The Galactic dynamics

revealed by the filamentary structure in the

neutral atomic hydrogen emission

Juan Diego Soler
Istituto di Astrofisica e Planetologia Spaziali

THOR collaboration: H. Beuther, Y. Wang, J. Syed, Th. Henning, L. D. Anderson, N. M. McClure-Griffiths, P. F. Goldsmith, M. Heyer, M. Rugel, J. S. Urquhart, J. Stil, R. Shanahan

ECOgal collaboration: S. Molinari, R. S. Klessen, P. Hennebelle, S. C. O. Glover, A. Trafficante, E. Schisano, D. Elia, M. Sormani, R. Treß, P. Girichidis, R. J. Smith, T. Colman

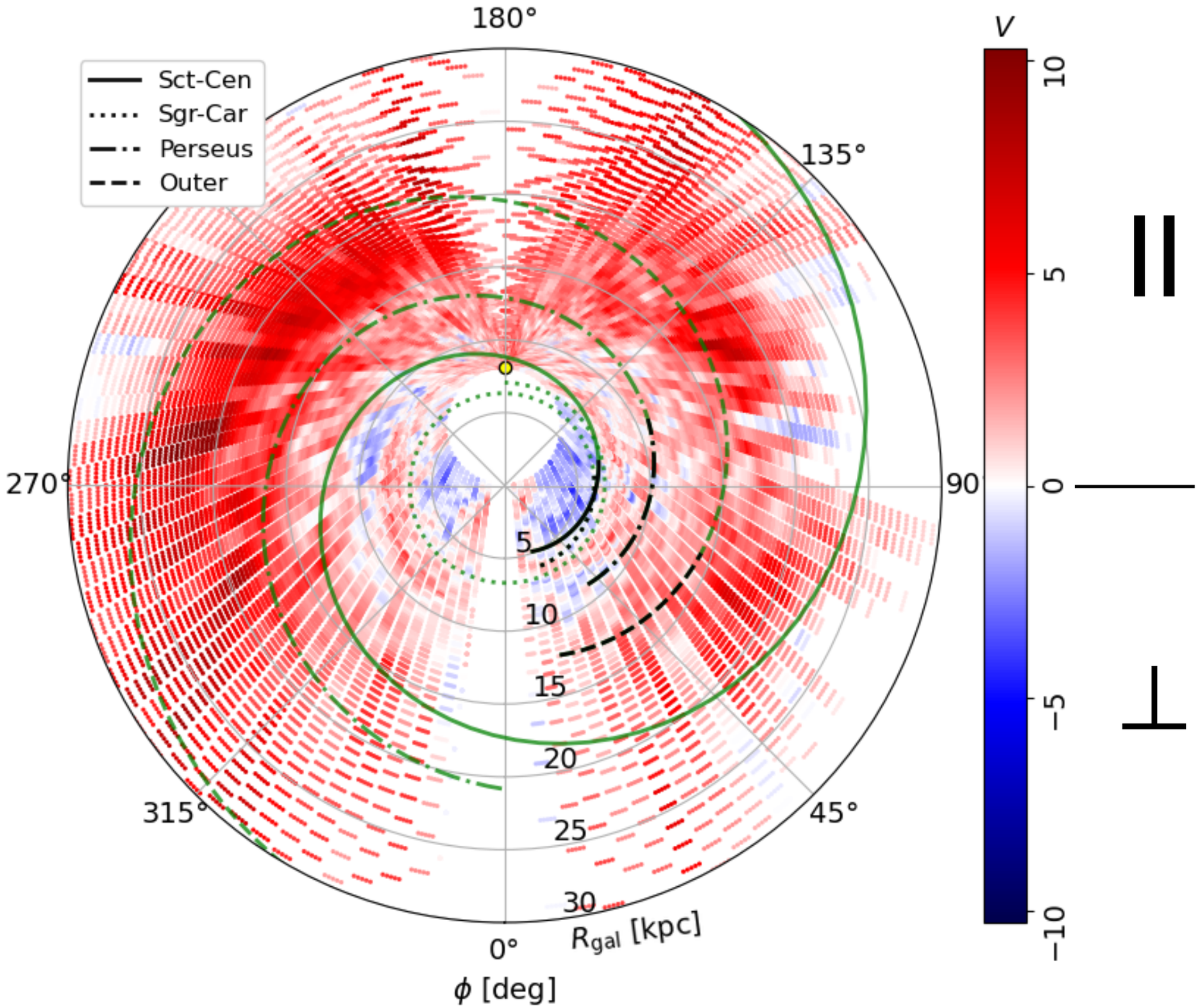
Emission by atomic hydrogen gas in the Milky Way

GALFA-HI survey

Juan Diego Soler and the ECOGAL collaboration

Orientation of HI filaments with respect to the Galactic plane

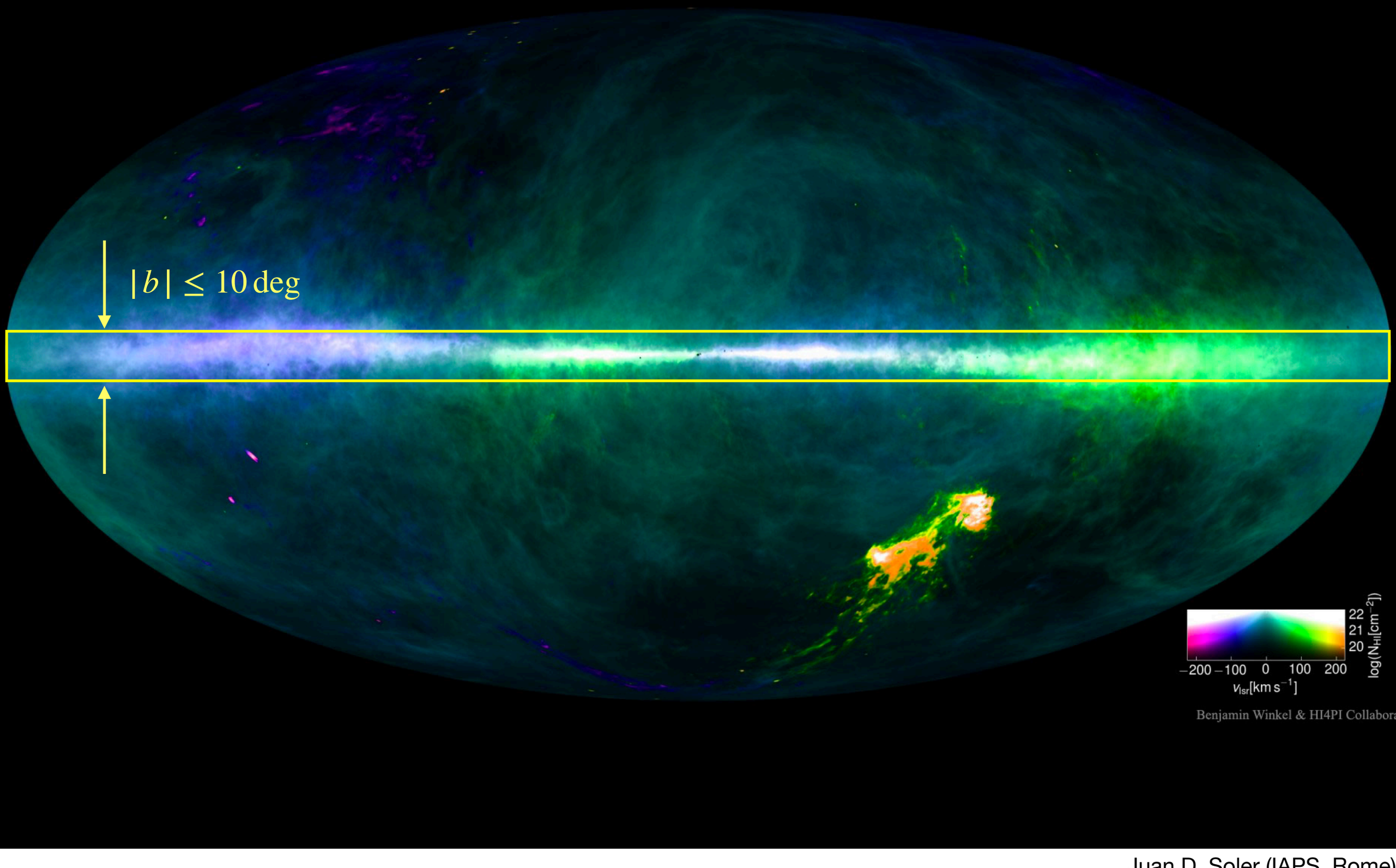
Soler, J.D. et al. A&A (2022)



Atomic hydrogen emission

HI4PI Collaboration. A&A (2016)

HI4PI
16.5’ FWHM
Δv=1.29 km/s

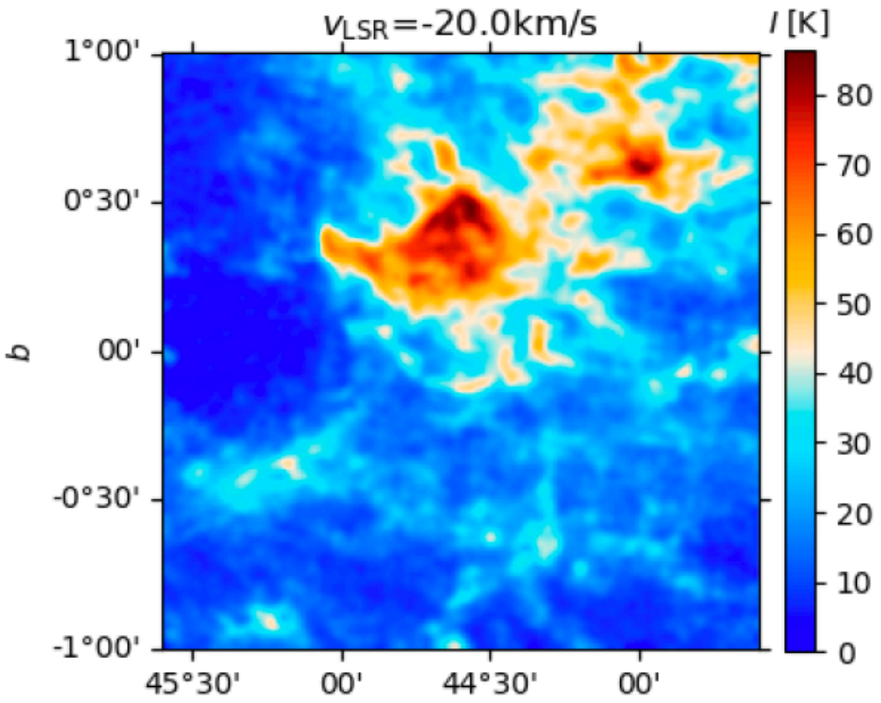


Juan D. Soler (IAPS, Rome)

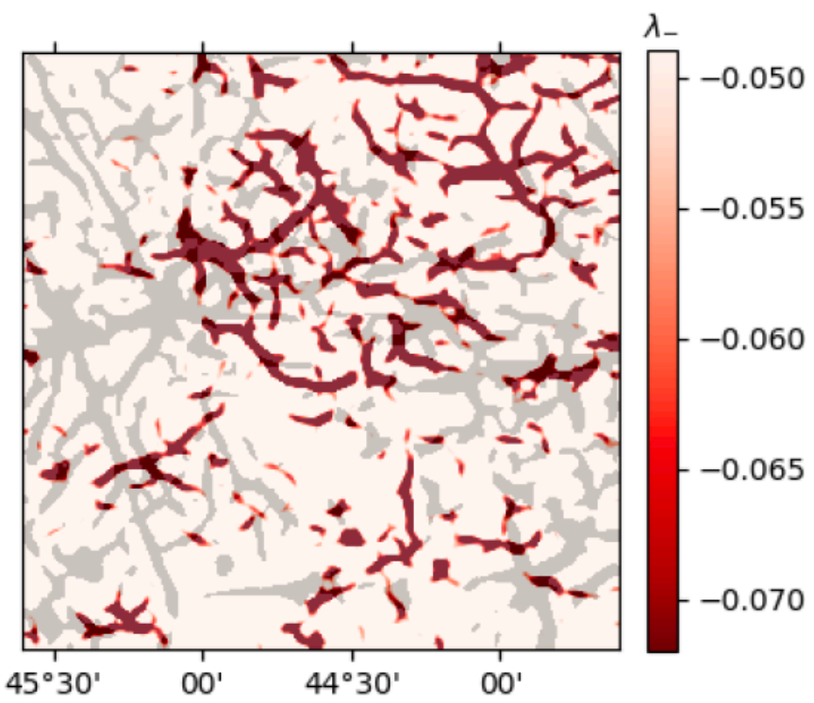
HI filaments - Hessian matrix method

THOR-HI. Beuther et al. A&A (2016)
Soler, J.D. et al. A&A (2020)

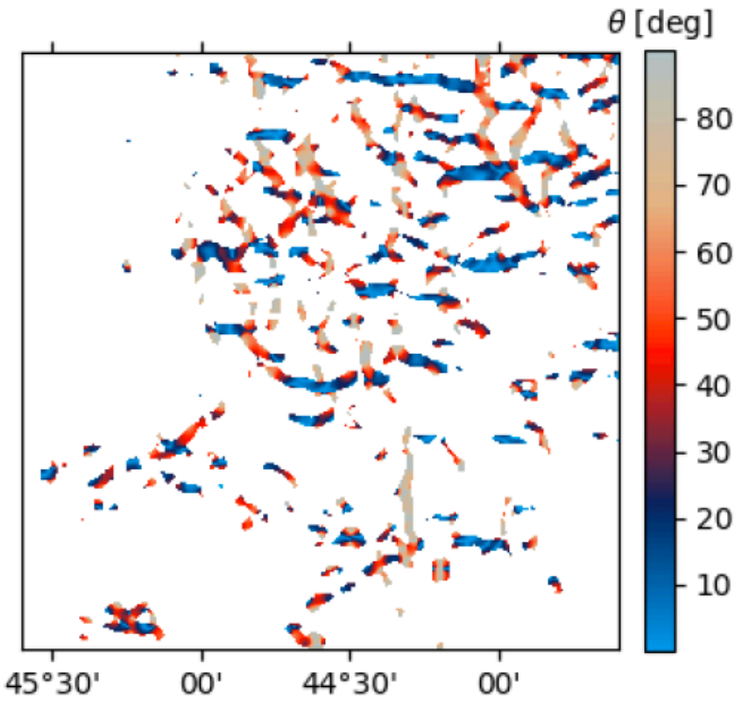
Emission



Filaments

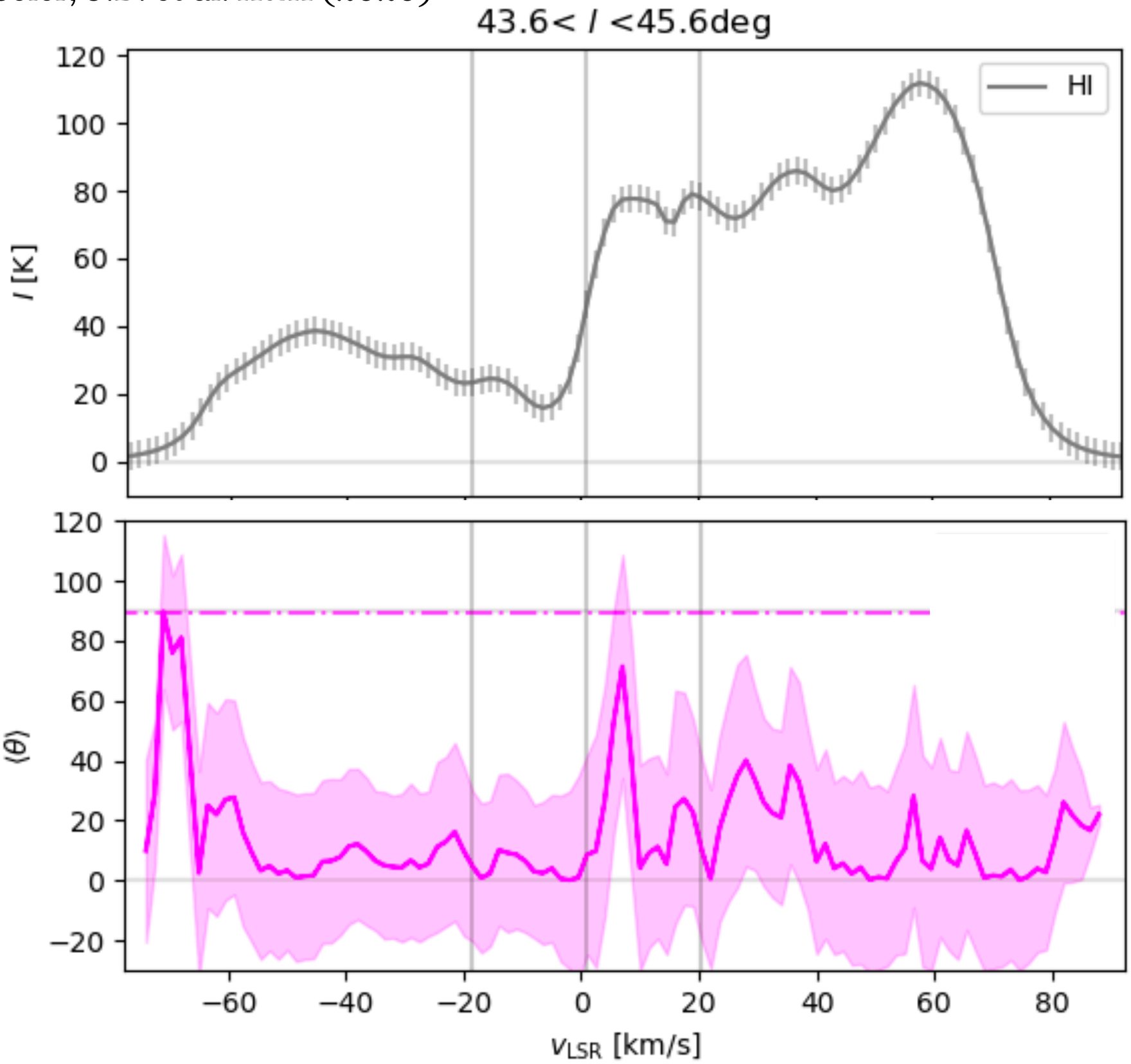


Orientation



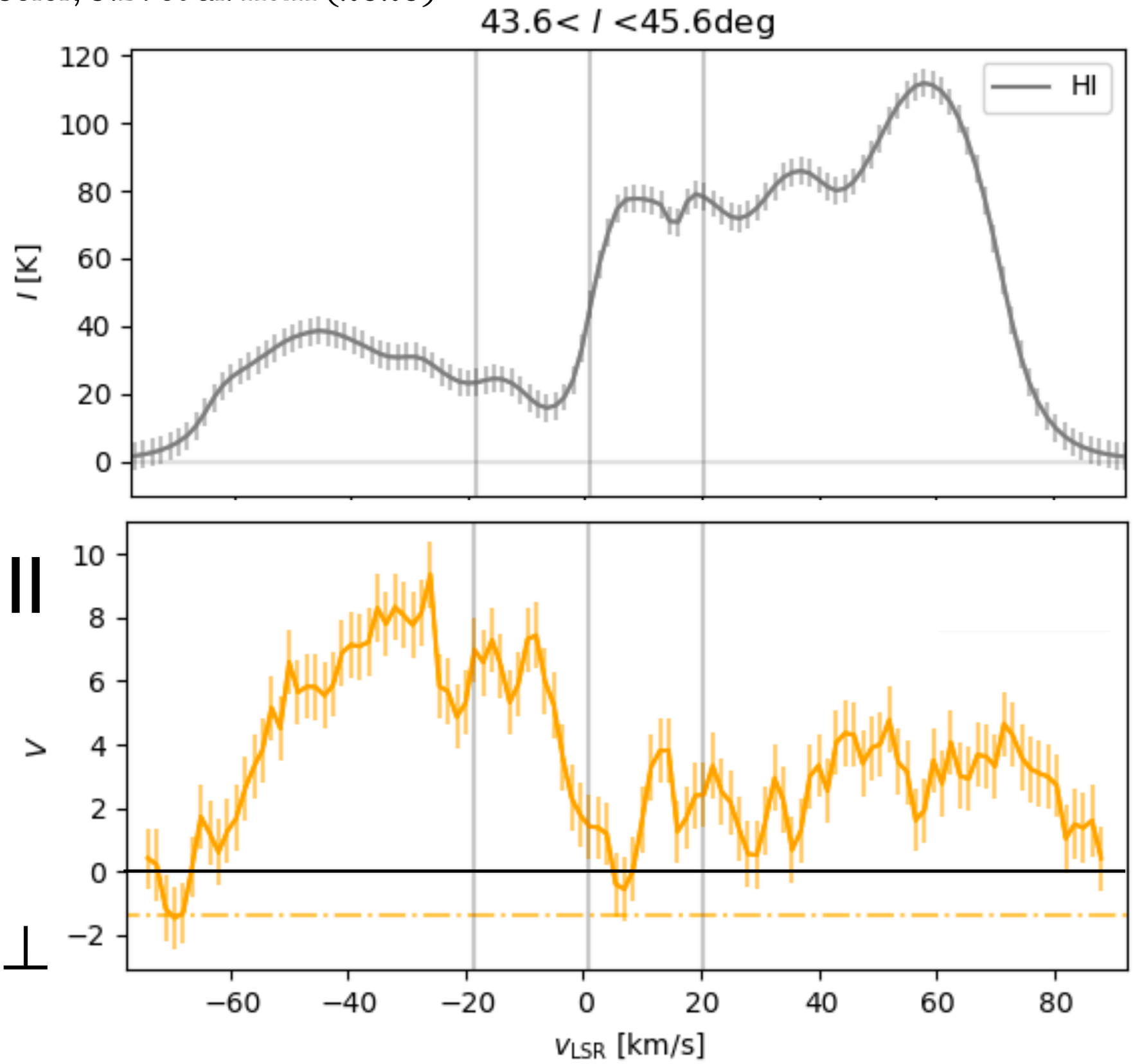
HI filament orientation

Soler, J.D. et al. A&A (2020)



HI filament orientation

Soler, J.D. et al. A&A (2020)



Projected Rayleigh statistic

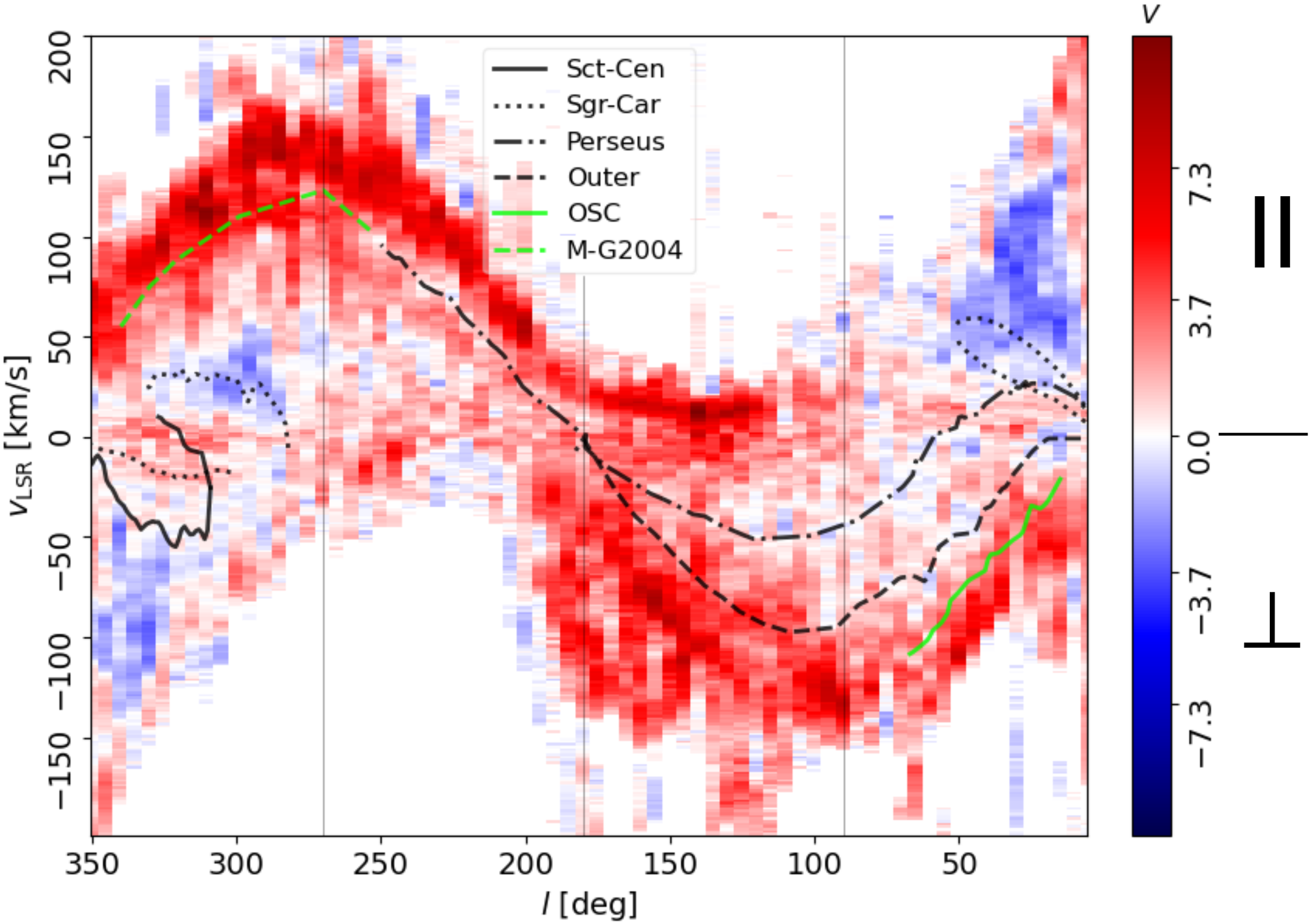
Jow et al. (2018)

Soler et al. (2019)

$$V = \frac{\sum_{ij}^{n,m} w_{ij} \cos(2\theta_{ij})}{\sqrt{\sum_{ij}^{n,m} w_{ij}/2}}$$

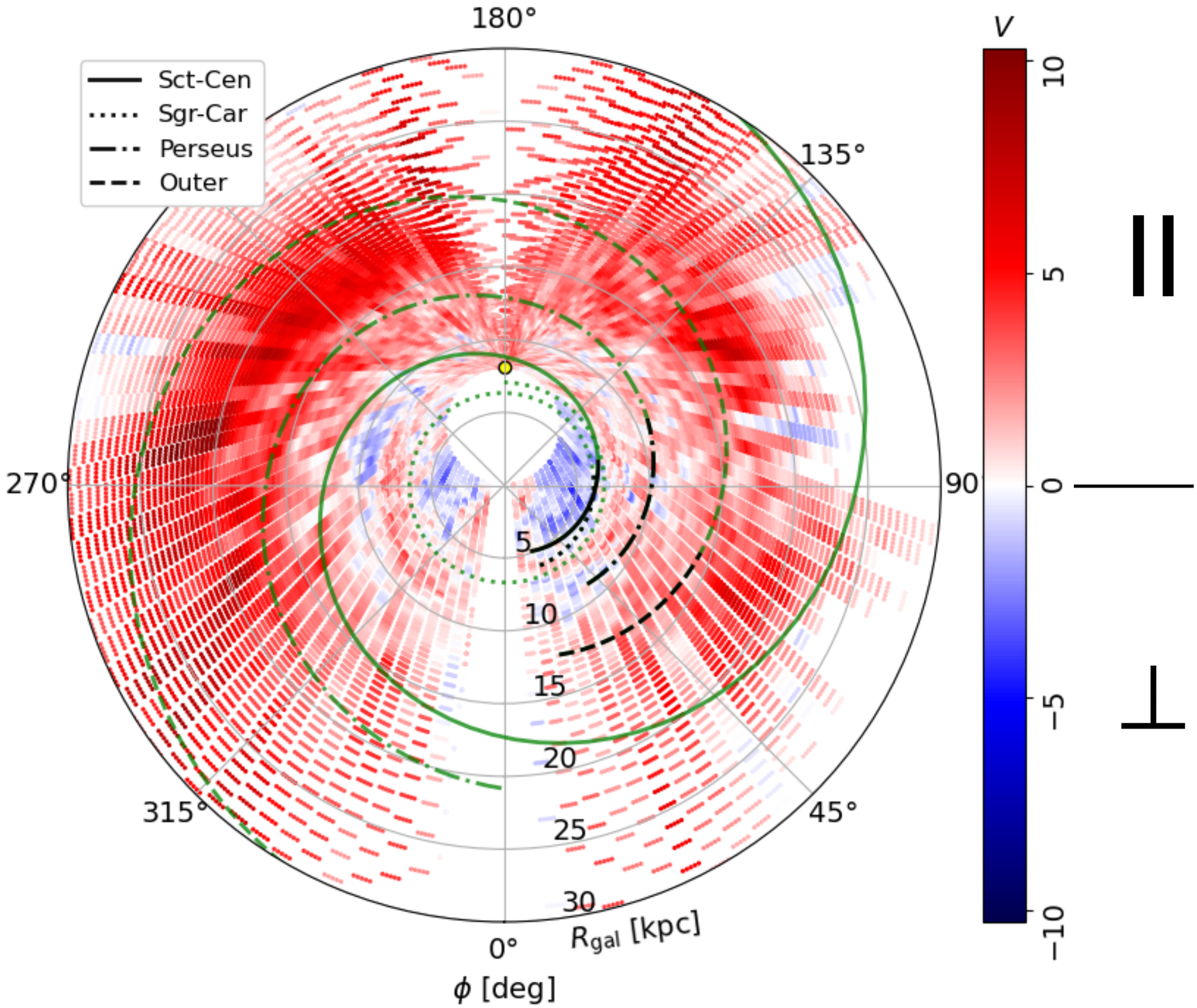
HI filament orientation

Soler, J.D. et al. A&A (2022)



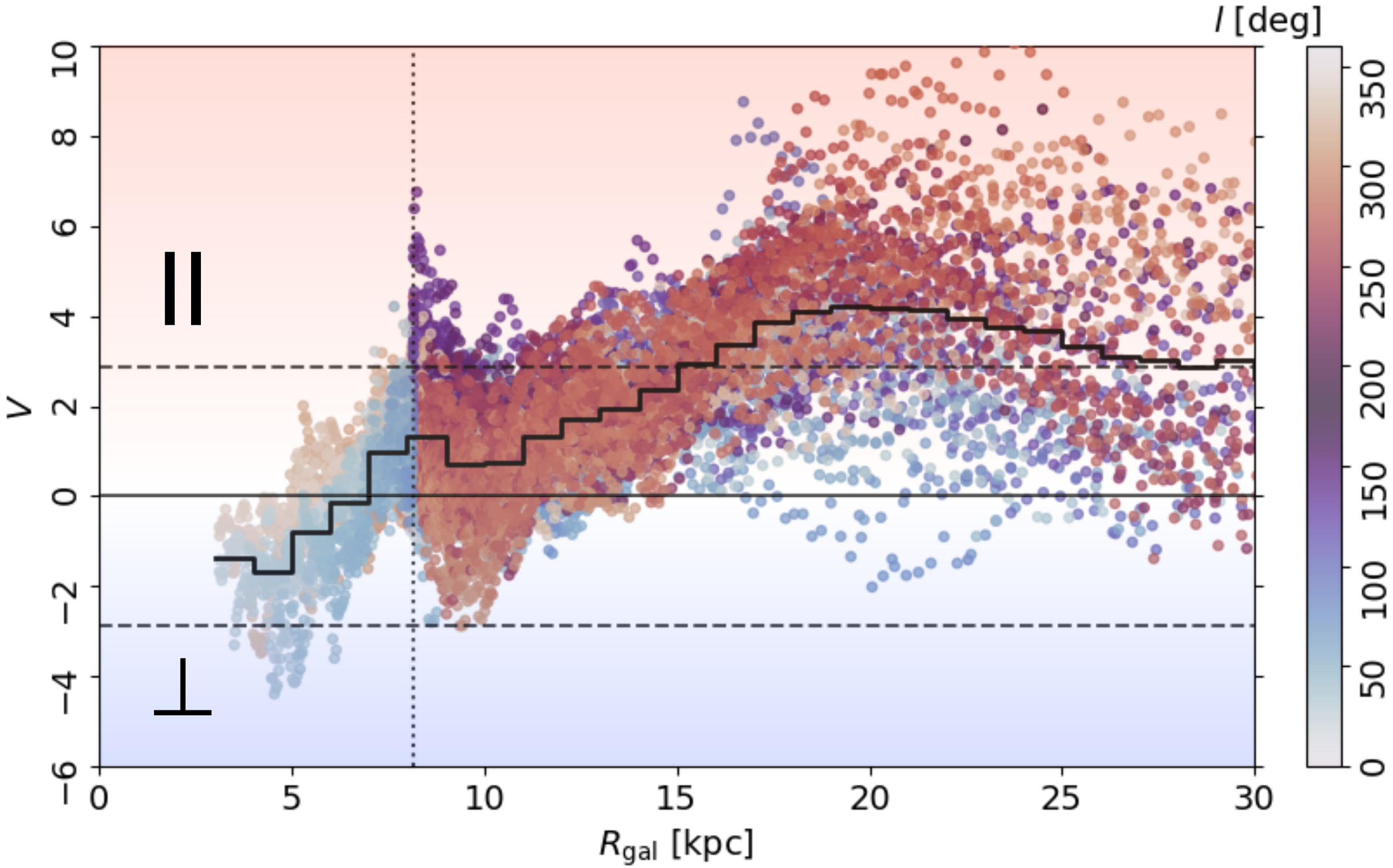
HI filament orientation

Soler, J.D. et al. A&A (2022)



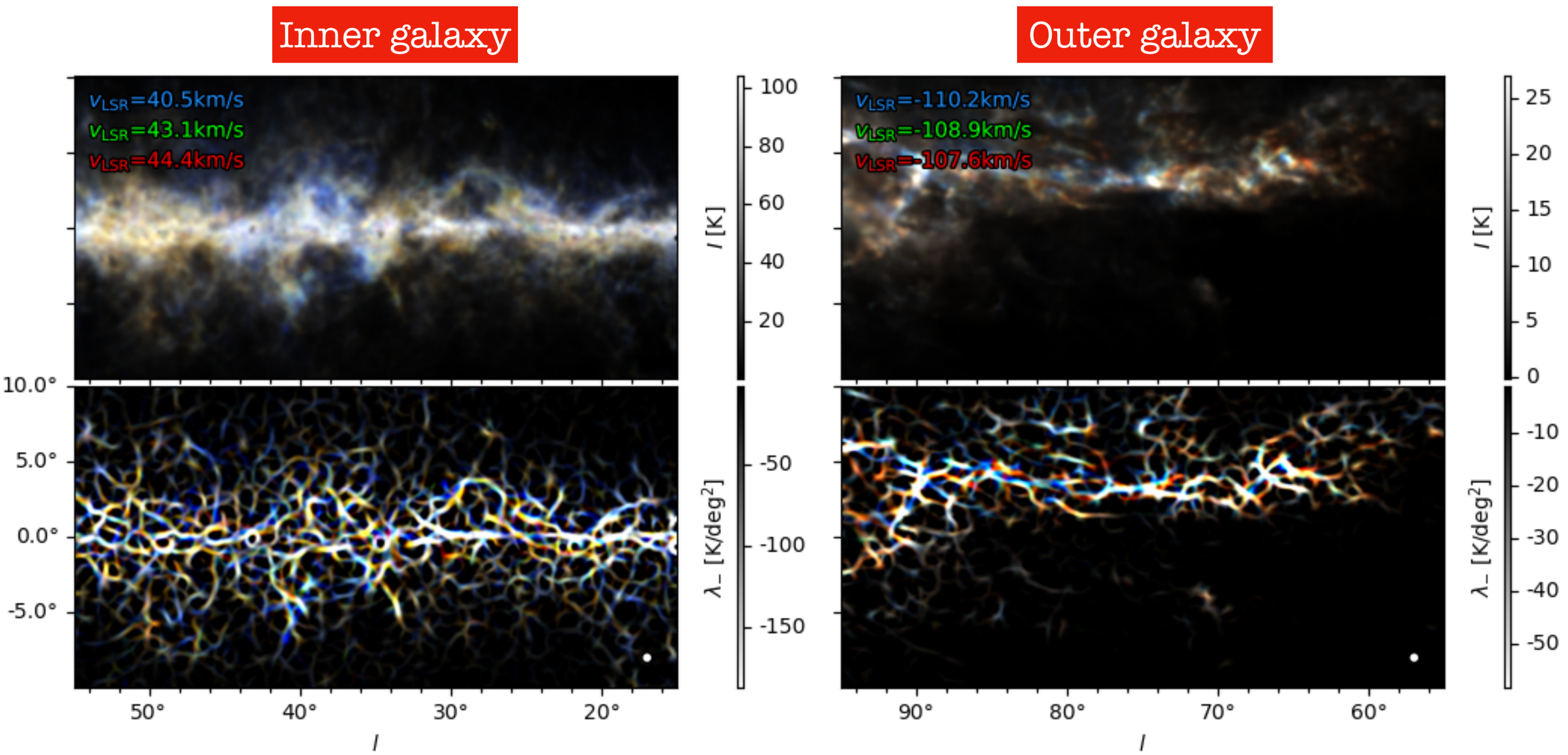
HI filament orientation

Soler, J.D. et al. A&A (2022)



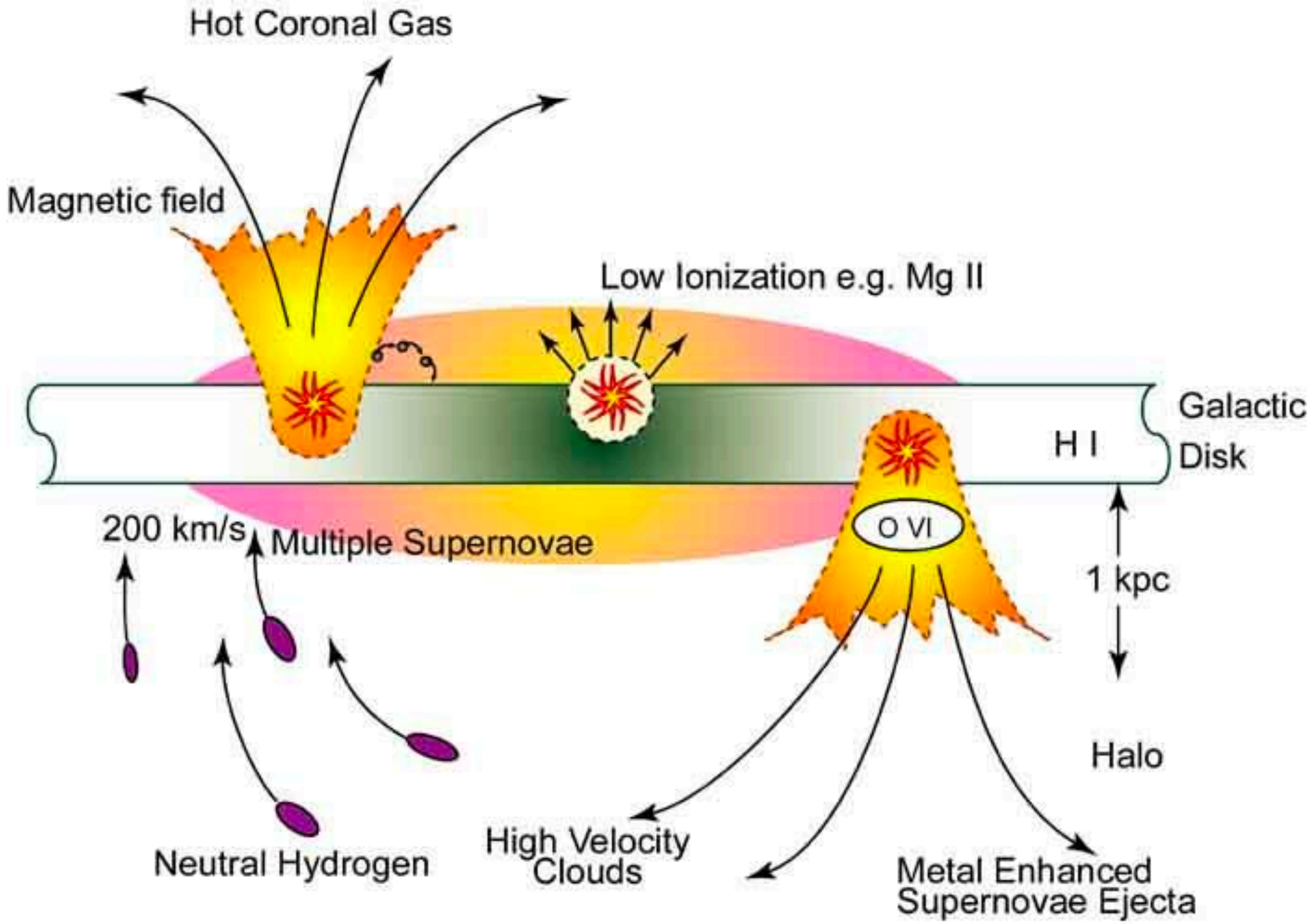
HI filaments

Soler, J.D. et al. A&A (2022)



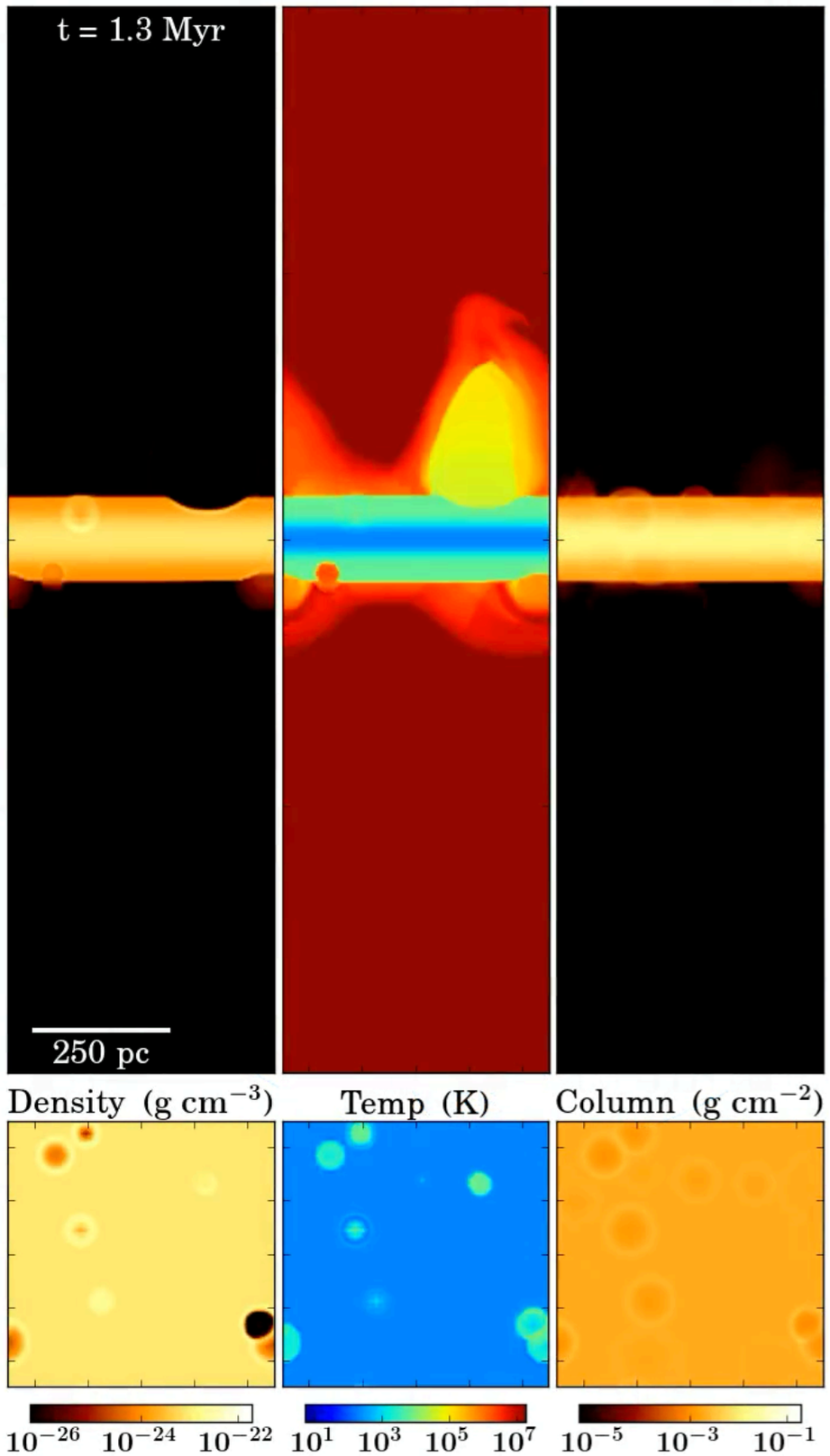
Atomic worms and chimneys

Heiles, 1994



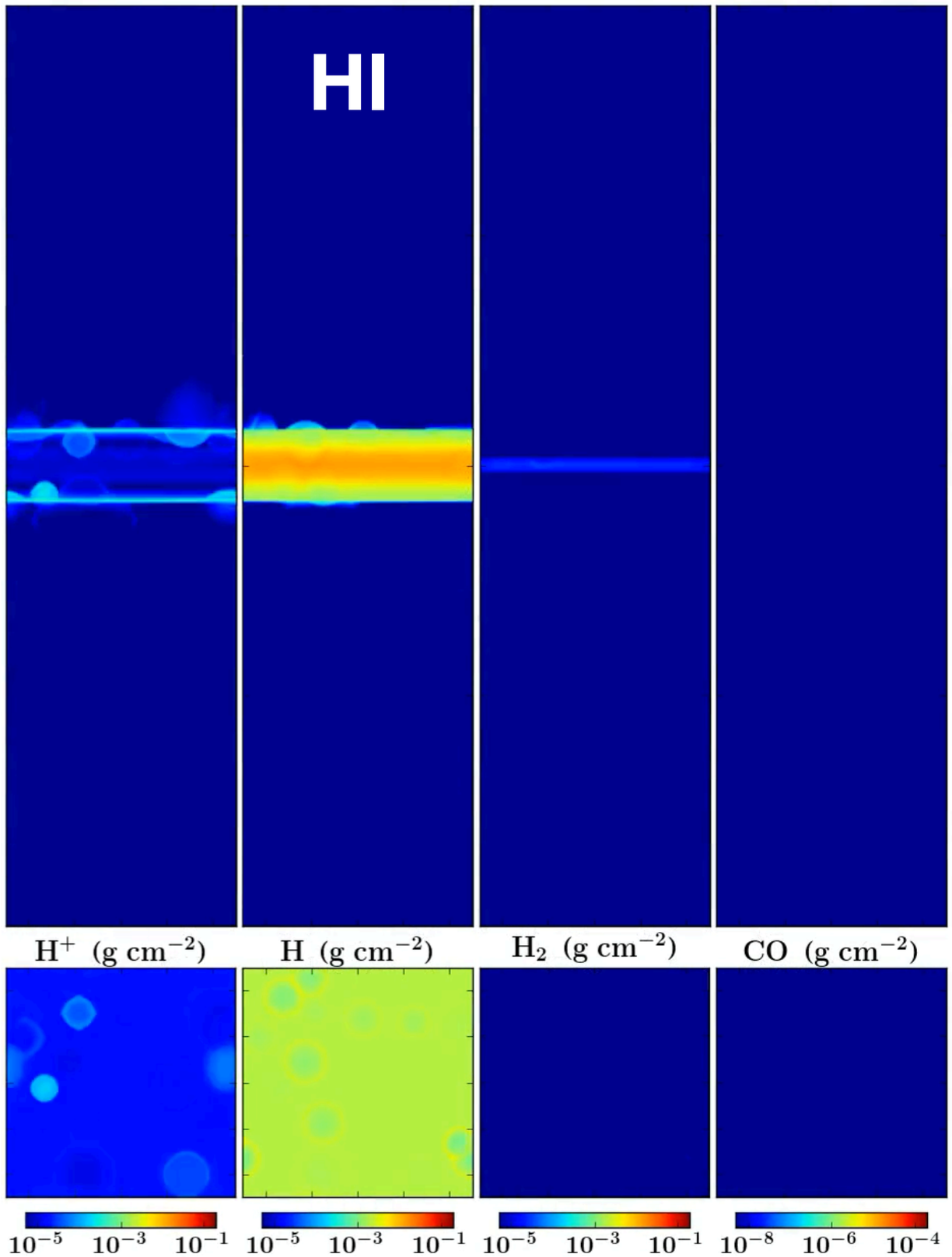
Atomic filament orientation and HI bubbles

Girichidis et al. MNRAS (2021). SILCC: Simulating the LifeCycle of molecular Clouds



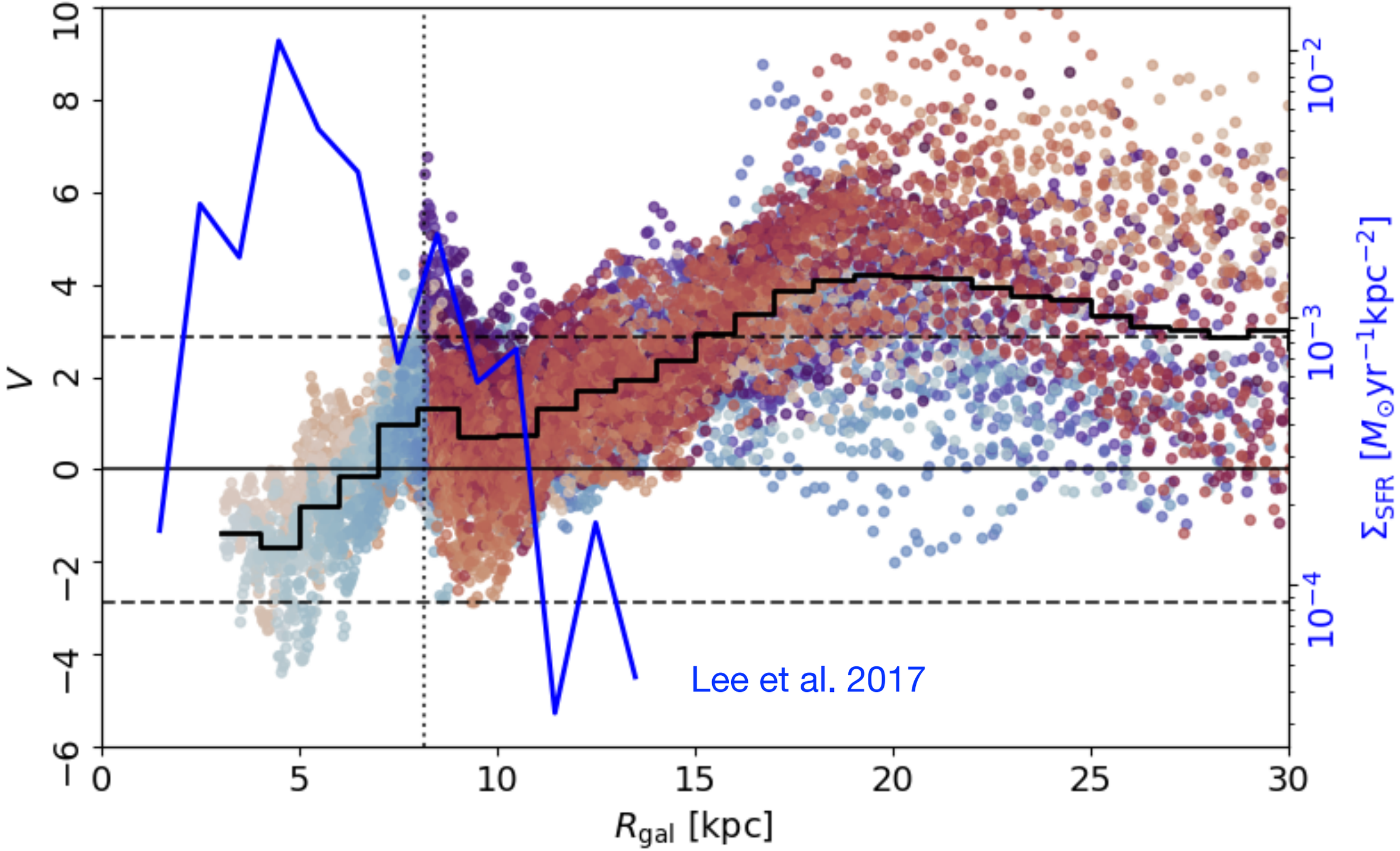
Atomic filament orientation and HI bubbles

Girichidis et al. MNRAS (2021). SILCC: Simulating the LifeCycle of molecular Clouds



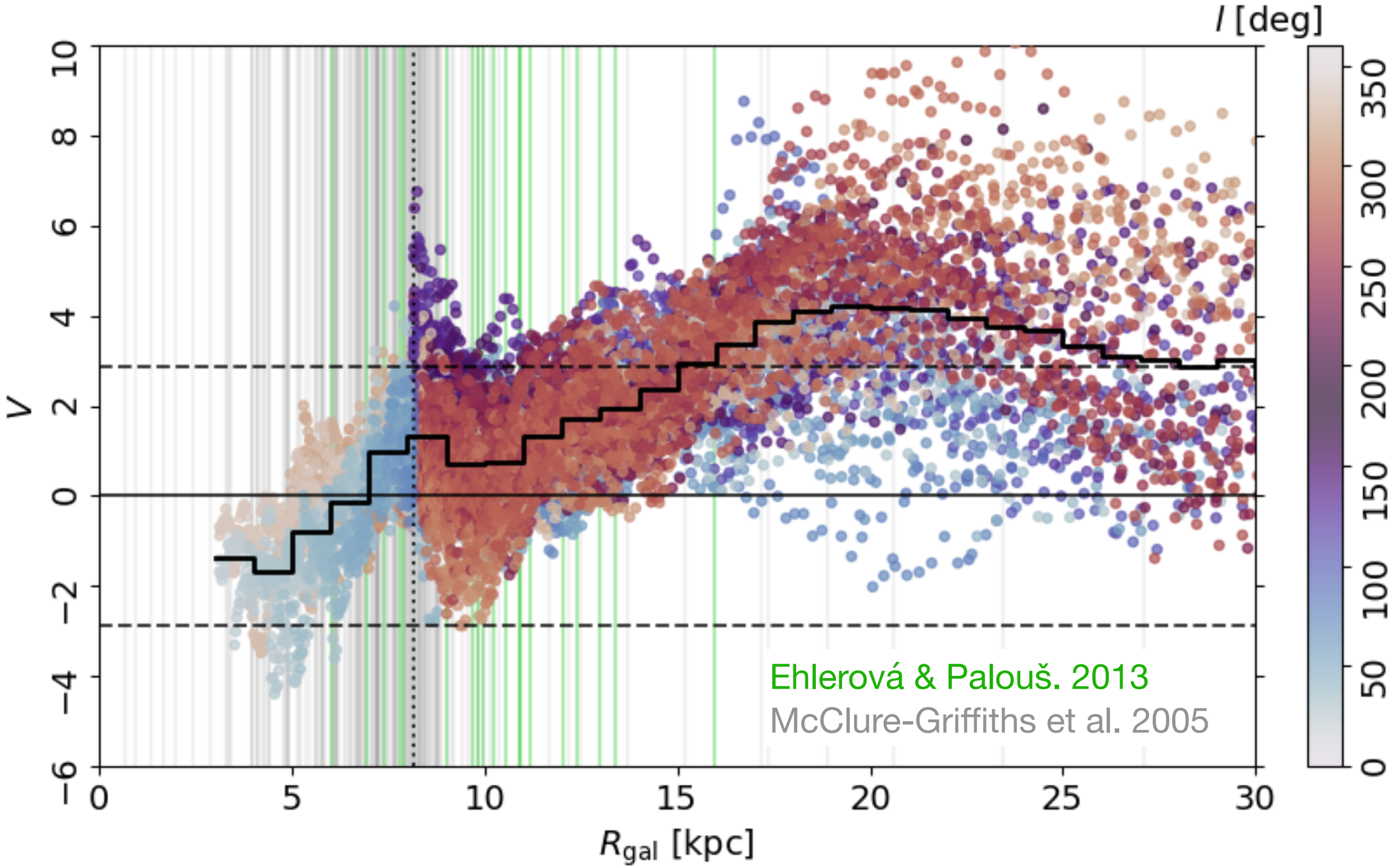
HI filament orientation and star formation

Soler, J.D. et al. A&A (2022)



HI filament orientation and HI bubbles

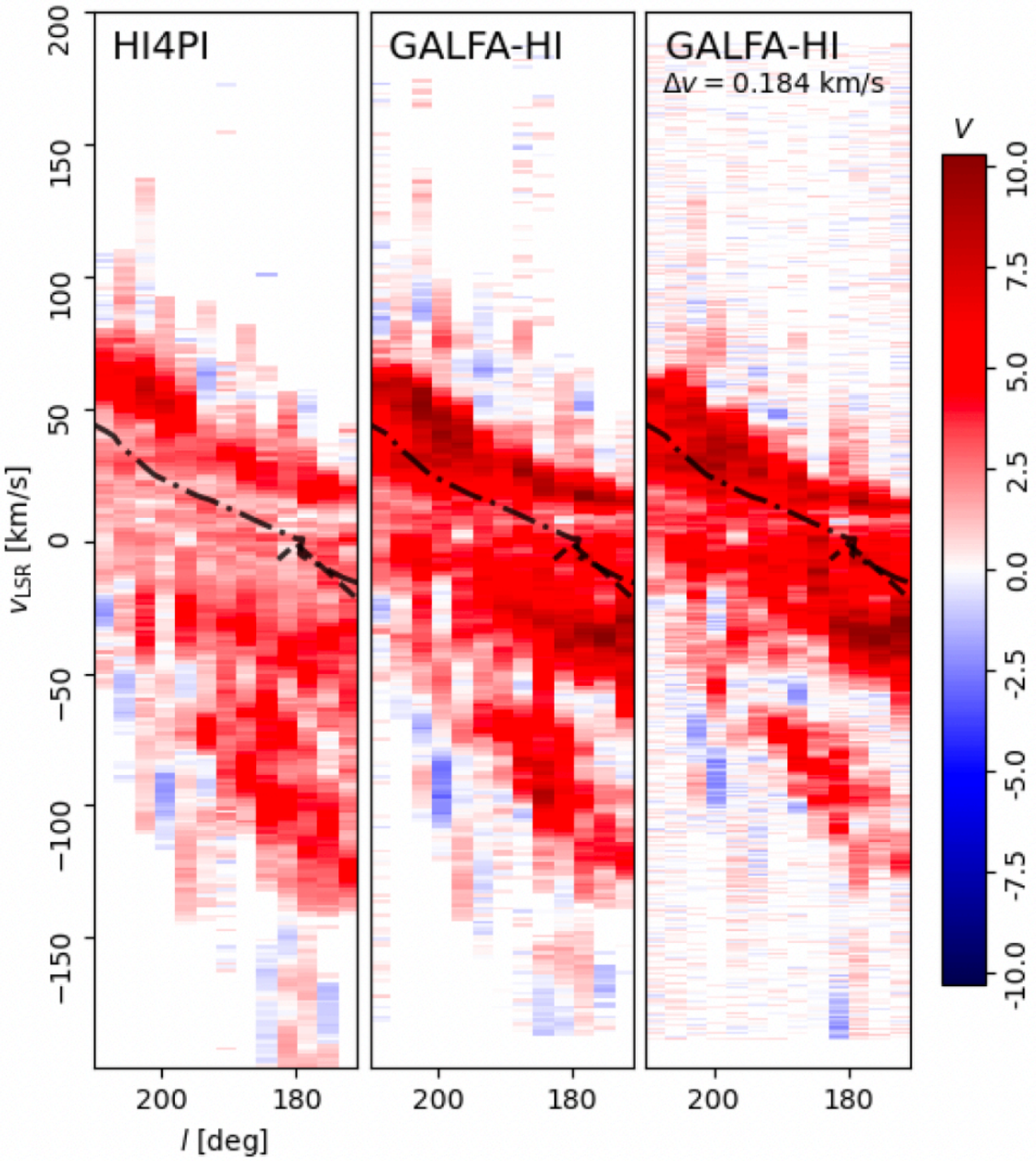
Soler, J.D. et al. A&A (2022)

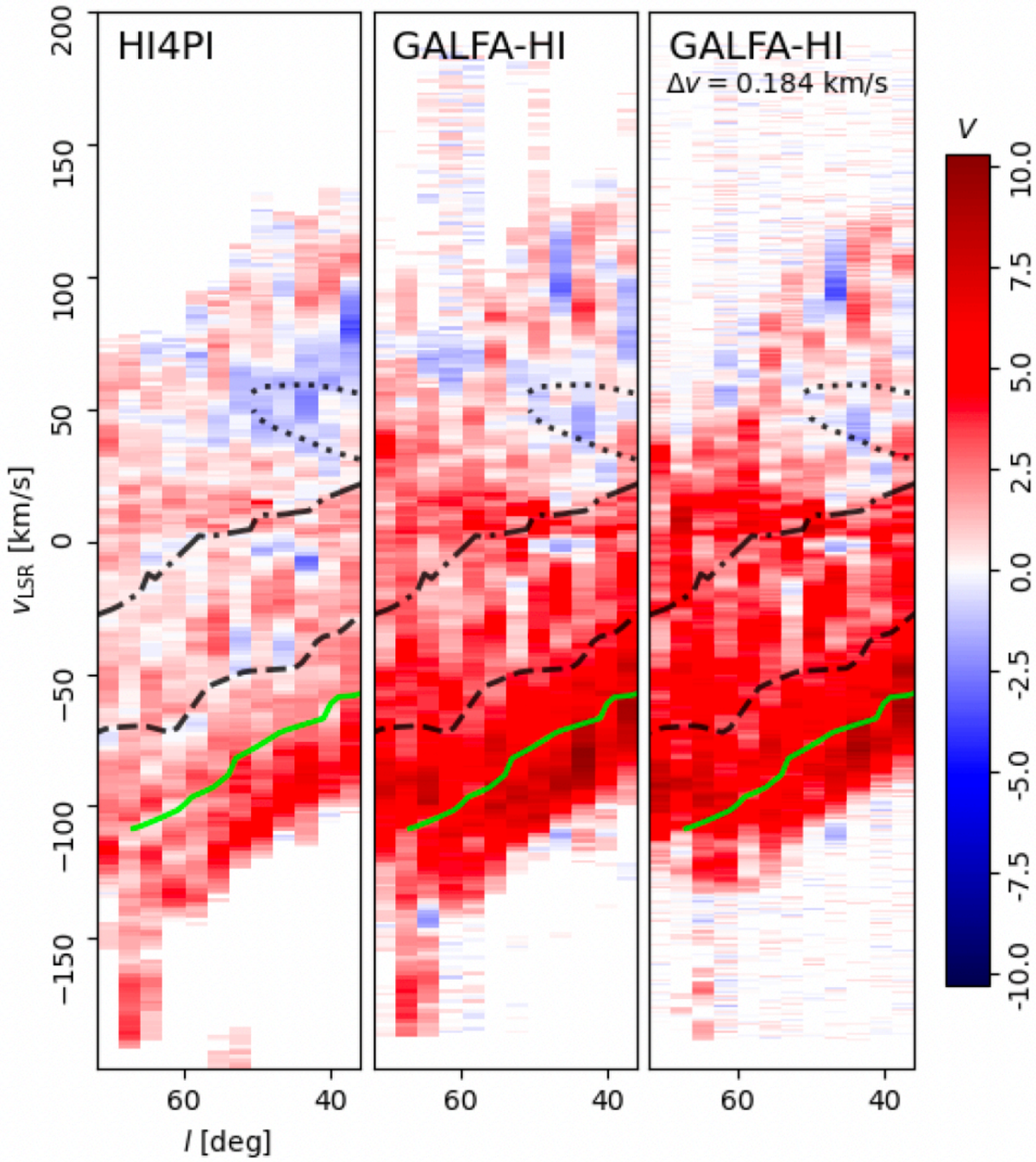


HI filaments at higher angular resolution

GALFA-HI, Peek et al. ApJ (2018)
Soler, J.D. et al. A&A (2022)

GALFA-HI
4’ FWHM
Δv=0.184 km/s

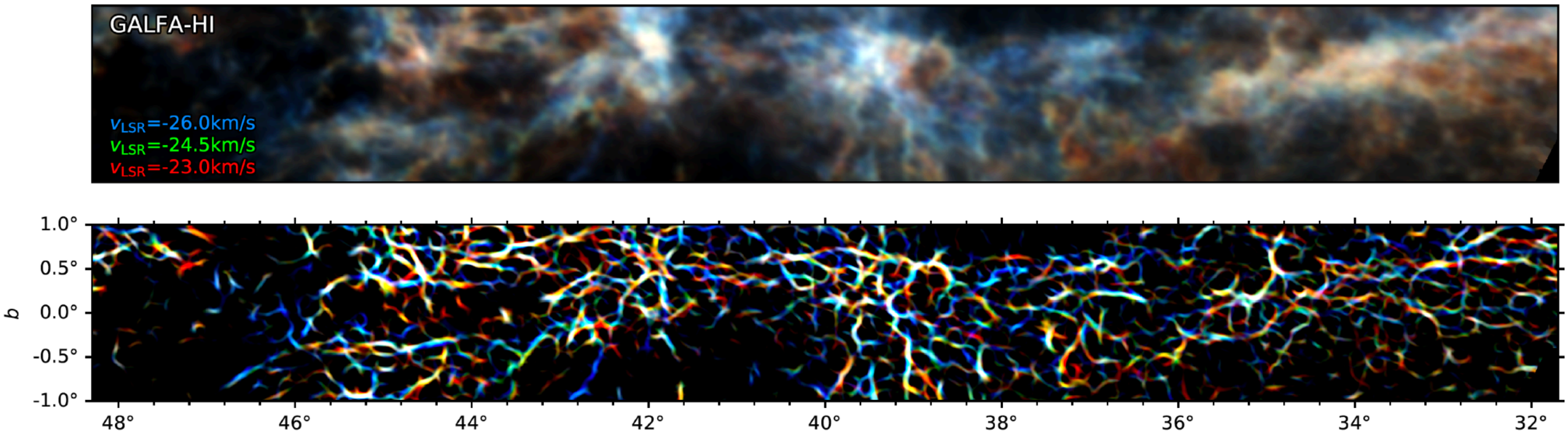




HI filaments (GALFA)

GALFA-HI. Peek et al. ApJ (2018)
Soler, J.D. et al. A&A (2020,2022)

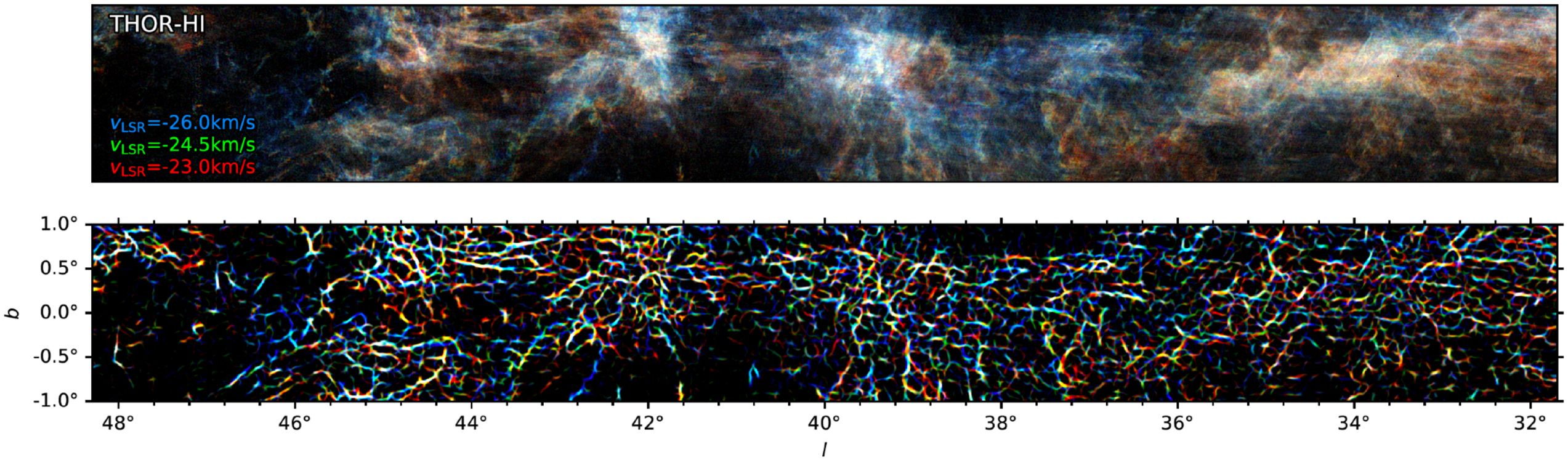
GALFA-HI
4’ FWHM
Δv=0.184 km/s



HI filaments (THOR)

THOR-HI. Beuther et al. A&A (2016); Wang et al. A&A (2020)
Soler, J.D. et al. A&A (2020)

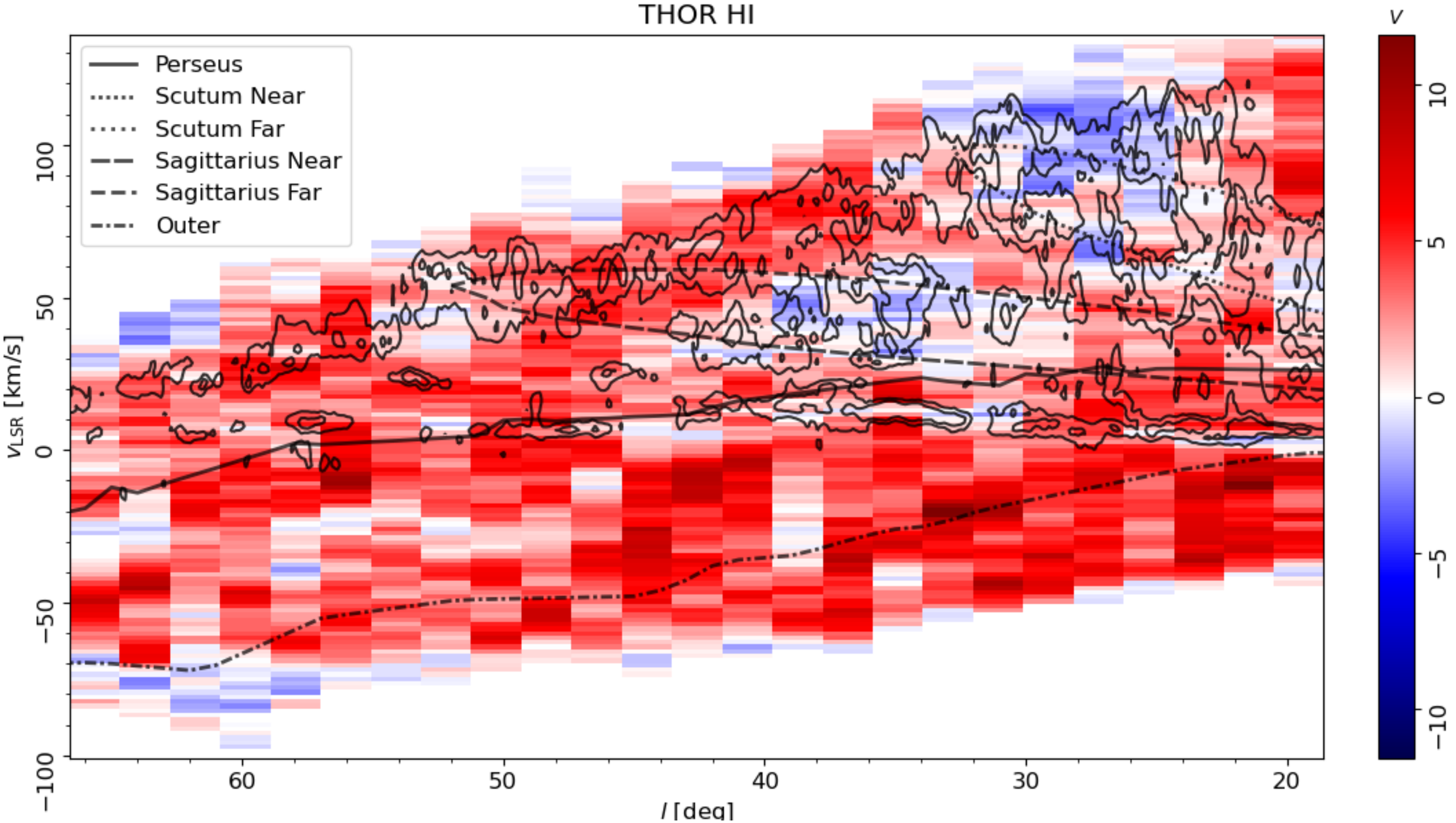
THOR-HI
40” FWHM
Δv=1.5 km/s



HI at even higher angular resolution

THOR-HI. Wang et al. A&A (2020), Beuther et al. A&A (2016)
Soler, J.D. et al. A&A (2020)

THOR-HI
40” FWHM
Δv=1.5 km/s



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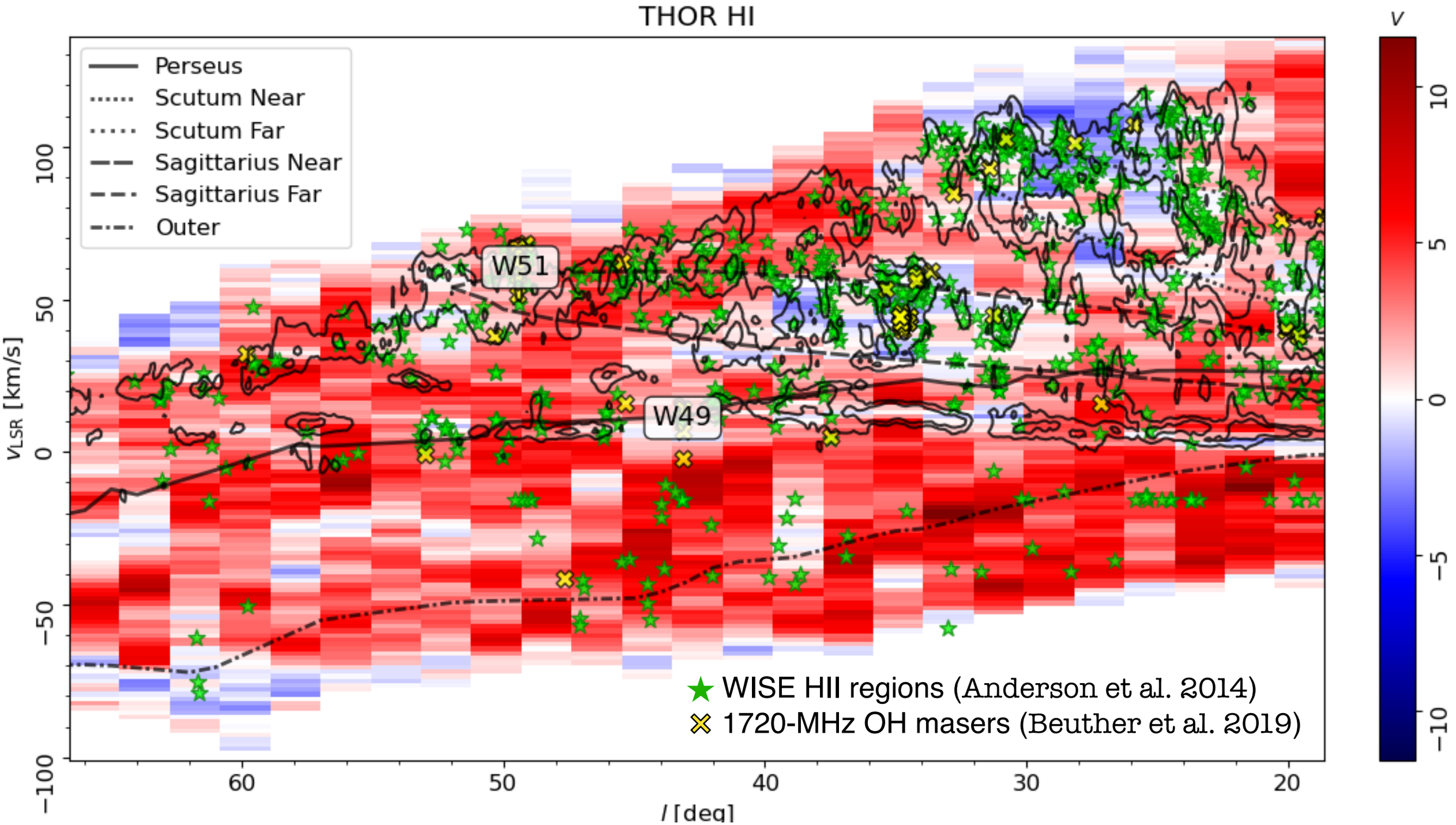
HI at even higher angular resolution

THOR-HI. Wang et al. A&A (2020), Beuther et al. A&A (2016)
Soler, J.D. et al. A&A (2020)

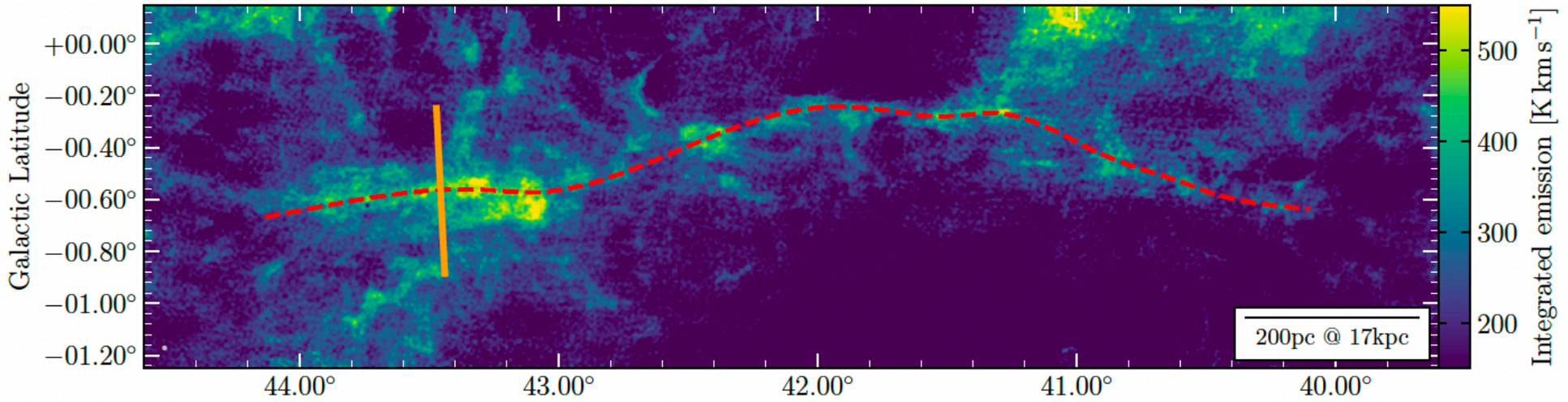
THOR-HI
40” FWHM
Δv=1.5 km/s



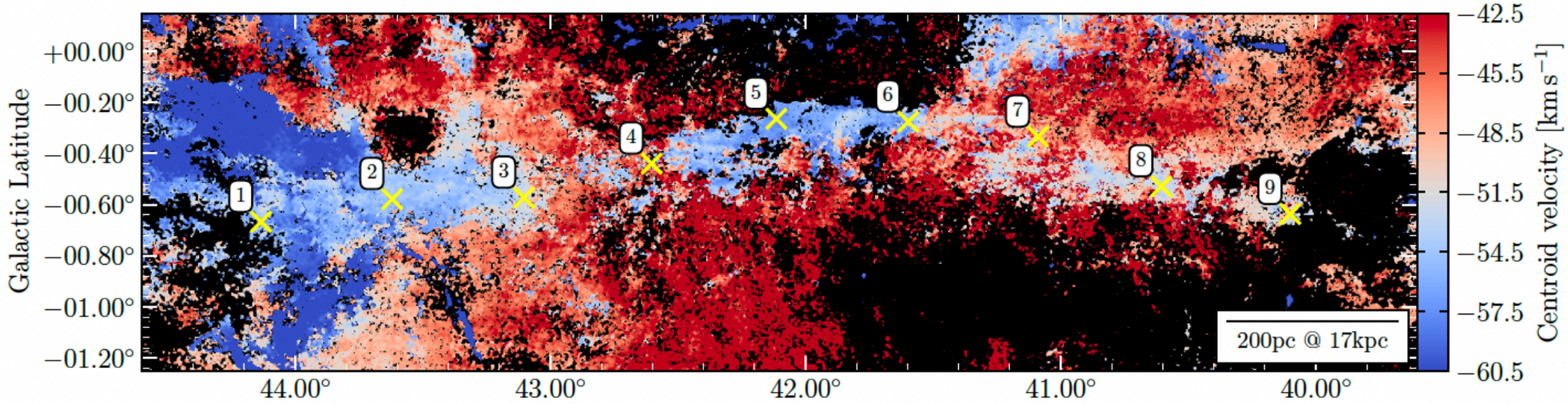
The Magdalena (Maggie) filament

Syed, J., et al. (2022), Soler, J.D. et al. (2020)

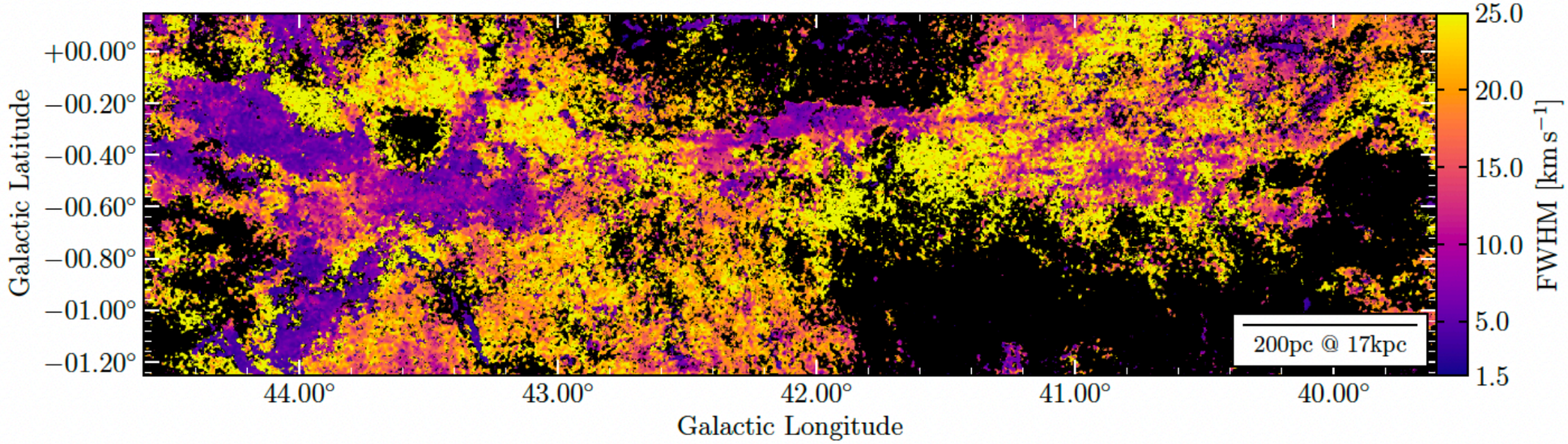
N_{H}



$\langle v \rangle$

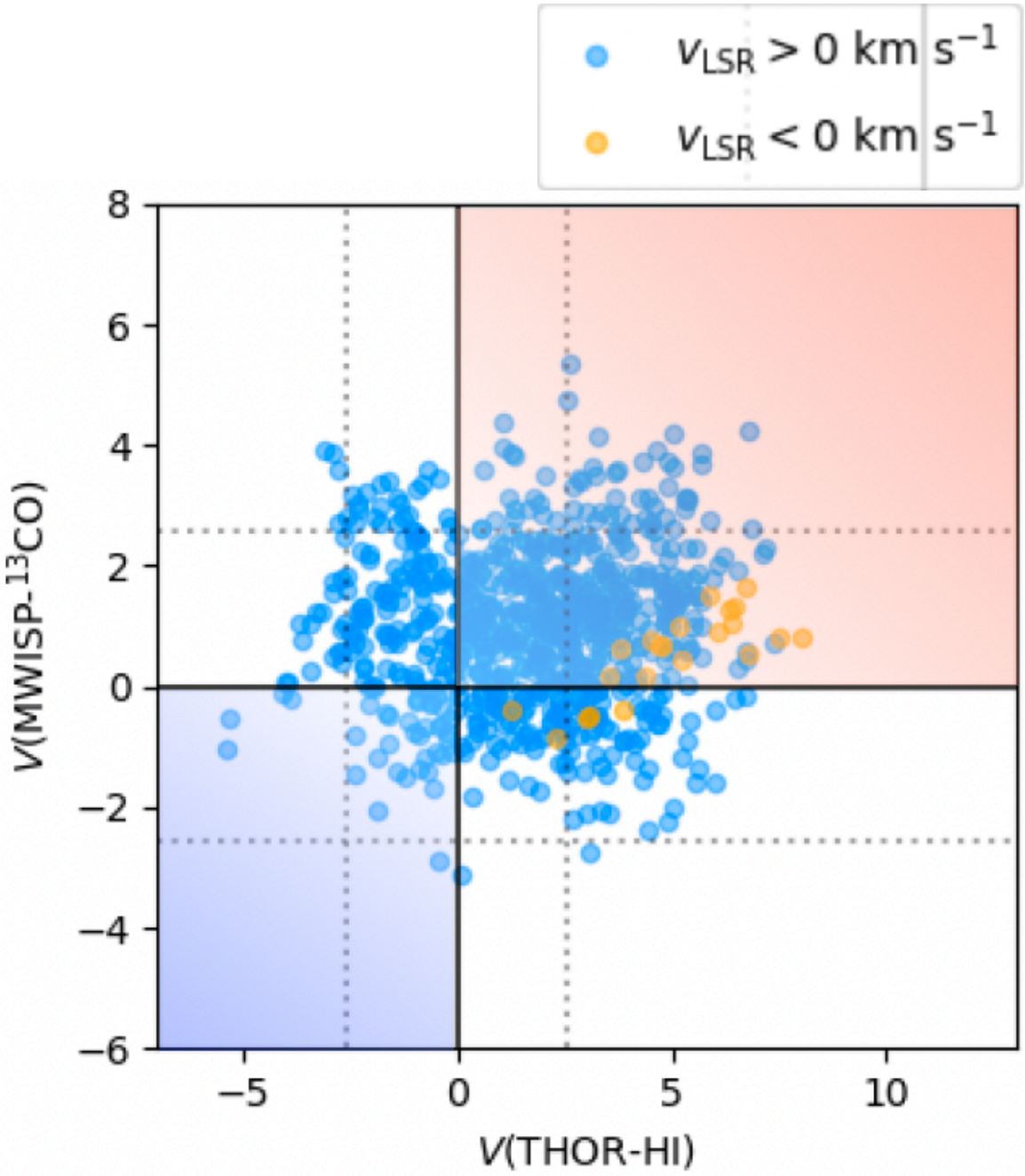


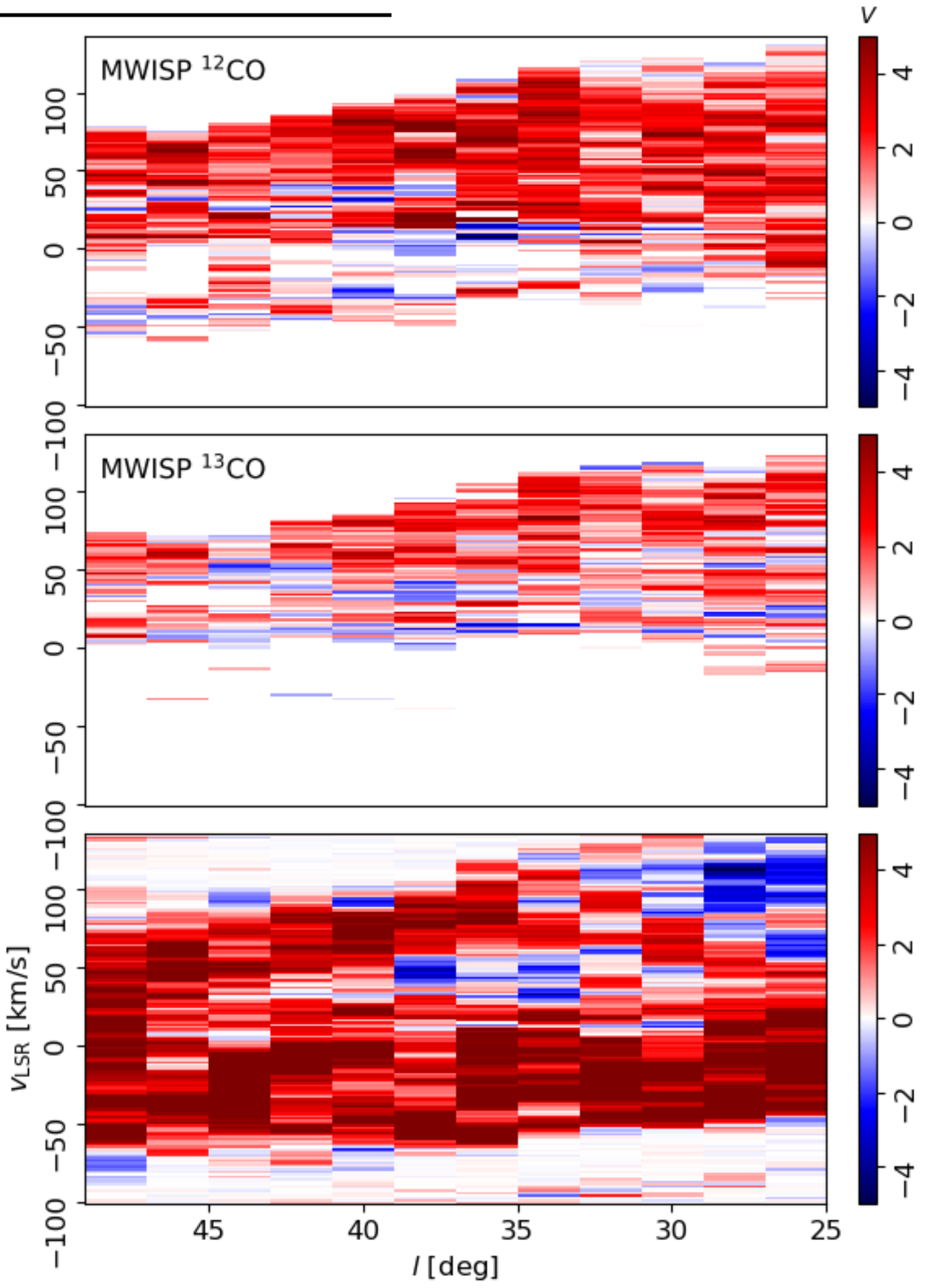
σ_v



CO filament orientation

MWISP CO survey. Sun et al. (2018)
Soler, J.D. et al. A&A (2021)





We studied the **orientation of the filamentary structure**
in the **HI emission toward the Galactic plane.**

We found that the **HI filament orientation changes**
from mostly perpendicular to mostly parallel to the Galactic plane
with increasing distance from the Galactic center.

We interpret the **change in the HI filament orientation**
with Galactocentric radius as the
signature of the energy and moment input from supernovae.

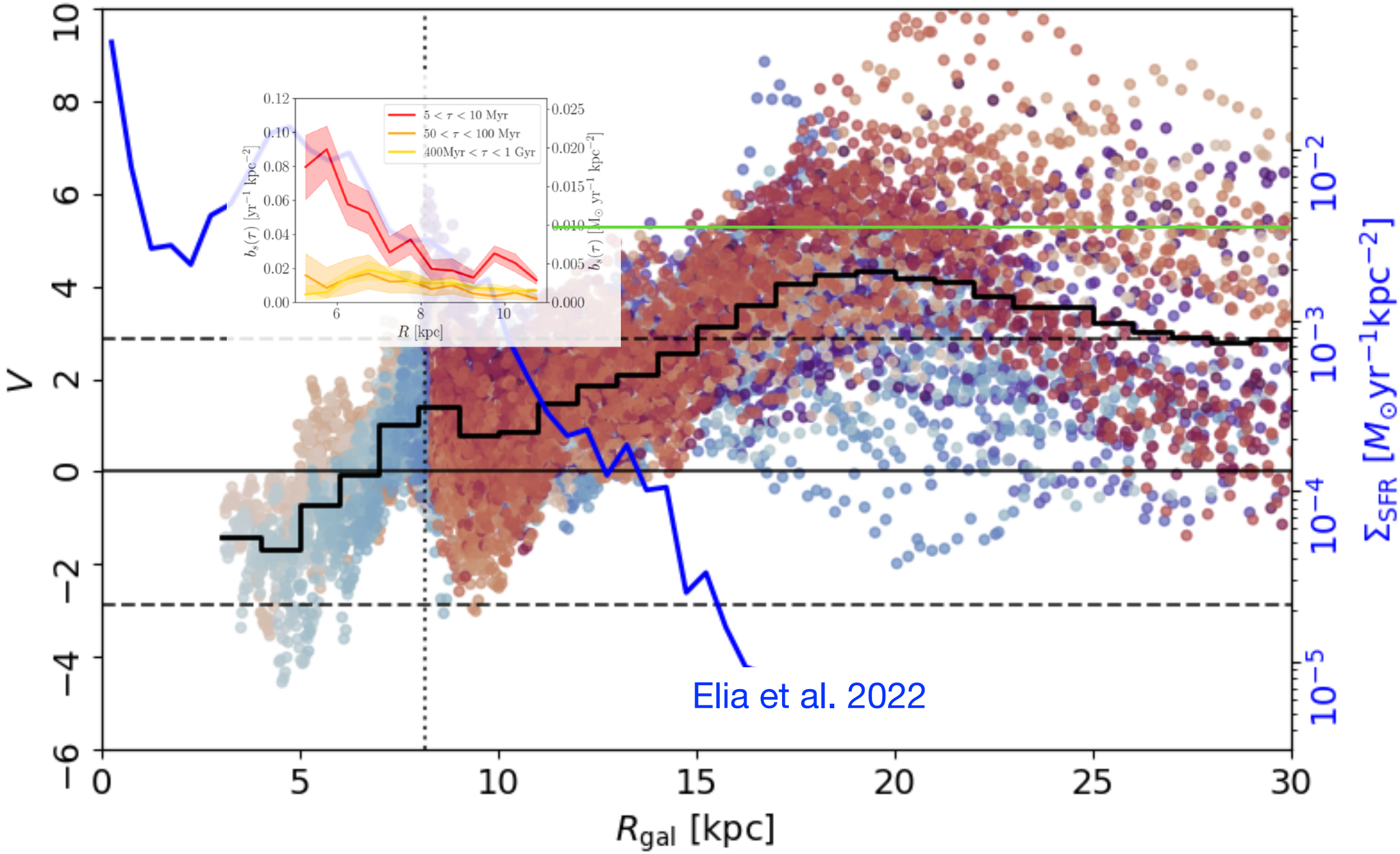
The prevalent **HI filament orientation** is
not inherited by the CO filaments.

Soler, Miville-Deschênes, Molinari et al. A&A (2022)
Soler, Beuther, Syed et al. A&A (2021)
Soler, Beuther, Wang et al. A&A (2020)

Extra slides

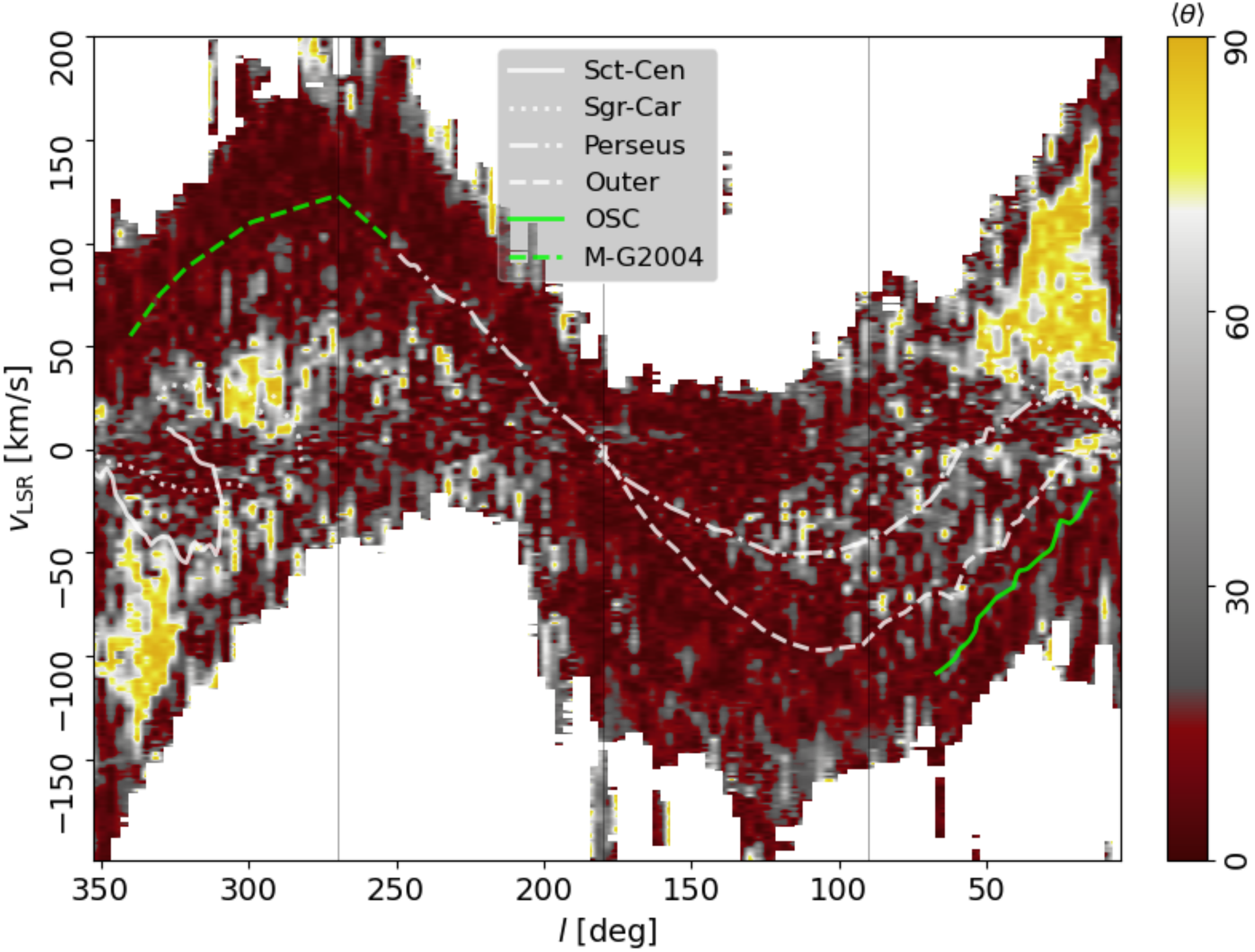
HI filament orientation and star formation

Soler, J.D. et al. A&A (2022)



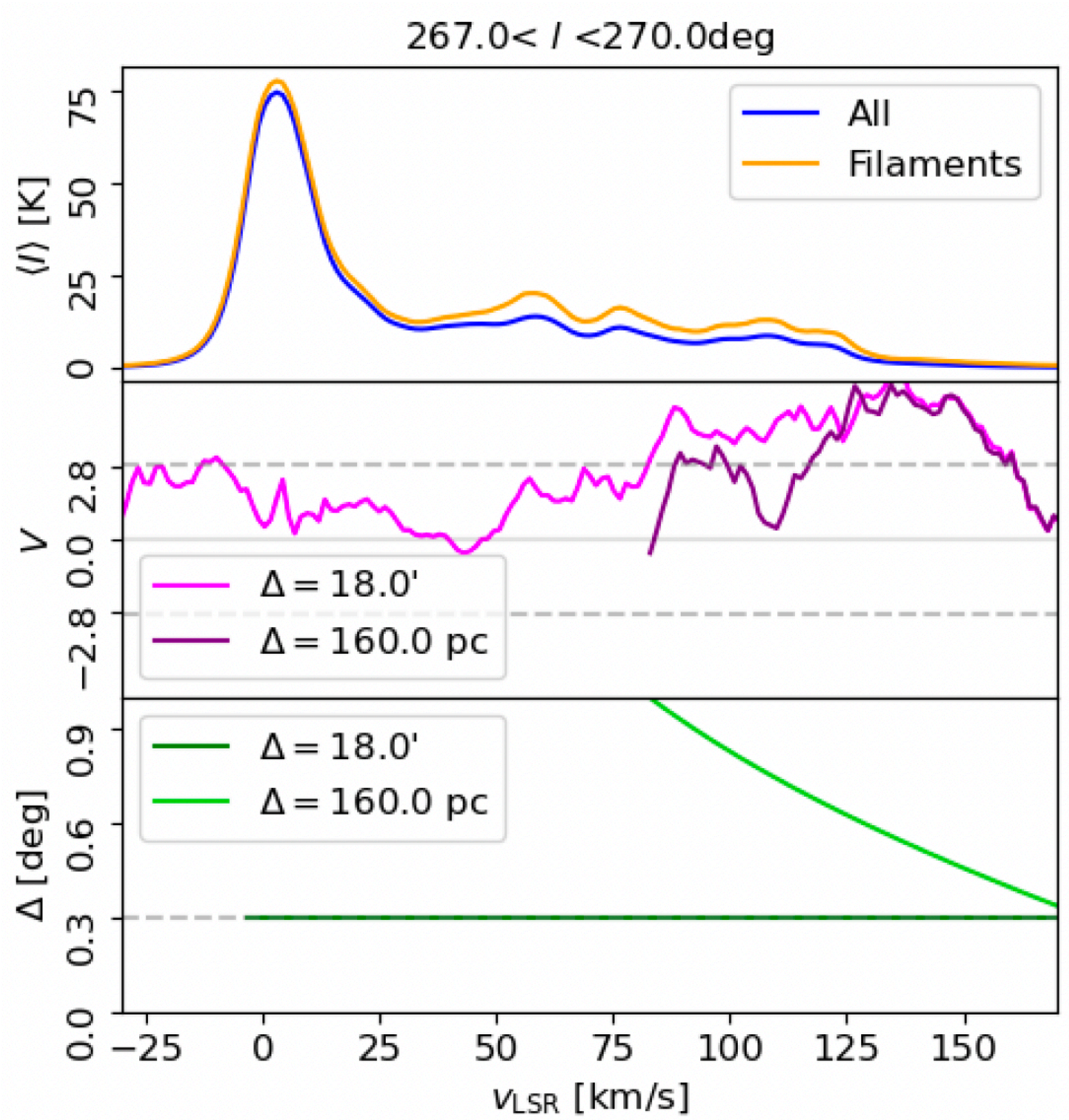
HI filament orientation

Soler, J.D. et al. A&A (2022)



Fixed-scale derivative kernel

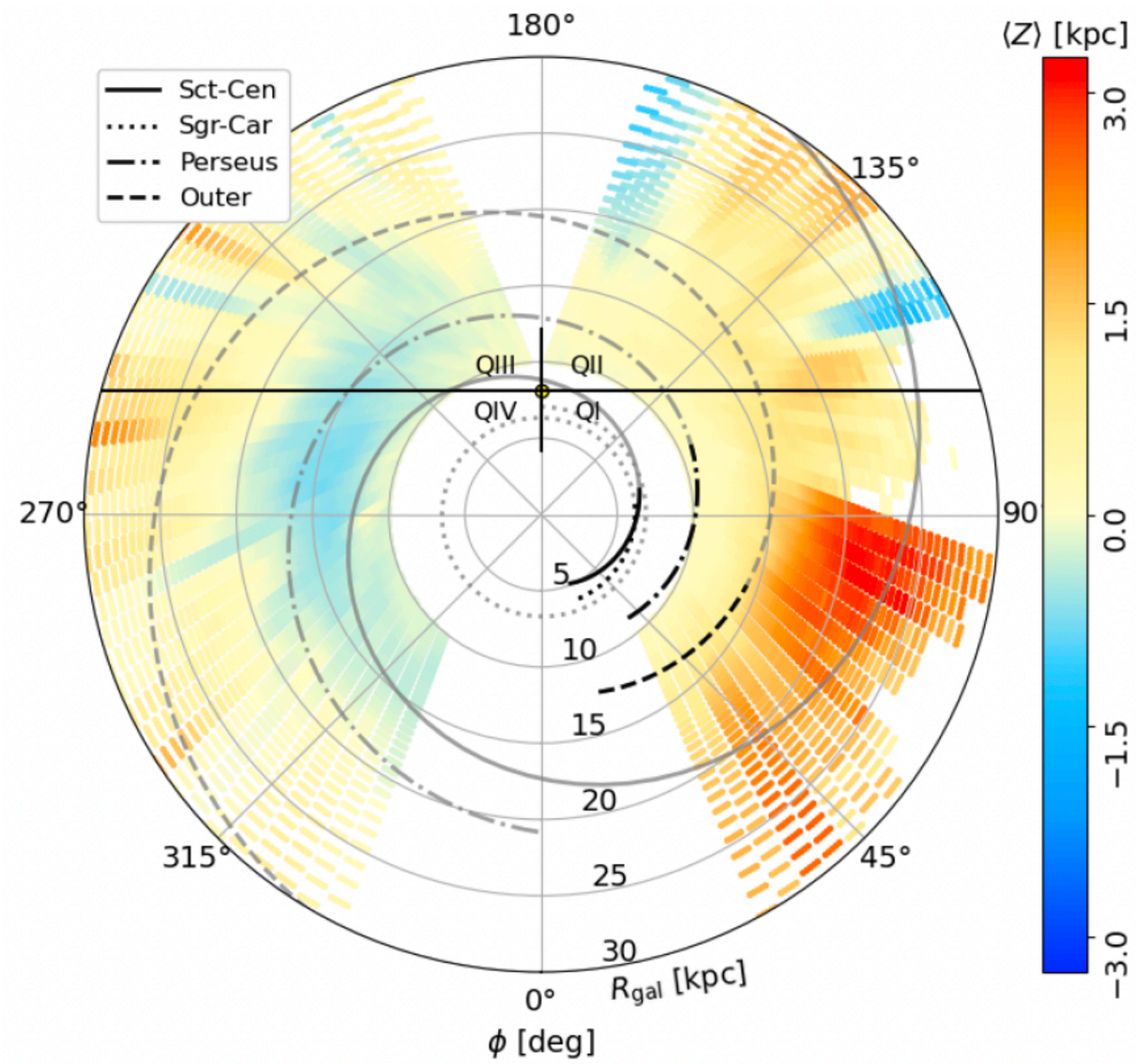
Soler, J.D. et al. A&A (2022)



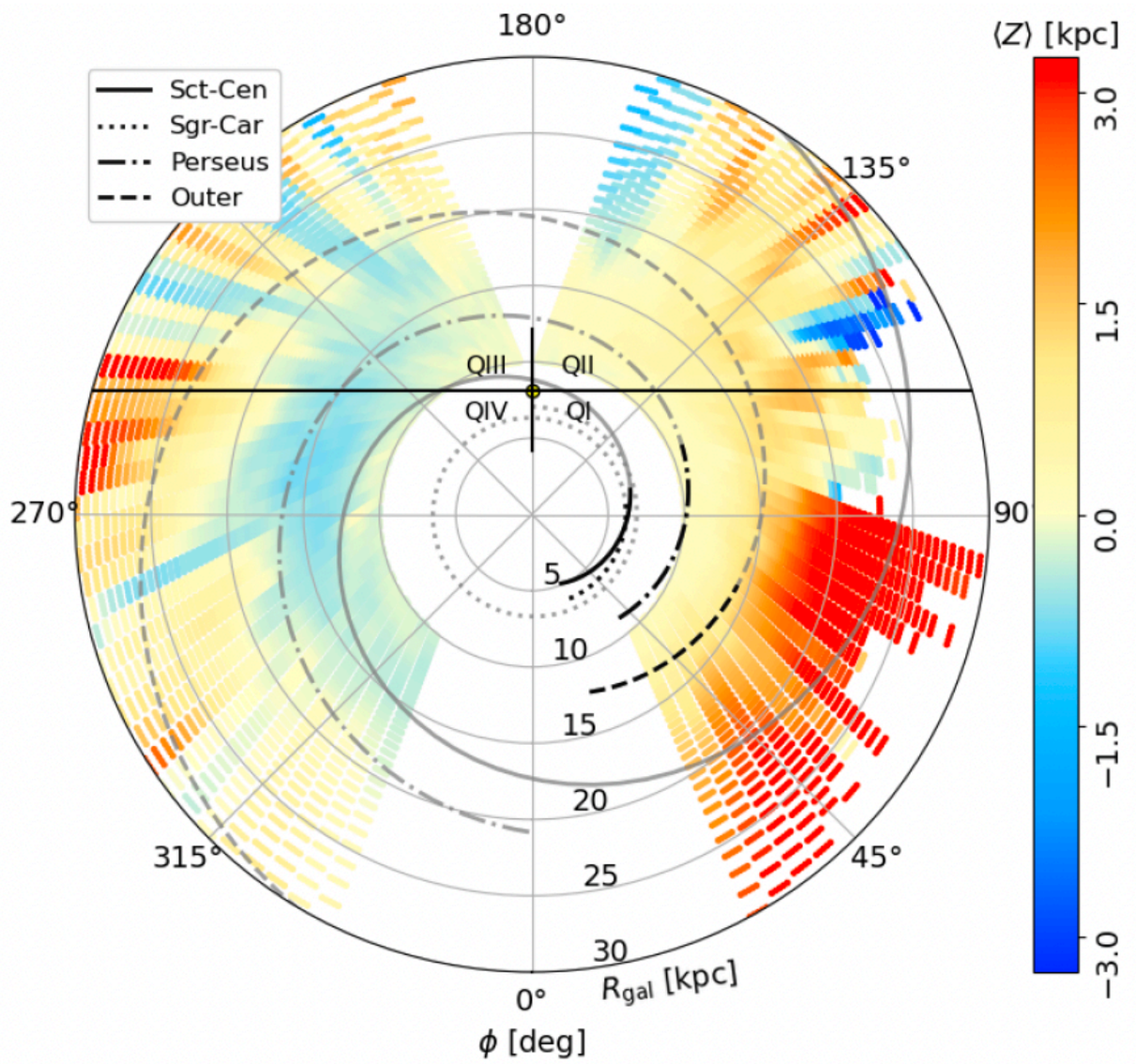
Galactic warp

Soler, J.D. et al. A&A (2022)

All



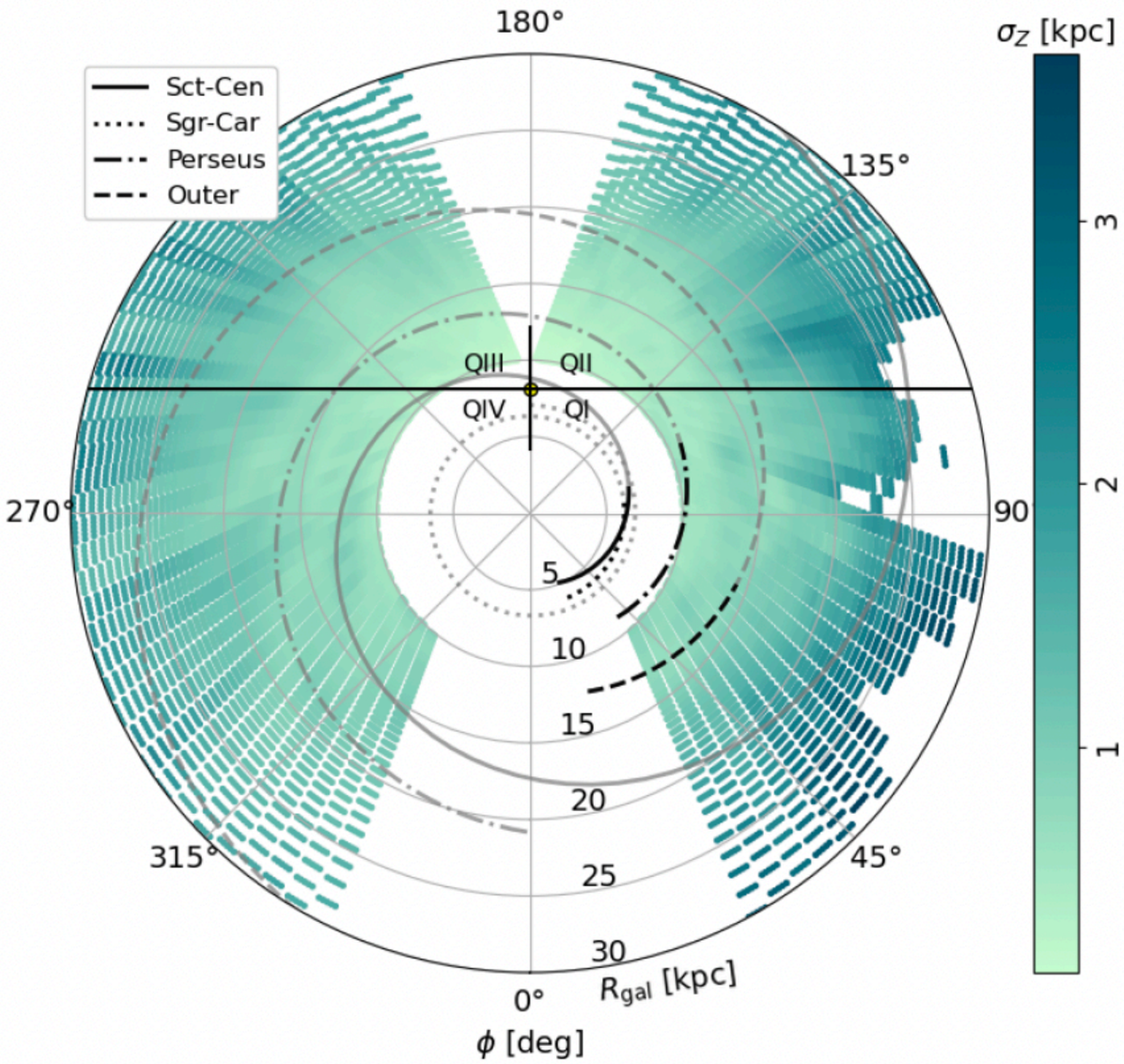
Filaments



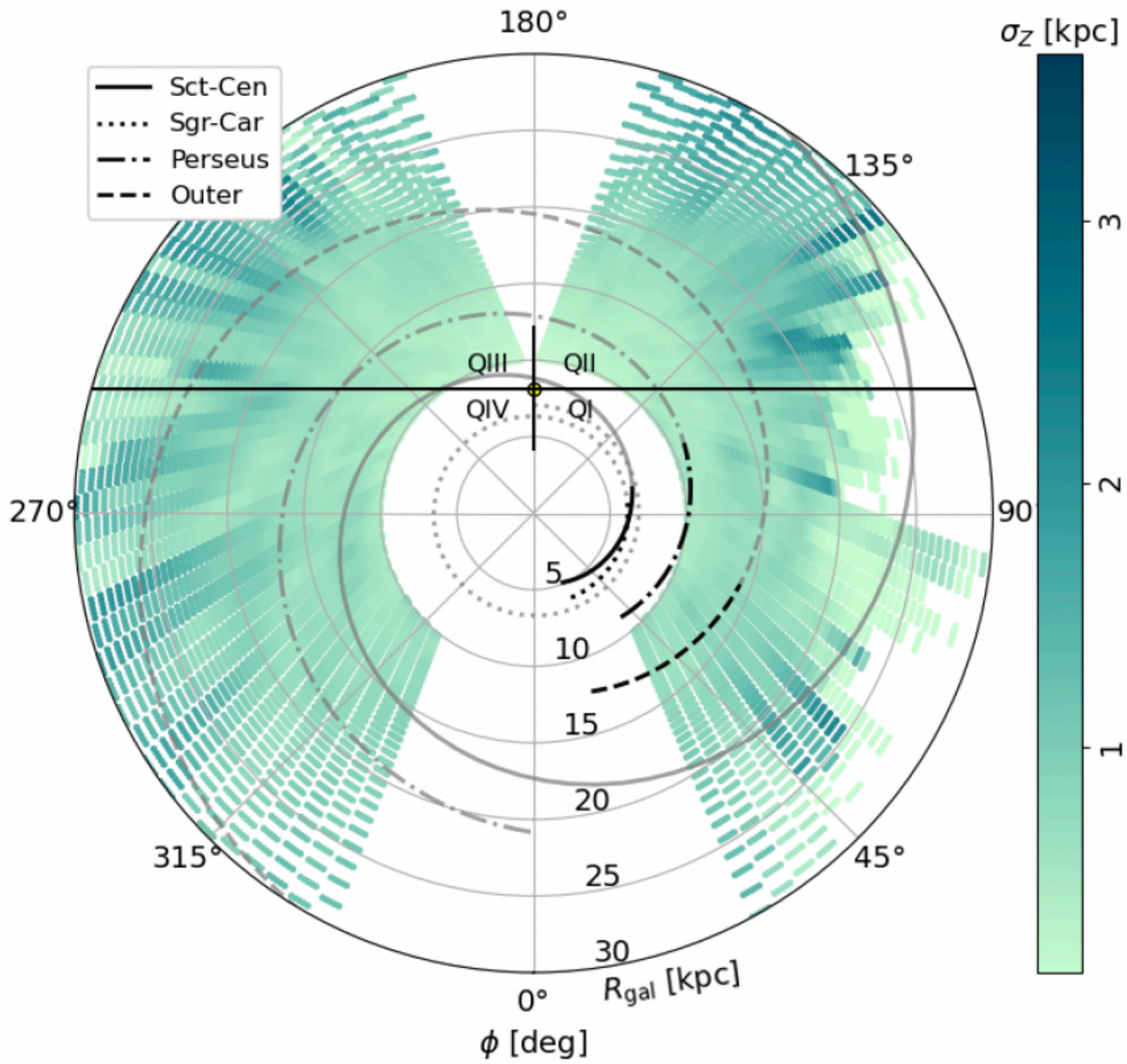
Galactic flaring

Soler, J.D. et al. A&A (2022)

All

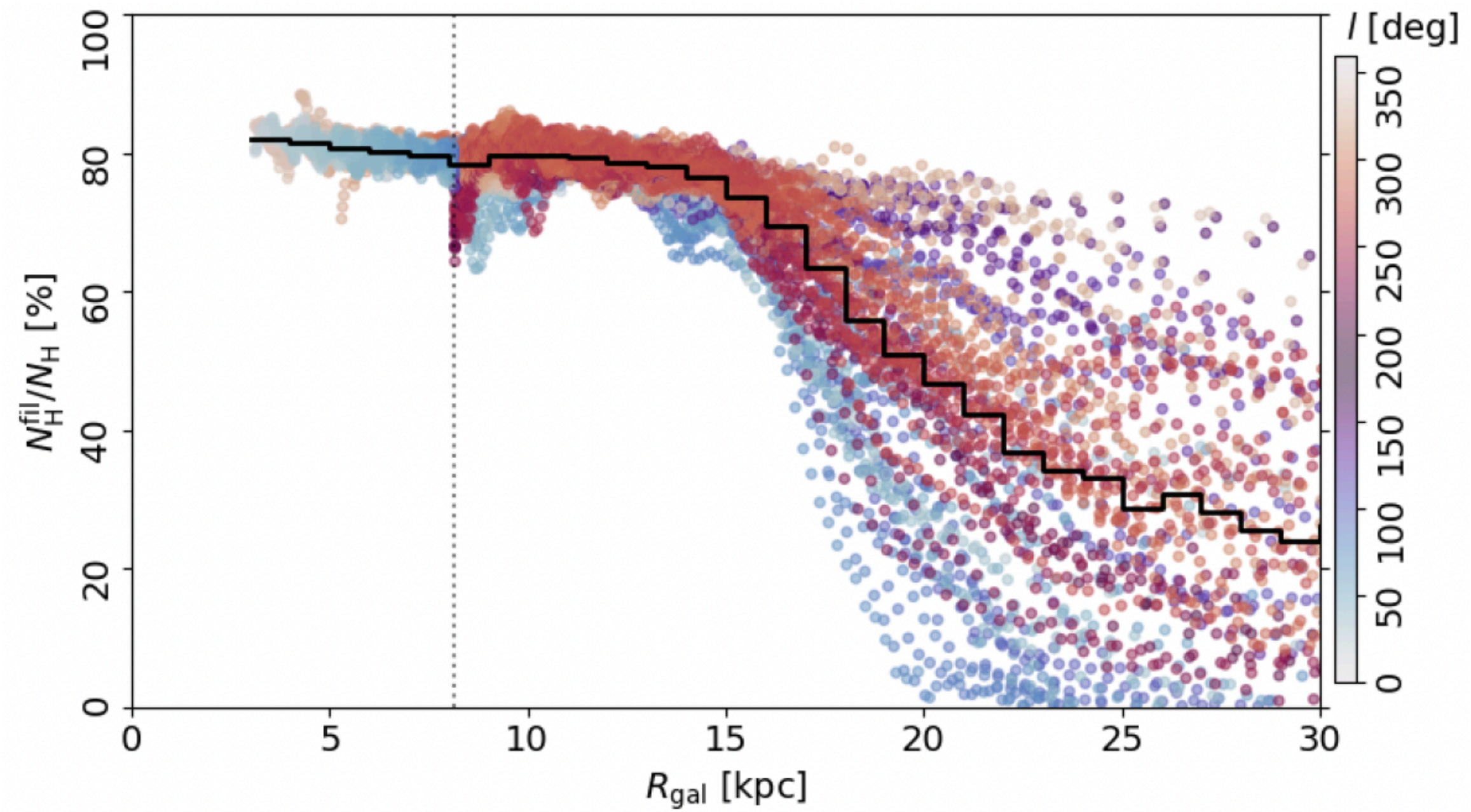


Filaments



Column density in filaments

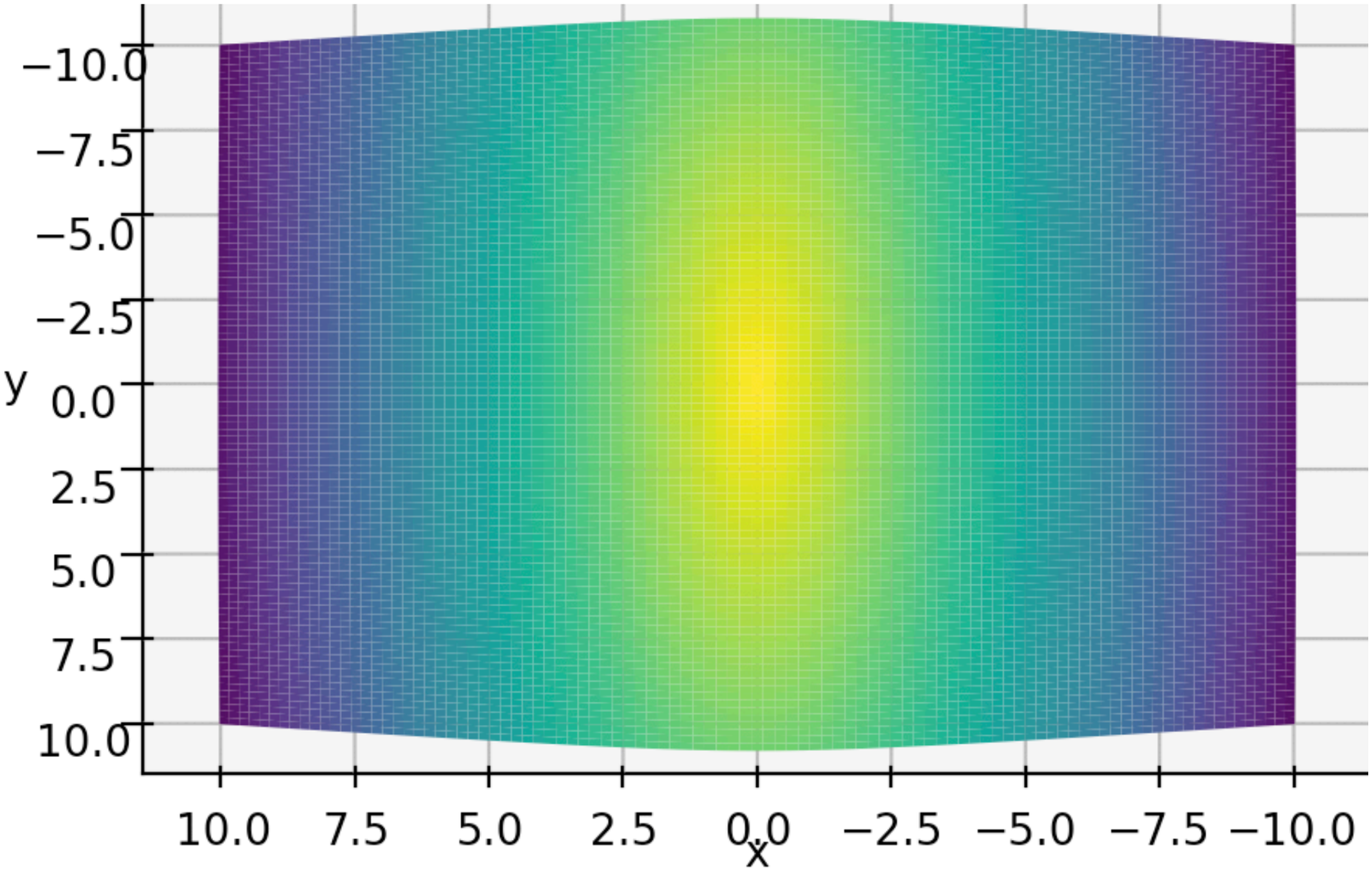
Soler, J.D. et al. A&A (2022)



Machine vision: Hessian matrix method

Soler, J.D. et al. A&A. 2020

Polychroni et al. 2013
Planck XXXII (Bracco, A. et al.), 2016

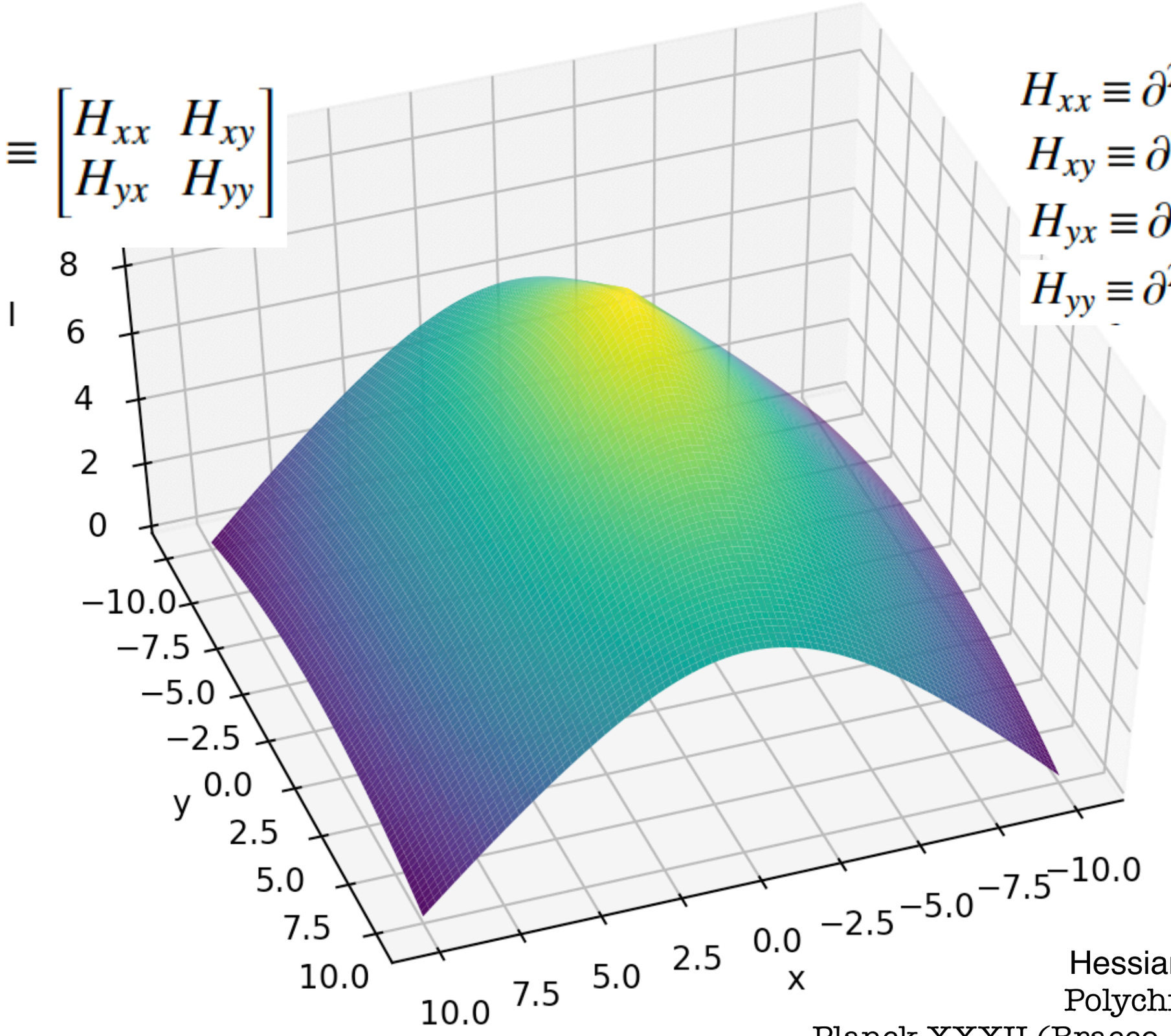


Machine vision: Hessian matrix method

Soler, J.D. et al. A&A. 2020

$$\mathbf{H}(x,y) \equiv \begin{bmatrix} H_{xx} & H_{xy} \\ H_{yx} & H_{yy} \end{bmatrix}$$

$$H_{xx} \equiv \partial^2 I / \partial x^2$$
$$H_{xy} \equiv \partial^2 I / \partial x \partial y$$
$$H_{yx} \equiv \partial^2 I / \partial y \partial x$$
$$H_{yy} \equiv \partial^2 I / \partial y^2$$



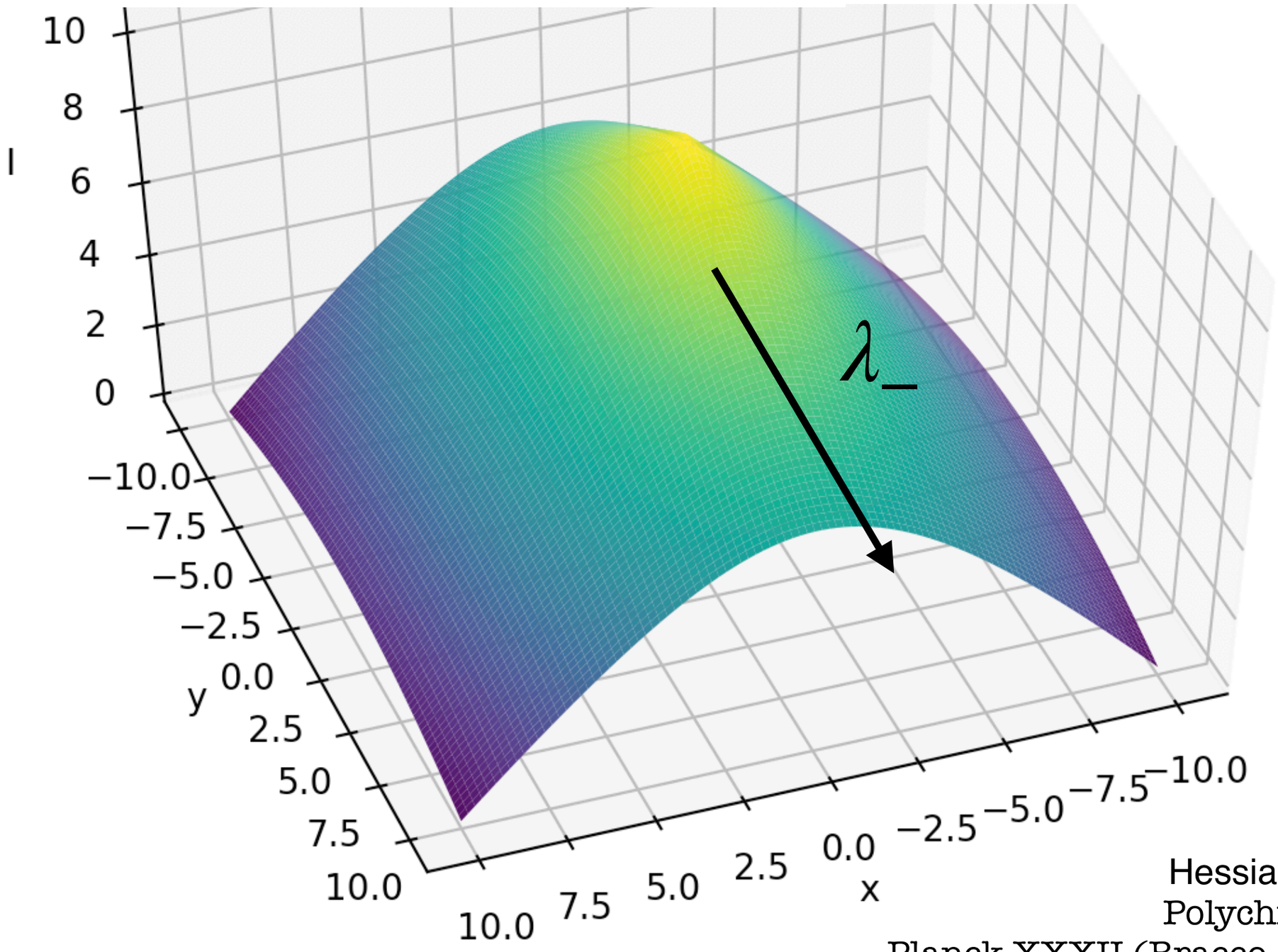
Hessian matrix method
Polychroni et al. 2013
Planck XXXII (Bracco, A. et al.), 2016

Machine vision: Hessian matrix method

Soler, J.D. et al. A&A. 2020

$$\lambda_{\pm} = \frac{(H_{xx} + H_{yy}) \pm \sqrt{(H_{xx} - H_{yy})^2 + 4H_{xy}H_{yx}}}{2}$$

$$\theta = \frac{1}{2} \tan^{-1} \frac{H_{xy} - H_{yx}}{H_{xx} - H_{yy}}$$



Hessian matrix method
Polychroni et al. 2013
Planck XXXII (Bracco, A. et al.), 2016

HI filament orientation: random walk interpretation

Soler, J.D. et al. A&A. 2020

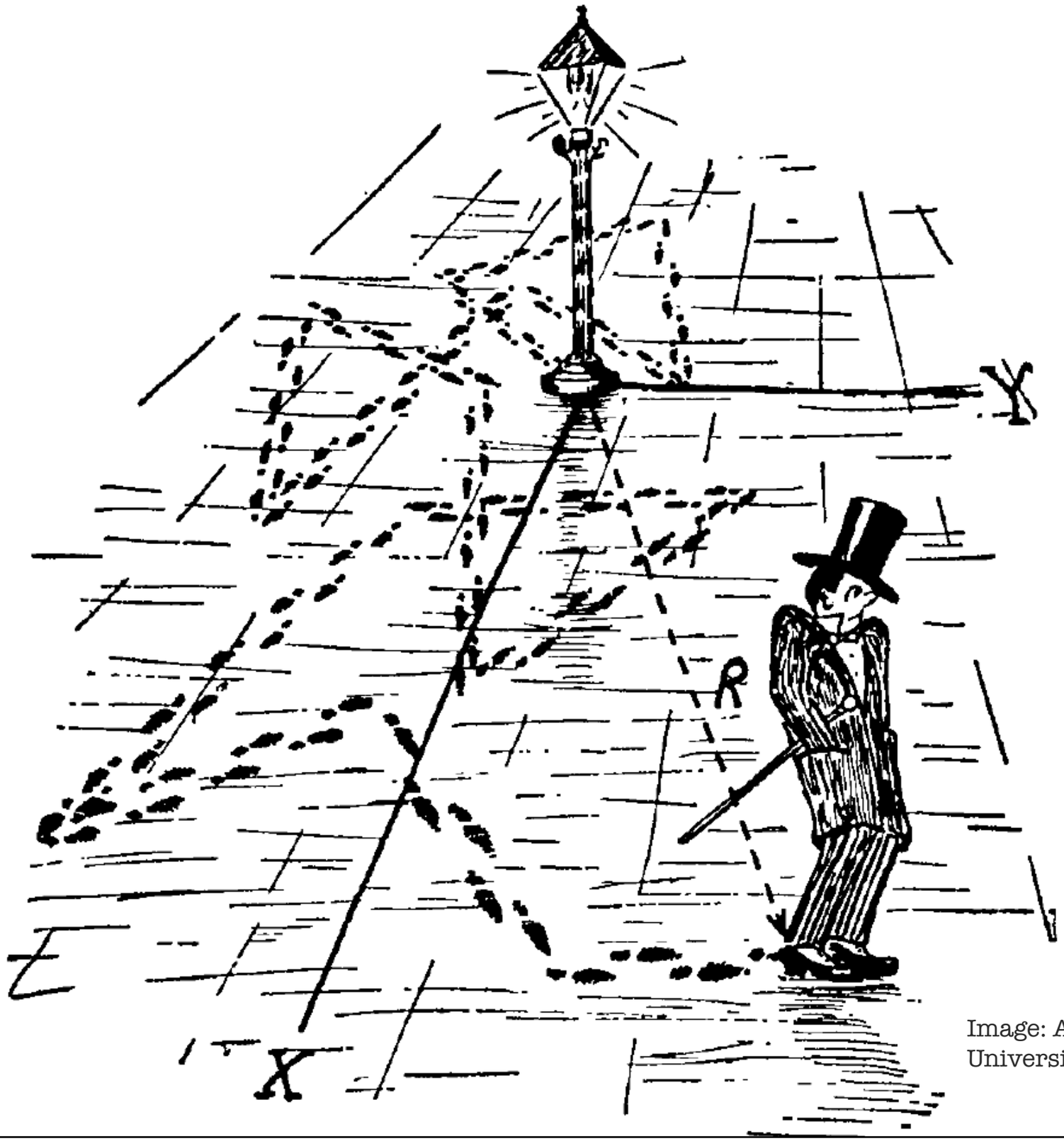
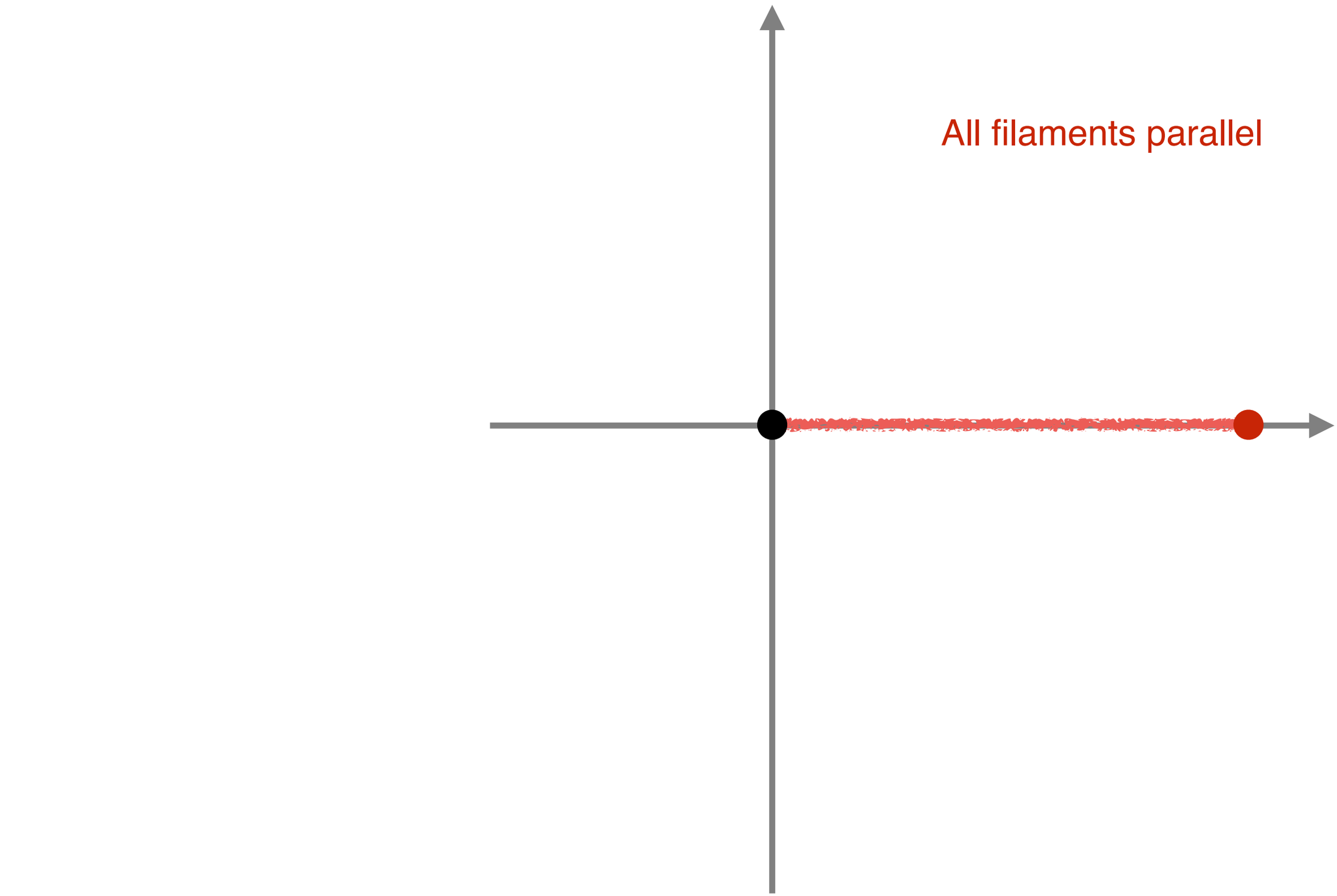


Image: Advanced Design Studies
University of Tokyo

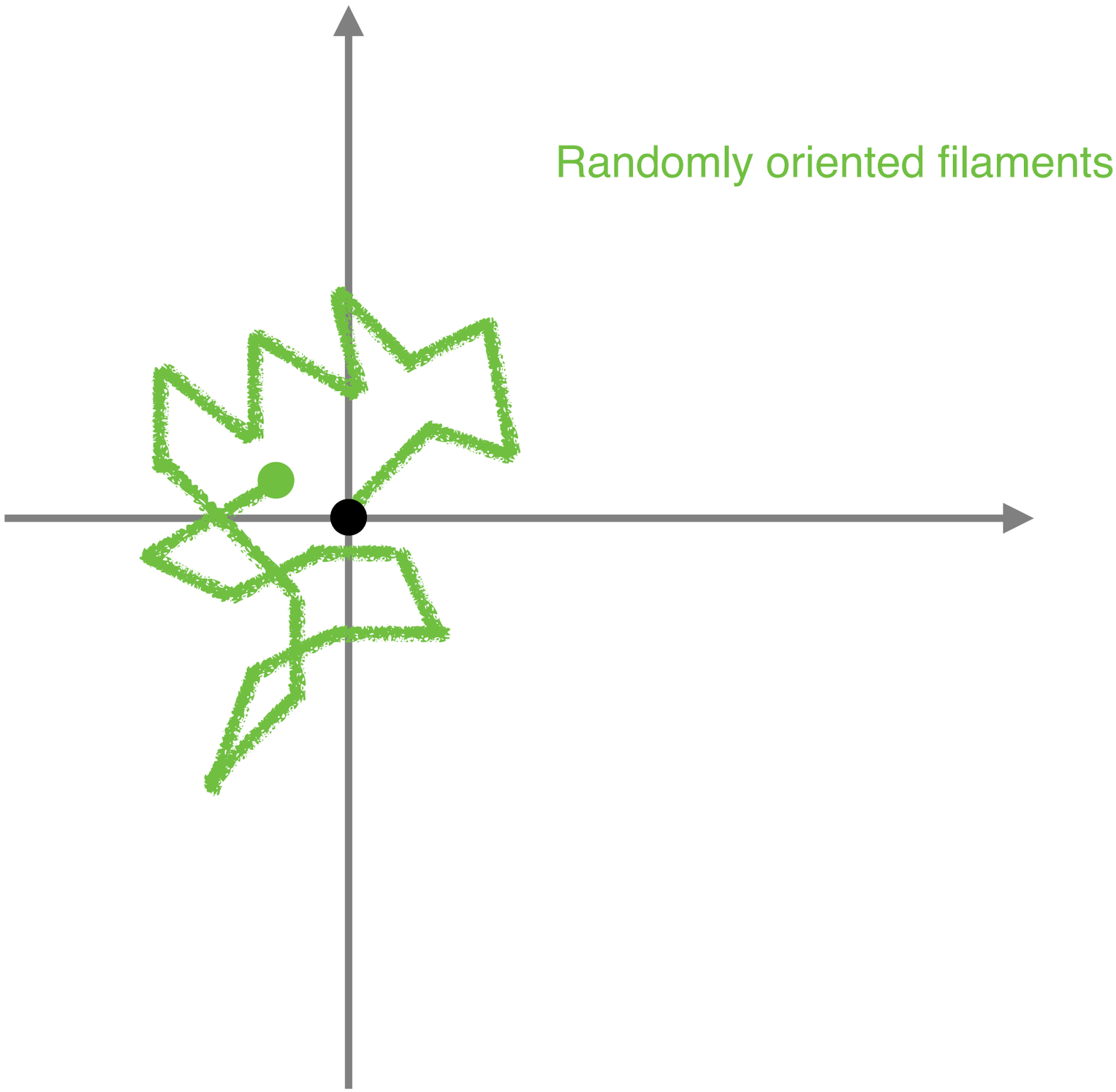
HI filament orientation: random walk interpretation

Soler, J.D. et al. A&A. 2020



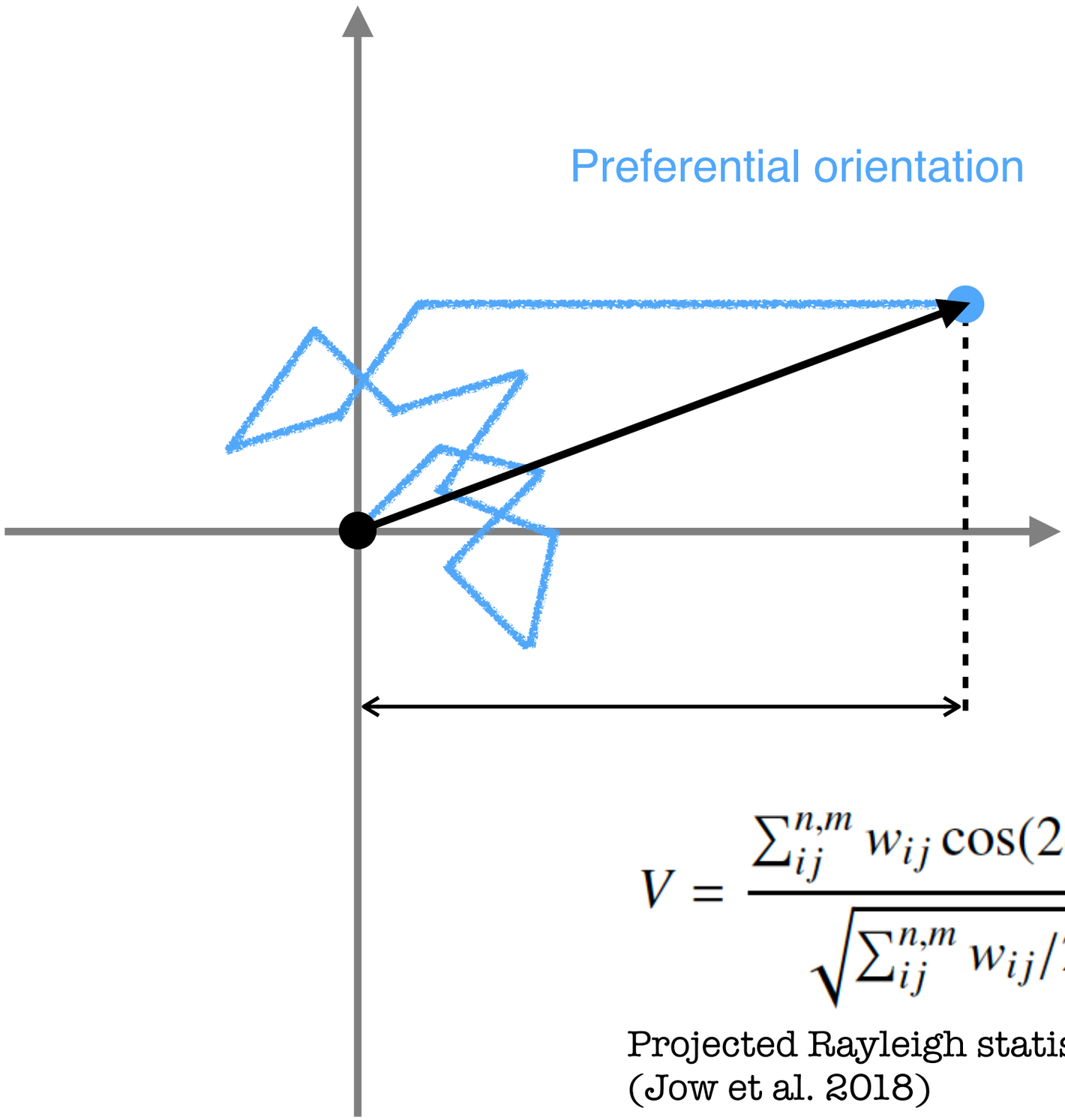
HI filament orientation: random walk interpretation

Soler, J.D. et al. A&A. 2020



HI filament orientation: random walk interpretation

Soler, J.D. et al. A&A. 2020

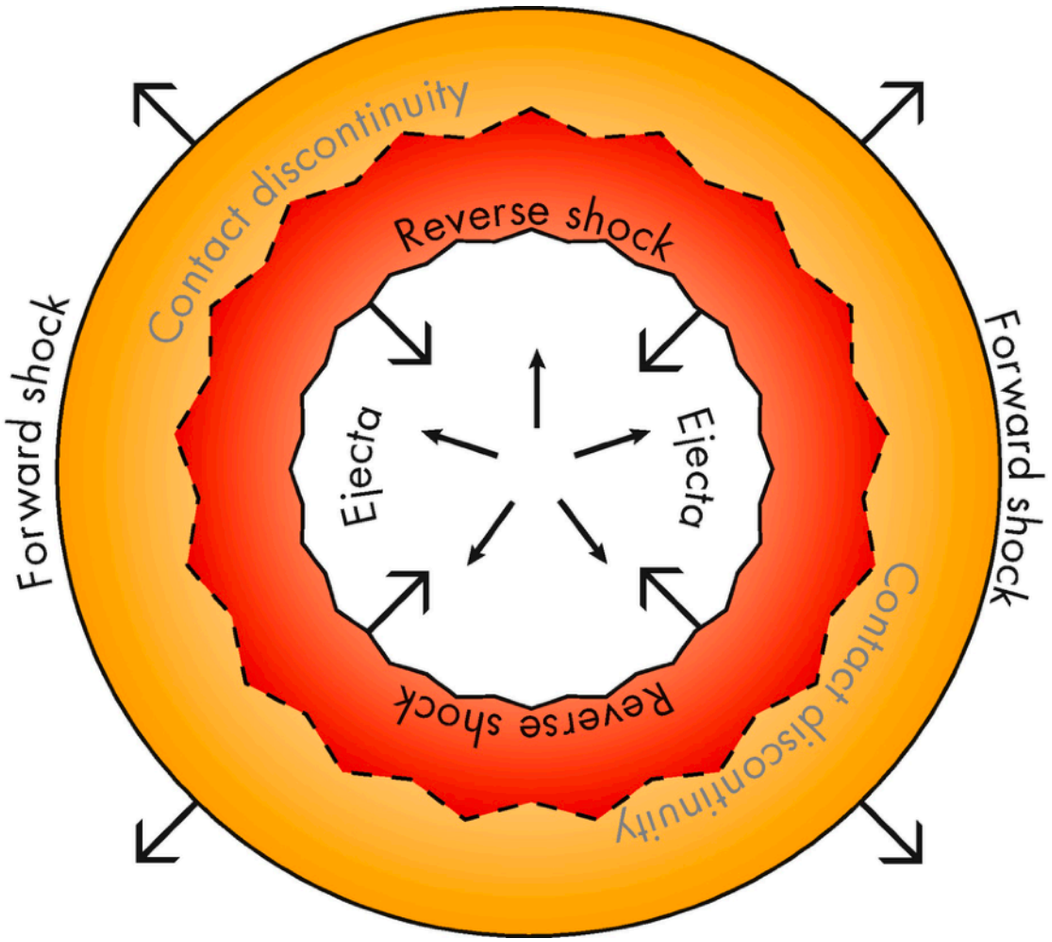


$$V = \frac{\sum_{ij}^{n,m} w_{ij} \cos(2\theta_{ij})}{\sqrt{\sum_{ij}^{n,m} w_{ij}/2}}$$

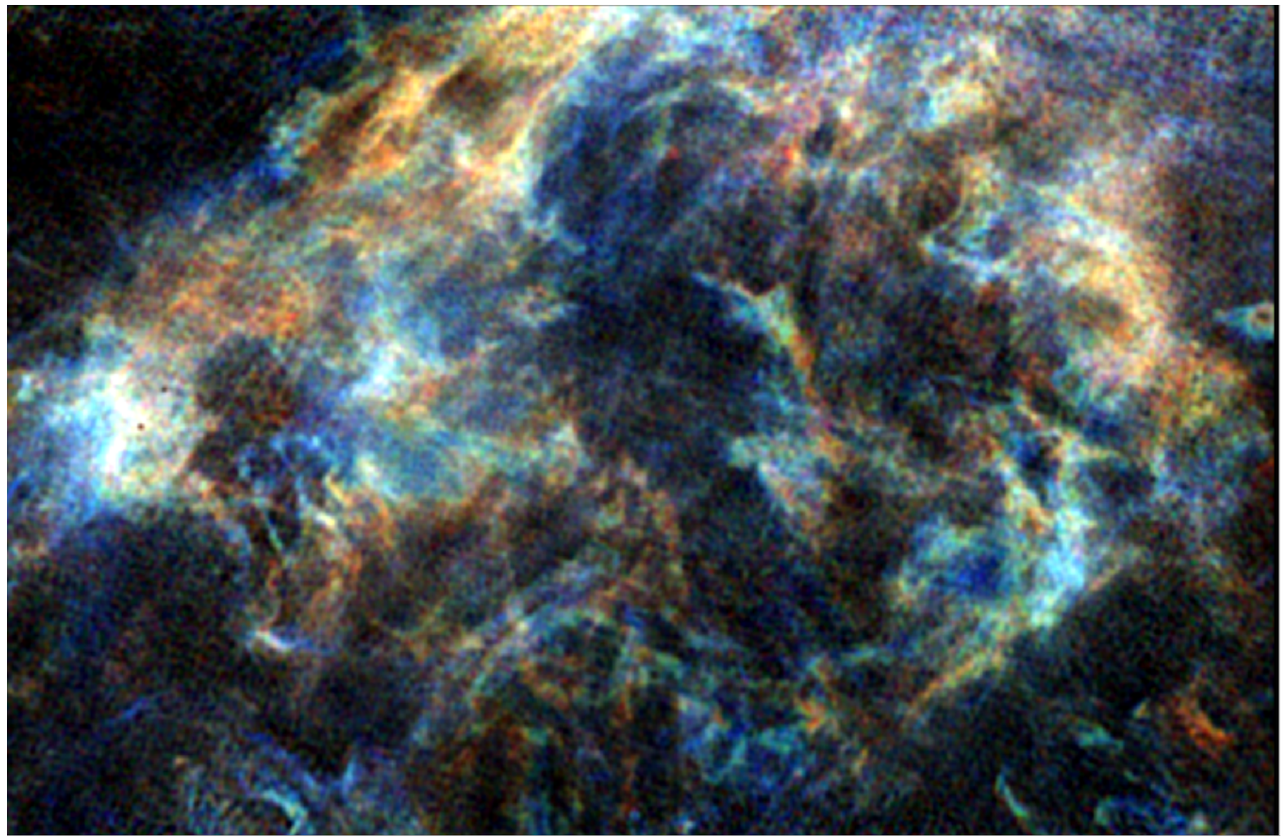
Projected Rayleigh statistic
(Jow et al. 2018)

Atomic shells pushed by supernovae

Supernova Remnant Evolution. Vink, 2020.

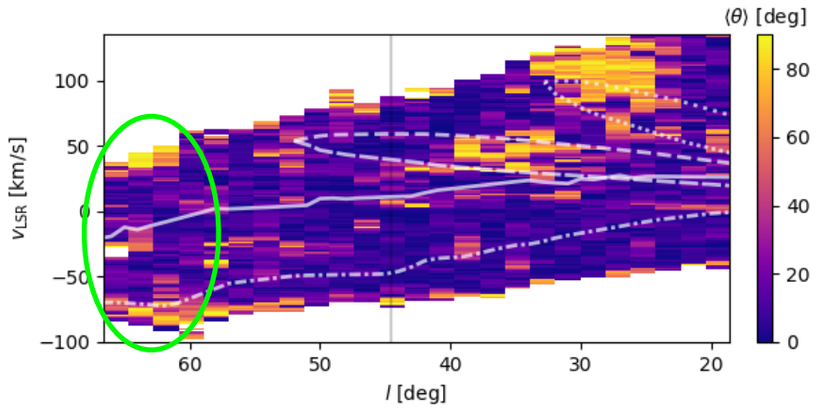


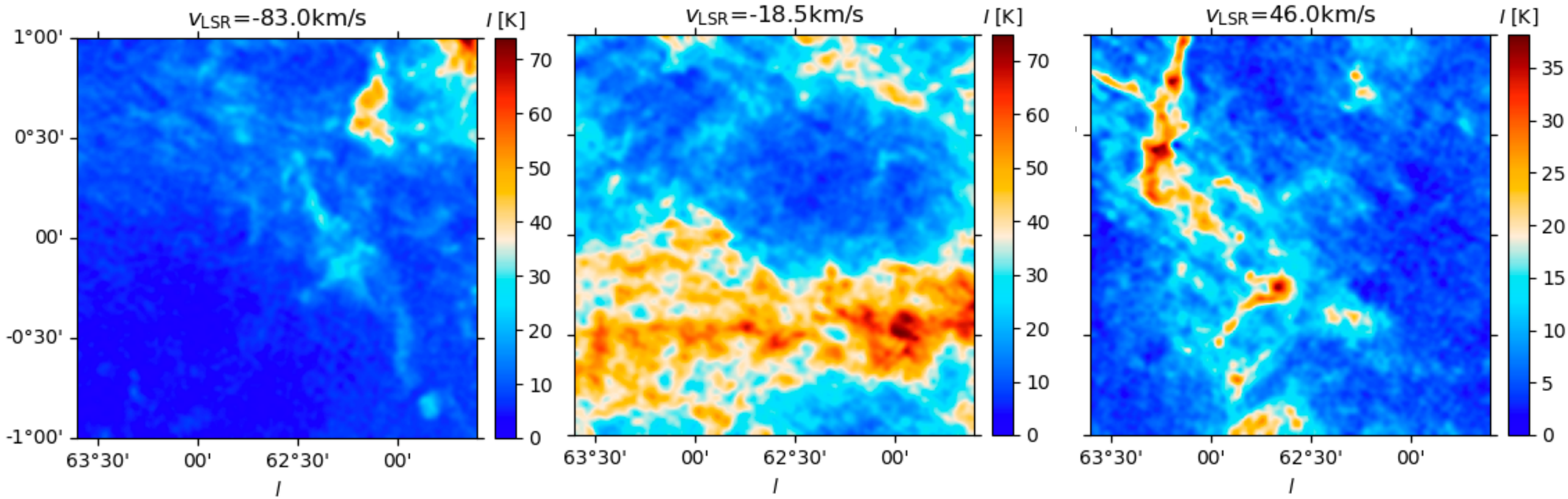
HI shell in THOR



HI filaments - terminal velocities

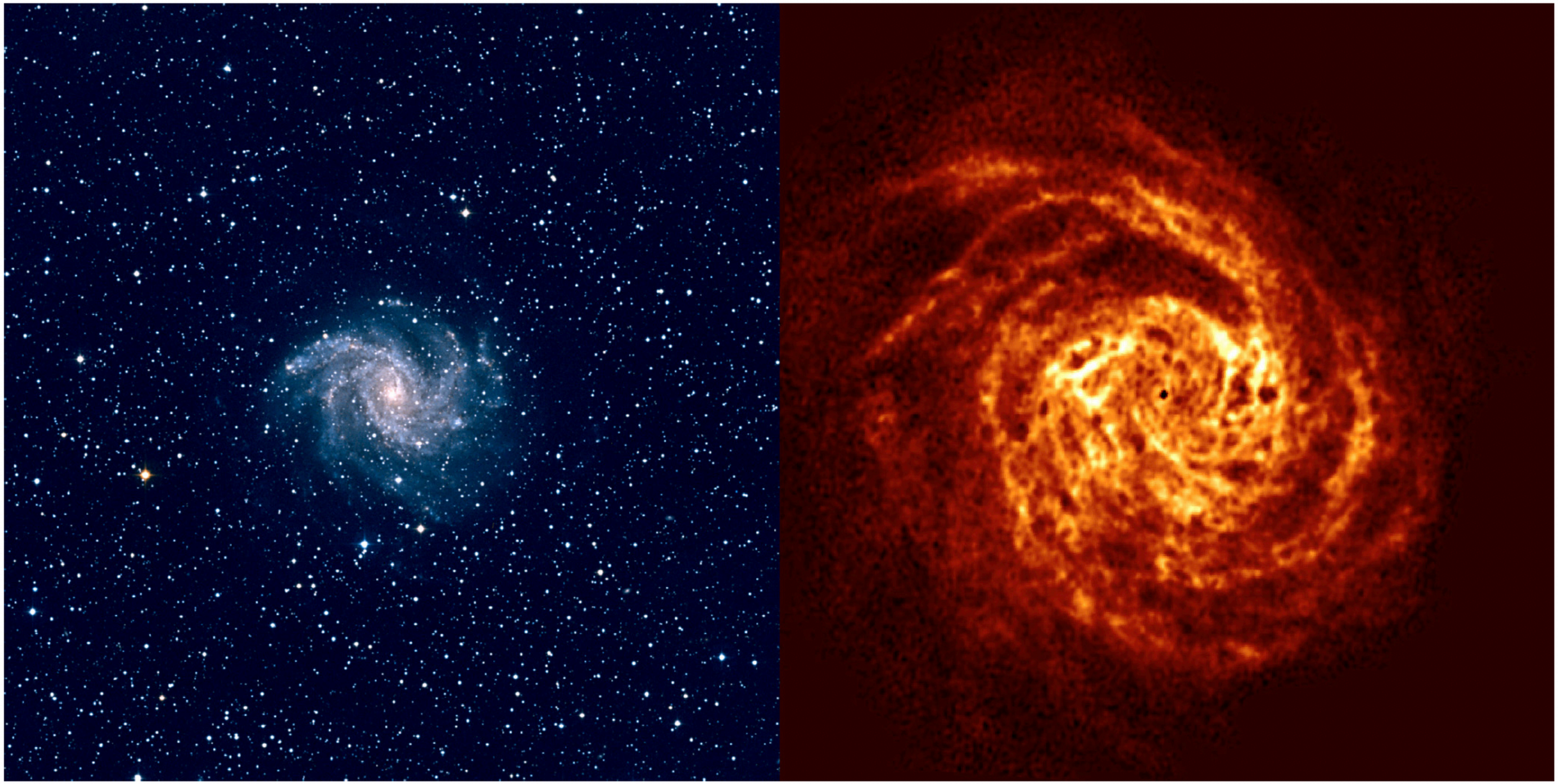
Soler, J.D. et al. A&A. 2020





HI holes in the spiral galaxy NGC6946

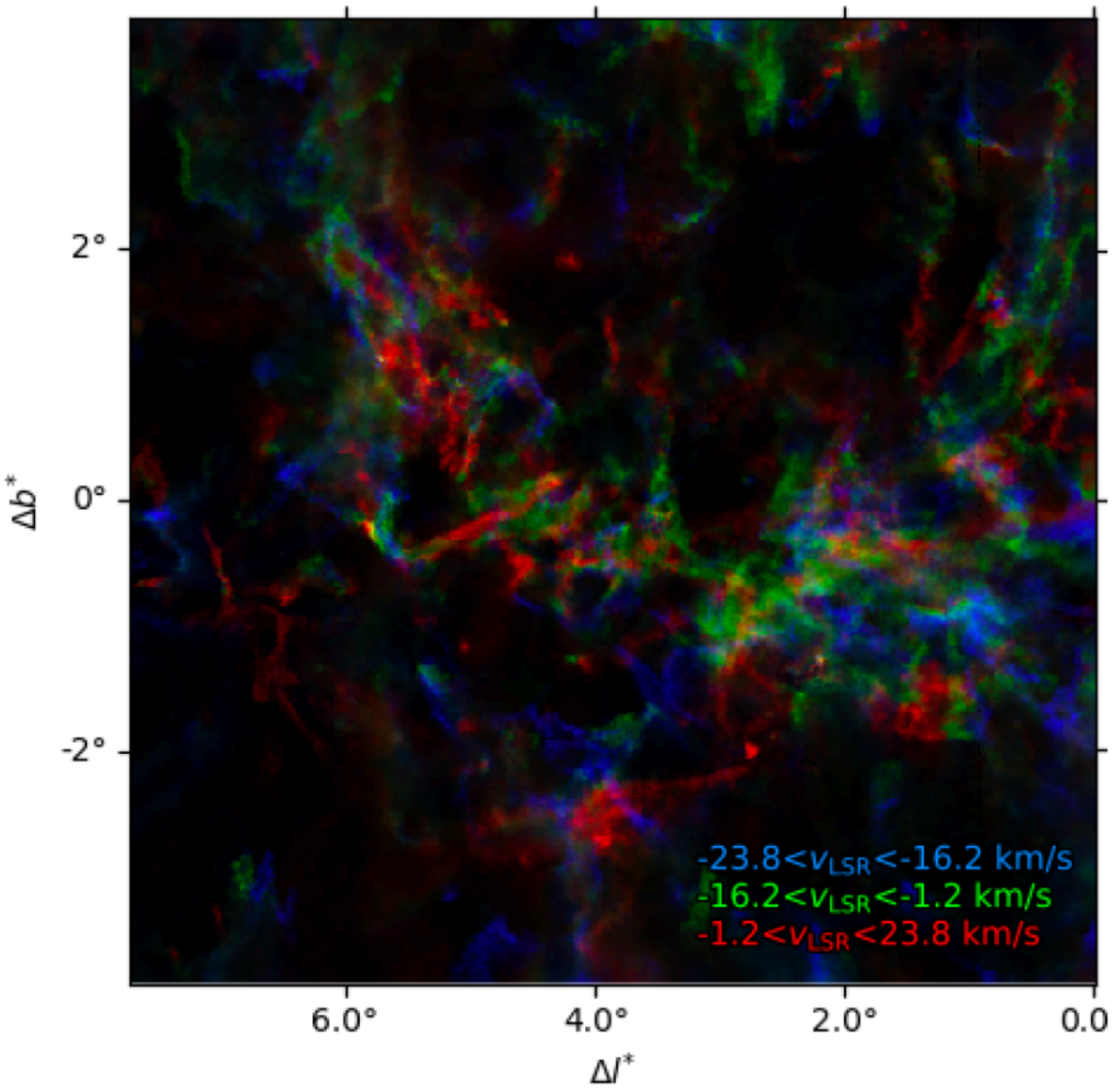
Boomsma et al. A&A 2008



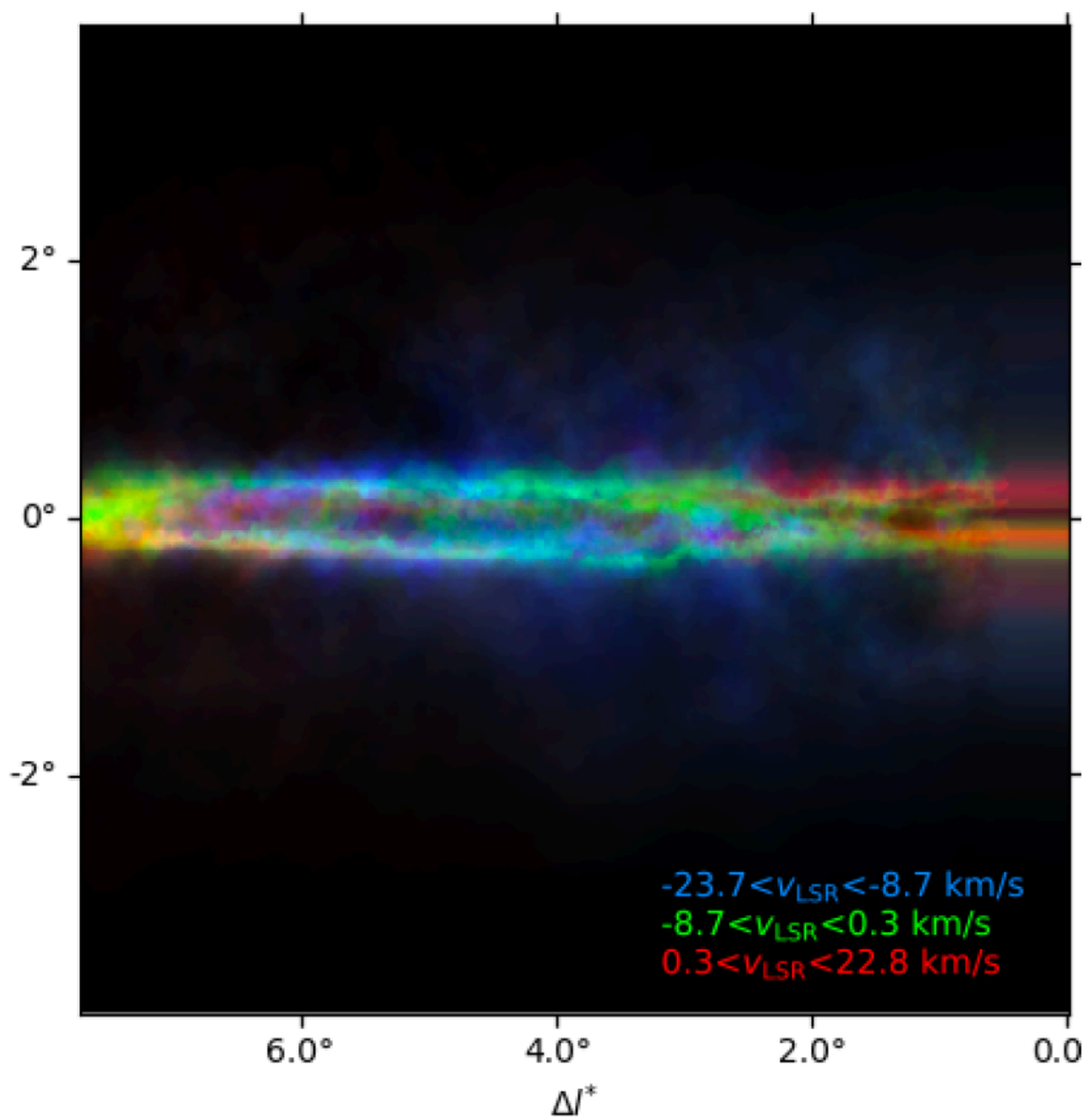
HI filaments in MHD simulations

CloudFactory simulations. Smith et al. A&A (2020)
Soler, J.D. et al. A&A (2020)

Feedback-dominated



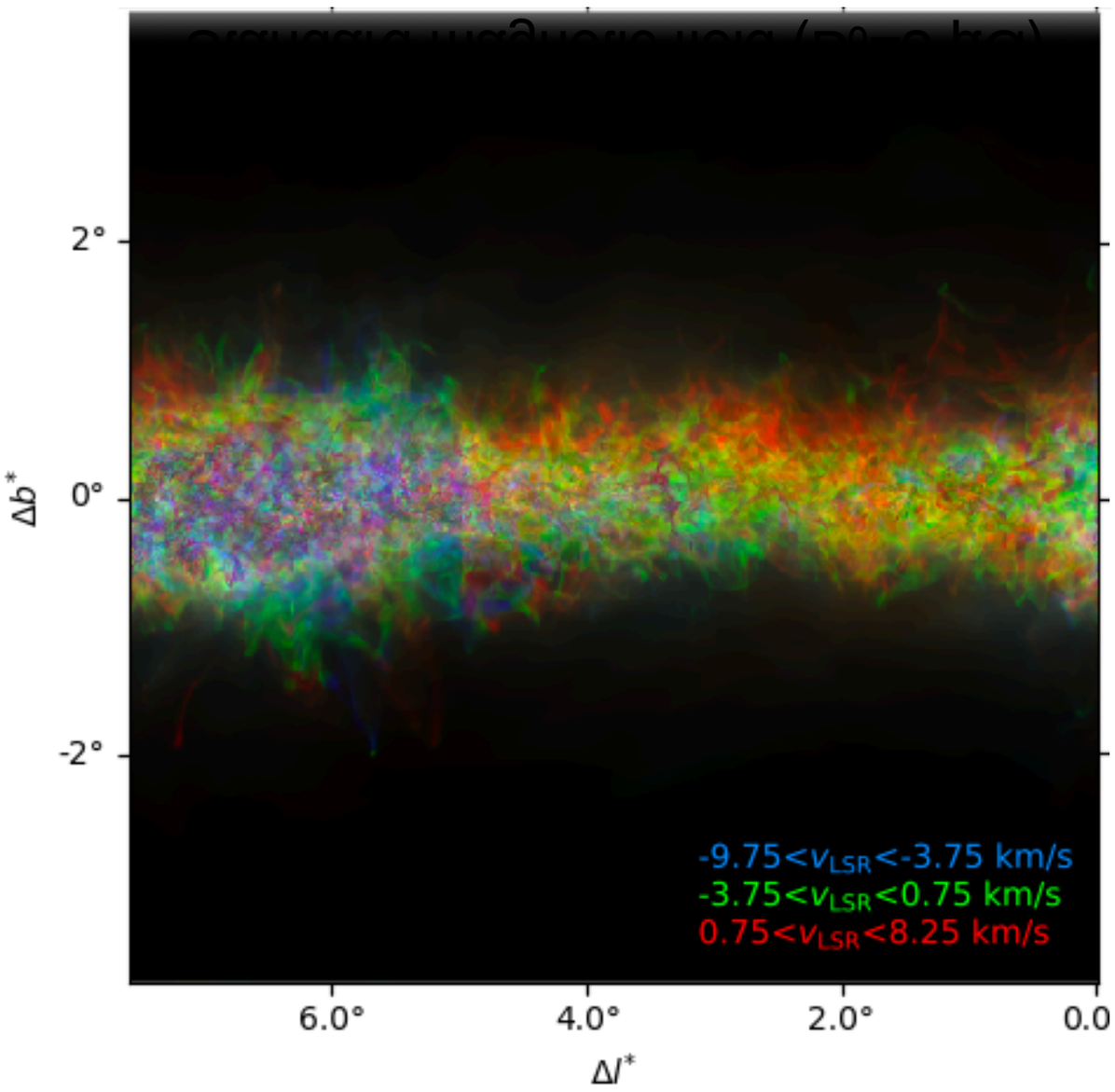
Potential-dominated



HI filaments in MHD simulations

FRIGG simulations. Hennebelle et al. A&A (2018)
Soler, J.D. et al. A&A (2020)

Standard magnetic field (B_0=3 μG)



Strong magnetic field (B_0=12 μG)