Astrometric Positions for 18 Irregular Satellites of Giant Planets from 23 Years of Observations

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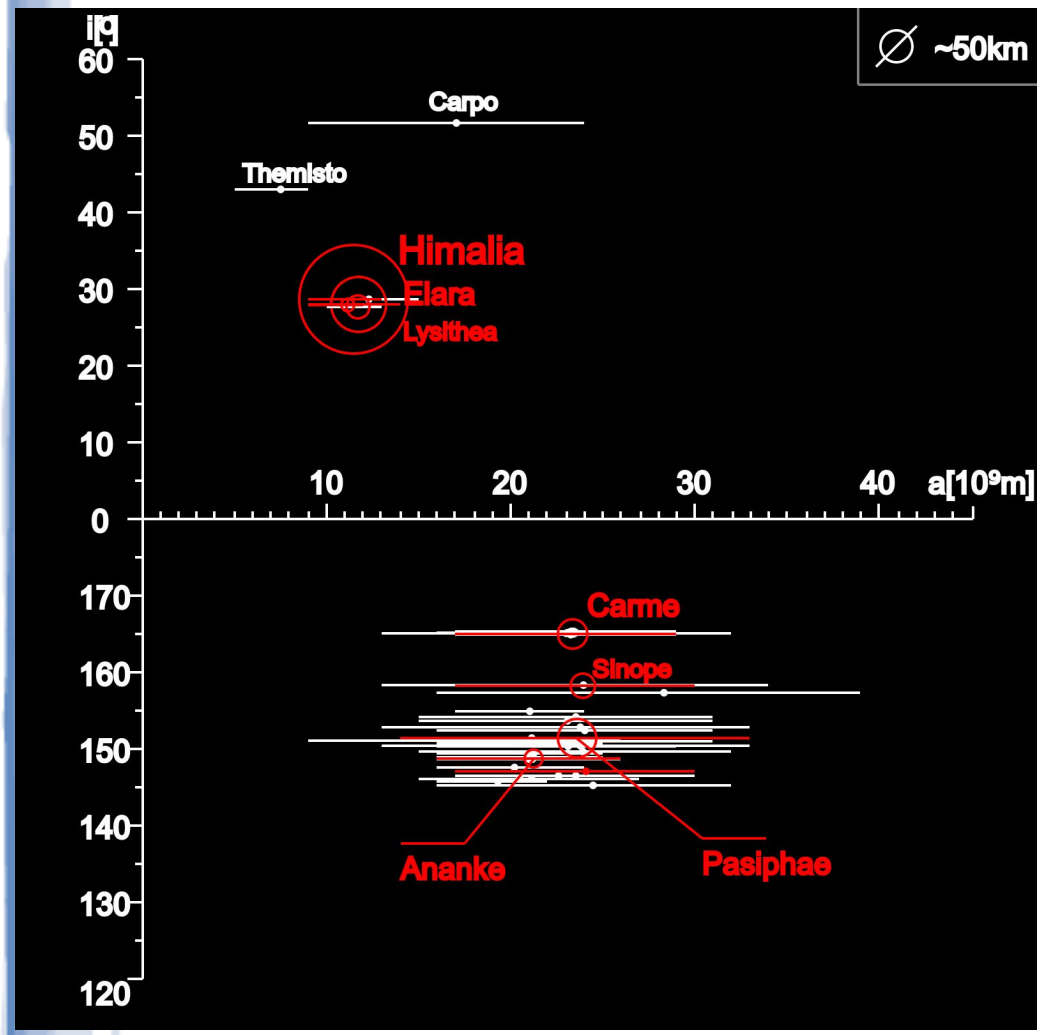
Irregular Satellites

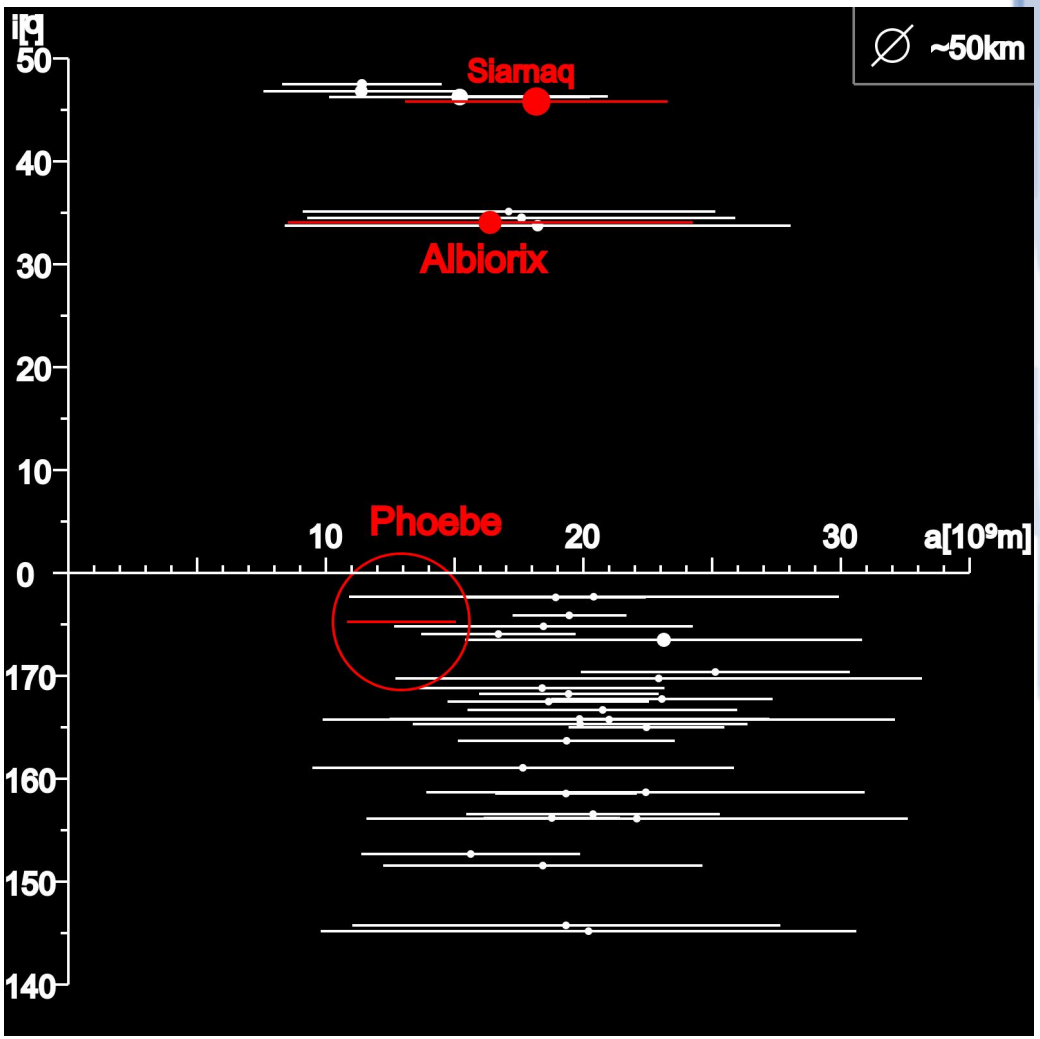
- Burns (1986): Satellites are irregular when their orbital planes precess primarily under the influence of torques from the Sun.

- Their orbits are eccentric, usually highly inclined and distant from their planets. The direction of their movements can be prograde or retrograde.

Irregular Satellites



Satellites of Jupiter



Satellites of Saturn

Irregular Satellites

- Capture:
  - Gas Drag (Cuk & Burns, 2003);
  - 3-body interation (Nesvorný et al., 2007);
  - Collision (Sheppard, 2006).

- Orbital Evolution:
  - Origin of the orbital family of satellites (Nesvorný et al., 2004);

Goal

- Organize and reduce three database with images of the irregular satellites of the giant planets observed between 1992 e 2014 at OPD, OHP e ESO.
- Obtain precise positions from these observations which can be used to:
  - New numerical integrations of the orbits of these satellites.
  - Predict and observe stellar occultations by these objects.

Observations

OPD (Itajubá) Telescopes

- 3 Telescopes: Perkin-Elmer (1.6m), Boller&Chivens (0.6m) and Zeiss (0.6m);
- 11 Detectors used;
- FOV: 5'x5' – 13'x13';
- Pixel Scale: 0.176" – 0.702";
- Filters used: Clear, U, B, V, R, I;
- 5248 observations (1992-2014).

OHP Telescope

- Aperture of 1.2m;
- CCD 1024x1024 pixel;
- Pixel scale of 0.69";
- FOV of 12'x12';
- Filters used: V, R, I;
- 2408 observations (1998-2008).

ESO Telescope

- 2.2m Max-Planck Telescope;
- Wide Field Imager Detector with 8 CCDs;
- The size of each CCD is 2k x 4k pixel with a pixel scale of 0.238”;
- Each CCD has a FOV of 7.5'x15';
- The filter used was a broad-band R filter (ESO#844) with $\lambda c = 651.725$ nm and $\Delta\lambda = 162.184$ nm;
- 810 observations (2007-2009).

Reduction Process

- Bias and flat-field calibration.
- PRAIA (Assafin et al., 2011):
  - Extract data of the header of the images;
  - Detect objects in the image (x, y);
  - Identify catalogue reference stars;
    - UCAC4
  - Obtain (α,δ) from gnomonic projection;
  - Global Reduction (Assafin et al., 2012) for the mosaic CCDs;
  - Identify targets in the images.
    - JPL ephemeris.

Astrometry

Telescope	Mean errors σ_α mas	σ_δ mas	UCAC4 stars
PE(OPD)	52±27	49±26	17
B&C (OPD)	56±10	55±10	36
Zeiss (OPD)	58±7	57±5	82
OHP	50±10	49±10	44
ESO	28±6	28±6	531

Mean errors are the standard deviations in the (O−C) residuals from (α, δ) reductions with the UCAC4 catalog.

RESULTS

Results

Satellite	Number of Positions OPD	OHP	ESO	Total	Jacobson*
Himalia	854	357	23	1234	1757
Elara	403	187	46	636	1115
Lysithea	60	84	90	234	431
Leda	6	48	44	98	178
Pasiphae	295	248	66	609	1629
Callirrhoe	9	-	16	25	95
Megaclite	-	-	10	10	50
Ananke	52	141	57	250	600
Praxidike	-	-	2	2	59
Carme	90	204	37	331	973
Sinope	41	169	11	221	854
Themisto	-	-	16	16	55

* Jacobson, R. A. et al, 2012, The Astronomical Journal

Results

	Number of positions				
Satellite	OPD	OHP	ESO	Total	Jacobson*
Phoebe	1239	516	32	1787	3479
Siarnaq	–	20	56	76	239
Paaliaq	–	–	11	11	82
Albiorix	–	–	46	46	137
Sycorax	–	–	35	35	237
Nereid	803	–	99	902	716

* Jacobson, R. A. et al, 2012, The Astronomical Journal

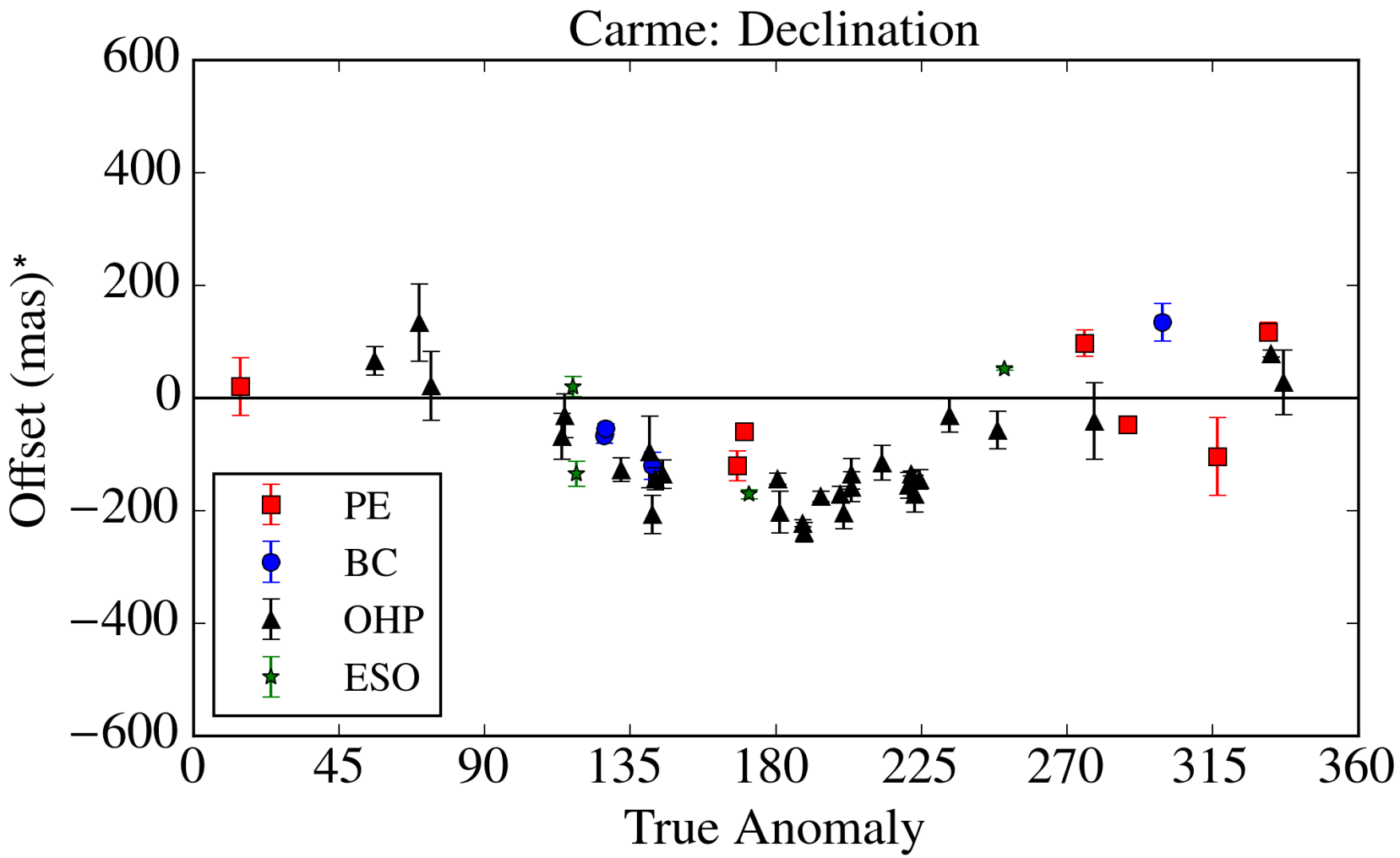
Results - Offsets

Satellite	OPD N	OPD $\Delta\alpha*$ mas	OPD $\Delta\delta$ mas	OHP N	OHP $\Delta\alpha*$ mas	OHP $\Delta\delta$ mas	ESO N	ESO $\Delta\alpha*$ mas	ESO $\Delta\delta$ mas
Himalia	854	-23±116	-16± 50	357	-10± 53	-0± 59	23	-49± 78	7± 47
Elara	403	23±102	-65± 67	187	4± 61	-40± 64	46	80± 81	6± 80
Lysithea	60	86± 90	-27± 79	84	-9± 81	-63± 58	90	63± 80	-32± 85
Leda	6	55±143	-100± 67	48	-10±115	-46± 74	44	146± 38	43± 89
Pasiphae	295	3±141	-86± 86	248	-62±109	-82± 86	66	83± 68	-87± 80
Callirrhoe	9	-5± 63	81± 33	-	-	-	16	225± 28	45± 33
Megaclite	-	-	-	-	-	-	10	-82± 50	62± 33
Ananke	52	-5± 95	-130±137	141	51±109	-88±101	57	154±143	-122± 24
Praxidike	-	-	-	-	-	-	2	-288± 6	-247± 27
Carme	90	-50± 79	-27±103	204	8±122	-101± 94	37	71± 89	-108± 75
Sinope	41	269±142	-63± 70	169	-48±204	-27± 82	11	2±188	-24± 46
Themisto	-	-	-	-	-	-	16	-684±549	610± 24
Phoebe	1239	6± 58	-23± 67	516	-4± 39	-1± 38	32	-32± 86	-45± 59
Siarnaq	-	-	-	20	-64± 79	-205±101	56	-39± 62	-123± 59
Paaliaq	-	-	-	-	-	-	11	468±238	-202± 68
Albiorix	-	-	-	-	-	-	46	152± 69	-296± 53
Sycorax	-	-	-	-	-	-	35	-27±136	-59± 81
Nereid	803	26±128	-28± 97	-	-	-	99	34±124	-42± 69

N: Number of positions

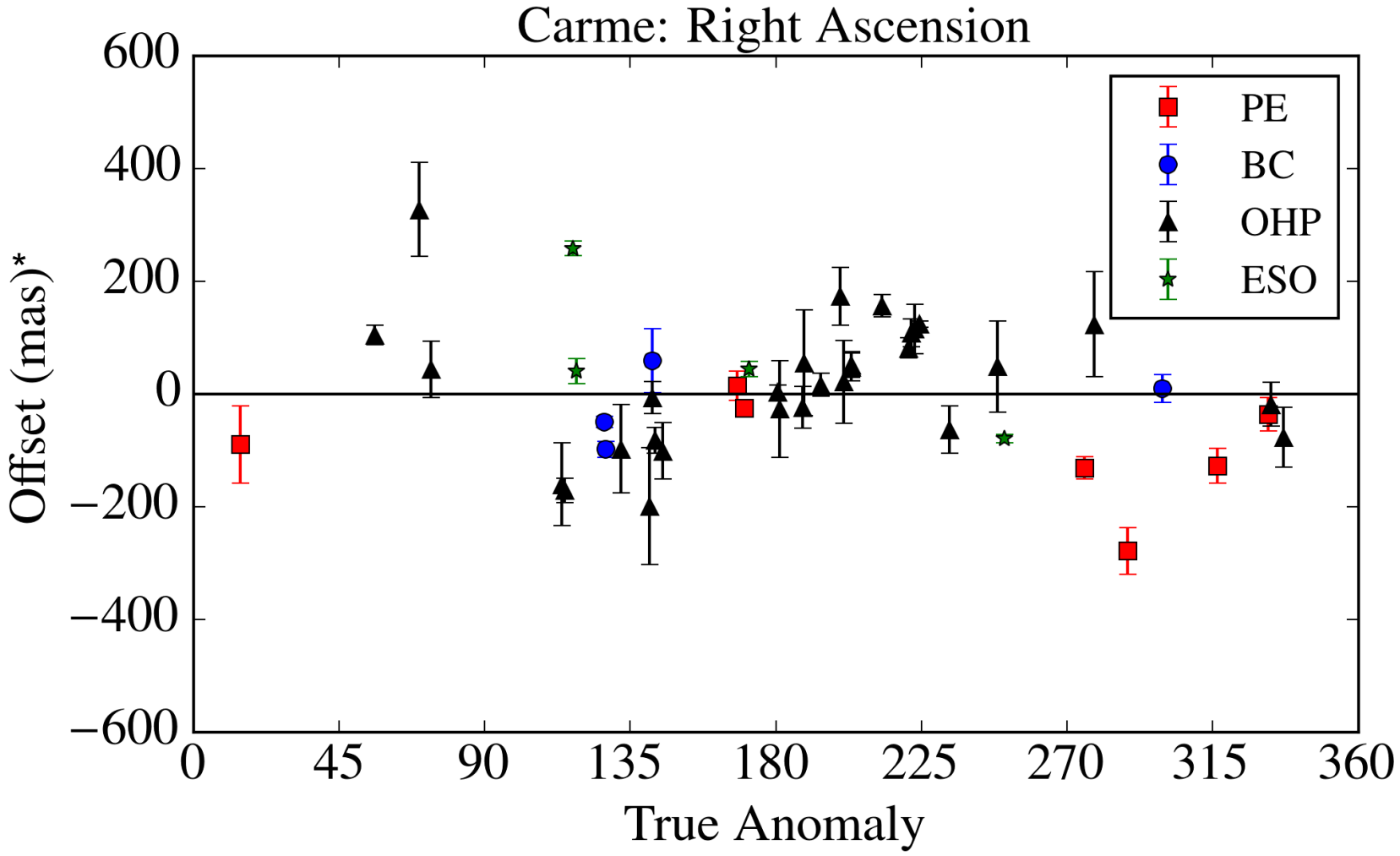
$\Delta\alpha^* = \Delta\alpha \cos\delta$

Results - Carme



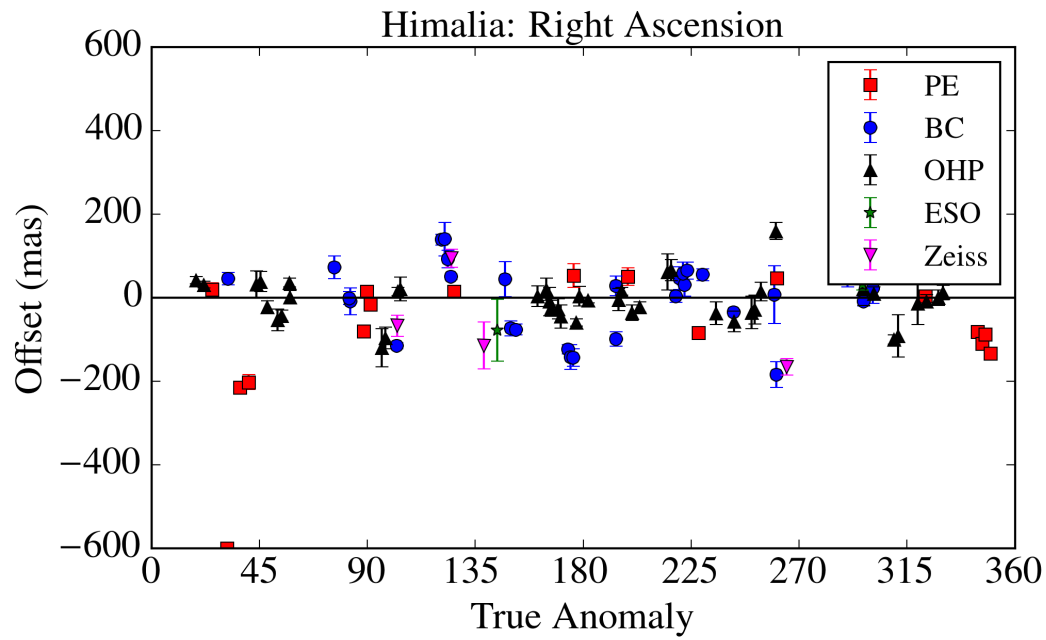
* Relative to JPL jup300 ephemeris

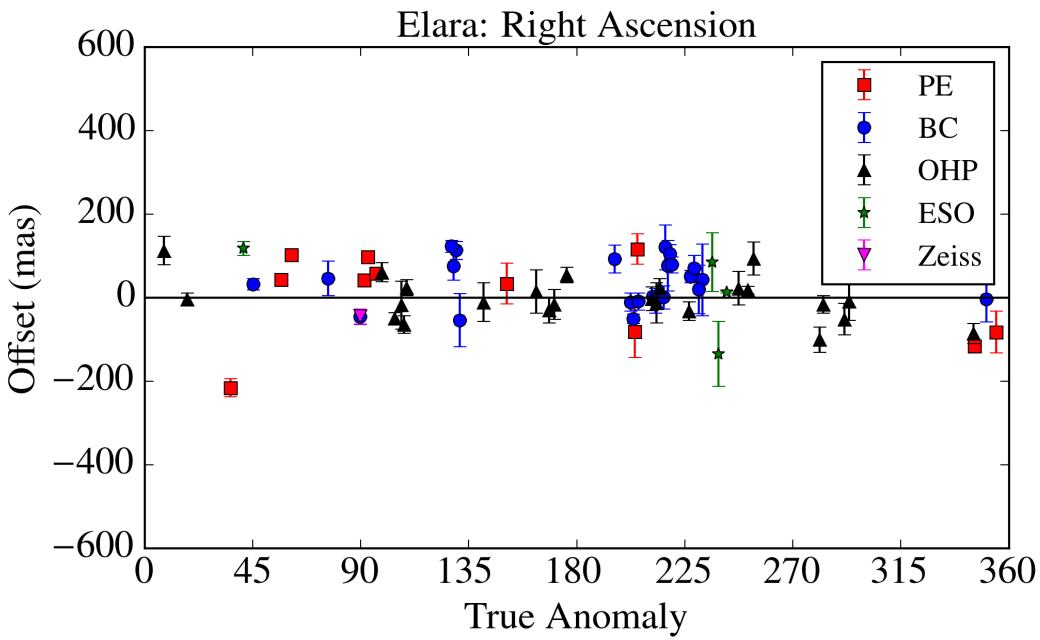
Results - Carme

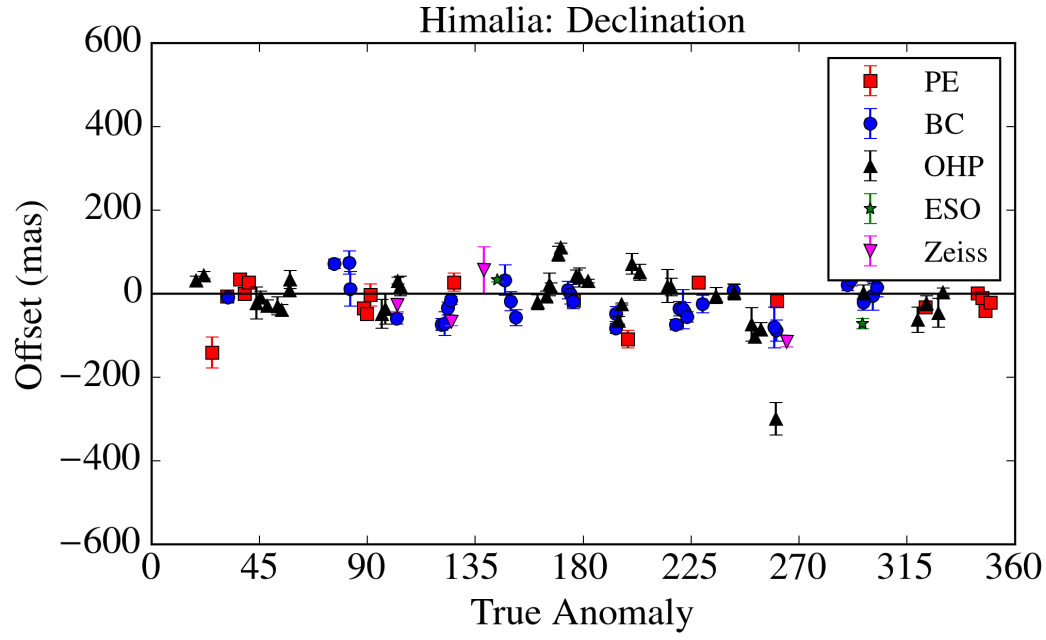


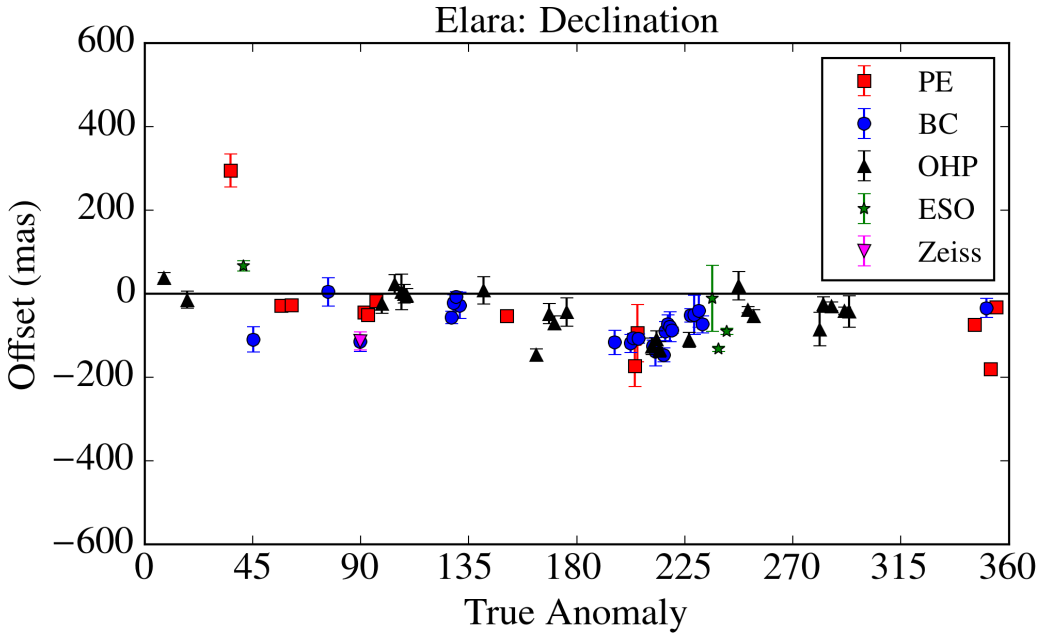
* Relative to JPL jup300 ephemeris

Results – Himalia and Elara

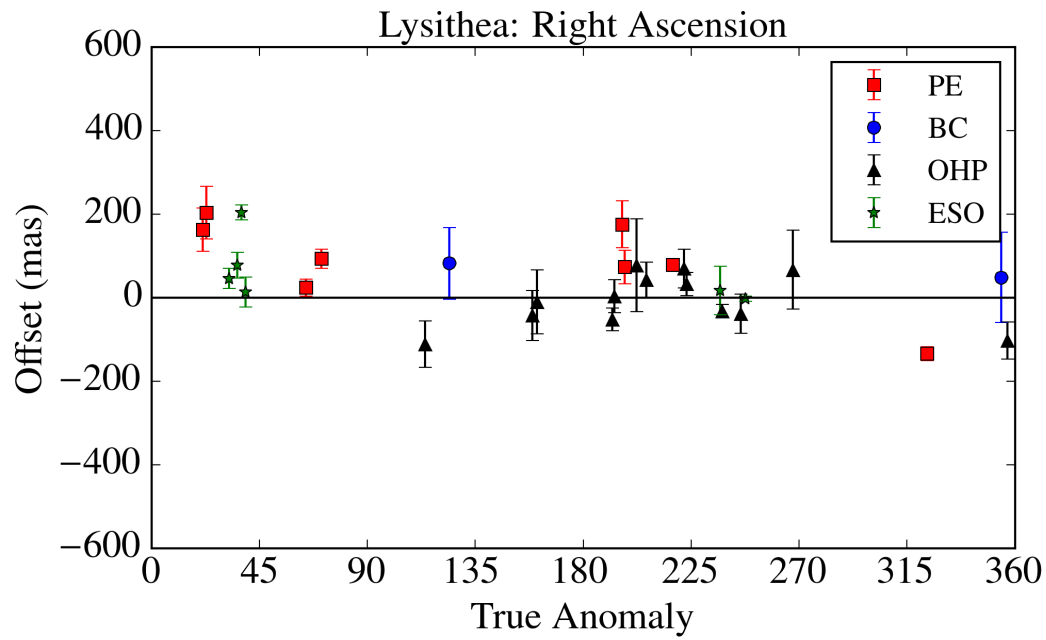


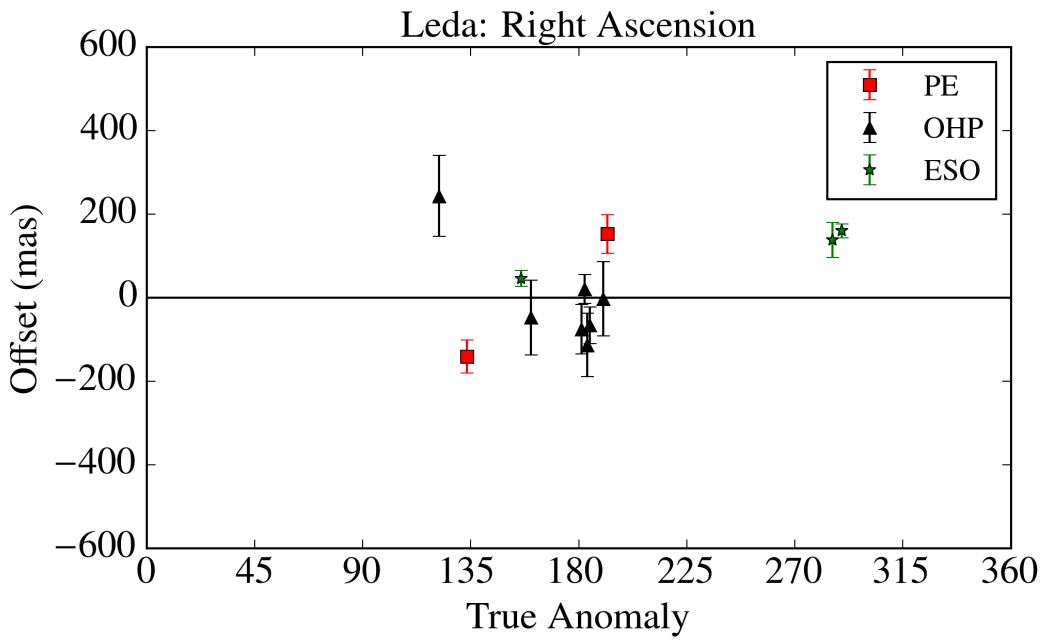


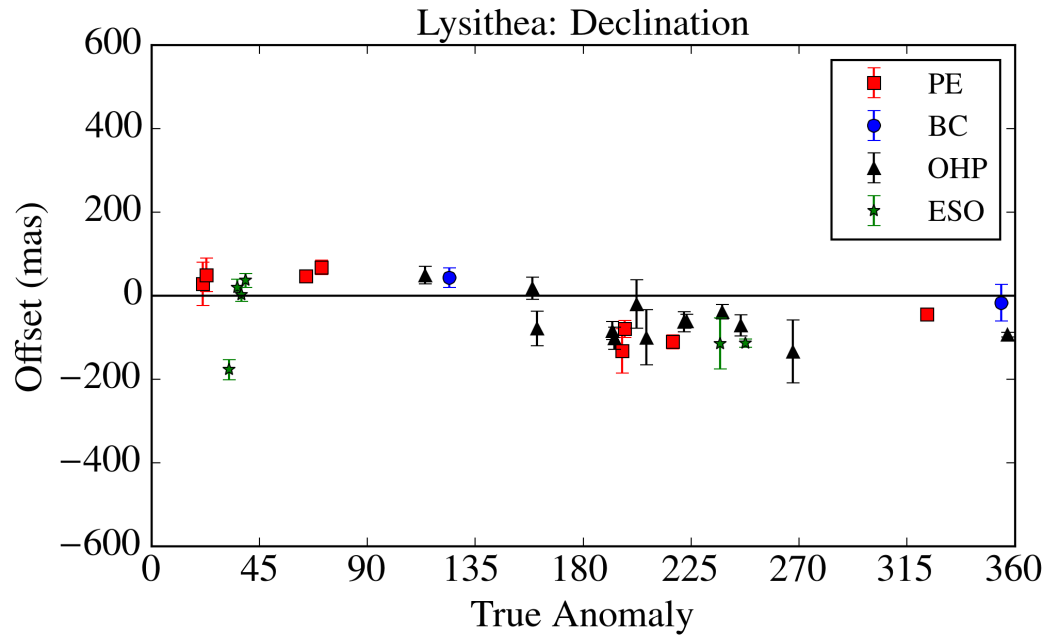


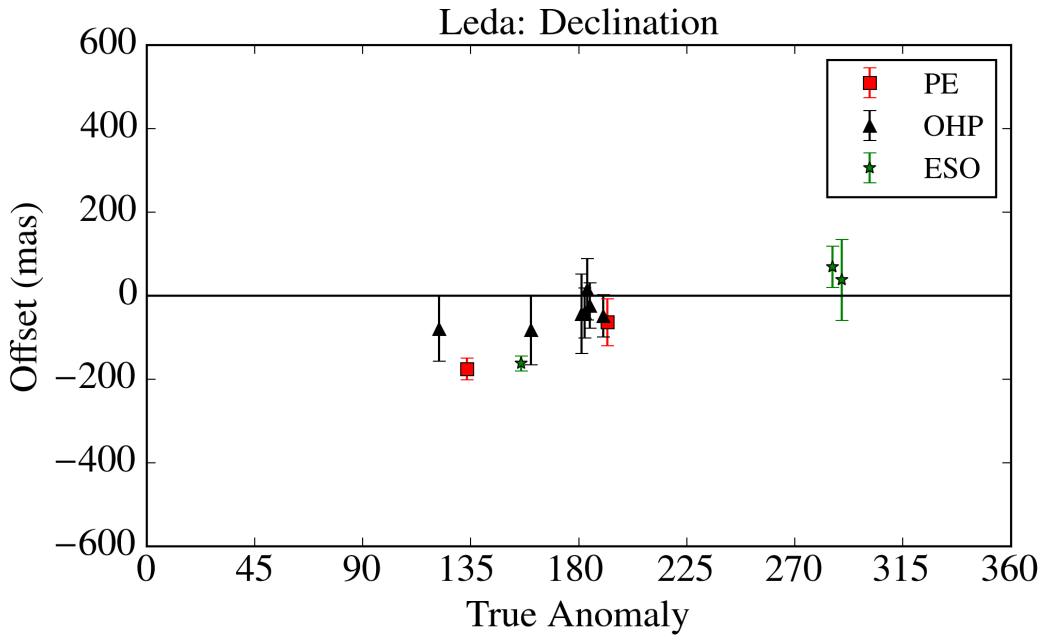


Results – Lysithea and Leda

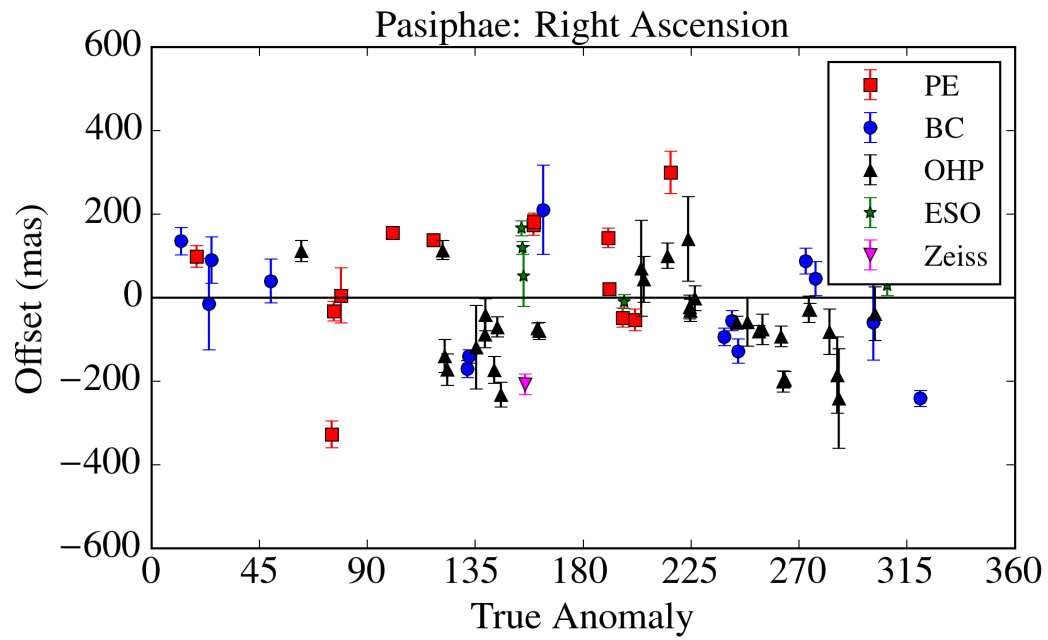


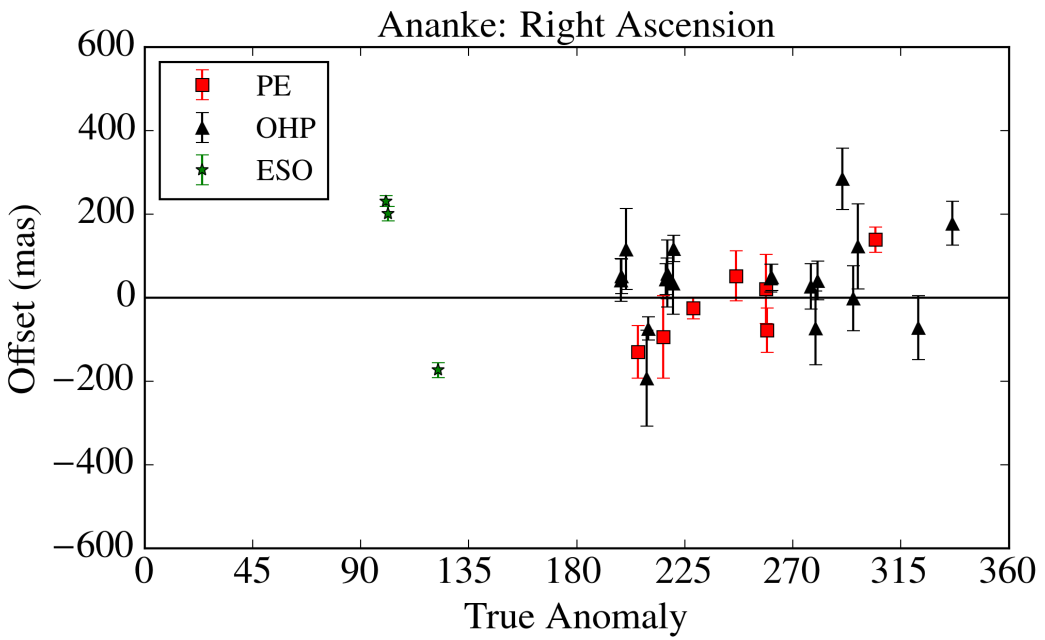


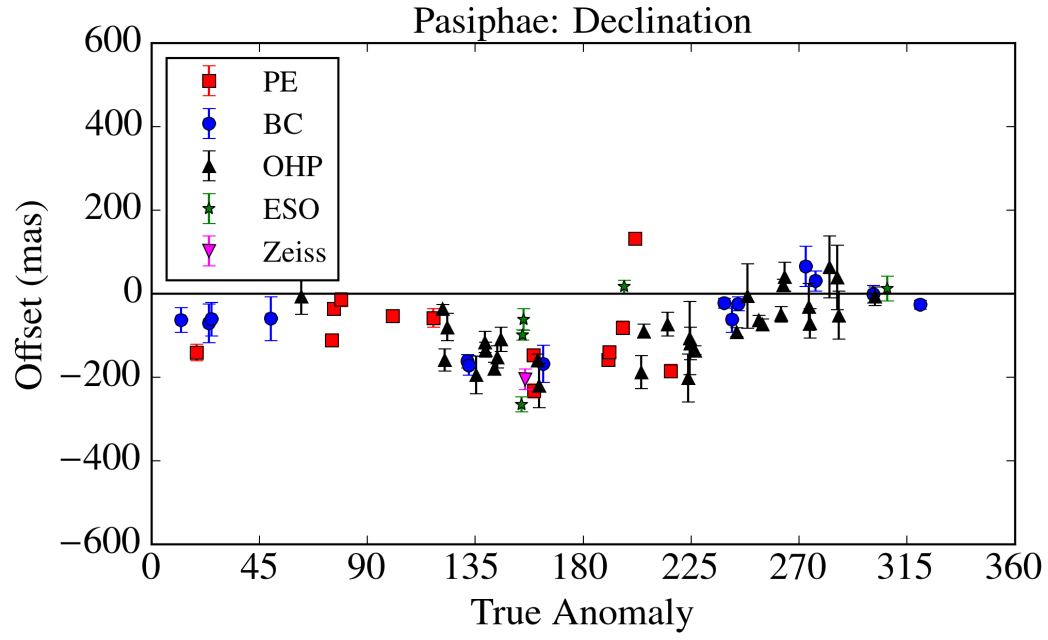


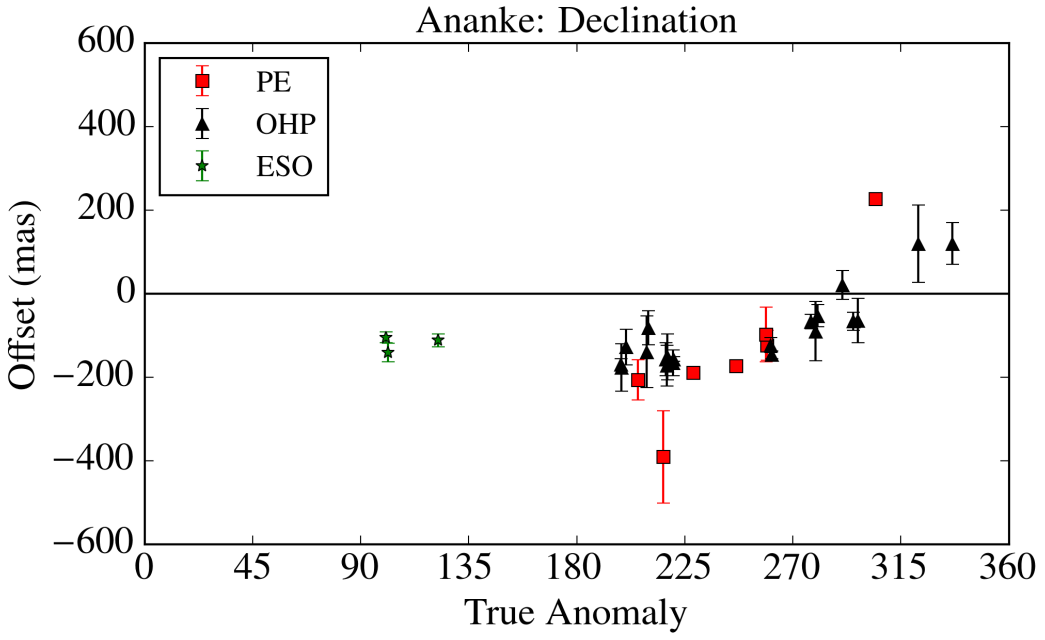


Results – Pasiphae and Ananke

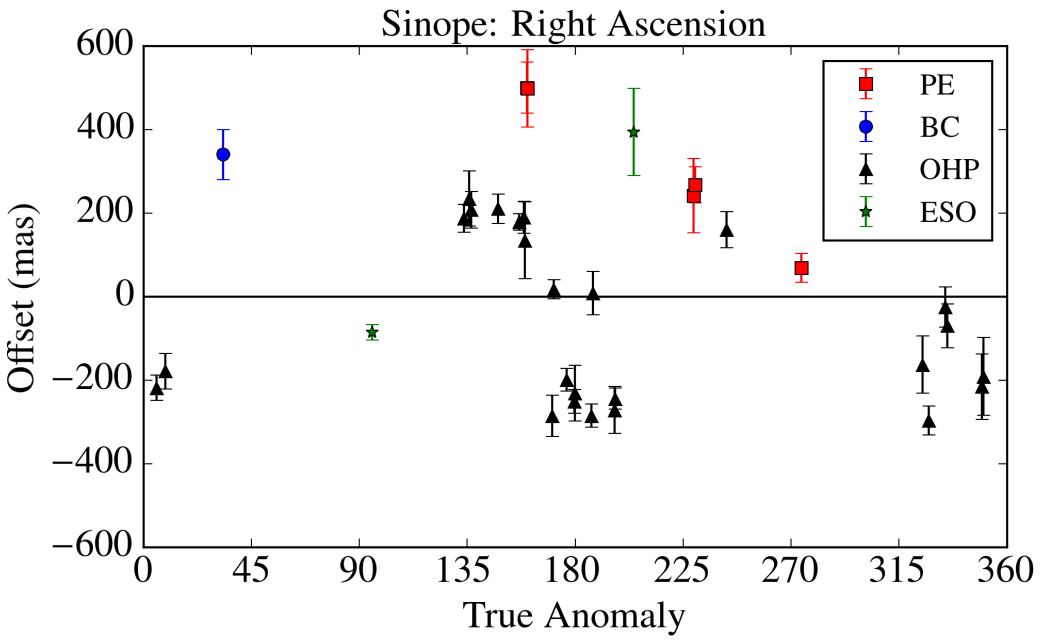


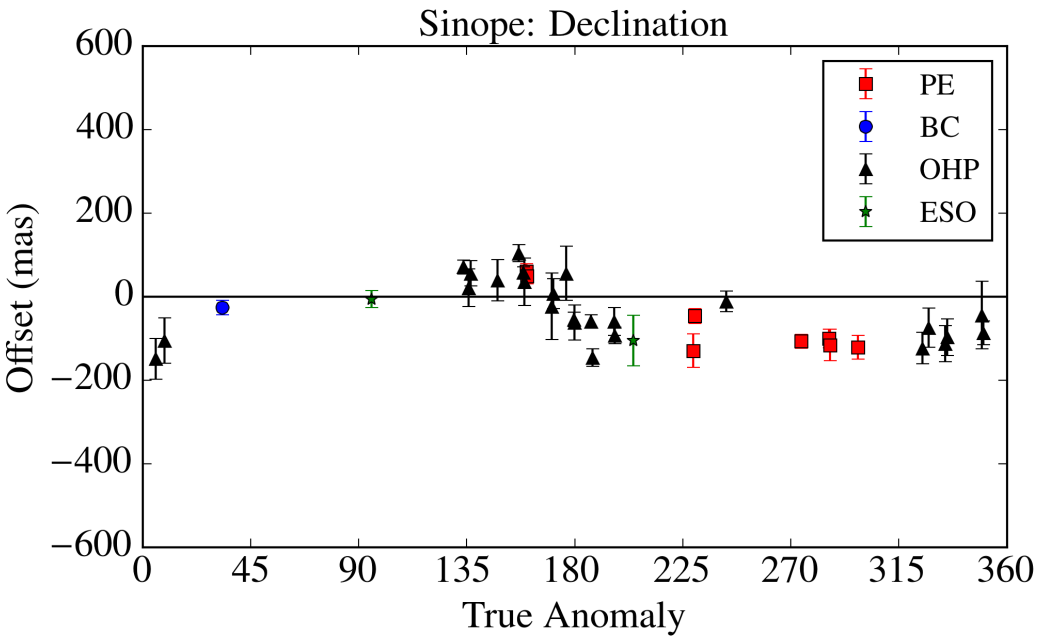




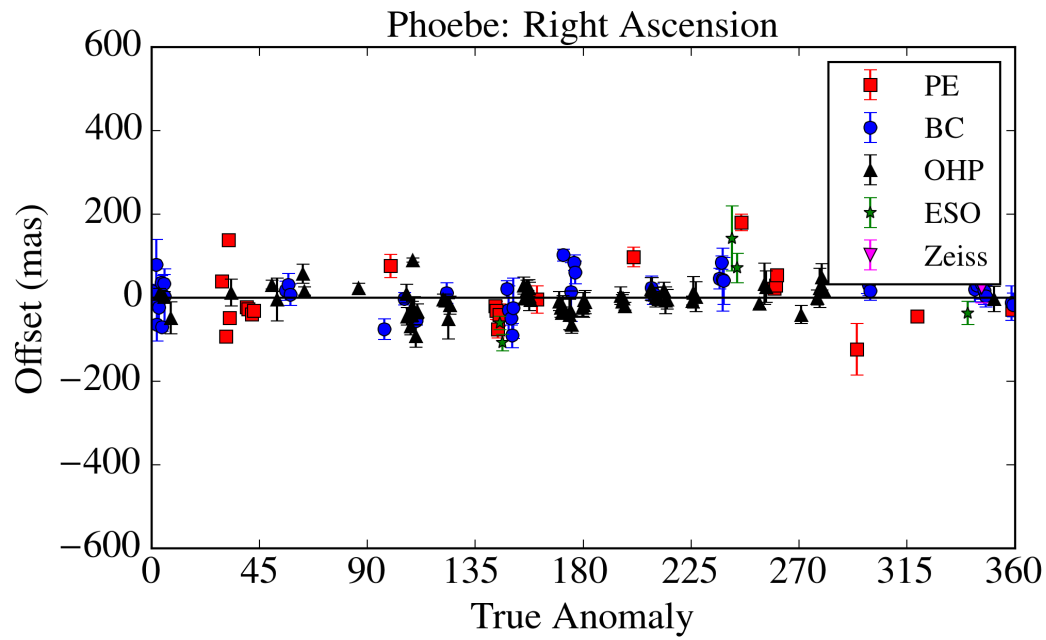


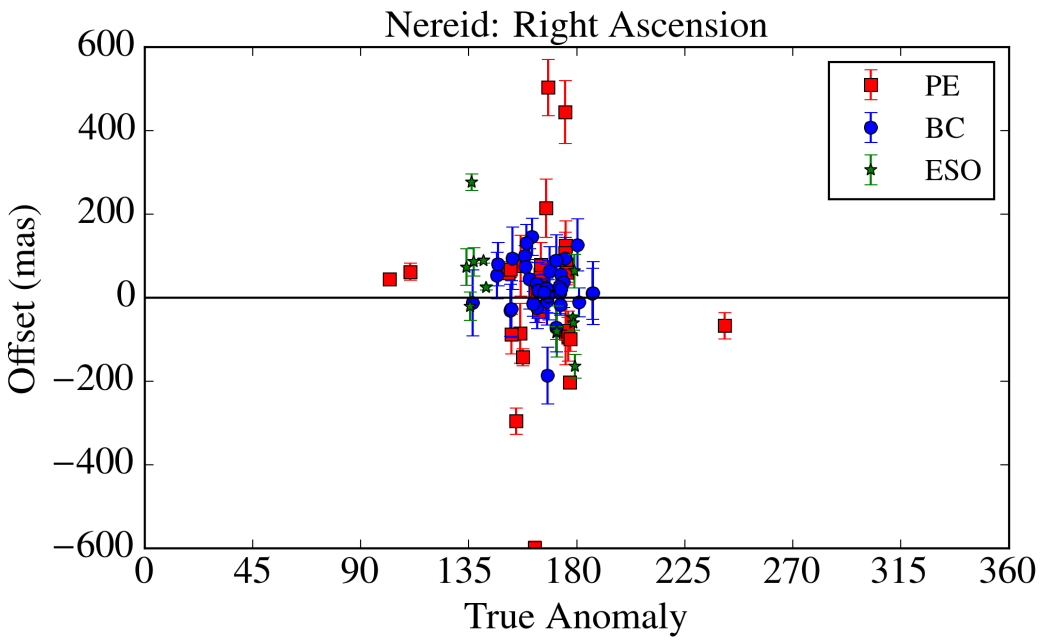
Results -Sinope

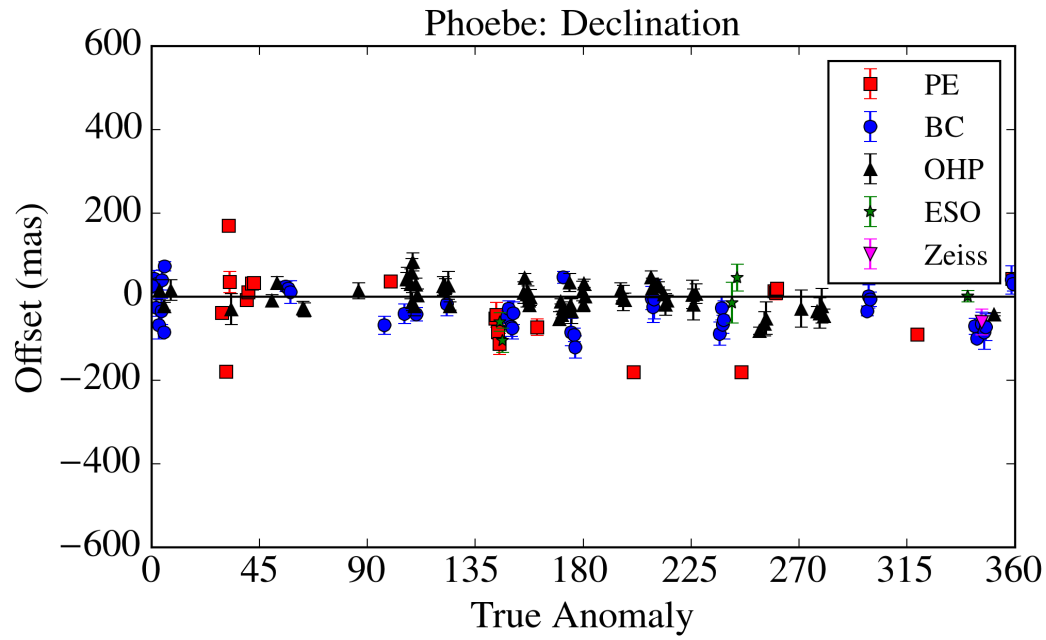


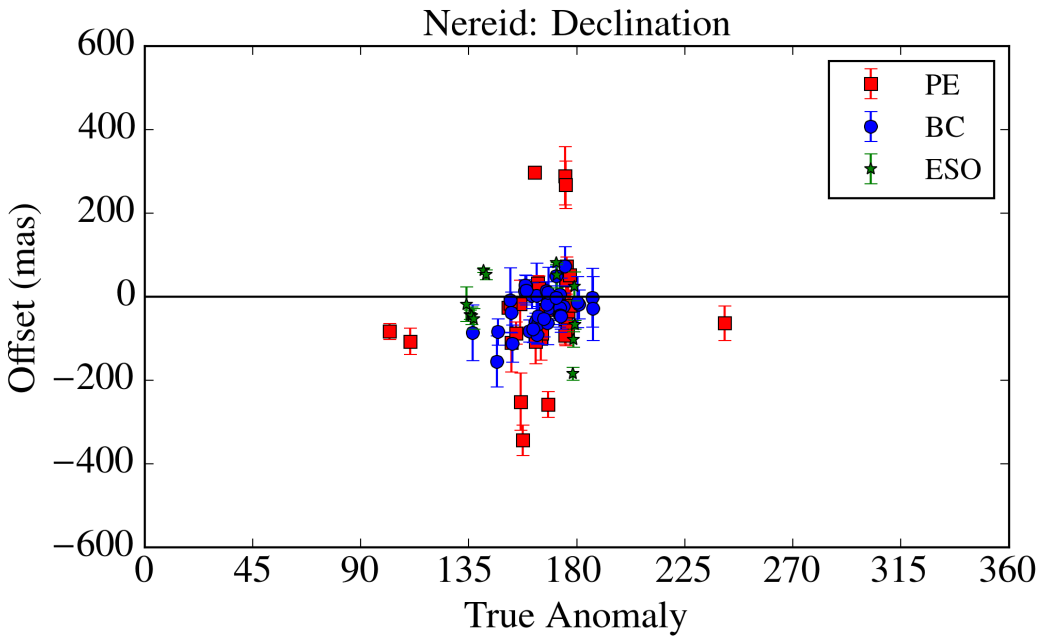


Results – Phoebe and Nereid









Conclusion

- We identified 8466 observations of irregular satellites, from which we obtained 6523 suitable astrometric positions.
- Position errors estimated of about 60-80 mas depending on brightness.
- All positions are available at the CDS

Results

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Astronomy & Astrophysics

Astrometric positions for 18 irregular satellites of giant planets from 23 years of observations⋆,⋆⋆,⋆⋆⋆,⋆⋆⋆⋆

A. R. Gomes-Júnior[1], M. Assafin[1,4], R. Vieira-Martins[1,2,3,4], J.-E. Arlot[4], J. I. B. Camargo[2,3], F. Braga-Ribas[2,5], D. N. da Silva Neto[6], A. H. Andrei[1,2,4], A. Dias-Oliveira[2], B. E. Morgado[1], G. Benedetti-Rossi[2], Y. Duchemin[4,7], J. Desmars[4], V. Lainey[4], and W. Thuillot[4]

Next Steps

- Numerical Integration of the orbits of the Irregular Satellites.
- Predict and observe stellar occultations by these objects.
- Re-reduce the observations with GAIA catalogue.

Thank You