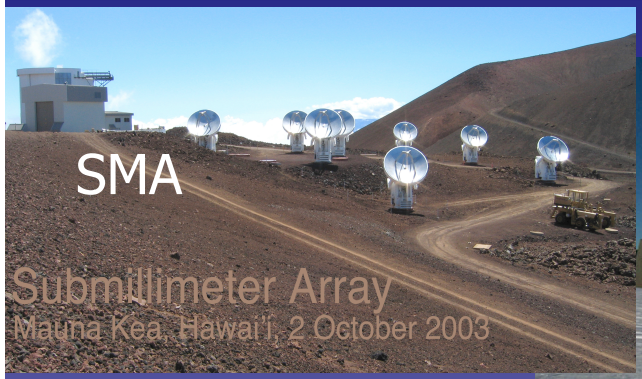
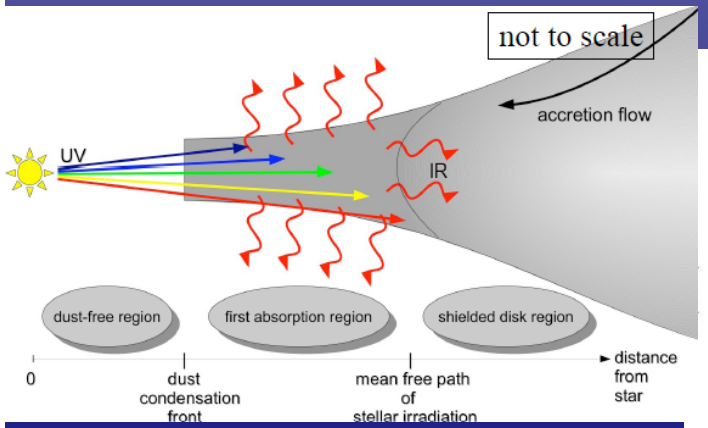
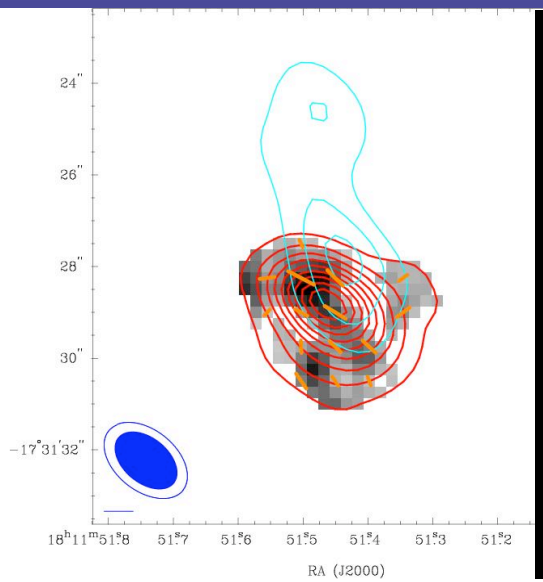
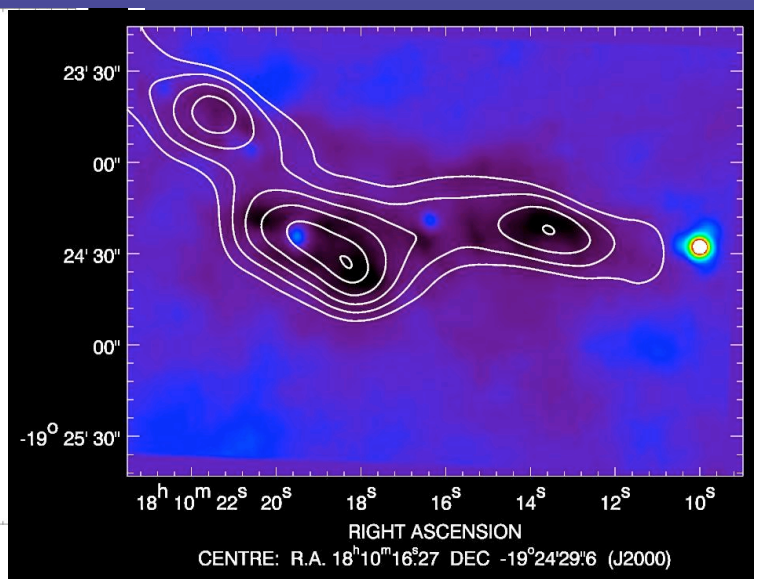
Formation and early evolution of massive stars

Henrik Beuther









Topics for today

- Some conceptual/theoretical ideas

- Characterizing the earliest evolutionary stages with Herschel

- What are the characteristics of accretion disks/large toroid in high-mass star formation?

- Can we constrain the magnetic field structure?

- Fragmentation and sequential star formation?

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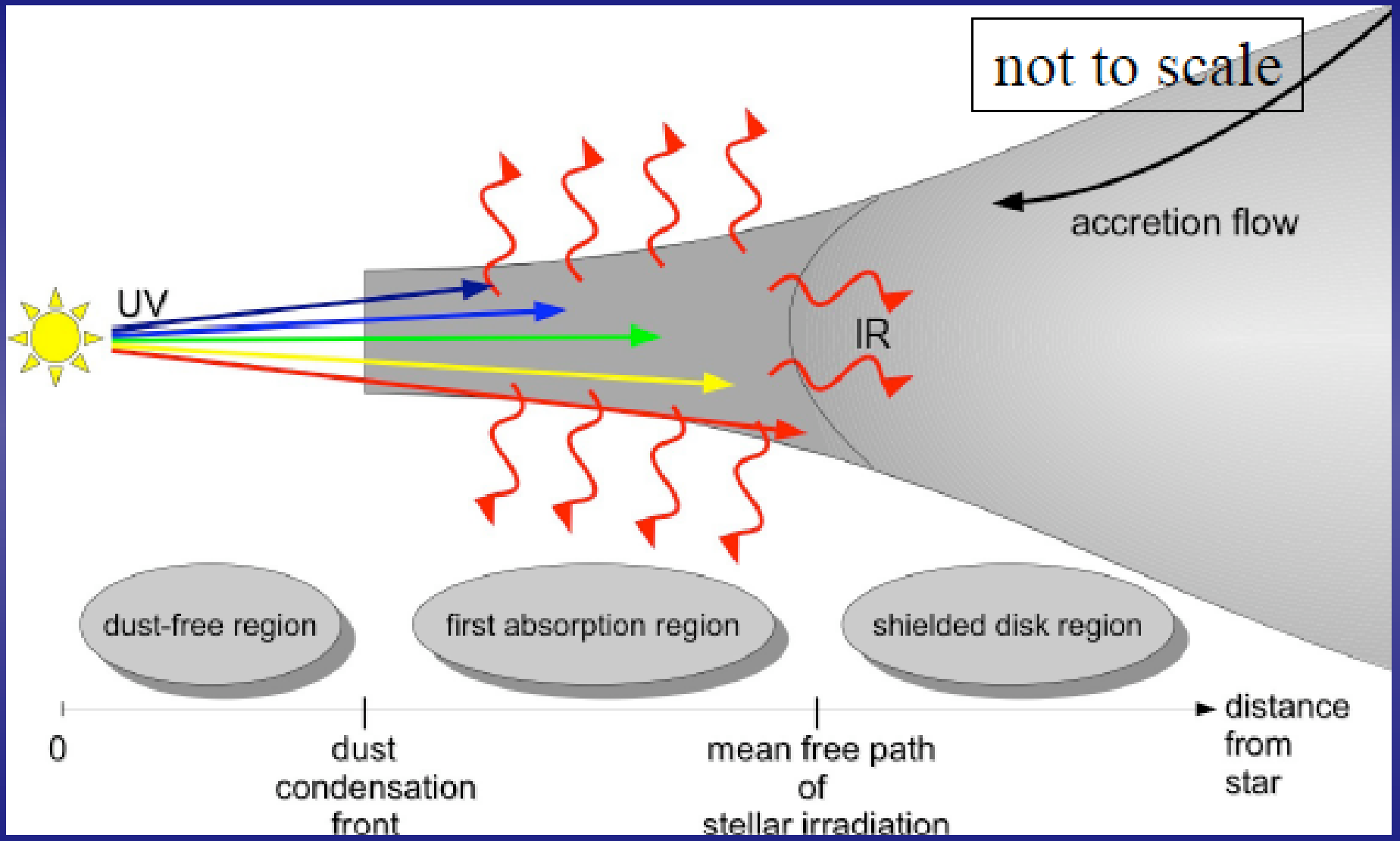
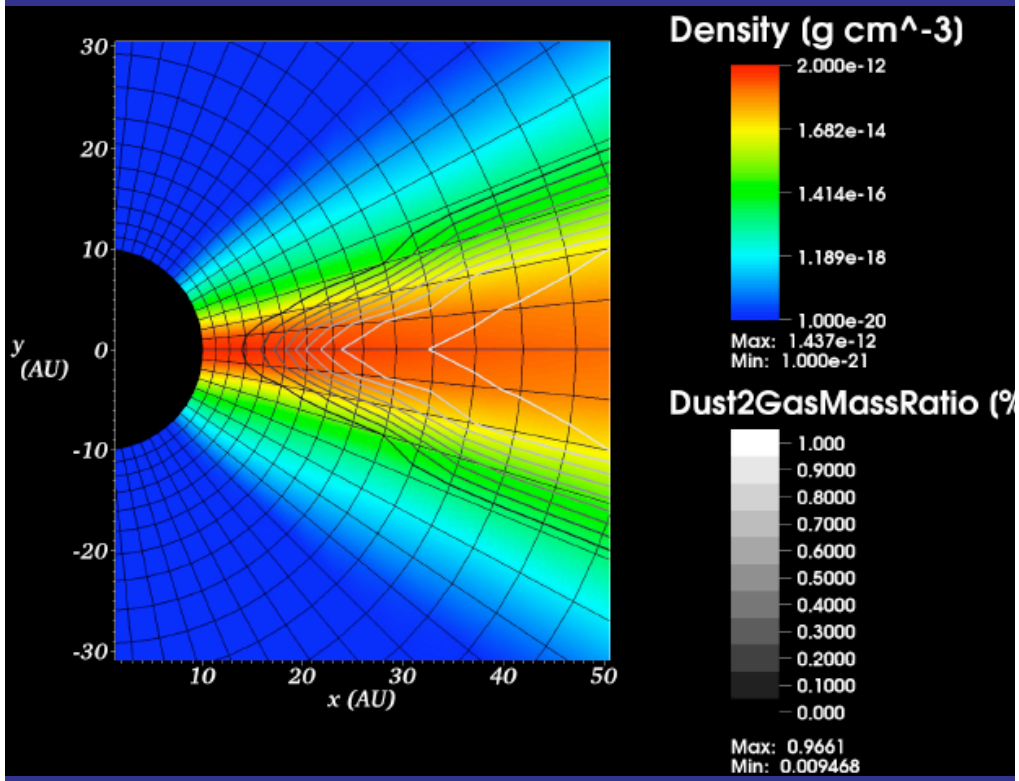
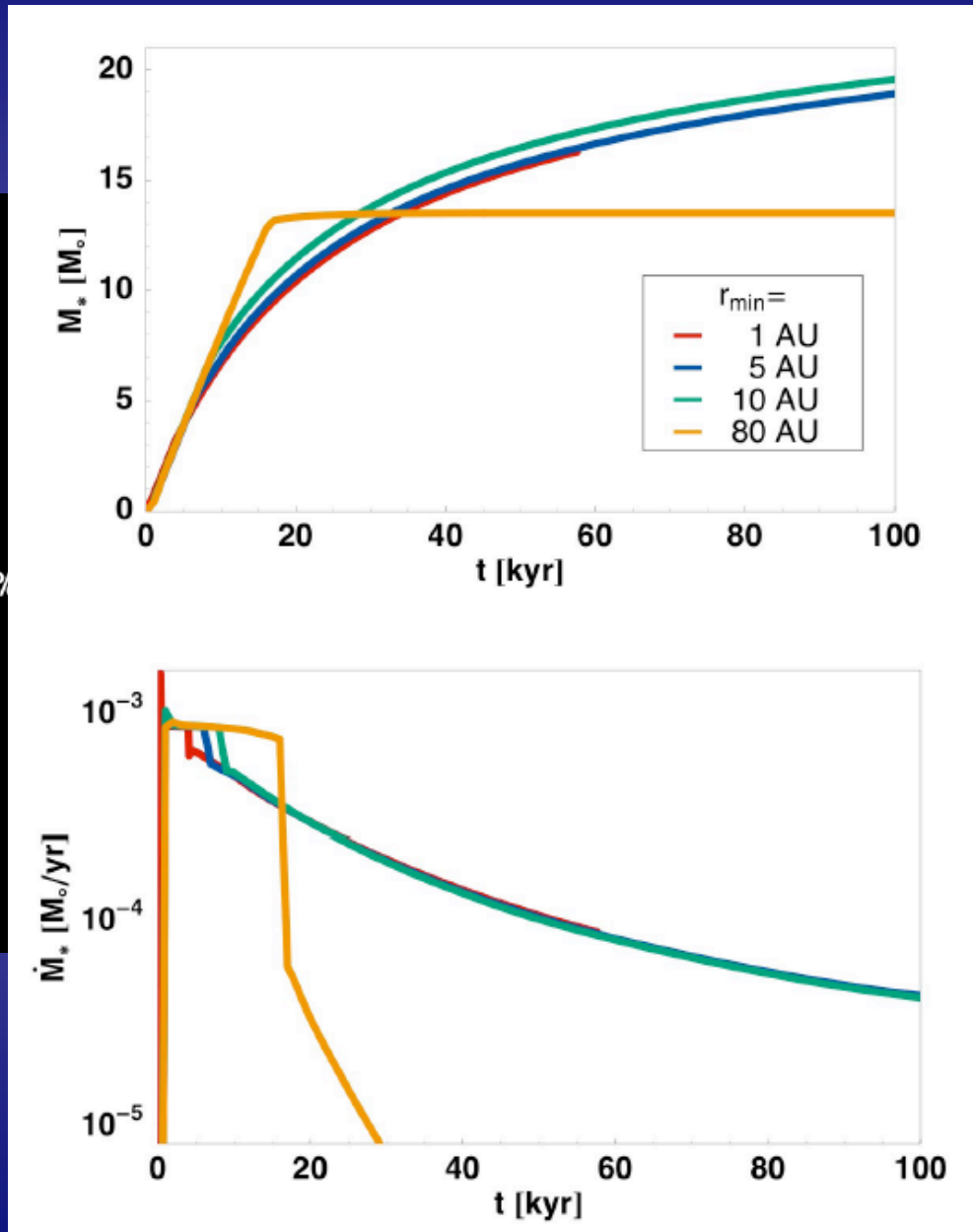
Conceptual ideas



Courtesy of Rolf Kuiper

Forming massive stars already in 2D





Kuiper et al. subm., see also his poster 16

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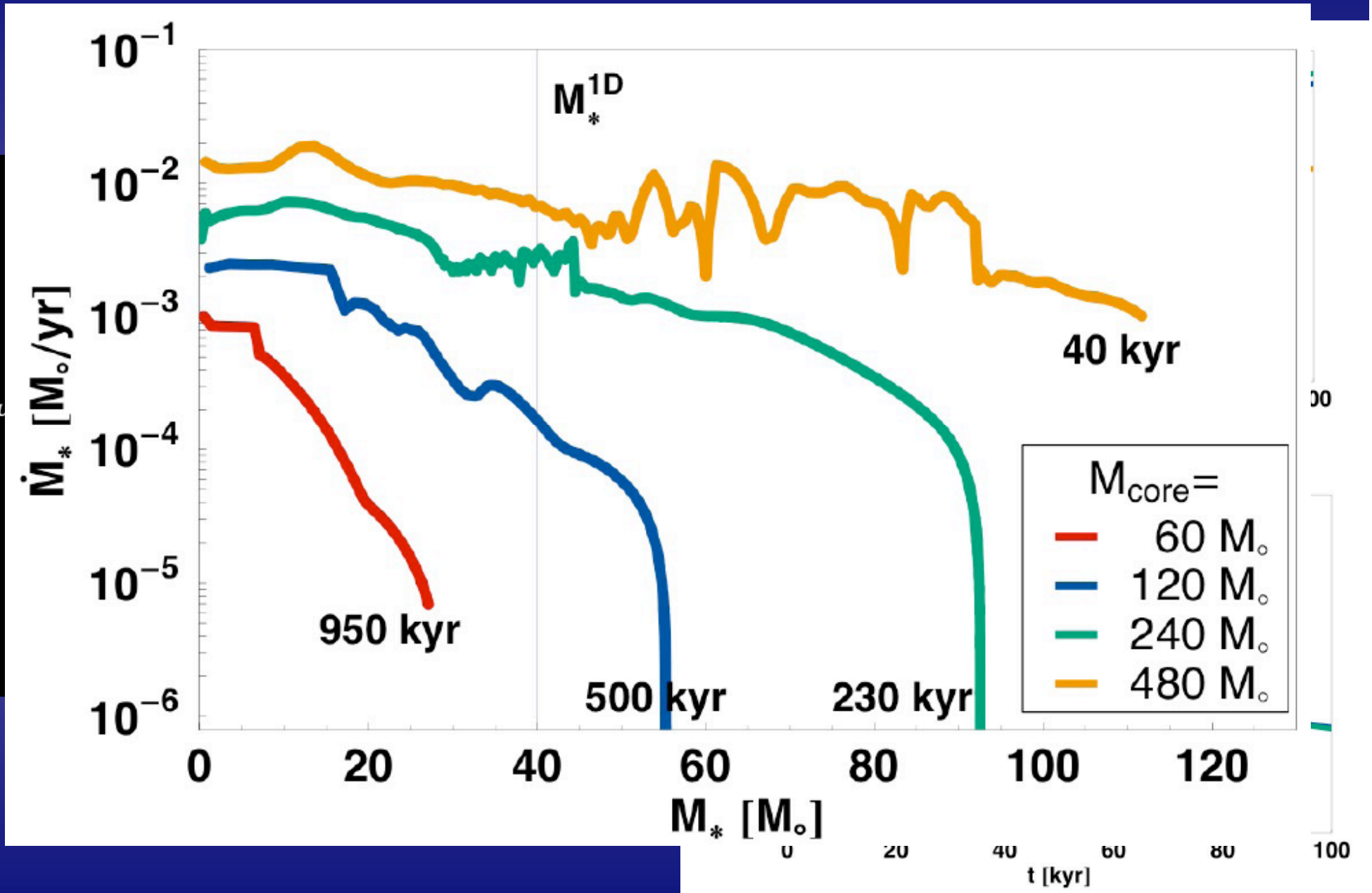

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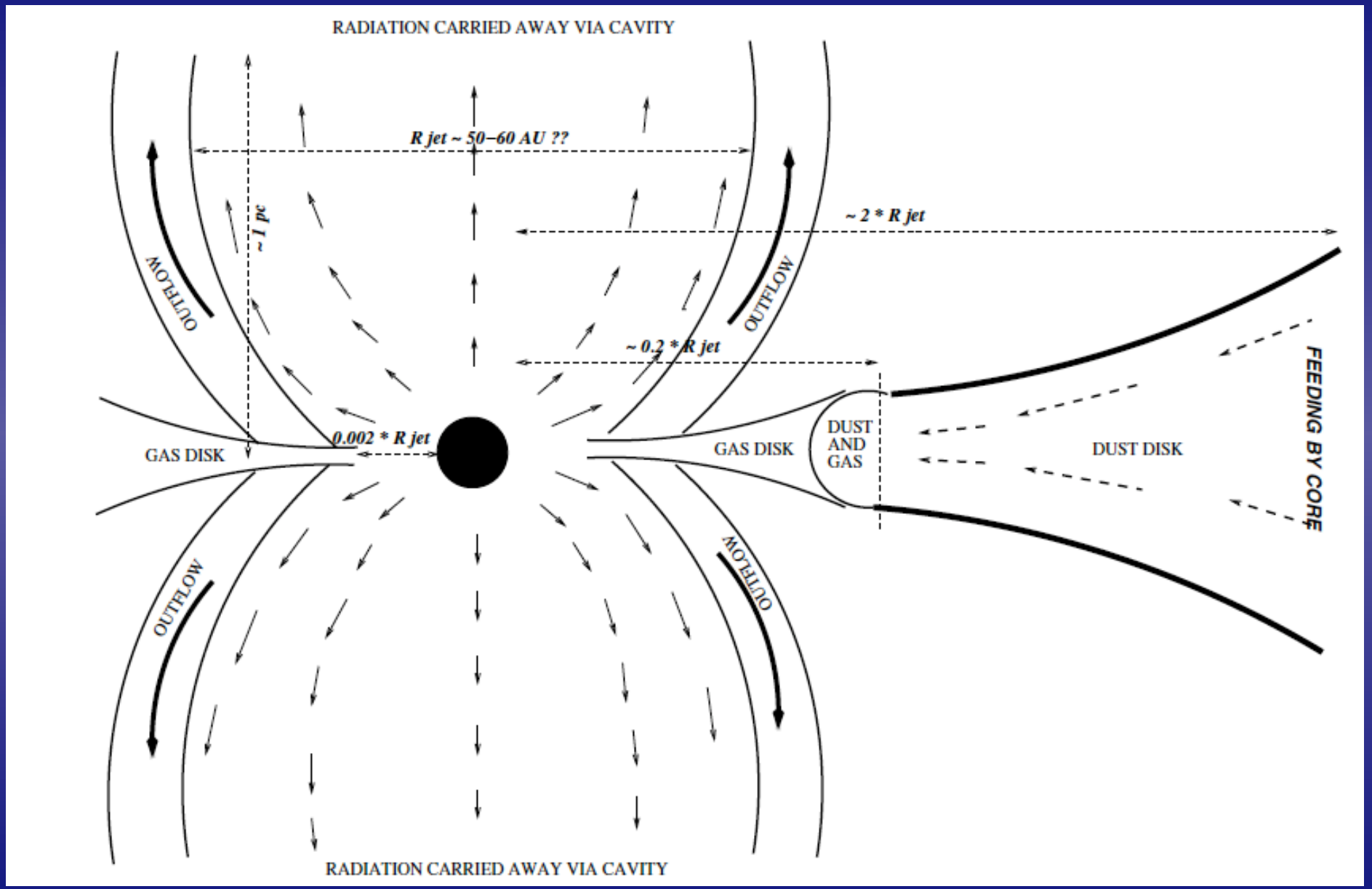
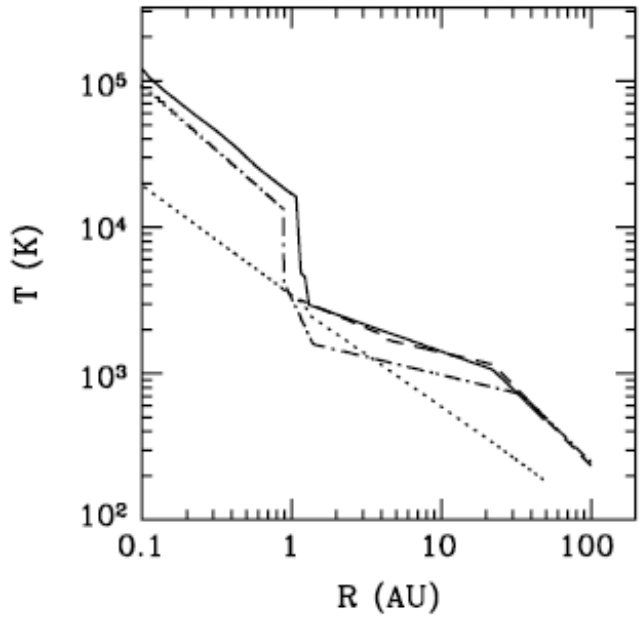
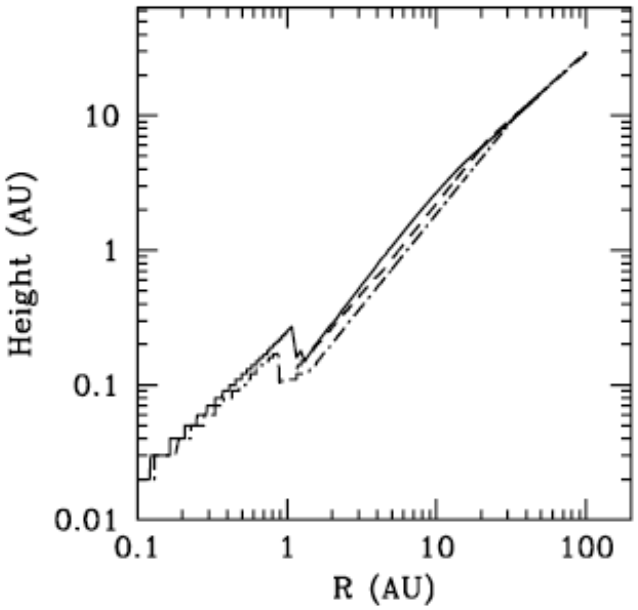
The innermost disk region

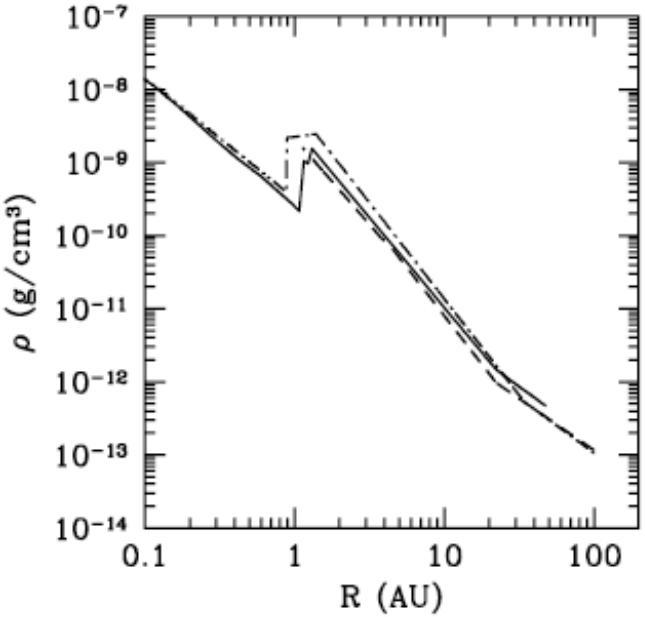


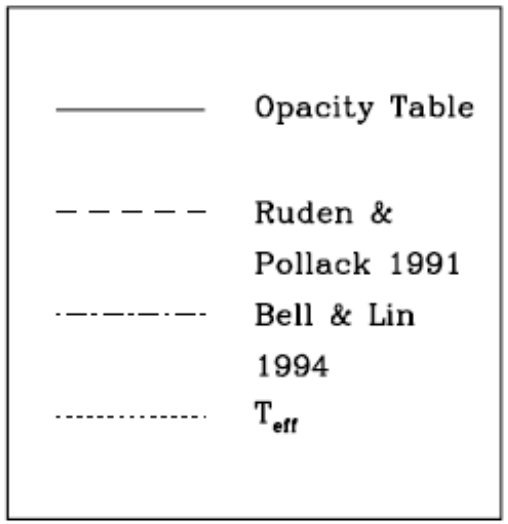
Vaidya et al. 2009

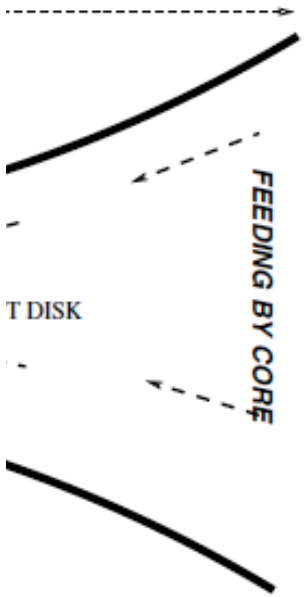
The innermost disk region











Vaidya et al. 2009

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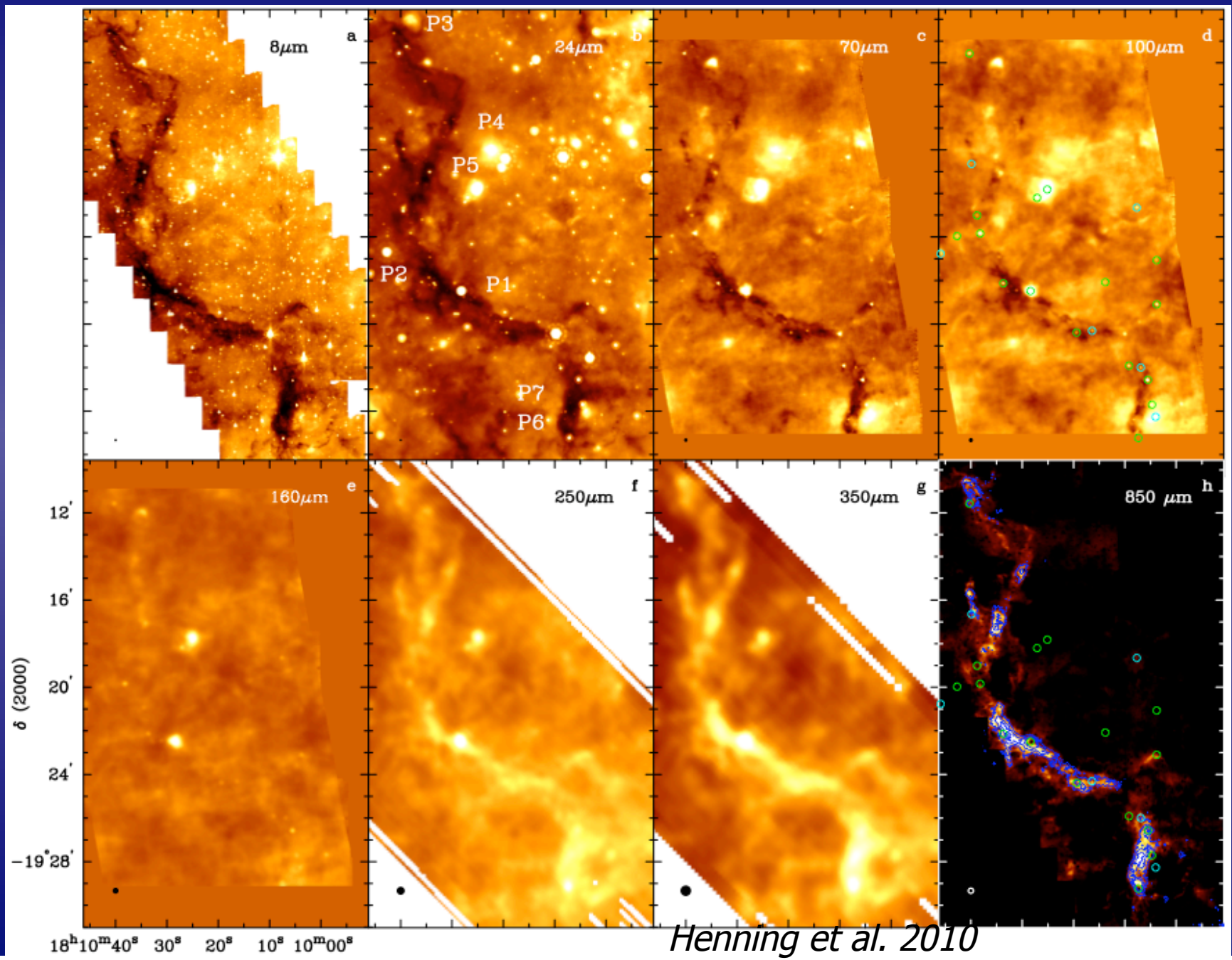
The Herschel view of the Snake G11.11



Henning et al. 2010

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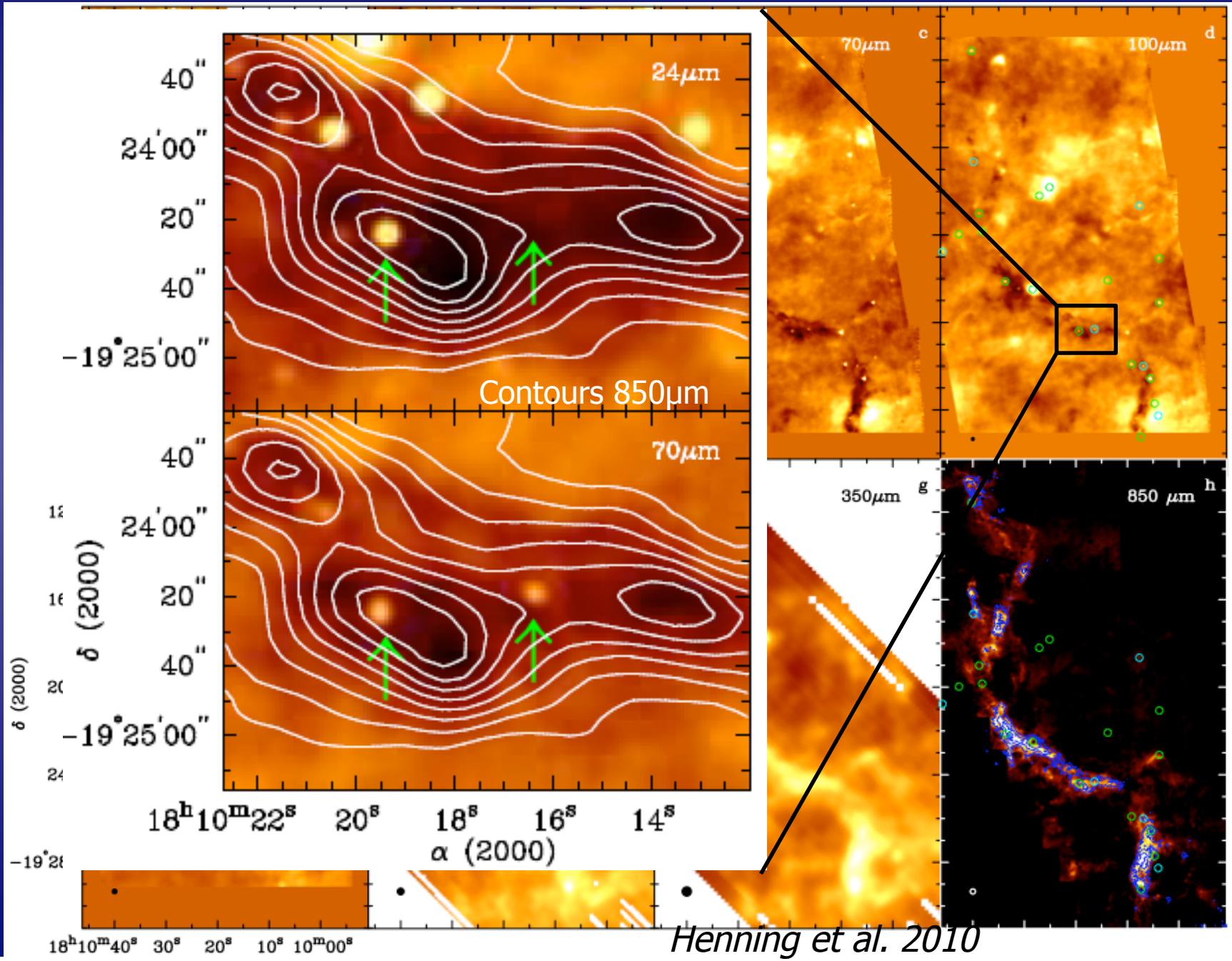
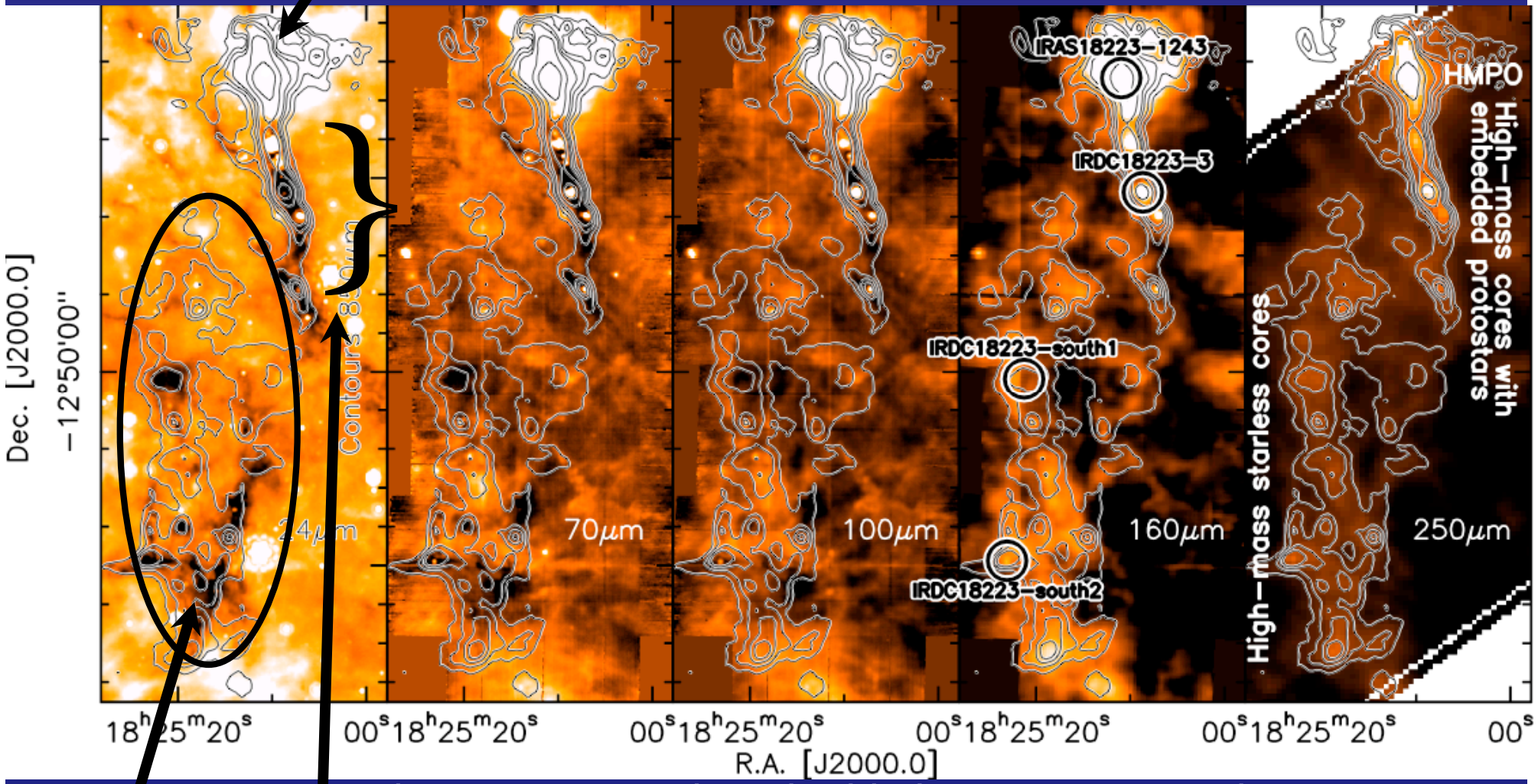


Henning et al. 2010

High-Mass Star Formation Complex I18223

High-Mass Protostellar Object (IRAS source)

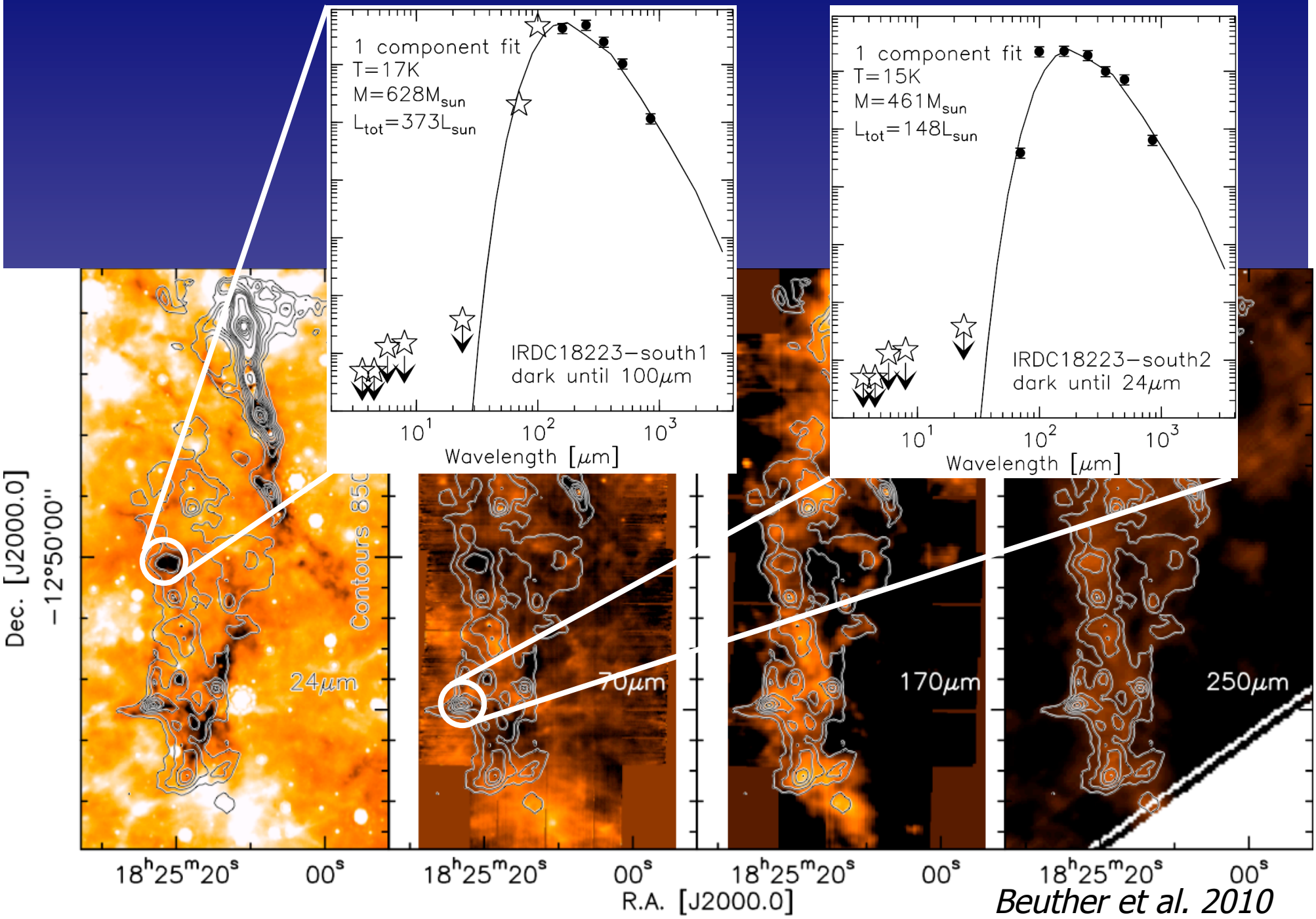


High-Mass Core with embedded low- to intermediate-mass Protostar destined to become massive at end of evolution.

High-Mass Starless Cores

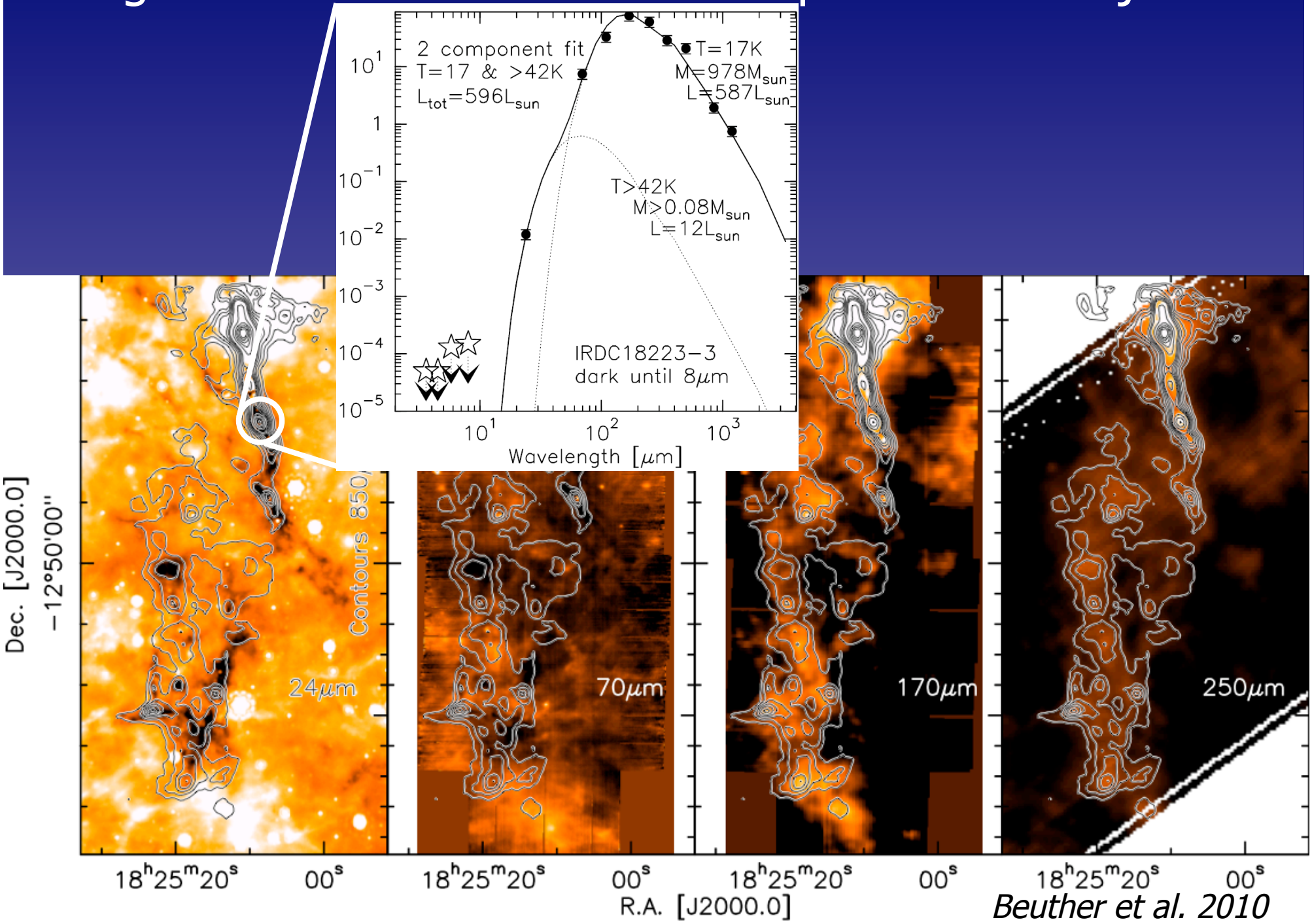
Beuther et al. 2010

High-mass starless clumps



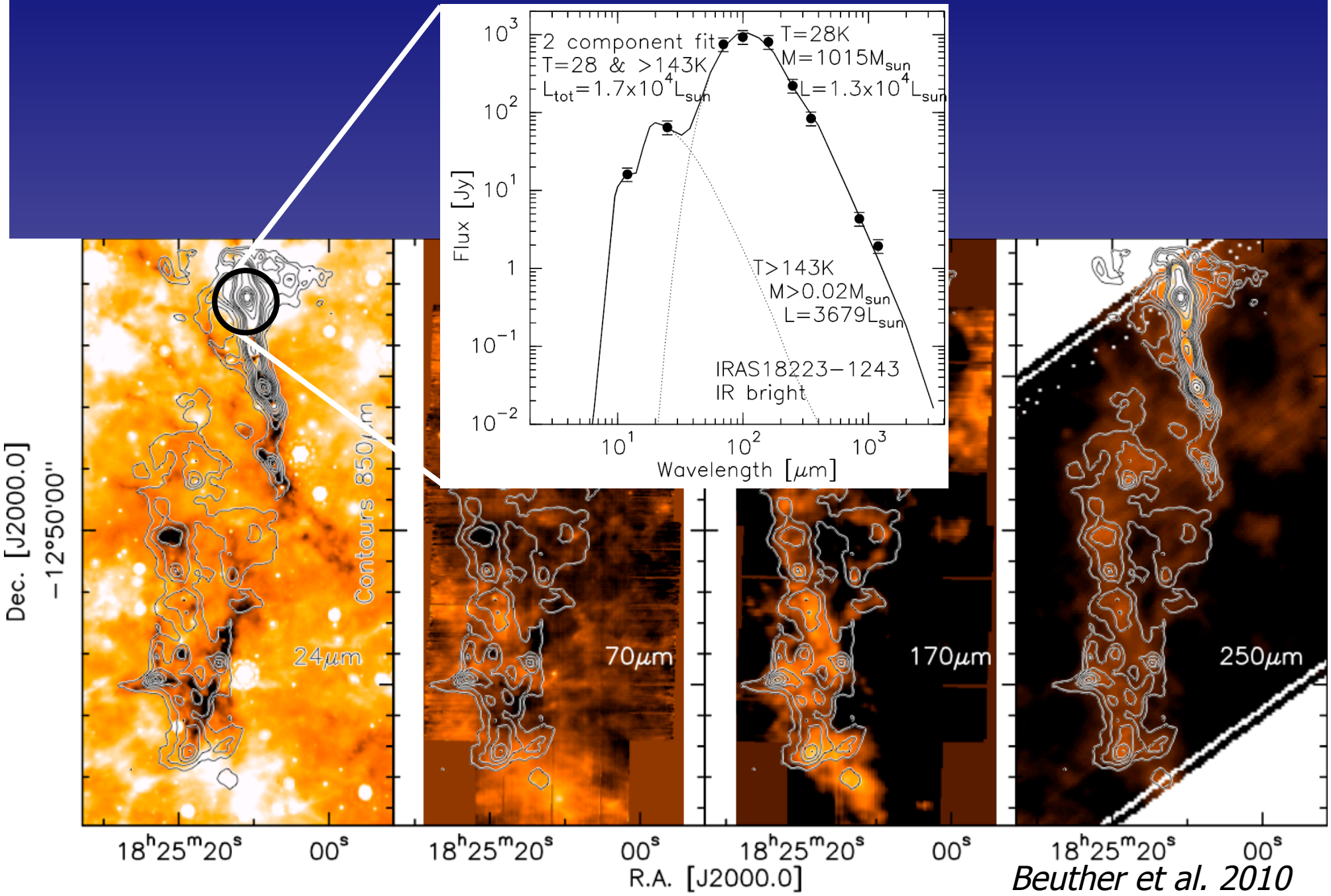
Beuther et al. 2010

High-mass core with embedded protostellar object



Beuther et al. 2010

High-mass protostellar object (IRAS18223-1243)



Beuther et al. 2010

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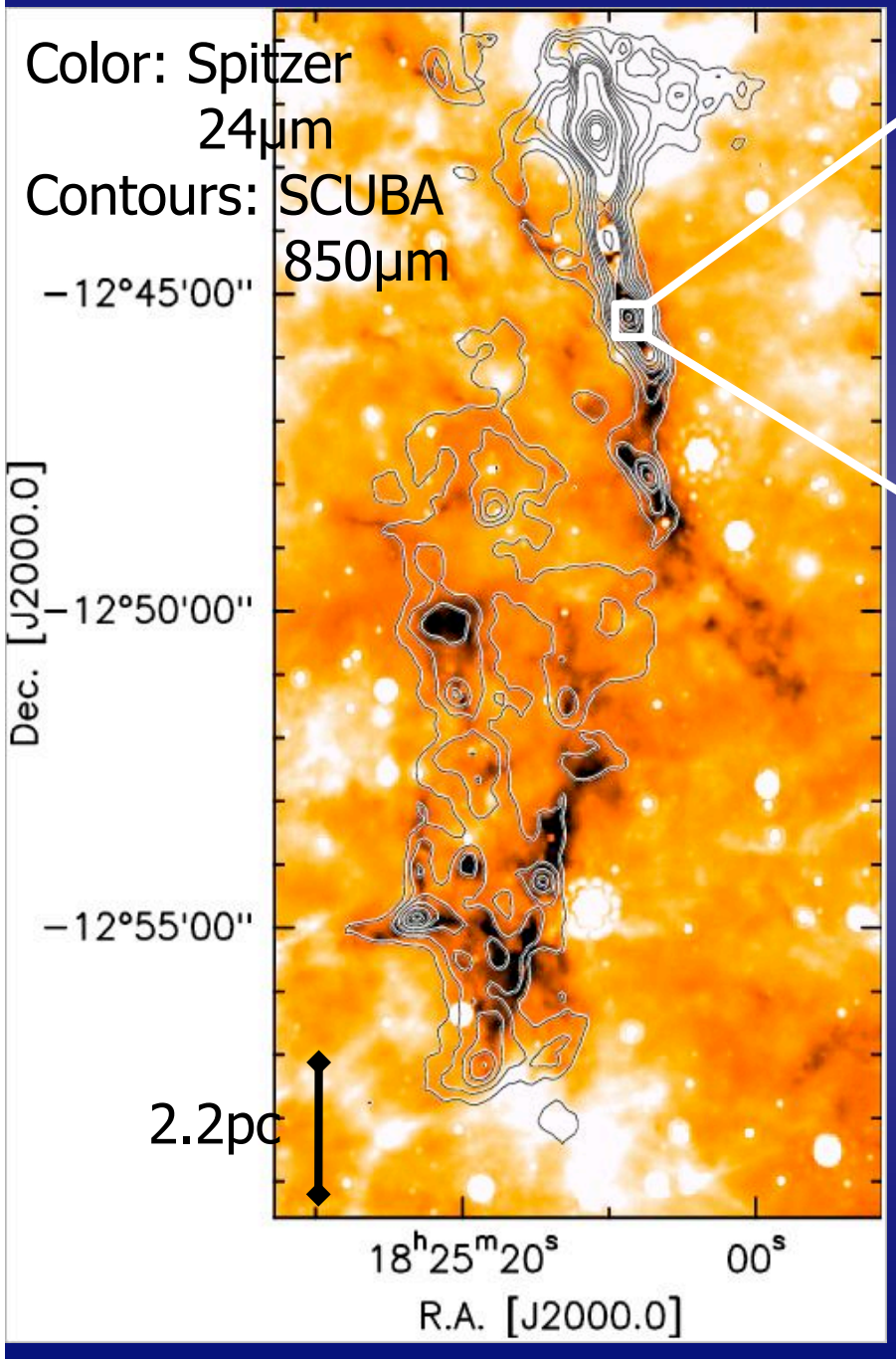
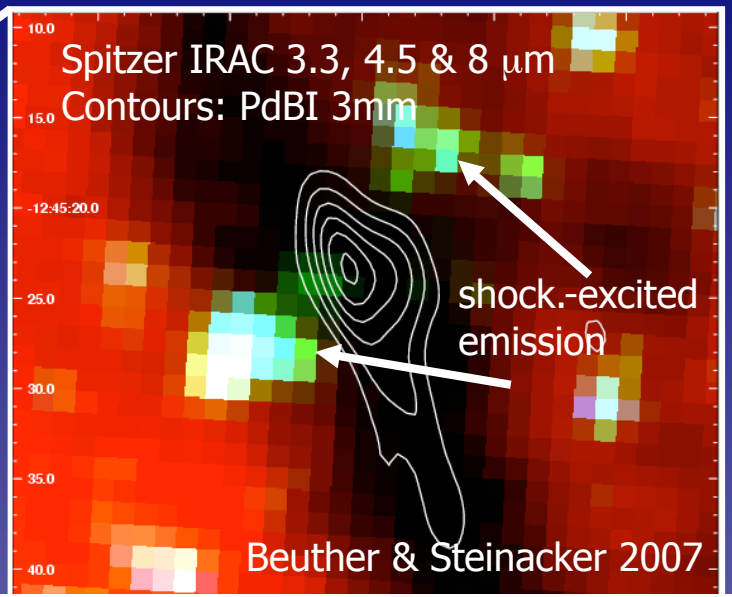
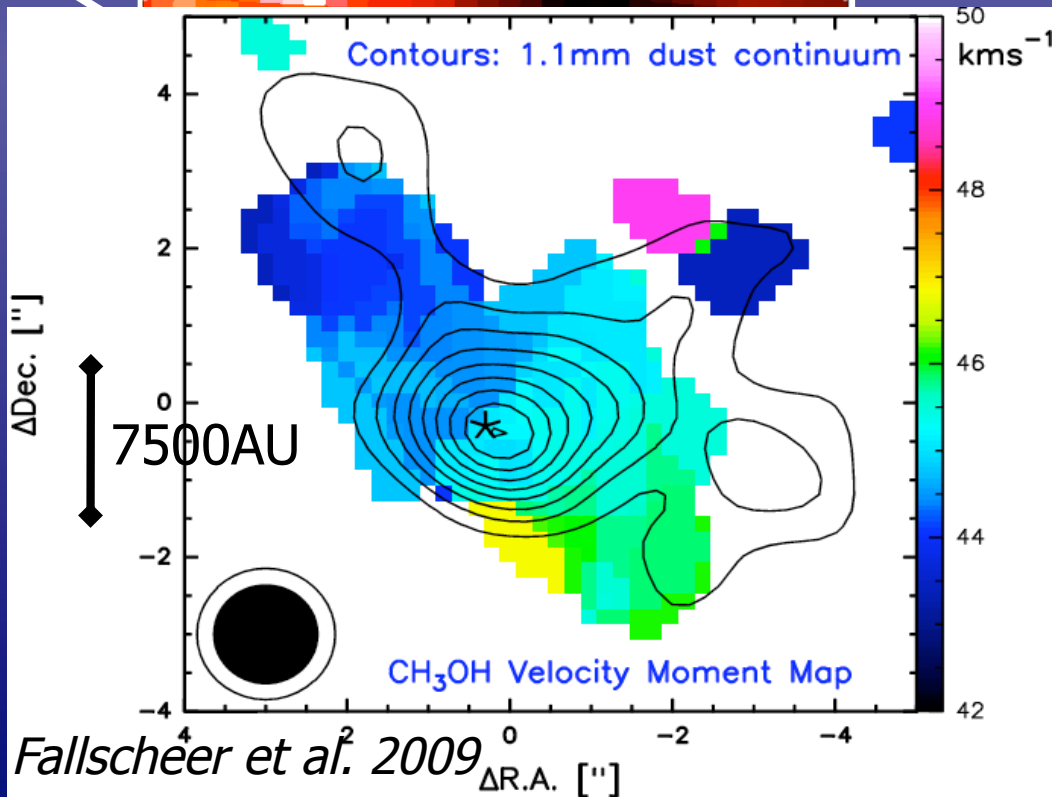
Rotation at the earliest evolutionary stages

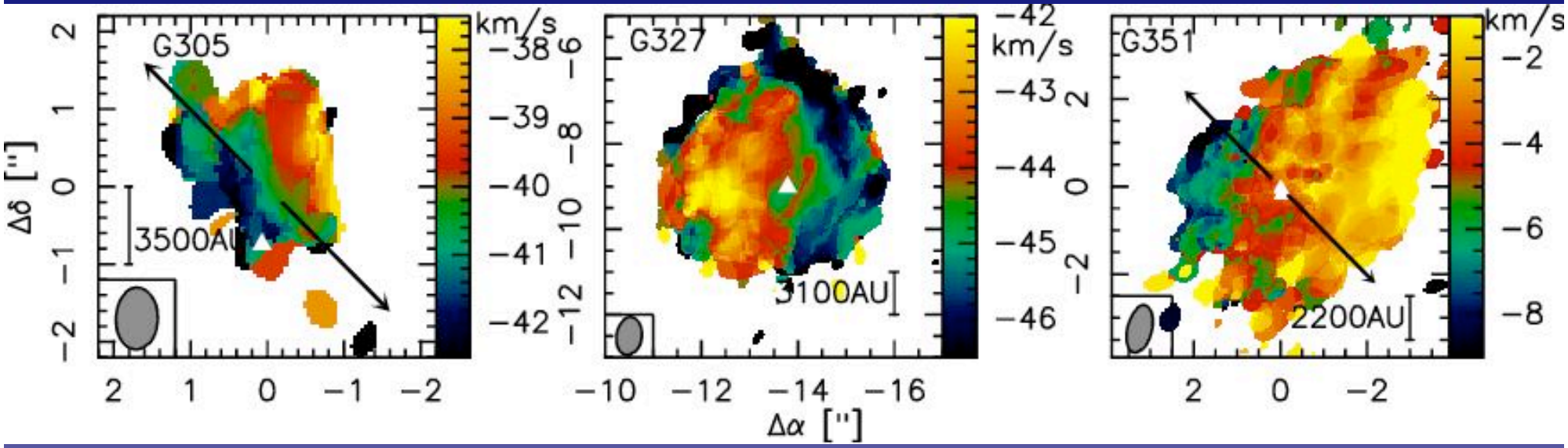






Fallscheer et al. 2009

A sample of 12 massive disk candidates



- Sample of 12 sources observed in NH3(4,4) & (5,5) with ATCA at arcsecond resolution.

- Excitation temperatures of lines E_{lower}=200 & 295K → trace hot inner gas.

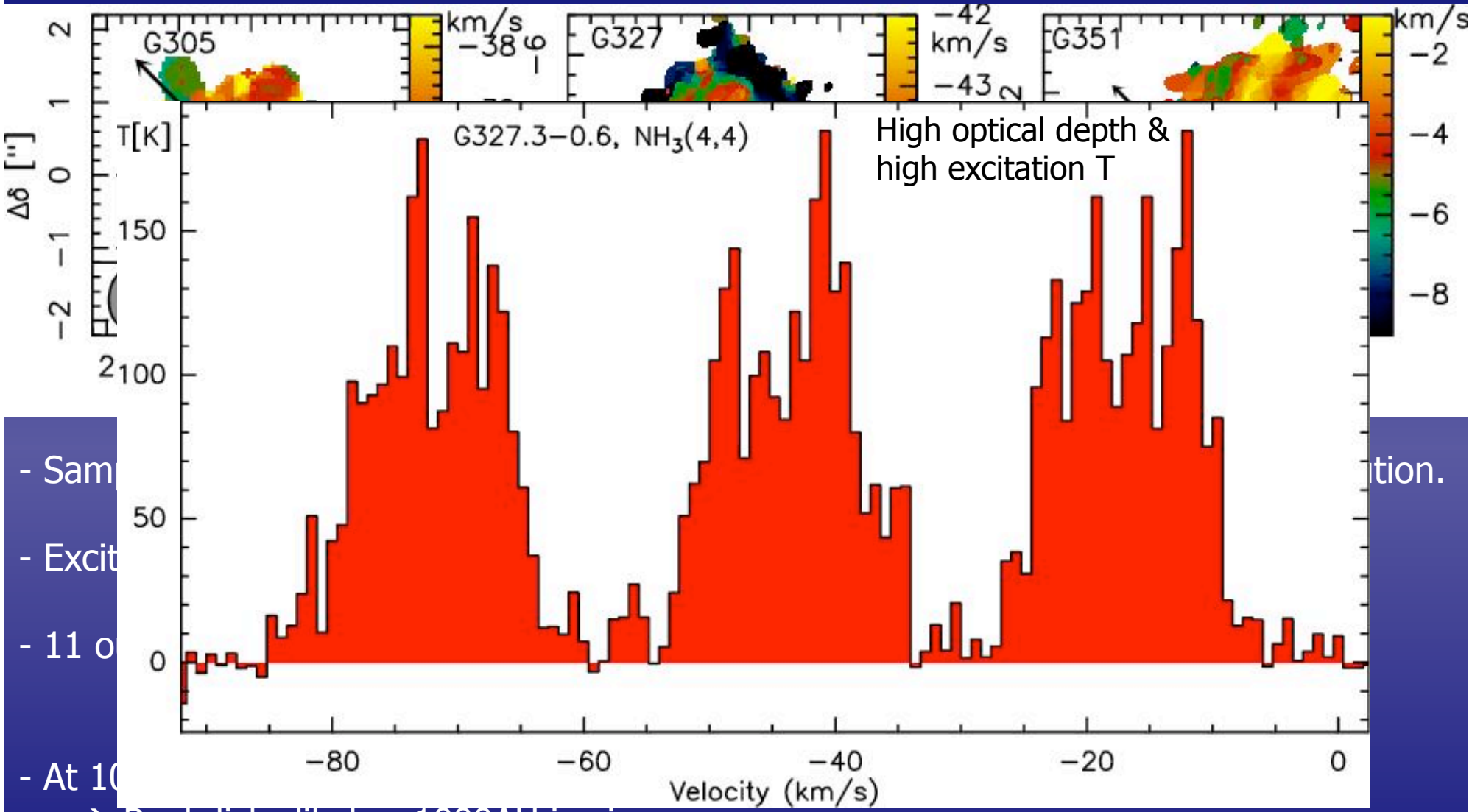
- 11 out of 12 sources detected, 6 with rotation and/or infall signatures.

- At 1000AU resolution, no flattened structures, no Keplerian signature.
  → Real disks likely <1000AU in size.

- Channel maps show clumpy sub-structure

Beuther, Walsh & Longmore 2009

A sample of 12 massive disk candidates



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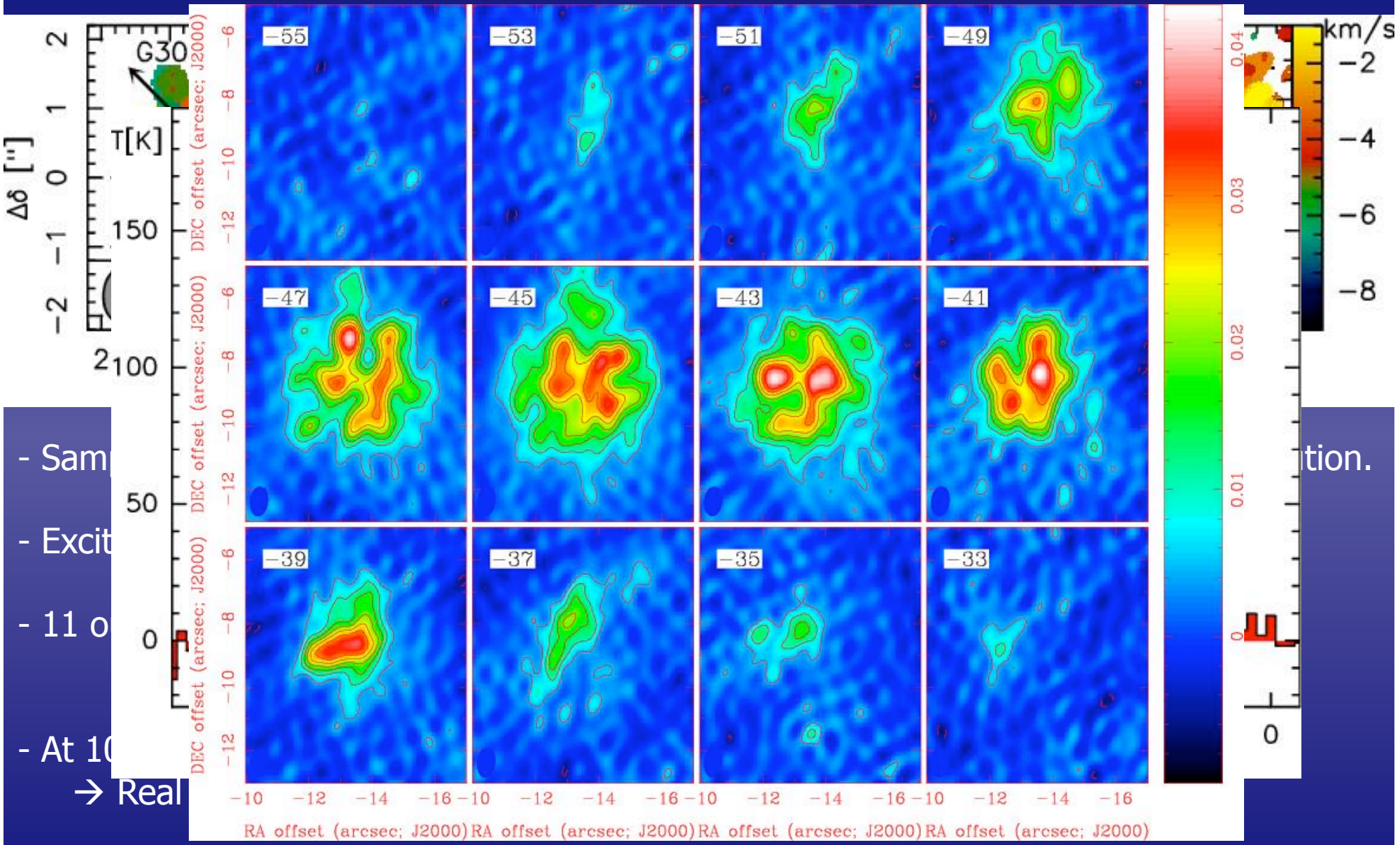

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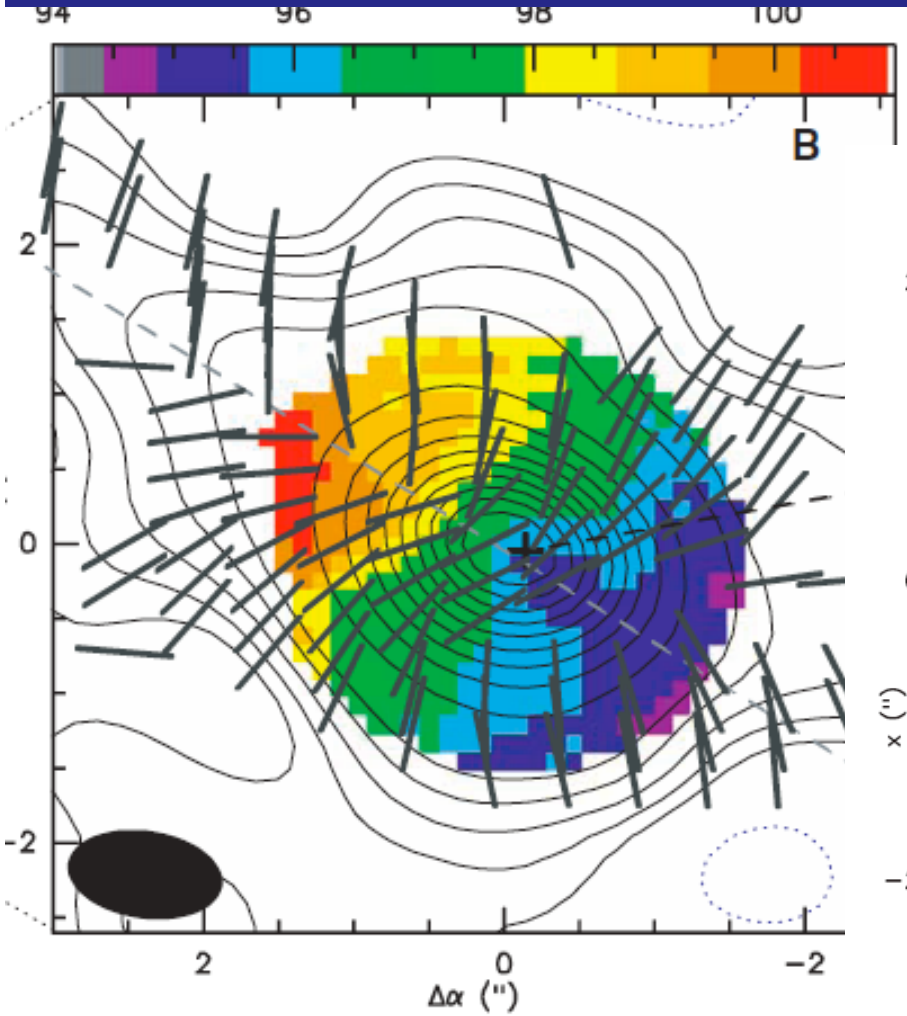
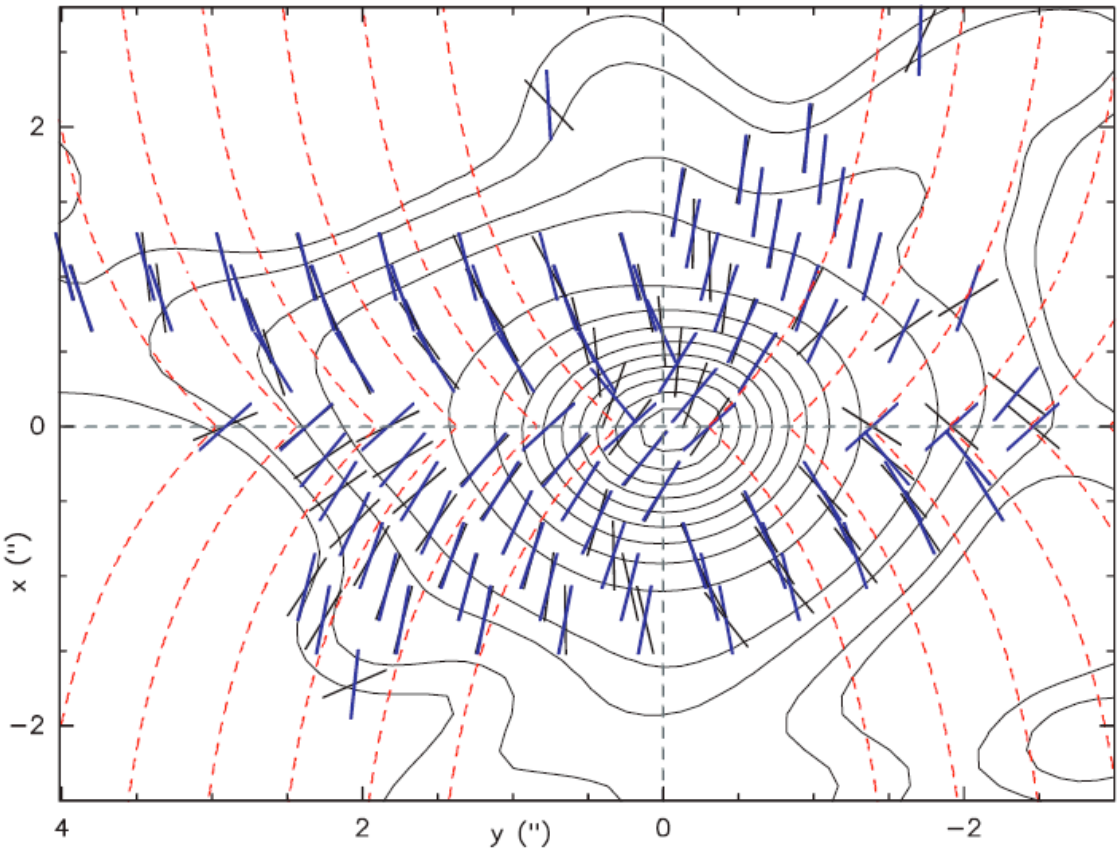
Magnetic field in the hot core G31.41

Color: 1st moment CH_3OH, contours: 879μm
bars: orientation of magnetic field
red: best fit field

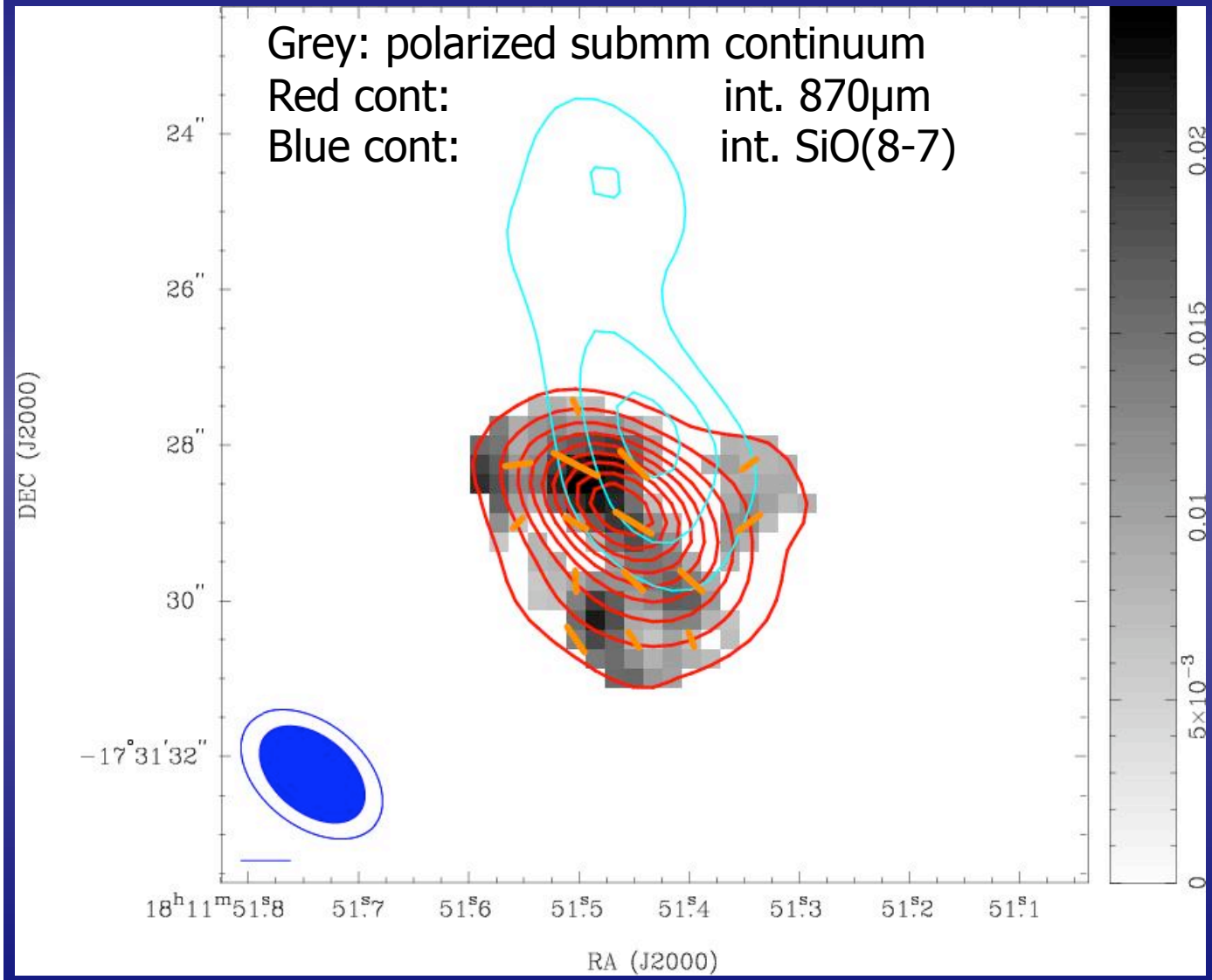


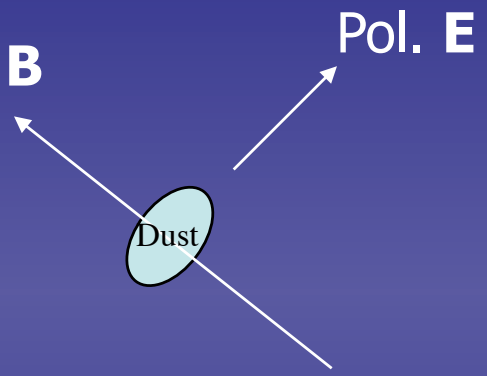


Collapse dominated by magnetic field
Magnetic energy dominates over turbulent and centrifugal energy

Girart et al. 2009

Magnetic field measurments from submm continuum and CO(3-2) observations





Beuther et al. subm.

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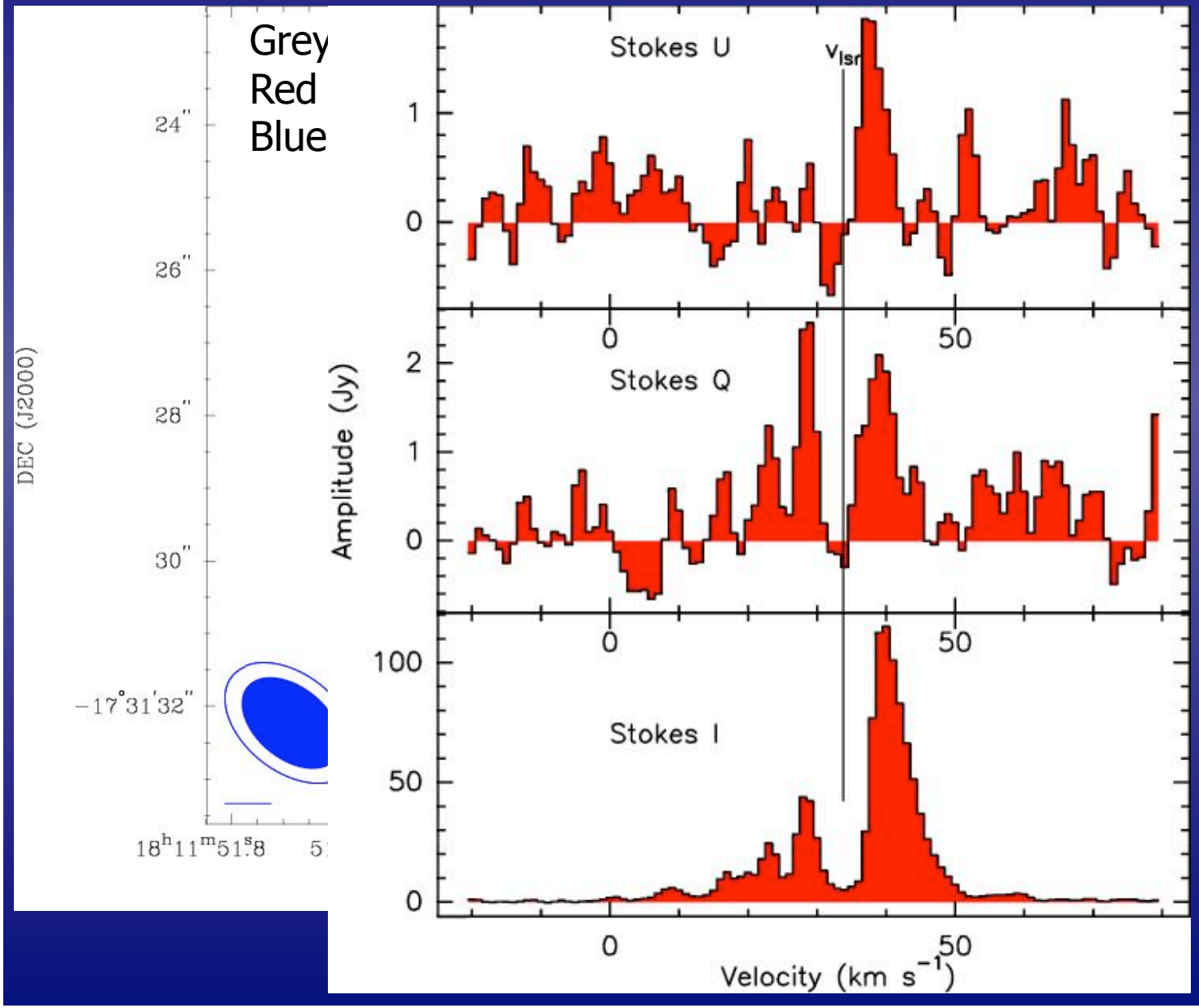

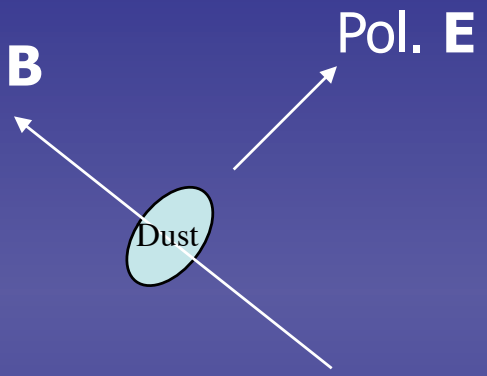

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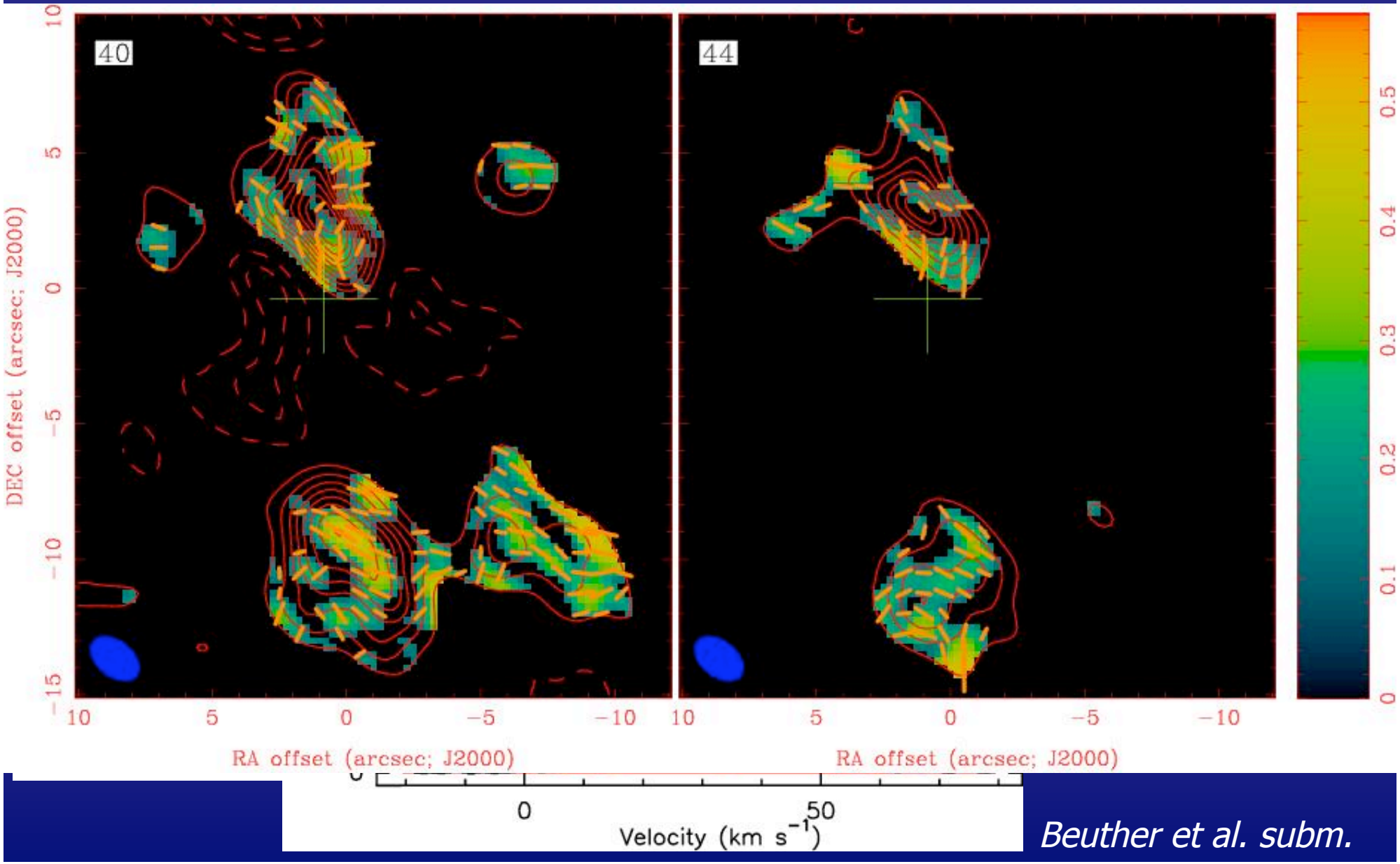

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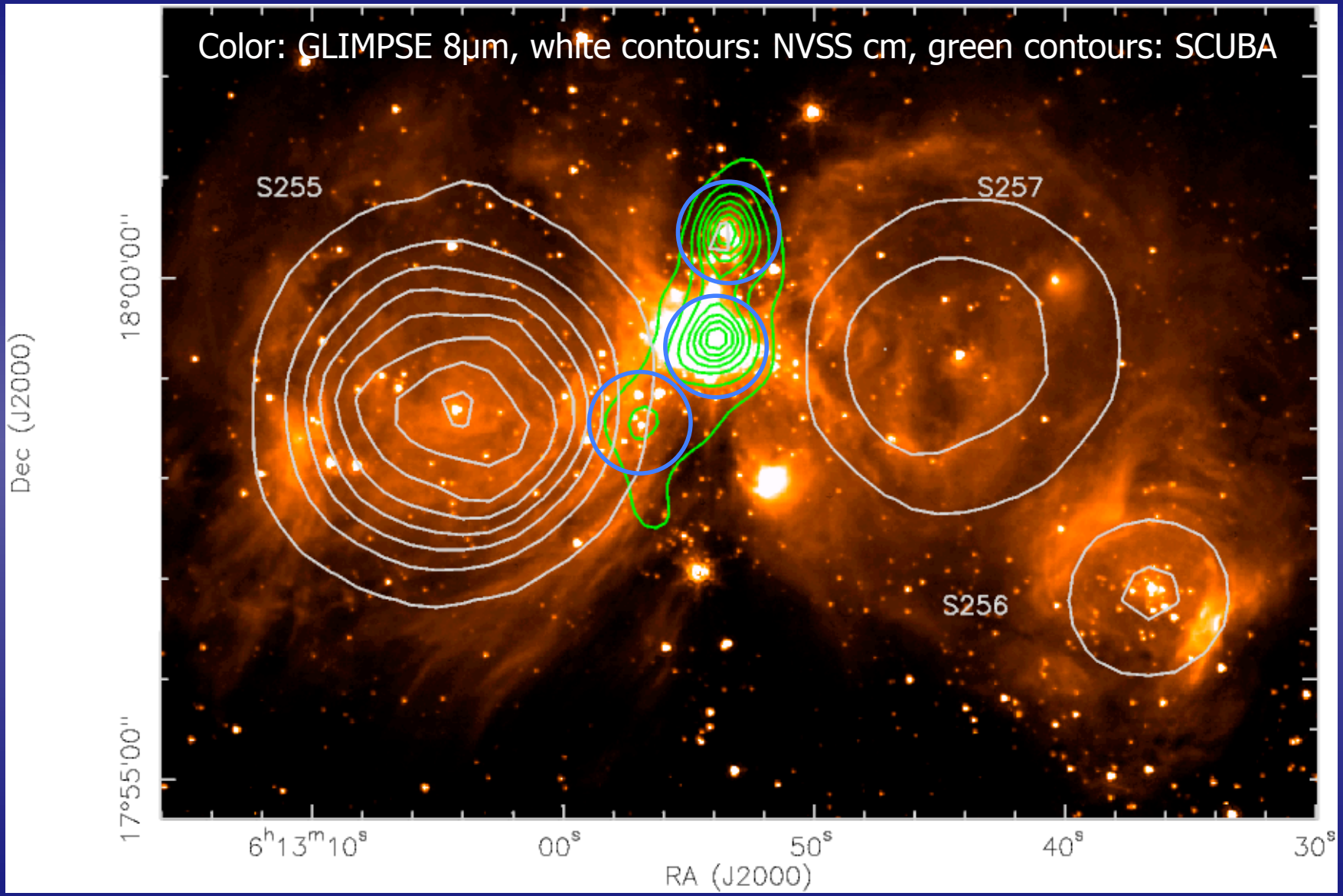
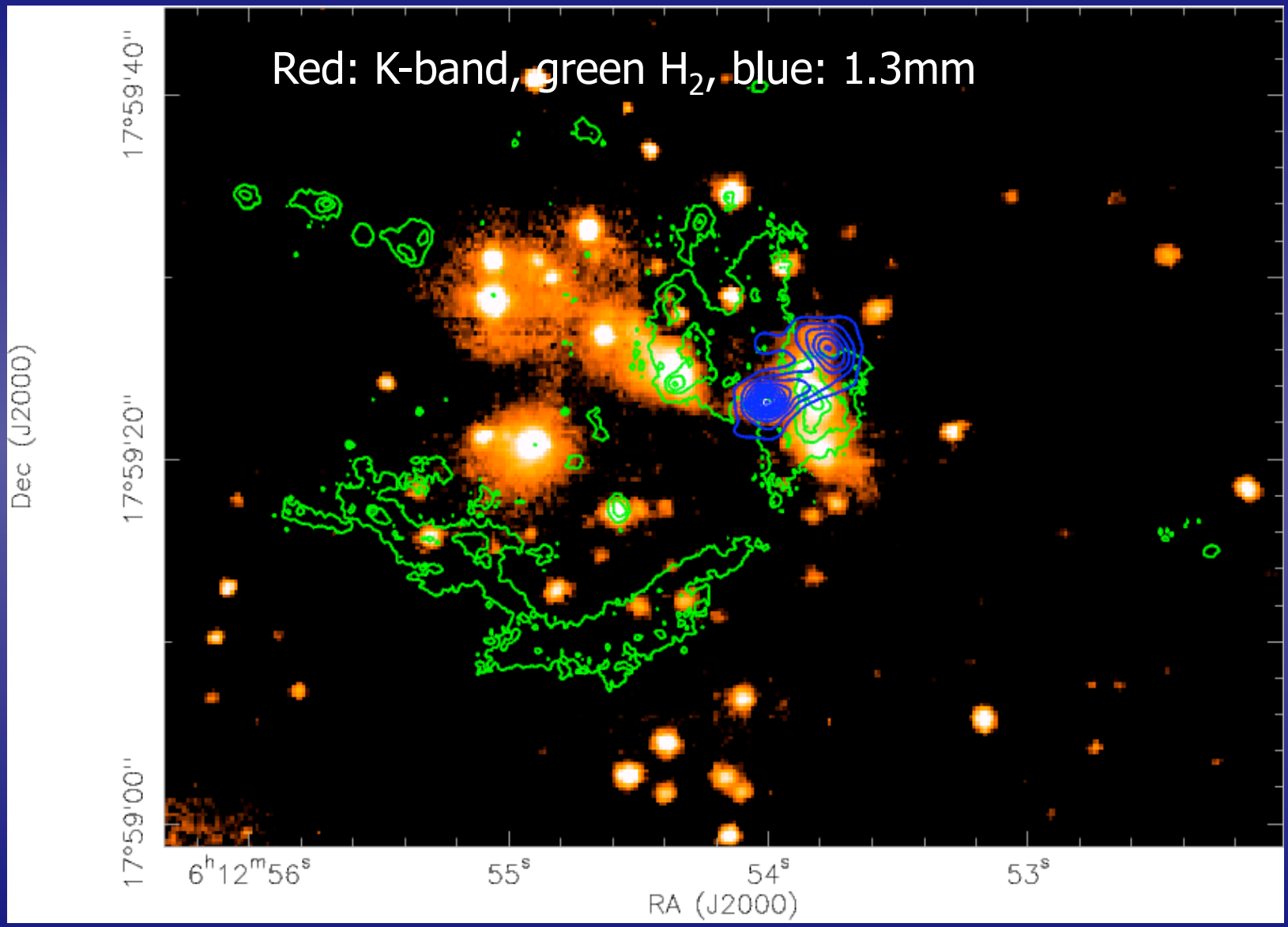
Sequential star formation around S255IR



Wang et al. in prep., see also poster 32

Sequential star formation around S255IR



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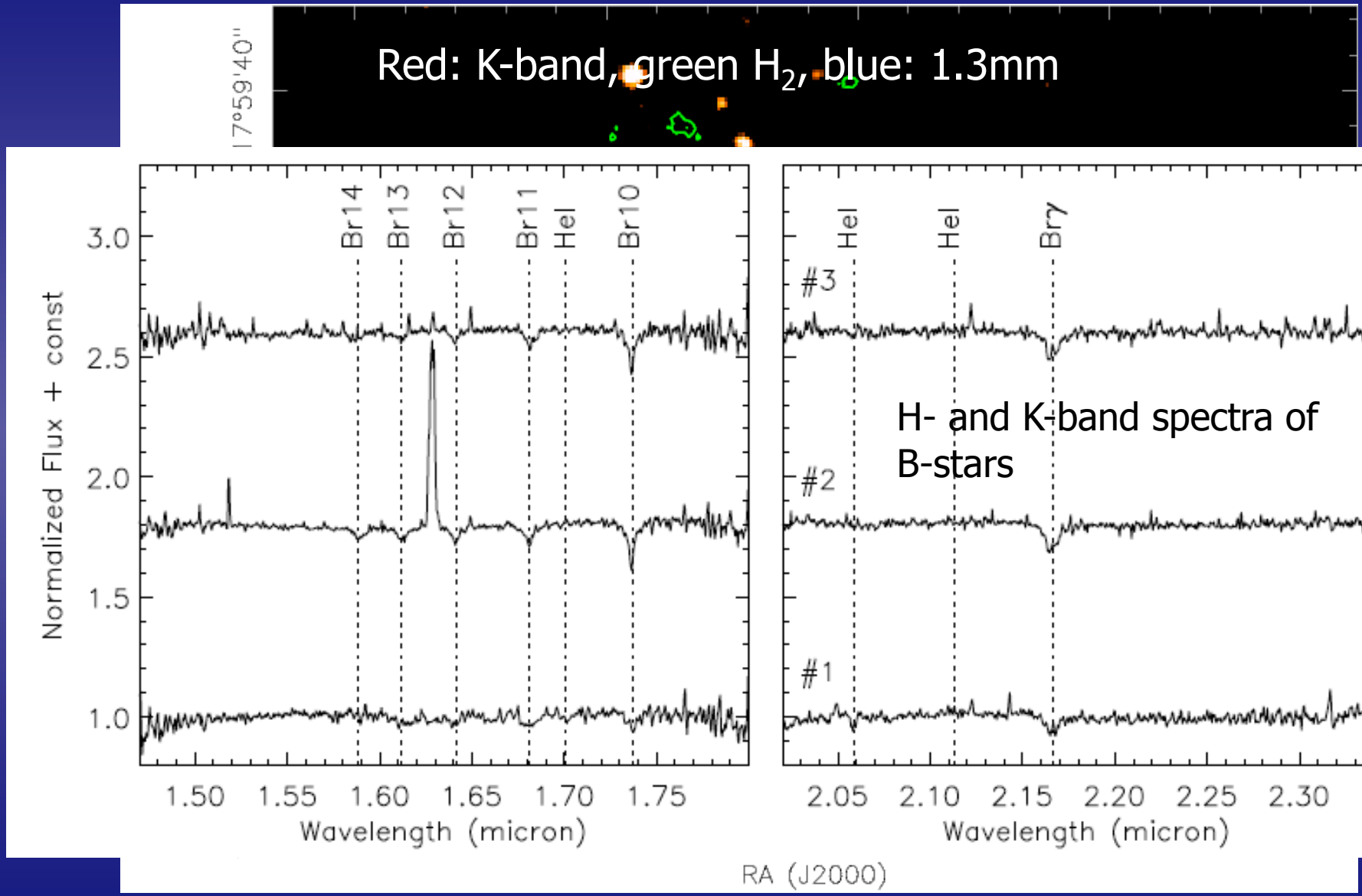
Sequential star formation around S255IR



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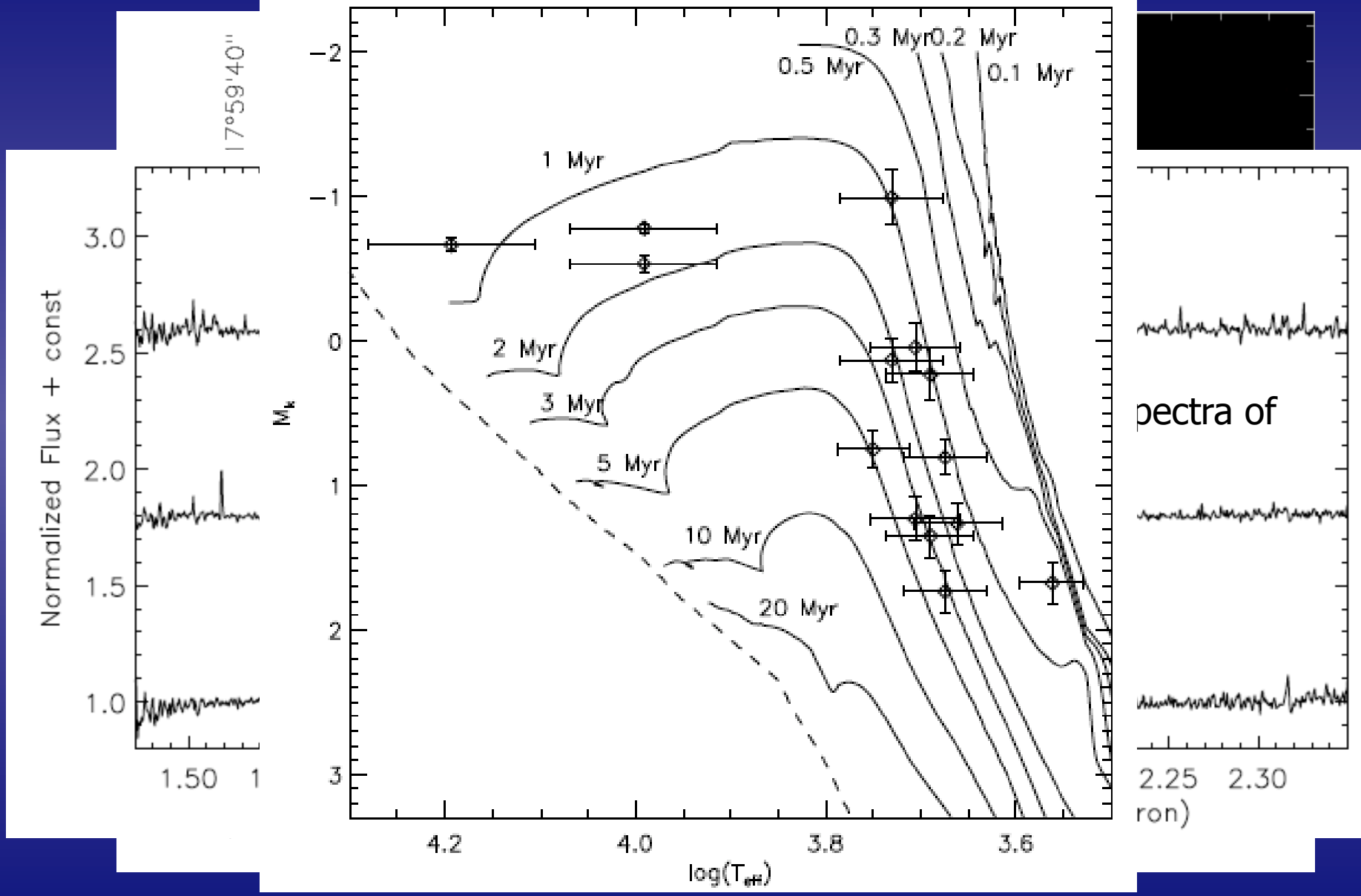

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Summary and Outlook

- Important to resolve dust condensation radius in simulations.

- Herschel starts to unravel the earliest formation stages.

- Rotating structures on scales of several 1000AU. Rarely Keplerian motions. Genuine disks likely on smaller scales below 1000AU.

- Magnetic field appears to be aligned with outflow direction on core and larger outflow scales.

- Different populations of stars within the same clusters

- Lots to come in the field with Herschel and ALMA.