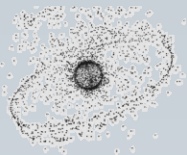


Optical Observation of Objects at High Altitudes

T. Schildknecht

*Astronomical Institute, University of Bern (AIUB),
Switzerland*

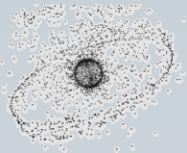
Panel Review on Space Situational Awareness, Space Weather
and Space Debris Research, July 19, 2012, Mysore, India



Why Space Debris Research?

- Knowledge regarding the space debris environment required to
 - Assess threats (e.g. risk to spacecraft)
 - Design protection measures (e.g. shields)
 - Devise efficient space debris mitigation and remediation measures
 - **Provide the scientific rationale to devise efficient measures enabling sustainable outer space activities**

Space Debris Research



- **Open Questions**
 - **Population**
 - how many?
 - size distribution?
 - orbit regions?
 - nature of objects?
 - sources, sinks?
 - **Physics/Mechanisms**
 - creation
 - evolution of orbits





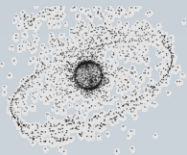
Research Objectives

- Aiming at a better understanding of the near Earth environment through
 - **Extending the catalogues** of “known” space objects towards smaller sizes (deterministic population)
 - enable active collision avoidance (safety of operations)
 - **Acquiring statistical orbit information** on small-size objects in support of statistical environment models
 - statistical risk analysis (e.g. mission analysis, shielding, etc.)
 - input data for environment models (e.g. MASTER, ORDEM)
 - input data for long-term evolution models
 - identification of debris sources
 - progenitors of debris clouds (breakup events)
 - disintegrations of spacecraft due to aging processes



Research Objectives

- Aiming at a better understanding of the near Earth environment through (cont.)
 - **Long-term monitoring** of environment
 - identification of new sources
 - verification of evolution models
 - **Characterizing objects**
 - physical characterization (size, shape, material, rotation state, etc.)
 - identification of (new) sources



ESA/AIUB Observation Campaigns

■ Four types of observations

1. GEO surveys:

- search area optimized for GEO orbits with 0–20° inclination
- blind tracking optimized for object in GEO

2. GTO surveys:

- search area and blind tracking optimized for GTO orbits with 0–20° inclination (Ariane GTO launches)

3. MEO surveys:

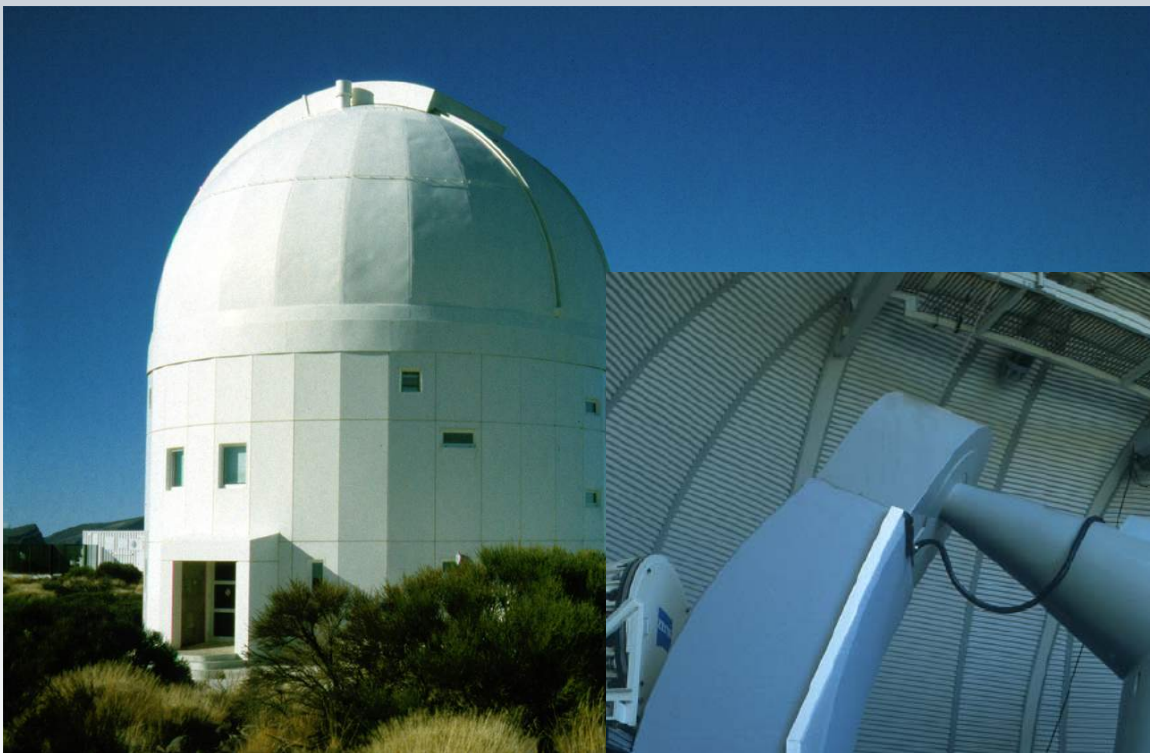
- survey of current MEO constellations completed (2011)
- surveys for eccentric MEO orbits to be started in 2012

4. Follow-up observation to maintain HAMR catalogue:

- follow-up of subset of objects discovered in surveys (maintenance of a catalogue of debris objects)
- arcs between a few hours up to many months



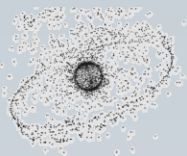
Surveys at the ESA 1-m Telescope, Tenerife



Continuous program since 1999
10–12 nights/month
operated by AIUB

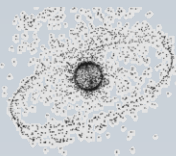
1-m ESA telescope (OGS)

T. Schildknecht: Optical Observation of Objects at High Altitudes
COSPAR-2012 Associated Event, July 19, 2012, Mysore, India

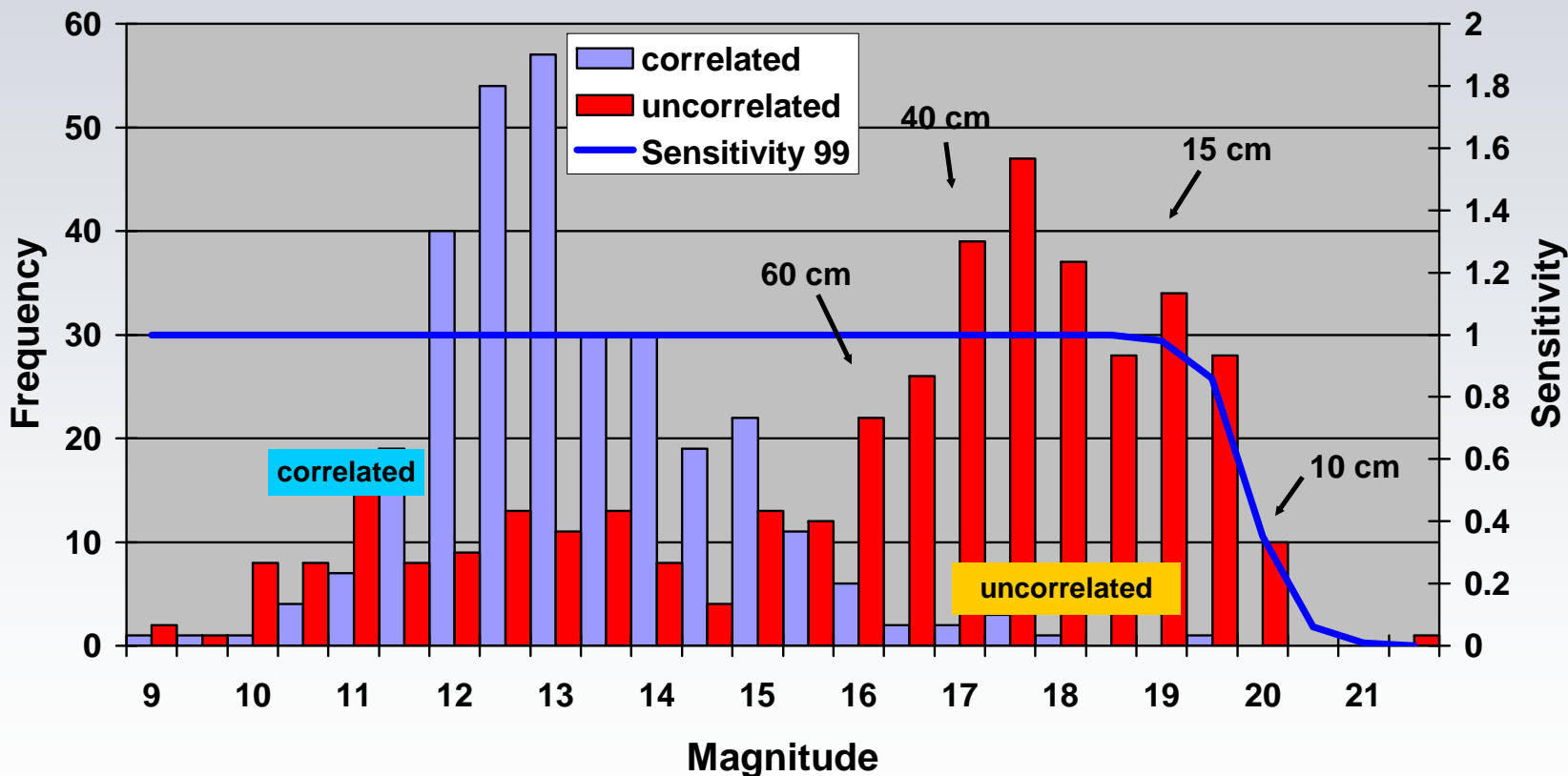


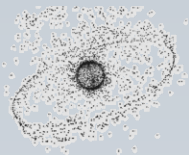
Key Scientific Results (several “firsts”)

- **Longest and most sensitive observations of the GEO/GTO regime**
 - **Discovery** of small-sized (dm) debris
 - ➔ sensors with most significant contribution for objects $< 0.4\text{m}$ in IADC GEO campaigns
 - **>10 years of continuous monitoring**
 - ➔ clusters of debris in orbital element space discovered, evolution studied
 - Input data for ESA MASTER environment model: introduction of "artificial" breakup events in order to model the observed clusters of debris in the 0.2 to 1 m size range
- **Discovery** of "new" (i.e. previously unknown) population of high area-to-mass (AMR) ratio objects
- **First** spectra of high area-to-mass (AMR) ratio objects



Small-Sized Fragments in GEO (example)





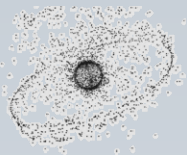
Contributing AIUB Sensors



1-m ZIMLAT
Switzerland

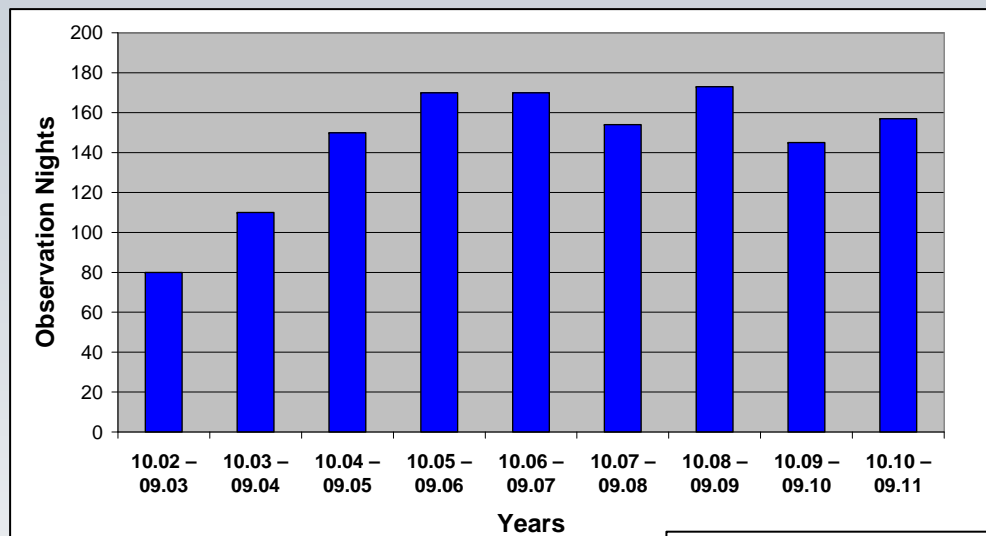


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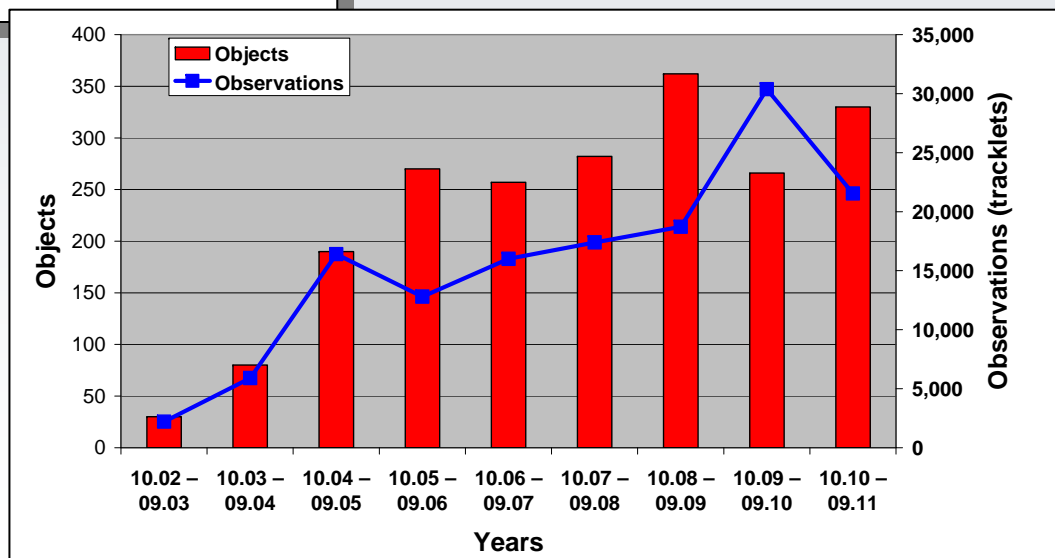
“Routine”, Continuous Operation

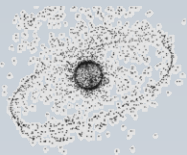
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ZIMLAT
Observation Nights

ZIMLAT
Observations / Objects





Catalogue of Small-Size Space Debris

- Build-up and maintenance of orbit catalogue of decimeter-sized debris in GEO (AIUB)

- Why?

- Density/collision risk lower than in LEO

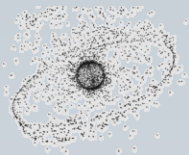
BUT:

- No sinks → population constantly grows
→ Mitigation of debris is important

- Need to know nature and sources of debris

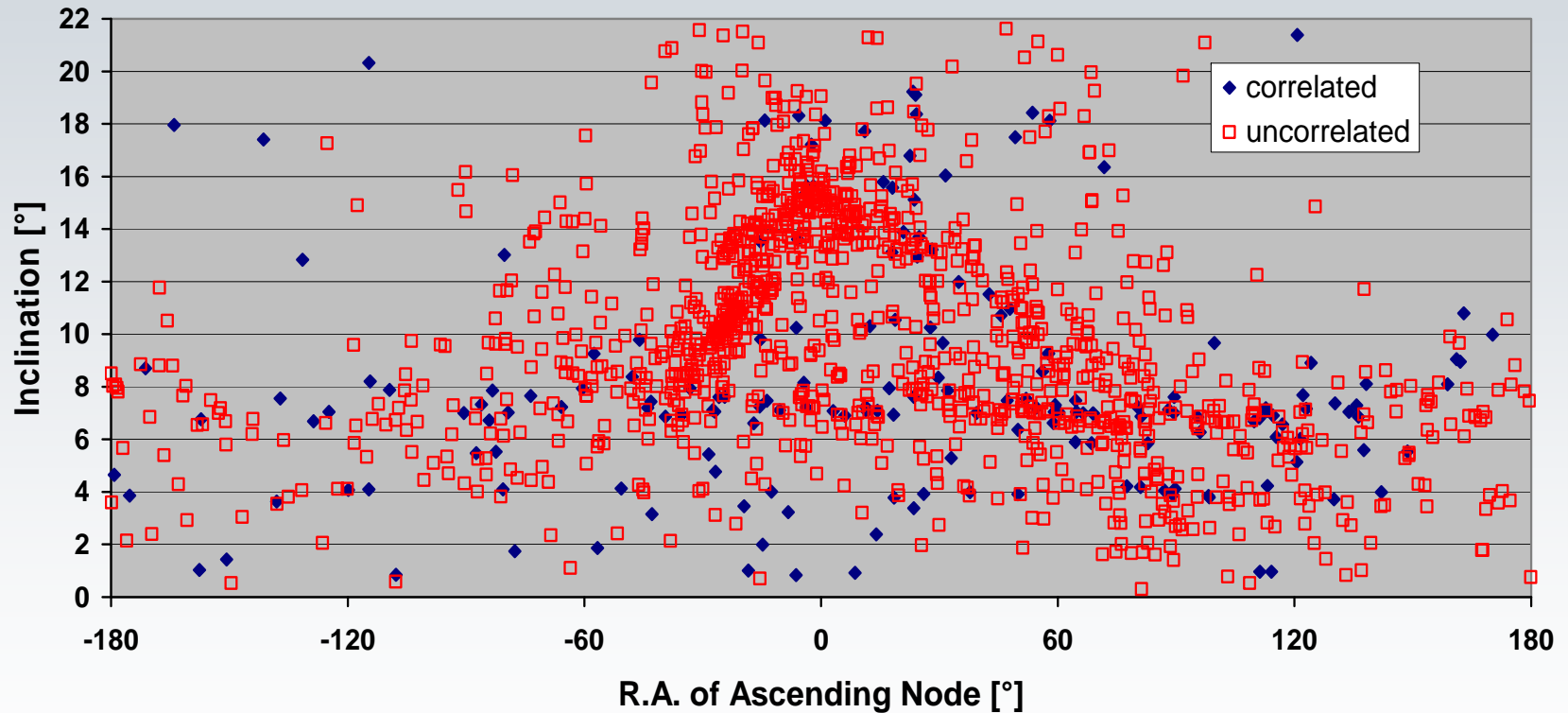
Requires:

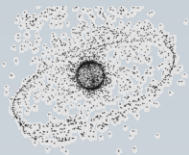
- Orbit catalogue
- Constant monitoring due to perturbations by non-gravitational forces



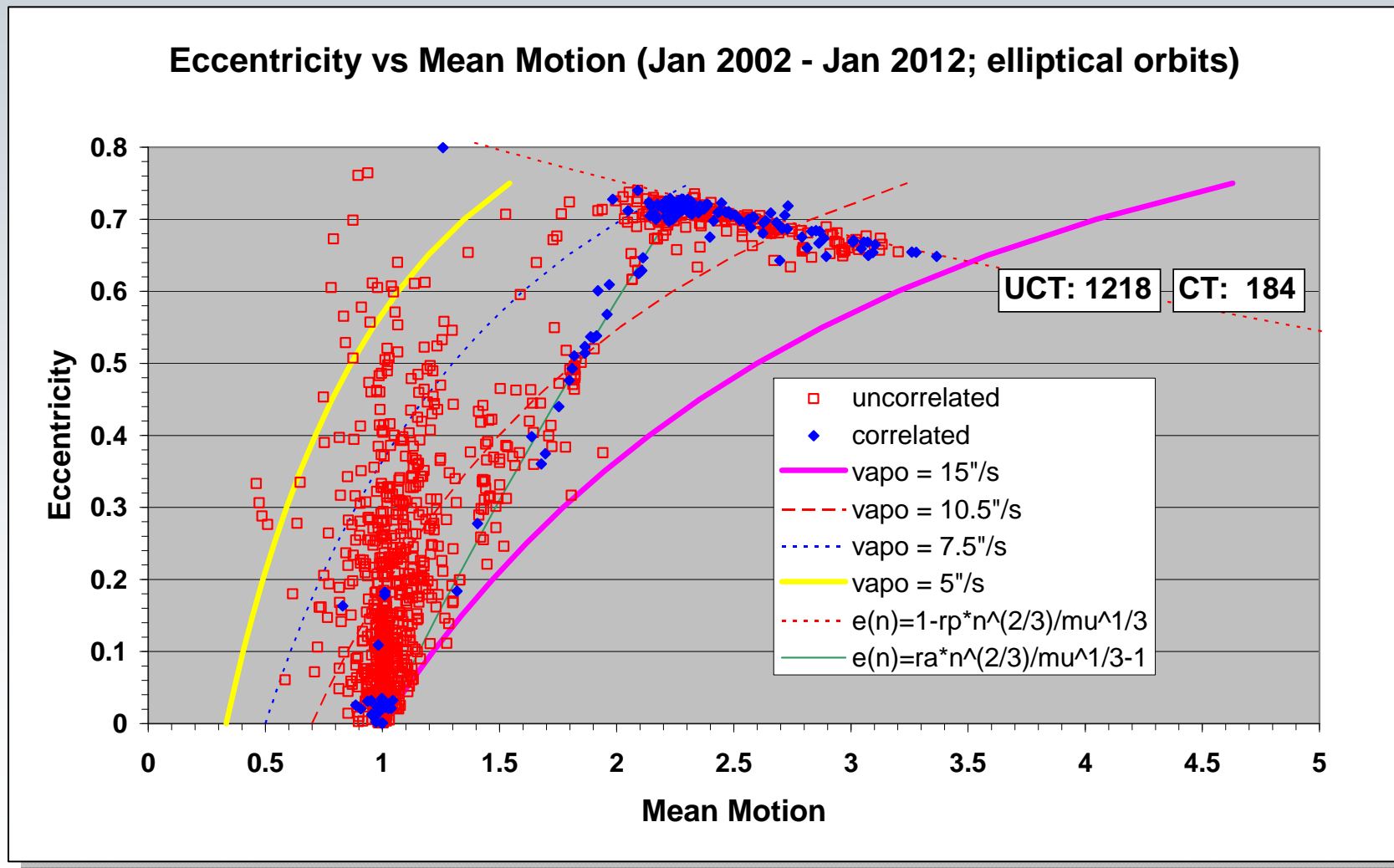
6-param. Orbits - i vs Ω

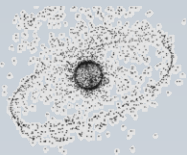
Orbital Elements (Jan 2002 - Jan 2012; elliptical orbits)



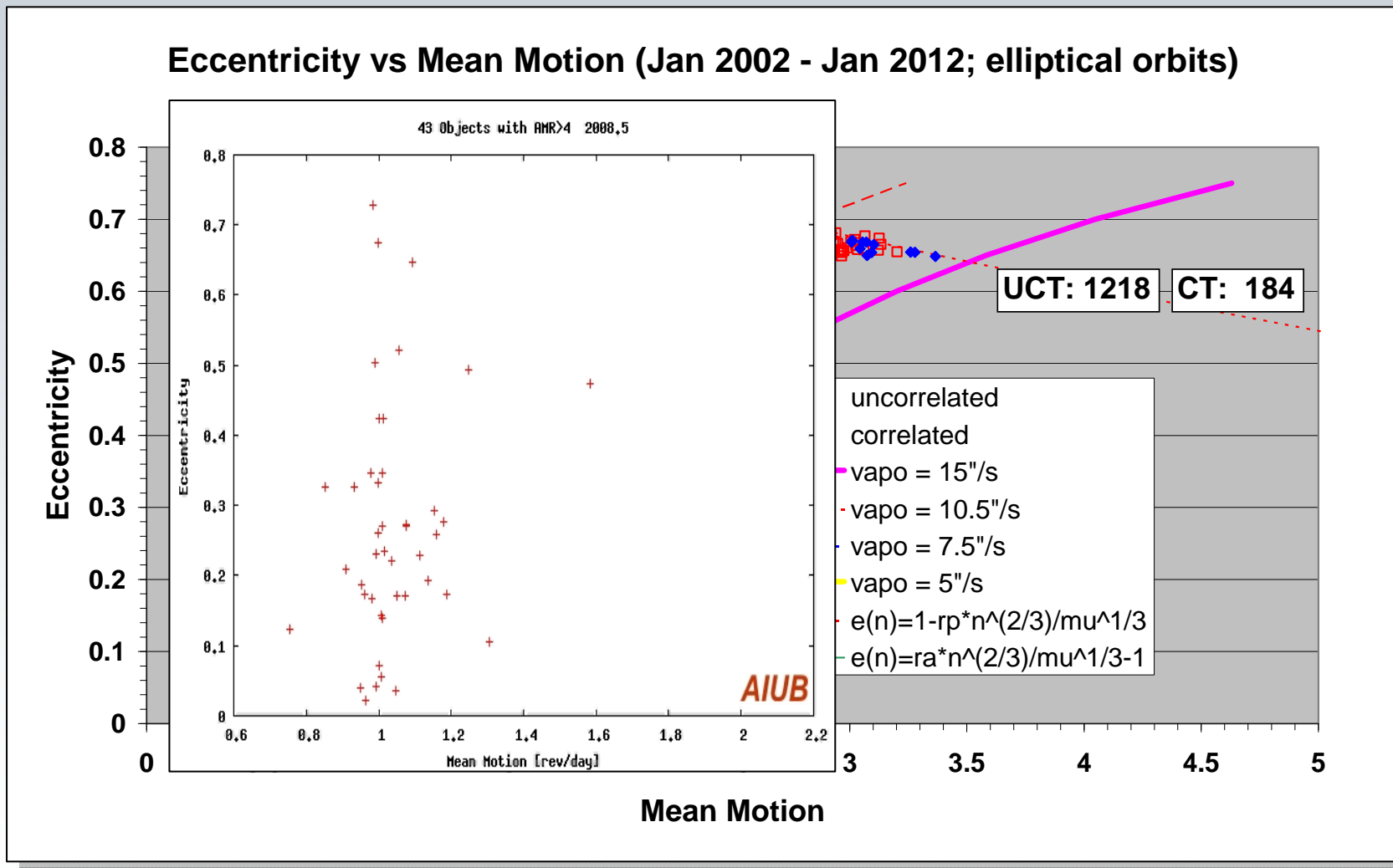


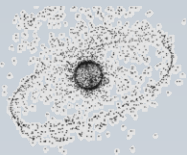
High AMR GEO/GTO Catalogue





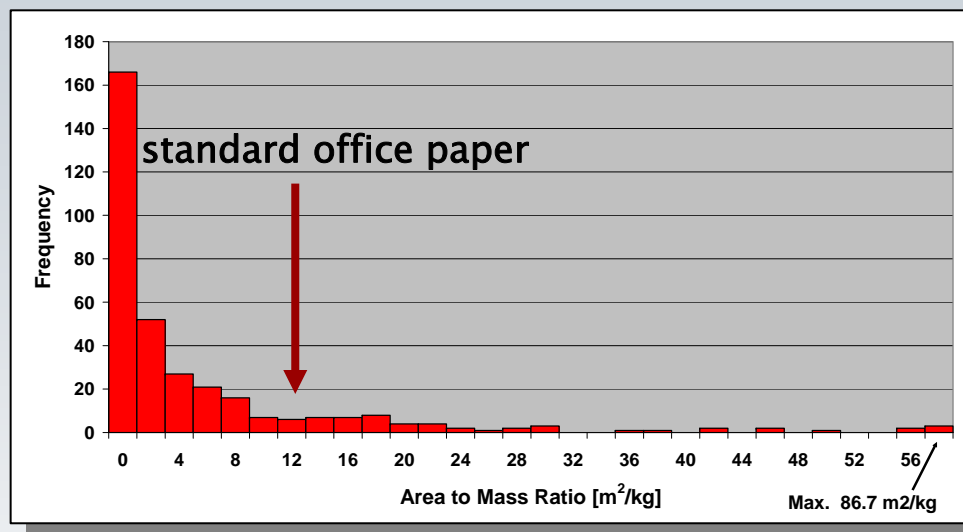
High AMR GEO/GTO Catalogue





Discovery of High AMR Objects

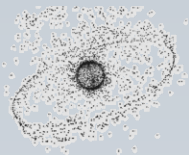
- Unexpected, not modeled class of objects
- Mean motion suggests release in GEO
- Eccentricity/inclination builds up (solar radiation pressure)
- Source & process of generation unknown
- Difficult orbit maintenance in catalogue of orbits → shows need of continuous monitoring, frequent follow-ups, and data exchange



→ MLI?, solar cells?

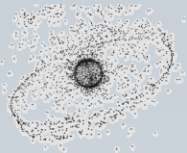
→ break-up event?

→ aging effects?



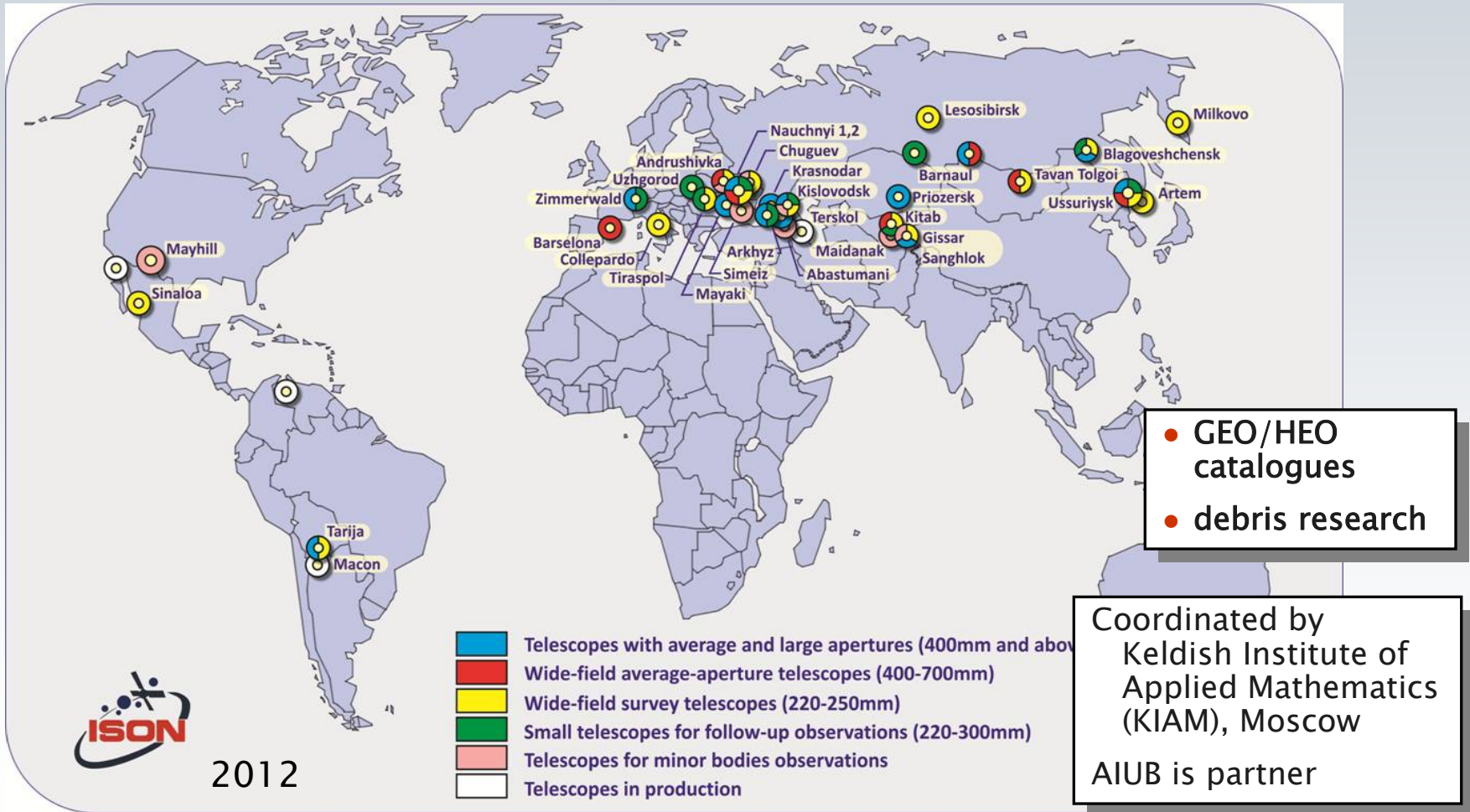
Networking is Essential

- **Discover new objects:** Obs. From Tenerife (OGS, AIUB)
 - **Secure orbits:** obs. from OGS, Zimmerwald (AIUB); near real-time handover OGS → Zimmerwald
 - **Maintain orbits:** obs. from OGS, Zimmerwald, international partners, International Scientific Optical observation Network (ISON), ...
 - **Daily orbit maintenance** at AIUB and Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM)
- Orbit catalogue of high-altitude space debris
- **Provide data:**
 - To other partners (ESA, CNES, JAXA, NASA, Roscosmos...)
 - → to investigate physical properties of objects

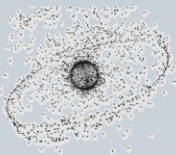


International Collaboration

International Scientific Optical Network (ISON)

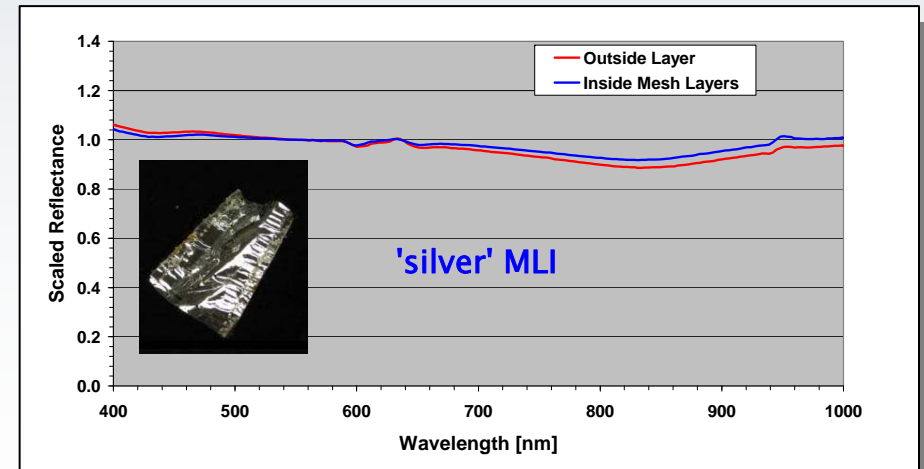
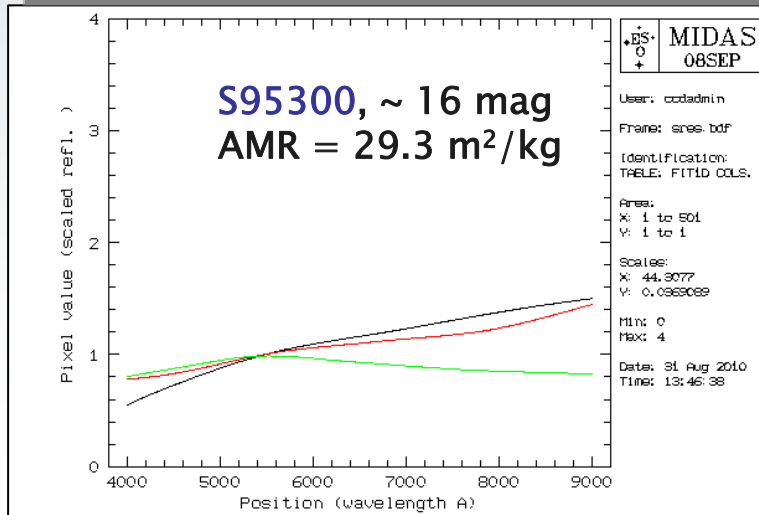
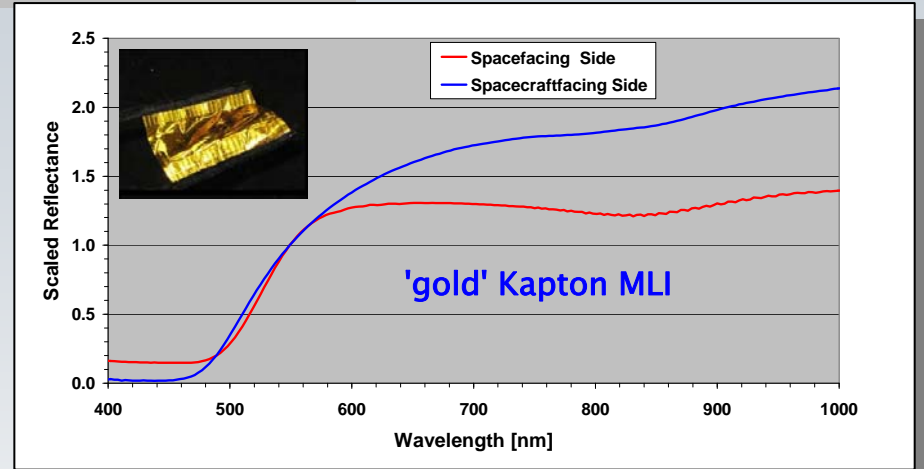
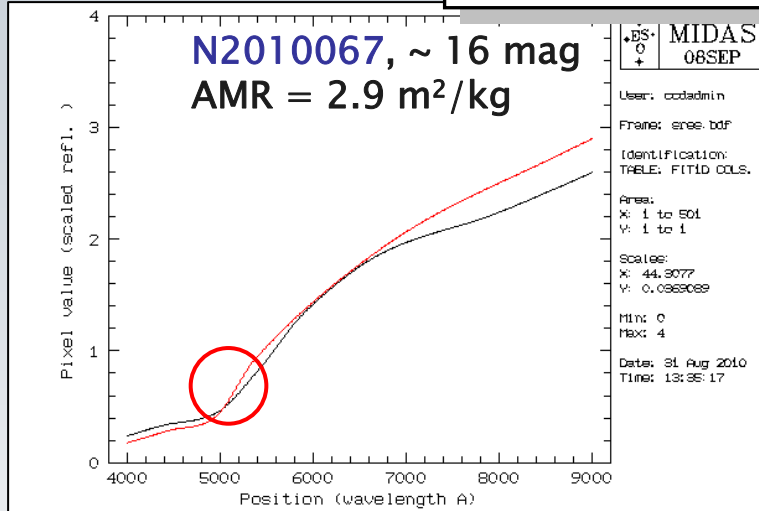


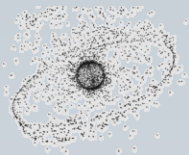
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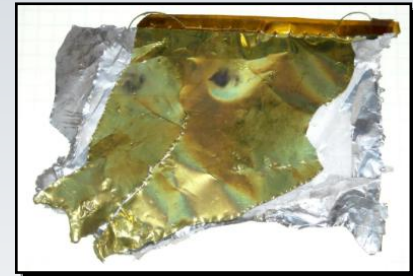
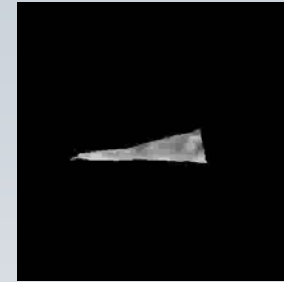
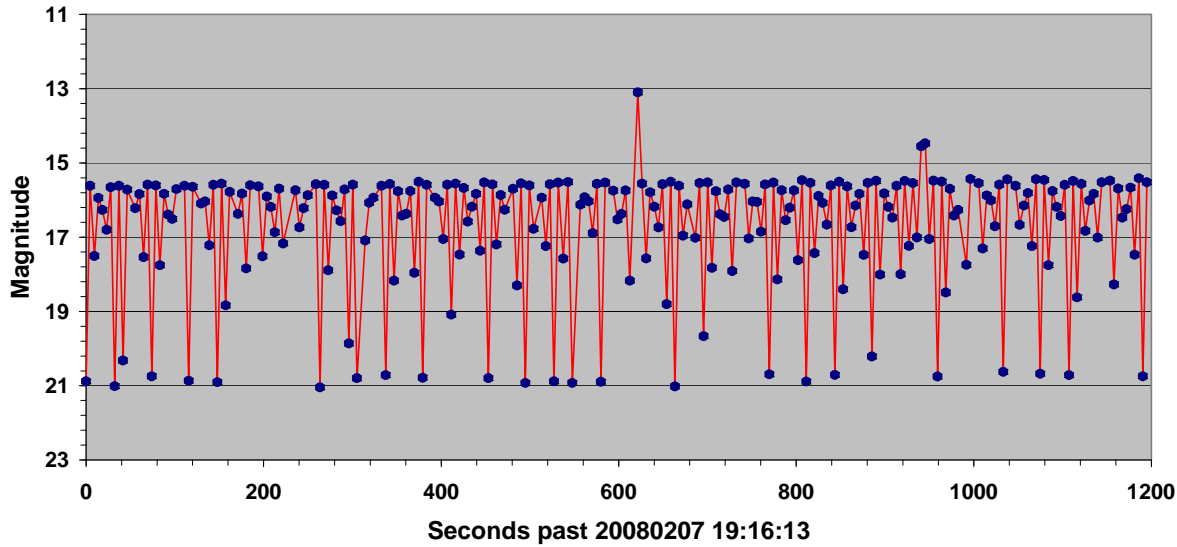
Characterization – Spectrophotometrie

Comparison with Lab Spectra



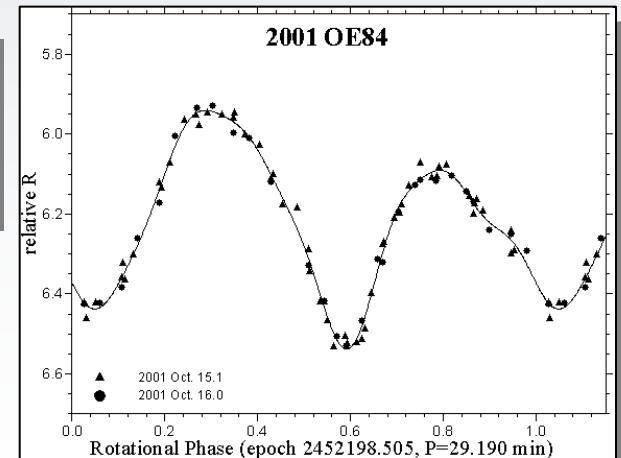


Characterization – Light Curves



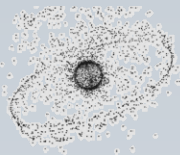
rotation period
spin axis, shape

● ZIMLAT



Conclusions

- **Continuous GEO/GTO/(MEO) surveys**
 - statistical orbit information
 - **long-term monitoring**
 - continuous search for **debris (high AMR) objects**
 - **Catalogue of high GEO/GTO objects**
 - major objective is to enable **physical characterization**
 - orbits maintenance by **sharing the data in a network of observatories** (KIAM, ISON)
 - **Provision of precise predictions** to other groups (ESA, CNES, JAXA, NASA, Roscosmos, ...)
 - **Physical Characterization**
 - area-to-mass ratio from orbital evolution
 - sizes from photometry
 - shapes from light curves
 - materials from color photometry, spectra
- **Scientific basis for sustainable use of outer space**



Limitations/Improvements/Recommendations

- **Sub-catalogue size Debris**
 - need international cooperation/collaboration
 - data exchange, tracking
 - invite Indian collaboration
- **Characterization**
 - New topic: tumbling rates of ADR targets
 - light curves
 - simultaneous multi-color observations
 - e.g. astronomical instruments for GRB
- **cm-sized debris**
 - Small space-based optical payload
 - sun-sync (piggy back)
 - combined NEO/space debris mission



Acknowledgments

- Great thanks to our staff and observers at the OGS and Zimmerwald observatories!
- Support in the form observations to maintain the orbits is provided by the Keldysh Institute of Applied Mathematics (KIAM) in the framework of the ISON collaboration (AIUB–KIAM collaboration).