4th IAA Planetary Defense Conference – PDC 2015
13-17 April 2015, Frascati, Roma, Italy

IAA-PDC-15-02-01
THE PAN-STARRS SEARCH FOR NEAR EARTH OBJECTS

Richard Wainscoat[(1)], Eva Lilly[(1)], Rob Weryk[(1)], Ken Chambers[(1)], Larry Denneau[(1)], Serge Chastel[(1)], Marco Micheli[(2)]

[(1)]*University of Hawaii, Institute for Astronomy, 2680 Woodlawn Drive, Honolulu, HI 96822, USA, +1-808-956-8429,*

[(2)]*ESA NEO Coordination Centre, Frascati (RM), Italy; SpaceDyS s.r.l., Cascina (PI), Italy, INAF-IAPS, Roma (RM), Italy,*

Keywords: *NEO discovery, ground-based search*

Extended Abstract—

The two Pan-STARRS telescopes, located on Haleakala, Maui, Hawaii, are 1.8-meter diameter telescopes equipped with 1.4 Gigapixel cameras that deliver 7 square degree fields of view. The first of these telescopes, Pan-STARRS1 (PS1), has been conducting a dedicated survey for Near-Earth Objects (NEOs). The second telescope, Pan-STARRS2 (PS2) is being commissioned.

PS1 has become the leading telescope in terms of NEO discovery. In 2014, PS1 discovered 621 Near Earth Asteroids (NEAs), of which 51 were Potentially Hazardous Asteroids (PHAs), and 7 had diameters greater than 1 km. In the first 3 months of 2015, PS1 discovered 233 NEAs, of which 23 were PHAs, and 4 had diameters greater than 1 km. Good weather in January 2015 resulted in discovery of a total of 108 NEAs.

The initial survey conducted by Pan-STARRS extended south to –30° declination. In 2014, experiments were performed to test image quality further south. From Hawaii, –50° declination has the same elevation as +90°. A southern limit for the Pan-STARRS NEO survey of –47.5° was chosen to ensure areas were available for an adequate amount of time to be surveyed. Image quality in the deep southern sky viewed from Haleakala is very good. The deep southern sky has been productive for PS1 in terms of NEO discovery, partly because NEO survey assets are dominantly in the northern hemisphere. Pan-STARRS also surveys the extreme northern sky, extending to the north celestial pole.

In 2014, PS1 cooperated with the G96 telescope of the Catalina Sky Survey in terms of field selection. Between declinations of –30 and +30 degrees, the telescopes alternated 1 hour-wide Right Ascension stripes each night. This strategy led to increased productivity, and eliminated accidental repeats of fields. In 2015, this cooperation was suspended. The principal reason for suspending the cooperation was a desire for Pan-STARRS to repeat fields that it had already surveyed to secure follow up of the large numbers of NEO candidates. The Right Ascension stripes produced difficult restrictions for this follow up, and fast moving objects leaked out of the stripes. In addition, the Pan-STARRS telescopes have altitude-azimuth mounts. The striping that was being performed introduced complex scheduling restrictions, particularly for fields that cross the zenith keyhole – a circular region of the sky near the zenith where the telescope cannot point. Because of its wide field of view, Pan-STARRS also has a large moon avoidance zone, which further complicates scheduling.

The distribution of H magnitudes of NEAs discovered by Pan-STARRS is quite different to the distribution for discoveries from the G96 telescope of the Catalina Sky Survey (which has a comparable aperture). In 2014, 45% of the PS1 NEA discoveries had H<22, compared to 23% for G96. PS1 is deficient in discoveries of smaller NEAs. There are two reasons for this. The most important reason is that the CCDs in the focal planes of both Pan-STARRS telescopes were designed for orthogonal transfer of charge. The intent was to move charge around the CCD to compensate for telescope shake and slow atmospheric motion. (Cosmetic issues have prevented implementation of this feature.) Each focal place consists of 60 CCDs, each with an 8x8 grid of cells with 600x600 pixels. As a result, each CCD has a checkerboard structure of active cells, with a grid surrounding each active cell. Smaller NEAs are faster moving, and as a result, are more likely to cross out of an active cell into the insensitive area around it. As a result, the efficiency for discovering smaller, faster

moving NEAs decreases. Our automated algorithms require at least 3 detections out of 4, and linear motion (with some curvature allowed). Faster moving NEAs may have only one or two clean detections, and therefore are missed. Additionally, faster moving NEAs are more difficult for recovery telescopes, because they are closer and positional errors are larger.

It is clear that a substantial number of smaller NEAs are being missed by PS1. The best way to correct this would be to refurbish the focal plane with large cosmetically clean CCDs that have many contiguous pixels. This would require sixteen 9000x9000 CCDs, and is expensive.

Archival data from Pan-STARRS likely contain a substantial number of unreported NEA detections that fail the automated detection criteria, either because of faintness, or because the detections cross cell boundaries into insensitive areas, or cross into cosmetically poor regions of the focal plane. As time permits, we search the archival data for detections of important NEAs.

The Pan-STARRS telescopes are very efficient at detecting cometary activity. PS1 discovered over half of the new comets in 2014, and discovered 10 comets in 10 nights in November 2014. Among the comet discoveries are several main-belt comets and a likely rotational breakup of an asteroid.

Recent improvements in image quality with PS1 have enabled fainter NEAs to be discovered. In good seeing conditions, PS1 can now reach to V=22.5. The fainter NEA candidates are more challenging for recovery telescopes, and require a telescope with substantial aperture.

PS1 continues to discover NEOs with diameter > 1 km, and discovered 4 of these objects in the first quarter of 2015. Some of these objects have high inclinations. The most recent discovery, 2015 ER61, is very large with H=12, and may be a comet that is not yet active, or a dead comet. If the present discovery rate of large objects is sustained, it will test our understanding of how many large NEOs remain undiscovered.

The present discovery rate of NEO candidates by PS1 is now overwhelming the external NEO follow-up resources, particularly for fainter NEOs. It has required that PS1 repeat fields to recover NEO candidates. Each month, a substantial number of PS1 NEO candidates are not followed up.

Pan-STARRS2 is presently being commissioned. Only the central part of its focal plane has good CCDs. However, the CCDs in GPC2 – the camera for PS2 – are significantly better than the CCDs in PS1. Correlated read noise and persistence problems that the CCDs in PS1 suffer from have been eliminated. And the good CCDs are cosmetically better. Delivery of the remaining CCDs required to complete the focal plans is expected in the next 2 months, and the complete focal plane is expected to be ready by summer 2015. The improvements in noise characteristics will permit deeper NEO searches. Current commissioning tasks are principally related to collimation and alignment.

We expect to transition to an increased amount of survey observing on PS2 in the coming months. We will initially target recovery of PS1 NEO candidates. This effort should improve the PS1 discovery rate, and should also lead to serendipitous discoveries.

As PS2 matures, and when G96 has its new camera, the combination of these three telescopes will facilitate a higher NEO discovery rate, and a better census of the NEOs in the sky. This will in turn lead to a better understanding of the size and orbit distribution of NEOs, and the corresponding hazard to Earth. The Pan-STARRS NEO survey is also likely to discover asteroids suitable for the NASA asteroid redirect mission.