A Unified Model of the Extinction, Emission, and Polarization from Interstellar Dust

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Image credit: ESA/NASA/JPL-Caltech
Model Predictions

- Predictions from extending the Draine & Li 2007 model to polarization
- Maximum polarization fractions of ~15%

Draine & Fraisse 2009
Dust Polarization with Planck

Planck sees dust polarization fractions in excess of 20%!
Dust Polarization with Planck

Difficult to reconcile both high (~20%) and frequency-independent polarization fraction with two component dust models!
Pushing the Envelope

Serkowski+ 1975

$P_{\text{max}}$ (%) vs $E_{B-V}$

13% vs 9%

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Polarimetry Confirms

Panopoulou, BH+, Submitted
Model Update Required

- Models must reproduce observed sub-mm polarization fractions of 20%.
- Models must account for characteristic ratios between starlight polarization and polarized sub-mm emission.
- Models must be consistent with I/NH observed by Planck—error bars at the few percent level!
What Else Have We Learned?

- NH/E(B-V) at low NH is ~50% higher than the classic Bohlin, Savage, & Drake value (Lenz, BH, Doré 2017)

- MIR extinction curve is very flat in the 3-8μm range

- Anomalous Microwave Emission (AME, “spinning dust”) is a generic, ubiquitous component of dust emission
Constraints on a Dust Model
A New Model: Ingredients

Silicate + Graphite + PAH
“Astrodust”
Silicate + Graphite + PAH

+ graphite?

- Astrodust = Amorphous silicate + hydrocarbon material + other components (e.g., Fe oxides, $\text{Al}_2\text{O}_3$, $\text{CaCO}_3$)
Constraints on a Dust Model

\begin{figure}
\centering
\begin{minipage}[t]{0.45\textwidth}
\hspace{0.3cm}
\includegraphics[width=\textwidth]{extinction.png}
\end{minipage}\hspace{0.5cm}
\begin{minipage}[t]{0.45\textwidth}
\hspace{0.3cm}
\includegraphics[width=\textwidth]{emission.png}
\end{minipage}
\end{figure}

![Extinction and Polarized Extinction](extinction.png)

![Emission and Polarized Emission](emission.png)
A New Model: Results

BH & Draine, in prep

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figures.png}
\end{figure}
Highlights: Size Distributions

Silicate
- MRN
- Draine & Li 2007
- Model

Carbonaceous
- Draine & Li 2007
- Model
Highlights: IR Extinction

- Indebetouw et al 2005
- Fitzpatrick & Massa 2007
- Wang et al 2013
- Xue et al 2016
- Schlafly et al 2016

- Model
- Silicate
- Carbonaceous
Highlights: IR Emission

\[ \frac{\lambda I_{\lambda}}{N_H} \left[ \text{erg s}^{-1} \text{sr}^{-1} \text{H}^{-1} \right] \]

\[ \times 1000 \]

\( \lambda \) [\( \mu \text{m} \)]

\( \lambda \) [\( \mu \text{m} \)]

(Data – Model)/Model

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Highlights: IR Polarization
What About the 3.4μm Feature?

- No polarization detected in the 3.4μm feature associated with aliphatic CH bonds
- Appears to rule out hydrocarbon material existing on same grains as amorphous silicate
What About the 3.4μm Feature?

- If 3.4μm absorption comes from a thin surface layer, it will come preferentially from smaller grains which are unaligned.

- We find 3.4μm polarization consistent with existing limits assuming it comes from a 100Å thick mantle.
Conclusions

- We demonstrate that a new model of interstellar dust based on PAHs and composite “astrodust” material (and a minor graphite component) can reproduce current observations of the extinction, emission, and polarization of dust from the UV to the microwave.

- Model papers nearly completed, coming to arXiv soon!