

The Galactic ISM in 3D

Brandon Hensley

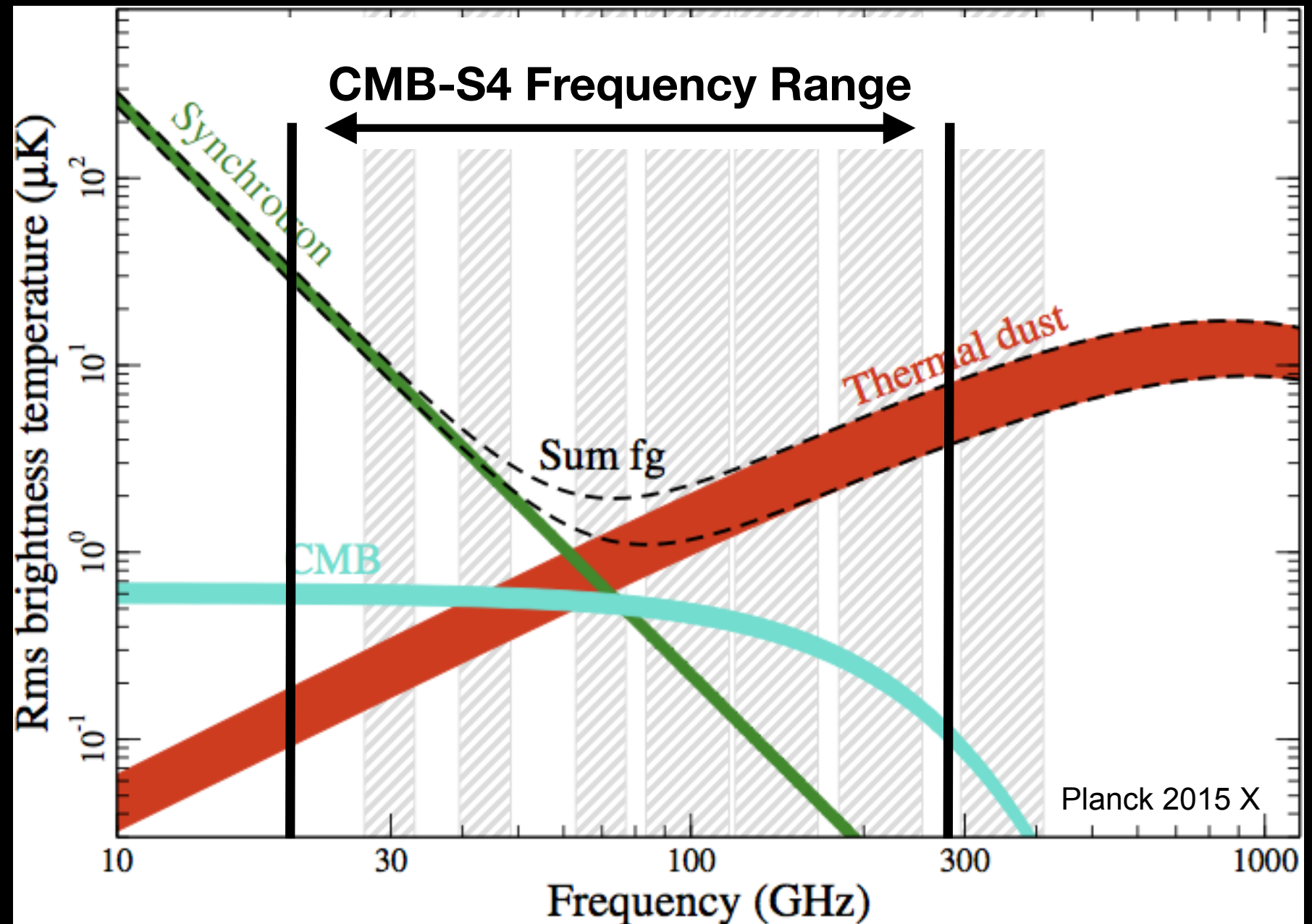
Spitzer Fellow, Princeton University

The CMB-S4 Summer 2021 Workshop

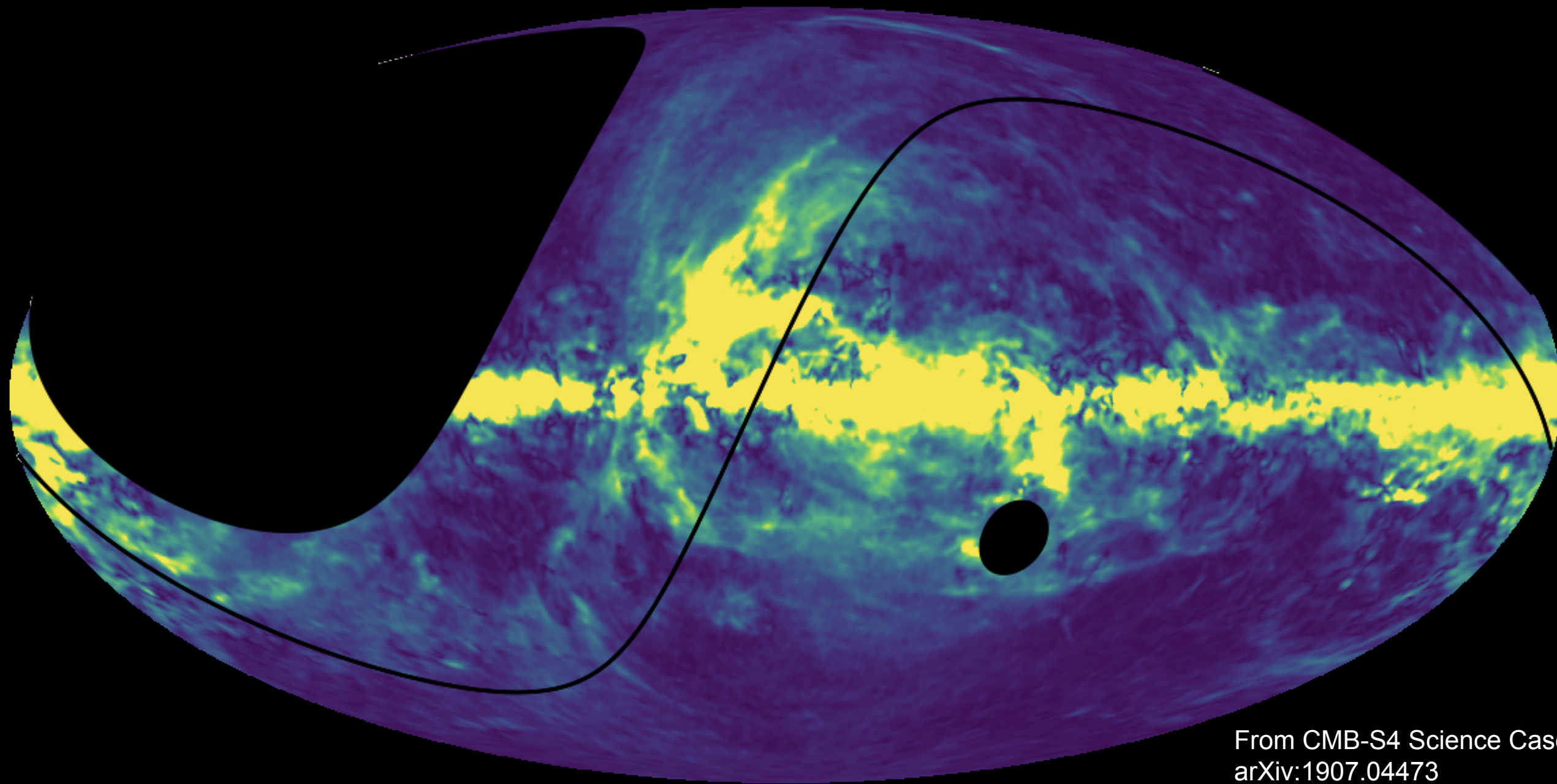
August 11, 2021

The Polarized mm Sky

- High frequencies: dust emission
- Low frequencies: synchrotron emission
- Both probe the local B-field



The Galaxy as Seen by CMB-S4



From CMB-S4 Science Case
arXiv:1907.04473

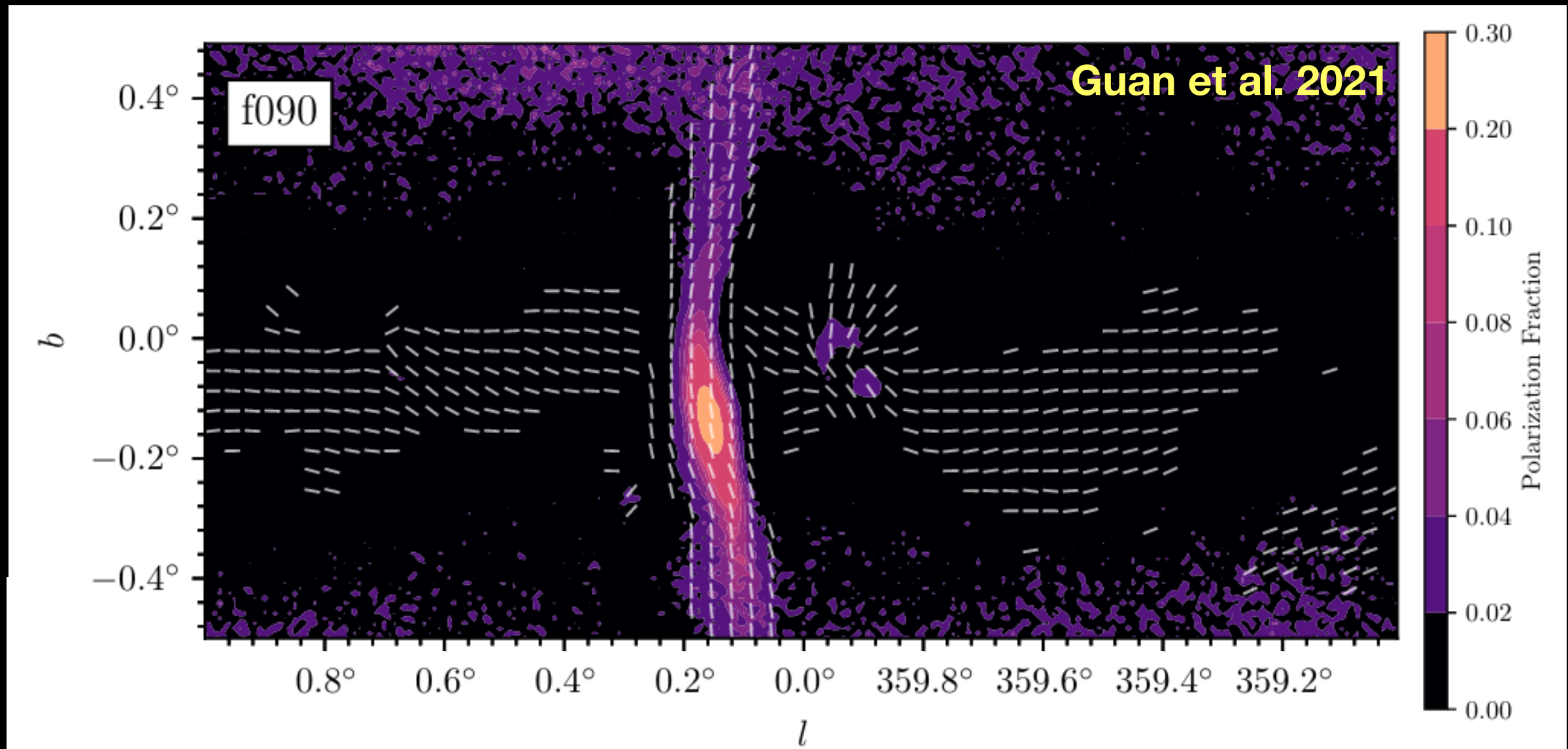
Galactic Science with CMB-S4

- What is the global structure of the Galactic magnetic field?
- Can we make a 3D map of gas, dust, and magnetic fields?
- How do magnetic fields affect star formation?
- How coherent are magnetic fields across different ISM phases?
- How filamentary is the ISM on small scales?
- All of these questions benefit from **a 3D view!**

Going to Three Dimensions

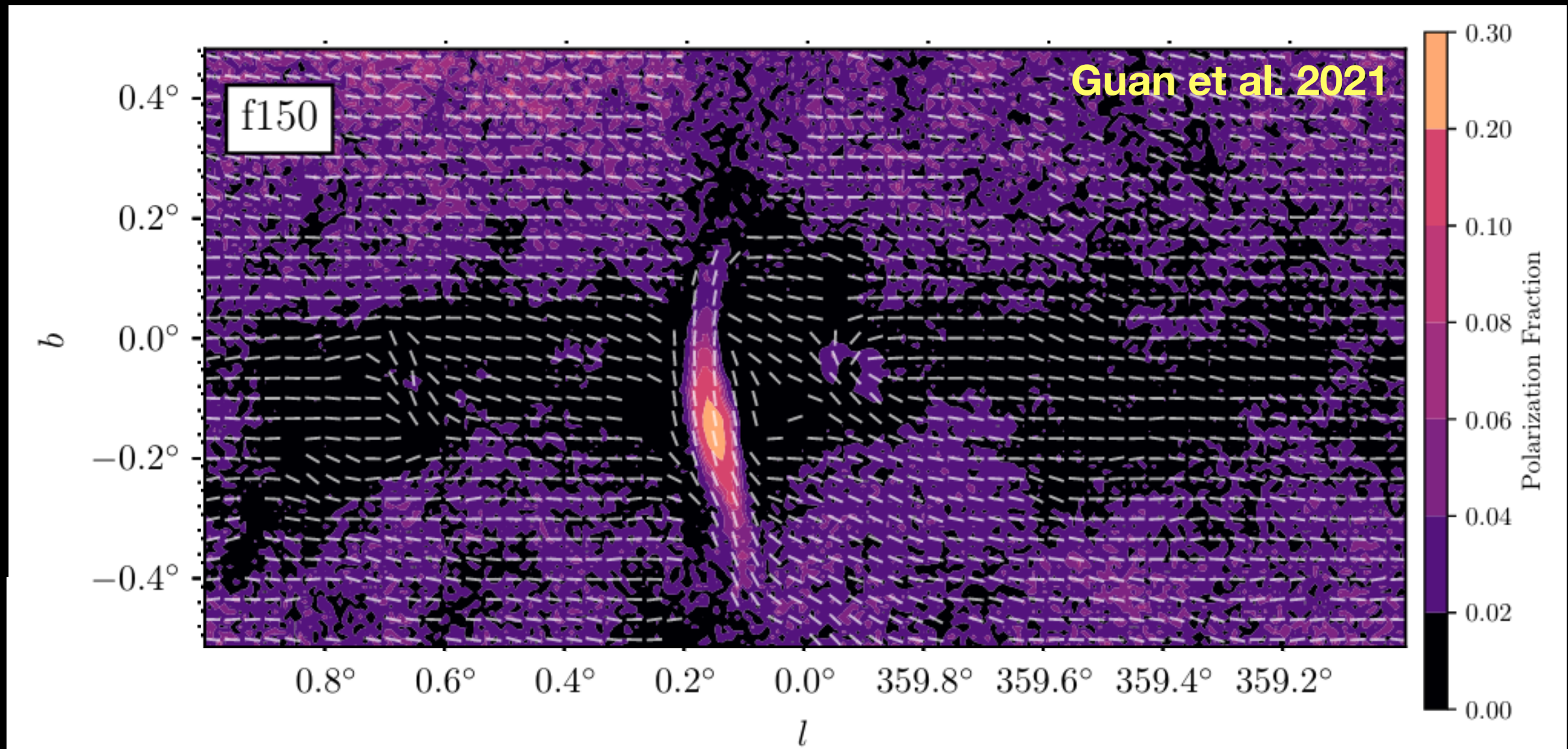
- Dust and synchrotron optically thin in the mm—inherently line of sight integrated probes
- However, 1) dust and synchrotron probe different regions along the line of sight

The ACT View of the Galactic Center



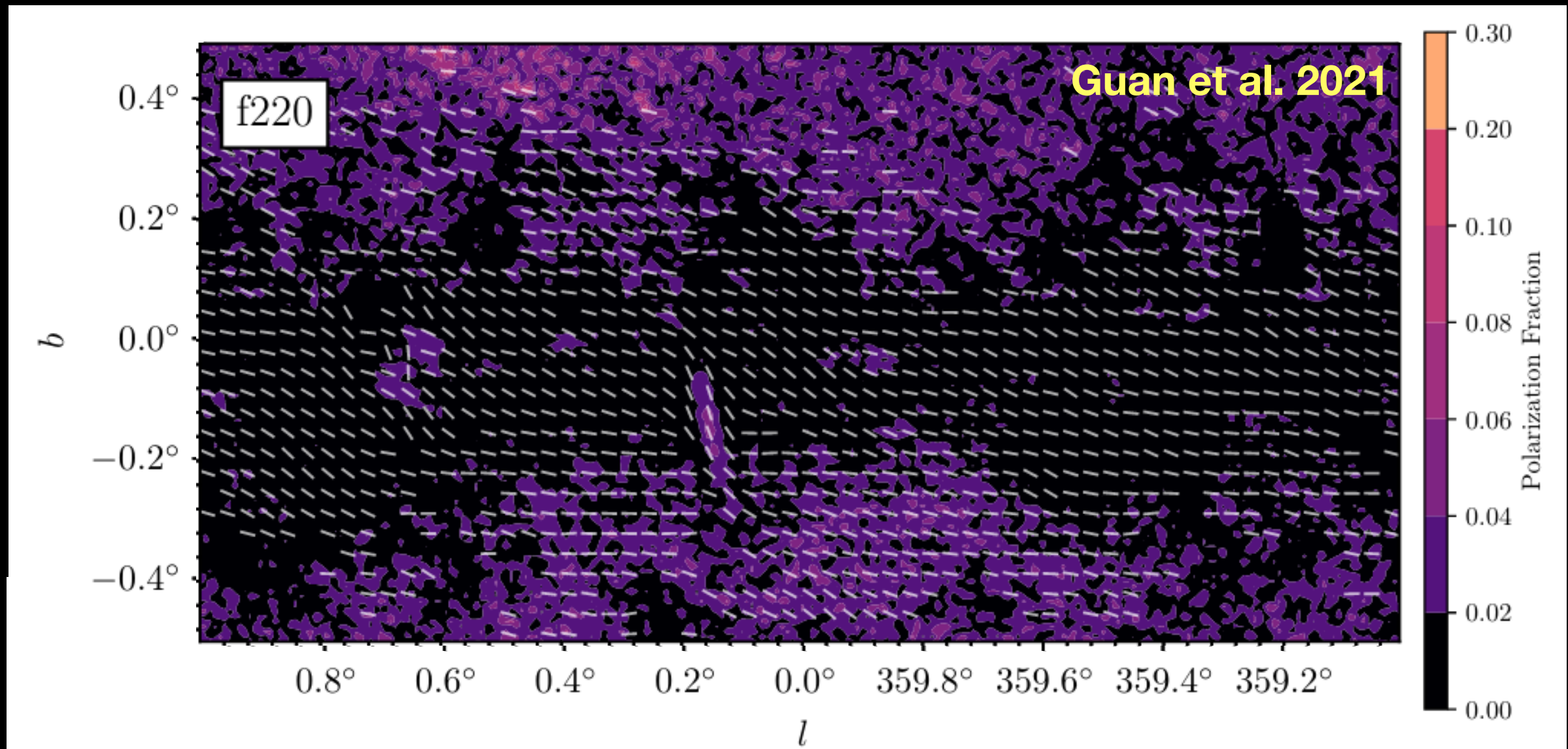
- 90, 150, and 220 GHz ACT data reveal different magnetic field morphologies
- S4 frequency coverage much wider, much more to do!

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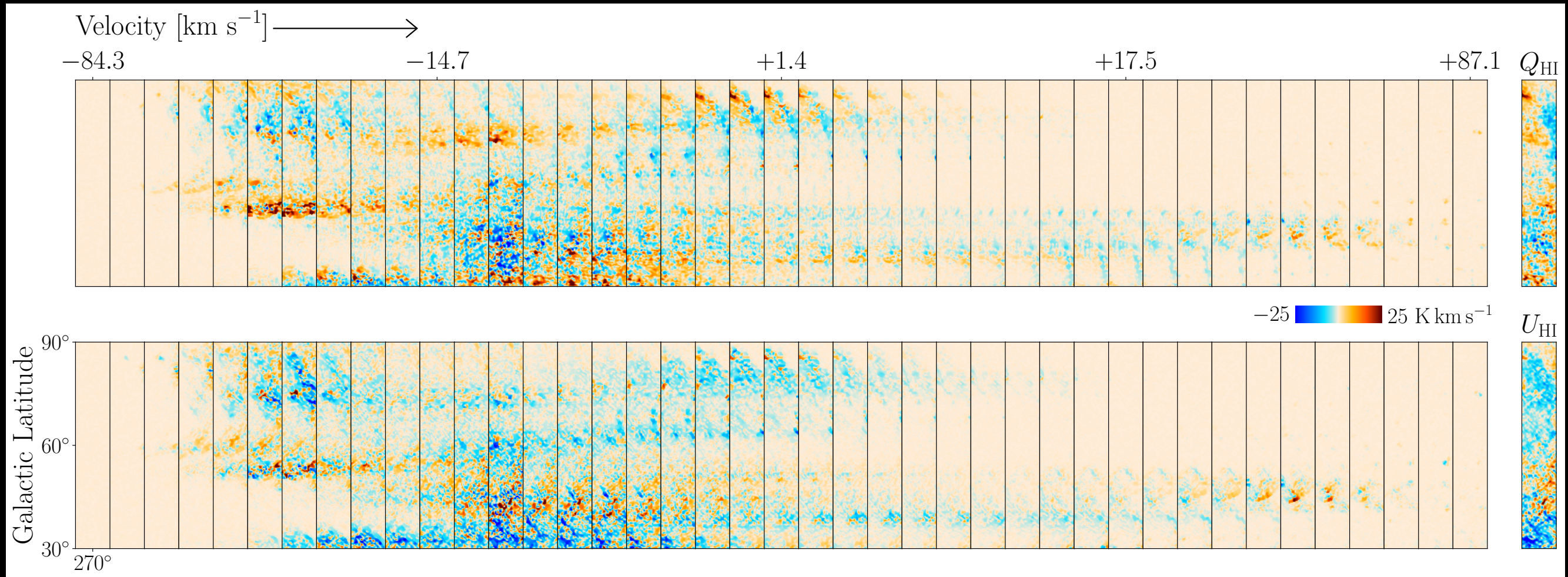
The ACT View of the Galactic Center



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Going to Three Dimensions

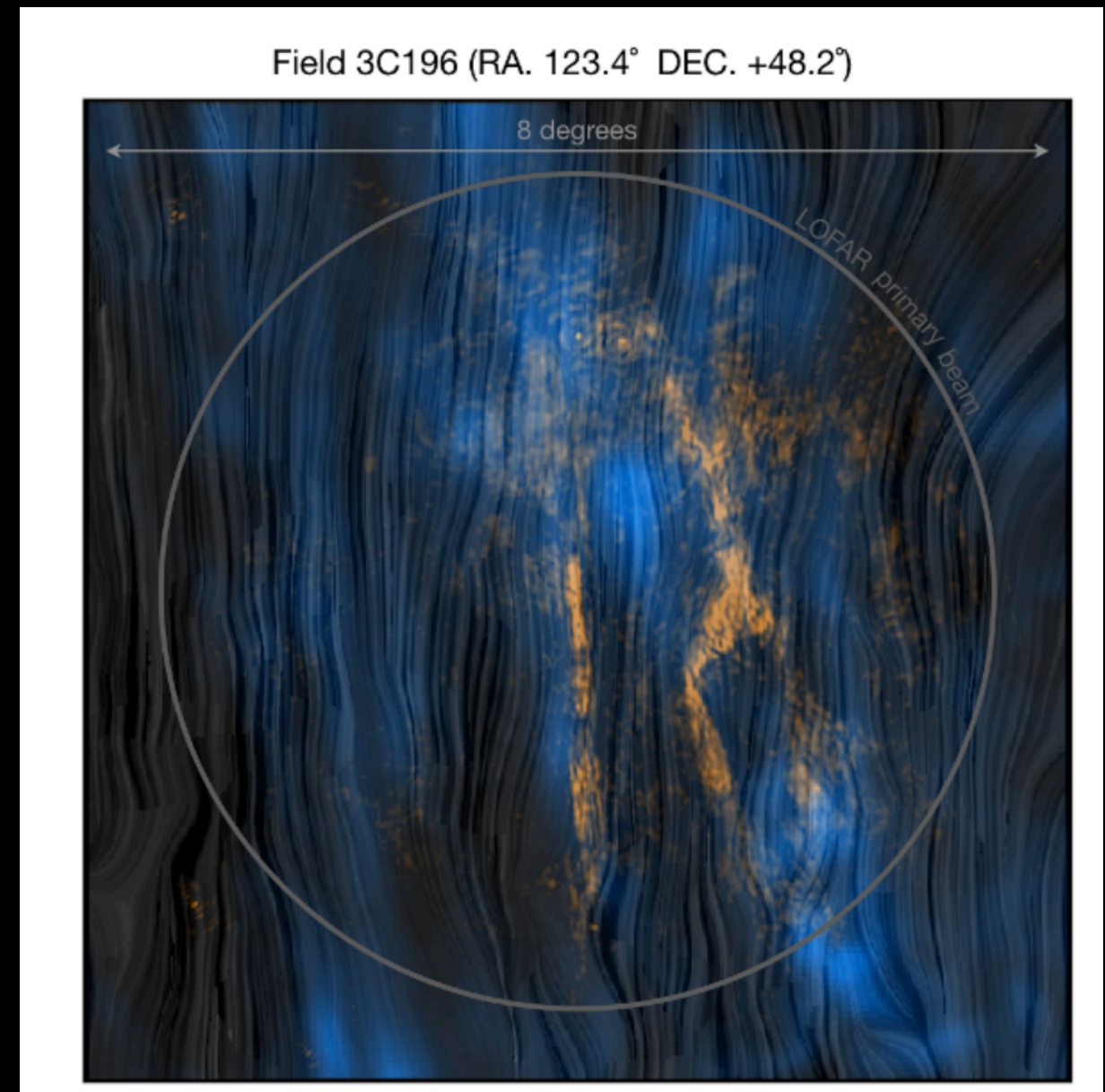
- 2) Can combine with gas velocity information from HI



Clark & BH 2019

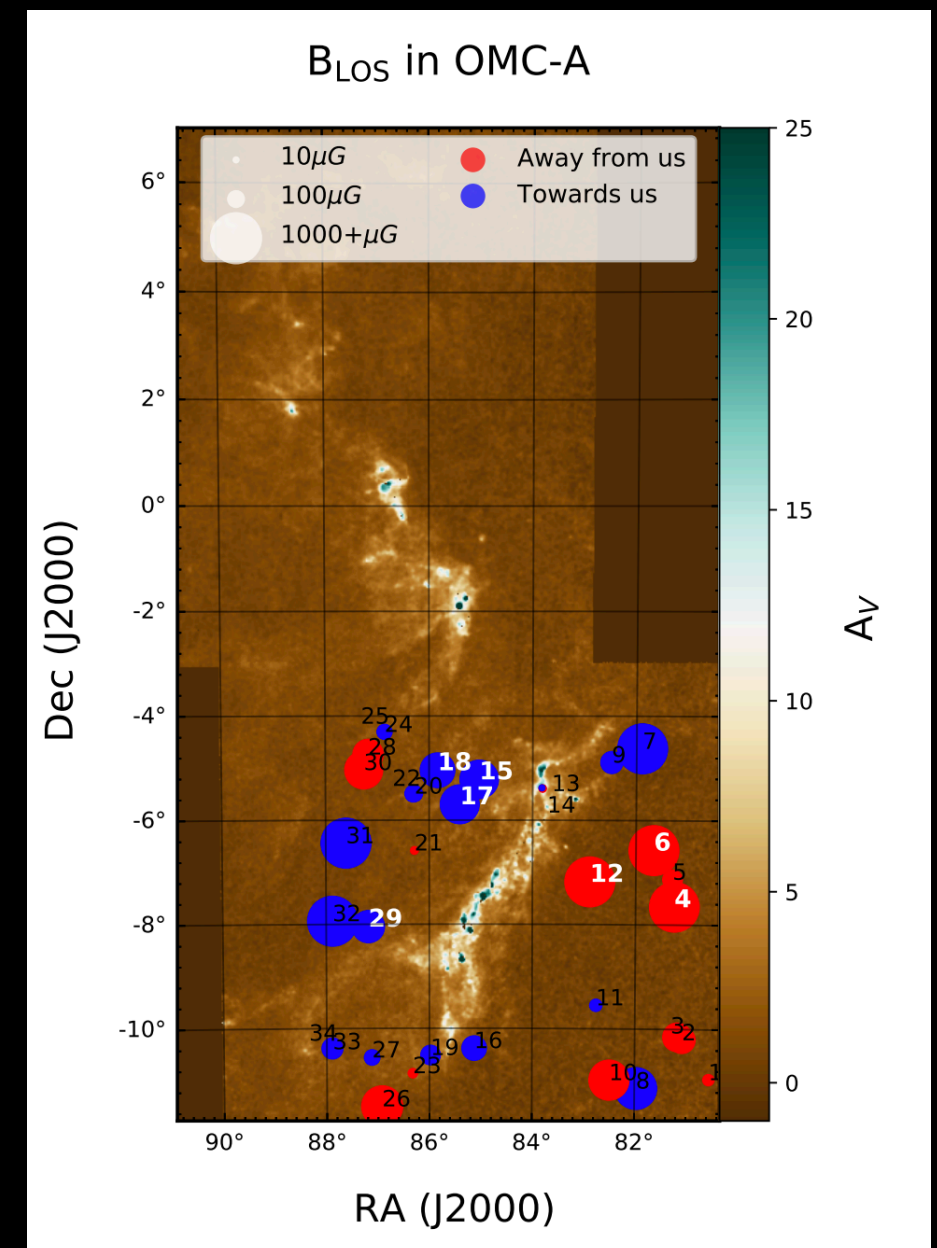
Going to Three Dimensions

- 3) Can combine with Faraday tomography
- Synchrotron polarization angle rotated as emission propagates through magnetic medium
- Striking correlation of Faraday rotation (orange), HI structures (blue), and dust-derived B-fields (Bracco, Jelic, et al. 2020)



Going to Three Dimensions

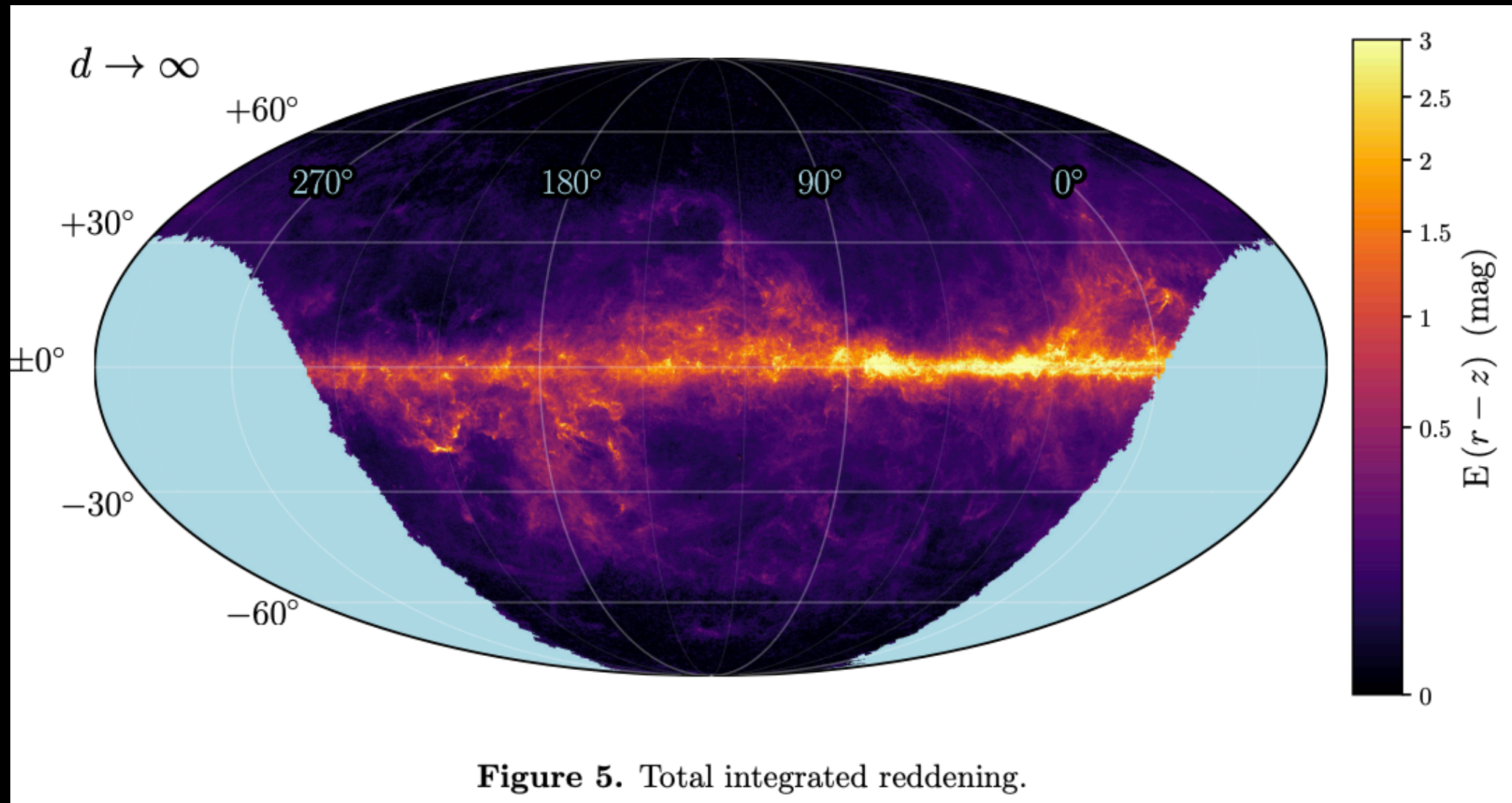
- 3) Can combine with Faraday tomography
- Powerful combination in molecular clouds to infer 3D B-field structure
- **Tahani et al. 2019** (right)



Going to Three Dimensions

- 4) Can combine with 3D dust extinction maps

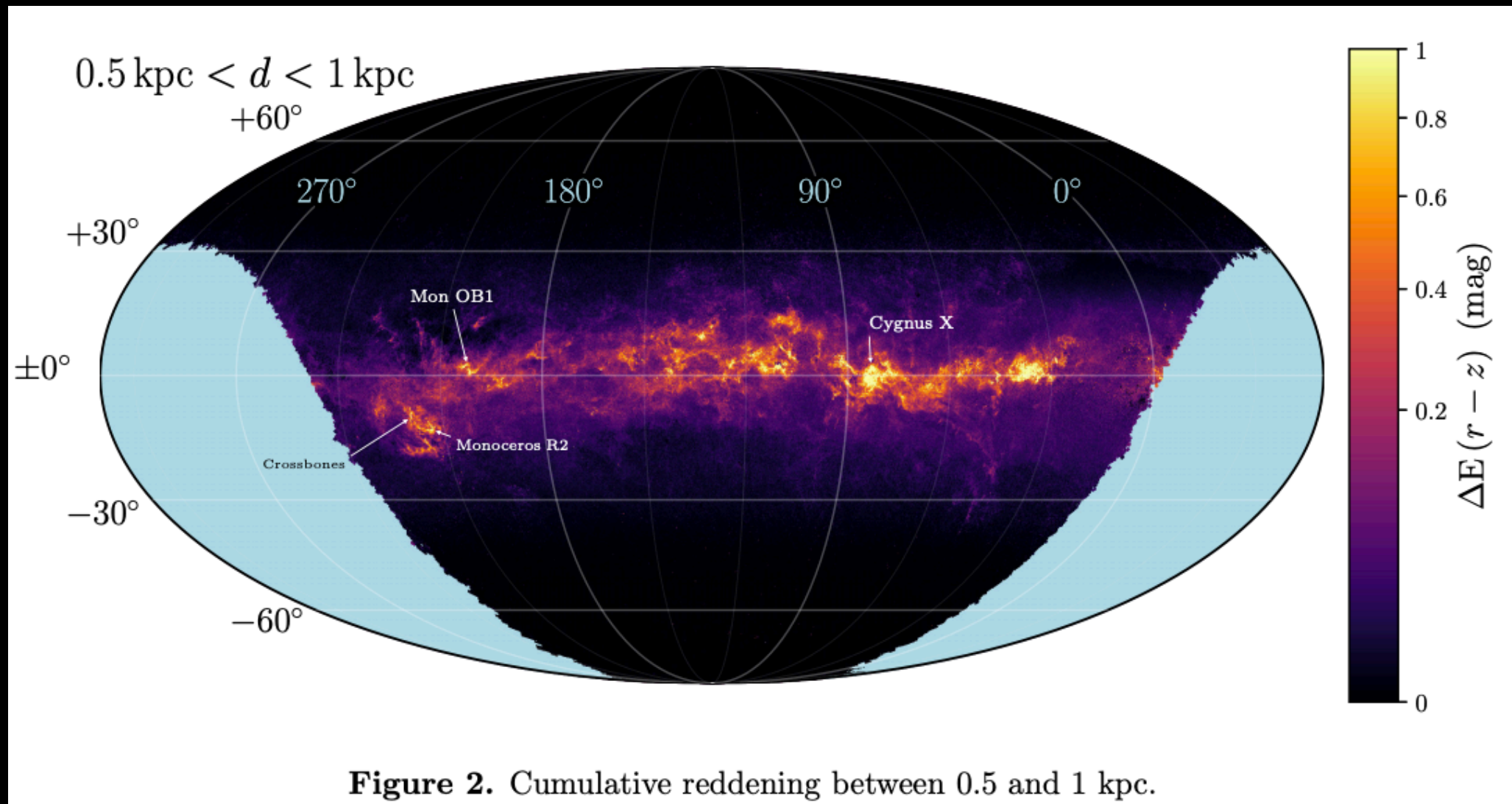
Green et al. 2019



Going to Three Dimensions

- 4) Can combine with 3D dust extinction maps

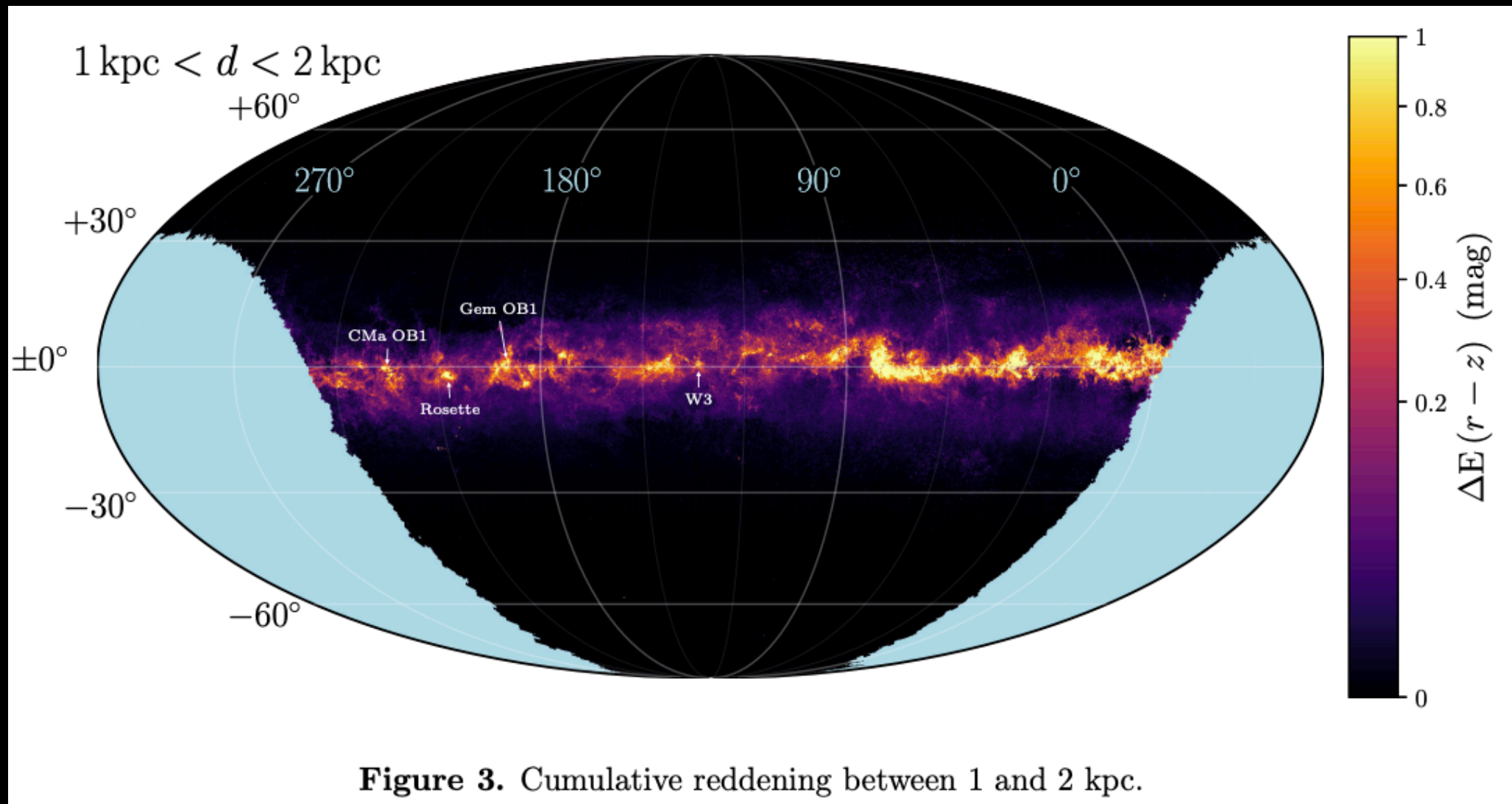
Green et al. 2019



Going to Three Dimensions

- 4) Can combine with 3D dust extinction maps

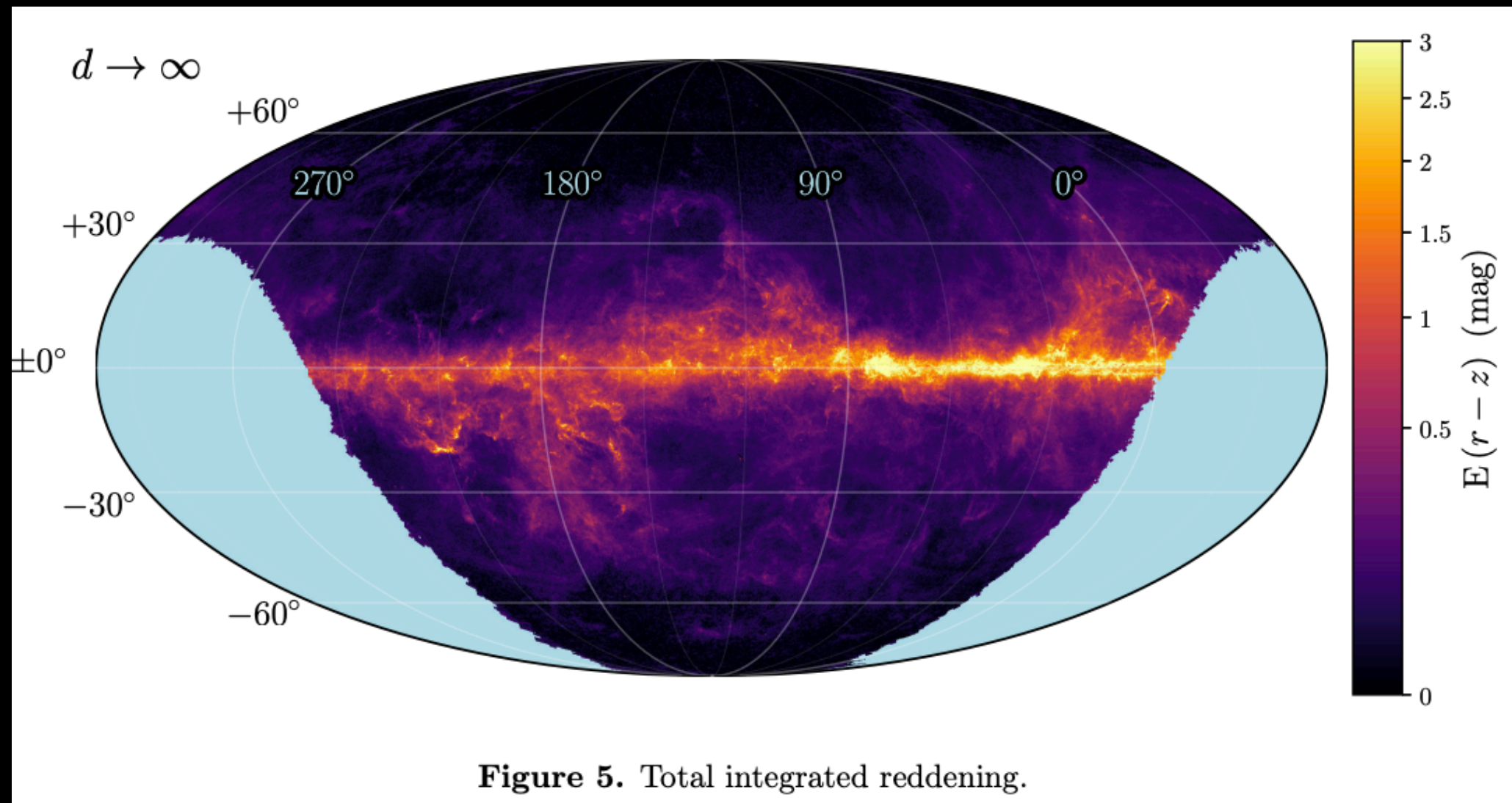
Green et al. 2019



Going to Three Dimensions

- Basis for 3D modeling (see Ioana Zelko's talk!)

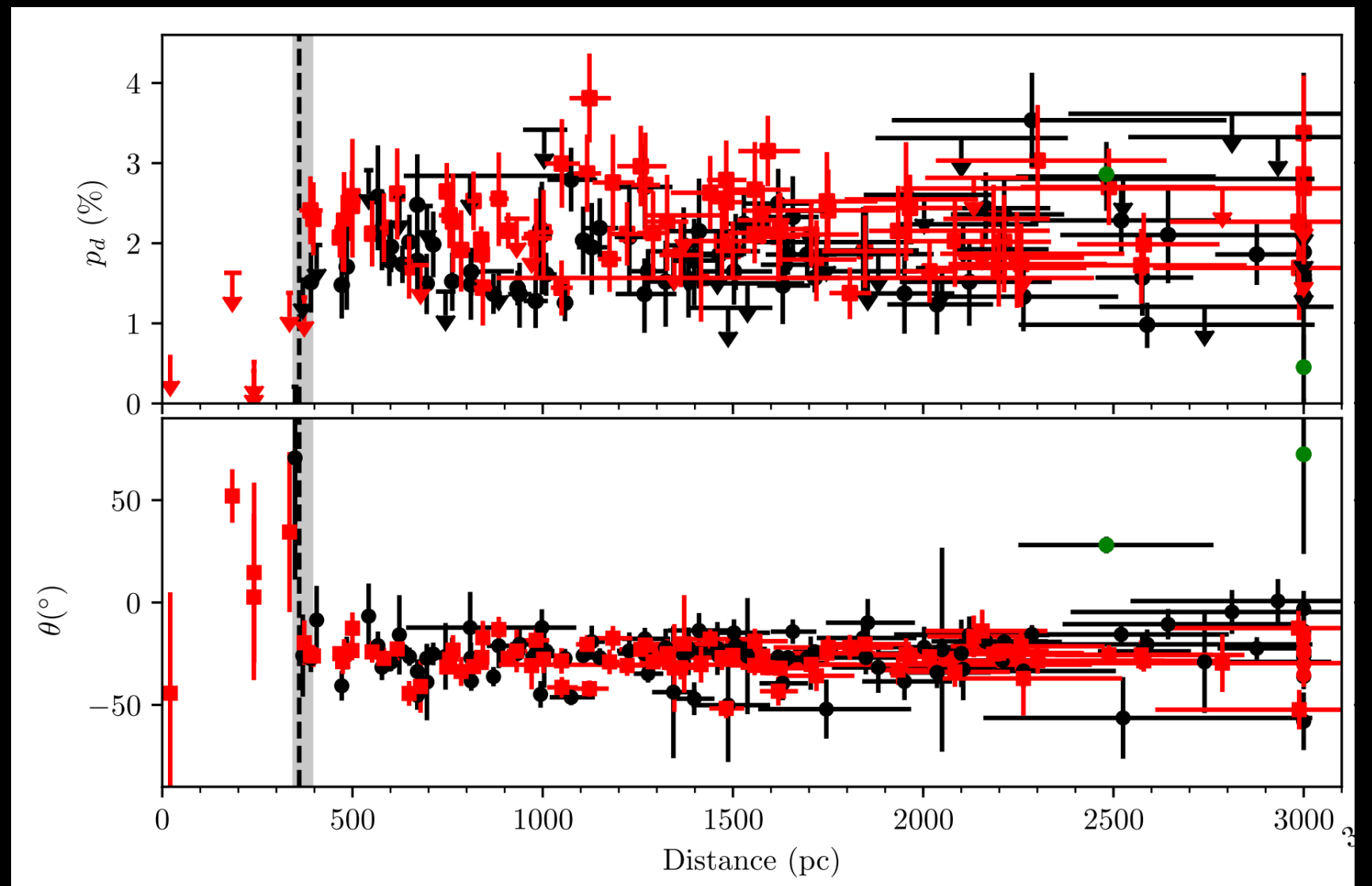
Green et al. 2019



Going to Three Dimensions

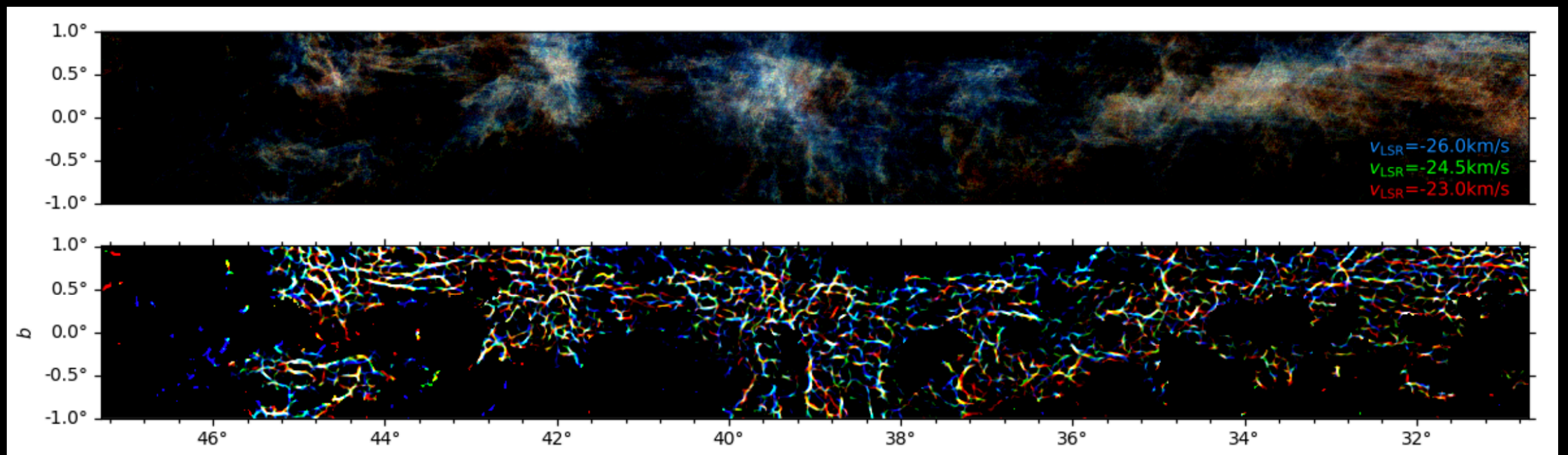
- 5) Can combine with stellar polarization

- Polarized extinction + Gaia distances = 3D magnetic fields!
(Panopoulou et al. 2019)



An ISM of Filaments

- Interstellar gas is highly filamentary (e.g., McClure-Griffiths 2006, Clark et al. 2015)
- THOR-HI filaments (Soler et al. 2020):



- Implications for dust TE, TB, EB, r^{TE} ... (Huffenberger et al. 2019, Clark et al. 2021)

An ISM of Filaments

- Can we use filaments as a basis of a model of dust polarization? (Hervias-Caimapo & Huffenberger 2021)

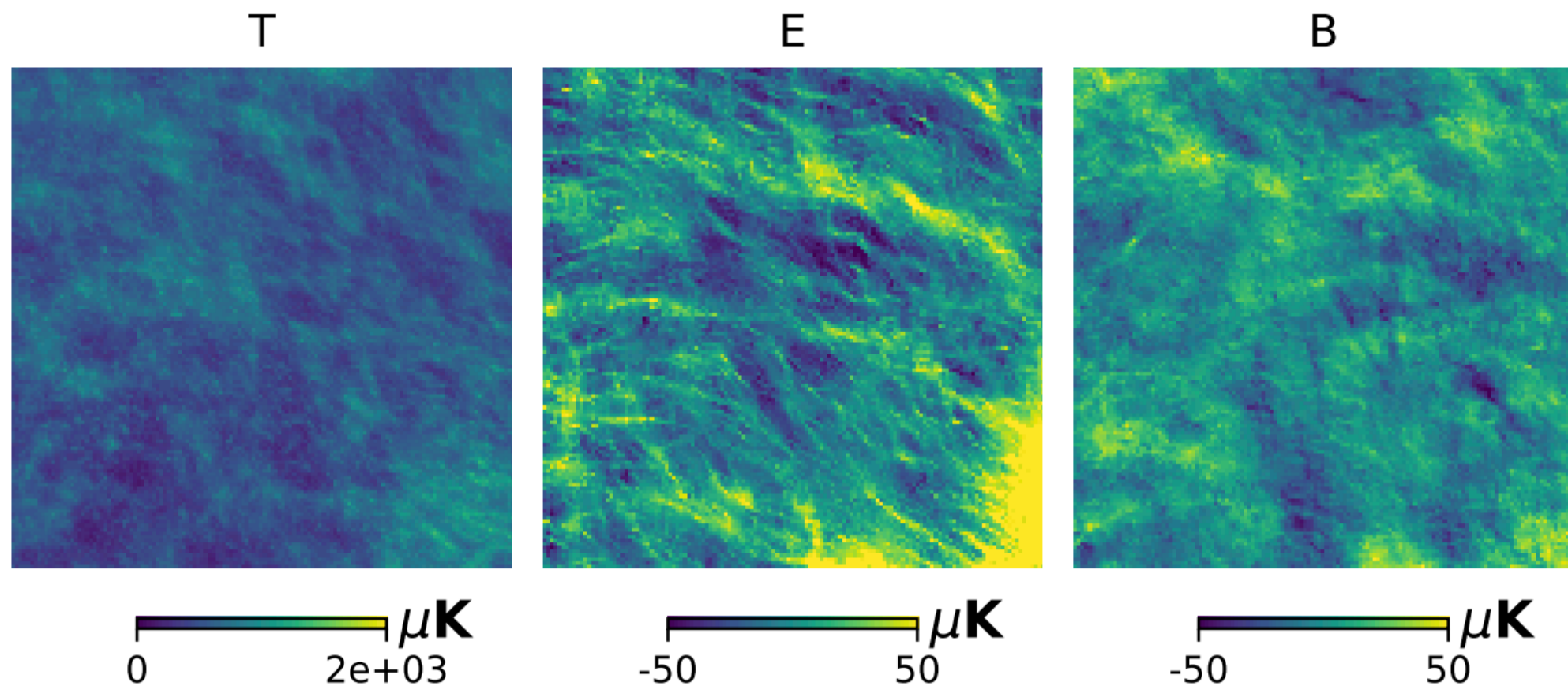


Figure 7. Close up on a $10 \times 10^\circ$ patch centered at the North Galactic Pole of our filament model. We show the TEB maps. The mean of each patch is subtracted from the E and B maps.

Key Questions

- What datasets should we be combining with S4 to probe the ISM in 3D? What communities should we be connecting with?
- What groundwork can be laid now? In the next few years?
- What other science questions do these data have the potential to address?

Join Our Session!

- The ACT View of the Galactic Center Yilun Guan
- Multi-tracers Analysis of the Faraday Tomographic Data Vibor Jelic
- Reconstructing 3D Magnetic Fields Associated with Filamentary Molecular Clouds Mehrnoosh Tahani
- Filaments, Bubbles, Super-bubbles, and Other Features of the Magnetized Solar Neighborhood Juan Diego Soler
- Combining CMB Observations with Extinction Data to Create a 3D Dust Temperature Map Ioana Zelko
- A New 3D Model of Galactic Microwave Emission Foreground Dust Emission Based on Filaments Carlos Hervias-Caimapo