The Composition of Interstellar Dust

Implications for Galactic Science and Foreground Subtraction

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Outline

Simple Parametric Model

Dust heated to temperature T_d emits (roughly) as a modified blackbody

$$I_\nu^{\text{dust}} = A \left(\frac{\nu}{\nu_0} \right)^\beta B_\nu \left(T_d \right)$$

A = How much dust?
T_d = How hot is the dust?
β = What is the dust made of?

Simple Parametric Model

Extending to polarization:

$$P_\nu^{\text{dust}} = Af \left(\frac{\nu}{\nu_0}\right)^{\beta} B_\nu\left(T_d\right) \sin^2 \Psi$$

f = How aligned is the dust?
Ψ = What is the viewing geometry?
Note: $P/I = \text{constant}!$

Multiple Dust Compositions

What if there is more than one kind of dust?

$$I_\nu^{\text{dust}} = A_1 \left(\frac{\nu}{\nu_0}\right)^{\beta_1} B_\nu\left(T_{d,1}\right) + A_2 \left(\frac{\nu}{\nu_0}\right)^{\beta_2} B_\nu\left(T_{d,2}\right)$$

$$P_\nu^{\text{dust}} = \left[A_1 f_1 \left(\frac{\nu}{\nu_0}\right)^{\beta_1} B_\nu\left(T_{d,1}\right) + A_2 f_2 \left(\frac{\nu}{\nu_0}\right)^{\beta_2} B_\nu\left(T_{d,2}\right)\right] \sin^2\Psi$$

Note: $P/I =$ NOT constant!
Much more room for SED variations

Dust Building Blocks

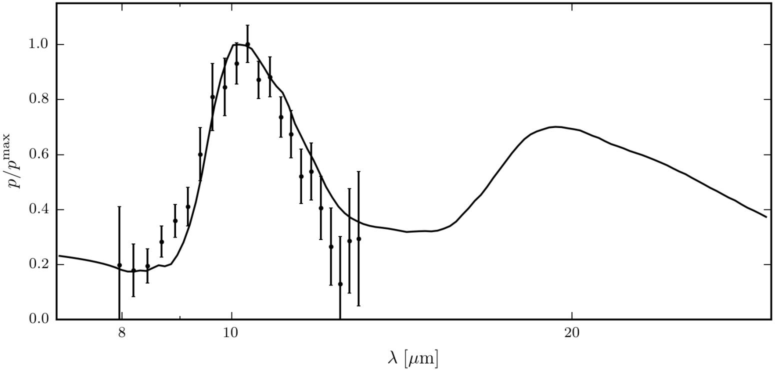
- ISM abundance measurements: how much of each element is in the gas, and how much is locked up in dust?
- Dust is made mostly of C, O, Mg, Si, Fe
- Question: how are these assembled into grains?

Where is the Interstellar C? Fe?

- Large amount of C in dust: PAHs, big carbonaceous grains, carbonaceous mantles?
- Interstellar silicates ($Mg_xFe_ySiO_4$) appear Fe-deficient. Where is the Fe?

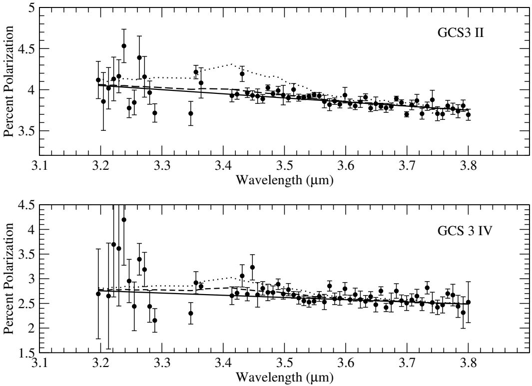
The Silicate Feature

Spectroscopic signatures of silicate grains strongly detected in polarization



The Search for Aligned Carbonaceous Grains

- Silicate Features– Polarization detected
- Carbonaceous Features– Unpolarized



Chiar et al 2006

The Case for Two Components

Whenever fits include $\lambda < 100\,\mu$m data, two dust components seem to be preferred over one:

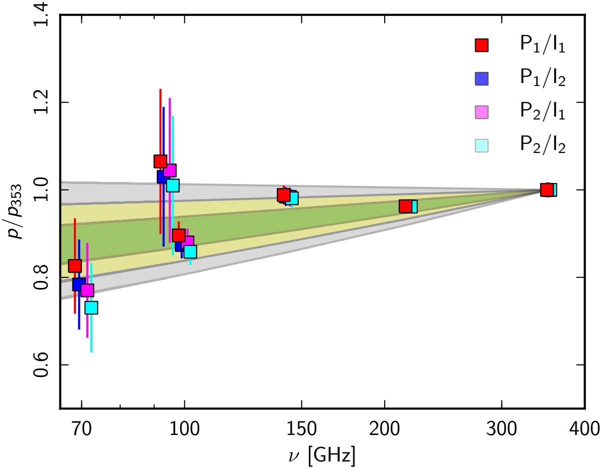
- Finkbeiner, Davis, Schlegel 1999 (FIRAS/DIRBE)
- Meisner & Finkbeiner 2015 (*Planck*/DIRBE)
- Zheng et al 2017 (Global Sky Model)

The Polarization Test

Hypothesis: If there are multiple distinct populations of big grains, the polarization fraction must be frequency-dependent.

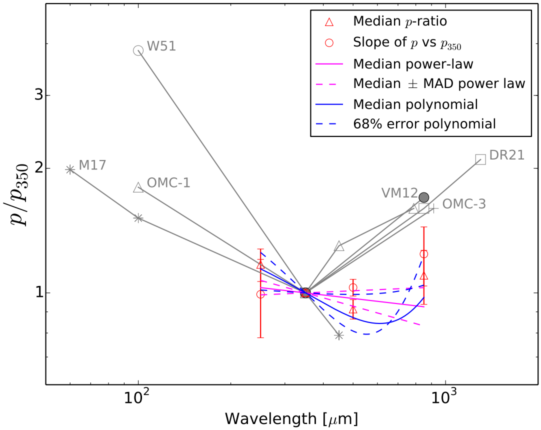
Current status: *Planck*

No strong evidence of evolution with frequency (Planck Int. XXII, Planck Int. LIV)

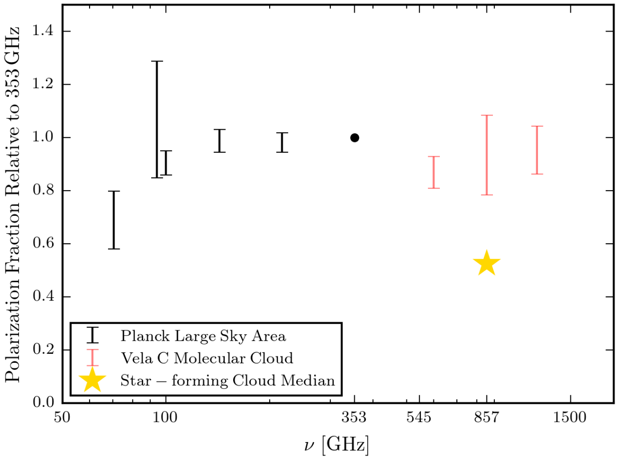


Current status: BLASTPol

No strong evidence of evolution with frequency (Gandilo et al 2016)

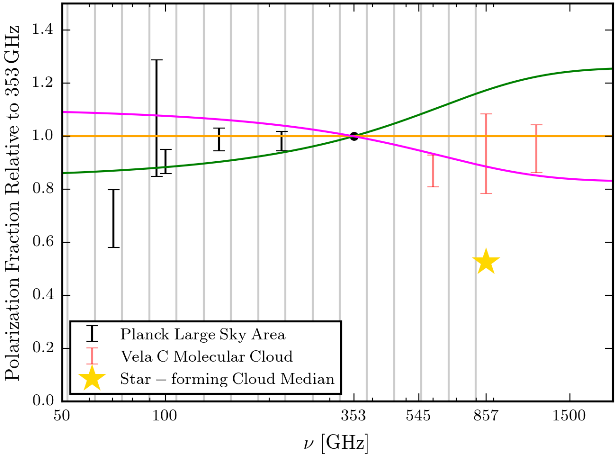


Current status: Summary



Future status: PICO

Can constrain polarization fraction of each component in a Meisner & Finkbeiner-type model to $\sim 1\%$



Polarized Emission from Disks

- Interstellar dust properties often assumed when building disk models or interpreting observations
- The optics problem is **hard** because wavelengths are about the size of the grains, grain properties degenerate with grain size distribution
- Is that polarization signal scattering or emission or both?

Synergy with PICO

- Optics problem is **easy**–ISM grains much smaller than the wavelengths
- Can derive intrinsic optical properties, including polarization efficiencies
- Caveat going from ISM to disk, but also much science there (e.g., chemical processing, grain growth, etc.)

Outline

1. The polarization-sensitive high frequency bands of PICO will provide a stringent test of the multi-component dust paradigm
2. Strong constraint on parametric dust models
3. Derived dust polarization properties may be useful in interpreting emission from protoplanetary disks