SPACEWATCH® Near-Earth Astrometric Follow-up and Lightcurves

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The Brinson Foundation

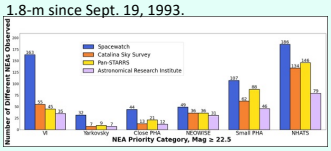
SPACEWATCH® was founded at the University of Arizona's Lunar and Planetary Laboratory (LPL) by Prof. Tom Gehrels and Dr. Robert S. McMillan in 1980. The original mission was to explore populations of minor planets in the solar system with the Steward Observatory 0.9-m telescope on Kitt Peak. This discovery survey included studies of Main Belt asteroids, Trojan asteroids, Centaurs, Trans-Neptunian objects, comets, and near-Earth asteroids (NEAs).

Today, Spacewatch is led by Dr. Melissa Brucker with the mission to perform follow-up astrometry of near-Earth objects (NEOs) of planetary defense and/or scientific interest, especially virtual impactors (VIs) and Potential Hazardous Asteroids (PHAs).

- We lead in follow-up astrometry of PHAs while they are faint (V ≥ 22.5)
- More than 80% of our NEO observations are unique for that date
- More than 25% of Minor Planet Electronic Circulars in which our observations appear contain one of our tracklets as the final tracklet before designation.

Targets:

Our NEA astrometric target selection from highest priority to lowest: Virtual Impactors (VIs), NEO Confirmation Page objects, candidates for detection of the Yarkovsky Effect, PHAs that will be within 0.03 AU of Earth within the next 40 years, NEAs listed on NEODyS's Priority and Faint Priority lists, potential targets of planetary radar, NEAs observed by the NEOWISE mission, small NEAs that will be within 0.03 AU of Earth within the next 40 years, and objects listed on the JPL Near-Earth Object Human Space Flight Accessible Targets Study (NHATS) webpage, then plain NEAs. We also prioritize observing faint targets over bright. According to the PDS Small Bodies Node, Spacewatch is sixth in discovery MPECs and seventh in Precovery MPECs with the 0.9-m and fifth in contributing to MPECs with the 1.8-m since Sept. 19, 1993.



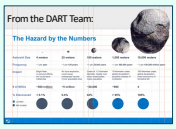
Number of faint NEAs observed (magnitudes ≥ 22.5) in Spacewatch priority categories by a few NASA-funded NEA surveys and follow-up groups from Nov. 16, 2019 through Feb. 15, 2023. Figure: C. Lejoly

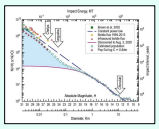
VIs	631
Yarkovsky	121
Close PHAs	122
NEODyS	3111
Radar	132
NEOWISE	363
Close Small	566
NHATS	920

Unnumbered NEOs observed by Spacewatch 3/1/21 – 4/19/24 (NEAs can be in >1 category)

VIs are our highest priority targets; therefore we have a program specifically to recover faint VIs with larger telescopes. We apply for time on Keck I, Gemini North, Gemini South, the MMT, and the Blanco 4-m telescope. We measure VI astrometry to reduce the uncertainty in knowledge of the VIs' heliocentric orbital elements during their discovery apparitions (and beyond) to rule in or out possible impact(s).

Why worry about potential impactors? Check out this graphic from the DART Team and Harris & Chodas' figure from the 2023 Decadal survey.





We observed the VI 2022 LX with LRIS on Keck I as an example result from the 2022A observing semester. We created 3 stacks of 12 30s exposures using JPL Horizons ephemeris rate. 2022 LX is circled in yellow. The thin black squiggles and lines are cosmic rays.

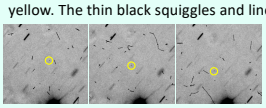


Figure: sets of images stacked at 2022 LX's rate of motion. Figure: C. Lejoly

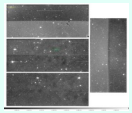
Orbital Element	Value Before	1-σ Uncert.	Value After	1-σ Uncert.	Units	% Diff. in Uncert.
e	0.59164865	1.3219E-04	0.59174542	9.2783E-05		29.81
a	2.41228112	7.7065E-04	2.41284546	5.4110E-04	au	29.79
i	0.86824794	1.2330E-04	0.86833774	8.7021E-05	deg	29.42
Ω	310.011834	2.1130E-03	310.013409	1.4534E-03	deg	31.22
ω	351.017501	1.7744E-03	351.01617	1.2108E-03	deg	31.76

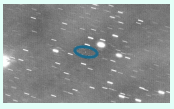
Table of 2022 LX's orbital uncertainty improvement where Ω is the longitude of the ascending node and ω is the argument of perihelion. The 'after' values are from JPL's Small-Body Database Lookup webpage in February 2023.

Please contact me at mbrucker@arizona.edu or on the DPS Slack if you are interested in a combined software and telescope operator position with Spacewatch.

Photo: Melissa Brucker

Steward Observatory 0.9-m/36": This 1921 Warner & Swasey telescope was moved from the UofA campus to Kitt Peak in 1962. Pictured L to R: The telescope on its equatorial mount in the dome and the Spacewatch mosaic camera as they are today.
Photos: Roger E. Carpenter, MD.





Left: single mosaic image from the 0.9m containing 2020 UZ3. Right: set of images stacked at 2020 UZ3's rate of motion. The blue oval highlights the target.

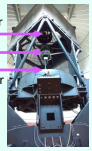
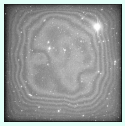
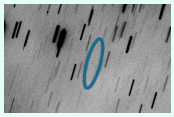


Photo: Jim Scotti Photo: Melissa Brucker

LPL 1.8-m/72": Dedicated in 1997, full-time operations began in 2002.L & R: The top arrow points to the secondary mirror, the middle arrow points to the suspended camera, and the bottom arrow points to the primary mirror's cover.





Left: single image from the 1.8-m containing 2021 CZ4. Right: set of images stacked at 2021 CZ4's rate of motion, zoomed in on target. The blue oval highlights the target.

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The astronomical community is honored to have the opportunity to conduct astronomical research on Iolkam Du'ag (Kitt Peak) in Arizona. We recognize and acknowledge the very significant cultural role and reverence that this site has to the Tohono O'odham Nation.

University of Arizona Land Acknowledgement: We respectfully acknowledge the University of Arizona is on the land and territories of Indigenous peoples. Today, Arizona is home to 22 federally recognized tribes, with Tucson being home to the O'odham and the Yaqui. Committed to diversity and inclusion, the University strives to build sustainable relationships with sovereign Native Nations and Indigenous communities through education offerings, partnerships, and community service.

Observing:

SPACEWATCH® operates the Steward Observatory 0.9-m telescope (691) and the LPL Spacewatch II 1.8-m telescope (291) at the Kitt Peak station of Steward Observatory. We use these telescopes 24 nights dark/grey time per lunation for astrometric follow-up of near-Earth asteroids (NEAs). We use 6 nights per lunation on the Steward Observatory Bok 2.3-m telescope for follow-up of fainter targets during bright time (obscode 695).

In addition, we collaborate with the Catalina Sky Survey and the University of Minnesota to use the Bok 2.3-m to survey (obscode V00) for faint NEOs during dark/grey time.

Telescope	MPC Observatory Code	Maximum TEM[a]	FOV	Image Scale (″/pixel)	Pixel Size (mm)	Pixels	f ratio	Filter[b]
0.9m	691	V ~ 22.2	1.7″x1.7°	1.00	13.5	4x4608x2048	f/3	Schott OG 515
1.8m	291	V ~ 23.0	20′ x20′	0.62	15	2048x2048	f/2.7	Schott OG 515
Bok 2.3m/SCC	″695	V ~ 24.2	5′ x5′	0.26	15	2048x2048	f/9	open/Schott OG 515

Table of telescope parameters.
[a]The TEM is the Target Ephemeris apparent Magnitude
[b]The filter was added to the SCC in mid-2019.

Output:

From March 1, 2021 to April 19, 2024, with observatory codes 691, 291, and 695, we submitted to the MPC 112,856 lines of astrometry, 20,577 of which were of NEOs. We observed 3761 different NEOs, 401 of which were PHAs. 227 of the PHA measurements were while V ≥ 22.50.

The Bok NEO Survey collaboration with observatory code V00 submitted 1,645,083 lines of astrometry, 8732 of which were of NEOs. 1683 different NEOs were observed, 204 of which were PHAs.

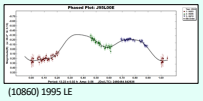
Lightcurves:

The Brinson Foundation of Chicago supports Spacewatch to observe NEAs for rotational lightcurves and period determination with the 0.9-m telescope. Our targets may be potential targets of planetary radar, VIs, candidates for detection of the Yarkovsky Effect, NEAs with characterization data, or specific requests of scientific or planetary defense interest. We refer to the Asteroid Lightcurve Database (Warner *et al*. 2009, *Icarus* **202**, 134) and the Minor Planet Bulletin as resources when choosing targets. This year our targets included (10860) 1995 LE, (275545) 1998 UN1, and (439437) 2013 NK4.

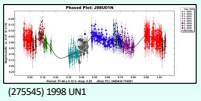
Analysis and Figures: C. Lejoly

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	Grp
10860	J95L00E	2024 06/03-06/10	38.4-40.1	292.5	2.3	13.23	0.02	0.56	Amor
275545	J98U01N	2024 05/02-05/09	23.9-26.3	237.4	17.8	37.48	0.12	0.20	Amor
439437	K13N04K	2024 04/29-05/01	20.3-22.4	206.6	-1.8	81.9	0.10	1.25	Apollo

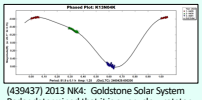
Table I. Observing circumstances and results. The phase angle is given for the first and last date. If preceded by an asterisk, the phase angle reached an extrema during the period. L_{PAB} and B_{PAB} are the approximate phase angle bisector longitude/latitude at mid-date range (see Harris et al., 1984). Grp is the asteroid family/group (Warner et al., 2009).



(10860) 1995 LE



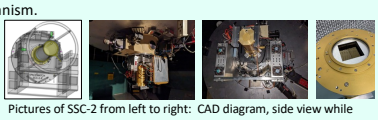
(275545) 1998 UN1



(439437) 2013 NK4: Goldstone Solar System Radar determined that it is a very slow rotator. Our observations do not span an entire rotation.

Engineering progress:

We continue to design and build a new Cassegrain camera, the SSC-2, for the Bok 2.3-m with a larger field of view than our current camera. In the past year, we had our dewar serviced, increasing the LN2 hold time. We determined a configuration that greatly reduced the read noise. We also eliminated most of the channel crosstalk and prevented the temperature sensor from adding to the CCD noise. Next, we will increase the readout speed and work on our shutter mechanism.



Pictures of SSC-2 from left to right: CAD diagram, side view while mounted to the Bok, bottom view while mounted, and the CCDs inside the dewar ring. Diagram and photos: M. Read