Asteroid data mining and precoveries in the Gaia era

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Asteroid data mining and precoveries in the Gaia era

Interest of ancient observations for asteroids?

Improvement of …

- the orbital elements / ephemerides
- orbital caracterization and identification
- observations connection
- predictions of events (stellar occ., …)
- impact risk assessment (PHAs)

=> Strong interest for NEAs / PHAs science

Asteroid data mining and precoveries in the Gaia era

Outline

- Asteroid database and precision: global overview
- Data mining: what are the possibilities / what impact ?
- The 99 942 Apophis case

Asteroid database and precision: global overview

Asteroid Observations: global overview

From Minor Planet Center (http://www.minorplanetcenter.net/)

Astrometric measurements

code	type	number	percentage	timespan
C	CCD	82 849 054	93.74%	1986-2012
S/s	Satellite observation	4 006 902	4.53%	1994-2011
	HST	3 544	0.09%	1994-2010
	Spitzer	114	0.00%	2004-2004
	WISE	4 003 244	99.91%	2010-2011
A	Observations from B1950.0 converted to J2000.0	647 649	0.73%	1802-1999
c	Corrected without republication CCD observation	462 065	0.52%	1991-2007
P	Photographic	352 113	0.40%	1898-2011
T	Meridian or transit circle	26 968	0.03%	1984-2005
X/x	Discovery observation	16 706	0.02%	1891-2010
M	Micrometer	12 081	0.01%	1845-1954
H	Hipparcos geocentric observation	5 494	0.01%	1989-1993
R/r	Radar observation	1 602	0.00%	1968-2006
E	Occultations derived observation	1 571	0.00%	1961-2011
V	"Roving observer" observation	372	0.00%	2000-2010
n	Mini-normal place derived from averaging observations from video frames	93	0.00%	2009-2011
e	Encoder	16	0.00%	1993-1995

J. Desmars et al. 2012 in preparation

Asteroid Observations: global overview

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Asteroid Observations: global overview

From AstDyS-2 (http://hamilton.dm.unipi.it/astdys/)

type	name	number of measurement	percentage of accepted measurement	accuracy	
C	CCD	73 938 542	99.48%	0.401	arcsec
S	Wise	1 497 360	99.89%	0.579	arcsec
S	Hubble Space Telesc.	867	96.54%	0.577	arcsec
S	Spitzer	48	33.33%	1.672	arcsec
A	B1950 to J2000	631 982	81.68%	1.175	arcsec
c	Corrected CCD obs.	419 070	99.68%	0.509	arcsec
P	Photographic	345 698	93.17%	1.088	arcsec
T	Meridian/transit circle	26 968	99.74%	0.288	arcsec
M	Micrometer	12 081	90.65%	1.896	arcsec
H	Hipparcos obs.	5494	100.00%	0.201	arcsec
E	Occultations	1570	100.00%	0.126	arcsec
R	Ranging	546	95.79%	5.695	km
R	Doppler	401	99.00%	7.128	km/s
V	Roving observer	356	49.72%	0.829	arcsec
e	Encoder	16	100.00%	0.557	arcsec

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Uncertainty parameters

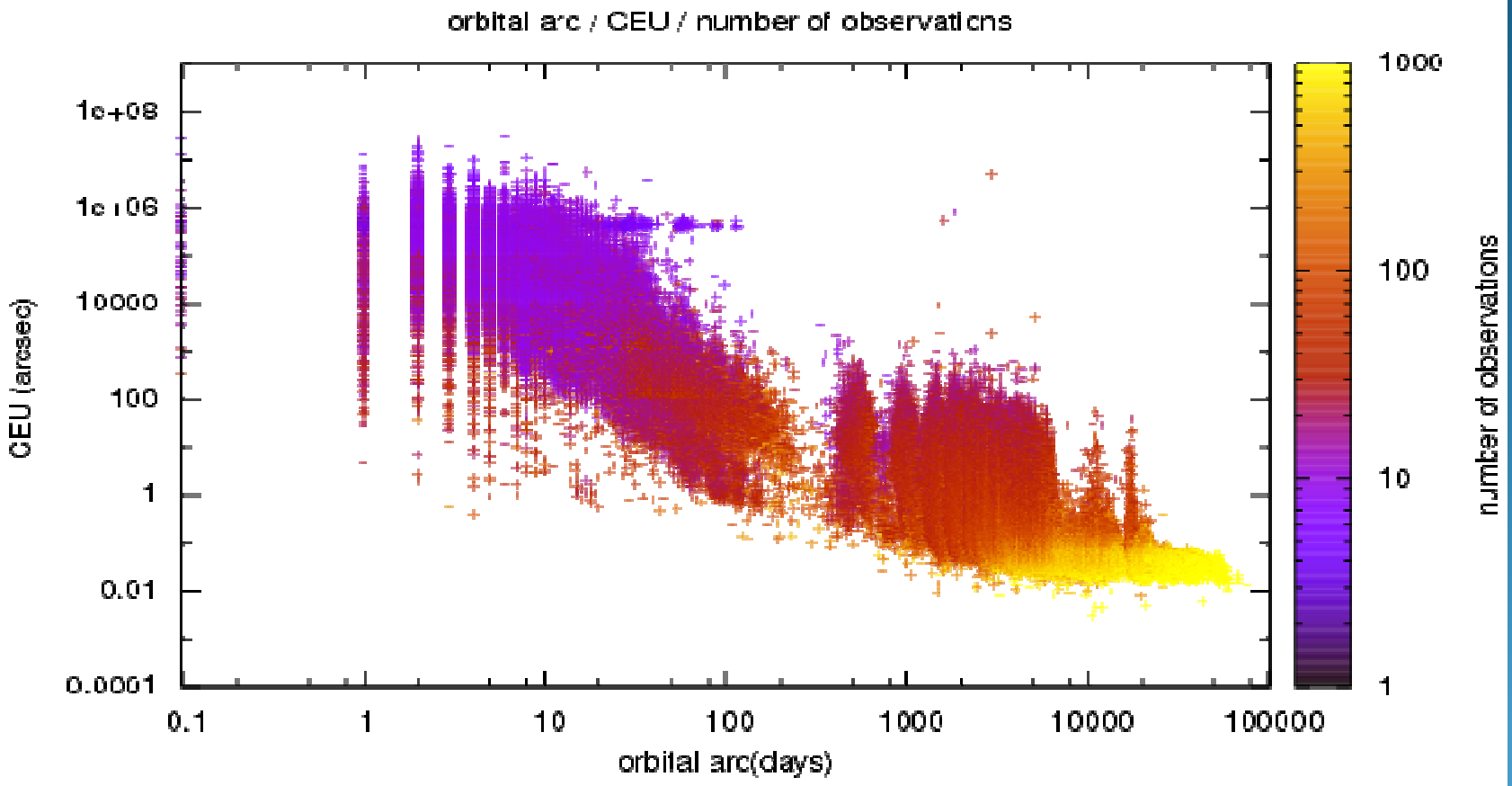
- From Lowell obs. (Bowell E.)
  (ftp://ftp.lowell.edu/pub/elgb/astorb.html)

- ASTORB database provides five parameters measuring uncertainty

Sky plane uncertainty at a given date

- ***CEU*** **(**arcsec): current 1-σ uncertainty
- ***CEU rate*** (arcsec/day)
- ***Date of CEU***
- ***PEU*** (arcsec) : next peak uncertainty
- ***Greatest PEU***: (arcsec) : 2 parameters:
  (1):greatest PEU in 10 years from date of CEU
  (2): greatest PEU in 10 years from date of PEU

ASTORB data base



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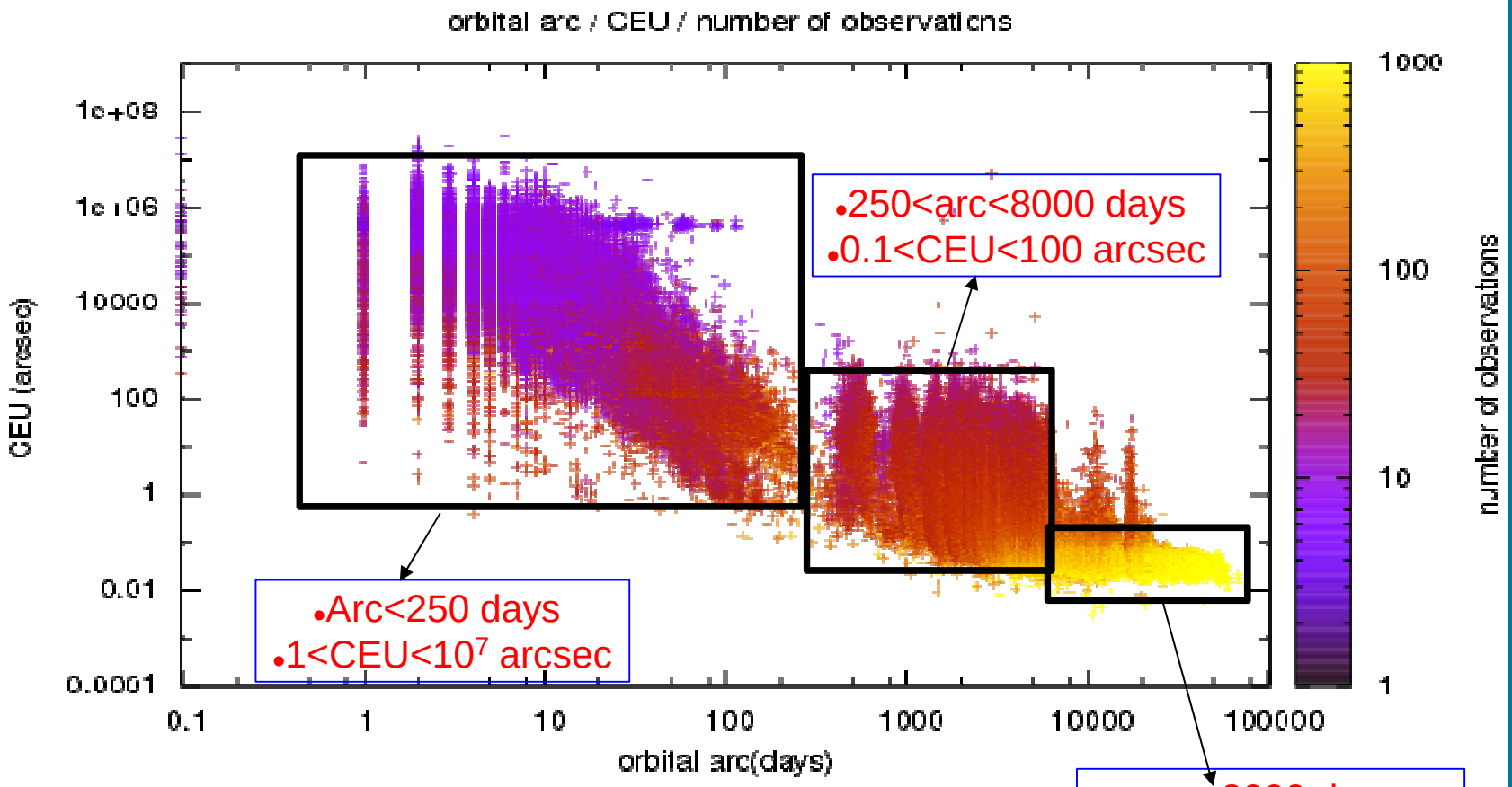
ASTORB data base



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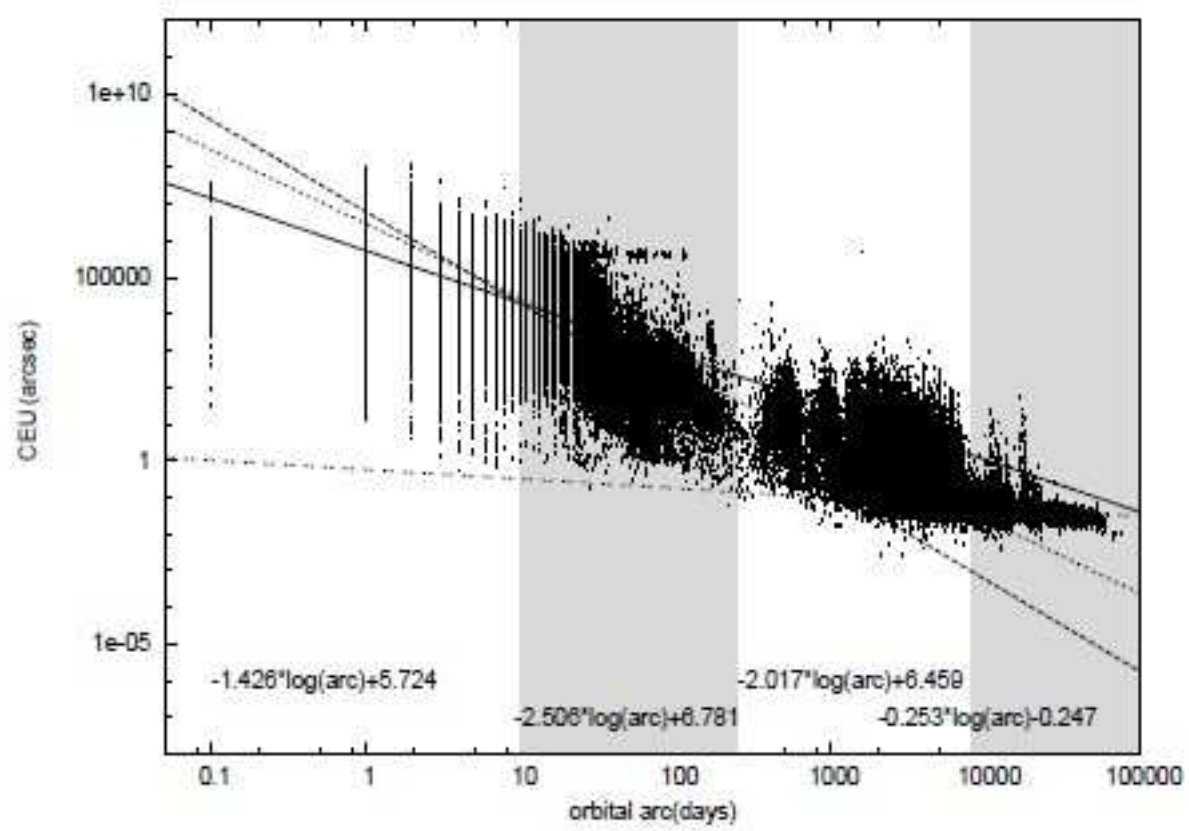
Precision vs. Length of arc



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Datamining: what are the possibilities / what impact ?

Data mining

Search for precovery data (pre-discovery recoveries) ?

- Skybot web service (skybot.imcce.fr):

  pre-computed ephemeris (see talks by J. Berthier + M. Birlan)

- Different approaches:
  - ✓ Intensive data mining of large source databases
  - ✓ Mining of a survey catalogue > list of new obs. of asteroids
  - ✓Mining a collection of catalogues > to get astrom. of one peculiar target

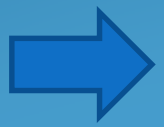
- Some limitations for astrometry (timing, reduction, faintness, metadata,...)

Re-reduction

Method to use for extending the period of observation?

by applying Re-reduction to:

- prioritary objects : PHA, space mission targets,…
- selected CCD frames
- selected digitized photographic plates



✓ The best stellar astrometry possible
=> the best accuracy of asteroid positioning
✓ Impact of the future Gaia catalogue?

http://www.minorplanetcenter.net/

99 942 Apophis
Discov.: 2004 June 19

MPCObs

Datamining
6 obs in
2004 March

IAU Minor Planet Center

Search MPC

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NEO Services Overview
NEO Confirmation
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(99942) Apophis = 2004 MN4

Discovered at Kitt Peak on 2004-06-19 by R. A. Tucker, D. J. Tholen, and F. Bernardi.
(99942) Apophis = 2004 MN4

Also known as Apep, the Destroyer, Apophis is the Egyptian god of evil and destruction who dwelled in eternal darkness. As a result of its passage within 40 000 km of the earth on 2029 Apr. 13, this minor planet will move from the Aten to the Apollo class. [Ref: *Minor Planet Circ.* 54567]

Orbit

Orbit type: Aten
Potentially Hazardous Asteroid
Critical list numbered object.

Interactive Orbit Sketch Note: WebGL enabled browsers only (e.g. Firefox, Safari, Chrome, Opera), but not IE.

epoch	2012-03-14.0	semimajor axis (AU)	0.9222957	uncertainty	0
epoch JD	2456000.5	mean anomaly (°)	150.13477	reference	MPO 231943
perihelion date	2011-10-31.07810	mean daily motion (°/day)	1.11275310	observations used	1512
perihelion JD	2455865.57810	aphelion distance (AU)	1.09900	oppositions	2
argument of perihelion (°)	126.42424	period (years)	0.89	arc length (days)	2976
ascending node (°)	204.42933	P-vector [x]	0.87281527	first opposition used	2004
inclination (°)	3.33194	P-vector [y]	-0.46431986	last opposition used	2012
eccentricity	0.1910904	P-vector [z]	-0.15033488	residual rms (arc-secs)	0.40
perihelion distance (AU)	0.7460538	Q-vector [x]	0.48745844	perturbers coarse indicator	M-v
		Q-vector [y]	0.81419717	perturbers precise indicator	003Eh
		Q-vector [z]	0.31538427	first observation date used	2004-03-15.0
		absolute magnitude	19.2	last observation date used	2012-05-08.0
		phase slope	0.15	computer name	MPCW

Observations

1519 total observations over interval: 2004 03 15.10789 – 2012 05 08.27193
These data are available for download (format description).

« Previous 1 2 Next »

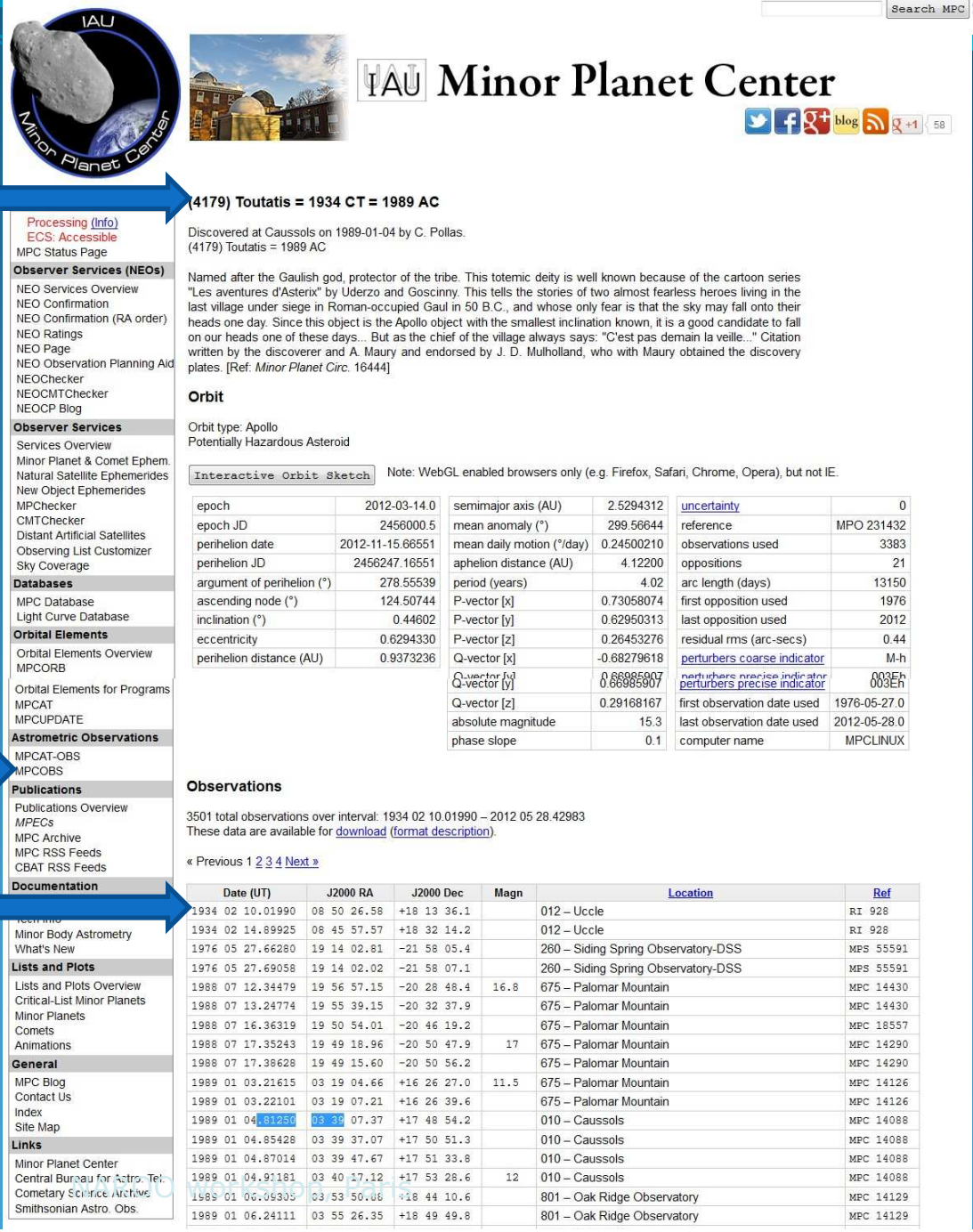
Date (UT)	J2000 RA	J2000 Dec	Magn	Location	Ref
2004 03 15.10789	04 06 08.08	+16 55 04.6		691 – Steward Observatory, Kitt Peak-Spacewatch	MPS 126394
2004 03 15.11039	04 06 08.58	+16 55 06.1		691 – Steward Observatory, Kitt Peak-Spacewatch	MPC 53585
2004 03 15.12365	04 06 11.75	+16 55 15.5		691 – Steward Observatory, Kitt Peak-Spacewatch	MPC 53585
2004 03 15.12628	04 06 12.40	+16 55 17.7		691 – Steward Observatory, Kitt Peak-Spacewatch	MPC 53585
2004 03 15.13723	04 06 14.90	+16 55 25.4		691 – Steward Observatory, Kitt Peak-Spacewatch	MPC 53585
2004 03 15.13998	04 06 15.58	+16 55 27.1		691 – Steward Observatory, Kitt Peak-Spacewatch	MPC 53585
2004 06 19.17015	09 44 29.658	+13 18 50.95		695 – Kitt Peak	MPC 54280
2004 06 19.17015	09 44 29.658	+13 18 50.95		695 – Kitt Peak	MPC 54280
2004 06 19.170150	09 44 29.677	+13 18 50.67		695 – Kitt Peak	MPS 298141
2004 06 19.17486	09 44 30.584	+13 18 46.78		695 – Kitt Peak	MPC 54280
2004 06 19.174861	09 44 30.604	+13 18 46.81		695 – Kitt Peak	MPS 298141
2004 06 19.179676	09 44 31.507	+13 18 42.91		695 – Kitt Peak	MPS 298141
2004 06 19.17968	09 44 31.494	+13 18 43.09	20.9 R	695 – Kitt Peak	MPC 54280
2004 06 20.15951	09 47 41.080	+13 05 24.97		695 – Kitt Peak	MPC 53585
2004 06 20.159514	09 47 41.116	+13 05 24.49		695 – Kitt Peak	MPS 298141
2004 06 20.164317	09 47 42.006	+13 05 20.50		695 – Kitt Peak	MPS 298141

http://www.minorplanetcenter.net/

Toutatis
Discov.: 1989

MPCObs

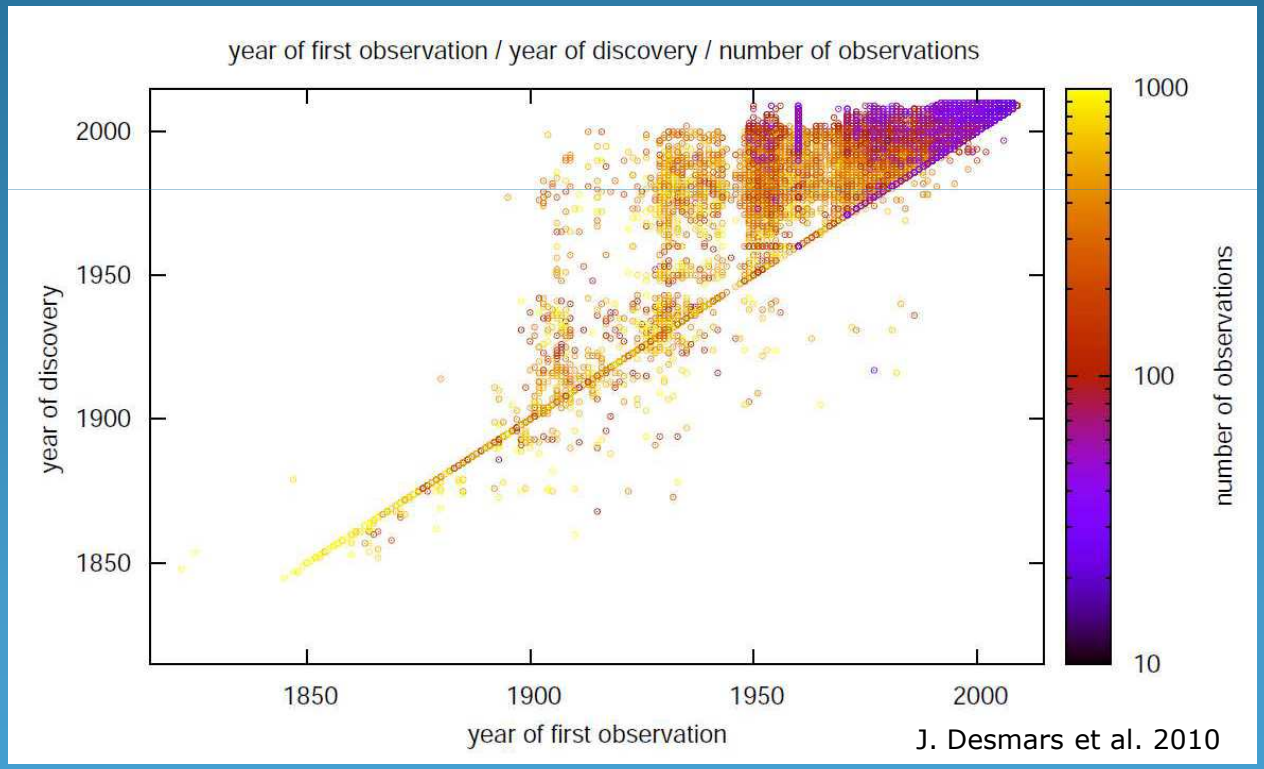
Datamining:
2 obs in 1934
2 in 1976
5 in 1988
2 in 1989



ASTORB data base: Data mining done

Year of discovery / year of first observation

380 000 asteroids : Global view of the data issued from data mining



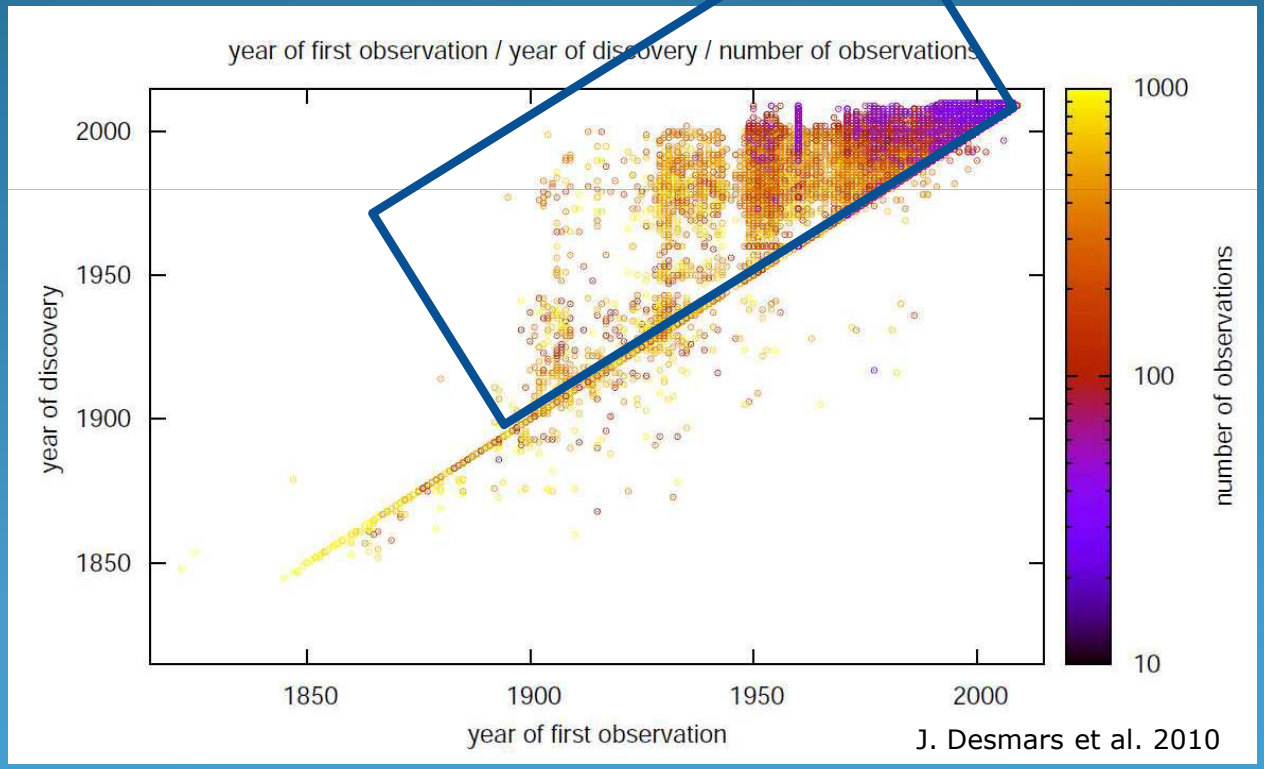
J. Desmars et al. 2010

ASTORB data base: Data mining done

Date discovery > date 1st obs.
Measurements done through data mining:

380 000 asteroids

273 970 (71%)



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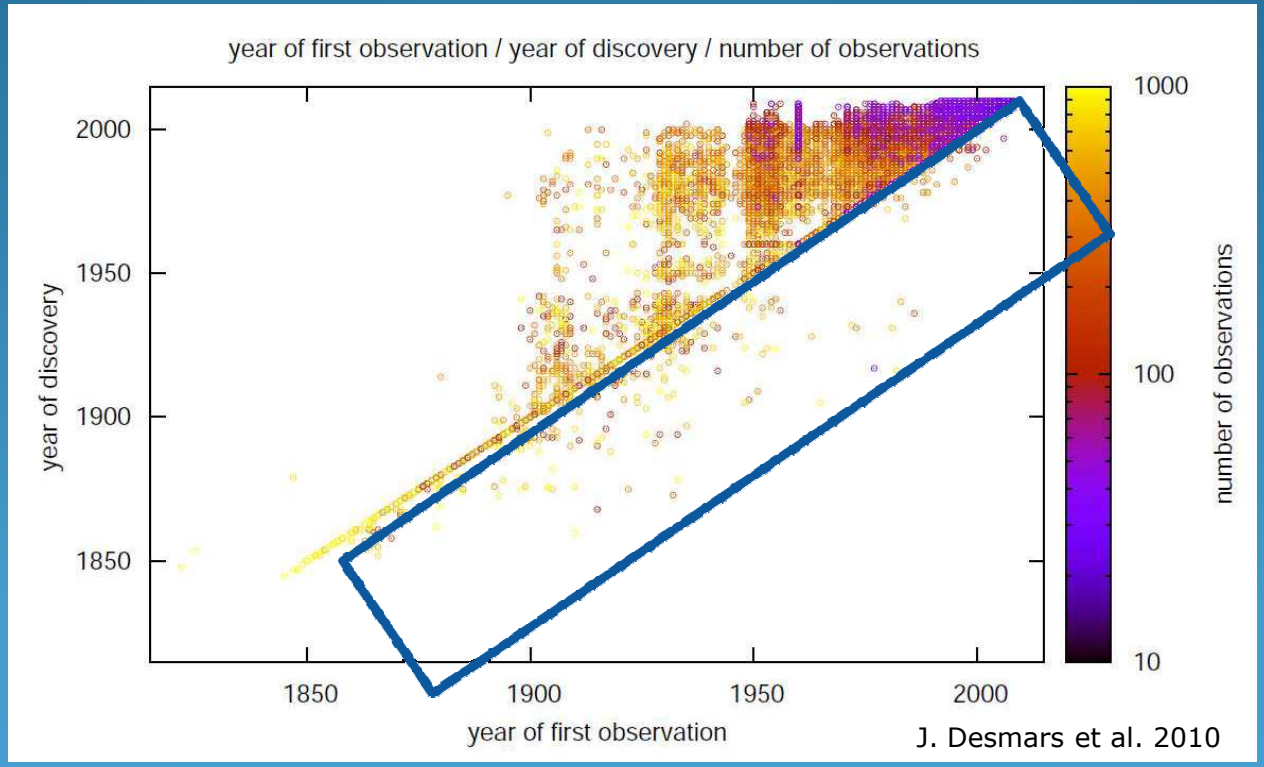
ASTORB data base: Data mining done

380 000 asteroids

Date discovery < date 1st obs.
1st observation too unprecise?
not registered as date of discovery



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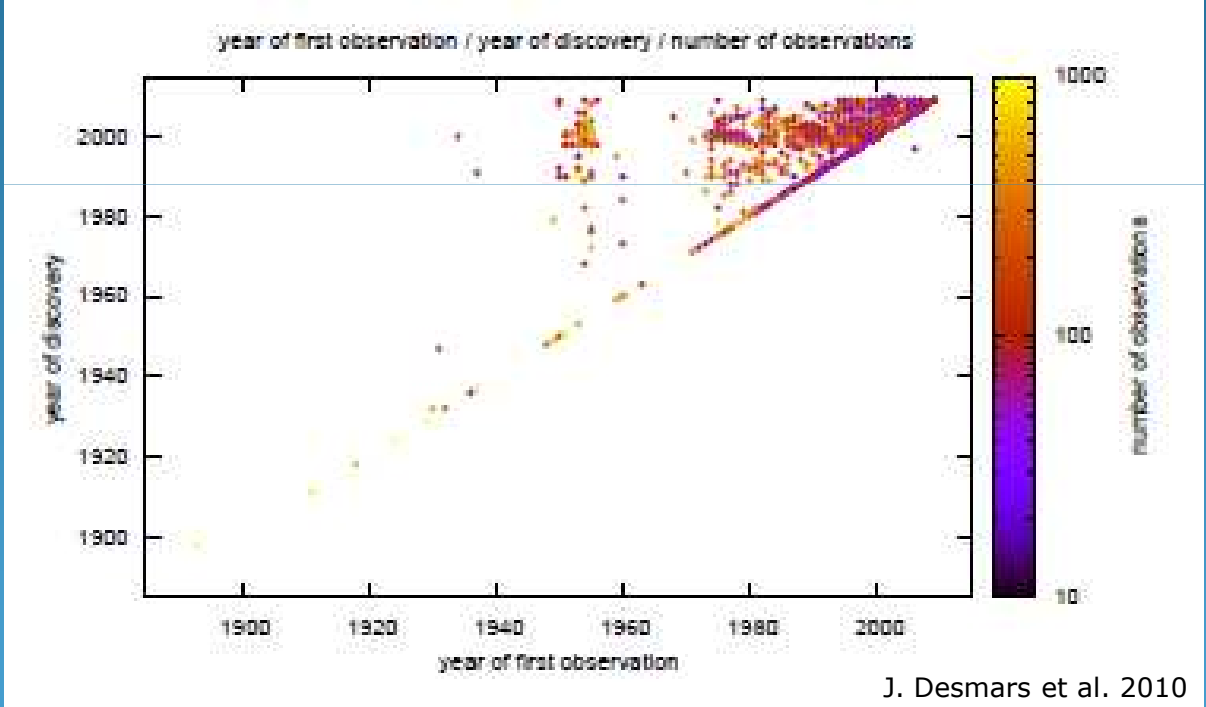
ASTORB data base: Data mining done

Only NEAs
2691



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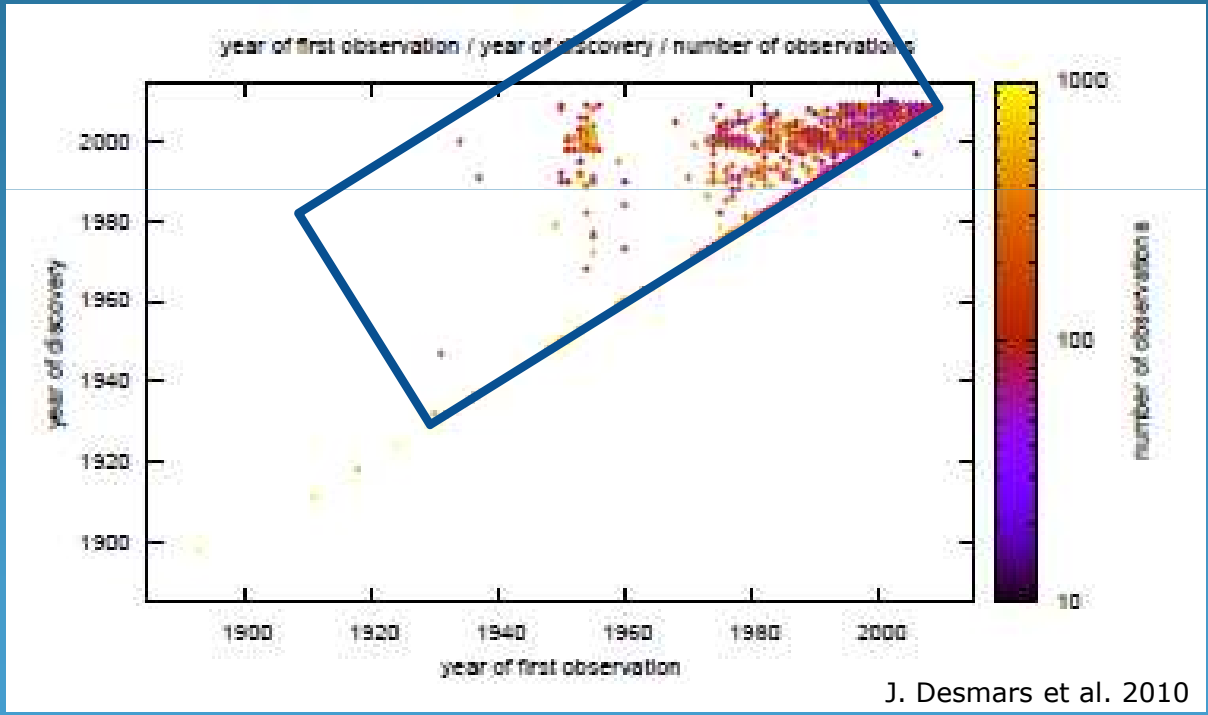
ASTORB data base: Data mining

782 NEAs (29%)

Only NEAs
2691



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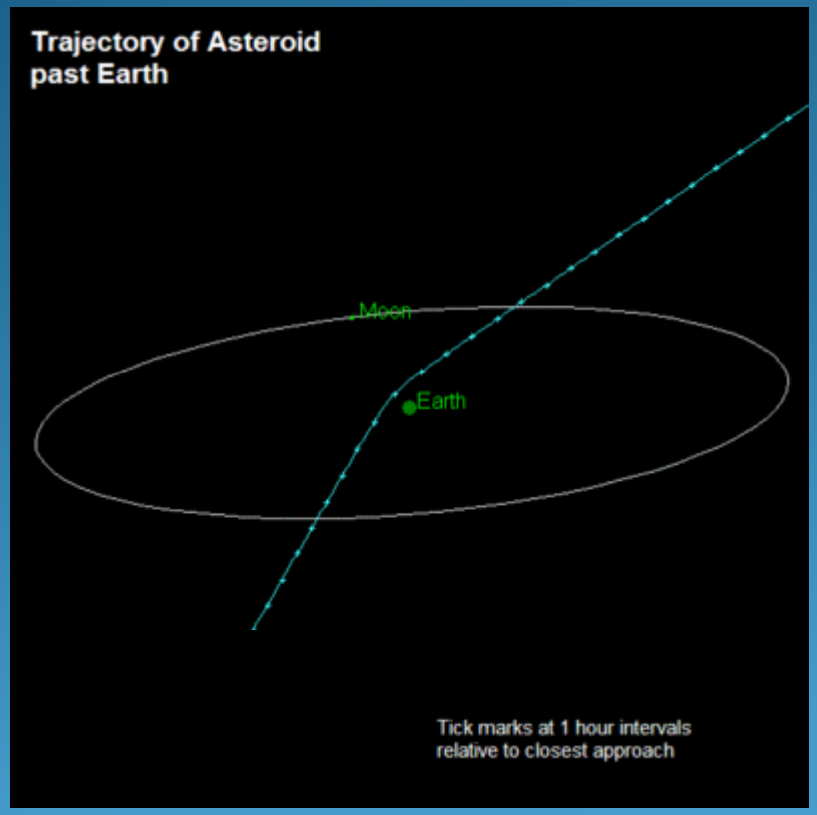
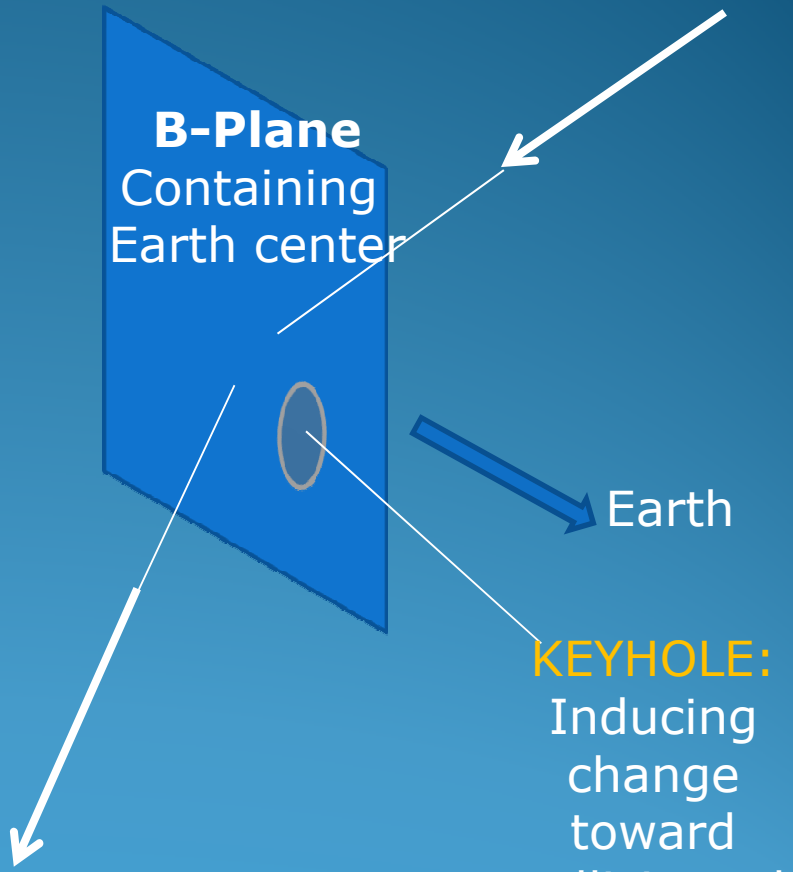
Case of 99942 Apophis

Bessel plane / Keyholes





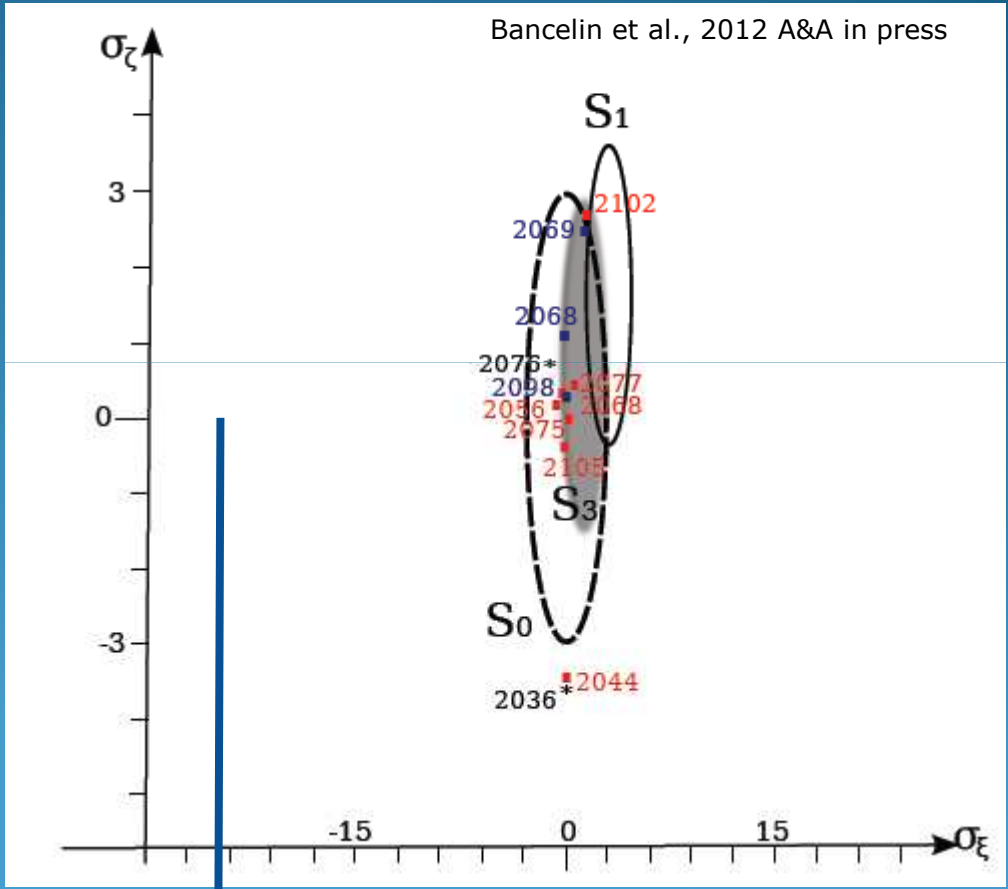
B-plane of 99942 Apophis

Apophis 2029 B-plane

- obs. 2004-2011
- 3σ uncertainty ellipses
- S0: 15 km x 350 km
- S3: 15 km x 245 km
- Keyholes

Year	Resonance	Keyhole size (m)
2034	5 :4	560
2035	6 :5	560
2036	7 :6	610
2037	8 :7	570
2046	17 :15	660
2048	19 :17	410

Chesley, 2006

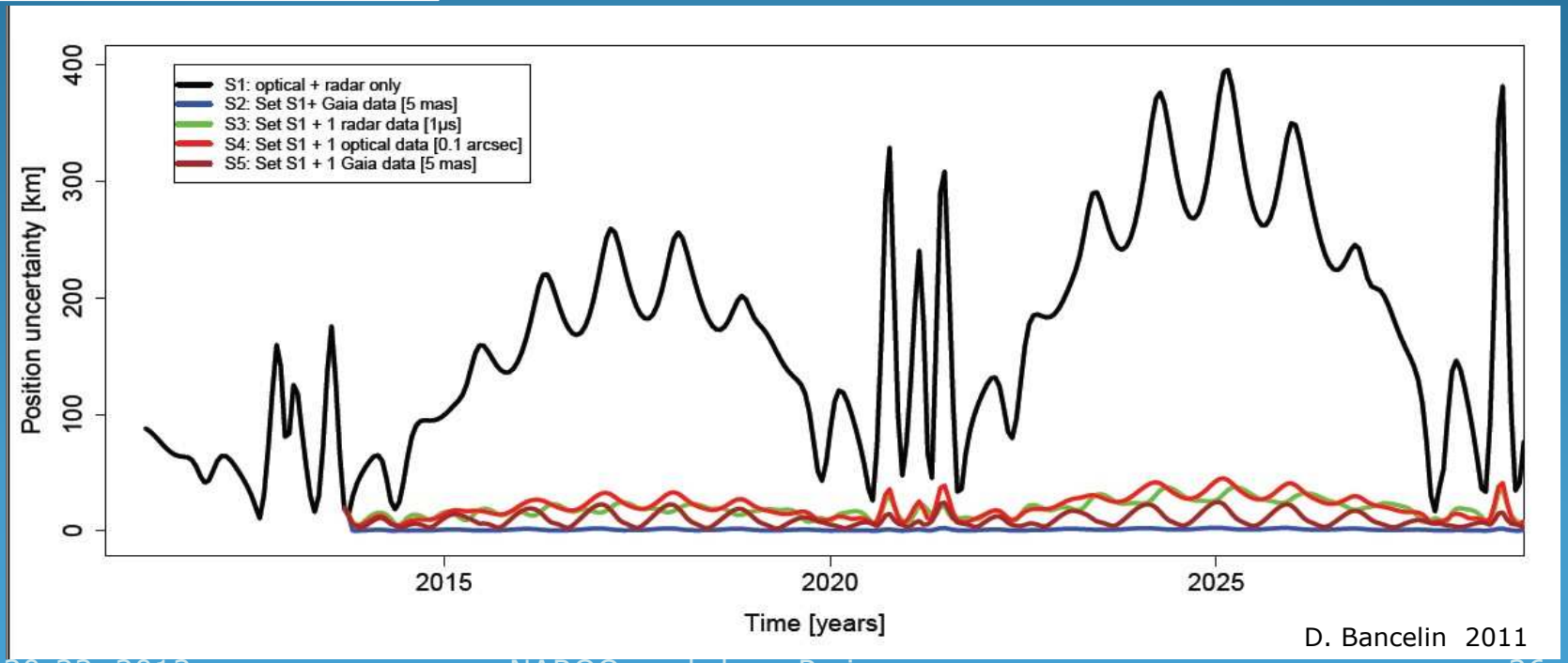


Impact of direct Gaia observations on the orbital model of 99942 Apophis

- simul. direct Gaia obs. of Apophis
- Propagation of error
- covariance matr. Tech.

Position known to less than 50 km on the period

- Sets of observations
- S1: optical 2004-2011 + radar
- S2: S1 + 12 Gaia obs. (5mas)
- S3: S1 + 1 radar in 2013 (1 μs)
- S4: S1 + 1 optical (100 mas)
- S5 : only 1 observation by Gaia (5 mas)



D. Bancelin 2011

Impact of the Gaia catalogue on the orbital model of Apophis

Current stellar catalogues :

- Systematic errors => impact on the asteroid orbital models
- Estimate of biases => Zonal corrections

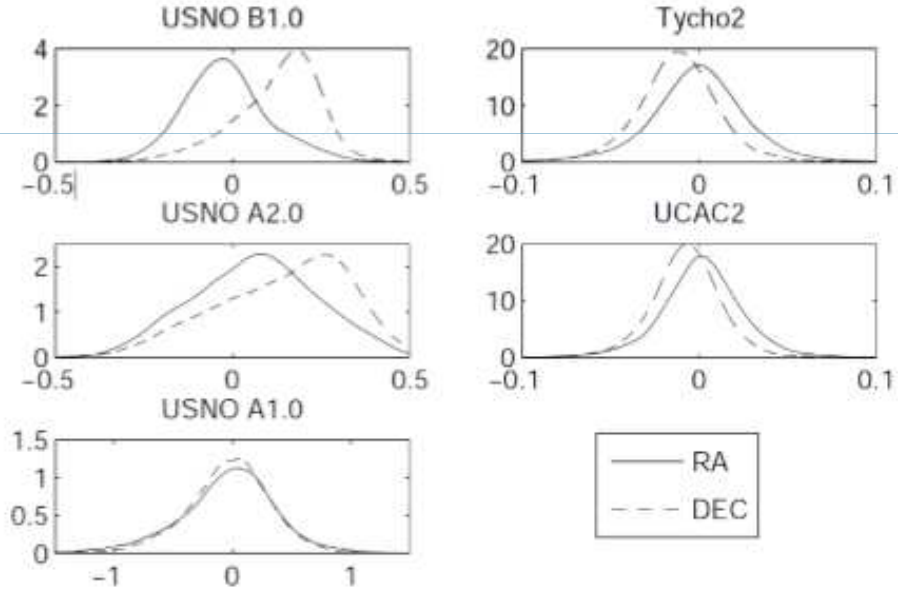


Figure 5.2: *Probability densities of inter-catalogue systematic errors, as compared to the 2MASS catalog. For each plot, the abscissa is the difference in arcsec between the given catalogue and 2MASS and the ordinate is the associated probability density in arcsec^{-1}. Note that the plots are not all on the same scale (source: Chesley et al. (2009))*

Impact of the Gaia catalogue on the orbital model of Apophis

D. Bancelin (2011, Phd Thesis)

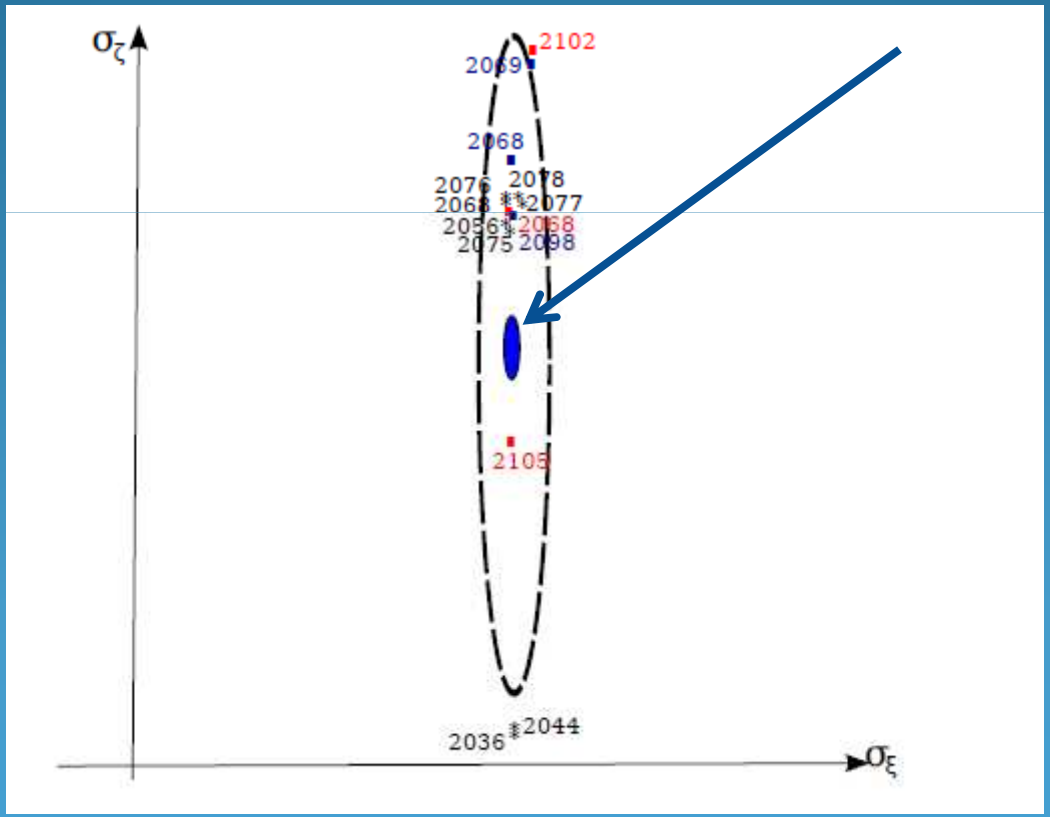
- Simulation of re-reduction with the Gaia catalogue (50 mas)
- improvement of uncertainty by 10 (a, e, Ω, M) and 100 (i)

	without	with Gaia cat.
a [UA]	1.3×10^{-08}	1.3×10^{-09}
e	5.7×10^{-08}	4.9×10^{-09}
i [°]	1.8×10^{-06}	9.9×10^{-09}
Ω [°]	8.0×10^{-05}	3.9×10^{-06}
ω [°]	8.0×10^{-05}	3.9×10^{-06}
M [°]	5.5×10^{-05}	5.6×10^{-06}

Impact of the Gaia catalogue on the orbital model of Apophis

D. Bancelin (2011, Phd Thesis)

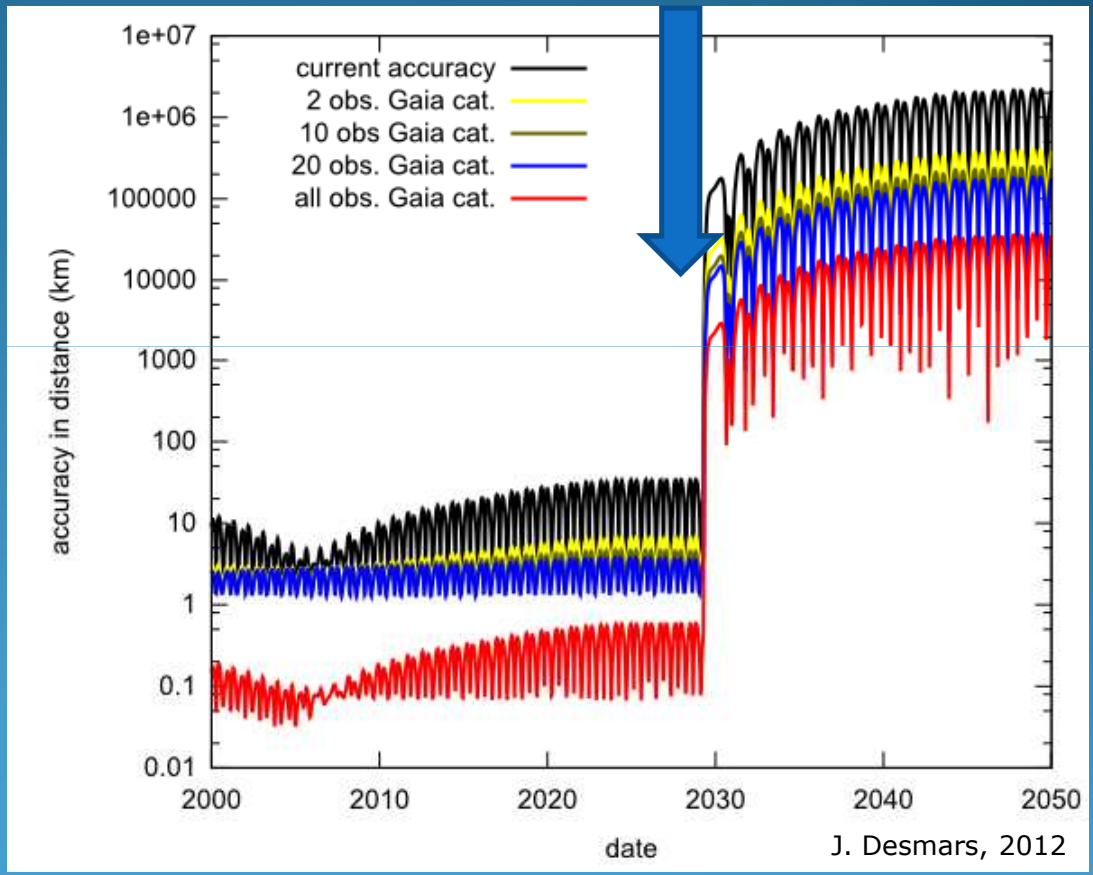
- Simulation of re-reduction with the Gaia catalogue (50 mas)
- 2019 B-Plane of Apophis: uncertainty ellipse reduced by factor 10



Impact of the Gaia catalogue on the orbital model of Apophis

Close approach 2029

- Accuracy in helioc. distance (km)
- Error propagation (covariance matrix techn.)
- NEODys obs (2004 to 2012) => nominal values



Simulation of re-reduction with the Gaia Catalogue (10 mas):

- ✓All observations
- ✓20 (10 first and 10 last)
- ✓10 (5 first and 5 last)
- ✓2 (1st and last ones)

Strong improvement (/1000)

Thank you!

Acknowledgements:
a part of this work was supported by the ESA contract
ESA/22885/F/MOS/100409-R from European Space Agency