

Light Scattering from Graphite Powder - an Analog to Asteroid Surfaces

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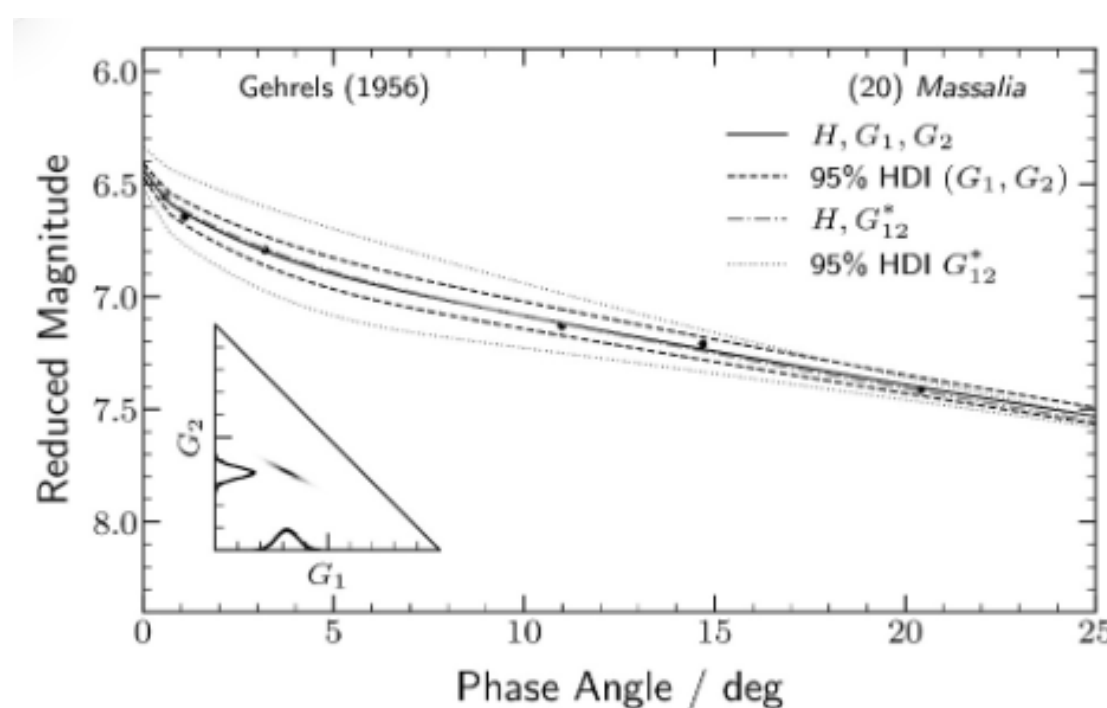
INTRODUCTION & AIM

The surface of asteroids and planets are covered with a layer of dust called *regolith*. It is very important to study regolith properties because they contain valuable minerals and metals that can be useful for future space programs.

Regolith can be studied in-situ (i.e. on the spot) by a spacecraft or remotely from earth by studying its light scattering nature in a phase curve – a graph between intensity or polarization with phase angle.



Neil Armstrong's footprint on lunar regolith
(Credit: NASA)

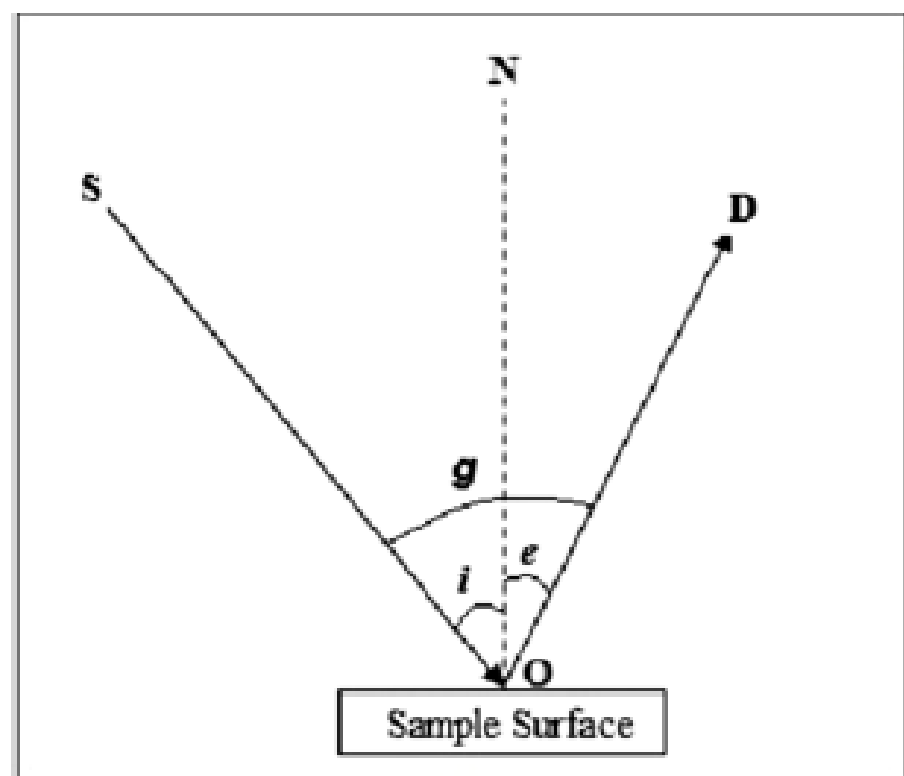


Phase curve of asteroid Massalia
(Source: Mahakle et al. 2021)

This work aims to generate light scattering data and phase curves from simulated regolith within laboratory which will help gain our understanding of light scattering from regolith. Also, these data can be used as a ground truth for remote sensing data and spacecraft observations.

METHOD

Scattering geometry from regolith is shown below. Phase angle is the angle subtended between incident and scattered component of light from the scattering surface.



Scattering geometry
(Source: Deb and Chakraborty 2022)

The bidirectional reflectance $r(i, e, g)$ is the ratio between scattered light intensity I and incident light's irradiance J .

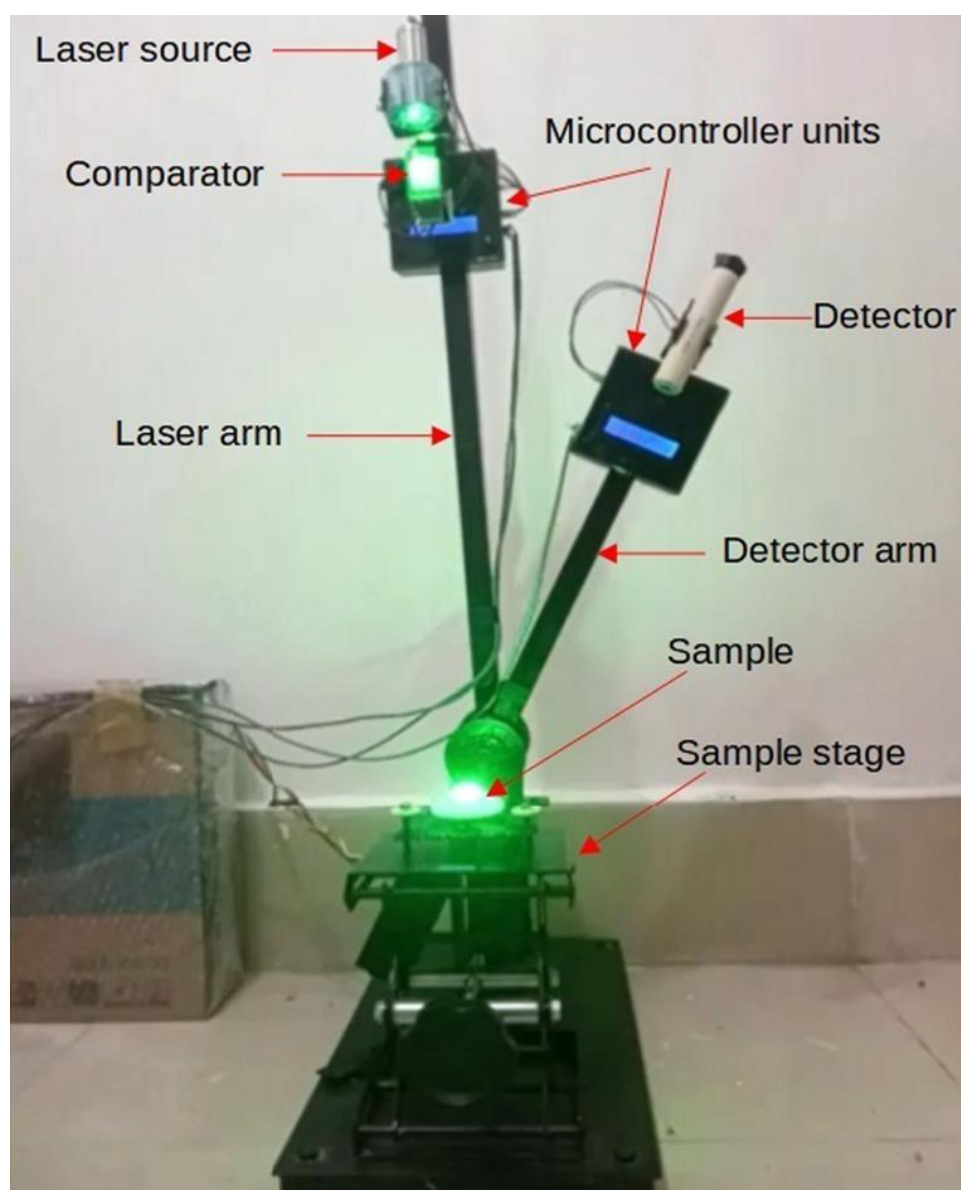
$$r(i, e, g) = I(i, e, g) / J \quad \text{----- (1)}$$

Regolith parameters that affect $r(i, e, g)$ are

1. Particle size
2. Composition
3. Particle shape
4. Distribution of particles
5. Porosity

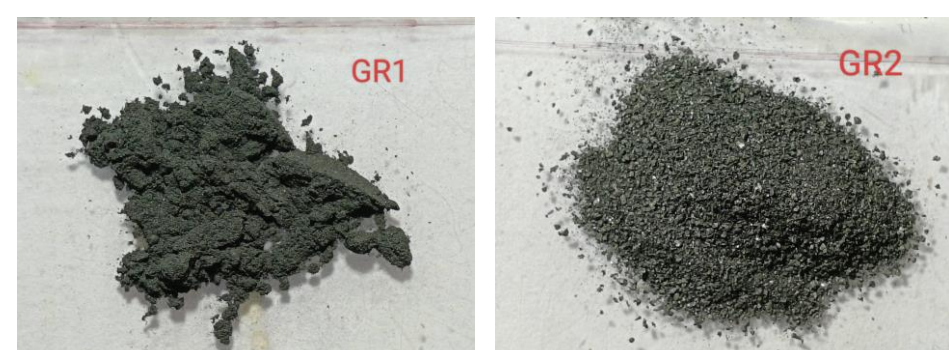
Our aim is to generate light scattering data (r v/s g) from samples of known parameters so that they can be used as ground truth for in-situ or remote observations.

This experiment uses a goniometric instrument developed indigenously as shown in below image.



Goniometer for light scattering measurement
(Source: Deb and Chakraborty 2022)

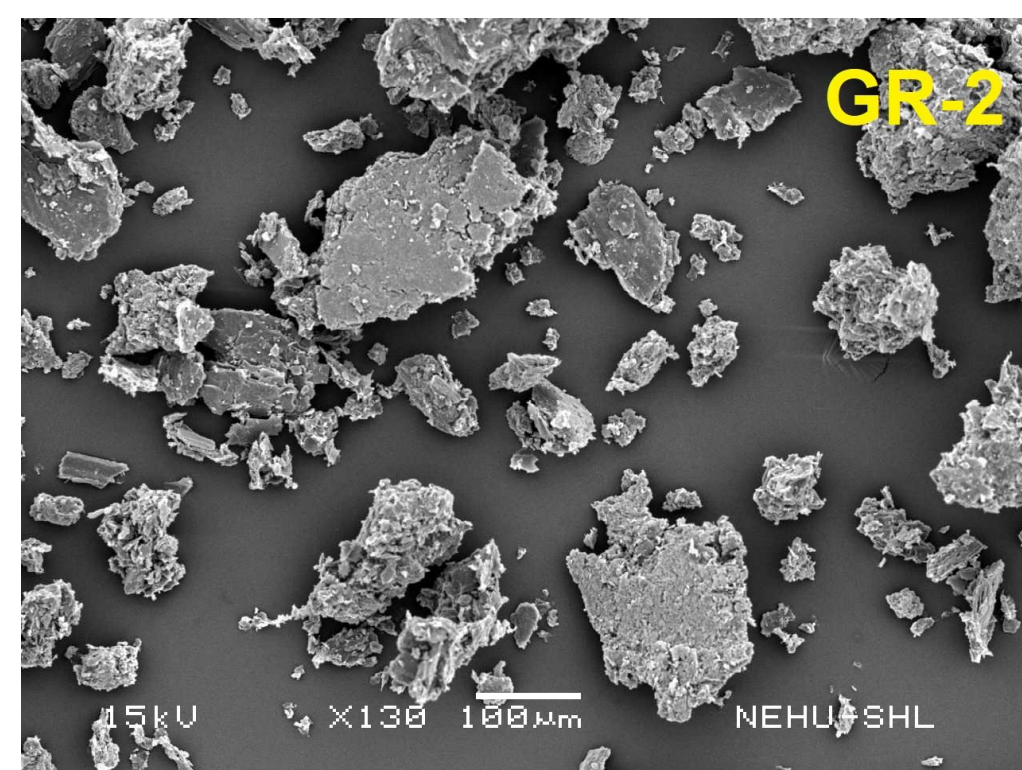
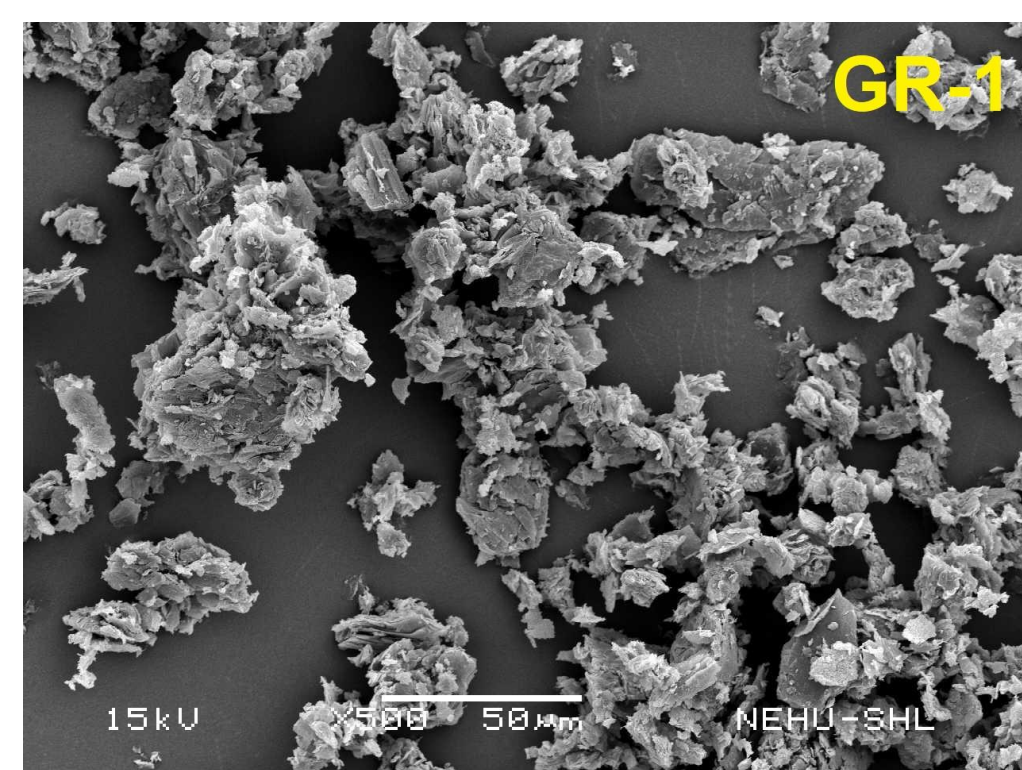
Collimated beam of light at 535 nm is the source of light and TSL237 light sensor used as detector. This computerized device can collect intensity measurements at angular resolutions 1° .



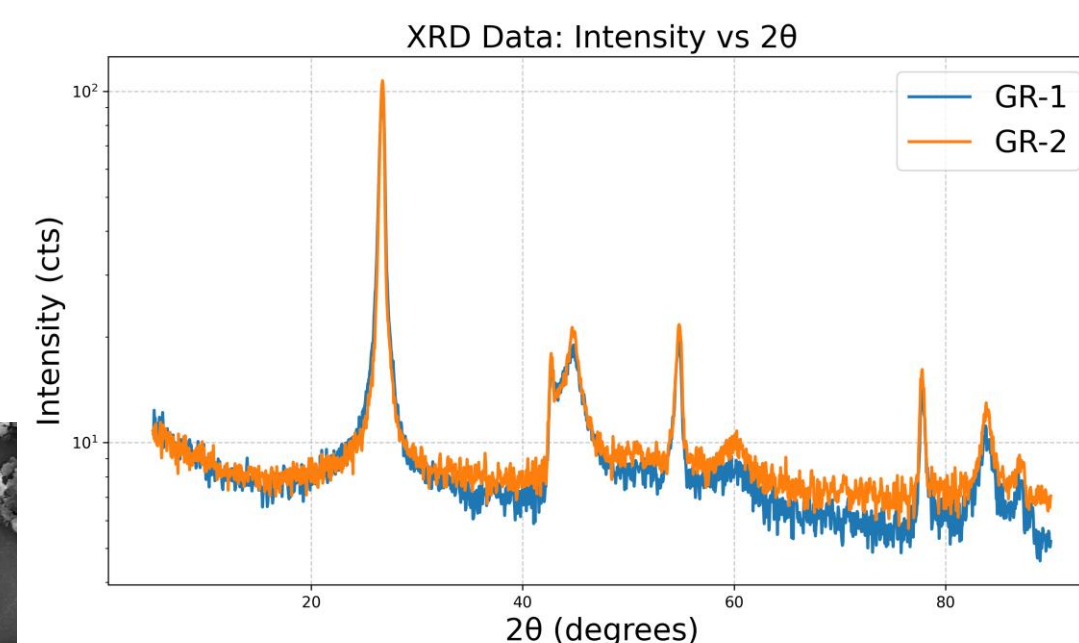
Samples used are Graphite powders of two different size ranges - GR1 is fine and GR2 is coarse. Graphite grains are found in B or C-type asteroids (e.g. Bennu).

RESULTS & DISCUSSION

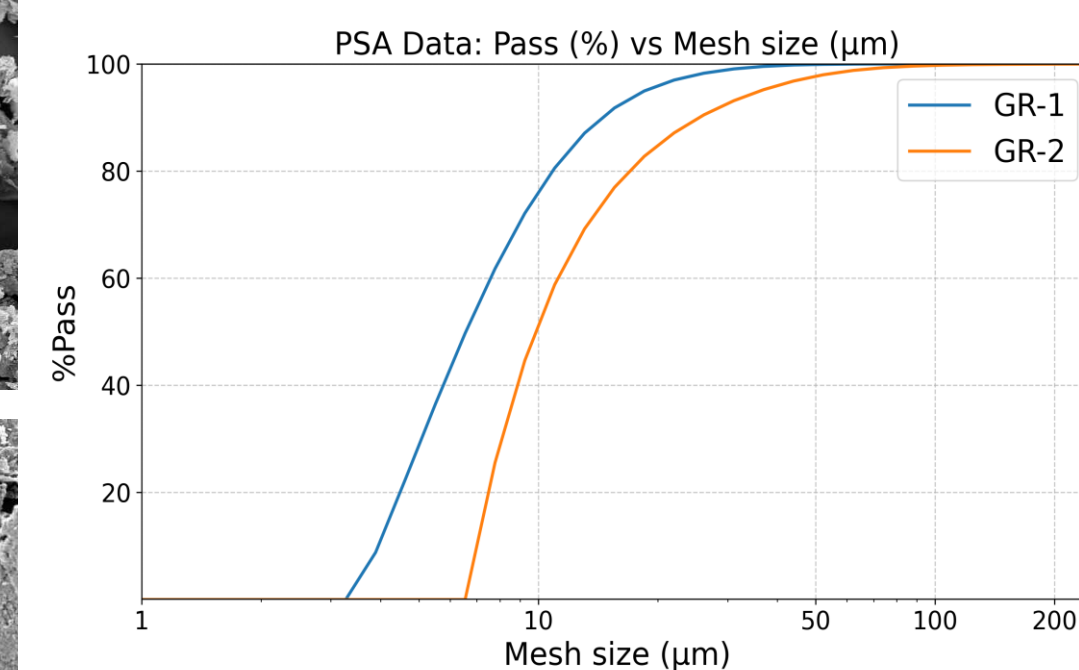
The sample properties were tested by using SEM image (NEHU, Shillong, India) for shape, XRD (NIT Silchar, India) for composition, and PSA (IIT Kanpur, India) for Particle Size Distribution (PSD).



SEM images of Graphite samples.
Magnification 500x (GR-1) and 130x (GR-2)

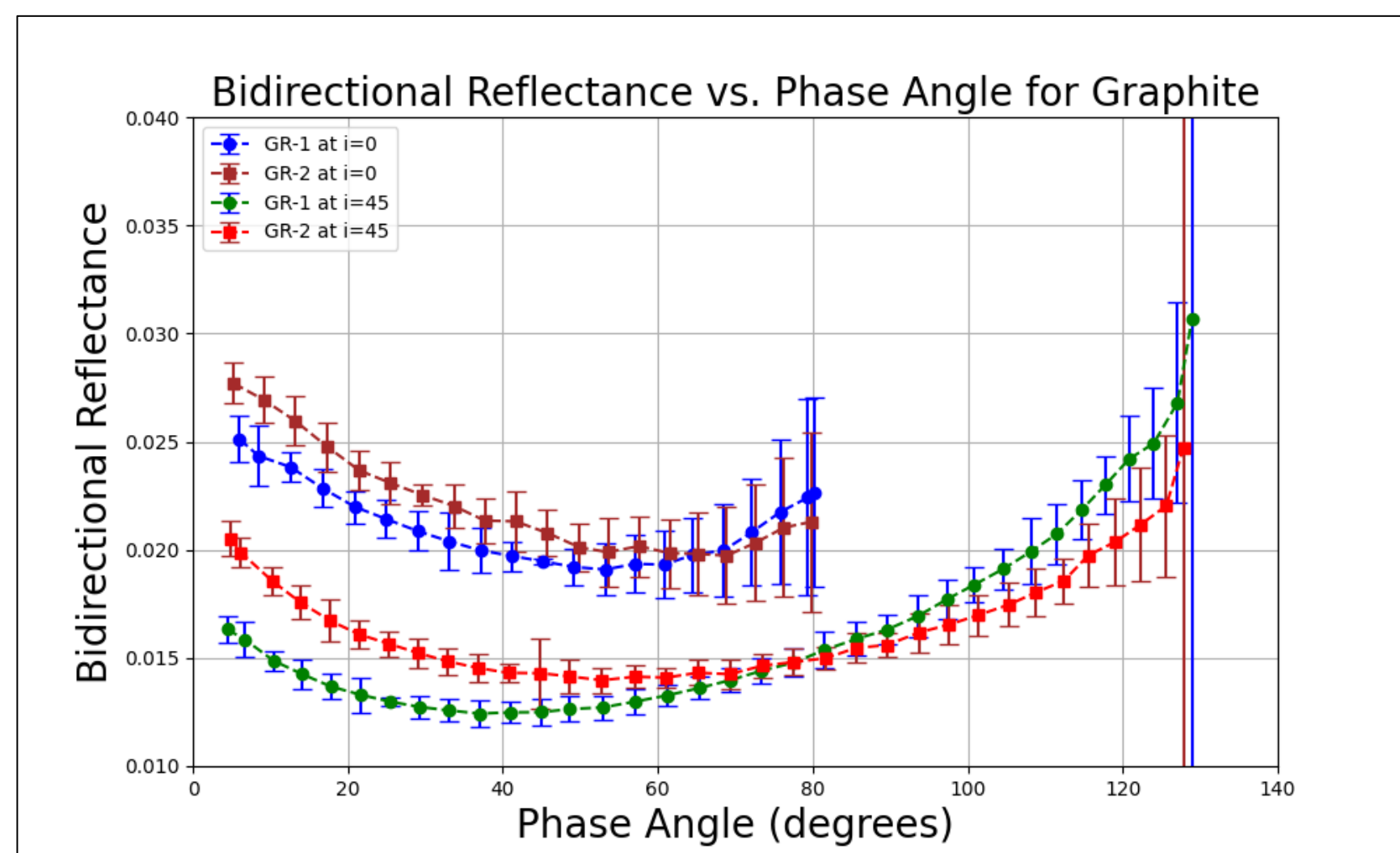


XRD 2θ plot for GR-1 and GR-2
(Y-axis logarithmic)



Cumulative PSD plot for GR-1 and GR-2
(X-axis logarithmic)

The figure below shows the light scattering results for GR-1 and GR-2 from goniometer at two different angles of incidence $i=0^\circ$ and $i=45^\circ$. Both sets of curves intersect each other between 60-80 degrees.



Light scattering data from GR-1 and GR-2

CONCLUSION

The SEM images show that the particles of both the samples are irregular in shape. XRD results show that the absorption peaks of both the samples indicate a highly pure graphite composition. PSA results show that GR-1 is dominated by much smaller particles than GR-2. Light scattering results show that at phase angles smaller than about 65° , the reflectance of larger particles (GR-2) is more than that of smaller particles (GR-1) which is an unusual behavior predicted by theory that needs thorough investigation.

REFERENCES

Reference:

1. Deb, D., Chakraborty, P. A photometric study of regolith intimate mixing with ice-like impurity. Eur. Phys. J. Plus 137, 829 (2022).
2. Mahlke, M., Carry, B., Denneau, L., Asteroid phase curves from ATLAS dual-band photometry, Icarus, Volume 354, 2021, 114094, ISSN 0019-1035,