A deep analisys for New Horizons' TNO search images

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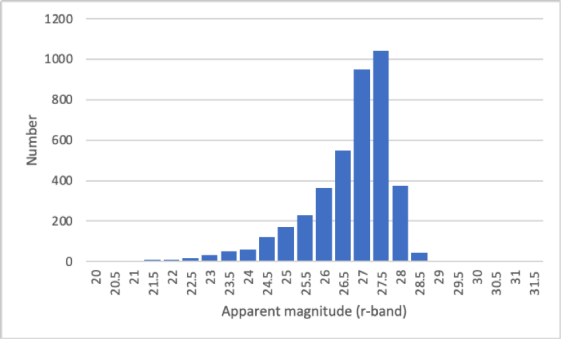
NASA's New Horizons is a flyby mission to investigate the Pluto system and TNO objects. The spacecraft was launched in 2006, reached the Pluto system in 2015, and did a flyby of (486958) Arrokoth, one of the Classical TNOs, in 2019. New Horizons has revealed the surface layers of outer solar system bodies for the first time. Data analysis is ongoing, with a series of excellent results being published.
An extended mission to continue investigating the outer solar system after the Arrokoth flyby has been approved and Japanese scientists have joined the science members in this extended mission from April 2020. The primary objective of the Japanese participation is to use the Subaru Telescope and its wide-field camera (HSC) to discover (1) a second TNO flyby candidate and (2) TNO objects that can be observed from the spacecraft.
The objective of above (1) is obvious. The purpose of (2) is to observe TNOs from the spacecraft in the Kuiper Belt. From the ground, only TNOs with a solar phase angle of nearly 0 degrees can be observed, but if observations are made from the spacecraft when it is in the Kuiper Belt, TNOs can be observed in configurations with large solar phase angles. The combination of ground-based observations at near-zero solar phase angle and observations from the Kuiper Belt will provide surface reflectance of TNOs at a wide range of solar phase angles, which can be used to infer information about the TNO surface (e.g., grain size, roughness, etc.). This observation can only be realized while the spacecraft is in the Kuiper Belt, making it a rare observation opportunity indeed.

Therefore, the TNO survey in the direction of the New Horizons spacecraft was started with the Subaru Telescope + HSC in May 2020. The area to be surveyed was set to avoid bright stars, and two fields of view of HSC were set within the range where the New Horizons spacecraft can do a flyby. Using a half night, one field of view of the HSC was continuously imaged with 90-second integrations. The next day, the other field of view is imaged in the same manner. With about a month interval, and the same observation was repeated to extend the observation arc. In this way, the accuracy of orbit determination of the detected TNO sources will increase.
Unfortunately, the series of observations did not find any objects that could be flybyable by the time the New Horizons spacecraft passed through the Kuiper Cliffs, the outer edge of the Kuiper Belt (estimated to be at a heliocentric distance of around 50 au). Nevertheless, we were able to detect many TNOs, and this data set will allow us to study the orbital distribution of Kuiper Belt objects in detail.

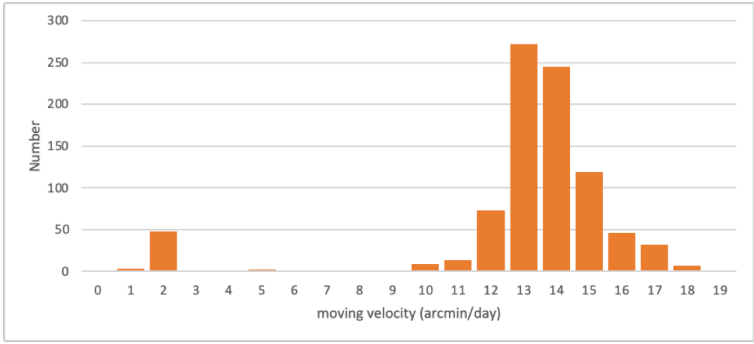
Our research group attempted to detect fainter objects using the data set obtained above. As a base, we used the FPGA-based image superposition + moving object search system, which is already in practical use for the detection of small near-Earth asteroids. From the data set of each field of view of the HSC, 32 images taken in equal time interval were selected and applied to the analysis system to search for moving objects. With 32 superimposed images, which is equivalent to 2880 minutes of integration time (90 seconds x 32 images).
The total number of moving objects detected in this way is 4497. Based on the moving speed, it is estimated that main belt asteroids, Jupiter Trojan group asteroids, Centaurs, TNOs, etc. have been detected. Although the detection limit is still under investigation, some objects around 28 mag have been detected, and since the detection limit for a single HSC 90 second integration image is typically 24-25

mag, this system clearly detects fainter objects.
We will now proceed to determine the orbits of the detected objects. Currently, the number of superimpositions is limited to 32 due to limitations imposed by the FPGA-based system; modifications are currently being developed to expand the 32 superimpositions to 64, which will allow for a slightly deeper search.

Keywords: Trans-Neptunian objects, Subaru telescope, New Horizons, Survey observation, Moving object search



Apparent magnitude distribution of detected moving objects. The detection limit is around 27.5 magnitude (r-band).



Velocity distribution (arcmin/day) of moving objects detected during the observation in June 2020, when the position of the observation field was closest to the opposition. The group of objects with a peak at 13 arcmin/day are probably main belt asteroids; the group with a peak at 2 arcmin/day are TNO candidates. Fifty-two TNO candidates were found during this observation.

