Exploring the Solar System in mm wavelengths

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ASTEROIDS IN MM WAVELENGTHS

- Fluxes in optical and IR ranges have a major contribution from reflected solar light.
- In mm waves, the observed radiation is mostly from emission.
- Millimeter observations constitute of radiation from below the surface.
- They carry important information about the surface and sub-surface layers.
- Can be potentially used for better classification and sorting of bodies than what currently exist.

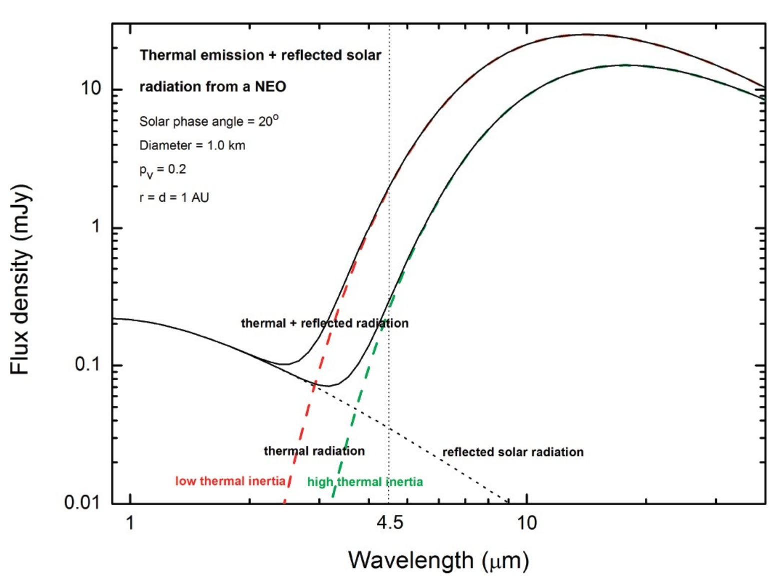

Fig. 1: Flux composition for an asteroid. https://nap.nationalacademies.org/read/25476/chapter/7#39

FLUX DISCREPANCY IN LONGER WAVELENGTHS

- Asteroids observed at longer wavelengths have consistently shown lower than expected flux.
- Johnston et al. (1982) observed dwarf planet Ceres in microwave (2 and 6 cm) and the observed flux signaled a $T_B \sim 120$ K, in contrast to the expected $T_{eq} = 165$ K. Conclusion: diameter estimate might be incorrect, misalignment of rotational axis, unknown thermal properties.
- They also noted that such a drop is consistent with other contemporary mm wave observations.
- Works like Webster et al. (1988) and Redman et al. (1992) again confirmed the flux discrepancy.

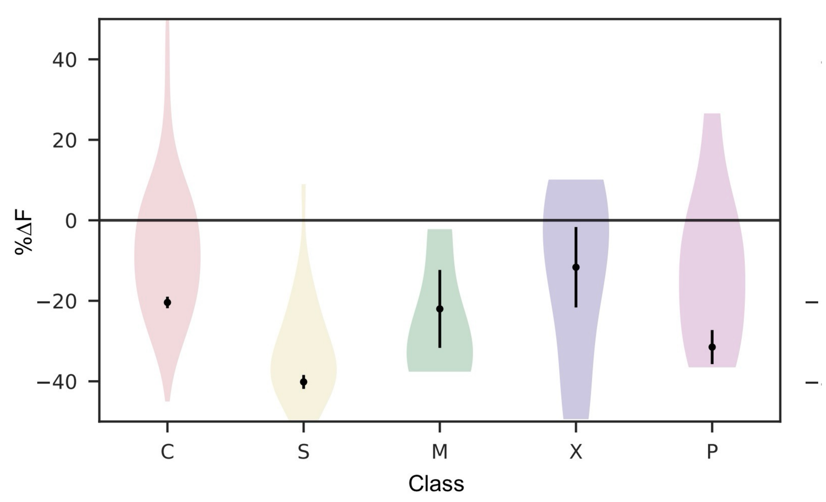

Fig. 2: Population distribution of difference in flux for various classes of asteroids compared to prediction based on WISE data as shown by Orlowski-Scherer et al. (2024).

- Historically, researchers have attributed the drop in flux to a reduced effective emissivity.
- Keihm et. al. (2013) proposed that this may be caused by the sharp temperature gradient below the surface, while emissivity remains near unity.

OUR THERMOPHYSICAL MODEL

- Our thermophysical model can simulate asteroid temperatures throughout the body.
- We take the shape model of asteroid with triangulated surface.
- For every facet on the surface, we solve an implicit finite difference version of the 1-D heat equation along a strand running from the surface to the core of the asteroid.

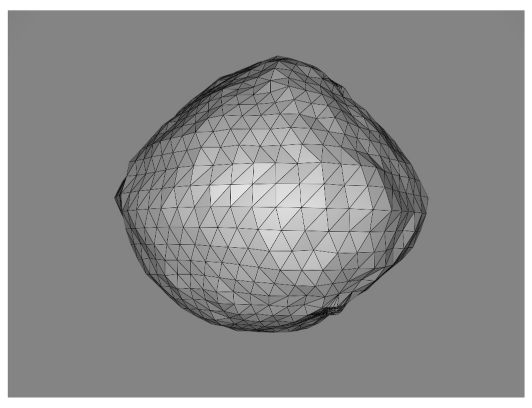

Fig. 3: The shape model of asteroid Bennu showing its triangulated surface which had been used for some initial tests is shown here as an example. The surface has been divided into 2692 triangles.

- With JPL Horizons data for exact ephemeris, proper spin axis and a date corresponding to the initial orientation of the shape model, we can simulate the exact orientation of the asteroid at the time of observation.
- This gives us a tool to investigate whether subsurface temperature drop can solve for the flux discrepancy.

COMPARISON WITH OTHER MODELS

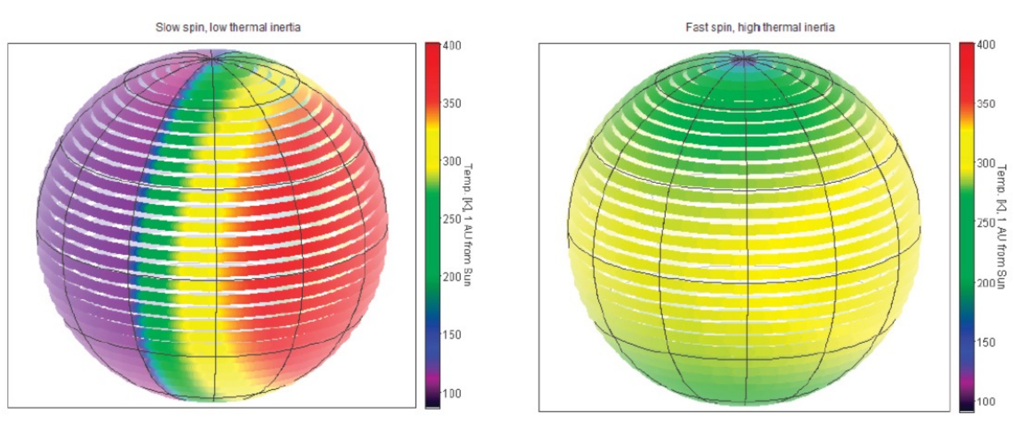

Fig. 4: Other simpler models

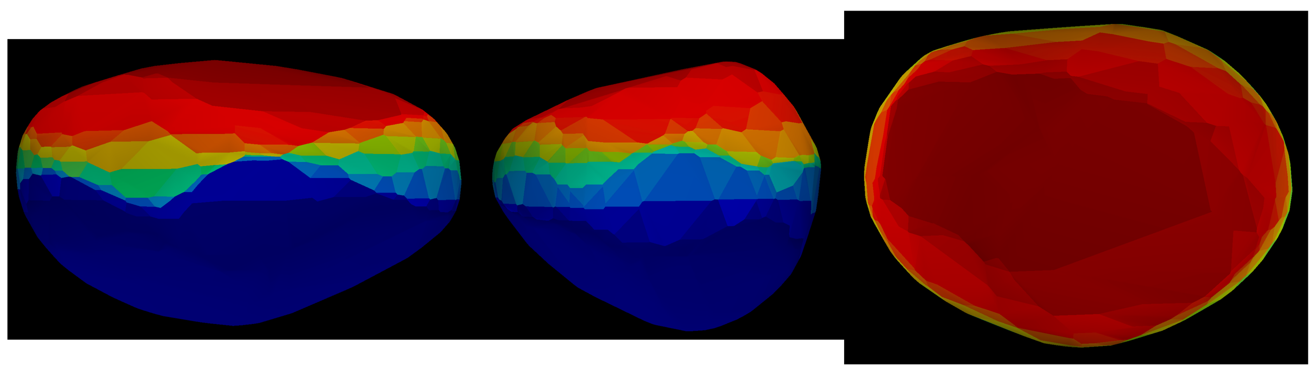

Fig. 5: Our model

OUR OBJECTIVE

- Understand the physical process responsible for discrepancy between predicted and observed asteroid flux at mm wavelengths.
- Develop the ability to accurately predict and model asteroid flux at mm wavelengths.
- Improve our understanding about asteroid composition and subsurface conditions, encompassing materials, and particle size distribution.

ASTEROID 22 KALLIOPE FLUX SIMULATED

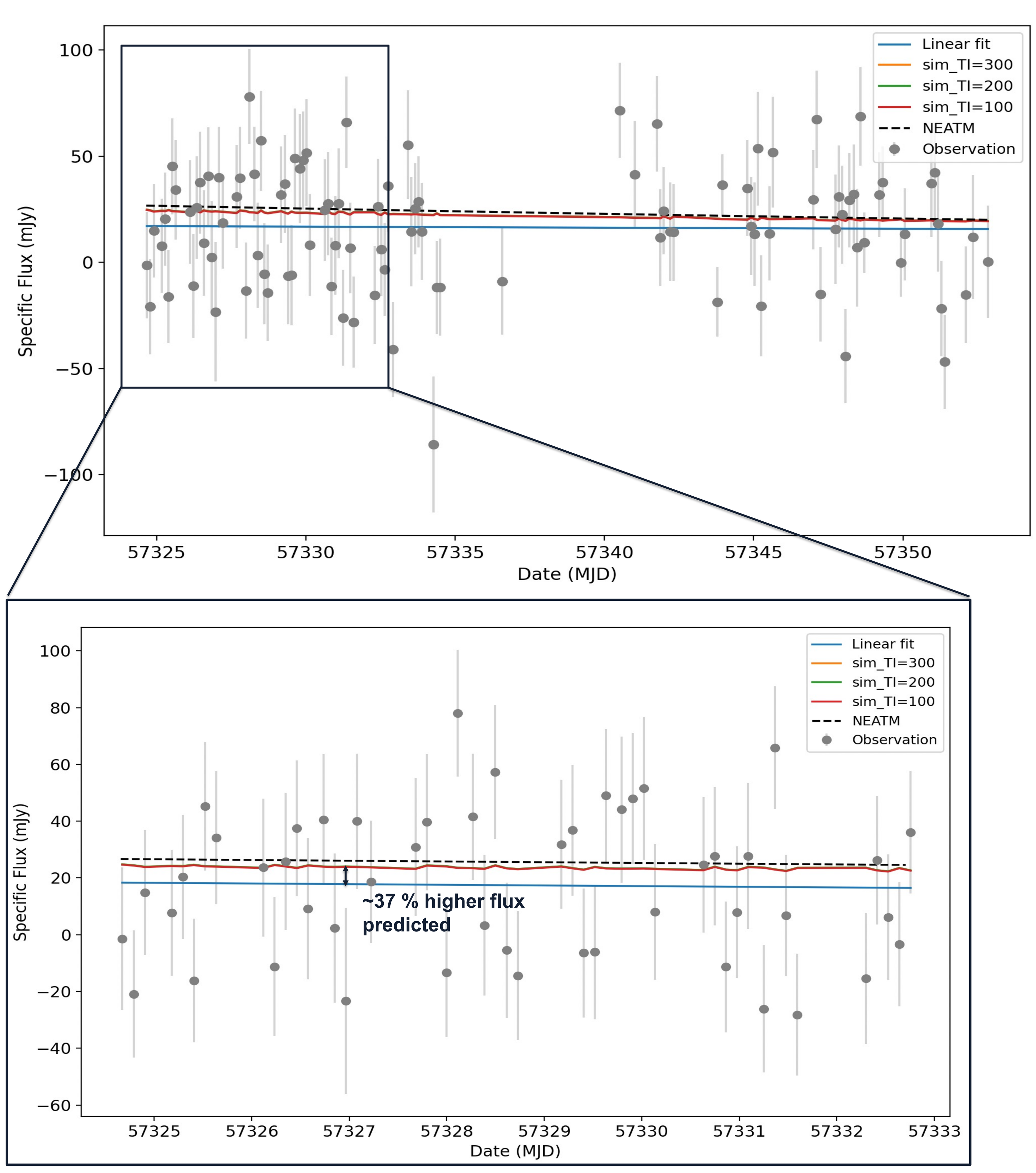

Fig. 6: Comparing the simulated flux of asteroid Kalliope for different thermal inertias and NEATM prediction with SPT data (150 GHz) (Chichura et al. (2022))

- Naïve fit gives high discrepancy in flux values.
- Flux discrepancy may not an exclusively thermal effect.

Scan this QR code to see a 360-degree thermal map of asteroid Kalliope obtained from our simulation. Thermal inertia of 200 TIU is considered for this case.

ALTERNATE EXPLANATION

- de Kleer et al. (2021) found that thermal emission from M type asteroid Psyche is largely unpolarized.
- Combining that with other observed characteristics, they inferred that surface roughness alone cannot be the cause.
- They suspect that sub-surface scattering might be the only plausible reason.

FUTURE PROSPECT

- Insight gained from this work can be used to better understand asteroid data in microwave obtained from other surveys: SPT, ACT, Simons Observatory etc.
- This thermophysical model can be used to analyze data obtained from targeted asteroid missions too.
- With better sensitivity, future missions can provide asteroid fluxes with lower noise and scatter, giving us a good chance to peek below the surface of asteroids.

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