Intensity and Polarization of Galactic Dust Emission in the Planck Bands

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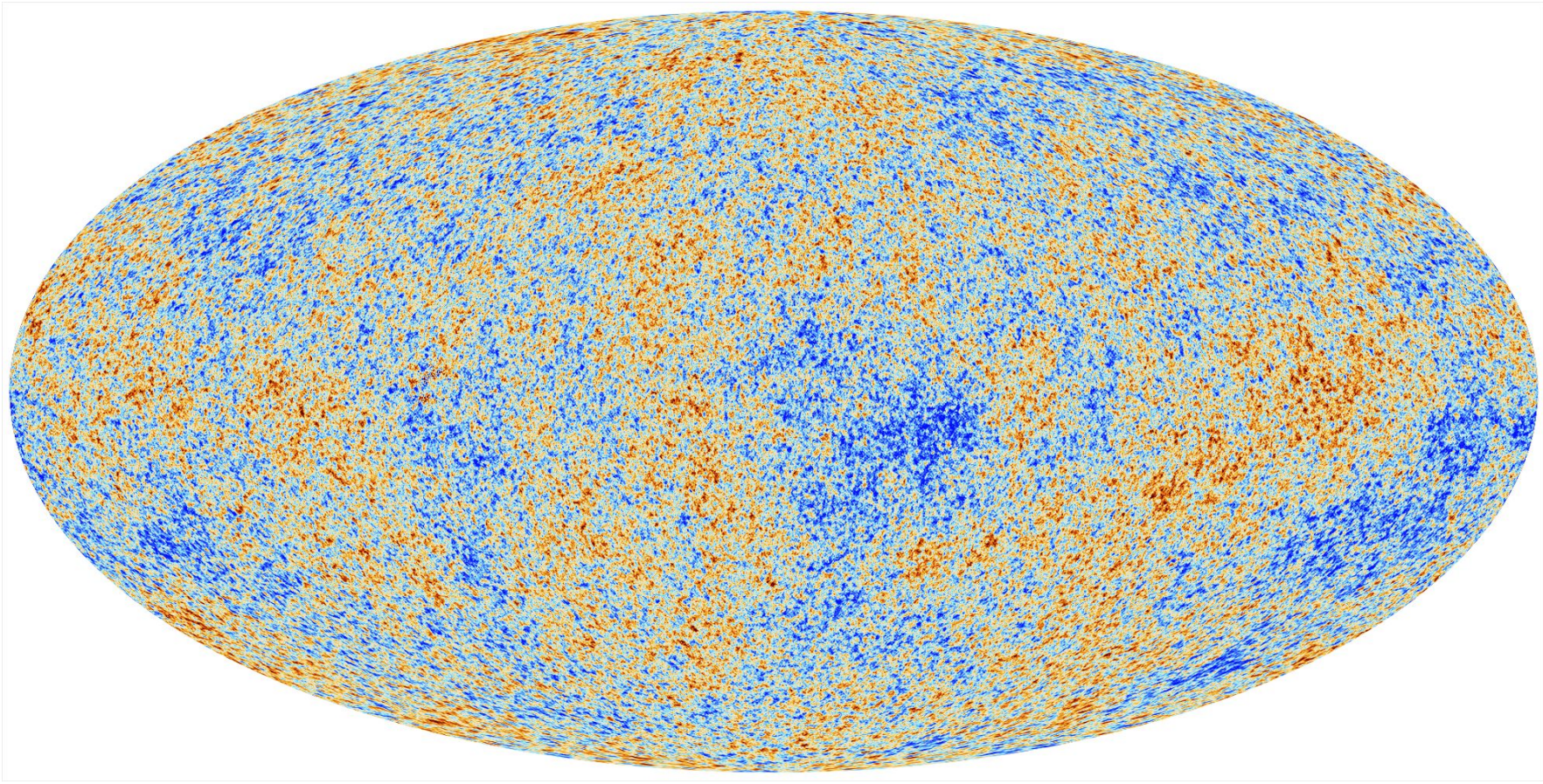
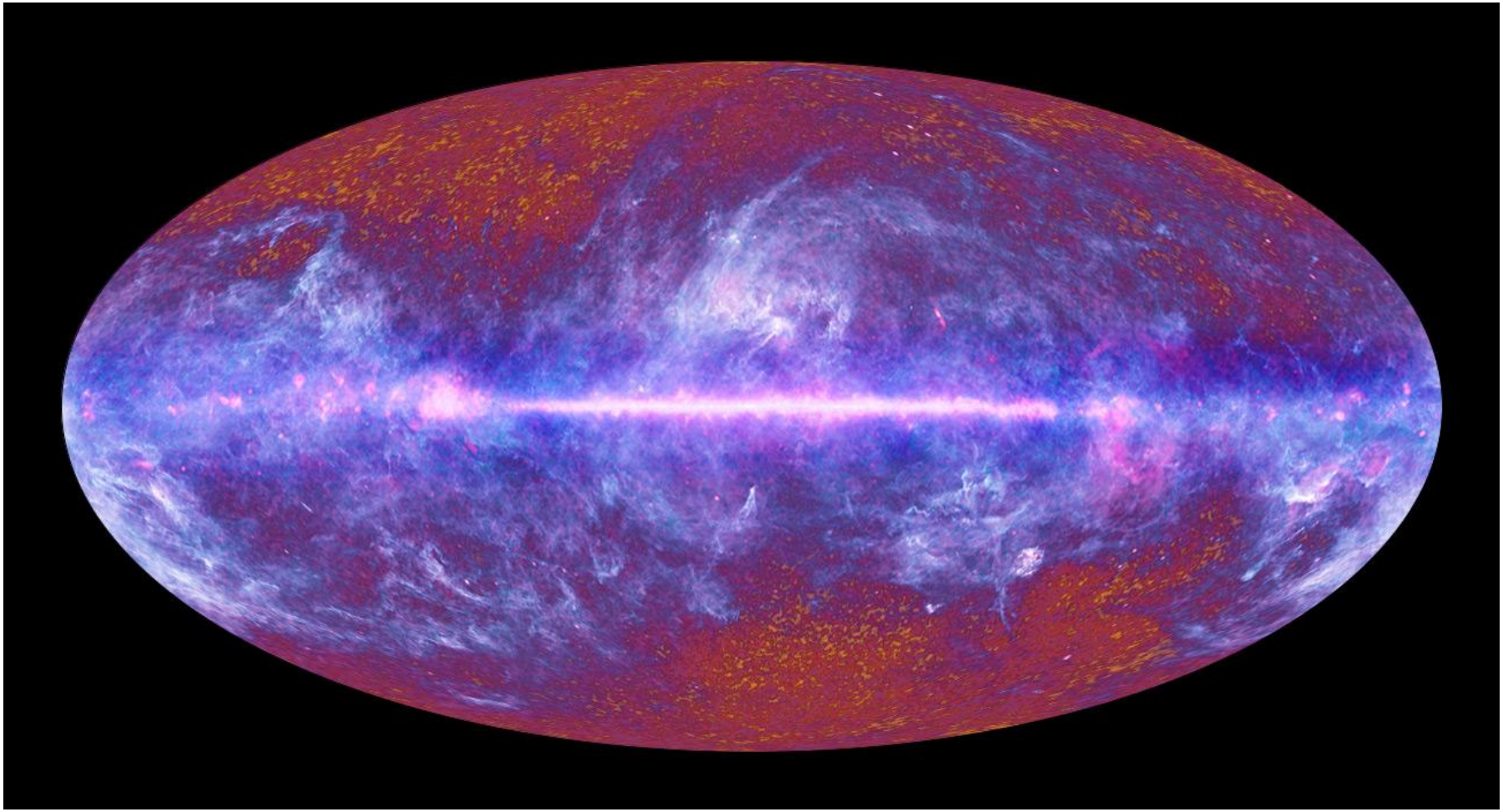
Era of Precision Cosmology



Era of Precision Dust Modeling?

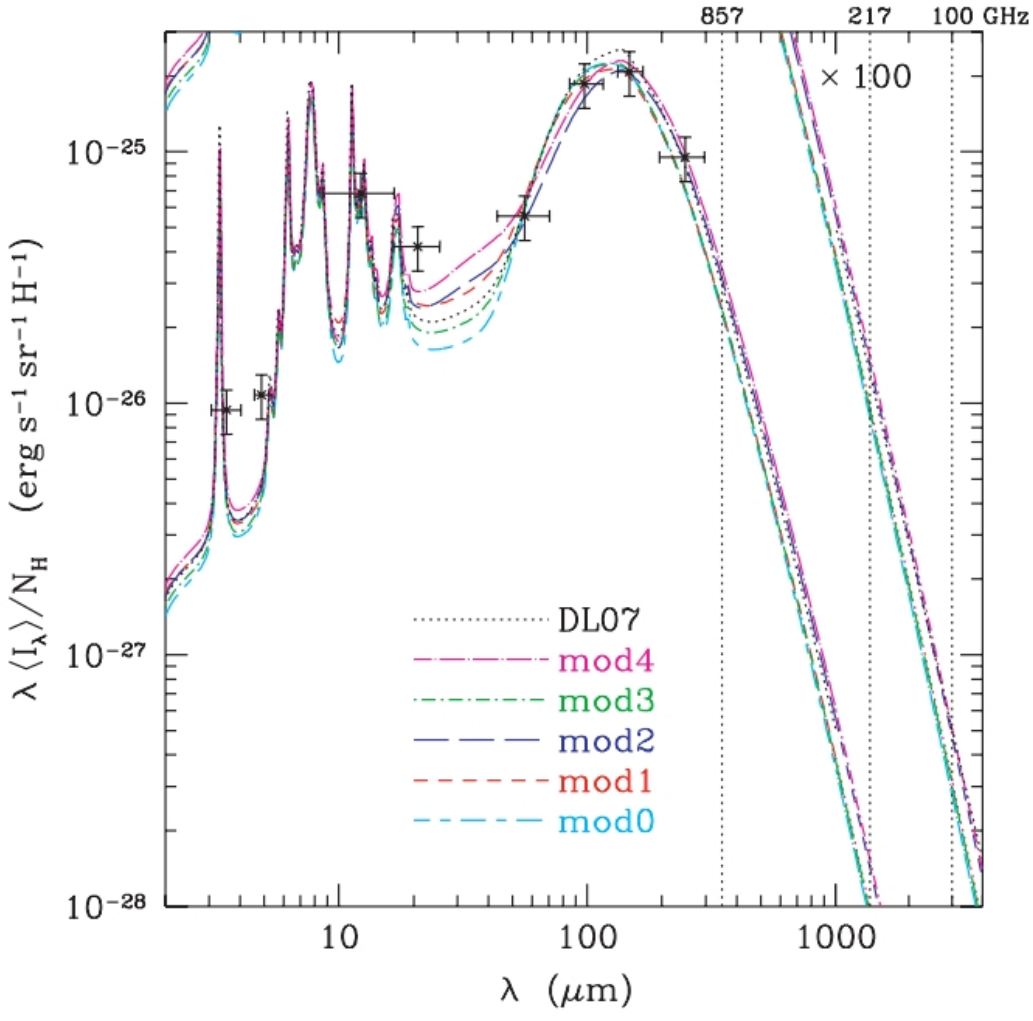


Constraining Dust Models

- Any dust model must obey observational constraints on:
  - Extinction
  - Polarization
  - Emission
- Draine and Fraisse 2009 built one such model, and we use that as our jumping off point

Draine and Fraisse 2009

- We consider a contribution to the infrared emission from magnetic grains
- We present an updated model with predictions for the frequency-dependent polarization in the Planck bands

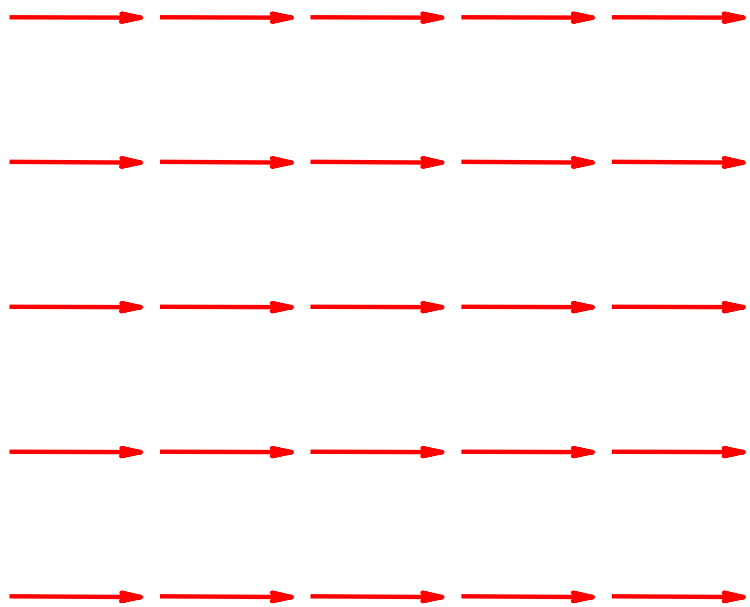


Draine and Fraisse 2009

Magnetic Materials

- **Ferromagnetic** materials, such as metallic Fe, have all unpaired spins aligned along a preferred axis
- Preferred direction of magnetization implies a minimum energy state with all unpaired spins aligned along preferred direction
- **Ferrimagnetic** grains such as Fe_3O_4 and γ-Fe_2O_3 are also viable

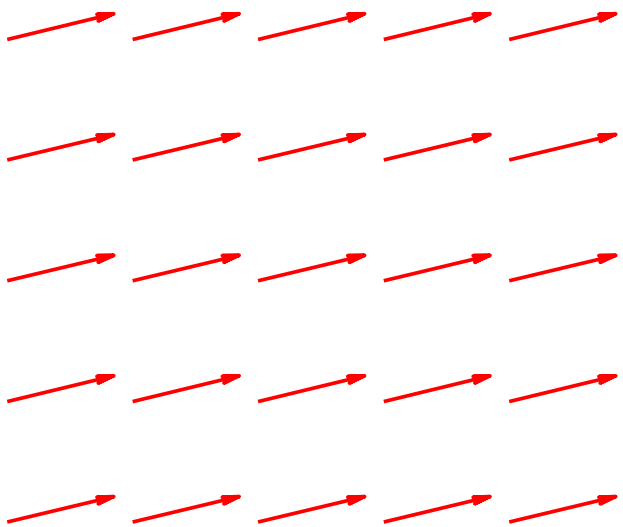
Ferromagnetic spin lattice



Magnetic Dipole Emission

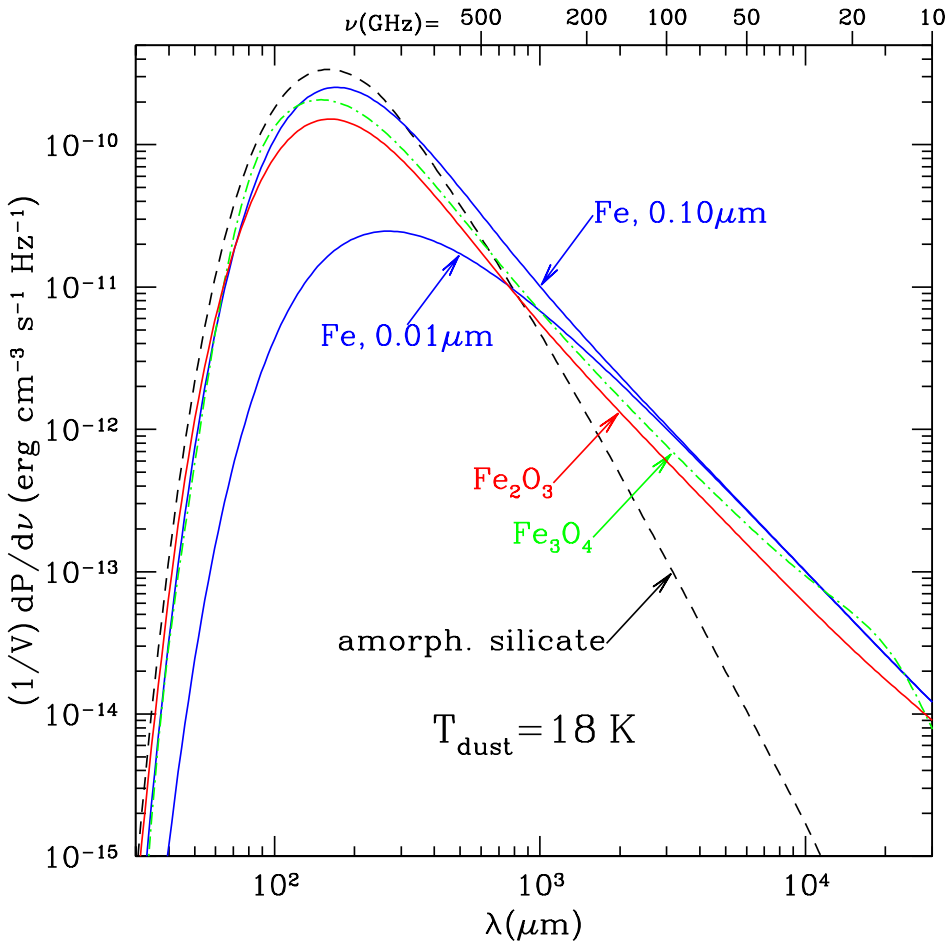
- Thermal fluctuations can move the spins away from this state
- Then magnetization vector precesses about the preferred direction and produces radiation

Response to a fluctuation



Emissivities

- **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 2012a

Polarization

- Polarization depends on whether grains are **free-fliers** or **inclusions** in larger grains

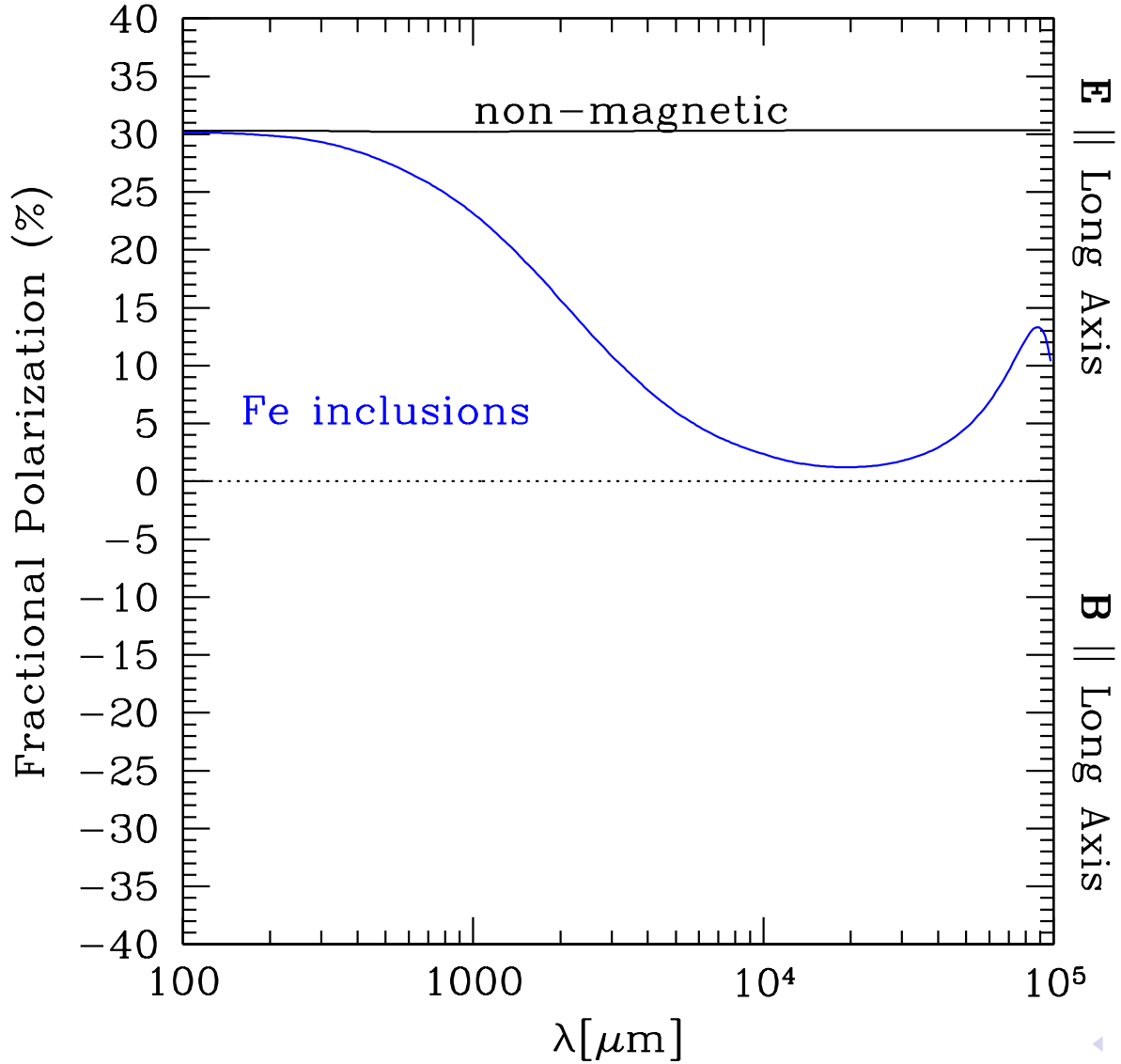
Free-Fliers

Inclusions

Inclusions

Of course, interstellar grains are nonspherical...

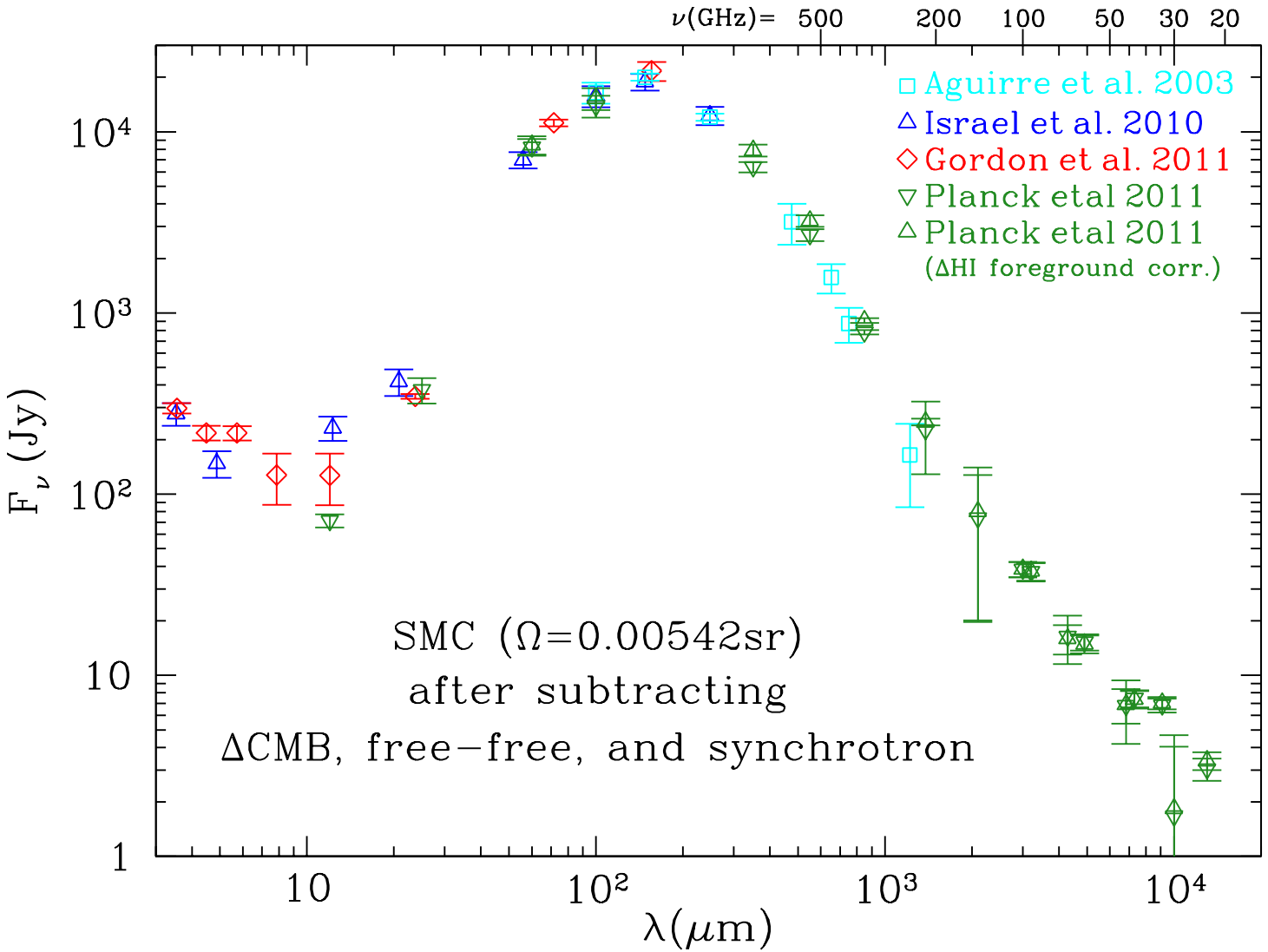
Polarization



Magnetic Grains in the SMC

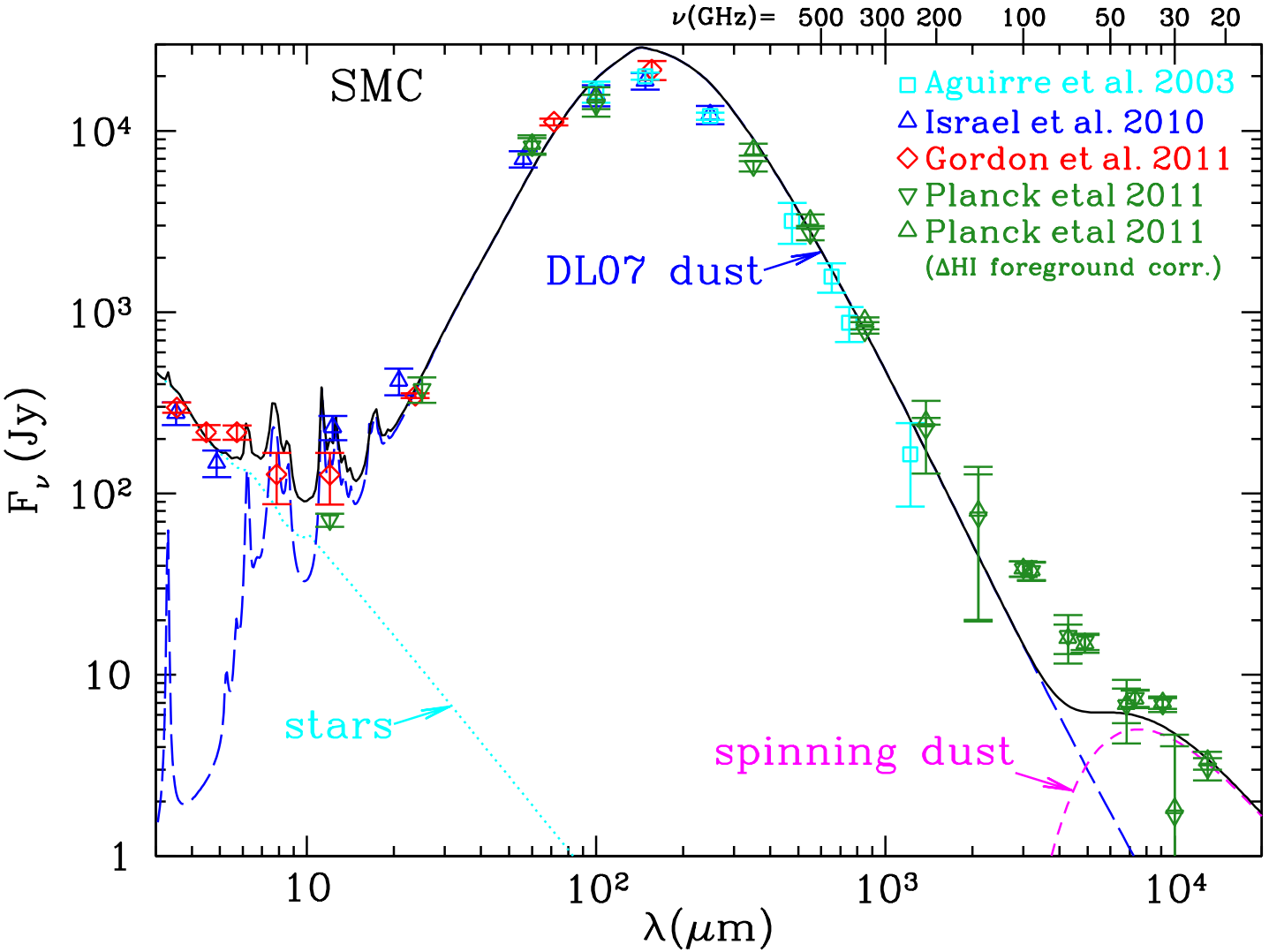
- Magnetic grains are able to explain the stronger than expected sub-mm and mm emission from the SMC

SMC SED



Draine and Hensley 2012

Fitting Dust Models

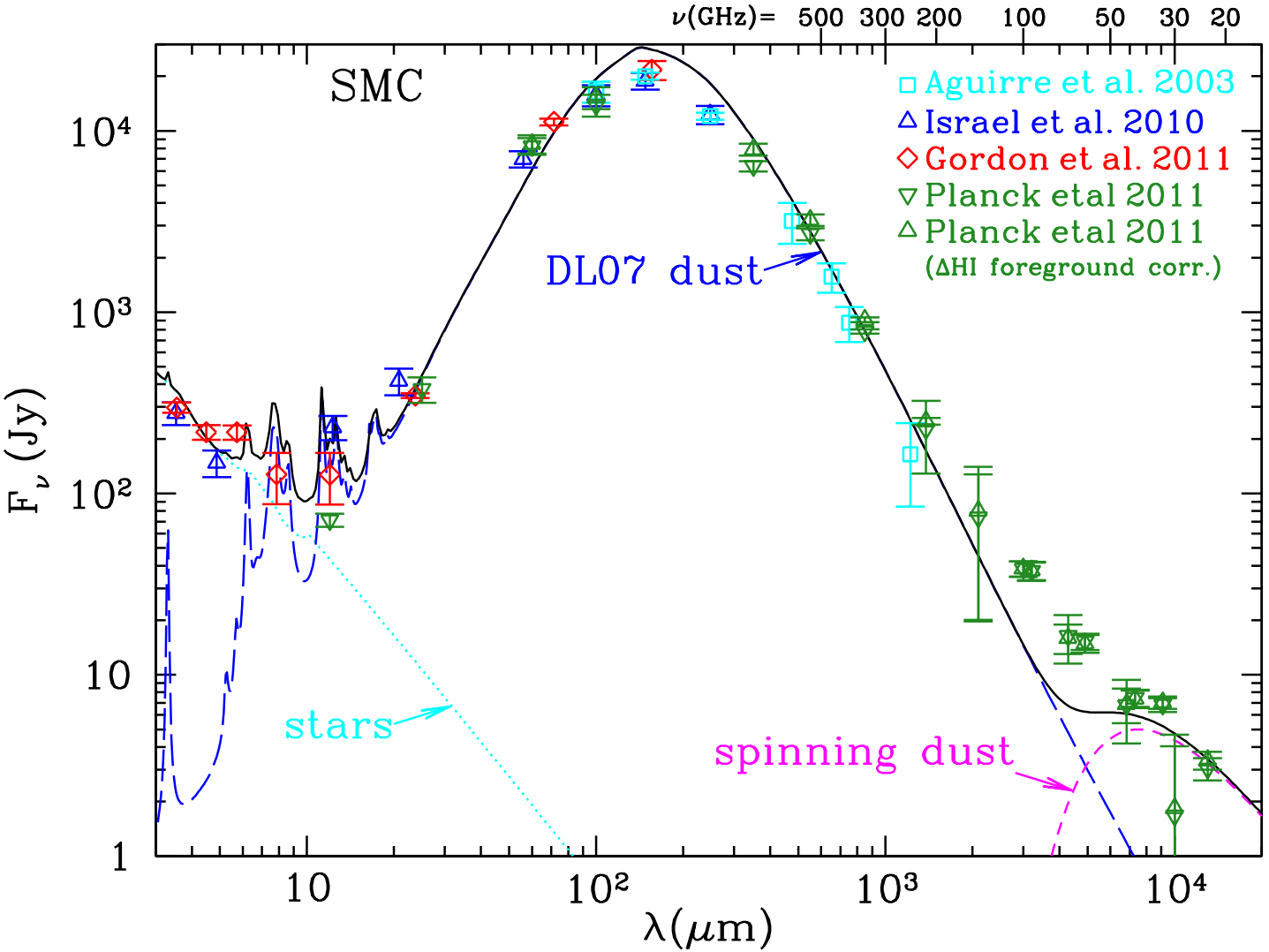


Draine and Hensley 2012

Fitting Dust Models

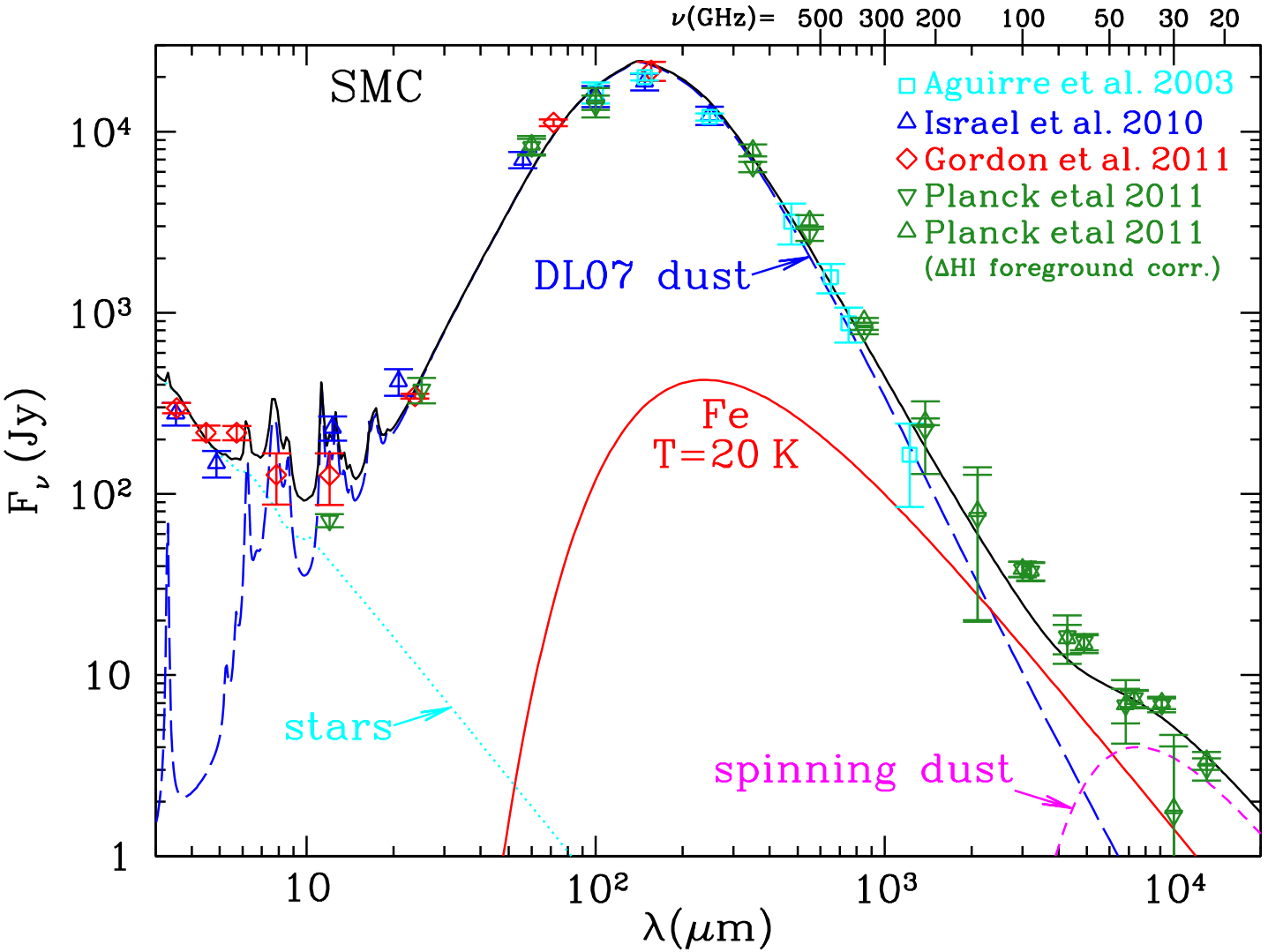
- Likewise, Planck Collaboration 2011 was unable to fit the emission with reasonable dust models

Fitting a Model with Magnetic Grains



Draine and Hensley 2012

Fitting a Model with Magnetic Grains

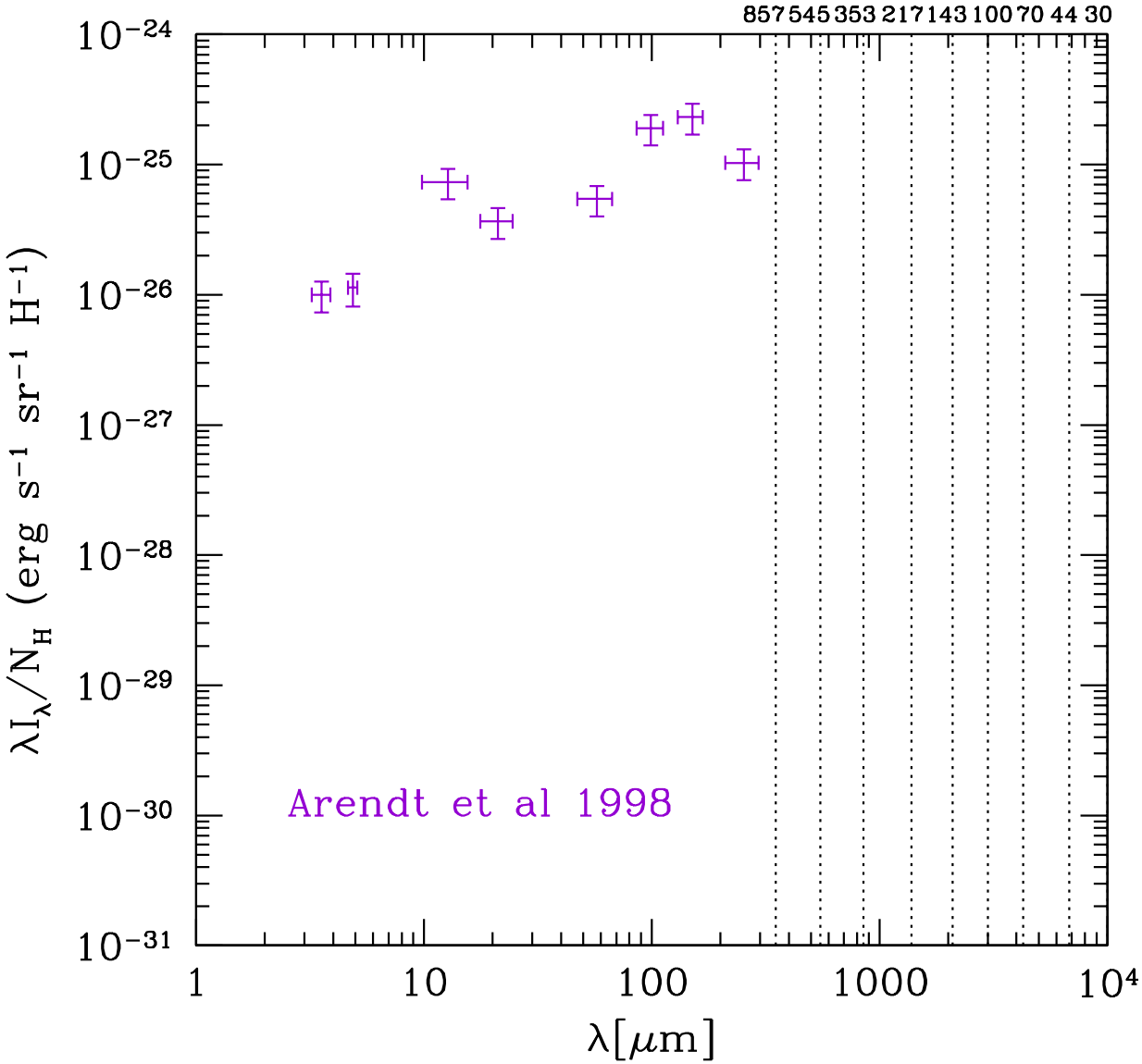


Draine and Hensley 2012

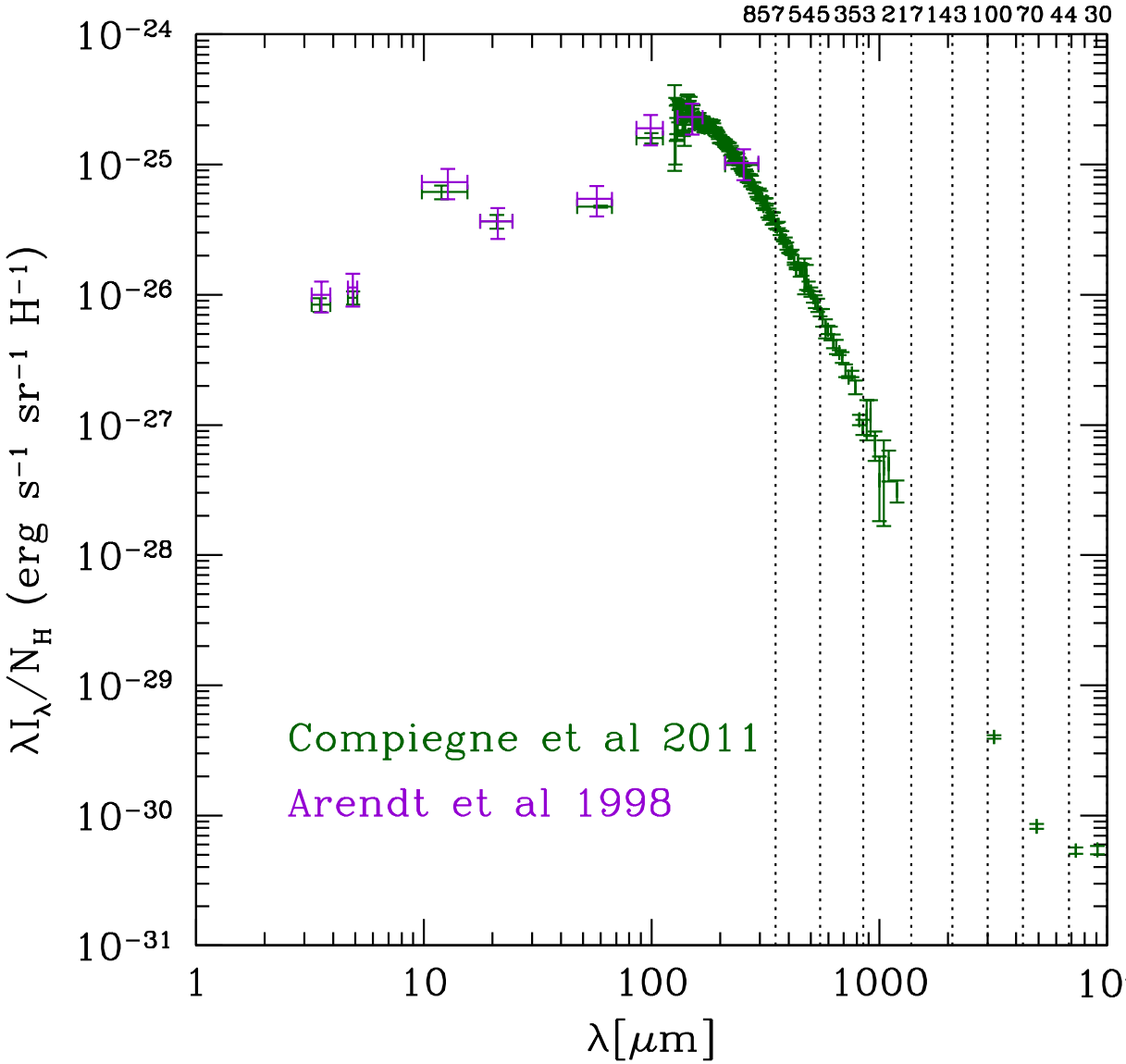
Dust Models with Magnetic Grains

- We will first extend Draine and Fraisse to include magnetic grains, and discuss polarization predictions
- Then we will discuss the polarization predictions for models of the SMC

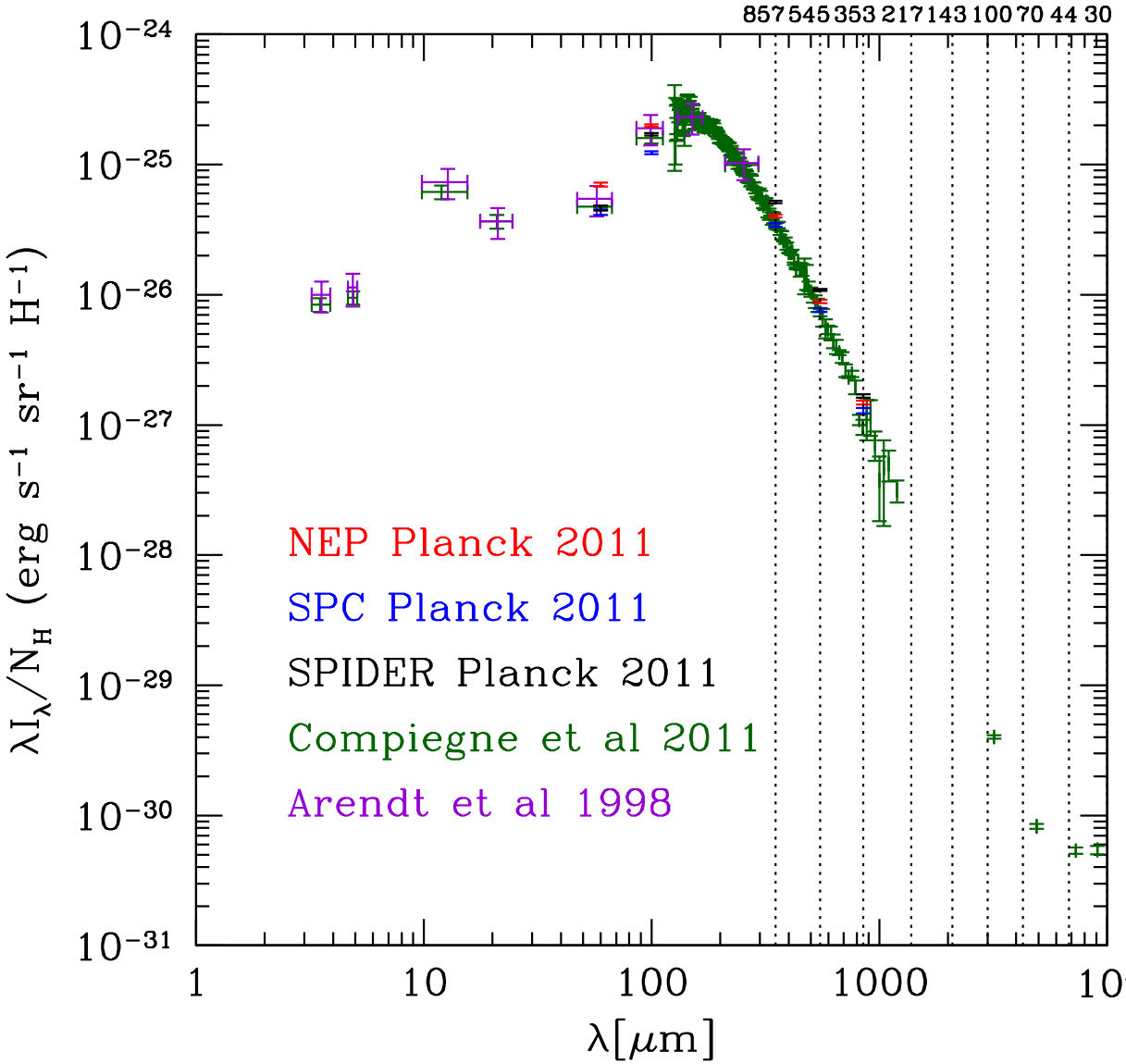
Additional Observations



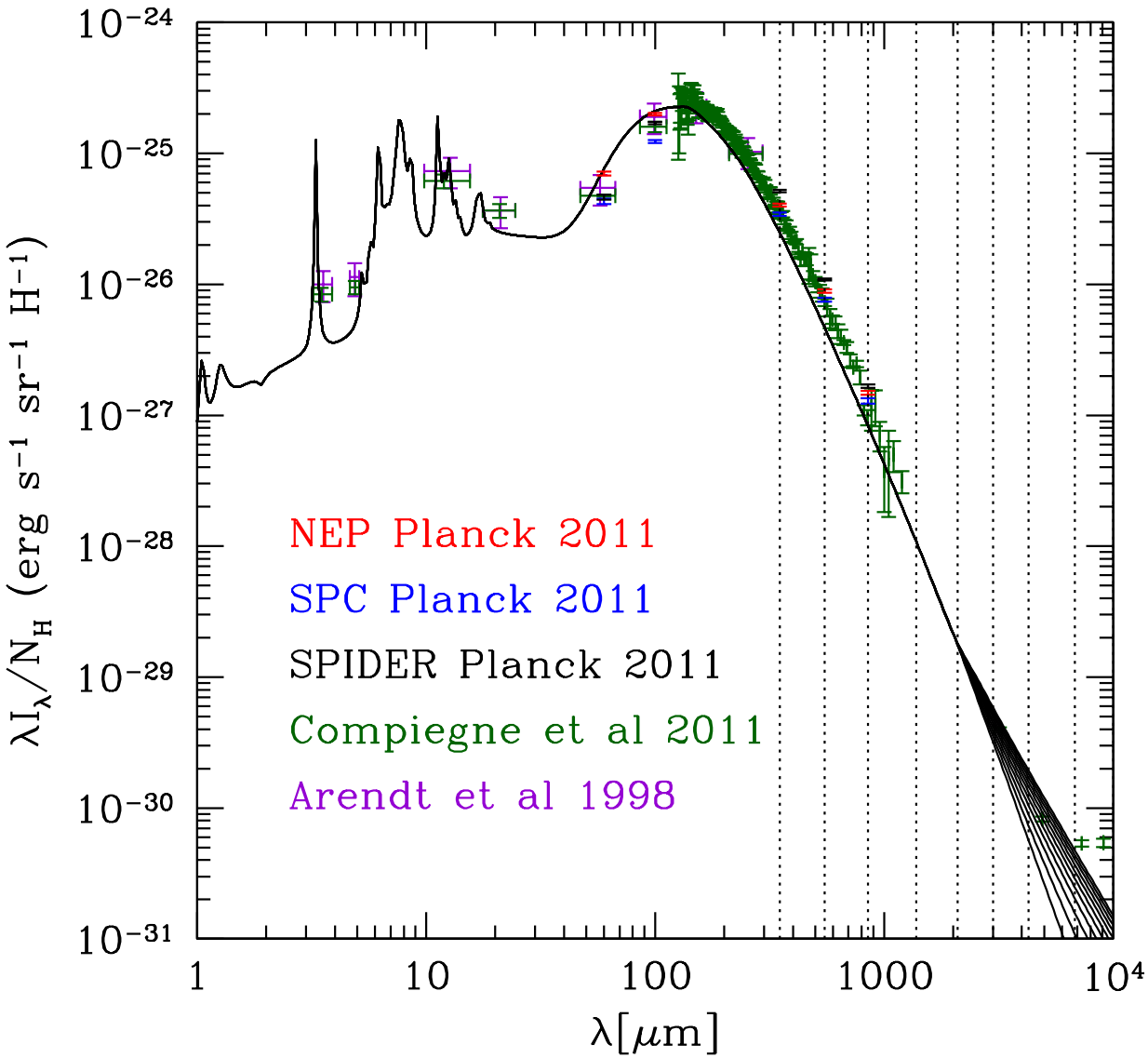
Additional Observations



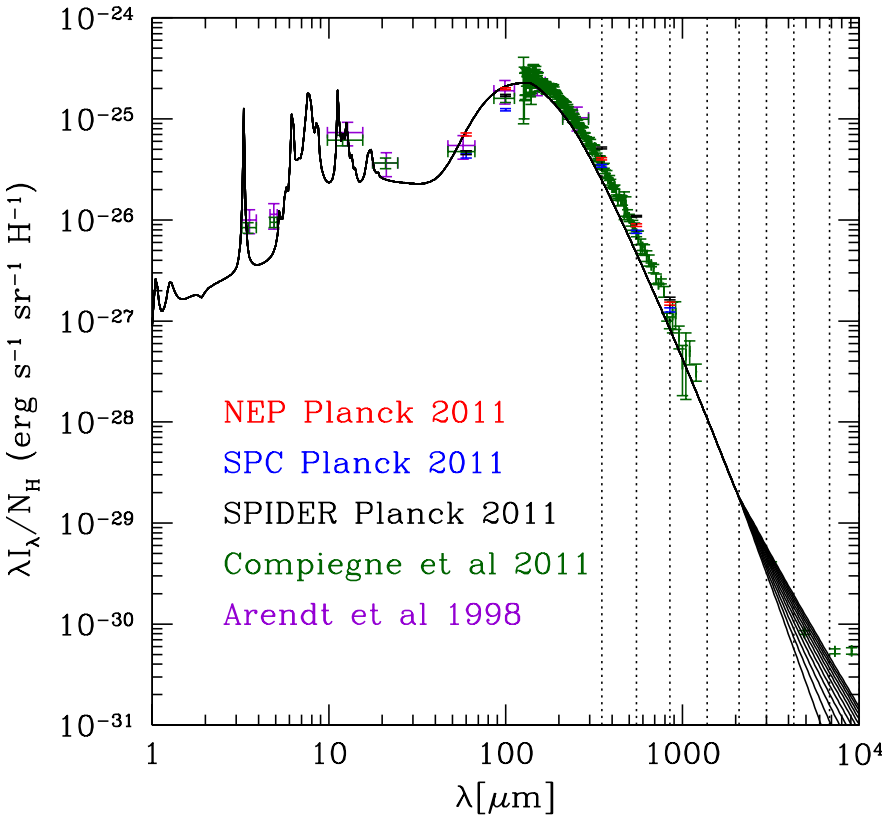
Additional Observations



Additional Observations



Polarization Predictions

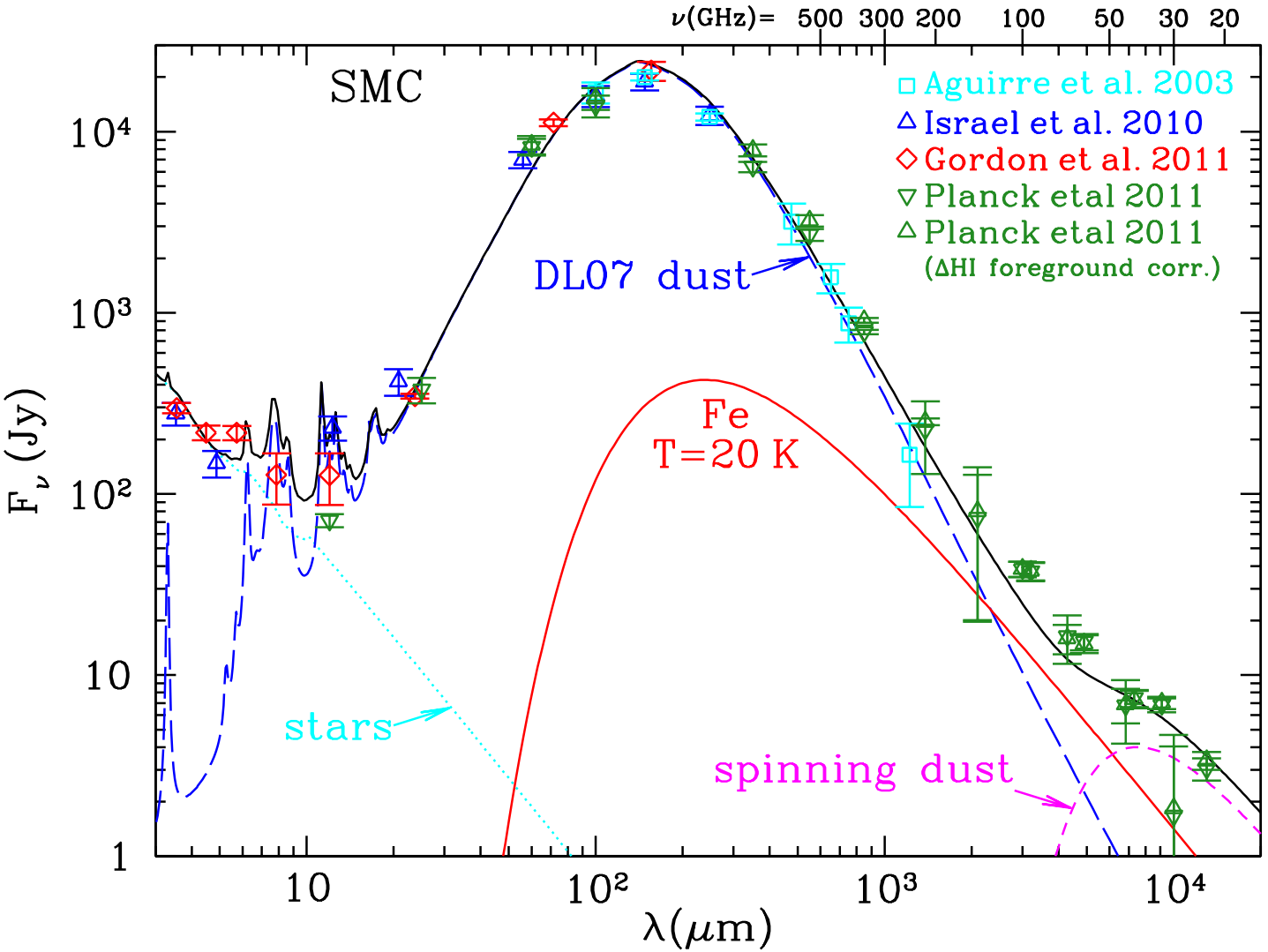


Note: Model does not yet include spinning dust emission

Magnetic Grains in the SMC

- If the SMC in fact has substantial emission from magnetic grains, what is its polarization signature?

Magnetic Grains in the SMC



Draine and Hensley 2012

Magnetic Grains in the SMC

Summary

- New long-wavelength data are driving an upgrade of dust models
- Magnetic grains may contribute significantly to sub-mm and mm dust emission, and will make a pronounced impact on polarization

In Progress

- Updating the Draine and Fraisse model to better match the emission constraints
- Investigating models which predict large polarization fractions, such as the $> 15\%$ reported by Planck

References:
Draine and Fraisse 2009, ApJ 696 1
Draine and Hensley 2012, ApJ 757 103
Draine and Hensley 2013, ApJ 765 159
Hensley and Draine 2013, in prep.

Constraints on Dust Properties

- Extinction

$$\sigma_{\rm ext}^{\rm obs} = 0.4\,(\ln 10)\,\frac{A_\lambda/{\rm mag}}{N_{\rm H}} \tag{1}$$

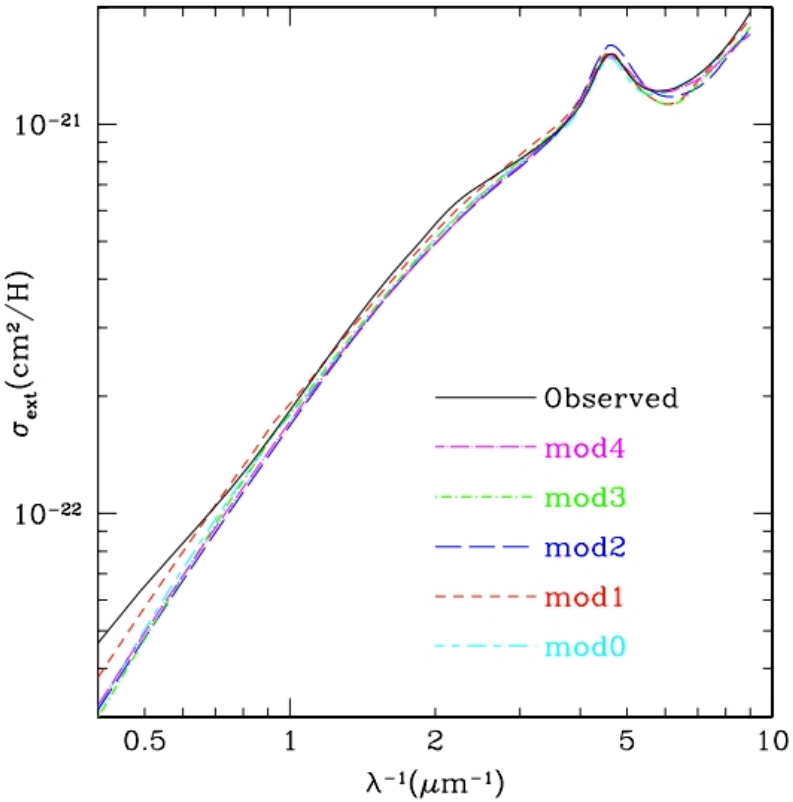
- Polarization

$$\sigma_{\rm pol}^{\rm obs} \approx \frac{p\,(\lambda)}{N_{\rm H}} \tag{2}$$

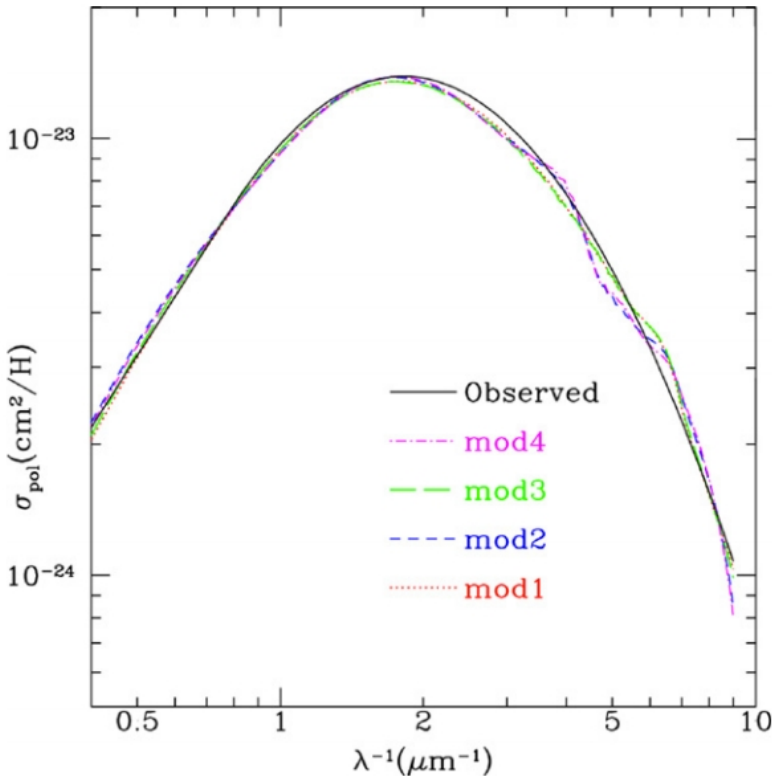
- Emission

Draine and Fraisse 2009

- Model consistent with extinction and optical polarization



Draine and Fraisse 2009



Draine and Fraisse 2009

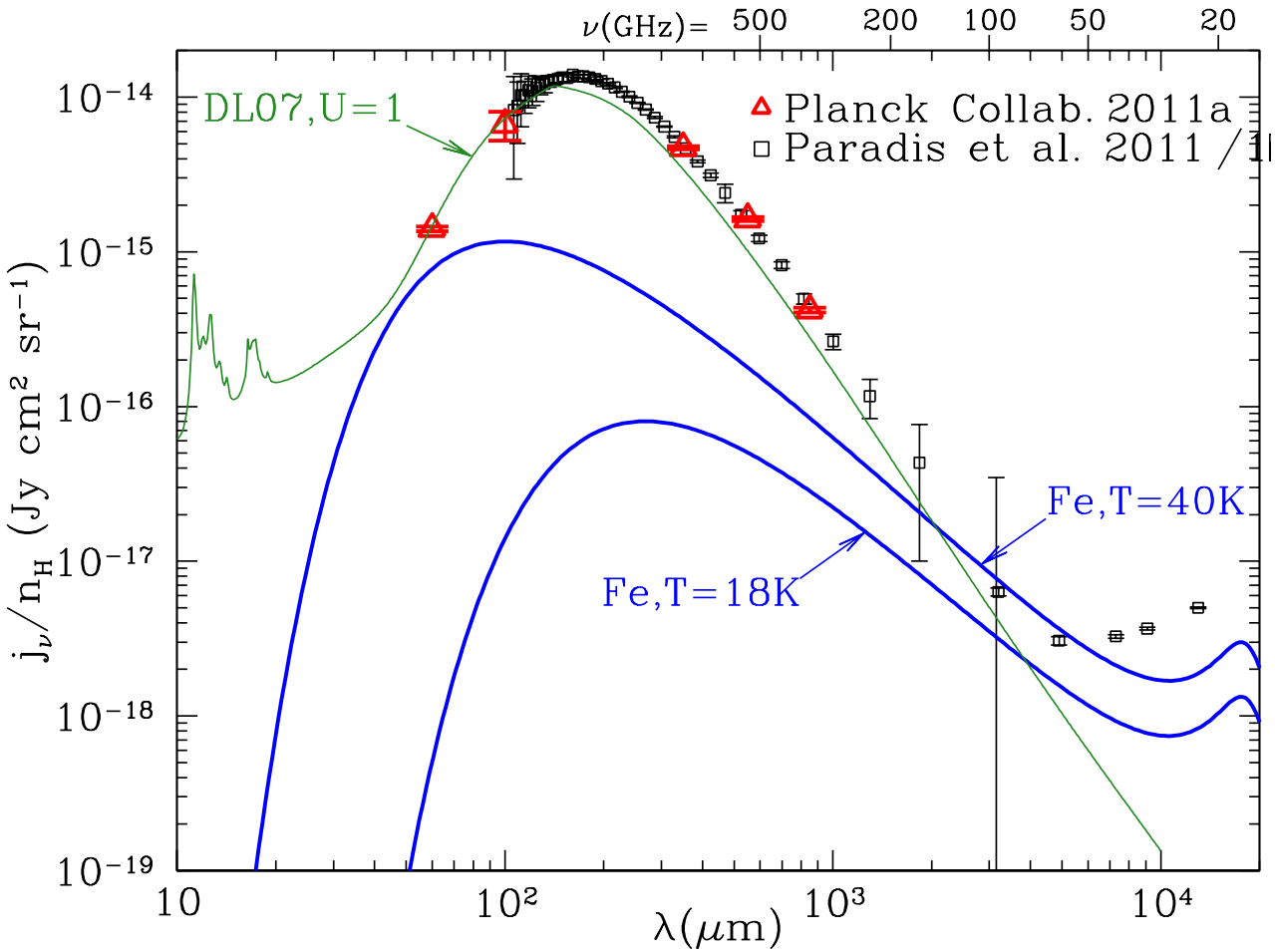
Modeling the Emission

- Gilbert Equation

$$\frac{d\vec{\mathrm{M}}}{dt} = \gamma\vec{\mathrm{M}} \times \vec{\mathrm{H}}_T + \alpha_{\mathrm{G}}\frac{\vec{\mathrm{M}}}{|\vec{\mathrm{M}}|} \times \frac{d\vec{\mathrm{M}}}{dt}$$

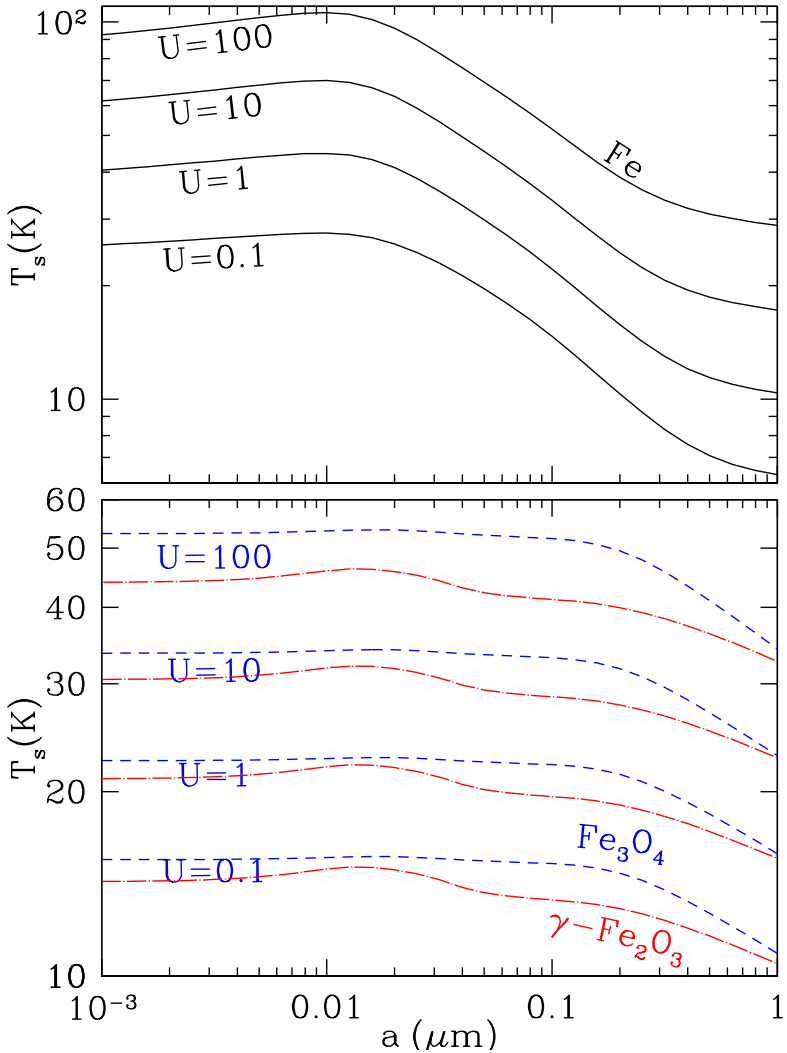
- First term describes precession of the magnetization about the fictitious "effective field" $\vec{\mathrm{H}}_T$
- Second term describes the relaxation of the magnetization toward minimum energy solution (i.e. $\vec{\mathrm{M}}$ and $\vec{\mathrm{H}}_T$ parallel)

Magnetic Grains in the Milky Way



Draine and Hensley 2012a

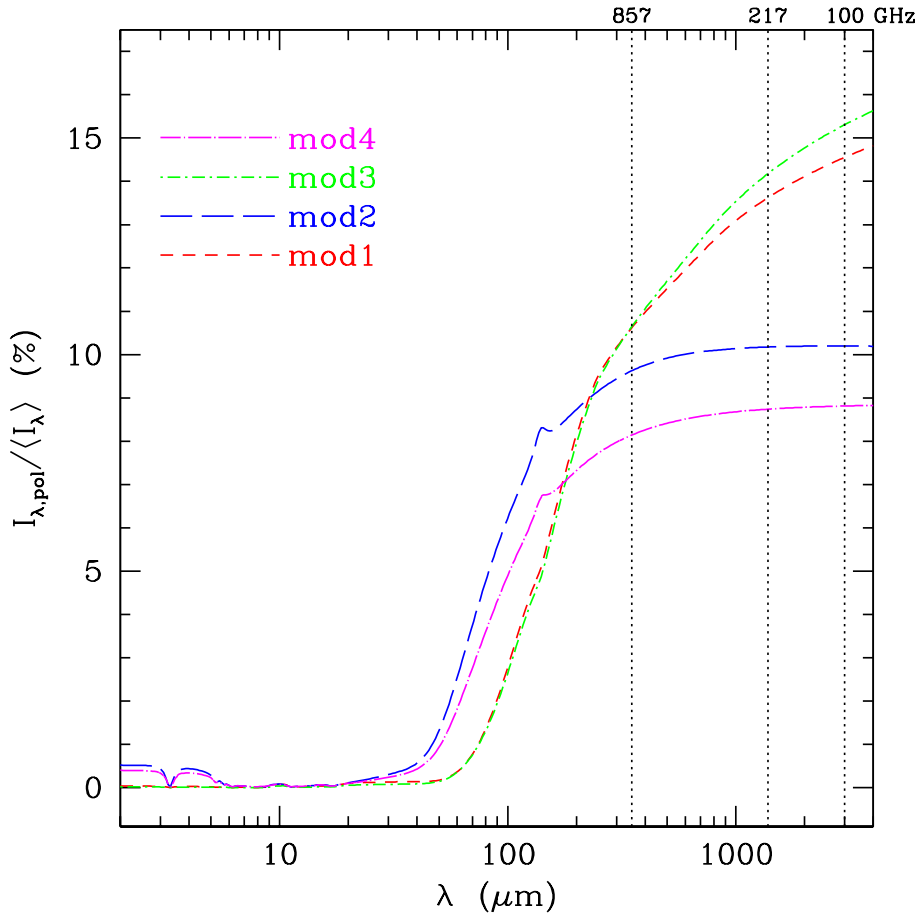
Magnetic Grain Temperatures



Draine and Hensley 2012a

Polarization of Dust Emission

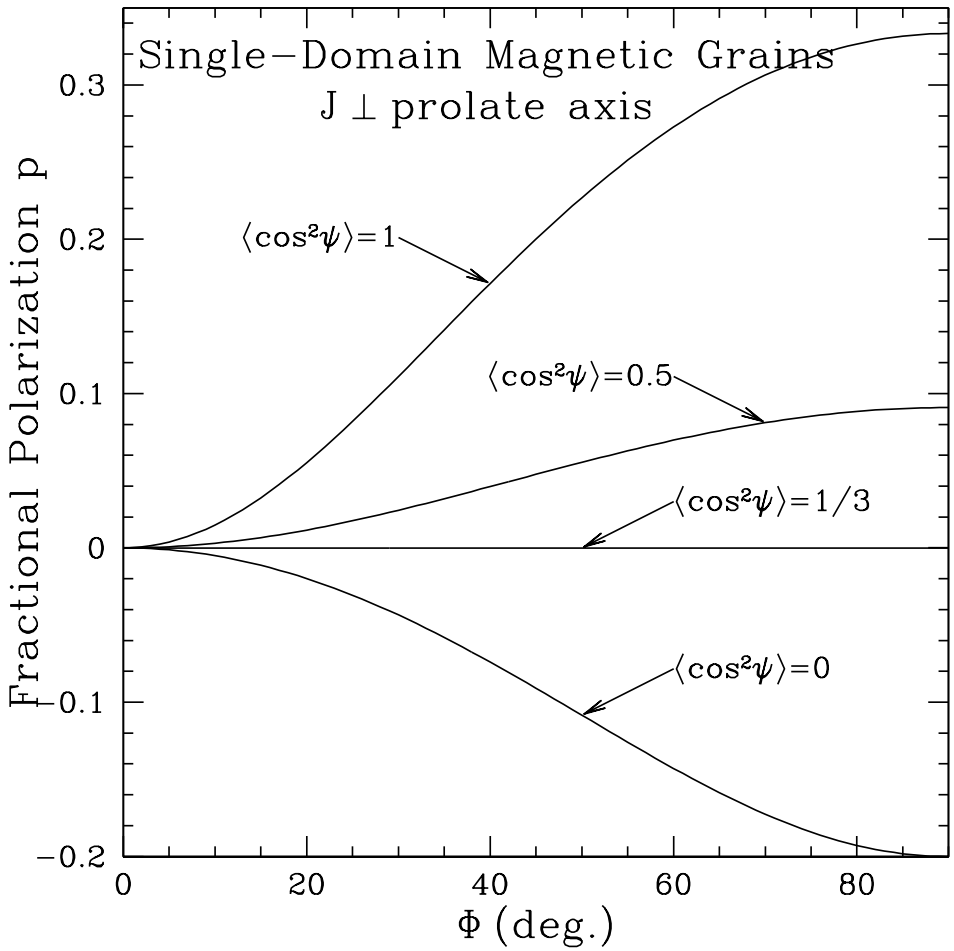
- If carbonaceous grains are relatively unpolarized, then the polarization fraction is expected to increase at longer wavelengths (Models 1 and 3)
- The presence of two grain populations would complicate the interpretation of polarization data at long wavelengths



Draine and Fraisse 2009

Polarization of Free-flying Grains

- The polarization fraction will depend upon the degree of alignment of the angular momentum vector with the magnetic field



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