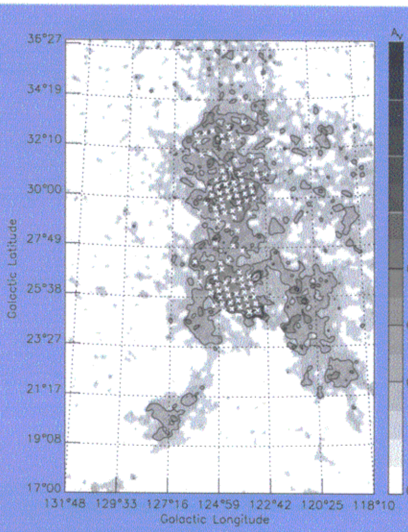
Far–Infrared Dust Opacity and visible Extinction

L. CAMBRÉSY (IPAC/JPL), F. BOULANGER (IAS ORSAY)
G. LAGACHE (IAS ORSAY), B. STEPNIK (IAS ORSAY)



The Polaris Flare

THE Polaris flare is a nearby molecular cirrus (Heithausen & Thaddeus 1990), probably reprocessed by a supernova shock (Meyerdierks et al. 1991). We have used the USNO-PMM *B* photometry to map the extinction using the star count method described in Cambrésy (1999). Visual extinction is lower than 1 mag in most of the cloud.

PRONAOS submillimeter observations of this cirrus revealed regions of very low dust temperature (13 K, Bernard et al. 1999) that are not expected in such a low extinction area. They suggested that grain optical properties are different in the cloud compared to the dust found in the diffuse interstellar medium.

Using DIRBE, Lagache et al. (1998) analyzed large scale dust properties and proposed a decomposition of the dust in *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 B star counts using the USNO-PMM catalogue. White crosses represent the DIRBE pixels used to compare the star counts based extinction map with the SFD98 extinction map based on FIR emission.*

The distinction between *cold* and *warm* emission components characterizes different dust temperatures and small grain abundances. It is corroborated by submillimetric observations at higher angular resolution for which the spatial separation of the infrared emission from diffuse and dense gas is easier than with the DIRBE data (Laureijs et al. 1996, Bernard et al. 1999, Stepnik et al. 2001). The whole Polaris flare appears to have a important *cold* component (Figure 2).

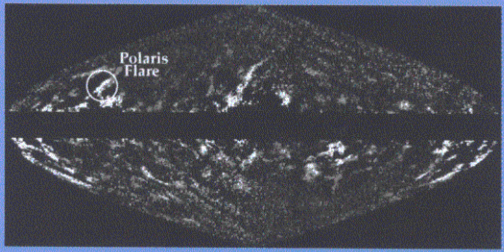


Figure 2. — *Cold component of the dust emission at 240 μm from Lagache et al. (1998).*

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.
(1) both maps are in agreement outside the cirrus.
(2) the difference increase with this extinction.
We find the SFD98 map overestimates the extinction by a factor of 2.

Possible explanations:
1) Unresolved cloud structures in the star count map. Rossano (1980) studied the consequences of the cloud surface filling factor in star count techniques. Using his results, a difference of a factor of 2 for an A_V of 2 mag would require a filling factor lower than 0.1. Such low surface filling factor is incompatible with results from Thoraval et al. (1997) and Lada et al. (1999).
2) Temperature variations along the line of sight. These variations are ignored in SFD98. If we assume that the cloud is at a lower temperature that the diffuse interstellar medium, the temperature used by SFD98 in their calibration is an effective temperature always greater than the cloud temperature. However this effective temperature leads to underestimate the optical depth. We observe the opposite effect.

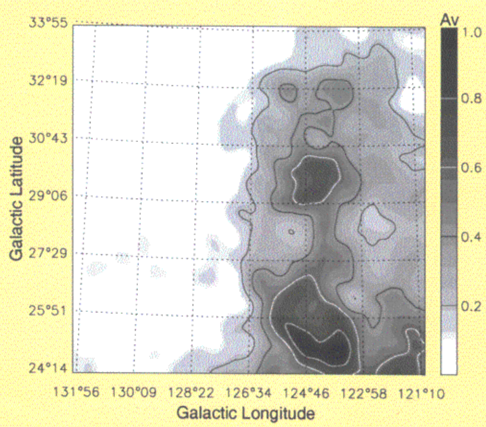


Figure 3.— *Difference between the SFD98 extinction map and the star count extinction map, both converted to the DIRBE resolution.*

3) Dust emissivity variations in the FIR. We propose to explain the extinction discrepancy by variations of the τ_{FIR}/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: $A_V = A_V^w + A_V^c$.
We have:

$$A_V^w = \tau_{100}^w \times \left(\frac{\tau_{100}}{A_V}\right)_w^{-1} \quad (1)$$

$$A_V^c = \tau_{100}^c \times \left(\frac{\tau_{100}}{A_V}\right)_c^{-1} \quad (2)$$

where the ratio $(\tau_{100}/A_V)_{w,c}$ 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 *warm* component, $(\tau_{100}/A_V)_w$, the ratio measured by SFD98 in low extinction regions and $\tau_{100}^{w,c}$ are the optical depths derived from the *warm/cold* decomposition of the FIR emission. Then, we can derive A_V^w using Eq. 1 and the emissivity of the *cold* component is:

$$\left(\frac{\tau_{100}}{A_V}\right)_c = \frac{\tau_{100}^c}{A_V - A_V^w} \quad (3)$$

Results

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

The change in the emissivity is interpreted as an evolution of dust grains from diffuse interstellar medium to molecular clouds. The most likely processes to lead to grain with significant porosity are grain-grain coagulation and accretion of gas species (Draine 1985).
Dwek et al. (1997) studied the effect of composite fluffy grains on the dust opacity. (1) Grain growth to size comparable to UV/visible wavelengths while the small grain limit (Rayleigh limit) always applied in the FIR makes the ratio τ_{FIR}/A_V dependent of the grain size. (2) Optical properties of composite grains differ from the optical properties of their constituents. For the specific case of composite carbon-silicate grains this leads to a significant enhancement of the opacity in the FIR relative to that in the visible.

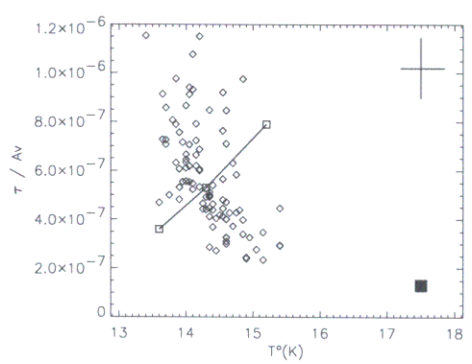


Figure 4.— Emissivity variation versus temperature in the Polaris Flare, with the typical statistical (cross in the upper right corner) and systematic (squares) uncertainties. The filled square represents the SFD98 value which corresponds to the *warm* component emissivity. Dust emissivity of the *cold* component is 4.0 times larger than the *warm* one.

Conclusion

WE found SFD98 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 cirrus.
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 size/porosity of grain from the diffuse interstellar medium to the cloud. Similar results are obtained by Stepnik et al. (2001) in a Taurus filament using a dust model (Désert et al. 1990) constrained by PRONAOS observations and a extinction map derived from 2MASS star counts.

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