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COMPOSITE GRAINS: APPLICATION TO CIRCUMSTELLAR DUST

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ABSTRACT. Using the discrete dipole approximation (DDA) we calculate the absorption efficiency of the composite grain, made up of a host silicate spheroid and inclusions of graphite, in the spectral region 5.0-25.0μm. We study the absorption as a function of the voulume fraction of the inclusions. In particular, we study the variation in the 10.0μm and 18.0μm emission features with the volume fraction of the inclusions. Using the extinction efficiencies, of the composite grains we calculate the infrared fluxes at several dust temperatures and compare the model curves with the observed infrared emission curves (IRAS-LRS), obtained for circumstellar dust shells around oxygen rich M-type stars.

1. Introduction

Circumstellar dust grains are more likely to be non-spherical and composites of many small grains glued together, due to grain-grain collisions, dust-gas interactions and various other processes. Since there is no exact theory to study the scattering properties of the composite grains there is a need for formulating models of electromagnetic scattering by the composite grains. Mathis [1] has used effective medium theory to model the composite grains, Iati et al. [2] have used the transition matrix approach to study the optical properties of the composite grains. We use discrete dipole approximation (DDA) [3]to calculate the absorption efficiencies for the composite grains in the spectral region 5.0-25.0μm. The composite grains consist of host silicate spheroids and inclusions of graphite. Using these absorption efficiencies of the composite grains we calculate the infrared flux at various dust temperatures and compare the model curves with the observed IR emission curves from circumstellar dust [4].

2. Composite grain Models

We have used the modified DDSCAT code [5] to generate the composite spheroidal grain models. The code initially carves out an outer spheroid from a lattice of dipole sites and once the host grain is formed, the code locates the centres for internal spheres to form the inclusions. The inclusions are of a single radius and their centres are chosen randomly.

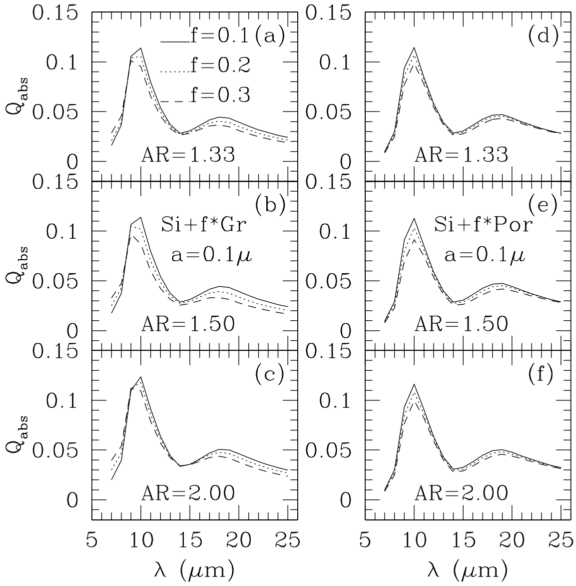

Figure 1. Absorption efficiencies for the composite grains with host silicate spheroids and graphites as inclusions for all three axial ratios N=9640 (AR=1.33), N=25896 (AR=1.50), and N=14440 (AR=2.00) displayed on the panels (a-c) and for porous inclusions on panels (d-f). See Ref. [4] for more details.

The code finally outputs a three dimensional matrix specifying the material type at each dipole site. In the present case the sites are either silicates, graphites or vacuum.

We have studied composite grain models with a host silicate spheroid containing N=9640, 25896 and 14440 dipoles, having axial ratio 1.33, 1.50 and 2.00 respectively; each carved out from $32\times24\times24$, $48\times32\times32$ and $48\times24\times24$ dipole sites respectively. The complex refractive index for silicates and graphites are obtained from Ref.[6]. The volume fractions of the graphite inclusions used are 10%, 20% and 30% (denoted as f=0.1, 0.2 and 0.3) Details on the computer code and the corresponding modification to the DDSCAT code [7] are given in Refs. [4, 5, 6, 8]. For an illustrative example of a composite spheroidal grain with N=9640 dipoles, please refer Figure 1, given in Ref. [4].

3. Results

Figure 1 (a-b) shows the absorption efficiencies for the composite grains with the host silicate spheroids and graphite inclusions. It is seen that the 10μm feature shifts shortwards as the volume fraction of the graphite inclusions increases.

We have also calculated the absorption efficiencies of the porous grains. Figure 1 (d-f) shows the absorption efficiencies of the composite grains with the host silicate spheroids and voids as inclusions. These results on the porous silicate grains do not show any shift

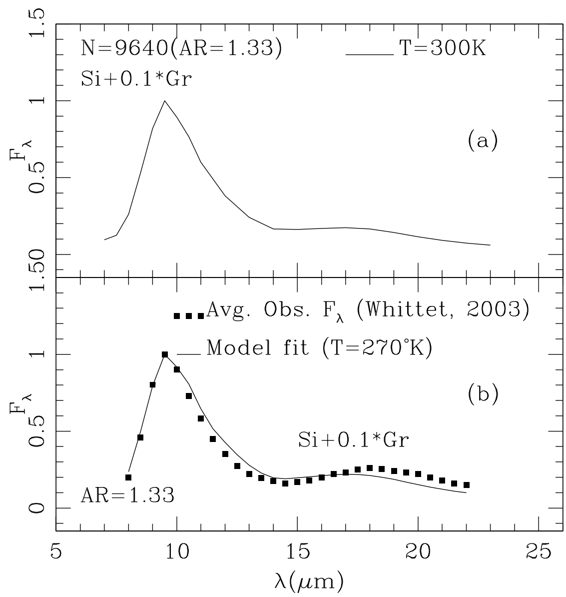

Figure 2. Infrared flux at T=300K for the composite grains with graphites as inclusions shown in the top panel (a). Composite grain model emission curve (silicates with graphite inclusions) fitting with the average observed infrared flux for the IRAS-LRS curve [13] shown in the bottom panel (b).

in the $10\mu m$ feature. We also note that there is no shift in the 18μm feature either with the graphite inclusions or the porosity.

It must be noted here that Iati et al. [9] and Voshchinnikov et al. [10] found shift in these features with higher porosities (∼40-90%).

Using the absorption efficiencies of the composite grains and a power law MRN dust grain size distribution [11] viz. a=0.005-0.250μm, we calculate the infrared flux, F_λ at various temperatures of the dust. Figure 2(a) shows the infrared flux at the dust temperature T=300K for the composite grains containg number of dipoles N=9640.

In Figure 2(b), we compare the best fit χ^2 minimized composite grain models (silicates with graphite inclusions) with the average observed infrared flux for the IRAS-LRS curve.

We have also studied the effect of inclusions on the flux ratio R=F18/F10. These results show that the ratio R decreases with the volume fraction of the graphite inclusions. The model flux ratio compares well with the observed ratio for the circumstellar dust [12].

4. Summary and Conclusions

Using the discrete dipole approximation (DDA) we have studied the variation of the absorption efficiency for the composite spheroidal grains, with the volume fractions of the inclusions in the wavelength region of 5.0-25.0μm. The results on the composite grains show the shift in the peak absorption wavelength 9.7 μm with the volume fraction of the inclusions. The composite grain models with the axial ratio 1.33-2.0 and volume fraction of inclusions 0.1-0.3, and dust temperature between 210-340K, fit the observed IR emission from circumstellar dust reasonably well. The flux ratio, R=F18/F10, for the composite grains is consistent with the observed ratio for the circumstellar dust.

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