

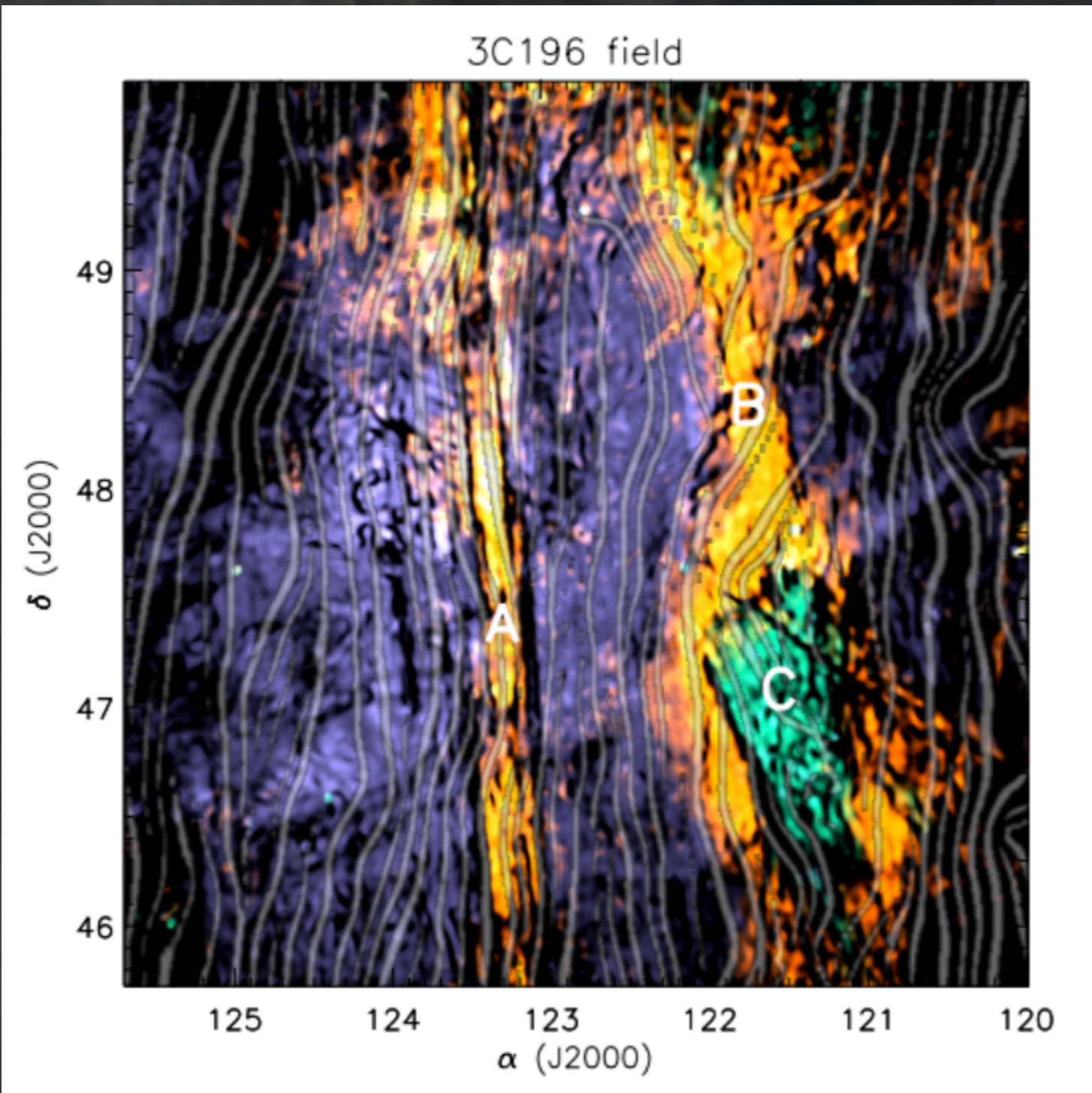
Galactic HI and the magnetic ISM *foreground*

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

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

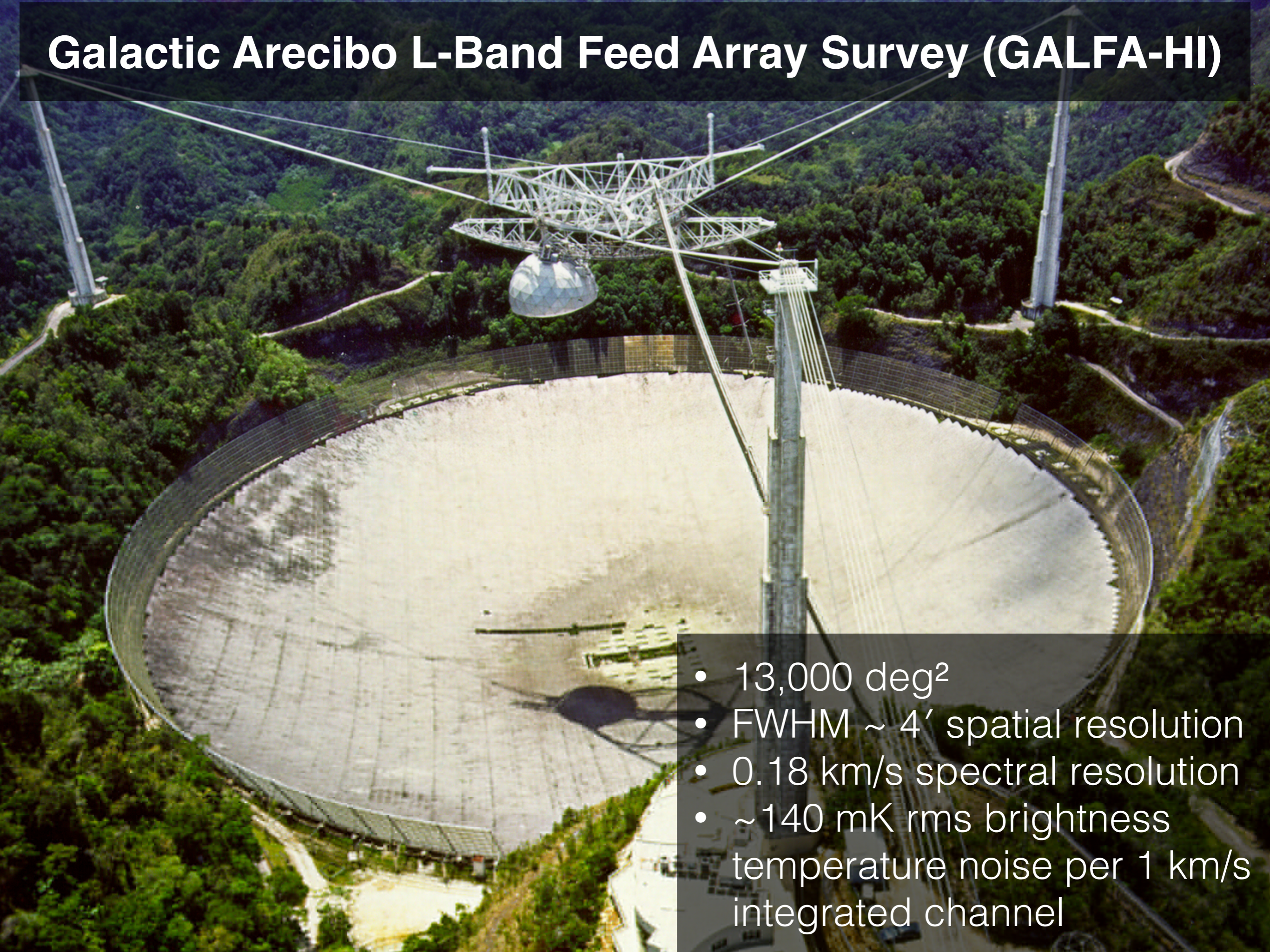
Low frequency observations show complicated polarization structure.

Zaroubi+ 2015
Jelić+ 2015



-3 to -0.5 rad / m²
+0.5 rad / m²
+1 to +4.5 rad / m²
Planck B-field

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



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



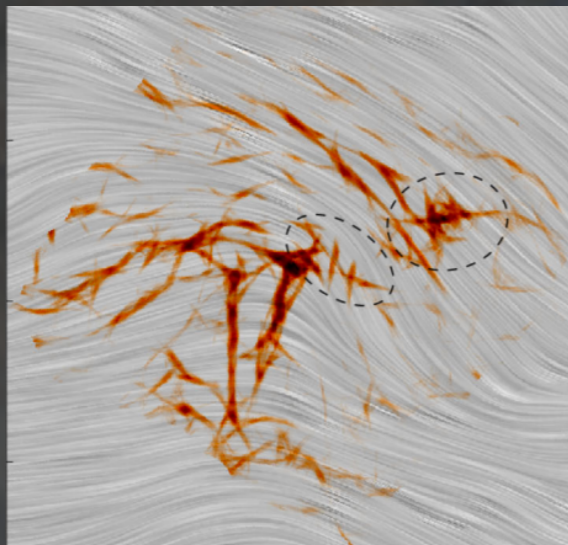
**Do linear HI structures trace
the magnetic field?**

The Rolling Hough Transform

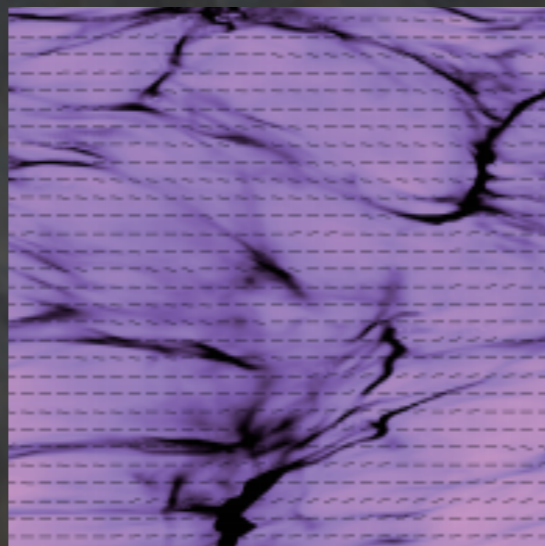
Clark, Peek, & Putman 2014, ApJ 789, 82



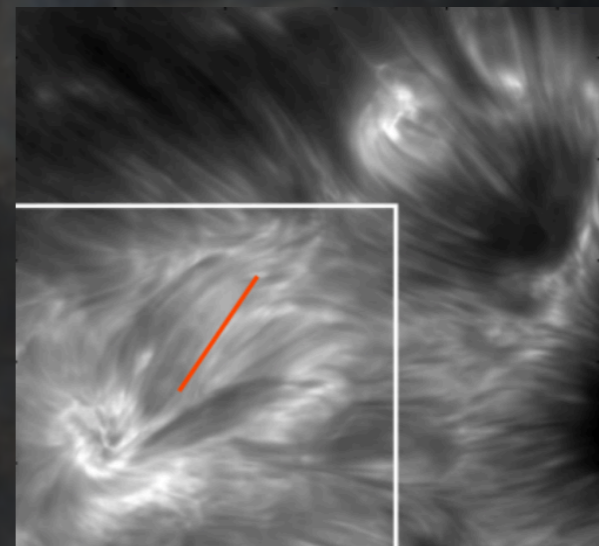
github.com/seclark/RHT



Malinen+ 2016



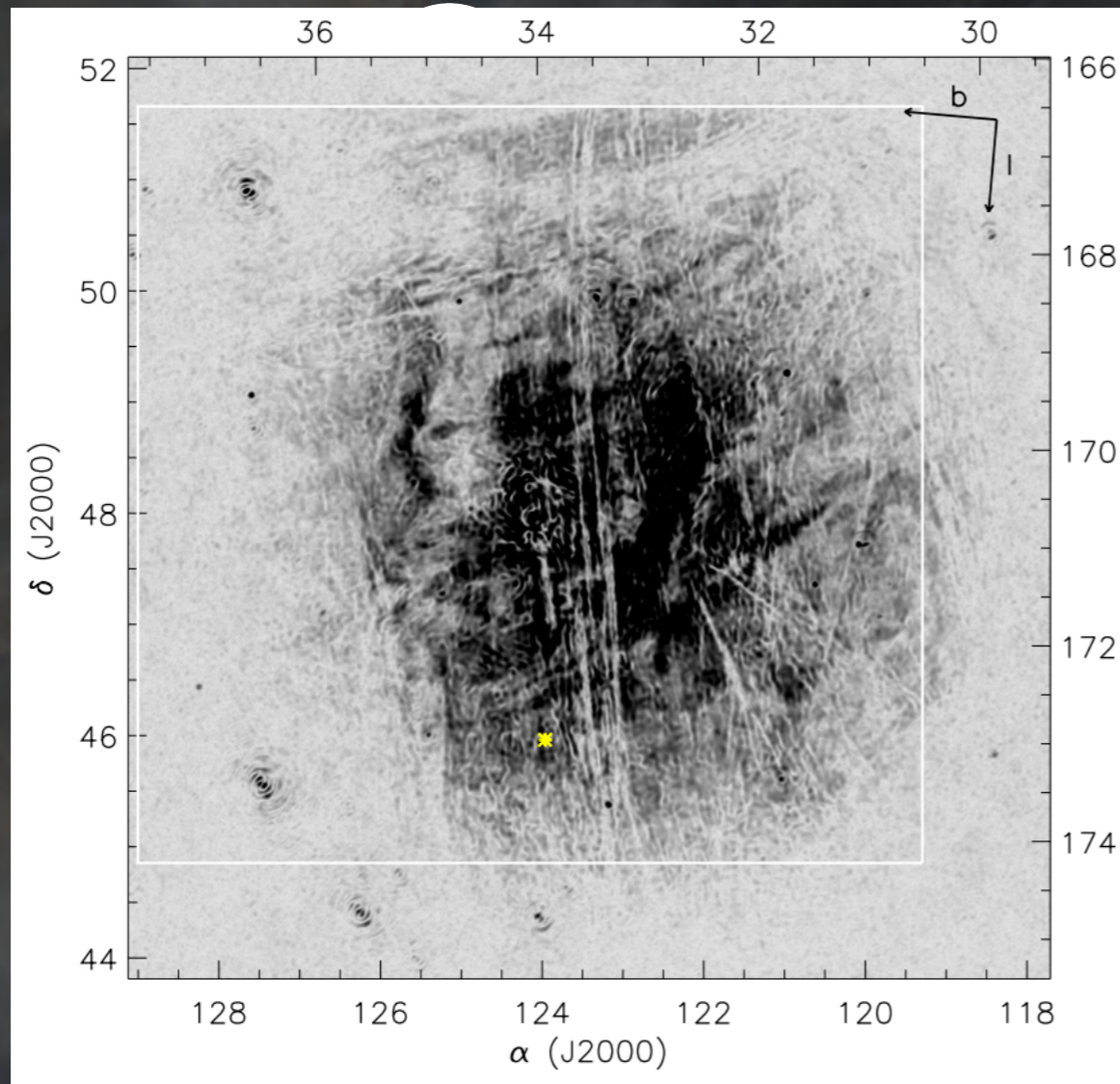
**Inoue & Inutsuka
2016**



Asensio Ramos+ 2017

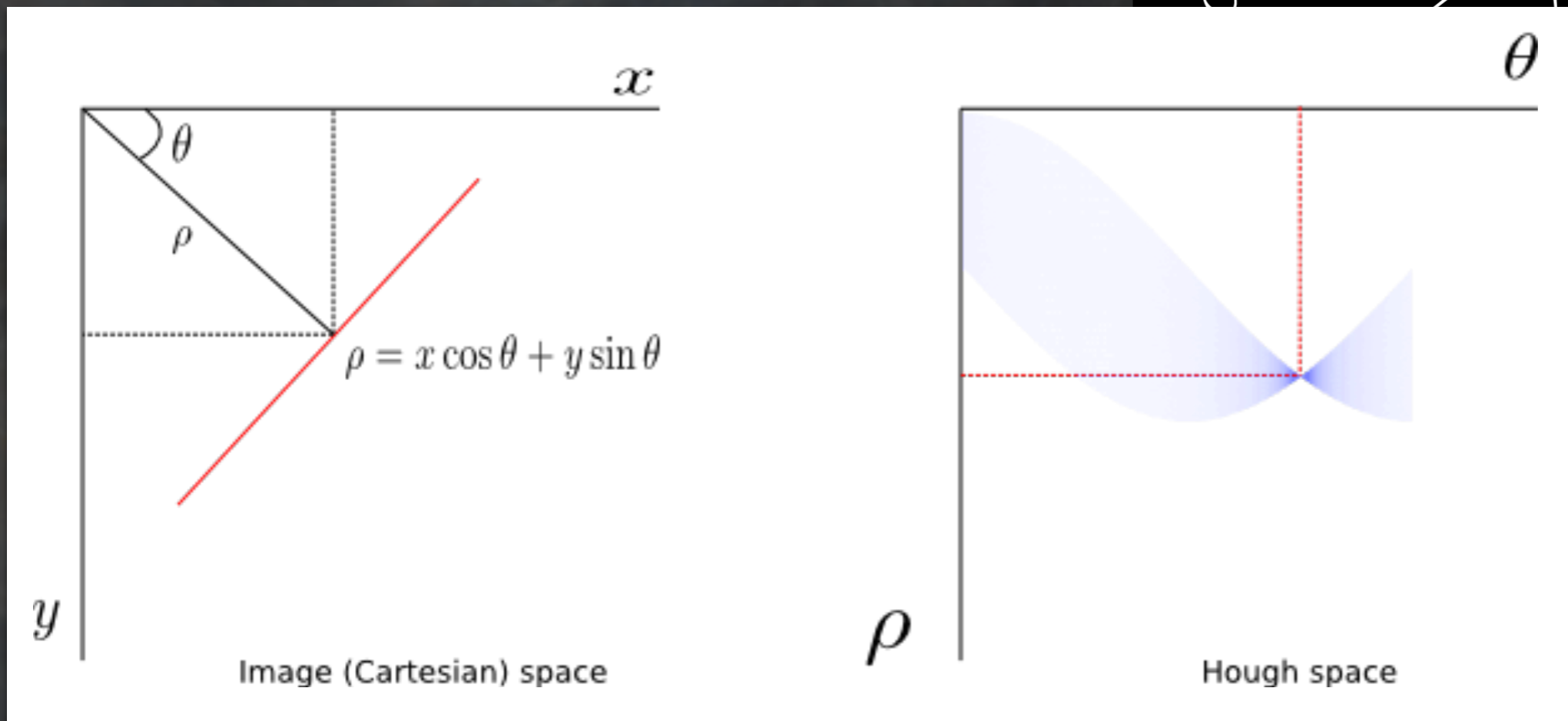
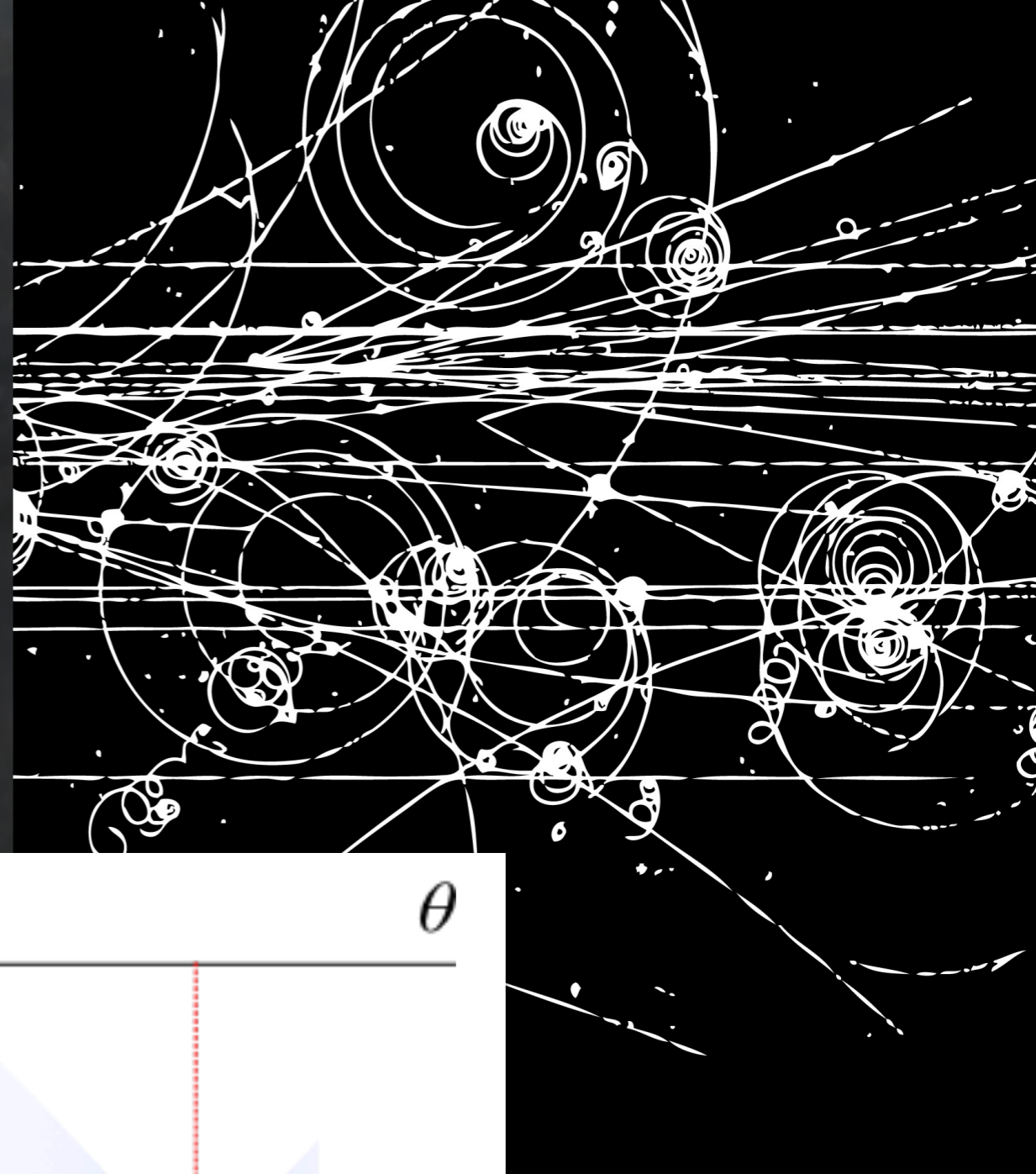
The Rolling Hough Transform

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

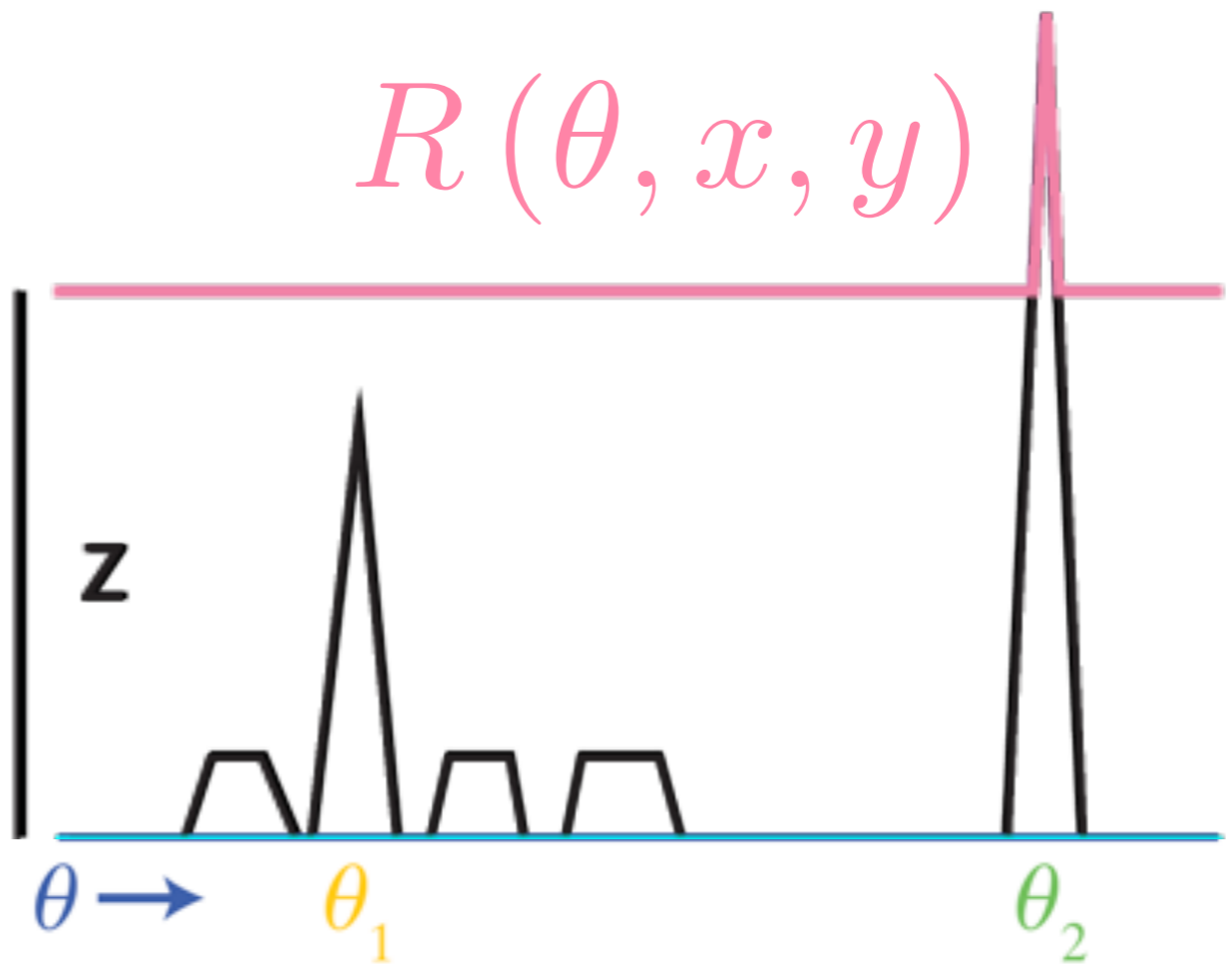
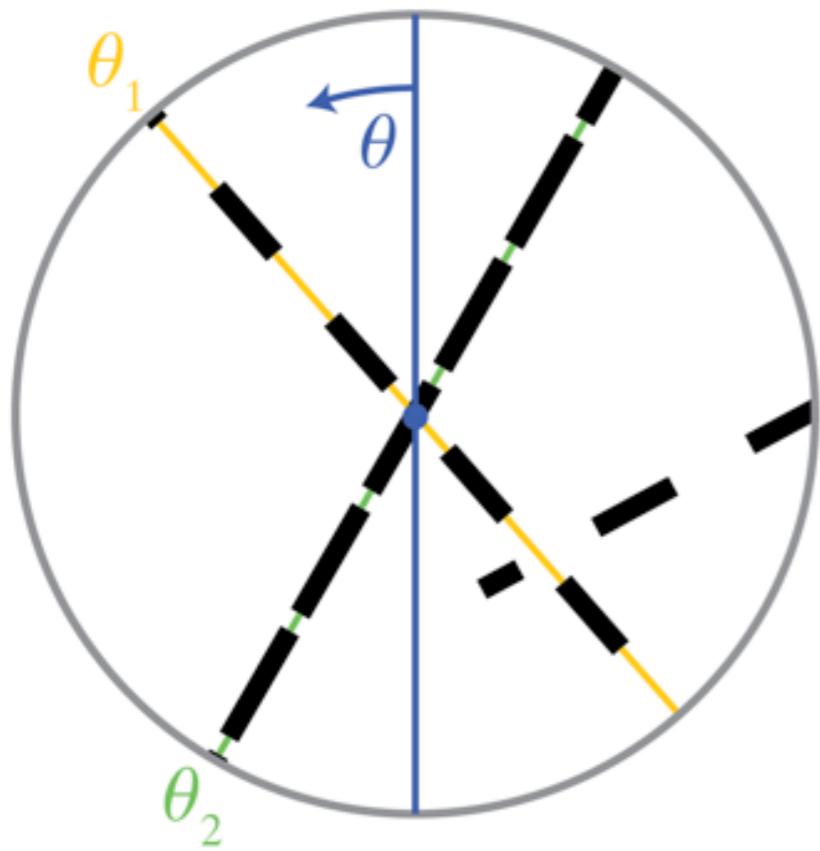


See poster by
David Prelogović,
Dora Klindžić,
Vibor Jelić

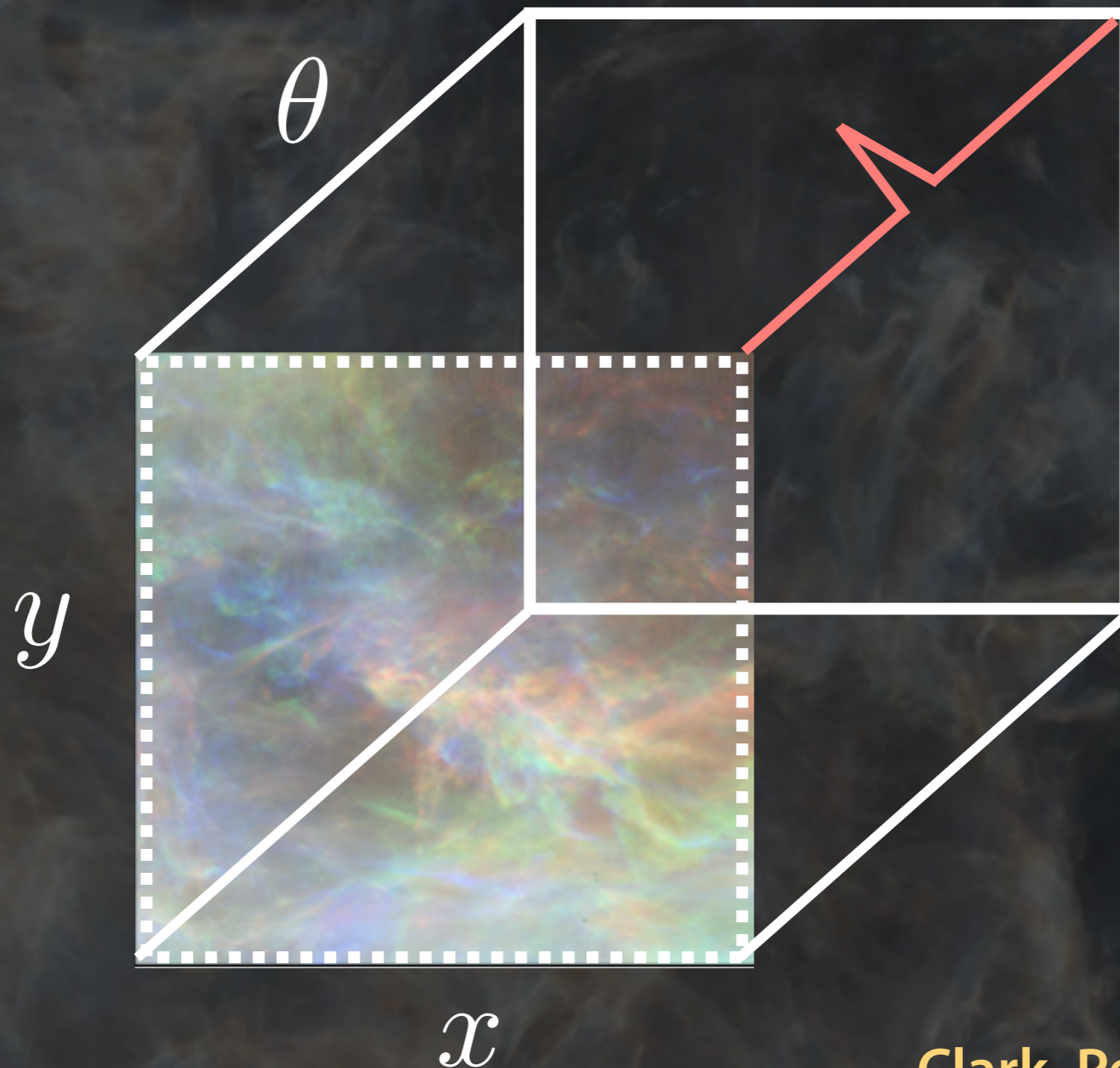
The Hough Transform was originally conceived to detect lines in bubble chamber photos.



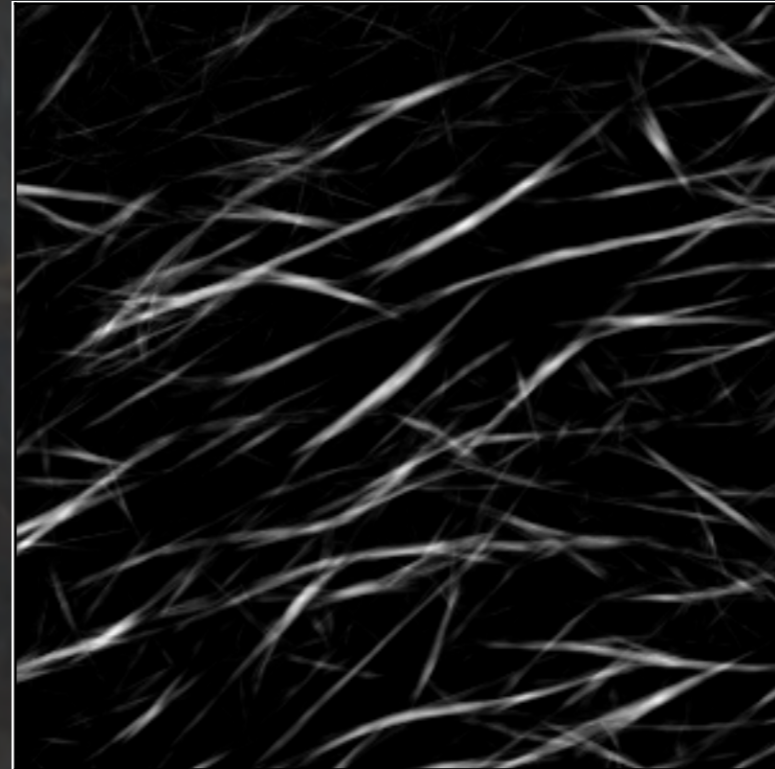
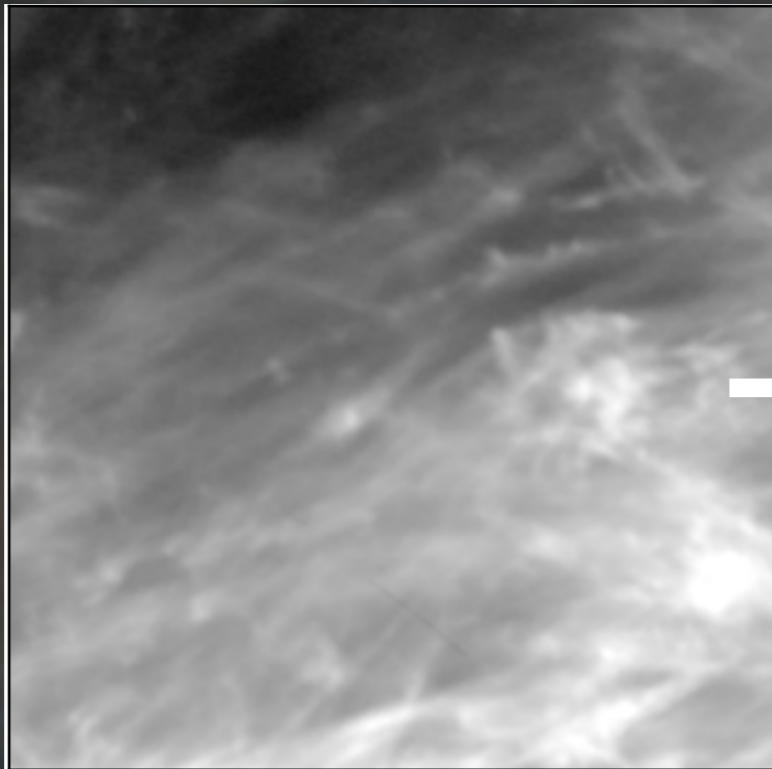
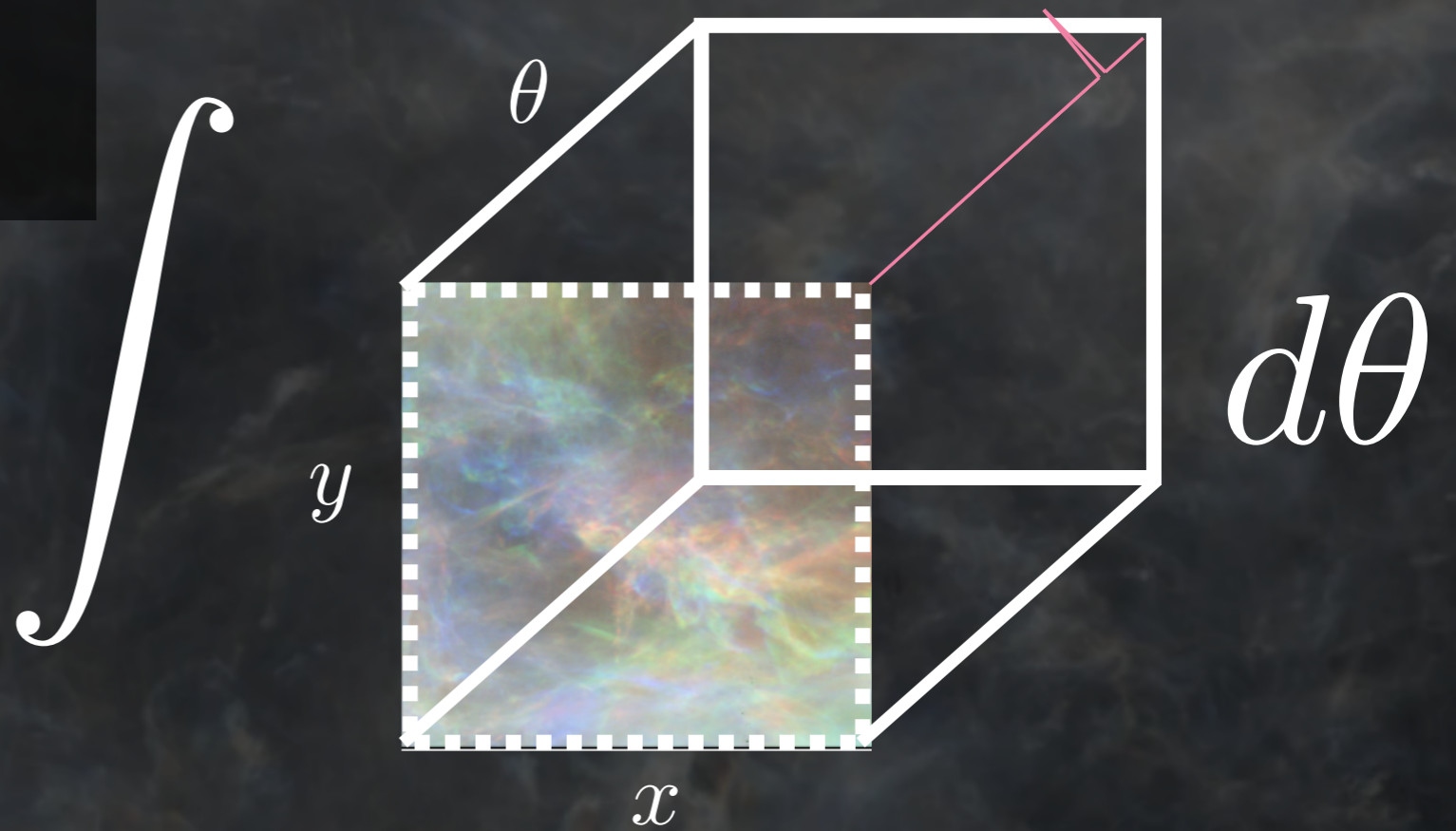
Measure intensity as a function of angle.



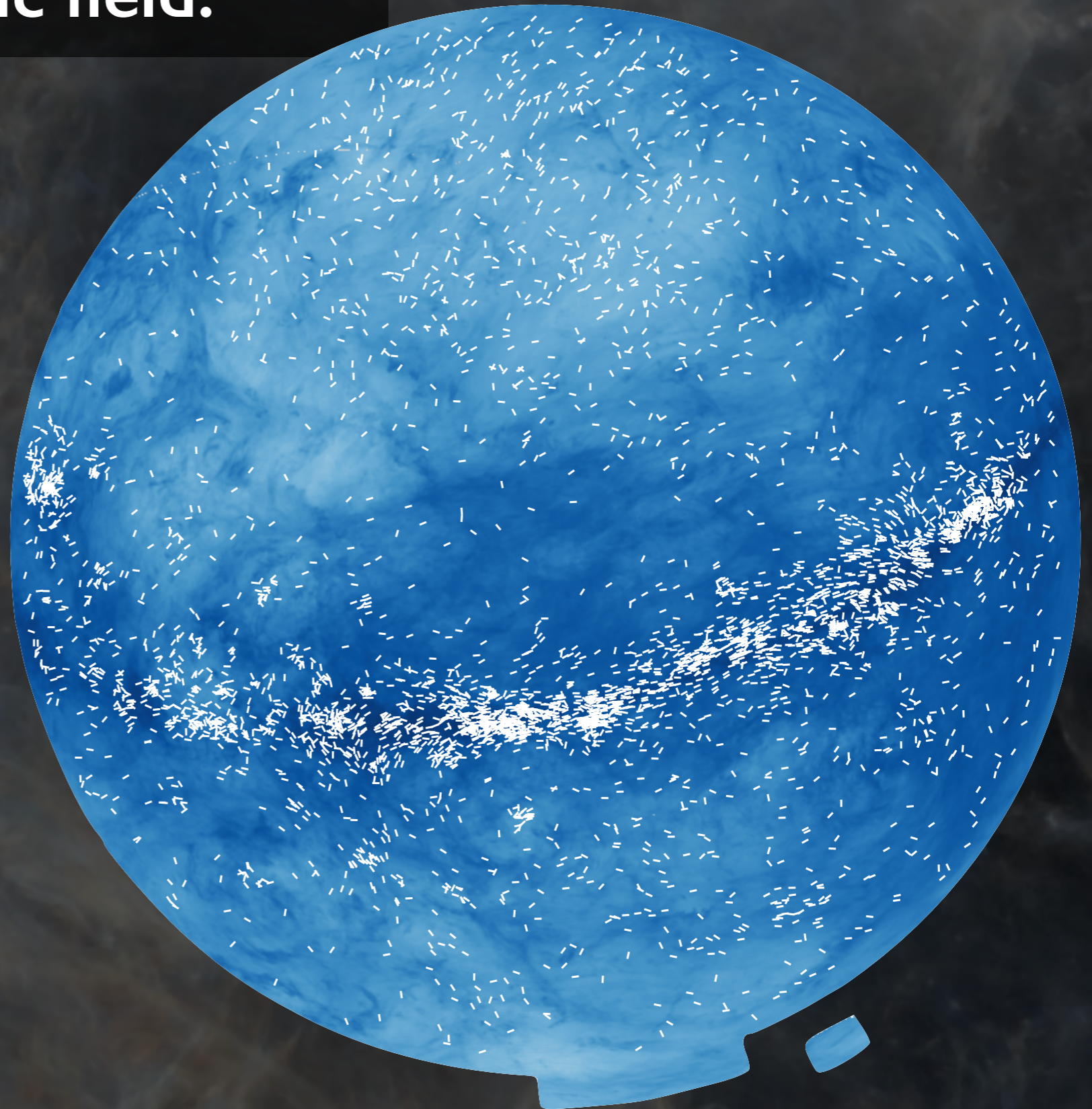
Store intensity as a function of angle
for every image pixel.



Visualize linear power
in the backprojection.



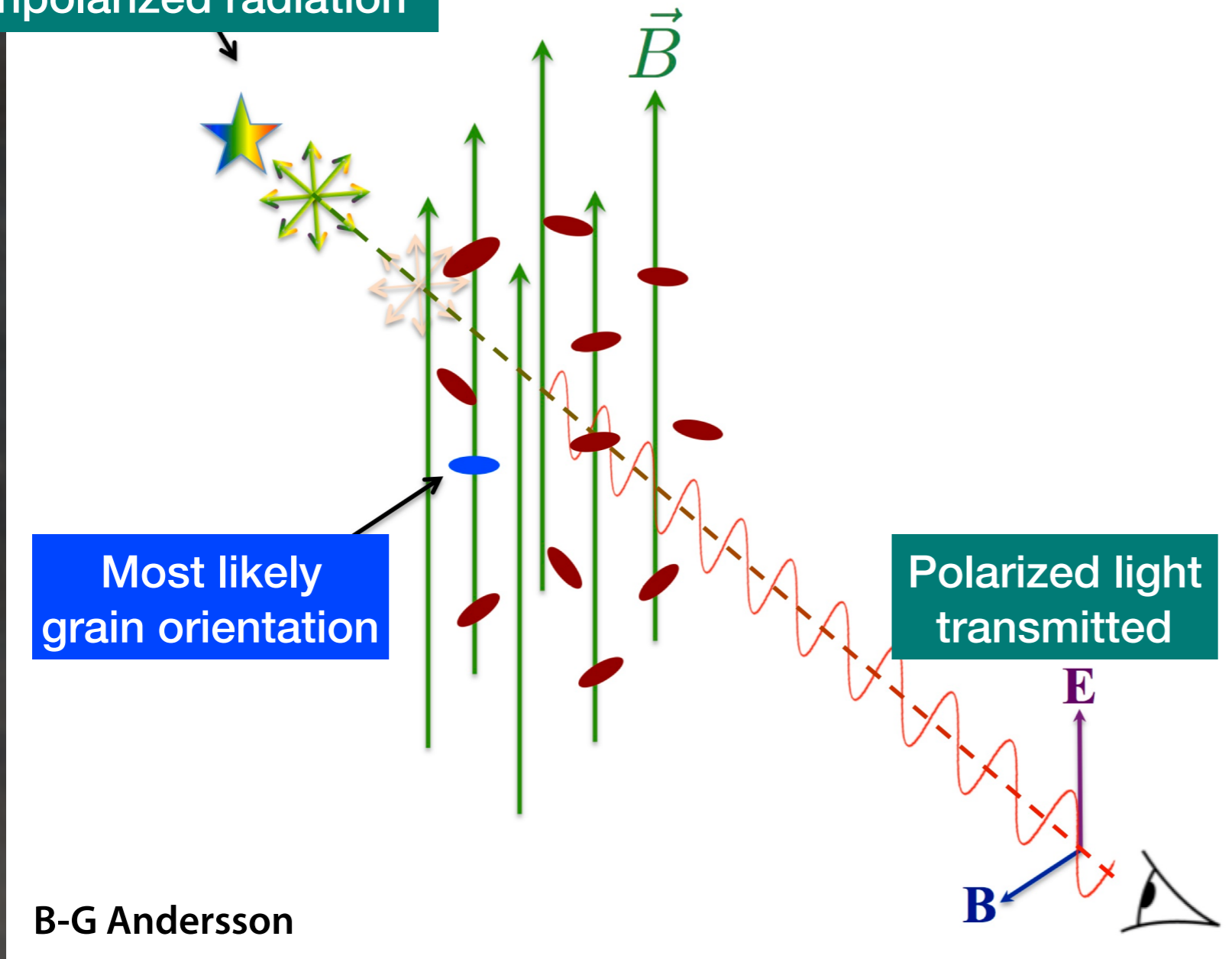
**Starlight polarization traces the
plane-of-sky magnetic field.**



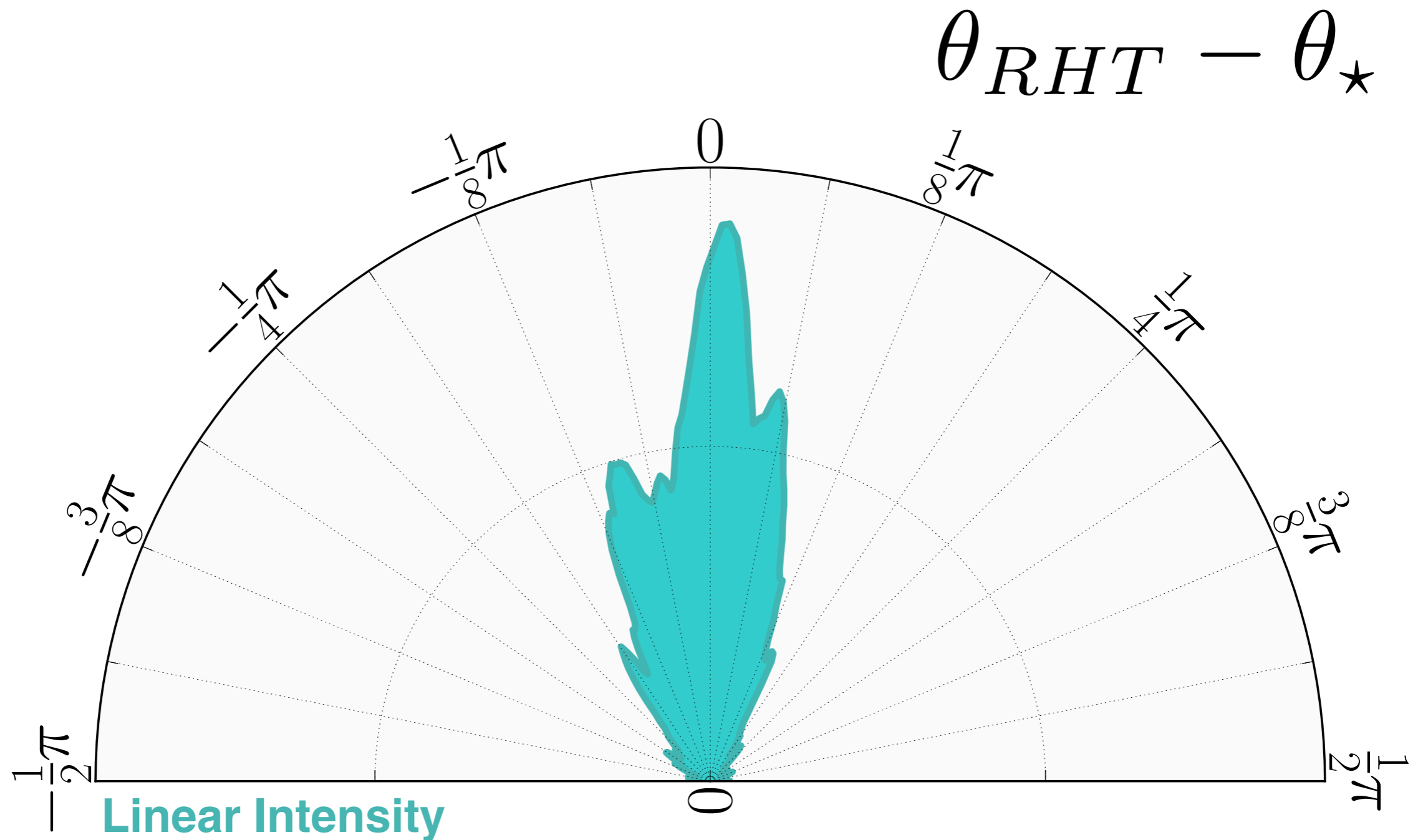
Stars: Heiles 2000

Starlight polarization traces the plane-of-sky magnetic field.

Background star emits unpolarized radiation

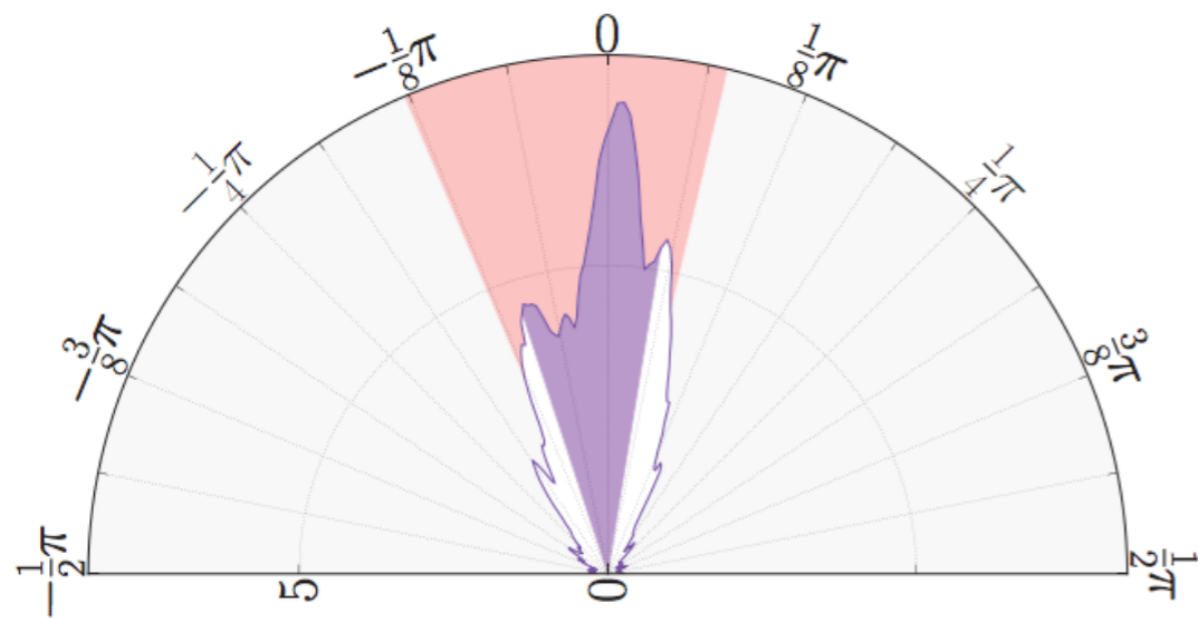


Linear features in HI correlate with starlight polarization.

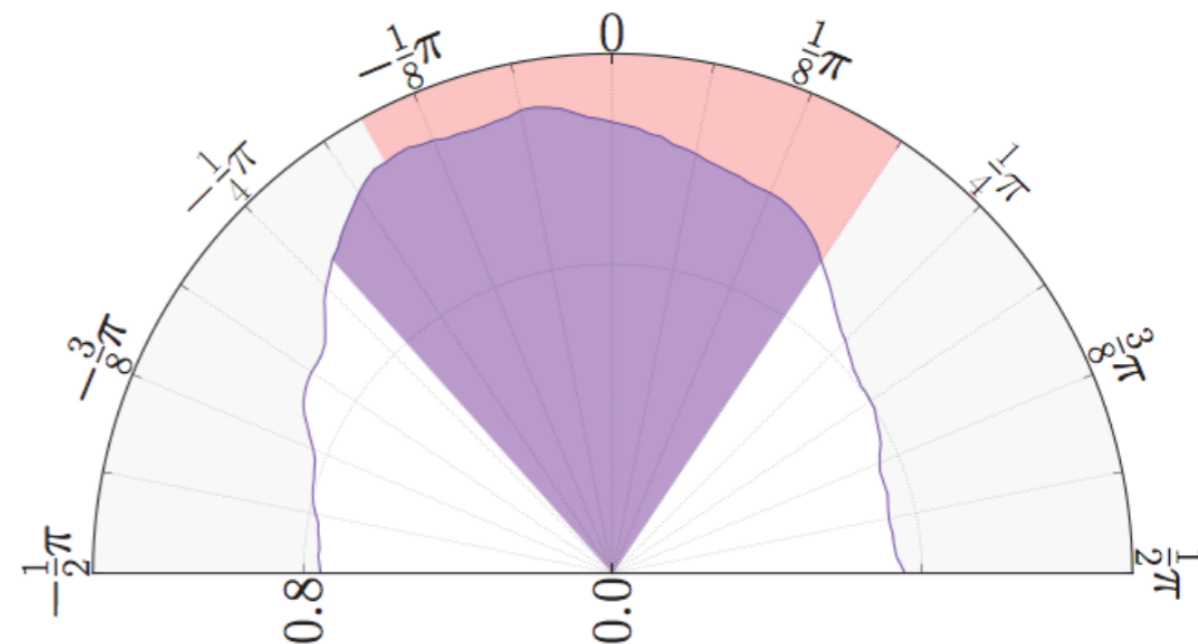


The correlation is tighter with high-resolution HI.

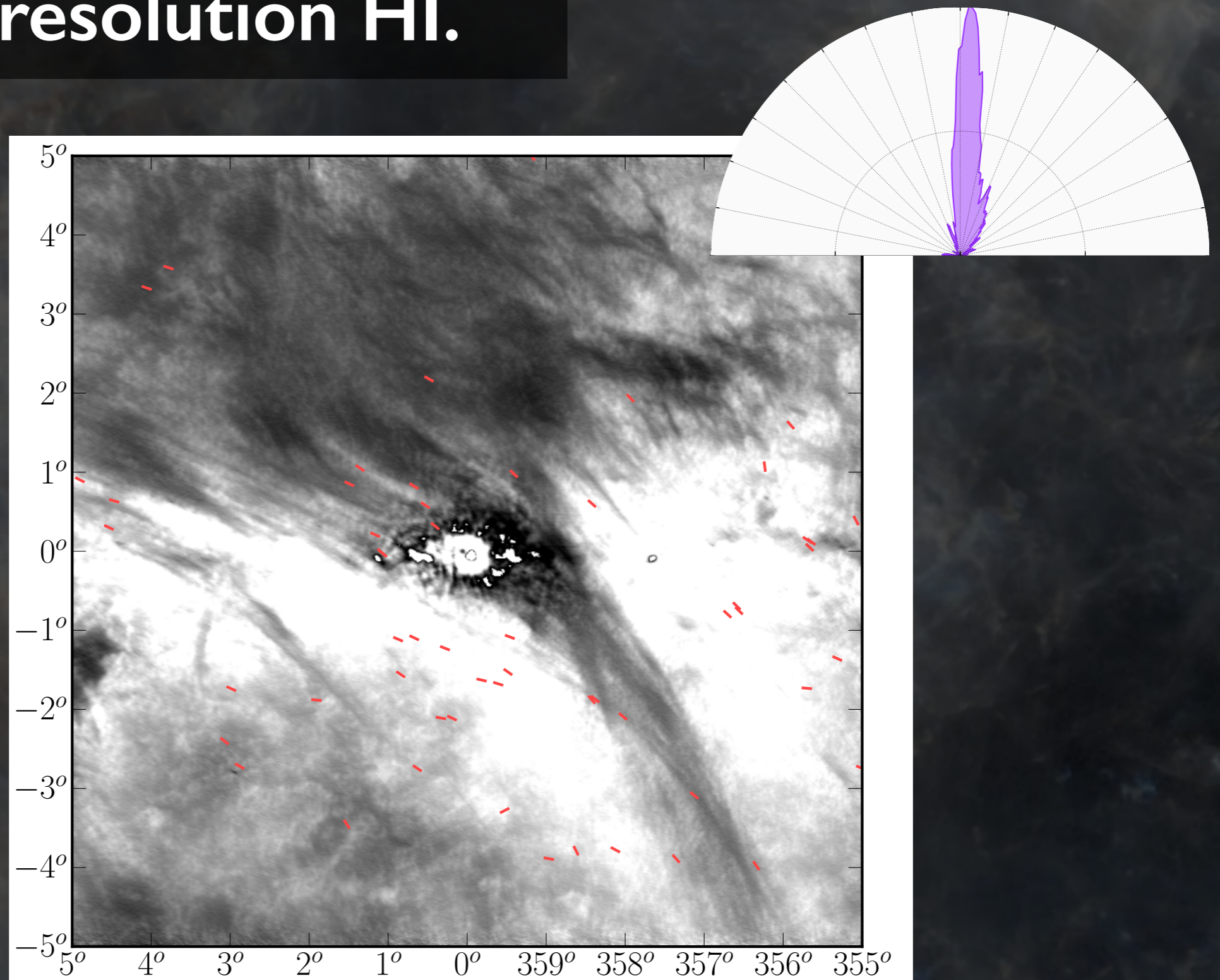
GALFA-HI : 4'



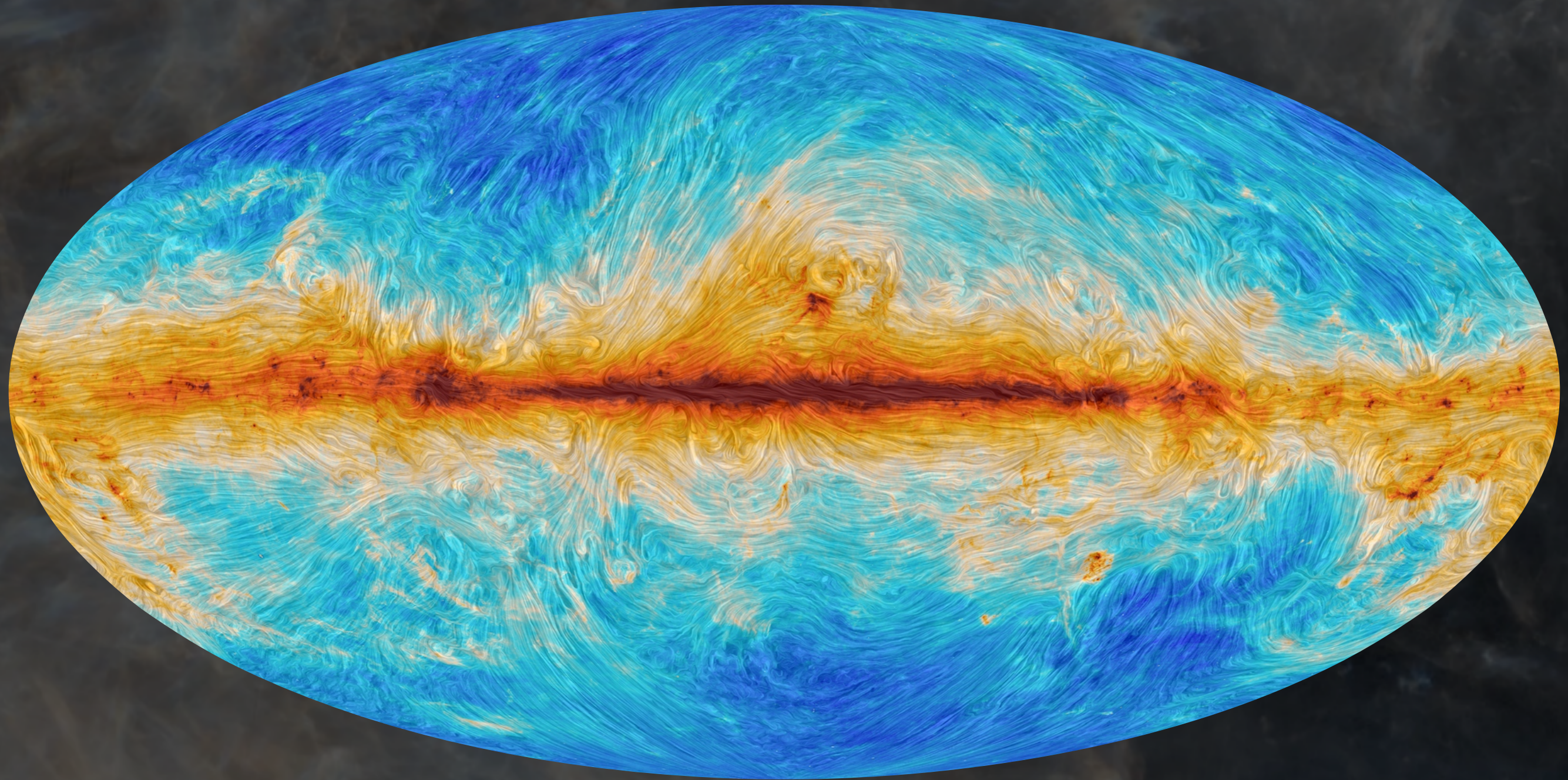
Parkes GASS : 16'



The correlation is tighter
with high-resolution HI.



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.

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

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



Calculate HI and *Planck* magnetic field orientation.

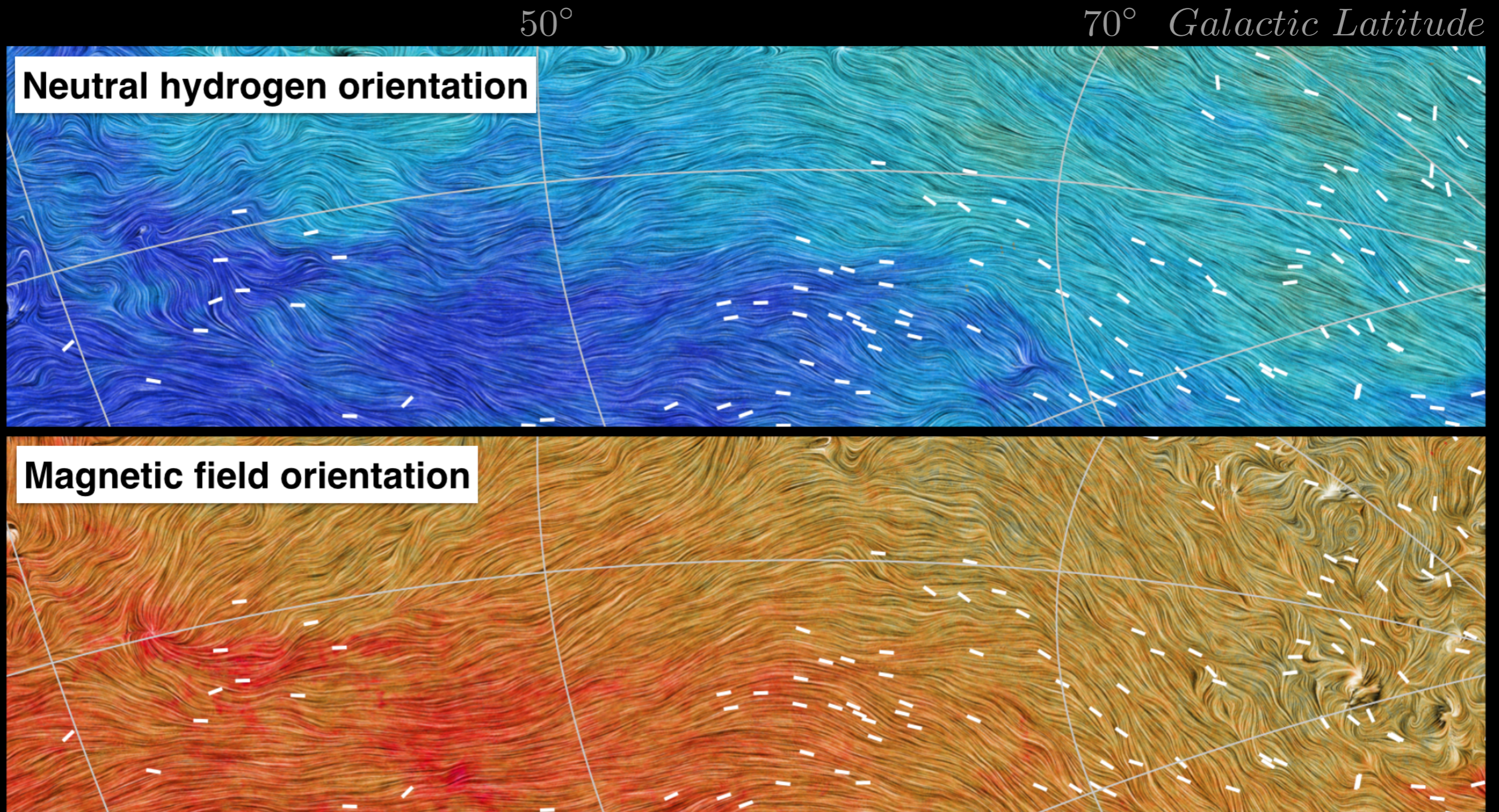
Neutral hydrogen orientation

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

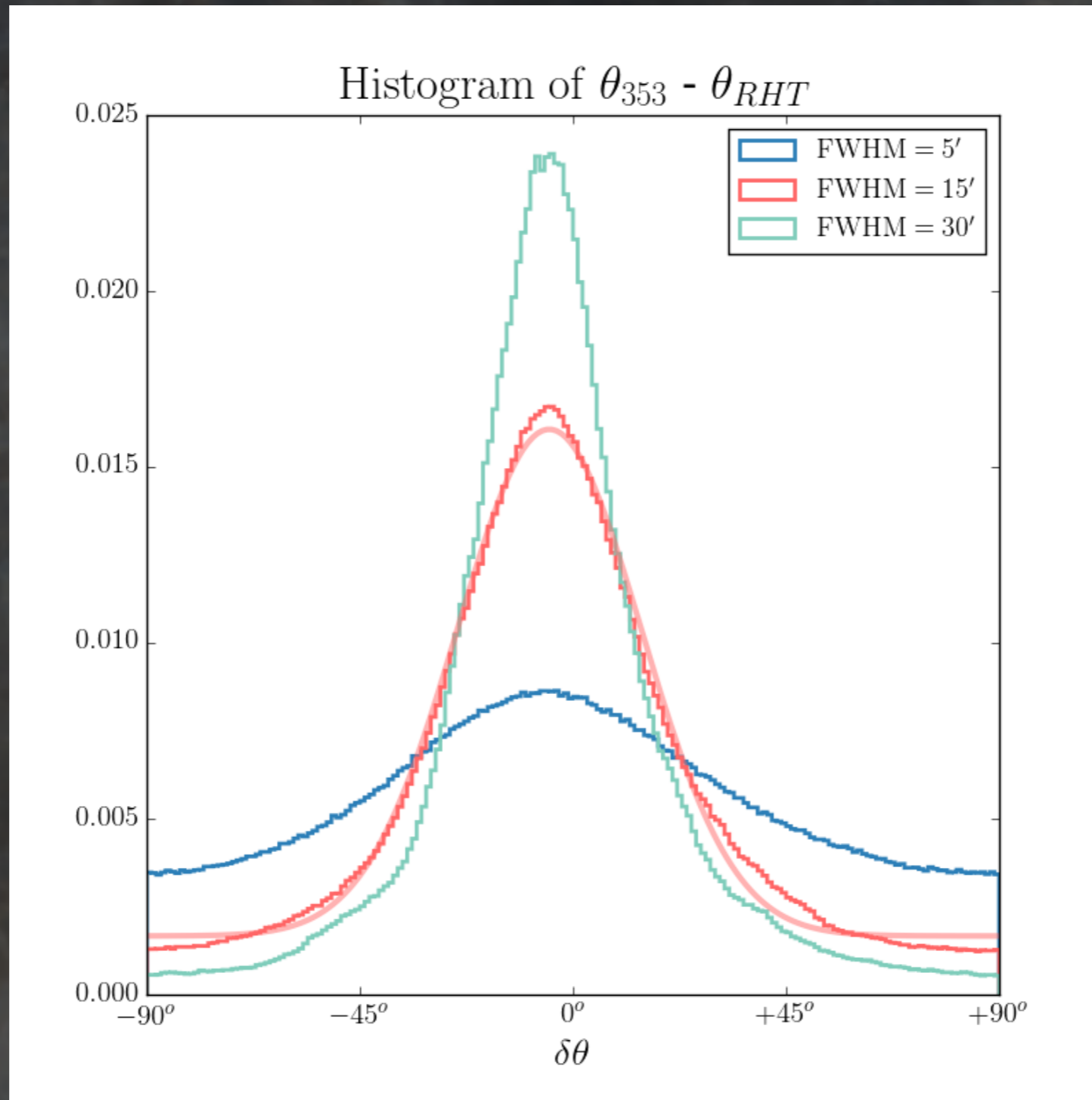
Planck magnetic field orientation

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

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

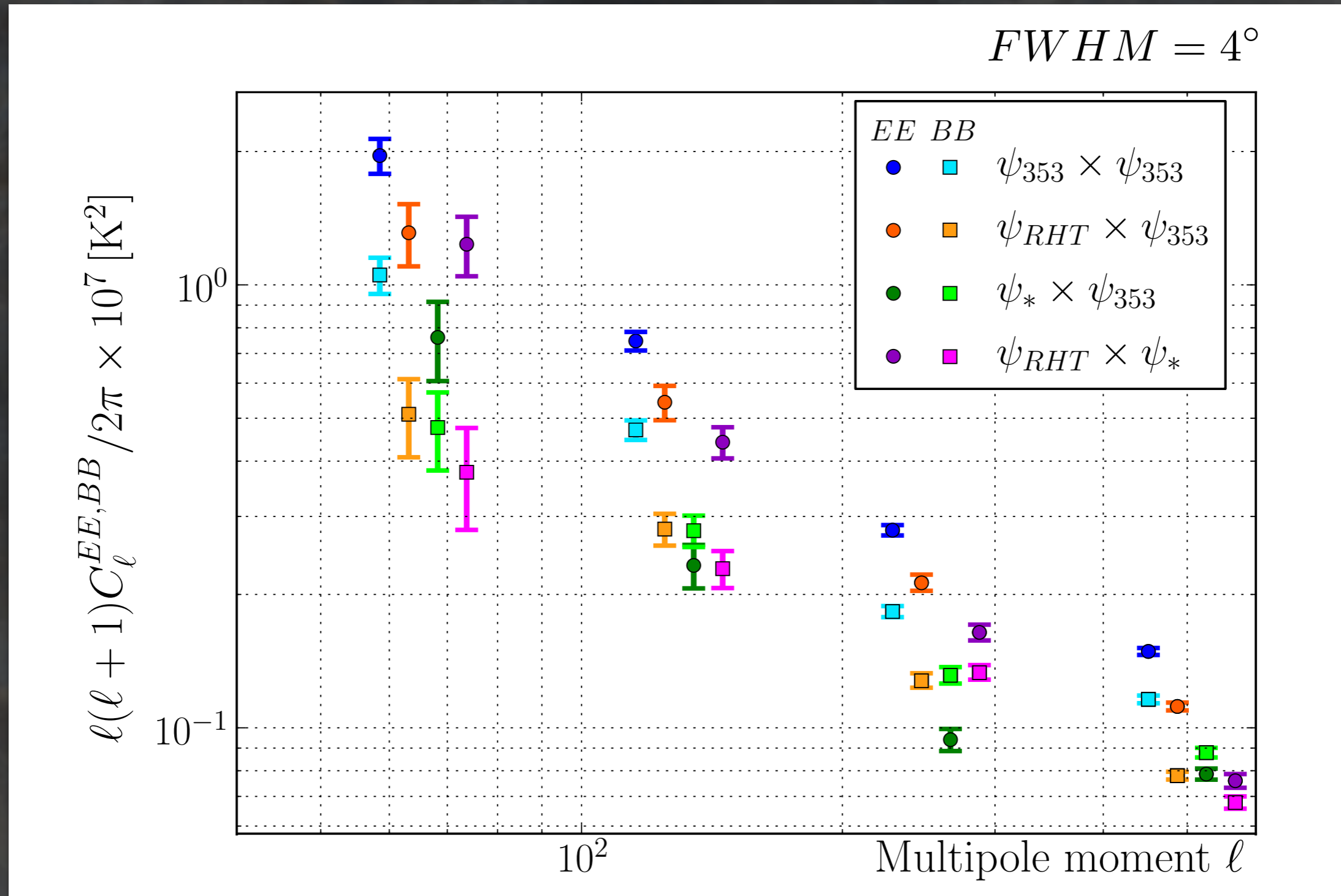


High latitude GALFA-HI structures are aligned with the Planck magnetic field orientation.



FWHM = 30'
 $\sigma \sim 14^\circ$

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



EE/BB asymmetry:

Planck Intermediate Results XXX, XXXVIII

Clark+ 2015, PRL

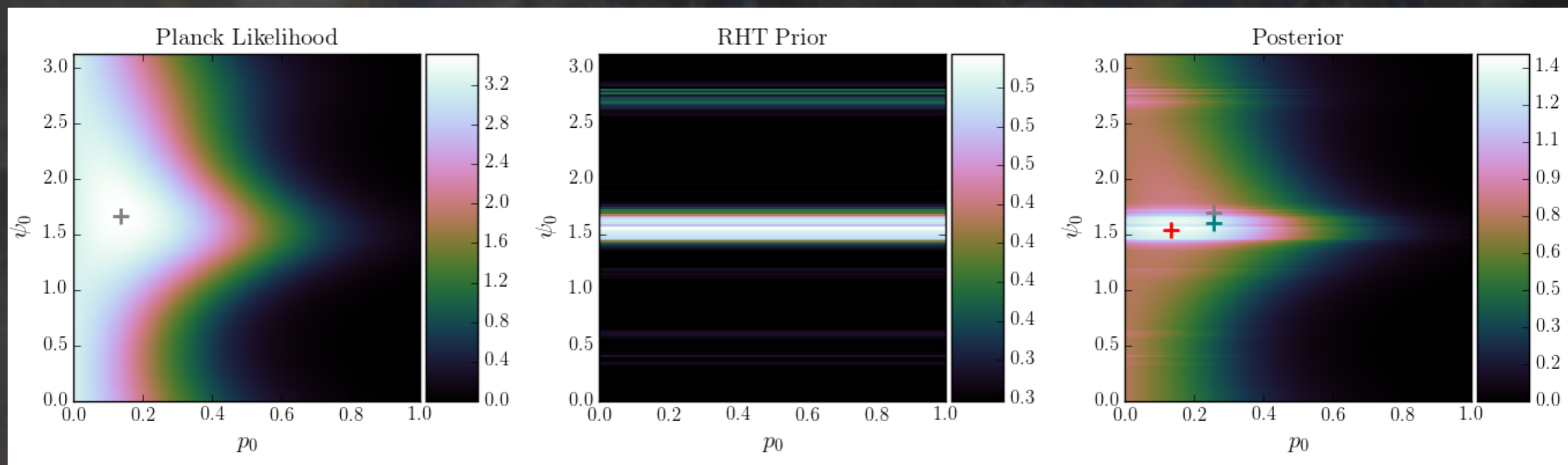
We use HI data to better constrain the plane-of-sky magnetic field orientation.

Planck
likelihood

RHT
HI prior

Posterior

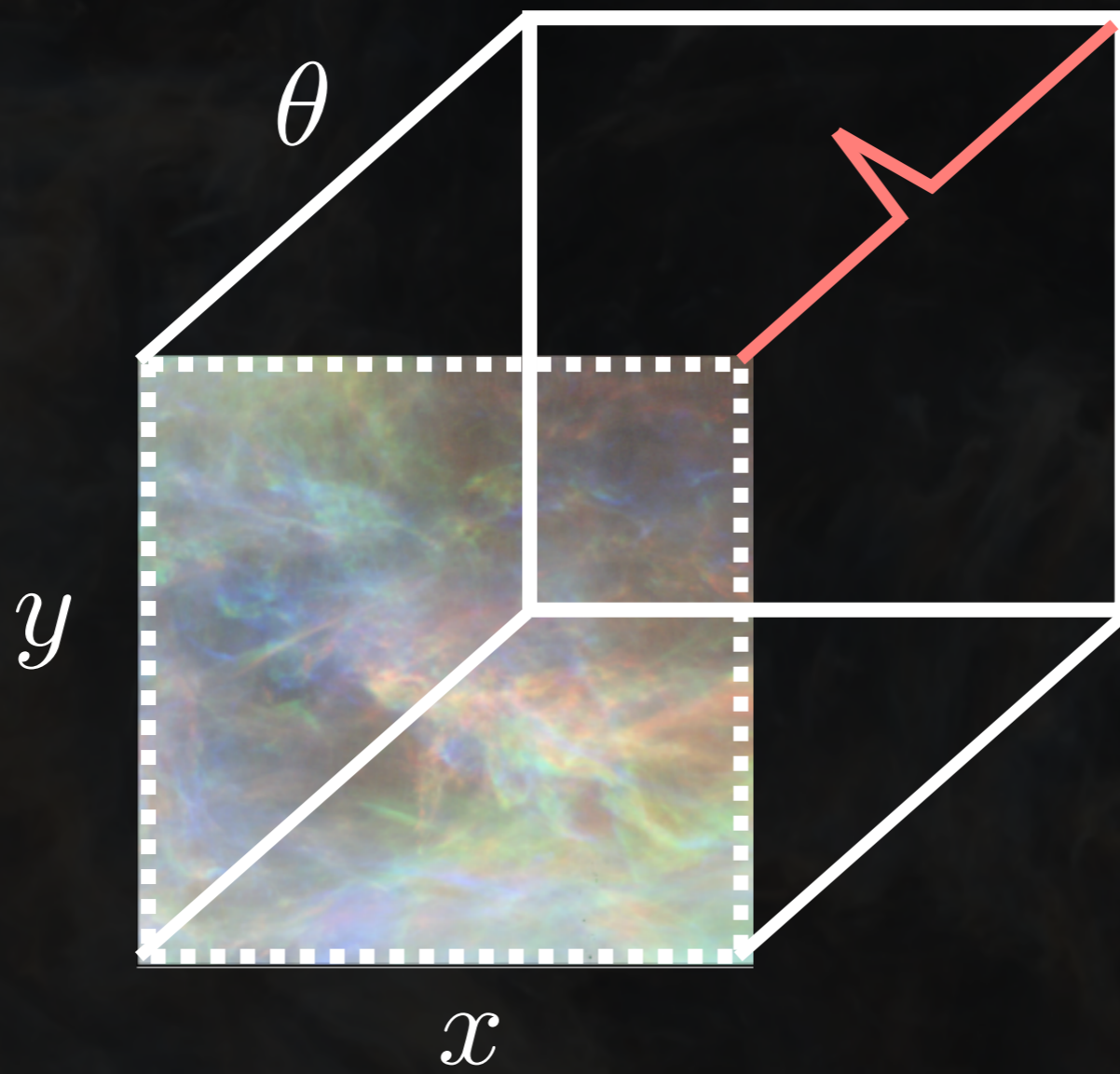
θ_0



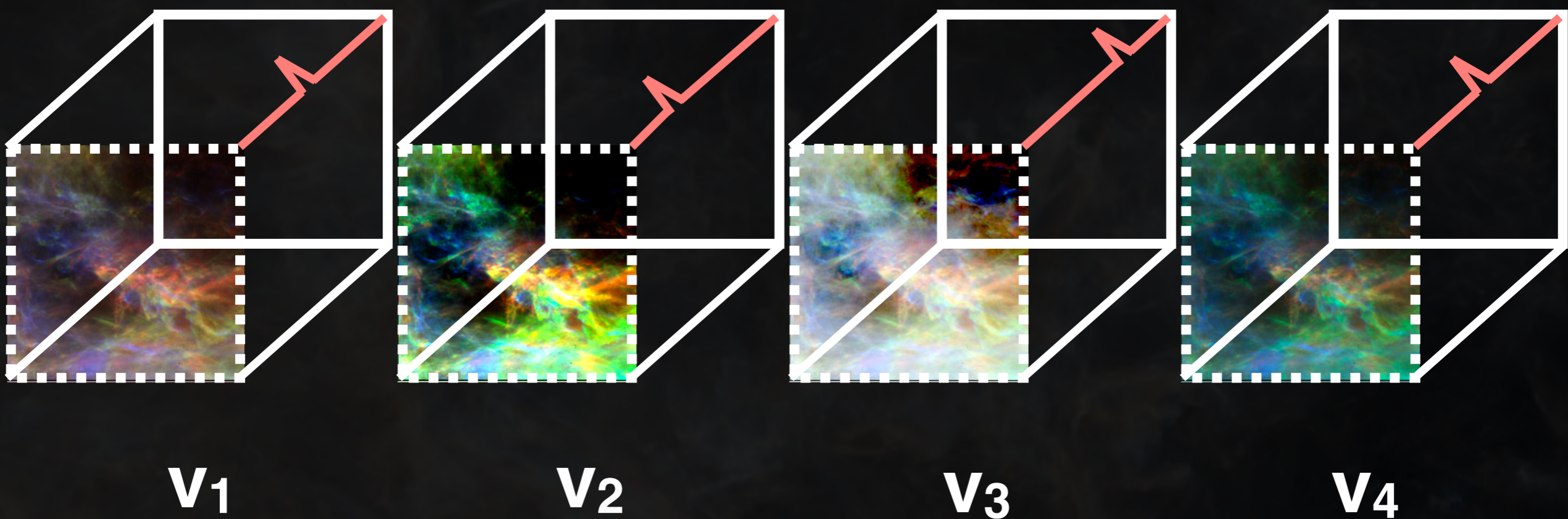
p_0

With J. Colin Hill,
Josh Peek,
Ludovic Montier

Clark+, in prep



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



Distance

Can we learn about the LOS magnetic field?

HI velocity channel

higher fractional polarization

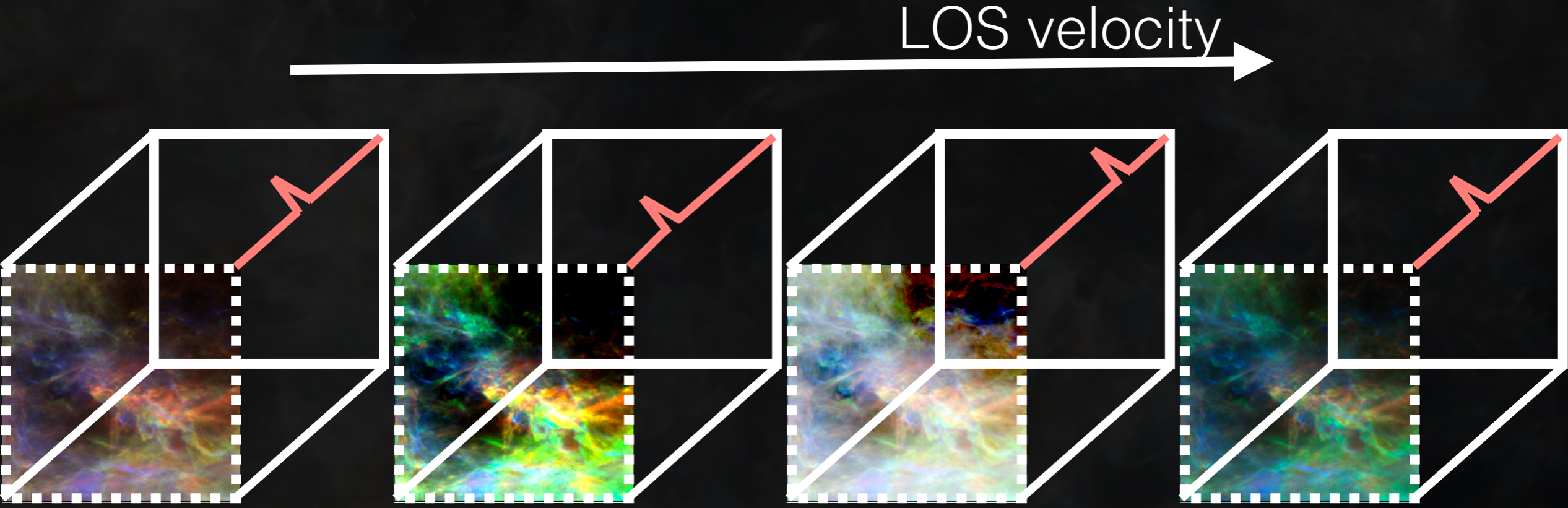


lower fractional polarization



LOS velocity

Can we learn about the LOS magnetic field?



1

2

3

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

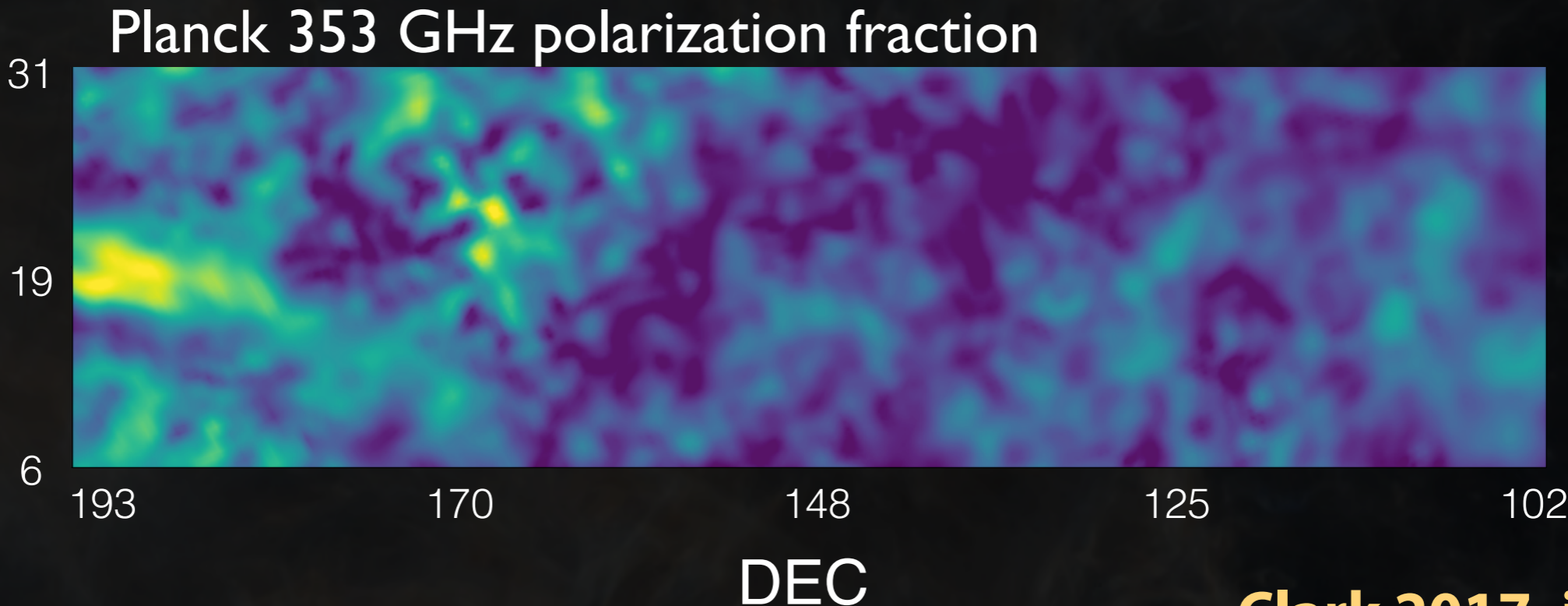
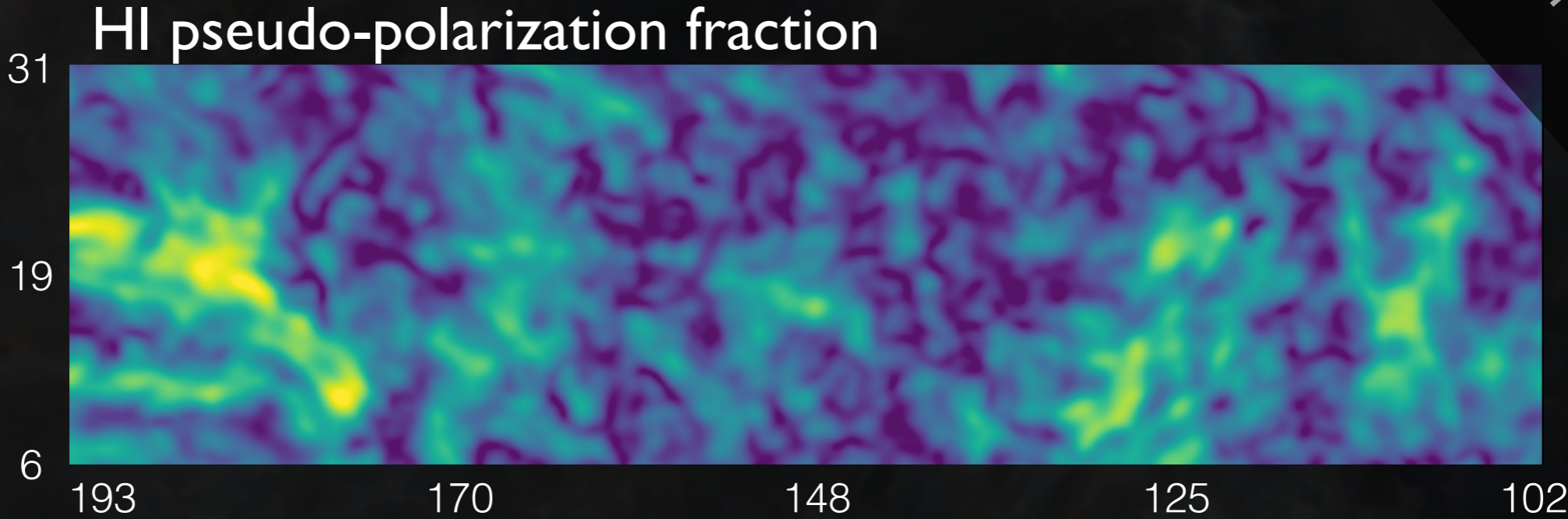
$$U_v = I_v \sin(2\theta_{RHT})$$

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

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

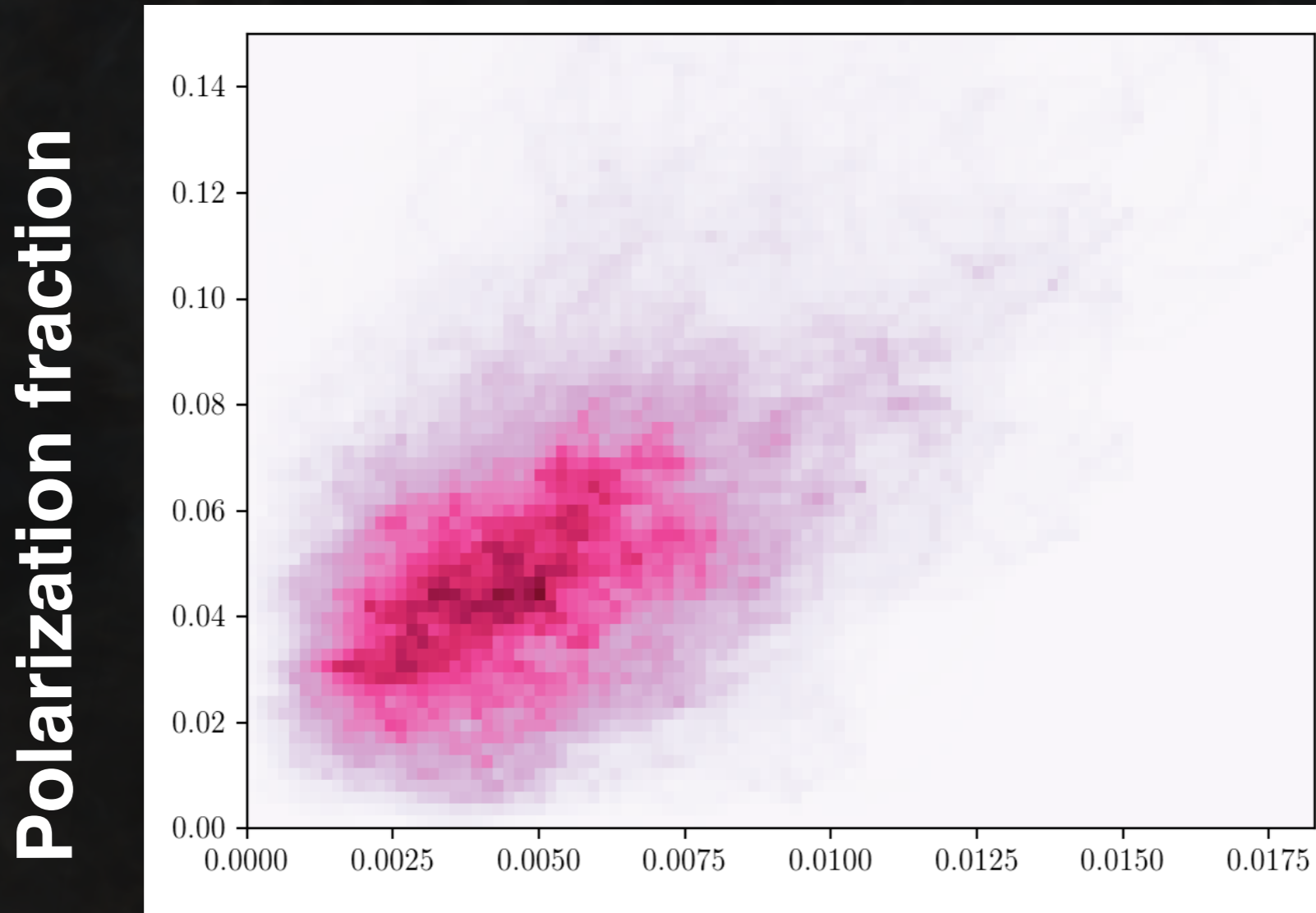
The dispersion of HI orientation traces LOS depolarization.

preliminary



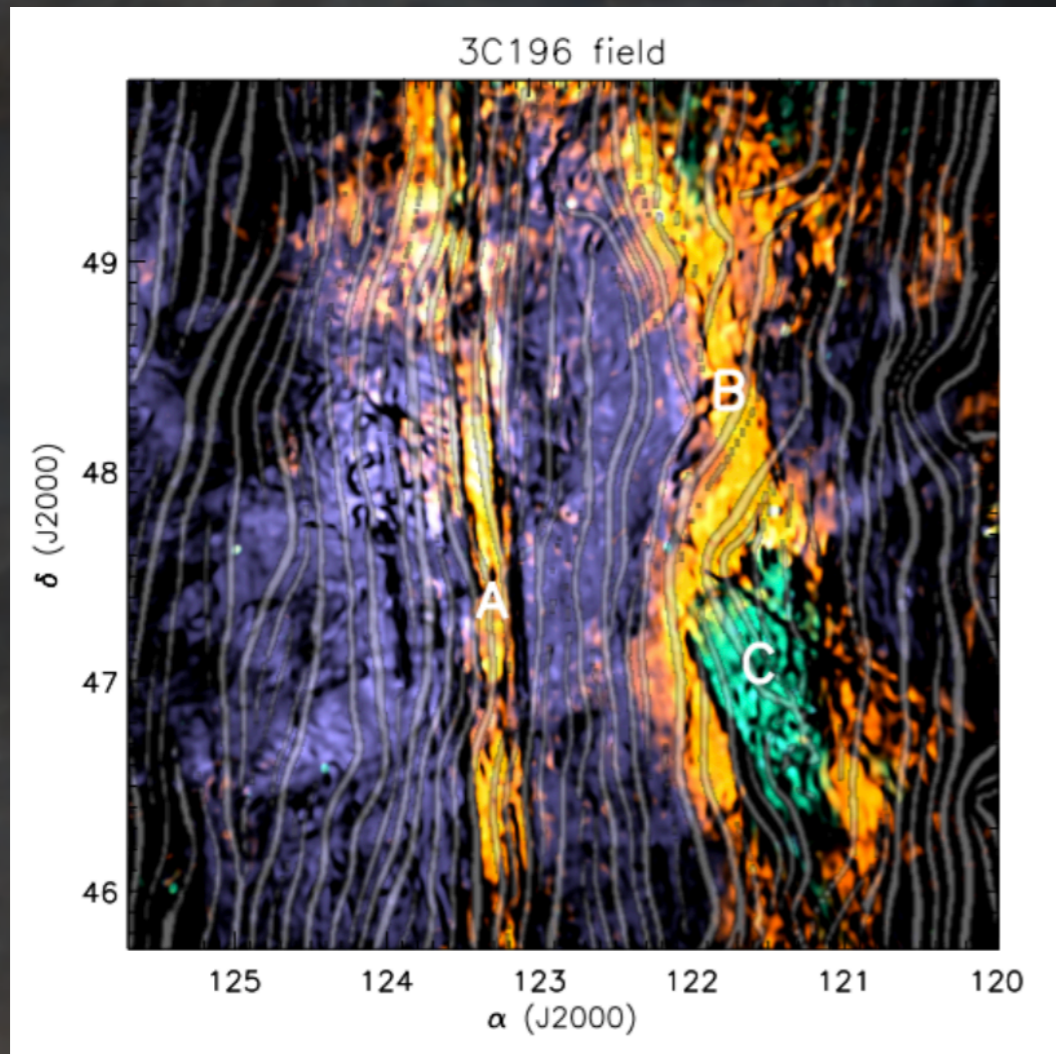
The dispersion of HI orientation traces
LOS depolarization.

preliminary

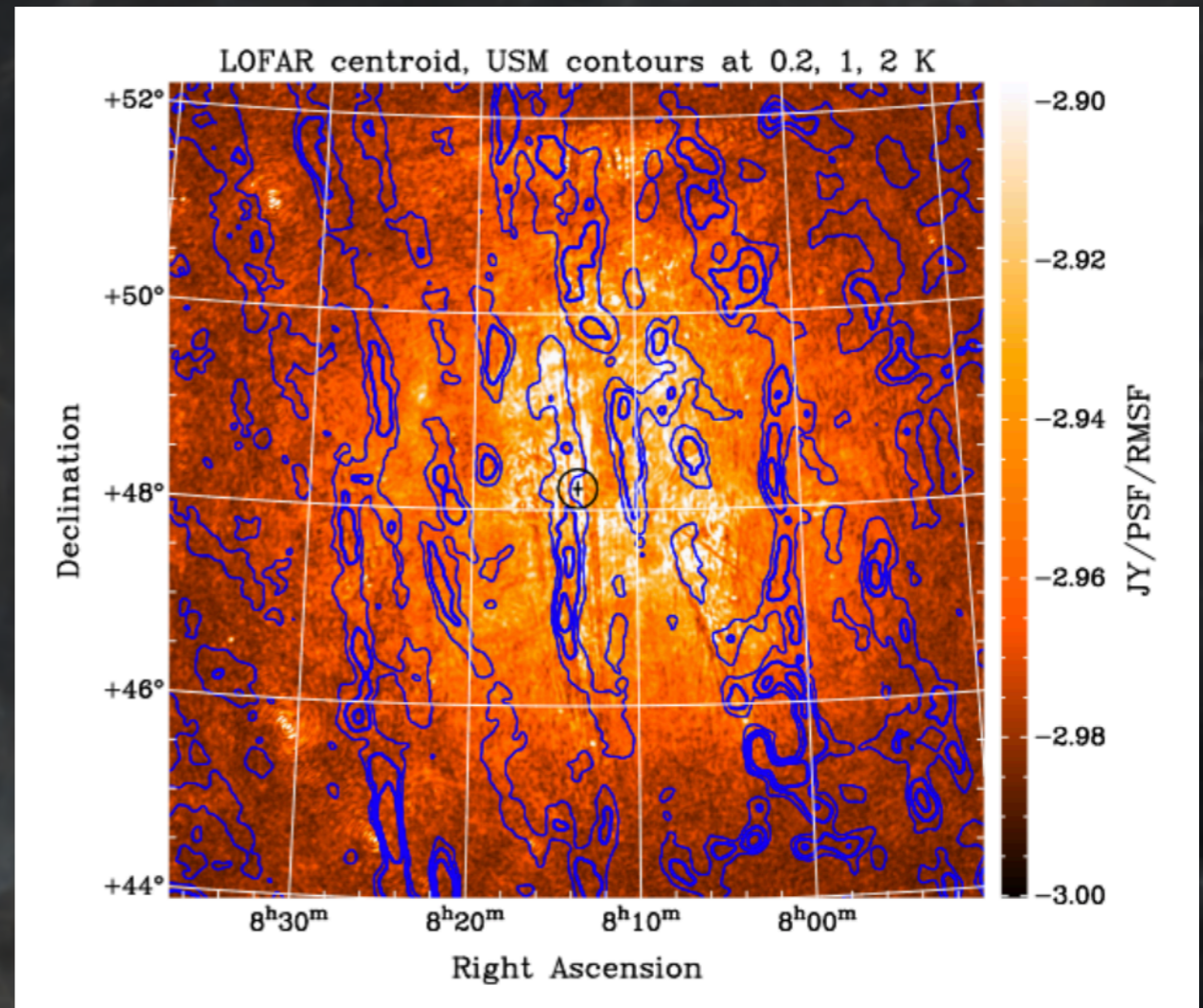


HI orientation dispersion
("pseudopolarization fraction")

Multiwavelength explorations will reveal the nature of the magnetic ISM.



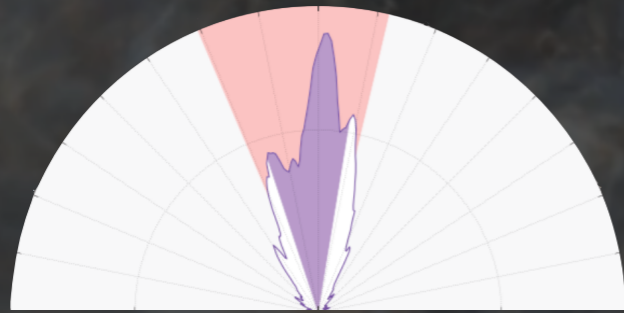
Zaroubi+ 2015
Jelić+ 2015



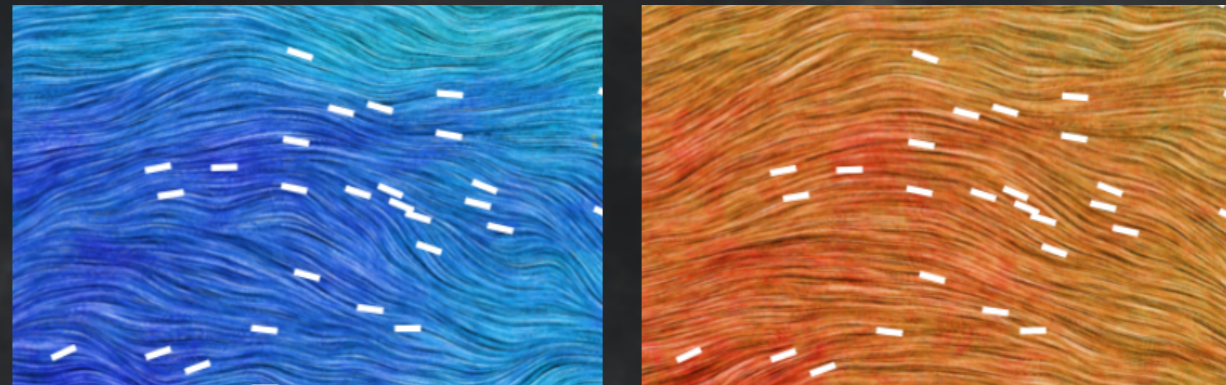
Kerp & Kalberla 2016
Kalberla+ 2017

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

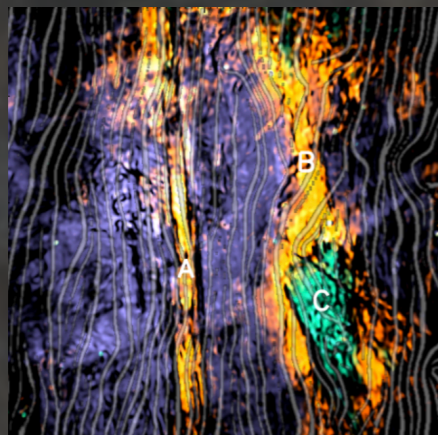
Clark+ 2014, ApJ



Clark+ 2015, PRL



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



Radio-polarimetric structures discovered by EoR experiments are not yet well understood.

Jelić+ 2015, Zaroubi+ 2015,
Lenc+ 2016 , van Eck+ 2017, etc

DR2 of GALFA-HI will soon be public!

Peek+ 2017, accepted