# Constraining Size of Cometary Dust Particles Using the 10-$\mu$m Silicate Feature

E. Chornaya[1,2], E. Zubko[3], and G. Videen[3,4]

[1] Institute of Applied Astronomy, Russian Academy of Sciences, Saint Petersburg, Russia,
ekaterina.d.chornaya@gmail.com
[2] Far Eastern Federal University, Vladivostok, Russia
[3] Humanitas College, Kyung Hee University, Yongin-si, Republic of Korea
[4] Space Science Institute, Boulder Suite, USA

**Abstract.** We study the emissivity of agglomerated debris particles using the discrete dipole approximation (DDA). Using numerical simulation, we find that the 10-$\mu$m silicate feature is present in these particles. Based on Mie theory, constraints on size and/or morphology of dust, this feature should not exist in particles whose size exceeds 1 $\mu$m; or particles must have a very fluffy morphology with their constituents being such smaller than 1 $\mu$m.

**Keywords:** comets: general
DOI:10.26119/978-5-6045062-0-2_2020_327

## 1 Introduction

Mid-IR observations of various comets reveal the so-called 10-$\mu m$ silicate feature, a series of peaks arising in their spectra between 8 and 13 $\mu m$. These peaks result from stretching vibrations in Si–O bonds in the silicate species of comets (Hanner & Bradley 2004). It has long been thought that the silicate feature places a strict constraint on size and/or morphology of dust in comets. Namely, if dust particles are compact, their radius should not exceed 1 $\mu m$; otherwise, particles must have a very fluffy morphology with their constituents being smaller than 1 $\mu m$ (Hanner & Bradley 2004). However, recent laboratory measurements suggest this constraint is overrestrictive (e.g. Chornaya et al. 2020b). In this work we study the 10-$\mu m$ silicate feature in the agglomerated debris particles. These are highly realistic model particles (see ten exemplars on top of Fig. 1), whose irregular shape mimics what was found in cometary dust in situ (e.g. Zubko et al. 2020). Furthermore, agglomerated debris particles have proven capability of fitting astronomical observations of comets in the visible (Zubko et al. (2020), for review). It is of high practical interest, therefore, to investigate the applicability of the agglomerated debris particles also to mid-IR observations of comets.

## 2 Modeling Thermal Emissivity

We study emissivity of agglomerated debris particles using the discrete dipole approximation (DDA). We refer to Zubko et al. (2020) for more details on the algorithm of generation of the agglomerated debris particles and on DDA computation of their light-scattering response. The emissivity depends on the complex refractive index of their material $m$ and by ratio of the radius $r$ to $\lambda$ of the incident radiation. We adapt $m$ for Mg-Fe pyroxene glass ($Mg_{0.5}Fe_{0.5}SiO_3$) from Dorschner et al. (1995) and investigate particle radii $r$ = 1, 5, 10, and 20 $\mu m$ over the wavelength range $\lambda = 8 - 13.5$ $\mu m$. In each pair of $m$ and $r$, we consider a minimum 500 randomly generated samples for statistical reliability.

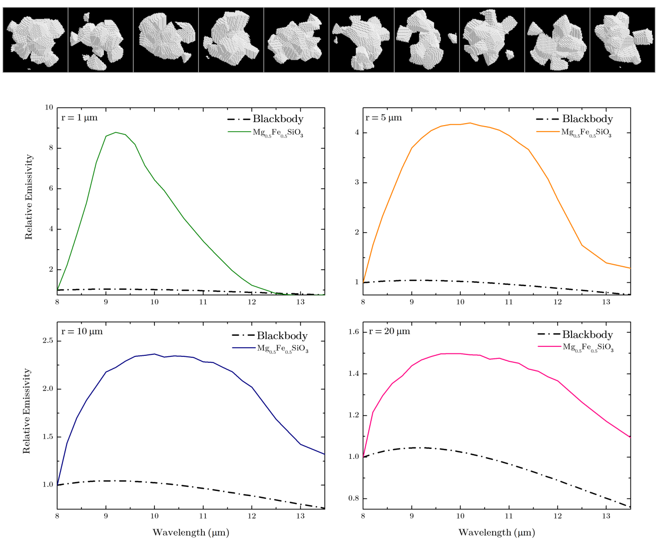


**Fig. 1.** Ten samples of the agglomerated debris particles (top) and mid-IR spectra of their emissivity (middle and bottom) at four different sizes (solid line) and the Blackbody radiation spectra at 300 K (dash-dot line).

## 3 Results and Discussion

The four lower panels in $Fig.1$ show the emissivity spectra of agglomerated debris particles of various sizes which correspond to blackbody temperature 300

K (solid line). In all cases, one can see a noticeable excess of emissivity compared to that of pure blackbody radiation (dash-dot line). Another interesting phenomenon is the shift of maximum of emissivity with increasing particle size. Indeed, while the smallest agglomerated debris particles with $r = 1\ \mu m$ reveal a maximum of emissivity at $\lambda = 9.4\ \mu m$, the particles with $r = 5\ \mu m$ show it at $\lambda = 10.2\ \mu m$, $r = 10\ \mu m$ – at $\lambda = 10.8\ \mu m$, and $r = 20\ \mu m$ – at $\lambda = 11.4\ \mu m$. It is finally worth noting that the polarimetric response from comets in the visible is dominated by dust particles whose radii do not exceed 3 $\mu m$ (Zubko et al. 2020). On the other hand, as appears from $Fig.$1, the 10-$\mu m$ silicate feature may be produced by larger particles. Such particles produce a minor effect on polarization. This may explain the lack of significant correlation between polarization and the 10-$\mu m$ silicate feature that was noticed in some comets (e.g. Manset & Bastien 2000).

## Bibliography

Chornaya, E., Zakharenko, A. M., Zubko, E., et al. 2020b, Icarus, 350, 113907

Dorschner, J., Begemann, B., Henning, T., Jäger, C., & Mutschke, H. 1995, Astron. Astroph., 300, 503

Hanner, M. S. & Bradley, J. P. 2004, in Comets II eds. M. C. Festou, H. U. Keller, H. A. Weaver. University of Arizona Press, 555

Manset, N. & Bastien, P. 2000, Icarus, 145, 203–219

Zubko, E., Videen, G., Arnold, J. A., et al. 2020, Astrophys. J., 895, 110