

The background of the slide is a colorful, multi-wavelength image of the Galactic Center, showing complex structures of dust and gas in shades of purple, blue, and green, with a bright central region.

Beyond Foregrounds: Galactic Science in the 2020s

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**On behalf of the ACT and Simons Observatory
Galactic Science Working Groups**

From Planck to the Future of CMB

Ferrara, Italy

May 25, 2022

Galactic Science with CMB Data

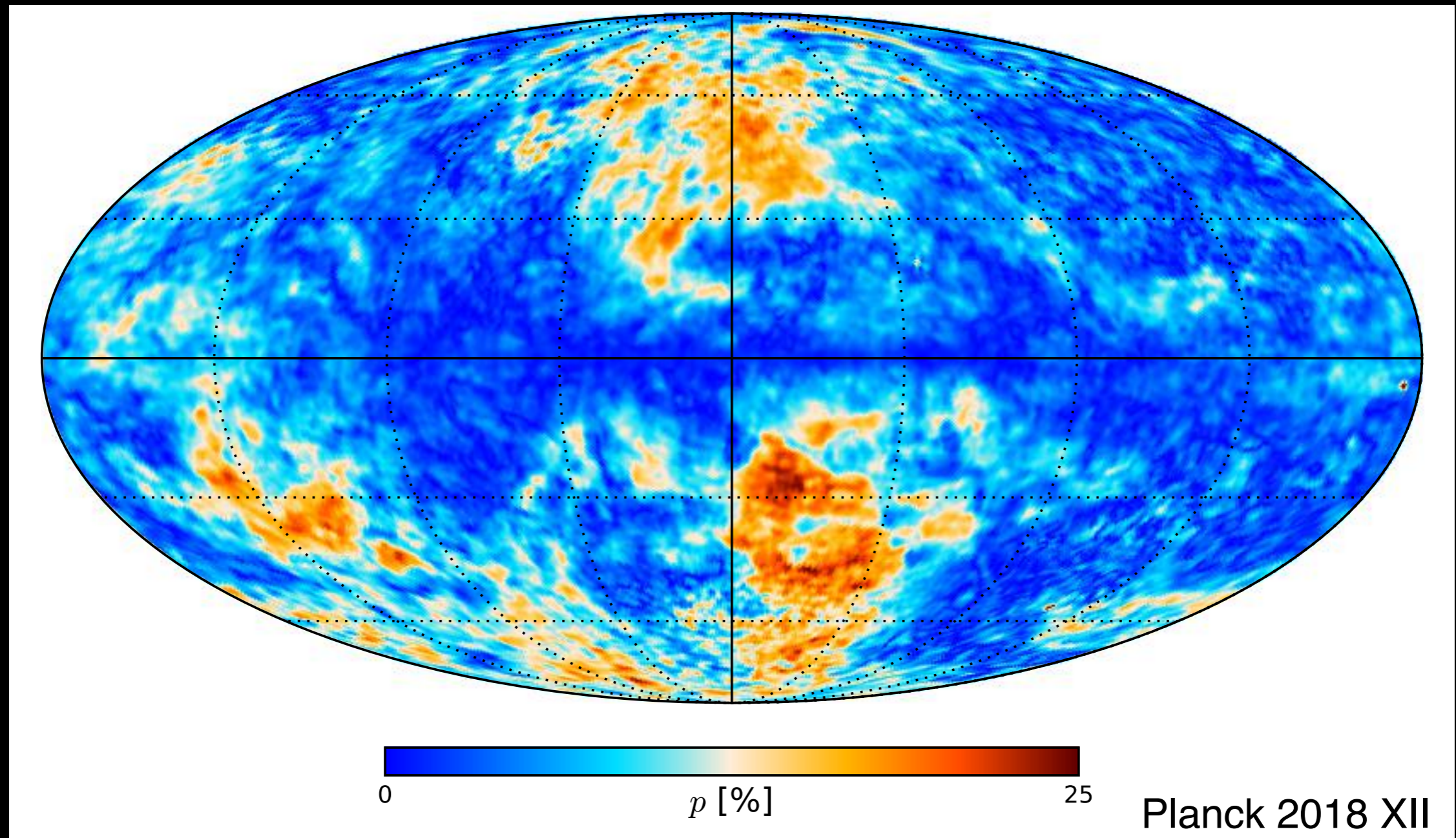
- Large sky areas needed for B-mode and other science: moving away from scan strategies that avoid the Galaxy
- Astro2020 prioritized CMB-S4 in part because data is useful to more than just CMB community
- Planck has blazed a trail in Galactic astrophysics, and we're already getting started on the ground with ACT and have big plans for Simons Observatory

Galactic Science with Planck

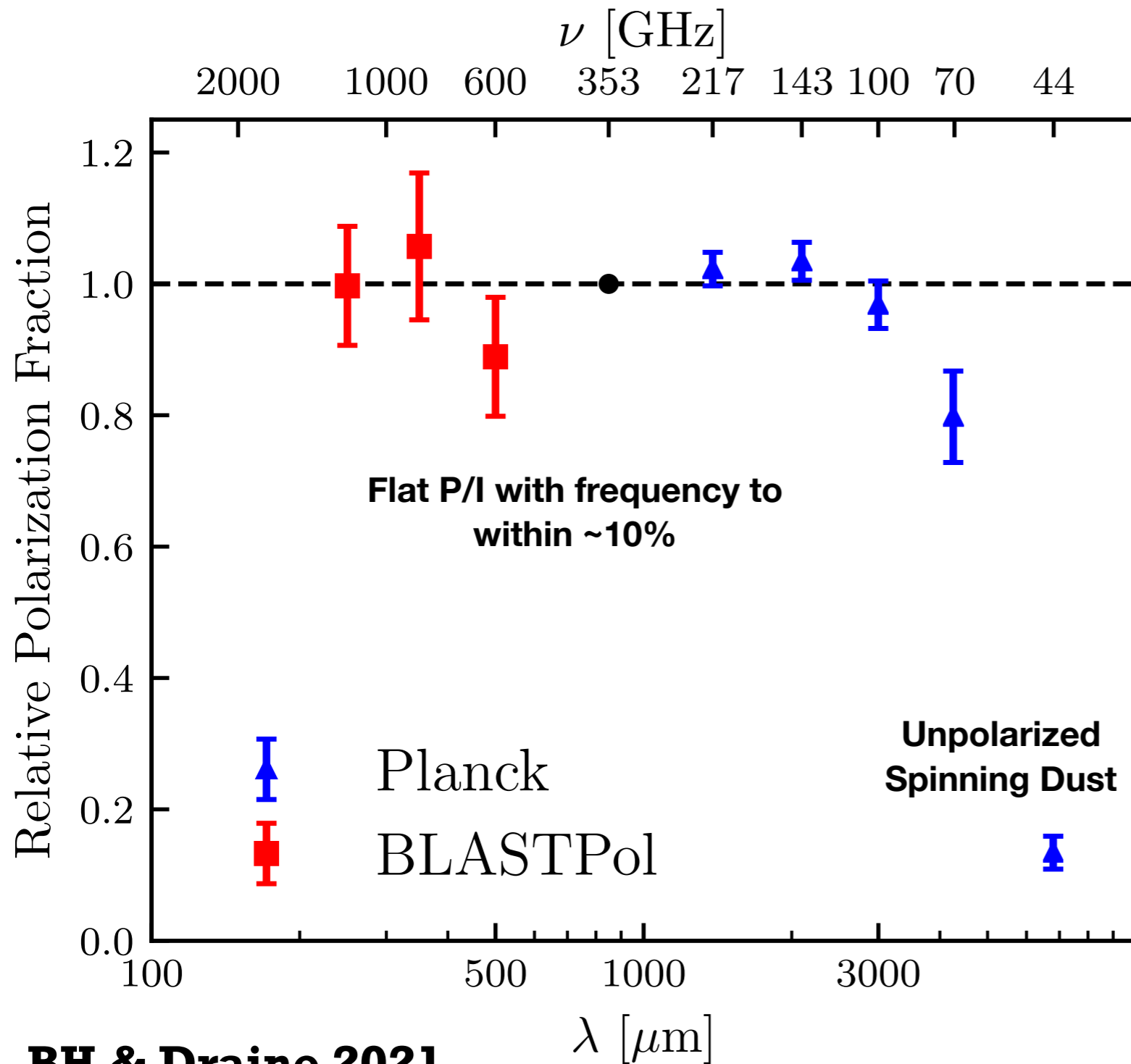
- First full-sky look at dust polarization
 - Relationship between dust, gas, and magnetic fields in star-forming regions and across the sky
 - Applications of statistics like EE/BB and TE from cosmology to understand MHD turbulence in the ISM
 - Measurements of the polarized dust SED and its connections to starlight polarization, constraining grain composition, shape, and porosity

Dust Polarization with Planck

Dust polarization fractions in excess of 20%!



Polarization Fraction































BH & Draine 2021

- Difficult to reconcile both high ($\sim 20\%$) and frequency-independent polarization fraction with two component dust models
- Dust β in total intensity and polarization roughly equal

Dust Science with CMB Data

- We seek to build on the incredible Galactic Science legacy of Planck
- SO Galactic Science Working Group (co-lead with Susan Clark): new forecasting paper outlining our vision
- ACT Galactic Science (co-coordinator with Susan Clark): will share some first results with much more to come!

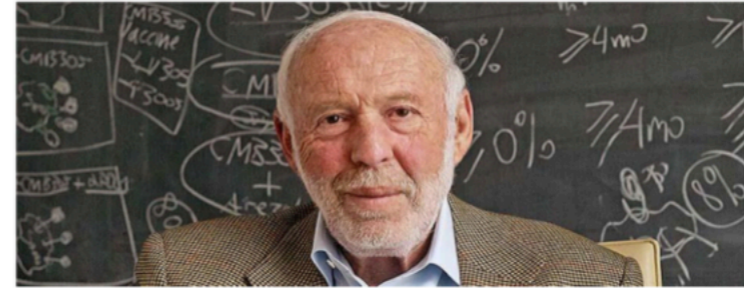
The Simons Observatory: Galactic Science Goals and Forecasts

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Simons Observatory (SO)

SIMONS
FOUNDATION

HEISING-SIMONS
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Construction of nominal project is funded privately and has already begun. >200 collaborators

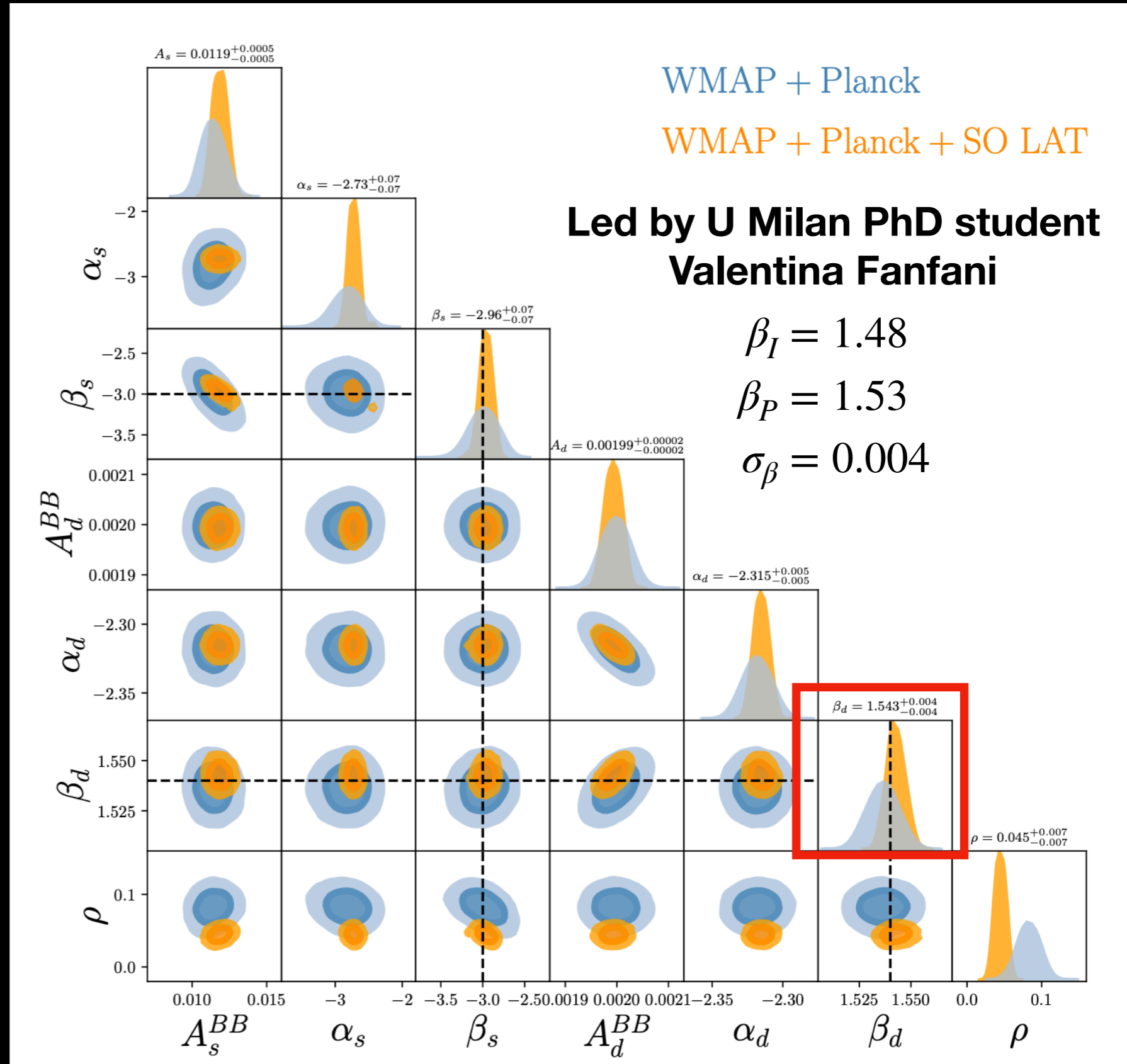


Testing Dust Models

- Planck measurements of the polarized dust SED broke the previous generation of dust models
- Currently no significant difference in SED in intensity (“T”) vs polarization (“P”), but best fit values of dust β differ by $\sim 2\sigma$
- Sensitive polarimetry from SO can make the definitive test while marginalizing over uncertainties in Galactic emission properties

SO Forecast

- How well can we constrain dust SED in polarization?
- Factor of ~ 2 improvement from WMAP+Planck
- Enough to establish β difference in T vs P if current best fit values are accurate

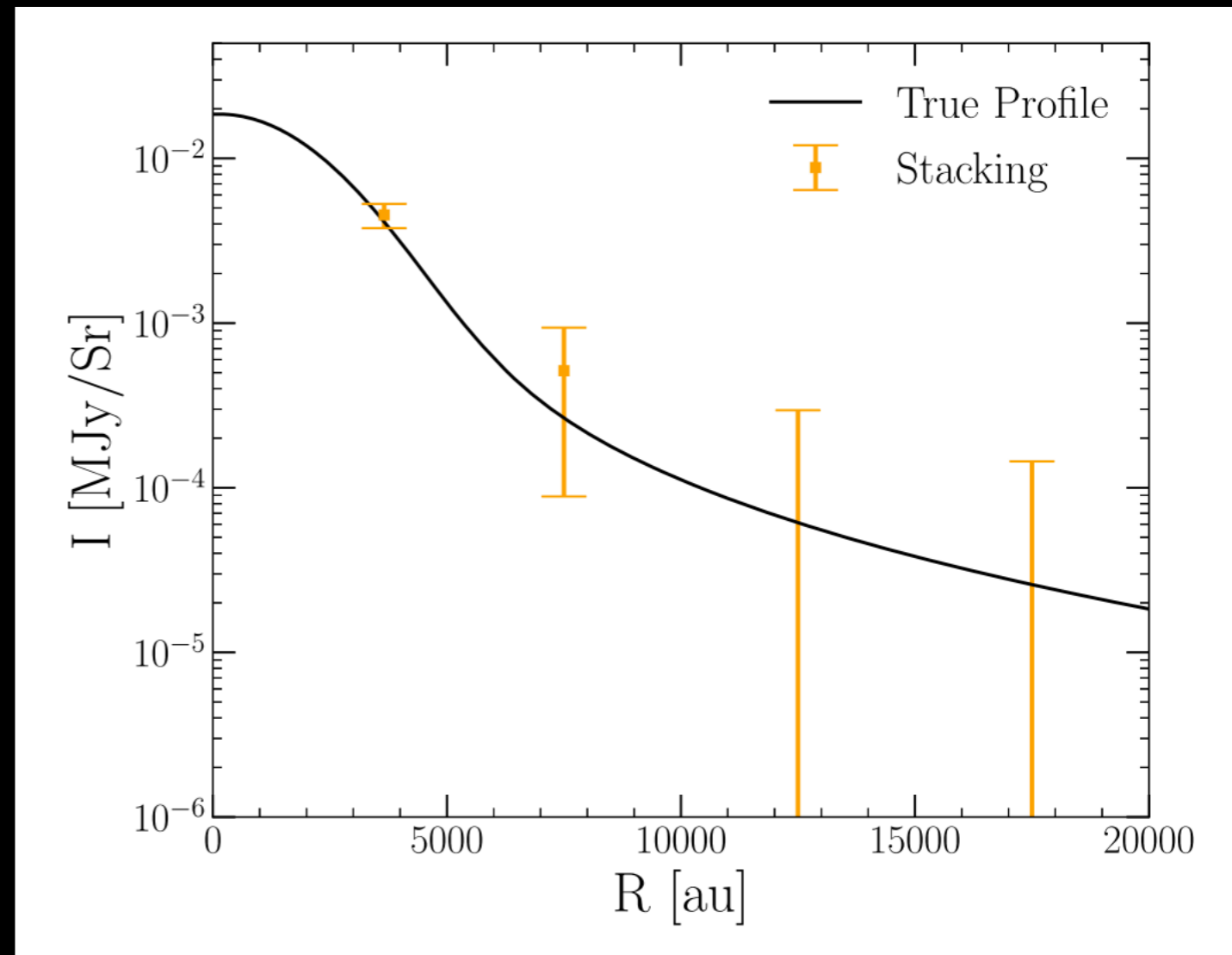


Exo-Oort Clouds

- 2×10^4 au Oort cloud at 300 pc = 1 arcmin
- CMB telescopes well matched for detecting thermal emission with stacking
- Methodology already used to constrain debris disks with Planck (Nibauer+ 2020)
- We expect $\sim 3\sigma$ detection of exo-Oort clouds with SO for fiducial model

2022 ApJ, 929, 166

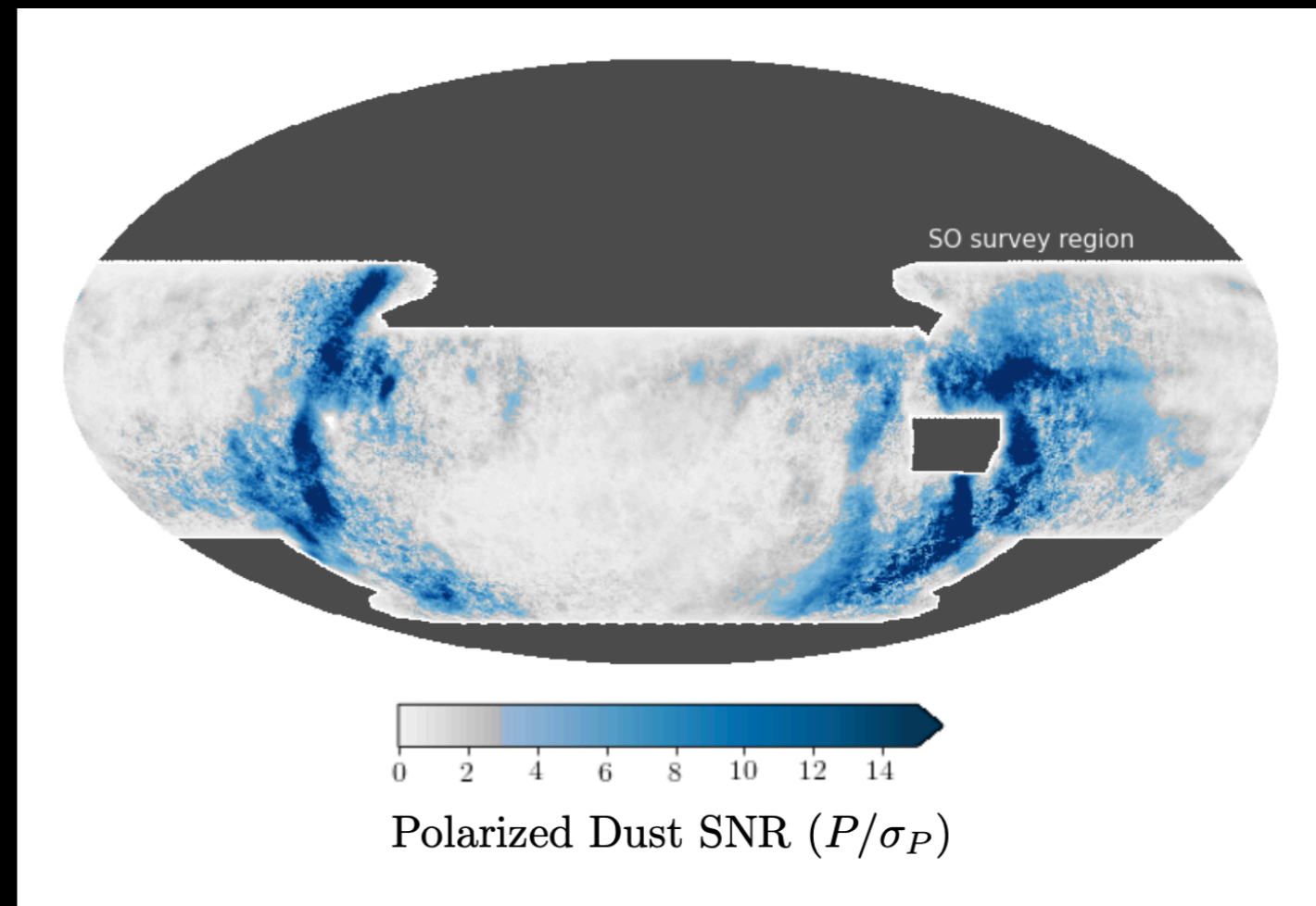
led by Jake Nibauer (Princeton PhD student)



Other Galactic Science Cases

- Measure 850 molecular clouds with at least 1pc resolution and 50 polarization vectors
- Map CO(2-1) and detect/limit CO polarization
- Search for AME polarization
- Test models of ISM turbulence

2022 ApJ, 929, 166

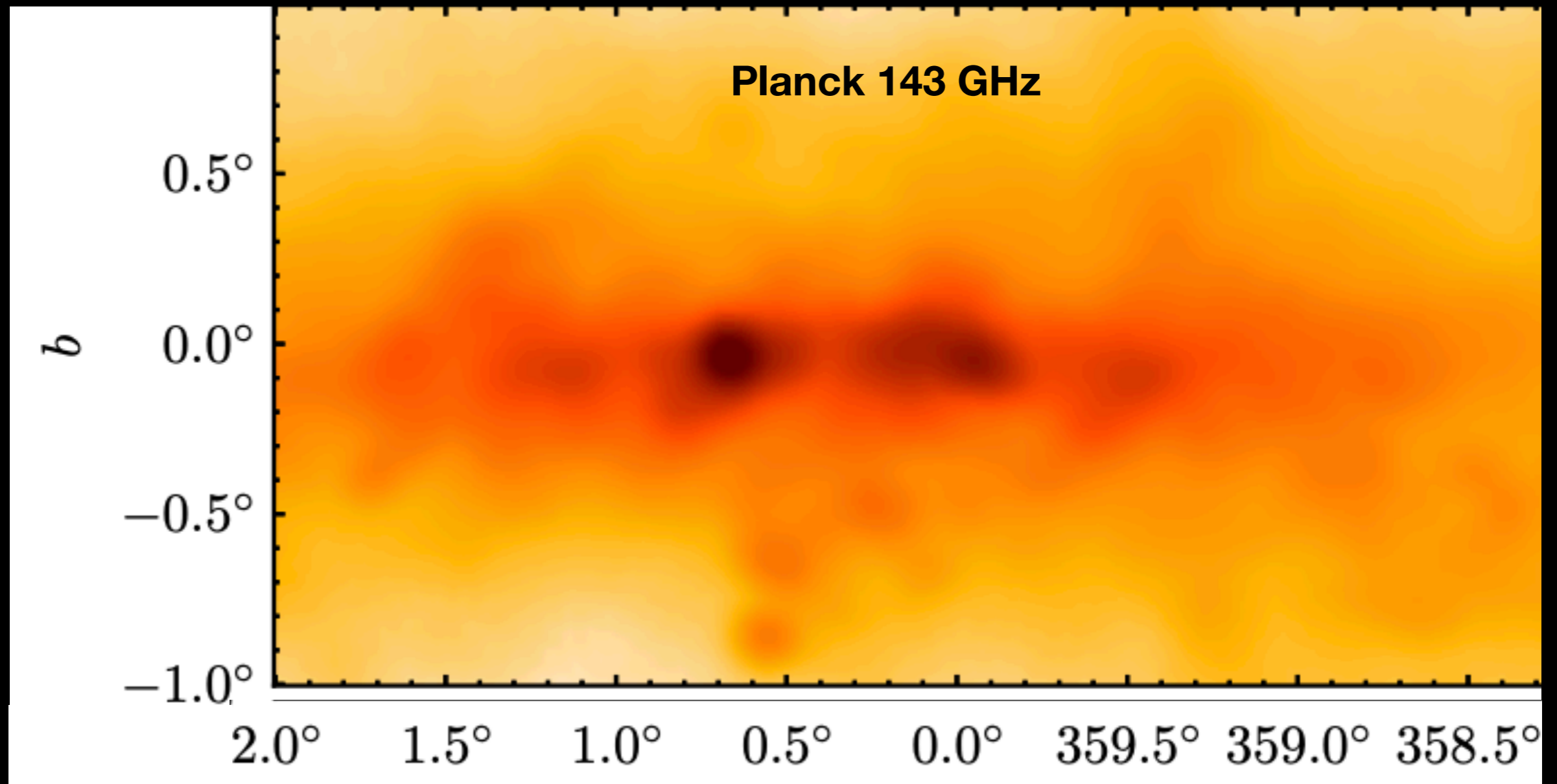


280 GHz at 3.4' resolution

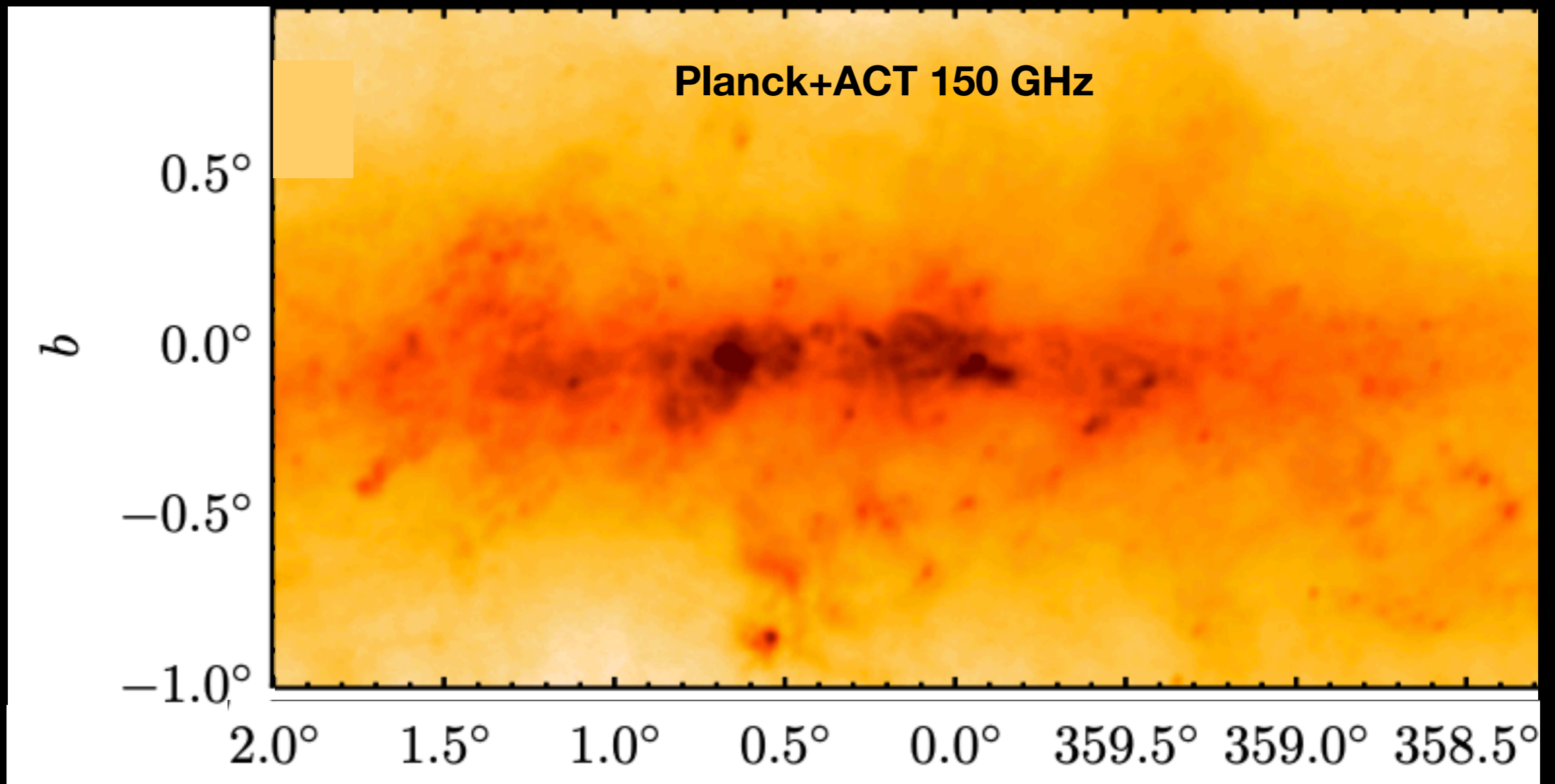
ACT Galactic Science

- ACT footprint is $\sim 40\%$ of the sky, including regions of the Galactic plane
- Dedicated observations of the Galactic Center
- Active Galactic Science group leveraging these data for a diverse range of astrophysics

The Galactic Center as Seen by Planck

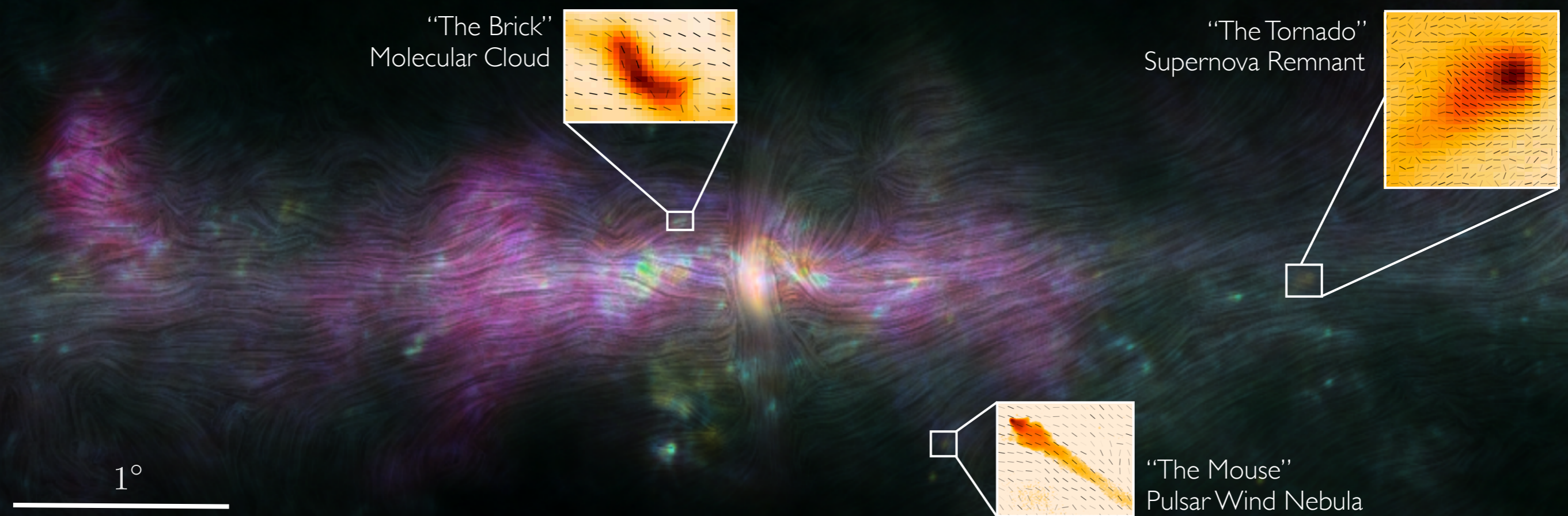


The Galactic Center as Seen by Planck+ACT

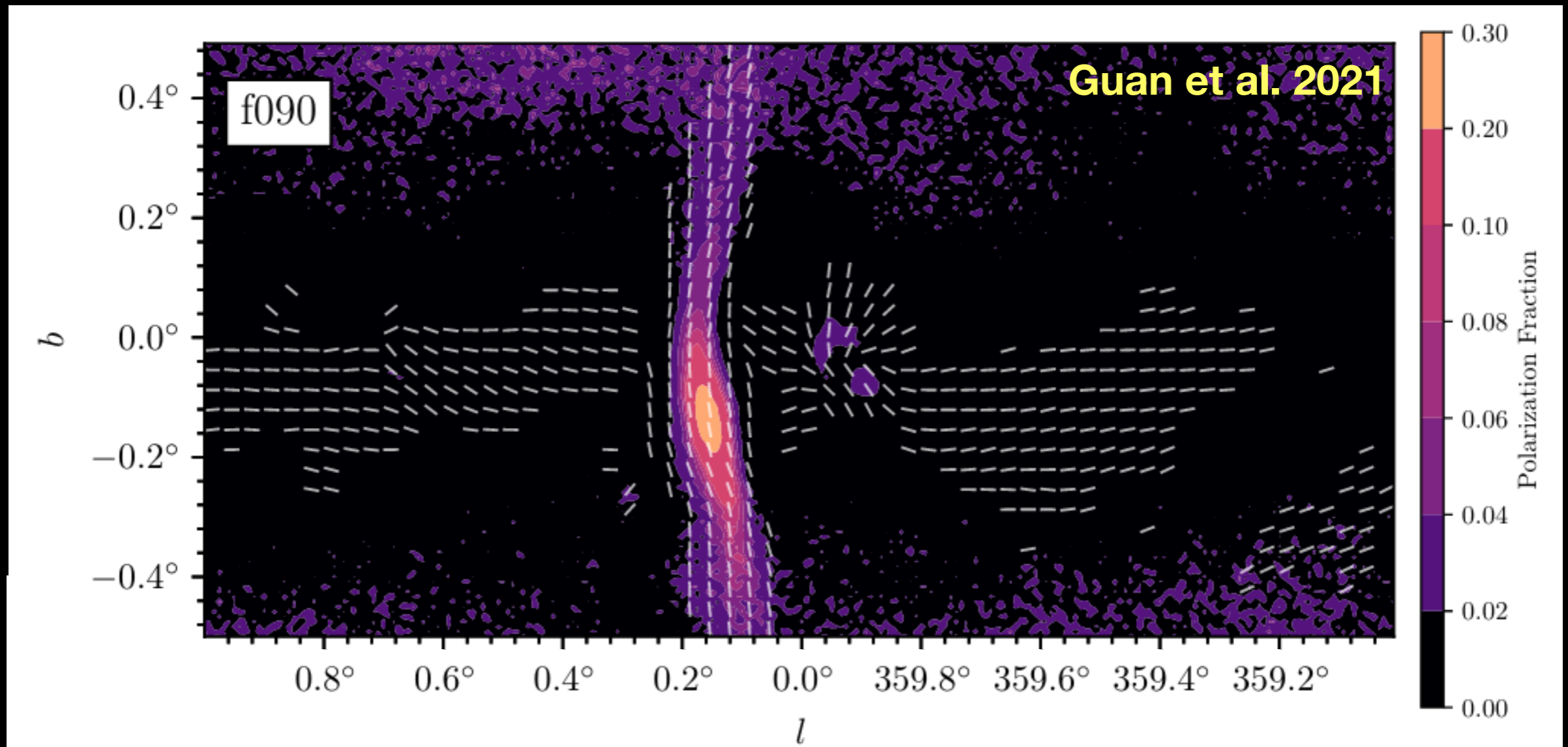


New Views of the Galaxy with CMB Telescopes

Three-frequency (90, 150, 220 GHz) map of the Galactic Center from ACT (**Guan**, Clark, **BH**, et al., 2021, ApJ)

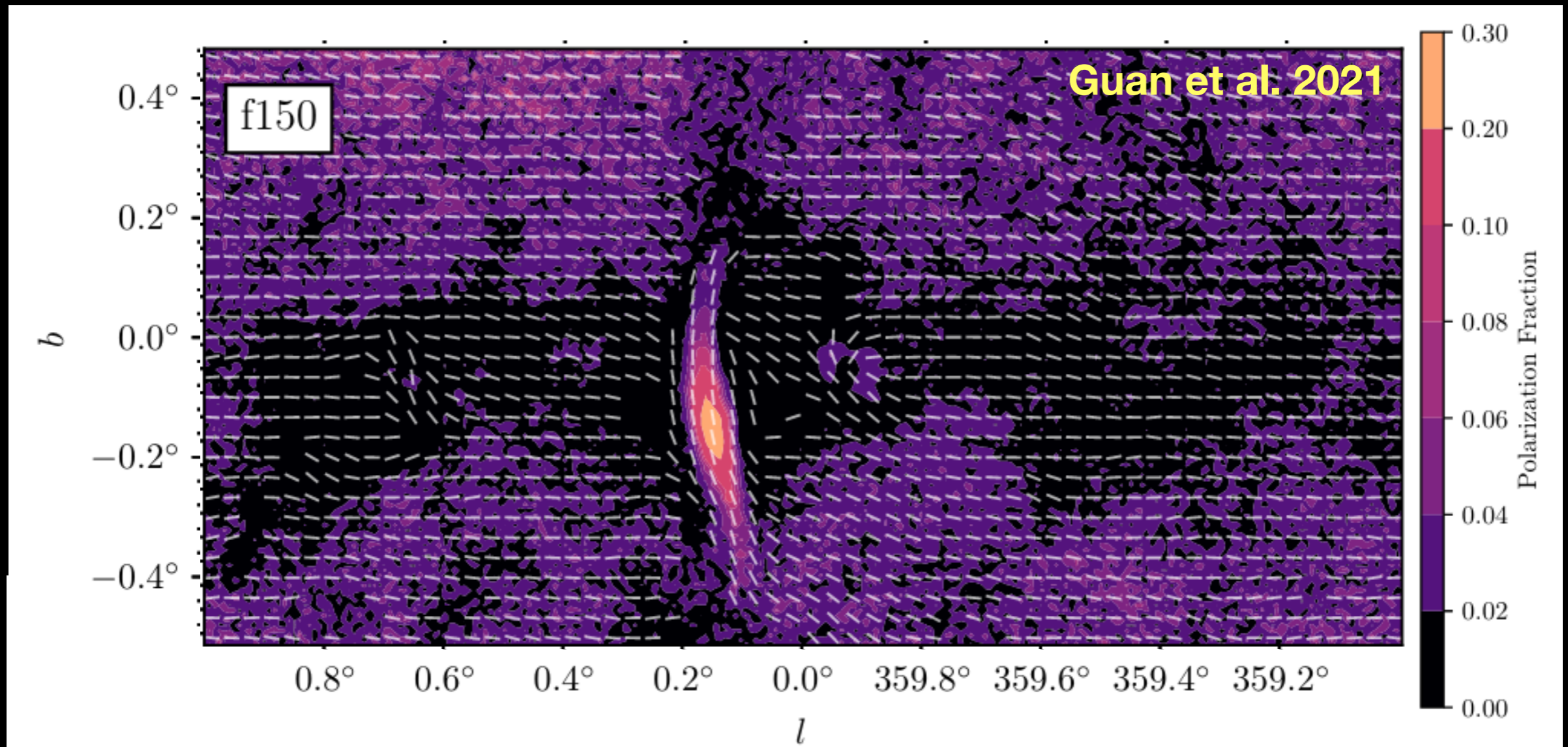


The Galactic Center as Seen by ACT



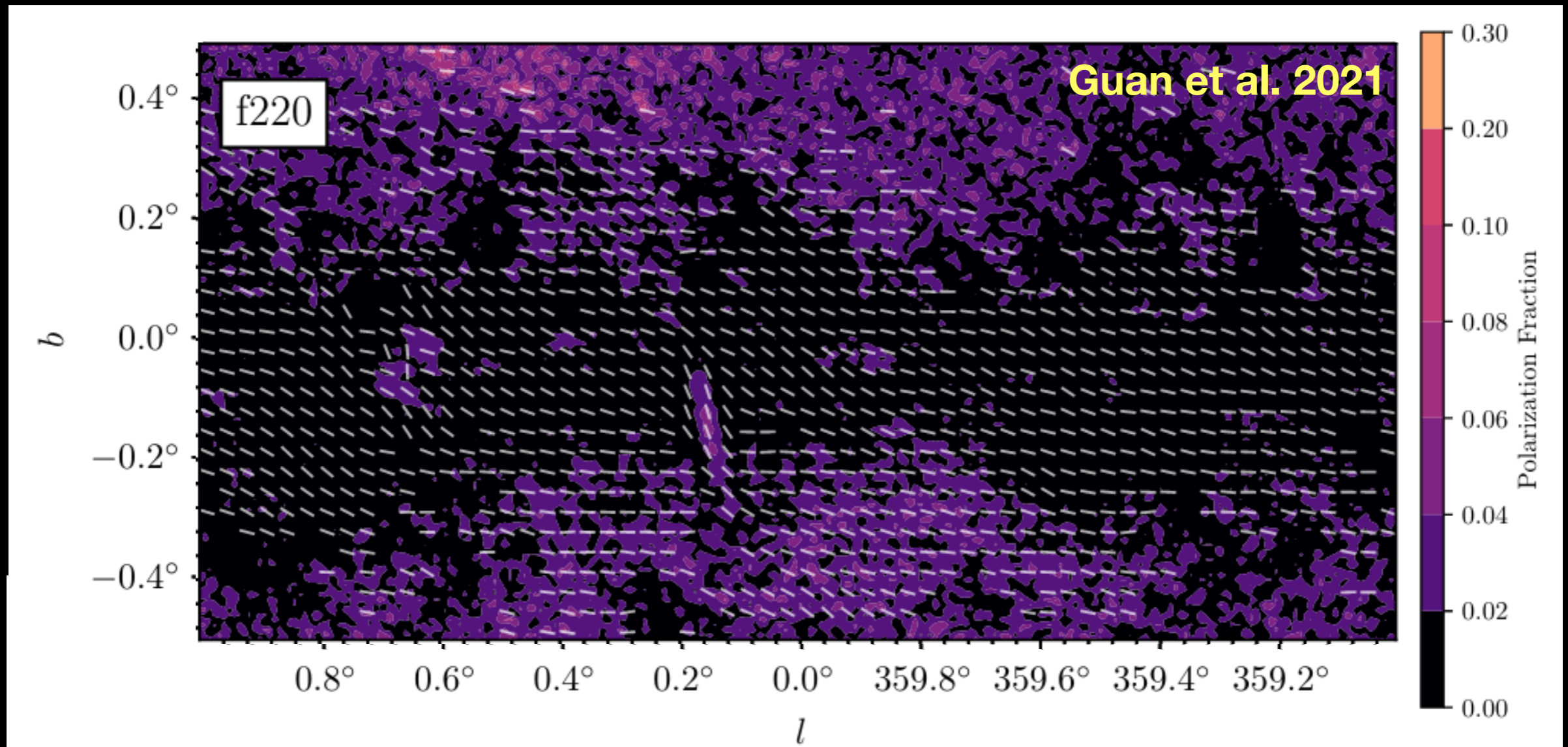
90, 150, and 220 GHz ACT data reveal different magnetic field morphologies

The Galactic Center as Seen by ACT



90, **150**, and 220 GHz ACT data reveal different magnetic field morphologies

The Galactic Center as Seen by ACT

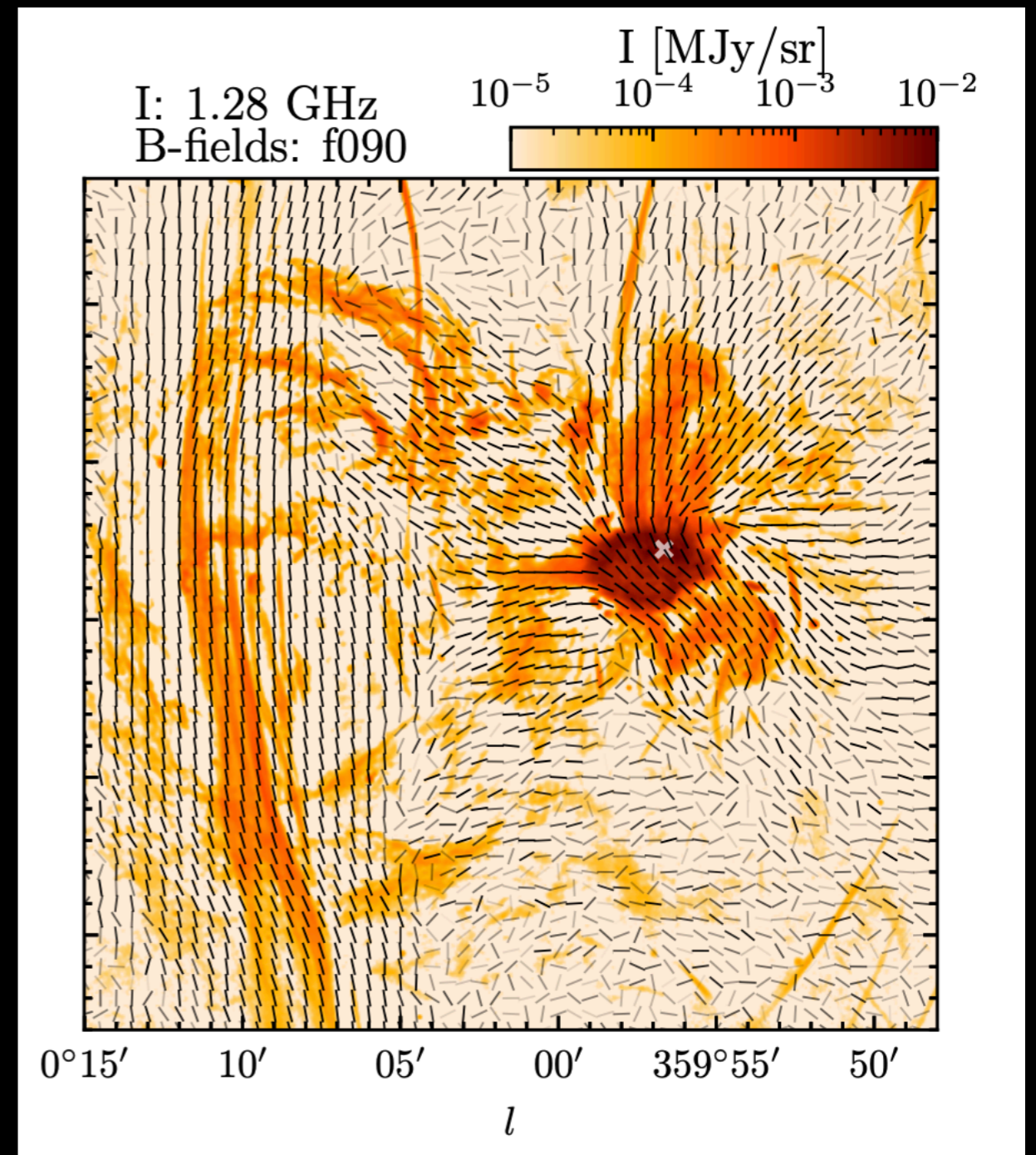


90, 150, and 220 GHz ACT data reveal different magnetic field morphologies

The Galactic Center as Seen by ACT

Guan et al. 2021

- Sgr A* and the radio arcs
- Comparison of radio emission from MeerKAT (image) and ACT polarization vectors
- Excellent agreement: *unrotated* synchrotron emission at 90 GHz!



ACT Galactic Science

- Study of variations in the dust SED in the Orion region with evidence for a mysterious 90 GHz excess (Lowe et al. 2022)
- Other analyses in the works leveraging our sensitivity to small scales, large footprint, and frequency range spanning 30 to 220 GHz: stay tuned!

Other Galactic Science Goals

- Have focused here in Galactic ISM, but other Milky Way science of great interest (and often with dedicated working groups):
 - Search for Planet 9 and other Solar System science
 - Transient science

Galactic Science to Foregrounds

- Leveraging Galactic ISM expertise to make next generation full-sky simulations of Galactic emission with PySM: <https://github.com/galsci/pysm>
- Work being done in the Pan-Experiment Galactic Science Group—get in touch if you are interested in participating!

Summary

- Not just foregrounds! Galactic astrophysics is an exciting science opportunity for CMB data (that feeds back into foreground modeling, too!)
- Roadmap in place that builds on the Planck legacy with work already starting with ACT data
- Looking ahead to 2030s too, with CMB-S4 and LiteBIRD