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Physical Characterisation of Near-Earth Asteroid (68346) 2001 KZ66 from Optical and Radar Observations

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Abstract

The (YORP) effect [1] is a torque due to incident solar radiation and the subsequent recoil effect from the anisotropic emission of thermal photons on small bodies in the Solar System. The YORP effect can: change rotation rates and spin-axis orientations over relatively short time-scales; modify orbits (semi-major axis drift from the related Yarkovsky effect depends on the obliquity) and thus plays a key role in replenishment of the near-Earth asteroid (NEA) population; cause regolith mobility and resurfacing as spin rates increase, form binary asteroids through equatorial mass loss and re-aggregation and cause catastrophic disruption. When we began our systematic monitoring programme in 2010, the YORP effect had only been detected for three asteroids [2-4] with a marginal detection following in 2012 [5]. That has now increased to six [6-7]. We are conducting an observational programme of a sample of NEAs to detect YORP-induced rotational accelerations. For this, we use optical photometry from a range of small to medium size telescopes. This is supplemented by thermal-IR observations and thermophysical modelling to ascertain expected YORP strengths for comparison with observations. For selected objects, we use radar data to determine shape models. We will present our latest results for one of our sample NEAs, (68346) 2001 KZ66.

1. Observational Campaign

<u>Optical photometry and the search for YORP</u>: Detection of rotational acceleration requires measurement of phase shifts in rotational light curves at a minimum of three apparitions. As part of our ESO Large Programme, (68346) 2001 KZ66 was observed at the NTT for a total of 9 nights in April 2010, February 2012, March 2014, and January 2019. An additional lightcurve was also obtained from the Isaac Newton Telescope (La Palma, Spain) in May 2012. We have also made use of published light curve data [8-9]. The complete optical-photometry dataset of (68346) 2001 KZ66 contains a total of 17 light curves spanning 2010 until 2019. We use an established light curve inversion code, e.g. [10], modified to include YORP-induced sidereal rotation period changes, to derive shape and spin state models.

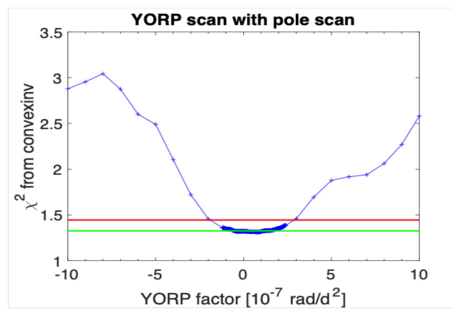

Figure 1. For a set of YORP factors, a grid of pole positions was scanned with the shape and period optimised at each point. The quality of the fit was recorded and the smallest value for each YORP plane is plotted here against its corresponding YORP factor. The green line marks the best-fit chi-squared minimum +1 %, red + 10%. A YORP-induced spin-up of 7.7×10^{-8} rad/day^2 gives the best fit to the observational data, but the constant period solution cannot be discarded.

<u>Planetary radar programme</u>: Radar observations can greatly improve the spin-state analysis by providing a fully independent shape model, thus greatly reducing the range of potential solutions for YORP. The ability of radar to detect surface concavities is an important advantage as many asteroids are reported to have bi-lobed or contact-binary configurations [11]. Radar data can also be merged with optical light curve data to provide tighter constraints on rotational pole

positions and shape and spin-states. Such detailed shape models also allow for more rigorous modelling of the YORP and Yarkovsky effects [12]. The radar observations used in this programme were obtained using the Arecibo Planetary Radar (Puerto Rico) facility.

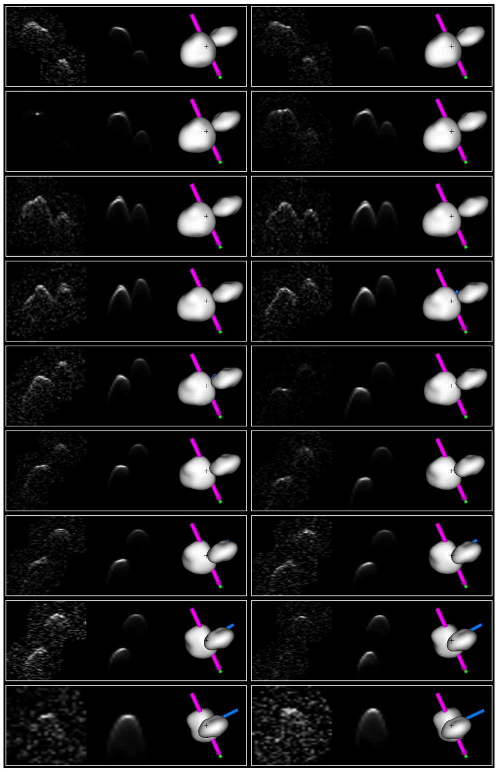

Figure 2. The tiles include three components. On the left is the delay-Doppler data, in the centre is a synthetic delay-Doppler image, and on the right is the plane-of-sky projection of the best-fit model of the asteroid. The green, red, and blue rods mark the asteroid's inertial axes, and the pink arrow shows direction of the spin-axis. Time progresses from left to right, then top to bottom. The object was observed over two nights on 28 and 29 October 2003.

2. Preliminary Results

Spin-State and Shape Modelling: Using our photometry data we have determined a rotation period of 4.985988 ± 0.000489 hours, in agreement with the period determined by B. Warner [8-9]. Using convex-inversion techniques we performed a pole scan optimising the shape and period over a grid of pole positions covering the entire sky with a resolution of 5º × 5º, we did this for a set of YORP strengths ranging from -1×10^{-6} to 1×10^{-6} rad/day^2 (Fig. 1). The best solution from this is a YORP-induced spin-up of $(7.7 \pm 13.2) \times 10^{-8}$ rad/day^2, however, a constant period solution remains possible at this stage of the analysis.

From the Arecibo delay-doppler images, it is evident that (68346) 2001 KZ66 is a contact binary asteroid. Using a simple bilobate ellipsoid model as a starting point, we combined both our radar and optical light curve datasets to iteratively fit a shape model. The asteroid has a rotation pole direction of λ = 165º, β = -75º, and an effective diameter, D_{eff}, of 0.75 km. The axial measurements of the asteroid are 1.36 km, 0.59 km, and 0.68 km corresponding to the long, intermediate, and short inertial axis respectively. The current best-fit shape model has the somewhat usual configuration of two fairly flat ellipsoids.

Acknowledgements

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