Modeling the Frequency Dependence of Polarized Dust Foregrounds

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Hensley & Bull arXiv:1709.07897

Government sponsorship acknowledged.

CMB Foregrounds Workshop
November 29, 2017

Frequency Dependence of Dust Emission

1. What dust properties are likely to vary from sightline to sightline?
2. How do these properties affect the dust SED?
3. SED variations → frequency decorrelation

Simple Parametric Model

Dust heated to temperature T_d emits as a modified blackbody

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

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

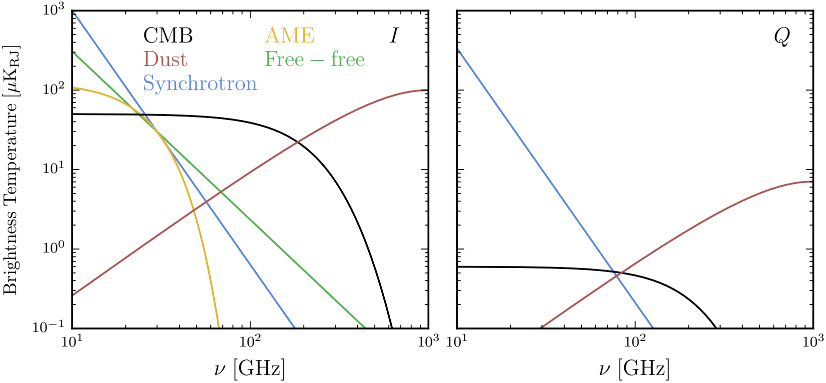
Key Questions

- Are modified blackbody parameterizations robust enough for realistic dust complexity?
- What dust complexities are most difficult for analysis and how can they be best mitigated?

Single Pixel Paradigm

1. Work with one realization of all non-dust components in the microwave sky, set to representative amplitudes and SEDs

The Microwave Sky in Intensity and Polarization



Emission Components

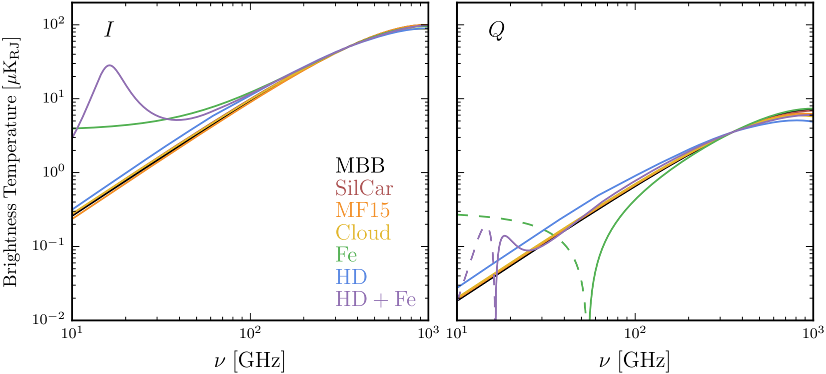
Synchrotron

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

Single Pixel Paradigm

1. Work with one realization of all non-dust components in the microwave sky, set to representative amplitudes and SEDs
2. Employ a suite of dust models encompassing a range of dust physics

A Suite of Dust Models



Single Pixel Paradigm

1. Work with one realization of all non-dust components in the microwave sky, set to representative amplitudes and SEDs
2. Employ a suite of dust models encompassing a range of dust physics
3. Employ a suite of mock instruments measuring in seven log-spaced frequency bins

$$\nu_{\rm min} = \{20, 30, 40\}\,{\rm GHz}$$
$$\nu_{\rm max} = \{300, 400, 500, 600, 700, 800\}\,{\rm GHz}$$

Single Pixel Paradigm

1. Work with one realization of all non-dust components in the microwave sky, set to representative amplitudes and SEDs
2. Employ a suite of dust models encompassing a range of dust physics
3. Employ a suite of mock instruments measuring in seven log-spaced frequency bins
4. Add noise based on forecasts for next-generation CMB experiments (100 realizations)
5. Perform component separation

Fitting Functions

One component MBB

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

Two component MBB

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

Component Separation

Input: 14 data points (Q and U in seven frequencies)

1. Fit with MBB dust

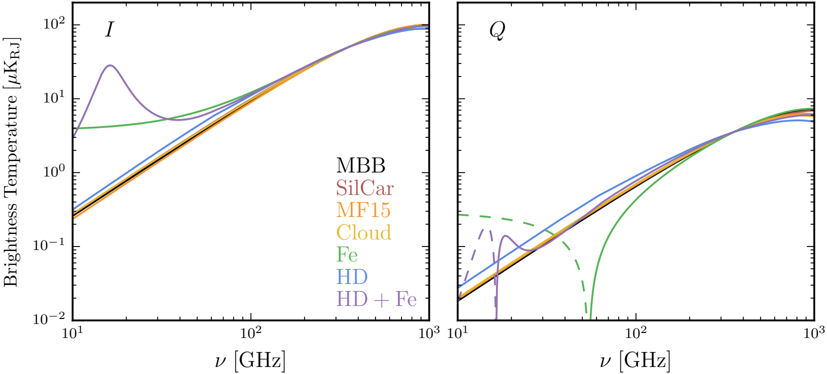
2. Fit with 2MBB dust

Perform MCMC fit for each band configuration (18), dust input model (7), dust fit model (2), and noise realization (100) (that’s over 25,000 MCMCs)

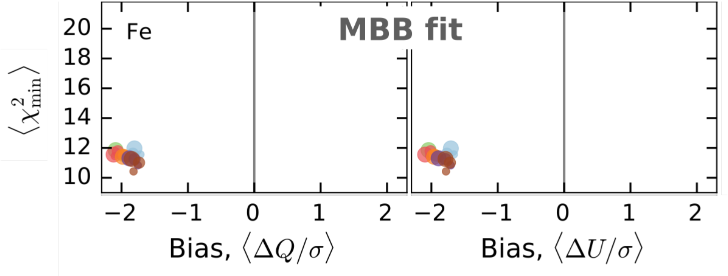
Magnetic Dust

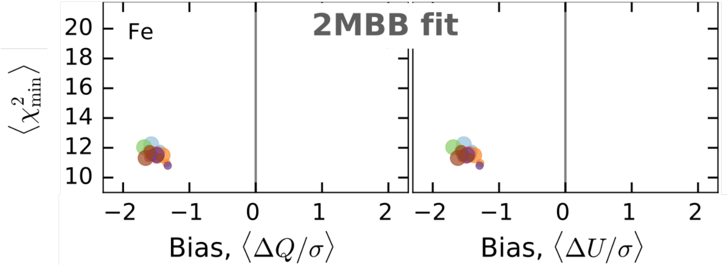
- Interstellar grains found by Stardust and Cassini were amorphous silicate with iron inclusions
- Ferromagnetic iron can be emissive in the microwave due to magnetic effects (Draine & Hensley 2012, 2013)
- Polarized emission from magnetic iron is **orthogonal** to polarized emission from non-magnetic grains, resulting in a unique polarization signature

A Suite of Dust Models

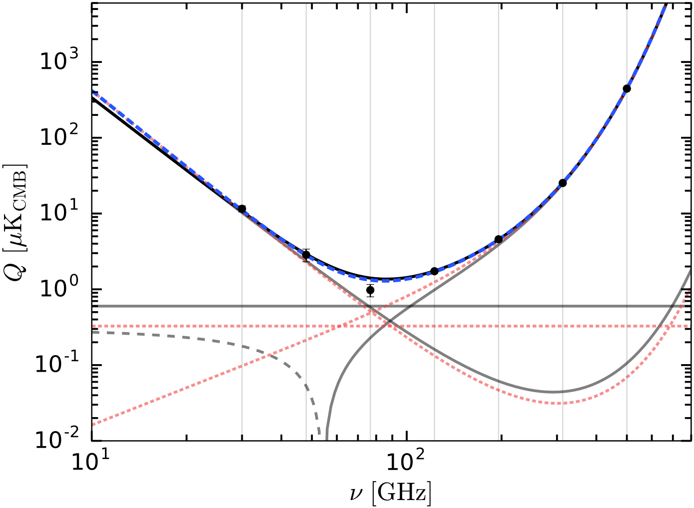


Fit Results

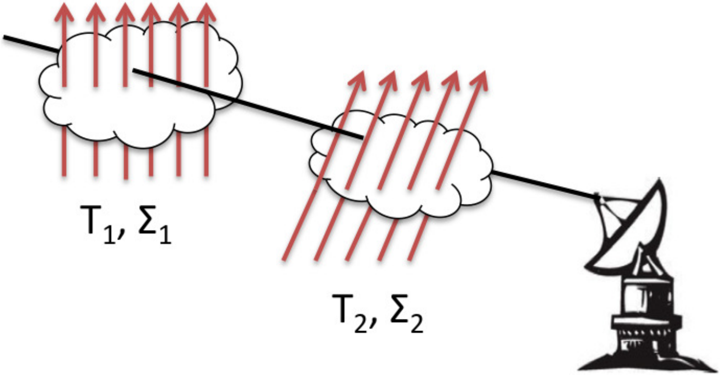

MBB fit
Fe
$\langle \chi^2_{\rm min} \rangle$
20
18
16
14
12
10
−2
−1
0
1
2
Bias, $\langle \Delta Q/\sigma \rangle$
Bias, $\langle \Delta U/\sigma \rangle$


2MBB fit
Fe
$\langle \chi^2_{\rm min} \rangle$
20
18
16
14
12
10
−2
−1
0
1
2
Bias, $\langle \Delta Q/\sigma \rangle$
Bias, $\langle \Delta U/\sigma \rangle$

Best Fit Model



Cloud Model

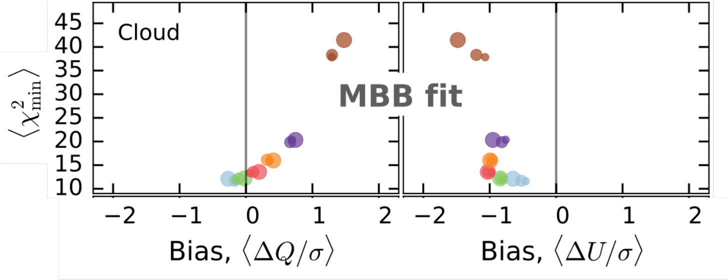


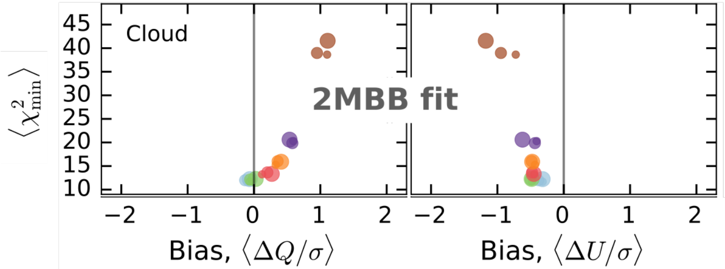
Tassis & Pavlidou 2015

Frequency Decorrelation

- Even if you know what the dust is doing at one frequency, hard to extrapolate to other frequencies due to the non-trivial way polarizations sum
- Big threat to template-based component separation techniques
- We know the dust SED varies across the sky– reasonable to think it also varies along the line of sight

Fit Results


Cloud
MBB fit
$\langle \chi^2_{\rm min} \rangle$
45
40
35
30
25
20
15
10
−2
−1
0
1
2
Bias, $\langle \Delta Q/\sigma \rangle$
Bias, $\langle \Delta U/\sigma \rangle$


Cloud
2MBB fit
$\langle \chi^2_{\rm min} \rangle$
45
40
35
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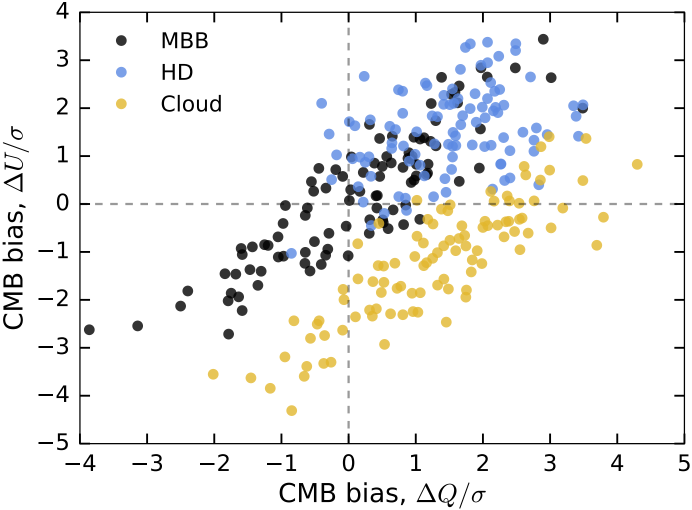
20
15
10
−2
−1
0
1
2
Bias, $\langle \Delta Q/\sigma \rangle$
Bias, $\langle \Delta U/\sigma \rangle$

CMB Polarization Angle



Summary

1. Line of sight effects (decorrelation!) and iron grains are the most pernicious complexities for biasing the fit CMB
2. High frequencies can be critical for identifying model failures