On the Uncertainty of Asteroidal Occultation Predictions in the (Pre-) Gaia Era

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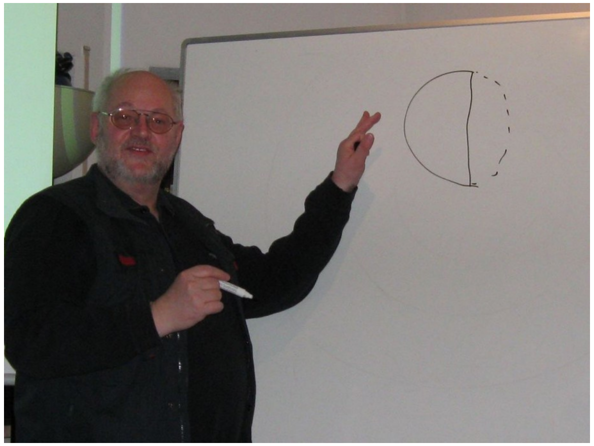
ESOP XXV, Guilford, UK
August 19-23, 2016

In Memoriam

Alfons Gabel

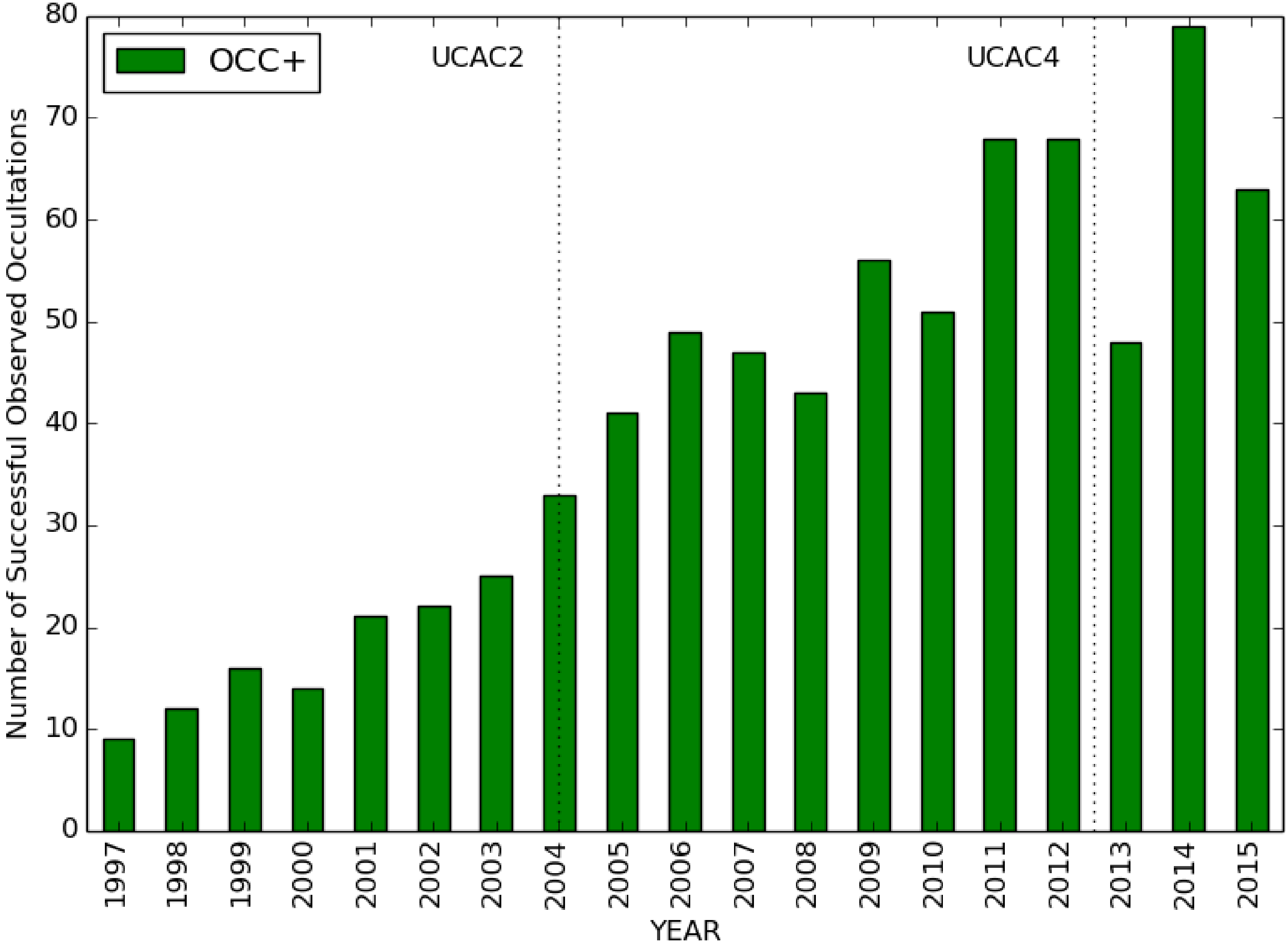
1952 – 2016



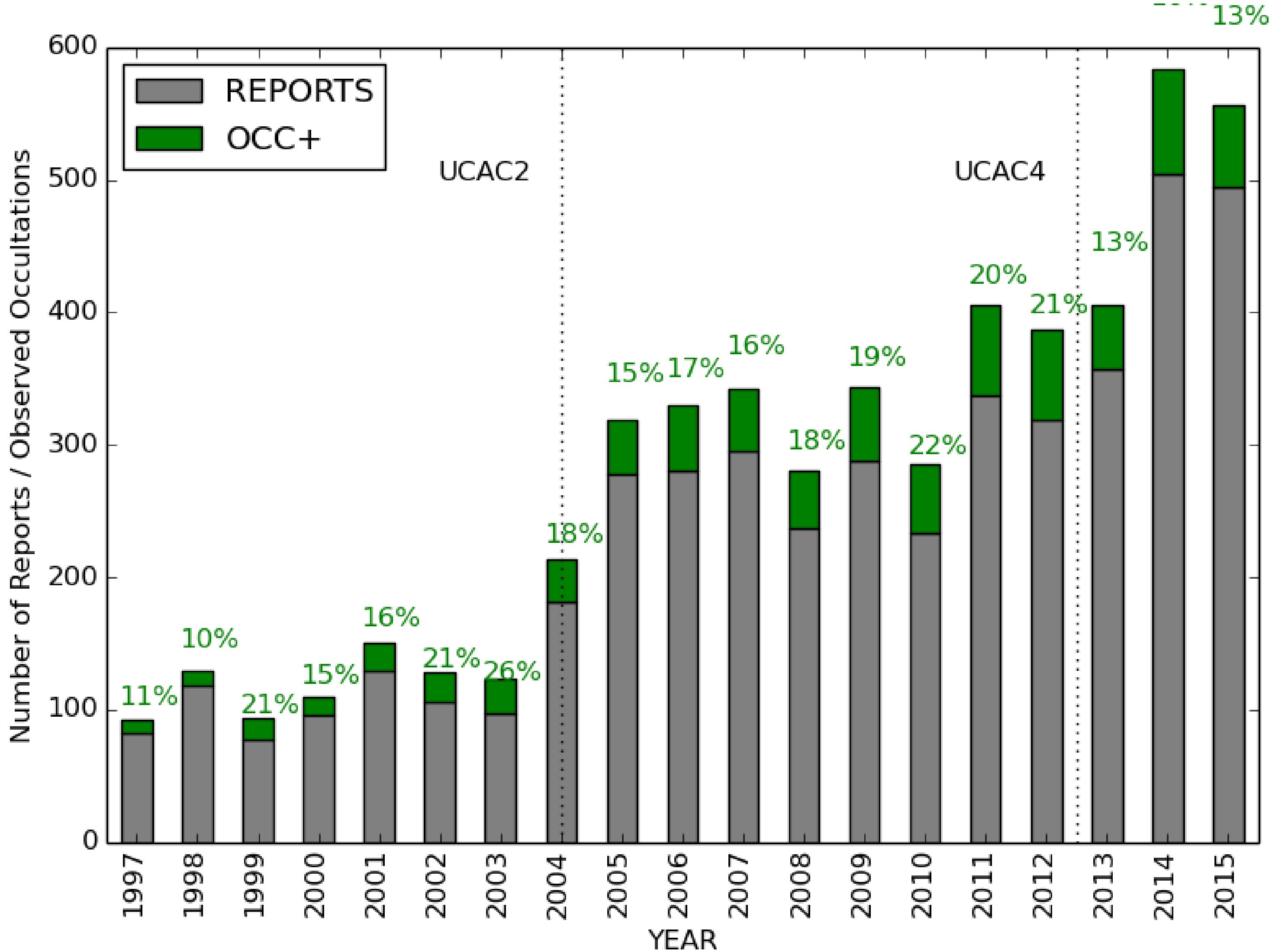
Ottó Faragó

1960 – 2016

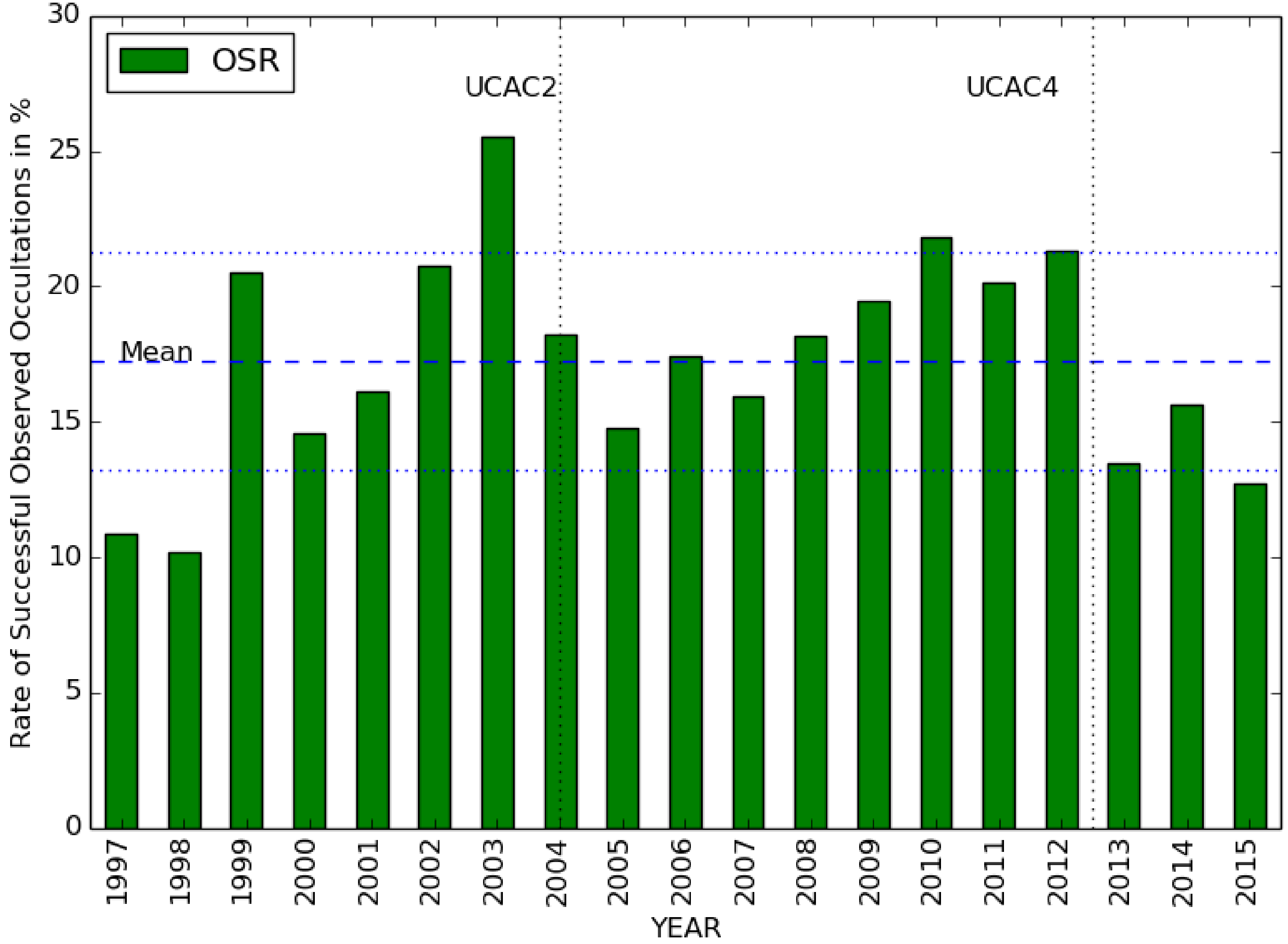
Occultation Success Rate



Occultation Success Rate



Occultation Success Rate



OCC+ rate for individuals
(http://occult.kretlow.de/occrep/)

Asteroidal Occultation Reports Database

Home (Observations) | Results and Lists | Informations and Credits | Home (Predictions) | Top (Mike Kretlow)

Results | Incomplete Reports | LC Candidates | Observers Activity Report | Annual Statistics | Star Catalog Statistics | Top-20 List

Top 20 List

Rank	Object (total)	Object (O+)	Observer (total)	Observer (O+)	Country (total)	Country (O+)
1	(472) Roma (233)	(345) Tercidina (78)	E. Frappa/A. Klotz (1081 | ISR = 8%)	E. Frappa/A. Klotz (85 | ISR = 8%)	FR (2945)	FR (468)
2	(420) Bertholda (147)	(420) Bertholda (77)	Stefano Sposetti (437 | ISR = 10%)	Jean Lecacheux (53 | ISR = 20%)	ES (1737)	DE (297)
3	(345) Tercidina (100)	(472) Roma (59)	Gerhard Dangl (351 | ISR = 9%)	Stefano Sposetti (45 | ISR = 10%)	DE (1399)	ES (270)
4	(925) Alphonsina (89)	(U III) Titania (55)	Carles Schnabel (340 | ISR = 11%)	Carles Schnabel (37 | ISR = 11%)	UK (891)	IT (151)
5	(41) Daphne (82)	(41) Daphne (43)	Jean Lecacheux (267 | ISR = 20%)	Joan Rovira (35 | ISR = 29%)	IT (801)	CZ (140)
6	(39) Laetitia (71)	(216) Kleopatra (40)	C. Perello/A. Selva (242 | ISR = 10%)	Gerhard Dangl (32 | ISR = 9%)	CZ (800)	CH (120)
7	(409) Aspasia (63)	(925) Alphonsina (37)	Tomas Janik (236 | ISR = 6%)	Oscar Canales (26 | ISR = 22%)	NL (784)	UK (118)
8	(U III) Titania (61)	(9) Metis (34)	Wolfgang Rothe (224 | ISR = 11%)	Wolfgang Rothe (25 | ISR = 11%)	CH (704)	NL (91)
9	(423) Diotima (59)	(409) Aspasia (30)	Harrie Rutten (184 | ISR = 8%)	C. Perello/A. Selva (25 | ISR = 10%)	BE (436)	BE (65)
10	(9) Metis (54)	(144) Vibilia (25)	Jan-Maarten Winkel (169 | ISR = 12%)	Jan-Maarten Winkel (20 | ISR = 12%)	AT (408)	SK (53)
11	(216) Kleopatra (52)	(423) Diotima (24)	Henk De Groot (162 | ISR = 12%)	Henk De Groot (19 | ISR = 12%)	PL (313)	CL (52)
12	(50000) Quaoar (49)	(39) Laetitia (23)	Simone Bolzoni (161 | ISR = 9%)	Pietro Baruffetti (19 | ISR = 13%)	SK (171)	AT (44)
13	(554) Peraga (47)	(85) Io (21)	Oernulf Midtskogen (149 | ISR = 2%)	Alberto Ossola (18 | ISR = 35%)	NO (156)	US (40)
14	(791) Ani (47)	(51) Nemausa (20)	Pietro Baruffetti (146 | ISR = 13%)	F. Van Den Abbeel (18 | ISR = 19%)	PT (132)	PT (32)
15	(773) Irmintraud (46)	(275) Sapientia (19)	Patrick Degrelle (120 | ISR = 6%)	Eberhard Bredner (17 | ISR = 49%)	RU (122)	RU (29)
16	(85) Io (45)	(87) Sylvia (18)	Oscar Canales (119 | ISR = 22%)	Eric Frappa (17 | ISR = 40%)	BY (85)	PL (23)
17	(121) Hermione (45)	(308) Polyxo (17)	Joan Rovira (119 | ISR = 29%)	Jan Manek (16 | ISR = 31%)	HU (70)	GR (21)
18	(144) Vibilia (42)	(17) Thetis (17)	Hilari Pallares (118 | ISR = 5%)	Zdenek Moravec (16 | ISR = 20%)	US (68)	SE (21)
19	(87) Sylvia (41)	(554) Peraga (16)	Henk Bulder (118 | ISR = 11%)	Tim Haymes (16 | ISR = 14%)	GR (67)	JP (13)
20	(712) Boliviana (40)	(372) Palma (16)	Tim Haymes (117 | ISR = 14%)	Tomas Janik (15 | ISR = 6%)	CL (57)	UA (13)

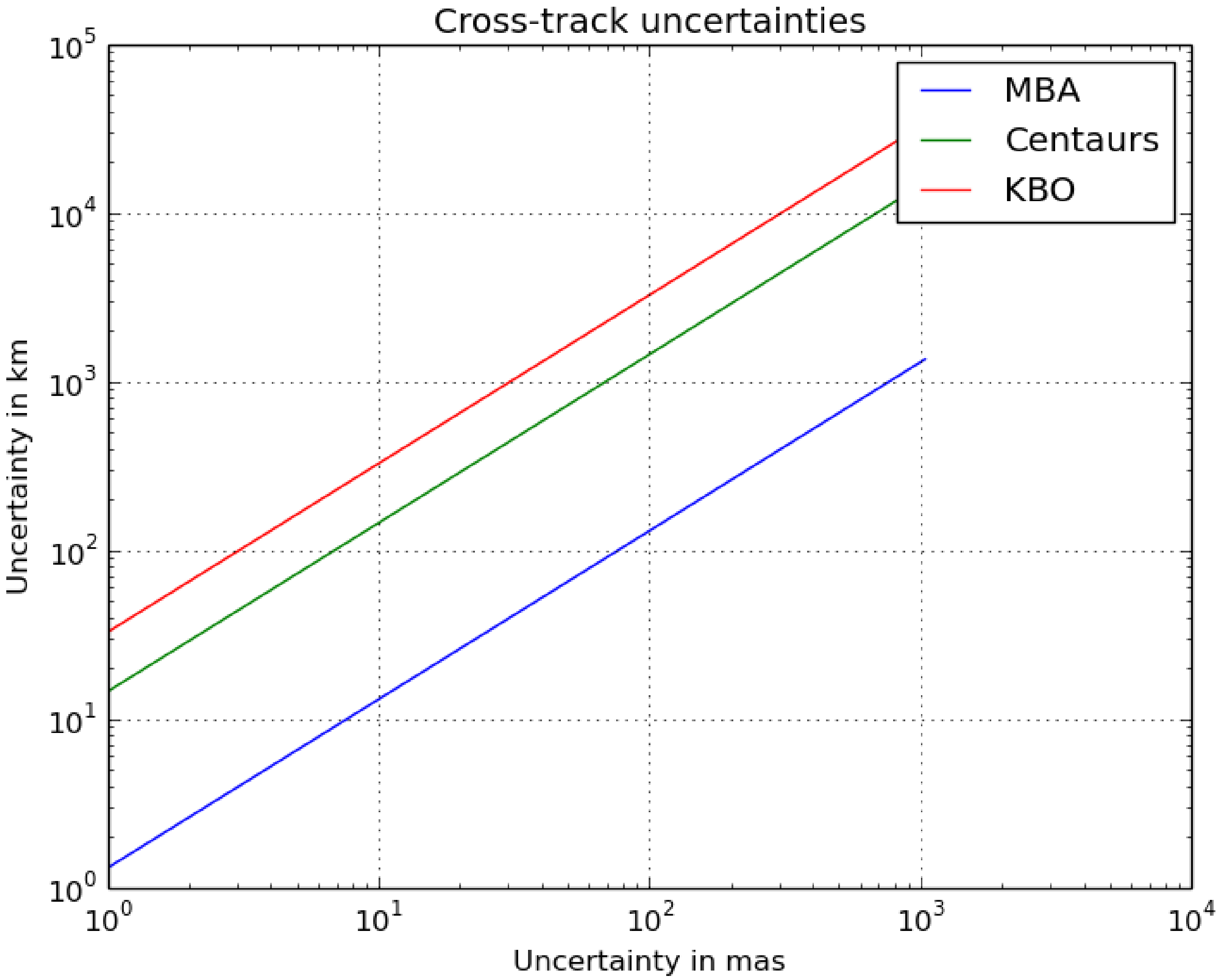
ISR = O+ / total, i.e. the 'individual success rate' in percent (Note).
For observers only the db field 'observer' is considered, not observer mentioned in the 'comment field'.
If the name has different notations, this is not considered (e.g. 'E. Hubble' and 'Edwin Hubble' doesn't count twice).

Post-Hipparcos (Pre-Gaia) Era

- Typical uncertainty for current star positions:
  - URAT1 : < ~ 50 mas
  - UCAC4: < ~100 mas

- Typical ephemeris uncertainty for MBA's: Anything from ~30...500 mas (dedicated updated orbit solutions typically < 50 mas)

Cross-track uncertainties

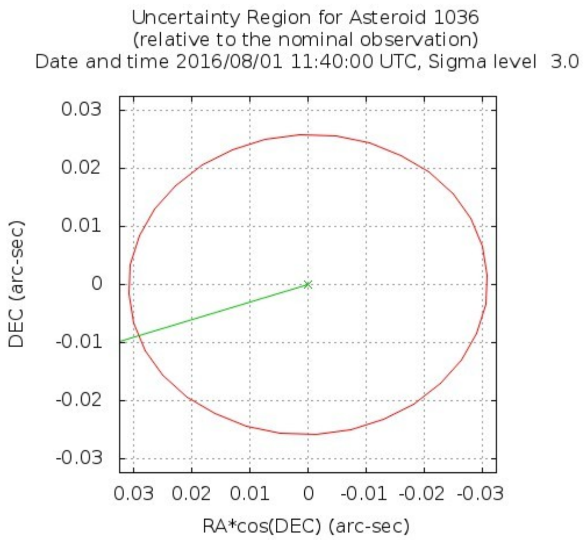


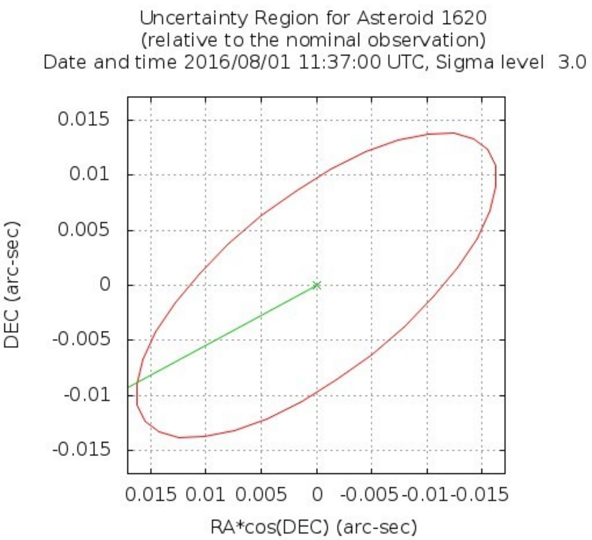
Ephemeris uncertainties: CEU

astorb.dat contains information about the accuracy of the orbit, **CEU :** current ephemeris uncertainty.

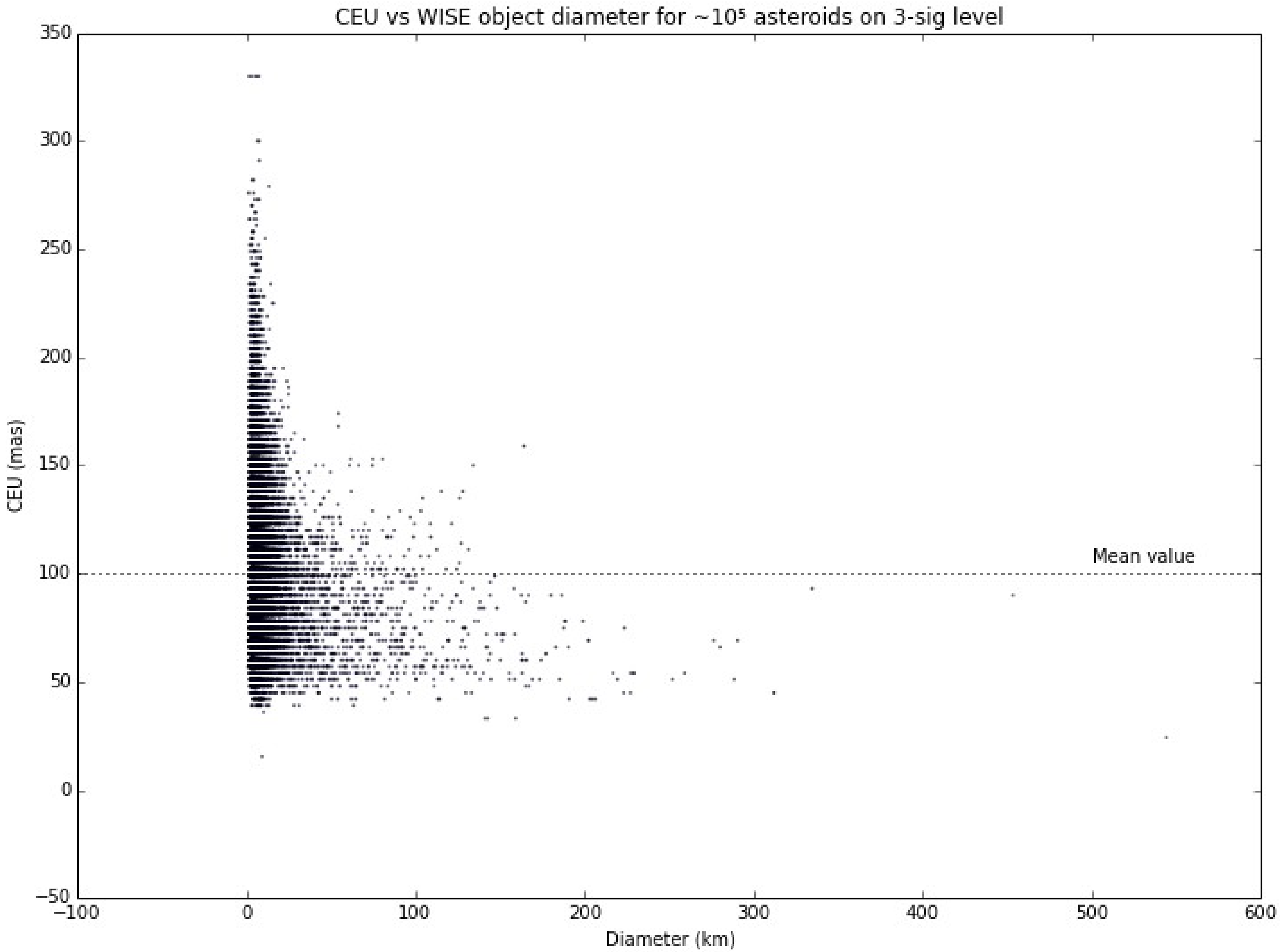
- CEU gives the length of the major axis of the uncertainty ellipse (1-sig level).
- The axis is usually lying on the line of variation => major part of uncertainty in event time, not in cross-track component (good !).

CEU >> angular diameter Θ of the asteroids means low prediction accuracy (i.e. low occultation probability for the observer).

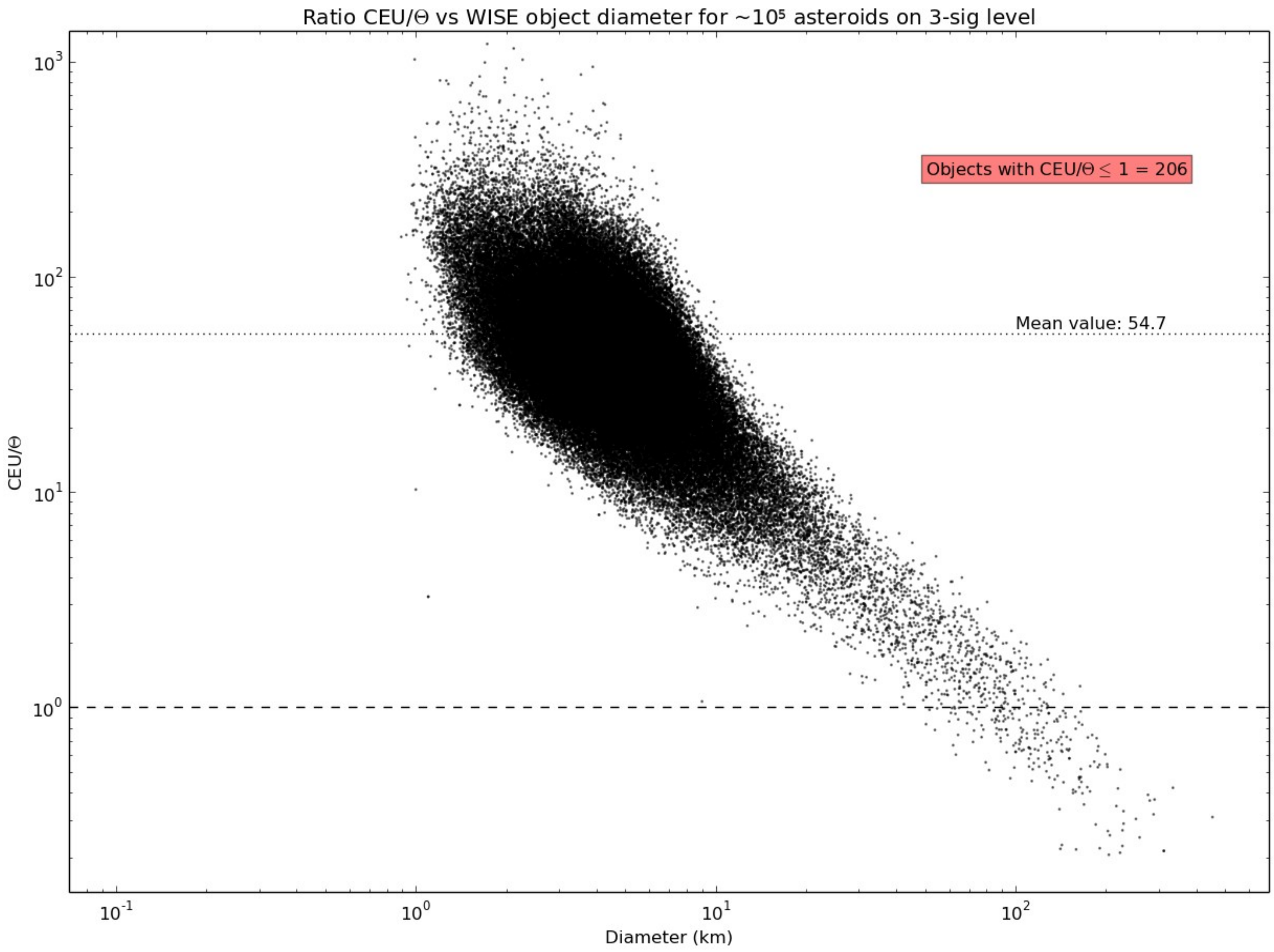




Ephemeris uncertainties



Ephemeris uncertainties



Ephemeris uncertainties

Asteroid astrometric observations are

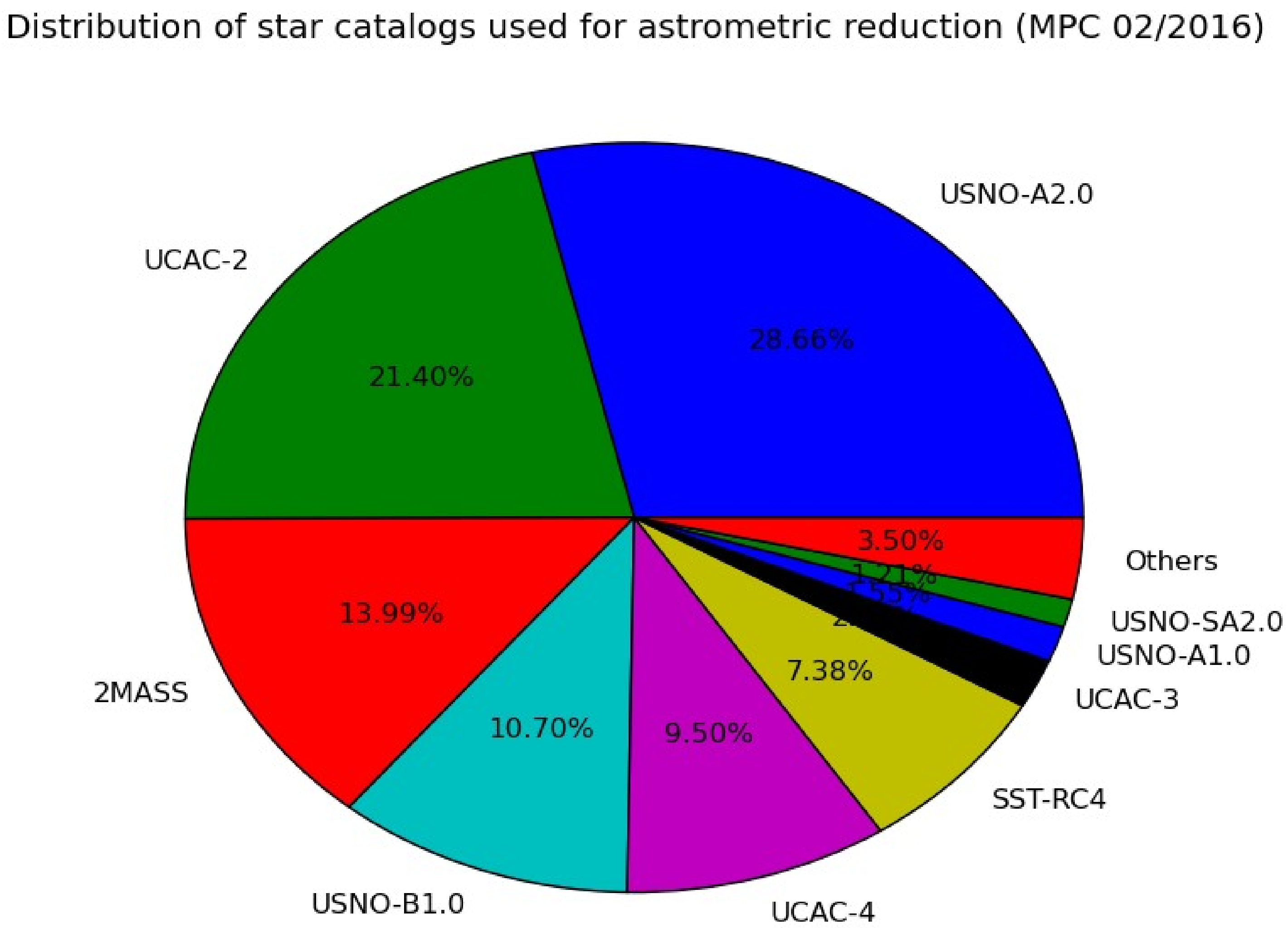
- influenced and limited in their accuracy by the observation process itself (instruments etc.).
- limited by the star catalogue accuracy, and
- biased due to systematic errors in the star cataloges used to reduce the astrometry (Carpino et al. 2003).

Ephemeris uncertainties

Pan-STARRS PS1 is one of the most accurate asteroid surveys with an astrometric quality of the order of 0.1" (100 mas).

Nevertheless, Milani et al. (2012) found that Pan-STARRS PS1 data have surprisingly high biases on the order of 0.05–0.1” with a strong regional dependence.

Astrometric observations



Total: 141,758,509

Systematic catalogue differences

Procedure:

- Select a „reference“ catalogue.
- For each catalogue cross identify all stars common in both catalogues.
- Compute difference in position (and proper motion).

Two Micron All Sky Survey (2MASS):

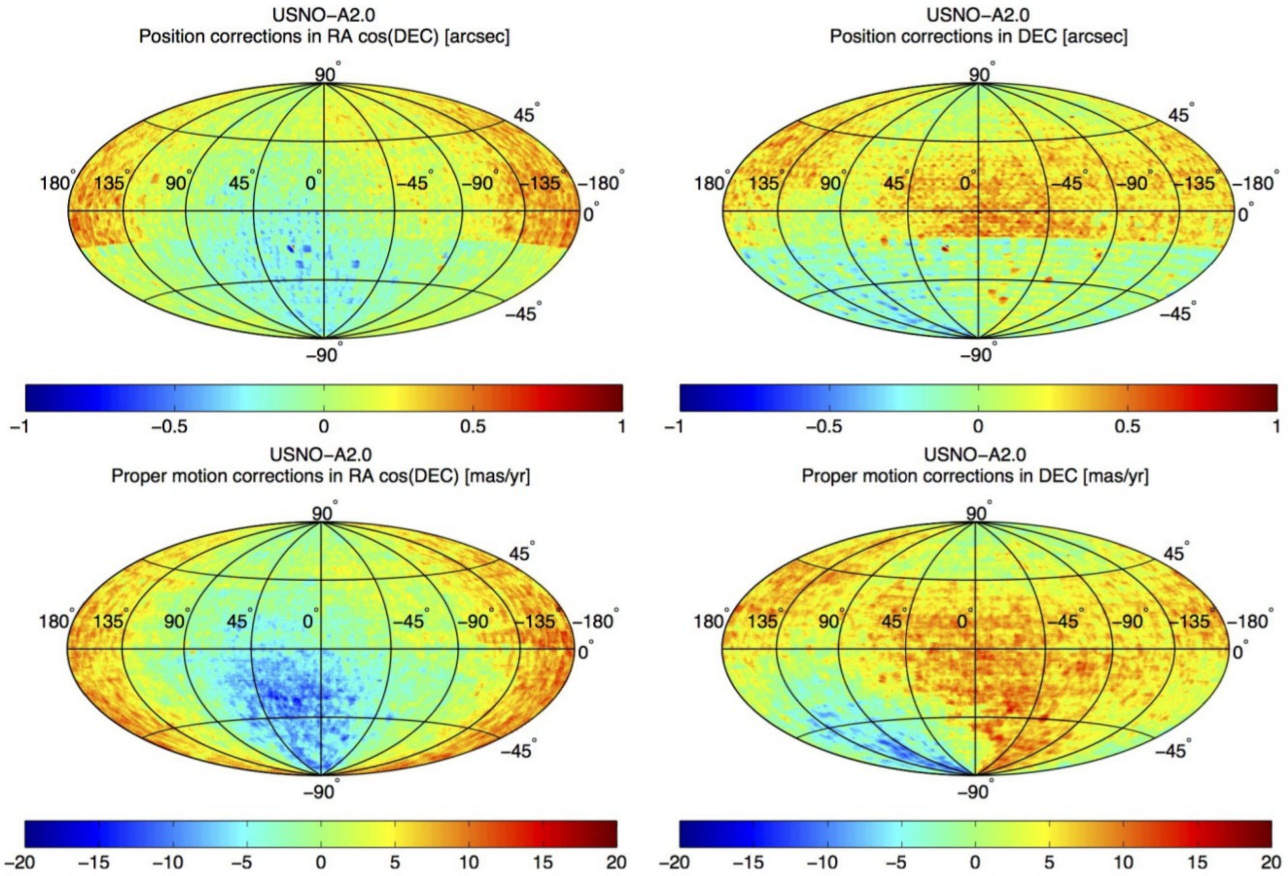
- All-Sky, deep and dense („complete“). ~471 Mio. point sources.
- Rather good accuracy at epoch J2000: 100mas wrt to HIP/TYC2.
- But no proper motions ! Solution: take them from PPMXL

Systematic catalogue differences

Catalog	$\overline{\Delta \mathrm{RA}}_{2000}$ [arcsec]	$\overline{\Delta \mathrm{DEC}}_{2000}$ [arcsec]	PM inc.	$\overline{\Delta \mu}_{\mathrm{RA}}$ [mas/yr]	$\overline{\Delta \mu}_{\mathrm{DEC}}$ [mas/yr]	Sky coverage
Tycho-2	0.02	0.02	Yes	0.7	0.7	100%
ACT	0.02	0.02	Yes	1.5	1.4	100%
2MASS	0.03	0.02	No	5.8	6.4	100%
USNO-A1.0	0.45	0.37	No	5.1	5.7	100%
USNO-SA1.0	0.45	0.37	No	5.0	5.5	100%
USNO-A2.0	0.21	0.24	No	5.1	5.7	100%
USNO-SA2.0	0.21	0.24	No	5.0	5.6	100%
USNO-B1.0	0.12	0.17	Yes	4.4	4.9	100%
UCAC-1	0.03	0.03	Yes	5.8	7.4	39%
UCAC-2	0.01	0.01	Yes	2.5	2.2	88%
UCAC-3	0.02	0.02	Yes	5.0	4.6	100%
UCAC-4	0.02	0.02	Yes	2.2	2.5	100%
GSC-1.1	0.47	0.38	No	6.8	6.6	100%
GSC-1.2	0.20	0.18	No	6.7	6.6	100%
GSC-ACT	0.15	0.13	No	6.7	6.6	100%
NOMAD	0.10	0.15	Yes	3.7	4.3	100%
PPM	0.23	0.24	Yes	4.1	4.2	100%
CMC-14	0.03	0.04	No	6.3	7.0	62%
SDSS-DR7	0.05	0.07	Yes	2.6	3.2	31%

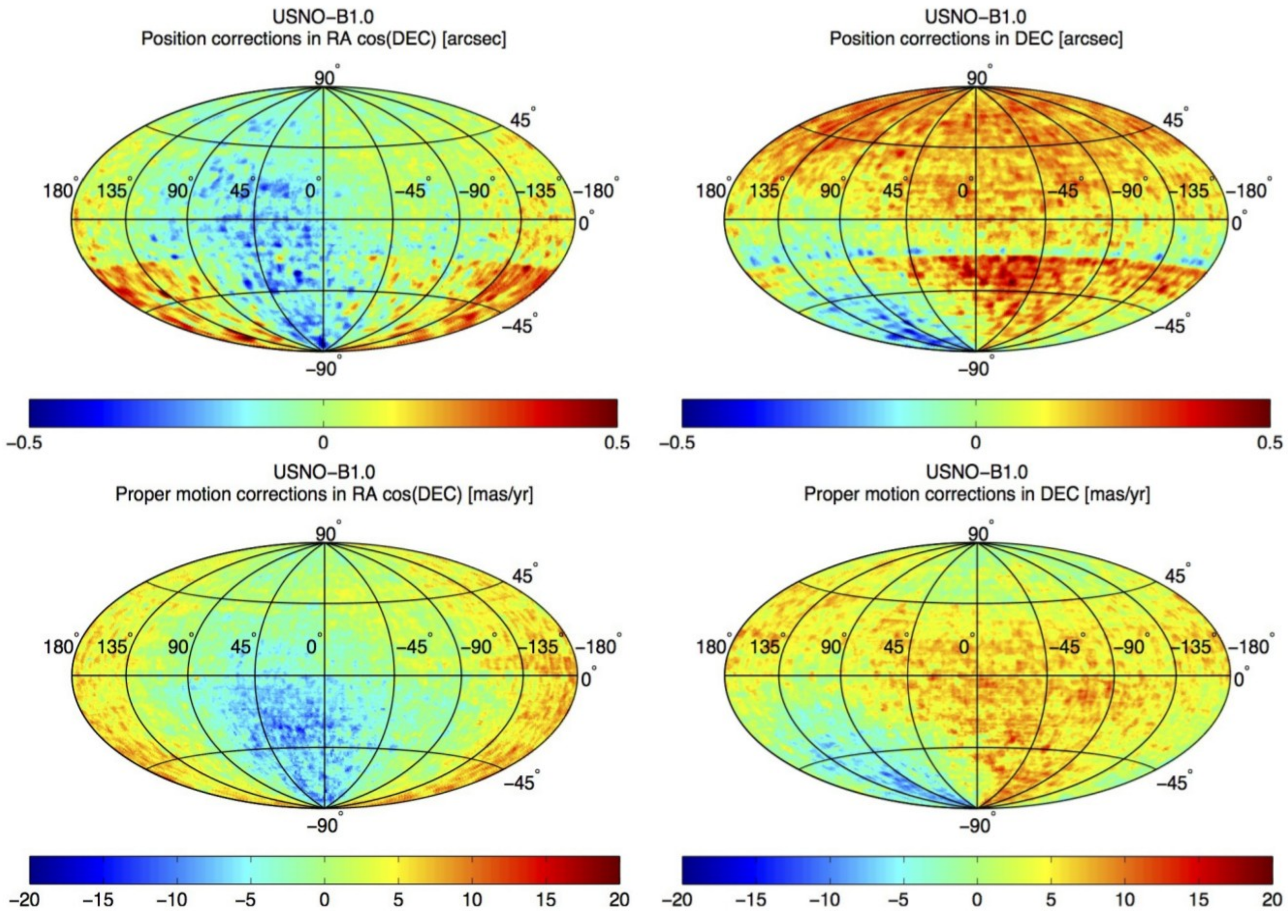
Farnocchia et al., 2014

Systematic catalogue differences

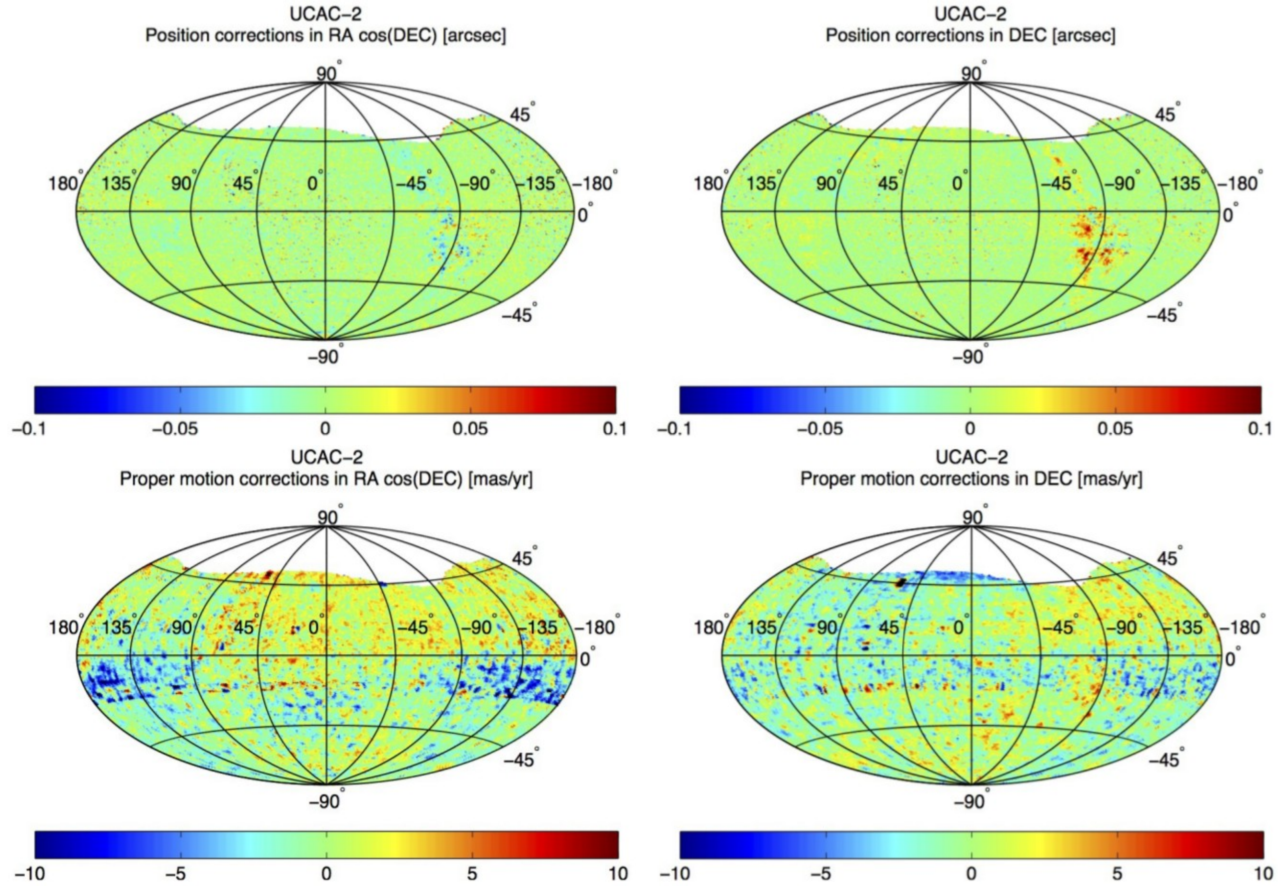


Farnocchia et al., 2014

Systematic catalogue differences

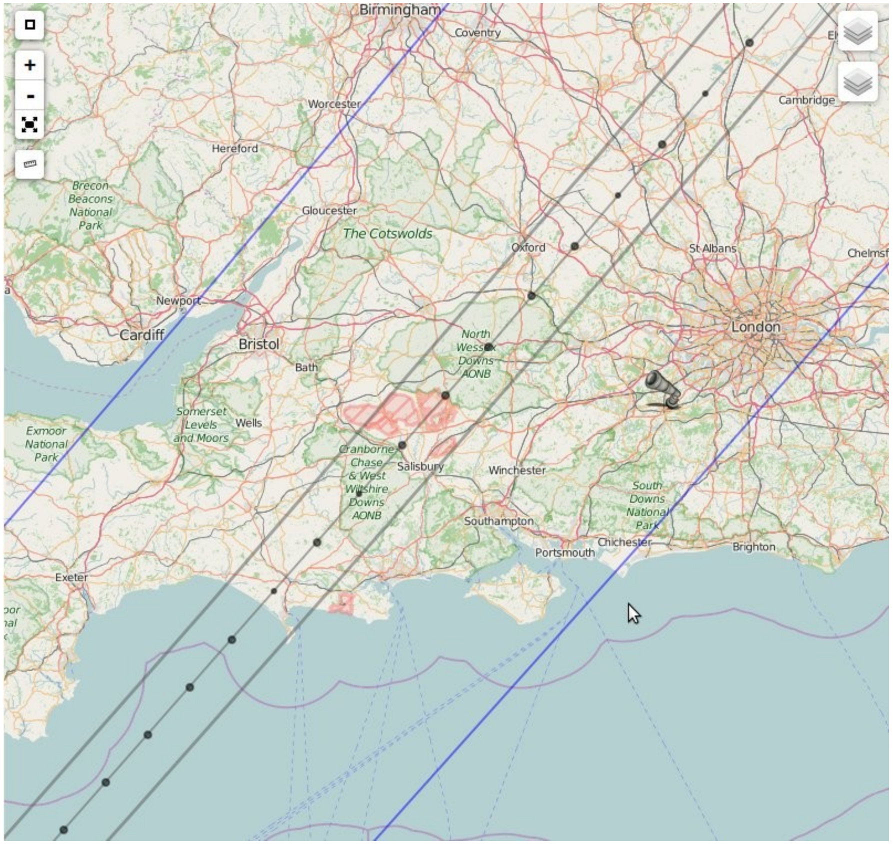


Systematic catalogue differences

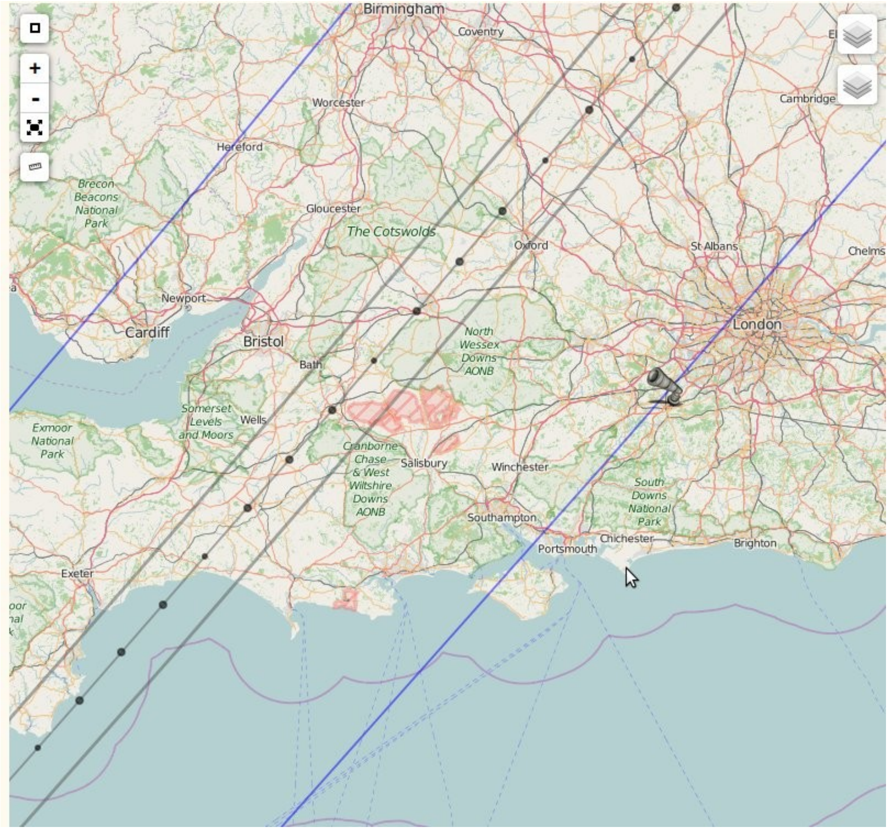


Occultation prediction w/o debiasing

(922) Schlutia – 1UT 475-531156



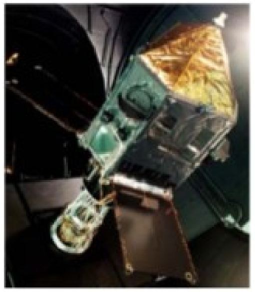
RMS = 0.26

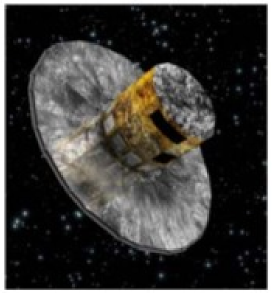


RMS = 0.29

From Hipparcos to Gaia

	Hipparcos	GAIA
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	~20 mag
Bright limit	~0	~3-7 mag
Number of objects	120 000	26 million to V = 15 250 million to V = 18 1000 million to V = 20
Effective distance limit	1 kpc	1 Mpc
Quasars	None	$\sim 5 \times 10^5$
Galaxies	None	10^6 - 10^7
Accuracy	~1 milliarcsec J1991.25	7 μarcsec at V = 10 12-25 μarcsec at V = 15 200-300 μarcsec at V = 20
Broad band	2-colour (B and V)	5-colour to V = 20
Medium band	None	11-colour to V = 20
Radial velocity	None	1-10 km/s to V = 16-17
Observing programme	Pre-selected	Complete and unbiased





The Gaia Era

What can we expect from Gaia (data)?

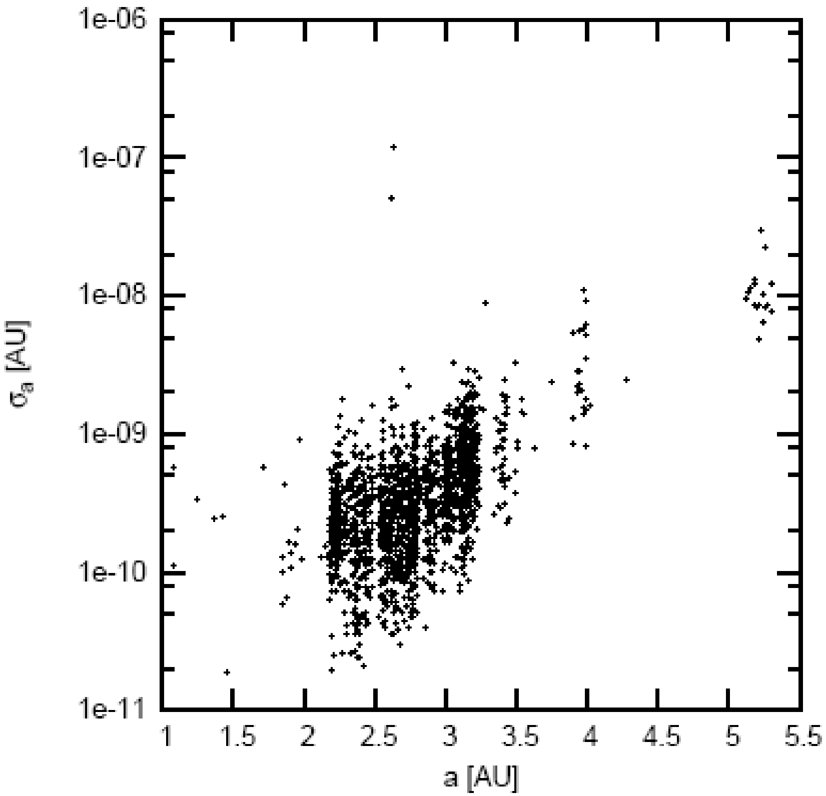
- Immediately: far better (10^2...10^3) star positions.

- Intermediate: better asteroid orbits over the next yrs:
  - Gaia catalogue reduced astrometry.
  - Better debiasing tables (wrt Gaia).

- Long-Term: high-accuracy orbits based on Gaia observations only !?

Orbit improvement

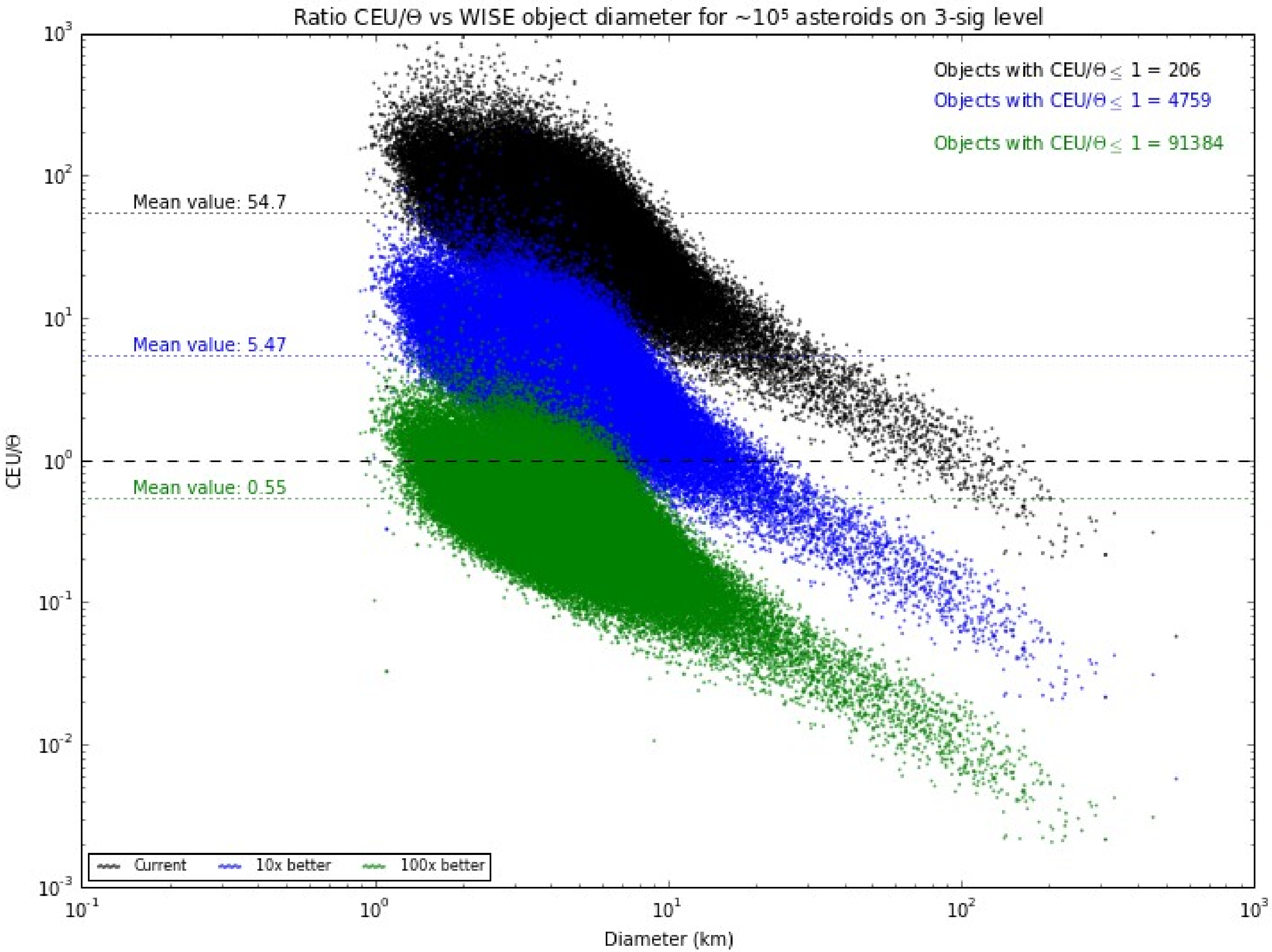
M. Gravnik (2007)



Accuracy from a pure Gaia data set:

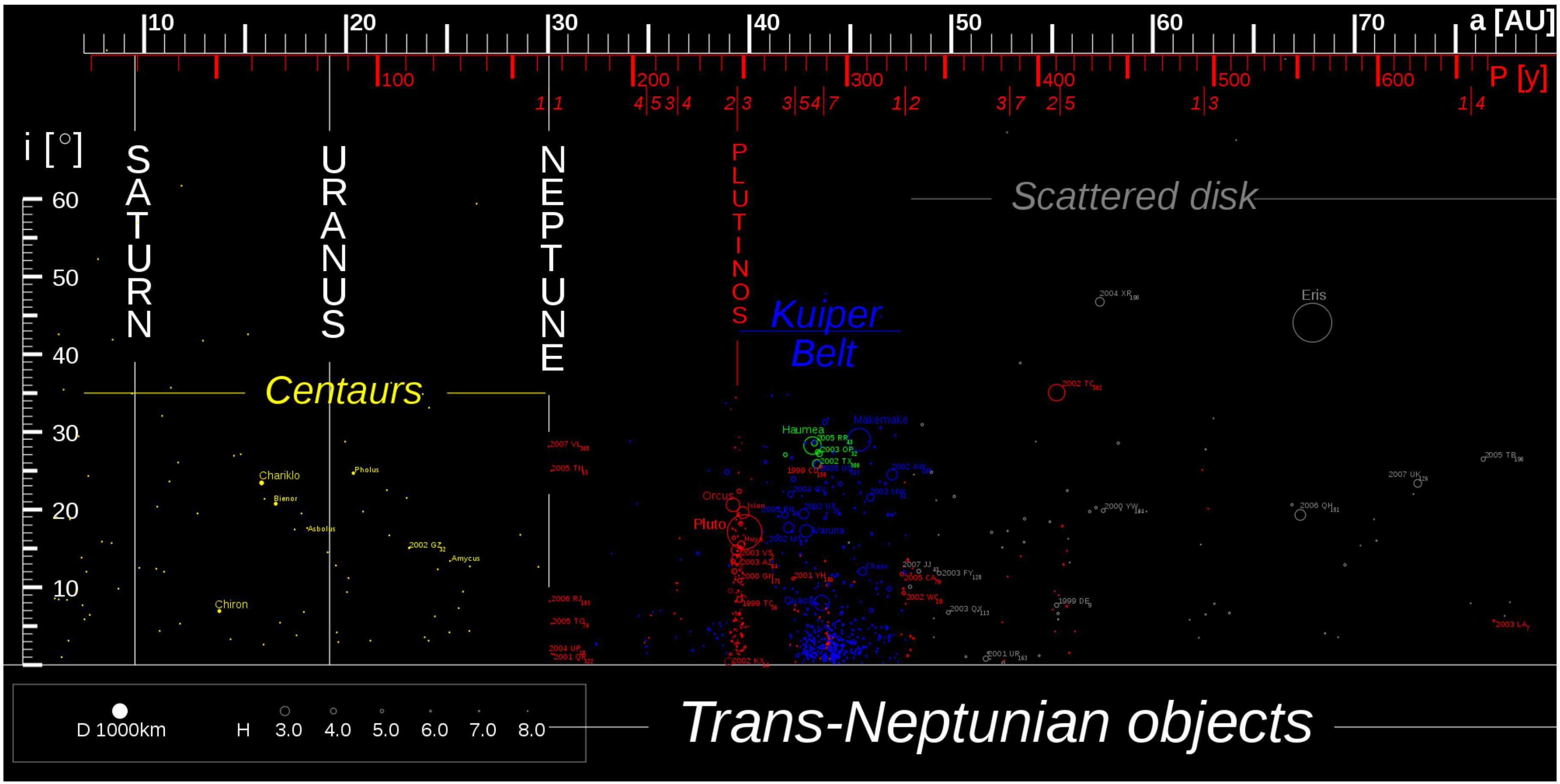
$10^2 - 10^3$ better than current.

The Gaia Era

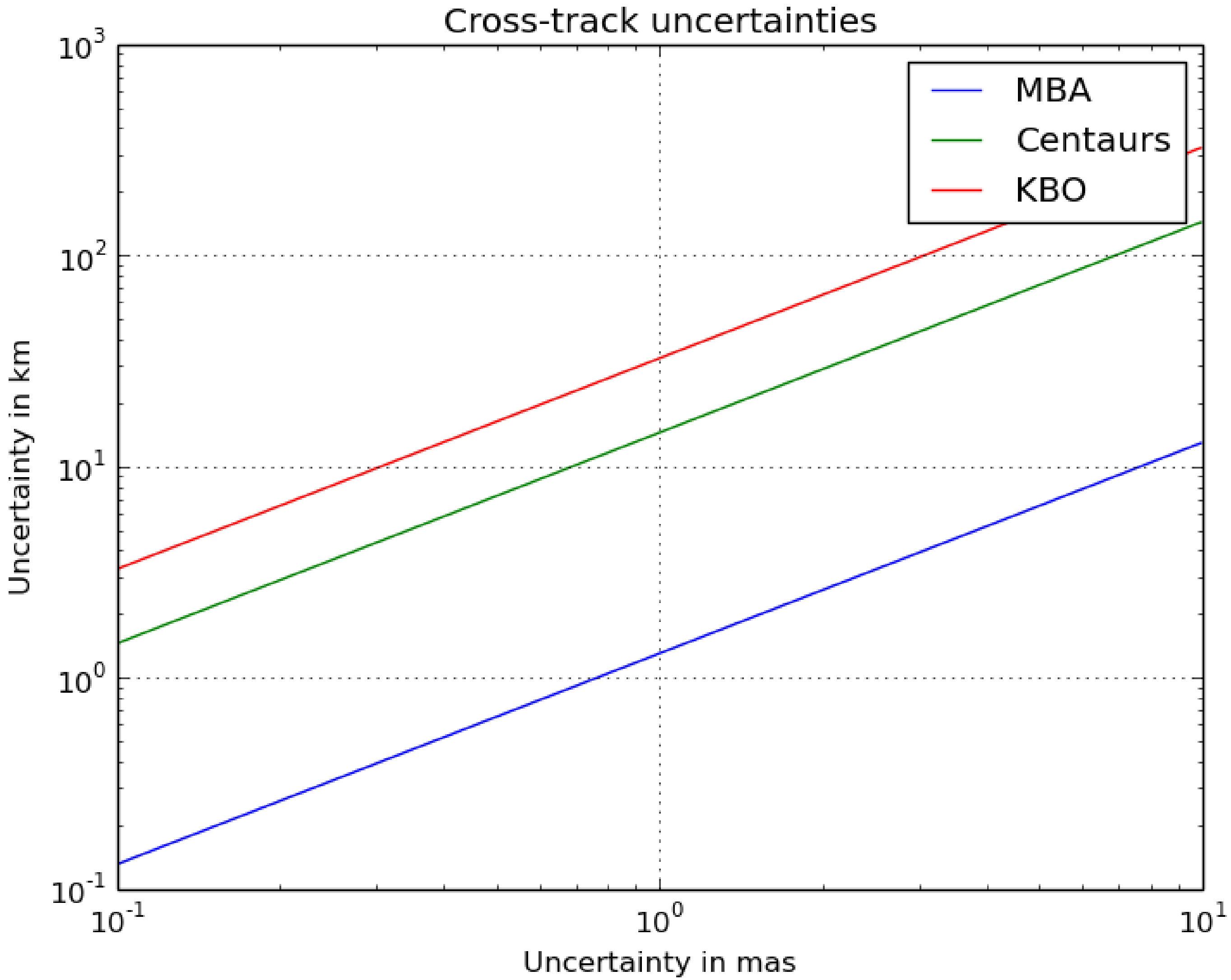


Ratio CEU/Θ vs WISE object diameter for ~10⁵ asteroids on 3-sig level
Objects with CEU/Θ ≤ 1 = 206
Objects with CEU/Θ ≤ 1 = 4759
Objects with CEU/Θ ≤ 1 = 91384
Mean value: 54.7
Mean value: 5.47
Mean value: 0.55
CEU/Θ
Diameter (km)
Current
10x better
100x better

What about TNO's / KBO's?



Cross-track uncertainties



Thank You for Your Attention !

Asteroids: Main Belt