Far-infrared properties of high latitude cirrus clouds

R. J. Laureijs

ISO Science Operations Centre, Astrophysics Division of ESA, Villafranca, Apdo. 50727, E-28080 Madrid, Spain

L. Haikala

Observatory, P.O. Box 14, FIN-00014 University of Helsinki, Finland, and ESO

Abstract. Far-infrared scans in the 60, 90, 135 and 200 μm filter bands of ISOPHOT were obtained for 4 quiescent high latitude clouds. The targets have been selected from IRAS images and have different central opacities spanning a range from less than one to several magnitudes of visual extinction. For each cloud we find that the ratio between the emission in the C_135 and C_200 bands (I_{135}/I_{200}) is independent of the strength of the C_200 emission. This suggests that the observed dust temperature is constant throughout each cloud. On the other hand we find that I_{135}/I_{200} varies from cloud to cloud indicating global temperature variations between clouds. The 60 μm emission was marginally detected. At 90 μm we have measured a significant decline in emission towards the centre of the clouds. This indicates that a fraction of the emission in the 90 μm band is due to a dust component different from the one giving rise to the 135 and 200 μm emission.

1. Introduction

Since IRAS our knowledge of infrared properties of dust in diffuse and dense interstellar clouds has improved substantally. In addition, IRAS provided complete images of these clouds down to a resolution of a few arcminutes. With ISO we have now the opportunity to detect low surface brightness regions of extended targets at wavelengths beyond 100 μm up to 200 μm which were not available with IRAS. Even though the ISO mirror has the same size of that of IRAS (60 cm diameter), the availability of dedicated mapping modes allow the maximum spatial resolution which is better than IRAS even in the ISOPHOT 200 μm band C_200.

We have used ISOPHOT (Lemke et al., 1996) to obtain one dimensional scans at the longest far-infared wavelengths accessible with ISO. Our aim is to investigate the far-infrared properties of diffuse and dense clouds at wavelengths beyond the maximum IRAS wavelength of 100 μm. In this study we present some preliminary results for a small sample of clouds. A similar study on one of the clouds (G301.2-16.5, see below) can be found in Laureijs et al. (1996).

2. Observations

With the ISOPHOT C100 and C200 cameras commanded using AOT P22 in staring raster mode we have obtained far-infrared scans for a sample of 4 clouds. All scans were at least 30' long in order to cover the entire extent of the cloud (Table 1) as well as the background necessary to define the cloud zero brightness level. The clouds were selected on the basis of the IRAS surface brightness images at 60 and 100 μm.

In Table 2 we list the general cloud properties. Table 2 includes estimates of the cloud central opacities as well as the cloud distances. All clouds are high latitude clouds and are presumably part of the local solar neighbourhood.

Table 1. ISOPHOT observing parameters

Filter	lambda	raster	stepsize	Camera
C_60	63	15×3	$138'' \times 92''$	C100 (3×3 pixels of 46")
C_90	89	15×3	$138'' \times 92''$	C100
C_135	155	11×3	$180'' \times 92''$	C200 (2×2 pixels of 92")
C_200	210	11×3	$180'' \times 92''$	C200

The ISOPHOT data have been processed using ISOPHOT Interactive Analysis (PIA Version 6, Gabriel et al., 1996) using the most recent photometric calibration files. The uncertainty in the ISOPHOT absolute photometric calibration is better than 30% at wavelengths shorter than 100 μm. The uncertainty can be higher at the longer wavelengths. The C100 observations at 60 and 100 μm were smoothed to the pixel resolution of the C200 detectors.

Table 2. General properties of the clouds

Cloud	R.A. (1950)	Dec.	A_V (mag)	distance (pc)
G6.5+36.4	$15^h\ 53^m\ 24^s$	$-02^o\ 36'\ 00''$	<1 mag	110 pc
MBM55	23 06 06	14 29 30	<1	<300
G301.7-16.6	12 22 14	−79 06 11	>4	140
G301.2-16.5	12 13 26	−79 00 29	4	140

3. Analysis and results

As an example we show the far-infrared slices over the densest cloud in our sample G301.7–16.6 in Fig. 1. Typically, the scans at 60 μm show a depression in surface brightness in the cloud centers. For the densest cloud G301.7–16.6 also the 90 μm scan shows a clear depression (Fig. 1).

In Fig. 2 we show the correlation diagrams for G301.7–16.6. For the abscissa we have chosen the 200 μm surface brightness. We assume that the far-infrared emission at 200 μm is a direct measure for the cloud's column density. We have used the data from 2 scan legs (see Table 1) to construct the diagram. In the outer regions of the cloud - within the observed scatter - the 90 μm emission is proportional to I_{135} and I_{200}. In the centre of the cloud where

Figure 1. Far-infrared slices through G301.7–16.6 which is the densest cloud in the sample. Offsets have been added to the 200 and 135 μm scans for clarity

Figure 2. The correlation between I_{135} and I_{200} (filled circles) and between I_{90} and I_{200} (open circles) for G301.7–16.6

I_{200} reaches its maximum, the proportionality of I_{90} breaks down whereas I_{135} remains proportional to I_{200}. Although the decline in the 90 μm emission is less pronounced for the other clouds which have lower central opacities, it is still significant.

The far-infrared brightness ratios I_{135}/I_{200} and I_{90}/I_{200} for the sample are presented in Table 3. The ratios I_{135}/I_{200} and I_{90}/I_{200} (outer regions) were obtained from linear regression fits. The ratios I_{90}/I_{200} for the inner cloud parts were derived by dividing the brightness values from a small region in the cloud centres.

By comparing flux ratios among clouds we are less dependent on systematic calibration errors. In contrast, derived temperatures are only indicative and can contain a systematic offset for all clouds due to uncertainties in the absolute calibration. This offset can be higher $+2.1$ K in case of a systematic uncertainty in excess of 30%.

Except for G6.5+36.4 the 90 μm emission shows a drop of about 10-20% towards the centre of the clouds w.r.t. I_{200} which is not seen for I_{135}. The 90 μm decline suggests a dust temperature drop of more than 0.3 K towards the cloud centre depending on the cloud geometry. Since this is not seen in I_{135}/I_{200}, a

Table 3. Far-infrared properties of the cloud sample

Cloud	I_{135}/I_{200}	$T(\lambda^{-2})$ K	I_{90}/I_{200} outer	I_{90}/I_{200} centre
G6.5+36.4	0.705±0.031	13.1±0.3	0.21±0.05	0.20±0.05
MBM55	0.801±0.009	14.0	0.260±0.012	0.22±0.02
G301.7-16.6	0.678±0.008	12.8	0.096±0.008	0.08±0.01
G301.2-16.5	0.691±0.007	12.9	0.240±0.014	0.21±0.02

more likely explanation is the disappearance of an additional emission component in the 90 μm band [1].

4. Discussion and conclusions

The very constant I_{135}/I_{200} brightness ratio indicates that the temperature of the (classical) large grain component is constant for different column densities in the cloud. Possible explanations are: (a) the radiation field heating these grains is homogeneous throughout the cloud. This can be due to a clumpy/filamentary cloud structure unresolved by ISO ($<$ 1 arcmin). (b) ISOPHOT is not sensitive to emission from regions below a given temperature. (c) The coldest regions in the clouds are smaller than the ISOPHOT resolution.

On the other hand, the ratio I_{135}/I_{200} varies (significantly) from cloud to cloud indicating that the implied grain temperature for a given cloud is still affected by global cloud properties. Although the sample is not conclusive, I_{135}/I_{200} appears to be lower for clouds with higher central opacity.

The drop in I_{90}/I_{200} towards the cloud centre suggests a grain component different from the large grain component still emitting in the 90 μm band in the outer regions of the clouds.

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[1] $I_{90}/I_{200} = 0.2$ corresponds to a colour temperature of 15.6 K; in view of the calibration uncertainties, this result is still consistent with the I_{135}/I_{200} temperatures.