An Optical Survey for Space Debris on Highly Eccentric MEO Orbits

T. Schildknecht, J. Silha, A. Hinze, A. Vananti

Astronomical Institute, University of Bern, Switzerland

T. Flohrer

Space Debris Office, ESA/ESOC, Germany

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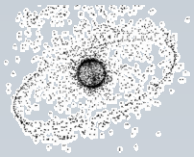

Outline

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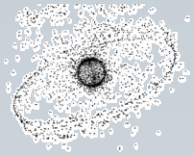
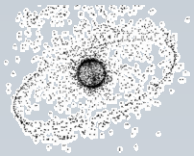
2. Current TLE Population
3. Survey Strategies
4. Observations and Results
5. Conclusion



Main Objectives

- **Background:**
  Fragmentation events (including deliberate events) in highly-eccentric MEO, in particular in Molniya-type orbits, are known.
- **Objectives:**
  - Develop observation strategies and make a comparative analyses
  - Demonstrate the feasibility and performance of the proposed observation strategies through an experimental observation campaign
  - Build-up and maintain a temporal catalogue

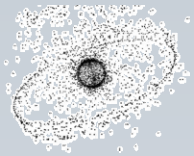


TLE Molniya Population

- Selection criteria
  - $60° < i < 67°$
  - $0.5 < e < 0.8$
  - $20000\text{km} < a < 30000\text{km}$

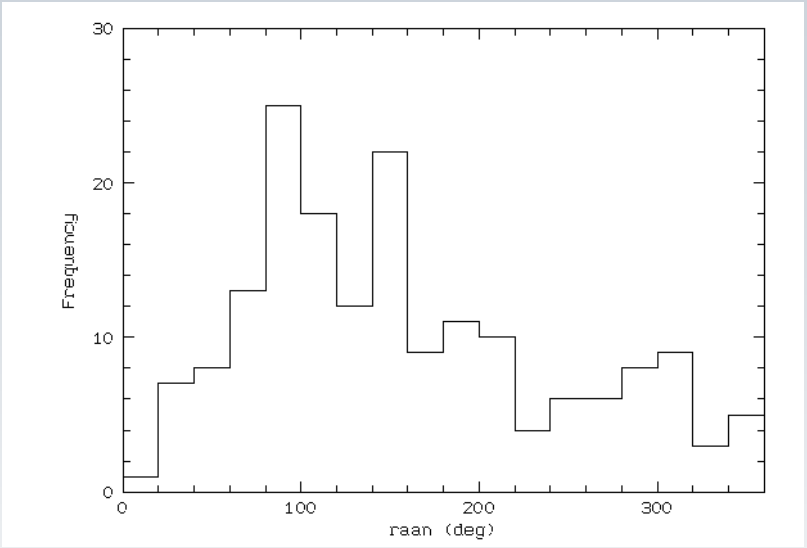
Objects	Quantity
MOLNIYA satellites	41
MERIDIAN satellites	4
Rocket bodies	73
Others	53
TOTAL	171

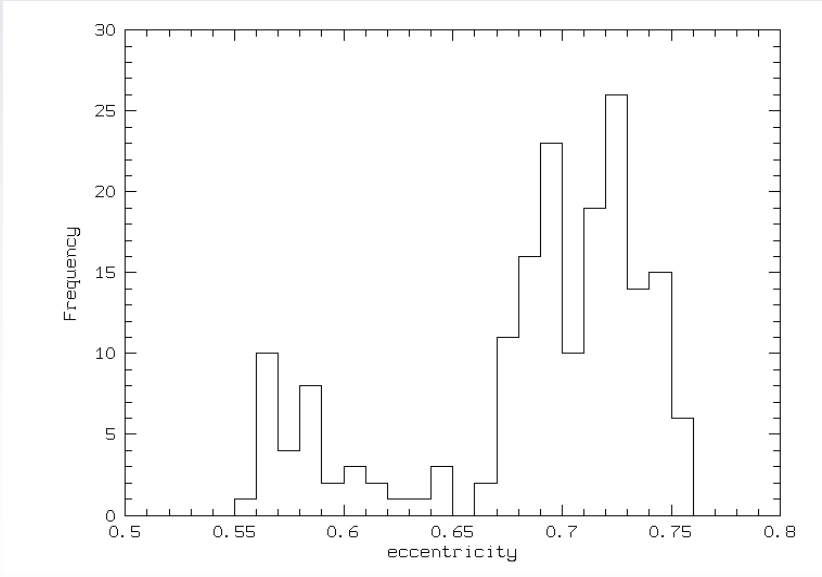
USSTRATCOM catalogue to January 2012



Current Population

- Node distributed over the whole range
- More objects between 80° and 160°

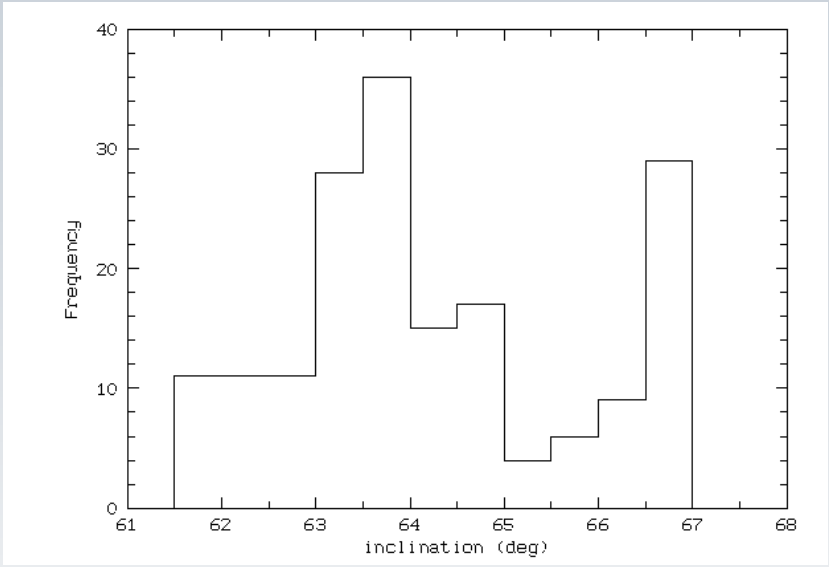


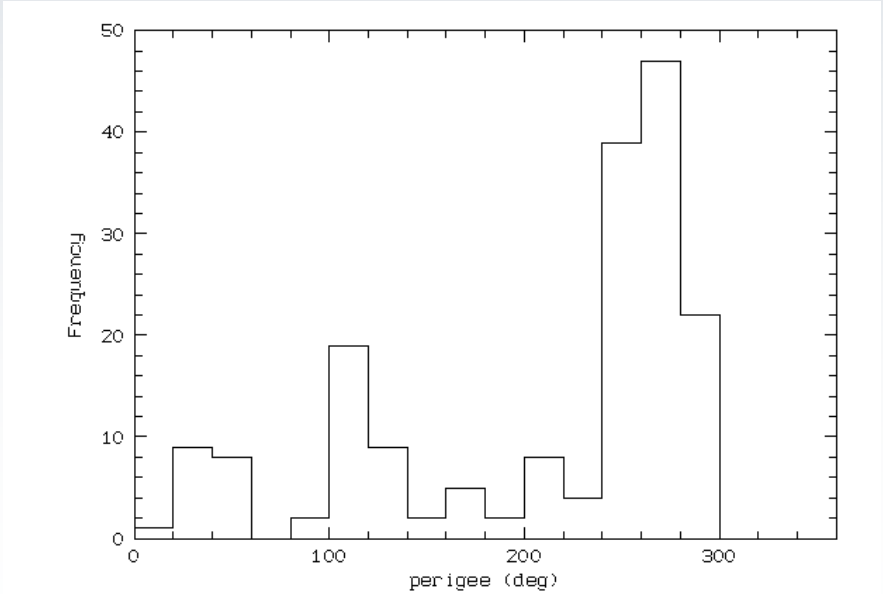


- 2 groups
- e < 0.65
  - Similar launch dates
  - perigee < 180 deg

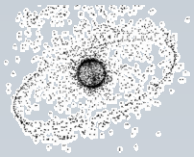
Current Population

- i > 65 -> e < 0.65
- Most objects distributed around 63.4 deg



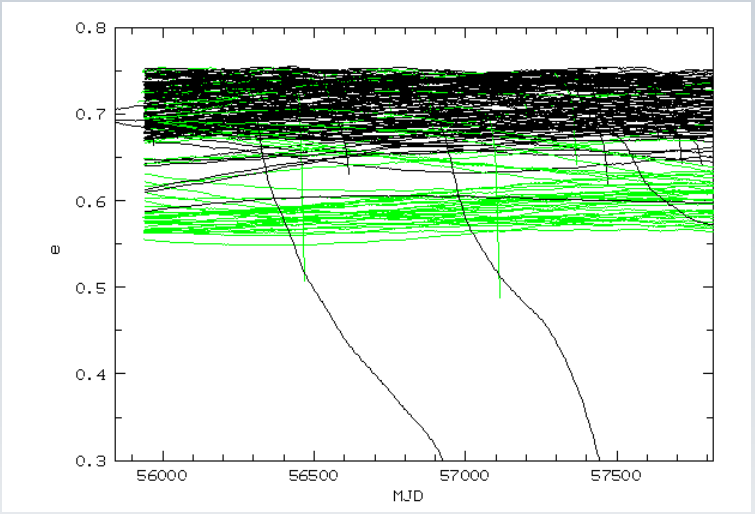


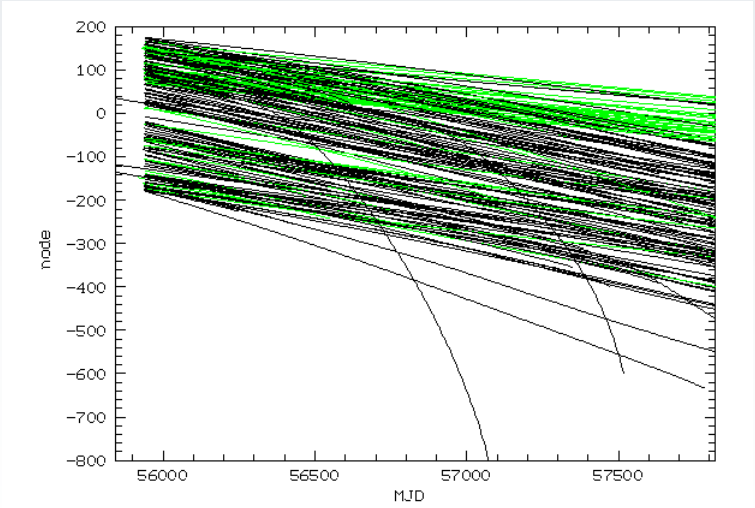
- Cover whole range
- Perigee for most of the objects around 270 deg

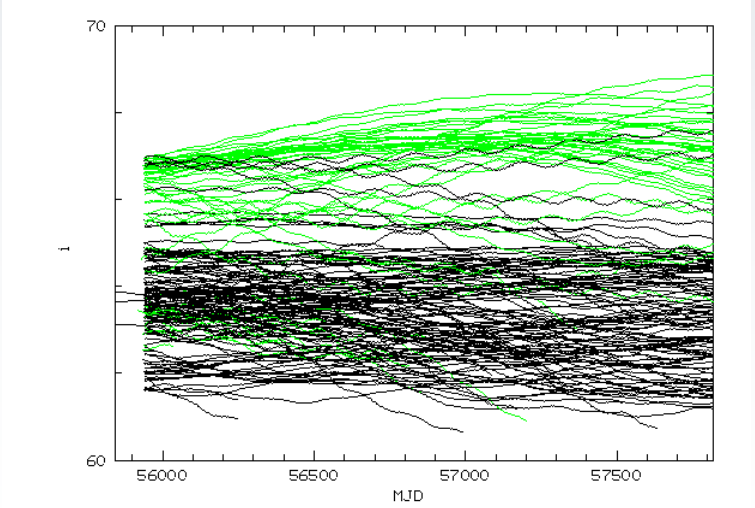


Evolution over 10 Years

- Evolution over 20 years
- green: e < 0.65
- Similar distribution of orbital elements
- Node drift -0.1° to -0.2 ° per day -> 36°/year

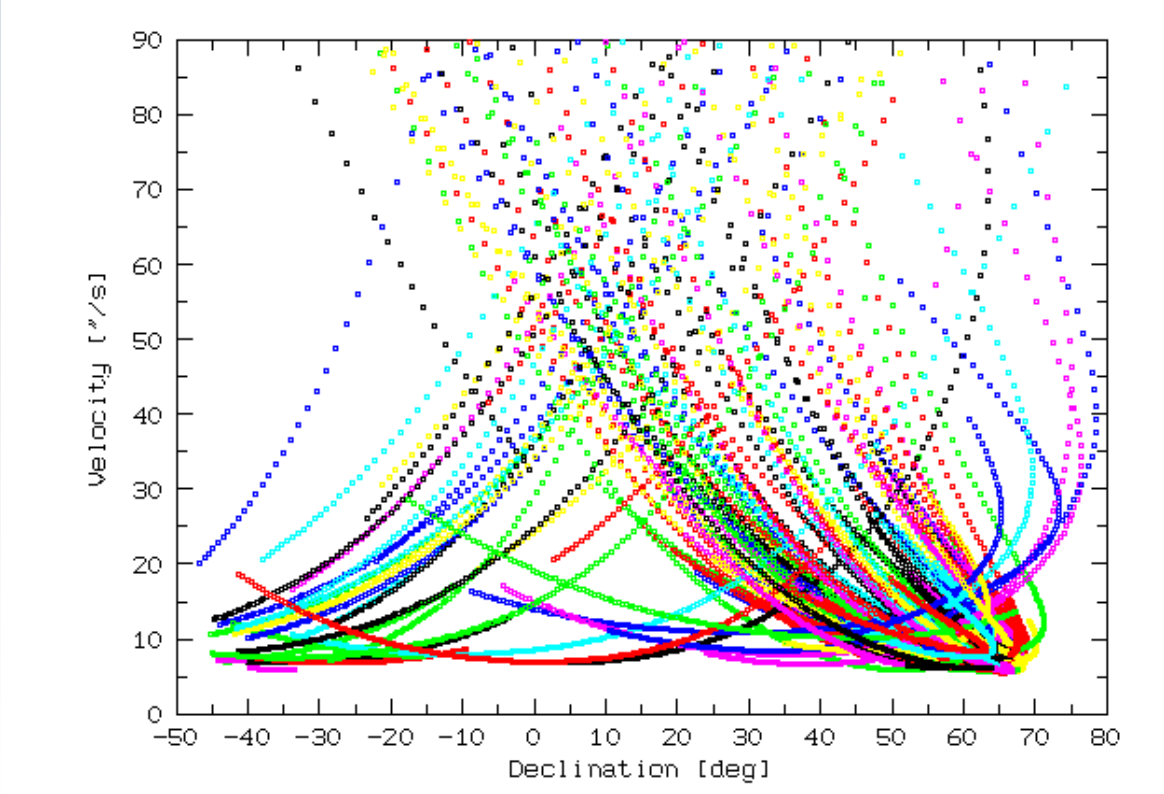






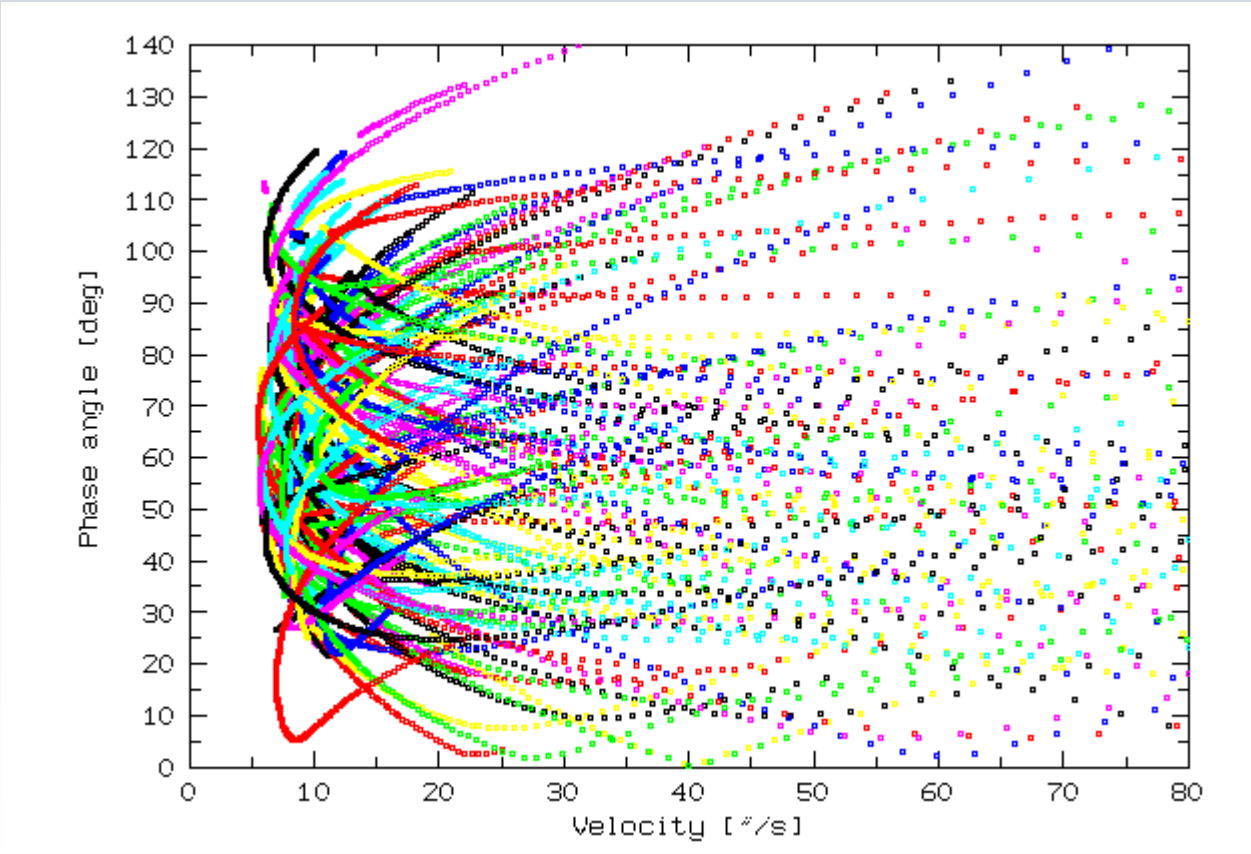
MEO Observation Strategies

- Angular velocities (topocentric, OGS)
  - V_{min} = 5-10 arcs/s -> apogee



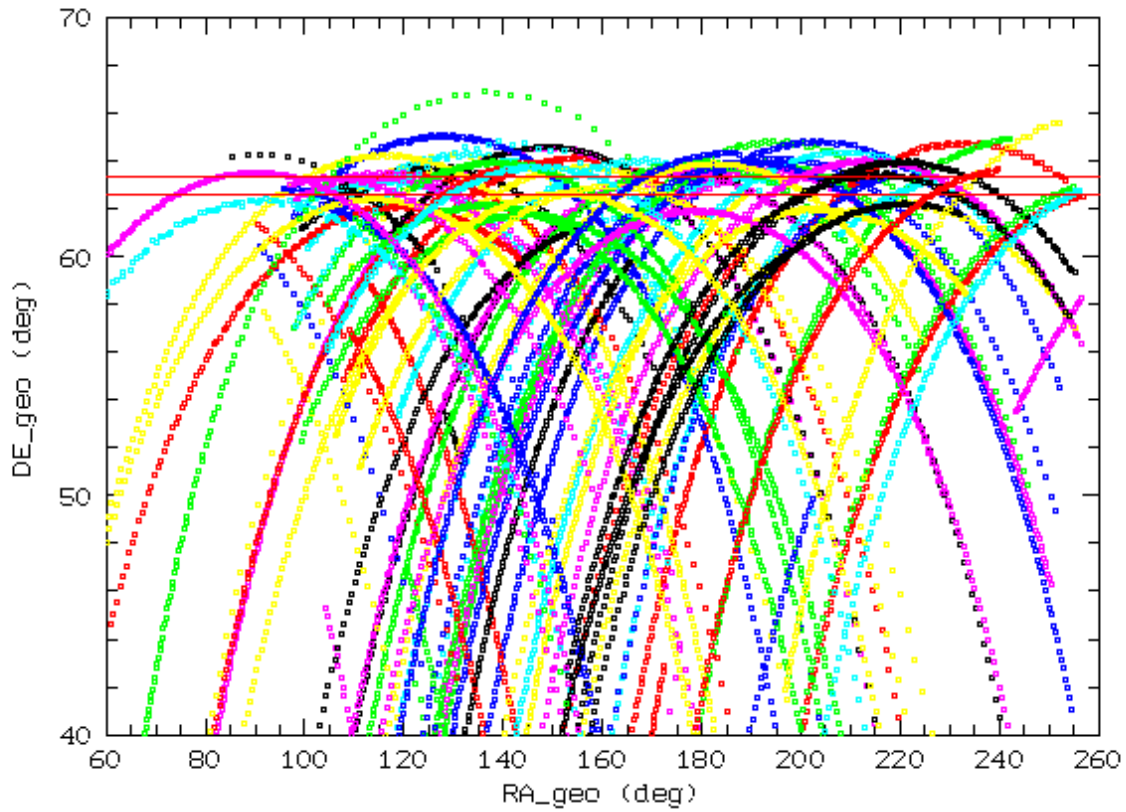
MEO Observation Strategies

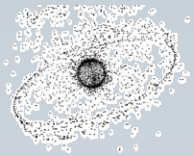
- Phase angles (topocentric, OGS)



MEO Observation Strategies

- Where to look?
  - Geocentric passes; OGS, one night

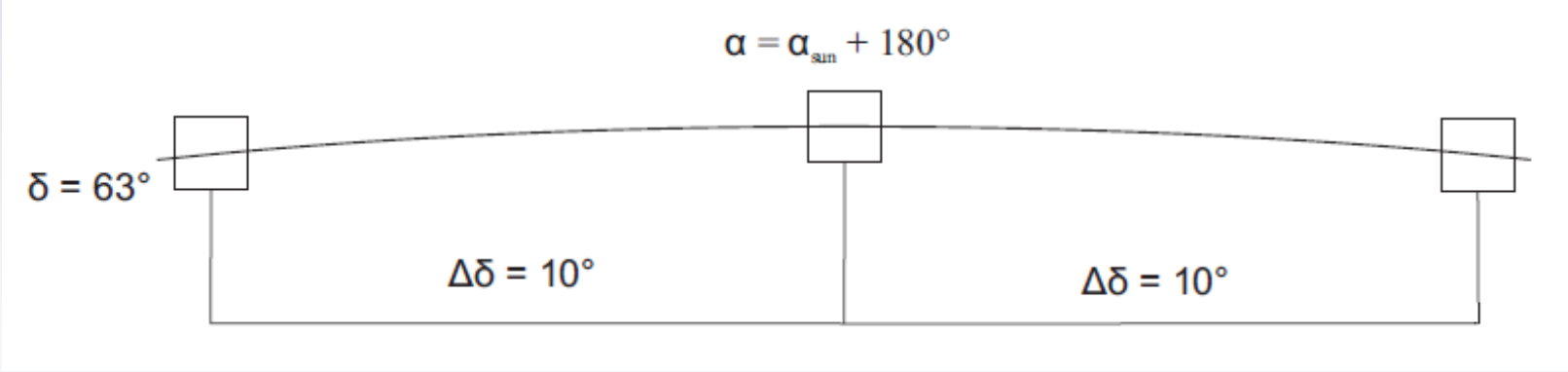




Observations

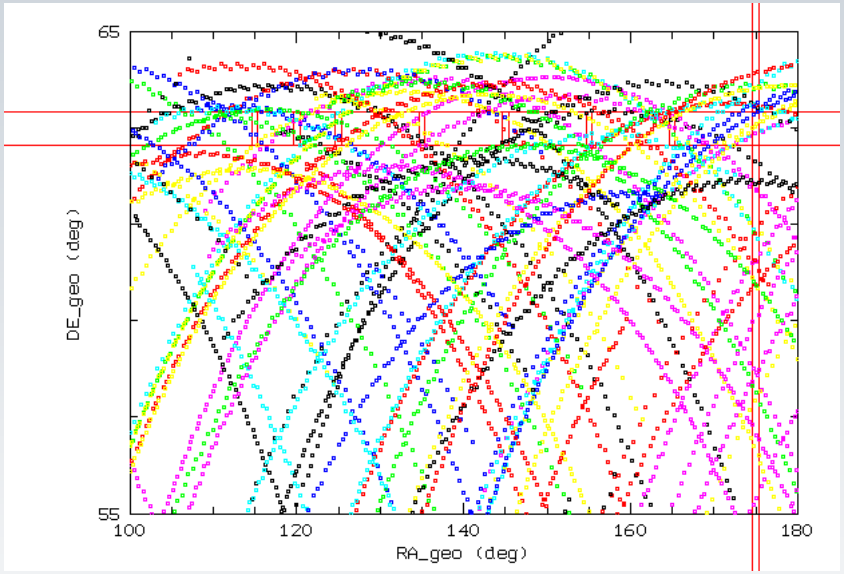
- First observations in December 2012 at OGS, 1-m Zeiss telescope, 0.7x0.7 square degrees
- Survey fields in anti-sun direction (right ascension)
- First test field
  - all known TLE objects were found
  - no uncorrelated objects found
- Survey and follow-up observations were performed
  - In January 3 successful nights of observations
  - In February 3 successful nights of observations
  - In April 3 successful nights of observations
  - In July 3 successful nights of observations
  - In August 1 night
- Follow-up observations performed with ZIMLAT

- Survey strategy with 3 fields per month displaced by 10° in right ascension



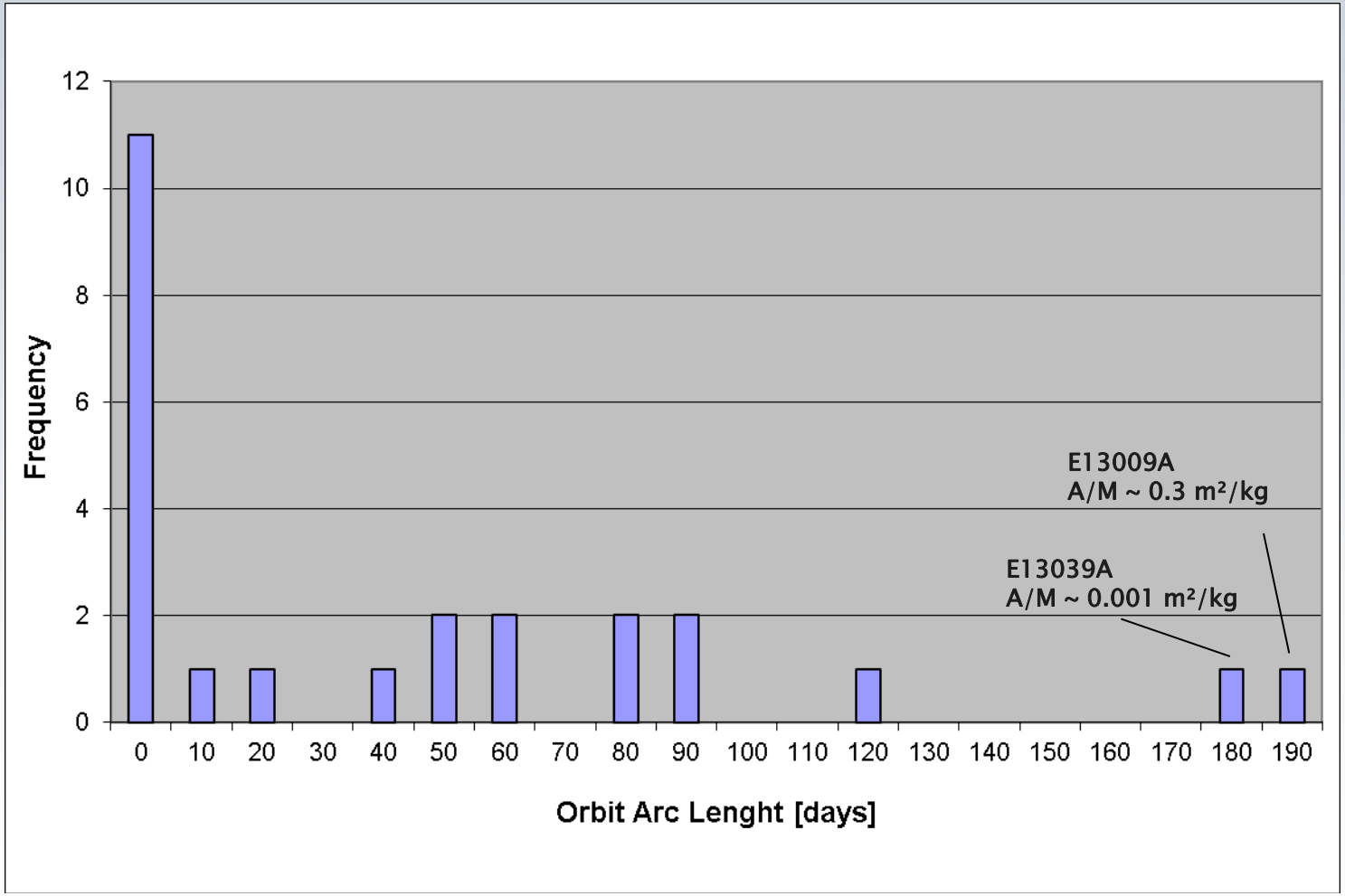
Survey Fields

- 13 nights -> 13 fields
- ΔRA = 10deg
- Each survey = 11 min
- 11-42 surveys/night
- 257 surveys (~47.1h)
- 30 uncorr. objects found (~0.6 objects/hour)
- Follow-up observations of 25 objects performed
- 5 objects still „active“



Uncorrelated Molniya

Molniya objects (Jan 2013 – Aug 2013)



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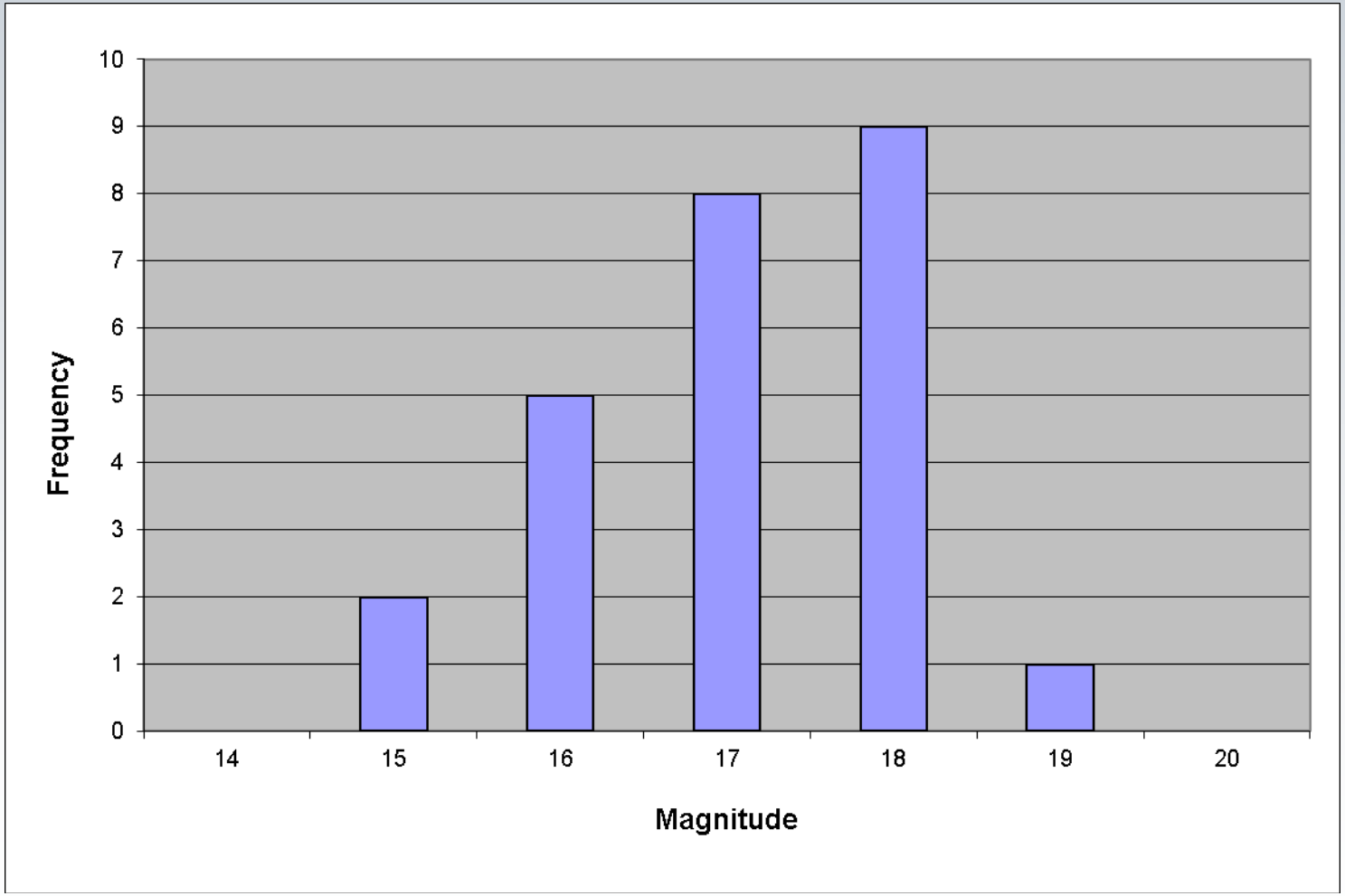

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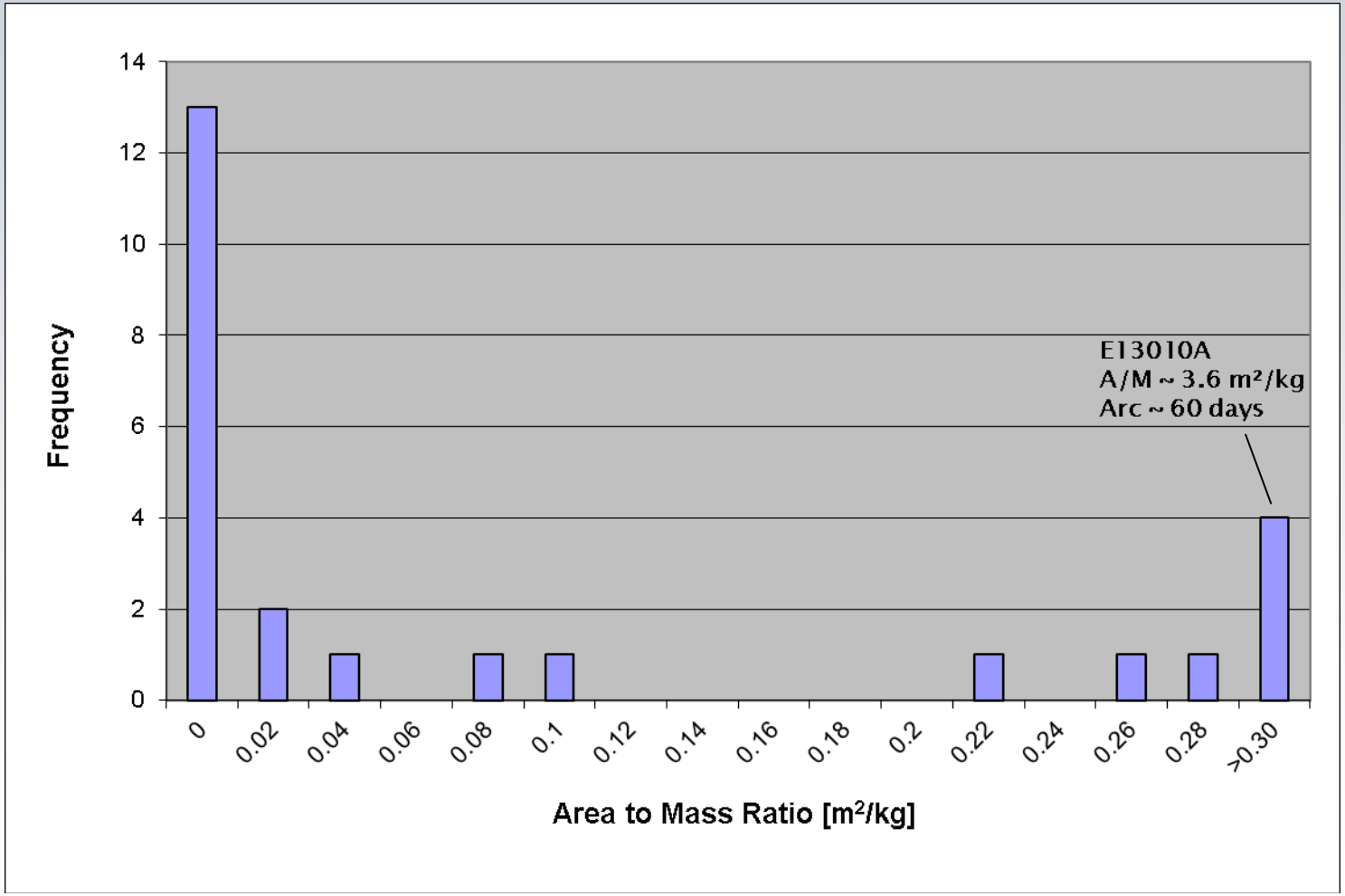
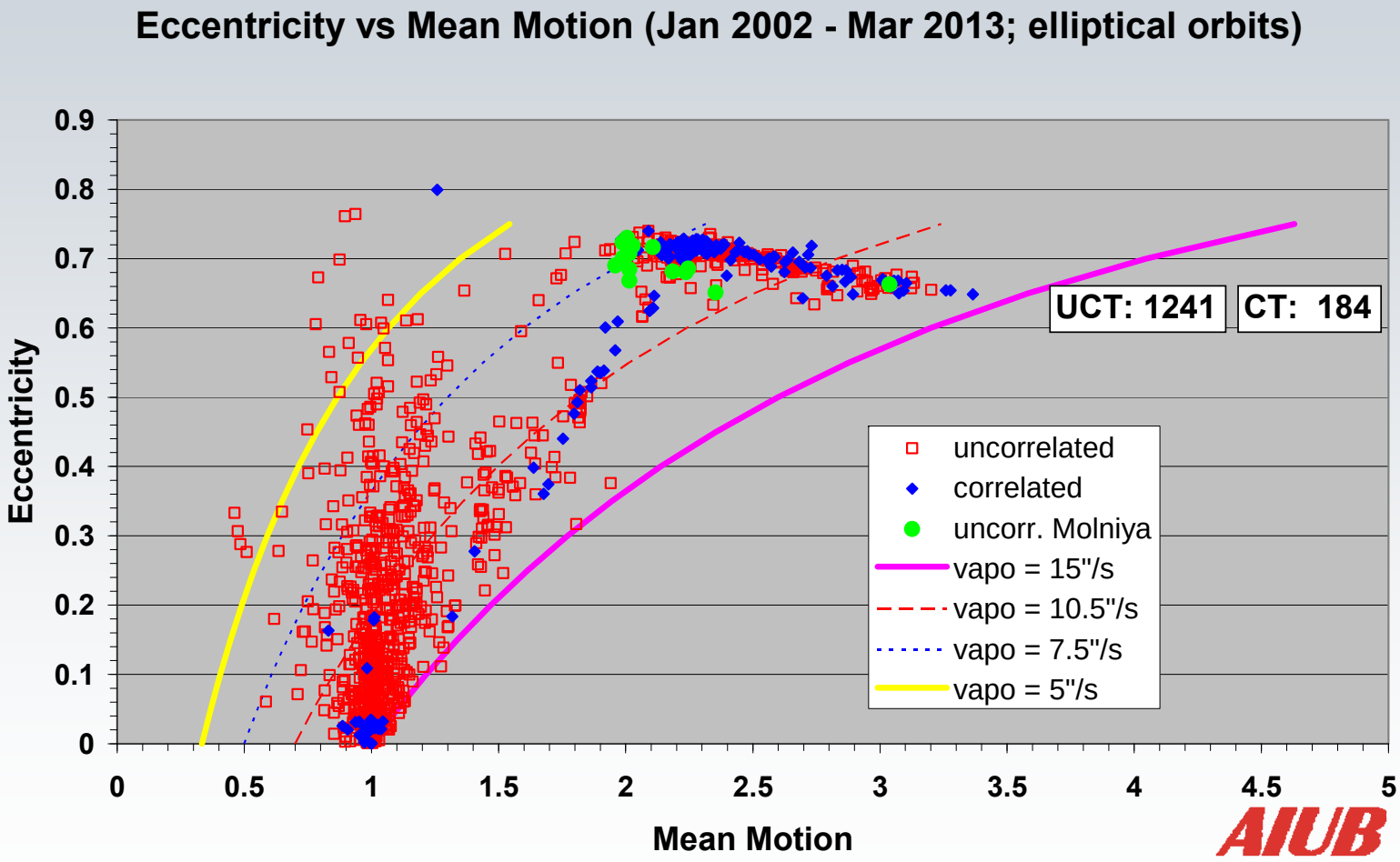
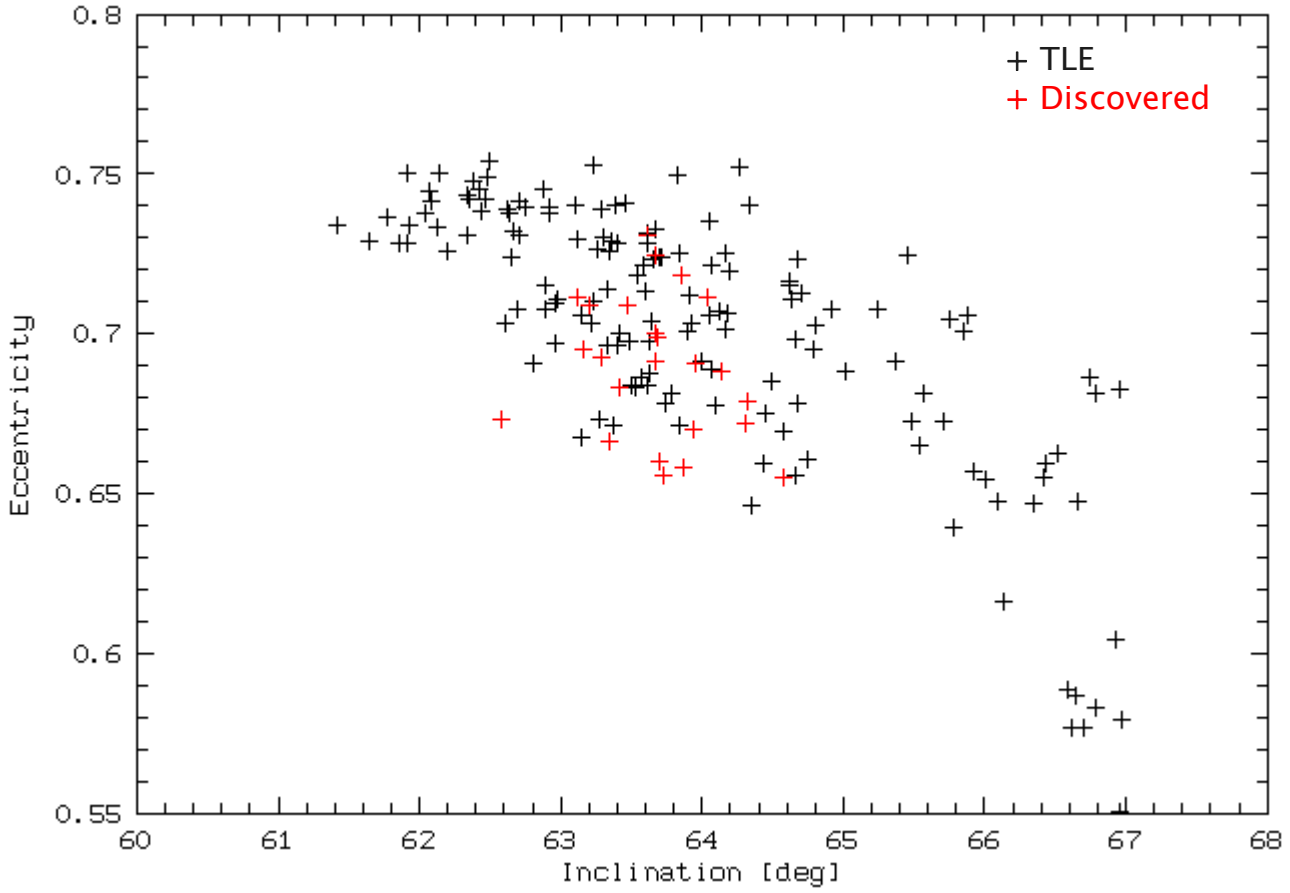


Uncorrelated Molniya



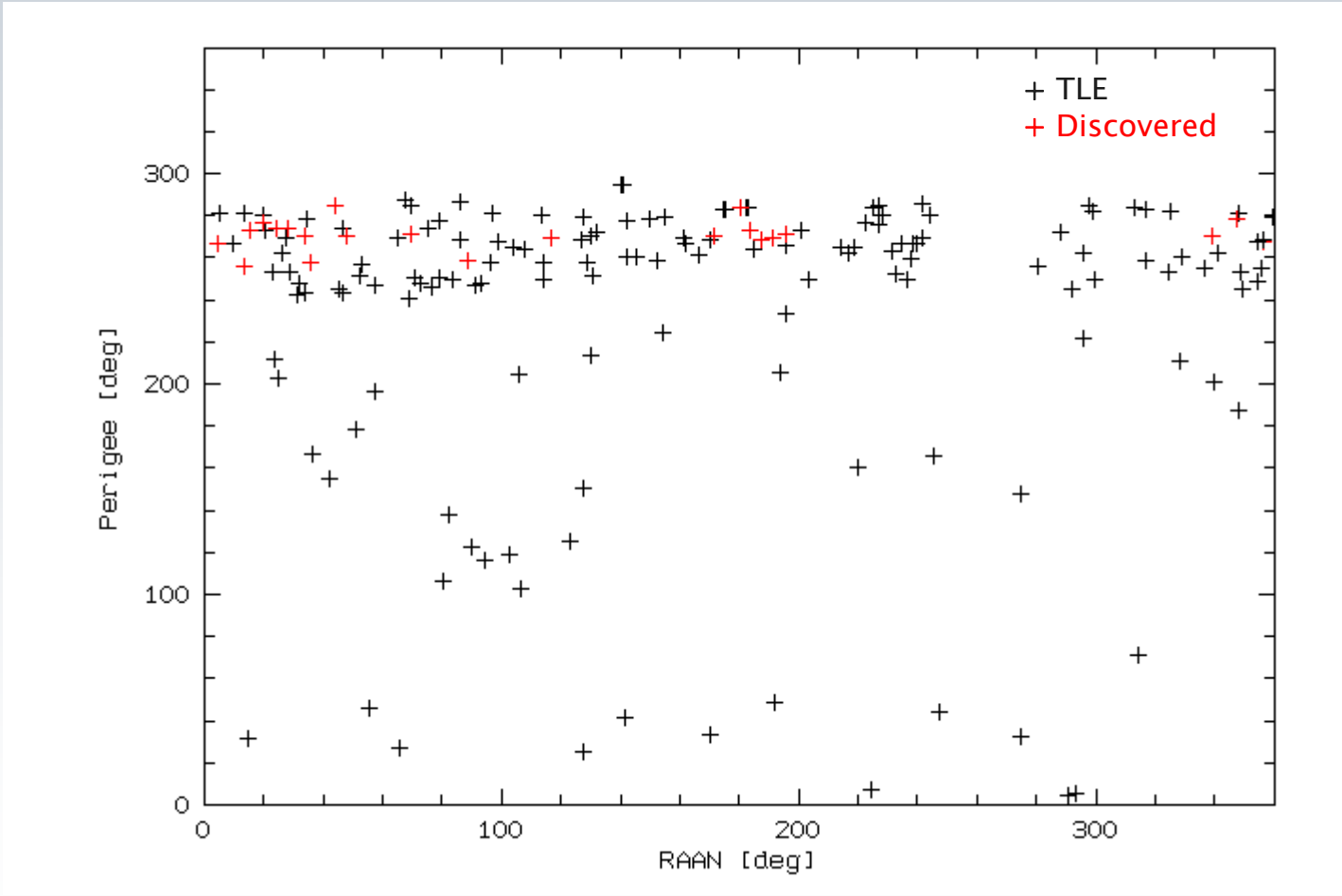
e vs *i*

Molniya objects (Jan 2013 – Aug 2013)

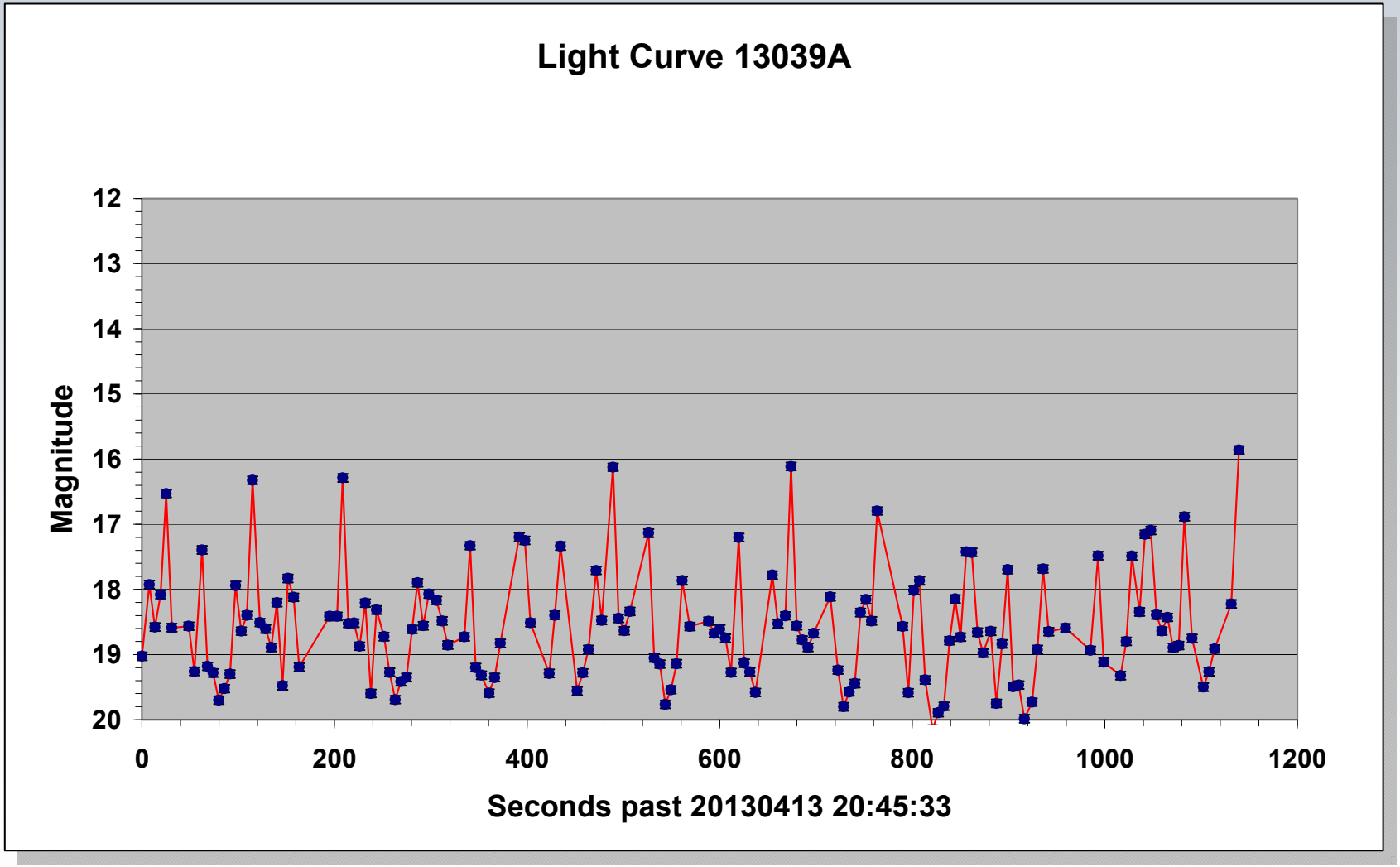


Perigee vs Node

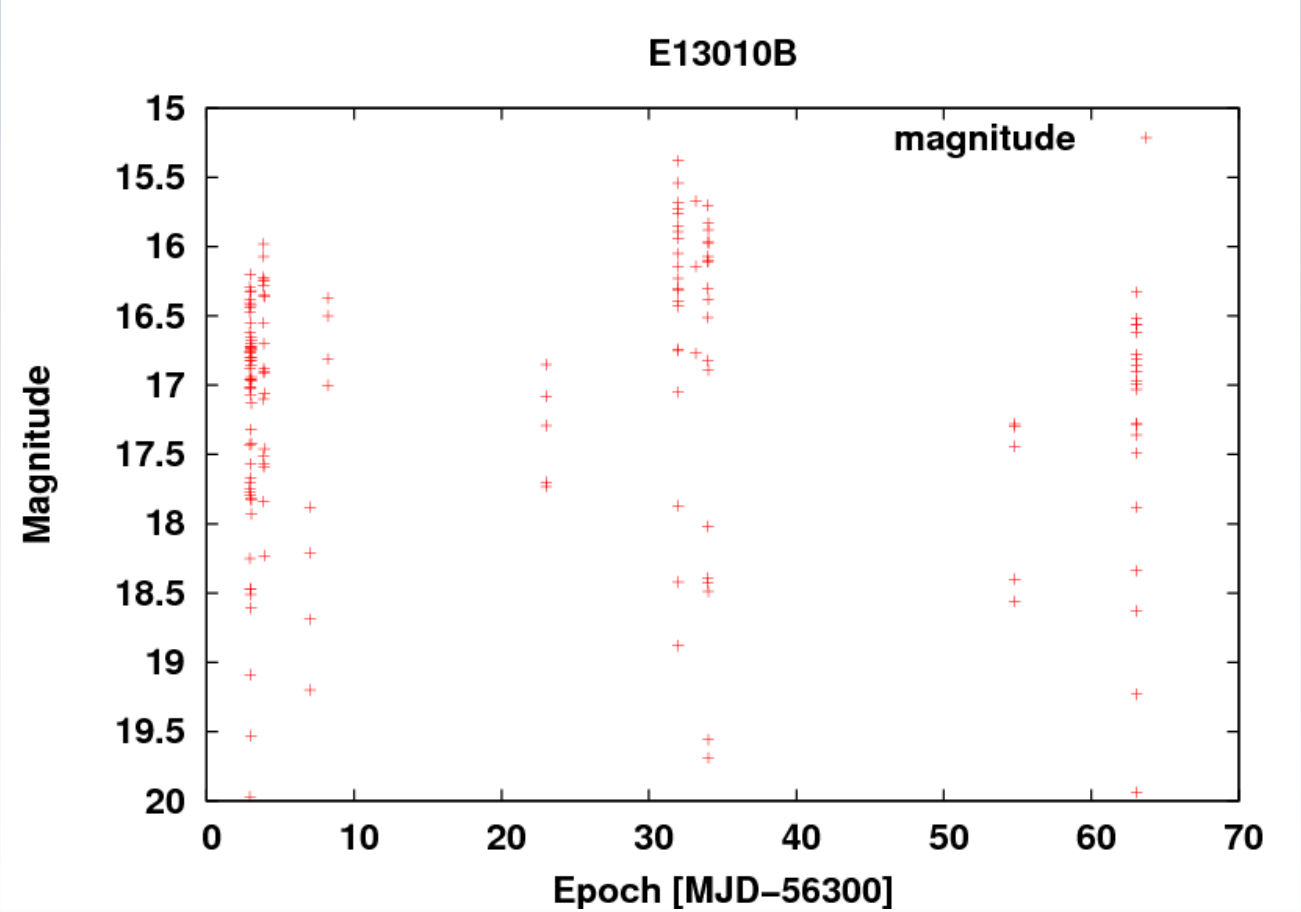
Molniya objects (Jan 2013 – Aug2013)

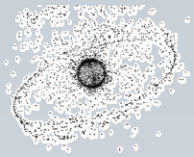


Brightness Variation



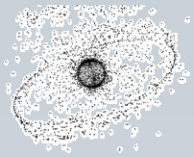
Brightness variation





Conclusions

- Efficient observation scenarios for eccentric MEO orbits (particularly Molniya) were developed and their performance assessed
- Test observations (13 nights)
  30 uncorrelated objects found (~0.6 objects/hour)
- Objects highly variable in brightness
  → light curves acquired
- High percentage of higher A/M objects, also HAMR objects
- Objects often too faint to follow up with ZIMLAT, only 5 objects still in catalogue
- Observation campaign is ongoing…



Future work

- Statistical evaluation to follow (feedback to models)
- Comparison with models by using ESA PROOF-2009 program
- ESA MASTER statistical population comparison with real observations
- The “shows” and “no-shows” analysis with TLE population