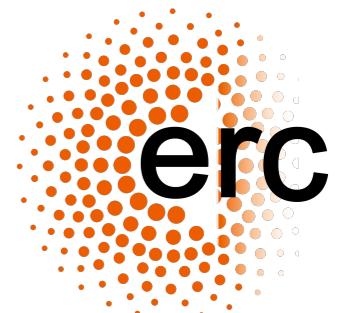


The atomic envelope of molecular clouds as revealed by machine vision

A talk by Juan Diego Soler
Max Planck Institute for Astronomy, Heidelberg

The Physics and Chemistry of the Interstellar Medium
Avignon, France. September 2-6, 2019



In collaboration with

Max Planck Institute for Astronomy

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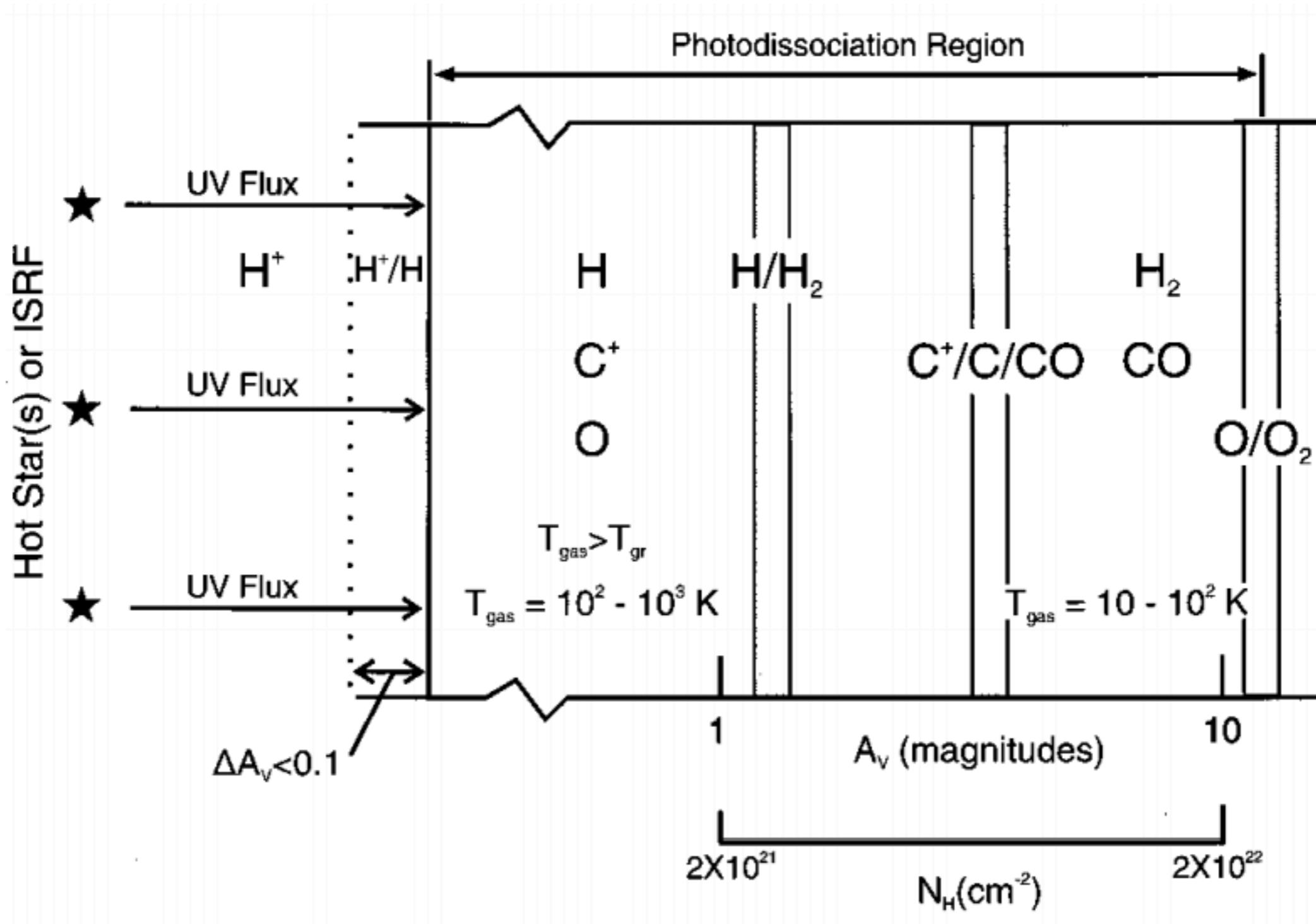
P. Hennebelle

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J. Stil
R. Shanahan

Structure of photodissociation regions

Hollenbach, D.J., & Tielens, A.G.G.M. Reviews of Modern Physics. 71 (1999) 173-230



Idealized molecular clouds

Andersson, B.-G.; Wannier, P. G. ApJ. 402 (1993) 585A



CO

Idealized molecular clouds

Andersson, B.-G.; Wannier, P. G. ApJ. 402 (1993) 585A

HI

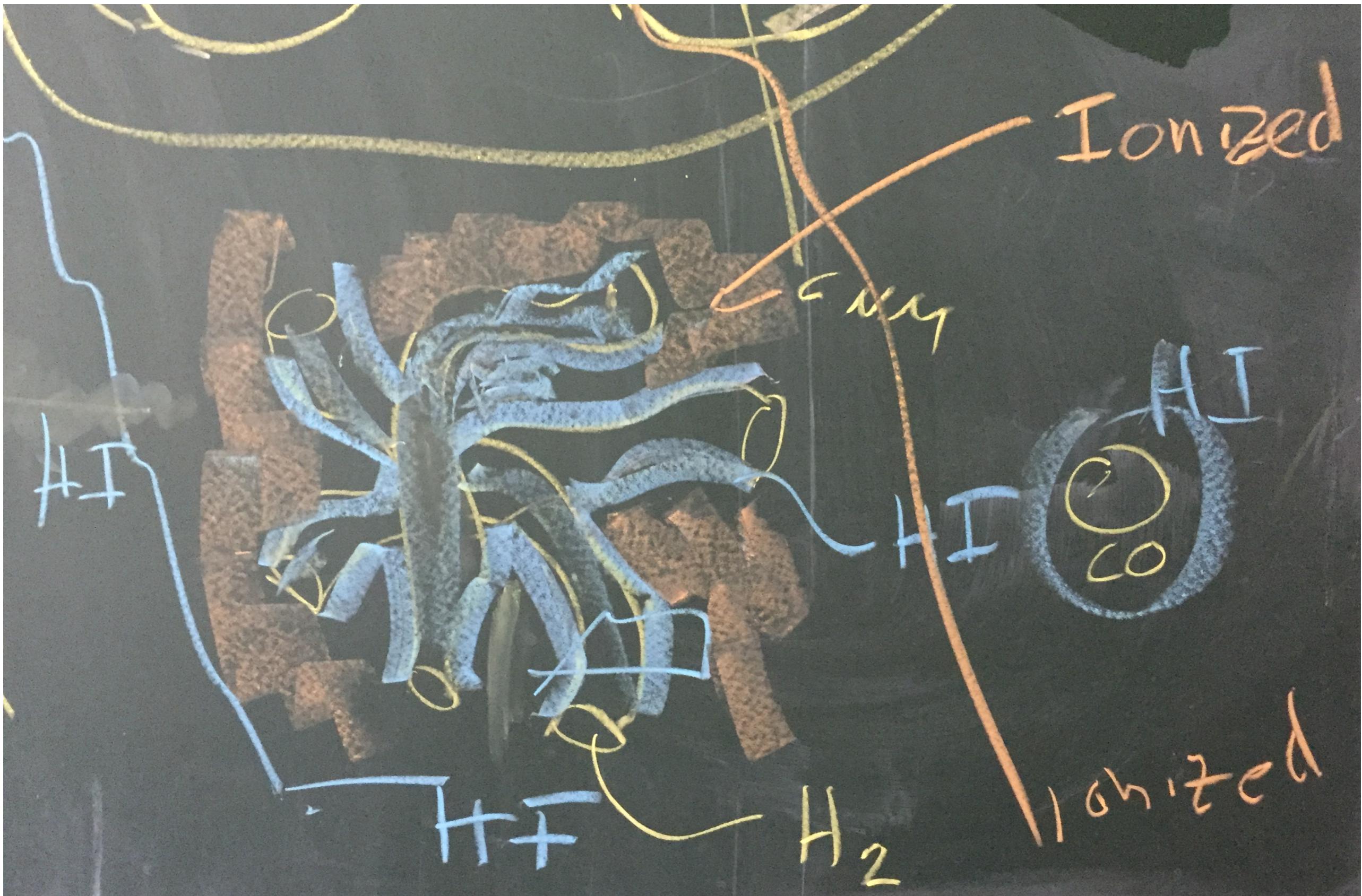


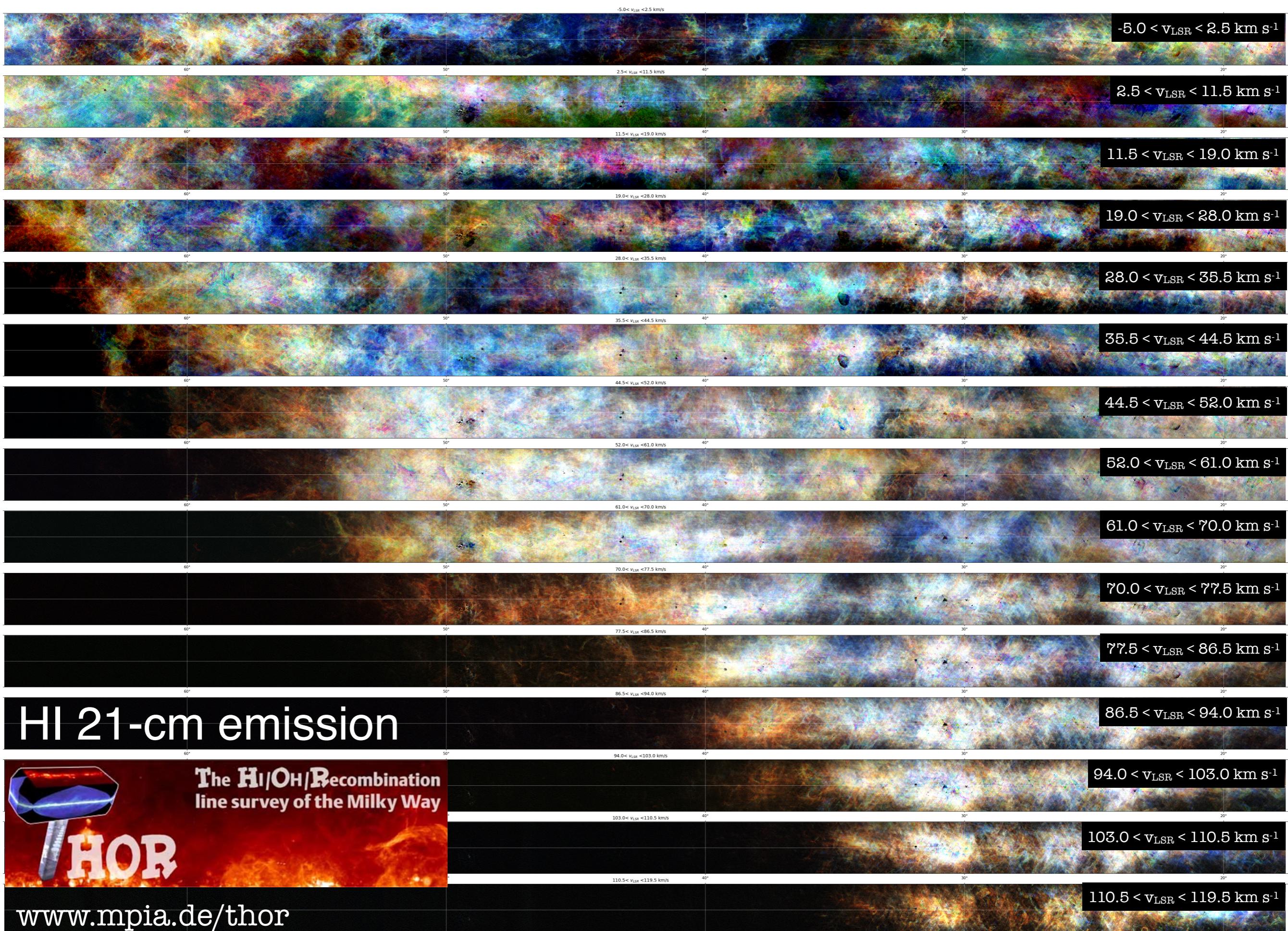
CO



Less-idealized molecular cloud

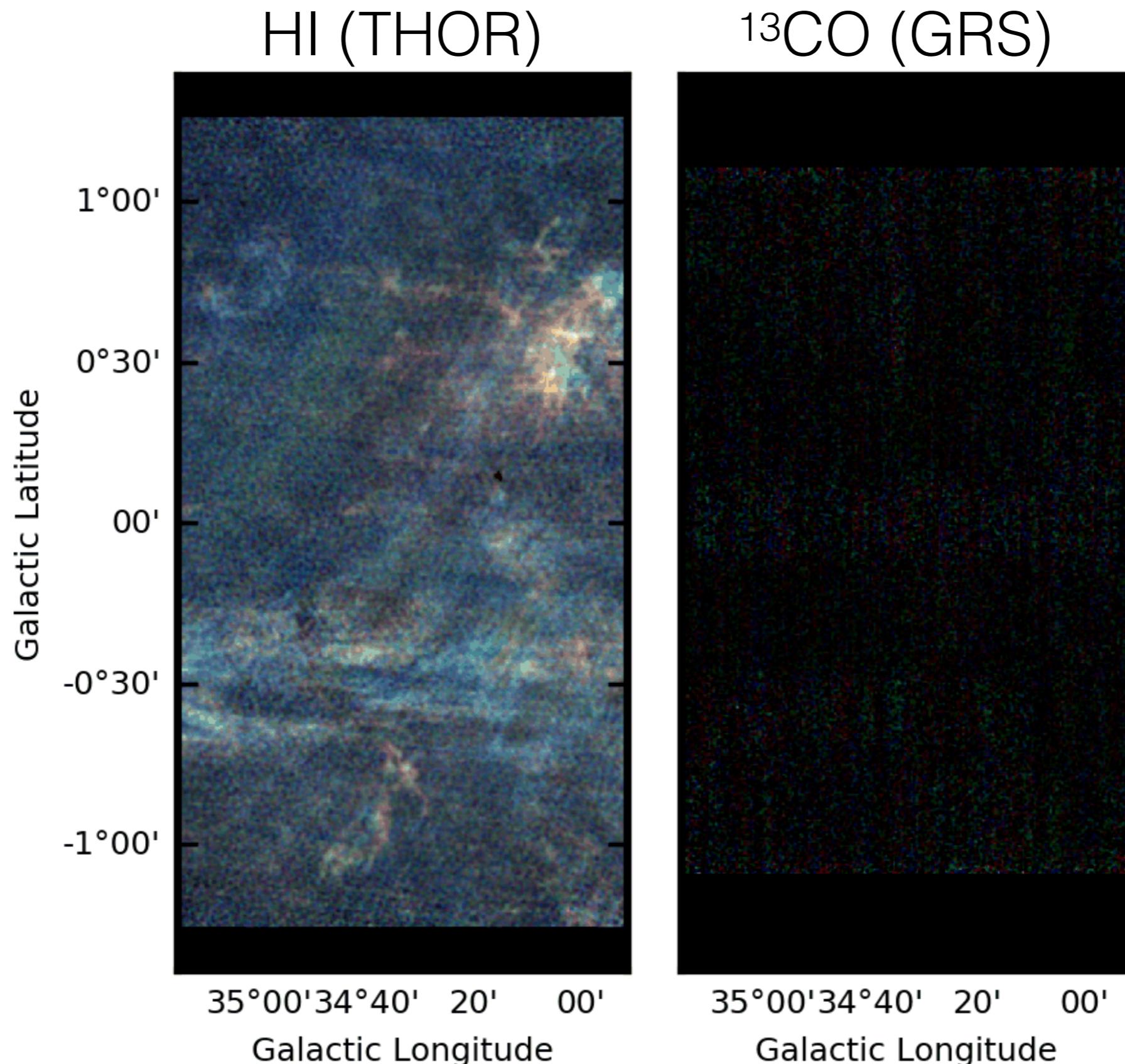
Goodman, A. HHSF2018





Proof of concept: histogram of relative orientations (HOG)

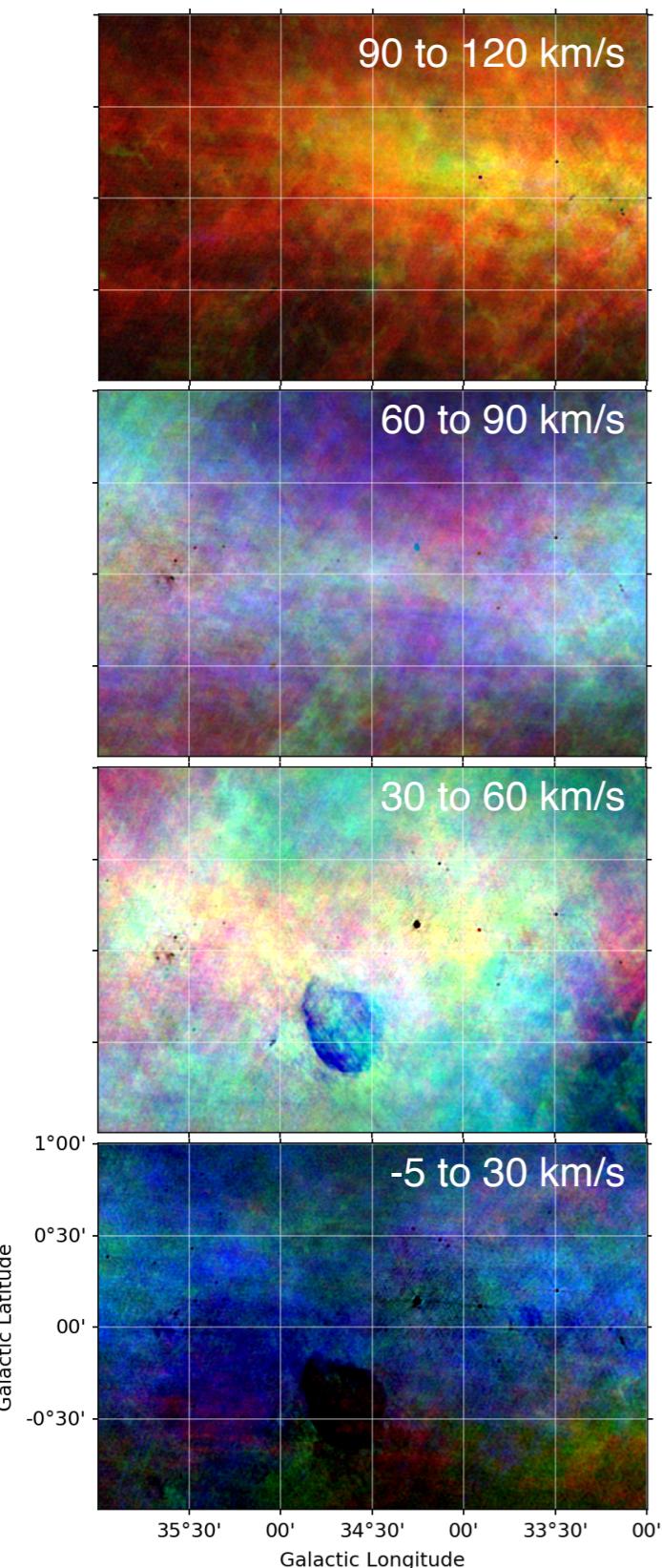
Soler, J.D. et al. A&A 622A (2019) 166S



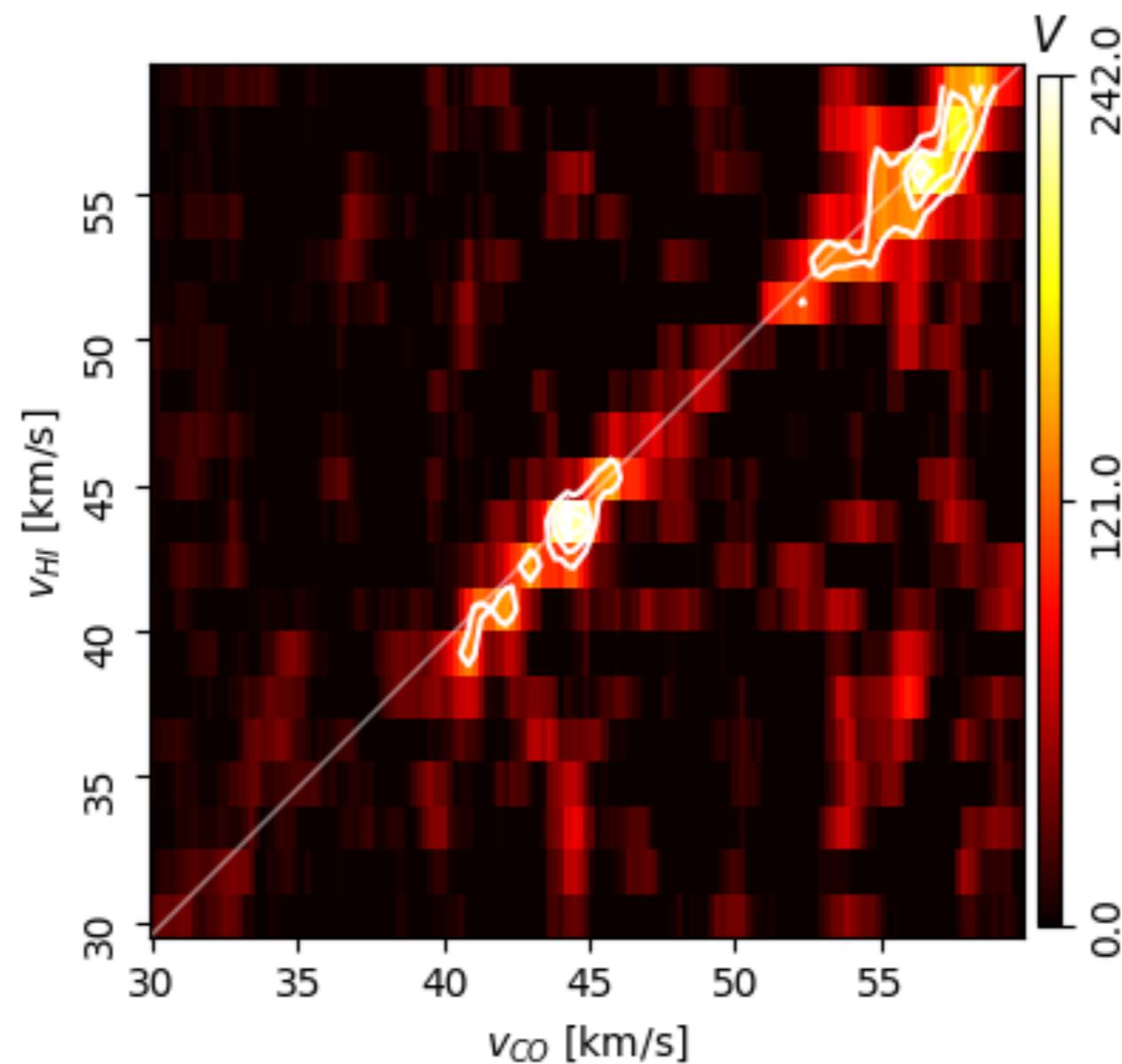
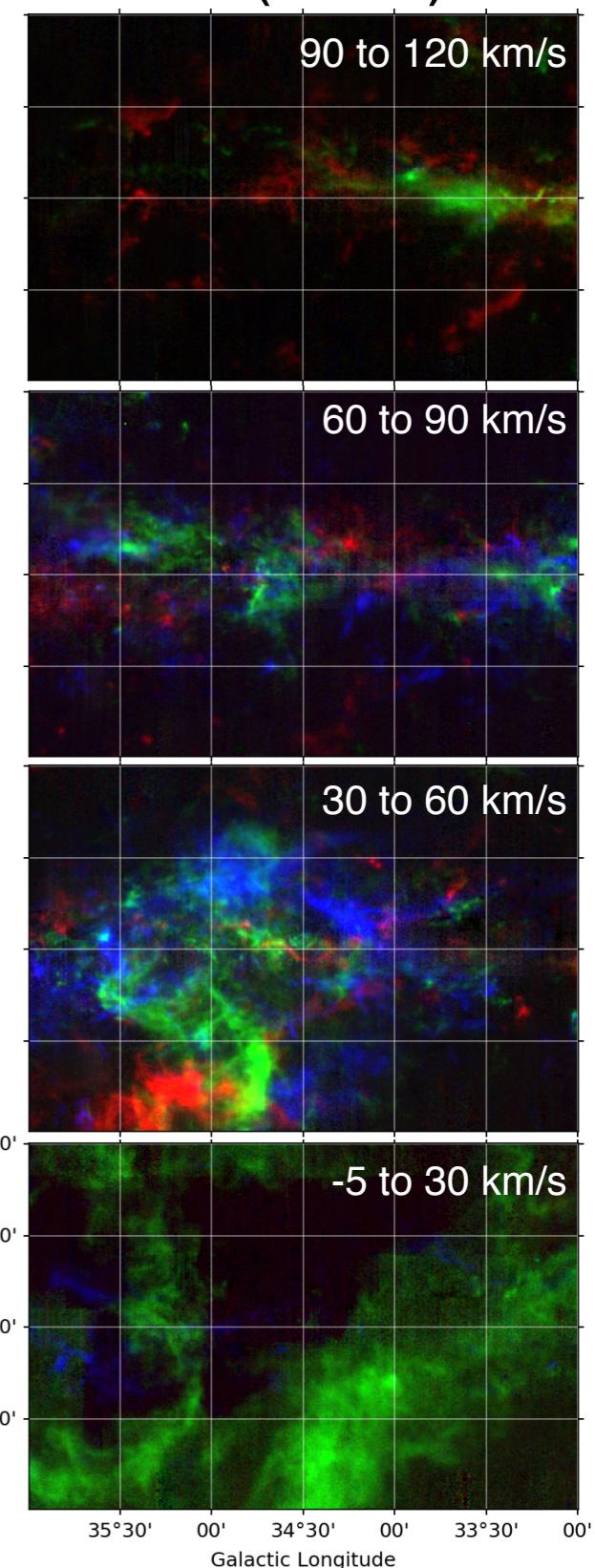
Proof of concept: histogram of relative orientations (HOG)

Soler, J.D. et al. A&A 622A (2019) 166S

HI (THOR)



^{13}CO (GRS)



Histogram of oriented gradients (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



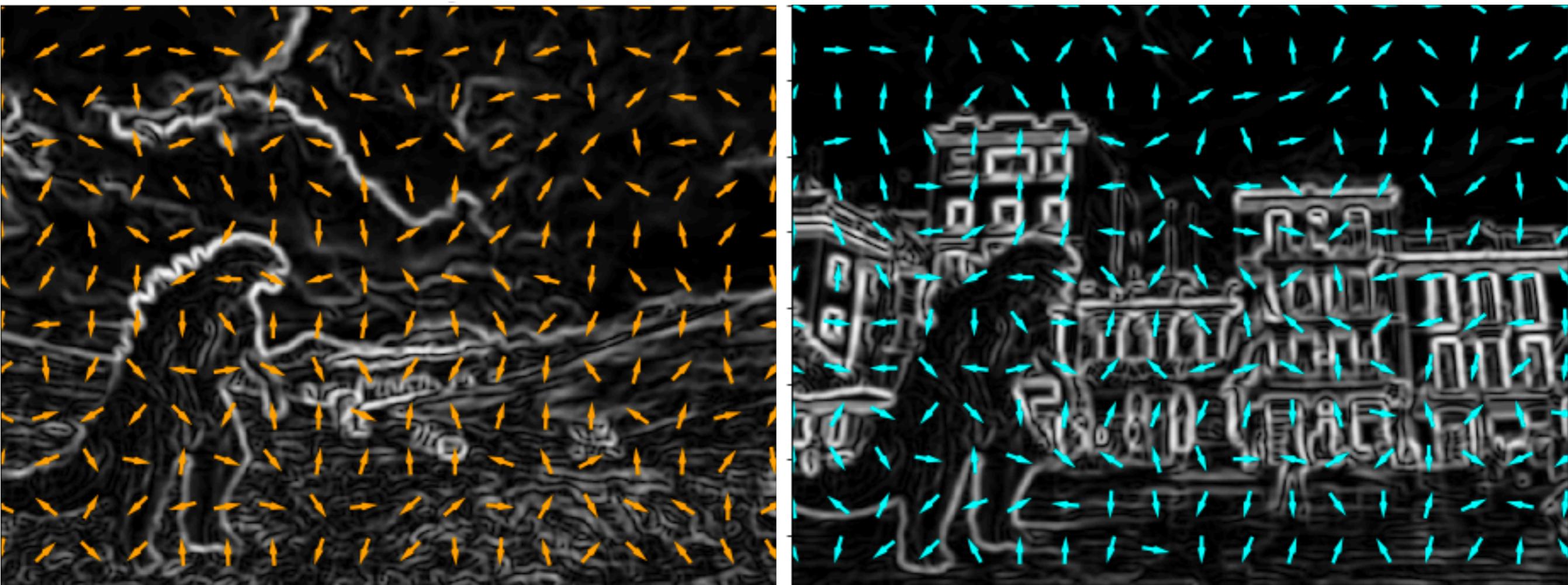
Histogram of relative orientations (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



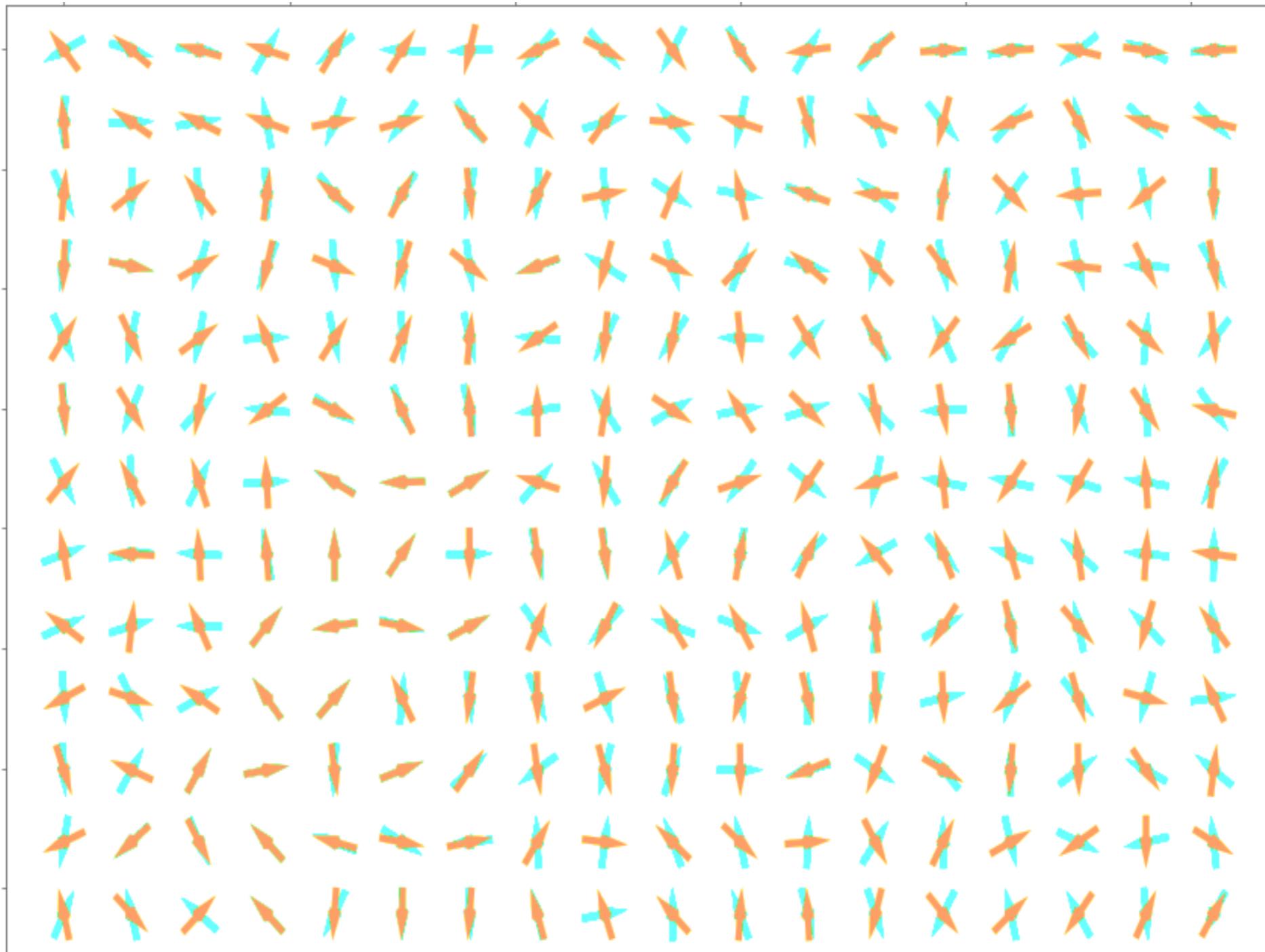
Histogram of relative orientations (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



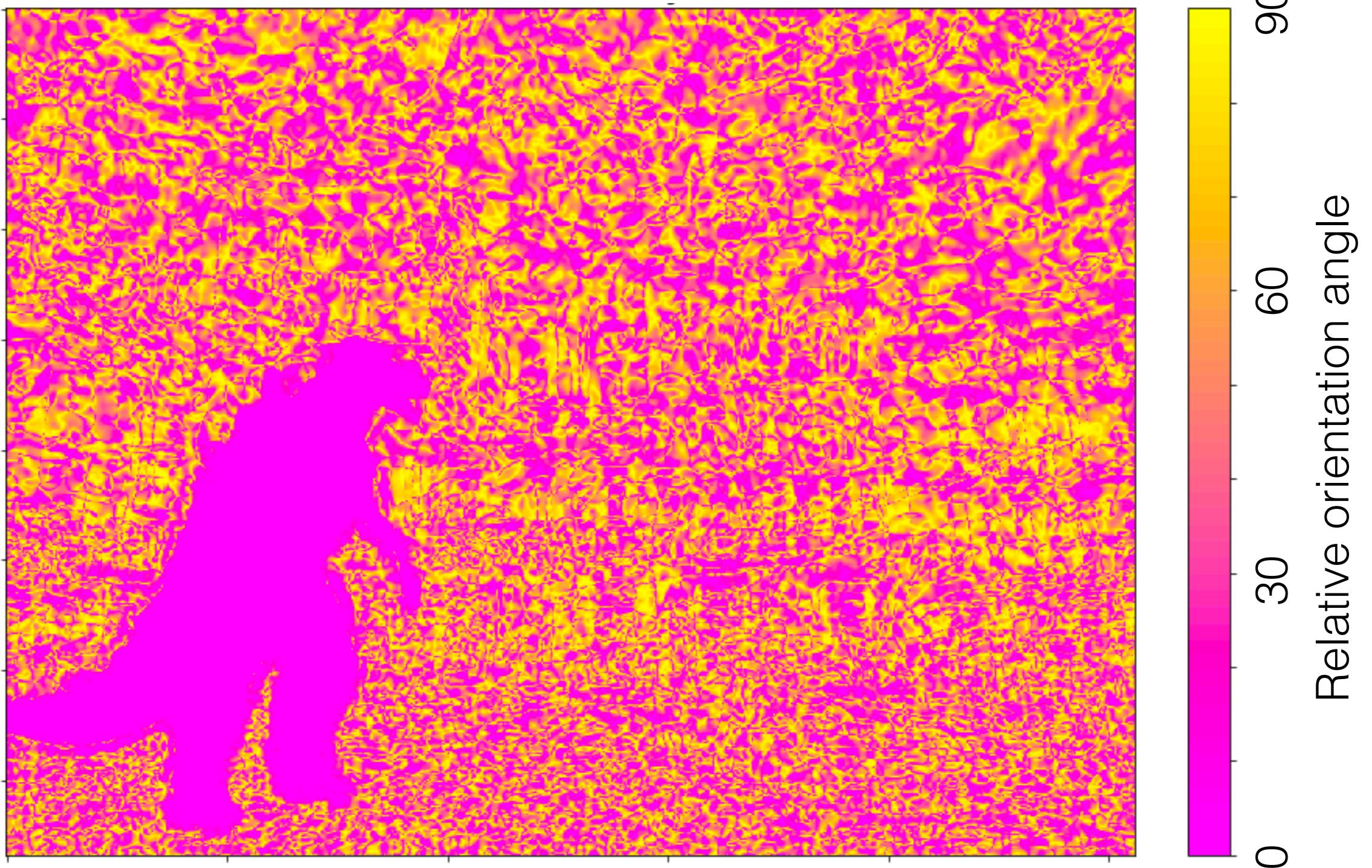
Histogram of relative orientations (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



Histogram of relative orientations (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166

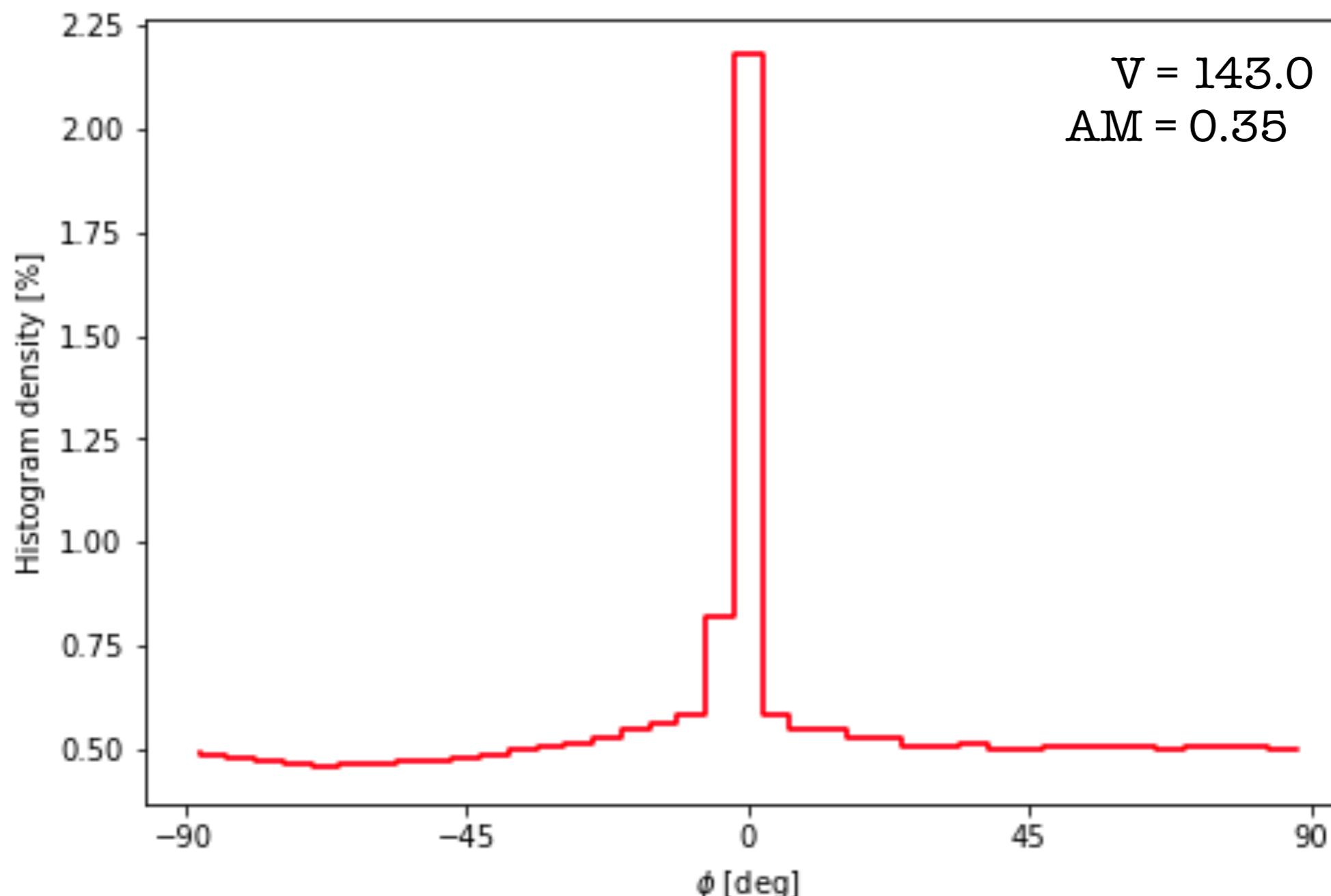


Histogram of relative orientations (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166

$$V = \frac{\sum_k^N w_k \cos 2\phi_k}{\sqrt{\sum_k^N (w_k)^2 / 2}}$$

$$\text{AM} = \langle 2 \cos \phi_{ij} - 1 \rangle_{ij}$$



Spatial correlation

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166

Image group A

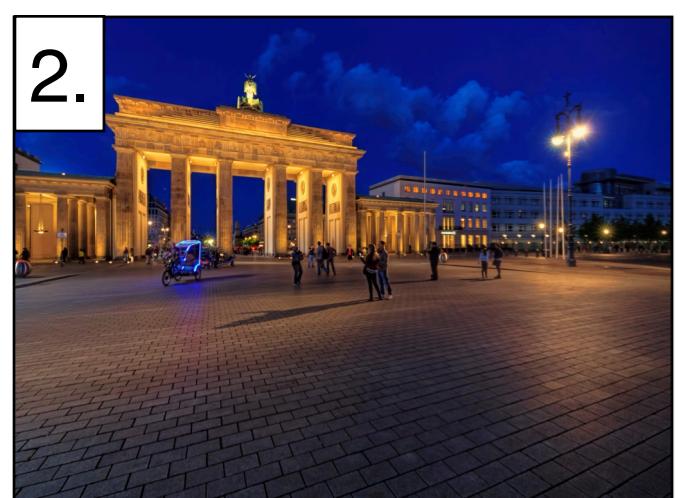
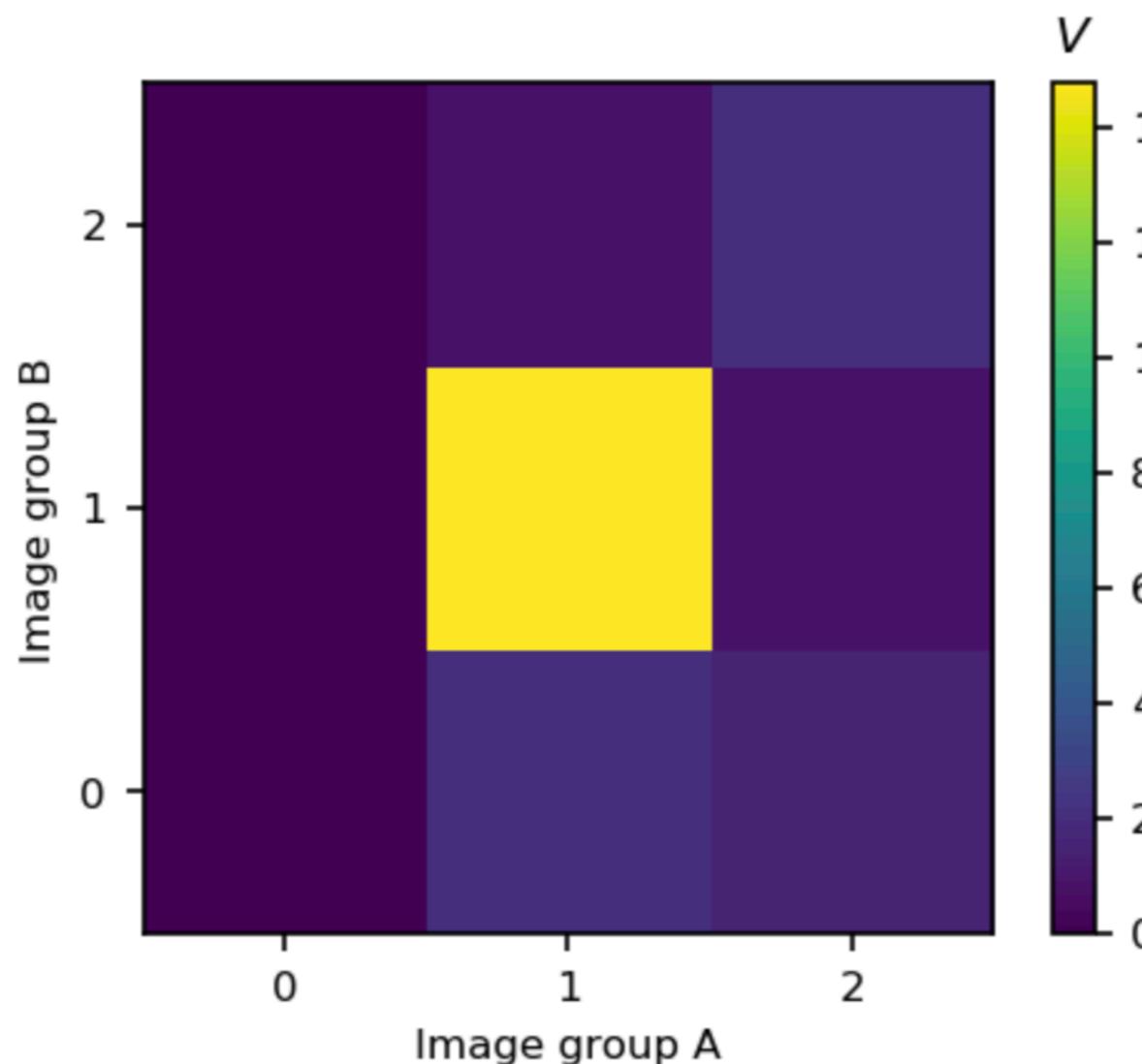
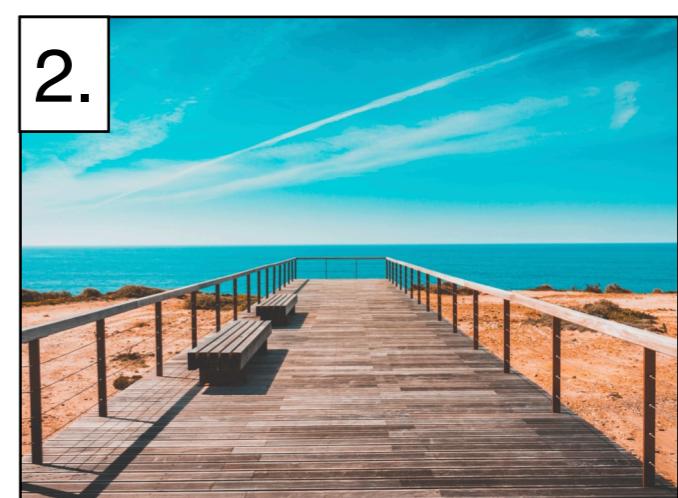
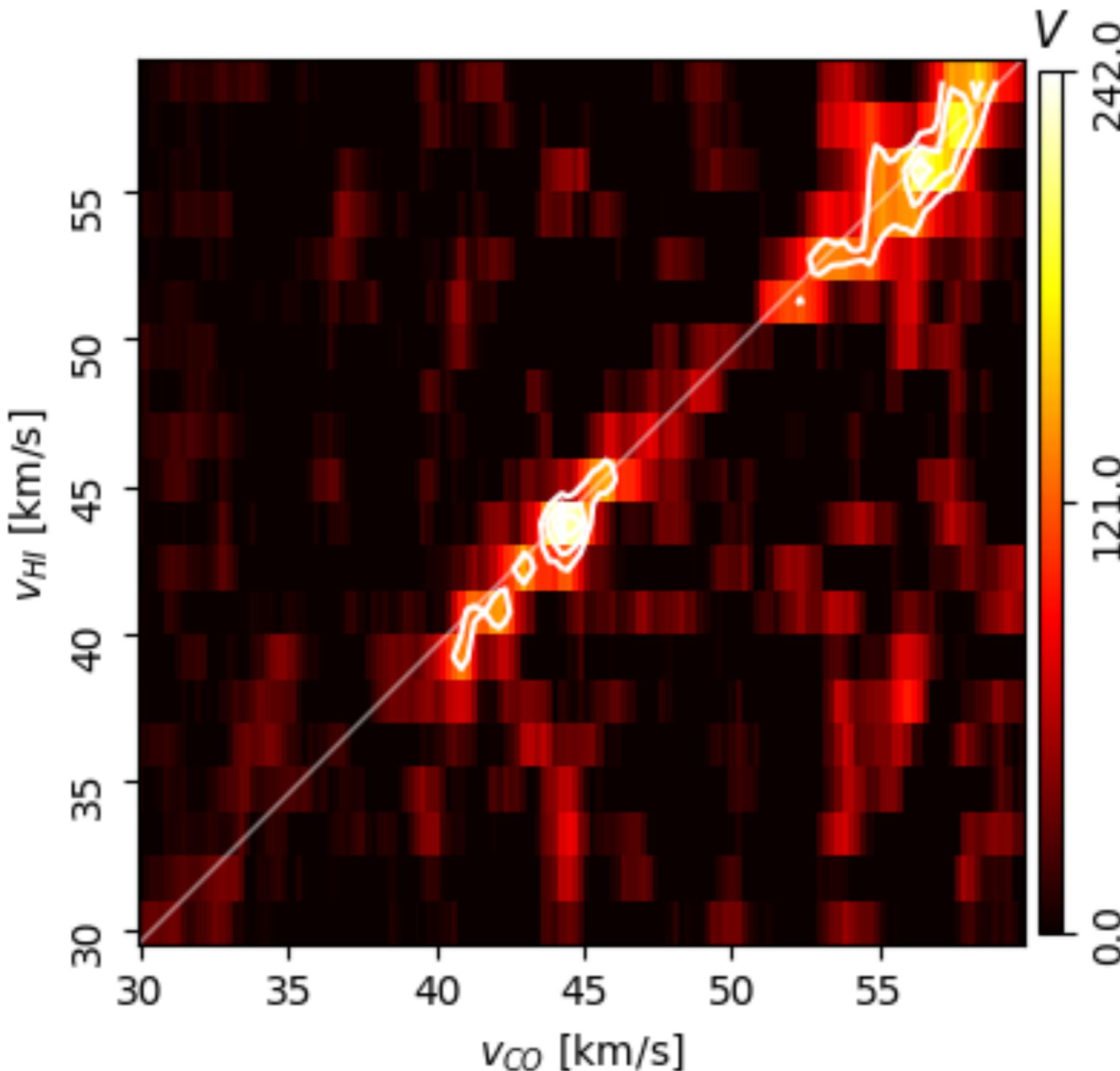


Image group B



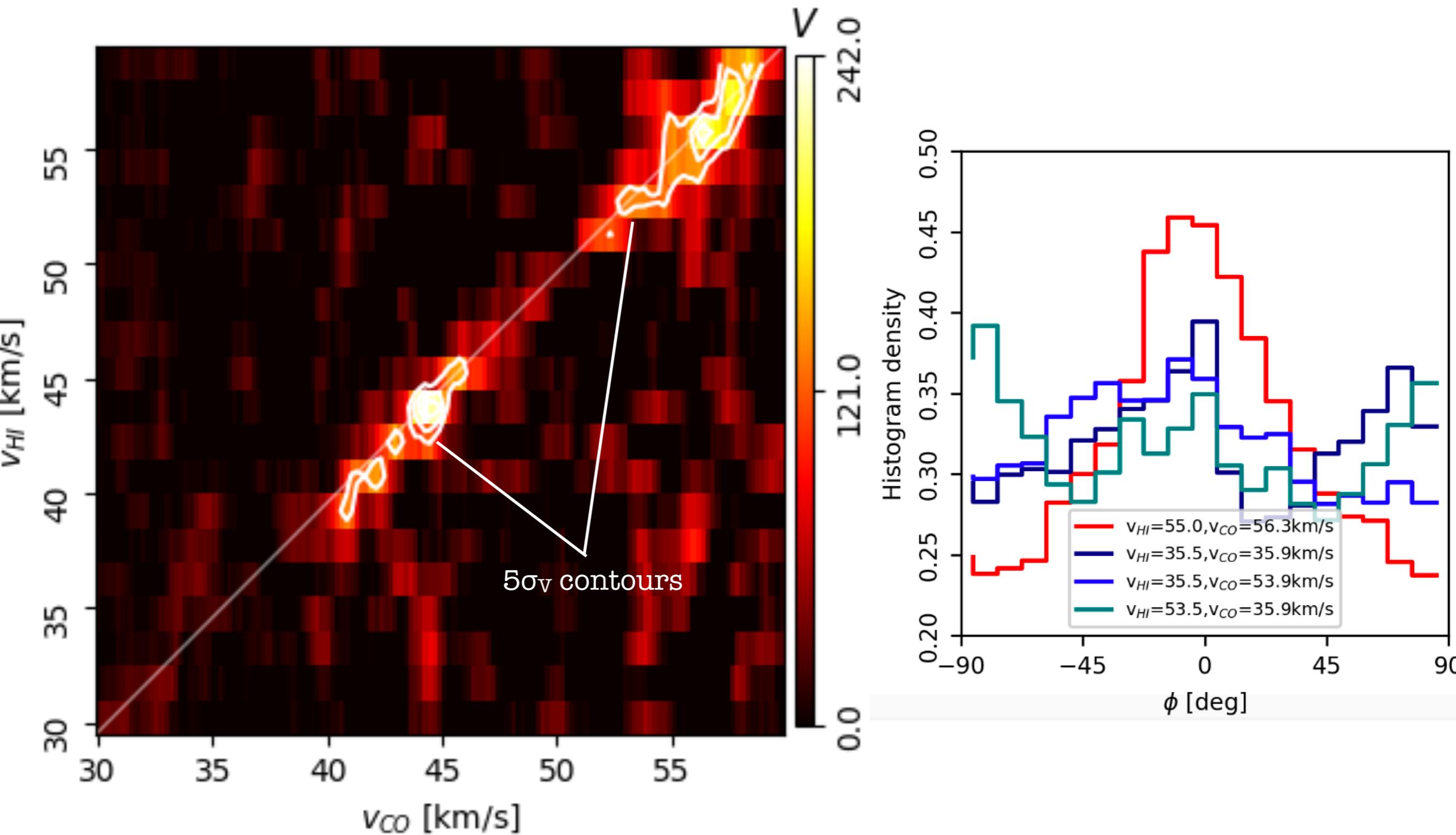
Spatial correlation between HI and ^{13}CO

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



Spatial correlation between HI and ^{13}CO

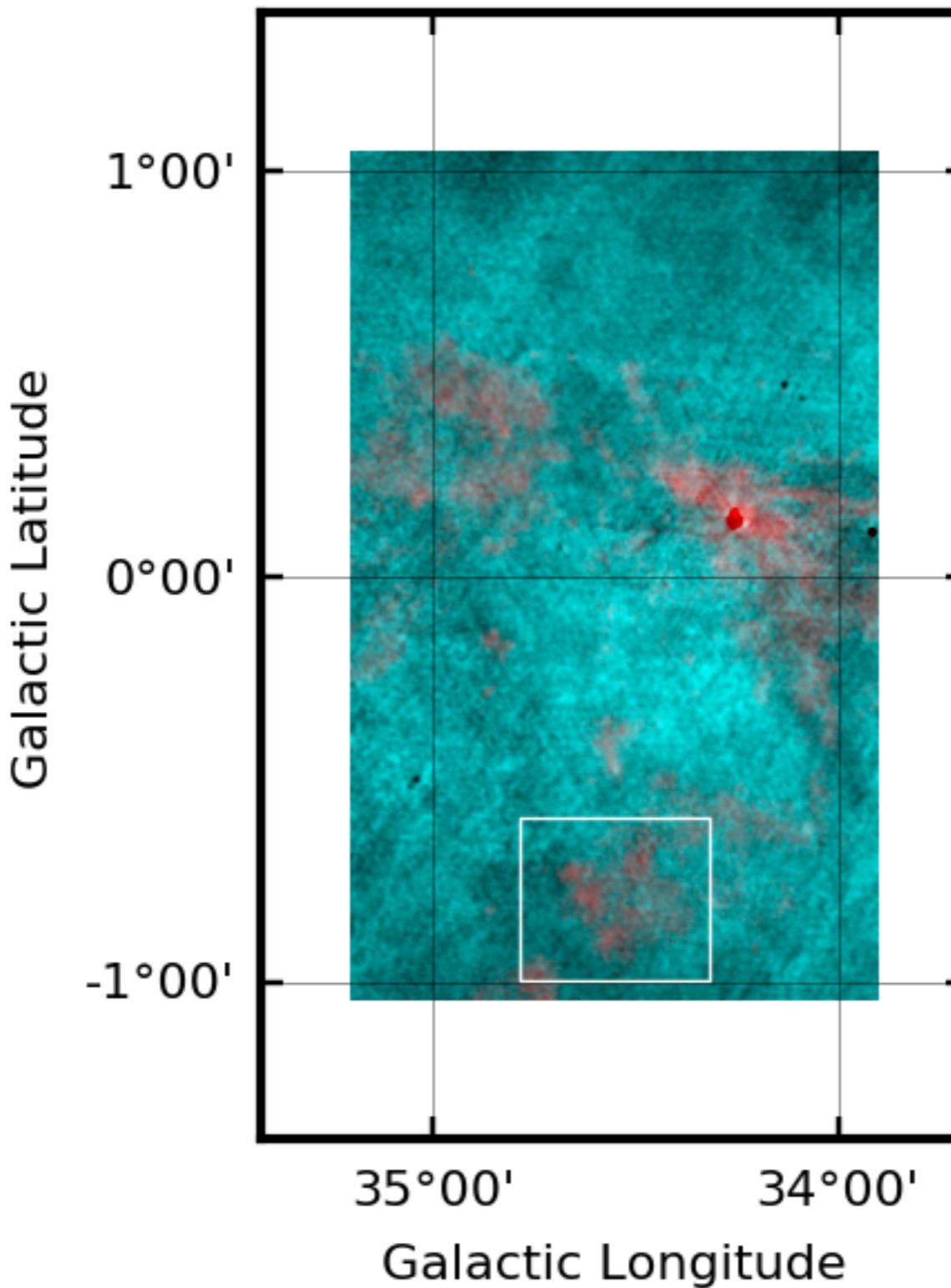
Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



Spatial correlation between HI and ^{13}CO

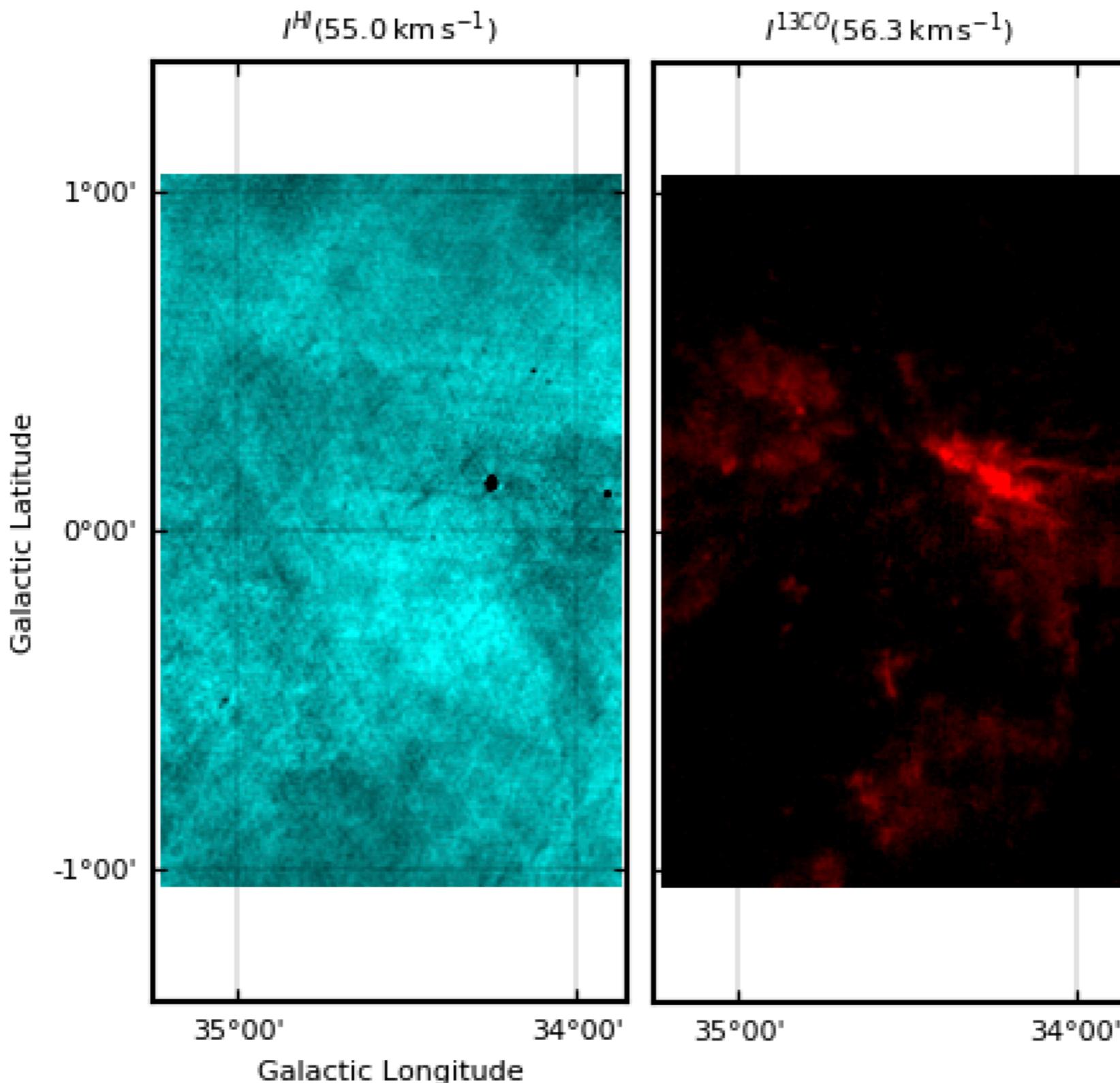
Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166

$$I^{\text{HI}}(55.0 \text{ km s}^{-1}), I^{^{13}\text{CO}}(56.3 \text{ km s}^{-1})$$



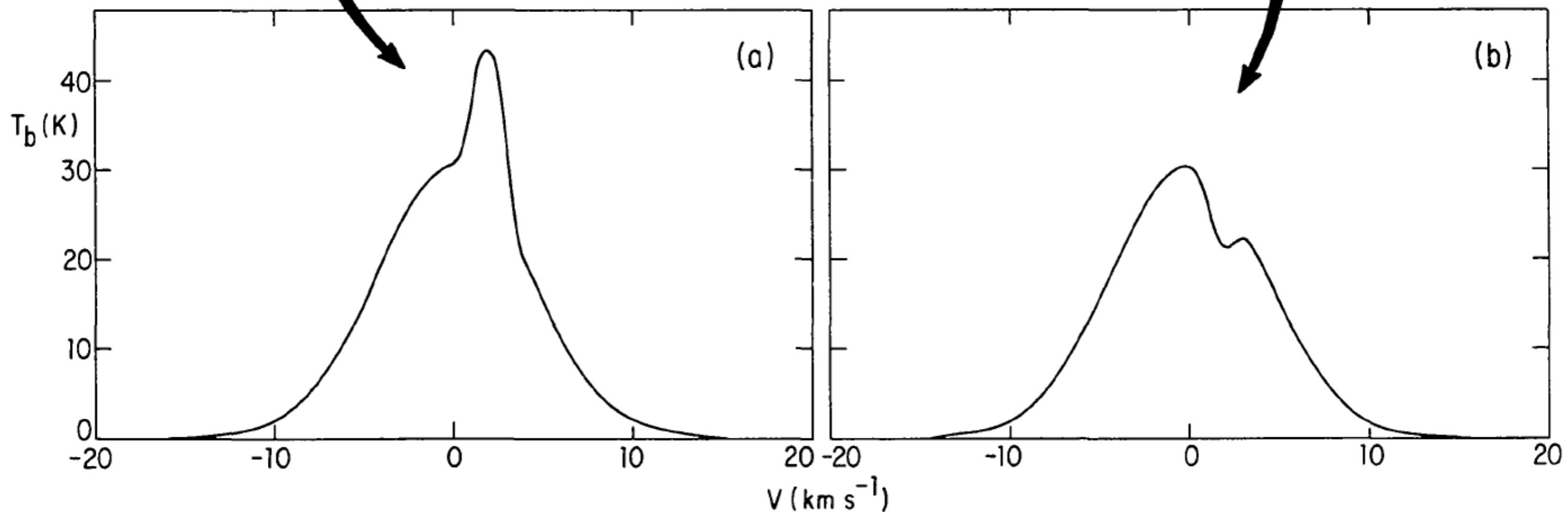
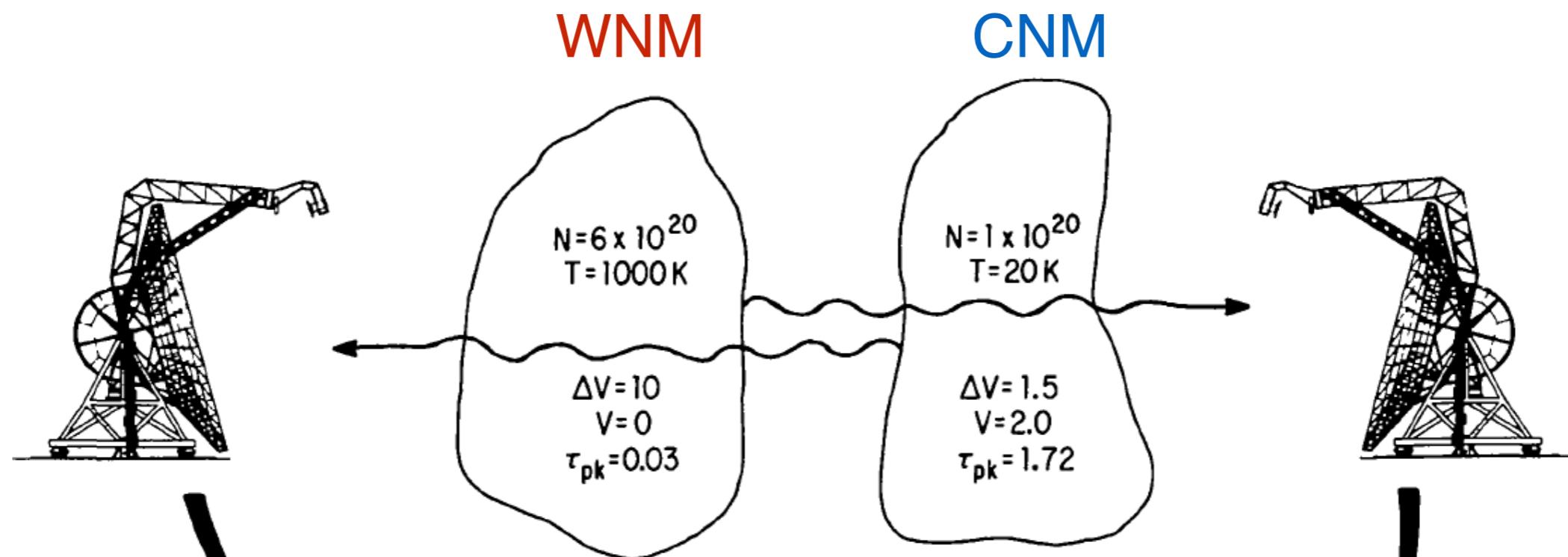
Spatial correlation between HI and ^{13}CO

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



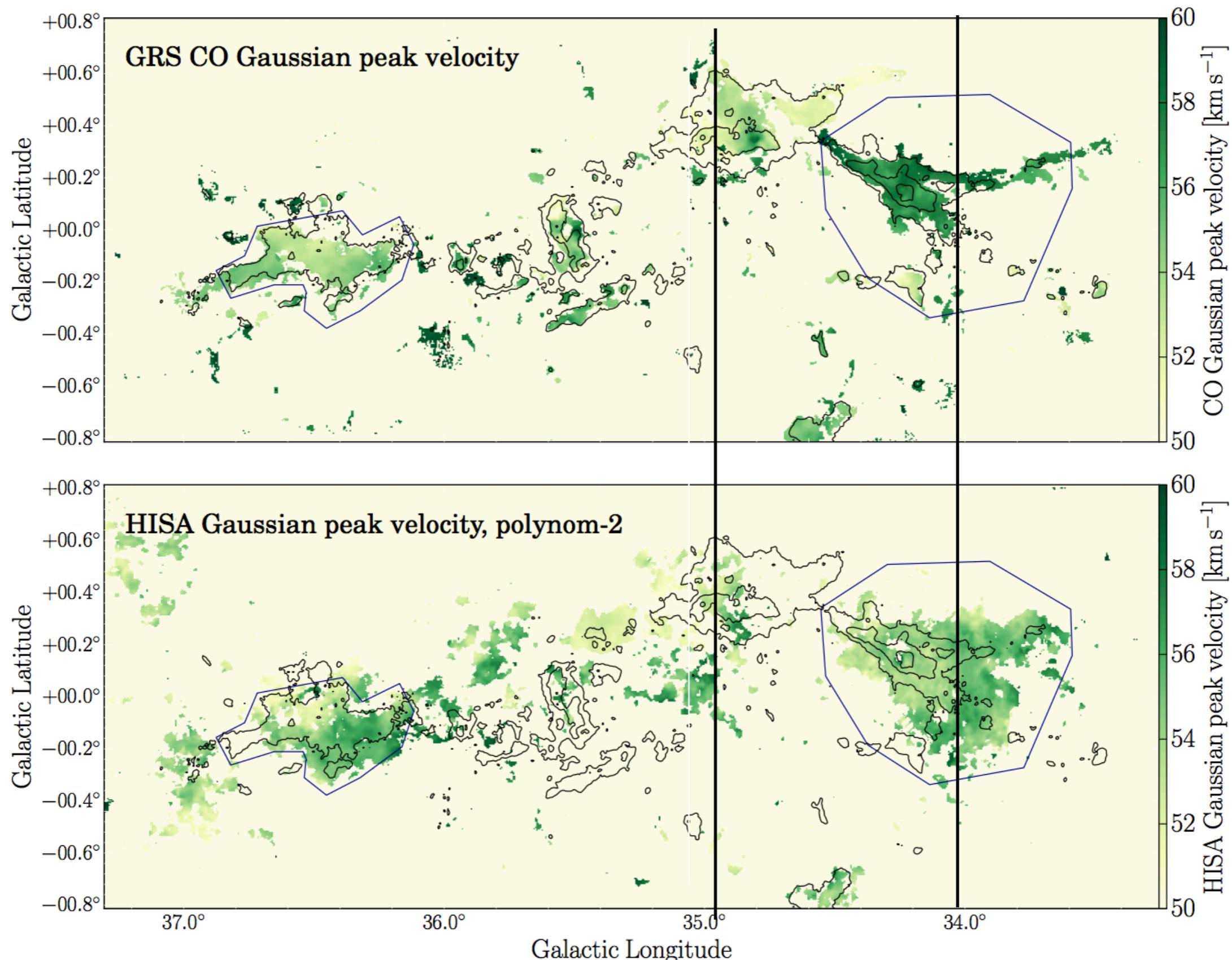
HI self-absorption (HISA)

Dickey, J. & Lockman, F. (1990).



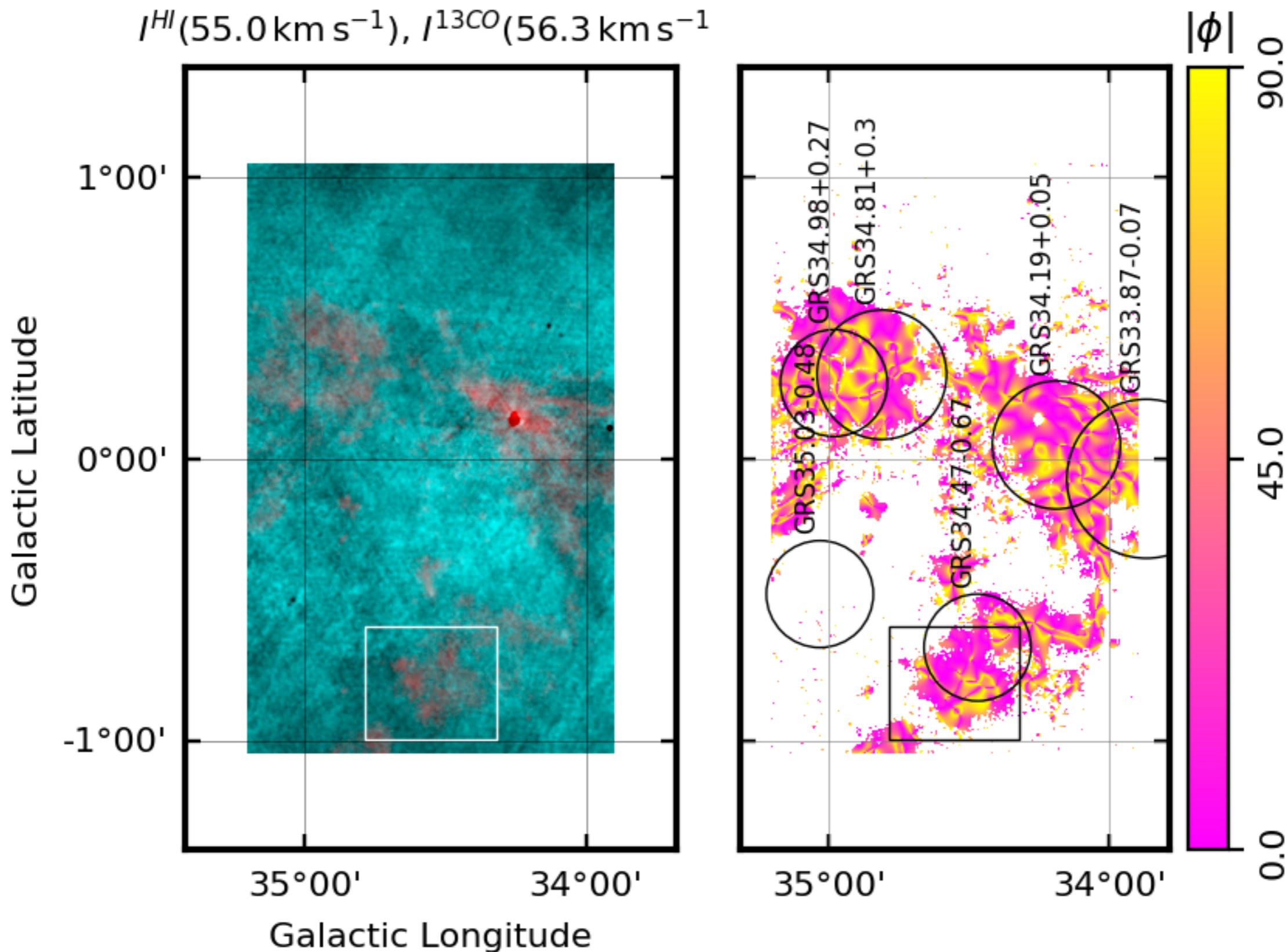
HISA and ^{13}CO

Wang, Y. and the THOR collaboration. A&A submitted.



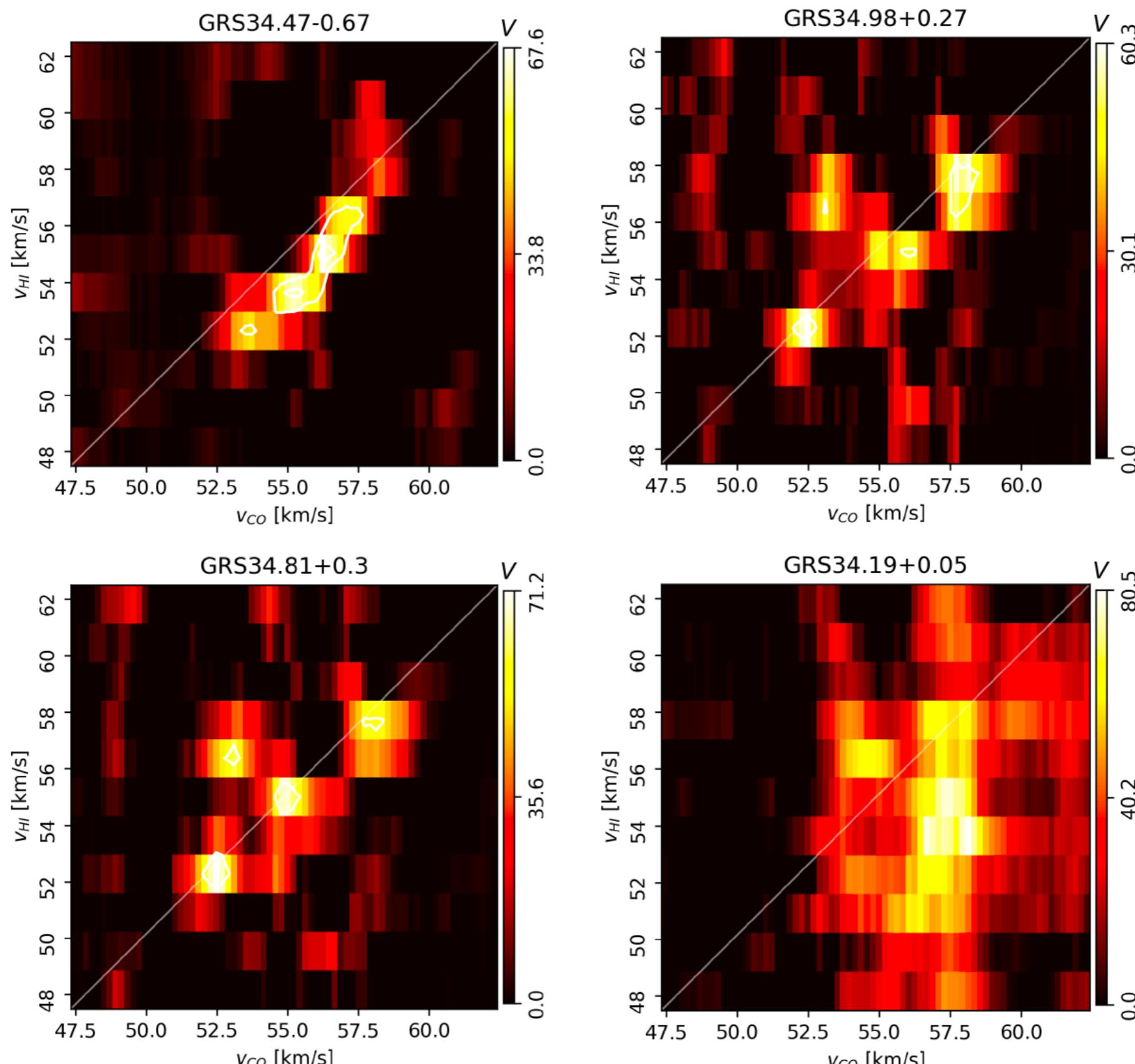
Spatial correlation between HI and ^{13}CO

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



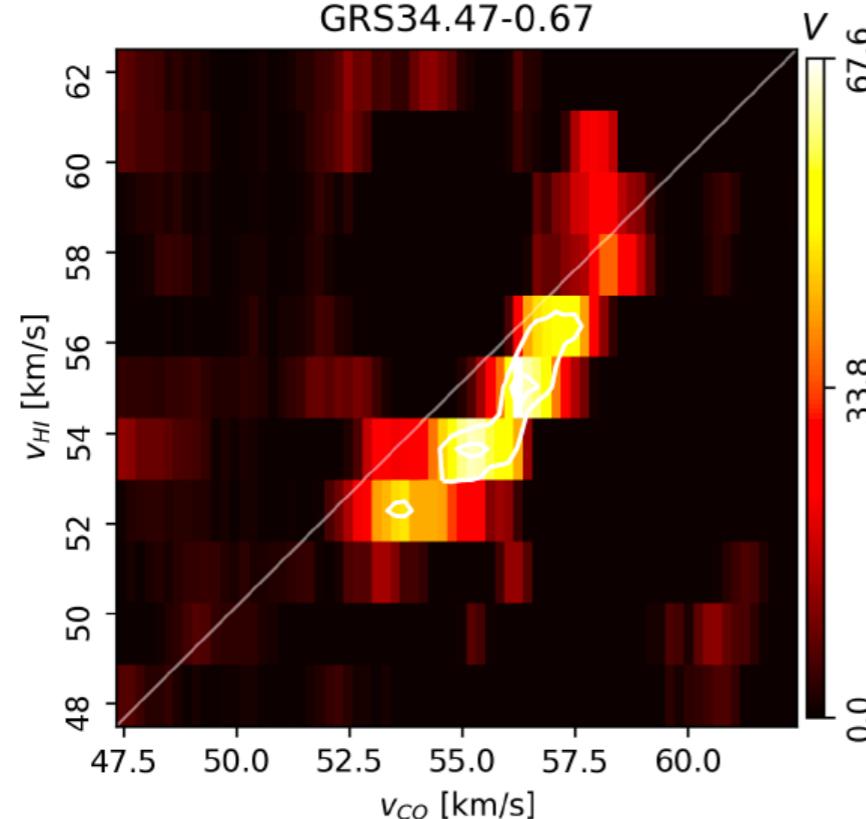
Spatial correlation between HI and ^{13}CO

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



Spatial correlation between HI and ^{13}CO

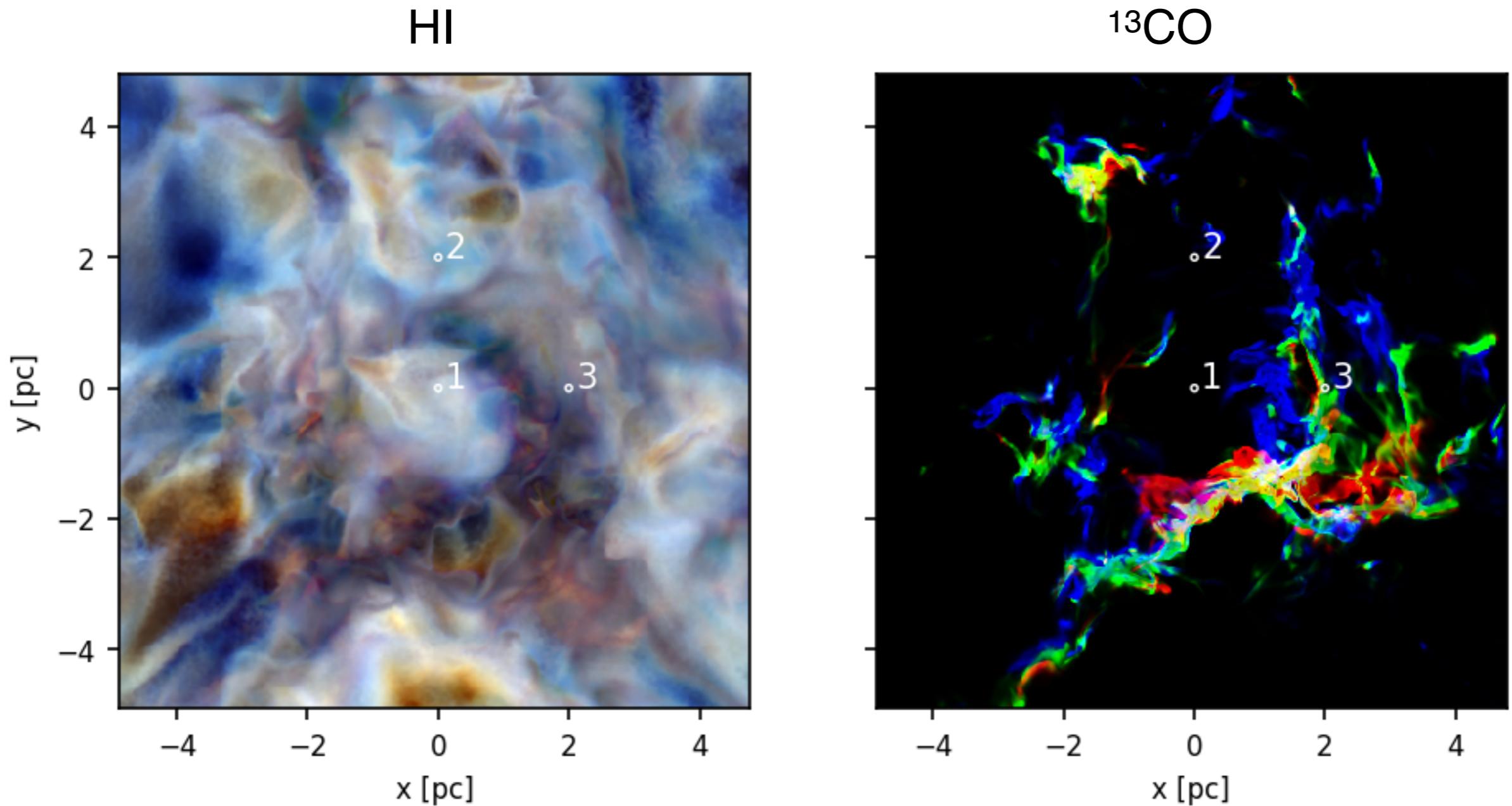
Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



Synthetic observations of a collision of atomic clouds

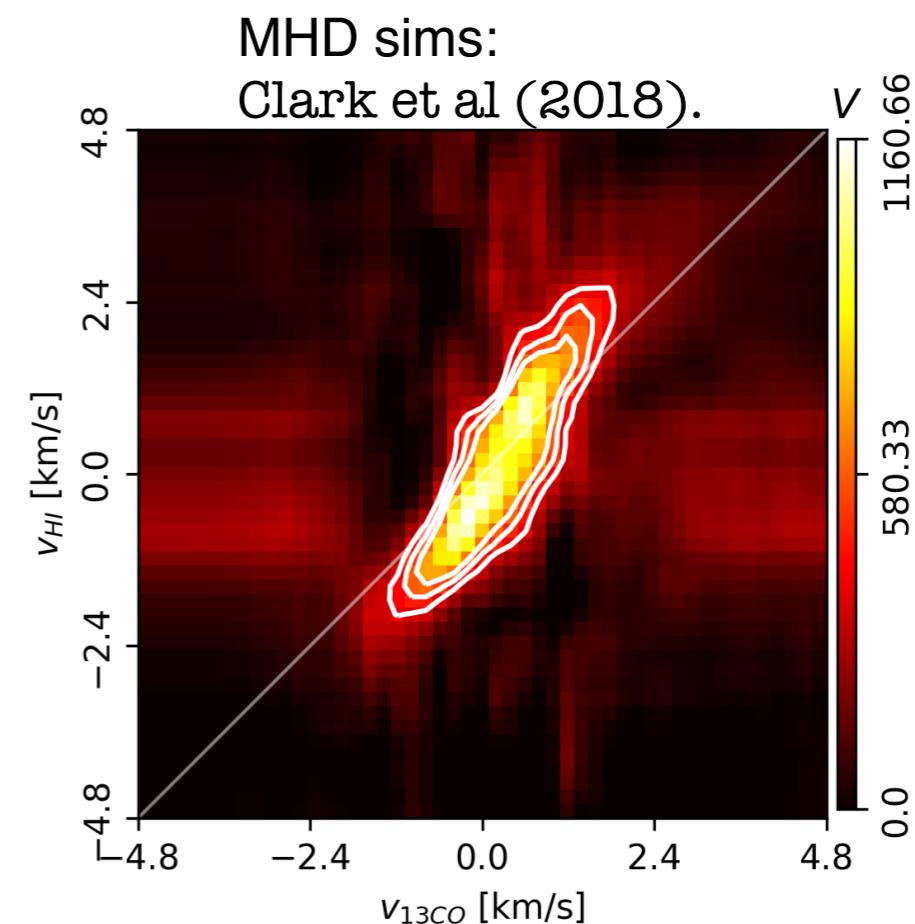
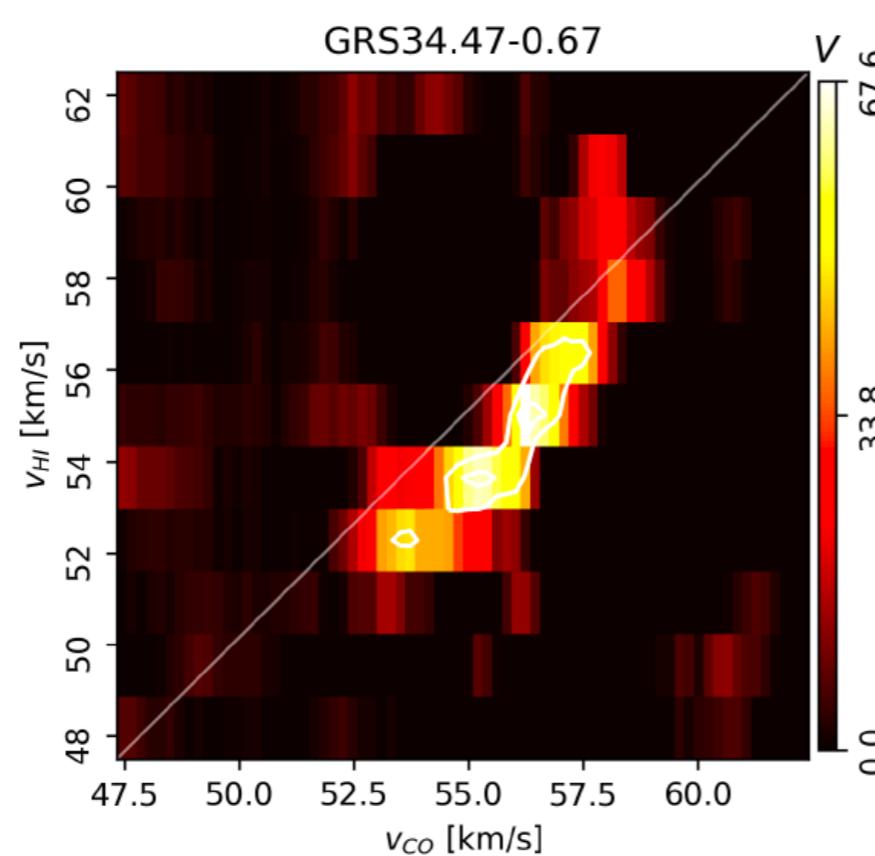
Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166

Clark, P.C., et al. MNRAS 486 (2019) 4622C



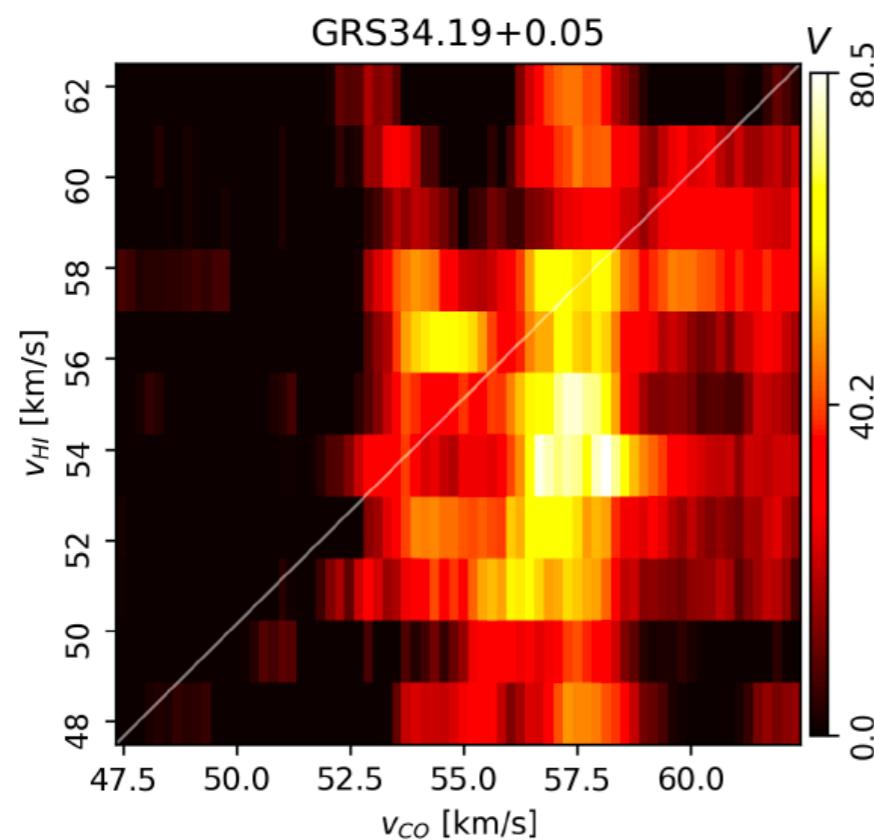
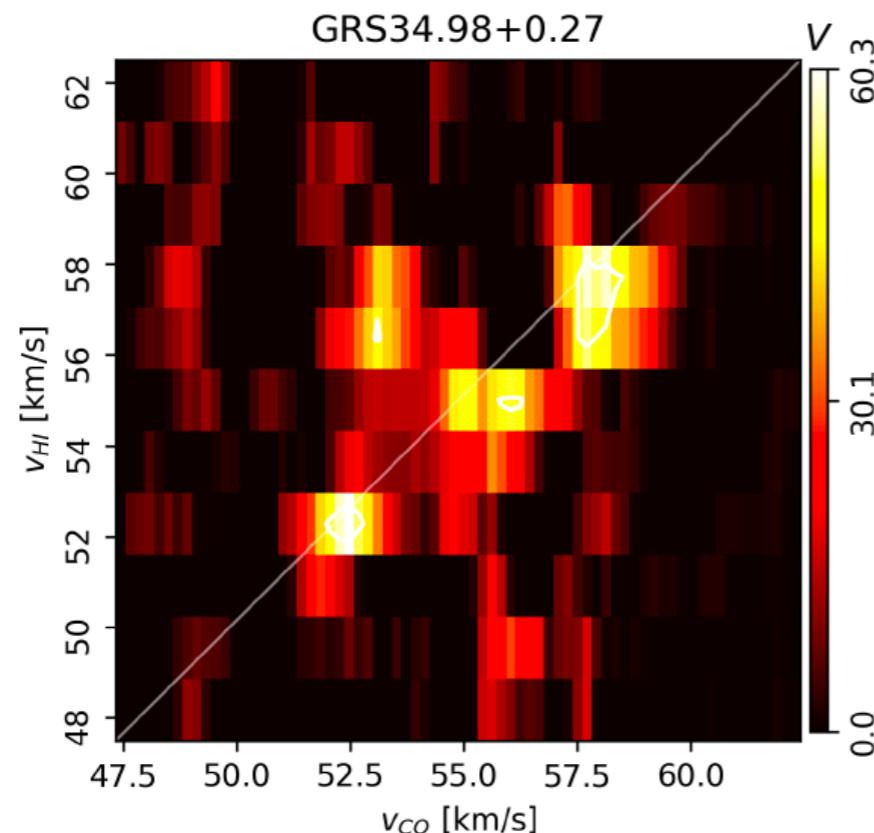
Spatial correlation between HI and ^{13}CO

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



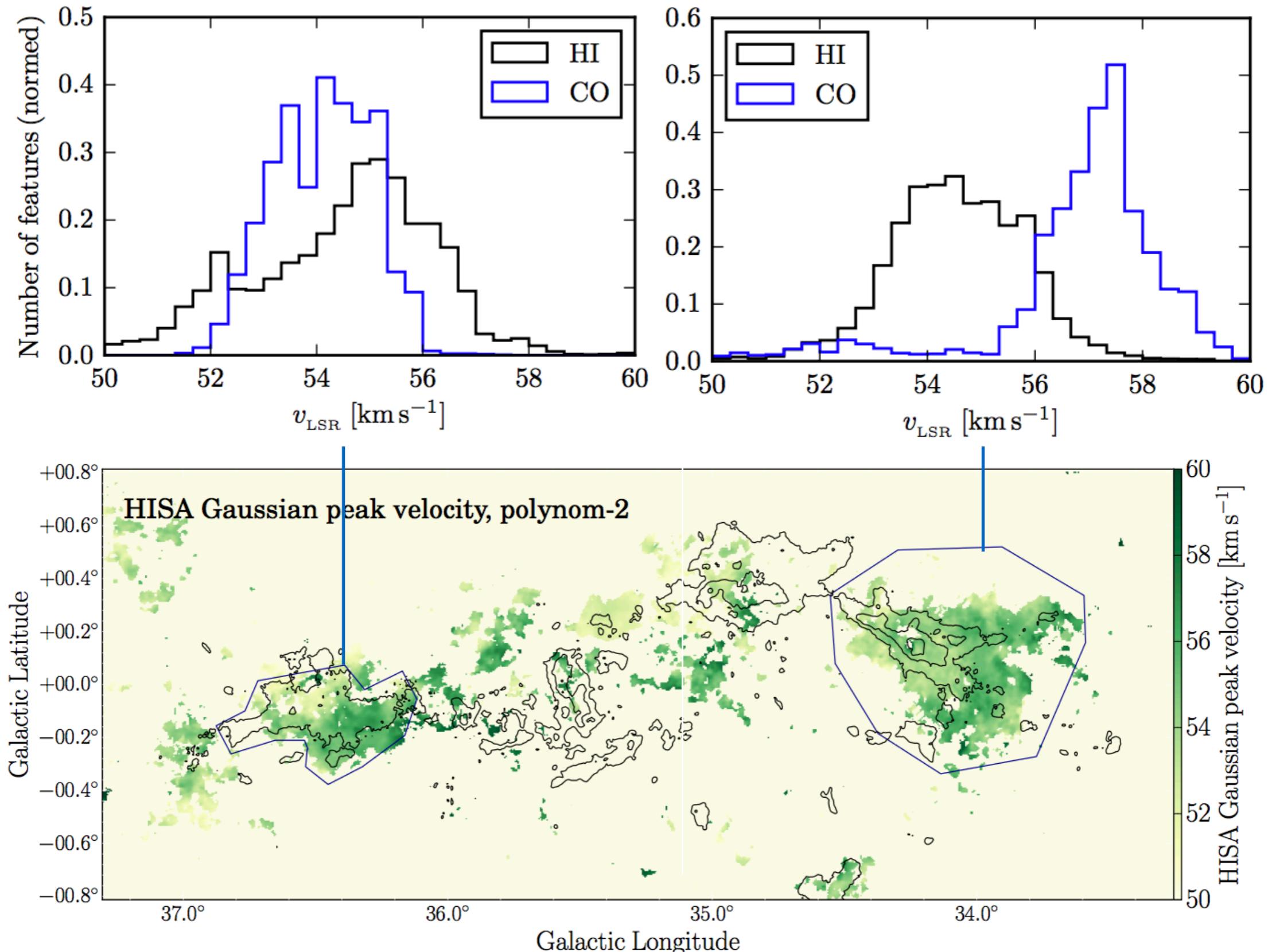
Spatial correlation between HI and ^{13}CO

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



HISA and ^{13}CO

Wang, Y. and the THOR collaboration. A&A submitted.



Conclusions

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



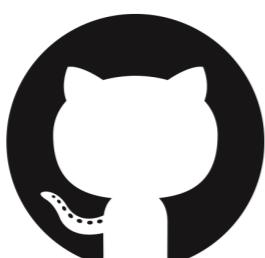
We found a **#MorphologicalCorrelation** between the HI and ^{13}CO emission using **#HOG**, a tool from **#MachineVision**.



The **#MorphologicalCorrelation** is found in velocity channels with $v_{\text{HI}} \approx v_{\text{CO}}$, but also in channels separated by a few km/s, particularly toward **#HIIregions**.



We are using this **#StatisticalTool** to systematically study other regions in the Galactic plane and study **#SyntheticObservations** of stellar feedback **#MHDsims**.



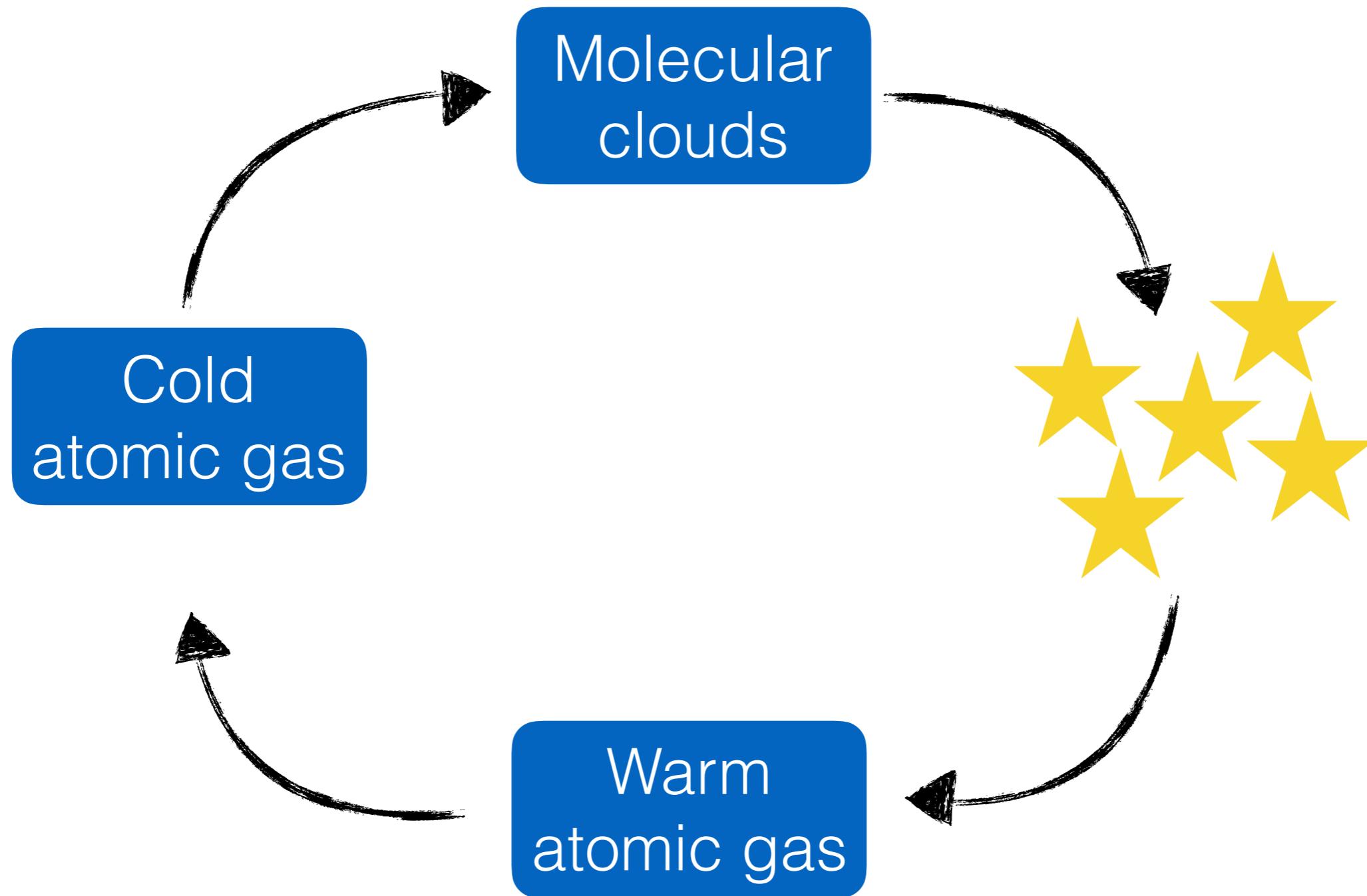
Tools and data available at:

<https://github.com/solerjuan/astrohog>

<http://www.mpi-a.de/thor>

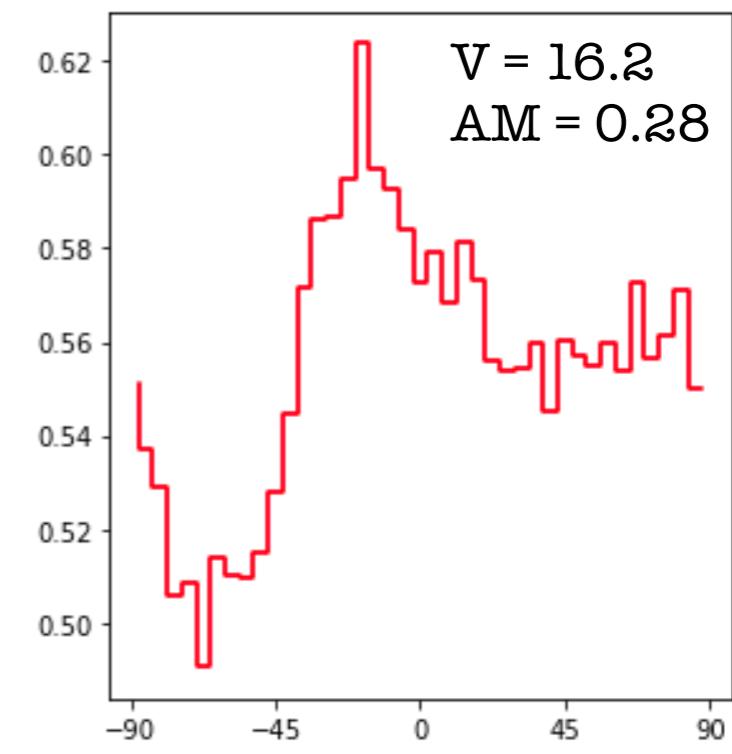
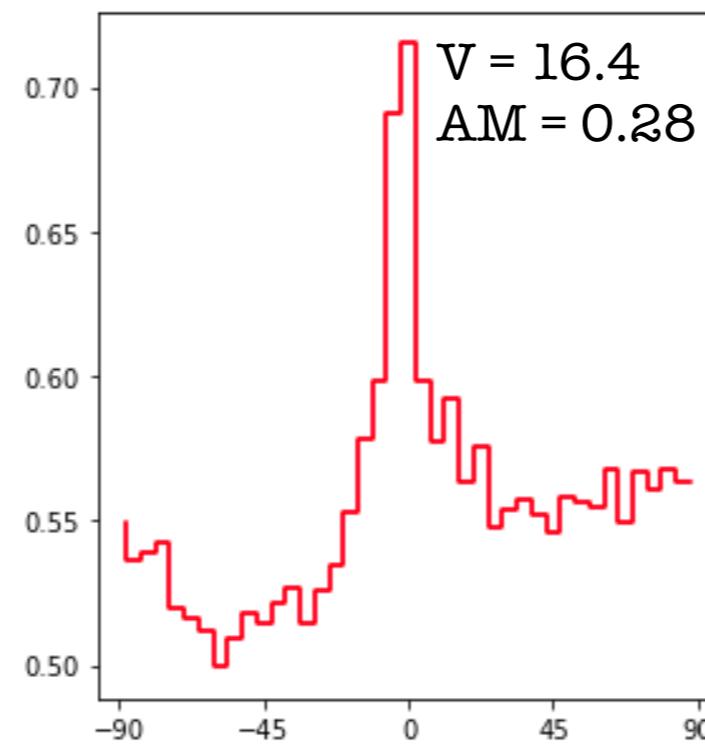
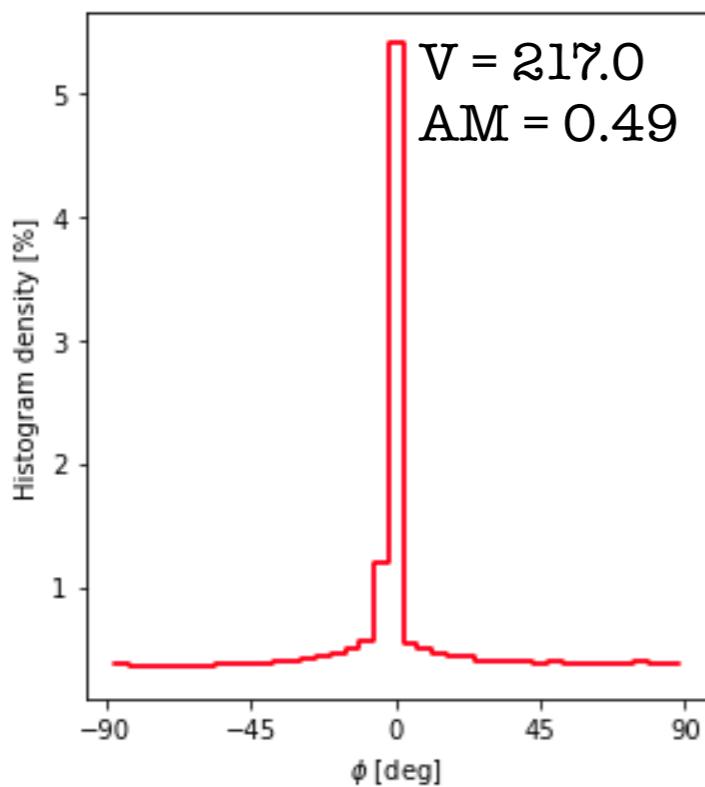
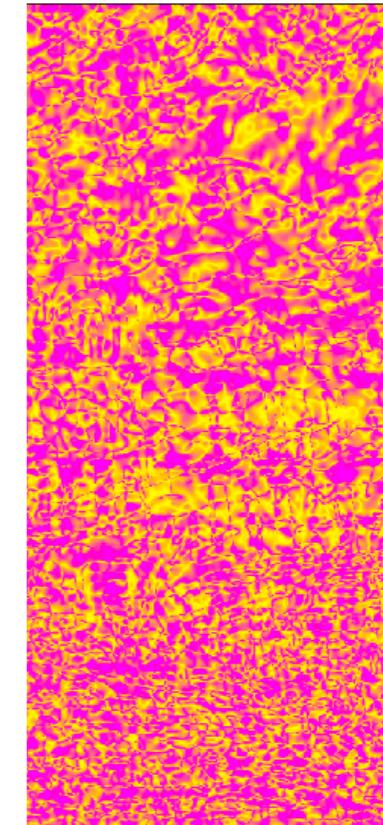
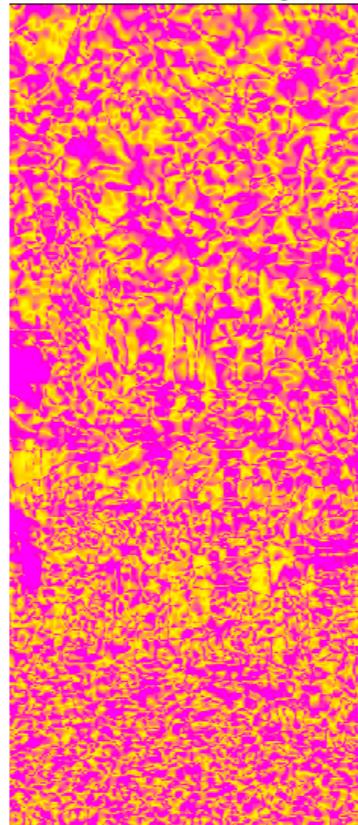
Extra Slides

From gas to stars



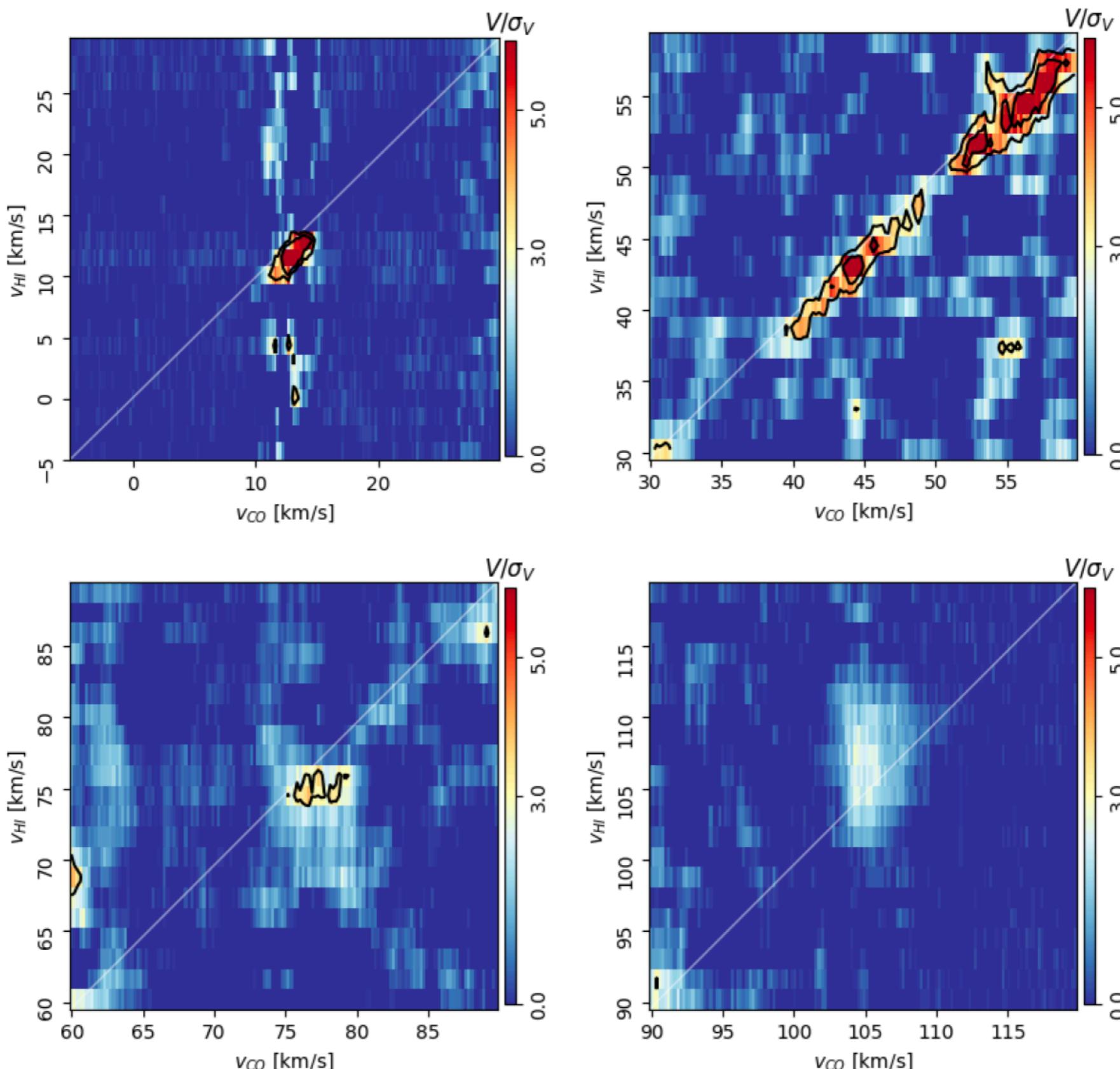
Histogram of relative orientations (HOG)

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



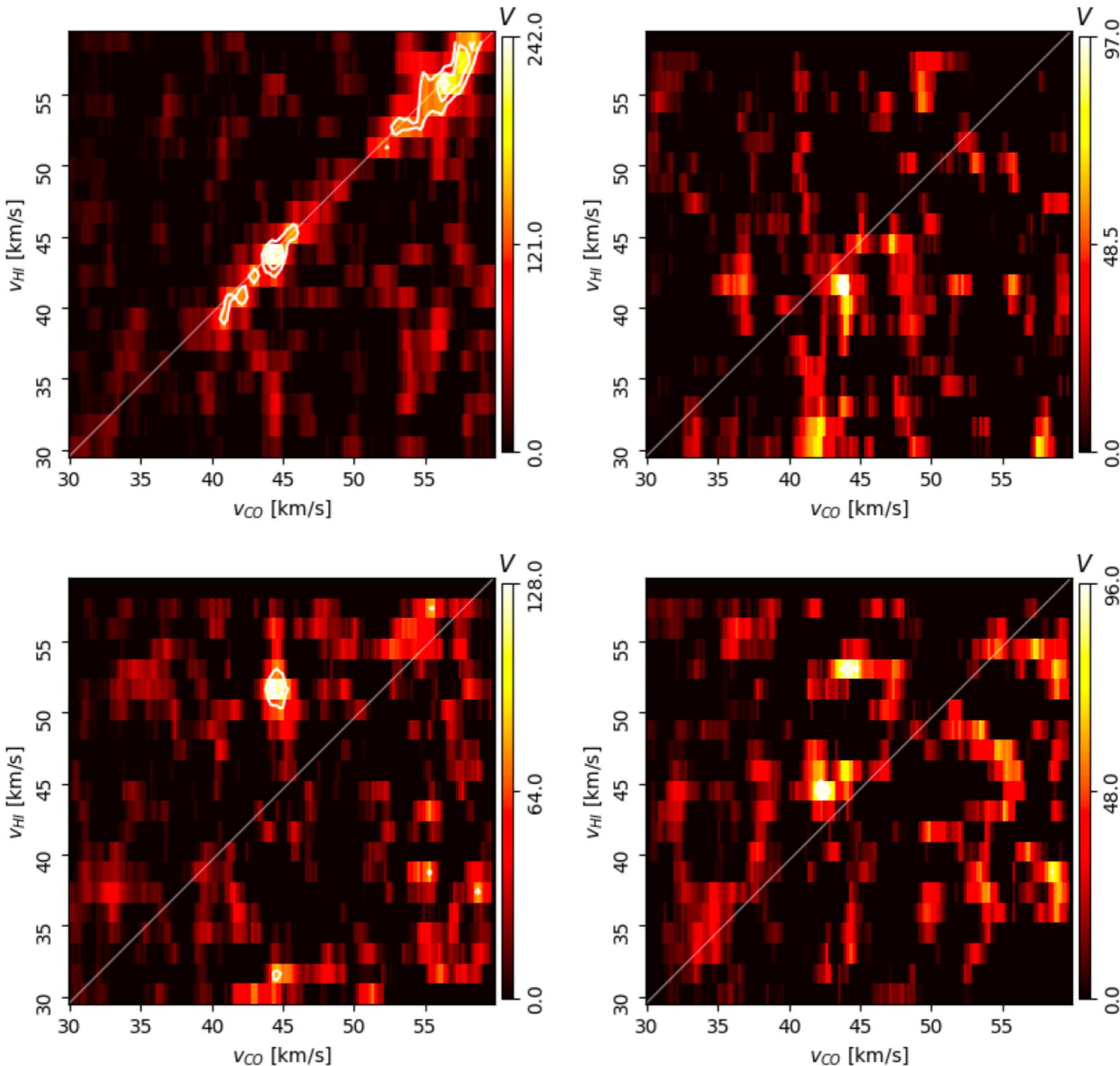
HOG statistical tests - Montecarlo sampling

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



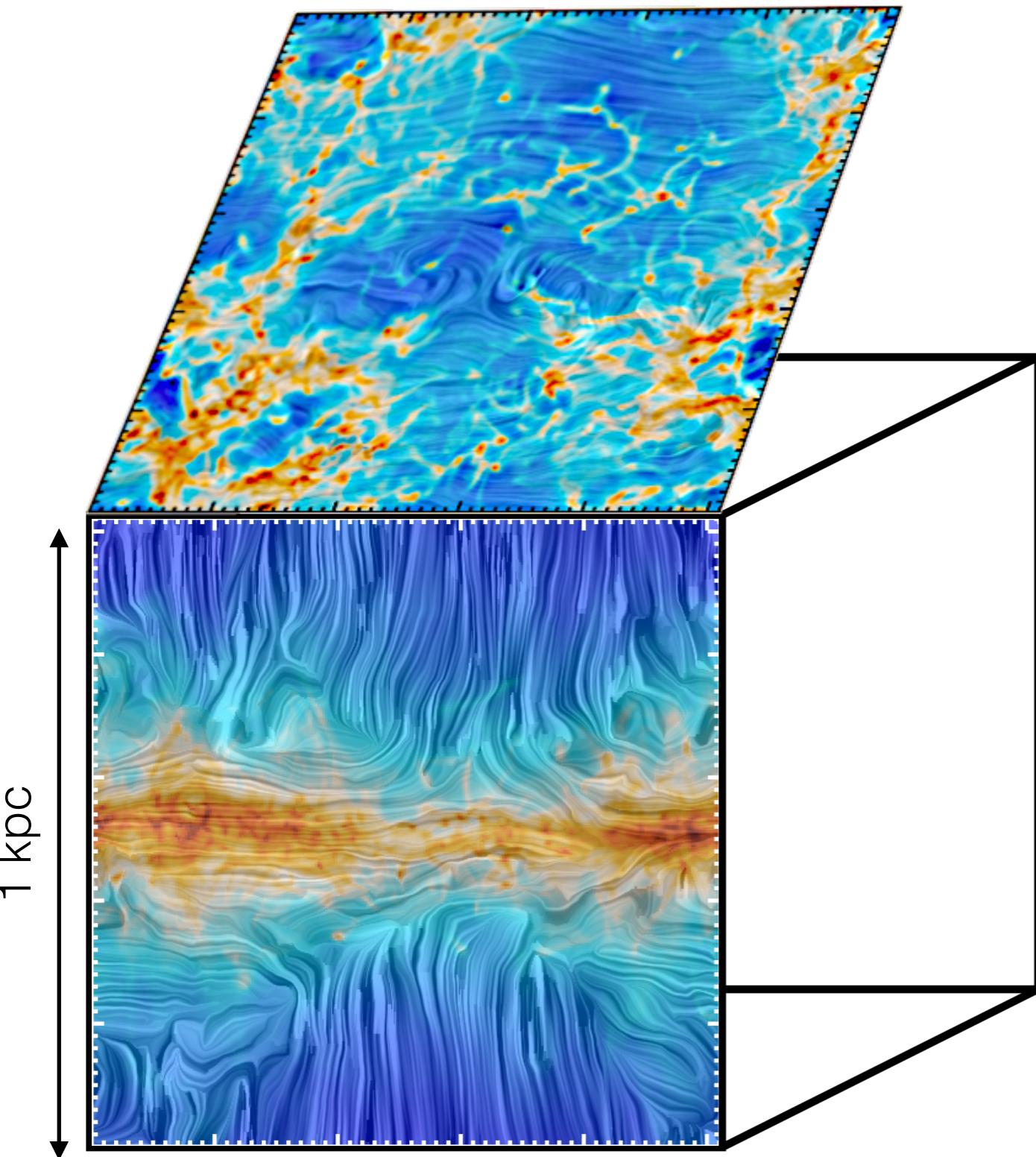
HOG statistical tests - jack-knife tests

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



From diffuse gas to molecular clouds

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166

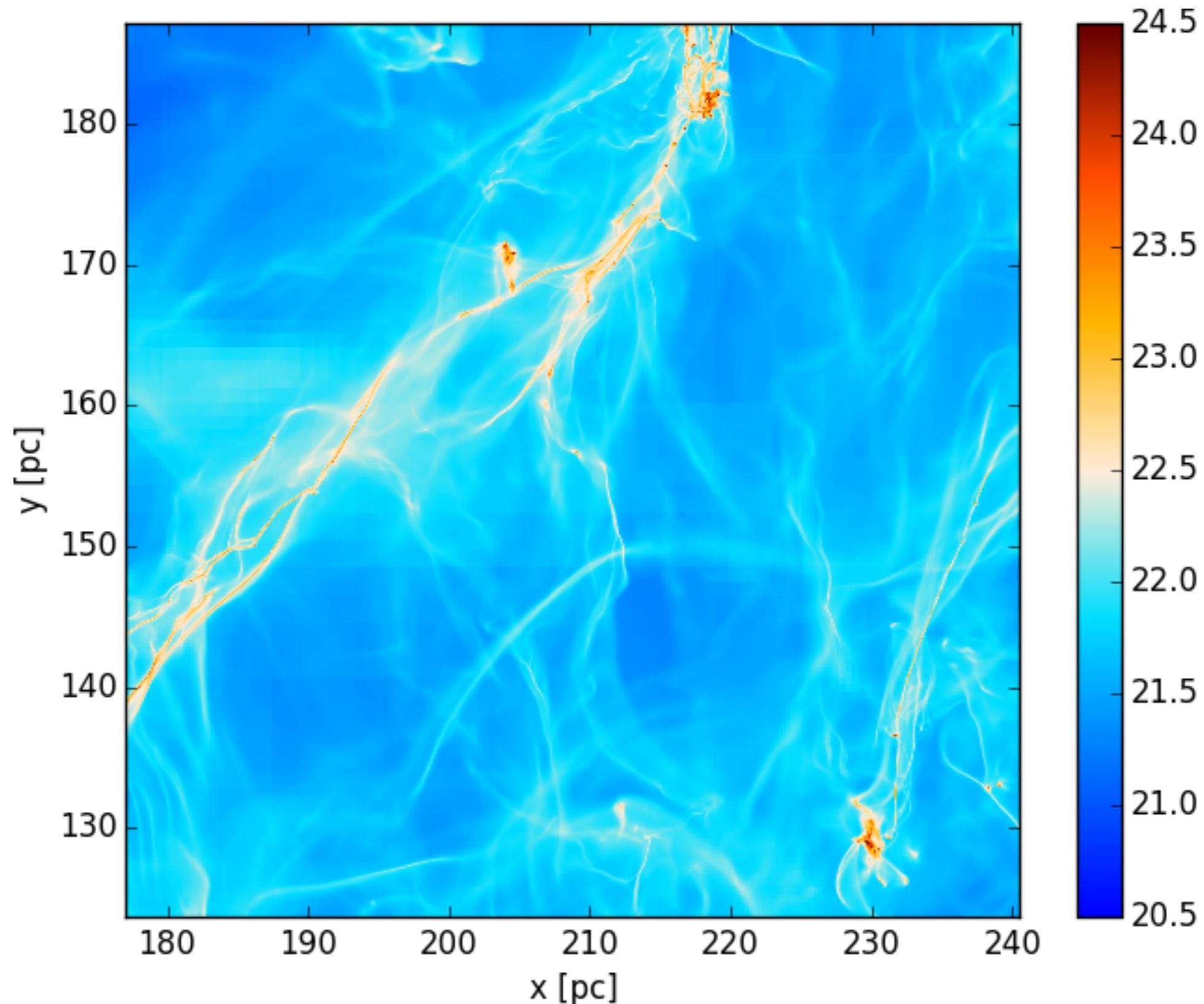


RAMSES simulation
 $L = 1 \text{ kpc}$ (up to $2 \times 10^{-3} \text{ pc}$ resolution)
Turbulence driven by SNe

Hennebelle & Iffrig, 2014, 2015
Hennebelle, 2018

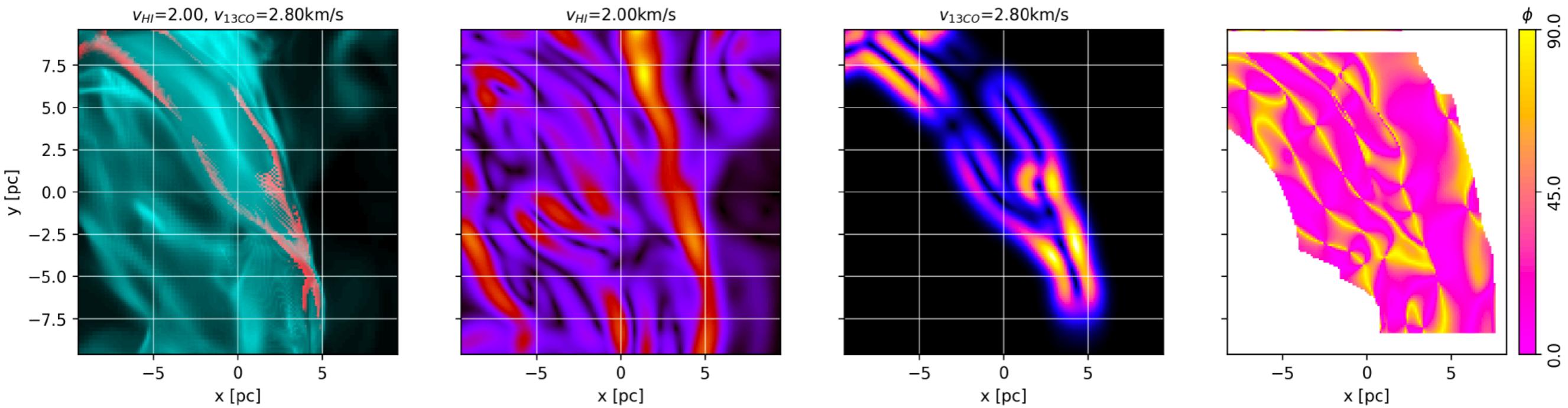
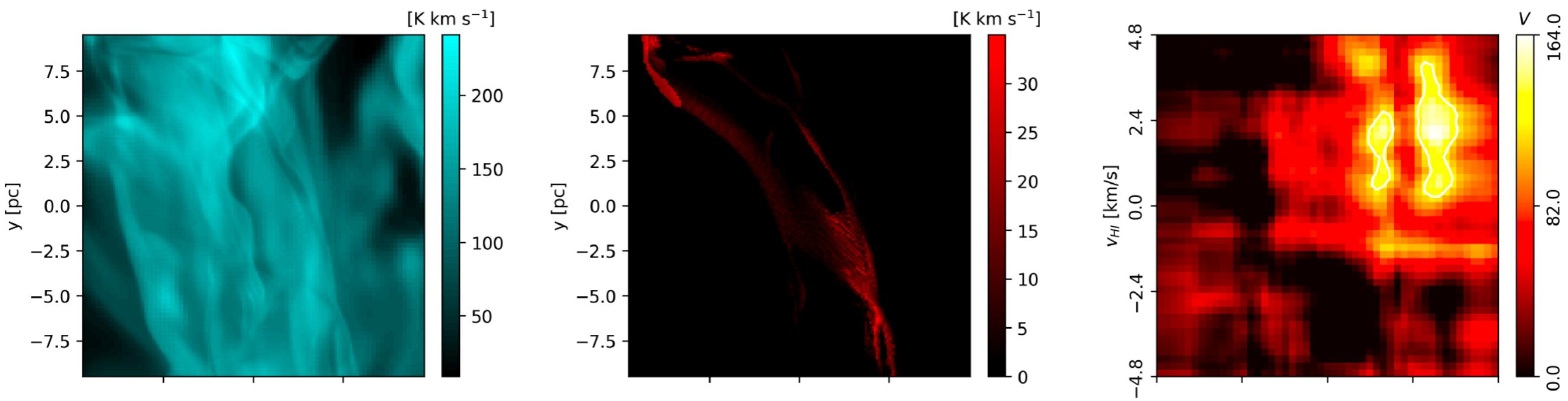
From diffuse gas to molecular clouds

Soler, J.D., and the THOR collaboration. A&A, 622 (2019) A166



FRIGG simulations - synthetic observations

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From diffuse gas to molecular clouds

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