

Novel Techniques to Probe 3D Interstellar Magnetic Fields

Using Faraday Rotation & Dust Polarization

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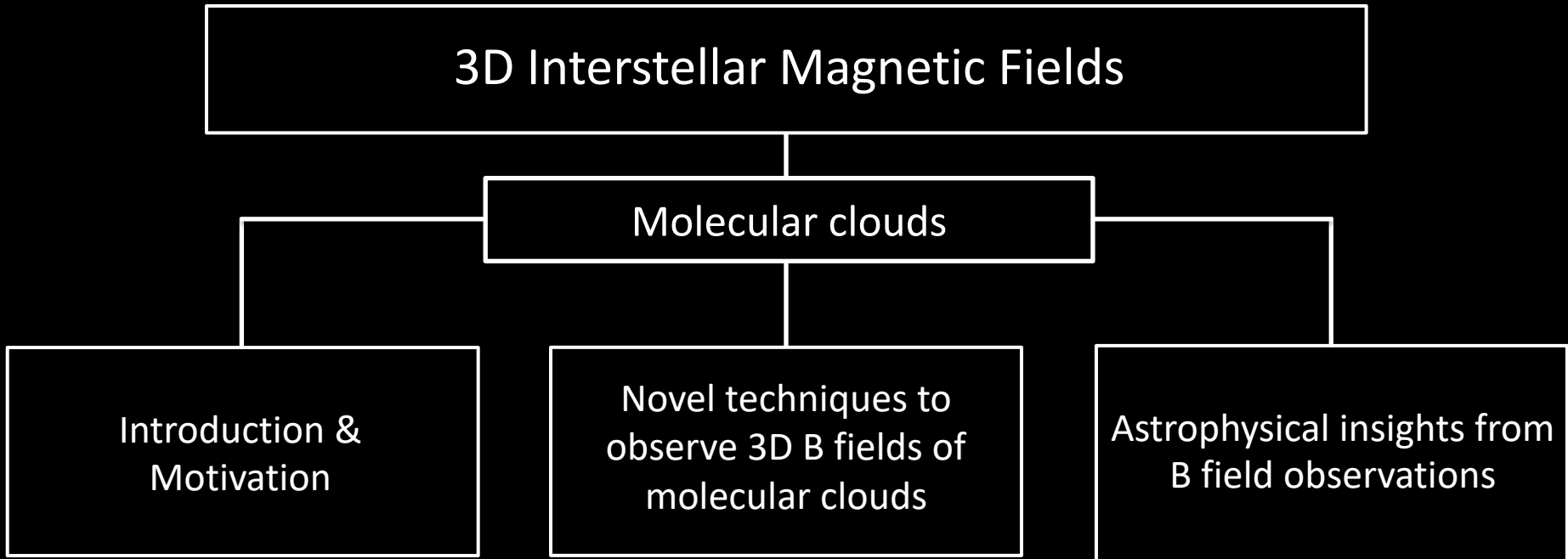
*: student



BANTING FELLOWSHIP (SPONSORED BY THE
GOVERNMENT OF CANADA)

Stanford

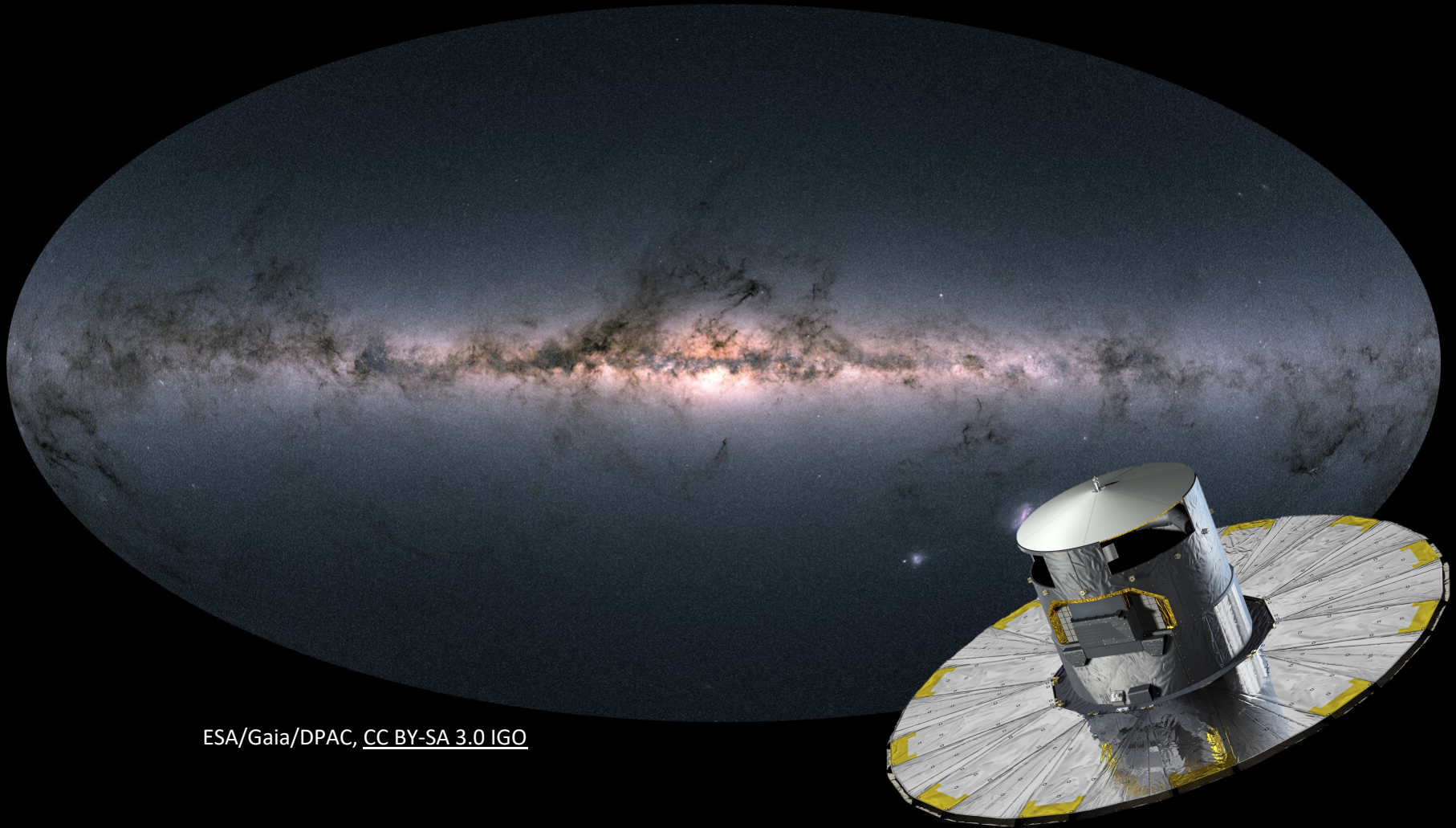
KIPAC FELLOWSHIP (KAVLI INSTITUTE FOR
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B Field: Magnetic field

Pesky Galactic Foreground? 🤔

3D Galactic Structure & Evolution



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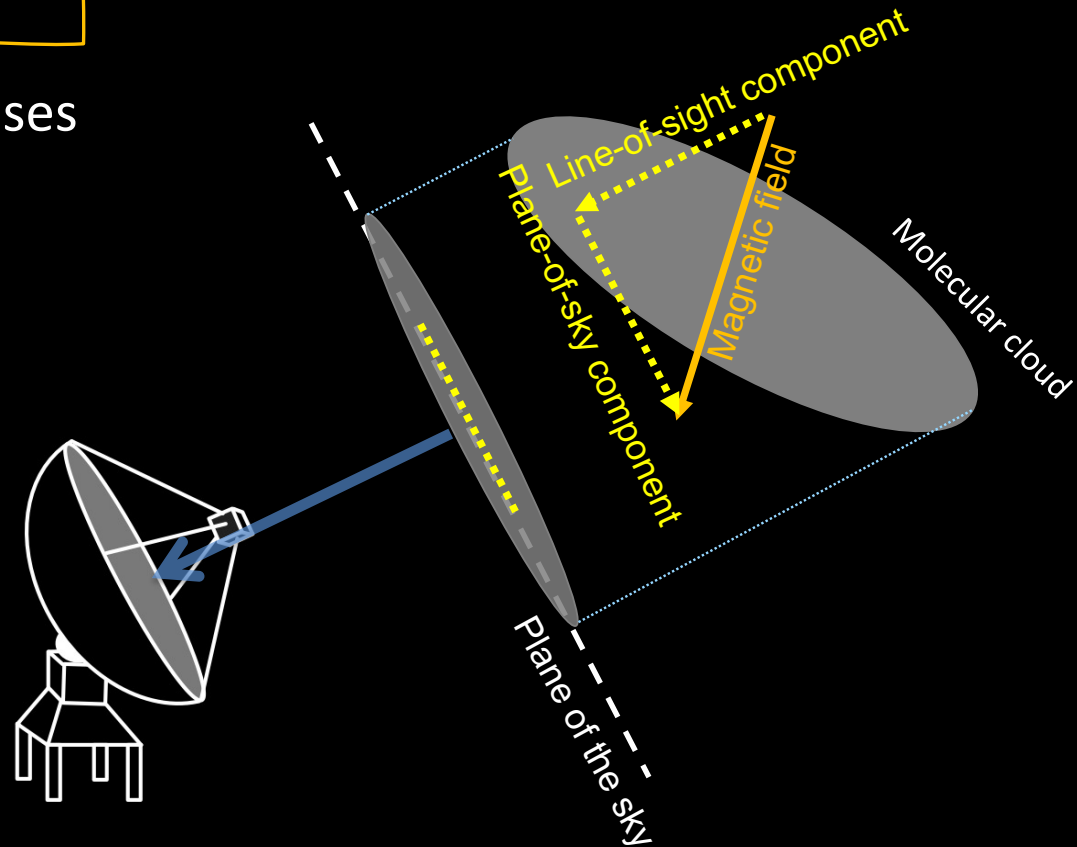
B Fields in Star Formation

Friend, Enemy, Frenemy?



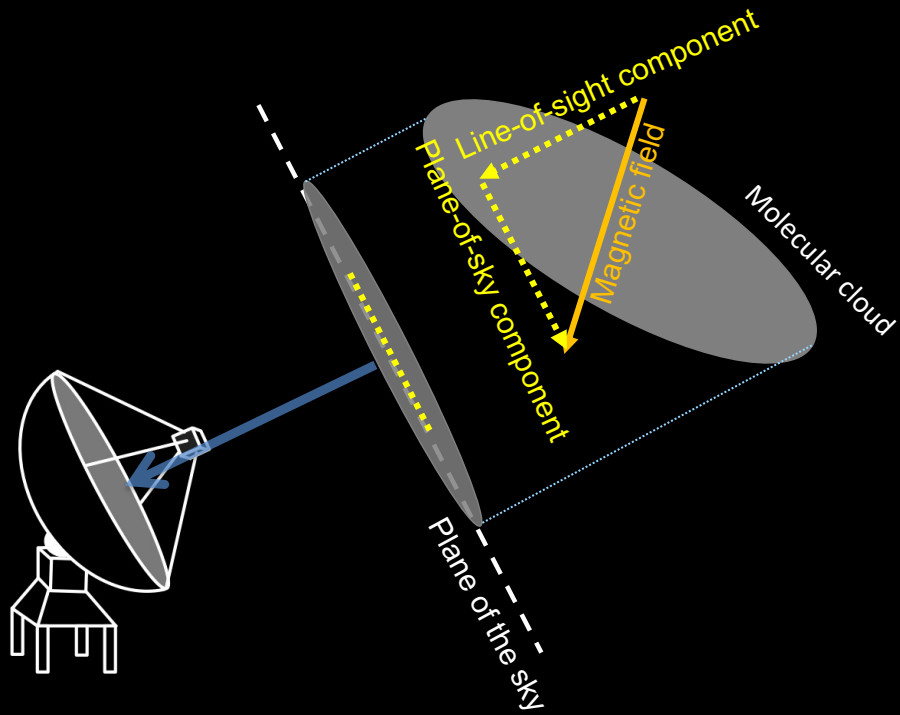
We know

- Influence from the early phases
- Can slow down the process (depending on orientation)
- No stars without magnetic fields! (magnetic braking)

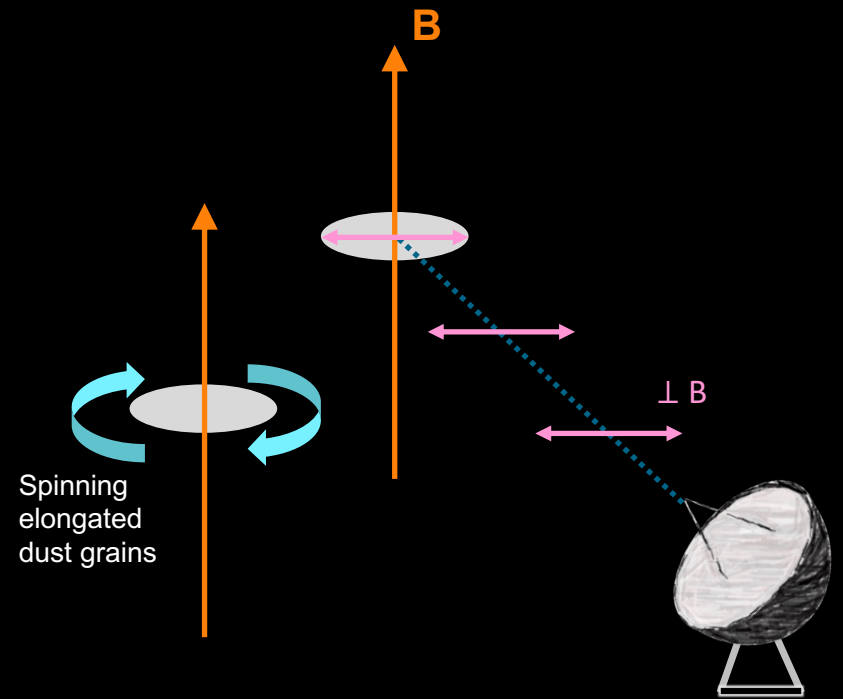


3D Magnetic Fields of Molecular Clouds

Plane of Sky



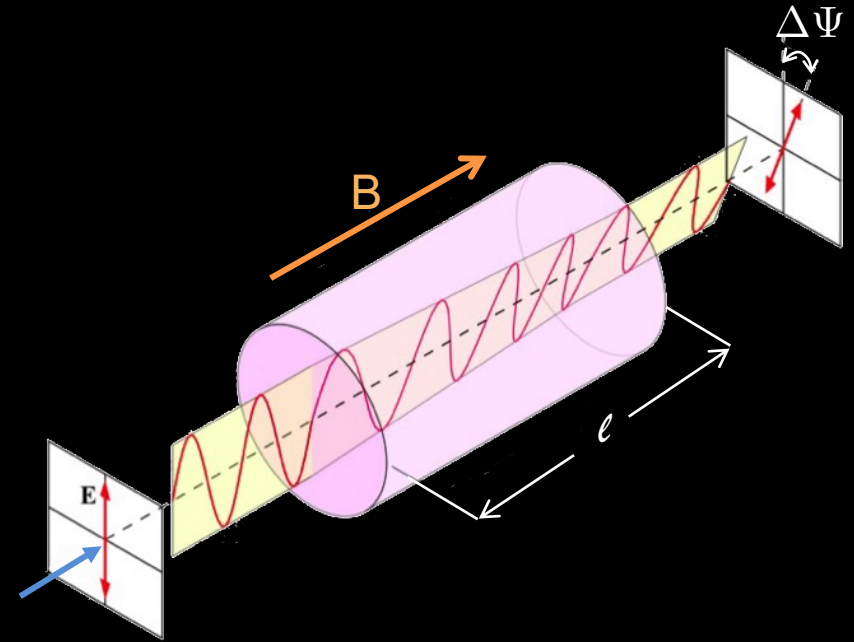
Dust Polarization



3D Magnetic Fields of Molecular Clouds

Line of Sight

- Linearly polarized electromagnetic wave
- Magnetized region with free electrons
- Plane of polarisation rotates



$$\Delta\Psi \text{ (rad)} = \lambda^2 \left(0.812 \int n_e \mathbf{B} \cdot d\mathbf{l} \right) = \lambda^2 \text{RM}$$

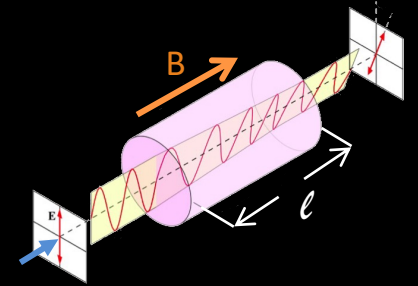
λ : wavelength

n_e : electron volume density

RM: rotation measure

Finding B of Molecular Clouds Using Faraday Rotation

Q1: How can we decouple the Galactic Faraday rotation from the filamentary structure?



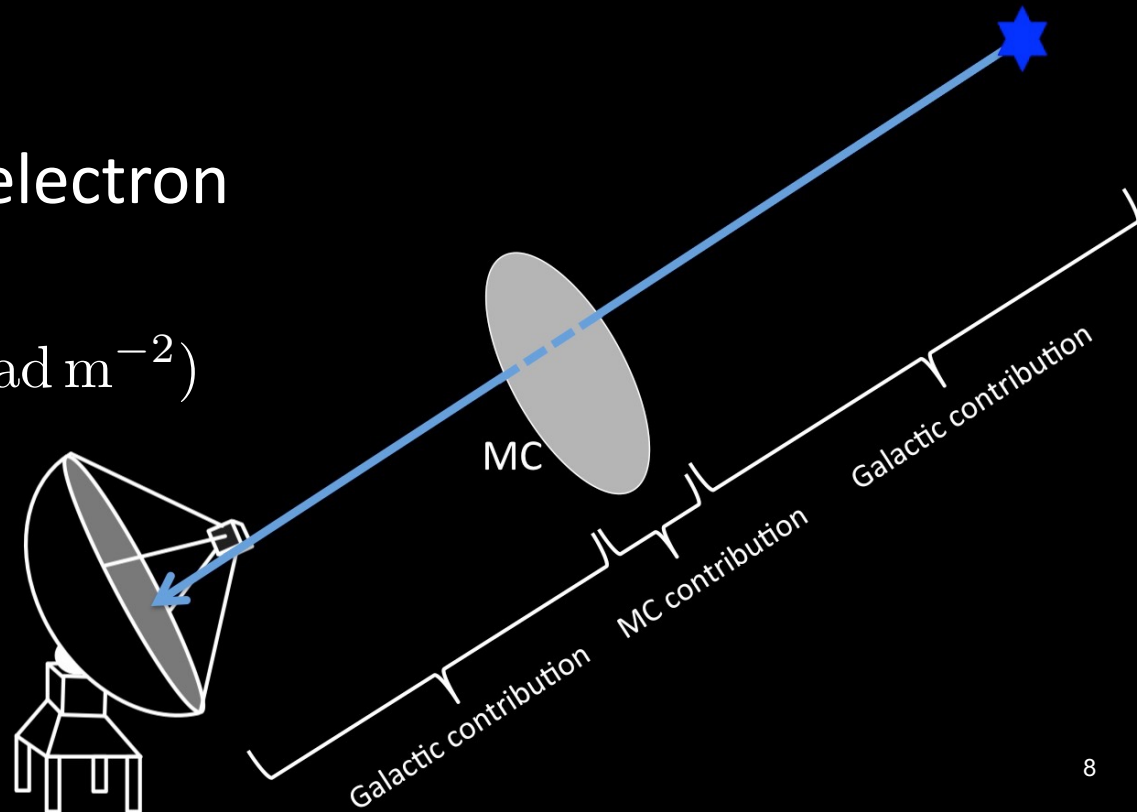
on-off approach

Q2: How can we find electron density and dl ?

$$0.812 \int n_e \mathbf{B} \cdot d\mathbf{l} = \text{RM} \text{ (rad m}^{-2}\text{)}$$

Column density maps (Kainulainen et al. 2009)

Chemical evolution code (René Plume)



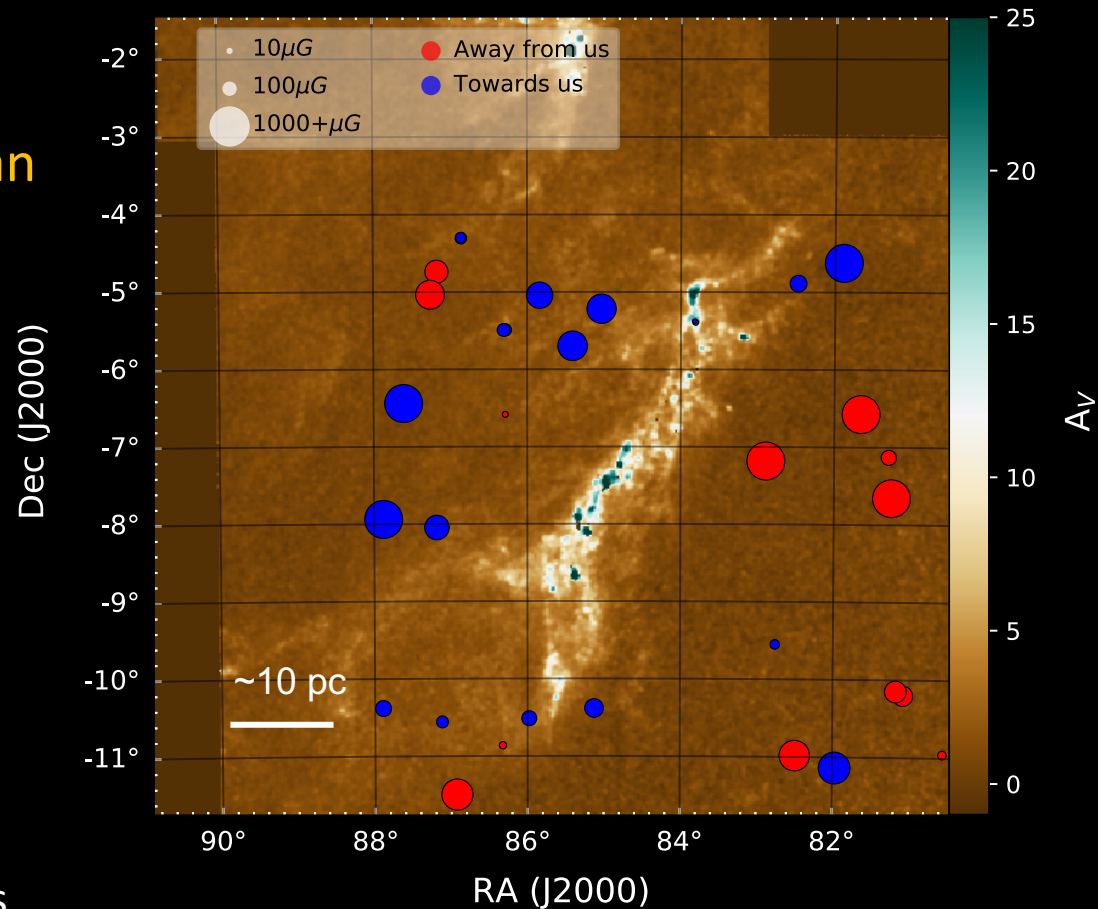
Line-of-Sight B Fields

- Significant Results
 - Consistent with existing nearby molecular Zeeman measurements
 - Orion A cloud:
 - Previous observations
 - Investigated in theoretical studies



GitHub:
MehrnooshTahani/
MappingBLOS_MolecularClouds

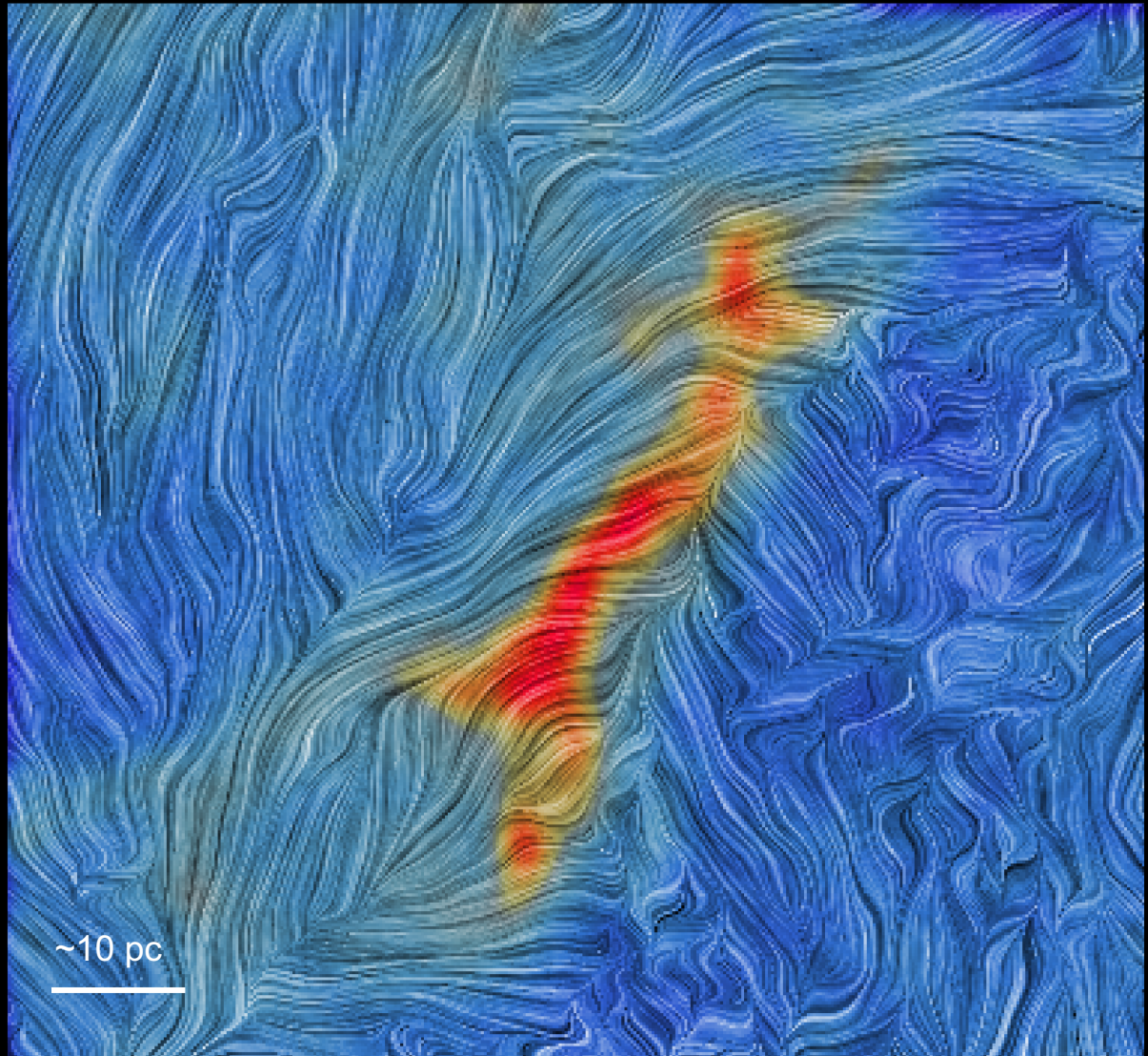
Magnetic Field Measure in Orion A



Tahani et al. 2018, A&A, 614, A100

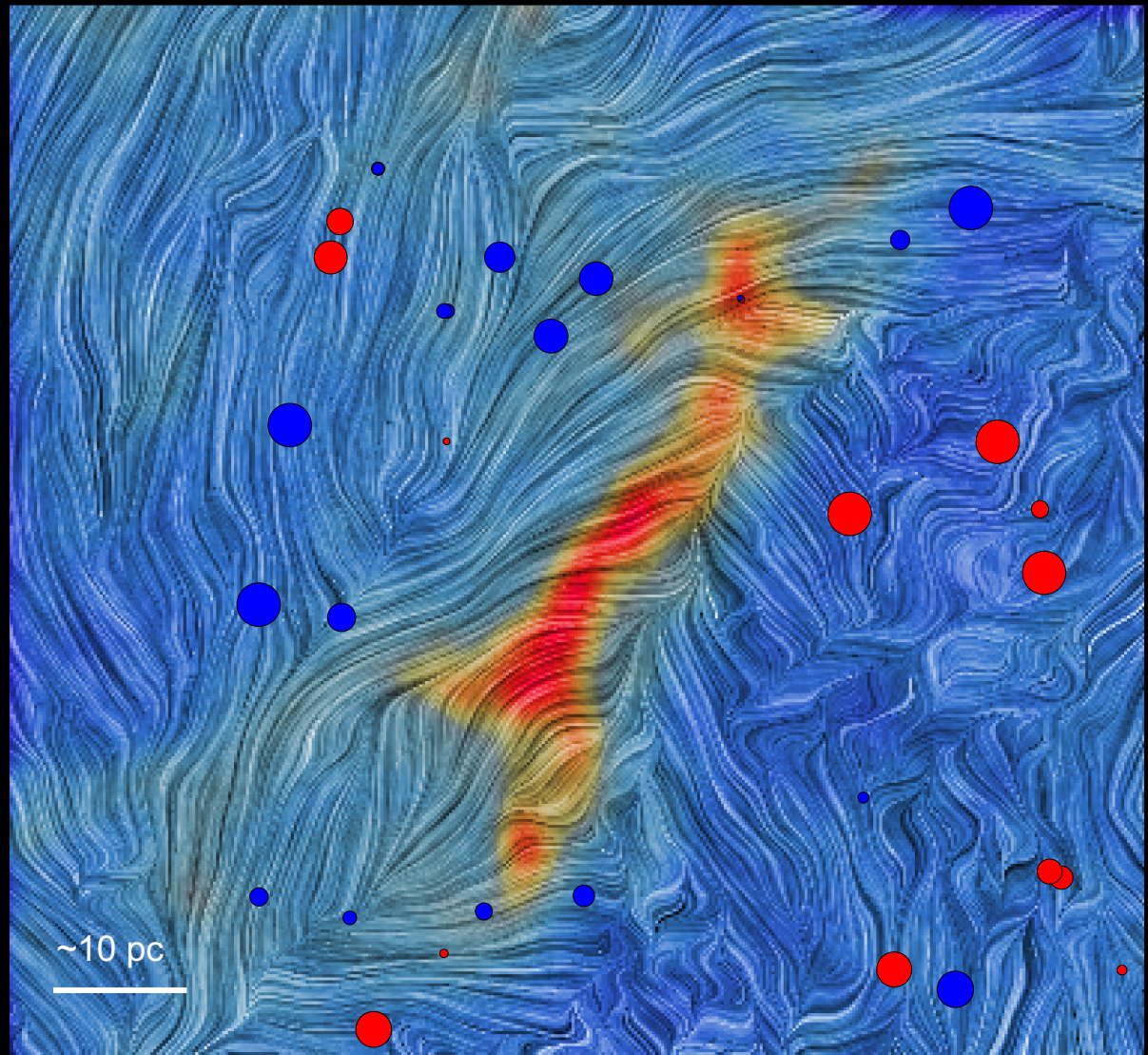
The 3D Magnetic Field of Orion A

- Planck's plane-of-sky and our line-of-sight magnetic field results
- Constructed models that could explain the line-of-sight observations



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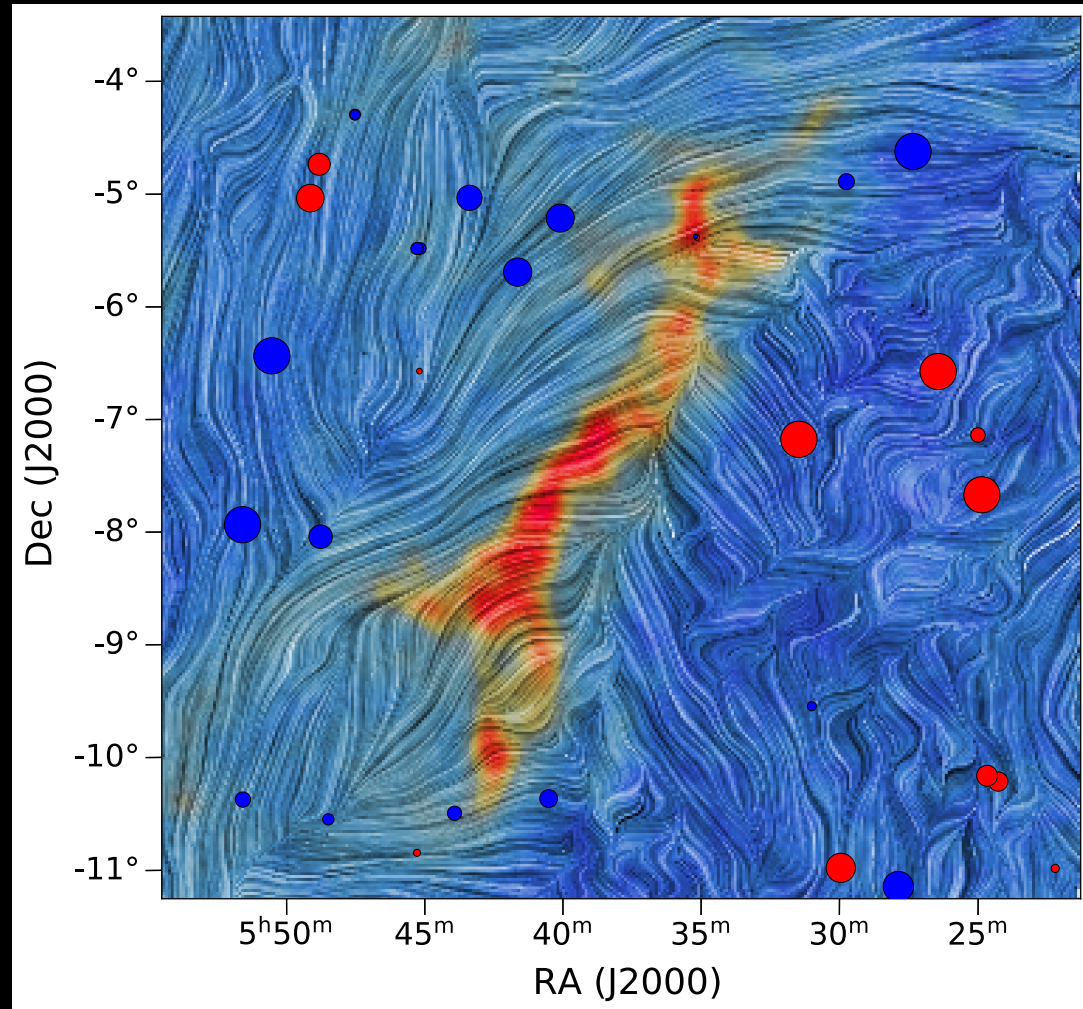
Monte-Carlo Analysis

+

Investigating a range
of systematic biases

+

χ^2 probability values



Tahani et al. 2019, A&A 632, A68

The 3D Magnetic Field of Orion A

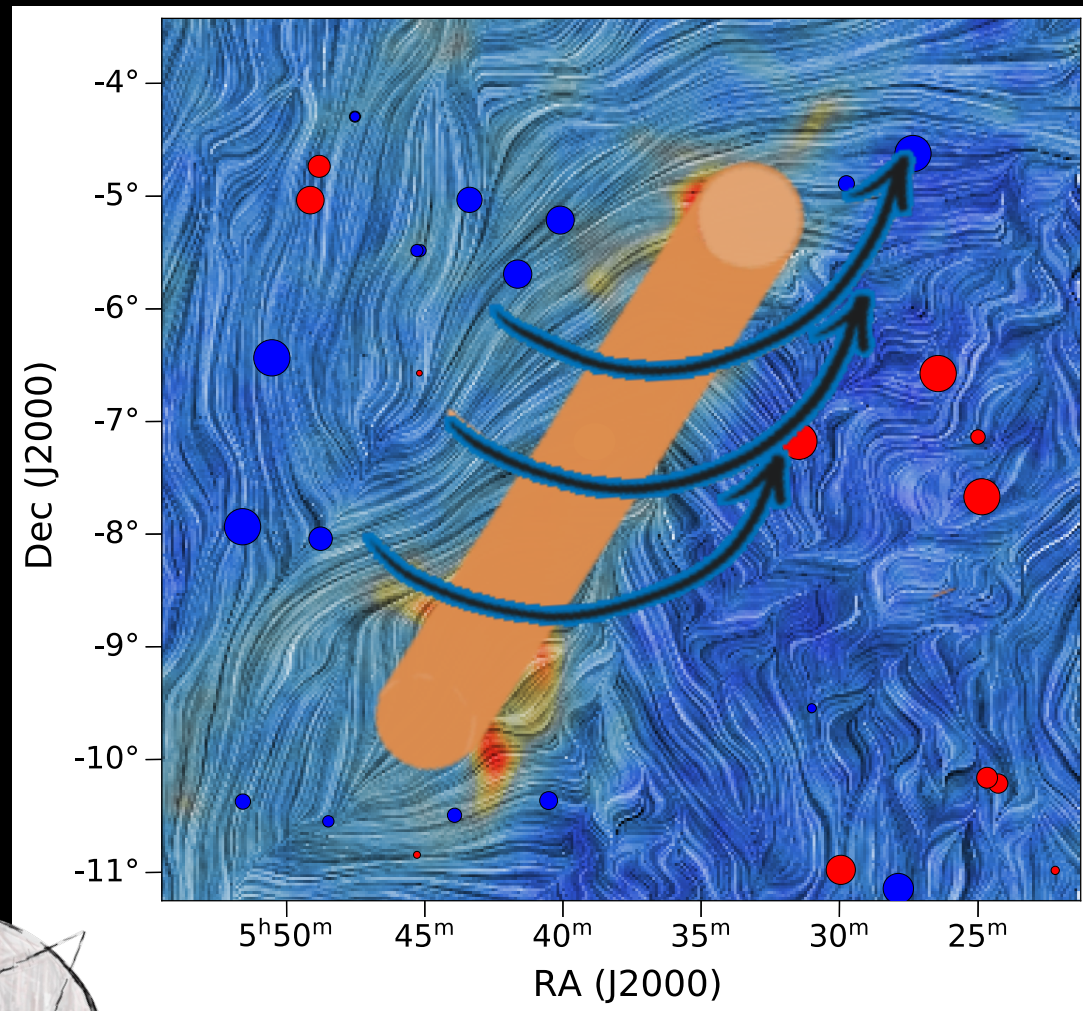
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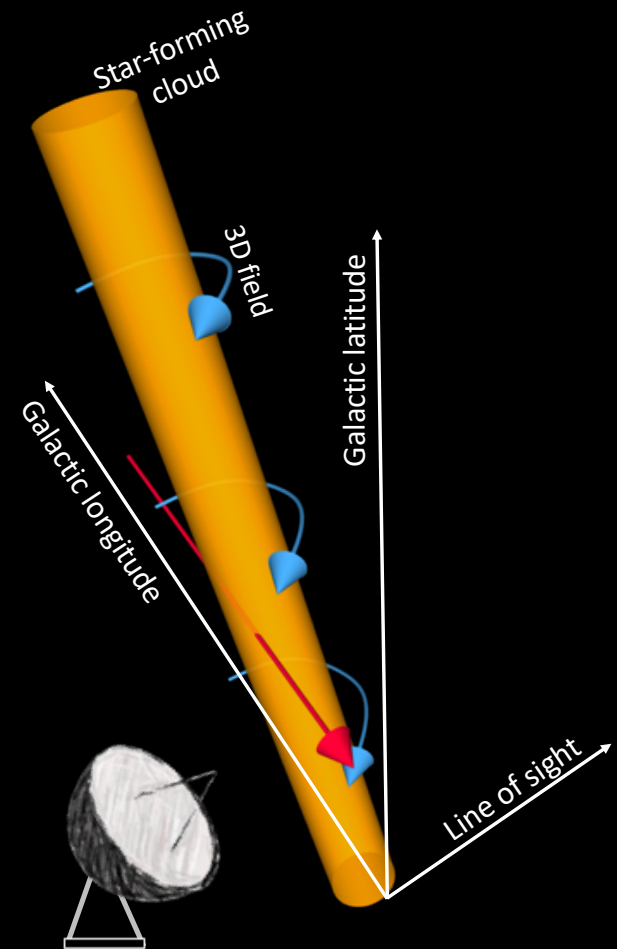
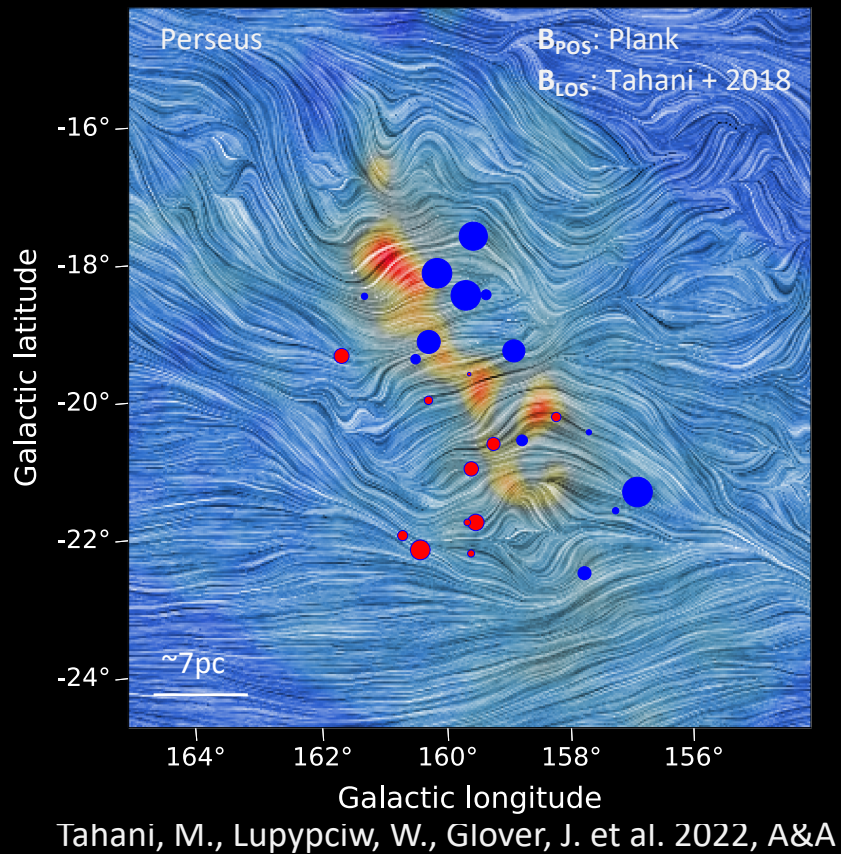
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χ^2 probability values



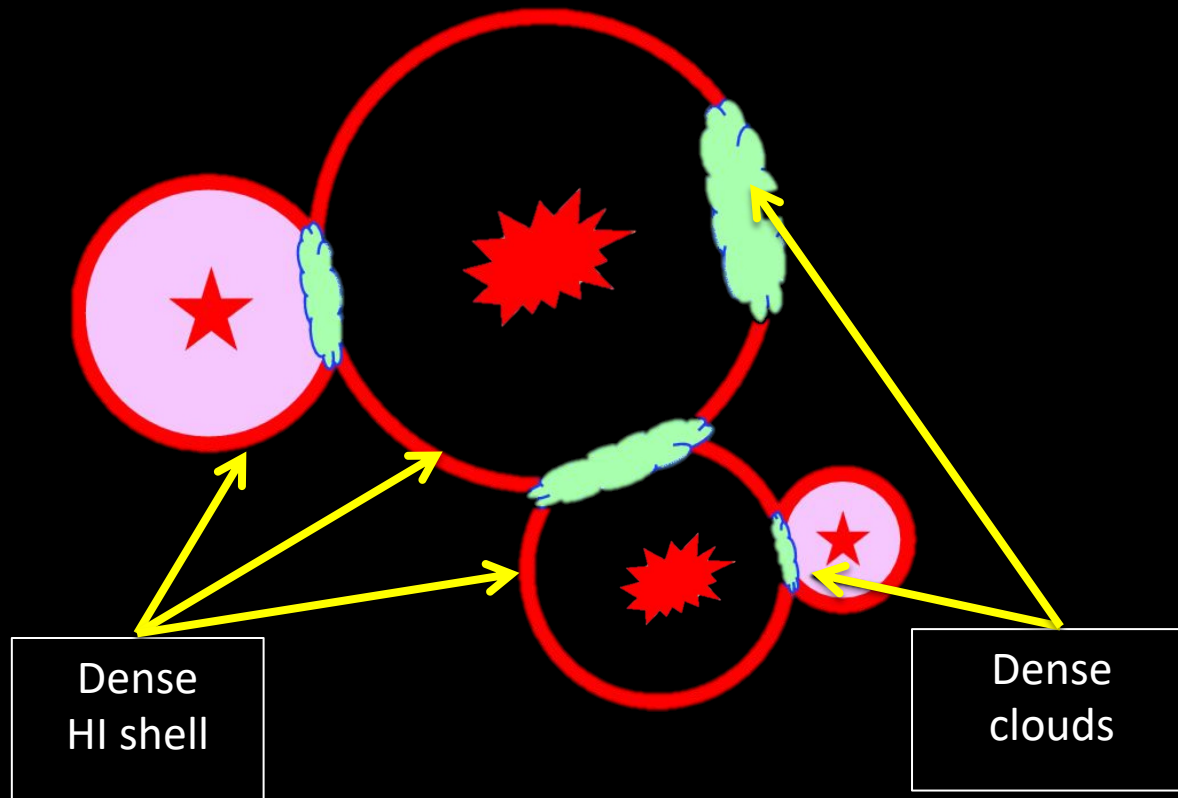
Tahani et al. 2019, A&A 632, A68

Complete 3D Magnetic Field Morphologies



Astrophysical Insights from B Field Observations

Cloud Formation

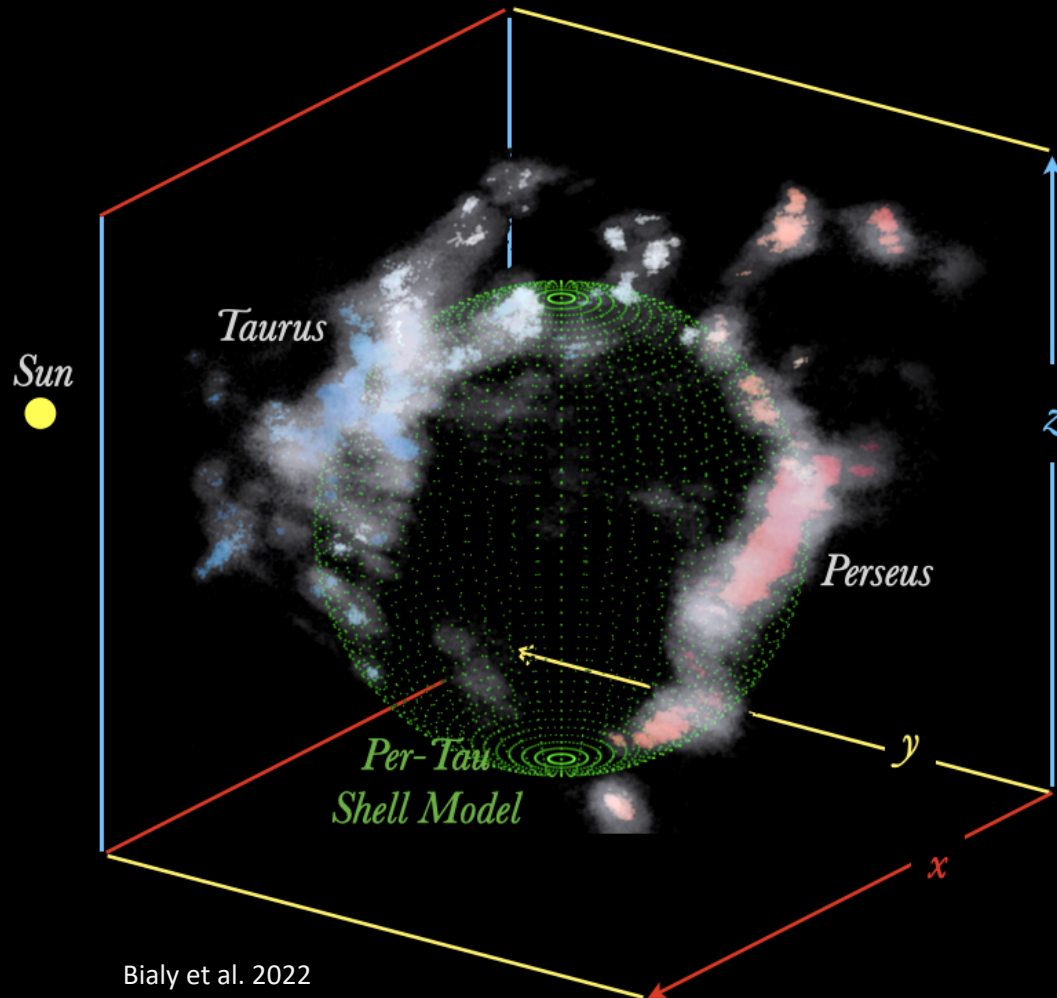


Inutsuka et al. 2015

Astrophysical Insights from B Field Observations

Cloud Formation

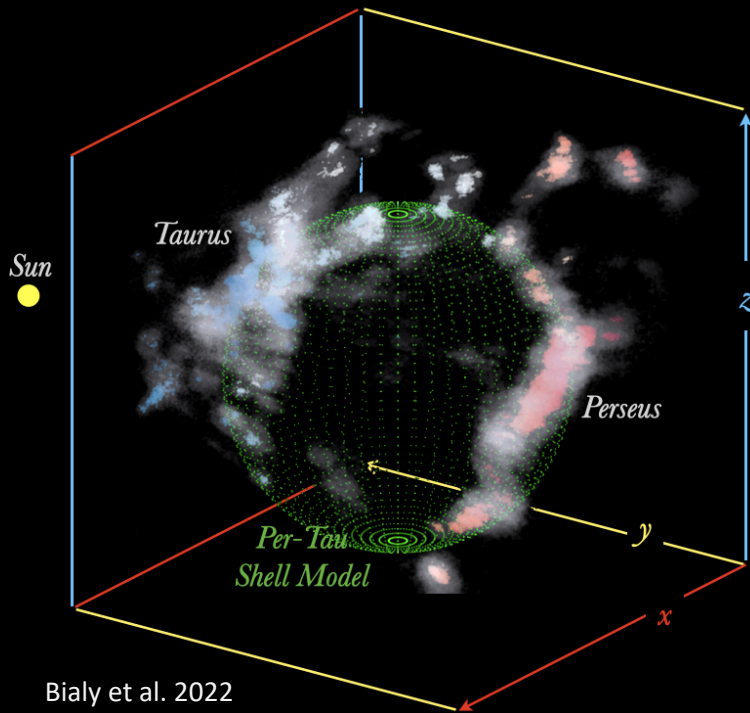
“side-on” view of Per-Tau Shell, Sun at left



Astrophysical Insights from B Field Observations

Cloud Formation

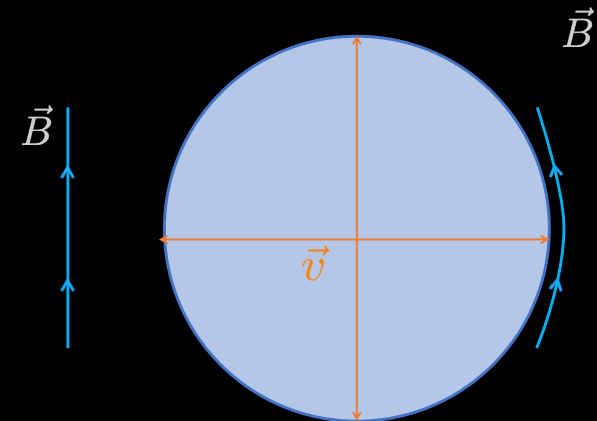
“side-on” view of Per-Tau Shell, Sun at left



Bialy et al. 2022

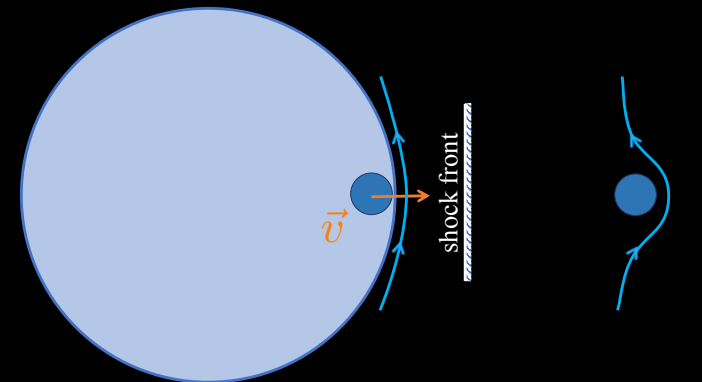


*



initial magnetic field

moderate magnetic field bending caused by the Per-Tau bubble



before interaction

after interaction

Kounkel et al. 2022

Tahani et al. 2022

To map the 3D magnetic field employing multi-wavelength approaches, we require new and improved observations!

Summary

- Magnetic fields influence the evolution of galaxies and the formation of structures, clouds, substructures within clouds, and ultimately stars.
- We developed techniques to probe the line-of-sight and three-dimensional magnetic fields of molecular clouds.
- Observations of 3D magnetic fields enable us to paint a comprehensive picture of various astrophysical phenomena, such as cloud formation.

