ALMA reveals a candidate to hot accretion disk around the O-type protostar IRAS 16547-4247

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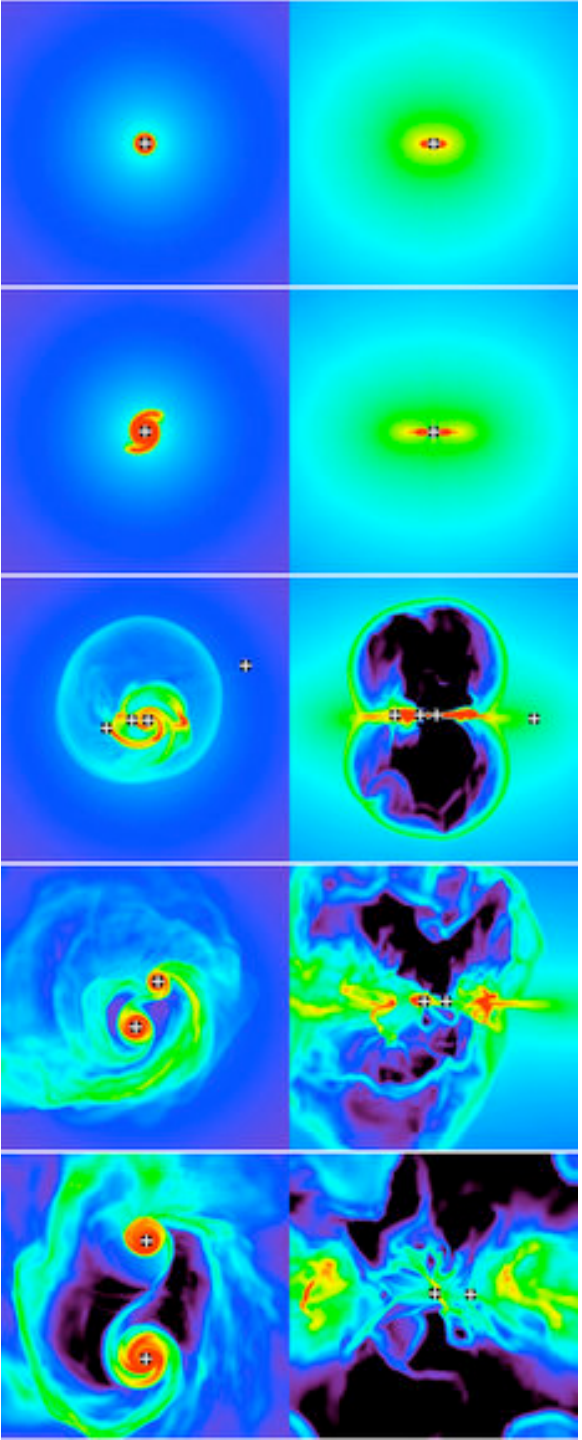
Two modes for the massive star formation.

-> Throughout disks and outflows as low mass stars.

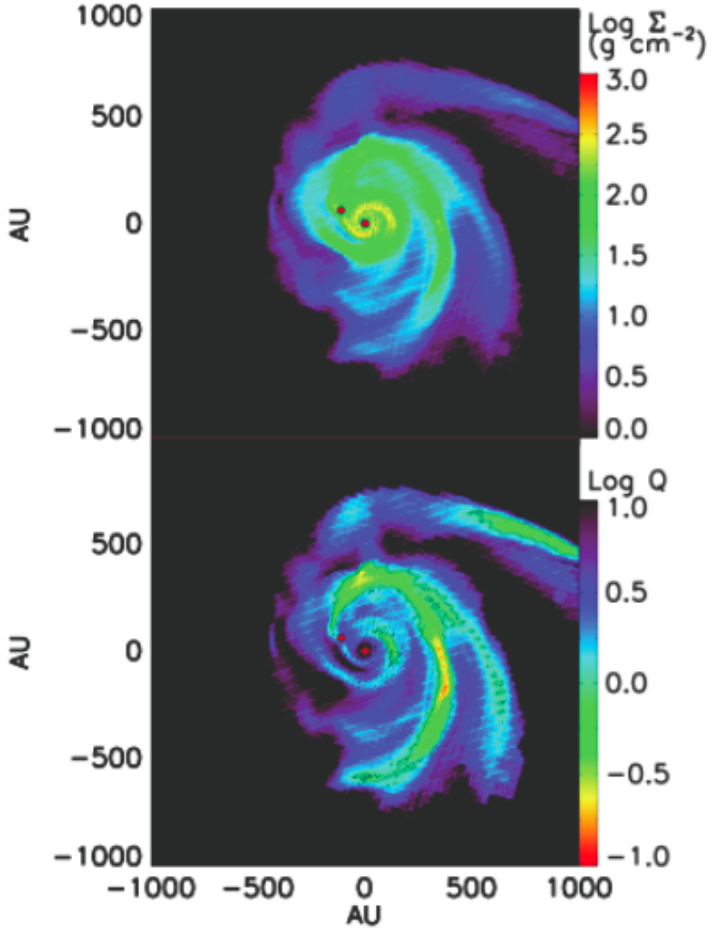
-> Mergers of low- and intermediate- mass young stars in dense clusters.

-> or both… (e.g. Orion KL)



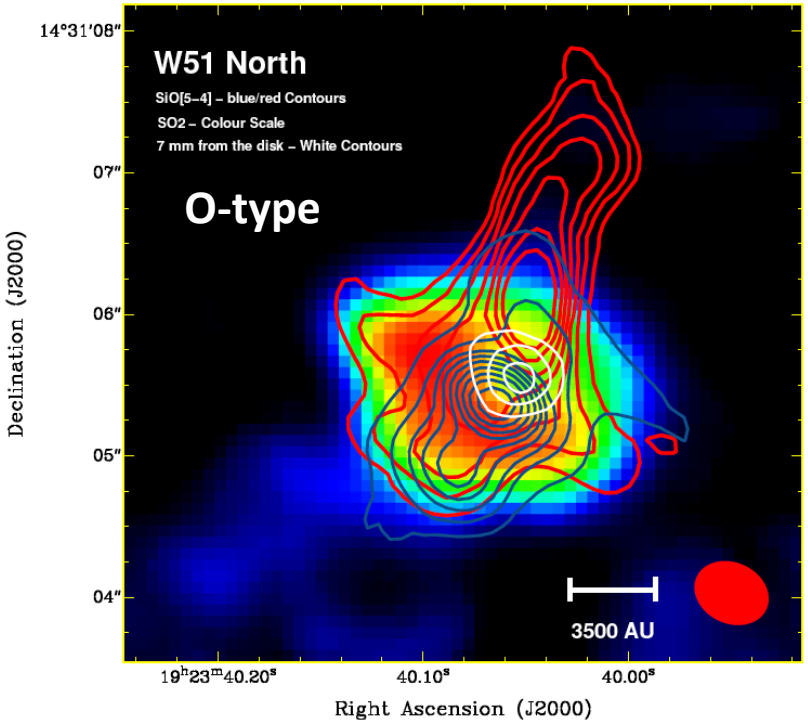
MHD simulations
Disks around high-mass stars

Krumholz et al. (2009)
Kuiper et al. (2010)
Peters et al. (2010)

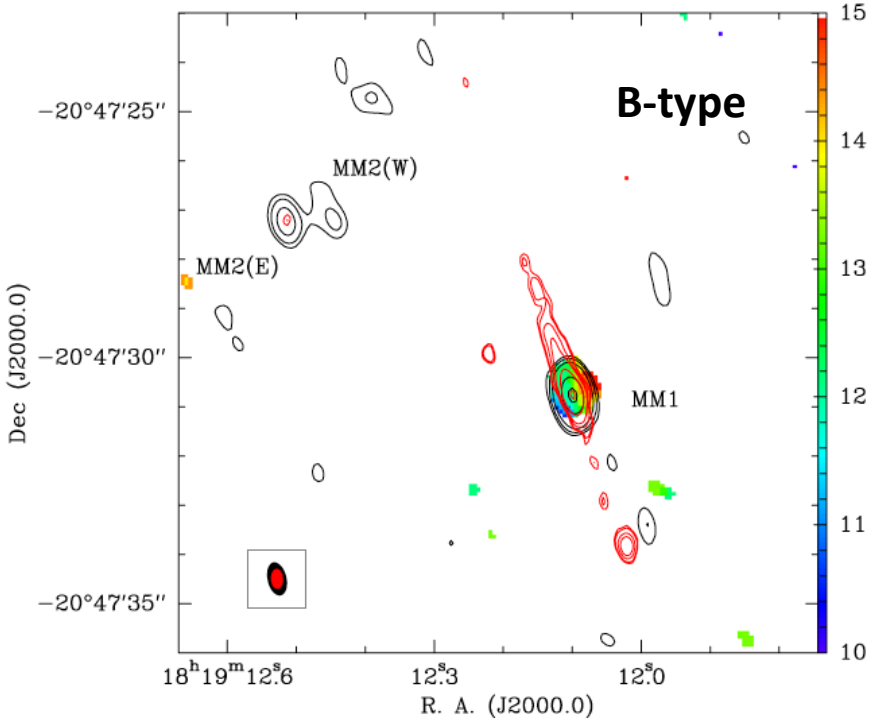


Note the sizes of the massive disks

Some observational cases of disks around massive stars



Zapata et al. (2009)
Zapata, Tang and Leurini (2011)
Goddi et al. (2015)

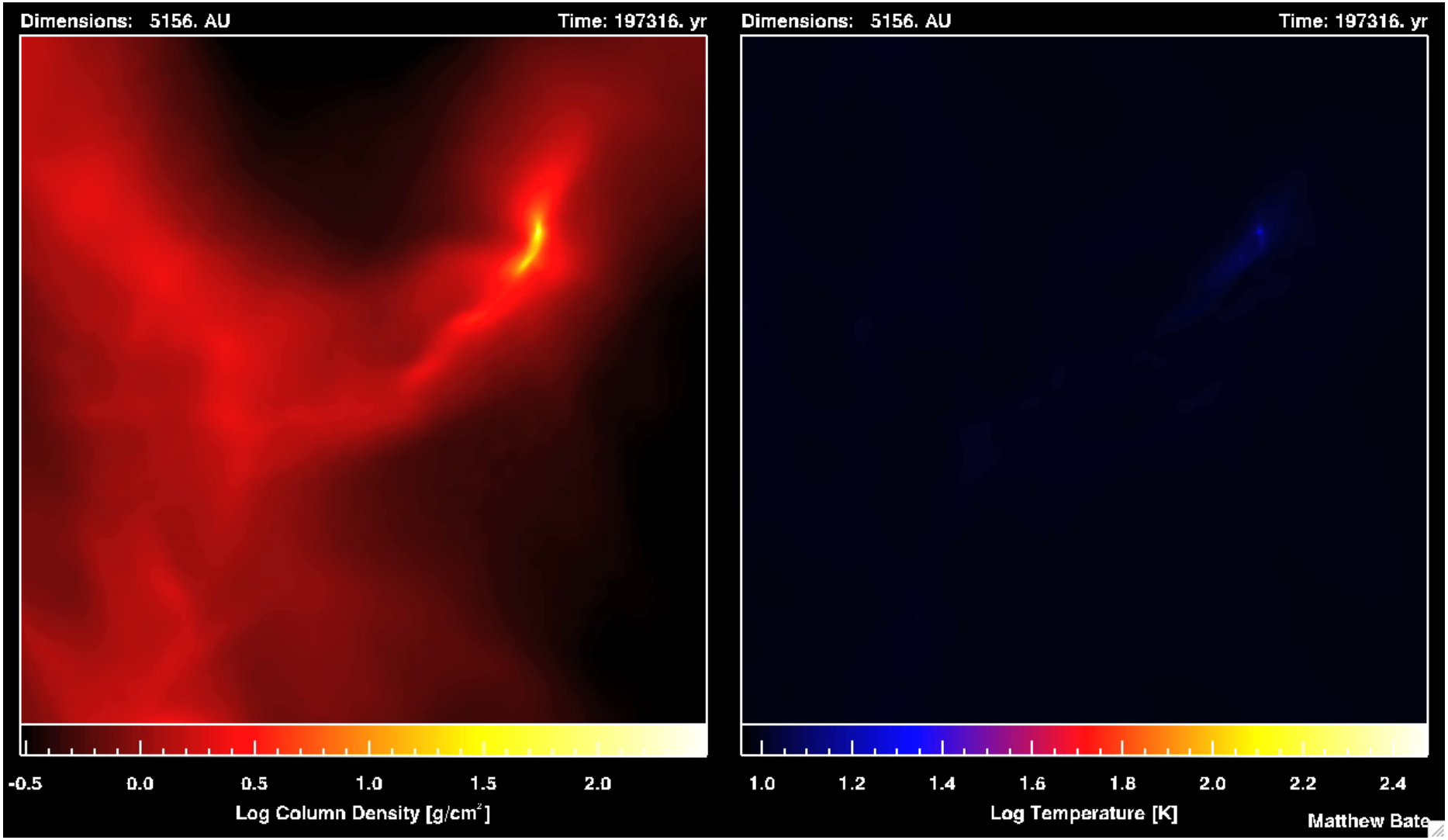


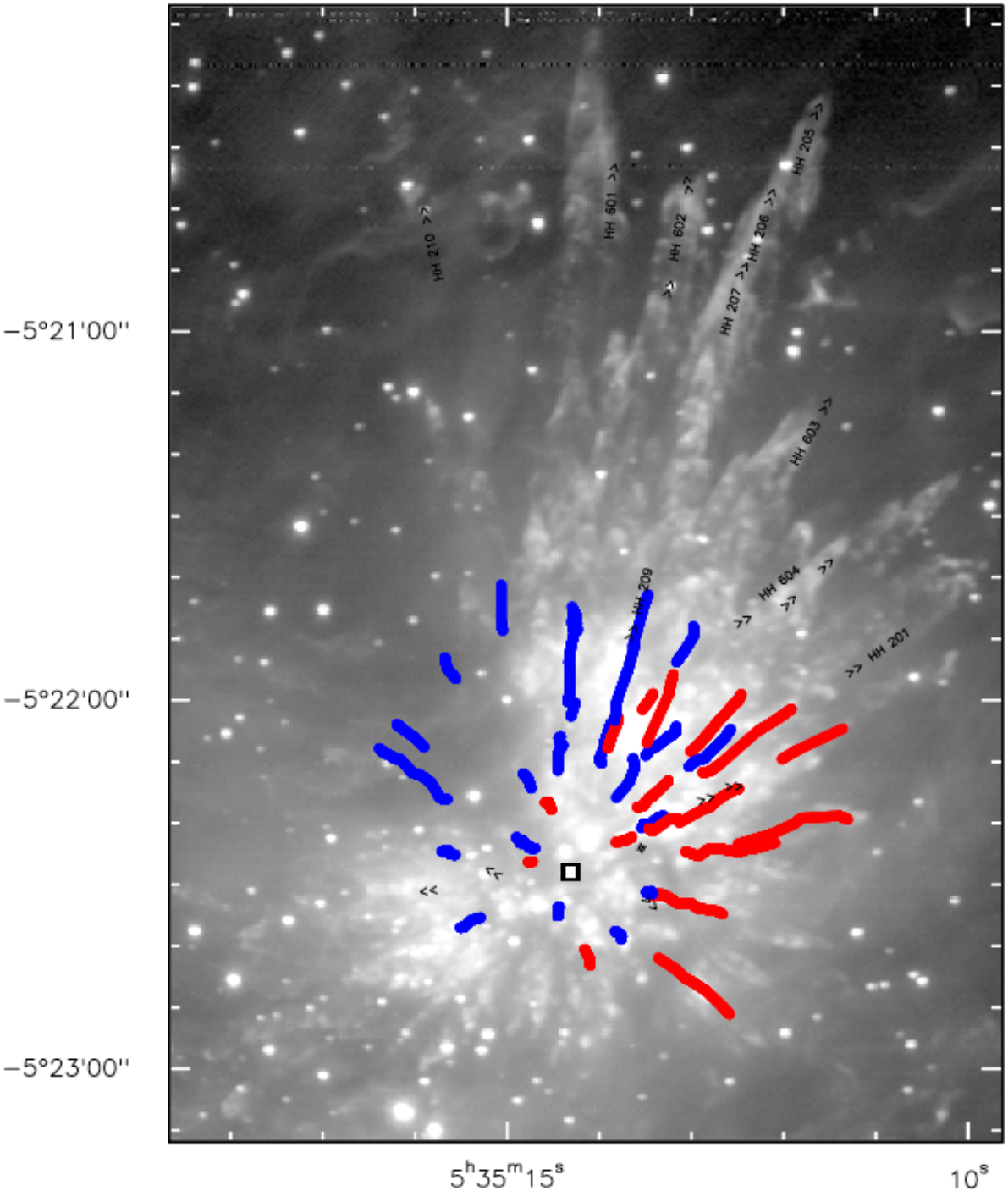
Fernández-López et al. (2011)
Carrasco-González et al. (2014)
Girart et al.
Qiu, Zhang et al.

Mergers of low- and intermediate- mass young stars in dense clusters.

MHD Simulations

Ian Bonnell, Matthew Bate, et al.

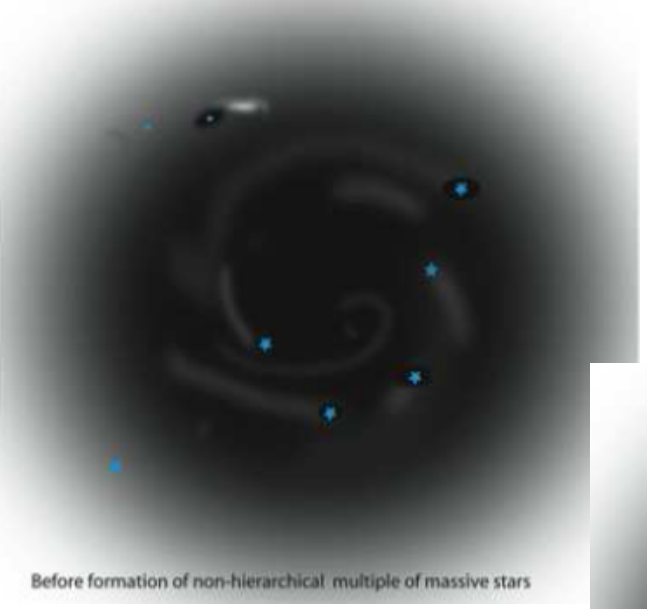


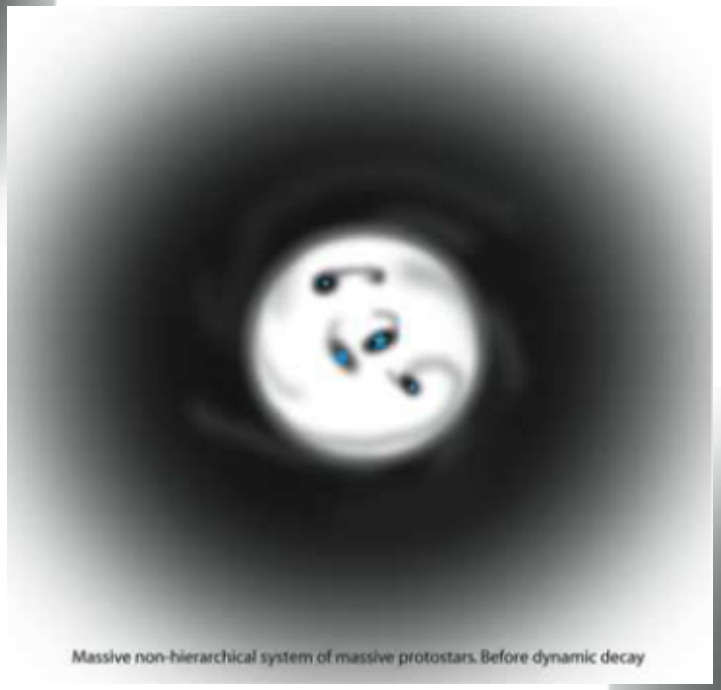


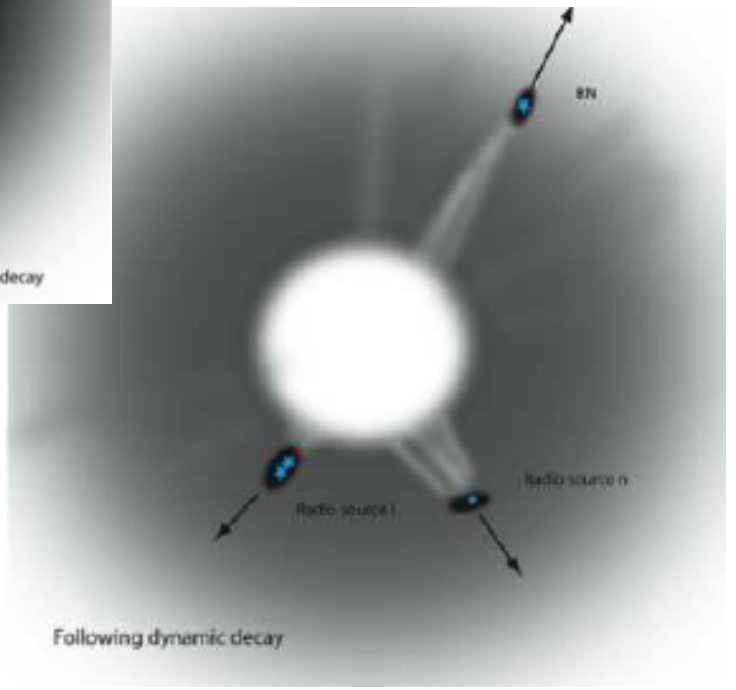
Merge of massive protostars?

Zapata et al. (2009)

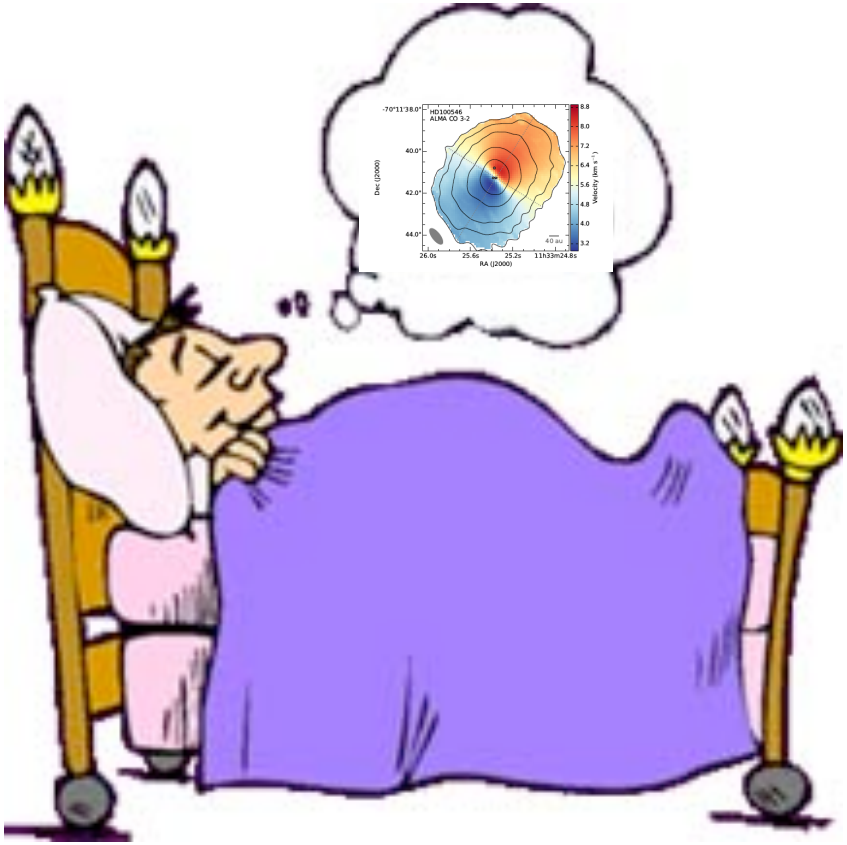
Mergers…





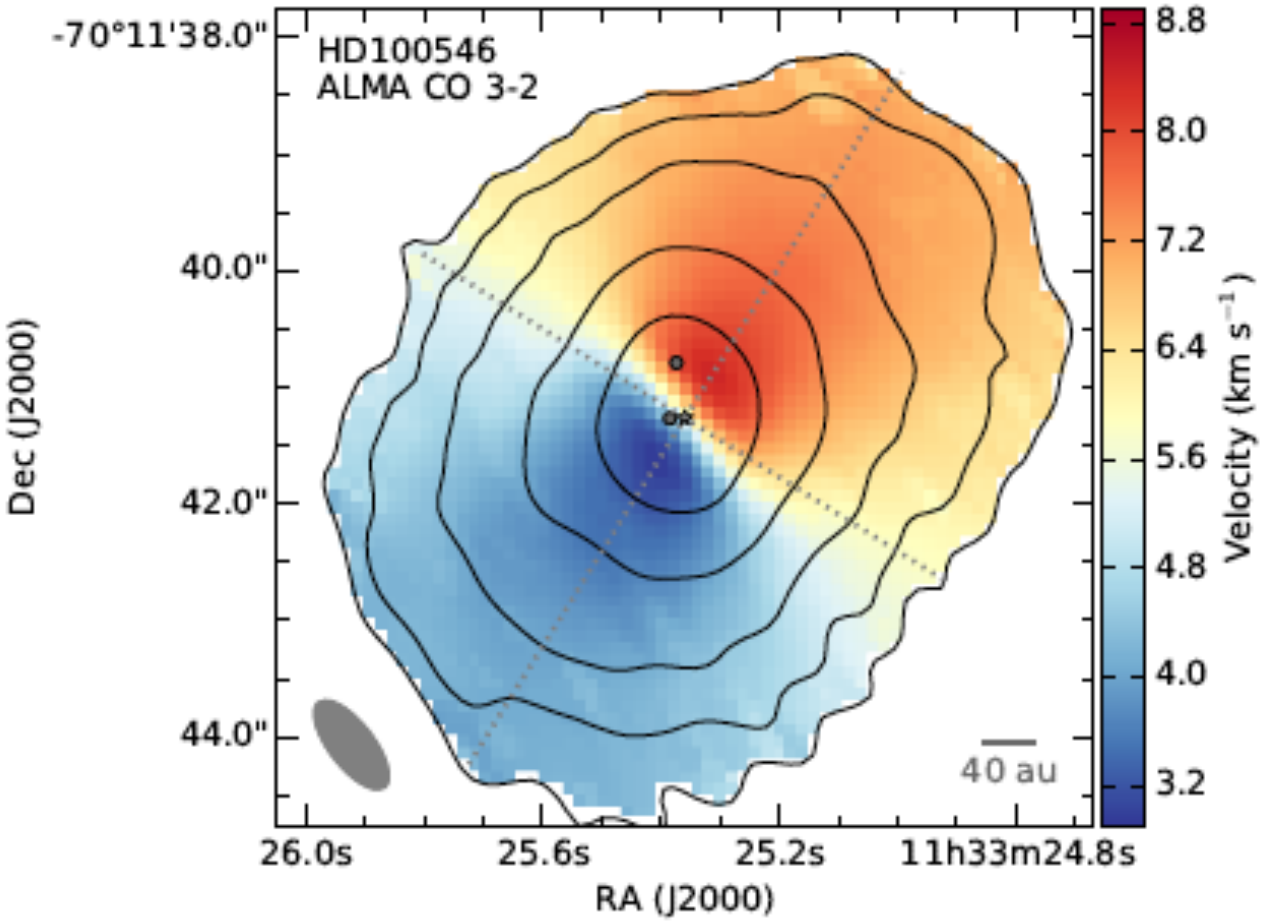


Bally and Zinnecker (2005); Reipurth (2000)



What we are looking for?

Our dreams about disks around massive stars...



Pineda et al. (2014)

Pineda et al. (2014)

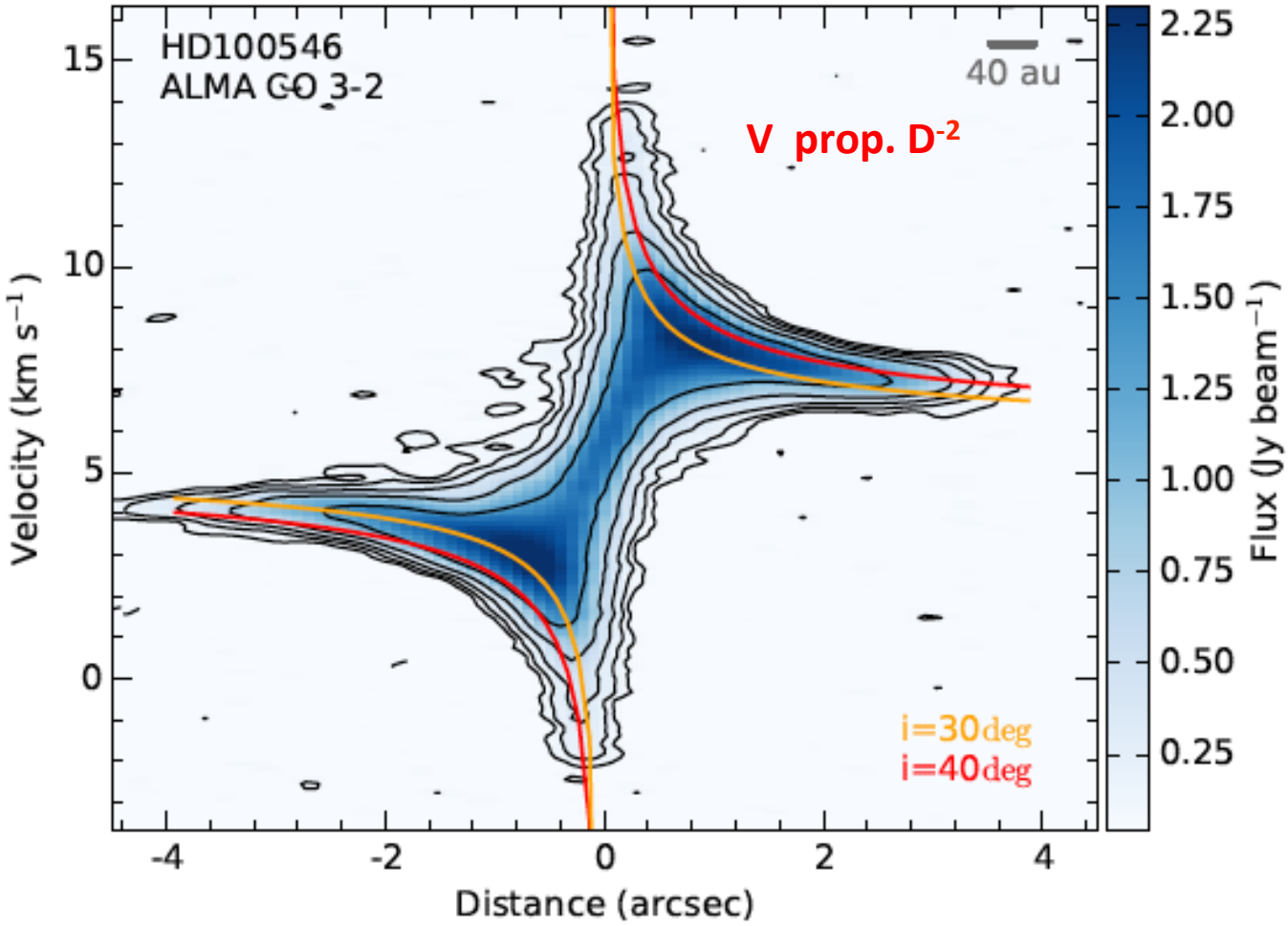
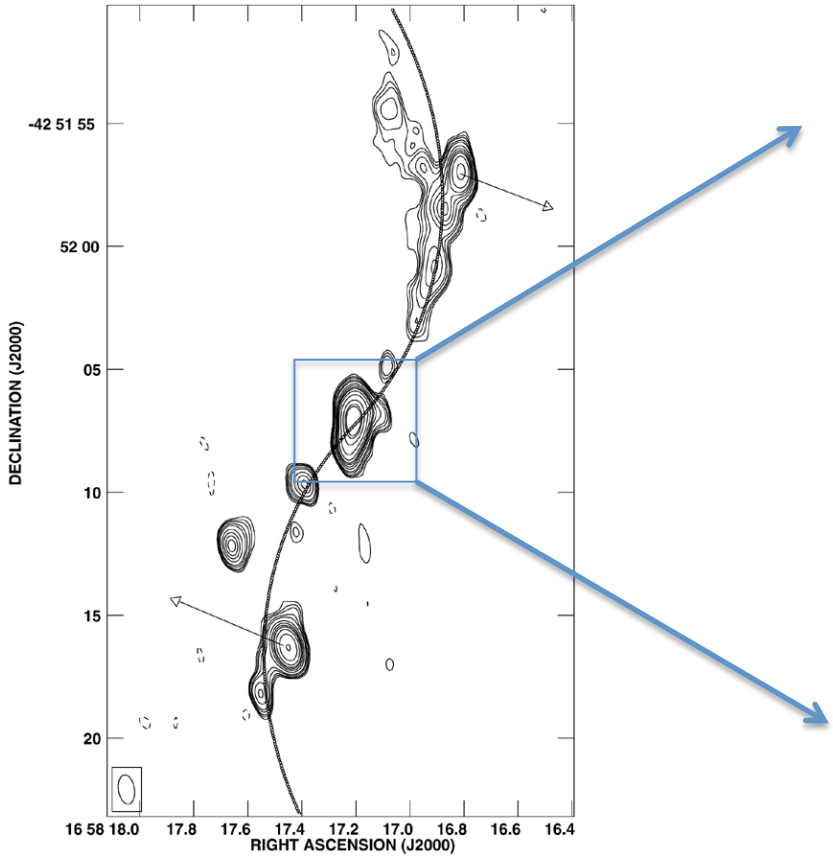


FIG. 4.— PV diagram of CO (3–2) along the major axis shown in Fig. 3. Contours are shown at [3,6,12,24,48,96]×rms, where rms is 27 mJy beam^{-1} per channel. Negative contours are shown by dashed lines. Orange and red curves show the expected keplerian velocity for a central star of 2.4 $M_\odot$ and inclination angle of 30° and 40°, respectively. See Section 4.4 for discussion.

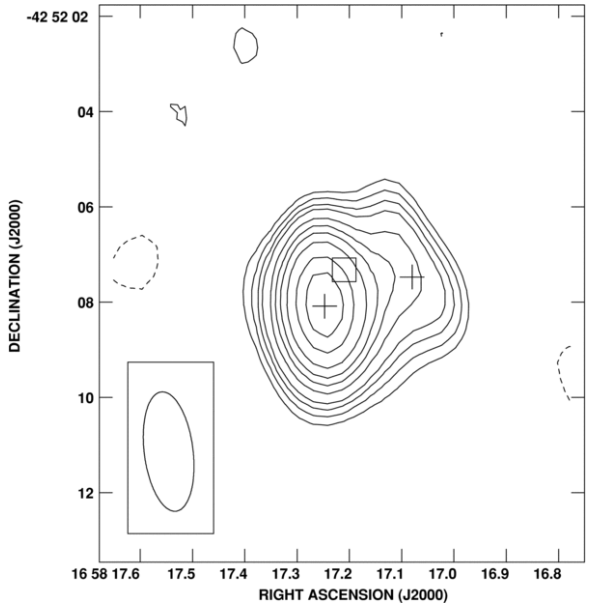
IRAS 16547-4247: A young O-type Star.

At a distance of 2.9 kpc, it has a bolometric luminosity of 6.2 x 10^4 L_{sun} , equivalent to that of a single O8 zero-age main-sequence star.

VLA – 3.6 cm



SMA – 1.3 mm

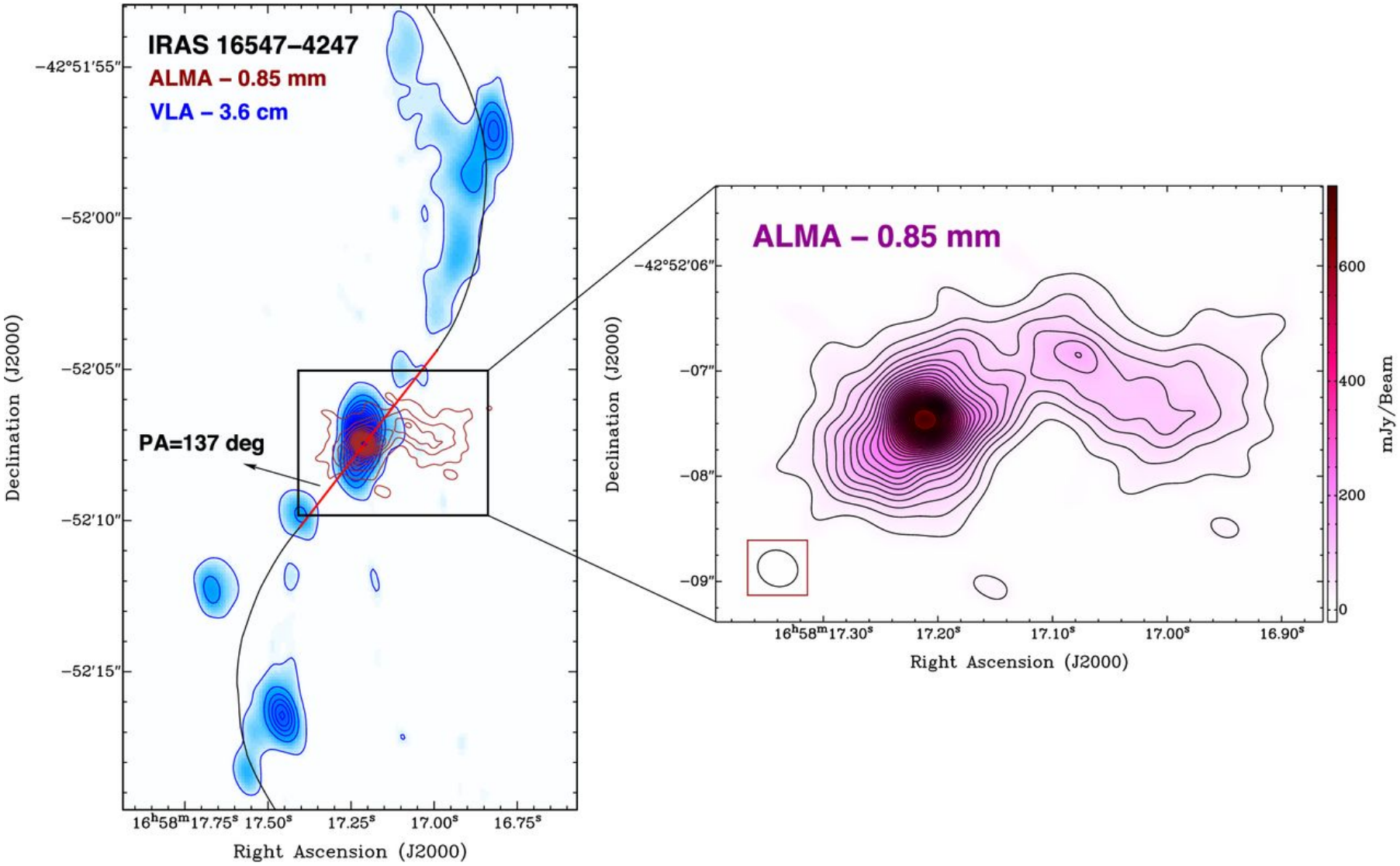


Rodríguez et al. (2005)
Franco-Hernandez et al. (2009)

ALMA – Atacama Larger Millimeter Array Telescope → Chile

66 Antenna Array

IRAS 16547- ALMA



Detected spectral lines in IRAS 16547

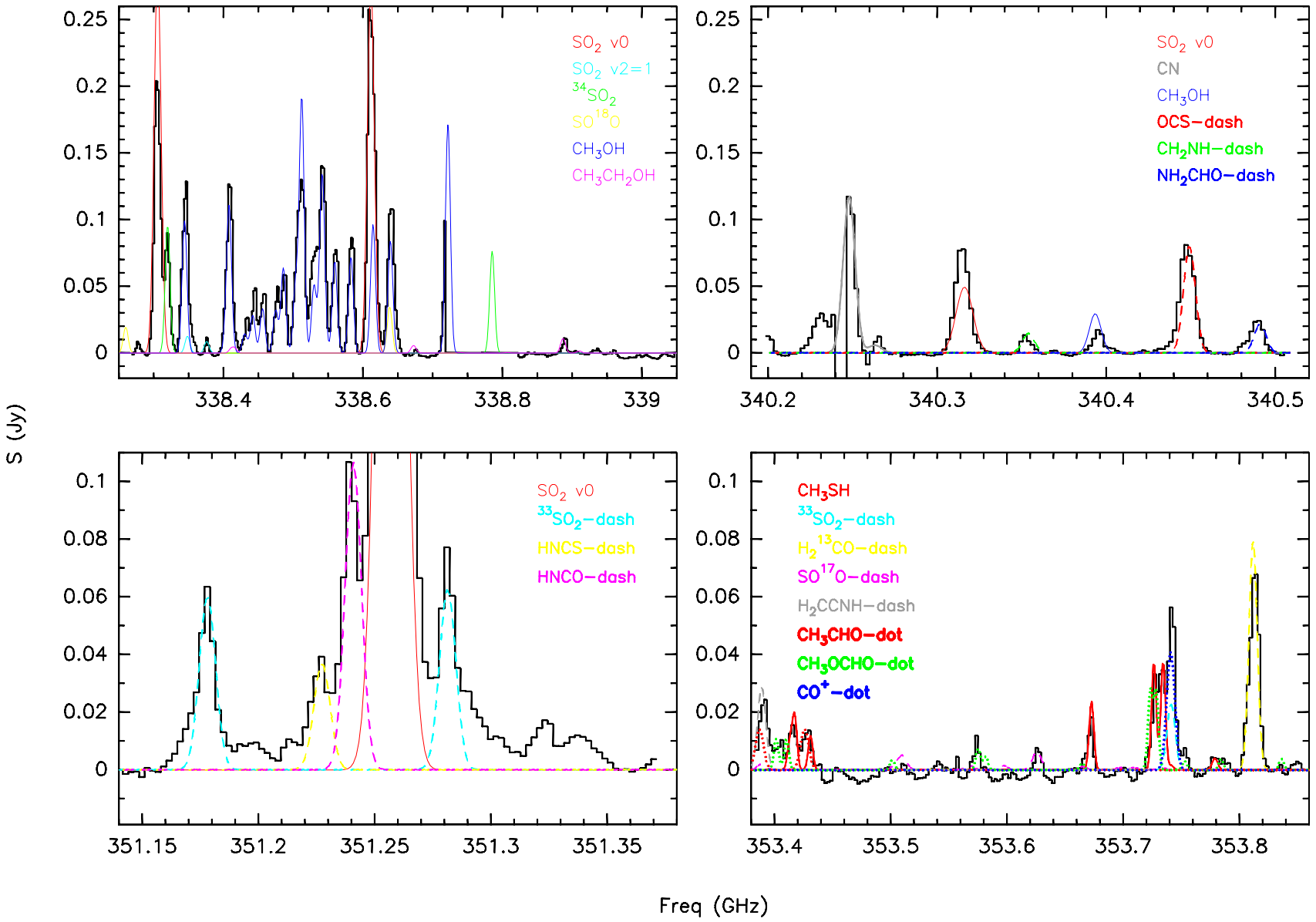
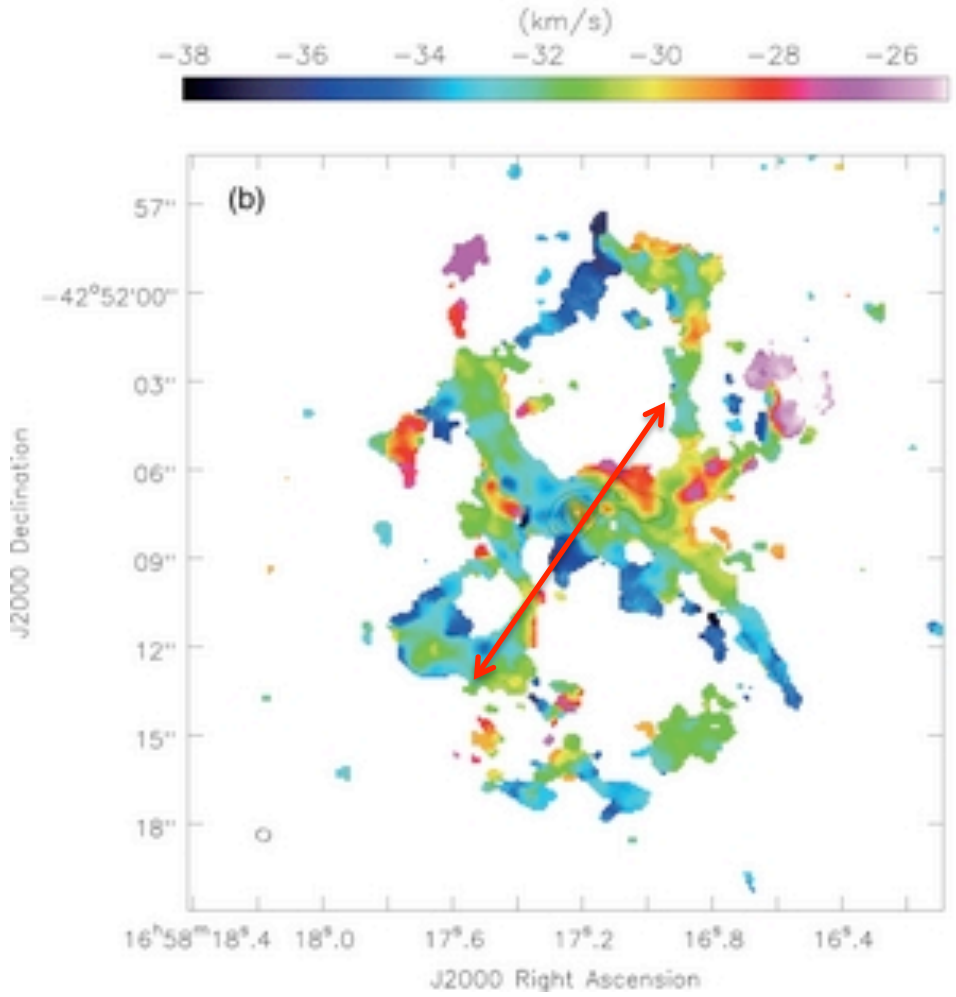


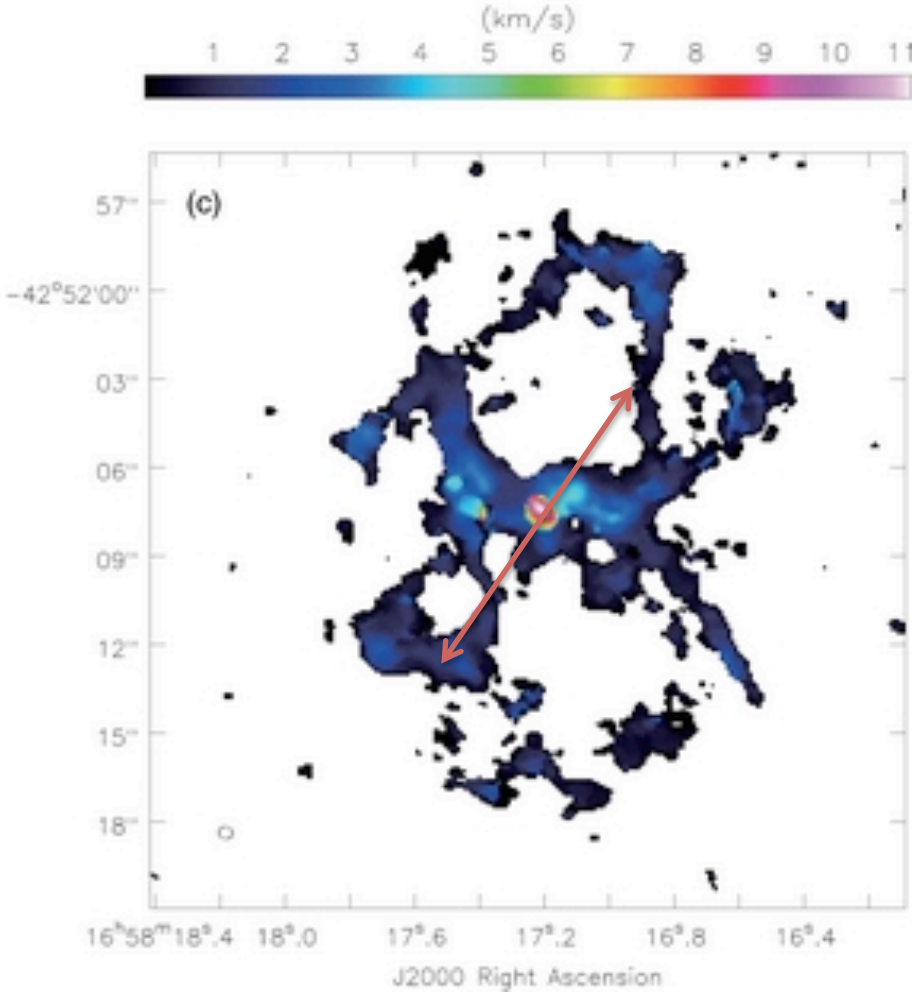
Table 1. Transitions detected toward IRAS 16547

Molecule	Transition	Rest Freq. (GHz)	$S_{ij}{}^1\mu^2$ (D^2)	E_u (K)
SO_2 v=0	$18_{4,14}$–$18_{3,15}$	338.30599	26.81	197
	$20_{1,19}$–$19_{2,18}$	338.61181	26.02	199
	$28_{2,26}$–$28_{1,27}$	340.31641	32.05	392
	$5_{3,3}$–$4_{2,2}$	351.25722	7.32	36
SO_2 v_2=1	$4_{3,1}$–$3_{2,2}$	338.34874	7.07	792
	$8_{2,6}$–$7_{1,7}$	338.37638	5.09	803
$^{34}SO_2$ v=0	$13_{2,12}$–$12_{1,11}$	338.32036	13.59	93
$^{33}SO_2$ v=0	$8_{4,4}$–$8_{3,5}$, F=19/2–19/2	351.17796	11.16	73
	$9_{4,6}$–$9_{3,7}$, F=21/2–21/2	351.28137	12.88	81
	$19_{4,16}$–$19_{3,17}$, F=41/2–41/2	353.74156	25.37	217
$SO^{18}O$	$20_{0,20}$–$19_{1,19}$	338.63882	43.41	184
OCS	28–27	340.44927	14.32	237
HNCS *a*-type	$30_{1,30}$–$29_{1,29}$	351.22743	80.60	324
$SO^{17}O$	$20_{1,20}$–$19_{0,19}$	353.62533	263.56	186
CH_3SH	14_{13}–13_{13} −/+A	353.41736	3.32	864
	14_{13}–13_{13} E	353.43107	3.33	863
	14_{9}–13_{9} −/+A	353.67282	14.10	479
	14_{2}–13_{2} −A	353.72626	23.60	147
	14_{8}–13_{8} −/+A	353.73446	16.20	406
	14_{8}–13_{8} E	353.74153	16.27	408
	14_{7}–13_{7} E	353.77778	18.11	341
	14_{-7}–13_{-7} E	353.78050	18.11	342

Three classes of the line emission depending on the excitation temperature in the upper levels.

CH_3OH -- ALMA

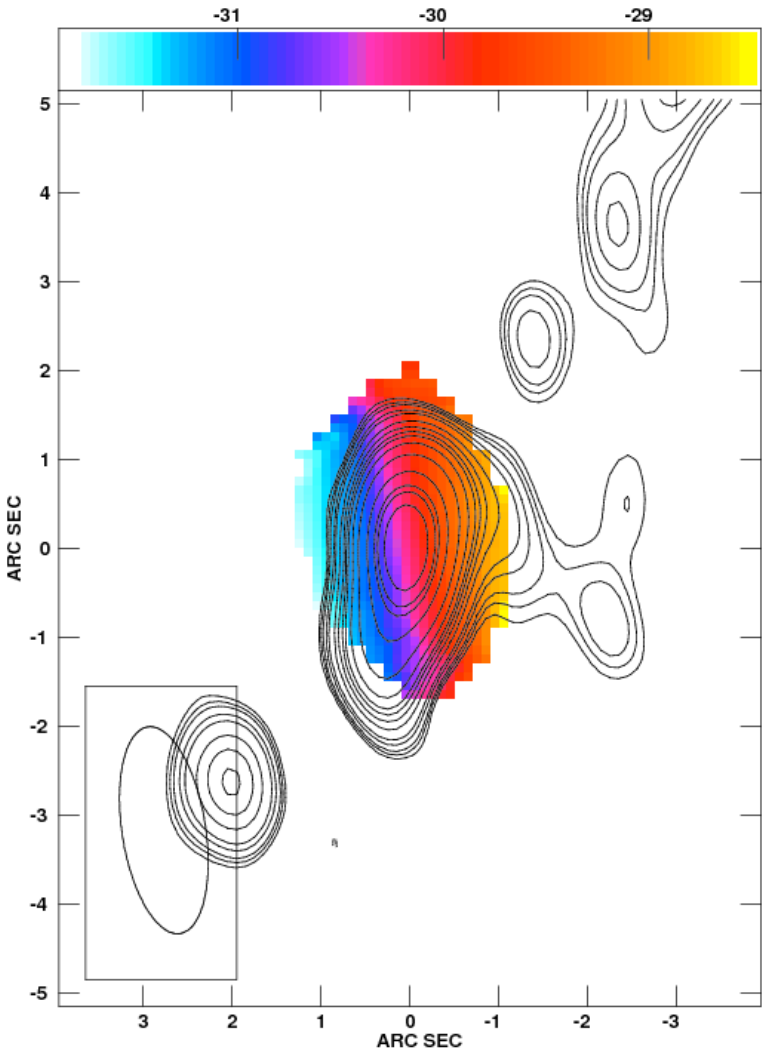




Higuchi et al. (2014)

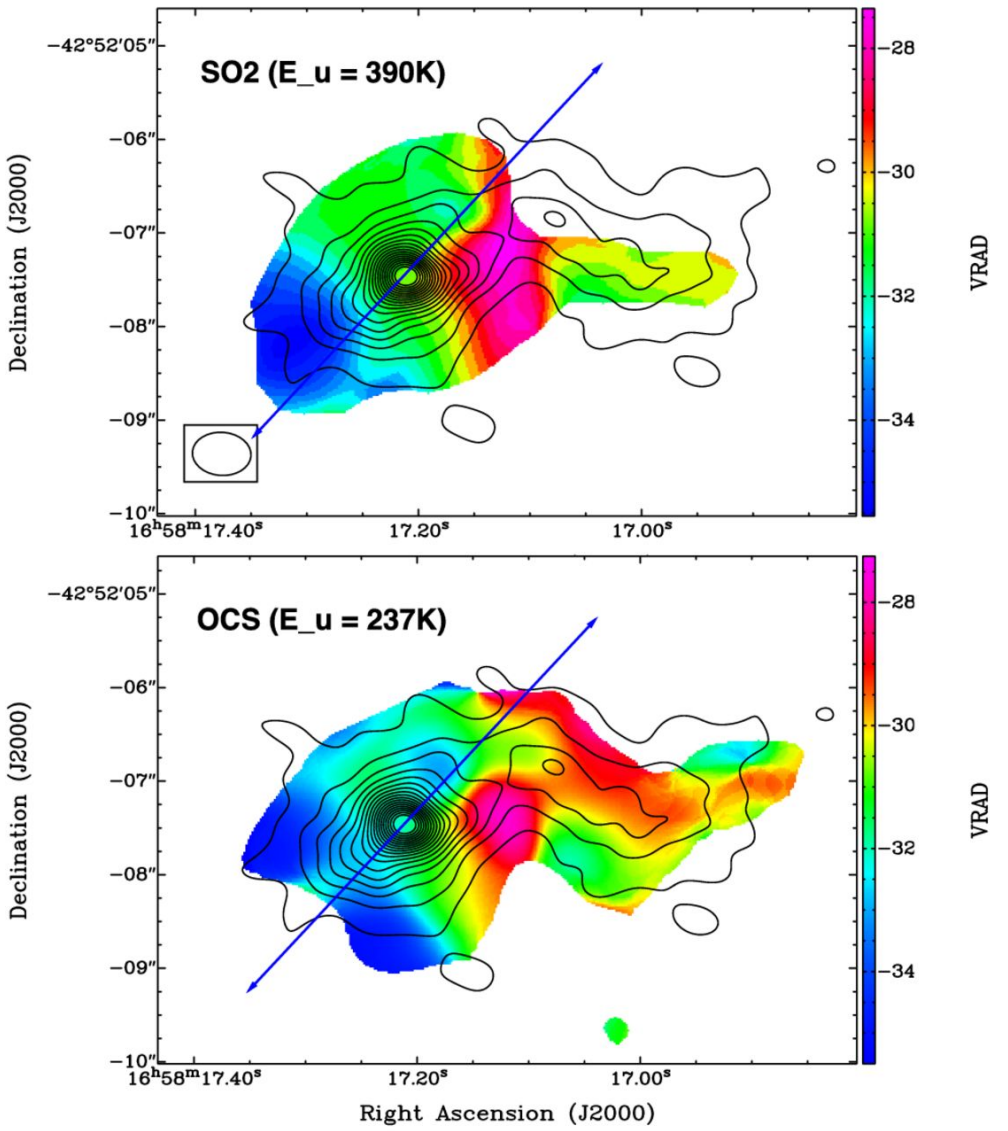
Low temperatures in the upper levels (about 100 K)

SO_2 -- SMA



Franco-Hernandez et al. (2009)

SO_2 / OCS -- ALMA

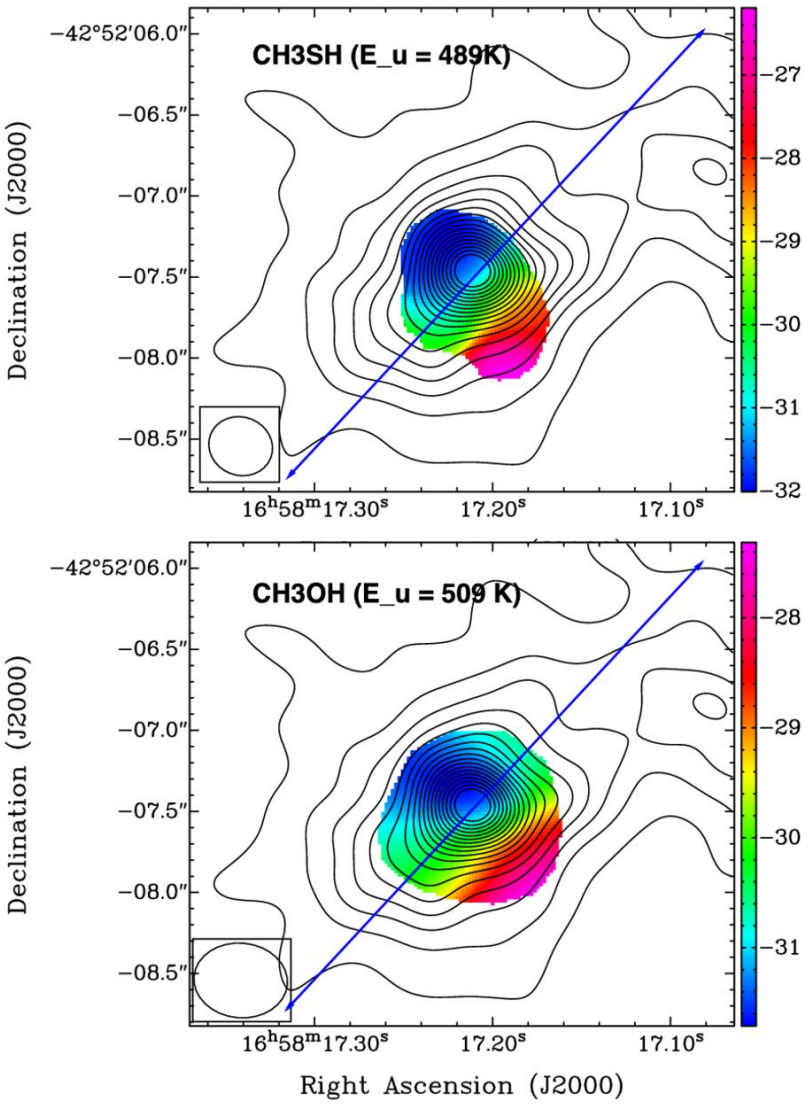


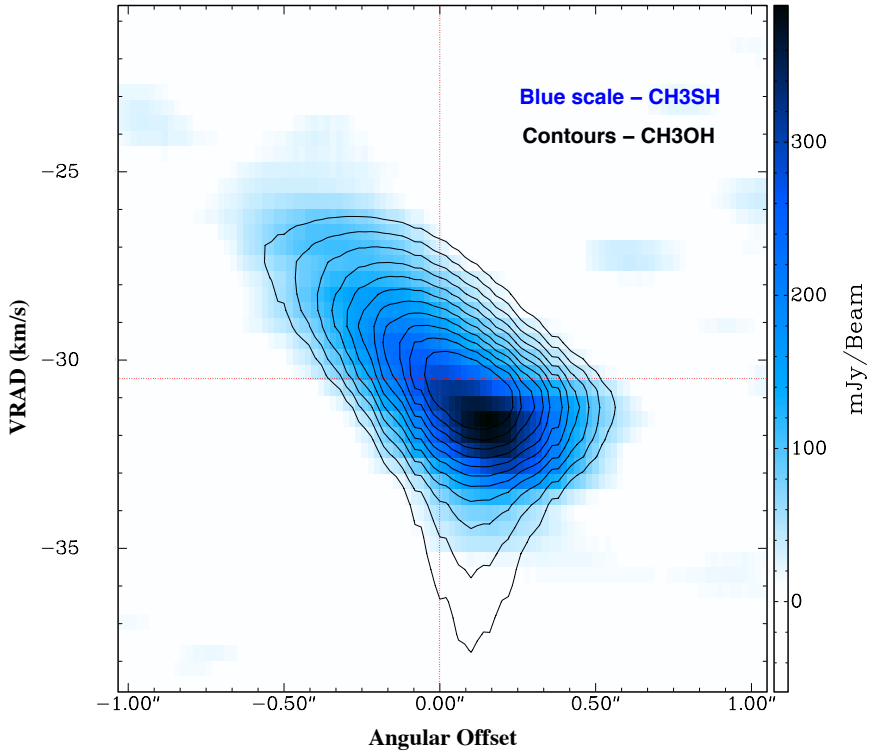
Temperatures in the upper levels (about 200 K)

Candidate to Rotating Disk around an O-type (proto)star

IRAS 16547

Size of the disk about 1000 AU





Temperatures in the upper levels (about > 400 K)

Candidate to Rotating Disk around an O-type (proto)star

Pros:

1. Very compact rotating molecular structure (about 1000 AU)
2. Elongated perpendicular to the radio jet and molecular outflow
3. Traced by highly excited complex molecules

Cons:

1. No Keplerian motions at all in the innermost parts