Anomalous Microwave Emission: Polarized CMB Foreground?

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U.S. Radio/Millimeter/Submillimeter
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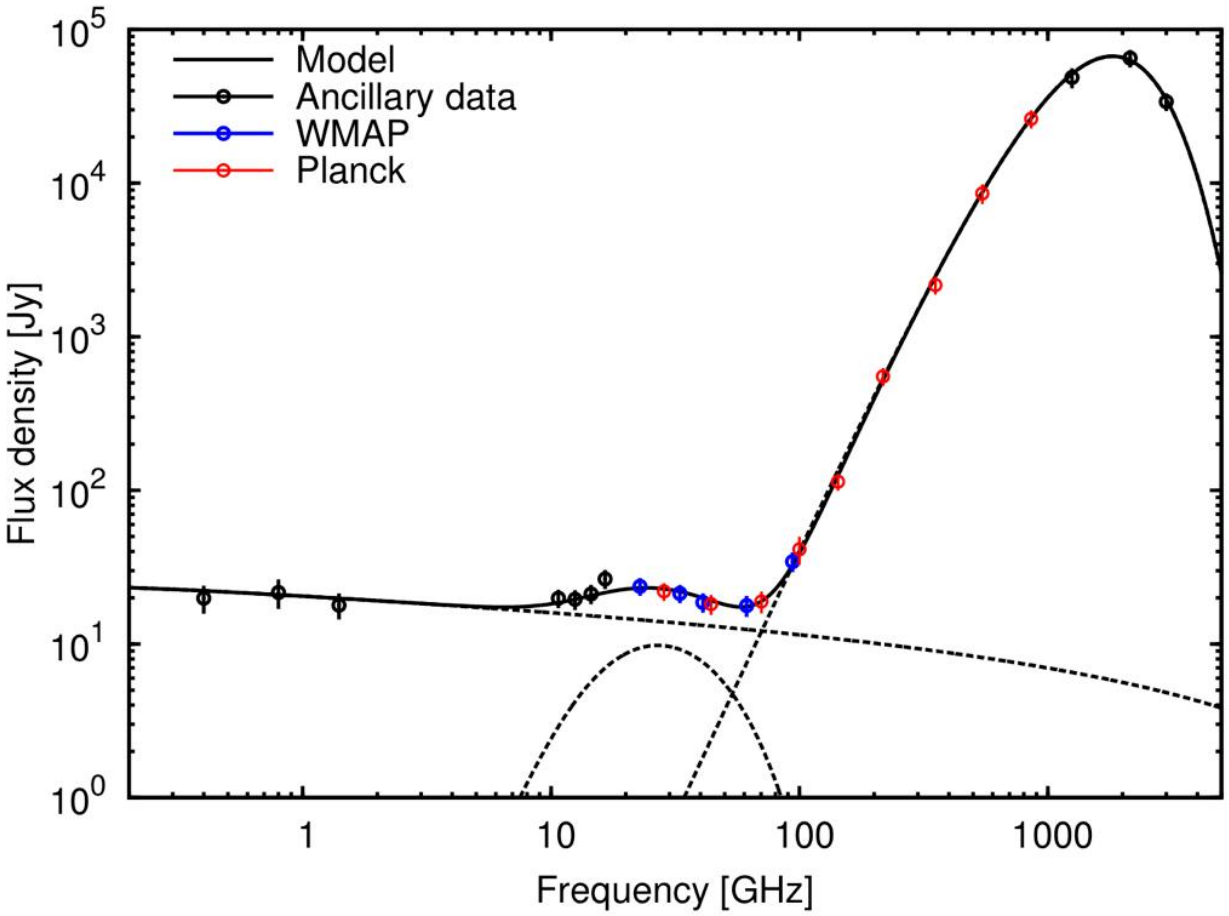
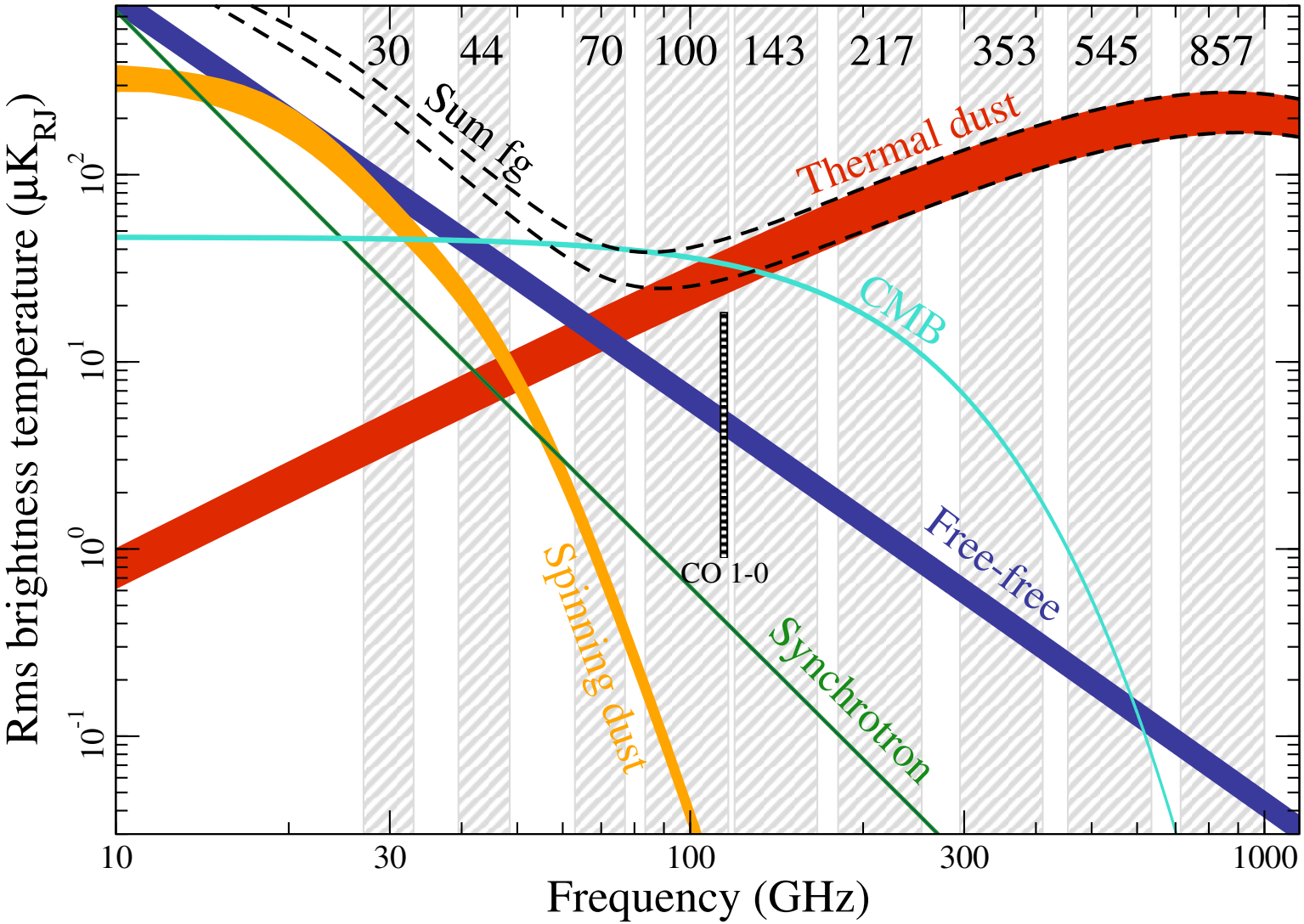
Anomalous Microwave Emission

Planck Early XX – Perseus Molecular Cloud



The Microwave Sky in Intensity

Planck 2015 X

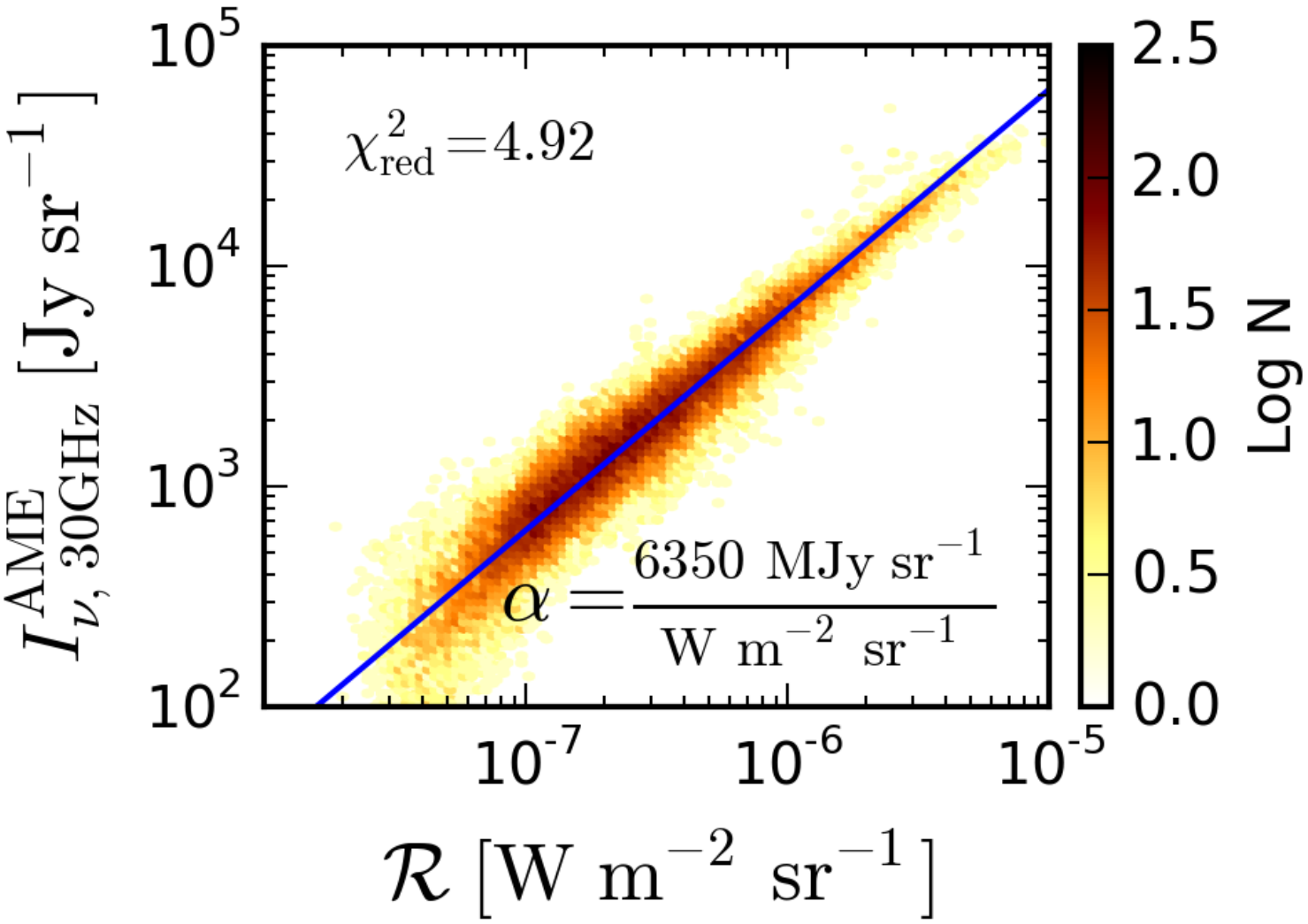


Empirical Picture

- Peaks between 20 - 50 GHz
- Tightly coupled to dust emission, especially short-wavelength emission and dust radiance
- No detected polarization down to sub-% levels

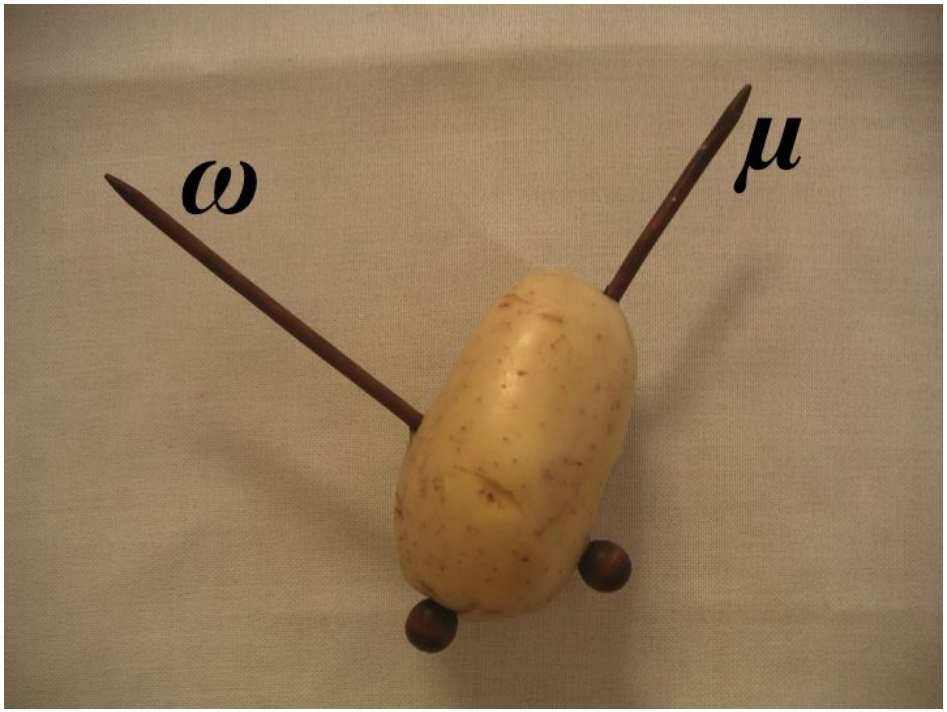
Correlation with Dust Radiance

Hensley, Draine, and Meisner 2016



Spinning Dust Physics

- AME can be explained by spinning dust grains (Draine & Lazarian 1998ab)
- Very small grains (e.g. PAHs) can get spun up by gas collisions, radiative torques, and other processes
- If grains have a dipole moment, this rotation causes them to radiate



Credit: Yacine Ali-Haïmoud

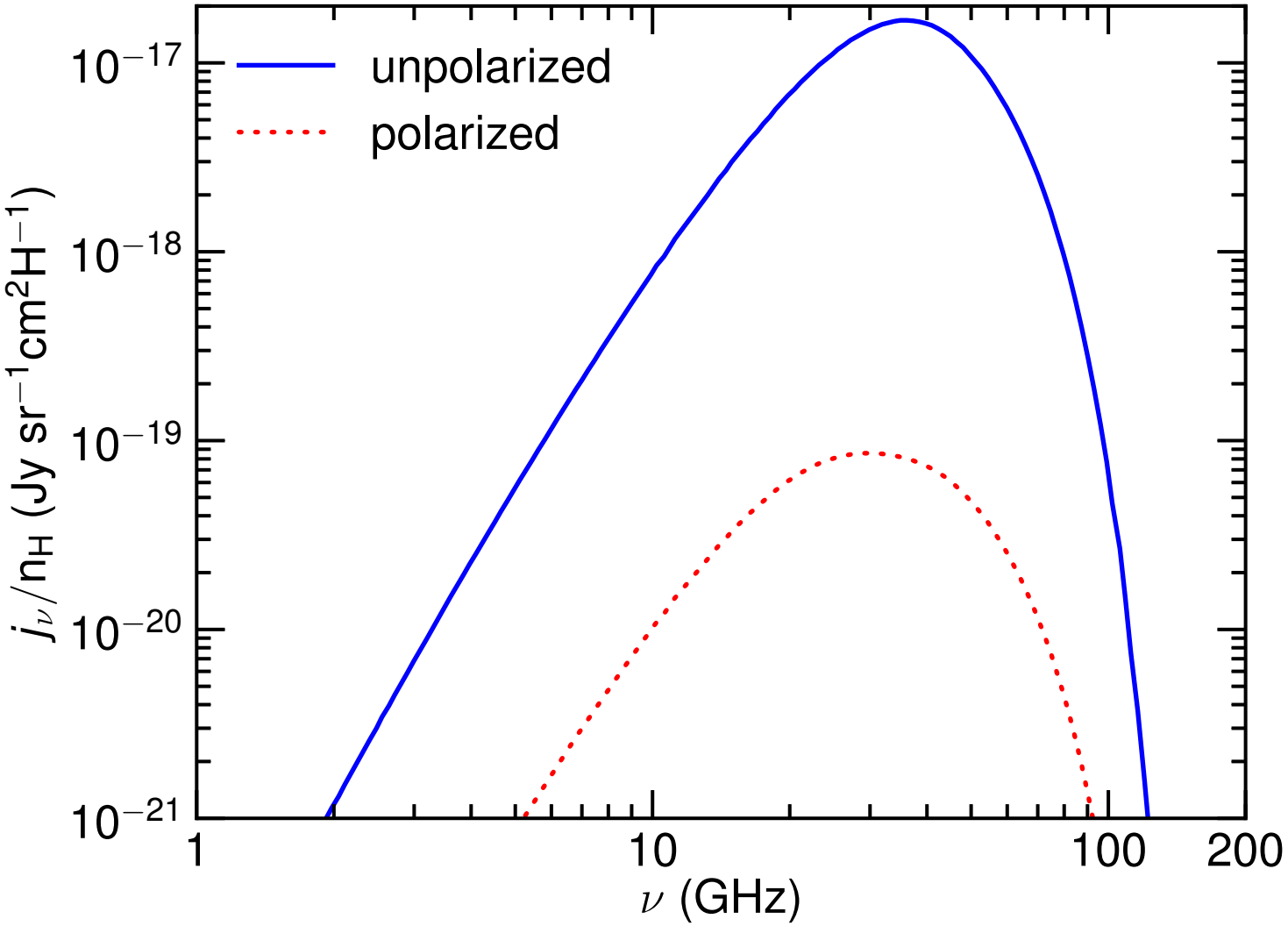
Spinning Dust Polarization

- Emission from rotating dipole– 100% polarized!
- ...if the grains aligned with the interstellar magnetic field

Grain Alignment

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

Spinning Dust Polarization



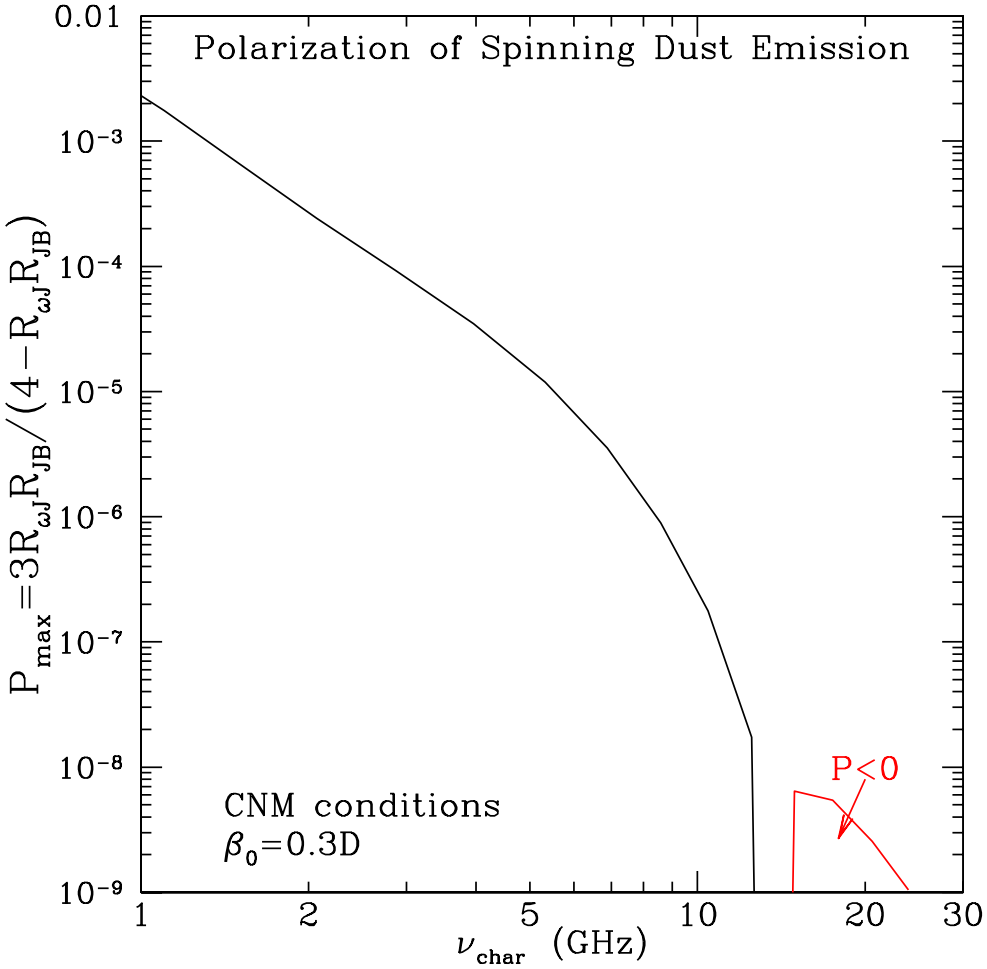
Hoang, Lazarian, & Martin 2013

Quantum Suppression

- Small grains in the quantum limit
- Angular momentum quantized, vibrational energy quantized – Not so easy to interchange when levels are few!

Quantum Suppression

Spinning dust emission effectively unpolarized
Draine and Hensley 2016

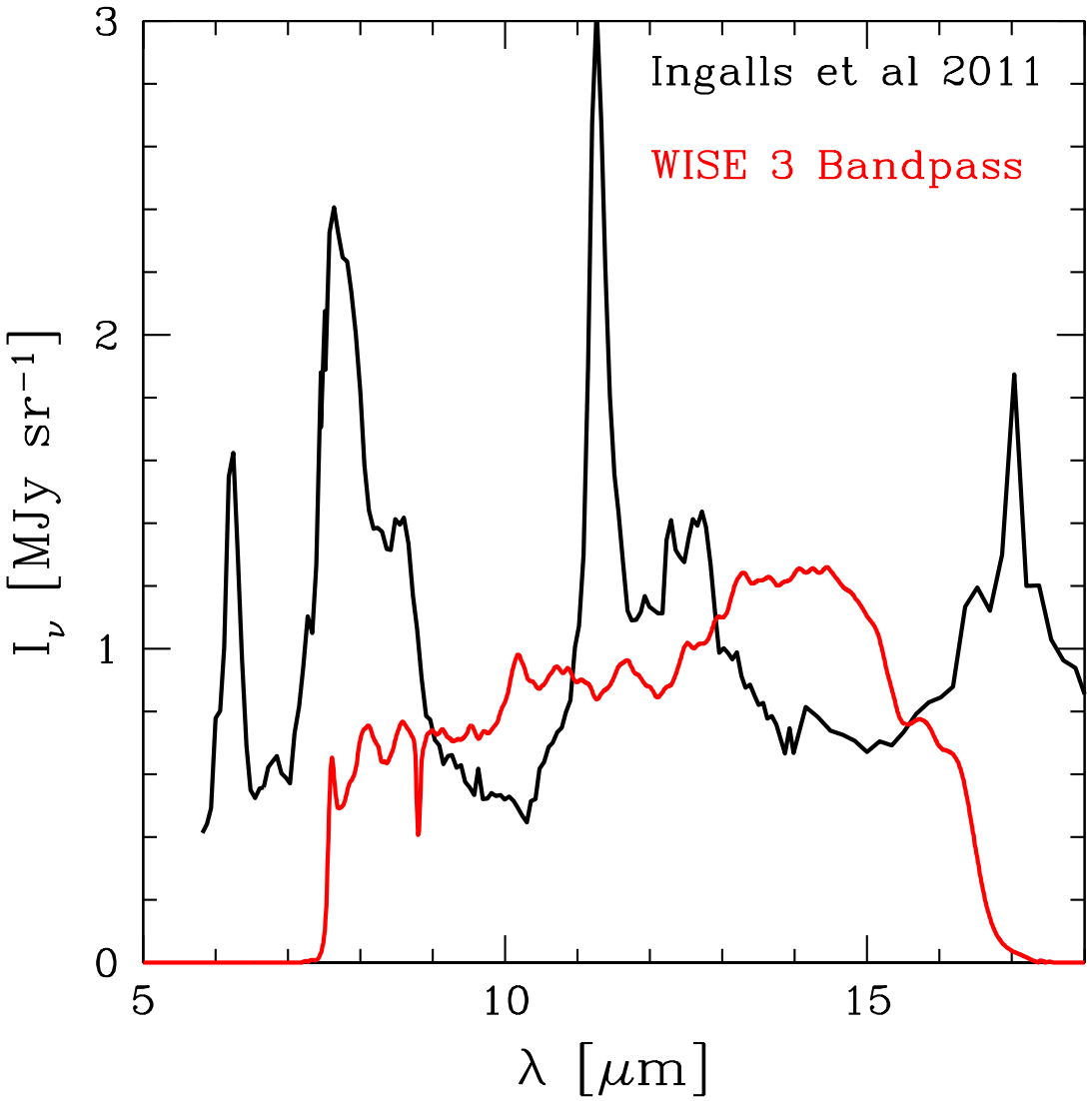


Big Question

Are we confident that AME is 100% accounted for by emission from spinning ultrasmall grains?

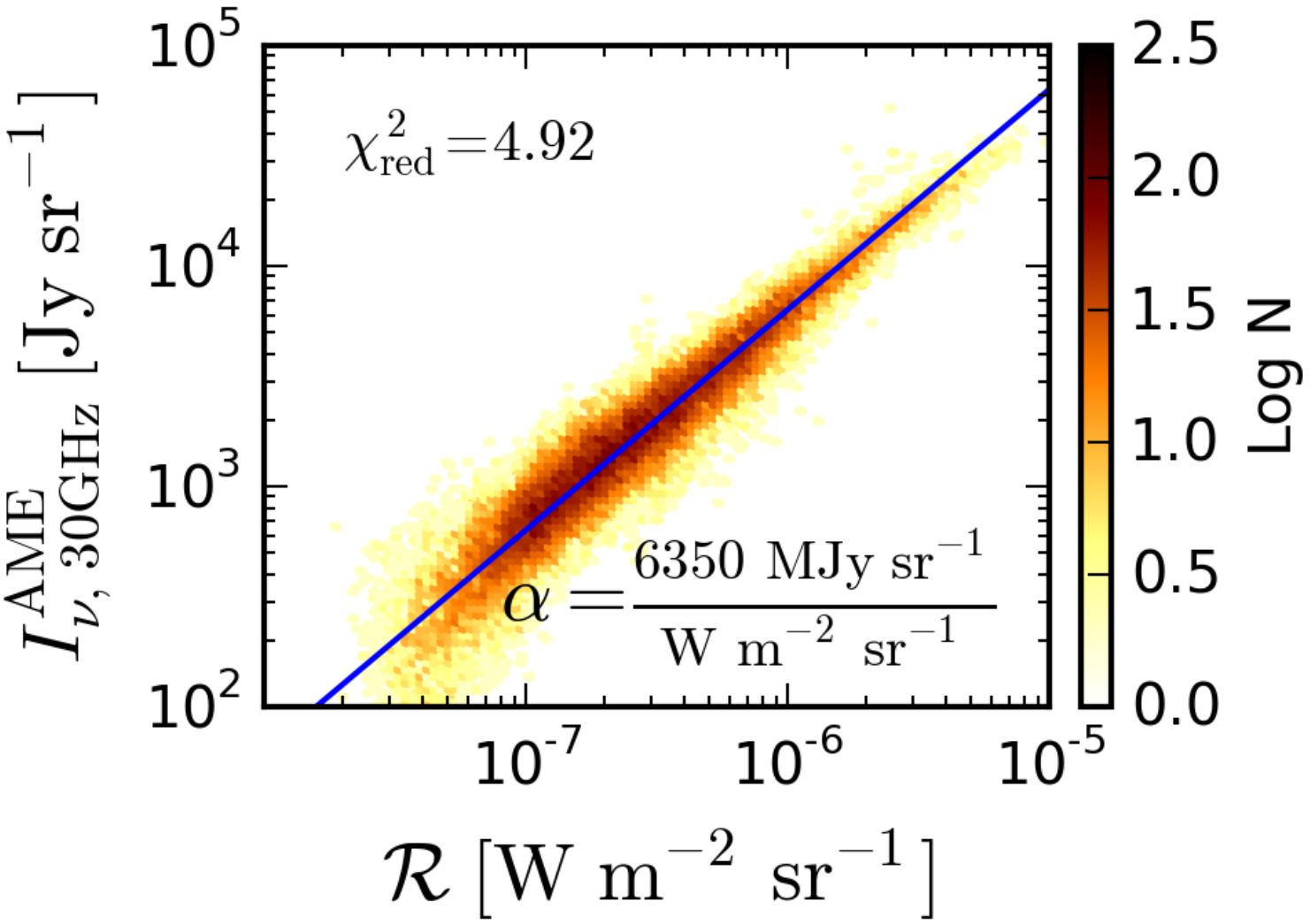
PAHs

- Attractive AME carrier because they are small and ubiquitous
- Abundance traced by IR emission features at 8 and 12 μm



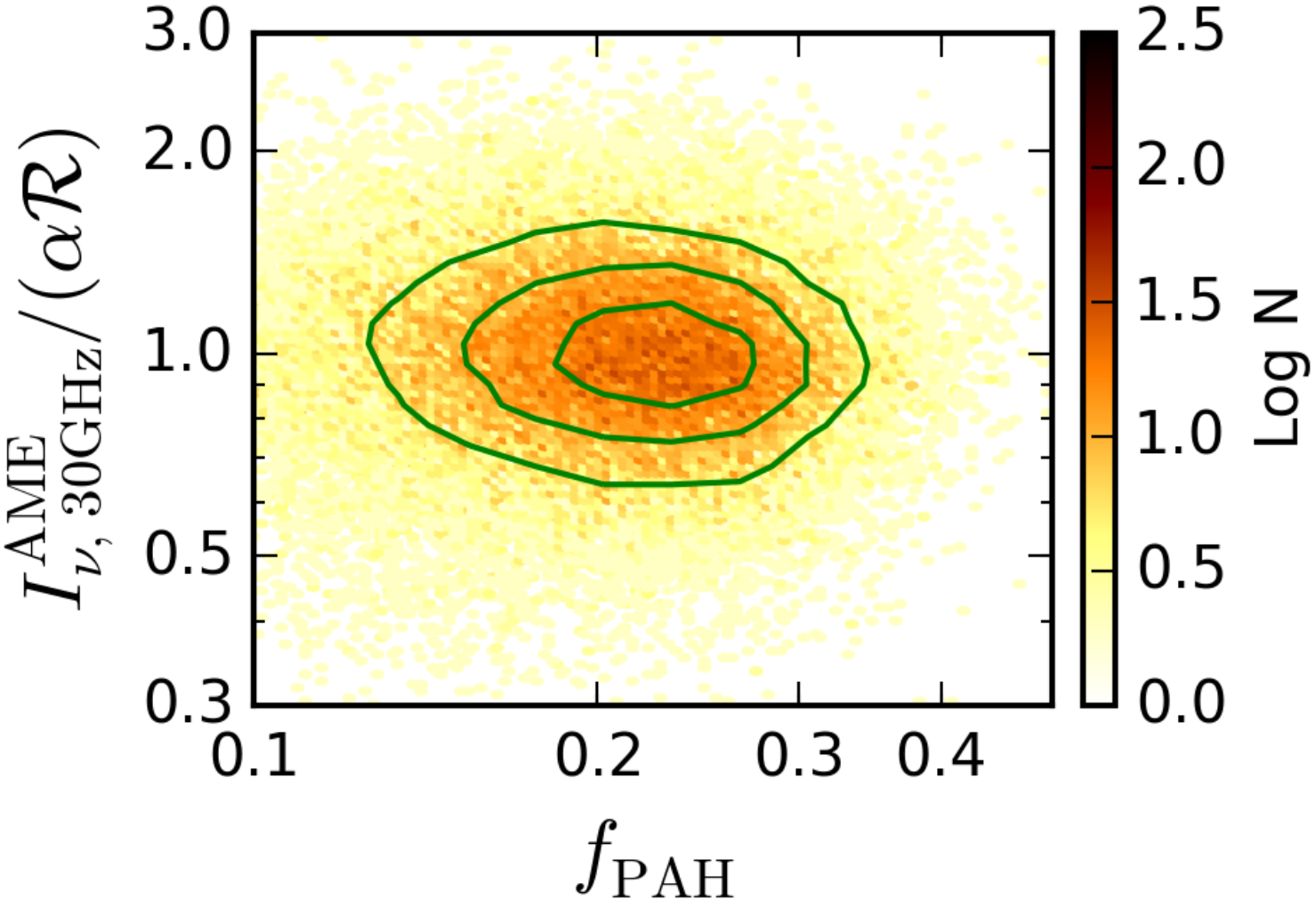
Testing the Spinning PAH Hypothesis

Does PAH abundance explain fluctuations in AME/$\mathcal{R}$?



Correlation with $f_{\rm PAH}\mathcal{R}$

- $f_{\rm PAH}$ does **NOT** improve the correlation with $\mathcal{R}$



Big Question

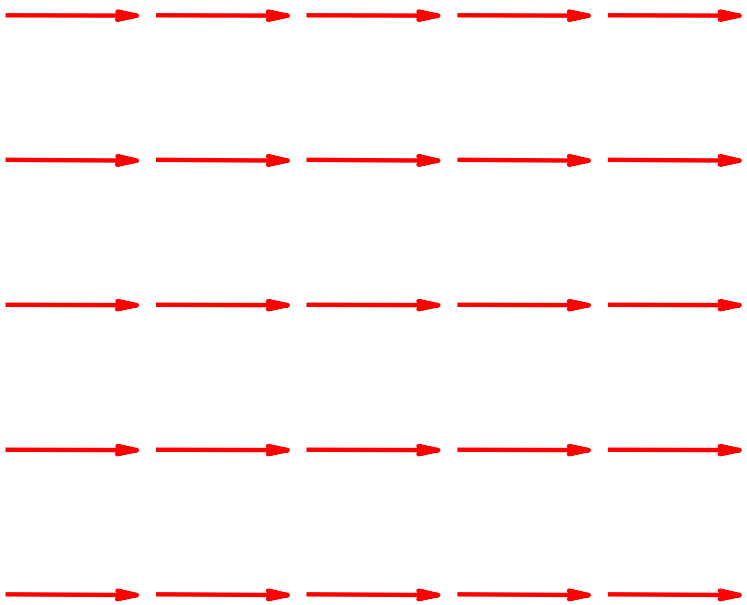
Are we confident that AME is 100% accounted for by emission from spinning ultrasmall grains?

- Need to firmly establish link between ultrasmall grains and AME
- Need to investigate possibility of other, possibly sub-dominant, dust emission mechanisms

Magnetic Materials

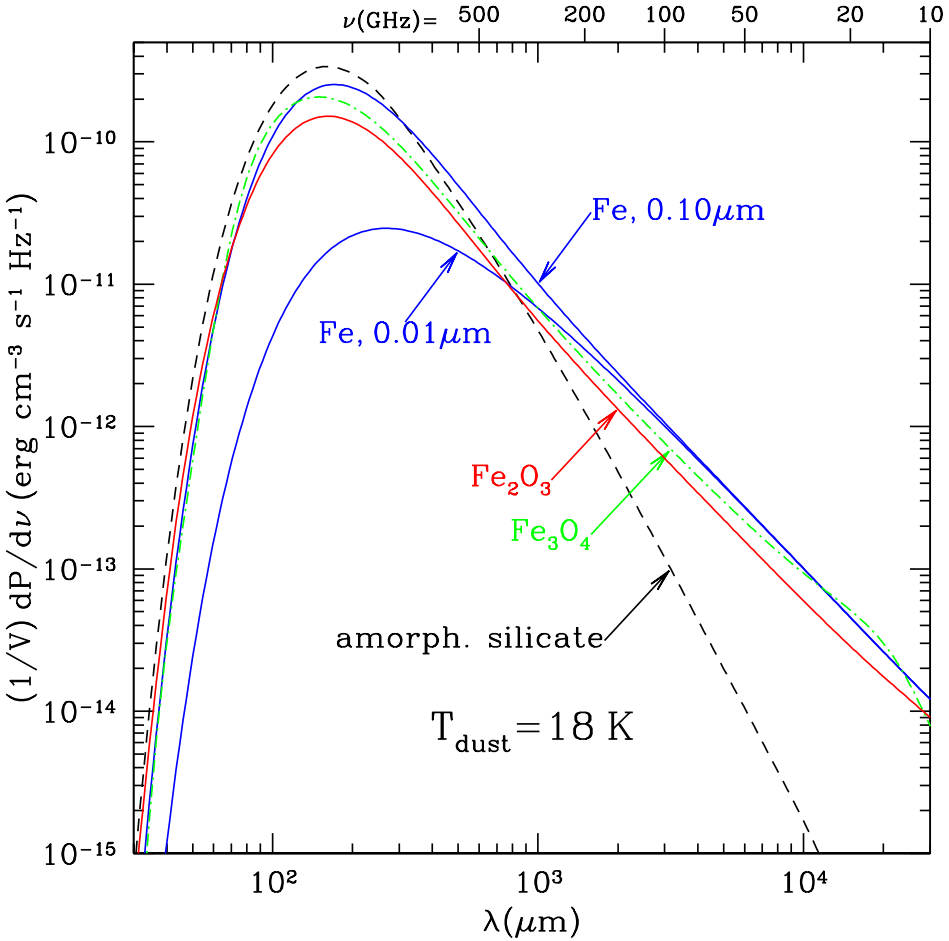
- Ferromagnetic materials, such as metallic Fe, have all unpaired spins aligned along a preferred axis
- Thermal excitations can move the spins away from this state
- Then magnetization vector precesses about the preferred direction and produces radiation

Ferromagnetic spin lattice



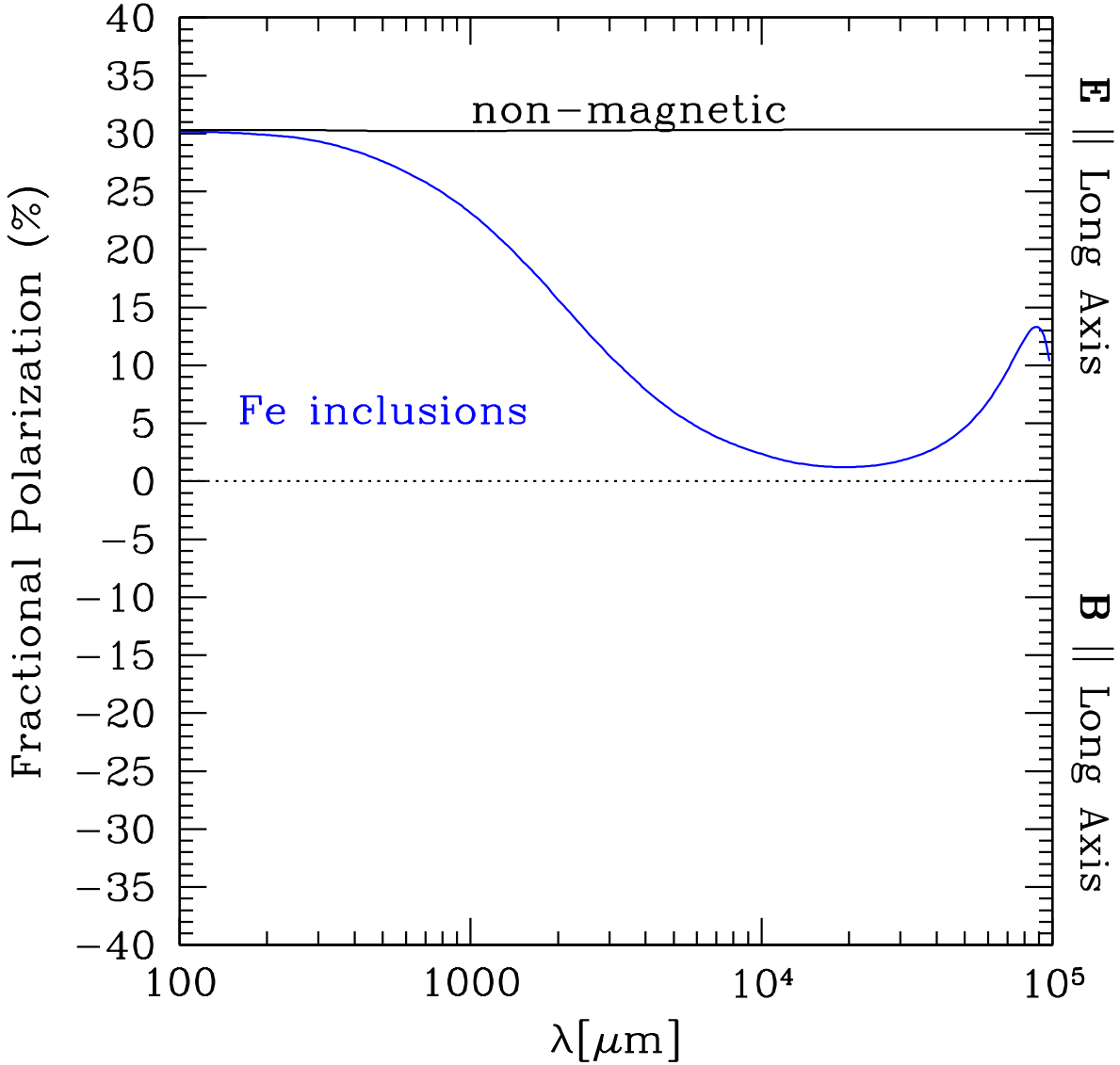
Magnetic Nanoparticles

- **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

Polarization



Magnetic Dust

Probably can't explain 100% of the AME

- Not great at reproducing the shape of the SED
- Emission would likely be strongly polarized, in conflict with observations

Other Thermal Dust Emission

- Two Level Systems
- Other modifications to the (poorly-measured!) microwave properties of amorphous materials

Observational Hints

- Peculiar dust SED of the SMC
- Frequency decorrelation in dust polarization

Conclusions

- Spinning dust emission will be negligibly polarized due to quantum suppression of alignment
- It remains unclear if the AME is entirely spinning dust emission or whether other mechanisms may also be acting
- Observations elucidating evolution of the AME with environment are needed for better understanding and modeling of this emission