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Science highlights from the Pan-STARRS search for Near-Earth Objects

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Abstract

Pan-STARRS has become one of the leading surveys of the solar system. It is one of the leading discoverers of Near-Earth Objects (NEOs), discovers approximately half of all new comets, discovered a new class of low-activity comets – the "Manx" comets, and in October 2017, discovered the first interstellar object, `Oumuamua. A selection of science highlights from Pan-STARRS will be discussed.

1. Introduction

Pan-STARRS comprises two 1.8-meter diameter telescopes located at an altitude of approximately 3,000 meters, on Haleakala, on the island of Maui in Hawaii. Each telescope has a very large CCD camera with approximately 1.4 billion pixels, and a field of view of approximately 7 square degrees. The first telescope, Pan-STARRS1, started operating in 2010, and the second telescope, Pan-STARRS2, started surveying the sky for NEOs in a limited manner in 2018. The Pan-STARRS2 telescope is expected to be fully commissioned during 2019.

Pan-STARRS1 conducted a multipurpose survey of the sky north of –30º declination in the period 2010–2014. Since early 2014, much of the observing time with Pan-STARRS1 has been dedicated to a search for Near-Earth Objects, and the area surveyed has been extended to –50º declination. Pan-STARRS has become one of the leading NEO discovery telescopes, and discovers more than half of the larger (> 140 meter diameter) NEOs.

Pan-STARRS1 has submitted approximately 39 million asteroid detections to the Minor Planet Center. These comprise 26.8 million observations of numbered asteroids, 4.4 million observations of unnumbered asteroids, and 7.8 million observations in the Isolated Tracklet File.

2. Completing the inventory of brighter asteroids

During the search for NEOs, many other asteroids are detected, including some whose motion mimics that of NEOs. Hungarias commonly have motions typical of NEOs, but do not come close to Earth, and do not pose any threat.

Substantial resources are invested into following up observations of Hungarias. Many observations of Hungarias have been obtained, but for many, only preliminary orbits have been calculated, and repeated observations have not been linked.

A large number of observations of isolated tracklets together with observations that form short-arc preliminary designations have been linked. Work to date has linked more than 140,000 separate objects, and this sample includes many Hungarias. Many of these orbits are now good enough for the asteroids to be numbered.

It is highly desirable to reach the point that we have a good inventory of all known asteroids (including good orbits), down to an observed magnitude limit of at least as faint as V=21. Once we have that, any new brighter object will warrant further attention, and NEO confirmation resources will be better directed towards objects of interest.

3. Precision astrometry

Pan-STARRS images have pixel sizes of approximately 0.25 arc seconds. Using the new GAIA astrometric catalog, Pan-STARRS is able to report astrometry of asteroids that is often accurate to 0.05 arc seconds or better.

Precision astrometry of Near-Earth Object candidates provides clues to the size of the object and its distance from Earth. Many Pan-STARRS NEO candidates exhibit curvature in their motion. This apparent acceleration in sky-plane motion arises due to proximity to Earth, and the motion of the observer during the sequence of observations.

In typical seeing conditions, Pan-STARRS can usually deliver astrometry of better than 0.05 arc seconds for NEO candidates with motions of less than 1 degree per day (i.e., only modestly trailed in a 45-second exposure). This allows better predictions of future location for recovery telescopes to acquire additional astrometry leading to preliminary orbit determination.

4. Interstellar Objects

Pan-STARRS1 discovered the first interstellar object — `Oumuamua — in October 2017. This object was moving at a rate of 6.2 degrees/day, when discovered; Pan-STARRS is relatively inefficient at discovering rapidly moving objects due to the cell structure of its CCD detectors. Interstellar objects had been expected to have a cometary appearance, but `Oumuamua appeared to be point-like in ground-based images and in images from the Hubble Space Telescope

`Oumuamua had a light curve indicative of a highly elongated or flattened shape, and it appeared to be tumbling. It accelerated slightly as it left the solar system. This behavior can be most easily explained as low-level cometary activity.

Over the 9+ years that Pan-STARRS1 has operated, many NEO candidates have been reported that were never recovered. It is possible that some of these were Interstellar Objects. With Pan-STARRS2 coming into full operation, and with the recent upgrade to the Catalina Sky Survey's 1.5-meter telescope camera, it is less likely that Interstellar Objects will be able to pass close to Earth without discovery. It is therefore likely that more of these objects will be discovered soon, enabling some of the puzzles of their nature and origin to be explored.

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