The Galactic ISM in 3D: Plenary summary
Imprint of Galactic magnetic field at CMB frequencies
Dust
A new era for ISM studies: Open questions post-Planck

Structure of the Galactic Magnetic Field
- (How) can we create an accurate 3D model?
- What is the effect of local (~kpc radius from Sun) ISM structure on polarization maps?

Initial conditions of star formation
- How do star-forming clouds form from the diffuse, strongly magnetized ISM?
- How is the evolution of cloud structure affected by the magnetic field?

Microphysics of dust grains
- What is the composition of dust grains?
- How are dust properties affected by galactic environment?

MHD turbulence in multiphase ISM
- What leads to structural correlation between cold neutral and ionized phases?
- How does turbulence influence the propagation of cosmic rays?
Current models of Galactic Magnetic Field

Which one (if any) is correct?

Jaffe (2019)
Current observations (Planck) cannot discriminate between models

Situation worse with dust emission: no model reproduces observed properties

Accurate models of 3D Galactic Magnetic Field are missing, but essential...
Large-scale B field structure needed to test models for molecular cloud formation

M. Tahani’s talk

Clouds proposed to form from consecutive compressions driven by SN shocks

3D B field would show bow shock geometry related to initial velocity and Galactic magnetic field

Inutsuka et al. 2015

Inoue (2018)
Hint of bow shock geometry from Rotation measures towards Perseus cloud

Need initial configuration of B field to distinguish from alternative formation scenarios
SN + stellar winds shape Galactic B field => nearby superbubbles appear large on sky

Galactic B field models missed memo about structures within our neighborhood

Evolution of cloud structure depends on B field - so does star formation

Access to high resolution critical
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New insights on MHD turbulence motivated by Planck

Filaments parallel or perpendicular to B field are attractor solutions of MHD equations (Soler+Hennebelle 2017)

Level of magnetization determines the relative orientation between filaments and the magnetic field
Simulations by Walch+(2015)

Traced by Planck polarized dust emission

But Planck only sees part of the turbulent cascade

To probe the magnetized ionized medium we need a different tracer...
Faraday rotation probes ionized medium.. in 3D!

V. Jelic’s talk

\[ \theta = \theta_0 + \lambda^2 \left( \text{const.} \int_0^d n_e B \cdot dl \right) \]

Measurable at low frequencies (< 5 GHz) for general ISM
Faraday rotation probes ionized medium in 3D!

V. Jelic’s talk

Faraday tomography/RM synthesis

\[ \theta = \theta_0 + \lambda^2 \left( \text{const.} \int_0^d n_e B \cdot dl \right) \]

\[ P(\lambda^2) = Q(\lambda^2) + i U(\lambda^2) \]

\[ F(\Phi) = \int_{-\infty}^{+\infty} W(\lambda^2) P(\lambda^2) e^{-i2\Phi\lambda^2} d\lambda^2 \]
Faraday rotation probes ionized medium... in 3D!

Along each LOS: spectrum of Faraday rotating components

van Eck+ (2017)
Faraday tomography finds surprising correlation between ISM phase structure & B field

Alignment between:
Neutral medium HI filaments
Magnetic field
Faraday depth structures (Pol. intensity enhancements + decrements)

Origin of correlations still unknown, but we can still make empirical models for modeling foregrounds...
All-sky dust emission modeling based on filaments

C. Hervias-Caimapo's talk
Model reproduces Planck power spectra up to much higher multipoles

Can be used to see effect of decorrelation

C. Hervias-Caimapo’s talk
ISM properties (including dust) change along the LOS.

We now have maps of local ISM to exploit!
ISM structure revealed by 3D dust extinction maps

Lallemand et al. 2019

Increasing distance from Sun

Green et al. (2019)
Dust properties are measured to vary on large (kpc) scales.

Variations in extinction law tied to changes in emission

Ioana Zelko’s talk

Schlafly+2016

Schlafly+2017
Dust grain composition changes along with grain size distribution one way to explain observed variations

Ioana Zelko’s talk

Zelko+2020
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The path forward

Combination of synchrotron & dust emission

Developing tools & diagnostics for existing data

Testing dust models in 3D

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