

# Disk structures and associated outflows in high-mass star formation

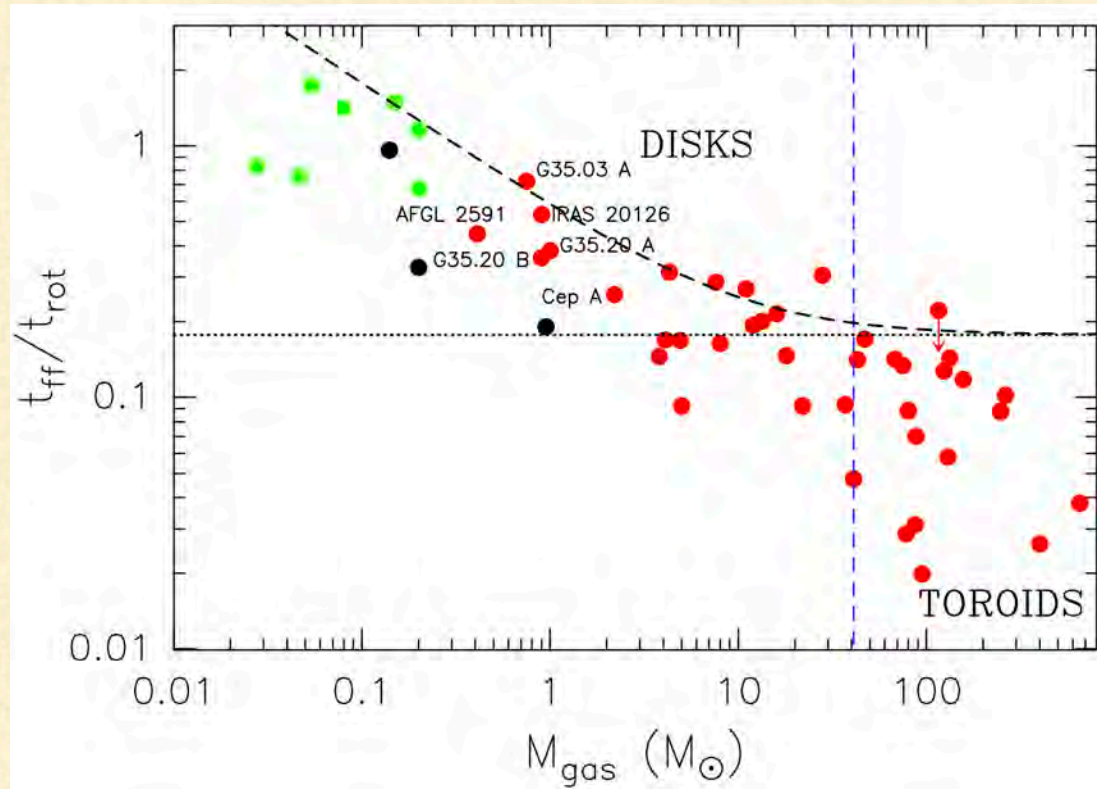
Henrik Beuther, MPIA

**Tracing the flow**, Lake Windermere, July 5, 2018



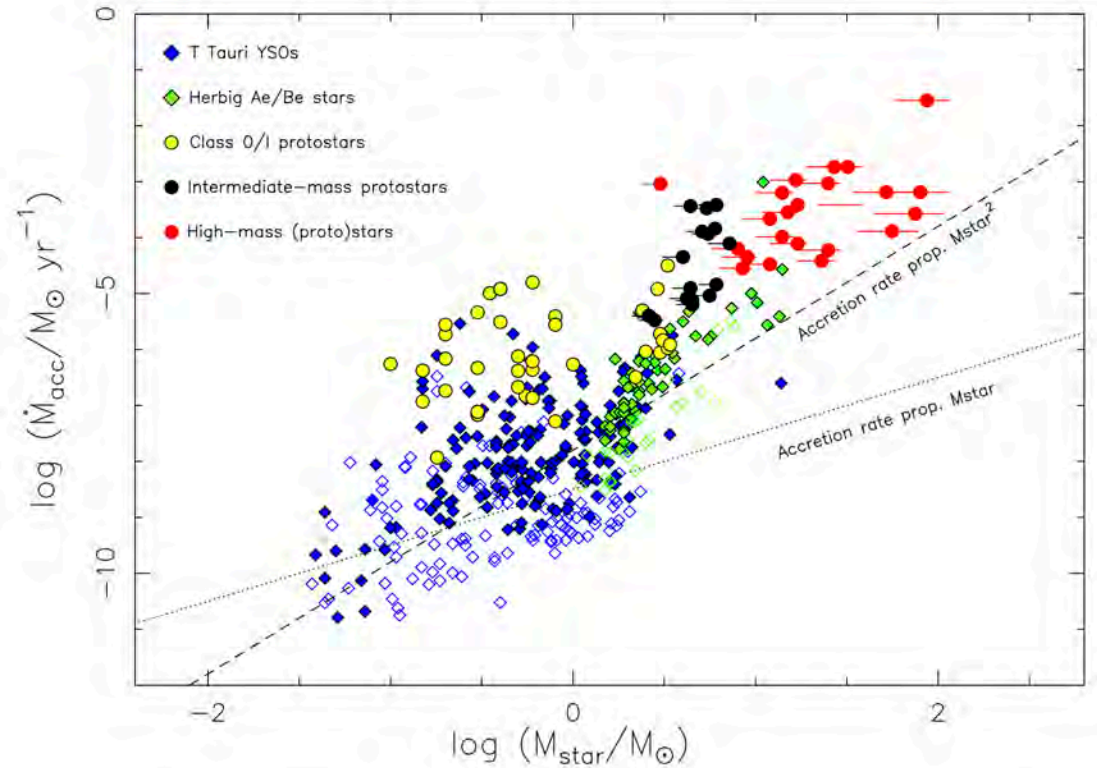
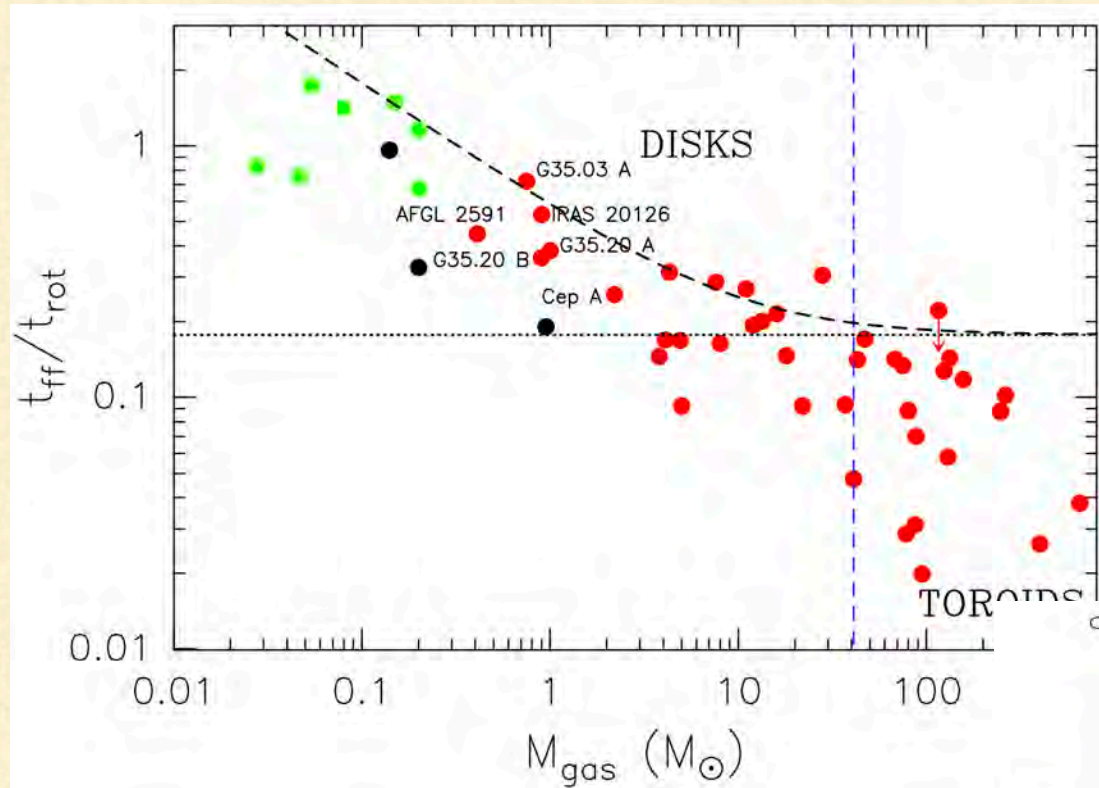


# Where were we a few years ago?





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$10^4$ - $10^3$  au

(sub)mm – cm

$10^3$ -  $10^2$  au

(sub)mm – cm

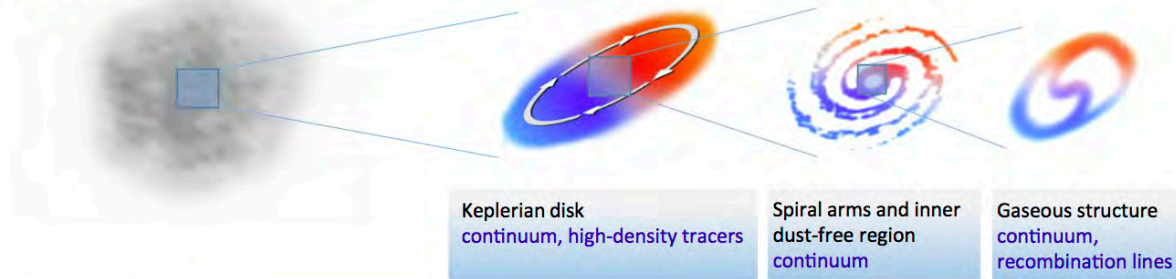
$10^2$ -10 au

NIR – MIR

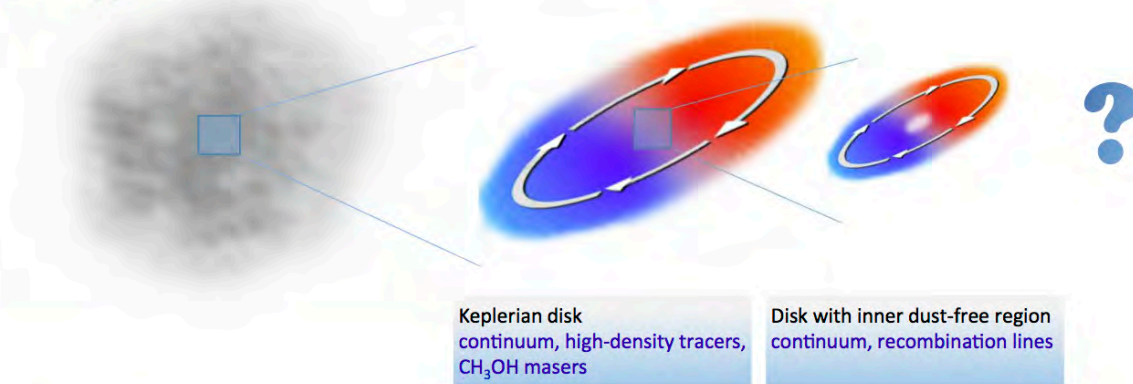
10-0.1 au

NIR – MIR

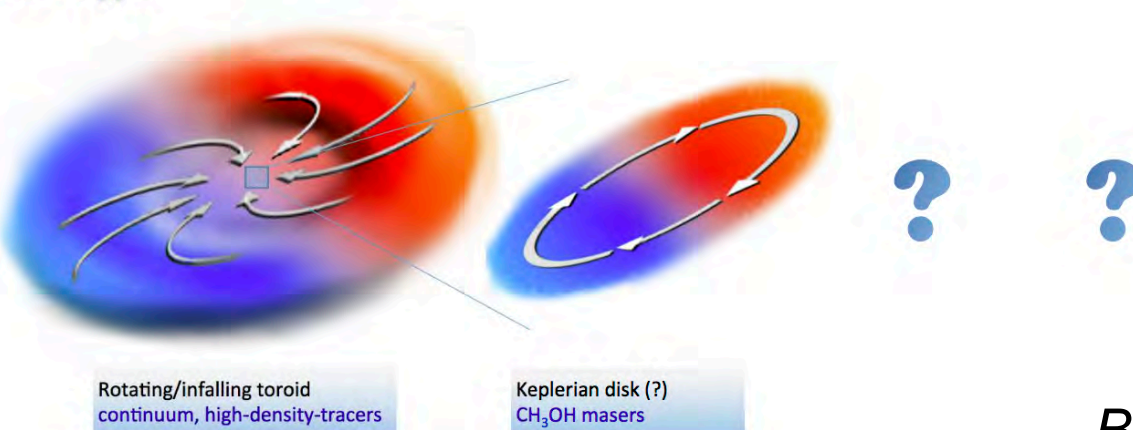
### A - type



### B - type

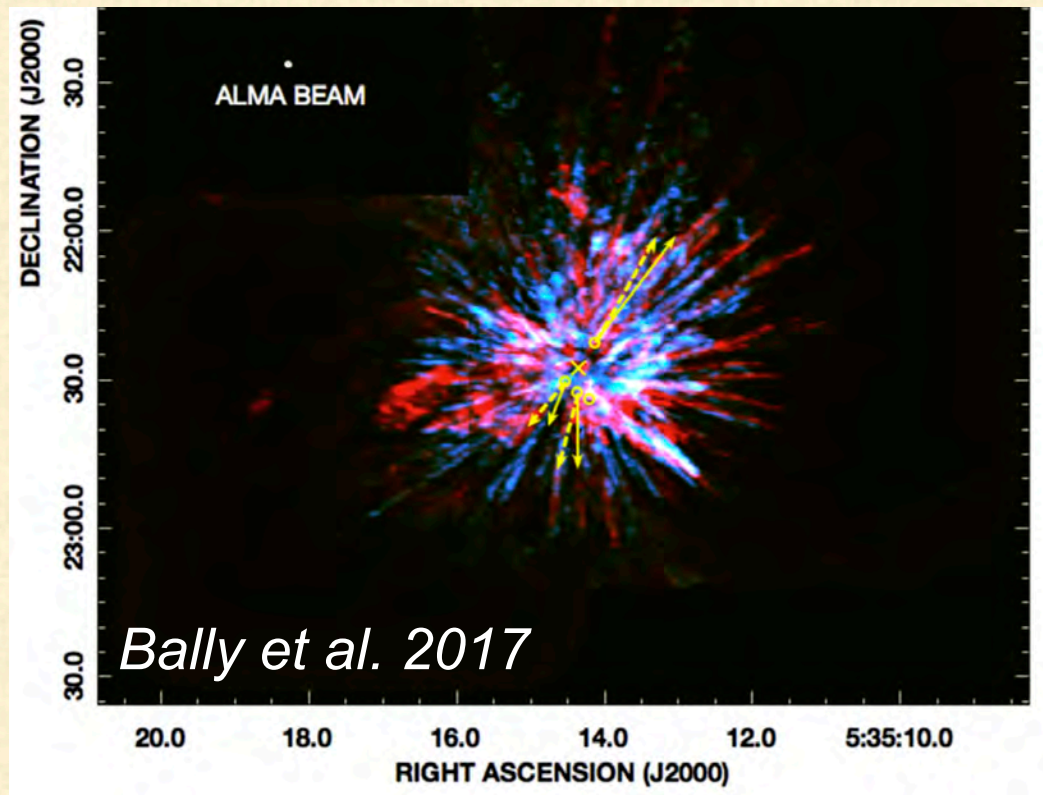


### O - type



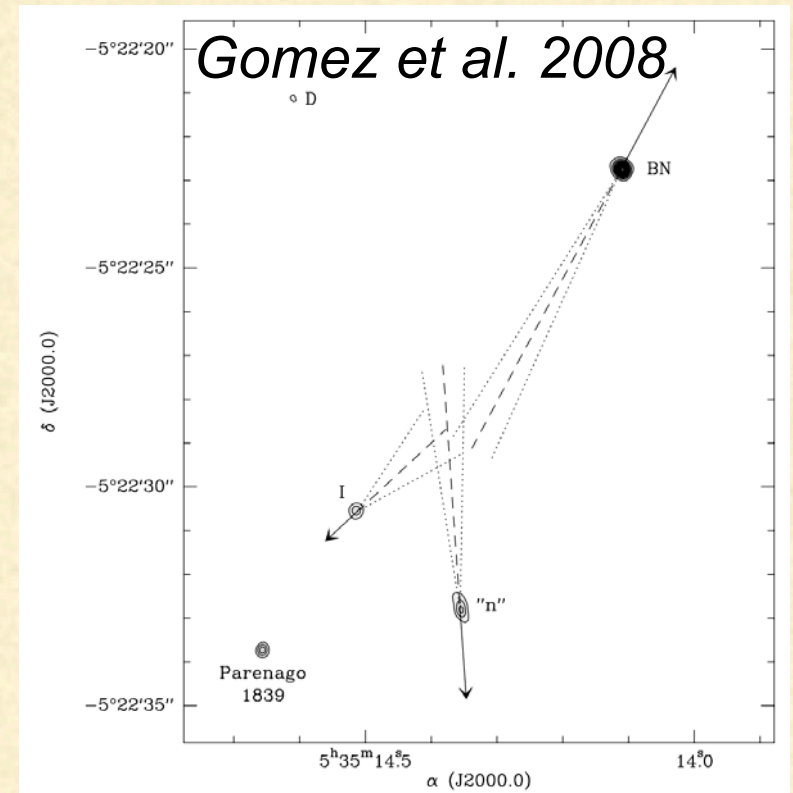
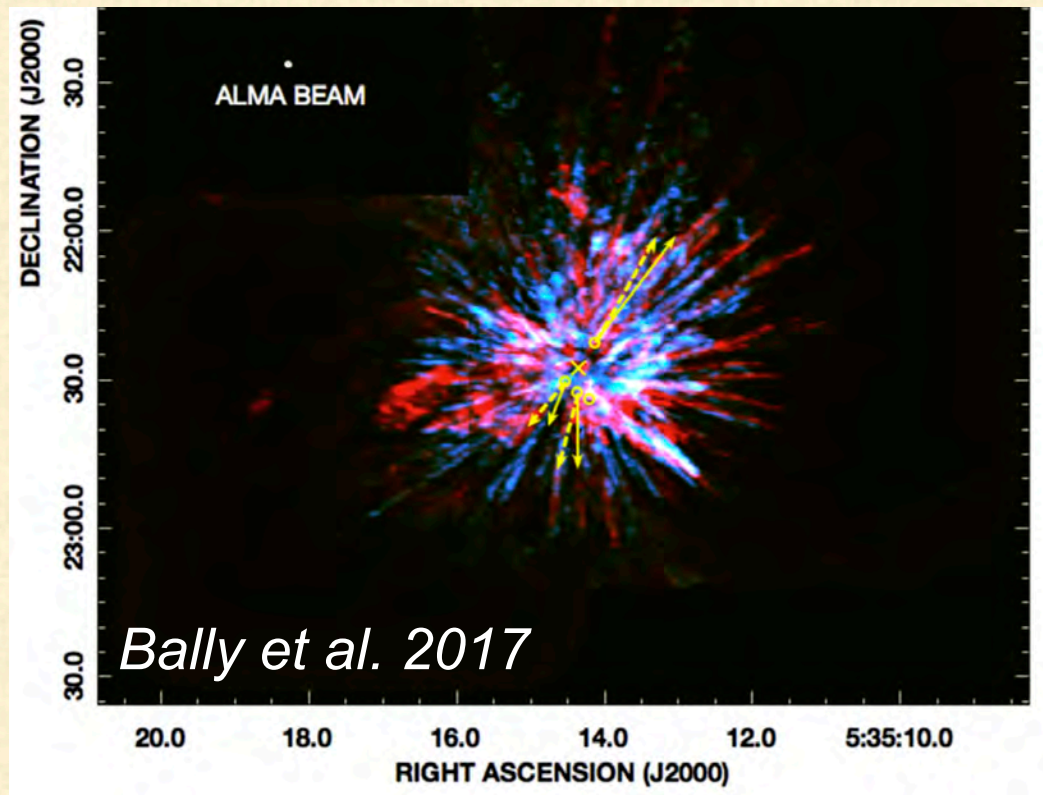


# Orion explosion and source I disk

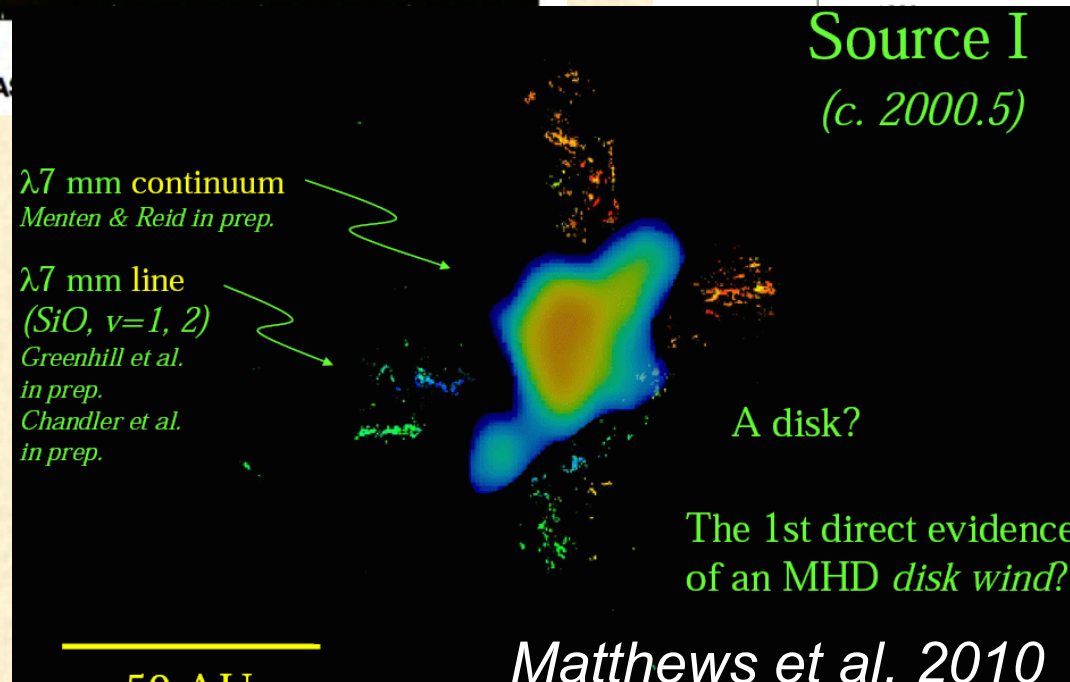
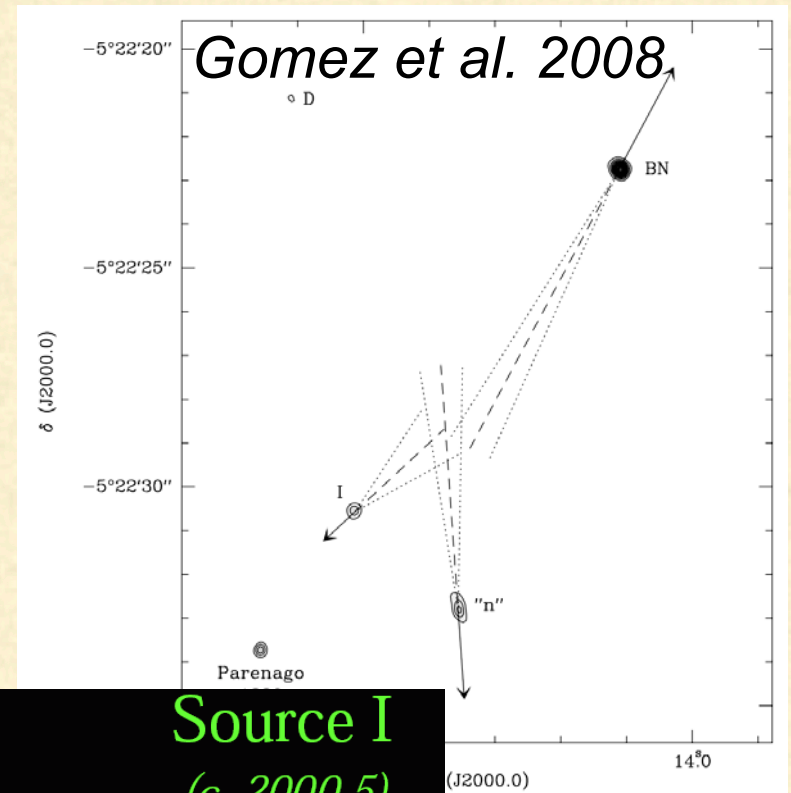
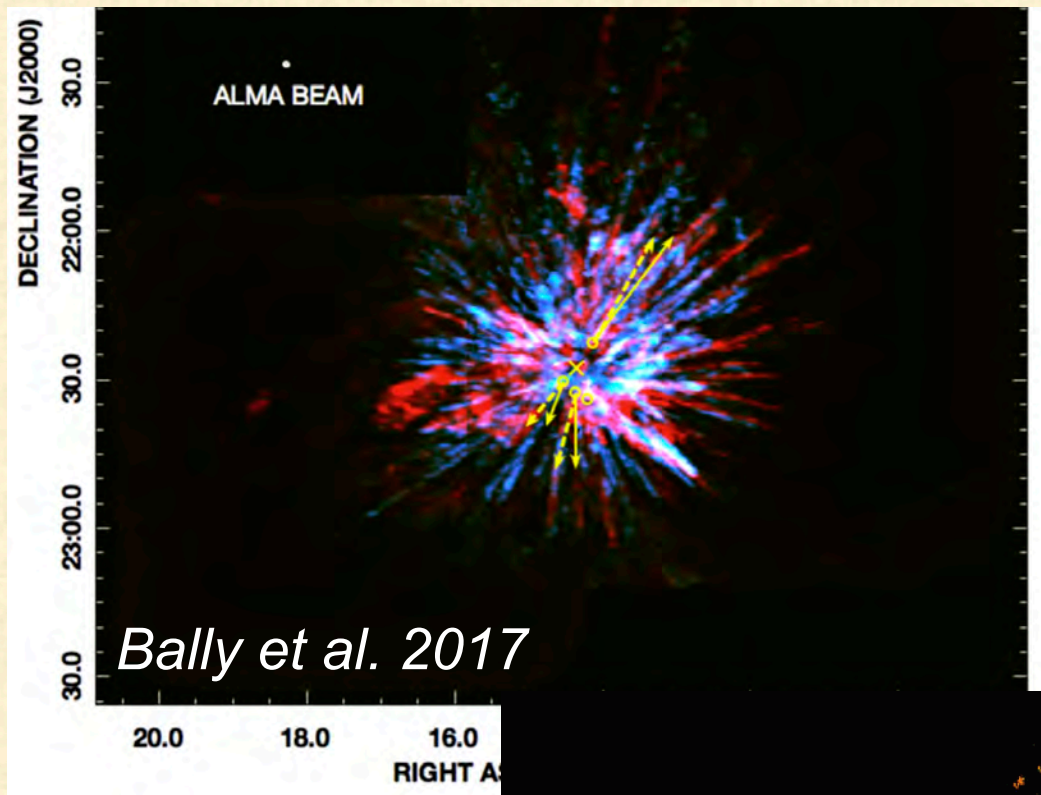




# Orion explosion and source I disk

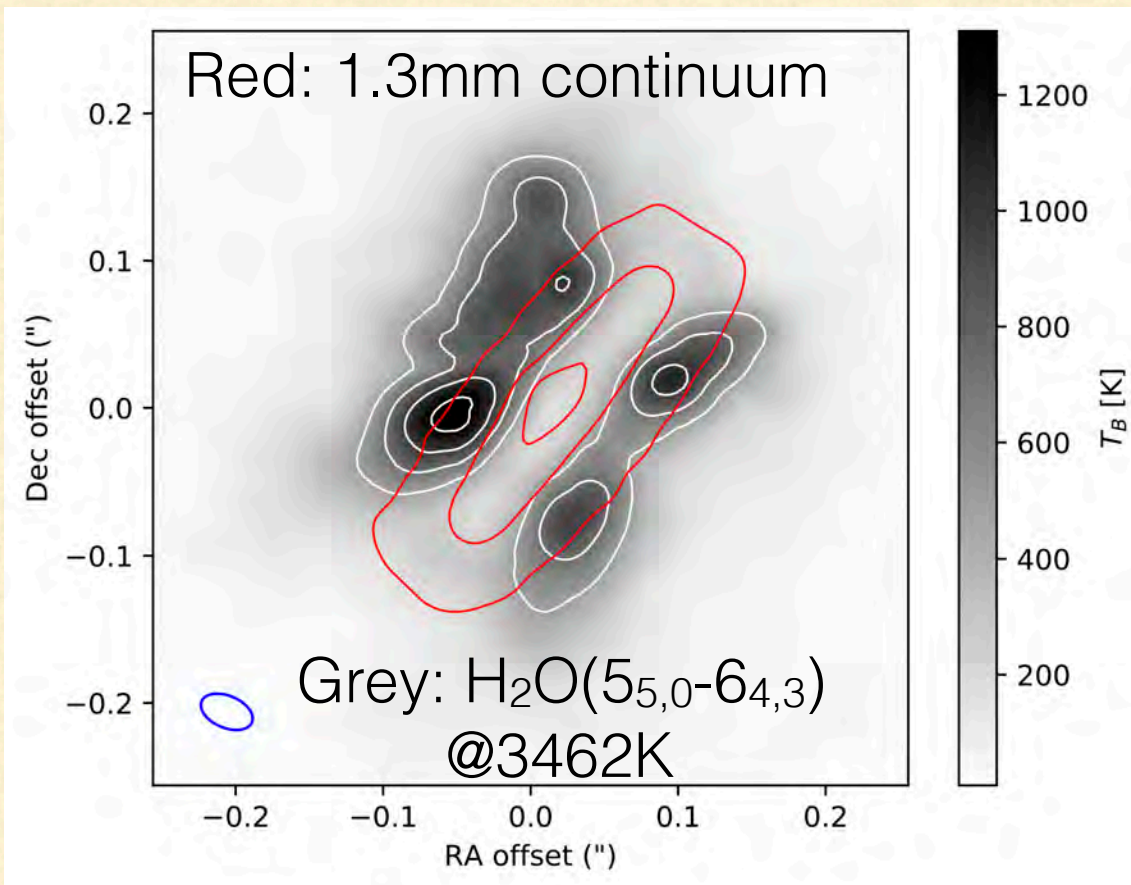


# Orion explosion and source I disk



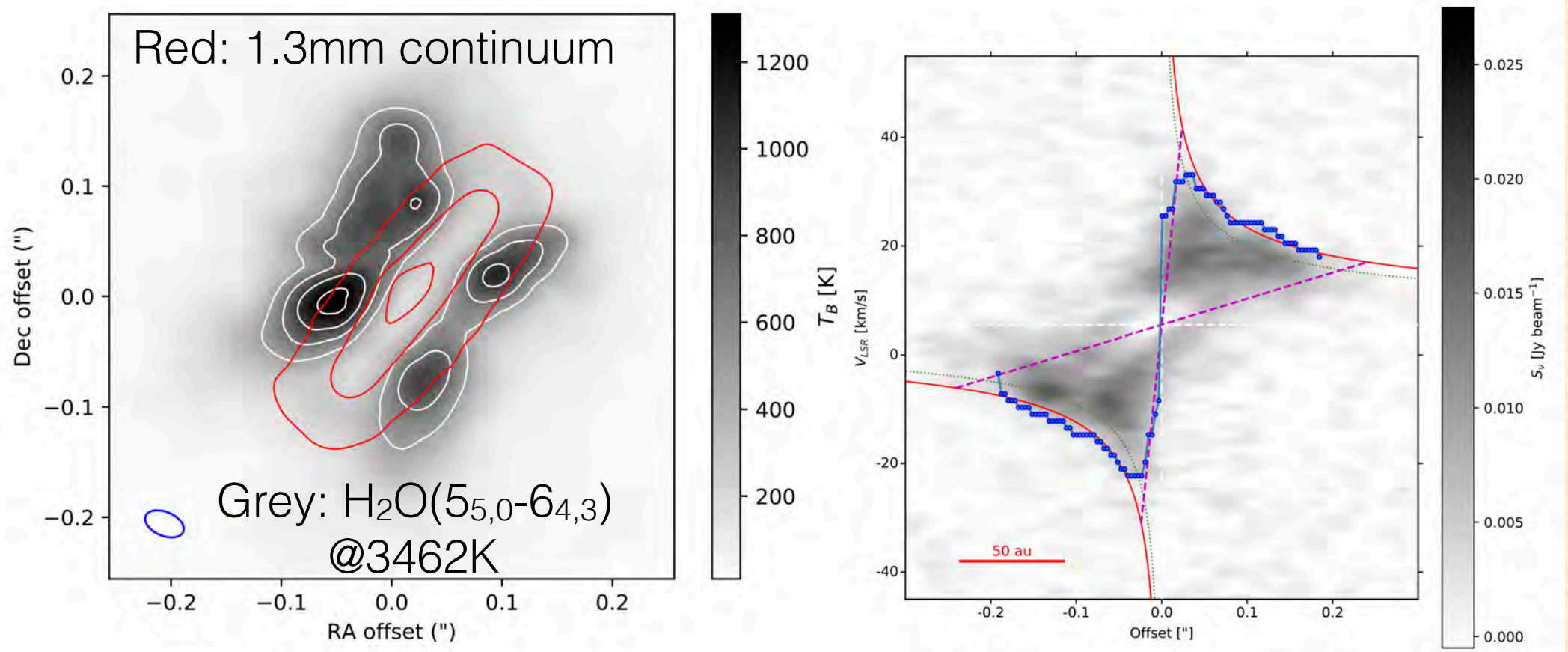


# Source I disk





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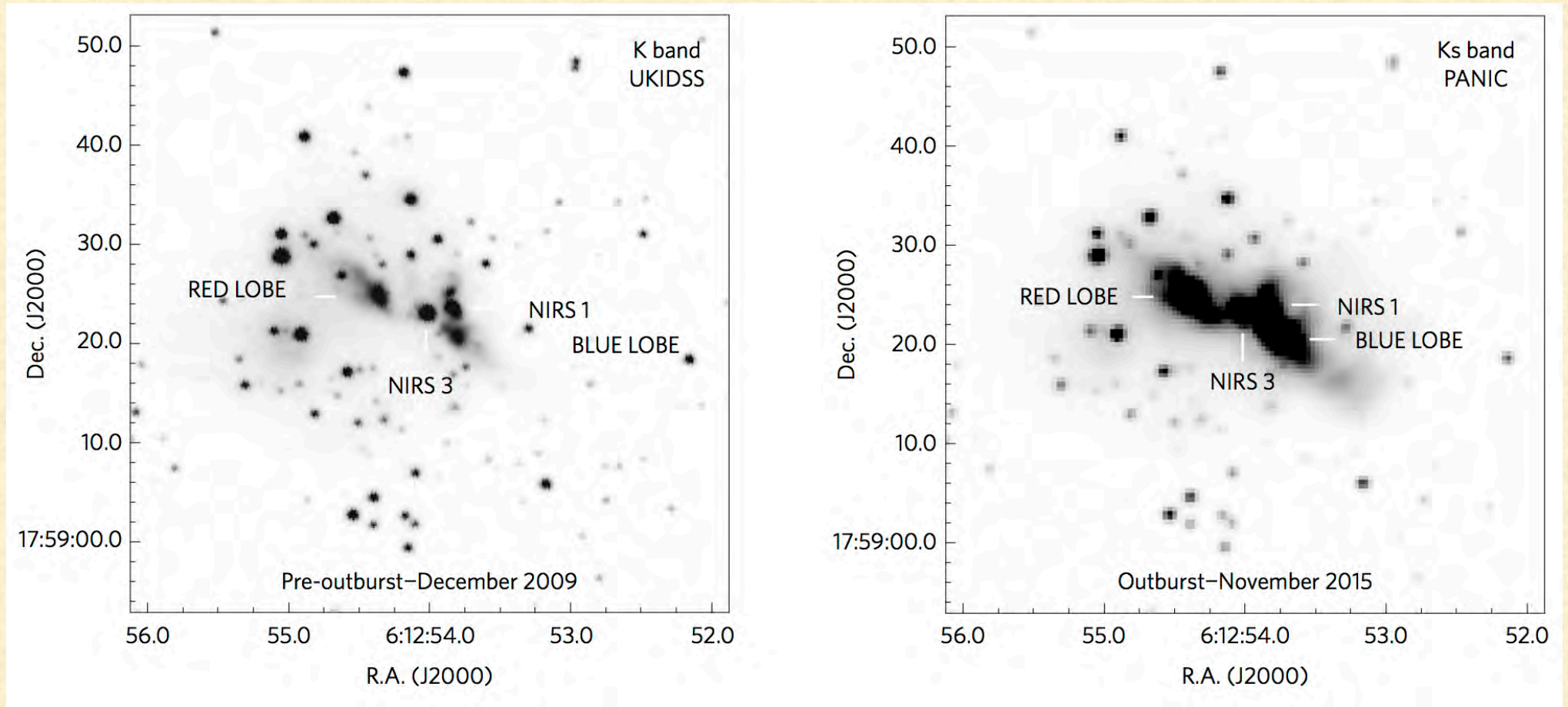


—>  $15M_{\text{sun}}$  central object



# Accretion burst

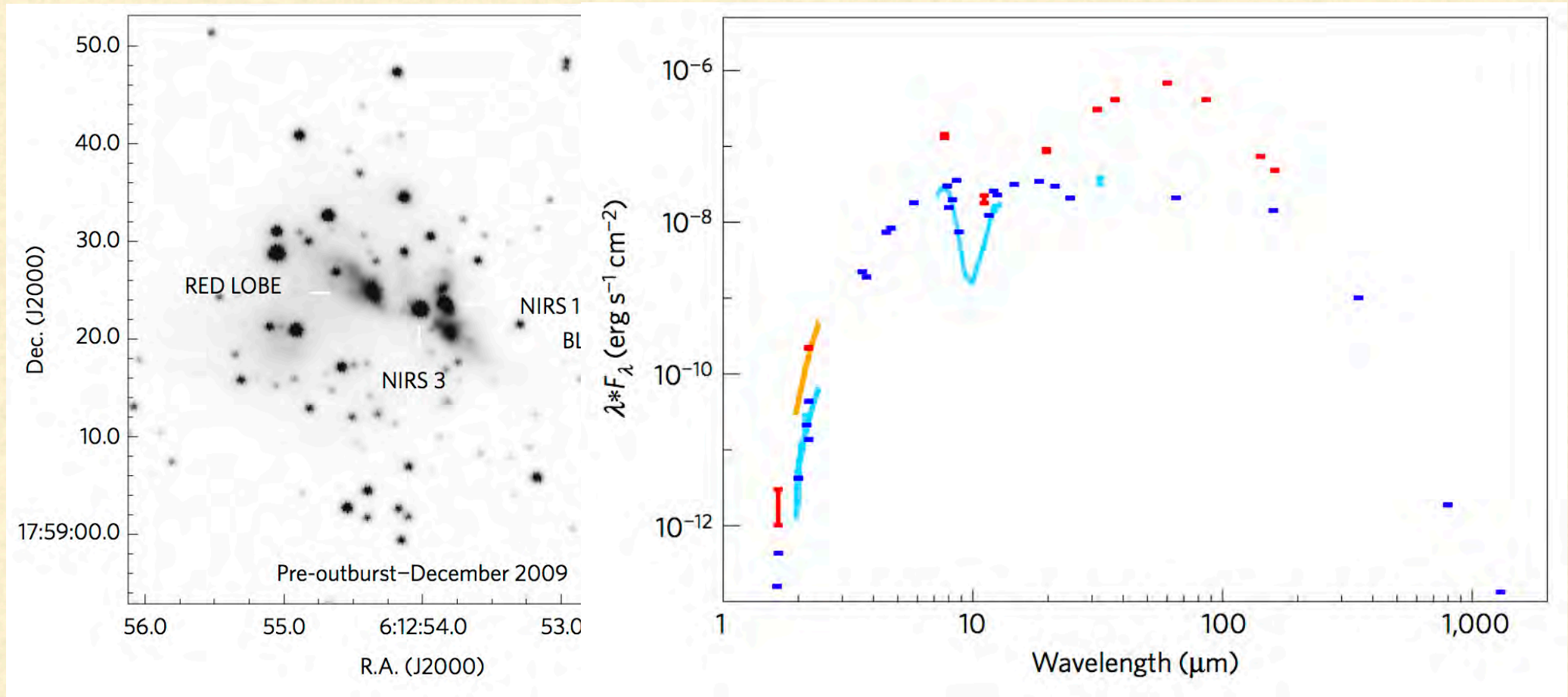
S255





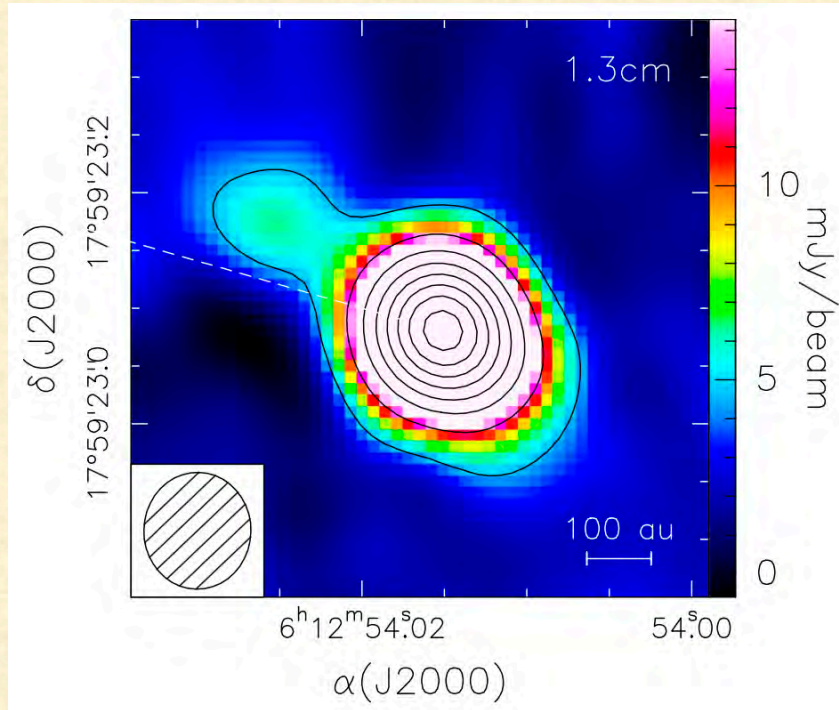
# Accretion burst

S255



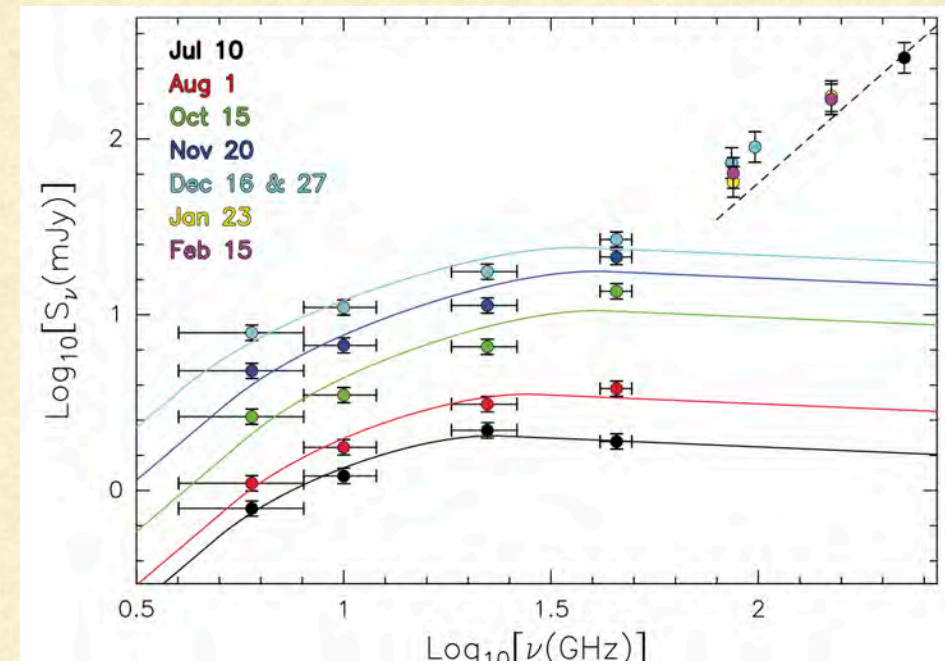
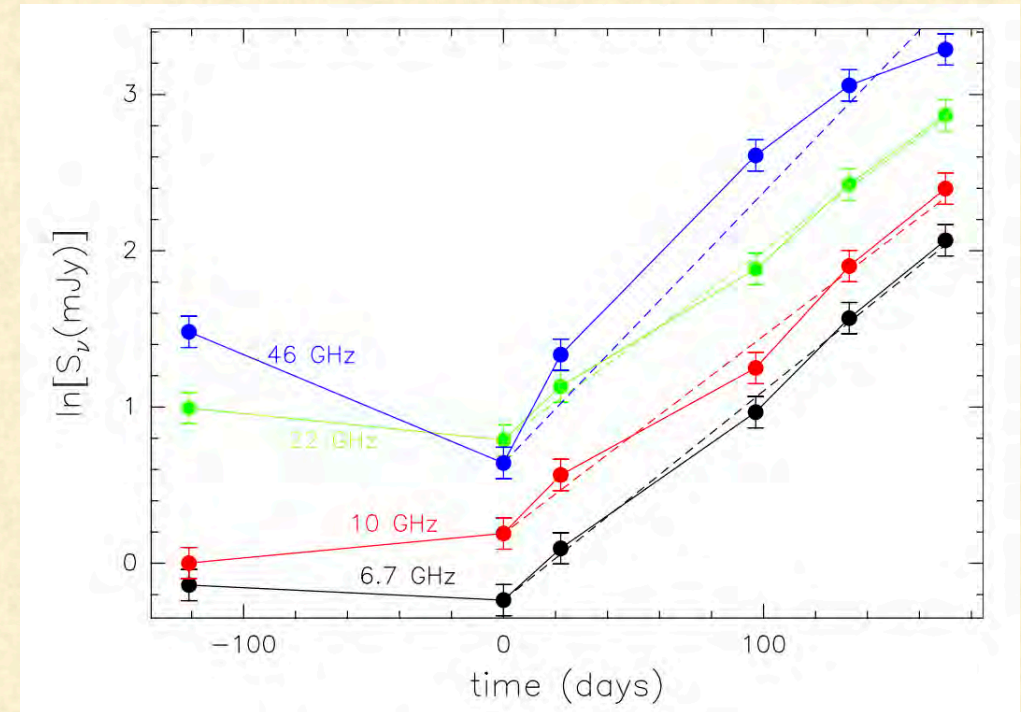
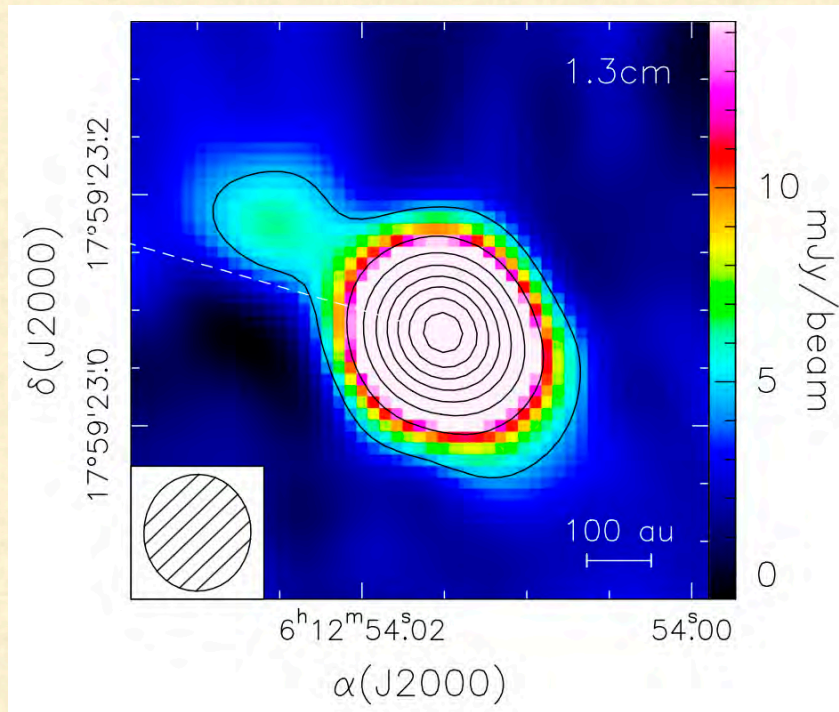


# Radio jet outburst





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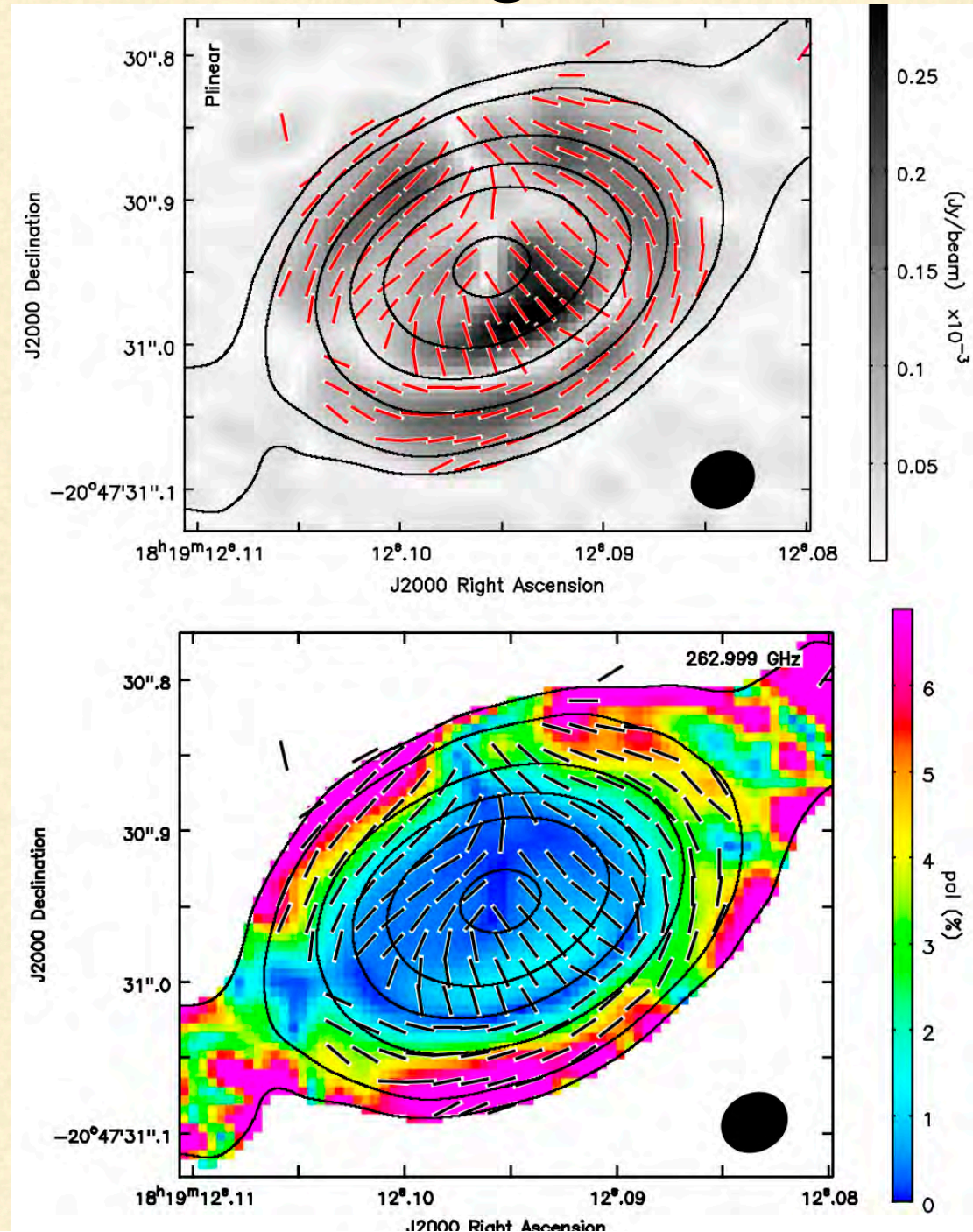
# Polarization in high-mass disks

Grey:  
polarized intensity

Contours: Stokes I

Segments:  
polarisation angles

Color: polarization  
fraction





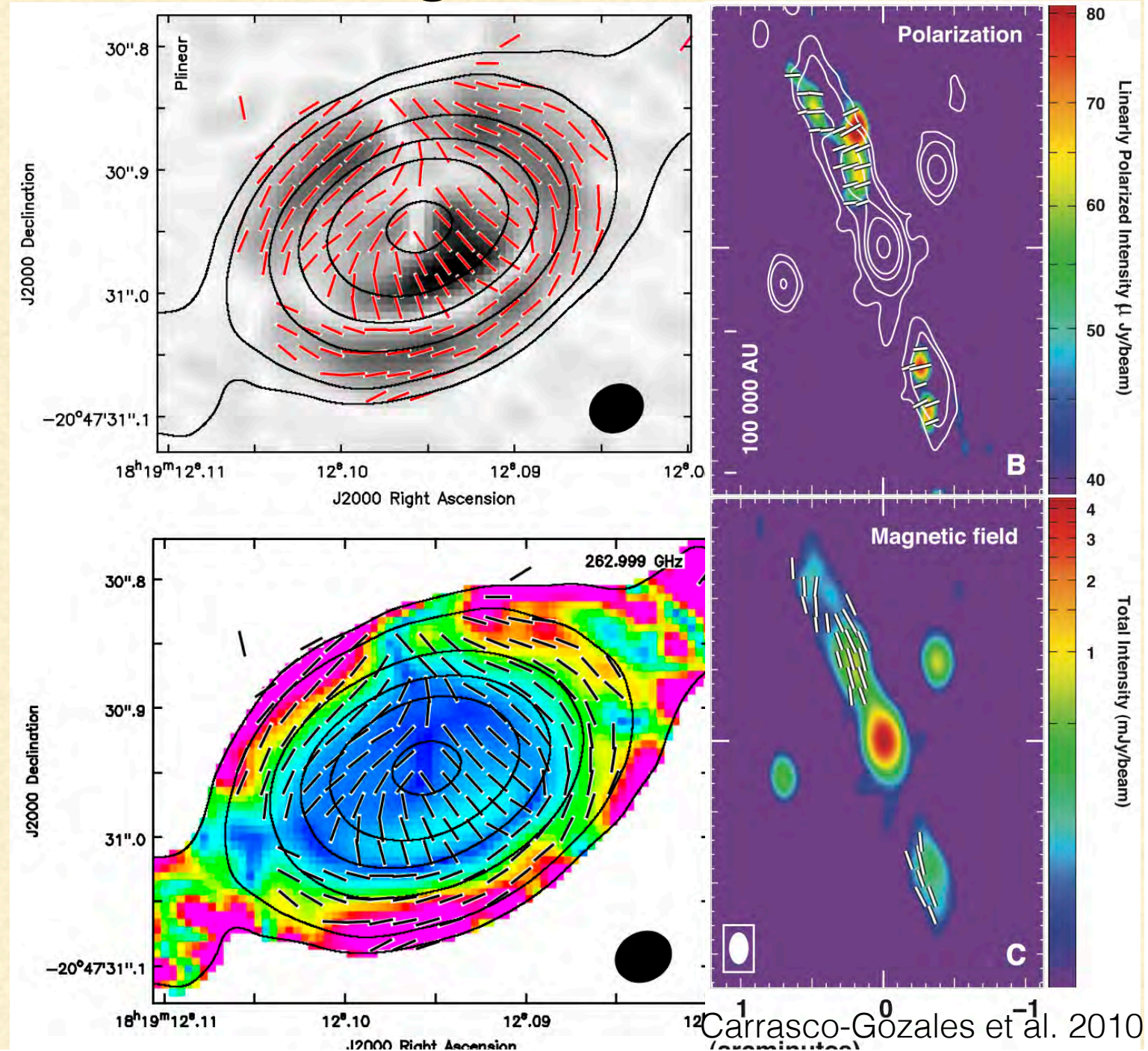
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polarized intensity

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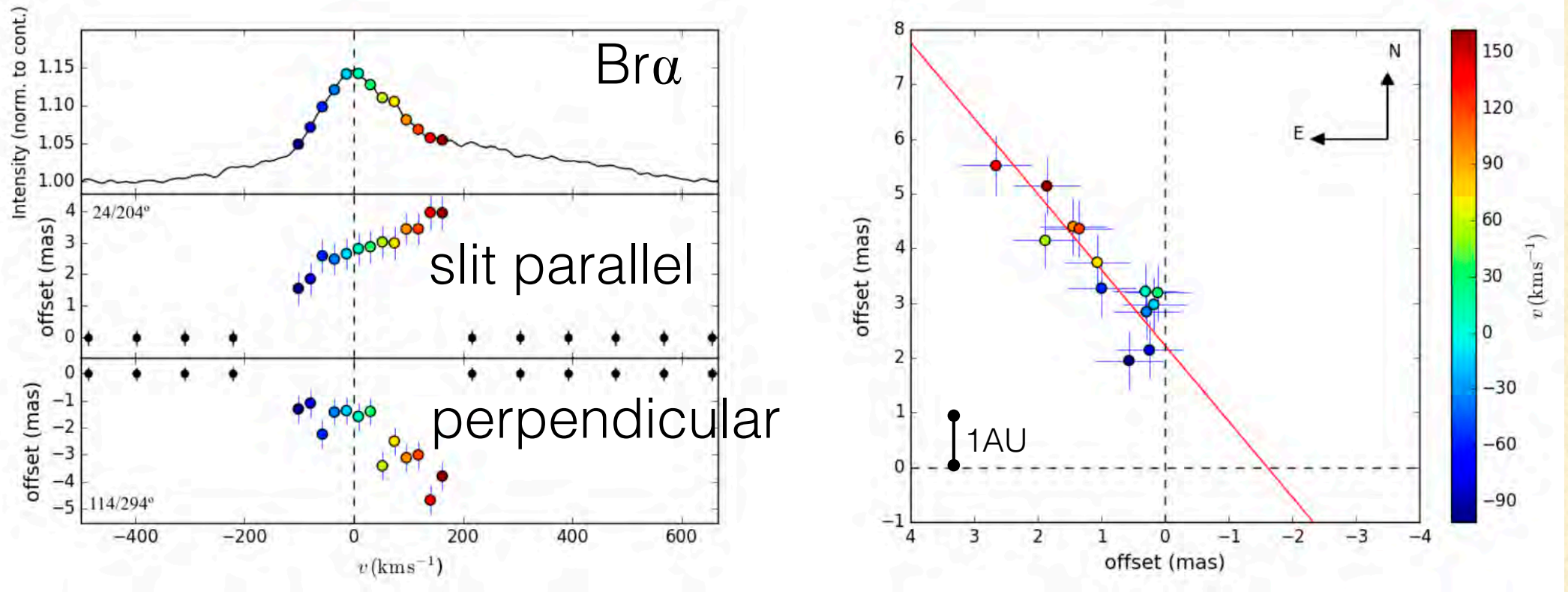
Segments:  
polarisation angles

Color: polarization  
fraction



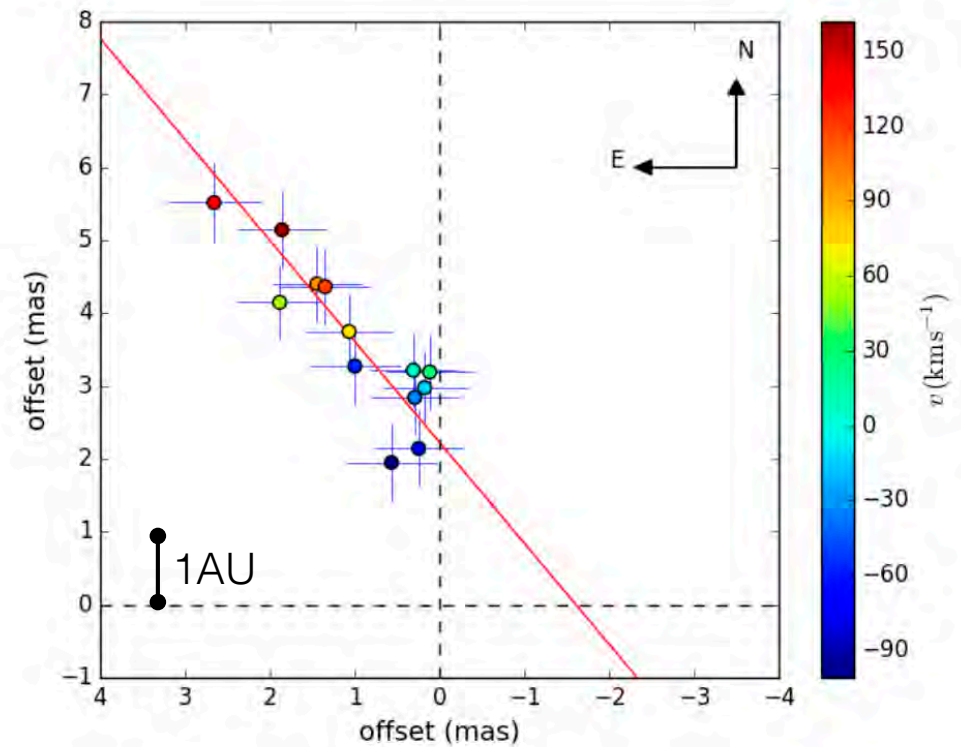
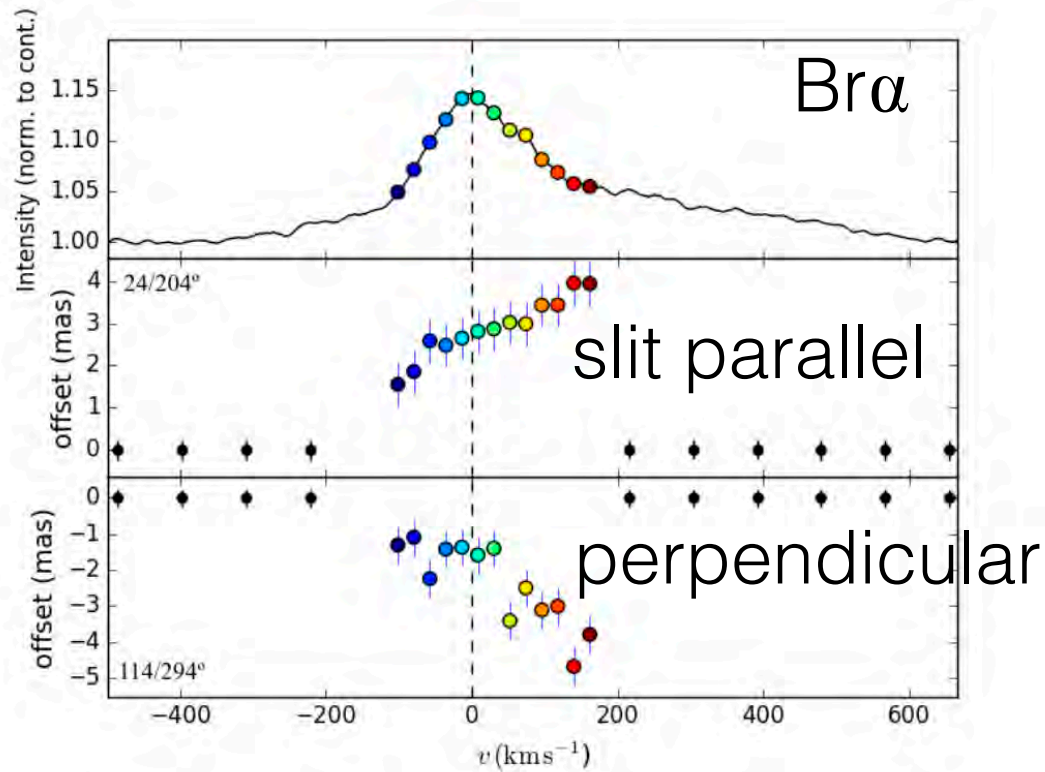


# AU-scale jet emission (IRAS13481)



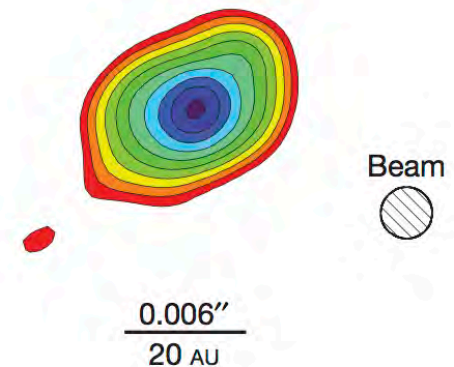


# AU-scale jet emission (IRAS13481)



2.2  $\mu$ m

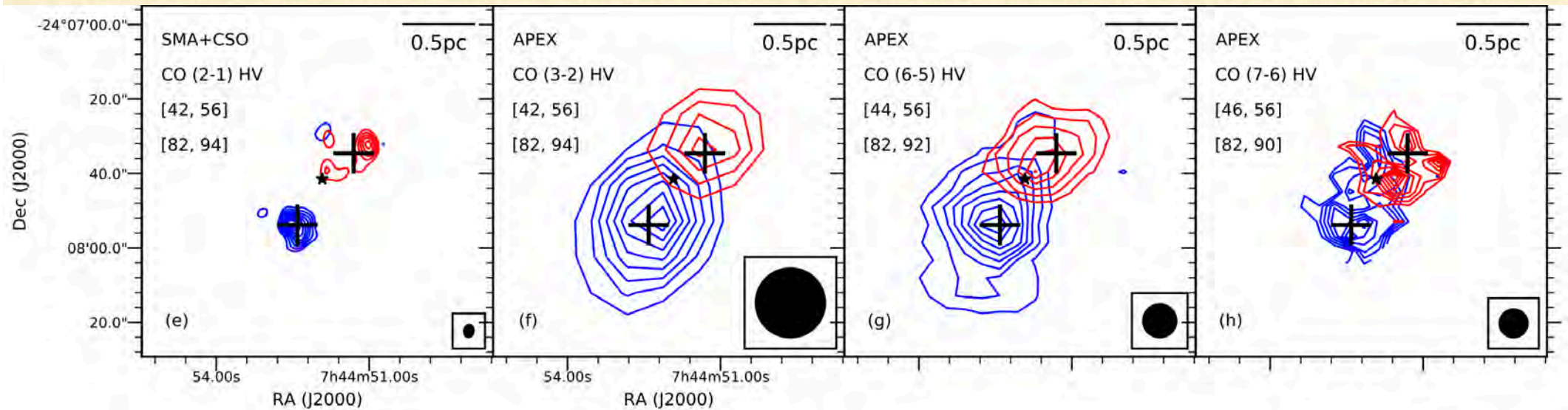
Kraus et al. 2010



*Fedriani et al. 2018*

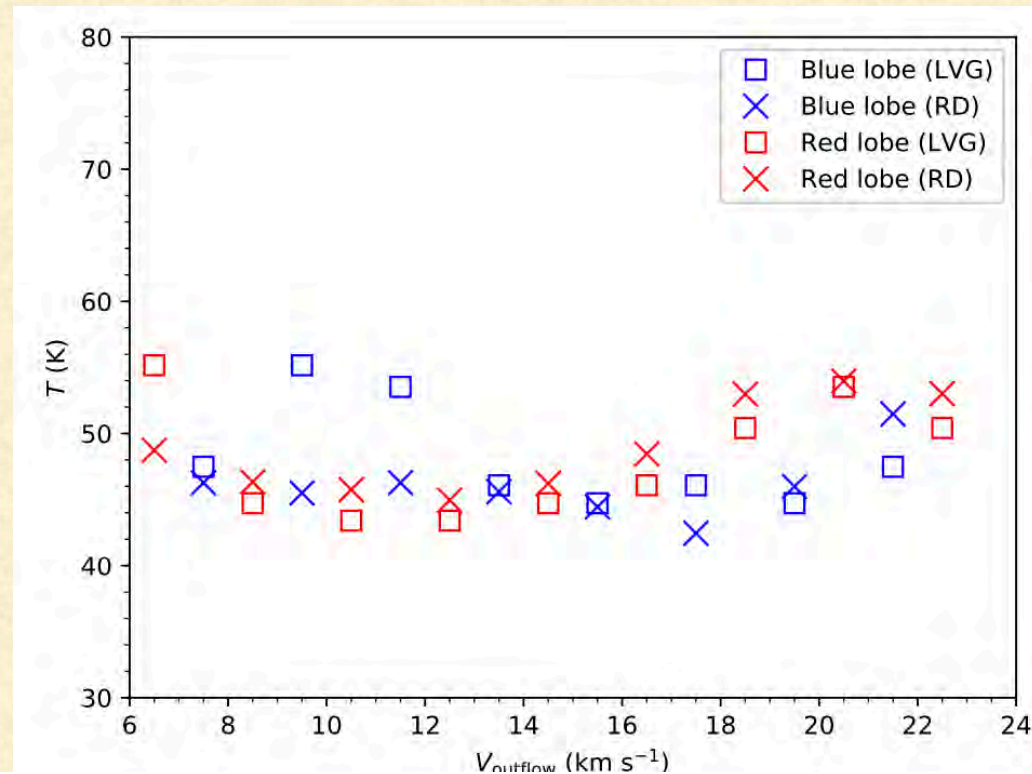
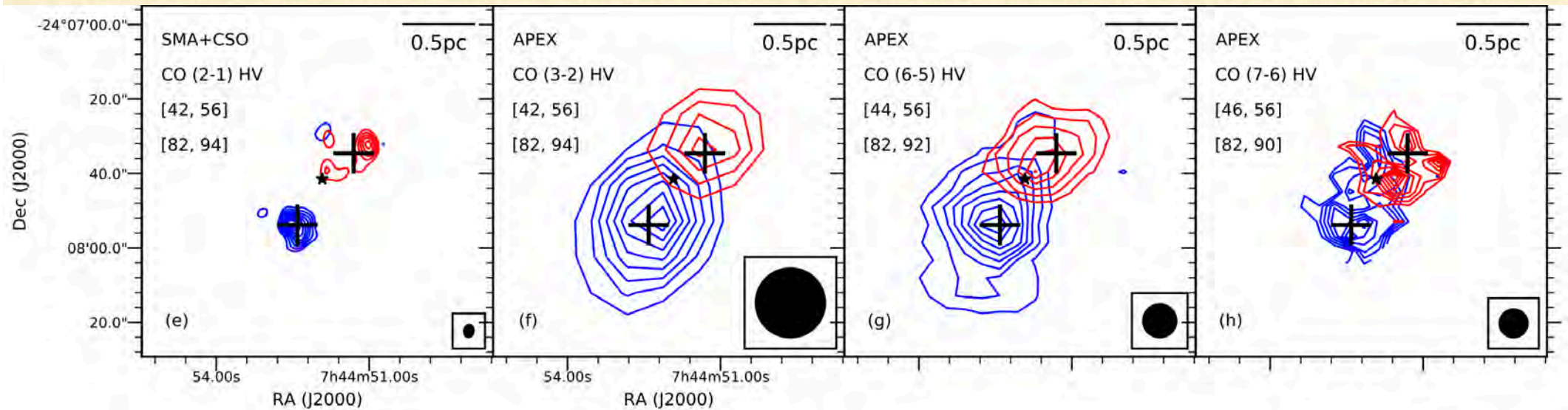


# Isothermal outflow properties



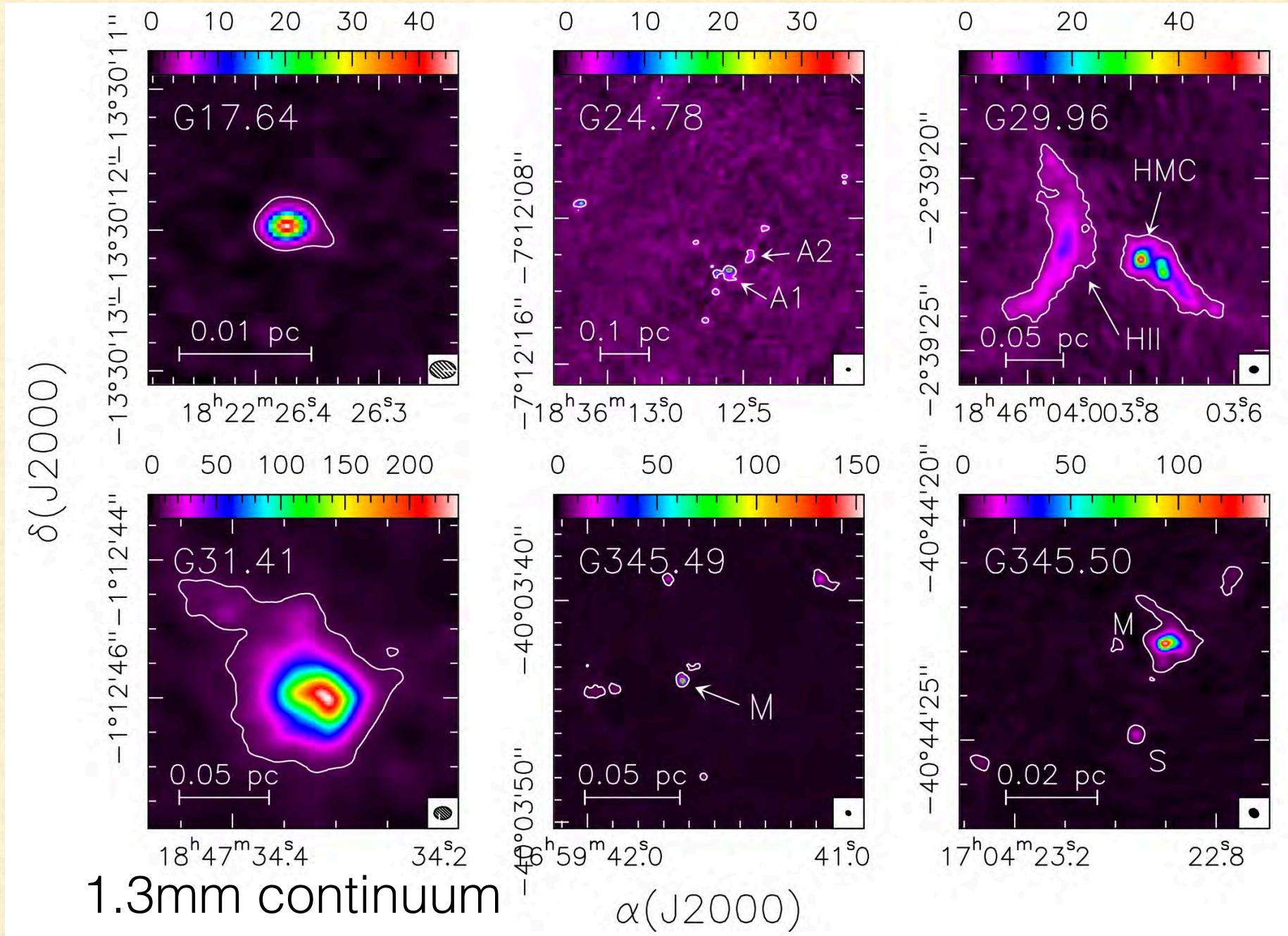


# Isothermal outflow properties



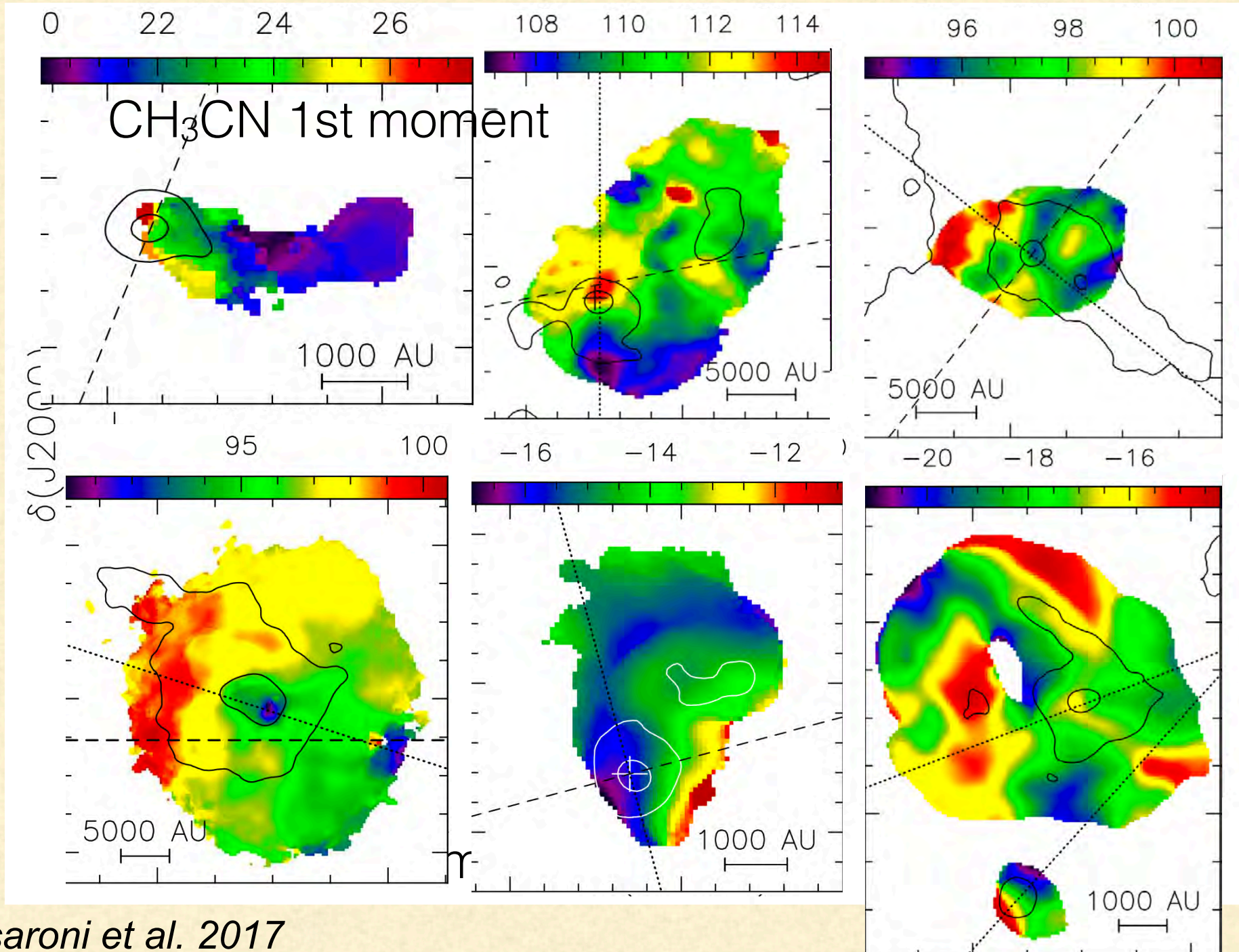


# Possible disks around O-type sources





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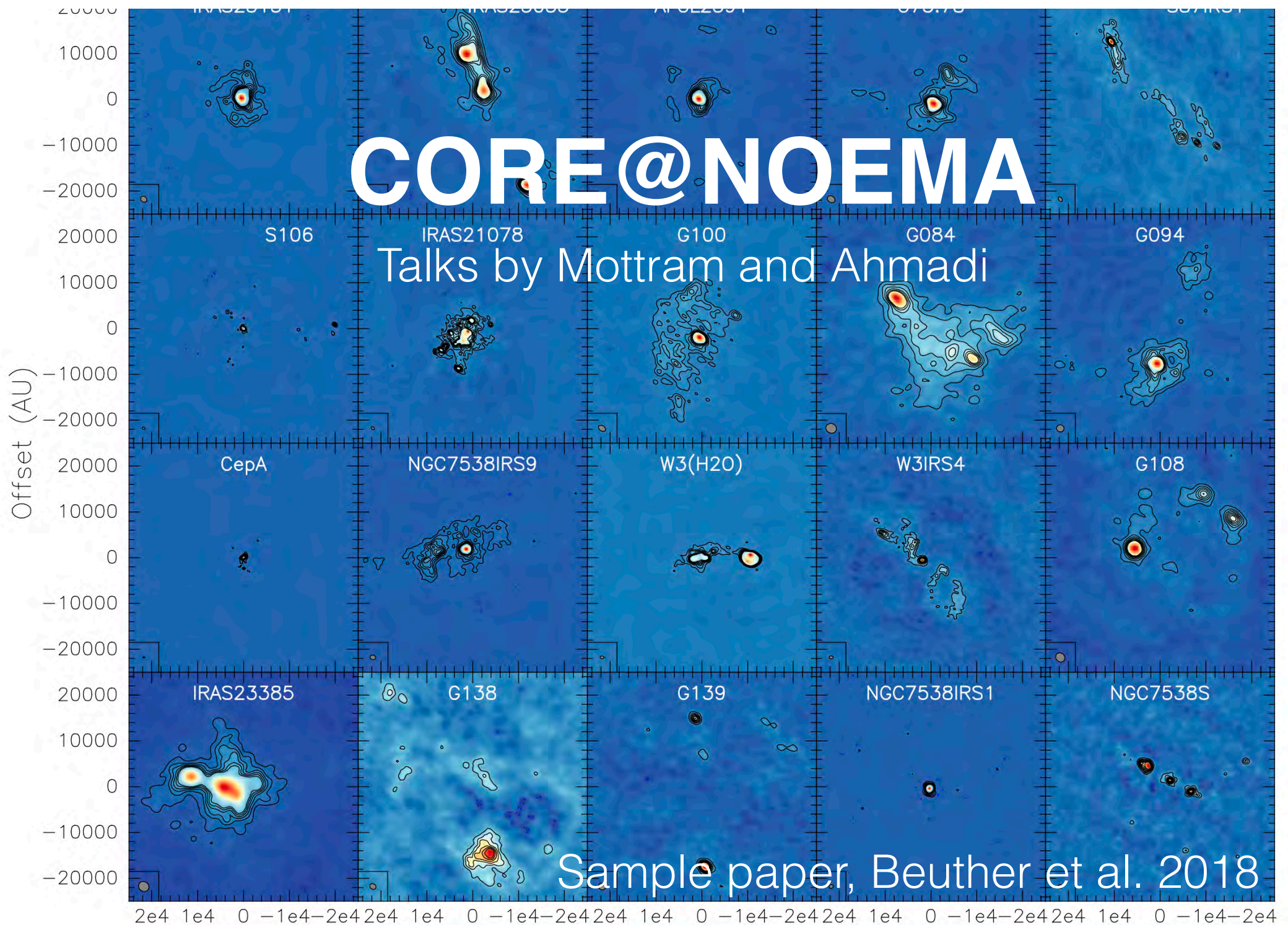




# CORE@NOEMA

Talks by Mottram and Ahmadi

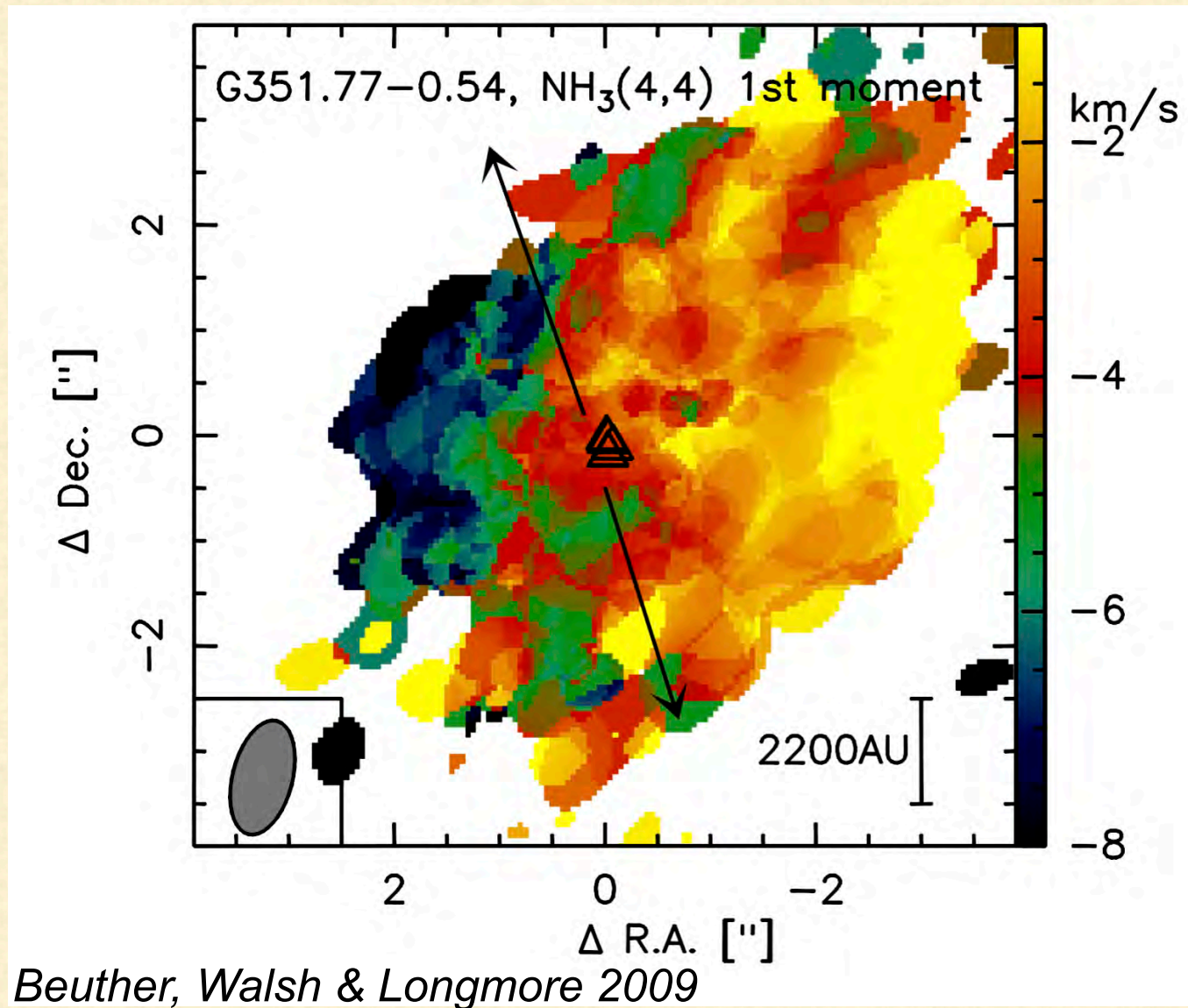
Offset (AU)



Sample paper, Beuther et al. 2018

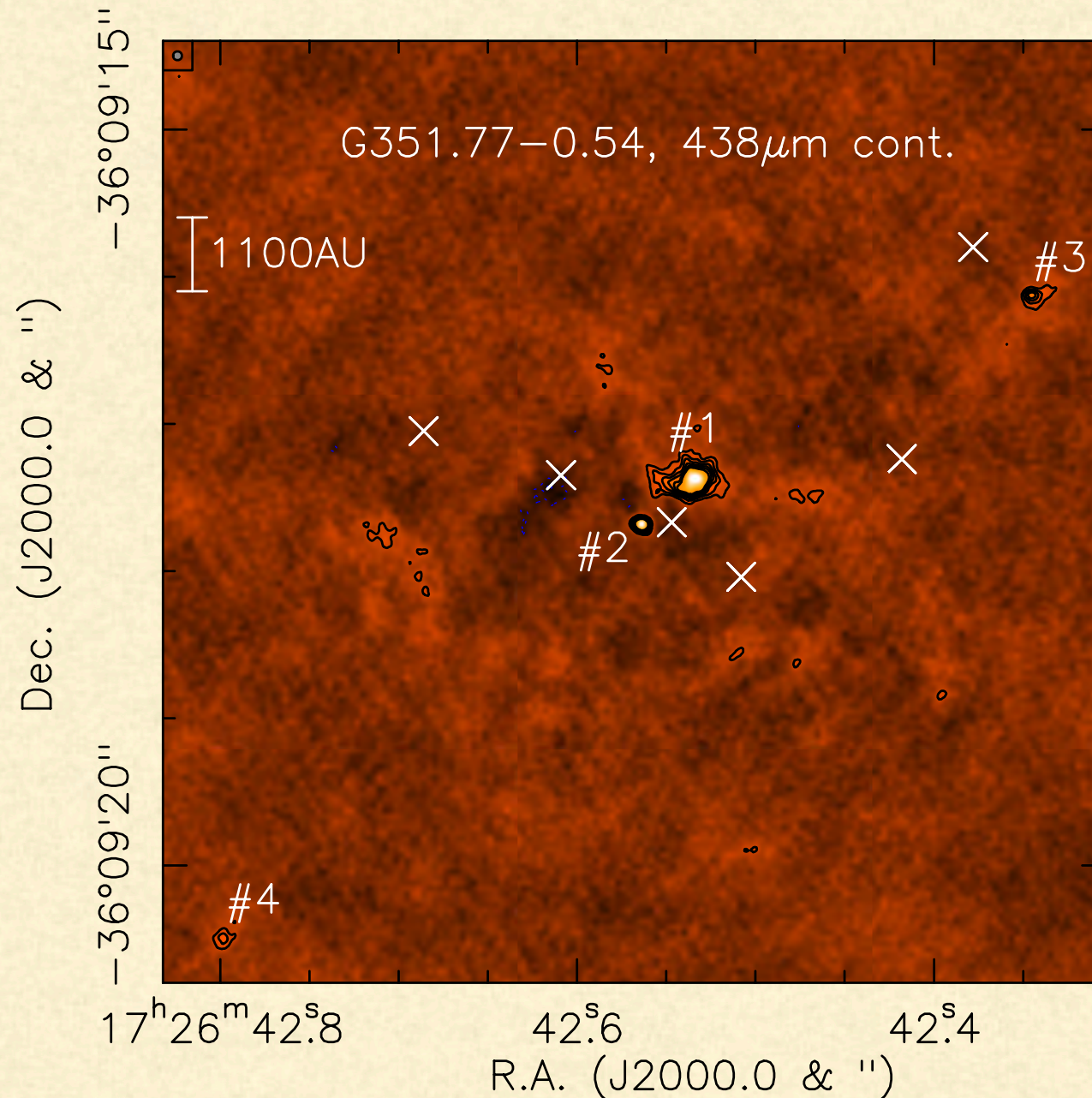


# The hot core G351: ALMA@690GHz & 0.06''





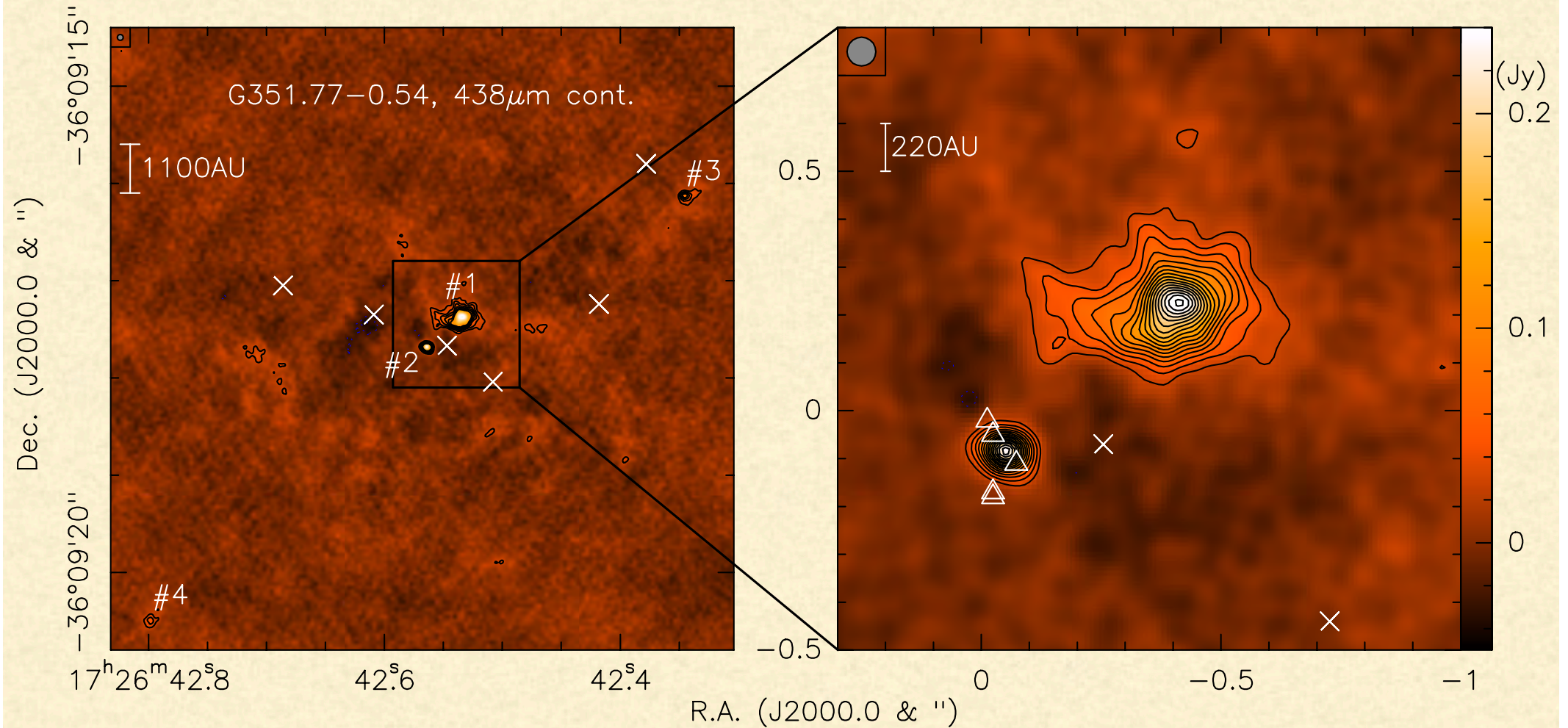
# The hot core G351: ALMA@690GHz & 0.06''



*Beuther et al. 2017*

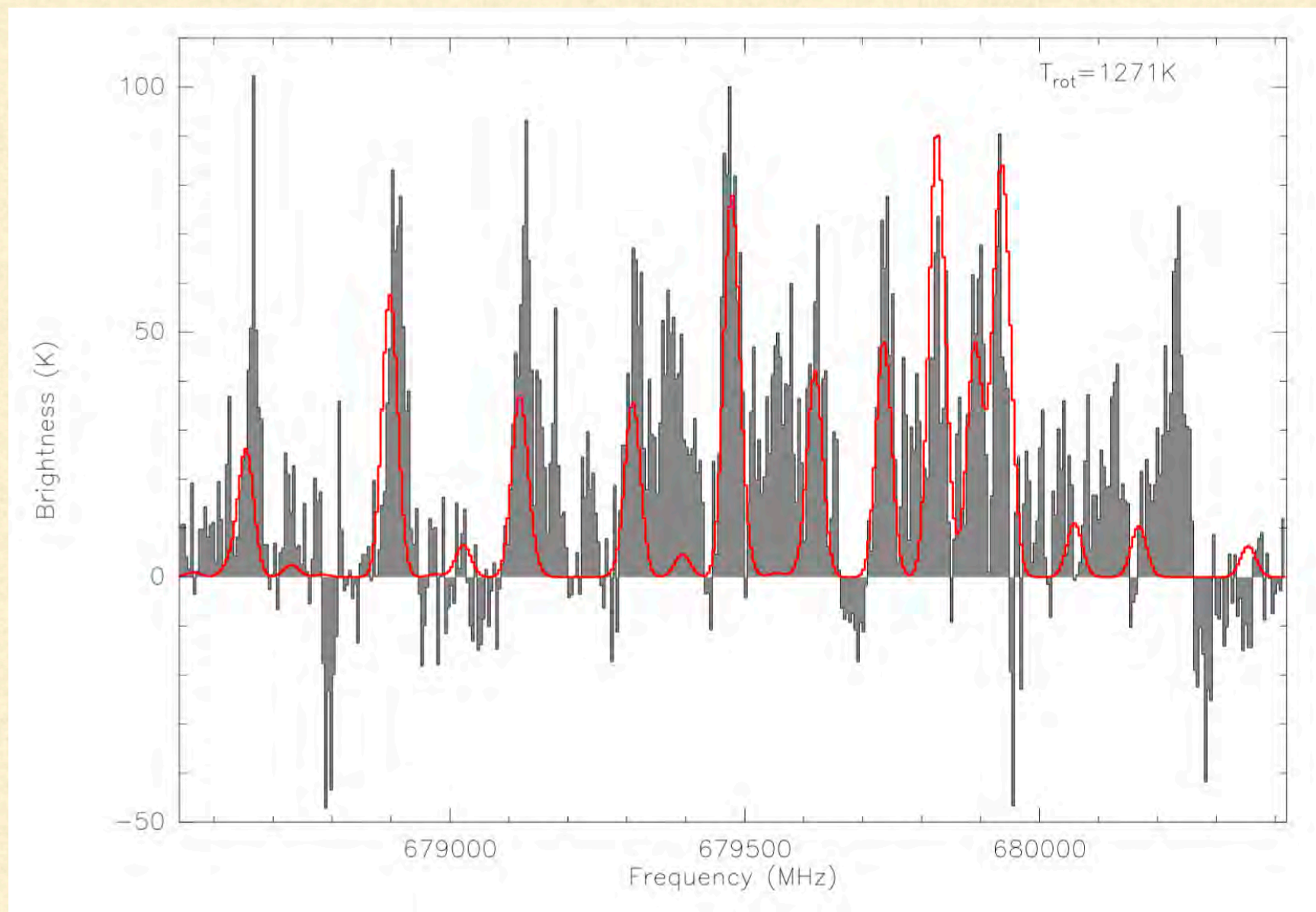


# The hot core G351: ALMA@690GHz & 0.06''



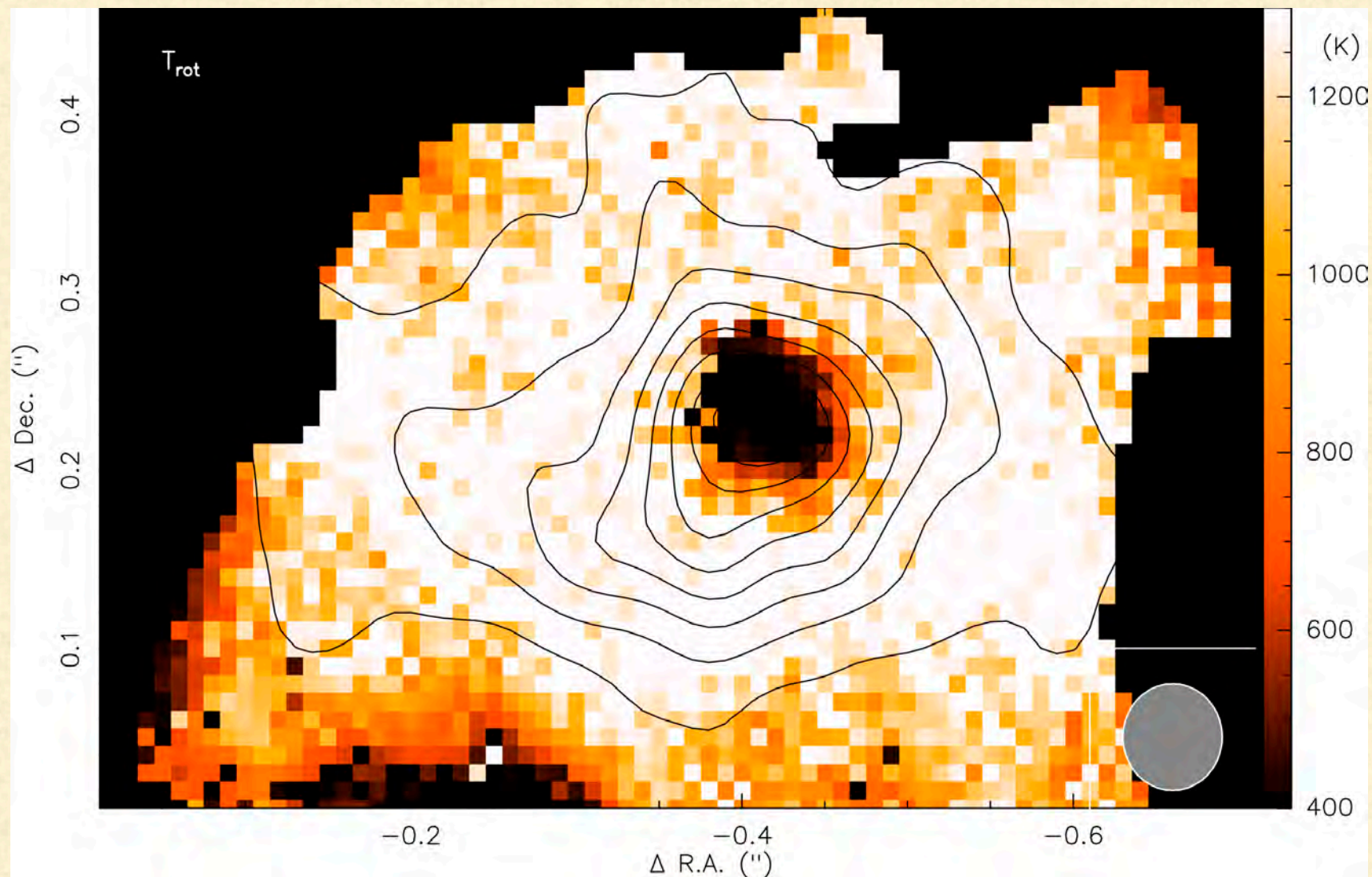


# Temperature measurement



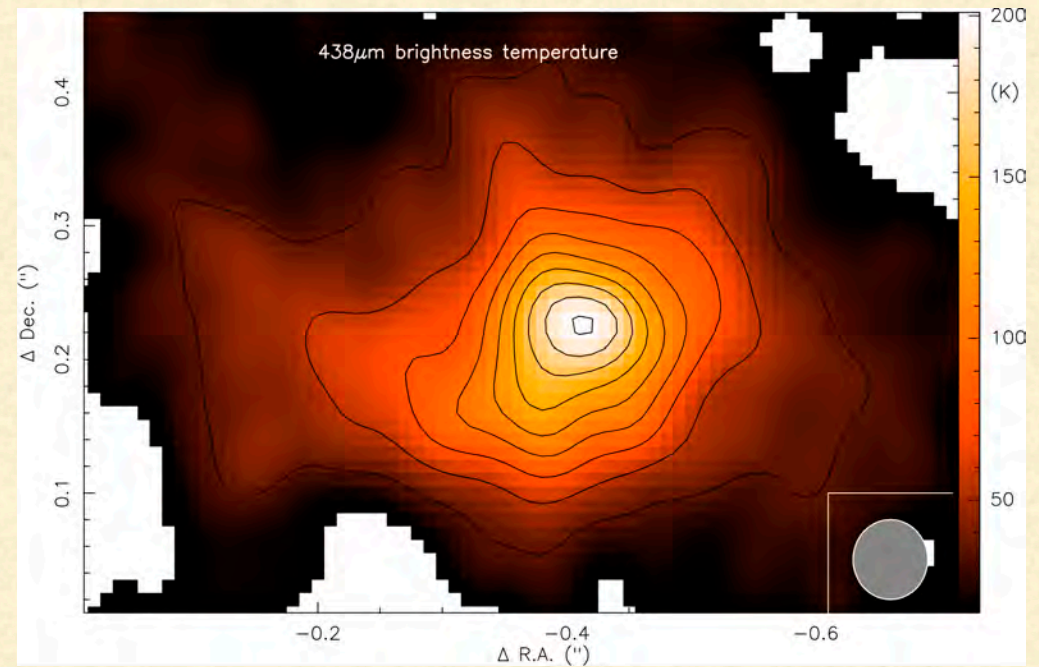
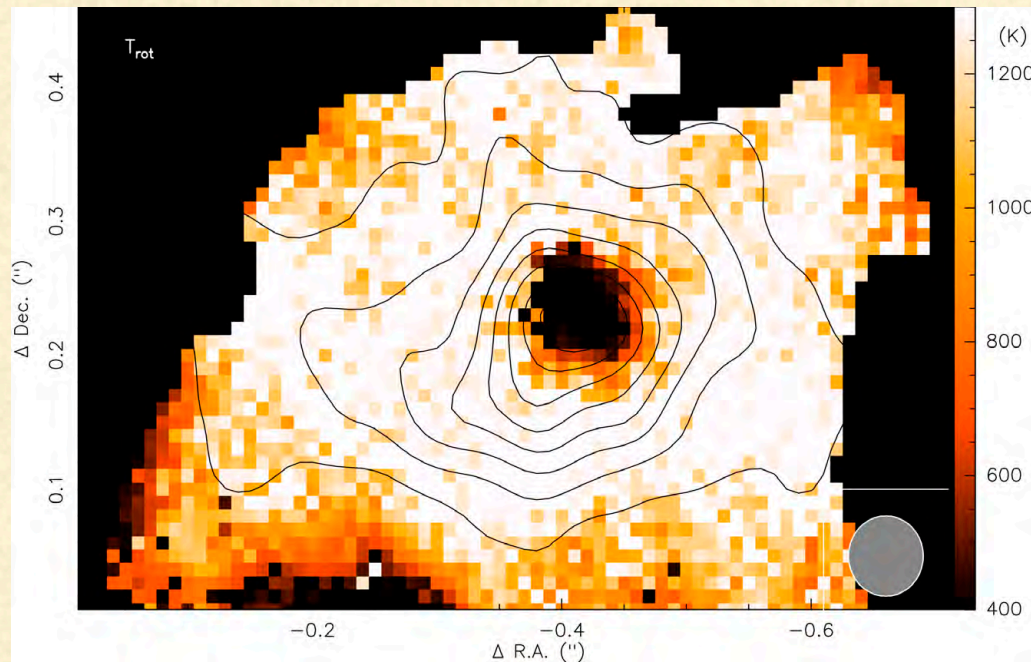


# Temperature measurement





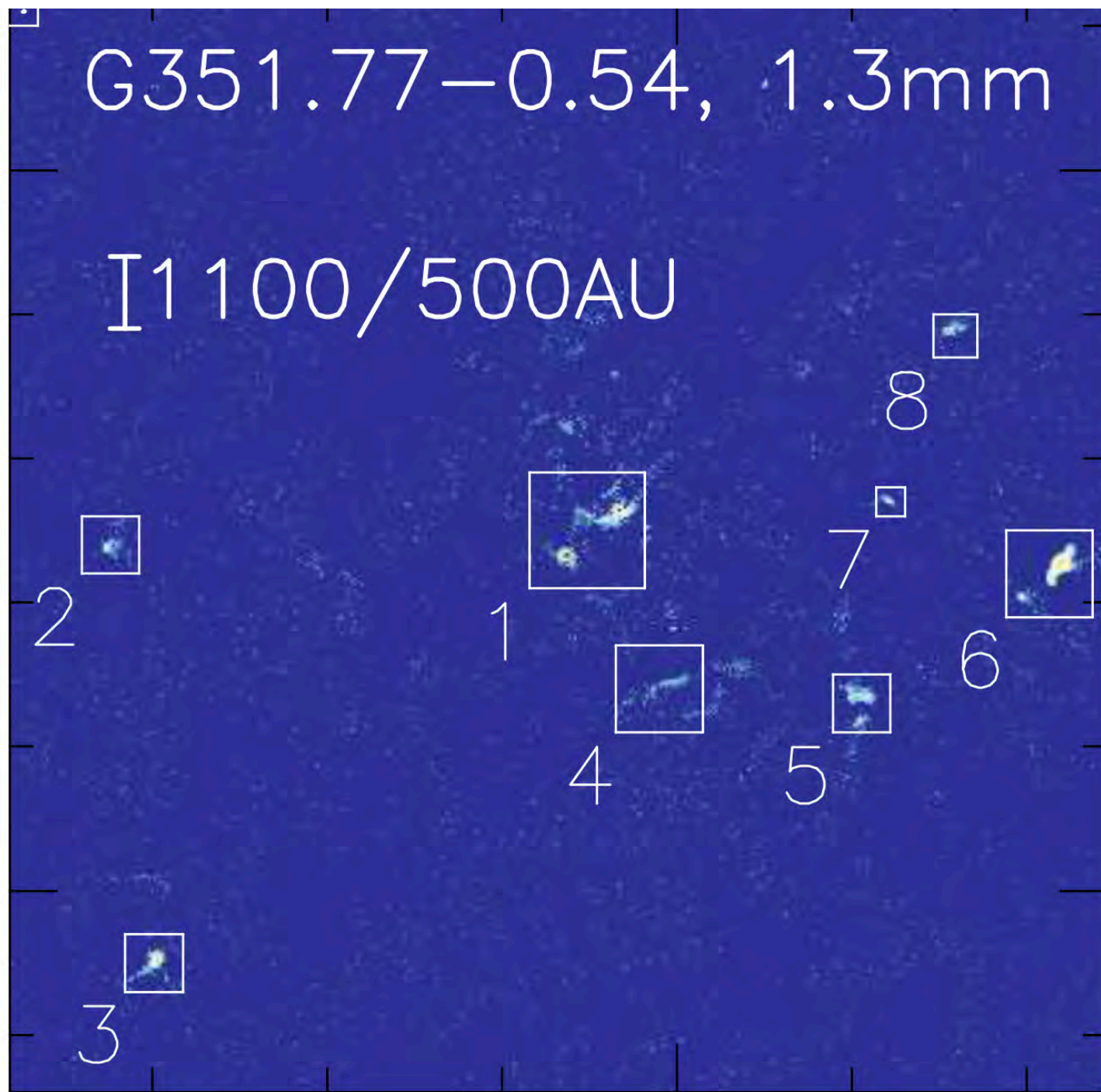
# Temperature measurement





—36°09'20"

—36°09'11"

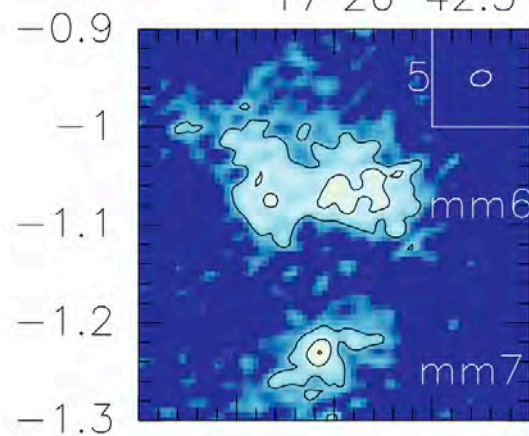
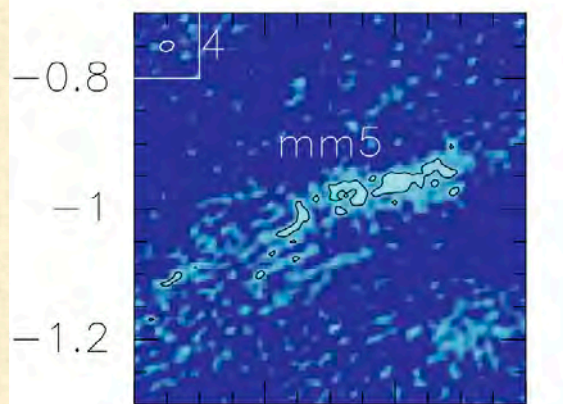
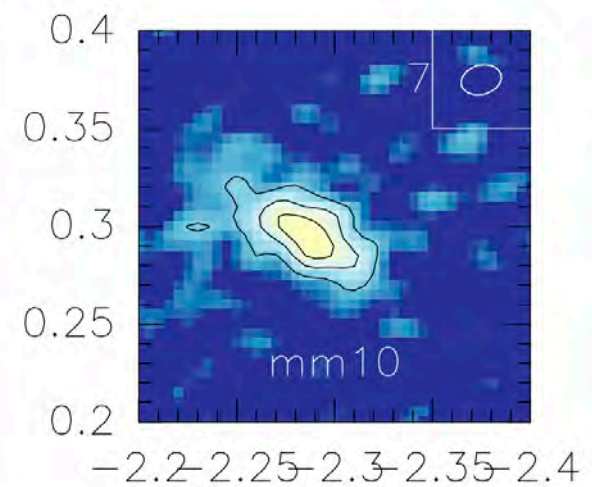
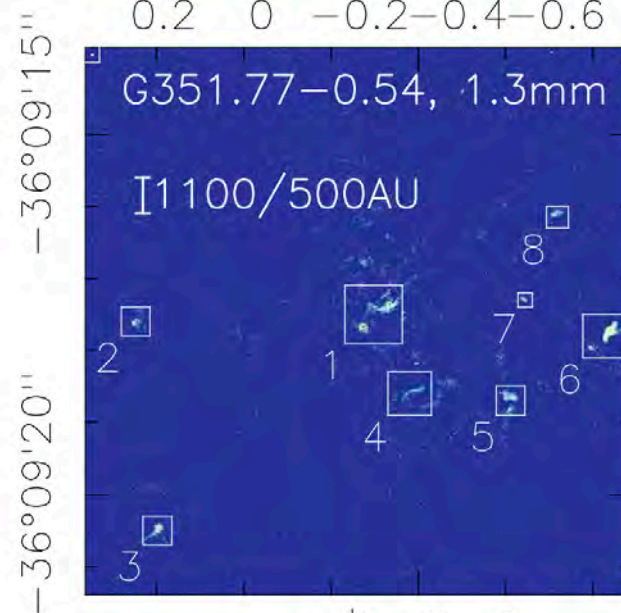
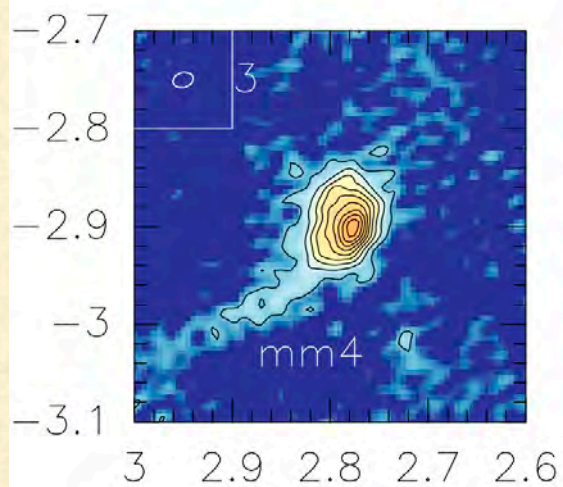
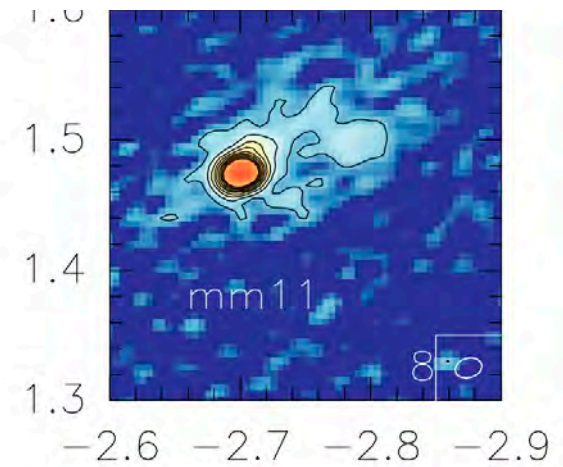
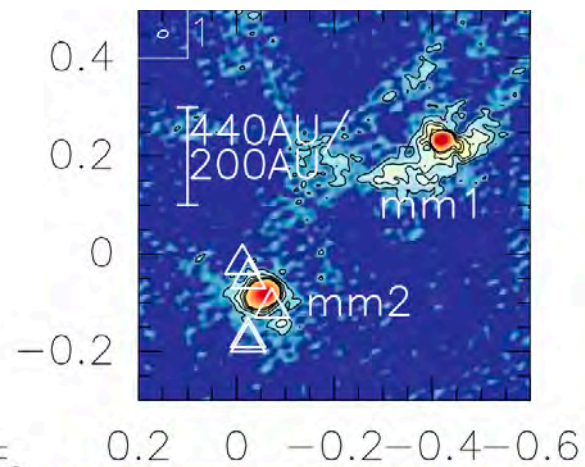
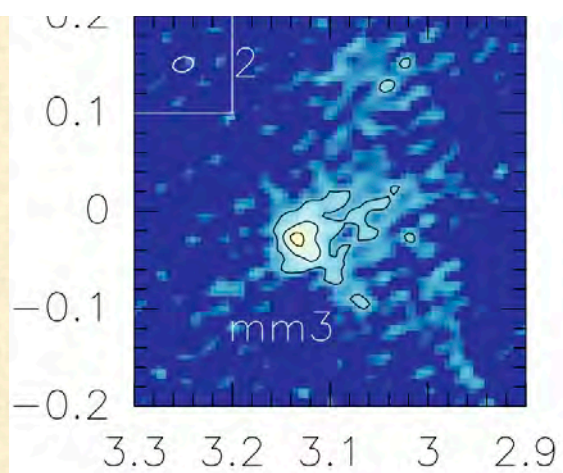


G351.77-0.54, 1.3mm

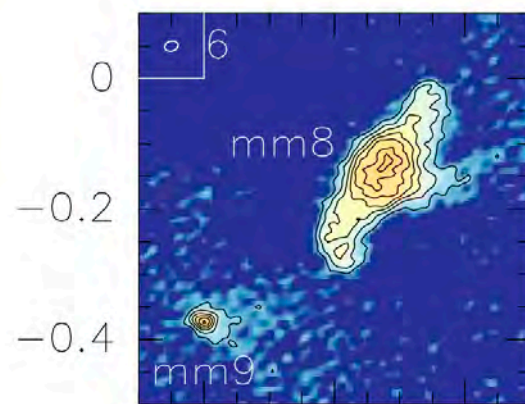
I1100/500AU

17<sup>h</sup>26<sup>m</sup>42<sup>s</sup>.5

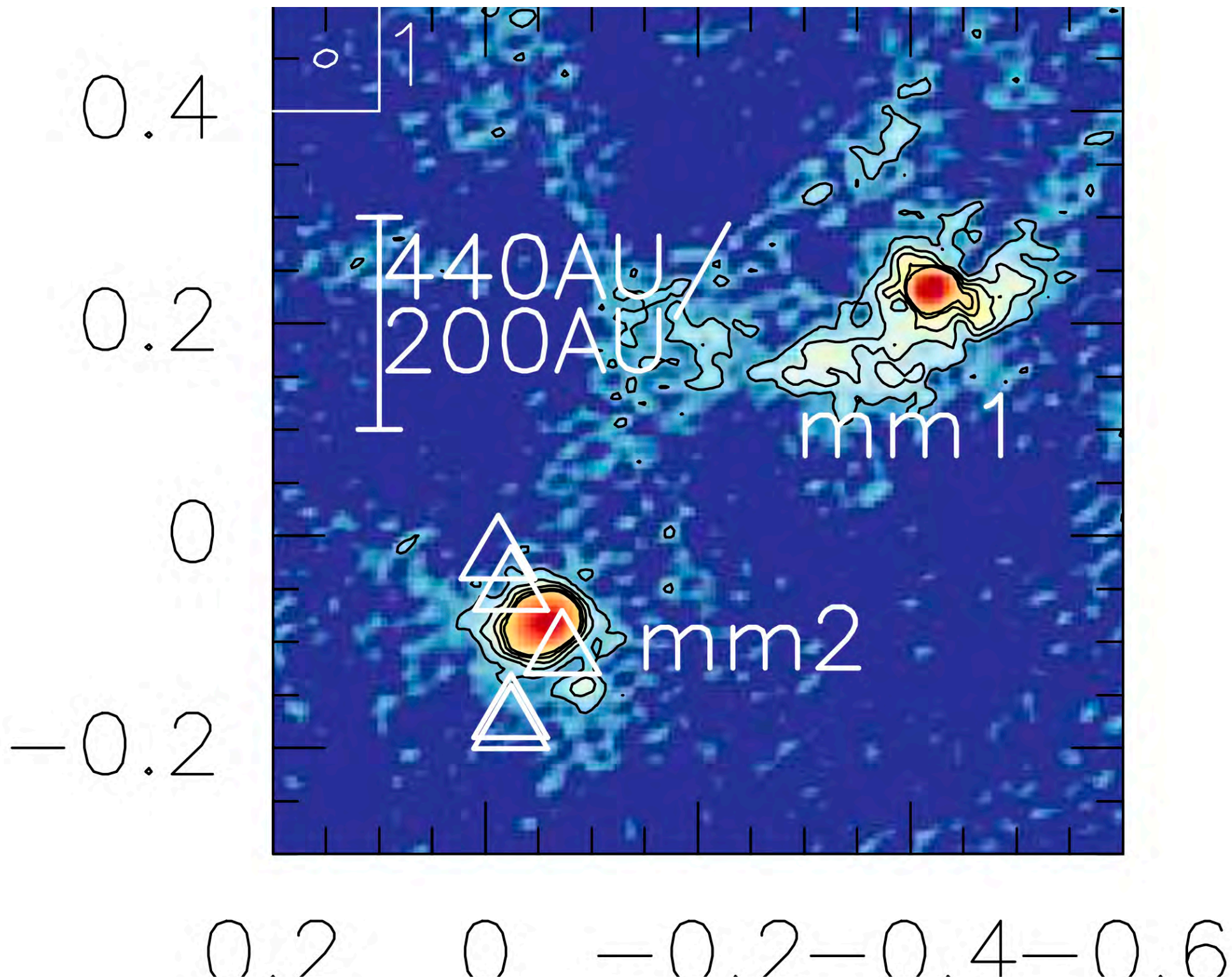




*Beuther et al. in prep.*

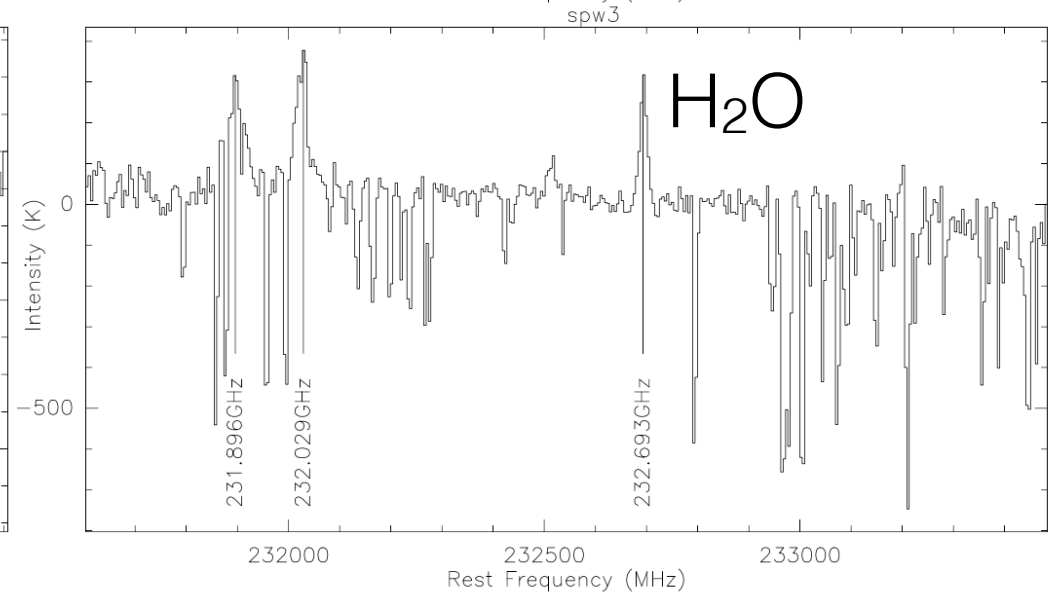
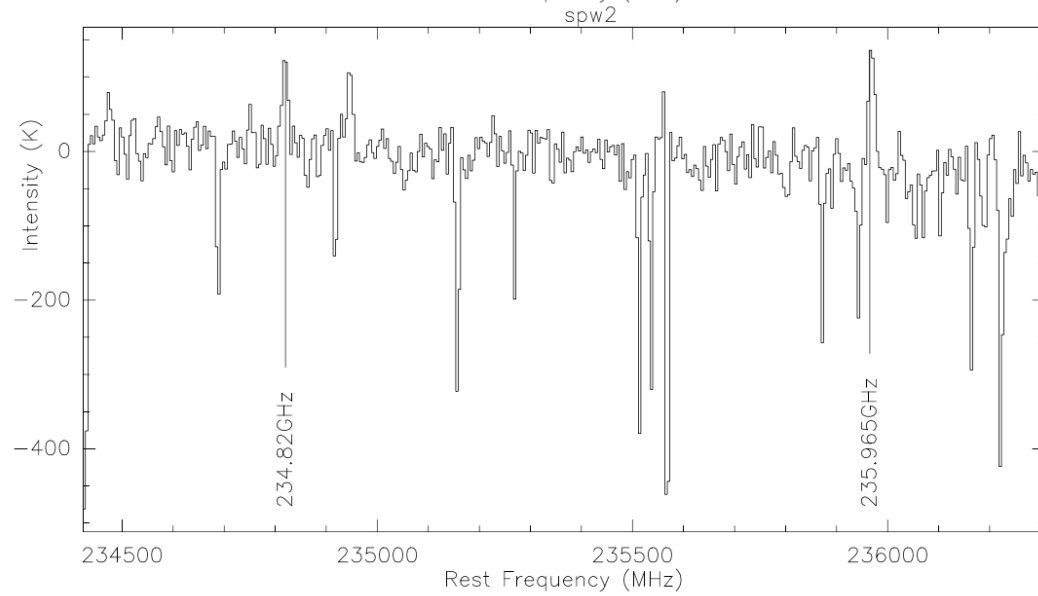
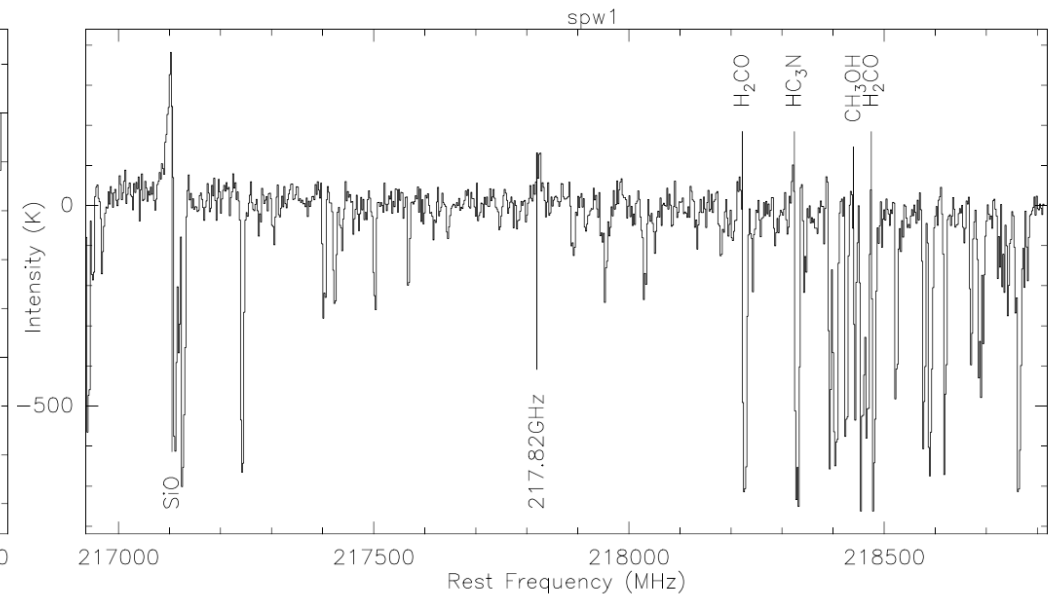
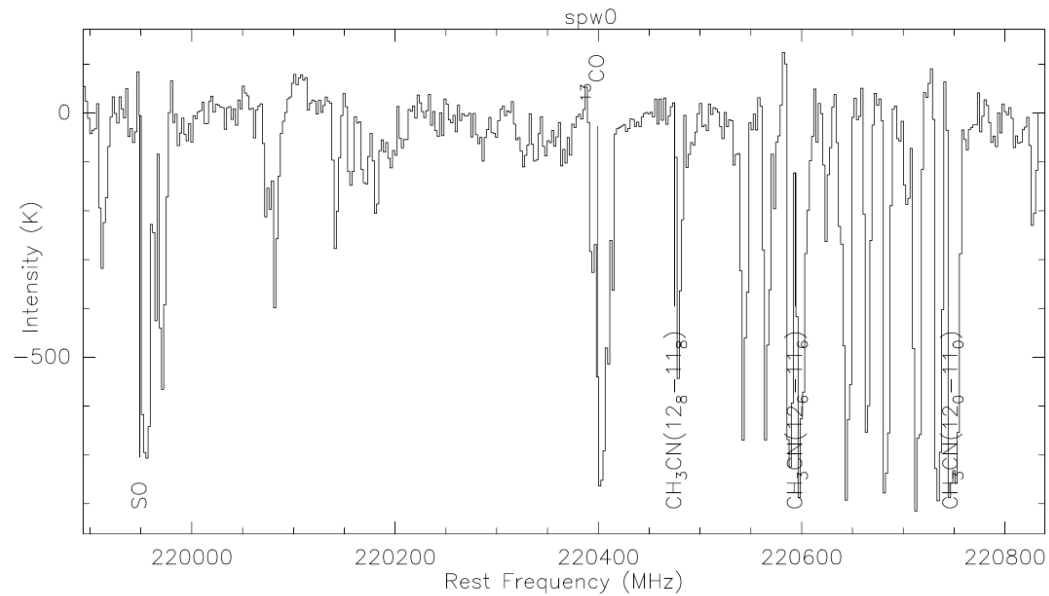






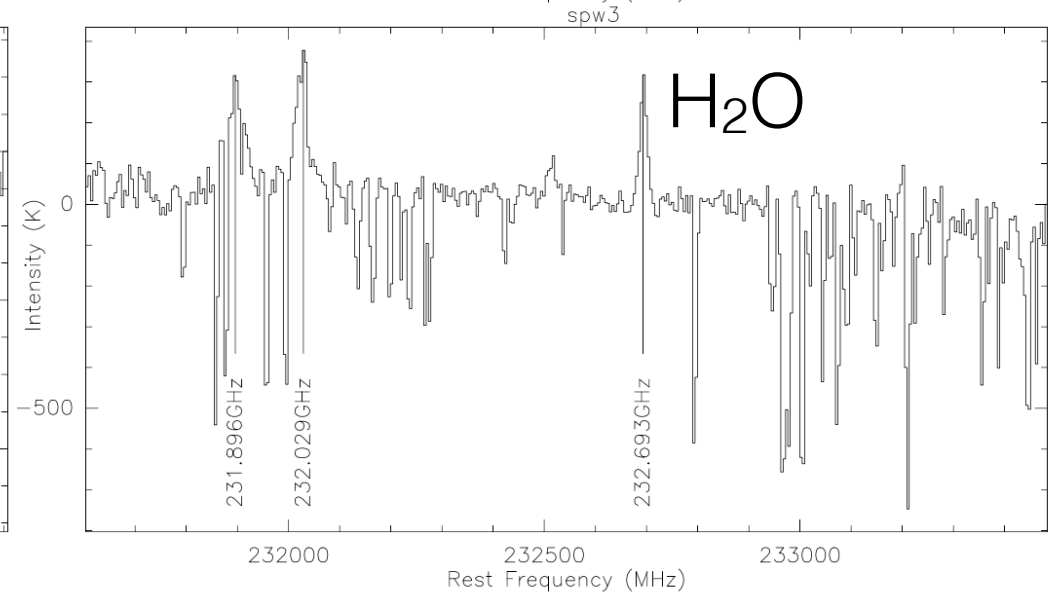
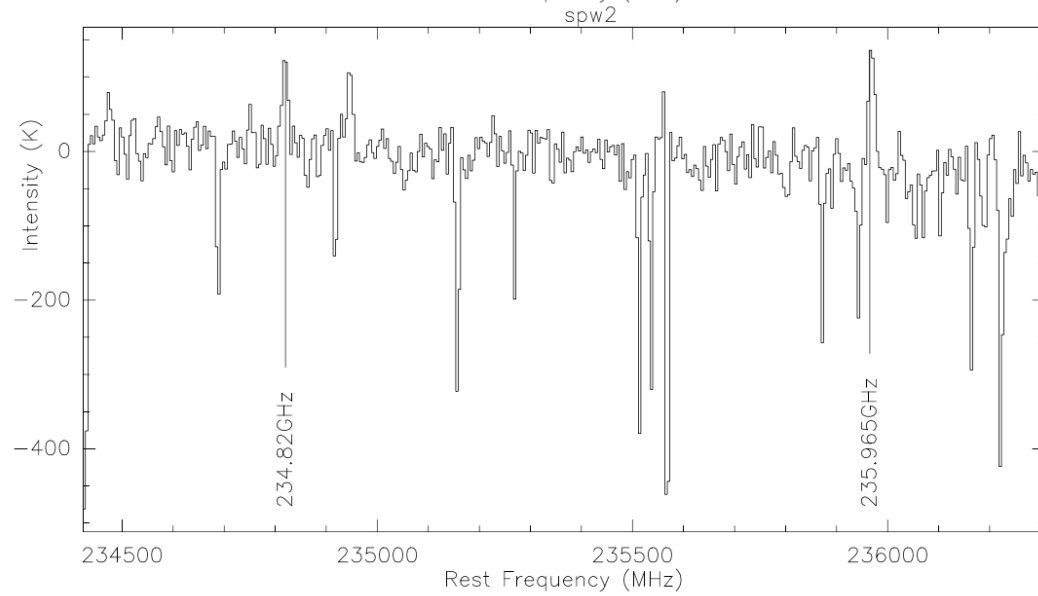
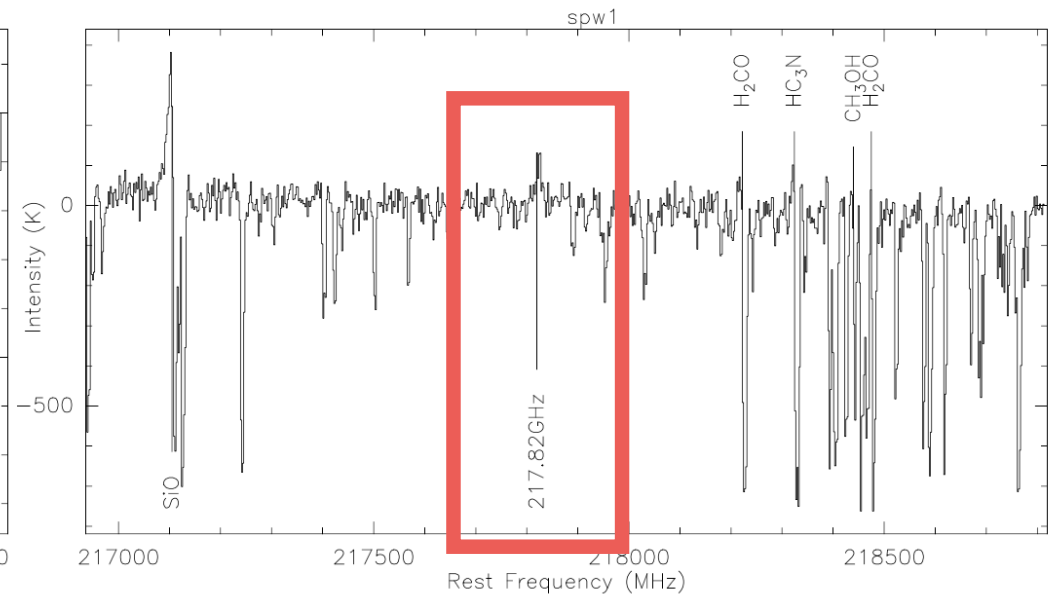
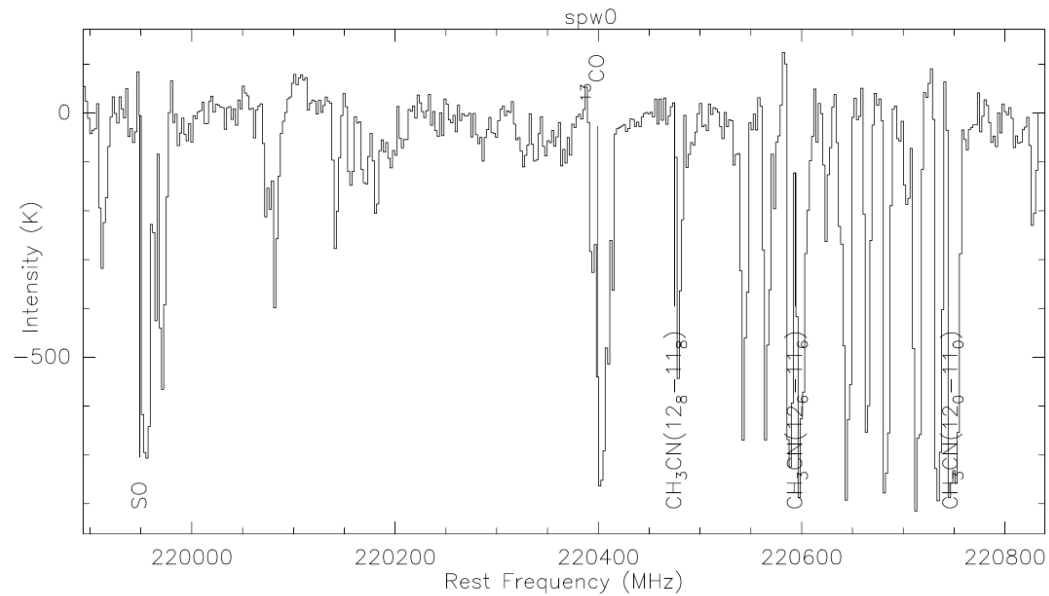


# Spectral lines



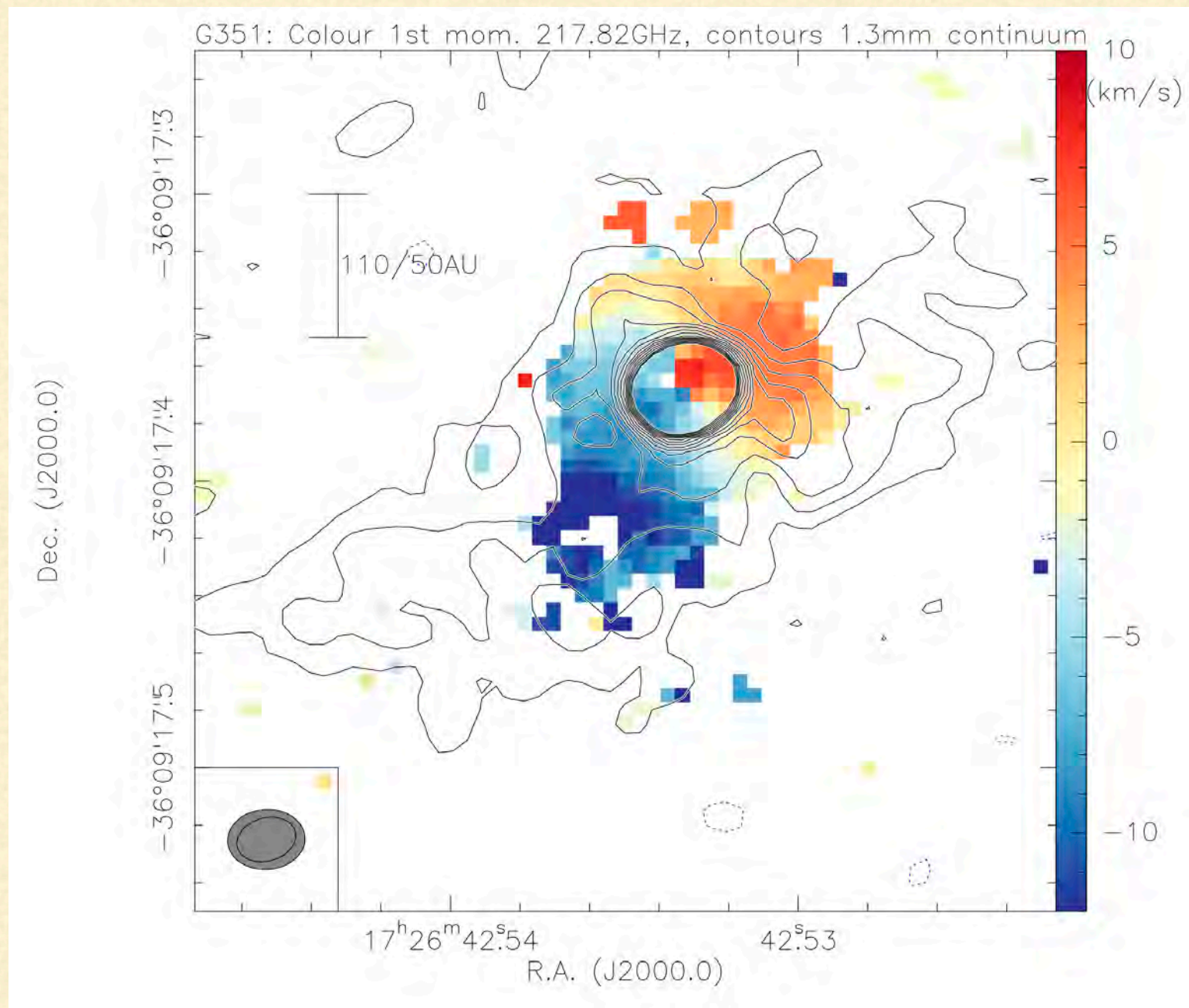


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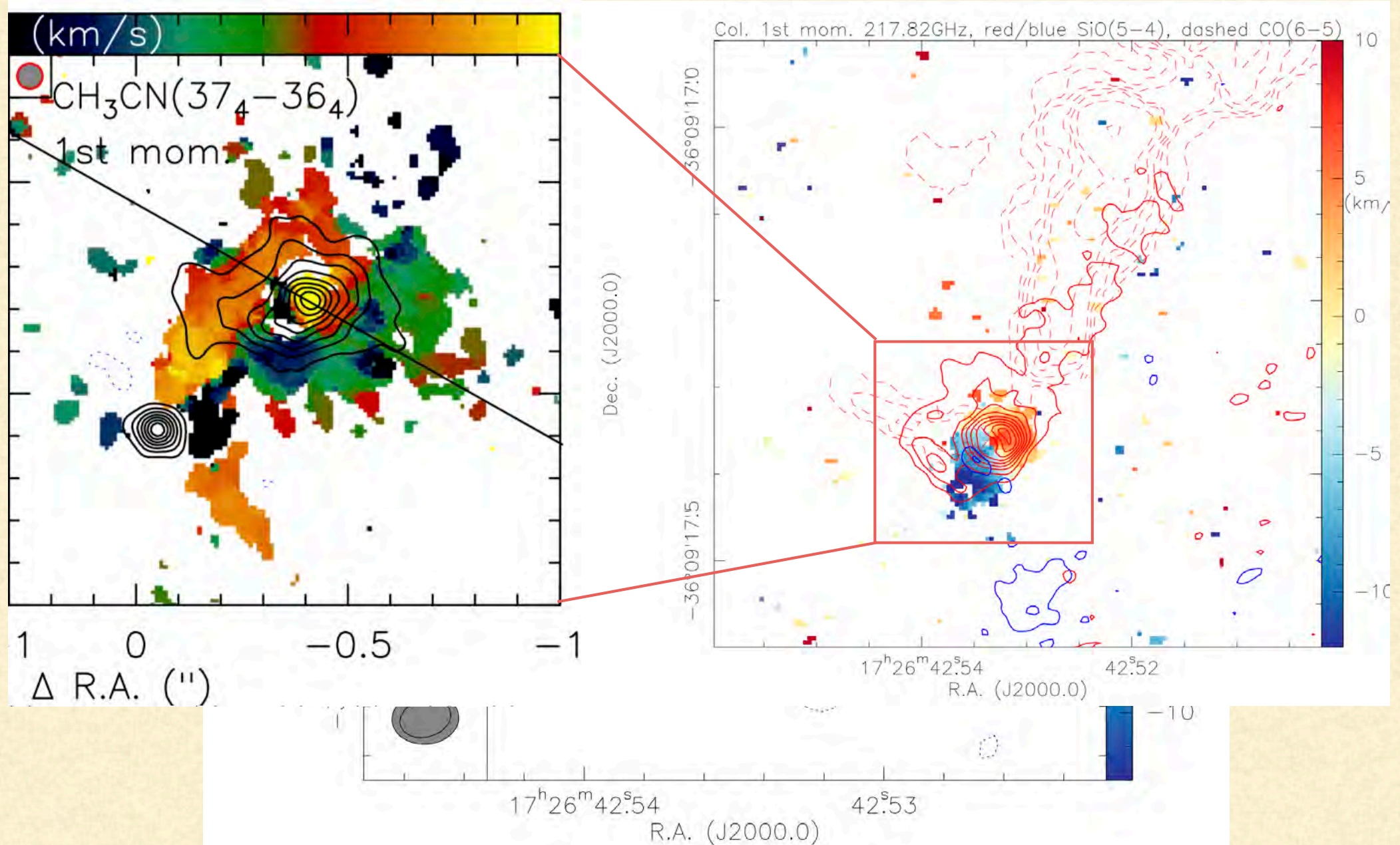


# Gas velocities



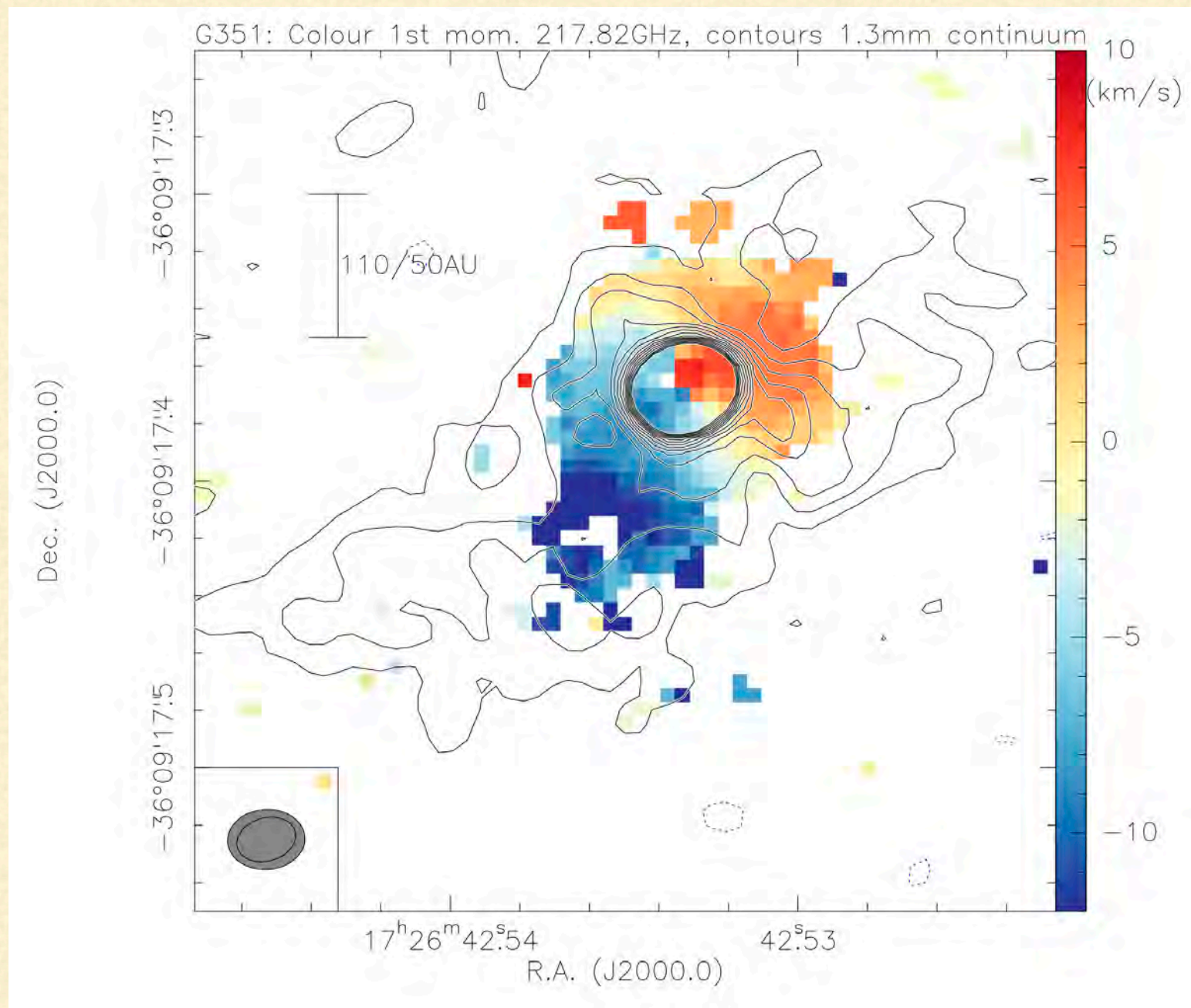


# Gas velocities





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# Summary

- Keplerian disks for O-type stars still difficult, but early examples exist
- Accretion seems an episodic process, also visible in jets
- Jet-ionization degree is low, outflows rather isothermal
- Magnetic fields in toroids and envelopes, not yet in disks
- Regions split up on sub-1000AU scales
  - > disks seem often to be very small
  - > can be fed from the larger-scale reservoir by filaments

**—> more statistical studies needed!**