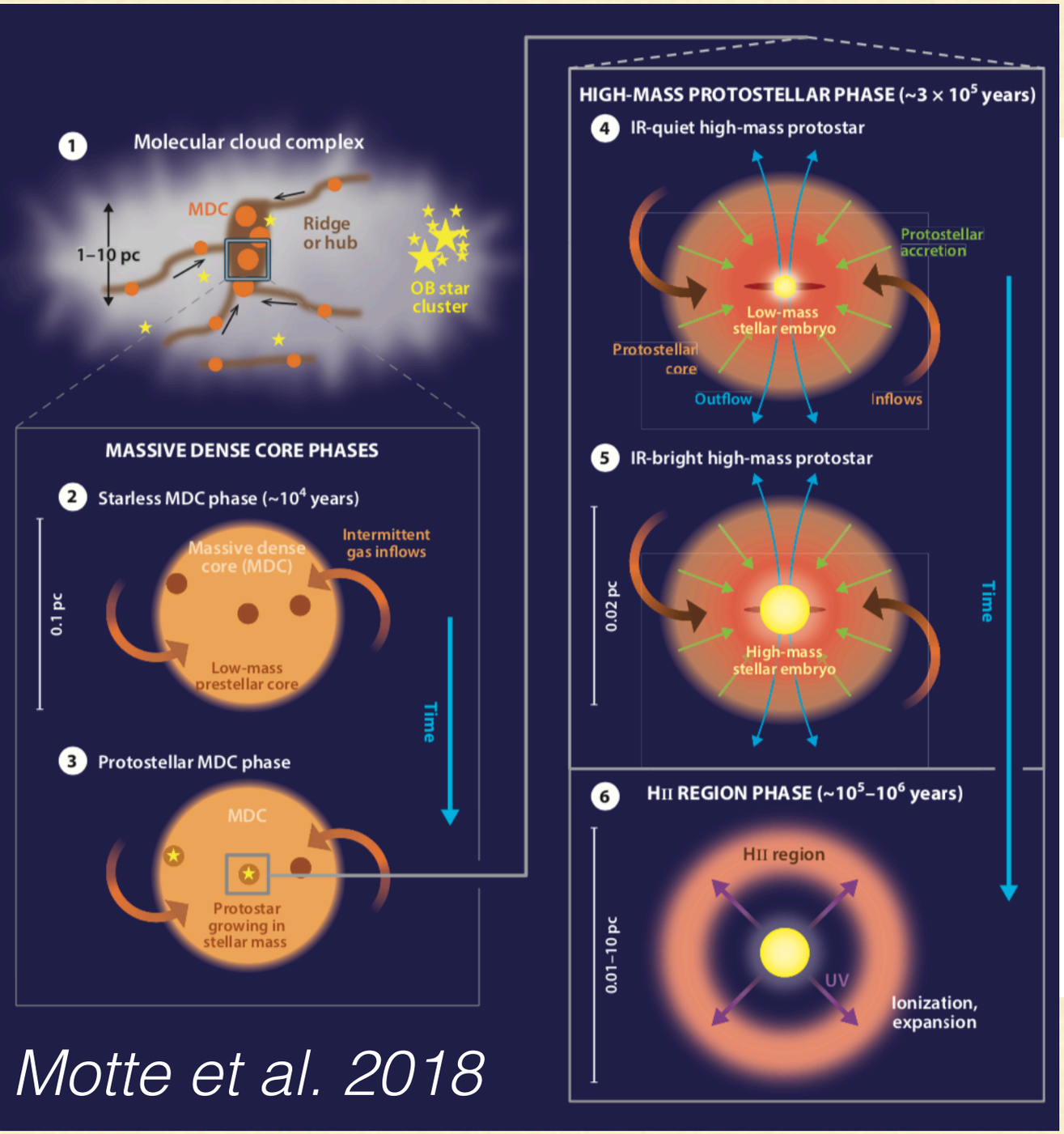
High-mass star formation

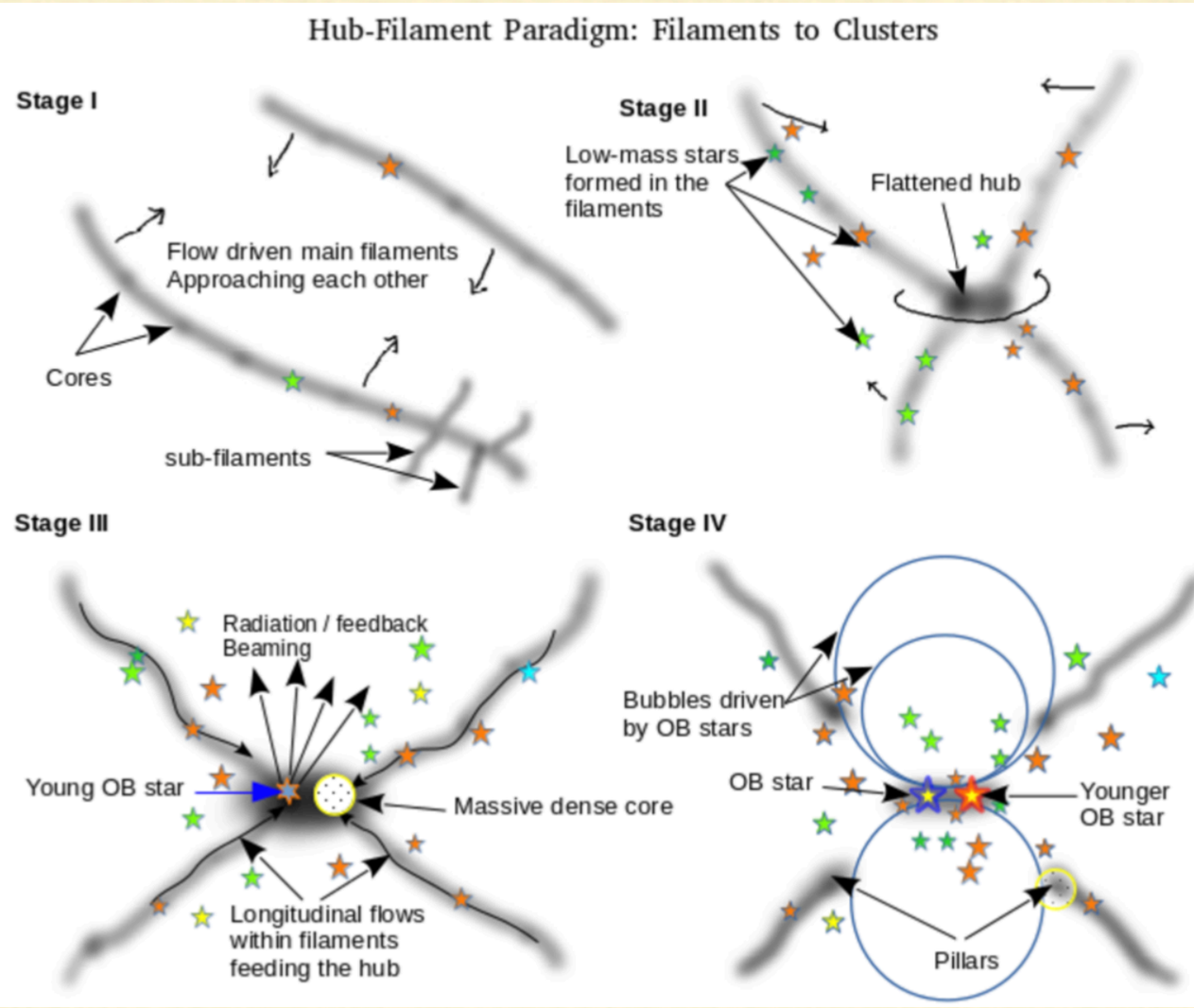
Henrik Beuther, MPIA

EPOS 2022, April 24-29

High-mass star formation paradigms

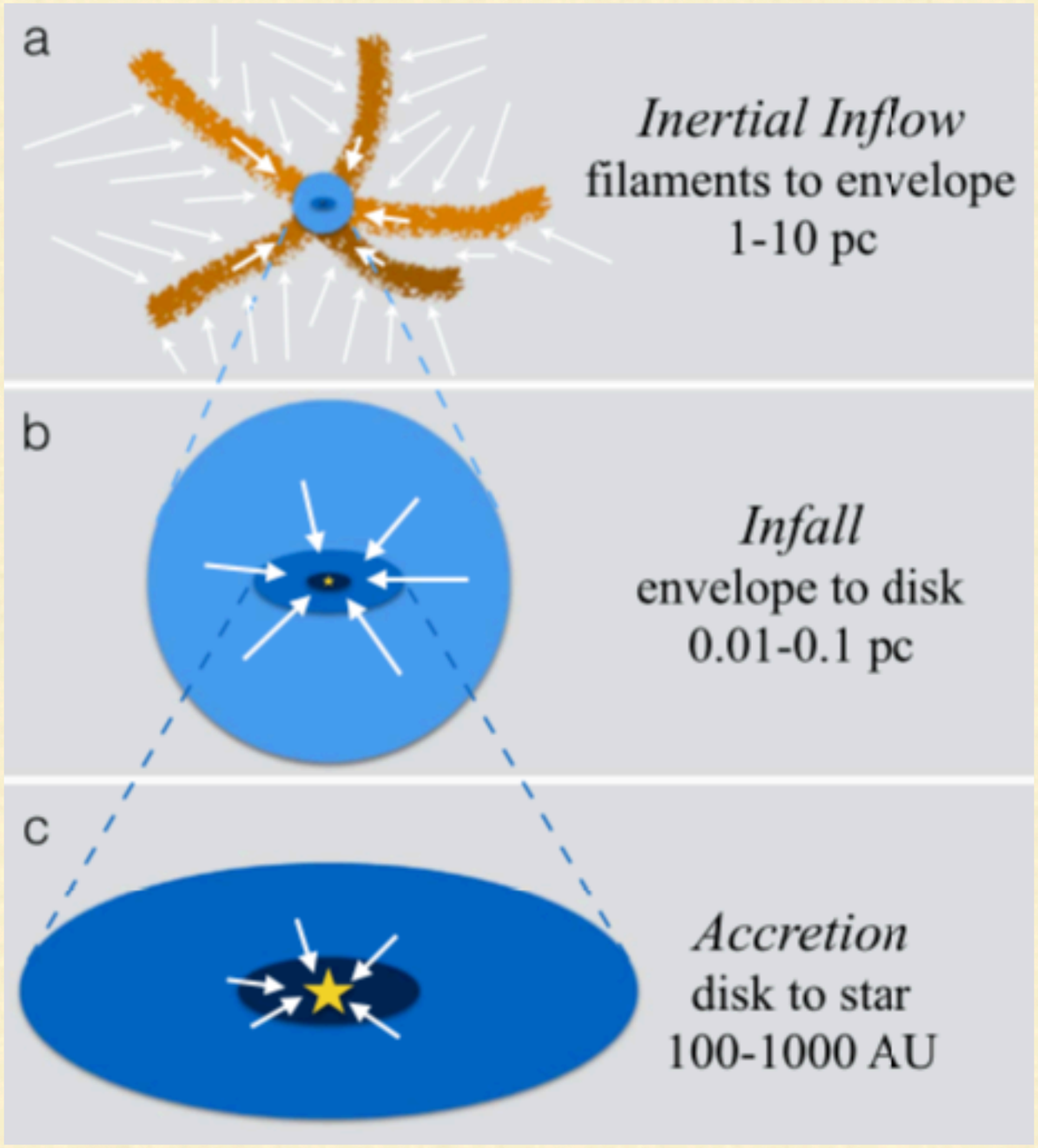


Motte et al. 2018

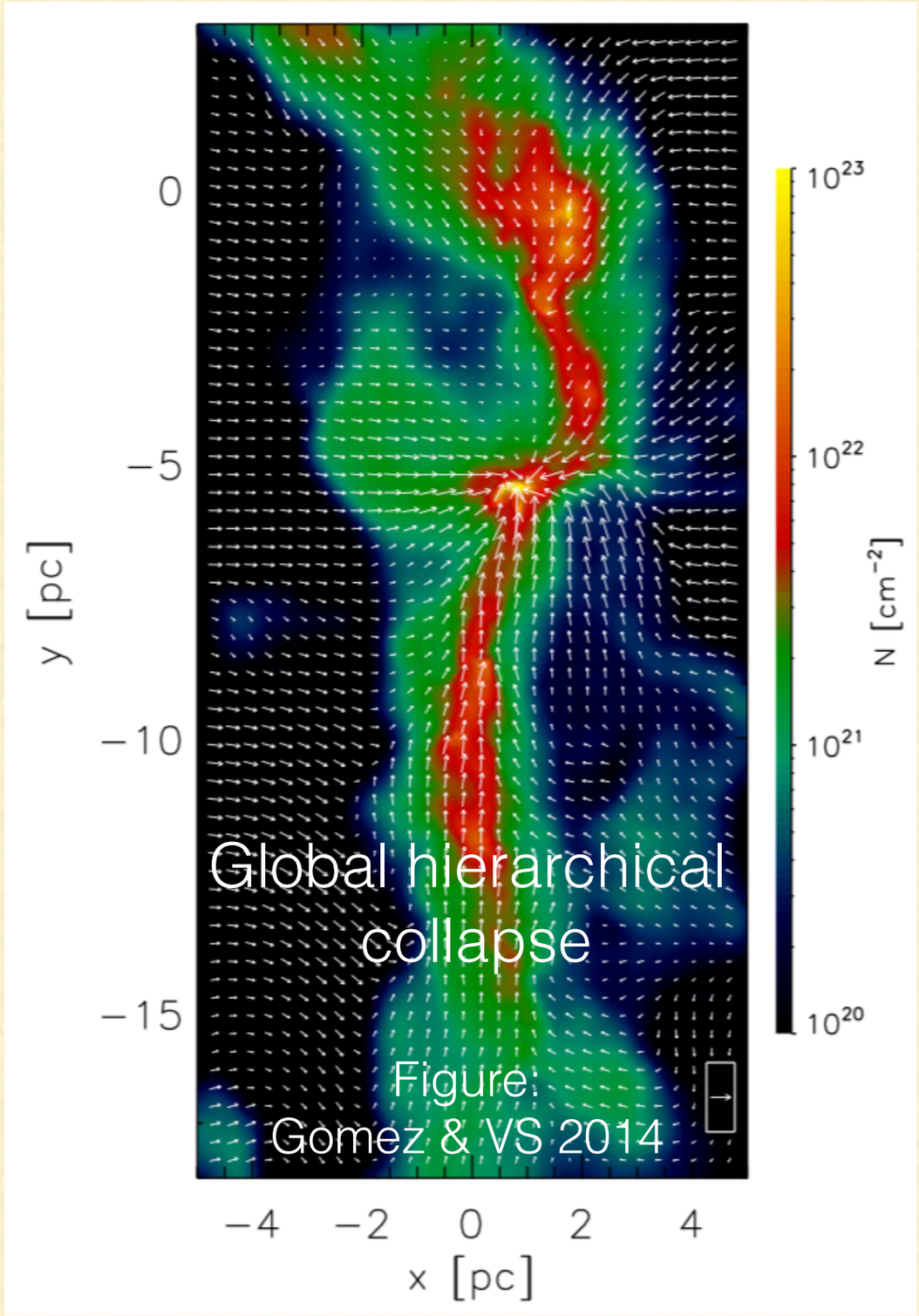


Kumar et al. 2020

High-mass star formation paradigms



Padoan et al. 2020



Vazquez-Semadeni et al. 2019

Topics

Infall/Inflow on large scales

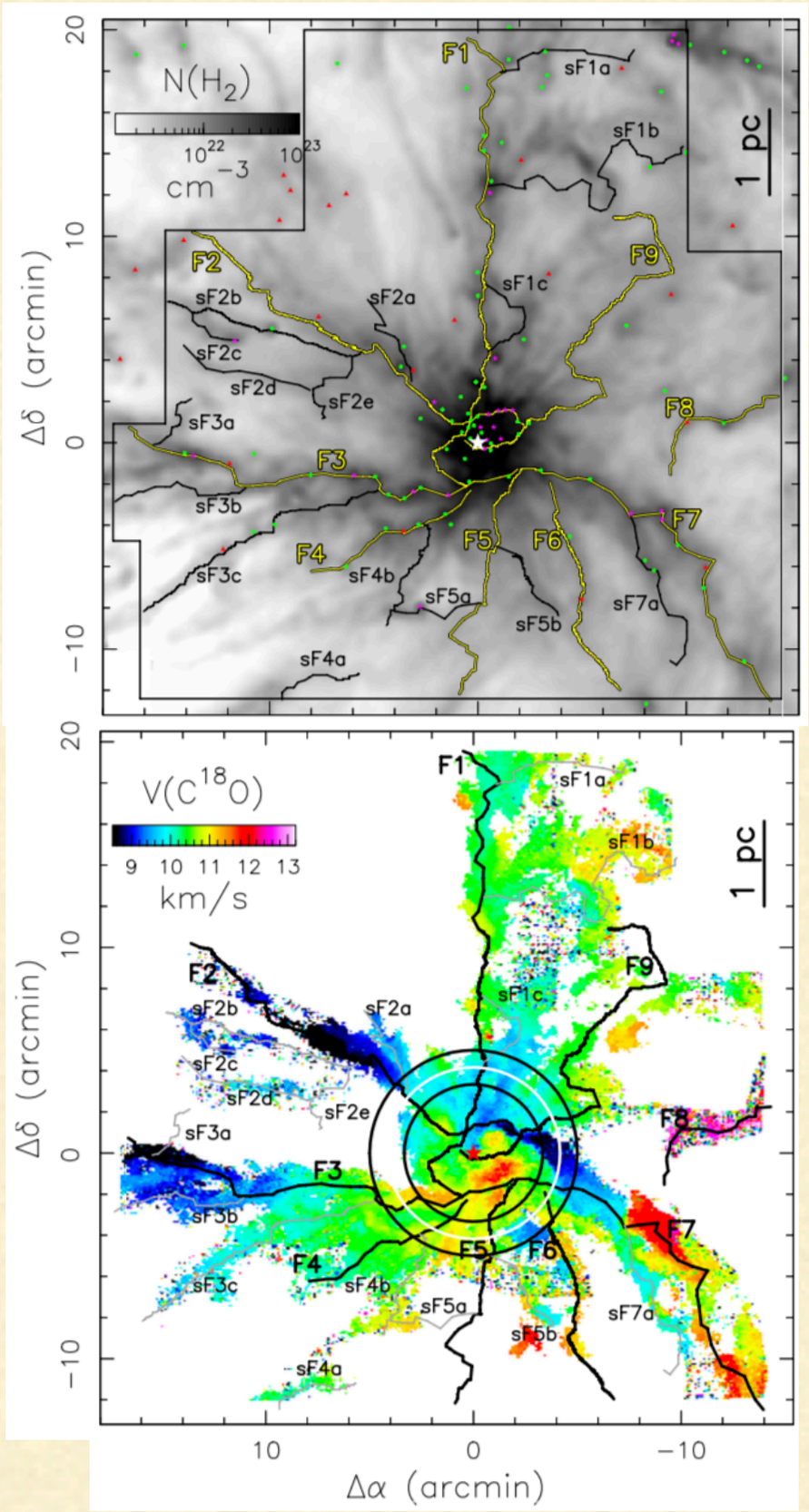
Physical and chemical properties

Disks

Magnetic fields

(Episodic accretion —> Talk by H. Linz)

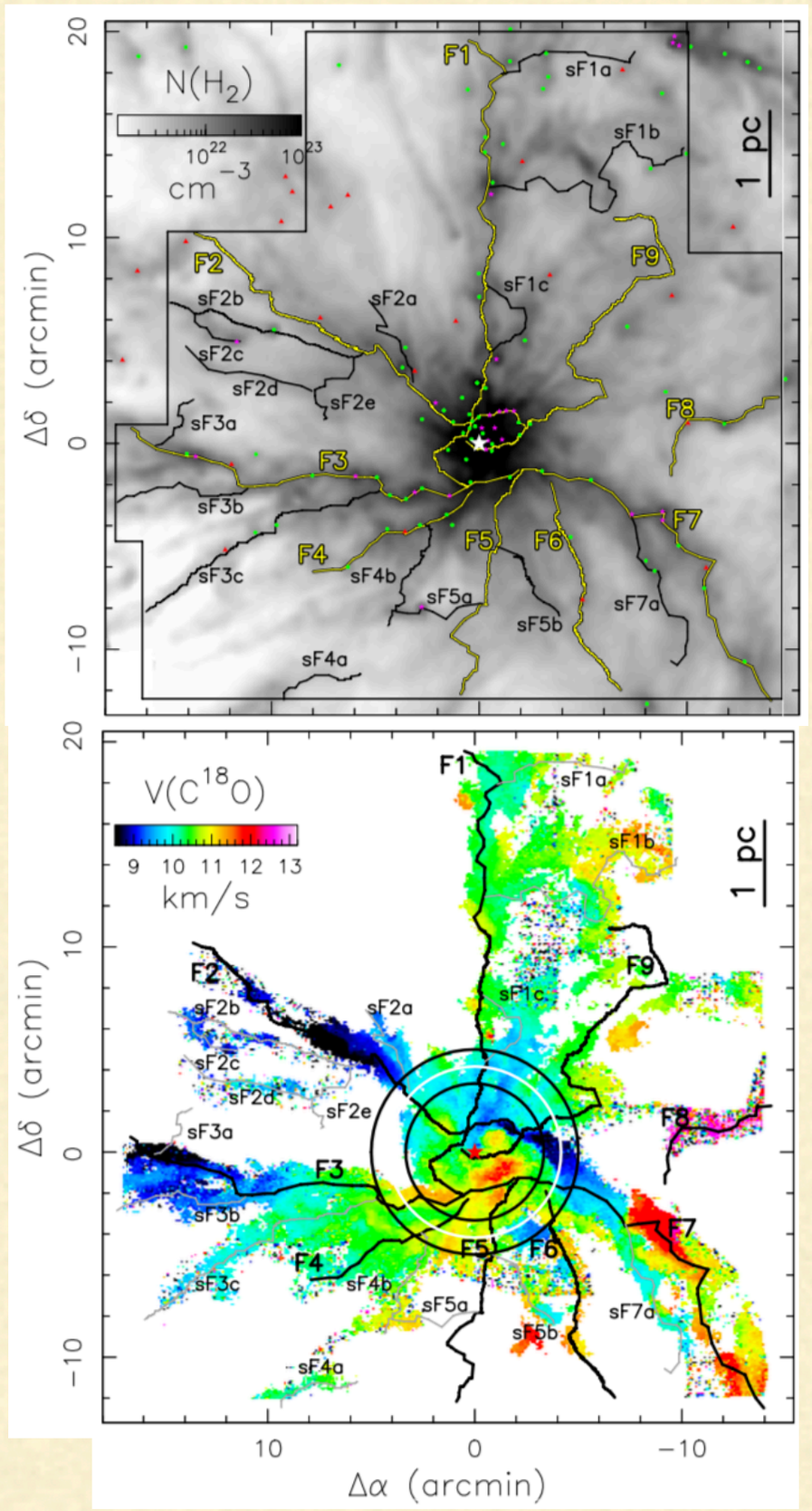
Hub-filament accretion

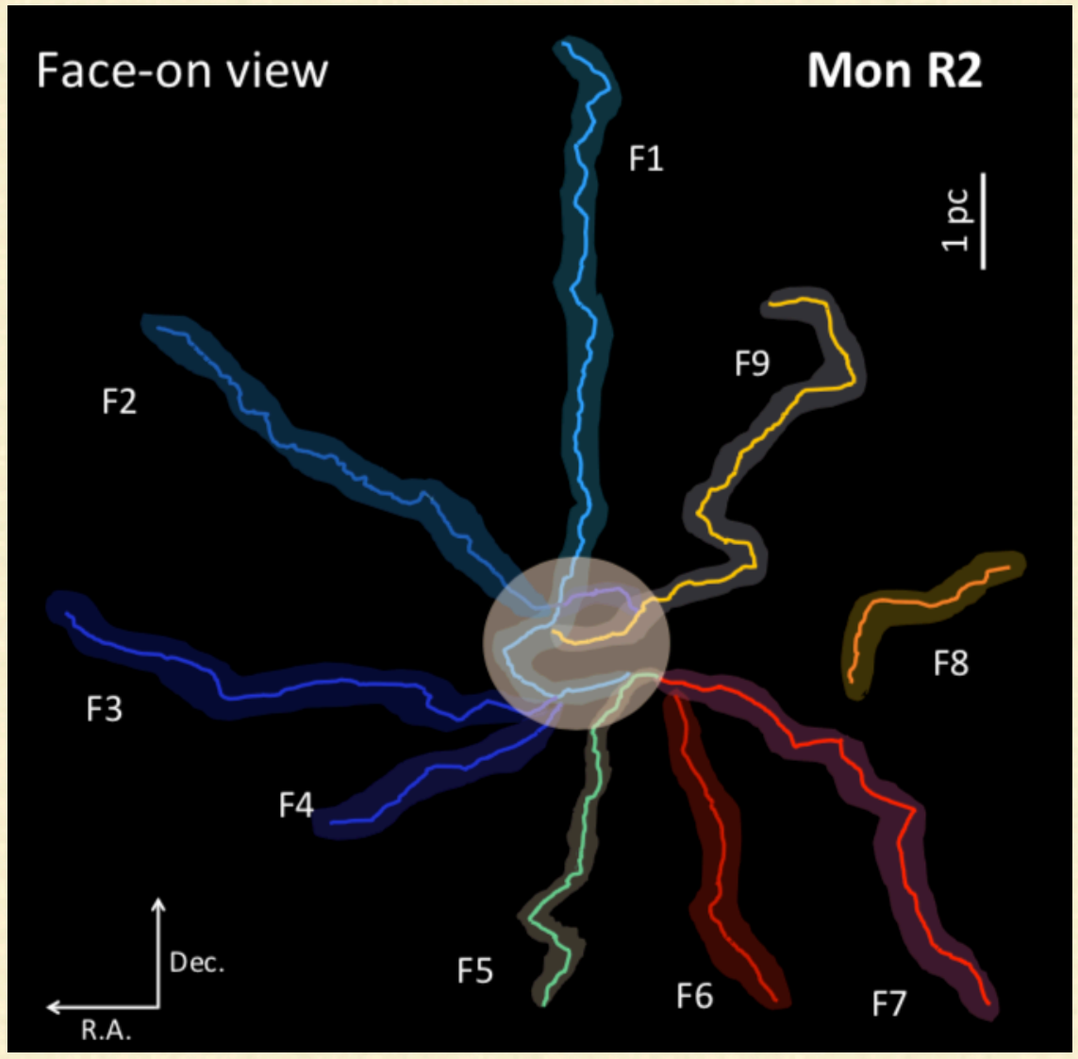


- Inflow rates ~ 10^{-4} -10^{-3} Msun/yr
- v-gradients increase towards center

Trevino-Morales et al. 2019

Hub-filament accretion





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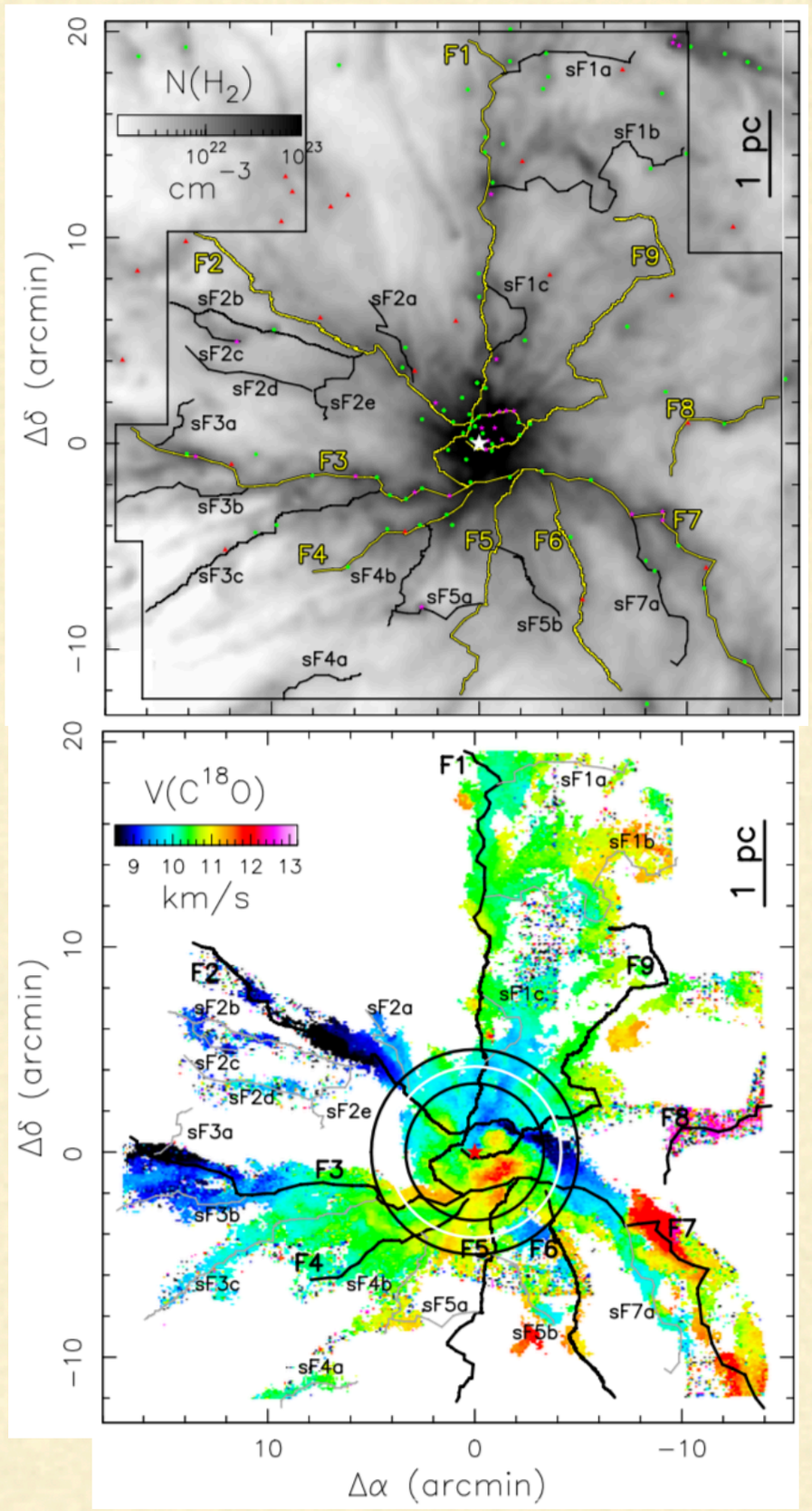
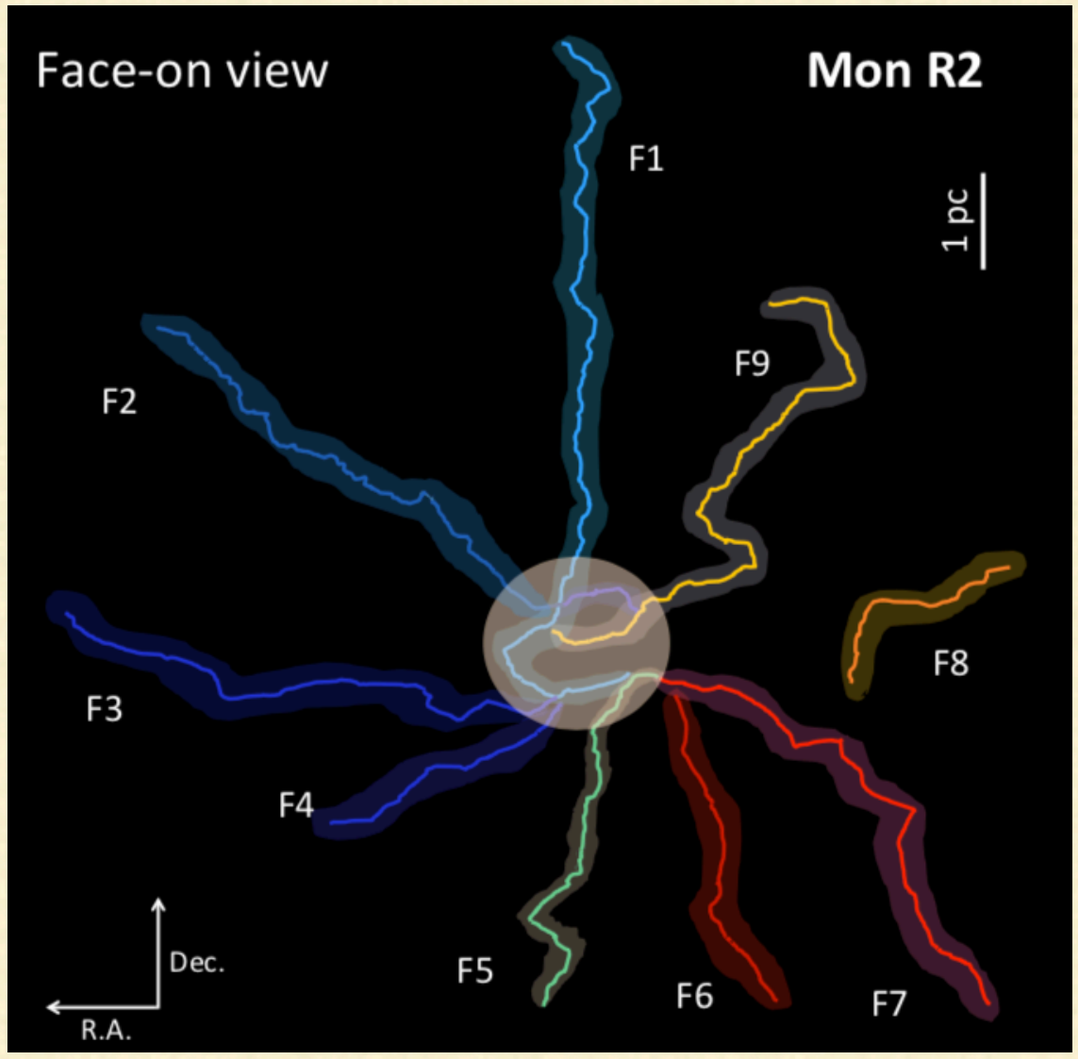


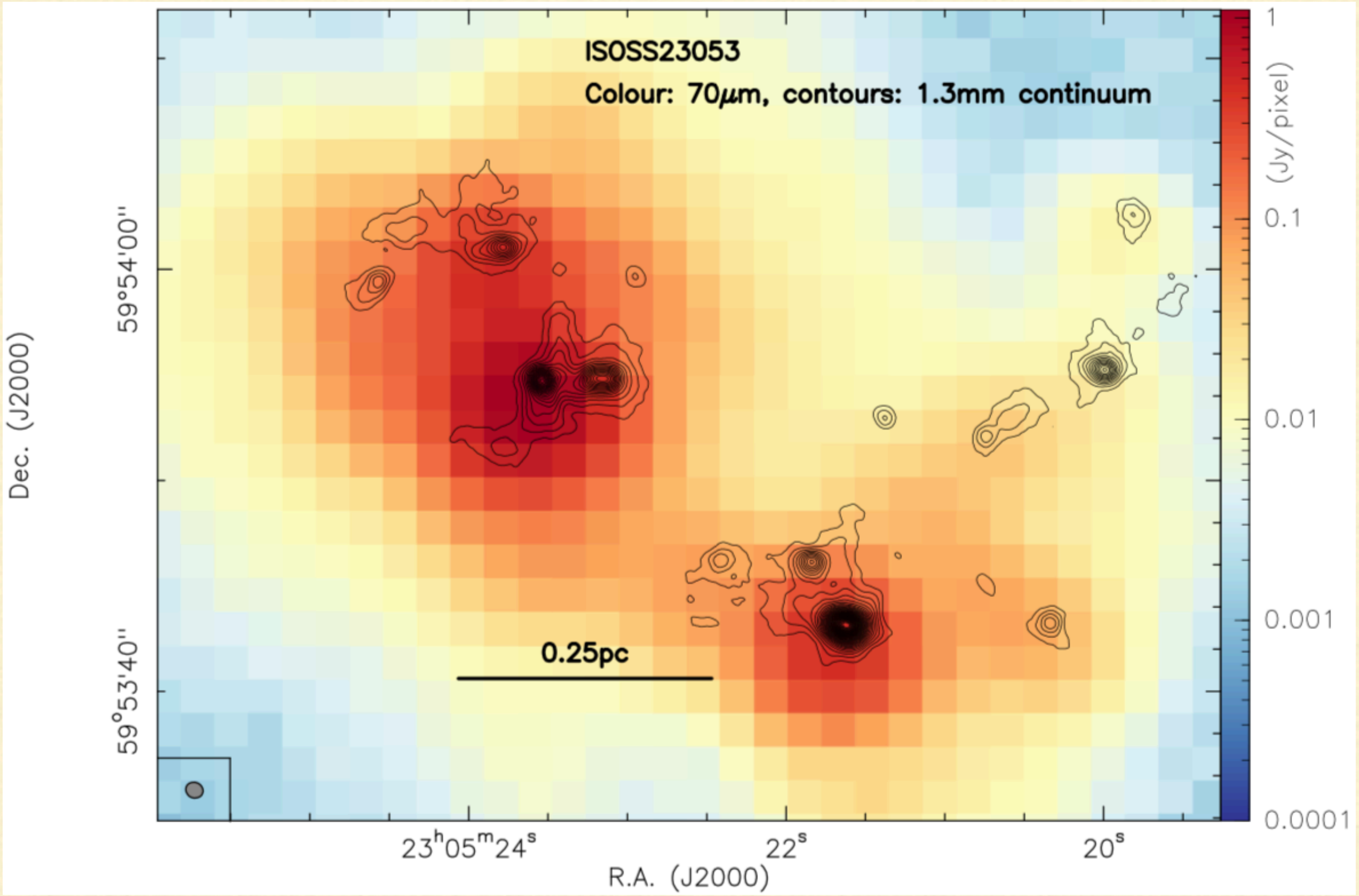
Trevino-Morales et al. 2019



- Inflow rates ~ 10^{-4} -10^{-3} Msun/yr
- v-gradients increase towards center

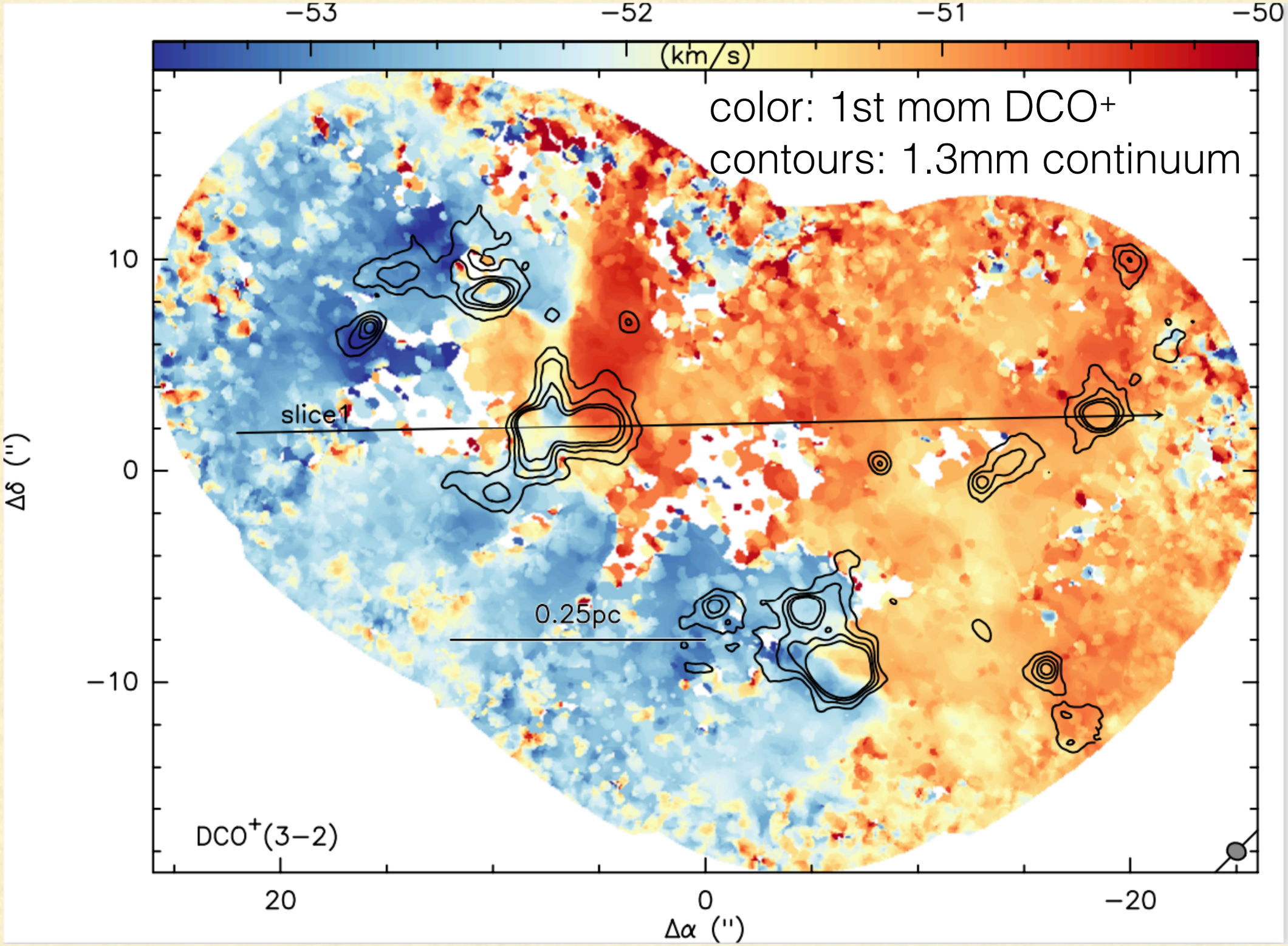
Other examples: Peretto+2014
Hacar+217, Kumar+2022, etc.

Dynamics at the earliest stages I



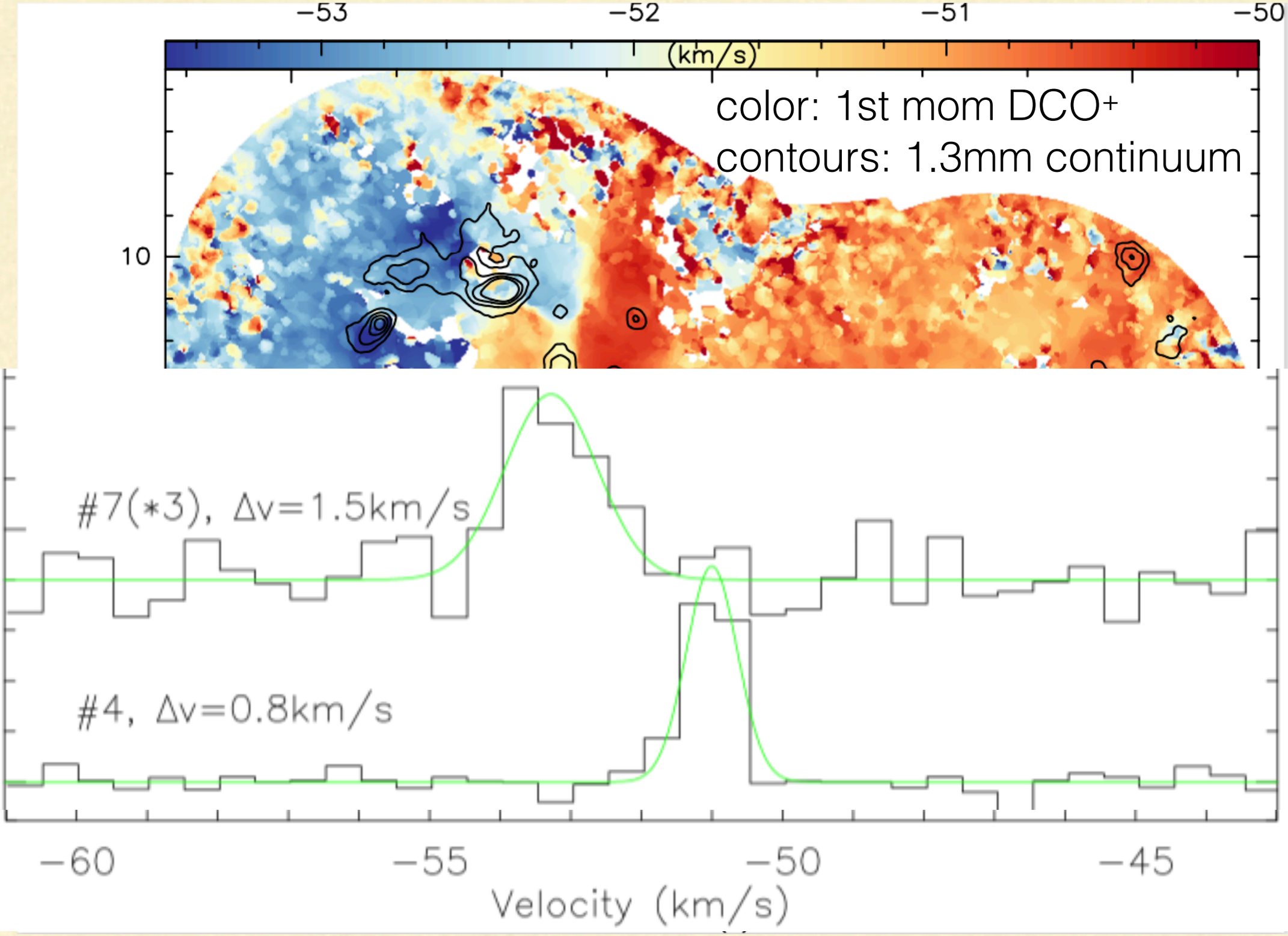
Beuther et al. 2021

Dynamics at the earliest stages II



Beuther et al. 2021

Dynamics at the earliest stages II



Beuther et al. 2021

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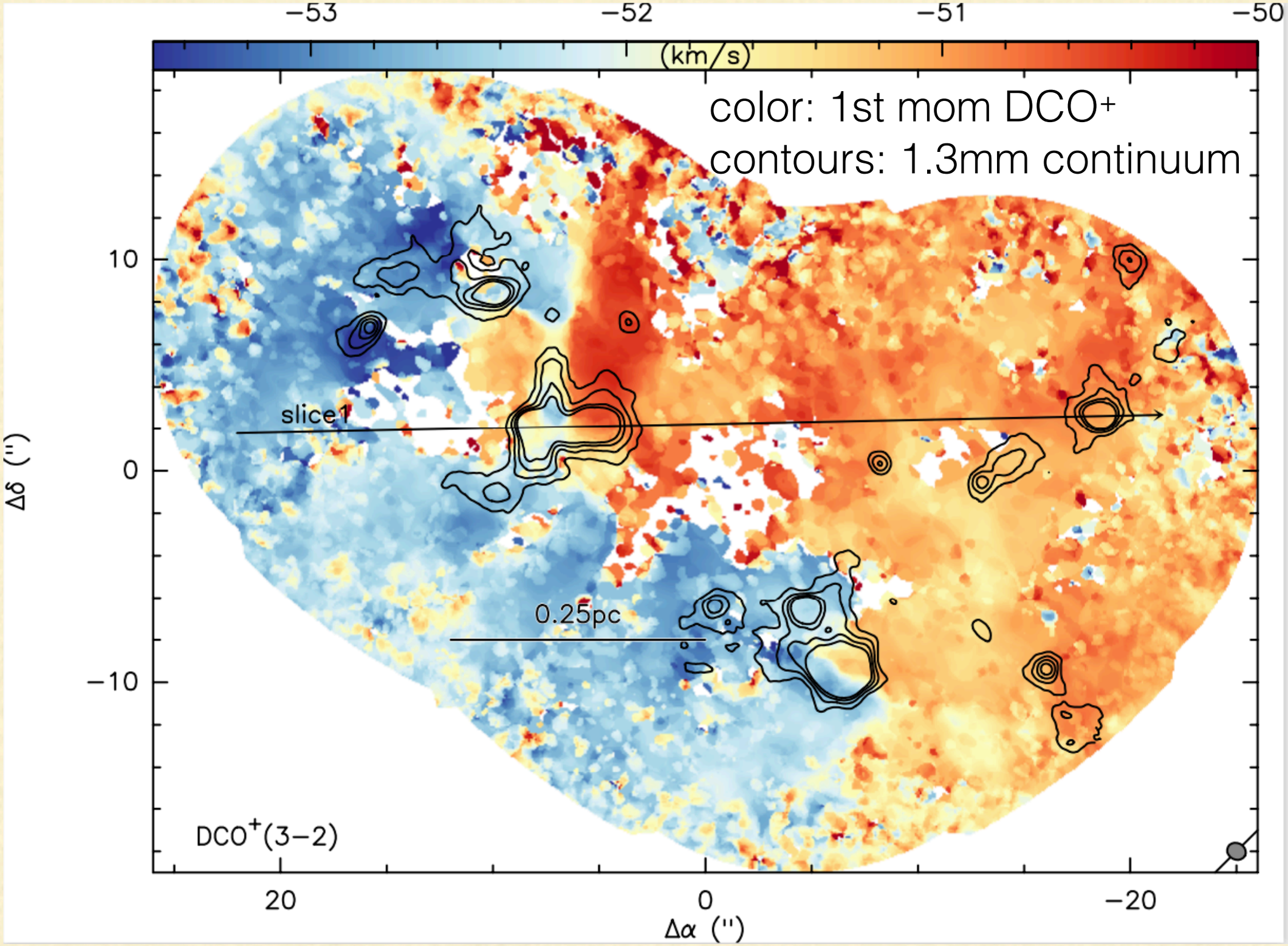
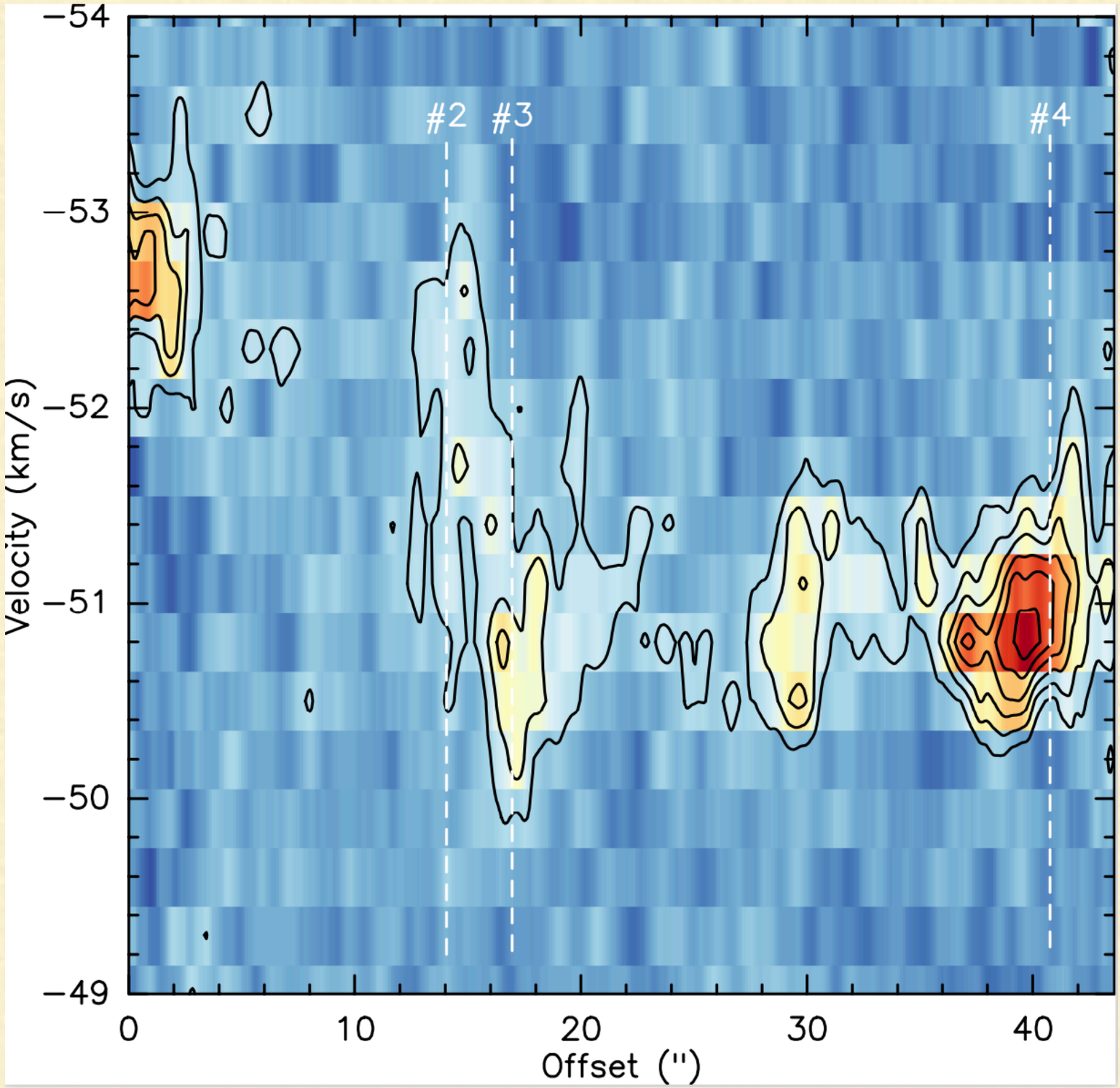


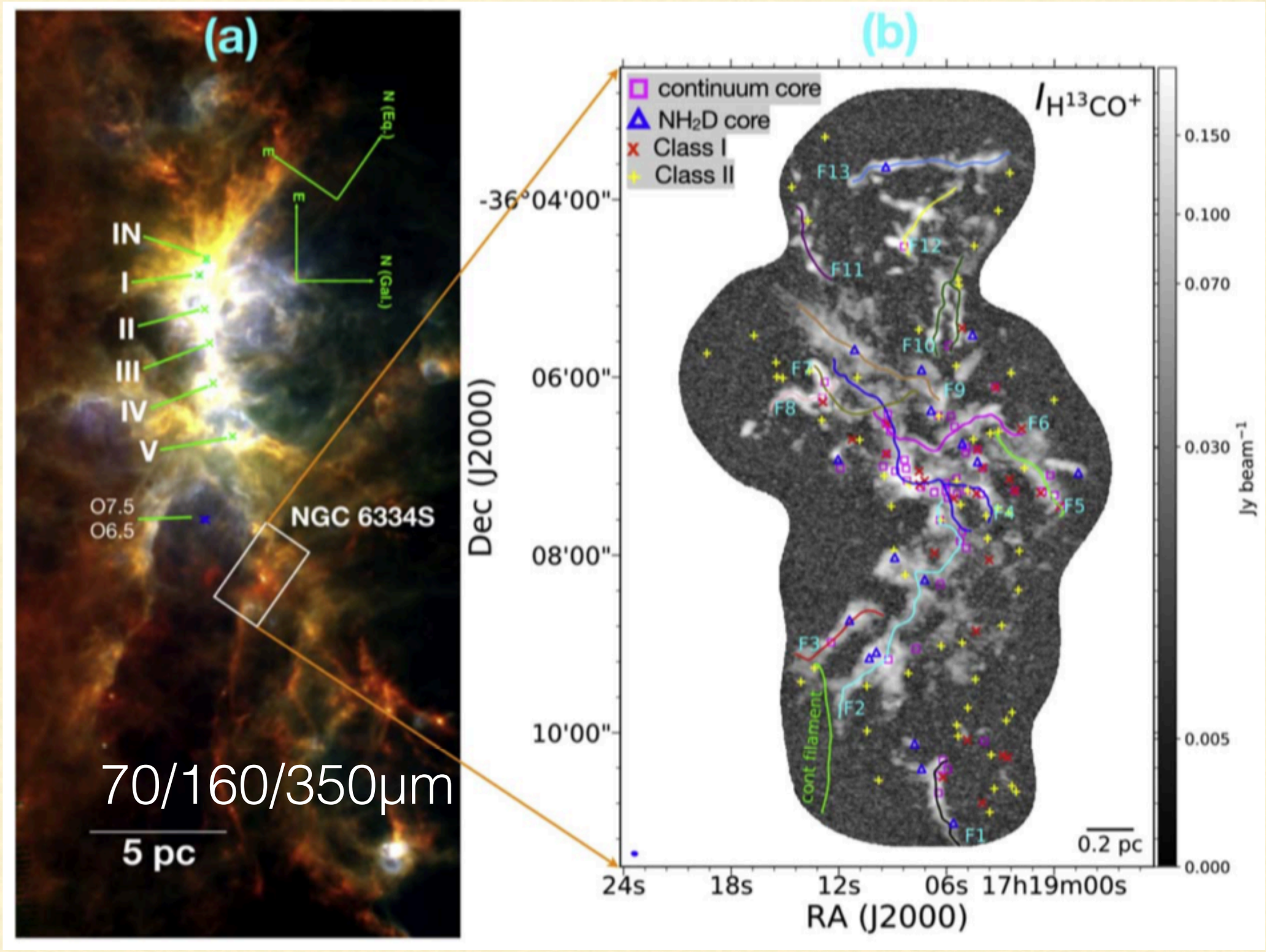
Beuther et al. 2021

Converging gas flow signatures



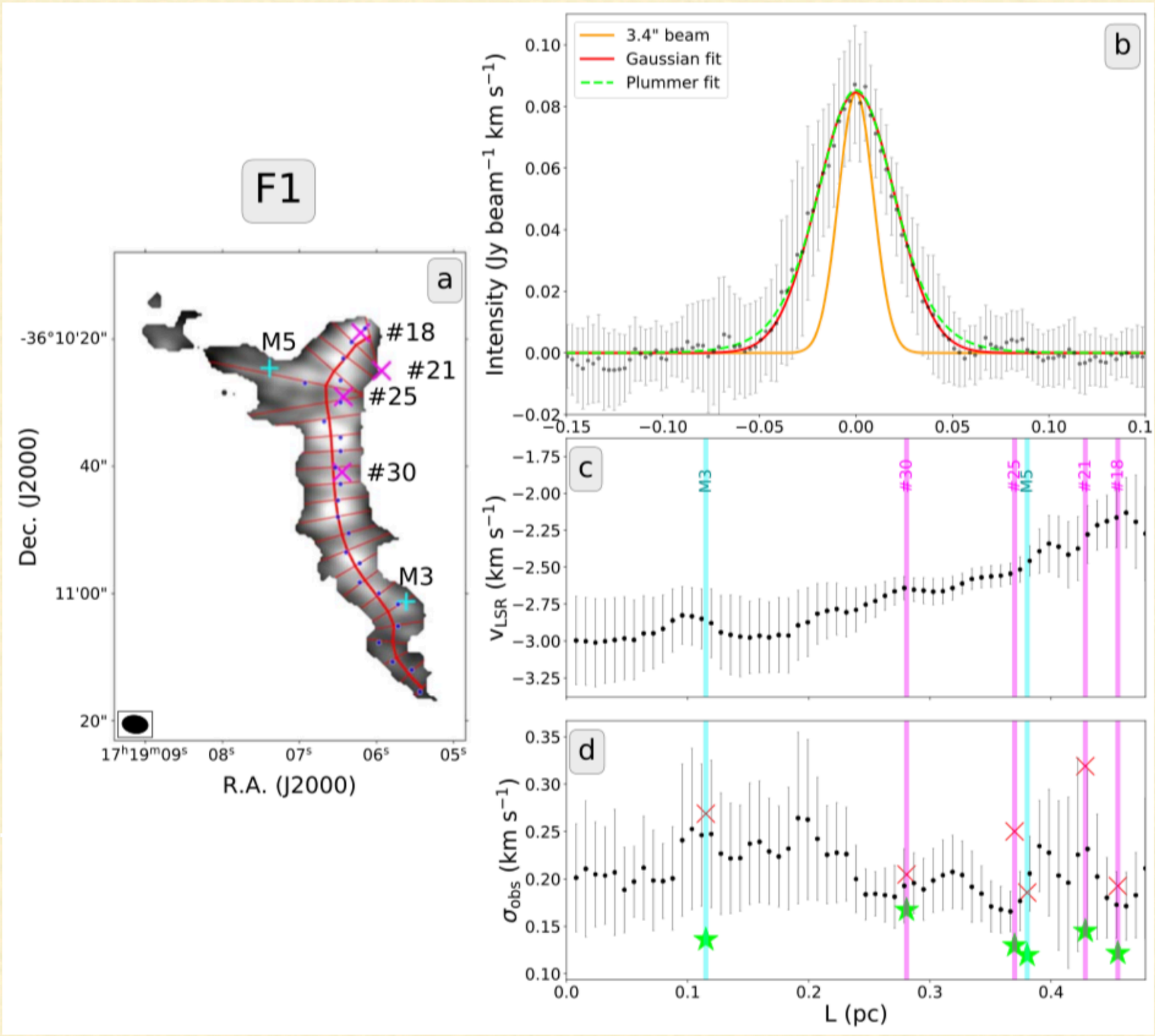
Beuther et al. 2021

Filamentary sub-structures



Li et al. 2020, 2022

Filamentary sub-structures



Li et al. 2020, 2022

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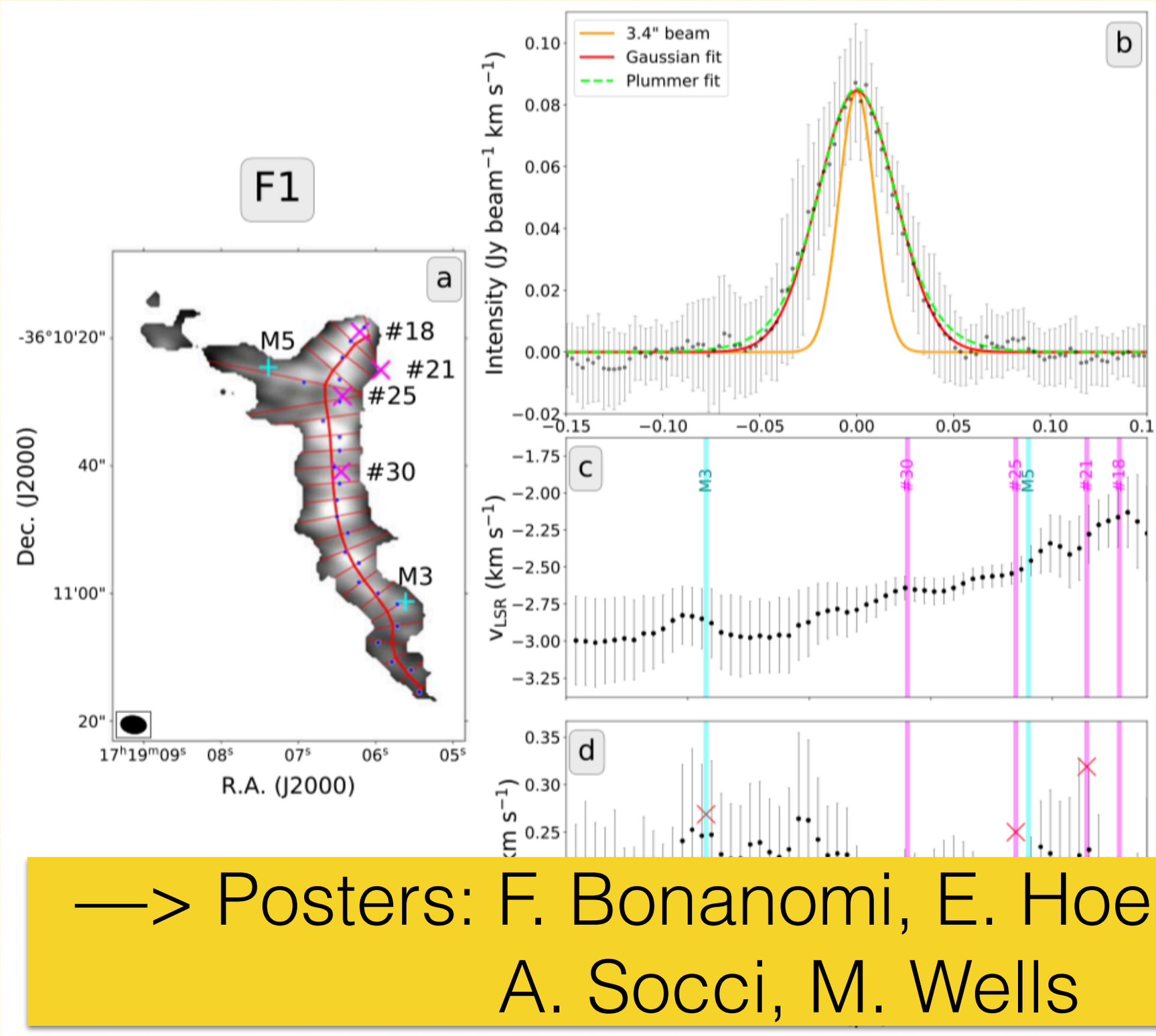
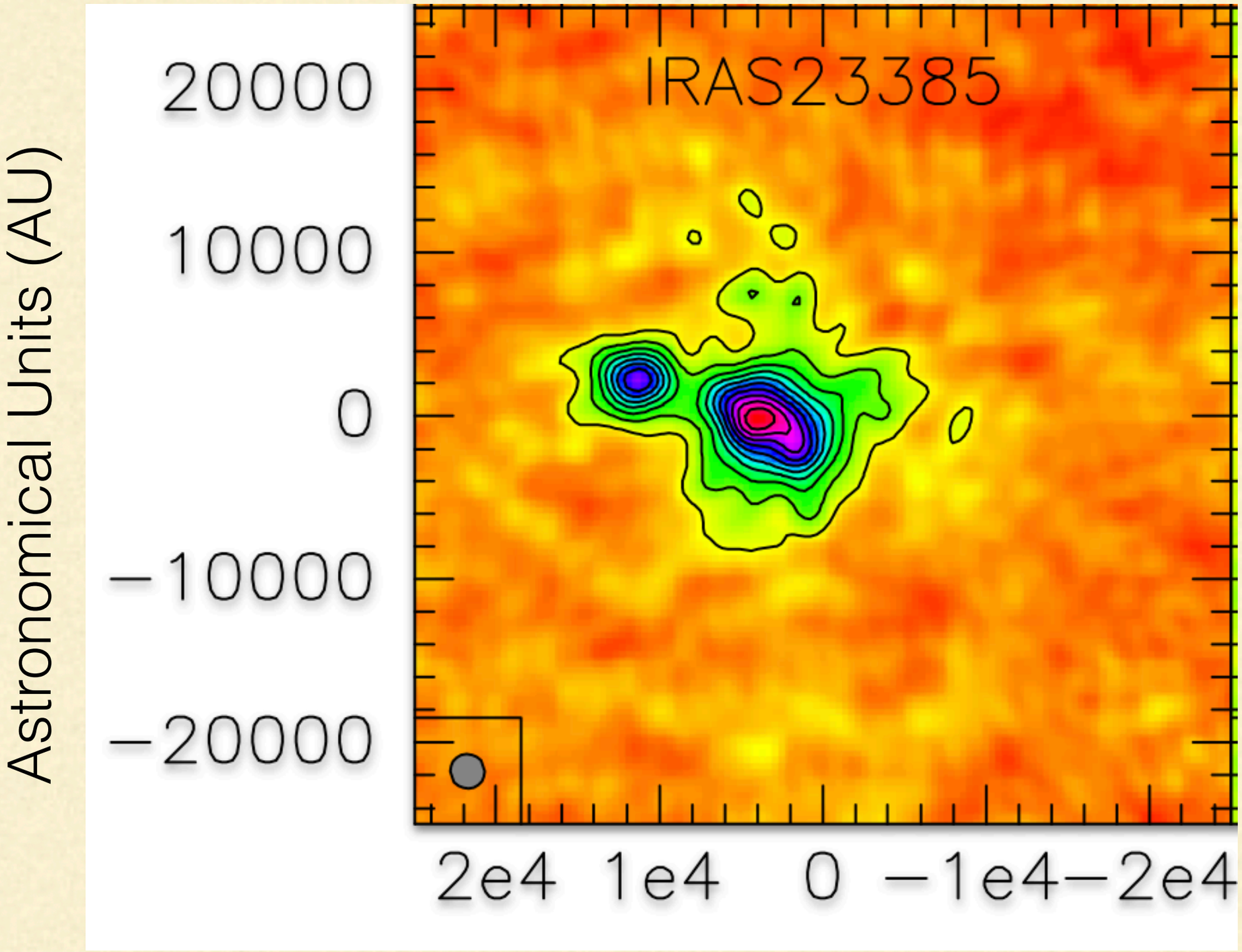


—> Posters: F. Bonanomi, E. Hoemann
A. Socci, M. Wells

Li et al. 2020, 2022

Dense cores in 1.3mm continuum



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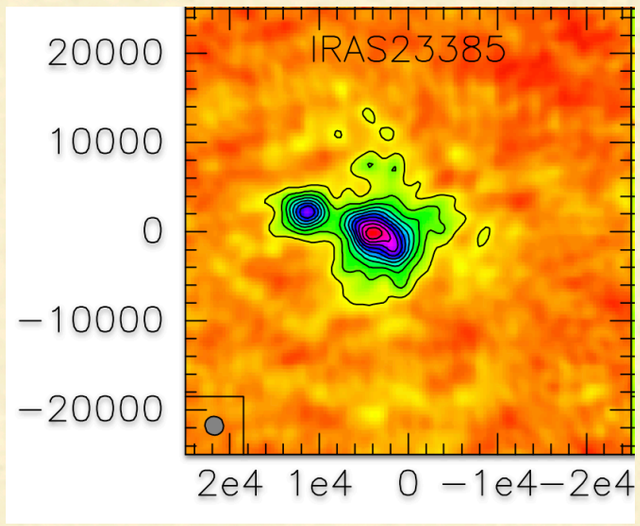


Linear scales

IRAS23151 | IRAS23033 | AFGL2591 | G75.78 | S87IRS1

S106 | IRAS21078 | G100 | G084 | G094

CepA | NGC7538IRS9 | W3(H2O) | W3IRS4 | G108

IRAS23385 | G138 | G139 | NGC7538IRS1 | NGC7538S

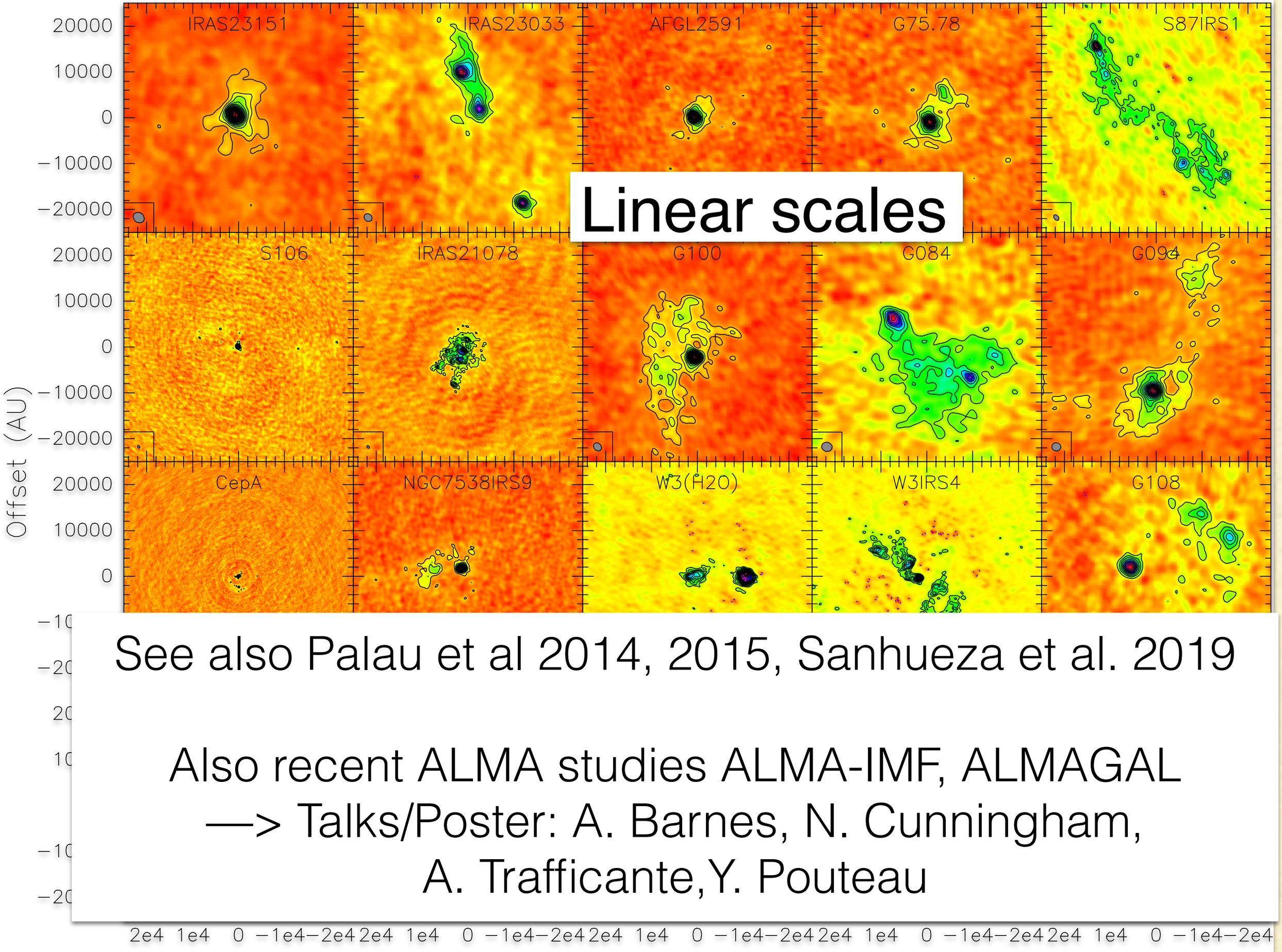
Offset (AU)

20000 10000 0 −10000 −20000

2e4 1e4 0 −1e4 −2e4

Beuther et al. 2018

Offset (AU) **http://www.mpia.de/core**



Linear scales

See also Palau et al 2014, 2015, Sanhueza et al. 2019

Also recent ALMA studies ALMA-IMF, ALMAGAL
—> Talks/Poster: A. Barnes, N. Cunningham,
A. Trafficante,Y. Pouteau

Beuther et al. 2018

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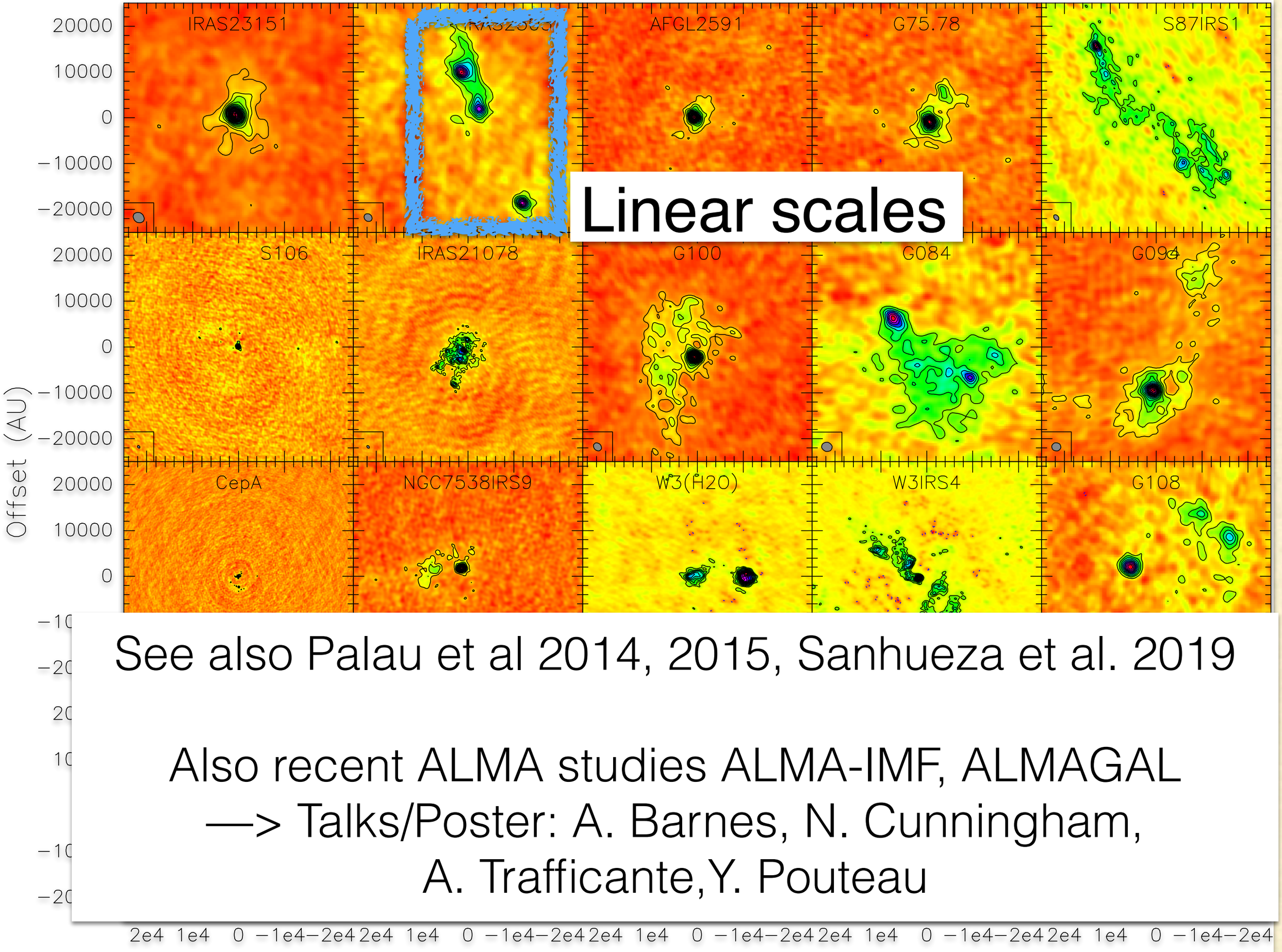

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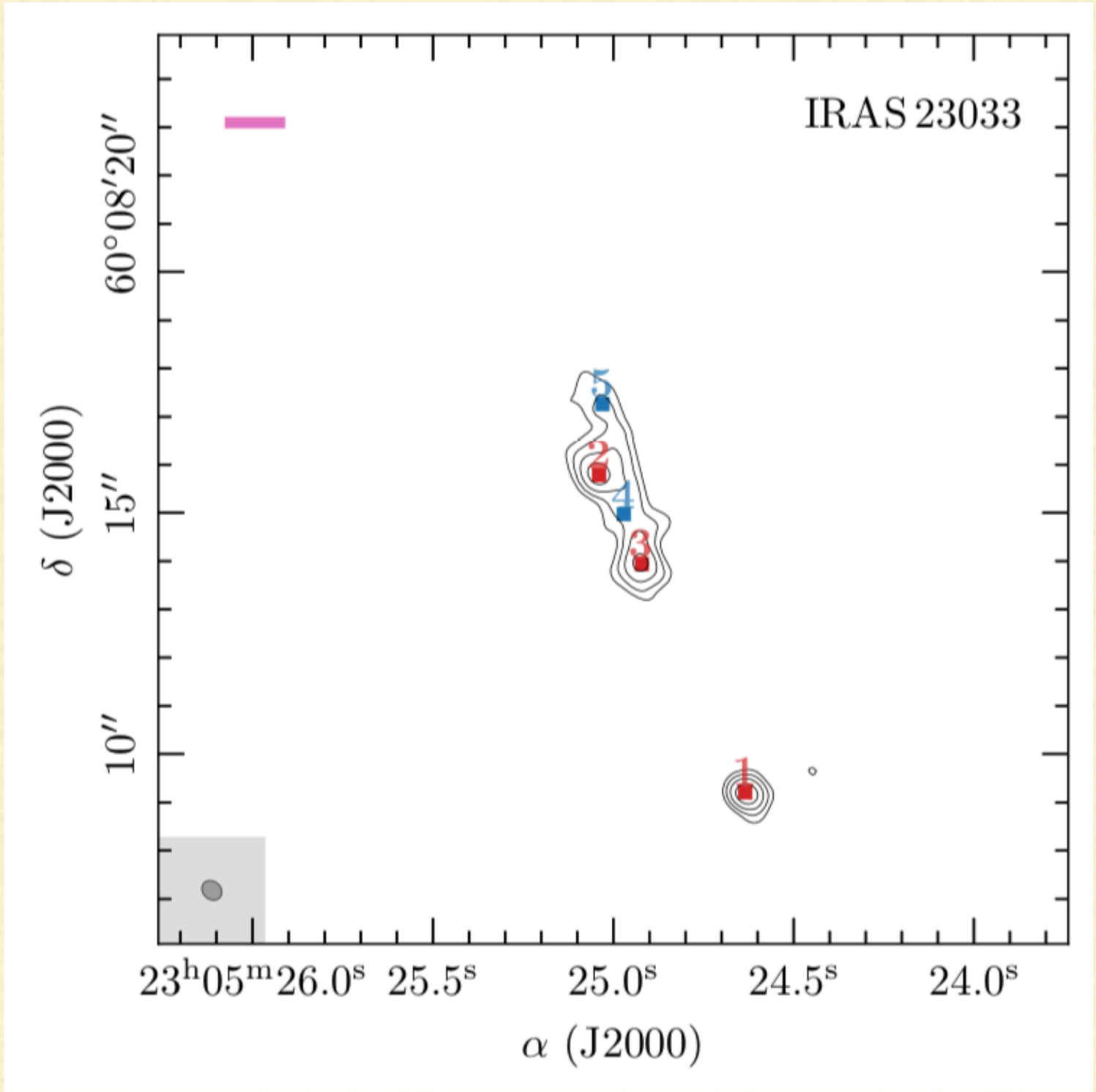
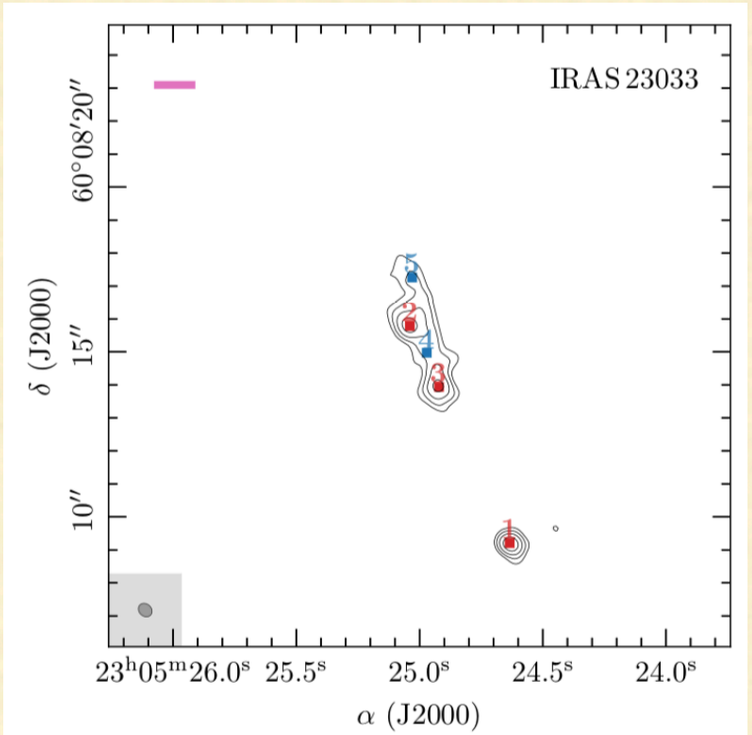
Physical properties

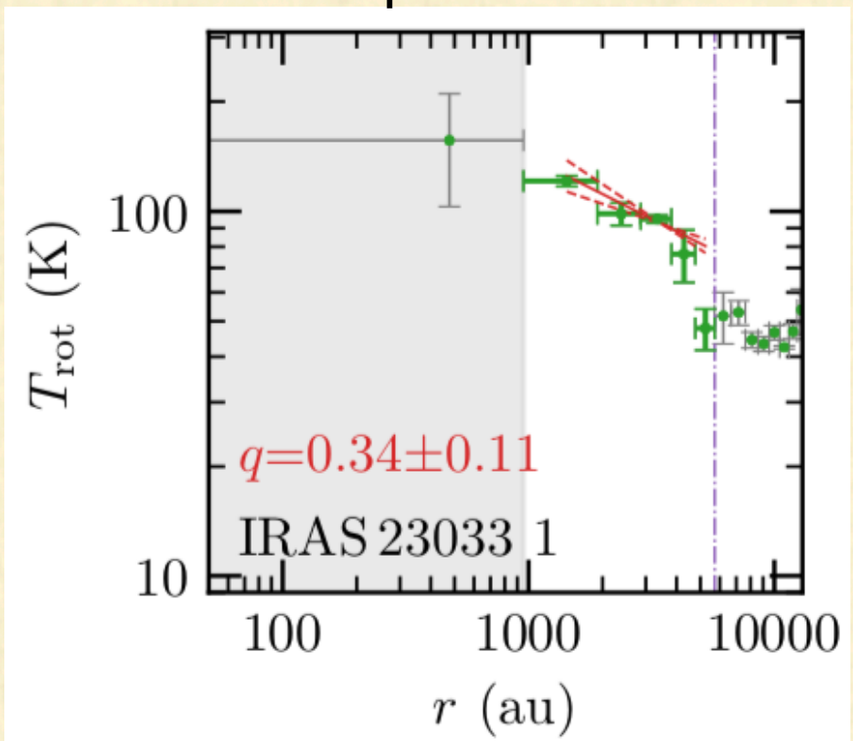


Gieser et al. 2021

Physical properties

Temperature





Gieser et al. 2021

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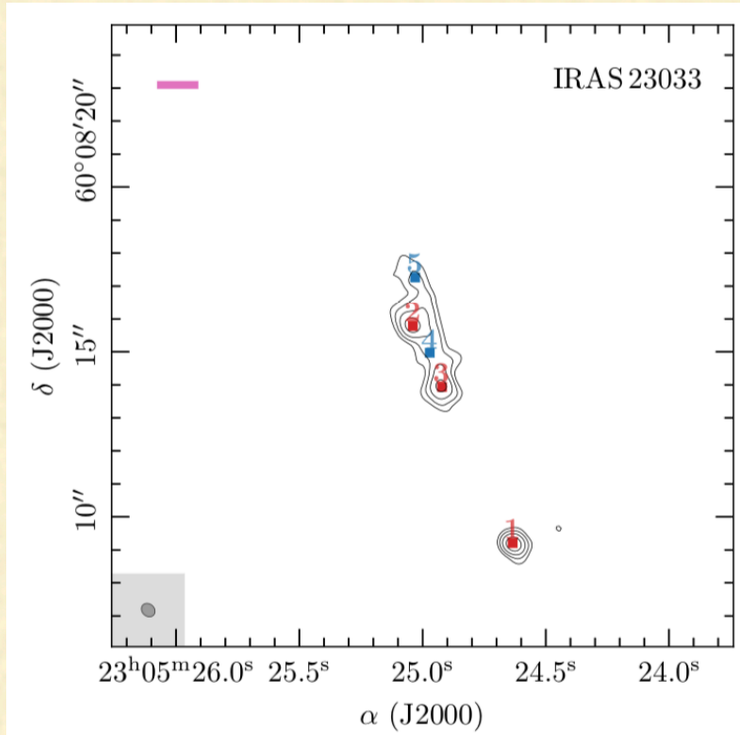
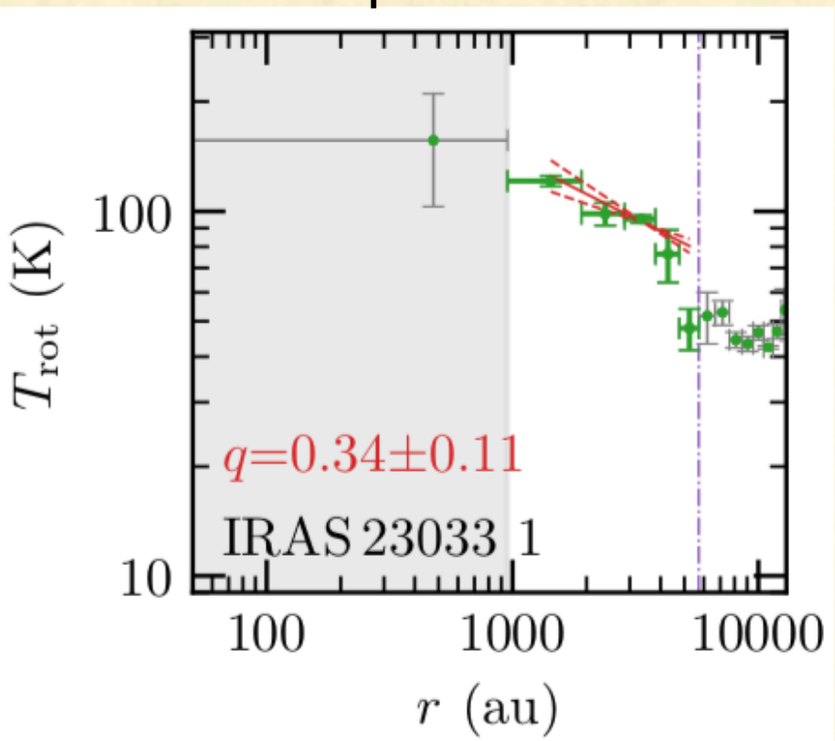
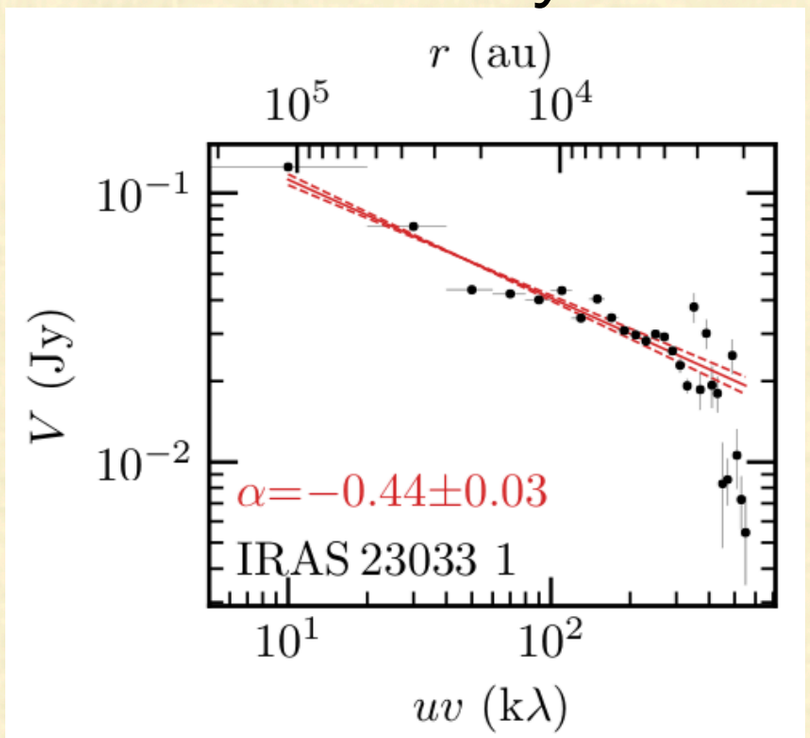




Intensity



Gieser et al. 2021

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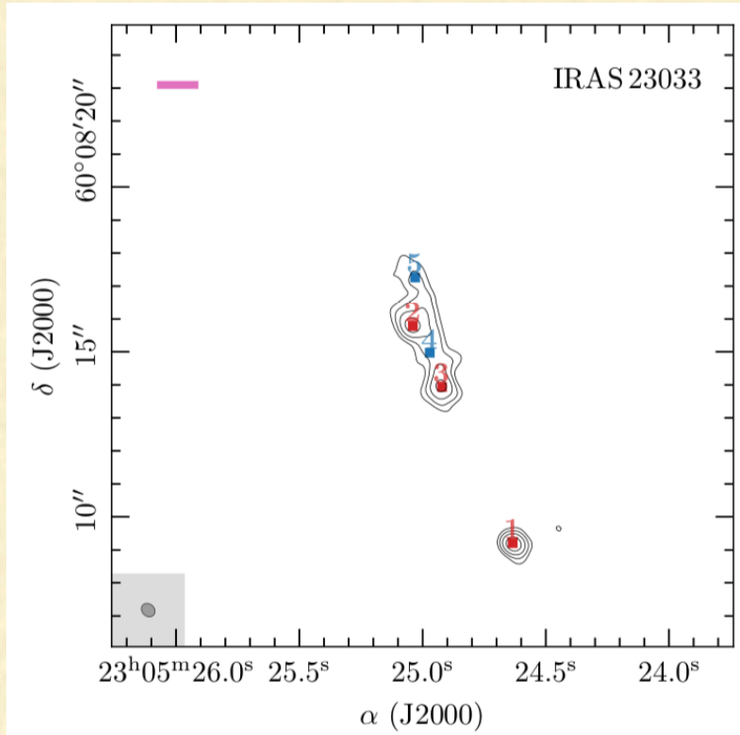

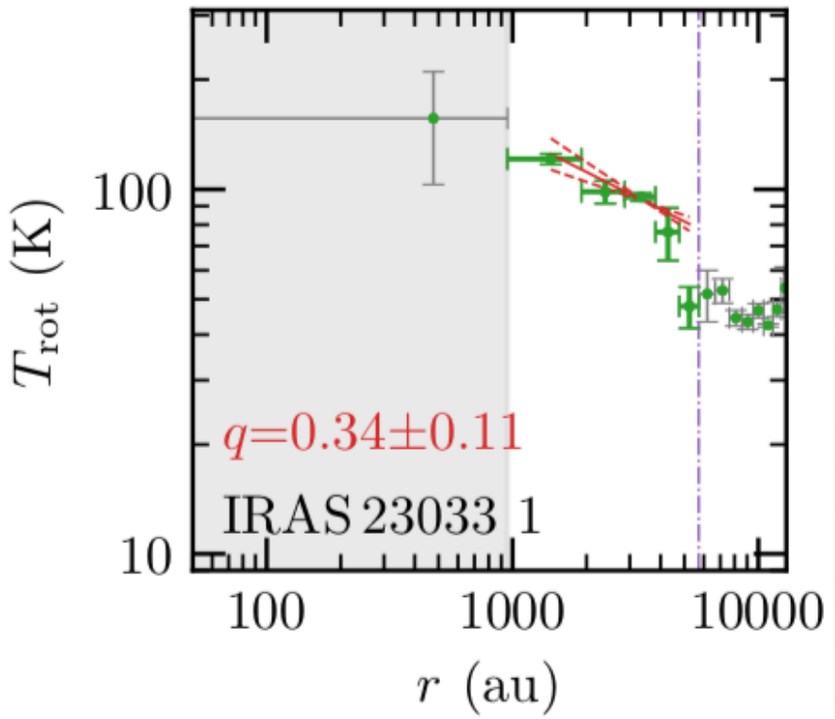

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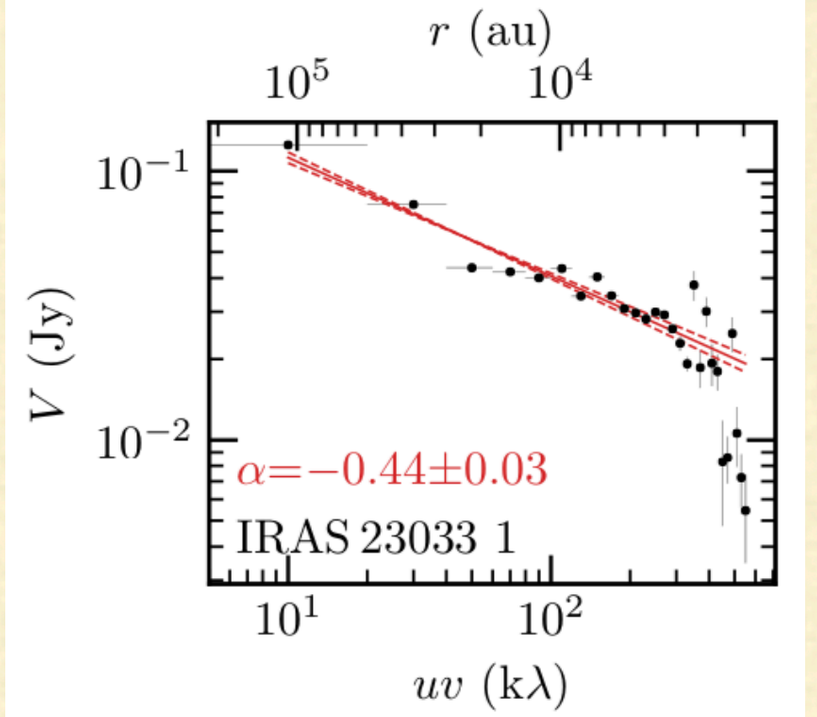
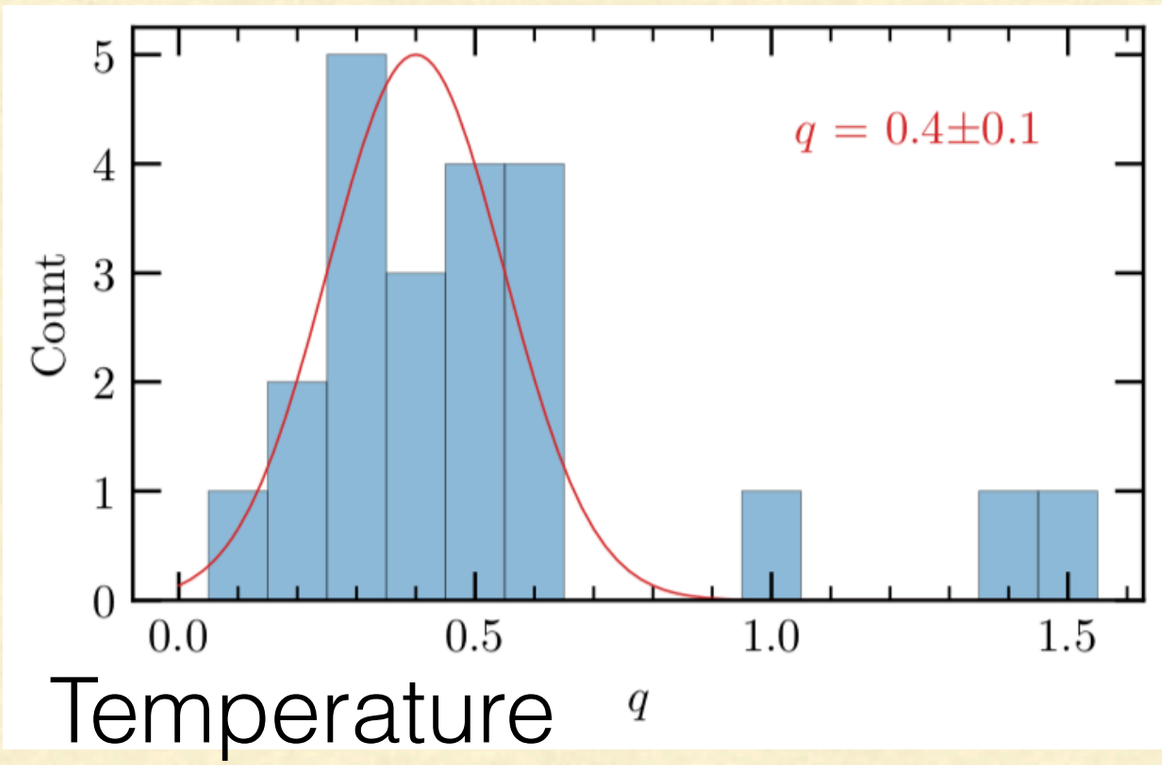
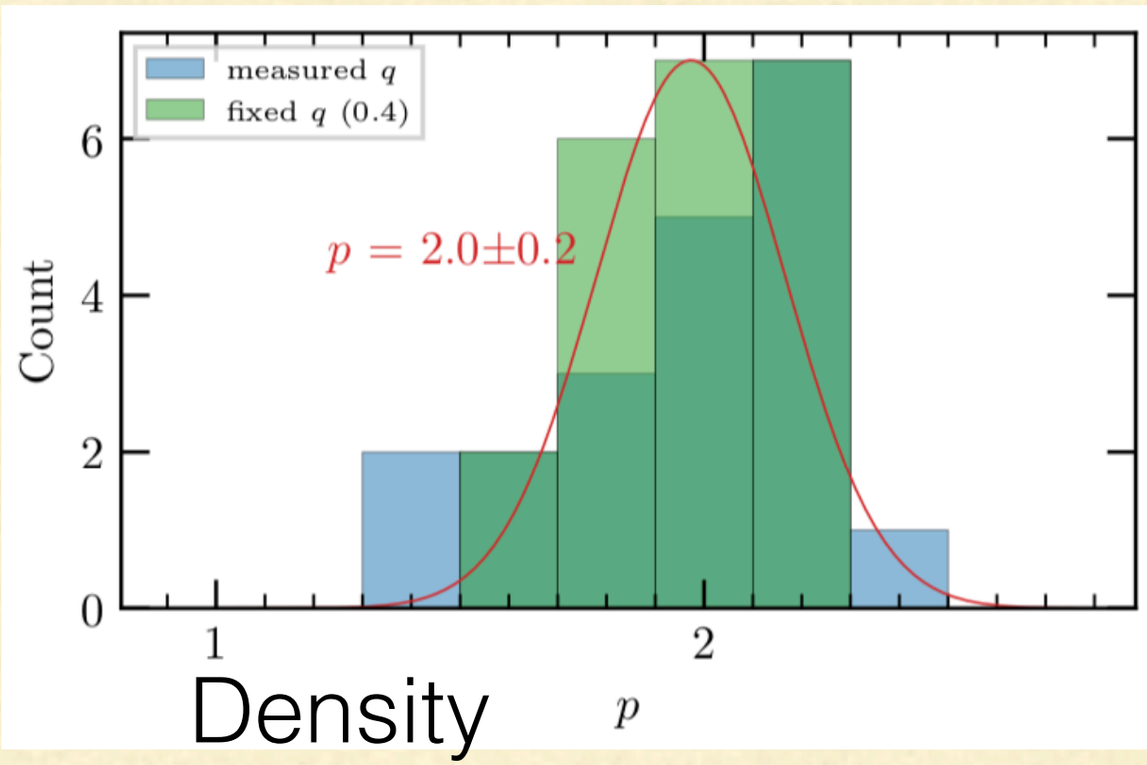




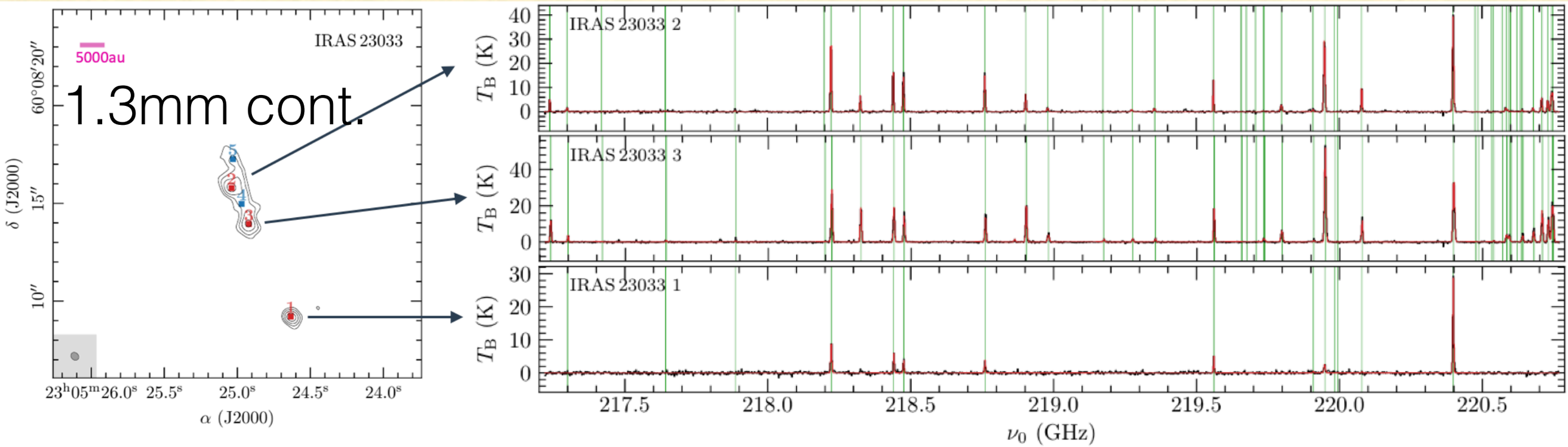
Temperature



Density

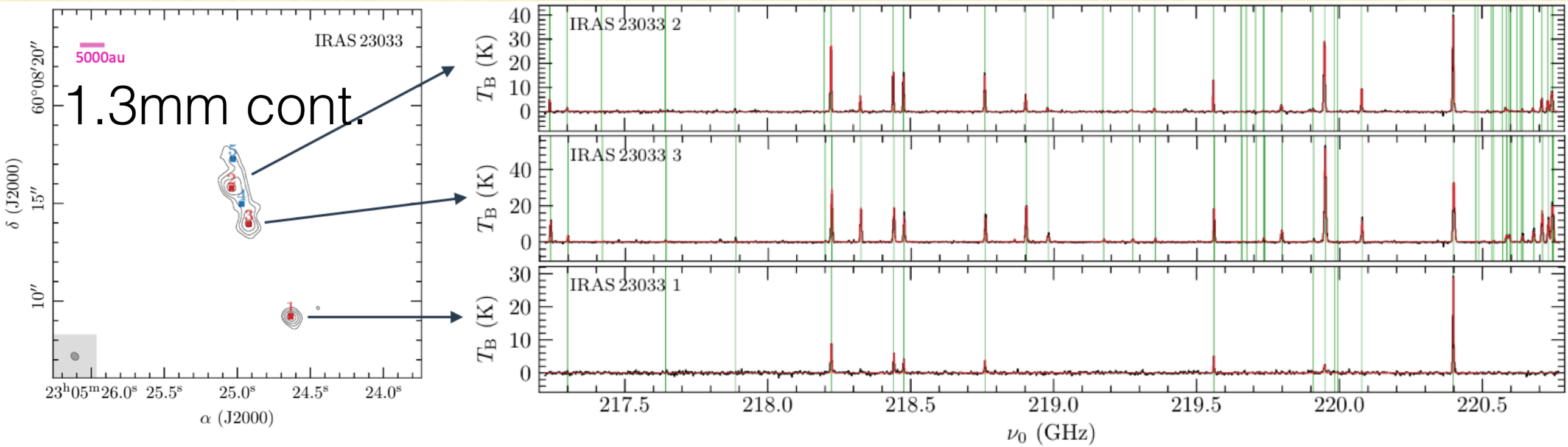
Gieser et al. 2021

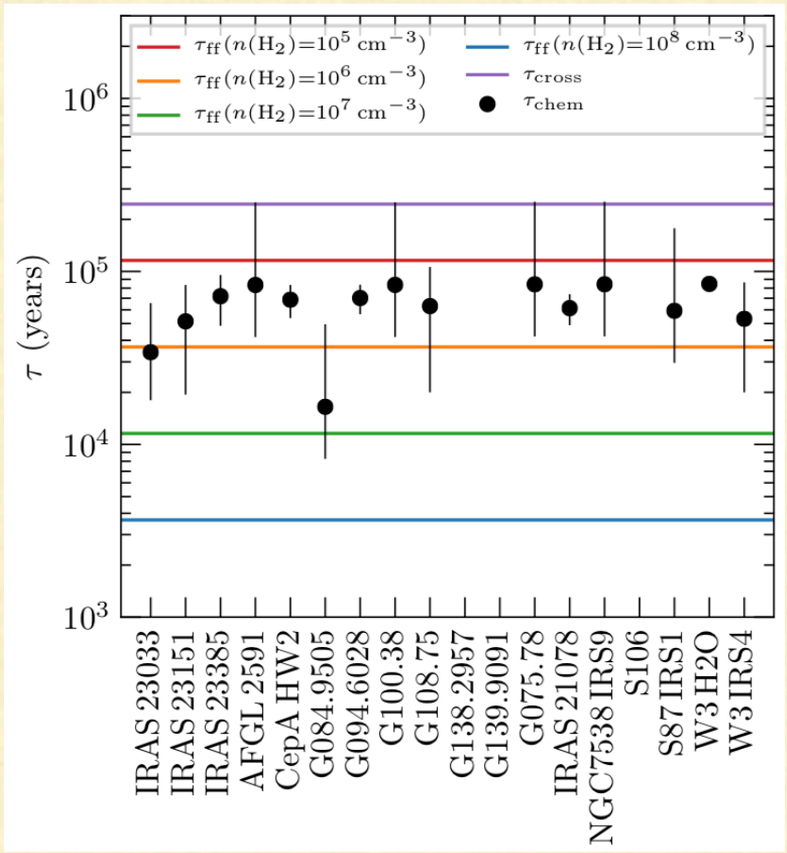
Chemical properties



Gieser et al. 2021, 2022

Chemical properties





Gieser et al. 2021, 2022

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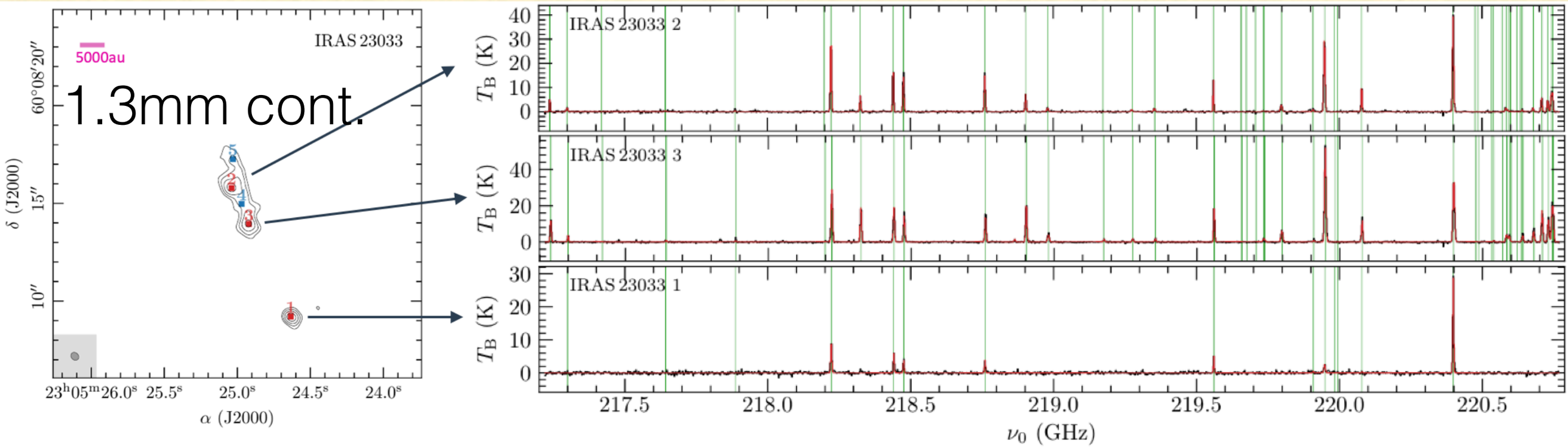

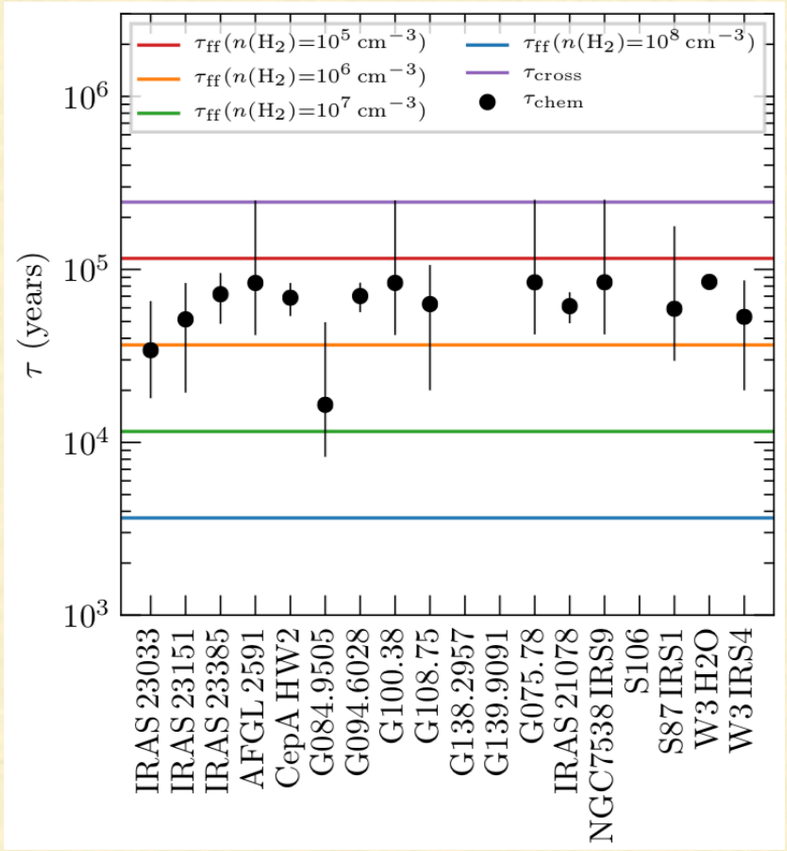

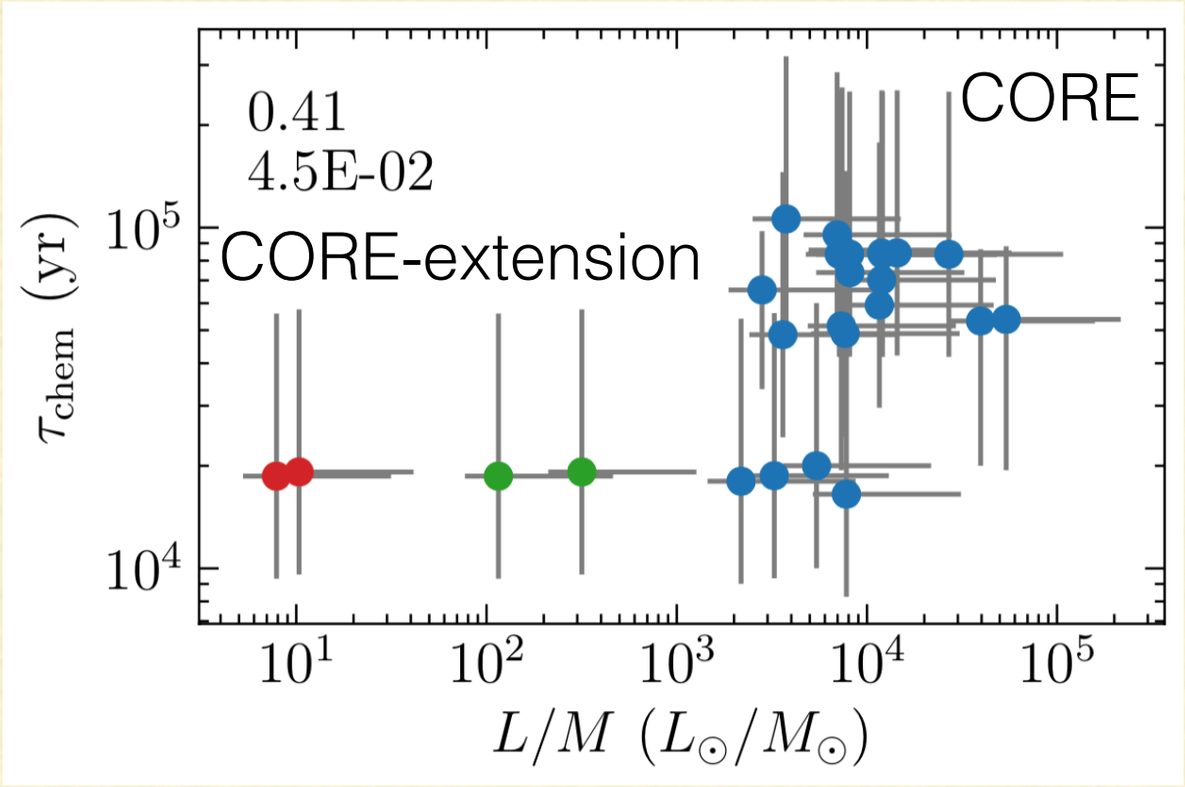

Gieser et al. 2021, 2022

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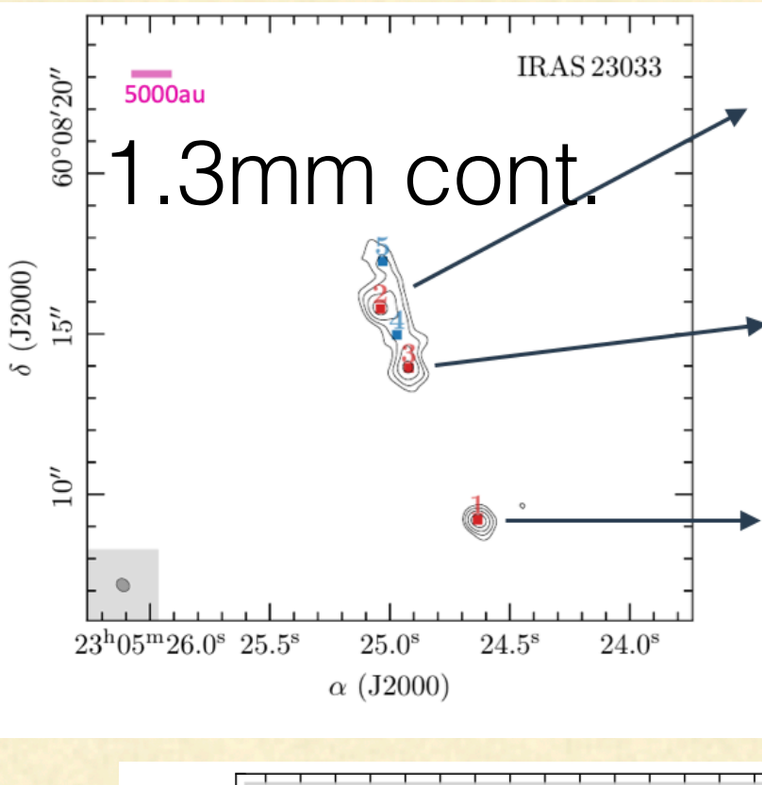
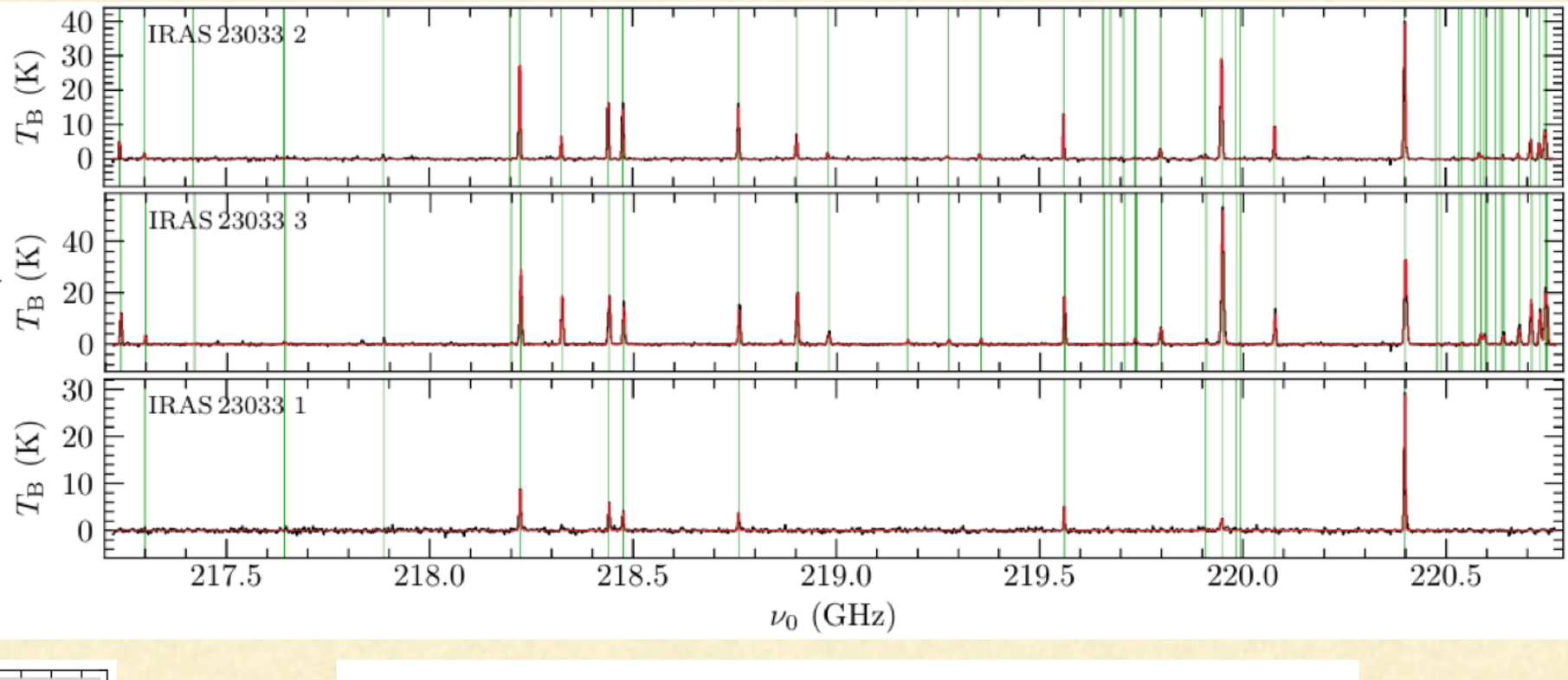
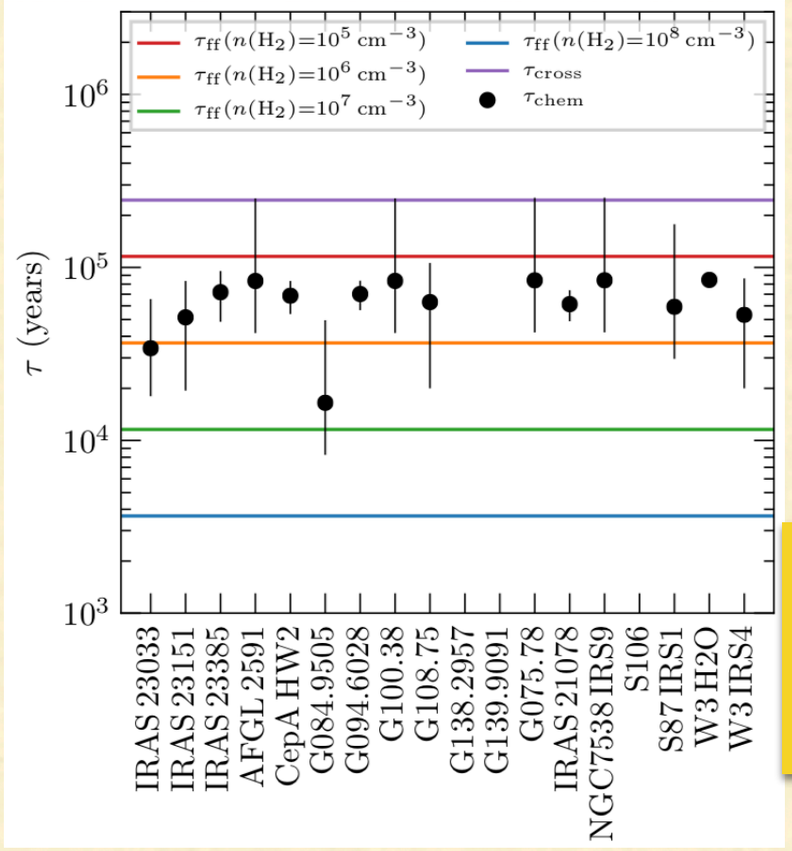
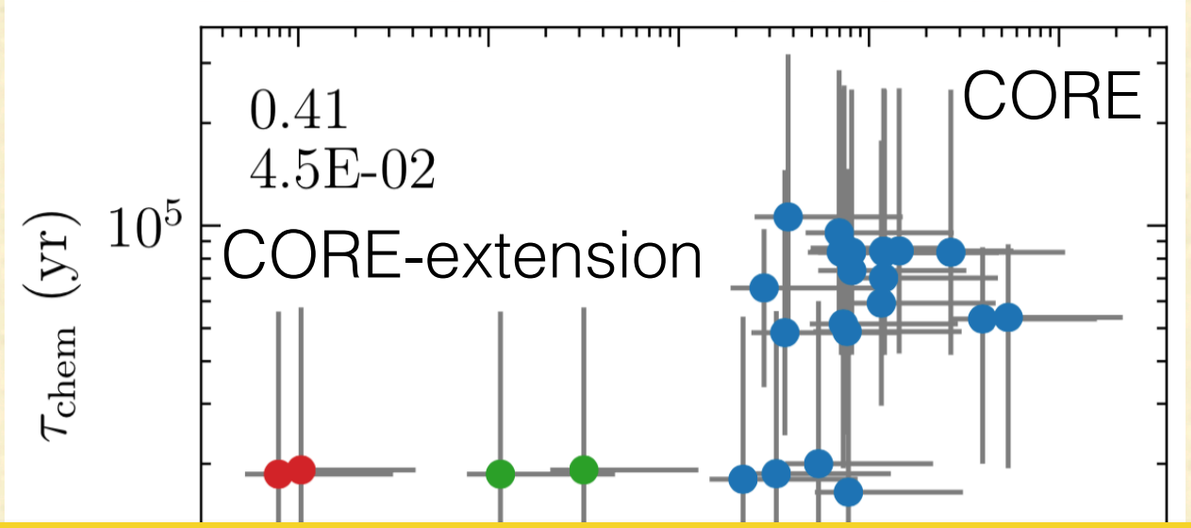




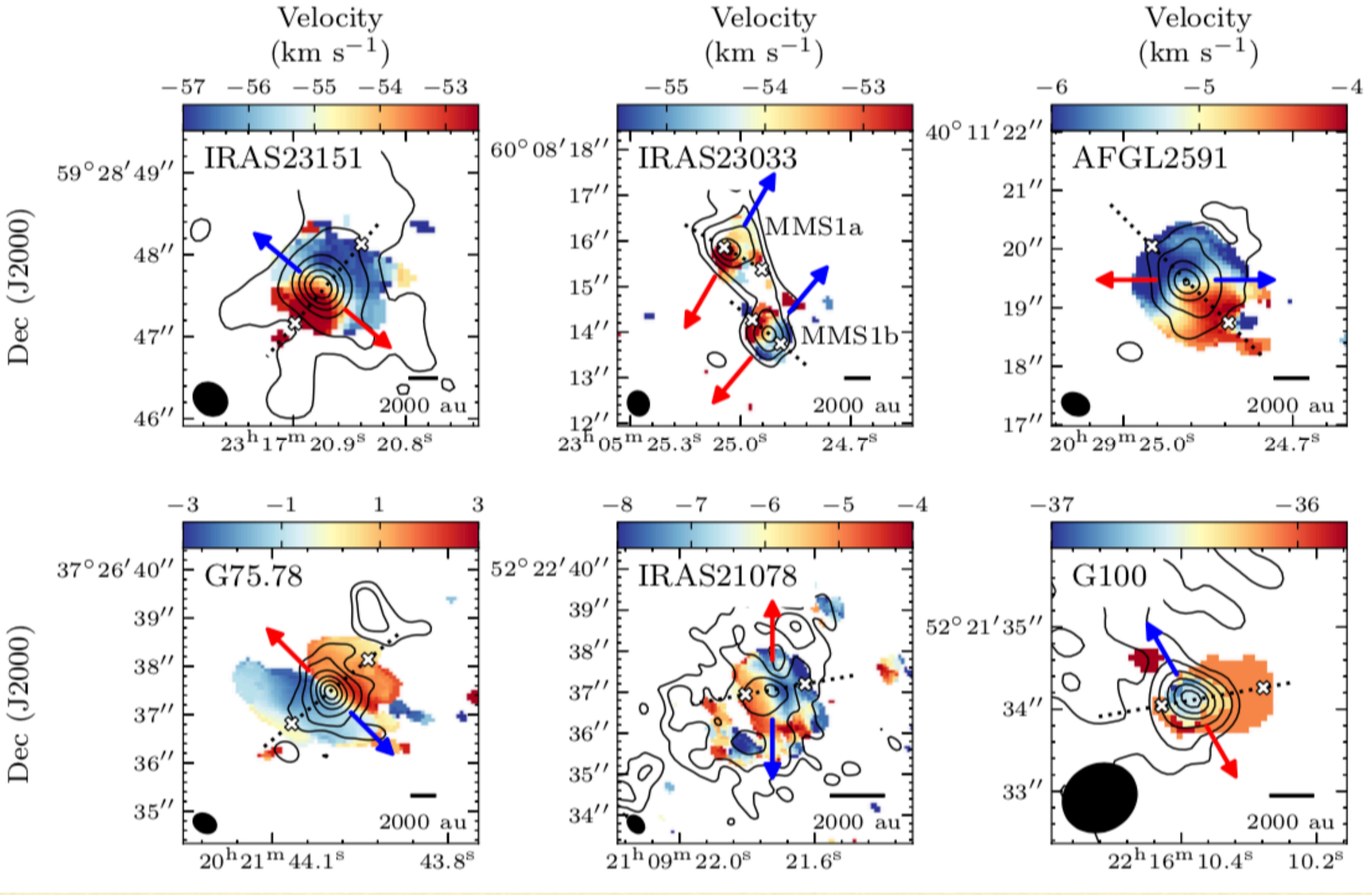




—> Poster Caroline Gieser

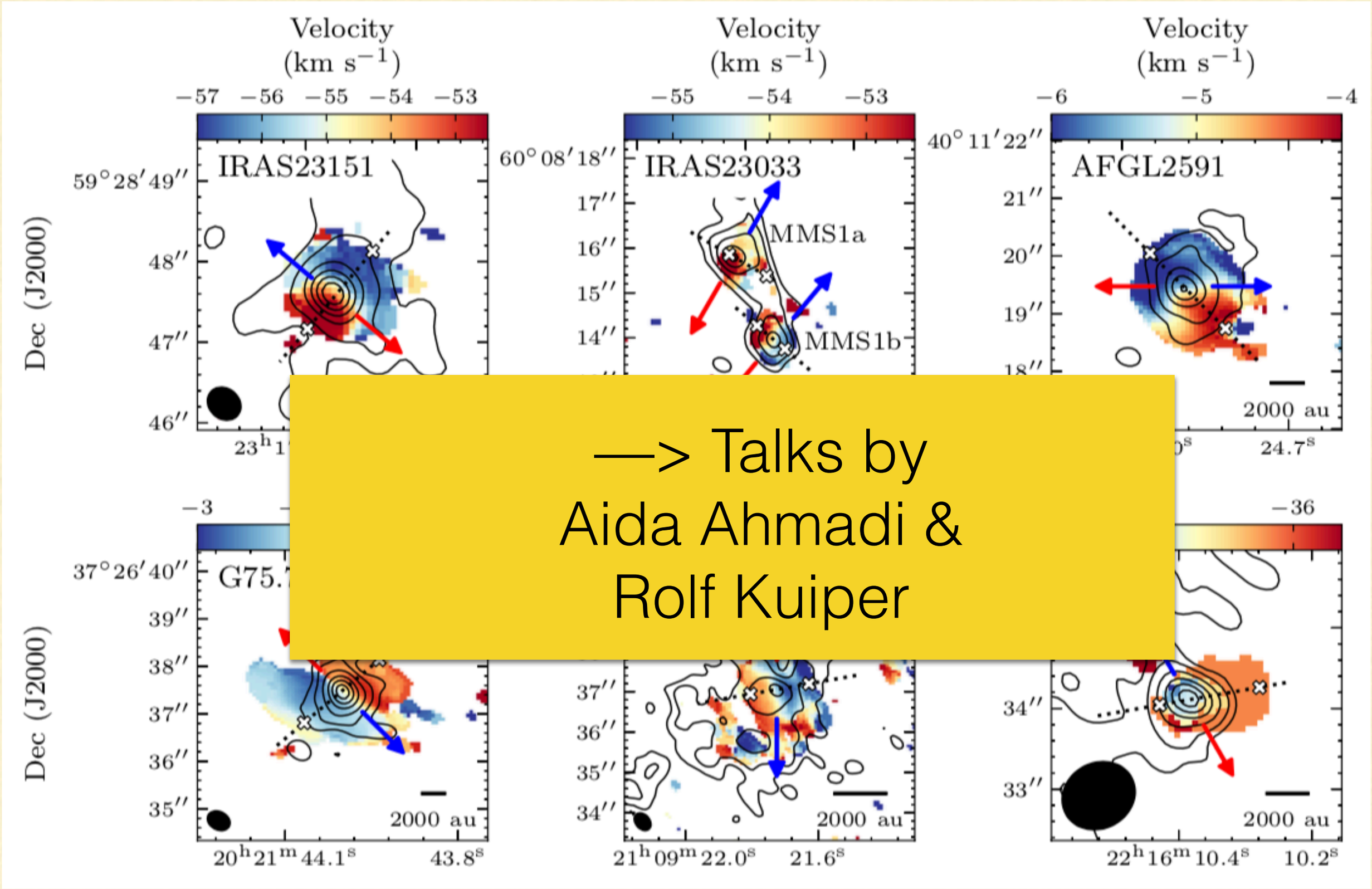
Gieser et al. 2021, 2022

Rotational properties



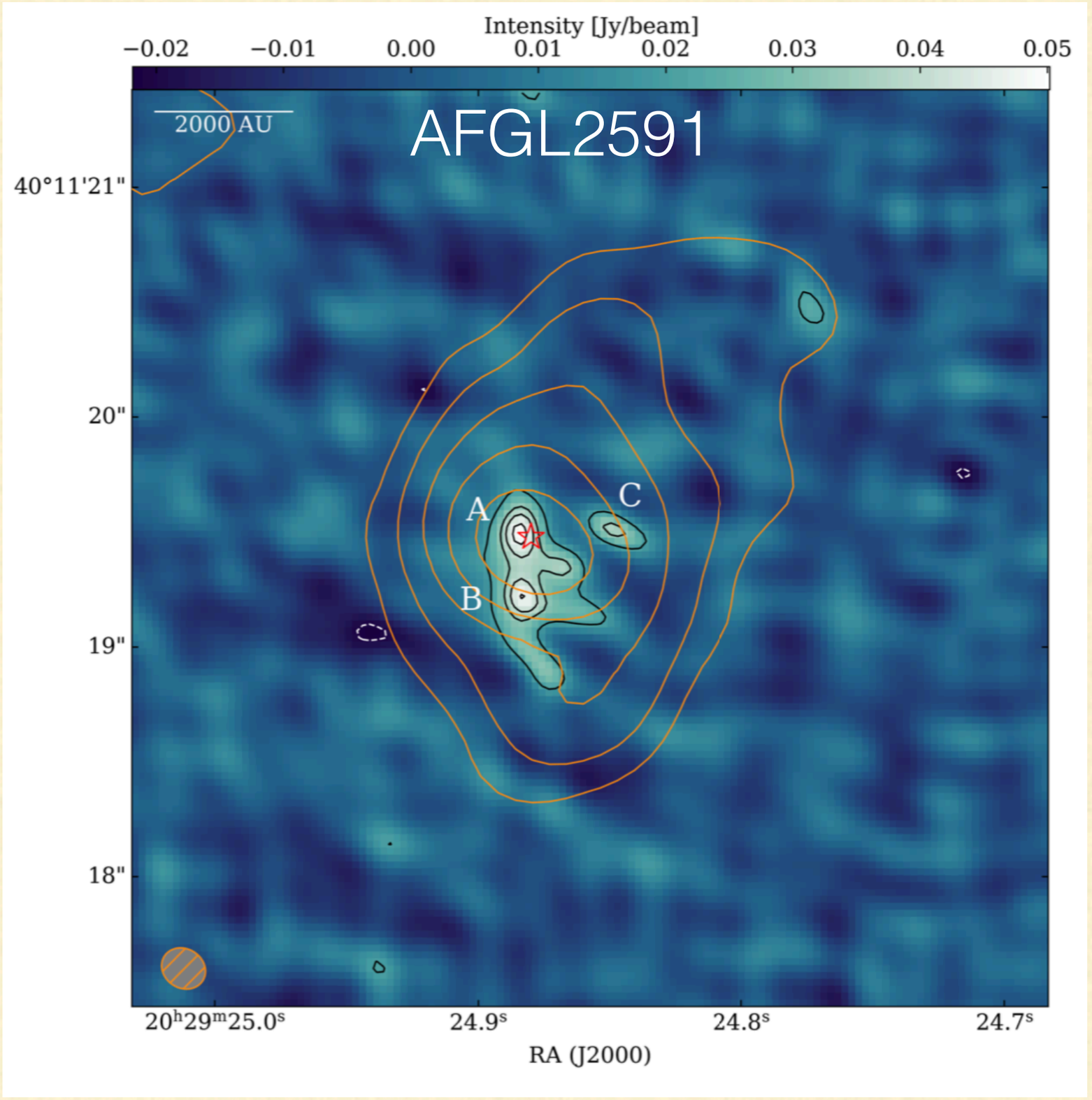
Ahmadi 2020, in prep.

Rotational properties



Ahmadi 2020, in prep.

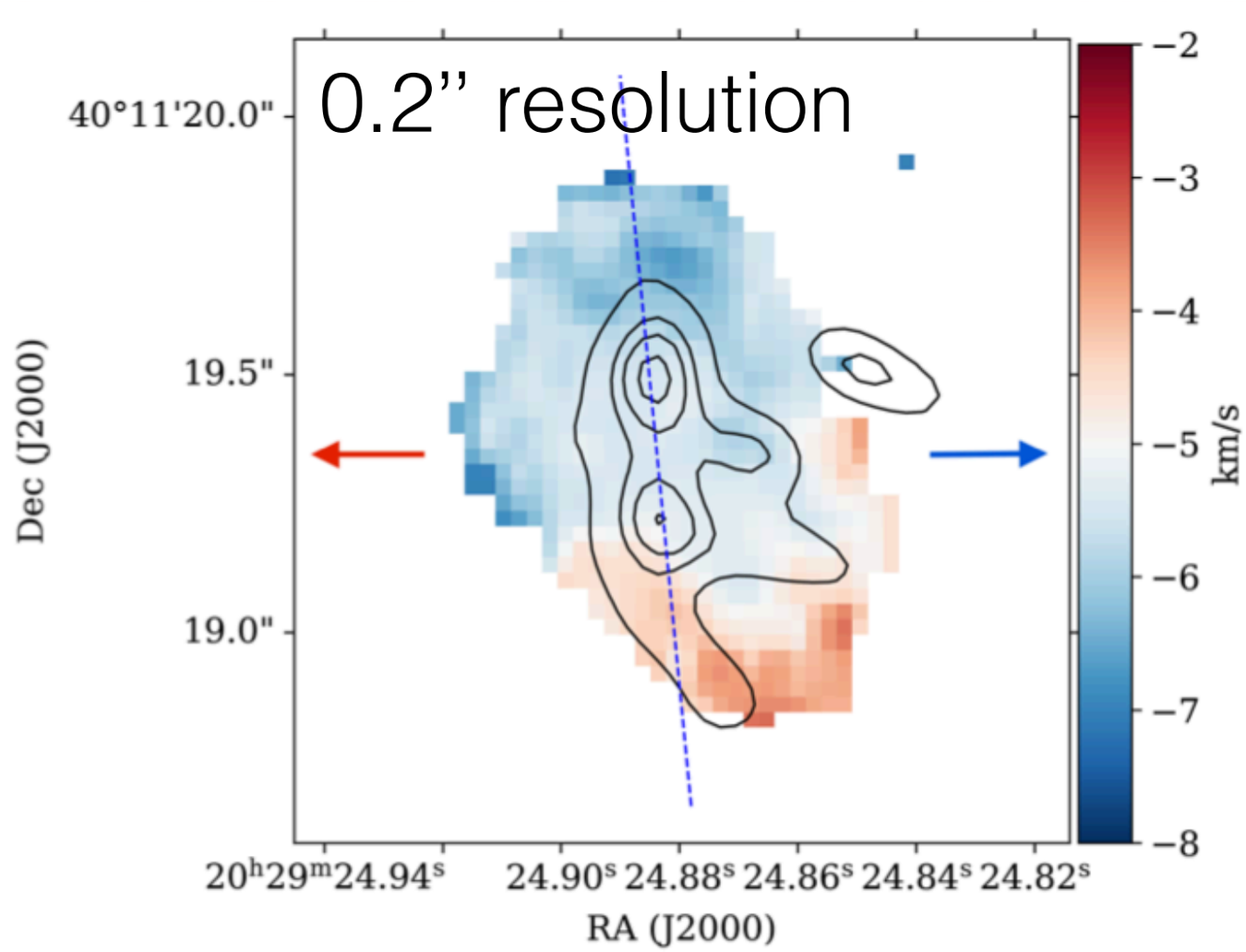
Disk fragmentation: NOEMA 850μm

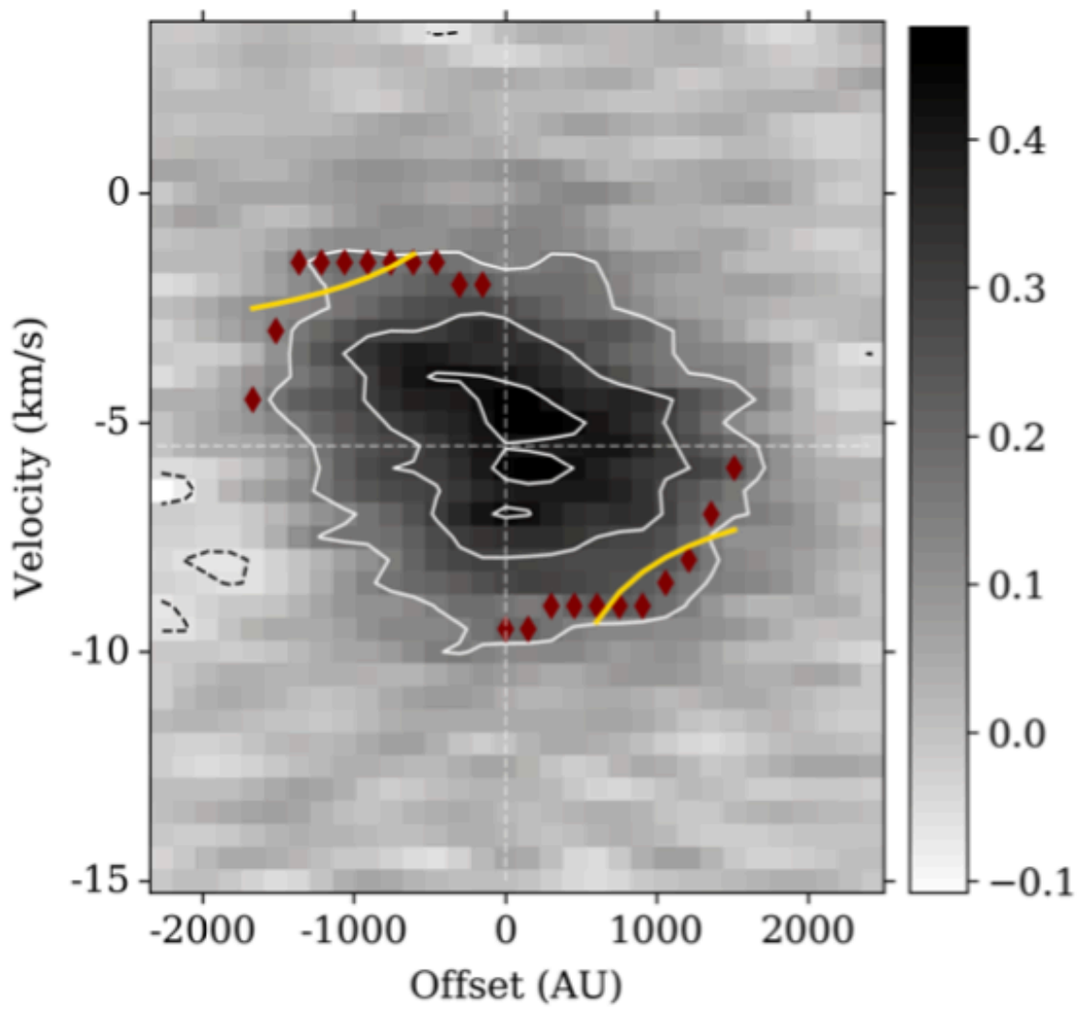


Suri et al. 2021

Disk fragmentation: NOEMA 850μm

AFGL2591



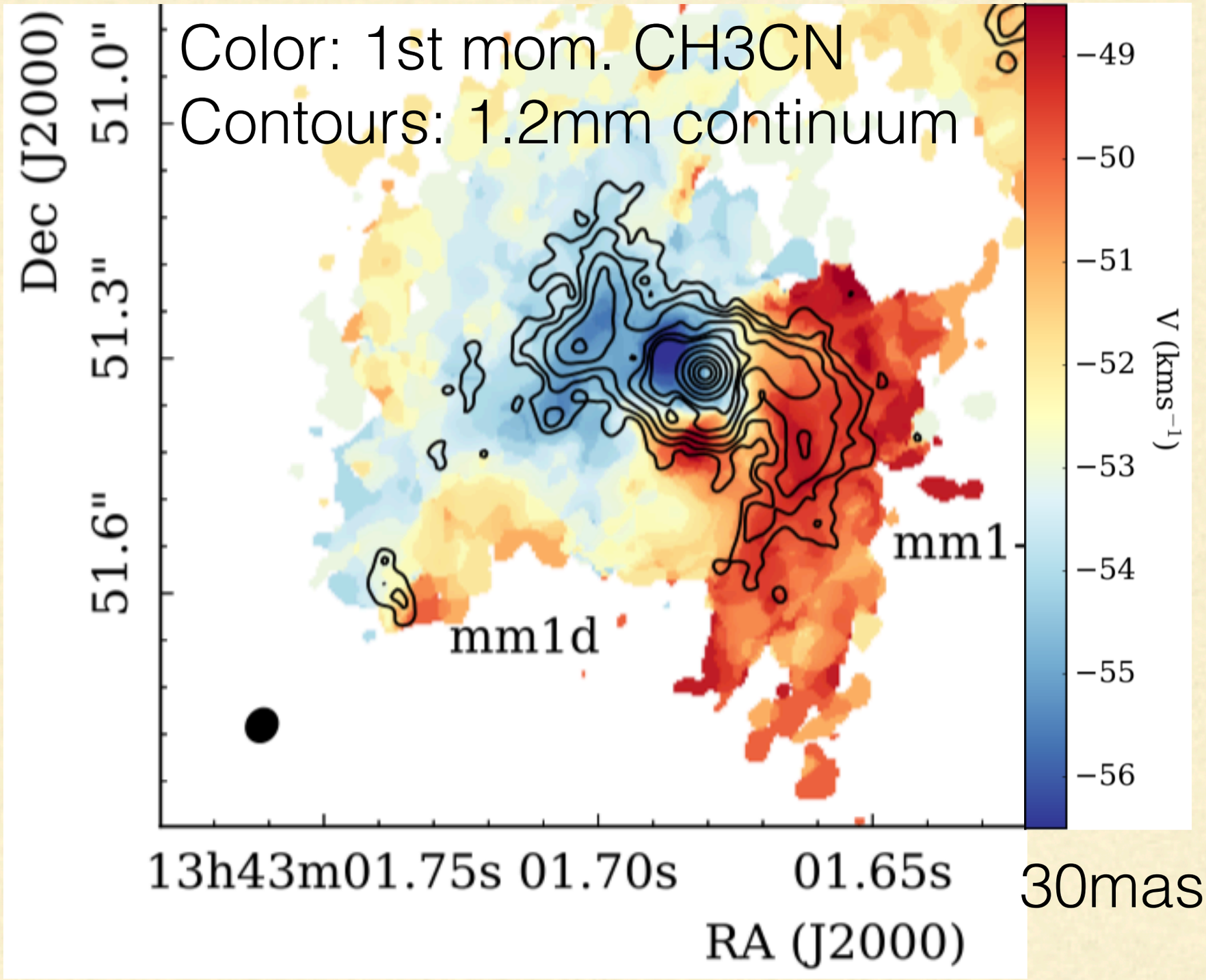


color: 1st moment HCN
contours: 843μm continuum

position-velocity cut

Suri et al. 2021

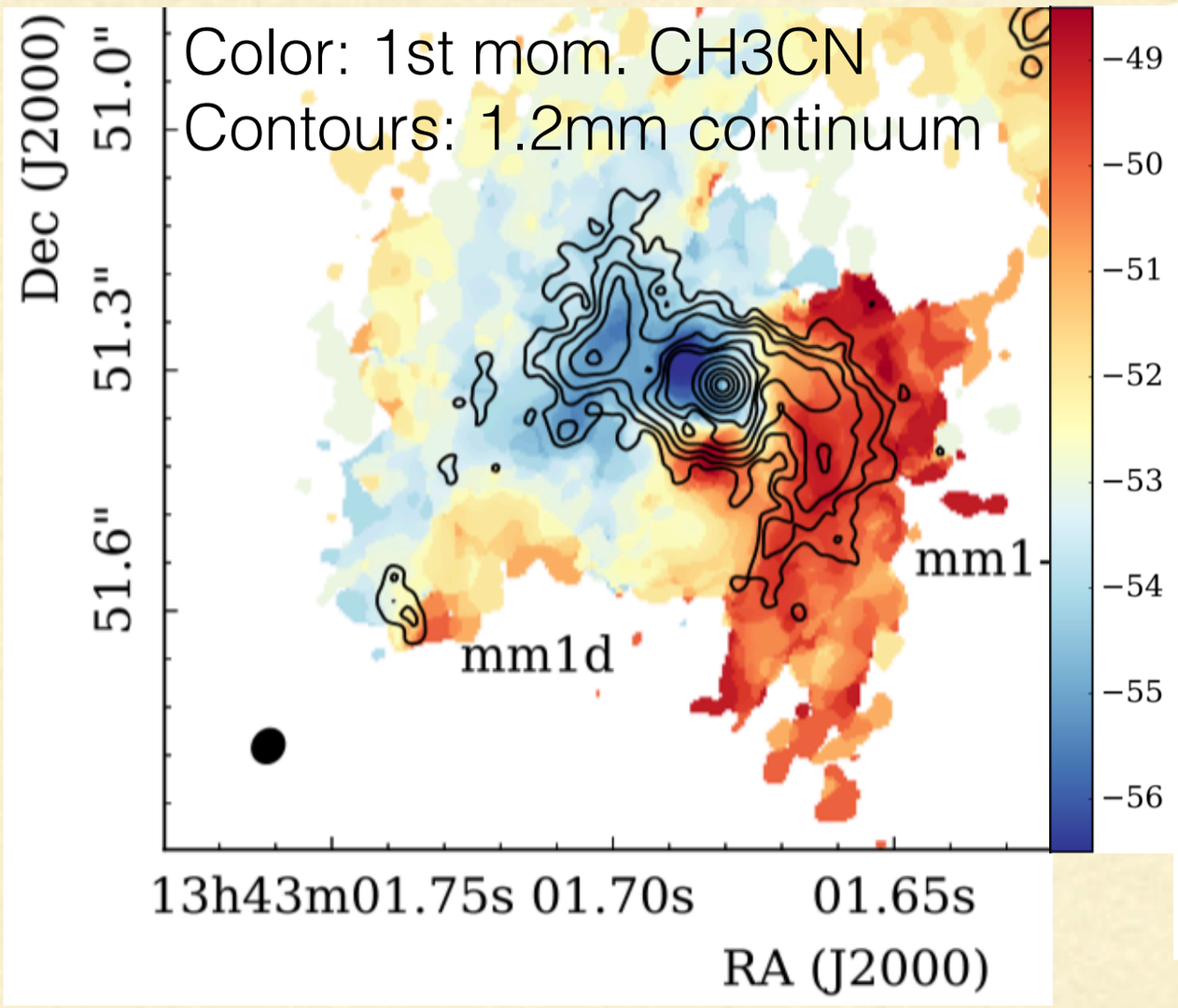
Massive disk sub-structures I

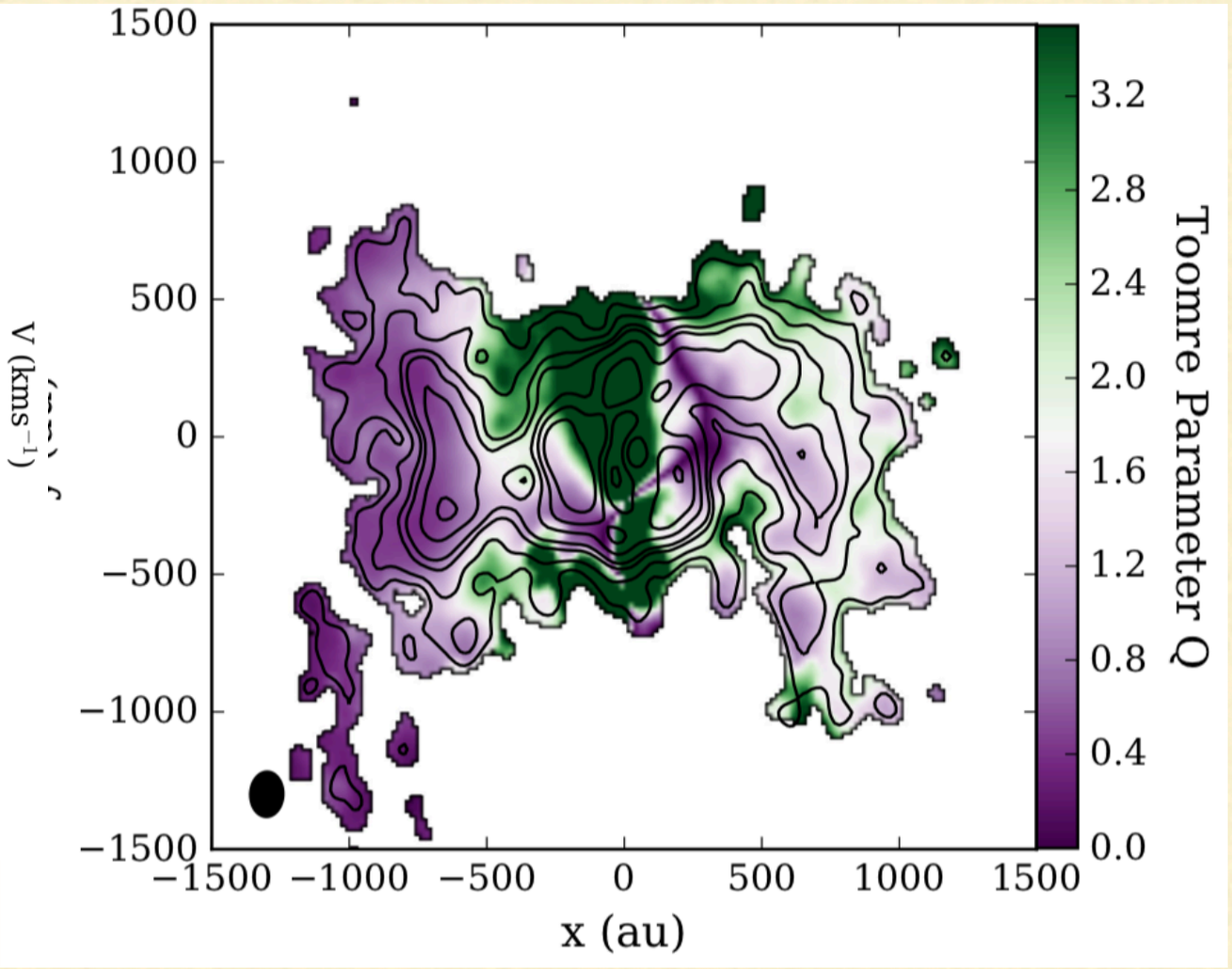


30mas ~ 130AU

Johnston et al. 2020

Massive disk sub-structures I





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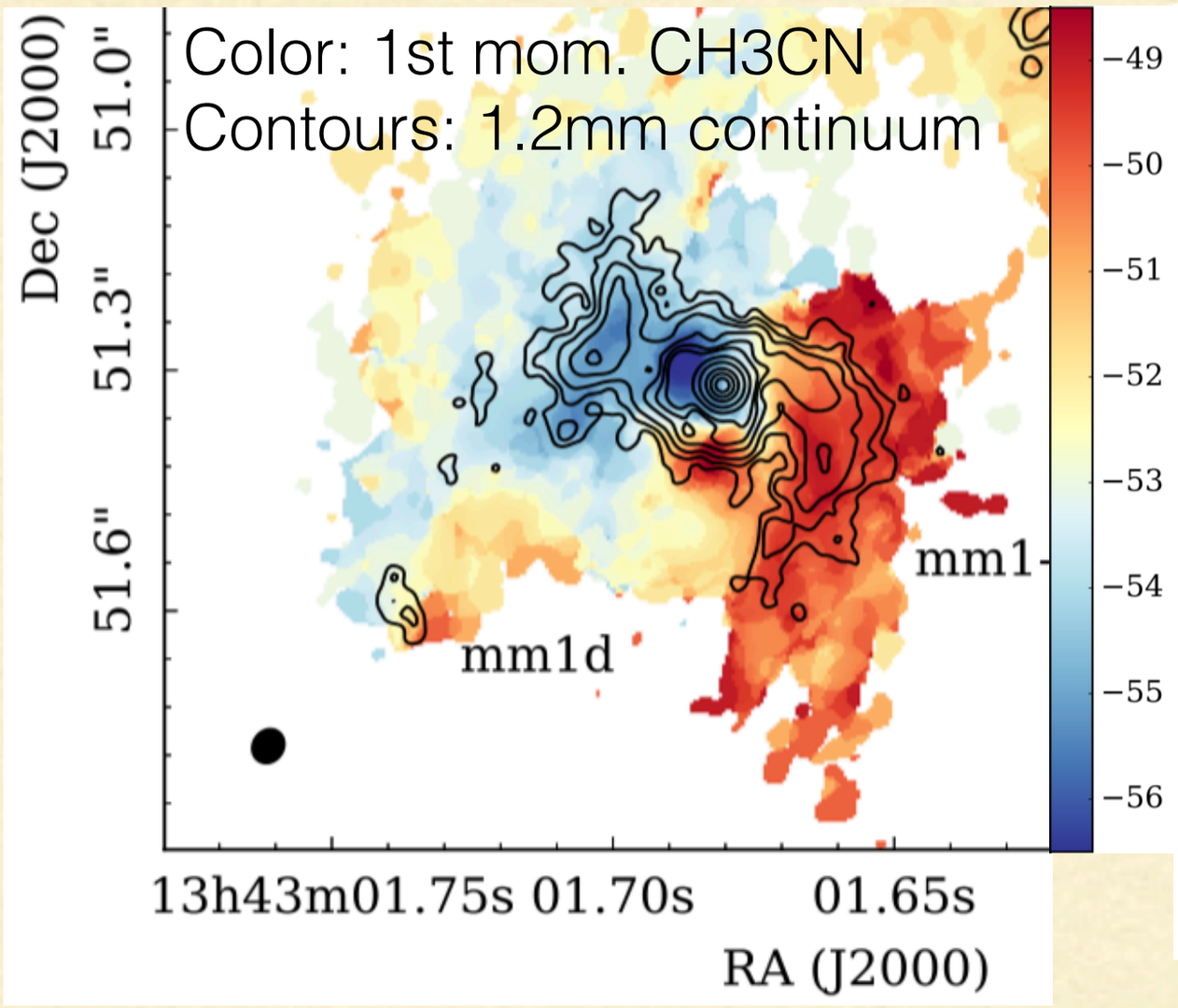
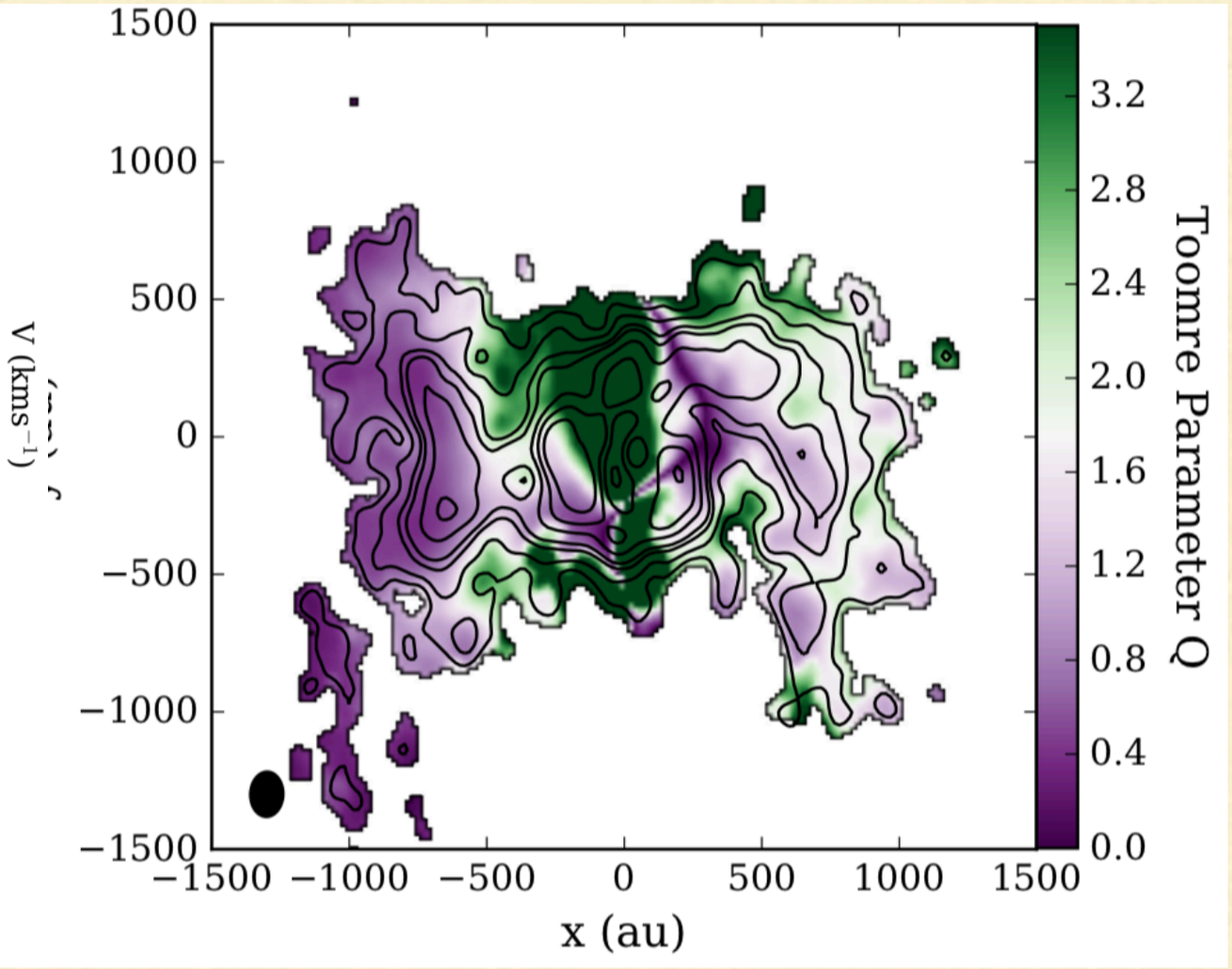




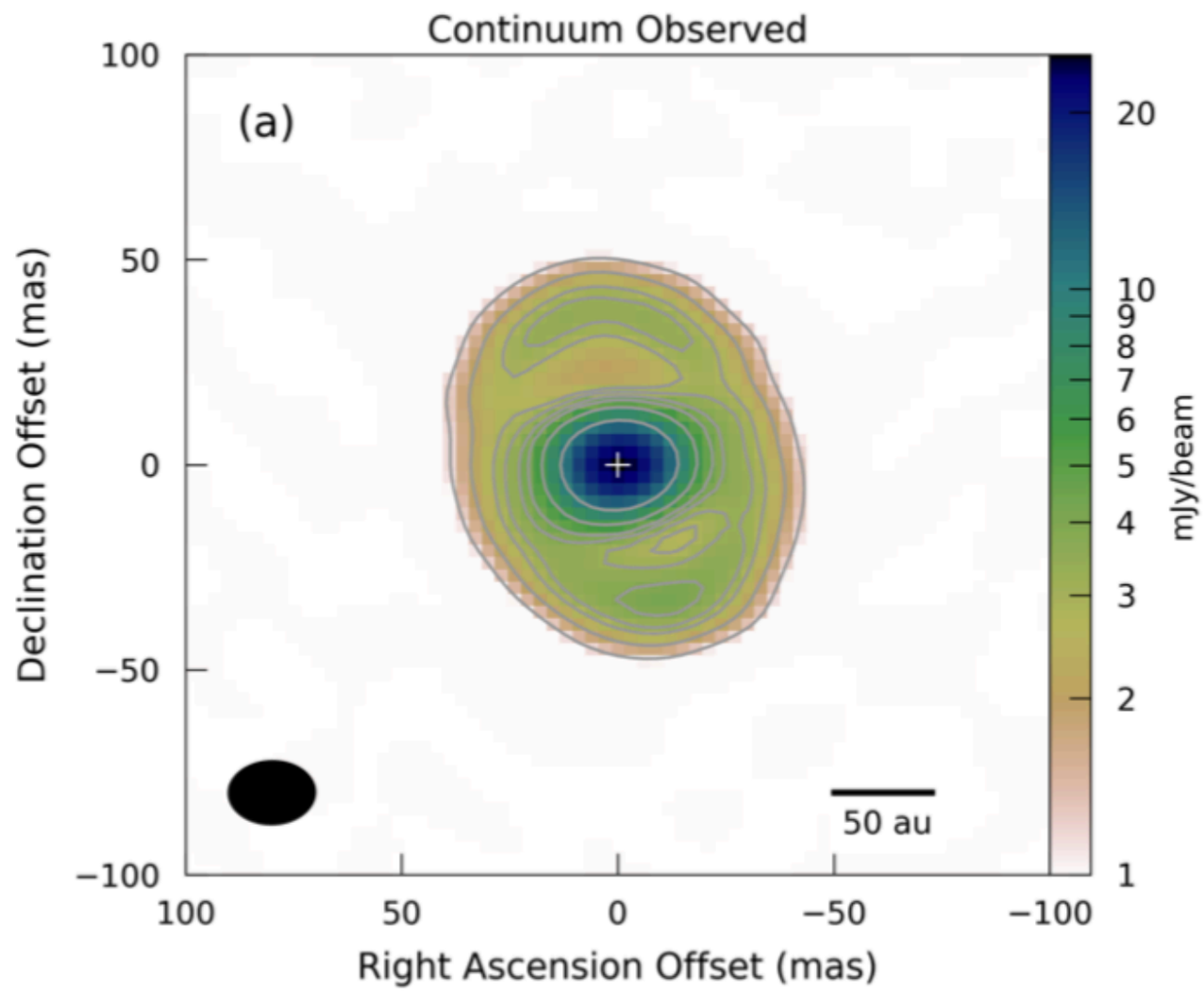
30mas ~ 130AU

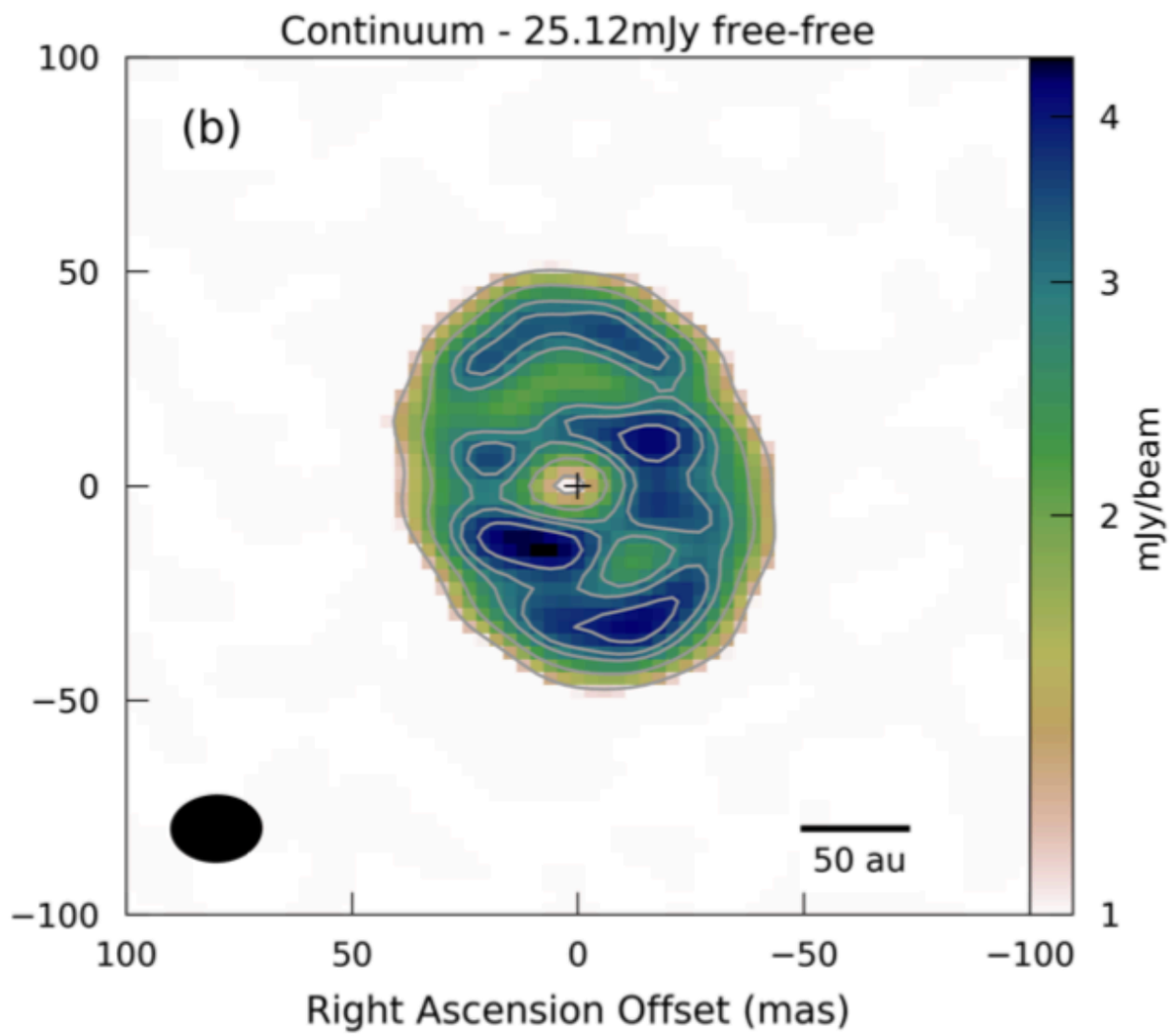
Similar spiral-like features in Sanna et al. 2021

Johnston et al. 2020

Massive disk sub-structures II

G17.64: 20x15mas —> 44x33AU

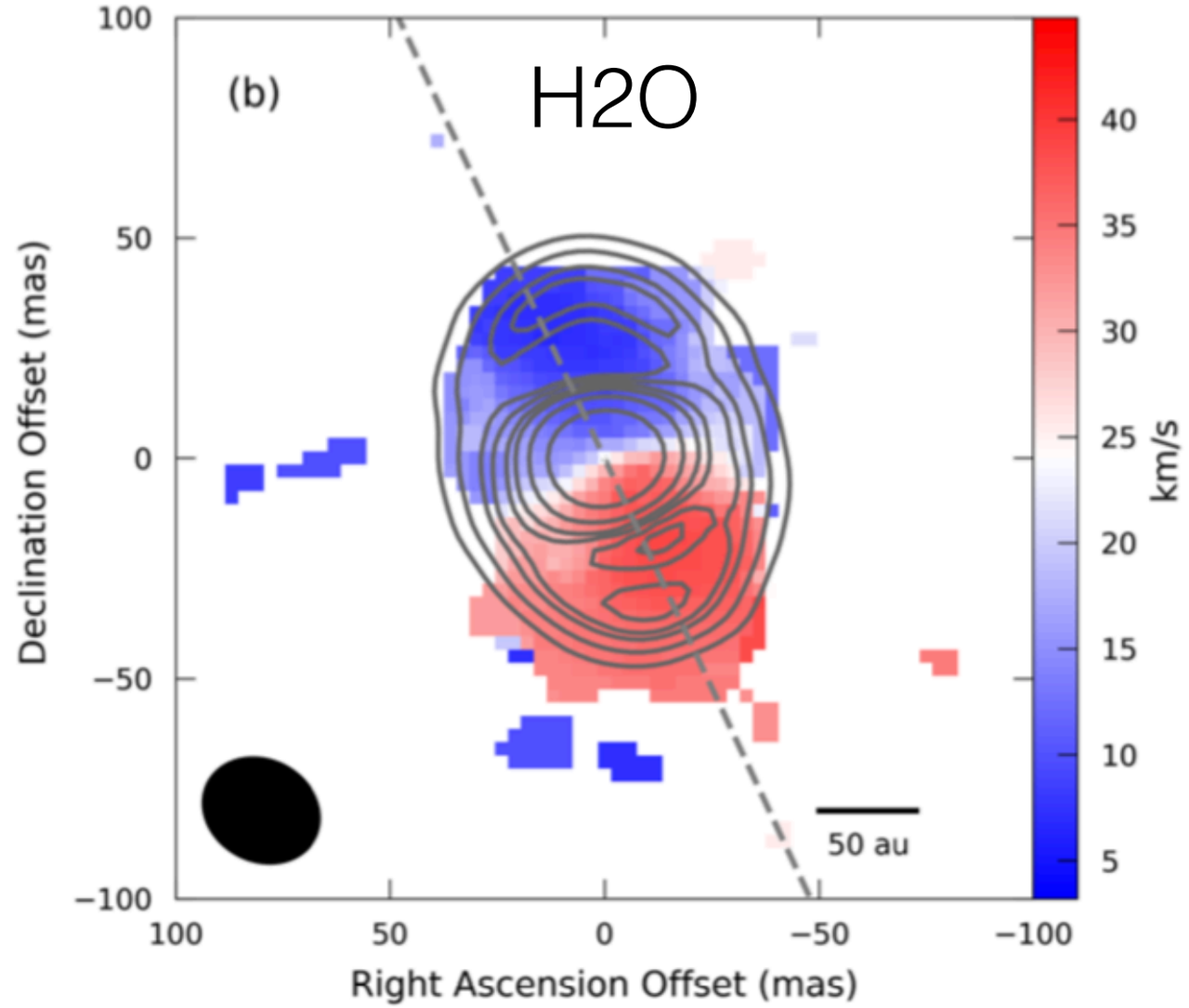


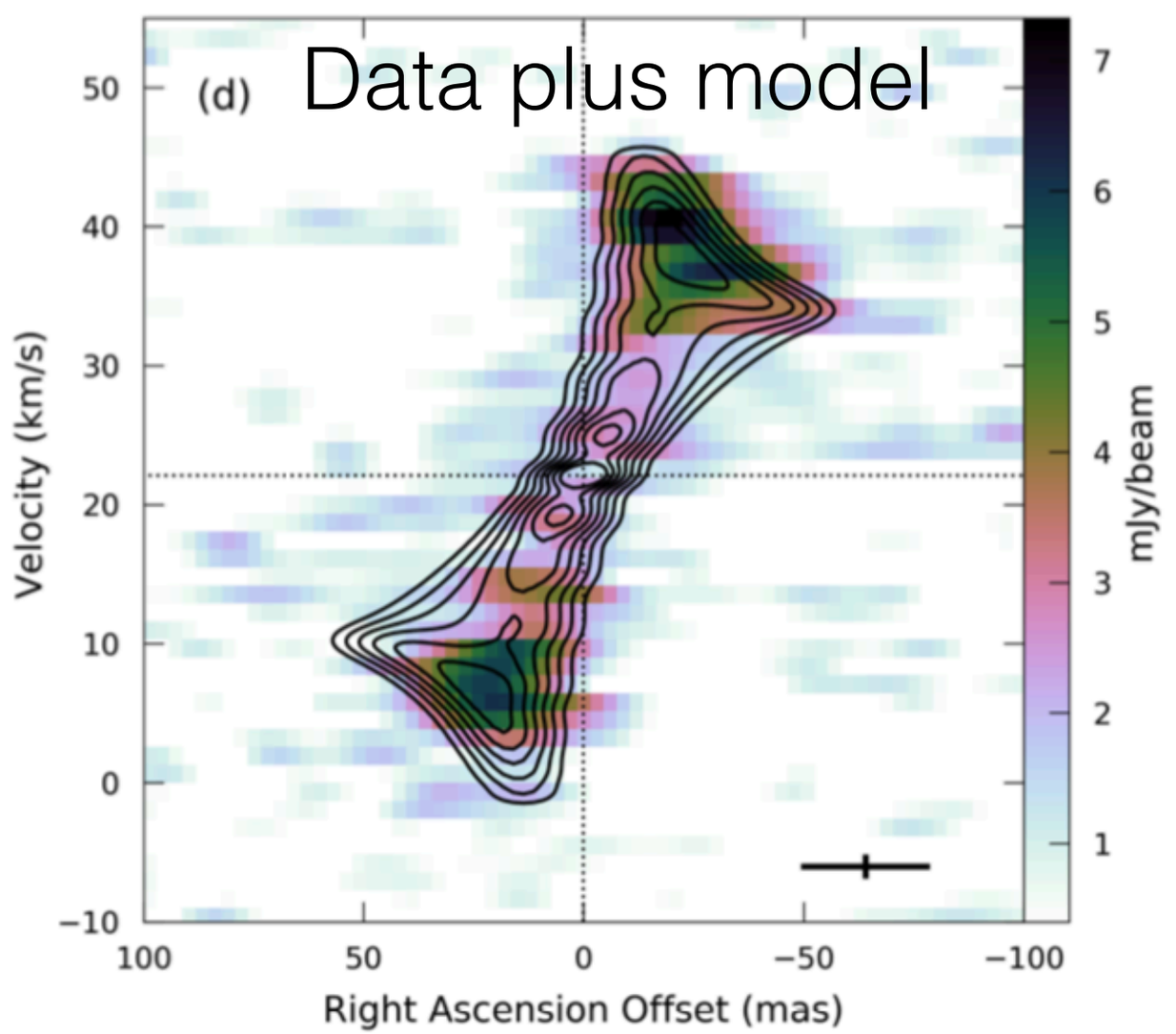


Maud et al. 2019

Massive disk sub-structures II

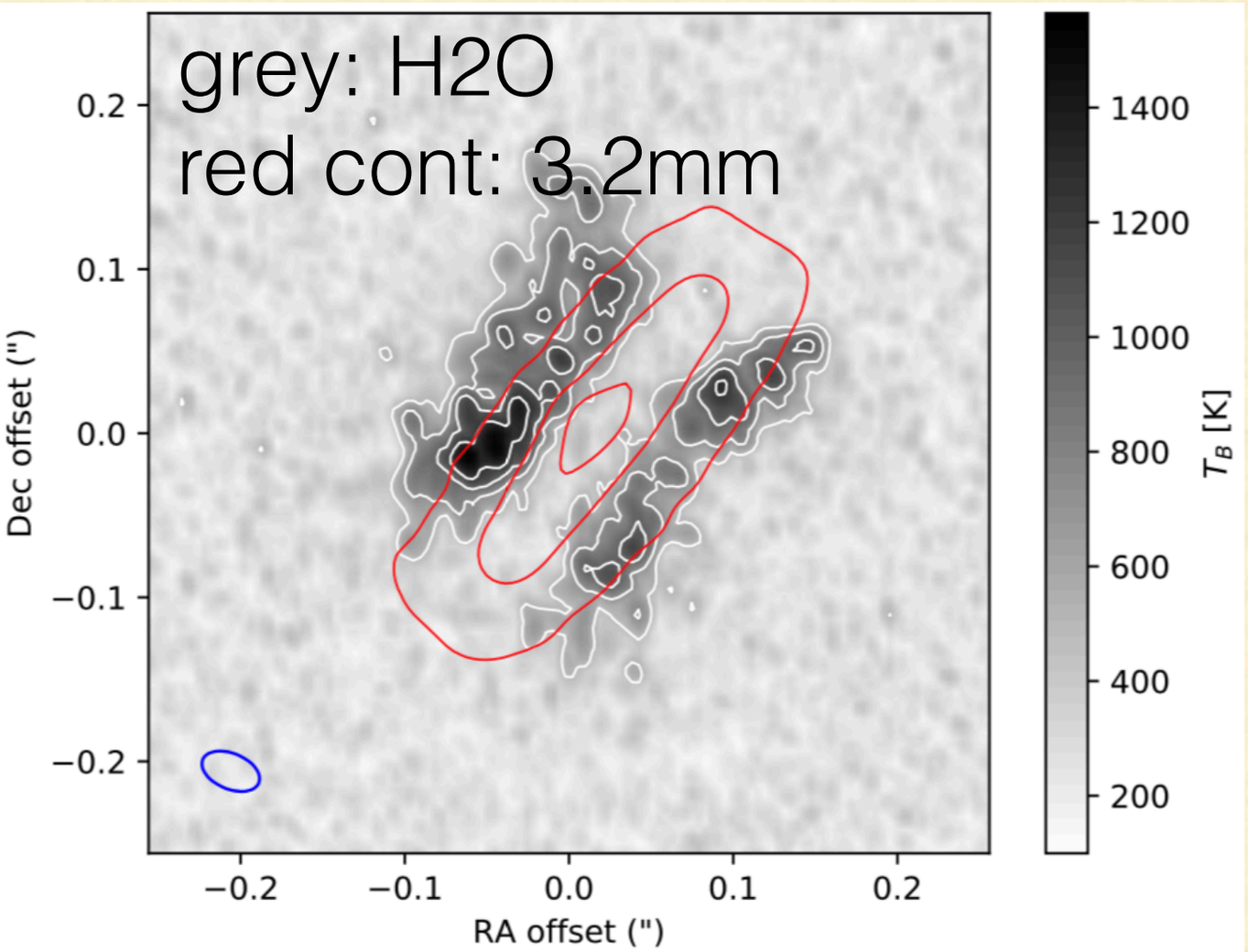
G17.64: 20x15mas —> 44x33AU

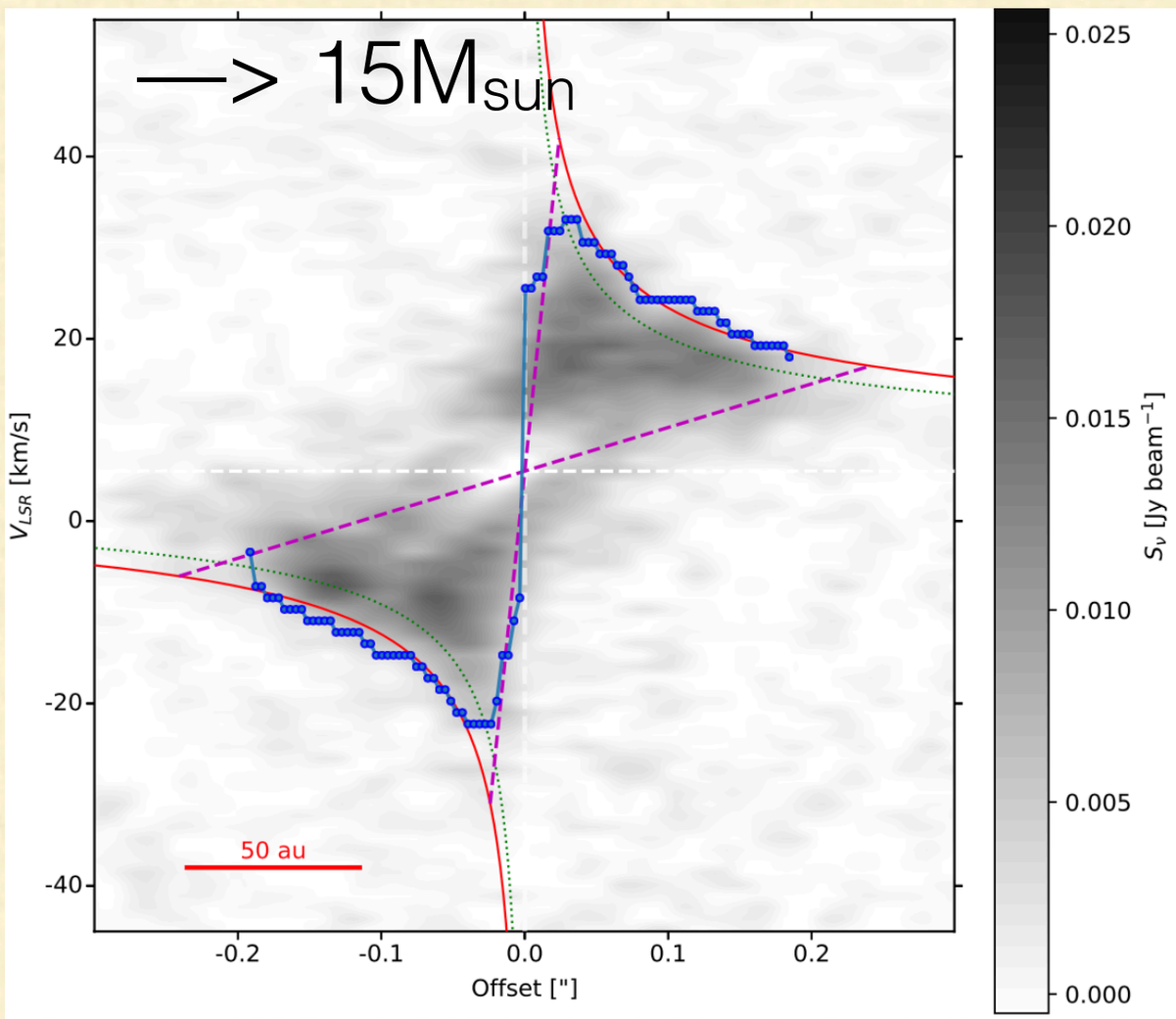




Maud et al. 2019

The disk in Orion source I

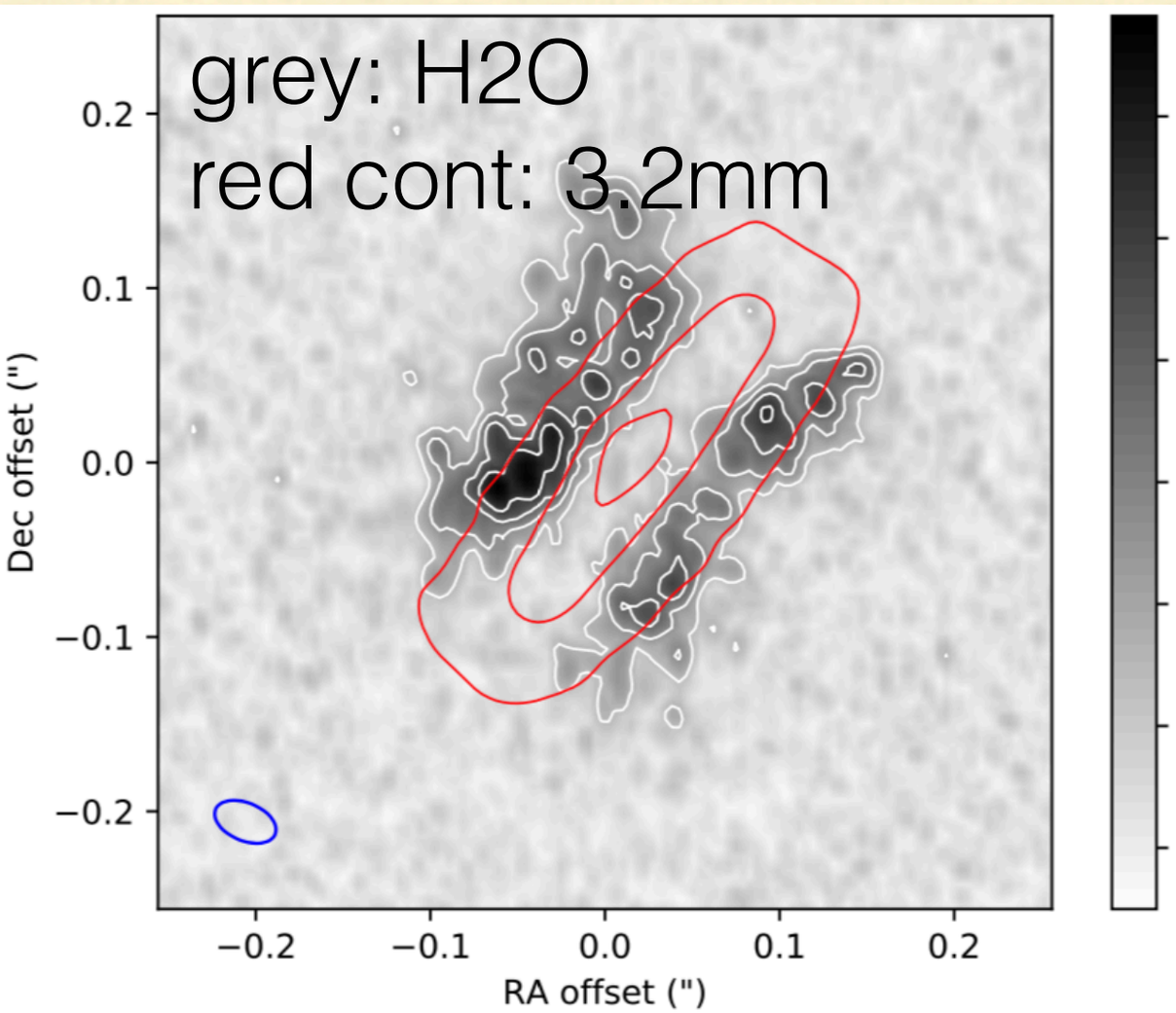


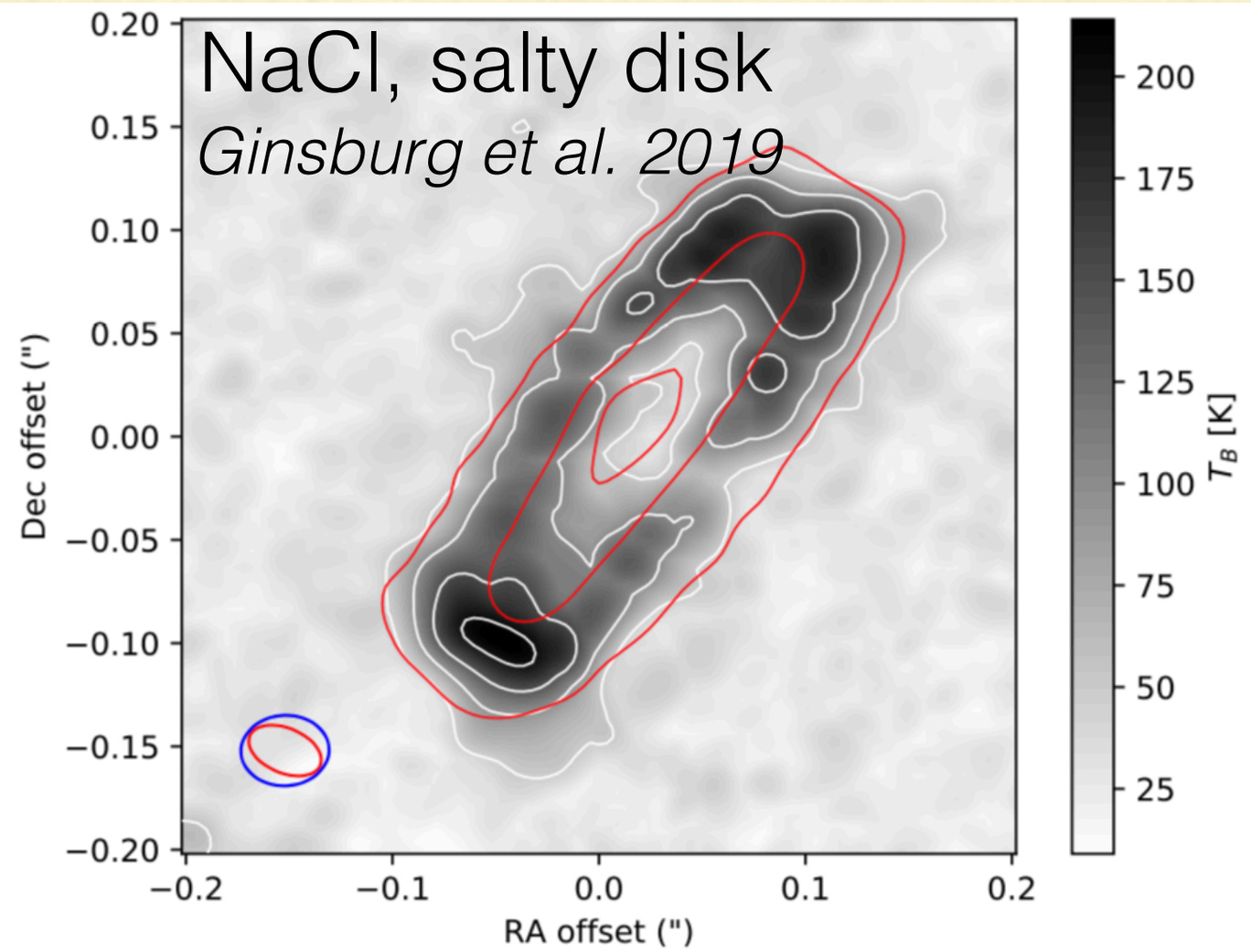


30mas —> 12AU

Ginsburg et al. 2018

The disk in Orion source I



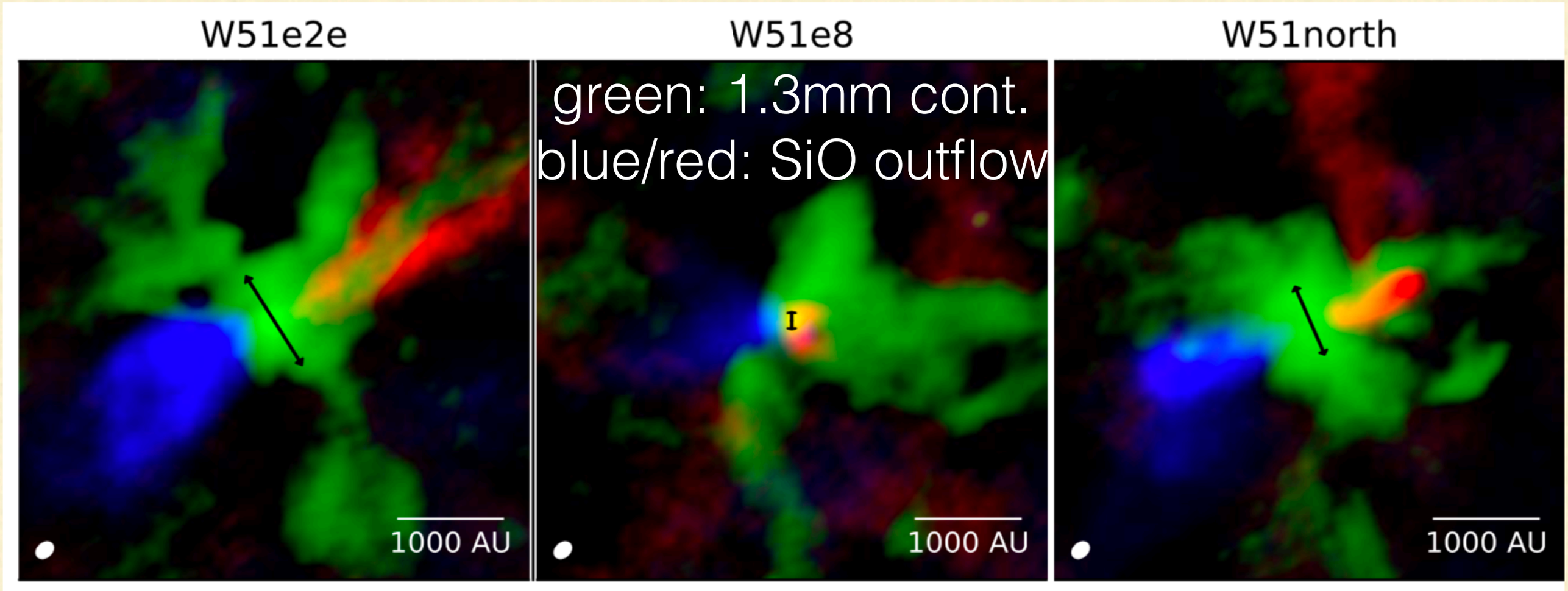


30mas —> 12AU

Ginsburg et al. 2018

No clear disk in W51e

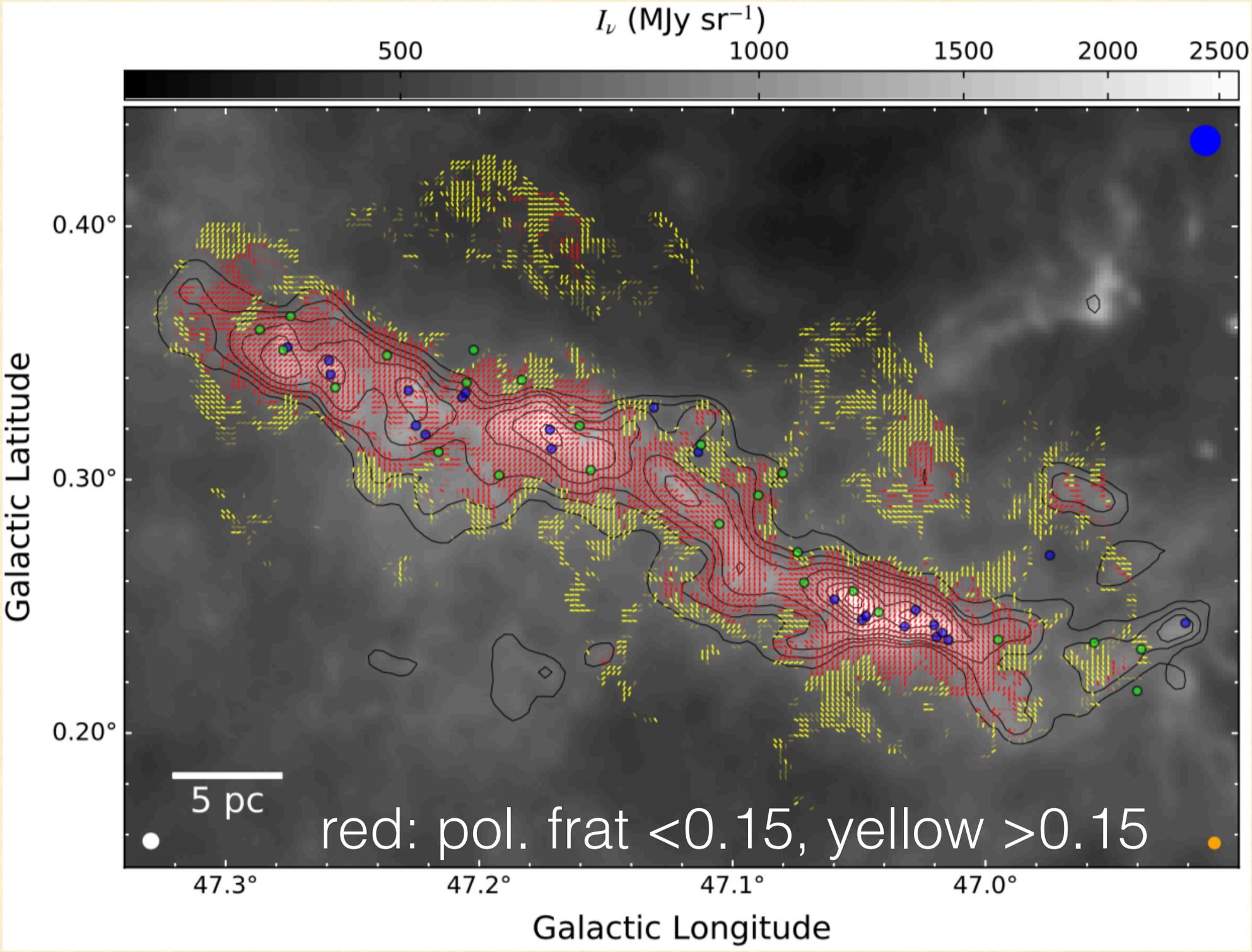
20mas@5.4kpc~100AU resolution



- No disk identified at resolution limit.
- Existence of outflows indicate disks at smaller scales
- Accretion streamer feeding the central region.

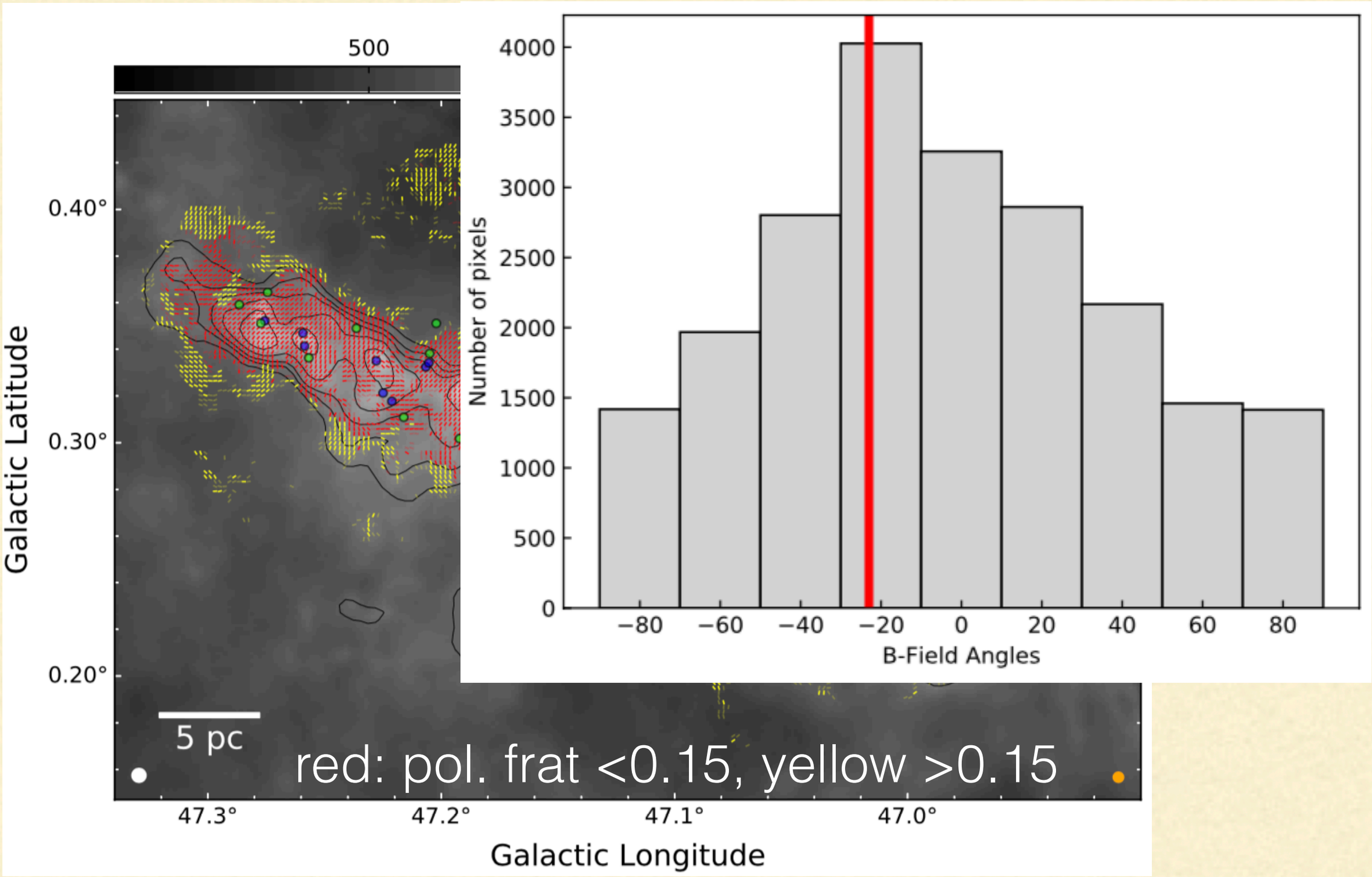
Goddi et al. 2020

Large-Scale magnetic field in dense gas



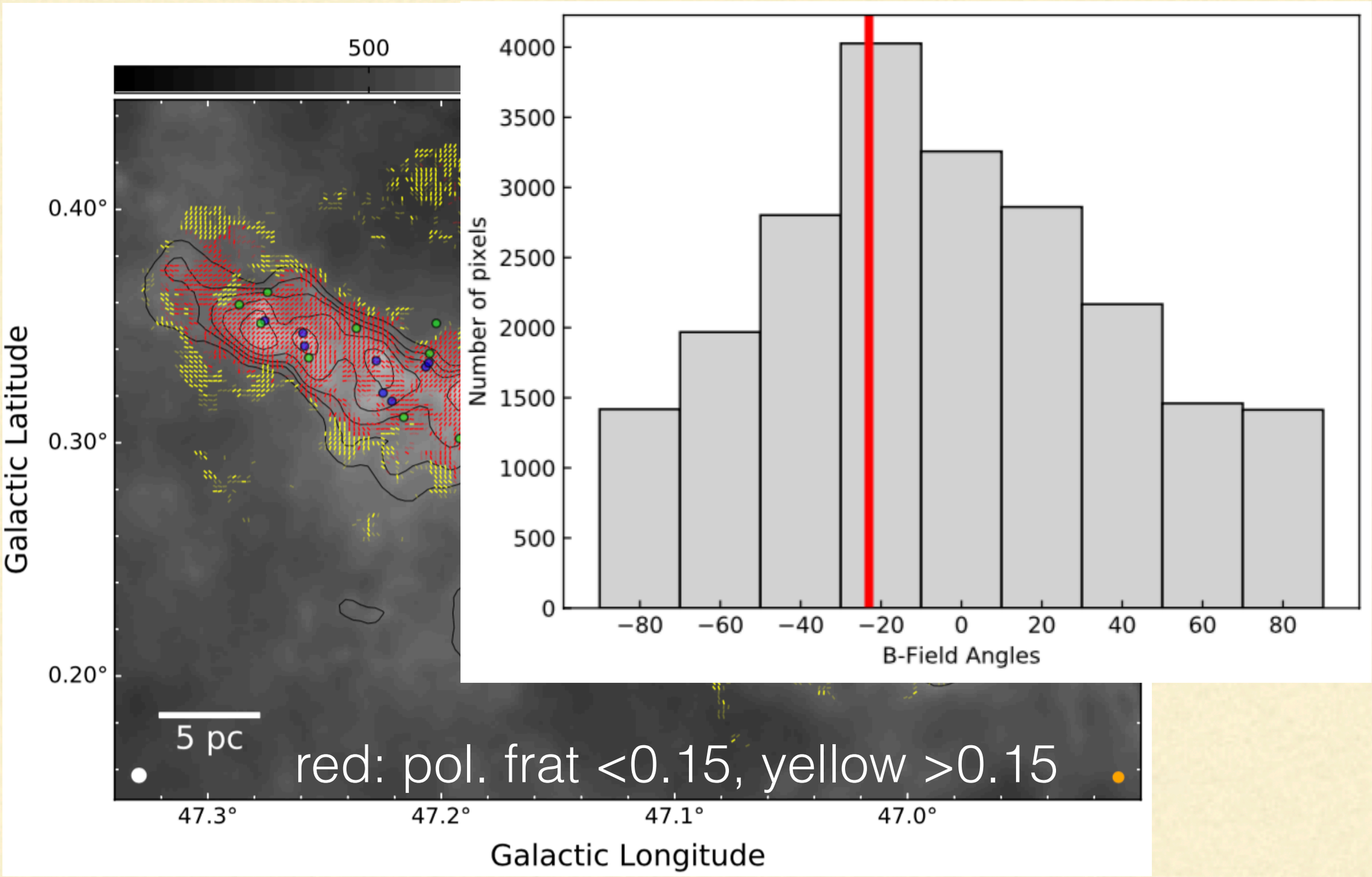
Stephens et al. 2020

Large-Scale magnetic field in dense gas



Stephens et al. 2020

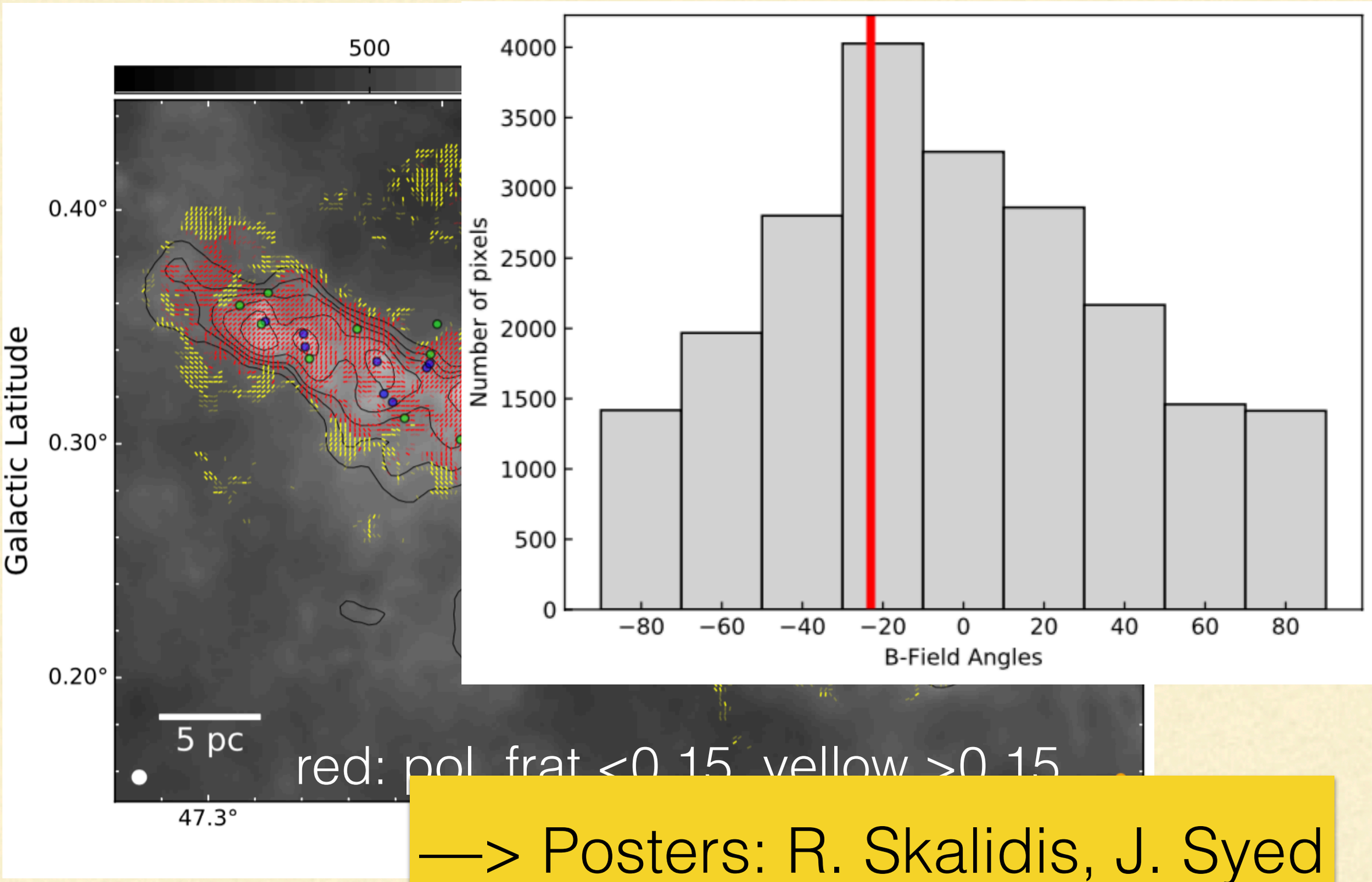
Large-Scale magnetic field in dense gas



See also Pillai et al. 2020

Stephens et al. 2020

Large-Scale magnetic field in dense gas

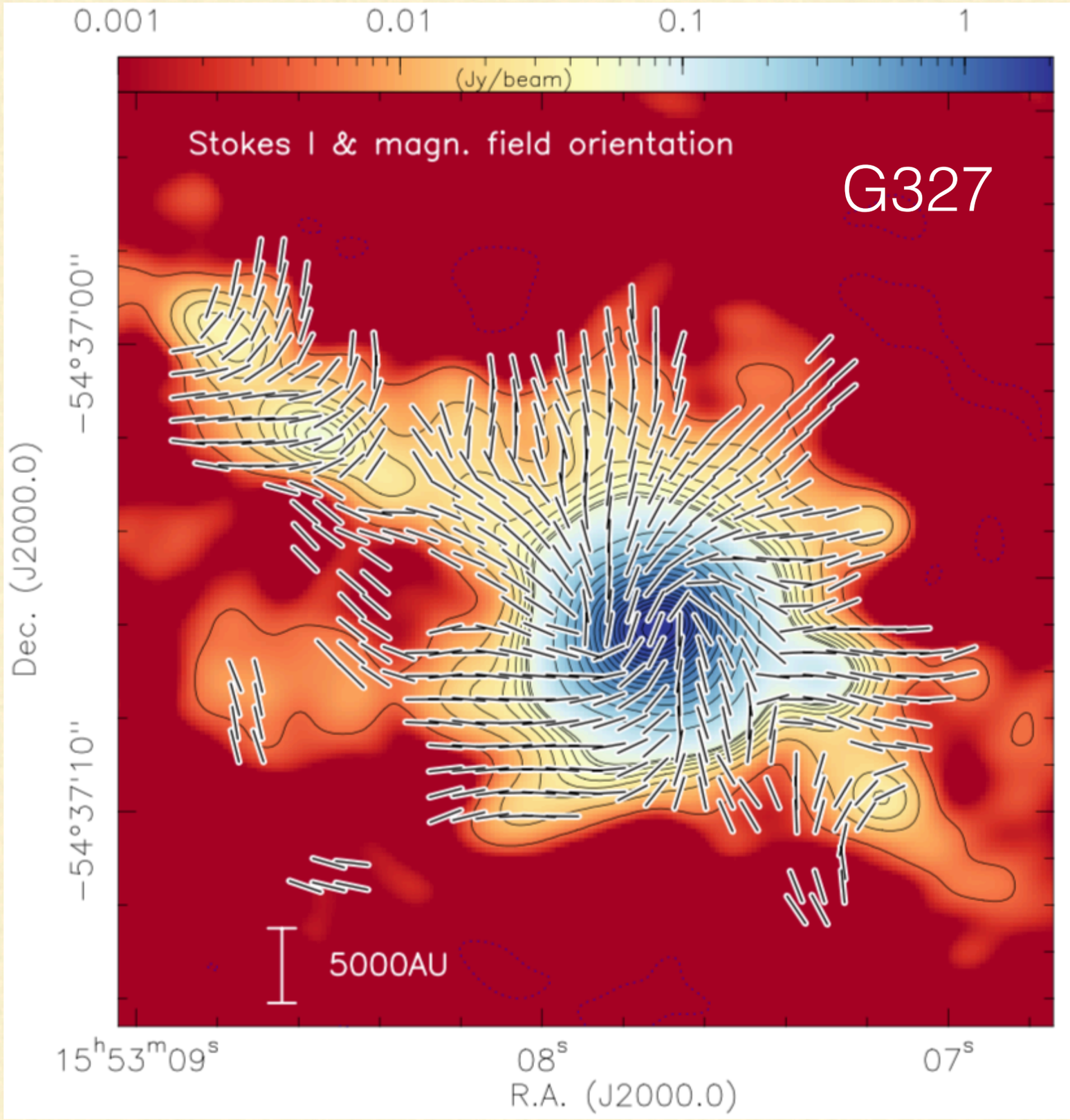


—> Posters: R. Skalidis, J. Syed

See also Pillai et al. 2020

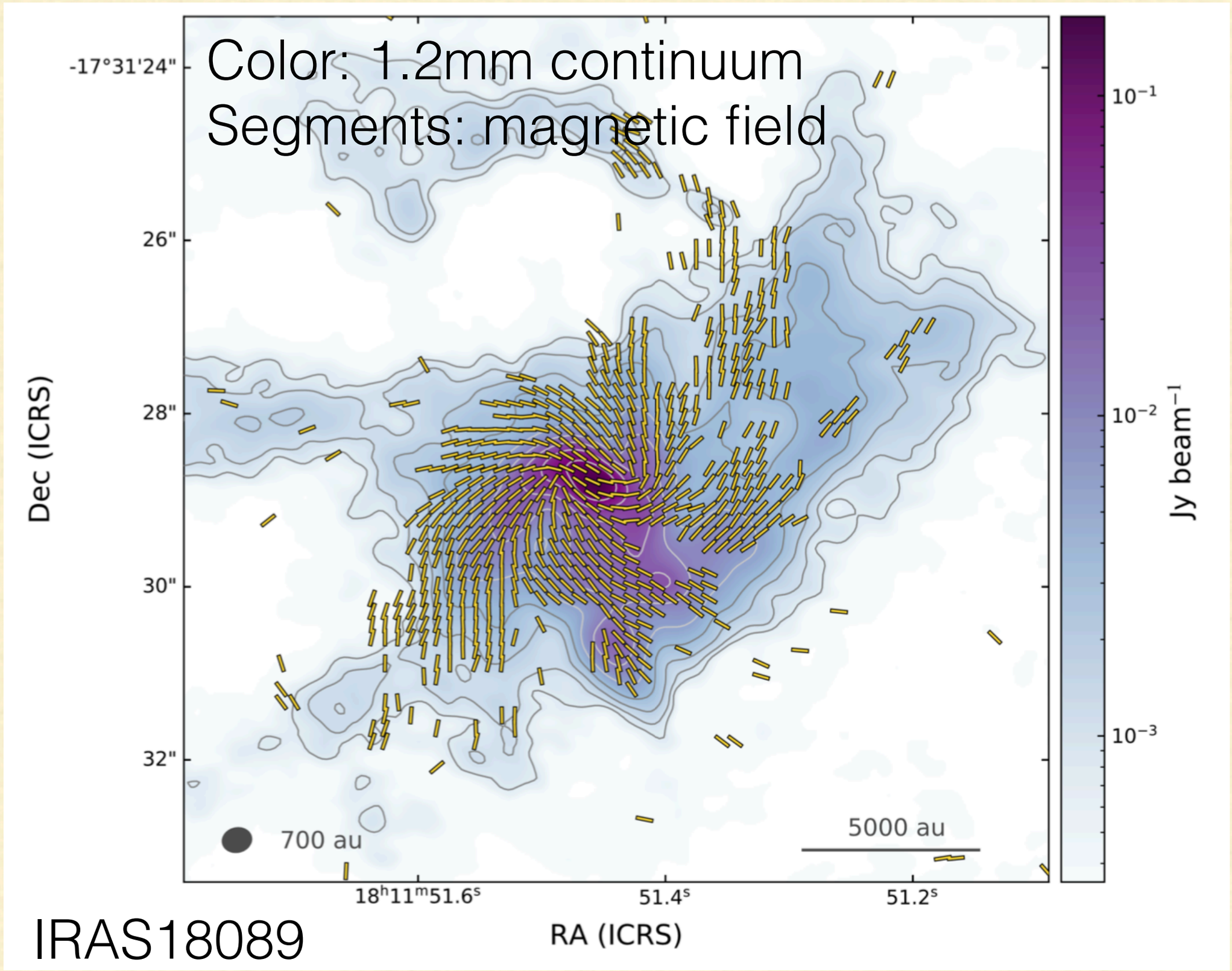
Stephens et al. 2020

Gravity, rotation and magnetic field



Beuther et al. 2020

Gravity-dominated magnetic field



IRAS18089

Sanhueza et al. 2021

Summary

- Dynamics important on all scales.

- Future focus likely:

    - Infall on all scales, connections of scales

    - Fragmentation and the formation of the IMF

    - Disks at highest angular resolution

    - Chemical evolution, also JWST

    - Magnetic fields

    - Episodic accretion