Magnetism & Morphology in the ISM

Susan E. Clark | Hubble Fellow,
Institute for Advanced Study

Josh Peek (STScI), Mary Putman (Columbia),
J. Colin Hill (IAS), The GALFA-HI Collaboration

Morphology

encodes complex physical information

Cloud Identification Chart

Clouds of Great Vertical Extent


Cumulonimbus calvus


Cumulonimbus cantillatus


Cumulonimbus capillatus

Cloud Names

Clouds are classified by ***family*** based on their altitude: high, middle, low, or vertical. The families include 10 principal cloud types called ***genus*** which are named after their altitude and form. Each genus is subdivided into ***species*** describing the size, shape, and form of cloud elements within a layer.

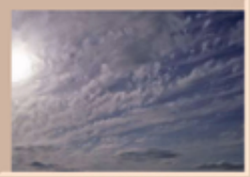
	Genus	Species
High Family	Cirrus	castellanus fibratus floccus spissatus uncinus
	Cirrocumulus	castellanus floccus lenticularis stratiformis
	Cirrostratus	fibratus nebulosus
Middle Family	Altocumulus	castellanus floccus lenticularis stratiformis
	Altostratus	none
	Nimbostratus	none
Low Family	Cumulus	fractus humilis mediocris congestus
	Cumulonimbus	calvus capillatus
	Stratus	fractus nebulosus
	Stratocumulus	castellanus lenticularis stratiformis

Not shown here is the subdivision of species called ***variety***. The variety describes layer thickness, the arrangement of cloud elements, or the presence of multiple layers.

Example Names

Genus only: Altocumulus
Genus + species: Altocumulus castellanus
Genus + species + variety: See website

High Family

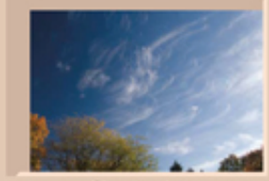

Cirrus castellanus

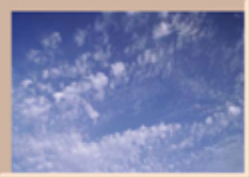

Cirrus fibratus


Cirrus fibratus


Cirrus floccus with virga


Cirrus spissatus


Cirrus uncinus


Cirrocumulus castellanus


Cirrocumulus floccus

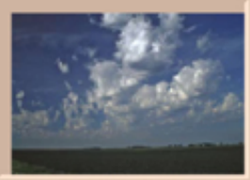

Cirrocumulus lenticularis

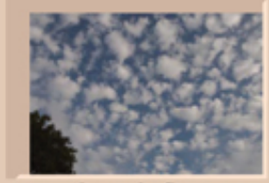

Cirrocumulus stratiformis


Cirrostratus fibratus


Cirrostratus nebulosus

Middle Family


Altocumulus castellanus


Altocumulus floccus

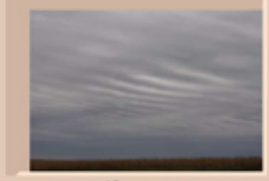

Altocumulus lenticularis


Altocumulus lenticularis


Altocumulus stratiformis


Altocumulus stratiformis


Altocumulus stratiformis


Altostratus


Altostratus

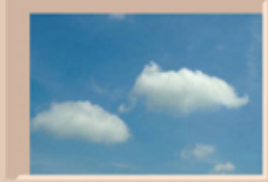

Altostratus


Altostratus

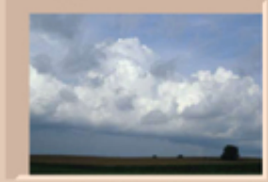

Nimbostratus

Low Family


Cumulus fractus

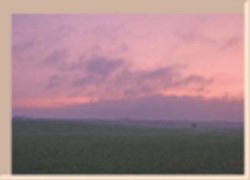

Cumulus humilus


Cumulus mediocris


Cumulus congestus

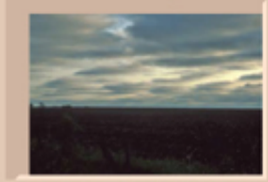

Stratus (Fog)

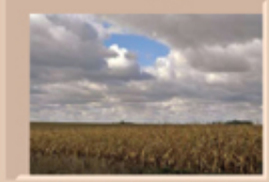

Stratus fractus

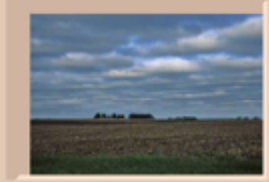

Stratus fractus


Stratus nebulosus

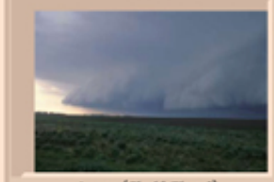

Stratocumulus castellanus


Stratocumulus lenticularis


Stratocumulus stratiformis


Stratocumulus stratiformis

Accessory Clouds


Arcus (Shelf Cloud)

Mamma

Pileus (Cap Cloud)

Identifying Clouds

By Form

Cirriform: Thin, wispy, with white delicate filaments, patches or narrow bands.

Cumuliform: Puffy, rounded, tufted clouds with distinct vertical cells or elements.

Stratiform: Layered, sheet-like clouds with a smooth appearance.

By Altitude

High Family

Above 16,500 feet (5,000 m)

Temperatures:	Below freezing
Content:	Ice crystals and some supercooled water
Cloud forms:	Cirriform, stratiform, cumuliform
Principal types:	Cirrus, cirrocumulus, cirrostratus

Middle Family

6,500 to 20,000 feet (2,000 - 6,000 meters)

Temperatures:	Above and below freezing
Content:	Supercooled water, water, and ice crystals
Cloud forms:	Cumuliform, stratiform
Principal types:	Altocumulus, altostratus, nimbostratus

Low Family

Below 6,500 feet (2,000 meters)

Temperatures:	Above and below freezing
Content:	Water, supercooled water, and ice crystals
Cloud forms:	Stratiform, cumuliform
Principal types:	Stratus, cumulus, stratocumulus, cumulonimbus

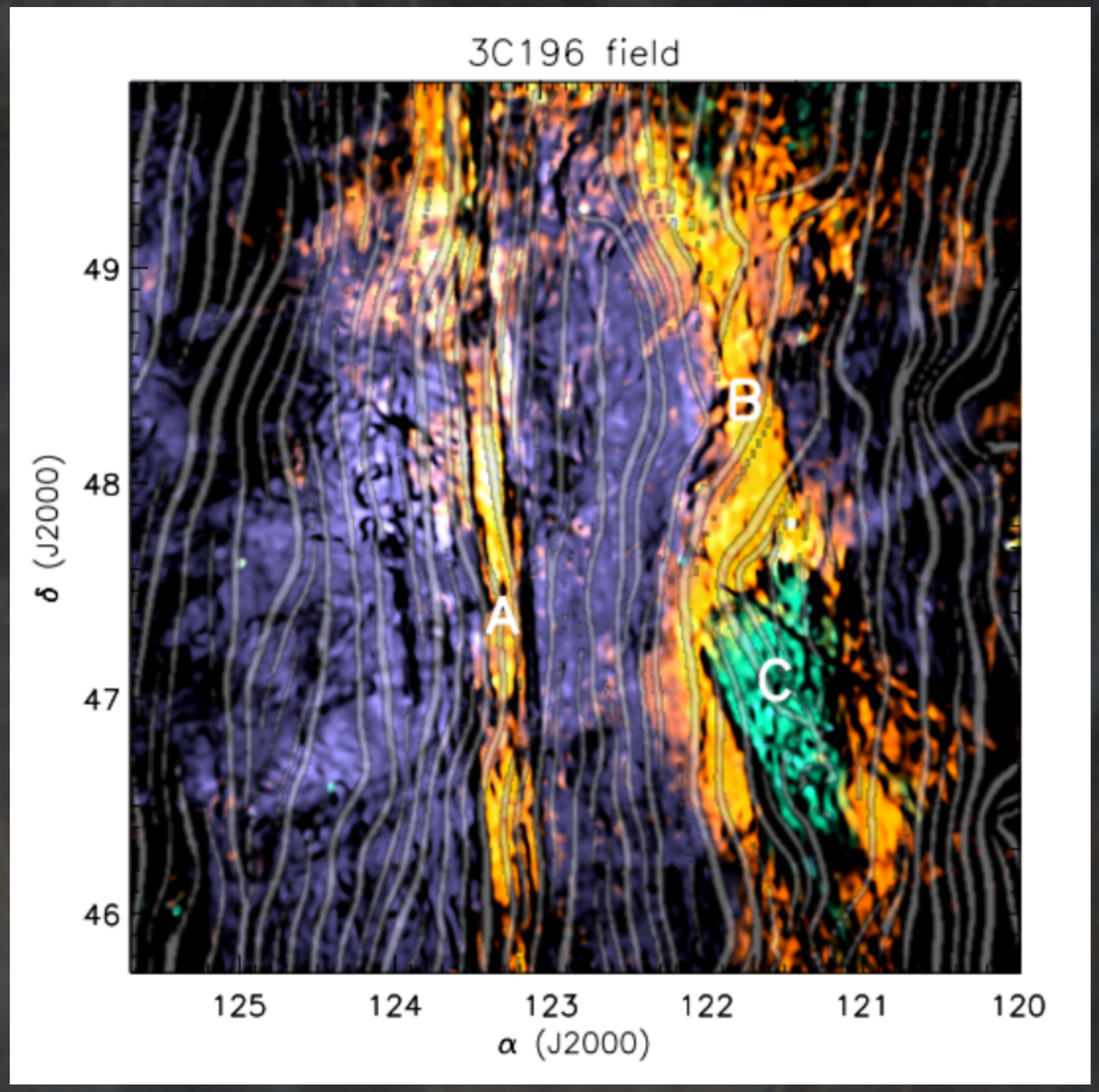
These altitudes are typical of the middle latitudes. Clouds may be lower in polar regions and reach higher altitudes in the tropics.

Accessory Clouds
A cloud that depends on a parent cloud for its existence. It may be an appendage but it is often found adjacent to the parent cloud.

Clouds of Great Vertical Extent
These clouds extend through multiple layers. When their base forms in the low level they are classified as a low cloud.

Learn more at www.weatherbriefing.com

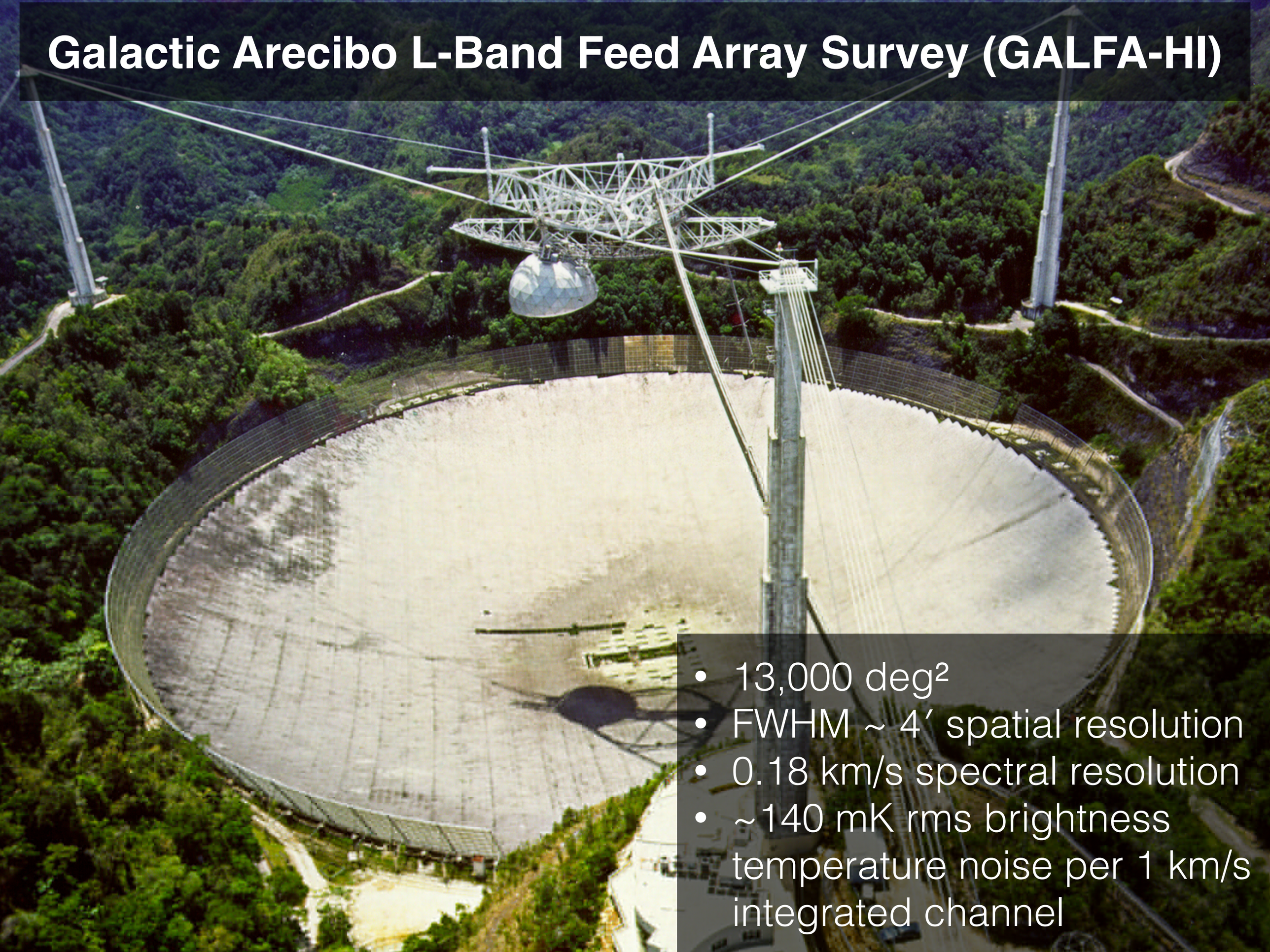
Low frequency observations show complicated polarization structure.



Zaroubi+ 2015
Jelić+ 2015

-3 to -0.5 rad / m^2
+0.5 rad / m^2
+1 to +4.5 rad / m^2
Planck B-field

Galactic Arecibo L-Band Feed Array Survey (GALFA-HI)



- 13,000 deg²
- FWHM ~ 4′ spatial resolution
- 0.18 km/s spectral resolution
- ~140 mK rms brightness temperature noise per 1 km/s integrated channel

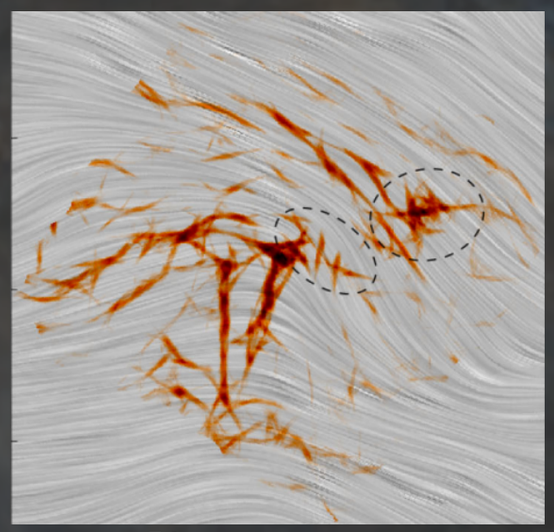
Do linear HI structures trace the magnetic field?

GALFA-HI: Peek+ in prep

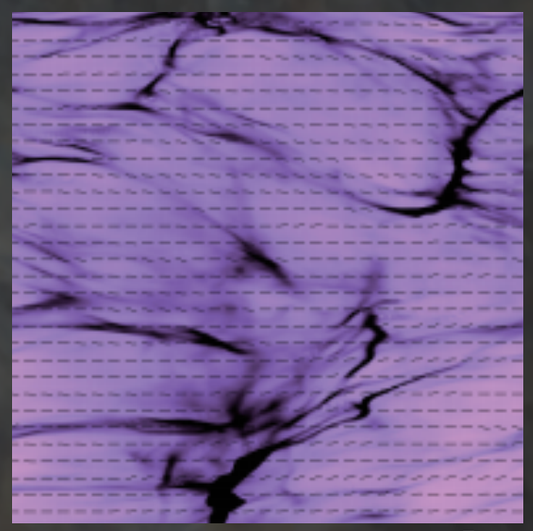
The Rolling Hough Transform

Clark, Peek, & Putman 2014, ApJ 789, 82

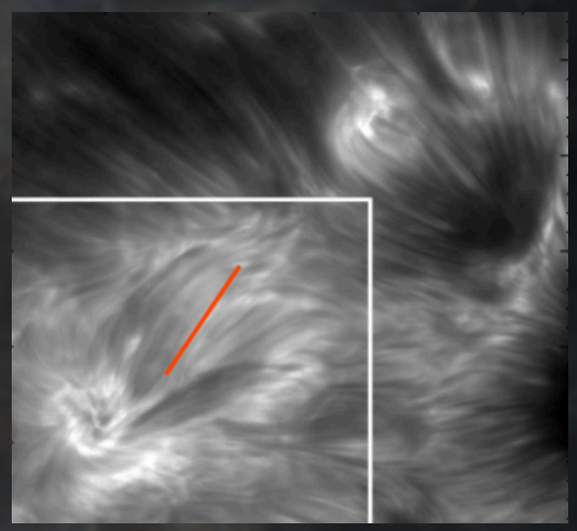
github.com/seclark/RHT



Malinen+ 2016

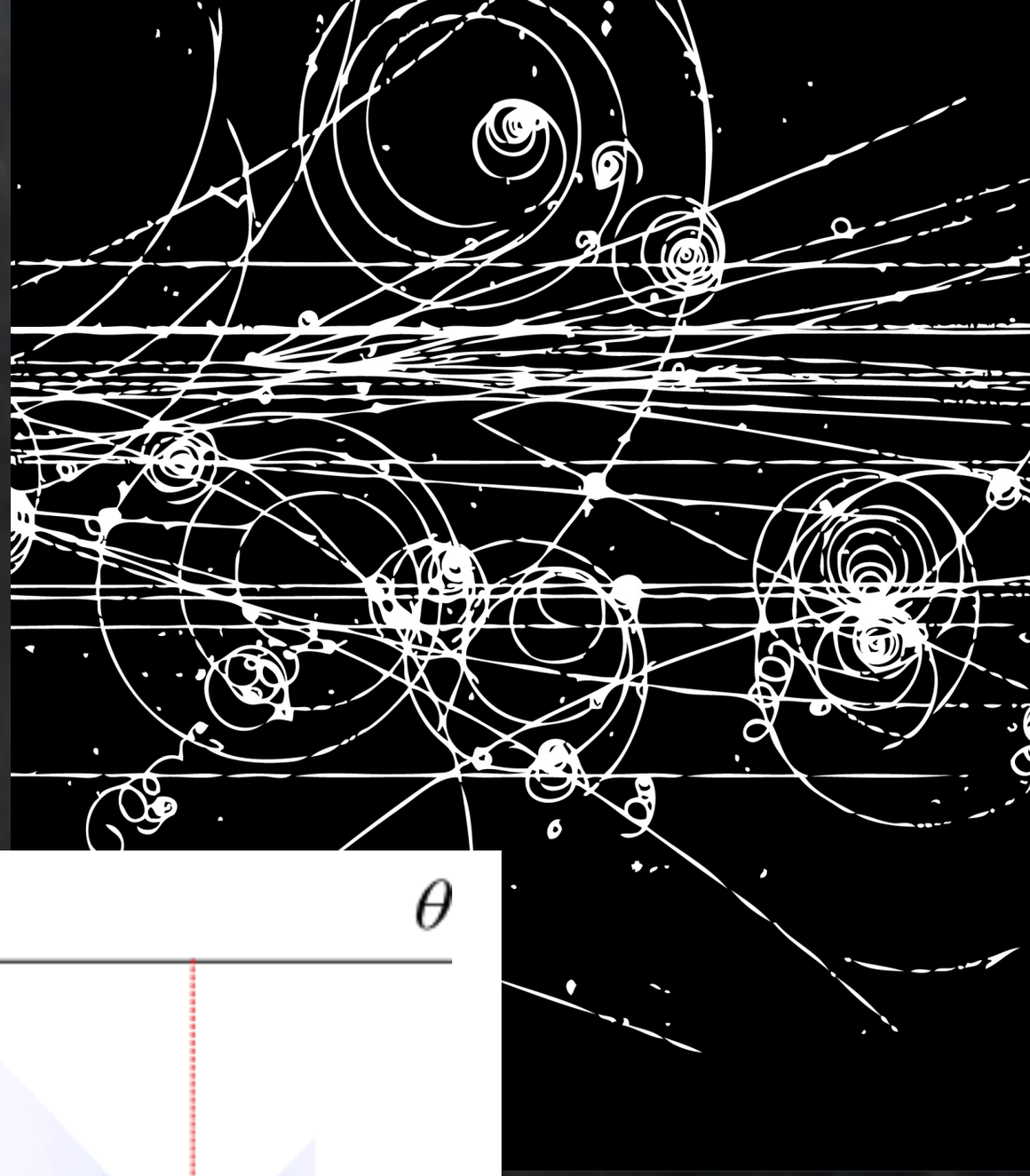


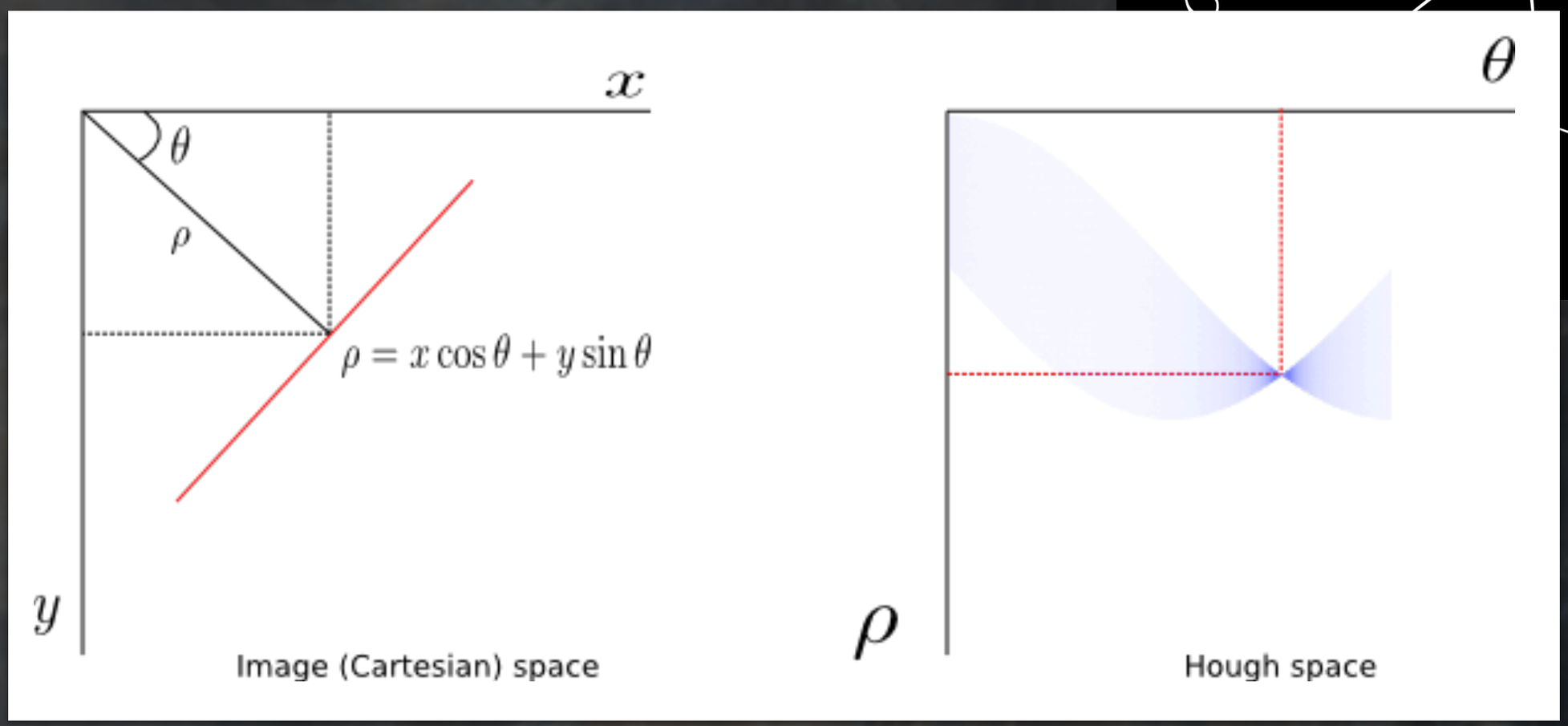
Inoue & Inutsuka 2016



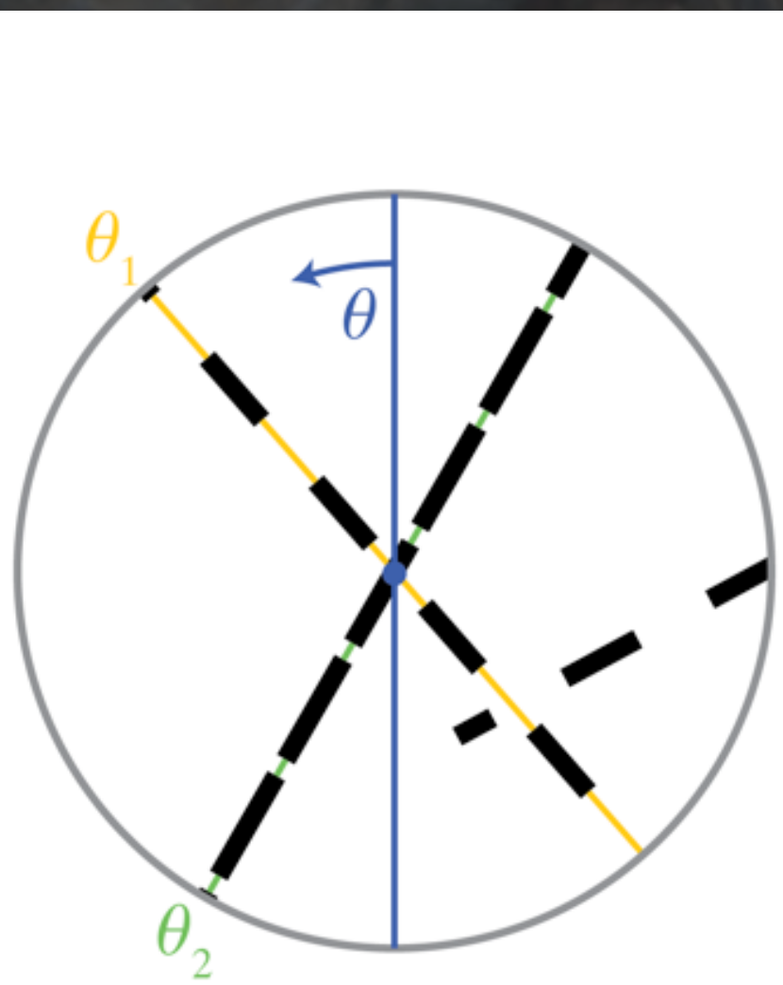
Asensio Ramos+ 2017

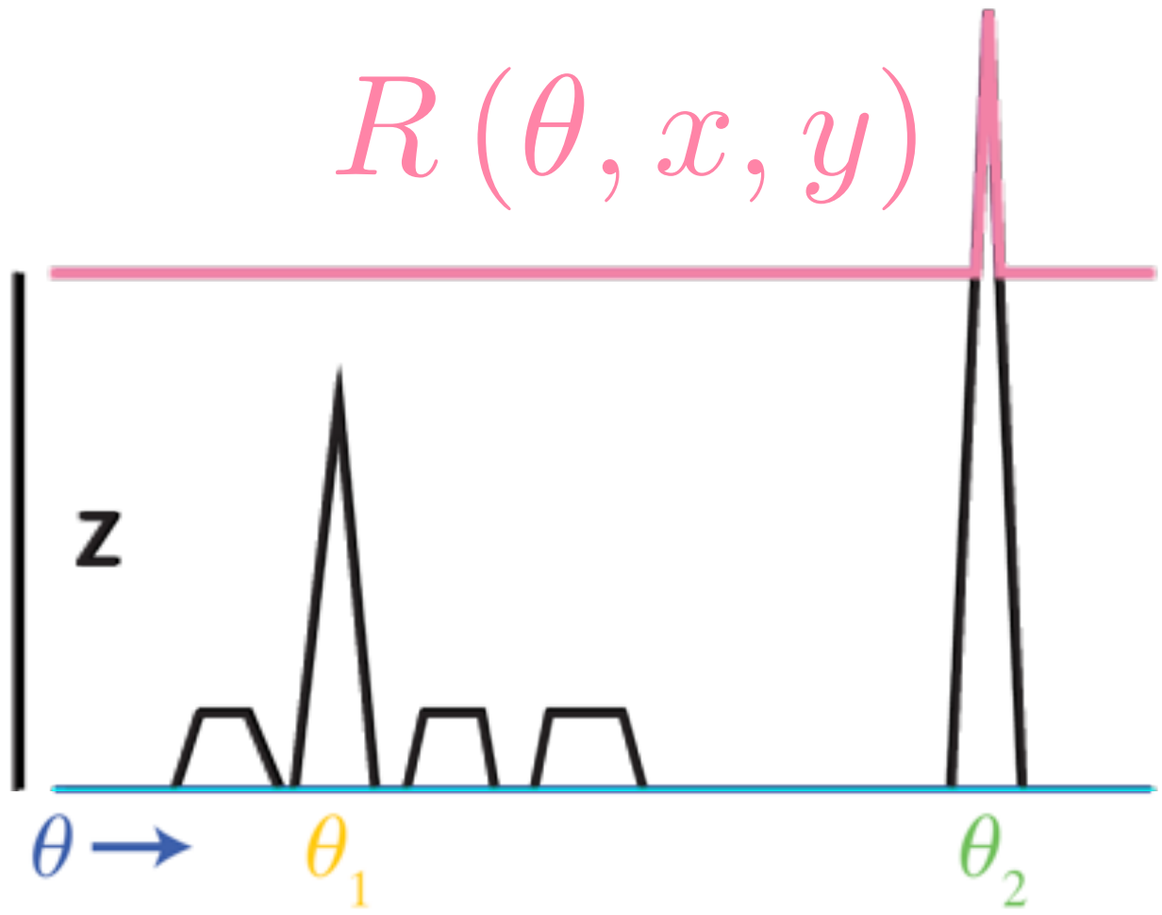
The Hough Transform was originally conceived to detect lines in bubble chamber photos.





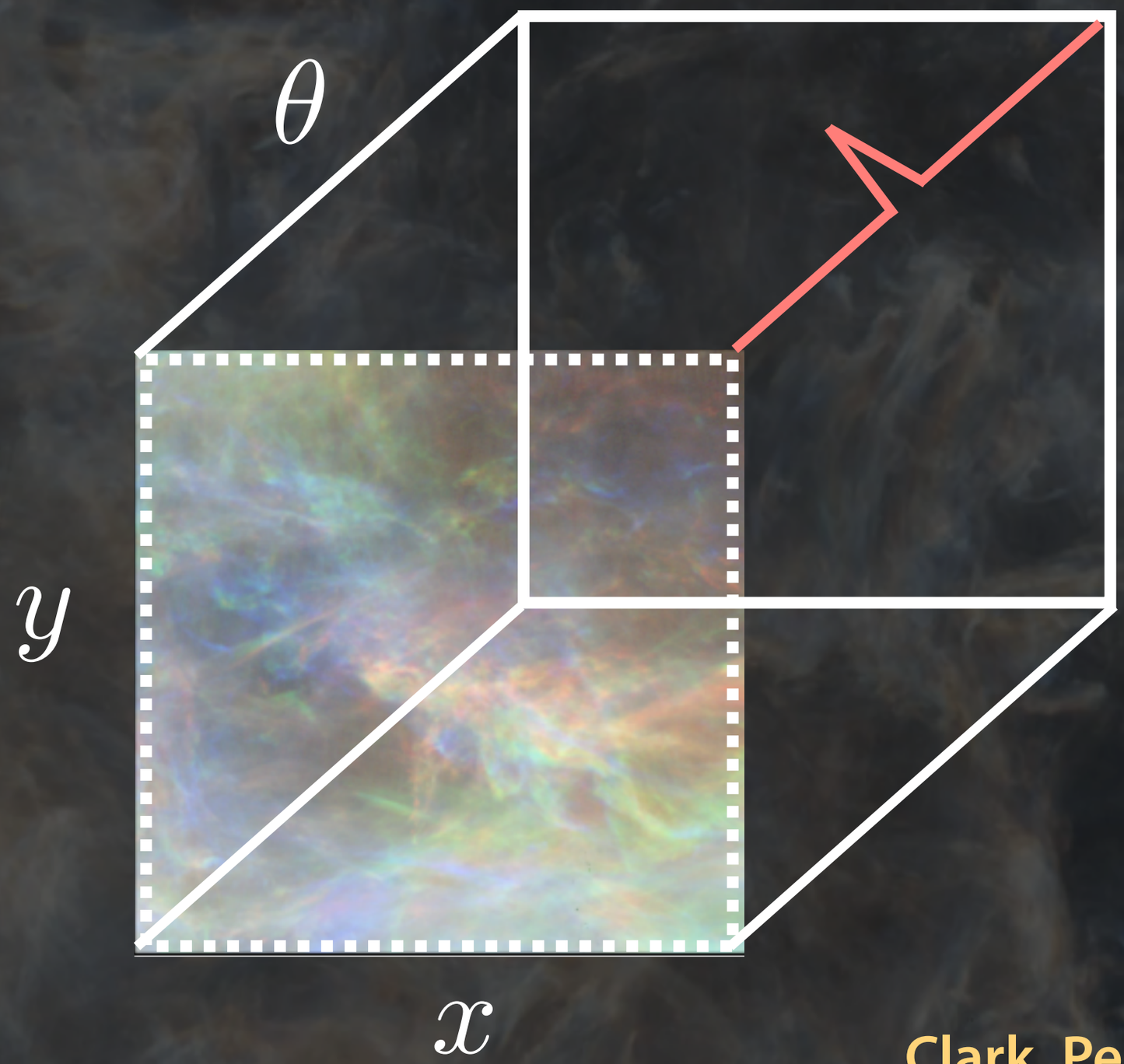
Measure intensity as a function of angle.





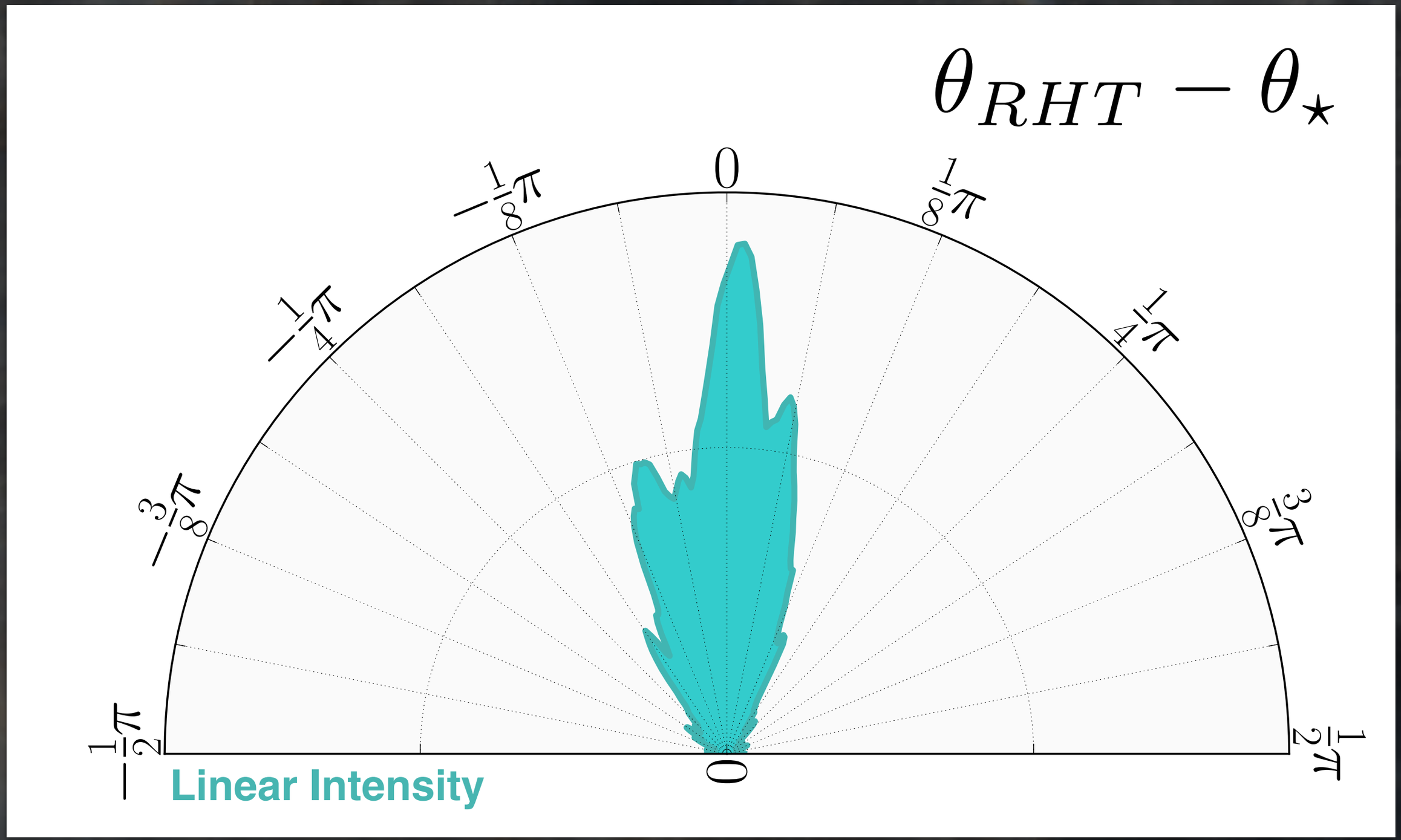
Clark, Peek, & Putman 2014

Store intensity as a function of angle for every image pixel.



Clark, Peek, & Putman 2014

Linear features in HI correlate with starlight polarization.

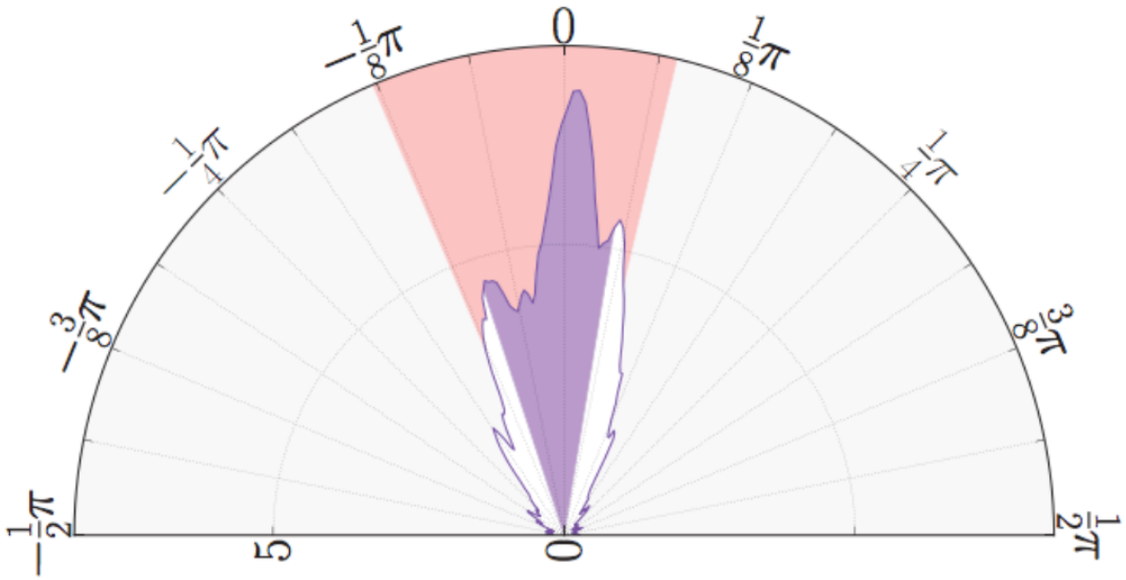


Starlight polarization: Heiles 2000

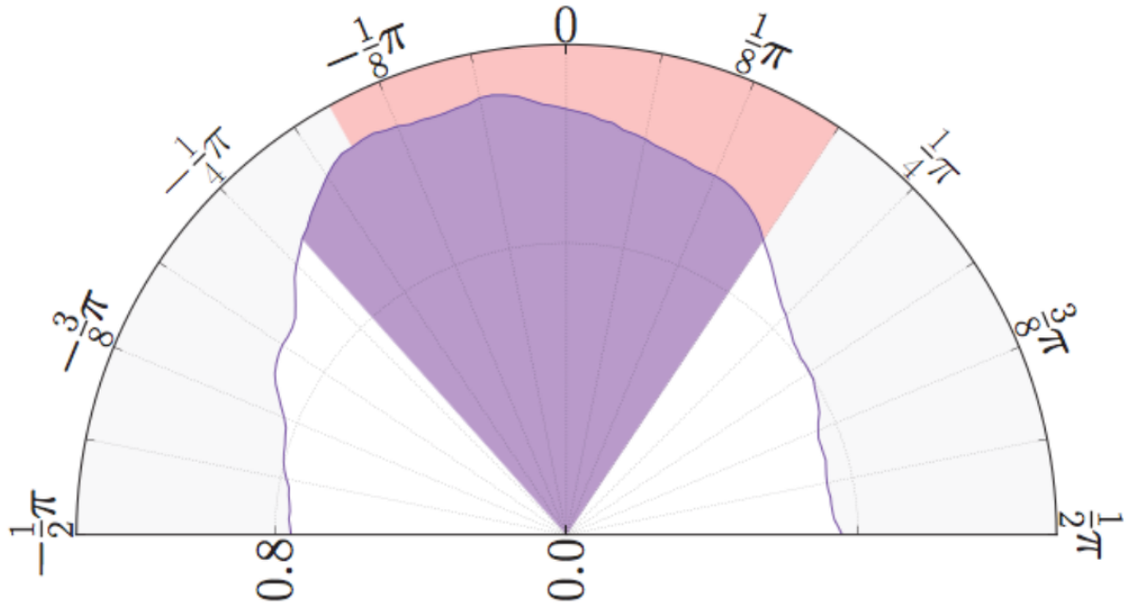
Clark, Peek, & Putman 2014

The correlation is tighter with high-resolution HI.

GALFA-HI : $4'$



Parkes GASS : $16'$



Clark, Peek, & Putman 2014

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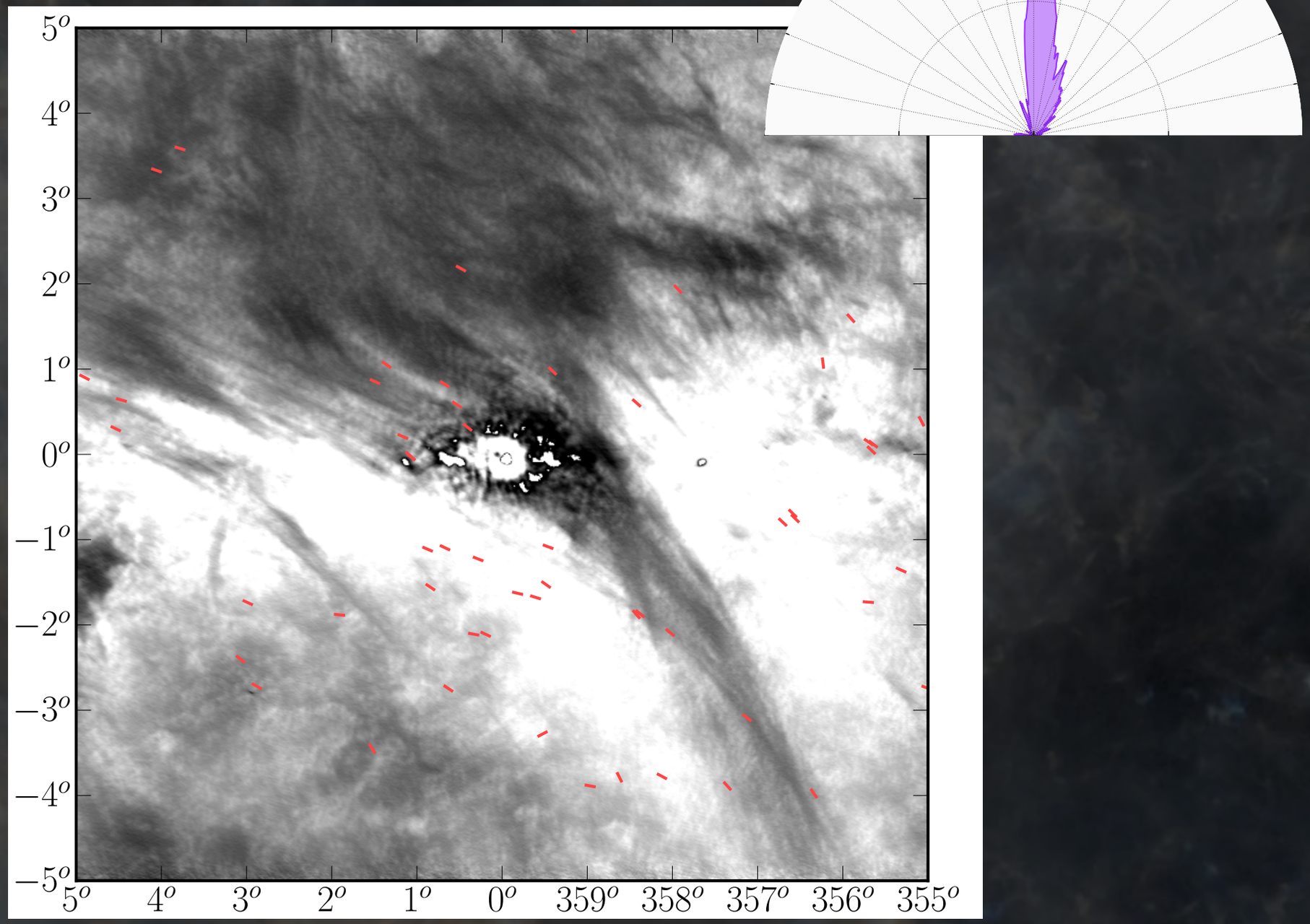
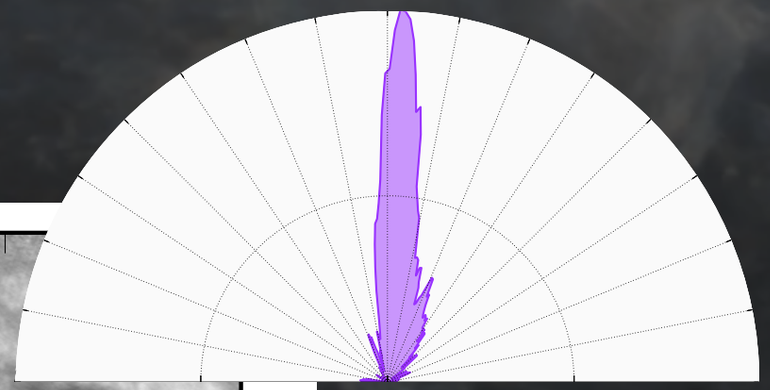
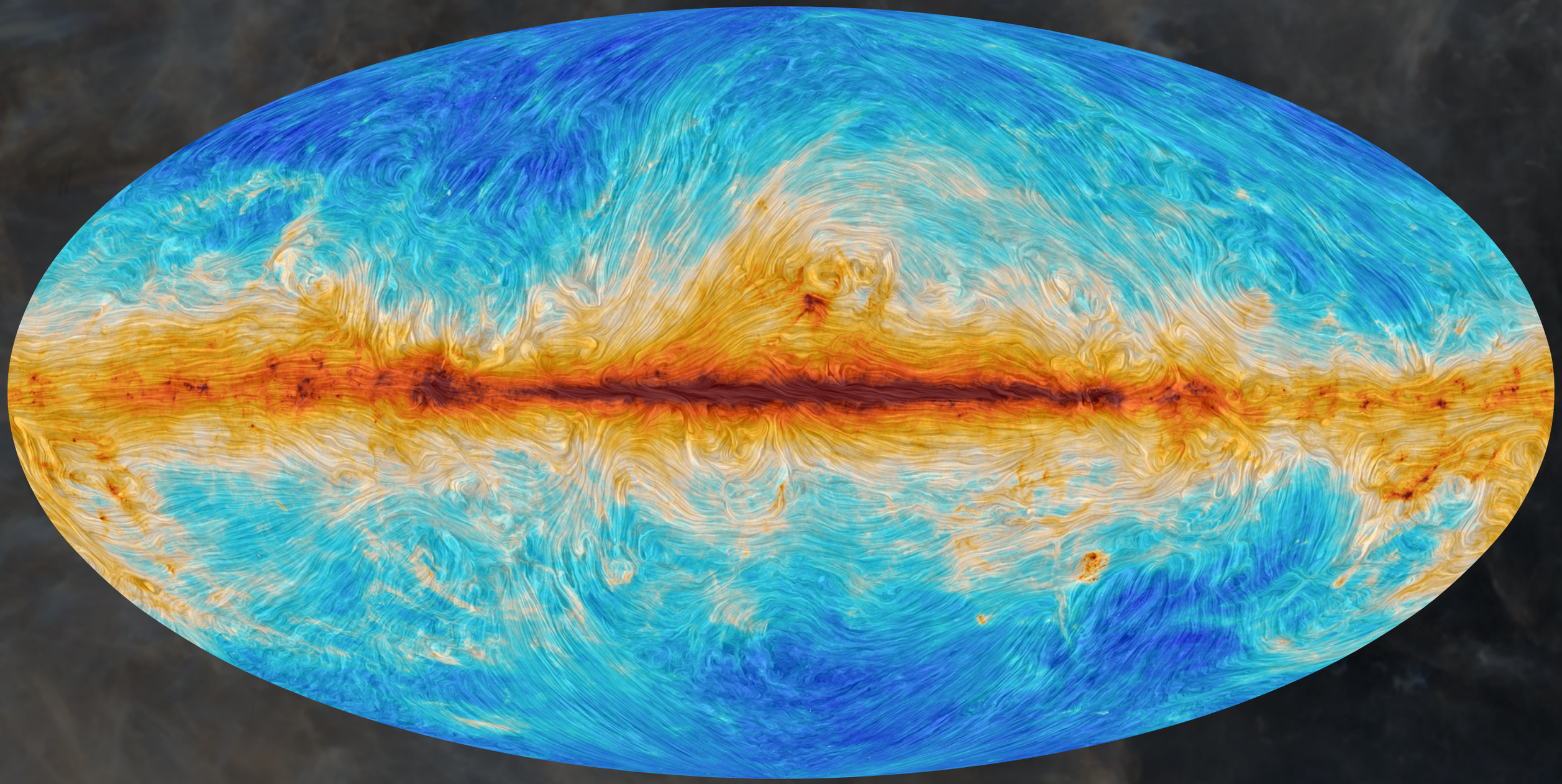




SGPS GC Survey
McClure-Griffiths+ 2006

Clark, Peek, & Putman 2014

The Planck satellite mapped the full sky in 353 GHz polarized dust emission.



ESA/Planck Collaboration
Planck Intermediate Results XIX

Calculate Stokes parameters from the HI orientation.

$$Q_{RHT} = \int \cos(2\theta) \cdot R(\theta)\ d\theta$$

$$U_{RHT} = \int \sin(2\theta) \cdot R(\theta)\ d\theta$$

Clark+ 2015, PRL

Calculate HI and *Planck* magnetic field orientation.

Neutral hydrogen orientation

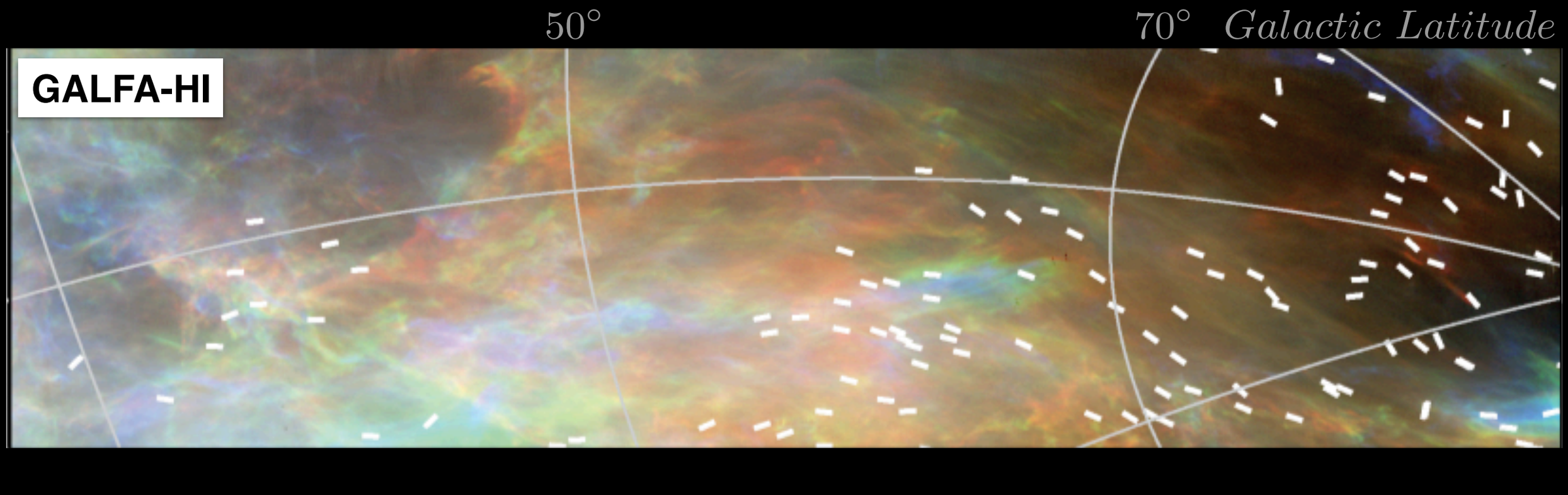
$$\theta_{RHT} = \frac{1}{2} \arctan \frac{U_{RHT}}{Q_{RHT}}$$

***Planck* magnetic field orientation**

$$\theta_{353} = \psi_{353} + 90^o$$

Clark+ 2015, PRL

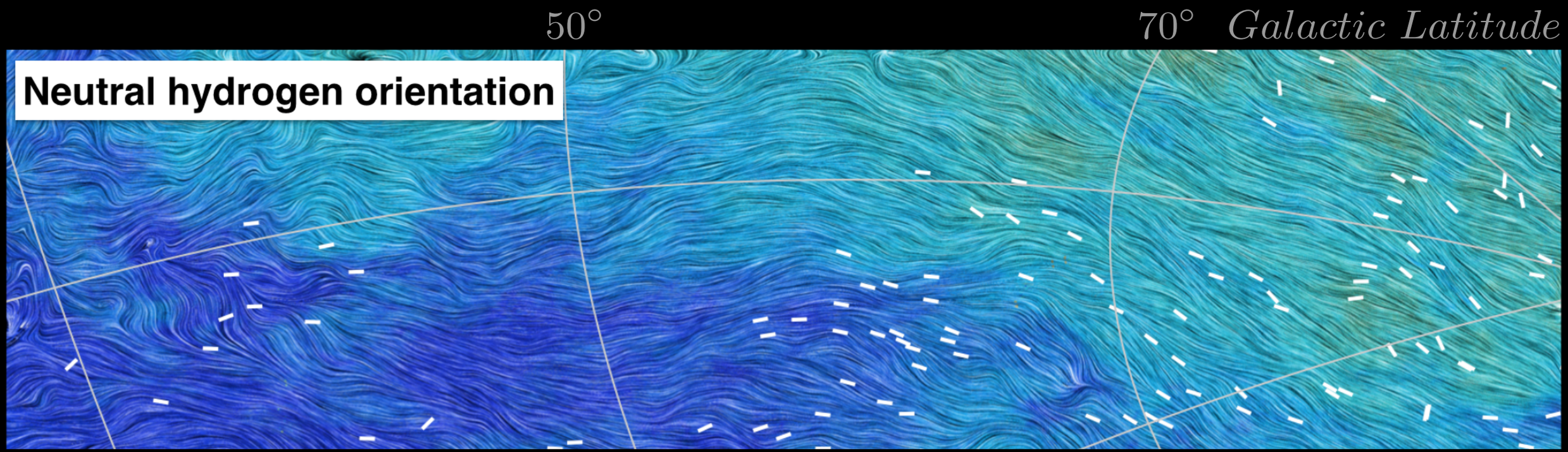
Characterize the orientation of high-latitude GALFA-HI structures.



Starlight polarization: Heiles 2000

Clark+ 2015, PRL

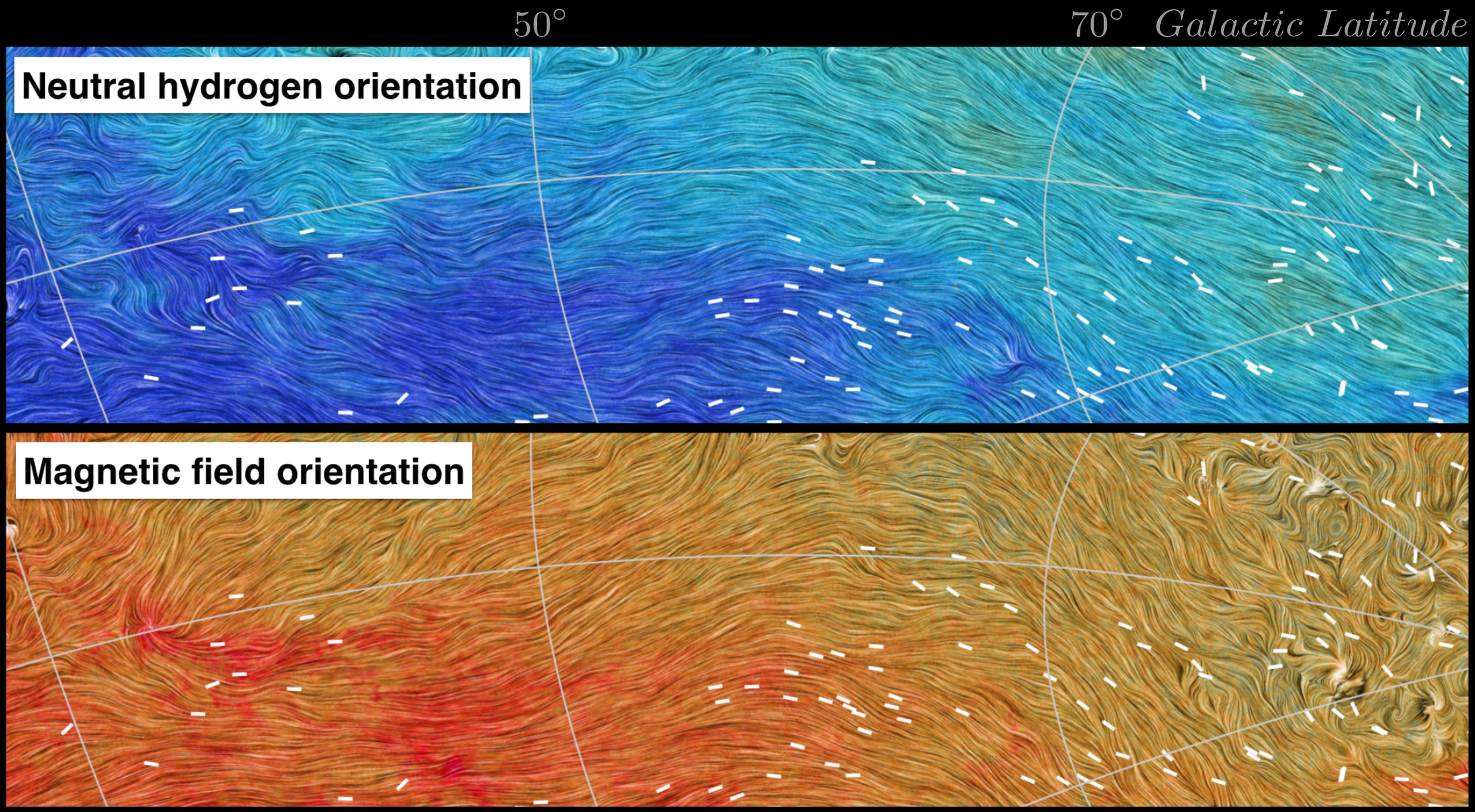
Characterize the orientation of high-latitude GALFA-HI structures.



Starlight polarization: Heiles 2000

Clark+ 2015, PRL

High latitude GALFA-HI structures are aligned with the Planck magnetic field orientation.



Starlight polarization: Heiles 2000

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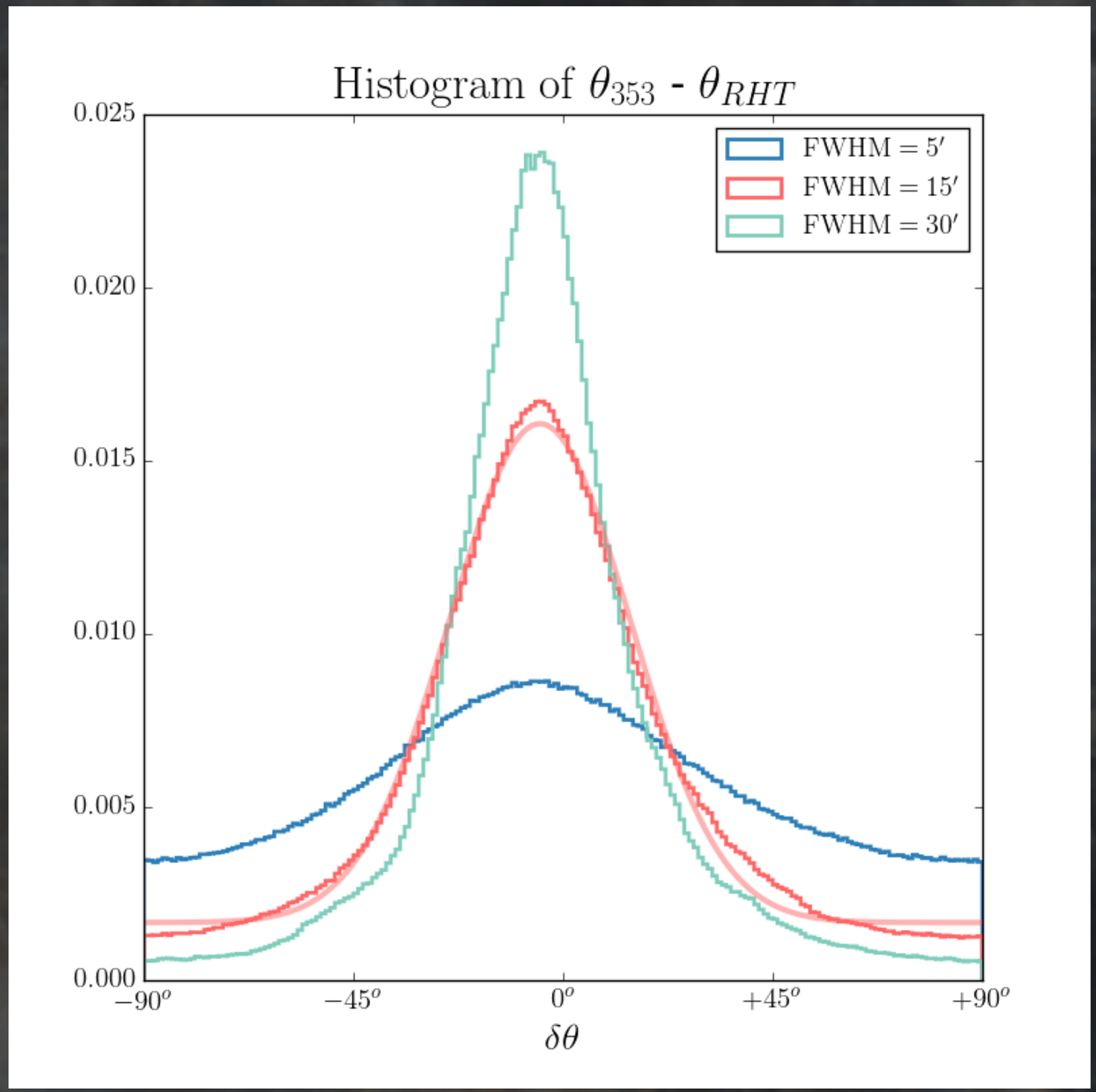


$\mathrm{FWHM} = 30'$

$\sigma \sim 14°$

Clark+ 2015, PRL

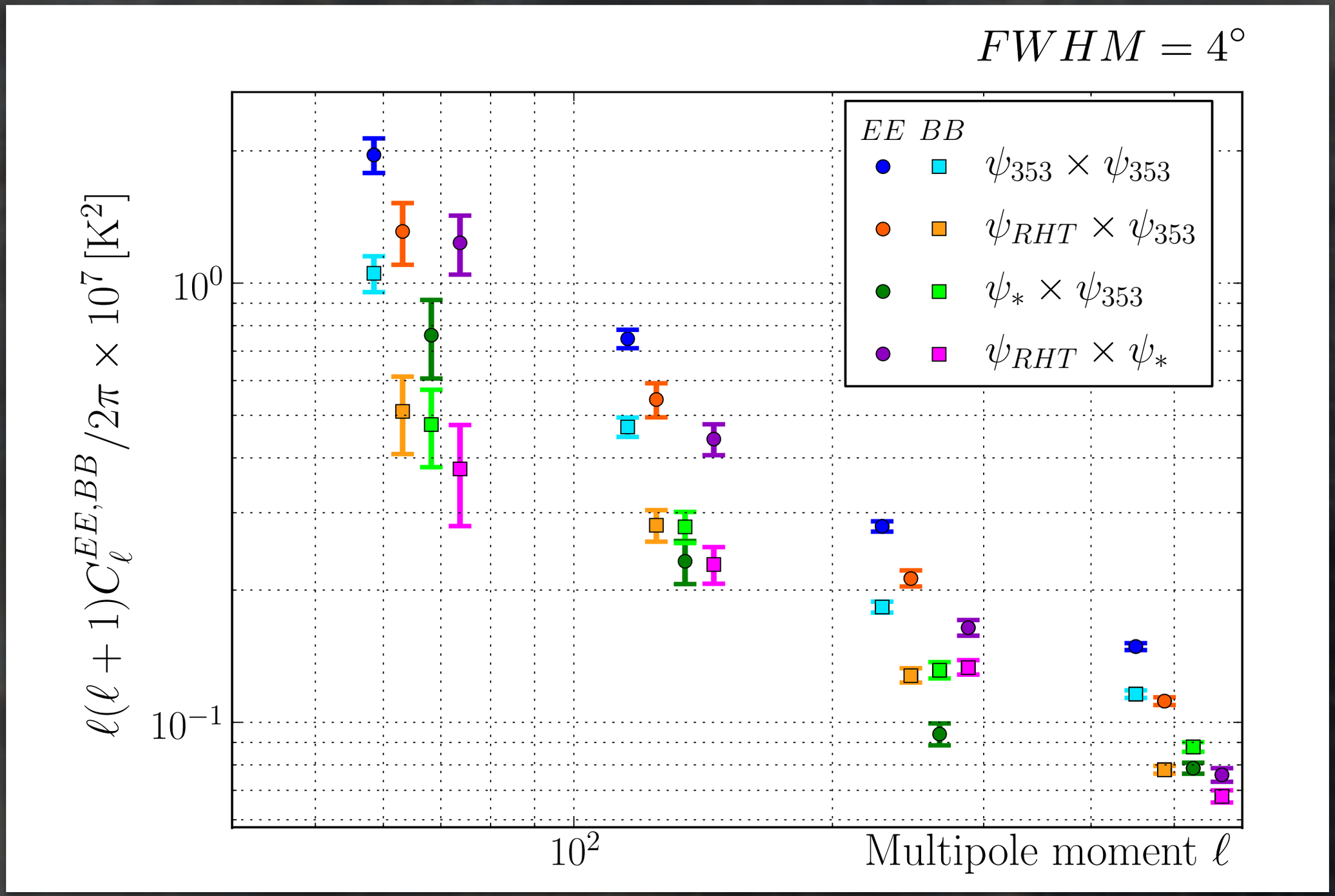
We study the E/B decomposition of template maps derived from HI orientation.

$$Q' = I_{353} \cdot \cos(2\theta)$$

$$U' = I_{353} \cdot \sin(2\theta)$$

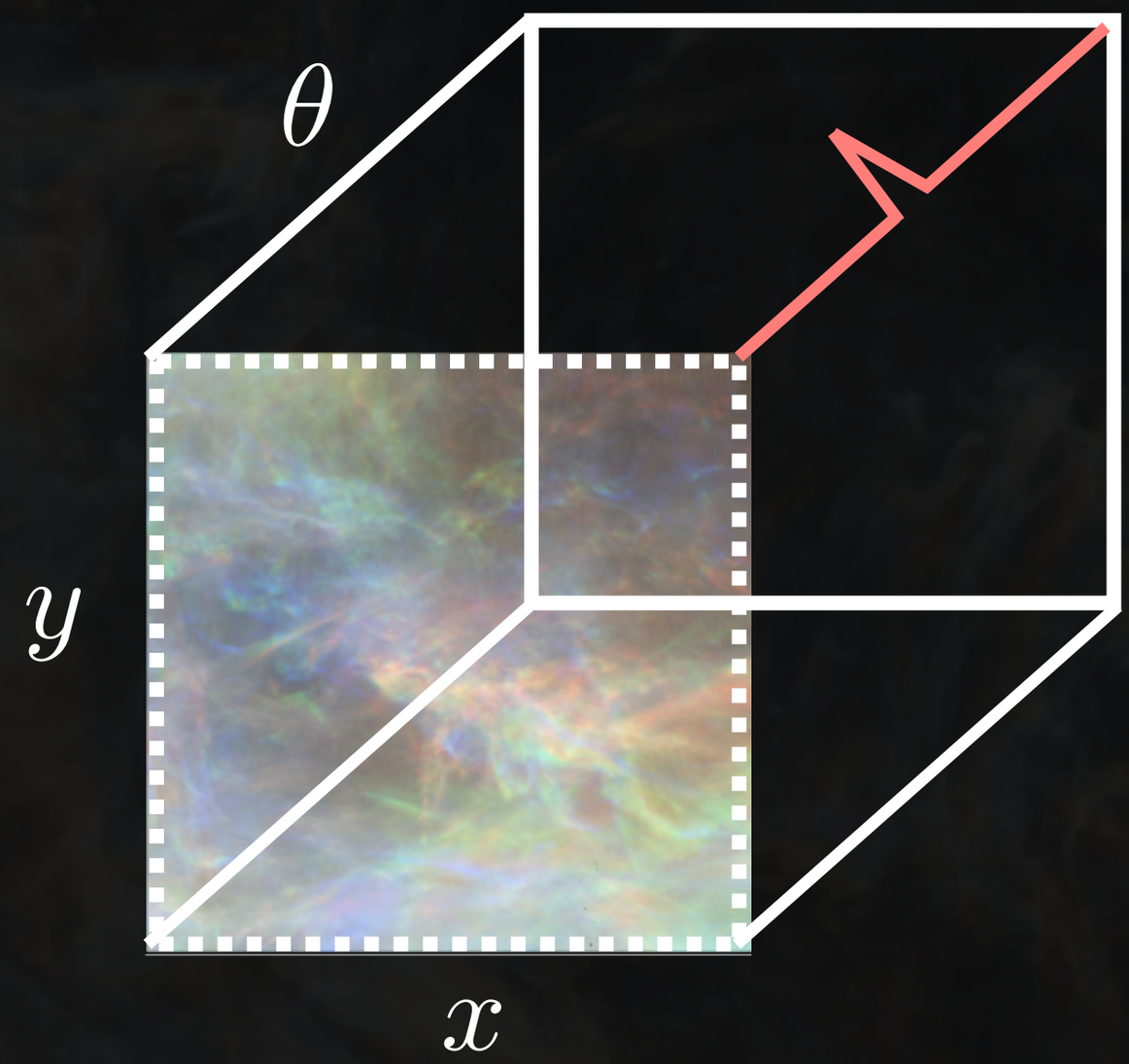
θ_{RHT} θ_{353} $\theta_\star$

We detect strong cross-correlations between RHT, 353 GHz, and starlight polarization angles.

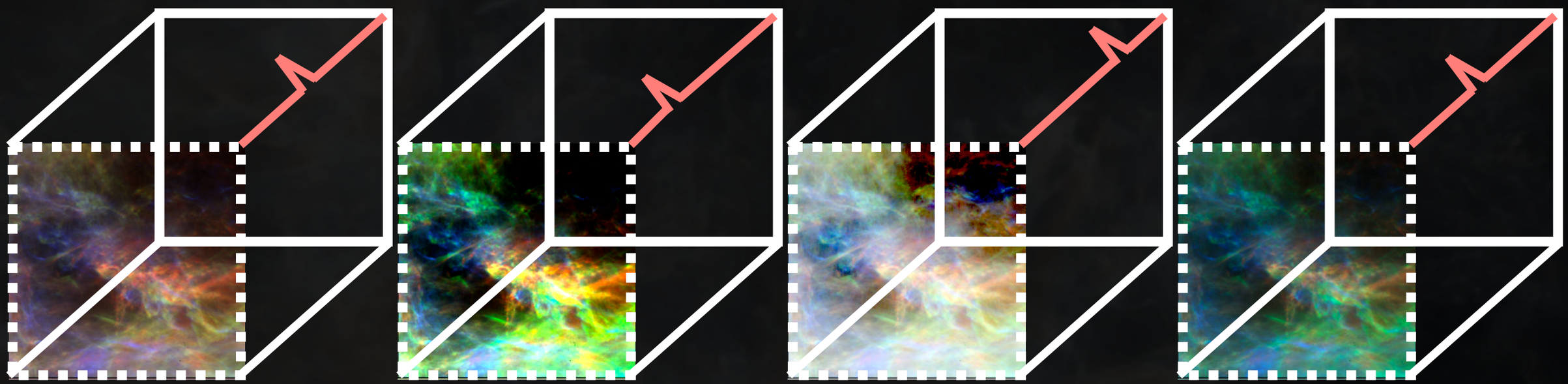


EE/BB asymmetry:
Planck Intermediate Results XXX, XXXVIII

Clark+ 2015, PRL


θ
y
x

What can we learn about the magnetized ISM from the velocity structure of HI linearity?



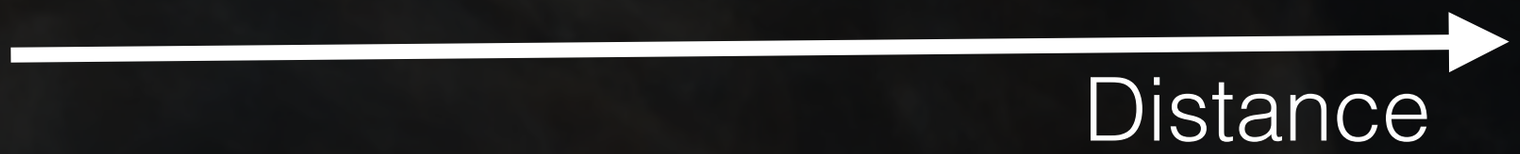
fourth dimension: velocity

Can we learn about the LOS magnetic field?

Polarized dust emission region

higher fractional polarization

lower fractional polarization

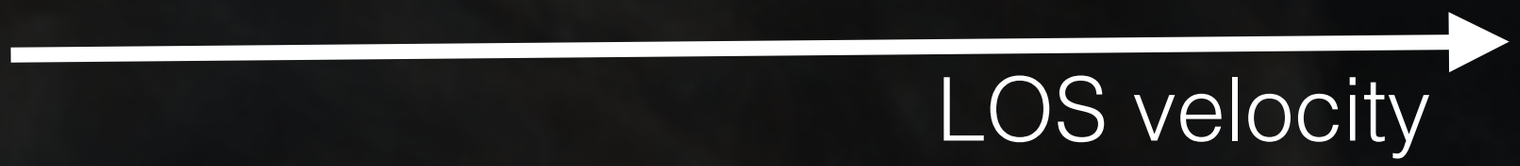


Can we learn about the LOS magnetic field?

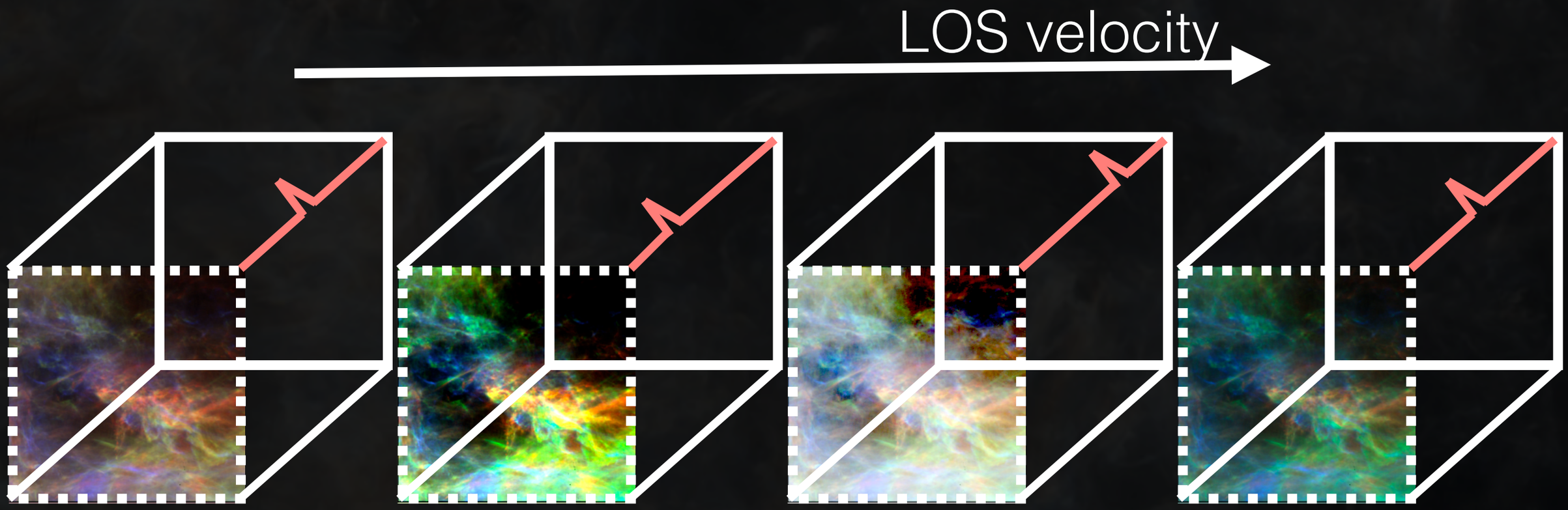
HI velocity channel

higher fractional polarization

lower fractional polarization



Can we learn about the LOS magnetic field?



1

$$Q_v = I_v \cos(2\theta_{RHT})$$
$$U_v = I_v \sin(2\theta_{RHT})$$

2

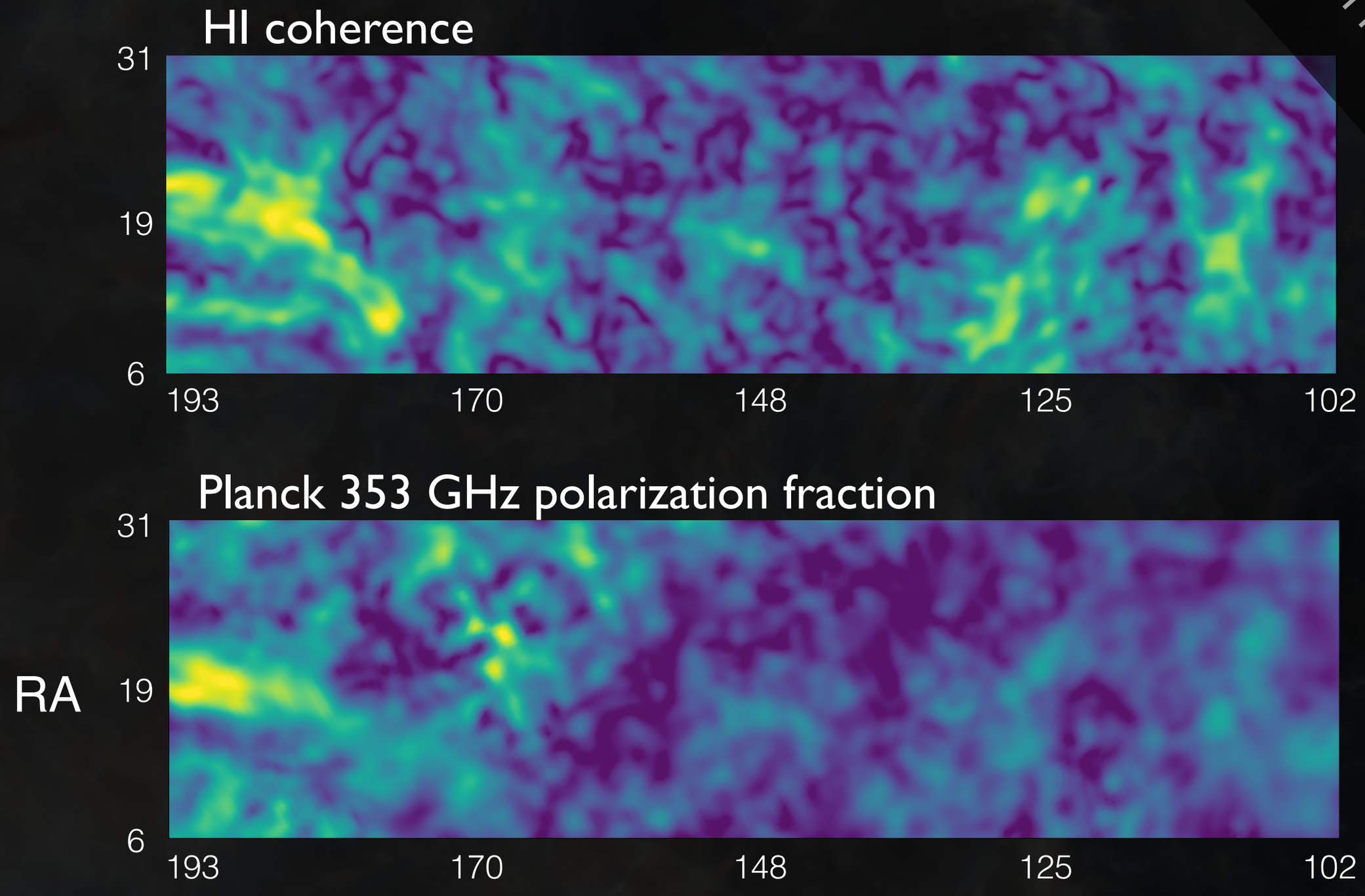
$$Q_{HI} = \int Q_v dv$$

3

$$p_{HI} = \frac{\sqrt{Q_{HI}^2 + U_{HI}^2}}{I_{HI}}$$

The dispersion of HI orientation traces LOS depolarization.

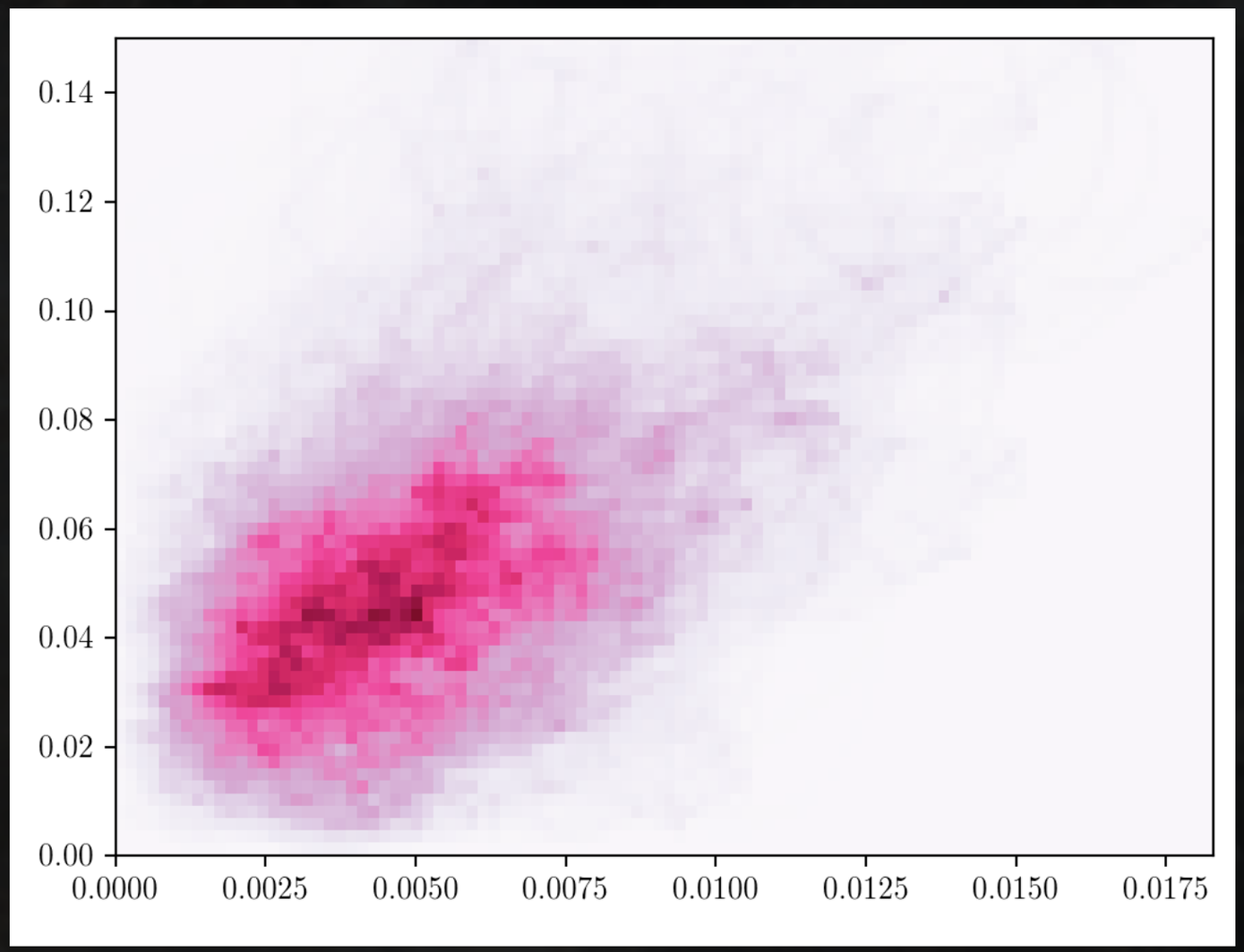
preliminary



Clark 2017, in prep

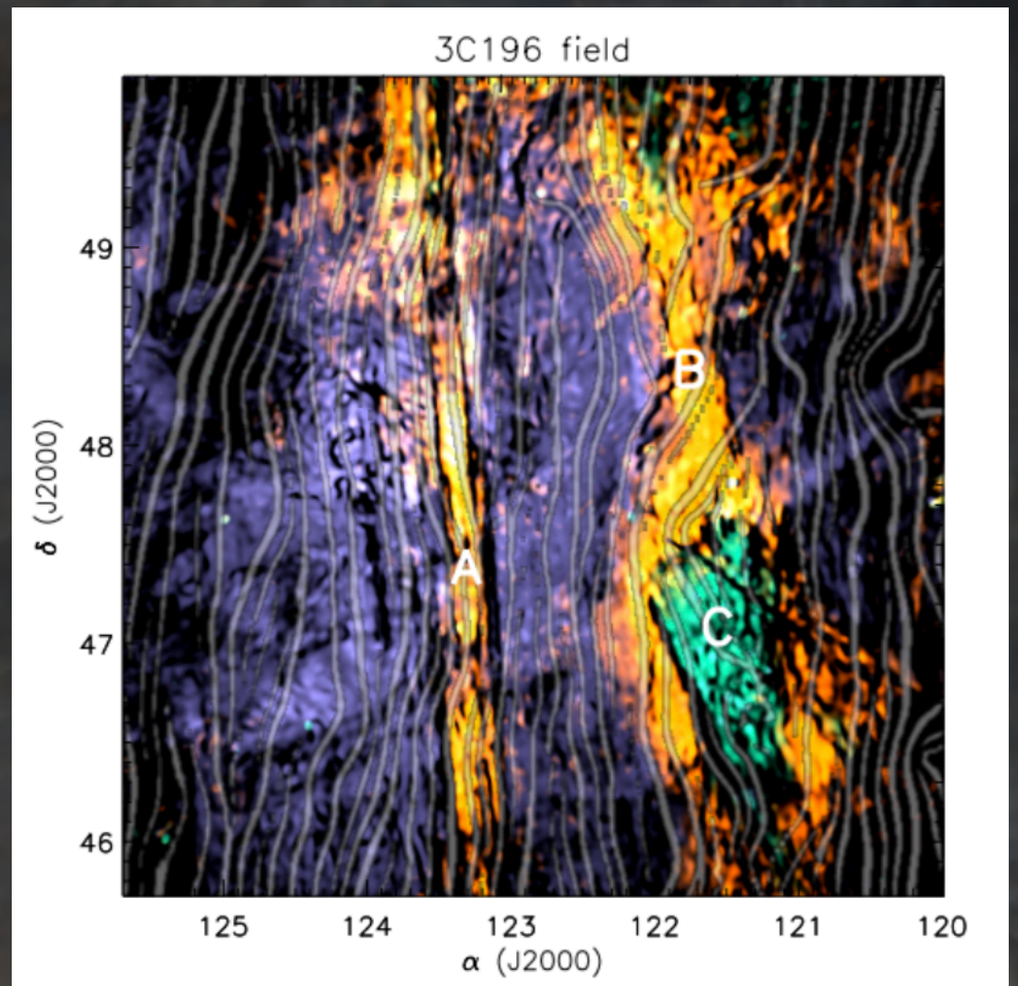
The dispersion of HI orientation traces LOS depolarization.

preliminary

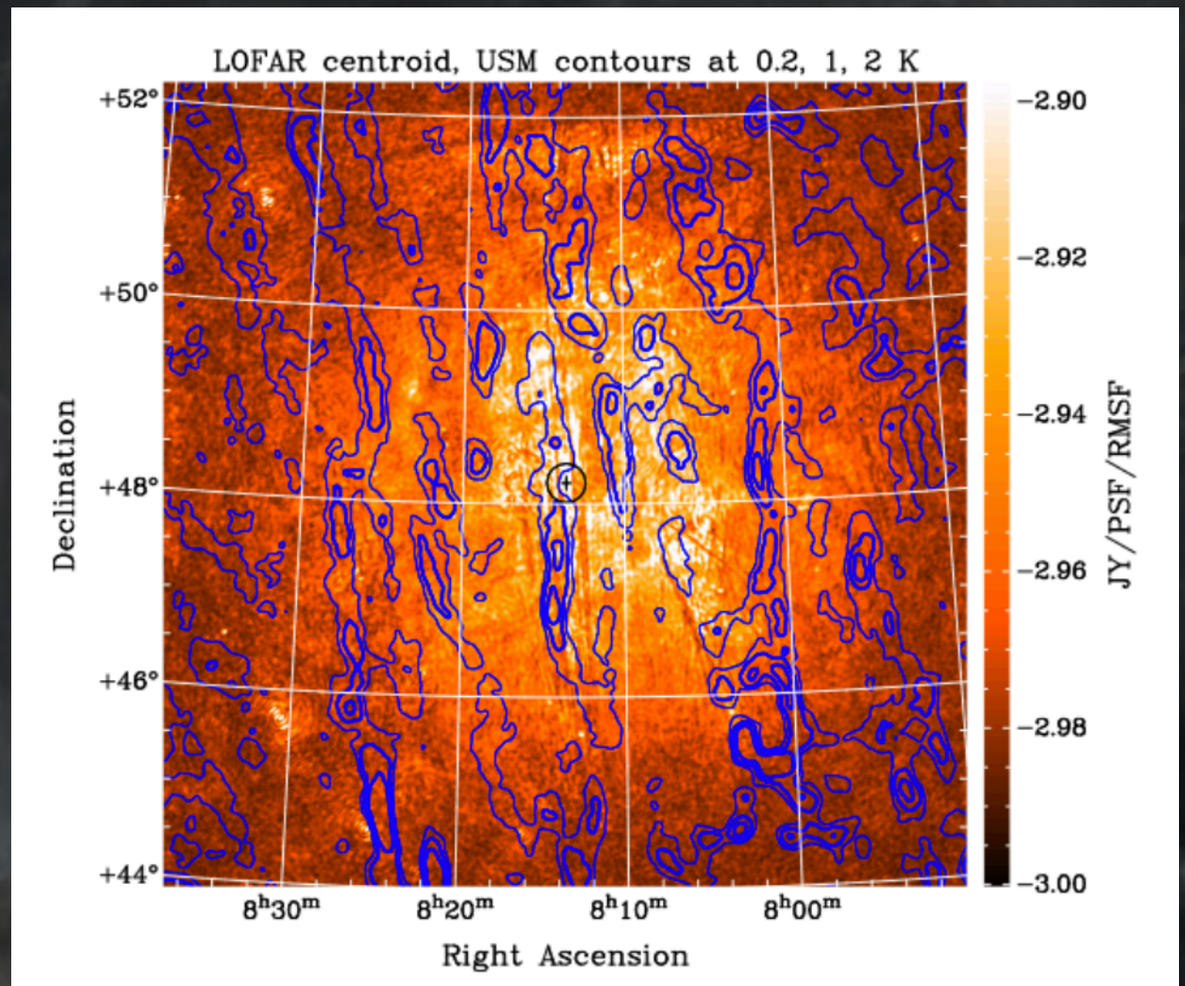


Clark 2017, in prep

Multiwavelength explorations will reveal the nature of the magnetic ISM.



Zaroubi+ 2015
Jelić+ 2015

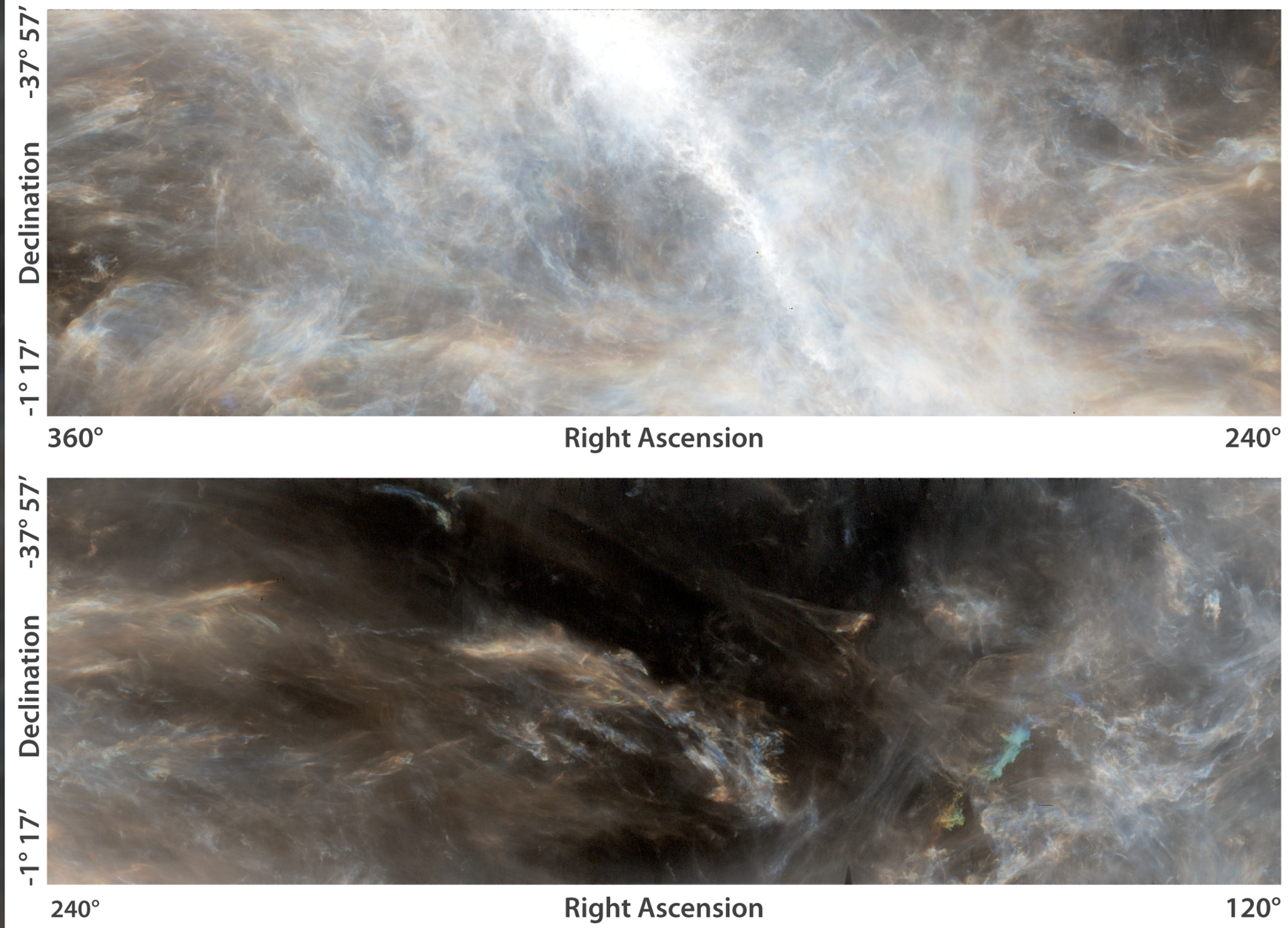


Kerp & Kalberla 2016
Kalberla+ 2017

GALFA-HI DR2

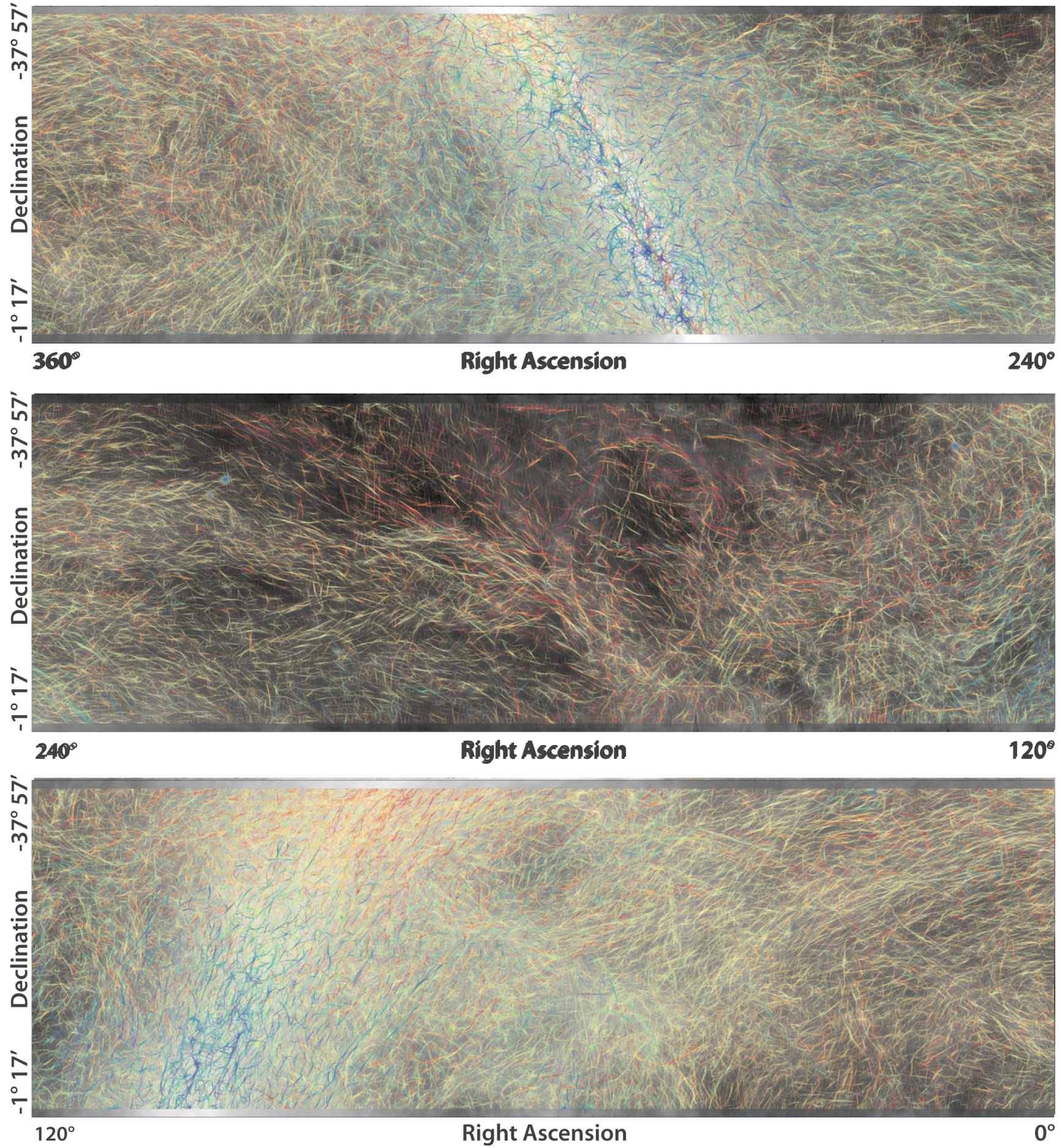
+PPV data
+HI column density
+RHT maps

Peek+ in press



GALFA-HI DR2

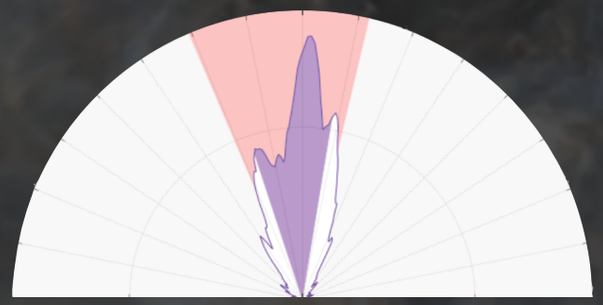
+PPV data
+HI column density
+RHT maps



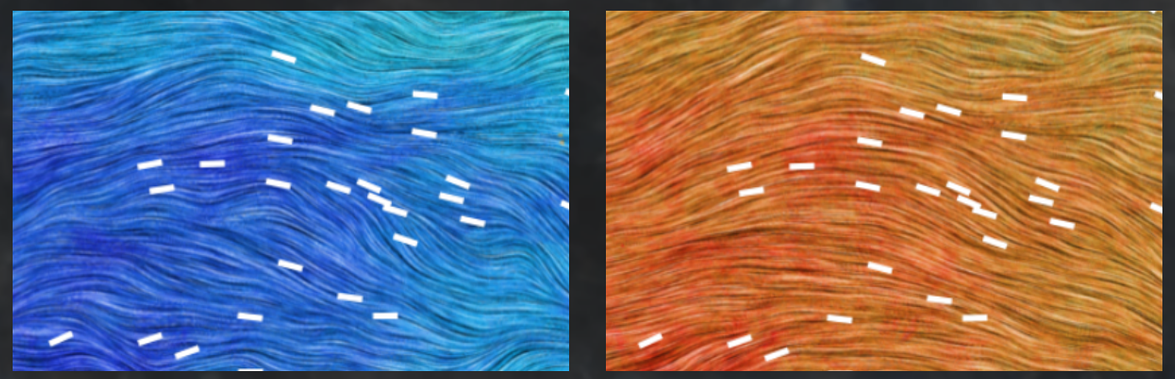
Peek+ in press

Neutral hydrogen in the diffuse ISM is aligned with the interstellar magnetic field.

Clark+ 2014, ApJ



Clark+ 2015, PRL



The velocity structure of HI morphology probes line-of-sight magnetic field tangling. Clark 2017, in prep