SYORP EQUILIBRIA OF BINARY ASTEROIDS: DATA ANALYSIS. Vladyslav Unukovych[1], Oleksiy Golubov[1,2,3], Daniel J. Scheeres[3]. [1]V. N. Karazin Kharkiv National University, 4 Svobody Sq., Kharkiv, 61022, Ukraine; unukovich.vladislav@gmail.com. [2]Institute of Astronomy of V. N. Karazin Kharkiv National University, Kharkiv, Ukraine. [3]Department of Aerospace Engineering Sciences, University of Colorado at Boulder, CO.

Introduction:

The binary systems of asteroids are commonly formed by normal YORP and decay due to the influence of the binary YORP (BYORP) effect. As it appears, there is no obligation for the binary systems to be only in the continuous evolution, so they can fall into the equilibrium states [1,2,3]. The evolution of the binary systems is dictated by the YORP torques, which are dependent on poorly constrained parameters, such as the heat conductivity and the average values of the binary YORP and tangential YORP (TYORP) [4].

In the most general scenario of equilibrium for singly synchronous binary asteroids, the BYORP and tidal torques act on the smaller asteroid in the binary system, while NYORP, TYORP and tides act on the larger asteroid in the system [3]. Thus, assuming the observable singly synchronous binaries to be in the mentioned equilibrium state, some estimations for the heat conductivity, average values of BYORP and NYORP coefficients and the ratio of the tidal Love number to the quality factor can be obtained.

As another approach, the binary system may reside not in the full equilibrium, but only in the equilibrium for the smaller asteroid, caused by BYORP and tides (Bt-semiequilibrium) [5].

Here we give the explanations for our calculations and provide estimated values of poorly constrained parameters mentioned above.

Results: Basing on the maximum likelihood method, we estimate heat conductivity, average values of BYORP and NYORP coefficients and the ratio of the tidal Love number to the quality factor. The value of the heat conductivity also can be obtained from the constraints for Monte Carlo generated asteroids and observable data (Figure 1) [6]. Both methods give similar results, close to the heat conductivity of regolith. Thus, it can imply that TYORP is mainly produced by regolith.

Assuming the tidal Love number power dependence of radius of the largest asteroid, we obtain the power index close to the result given by Nimmo & Matsuyama [7]. Hence, the estimation of the product of BYORP coefficient and the quality factor to the tidal Love number ratios, obtained from the maximum likelihood method and Bt-semiequilibrium state corresponds one to another, and also similar to the results obtain by Jacobson & Sheers [5].

The average value of NYORP coefficient much lower than the average value for single asteroids, but in a good agreement with the average value for binaries.

Applying the calculated values, we plot the theoretical dependency over the observable binaries (Figure 2). Most known singly synchronous binaries lie within the 2σ-margin, as the part of binaries of unknown synchronicity, which might be expected to appear as singly synchronous.

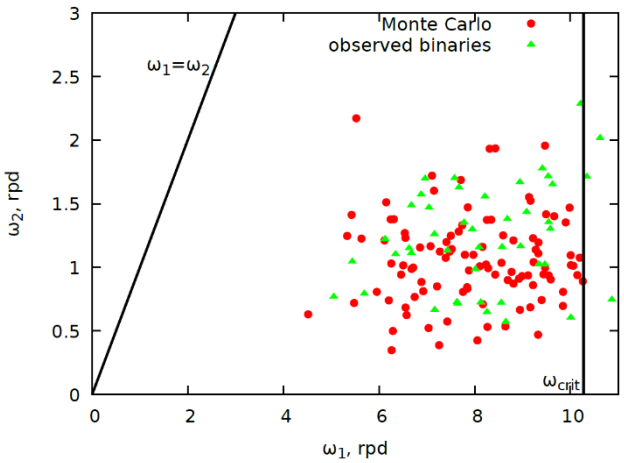

Figure 1. Distribution of asteroids. Red circles are the asteroids generated by Monte-Carlo, green triangles are the known asteroids, to which the maximum likelihood method was applied.

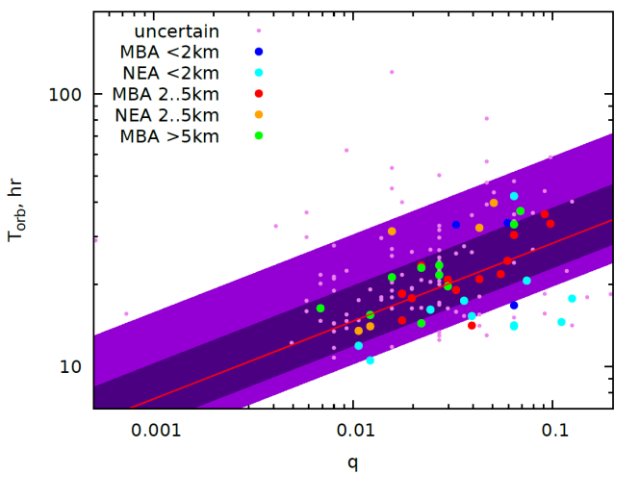

Figure 2. Rotation periods of singly synchronous binaries and binaries of uncertain synchronicity T_{orb} as a function of the mass ratio q. Red line corresponds to the theoretical prediction for singly synchronous binaries. Dark violet and violet stripes highlight 1σ- and 2σ-margins.

Conclusions:

The results obtained from different data analysis methods of singly synchronous binaries correspond to each other, and to the results of other authors. The results provide good agreement between theoretical expectations and observable data. Also, some substantial questions arise. Is TYORP produced mainly by the regolith part of the asteroid? How plausible the reviewed scenario compared to the continuous evolution of the binary system? Is the concentrated clustering of observable binaries in rotation rates indeed attributed to the considered equilibrium? (Figure 1)

Acknowledgements: OG and VU are grateful to the Celestial and Spaceflight Mechanics Laboratory of CU Boulder for the financial support. Authors also would like to thank Peter Pravec and Vasilii Chiorny for fruitful discussions.

References: [1] Jacobson, S. A., Scheeres, D. J. (2011). *ApJL* **736**, L19. [2] Golubov, O., Scheeres, D. J. (2016). *ApJL* **833**, 23. [3] Golubov, O., Unukovych, V., Scheeres, D. J. (2018). *ApJL* **857**, L5. [4] Golubov, O., Scheeres, D. J. (2019), *ApJ* **157**, 105. [5] Jacobson, S. A., Scheeres, D. J. (2011). *ApJL* **736**, L19. [6] Pravec, P., Fatka, P., Vokrouhlický, et al, (2019). *Icarus*. [7] Nimmo, F., & Matsuyama, I. (2019). *Icarus*, *321*, 715-721.