UV feedback in stellar clusters: photo-evaporation of planet forming disks and proplyds

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Rice University

UV feedback in stellar clusters: photo-evaporation of planet forming disks and proplyds (and outflows).

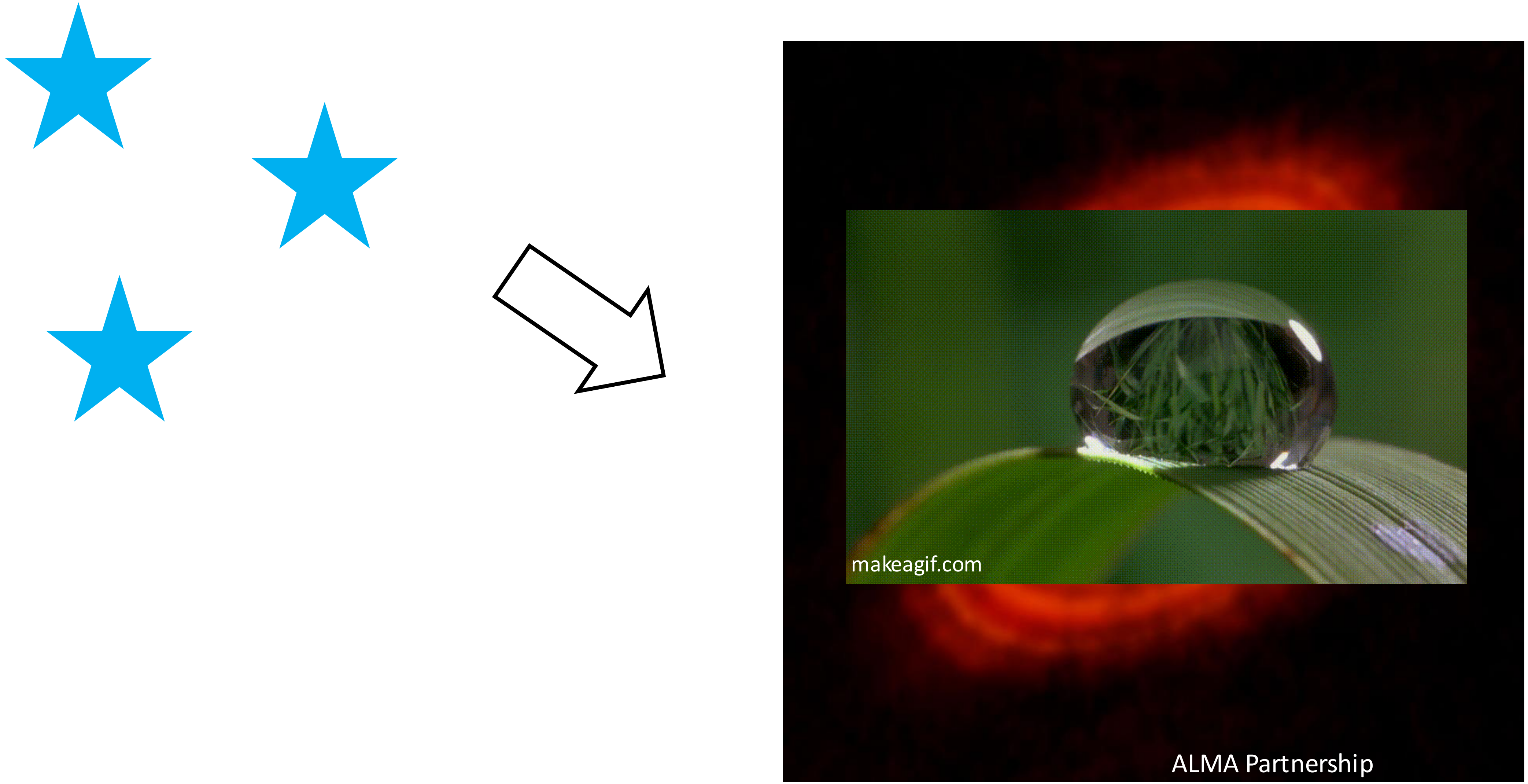
ACKNOWLEDGEMENTS

We would like to thank John Bally for a prompt and helpful referee report. We would also like to thank Dirk Froebrich and Bo Reipurth for quickly providing MHO and HH numbers for this paper and their

Reiter et al. 2022

NIRCAM
F187N
F444W
F470N

Feedback (esp. radiation) from massive stars affects planet-forming disks by heating and photoevaporating them.



Photoevaporating protoplanetary disks (proplyds) are direct evidence of external photoevaporation of disks.

BALLY ET AL. 2005

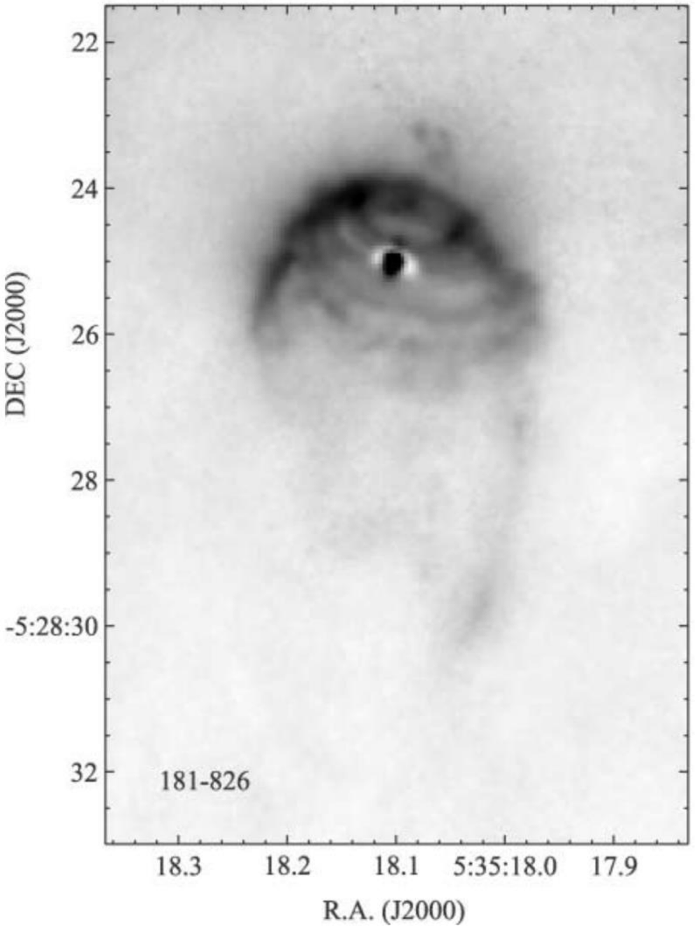
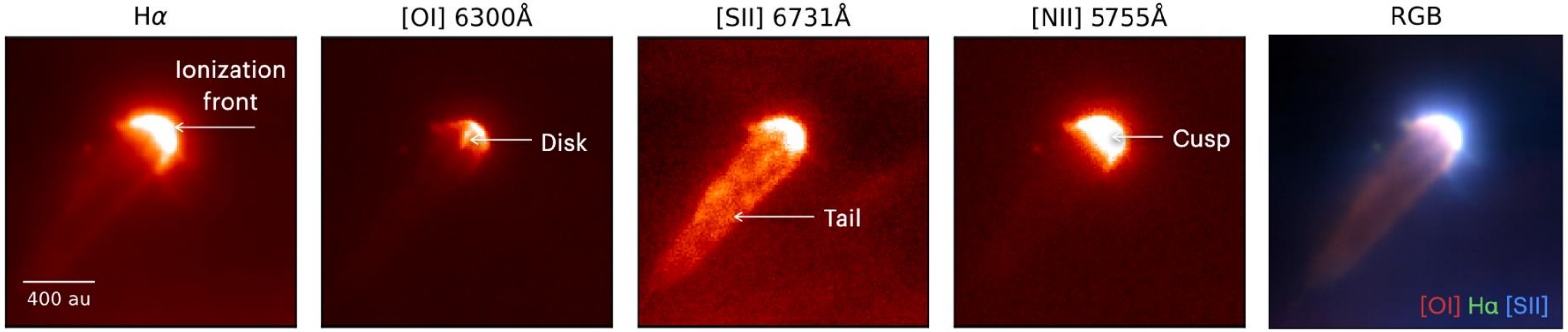
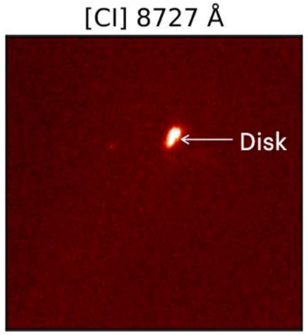
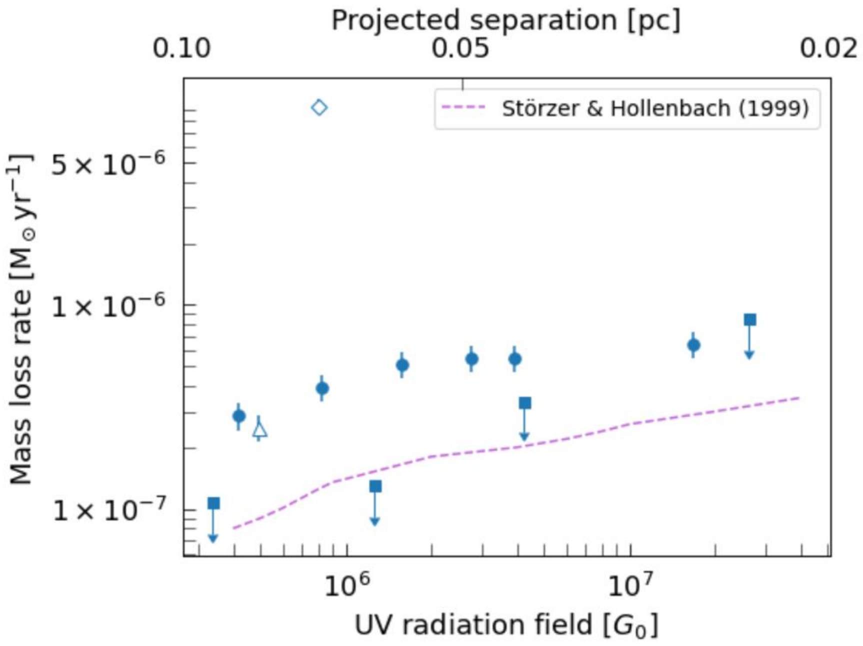


FIG. 1.—ACS F658N image of the giant proplyd 181−826 showing the silhouette disk, axial nebula, and rings surrounding the disk axis.







Aru et al. 2023, 2024

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6 BALLY ET AL. 2005 Vol. 129

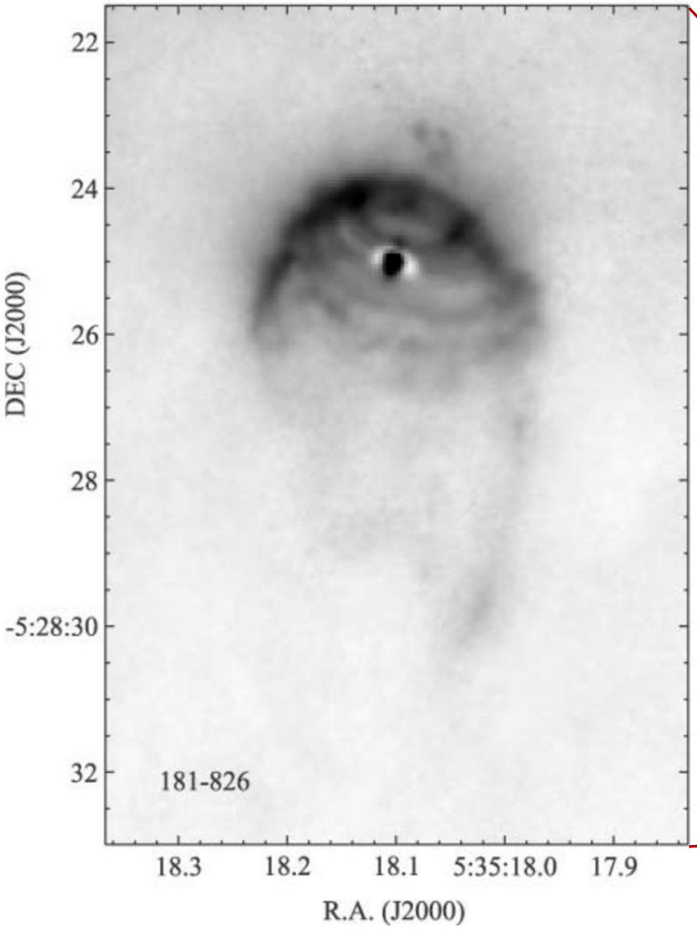


Fig. 1.—ACS F658N image of the giant proplyd 181–826 showing the silhouette disk, axial nebula, and rings surrounding the disk axis.

358 BALLY ET AL. Vol. 129

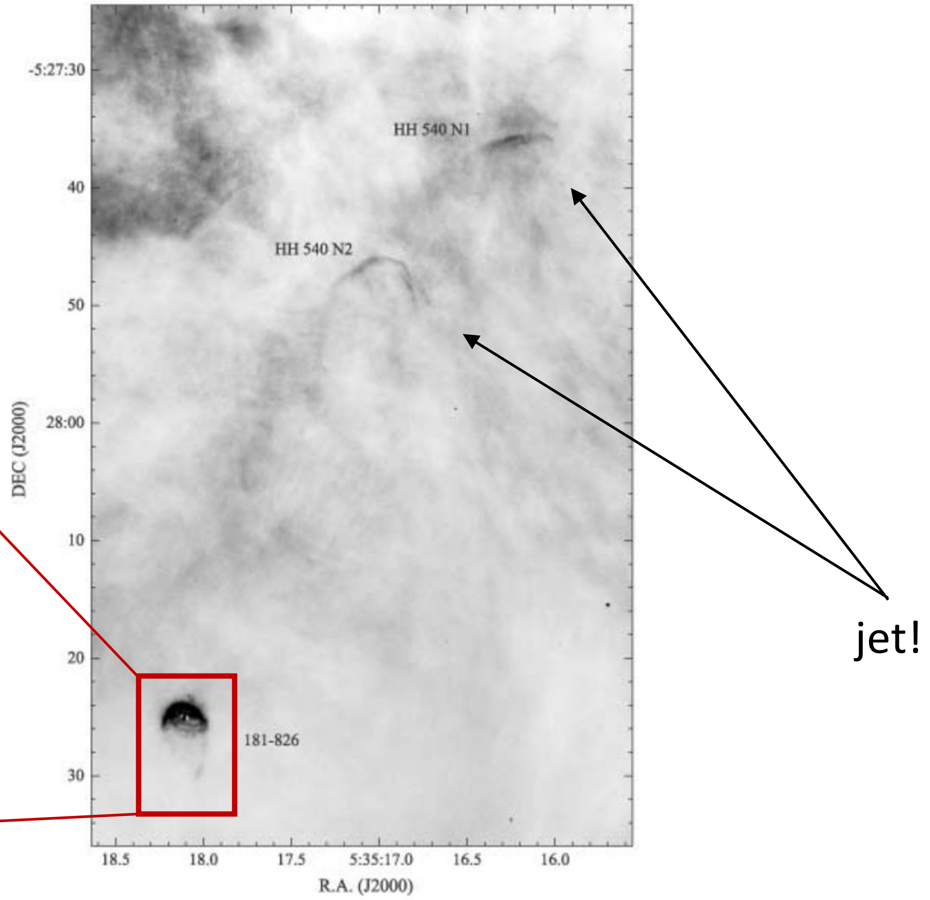
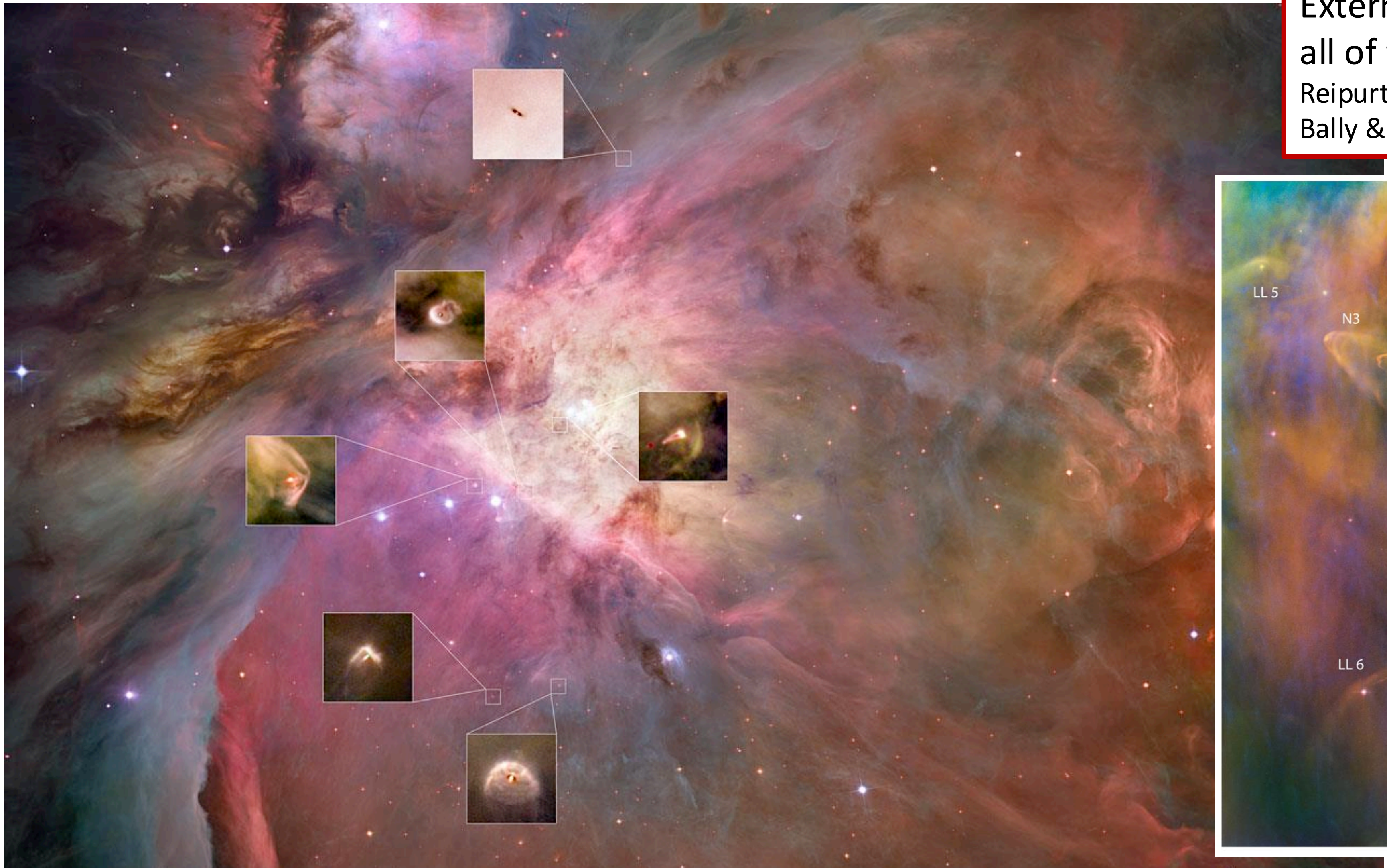


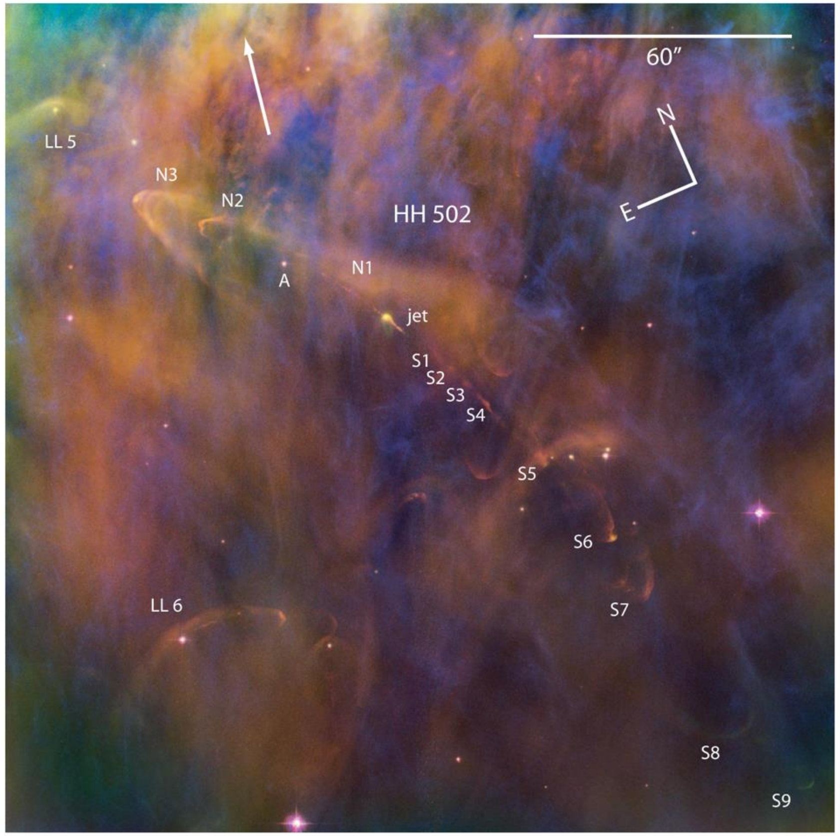
Fig. 2.—ACS F658N image showing the proplyd 181–826 and the two candidate shocks in the HH 540 counterflow, HH 540 N1 and HH 540 N2.

UV radiation from high-mass stars illuminated everything in the vicinity – disks, globules, outflows…

External illumination to measure all of the mass in the outflow?
Reiputh, Bally, et al. 1998
Bally & Reipurth 2001

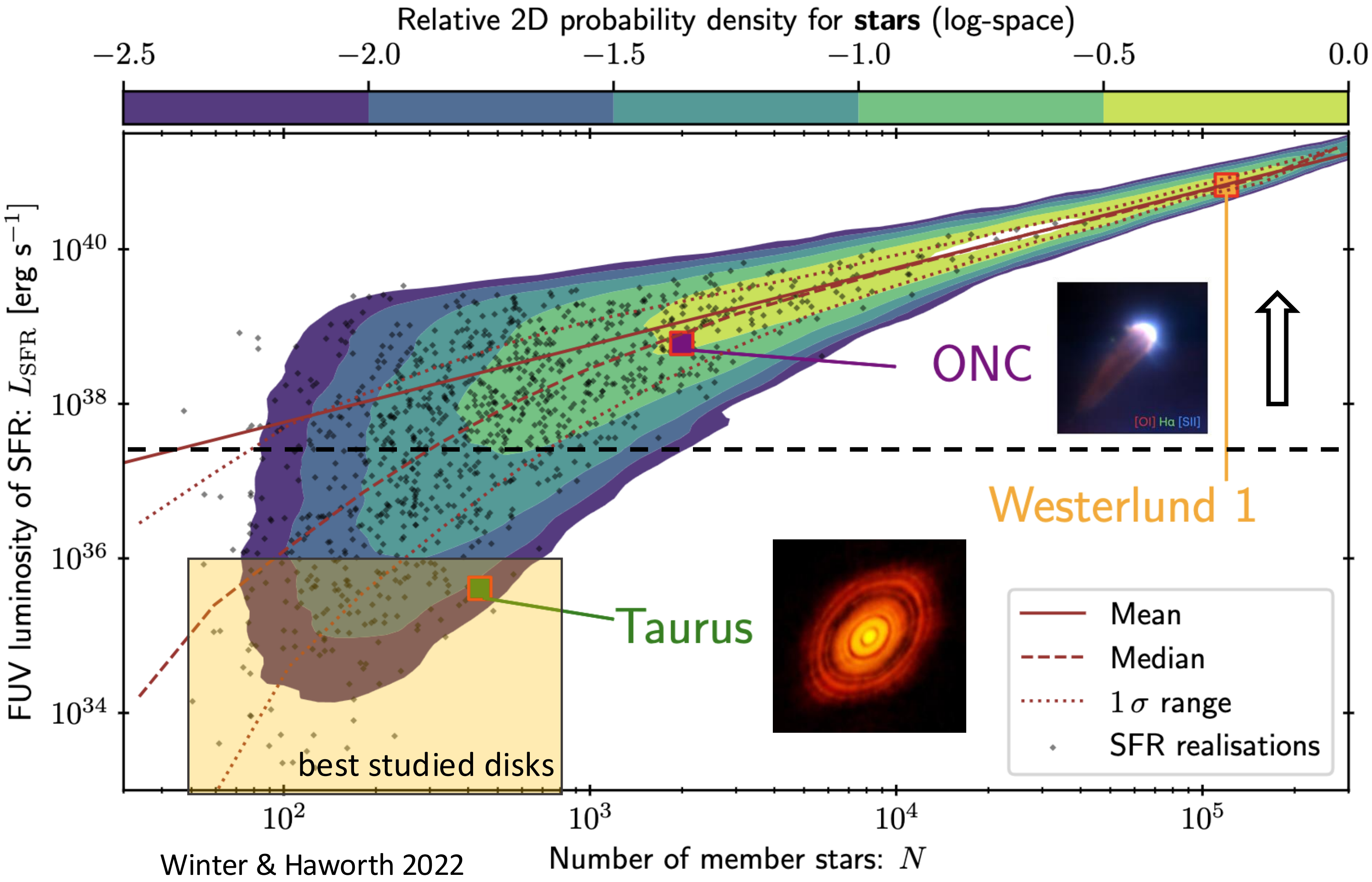


NASA, ESA, M. Robberto (STScI/ESA), the Hubble Space Telescope Orion Treasury Project Team and L. Ricci (ESO)



Bally et al. 2006

Most stars form near high-mass stars that will illuminate and evaporate the planet-forming disks around nearby low-mass stars.



Winter & Haworth 2022

Feedback (esp. radiation) from massive stars affects planet-forming disks by heating and photoevaporating them.

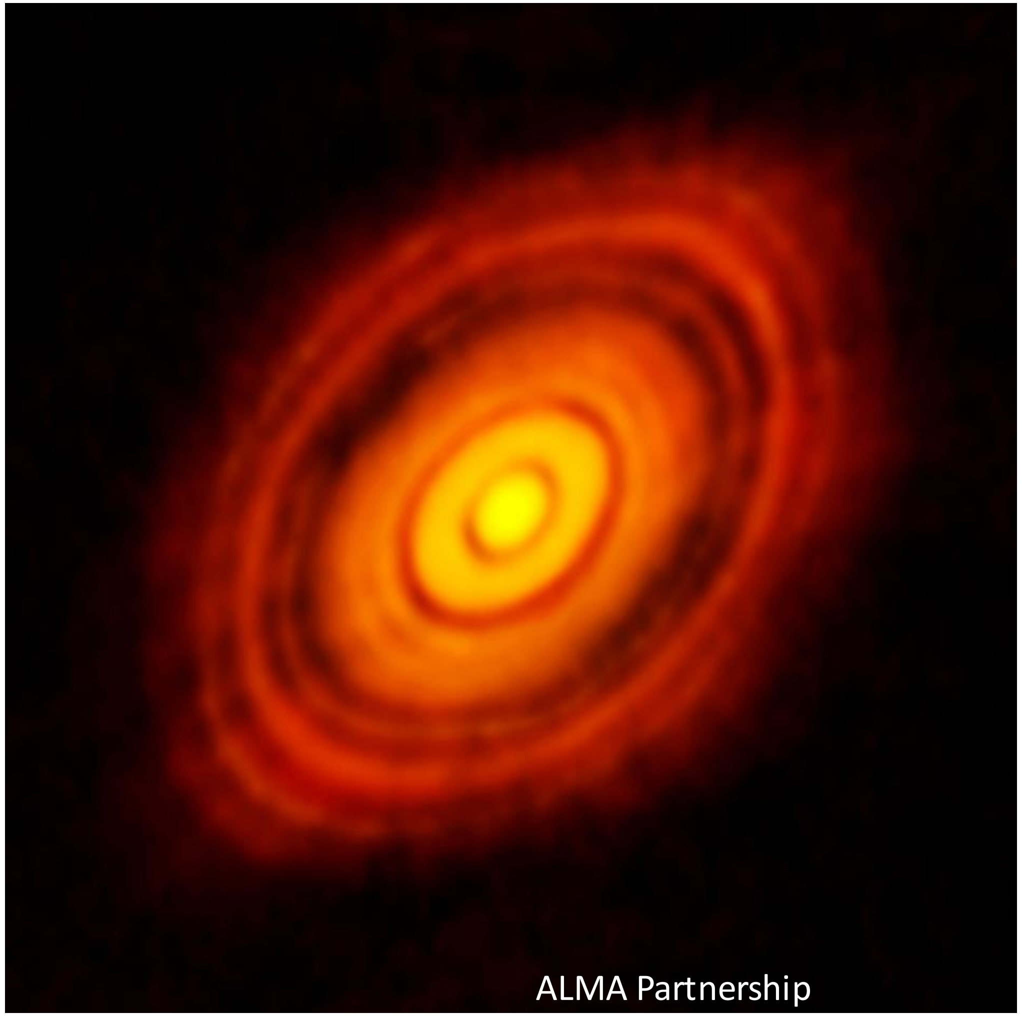
1. the **timescale** for planet formation

→ see Sam Millstone's poster

Feedback (esp. radiation) from massive stars affects planet-forming disks by heating and photoevaporating them.

1. the **timescale** for planet formation

2. the **ingredients** for terrestrial planets


ALMA Partnership

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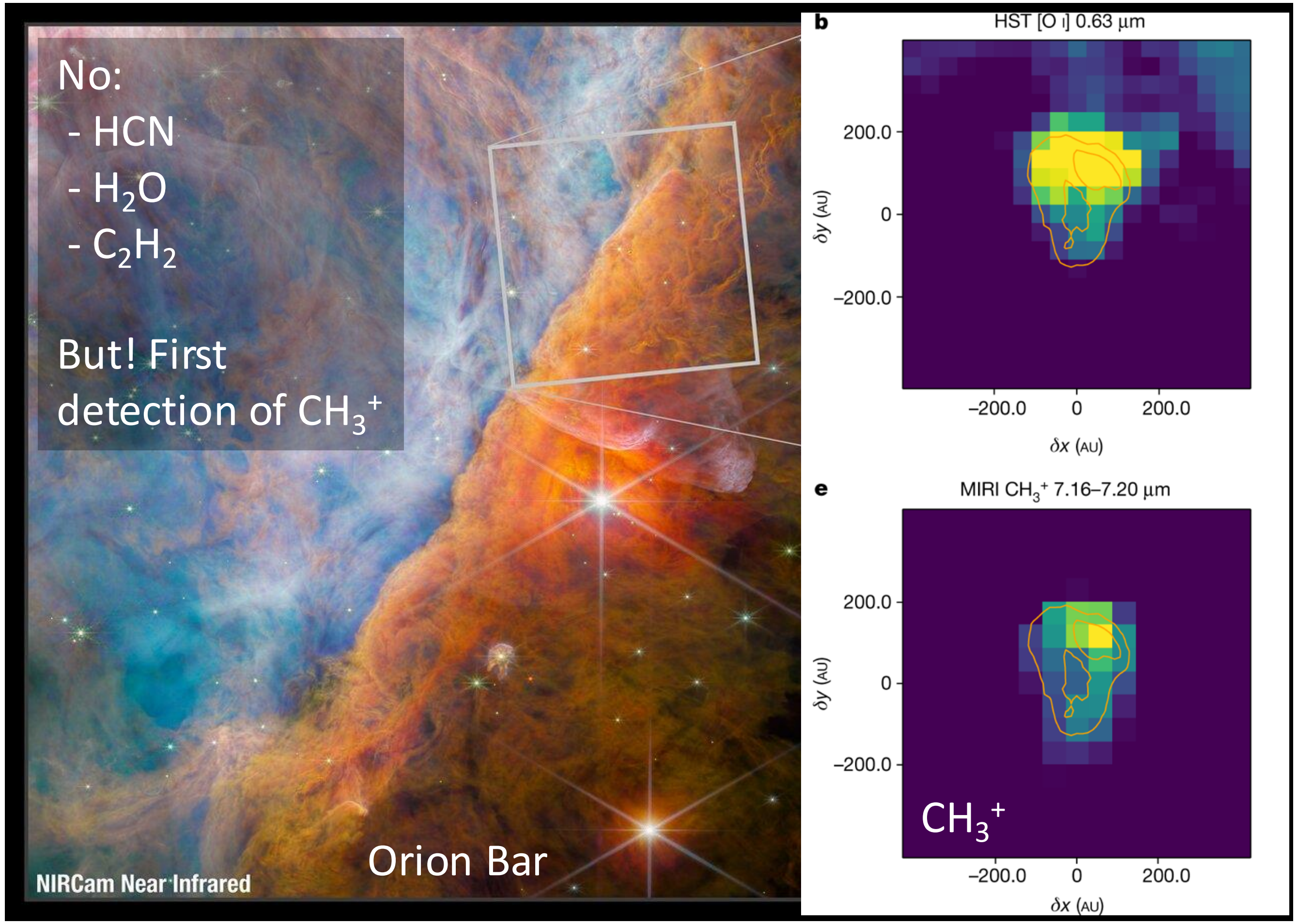
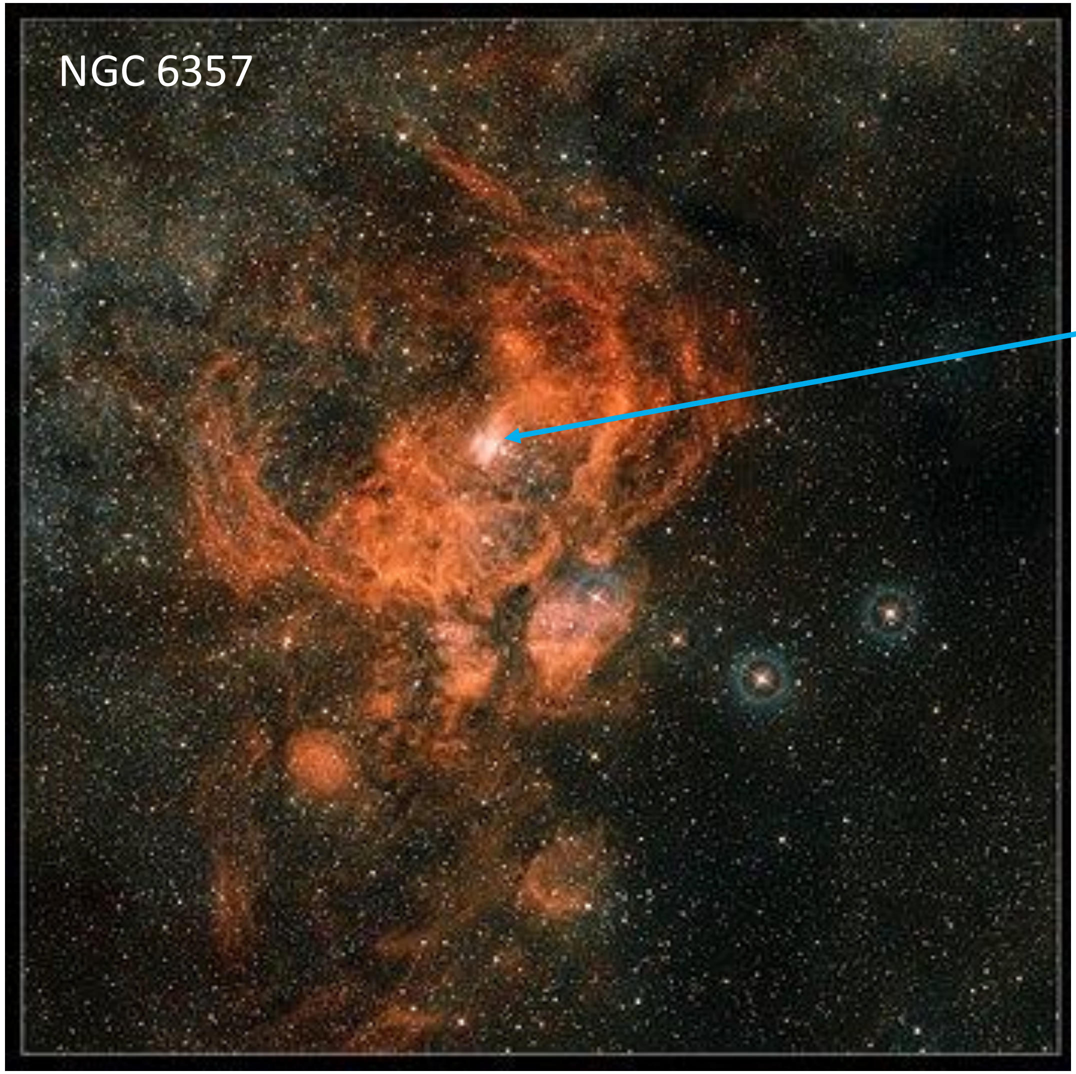
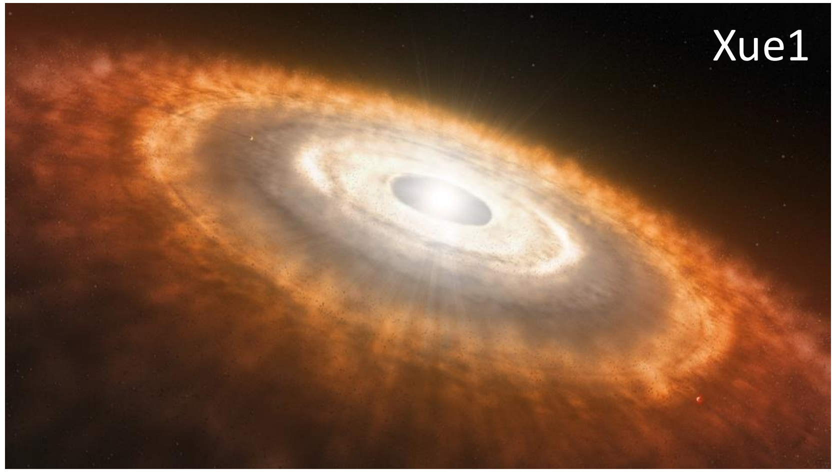


Berné et al. 2023

Xue1 has all the elements to make Earth-like planets despite living in an H II region more extreme than Orion.



ESO/VVV Survey/Digitized Sky Survey 2/D. Minniti. Acknowledgement: Ignacio Toledo



1/15 disks in NGC 6357 observed with MIRI

Ramirez-Tannus et al. 2023

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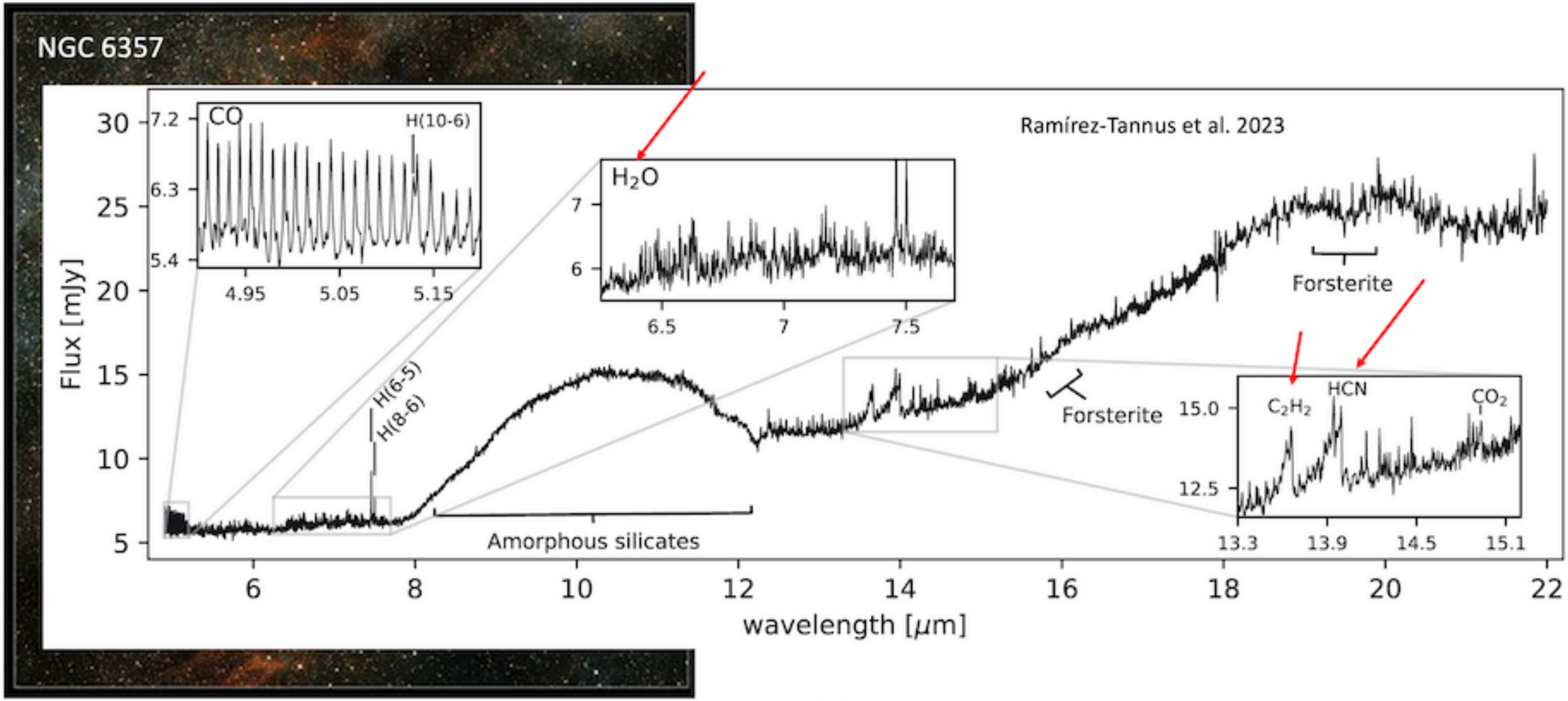

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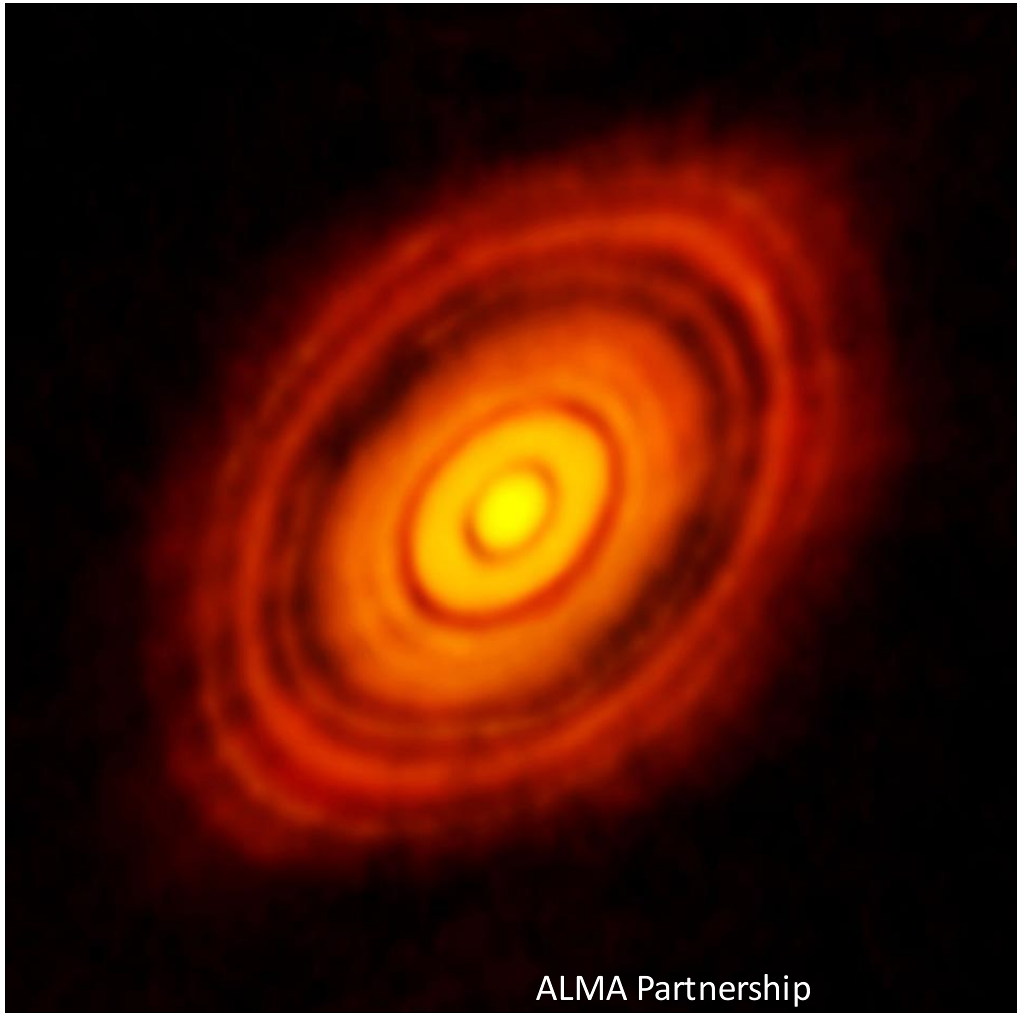
Feedback (esp. radiation) from massive stars affects planet-forming disks by heating and photoevaporating them.

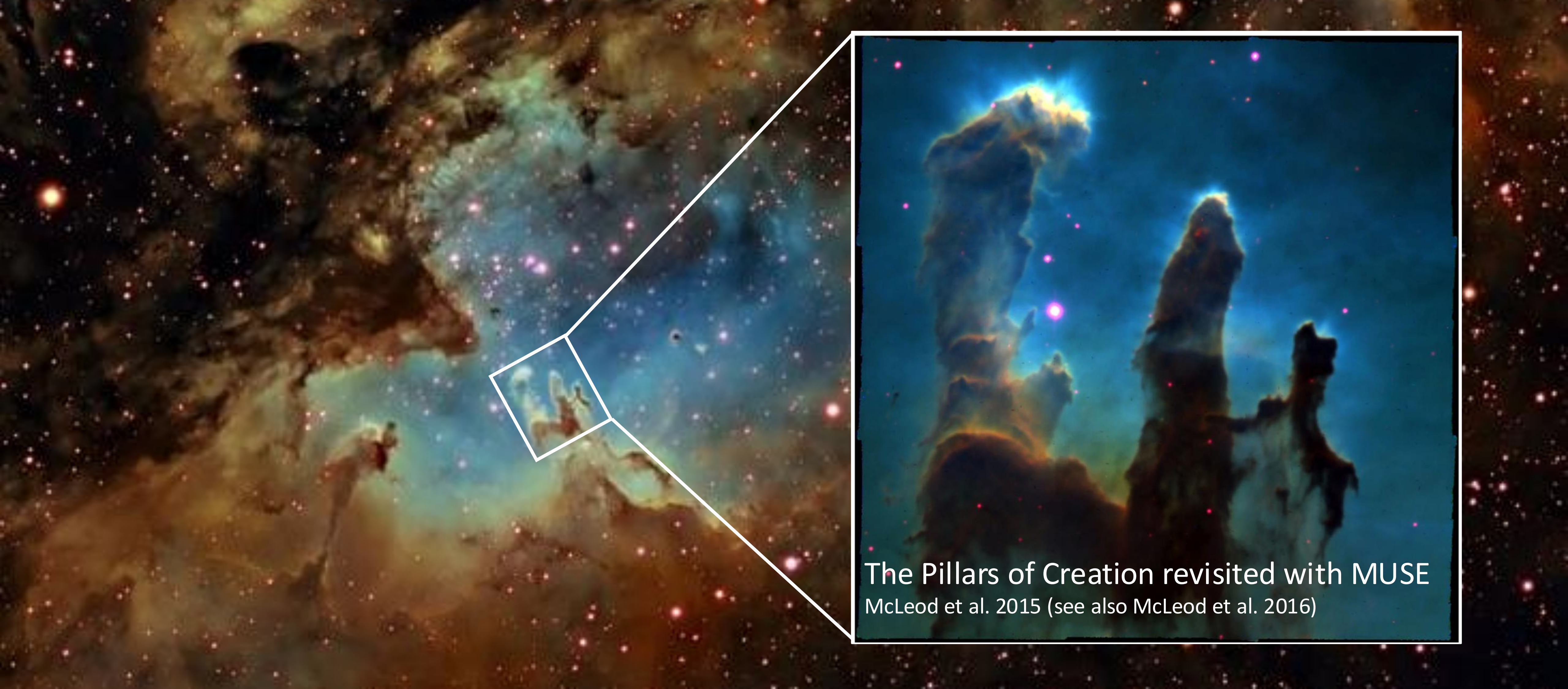
1. the **timescale** for planet formation

2. the **ingredients** for terrestrial planets

3. how the ecosystem evolves, thus regulating exoplanet **demographics**

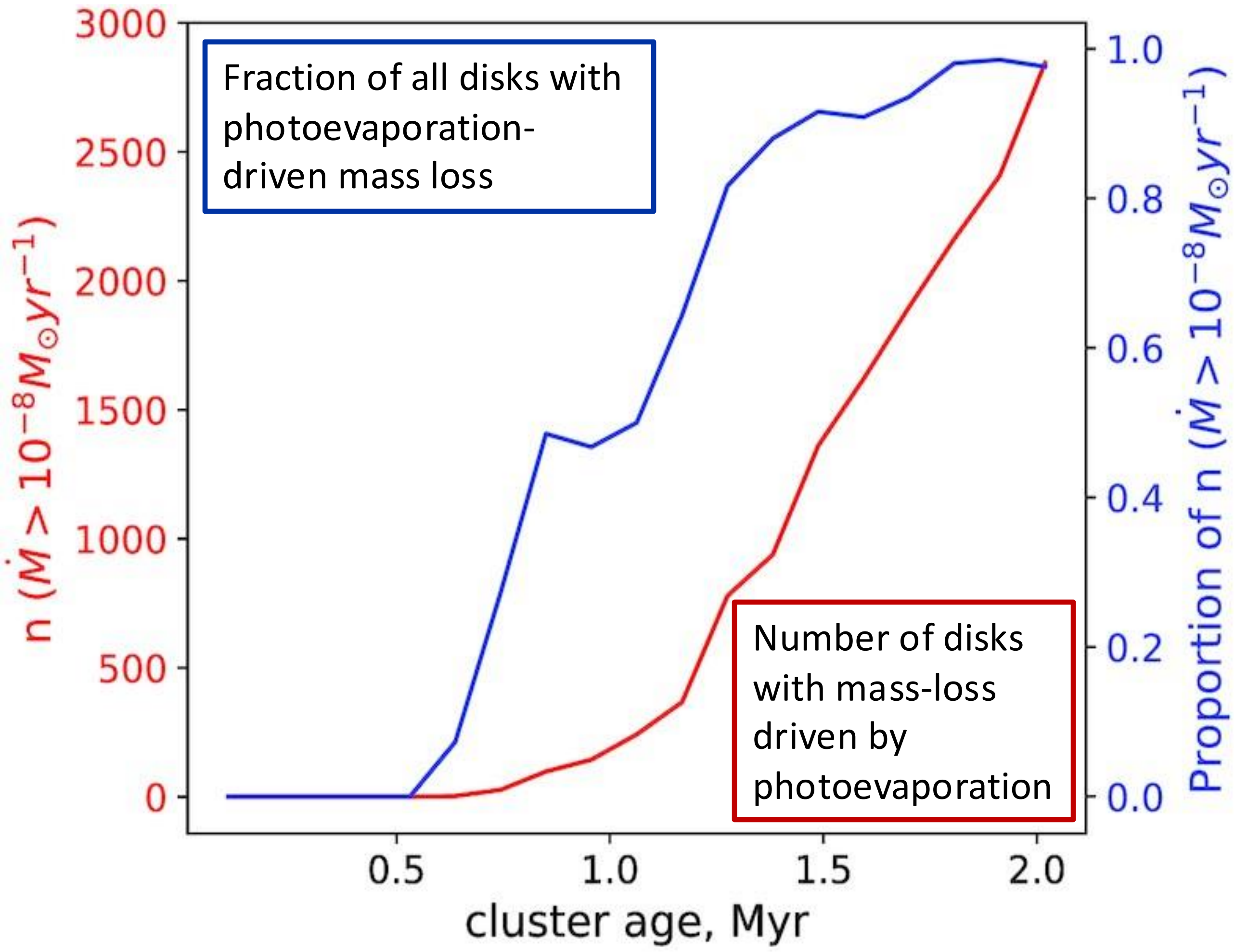


Remaining gas and dust in the star-forming ecosystem protects disks, affects dynamical evolution, may aid enrichment, ...

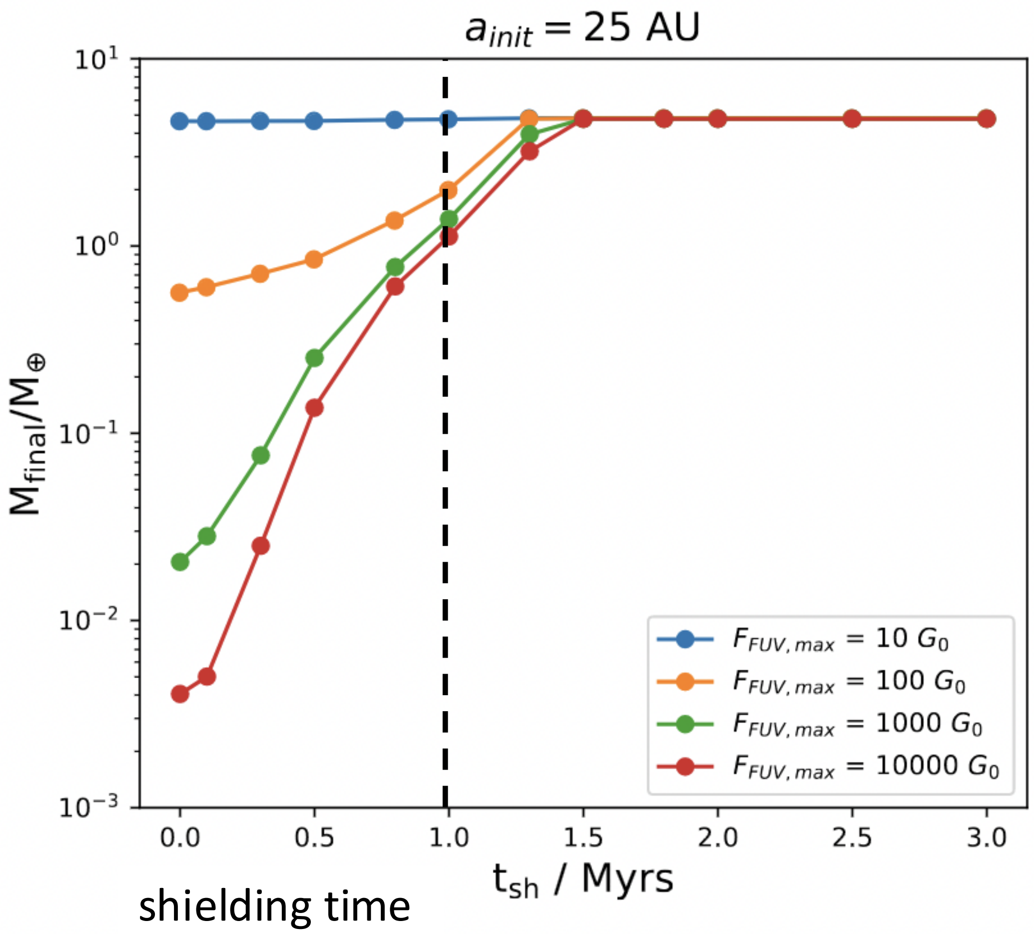


The Pillars of Creation revisited with MUSE
McLeod et al. 2015 (see also McLeod et al. 2016)

Shielding time has a strong impact on the final mass and orbital radii of single planets (pebble accretion models).

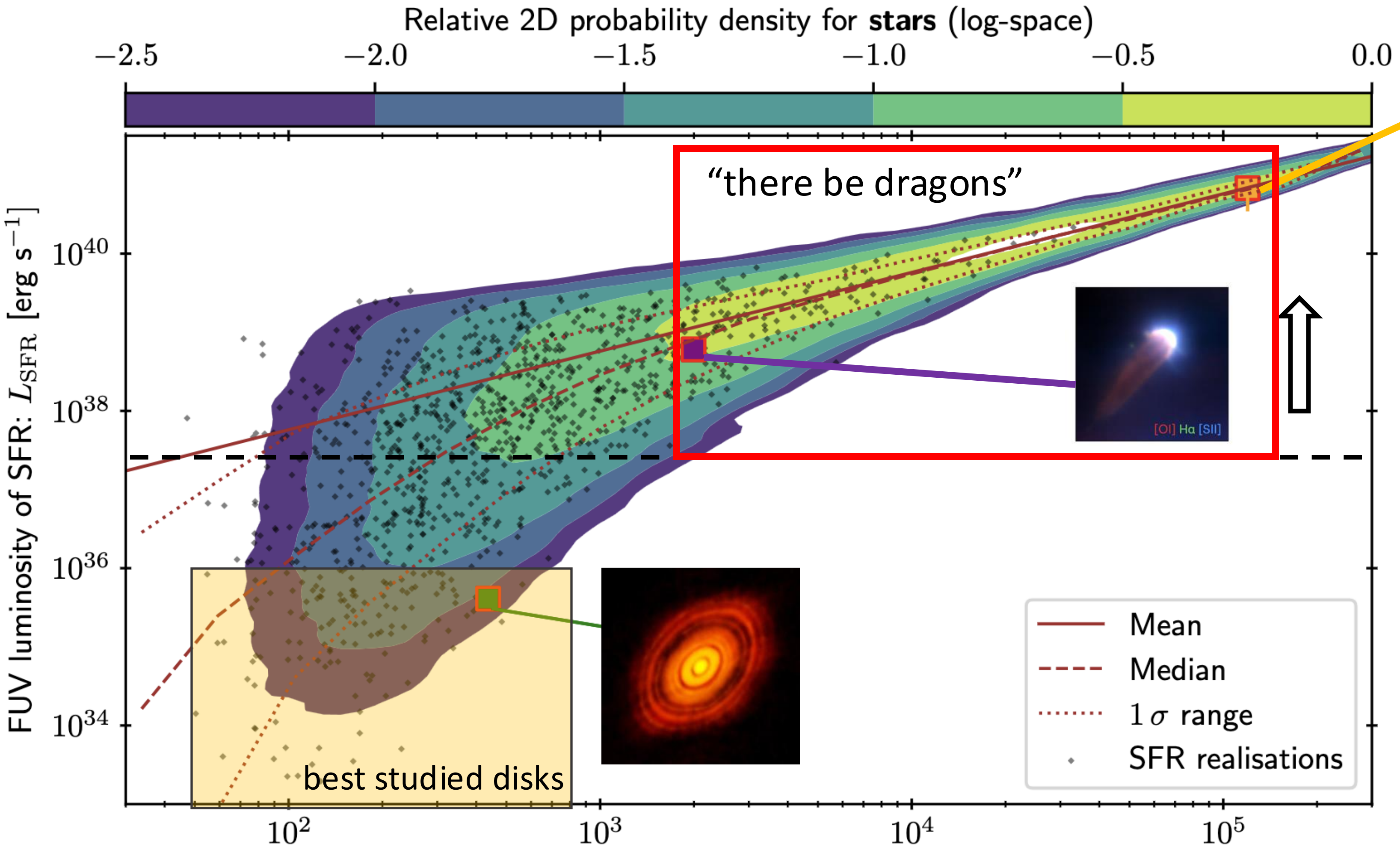


Qiao et al. 2022

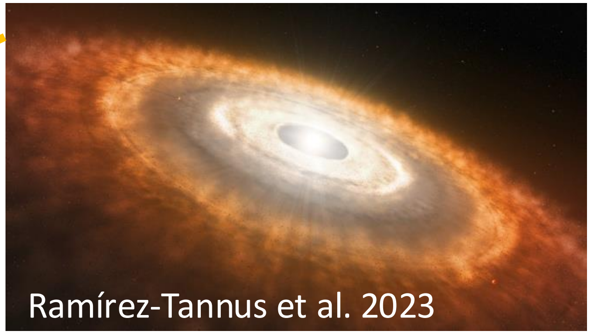


Qiao et al. 2023

Most planet-forming disks will be affected by UV from nearby high-mass stars.



Winter & Haworth 2022



Ramírez-Tannus et al. 2023

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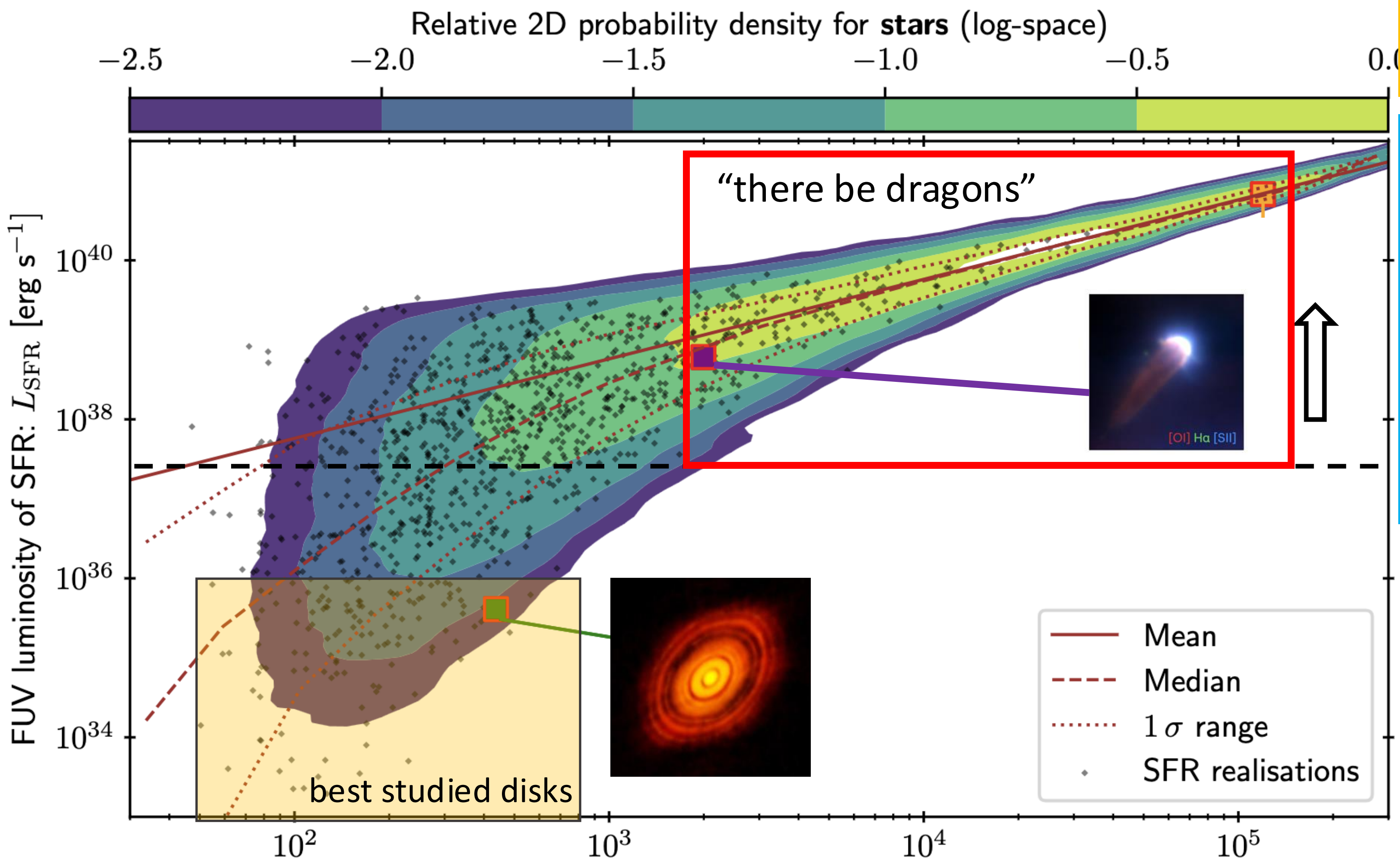


Winter & Haworth 2022

Timescale: external UV destroys disks, reducing time & mass for planet formation

→ Need surveys of different high-mass regions

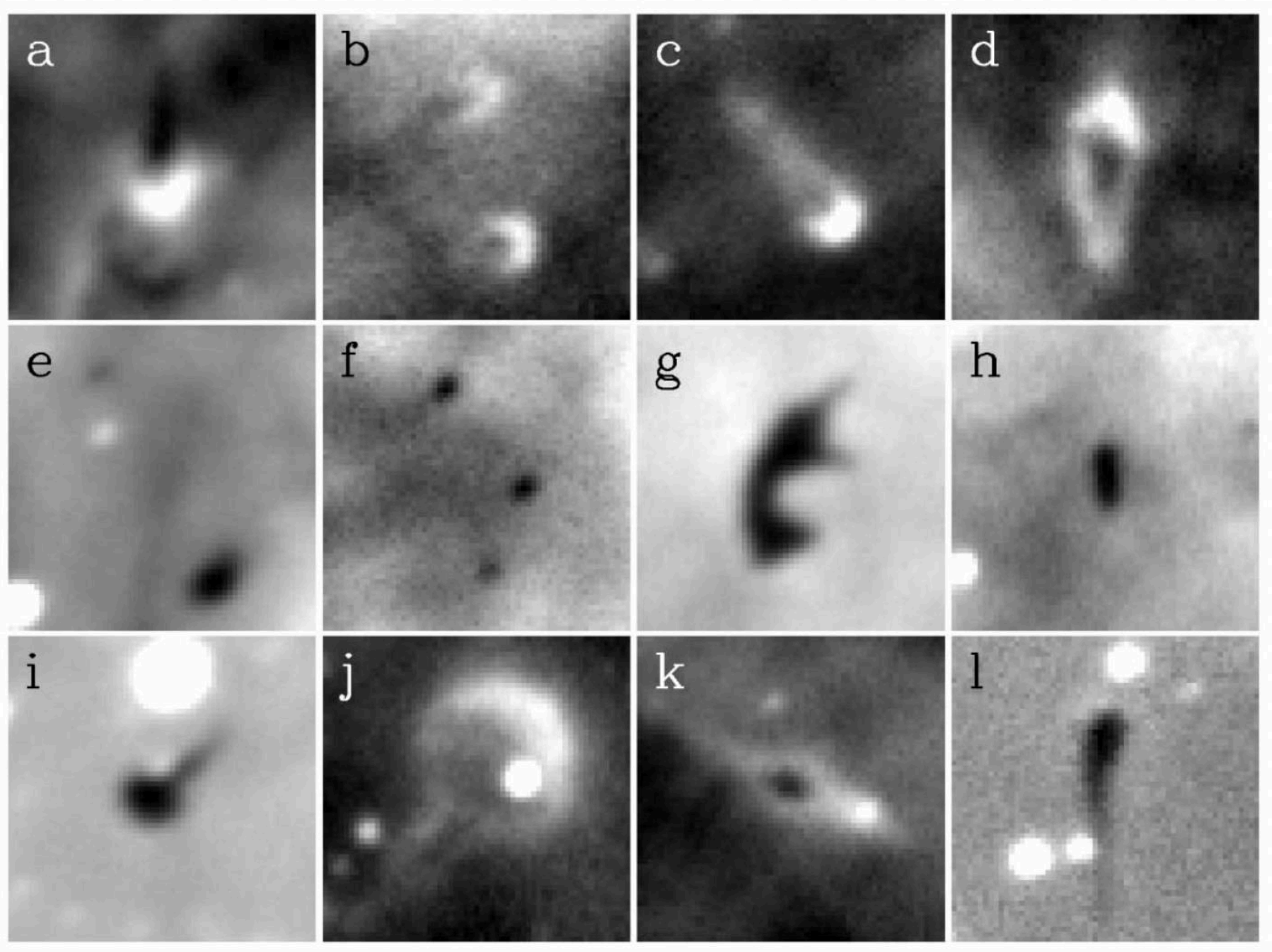
Ingredients: UV may leave organics intact and/or enable organic chemistry – need more representative samples

→ Need sample of low-mass sources in different UV environments

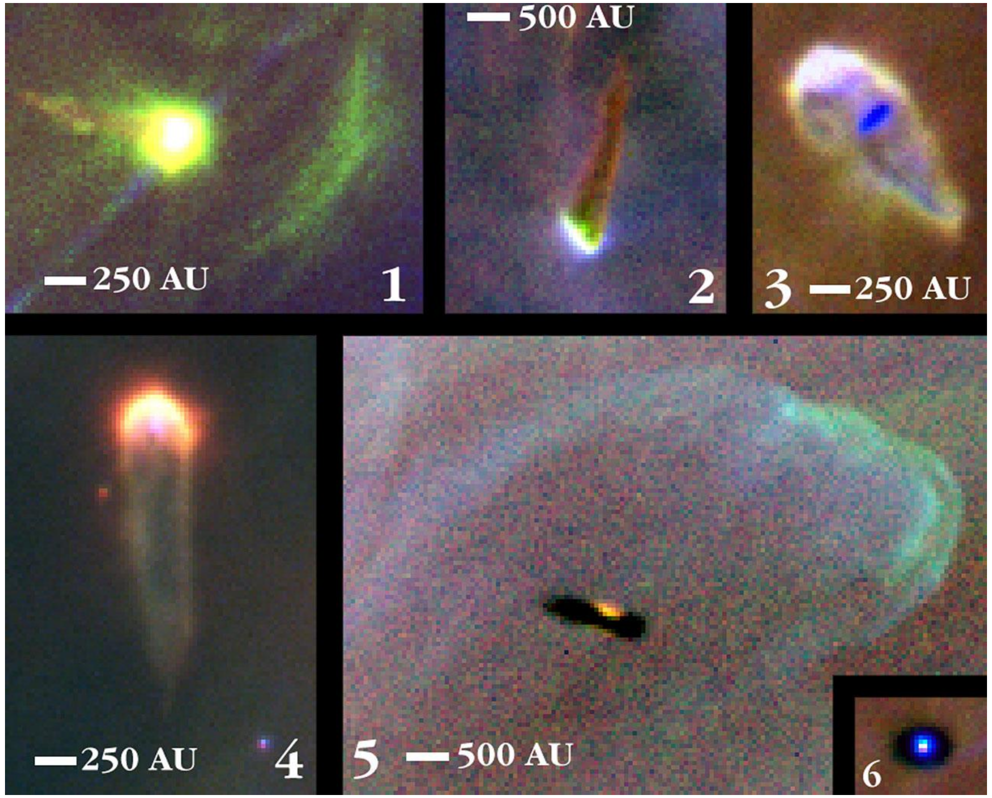
Environment: evolution may be crucial to understand the demographics of exoplanets

→ Need to measure the local gas/dust environment

True proplyds are small, ~250-500 AU, not well-resolved for d ≥ 2 kpc with the best-available instruments.

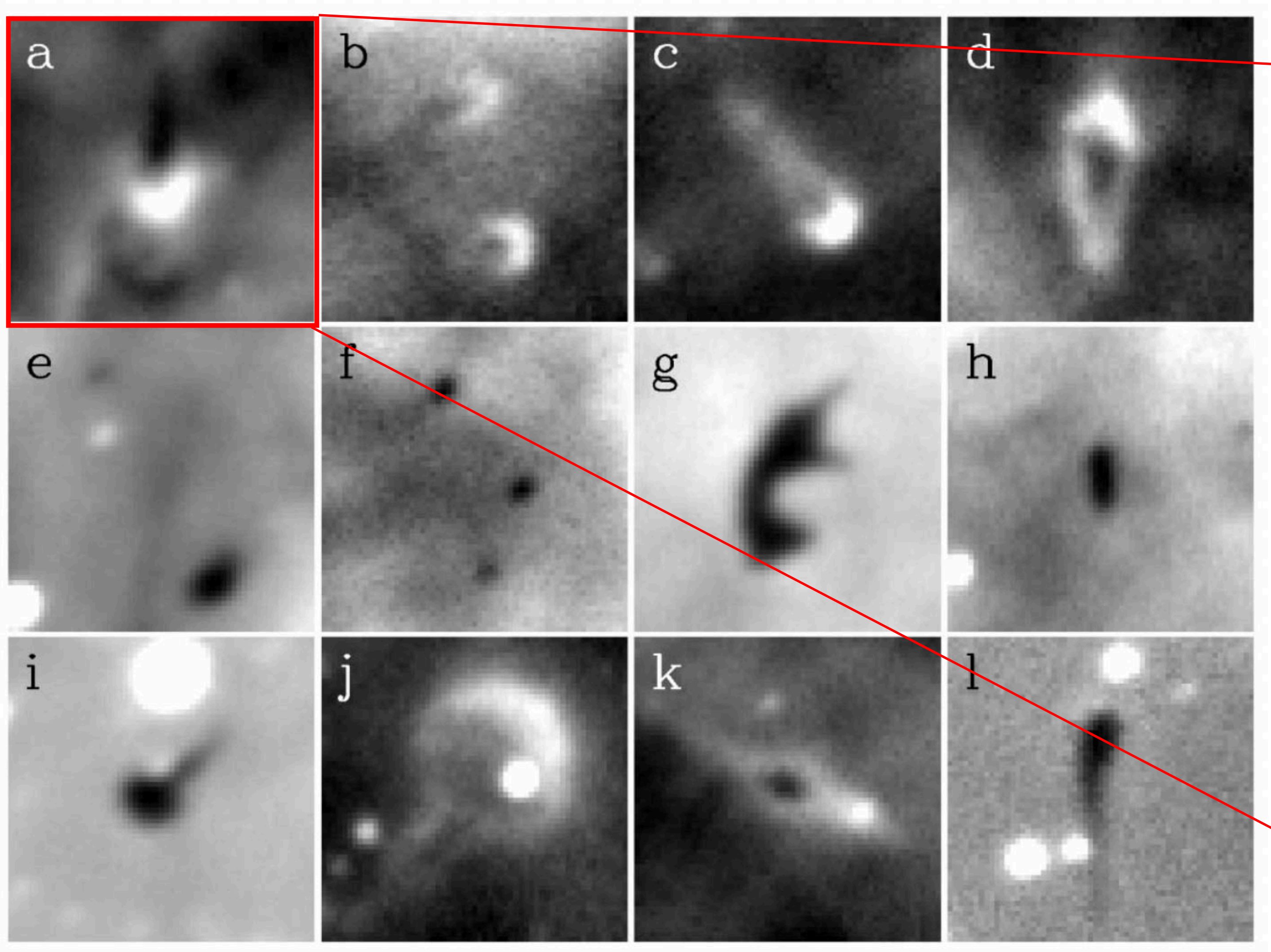


Smith, **Bally**, & Morse et al. 2003



ESA/Hubble

Protostellar jets have enabled the first and so far only ALMA observations of disks in d ≥ 2 kpc regions.



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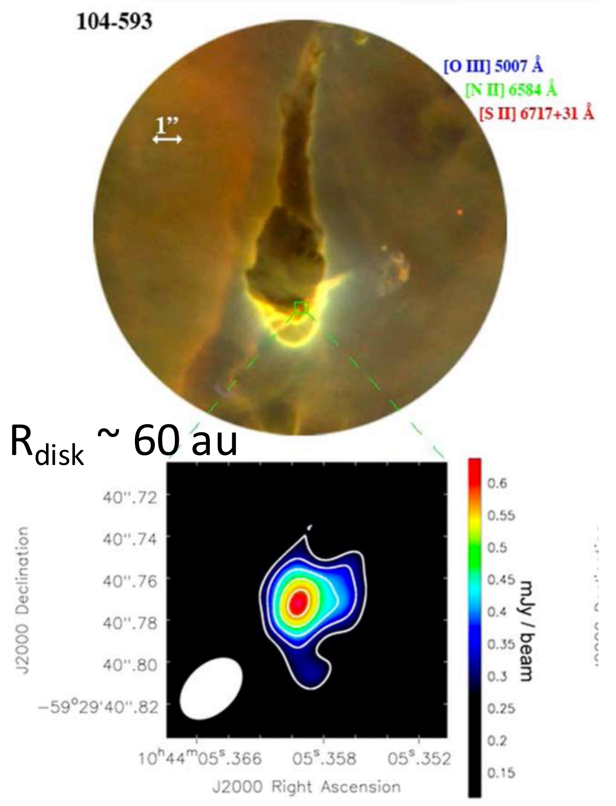

Mesa-Delgado et al. 2016

→ see also Cortes-Rangel et al. 2020, 2023, Reiter et al. 2020

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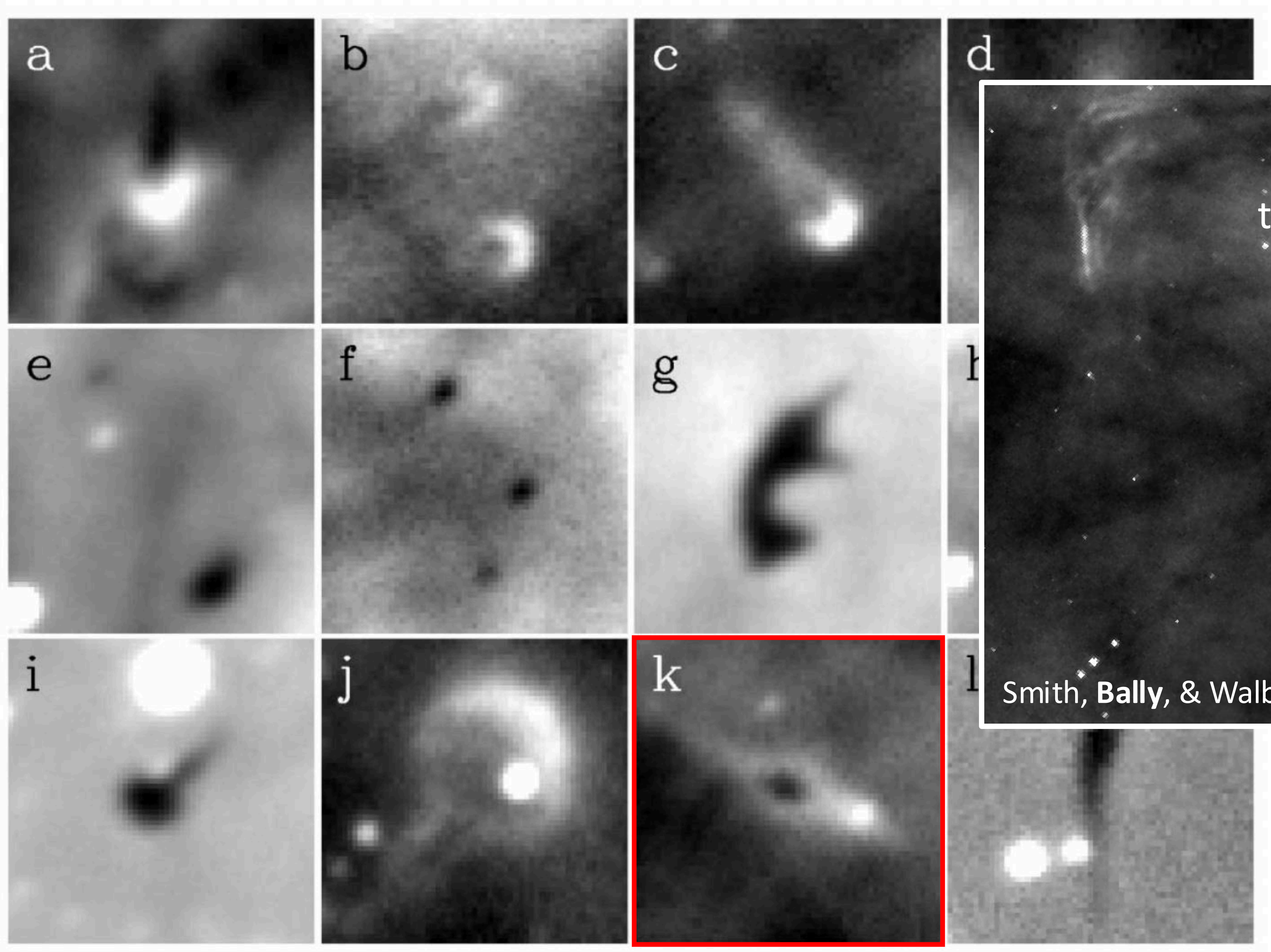

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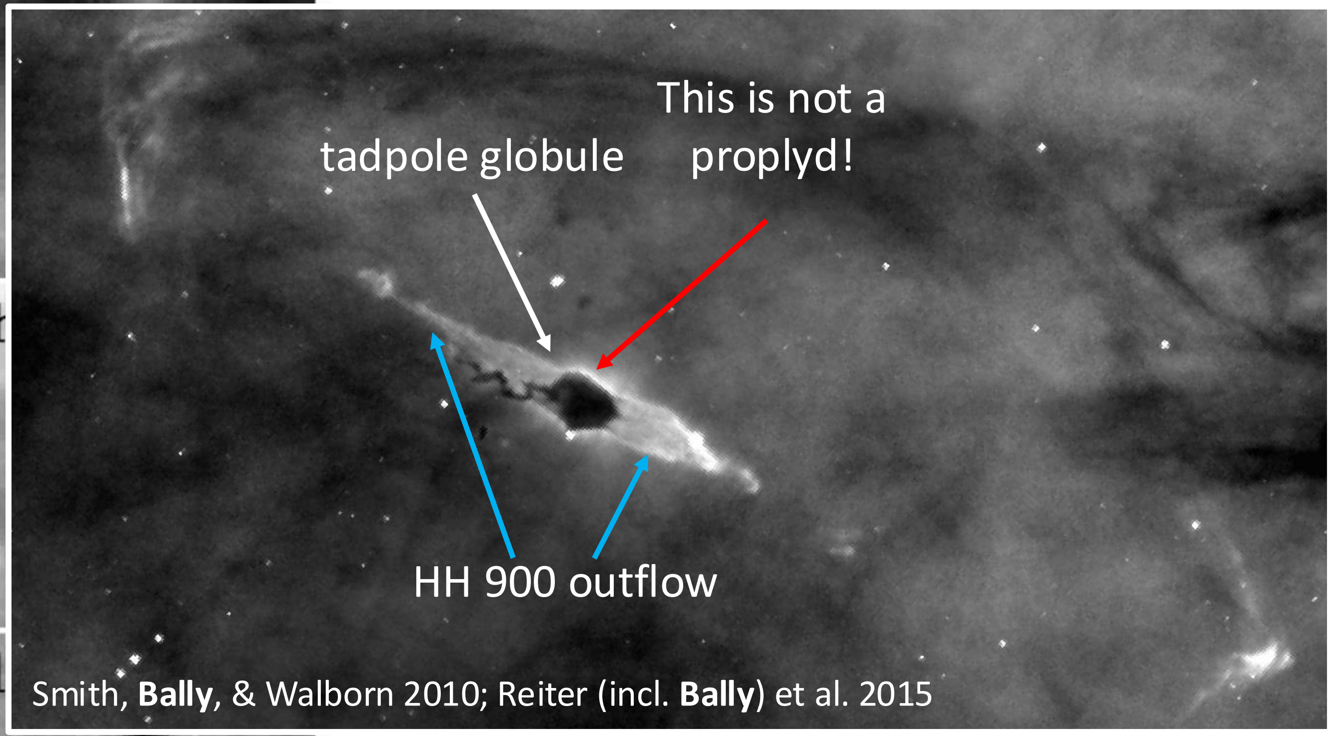

Smith, **Bally**, & Walborn 2010; Reiter (incl. **Bally**) et al. 2015

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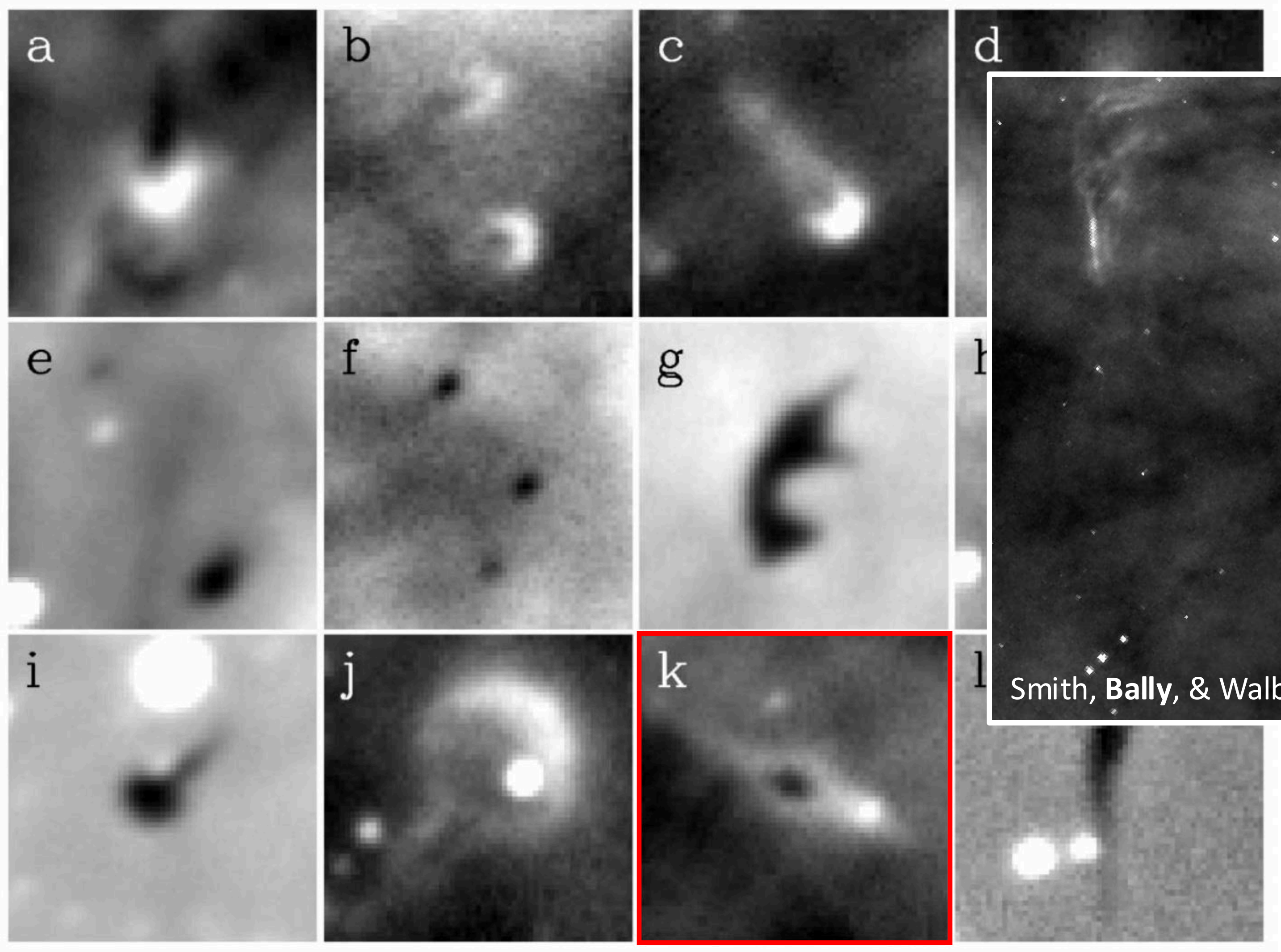

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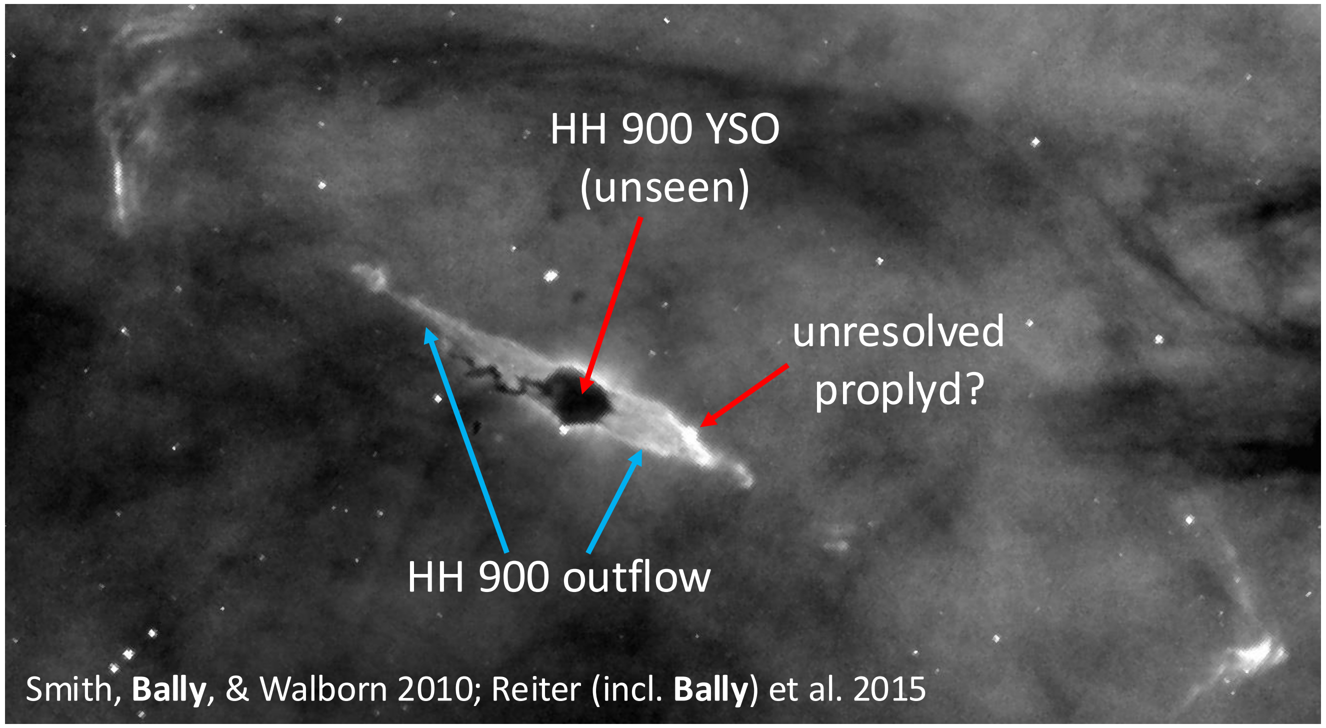

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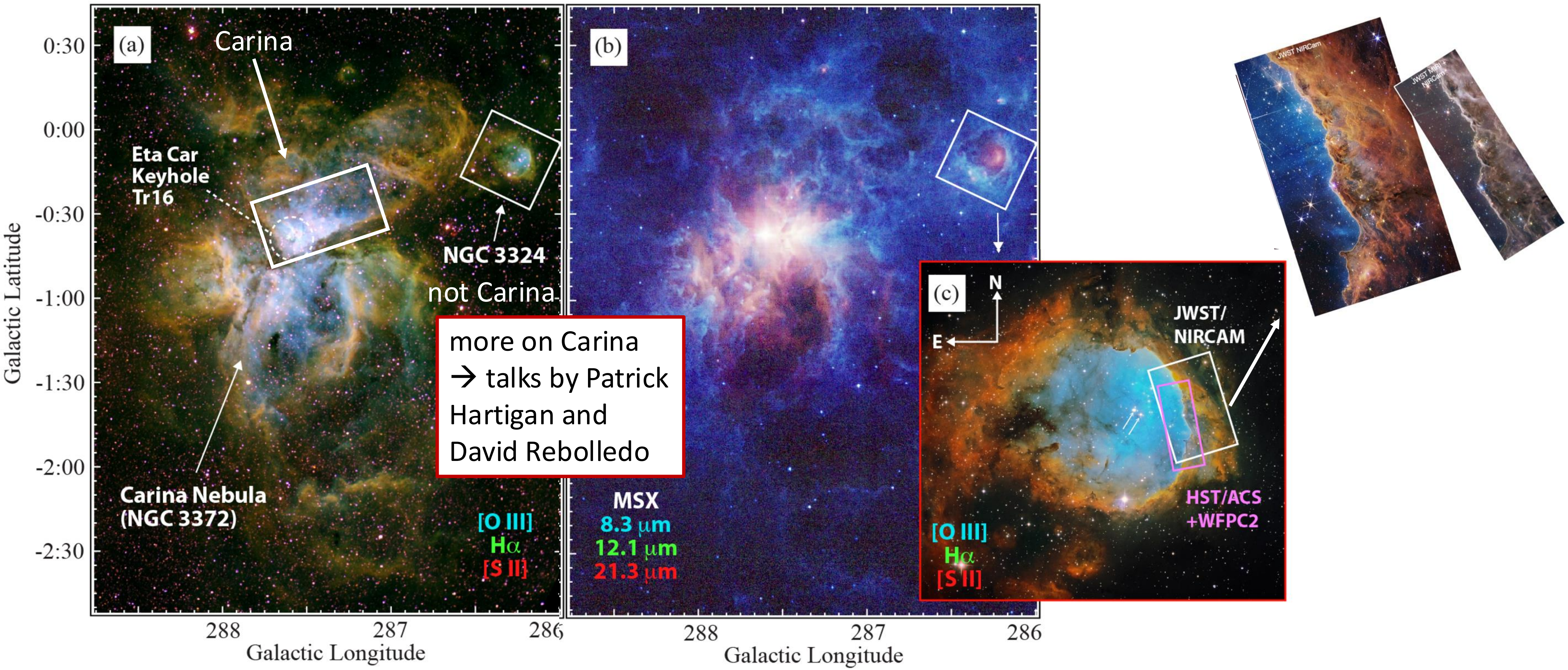
Illuminating the tadpole's metamorphosis: UV radiation from >70 O-type stars floods the Carina region.



more on Carina → talks by Patrick Hartigan and David Rebolledo

Reiter et al. 2022; adapted from Smith et al. 2000 and Smith & Brooks 2007 and Telescope Live with permission (image credit: V. Unguru / Telescope Live).

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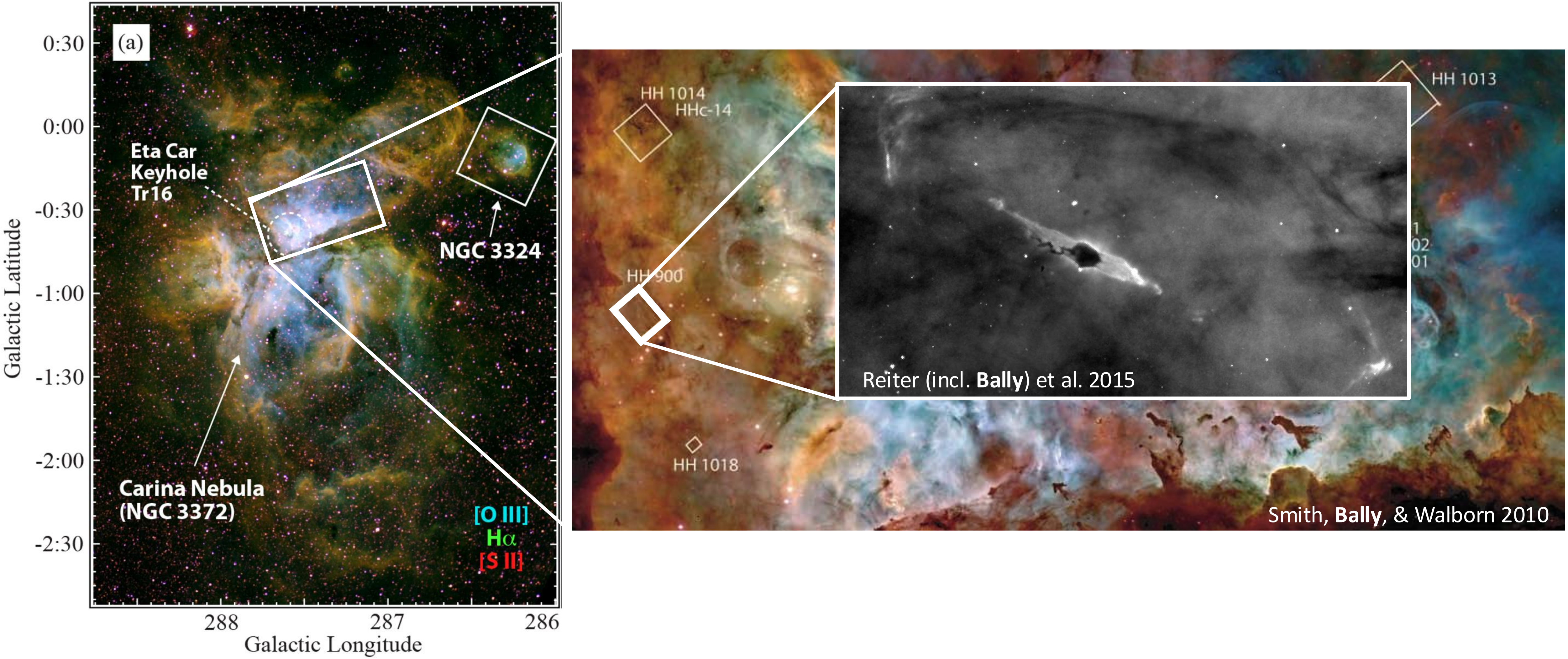
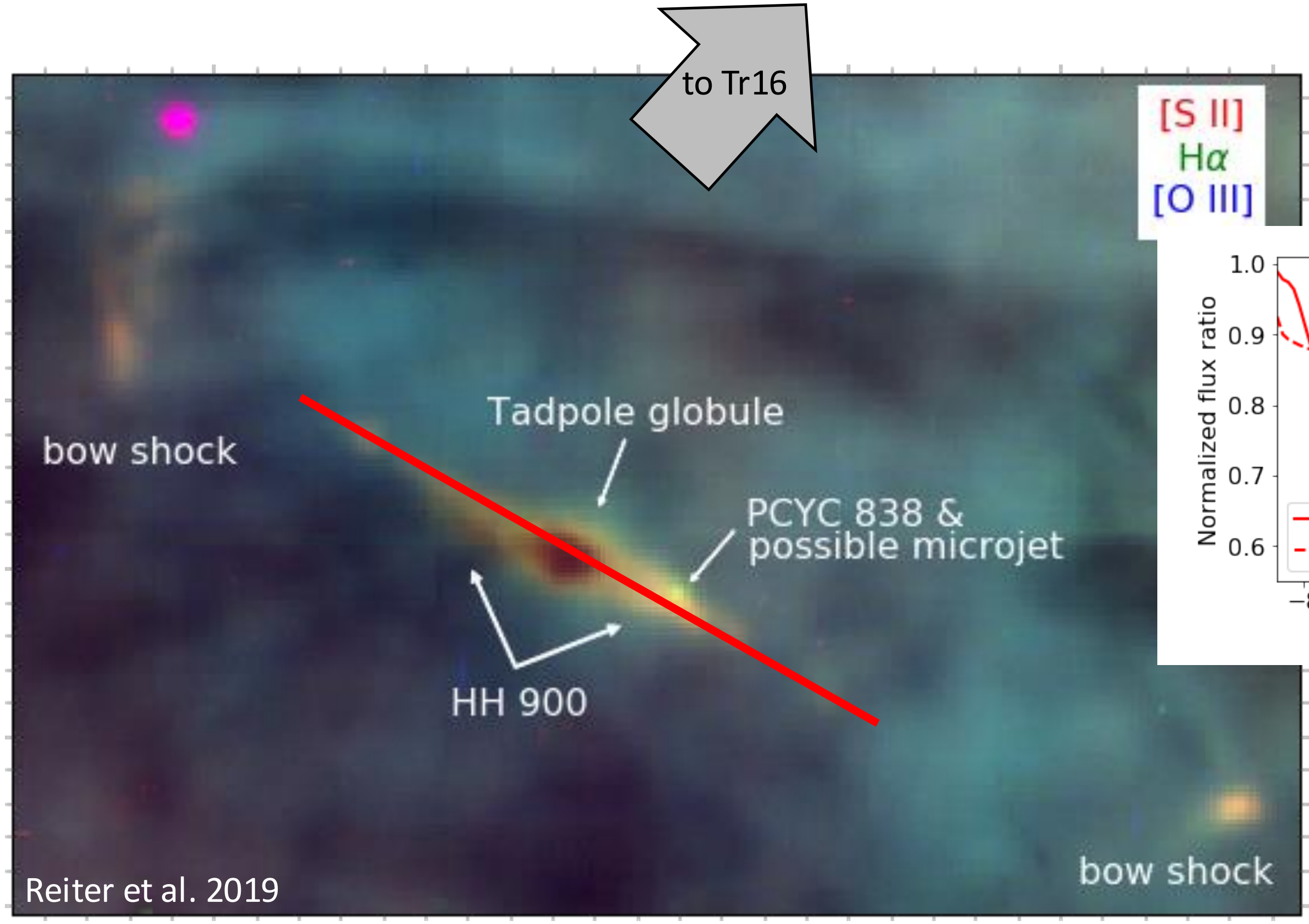


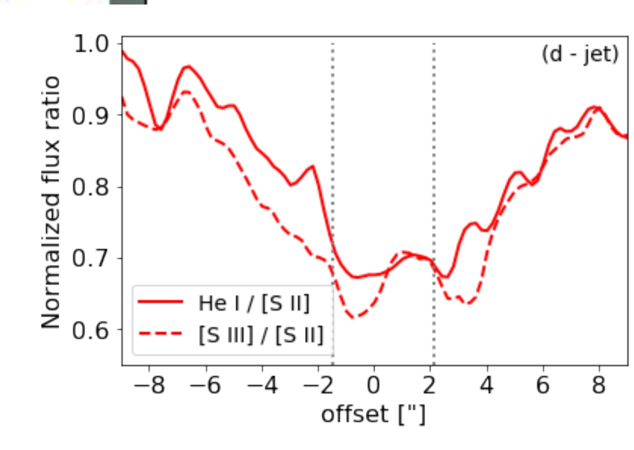
Reiter et al. 2022; adapted from Smith et al. 2000 and Smith & Brooks 2007 and Telescope Live with permission (image credit: V. Unguru / Telescope Live).

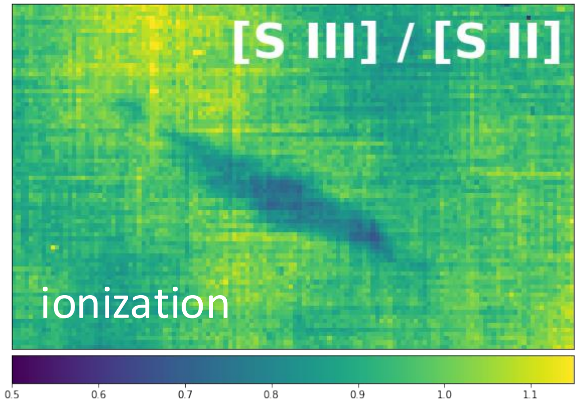
Using MUSE to put star/planet-forming disks in context: ionization front properties of the globule and outflow.



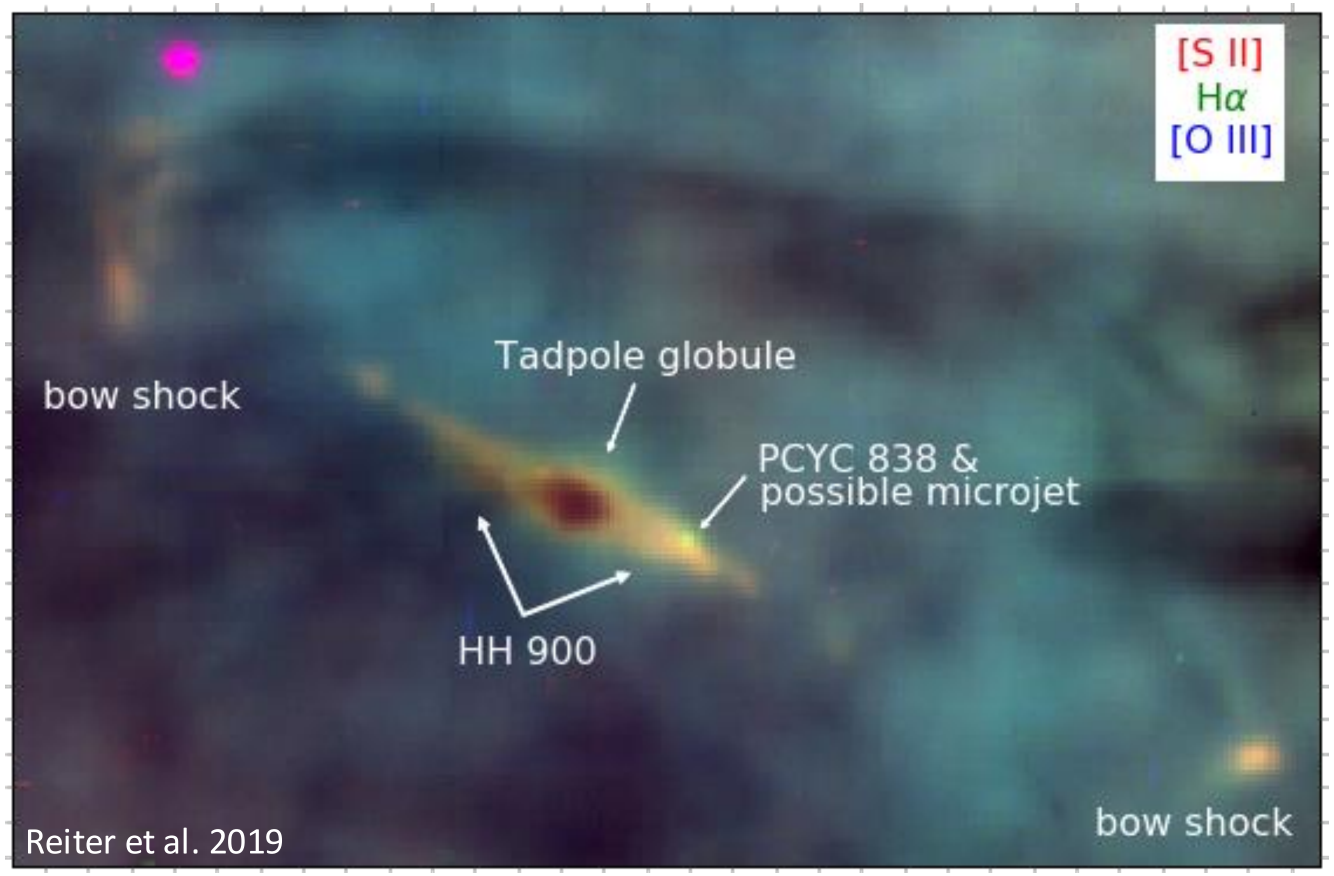
Externally illuminated by nearby OB stars?

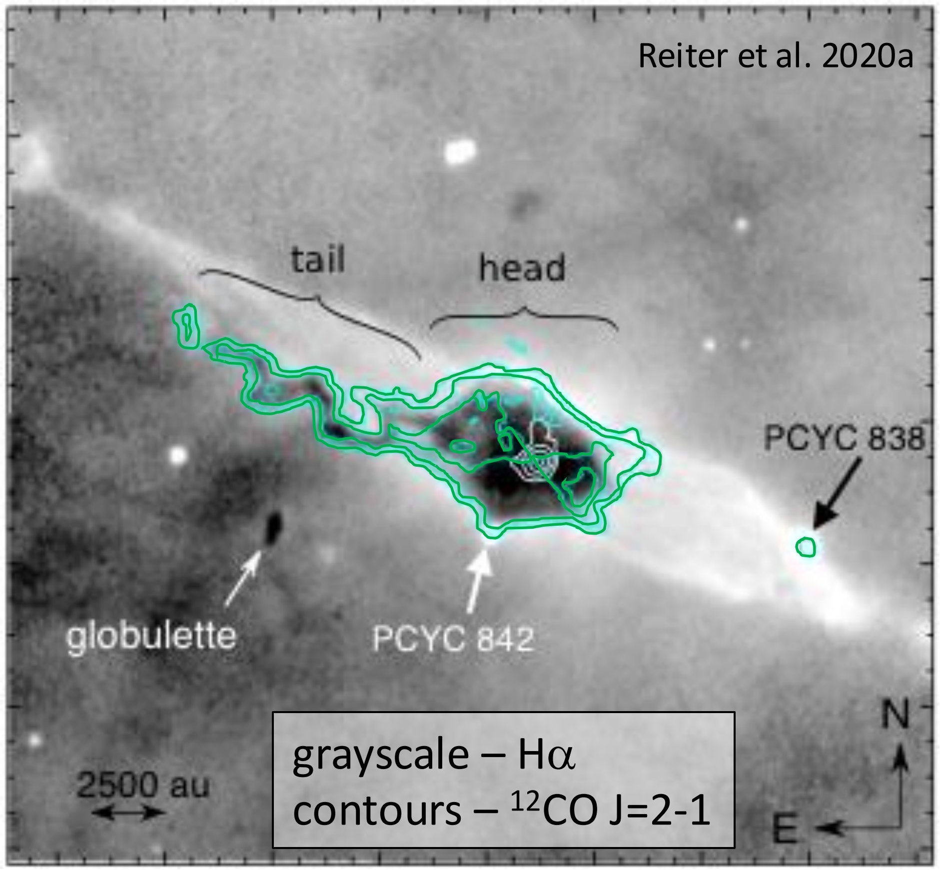
→ Yes! Outflow ionization increases with time



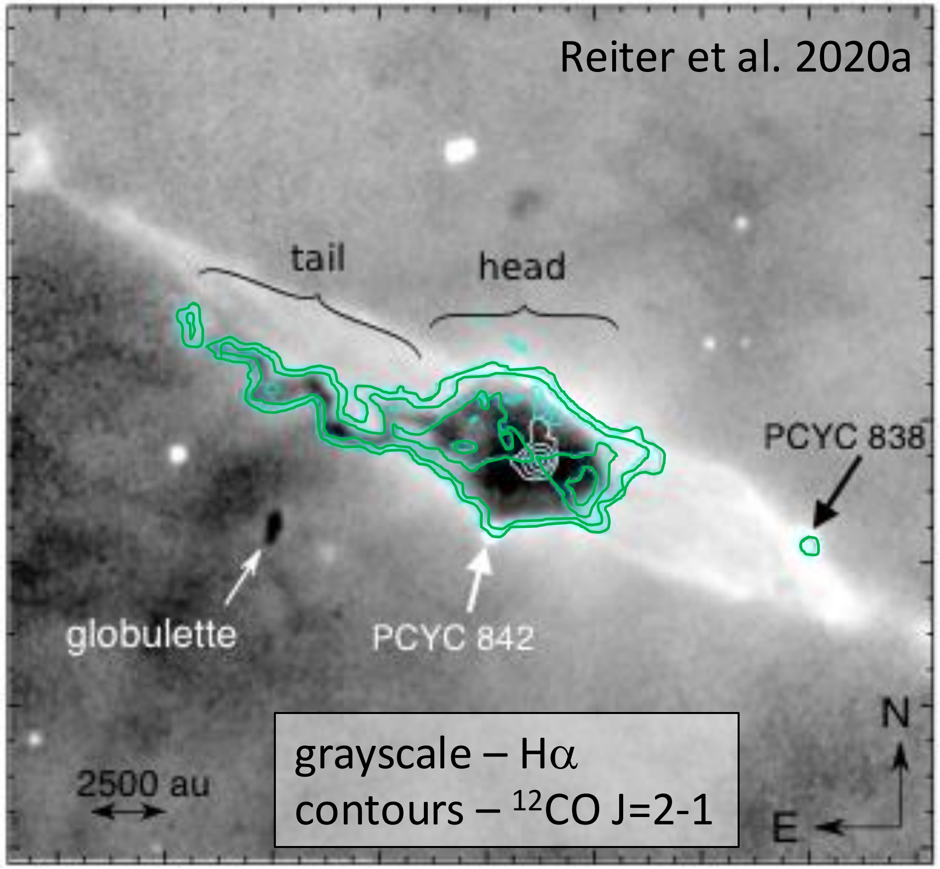


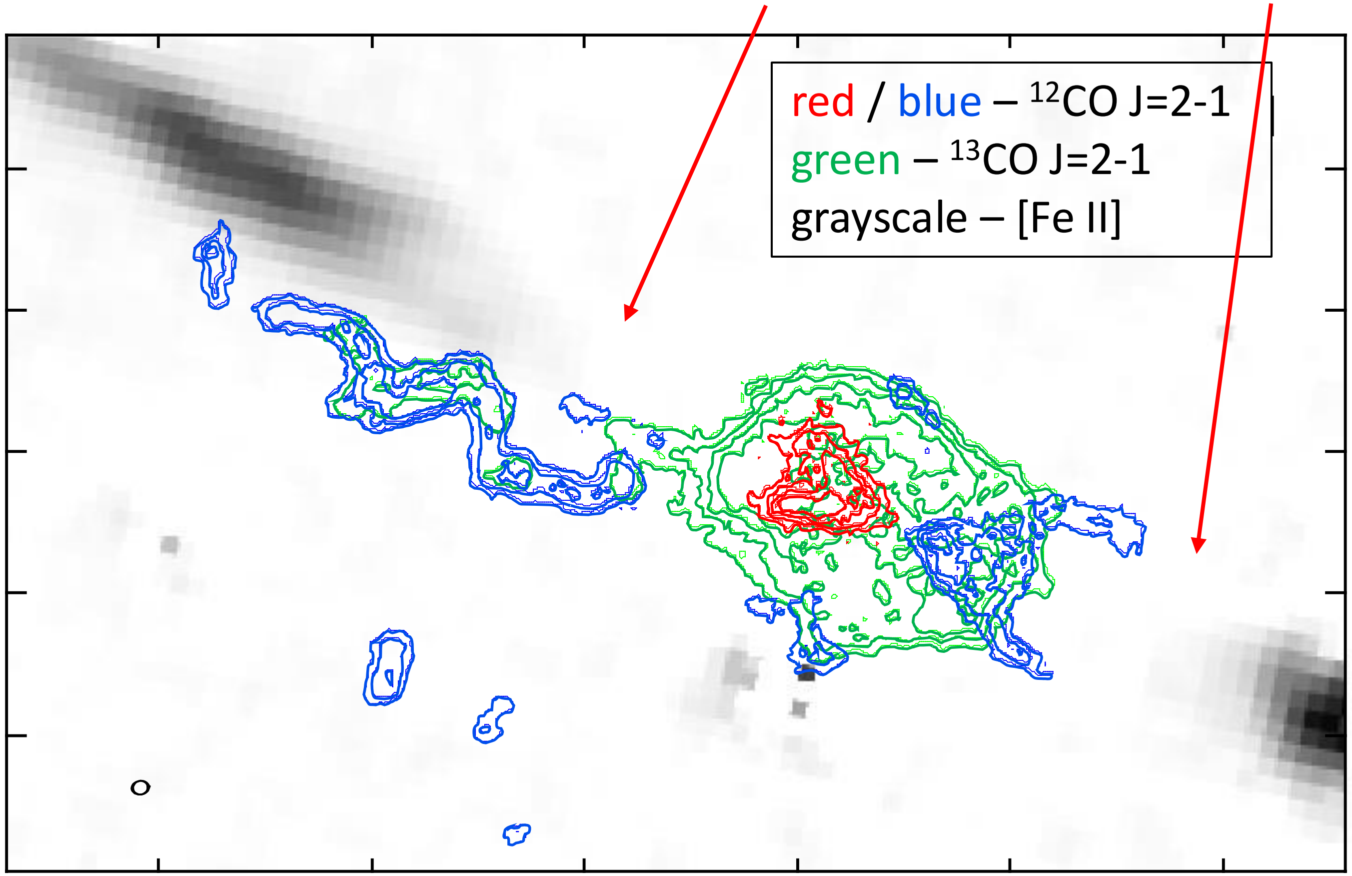
MUSE+ALMA connects the ionized outflow (in the HII region) and the molecular outflow (in the globule).





Molecules are rapidly dissociated once the outflow enters the H II region – no cold CO, only hot H_2.





→ *molecules rapidly dissociate outside the globule*

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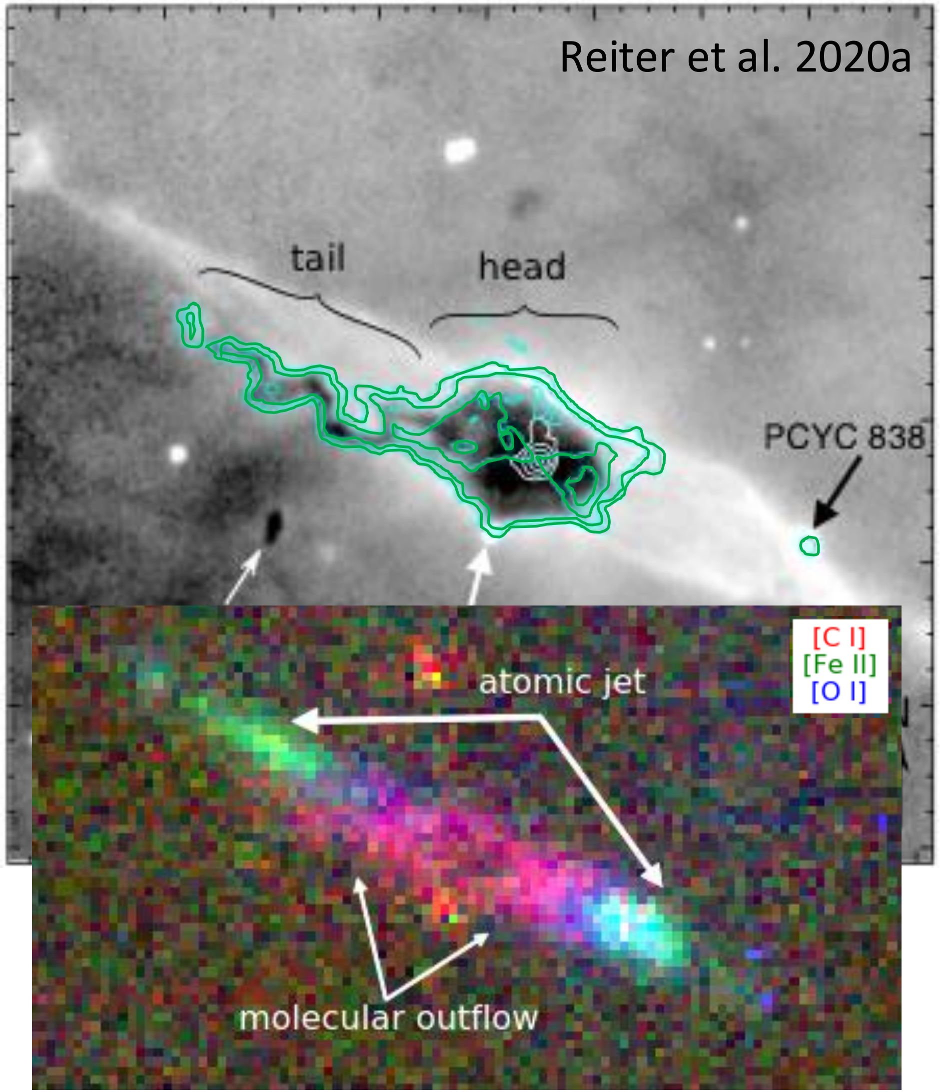

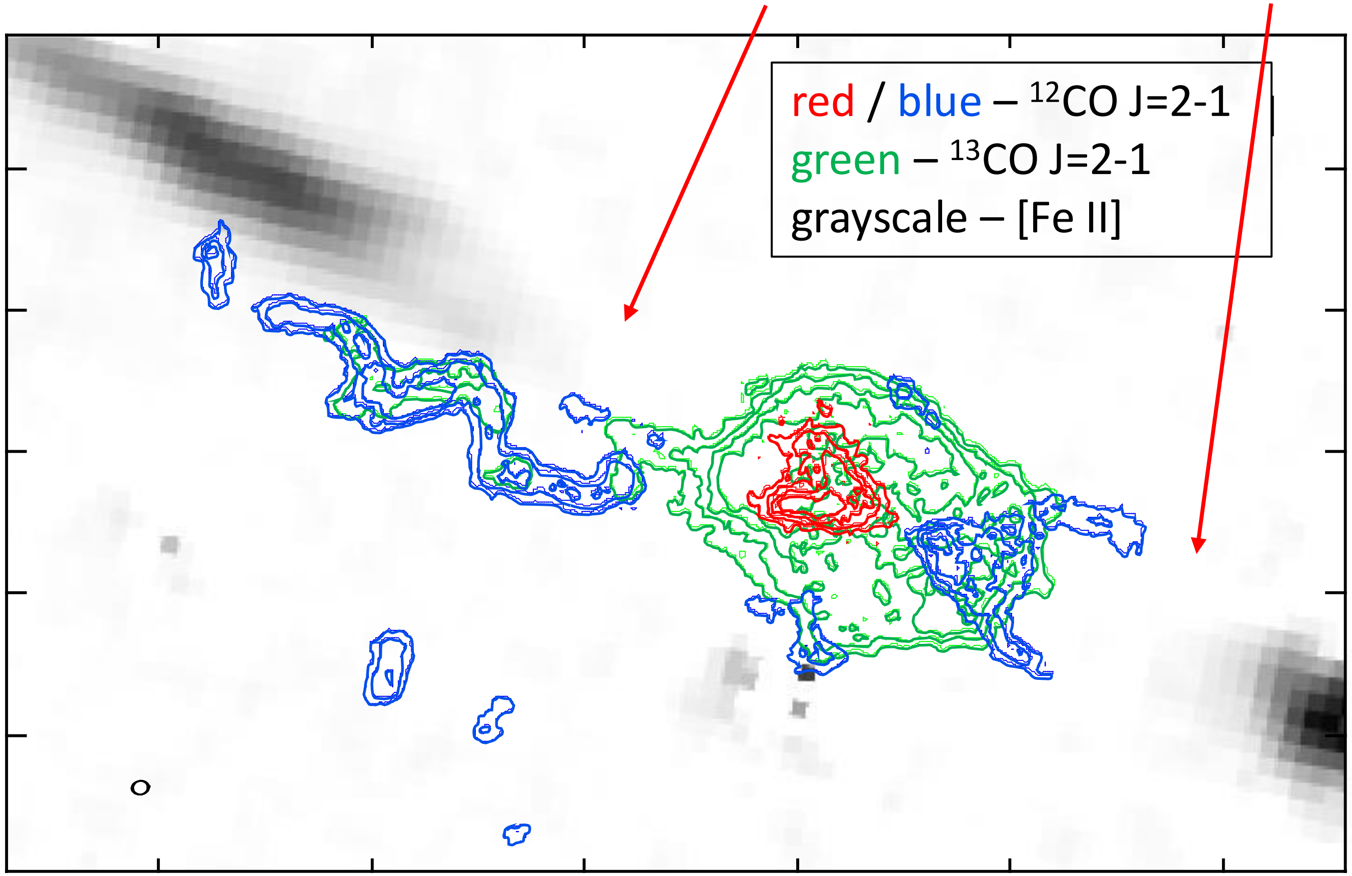

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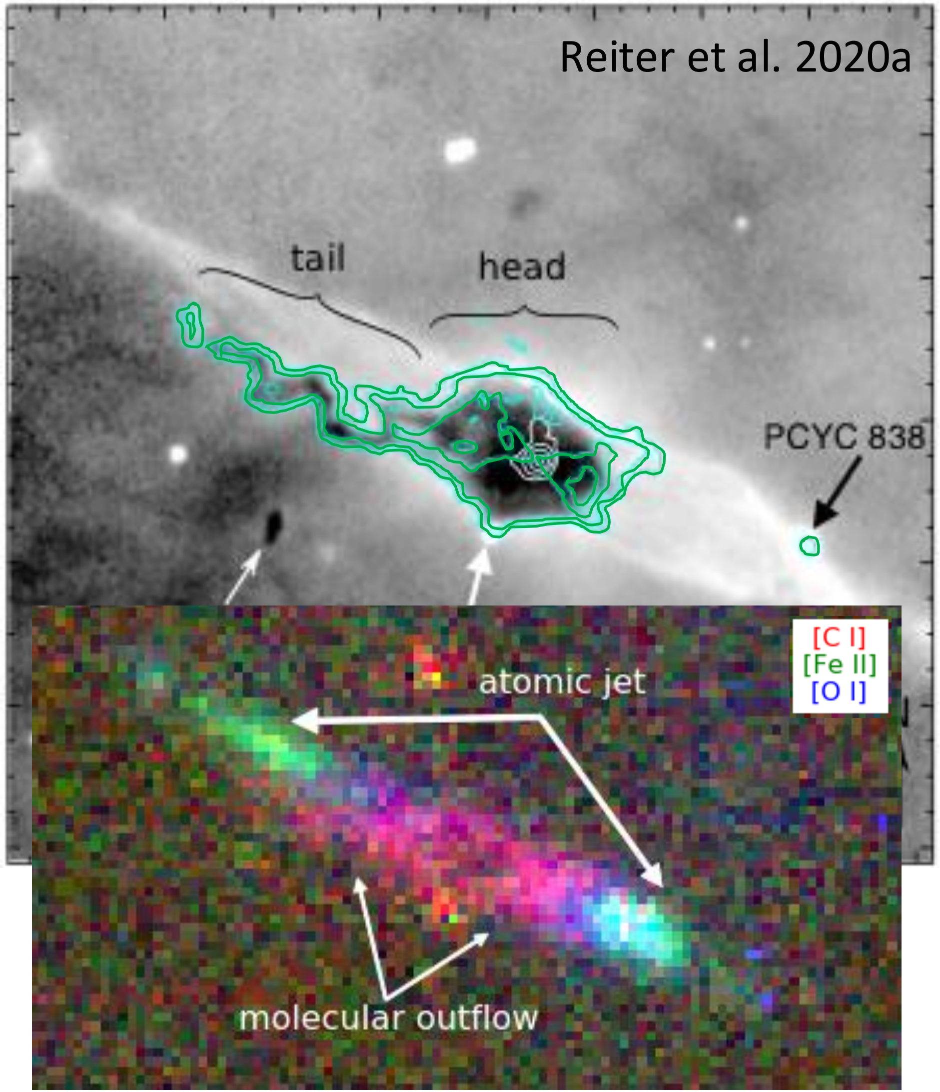
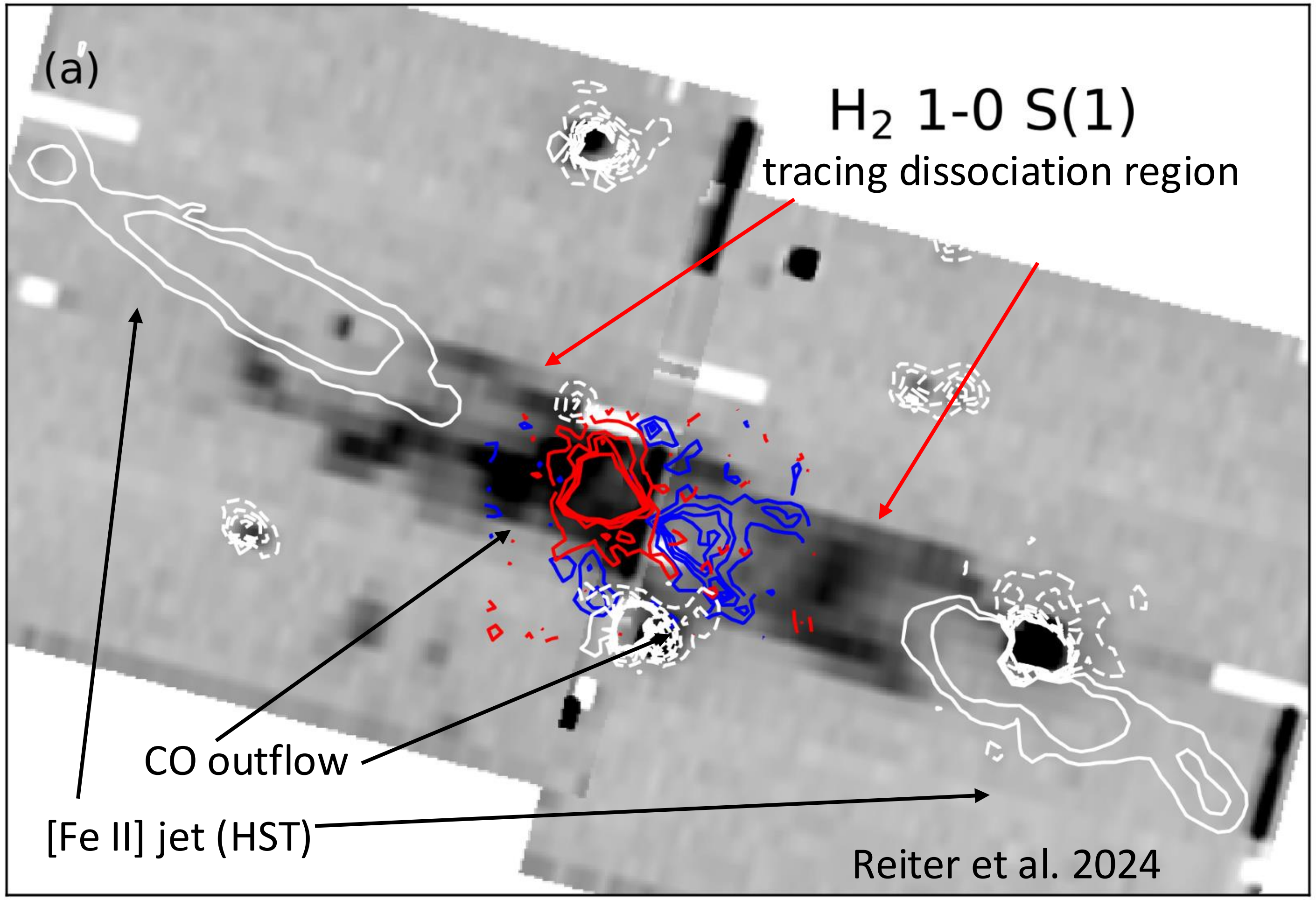
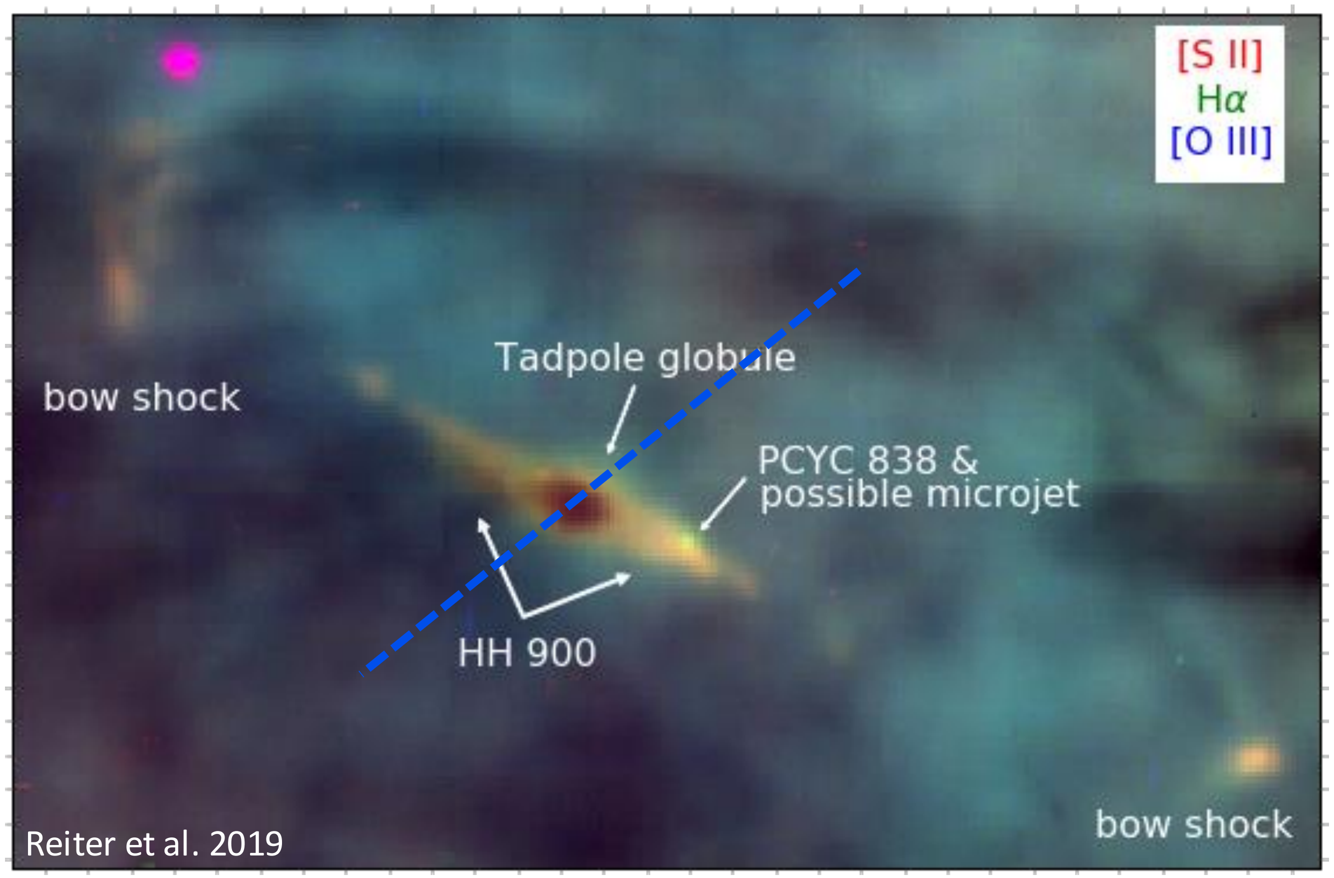
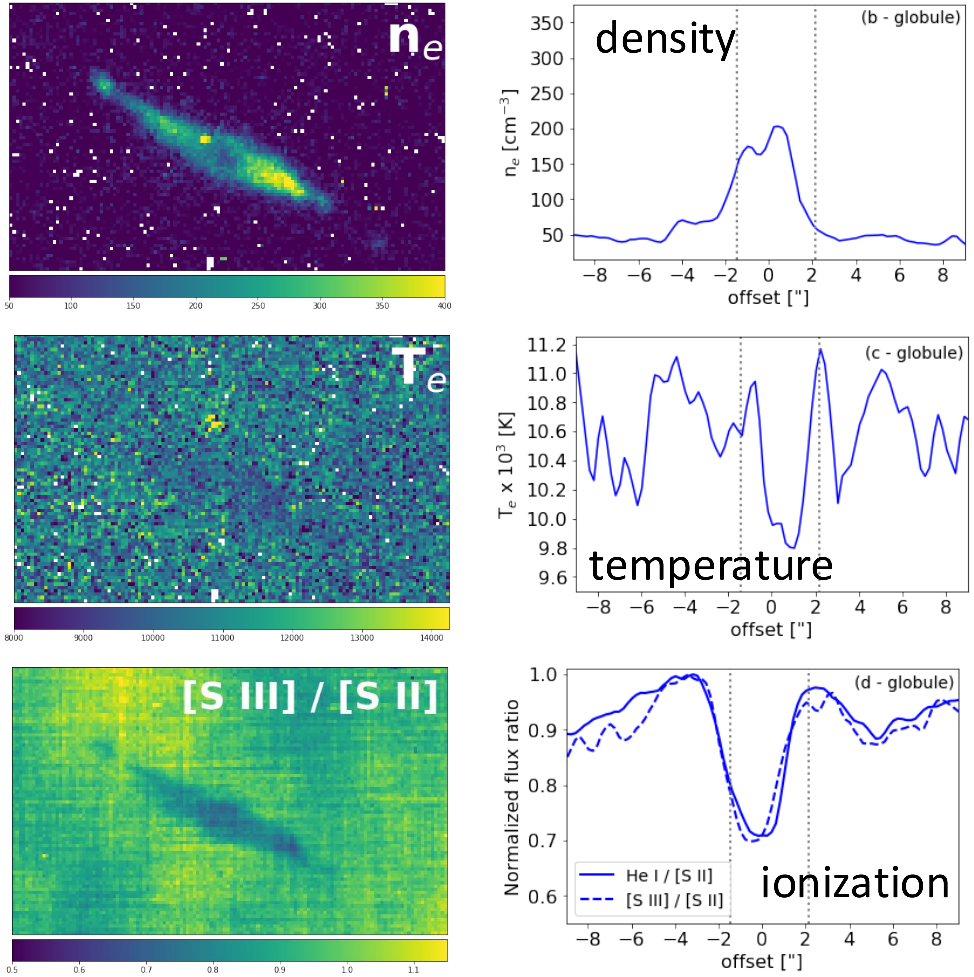




(JWST scheduled in Cycle 3)

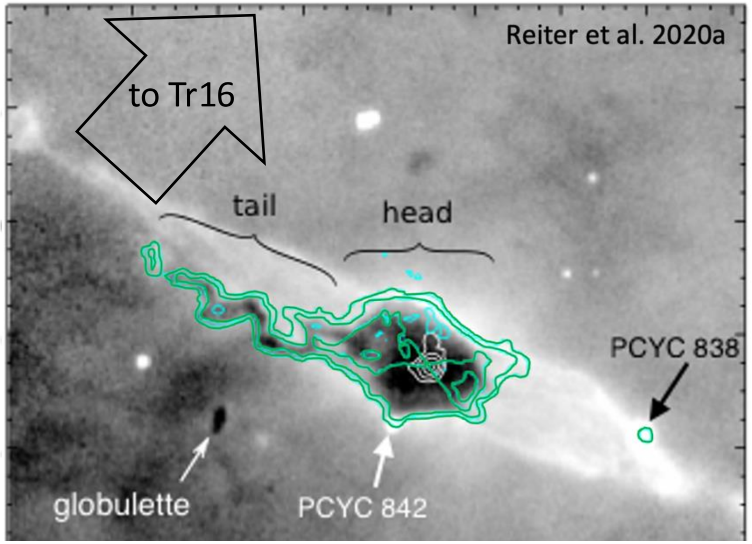
Using MUSE to put star/planet-forming disks in context: photoevaporation rate and lifetime of the globule.

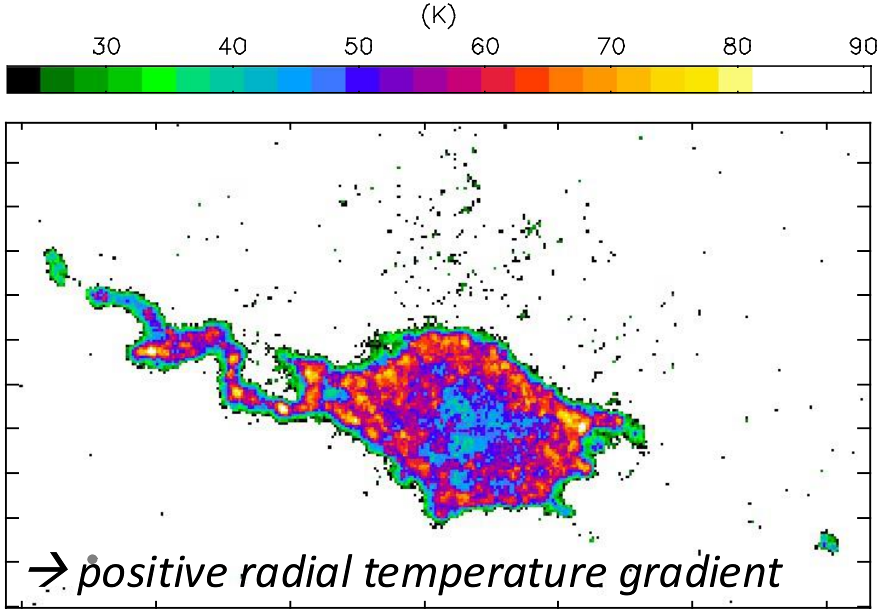


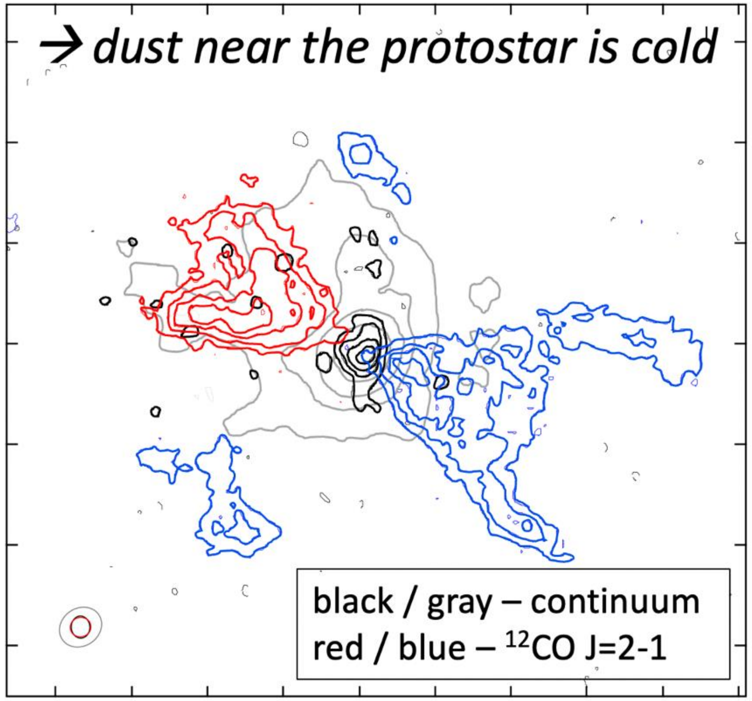


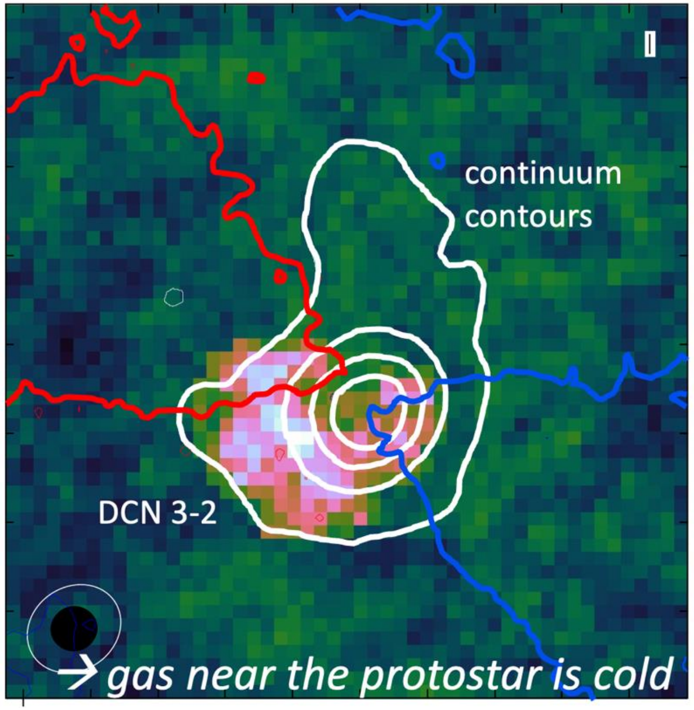
→ *globule will be completely ablated in ~4 Myr*

Quantify the impact of external heating on the chemistry and kinematics of the star-/planet-forming system.



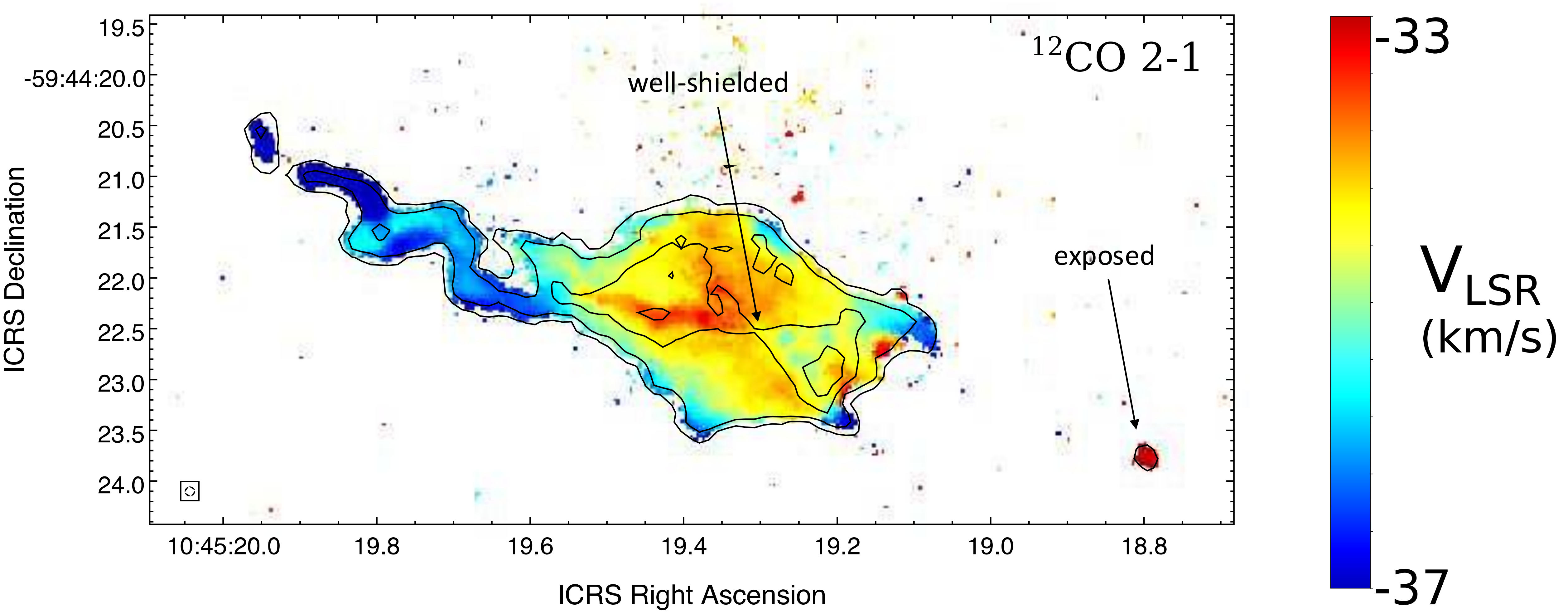






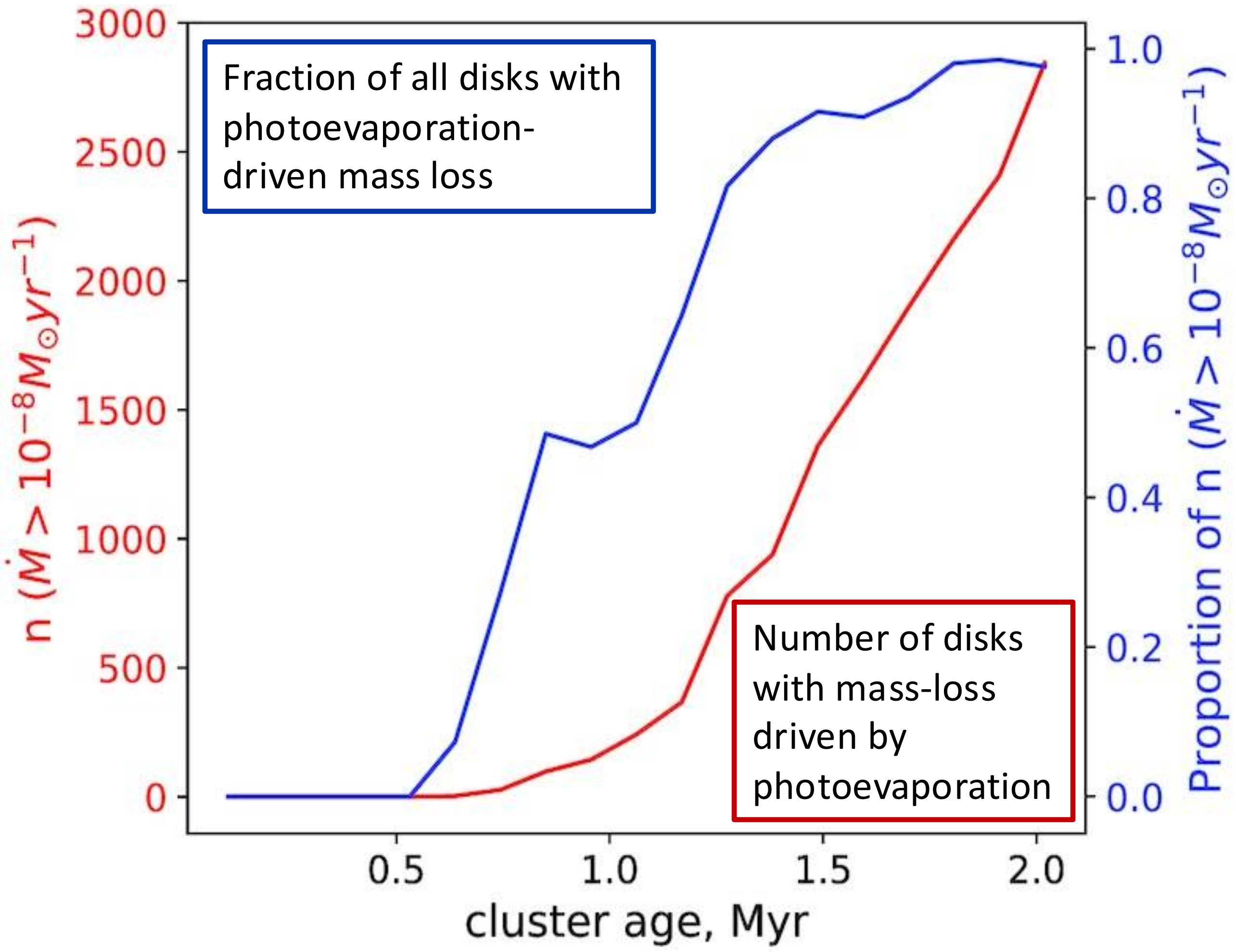
→ globule will be completely ablated in ~4 Myr

Protostars embedded in dense cocoons may not notice their environment; exposed YSOs absolutely will.

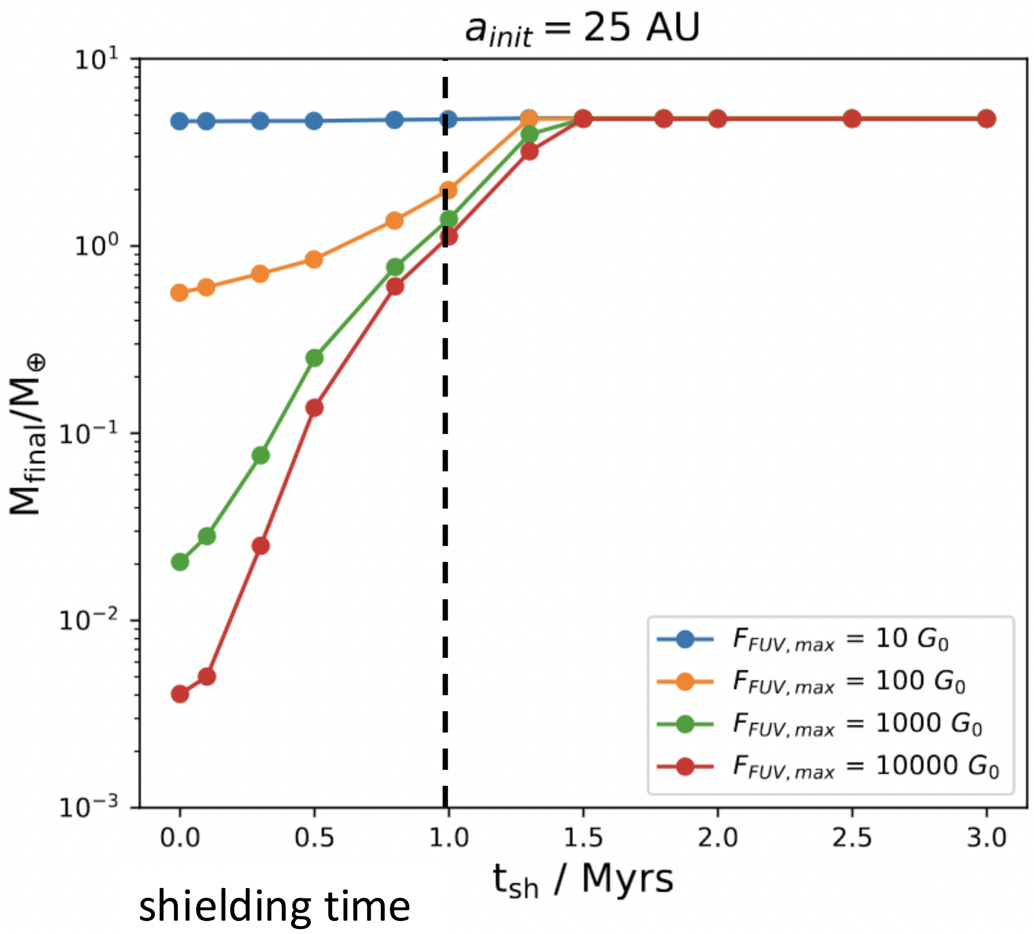


Reiter et al. 2020a

Shielding time has a strong impact on the final mass and orbital radii of single planets (pebble accretion models).



Qiao et al. 2022



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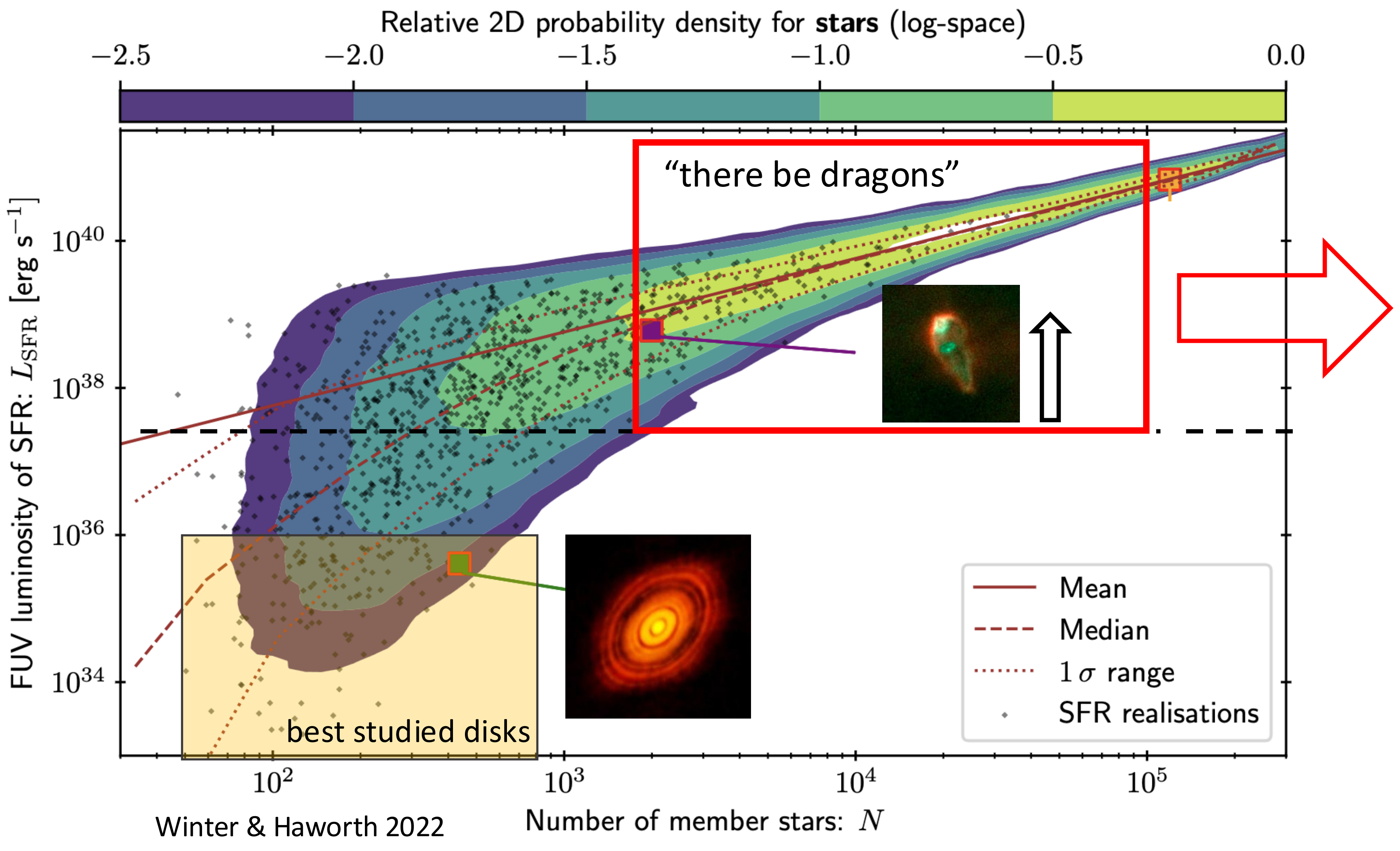
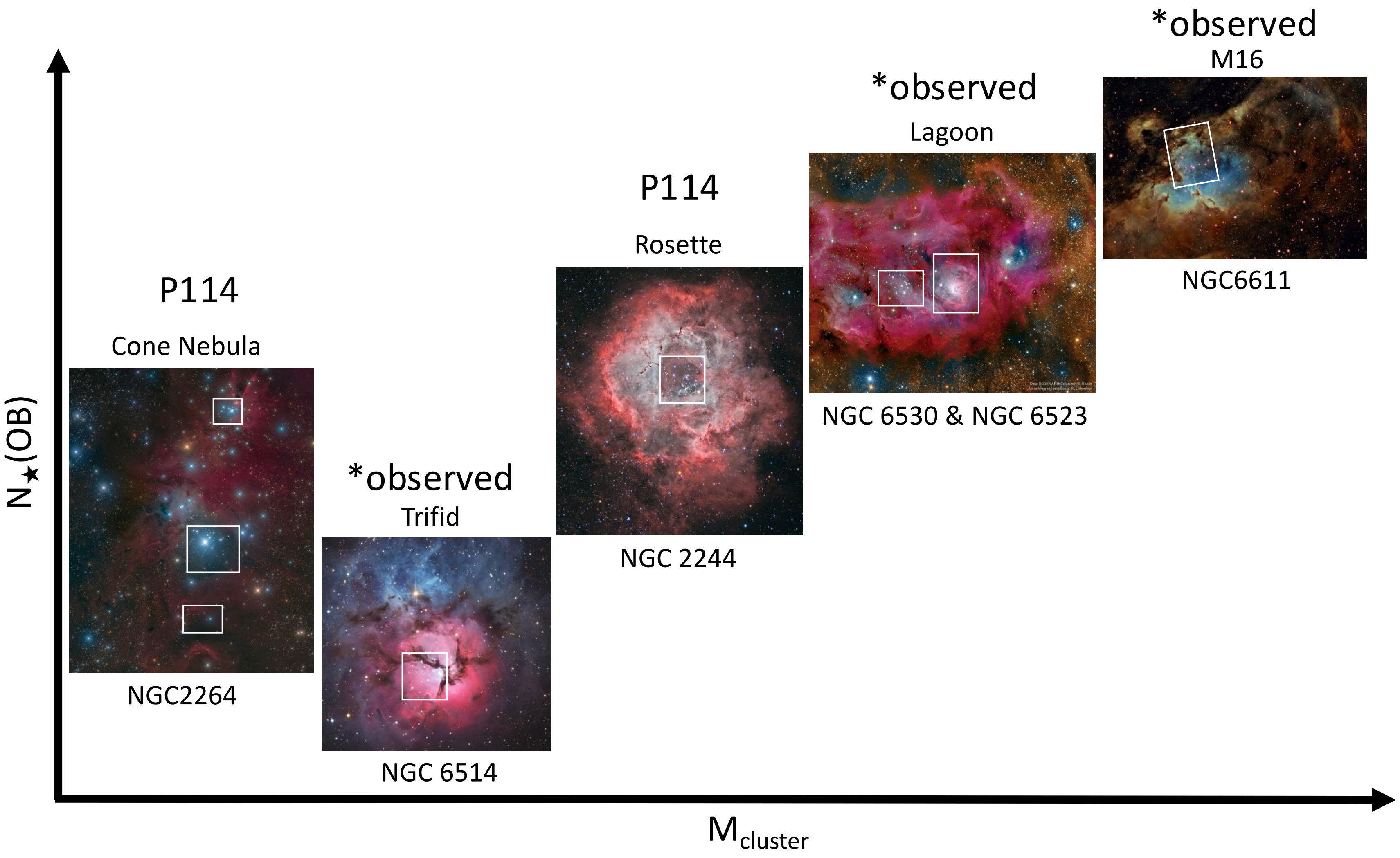


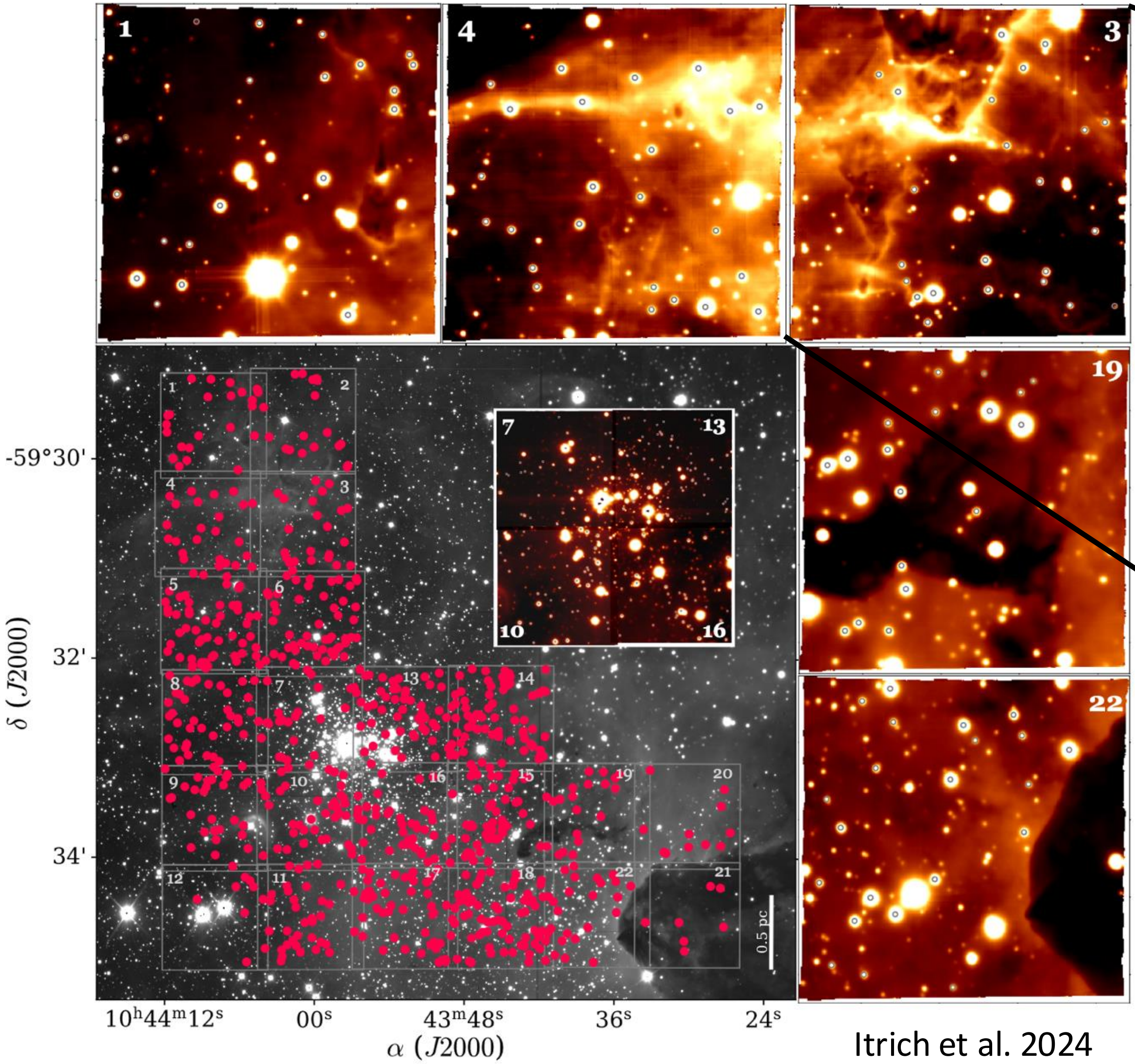
MUSE Clusters Survey

Quantifying the impact of external photoevaporation on planet-forming disks requires a survey of typical conditions.

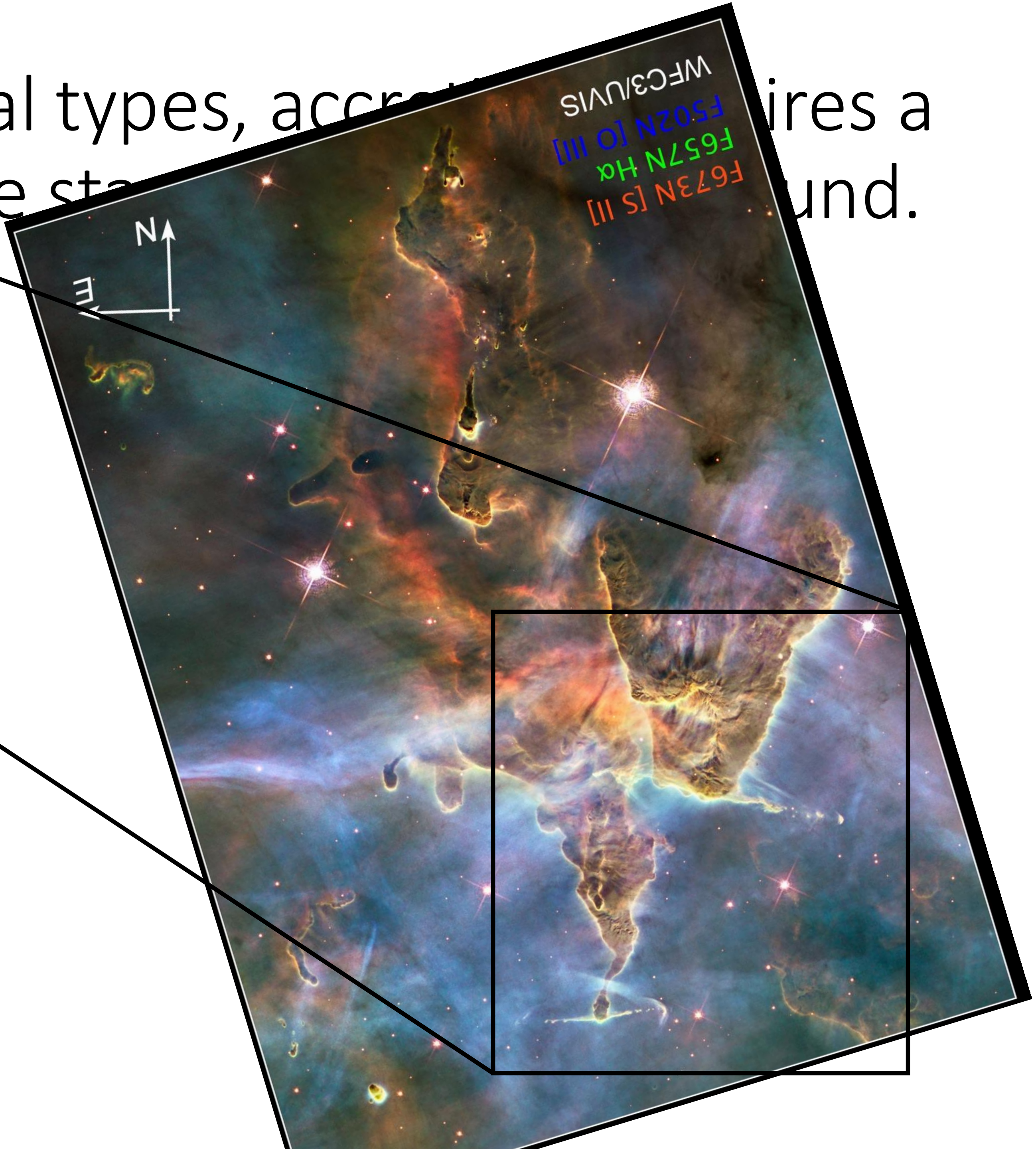


MUSE VLT: 112 hours awarded
72 hours observed
PI: M. Reiter
NSF CAREER grant 2339164

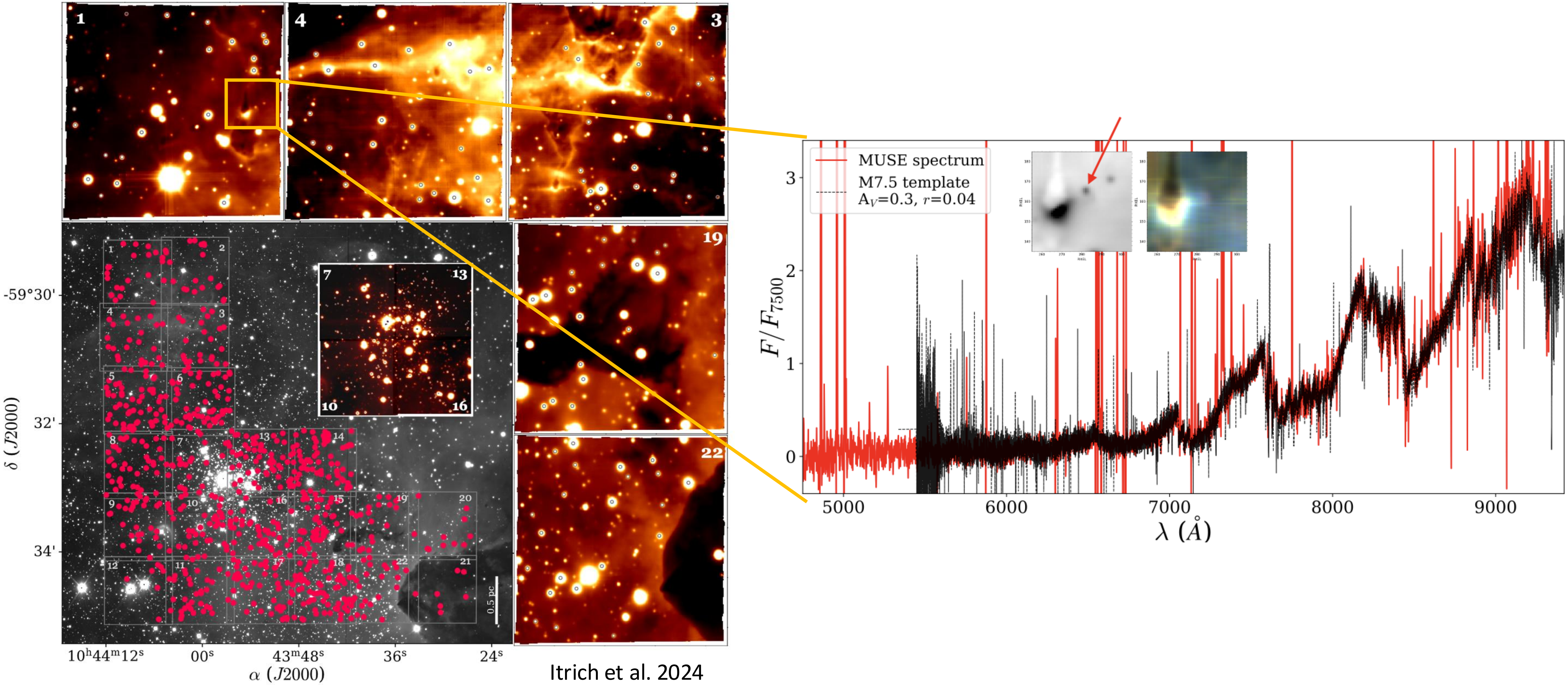
With MUSE, measure spectral types, accr… ires a disk!), outflows, *and* separate sta… und.



Itrich et al. 2024

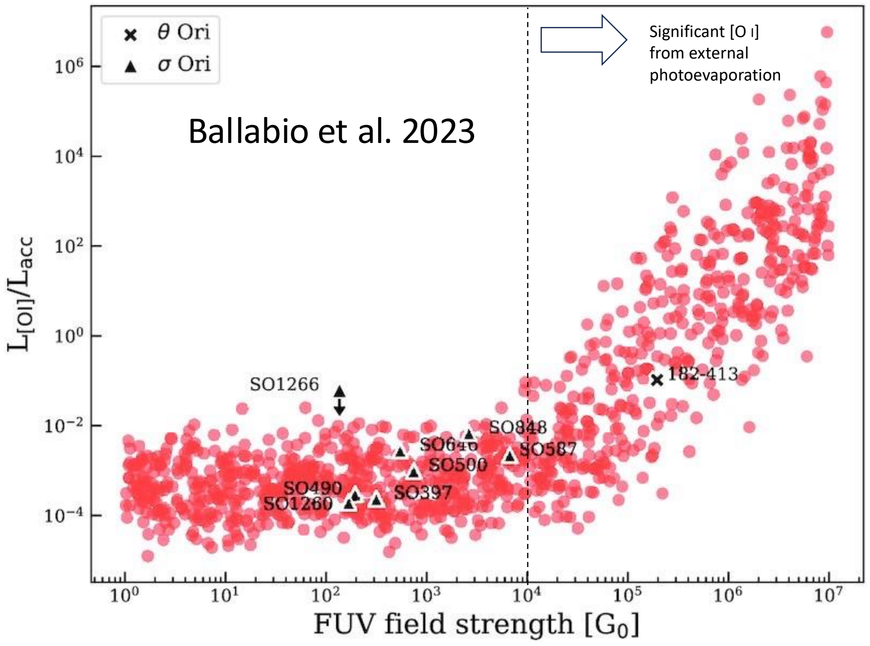


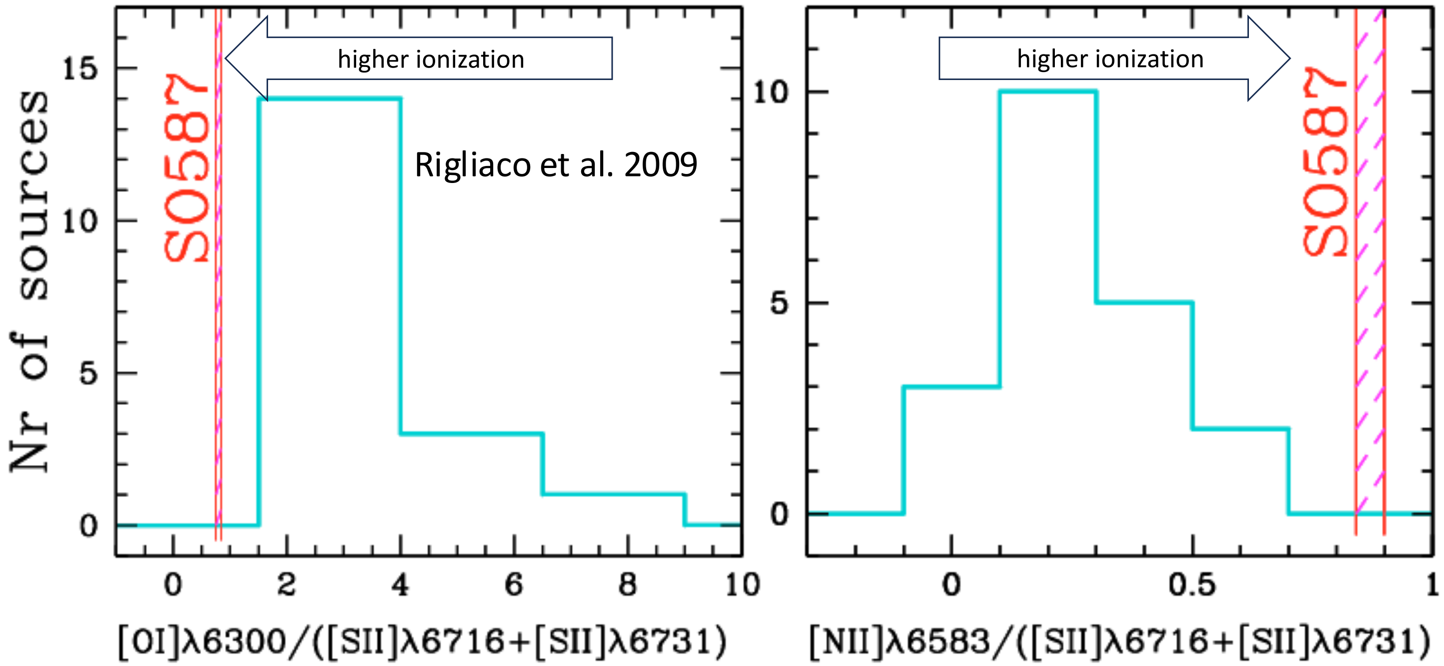
With MUSE, measure spectral types, accretion (requires a disk!), outflows, *and* separate stars from the background.

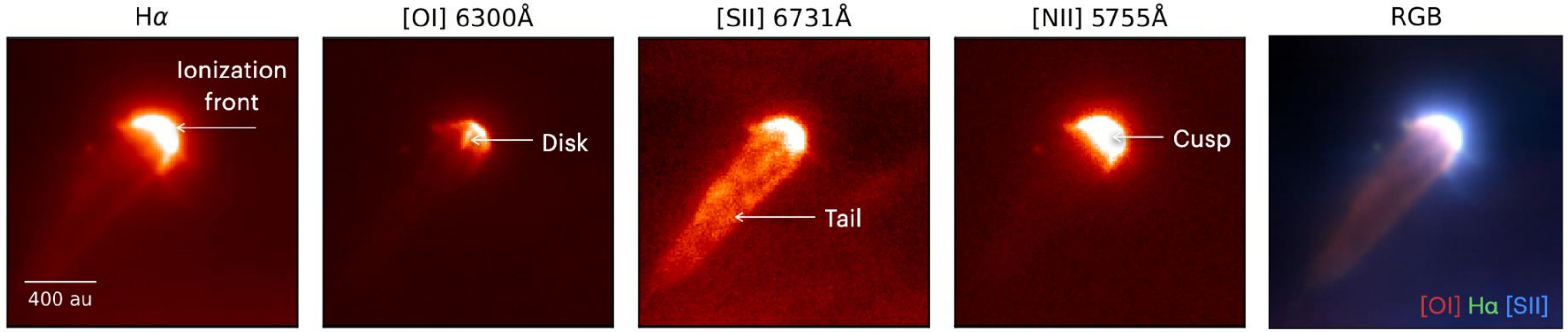


Itrich et al. 2024

Building on resolved observations of proplyds, identify spectral signatures of external photoevaporation.

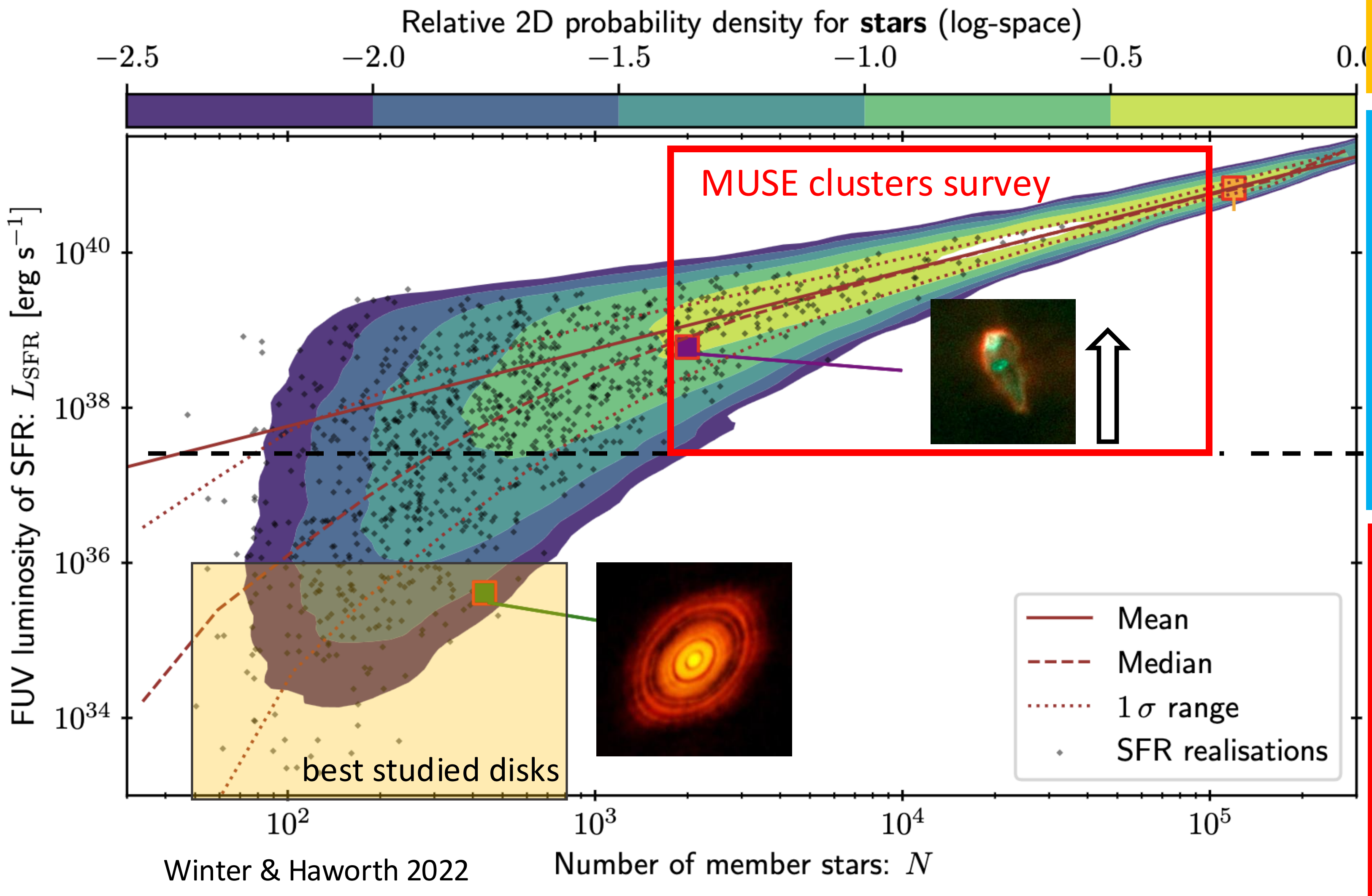




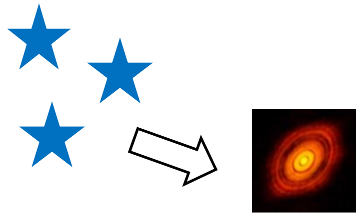


Aru et al. 2023, 2024

Most planet-forming disks will be affected by UV from nearby high-mass stars.

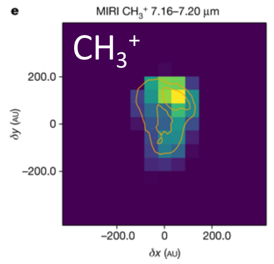


Timescale: external UV destroys disks, reducing time & mass for planet formation



→ see Sam Millstone's poster

Ingredients: UV may leave organics intact and/or enable organic chemistry – need more representative samples



Berné et al. 2023

Environment: evolution may be crucial to understand the demographics of exoplanets