AN ISOPHOT STUDY OF INTERSTELLAR DUST HEATED BY RED GIANTS STARS

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ABSTRACT

We present results of an ISOPHOT program (ISM_AGB) dedicated to study the structure and infrared emission of interstellar matter surrounding red giants. This emission is detectable within about 2 pc of these stars, and the dust is heated to temperatures of 30–50 K, significantly warmer than the average temperature of diffuse ISM dust. In most cases, the dust mass within this volume is dominated by interstellar dust rather than circumstellar dust. We briefly present here the illustrating cases of R Aqr and μ Cep.

Key words: dust, extinction – Interstellar Medium – Stars: individual: R Aqr, μ Cep

1. INTRODUCTION

Several of the reasons for investigating interstellar dust heated by red giants are the following. To the difference of early-type O-B stars, red giants do not emit ultraviolet radiation so that one can properly isolate the emission of the ISM big grains from the other components (small grains, PAH); the surrounding volume is also not ionized. Red giants do not have energetic winds which would significantly modify their interstellar environment; finally red giants can be found at large heights above the galactic plane, so that the ISM can be probed far from the disk.

We have obtained several ISOPHOT maps at 60 and 90 μm. The fields are 7 arcmin×7 arcmin, with pixel size 45 arcsec. These maps are centered at 4.7 arcmin from the central stars for which circumstellar envelopes and distances are particularly well known (e.g. through the period-luminosity relation for Miras). The typical size of the probed volume is 1 to 3 pc.

The first results of this investigation have been presented in Le Bertre et al. (1998). In the following we detail the fields at proximity of two sources. The data have been reduced with the version 6.1 of PIA[1]. The final processing is described in Le Bertre et al. (1998).

2. FIELD AT PROXIMITY OF R Aqr

R Aqr is an O–rich Mira of period 396 days. Using the period–luminosity relation for O–rich Miras determined by Feast (1996), Le Bertre & Winters (1998) derive a luminosity of $8\,10^3\,L_\odot$ and estimate the distance to 215 pc. At this distance, the pixel in the map corresponds to 0.045 pc (Figures 1 & 2). Also at this distance, it should be located at ~ 200 pc from the galactic plane.

R Aqr is the most nearby source in our sample. Its distance is comparable to the one of U Hya (350 pc, Waters et al. 1994) and to the one of Y CVn (250 pc, Izumiura et al. 1996) for which extended circumstellar emissions have been reported. However, Young et al. (1993) did not resolve its IRAS emission. It is known to be surrounded by a 1 arcmin×2 arcmin optical nebula, but this nebula is out of the ISO field. The emissions at 60 μm (Figure 1) and at 100 μm (Figure 2) are clearly patchy.

3. FIELD AT PROXIMITY OF μ Cep

μ Cep is a red supergiant with a large luminosity ($\sim 4\,10^5\,L_\odot$). It is known to be surrounded by an extended circumstellar envelope which has been detected up to 1 arcmin (Mauron et al. 1986; Mauron 1997).

[1]PIA is a joint development by the ESA Astrophysics Division and the ISOPHOT Consortium. Contributing ISOPHOT Consortium institutes are DIAS, RAL, AIP, MPIK, and MPIA.

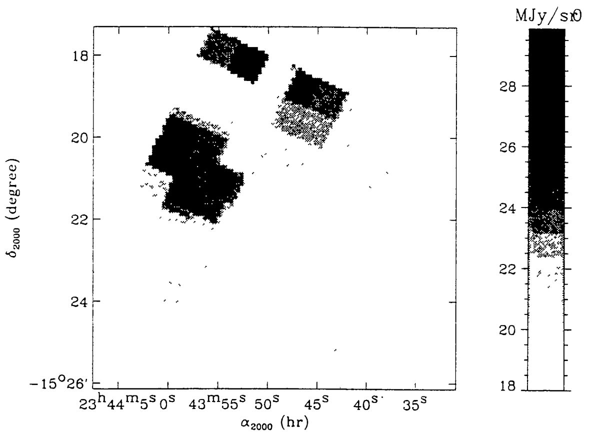

Figure 1. Field near R Aqr at 60 μm; the rotation angle w.r.t. celestial coordinates is 64.7°. At 215 pc, the pixel corresponds to 0.045 pc. The heating source is outside the map, near the upper part of the right superior edge. Its coordinates are: $\alpha_{2000.} = 23^h\ 43^m\ 49.2^s$, $\delta_{2000.} = -15°\ 17'07''$

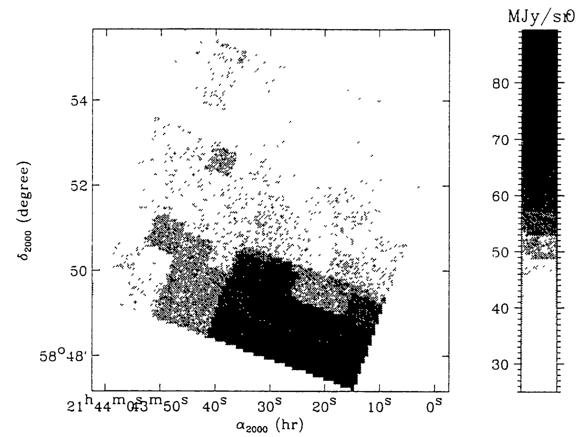

Figure 3. Field near μ Cep at 60 μm; the rotation angle w.r.t. celestial coordinates is 160.2°. At 830 pc, the pixel corresponds to 0.18 pc. The heating source is outside the map, near the right part of the lower left edge. Its coordinates are: $\alpha_{2000.} = 21^h\ 43^m\ 30.4^s$, $\delta_{2000.} = 58°\ 46'48''$

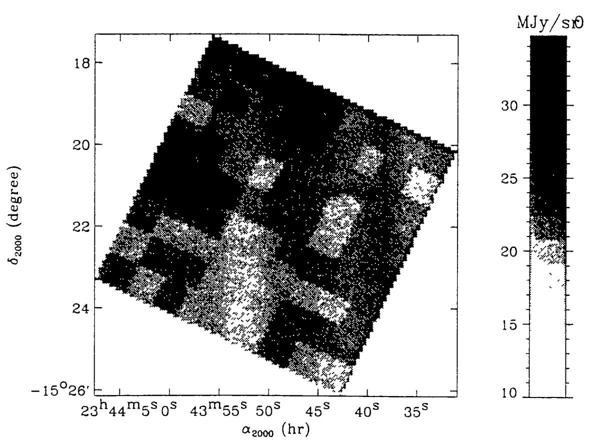

Figure 2. Same as Figure 1, but at 90 μm.

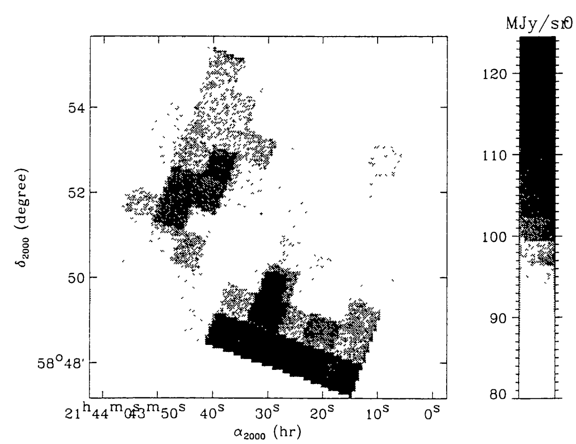

Figure 4. Same as Figure 3, but at 90 μm.

At a distance of 830 pc (Humphreys 1978), the pixel in the map corresponds to 0.18 pc. The nearest point in the ISO maps (Figures 3 & 4) is at 1.3 arcmin (0.32 pc) from the heating source. The ISO field is North of μ Cep in a region of low IRAS emission (Stencel et al. 1988).

We know relatively little about the surrounding matter of this remarkable star. Concerning small scales, the circumstellar matter has been studied in the resonance lines of potassium (7665–7699 Å) by Mauron (1997) who finds evidences of inhomogeneities. The typical size of the inhomogeneities is ~ 3 arcsec and of their separations, ~ 10 arcsec. However, it is clear that these small scales will be washed out with the ISOPHOT resolution. Nevertheless, an interesting point coming from these KI data is that, on the mean, the density of (circumstellar) matter is found compatible with an r^{-2} decrease, up to about 1 arcmin from the star. Consequently, at the distance from the star probed in the ISO maps (more than 1 arcmin), one can assume that the wind density is relatively small compared to the mean interstellar medium. It will be interesting to try to make an estimate of the heated dust mass seen in the 60 and 90 μm maps, which display very clear gradients, and compare it to any supposed detached circumstellar shells that could have been ejected in the past (like shells of luminous blue variables). Order of magnitude calculations suggest that it is pure diffuse interstellar matter that we see on the ISO maps.

4. CONCLUSION AND FUTURE WORK

The majority of the maps that we have examined show the expected gradient of brightness due to stellar heating of the ISM. We intend to make a systematic study of this gradient in two colors, and compare it to dust heating models.

The ISM structure at small scale (0.1-0.3 pc), the general heating effects of ISM by red giants, and other characteristics such as the filling factor or differences with the height above the galactic plane will be investigated in the future with our complete sample of 18 two-color maps.

We will re-reduce all our images with the final version of PIA and the most recent set of calibration parameters. We hope also that progresses can be made on the absolute photometric calibration of ISOPHOT C100 data. This is a difficult problem, but it would bring much for the interpretation of the maps, especially regarding to the temperature of the grains, their absorption properties, and the dust mass.

ACKNOWLEDGMENTS

Our participation to the Conference has been financially supported by the CNRS programme "Physique et Chimie du Milieu Interstellaire" (PCMI).

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