STABILITY OF SMALL GRAINS IN HII REGIONS AND REFLECTION NEBULAE

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ABSTRACT We have analyzed IRAS data to assess the relative amounts of small and large grains in HII regions and reflection nebulae. Our most important finding is that no evidence for small grain destruction is seen in reflection nebulae, even for [high] values of the radiation energy density at which significant grain destruction apparently occurs in HII regions. This suggests that it is not only the total radiant energy density but also the energy per photon which determines the stability of small grains in astrophysical environments.

INTRODUCTION

The mid-infrared emission from interstellar dust is in many cases considerably enhanced by a large contribution due to non-equilibrium emission from very small grains. Sellgren (1989; this volume) discusses the evidence that the 3 to 25 μm radiation from reflection nebulae must be mainly due to non-equilibrium emission from small grains, and many authors have shown that non-equilibrium emission must be responsible for much of the 12, 25 and even 60 μm radiation seen by IRAS from the diffuse cirrus (Weiland *et al.*, 1986), from interstellar dust in other regions of the Milky Way, and from external galaxies as well. For the present discussion we need not distinguish between the "macromolecule" and "micrograin" picture of these small particles, and refer to them simply as "small grains". Ultimately, however, we hope that improved understanding of the stability of these small grains under varying conditions will provide useful constraints on their nature. .

Although the prevalence of the enhanced short wavelength emission suggests that the small grains are a hardy and ubiquitous species, there is evidence that this emission is suppressed under certain circumstances. In particular, Helou, Ryter and Soifer (1991) summarize data on three extended interstellar sources showing that the 12um to (60um + 100um) brightness ratio, gamma, defined here as

$$\Gamma = \frac{VI_\nu(12pm)}{\Delta\nu I_\nu(60\mu m) + \Delta\nu I_\nu(100\mu m)} \quad (1)$$

decreases asthe60/100um brightness ratio, theta

$$\Theta = \frac{I_\nu(60\mu\mathrm{m})}{I_\nu(100\mu\mathrm{m})} \tag{2}$$

increases. Because Γ is related to the abundance ratio of small to large grains, and Θ to the temperature of the large grains which are in equilibrium with the heating starlight, this correlation suggests that the small grains are preferentially destroyed in regions of higher radiation energy density.

Helou *et al.* find that this effect is much more pronounced for two HII regions (σ Sco and the California Nebula) than for the reflection nebula associated with HD147889, which is also included in their sample. The current study was, in fact, motivated by our observation that a group of reflection nebulae studied by Sellgren, Luan and Werner (1990) showed no variation of Γ with Θ. We therefore inferred that there might be differences in the behavior of small grain populations in reflection nebulae and in HII regions. We have explored this conjecture by using the IRAS data to study the spatial distribution of the infrared radiation from HII regions and reflection nebulae and to investigate the relative small grain population as a function of both the stellar temperature and energy density of the illuminating radiation. A more complete discussion of these data and their implications is presented by Gautier *et al.*, (1993).

RESULTS

We used the recently released Infrared Sky Survey Atlas (ISSA) data to obtain surface brightness measurements of reflection nebulae and HII regions at wavelengths of 12, 60 and 100 microns. Our surface brightness measurements were confined to the visible boundary of the nebulae, as determined from the Palomar prints. Background emission was removed based *on* measurements in the surrounding regions and linear interpolation across the program targets; the errors in the brightness measurements were estimated from the deviations of the background emission from this linear fit. For each nebula, a series of measurements spaced by about 6 arcmin were made using a 4.5 x 4.5 arcmin square aperture.

Figure 1 shows measurements of Γ vs. Θ for two HII regions [the California nebula and the Rosette nebula], while Figure 2 shows similar measurements for the Pleiades and NGC7023 reflection nebulae. Typical errors are shown for a few points in NGC7023; for the other sources, the errors are considerably smaller, as can be seen as well from the systematic clustering of the measurements. Note that the reflection nebula and HII region data extend over the same range of log Θ, from < –0.7 to >0.0, corresponding empirically to starlight energy densities in the range <1 to >80 ev/cm^3 (Boulanger *et al.*, 1988).

Over this range of Θ, the relative amount of emission from small grains, as measured by the parameter Γ, decreases by about an order of magnitude in each of the HII regions but is essentially constant in the reflection nebulae. The points shown in Figures 1 and 2 are scattered throughout the nebulae under study, but the variation [or lack thereof] of Γ with Θ is seen systematically on radial cuts from the edge to the center of the individual nebulae as well.

The most natural explanation of this result is that the small grains are preferentially destroyed in regions of increased radiation energy density within HII regions but are able to survive in similar radiation fields in the reflection nebulae. For this purpose, the most significant difference between the HII regions and the reflection nebulae is probably the presence of higher energy photons in the former. The effective temperatures of the 06 stars which excite the HII regions in our study are about twice those of the B3-B7 stars which illuminate the selected reflection nebulae. This suggests that it is not only the total energy density, but also the energy per photon, which determines whether the small grains will be stable, and thus that one-or-two-photon processes may be responsible for destroying the small particles. Two processes which should be considered in this context are double ionization of large molecules followed by dissociation (Leach, 1989), or enhanced evaporation resulting from thermal pulsing induced by absorption of two or more photons in rapid succession (Leger and Puget, 1984).

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REFERENCES

Boulanger, F., Beichman, C., Desert, F. X., Helou, G., Perault, M., and Ryter, C. 1988, *ApJ*, **332**, 328

Gautier, T. N., Werner, M. W., and Cawlfield, T. 1993, in preparation.

Helou, G., Ryter, C. and Soifer, B.T. 1991, *ApJ*, 376, 505

Leach, S. 1989, in *Interstellar Dust, IAU Symposium 135*, eds L.J. Allamandola and A. G.G.M. Tielens, Dordrecht: Kluwer, 155

Leger, A., and Puget, J.L. 1984, *A&A*, 137, L5

Sellgren, K. 1989, in *Interstellar Dust, IAU Symposium 135*, eds L.J. Allamandola and A. G.G.M. Tielens, Dordrecht: Kluwer, 103

Sellgren, K., Luan, L, and Werner, M.W. 1990, *ApJ*, 359, 384

Weiland, J., Blitz, L., Dwek, E., Hauser, M. G., Magnani, L., and Rickard, L.J. 1986, *ApJ*, 306, L101

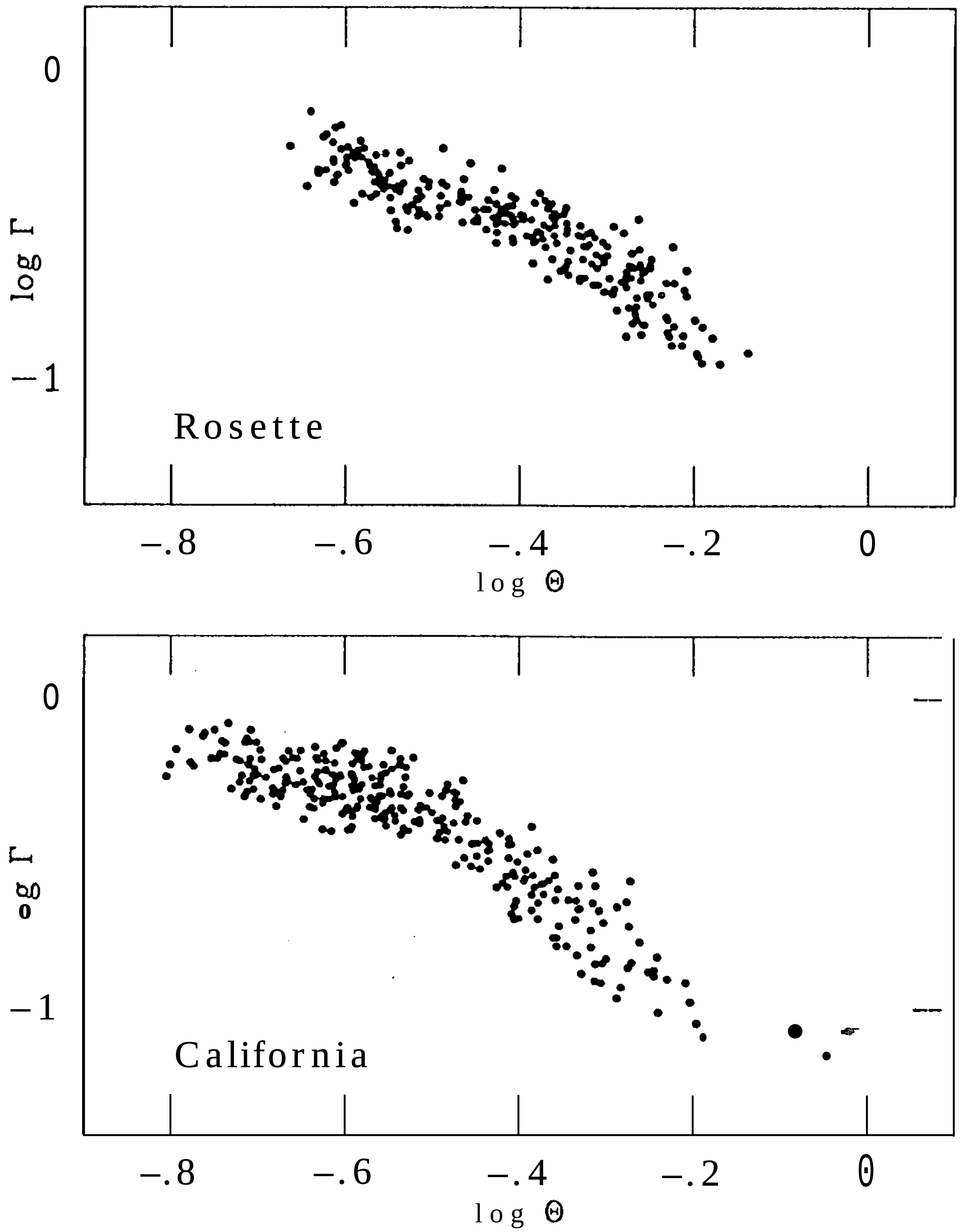

Figure 1. Measurements of gamma vs. theta for two HII regions, the Rosette and California nebulae. $\Gamma = \nu I_\nu(12\mu m)/\Delta\nu I_\nu(60\mu m) + \Delta\nu I_\nu(100\mu m)$, is a measure of the relative abundance of small grains, while $\Theta = I_\nu(60\mu m)/I_\nu(100\mu m)$ is a measure of the overall radiant energy density. The measurements were made on the IRAS Sky Survey Atlas data with a 4.5 arcmin square aperture at points space 6 arcmin apart across the entire nebulae.

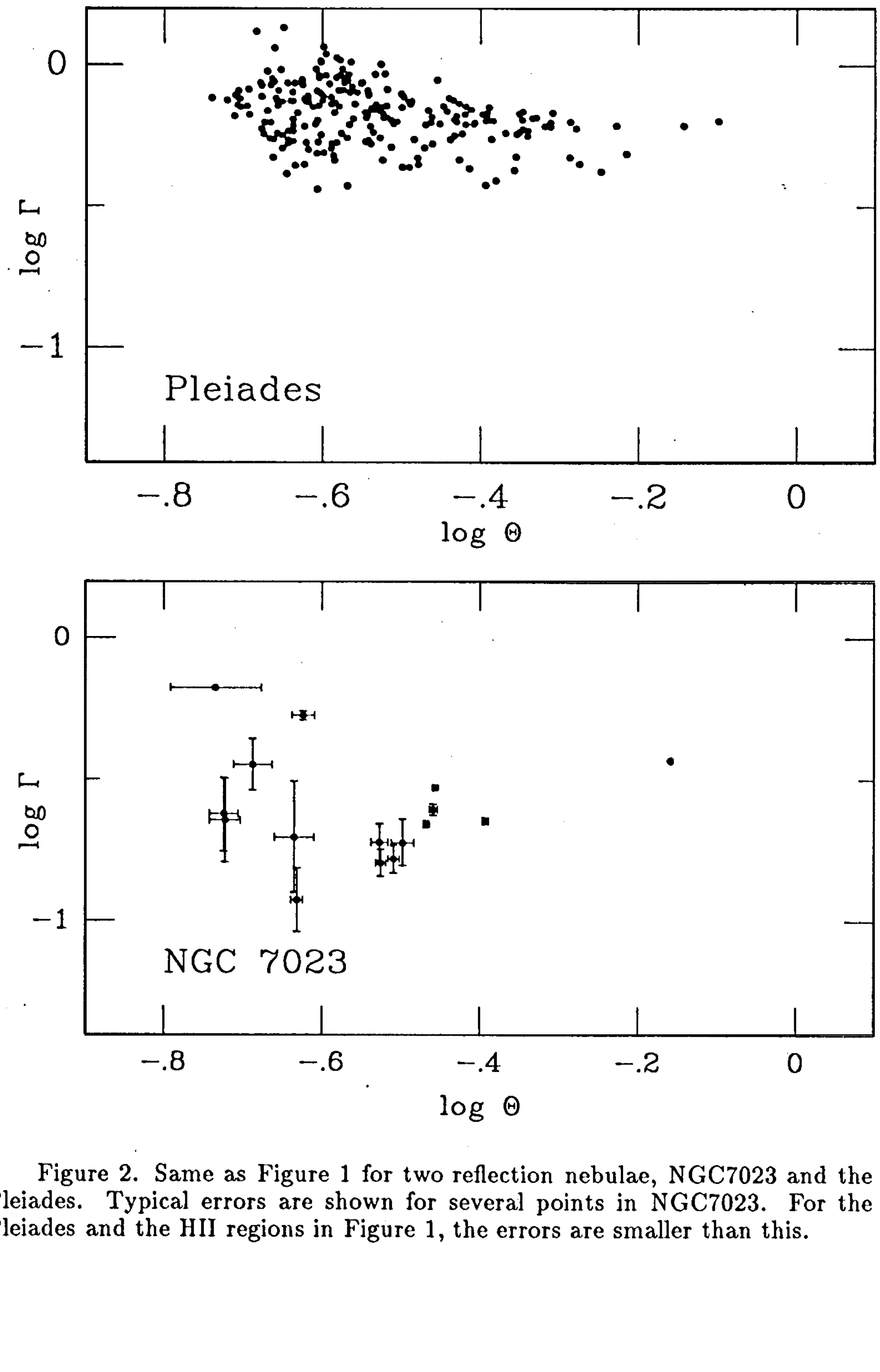

Figure 2. Same as Figure 1 for two reflection nebulae, NGC7023 and the Pleiades. Typical errors are shown for several points in NGC7023. For the Pleiades and the HII regions in Figure 1, the errors are smaller than this.