Validation of a non-radar-based deep learning approach to asteroid detection

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1 Introduction

Traditional asteroid detection techniques often make use of a radar style system [1], where a signal is transmitted from earth to an asteroid of interest, and the received signal is captured by a telescope and used to glean information about the target. Measurements by the Rosetta mission have shown the existence of a drop in flux at mm wavelengths thought to be caused by a temperature gradient through the surface of the asteroid [2]. These measurements have brought about the requirement for more detailed cm and sub-mm measurements of asteroids. Previous studies have proven the viability of millimetre (mm) and sub millimetre (sub-mm) measurements of asteroids [3]. The Atacama Large Millimetre/Submillimetre Array (ALMA), and recent work by the South Pole Telescope (SPT) has produced promising initial measurements in this space. The unique advantage of mm/sub-mm techniques is that they are able to leverage already accepted sky surveys being carried out by existing cosmology experiments. Measurements by the SPT are unique in that they are already being commissioned to take large survey images of the sky at mm/sub-mm wavelengths, making the additional requirements for a mm wave asteroid survey negligible. **We propose to repeat the measurements carried out in previous years from [4], with the new SPT-3G instrument.** In addition to refining the measurements previously taken, we hope to be able to detect additional unknown asteroids from the new measurements using deep learning techniques.

2 Scientific Justification

We wish to build upon the work in [4] where multiple asteroids were detected over the course of a sky survey. The beam of the SPT aims towards a region of space where multiple asteroids are known to be present in the fields of view of the telescope. Alongside these known asteroids based on previous measurements, analysis of the JPL Small-Body Database (SBD) [5] shows multiple possible asteroids which could enter the area.

Additional justification is provided by computations carried out for the Atacama Large Millimeter Array, which shows that almost all of the asteroids currently detectable via radar measurements would also be observable to ALMA in Figure 1, which has similar properties to SPT-3G. Extrapolating from here, we can leverage these already planned high resolution measurements to perform additional detection of as yet unknown asteroids which may pose a threat to earth, without needing to build additional equipment or sacrificing observing time.

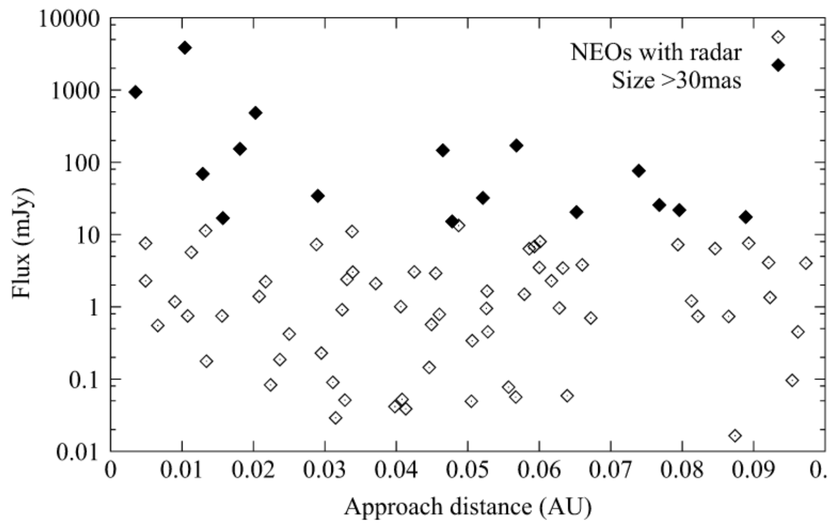

Figure 1: Predicted visible asteroids from ALMA. Figure from [3]

Observations from the SPT-3G antenna are already slated to observe the areas shown in Figure 2, and the data being collected can be leveraged for additional detection of small objects. This capability is not unique to the SPT-3G instrument, but with its ability to probe high frequencies, and the already committed search areas, SPT-3G is an ideal choice for this mission.

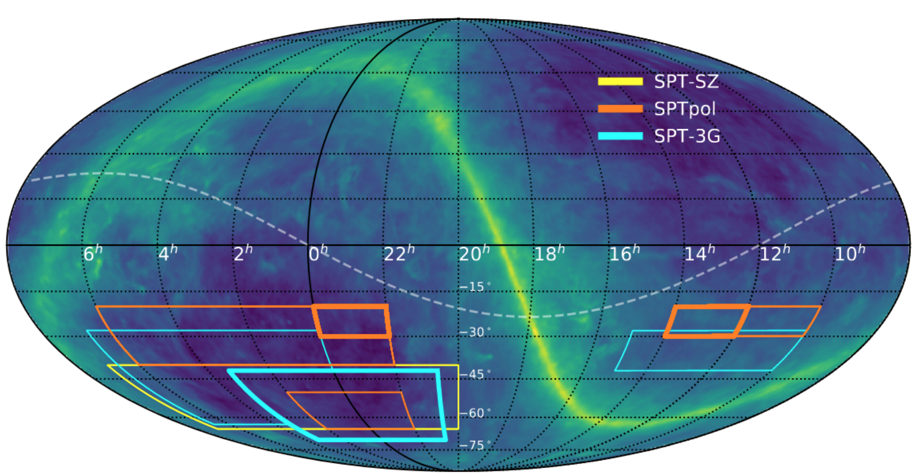

Figure 2: Range of the sky covered by the old and new South Pole Telescope Instruments. Figure from [4]

3 Technical Justification

The SPT conducts regular surveys of the sky periodically, and we wish to leverage these existing surveys to extract additional measurements. Previous studies have used a method where objects are first taken from the SBD, then flux density is computed using a "Standard Thermal Model" from [6], and a subset are selected with a flux above 0.5 mJy, a 2σ fluctuation of the SPT-3G field over a 5 year observing window. Objects were then selected which were within the observing window, and a full selection of candidate targets are shown in Fig 3. **Following the results of [4], we will also request to run the observations by SPT-3G in the ra13hdec-25 and ra23hdec-25 fields of the SPT. These fields are already of interest for observation, so it should take no additional time to make these observations available.** In addition to the known asteroids slated for observation above, we also propose to use deep learning methods to detect as yet unknown asteroids which may be revealed in this survey. Similar methods have been used previously in [7], which have been proven before in prior studies. This is a reach goal for the project, and even if the data does not prove amenable to our machine learning techniques, the asteroids listed in the figure should provide promising new data. Preliminary measurements taken in 2020 with the SPT-3G instrument are show in Figure 4, showing the validity of the conventional measurement technique.

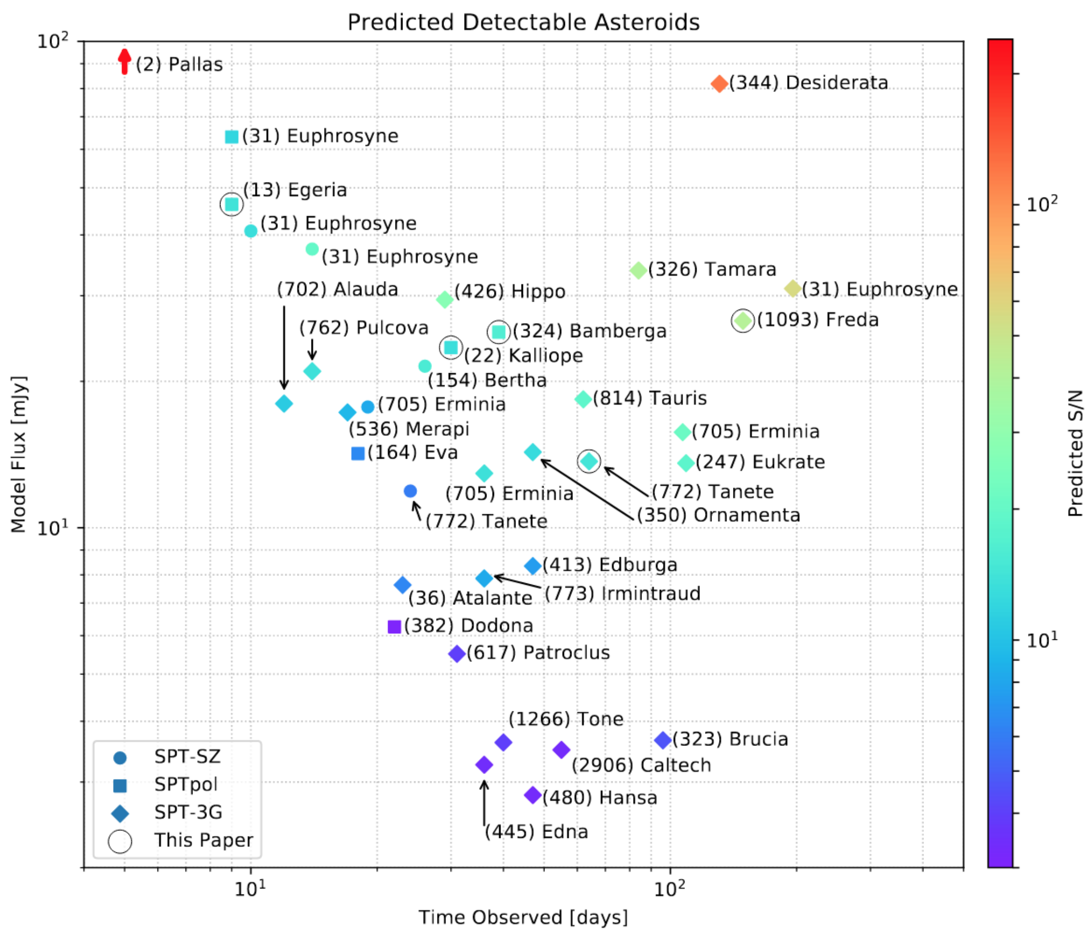

Figure 3: Asteroids with a predicted S/N over 3 observable by SPT-3G. Figure from [4]

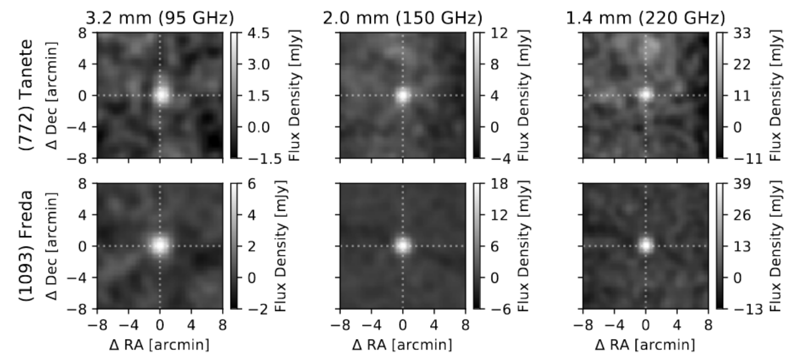

Figure 4: Several example flux measurements taken by SPT-3G in 2020 austral winter. Figure from [4]

4 Conclusion

We would like to request access to the output of the SPT-3G telescope over the course of the next observation season. **This measurement will not interfere with the existing cosmological survey, and will require no special weather considerations.** All additional work consists of post-processing, and will provide valuable additional insight from the new instrument, without causing interference with the primary scientific mission.

References

[1] Rivera-Valentin et al. Radar observations of near-Earth asteroids from Arecibo Observatory. 48:329.10, October 2016.

[2] F. Peter Schloerb et al. MIRO observations of subsurface temperatures of the nucleus of 67P/Churyumov-Gerasimenko. *Astronomy & Astrophysics*, 583:A29, November 2015.

[3] Amy J. Lovell. Observations of asteroids with ALMA. *Astrophysics and Space Science*, 313(1):191–196, January 2008.

[4] P. M. Chichura et al. Asteroid Measurements at Millimeter Wavelengths with the South Pole Telescope. *The Astrophysical Journal*, 936(2):173, September 2022.

[5] Jet Propulsion Laboratory. Small-body database lookup.

[6] Larry A. Lebofsky et al. A refined "standard" thermal model for asteroids based on observations of 1 Ceres and 2 Pallas. *Icarus*, 68(2):239–251, November 1986.

[7] Maggie Lieu, Luca Conversi, Bruno Altieri, and Benoît Carry. Detecting Solar system objects with convolutional neural networks. *Monthly Notices of the Royal Astronomical Society*, 485(4):5831–5842, June 2019.