

A 1987 view: Shu, Adams & Lizano, ARAA 25, 23

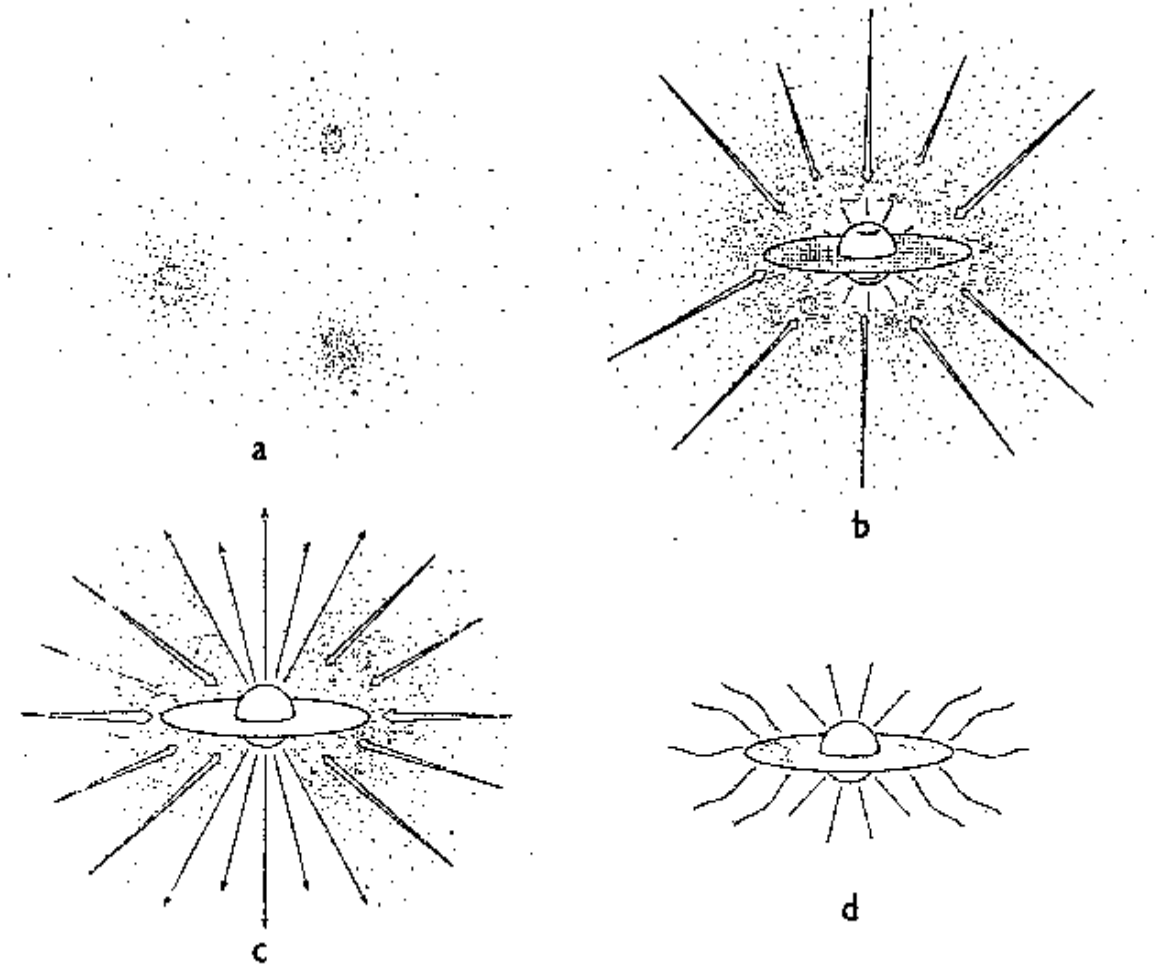
a) Pre-stellar core

b) Gravitational Collapse,
disk formation

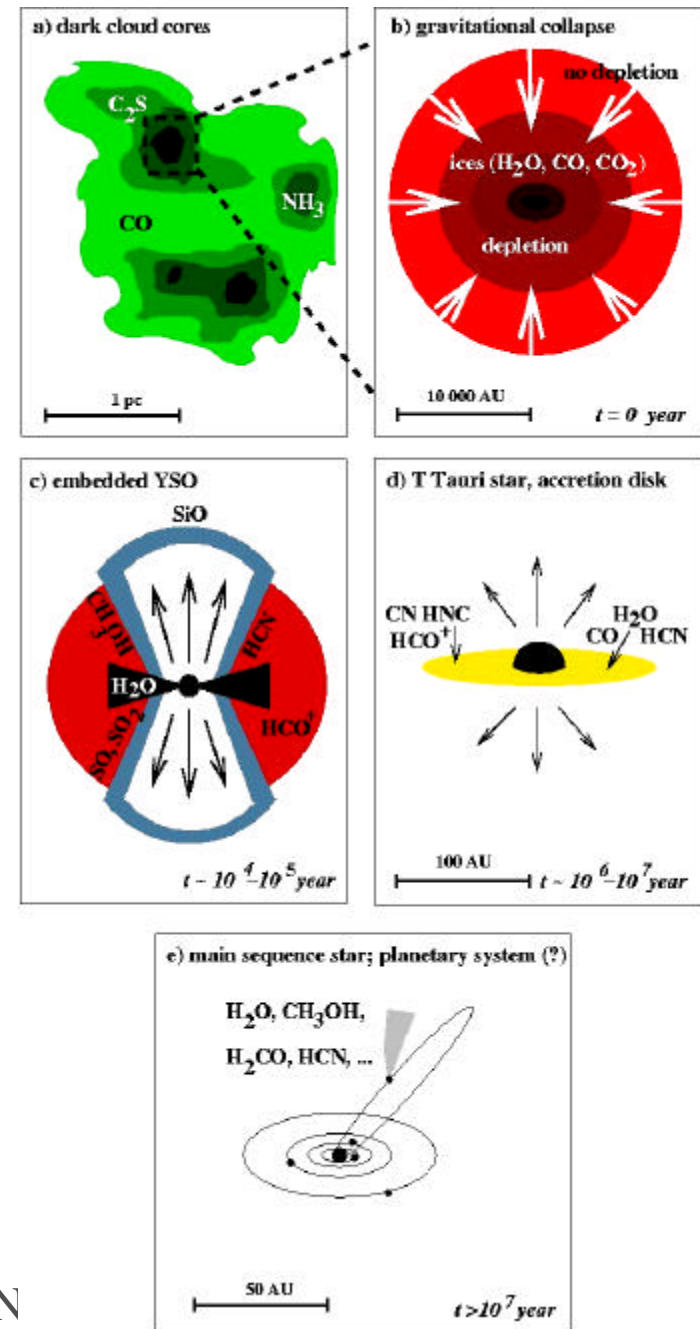
c) Outflow, accretion continues

d) Classical TTS

(Solar-mass stars)



A more modern picture:



Resolution and sensitivity!!!



➤ **The initial conditions of star formation**

- **Structure of interstellar clouds**
- **Millimeter absorption spectroscopy**
- **Dense pre-stellar cores**

➤ **Young stellar Objects**

- **The structure of protostellar envelopes and disks**
- **Outflows**
- **Fragmentation and multiplicity**
- **Dispersal of circumstellar material**
- **High-mass star formation**

➤ **Chemistry of star-forming regions**

- **Cold collapse envelopes**
- **Embedded phase and outflows**
- **Hot cores**
- **Photon-Dominated Regions**

➤ **Protoplanetary disks**

- **Massive protoplanetary disks around PMS stars**
- **Dispersal of dust and gas in disks**
- **Debris disks and zodiacal light systems**
- **Chemistry in protoplanetary disks**



- **Dense cores:**
the collapse phase

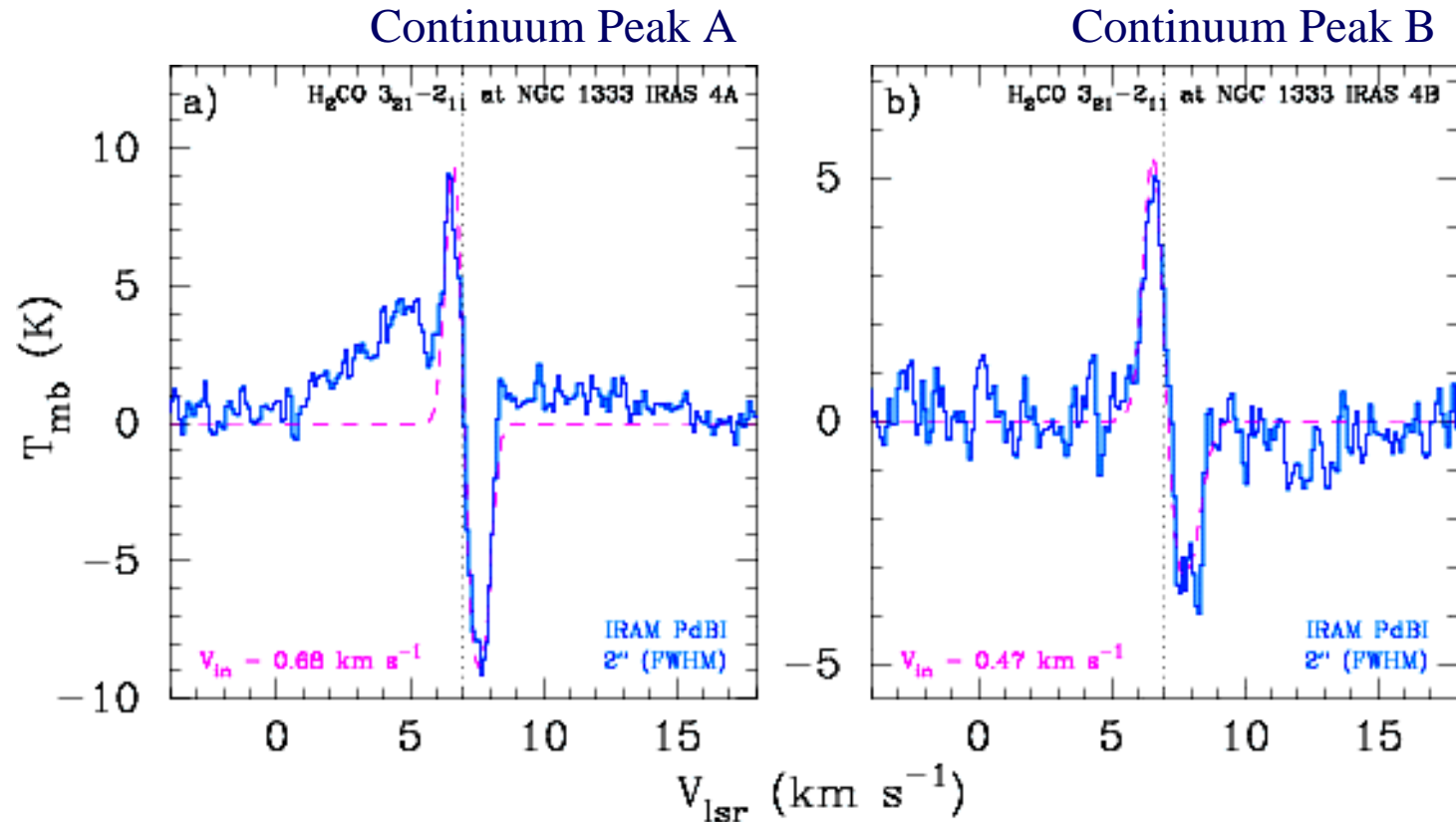
- **Brown dwarfs and below:**
formation mechanisms

- **Disk evolution:**
toward planet formation



Evidence of collapse in NGC 1333 IRAS 4

- At least four very embedded objects within 30''
- D~350 pc



[Di Francesco et al. 2001]

PdB, 2arcsec beam



Antonella Natta, Science with ALMA, Garching, November 8, 2002

What will we gain with ALMA:

- Higher spatial resolution
 - probing the innermost regions, where the infall velocity is higher
 - detecting the accretion disk
- Higher frequency
 - access to lines that probe higher density/temperature
 - Eliminate confusion with cloud material
 - Get a statistically significant sample
 - See the disk in its early phase

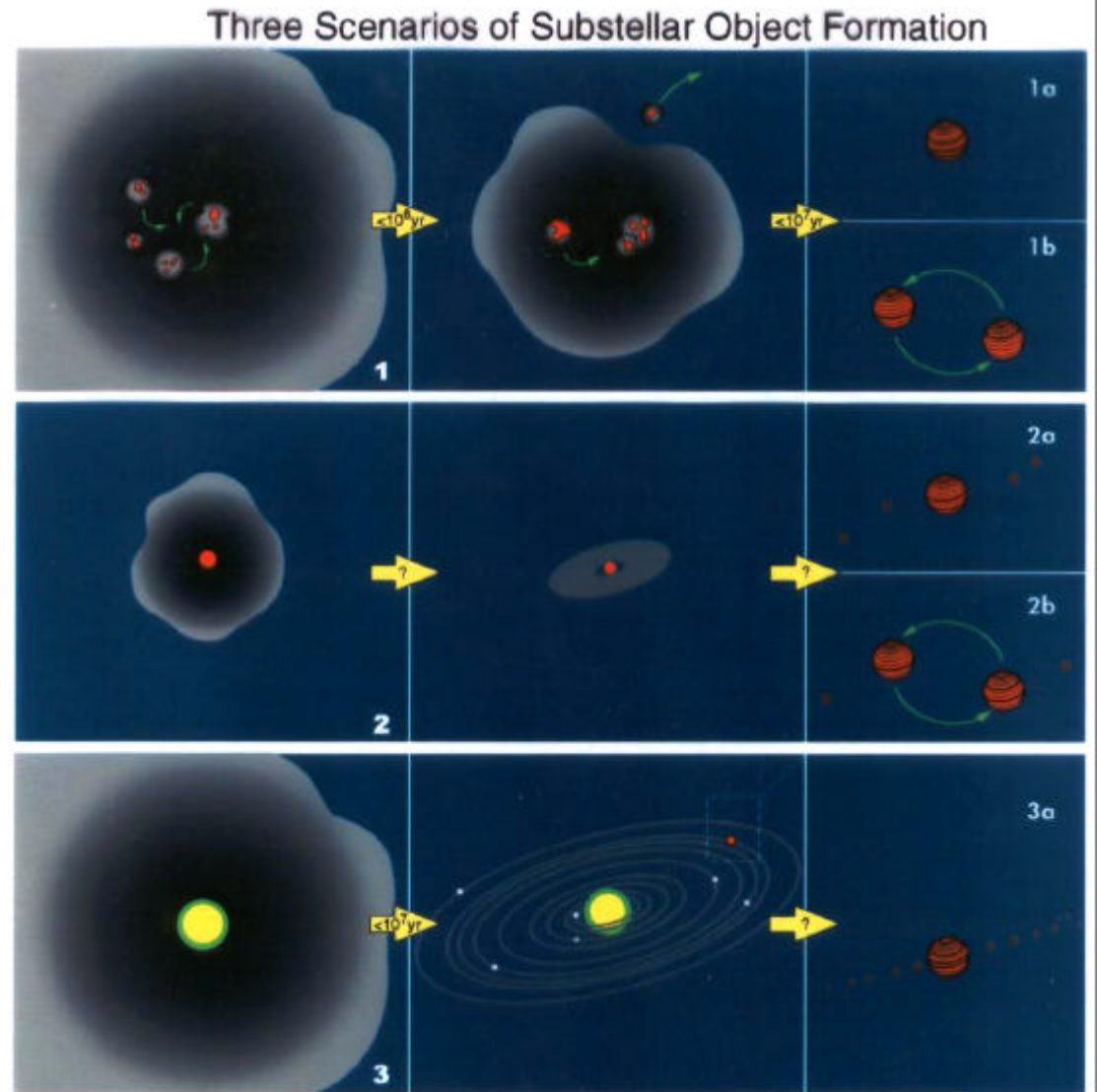


Brown dwarfs and planetary-mass objects

➤ Many in star-forming regions
(75 M_J -- 3 M_J)

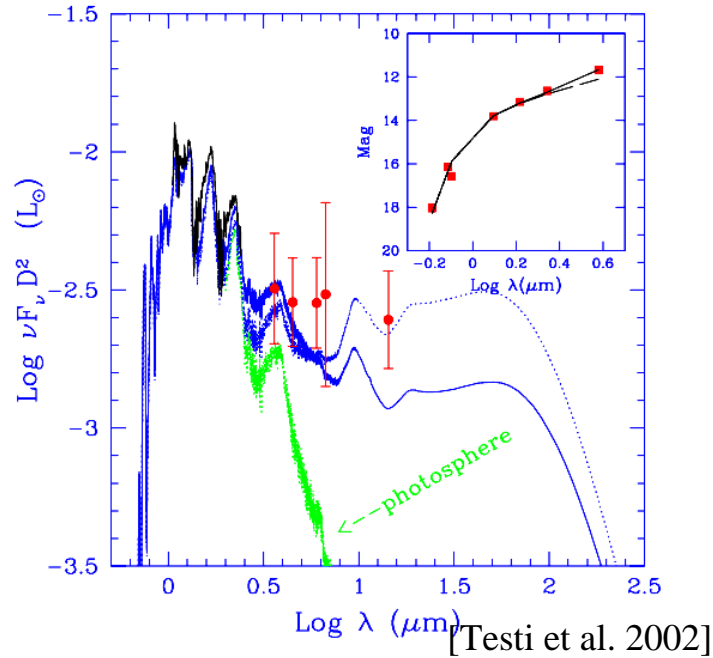
➤ How do they form?

- Frequency and properties of circumstellar disks
- Binary statistics
- IMF

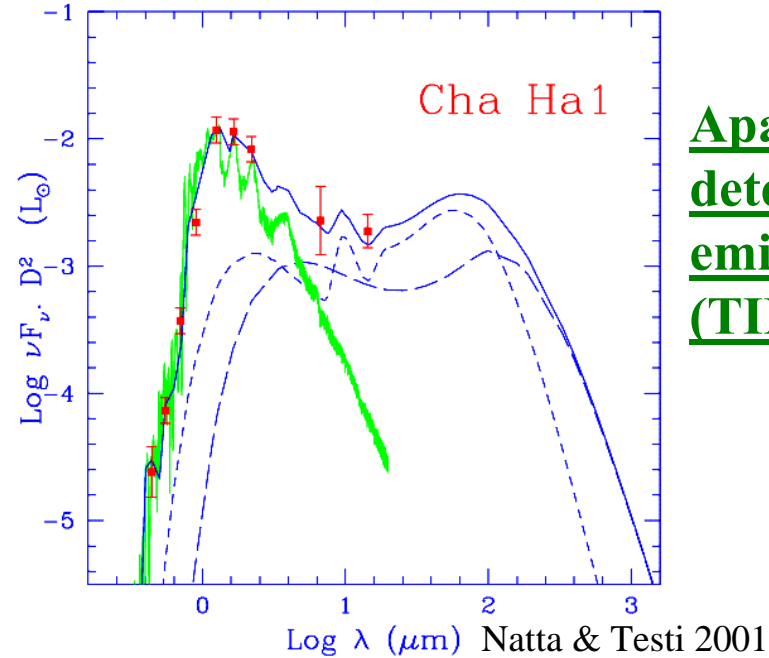


Brown Dwarfs have disks:

Ophiucus: GY11, $M \sim 10 M_J$



Chamaelion: Ha1, $M \sim 30 M_J$



Apai et al did not detect silicate emission in Ha2 (TIMMI2)

So far, no mm detection:

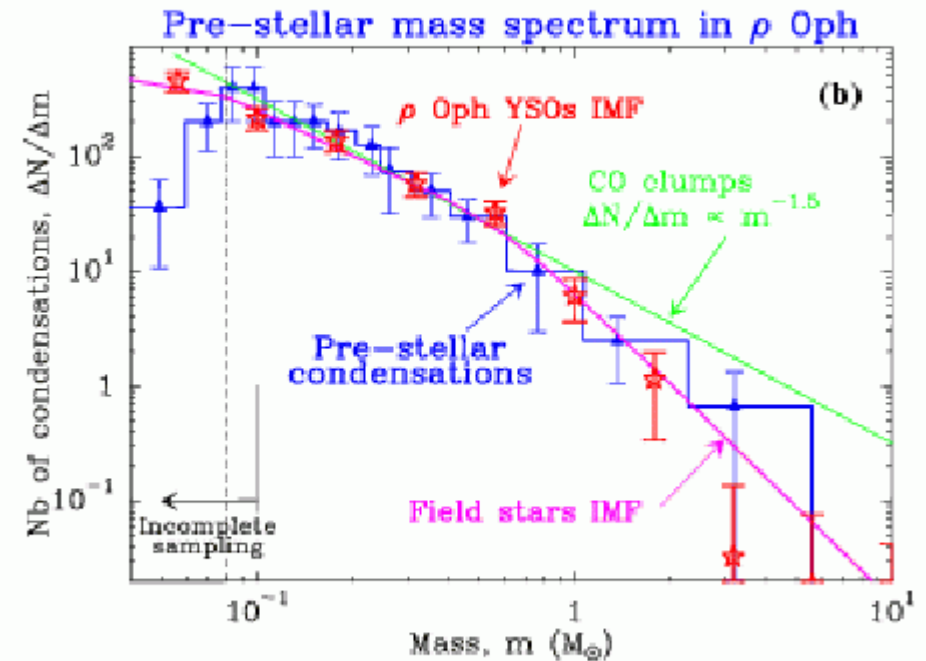
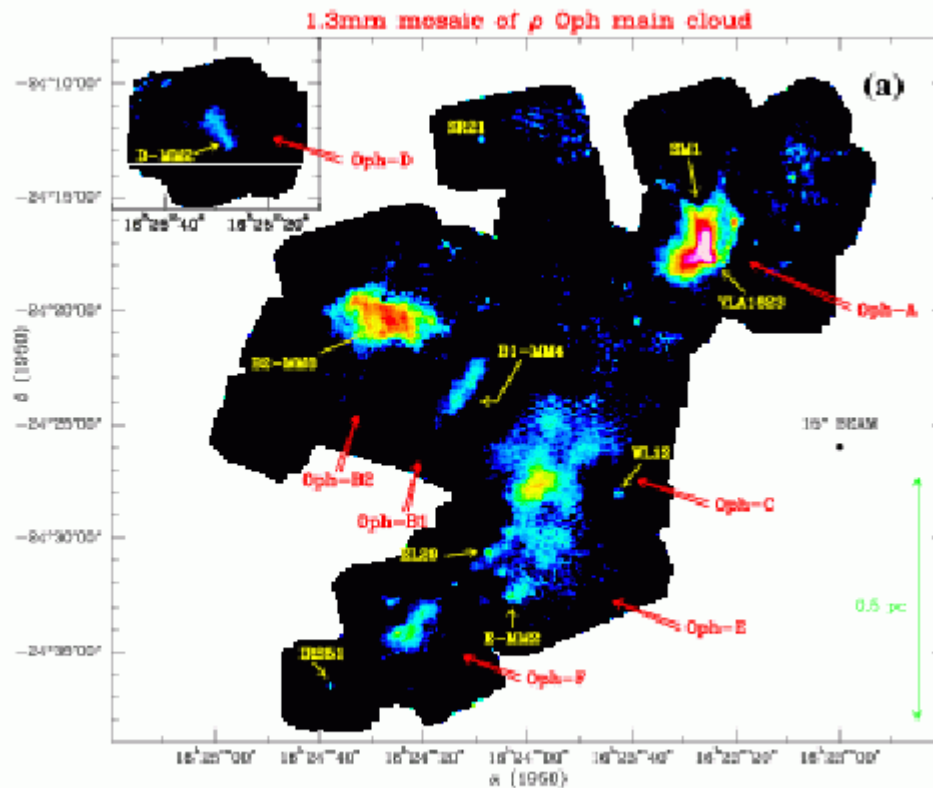
- No mass
- No size
- No discrimination between models

**ALMA: sensitivity
resolution
(confusion)
higher frequency**



Very low-mass dense cores: $M_{\text{Jeans}} \sim T^{3/2} n^{-1/2}$

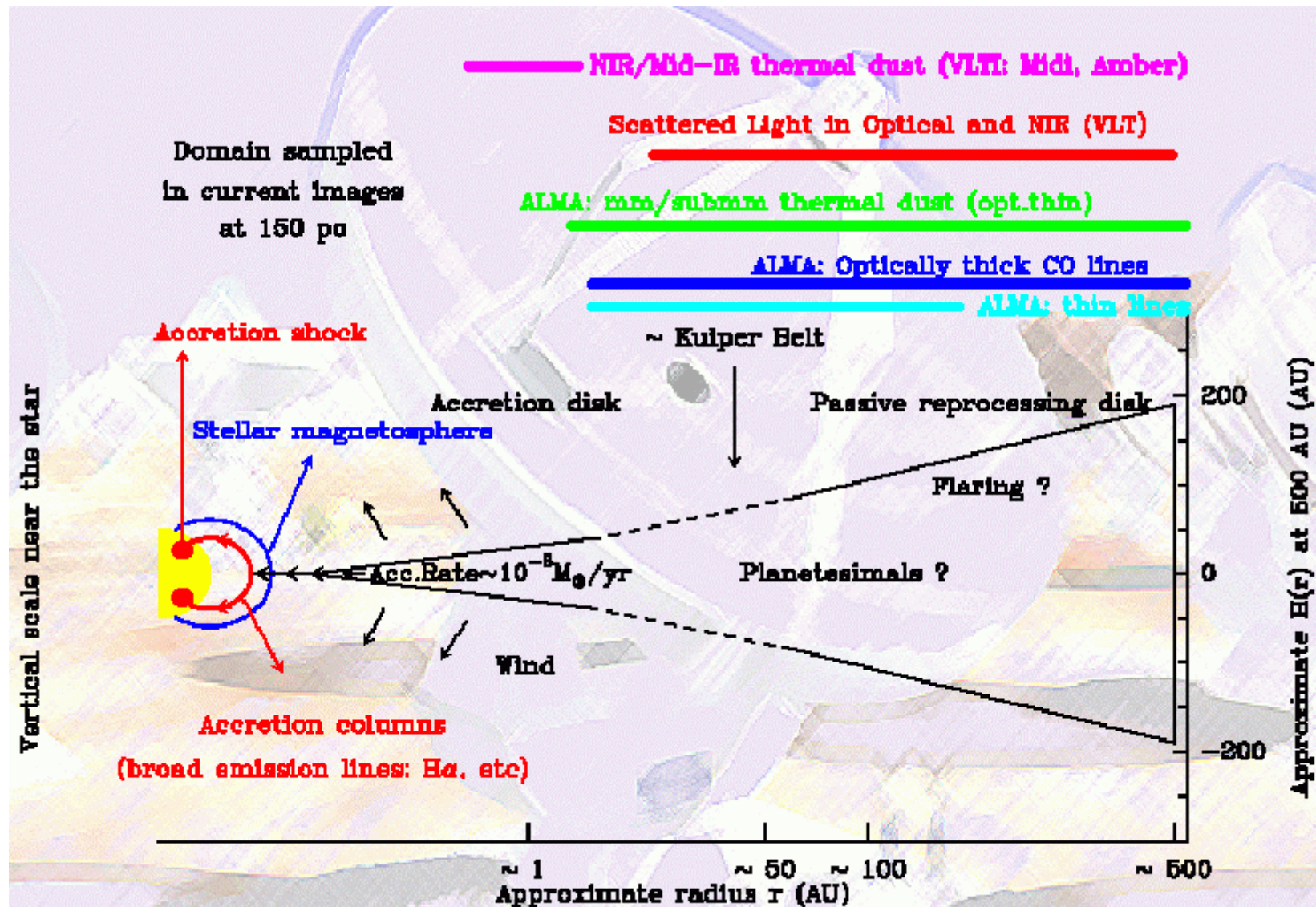
[Motte et al. 2000, IRAM 30m]



What is the lower limit?



Disk structure and evolution



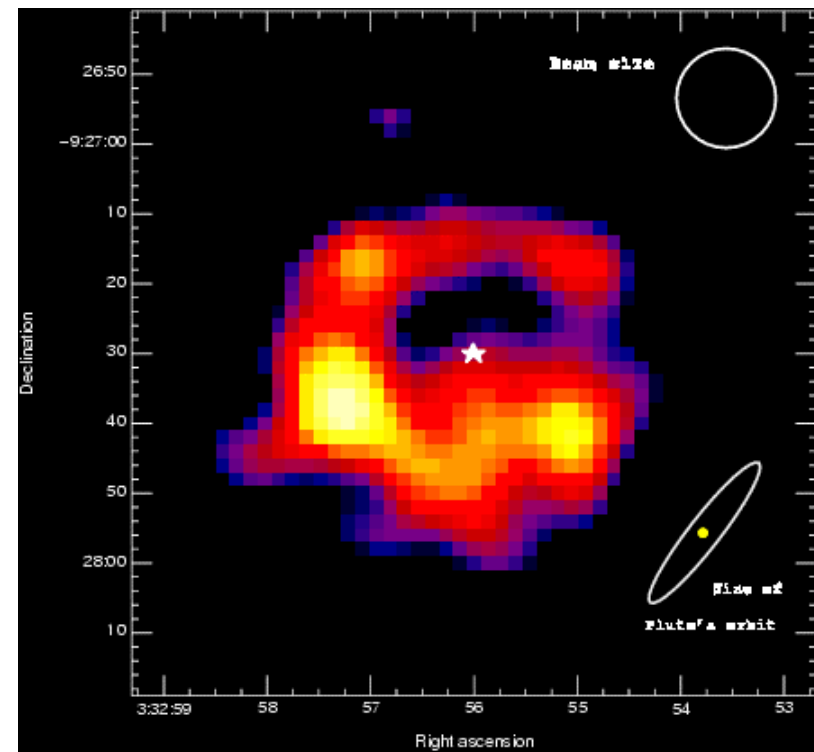
A. Dutrey, 2001

Antonella Natta, Science with ALMA, Garching, November 8, 2002

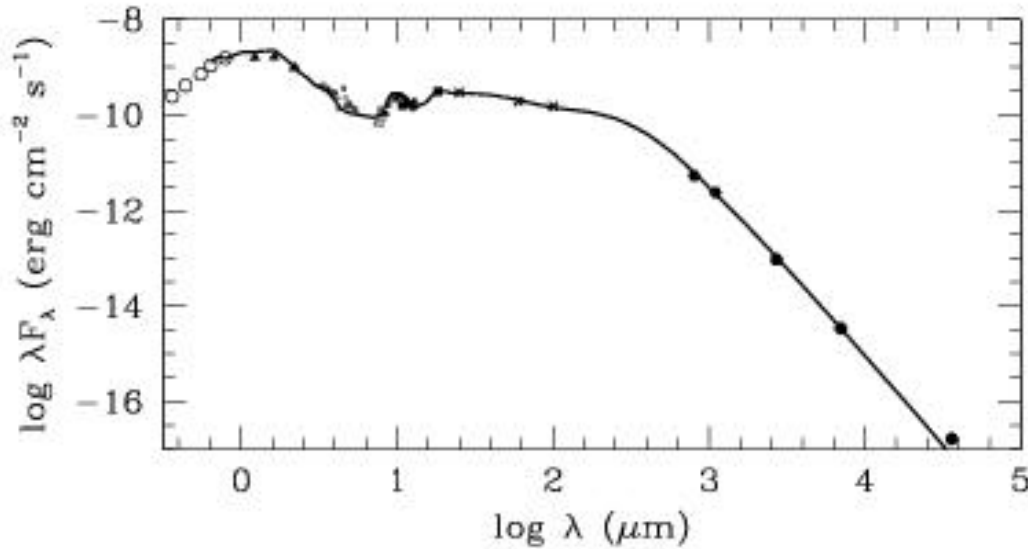


Evidence of planet formation in disks

- Grain growth to ~cm sizes by combining mm fluxes and images: first results
 - TW Hya (Calvet et al. 2002), CQ Tau (Testi et al. 2001, 2003), IRAS 04302+2247 (Wolf et al. 2002)
- Structures (in density and/or opacity) created by giant planet in dense, PMS disks or in optically thin debris disks

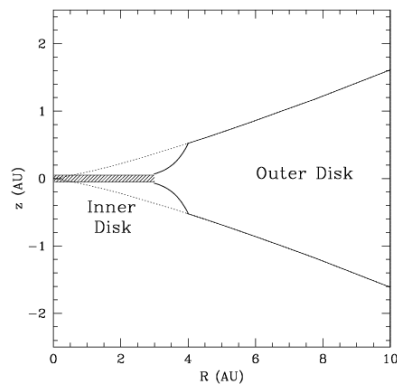
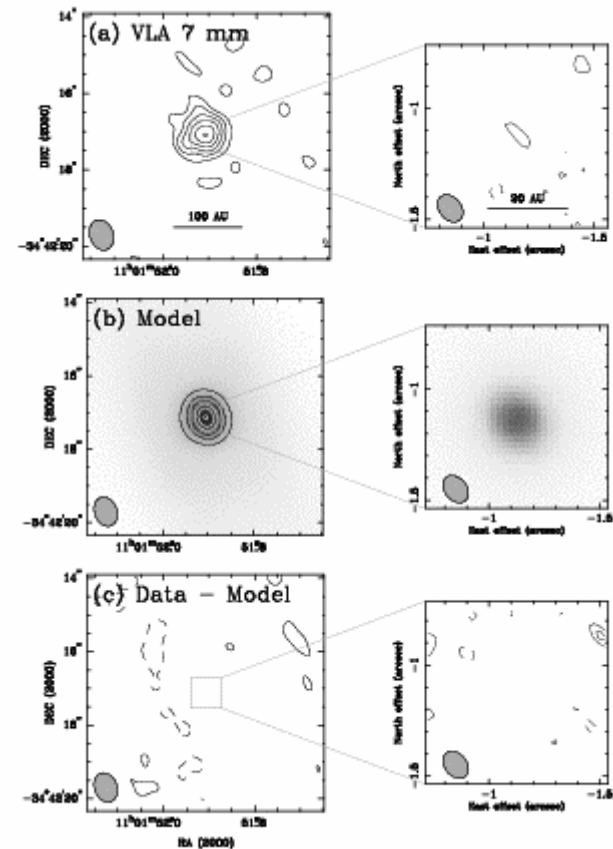


Evidence of grain growth in the outer disk: TW Hya



Wilner et al., 2000

Calvet et al., 2002



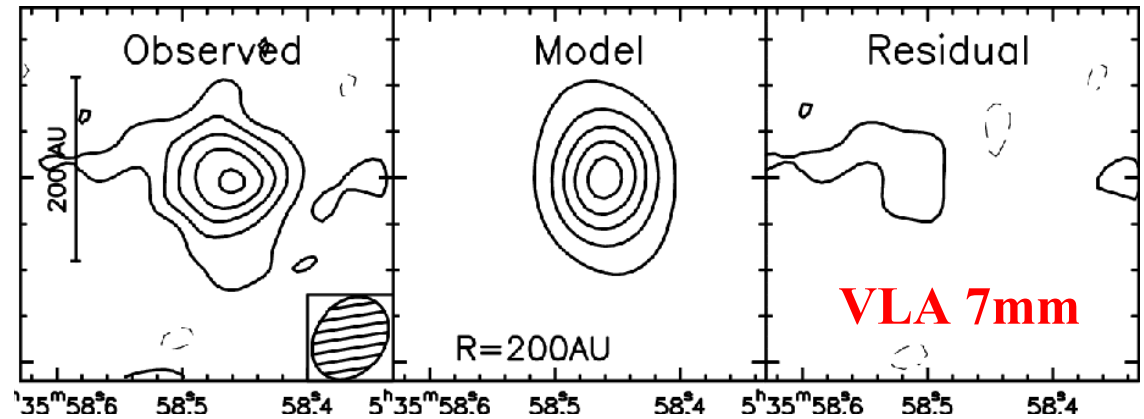
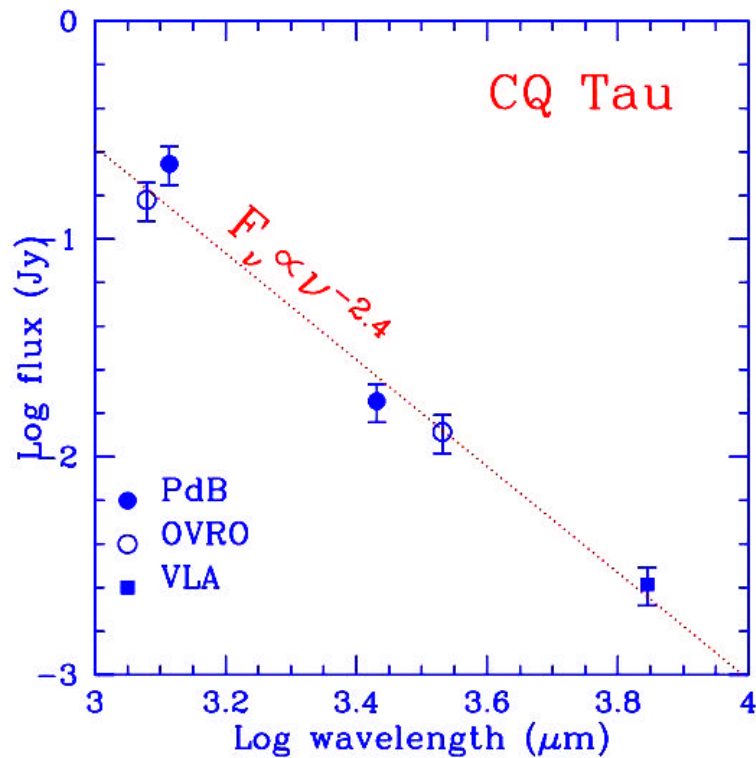
TW Hya:

$R_{7\text{mm}} > 50\text{AU}$

→ grains > 1cm



Evidence of grain growth in the midplane: CQ Tau



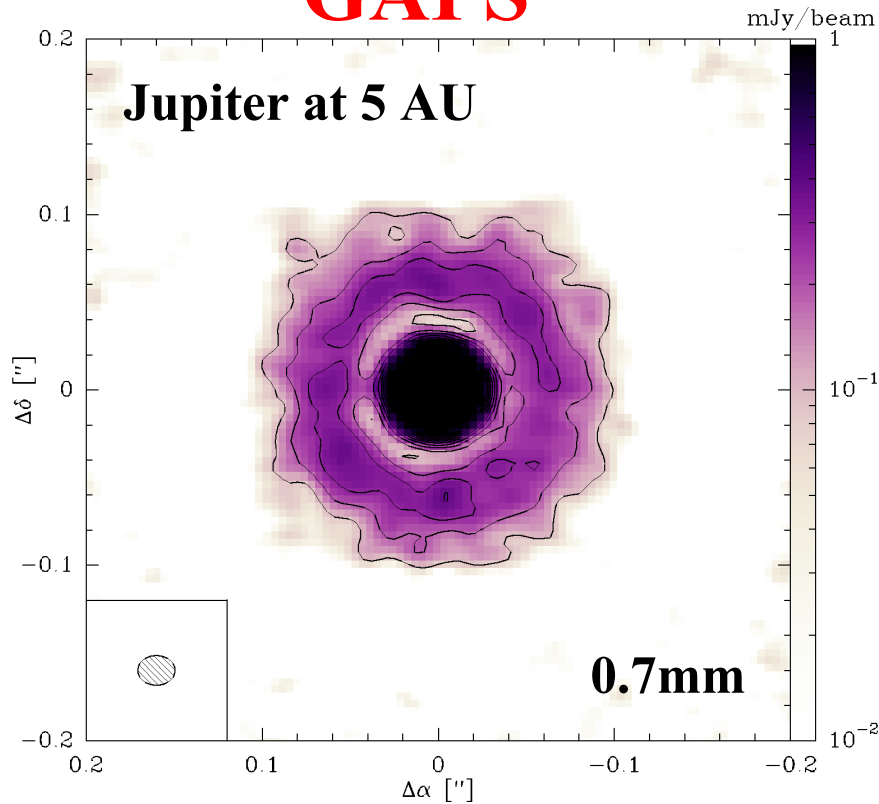
Testi et al, 2002

$a_{1.1-7\text{mm}} \sim 2.4$
 $R_D \sim 200 \text{ AU} (p=1.5)$
Dust Opacity $\sim 1^{-0.6}$



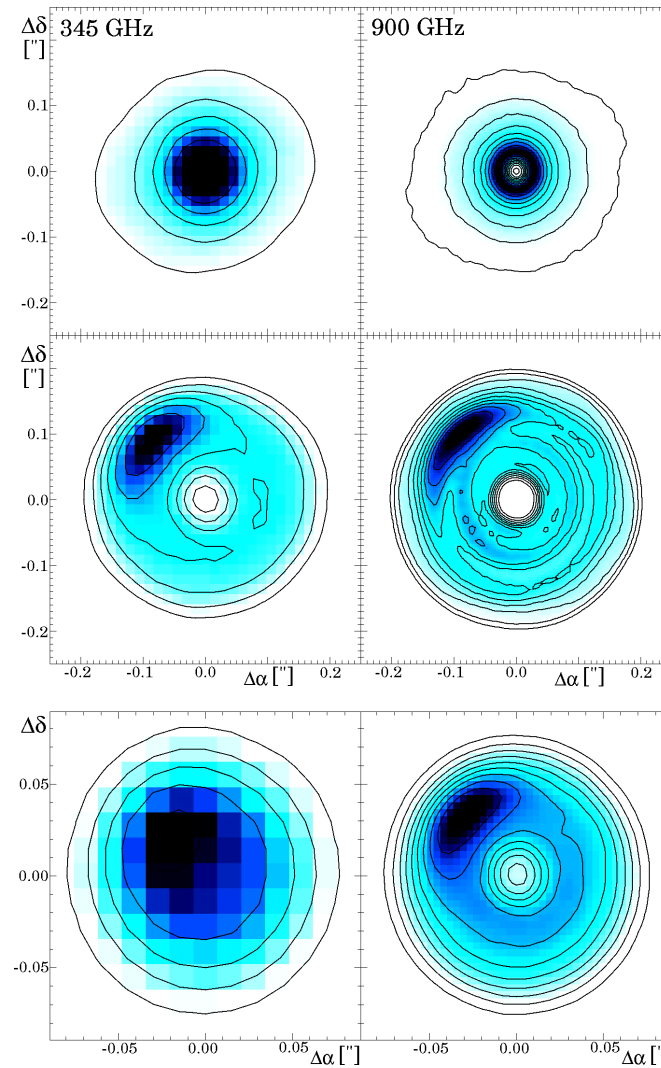
ALMA will see structures in the disk:

GAPS



[Wolf et al. 2002]

Vortices



Undisturbed,
D=50 pc

Vortex,
D=50 pc

Vortex,
D=140 pc



My idea of ALMA science in November 2002 :

- Core Collapse
 - **Map velocity and density in collapsing cores**
 - **Detect disks in the earliest phases of star formation**

- Brown dwarfs and below
 - **Measure disk frequency, mass and size**
 - **Detect (collapsing) cores of lower and lower mass**

- Disk evolution and planet formation
 - **Grain properties in disks**
 - **Detect disk structures caused by planets**



The inner disk with VLTI

