THE INCREASING SPIN RATE OF ASTEROID (54509) 2000 PH5: A RESULT OF THE YORP EFFECT.

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Introduction: Theory predicts an evolution of the spin state of small solar system bodies due to the absorption and asymmetric re-emission of sunlight, the Yarkovsky-O'Keefe-Radzievskii-Paddack (YORP) effect. The resultant torques are thought to realign the spin axis while increasing or decreasing the spin rate of the object [1]. We present observations and simulations which establish that the observed increase in the spin rate of ~110 m diameter (54509) 2000 PH5 [2] is due to the YORP effect [3]. The YORP effect can elucidate several outstanding issues in asteroid dynamics including why asteroids under 10 km in diameter exhibit an excess of slow and fast rotators [4] and how binary systems are formed [5].

Observations: 2000 PH5, a co-orbital companion of Earth, had annual close approaches conducive to optical [2] and radar observations between 2001 and 2005. The Doppler broadening of the radar echo by the target's rotation constrains the spin pole to within 10° of (180°, -85°) in J2000 ecliptic coordinates. High resolution images in range-Doppler shift space allow us to produce a detailed shape model of 2000 PH5.

Results: A change in sidereal spin rate is necessary to fit the radar and lightcurve data over time. We produced a simple shape model to fit the lightcurve data, allowing an arbitrary phase shift for each lightcurve to match the phase of the shape model's synthetic lightcurves. The resulting phase shifts (Fig. 1) necessary to link the lightcurves are well fit by a quadratic function in time or, equivalently, a linear change in spin rate. The fitted sidereal spin rate is 42582.41 ± 0.02 deg/day (12.17 minute period) at the initial epoch of 27 July 2001, and the change in spin rate is $(2.0 \pm 0.2) \times 10^{-4}$ deg/day^2, in perfect agreement with [2].

We produced a family of models with a range of surface "roughness" based upon large, medium, and small scale topography to determine both the shapes that best fit the entire collection of radar and optical data and how roughness affects YORP acceleration calculations. Despite different surface roughnesses, the silhouettes of the models are very similar. Assuming a uniform density of 2.5 g/cm^3 and an ideal Lambertian scattering surface, two independent YORP acceleration models [6, 7] predict changes in spin rate 2-7 times faster than observed with the smoother models providing better matches. The agreement between observation and theory within an order of magnitude confirms that the observed spin change is attributable to YORP.

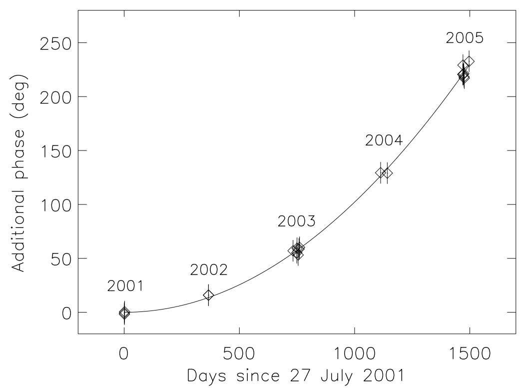

Figure 1. Additional phase required to link 20 optical lightcurves [2] from 2001 to 2005 due to a linear change in spin rate.

Discussion: The observation of a continuously increasing asteroid spin rate along with the agreement with theoretical models establishes the YORP effect as an important process for altering the spin state of small solar system bodies. By evolving spin states, the YORP effect can help explain the observed distribution of spin rates among sub-10 km diameter asteroids and may describe how at least some binary NEAs are formed from the spin-up and resulting rotational fission of a parent body.

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