ON THE SOLAR DUST RING(S)

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ABSTRACT. Based on a mechanism to form the solar dust ring, it is proved that the observed peak in infrared F-corona cannot be explained by silicate type grain alone. Preliminary analysis on the recent infrared data of F-corona by Maihara et al. (1984) has suggested that the ring particle has different physical properties compared with the dust grains, which produce the background F-corona.

1. INTRODUCTION

In the F-corona, Peterson (1967) and MacQueen (1968) independently detected the peaks in infrared intensity for a wavelength \( \lambda \) of 2.2 \( \mu \text{m} \) over the range of 4-10 solar radii \( R_\odot \) from the sun, and Lena et al. (1974) confirmed the flux peak at 4 \( R_\odot \) in the middle infrared at \( \lambda=10\mu\text{m} \). Recently, Maihara et al. (1984) obtained the infrared brightness of F-corona at \( \lambda=1.25, 1.65, 2.25 \) and 2.8 \( \mu\text{m} \) by balloon observation at the total solar eclipse on June 10, 1983 in Indonesia. Their results have clearly shown the existence of the flux peak near 4 \( R_\odot \).

Based on the dynamical behaviour of grains near the sun, Mukai et al. (1974), and Mukai and Yamamoto (1979) proposed a mechanism to form the solar dust ring and explained the observed flux peak as the combination of thermal and scattered light from such a solar dust ring consisting of grains suffering sublimation. Although their model has succeeded to construct the dust ring near the sublimation zone of grains, there still remains some uncertainty in identification of the material of ring particles. In this paper I shall reexamine whether silicate grains alone can produce the observed peak of infrared flux or not, and make a preliminary analysis of multiphotometric data by Maihara et al. (1984).

2. IS SILICATE A CARRIER OF INFRARED FLUX PEAK?

A complete dynamical analysis to form a solar dust ring has already been investigated in Mukai et al. (1974), and Mukai and Yamamoto (1979). I will therefore simply summarize the mechanism here. A radial velocity of the grain spiraling toward the sun under the Poynting-Robertson effect...
suddenly decreases due to an increase of a relative radiation pressure on a grain. This is caused by a decrease of grain radius under sublimation. Consequently, a concentration of grains arises near the sublimation zone in the outer solar corona. The zodiacal cloud is displayed near the ecliptic plane and almost all of its grains fall toward the sun by the Poynting-Robertson effect, keeping its inclination of orbits. Then, such a concentration in number density of circumsolar grains would make a ring structure around the sun. It is called, therefore, the solar dust ring.

To produce a sharp peak of space density of grains, the temperature of grain should be almost independent of grain radius. In other words, when each grain with a different radius begins to sublime at nearly the same distance from the sun, the enhancement of spacial density of circumsolar grains becomes narrow and sharp. It was found in Mukai and Yamamoto (1979) that the ratio of the lifetime of grain with radius $s$, $t_s=s/|ds/dt|_{\text{sub}}$, to a period of Kepler orbit, $t_K$ becomes a good indicator of the position of the ring, where $|ds/dt|_{\text{sub}}$ denotes a sublimation rate. Namely, the grain suffering sublimation keeps its solar distance from the sun against the Poynting-Robertson effect during $10^2$ to $10^3$ orbital revolutions till it completely sublimes. This result agrees with the numerical calculations by Lamy (1976).

The shaded area in figure 1 denotes the region between $t_s/t_K=10^2$ and $10^3$. For silicate and silicate with impurity, I calculated a ratio of $t_s$ to $t_K$ as follows. That is, based on the Maxwell-Garnet expression the complex refractive index of heterogeneous silicate is derived (see Chylek and Srivastava 1983). Then using the Mie theory and the energy balance equation for a grain, the temperature of the grain is obtained by the same treatment as shown in Mukai and Schwehm (1981). Finally, referring to the sublimation rate of silicate, a ratio of $t_s/t_K$ is computed as functions of grain radius and solar distance. As shown in figure 1, a ratio of $t_s$ to $t_K$ varies with grain radius because the temperature of silicate strongly depends on grain radius (see Mukai and Schwehm 1981). This unfavorable feature in the formation of a sharp concentration of grains remains even when other materials such as impurities in the silicate matrix are included. Therefore, it can be said that silicate can hardly produce a sharp and narrow structure of ring near $4R_\odot$.

**Fig.1.** Computed ratio of $t_s$ (a lifetime of a grain) to $t_K$ (its Kepler period) for obsidian, and obsidian with impurity, where number of percentage means a volume fraction of impurity.