Photocenter offset: Case study of two NEAs

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Introduction

The photocenter-barycenter offset refers to the difference between the measured photocenter and the actual centre of mass of an object. In the case of near-Earth objects, this offset can lead to biases and uncertainties in orbit determination. However, recent advancements in Gaia astrometry have made it possible to detect this effect, allowing for a more accurate determination of asteroid orbits. This effect can have a significant impact on asteroid astrometry, with the offset being up to 10-20% of the asteroid's apparent diameter.

Methodology

To determine the offset for each epoch of observation, a syntetic image based on an asteroid shape model is created for a given Sun-asteroid-observer geometry. The photocenter is then determined by comparing the center of brightness of the image to the mass centre of the model. The displacement vector between the center of brightness and center of mass is scaled based on the asteroid's size and the observer's distance, with right ascension (RA) and declination (DEC) as its components.

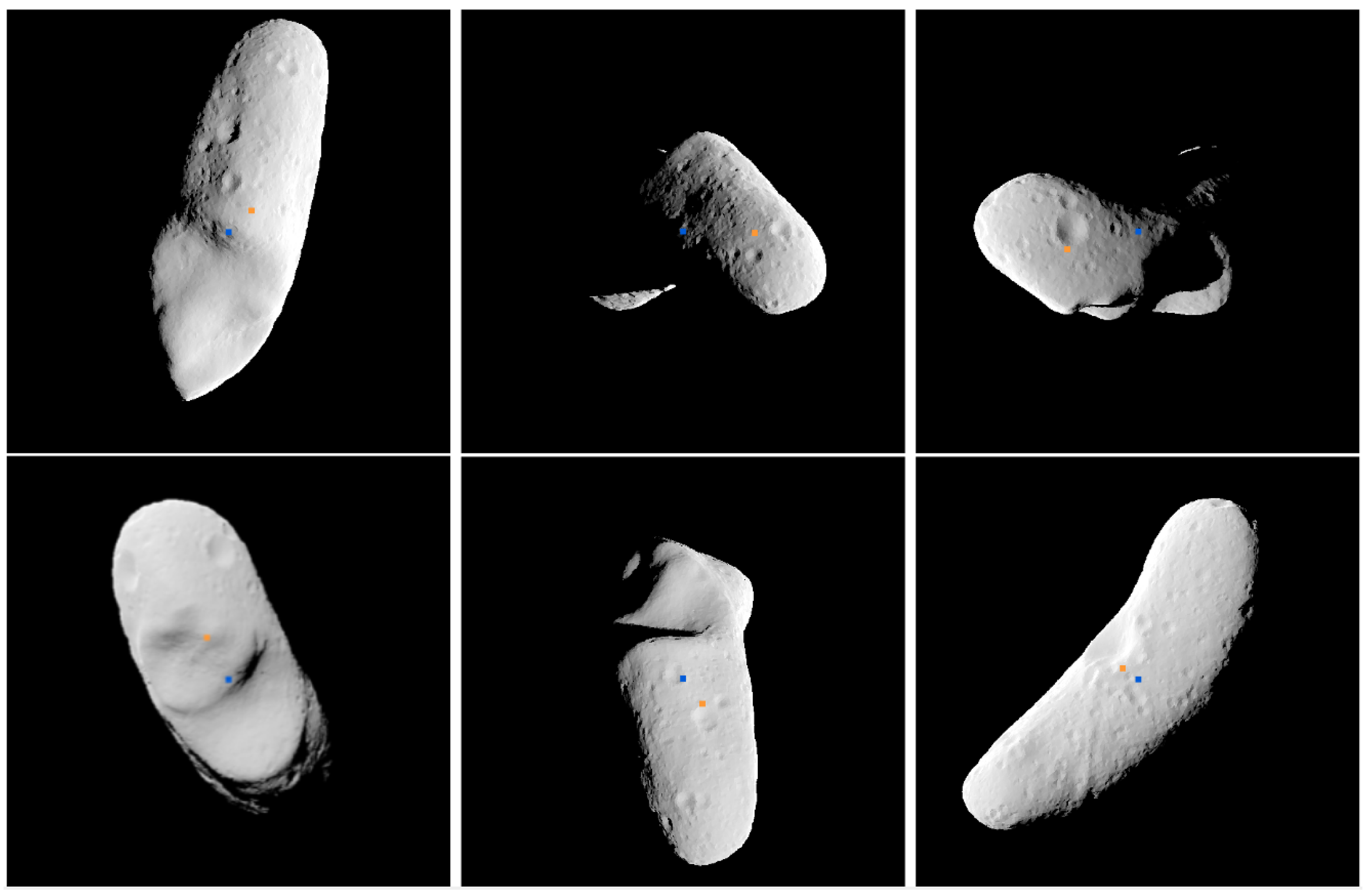

Figure 1. Difference between photocenter and barycenter (orange vs blue dots) of asteroid (433) Eros, for various oppositions. Shape model [Gaskell, 2008, Stooke, 2015].

In Fig. 1 we display the model of asteroid (433) Eros at multiple oppositions. Photocenter is represented by the orange dot and the barycenter as the blue dot. The model is based on NEAR Shoemaker spacecraft data. The photocenter offset varies over time and depends on asteroid's geometry (distance and aspect angle) during each opposition.

In Fig. 2 we present the values of the offset in RA and DEC determined based on the model of (433) Eros. The values reach 6 mas during Eros close approaches to Earth.

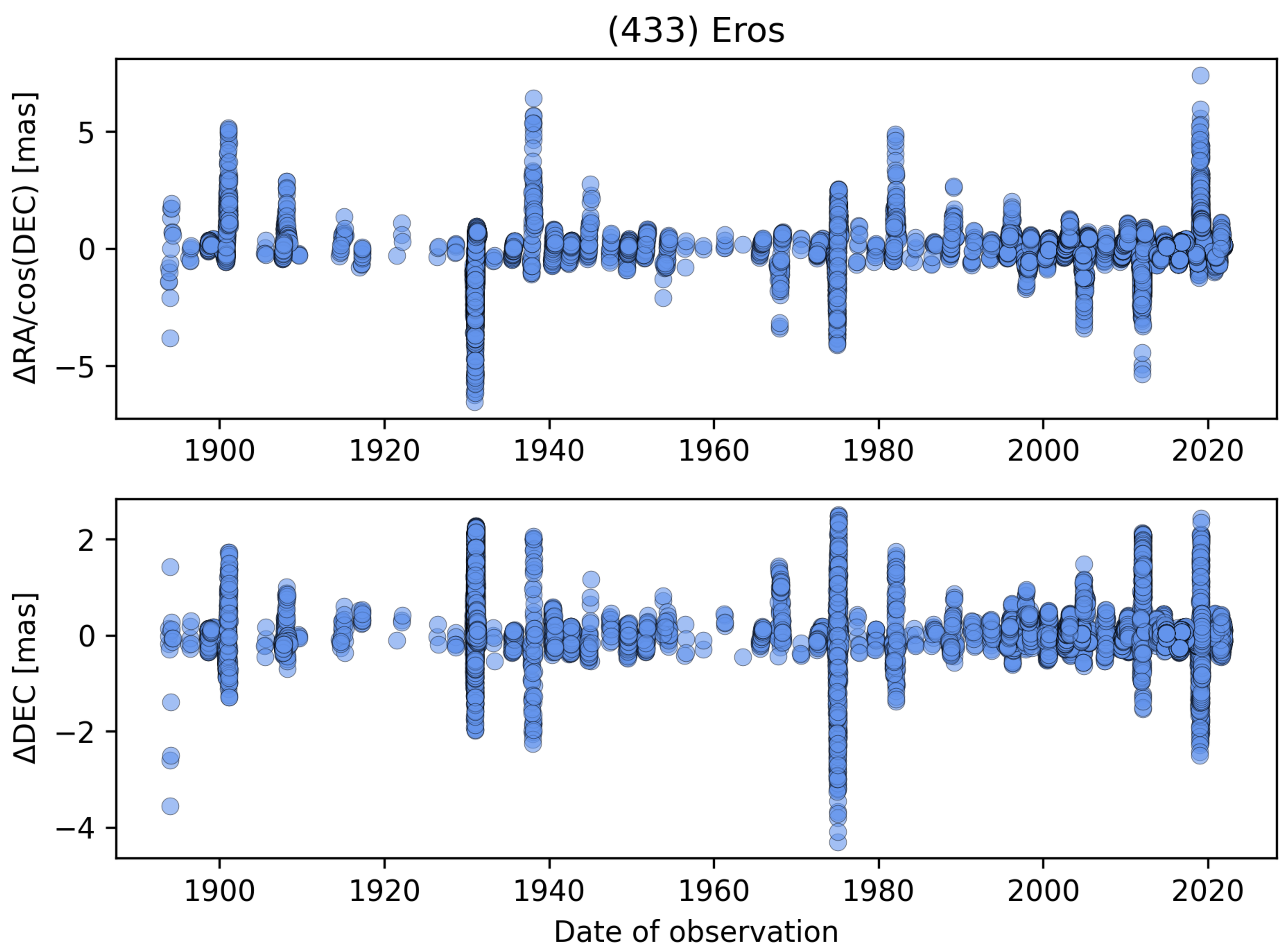

Figure 2. Value of the photocenter offset in RA and DEC for all observations of (433) Eros.

Results

Figure 3. Data used for orbit determination.

We determined the photocenter-barycenter offset for two near-Earth asteroids (NEAs) with well-determined non-convex shape models: (433) Eros and (1620) Geographos.

We used a combination of ground-based and satellite observations from the Minor Planet Center, JPL Horizon radar data, and Gaia data release 3 (DR3) asteroid astrometry. We applied the photocenter offset correction to the submilliarcsecond asteroid astrometry of the ESA Gaia mission [Tanga P., 2022].

Next, we computed the orbits based on original and photcenter offset corrected astrometry. For the orbit determination, we used OrbFit software. We applied the offsets for all Gaia DR3 observations and determined 7 orbital parameters (7th being the non-gravitational transverse acceleration). The post-fit residuals on the Along Gaia scan (AL) are presented in Fig. 4 for the two cases, respectively.

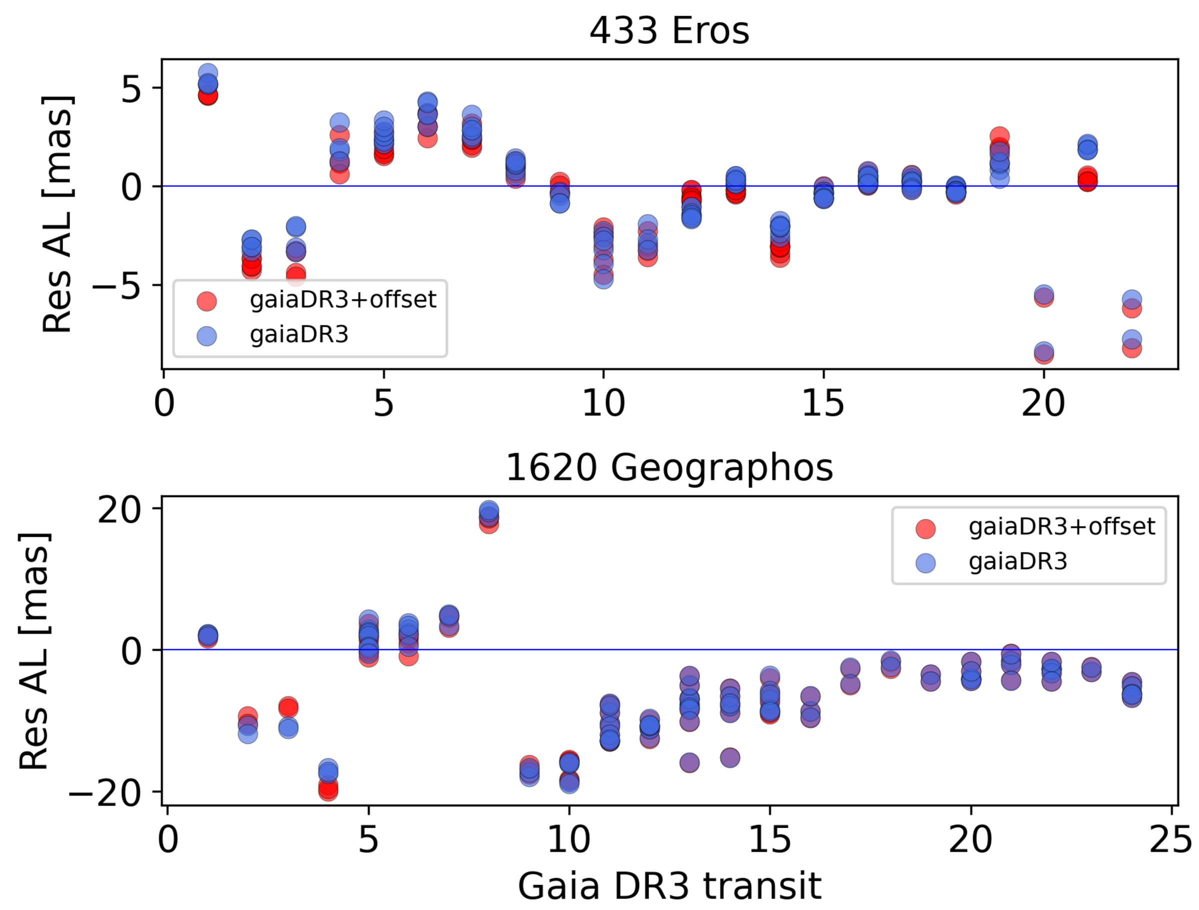

Figure 4. Preliminary results of AL post fit residuals using normal Gaia data (blue) and using Gaia data including photocenter offset (red) for two asteroids (433) Eros and (1620) Geographos.

The Photocenter-barycenter effect can be observed in the Gaia DR3, and its detection can enhance the accuracy of astrometry measurements. Overall, accounting for the photocenter-barycenter effect is a crucial step in improving our understanding of NEOs and their potential Earth encounters.

Conclusions

- We determined the photocenter offset for two NEAs.
- The offset was applied to all Gaia DR3 data prior to the orbit determination process
- Our study shows promising preliminary results for both (433) Eros and (1620) Geographos. Applying the offset to the Gaia observations only resulted in a decreased global RSM value.

References

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[Tanga P., 2022] Tanga P., e. a. (2022). Gaia data release 3: the solar system survey. *accepted in Astronomy & Astrophysics*.

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