The Physics of Polarized Dust Emission

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Outline

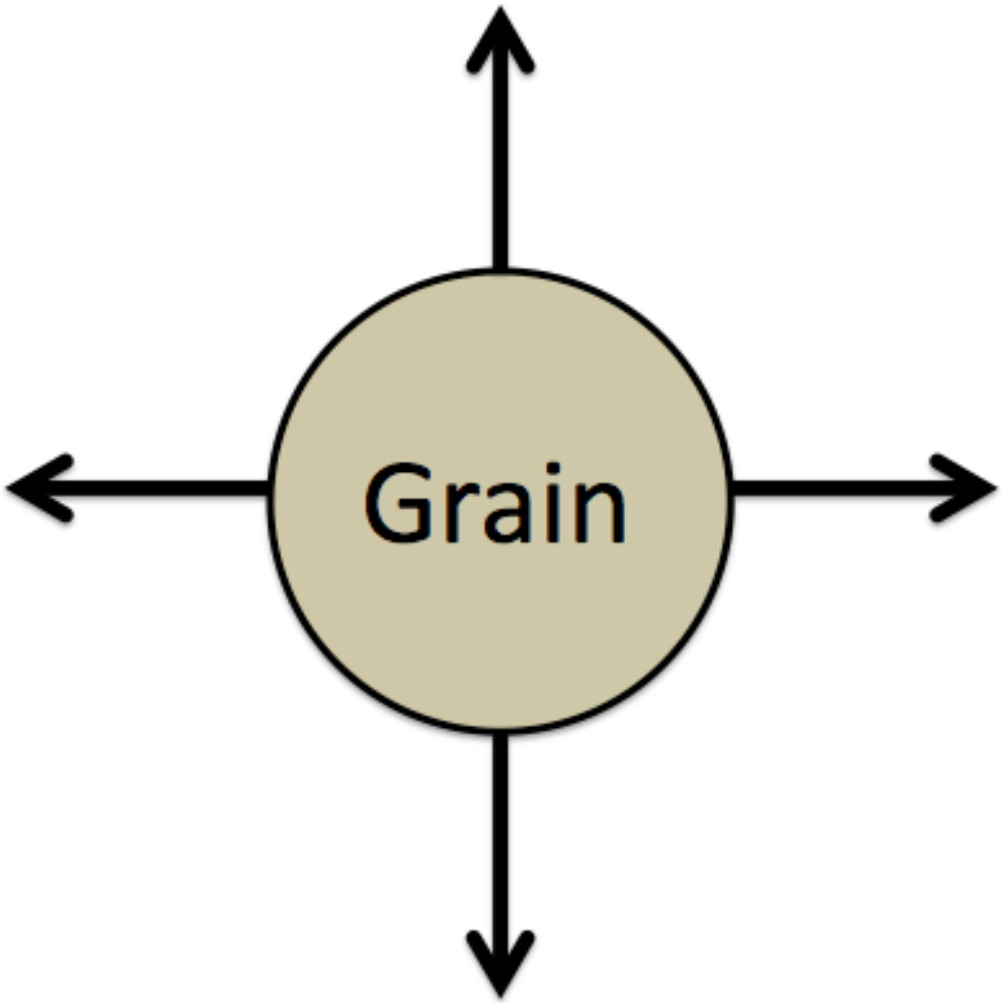
1. Why is dust emission polarized?
2. What determines the degree of polarization?
3. Could the polarization fraction be frequency-dependent?

Why is Dust Emission Polarized?

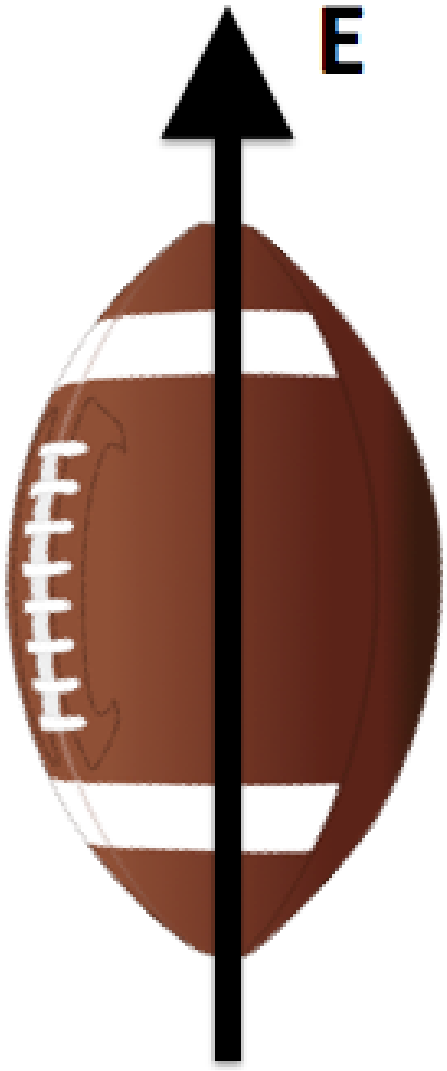
Two ingredients required:

1. Grains must be aspherical
2. Grains must be aligned

Grain Shape

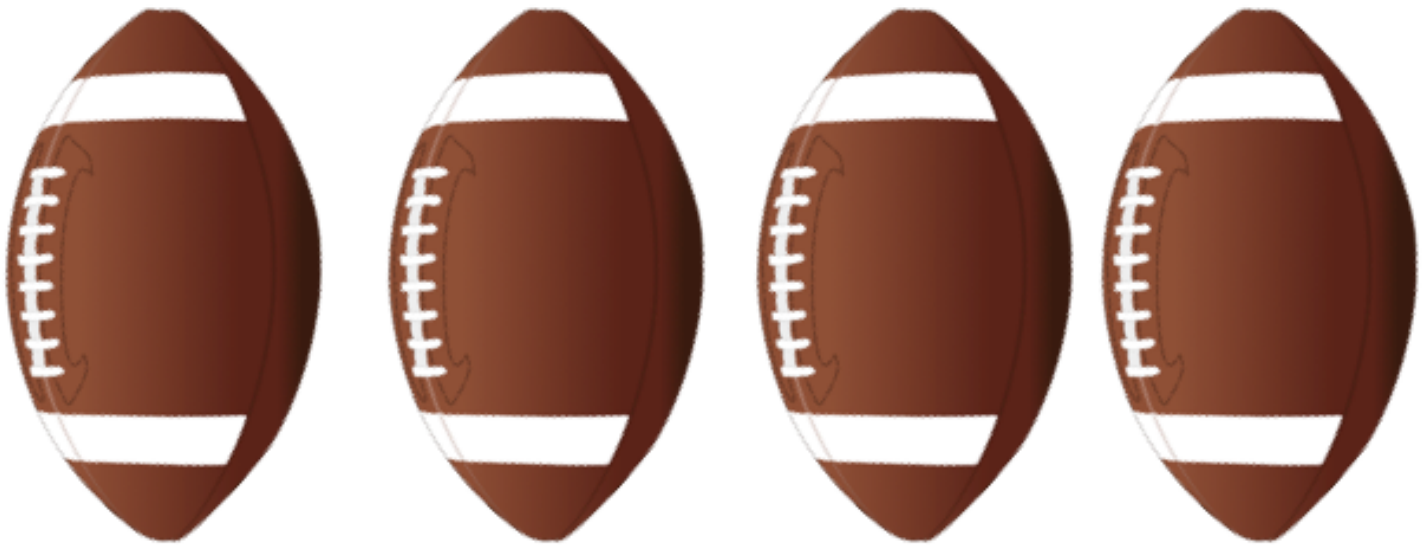


Grain Shape



Grain Alignment

Grain Alignment



Grain Alignment

Grain spins about $\vec{J}$
$\vec{J}$ systematically aligns with $\vec{B}$

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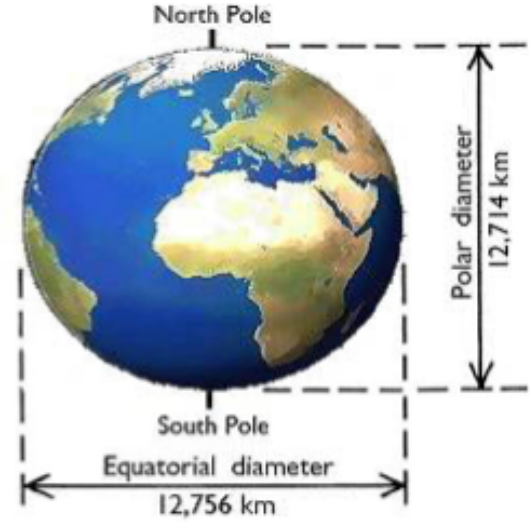
Grain Shape


North Pole
Polar diameter
12,714 km
South Pole
Equatorial diameter
12,756 km

Alignment Efficiency

$\vec{\mathbf{J}}$ and $\vec{\mathbf{B}}$ may be misaligned

Composition

Grains are of different composition appear to have different polarization properties

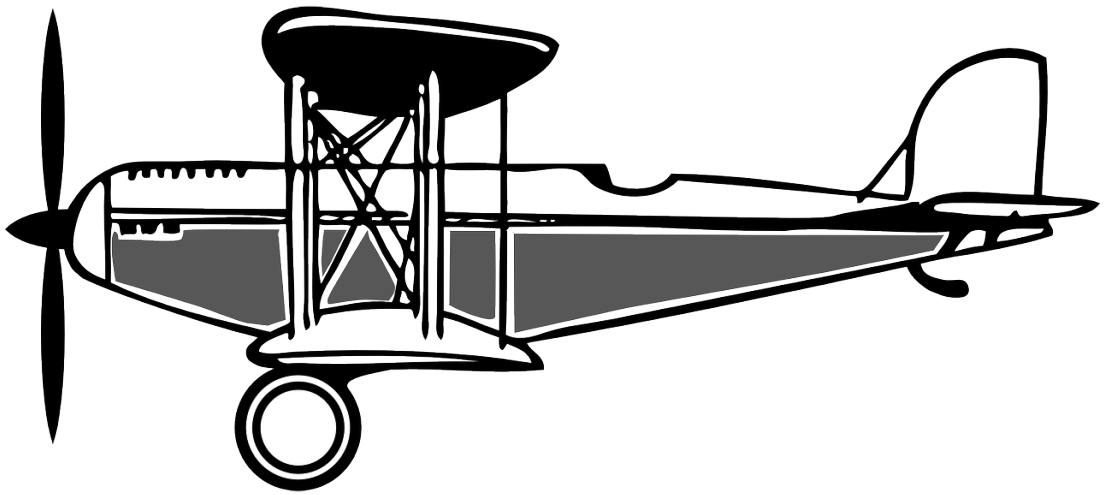
- Silicate Features– Polarization detected
- Carbonaceous Features– Unpolarized

Viewing Angle

If magnetic field is aligned with the line of sight, then minimal polarization

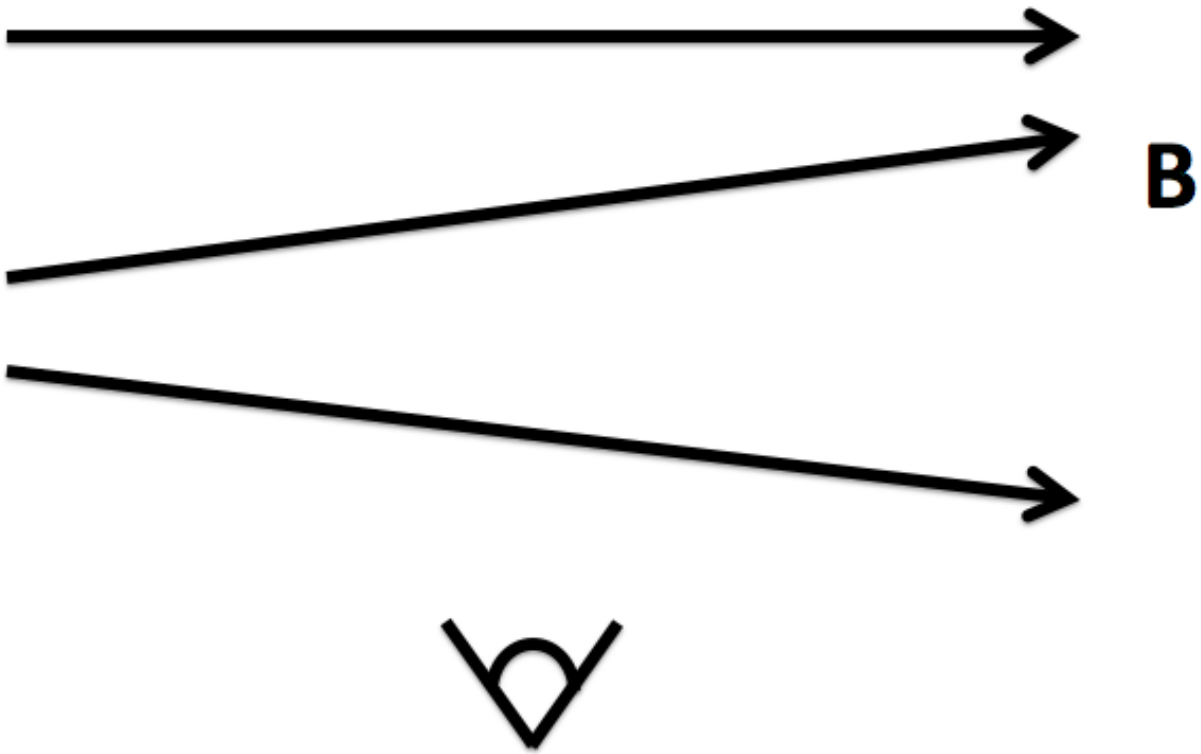
Viewing Angle

If magnetic field is in the plane of the sky, maximal polarization



Field Geometry

Tangling of the magnetic field along the line of sight reduces polarization



Summary

1. Dust grains produce polarization because they are aspherical and aligned

2. Degree of polarization depends on viewing angle, magnetic field geometry, and grain properties like:
   - Alignment efficiency
   - Composition
   - Shape

Outline

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✓ What determines the degree of polarization?

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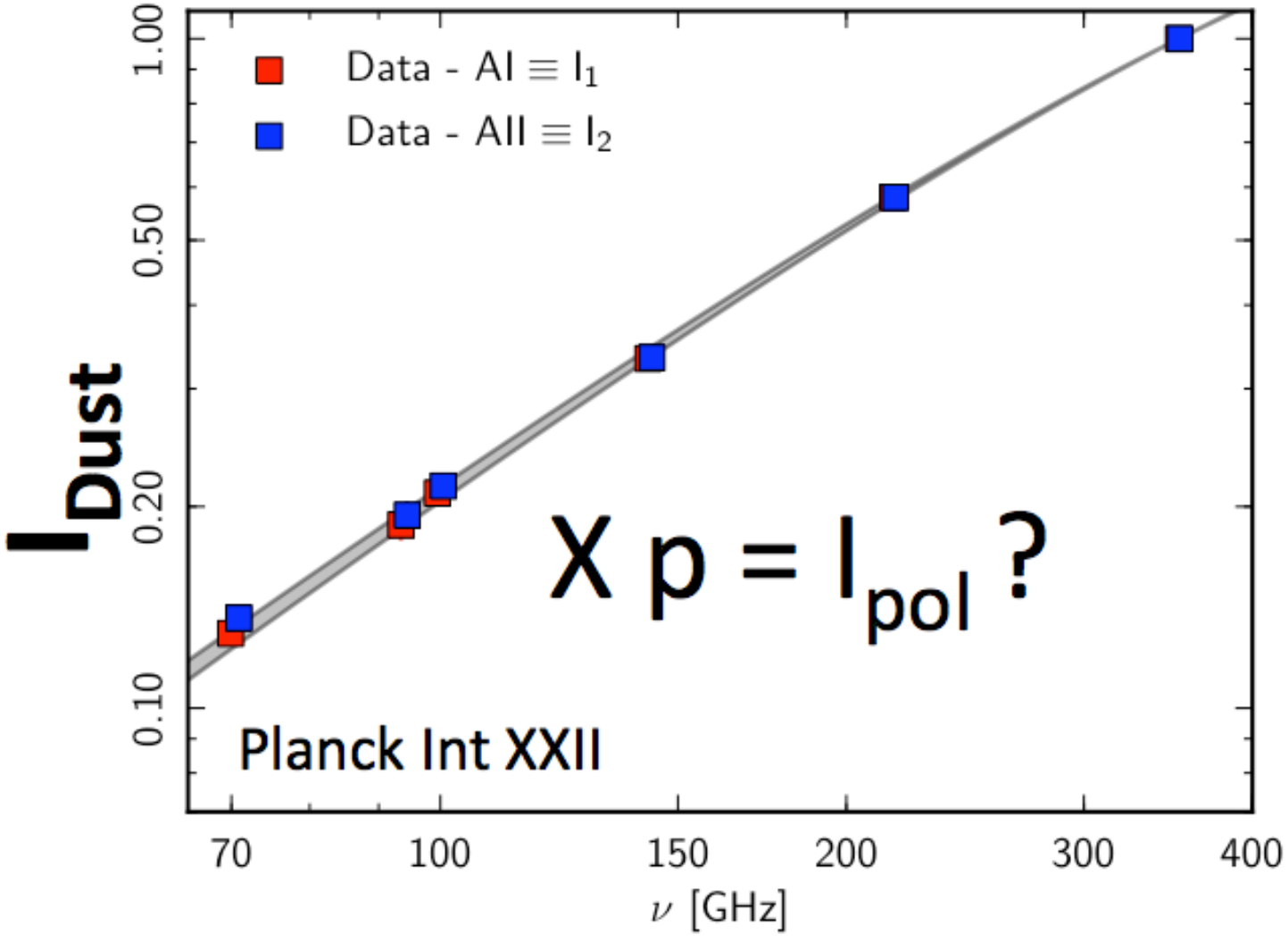
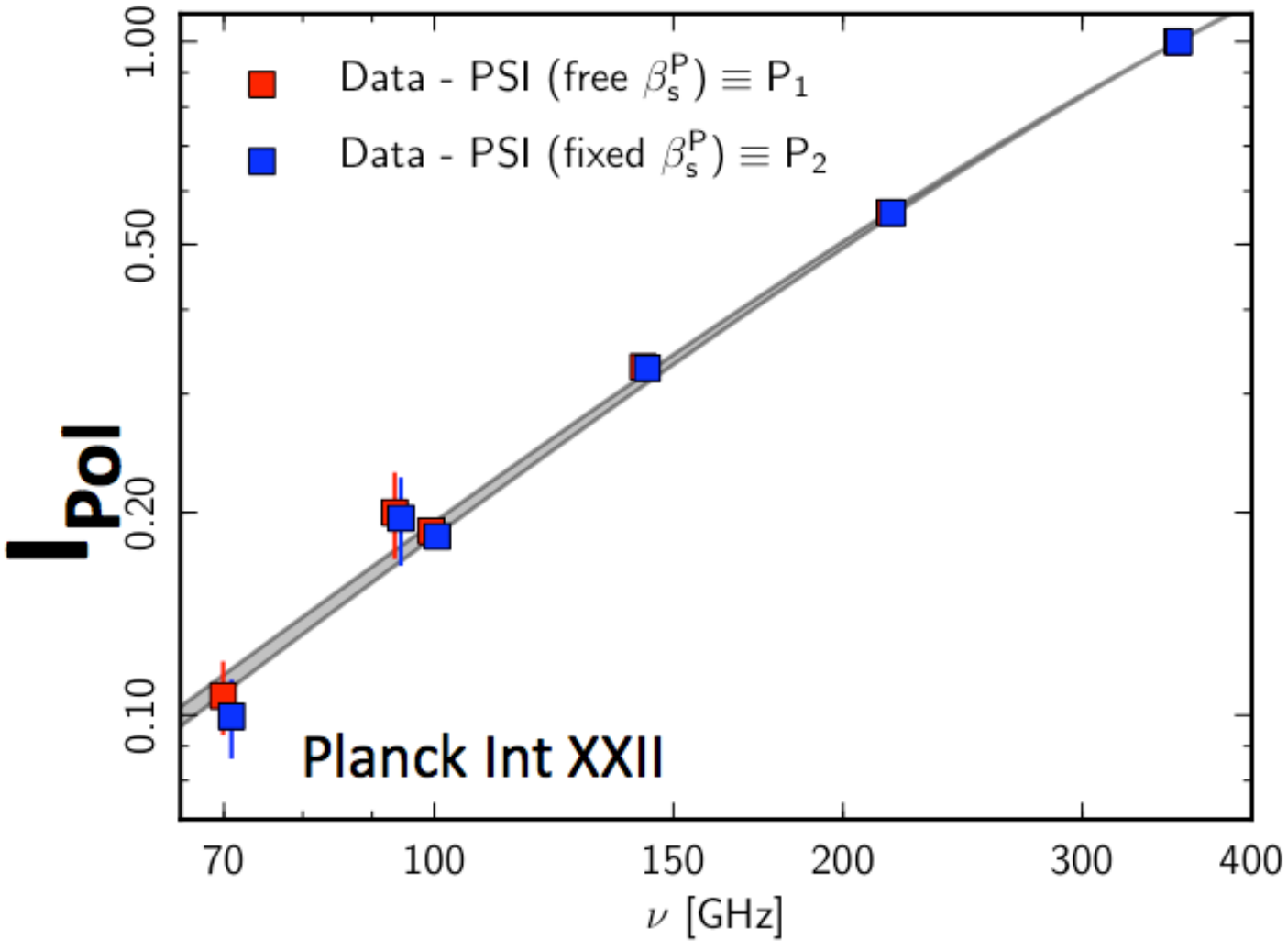
Ideal Picture

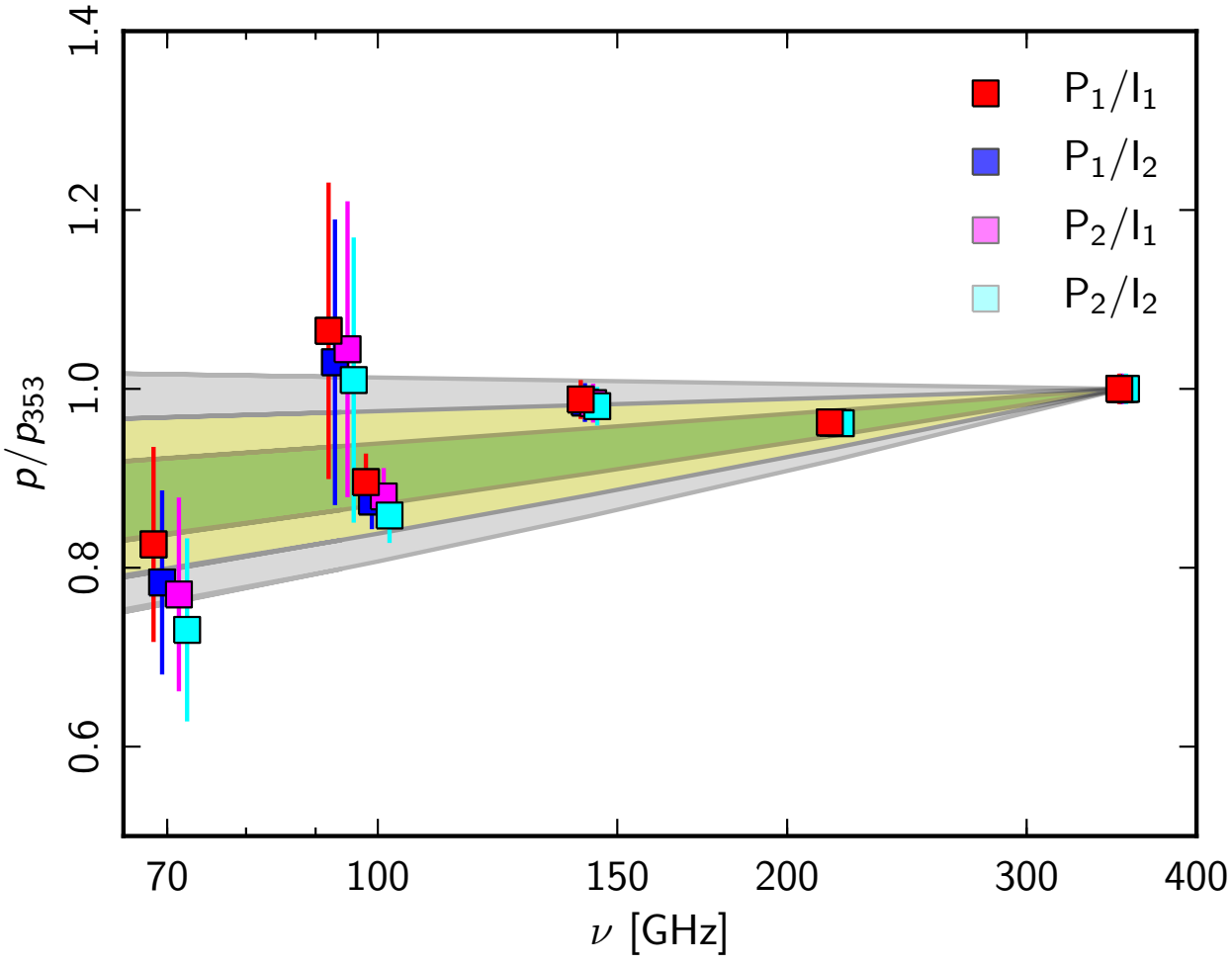


Ideal Picture



Planck Results

We know this isn't entirely the case... Why?



Planck Int XXII

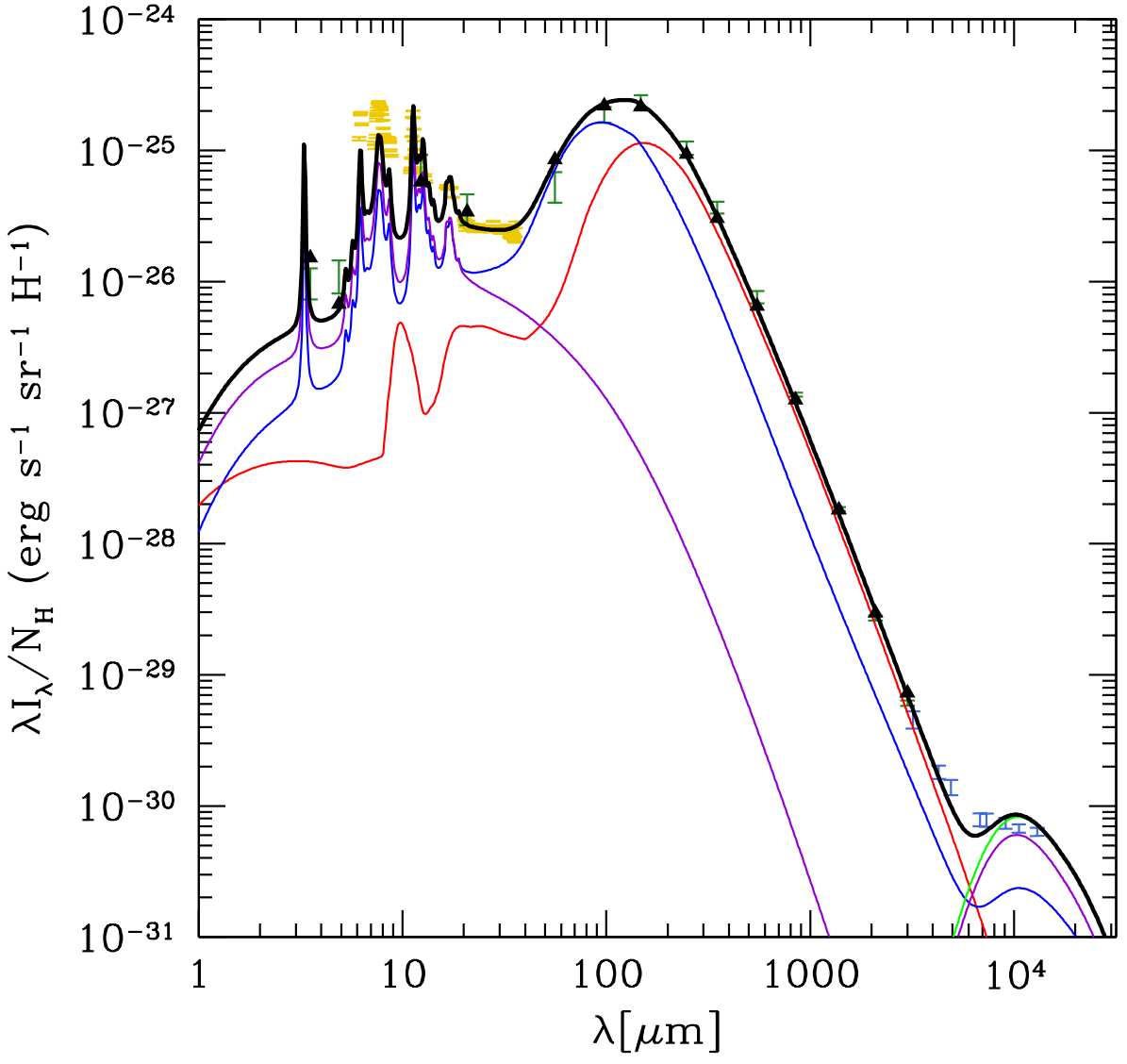
Composition

- Dust of different composition seems to have different polarization properties

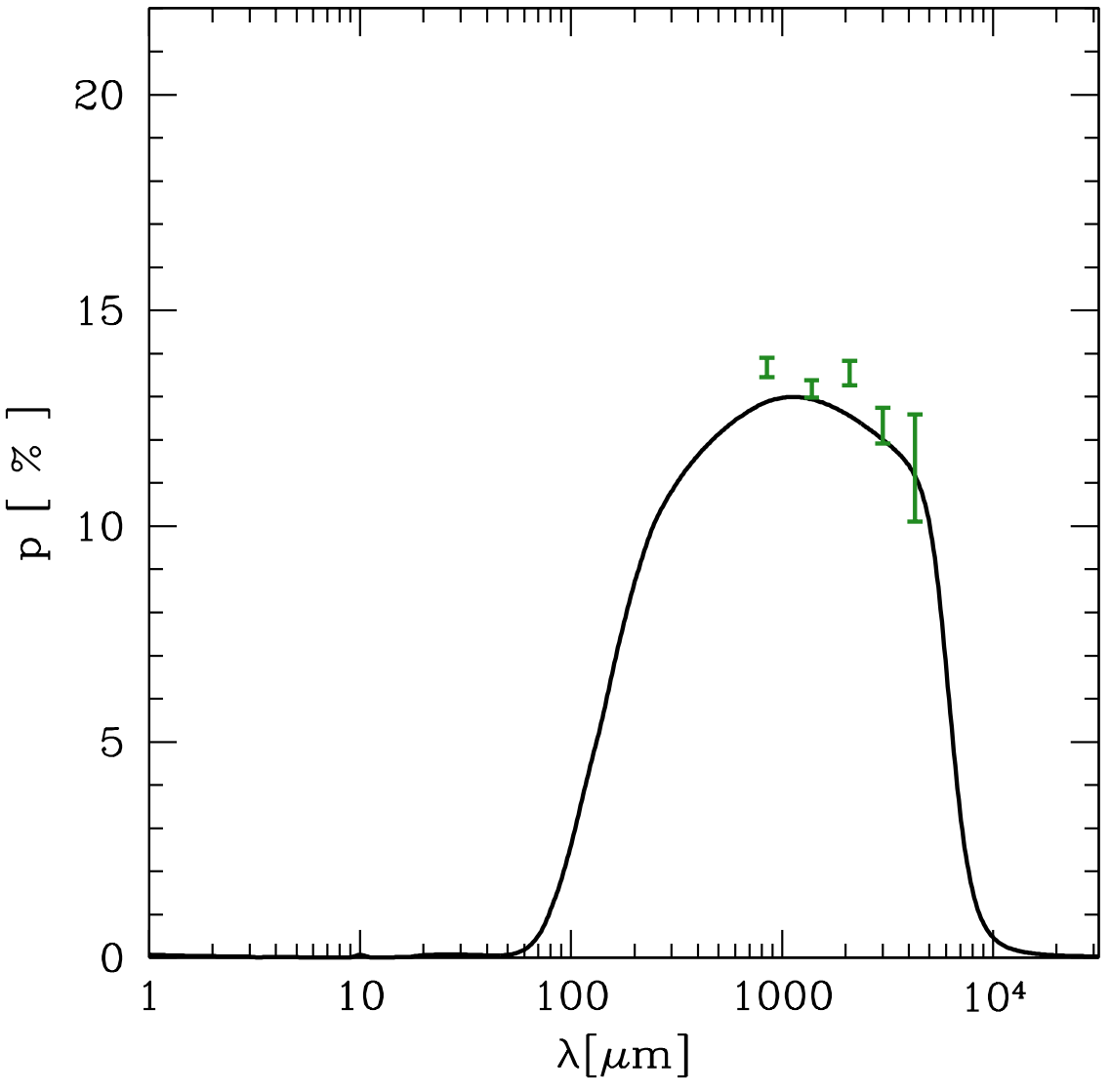
- If they have different SEDs, polarization fraction will evolve

$$p(\nu) = \frac{I_{\mathrm{pol}}^{\mathrm{sil}} + I_{\mathrm{pol}}^{\mathrm{car}} + I_{\mathrm{pol}}^{??}}{I_{\mathrm{tot}}}$$

Composition

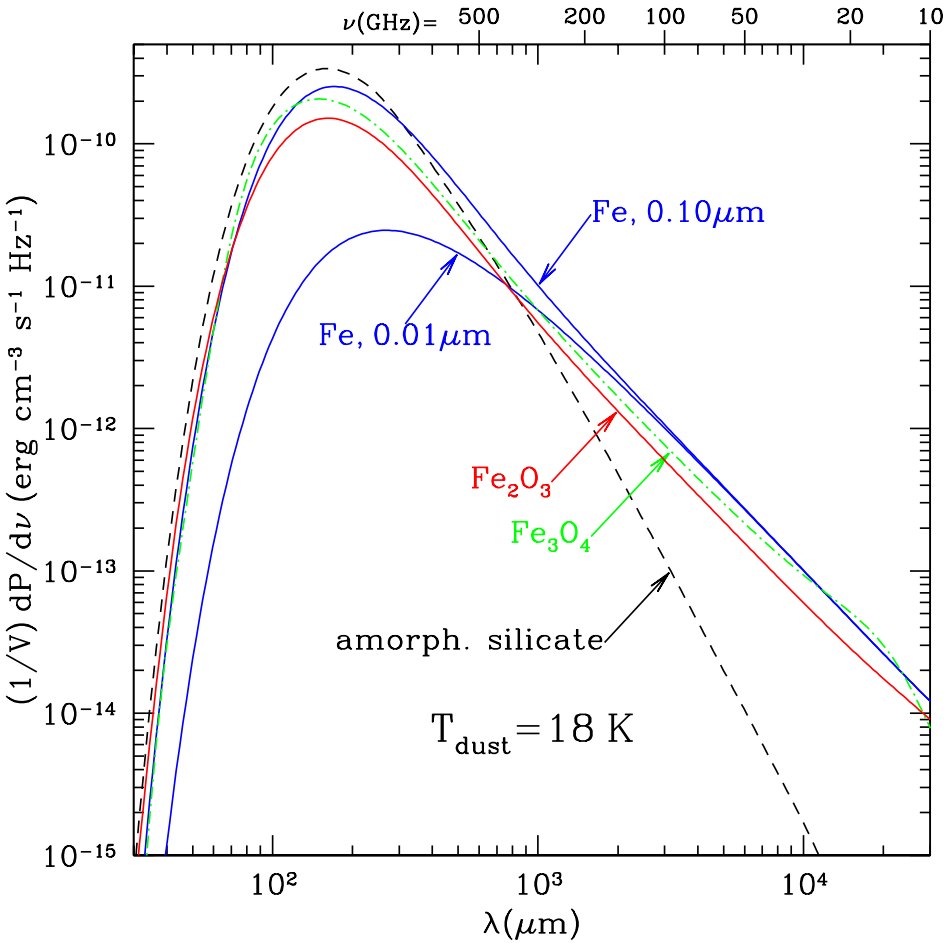


Composition



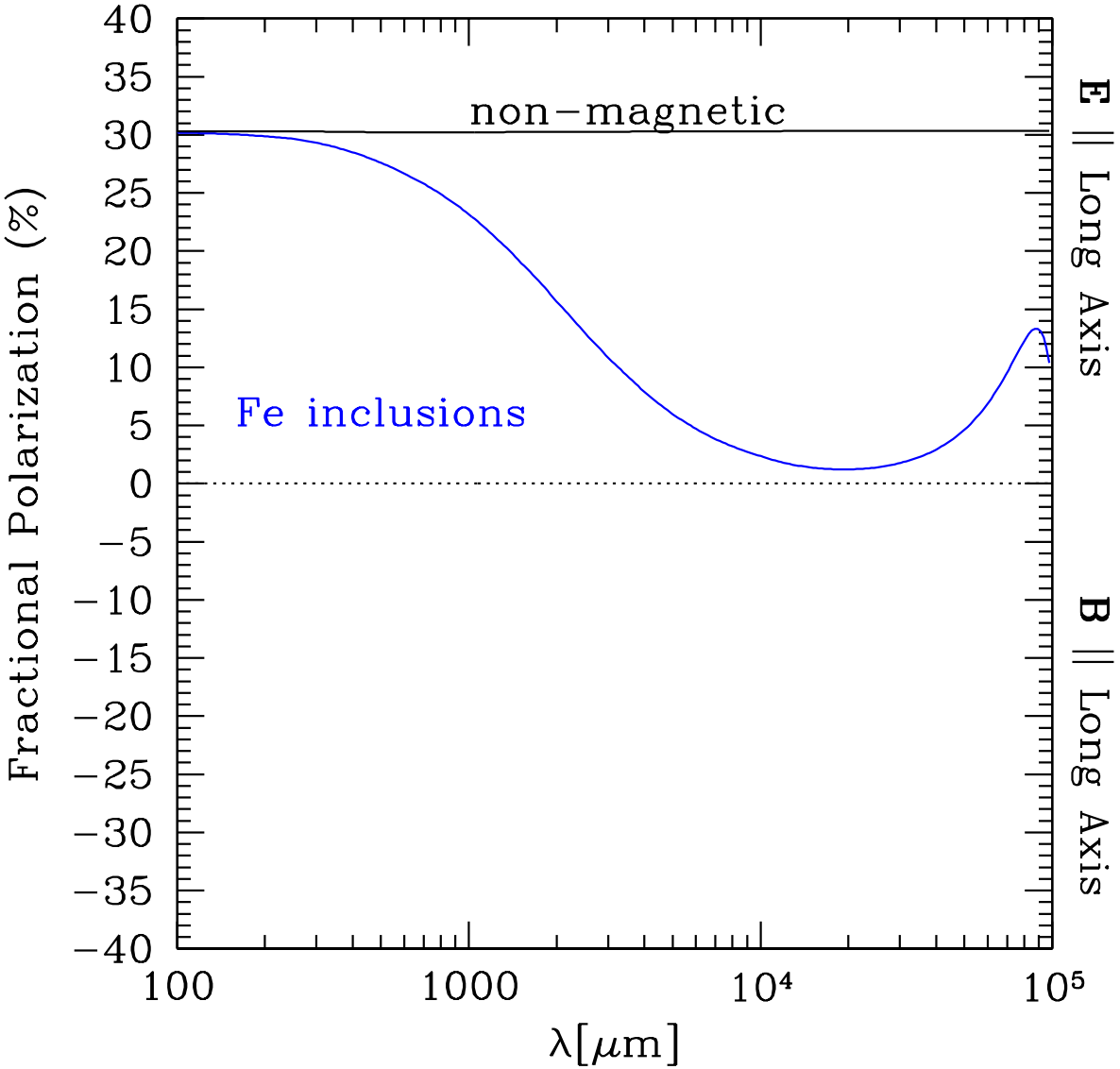
Magnetic Nanoparticles

- **Emissivity per unit volume** of 0.01μm grains heated to 18K
- Emissivity in mm and sub-mm much stronger than amorphous silicate grains

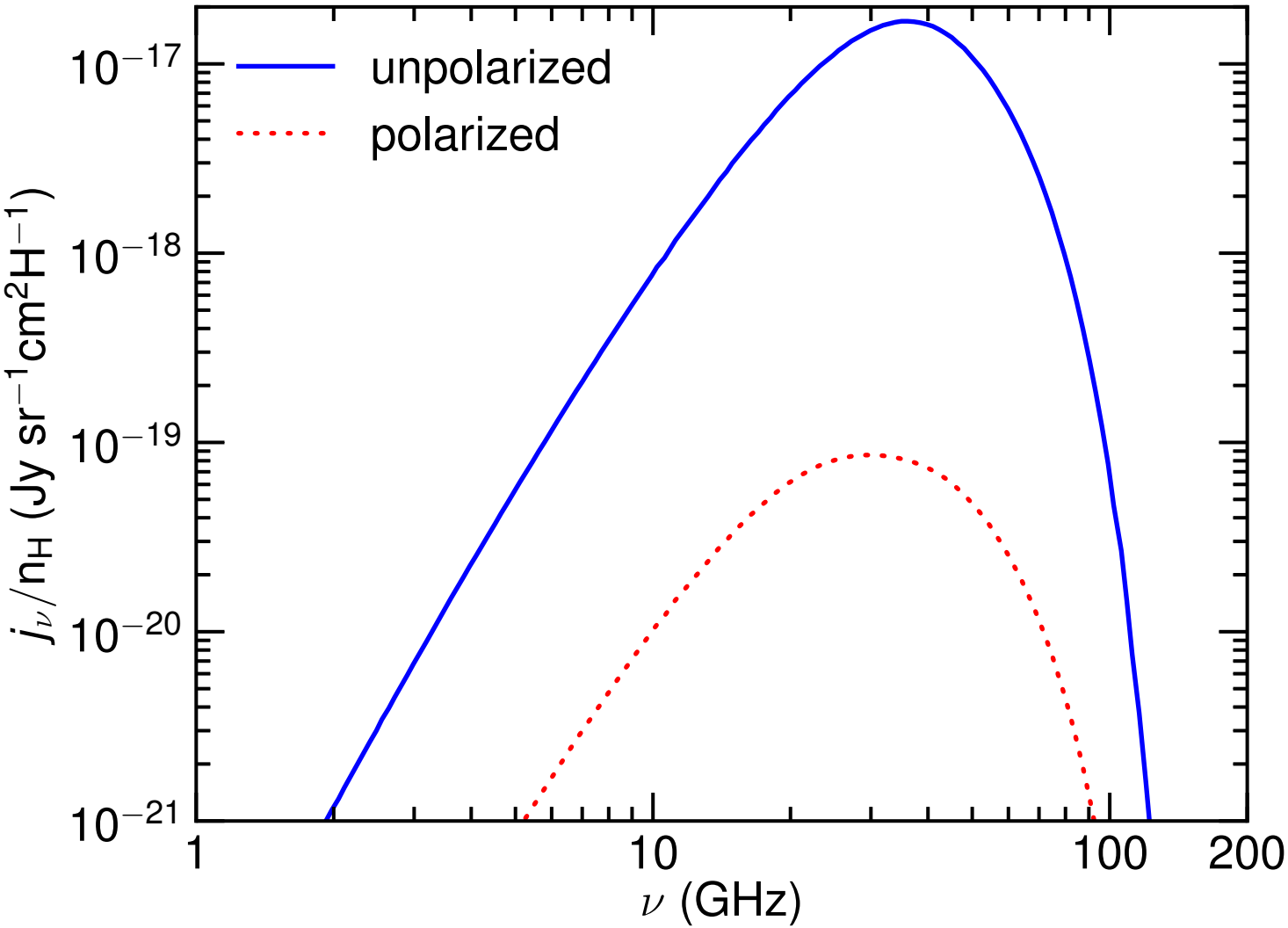


Draine and Hensley 2013

Magnetic Nanoparticles



AME Polarization



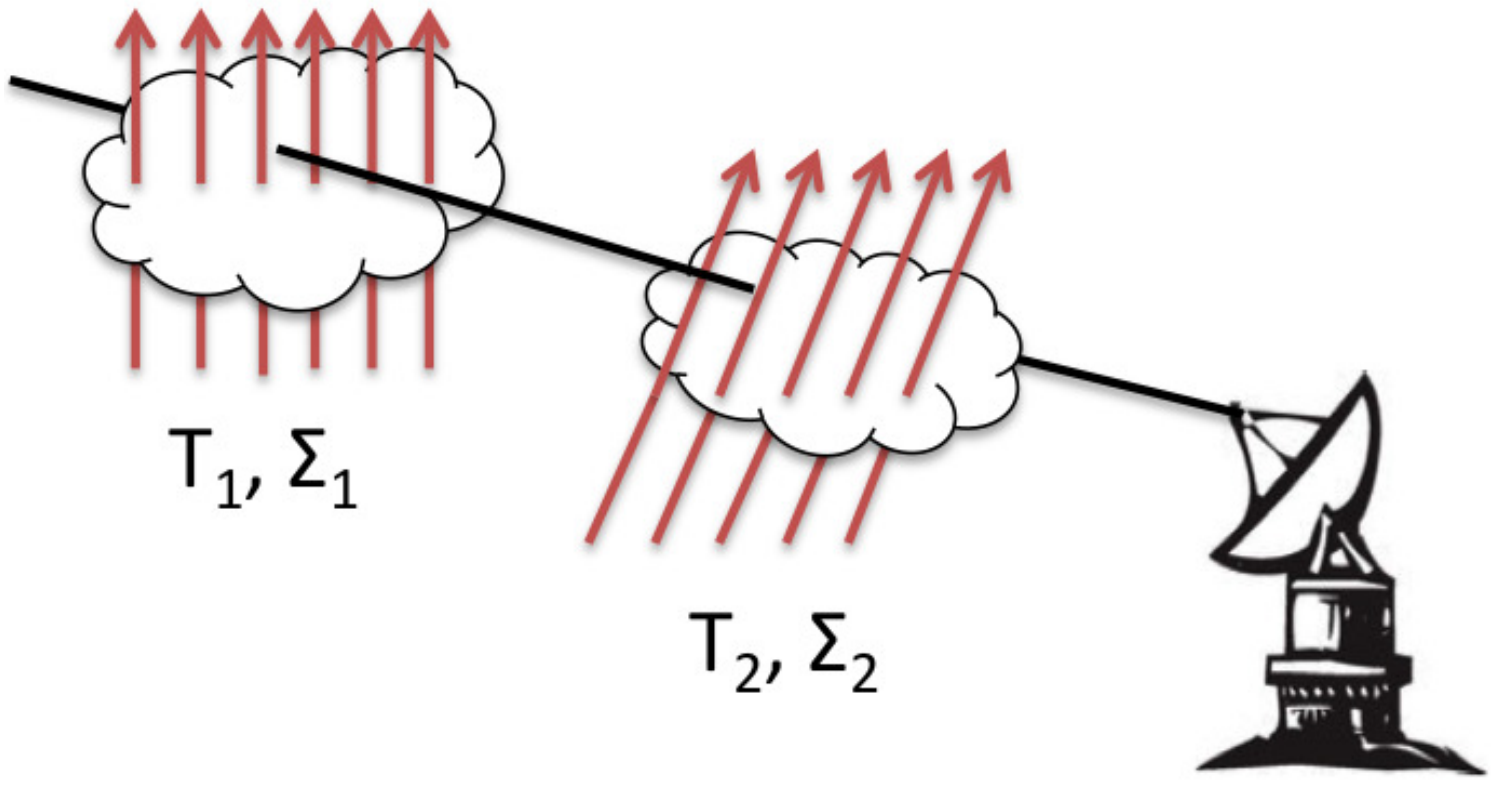
Hoang, Lazarian, & Martin 2013

Solution

Need to better understand polarization properties of different dust components:

- AME polarization detection
- Dust spectropolarimetry
- Ancillary dust polarization measurements to test models

Depolarization



Tassis & Pavlidou 2015

Solution

> “Magnetic tomography of the interstellar medium could immediately identify lines of sight with severe misalignments of the magnetic field along the line of sight, and these lines of sight could be simply masked from B-mode analyses, akin to the treatment of point sources.”
>
> — Tassis & Pavlidou 2015

Summary

1. Dust grains produce polarization because they are aspherical and aligned
2. Many uncertainties still exist in the polarized dust SED due to dust composition and depolarization effects
3. These uncertainties can be mitigated with ancillary polarimetric measurements of dust emission and extinction