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# Physical characterisation of near-Earth asteroid (2102) Tantalus from optical and radar observations

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## Abstract

We are conducting a ground-based observing campaign aimed at refining physical models of the YORP effect through new detections and detailed physical characterisation of selected near-Earth asteroids. Between 2010 and 2017 we have collected new optical and near infra-red observations of the potentially hazardous NEA (2102) Tantalus using ESO facilities. The lightcurve data is supplemented by radar imaging data available from Arecibo. The object appears to be very symmetrical showing a low amplitude lightcurve variation and no large-scale features in the radar images. Moreover, Tantalus' rotation rate is near its rotational fission limit, which means the asteroid was likely shaped through its fast spin. It is most likely similar in shape to YORP-evolved highly-symmetrical bodies like 1999 KW4 [1].

## 1. Introduction

The asteroidal YORP effect is a tiny recoil torque resulting from reflection, absorption and re-radiation of thermal photons illuminating surfaces of small bodies [2, 3, 4]. It is considered to be the main driver in the physical and dynamical evolution of small asteroids close to the Sun. Notably all six direct detections to date are in the spin-up sense.

In order to increase the number of detections to aid theoretical advances in this area we are conducting a long-term observing campaign. Observations of 42 NEAs were carried out primarily in our ESO Large Programme aimed at optical and infra-red photometric monitoring using ESO facilities between 2010 and 2014. While this initial phase is now completed, additional data is still being collected with associated programmes at other ground-based facilities.

Asteroid (2102) Tantalus is a PHA target selected as one of our YORP-detection candidates and classified as an Sr spectral type [5]. It was observed photometrically in 1995 and 1996 [6] and more recently in 2014 and 2017 [7, 8, 9]. The published optical lightcurve observations suggest a spin period around $2.38 - 2.39\,\mathrm{h}$, close to the rubble pile rotationally-induced fission limit. The asteroid size was most recently estimated to be $1.762 \pm 0.603\,\mathrm{km}$ with the NEOWISE survey [10].

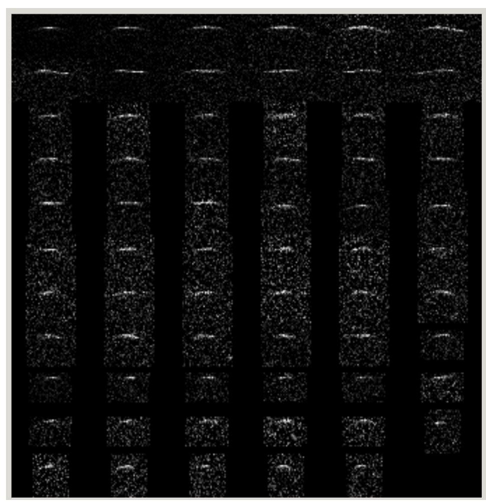

Figure 1: The delay-Doppler imaging data from the Arecibo planetary radar observations collected in January 2017. The spatial resolution in delay (vertical axis on the images) is $150\,\mathrm{m}$. The radar echoes were collected over a wide range of rotational phases but display very little variation indicative of a highly symmetrical object. The shape is likely due to the YORP-induced evolution and surface material rearrangement.

## 2. New observations

We observed Tantalus through our long-term YORP detection programme primarily with the $3.5\,\mathrm{m}$ NTT telescope at ESO's La Silla Observatory in Chile on 9 nights between August 2010 an November 2013, obtaining optical lightcurve data and optical spectra. We collected further optical lightcurves in June and July 2017 with the Danish $1.54\,\mathrm{m}$ telescope, also located at La Silla. We collected thermal-infrared photometry with the VISIR instrument on Unit 3 of the $8.2\,\mathrm{m}$ VLT array at ESO's Paranal Observatory in Chile on two nights (on 11 January 2011 and 1 July 2017).

The asteroid was observed with the Arecibo planetary radar over 5 nights in January 2017. Two types of radar data were collected: continuous-wave observations and delay-Doppler imaging. The continuous-wave observations display the Doppler shift of the signal reflected off the asteroid's surface due to asteroid movement and rotation. The other type is delay-Doppler imaging, which record radar echo power as a function of both Doppler shift and delay of the returning signal. The imaging frames were collected mainly with a $150\,\mathrm{m}$ resolution in delay, as shown in Fig. 1.

## 3. Preliminary results

Successful YORP detection requires precise information about spin-state of the object. The rotation rate and pole orientation can both be determined using lightcurve data alone. However, having an asteroid shape available makes it possible to directly compute rotational phase offsets between observations and synthetic lightcurves derived from the shape model. The YORP effect causes a linear change in rotation rate introducing a quadratic trend in measured rotational phase offsets between a constant-period solution and lightcurve observations. Having an independently-determined shape model, e.g. from radar observations, is beneficial to this method of YORP detection.

We have used the radar observations to determine the location of the rotational pole of Tantalus. A plot of goodness-of-fit $\chi^2$ value of the fit of tri-axial ellipsoid models to the radar data is shown in Fig. 2. The initial scan shows two families of possible solutions, around ecliptic latitudes $\beta = 30 - 70°$ and longitudes $\lambda = 0 - 60°$ and the second at $\beta = -10$ to $-50°$ and $\lambda = 150 - 270°$. The object appears almost spherical with the semi-major axes $0.916$, $0.913$ and $0.911\,\mathrm{km}$ (consistent with NEOWISE estimate) for the pole at $\lambda = 0°$, $\beta = 30°$. This result will be further refined.

Further work that will be presented at the meeting will include combining the radar and lightcurve data for shape and spin-state determination. Low amplitude lightcurves acquired at different observing conditions combined with lack of large-scale features in the radar images suggests a quite symmetrical shape, which might be a characteristic 'YORPoid' shape displayed by 1999 KW4 [1], or by the current sample-return mission targets Ryugu and Bennu. Using lightcurve data acquired between 2010 and 2017 with published lightcurves from 30 years prior should enable development of robust YORP limits for this target.

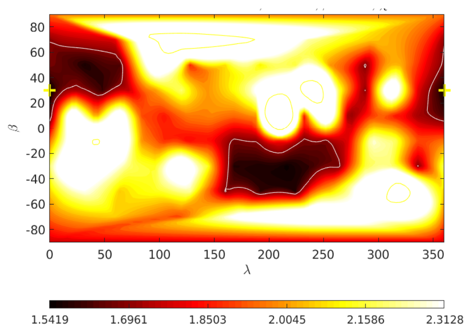


Figure 2: Results of preliminary pole search using only the 2017 Arecibo radar data and an ellipsoid shape model. The colours indicate $\chi^2$ goodness-of-fit values with darker colours marking lower $\chi^2$, and white areas indicating $\chi^2$ values increasing more than 50% above minimum. The preliminary best-fit pole at $\lambda = 0°$ and $\beta = 30°$ is indicated with a yellow '+'.

## References


[1] Ostro, S. J., Margot J. L., Benner L. A., et al., Science, Vol. 314, pp. 1276, 2006.

[2] Rubincam, D. P., Icarus, Vol. 148, pp. 2, 2000.

[3] Lowry S. C., Fitzsimmons, A., Pravec P. et al. Science, Vol. 316, pp. 272, 2007.

[4] Taylor, P.A., Margot, J.-L., Vokrouhlický et al., Science, Vol. 316, pp. 274 , 2007.

[5] Thomas, C. A., Emery, J. P., Trilling, D. E., et al., Icarus, Vol. 228, pp. 217, 2014.

[6] Pravec, P., Wolf, M., Šarounová, L., Mottola, et al. Icarus, Vol. 130, pp. 275, 1997.

[7] Warner, B. D. MPBu, Vol. 42, pp. 79, 2015.

[8] Vaduvescu, O., Macias, A. A., Tudor, V., et al., Earth Moon and Planets, Vol. 120, pp. 41, 2017

[9] Warner, B. D., MPBu, Vol. 44, pp. 223, 2017.

[10] Masiero, J. R., Nugent, C., Mainzer, A. K., et al., Astronomical Journal, Vol. 154, pp. 168, 2017.