Calculating the Scattering Properties of Fine-grained Particulates of Planetary Surfaces

Gen Ito, Timothy Glotch, Jessica Arnold
gen.ito@stonybrook.edu
Stony Brook University

Introduction

- Mid-IR emissivity spectra can be used to analyze surface compositions of planetary bodies.
- Emissivity spectra are dependent on the size of regolith particles.
- Describing the dependency of scattering properties on particle size is difficult with current light scattering models.
- In order to conduct precise analyses of the surfaces of SSERVI target bodies (Fig. 1), scattering models must improve.
- So far, Mie Theory, a single scattering theory, has been widely used to find the necessary scattering parameters, but this is replaced with a multiple scattering method here called Multiple Sphere T-Matrix (MSTM) (Mackowski and Mishchenko, 2011) (Fig. 2).

Fig. 1. SSERVI target bodies. Left: The Moon. Right: Near earth asteroids.

Objectives

- Calculate emissivities of fine-grained materials using multiple scattering model of Hapke (1996) combined with MSTM.
- Use forsterite as a test case to compare MSTM, Mie, and lab emissivities.

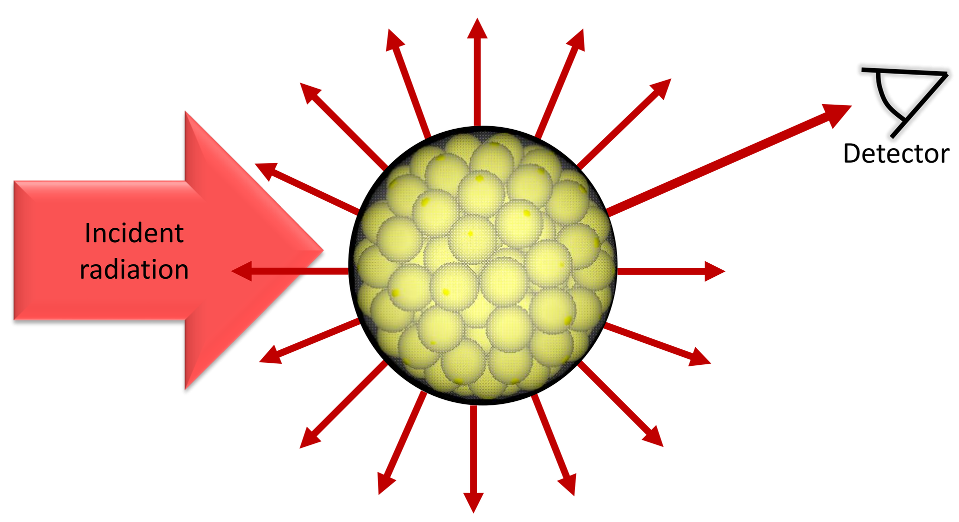

Fig. 2. Illustration of multiple scattering process in MSTM.

Methods

- Cluster of closely packed spheres were generated following Donev et al. (2007) (Fig. 3).
- Optical constants of forsterite and scale factors were assigned to each sphere.
- MSTM code ran using the inputs from the cluster of spheres.
- The outputs of MSTM code were further input into the equation to find emissivity according to Hapke (1996):

$$w = \frac{Q_{scatt}}{Q_{ext}}, \quad \gamma = \sqrt{1-w}, \quad \zeta = \sqrt{1-\xi w}$$

$$\text{Emissivity: } \epsilon = \frac{2\gamma}{(\zeta+\gamma)}$$

- These processes were repeated for every wavenumber of interest.
- Emissivities were also derived using scattering coefficients from Mie theory for comparison.
- Emissivities of corresponding grain-sized olivine were measured in a lab for comparison.

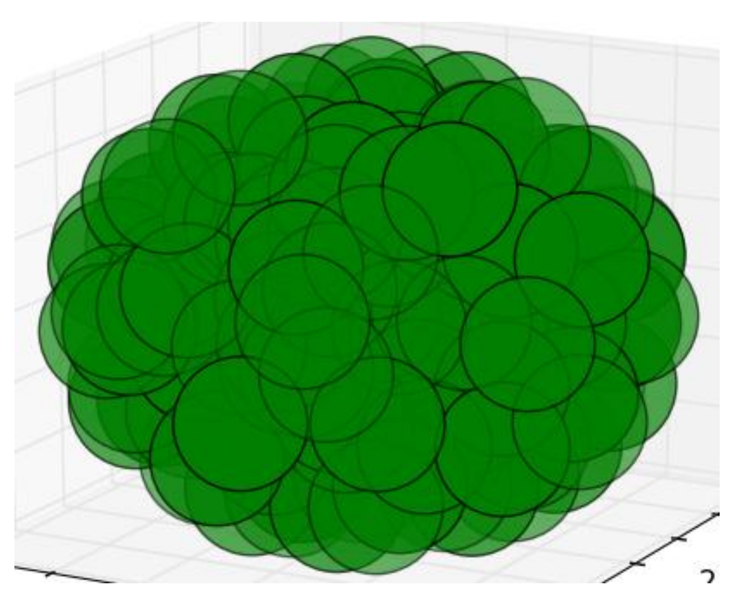

Fig. 3. A sample cluster containing 150 spheres.

Results

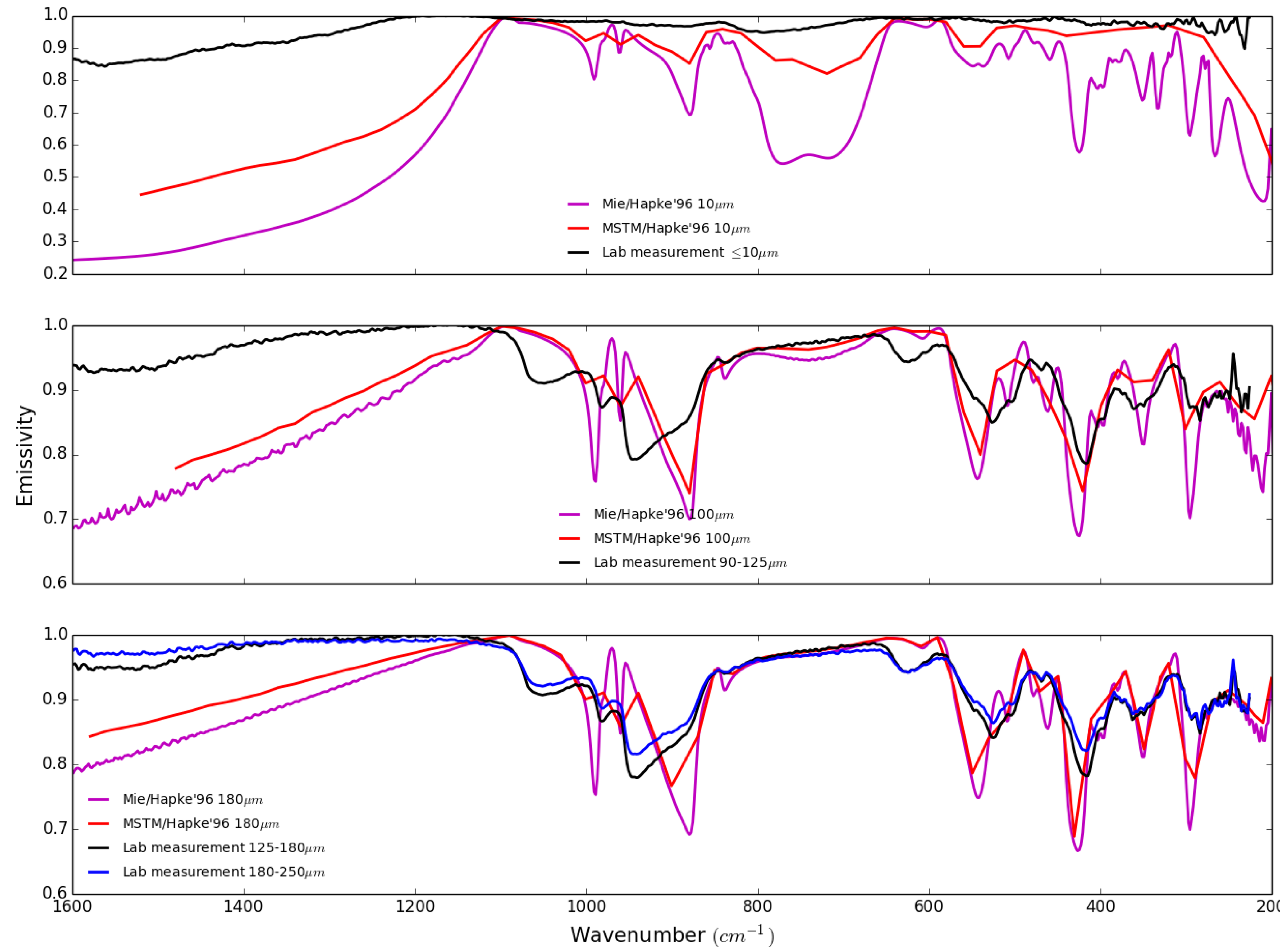

Fig. 4. Emissivities of forsterite as calculated by MSTM/Hapke and Mie/Hapke methods in the mid-infrared region. Lab measured emissivities are included as well. The particle sizes are: Top: 10 µm. Middle: 100 µm. Bottom: 180 µm.

Discussion

- The emissivity peaks in MSTM method corresponds to the lab measured values better than those of Mie theory.
- This is particularly apparent for 10 µm size particles at wavenumbers below ~1000 cm^{-1} (Fig. 4).
- Both MSTM and Mie methods underestimate emissivities at higher wavenumbers (Fig. 4).
- Part of the mismatch between lab and calculated values is caused by differences in optical constants due to slightly different olivine compositions used.

Conclusions

- MSTM method was generally able to better model forsterite emission spectra than Mie theory, but it needs to improve.
- Increasing the number of spheres in a cluster and relaxing the cluster packing may improve MSTM method.
- In future works:
  - sizes of the individual particles will be changed (Fig. 5).
  - more than one composition will be included.
  - ideally more realistic shapes will be used for the particles.

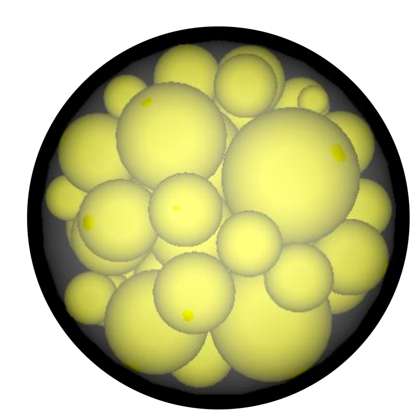

Fig. 5. A cluster containing spheres of different sizes.

References

- Donev, A., Stillinger, F. H., and Torquato, S., Calculating the free energy of nearly jammed hard-particle packings using molecular dynamics, *J. Comp. Phys., 225*, 509-527, 2007.
- Hapke, B., A model of radiative and conductive energy transfer in planetary regoliths, *J. Geophys. Res.*, 101, 16817-16831, 1996.
- Mackowski, D. W. and Mishchenko, M. I., A multiple sphere T-matrix Fortran code for use on parallel computer clusters, *J. Quantitative Spectroscopy & Radiative Transfer, 112*, 2182-2192, 2011.