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The Role of Particle Size in Producing the F- Coronal Scattered Brightness

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Abstract. Motivated by new infrared observations, we examine the contribution of various size intervals of interplanetary dust particles to visible and infrared scattered radiances of the solar F-corona, employing Mie theory and particle size distributions based upon differing interpretations of lunar microcrater evidence and interplanetary flux measurements.

1. Introduction

Scattered and thermally-emitted light from the solar F-corona involves physical processes relevant to the study of the properties of interplanetary dust. Since the fractional variation of both the incident light intensity and the dust particle scattering angle are large relative to the case of dust particles comprising the zodiacal cloud, studies of F-coronal scattering provide a useful supplemental diagnostic of interplanetary dust (Leinert and Grün 1990).

It is believed that analytic models involving diffraction theory plus isotropic scattering do provide a reasonable general description of the scattering properties of the solar F-corona (Davidson, et al. 1995), if the size parameter ($\alpha = 2\pi s/\lambda$) of the scattering particles is sufficiently large ($\alpha > 15 - 20$). A more exact formulation involves the use of Mie scattering theory. Despite limitations resulting from the usual assumption of smooth, spherical particles, computations by Röser and Staude (1978) clearly point out the efficacy of Mie scattering models, especially for F-coronal studies (cf. Leinert and Grün 1990).

Motivated by recent observations in the infrared spectral region, Mann (1992, 1993) and MacQueen and Greeley (1995) have begun examination of the relative roles of thermal emission and scattering by dust at infrared wavelengths. In this paper, we continue computations of the Mie-scattered brightness of the solar infrared F-corona employing different assumed particle size distributions of interplanetary dust particles (Grün et al. 1985; Lamy and Perrin 1986; Perrin and Lamy 1989). The relevant equations and modelling details are described in MacQueen and Greeley (1995). The goal of the present study is to understand quantitatively which particle size domains contribute to the F-coronal infrared scattered brightness for two different particle size distributions.

2. Computations

To determine the relative contribution of the differing sizes within each distribution, we have divided the range of the differential particle size distribution *n(s)ds* into 10 subintervals, logarithmically spanning the particle radius range 2.5e-06 cm to 5e-2 cm. We then compute the line-of-sight (LOS) brightness contribution due to each particle size subinterval for the given particle size distribution and compare this to the LOS brightness due to the entire particle size distribution. Each calculation is carried out for elongation angle corresponding 4 $R_\odot$ (from sun center) and for wavelengths 0.5 μm and 2.12 μm. The calculations employ Mie routines developed by Wiscombe (1980), with particle indices of refraction from Lamy and Perrin (1986). The fractional brightness contribution $f(\Delta s, \lambda) = Z(\epsilon, \lambda, \Delta s)/Z(\epsilon, \lambda)$, for each range interval Δs is the result. The average, or effective, particle size which contributes to the LOS integral is defined as:

$$\langle s \rangle_{LOS} = exp \left[\frac{\int_s ln(s)\ f(s)\ d\ ln(s)}{\int_s f(s)\ d\ ln(s)} \right]. \tag{1}$$

This integral yields the radius of the average optically effective size particle contributing to the LOS brightness. For comparison, we define the average particle size with respect to the distribution, $< s_{DIST} >$, in a similar manner. The two particle size distributions employed are those based upon interpretations of the interplanetary dust particle flux and lunar microcrater counts. We refer to them as the IF distribution (Grün et al. 1985) and the LC distribution (LeSergeant d'Hendecourt and Lamy 1980). As is well known, the two interpretations differ significantly in their predictions of the number density of submicron particles, a result of differing interpretation of the origin of the smallest lunar microcraters. The dust spatial distribution is assumed to follow $r^{-\nu}$ where ν is taken to be either 1.0 or 1.3.

Table 1. Average (Geometrical) and "Effective" Particle Sizes

Model Size Distribution	$< s_{DIST} >$ (μm)	ν	$< s_{LOS} >$ $\lambda = 0.5\mu$	$\lambda = 2.12\mu$
LC	0.032	1.0	0.54	2.8
		1.3	0.46	1.9
IF	0.034	1.0	7.4	9.6
		1.3	7.9	8.2

The results of the computation of $< s >_{DIST}$ and $< s >_{LOS}$ are summarized in the Table. We see that $< s >_{DIST} \approx$ 0.03 microns for both distributions; as would be expected, the average particle size is dominated by the population of

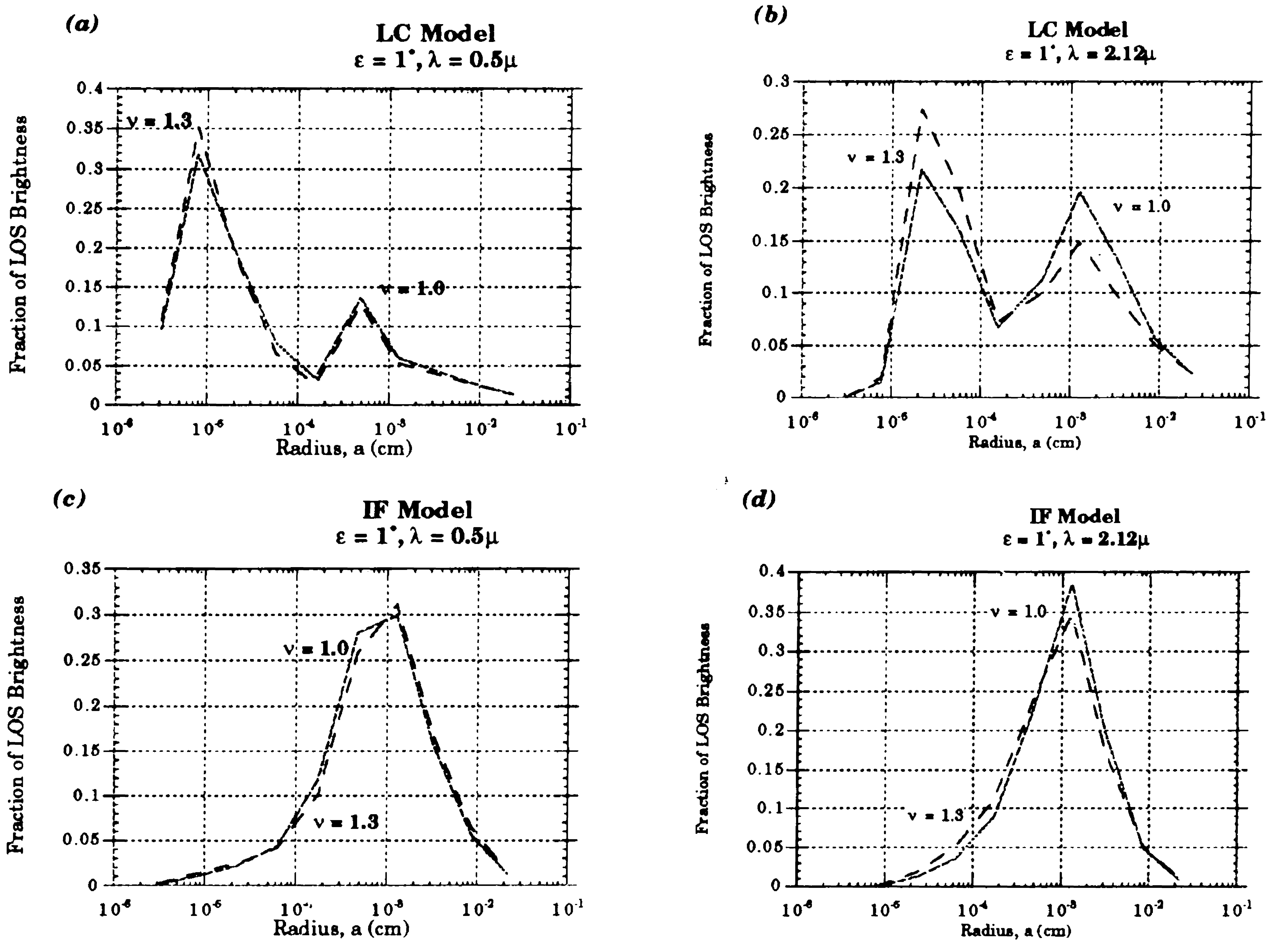

Figure 1. The fractional contribution to the LOS brightness of particle size subintervals for LC (panels a and b) and IF (panels c and d) particle size distributions, at the noted wavelengths, for space distribution exponents $\nu = 1$ and 1.3 and for $\epsilon = 1°$ Note scale changes.

smallest particles in both the LC and IF distributions, and the detailed distribution is irrelevant. However, the average optically effective size particle contributing to the LOS brightness, $< s >_{LOS}$, is very different for the two distributions. For $\lambda = 0.5$ μm, $< s >_{LOS}$ is about 0.5 microns for the LC distribution but is 7 microns in the case of the IF distribution. At 2.12 μm, $< s >_{LOS}$ is about 2-3 microns (LC distribution) and 8-10 microns (IF distribution). Thus, larger particles contribute relatively more to the LOS brightness produced by the IF distribution, irrespective of the wavelength. Note that in the case of the LC distribution, as the wavelength changes the contributing particle size changes in proportion. This is not the case with the IF distribution, which is flatter in shape.

3. Discussion

In Figure 1(panels a and b) we show the fractional contribution to the LOS brightness of each size interval (width e) for the LC distribution. At $\lambda = 0.5$ μm the effect of differing ν is subtle. In addition, small particles ($< 1\mu$ in size) dominate the line of sight integral. For $\lambda = 2.12$ μm, the relative contribution of the small particles is reduced, and that due to larger (but still submicron) particles enhanced. The fractional contribution is now more clearly "bimodal", (at least for $\nu = 1.0$). Also, at $\lambda = 2.12$ μm there is a more distinct–but still subtle–difference between the fractional contributions for $\nu = 1.0$ and $\nu = 1.3$: the contribution of smaller particles is enhanced for $\nu = 1.3$ because small particles are more effective in large angle scattering and there is an enhanced near-solar population for $\nu = 1.3$. The "bimodal" appearance has been found to be a rather sensitive function of the particular shape of the LC distribution; slightly different populations of either small or large particles alter the fractional contribution curve shape significantly.

For the IF model distribution, the fractional contribution of particles in each interval is presented in panels (c) and (d). Now the dominance of the larger particles in forming the LOS brightness is clear, as is the lack of sensitivity to the choice of exponent of spatial distribution. These results hold for both wavelengths. The range of particles contributing measurably to the LOS is broad, extending roughly from 2-80 microns; particles less than 0.1 micron in radius contribute trivially to the LOS F-coronal brightness.

These results clarify which particle sizes contribute to the $\lambda = 2.12$ μm infrared scattered brightness of the solar F-corona. The effective size parameter α based upon the computed averages $< s >_{LOS}$ is about 6 and 30, respectively for the LC and IF model distributions. Clearly, diffraction theory is inappropriate for the former case, and must be applied with care in the latter case. In addition, we see that any future multi-wavelength observations of the F-corona will sample differing particle sizes in a manner which depends strongly upon which particle size distribution is actually present.

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