# Lightcurve observations of near-Earth asteroids with the Unistellar's network of citizen astronomers

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## Abstract

The recently developed Unistellar's eVscope and eQuinox telescopes have been delivered to more than 5,000 customers around the globe. These telescope owners already represent the largest network of potential citizen astronomers. Due to the unified design and user-friendly operation via a smartphone app, several types of useful scientific observations are enabled and supported by Unistellar. In this work, we are interested in lightcurve observations of asteroids to study their physical properties - rotation periods, rotation axis, and 3D shape model. In 2021, we initiated several observing campaigns aiming at obtaining lightcurve data of several near-Earth asteroids (NEA) that were having close approaches to the Earth. Dozens of citizen astronomers provided their observations. Here we show the initial results obtained by analyzing these optical data. Clearly, the Unistellar's network of citizen astronomers has a great potential for the study of the physical properties of asteroids.

Fig. 1: Dumbell nebula as seen by an eVscope.

## Unistellar network of citizen astronomers

In 2017, Unistellar company raised through the Kickstarter platform more than $2.2 million to develop a compact telescope that amplifies light so users can see hundreds of nebulae and galaxies directly through its electronics eyepiece.

The eVscope is a 4.5" (11.4 cm) Newtonian-like (focal = 450 mm, magnification of 50) telescope designed specifically to work in urban and countryside environments. This compact (9 kg) connected device is equipped with a sensor, an onboard computer, and a projecting system. The eVscope is smart, autonomous, and able to deliver a color image of a celestial object in just a few seconds.

By December 2021, more than 5,000 customers around the globe already received their eVscopes. These telescope owners represent the largest network of citizen astronomers. Several science modes are supported, including photometry of asteroids and stellar occultations by asteroids.

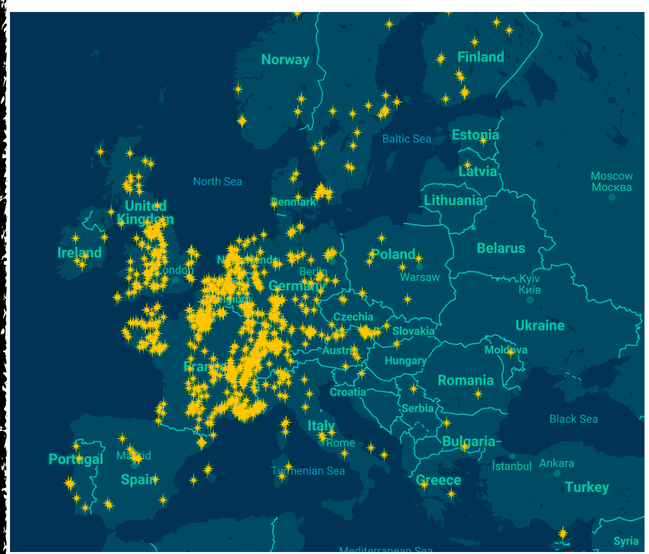


Fig. 2: Unistellar's network of citizen astronomers in Europe.

## Physical properties of NEAs based on the Unistellar's campaign

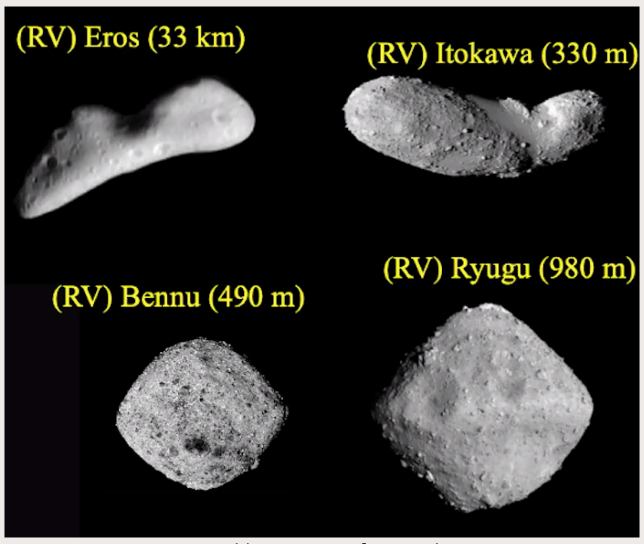


Fig. 3: NEAs visited by spacecrafts. Credit NASA,JAXA.

### Importance of NEAs

- Objects crossing the orbits of terrestrial planets (perihelion <1.3 AU), some has close approaches with the Earth
- Sizes from ~meters to 40 km
- Known NEAs: 27,189
- Delivered from the main belt via resonances and Yarkovsky drift
- NEAs sample the small population of main-belt asteroids
- It is more challenging to study the physical properties of MBAs in a similar size range as NEAs
- Large diversity – rocky, icy, metallic, mixtures
- Potential danger to the Earth – impact hazard
- Currently in the middle of interest – space missions OSIRIS-Rex, Hayabusa 1+2, DART, Hera, DESTINY+

### Photometric campaign

We initiated several observing campaigns aiming at obtaining lightcurve data of several NEAs that were having close approaches to the Earth. Dozens of citizen scientists provided their observations. We selected asteroids that get bright enough for at least one month, which provides a sufficiently wide window of opportunity for the eVscope users that are often limited by weather conditions. Also, these targets have unknown or poorly constrained physical properties, which results in the opportunity to contribute to their better characterization and understanding of this population of asteroids.

The direction of the spin axis and the convex shape can be constrained only if we have lightcurve dataset sampling various observing geometries. Typically, we need data from at least three different apparitions. Therefore, we need to combine data from different epochs and sources. In practice, we supplement the previously available data with data obtained by the eVscope citizen astronomers.

**(159857) 2004 LJ1** - clear changes due to rotation, a good candidate for shape modeling as data from previous apparition exist.

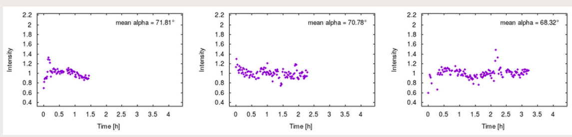

Fig 4: Optical lightcurves of asteroid (159857) 2004 LJ1.

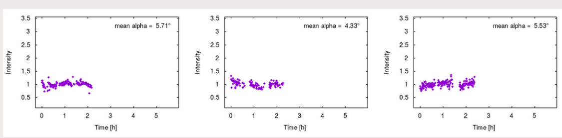

Fig 5: Optical lightcurves of asteroid (285571) 2000 PQ9.

**(450263) 2003 WD158** - lightcurves are rather flat. This can be either due to its roundness (i.e., low lightcurve amplitude) or it rotates slowly (P>10 h). This target is on the limits of the eVscope capabilities.

### First results

The lightcurve data obtained by the Unistellar's network directly provide the rotation period if the photometric accuracy is sufficient and the asteroid does not have a low (<~0.1 magnitude) amplitude of the lightcurve changes or a long rotation period (>~20h).

**(5143) Heracles** - tentative changes of the brightness consistent with the known 2.7h rotation period are present.

**(285571) 2000 PQ9** - changes of the brightness seem to suggest a rotation period of 5-6 hours.

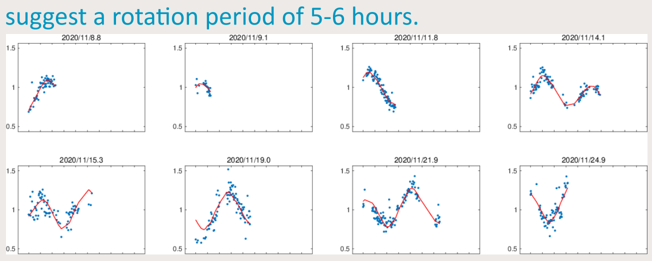

Fig.6: Optical lightcurves of asteroid (159402) 1999 AP10 obtained by eVscopes. Red line indicates the modelled data based on the shape model.

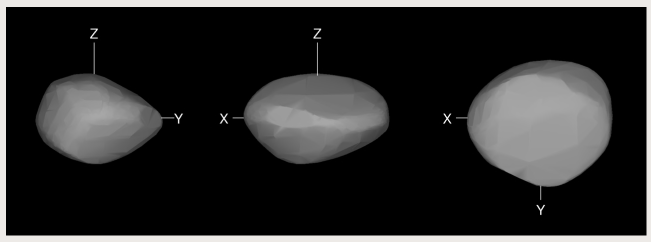


Fig 7: Shape model of 1999 AP10 obtained by eVscopes. The left and center views are equatorial, with a 90 degrees rotation, while the right one is pole-on.

**(159402) 1999 AP10** - About 80 optical lightcuves were collected by the network in November 2020. We derived a unique shape model and the rotation state from the new observations and archival data (publication in prep.).

## Conclusions and future prospects

- We are at the beginning of an era of large networks of citizen astronomers. The Unistellar's network of eVscope asteroids is currently the largest group of potential citizen astronomers who are interested in contributing to astronomy by providing photometric measurements of brighter asteroids.
- Together with SETI Institute, the scientific partner of Unistellar, we are exploiting the full potential of the eVscopes network by promoting observing campaigns aiming at photometrically monitor the near-Earth asteroids that get bright enough.
- We plan to continue monitoring suitable candidates for our photometric campaigns. Ideally, we want to trigger an observing campaign whenever there is such a candidate. As we are limited by the brightness of the object to be <15 magnitude, we should be not overwhelmed by the number of targets.
- Lightcurve observations of NEAs by Unistellar's citizen science network proved to be challenging. The main issues are the small brightness of many of our targets, their large sky motion, and various observing conditions the observers experience. While we provide a temporal window of opportunity for each target, some periods of inconvenient conditions are unavoidable - proximity to the moon or a bright star, or light pollution. Moreover, individual issues are also common - poor collimation, missing dark frames, off-centered frames, etc. The lesson learned here is that we should provide additional guidance to the observers to minimize the existence of unusable data.

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