Far-Infrared Dust Opacity and visible Extinction

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The Polaris Flare

The Polaris flare is a nearby molecular cloud (Heithausen & Thaddeus 1990), probably reprocessed by a supernova shock (Meier et al. 1991). We have used the USNO-PM2 catalog to map the extinction using the star count method described in Cambresy (1999). Visual extinction is lower than 0.1 mag in most of the cloud.

PRENAS: submillimeter observations of this region revealed regions of very low dust temperature (L. K. Bernard et al. 1999) that are not expected to exist in such a low extinction area. They suggested that grain optical properties are different in the cloud compared to the dust bound in the diffuse interstellar medium.

Using DIRBE, Lagache et al. (1998) analyzed large scale dust properties and proposed a decomposition of the dust into warm and cold components. With the 100, 140 and 240 μm maps, they were able to determine the dust temperature and the optical depth for each of these components along a line of sight.

Figure 1. — Visual extinction map of the Polaris Flare from star counts using the USNO-PM2 catalogue. White crosses represent the DIRBE pixels used to compute the star counts based extinction map with the SFD98 extinction map based on FIR emission.

Comparison with the Schlegel et al. (1998) extinction map

SCHLEGEL et al. (SFD98) derived an all-sky extinction map from the FIR dust opacity. Figure 3 represents the difference between the SFD98 map and our star count based extinction map.

3. Dust emissivity variations in the FIR. We propose to explain the extinction discrepancy by variations of the $y_{TIR}/A_V$ ratio between the low extinction regions used for the SFD98 calibration of $A_V$ and the extinction in the Polaris molecular cirrus.

The total extinction can be written as the sum of the extinction in the warm and in the cold components: $A_V = A_{Vw} + A_{Vc}$.

We have:

$$A_{Vw} = y_{TIR} \times \frac{1}{A_V}$$

$$A_{Vc} = \frac{9_{TIR} \times 13_{TIR}}{13_{TIR} - 12_{TIR}}$$

where $y_{TIR}$ are the emissivities of the dust at 100 μm for the warm and cold components, respectively. We take for the FIR to visible opacity ratio of the same component, $(y_{TIR}/A_V)_{w/c}$ the ratio measured by SFD98 in low extinction regions and $y_{TIR}$ are the optical depths derived from the warm/cold decomposition of the FIR emission.

Then, we can derive $A_{Vw}$ using Eq. 1 and the emissivity of the cold component is:

$$y_{TIR} = \frac{9_{TIR} \times 13_{TIR}}{13_{TIR} - 12_{TIR}}$$

Results

Figure 4 presents the dust FIR emissivity of the cold component versus the temperature. Each diamond corresponds to a white cross in Figure 1 which indicates positions with high signal-to-noise ratio for both temperature and extinction in the warm/cold decomposition of the cloud. The median value for the cold dust emissivity in the Polaris Flare is 4 times larger than the SFD98 value for the same component.

The change in the emissivity is interpreted as an evolution of dust grains from the warm/cold interstellar medium to molecular clouds. The most likely processes to lead to grains with significant porosity are grain-grain coagulation and accretion of gas species (Draine 1985).

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Conclusion

We found SFD98 to overestimate by a factor of 2 the extinction in the Polaris Flare and we propose this discrepancy results from a dust evolution within the molecular cloud.

On the basis of the warm/cold decomposition proposed by Lagache et al. (1998) we are able to quantify the increase of the dust emissivity in the FIR and we find a value 4 times larger for the cold dust than for the warm dust. We suggest that this results from an evolution of the warm/cold grains from the diffuse interstellar medium to the cloud. Similar results are obtained by Stepien et al. (2001) in a Dc spur filament using a dust model (De Marchi et al. 1990) constrained by PRONAOS observations and a extinction map derived from 2MASX star counts.

An important consequence is that one cannot derive the visible extinction from the FIR depth using a single factor for the whole sky. The SFD98 extinction map should therefore be used with caution in areas that contain cold emission. Low latitude regions ($b < -10^\circ$) and a small fraction of the high latitude sky require special attention.

Figure 3. — Difference between the SFD98 extinction map and the star count extinction map, both converted to the DIRBE resolution.

Figure 4. — Emissivity variation versus temperature in the Polaris Flare, with the typical statistical (cross in the upper right corner) and systematic (square) uncertainties. The filled square represents the SFD98 value which corresponds to the warm component emissivity. Dust emissivity of the cold component is 4 times larger than the warm one.

Figure 2. — Cold component of the dust emission at 240 μm from Lagache et al. (1998).