POPULATION OF SMALL ASTEROID SYSTEMS - WE ARE STILL IN A SURVEY PHASE. P. Pravec, P. Scheirich, P. Kušnirák, K. Hornoch, A. Galád, Astronomical Institute AS CR, Fričova 298, 251 65 Ondřejov, Czech Republic, petr.pravec@asu.cas.cz.

Introduction: Despite major achievements obtained during the past 15 years, our knowledge of the population and properties of small binary and multiple asteroid systems is still far from advanced. There is a numerous indirect evidence that most small asteroid systems were formed by rotational fission of cohesionless parent asteroids that were spun up to the critical frequency presumably by YORP, but details of the process are lacking. Furthermore, as we proceed with observations of more and more asteroids, we find new significant things that we did not know before. We will review a few such observations.

Primaries of asteroid pairs being binary (or ternary) themselves: The case of (3749) Balam was identified by Vokrouhlický [1, and references therein] . It is a paired asteroid (3749-2009BR60) where the primary Balam has one close (P_{orb} = 33.4 h) and one distant satellite. Our recent study of the inner couple showed that a solution for their mutual events cannot be obtained with the classical formalism of Keplerian orbit with apsidal precession for its moderately eccentric orbit; either a nodal precession (i.e., the satellite's orbit inclined wrt to the primary's equator) has to be included in the model, or a solution including perturbations from the distant satellite has to be made. For both, we will need more data to be taken during following apparitions.

Recently, we found 4 more asteroid pairs where the primary is binary. Estimated ages of the pairs are from 120 up to >1000 kyr; the pair 3749-2009BR60 is estimated to be about 300 kyr old (all the age estimates are uncertain to a few tens percent). The first apparition's data for the four "paired binaries" show them to be similar to our other photometrically detected binaries in the main belt, except for a possible tendency towards somewhat longer orbital periods from 29.5 to 56.5 h; orbital periods shorter than 1 day are lacking. One of the paired binaries shows also a second rotational lightcurve with period of 38.8 h, unsynchronous with its orbital period of 56.5 h (see below).

Semi-wide binaries with super-critical amount of total angular momentum content: In 2006-2007, within our BinAstPhotSurvey, we discovered three main-belt binaries with apparently super-critical total angular momentum content. They are (1717) Arlon, (4951) Iwamoto and (32039) 2000 JO23 ([2], [3], [4]). The α_L values (see [5]) for the first two are about 2 (within a few tens percent), and the third may have even higher specific total angular momentum. Their orbital periods are 117, 118, and about 360 h, respectively. Arlon and (32039) both show two rotational lightcurve components with shorter periods (5.15 and 18.2 h for Arlon, and 3.3 or 6.6 and 11.1 h for 32039), but Iwamoto shows what appears to be a synchronous rotation lightcurve - very curious, considering its estimated tidal synchronization time much longer than the age of the Solar System. The satellites of all the three systems are large, with D_2/D_1 between 0.5 and 1. Have the three unusual systems been formed by rotational fission like the majority of (closer) systems with typically smaller satellites that we predominantly observe? How were they moved to their current relatively wide orbits? Given their placement in the *Hic sunt leones* gap of the P_{orb}-D_1 space where both the photometric detection technique and the AO technique have been inefficient (see [6]), are the three just a "tip of the iceberg" of a large population of semi-wide small main-belt binaries?

Binaries with a second, non-synchronous rotational component: In seven (of several ten observed) binaries, we detected also a second rotational lightcurve component with period different from the orbital period. We summarize them in following table:

Asteroid	P_1 [h]	P_2 [h]	P_{orb} [h]	Ref
(10123) Fideoja	2.87	38.8	56.5	above
(1717) Arlon	5.15	18.2	117	above
(32039) 2000 JO23	(3.3)	11.1	~360	above
(1830) Pogson	2.57	3.26	24.2	[7]
(2006) Polonskaya	3.12	6.66	19.2	[7]
(2577) Litva	2.81	5.68	35.9	[7]
(16635) 1993 QO	2.21	7.62	32.2	[8]

Moreover, we found four asteroids (probable binaries) that showed two additive rotational lightcurve components, but no mutual events (hence P_{orb} undetermined):

Asteroid	P_1 [h]	P_2 [h]	P_{orb} [h]	Ref
(2486) Metsahovi	2.64	4.45	?	[9]
(3982) Kastel’	5.84	8.49	?	[10]
(5474) Gingasen	3.11	3.62	?	[11]
(114319) 2002 XD58	2.96	7.95	?	[12]

In some of the seven cases, a character of the observed lightcurve suggests that the P_2 component belongs to a third body of the system, not to the detected satellite producing the observed mutual events. So, we suspect that (some of) the systems are actually ternary. Could the third (presumably more distant) component be detected with AO?

We believe that more observations, both follow-up of the already known unusual systems as well as survey observations of the population of small main belt asteroids for new binary/multiple systems, are needed. While most currently known close binary asteroid systems are "KW4-like", we will need data on the more complex systems or systems with less usual parameters to get a more complete picture of the population of small asteroid systems. Though they are (apparently) less abundant than the "classical" (semi-)asynchronous close binaries, we will have to explain their existence and properties with our future, more advanced theories of binary/multiple asteroid formation and evolution.

References: [1] Vokrouhlický, D. (2009) *Astrophys. J. Letters, 706*, L37-L40. [2] Cooney, W. et al. (2006), *CBET, 504*. [3] Reddy, V. et al. (2007), *IAU Circ., 8836*. [4] Pray, D. et al. (2007), *CBET, 1147*. [5] Pravec, P., Harris, A.W. (2007), *Icarus*, 190, 250-259. [6] Pravec, P., Scheirich, P. (2012), *Planet. Space Sci.*, 73, 56-61. [7] Pravec, P. et al. (2012), *Icarus, 218*, 125-143. [8] Pray, D. et al. (2007), *CBET, 1143*. [9] Pikler, M. et al. (2007), *CBET, 860*. [10] Pravec, P. et al. (2005), *IAU Circ., 8609.* [11] Higgins, D. et al. (2008), *Minor Planet Bull., 35*, 173-175. [12] Pray, D. et al. (2005), *CBET, 328*.

Acknowledgements: In the first place, we thank our great collaborating photometric observers whose names can be found on the author lists of the papers cited. Without their observations, our knowledge of small main-belt asteroid systems would be much smaller. The work was supported by the Grant Agency of the Czech Republic, Grant P209-12-0229, by the Research Program LG12001 of the Czech Ministry of Education, and by Program RVO 67985815. Based on data collected with the Danish 1.54-m telescope at the ESO La Silla Observatory.