Small-Telescope Astronomy on Global Scales
ASP Conference Series, Vol. 246, 2001
W.P. Chen, C. Lemme, B. Paczyński

NEOPAT: Near-Earth Object PATrol program

Hong-Kyu Moon[1], Moo-Young Chun[1], Yong-Ik Byun[2], Wonyong Han[1], Seung-Lee Kim[1], Young-Beom Jeon[1], Yong-Woo Kang[2]

[1] *Korea Astronomy Observatory, Taejon, 305-348, Korea*
[2] *Dept. of Astronomy, Yonsei University, Seoul, 120-749, Korea*

Abstract. In 2000, Korea Astronomy Observatory launched the Near-Earth Object Patrol (NEOPAT) program. NEOPAT has conducted follow-up observations of NEOCP (NEO Confirmation Page) objects and discovered 52 new main-belt asteroids during the observation runs. We initiated collaboration with the Yonsei Survey Telescopes for Astronomical Research (YSTAR) team for NEO search. Wide-field of view, fast read-out time, and fully autonomous data pipeline will enable us to detect and track NEOs with a high efficiency. Scheduled to begin active operations in mid-2001, our survey system is going to be the first network of robotic telescopes for NEO search with automatic access to both hemispheres.

1. Introduction

Among the enormous numbers of bodies orbiting the sun, only a tiny fraction of them follow paths which bring them to the near-Earth space. About 90 percent of the Near-Earth Objects (NEOs) are near-Earth asteroids (NEAs) or short-period comets, and the other 10 percent are long-period comets. The objective of an NEO survey is to detect these objects during their periodic approaches to the Earth, to calculate their long-term orbits, and to verify the potential threat over the next few centuries. According to Chamberlin (2001), the statistics of NEAs discovered by predominant search programs in 2000 is as follows; LINEAR: 160, NEAT: 14, Spacewatch: 27, LONEOS: 38, Catalina: 13, others: 12. The total number of NEA is a steeply increasing function of time where the cumulative total in 2000 was 1244, while it was only 350 in 1995.

Being aware of past impacts and their destructive power, the general public as well as the astronomical community began to take anxious interest. The collision of the comet Shoemaker-Levy 9 with Jupiter, and such Hollywood films as "Armageddon" and "Deep Impact" added to the concern. Moreover, the first orbital calculations of two NEAs, 1997 XF11 and 1999 AN10 indicated that they could impact Earth in the next 50 years. However, further study has dismissed this probability. Recently, 2000 SG344 was covered on the evening news in Korea, with an animation which depicted the extinction of the dinosaurs in an exaggerated manner. The issue of an asteroid impact has widely attracted public interest, and encouraged the National Assembly and the Korean government to support astronomers to conduct NEO search. In 2000, Korea Astronomy Observatory launched the Near-Earth Object Patrol (NEOPAT) program designated

as National Research Lab by Ministry of Science and Technology. NEOPAT is now teamed up with YSTAR (Byun et al. 2001) for collaboration in NEO research. On the other hand, NEOPAT is conducting follow-up astrometry of newly discovered NEOs with existing facilities.

2. Follow-up Observations

Since early 2000, NEOPAT has been reporting on the results of follow-up observations of NEOCP (http://cfa-www.havard.edu/iau/ NEO/ToConfirm.html) objects to Minor Planet Center. The observations are carried out with the Sobaeksan Optical Astronomy Observatory (SOAO) 61cm telescope and the Bohyunsan Optical Astronomy Observatory (BOAO) 1.8m reflector with CCDs. The NEOCP gives access to ephemerides for newly-discovered moving objects in need of confirmation. SOAO allocates 4-5 days every month for NEO follow-up observation. With a PM512 CCD camera mounted on the 61cm reflector, we monitor the orbit of updated NEO candidates with $17 \leq m_R \leq 19$. The observations are made more than three times over an arc of several hours during the course of at least one night, with a typical exposure time of 200-300 sec. Although we have yet applied for BOAO 1.8m telescope time, follow-up astrometry is being performed at BOAO before astronomical twilight, or in bad seeing conditions in the middle of the regular observation run. Employing the 1.8m telescope, follow-up observations are made for 18-20 mag NEO candidates in V or R band with 30~300 sec exposures in binning mode.

In each image, one can determine accurate position and magnitude of a suspected NEO with ASTROMETRICA using field stars with known coordinates. The coordinates of the comparison stars are taken from the HST Guide Star Catalogue or USNO 2.0. In Table 1, we list the results of follow-up observations performed at SOAO and BOAO from January to December, 2000. The total number of observations reported to MPEC is 1060 during the season.

Table 1. Observation summary of NEOCP objects

	SOAO (345)			BOAO (344)			
Month (2000)	No. of data	No. of objects	MPEC	No. of data	No. of objects	MPEC	Reference
2	0	0	0	42	6	1	MPC38264
3	35	9	4	73	13	4	MPC38972
4	25	5	3	0	0	0	MPC39716
5	33	5	4	16	5	4	MPC40595
6	0	0	0	66	6	4	MPC40751
9	13	3	2	23	8	0	MPC41267
10	0	0	0	21	6	6	MPC41456
11	8	2	2	482	44	1	MPC41642
12	0	0	0	337	60	2	MPC41805

https://doi.org/10.1017/S0252921100078969 Published online by Cambridge University Press

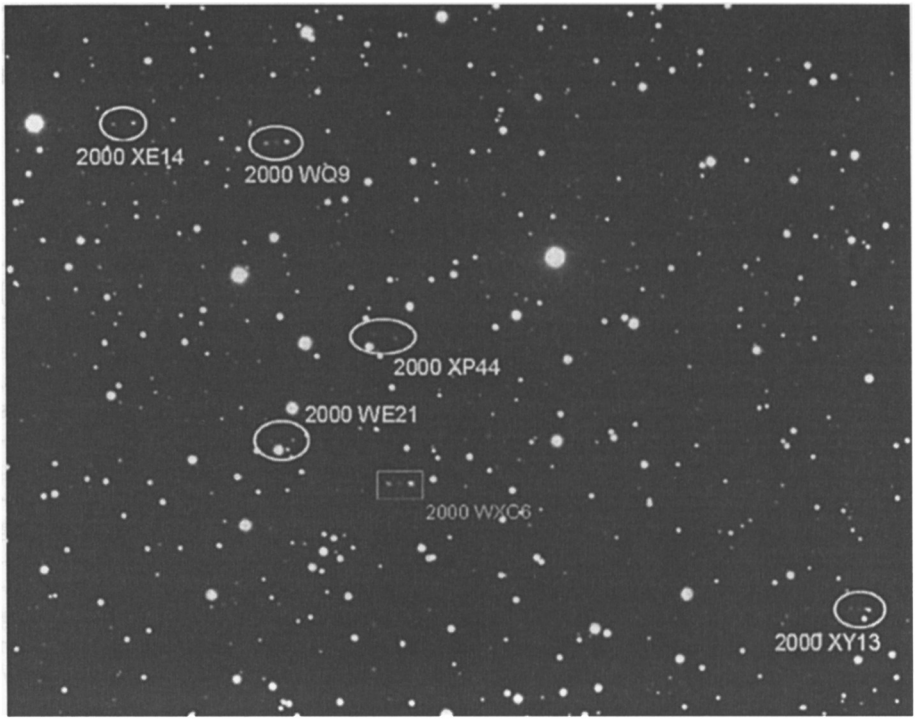

Figure 1. A CCD image obtained at BOAO on Dec. 7, 2000. Five new asteroids and one previously known asteroid are displayed in the same field. This is a color-coded image made from three consecutive V band CCD frames in which the asteroids were moving relative to the background stars.

3. Discovery of New Asteroids

Since May 2000, we have discovered 52 new asteroids during the follow-up observation of NEOCP objects, and also from color-coded images of the Crab nebula (M1) taken for public release. The first asteroid, 2000 KJ4 was found on May 28, 2000, and turned out to be a new main-belt asteroid with an absolute magnitude of (H)$\sim$15.6, after confirmation observations on consecutive nights. The name, date of designations, and observers of these serendipitous discoveries are summarized in Table 2.

Figure 1 shows a discovery image of Dec 7, 2000 taken from the BOAO 1.8-m reflector equipped with a SITe 2K CCD camera. It reveals five newly discovered asteroids, 2000 XE14, 2000 WQ9, 2000 XP44, 2000WE21, and 2000 XY13 marked with an ellipse, together with a known asteroid at the location shown by a box in the same field. This is a color-coded photograph made from three consecutive V band CCD frames where the asteroids were moving relative to the background stars, so they look slightly trailed with different colors. We conducted confirmation observations of the neighboring fields, and within

https://doi.org/10.1017/S0252921100078969 Published online by Cambridge University Press

Table 2. New main-belt asteriods discovered at BOAO

Designation				
2000 KJ4	2000 WQ9	2000 WE21	2000 WD21	2000 WR21
2000 WV28	2000 WV50	2000 WU50	2000 XY13	2000 XZ13
2000 XA14	2000 XB14	2000 XC14	2000 XD14	2000 XE14
2000 XJ15	2000 XK15	2000 XL15	2000 XM15	2000 XA44
2000 XB44	2000 XC44	2000 XD44	2000 WZ26	2000 XJ2
2000 XK2	2000 XO44	2000 XP44	2000 XQ44	2000 XR44
2000 XL53	2000 XM53	2000 XN53	2000 XO53	2000 XP53
2000 XQ53	2000 XT53	2000 YE04	2000 YB16	2000 YC16
2000 YD16	2000 YS30	2000 YDA1	2001 AN19	2001 AO19
2001 AP19	2001 AQ19	2001 AR19	2001 AS19	2001 BB03
2001 BC03	2001 BZ10			

a month, found forty new moving objects. The newly discovered objects are also known to be main-belt asteroids with semi-major axes, $2.2 \leq a \leq 3.4$AU, and ellipticities of the orbits ranging from 0.0 to 0.25. The reasons we discovered dozens of new objects in a relatively short period of time are that: (1) December is the most favorable season for astronomical observation in Korea, and period when the ecliptic rises high above the horizon, (2) We can reach as faint as 20th magnitude, provided that we make use of the 1.8-m telescope with a suitable exposure time. For the time being, there is no dedicated 2m class telescope in regular service for asteroid search.

4. NEOPAT-YSTAR Collaboration

A robotic telescope is suitable for repetitive and routine work such as discovery and tracking of NEOs with maximum efficiency. Undoubtedly, a survey project can be successfully accomplished with a global network of telescopes of this kind. NEOPAT team is developing such system in collaboration with YSTAR.

We employ wide field optics and a fast, fully automated computing pipeline. The 0.5m f/2.0 primary optics identical to the one prepared for the TAOS project (King 2001), provides 3.5 square degrees FOV onto an AP10 14μm CCD chip. The telescopes are being subjected to remote observation and safety tests. Our first telescope has just begun remote autonomous observations at Yonsei University Observatory, and after its launch in mid 2001, we plan to install the second telescope in Sutherland, at the South African Astronomical Observatory (SAAO). Before the SAAO installation, the NEOPAT-YSTAR team will complete the fine-tuning and development of the 3TB data storage system, the data pipeline, the observation planner/scheduler, and the off-site image archiving system. We intend to archive the data at the Korea Astronomy Observatory and to build a common database for ease of future analysis.

In a couple of years, we will expand the number of survey telescopes and place them home and abroad to increase the detection and tracking efficiency by multiplying the coverage. As such a network of survey telescopes is expected

to provide a huge search volume, a large number of new NEOs are expected to be found far from the ecliptic plane. Moreover, orbits of long-period comets are so elongated and inclined to the ecliptic plane that the warning time for objects of this kind would be as short as a year compared to decades or centuries for asteroids. In spite of their small apertures, our survey telescopes offer more frequent coverage of the entire sky for effective search of long-period comets.

5. Conclusions

The NEOPAT program has carried out confirmation observation of NEOCP objects and discovered 52 new asteroids, among them forty were found within a month. In 2000, the joint program between NEOPAT and YSTAR was launched. We have just started routine autonomous observation with our first telescope and the second one is scheduled to be installed at SAAO in summer 2001. In the coming years, a network of survey telescopes will be constructed around the globe for more efficient monitoring of NEOs.

References

Byun, Y.-I. et al. 2001, in these proceedings
Chamberlin, A. 2001, http://neo.jpl.nasa.gov/missions/stats.html
King, S. K. 2001, in these proceedings