Carina's Pillars of Destruction

The view from ALMA

Science & Technology Facilities Council
UK Astronomy Technology Centre

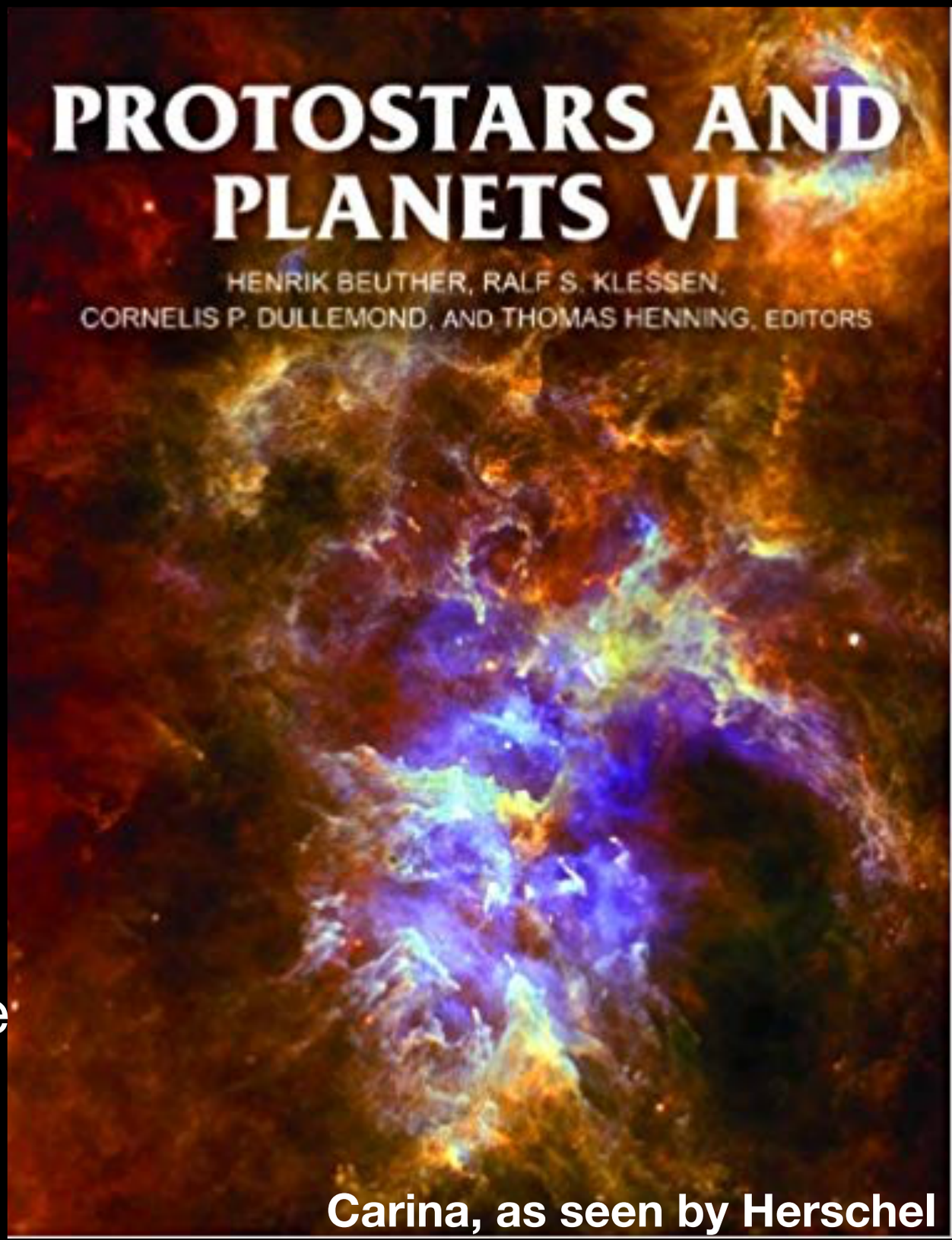
P. D. Klaassen, M. R. Reiter,
A. F. McLeod, J. C. Mottram

Outline

How does feedback from massive stars affect the local ISM?

To study this, look at the gas being shaped by nearby massive stars

- Overview of Model Predictions
- ALMA ACA Survey
  - Gas dynamics in the presence of multiple O stars



Carina, as seen by Herschel

Overview of Model Predictions

- Models are able to predict how ionising radiation can sculpt the local environment..
  - they all show bubbles, pillars, etc
    - So, how do we distinguish between their predicted outcomes?
- From models specific metrics include:
  - Gas Velocity Dispersion
  - Internal Pillar Motions
  - ‘Bodily’ motion of the pillar

- Models used for comparisons:
  - Gritschneder et al. 2009
  - Gritschneder et al. 2010
  - Dale et al. 2012
  - (Still need to compare to SILCC & Yule)

Model Predictions

Radiatively driven implosion of Bonor-Ebert Spheres

- Vel. dispersion: ~ 1-2 km/s
- Internal Flows: allowed
- Motion w.r.t cloud: none

Gritschneder et al. 2009

Model Predictions

Ionisation front + turbulent medium

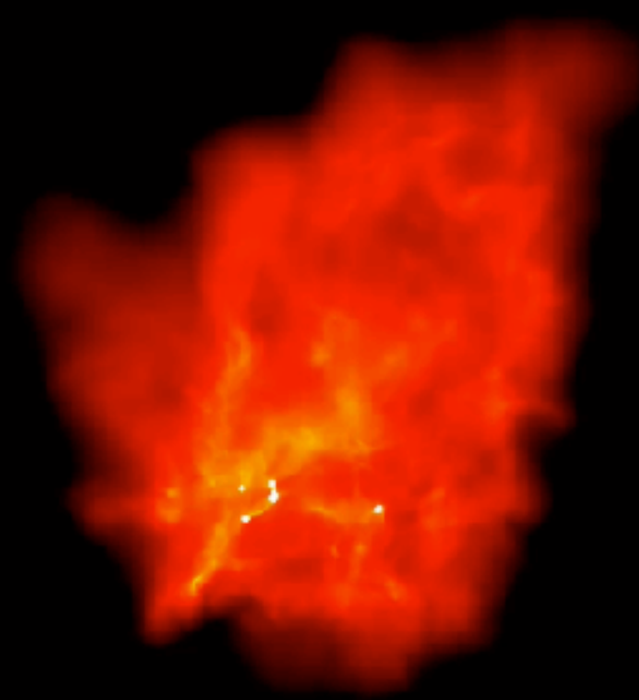
- Vel. dispersion: > 6 km/s
- Internal Flows: allowed
- Motion w.r.t cloud: none

Gritschneder et al. 2010

Model Predictions

Disruption of cloud by winds and ionisation

- Vel. dispersion: ~1 km/s
- Internal Flows: none
- Motion w.r.t cloud: maybe



Dale et al. 2012

Distinction through Kinematics

Model	Type	Velocity Dispersion	Internal Flows	Motion relative to cloud
Gritschneder+ 2009	Bonnor-Ebert Sphere	~1 – 2 km/s	yes	None
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What we Observed

- 13 pillars in Carina
- Cycle 4, ACA only
- cont, CO, ^{13}CO, $C^{18}O$ (J=2-1)
- non-detections: SiO, $C^{34}S$

Herschel RGB:
R: 250 micron
G: 160 micron
B: 70 micron

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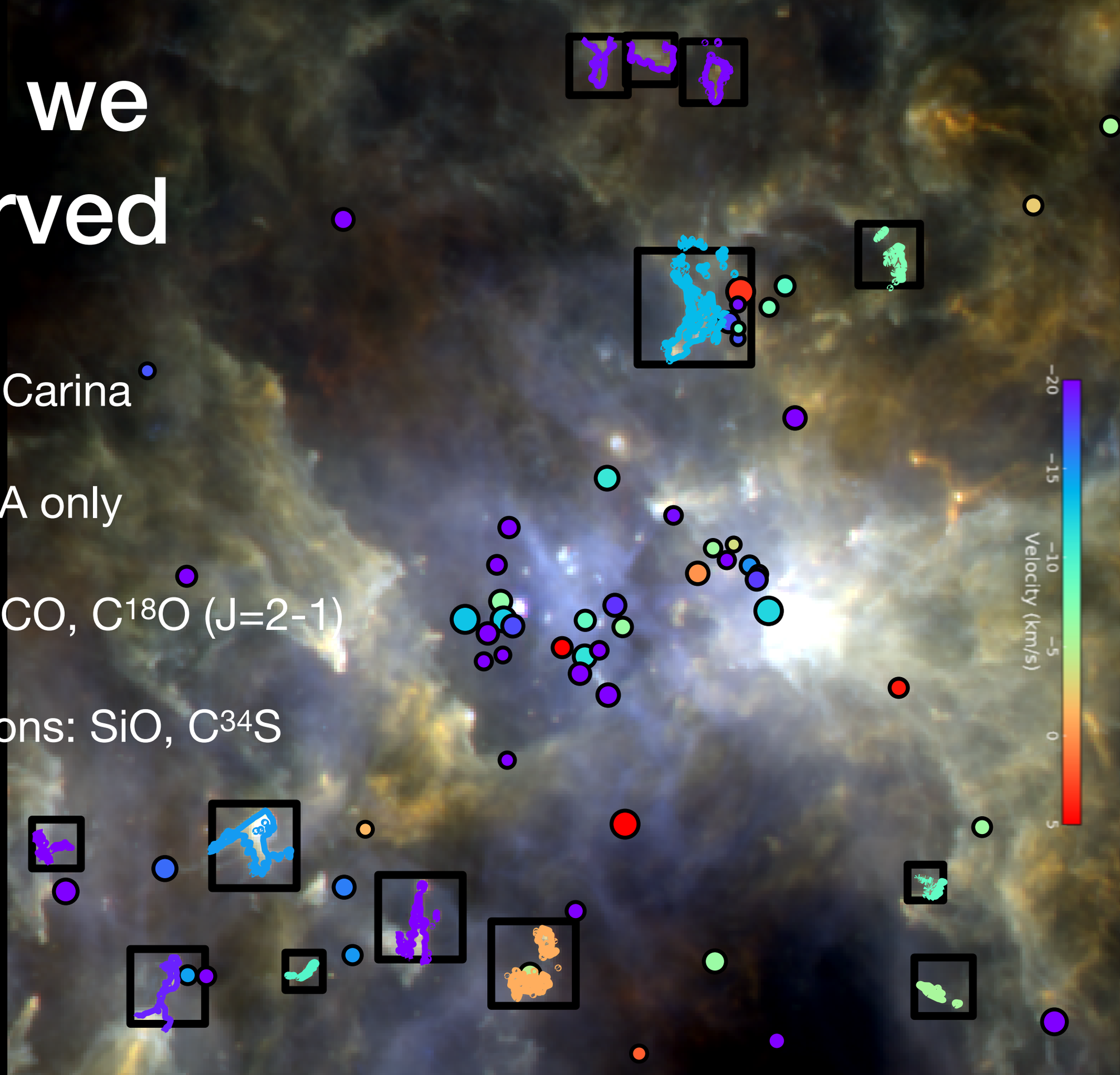
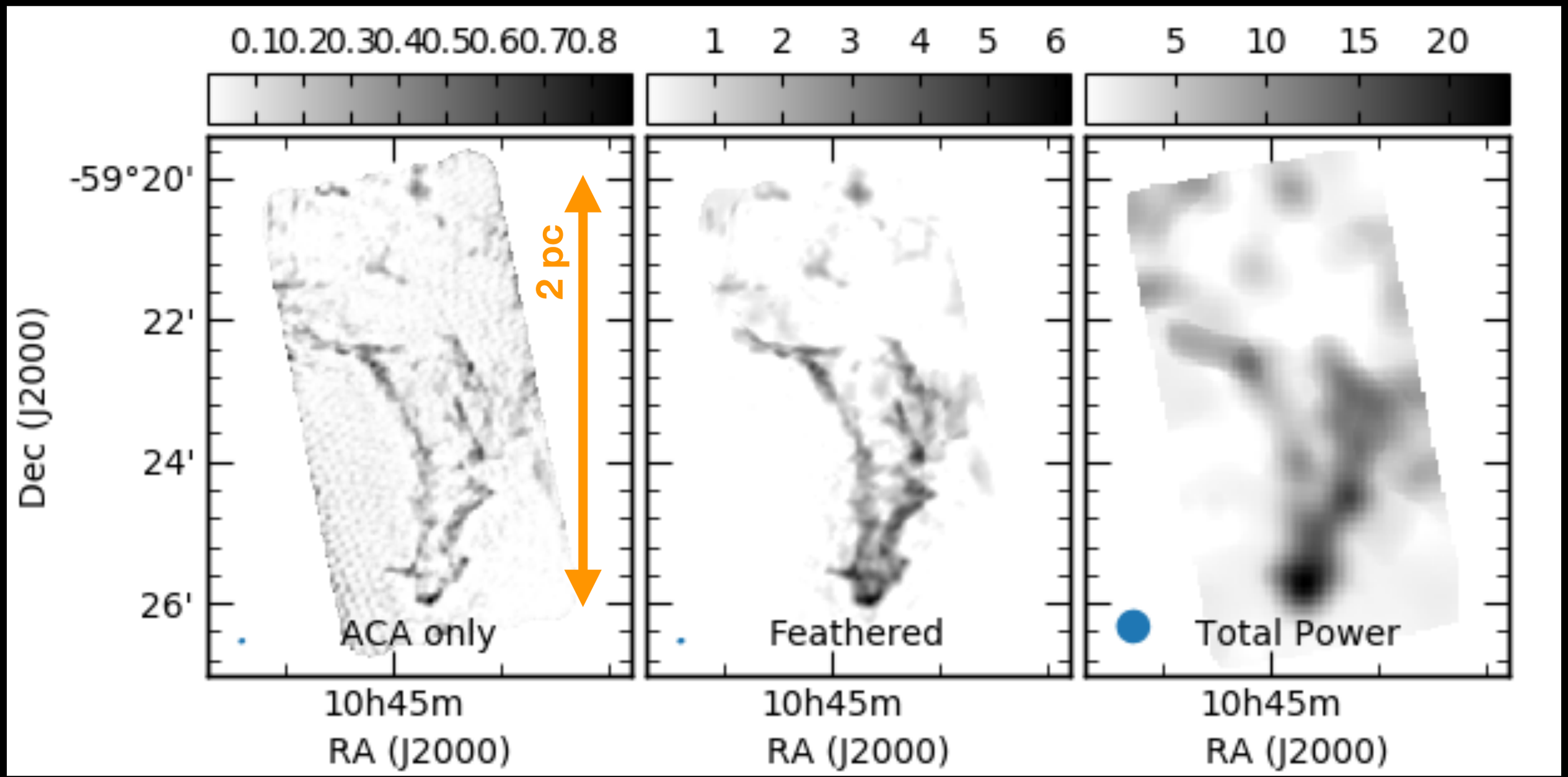
Star velocities:
Hanes et al. 2018

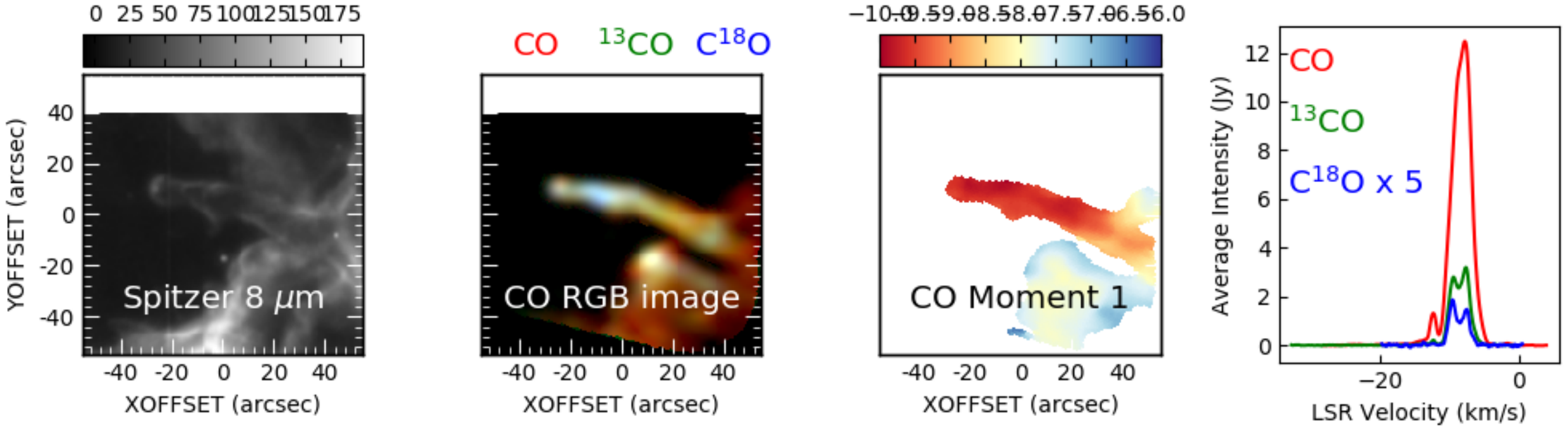


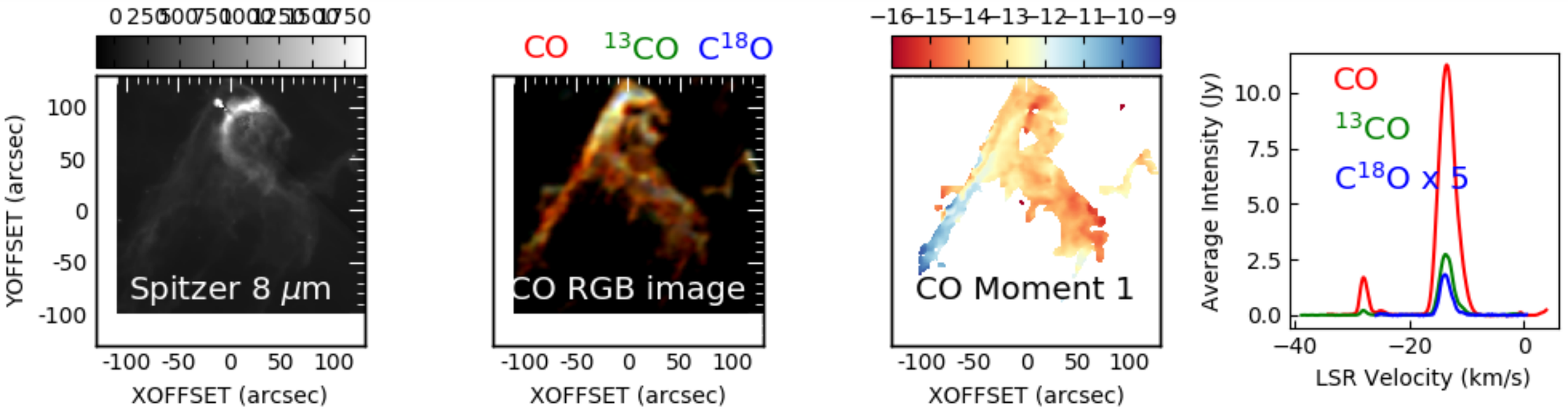
ACA observations

- Give a sense of how large these maps are… the beam is ~6” (0.066 pc)
- This map is 149 ALMA pointings (ACA PB = 45”).



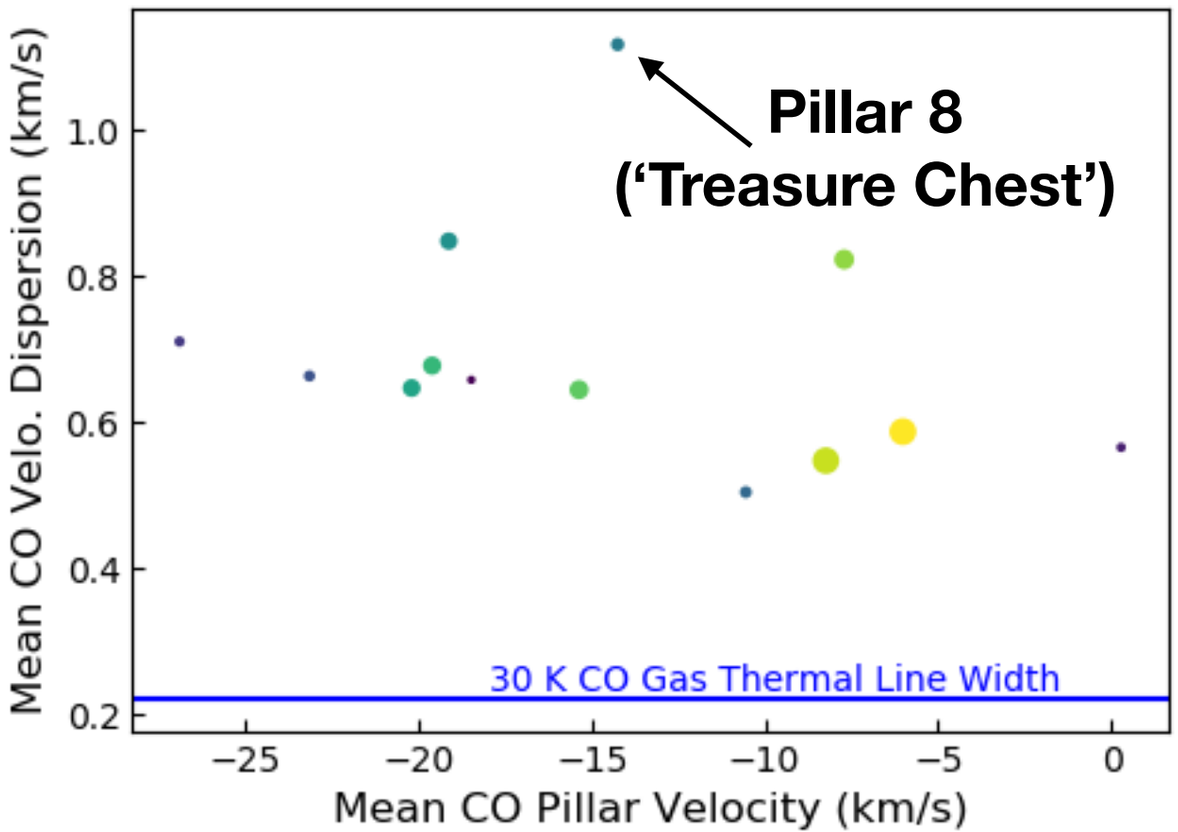
First Results

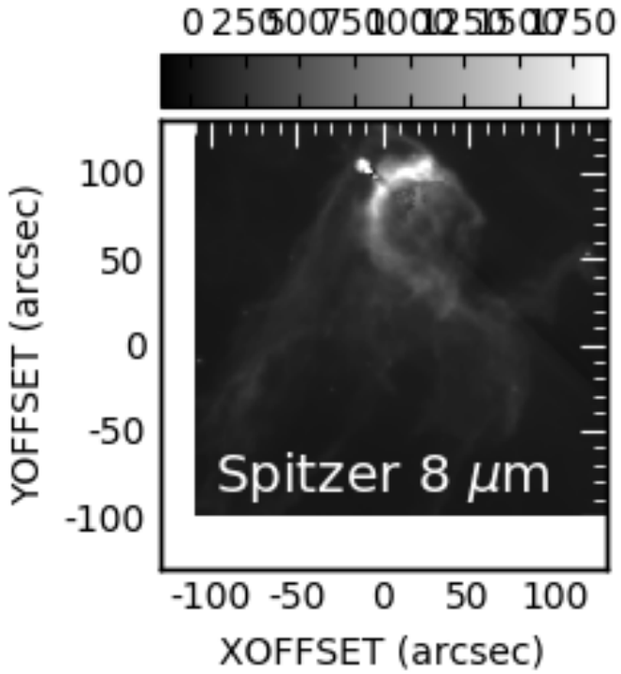


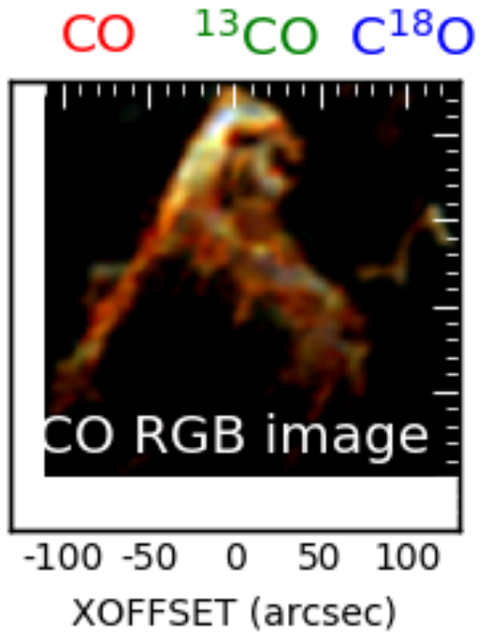


Pillar Velocity Dispersions

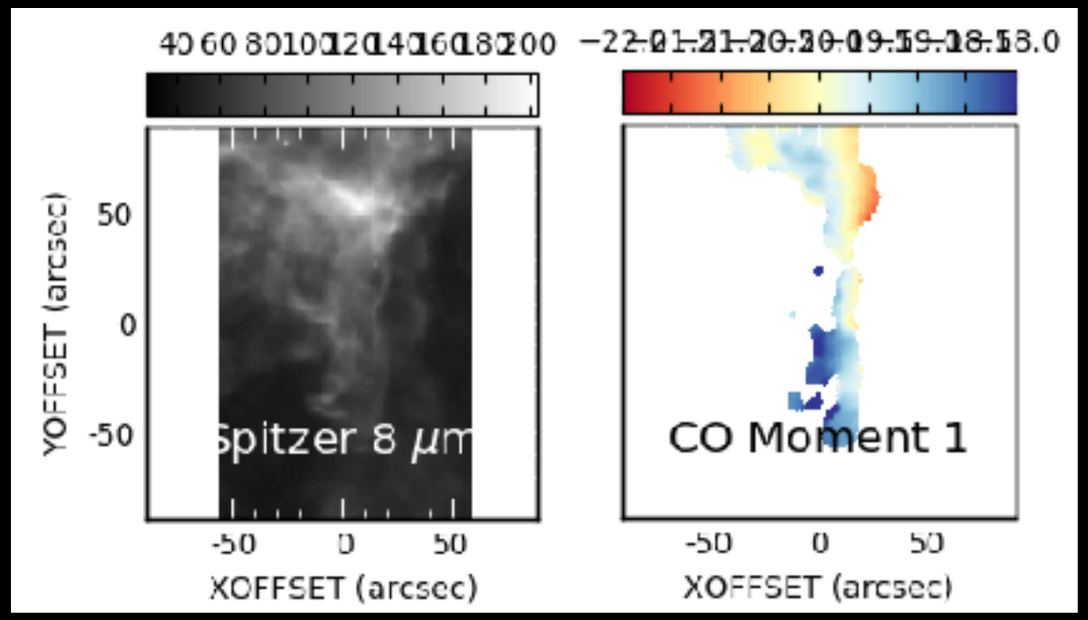
- mean line width (sigma) for each pillar
- All but one are below 1 km/s
- All show non-thermal line widths

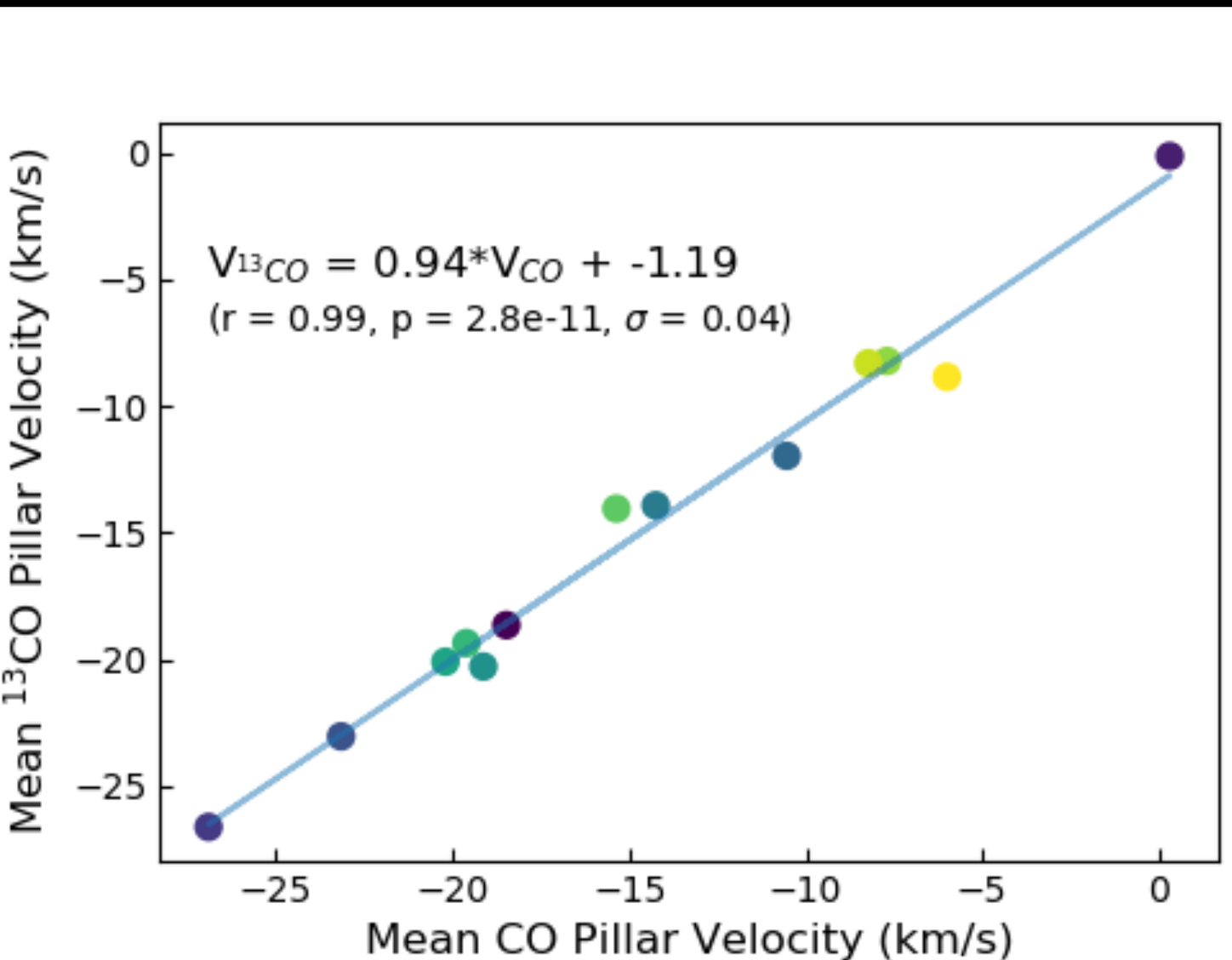






Pillar 8 has significant current star formation



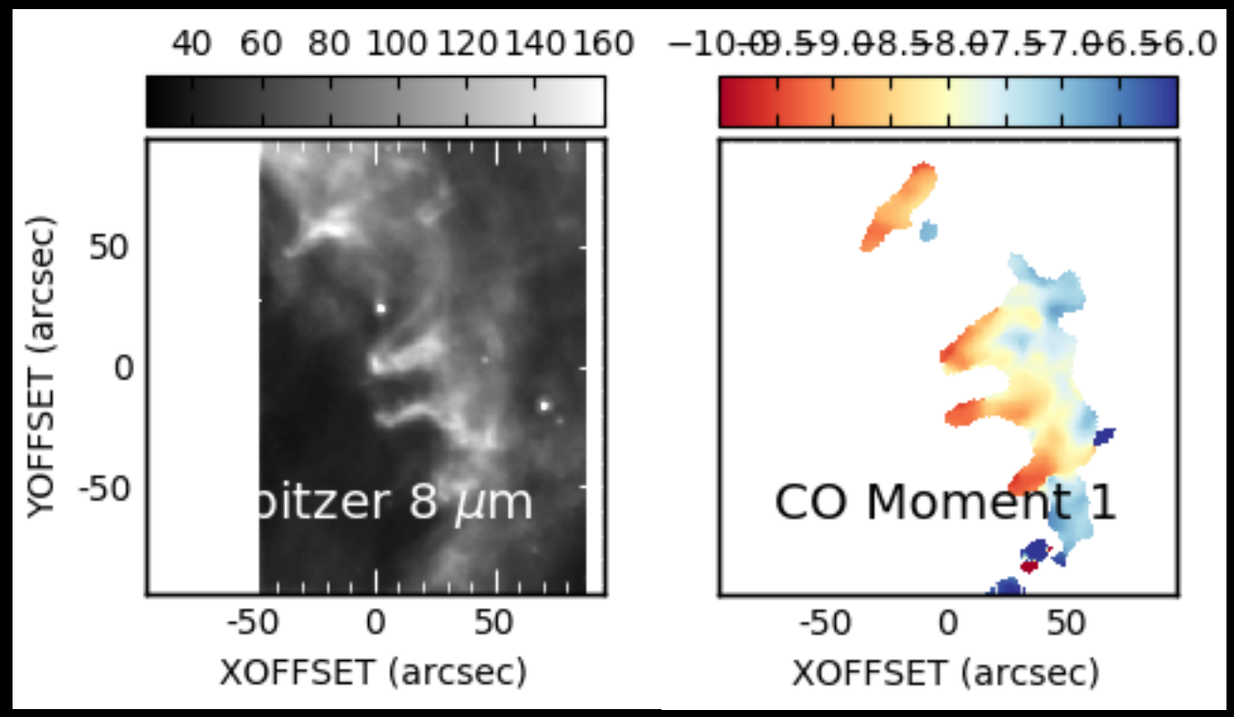


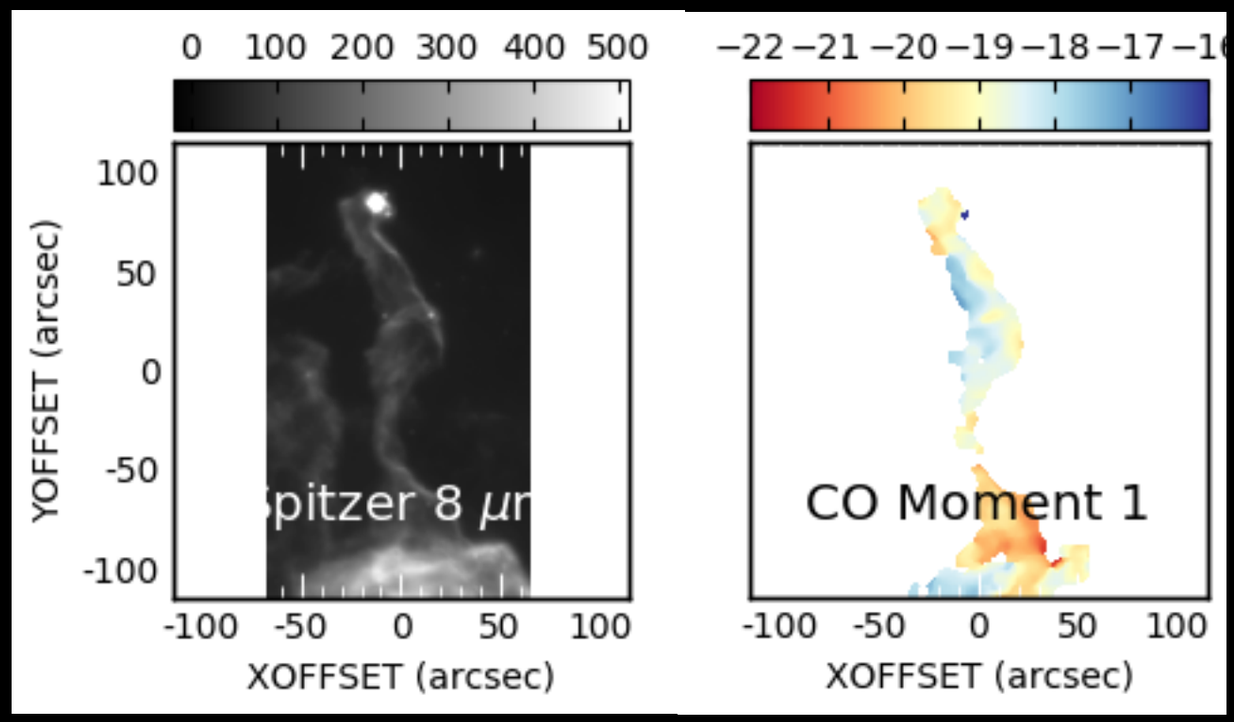
Internal Motions

- As the less abundance isotopologue ^{13}CO should trace gas deeper within each pillar
- The velocities in general seem to be consistent with each other
- The ^{13}CO systematic offset is being investigated

Pillar motion

- Dependent on environment
- (top): pillars distinct from base
- (bottom): pillar and base are at same velocity
  - but right edge is shifted (intense Ha emission at those positions)





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Other Preliminary Results

Masses of the pillars are of order 100's of M_sun

(optical depth corrected using ^{13}CO and $C^{18}O$)

Pillar	Mass $M_\odot$	Max N $10^{23}cm^{-2}$	Mean N $10^{20}cm^{-2}$	Velocity km/s
2	725.77±	5.59±0.36	17.07±0.03	-18.83
3	9665.83±	6.16±0.21	108.89±0.08	-1.04
4	319.37±	5.20±0.30	9.79±0.01	-26.02
5	38.53±	3.75±0.14	6.59±0.02	-22.38
6	51.17±	0.09±0.00	8.84±0.00	-9.61
8	1623.95±	9.04±0.50	19.34±0.02	-14.77
16	145.26±	3.26±0.26	4.02±0.01	-19.53
17	109.55±	0.02±0.00	4.23±0.00	-20.12
18	136.84±	0.04±0.00	5.81±0.00	-19.71
20	1780.25±	5.35±0.30	18.34±0.02	-13.41
22	245.18±	4.05±0.29	7.87±0.03	-7.51
44	118.16±	0.06±0.00	8.43±0.00	-8.91
45	92.71±	2.72±0.11	8.90±0.03	-5.48

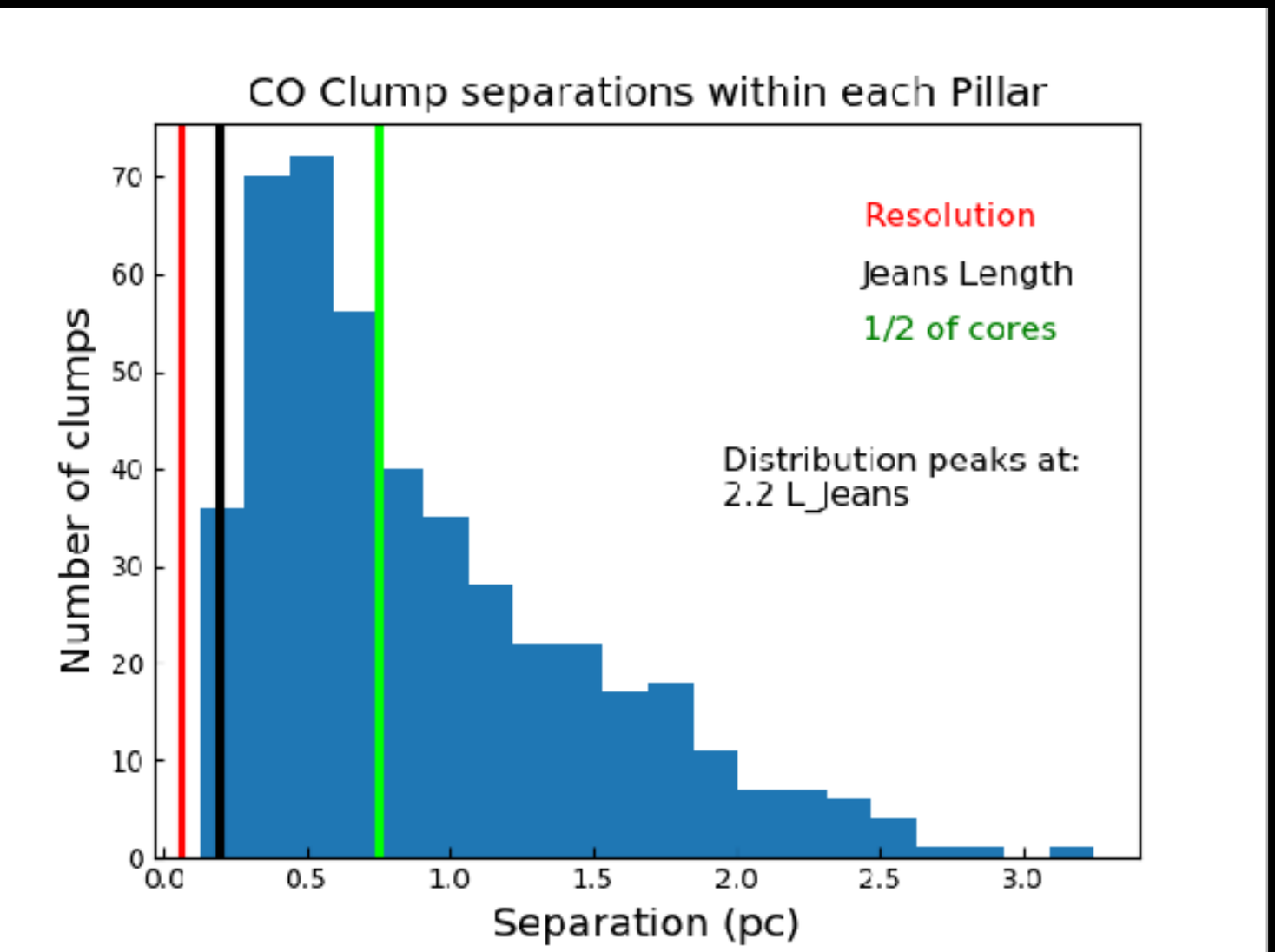
(There's a bug in the mass uncertainty estimate)

Other Preliminary Results

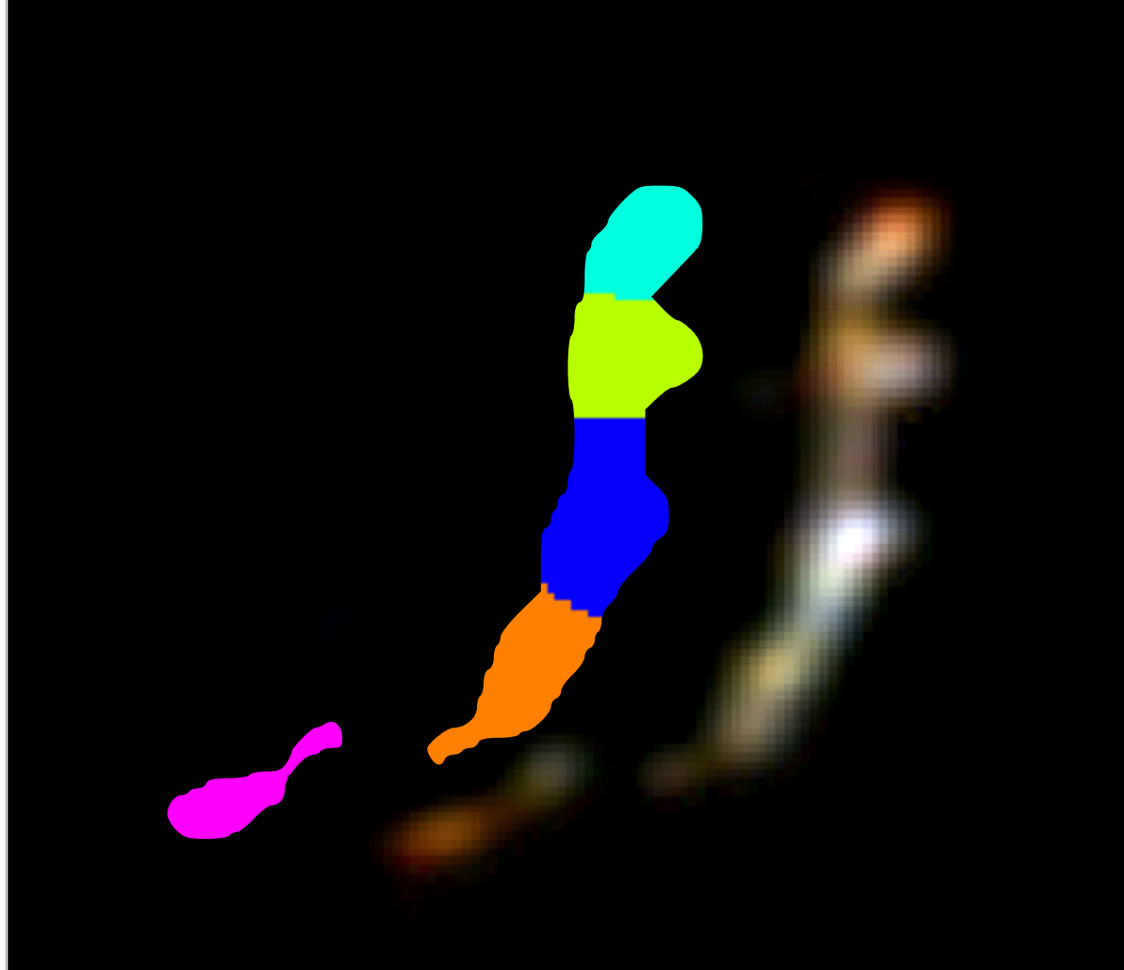
- Separations of cores in each Pillar

  Classification: Fell Walker

  Distances: Minimum Spanning Tree

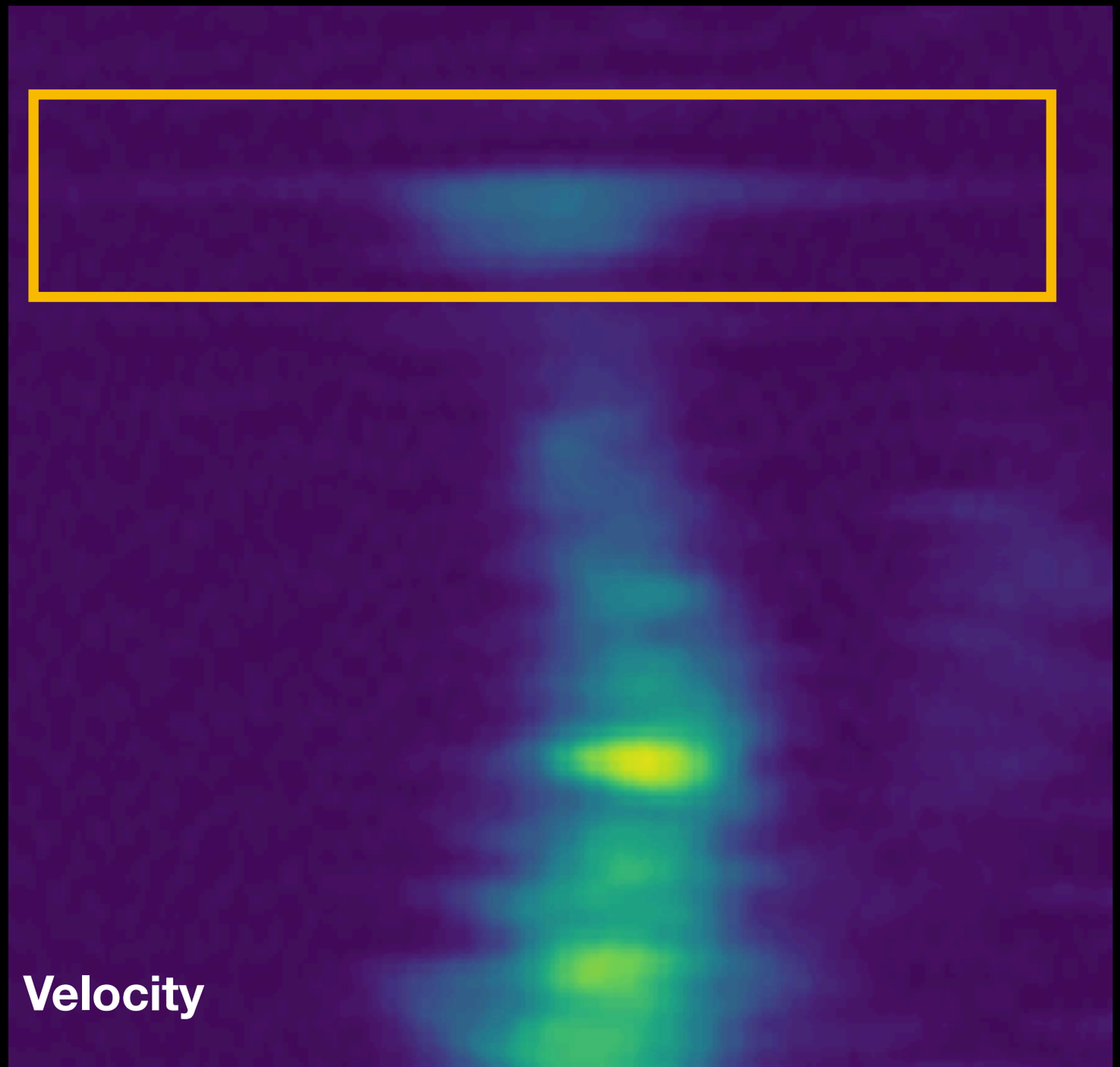


- most are < $4L_{Jeans}$
- some pillars have much more structure than others

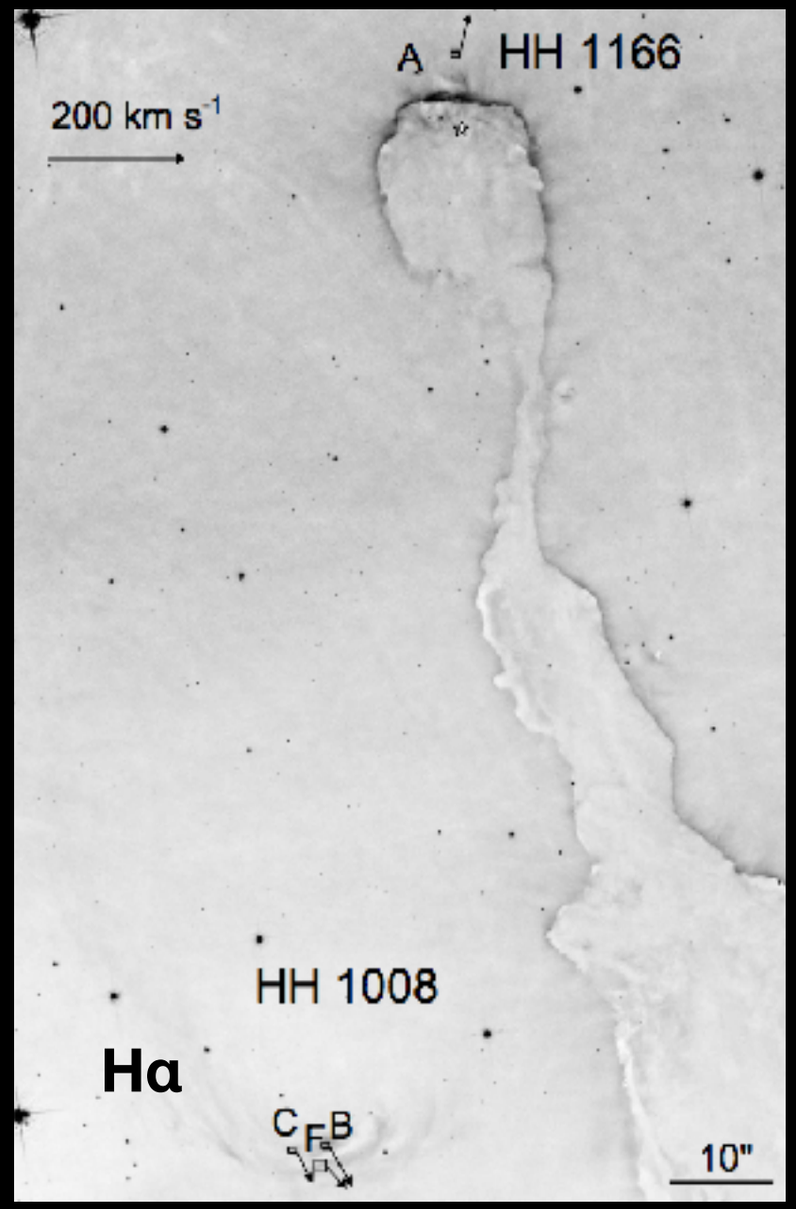


Other Preliminary Results

- High velocity dispersion at tip = CO outflow near HH object



Reiter et al. 2017



Conclusions

- Dale et al. models are most consistent with our observations
  - low velo. dispersions
  - no internal flows
  - some motion relative to rims
- Each (<~ 1pc) pillar has a few hundred M_sun of material
- cores in the pillars are separated by ~2-3 Jeans Lengths

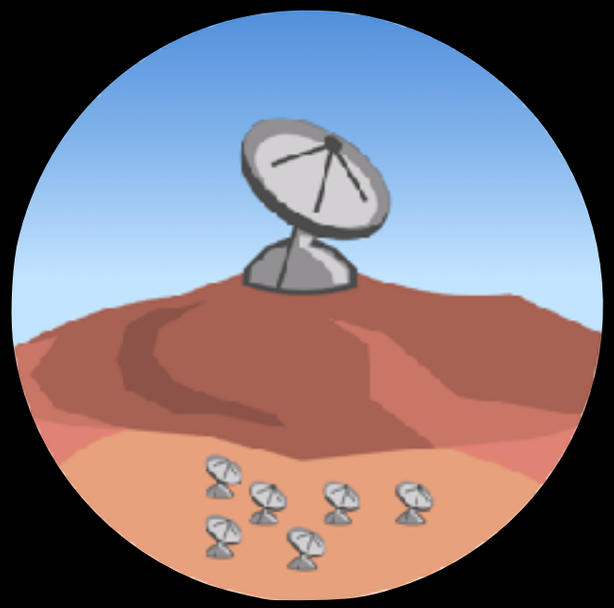
*to be proposed for

Next Steps

- Better understand the relationship between outflows and HH objects in these pillars

- Quantify the PDRs at the edges of each pillar

- comparing our data to MUSE, HST, JWST (GTO & ERS), and ALMA [CI]*



Long term: Map the whole region with a 50m class sub-mm telescope at the ALMA site

Atacama Large Aperture sub-mm telescope (AtLAST)

Science Workshop Sept 10-13
Royal Observatory Edinburgh