Cold Clouds in Cepheus Flare - Methods and Preliminary Results

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Abstract

We study the physical parameters of the interstellar medium in the Cepheus Flare Region. We investigated the large scale dust temperature and density distribution based on COBE DIRBE, IRAS and ISOSS data. We give optical B band extinction maps of 26 subregions covering $\approx$ 25 square degrees. We found several opaque spots on the extinction maps, examined their optical, infrared and radio properties. We selected the suspected pre-protostellar clouds in order to perform further detailed studies in the near future. Many of dense clouds we found have very low DIRBE temperature ($T < 15\,K$) and former ^{13}CO and NH_3 detection. The majority of the objects seem to be starless, one third of them show ongoing star formation.

1. Introduction

We intend to gather and analyse multiwavelength data on nearby low mass star forming regions focusing on the phases when no embedded stellar object is seen. Low mass star formation is expected in low and moderate mass (from ten to few hundred solar masses) clouds, in dense ($n(H_2) > 10^3\,cm^{-3}$) and cold ($T \approx 10\,K$) cores. These dense cold cloud cores are optically thick for the visible light and can be identified as obscuring spots on optical images in case of nearby ones. On the other hand they are optically thin for their own quasithermal emission, which has a spectral maximum in the far infrared between 100 and 200μm wavelength. This FIR radiation can efficiently cool the clouds and also helps us to reveal these clouds. In this paper we use the optical extinction and FIR emission data to explore the clouds of the Cepheus Flare.

2. Data processing

We used the Lynds Catalogue of Dark Nebulae (Lynds, 1962) to select the most interesting subregions of the Cepheus Flare, catalogued earlier as dense regions from optical data. The high resolution parts of our studies were made on these subregions. We computed the DIRBE FIR colour temperature and optical depth map of the whole region, defined opaque objects based on extinction maps of subregions and gave the DIRBE temperature at the position of object defined. The high resolution IRAS (HIRES) maps were made for all subregions. We examined the FIR properties of clouds and the relations between FIR and optical features.

2.1. Optical data

To draw extinction maps in the region we considered 26 selected subregions having dark optical clouds of LDN catalog. The fields of these subregions are 1x1 degree sized. Extinction maps were computed via performing star counts (Dickman, 1978) on a $3'$ grid up to 18 mag using the USNO A2.0 catalog data.

Reference counts for unobscured fields were obtained from the galaxy model by Wainscoat et al. (1992) using a FORTRAN programme written by L. Balázs. The actual value of extinction in magnitudes can be obtained according to the following formula:

$$A = \frac{1}{b} log\left(\frac{N_{ref}}{N}\right) \tag{1}$$

where N is the actual count, N_{ref} is the modelled reference count and b is the slope of the modelled $logN(m)$ function. We defined the clouds as ellipses surrounding the 2 mag contours. We estimated cloud masses by the formula given by Dickman:

$$M = (\alpha_c d)^2 (N_{\mathrm{H}_2}/A_V)\mu \sum_i A_V^i \tag{2}$$

where α is the size of a grid cell in radians, d is the distance to the cloud, (N_{H_2}/A_V) is the considered ratio of H_2 column density and the visual extinction, μ is the average mass of particles in the cloud and A_V is the actual visual extinction. Distance data were taken form Hilton & Lahulla (1995).

2.2. Infrared data

For infrared studies we used the data of COBE DIRBE at 60, 100, 140 and 240 μm, IRAS (HIRES) at 60 and 100 μm and ISOSS at 170 μm.

The COBE DIRBE maps having low (≈ 0.7 degree) resolution give the basis of IRAS data ($\approx 4'$ resolution) calibration at 60 and 100 μm as well as the dust temperature and optical depth determination at 100, 140 and 240 μm. The IRAS 60 and 100 μm data were used for further calibration to obtain the high resolution (90″) HIRES maps. The fields of high resolution maps are the same as the extinction map fields. The ISOSS data were calibrated by the DIRBE data interpolated to 170 μm. The interpolation, the temperature and the optical depth were computed assuming that the dust emission follows a modified Planck function with $\beta = 2$.

We computed 100 and 170 μm FIR colour excesses defined as $E_{100} = I_{100} - I_{60}/\theta_{60-100}$ and $E_{170} = I_{170} - I_{100}/\theta_{100-170}$ using the values of galactic cirrus $\theta_{60-100} = 0.21$ and $\theta_{100-170} = 0.28$. These quantities are related to the actual dust temperatures, which are typically in the 10–20 K range. High colour excess values are good tracers of cold matter mainly at the longer wavelengths. This way we obtained high resolution maps of temperature distribution of the subregions. We computed the the characteristic values of defined quantities for all of our dense objects.

2.3. Other data

We examined the presence of ^{13}CO clouds from the Nagoya survey (Yonekura et al., 1997), NH_3 detections (Benson & Myers, 1989), YSOs and Hα (Kun, 1998) emission stars within the boundaries of clouds defined above.

3. Results

Using the method described above we defined 61 dense objects in the region possessing extinction value greater than 2 mag. According to DIRBE data these objects are cooler than the 18 K cirrus emission; the coldest ones have temperatures below 15 K. The higher resolution FIR colour excess maps also show low temperatures for our objects. There are some warmer objects with known embedded heating sources, showing notably high extinction and molecular emission (e.g. LDN 1174, LDN 1251). We determined the mass of each cloud and found that they are in the range of ten to some hundred solar masses, which is expected for low mass star forming clouds. Two third (41) of the objects defined are apparently starless, half of them (21) are remarkably cold according to the colour excess maps. Some of them show molecular emission, these are the best candidates for early phase star forming clouds with no embedded point-like object.

4. Conclusions

We studied the multiwavelength features of dark clouds in the Cepheus Flare region. Our methods allowed us to distinguish between the clouds with ongoing star formation, staying at an early phase of prestellar collapse and non-star-forming cloudlets, considering optical and infrared data. We found a number of early phase star forming cloud candidates without any detectable embedded point-like object. However, there are areas in the region without any optically catalogued dense clouds, where the molecular emission in ^{13}CO or the high FIR excess suggest notably high density and low temperature. This inspires us to extend the study to the whole area of the region, in order to find a complete sample of these objects for detailed examination.

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