



The VLA Nascent Disk and Multiplicity (VANDAM) Survey: Protostellar Jets from the Centimeter to Far-Infrared

John Tobin

NWO Veni Fellow
Leiden Observatory

VANDAM Team:

John Tobin (PI), Lukasz Tychoniec (Leiden/AMU-Poland) and
Leslie Looney (Illinois), Zhi-Yun Li (Virginia), Claire Chandler (NRAO),
Mike Dunham (CfA), Kaitlin Kratter (Arizona), Dominique Segura-Cox (Illinois), Sarah Sadavoy (MPIA),
Laura Perez (NRAO), Carl Melis (UCSD), Robert Harris (Illinois), Lukasz Tychoniec (Leiden/AMU-Poland)

<http://home.strw.leidenuniv.nl/~tobin/VANDAM/>

Image: Bill Saxton (NRAO)

Survey Details

- 264 hour VLA large program
 - 8 mm/1 cm (207 hours) and 4 cm/6.4 cm (57 hours)
 - A and B configurations, 0.06" (15 AU) resolution
 - Perseus region ($d \sim 230$ pc), 92 YSOs (79 detected)
 - 43 Class 0, 37 Class I sources, 12 Class II
 - Luminosities range $0.1 L_{\text{sun}}$ to $30 L_{\text{sun}}$
- Goals:
 - Measure multiplicity fractions down to 15 AU
 - Resolve disks in dust continuum, measure dust masses
 - Jet properties from centimeter emission (free-free)
 - Inner ~ 10 s AU of the jet

Star Formation Process

Protostellar Phase

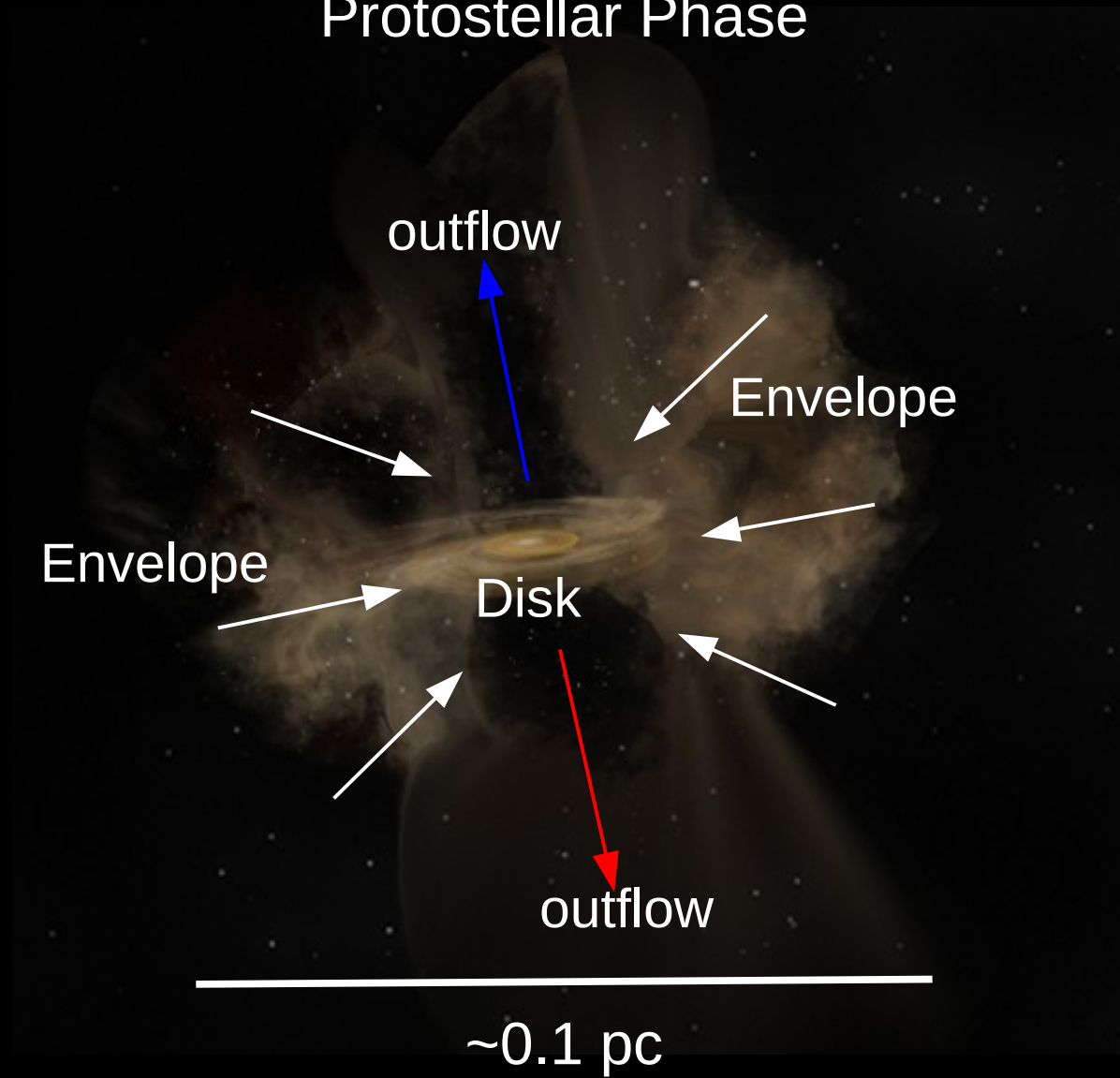
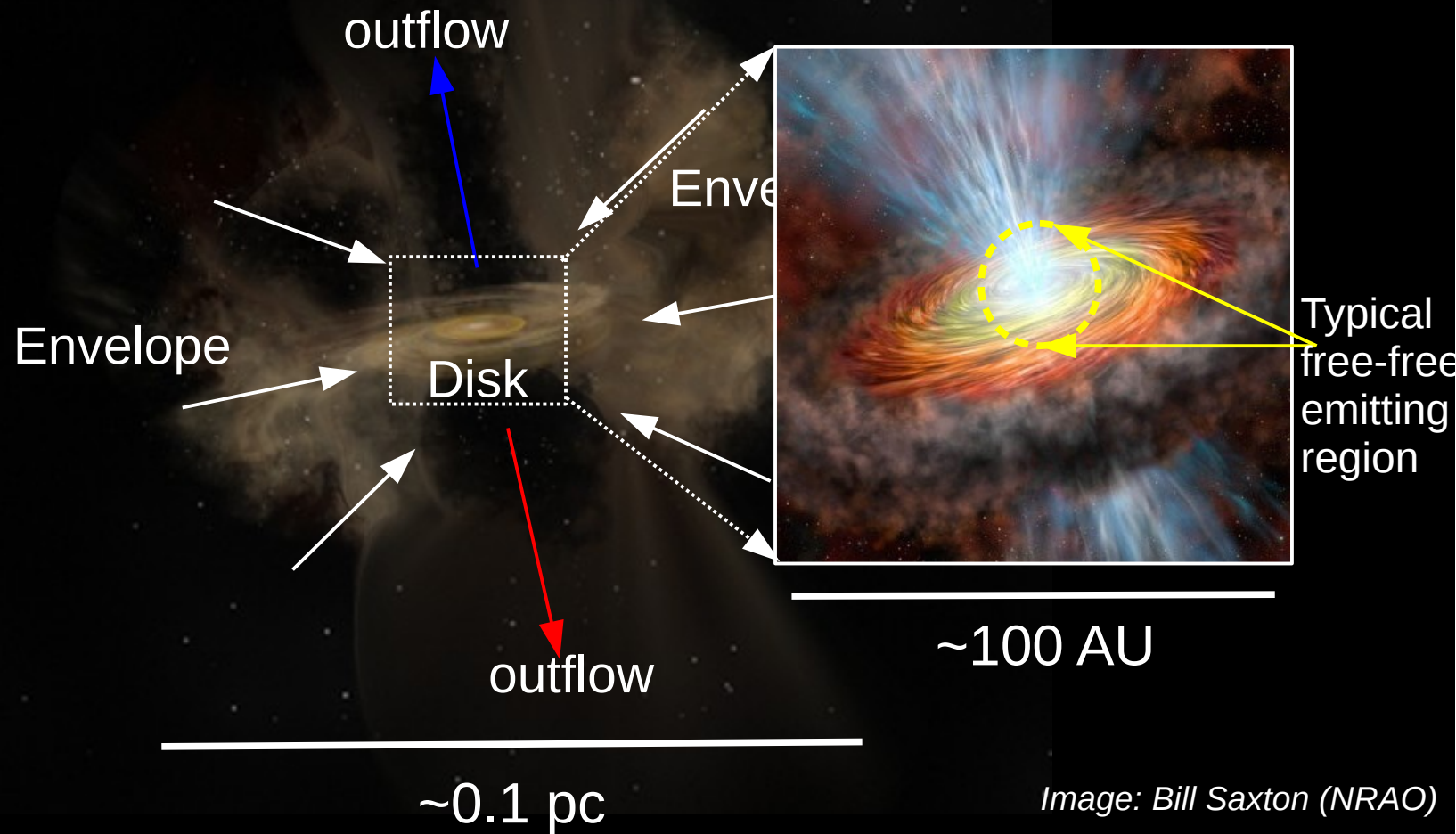


Image: Bill Saxton (NRAO)

Star Formation Process

Protostellar Phase



Western Perseus Molecular Cloud

NGC 1333

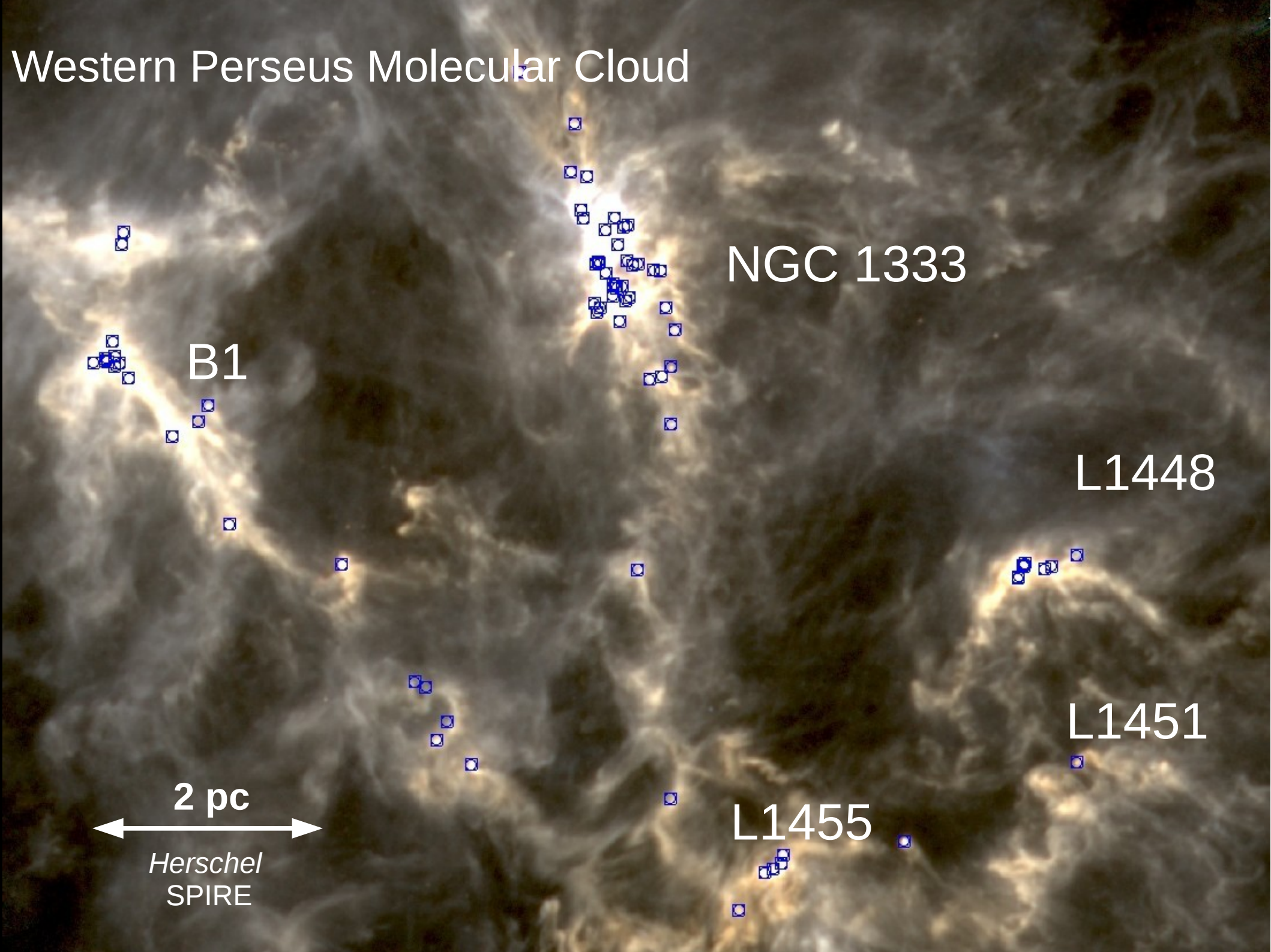
B1

L1448

L1451

L1455

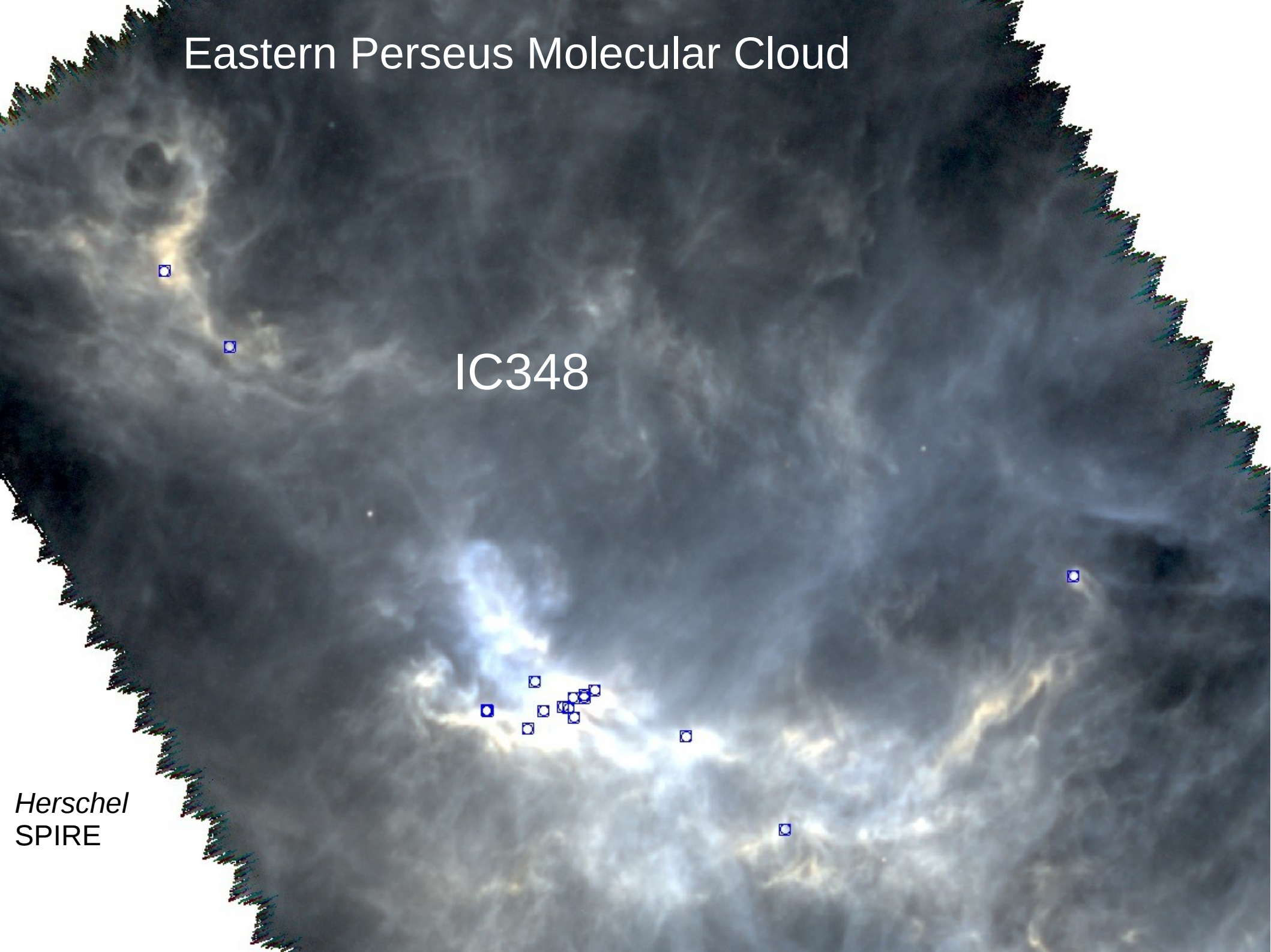
2 pc
Herschel
SPIRE



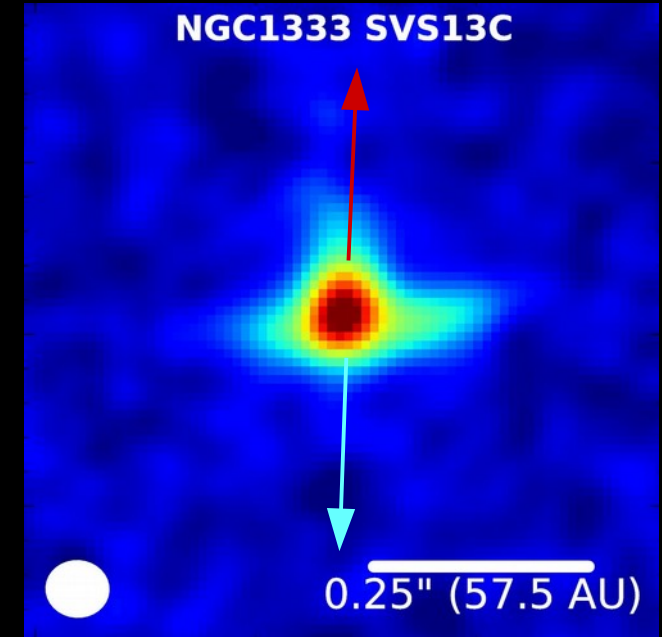
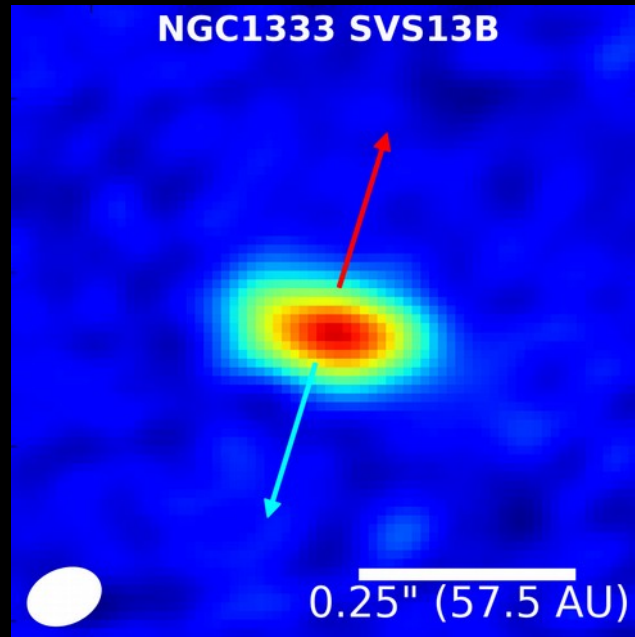
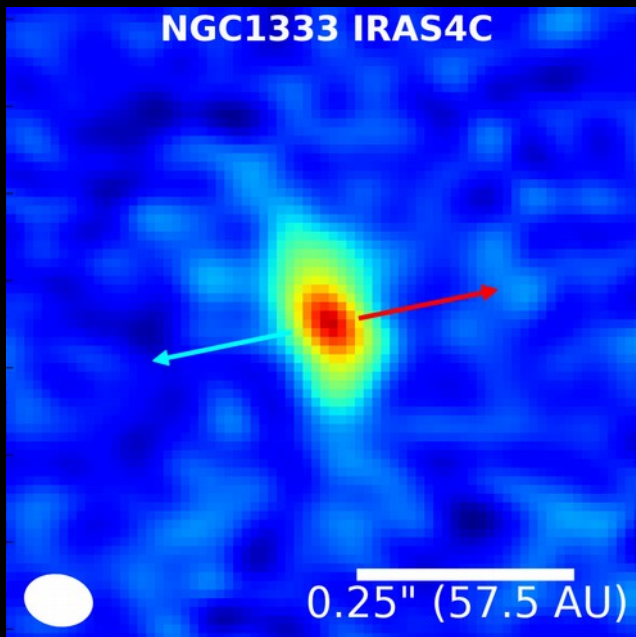
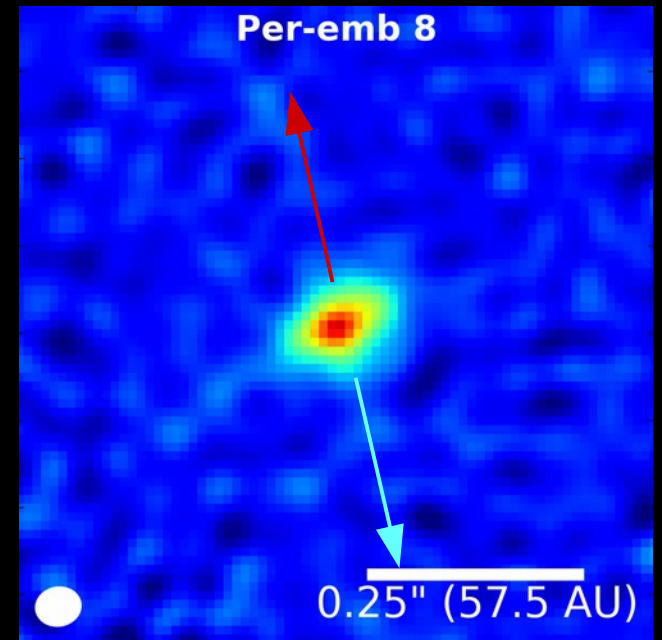
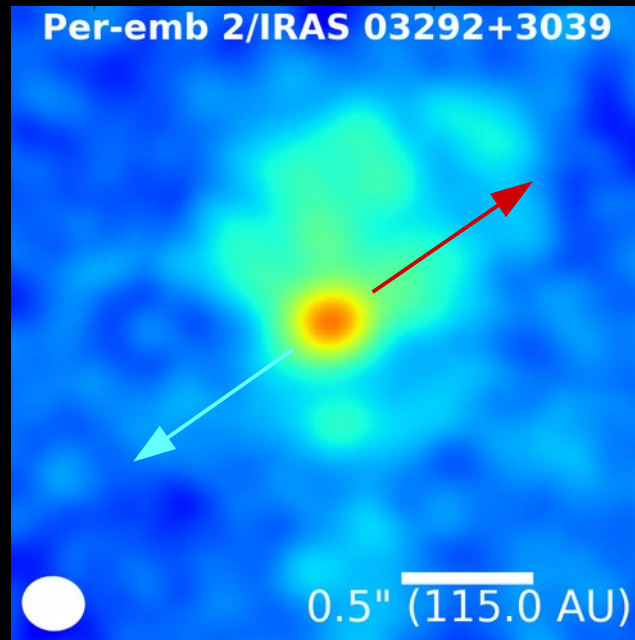
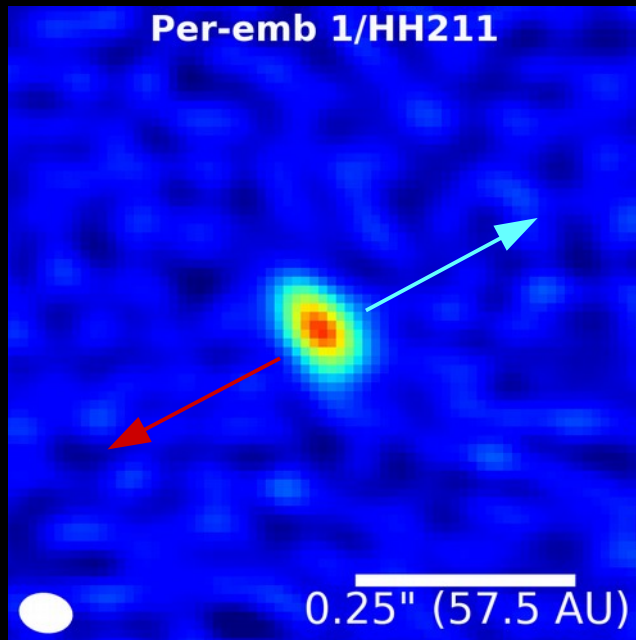
Eastern Perseus Molecular Cloud

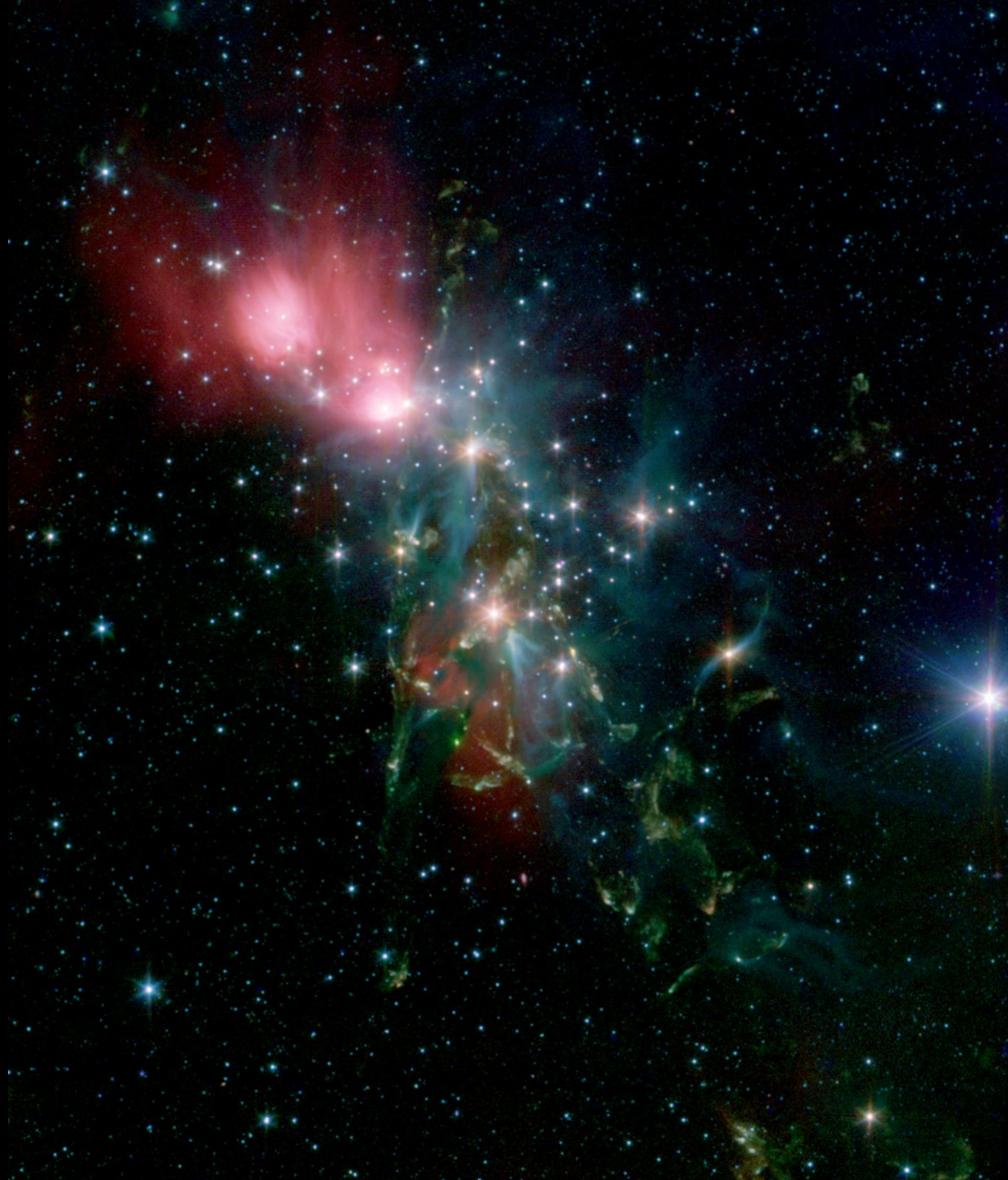
IC348

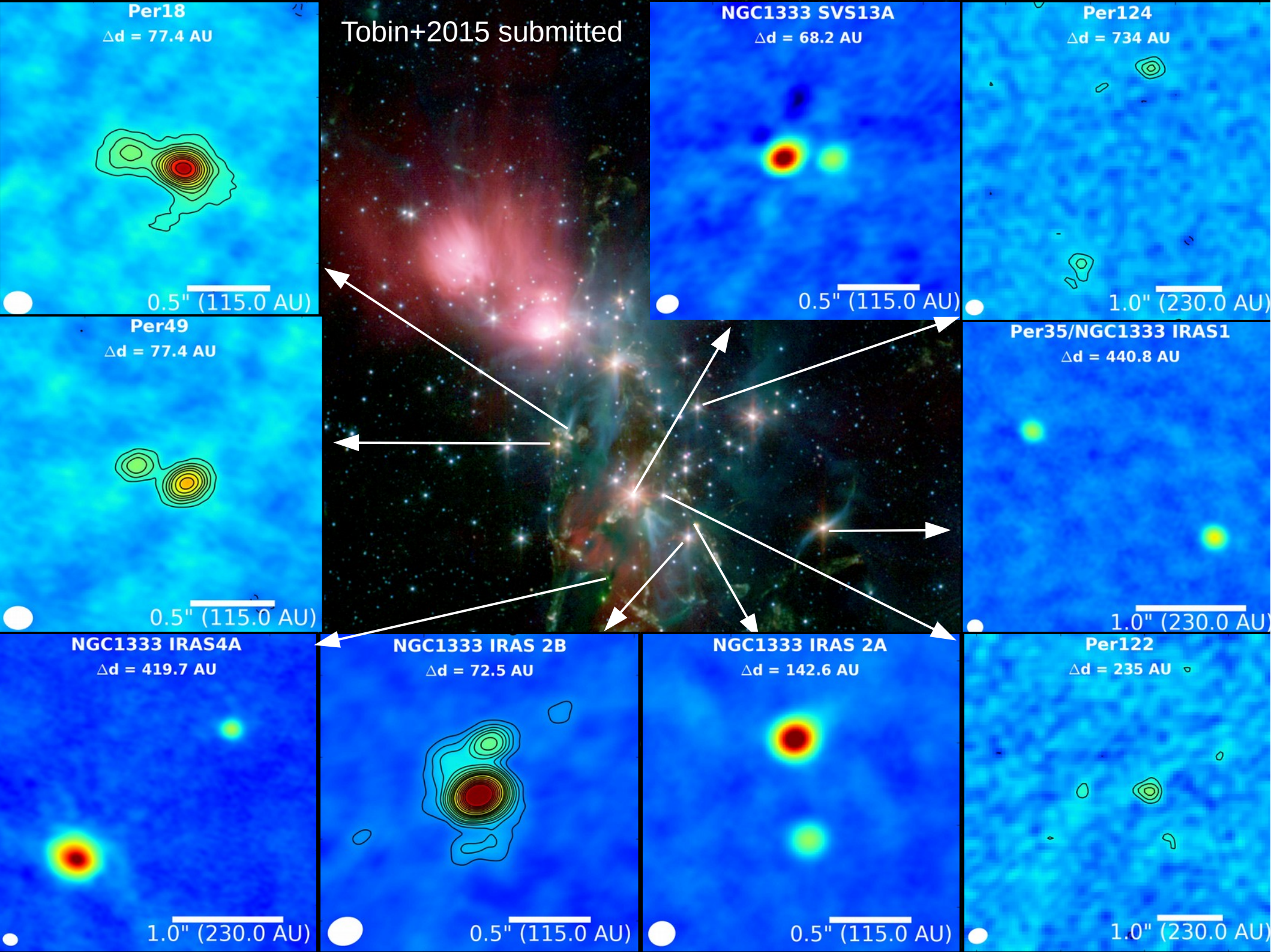
Herschel
SPIRE

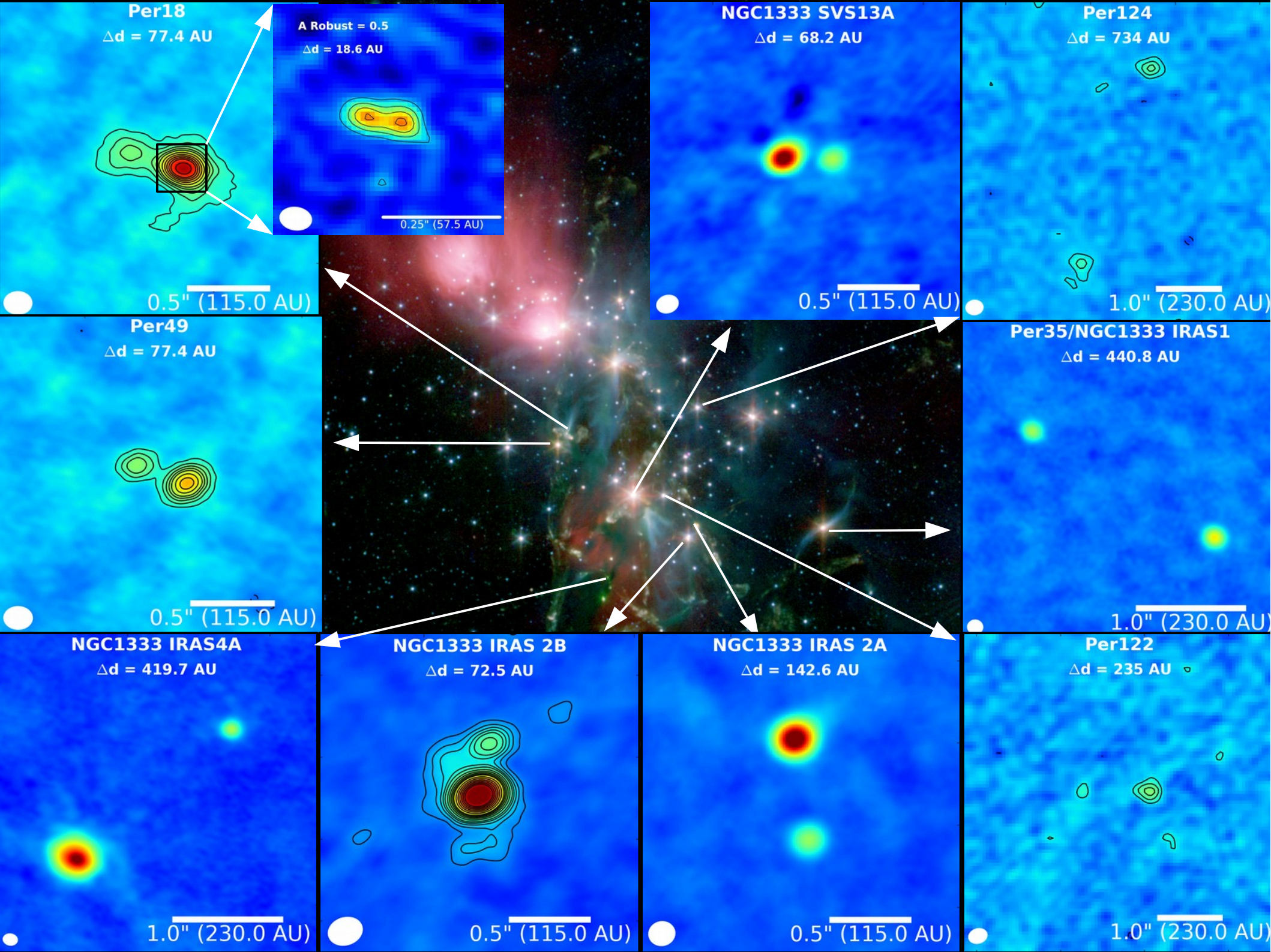


VANDAM Class 0 Disk Candidates

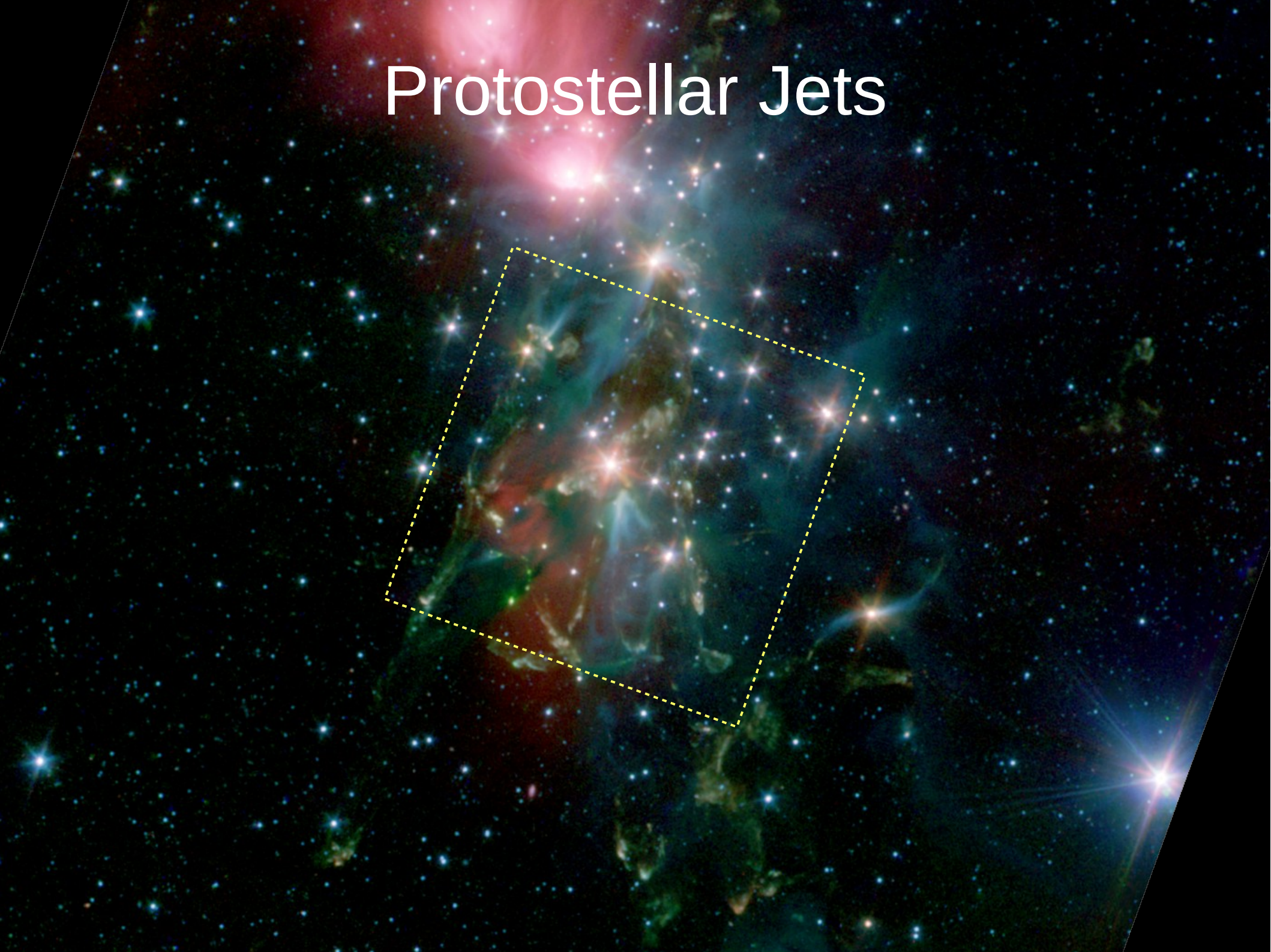




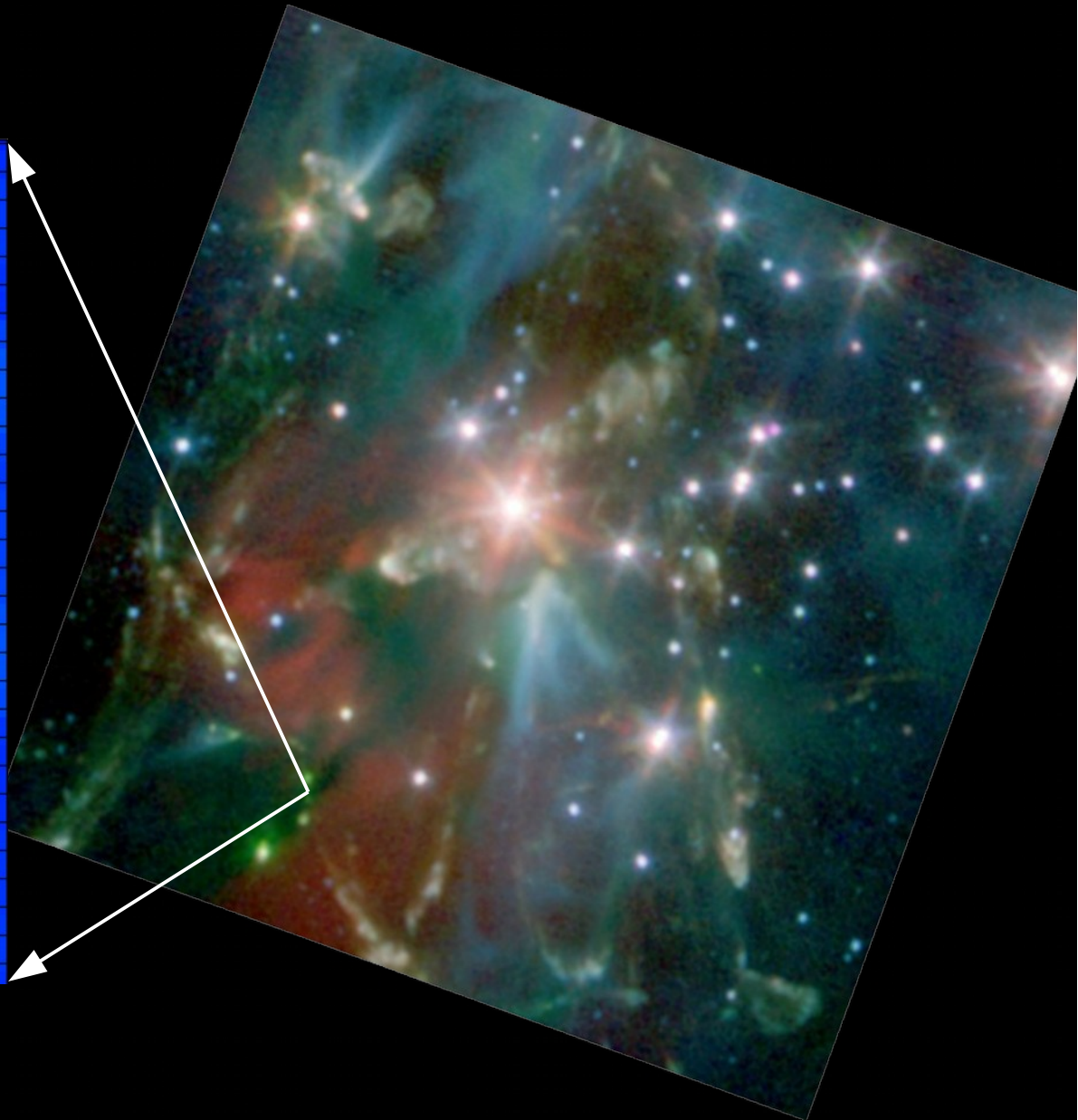
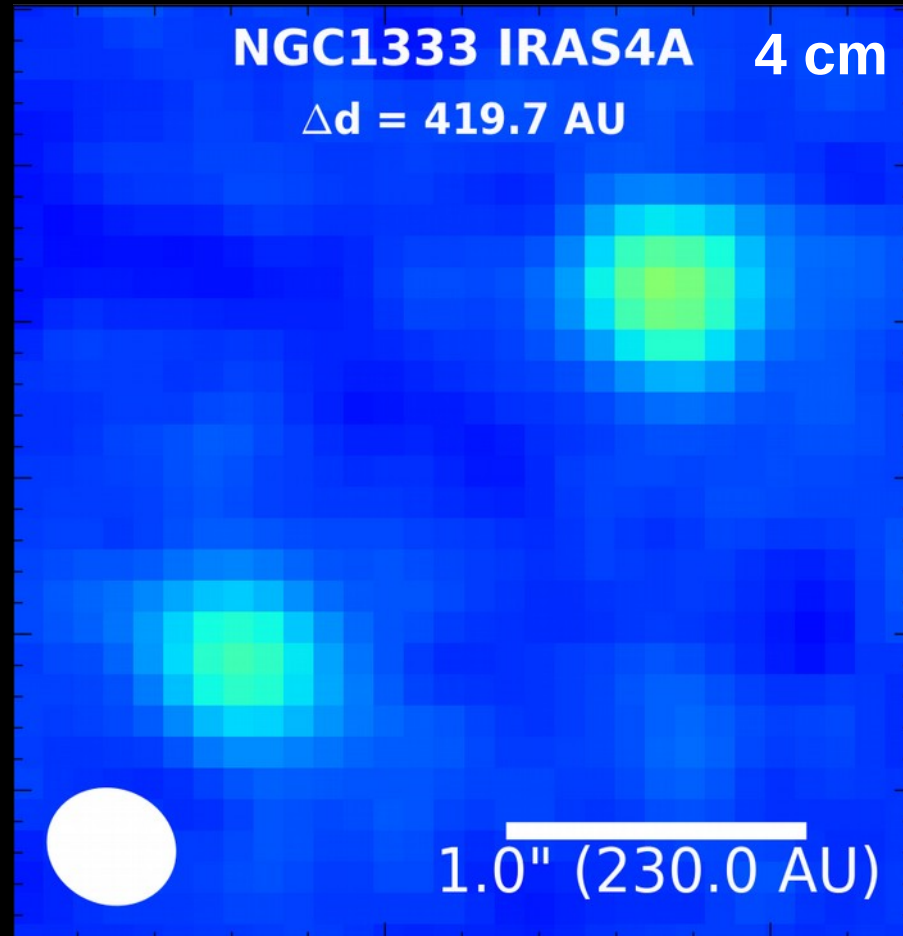




Protostellar Jets

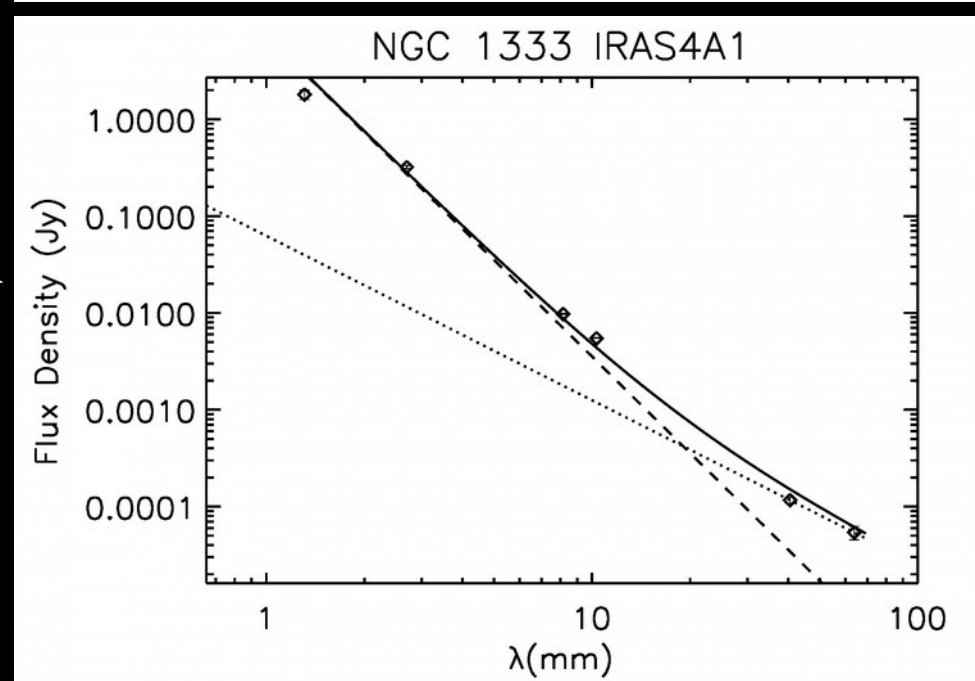
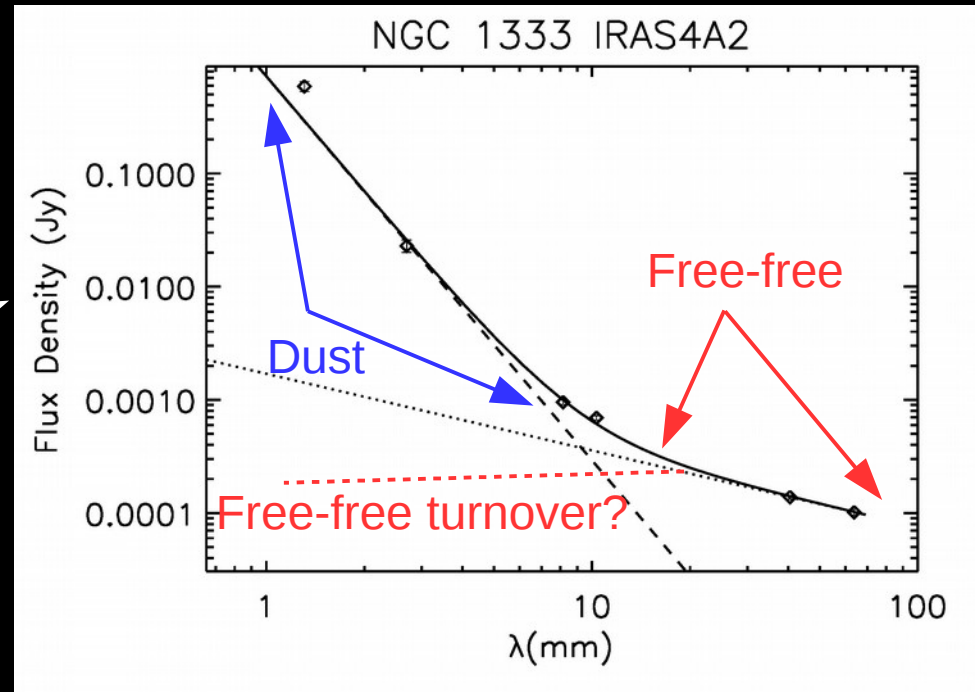
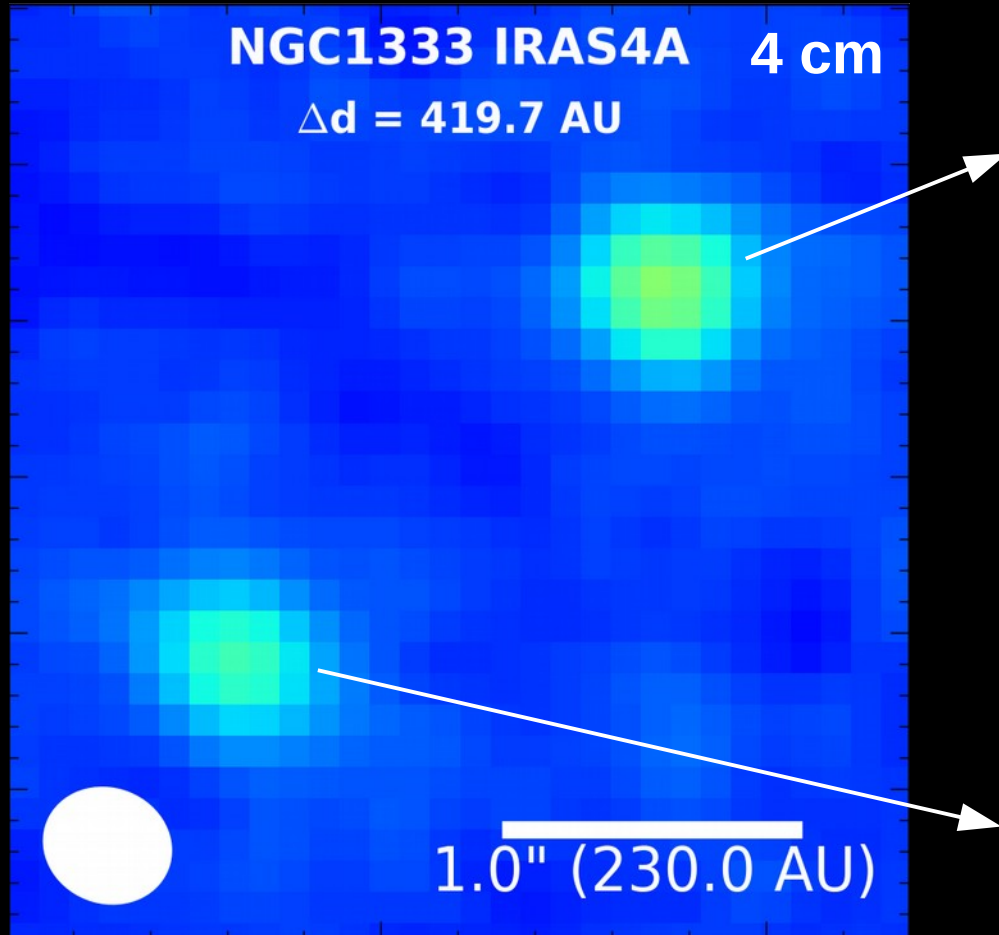


Protostellar Jets: IRAS4 A



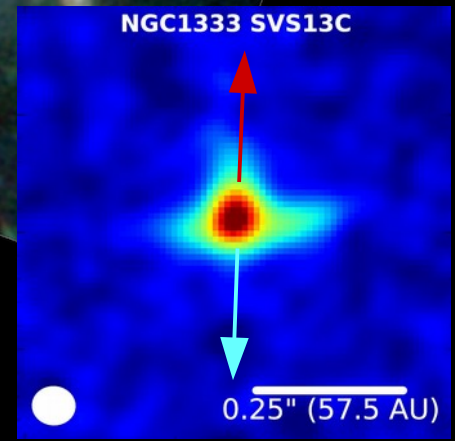
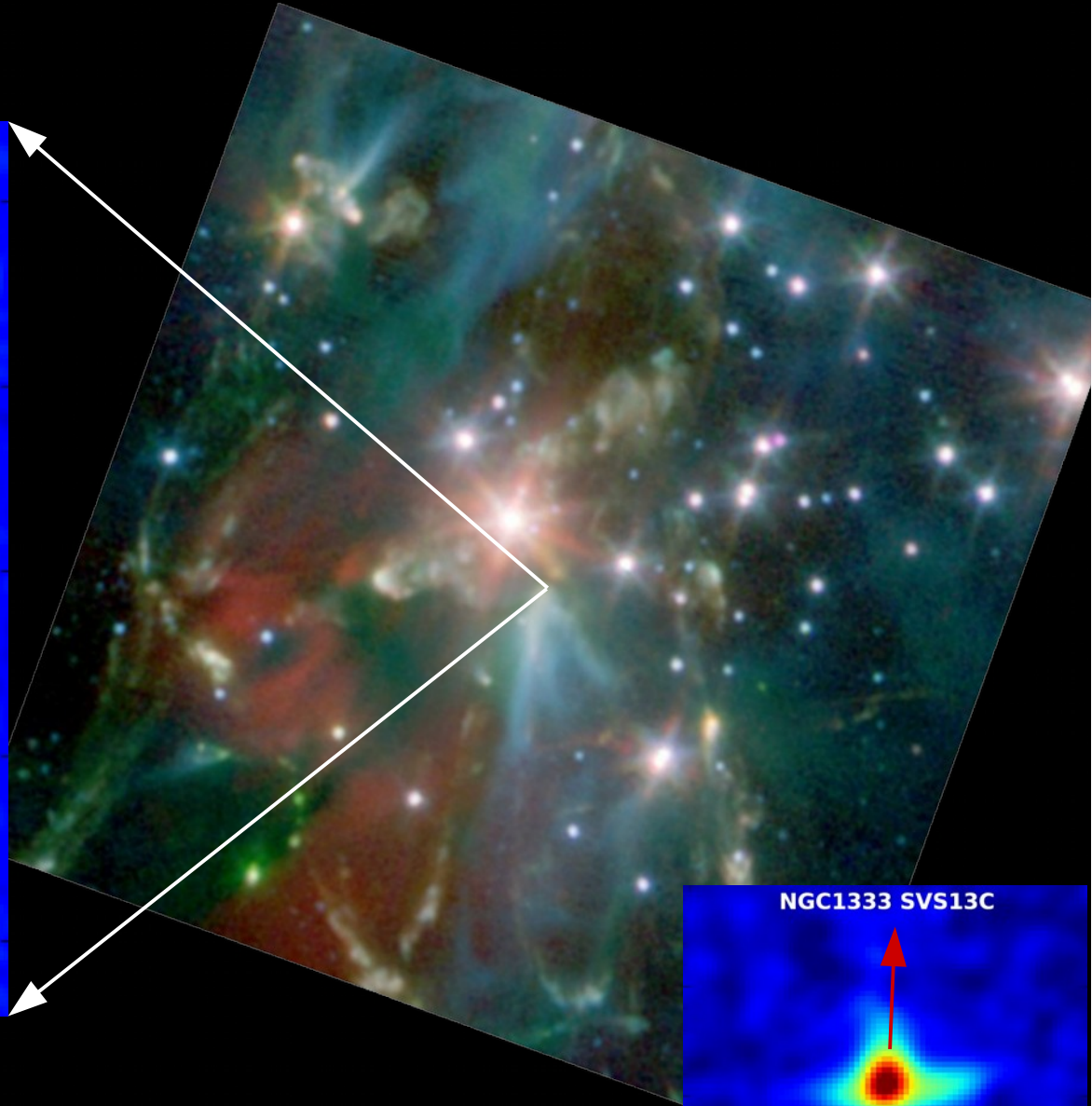
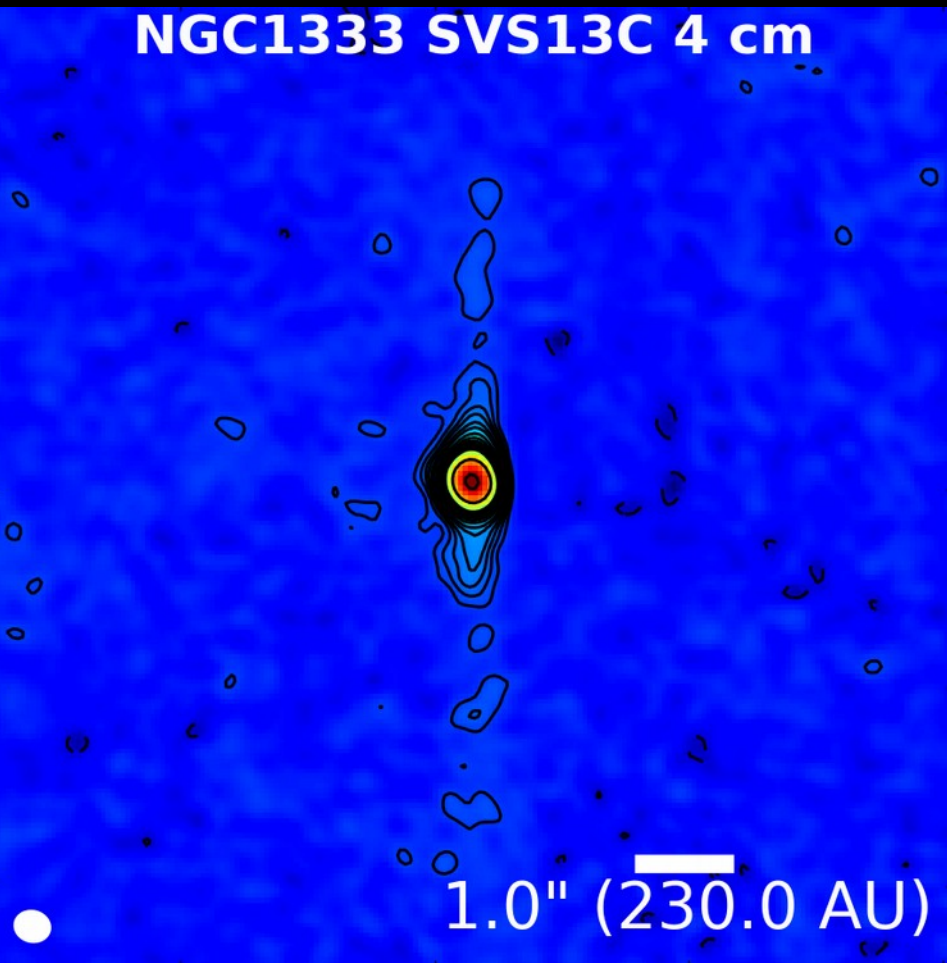
Tychoniec+2016 in prep.

Protostellar Jets: IRAS4 A



Tychoniec+2016 in prep.

Protostellar Jets: SVS13C

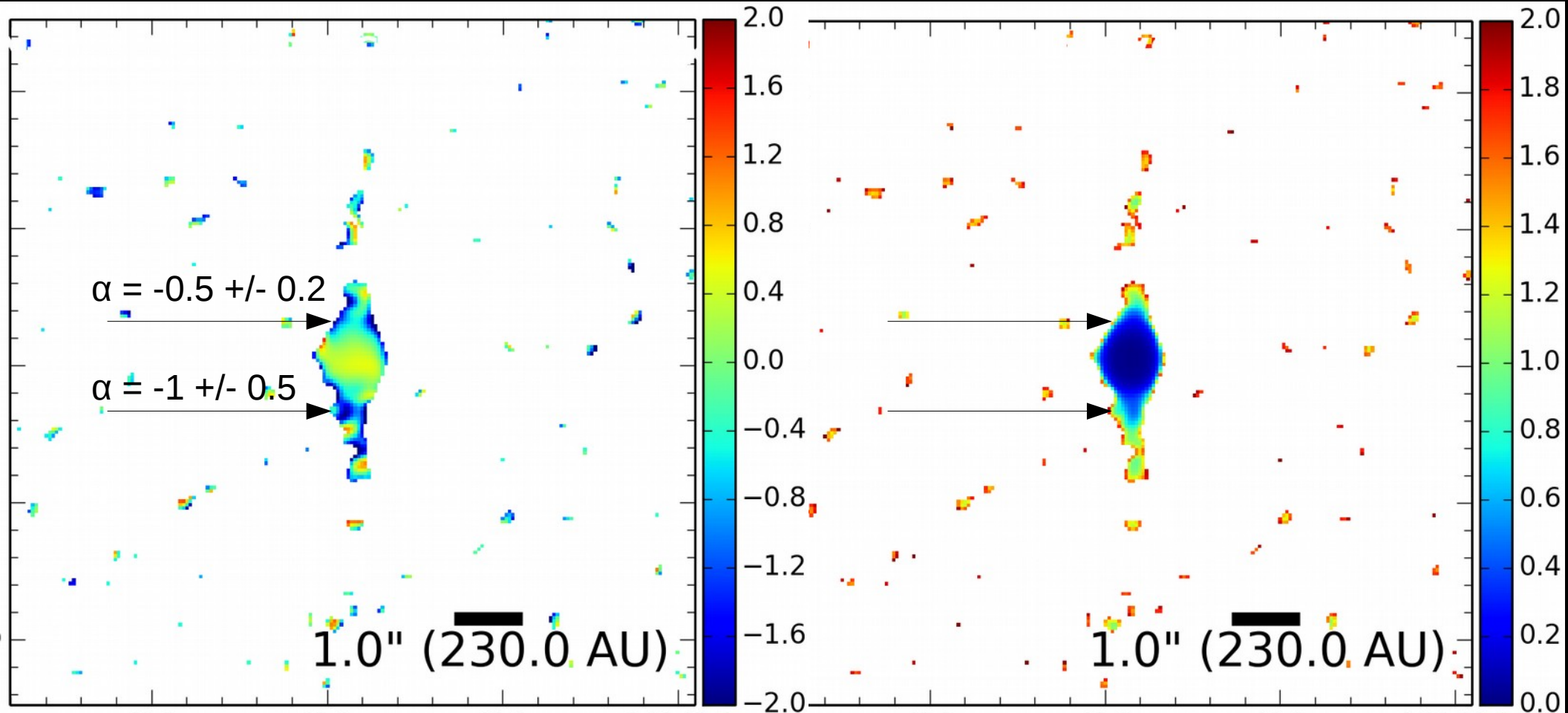


Tychoniec+2016 in prep.

Protostellar Jets: SVS13C

Spectral Index

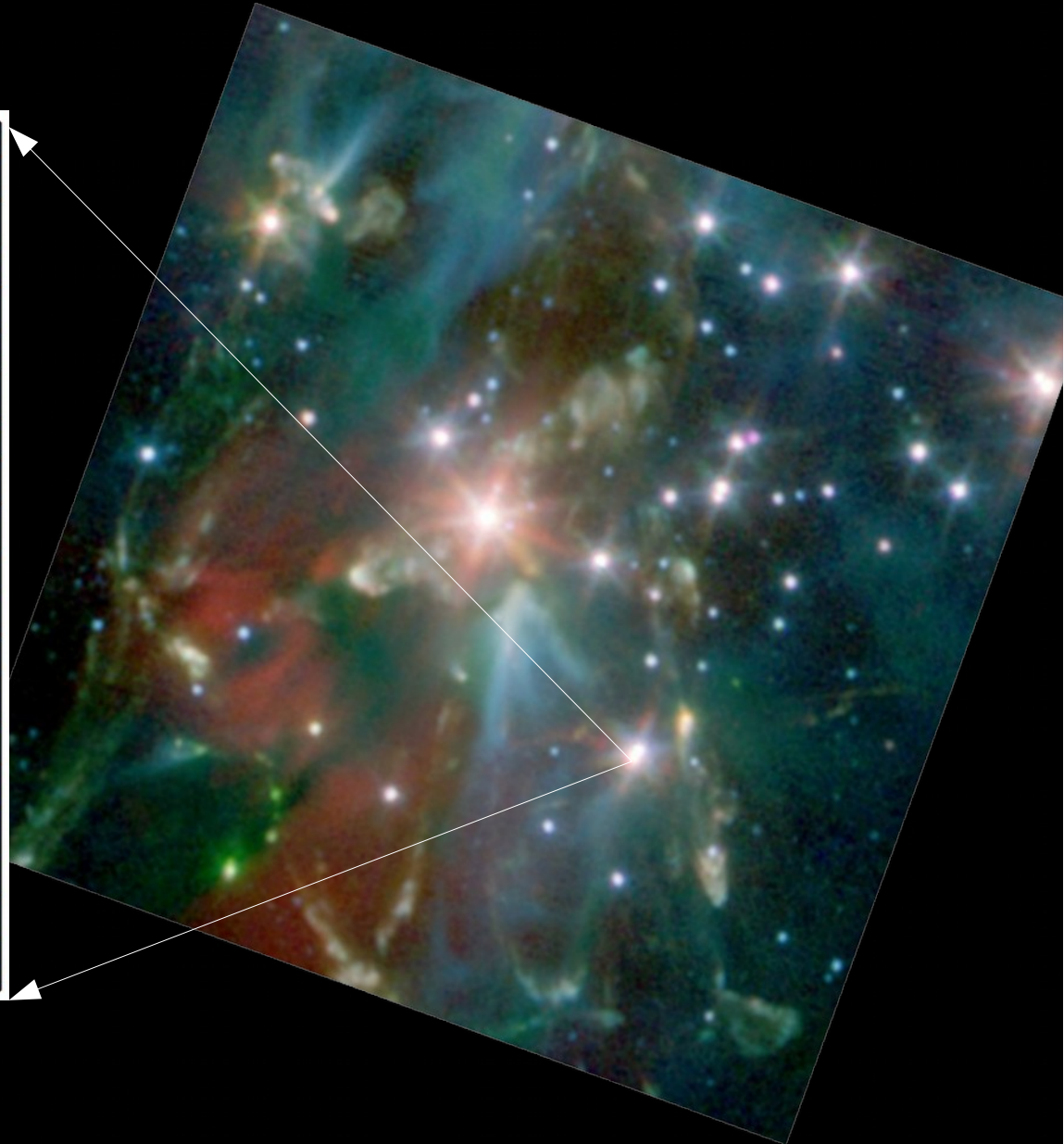
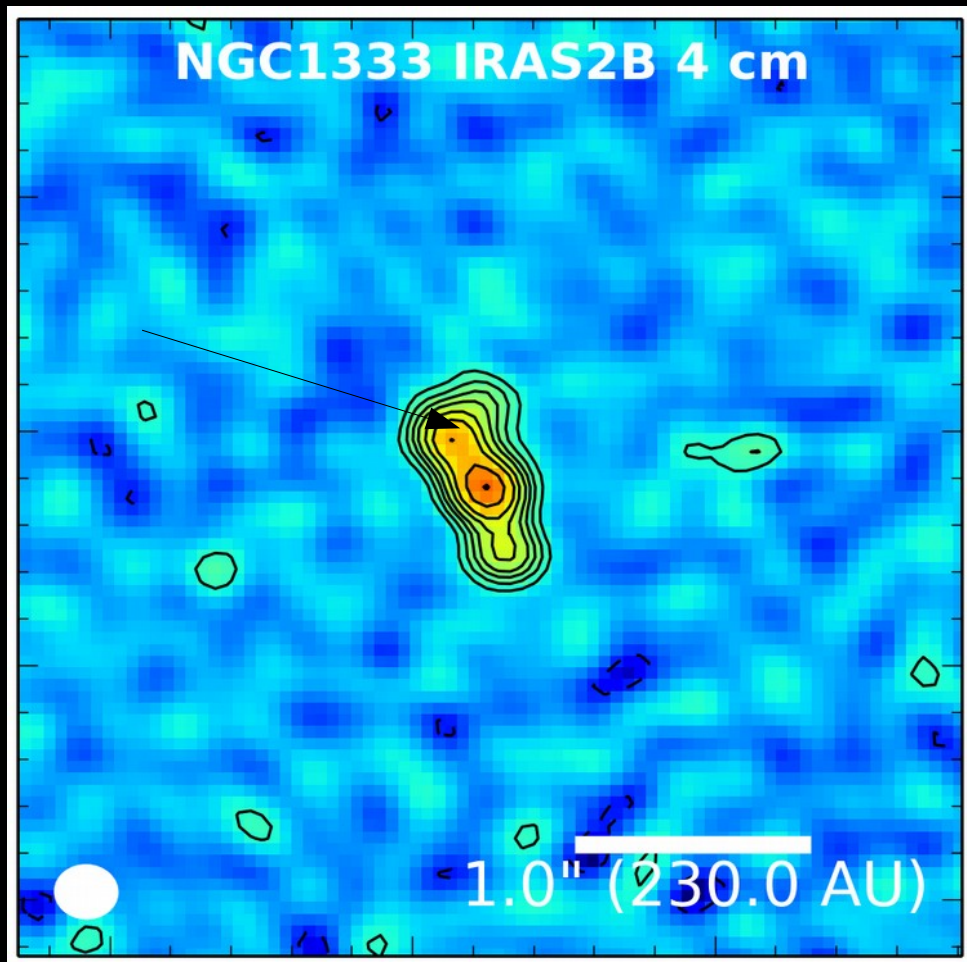
Spectral Index Error



Tychoniec+2016 in prep.

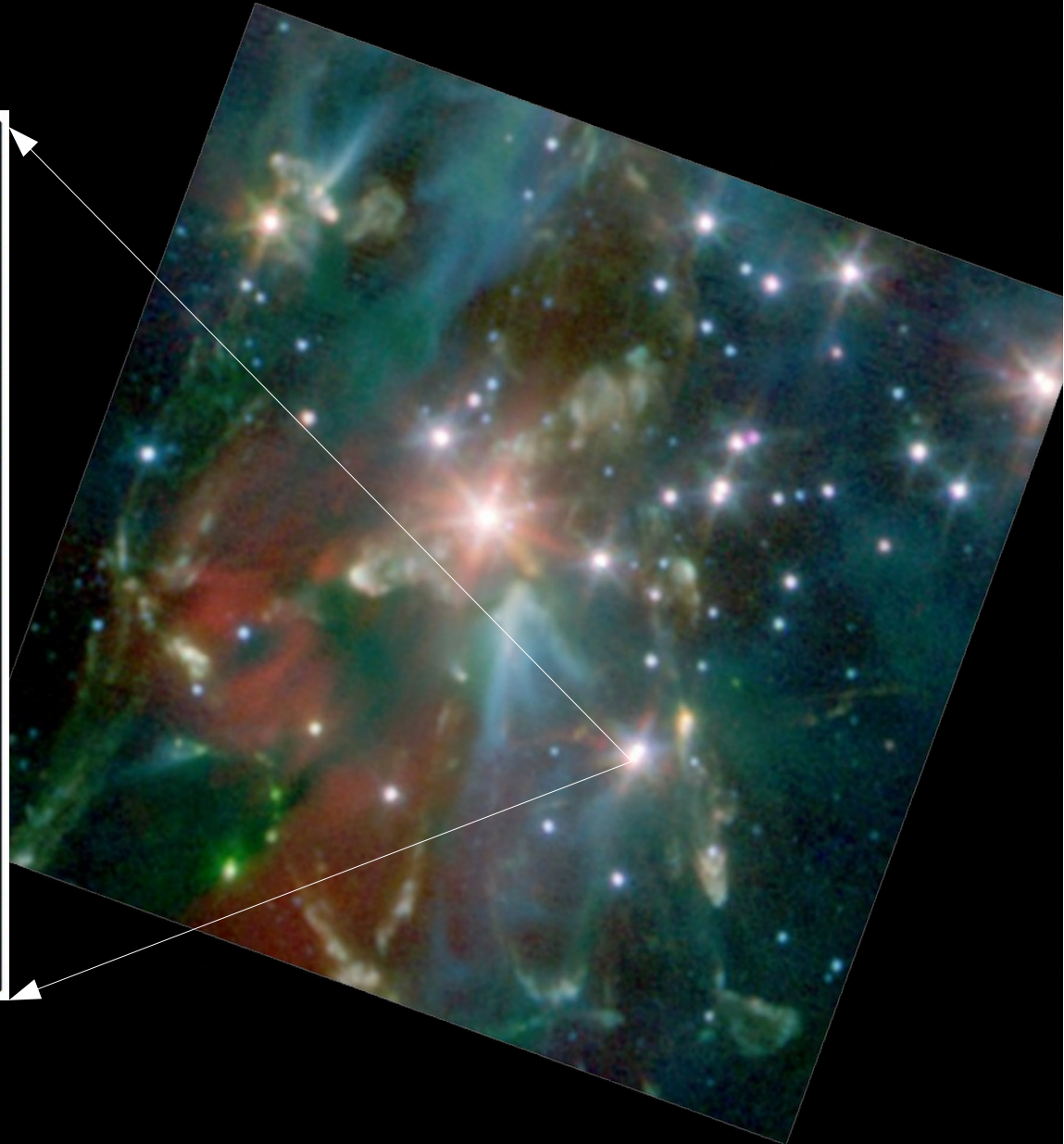
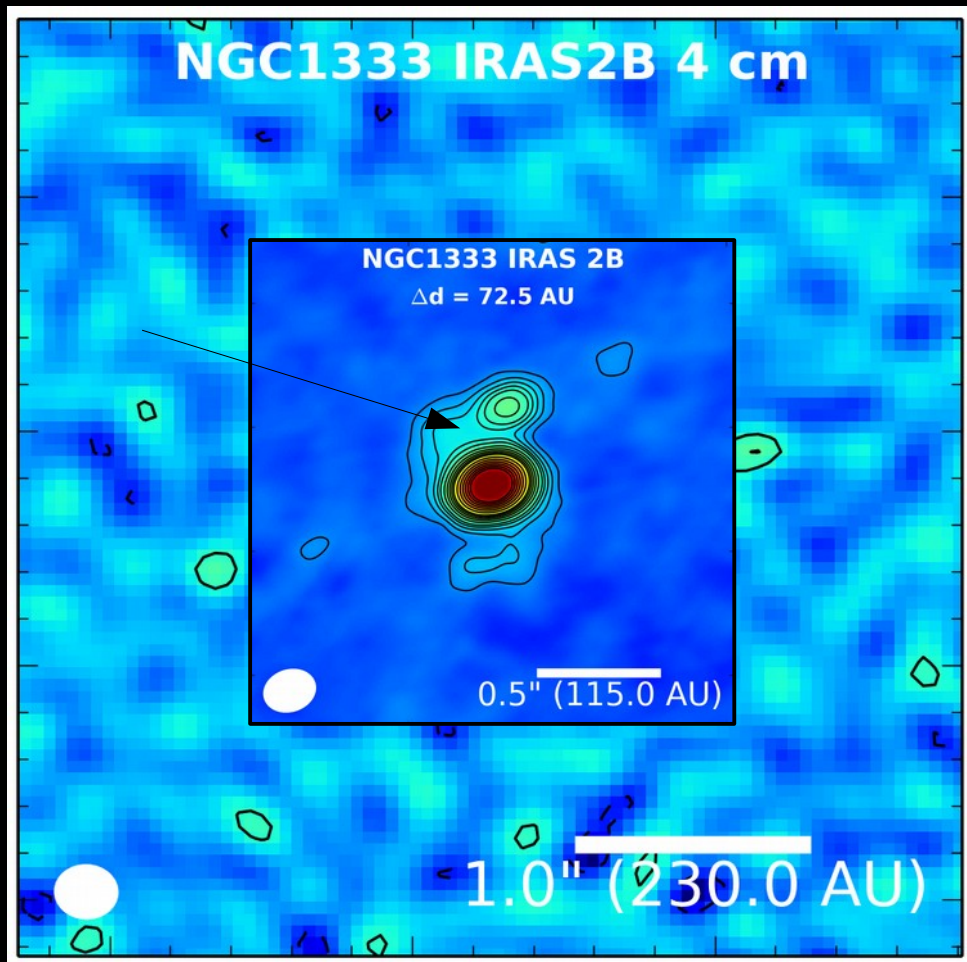
- No X-ray emission detected

Protostellar Jets: IRAS2B



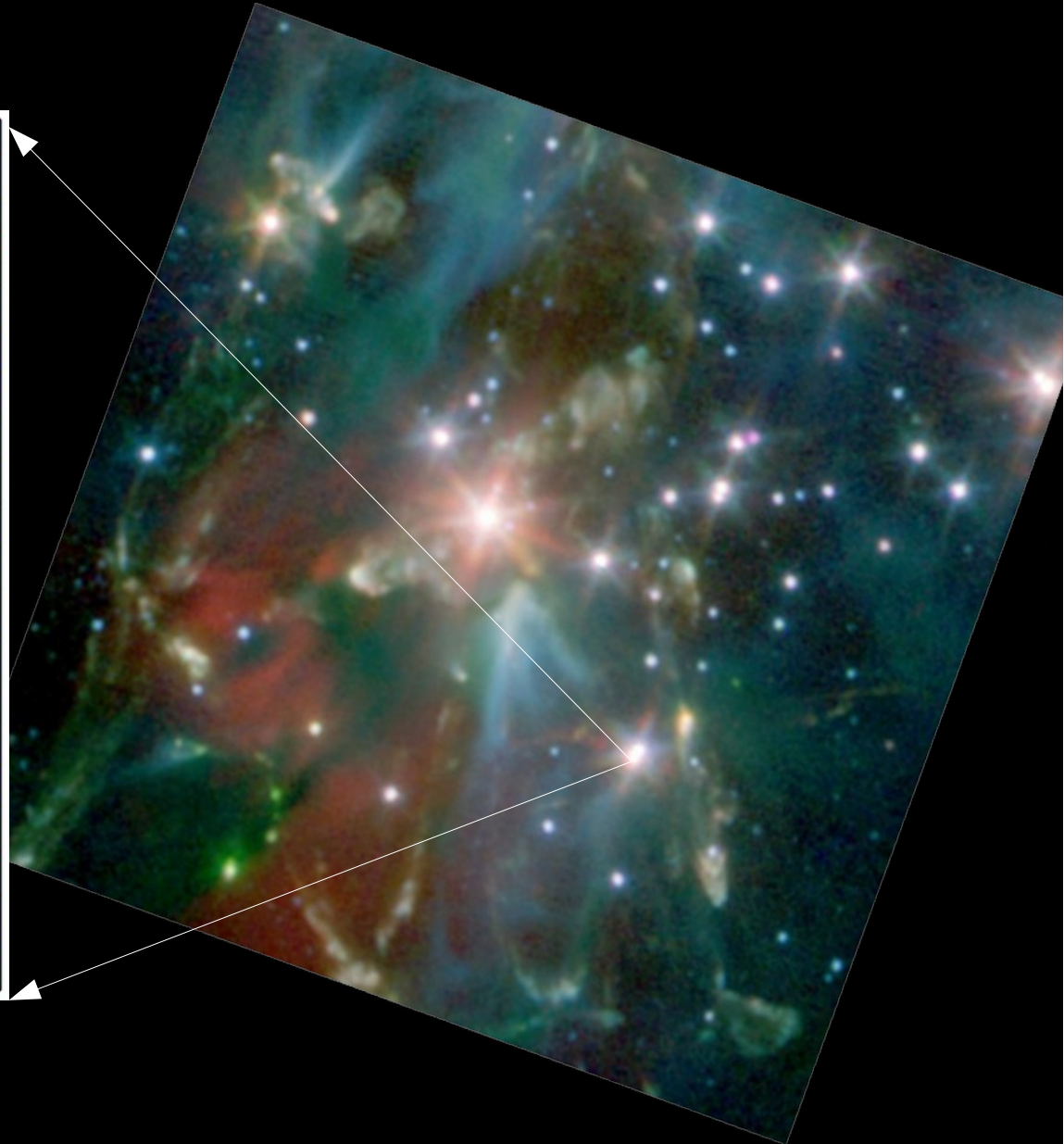
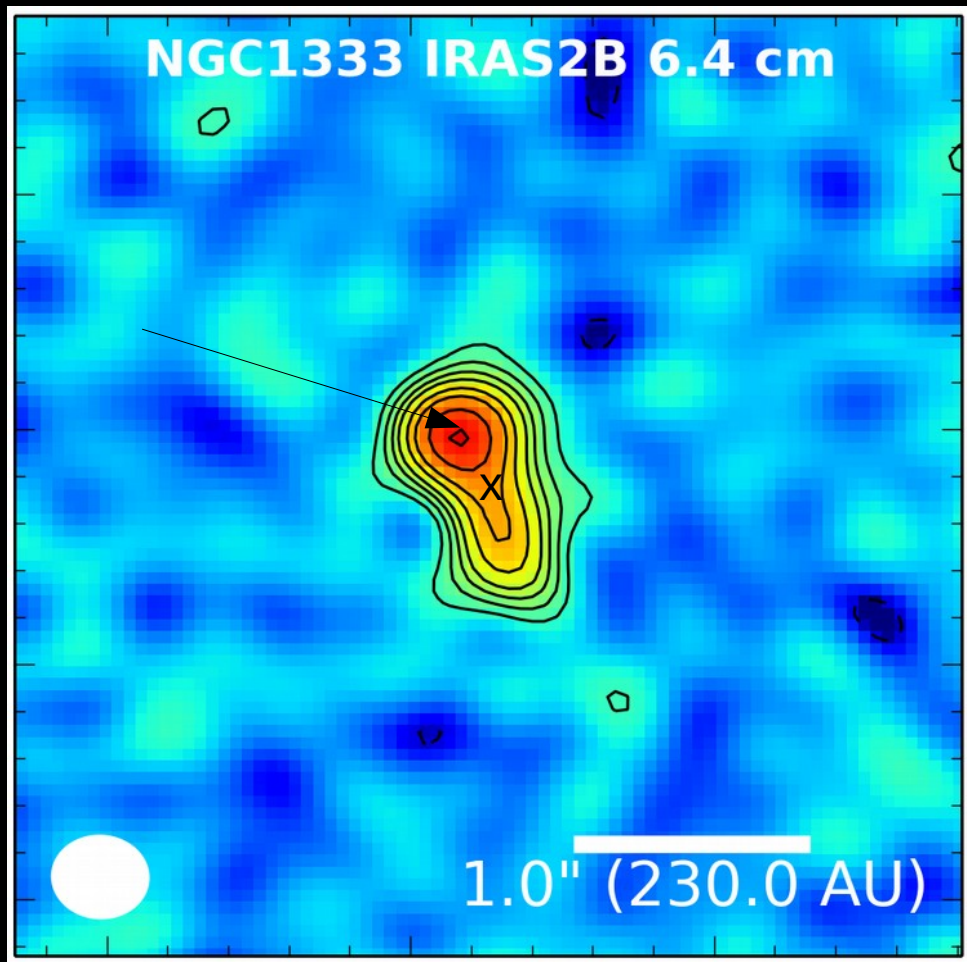
Tychoniec+2016 in prep.

Protostellar Jets: IRAS2B



Tychoniec+2016 in prep.

Protostellar Jets: IRAS2B

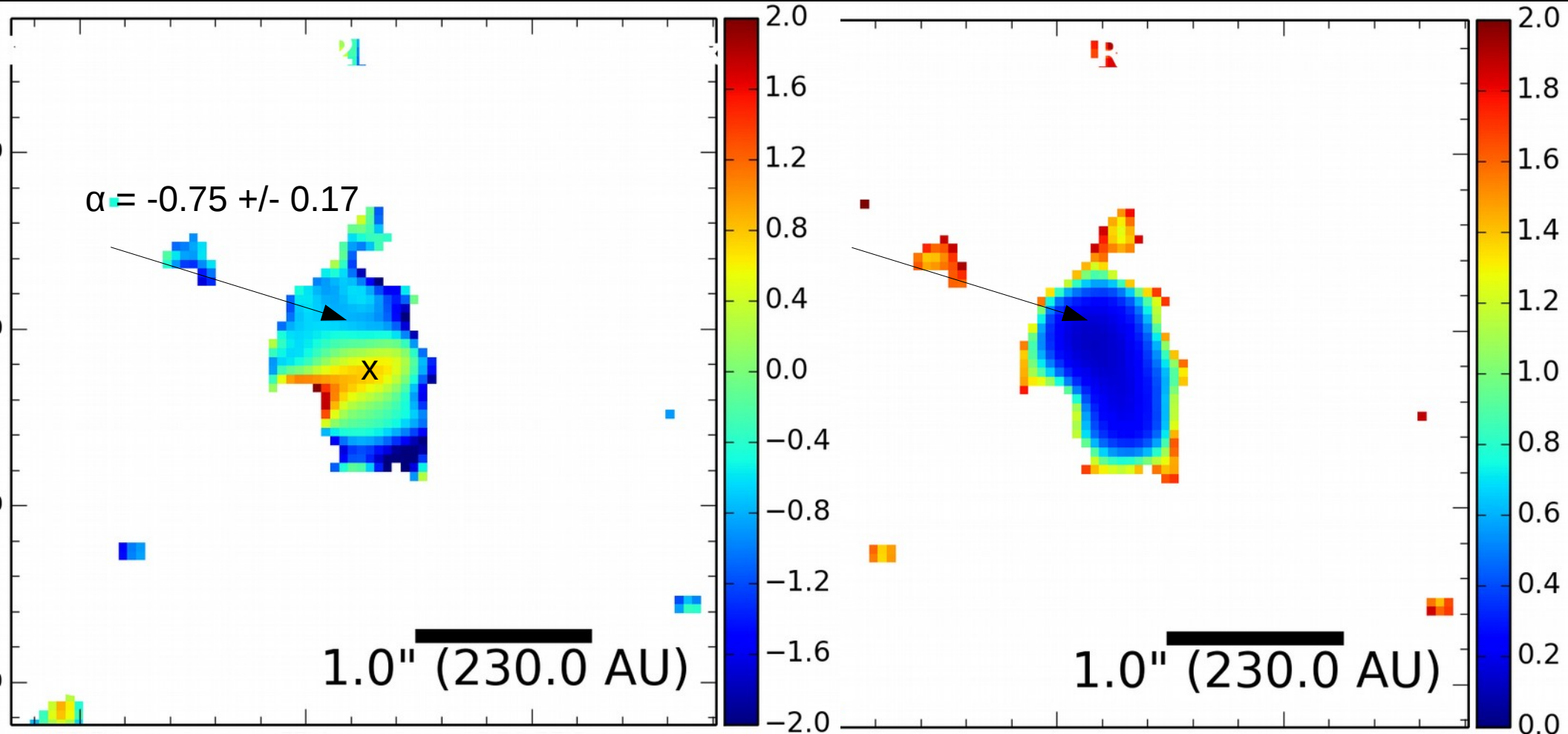


Tychoniec+2016 in prep.

Protostellar Jets: IRAS2B

Spectral Index

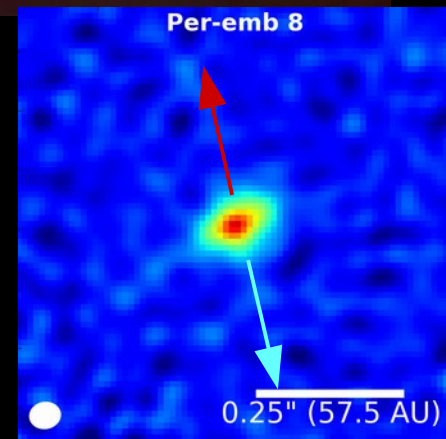
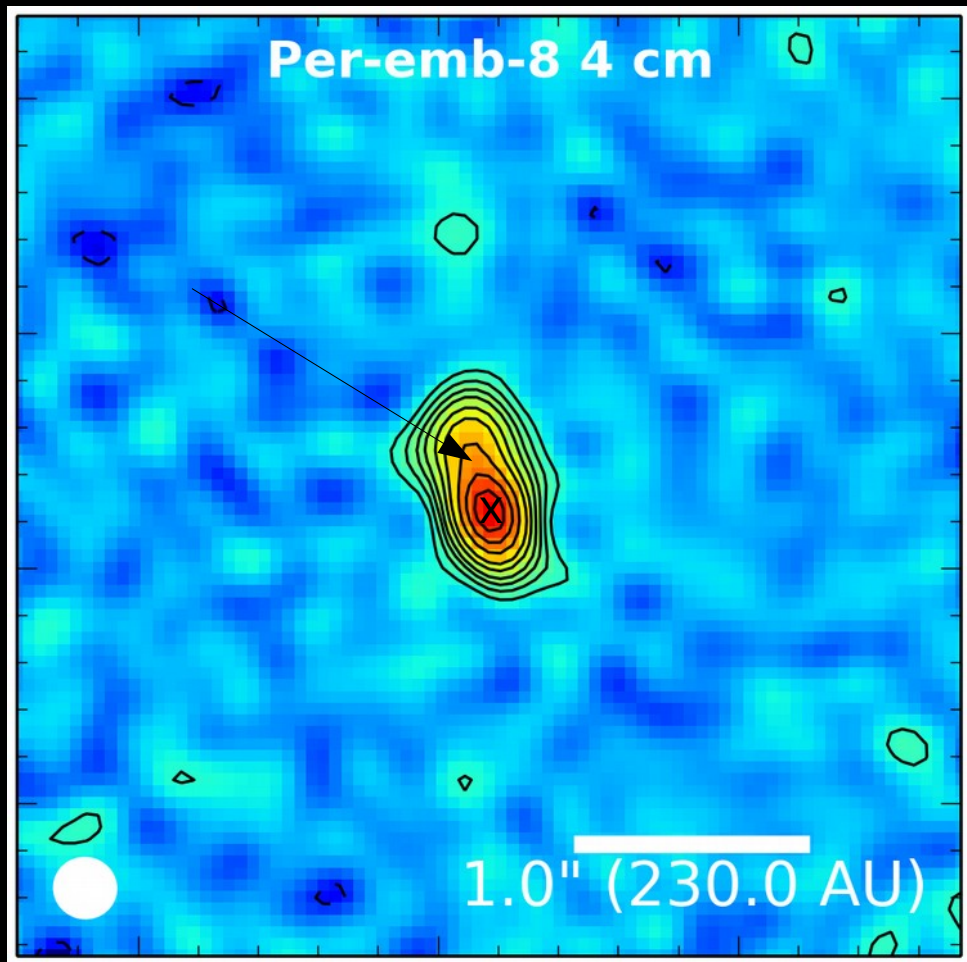
Spectral Index Error



Tychoniec+2016 in prep.

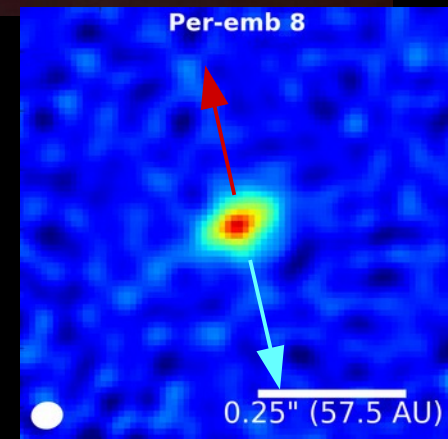
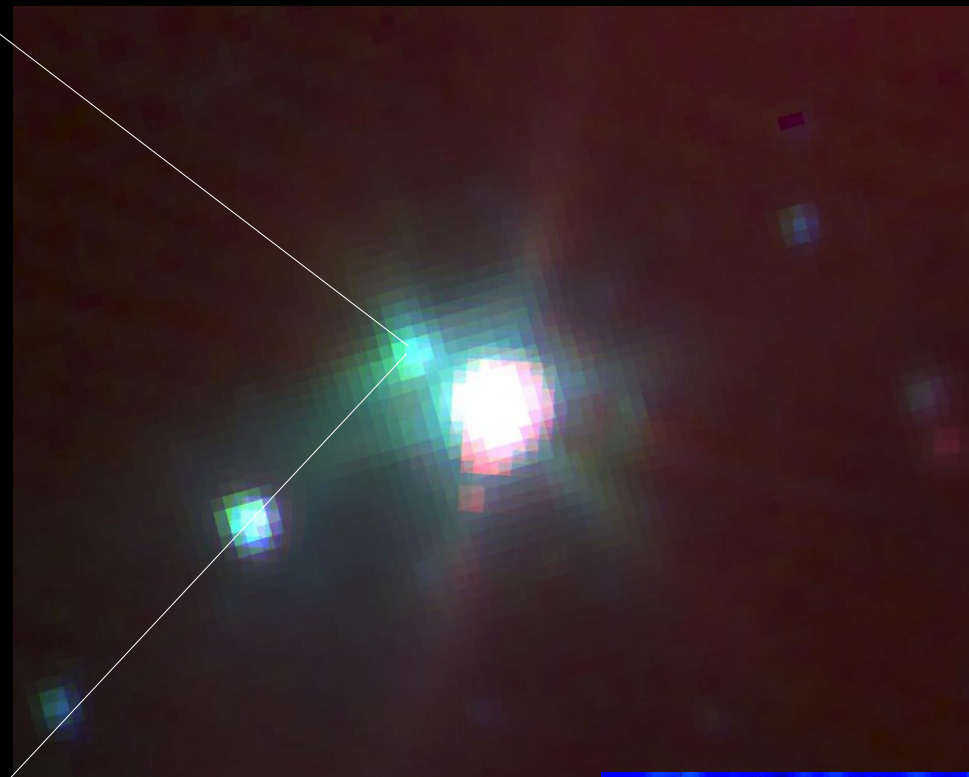
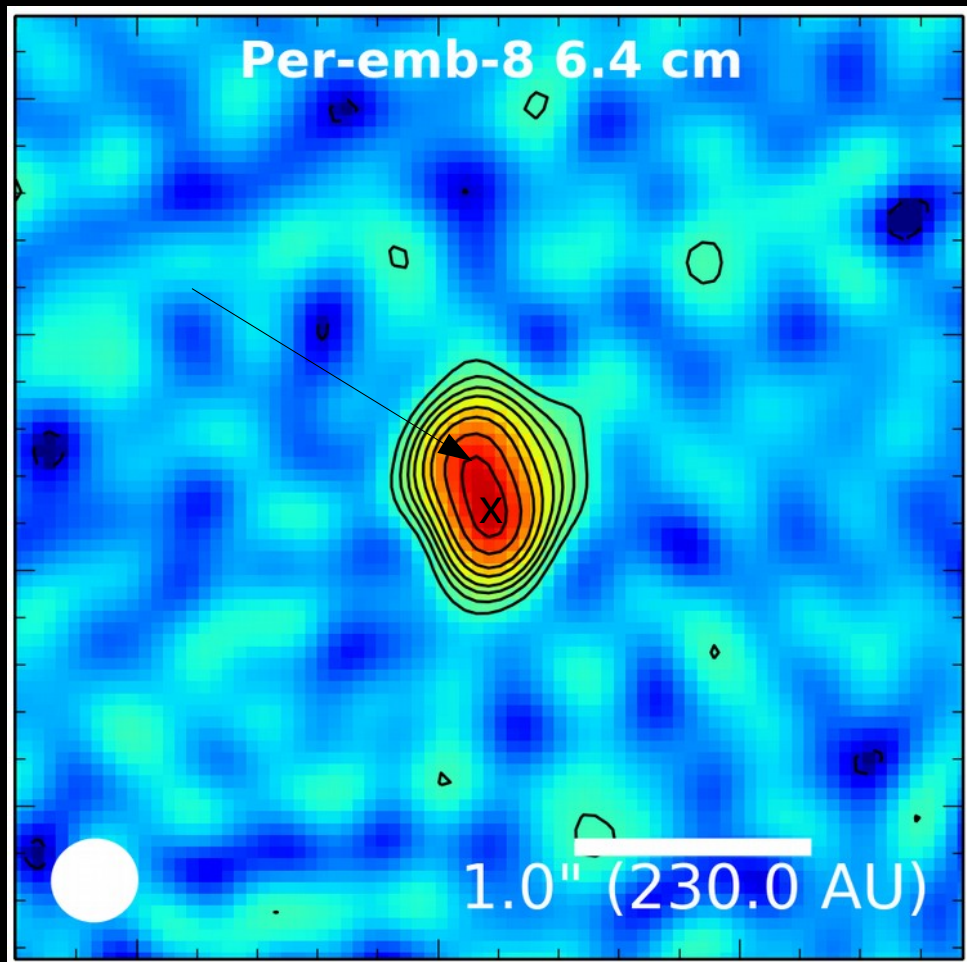
- X-ray emission possibly detected, blended with nearby Class III YSO
- Class III source has negative spectral index at 4 cm/6 cm

Protostellar Jets: Per-emb-8



Tychoniec+2016 in prep.

Protostellar Jets: Per-emb-8

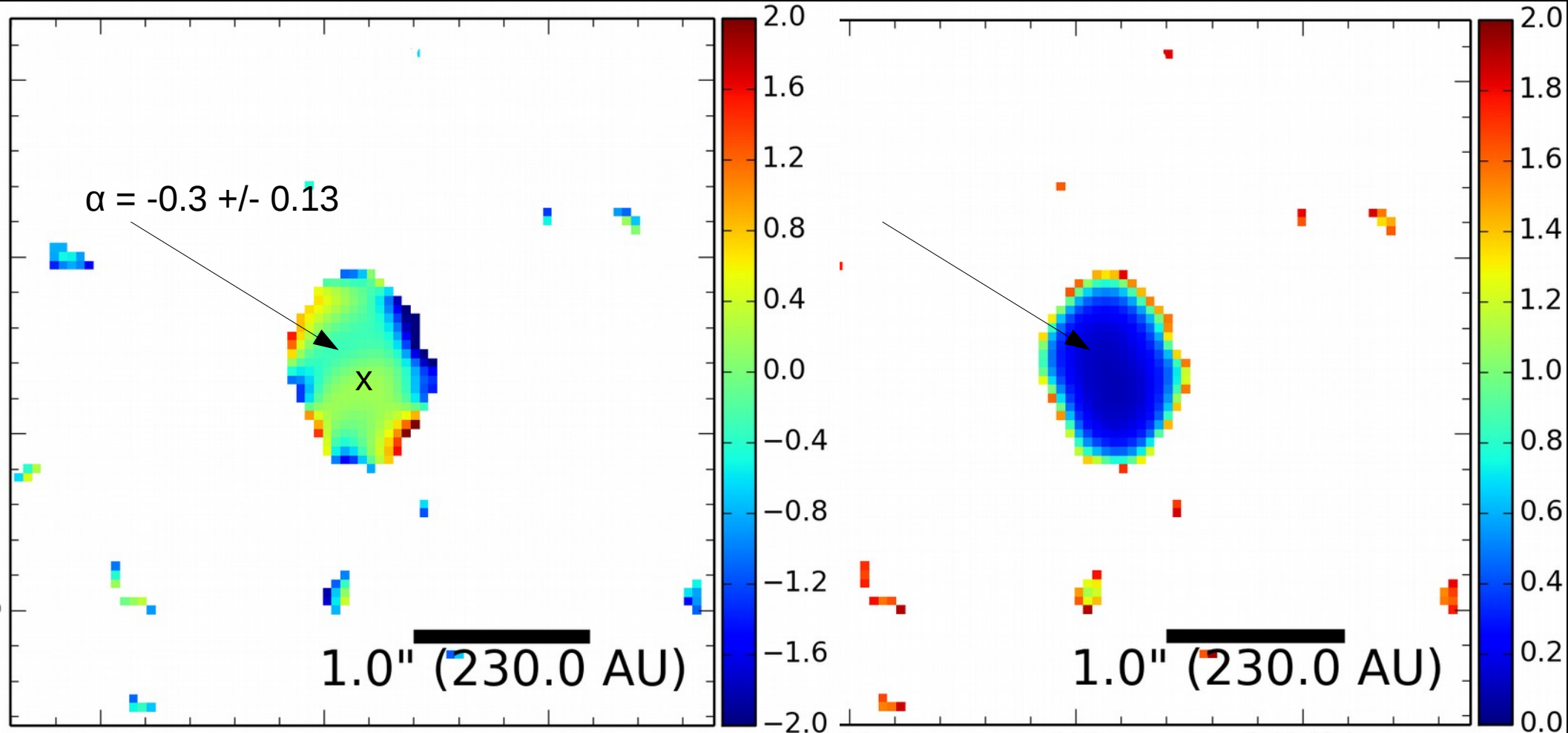


Tychoniec+2016 in prep.

Protostellar Jets: Per-emb-8

Spectral Index

Spectral Index Error

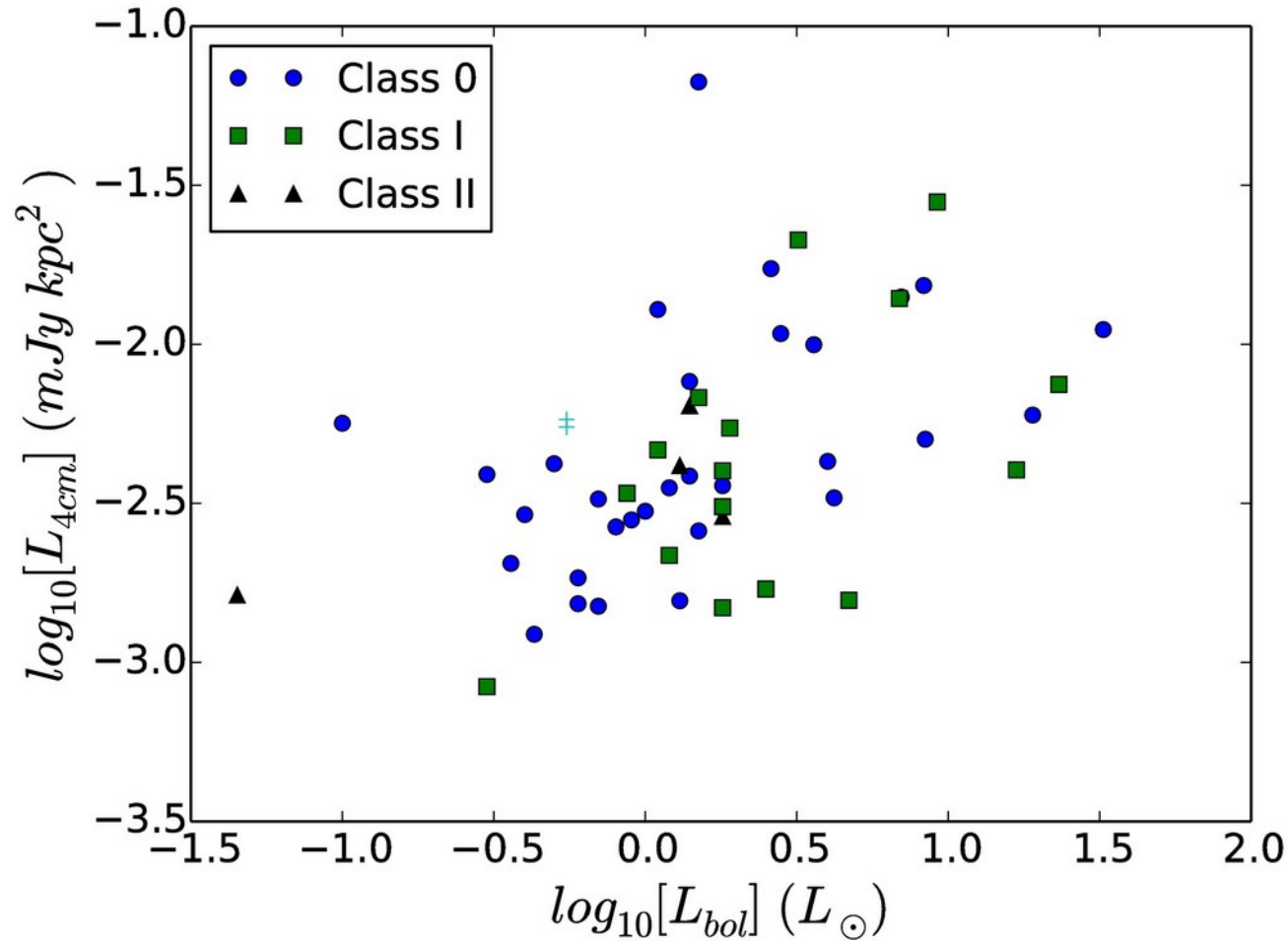


Tychoniec+2016 in prep.

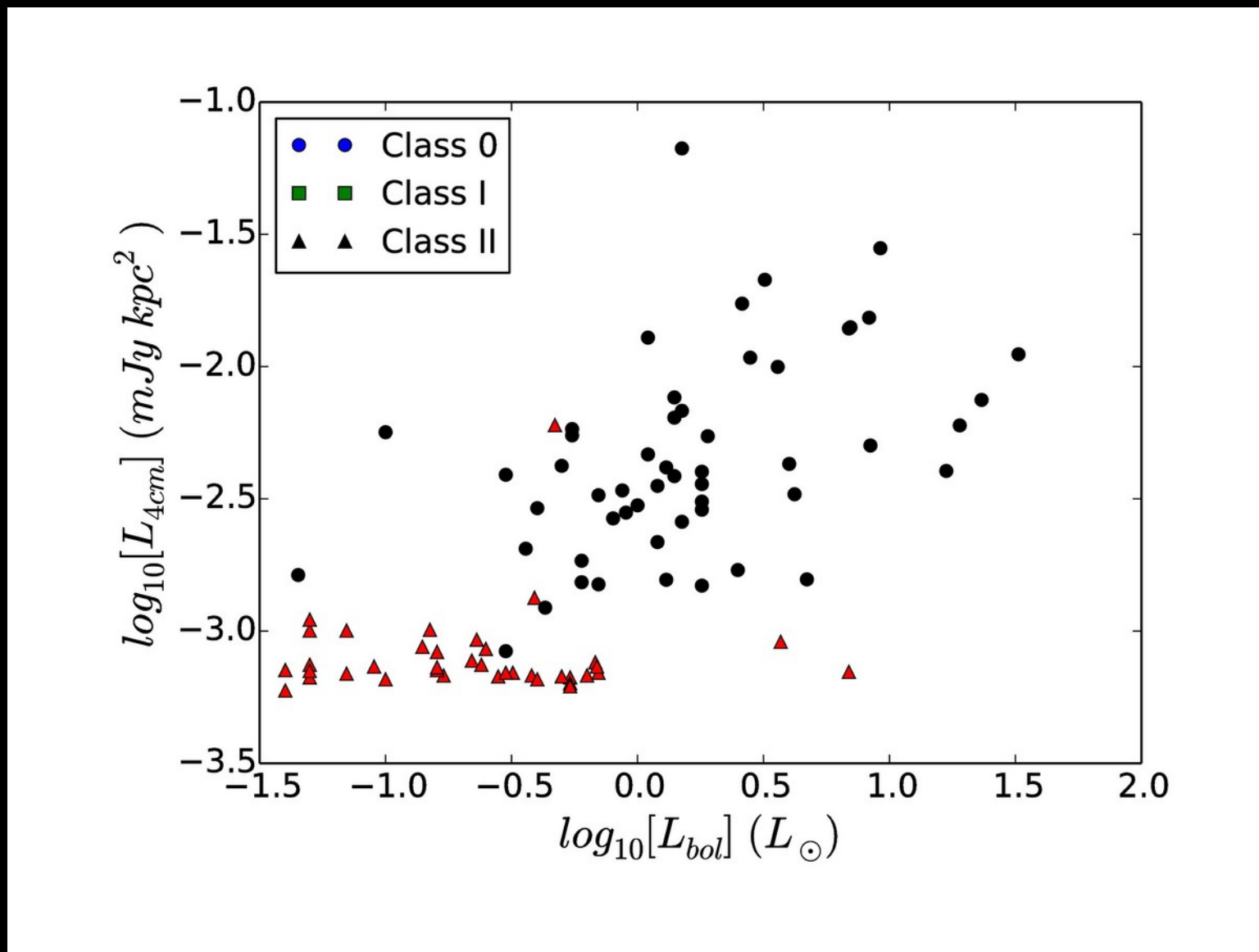
- No X-ray data

L_{cm} vs. Source Luminosity

L_{cm} vs. Source Luminosity

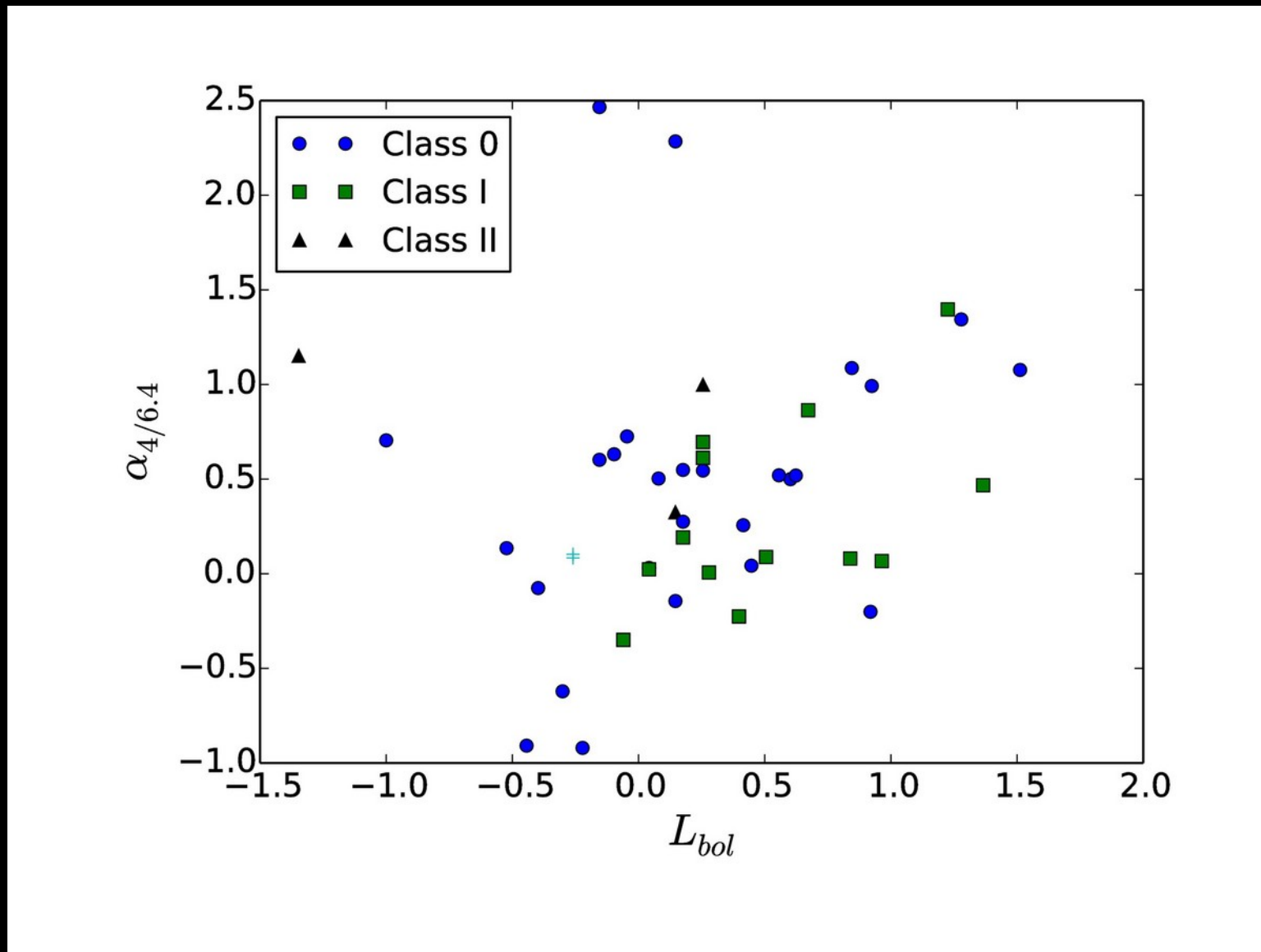


L_{cm} vs. Source Luminosity



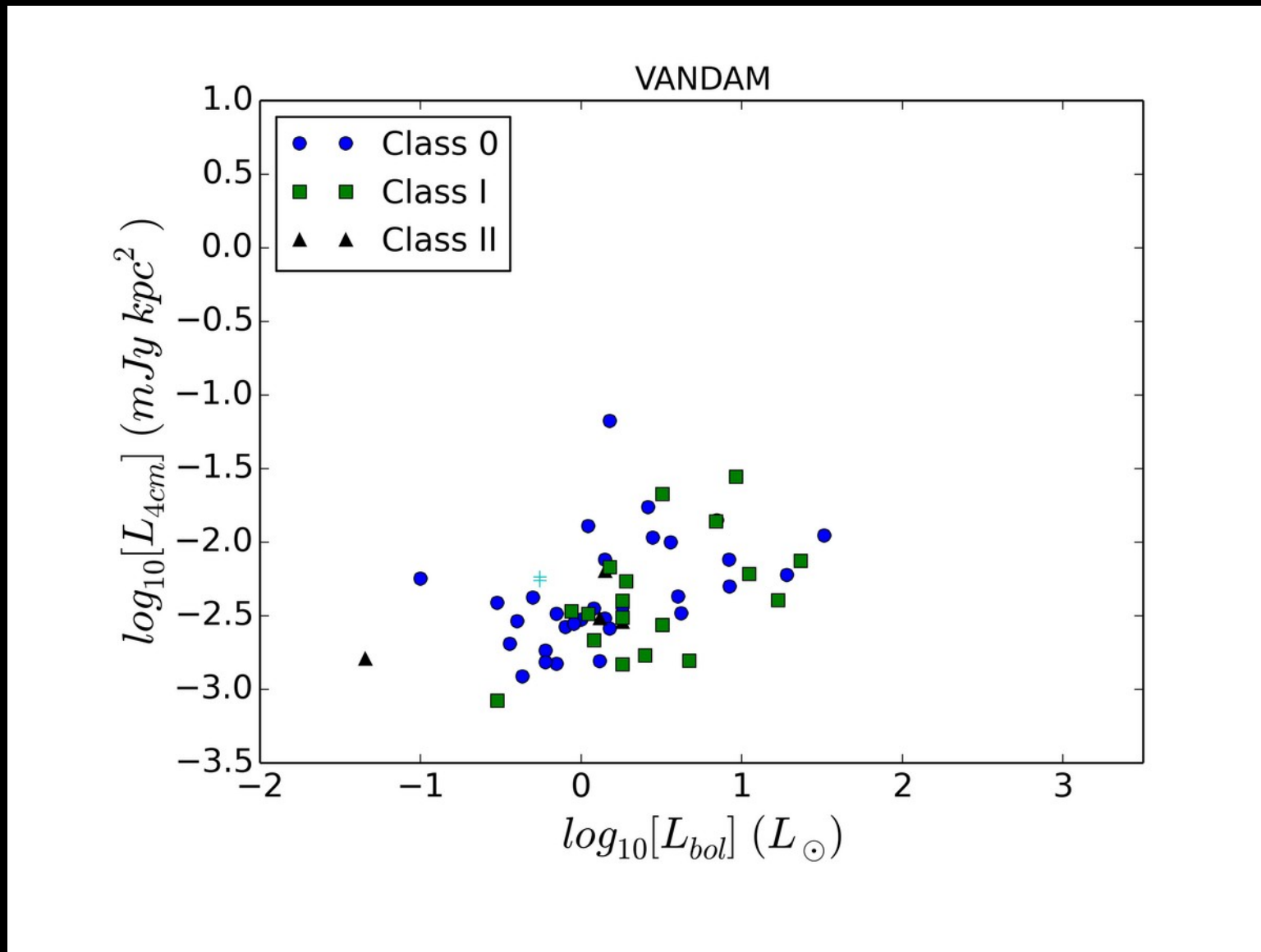
- 57% of protostars detected
- No detections toward FHSCs candidates

Spectral Index vs. Source Luminosity

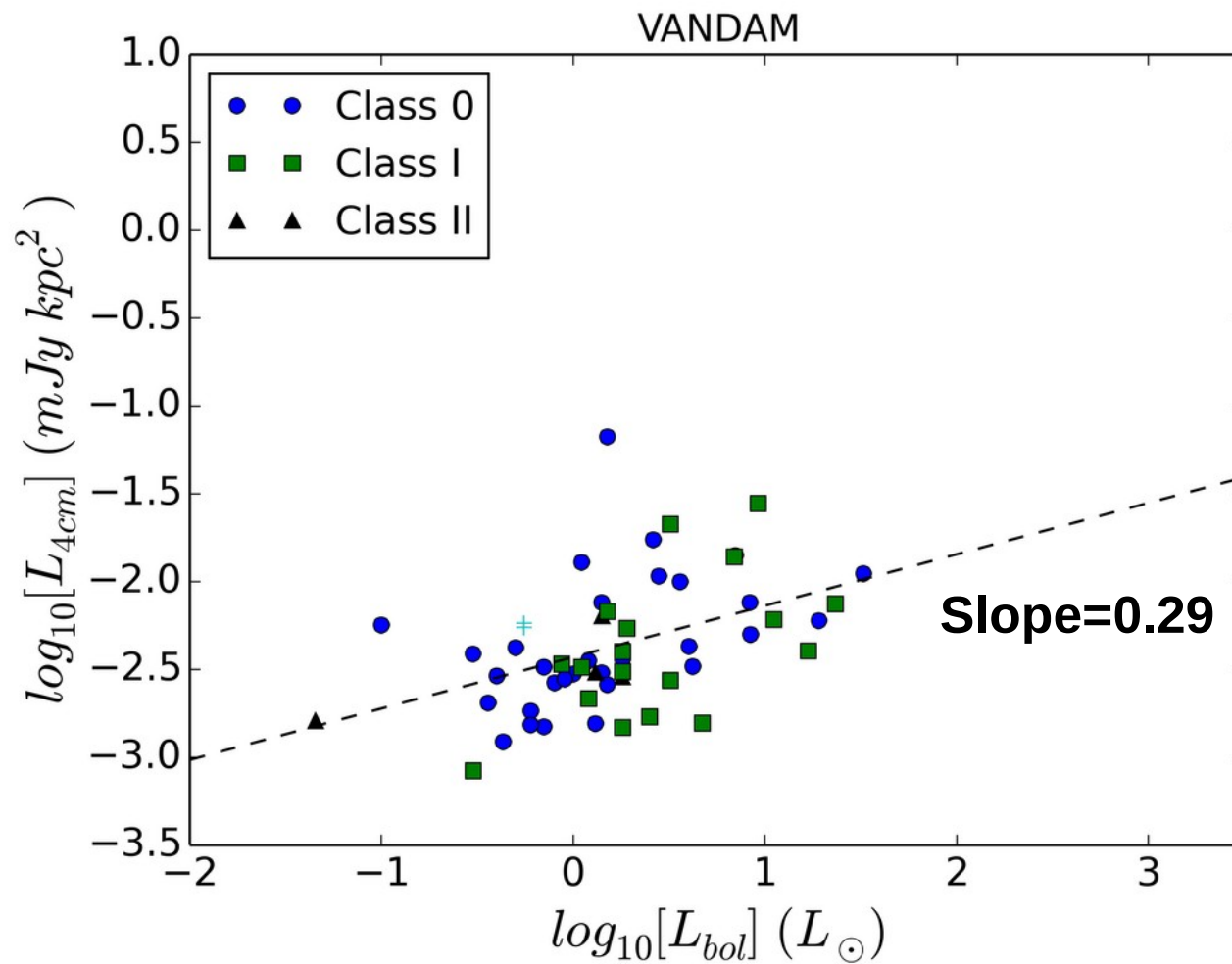


- Spectral index of ~ 0.25 'typical' for protostars with large scatter

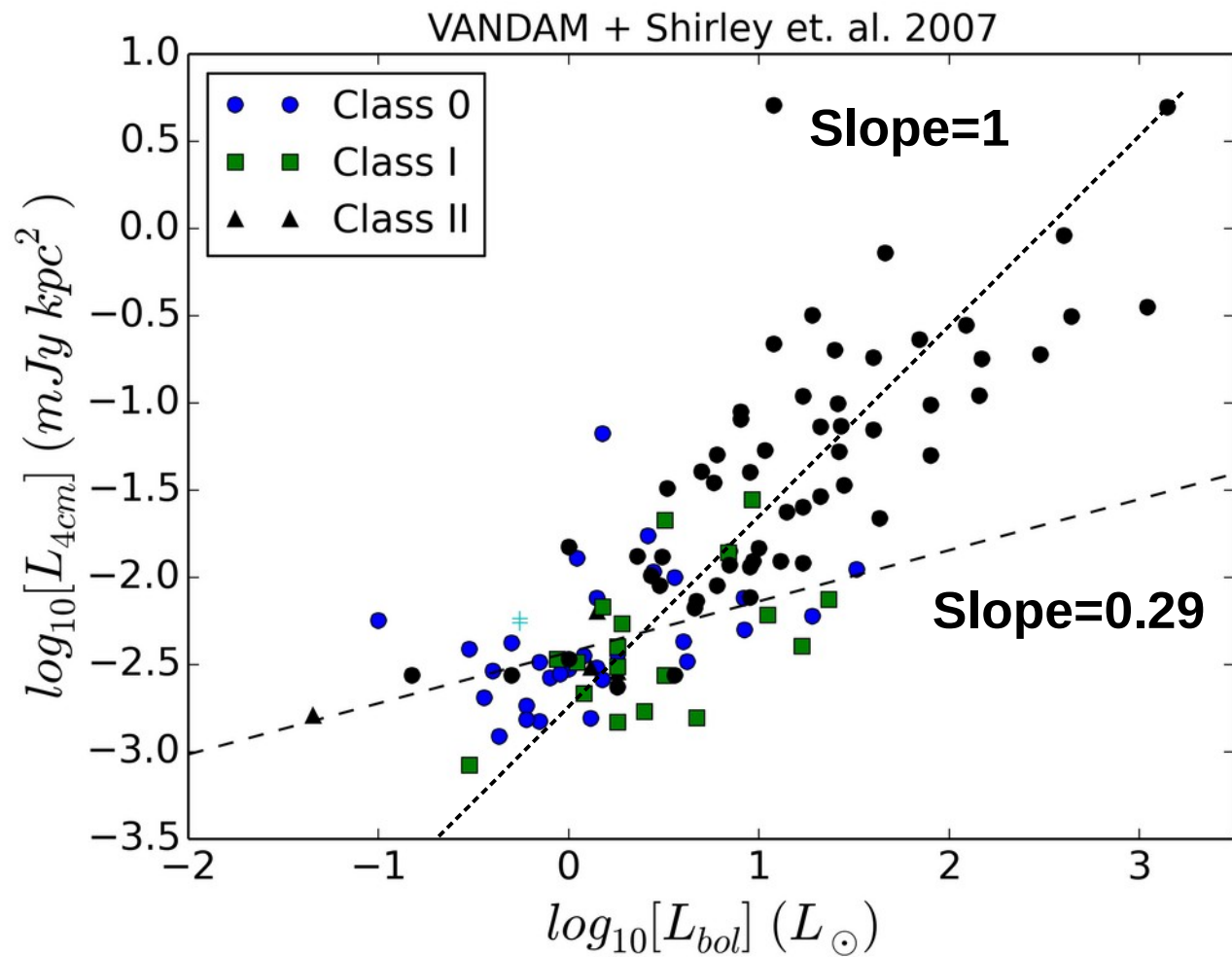
L_{cm} vs. Source Luminosity



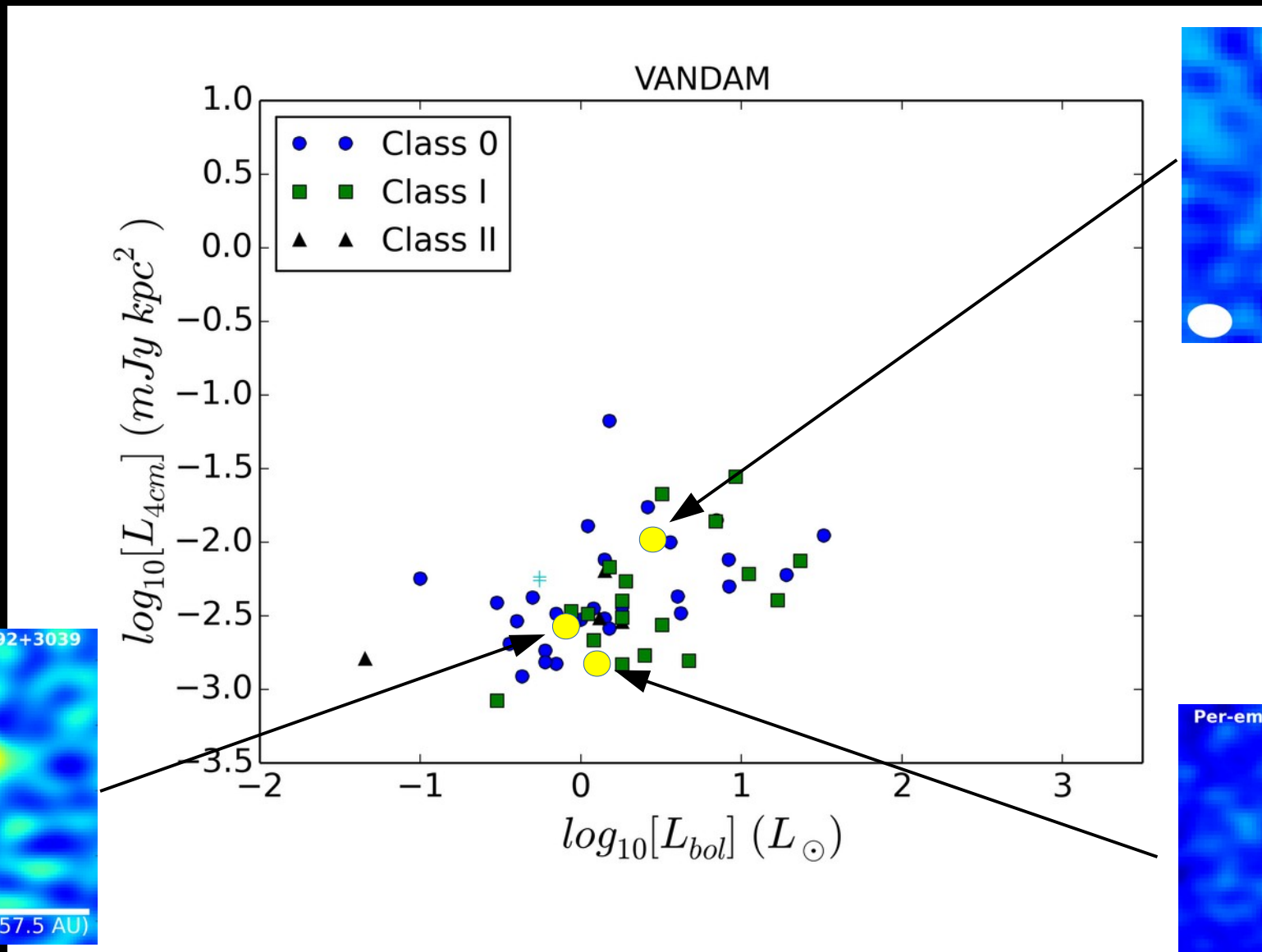
L_{cm} vs. Source Luminosity



L_{cm} vs. Source Luminosity

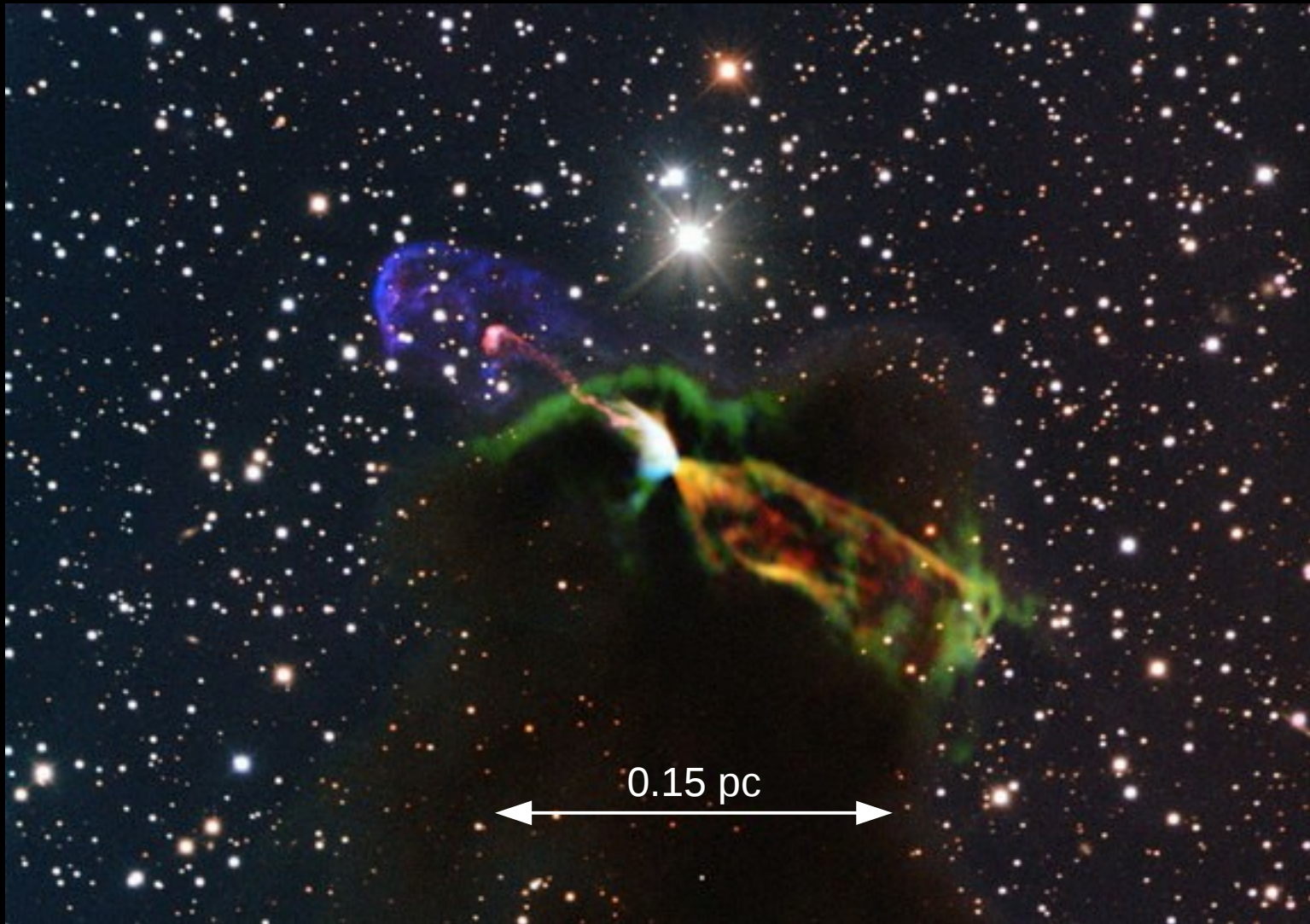


L_{cm} and Close Multiples



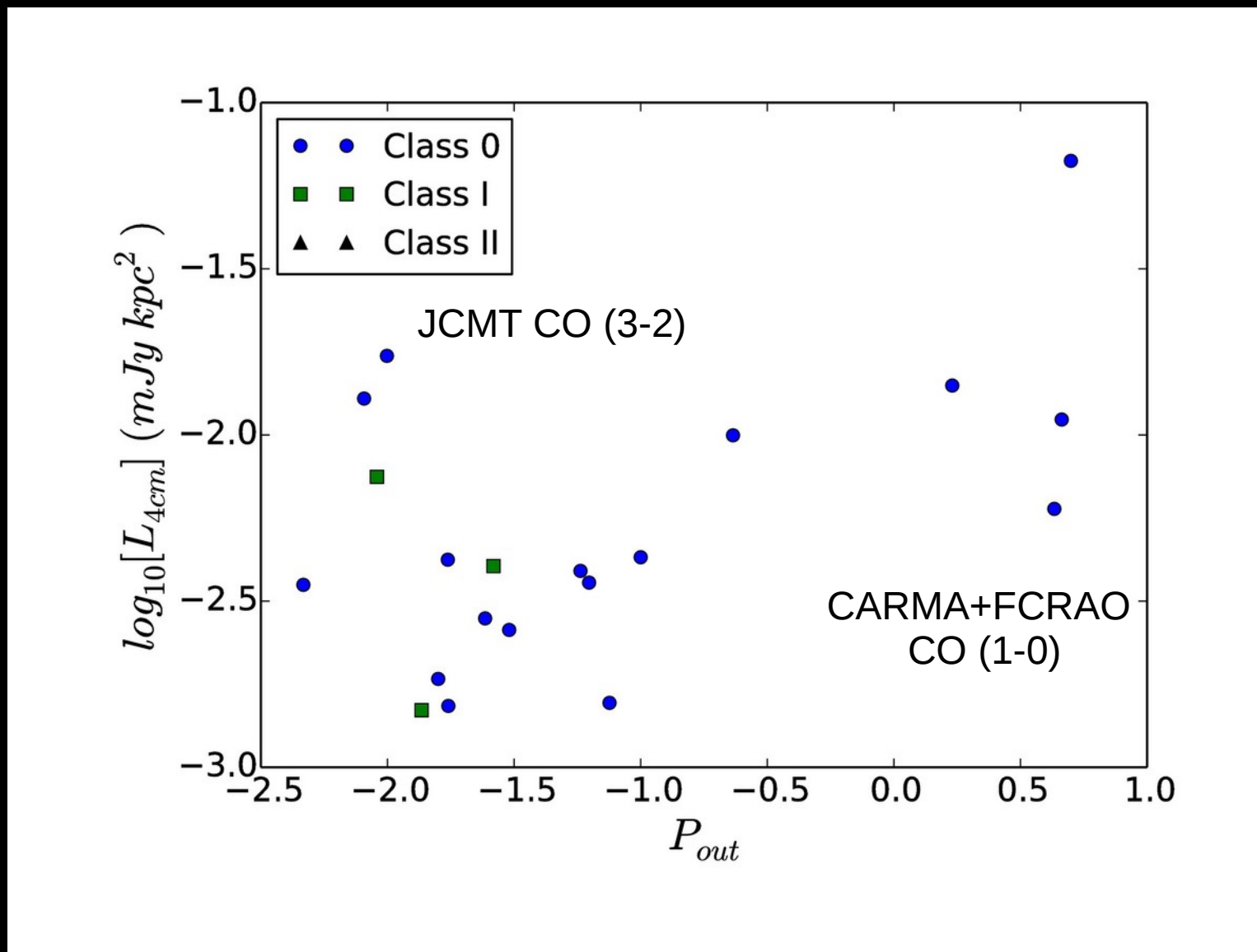
- Close multiples do not appear to affect production of free-free emission

L_{cm} vs. Molecular Outflow



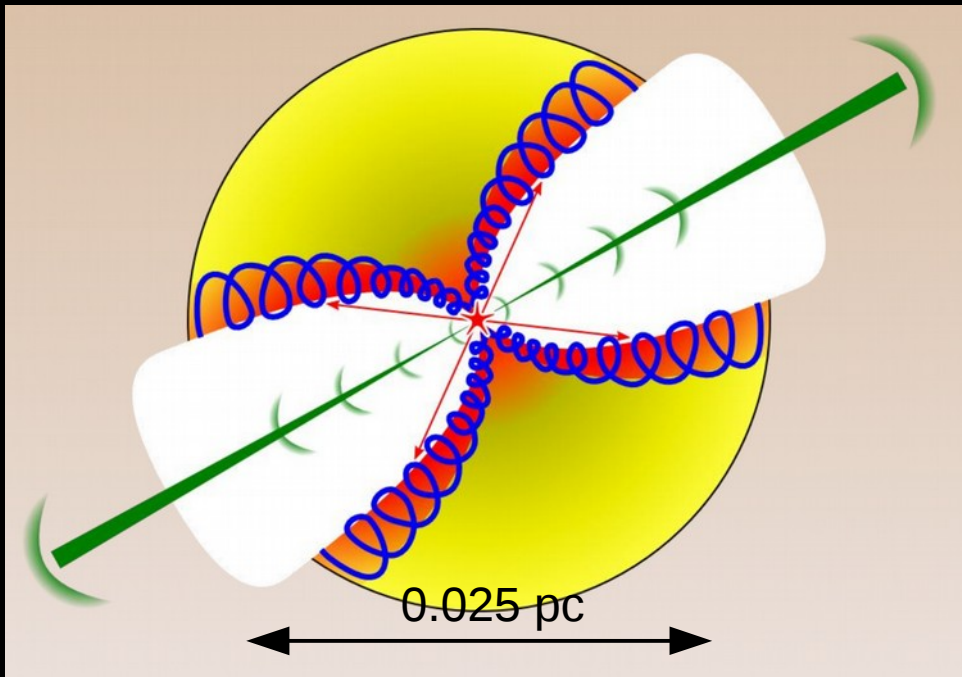
ALMA HH46/47; Arce+2014

L_{cm} vs. ^{12}CO

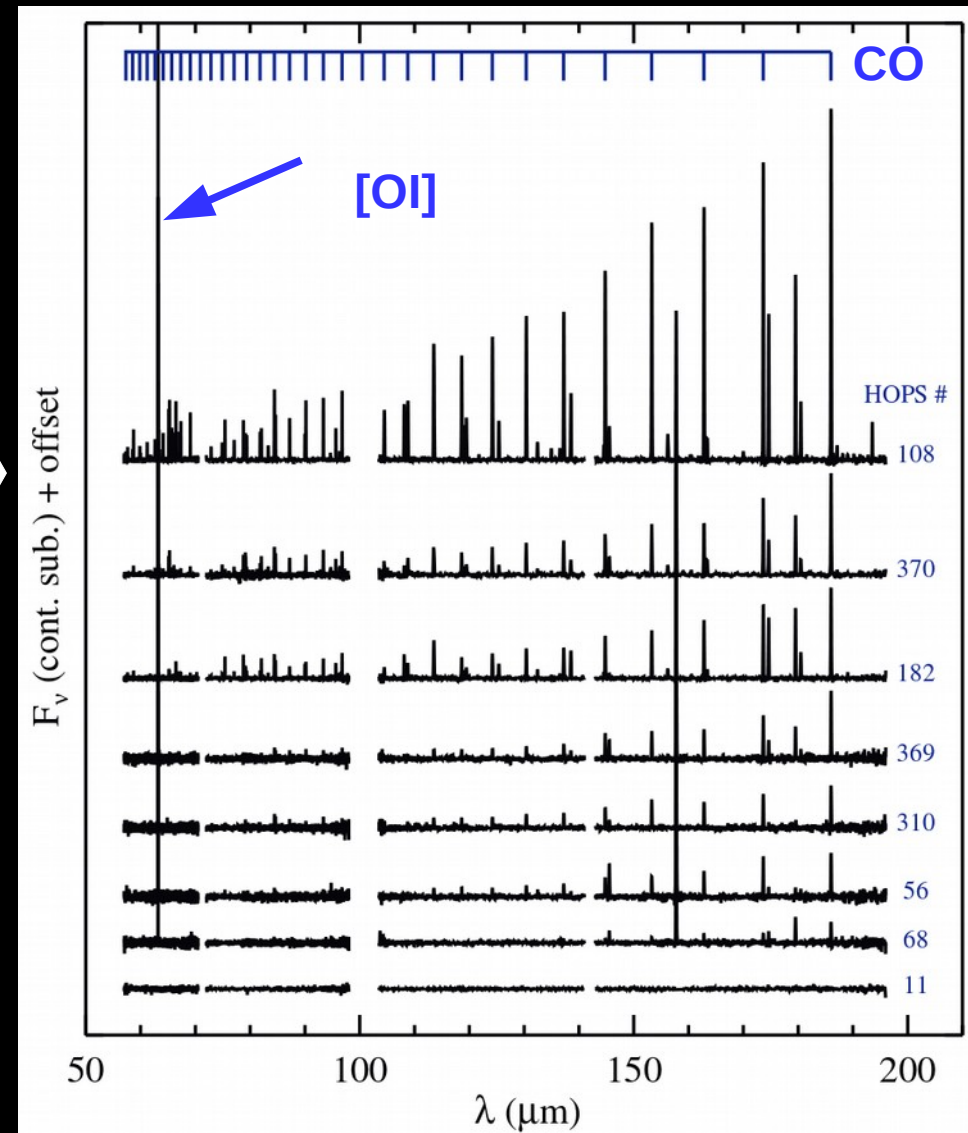


- Possible weak correlation with outflow momentum

L_{cm} vs. *Herschel*

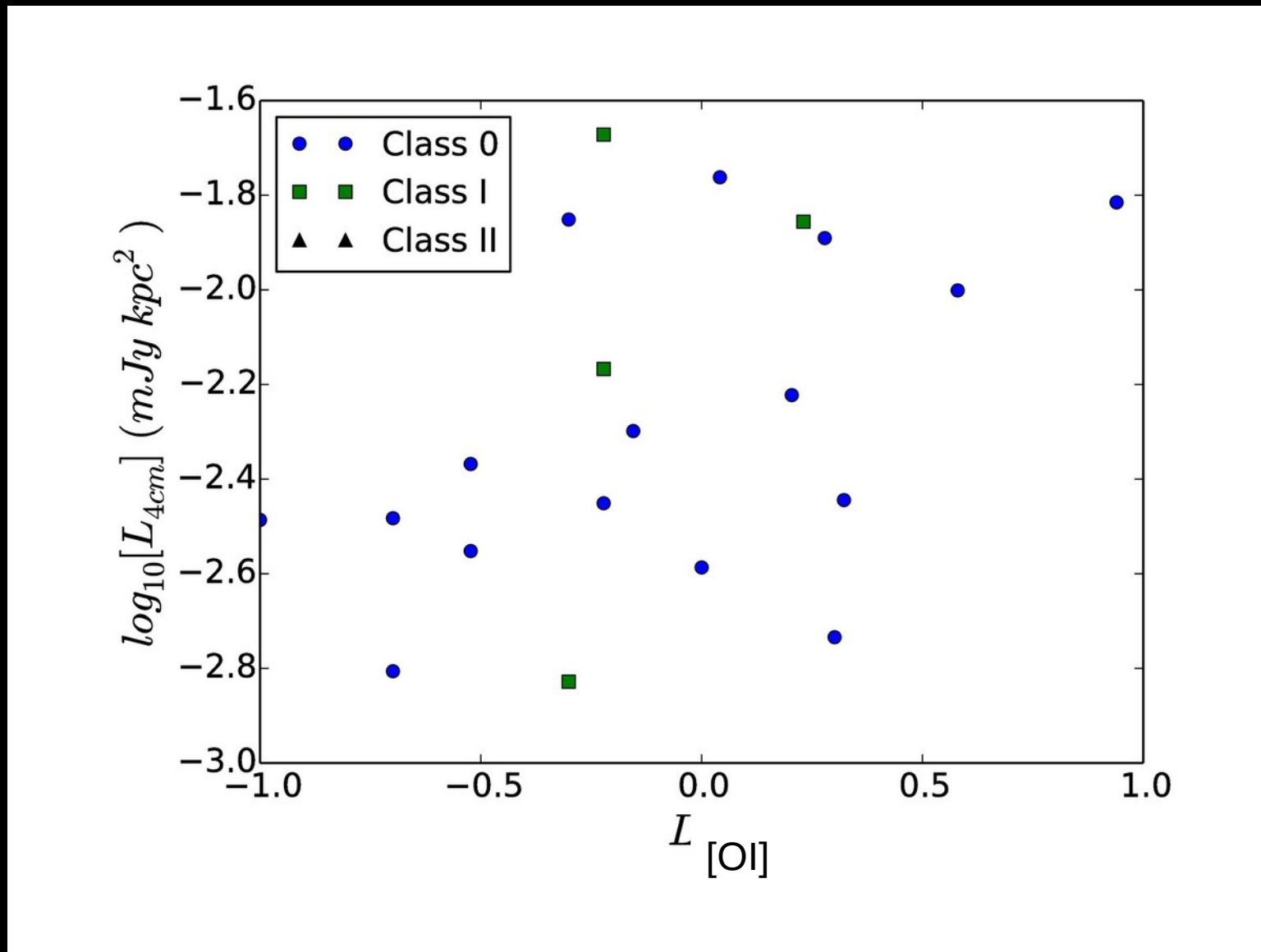


Credit: Ruud Visser



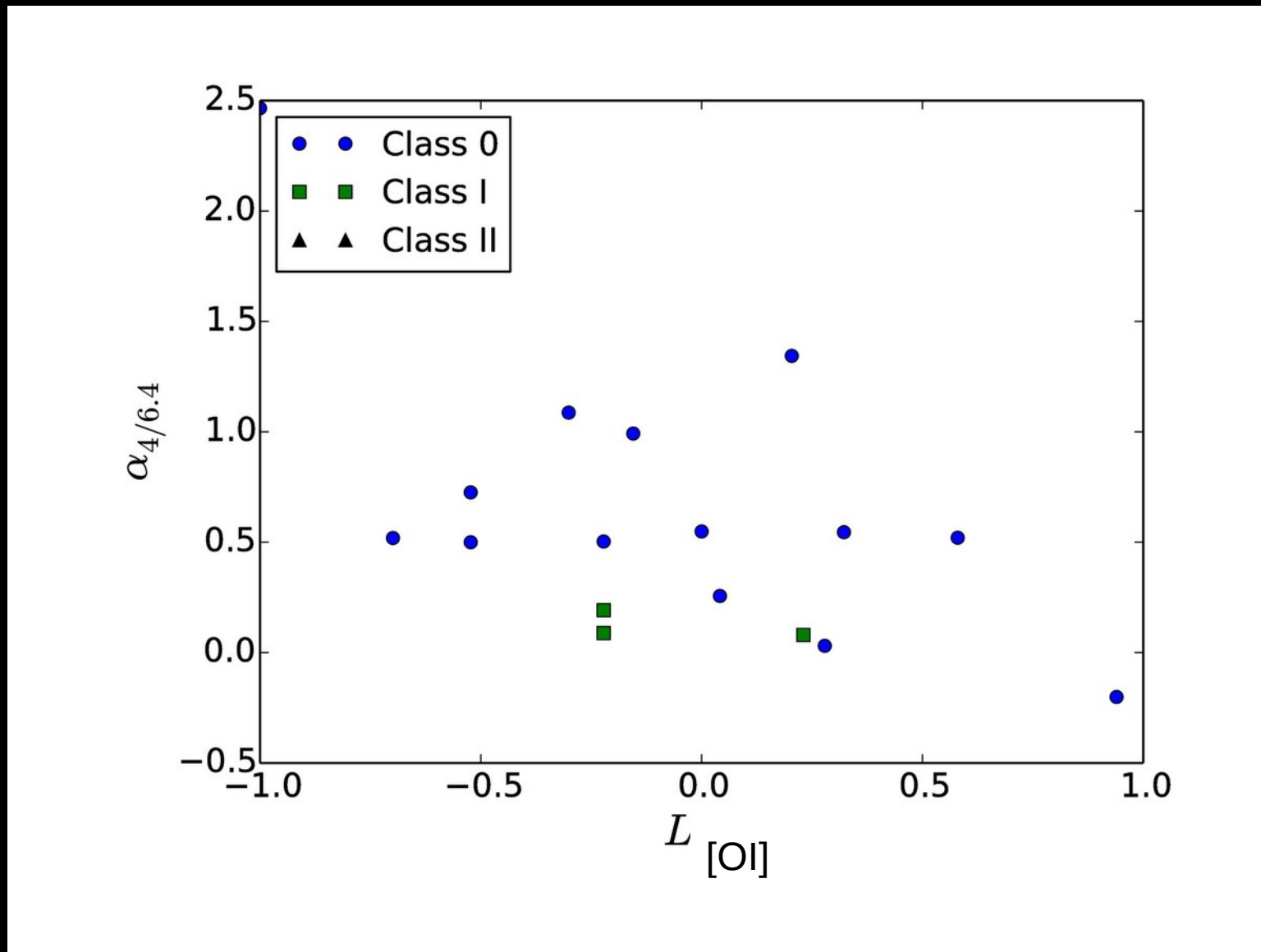
Manoj+2013; HOPS Survey

L_{cm} vs. *Herschel*: [OI]



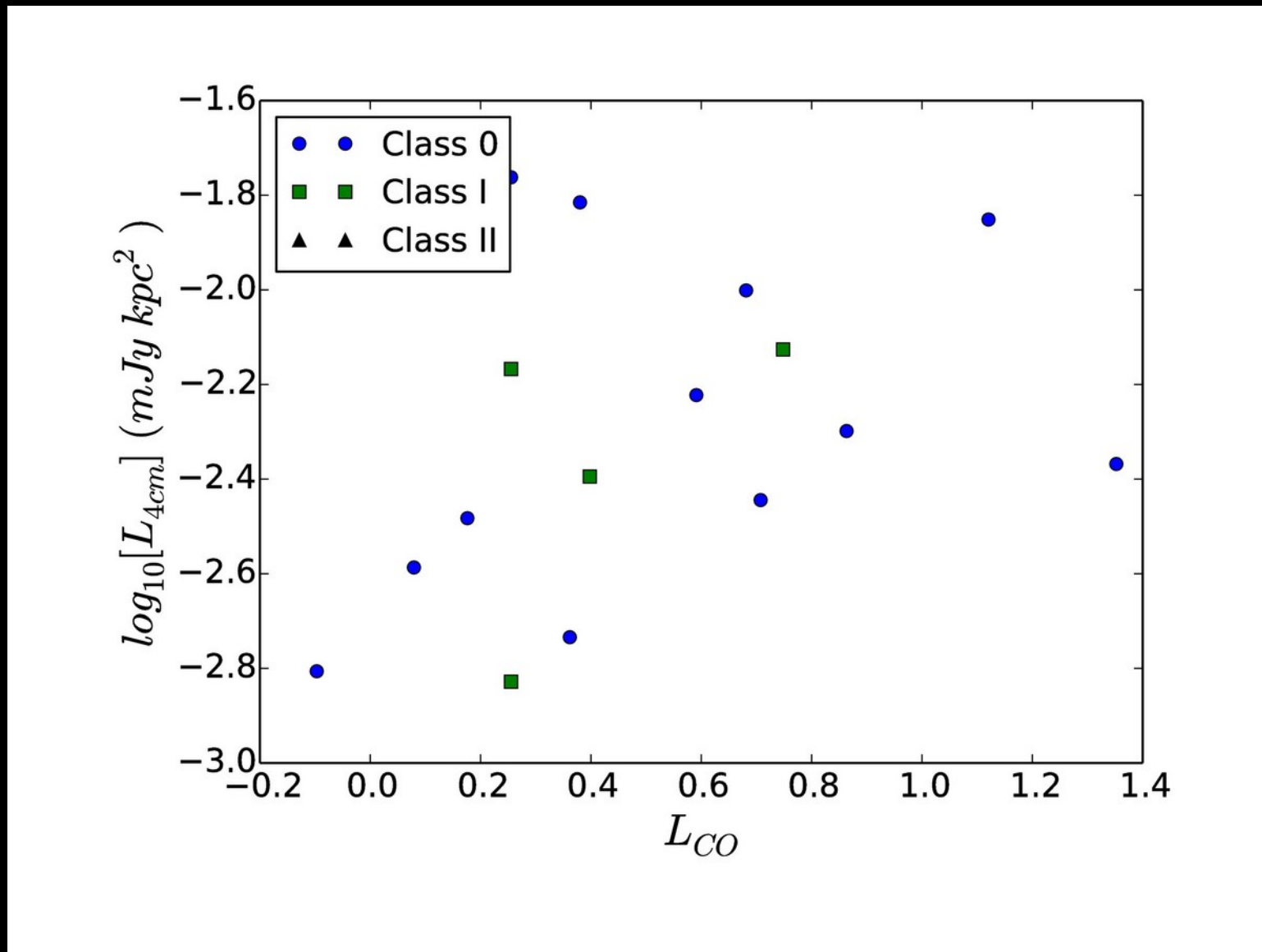
- Possible weak correlation with atomic jet probed with [OI]

Spectral Index vs. *Herschel*: [OI]



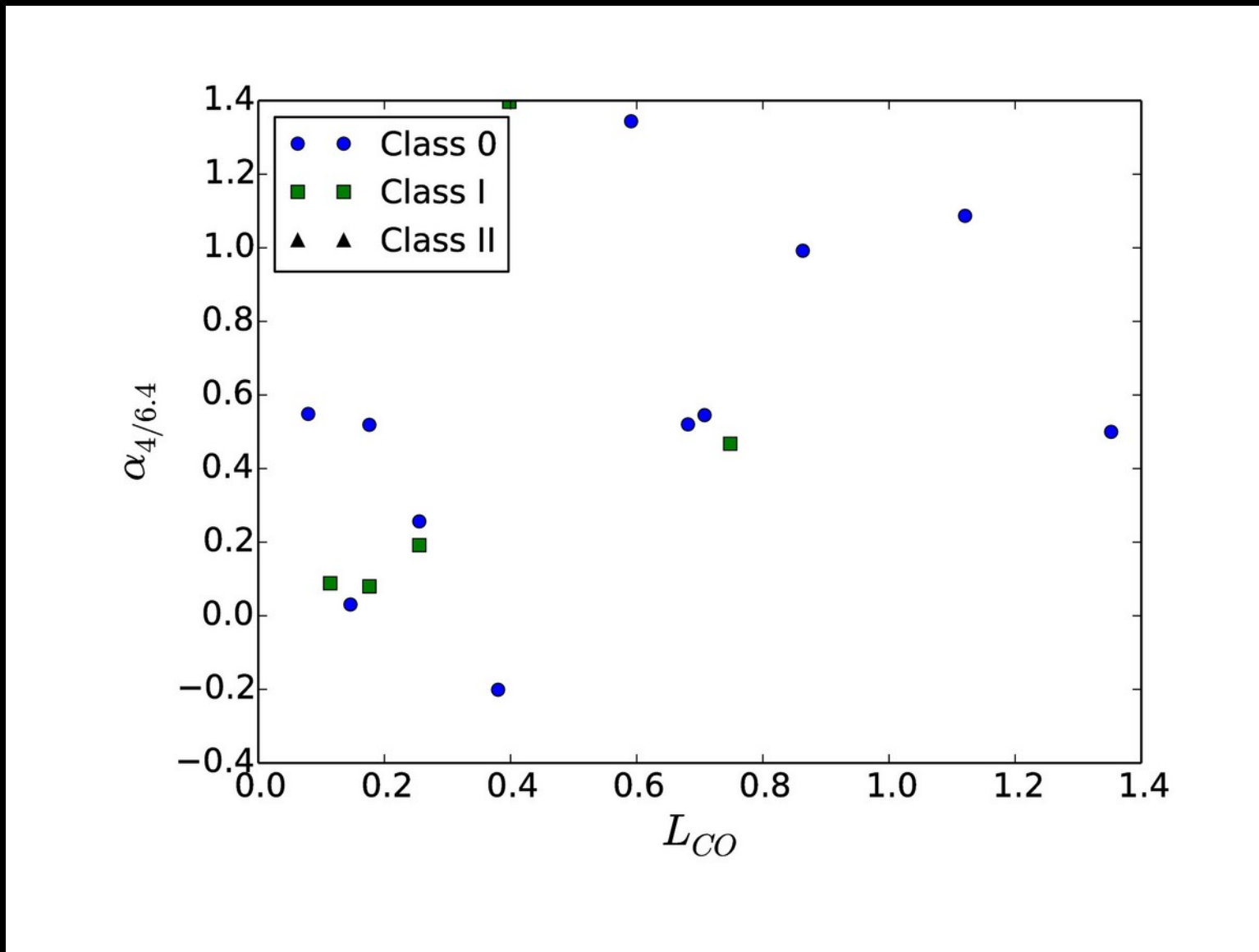
- No dependence of [OI] on cm-spectral index

L_{cm} vs. Herschel: L_{CO}



- Possible weak correlation with CO $J_{\text{up}} > 13$ luminosity

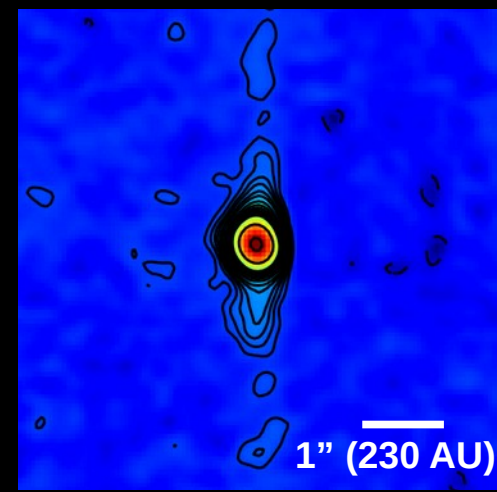
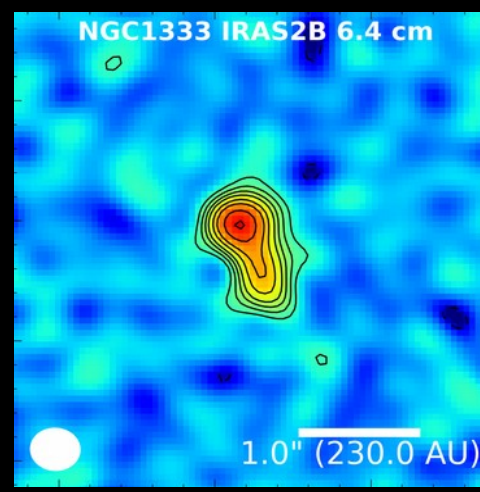
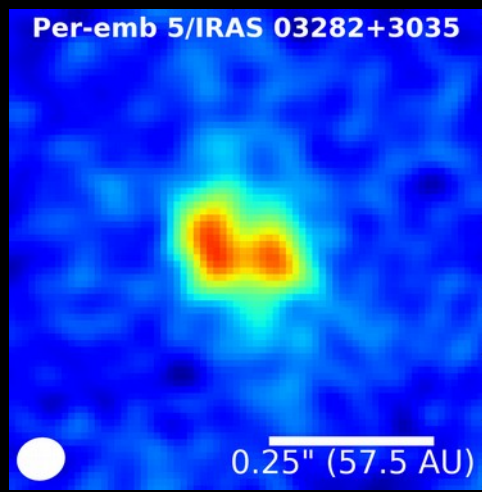
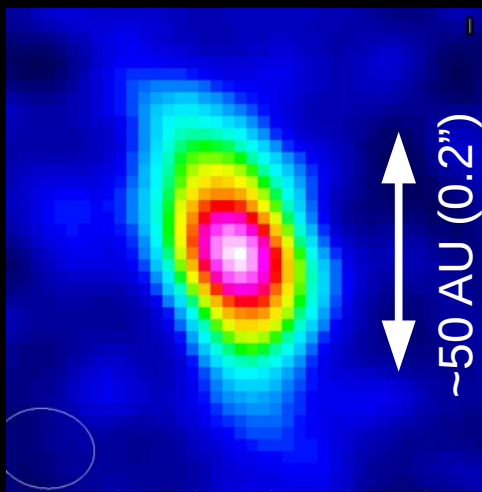
Spectral Index vs. Herschel: L_{CO}



- Possible weak correlation with CO $J_{up} > 13$ and cm-spectral index

Summary

- Unbiased surveys crucial for disk, multiplicity, and jet studies
- New views of protostellar jets
 - Possible offset synchrotron shocks in some sources
 - DG Tau analogues?
- Weak correlations with luminosity
- Poor (if any) correlations of free-free jets and molecular outflow
- Similarly poor correlations of free-free jets and *Herschel* lines
- Weak correlations due to different scales/mechanisms?



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- NRAO funded by National Science Foundation