INTERPLANETARY DUST CLOSE TO THE SUN

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1. ABSTRACT

The optical and infrared brightness of the Fraunhofer-corona is produced by light scattering at the zodiacal dust particles and by their thermal emission (see Koutchmy and Lamy 1985). It is modelled within the ecliptic ($4\ R_o \leq \varepsilon \leq 15\ R_o$) taking into account investigations of the global zodiacal dust cloud due to remote sensing and in situ experiments. The input of near solar dust to the corona brightness is discussed.

2. SPATIAL DISTRIBUTION OF ZODIACAL DUST

The global shape of the zodiacal cloud is assumed to be mainly undisturbed from collisional effects up to the beginning of the sublimation at a distance of 5 R_o (solar radii) close to the Sun. This zone of sublimation is based on the assumption of olivine particles representing a huge amount of silicates in interplanetary dust particles. Small components (up to 15%) of other materials give no drastic change.

3. BRIGHTNESS INTEGRALS

The brightness seen from the observer results from integration of all volume elements along the line of sight (LOS). The modelling applies a so called volume scattering function VSF(θ,r) describing the average scattering pattern of the interplanetary dust mixture at solar distance r:

$$\mathrm{VSF}(\theta,r) = \mathrm{VSF}(\theta,r_o)\ (r/r_o)^{-\nu^*} \quad \text{with } \nu^* = \alpha+\nu. \qquad (1)$$

It includes the change of particle number density with solar distance according to a power law with with exponent $-\nu$. The included albedo of particles changes with exponent $-\alpha$. The brightness integral is described

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A.C. Levasseur-Regourd and H. Hasegawa (eds.), Origin and Evolution of Interplanetary Dust, 187–190.

elsewhere (cf. Giese et al. 1986). The scattering function for scattering angles $\theta < 30°$ is calculated by diffraction of compact, isotropically scattering particles, considering the size distribution of interplanetary dust at $r = 1$ AU (cf. Grün et al. 1985). Under the assumption of a geometric albedo $A_o = 0.15$ (cf. Hanner et al. 1981) the function fits the empirical scattering function proposed by Leinert (see Weiß-Wrana 1983) for scattering angles $\theta > 30°$. For scattering angles $\theta > 30°$ the modellings are based on the latter function. Modelling of the thermal emission concerns an average temperature of particles per volume element $\langle T \rangle$ and an average emission cross section $\langle C_E \rangle$ as described elsewhere (cf. Dumont and Levasseur-Regourd 1988). The emission cross section is given as a product of emissivity $\langle E \rangle$ and average geometric cross section $\langle G \rangle$ of particles per volume element: $\langle C_E \rangle = \langle E \rangle \langle G \rangle$. The total surface of particles in a volume element is determined to amount $1.7\ 10^{-21} cm^{-1}$ at 1 AU. This is based on the parameters of the interplanetary flux model suggested by Grün et al. (1985). The variation of the albedo results in a change of emissivity: $E = 1 - A_o\ (r/r_o)^{-\alpha}$.

4. OPTICAL BRIGHTNESS

The modelled optical brightness is compared to observational data given by Blackwell et al. (1967) and Waldmeier (1965). The modelling refers to the brightness at $\lambda = 0.55$ µm. Further colour effects are not regarded.

	$\varepsilon = 4\ R_o$	$\varepsilon = 8\ R_o$	$\varepsilon = 15\ R_o$
ΔZ/%	52	62	71

Table 1: percentage ΔZ of the corona brightness that results from near solar regions ($r < 0.2$ AU)

A good fit to the data with deviations smaller than 25% is achieved by variation of the volume scattering function with exponent $\nu^* = 1.1 - 1.25$. Modelled brightness is rather sensitive on the distribution of particles close to the Sun. In spite of the increasing scattering function for small scattering angles, that gives rising input from particles close to the observer, the contribution of near solar particles (see table 1) is high.

5. POLARIZATION

The modelling of the polarization is based on the corona polarization data given by Blackwell et al. (1967), being less than 0.1 % at $\varepsilon = 8\ R_o$ and going up to 0.8% at $\varepsilon = 16\ R_o$. The polarization is modelled with respect to the relative shape of the polarization function given by Leinert (see Weiß-Wrana 1983). This function has its maximum within 80° and 85° scattering angle. That is consistent with results from S.Mukai et al., who found a move of the maximum polarization position to smaller scattering angles in case of a rough particle surface. A consistent fit to both, brightness and polarization data is achieved by variation of the polarization function with solar distance in the inner region around the Sun ($r < 0.2$ AU, see table 2). This decrease is much steeper than that found out for the outer dust cloud by Levasseur-Regourd (1991).

r/R_o	35	30	25	20	15	10
p_{max}	20%	13%	8.6%	4.2%	2.0%	0.6%

Table 2: maximum particle polarization p/% in relation to the solar distance r of particles.

6. INFRARED BRIGHTNESS

As well as the optical brightness the modelled thermal emission is increasing with decreasing elongation of the LOS. However in case of the thermal emission this increase is interrupted when the LOS crosses the dust free zone. Thus even thermal emission of very hot particles cannot explain the observed near infrared brightness of the F-Korona (McQueen 1968, Peterson 1967, 1969, Maihara et al. 1985). The near infrared brightness is affected by both, thermal emission and light scattering. The light scattering at dust particles has to be considered up to $\lambda = 5$ µm. The superposition of these two components leads to an edge in the near infrared brightness at the beginning of the dust free zone, that explains observational data in the near infrared. This enhancement in brightness is discussed controversy as pointed out by Tsurutani and Randolph, (this issue). The dependance of the mean temperature was assumed to be $\langle T \rangle (r) = T_o (r/r_o)^{-0.5}$. A change of this dependance with solar distance, that means a change of the exponent, as discussed for the zodiacal light (cf. Dumont and Levasseur-Regourd 1988) has only modest influence in the case of the corona. As well as the change of the emissivity (see section 3) has only modest influence on the calculated brightness. The spectral variation of the calculated corona brightness in the range $1.25 \leq \lambda \leq 3.6$ µm is in the range of converging observational data. The best fit, with deviations smaller than 25 % with exception of the McQueen data, was achieved for a temparature close to that of a grey body ($\langle T_o \rangle = 280$ K).

7. DISCUSSION

Both, optical and infrared corona brightness are engraved on near solar particles and have contributions from scattered solar irradiation. Within the ecliptic the spatial distribution of optical efficient particles is mainly continued from the interplanetary dust cloud into the most inner parts. The optical brightness demands for an increase of albedo and a steep decrease of polarization for the near solar particles. Both effects may indicate a change of particle properties in the most inner dust cloud, what has to be investigated further.

8. ACKNOWLEDGEMENT

This work was inspired and encouraged by the late Professor R.H. Giese. Thanks are due to Professor H. Fechtig who enabled the continuation of this work. The author thanks Dr. B. Kneißel for the lifely discussion of the work and for his helpful advices. The work was supported by the Bundesminister für Forschung und Technologie (Contract 010S89023).

9. REFERENCES

Blackwell, D.E. Dewhirst, D.W., and Ingham M.F. 1967: The Zodiacal Light, Adv. Astron. Astrophys. 5, 1

Dumont, R. and Levasseur-Regourd, A.-C. 1988: Properties of Interplanetary Dust from Infrared and Optical Observations.I.Astron. Astrophys. 191, 154

Giese, R.H., Kneißel, B., and Rittich, U. 1986: Threedimensional Models of the Zodiacal Dust Cloud: A Comparative Study, ICARUS 68, 395

Grün, E., Zook, H.A., Fechtig, H., and Giese, R.H. 1985: Collisional Balance of the Meteoritic Complex, ICARUS 62, 244

Hanner, M.S., Giese, R.H. ,Weiss, K., and Zerull, R.H. 1981: On the Definition of Albedo, Astron. Astrophys. 104, 42

Koutchmy, S. and Lamy, P.L., 1985, in: Properties and Interactions of Interplanetary Dust (Giese R.H. Lamy P.L., eds.), Reidel, Dordrecht, 63

Levasseur-Regourd, A.C. 1991: The Zodiacal Cloud Complex, this issue

MacQueen, R.M. 1968: Infrared Observations of the Outer Solar Corona, Astrophys. J. 154, 1059

Maihara, T., Mizutani, K., Hiromoto, N., Takami, H. and Hasegawa, H. 1985, in: Properties and Interactions of Interplanetary Dust (R.H. Giese and P.L. Lamy, eds.), Reidel, Dordrecht, 63

Mukai, S., Mukai, T., and Kikuchi, S., 1991: Scattering Properties of Cometary Dust Based on Polarimetric Data, this issue

Peterson, A.W. 1969: Coronal Brightness at 2,23 µm, Astroph. J. 155, 1009

Tsurutani, B.T. and Randolph, J.E., 1991: The NASA Solar Probe Mission: Dust Sciene, this issue

Waldmeier, M. 1965: The Corona, in: Landolt-Börnstein, Gr.IV, Bd. I, Springer, Berlin, 115

Weiß-Wrana, K. 1983: Optical Properties of Interplanetary Dust, Astron. Astrophys. 126, 240-250