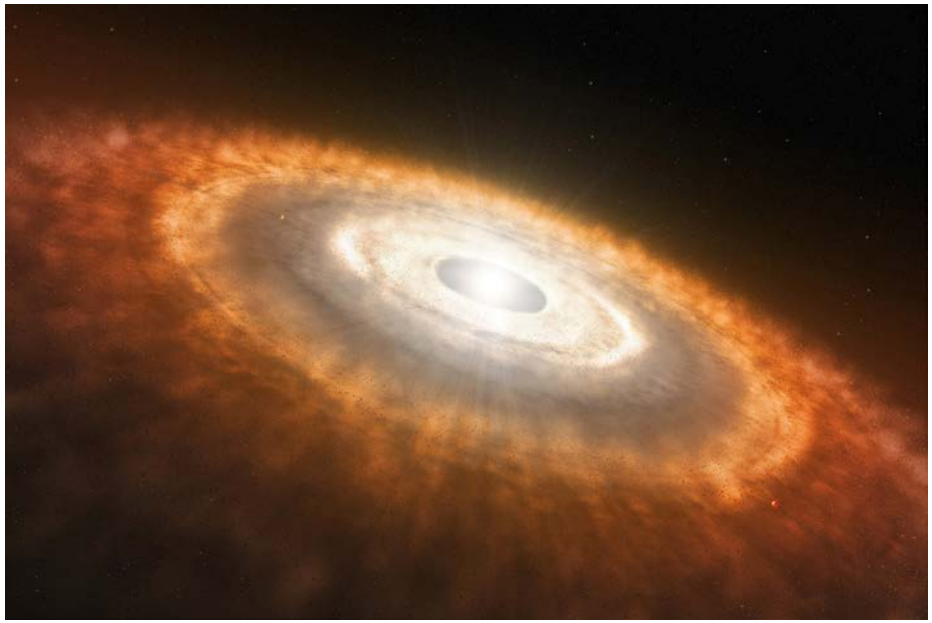
Subaru 20th Anniversary Conference
Nov. 19th, Kona, Hawaii

Multi-wavelength High Resolution Observations of Protoplanetary Disks

Takayuki Muto
(Kogakuin University)

Protoplanetary Disk

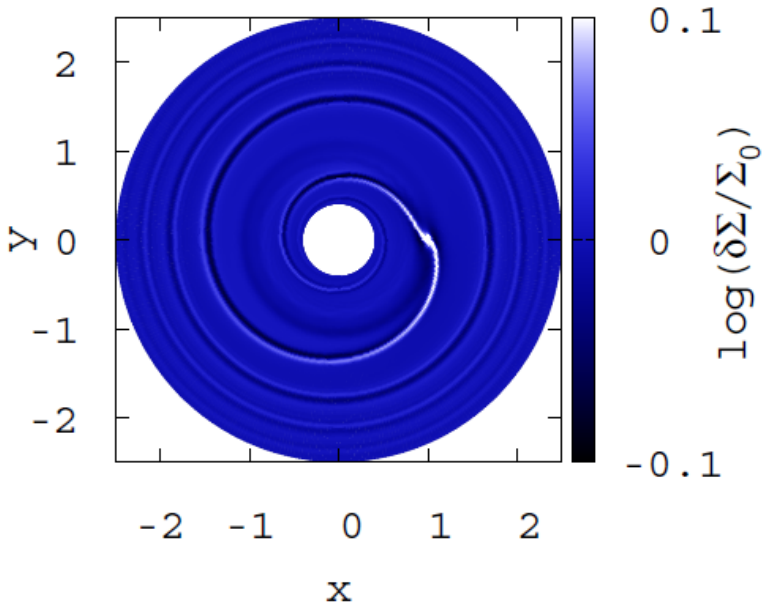


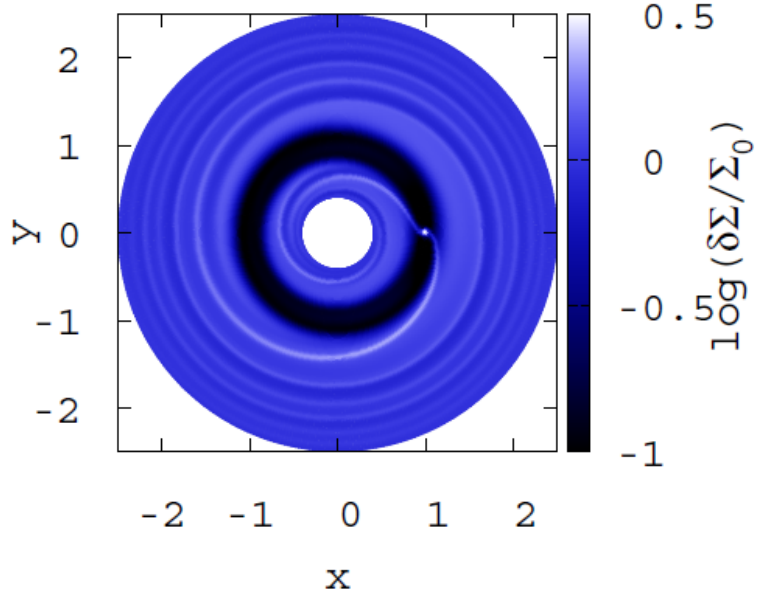
- Birthplace of planets
- ~100au scale at >140pc
- Imaging with <0.1asec

Image credit: L. Calçada / ESO

Protoplanetary Disk Imaging

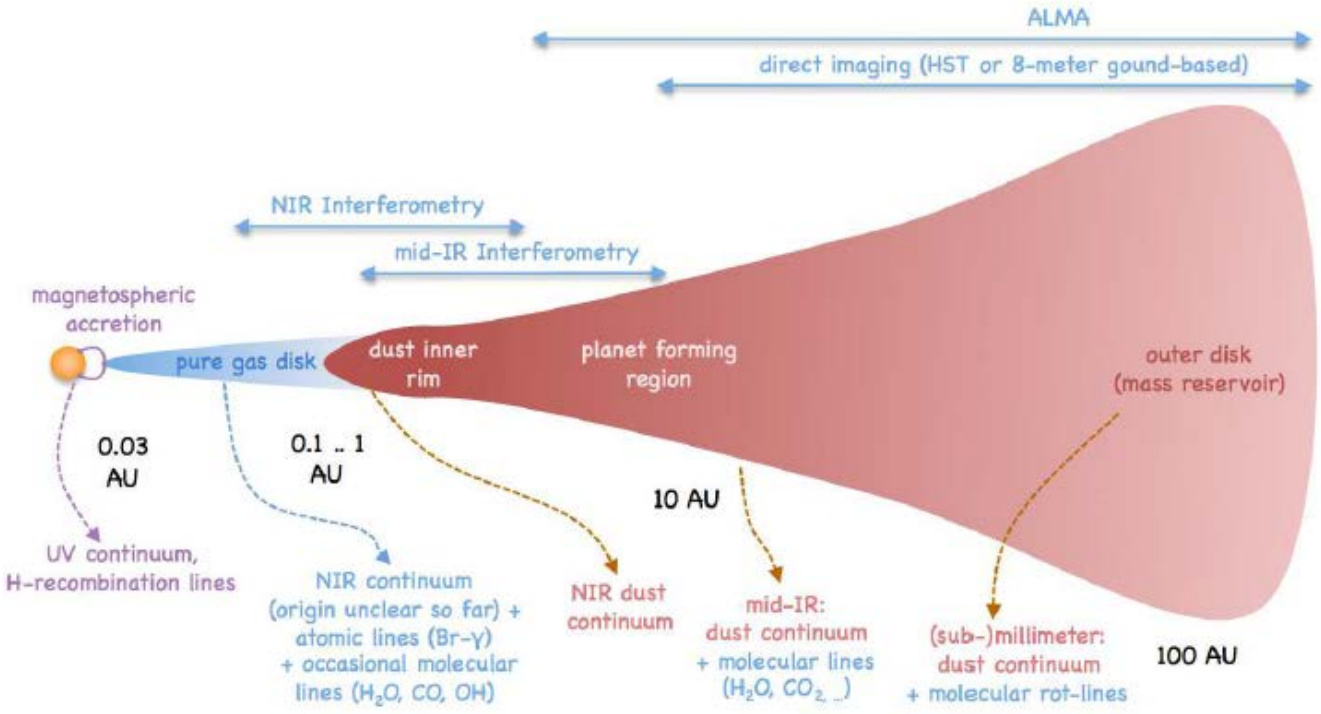
- Disk substructure and disk dynamics
  - Identify structures associated with disk dynamics
  - (Indirect) signature of planets
- Inner disk structures
  - Structures at “solar-system” scales





Multiwavelength Disk Imaging

- Disk component
  - Gas ➔ mainly with sub-mm, velocity structure
  - Dust ➔ NIR scattered light and sub-mm thermal emission



Dullemond and Monnier 2010

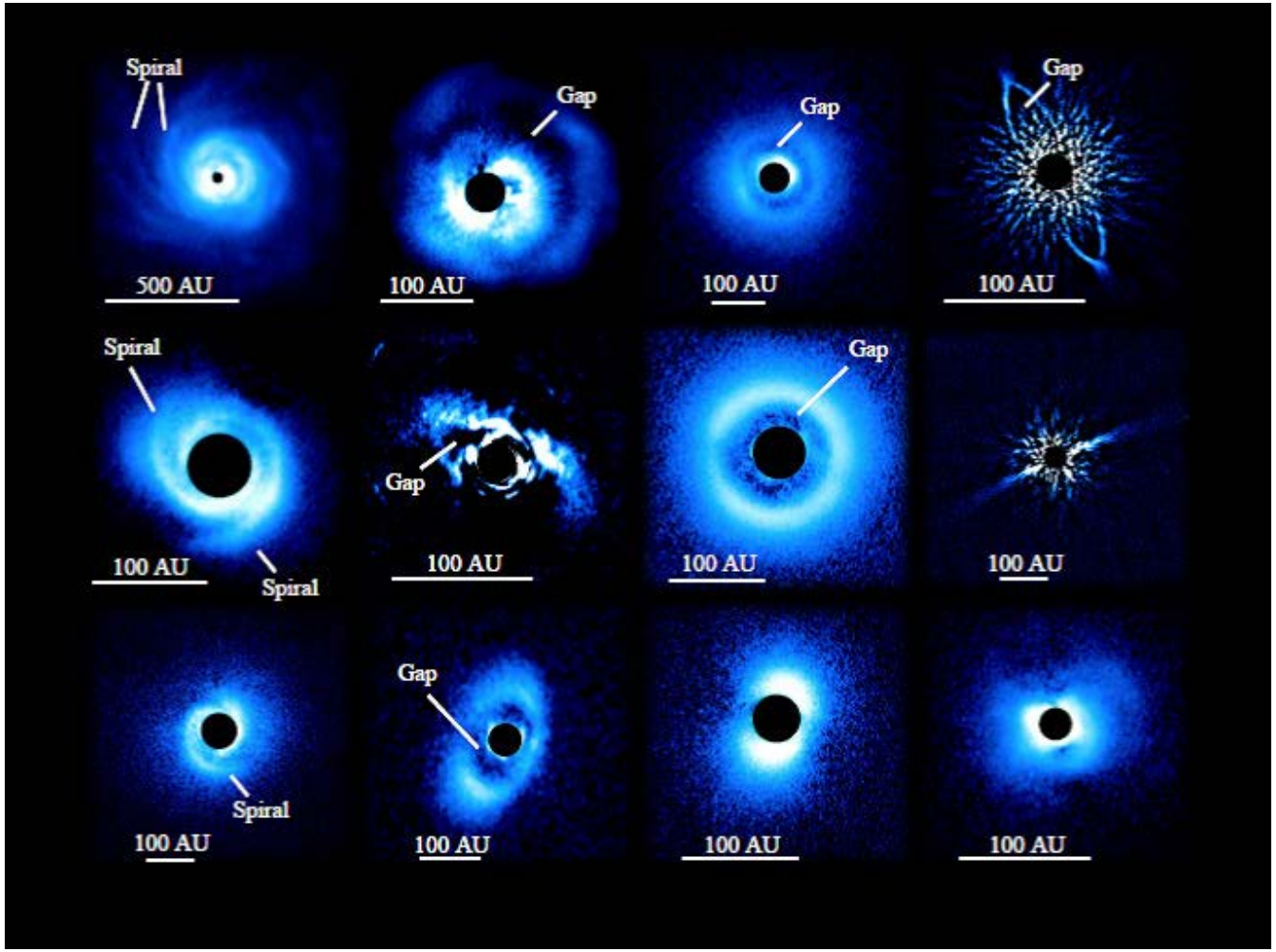
Spatial Resolution

- λ=1.6um with d=8m telescope (Subaru)
  - ~0.04asec ~ **6au at 140pc**

- λ=1mm with d=10km telescope (ALMA)
  - ~0.02asec ~ **3au at 140pc**

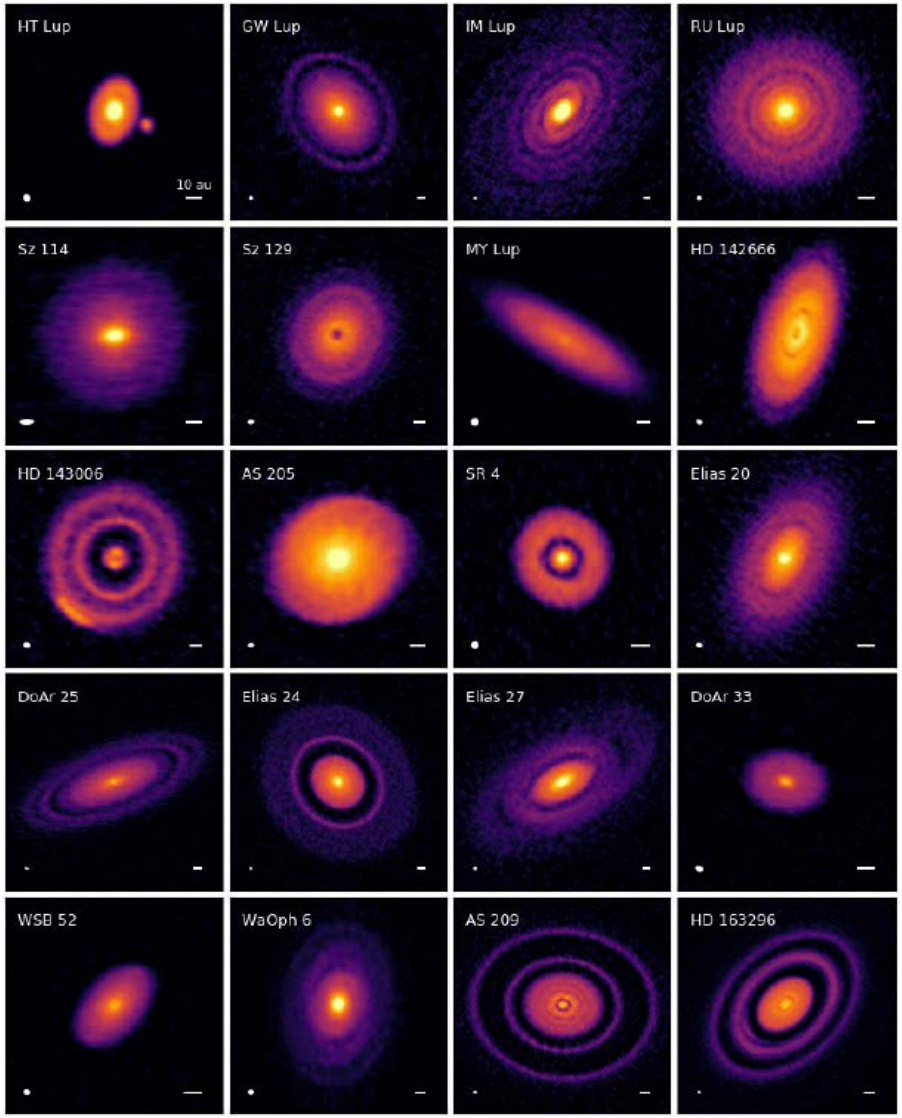
- **Spiral / gap structures by a planet at <30au**
- **Overall disk structures at <~10au**

High Resolution Obs. at NIR



Credit: NAOJ
https://subarutelescope.org/Pressrelease/2013/08/04/j_index.html

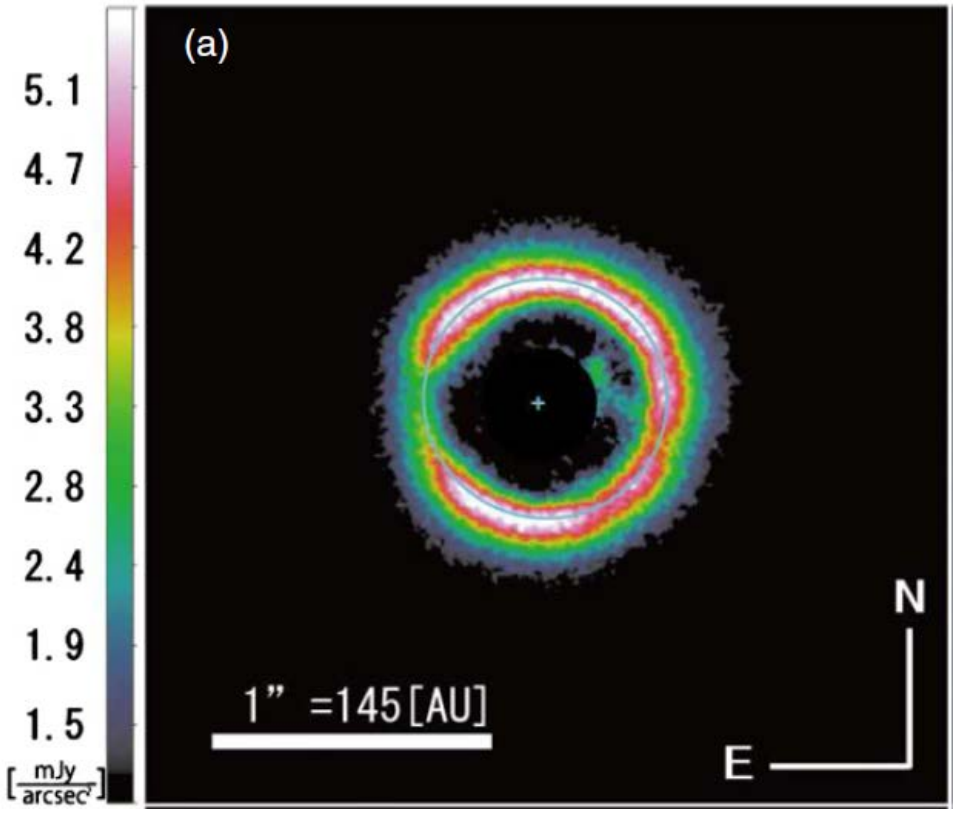
High Resolution Obs. at sub-mm



- Many ring-like structures
- Some asymmetries

Andrews et al. 2018

Case Study of Inner Disk: J1604

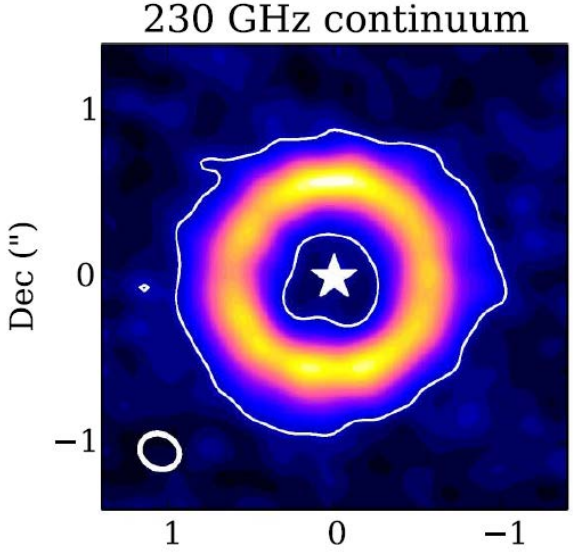


- In Usco OB Assoc.
- SpT: K2, M~1Msun
- Age ~ 4Myr
- Mdot ~ 10^{-9} Msun/yr

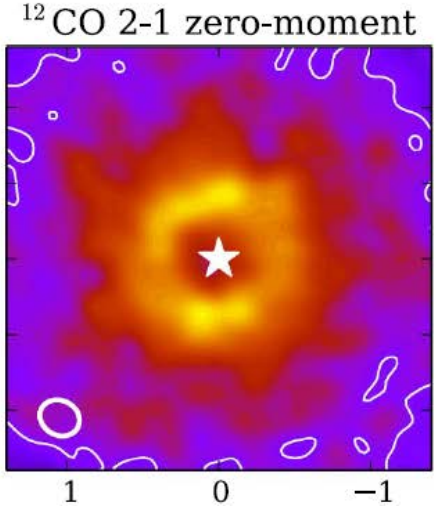
- NIR "ring" with Subaru
- R~63au

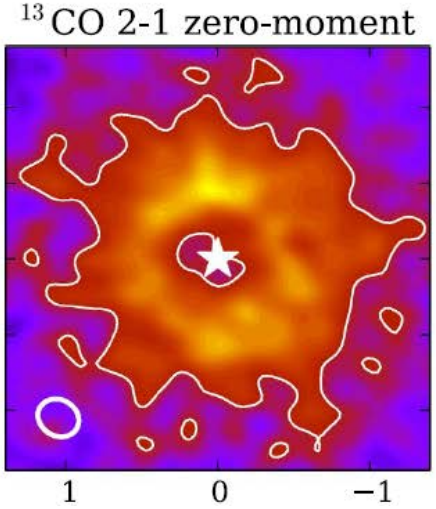
Mayama et al. 2012

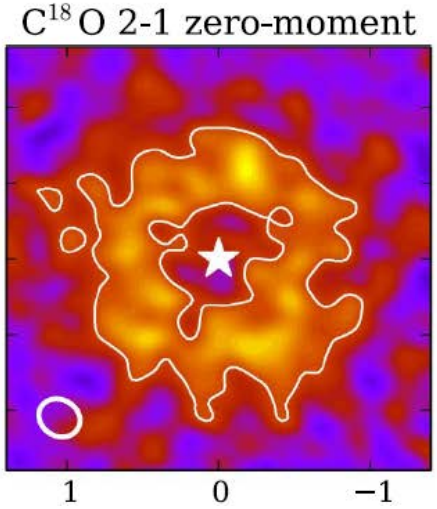
J1604 ALMA Obs.



- ~0.25asec~40au resolution
- Ring in dust and gas
- Different radii/profiles for different probes

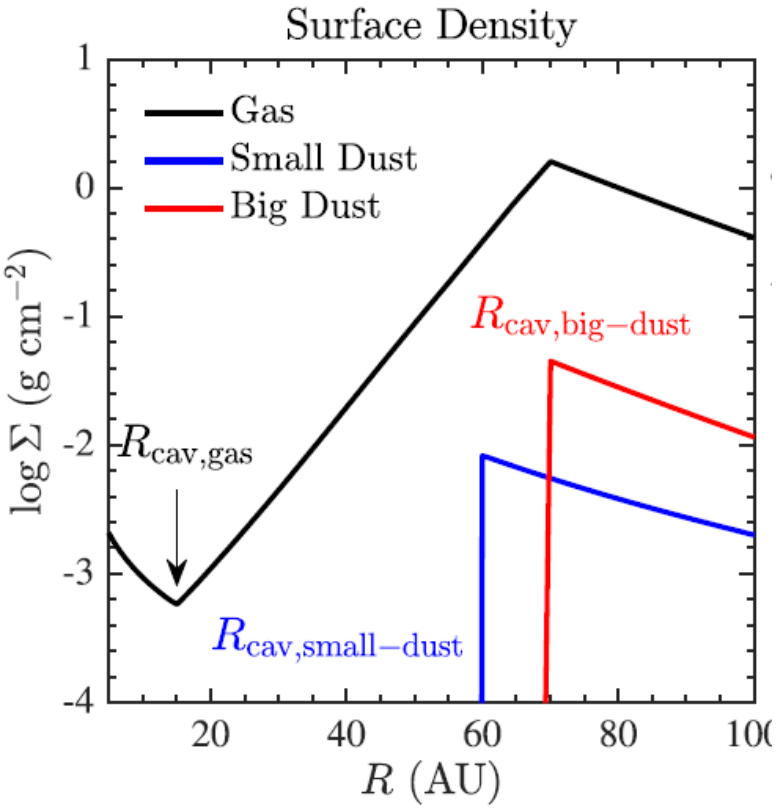






Dong et al. 2017

Distribution of Dust and Gas

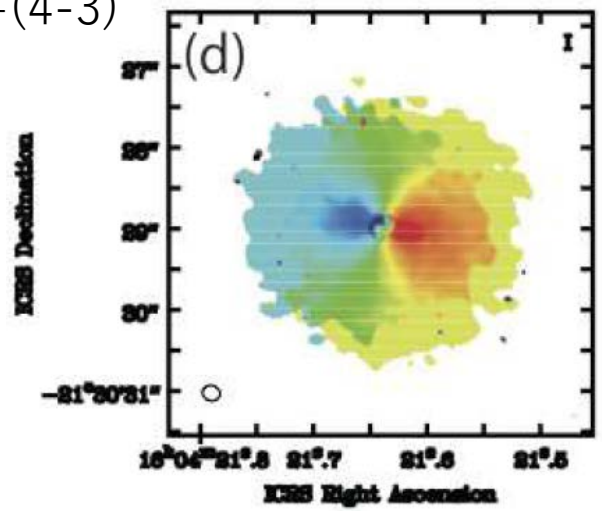


- Relatively smooth gas distribution
  - Planets?
- Sharp cutoff for dust distribution + low accretion rate
  - Photoevaporation?

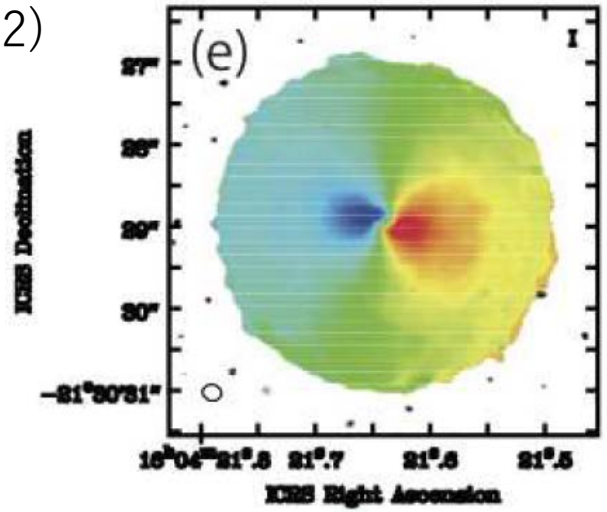
Dong et al. 2017

Inner gas structures

HCO+(4-3)



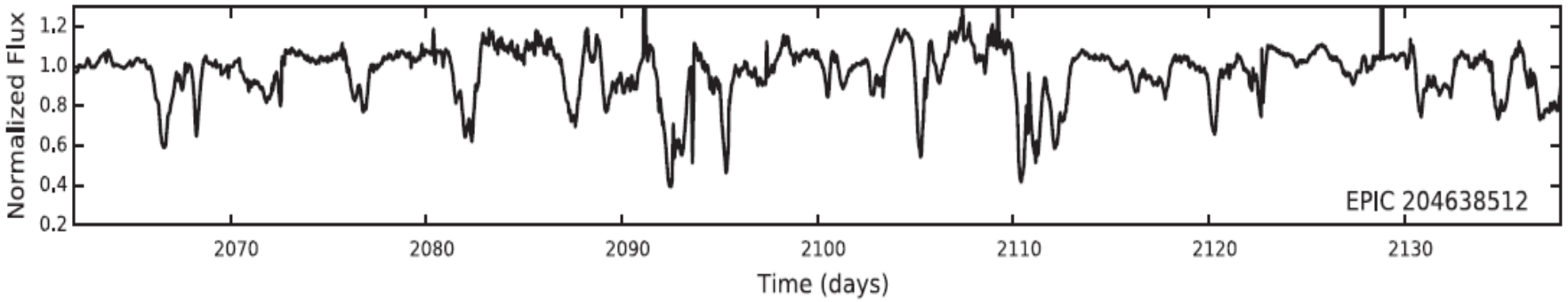
CO(3-2)



- Another ALMA obs. with ~0.2asec~30au resolution
- Velocity twist in the inner gas disk
- Misaligned inner disk?

Mayama et al. 2018

Dipper Phenomenon

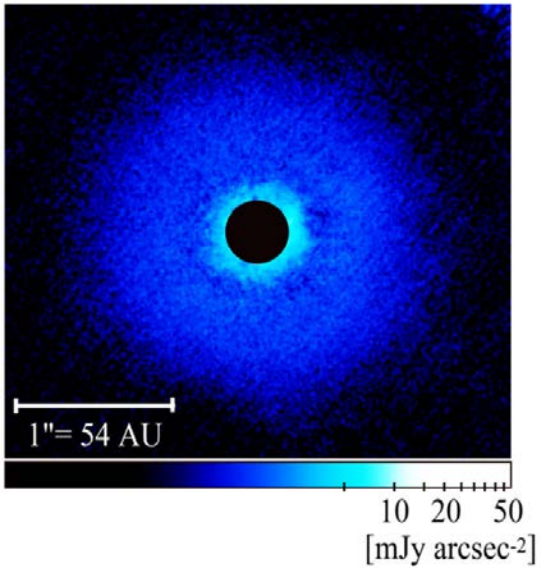


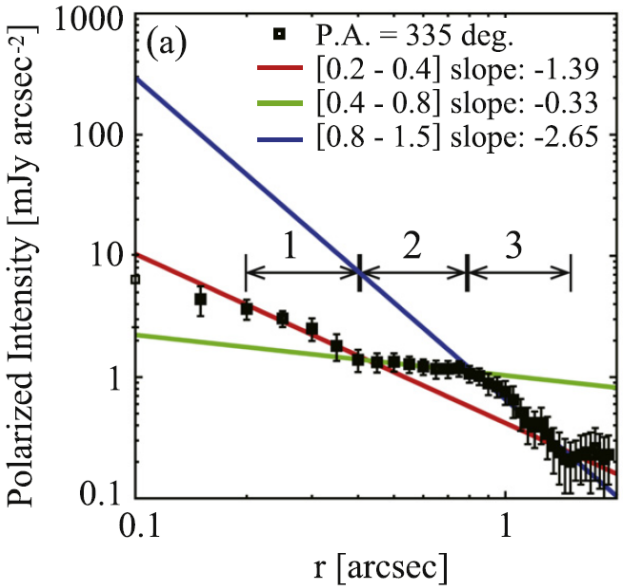
- Irregular light curve
  - Occultation by an inner disk
  - Should be inclined relative to the outer disk

- Consistent with the velocity structure?

Ansdell et al. 2016

Case Study of Planet(?): TW Hya

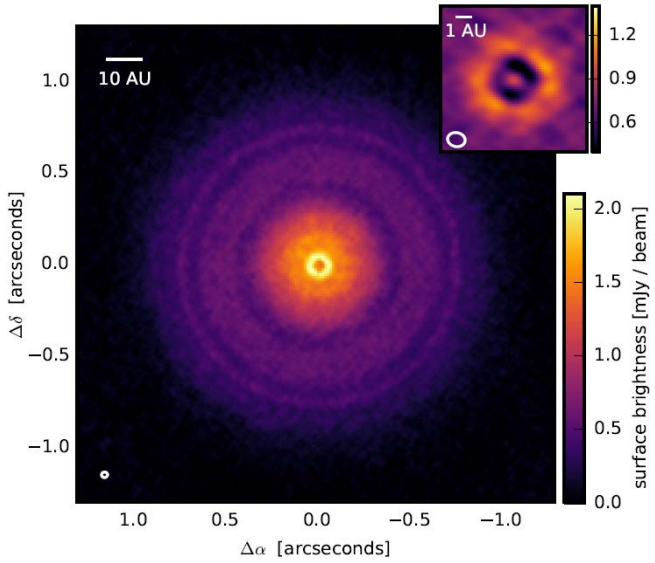


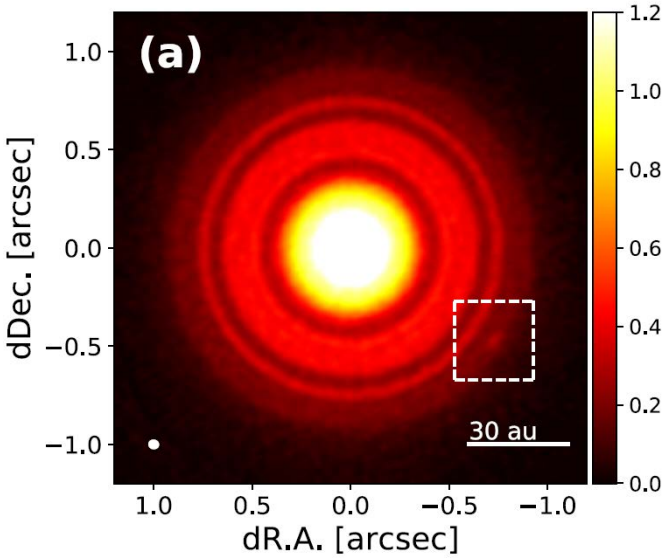


- Nearest (d~50pc) protoplanetary disk
- NIR image @ H-band
  - Different radial slope
  - Transition at ~20au
  - Strong flaring at 20-40au?

Akiyama et al. 2015

ALMA High Resolution Images



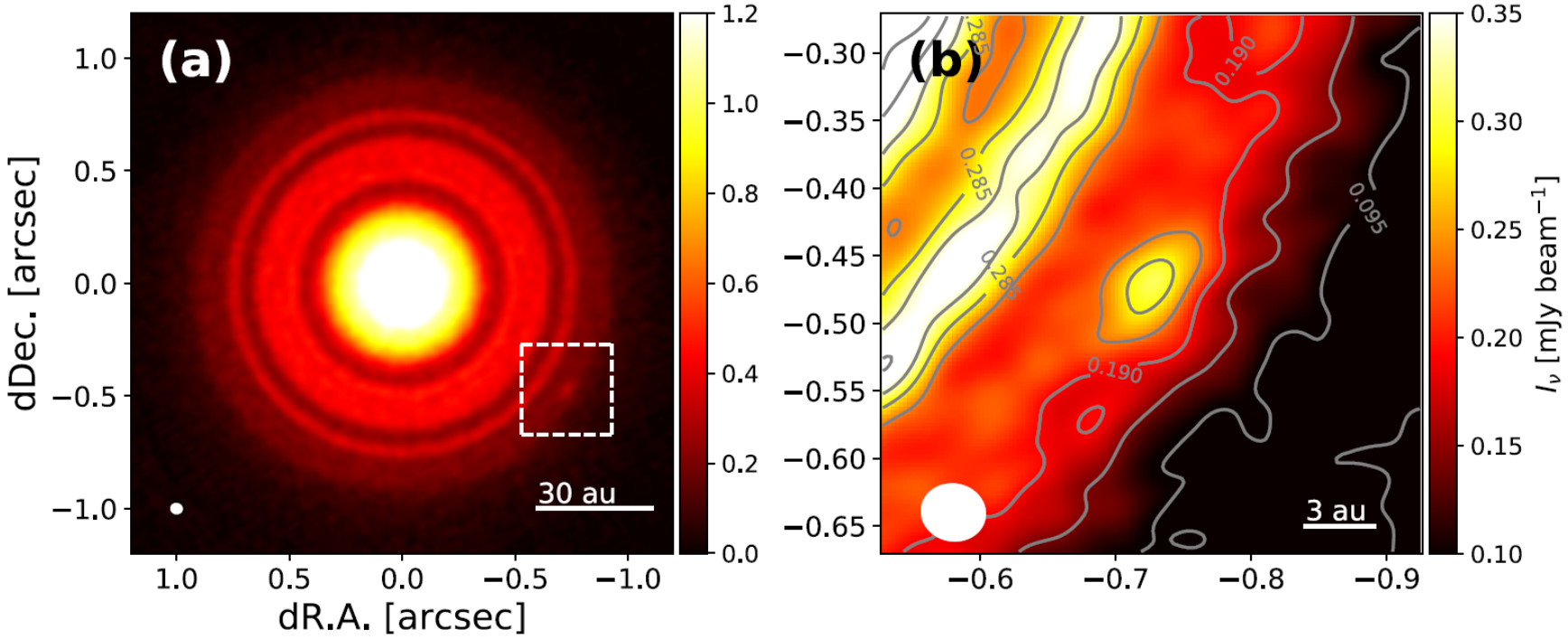


- ~1au resolution image at Band 7
- ~3au resolution image at Band 6

- Multiple gap structures
- Point source at ~50au

Andrews et al. 2016
Tsukagoshi et al. 2016, 2019

Point source? without a gap?

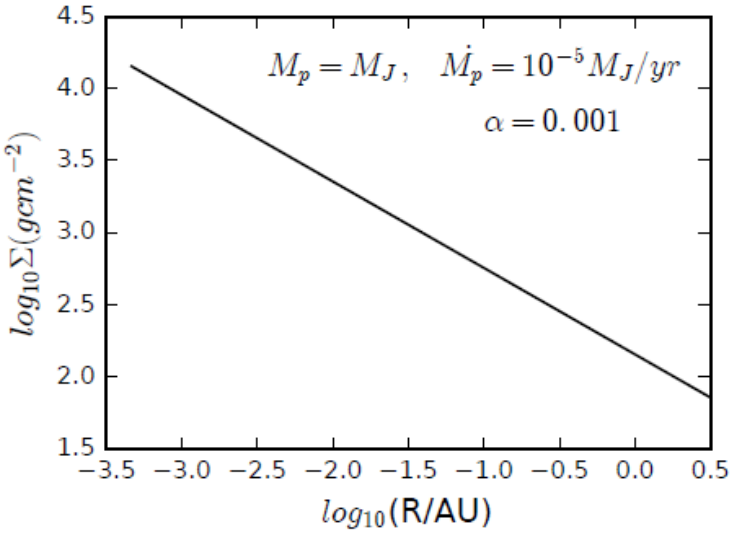


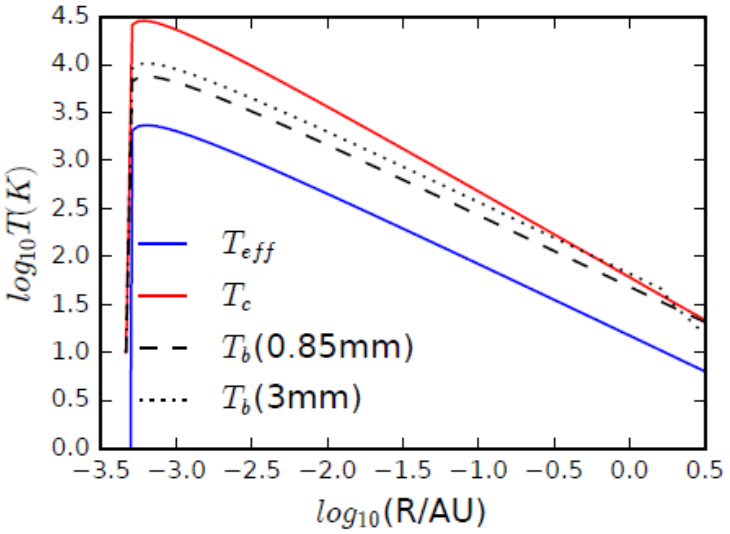
- Azimuthally elongated ~1au x 4au
- Circumplanetary disk? Dust clump?
- No gap: “planet” should be <Nep. mass

Tsukagoshi et al. 2019

CPD should be observed at NIR-MIR

- Gas accretion onto a planet
  - Gas temperature may be as high as ~1000K
- Sub-mm emission is from “cold” outer region of a circumplanetary disk
  - Emission looks similar to “dust clump”





Zhu et al. 2017

(Near) Future Scope of High Res. Imaging at NIR

- Inner disk
  - J1604: Warped inner disk in an inner hole
  - Better inner working angle?

- (Accreting) Planets in a disk
  - PDS70: NIR point source in a *gap*
  - TW Hya: sub-mm small source in a *disk*
  - Search for accretion signature – Halpha?