ON THE BIMODAL NATURE OF THE PARTICLE-SIZE-DISTRIBUTION FUNCTION OF COMETARY DUST

C.P. Liu[§] and H. Kimura[§]
Max-Planck-Institut für Aeronomie
D-3411 Katlenburg-Lindau
Federal Republic of Germany

ABSTRACT. The bimodal nature of distribution function $f(\gamma)$ is confirmed by analysing the optical isophotal maps of comets Kohoutek 1973 XII and Bennett 1970 II. Extending the dynamic analysis to the infra-red data of two comets, Kohoutek 1973 XII and IRAS-Araki-Alcock 1983 d, we demonstrate that the secondary component $f_2(\gamma)$, which dominates in the range of large particles, plays a much more important role in emitting the thermal radiation (IR) than in the case of light scattering (optical). The relative weight of two components, measured by their height ratio, g_2/g_1, should be increased by a factor of about 20, in order to obtain a good fitting to the infra-red data.

1. INTRODUCTION

Based on the mechanical theory, we have analysed the brightness distribution of comet Arend-Roland (1957 III) and obtained a distribution function $f(\gamma)$ of bimodal nature (Kimura and Liu, 1975; Liu and Kimura, 1982). Our result is different from the results by other authors (e.g., Sekanina, 1980; Campins and Hanner, 1982), in its bimodal nature, or in the unique manifestation of the secondary mode $f_2(\gamma)$. The bimodal size distribution might correspond to the two-component model suggested by the infrared observation of comet West 1976 VI (Oishi, et al. 1978). From this point of view, IRAS data of comet IRAS-Araki-Alcock, published quite recently (Walker, et al. 1984), and an earlier infrared (λ = 3.5 μm) data of comet Kohoutek (Ney 1974) are interesting. In the present work, in order for clarifying the nature of bimodal size distribution, the infrared data mentioned above have been studied by the method of dynamical analysis.

[§] On leave from Purple Mt. Observatory, Nanjing, China

R. H. Giese and P. Lamy (eds.), Properties and Interactions of Interplanetary Dust, 279–282.

2. THE DYNAMICAL ANALYSIS AND RESULTS

The method of analysis and the model of dust emission, described and used in earlier works (Kimura and Liu, 1977; Liu and Kimura, 1982), are generalized to include the anisotropy effect of particle ejection from the inner coma region. Anisotropy is represented by adding a lobe type.flux enhancement to the spherical (isotropic) flux of ejected particles.

At the date of Ney's observation, IR radiation of comet Kohoutek in the wavelength range λ = 3.5 µm was essentially due to thermal emission as indicated by the multiband photometry. If the bimodal distribution $f(\gamma)$ represents the existence of two components of cometary dust, we might reconcile the Ney's IR profile and the previous result of $f(\gamma)$ from the optical studies, simply by changing the relative weight of two components of $f(\gamma)$, namely, the ratio of two peak heights g_1 and g_2. In Fig. 1 the calculated intensity profiles in the main and sunward tails are shown for different values of the ratio g_2/g_1. Comparing with the observational data, it appears that $g_2/g_1 \cong 10$ gives the best result. The bimodal nature of $f(\gamma)$ is supported by our recent analyses of optical data for two comets, Kohoutek 1973 XII, and Bennett 1970 II. The details will be discussed in a separate article (Liu and Kimura in preparation), but the results on $f(\gamma)$ are summarized in Table 1.

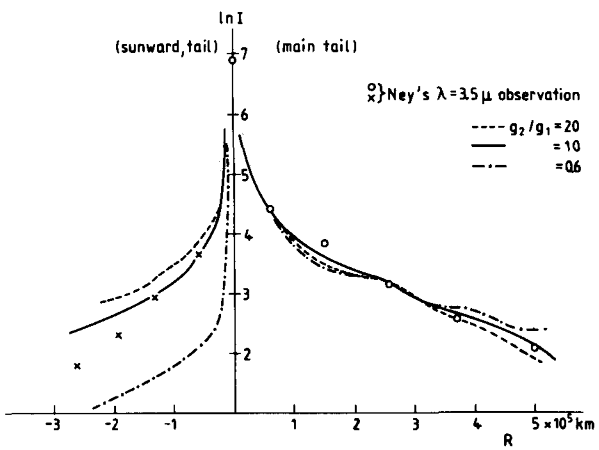

Figure 1. The IR(λ = 3.5 µm) intensity profile along the tail axis of comet Kohoutek, on Jan 1.7 (U.T.), 1974. The data from Ney's IR(λ = 3.5 µm) observation are shown by open circles (main tail side) and by crosses (sunward tail part). Three profiles calculated by assuming different peak height ratio, i.e., g_2/g_1 = 0.6, 10, and 20, are depicted by dash-dot, full, and broken lines, respectively.

TABLE 1 The parameters in the distribution function $f(\gamma)$

$$f(\gamma) = f_1(\gamma) + f_2(\gamma)$$

$$f_i(\gamma) = g_i(\gamma/\gamma_i)^{\beta_i} \exp\{(\beta_i/\alpha_i)|1 - (\gamma/\gamma_i)^{\alpha_i}|\}$$

Comet	Spectral Band	γ_1	γ_2	(g_2/g_1)
Bennett	orange	0.3	0.01	0.6
Kohoutek	orange	0.10	0.01	0.6
Kohoutek	IR(λ = 3.5 μm)	0.10	0.01	10
IRAS-A-A	IR(λ = 25 μm)	0.10	0.01	10
Arend-Roland	orange	0.10	0.01	0.6

Note 1. $\alpha_1 = 1.0$, $\alpha_2 = 0.5$, and $\beta_1 = \beta_2 = 4.0$ are common to all calculations treated in the present work.
2. γ_i: the γ-value at the i-th peak of the distribution.
3. g_i: the height of the i-th peak.
4. γ: repulsive force in unit of solar gravity.

Among the published IR data of comet IRAS-Araki-Alcock (Walker, et al., 1984), an isophot measured at λ = 25 μm was fitted by using a similar distribution function $f(\gamma)$ as that used in calculating the Ney's IR profile of comet Kohoutek, but with cutting off the contribution from particles in the range of γ larger than 0.3. This cutoff is intended to be a simplified treatment of the size effect for thermal emission from small particles. After incorporating the anisotropy effect in particle ejection, a fairly good agreement has been achieved, as is shown in Fig. 2, between the calculated isophotal contours and the observed ones.

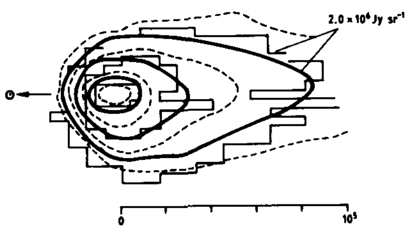

Figure 2. Brightness distribution of comet IRAS-Araki-Alcock, 1983 d. The isophotal contours from the λ = 25 μm observation are shown by thin broken and thick lines with flux level interval of a factor 2. The calculated contours are shown by thin lines with the flux level interval of a factor 4, which are to be compared with the thick line contours from observation. Scale is in km.

https://doi.org/10.1017/S0252921100084797 Published online by Cambridge University Press

3. DISCUSSION AND CONCLUSION

The bimodal nature of distribution function $f(\gamma)$, first obtained from the study of comet Arend-Roland, is confirmed by analysing the optical data of comets Kohoutek and Bennett.

Extending the dynamic analysis to the infrared data (of comets Kohoutek, and IRAS-Araki-Alcock), we have found that the contribution from the particles belonging to the second component, $f_2(\gamma)$, is very important in emitting thermal radiation. Numerical results show that the ratio of the thermal emission efficiency to the light scattering efficiency of the second component particles is higher than that of the first component, and $(g_2/g_1)_{IR} \sim 20\ (g_2/g_1)_{op}$. This suggests that the $f_2(\gamma)$ particles (large particles) are much more effective thermal emitters, i.e. presumably absorbing metallic particles.

Acknowledgements. We wish to thank K. Jockers and W.-H. Ip for discussions and S. Deutsch for preparing the manuscript. We acknowledge Visiting Fellowships from the Max-Planck-Society during this work.

REFERENCES

Campins, H., and Hanner, M.S. (1982), in "Comets", ed. L.L. Wilkening, p. 341

Hanner, M.S., Aitken, D.K., Knacke, R., McCorkle, S., Roche, P.F., Tokunaga, A.T. (1984) JPL-preprint, Comet. Sci. Team PP.S. No. 49

Ishida, K., and Kosai, H. (1971) Tokyo Astr. Bull., 2nd ser., No. 204

Kimura, H., and Liu, C.-P. (1977) Chinese Astr., 1, 235

Liu, C.P., and Kimura, H. (1982), Chinese Astron. Astrophys. 7, 11

Ney, E.P. (1974) Icarus 23, 551

Oishi, M., Okuda, H., and Wickramasinghe, N.C. (1978) Publ. Astr. Soc. Japan 30, 161

Sekanina, Z. (1980) in "Solid Particles in the Solar System, IAU Symp. No. 90," eds. I. Halliday and B.A. McIntosh, p. 251

Walker, R.G., Aumann, H.H., Davies, J., Green, S., de Jong, T., Houck, J.R., and Soifer, B.T. (1984) Astrophys. J. Lett. 278, L 11