IRAS OBSERVATIONS OF WOLF-RAYET STARS

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ABSTRACT. IRAS PSC, LRS, and CPC observations of Wolf-Rayet stars are used as diagnostics of hot circumstellar dust shells, cool dust in WR ring nebulae, the Ne/He abundance ratio, and the interstellar extinction. In two cases the IR energy distributions are indicative of a WR planetary nucleus status rather than a Population-I WR status.

1. INTRODUCTION

Groundbased IR photometry and spectrophotometry in the seventies had already demonstrated that WR stars can have three important characteristics in the IR: emission spectra of ionic He, C, and N recombination lines, f-f excesses caused by strong stellar winds, and thermal emission radiated by heated circumstellar dust. These data were limited to about 20 μm.

IRAS observations provide photometry at 12, 25, 60, and 100 μm, low resolution spectra (LRS) from 8 to 22 μm, and, with the Chopped Photometric Channel (CPC), 12'x9' maps at 50 and 100 μm.

2. OBSERVATIONS

The observations used are from the IRAS Point Source Catalog (1985), the IRAS Spectral Atlas (1985), and IRAS-CPC observations (Wesselius et al., 1985).

Invaluable for the interpretation of IRAS data are complementary near-IR ground based observations. For this purpose, three of us (KAvdH, PST and PMW) have, over the past five years, observed WR stars at $JHKLMN_1N_2N_3Q_0$ from ESO and UKIRT.

3. THE IR SPECTRUM OF γ^2 VELORUM

The IRAS LRS spectrum of γ^2 Vel shows strong (0.9×10^{-17} W/cm^2) emission of the fine structure line [NeIII]λ15.5μm.

Shortward of 13 μm the γ^2 Vel spectrum had been observed and identified by Aitken et al. (1982), who derived an abundance ratio of N(NeII)/N(He)=0.0026. The IRAS LRS spectrum allows an evaluation of the NeIII/He and thus the Ne/He abundance ratio. We find N(Ne)/N(He)=0.009, i.e. 7.5 times the cosmic value. This reflects the evolved status of the Wolf-Rayet stars. Evolutionary calculations by Maeder (1983) yield for WC

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stars N(Ne)/N(He)=0.0066, remarkably close to our result.

If the Ne abundance of γ^2 Vel is representative for all WC stars, then the 38 WC stars within 3 kpc from the Sun provide a ^{22}Ne input of 8.8×10^{-6} $M_\odot$/yr.kpc^3 for the chemical evolution of the solar neighbourhood.

Particulars of this study are given by van der Hucht and Olnon (1985).

4. LOW IONIZATION WR STARS WITH CIRCUMSTELLAR DUST

As the IRAS observations confirm, low ionization WR stars, i.e. WN10-11 and WC8-10 stars, have IR excesses indicative of thermal emission by hot (~900 K) circumstellar dust. For the brightest late WC stars, this has been known since 1974.

Speckle interferometry of WR104 (Allen et al., 1981) has shown that its dust shell radius is of the order of 100 A.U. This means that the grain size is of the order of 0.01 μm and that the dust is formed within the stellar wind sphere. The dust is most probably amorphous carbon. Because no variations have been observed in the past 10 years, the dust must be continually replenished at a distance of 100 A.U. from the star. As an example, the dust shell parameters of WR104 are T(dust)=900 K, M(dust)=$10^{-6} M_\odot$, and (with d = 1.58 kpc) $L_{IR} = 3.4 \times 10^4 L_\odot \approx 0.14 L_*$. The stellar winds of WR stars are among the most hostile environments in which grains are believed to form.

Particulars of this study are given by Williams et al. (1985).

5. THE 9.7 μm ABSORPTION FEATURE

Superimposed on the smooth energy distributions caused by hot circumstellar dust, the 9.7 μm silicate feature appears in absorption in WR104, WR112, and WR118. These observations confirm groundbased spectroscopy from 8 to 13 μm by Roche and Aitken (1984), who observed the same stars together with three more WR stars. They demonstrated that the silicate absorption features are entirely of interstellar origin. Using the most recent groundbased photometry and the intrinsic WR parameters given by Hidayat et al. (1985), we find for the relation between visual extinction and 9.7 μm absorption strength $A_V = 19.8\ (\pm 1.7)\ \tau_{9.7\mu m}$.

6. TWO NEW WR CENTRAL STARS OF PLANETARY NEBULAE

The IRAS data for WR72 and WR124 reveal energy distributions, which are significantly different from those of all other WR stars. They are indicative of circumstellar dust with temperatures of respectively 85 and 100 K. In that respect they resemble planetary nebulae (Pottasch et al., 1984).

In the case of WR72 (= Sand.3), it was hinted earlier that it is more likely the central star of a planetary nebula than a Pop.I WR star (Barlow and Hummer, 1982). The IRAS data confirm this.

M1-67, the nebula surrounding WR124 (=209 BAC), was for many years considered to be a planetary nebula (PK 50+3 1), till Cohen and Barlow (1975) argued for a Pop.I WR ring nebula status. The IRAS data, however, favour a planetary nebula status again. The fact that the central star WR124 is a single-line spectroscopic binary with a very small mass function (Moffat et al., 1982), suggests that it is a pre-cataclysmic variable, in view of current ideas on the evolution of binary central stars of planetary nebulae.

Particulars of this study are given by van der Hucht et al. (1985).

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7. DUST IN WOLF-RAYET RING NEBULAE

IRAS observations of most of the known WR ring nebulae were carried out with the IRAS-CPC instrument (Wesselius et al., 1985), providing 12'x9' maps at 50 and 100 μm with 1!5 spatial resolution. The WR ring nebula RCW58 has 50 μm IR isophots which coincide very well with the dark regions visible in its Hα picture . In a preliminary analysis, we find that the dust temperatures in RCW58, as well as in the other with the CPC observed WR ring nebulae, are of the order of 35 K, in good agreement with size and energy balance considerations.

An elaborate version of this paper has been published by us in: Birth and Evolution of Massive Stars and Stellar Groups, Proc. of a Colloquium in honour of Adriaan Blaauw (W. Boland & H. van Woerden, eds.).

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