Multi-directional, non-steady mass-accretion onto high-mass protostars

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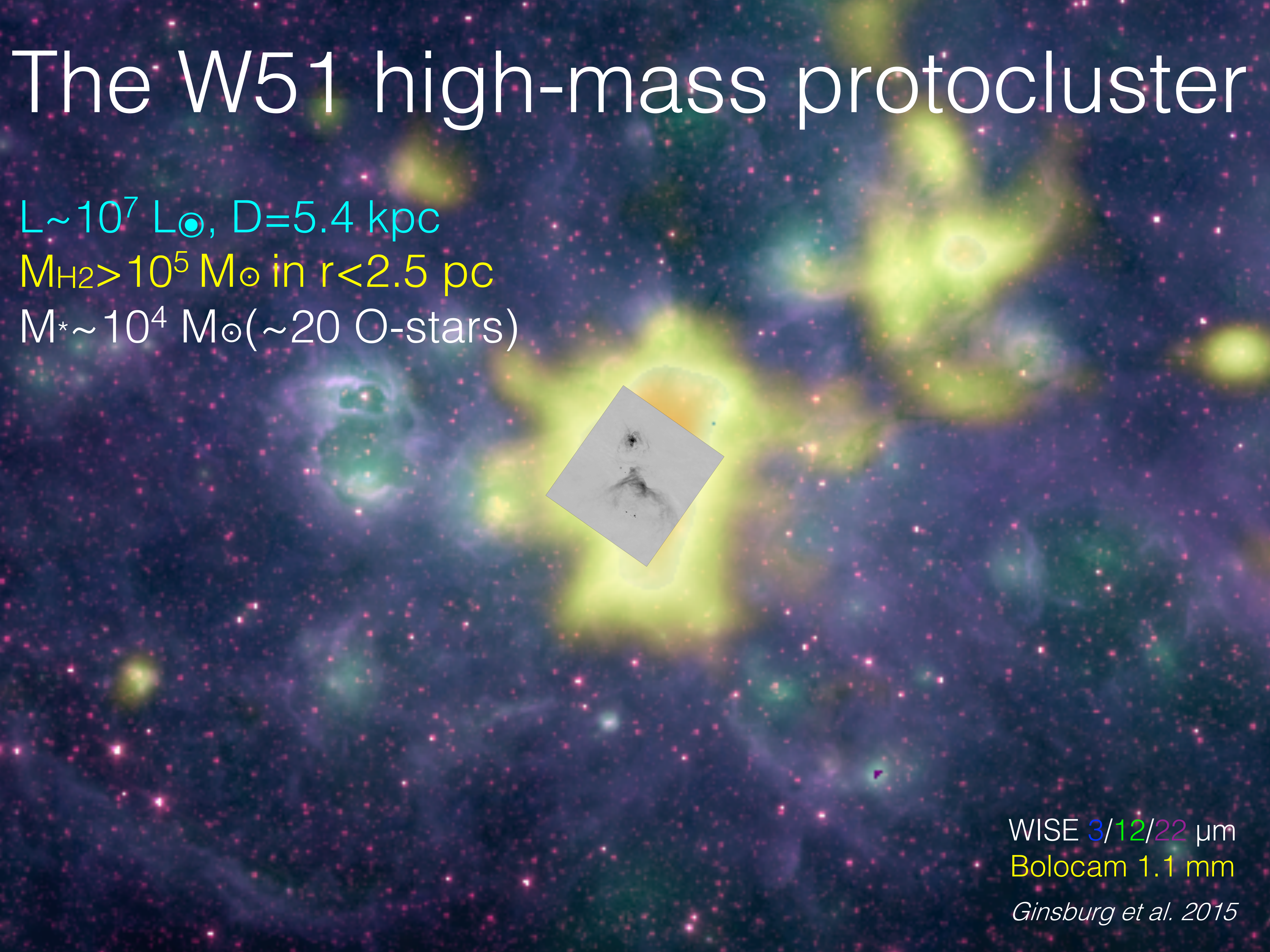
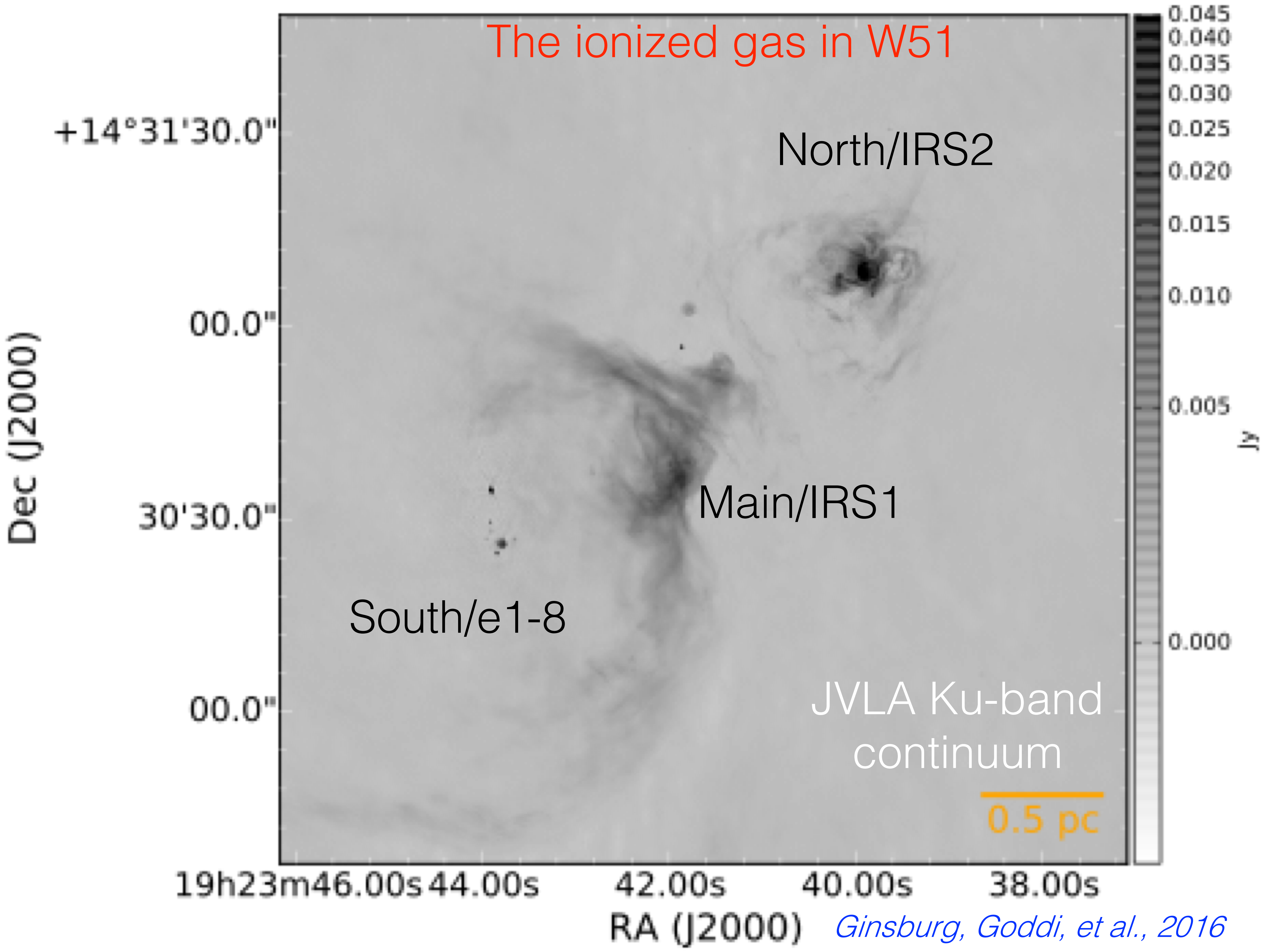
Open Questions

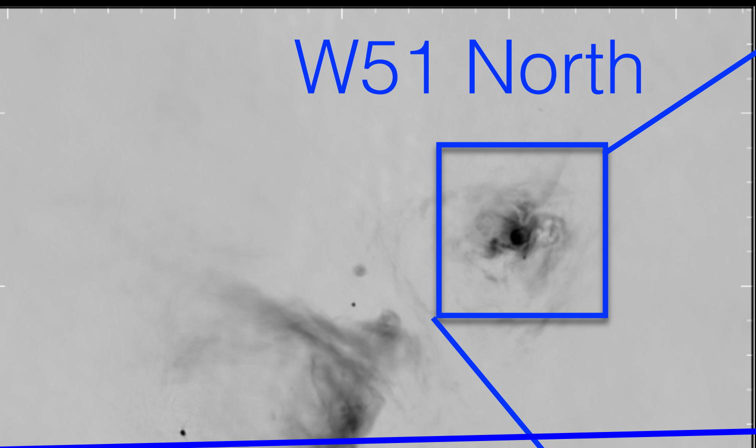
1. Does the feedback from O-type YSOs halt SF?
2. Do "switched-on" O-stars keep accreting?
3. Do proto-O-stars accrete their mass via disks?

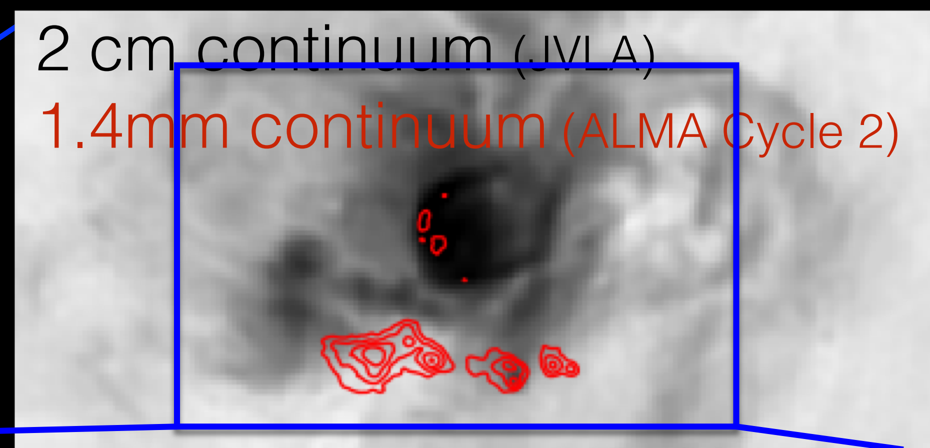
The W51 high-mass protocluster

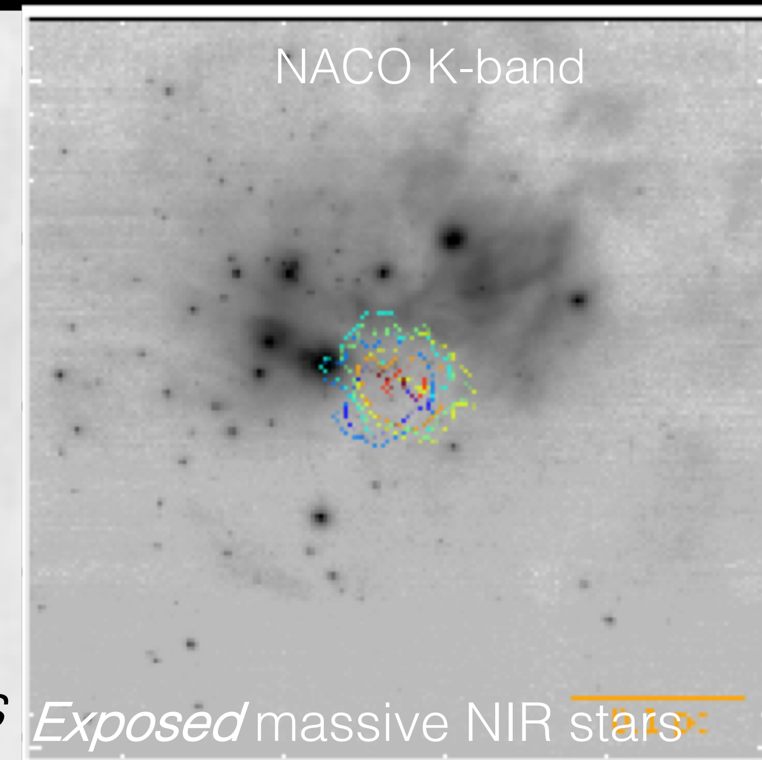



The ionized gas in W51
North/IRS2
Main/IRS1
South/e1-8
JVLA Ku-band continuum
0.5 pc
+14°31'30.0"
00.0"
30'30.0"
00.0"
Dec (J2000)
19h23m46.00s
44.00s
42.00s
40.00s
38.00s
RA (J2000)
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Jy
Ginsburg, Goddi, et al., 2016

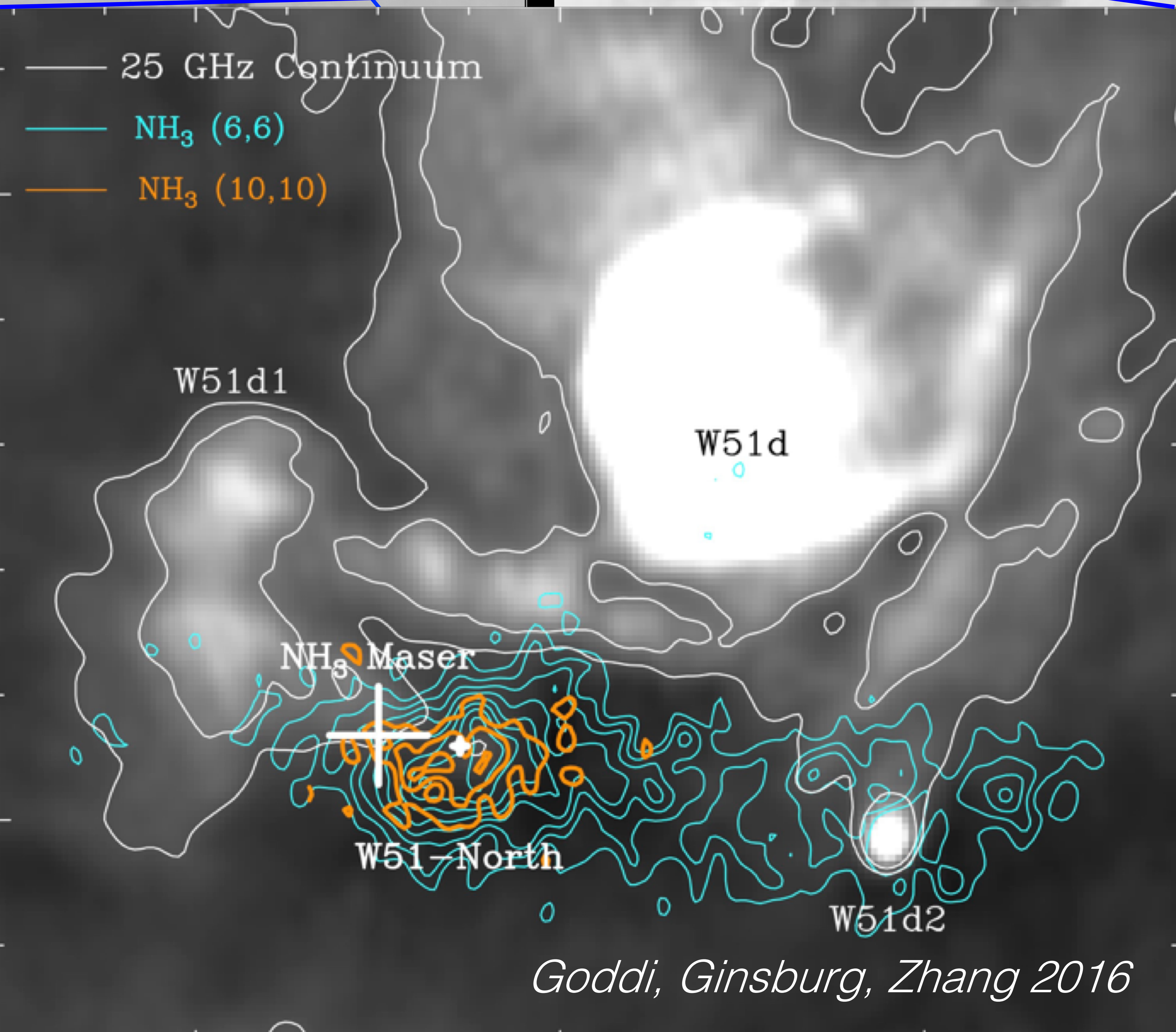
W51 North/IRS2







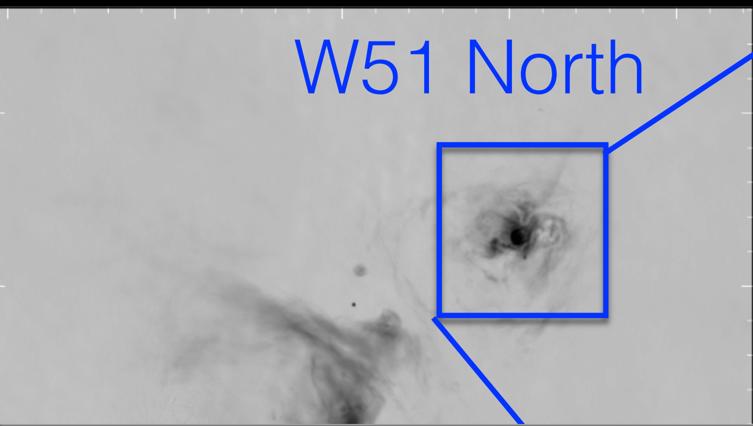
(Figuerêdo et al 2008)

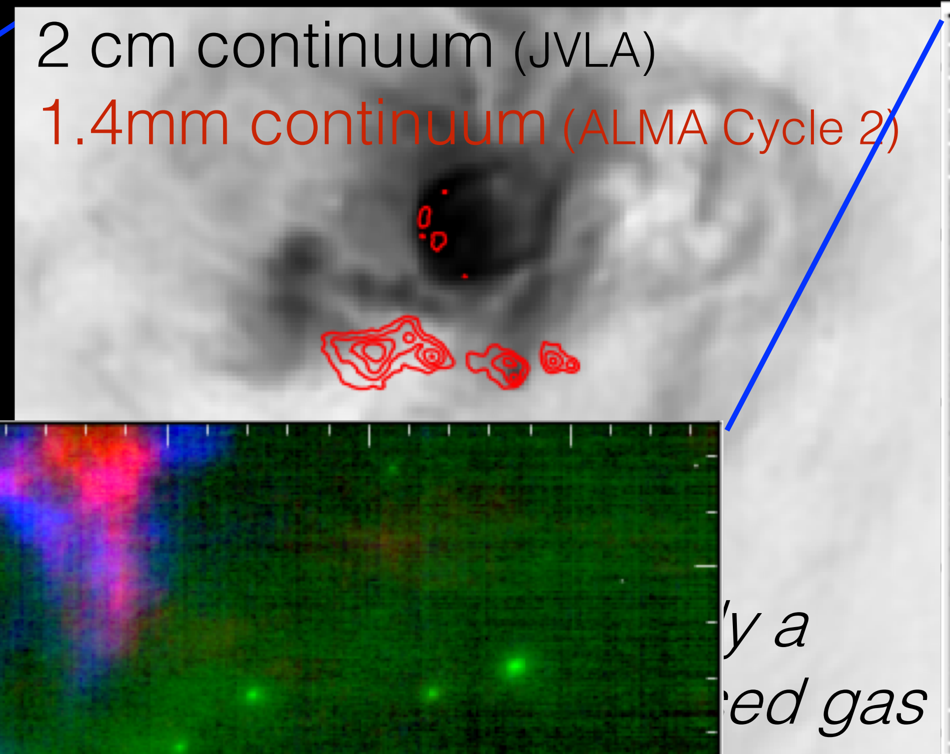


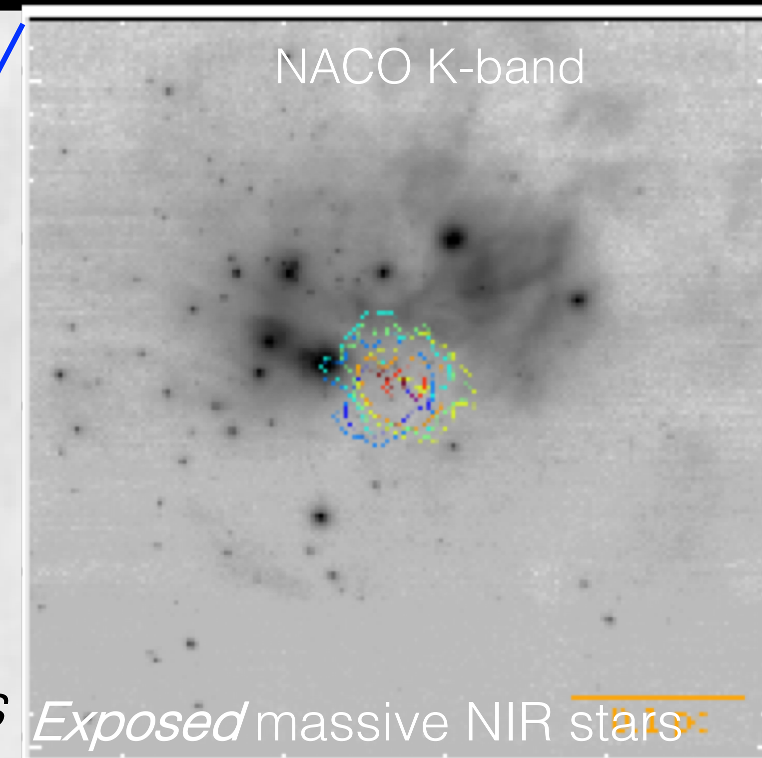
- **Cluster of** ***exposed*** massive NIR stars in the same region
- Extended HII regions, *pushing* the dense gas (and dust condensations)

=> Not much ongoing SF ?

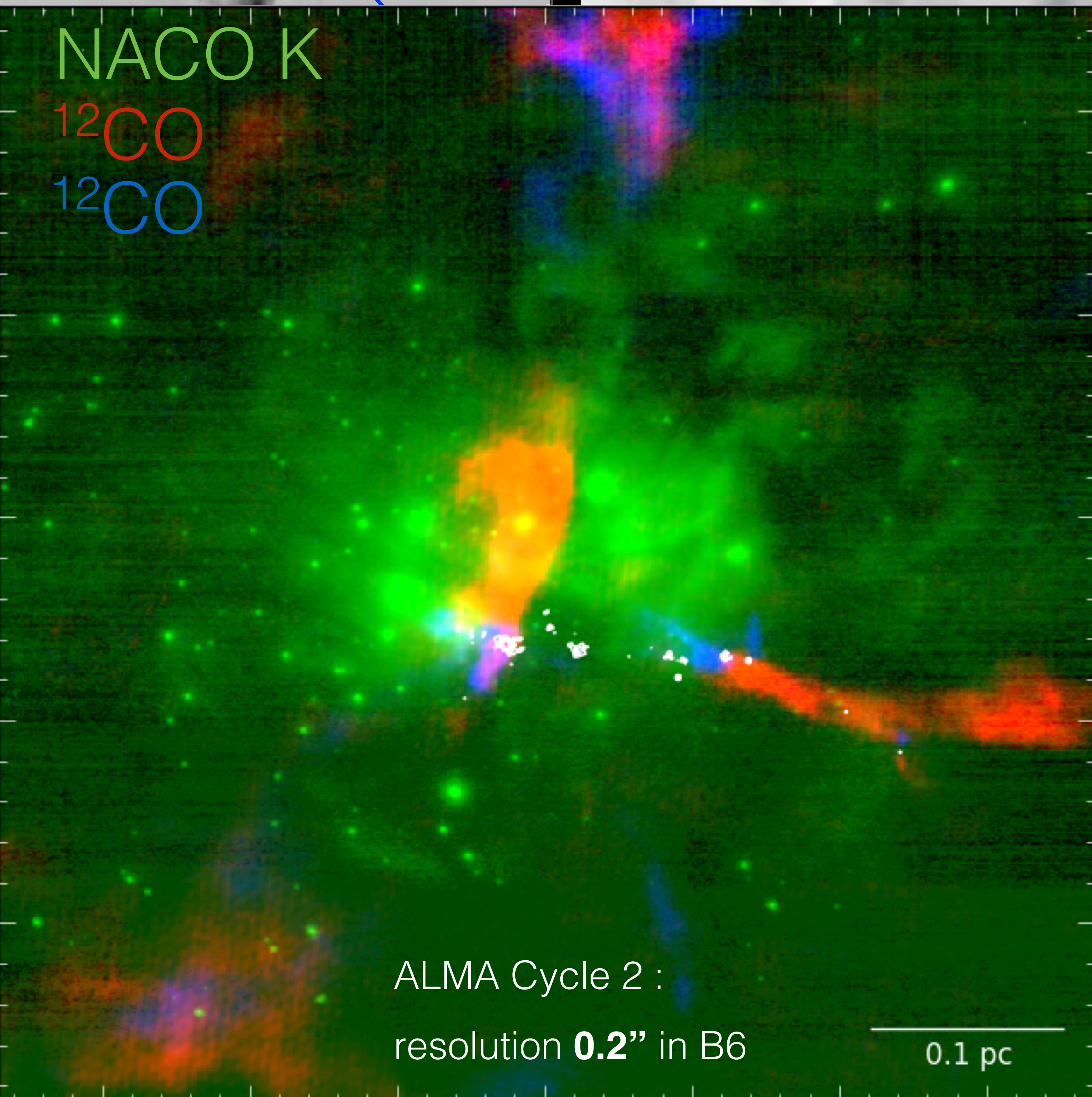
W51 North/IRS2





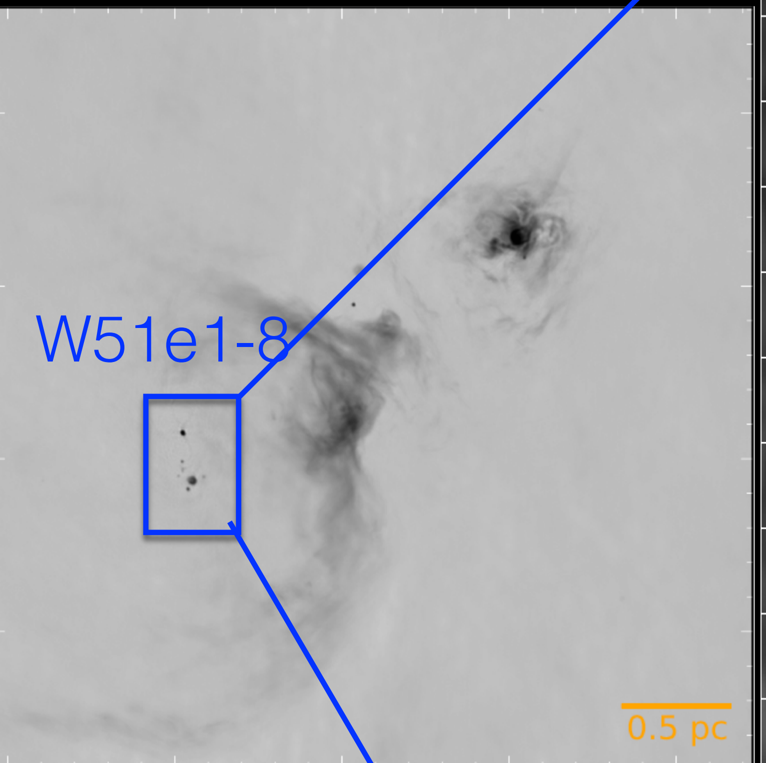


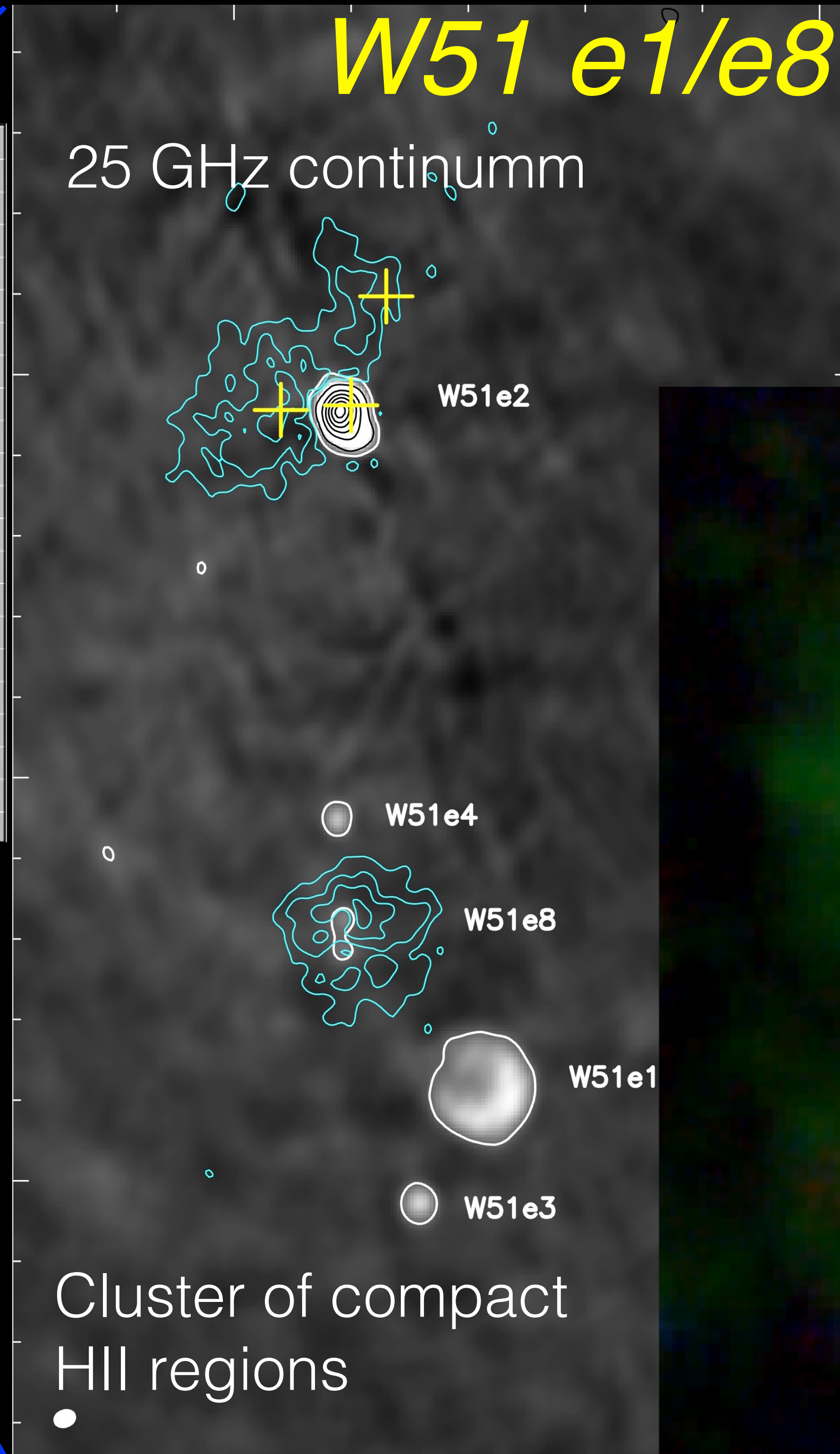
(Figuerêdo et al 2008)



ALMA identifies collimated outflows indicating that at least in some objects accretion is still ongoing

Ginsburg, Goddi, et al., 2017

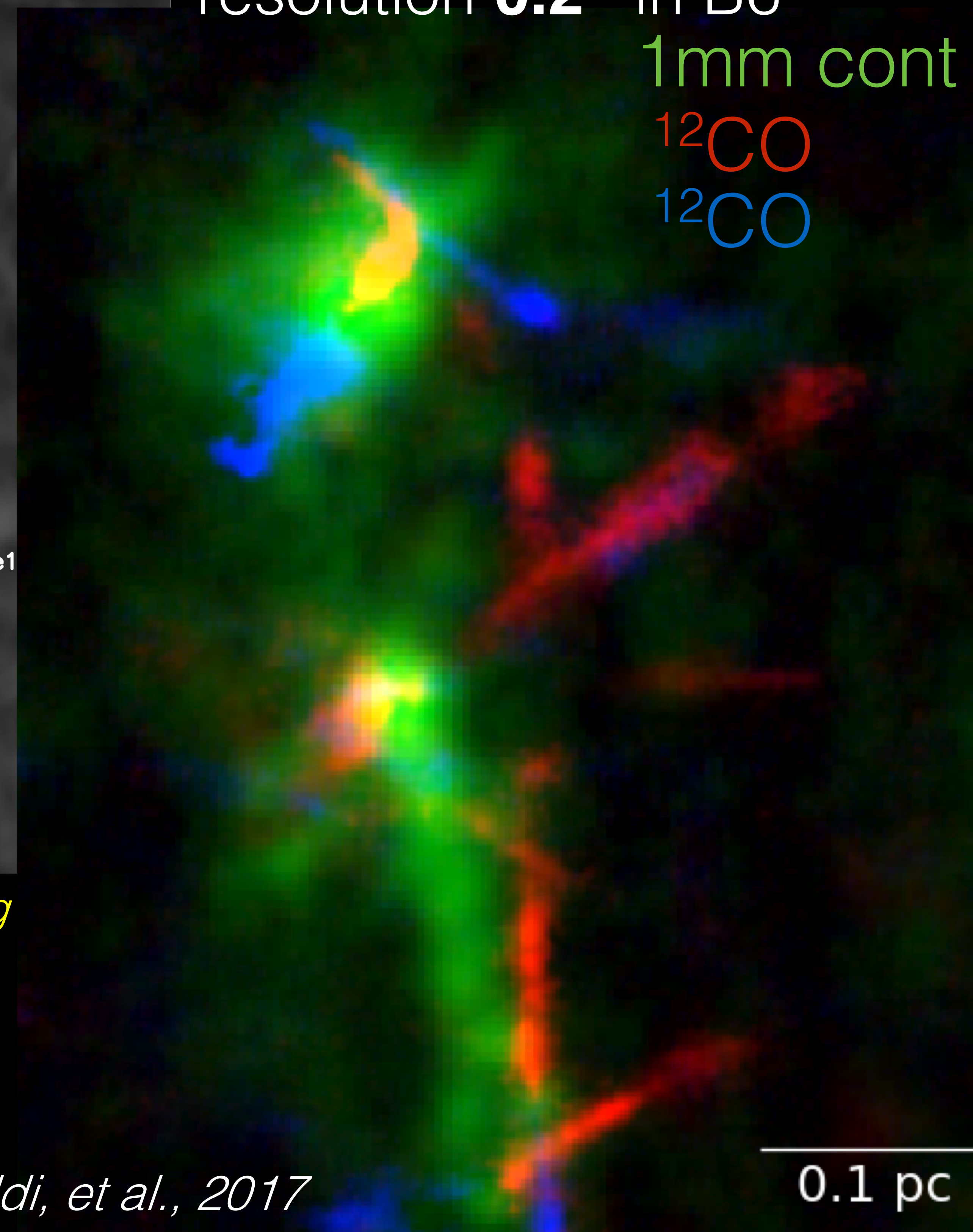




Goddi, Ginsburg & Zhang

ALMA Cycle 2 :

resolution **0.2”** in B6



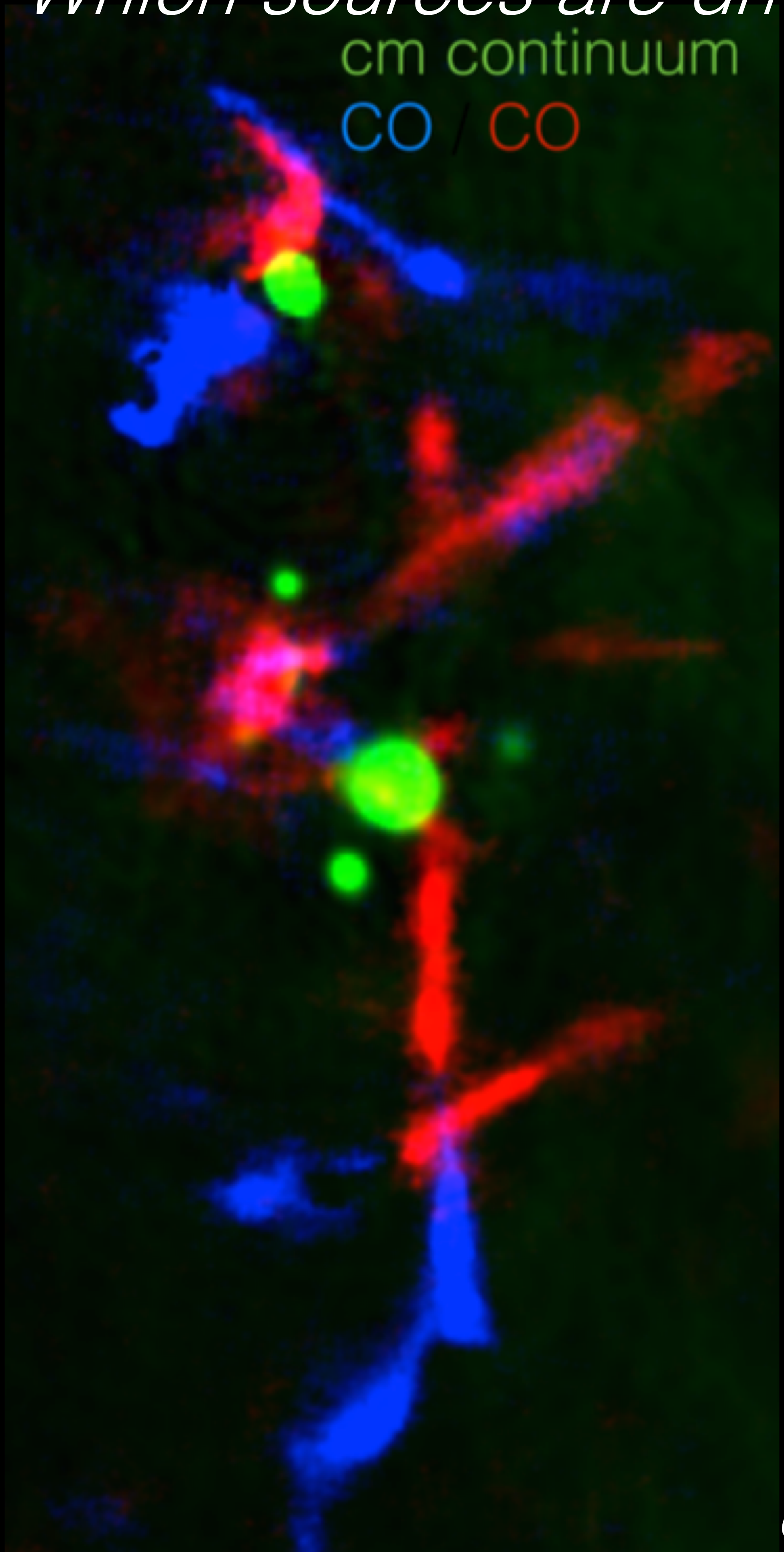
SF is vibrant in W51!

Ginsburg, Goddi, et al., 2017

Q1: Does the feedback from O-type YSOs halt SF?

NO

Which sources are driving these multiple collimated outflows?



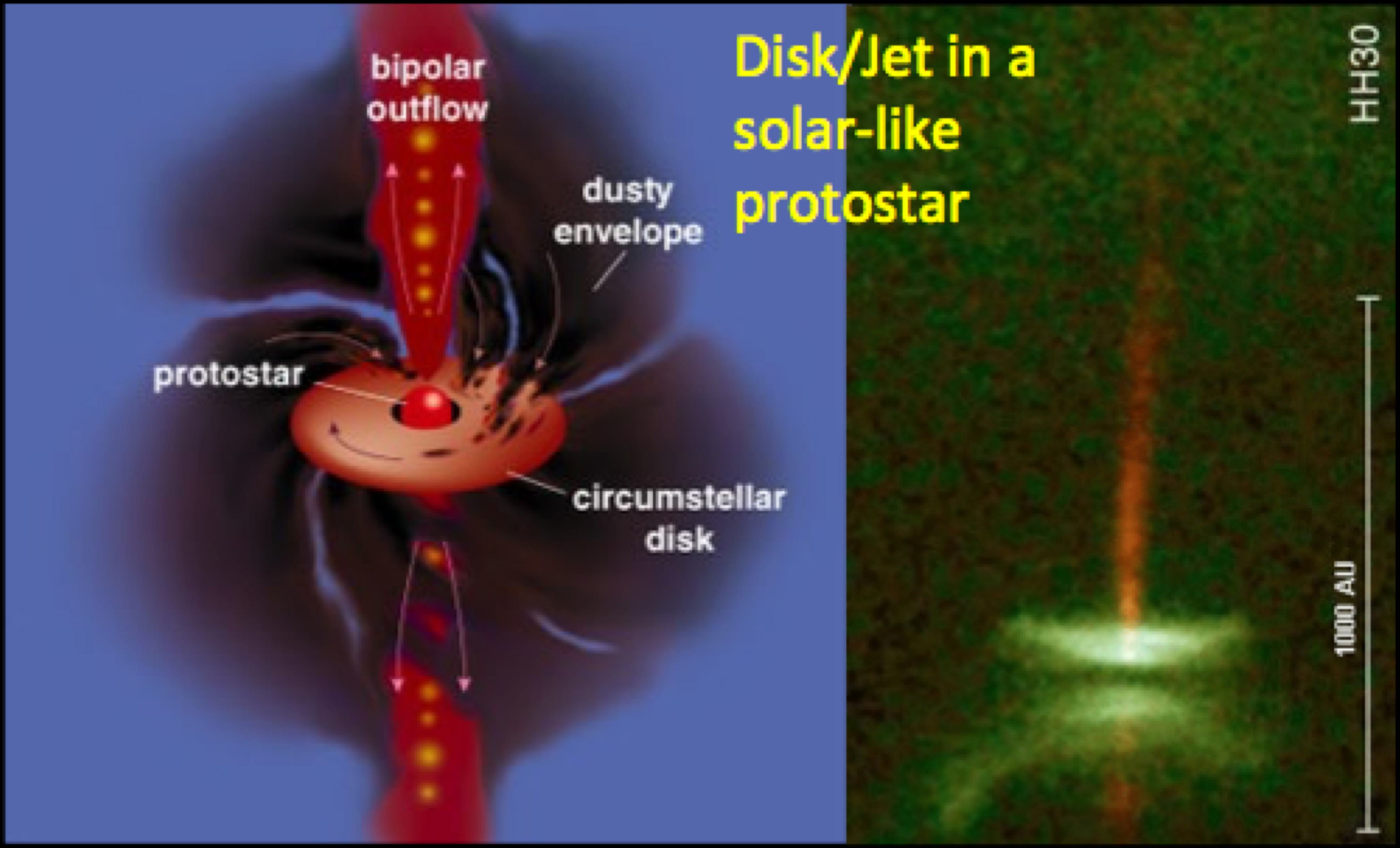
None of the outflows come from the HII regions

Q2: Do "switched-on" O-stars keep accreting?

NO

Ginsburg, Goddi, et al., 2017

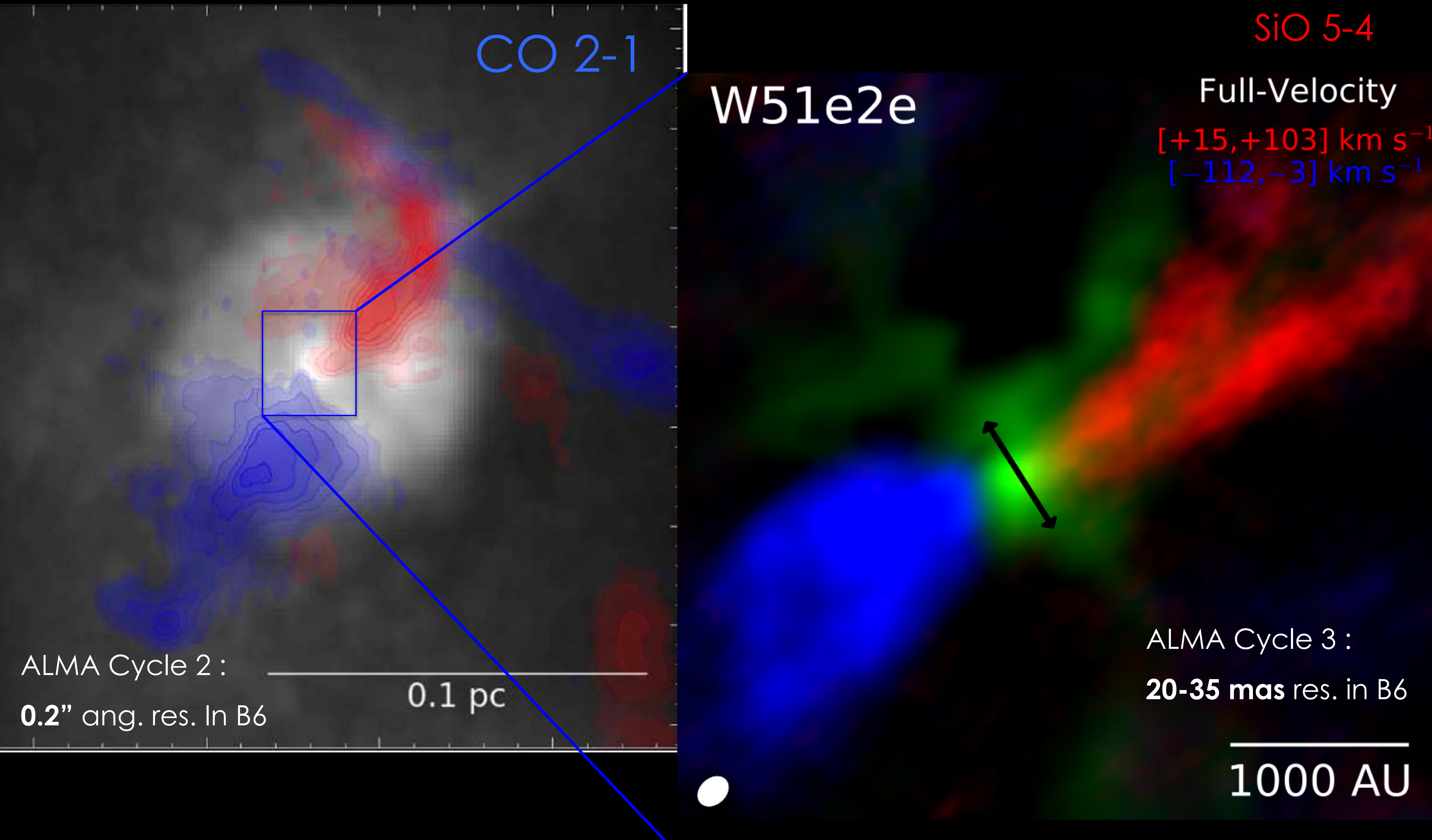
Q3: Do proto-O-stars accrete their mass via disks?



Do we see accretion disks similar to solar-like stars in W51 HMYSOs?

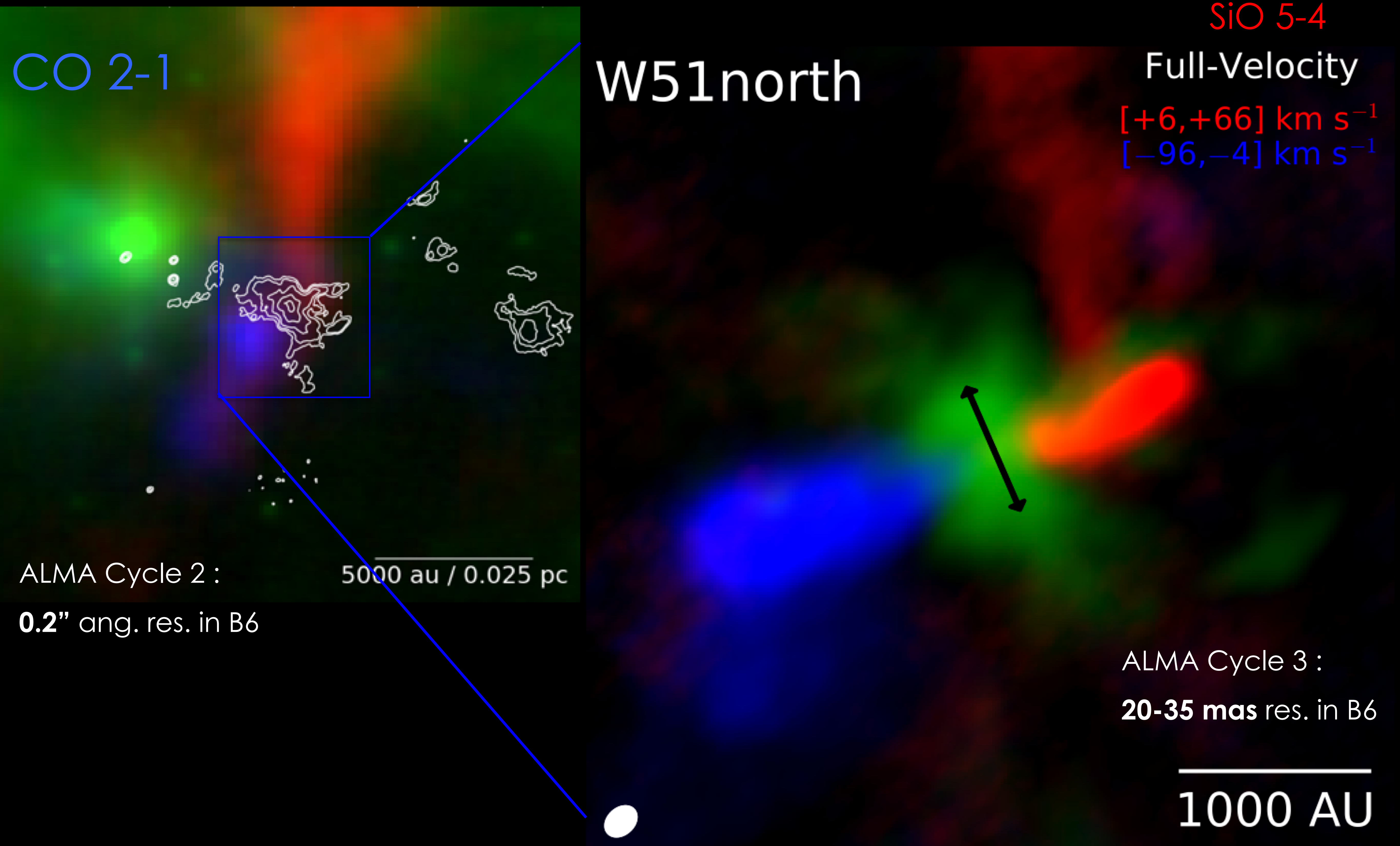
We used ALMA longest baselines to answer this open Q

Finding 1: Collimated outflows from dusty sources



- Fast (+-100 km/s), compact (<+-1000 AU), young (<100 yr) collimated SiO jet
- compact dusty source at the center of the collimated outflow

Finding 1: Collimated outflows from dusty sources



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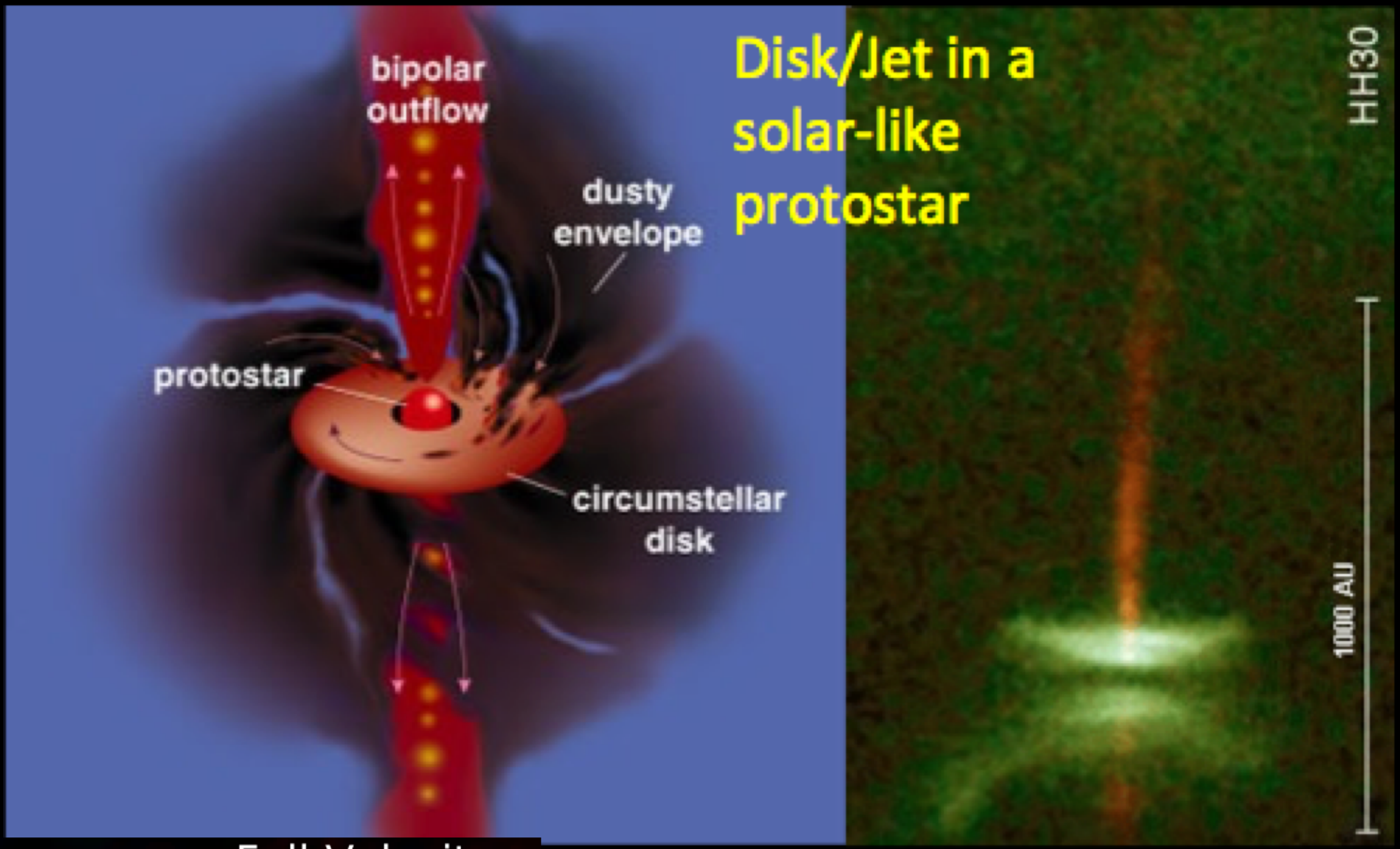
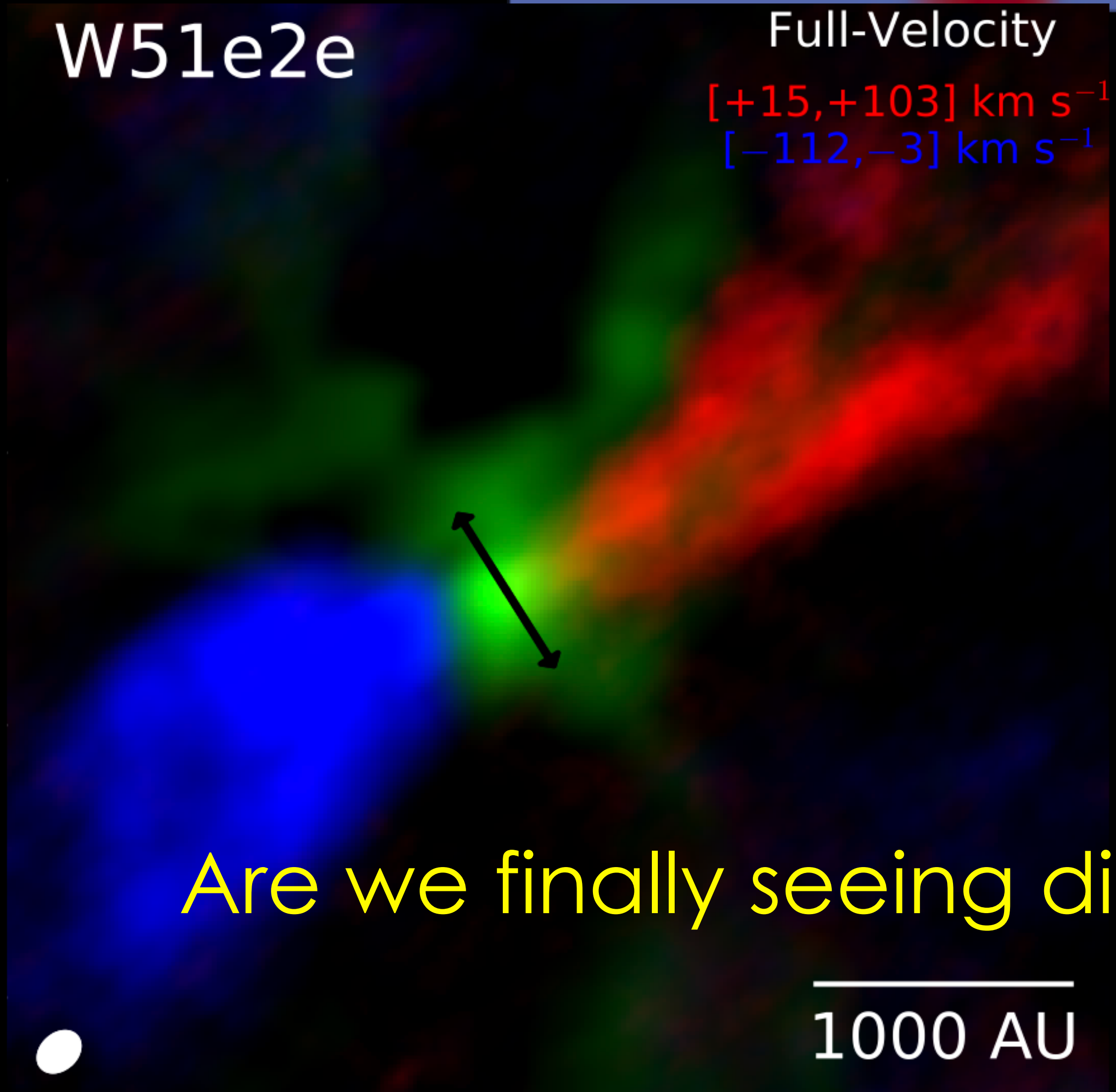
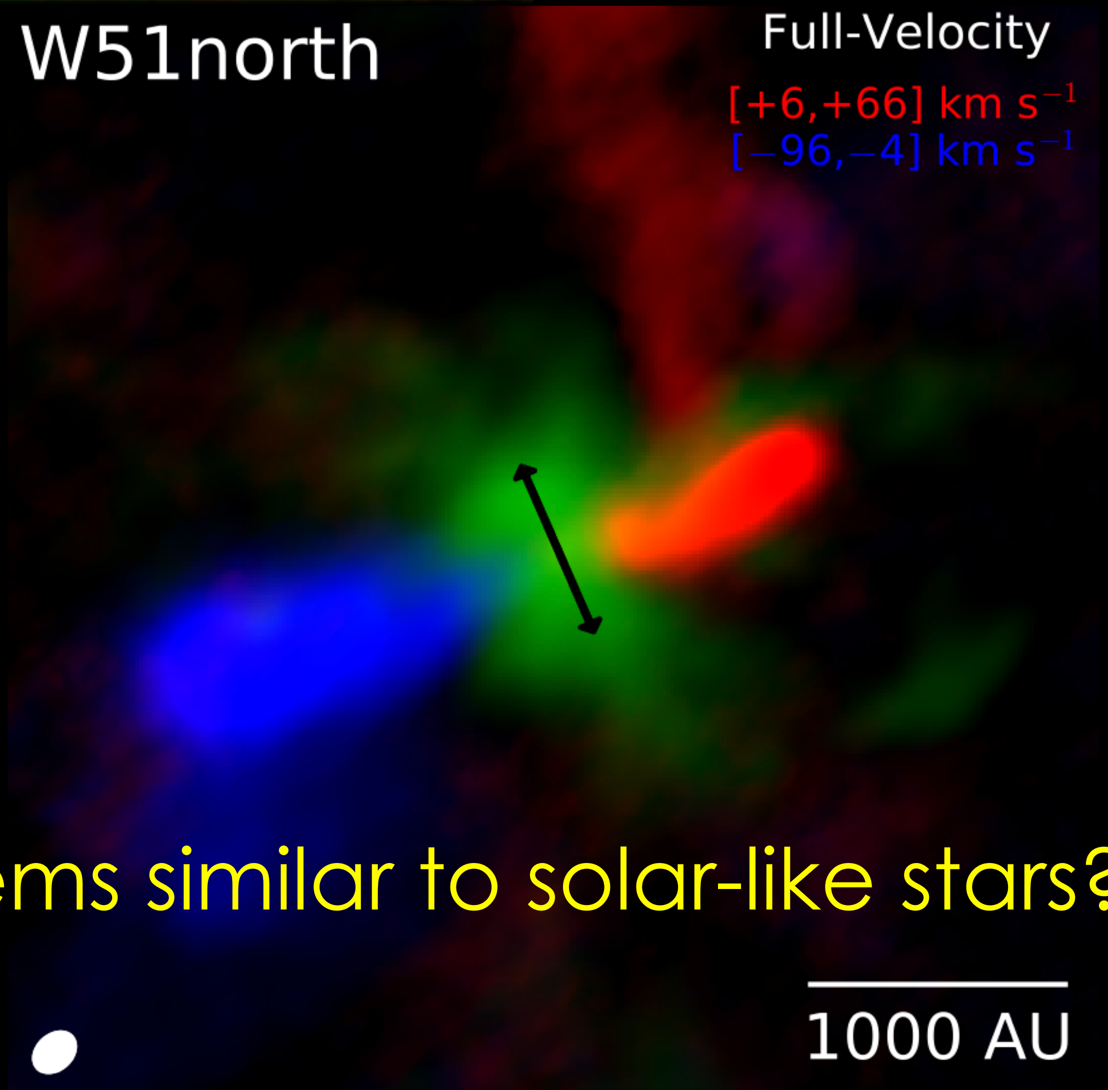
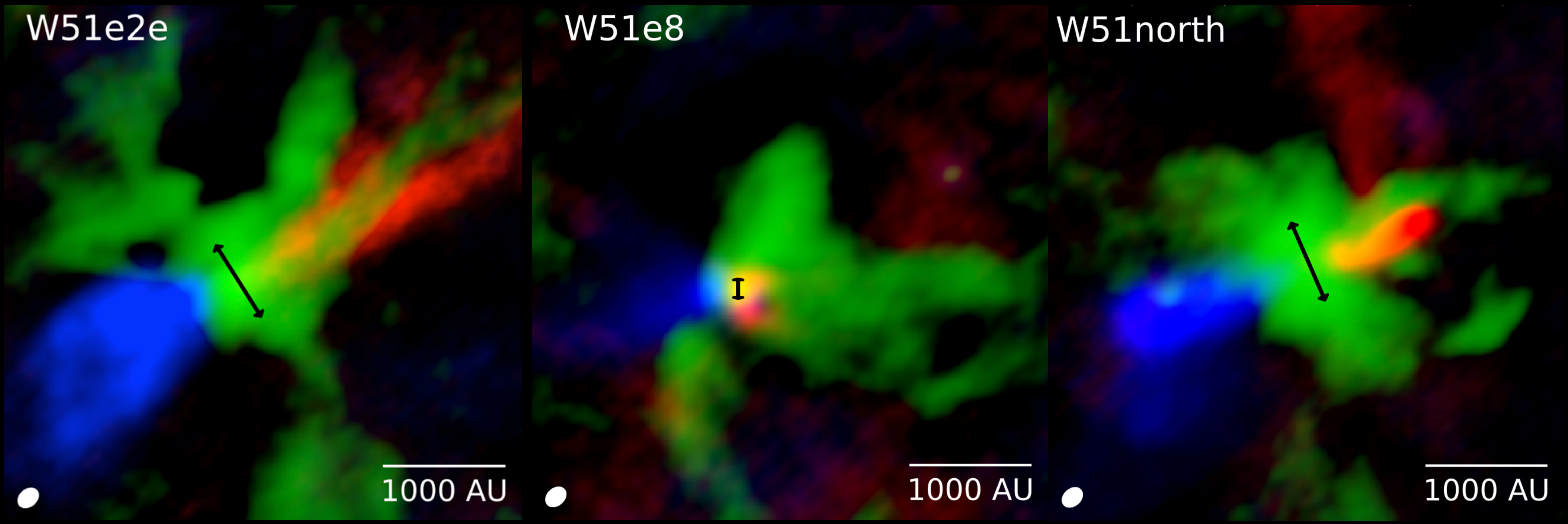






Are we finally seeing disk/jet systems similar to solar-like stars?

Finding 2: *Morphology of the mm dust emission continuum*

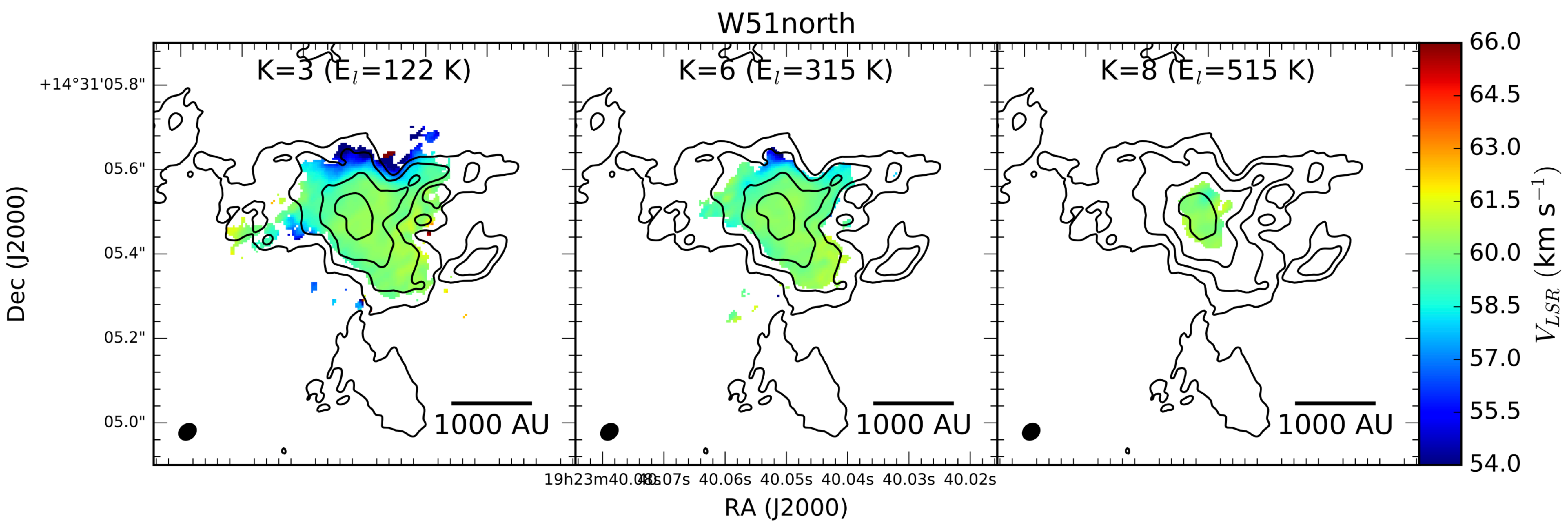


Continuum (green) does not show a simple flattened structure at the center of the outflows, but the emission is resolved into multiple dusty lanes converging onto the compact cores

Mass (and angular momentum) conveyed to the star via multiple channels?

Goddi, Ginsburg, Maud, Zhang, Zapata, arxiv:1805.05364

Finding 3: Gas kinematics from absorption lines



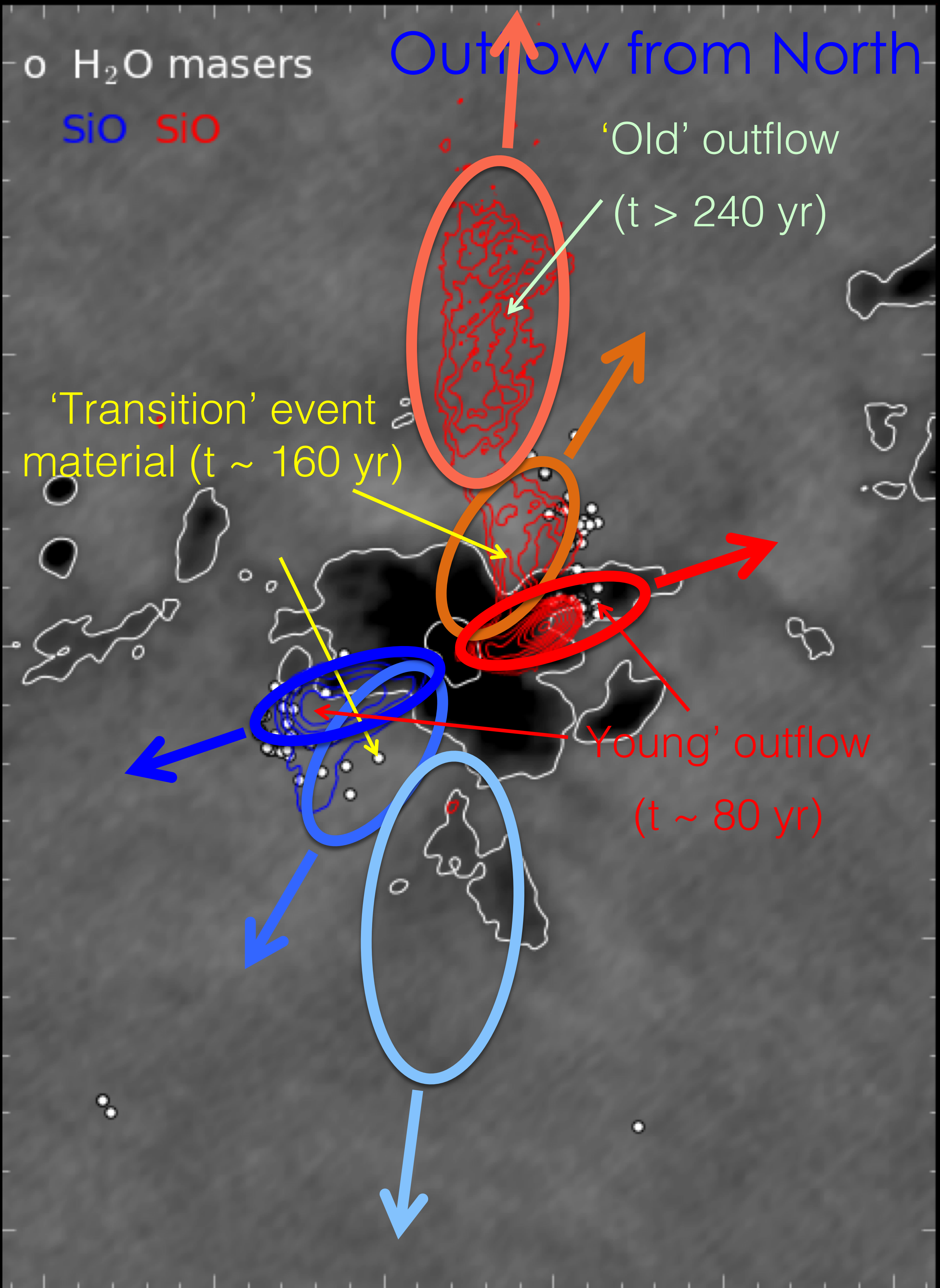
- striking velocity coherence towards the peak of the dust continuum
- no sign of velocity gradient and/ or structure

=> Continuum is extremely optically-thick

If present, disks should be very small (< 80 and <350 AU)

Goddi, Ginsburg, Maud, Zhang, Zapata, arxiv:1805.05364

Finding 4: Outflows have different P.A. on different scales



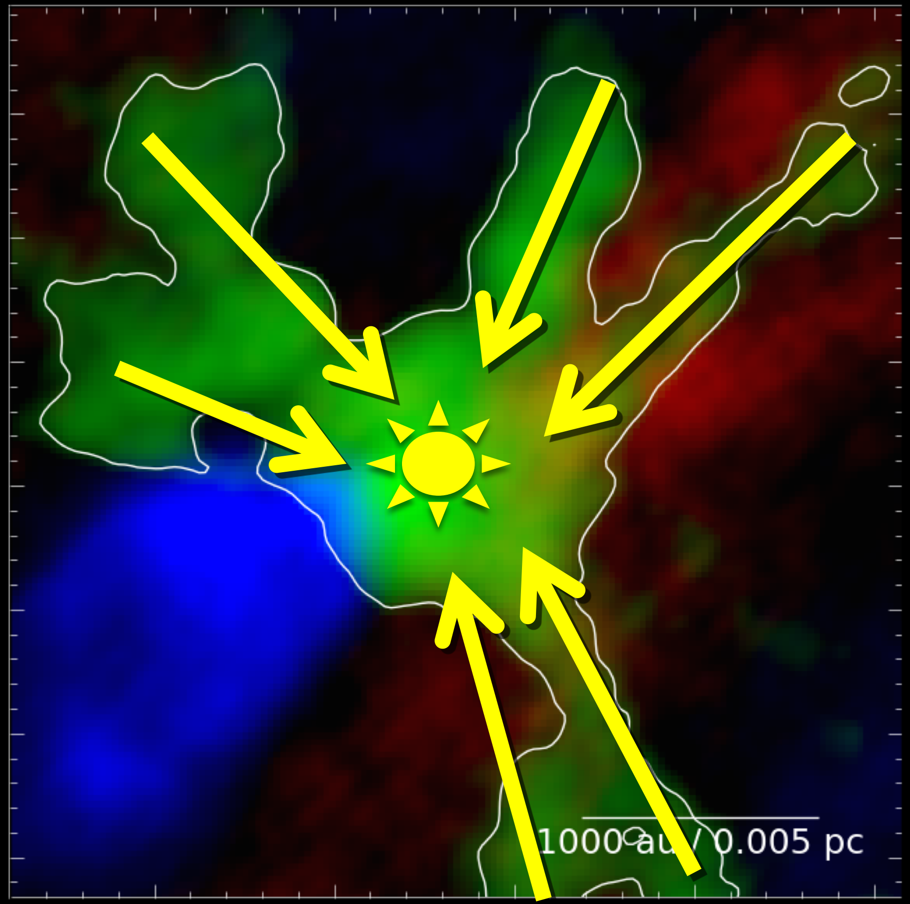
Possible mechanisms:

1. Independent outflows driven by multiple stars ✗
2. Precession in a binary? ✗
3. Single outflow changing orientation over time

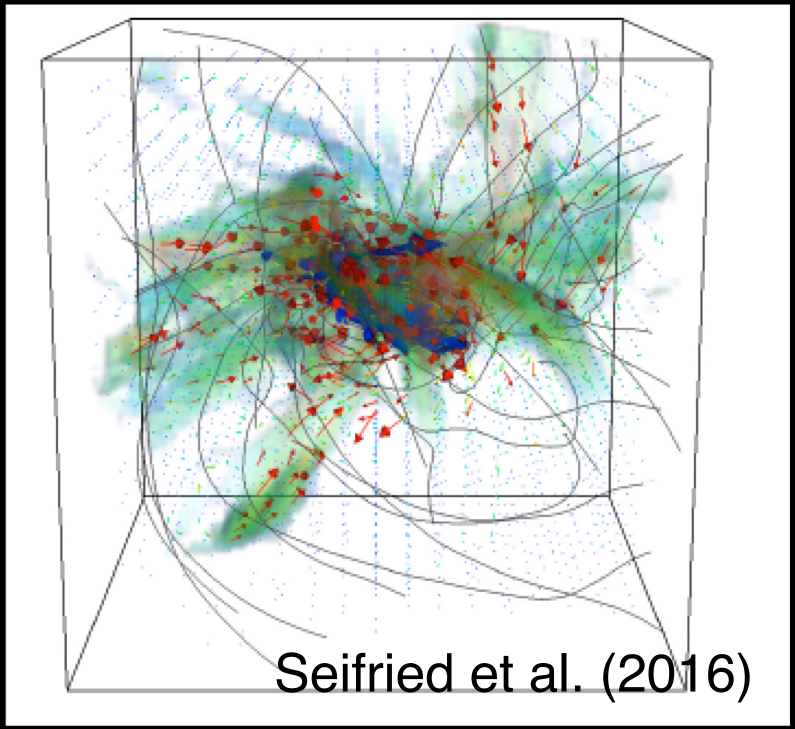
If accreting material has different angular momentum vectors, disks and jets could change P.A. over time

Q3: How do proto-O-stars accrete their mass?

Findings	Implications
1. Fast, young, collimated outflows	Disks must be present
2. Complex morphology of dusty sources	Multi-directional accretion
3. Lack of kinematics (no rotation)	Optical depth + small disks
4. Multi-component outflow structure	Episodic accretion



Multi-directional accretion via narrow channels?



Similar structures suggested by recent MHD simulations of turbulent and magnetised molecular cloud cores

Conclusions

I. The feedback from young O stars does not halt SF.

II. The stars exciting HC-HII regions show no evidence of ongoing accretion.

III. Accretion in proto-O-stars:

A. does not involve disks larger than ~100-300 AU

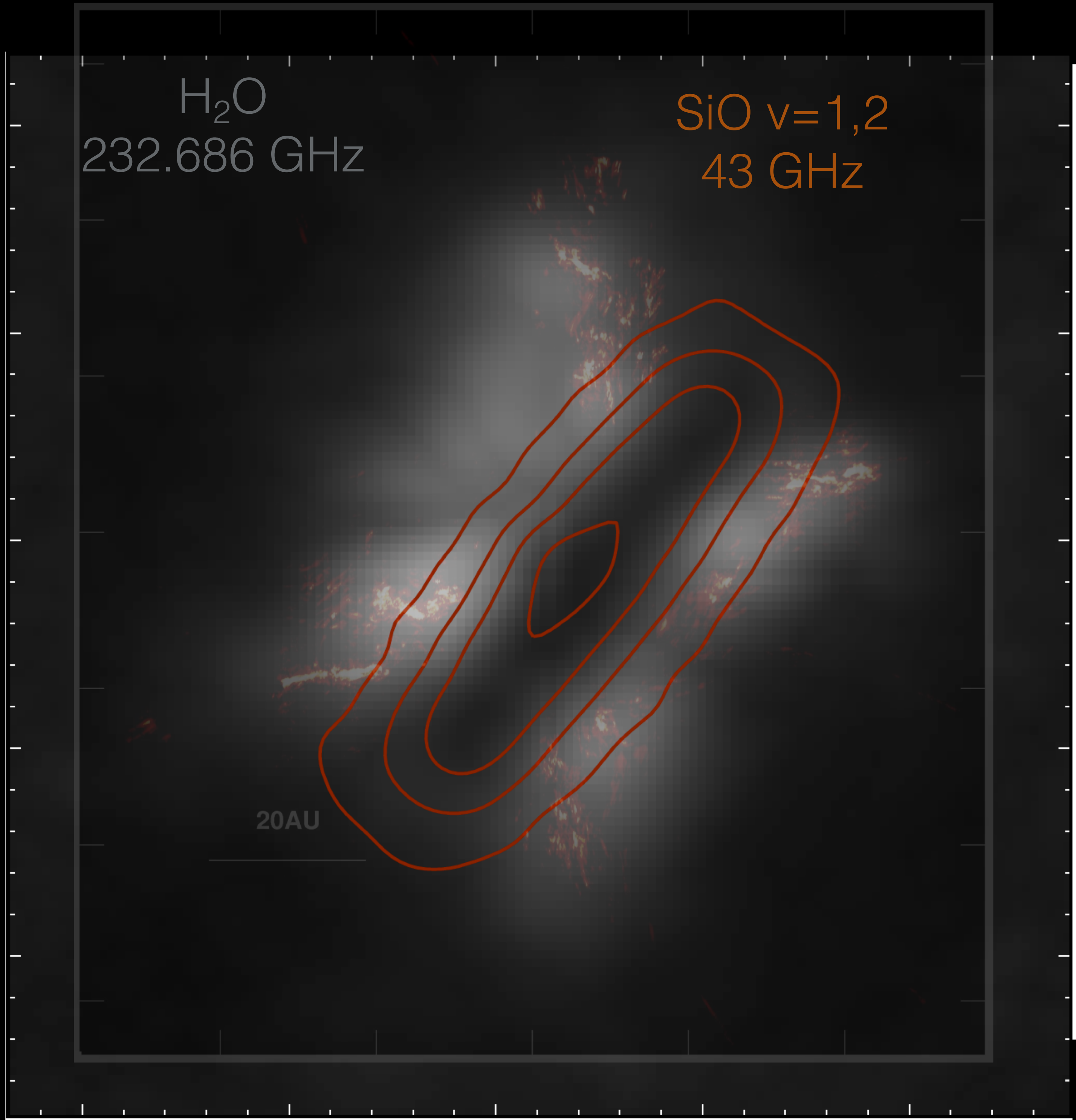
B. is multi-directional via narrow channels or filaments

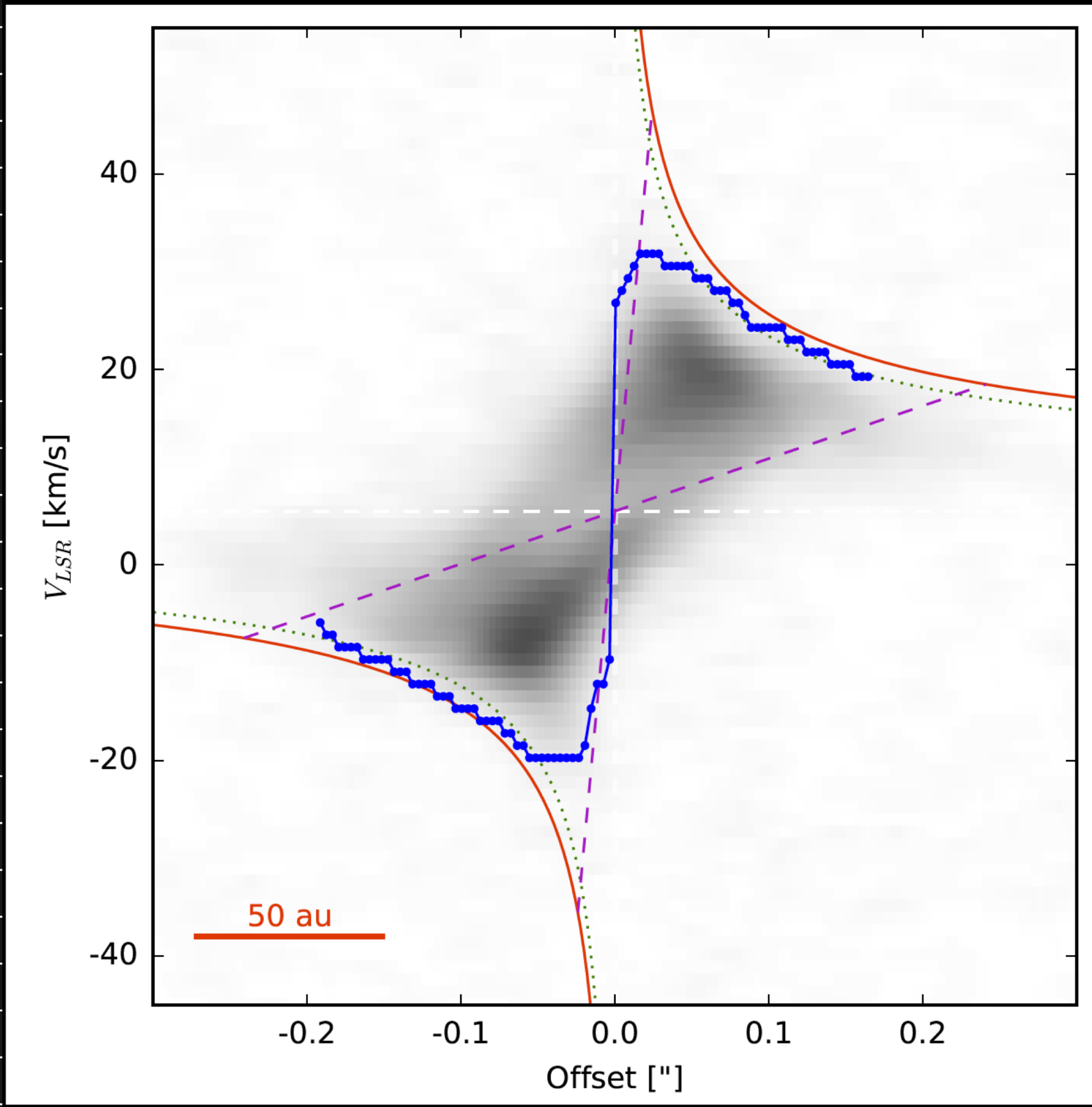
C. is episodic (fast collimated outflows change orientation with distance and/or over time)

A beautiful Keplerian Disk around a ~ 15 $M_\odot$ YSO
Orion Source I

ALMA Cycle V Band 6 Beamsize ~0.02-0.05"

Length ~ 90 AU, Height ~35 AU





Ginsburg, Bally, Goddi, Wright, Plambeck 2018