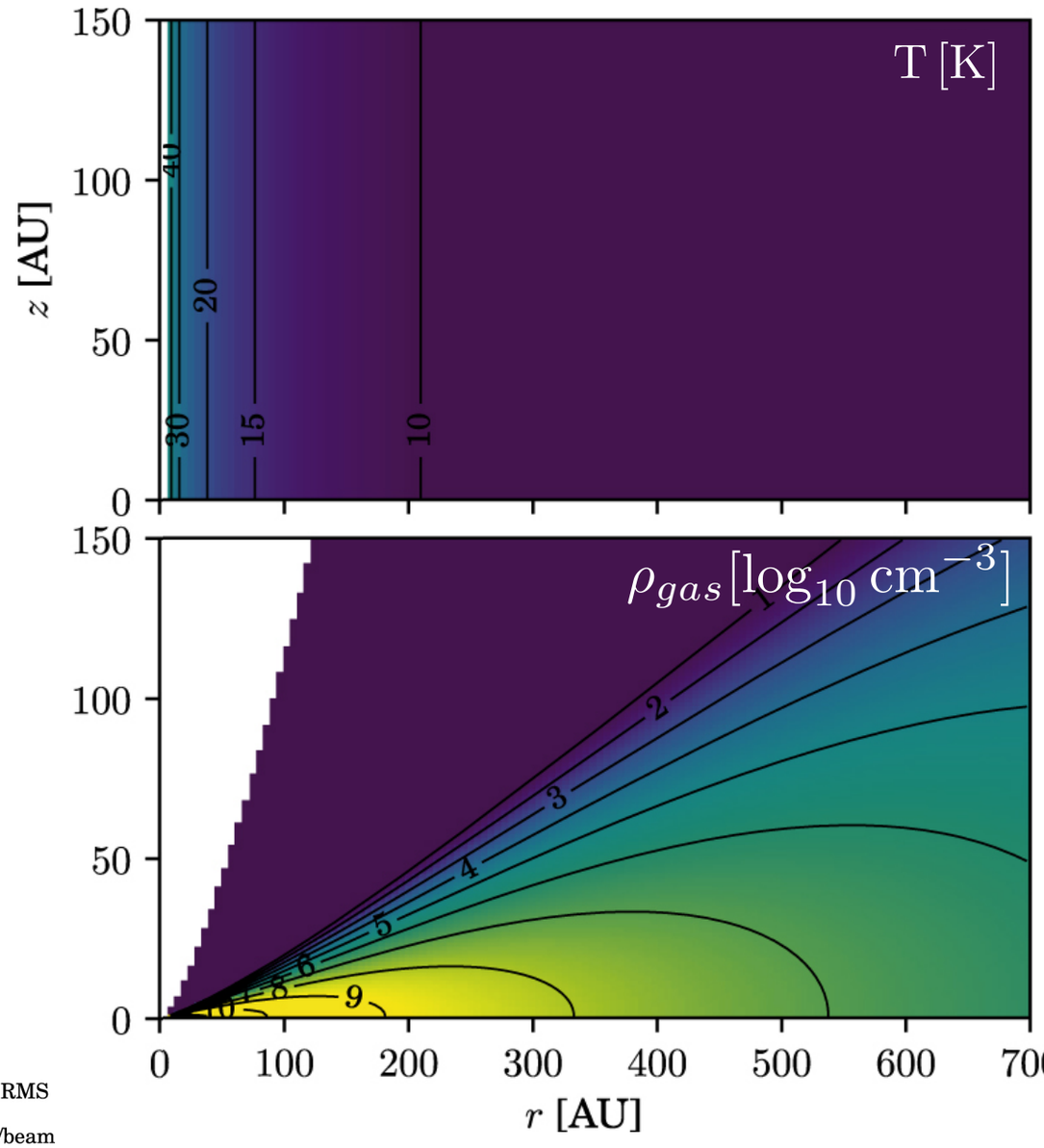
# Gas and stellar masses, disk structure

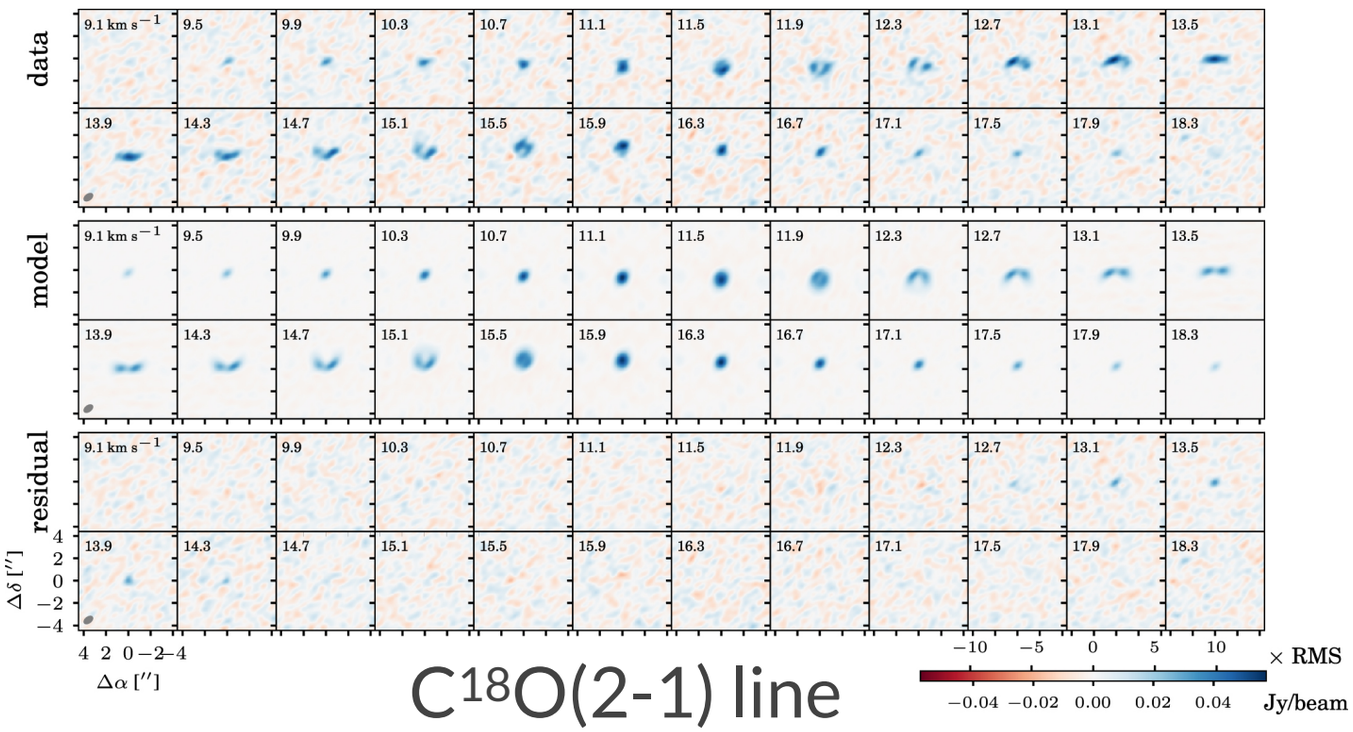
With this type of data (+ models), you can derive…

- stellar mass
- disk gas mass
- gas density profile
- disk temperature structure

## GW Ori

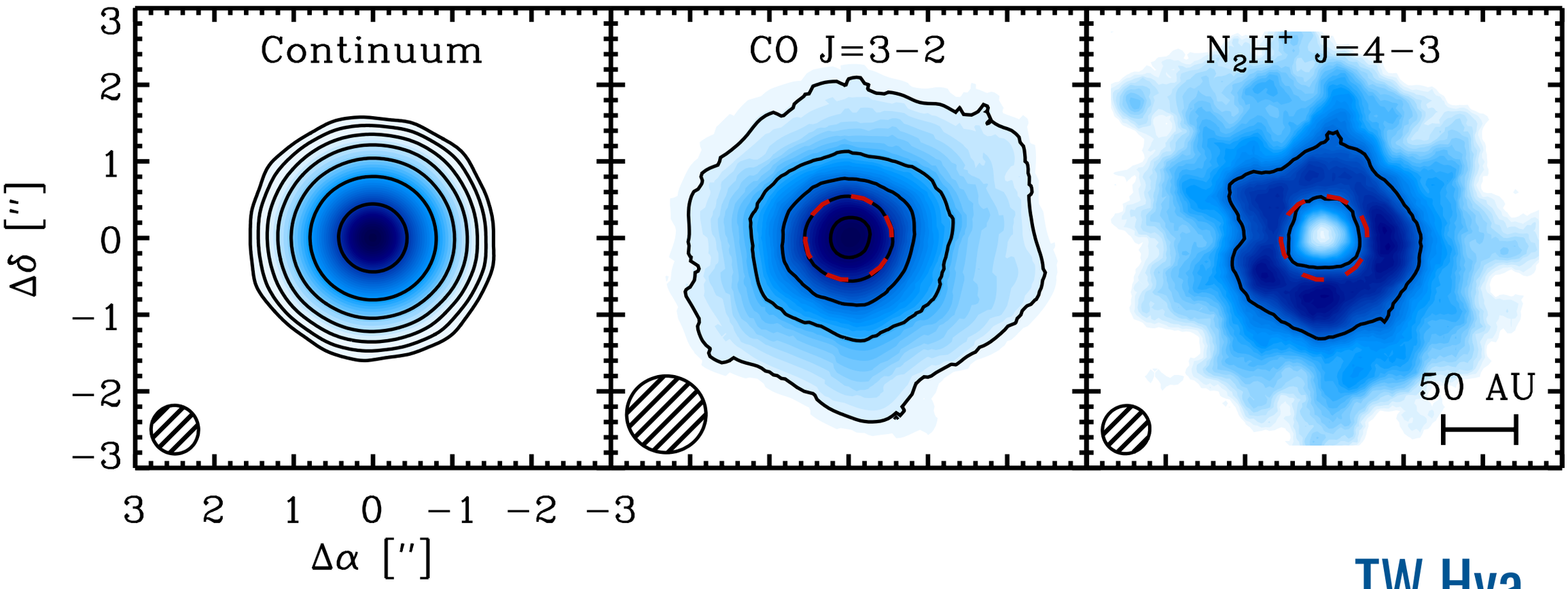
Czekala et al. 2018




$C^{18}O$(2-1) line

# Location of snow-lines



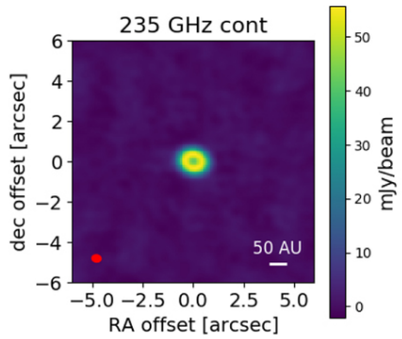

**TW Hya**

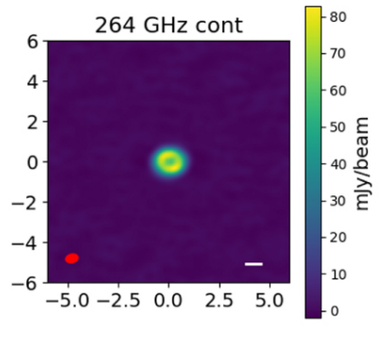
Qi et al. 2013

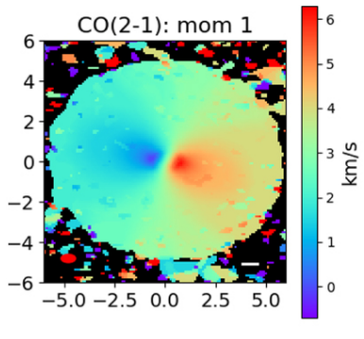
# Extremely rich chemistry, organic molecules

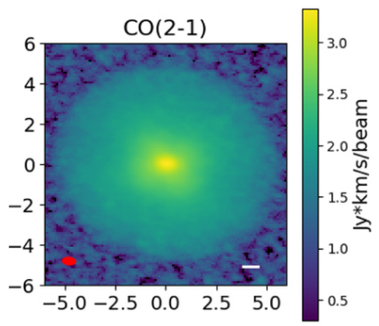
## V4046 Sgr

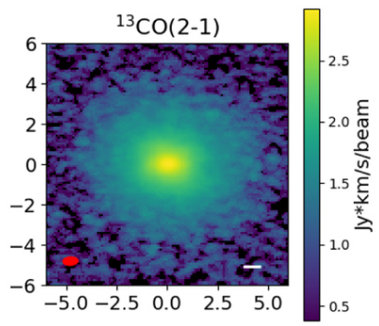
Kastner et al. 2018

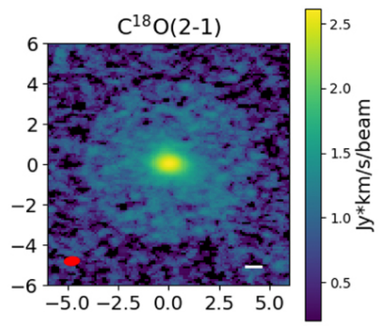


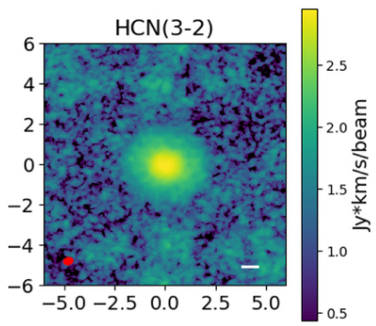



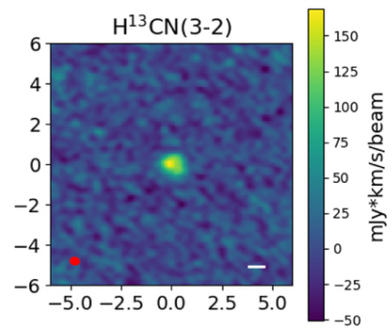



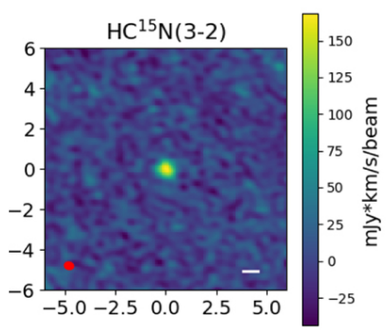



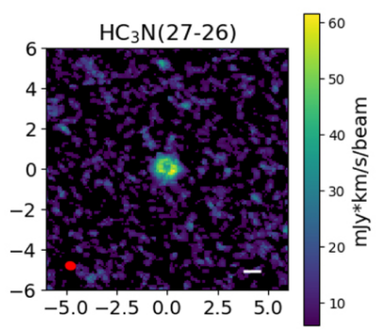



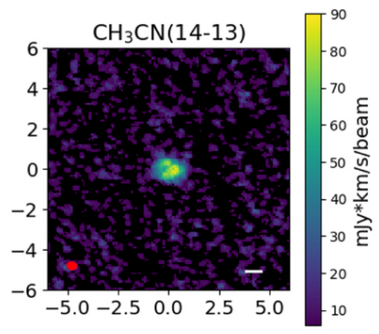



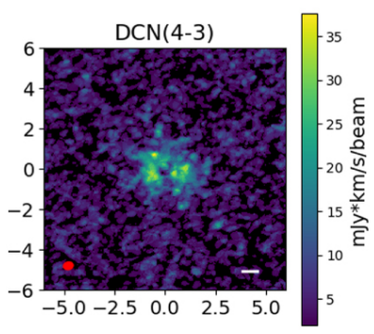



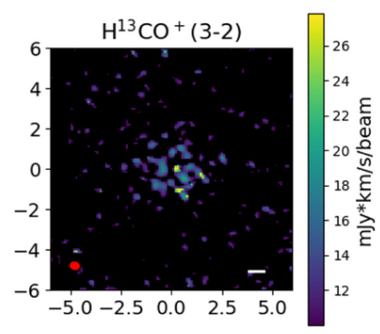



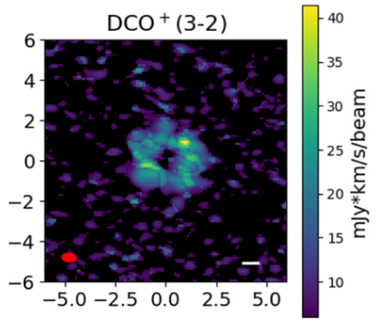



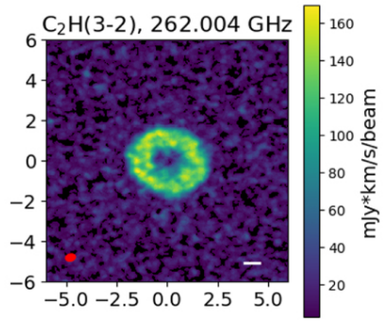



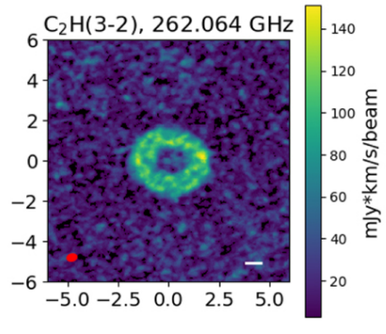



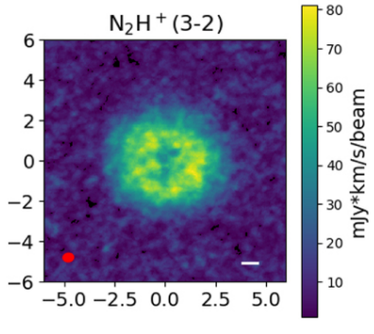



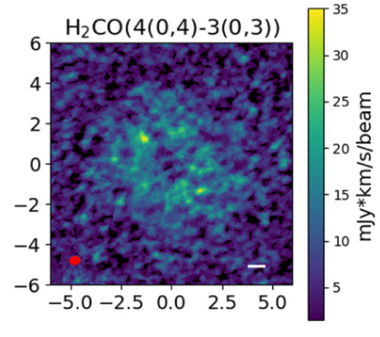



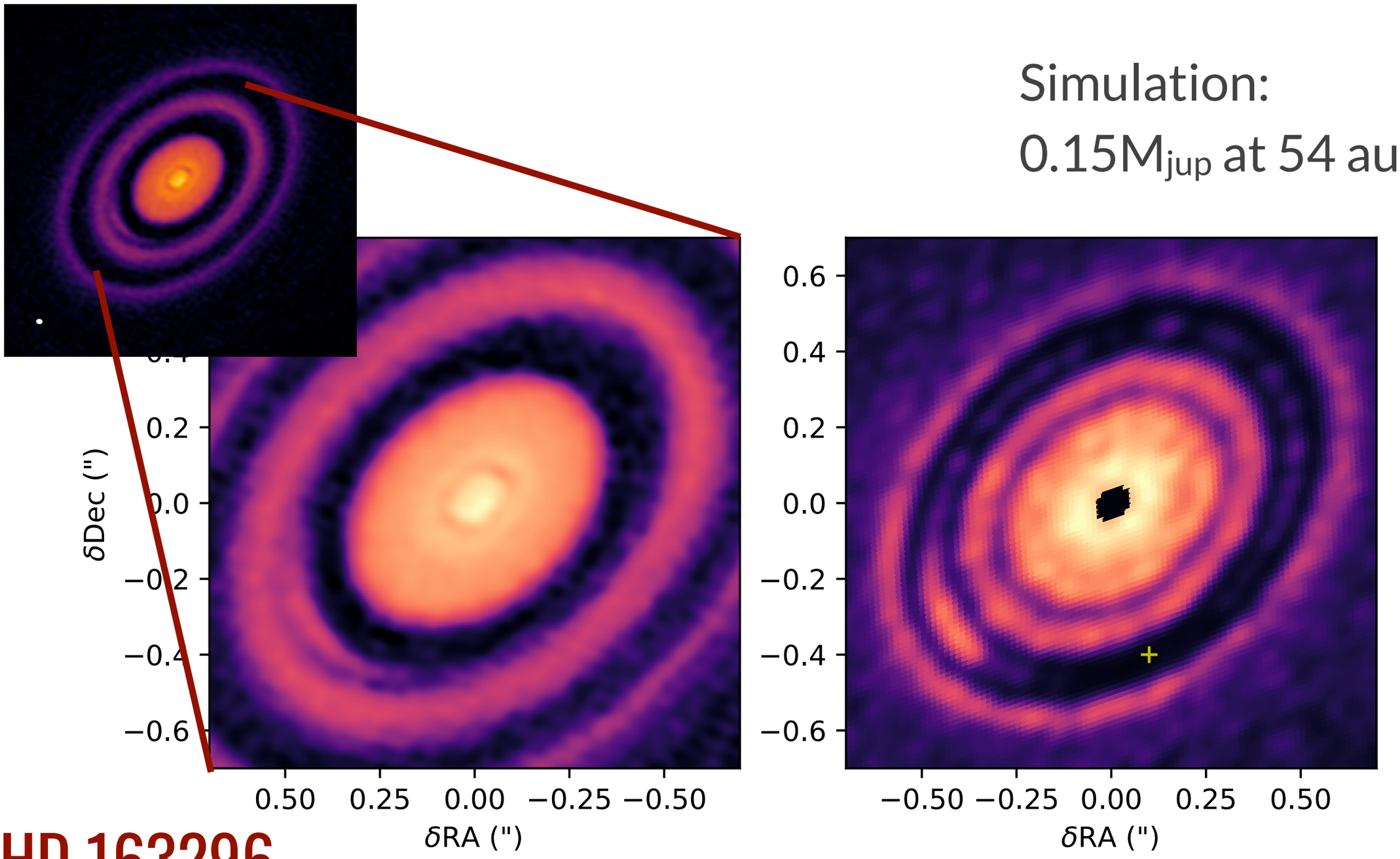



# Finding (proto)planets




Simulation:
0.15$M_{jup}$ at 54 au

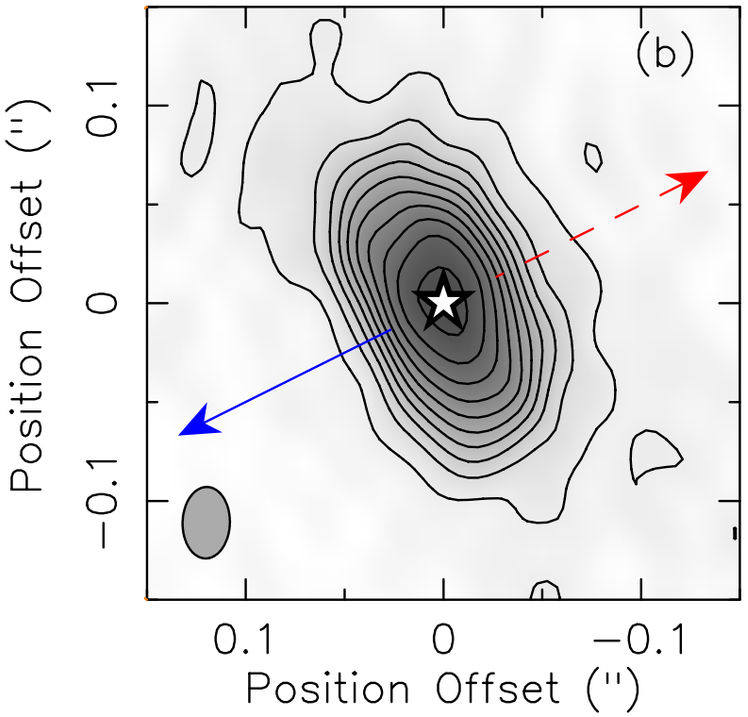
## HD 163296

Isella et al. 2018

# Extra slides

# Before and after protoplanetry disks

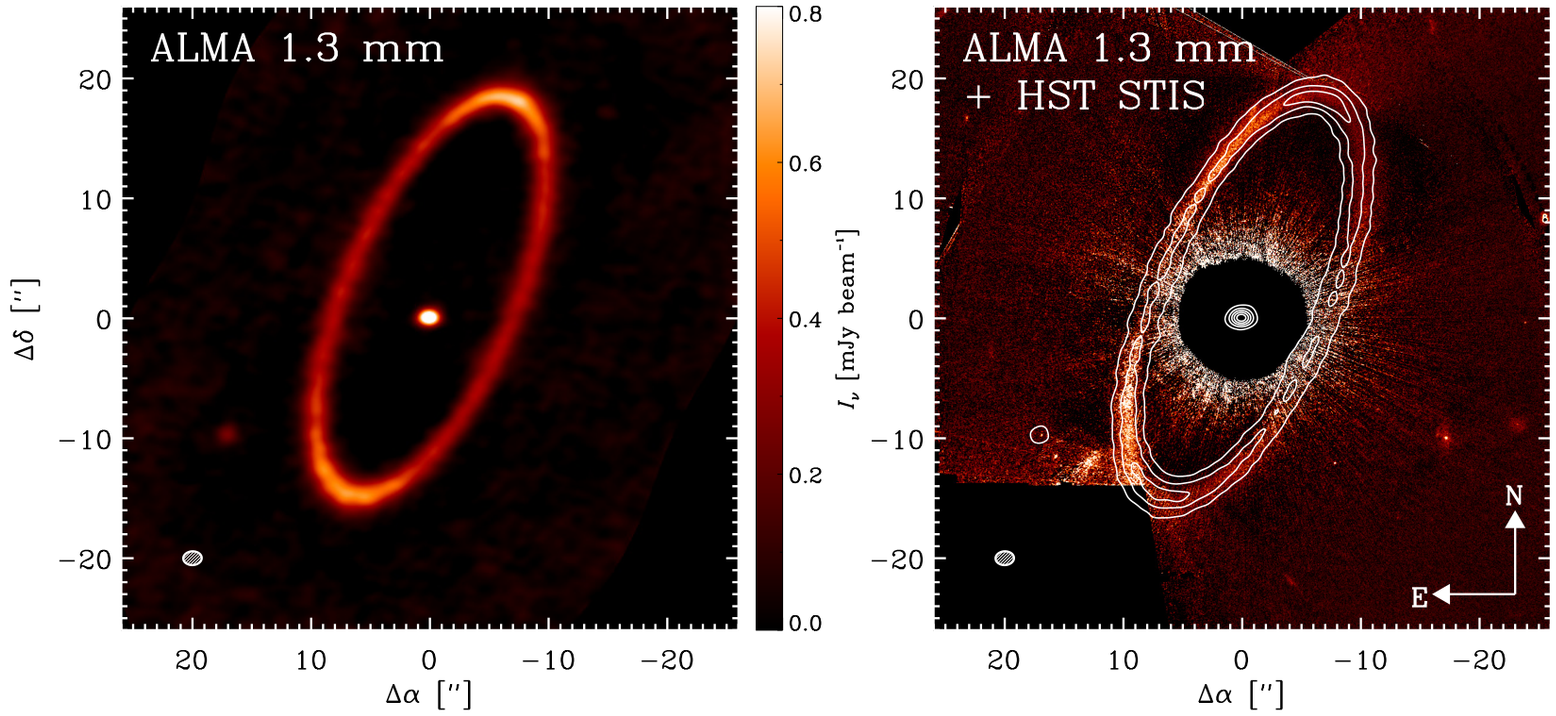
When do disks form?
**Class 0 disks**, size, rotation




## HH-221

Lee et al. 2018

The remnants of planet formation:
Debris disks, composition and structure

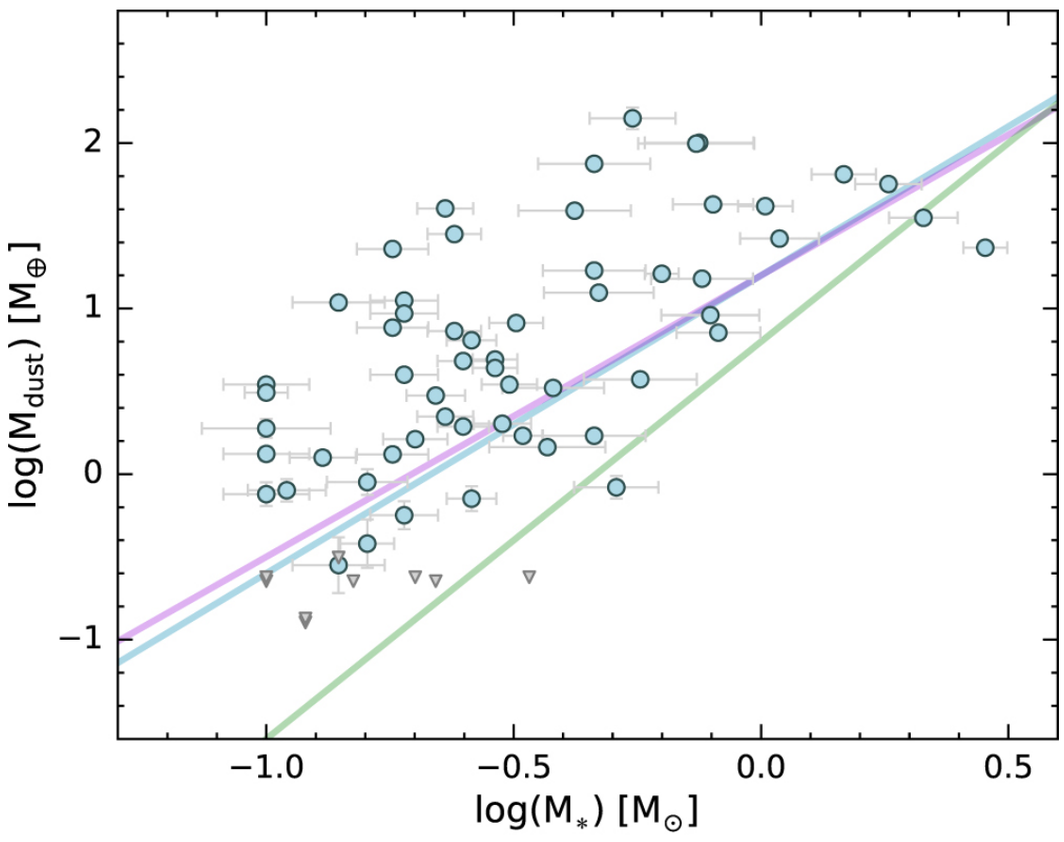



## Fomalhaut

MacGregor et al. 2017

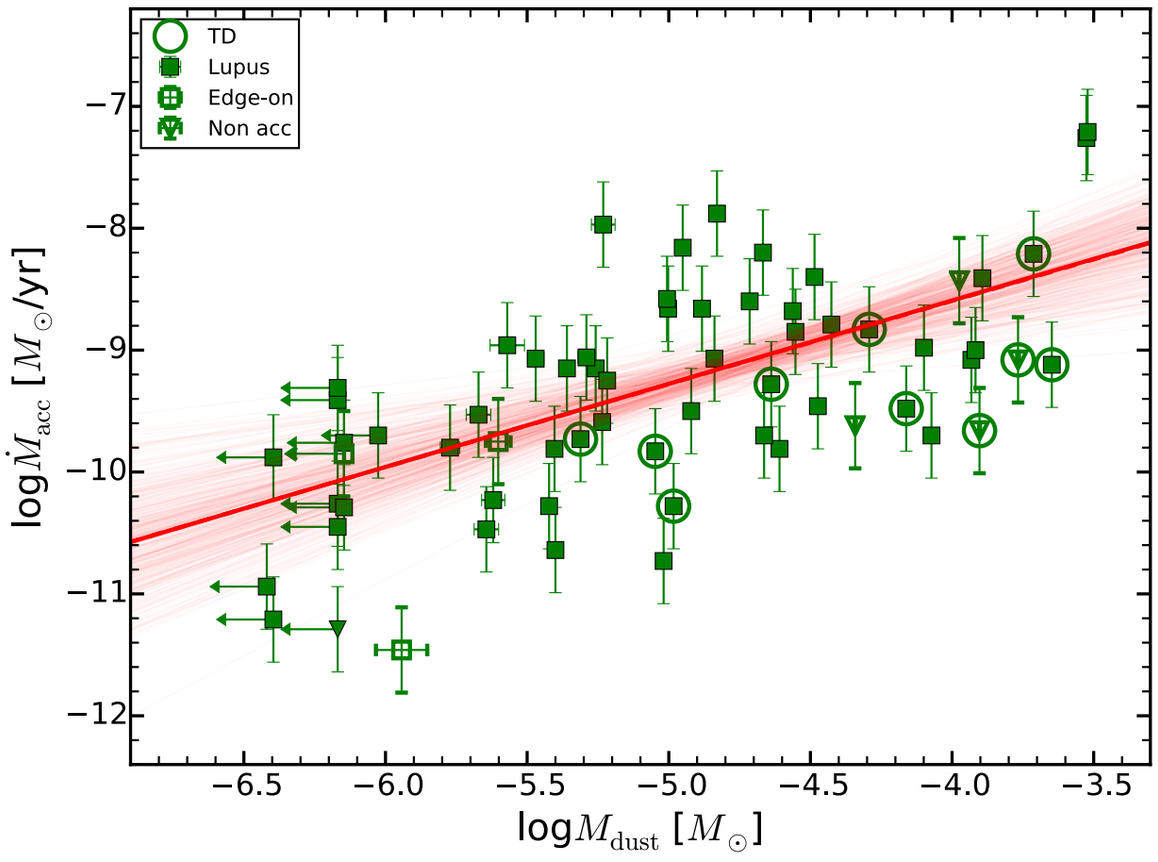
# Disk dust masses

## $M_{star}$ *vs* $M_{dust}$



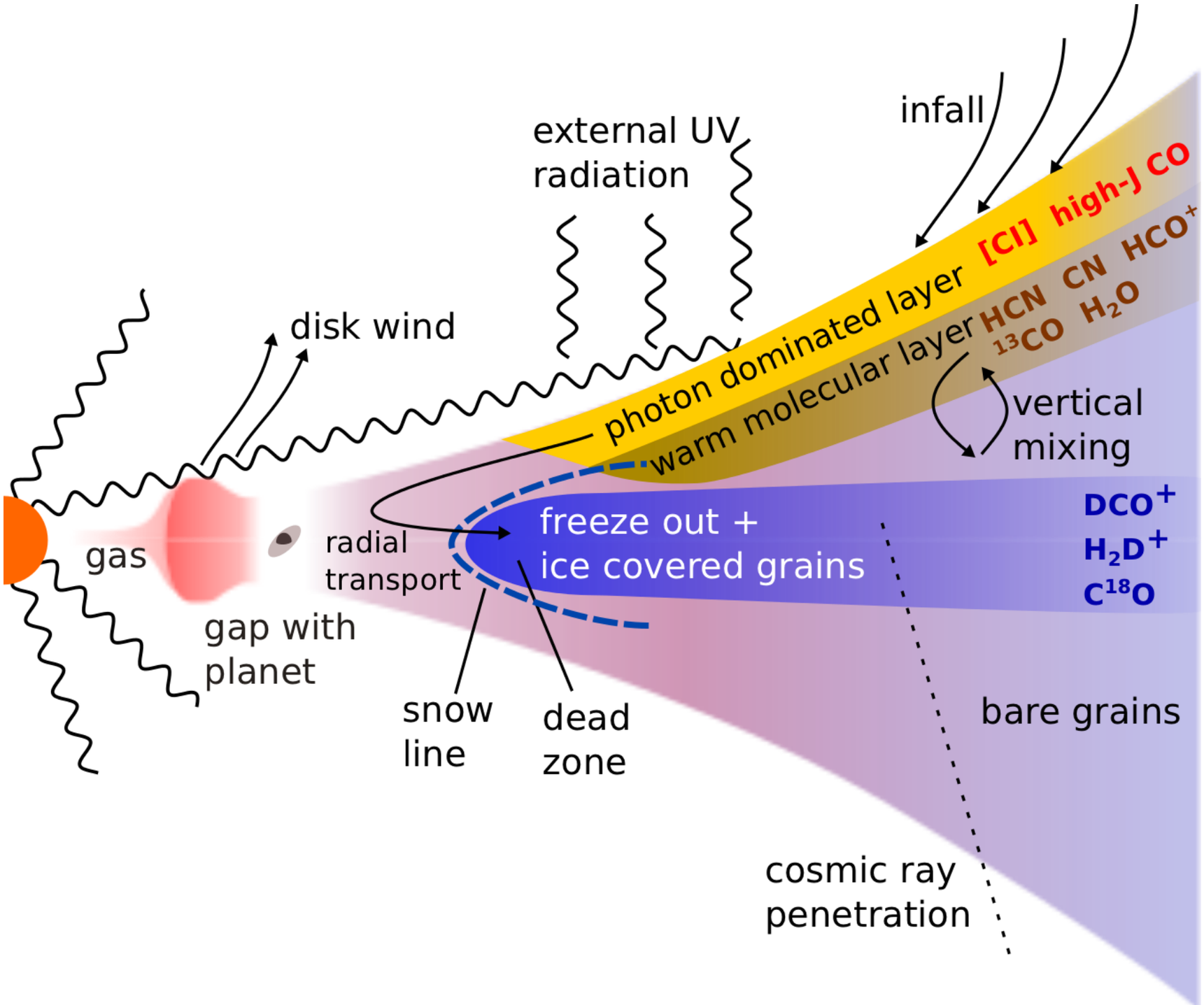

Ansdell et al. 2016

## $M_{dust}$ *vs* $M_{acc}$



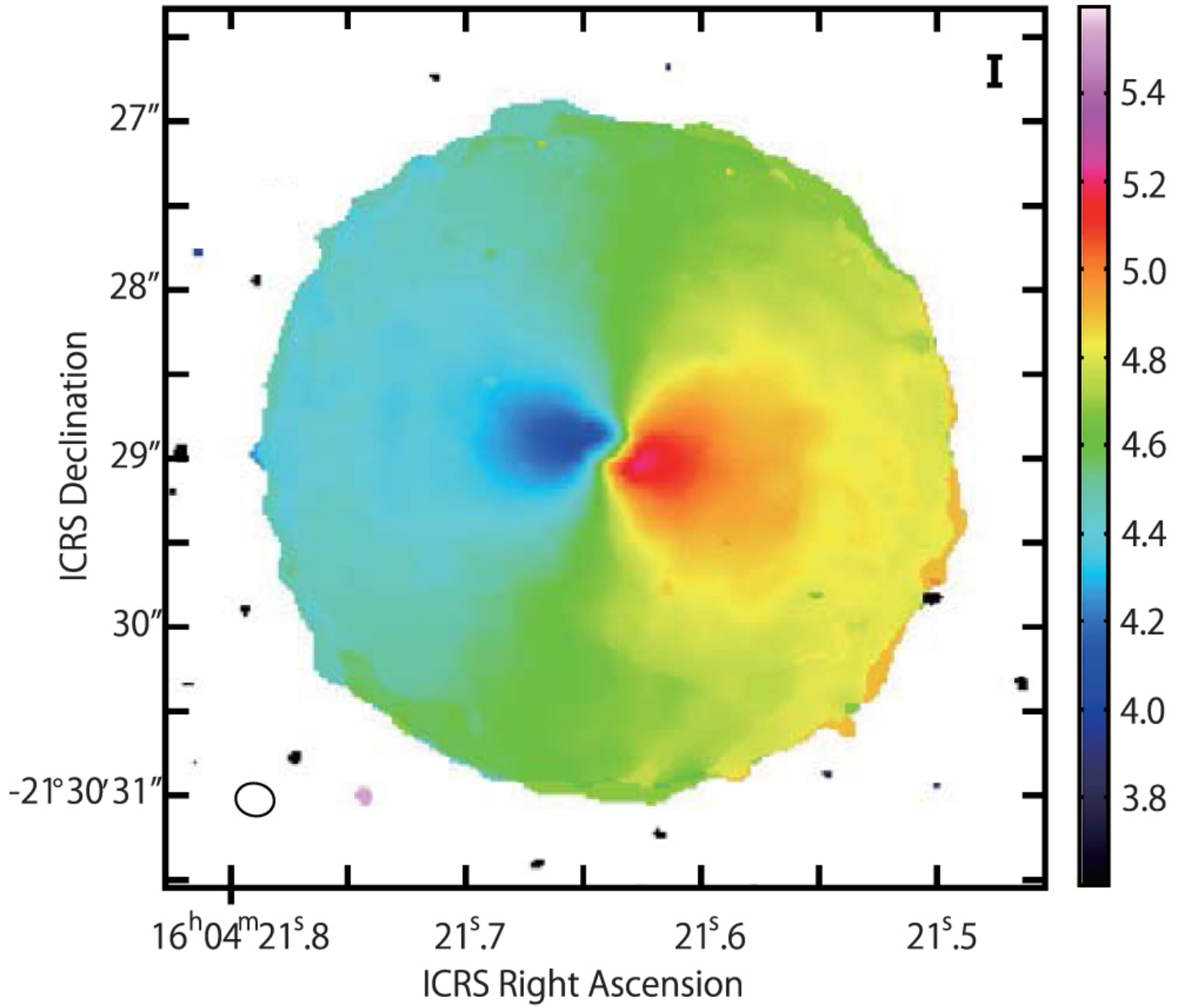

Manara et al. 2016

# Complex chemistry in protoplanetary disks




van Dishoeck 2014

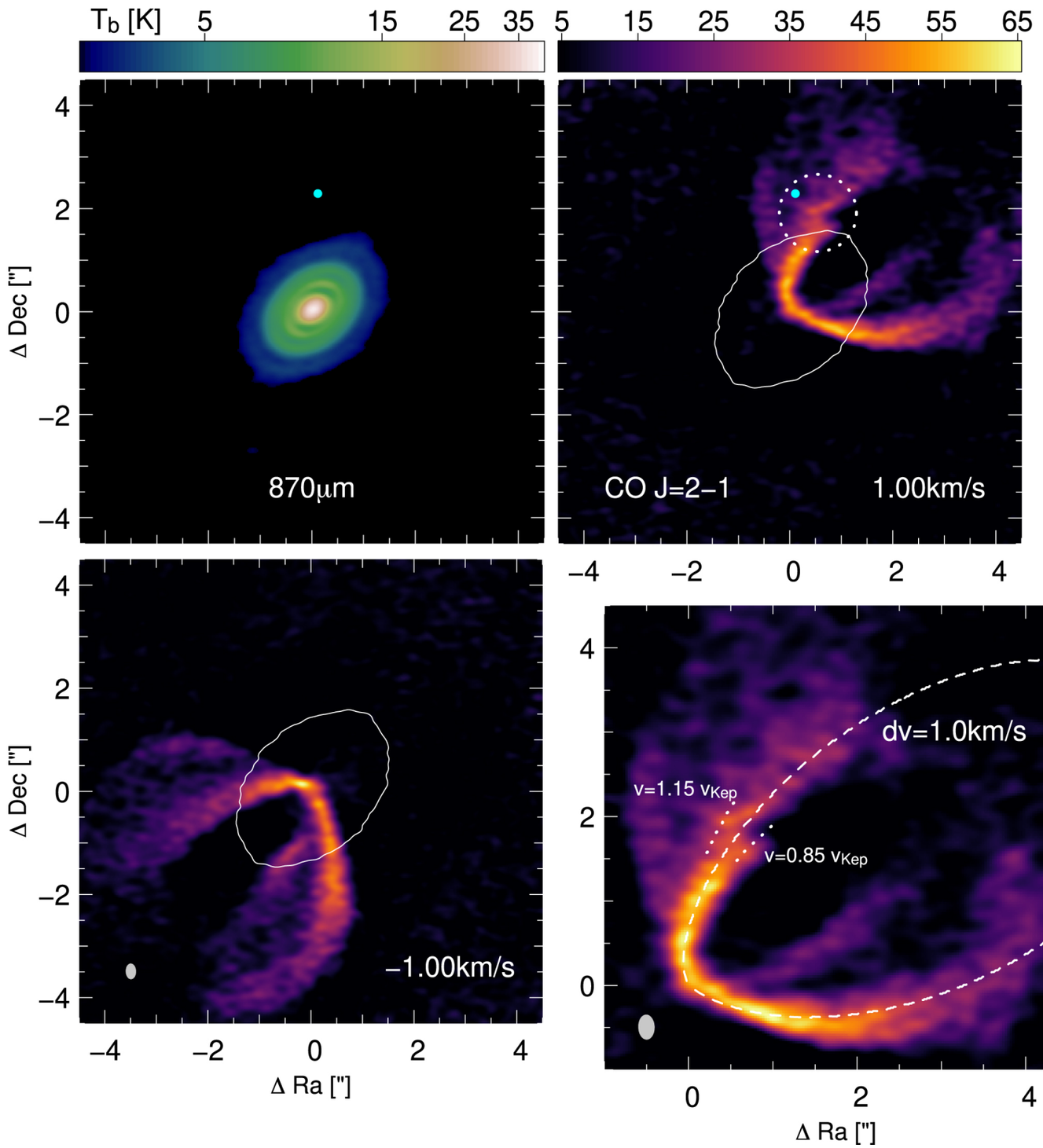
# Misaligned inner disks




**J1604-2130**

Mayama et al. 2018

# Finding planets: gas




## HD 163296

Pinte et al. 2018