Kinematics at different scales on ATLASGAL TOP-100 sample

Thanh Dat Hoang[1]
Friedrich Wyrowski[1], Min-Young Lee[2], Karl Menten[1]

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Max-Planck-Institut für Radioastronomie
UNIVERSITÄT BONN
IMPRS astronomy & astrophysics Bonn and Cologne

[1] Max Planck Institute for Radio Astronomy
[2] Korea Astronomy and Space Science Institute

Outline

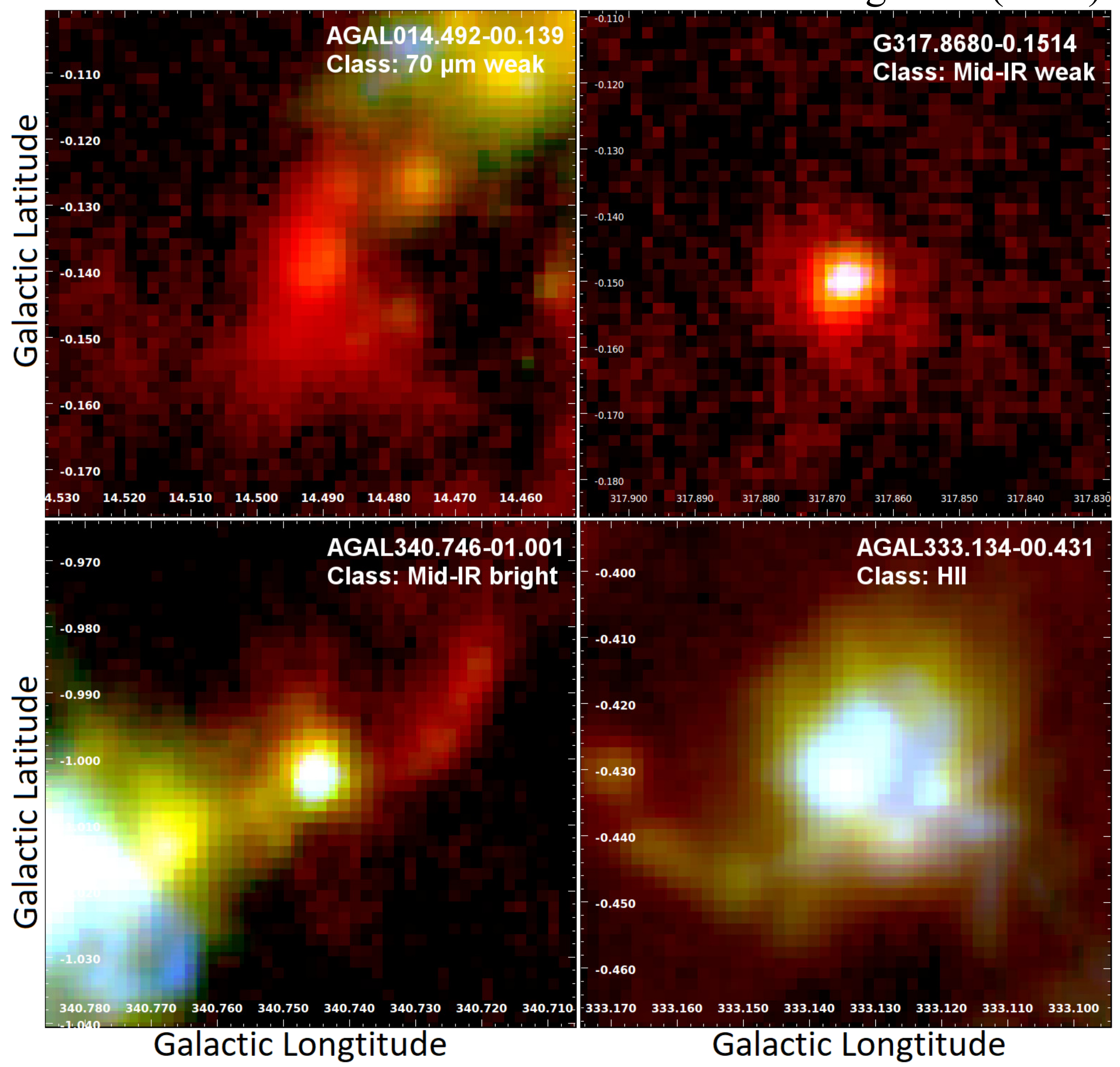
- The sample
- Observation of the warm gas envelope + results
- The case of low-mass star formation
- Association with bipolar outflows
- Association with larger scale environment (SEDIGISM data)

The ATLASGAL survey and TOP100 sample

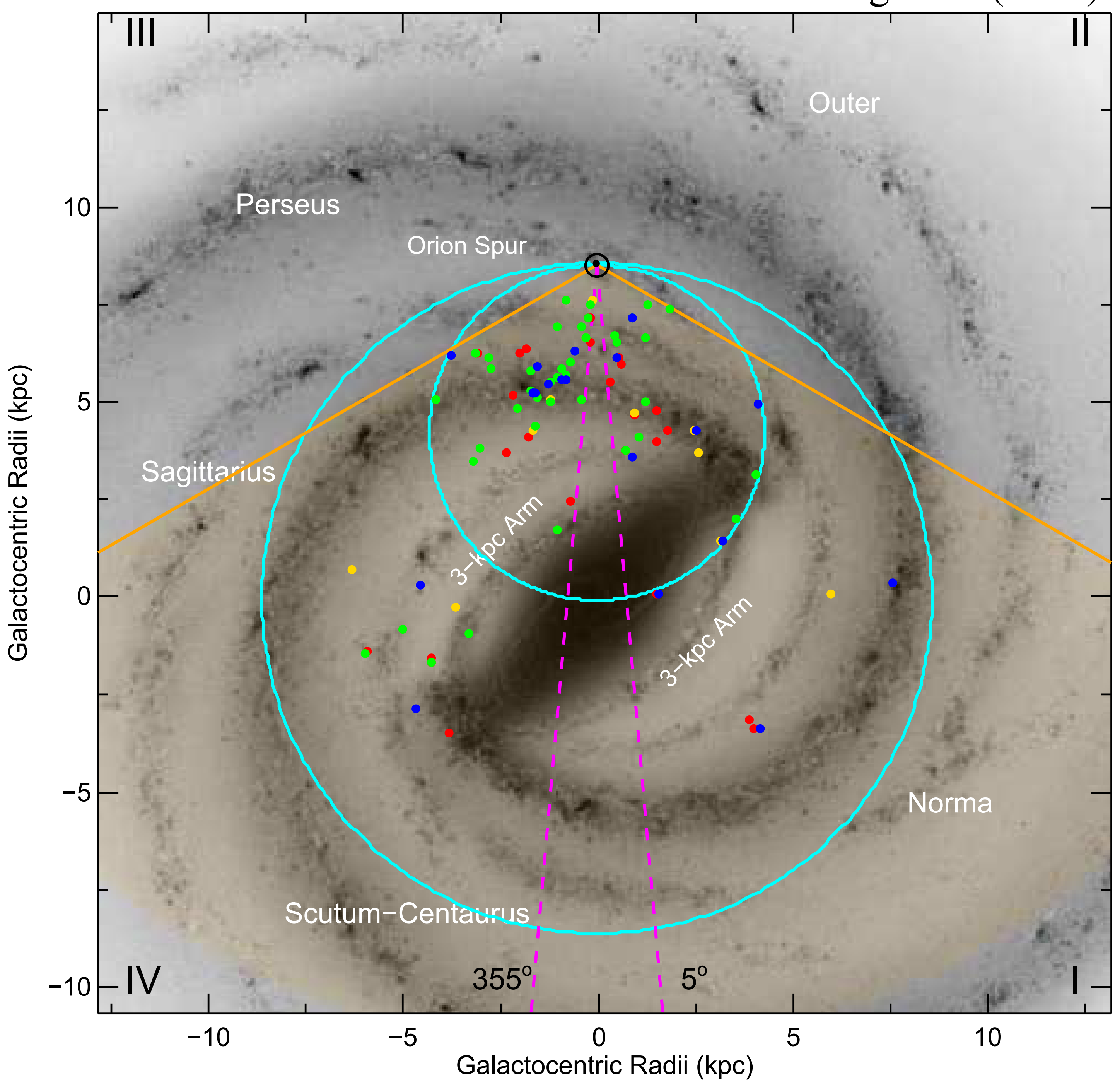
Schuller et al. (2009)

- TOP100 sample: 111 brightest sources from different stages
- Distance: 1-13 kpc
- Four evolutionary stages:
  + Starless/pre-stellar
  + Protostellar
  + High-mass protostellar
  + HII regions

König et al. (2017)



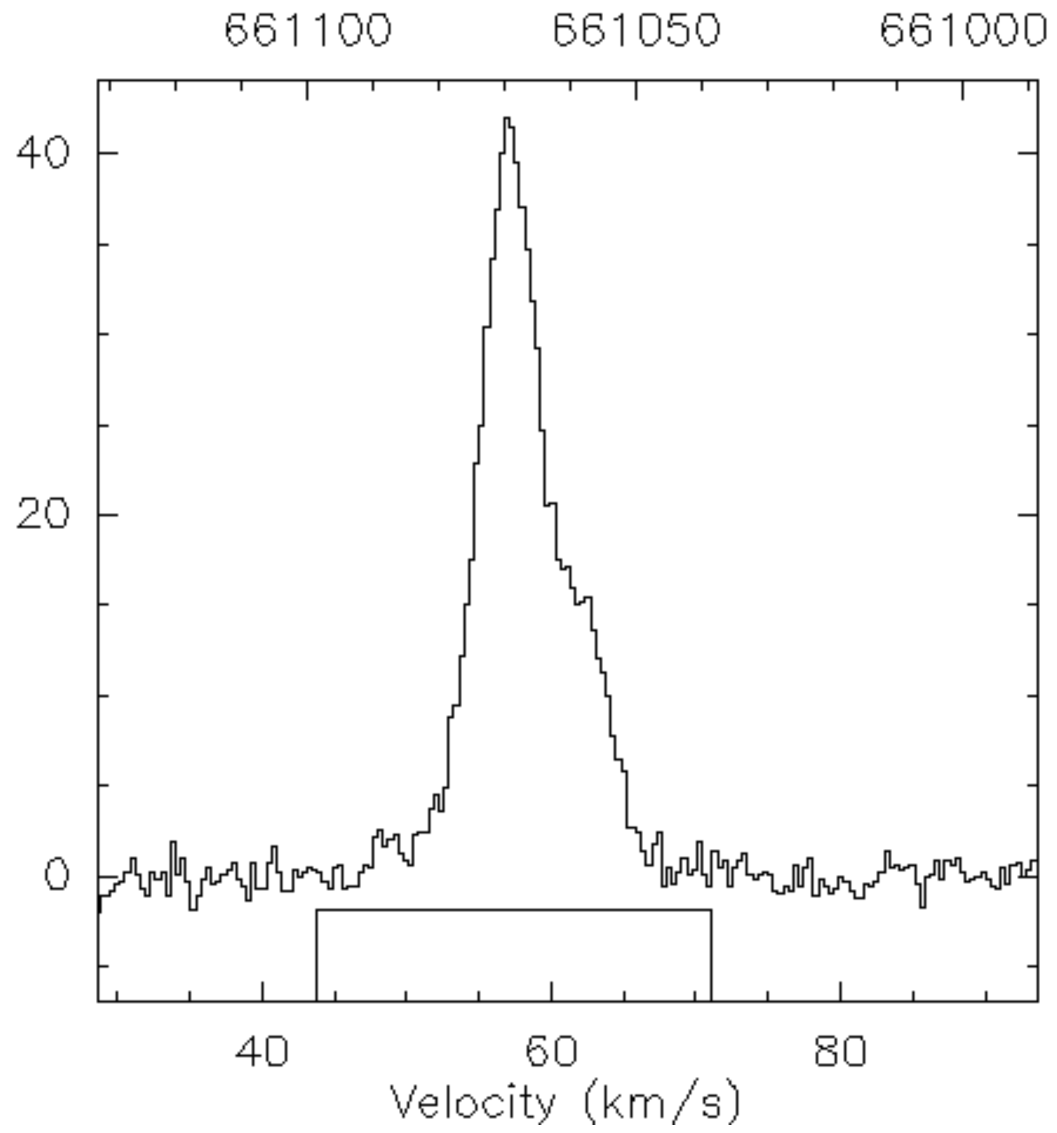
König et al. (2017)

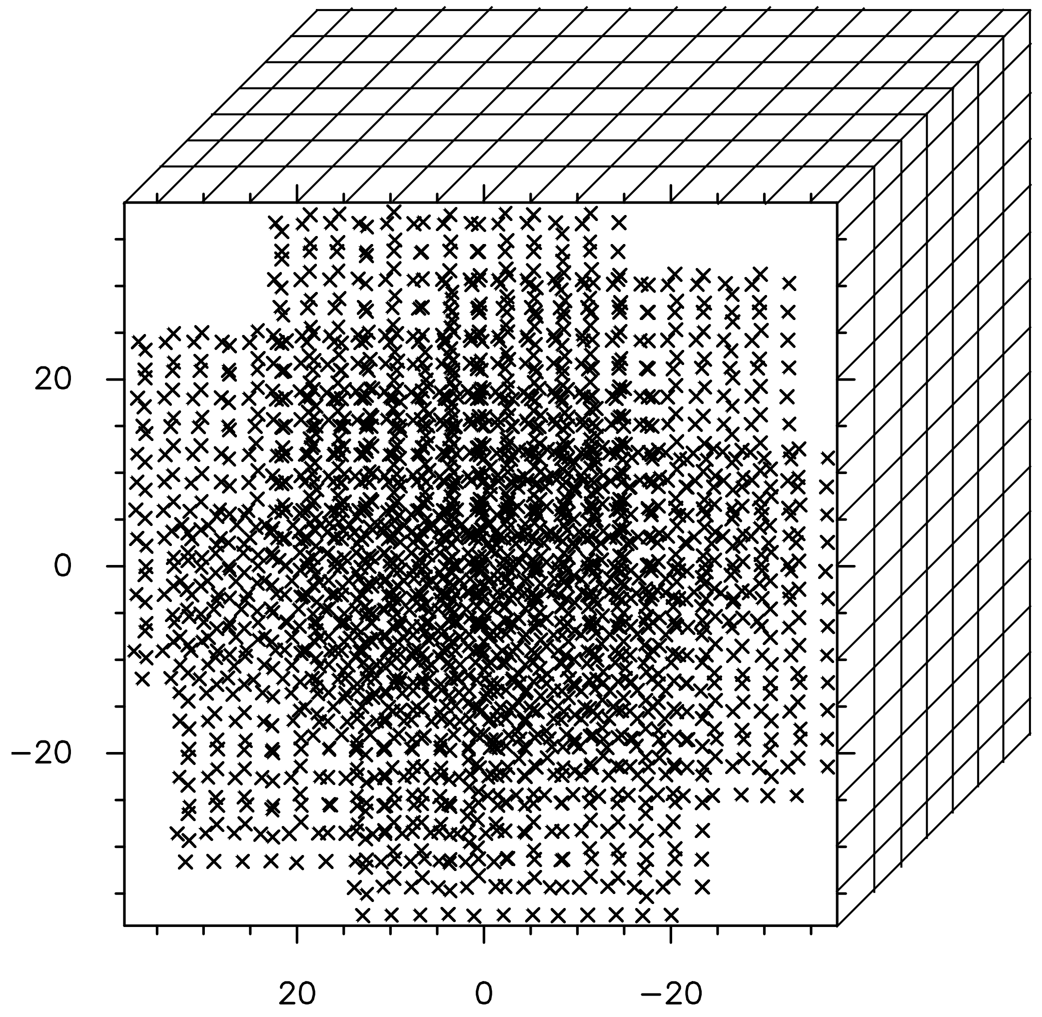


Inner envelope: observations + results

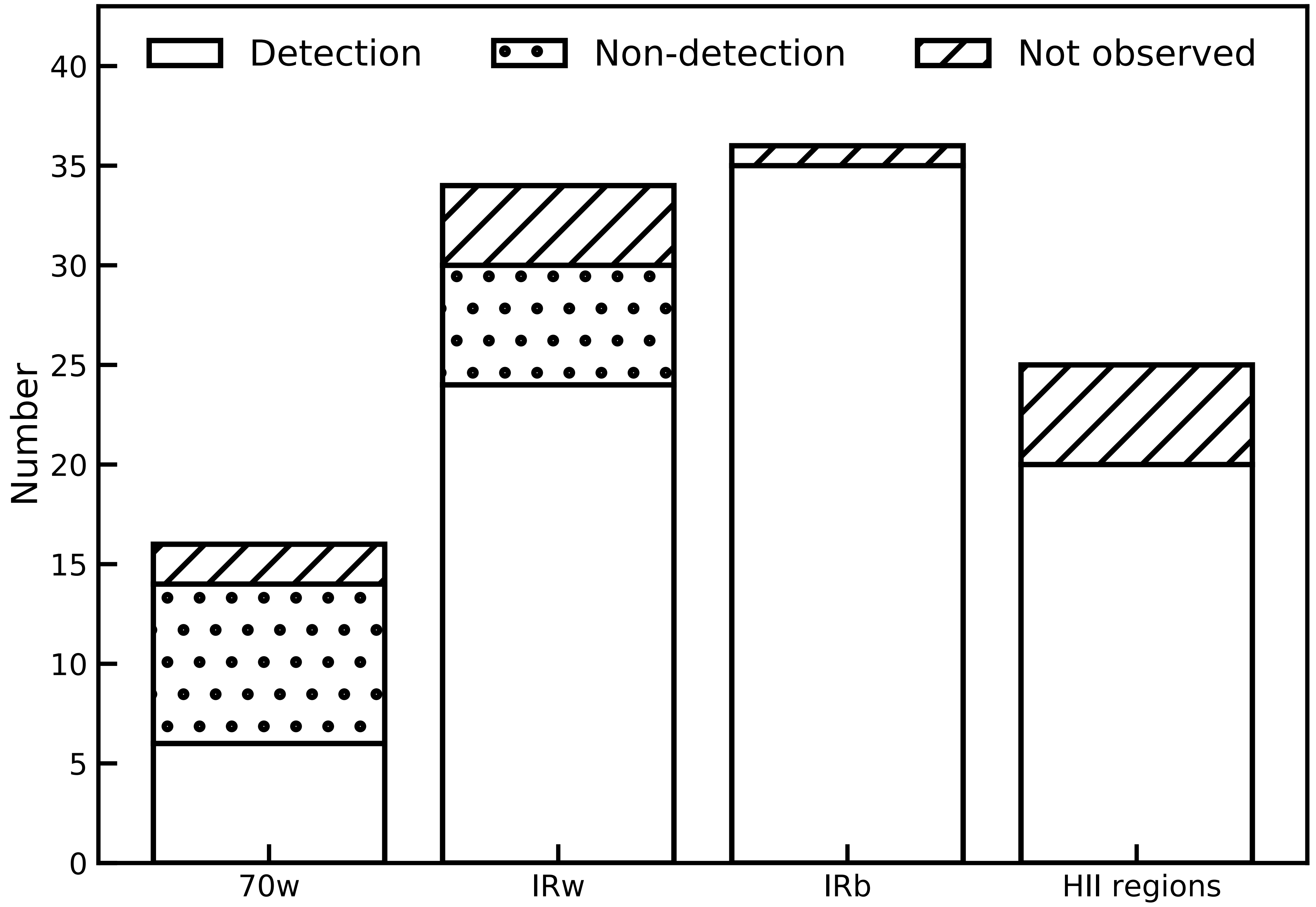
- Our target: inner warm envelopes of
  => trace star-forming activities and stellar feedbacks

- Using Champ$^+$ MPIfR PI receiver at APEX telescope:
  => We observed ^{13}CO J=6-5 + $C^{18}O$ J=6-5
  => Navarate et al. 2019 observed CO J=6-5 to study outflow properties





Linear map size: 0.7 - 4 pc



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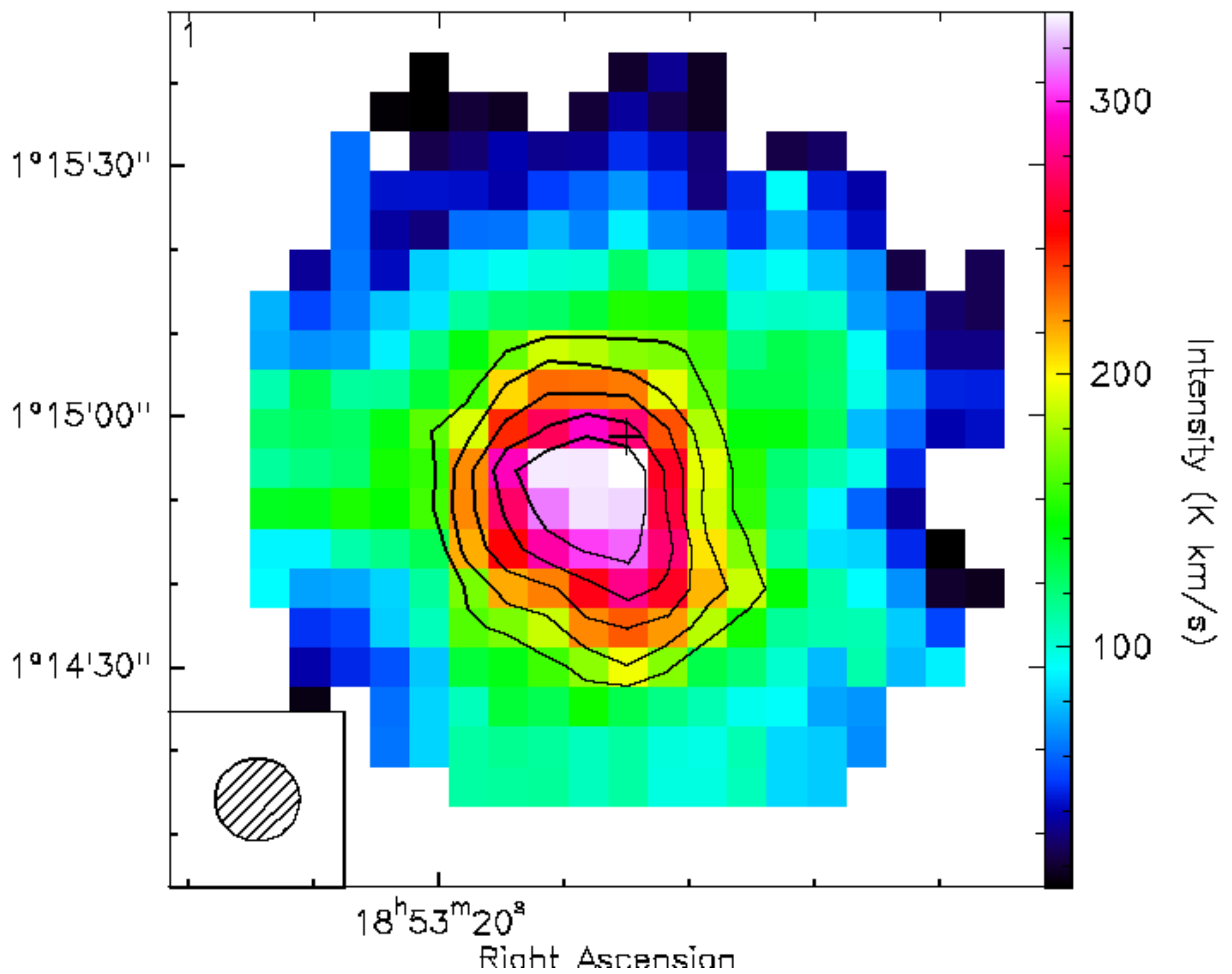
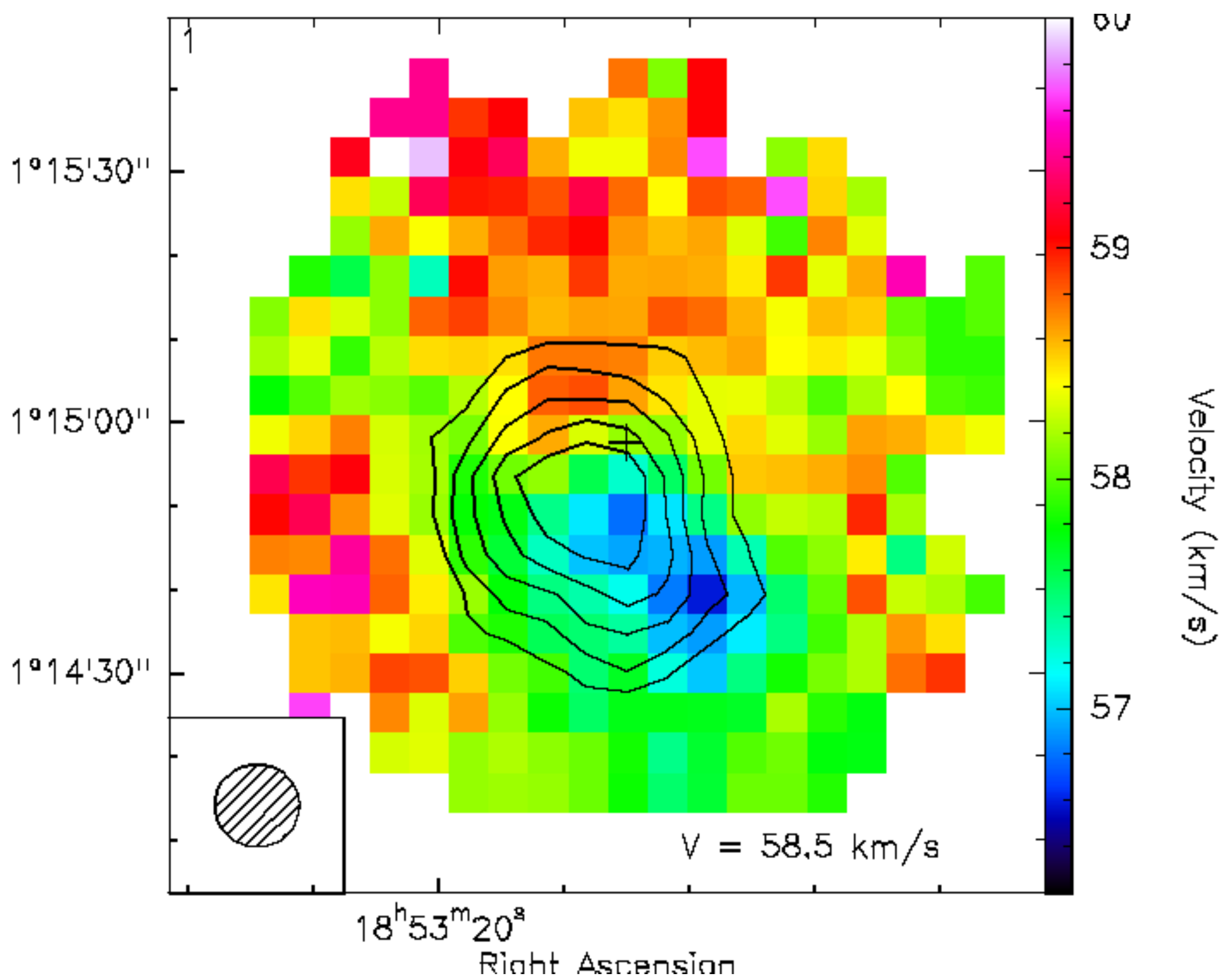
- Moment maps:

M_0



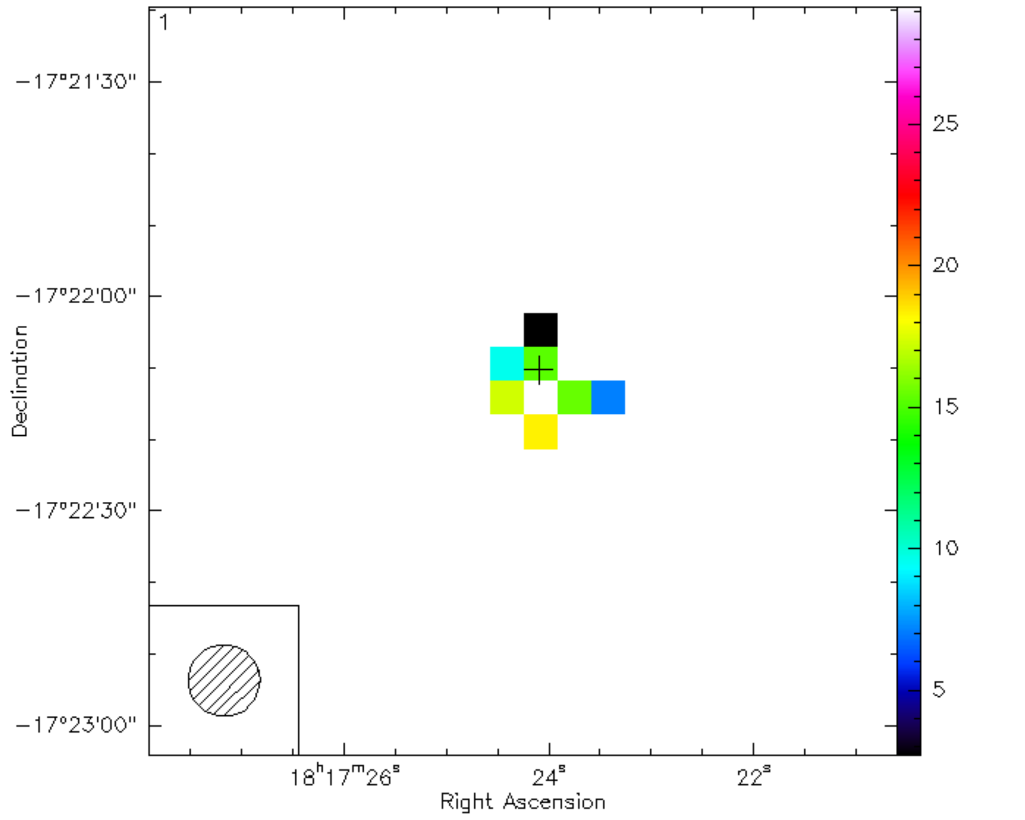
M_1



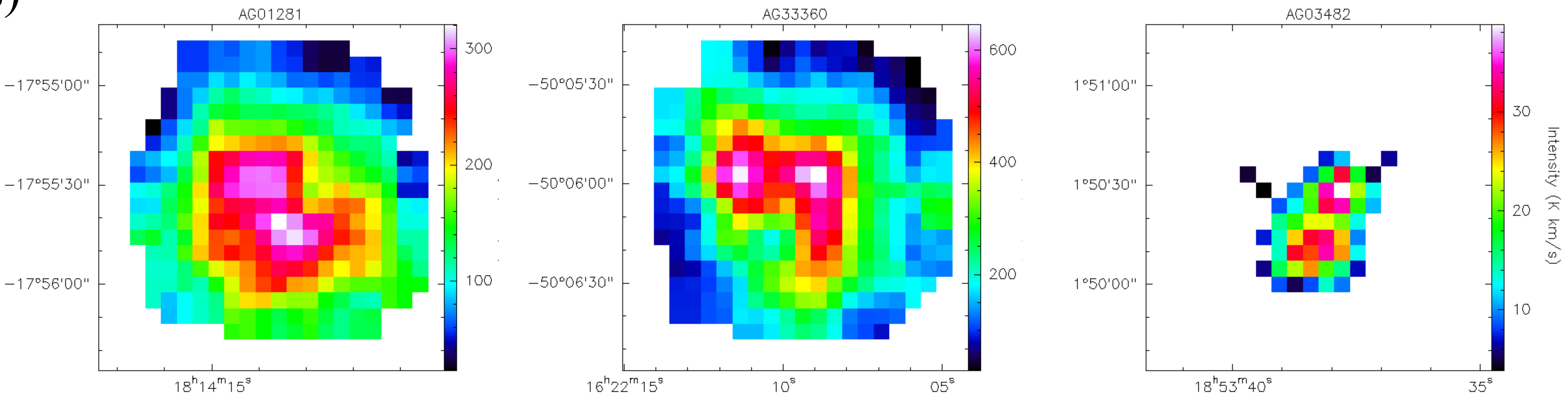
For kinematics study

Intensity maps

- Unresolved (24 sources): detected area < 4 beams

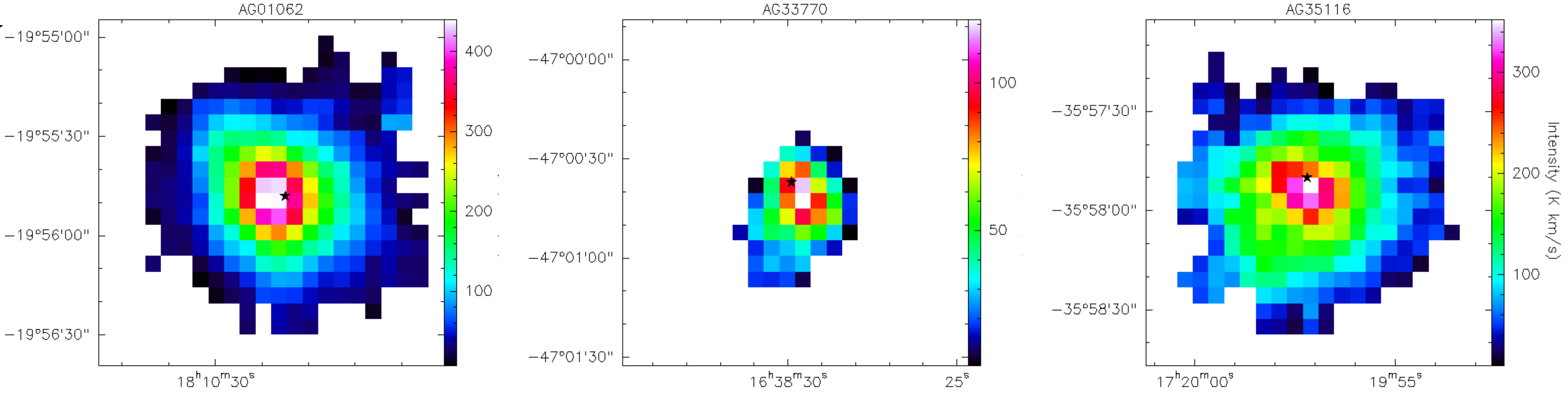


- Multiple cores (8 sources)



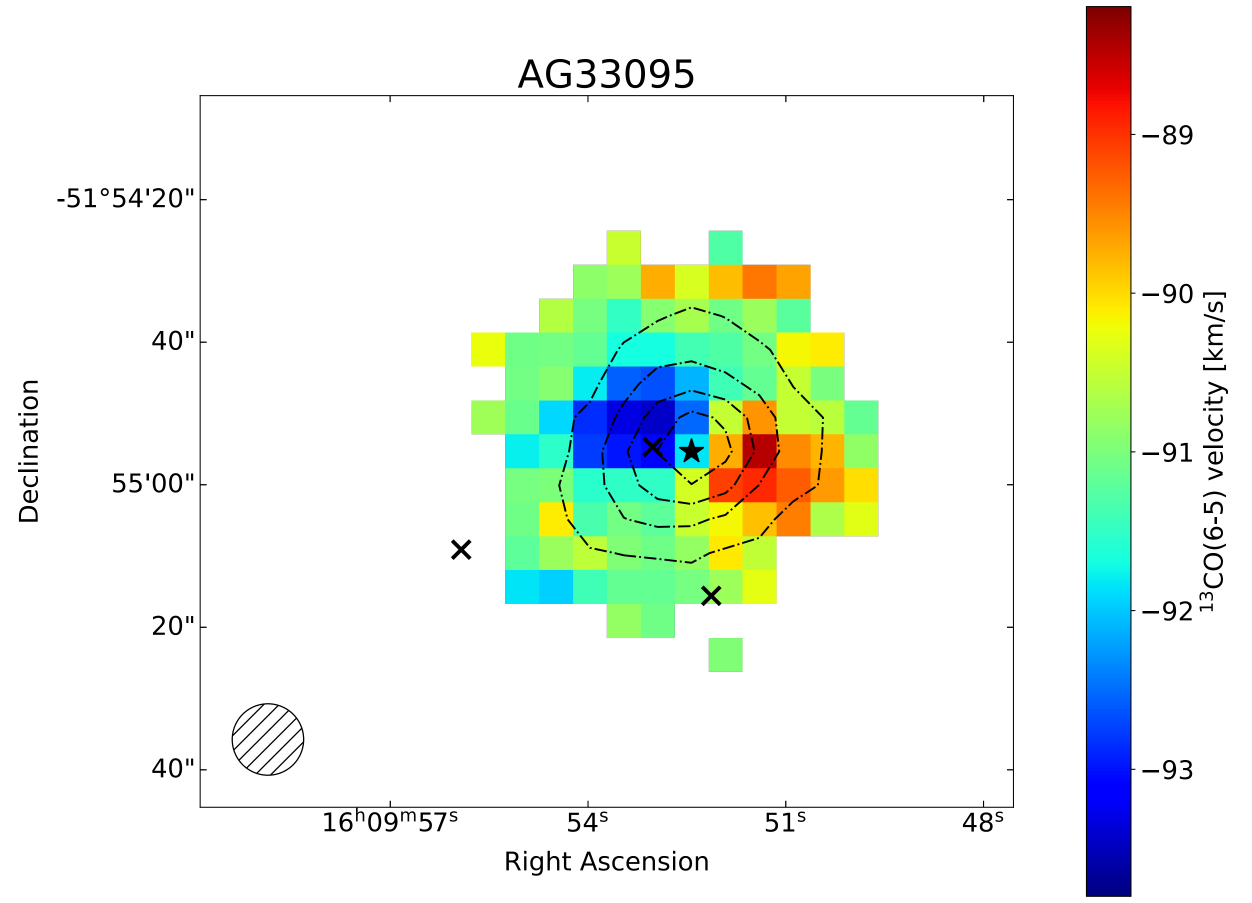
- Single core (51 sources) => further analysis

=> only HII, IRb, and IRw

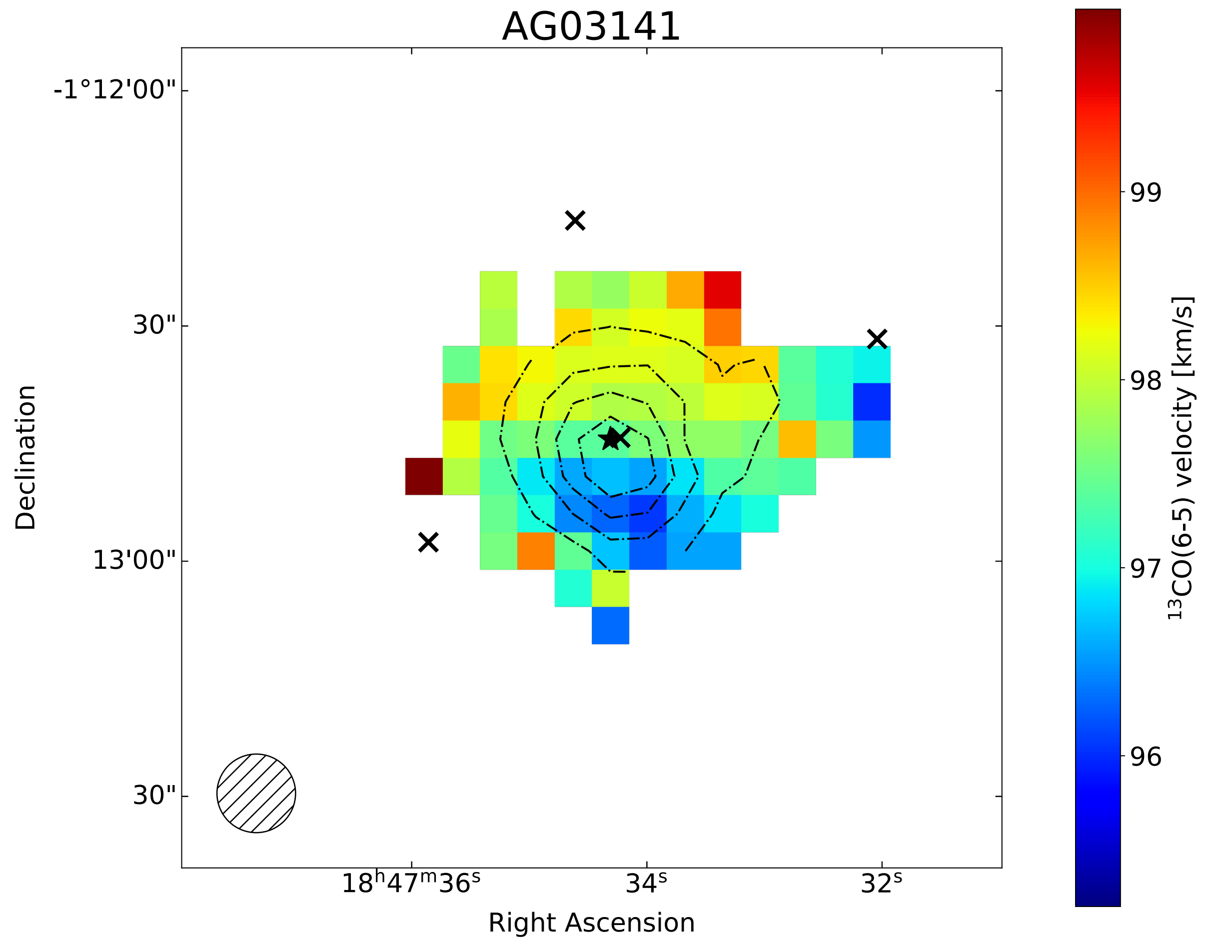


Velocity maps

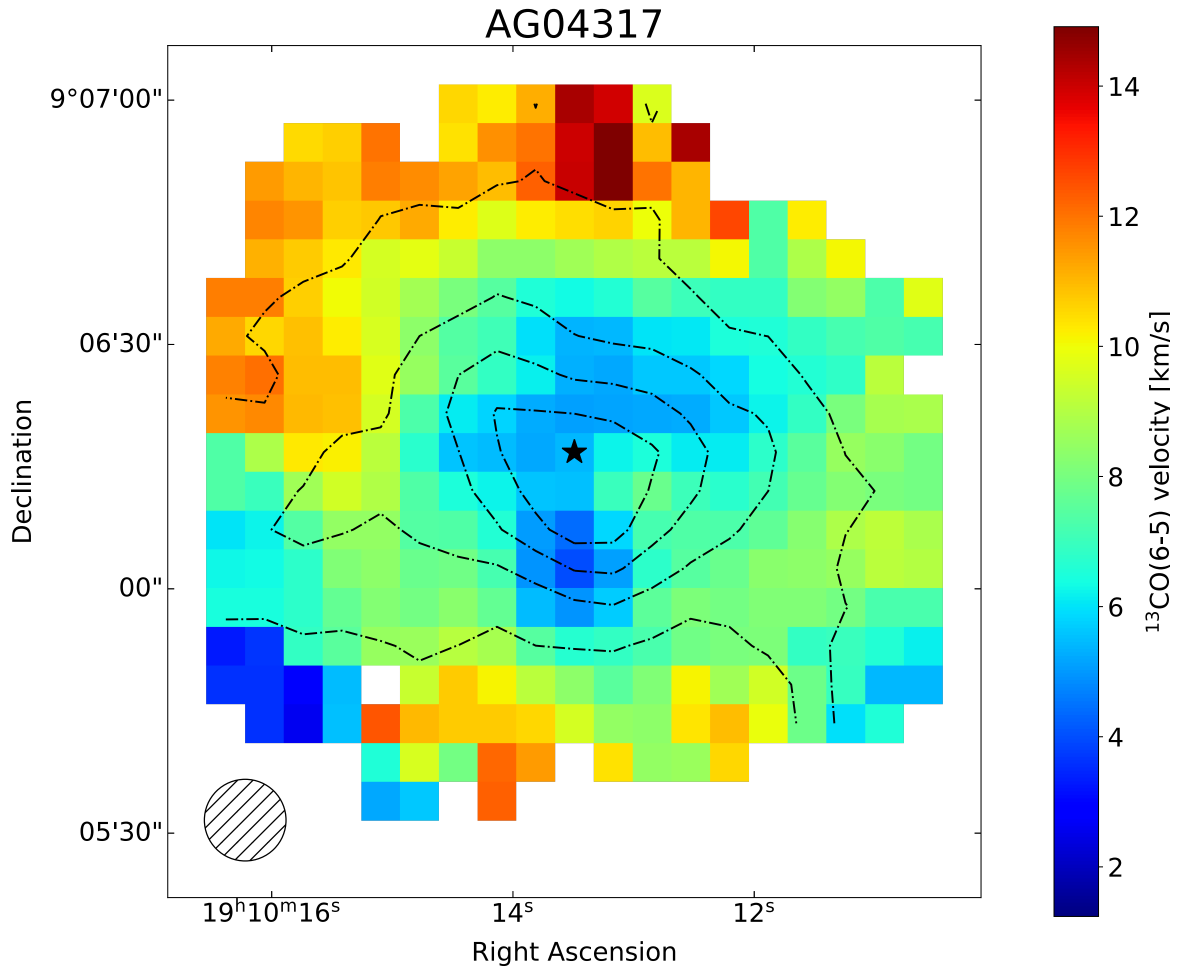
- 51 sources: mostly HII regions and IRb sources
- Visual inspection of M1 maps => multiple different behaviours:



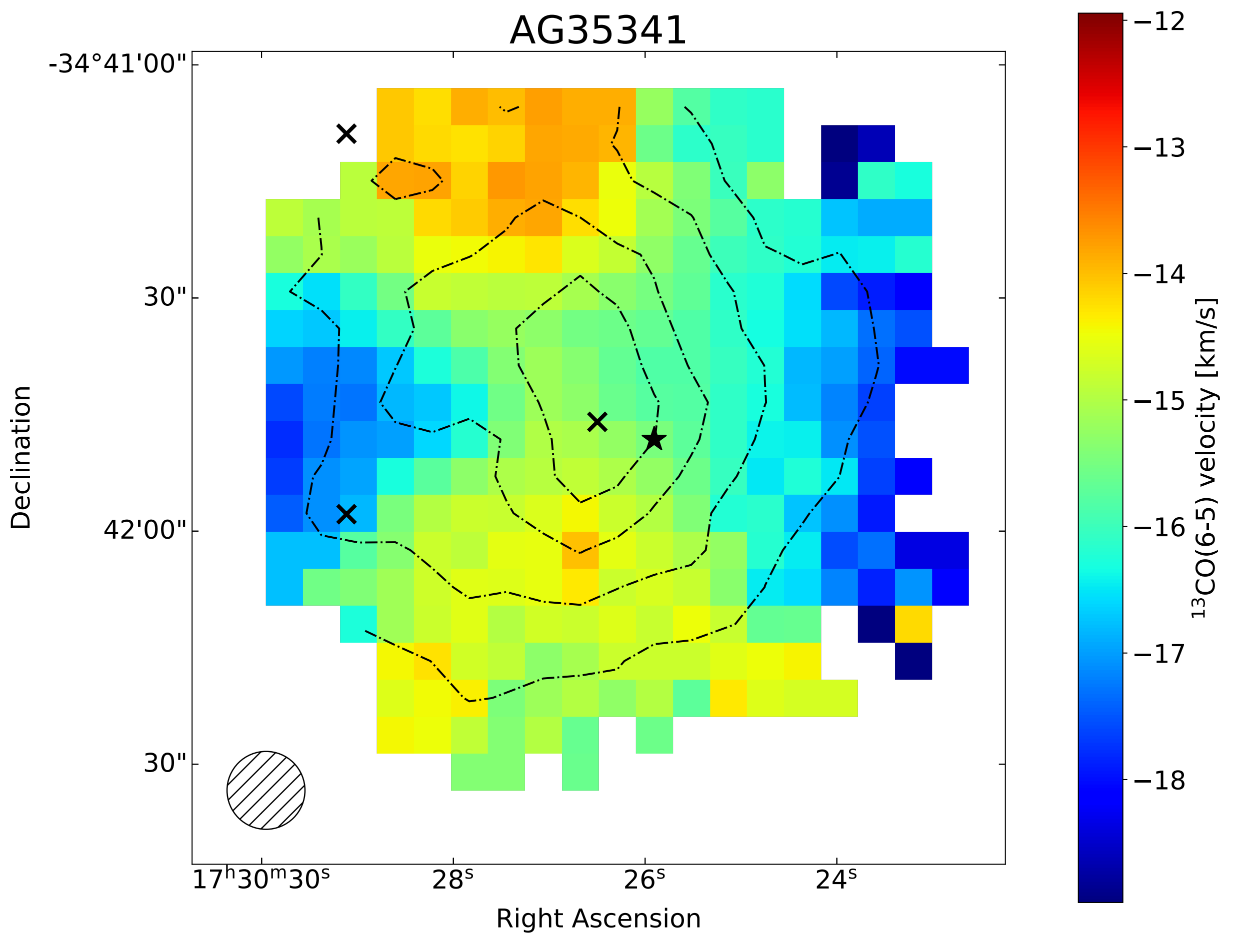
Outflow-like



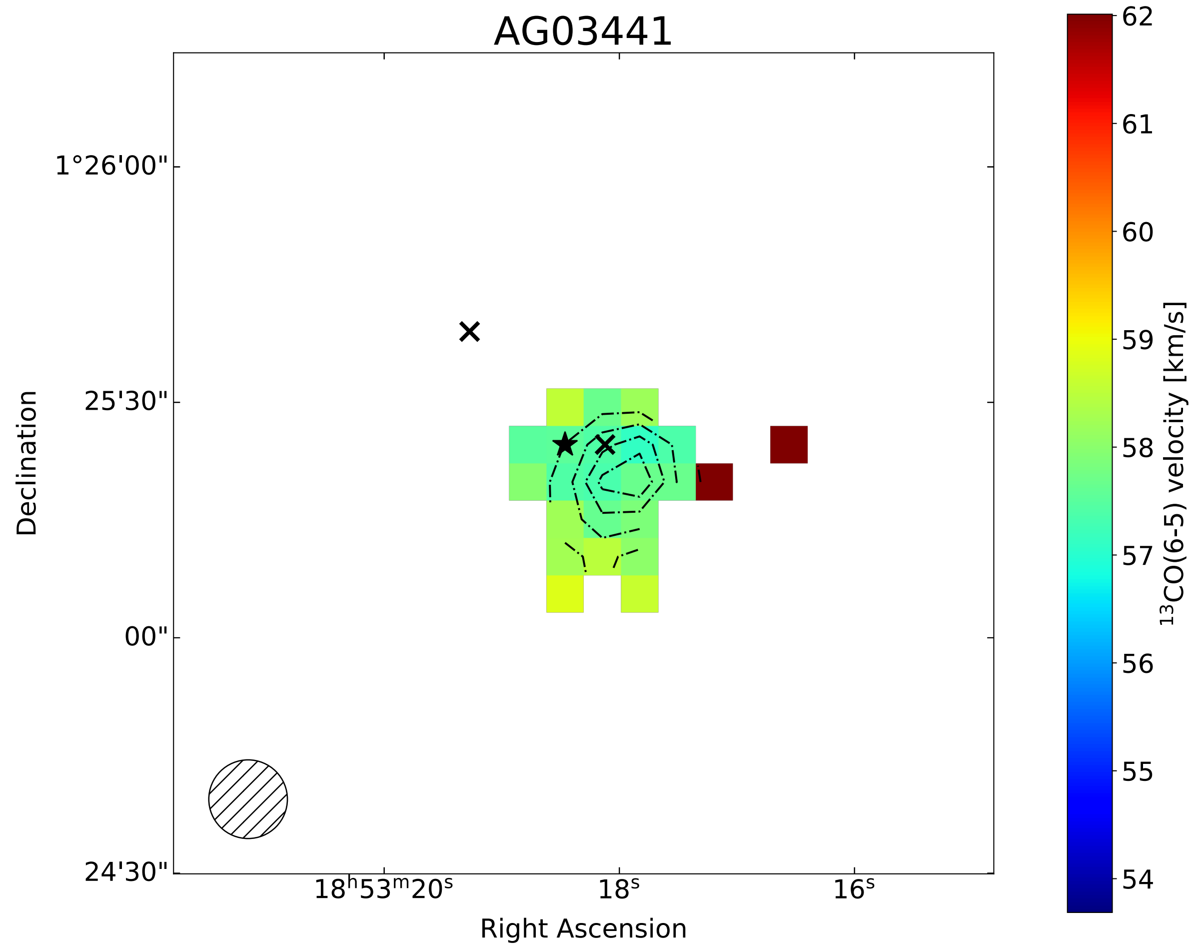
Gradient across peak



Localised velocity field



Hour-glass shape

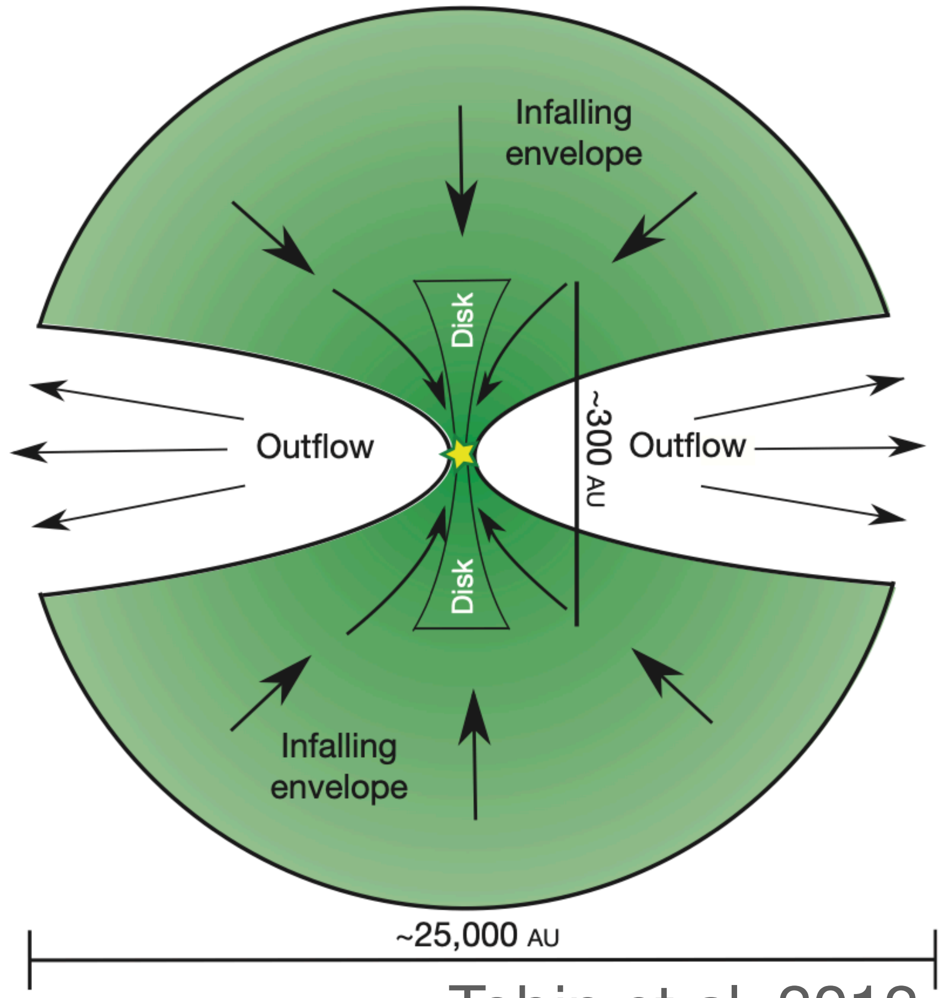


Quite plane

=> The warm gas traced by 13CO(6-5) moves differently from source to source

What is regulating the envelope kinematics?

- The envelopes in our sample is on scale 4 to 0.2 pc (effective size)
- Looking at the envelope in low-mass star-formation (LMSF) scenario



Tobin et al. 2012

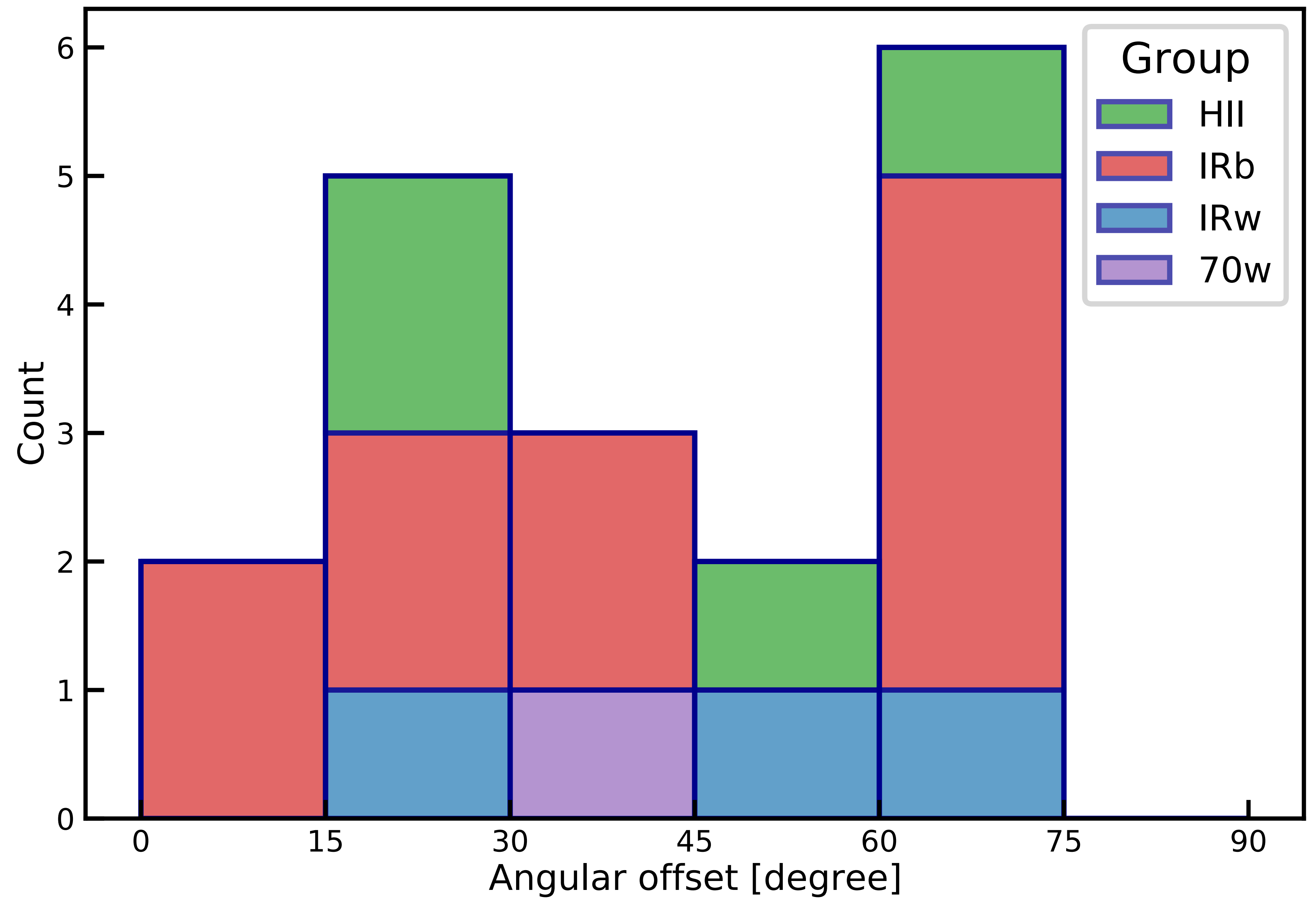
- **Envelope is on a small scale < 0.1 pc**
- **Envelope of class 0 protostar show a combination of both infall and rotation (Tobin et al. 2011)**

- Study of disk in high-mass star-formation (HMSF) found rotating disk/toroid as large as 22,000 AU (~ 0.1 pc) (Beltran et al. 2011)

=> Do inner envelopes in HMSF regions exhibit infall and rotation like the envelope of LMSF?

Association with outflows

- Fit MVG function (Goodman1993) on M1 maps and select 43 sources with gradient larger than 3-sigma
- Compute the difference between MVG and outflow (taken from Felipe) direction at 18 sources:



- Angular offset > 45 degree: 8 sources
- Angular offset < 45 degree: 10 sources

=> Binomial distribution test: p-value = 0.81

=> in general, the envelope is not rotating about the outflow axis. It's not necessary that it is not rotating at all

If the envelope is indeed rotating, our results could imply that the rotating axes change from envelope scale to disk scale

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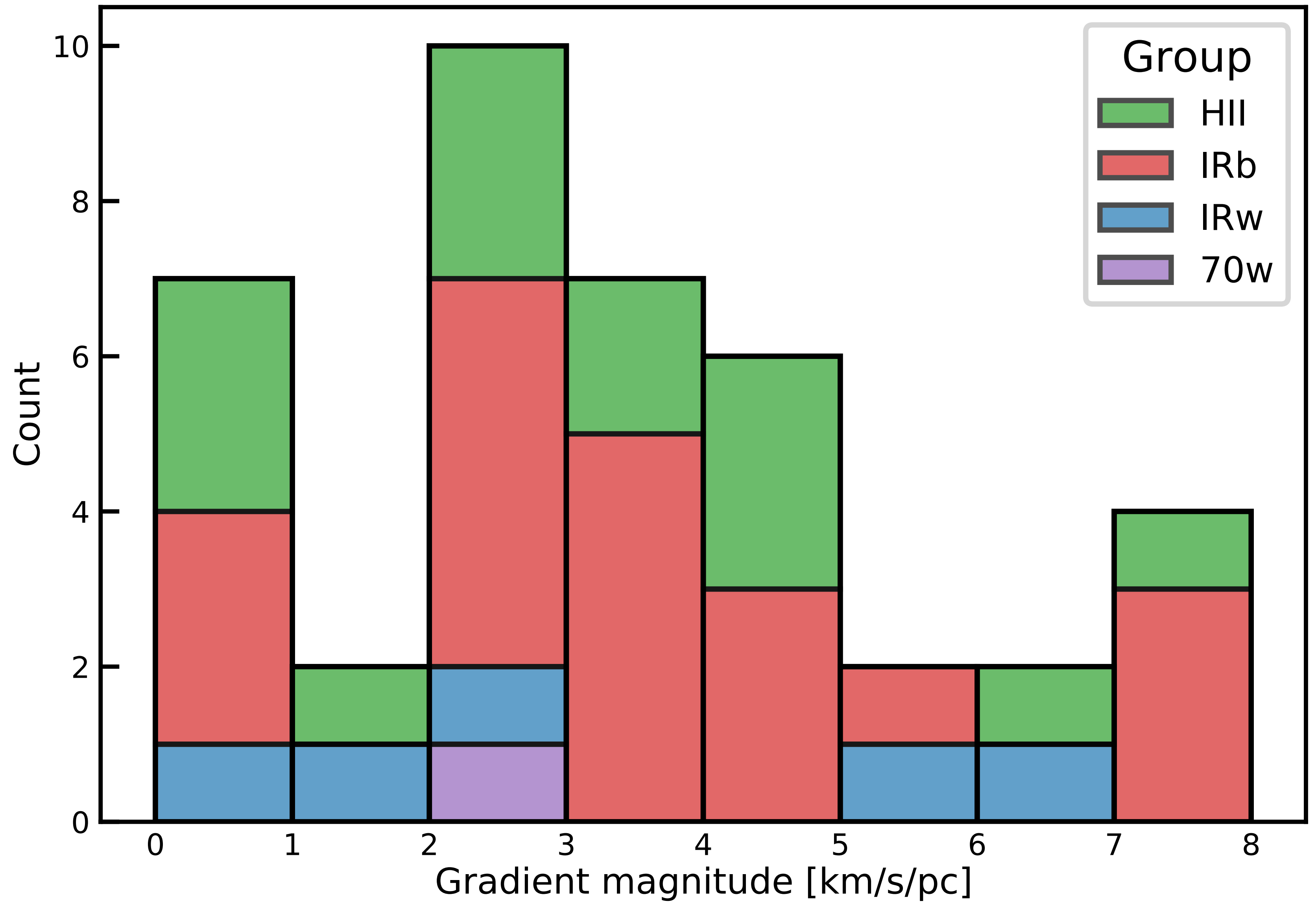

- MVG magnitude is in range: 0.4 to 8 km/s/pc except for one source whose magnitude is 20 km/s/pc
  => mean = 3.2 km/s/pc
- Tobin et al. 11 finds average MVG of class 0 protostar's envelope at 2.3 km/s/pc
  => close to our result

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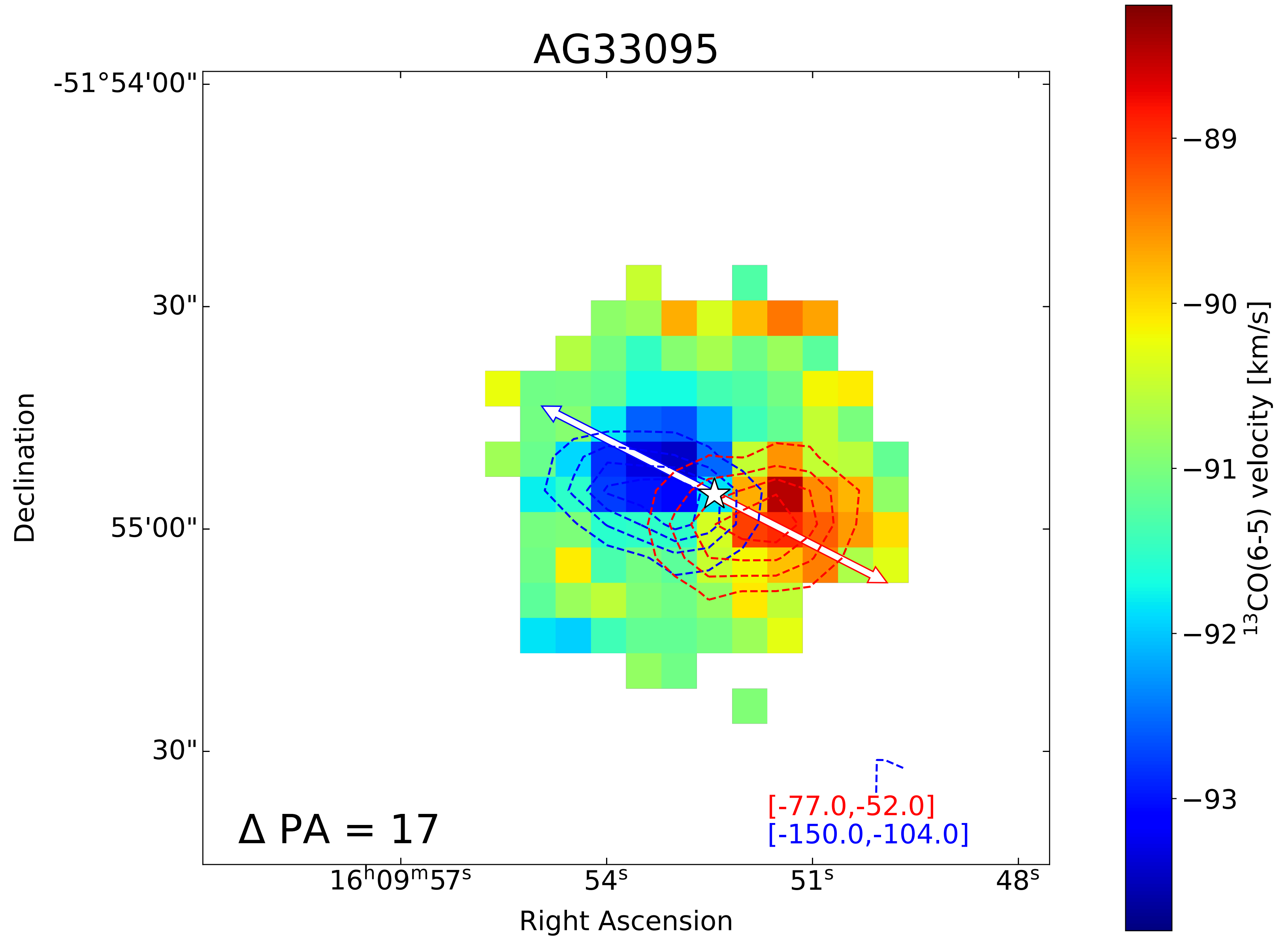
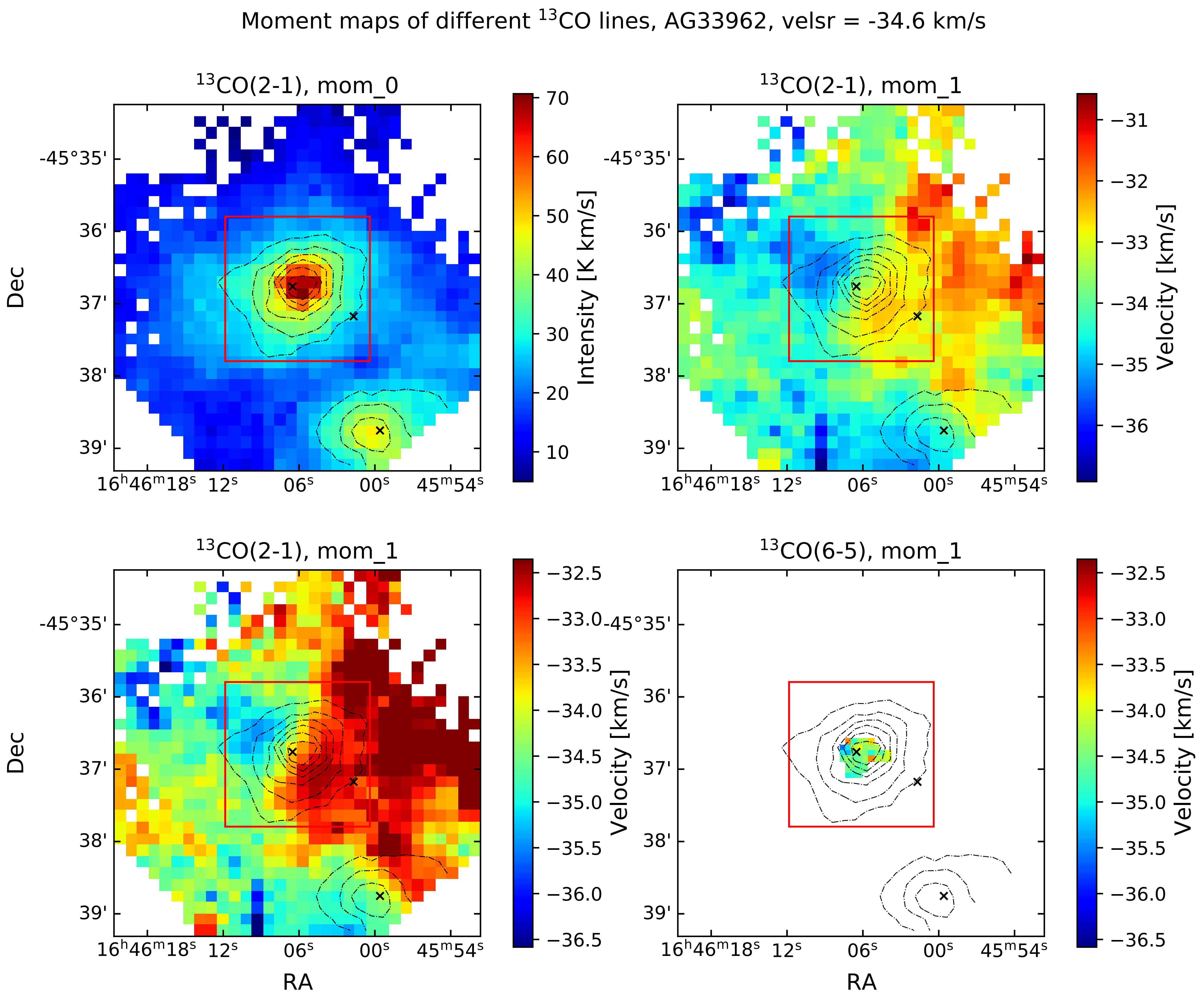


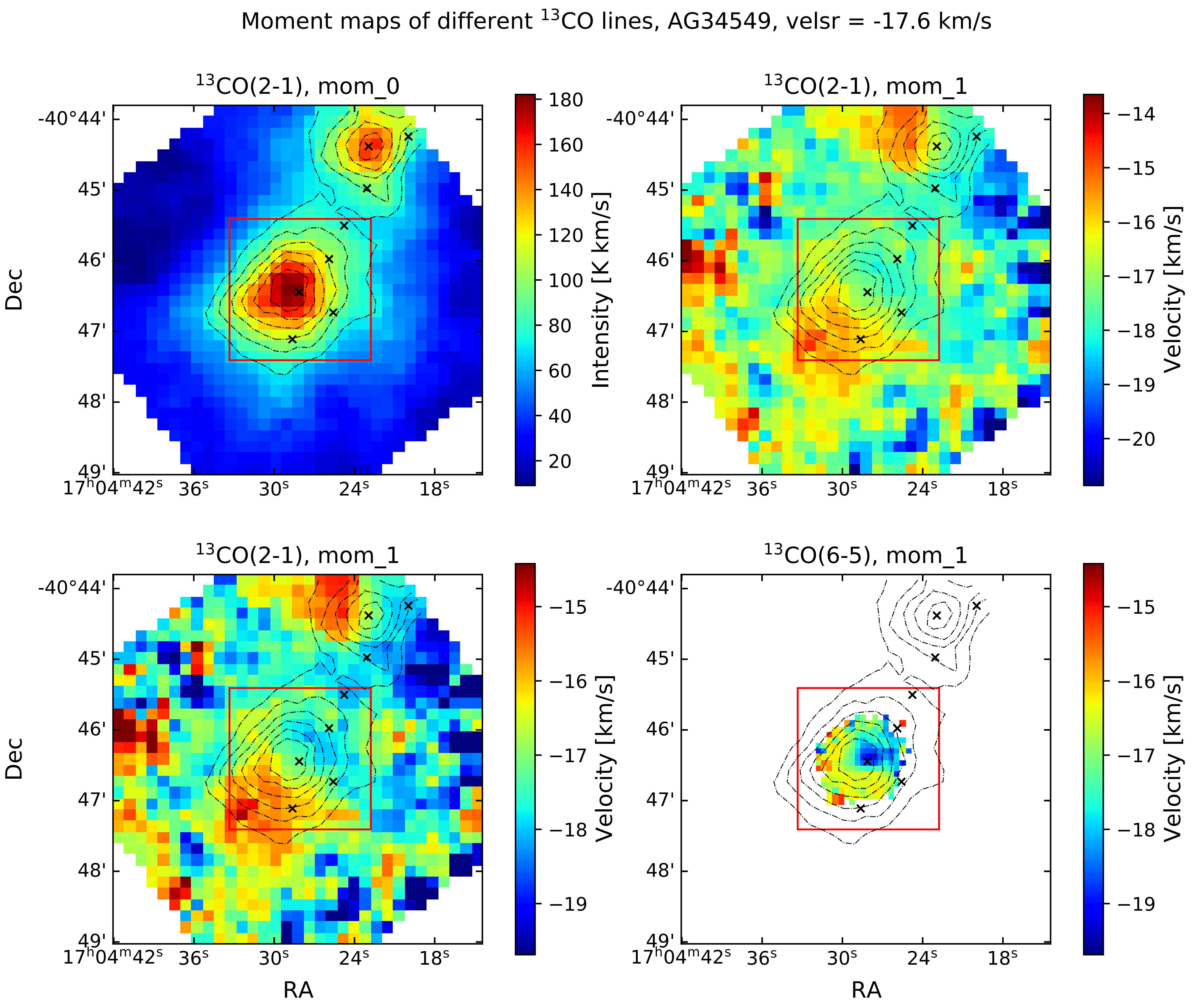
A special case where the red and blue shifted gas follow almost perfectly the outflow' red and blue lobe
=> evidence that outflow entrain the envelope, a good candidate to study outflow-envelope interaction

Connection with larger scale kinematics?

from lower density gas traced by 13CO(2-1) emission (SEDIGISM)

- 25 sources are in both our sample and SEDIGISM





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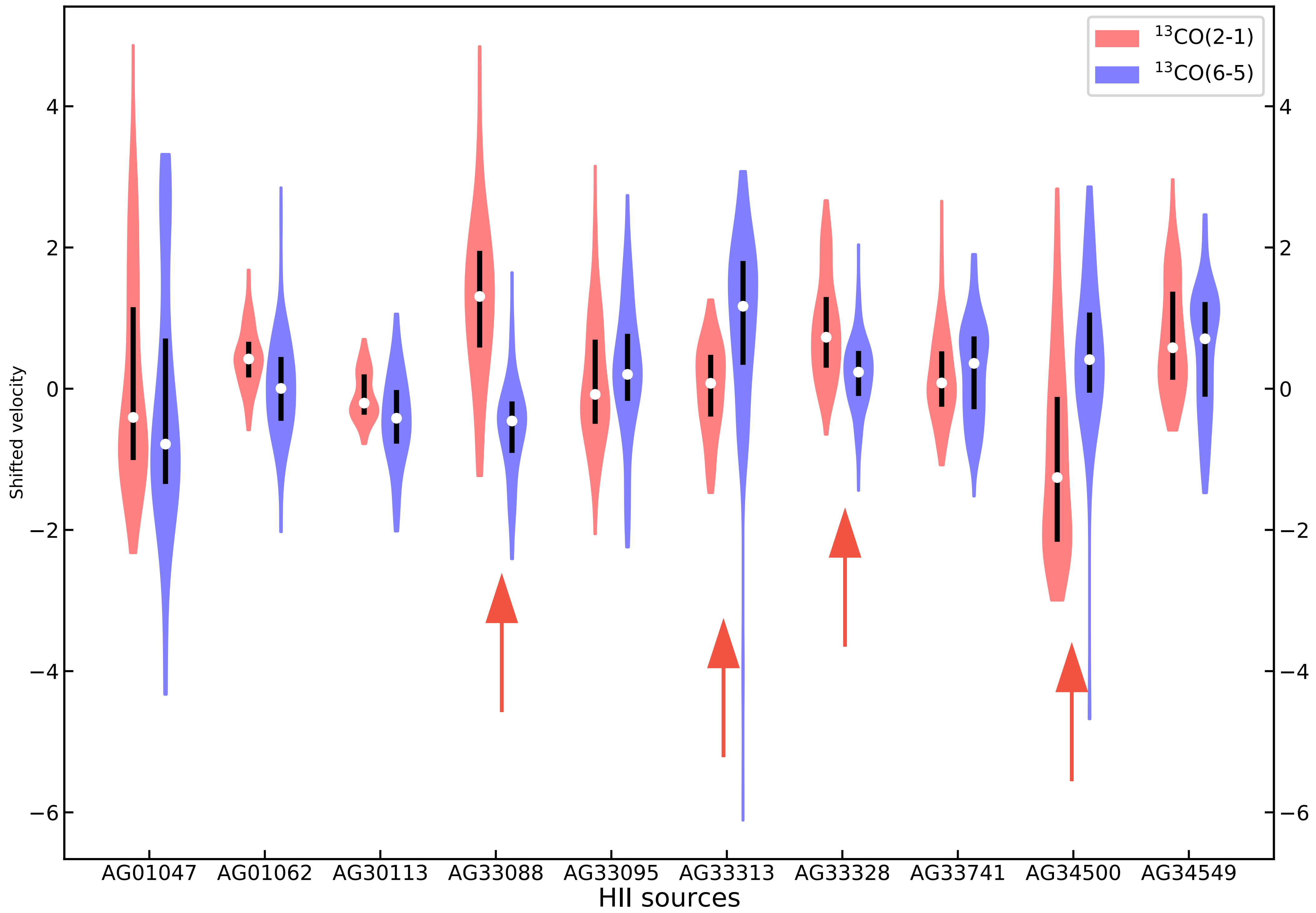

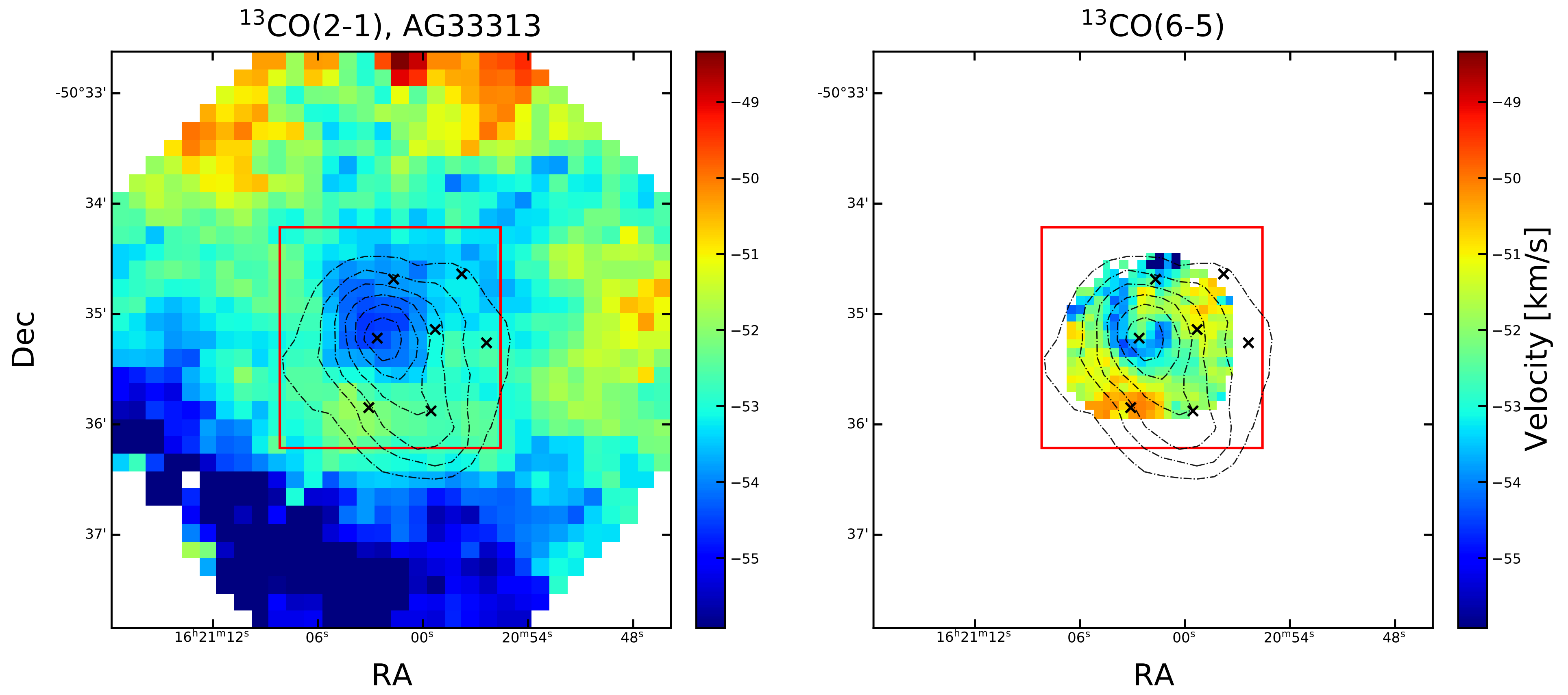

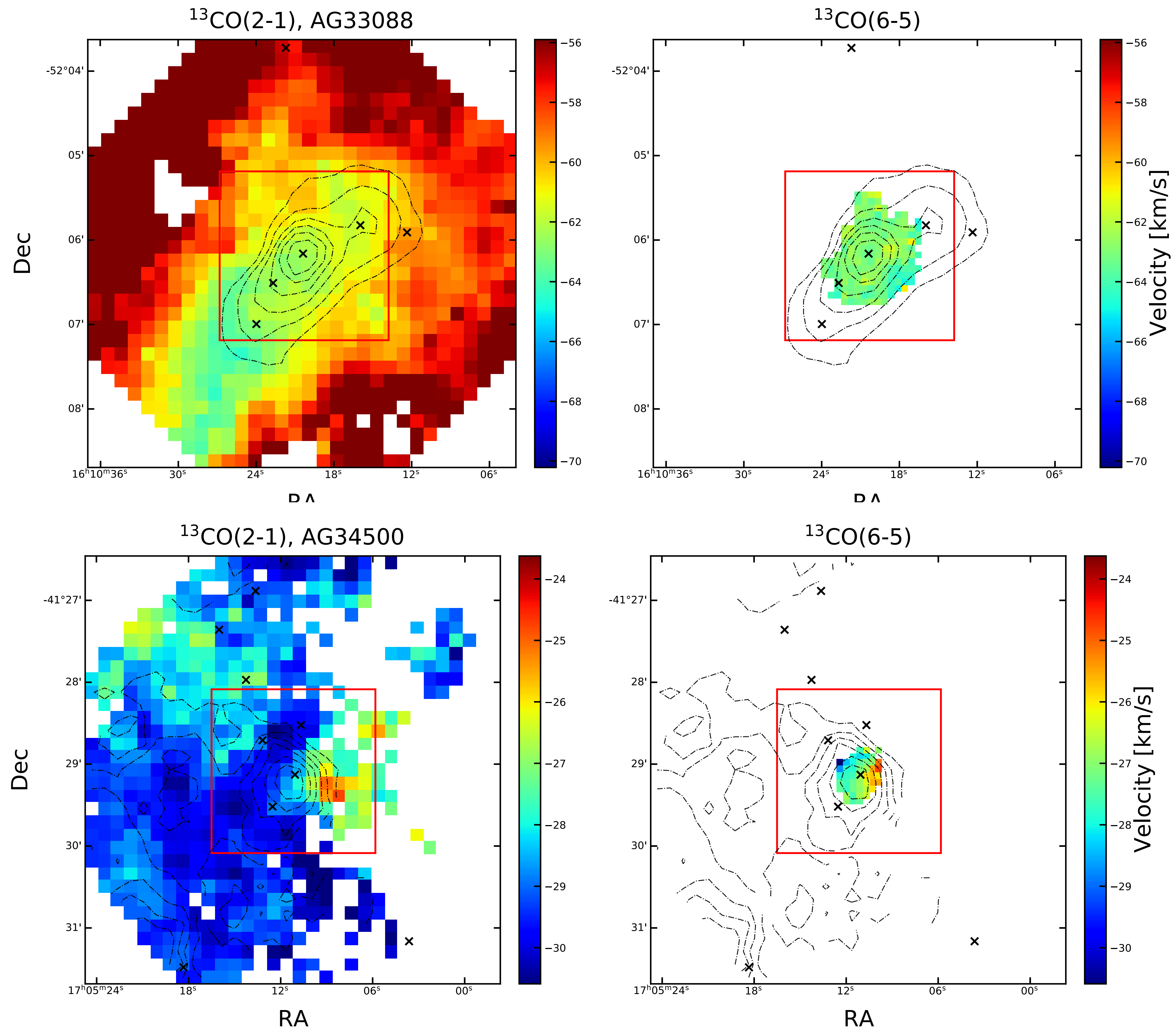

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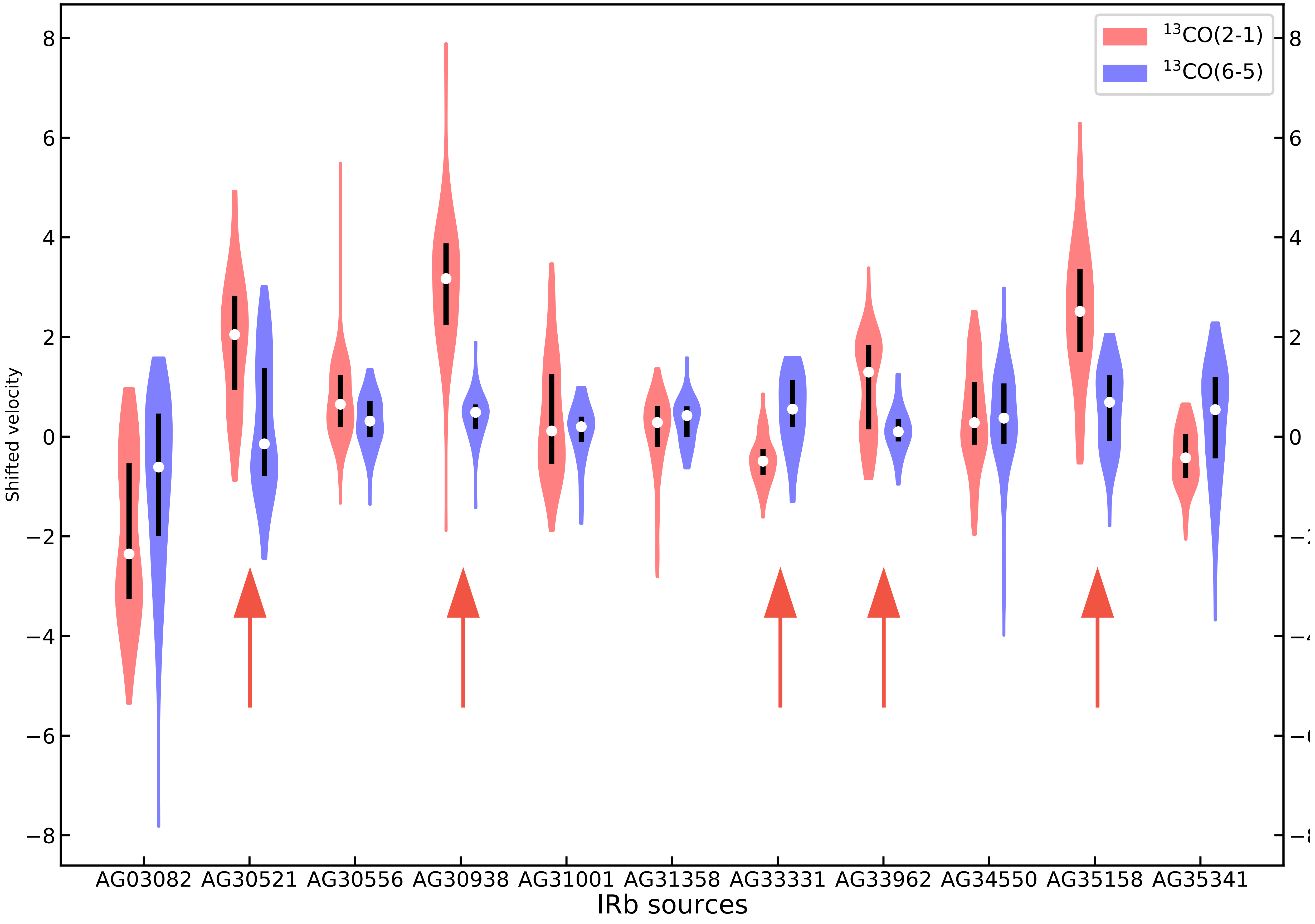

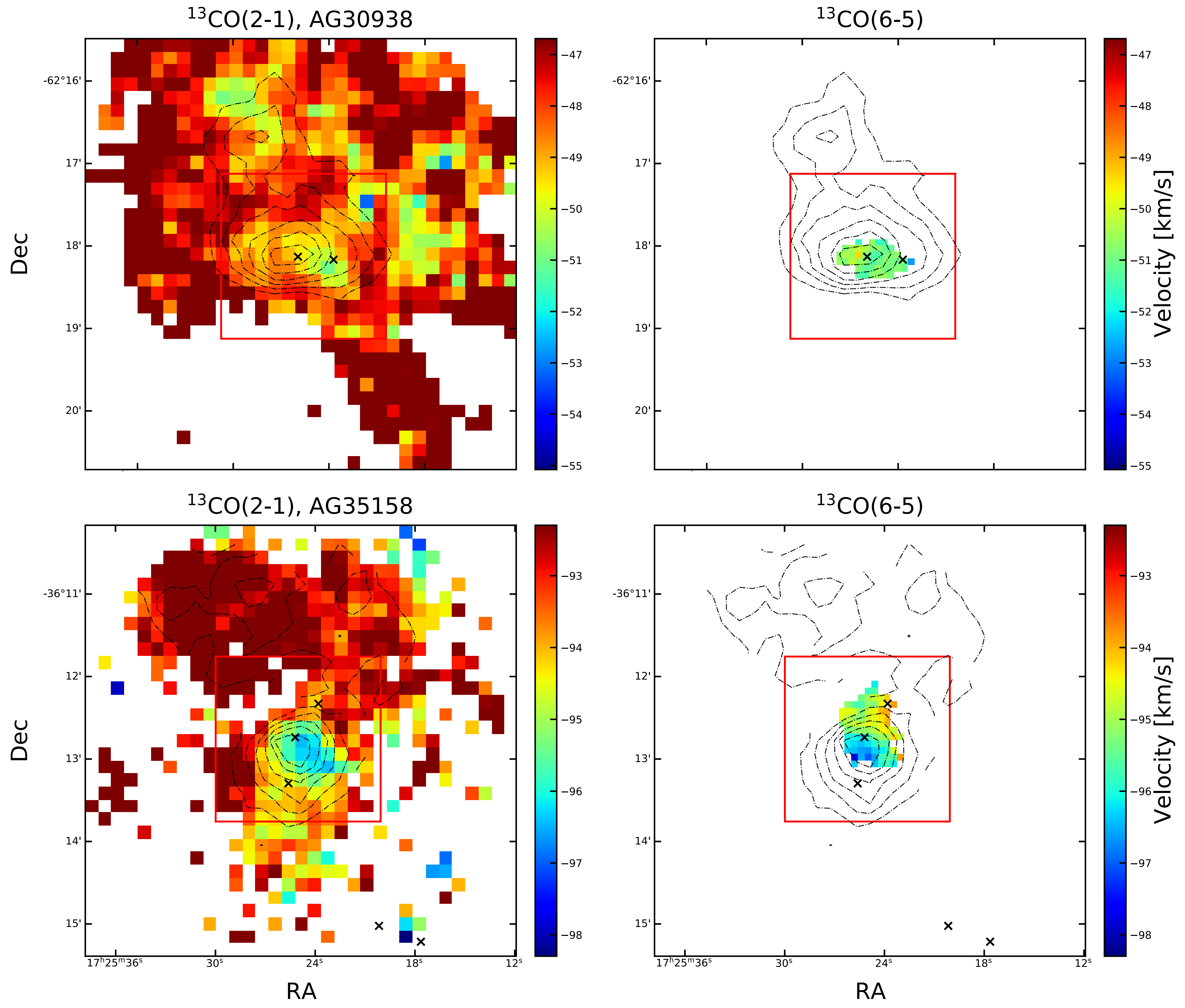

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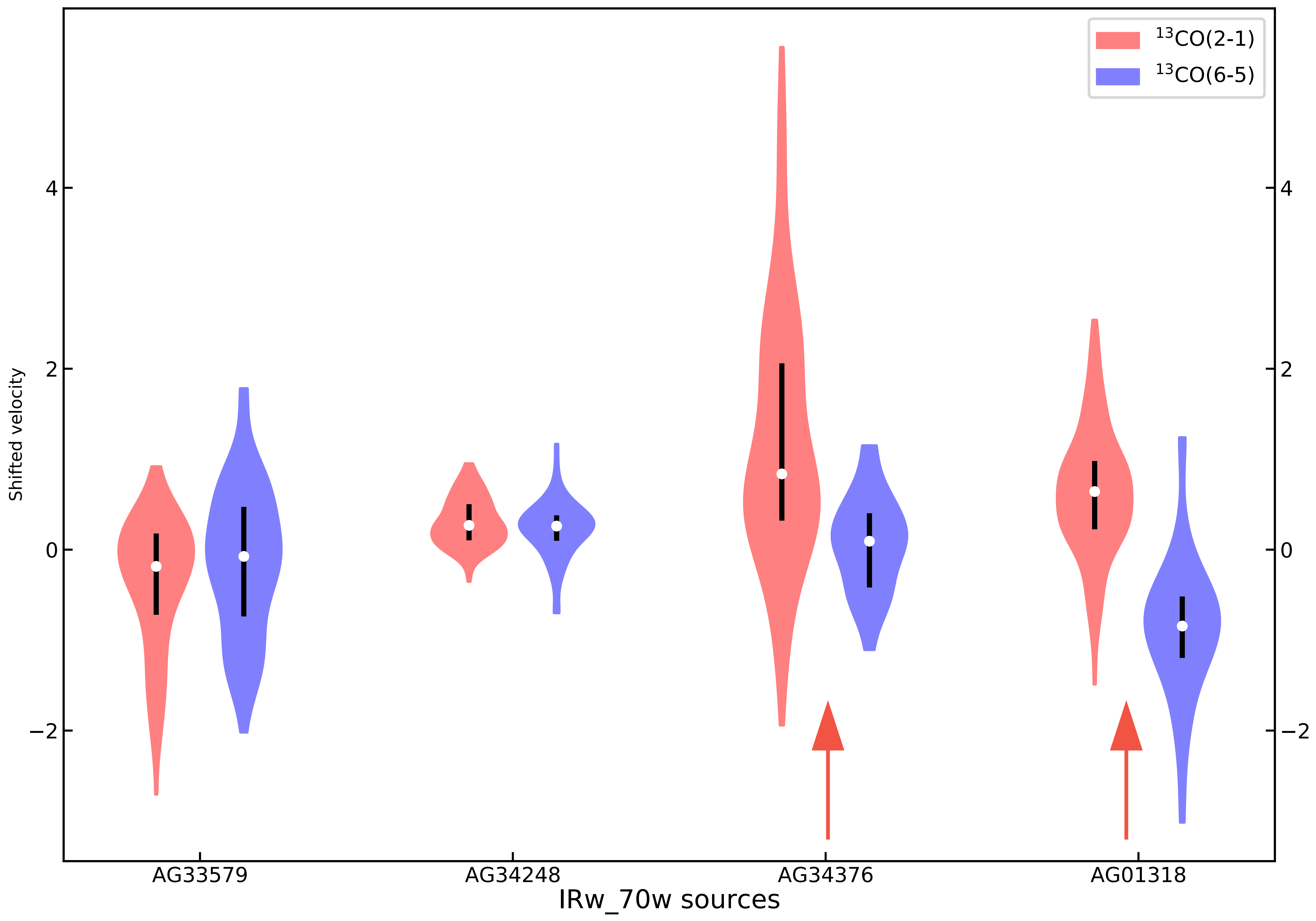
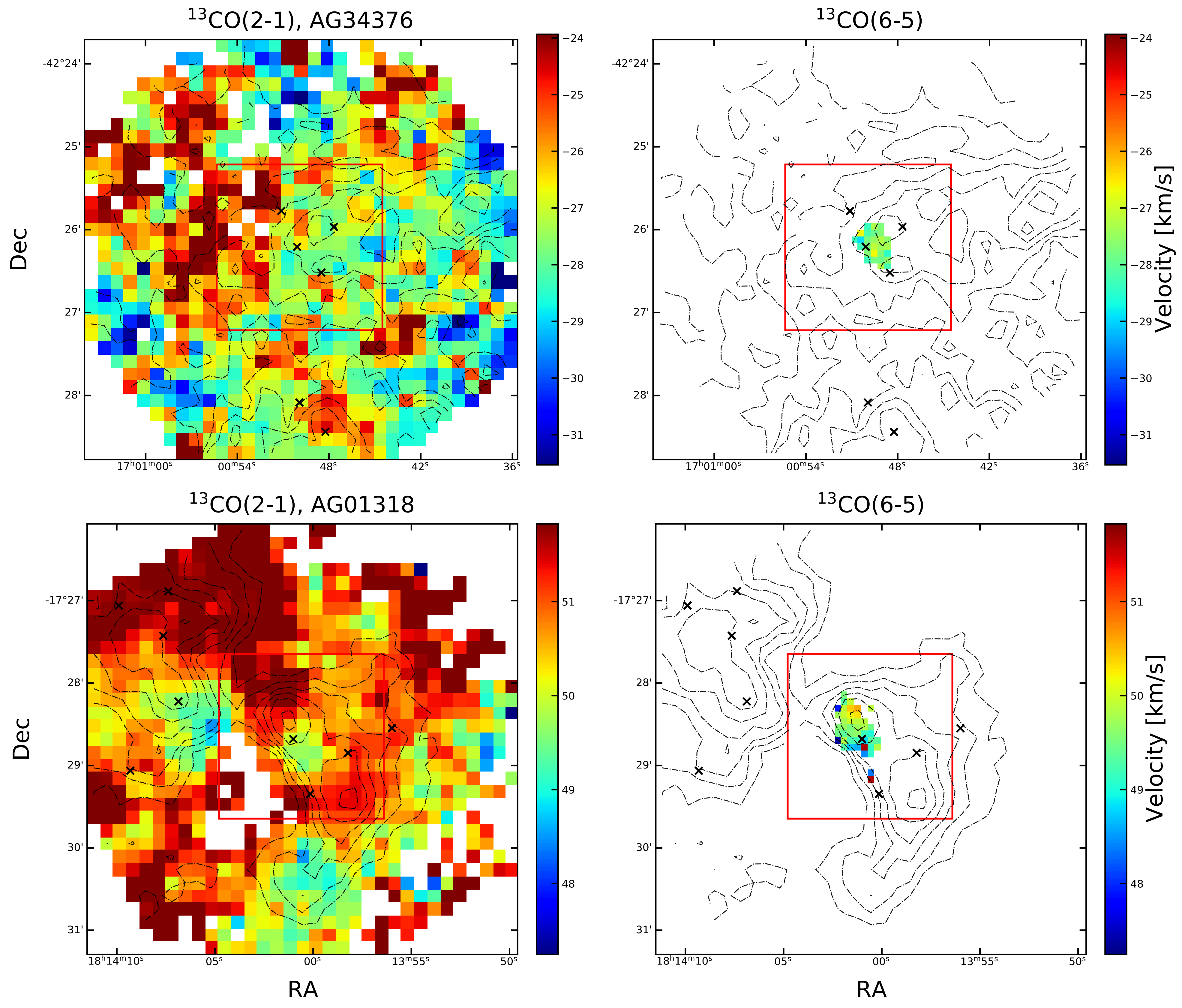


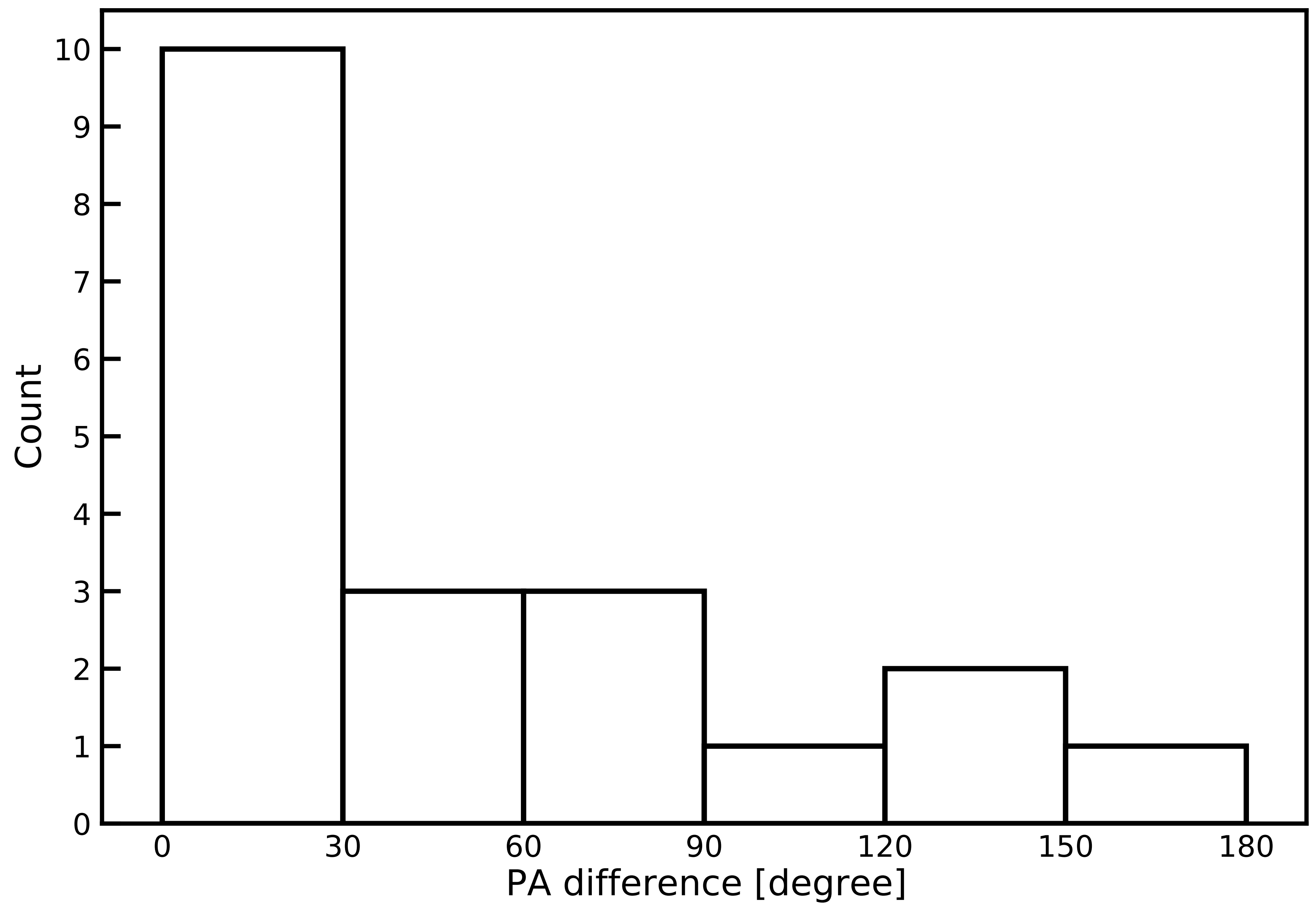


Connection with larger scale kinematics?

from lower density gas traced by 13CO(2-1) emission (SEDIGISM)

- 25 sources are in both our sample and SEDIGISM
- Fit MVG function for 13CO(2-1) velocity maps

=> compare the MVG fit results from both tracers



=> warm gas in the inner envelope inherits the velocity gradient from the parental clump

- It is not straightforward to compare the gradient magnitude due to different beam size

Summary

- The envelope is either not rotating, or rotating about a different axis than bipolar outflow
- The warm gas in the inner envelope show similar velocity trends with the cooler gas on the clump scale

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Thank you for your attention