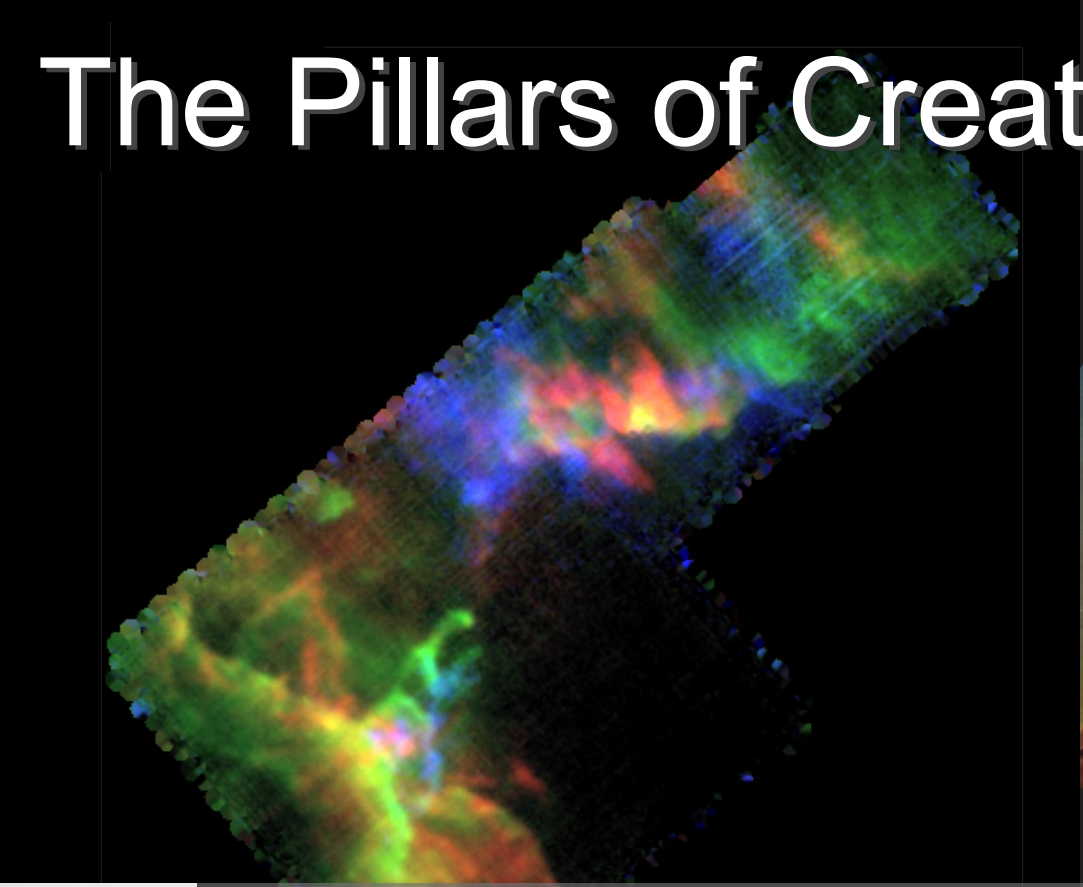
The Pillars of Creation in [CII]



Ramsey Karim, University of Maryland

February 28, 2022

Our Galactic Ecosystem: Opportunities and Diagnostics in the Infrared and Beyond

SOFIA FEEDBACK Legacy Project

March 1, Session on Massive Star Formation and Feedback

Talks:

Nicola Schneider

Maitraiyee Tiwari

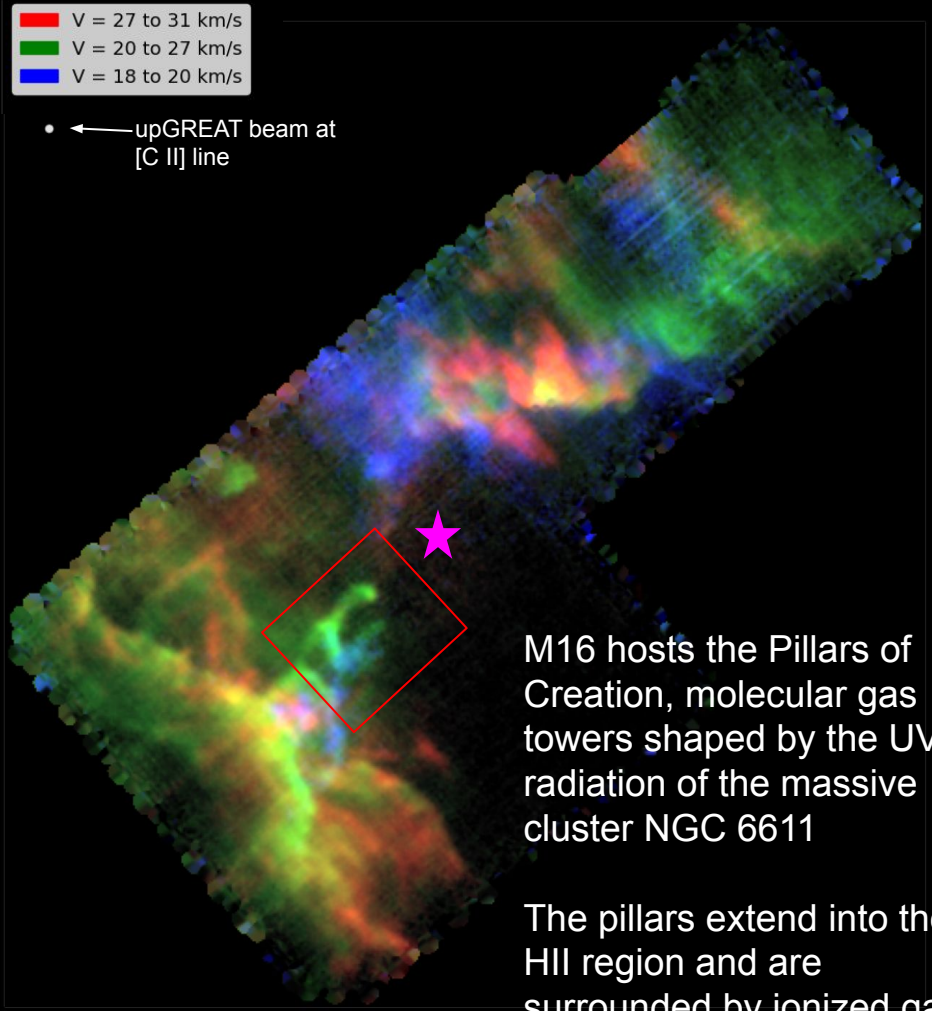
Lars Bonne

Cornelia Pabst

Image credit: Waynne Williams

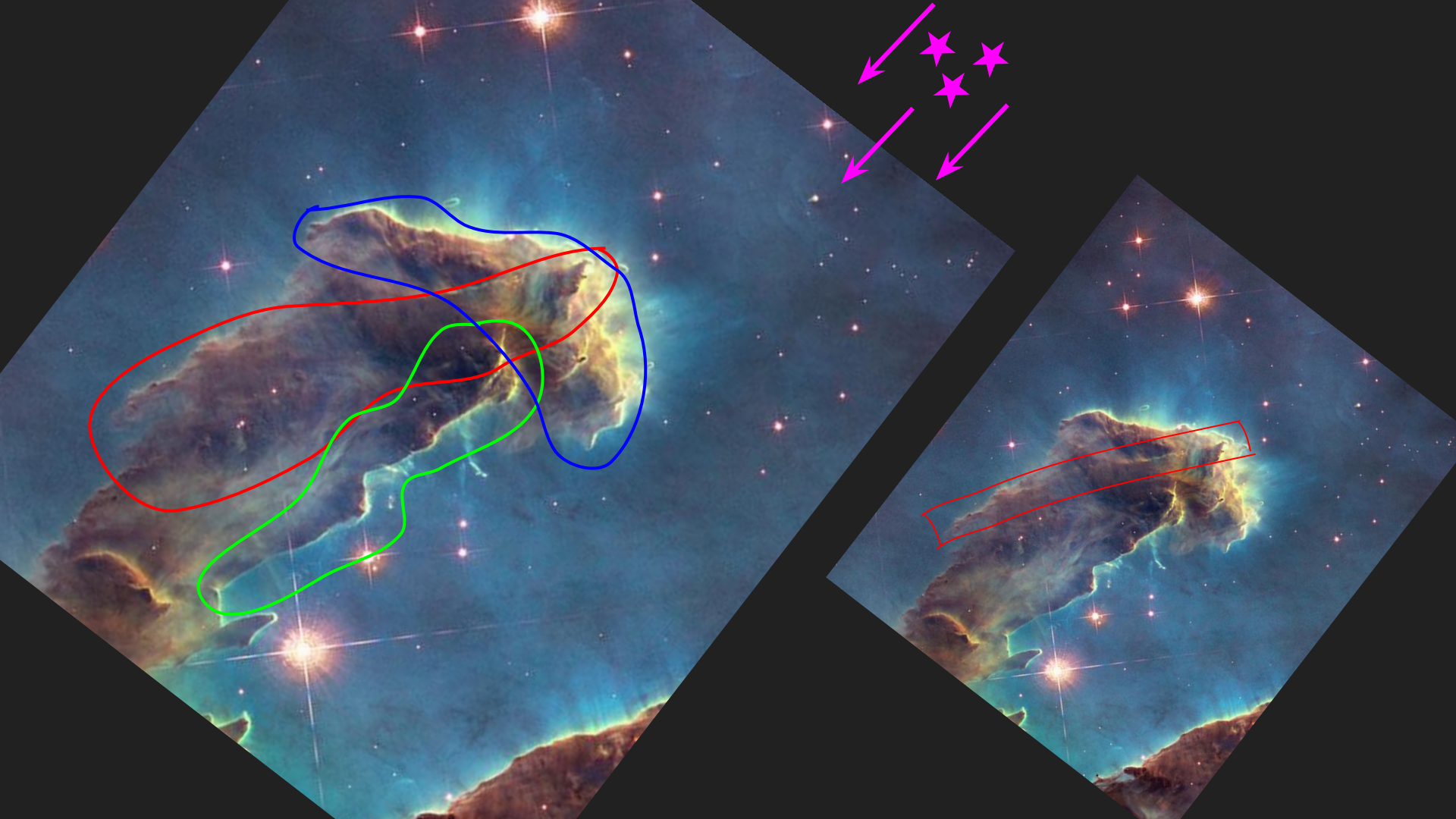
FEEDBACK
SOFIA C+LEGACY

GREAT



M16 hosts the Pillars of Creation, molecular gas towers shaped by the UV radiation of the massive cluster NGC 6611

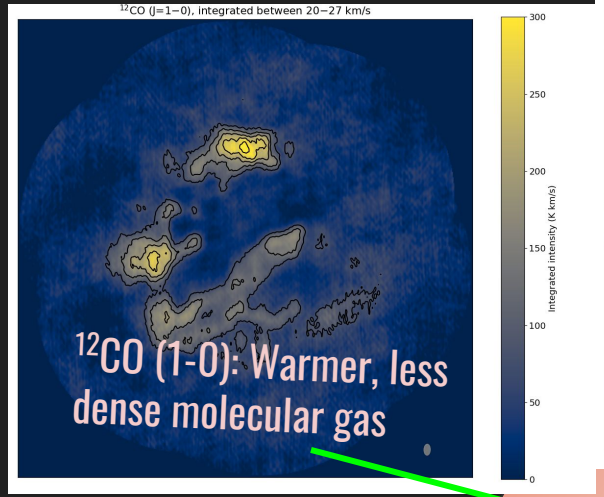
The pillars extend into the HII region and are surrounded by ionized gas

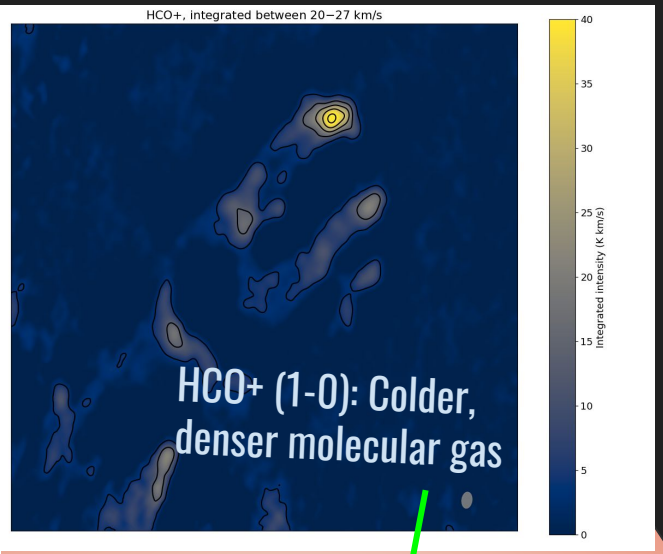


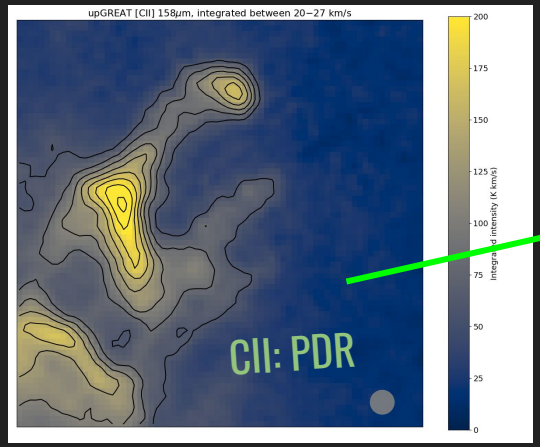
We have upGREAT [CII] 158 micron and [OI] 63 micron from the *SOFIA FEEDBACK Legacy Program*

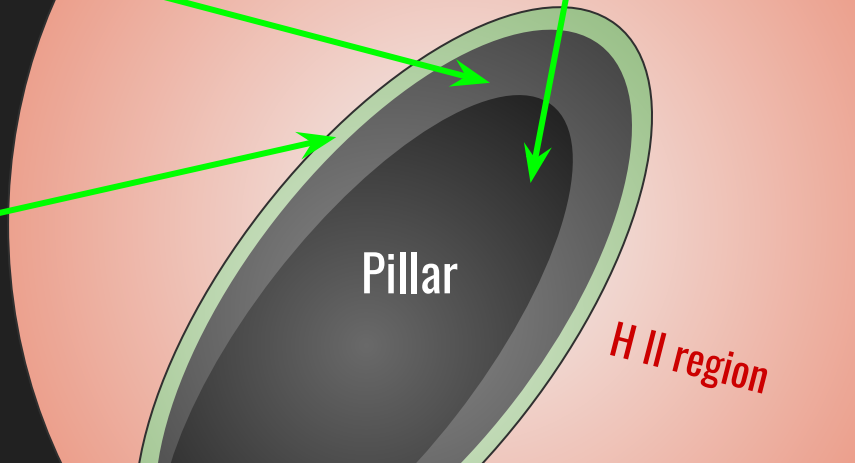
^{12}CO (1-0) from BIMA

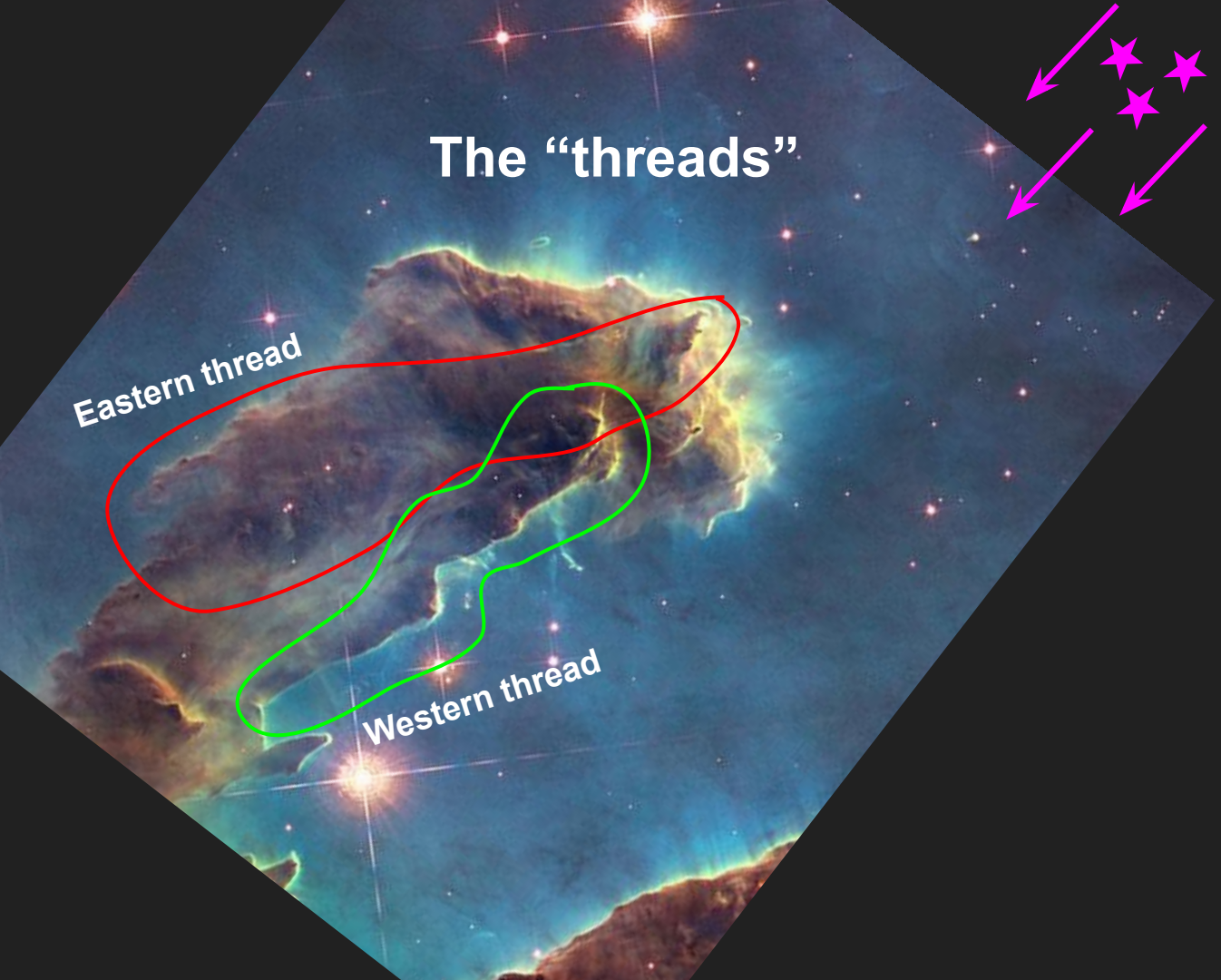
HCO+ (1-0) from CARMA

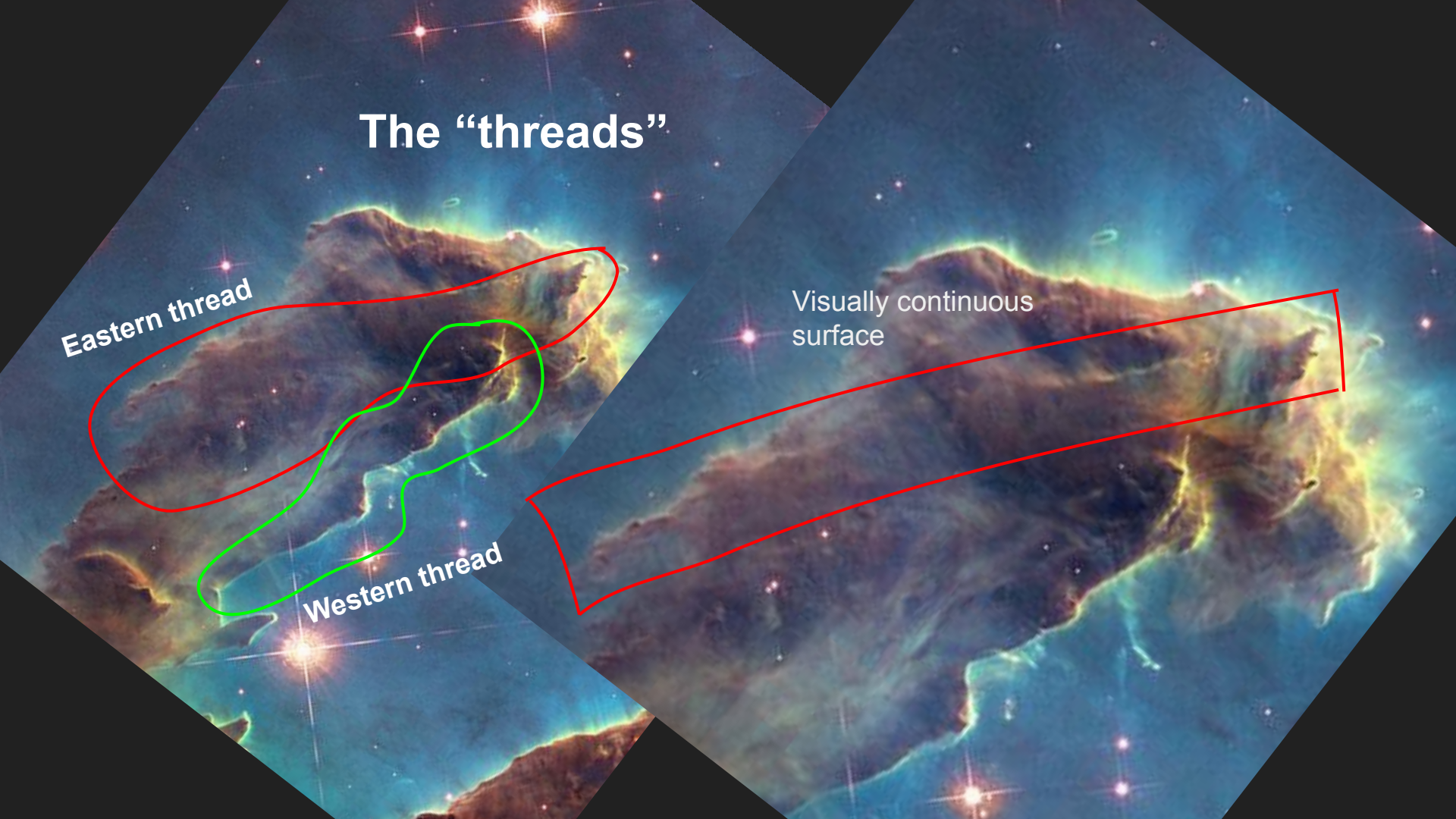


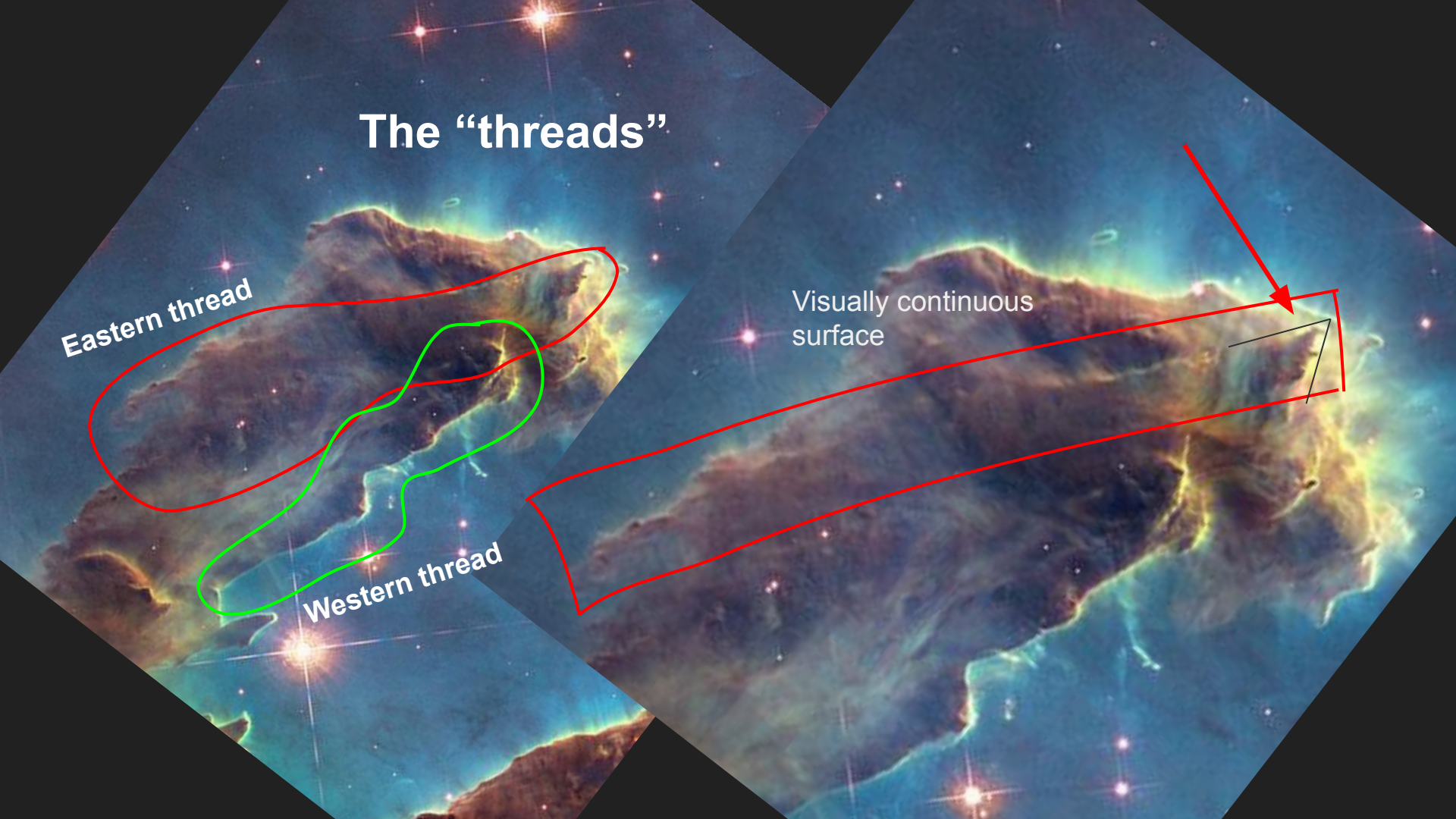


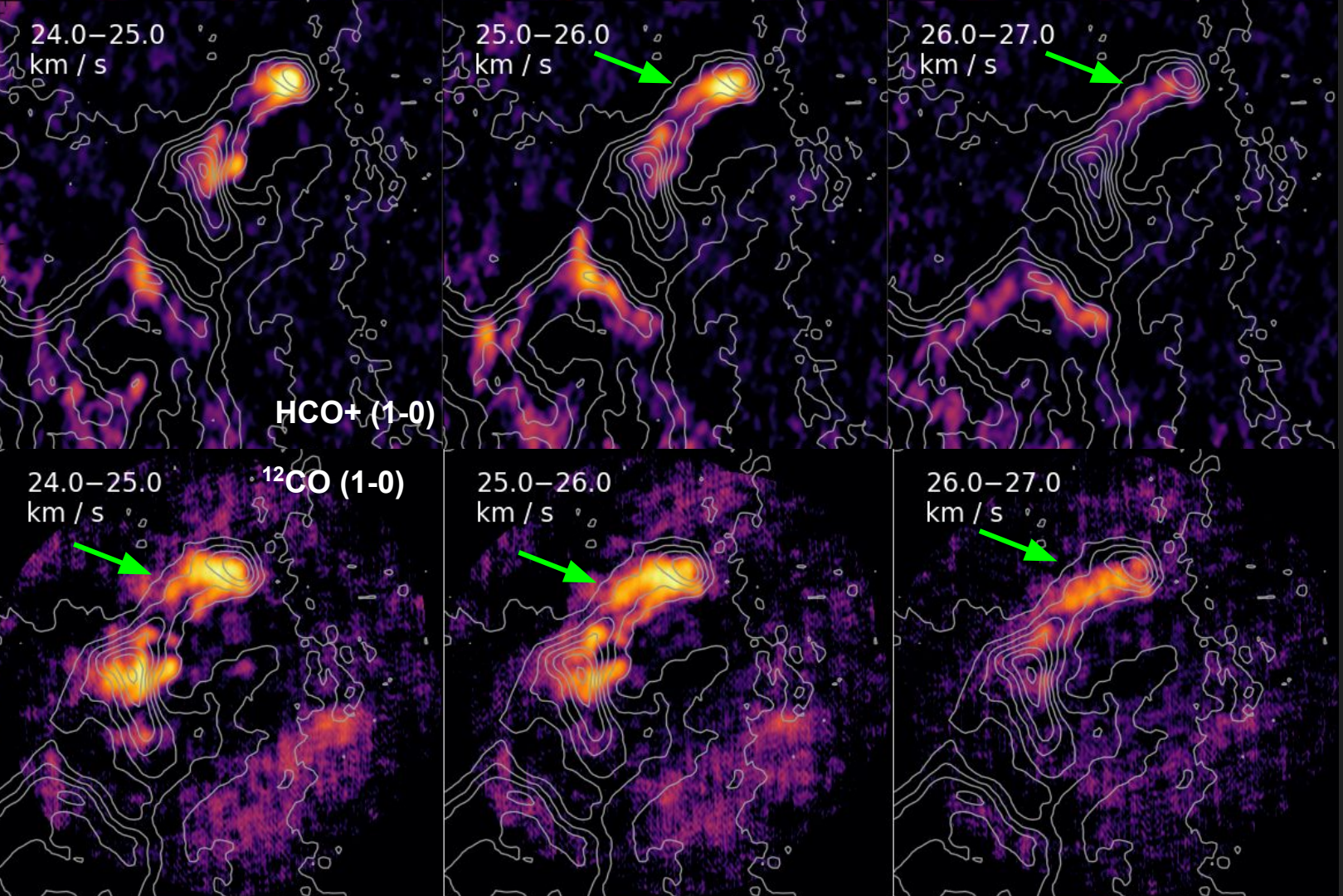





The “threads”
Eastern thread
Western thread


The “threads”
Eastern thread
Western thread
Visually continuous surface


The “threads”
Eastern thread
Western thread
Visually continuous
surface

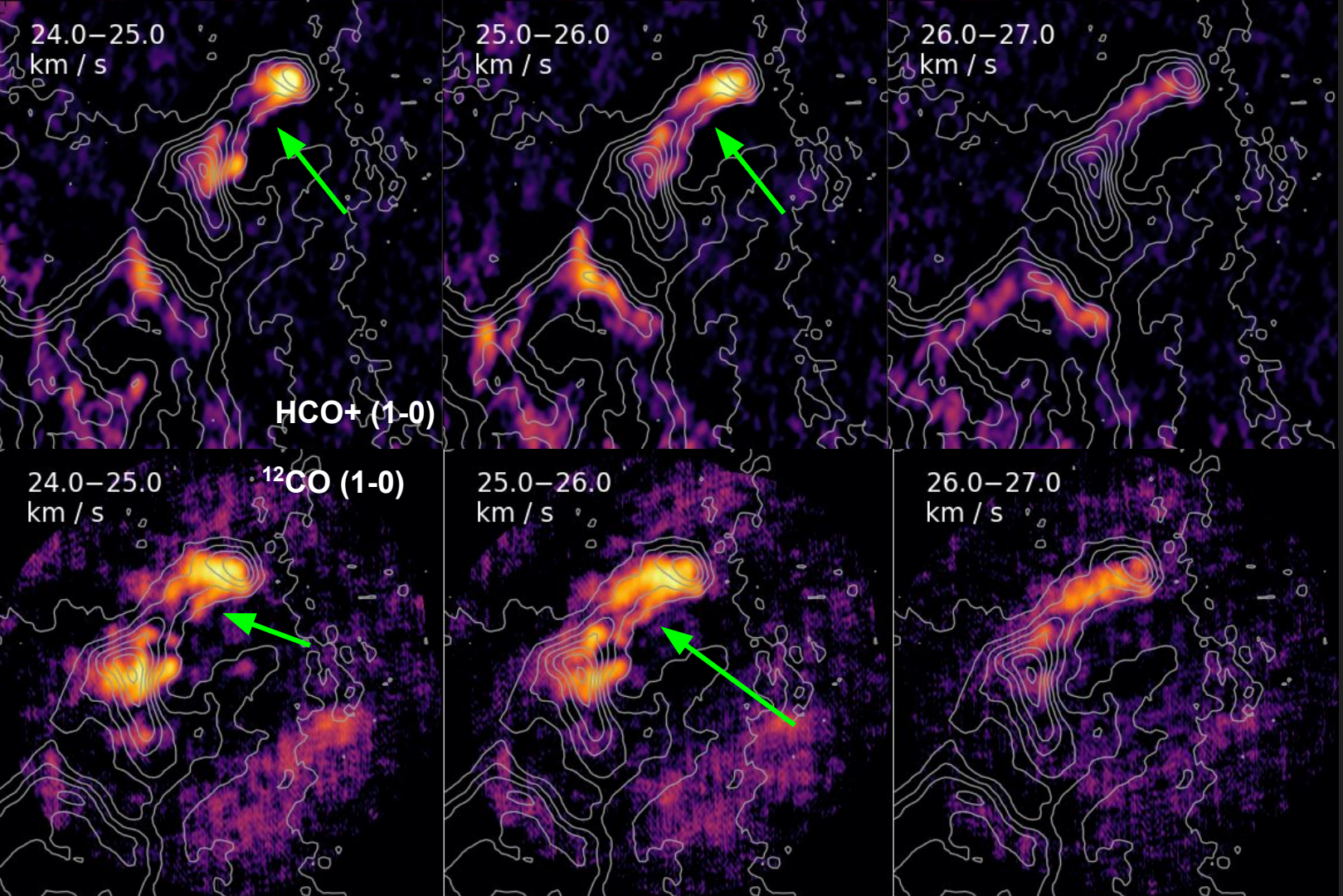


Double “thread” structure hanging down from the head of Pillar 1

Eastern thread

Western thread

Contours: [CII] integrated intensity between 20-27 km/s (contains all pillars)



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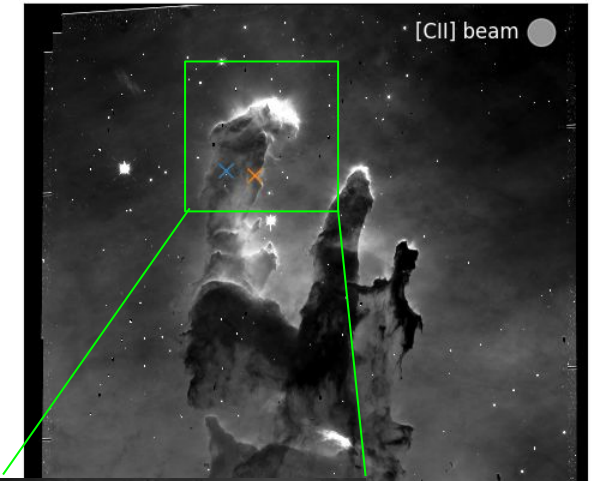
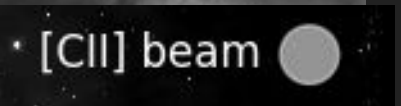
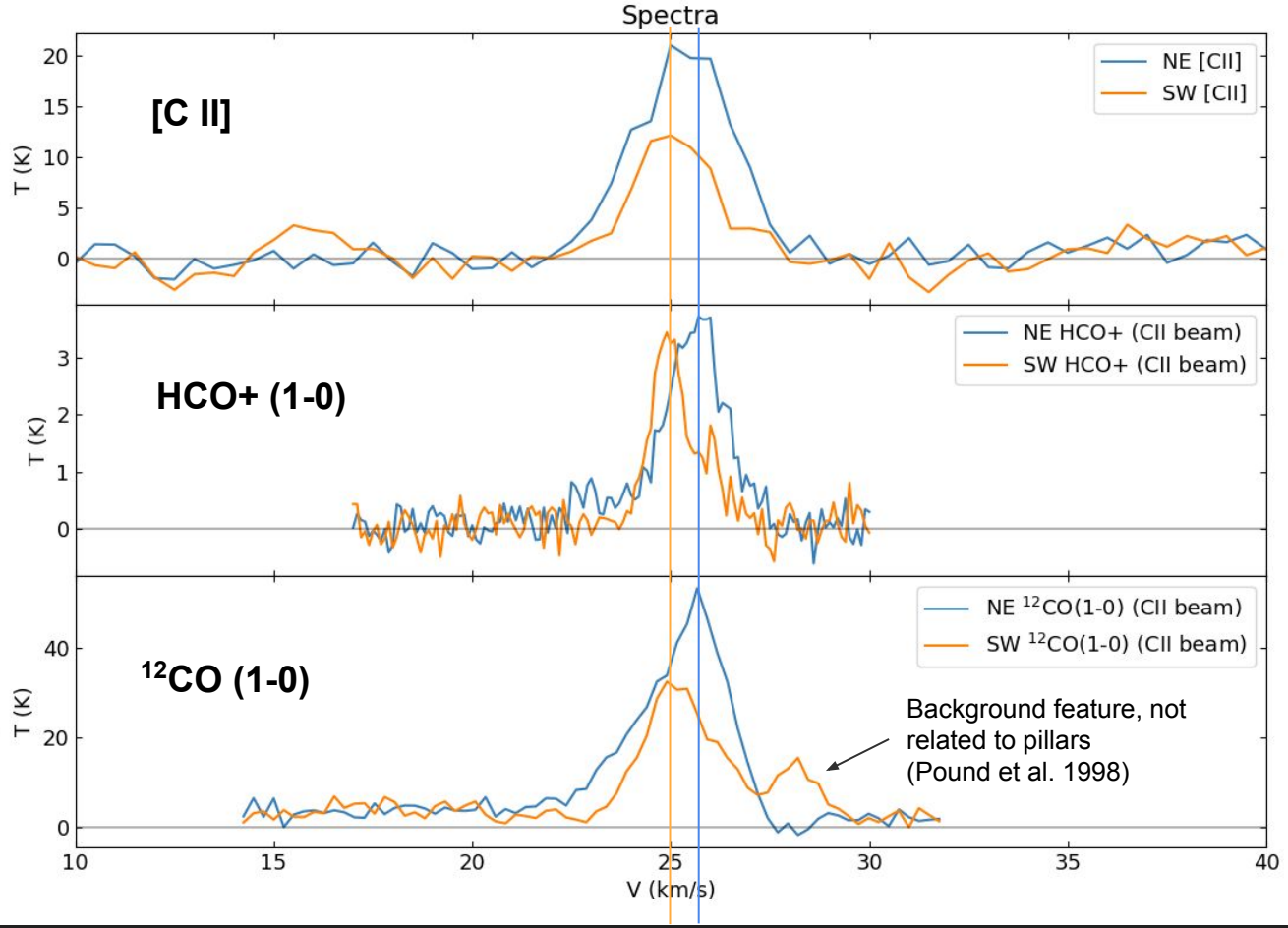
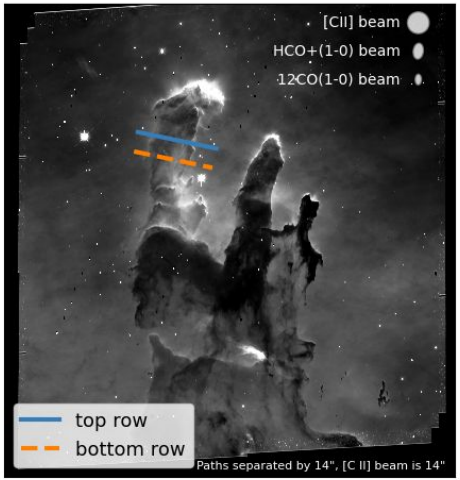
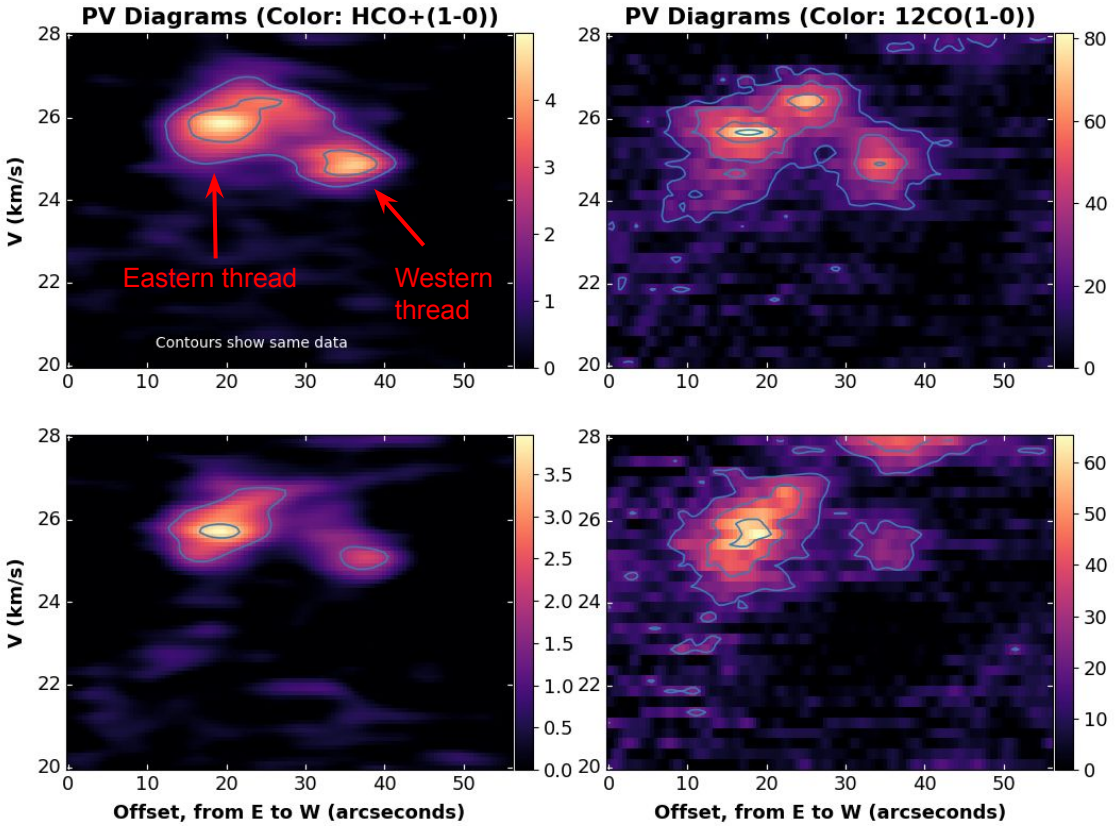

[CII] beam


[CII] beam


Spectra
[C II]
NE [CII]
SW [CII]
T (K)
HCO+ (1-0)
NE HCO+ (CII beam)
SW HCO+ (CII beam)
12CO (1-0)
NE 12CO(1-0) (CII beam)
SW 12CO(1-0) (CII beam)
Background feature, not related to pillars (Pound et al. 1998)
V (km/s)

HCO+ (1-0) in color in left column, CO (1-0) in color in right column

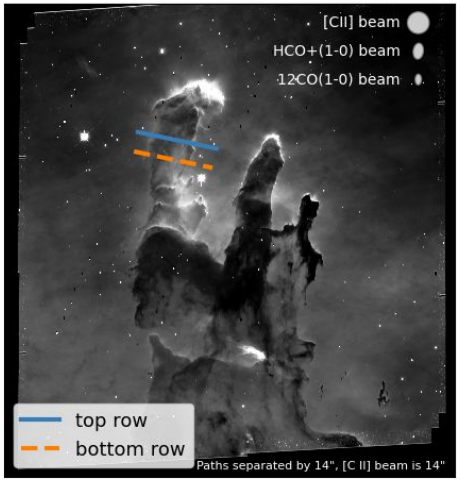


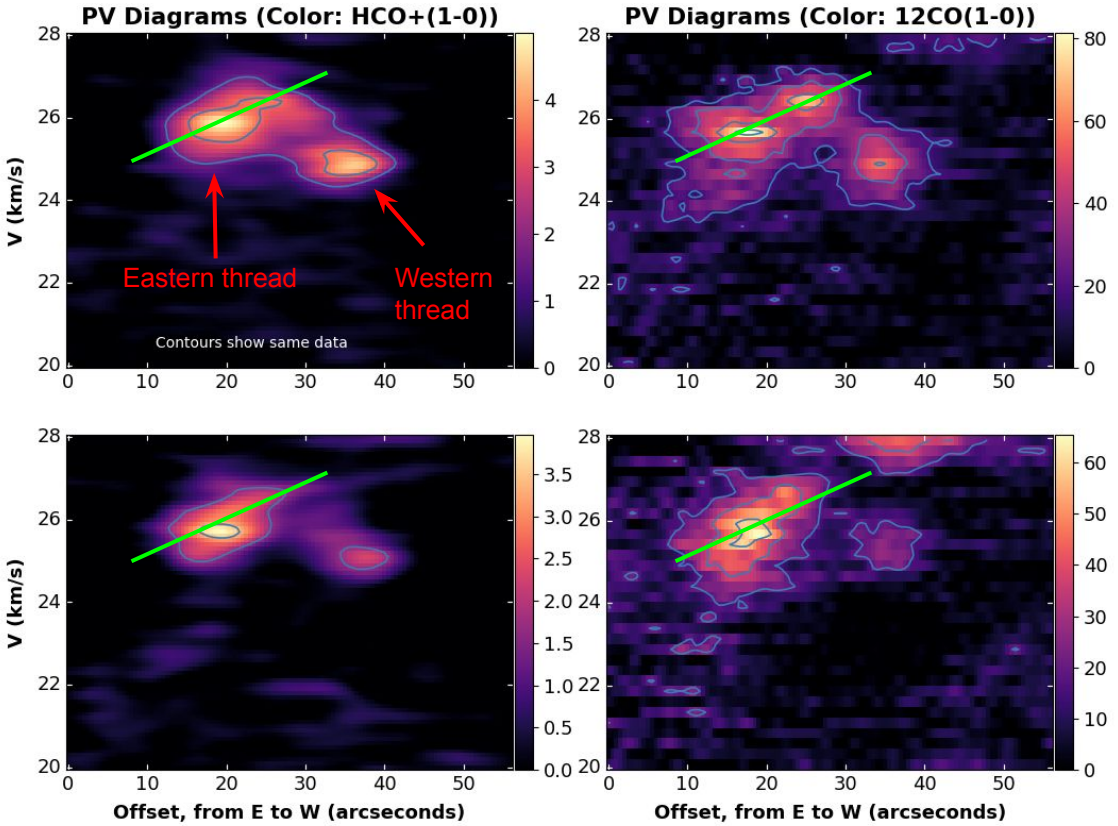


The two threads appear to be separate structures

The velocity gradient across the eastern thread does not “lead” towards the western thread

HCO+ (1-0) in color in left column, CO (1-0) in color in right column





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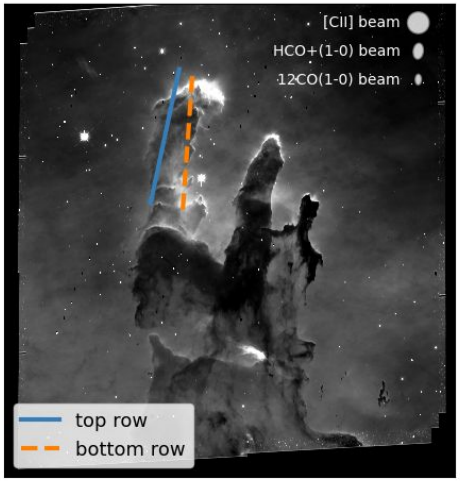
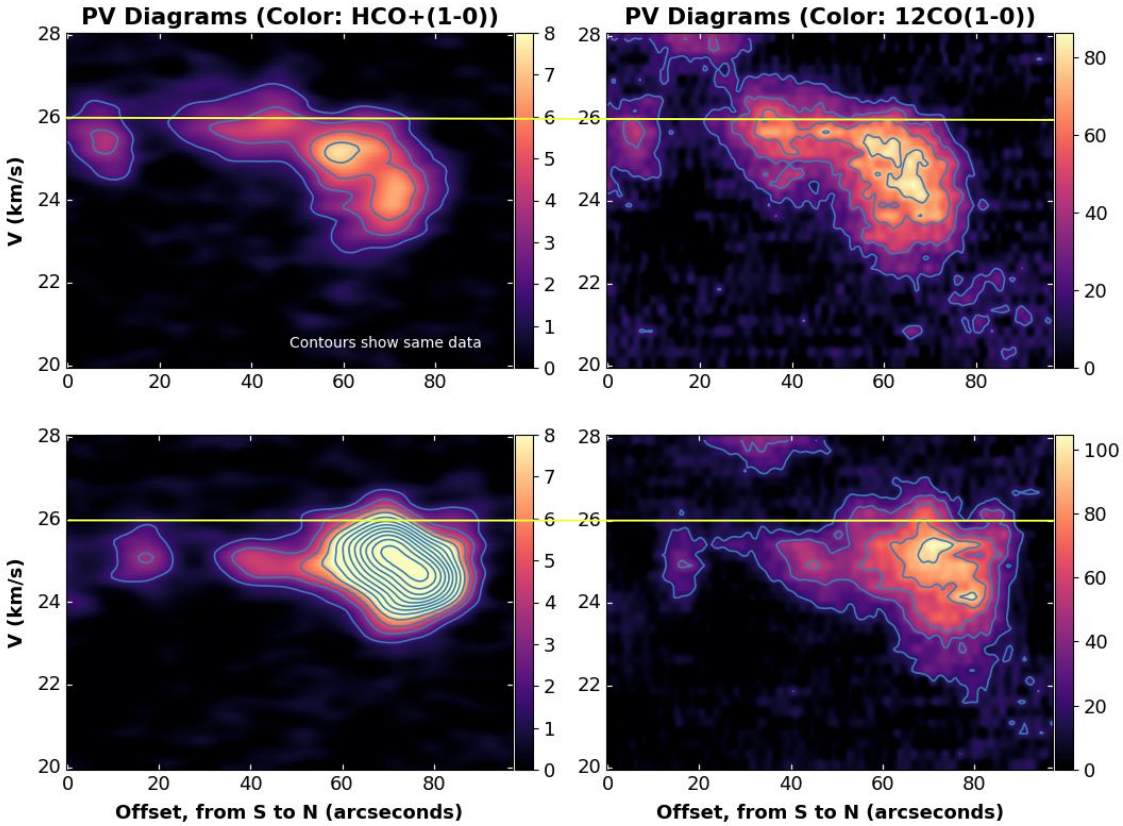
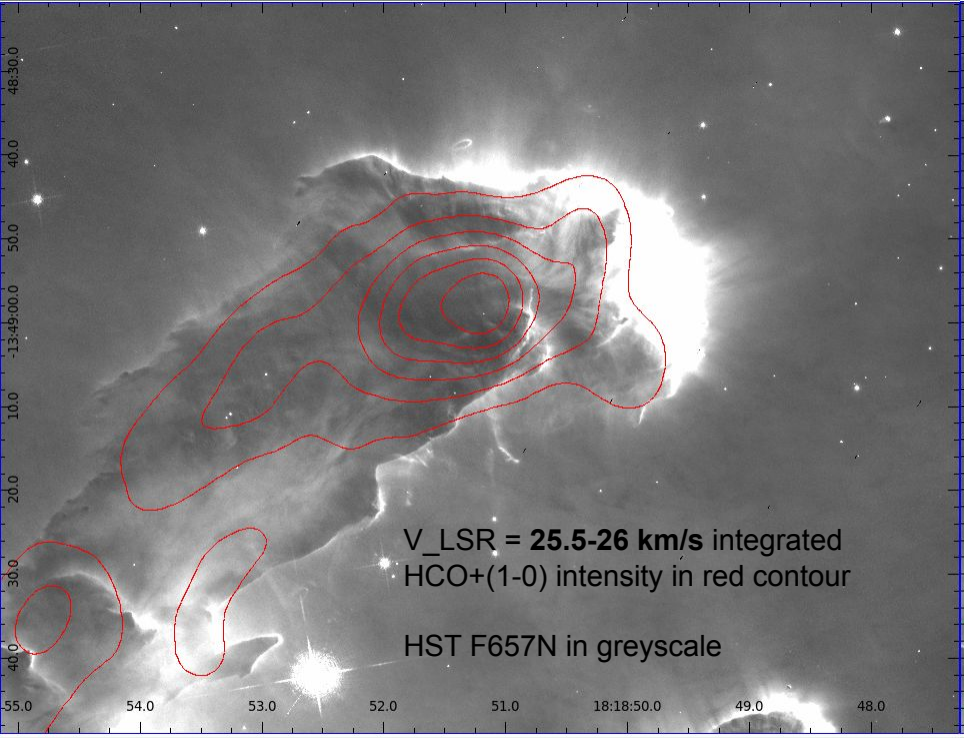
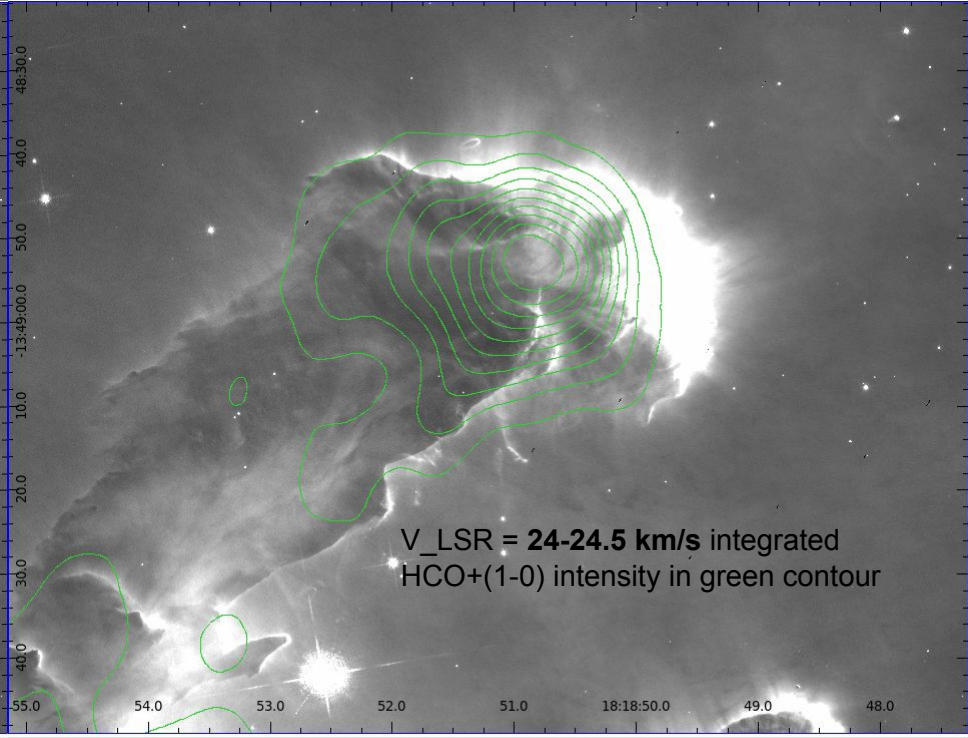




Velocity gradients along each thread are distinct

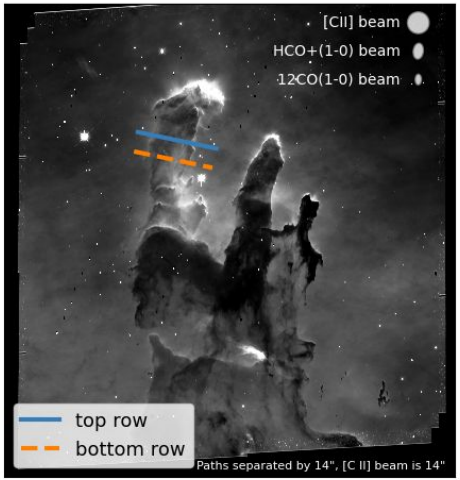

V_LSR = **25.5-26 km/s** integrated
HCO+(1-0) intensity in red contour
HST F657N in greyscale
48:30.0
40.0
50.0
-13:49:00.0
10.0
20.0
30.0
40.0
55.0
54.0
53.0
52.0
51.0
18:18:50.0
49.0
48.0

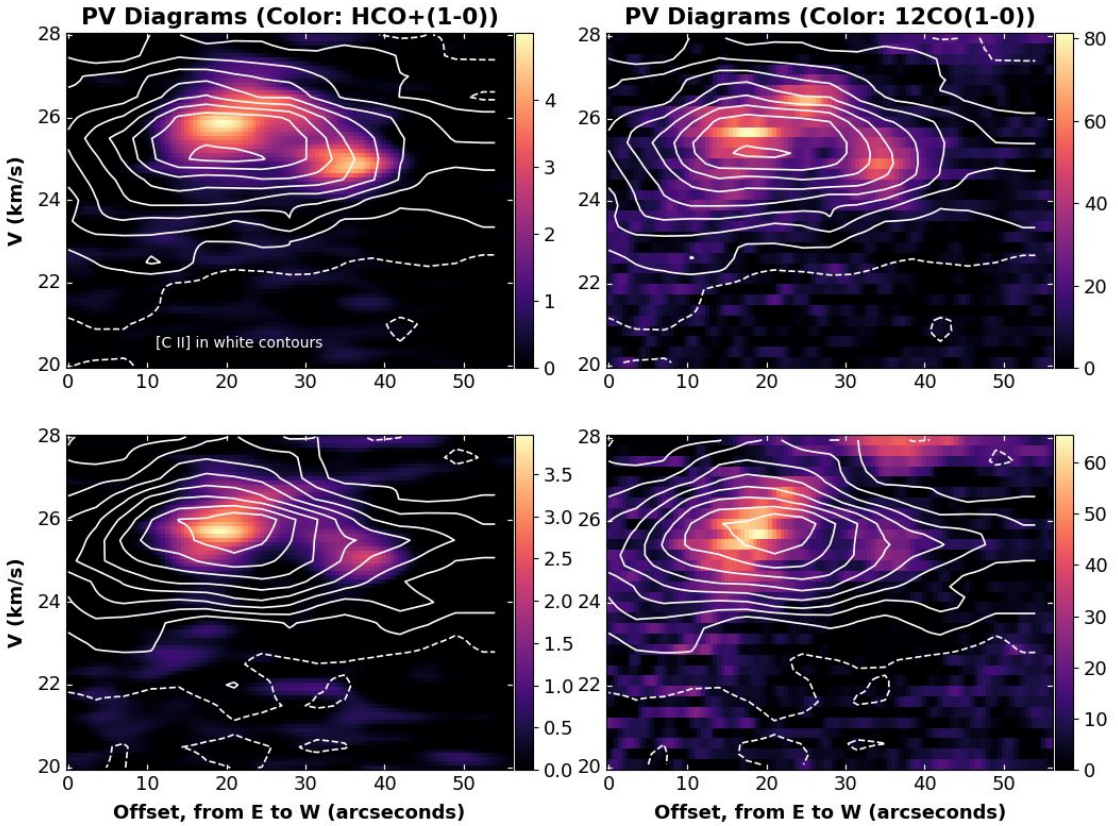

V_LSR = **24-24.5 km/s** integrated
HCO+(1-0) intensity in green contour
48:30.0
40.0
50.0
-13:49:00.0
10.0
20.0
30.0
40.0
55.0
54.0
53.0
52.0
51.0
18:18:50.0
49.0
48.0


0.06
0.12
0.18
0.24
0.3
0.36
0.42
0.49
0.55


0.06
0.12
0.18
0.24
0.3
0.36
0.42
0.49
0.55

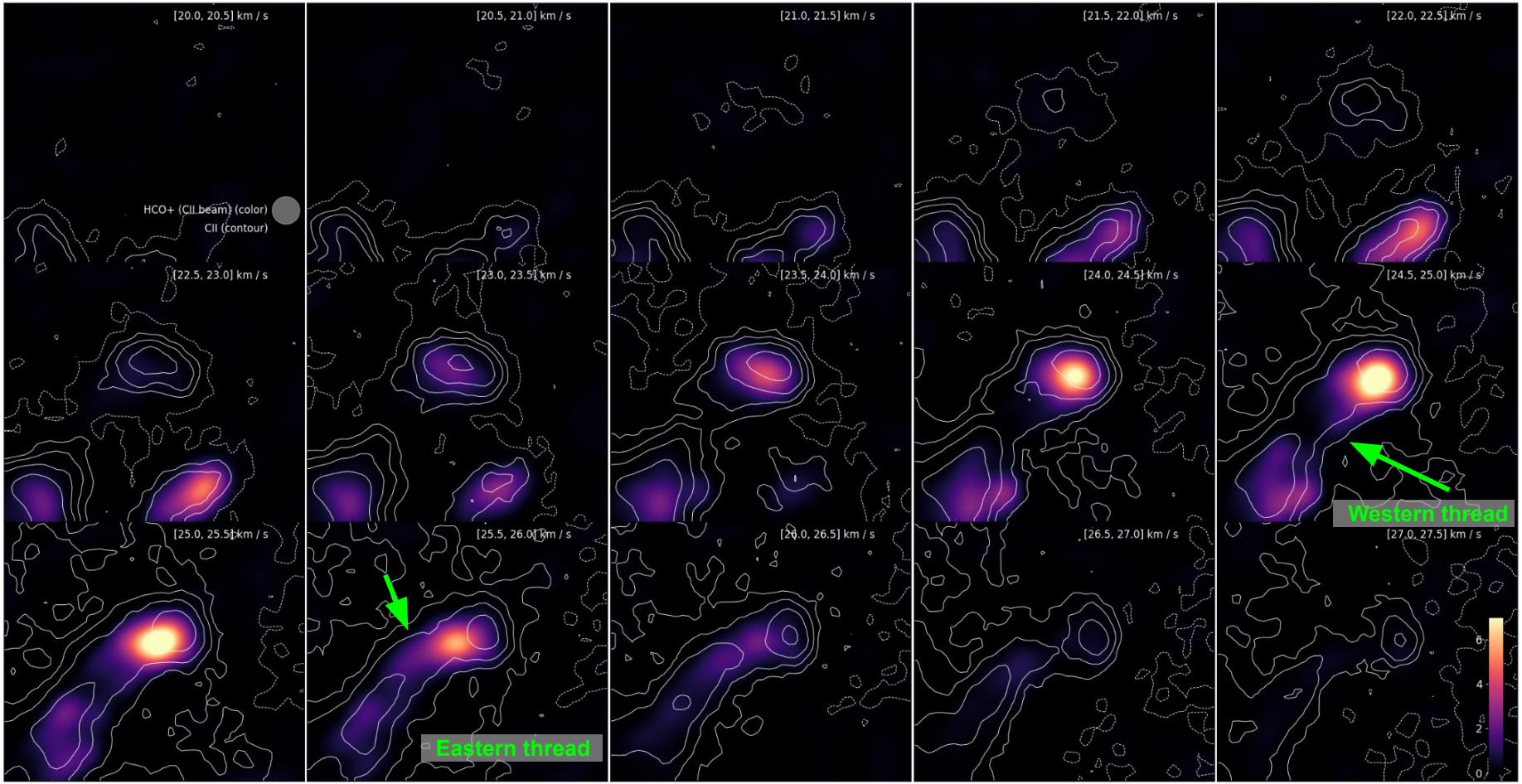
HCO+ (1-0) in color in left column, CO (1-0) in color in right column.
[C II] in contours.





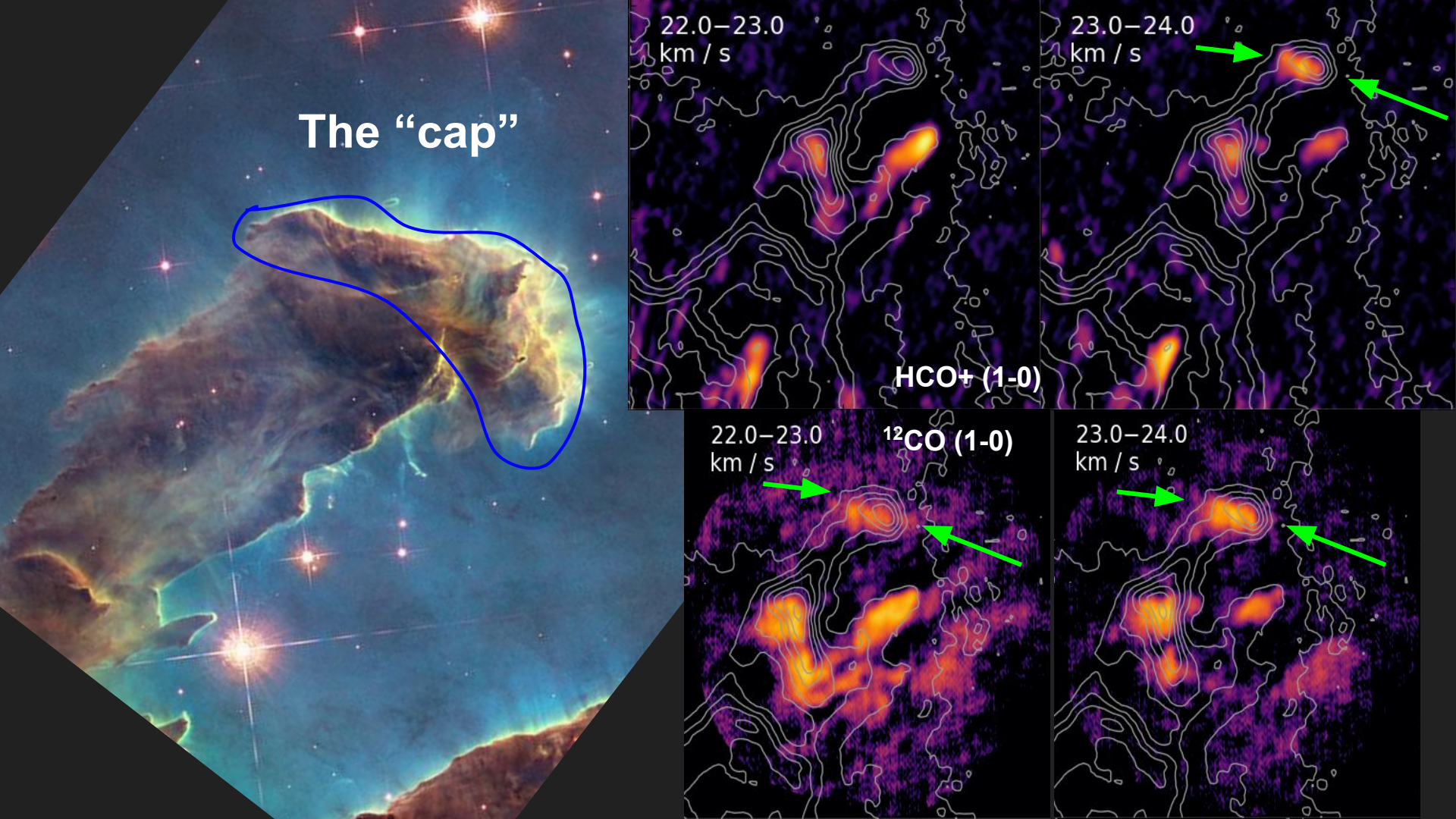
The two threads appear to be separate structures

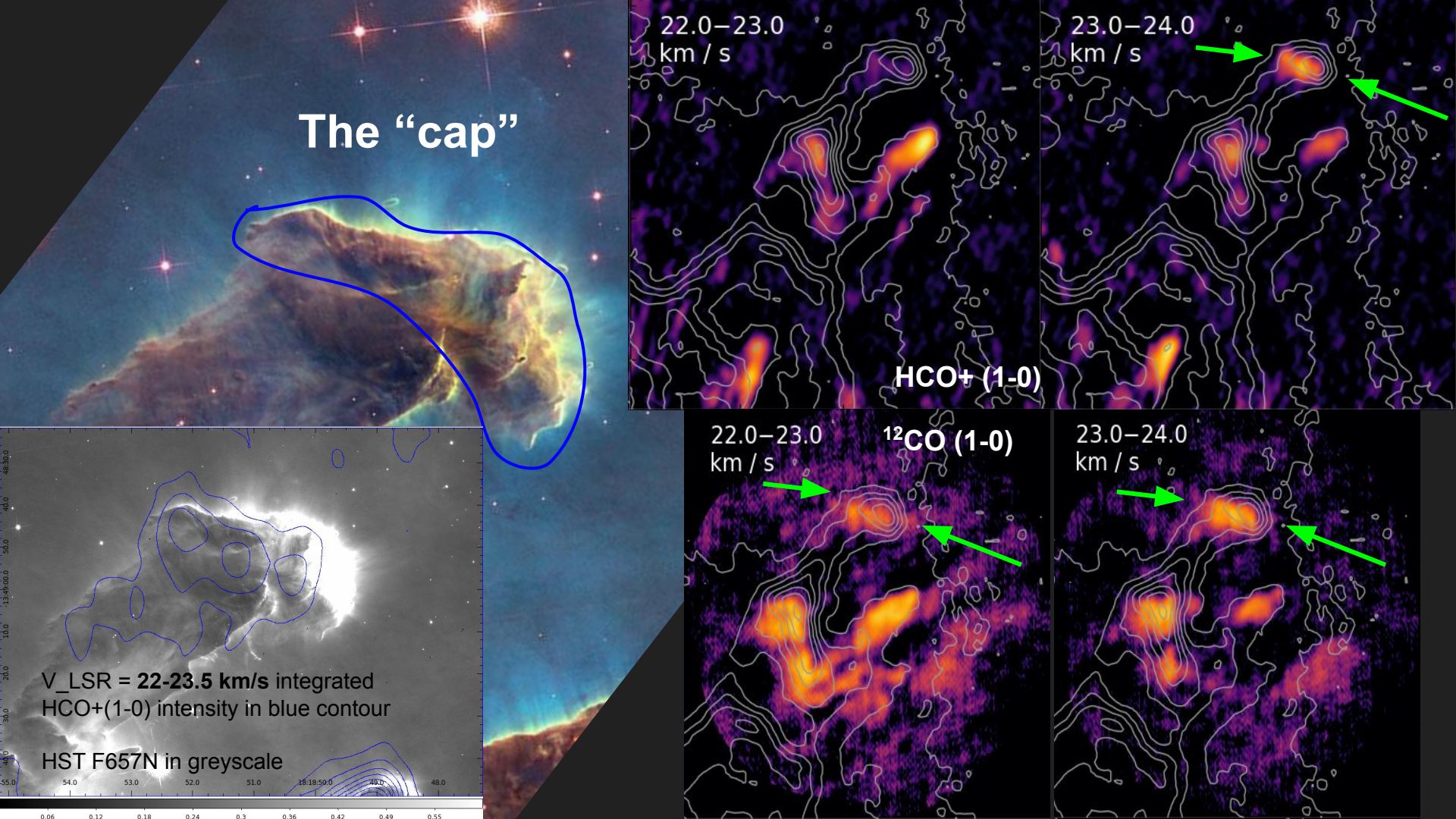
The velocity gradient across the eastern thread does not “lead” towards the western thread



Even at matched resolution, [C II] traces the eastern thread more clearly than the western thread

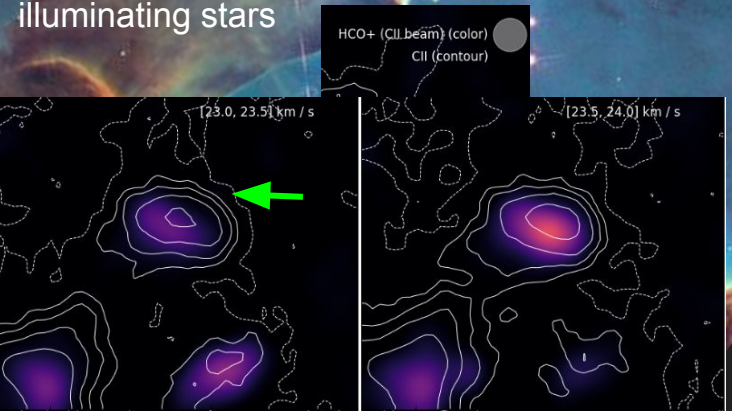

The “cap”

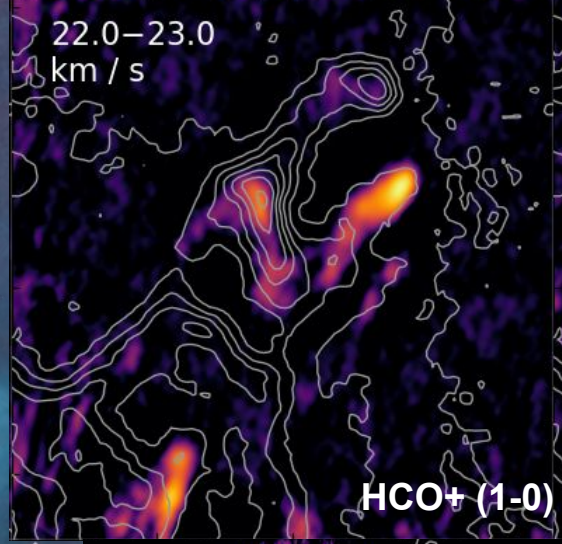

The “cap”
22.0–23.0
km / s
23.0–24.0
km / s
HCO+ (1-0)
22.0–23.0
km / s
12CO (1-0)
23.0–24.0
km / s

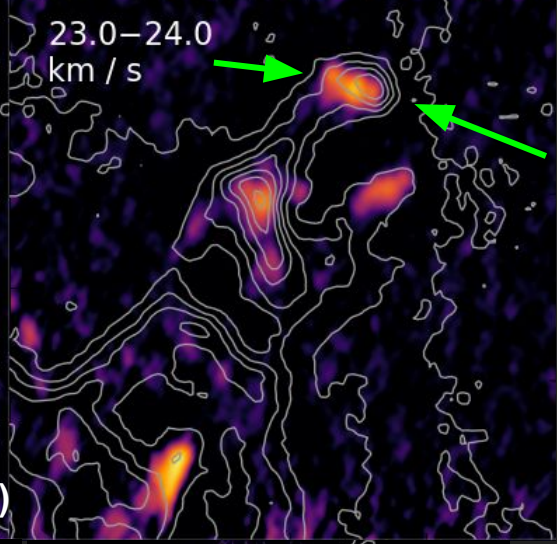

The “cap”
22.0–23.0
km / s
23.0–24.0
km / s
HCO+ (1-0)
22.0–23.0
km / s
12CO (1-0)
23.0–24.0
km / s
V_LSR = 22-23.5 km/s integrated
HCO+(1-0) intensity in blue contour
HST F657N in greyscale

The “cap”

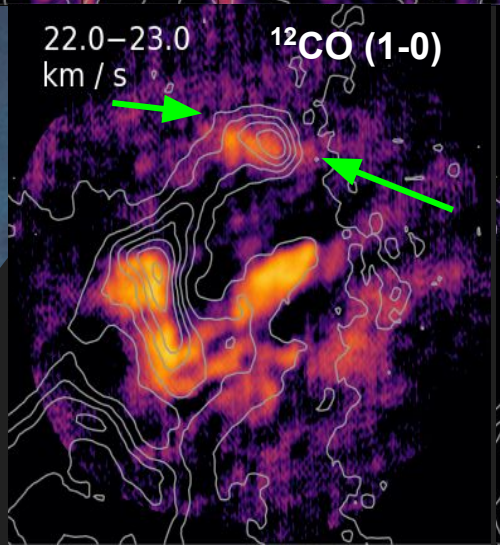
This “blue cap” is also observed in [C II] with the [C II] emission slightly offset towards the illuminating stars



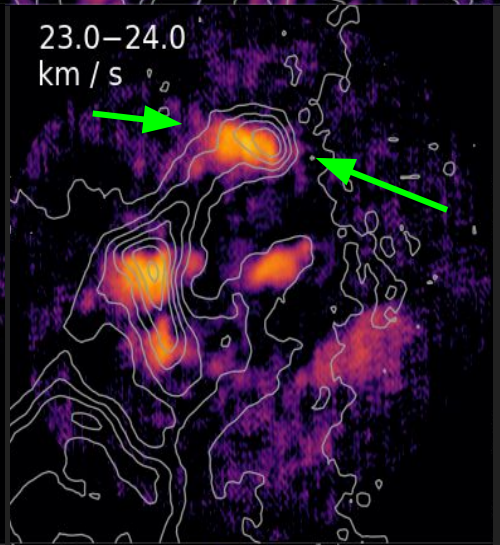


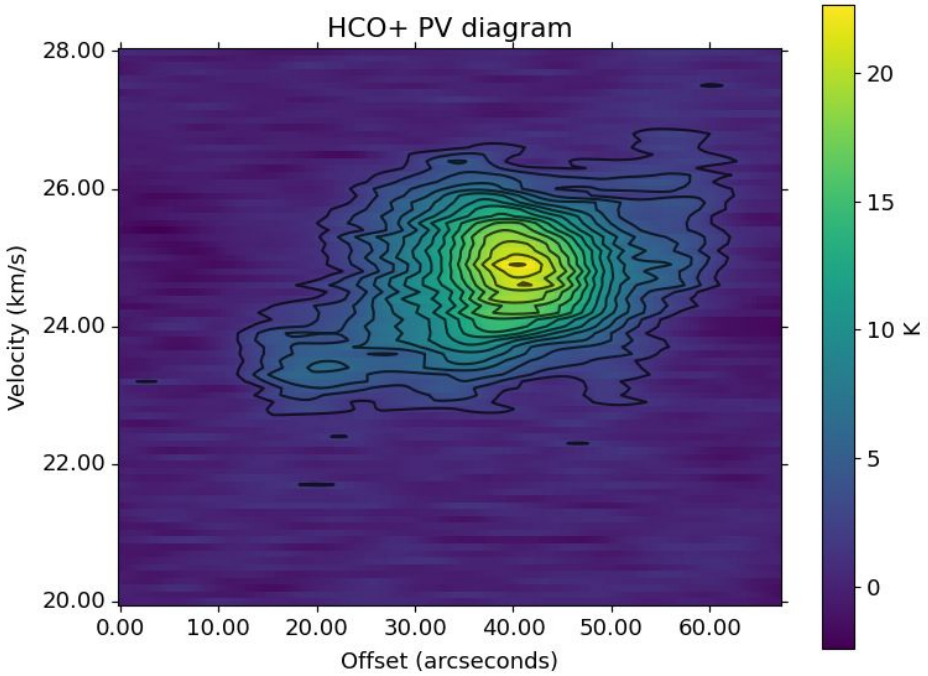


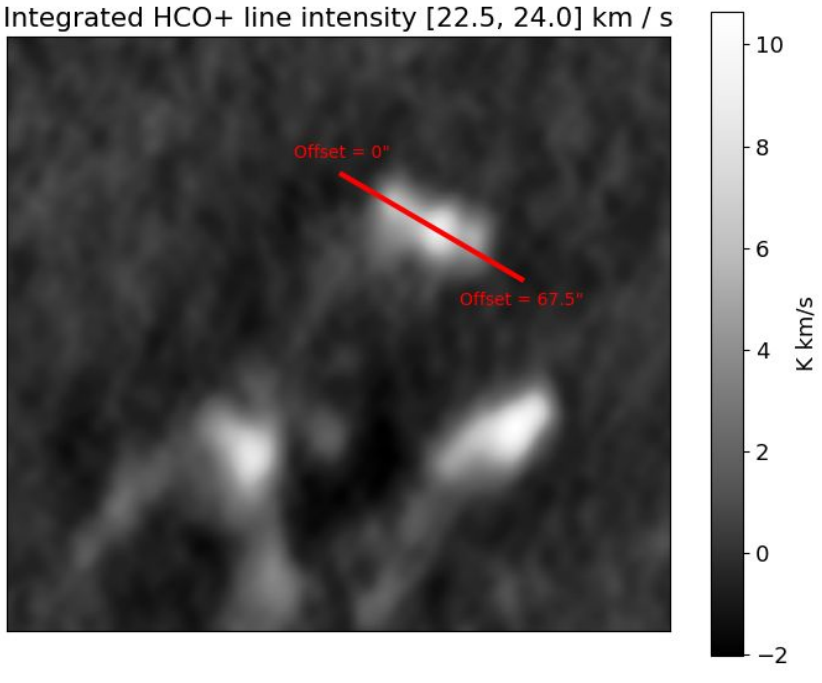
HCO+ (1-0)



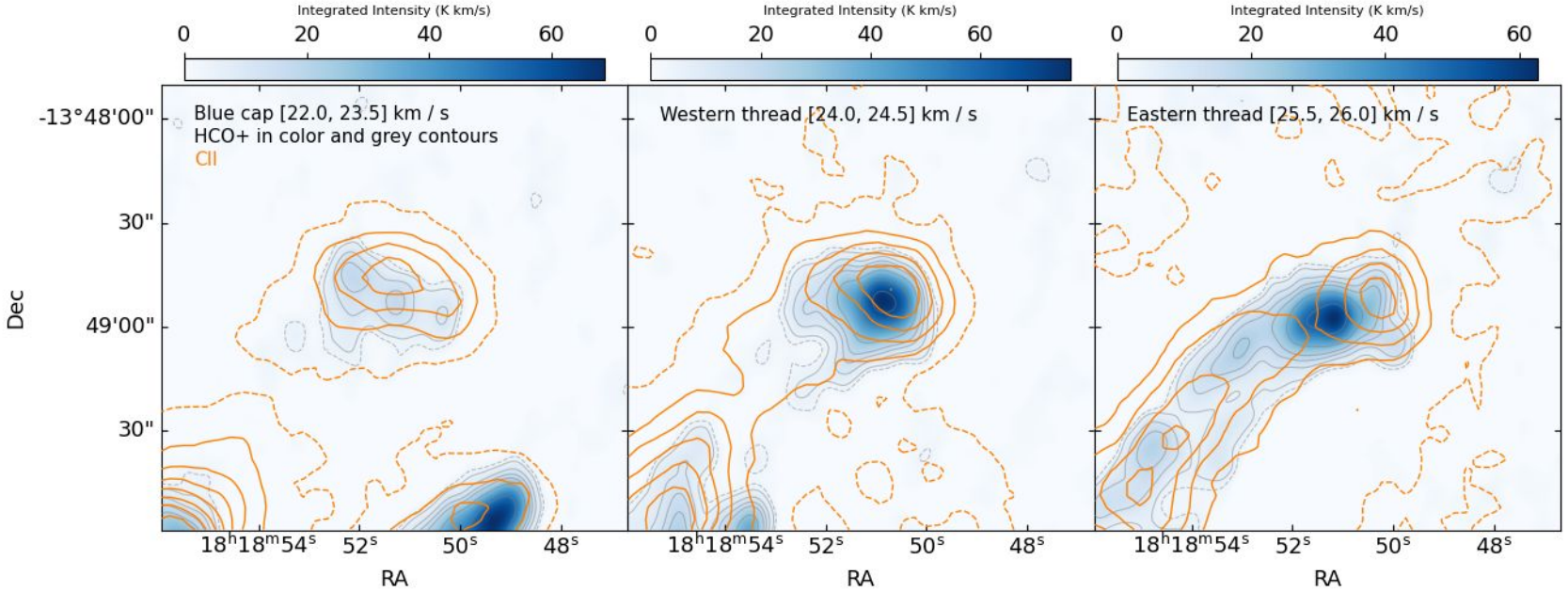
^{12}CO (1-0)





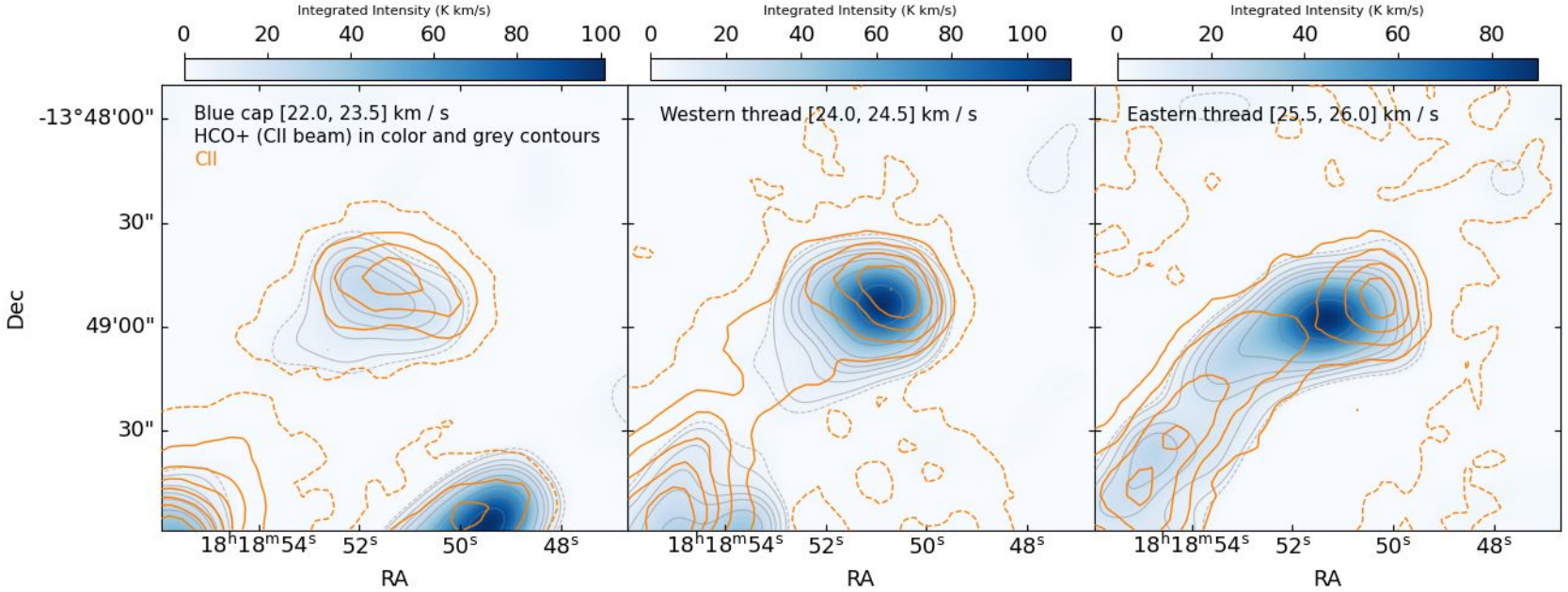


A velocity gradient is observed across the blue cap as well



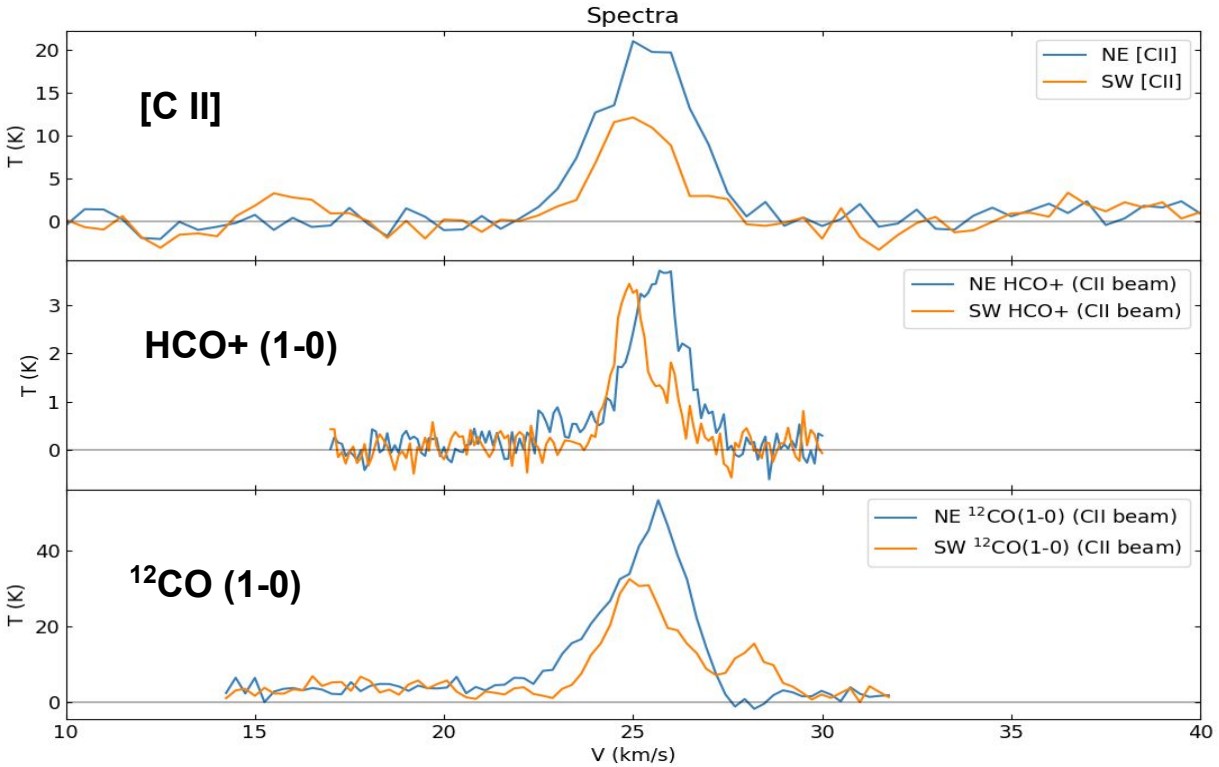
HCO+ at native resolution

Three distinct shapes are observed towards the pillar head at different velocities. Is the pillar head simply a composition of these three features? How do they relate to each other?



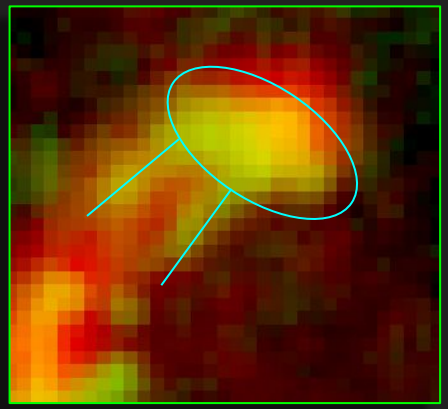
HCO+ at [C II] resolution

Three distinct shapes are observed towards the pillar head at different velocities. Is the pillar head simply a composition of these three features? How do they relate to each other?

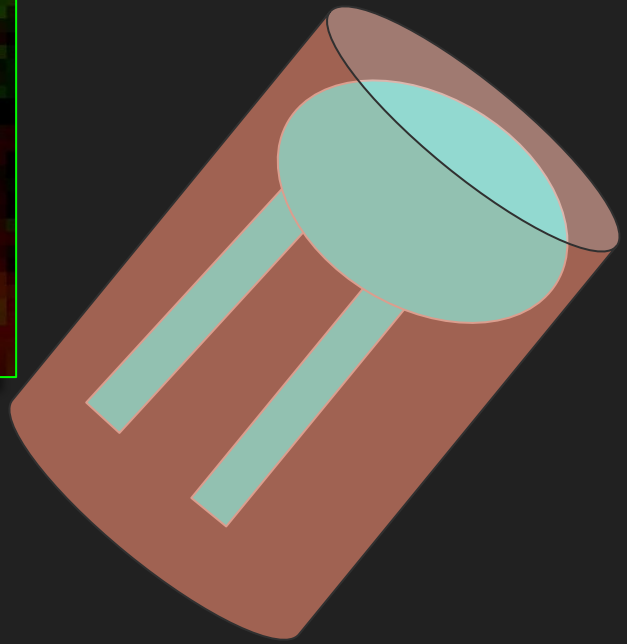


Did stellar feedback create these three features? Or did it “reveal” existing dense structures?

HCO+(1-0) intensity of ~few K suggests high (1e4,1e5) density, difficult for feedback to move this sort of gas. Likely pre-existing structures!



CII in red, HCO+ (1-0) in green. Integrated intensity between 24.5-25.5 km/s.

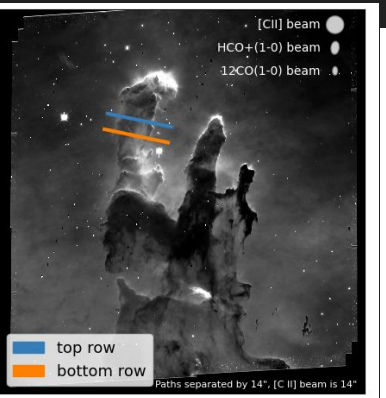


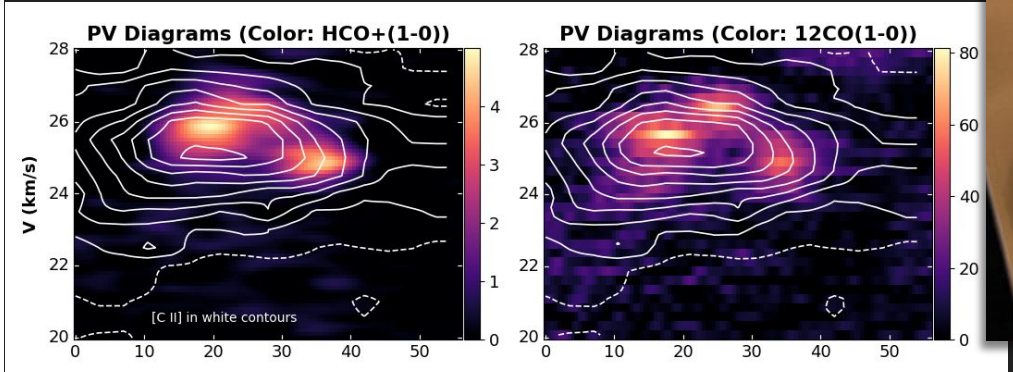
Inner molecular gas layers organized into threads, outer layers more diffuse and uniform.

Physical model for the head of Pillar 1: dense, filamentary gas encased in a more extended cloud of less dense gas bounded on the outside by the PDR.

Something like an object encased in jello. The jello is extended and has little-to-no substructure, but the object embedded within is dense and complex.

Physical Model of Pillars



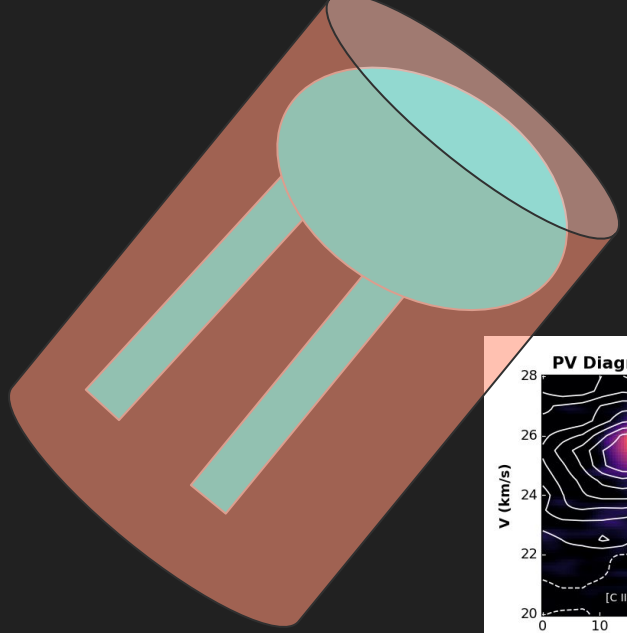


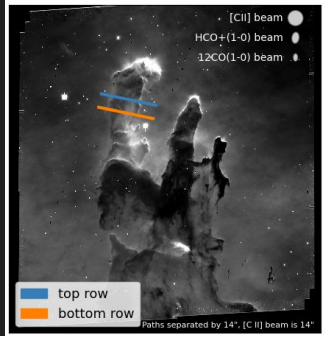
Takeaway:

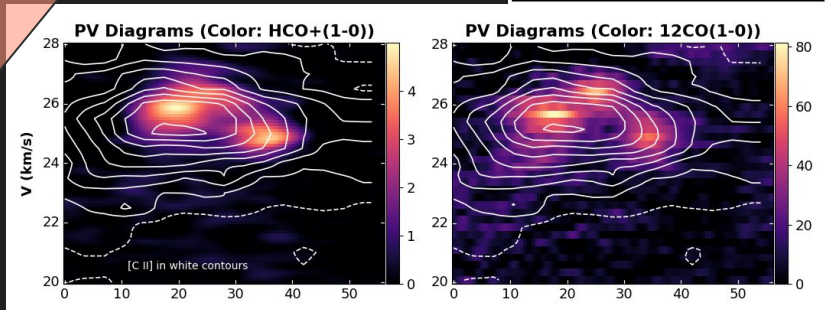
Velocity resolved [C II], HCO+(1-0), and ^{12}CO(1-0)

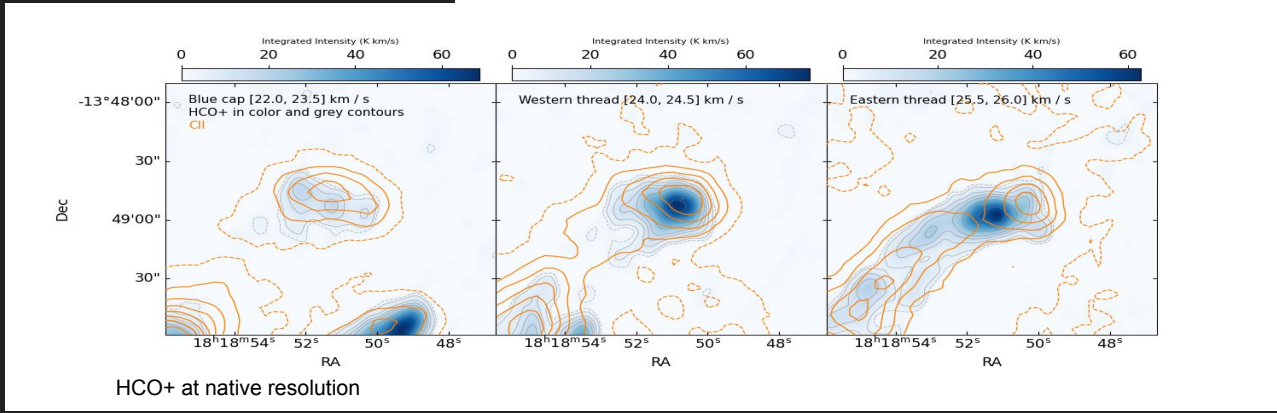
Consistent with head of Pillar 1 organized into dense, molecular gas threads encased in extended, less-dense gas cloud bounded by PDR.

Origin of this structure: feedback? Or pre-existing?









HCO+ at native resolution