Physical Characterization of High AMR Debris by Optical Reflectance Spectrometry

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61st International Astronautical Congress,
27 September – 1 October, 2010, Prague, Czech Republic
Outline

1. Introduction
2. Observation Setup
3. Extinction Correction
4. Observed Reflection Spectra
   - GEO s/c
   - bright GEO/GTO debris
   - faint HAMR GEO debris
5. Comparison with Lab Spectra
6. Summary
Objectives

- Acquire First Experience with Reflection Spectroscopy at the OGS
  - Spectrograph at OGS never used for “fast moving” targets
  - faint debris $\rightarrow$ very low signal–to–noise
  - observations have experimental character and are very time consuming

- Get First Spectra of Space Debris at High Altitudes
  - Ultimate goal are spectra of high area–to–mass ratio GEO–like objects
  - material
  - Start with bright, known objects
  - Use known surface material for calibration
  - Try fainter debris
ESA 1–m Telescope (OGS), Tenerife
Mounting the ESA OGS Spectrograph

- Position of the guider camera
- Rotation device incl. off-axis guider
- Filter wheel incl. grisms

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Spectrograph

- **Low resolution spectrograph**
- The OGS ESA spectrograph uses "grisms" as dispersive elements

- **wavelength**: 450 - 950 nm
- **dispersion**: 0.4 nm/pixels
Major Observational Challenges

- **Reflection spectroscopy**
  - quantitative comparison of the measured spectrum with the spectrum of the illuminating source
  - careful calibration of extinction

- **Tracking**
  - first acquisition of satellites/debris → often outside field of view of 13 arcmin (combination of mount model and ephemeris errors)
  - autoguiding not possible for satellites/debris objects → most objects remain in 6”-slit for < 4 minutes

- **Faint Objects**
  - Very low signal-to-noise
  - observations have experimental character and are very time consuming
Selection of Objects

- **Four types**
  - minor planets (results to be compared with published data)
  - large intact GEO objects (catalogue objects)
  - bright GEO and GTO debris objects
  - bright high AMR GEO objects

- **Selection criteria**
  - orbit quality
  - availability of manufacturer data on surface materials
  - brightness
  - visibility constraints (phase angle, Earth shadow, Milky Way, etc.)
  - …
Atmospheric Extinction

- Extinction
  - wavelength-dependent absorption
  - proportional to airmass \((1/\cos(z))\)

Example from Zimmerwald (Johnson–Cousins B, V)
m1–M: observed–catalogue
Extinction

Solar analogue stars at different air mass

| Air mass | 1.02 | 1.13 | 1.4 | 1.94 |

Graph showing pixel value (arb. units) vs. position (wavelength Å) for different air masses.
Extinction

- Two approaches for extinction correction:
  1. extinction curves for each night derived from the observations of solar analogue stars
  2. standard extinction curve
Spectra of GEO Spacecraft

MSG 1

Pixel value (scaled refl.) vs Position (wavelength A)
Phase Angle Dependence?

Meteosat MSG 1 at different phase angles:
- 53°
- 27°
- 60°

→ NOT significant
→ very red!
Phase Angle Dependence?

Artemis at different phase angles:
- 17°
- 52°

→ NOT significant
→ very red!
Bright GTO Debris Objects

GTO debris
- Magnitude 13.4 ± 1.2
- AMR = 0.02 m²/kg
- several nights
- very red ("reddening")
- "Type 1"

S92008

Pixel value (scaled refl.)

Position (wavelength Å)

-1 0 1 2 3 4

0 4000 5000 6000 7000 8000 9000

Dates: 31 Aug 2010
Time: 12:26:04
Bright GEO Debris Objects

GEO debris
- Magnitude 12.8±1.3
- AMR = 0.04 m²/kg
- several nights
- red (“reddening“?)
- two faces?
Bright GEO Debris Objects

- **GEO debris**
  - Magnitude $13.1 \pm 1.0$
  - AMR = $0.02 \, m^2/kg$
  - several nights

- blue/white
- “Type 2”

**Graph:**
- Position (wavelength A)
- Pixel value (scaled refl.)
- E08152A

Scale:
- X: 42,6667
- Y: 0.0363089

Date: 31 Aug 2010
Time: 12:51:03
Faint HAMR GEO Debris

- HAMR GEO debris
  - Magnitude ~16
  - AMR = 0.5 m²/kg
  - several nights
  - red
  - two faces?
  - “Type 1”

Graph showing pixel value (scaled refl.) vs. position (wavelength Å) for E07046Bn.
Faint HAMR GEO Debris

- Magnitude ~16
- AMR = 3 m²/kg
- several nights
- red
- “knee” at 500nm
- “Type 3”
Faint HAMR GEO Debris

- Magnitude 16.3 ± 0.8
- AMR = 29.3 m²/kg
- several nights
- blue/white
- “Type 1”
Comparison with Lab Spectra

N2010067, ~ 16 mag
AMR = 2.9 m²/kg

S95300, ~ 16 mag
AMR = 29.3 m²/kg
Summary

- Reflection Spectra of 34 objects in GEO, ‘eccentric GEO’ and GTO orbits
  - 4 s/c, 1 r/b, 16 HAMR GEO
- 3 categories of spectra identified
- Subset of objects with 2 different faces
- “reddening effect” significant (e.g. MSG 1)
- for 2 HAMR objects
  - indication for “silver” MLI
  - indication for Kapton “gold” MLI
- Additional step on a long way to identify the materials (and nature) of the HAMR objects
Acknowledgments

- The observations in Tenerife have been performed under ESA study contracts.
- Collaboration with the Keldysh Institute of Applied Mathematics (KIAM) and ISON is instrumental in maintaining the orbits of the targeted debris objects.
- G. Drolshagen (ESTEC), and F. Piergentili (La Sapienza) provided solar cell and MLI samples.
- K. Abercromby provided data on MLI.
- J. Kuusela and D. Abreu were mounting the spectrograph and taking the observations.