Massive Star Formation: The Role of Disks… And Beyond

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RASC – March 9, 2011

Outline

- The path I took to get here
- Intro to massive star formation
- Tools of the trade
- Two case studies
- Herschel Gould Belt Survey

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Steps along the way

- Internship at Fermilab
- Docent at the Kiwanis Chico Community Observatory
- Internship at Harvard-Smithsonian Center for Astrophysics
- Masters degree in astronomy at Wesleyan University
- PhD from MPIA in Heidelberg, Germany
- Postdoc at UVic/HIA

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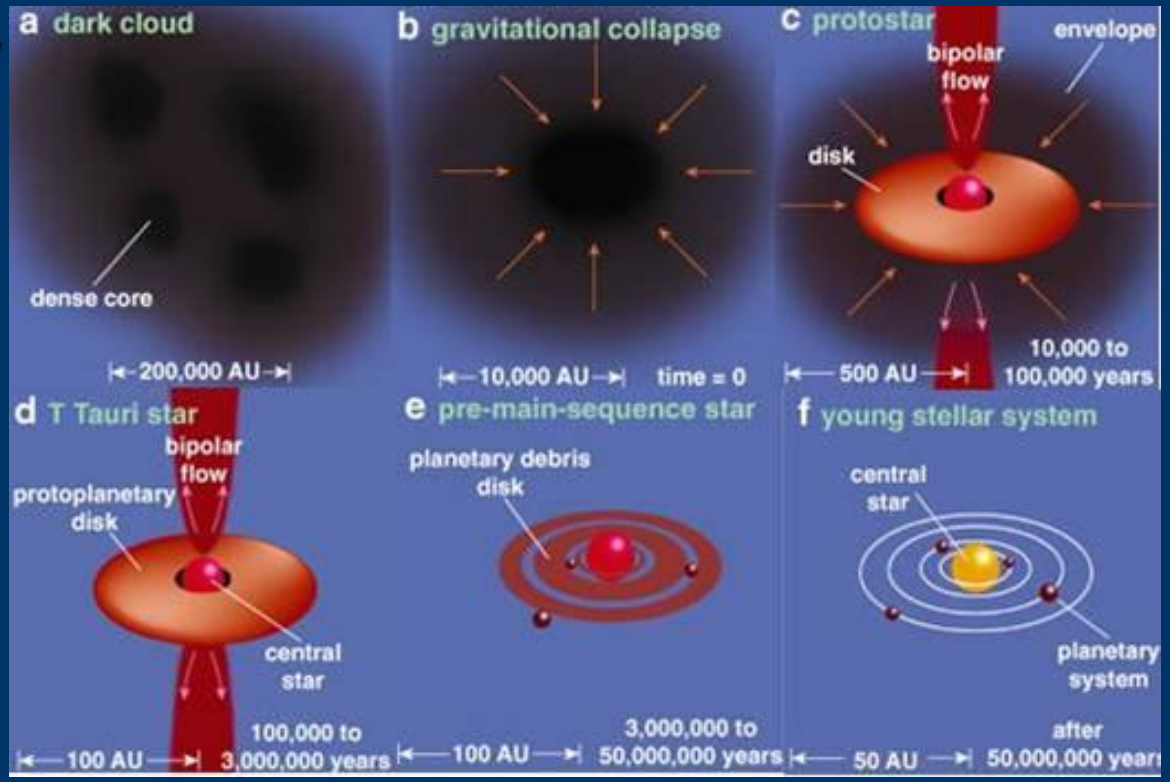
Underlying questions

- How do chemical species evolve kinematically and spatially in massive star formation?
- What role do disks play in massive star formation?
- How do disks evolve in massive star formation?

Some background

- Massive stars = M > $8M_{sun}$
- Two current formation theories
  1. scaled-up version of low mass SF (Yorke & Sonnhalter, 2002; Krumholz et al. 2007, 2009)
  2. competitive accretion (Bonnell et al. 1998, 2004, 2007)
- Should observe accretion disks in 1st scenario
- Typical outflows from low mass scenario aren't expected in 2nd scenario



Cartoon demonstrating Low Mass Star Formation

Rotational Structures

- Should see velocity gradient perpendicular to the outflow
- Limited by distance, clustered environment, deeply embedded sources
- Use (sub)mm interferometry
- Tracers of high density regions: $C^{34}S$, CH_3CN, N_2H^+, etc.
- Detailed study of two sources: IRDC18223-3, IRAS18151-1208

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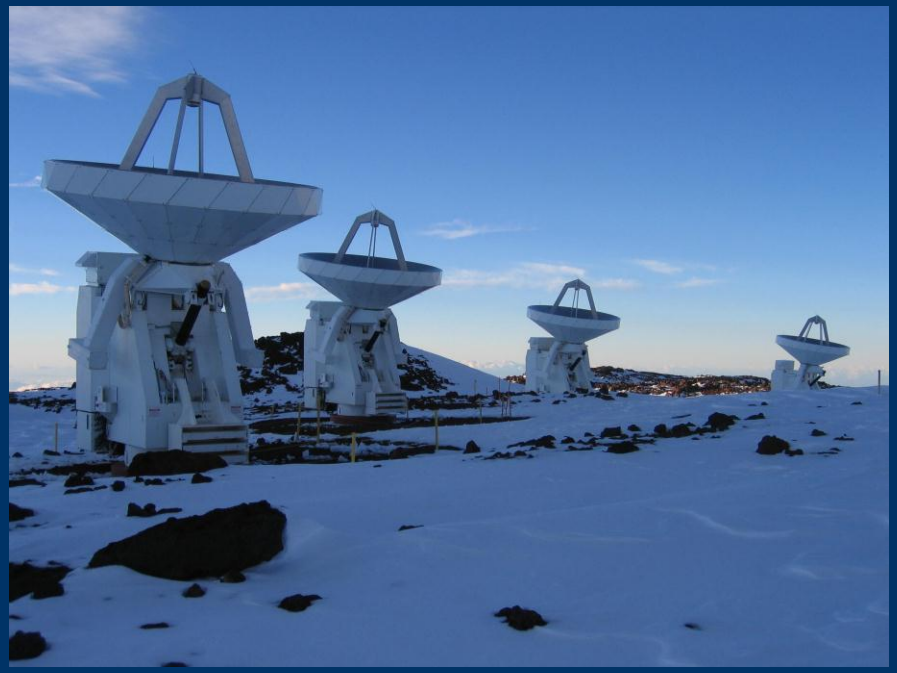
Radio Astronomy

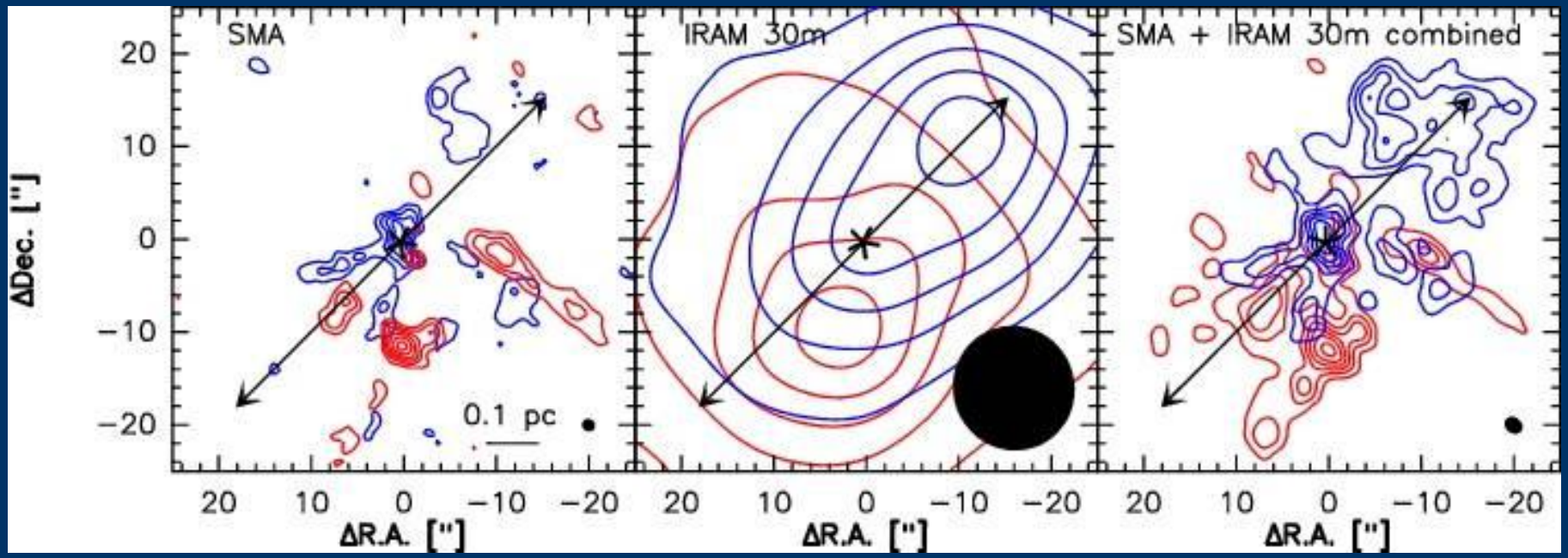
- Stars form deeply embedded in clouds of gas and dust
- High mass stars form in clusters
- Distance limitations
- Ang. resolution $\propto$ Wavelength/Diameter

IRAM 30m in Granada, Spain

Submillimeter Array



^{12}CO observations



- With and without short spacings

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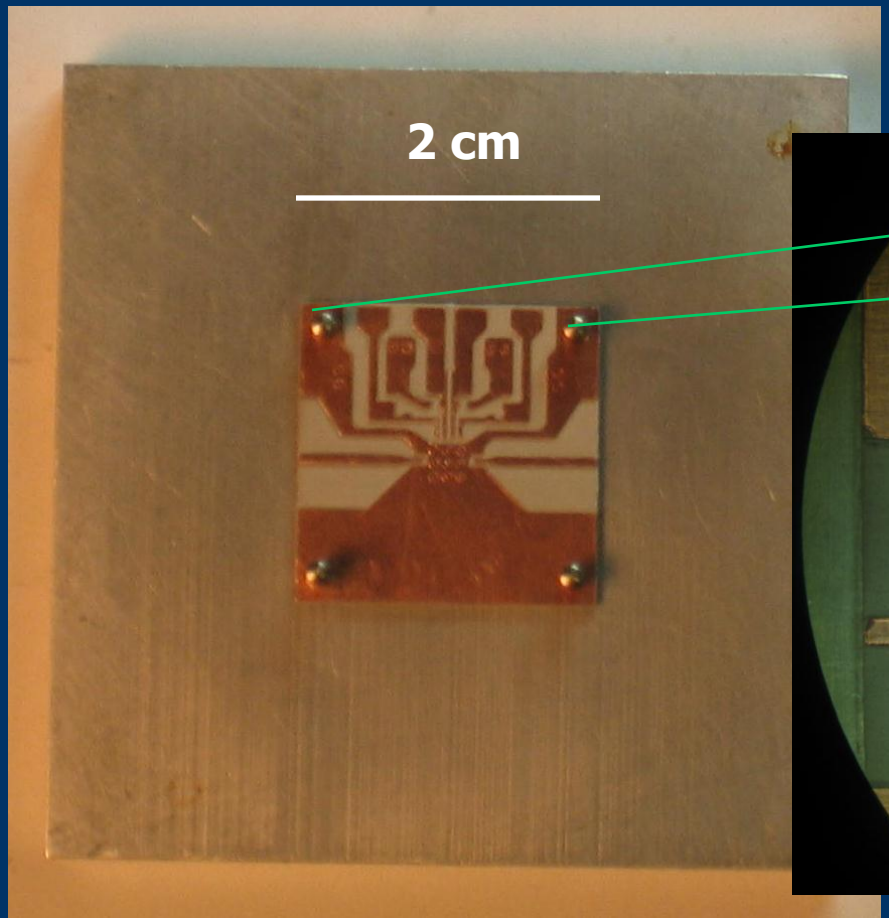
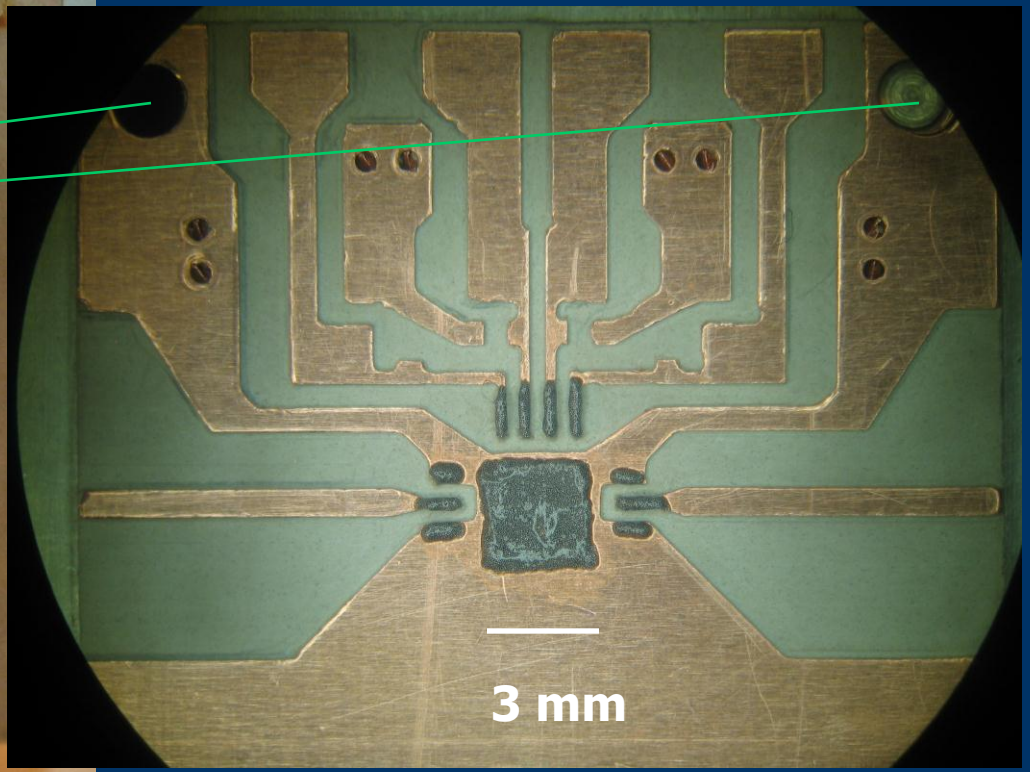
Phase Monitor Electronics

- Solder frequency multiplier chip onto copper coated Teflon board





Project Update

- Four frequency multipliers being used at the SMA sharing the pads with the antennas (Used to monitor phase shift due to water vapor in the atmosphere)
- One used in NASA's Deep Space Network; two more coming
- Two sent to SKA test sites in Australia and South Africa

Project Update

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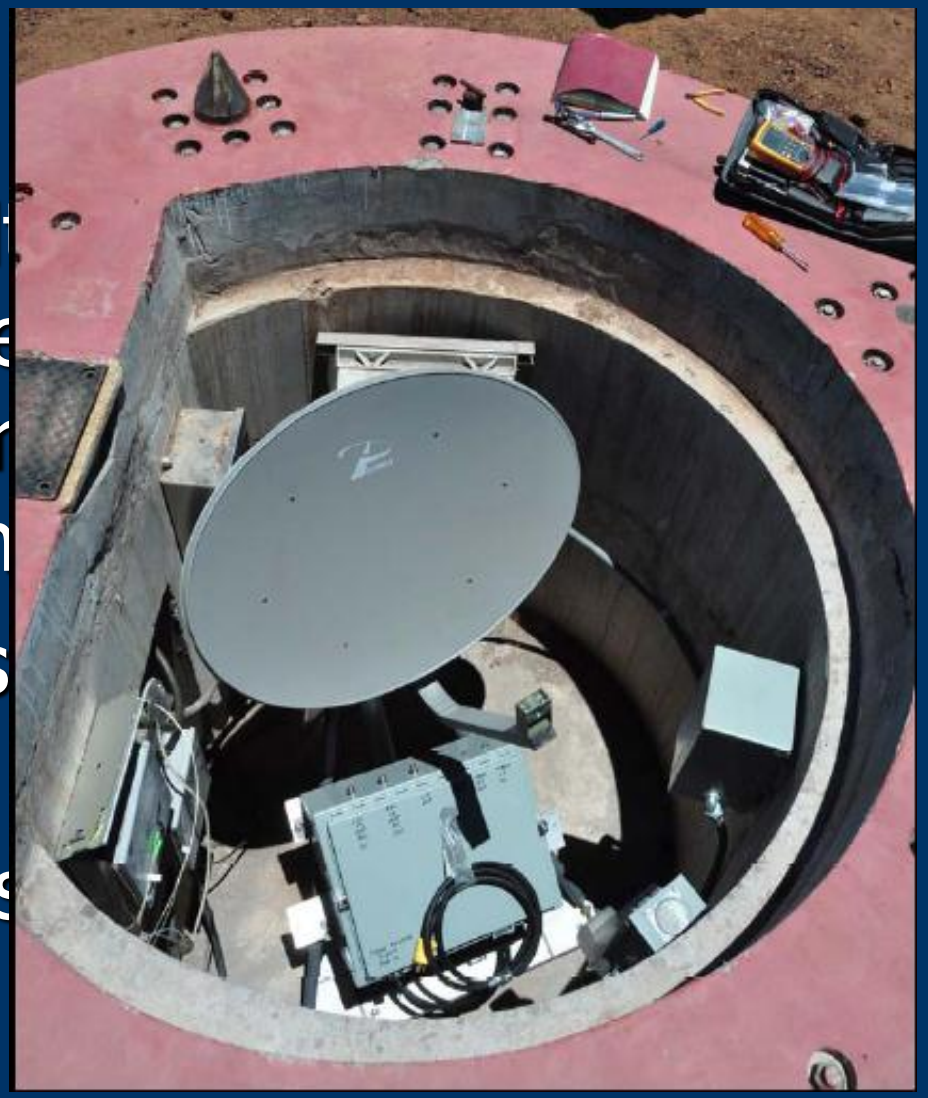

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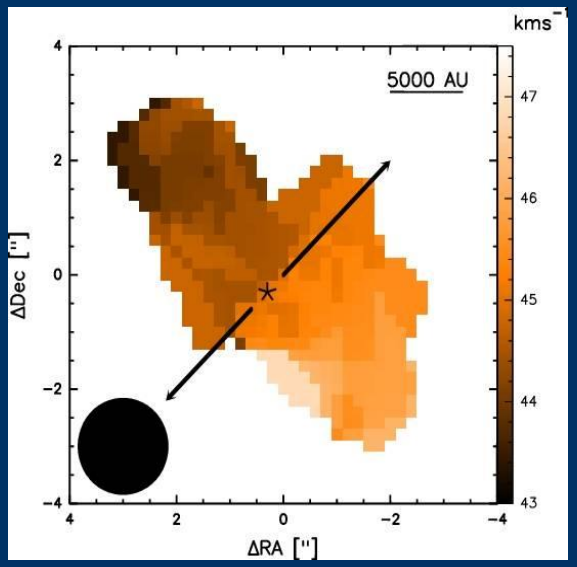
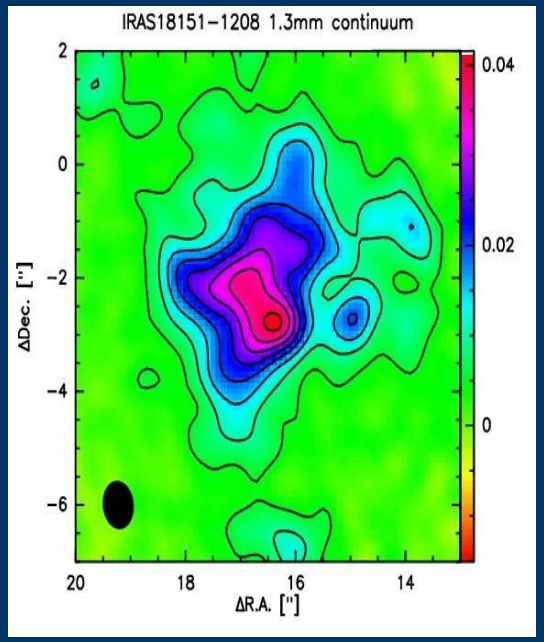
Two Case Studies

AGE

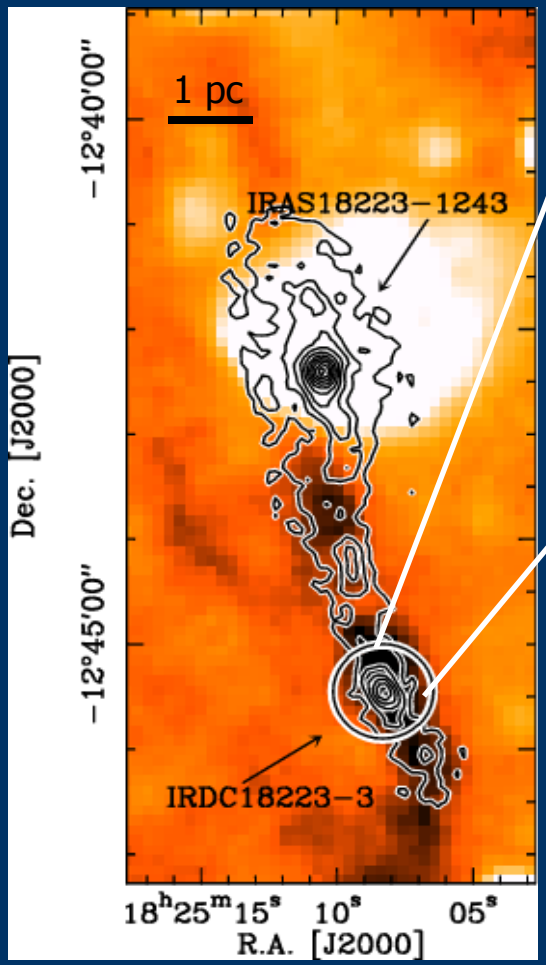
- IRDC 18223-3
- IRAS 18151-1208

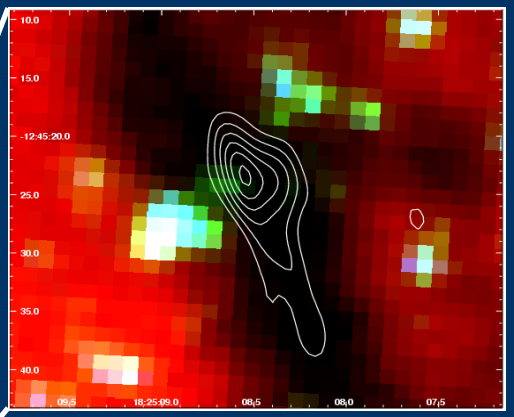




IRDC 18223-3: Infrared Dark Cloud

- Distance~3.7 kpc





3-color Spitzer image with
3mm cont. contours

1.2 mm single dish contours,
8 micron MSX image

Beuther, Sridharan &
Saito 2005

IRDC 18223-3: Infrared Dark Cloud

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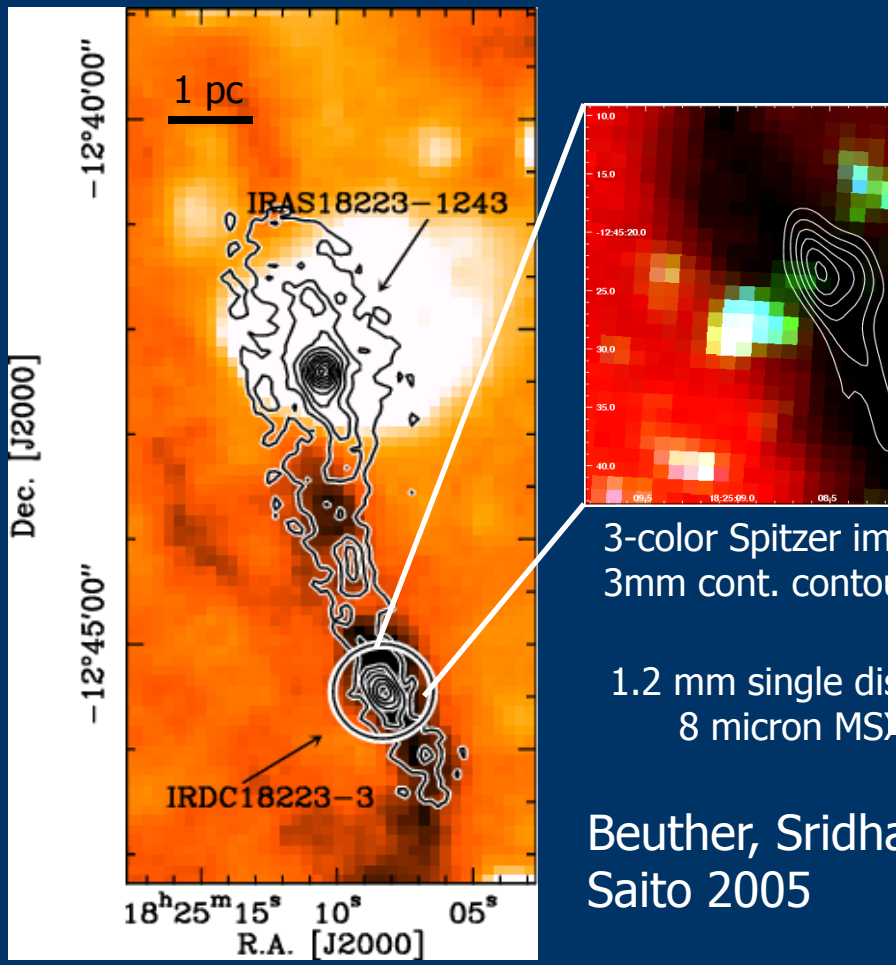

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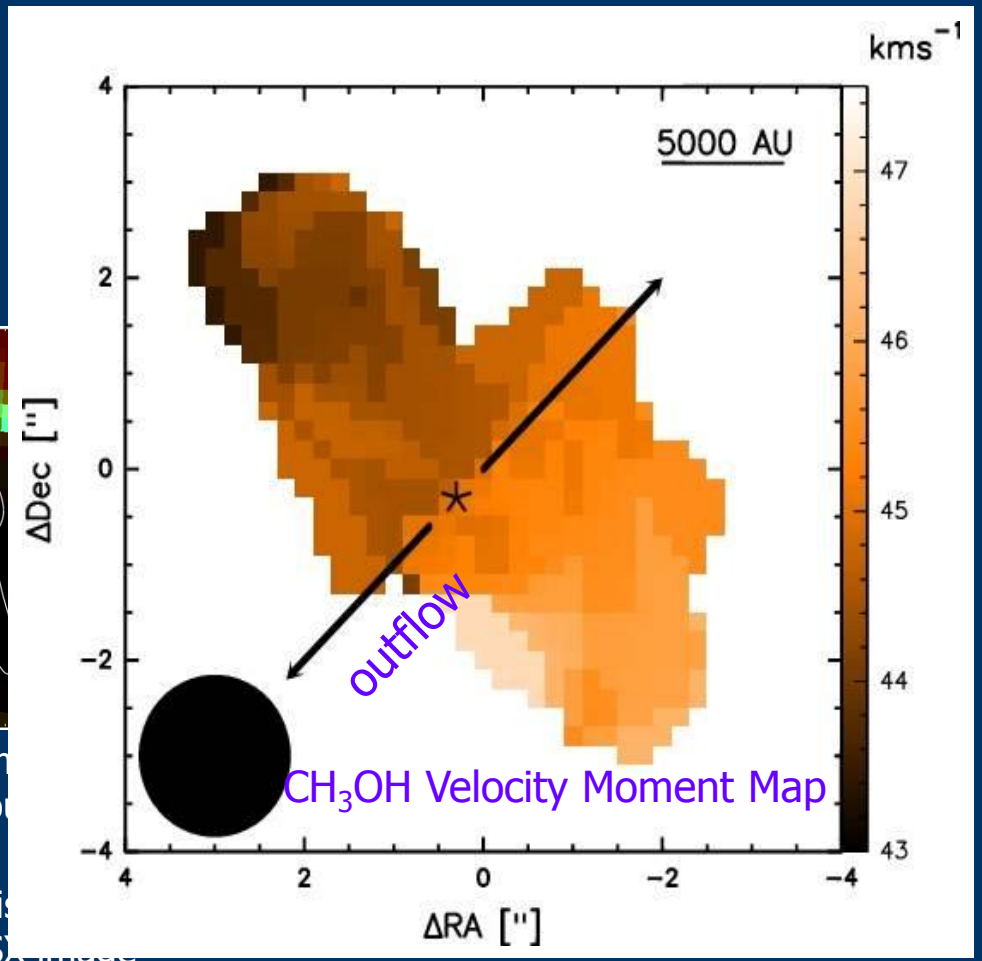
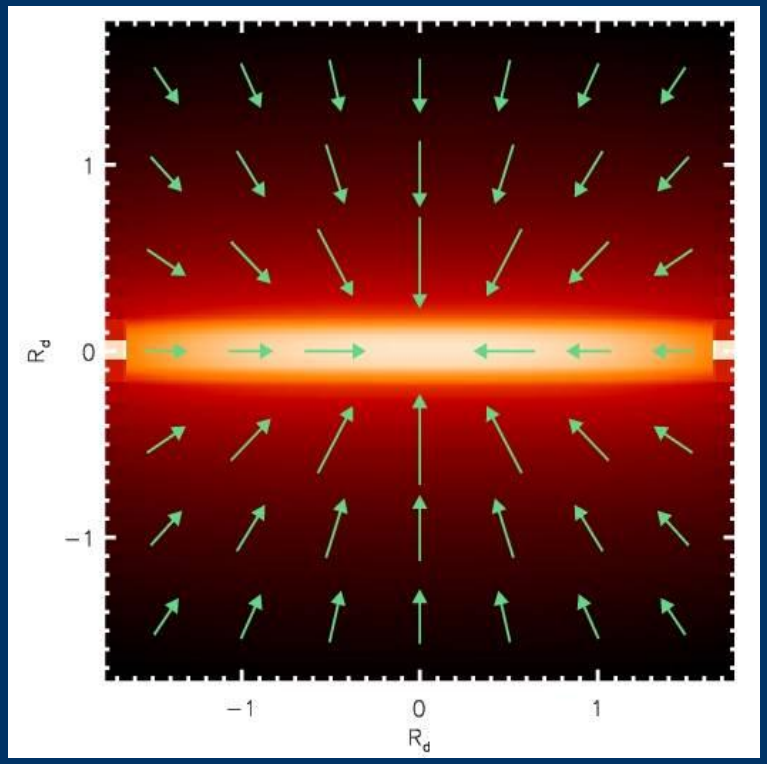
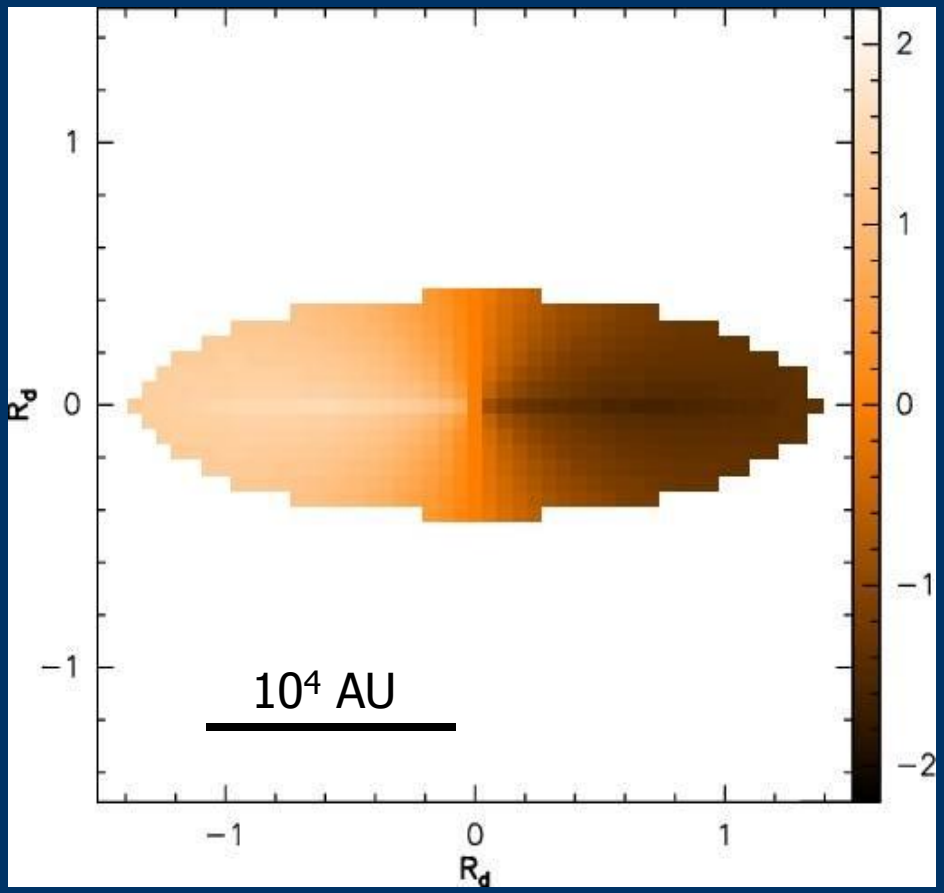


Fallscheer et al. 2009, A&A, 504, 127

Infall model



Density distribution



Velocity distribution

Model collapse of an initially rotating structure

Model includes gravity and conserves angular momentum

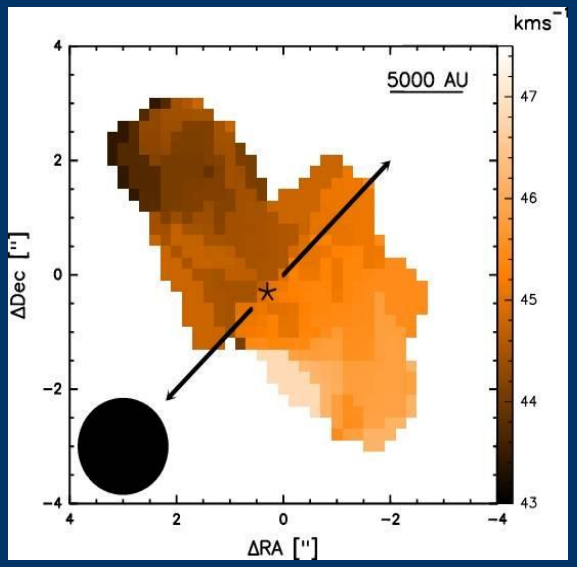
Input quantities:

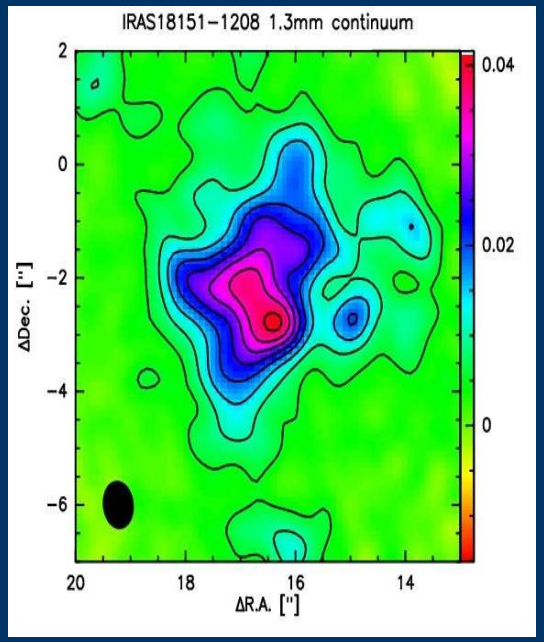
50 M_{sun}
1.5 km/s observed at 14000 AU

Two Case Studies

AGE

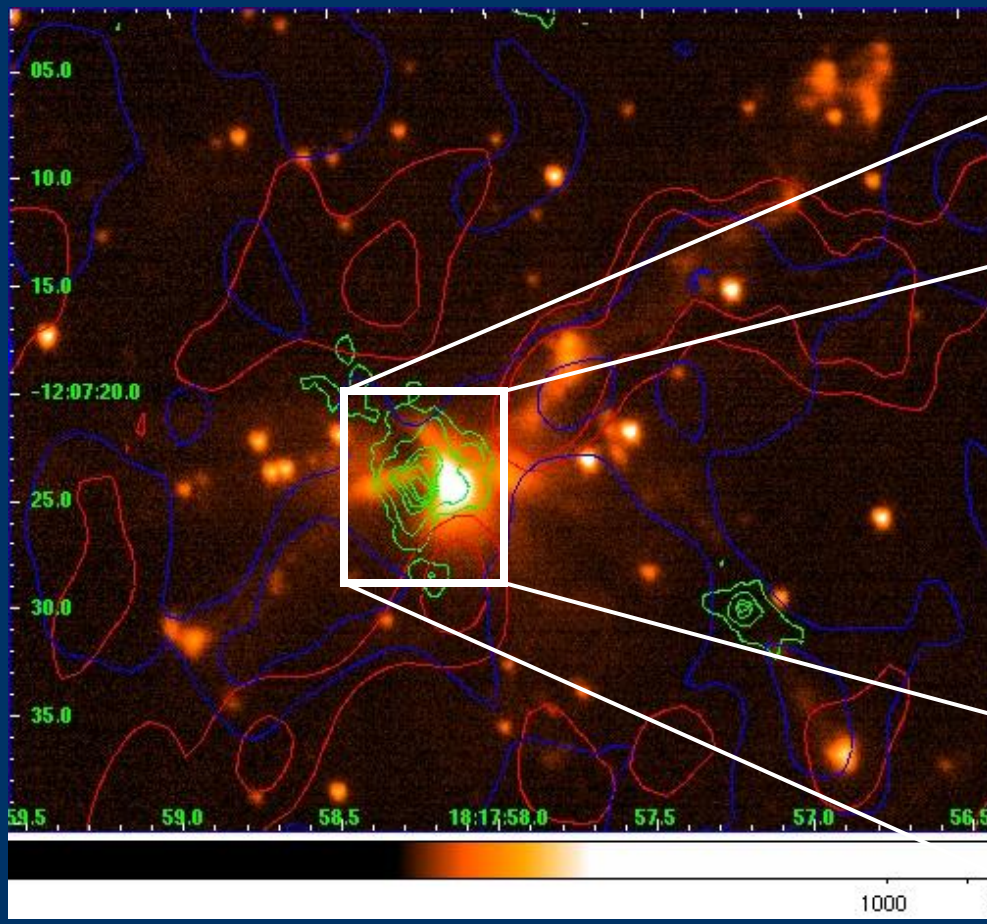
- IRDC 18223-3
- IRAS 18151-1208

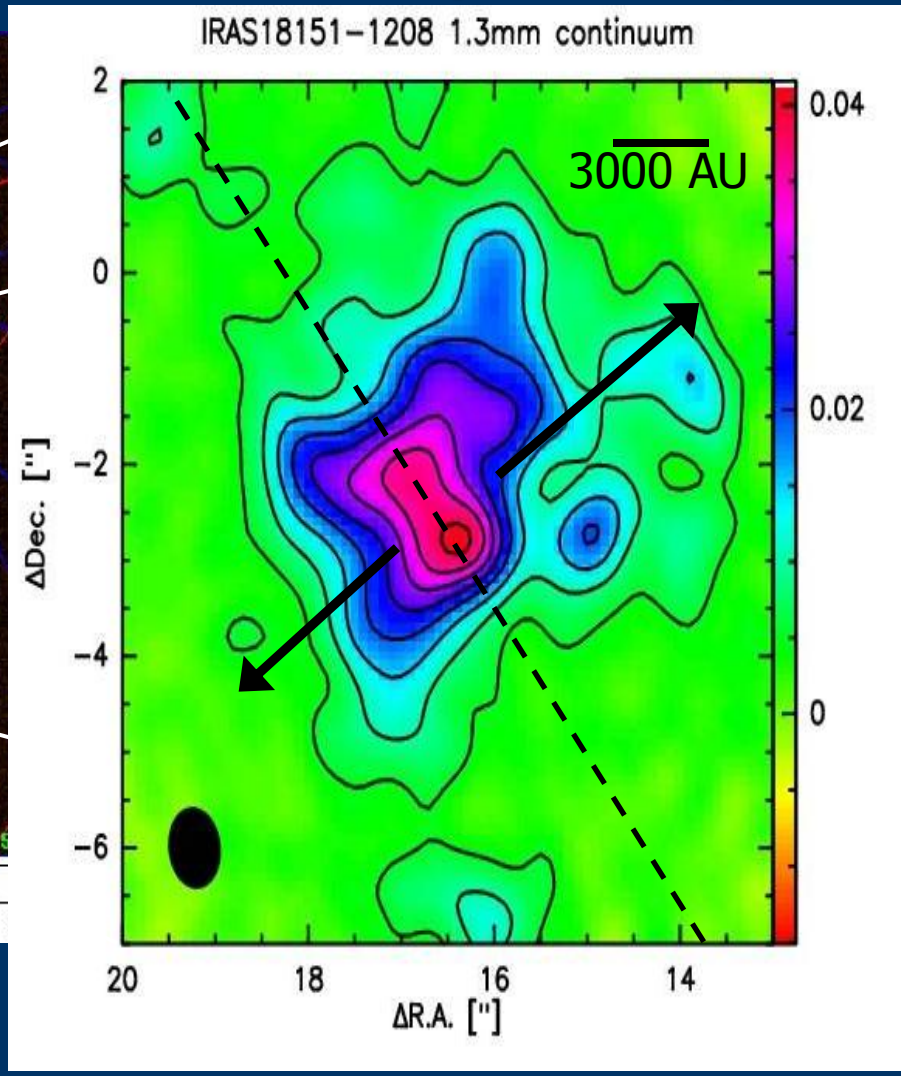




The high mass protostellar object IRAS 18151-1208

- 3.0 kpc away



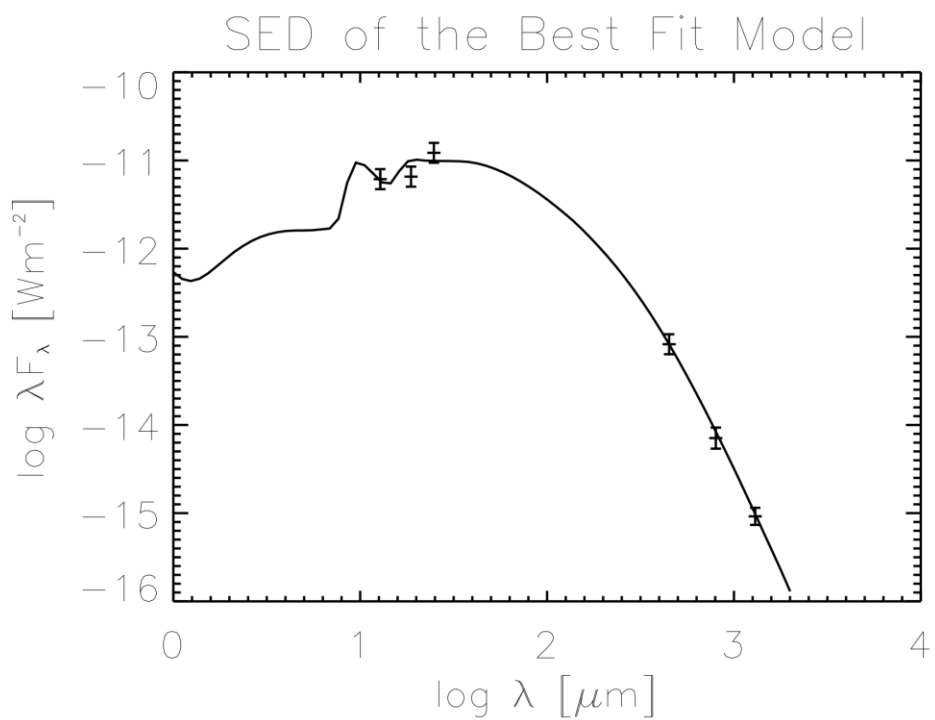


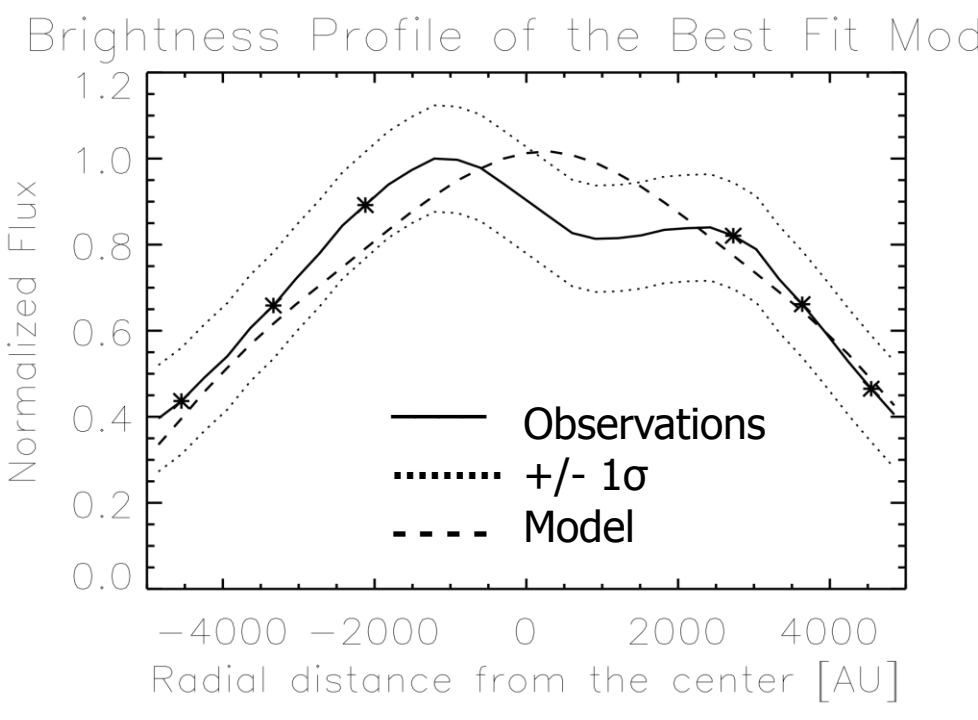
Davis et al. 2004, A&A, 425, 981

Modeling with MC3D

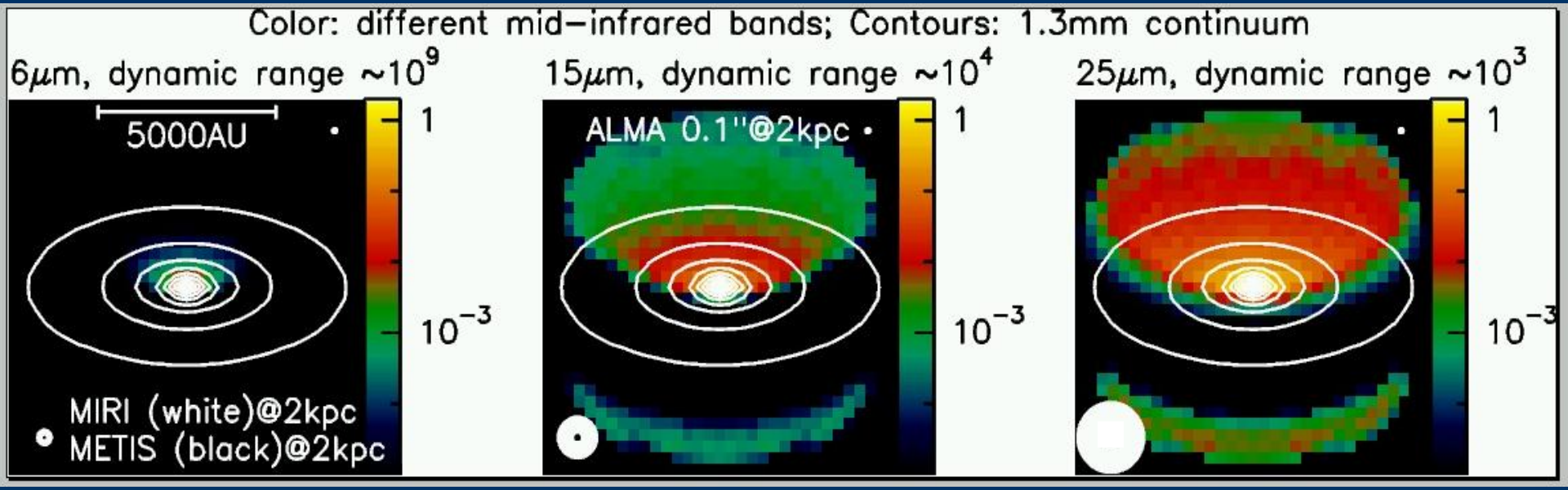
Fallscheer et al. 2011

	Low Mass: Butterfly Star	High mass: IRAS 18151-1208
α, radial density parameter	2.4	2.4
β, disk flaring parameter	1.3	1.3
M_{dust}	0.0007 $M_\odot$	2.2 $M_\odot$
R_{out}, radius where density=0	300 AU	5000 AU
R_*, T_*, L_*	2 $R_\odot$, 4000 K, 0.92 $L_\odot$	6.4 $R_\odot$, 25400 K, 16000 $L_\odot$





Predictions for the Future



- Predictions for ALMA, JWST, E-ELT
- Mid-infrared to millimeter wavelengths

Points to remember

- Elongated disk-like features decrease with evolutionary stage
- 20,000 AU velocity structure can be reproduced with a collapsing rotating model…disk possibly in the center
- Elongation in the dust continuum modelled with a scaled up version of a low mass disk

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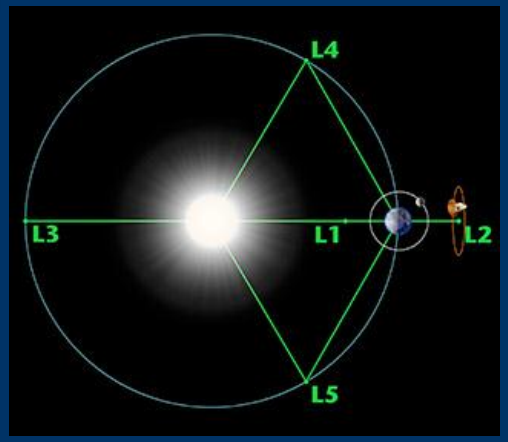
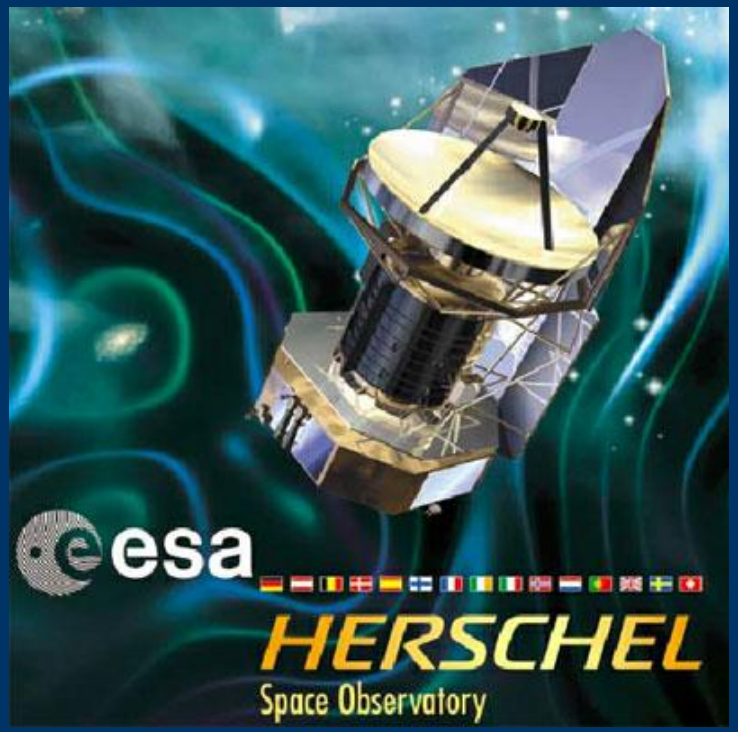
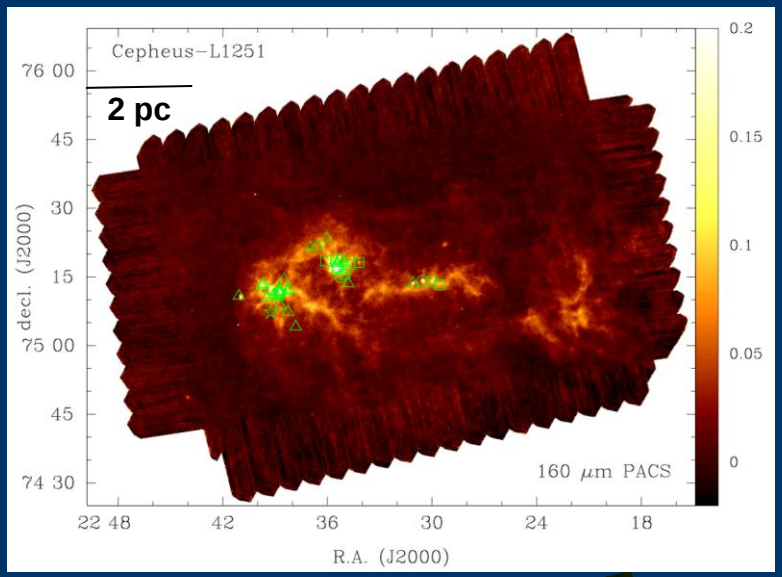
Herschel Space Observatory

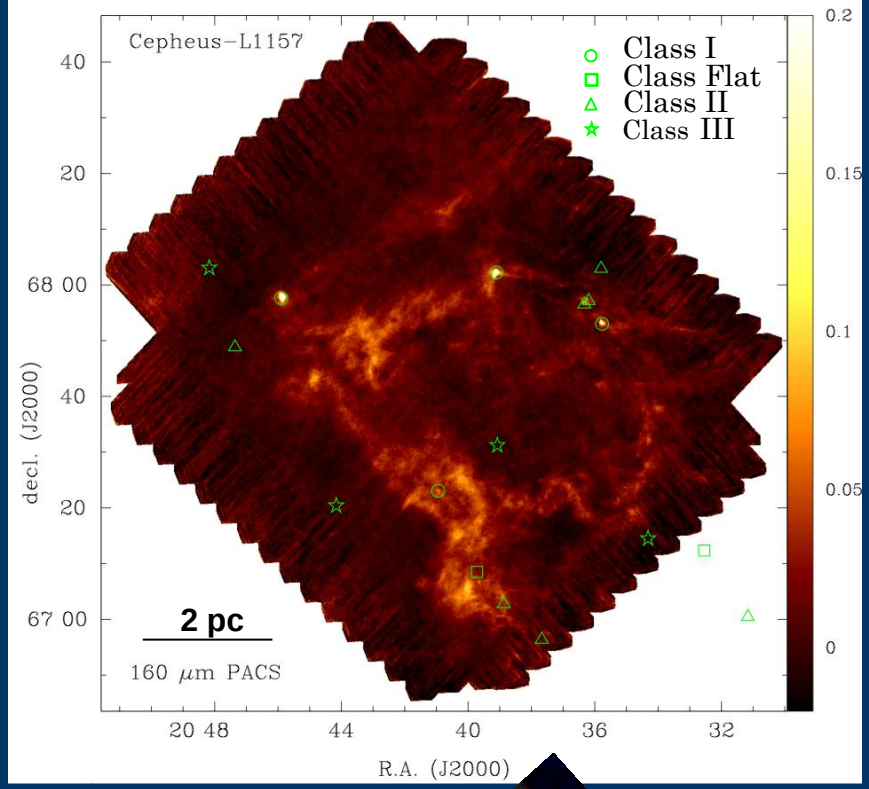
- Launched 14.May.2009
- Three year lifespan
- Solar orbit at L2
- 3.5 meter diameter
- 60-670 micron (PACS, SPIRE, HIFI)

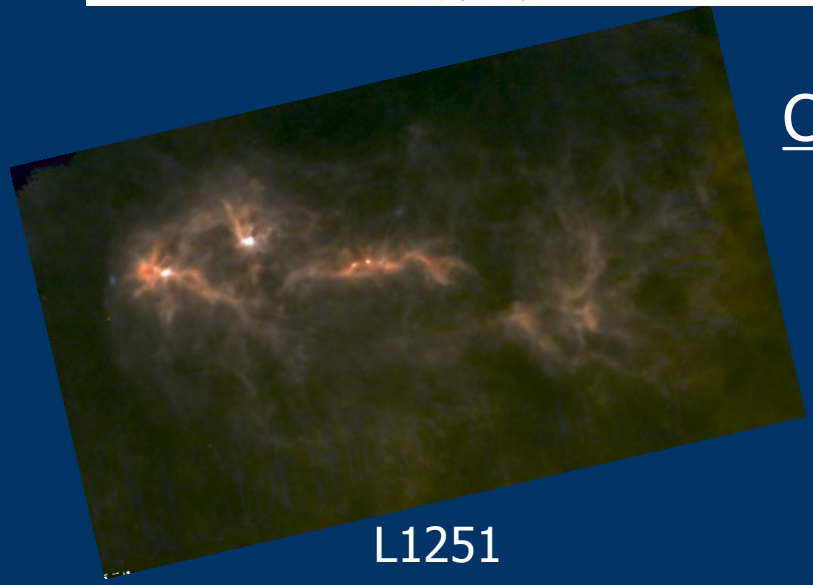




P. André & P. Saraceno (2005)





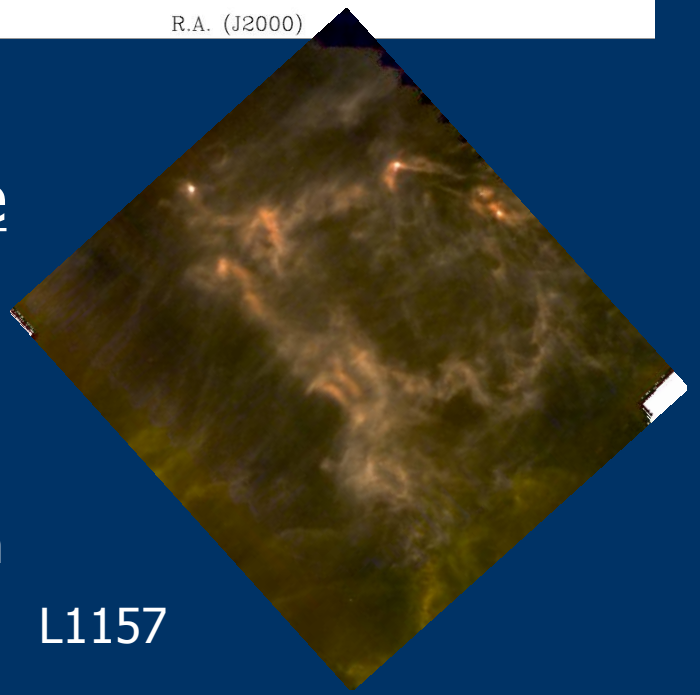


L1251

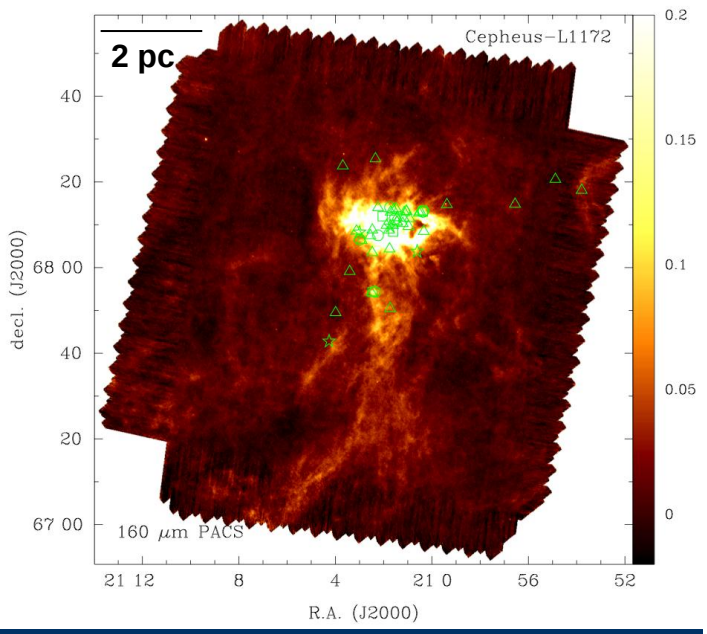
Cepheus Flare

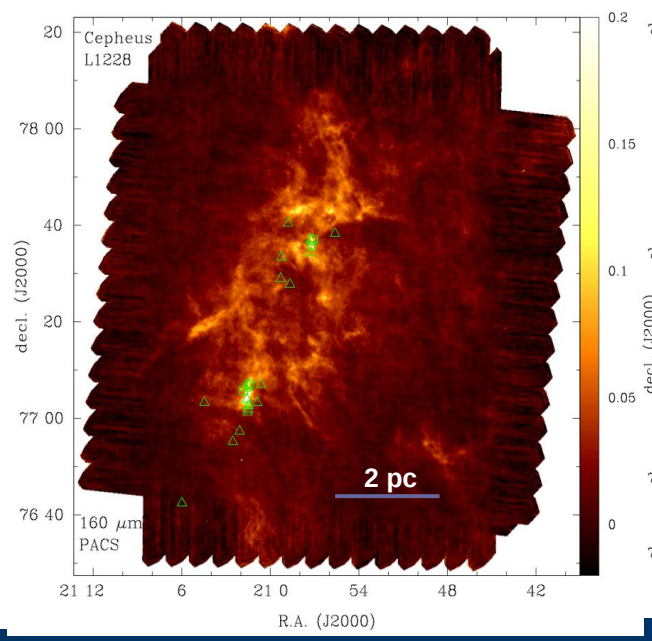
C. Fallscheer
J. Di Francesco
P. Martin
C. Wilson
S. Sadavoy
+ GBS team

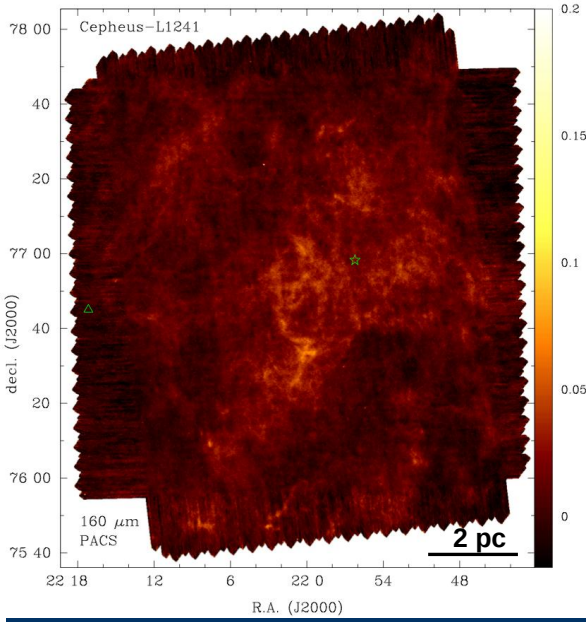
160 250 500 μm

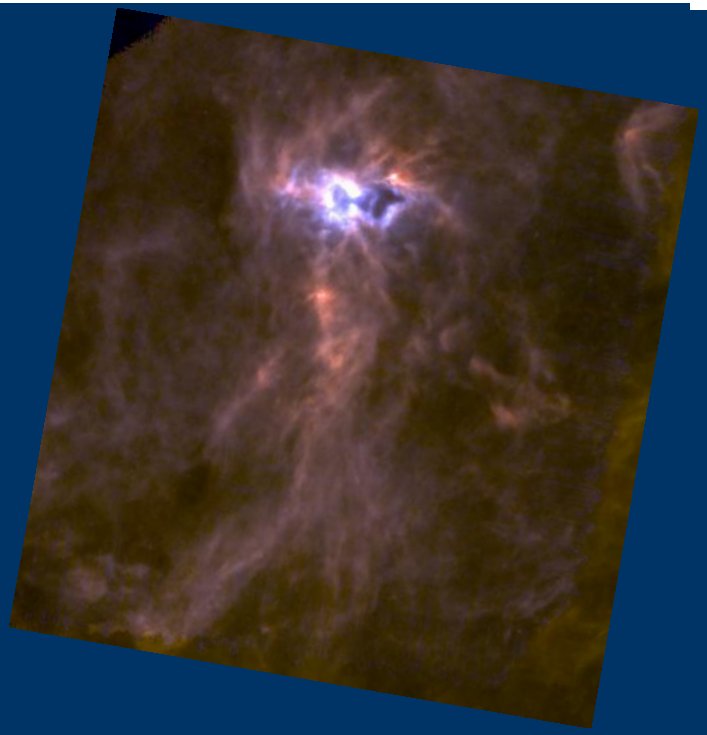


L1157









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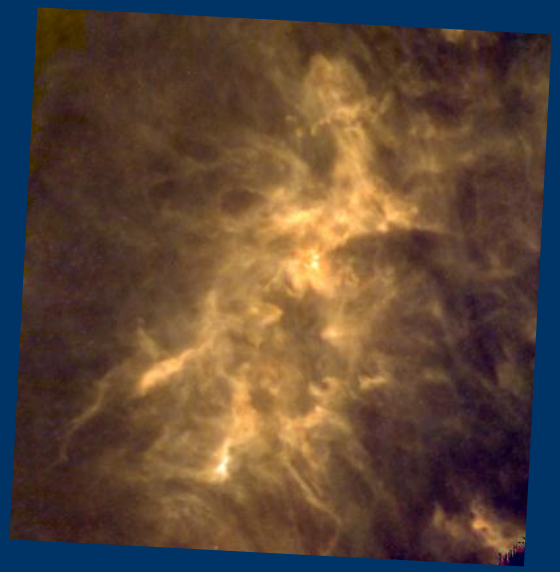
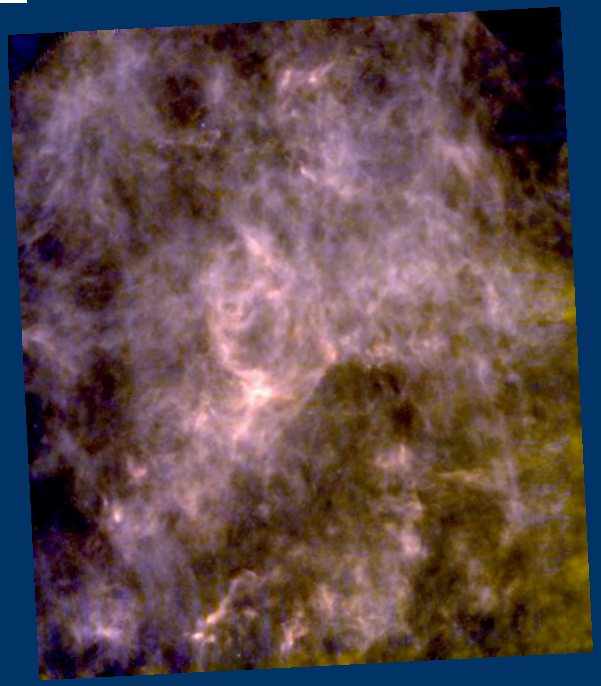


L1228
160, 250, 500 μm



L1241