Orbit Determination with Optical Observations of HAMR Objects

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AIUB

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Facilities AIUB

Follow-up

Detection

18/30 cm

AIUB

Follow-up

Light-
Curves

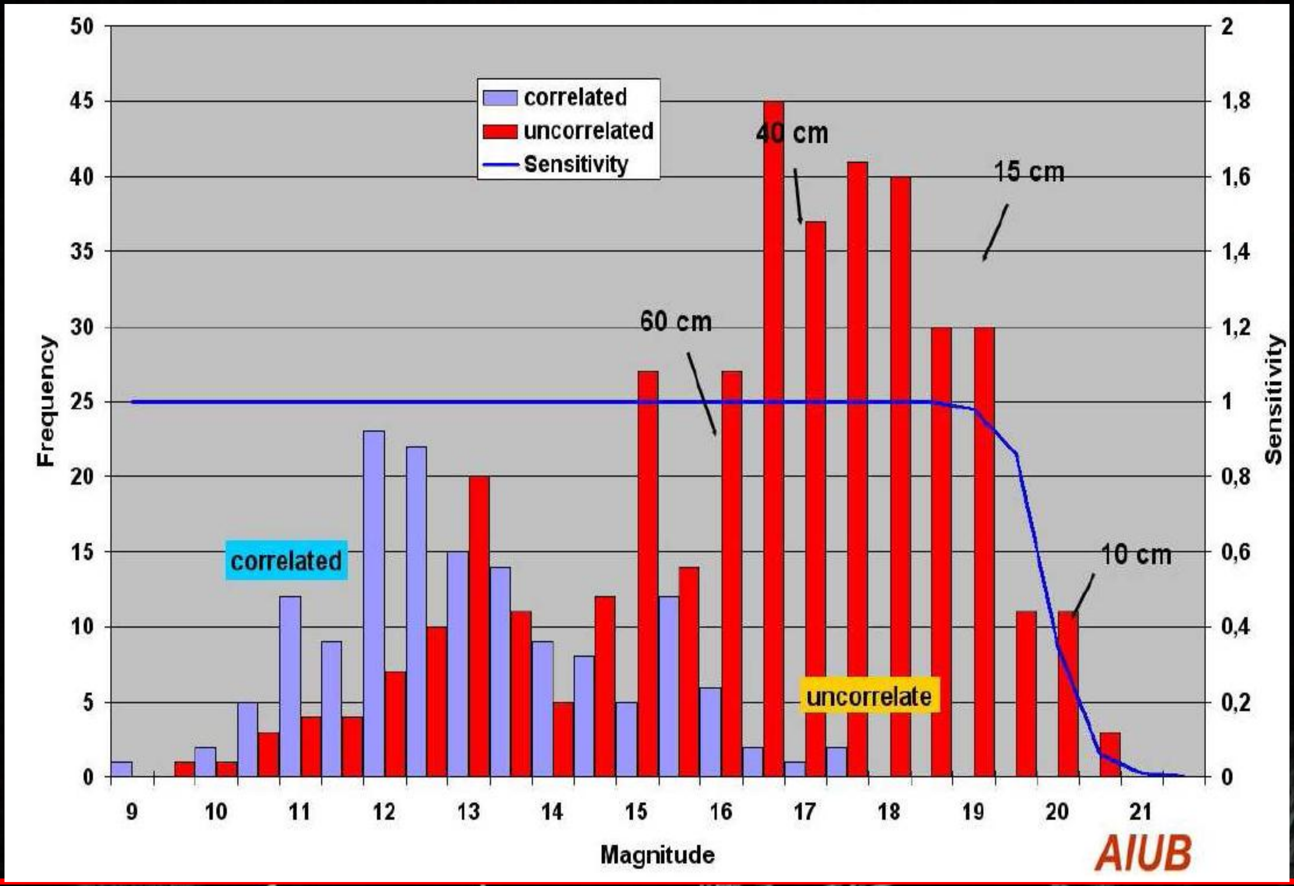
Detection

Follow-up

1 meter

Facilities AIUB

AIUB has a small independent orbital element and light curve catalogue of faint debris objects, including high area-to-mass ratio (HAMR) objects.



Orbit Determination and Propagation

Orbit determination and propagation with advanced version of *CelMech* tool (*G.Beutler, 2005*) with least square approach:

Including:

- Earth gravitational potential up to order and degree 12
- corrections due to earth/ocean tides
- relativity corrections
- modeling of earth shadow passes.
- Solve for parameter direct radiation pressure (AMR)

$$\boldsymbol{a}'_{\mathrm{rad}} = -\,\frac{\tilde{C}}{2}\,\frac{A_{\oplus}^{2}}{|\boldsymbol{r}-\boldsymbol{r}_{\odot}|^{2}}\,\frac{S}{c}\,\frac{A}{m}\,\boldsymbol{e}'_{\odot}$$

Orbit Determination of HAMR

Problems:

- Data is sparse with large gap between tracklets in some cases
- Non-regular spacing of observations

➡ In the investigation of HAMR orbits, how can different comparable orbits be generated?

First, investigation of orbits of objects with moderate area-to-mass ratio:

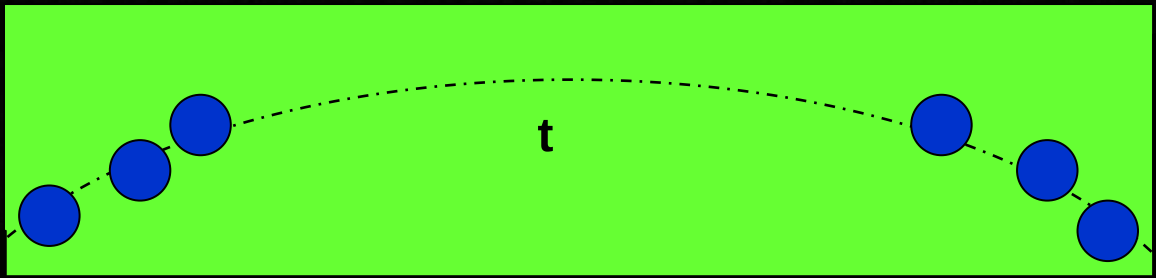
➡ Criteria: different orbits, but small differences between propagated ephemerides and observations.

Angular distance: 50 days since OD, averaged obs-ephm.

Sparse Data Setup

So-called parse-Data-Setup:

- Two Sets of at max 10 observations each
- Each sets consists of observations spread over max 4 days.
- Observations of different sensors:
  - ZIMLAT
  - ESASDT
  - ISON Sensors



NAME	epoch (MJD)	a (km)	e	i (deg)	AMR	Mag
E03174A	55208.0	41900	0.001	10.1	0.01	14.6
E06321D	55275.9	41400	0.035	7.00	2.29	15.3
E06327E	54470.1	40000	0.067	12.31	0.20	17.2
E08241A	55213.0	41600	0.041	13.26	1.24	16.1

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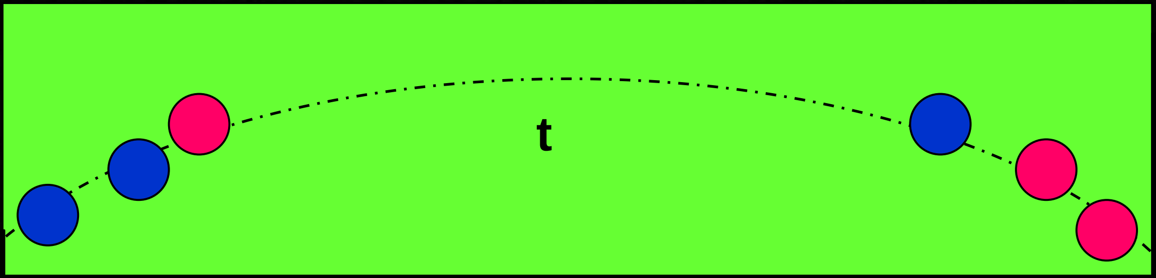

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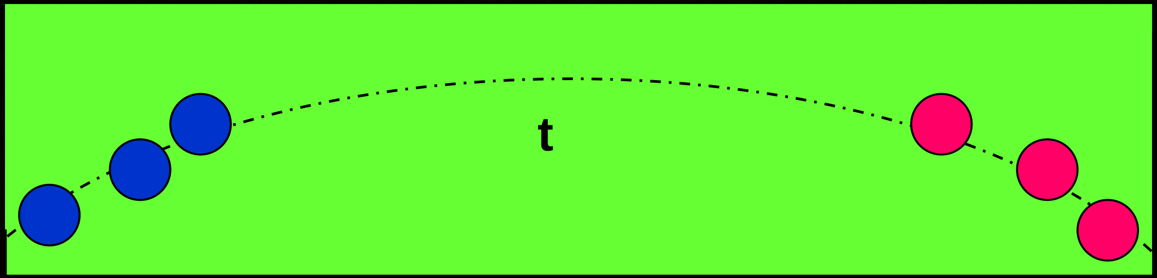

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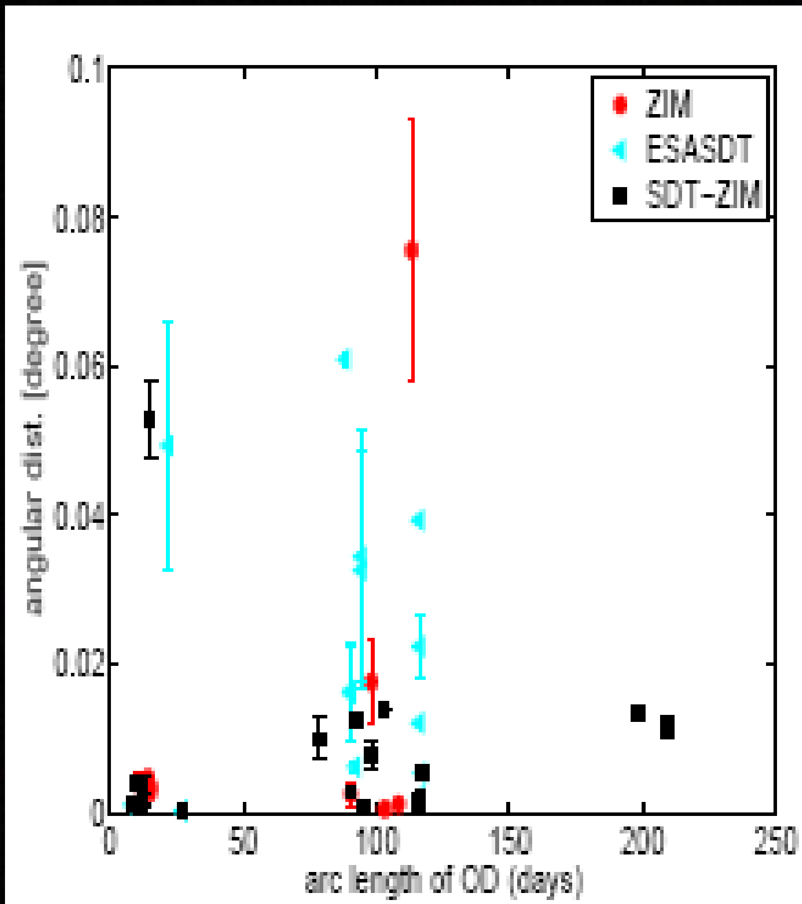
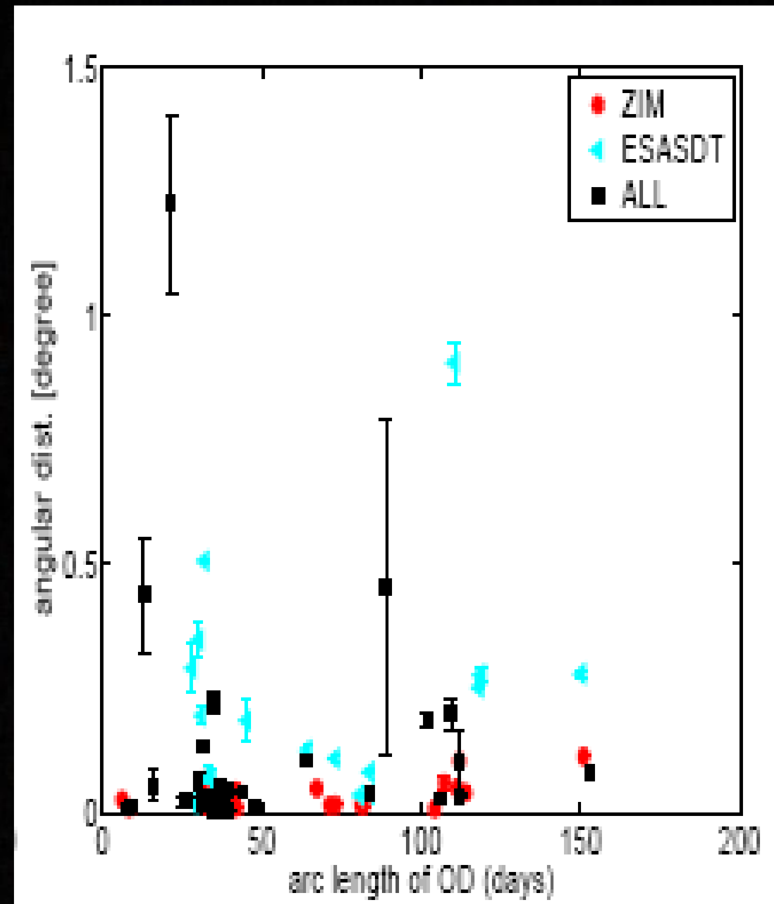
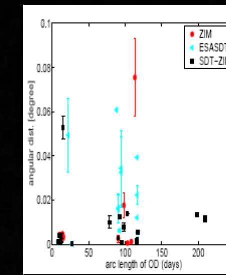
Dependence on Fitinterval of OD

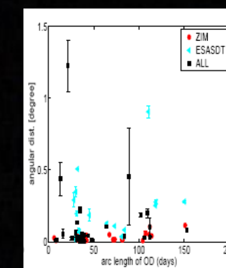
E03174A

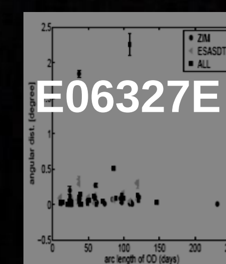


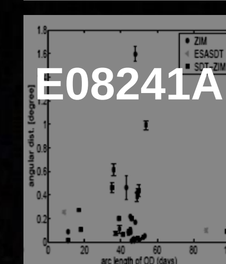
E06321D







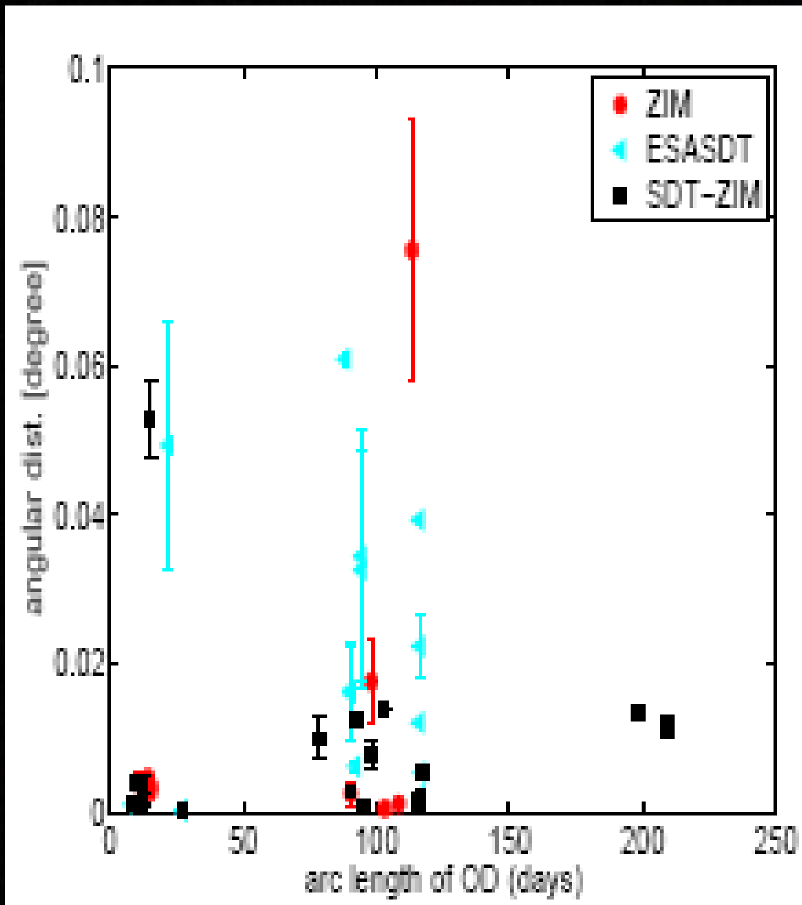




No strong correlation visible!

Dependence on Fitinterval of OD

E06327E



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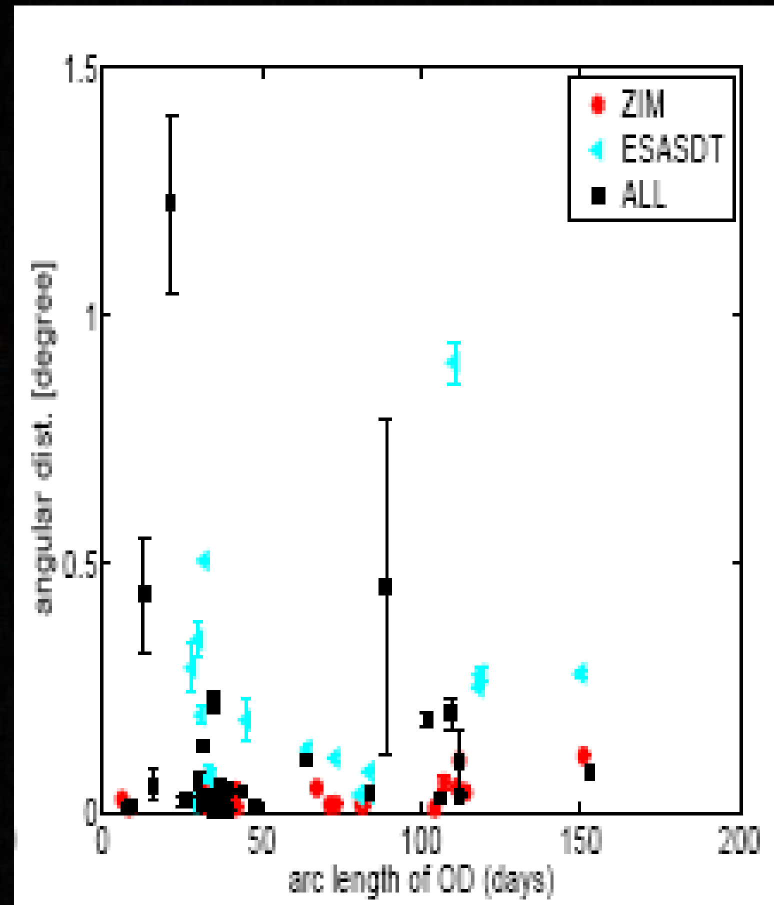

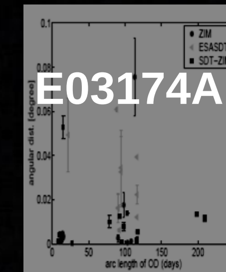

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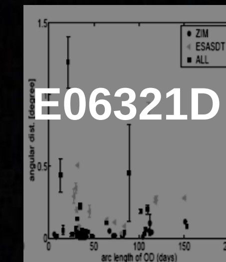

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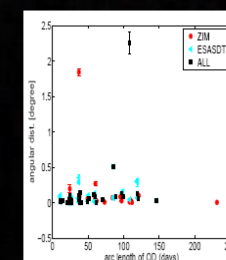
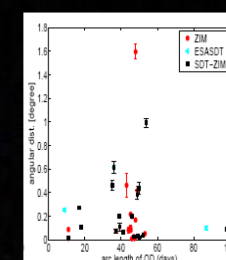
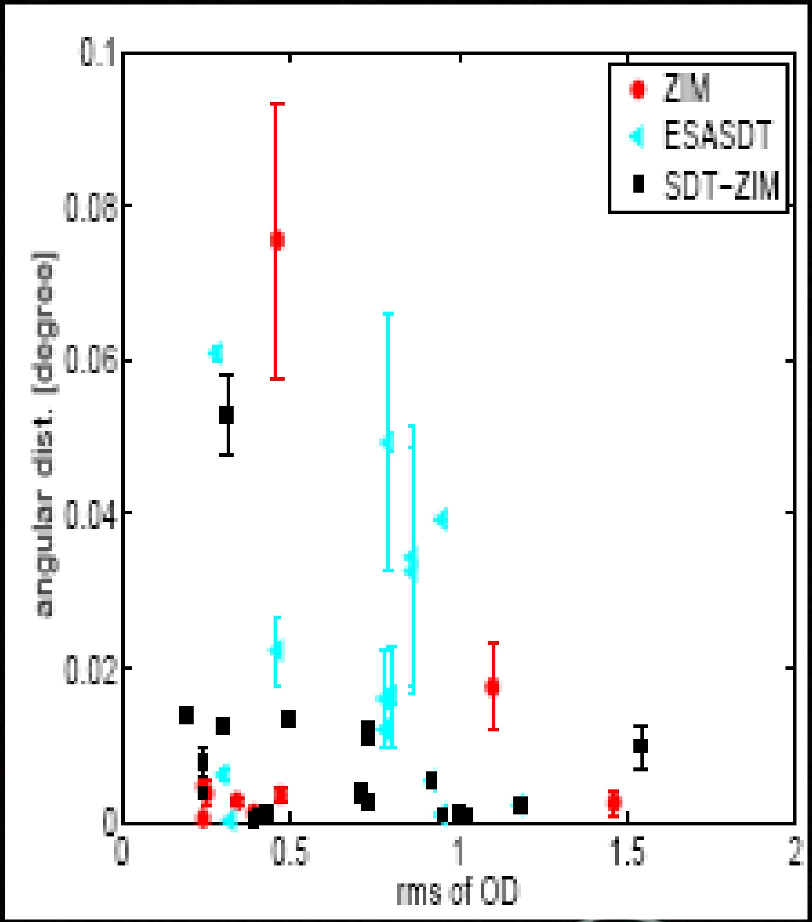




No strong correlation visible!

Dependence on root-mean-square of OD

E03174A



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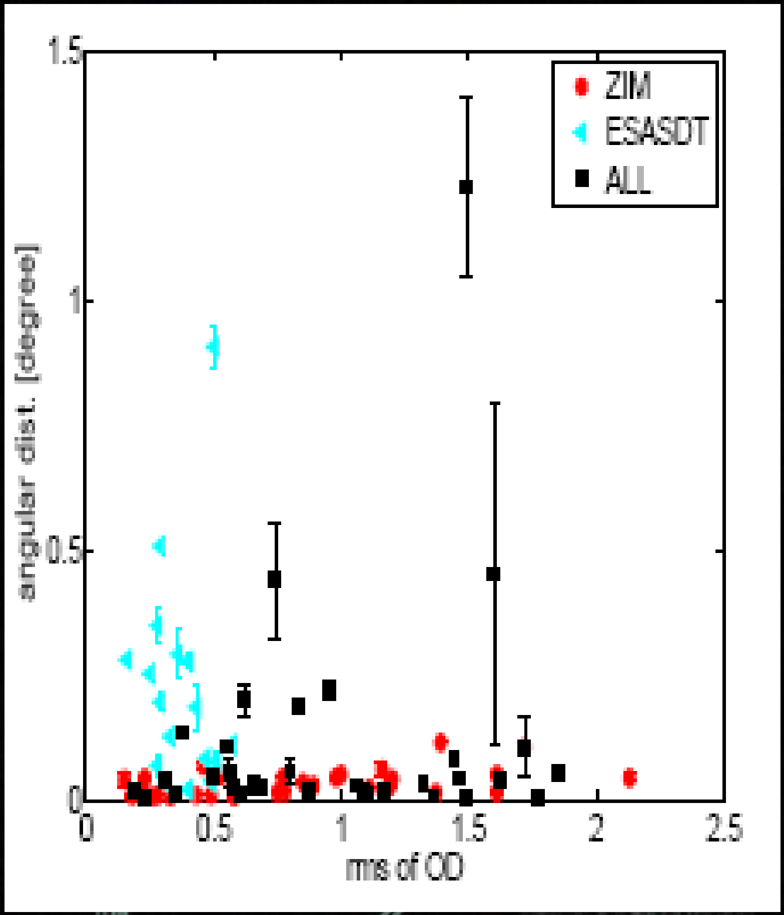

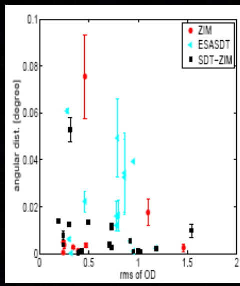

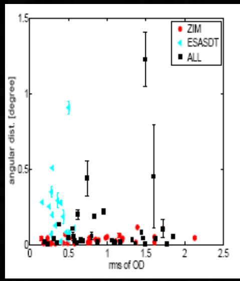

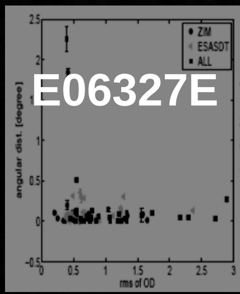

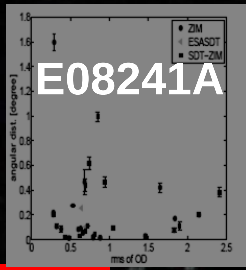

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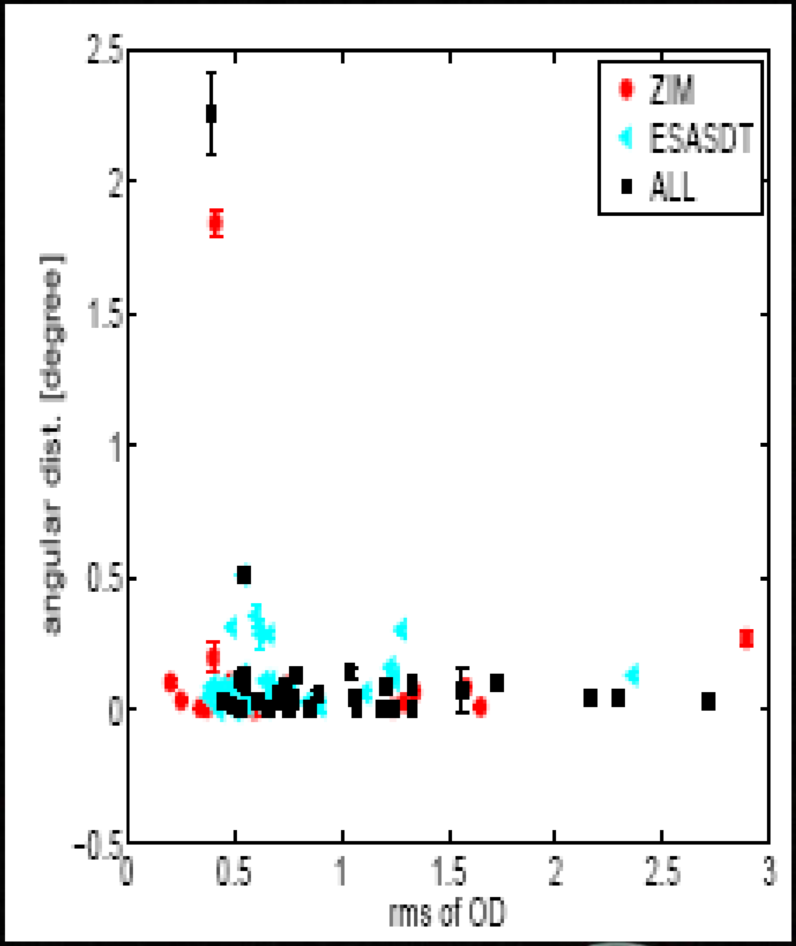

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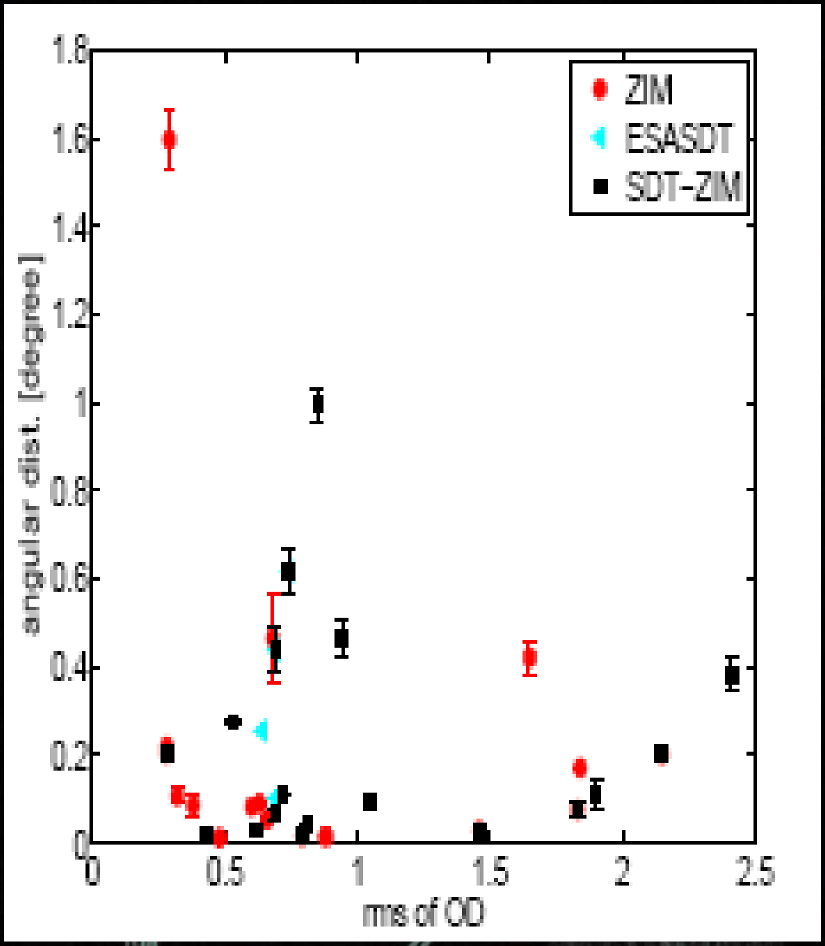

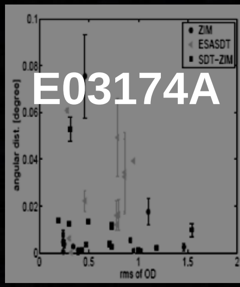

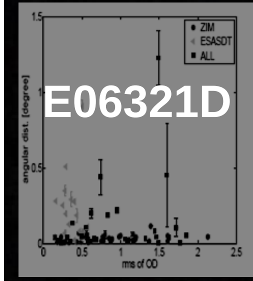

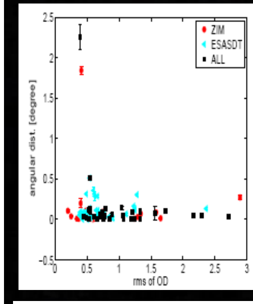

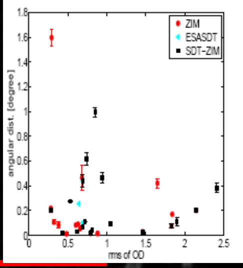

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Dependence on Number of Observations

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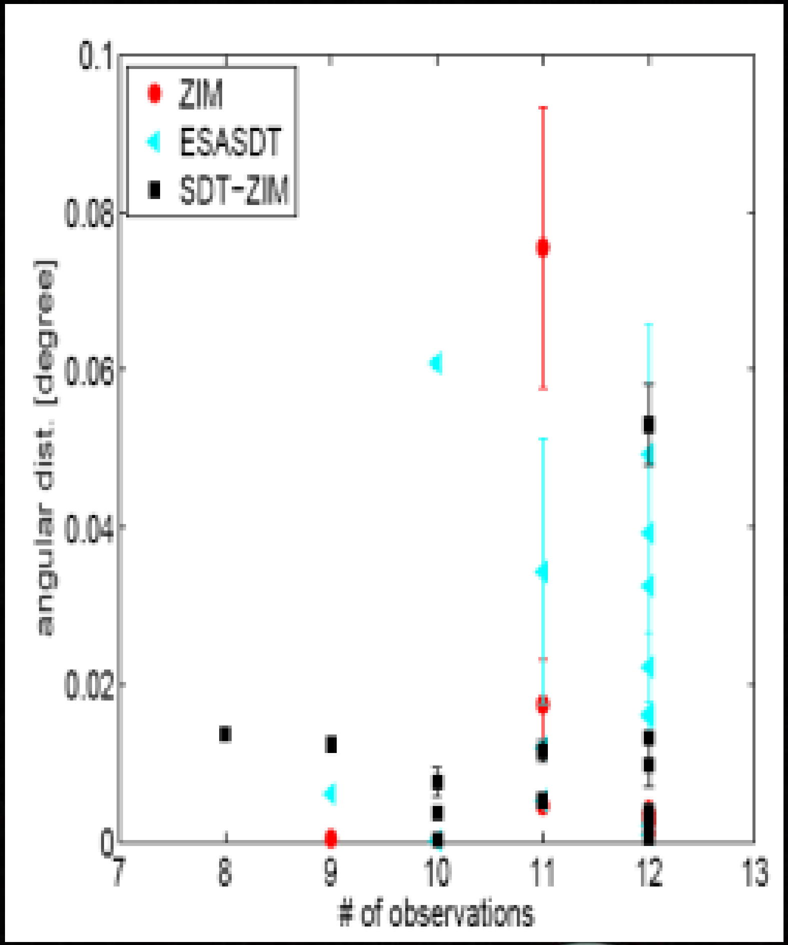

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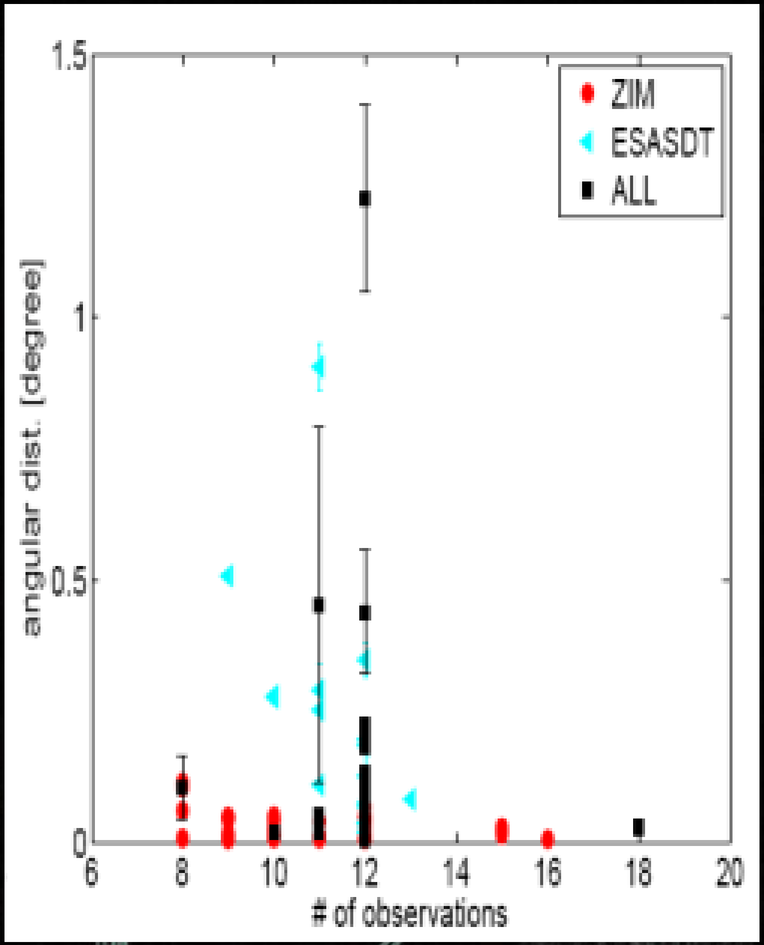

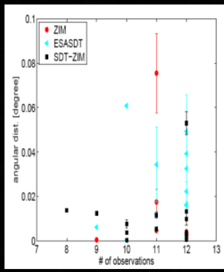

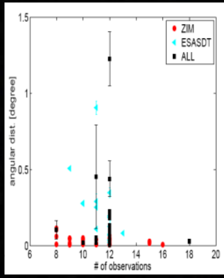

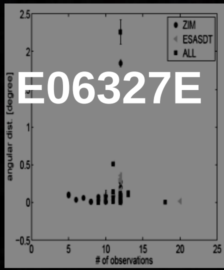

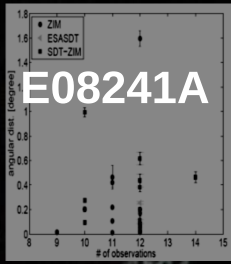

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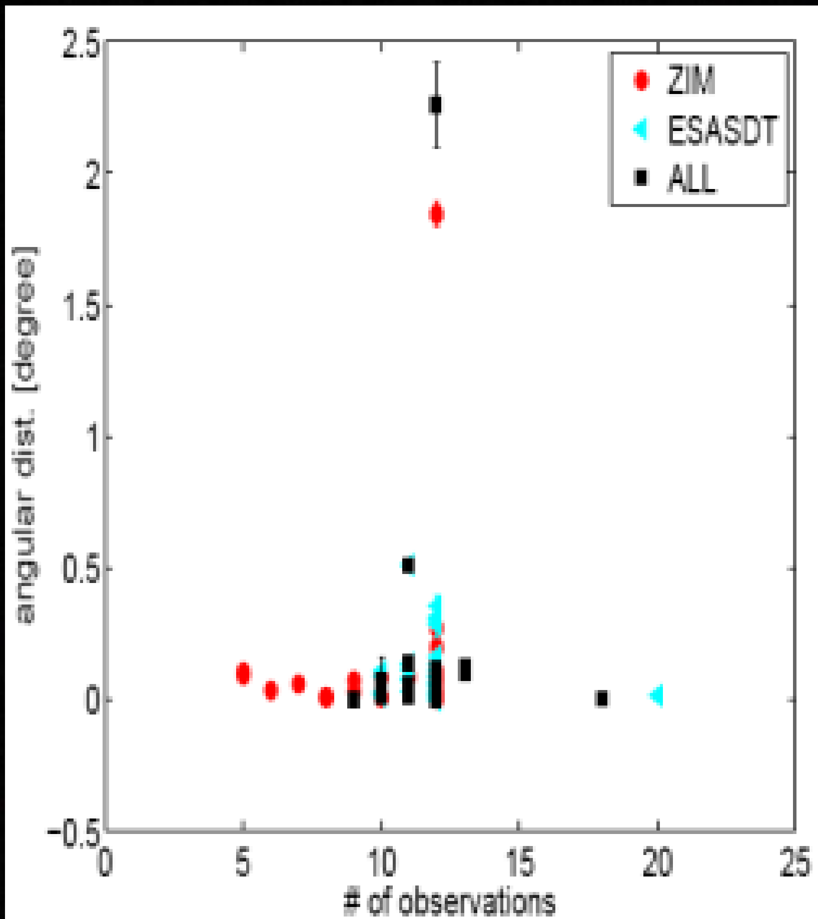

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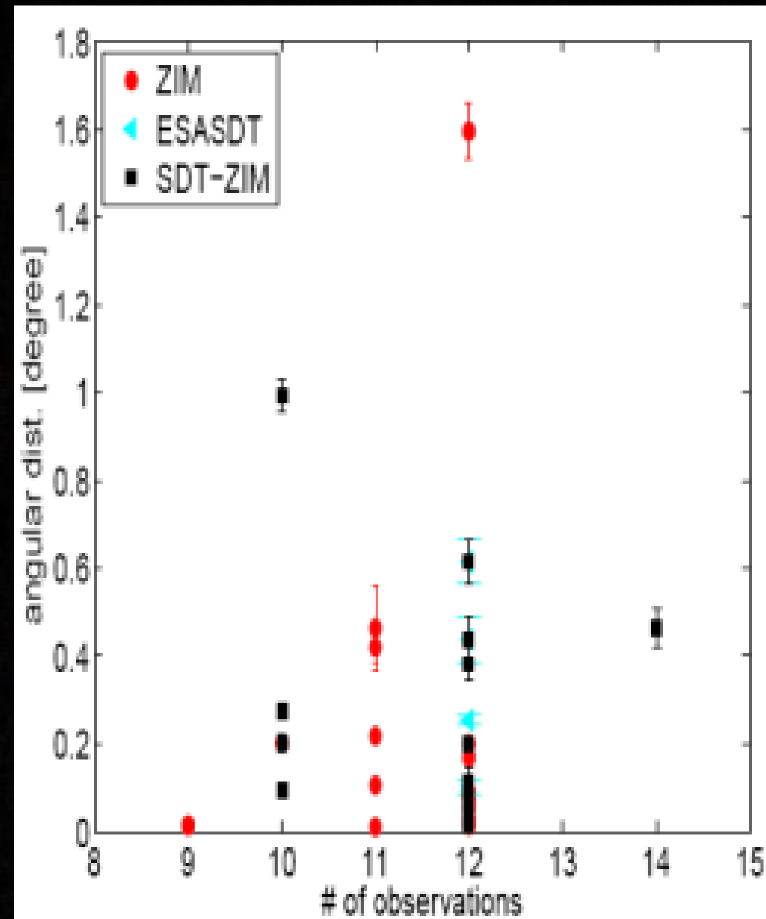
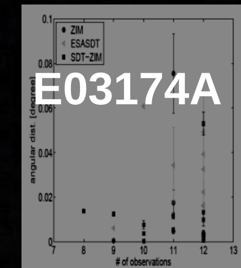
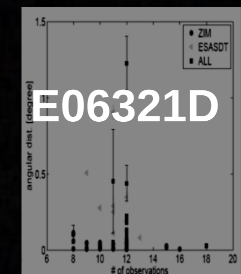
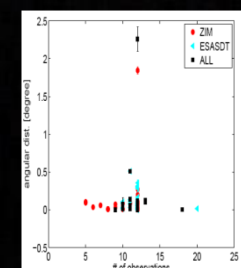
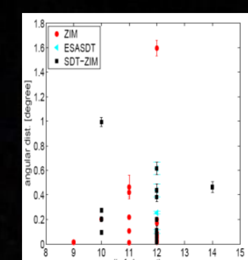






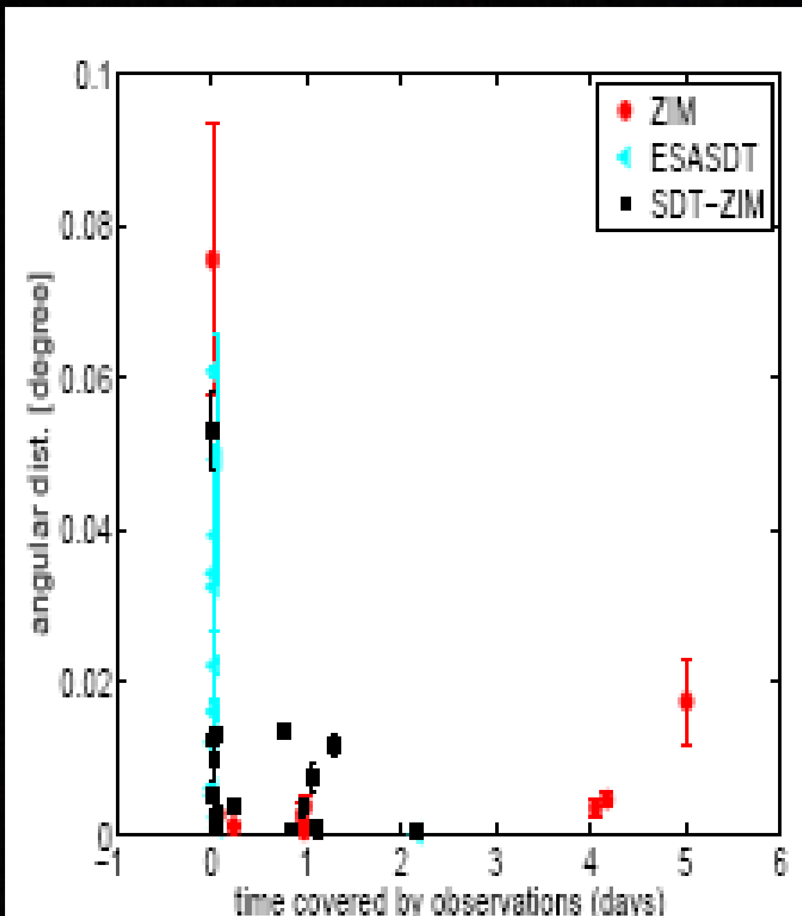




No strong correlation visible!

Dependence on Time Covered by Obs.

E03174A



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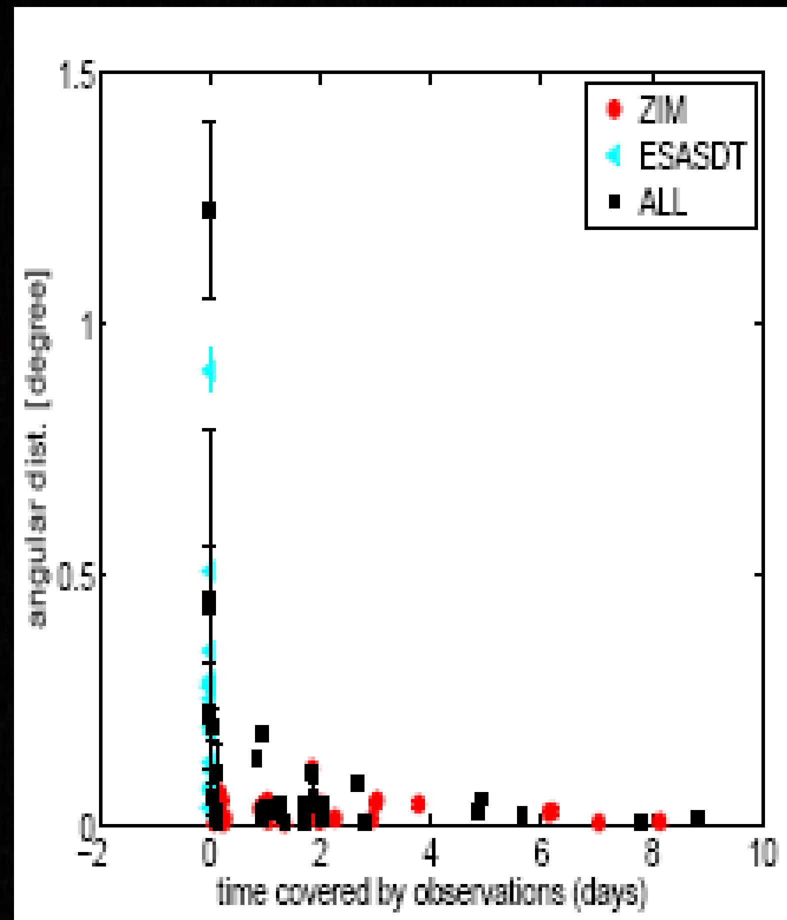
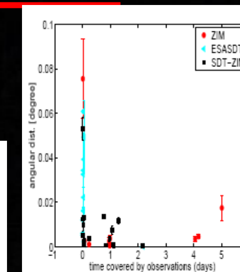
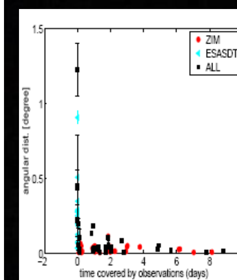
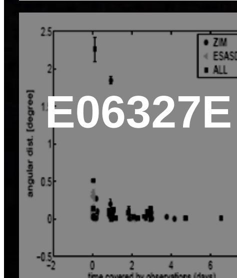
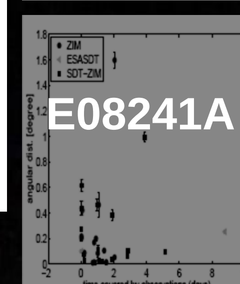






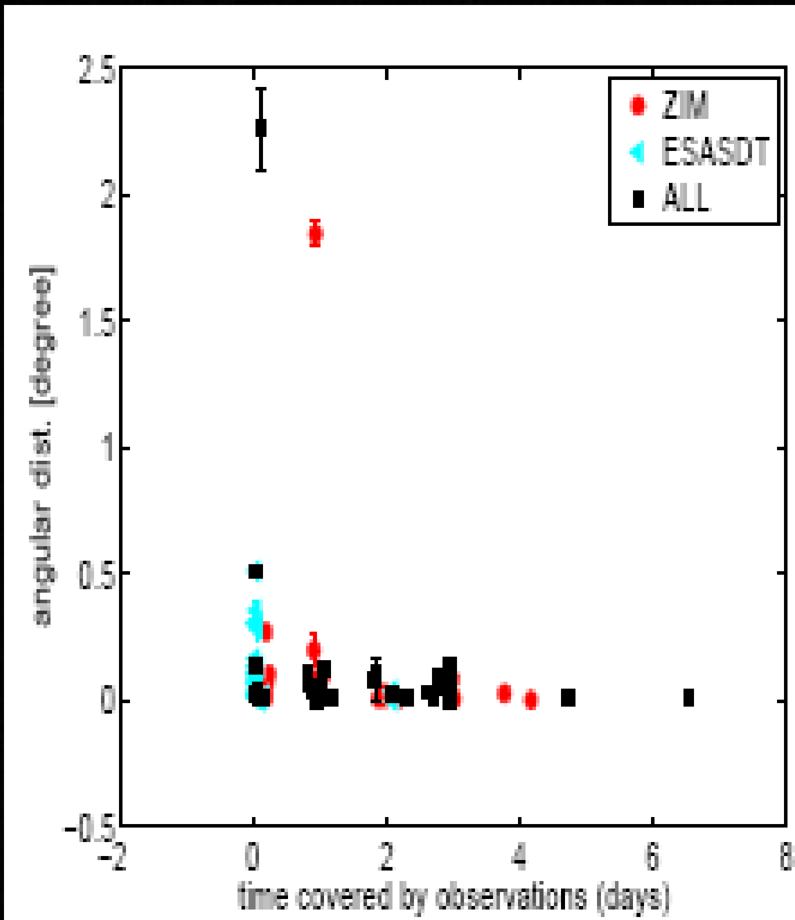




Correlation!

Dependence on Time Covered by Obs.

E06327E



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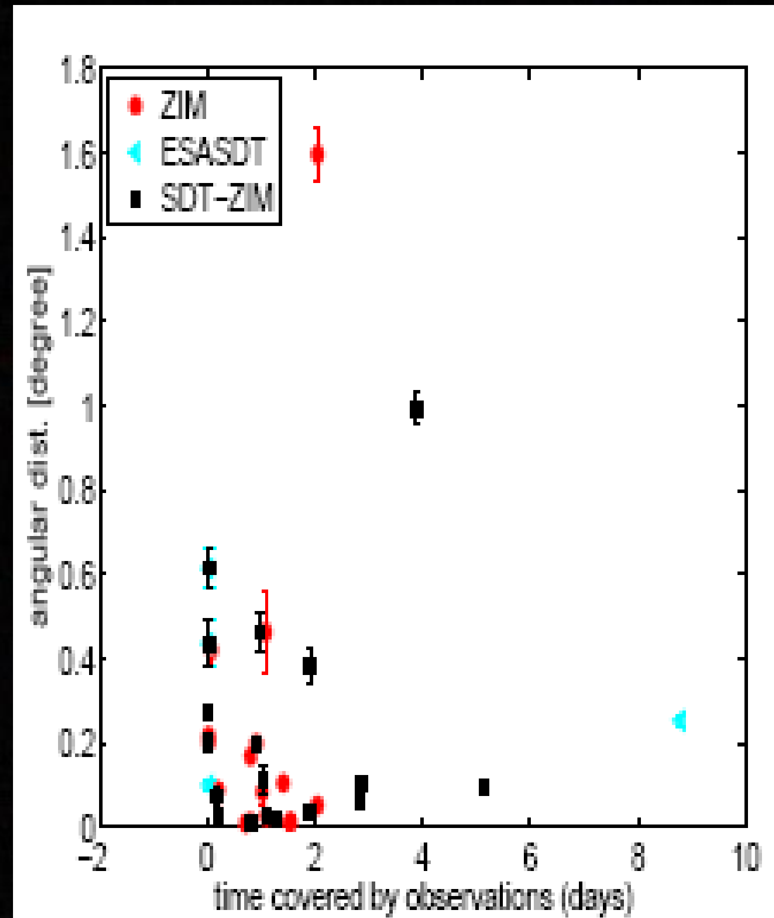
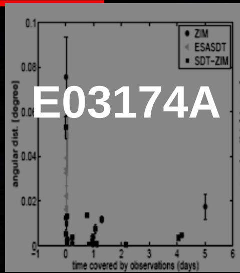
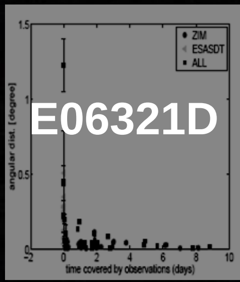
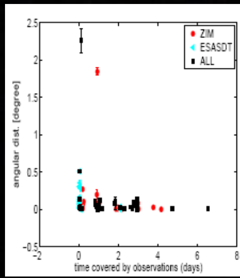
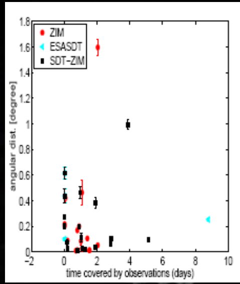










Correlation!

Orbit Determination and Propagation

- Even with only sparse data small differences between propagated ephemerides and observations can be reached.
- The relevant factor is the time actually covered by the observations and not the (possibly) long time interval between the sets.
- For objects with non nearly circular orbits, the distribution in anomaly is relevant.

➡ **1.2 h Coverage per set is enough for differences < 0.5°**

Orbit Determination of HAMR Objects

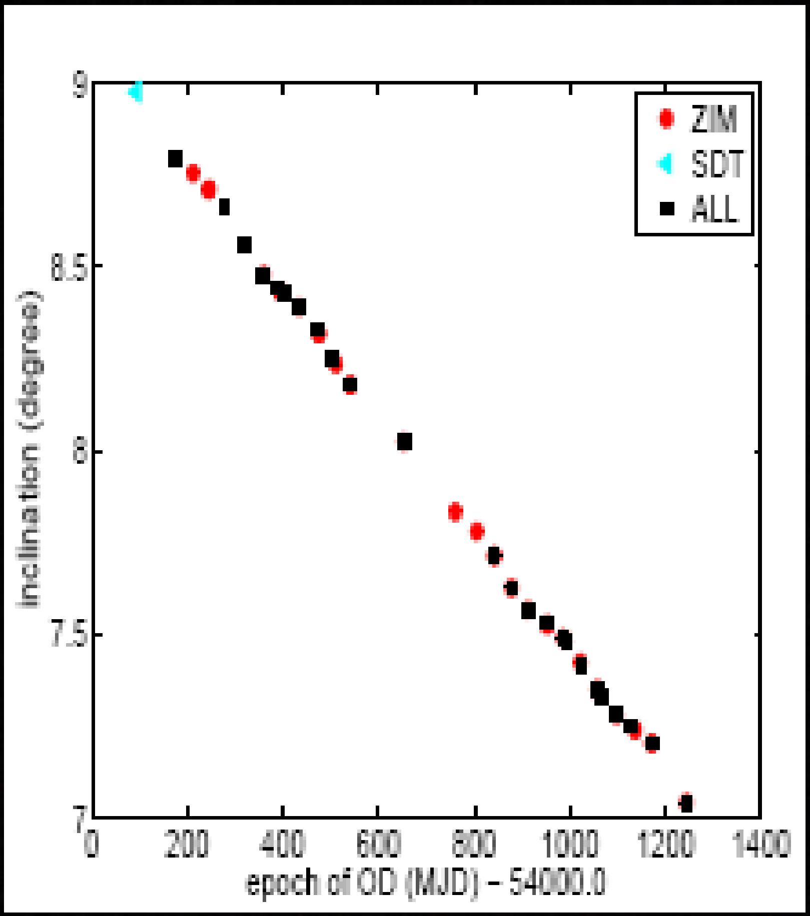
Applied to orbit determination with observations of HAMR objects.

Investigated AIUB catalogue objects:

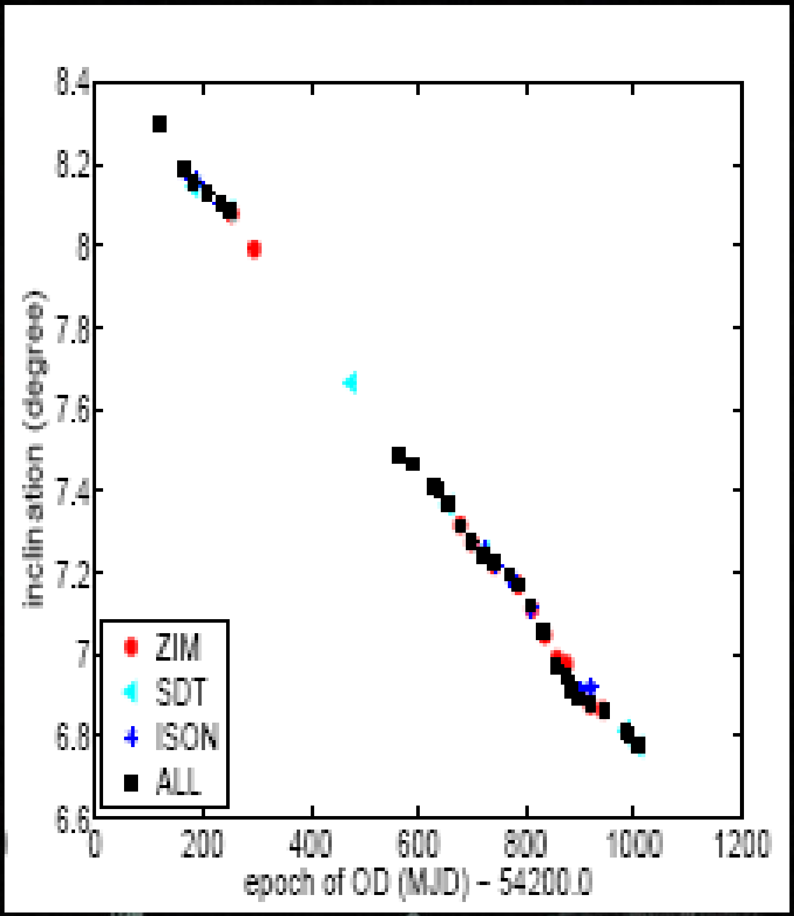
NAME	epoch (MJD)	a (km)	e	i (deg)	AMR	Mag
E06321D	55275.9	41400	0.035	7.00	2.29	15.3
E07194A	54877.0	40900	0.005	7.31	3.37	16.8
E07308B	54416.0	35600	0.264	7.63	8.83	15.8
E06293A	54951.0	40200	0.245	11.06	15.41	16.8

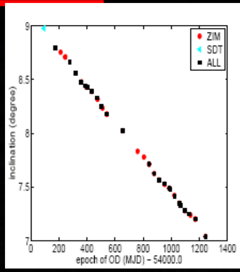
HAMR Objects: Inclination

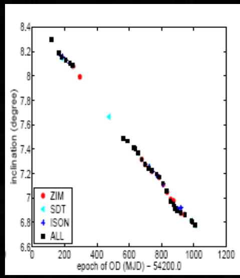
E06321D

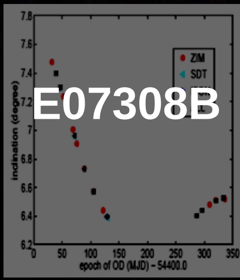


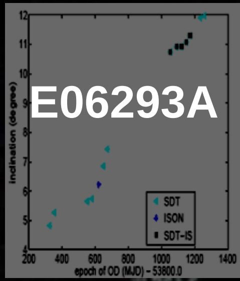
E07194A







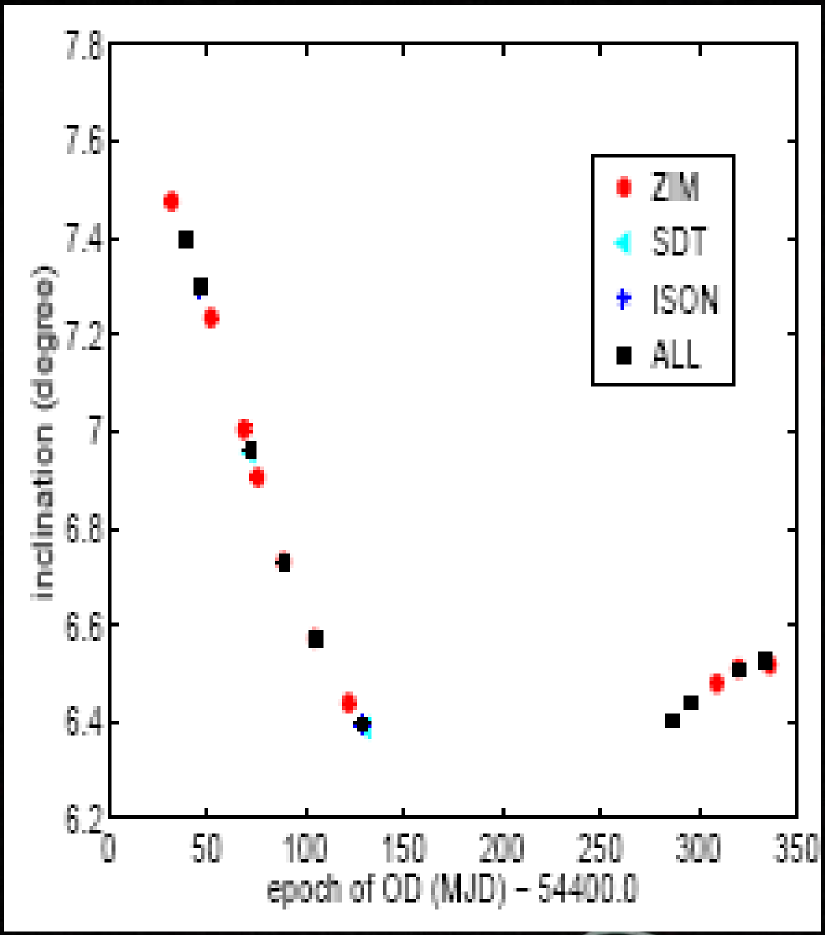




In agreement with theory.

HAMR Objects: Inclination

E07308B



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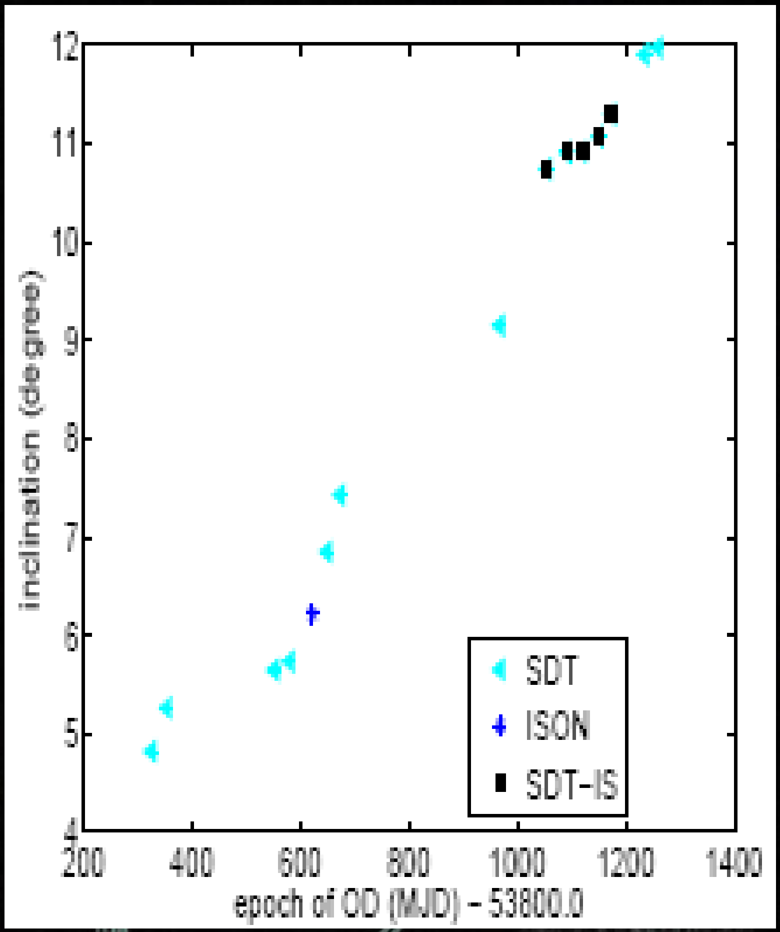
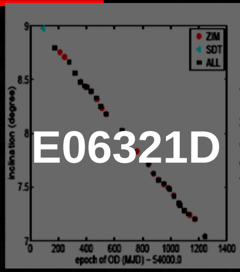
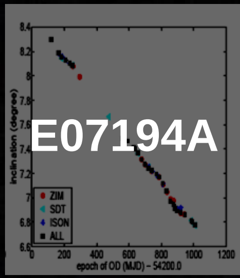
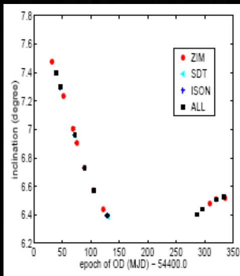
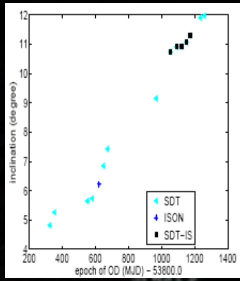






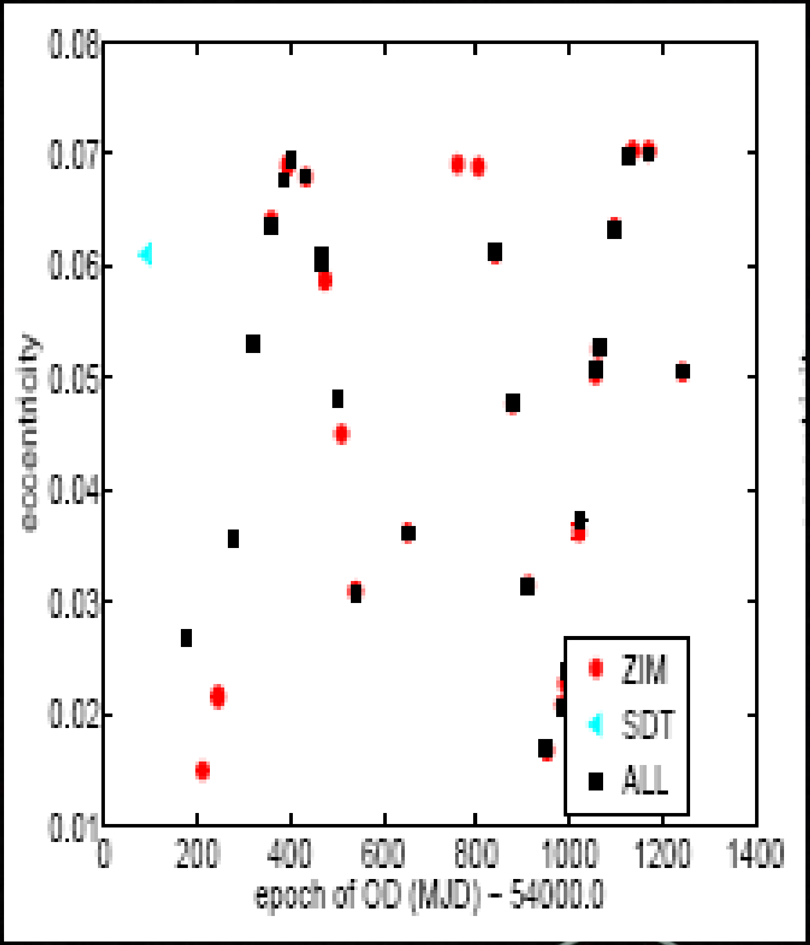




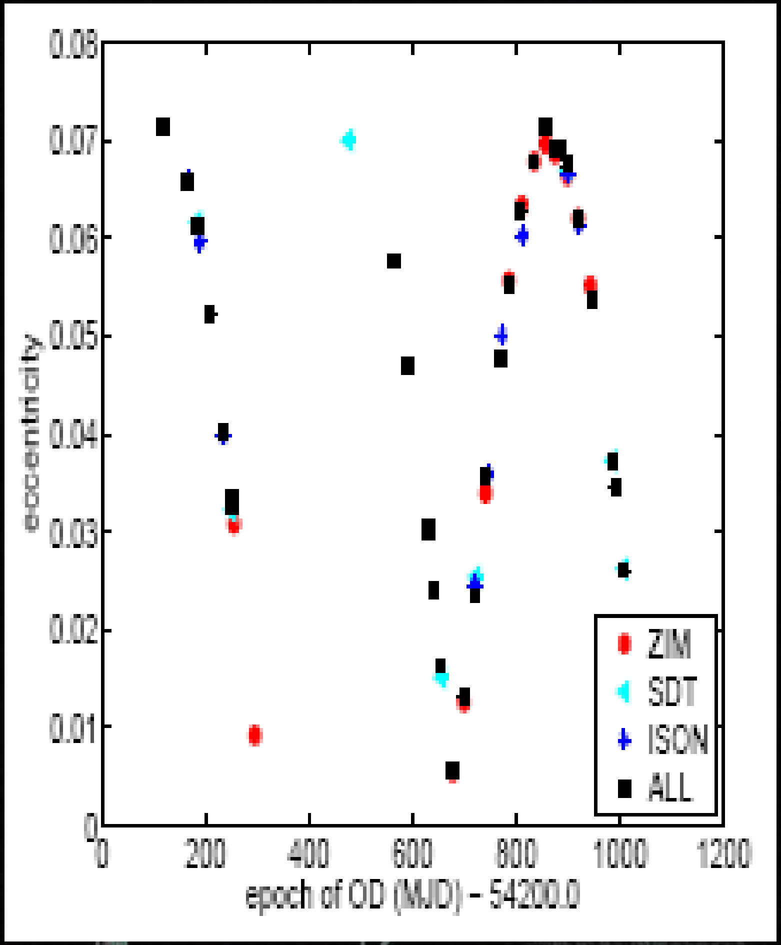
In agreement with theory.

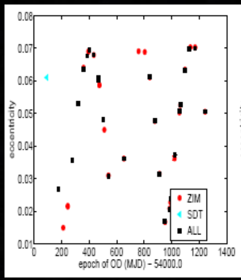
HAMR Objects: Eccentricity

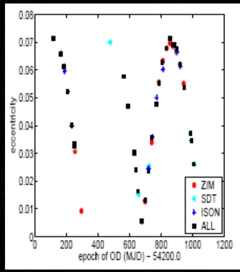
E06321D

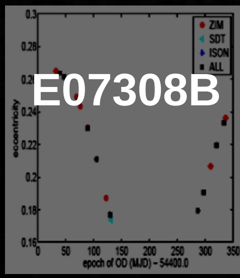


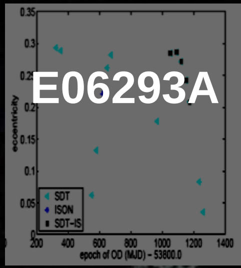
E07194A







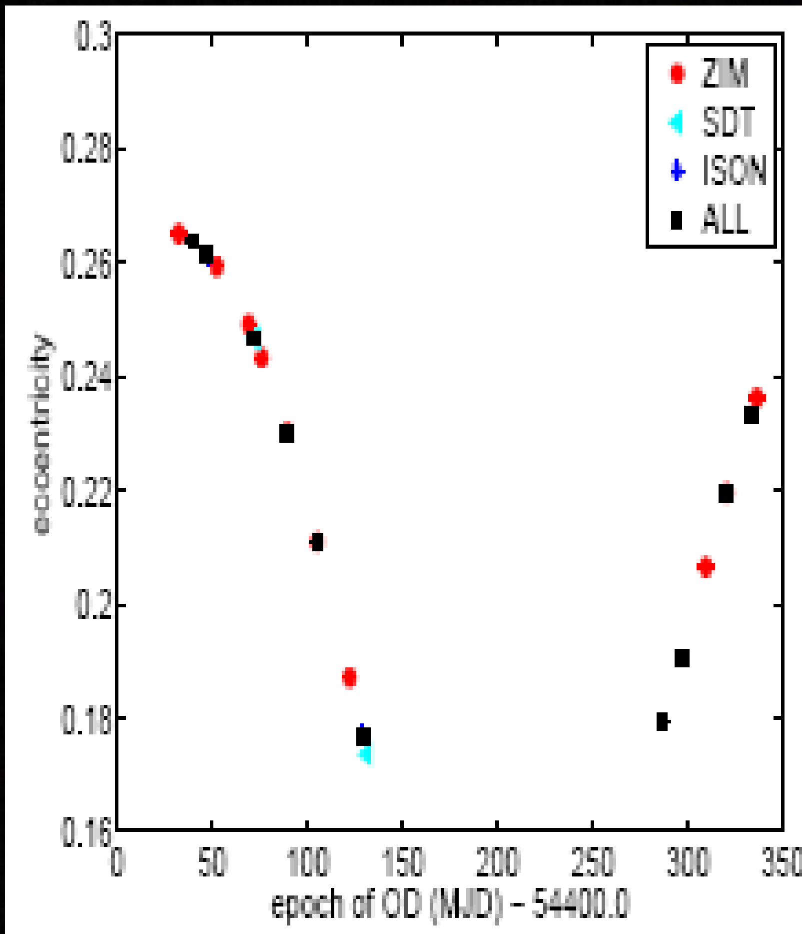




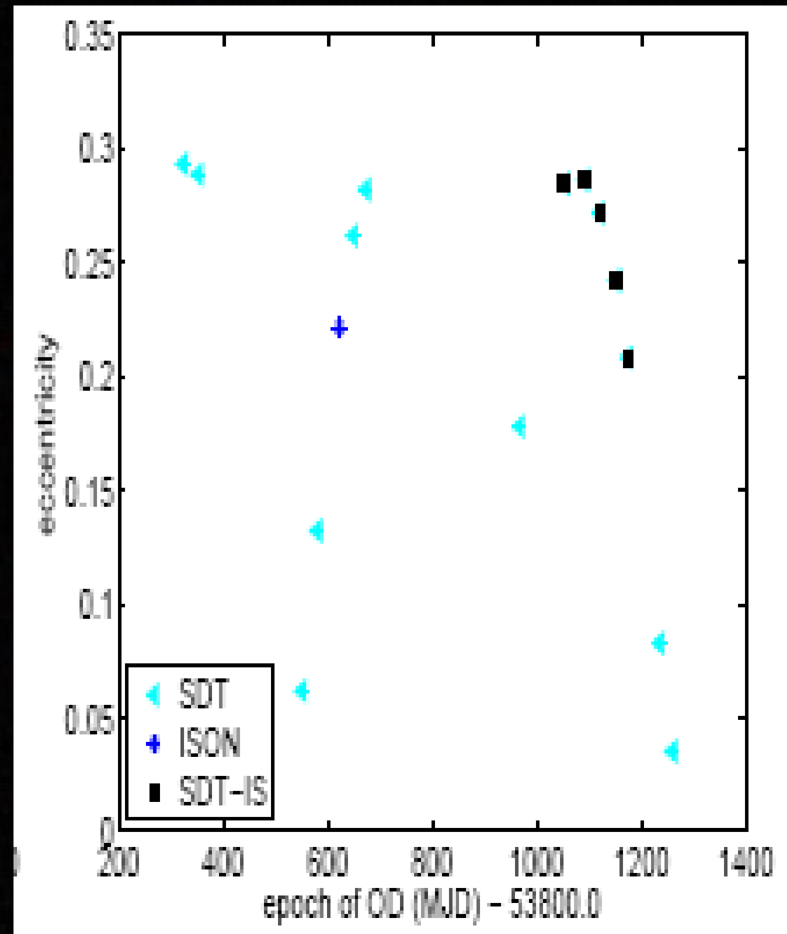
In agreement with theory.

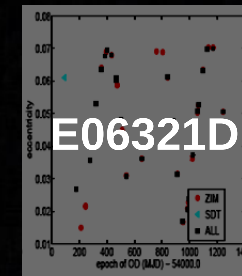
HAMR Objects: Eccentricity

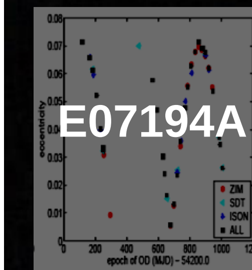
E07308B

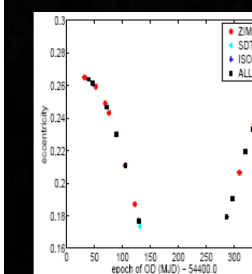


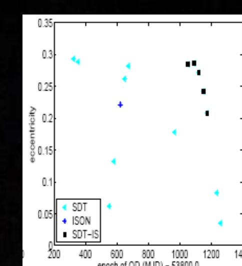
E06293A







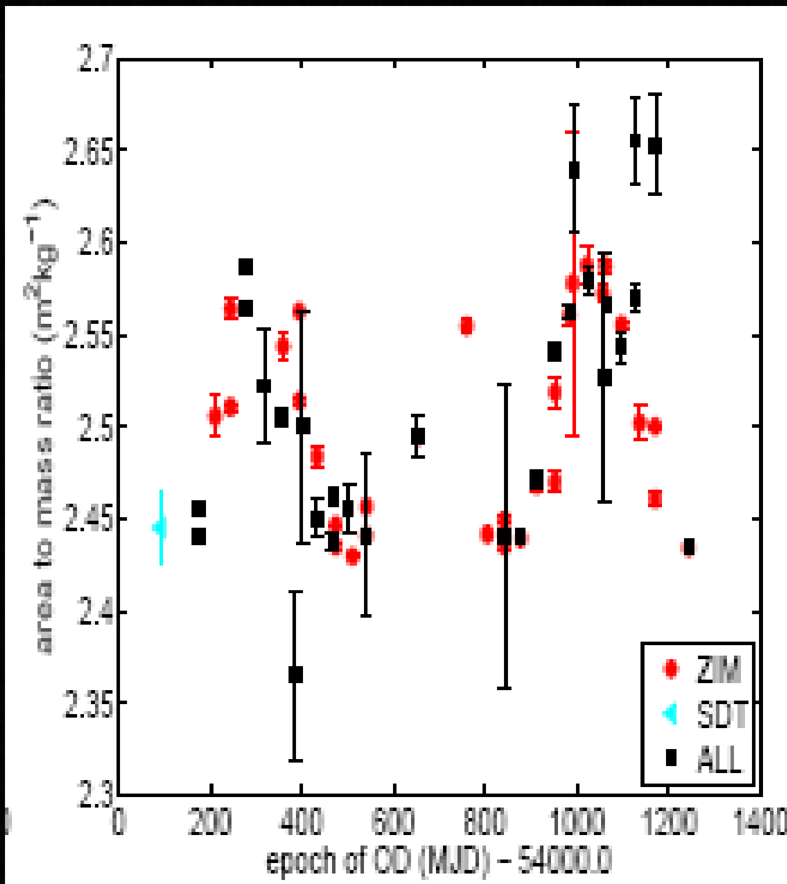




In agreement with theory.

HAMR Objects: AMR Variations

E06321D



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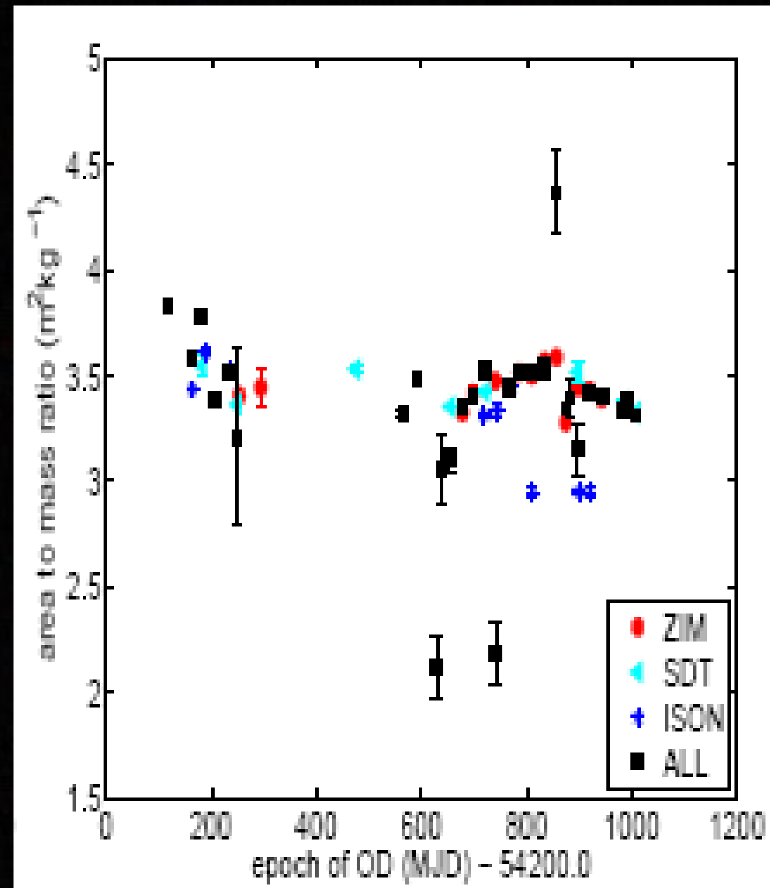

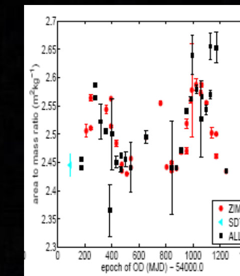

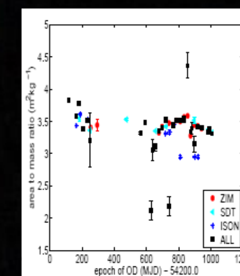

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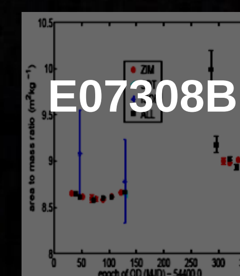

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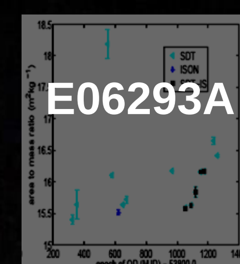
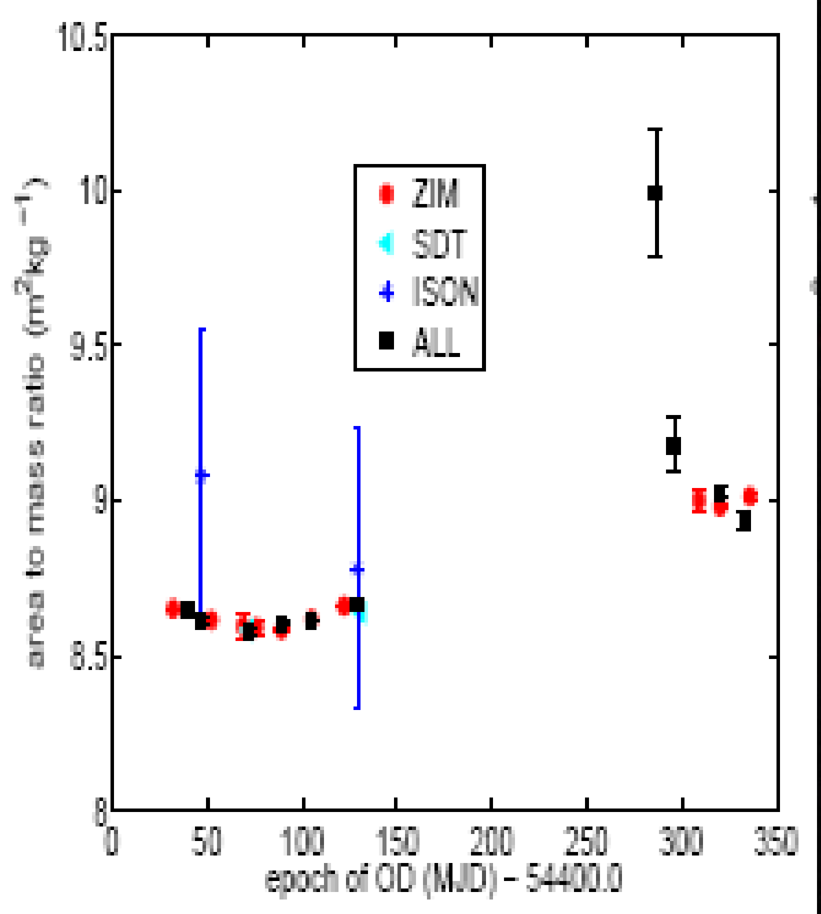


AIUB

Astronomical Institute, University of Bern

HAMR Objects: AMR Variations

E07308B



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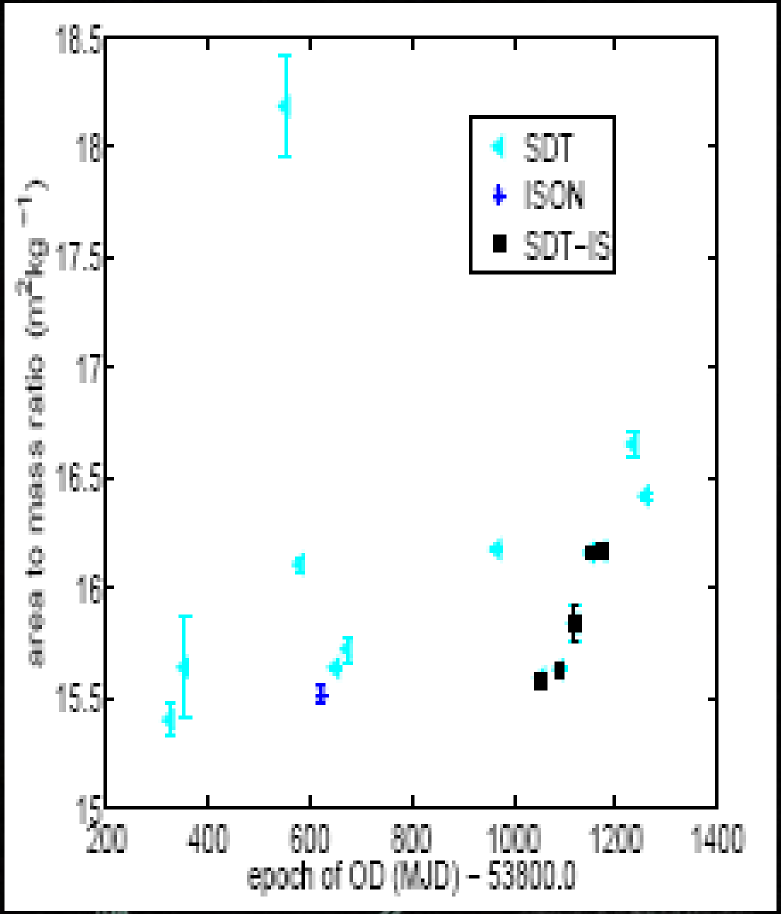
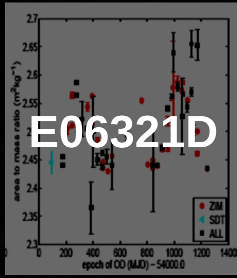
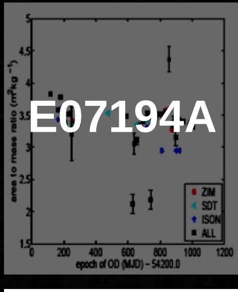
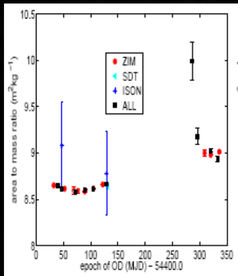
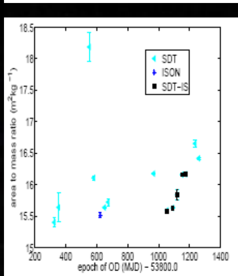


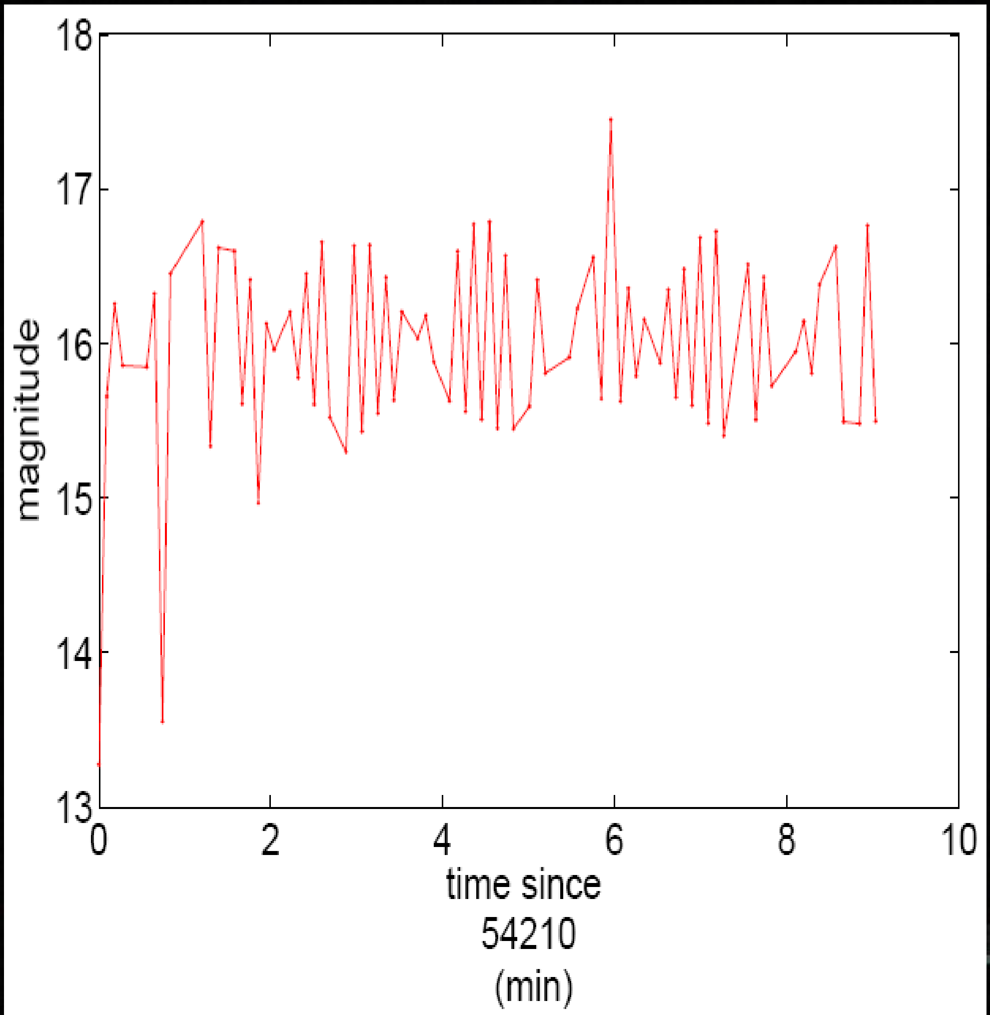








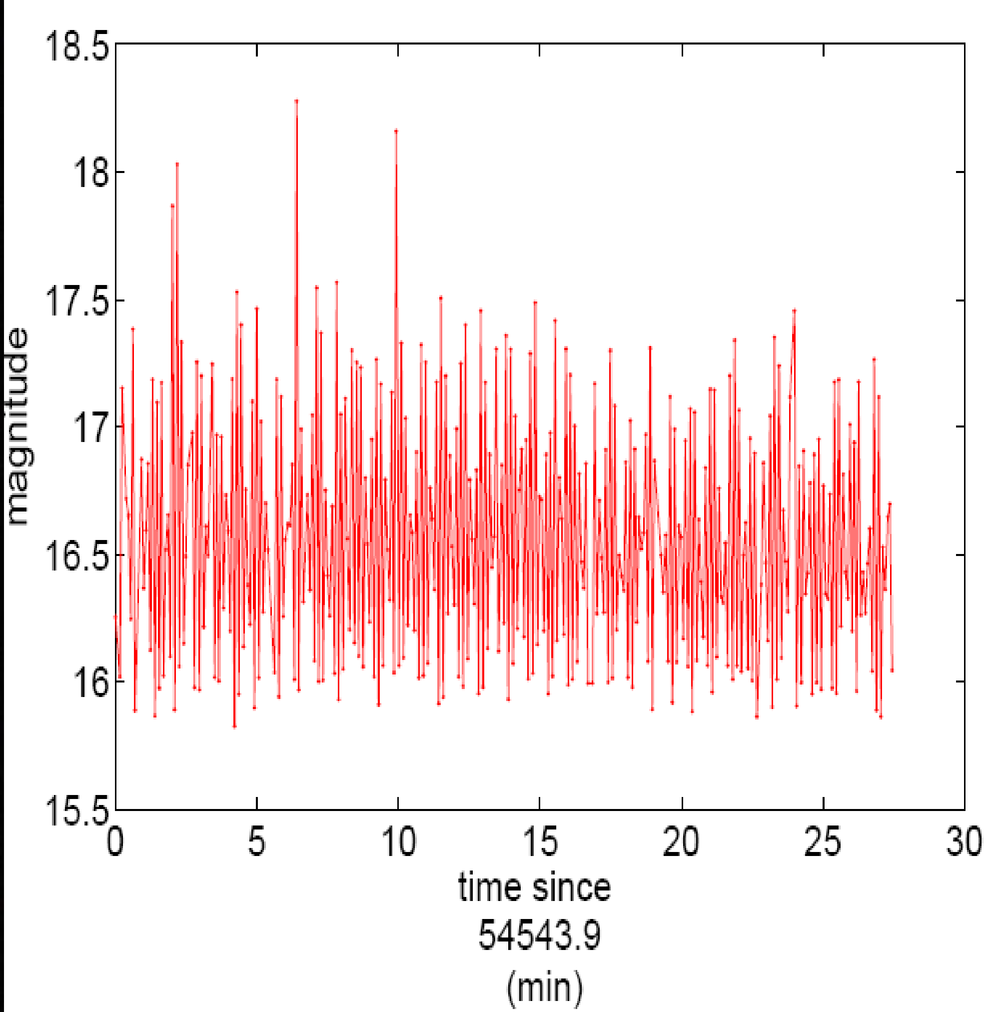
Observed Light Curves: E06321D



Apr 19 2007, 32°

- Variations in light curve pattern over time.
- Aliasing effects despite 3 sec. sampling rate.
- Fourier analysis shows short periods between 6 and 30 Sec.

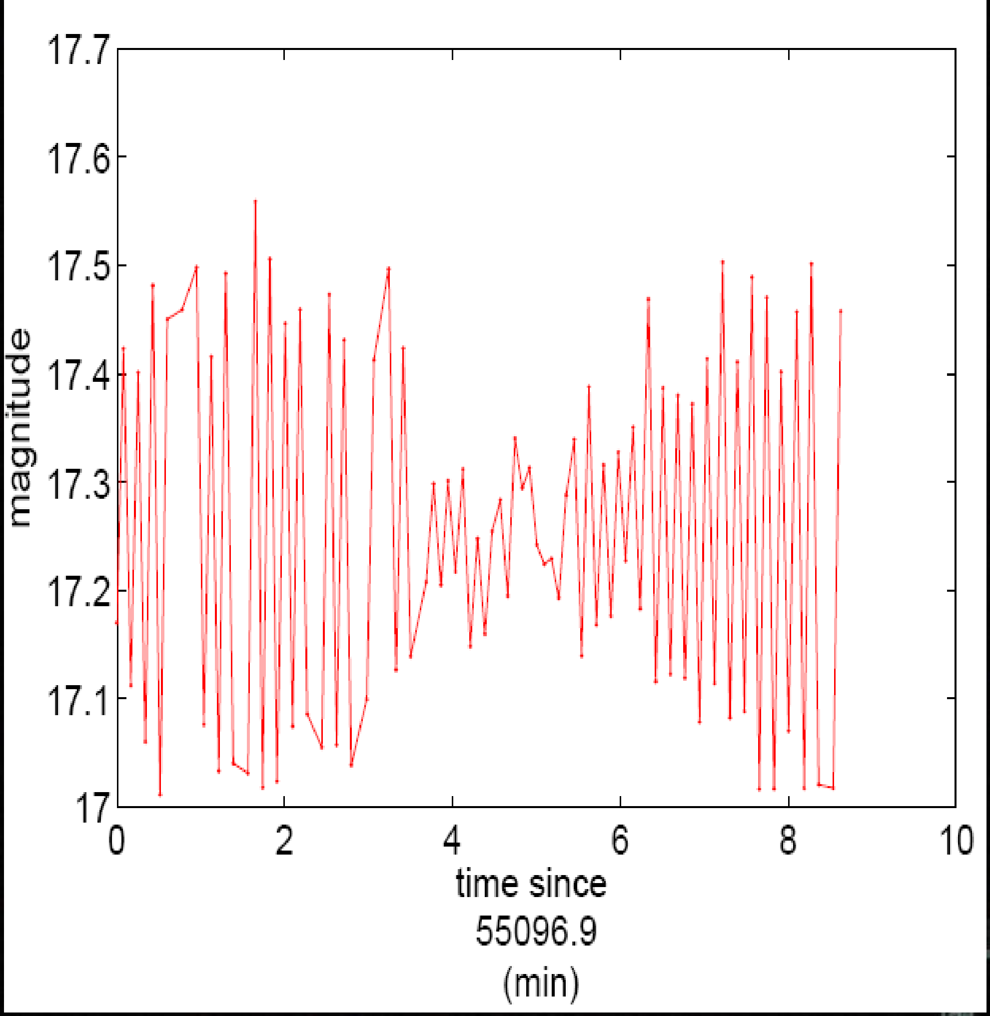
Observed Light Curves: E06321D



Mär 18 2008, 28°

- Variations in light curve pattern over time.
- Aliasing effects despite 3 sec. sampling rate.
- Fourier analysis shows short periods between 6 and 30 Sec.

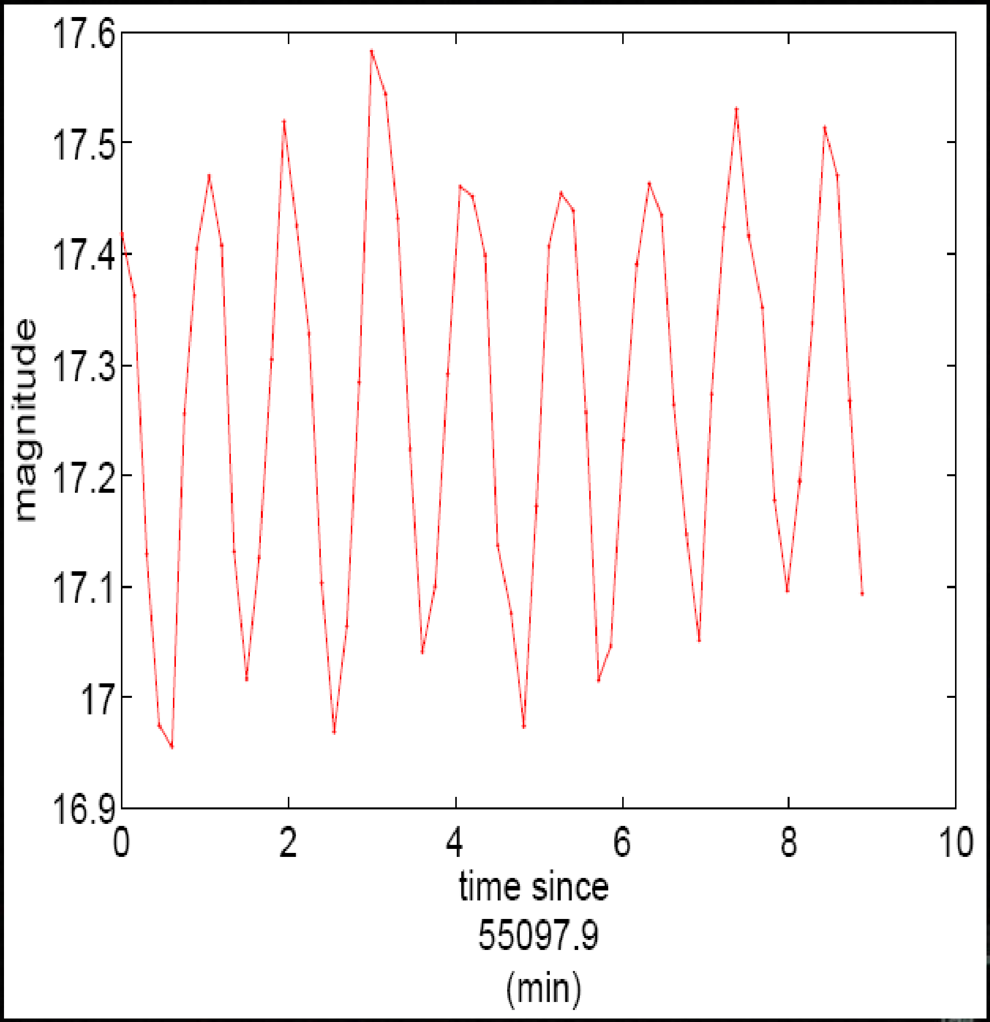
Observed Light Curves: E06321D



Sep 22 2009, 19°

- Variations in light curve pattern over time.
- Aliasing effects despite 3 sec. sampling rate.
- Fourier analysis shows short periods between 6 and 30 Sec.

Observed Light Curves: E06321D

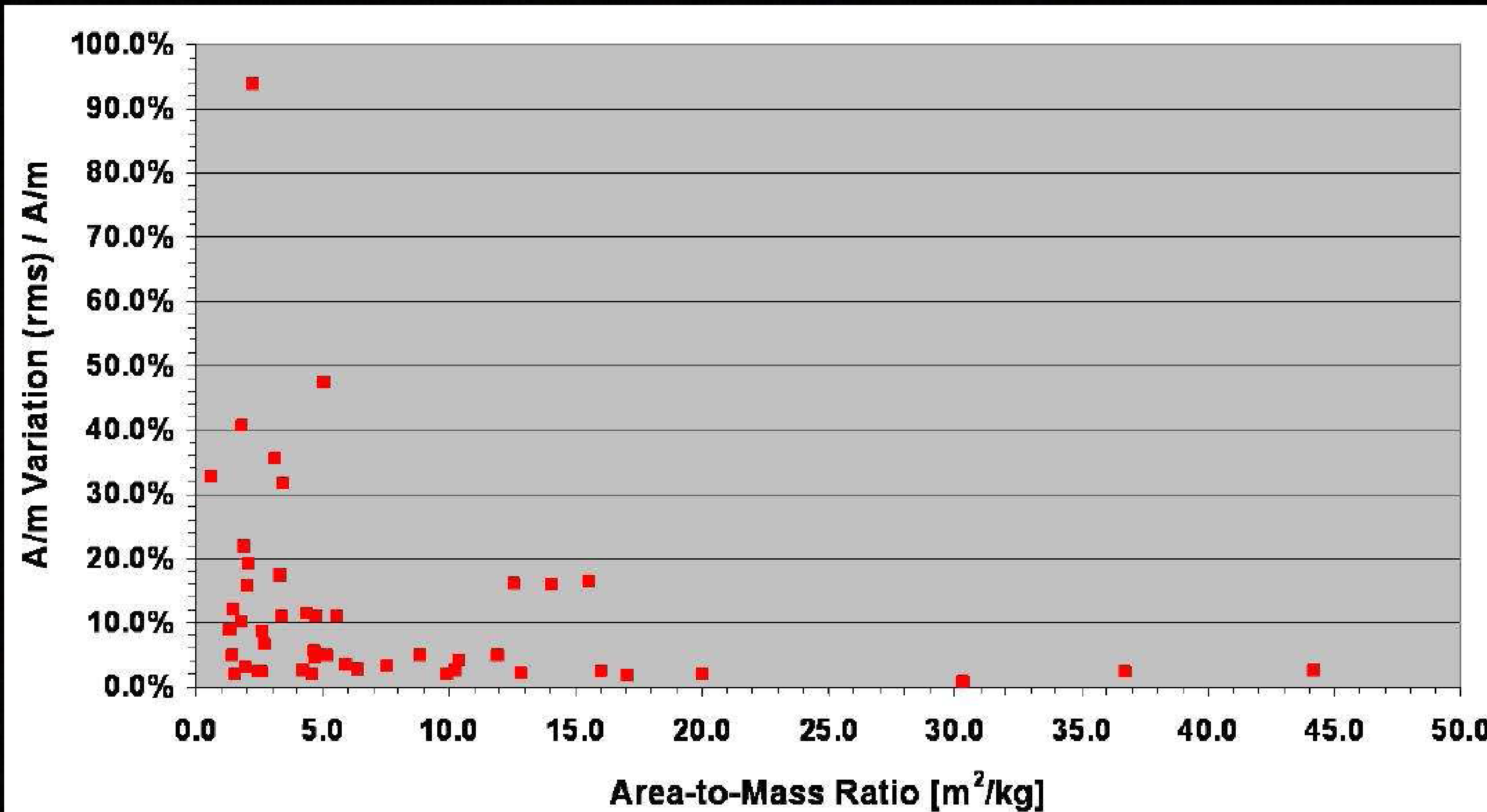


Sep 23 2009 , 40°

- Variations in light curve pattern over time.
- Aliasing effects despite 3 sec. sampling rate.
- Fourier analysis shows short periods between 6 and 30 Sec.

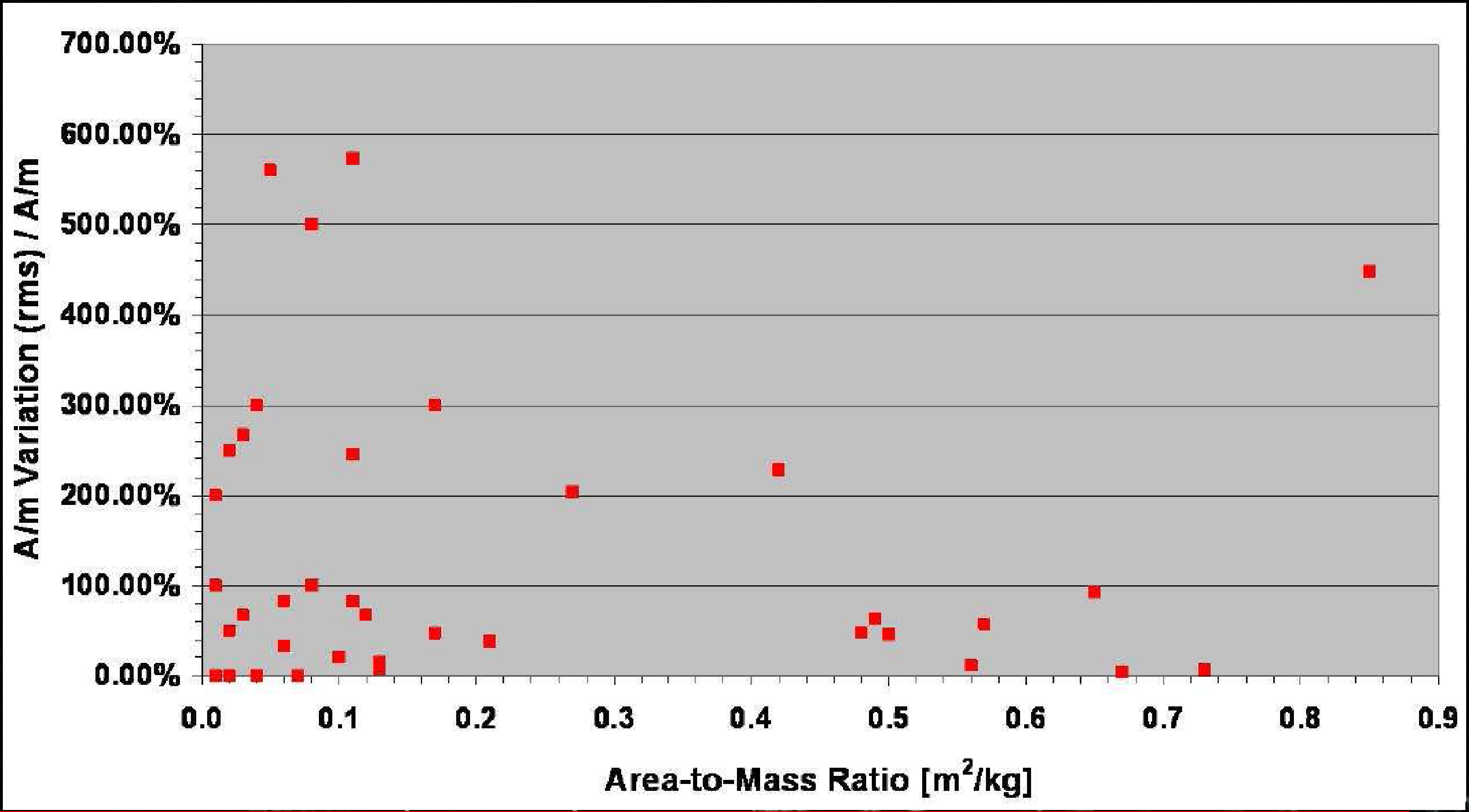
Relative Variation AMR

47 HAMR objects:



Relative Variation AMR

40 low AMR objects:



Orbit Determination of HAMR Objects

- No clear systematic trends are visible, especially no common ones for the objects.
- Those ARM values, which do not seem to follow a seemingly trend
  - Do not always have large errors
  - Do not always show large differences between propagated ephemerides and observations.
- This may could be a hint for a more complex attitude motion of the investigated objects, which is not equaled out over the fit interval of OD.

Thank you.

frueh@aiub.unibe.ch