References

Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

Howell, S.B. (2006). Handbook of CCD Astronomy (2nd ed.). Cambridge University Press.

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2016 Sep. *http://www.minorplanet.info/lightcurvedatabase.html*

LIGHTCURVES OF NEAR-EARTH ASTEROIDS 2024 ON, 2024 MK AND 1998 ST27 AS OBSERVED FROM TRAPPIST

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We report photometric observations of three near-Earth asteroids: 2024 ON, 2024 MK, and 1998 ST27. The observations were performed between June and October 2024 during their close approaches to Earth using the TRAPPIST network. Applying lightcurve analysis, we determined that the rotation period and amplitude of 2024 ON are $P = 6.0116 \pm 0.0003$ h and $A = 0.94 \pm 0.05$ mag. For 2024 MK we found two possible rotation periods. In the first case $P1 = 0.5028 \pm 0.0001$ h with $A1 = 0.67$ mag $\pm$ 0.02, and $P2 = 0.3663 \pm 0.0001$ h with $A2 = 0.45$ mag $\pm$ 0.02. In the second case $P1 = 0.7301 \pm 0.0011$ h with $A1 = 0.503$ mag, and $P2 = 0.5031 \pm 0.0005$ h with $A2 = 0.643$ mag. For 1998 ST27 we obtain $P = 3.56 \pm 0.02$ h and $A = 0.07 \pm 0.01$ mag. All measurements have been submitted to the ALCDEF database.

The telescopes used to obtain the lightcurves of 2024 ON, 2024 MK and 1998 ST27, are the TRAPPIST twins, 0.6-m Ritchey-Chrétien telescopes operated under the COMETA team of the University of Liège (Jehin et al., 2011). TRAPPIST-North (TN; MPC code Z53) is located in Morocco - Oukaïmeden, and TRAPPIST-South (TS; MPC code I40) is located in Chile - La Silla. The TN camera is an Andor IKONL BEX2 DD (0.59 arsec/pixel) and the TS camera is a FLI ProLine 3041-BB (0.66 arcsec/pixel).

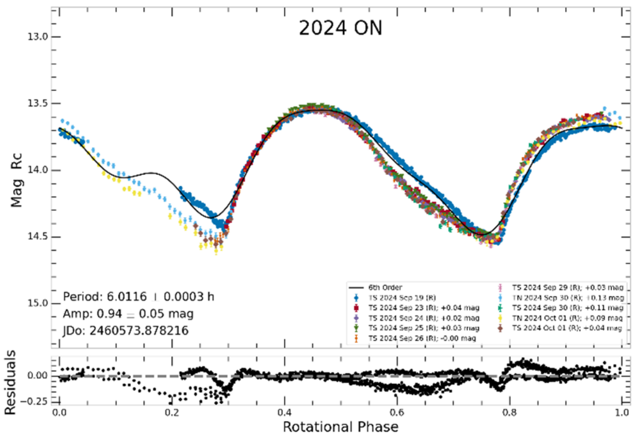
All images recorded were reduced by using standard image calibration with multiple darks, bias and flat frames taken every night onto the twilight sky. For creating calibration frames that are temperature matched, exposure and filter matched, and applying them, we used the internal pipeline of TRAPPIST, *Triton.* All the images that were affected by weather conditions or had any light source interference within 12 pixels with the asteroid due to their movement within the star fields, were excluded.

For the zero-point calibration and lightcurve construction, we used *Photometry Pipeline* (Mommert, 2017). The differential photometry and magnitude calibration was done with the PanSTARSS DR1 catalog with approximately 100 solar reference stars per image.

<u>2024 ON</u> was discovered on 2024 July 27 by the ATLAS network located in Mauna Loa, Hawaii, with a measured absolute magnitude of $H = 20.3$ (Herman et al., 2024). The asteroid has been categorized as a PHA due to its absolute magnitude that would translate to an approximate size of 350 m, and its MOID of 0.003 au (JPL, 2024a). Two months after its discovery, 2024 ON had a close approach to Earth on September 17 around 10:19 UT with a minimum distance of 0.0066 au or two and a half LD (JPL, 2024a). Observations by the Goldstone Solar System Radar on September 16 revealed that the asteroid is a contact binary (NASA/JPL-Caltech, 2024a).

During this close approach, we successfully observed the asteroid for a total of 10 nights, using both TN and TS. The asteroid was observed with TS using a Rc filter and binning 2×2 for many hours each night between September 19 and October 1. The data consists of 1355 photometric images, for a total of 26.6 hours spread during 8 nights. The exposure time was adjusted each night in order to obtain the best SNR and avoid trails on several pixels. The asteroid was too low on the horizon to be observed with TN during its closest approach but we managed to get data for two nights on September 30 and October 01, when the asteroid was fainter with $V = 17.2$, also using binning 2×2.

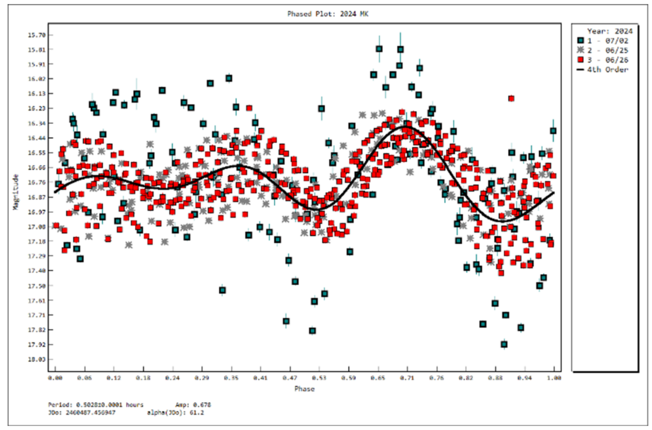
For the lightcurve measurements we used an aperture of 3.5 arcsec/pixel in all cases. The data was best fitted on the period of 6.0116 ± 0.0003 h and an amplitude of 0.94 ± 0.05 mag. We can observe that curve shape changed in time and it is not overlapping completely. At the time of writing, there is no reported value for the rotation period of this asteroid in the Lightcurve Photometry Database (LCDB; Warner et al., 2009).

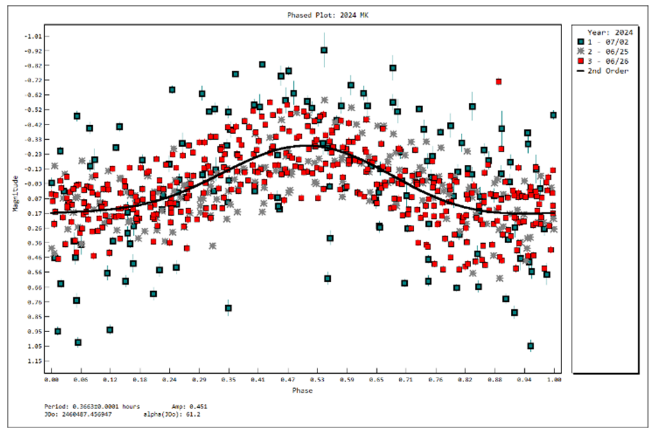


2024 MK was discovered by the ATLAS network, this time from the instrument located in Sutherland Observing Station in South Africa, on 2024 June 16. Its measured absolute magnitude is $H = 21.5$, and it was classified as a PHA as its Earth MOID = 0.0018 au (Hidas et al., 2024). Radar observations have been acquired between June 29 and July 02 (JPL, 2024b) resulting in a diameter of ~150-m (NASA/JPL-Caltech, 2024b).

We have obtained images on June 25 and 26 using TS. On both nights, the data was taken using 60 s exposure time with the Rc filter and binning 2×2. We also successfully observed the asteroid with TN using the Rc filter and binning 2×2 on July 02 with an exposure time of 60 s, and on the night of July 3 with an exposure time of 120 s. Due to the long exposure, the asteroid appears as a small trail on the images. For the photometry analysis from TS, we used an aperture of 3.5 arcsec/pixel. For TN, we measured the images using the *Tycho Tracker* version 11.7.2 software (Parrott, 2024), to be able to use an ellipse aperture. The trail measures an average length of 9 pixels (10.6 arcsec) and we used an aperture radius height and width of 3 and 5 pixels respectively.

Combining the data sets from both telescopes, the period search revealed two distinct periods, suggesting a possible tumbling behaviour. We address two possible cases of rotational periods that have similar RMSE. First case, $P1 = 0.5028 \pm 0.0001$ h with $A1 = 0.678$ mag, and $P2 = 0.3663 \pm 0.0001$ h with $A2 = 0.451$ mag where RMSE = 23.322. In the second case $P1 = 0.7301 \pm 0.0011$ h with $A1 = 0.503$ mag, and $P2 = 0.5031 \pm 0.0005$ h with $A2 = 0.643$ mag where RMSE = 23.319.





1998 ST27 was discovered on September 24 by the LINEAR (Lincoln Near-Earth Asteroid Search) program. It is classified as a PHA, with an absolute magnitude $H = 19.5$ and a rotational period in the realm of ~ 3 hours (JPL, 2024a). The last close approach was on October 12 at a minimum distance of 0.023 au or approximate 9 LD (JPL, 2024a).

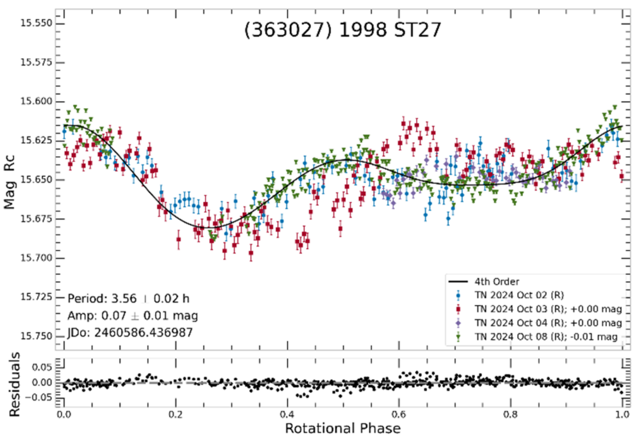
Sets of radar images have been taken for this asteroid since 2001 at Arecibo when it was discovered that it is a binary system (Benner, et al., 2001). Recent radar observations with the Goldstone Solar System Radar taken on October 11 revealed that it is actually a triple system (NASA/JPL-Caltech, 2024c).

Before its closest approach to Earth, we observed the asteroid with TN for four nights, between October 2 and 8, for a total of 1225 images resulting to ~18 hours of observations. The binning used was 2×2 and the aperture for photometry measurements was 3.5 arcsec/pixel. On October 4 and 8, we also observed the asteroid with the Rc, Ic, B, V filters, for color measurements. We produced three color indices, $B\text{-}V = 0.71 \pm 0.01$, $V\text{-}R = 0.36 \pm 0.01$ and $V\text{-}I = 0.67 \pm 0.01$. These values are consistent with a C-type asteroid (Dandy et al., 2023), that matches its low albedo value of 0.059 (*https://ssd.jpl.nasa.gov/)*.

Number	Name	yyyy mm/dd	Phase	L_{PAB}	B_{PAB}	Period(h)	P.E.	Amp	A.E.	Grp
	2024 ON	2024 09/19-10/01	*74.8, 73.8	35	-27	6.0116	0.0003	0.94	0.05	NEA
	2024 MK	2024 06/25-07/03	61.1,101.3	324	28	0.5028	0.0001	0.67	0.02	NEA
							0.3663	0.00010.45	0.02	NEA
	2024 MK	2024 06/25-07/03	61.1,101.3	324	28	0.7301	0.0011	0.53	0.02	NEA
							0.5031	0.00050.64	0.02	NEA
363027	1998 ST27	2024 10/02-08	34.5, 18.1	23	14	3.56	0.020.07	0.01NEA		

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).

Based on lightcurve analysis, the rotational period found is 3.56 ± 0.02 h with a maximum amplitude A = 0.07 ± 0.01 mag.



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References

Benner, L.A.M.; Nolan, M.C.; Ostro, S.J.; Giorgini, J.D.; Margot, J.L. (2001). "1998 ST_27" IAU Circ., No. 7730, #2 (2001). Edited by Green, D.W.E. *http://www.cbat.eps.harvard.edu/iauc/07700/07730.html#Item2*

Dandy, C.L.; Fitzsimmons, A.; Collander-Brown, S.J. (2003). "Optical colors of 56 near-Earth objects: trends with size and orbit". *Icarus* **163**, 363-373.

Harris, A.W.; Young, J.W.; Scaltriti, F.; Zappala, V. (1984). "Lightcurves and phase relations of the asteroids 82 Alkmene and 444 Gyptis." *Icarus* **57**, 251-258.

Herman, J.; Lowe, T.; Minguez, P.; Schultz, A.; Smith, I.; Chambers, K.; Boer, T.; Fairlamb, J.; Gao, H.; Huber, M.; Lin, C.-C.; Magnier, E.; Ramanjooloo, Y.; Wainscoat, R.; Weryk, R.; Rest, A.; Frieman, J.; Micheli, M.; Cano, J.L.; Rudawska, R. (2024). "2024 ON" MPEC 2024-S21. *https://www.minorplanetcenter.net/mpec/K24/K24S21.html*

Hidas, A.; Herman, J.; Lowe, T.; Minguez, P.; Schultz, A.; Smith, I.; Chambers, K.; de Boer, T.; Fairlamb, J.; Gao, H.; Huber, M.; Lin, C.-C.; Magnier, E.; Ramanjooloo, Y.; Wainscoat, R.; Weryk, R.; Denneau, L.; Siverd, R.; Tonry, J.; Weiland, H.; Erasmus, N.; Fitzsimmons, A.; Robinson, J.; Jacques, C.; Caetano, A.; Pimentel, E. (2024). "2024 MK" MPEC 2024-M31. *https://www.minorplanetcenter.net/mpec/K24/K24M31.html*

Jehin, E.; Gillon, M.; Queloz, D.; Magain, P.; Manfroid, J.; Chantry V.; Lendl, M.; Hutsemékers, D.; Udry, S. (2011). "TRAPPIST: TRAnsiting Planets and PlanetesImals Small Telescope." *The Messenger* **145**, 2-6.

JPL (2024a). Small-Body Database Lookup. *https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html*

JPL (2024b). Small-Body Radar Astrometry. *https://ssd.jpl.nasa.gov/sb/radar.html*

Mommert, M. (2017). "PHOTOMETRYPIPELINE: An Automated Pipeline for Calibrated Photometry." *Astronomy and Computing* **18**, 47-53.

NASA/JPL-Caltech (2024a). "NASA's Planetary Radar Spies (Another) Peanut-Shaped Asteroid". *https://www.jpl.nasa.gov/images/pia26451-nasas-planetary-radar-spies-another-peanut-shaped-asteroid/*

NASA/JPL-Caltech (2024b). "Detailed Planetary Radar Observations of Asteroid 2024 MK". *https://www.jpl.nasa.gov/images/pia26383-detailed-planetary-radar-observations-of-asteroid-2024-mk/*

NASA/JPL-Caltech (2024c). "Goldstone Radar Observations Planning: 1998 ST27, 2006 UY64, 2020 WG, and 1998 TU3". *https://echo.jpl.nasa.gov/asteroids/oct2024.goldstone.planning.html*

Parrot, D. (2024). Tycho software. *https://www.tycho-tracker.com*

Warner, B.D.; Harris, A.W.; Pravec, P. (2009). "The Asteroid Lightcurve Database." *Icarus* **202**, 134-146. Updated 2023 Oct. *https://www.minorplanet.info/php/lcdb.php*