A TWO-COMPONENT DUST MODEL FOR THE WOLF-RAYET RING NEBULA RCW 58

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The spectacular ring nebula RCW58 around the Wolf-Rayet star WR40 (HD 96548, WN8) has been observed by the *IRAS*-Survey instrument and by the *IRAS* Chopped Photometric Channel (*CPC*) to study its IR flux and morphology. The survey data were examined with the Groningen Exportable Infra-red High-resolution Analysis system (*GEISHA*) software, and analysed in terms of line and dust contributions.

The *IRAS* flux ratios for RCW 58, and in addition those of two other WR ring nebulae, *i.e.* NGC 6888 and S 308, were compared with predicted flux ratios based on the *MRN* (Mathis, Rumpl & Nordsieck, 1977, *Ap.J.* **425**, 433) grain model, assuming that all grains are in steady thermal equilibrium with the incident radiation. (The standard *MRN* grain mixture has a size distribution $N(a) \propto a^p$ for $a_{min} < a < a_{max}$ with $p = -3.5$, $a_{min} = 0.005\mu$ and $a_{max} = 0.25\mu$.) There is a clear problem, in that all three WR nebulae have anomalously large 25μ fluxes. For RCW58 the $60\mu/100\mu$ flux ratio can be fit if the grains have $T \approx 40K$, while the $25\mu/60\mu$ flux ratio would be too low by an order of magnitude. To increase the $25\mu/60\mu$ flux ratio it is necessary that the grains be hotter. Small grains tend to be hotter than large ones because of their lower emissivities. We have therefore tried a modified *MRN* model for which $a_{min} = 0.002\mu$ and $a_{max} = 0.008\mu$. There is an improved $25\mu/60\mu$ flux ratio, but a fit is not achieved. To fit just the $25\mu/60\mu$ flux ratio of RCW 58 with a *MRN* model requires a temperature of $T \approx 67K$, but for this model the $60\mu/100\mu$ flux ratio would be too large by a factor of 2.5.

Thus (i) grains with high temperatures ($T \approx 70K$) are needed to explain the $25\mu/60\mu$ flux ratio; and (ii) much cooler grains ($T \approx 40K$) are needed to explain the $60\mu/100\mu$ flux ratio. The need for a hot contribution might possibly be explained by the non-thermal-equilibrium heating (Temperature Fluctuations) of very small grains, whereby the absorption of a photon can briefly increase the temperature of a small grain to temperatures above $100K$.

Incorporating the non-equilibrium temperature distributions of very small grains greatly improves the agreement between model and observations. Very small grains could be produced by sputtering and shattering of larger grains, because of the physical conditions near WR stars.

Our best fit to the *IRAS* data of RCW 58 data uses a two-component model, in which most of the total grain mass is in large *MRN* grains and 10 percent of the grain mass is in the very small non-thermal component. In this model the large grains have a temperature $T \approx 39K$, while the small grains have temperatures ranging between 5 K to 200 K.

From the total IR luminosity of the WR ring nebula RCW 58, it is possible to use the theoretical emissivity to calculate a nebular mass. For our best fit model, we estimate a total dust mass of 0.005 $M_\odot$, which implies a total nebular mass of 0.6 $M_\odot$.

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Wolf-Rayet Stars and Interrelations with Other Massive Stars in Galaxies, 421.