EPSC Abstracts
Vol. 6, EPSC-DPS2011-312-1, 2011
EPSC-DPS Joint Meeting 2011

Anisotropic distribution of orbit poles of binary asteroids

P. Pravec (1), P. Scheirich (1), D. Vokrouhlický (2), A. W. Harris (3), P. Kušnirák (1), K. Hornoch (1), D. P. Pray (4), D. Higgins (5), A. Galád (1,6), J. Világi (6), Š. Gajdoš (6), L. Kornoš (6), J. Oey (7), M. Husárik (8), W. R. Cooney (9), J. Gross (9), D. Terrell (9, 10), R. Durkee (11), J. Pollock (12), D. Reichart (13), K. Ivarsen (13), J. Haislip (13), A. LaCluyze (13), Yu. N. Krugly (14), N. Gaftonyuk (15), R. Dyvig (16), V. Reddy (17), R. D. Stephens (18), V. Chiorny (14), O. Vaduvescu (19), P. Longa (19), A. Tudorica (19), B. D. Warner (20), G. Masi (21), J. Brinsfield (22), R. Gonçalves (23), P. Brown (24), Z. Krzeminski (24), O. Gerashchenko (25), and F. Marchis (26)

(1) Astronomical Institute, Academy of Sciences, Ondřejov, Czech Republic (ppravec@asu.cas.cz), (2) Institute of Astronomy, Charles University, Prague, Czech Republic, (3) 4603 Orange Knoll Ave., La Cañada, CA 91011, USA, (4) Carbuncle Hill Observatory, W. Brookfield, MA, USA, (5) Hunters Hill Observatory, Ngunnawal, Canberra, Australia, (6) Modra Observatory, Slovakia, (7) Leura Observatory, N.S.W., Australia, (8) Astron. Inst. Slovak Acad. Sci., Tatranská Lomnica, Slovakia, (9) Sonoita Research Observatory, Sonoita, AZ 85637, USA, (10) Dept. of Space Studies, Southwest Research Institute, Boulder, CO 80302, USA, (11) Shed of Science Observatory, Minneapolis, MN 55410, USA, (12) Physics and Astronomy Dept., Appalachian State University, Boone, NC 28608, USA, (13) Physics and Astronomy Dept., University of North Carolina, Chapel Hill, NC 27514, USA, (14) Institute of Astronomy of Kharkiv National University, Kharkiv, Ukraine, (15) Crimean Astrophysical Observatory, Simeiz, Ukraine, (16) Badlands Observatory, Quinn, SD 57775, USA, (17) Dept. of Space Studies, Univ. of North Dakota, Grand Forks, USA, (18) Goat Mountain Astronomical Research Station, CA, USA, (19) Instituto de Astronomia, Universidad Catolica del Norte, Antofagasta, Chile, (20) Palmer Divide Observatory, Colorado Springs, CO 80908, USA, (21) Campo Catino Obs., I-03016 Guarcino, Italy, (22) Via Capote Obs., Thousand Oaks, CA, USA, (23) Obs. Ast. de Linhaceira, Escola Superior de Tecnologia de Tomar, Instituto Politecnico de Tomar, 2300-313 Tomar, Portugal, (24) Elginfield Observatory, Dept. of Physics & Astronomy, Univ. of Western Ontario, London, Ontario, Canada, (25) Andrushivka Astronomical Observatory, Ukraine, (26) Univ. of California at Berkeley, Berkeley, CA 94720, USA

Abstract. Our photometric observations of 18 main-belt binary systems in more than one apparition revealed a strikingly high number of 15 having positively re-observed mutual events in the return apparitions. Our simulations of the survey showed that the data strongly suggest that poles of mutual orbits between components of binary asteroids are not distributed randomly: The null hypothesis of the isotropic distribution of orbit poles is rejected at a confidence level greater than 99.99%. Binary orbit poles concentrate at high ecliptic latitudes, within 30° of the poles of the ecliptic. We propose that the binary orbit poles oriented preferentially up/down-right are due to formation of small binary systems by rotational fission of critically spinning parent bodies with poles near the YORP asymptotic states with obliquities near 0 and 180°. An alternative process of elimination of binaries with poles closer to the ecliptic by the Kozai dynamics of gravitational perturbations from the sun does not explain the observed orbit pole concentration as in the close asteroid binary systems the J_2 perturbation due to the primary dominates the solar-tide effect.

Observations and survey simulations. We took photometric observations of 18 binary systems among main belt asteroids with primary diameters of 3 to 8 km during at least two apparitions from 2005–2011. In 15 cases, we observed mutual events (occultations/eclipses) between their components also in the return apparition. To characterize and eliminate selection effects of the photometric technique, we simulated the survey with a numerical model analogous to that we used for simulations of our survey for NEA binaries in [1]. In each simulation run, we generated 30000 binaries with orbit poles with a given trial distribution for each of the 18 binaries. Using the resulting probabilities of positive re-detections, we computed a probability density of getting $N_{2\mathrm{app}}$ of positive re-detections of the 18 studied binaries. This result was then compared to the observed number of 15 of the 18 binaries actually showing mutual events in their return apparitions.

Orbit pole distribution. The null hypothesis of an isotropic distribution of binary orbit poles was rejected at a high confidence level. The expected number of positive re-detections was 6 ± 3 (the 95% probability interval) while the probability of getting 15 positive re-detections among the 18 binaries was $< 10^{-4}$. See Fig. 1.

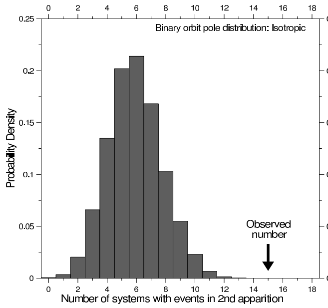

Figure 1: Estimated probability density of occurence of mutual events in the return apparition in $N_{2\mathrm{app}}$ of the 18 binary systems, assuming an isotropic distribution of orbit poles. The observed number (15) is much greater than the prediction for the null hypothesis.

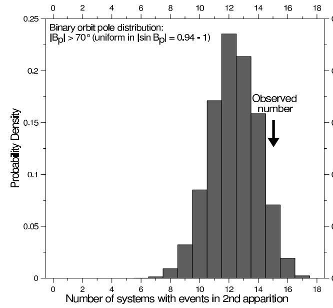

Figure 2: Estimated probability density of occurence of mutual events in the return apparition in $N_{2\mathrm{app}}$ of the 18 binaries, assuming an uniform distribution of orbit poles in the range $|\sin B_\mathrm{p}| = \sin 70°$ to 1.

Simulations with several trial pole distributions revealed that the binary orbit poles concentrate at high ecliptic latitudes, within $30°$ of the poles of the ecliptic. An example of the result for the uniform distribution in $|\sin B_\mathrm{p}|$ from $\sin 70°$ to 1 is shown in Fig. 2. An example of the orbit model solution using the method of [2] is shown in Fig. 3.

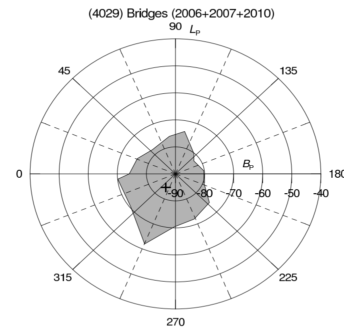

Figure 3: Range of admissible poles for the mutual orbit of (4029) Bridges in ecliptic coordinates. The south pole of the current asteroid's heliocentric orbit is marked with the cross.

Interpretation. We considered two processes that could produce the observed concentration of binary orbit poles near the ecliptic poles: (1) instability of satellite orbits with poles close to the ecliptic due to Kozai dynamics, and (2) formation of asteroid satellites with orbit poles preferentially at high ecliptic latitudes.

To study process (1), we constructed a numerical model that tracks orbital evolution of the satellite and the spin of the primary over a timescale of $\simeq 1$ My. For the observed parameters of the binary systems, we found that *the satellite motion is stable even for very small ecliptic latitudes of the orbital pole*. We also found the J_2 effect couples the primary rotational and the satellite orbital angular momenta such that the whole system behaves like a single gyroscope. This modifies the overall precession constant of the system (cf. [3]) and various evolutionary paths for the orbit pole of the satellite may be affected by Cassini resonances.

We propose that the concentration of the binary orbit poles toward high-ecliptic latitudes is due to their *preferential formation* at these states. Binary systems among small asteroids appear to be formed by rotational fission of parent bodies spun up by YORP torques (e.g., [4]). The observed binary orbit poles distribution is consistent with formation of binaries from parent bodies near the asymptotic states of the YORP evolution that are located at extreme obliquity values of 0 and $180°$ (e.g., [5]).

References.

[1] Pravec, P., 56 colleagues, 2006. Icarus 181, 63–93.
[2] Scheirich, P., P. Pravec, 2009. Icarus 200, 531–547.
[3] Ward, W.R., 1975. Astron. J. 80, 64–70.
[4] Walsh, K.J., D.C. Richardson, P. Michel, 2008. Nature 454, 188–191.
[5] Čapek, D., D. Vokrouhlický, 2004. Icarus 172, 526–536.