The Most Luminous Young Stellar Object in the Large Magellanic Cloud

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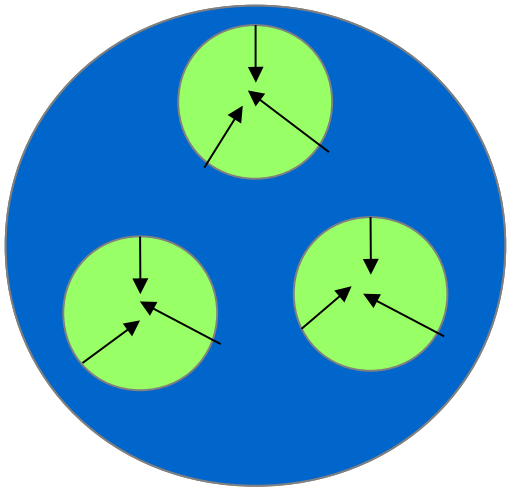
August 11, 2017

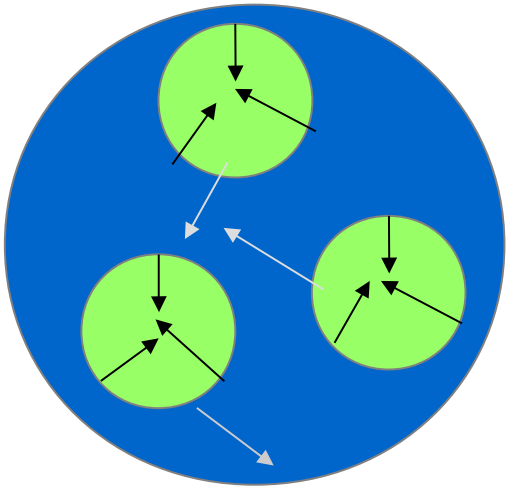
How do massive stars form?

Three Theories on Massive Star Formation

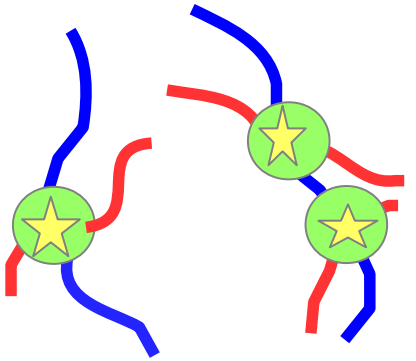
Monolithic Collapse
Zinnecker et al. (2007)



Competitive Accretion
Bonnell et al. (2004), Tan et al. (2004)



Filamentary Collision
Fukui et al. (2015)



- Definitions
  - Filaments: >10 pc long and <1 pc wide
  - Clump: 2-5 pc in size
  - Cores: <1 pc in size
- Massive star formation exclusive takes place in high density regions

The Large Magellanic Cloud

Distance: 50 kpc (Schaefer et al. 2008)

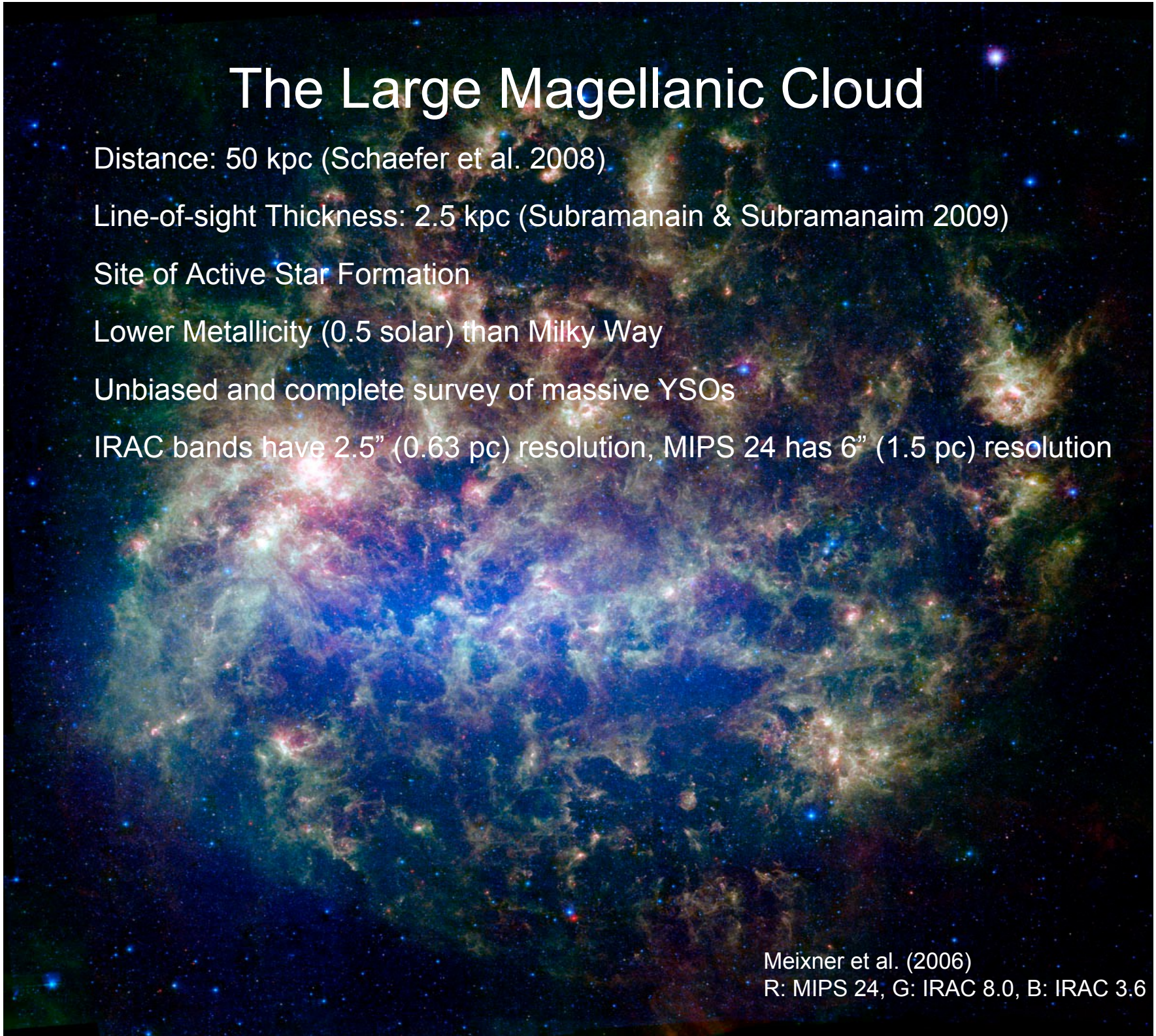
Line-of-sight Thickness: 2.5 kpc (Subramanain & Subramanaim 2009)

Site of Active Star Formation

Lower Metallicity (0.5 solar) than Milky Way

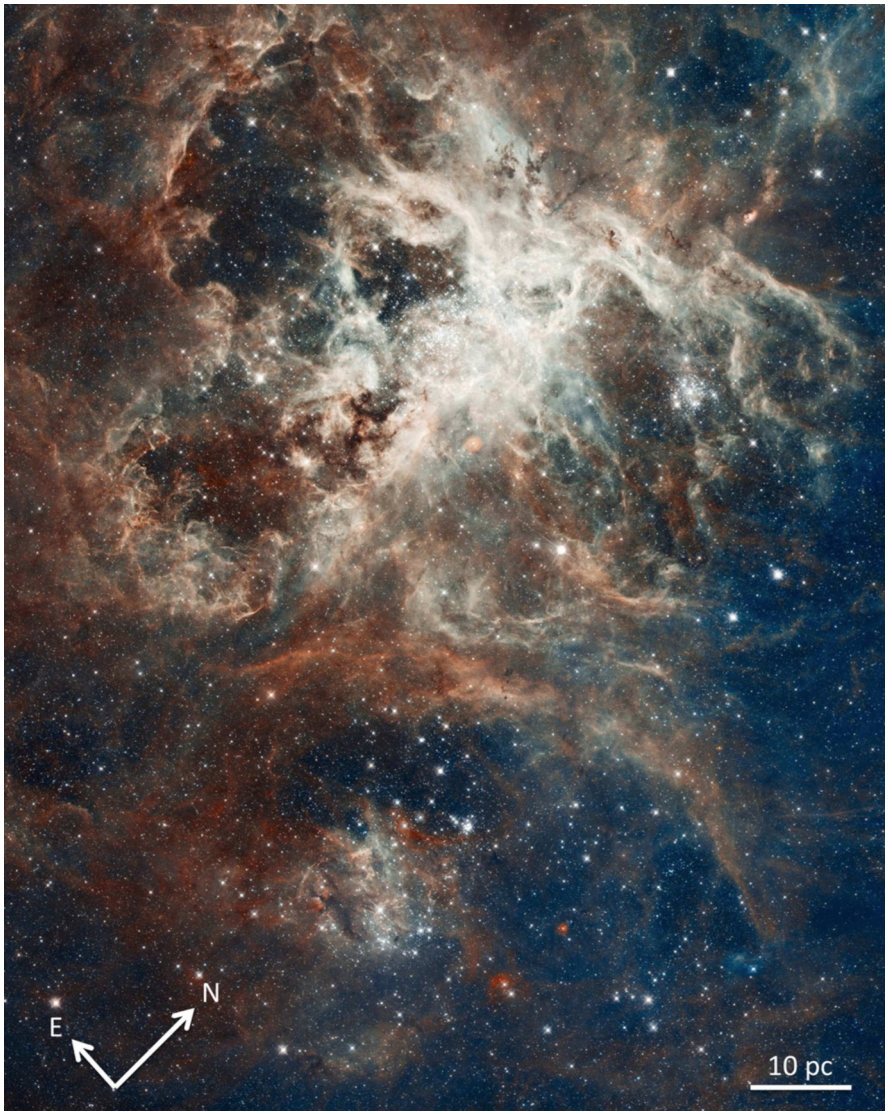
Unbiased and complete survey of massive YSOs

IRAC bands have 2.5” (0.63 pc) resolution, MIPS 24 has 6” (1.5 pc) resolution



Meixner et al. (2006)
R: MIPS 24, G: IRAC 8.0, B: IRAC 3.6

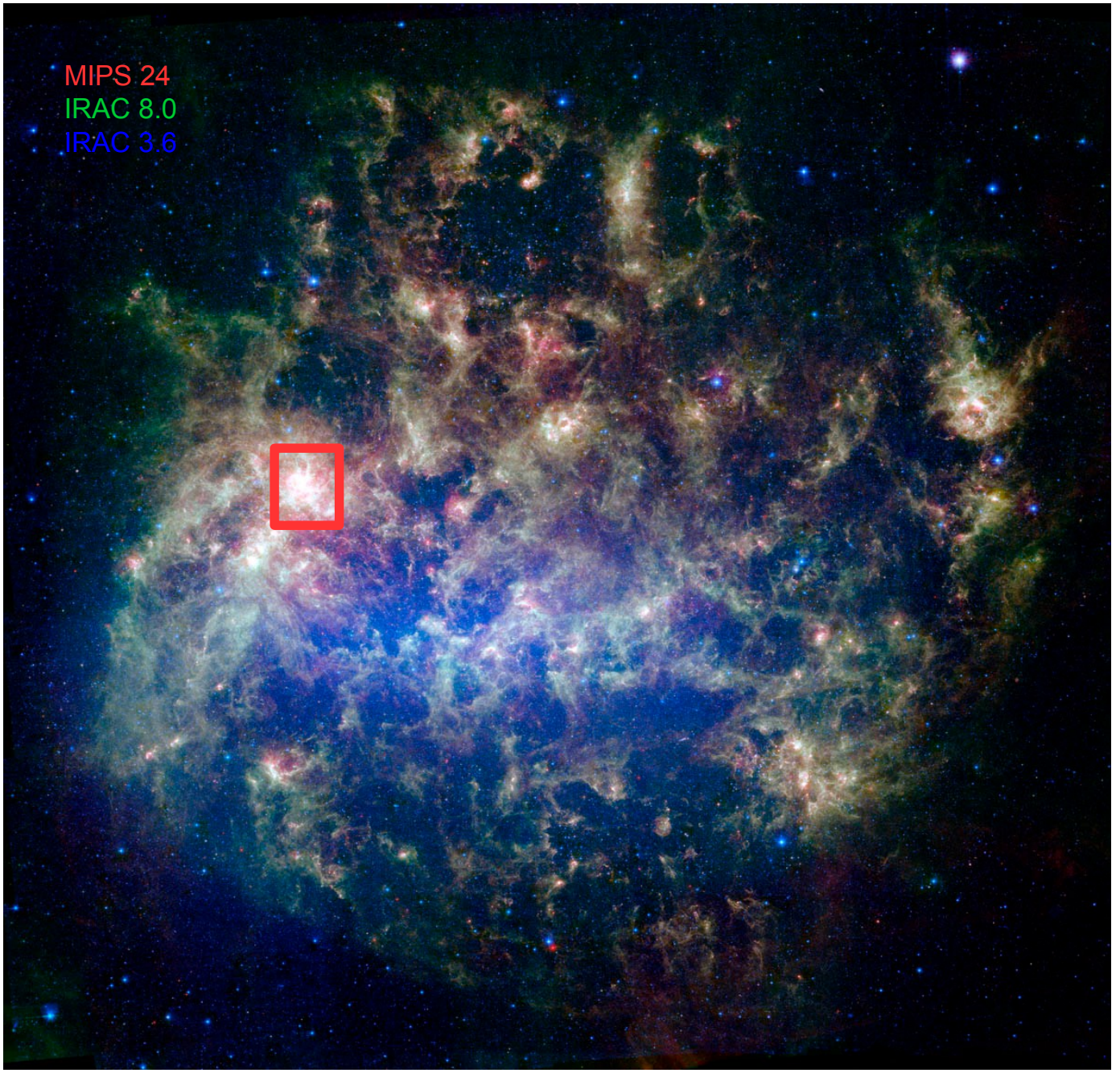
30 Doradus – Hunting for Massive Stars



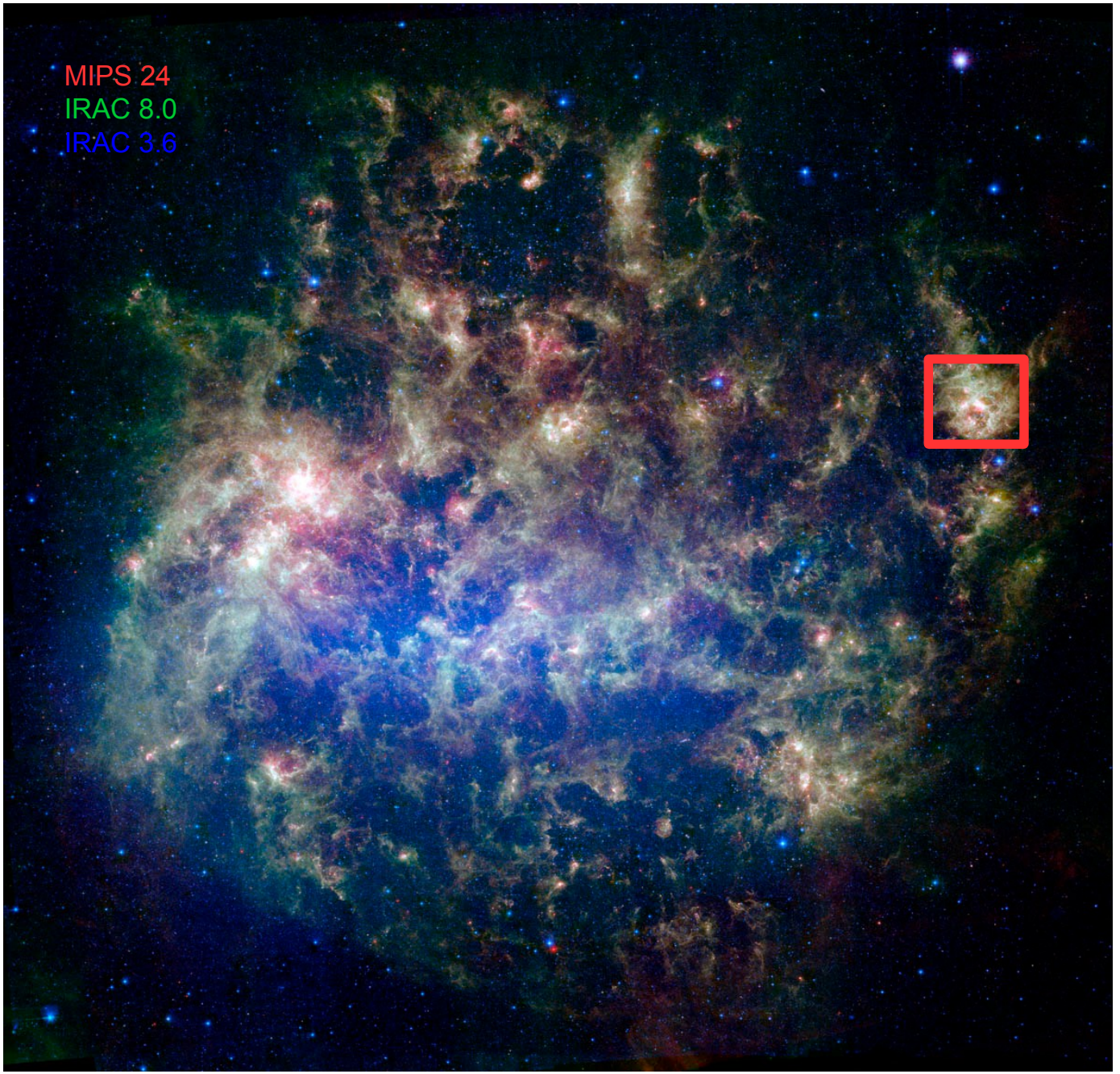
Sabbi et al. (2013)
R: H alpha, B: SII

- 30 Doradus is a giant HII region in the LMC
- R136 the the super star cluster located at the heart of 30 Doradus
- R136 has a total mass of 450,000$M_{\odot}$
- Many astronomers try to find the most massive stars in the R136 cluster

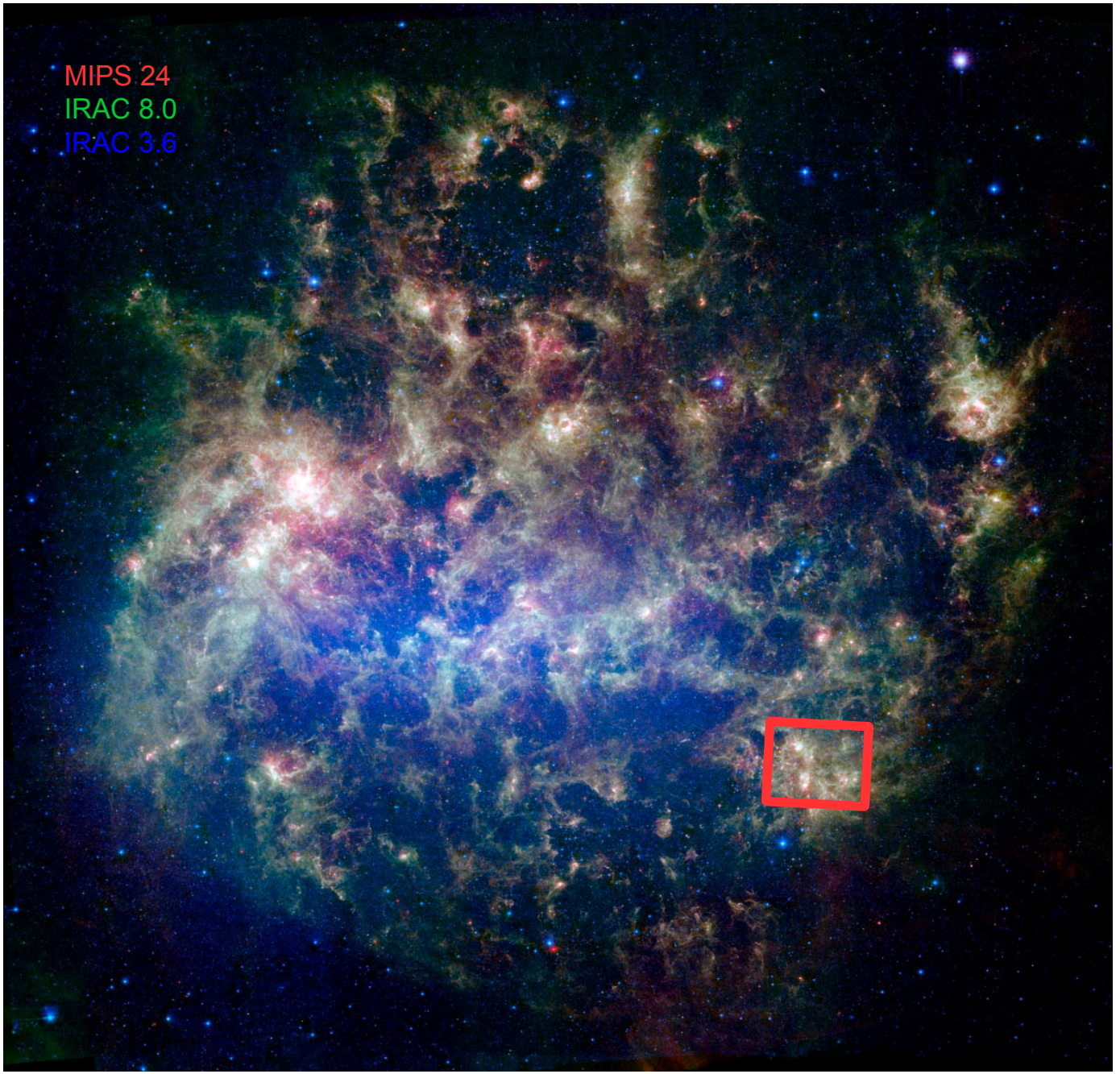
Where is the Most Luminous YSO Located? 30 Doradus?



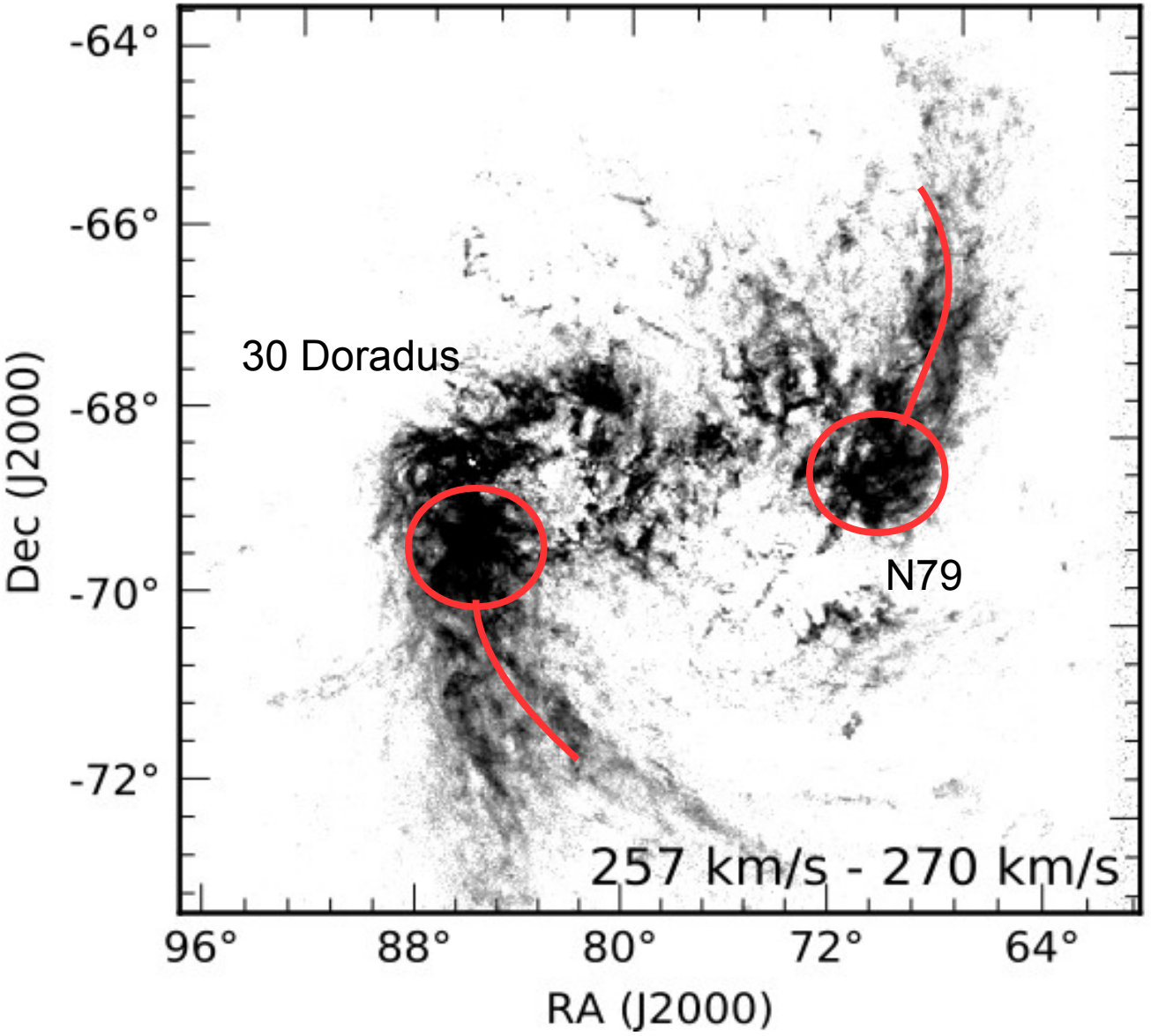
Where is the Most Luminous YSO Located? N11?



It is N79!

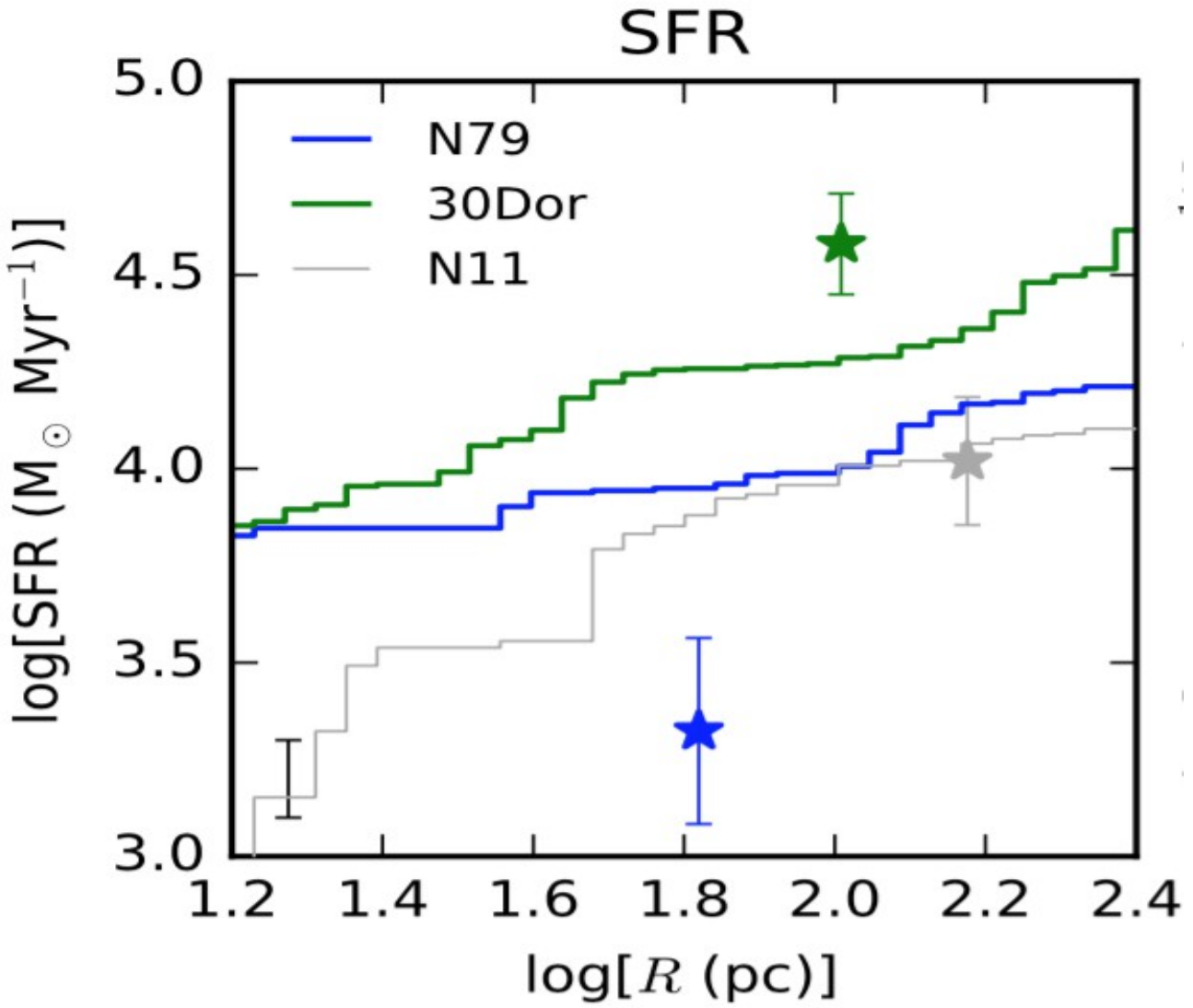


N79 and 30 Doradus are Symmetrical



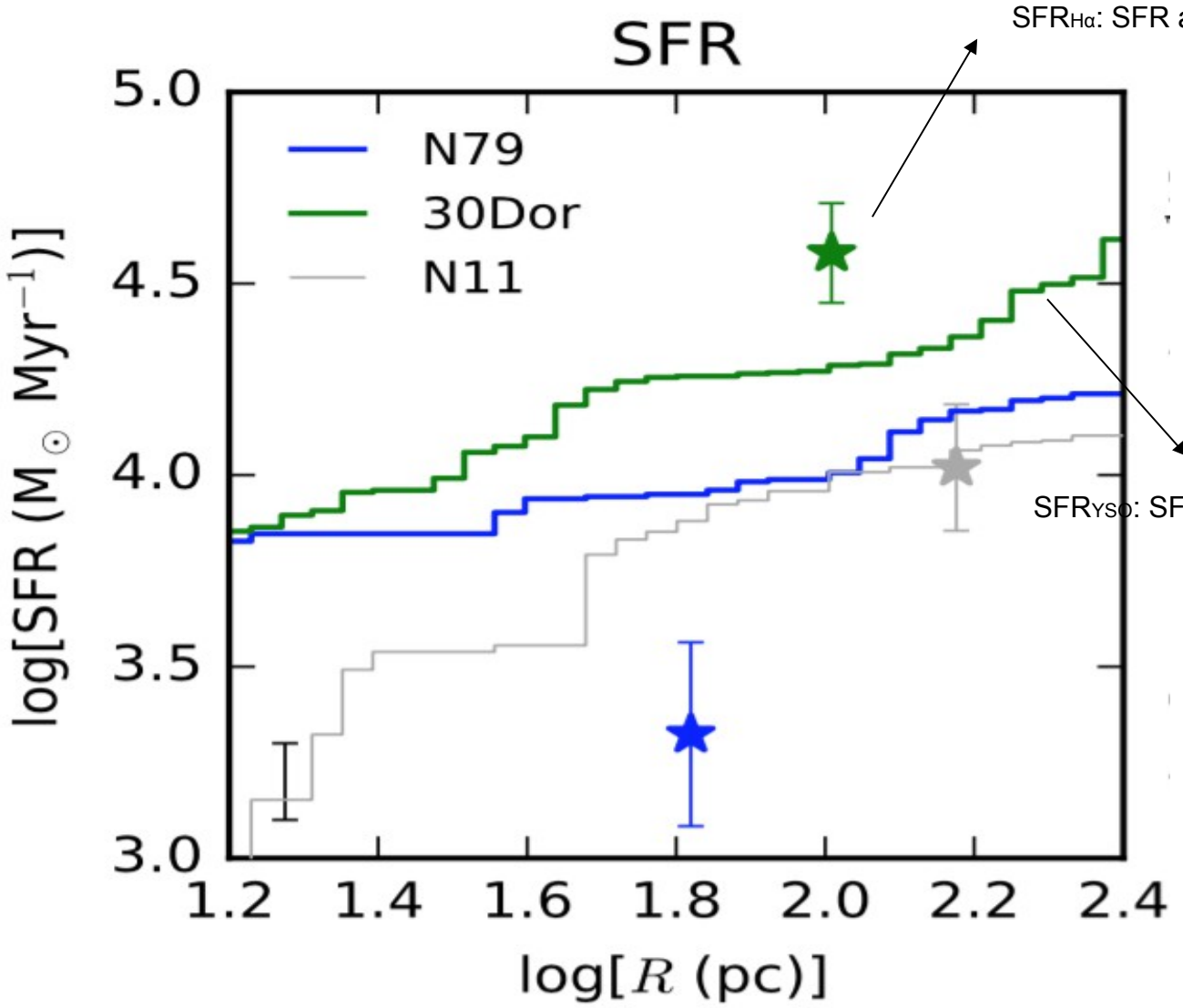
Stavley-Smith et al. (2003)

Comparison to 30 Doradus and N11



Ochsendorf et al. (2017, submitted)

Comparison to 30 Doradus and N11

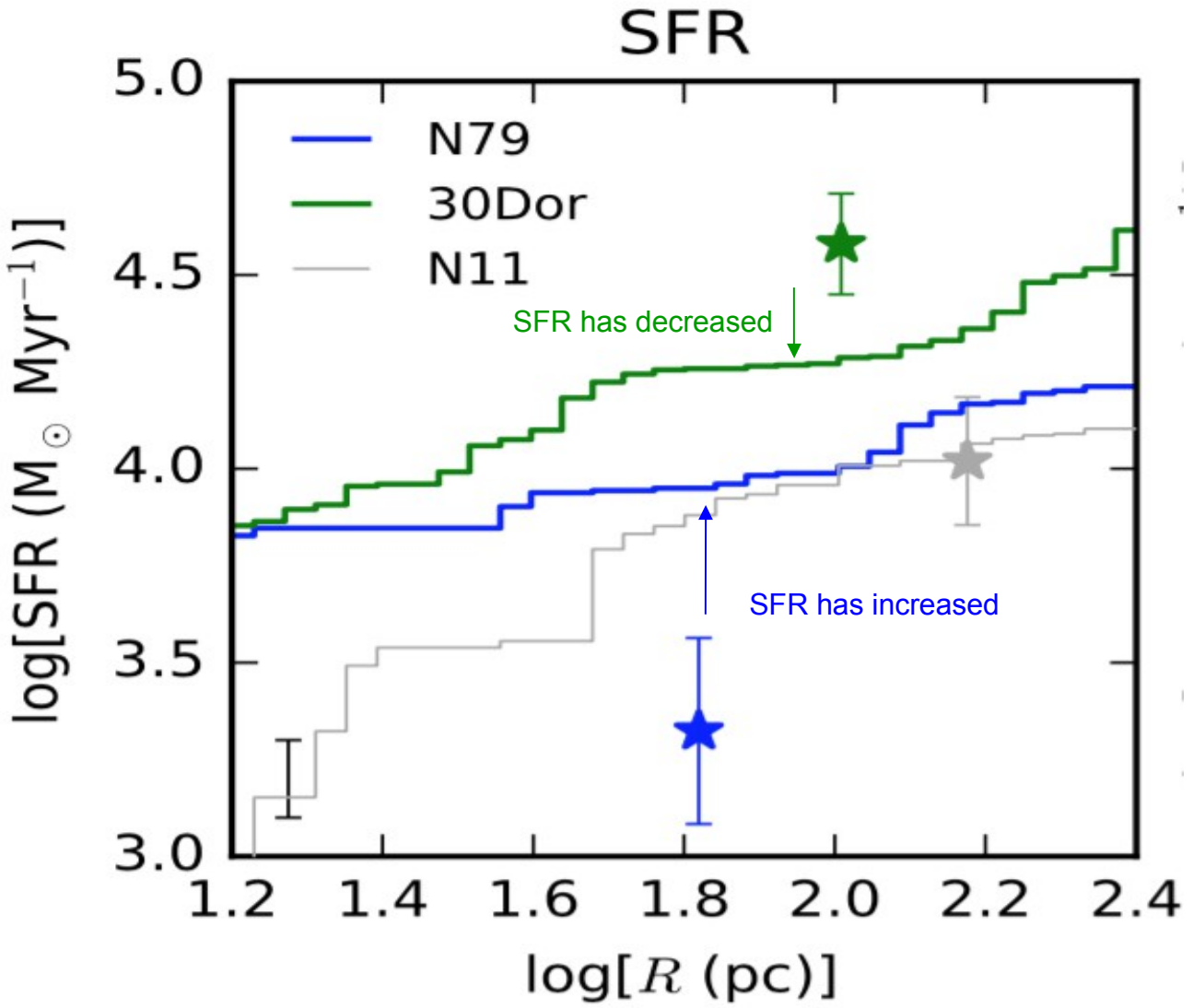


$SFR_{H\alpha}$: SFR averaged over 4Myr

SFR_{YSO}: SFR averaged over 0.5Myr

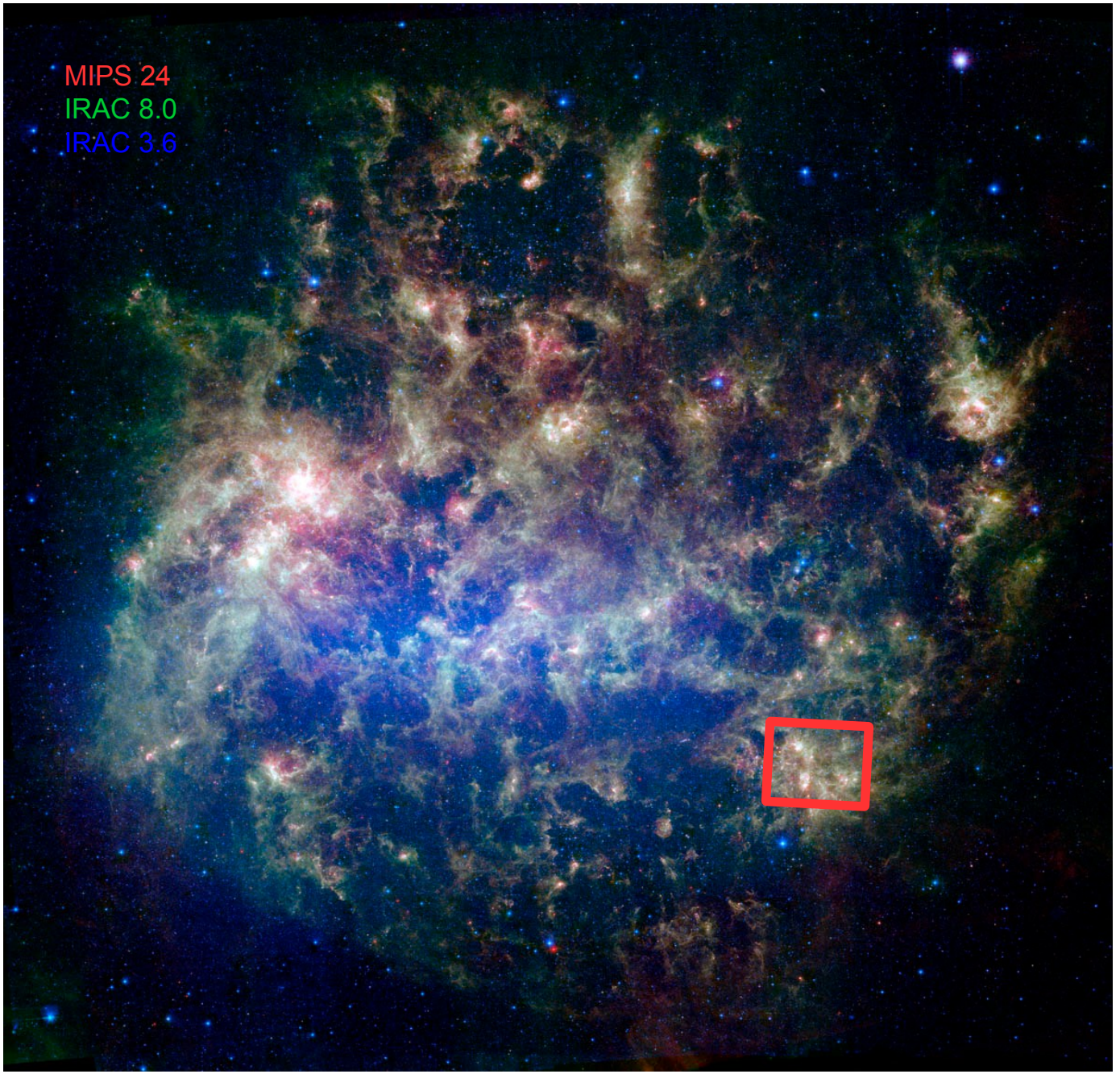
Ochsendorf et al. (2017, submitted)

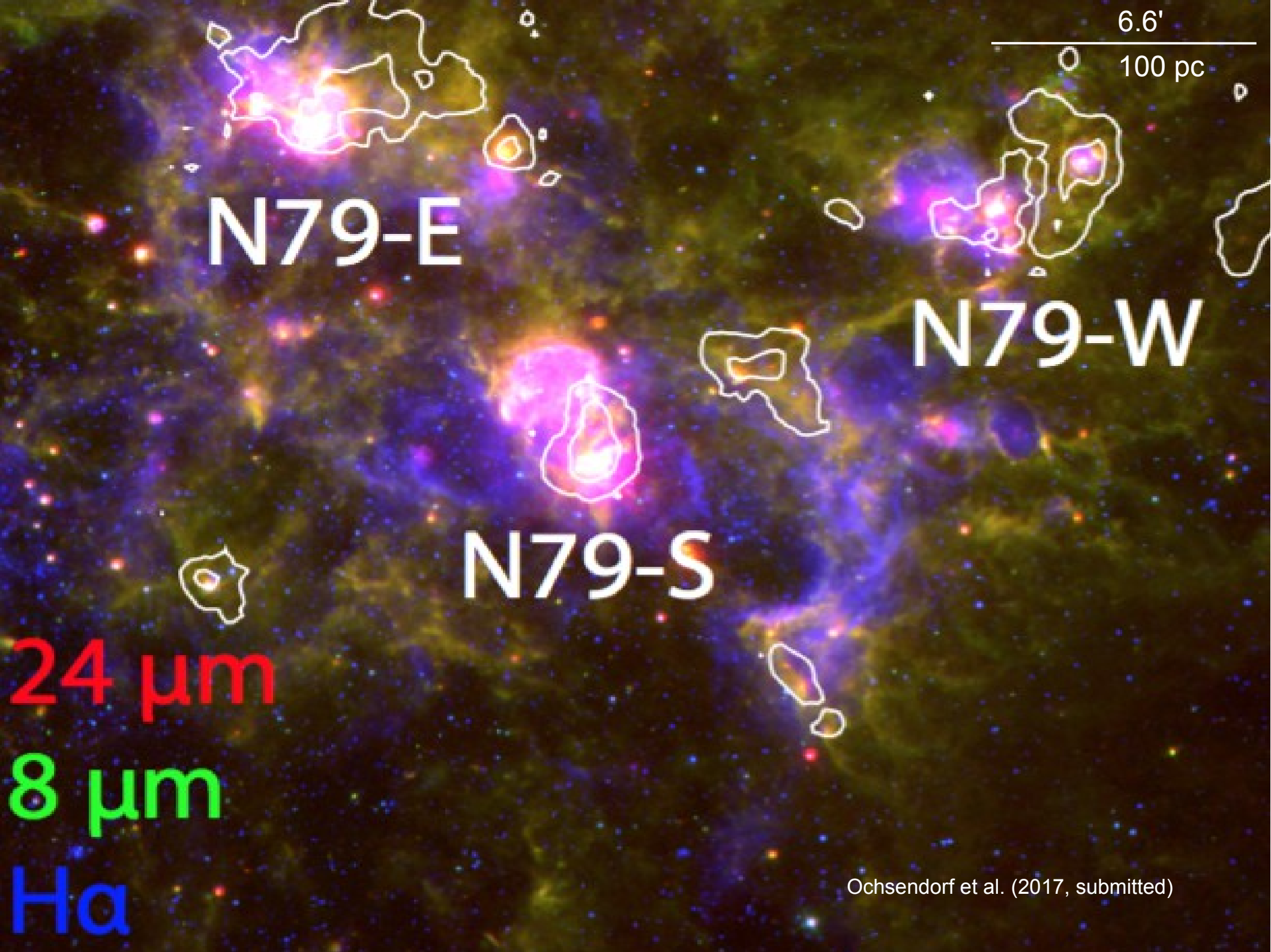
N79 is Younger Version of 30 Doradus



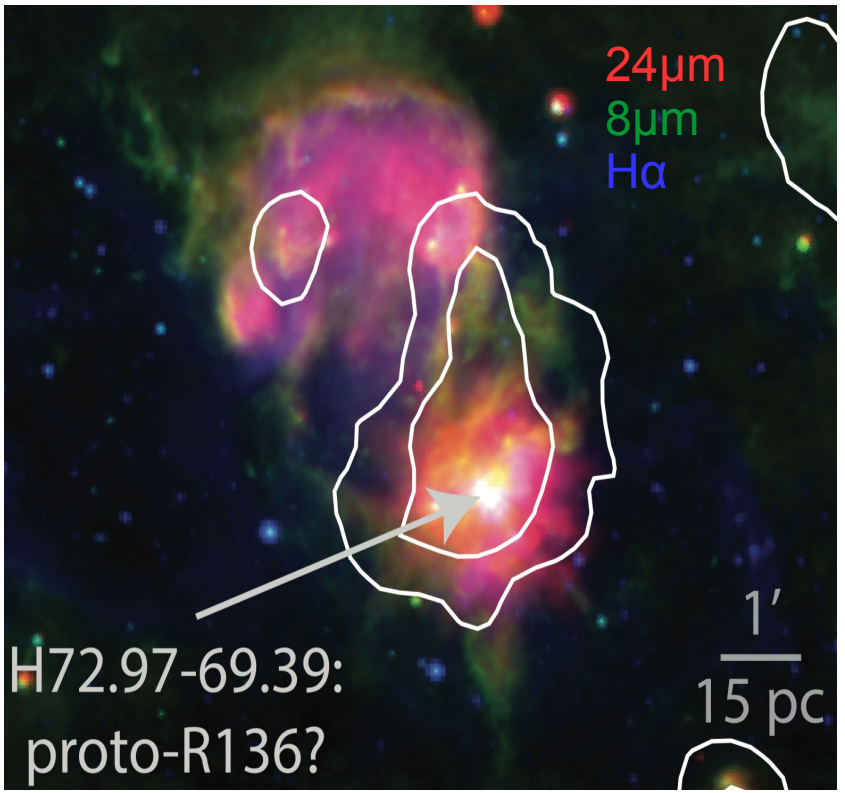
Ochsendorf et al. (2017, submitted)

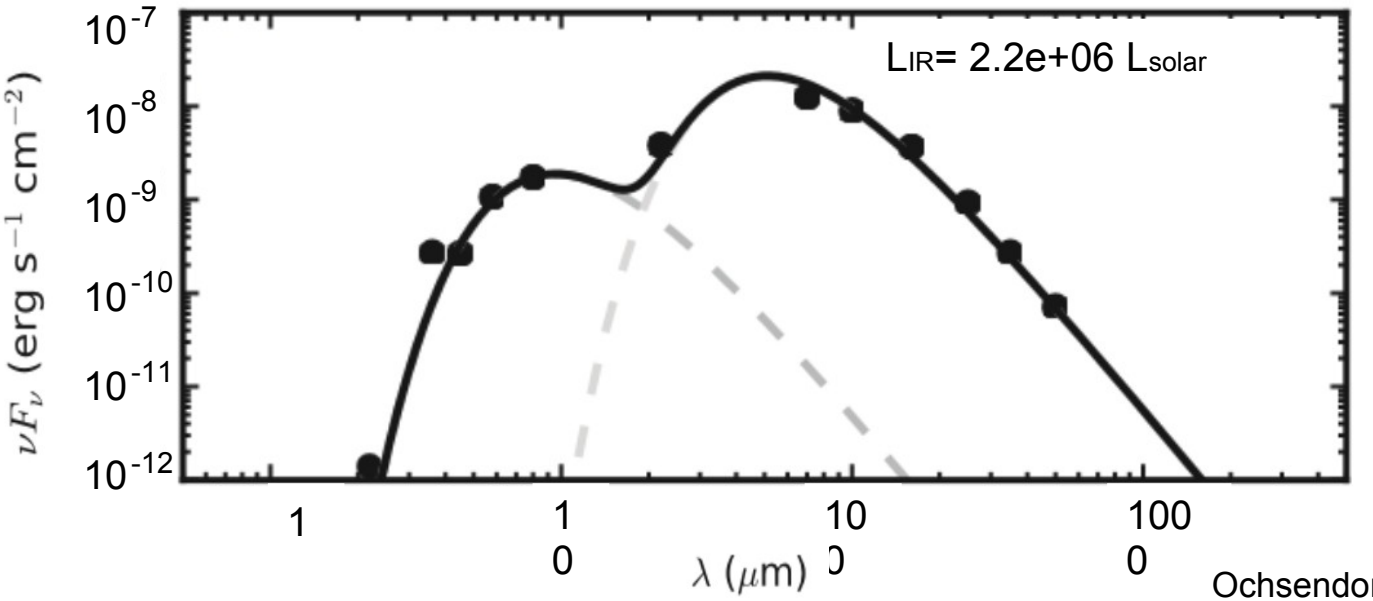
Let's Zoom in on the N79 Region




6.6'
100 pc
N79-E
N79-W
N79-S
24 μm
8 μm
Hα
Ochsendorf et al. (2017, submitted)

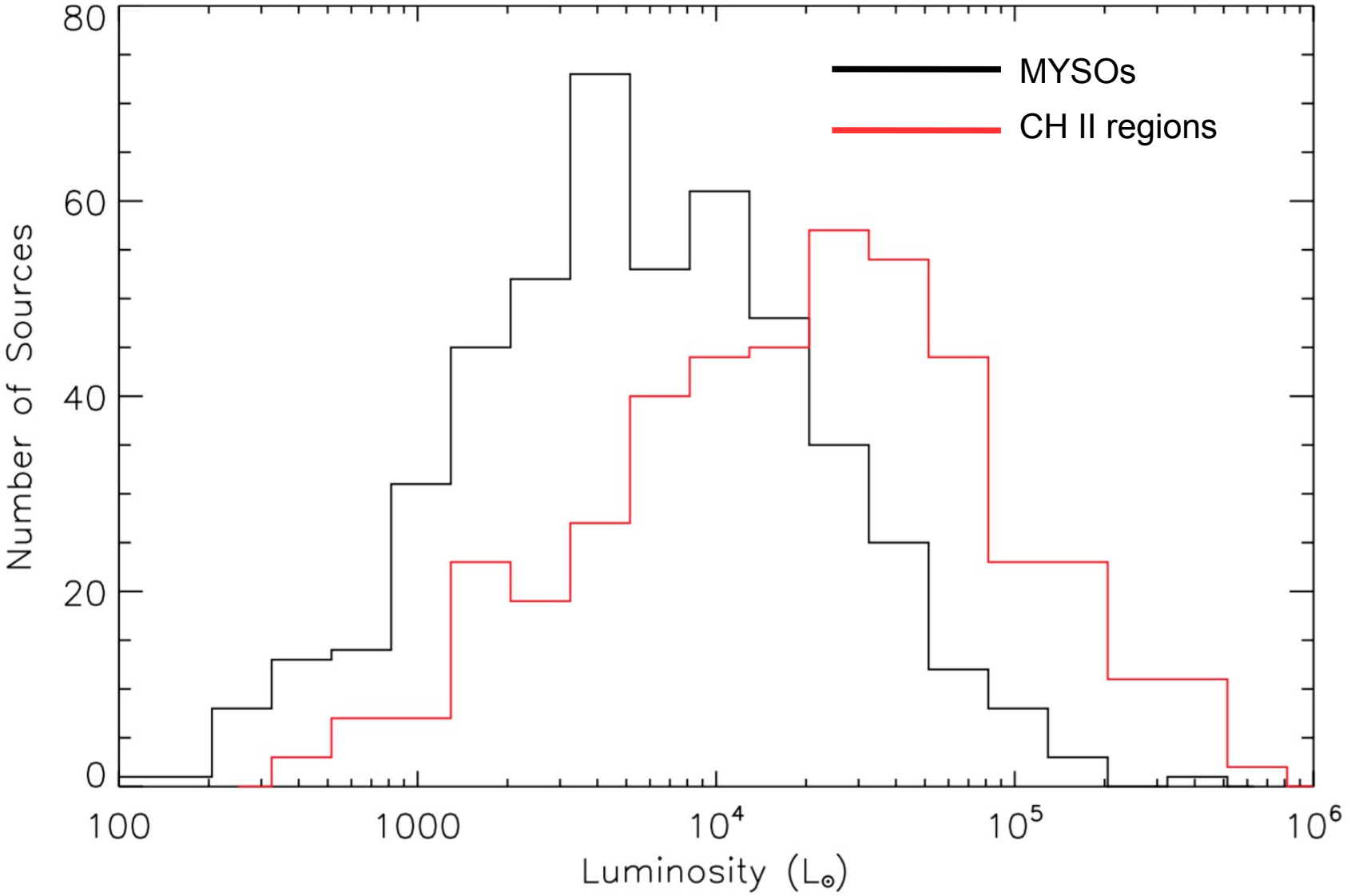
Luminosity is Over 2 Million Solar Luminosity!





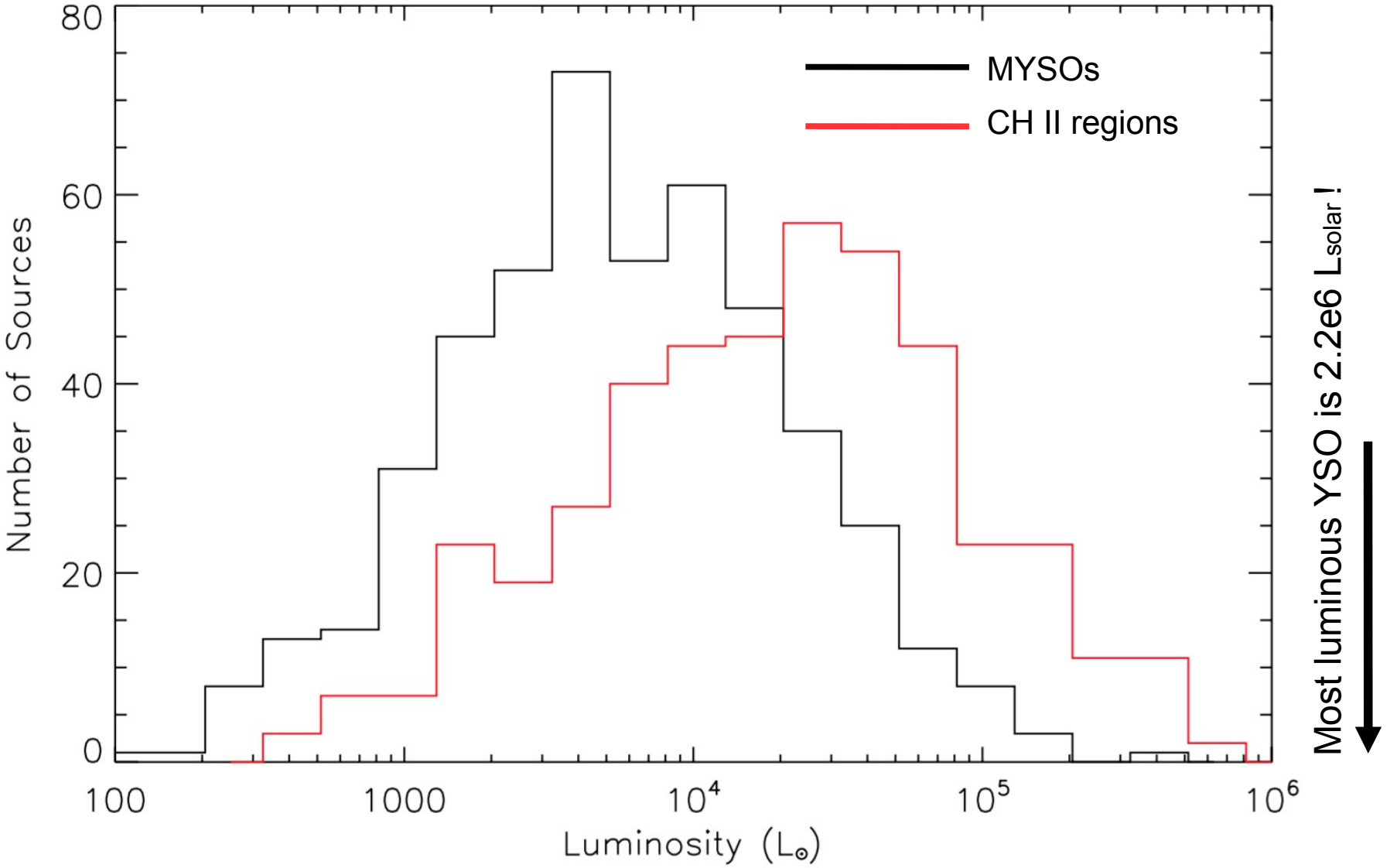
Ochsendorf et al. (2017, submitted)

How Luminous is the MYSO in N79?



Mottram et al. (2011)

How Luminous is the MYSO in N79?



Mottram et al. (2011)
Ochendort et al. (2017, submitted)

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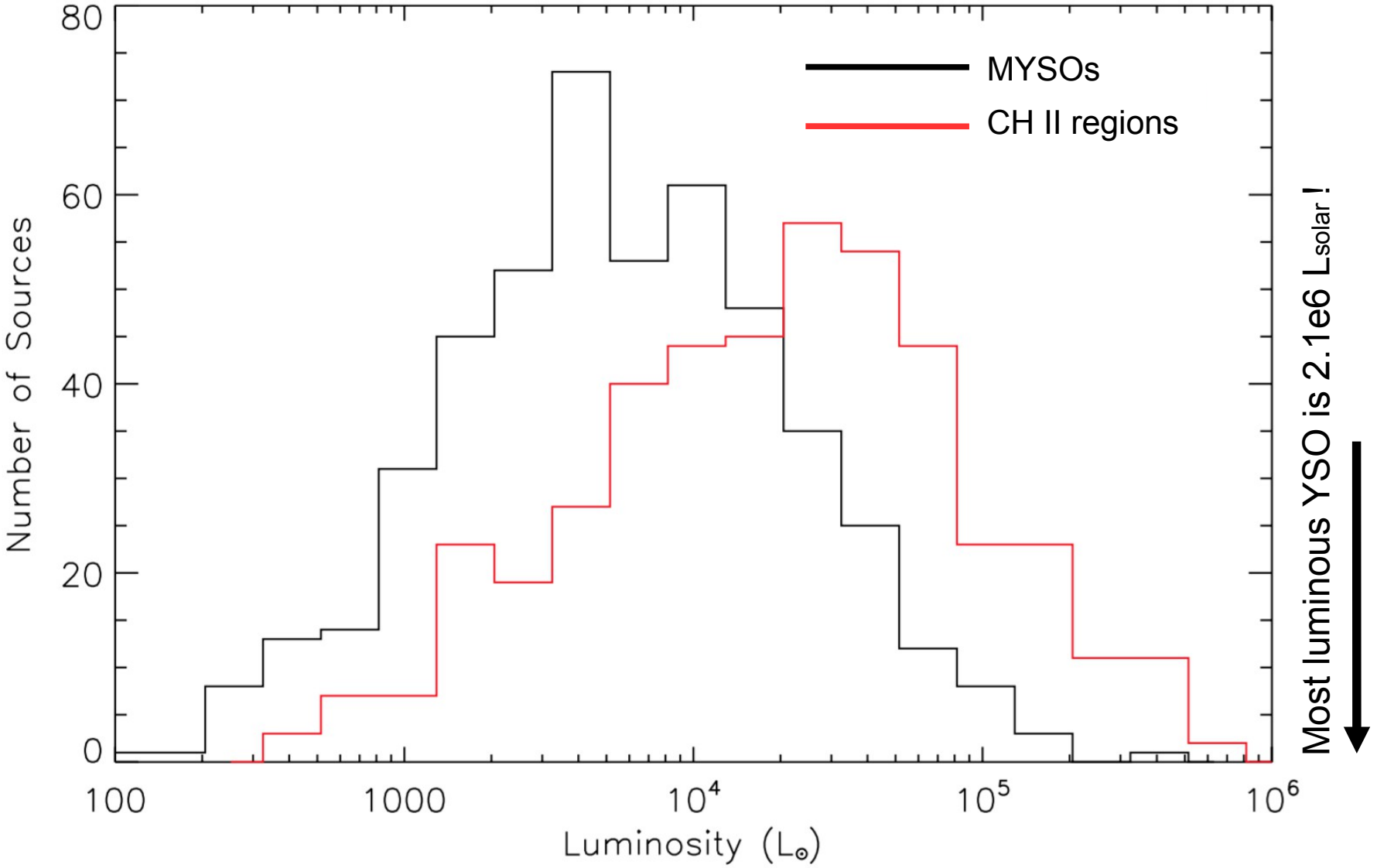
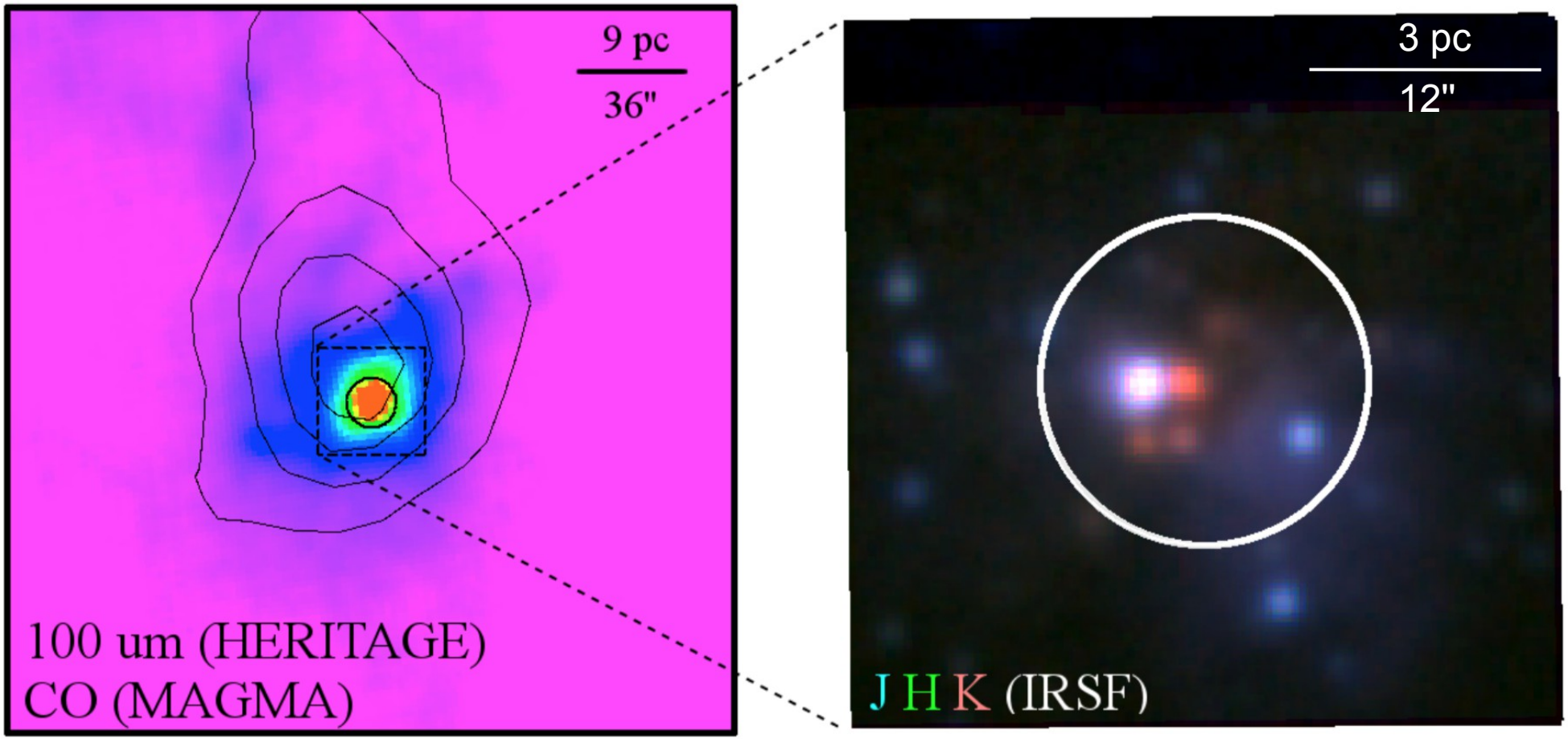


Mottram et al. (2011)
Jones et al. (2017)

Is This a Cluster?



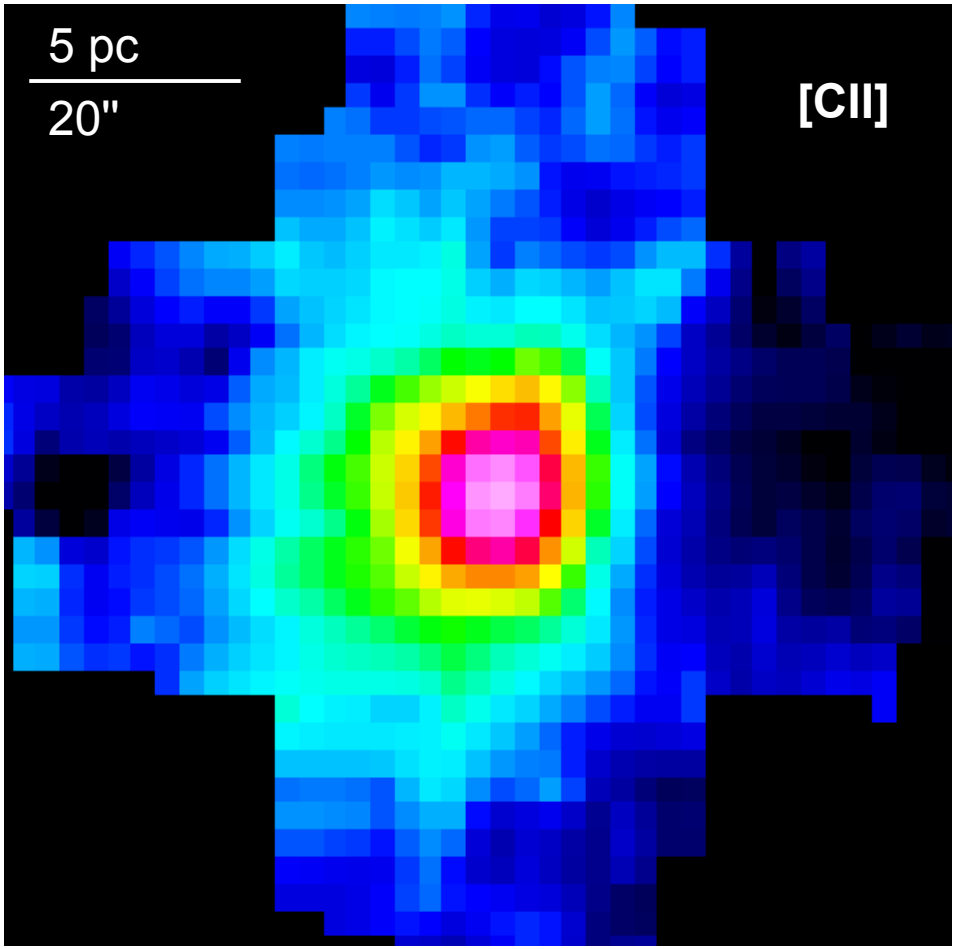
What are the environmental factors that led to the formation of this luminous YSO?

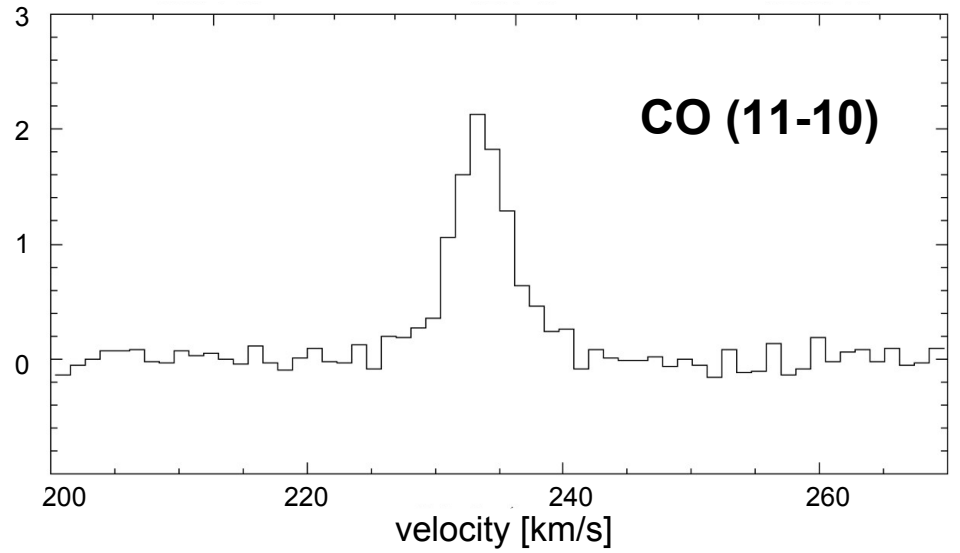
SOFIA – Constraining Outflow

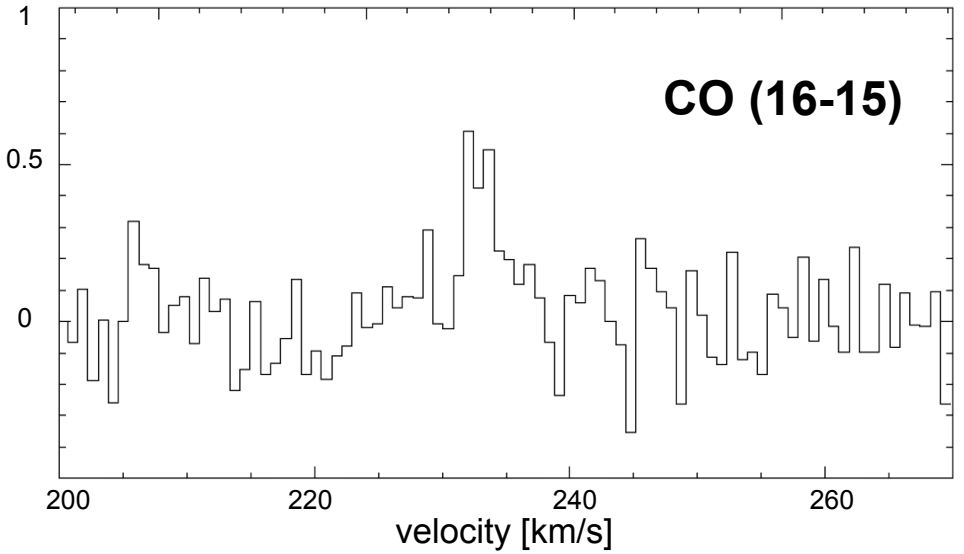
ALMA – Molecular Gas

FIRE Spectrograph – Ionization Region

Environment - SOFIA [CII] and High J-CO Constraining Outflow

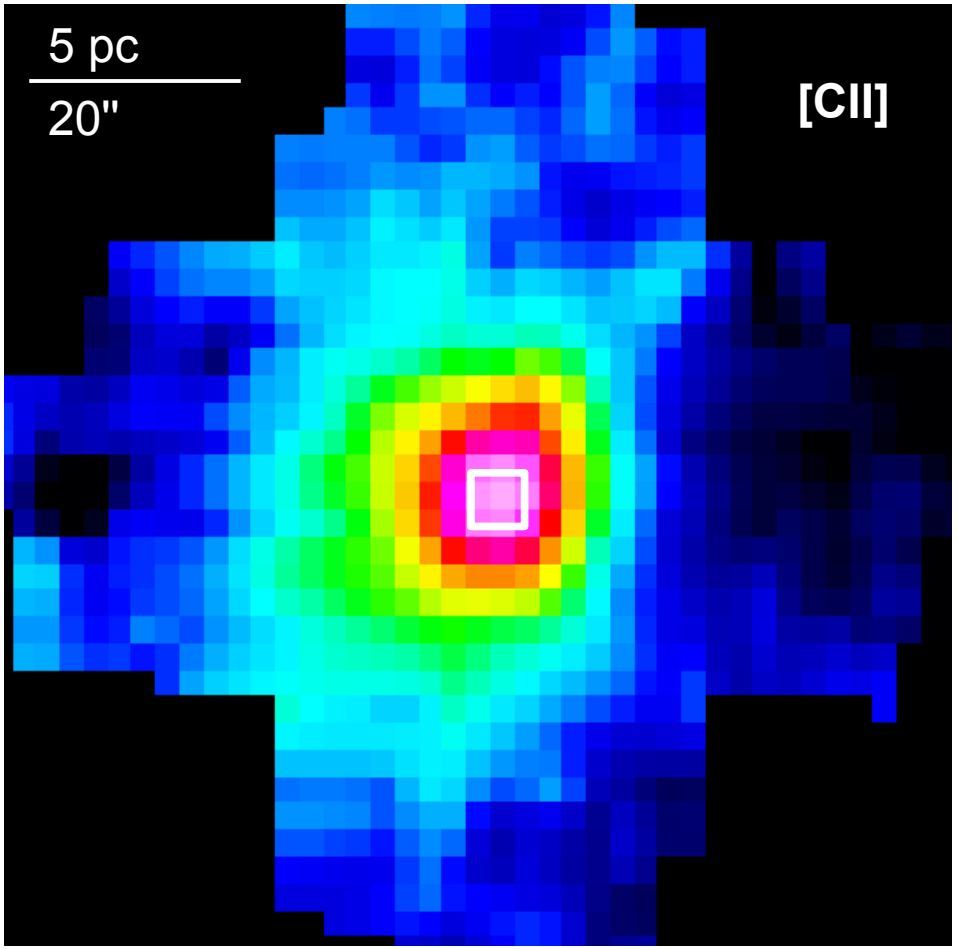


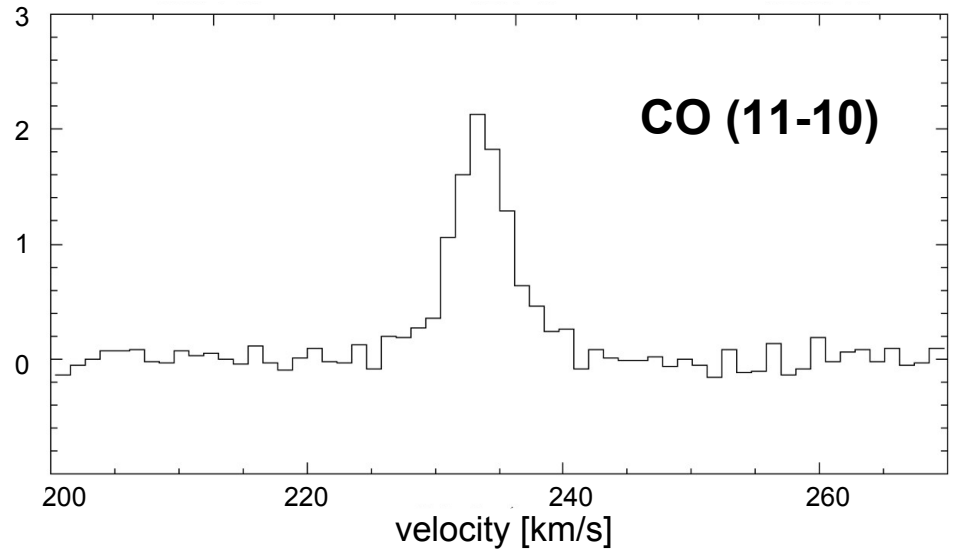


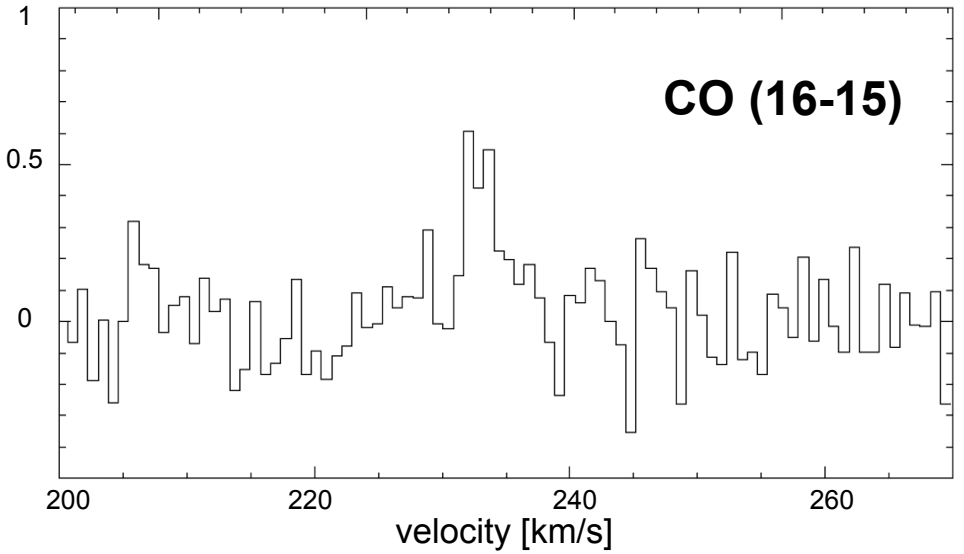


Nayak et al. (in prep)

Environment - SOFIA [CII] and High J-CO Constraining Outflow







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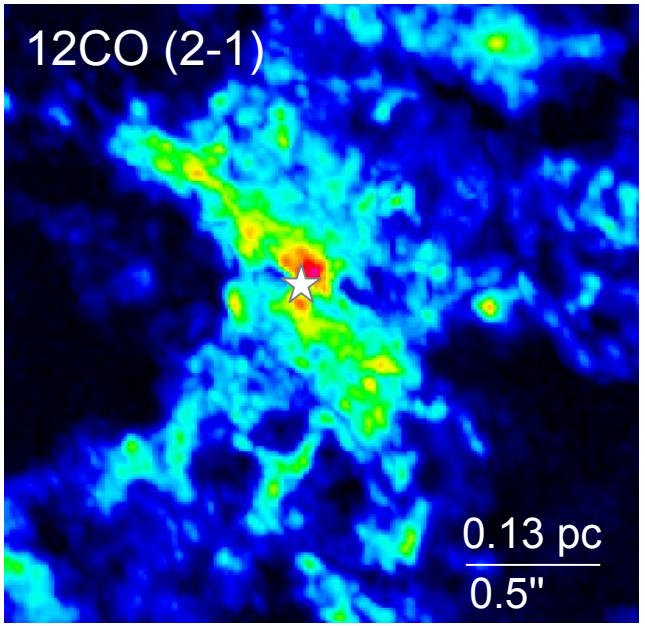
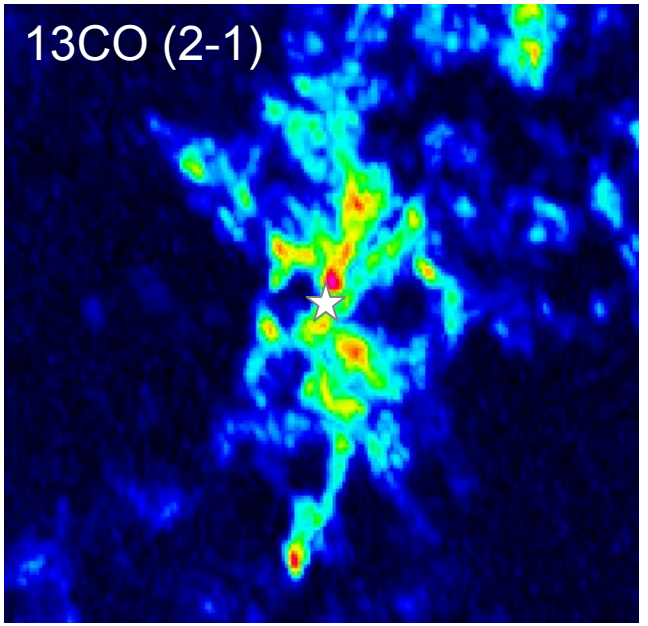
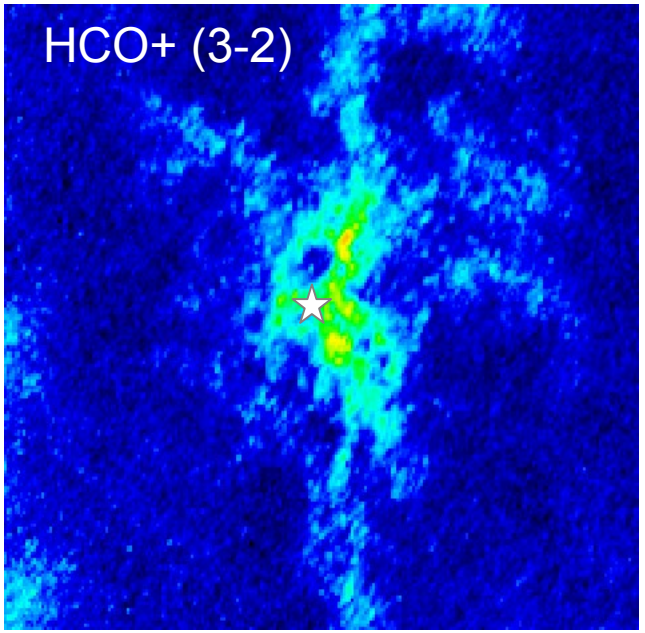
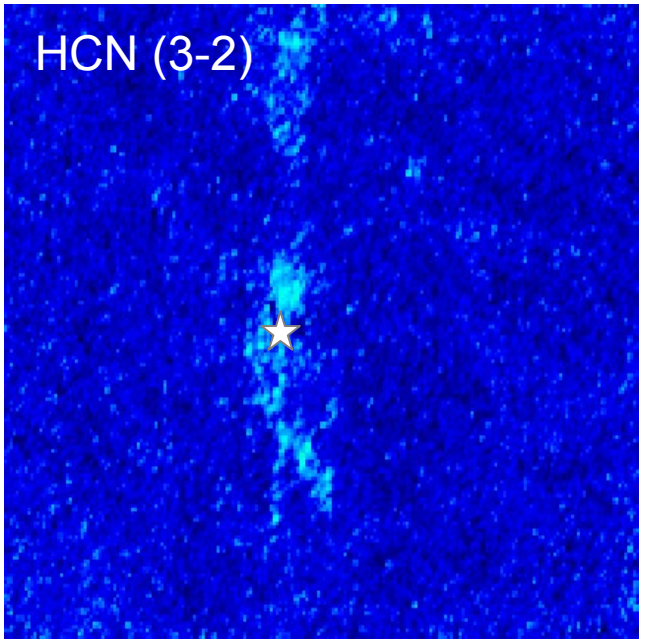
Environment - ALMA
Molecular Gas









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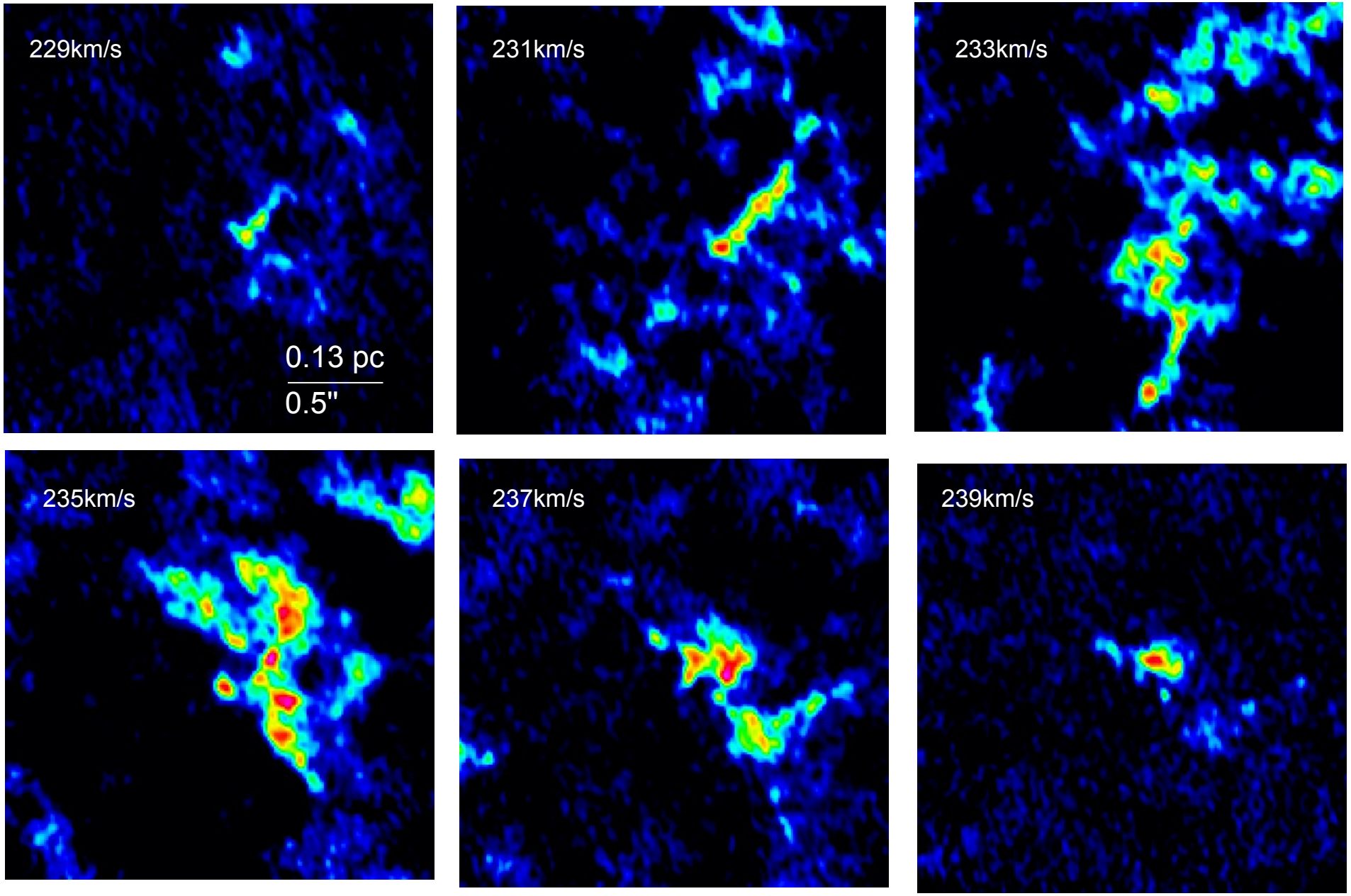
ALMA 13CO (2-1): Colliding Filaments



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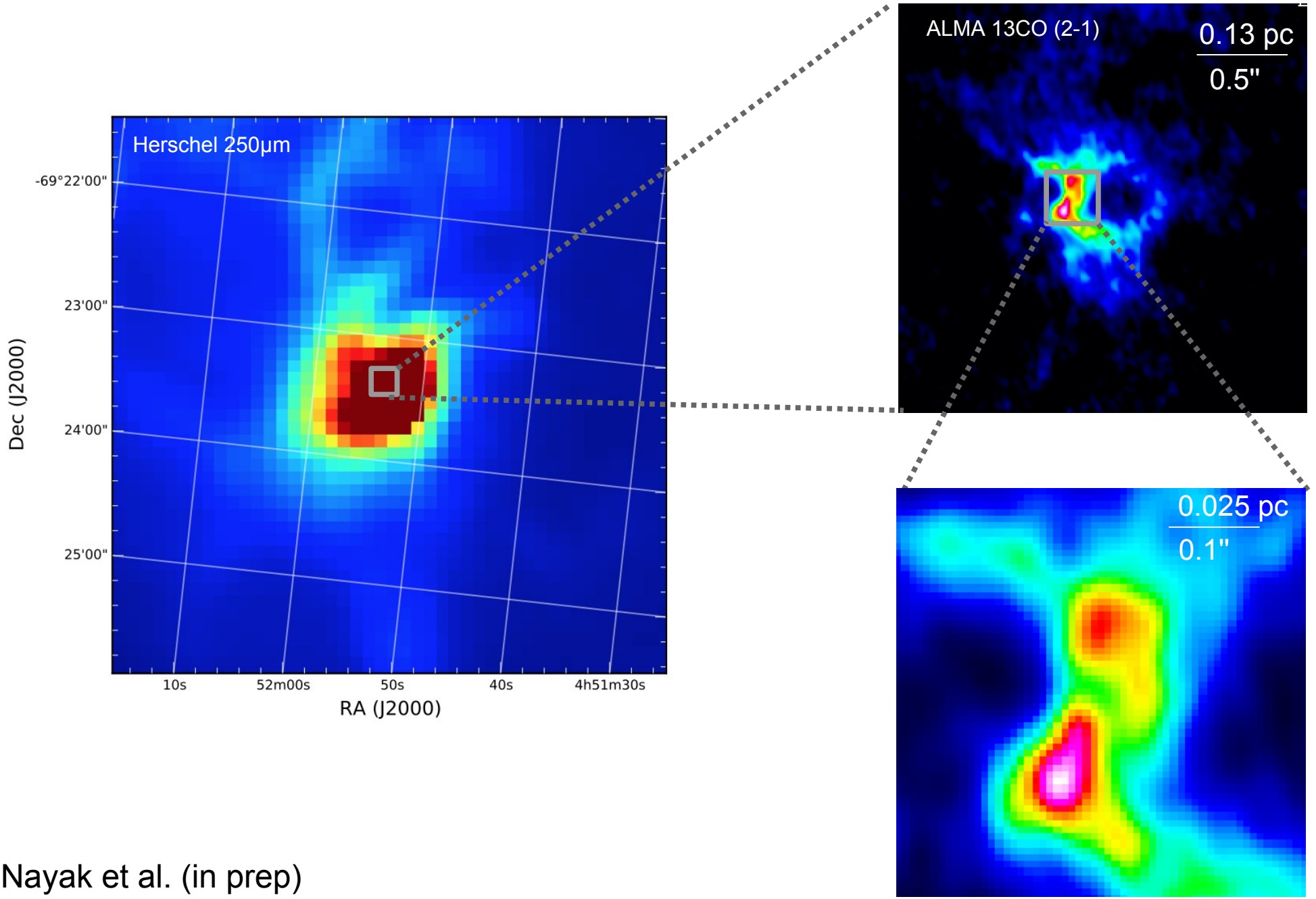
ALMA Resolves Kinematic Structure



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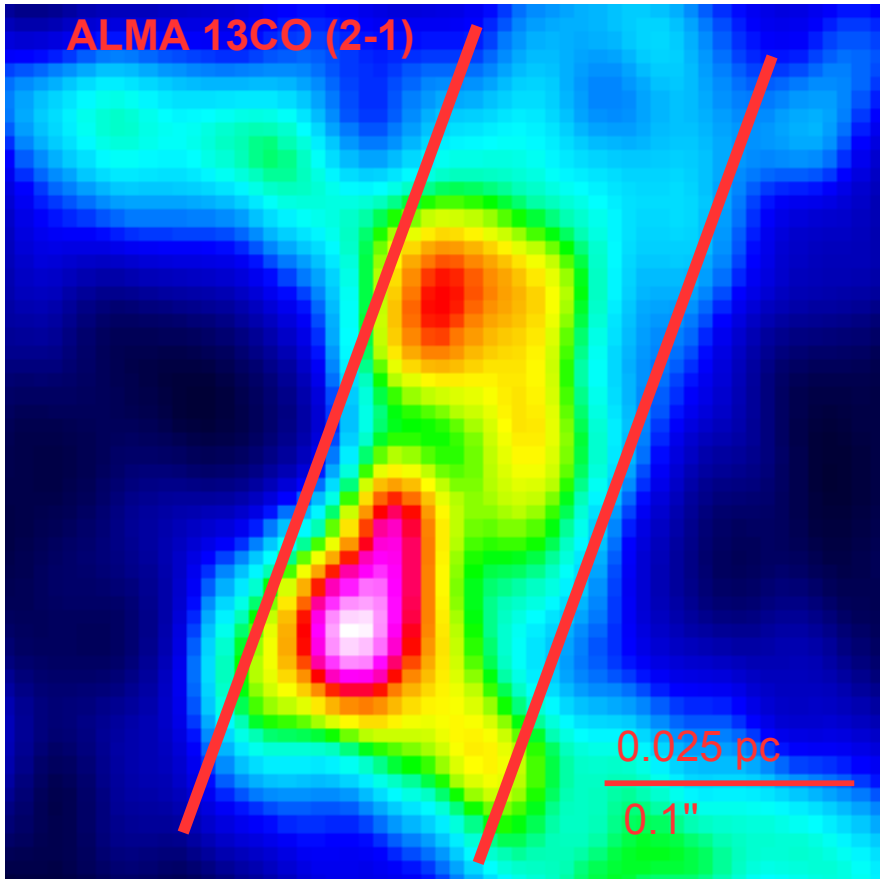
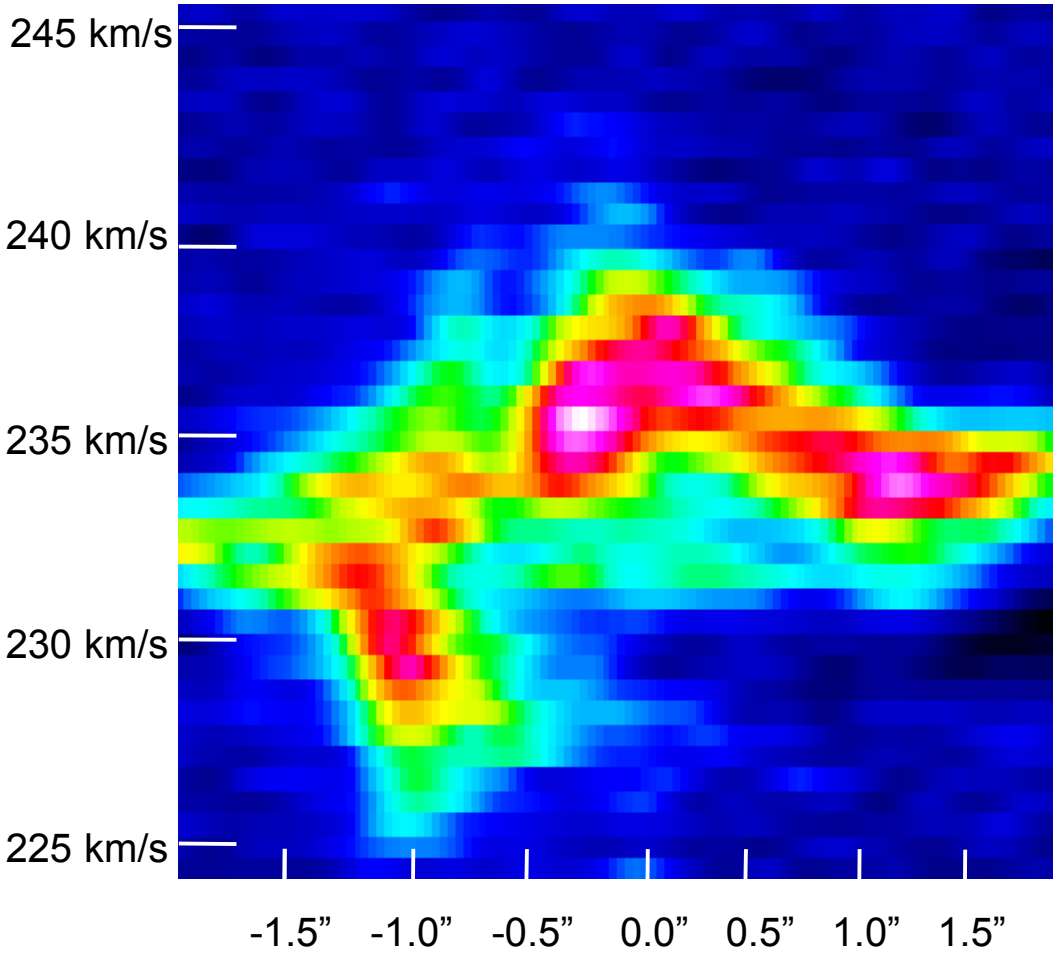
Is This an Outflow?





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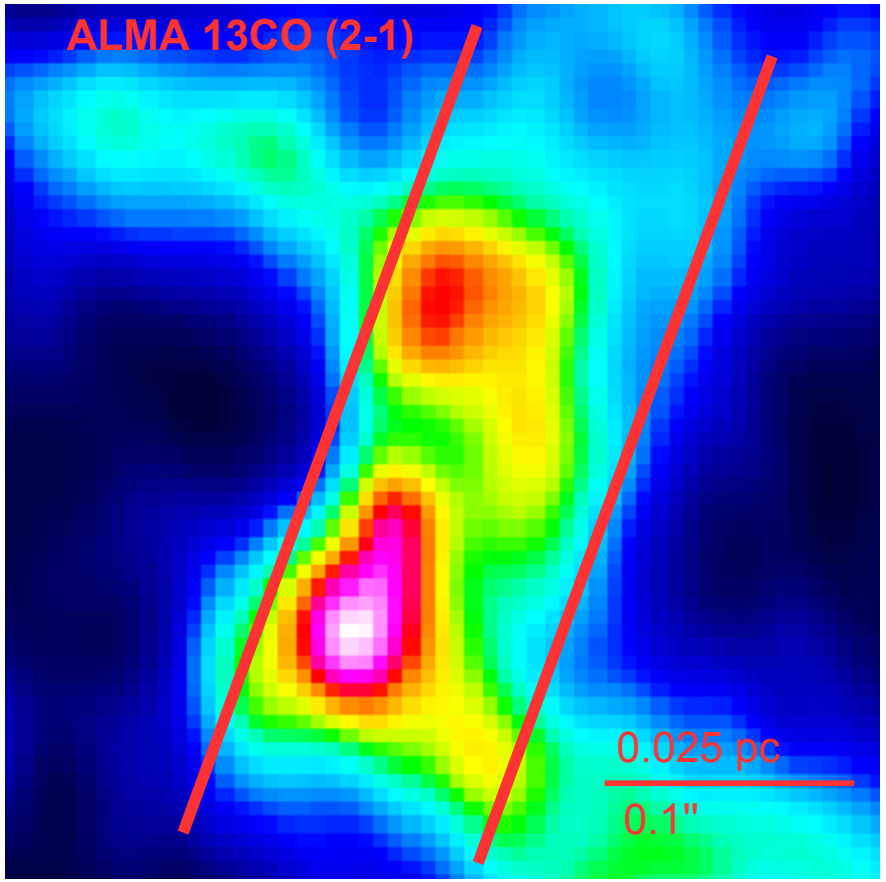
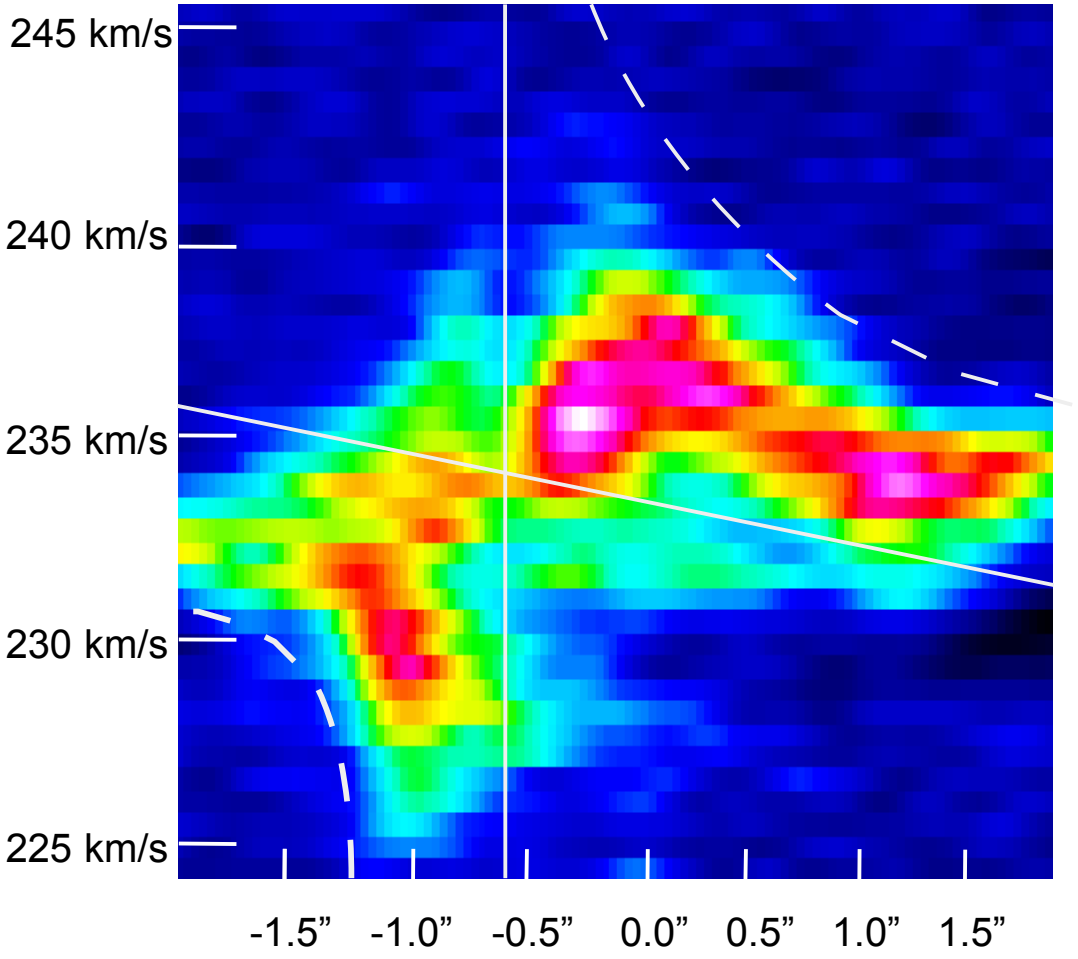
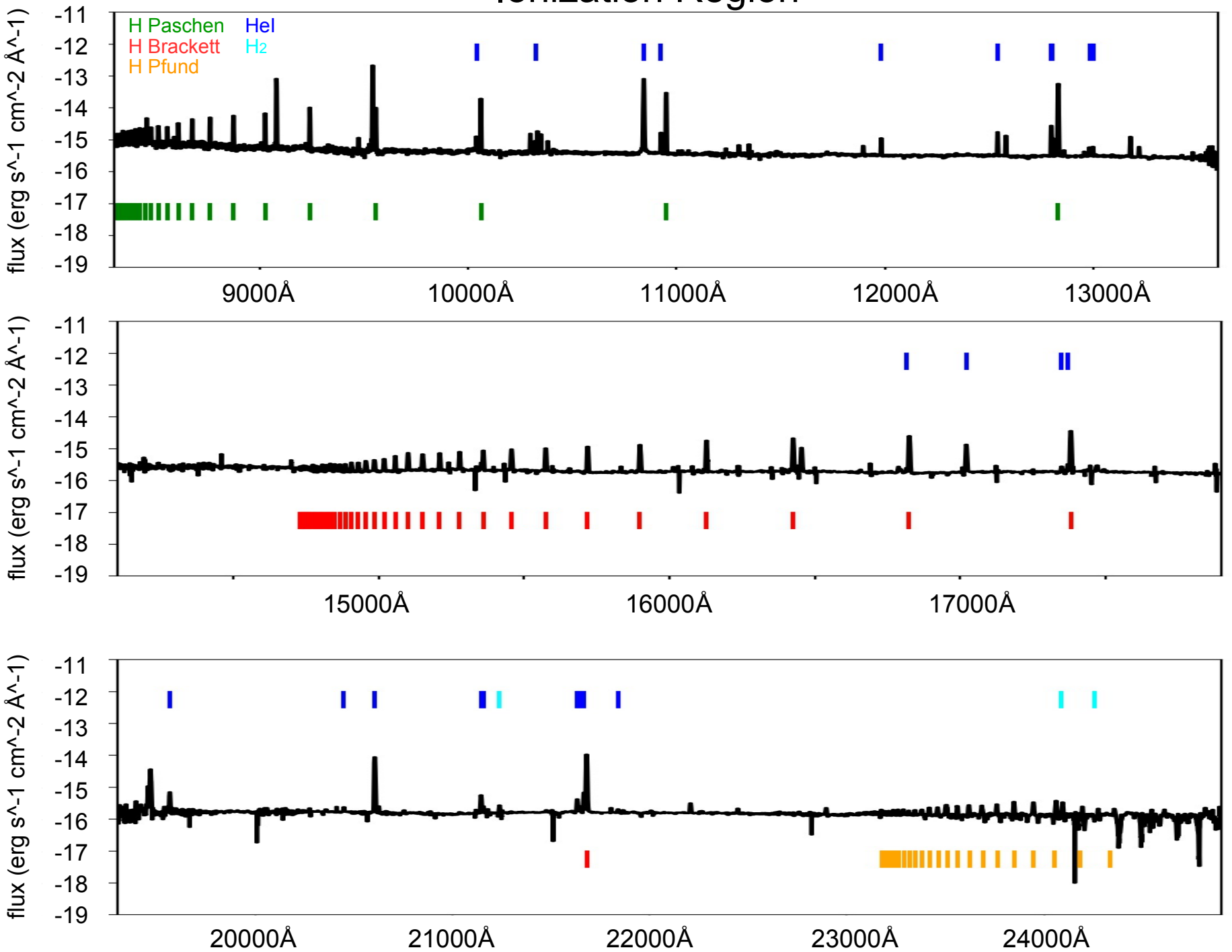
Or Signature of a Disk?





Nayak et al. (in prep)

Environment – FIRE Spectrograph
Ionization Region



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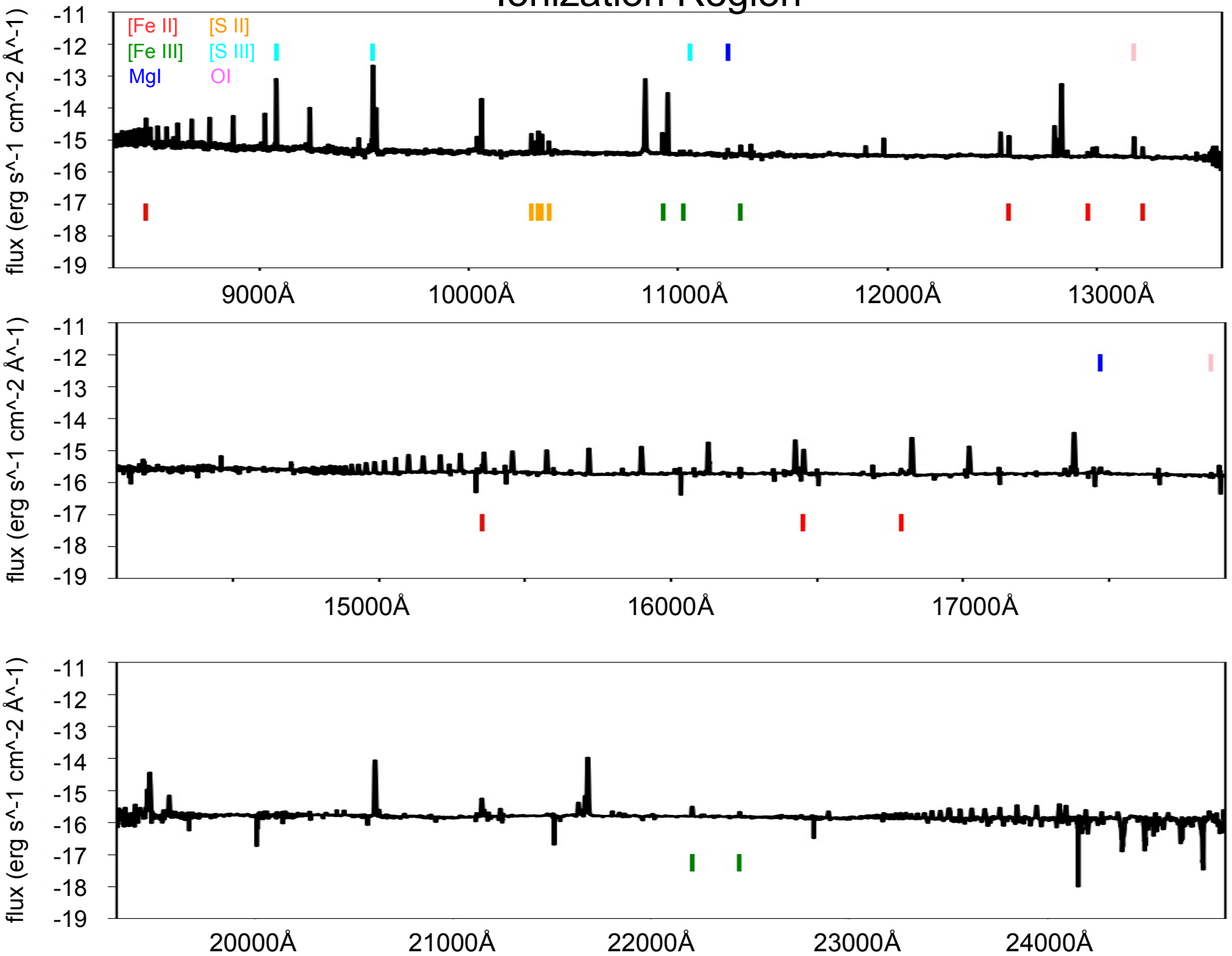

Nayak et al. (in prep)

Calculating the Extinction from [FeII]

- [FeII] 12570Å and [FeII] 16440Å line ratio used to calculate extinction to the source:

$$A_V = \left[2.5/\left(\frac{A_{\lambda_2} - A_{\lambda_1}}{A_V}\right)\right] \times \left(\log\frac{F_{\lambda_1}}{F_{\lambda_2}} - \log\frac{I_{\lambda_1}}{I_{\lambda_2}}\right)$$

- $2.5/((A_{\lambda 1} – A_{\lambda 2})/A_V)$ is dependent on which extinction law you use.
    - Values range from 21.99 to 28.70.
- $I_{\lambda 1}/I_{\lambda 2}$ is equal to the ratio of the spontaneous emission coefficients.
    - $I_{\lambda 1}/I_{\lambda 2}$ ranges from 0.80 to 0.96.
- $F_{\lambda 1}/F_{\lambda 2}$ is equal to 1.12

A_V equal 1.5 to 4.2

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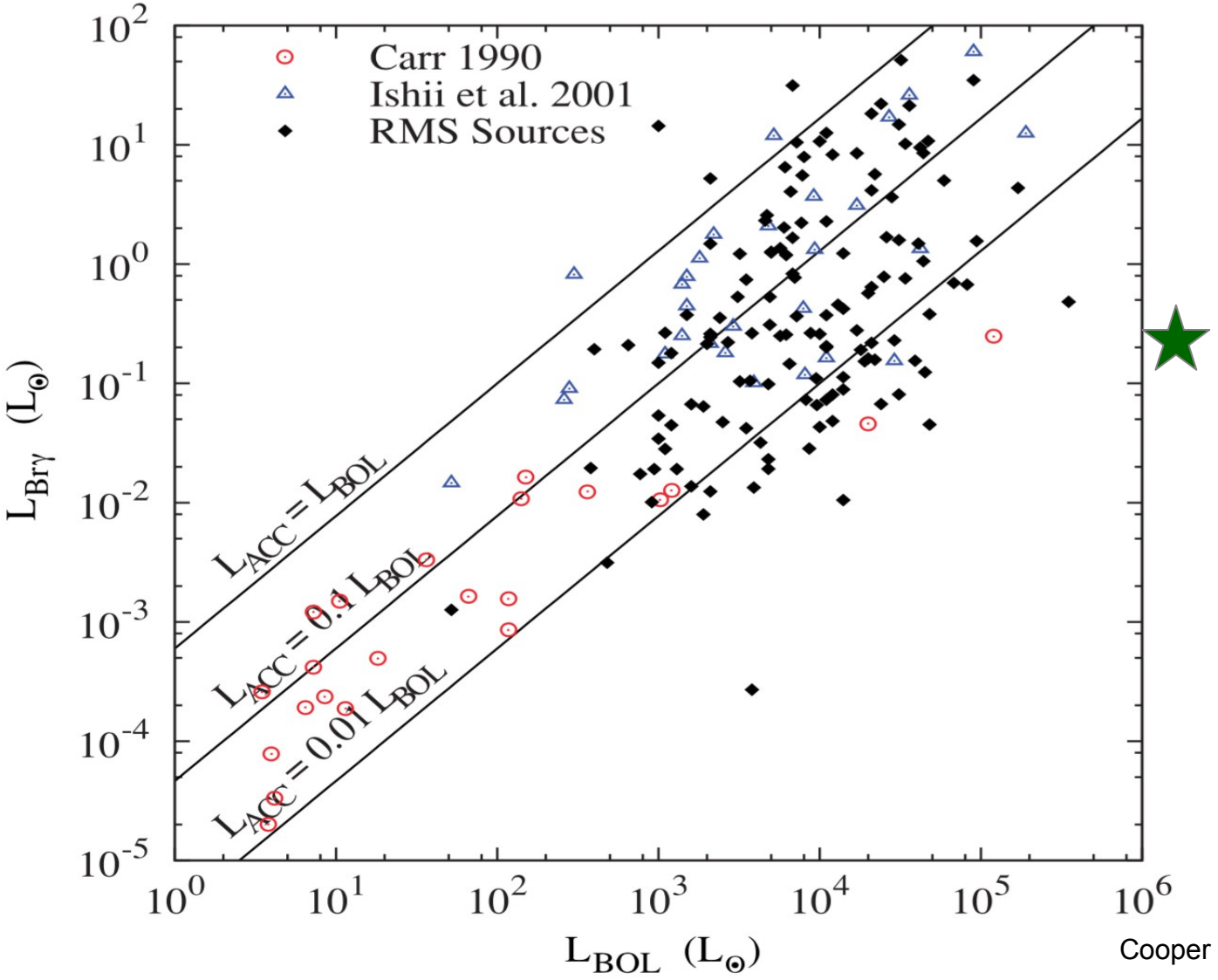
How do Emission Lines of the Massive YSO in N79 Compare to Milky Way YSOs?

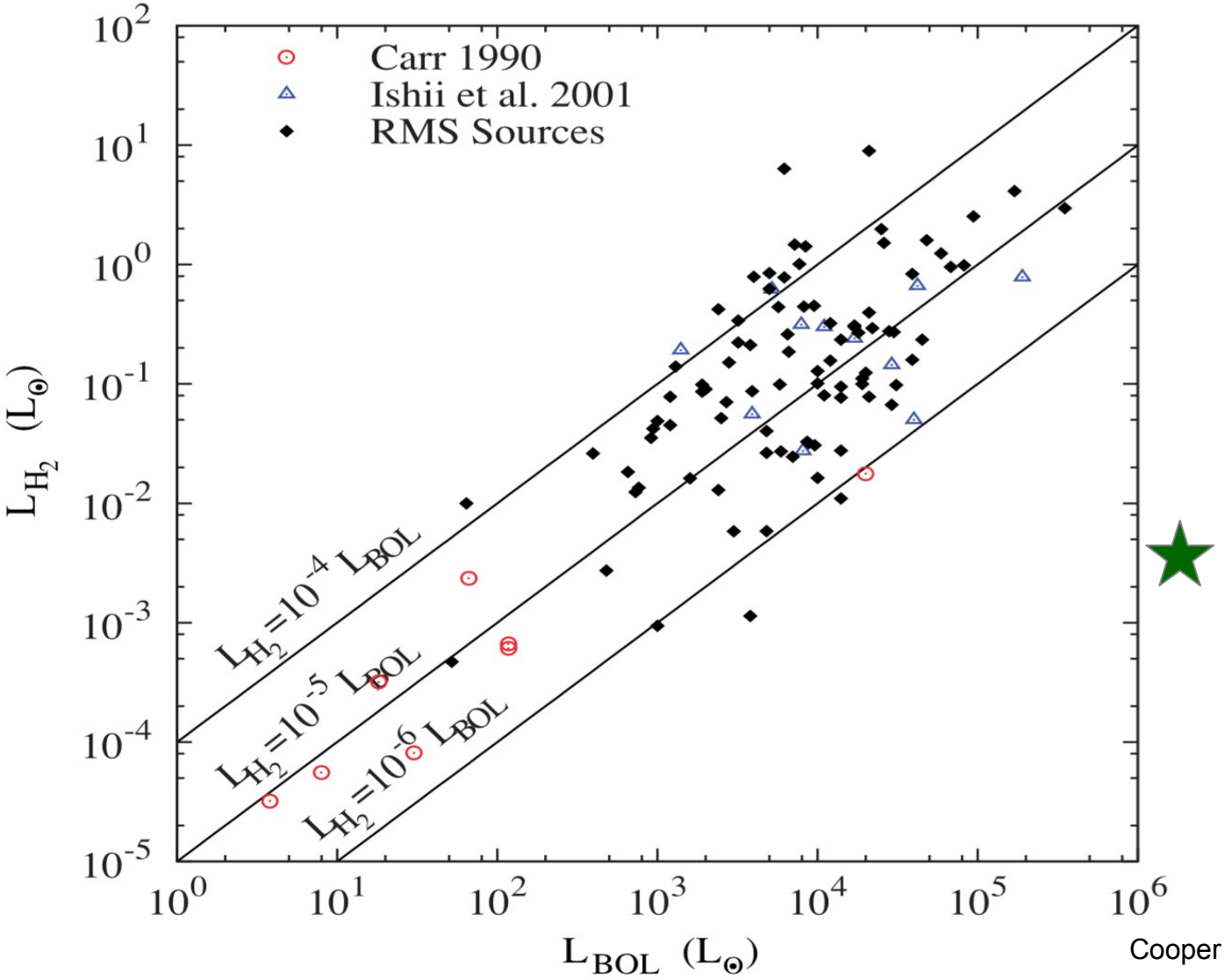
Brγ Traces Accretion



Cooper et al. (2013)

How do Emission Lines of the Massive YSO in N79 Compare to Milky Way YSOs?

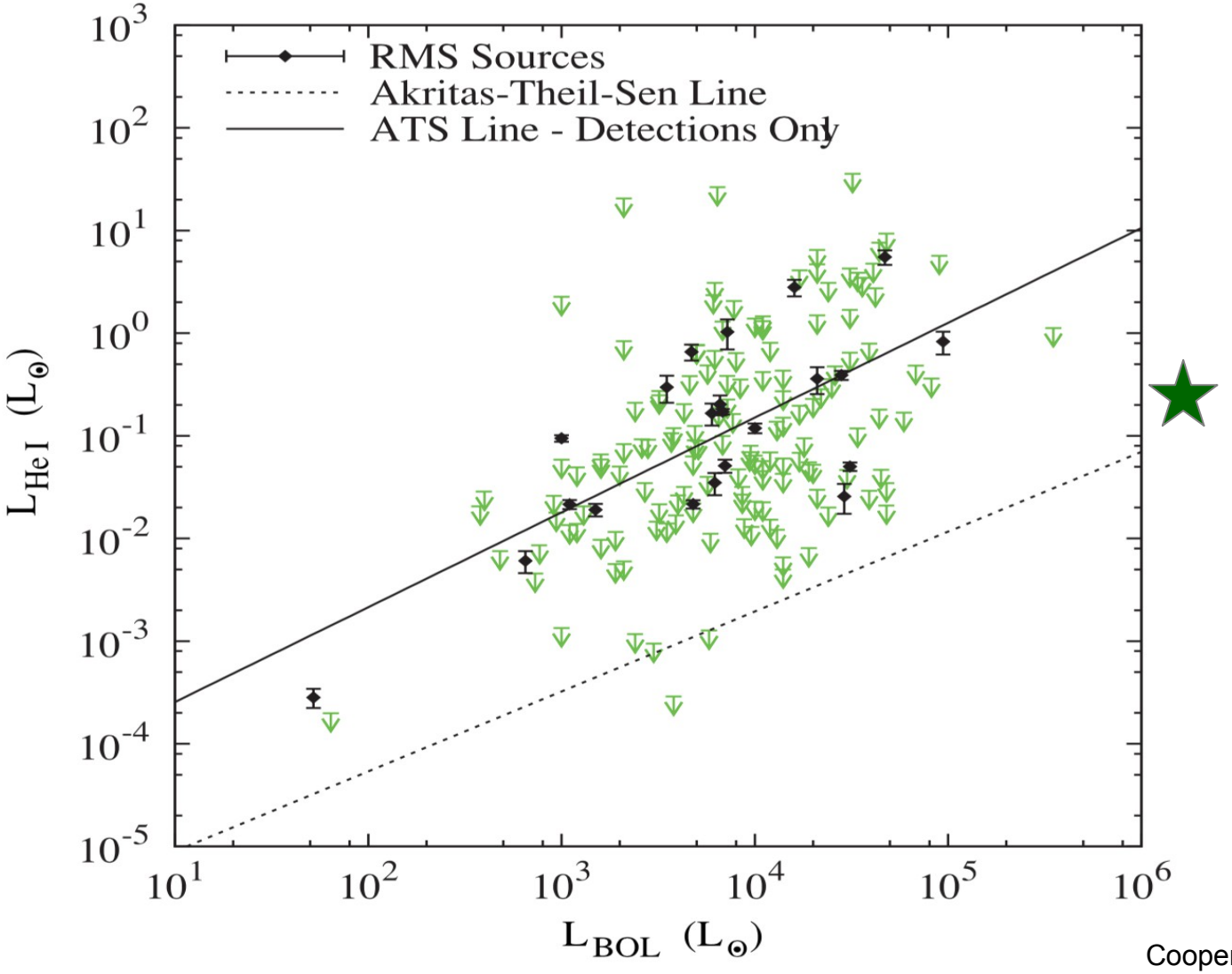
H_2 Emission Means there are Shocks



Cooper et al. (2013)

How do Emission Lines of the Massive YSO in N79 Compare to Milky Way YSOs?

MYSO in N79 is Hot Enough to Ionize He



Cooper et al. (2013)

Conclusion – More Results in Nayak et al. (in prep)

- H72.97-69.39 is the most luminous YSO
- Formation mechanism for massive YSOs:
  - H72.97-69.39 is at the center of colliding filaments
- Studying the environment:
  - SOFIA: Constraining Outflow
  - ALMA: Molecular gas structure
  - Magellan FIRE Spectrograph: Ionization region
- Future Observations
  - JWST
  - group based adaptive optics

Why is H72.97-62.39 so luminous?

What is special about the environment around H72.97-69.39 that lead to the formation of this massive star?

Will H72.97-69.39 be the next R136?