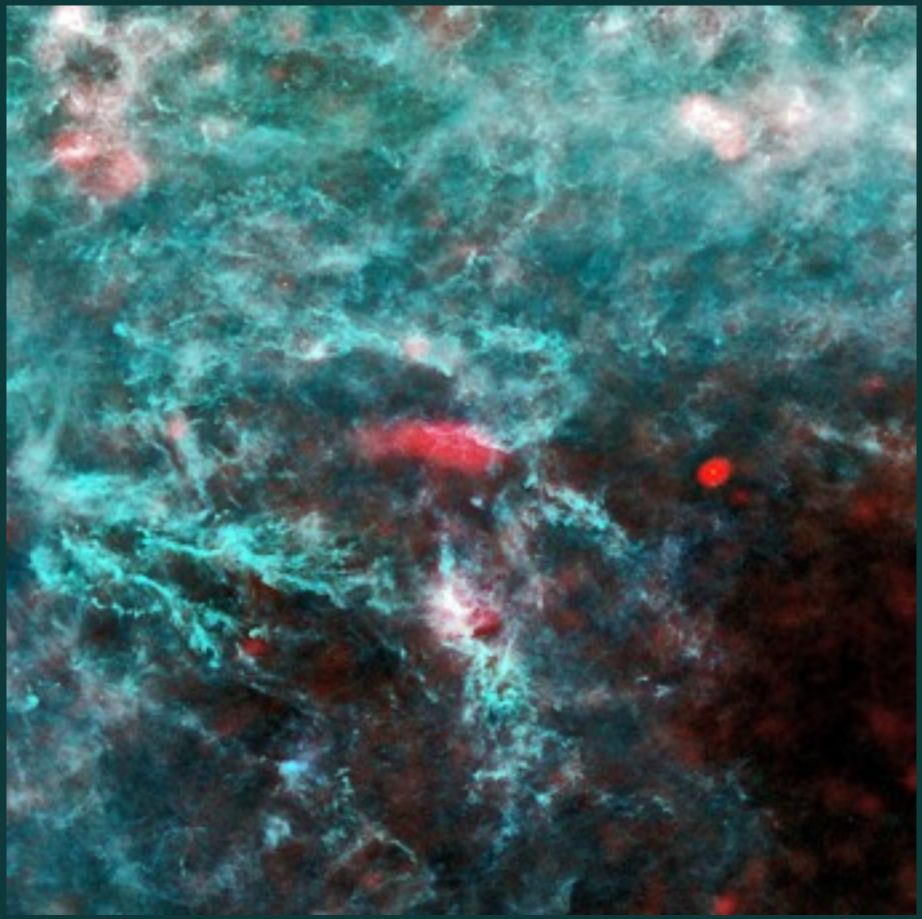
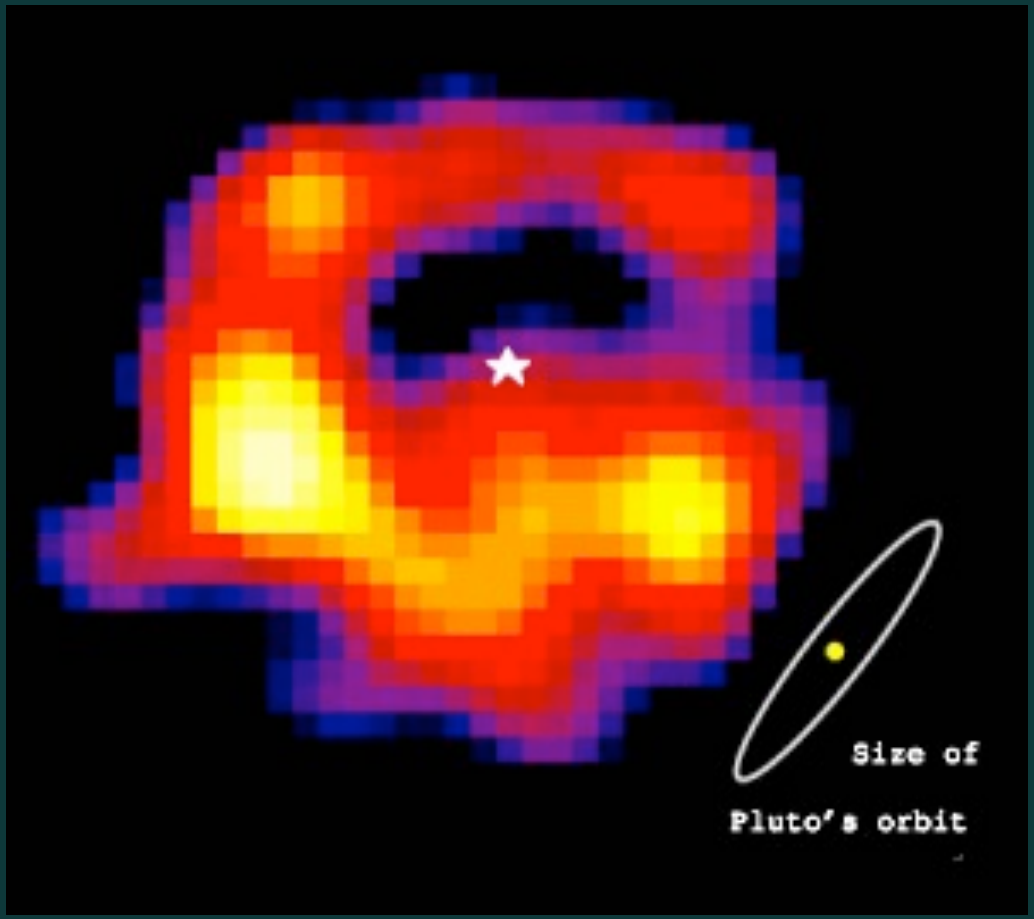
Probing the Origin of Stars and Planets with CCAT

John Carpenter (Caltech)



Taurus/Perseus

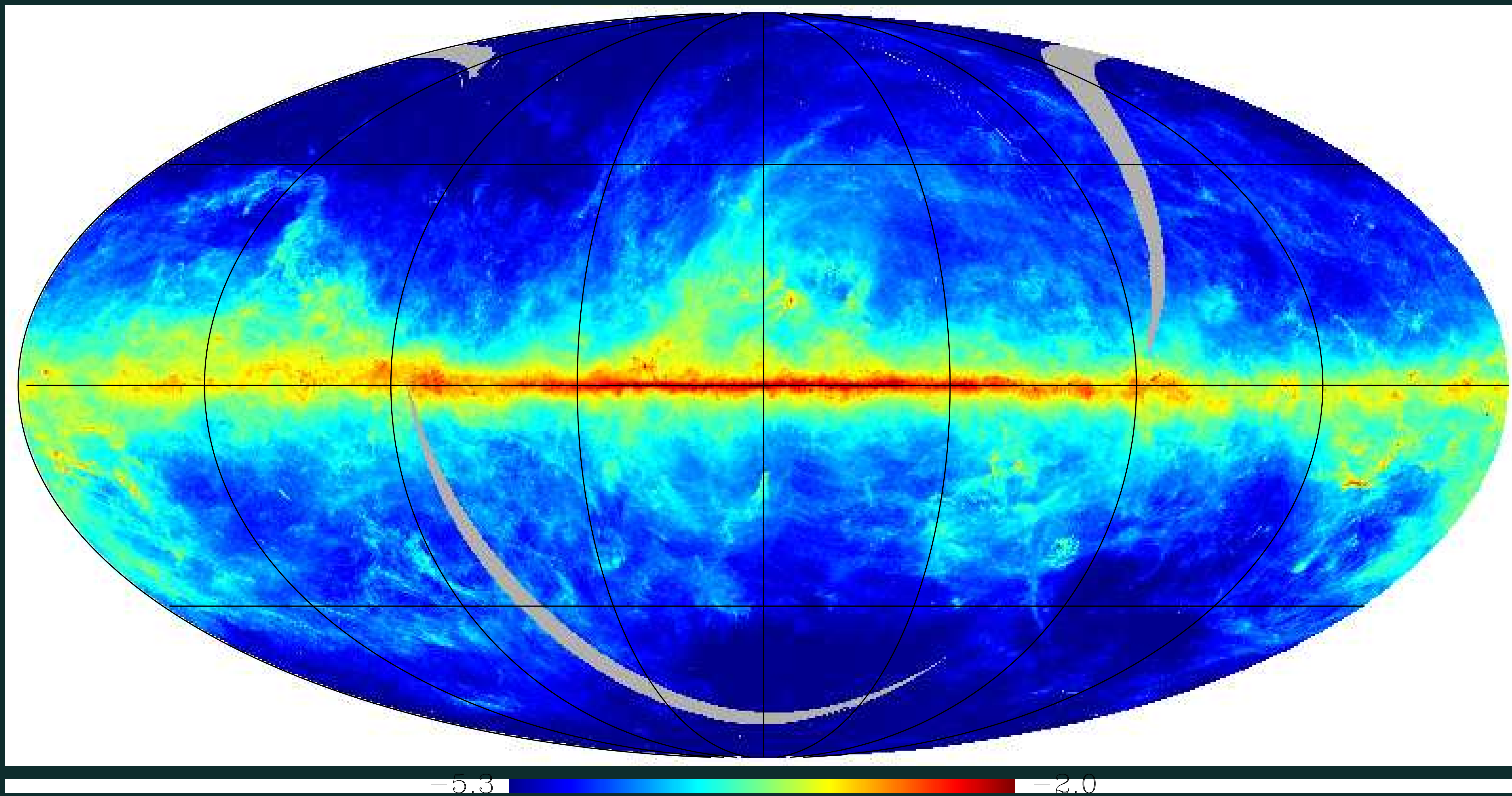


Epsilon Eridani

CCAT in brief

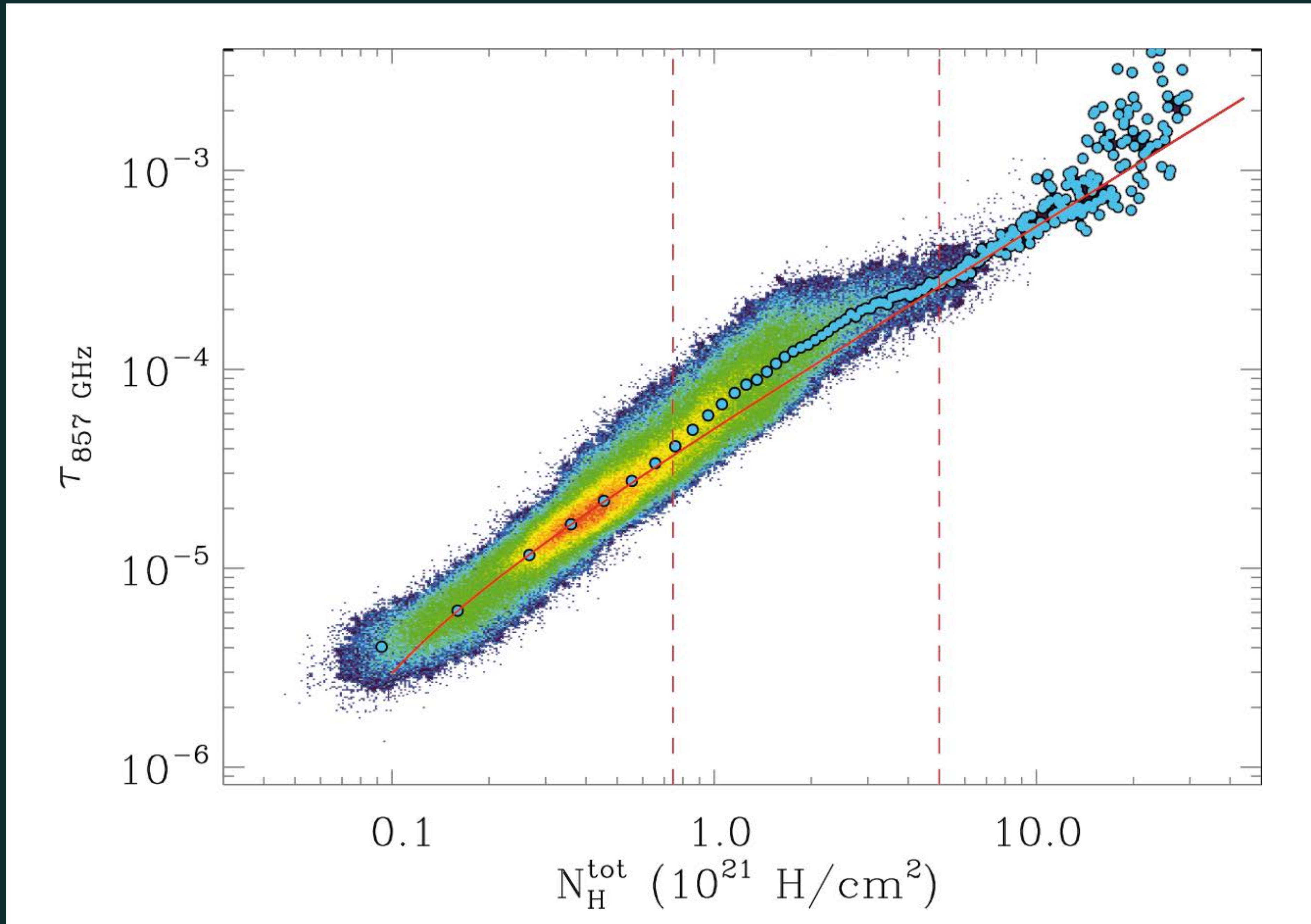
- 25 m submillimeter telescope in Chile
- 1 degree field-of-view
- Overviews by Jeff Zivick and Gordon Stacey

All-sky map of the 857 GHz optical depth



Planck Collaboration

Dust optical depth vs. Gas Column Density



- Gas content traced by HI and CO
- CO data : *NANTEN* and CfA
- First seen with IRAS (Desert et al 1988; Reach et al. 1994)

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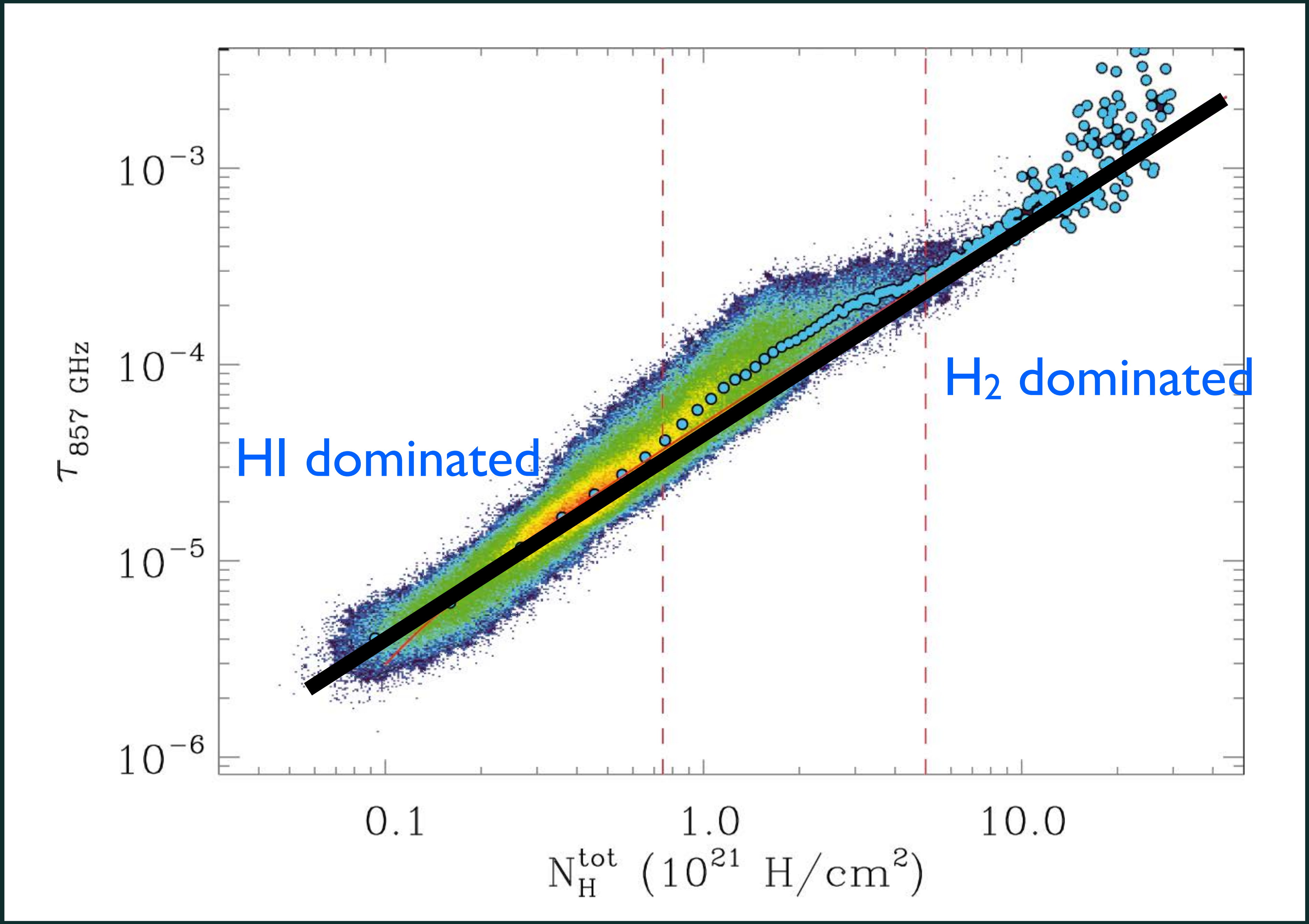

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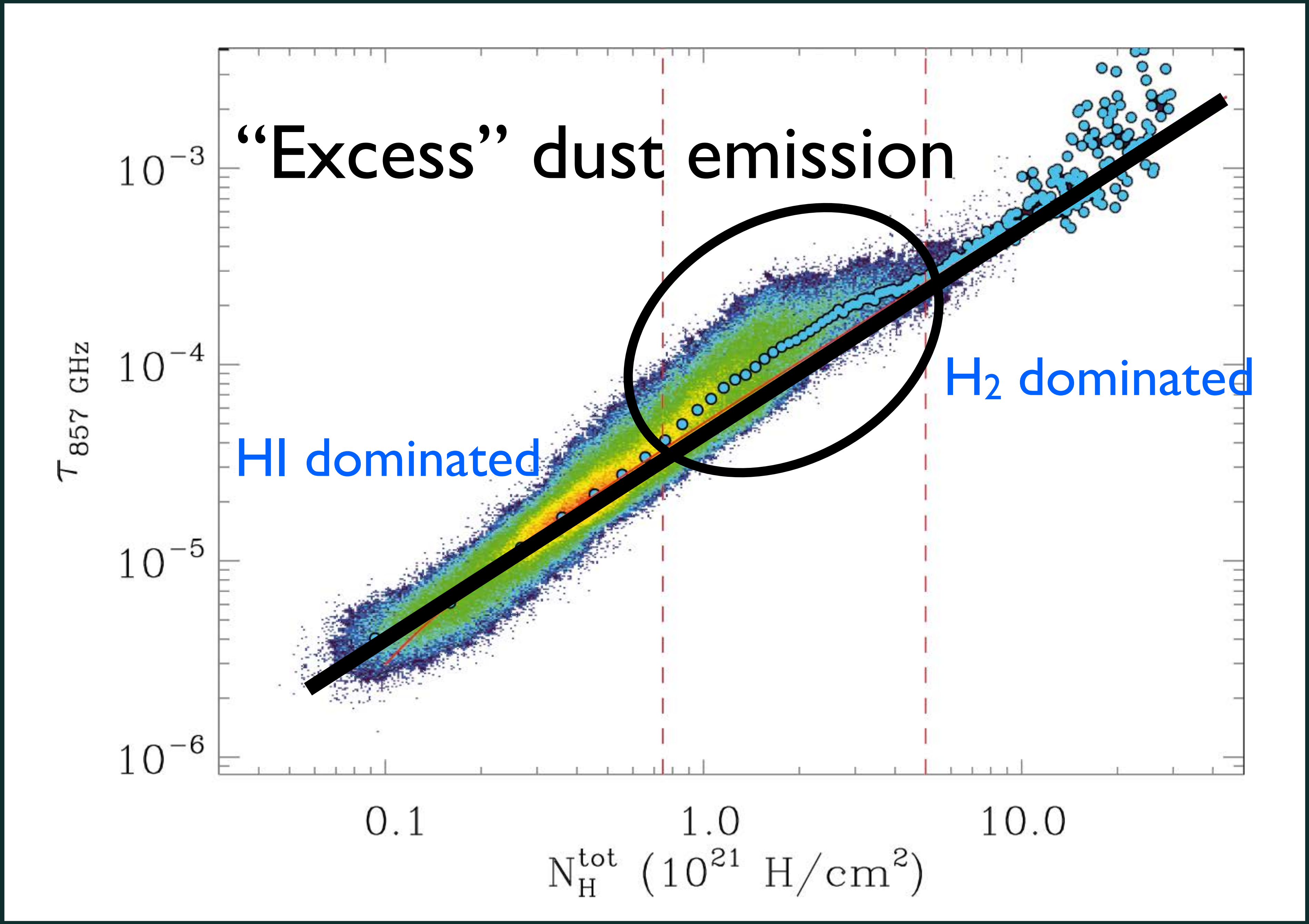

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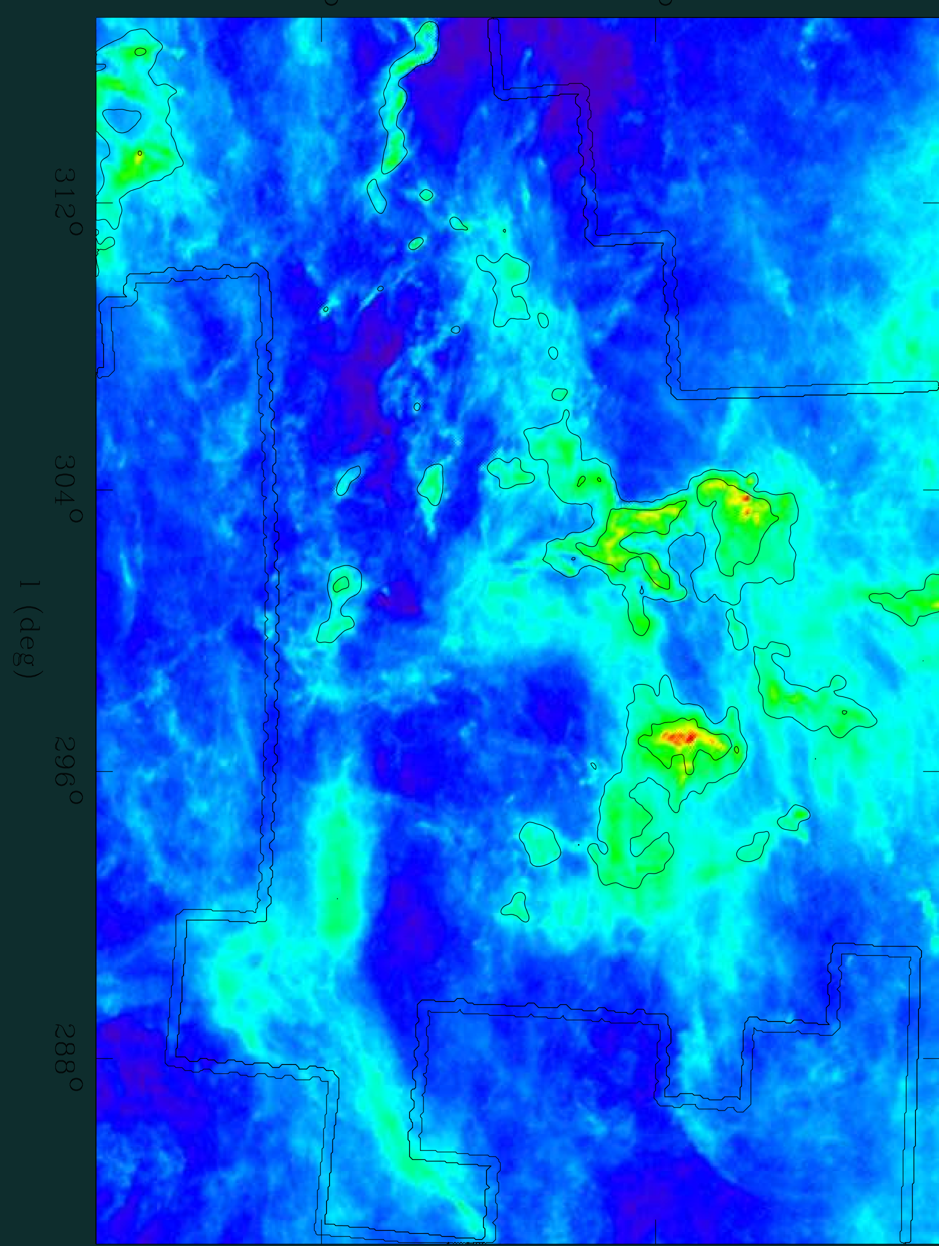
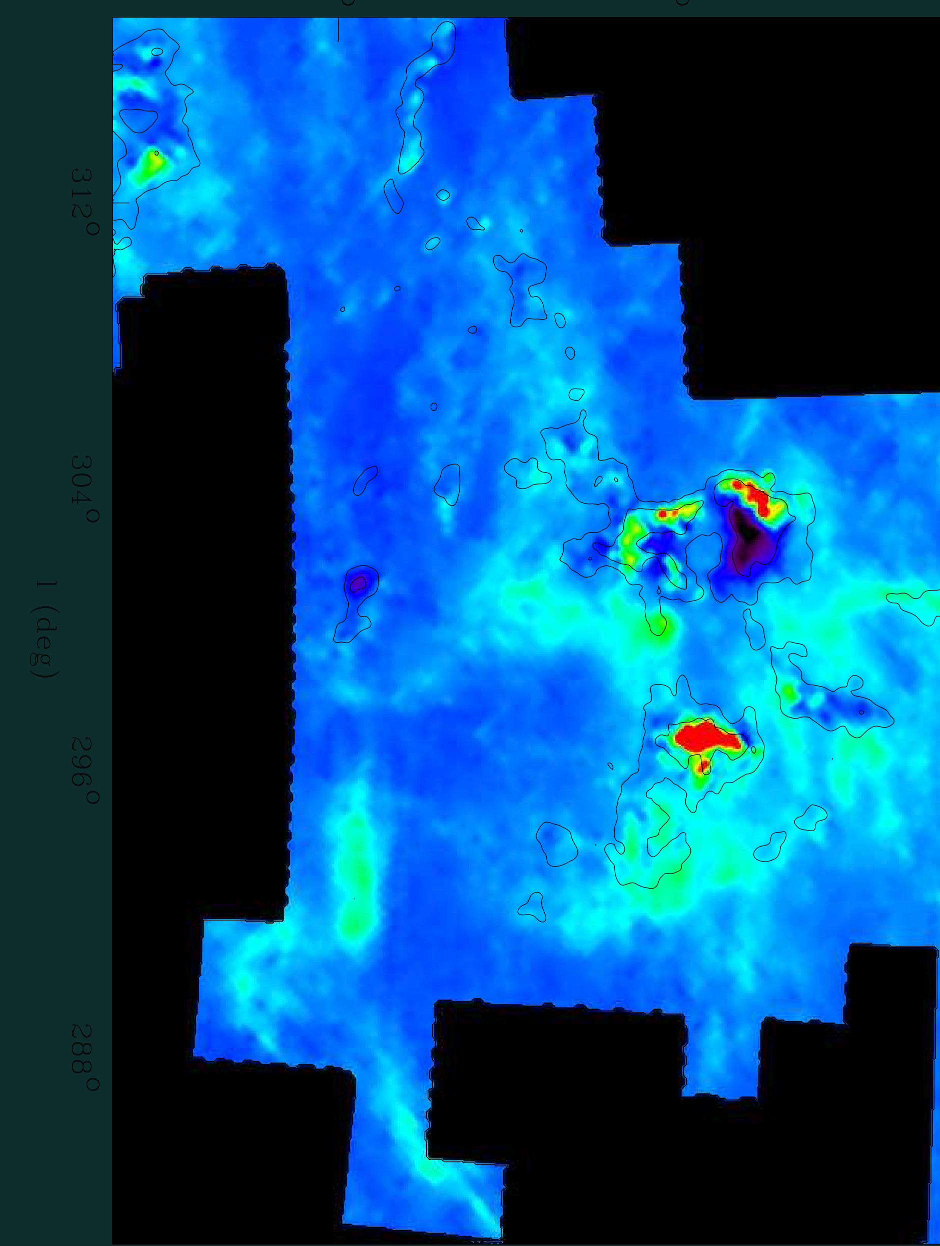
“Dark” Molecular Gas?

857 GHz optical depth



Excess Column Density

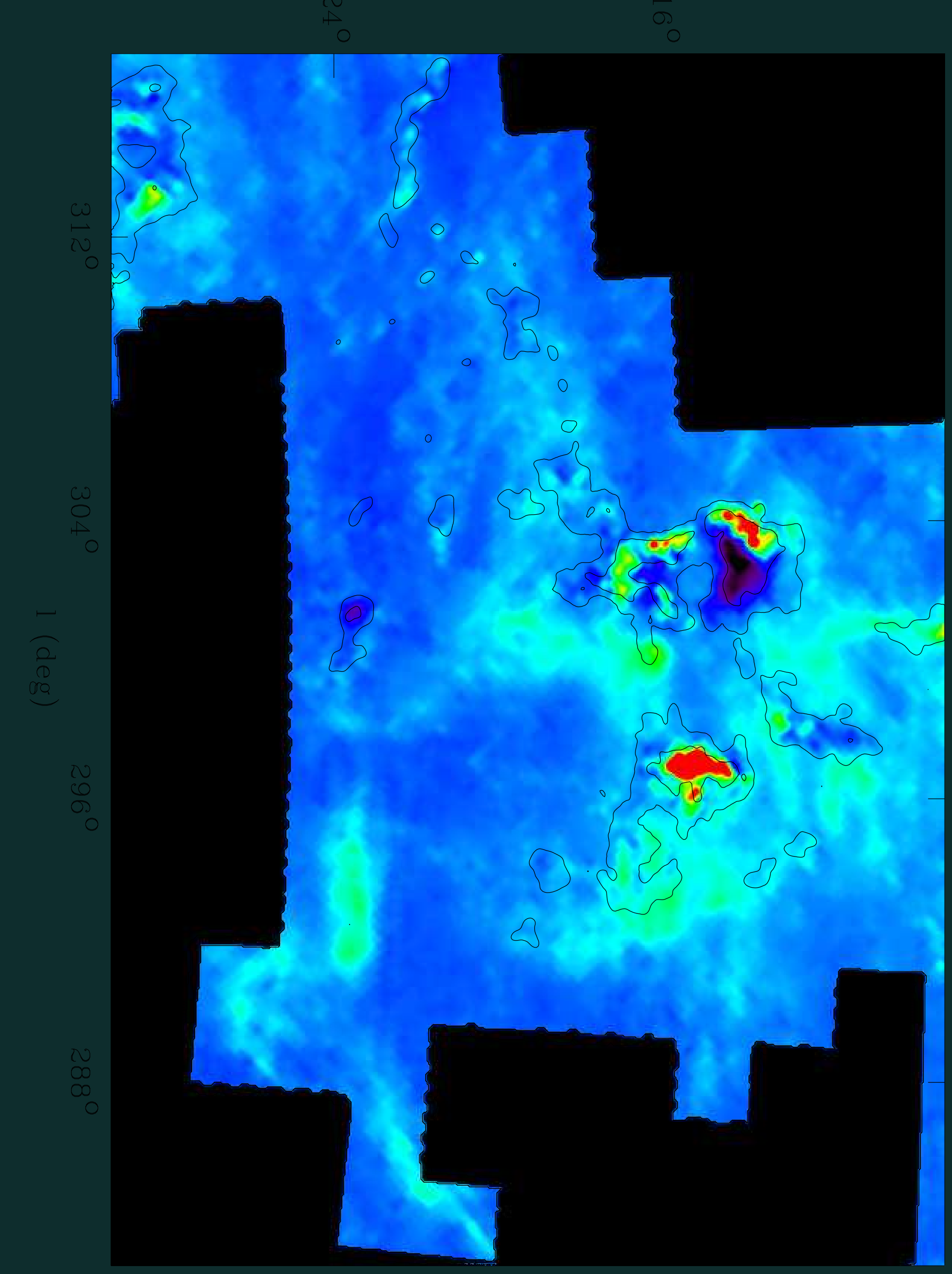


Chamaeleon Cloud Complex

“Dark” Molecular Gas?

- Some associated with CO (Onishi et al. 2001)
- Present at Av < 0.4 mag
- Mass(dark) ~ Mass(CO)
- Trace “dark” gas with [CI] and [CII]

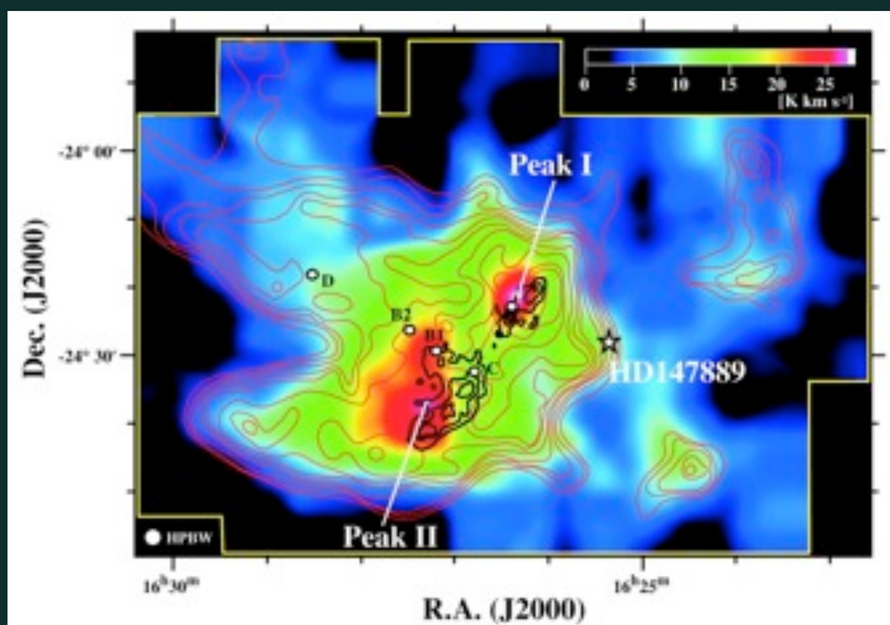
Excess Column Density

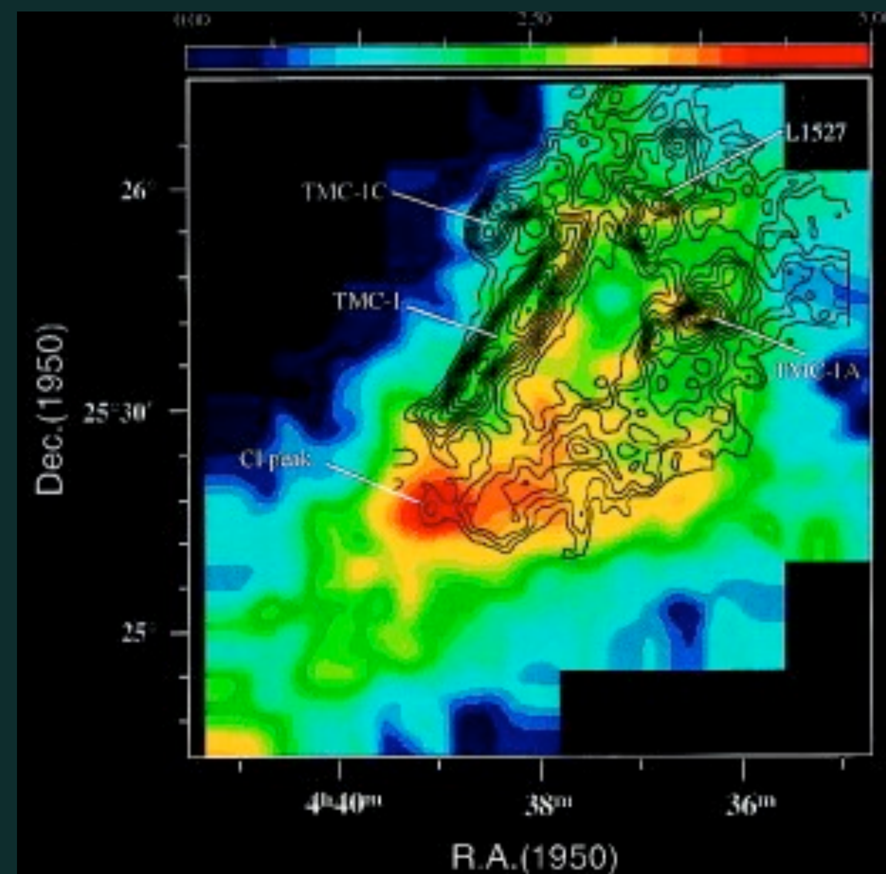


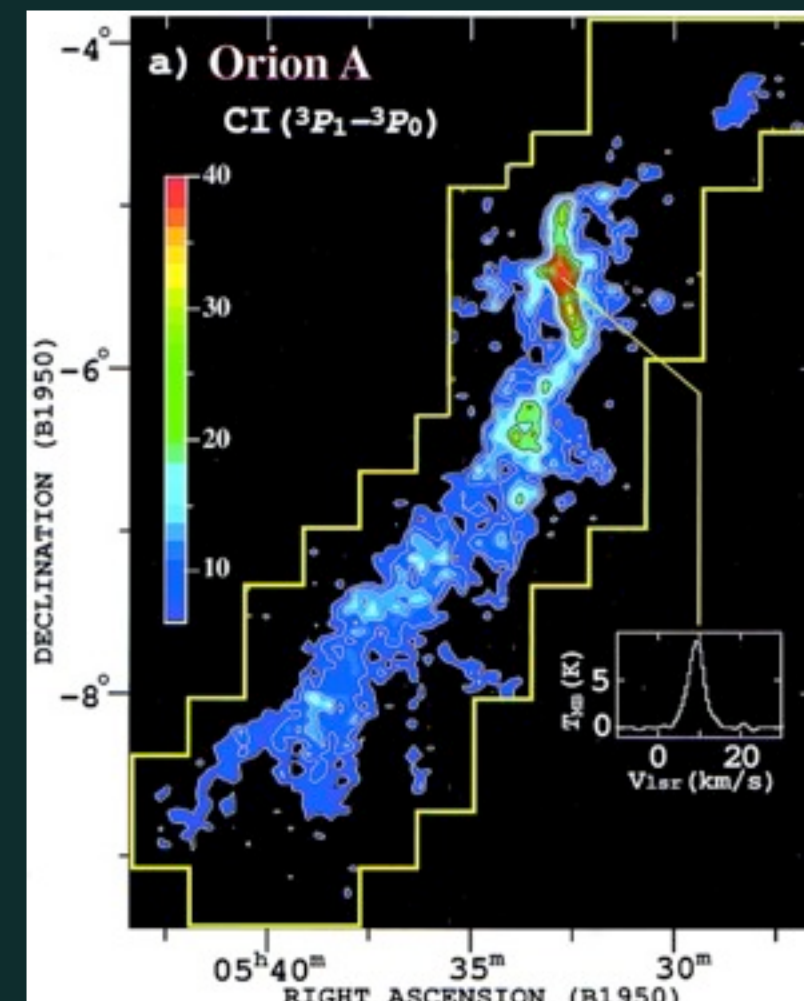
Chamaeleon Cloud Complex

[CI] Emission is Ubiquitous

Ophiuchus	Taurus	Orion





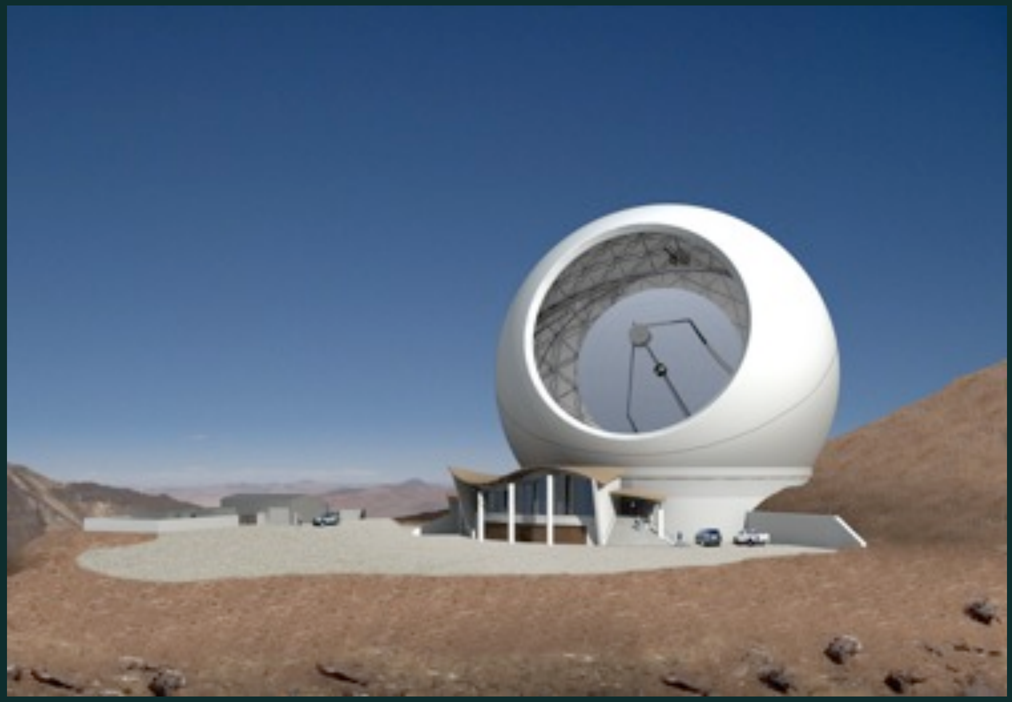


Kamegai et al. 2003	Maezawa et al. 1999	Ikeda et al. (2002)

Maps made with the Mt. Fuji Submillimeter Telescope

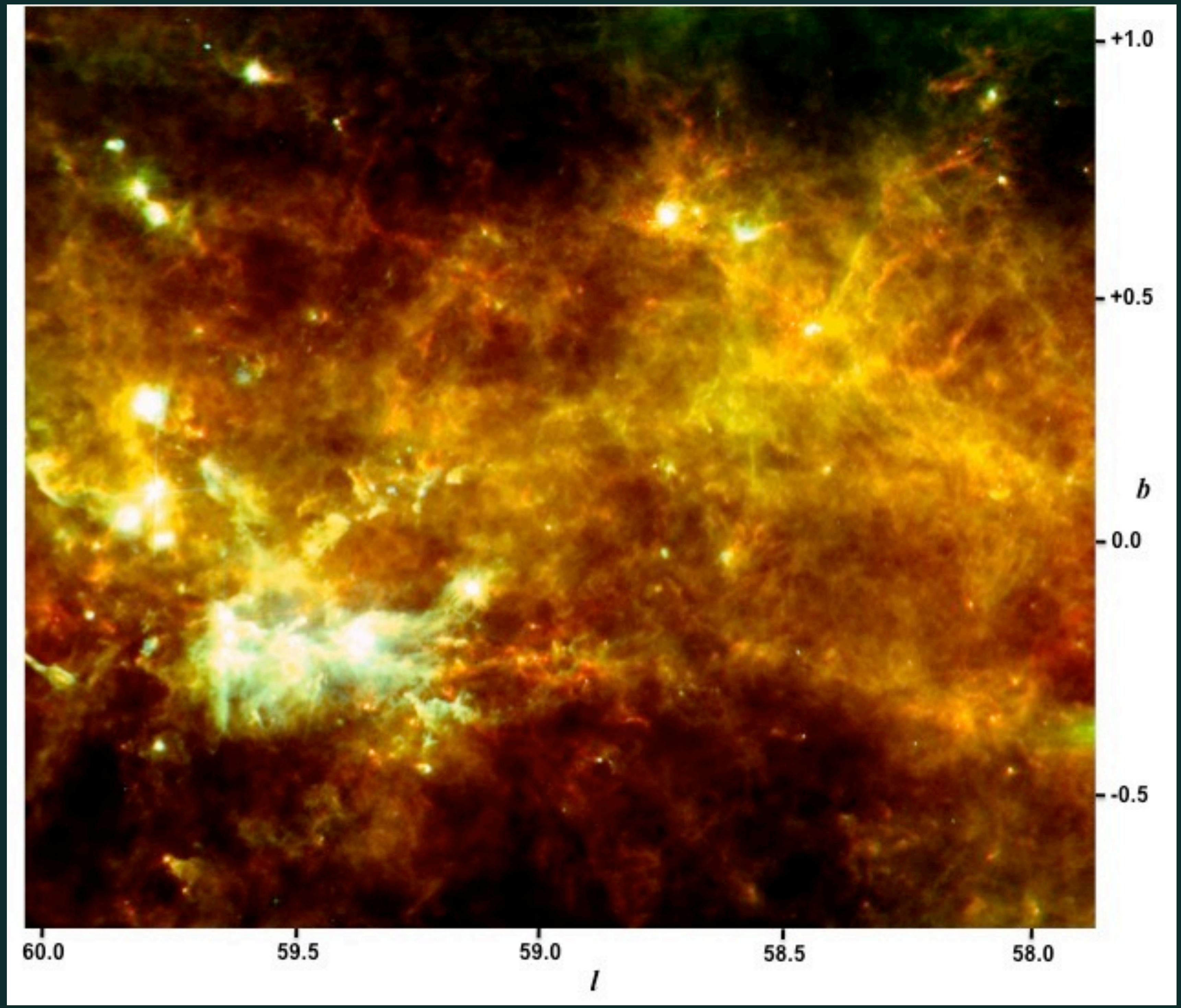
Role of CCAT

- Observe neutral carbon lines at 492 and 809 GHz
- 3.7 - 6.1″ resolution
- Trace transition between diffuse and dense gas
- Probe origin of turbulent motions in clouds
- Trace chemical evolution?



Structure of Molecular Clouds

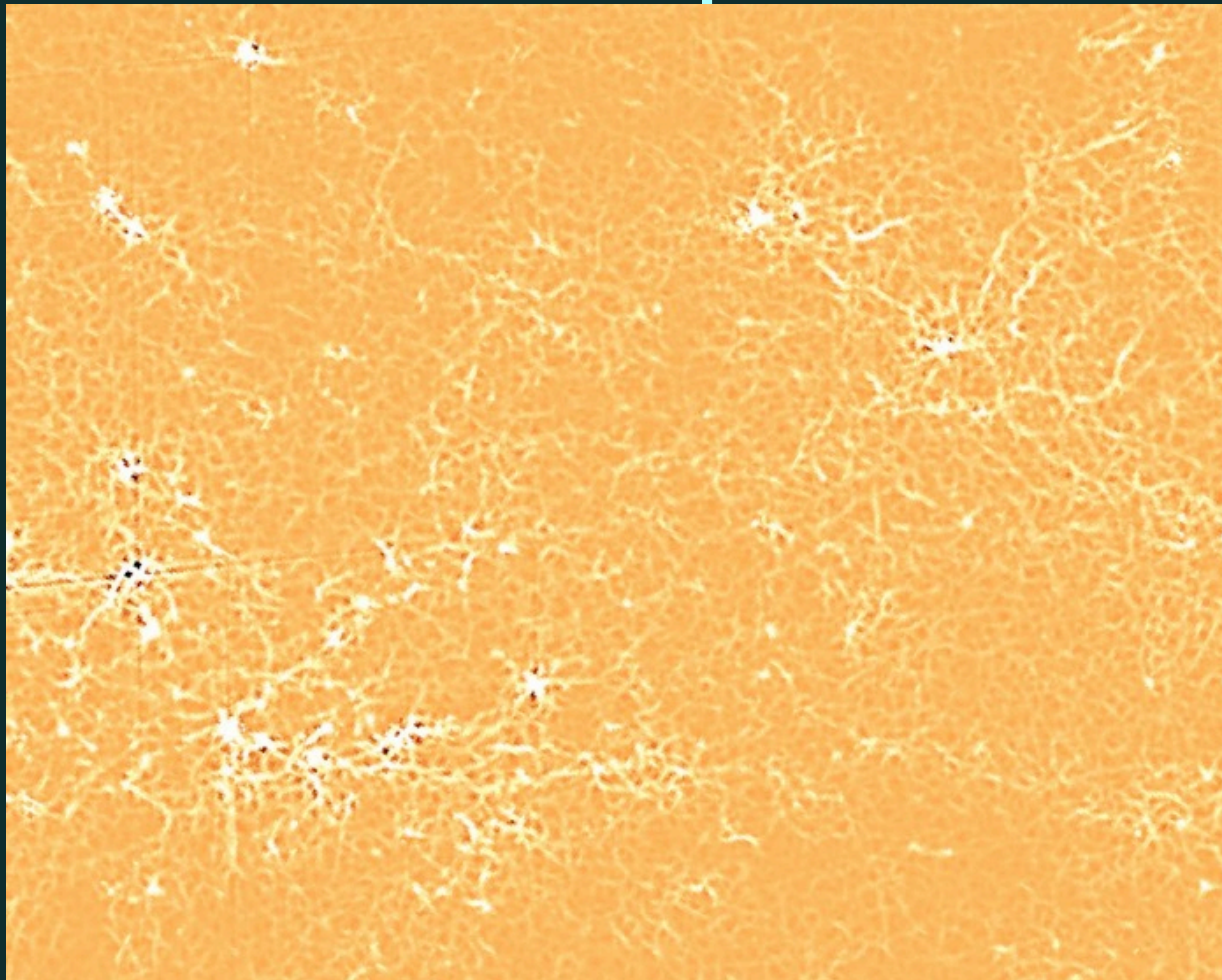
2 degrees



Molinari et al. 2010

Herschel 70μm, 160μm, and 350μm image at longitude = 59°

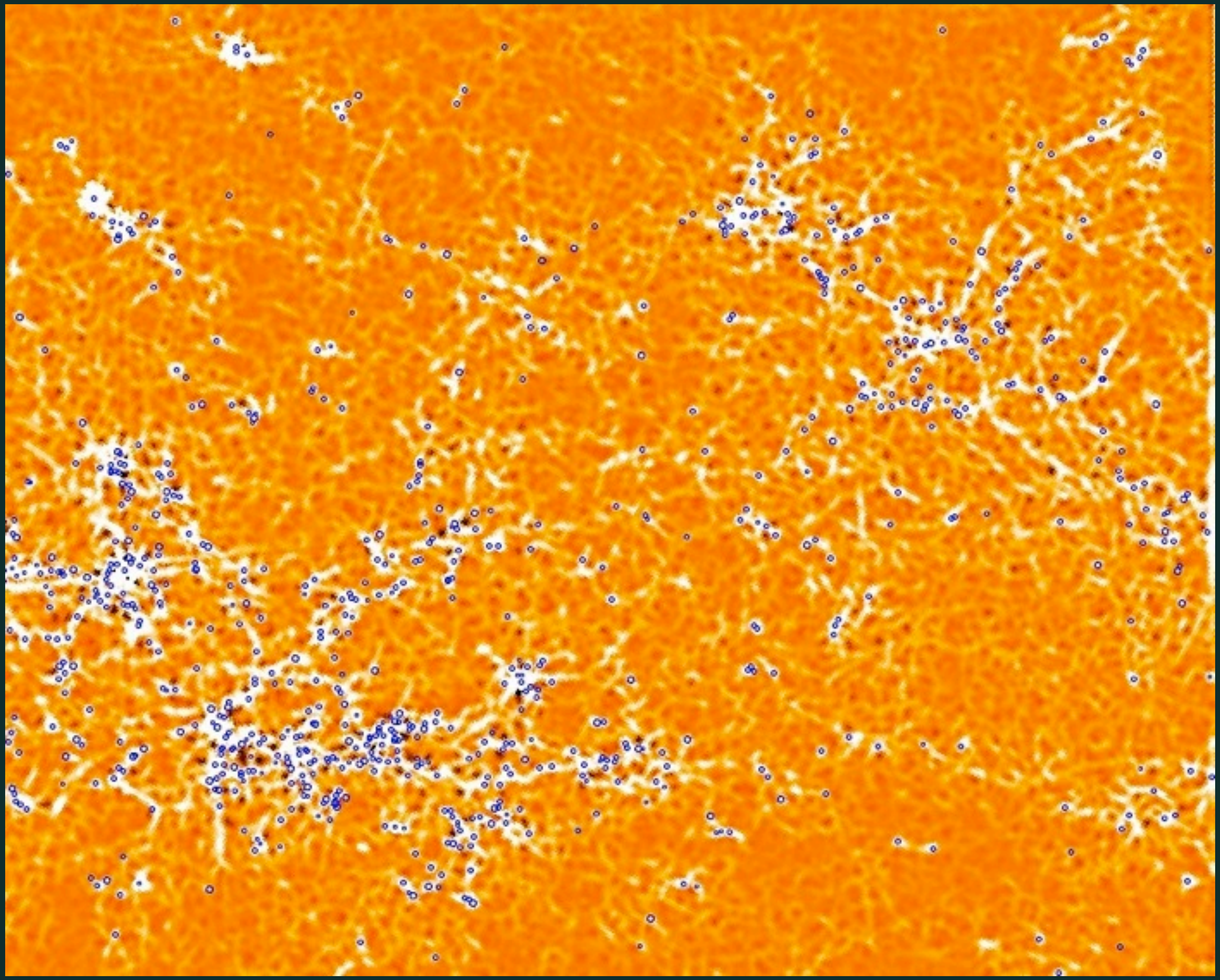
Filaments are pervasive ...



Molinari et al. 2010

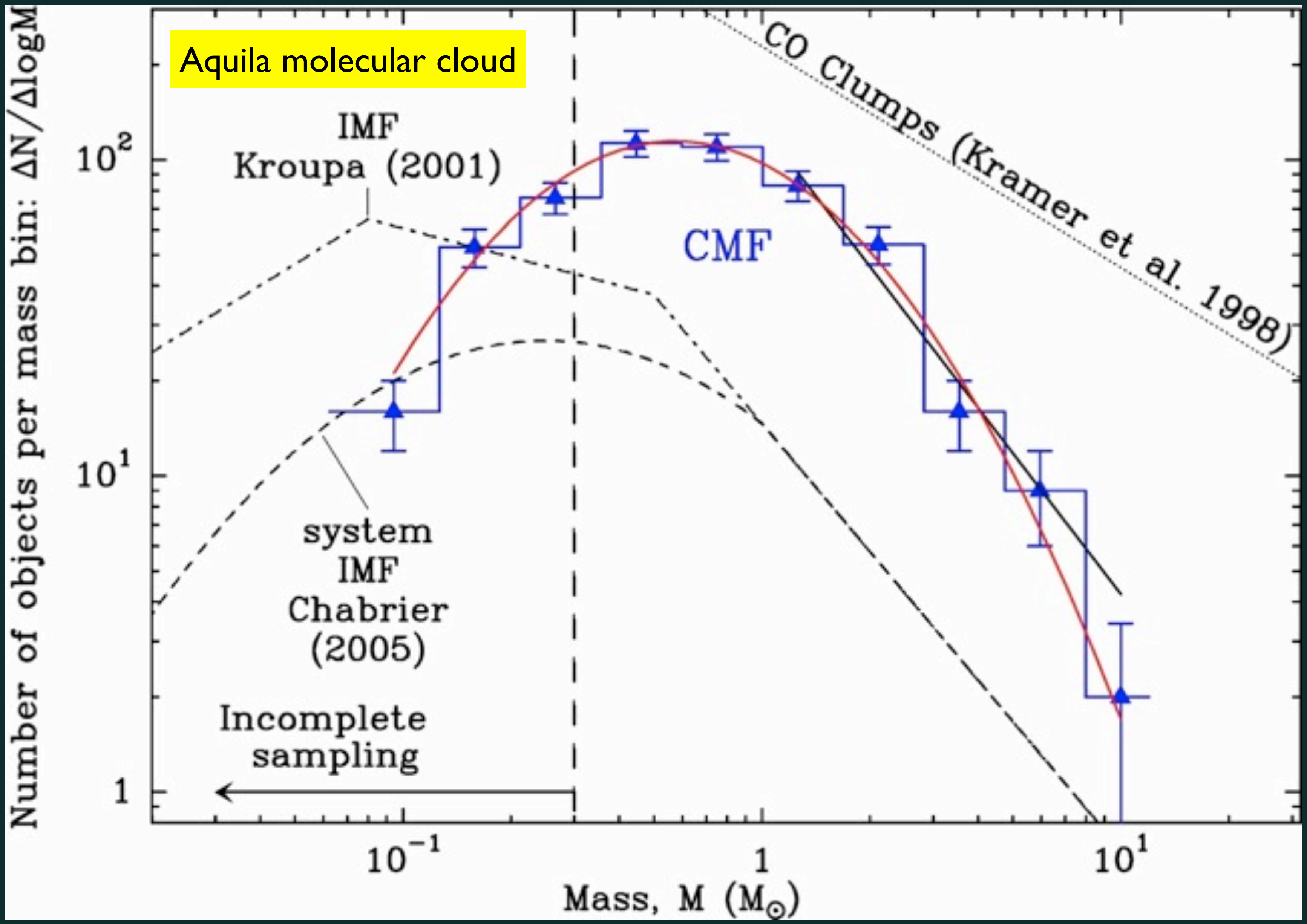
Filtered Herschel 250um image

... and are where stars form



Molinari et al. 2010

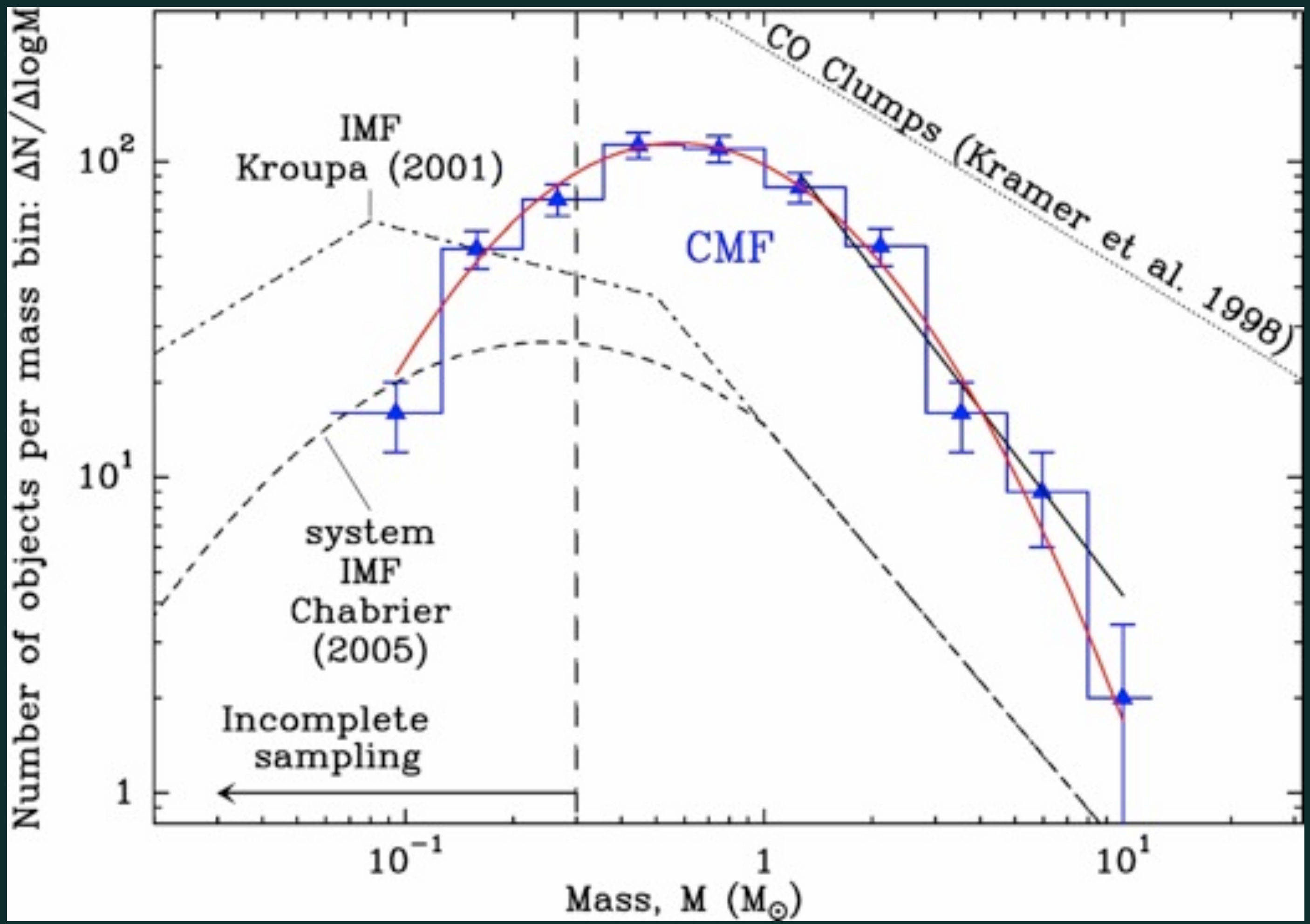
Filaments contains dense "clumps"



Andre et al. 2010

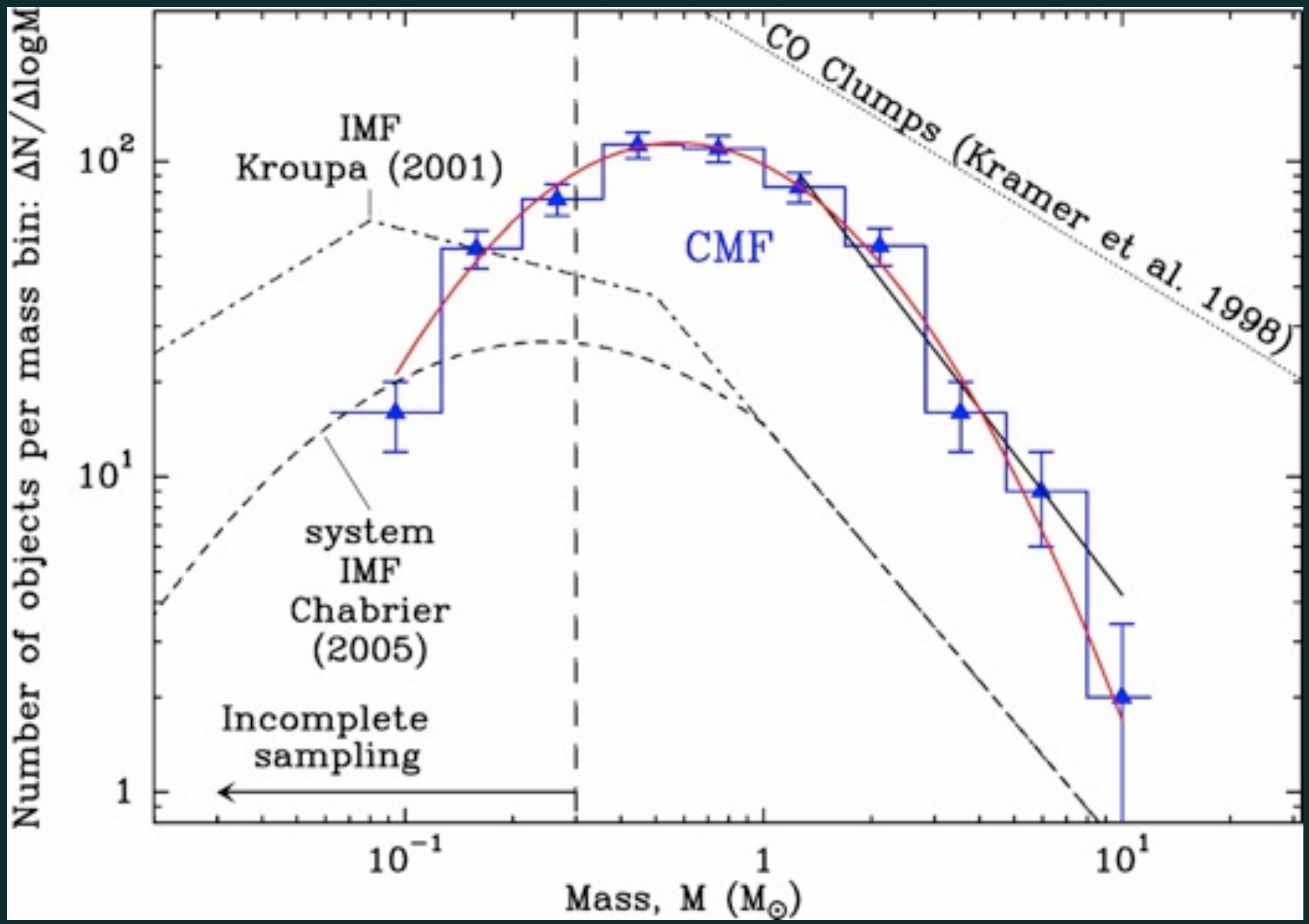
- Clump Mass Function similar in shape to Stellar Mass Function
- Is Stellar IMF imprinted in the cloud structure?

CCAT Surveys of Molecular Clouds



- CCAT @ 350μm will have 5x better resolution than Herschel @ 250μm
- CCAT will probe spatial scales of 500 AU in the nearest clouds
- CCAT will count individual cores over entire molecular clouds

CCAT Surveys of Molecular Clouds



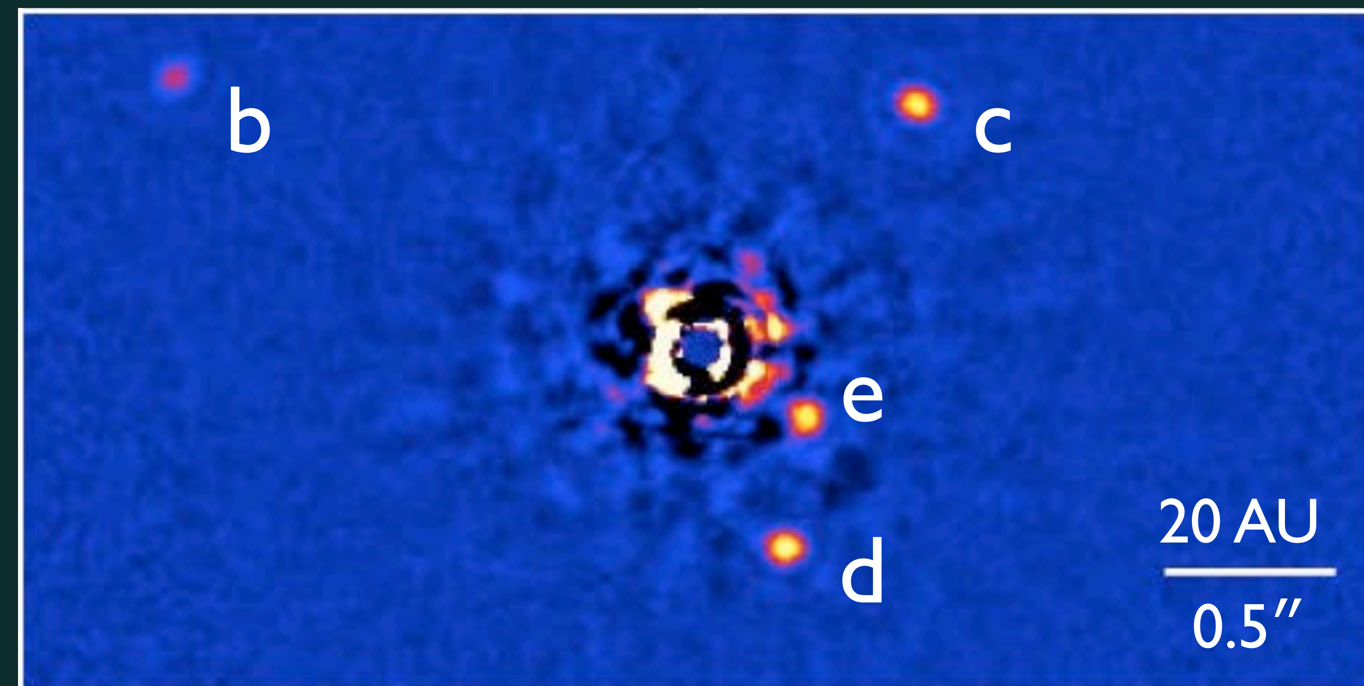
- CCAT will probe 25x lower masses than Herschel (down to 0.001 Msun @ 140 pc)
- CCAT will determine if clump IMF follows stellar IMF into the substellar regime
- CCAT will determine the efficiency in converting clumps into stars

Disks to Planets

Silhouette disks in Orion

McCaughrean & O'Dell 1995

Planets around HR 8799



Marois et al. (2011)

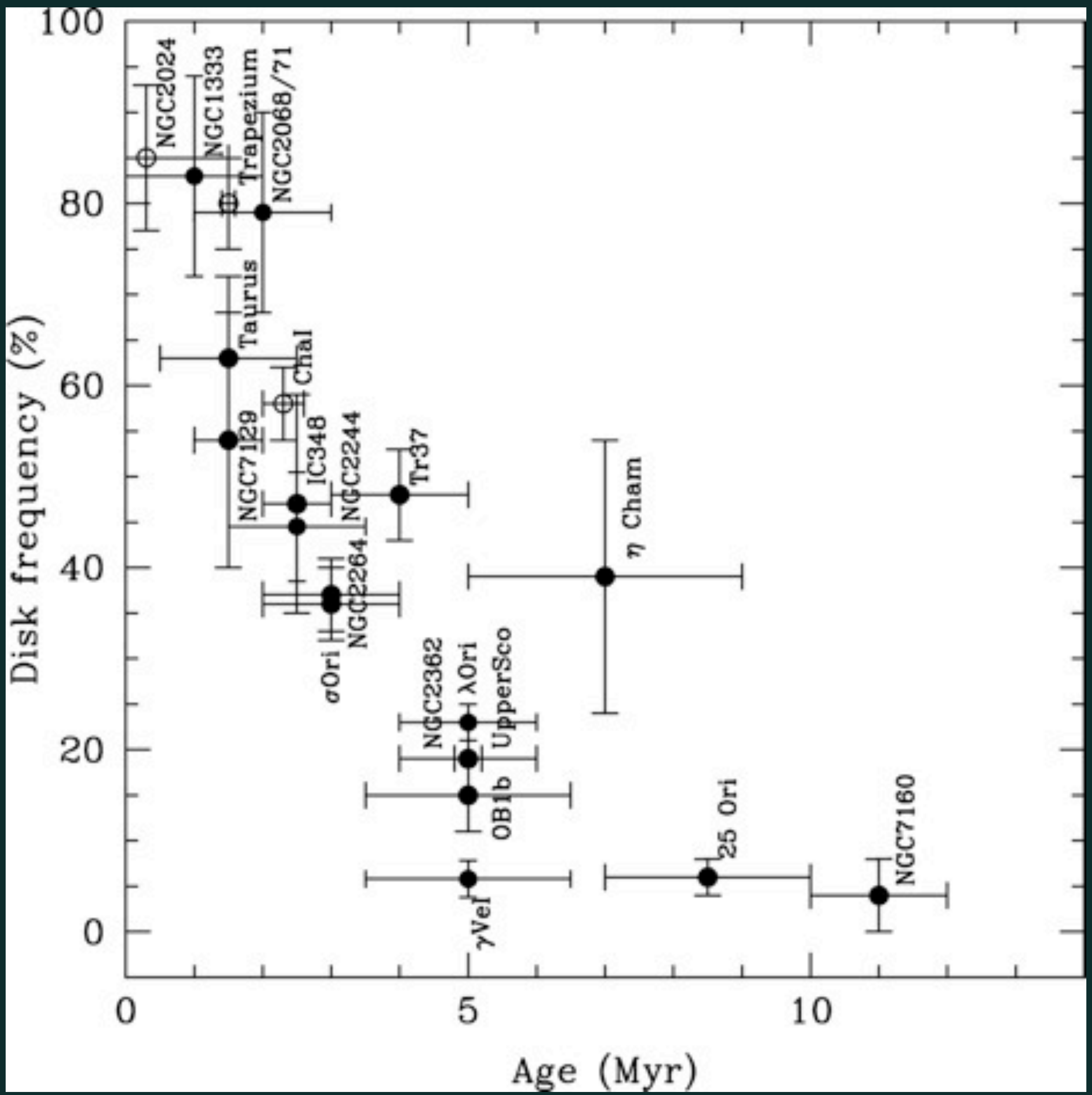
How much material is available to form planets?

How long does the disk persist?

➡ Observe the evolution in the dust content

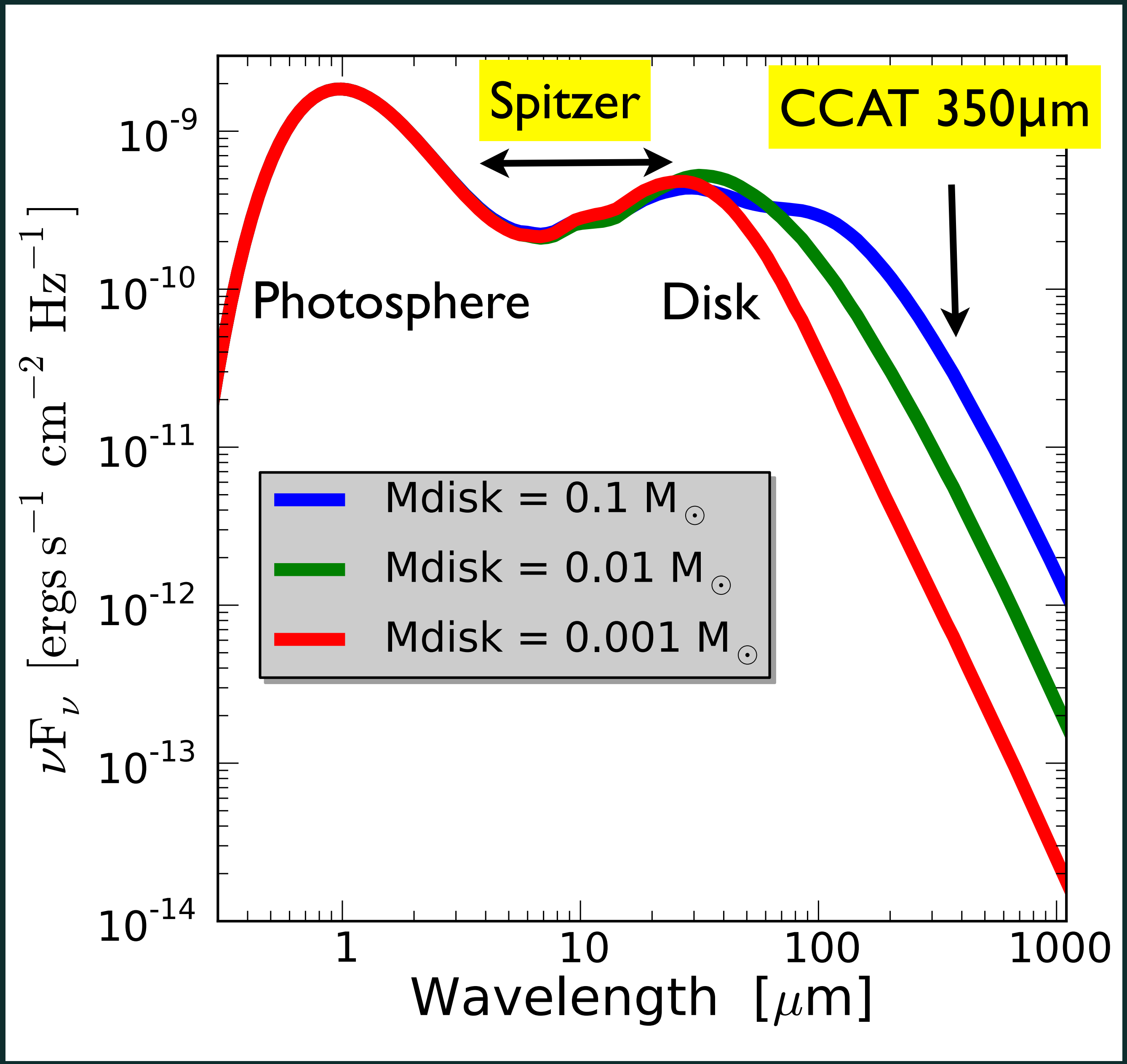
Evolution of disks

Disk lifetimes from Spitzer

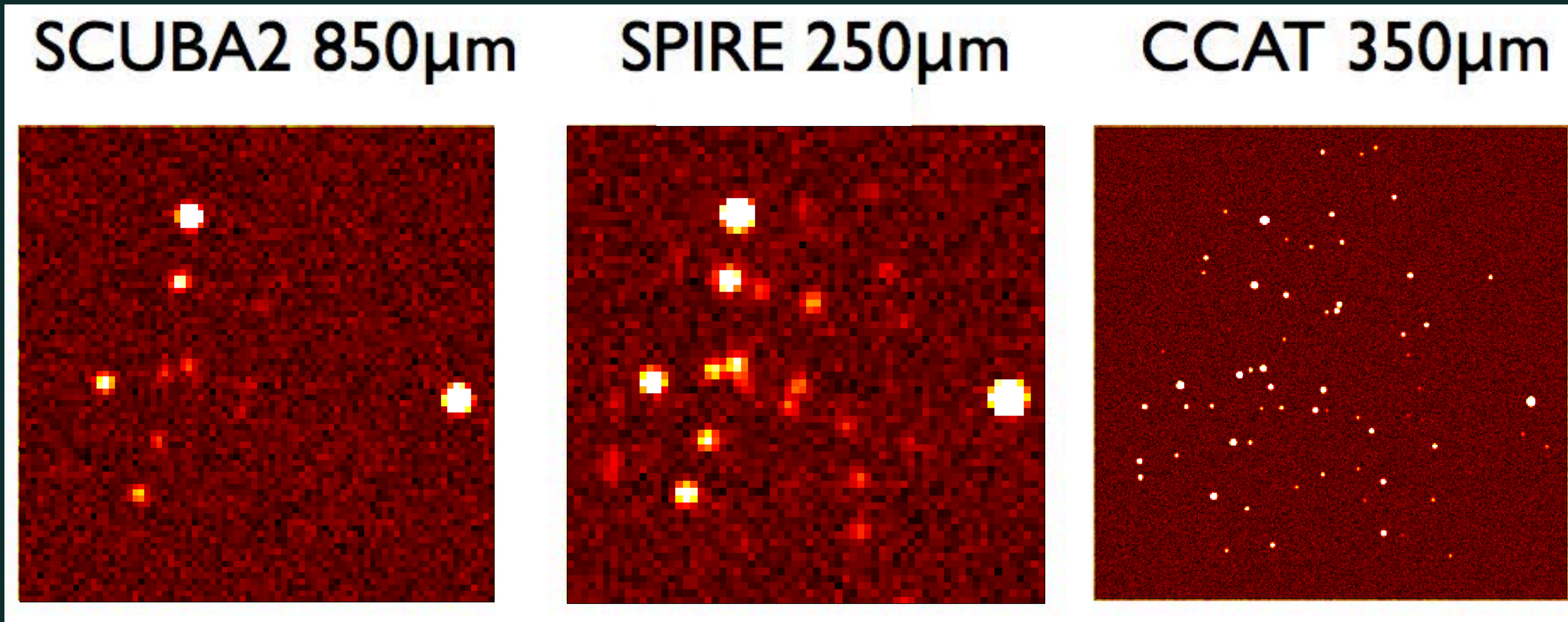


Hernandez et al. 2008

CCAT will trace the disk mass



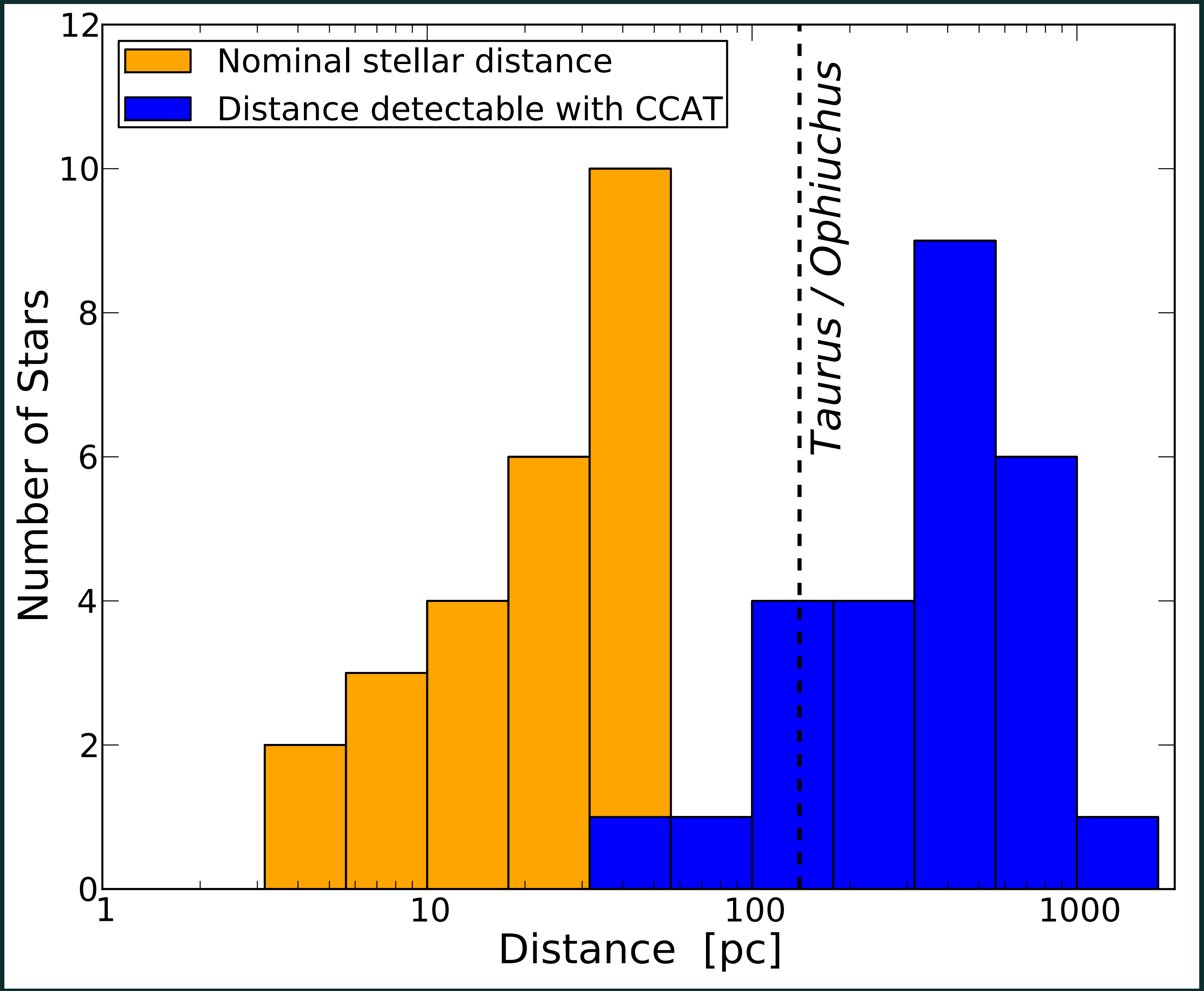
Simulated Observations of Cluster



- median disk mass of ≈10^{-3} Msun in Taurus cloud
- CCAT will provide 20-100x better mass sensitivity
- CCAT will trace the dissipation of optically thick disks

Formation of Debris Disks

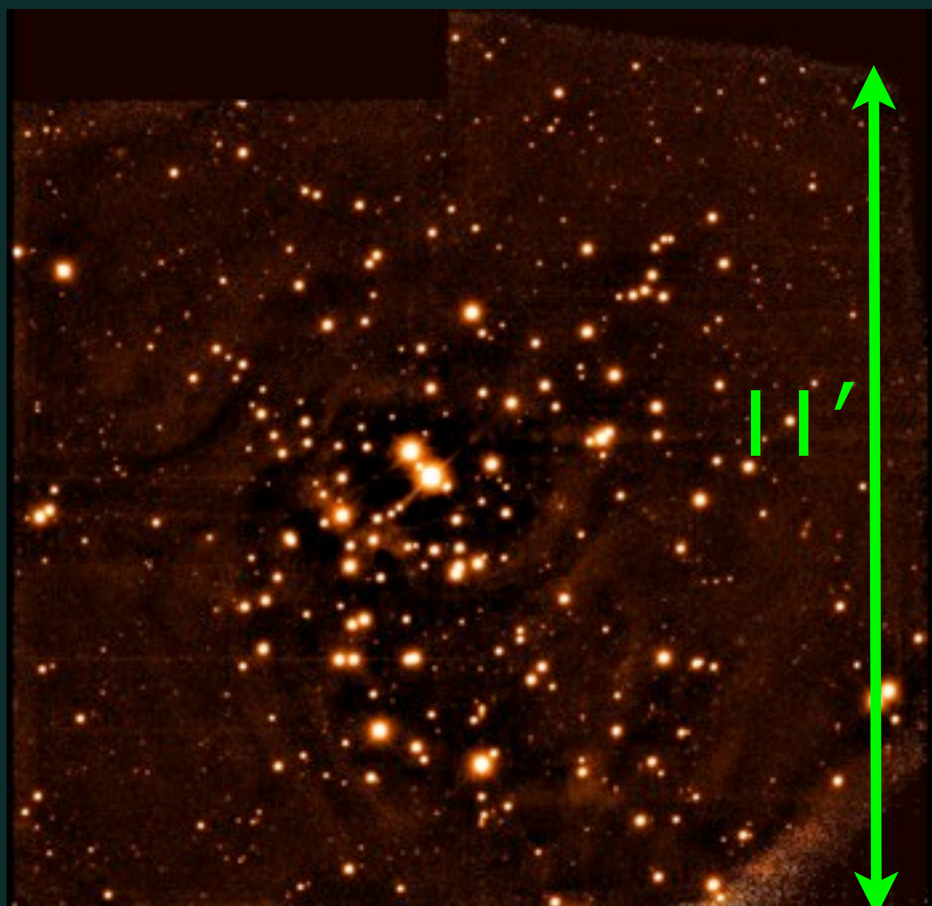
Compilation of debris disks detected in the submm

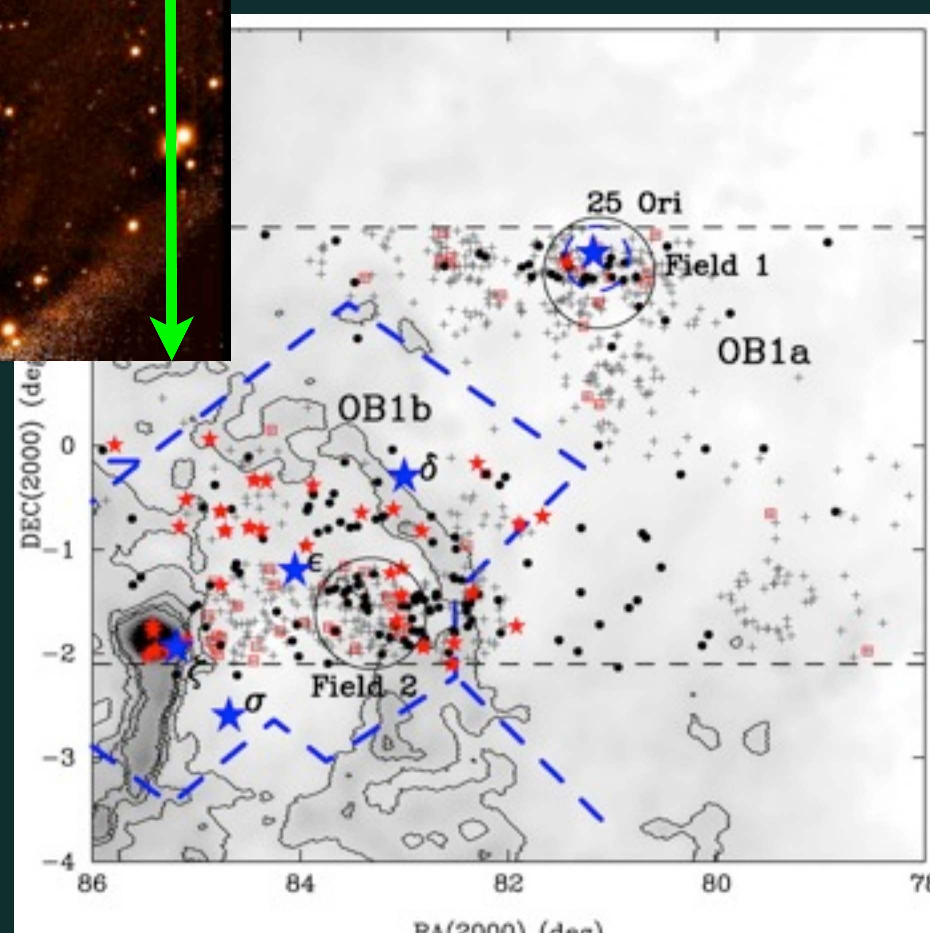


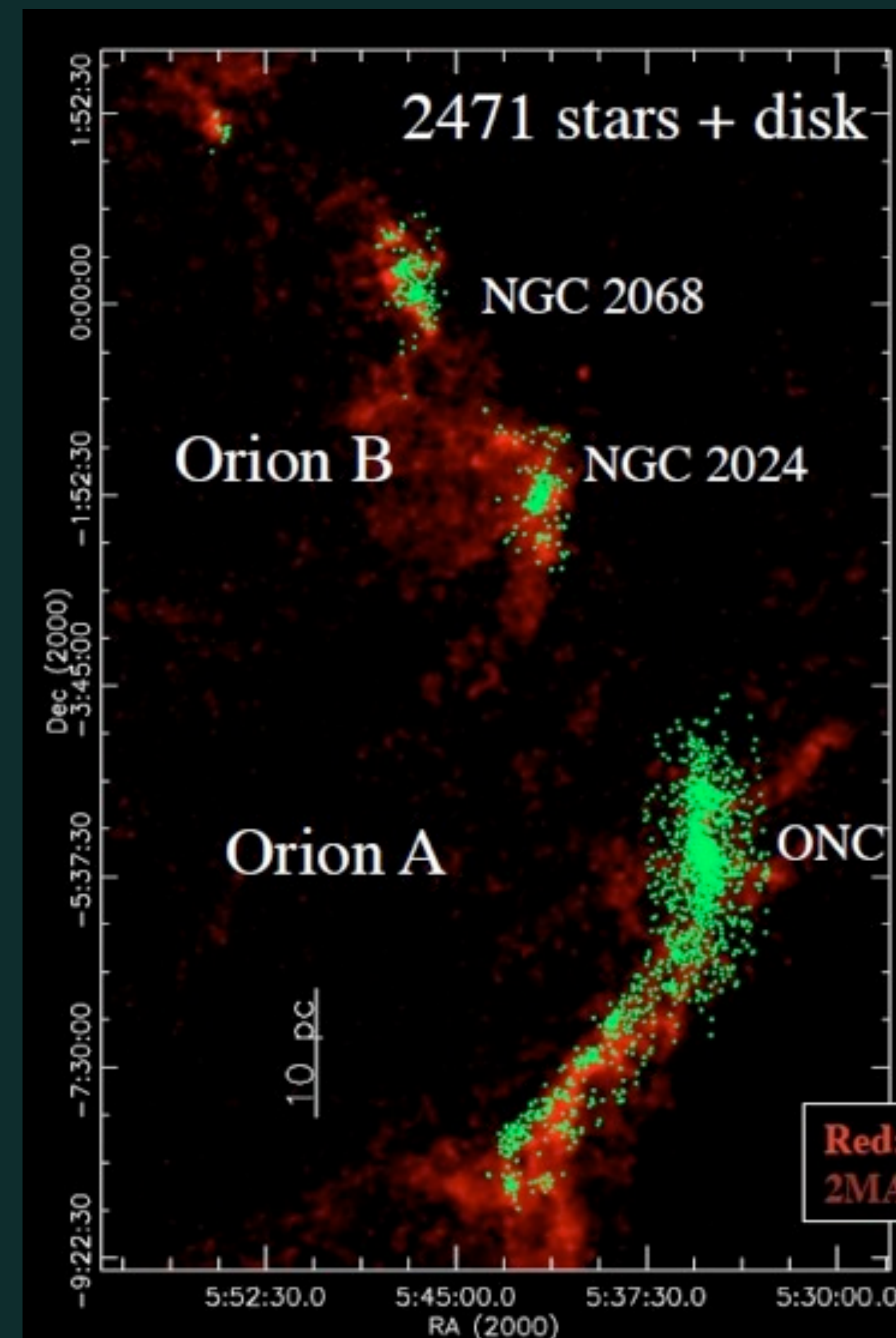
- As primordial disks dissipate, debris disks form
- Debris disks signify the onset of planet formation
- CCAT can detect known debris disks to > 100-200 pc
- CCAT will determine when primordial disks dissipate, and will catch the formation of debris systems

Wide Field of View is Essential

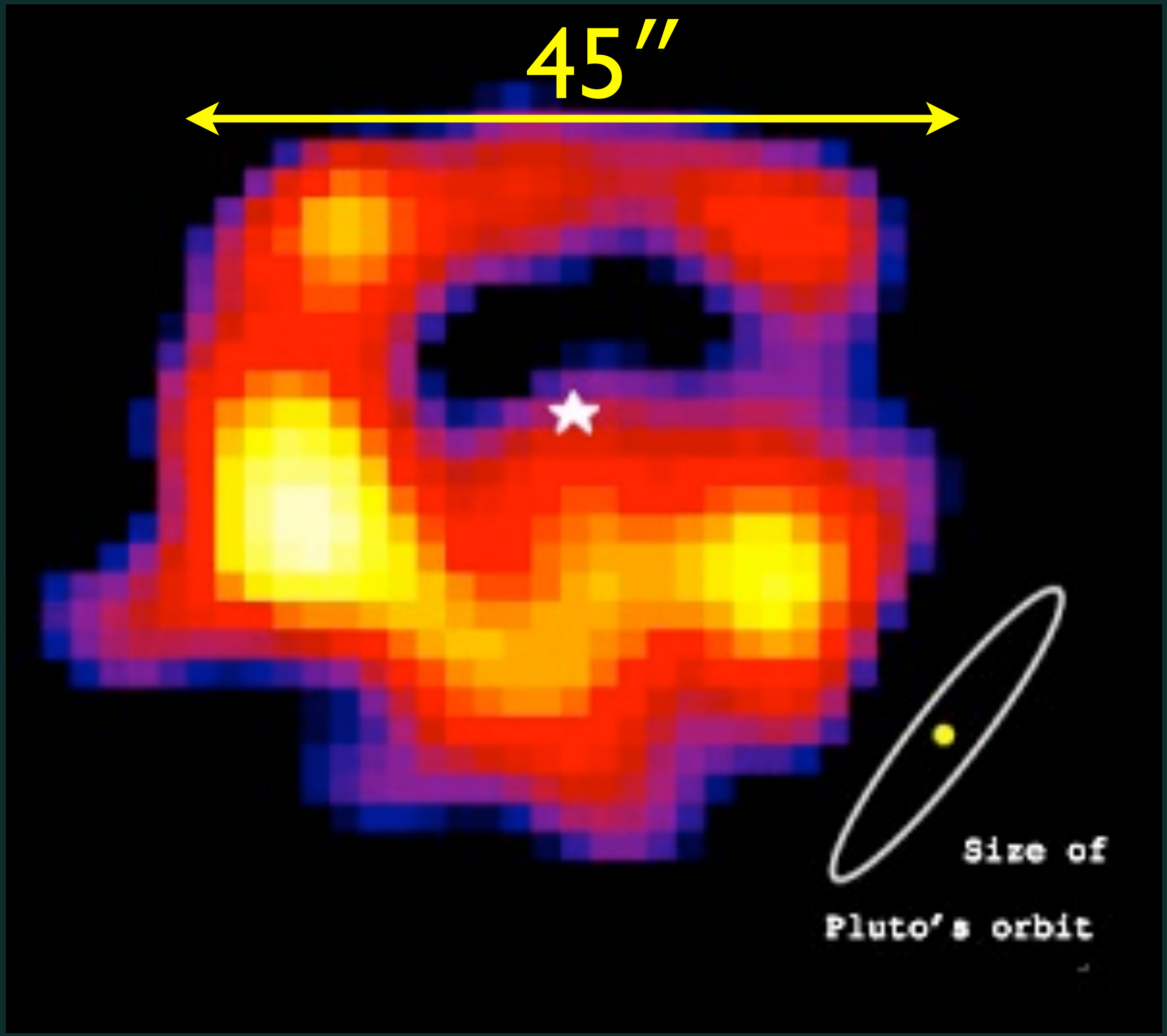
Young clusters and associations are arcmin to degrees in diameter







Debris Disks Around Nearby Stars

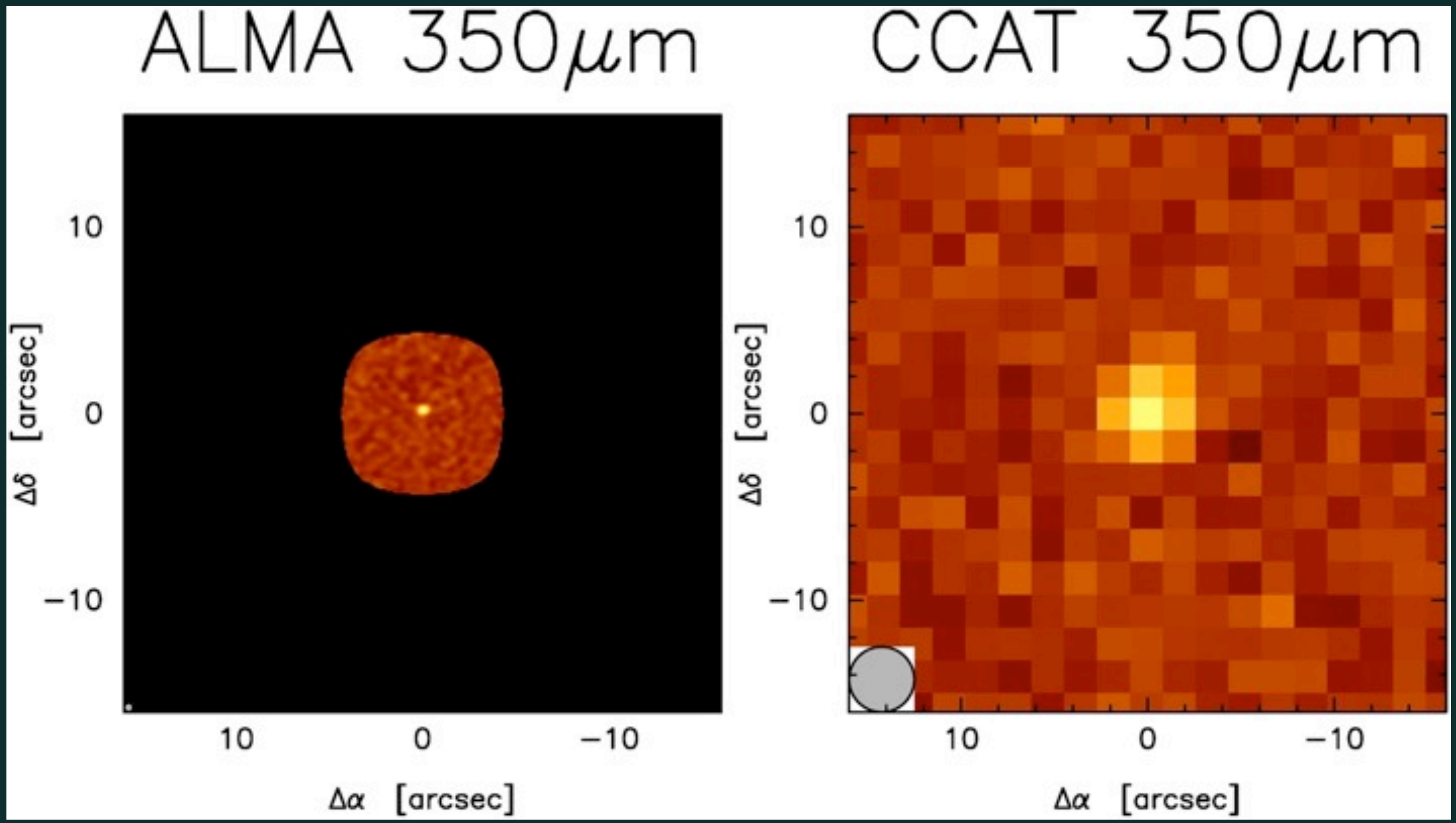


Epsilon Eridani
distance = 3.2 pc

- Disk structure encodes information on the architecture and formation history of the planetary system
- Nearest stars provide best spatial resolution and sensitivity to faint disks

CCAT vs. ALMA: Point Sources

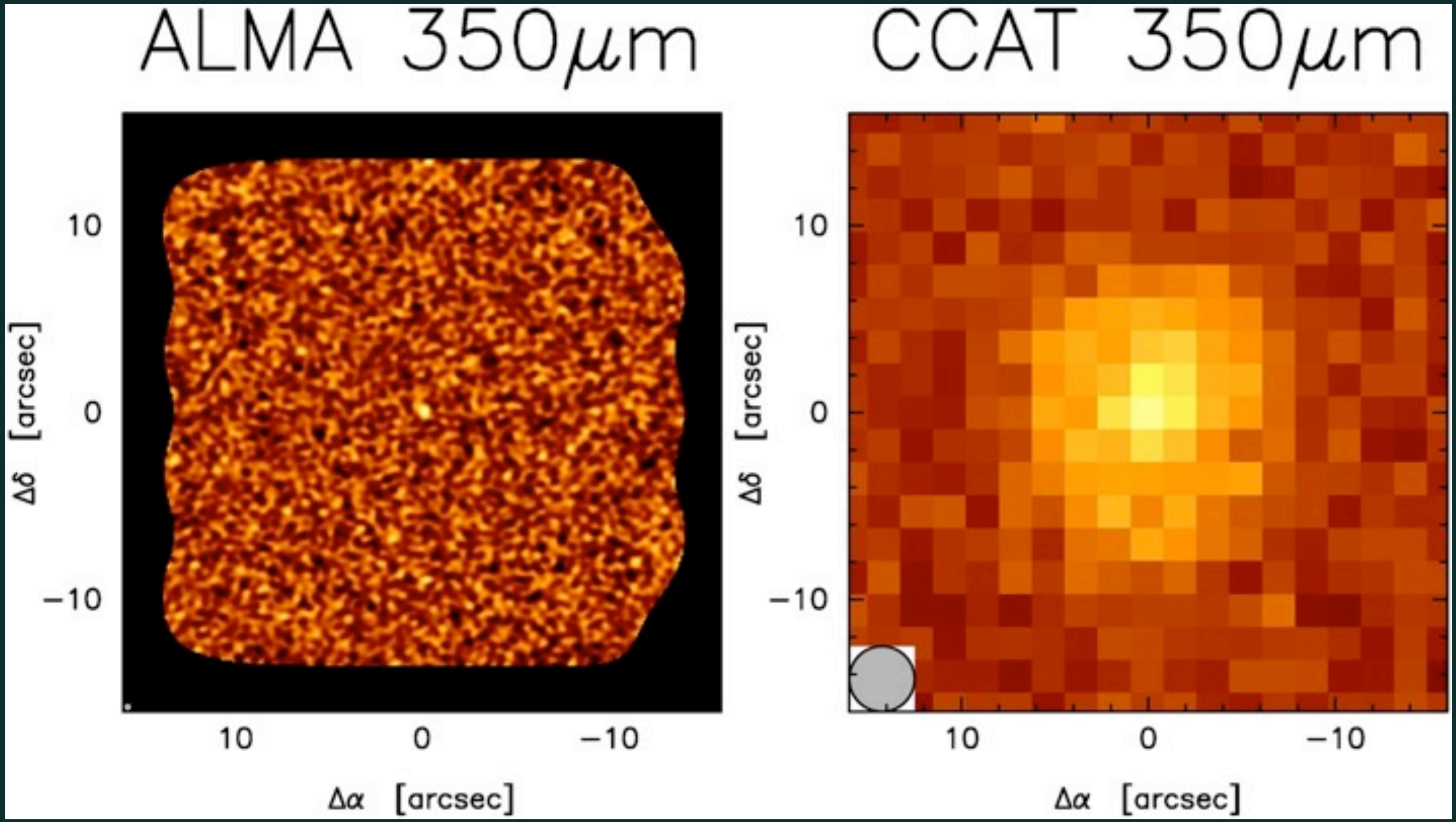
Similar *point source* sensitivity at 350 µm



- K2 star at 10 pc with no debris disk
- 4 hour integration with ALMA and CCAT

CCAT vs. ALMA: Extended Sources

CCAT is more sensitive to extended sources



- K2 star at 10 pc with debris disk
- 4 hour integration with ALMA (mosaic) and CCAT

Summary: CCAT will ...

- observe the transition from diffuse to dense clouds
- determine how clump IMF maps into the stellar IMF
- measure mass evolution of optically thick primordial disks
- identify the onset of debris disks
- probe architecture of planetary systems in the nearest debris disks