Physical Characterization of High AMR Debris by Optical Reflectance Spectrometry

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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

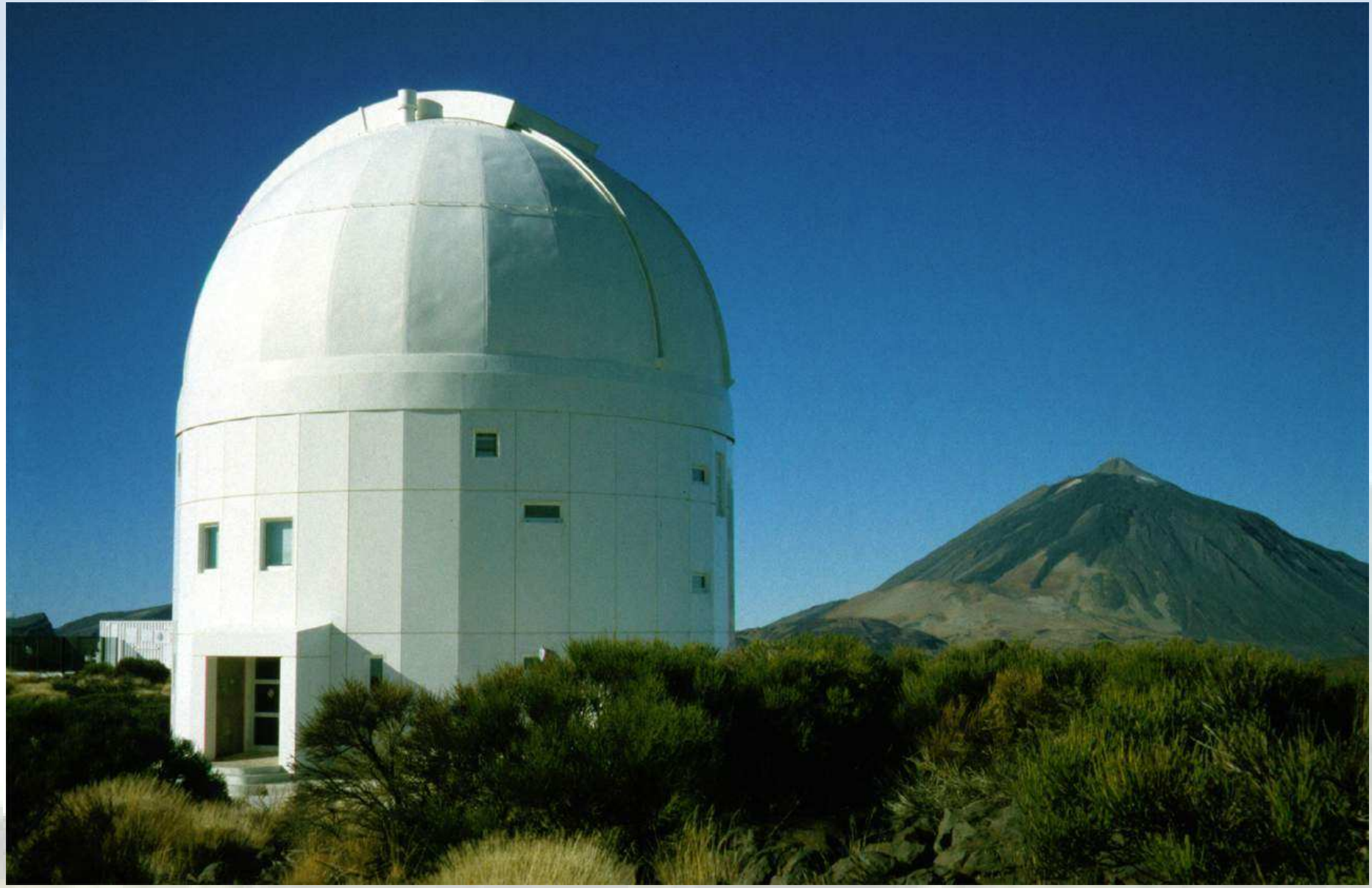
Objectives

- Acquire First Experience with Reflection Spectroscopy at the OGS
  - Spectrograph at OGS never used for “fast moving” targets
  - faint debris → 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

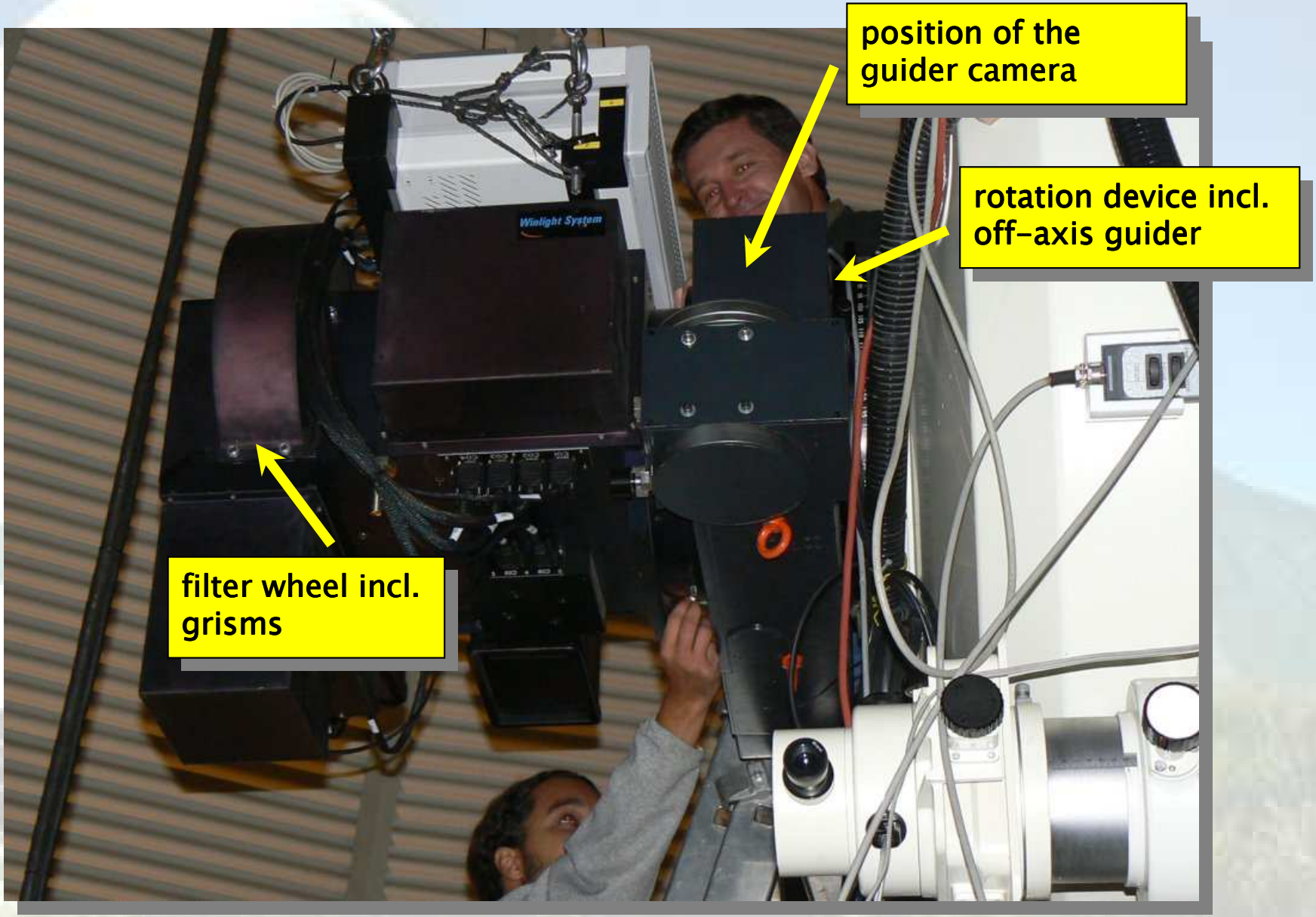
  → material
  - Start with bright, known objects

  → Use known surface material for calibration
  - Try fainter debris

ESA 1-m Telescope (OGS), Tenerife

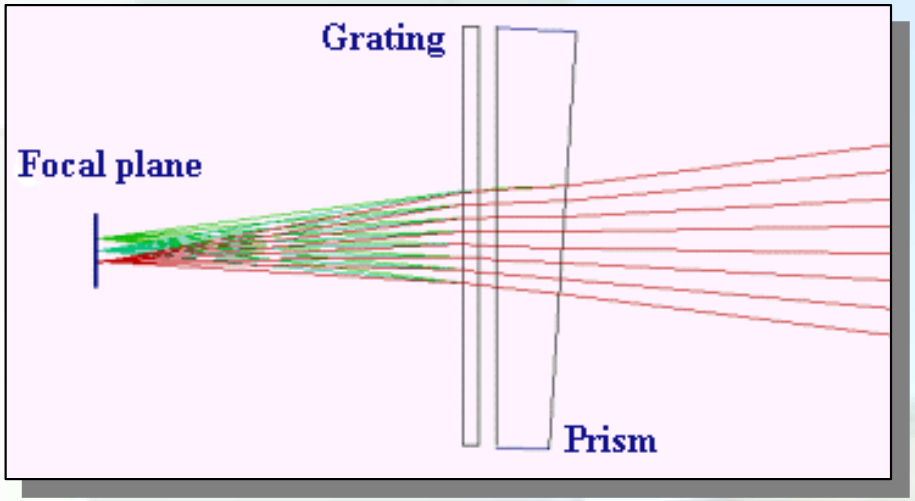


Mounting the ESA OGS Spectrograph



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

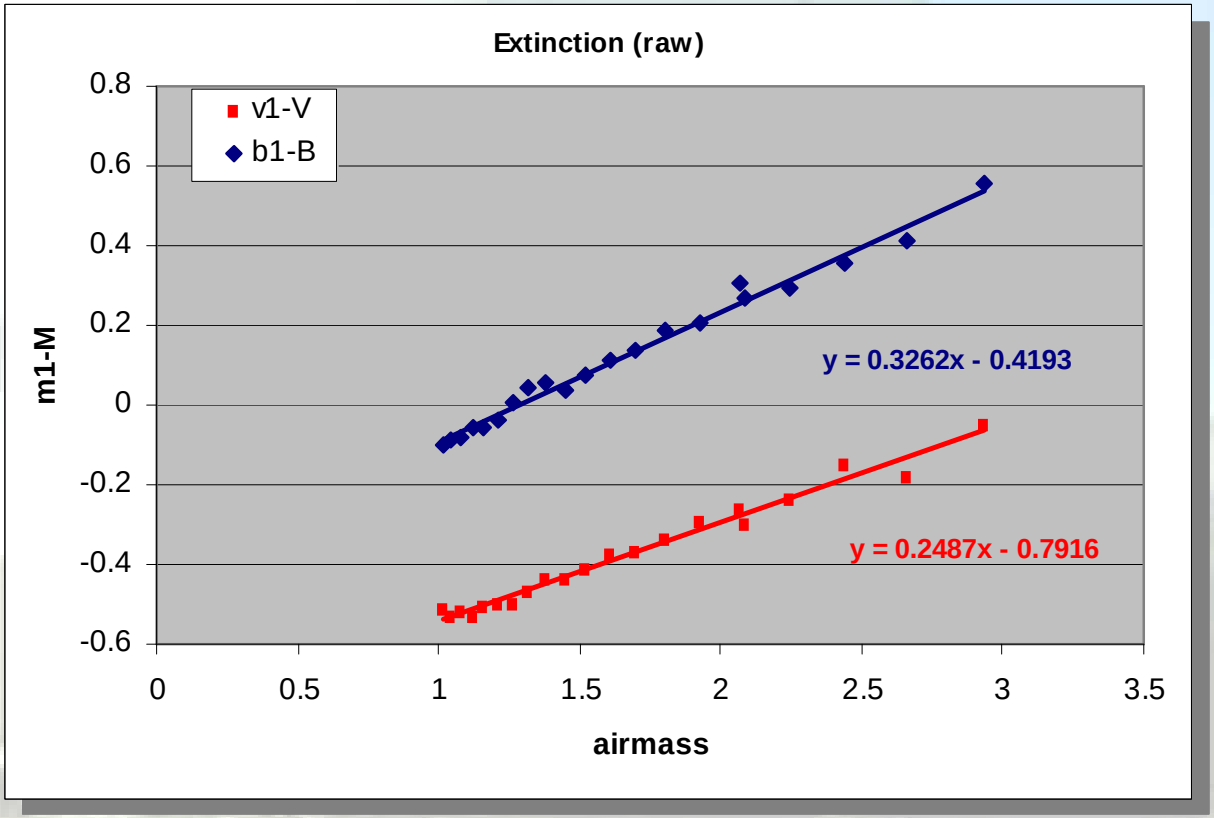
- Reflection spectroscopy
  - quantitative comparison of the measured spectrum with the spectrum of the illuminating source
  - careful calibration of extinction
- Tracking
  - first acquisition of satellites/debris
    → often outside field of view of 13 arcm
    (combination of mount model and ephemeris 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))

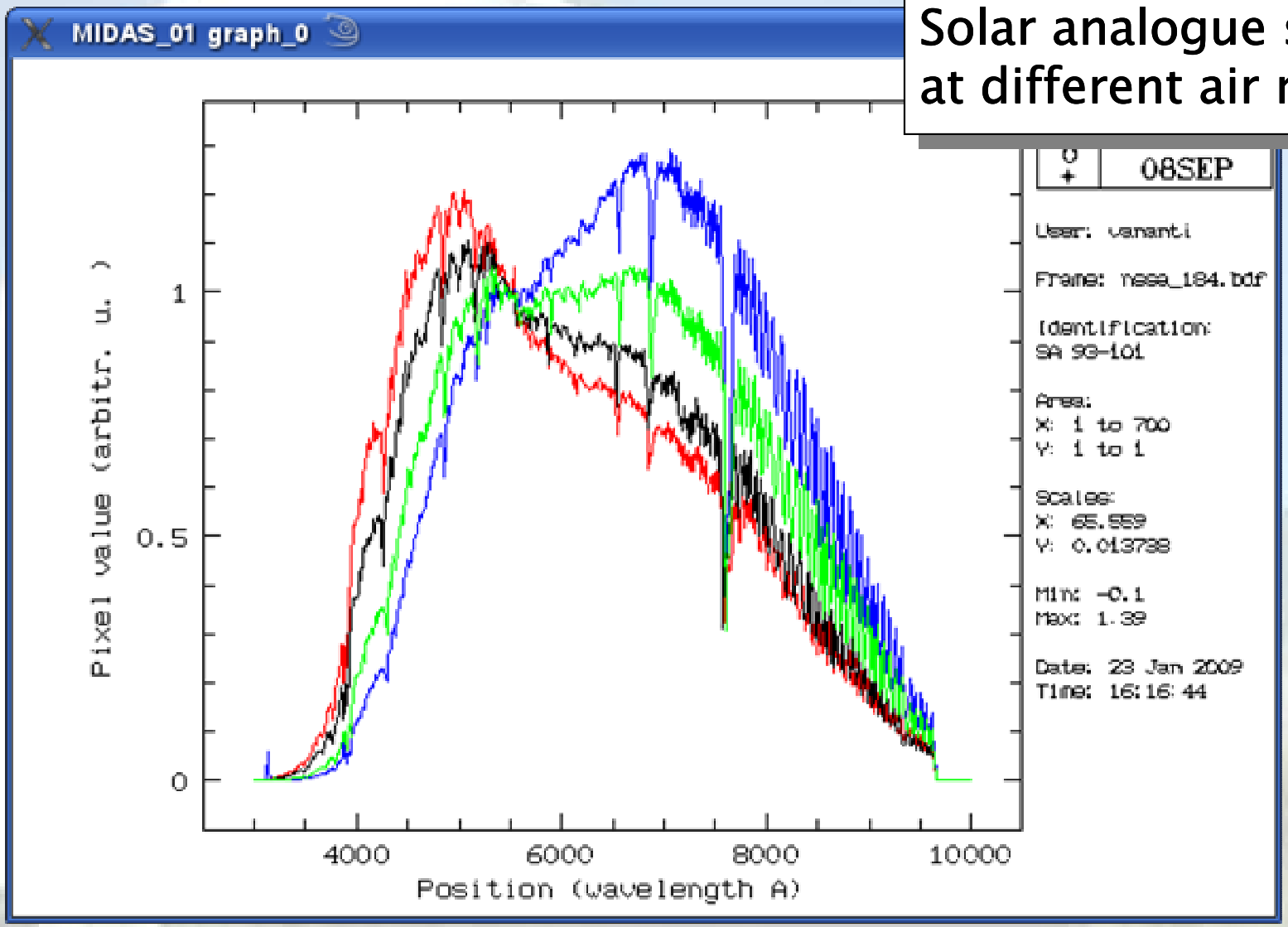


Example from Zimmerwald (Johnson-Cousins B, V)

m1-M: observed-catalogue

Extinction

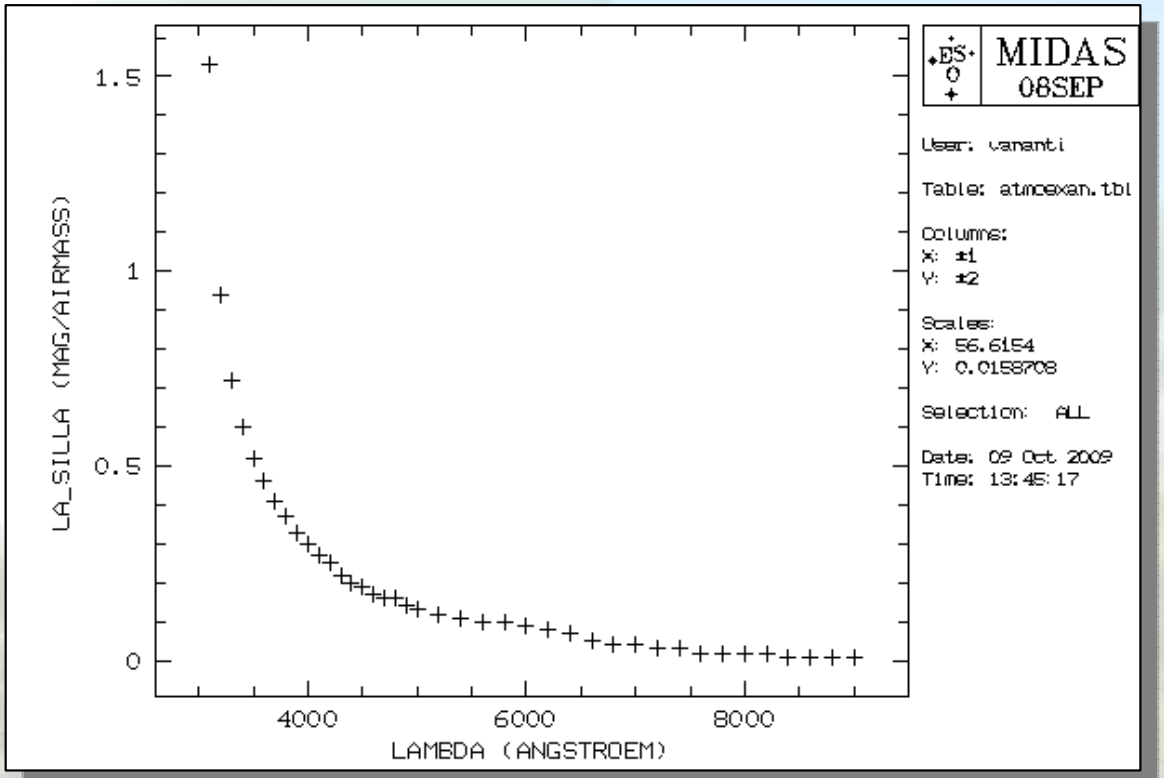
Solar analogue stars at different air mass



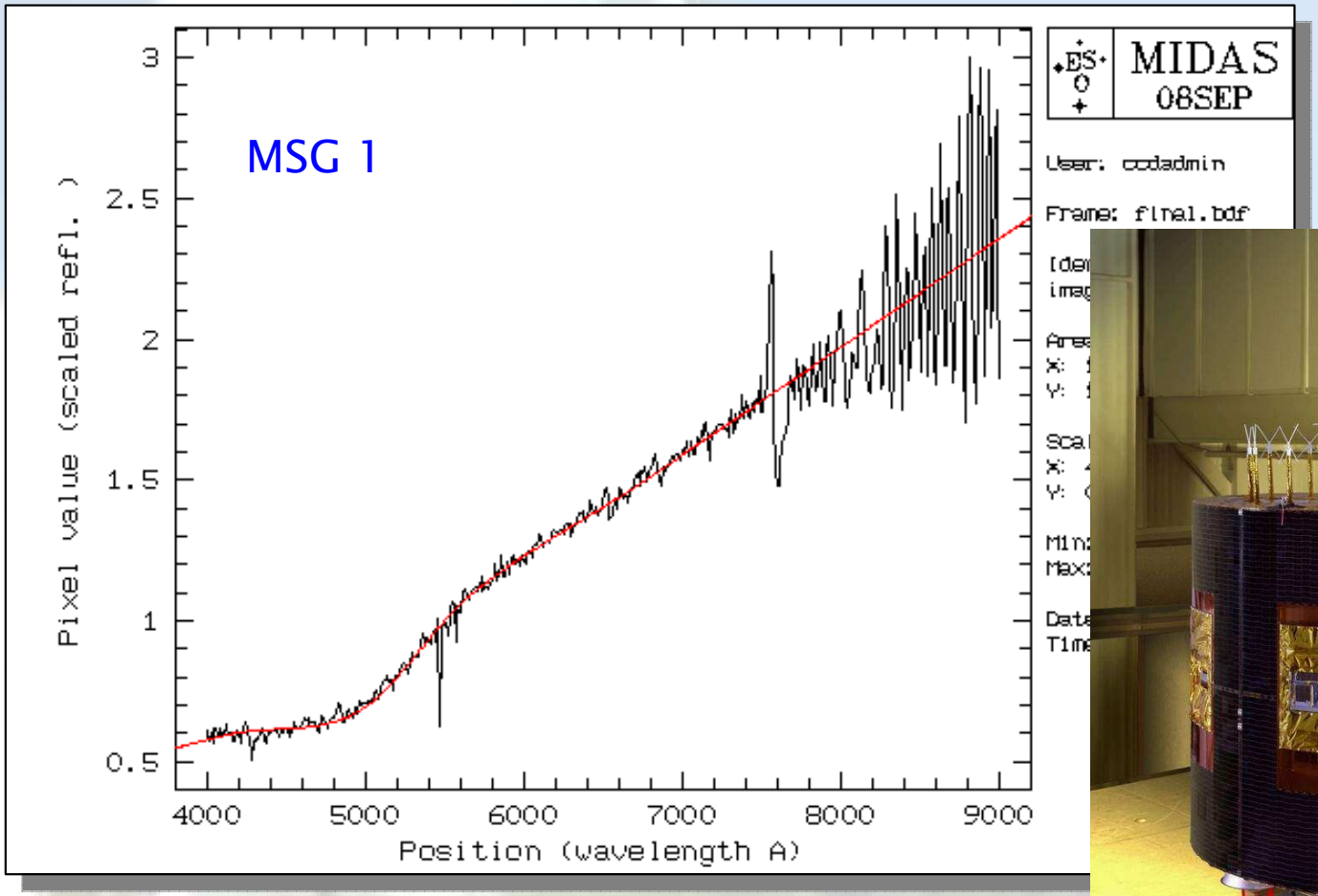
Air mass
1.02
1.13
1.4
1.94

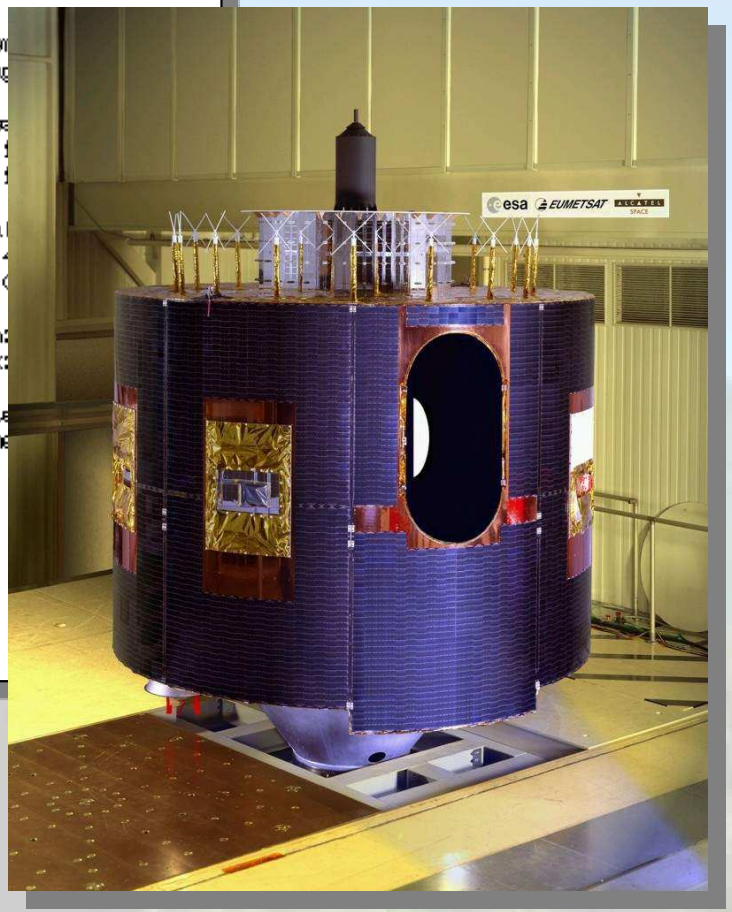
Extinction

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

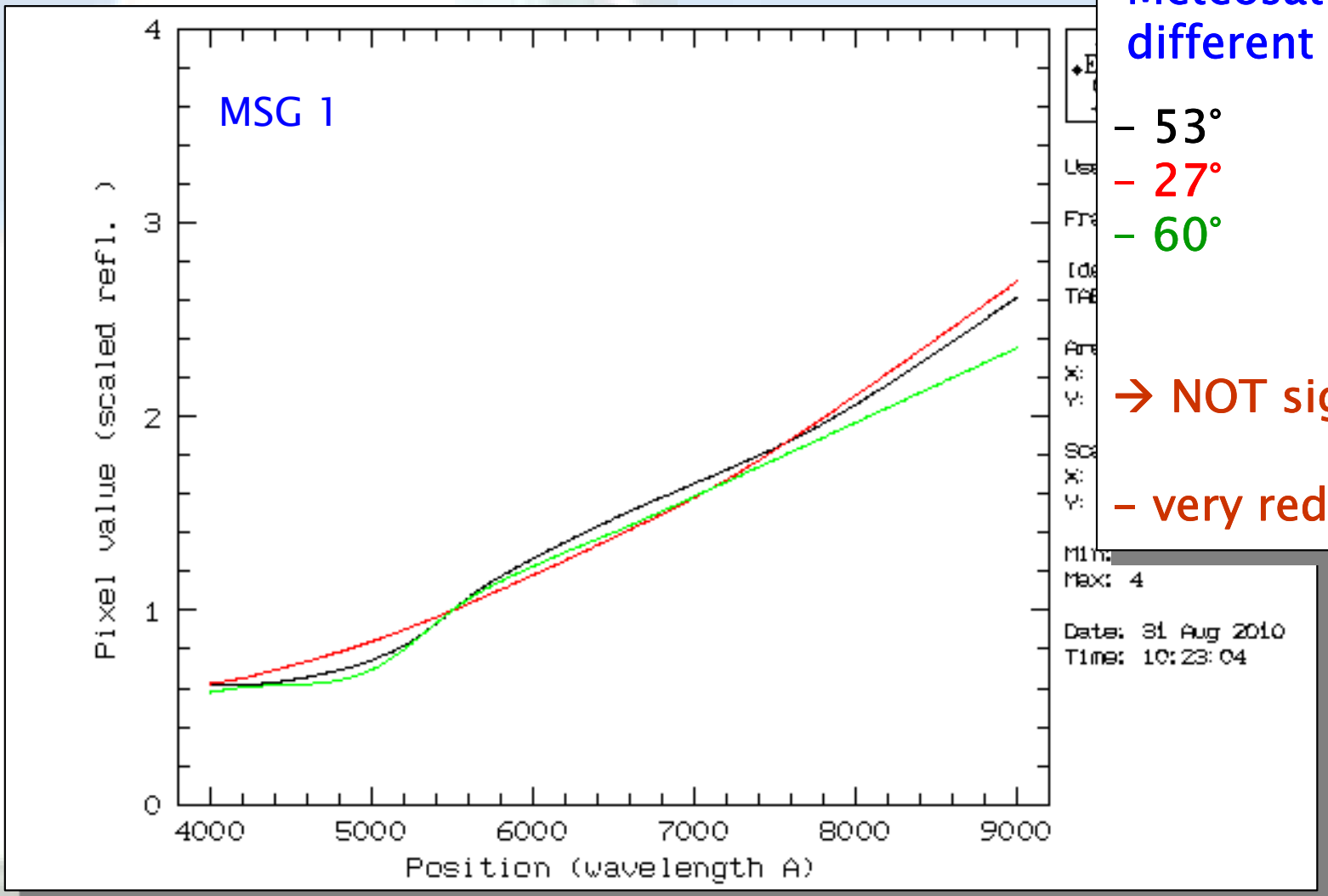


Spectra of GEO Spacecraft





Phase Angle Dependence?



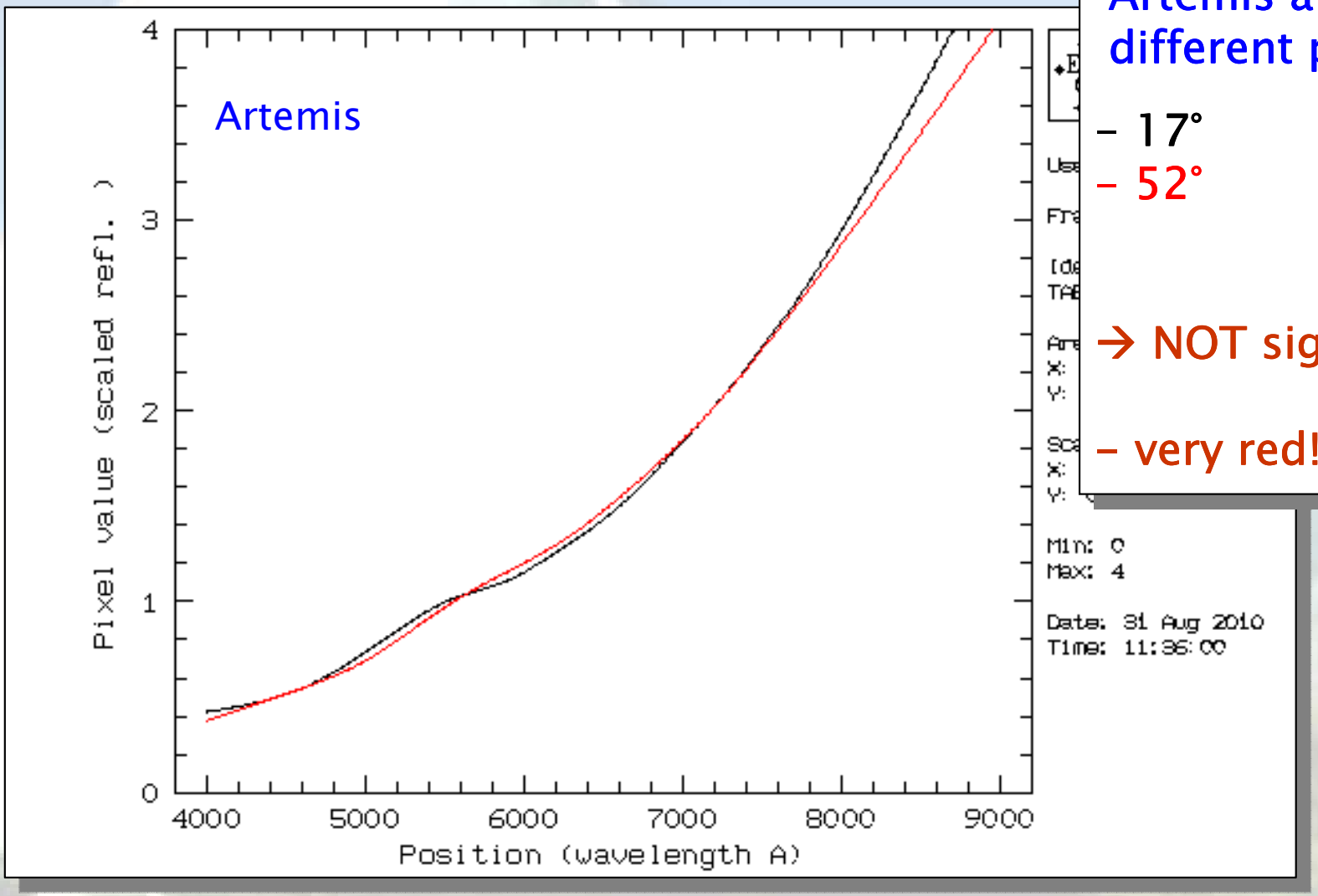
Meteosat MSG 1 at different phase angles:

- 53°
- 27°
- 60°

→ NOT significant

- very red!

Phase Angle Dependence?



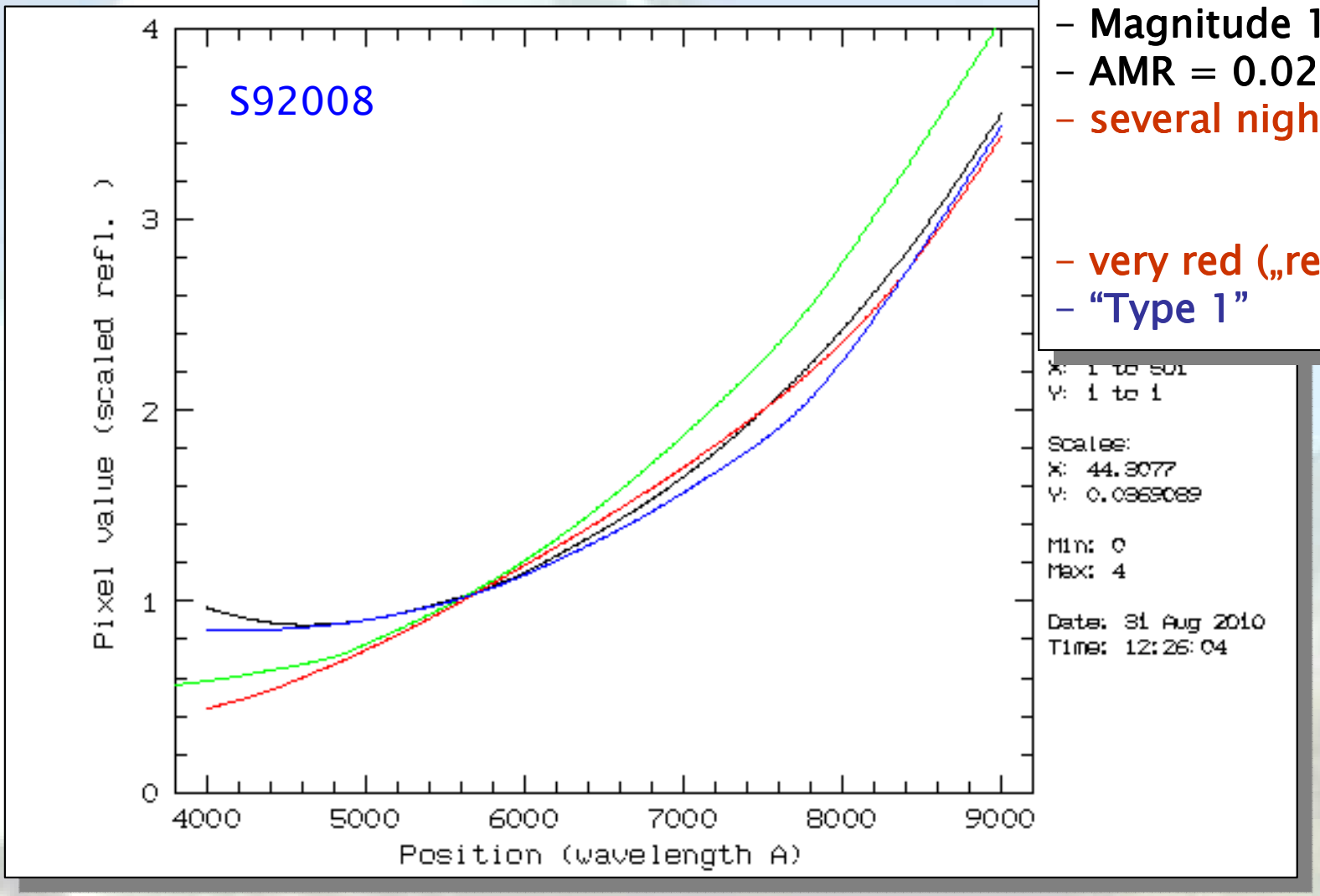
Artemis at different phase angles:

- 17°
- 52°

→ NOT significant

- very red!

Bright GTO Debris Objects

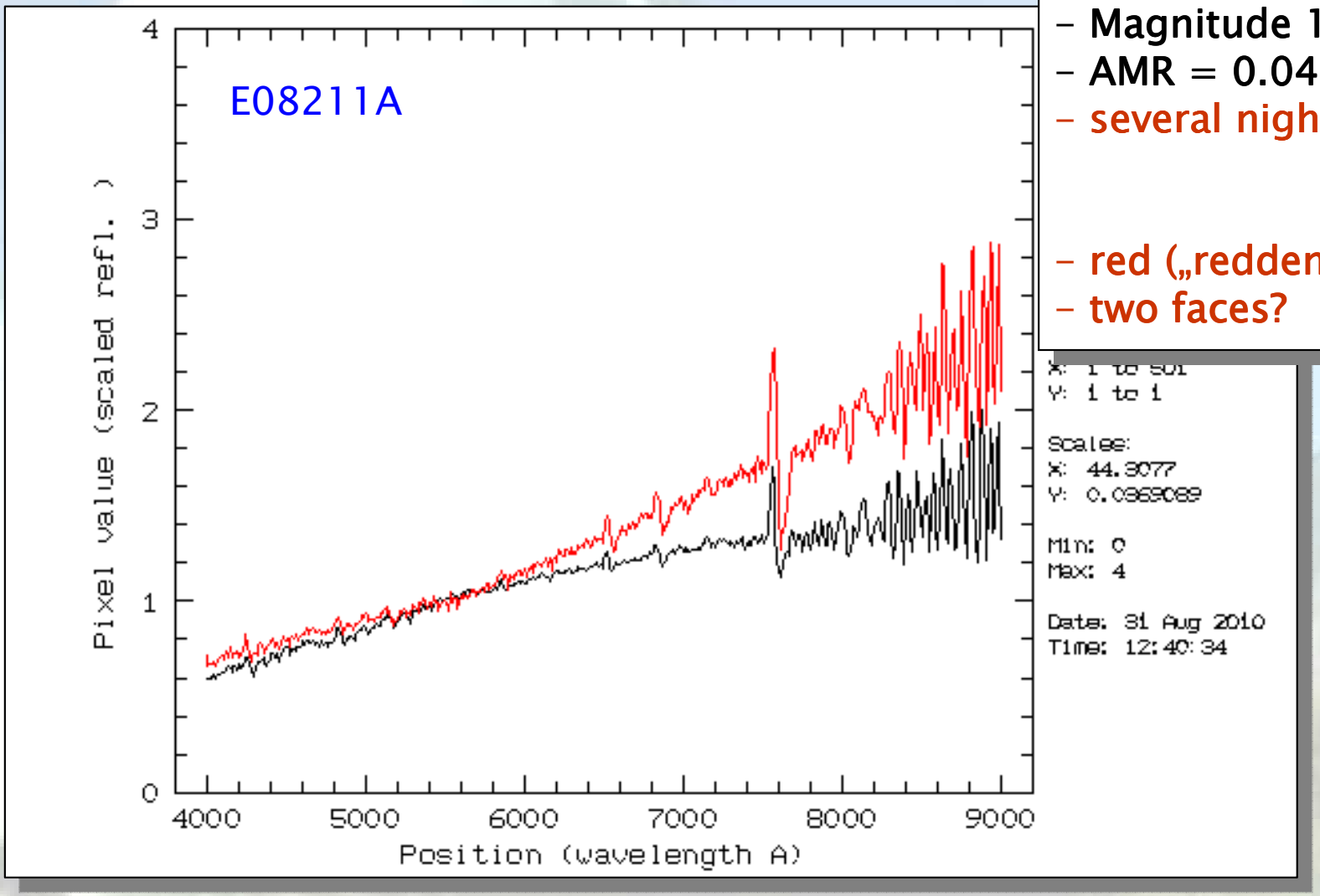


GTO debris

- Magnitude 13.4±1.2
- AMR = 0.02 m^2/kg
- several nights

- very red („reddening“?)
- “Type 1”

Bright GEO Debris Objects

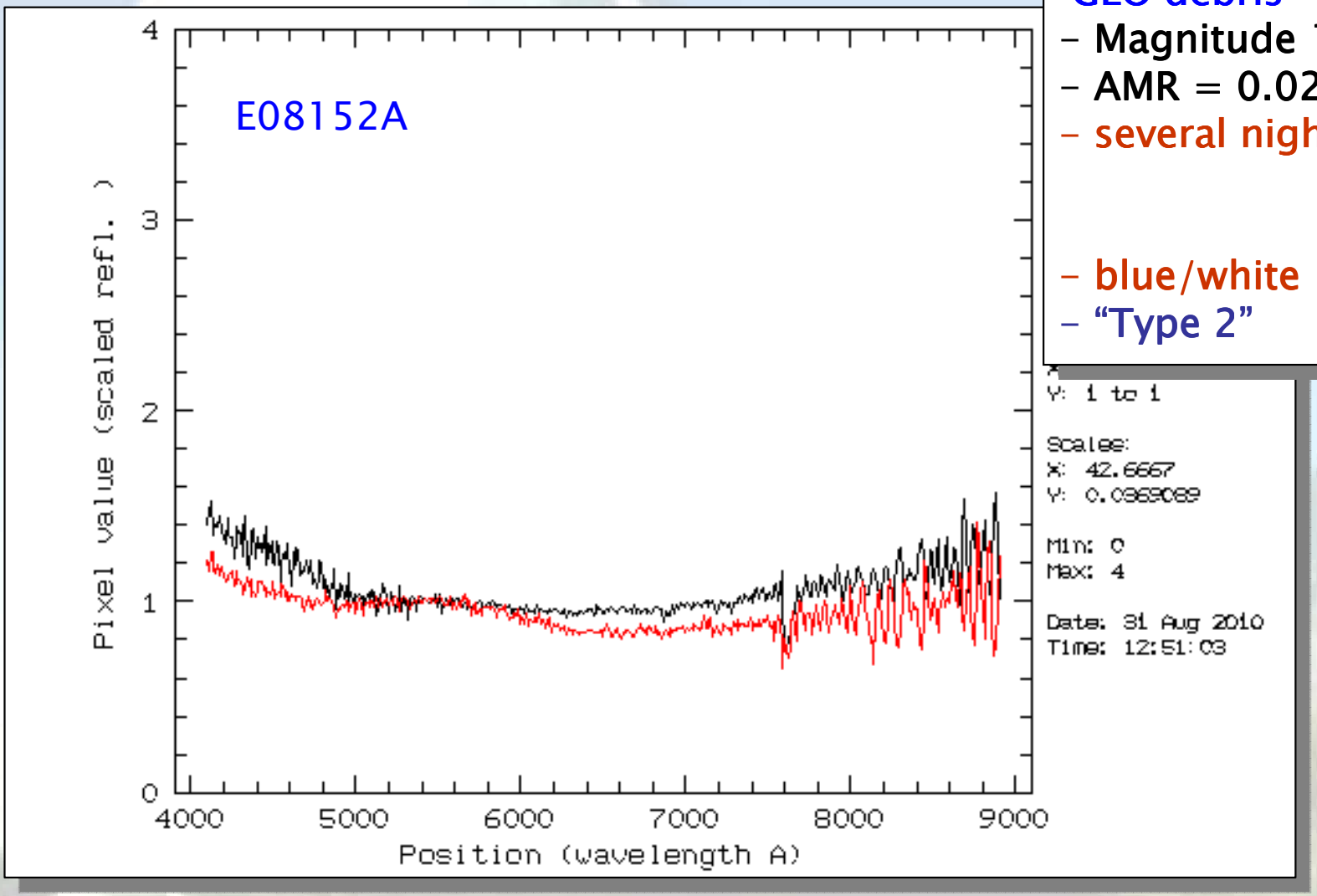


GEO debris

- Magnitude 12.8±1.3
- AMR = 0.04 m^2/kg
- several nights

- red („reddening"?)
- two faces?

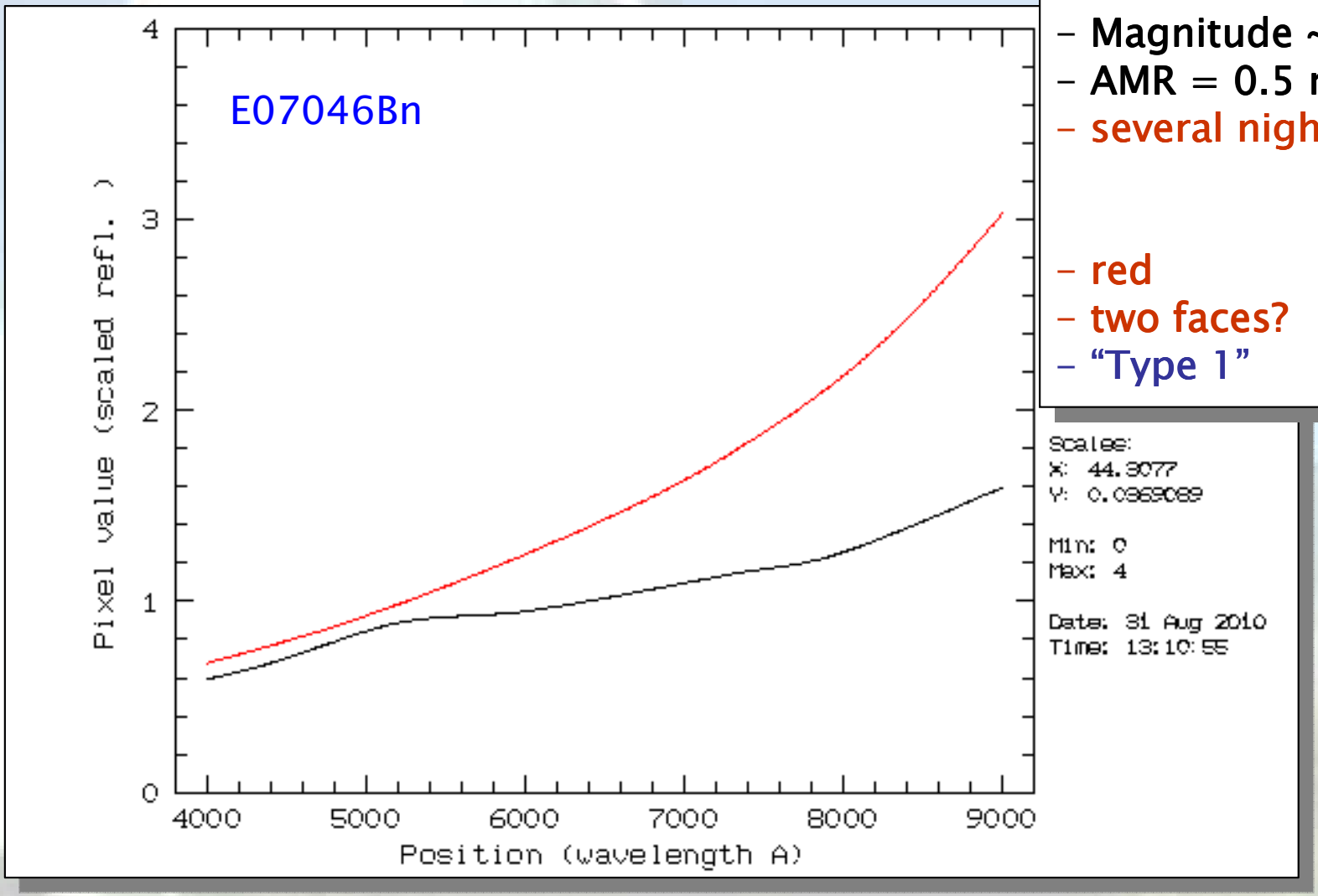
Bright GEO Debris Objects



GEO debris
- Magnitude 13.1±1.0
- AMR = 0.02 m^2/kg
- several nights

- blue/white
- "Type 2"

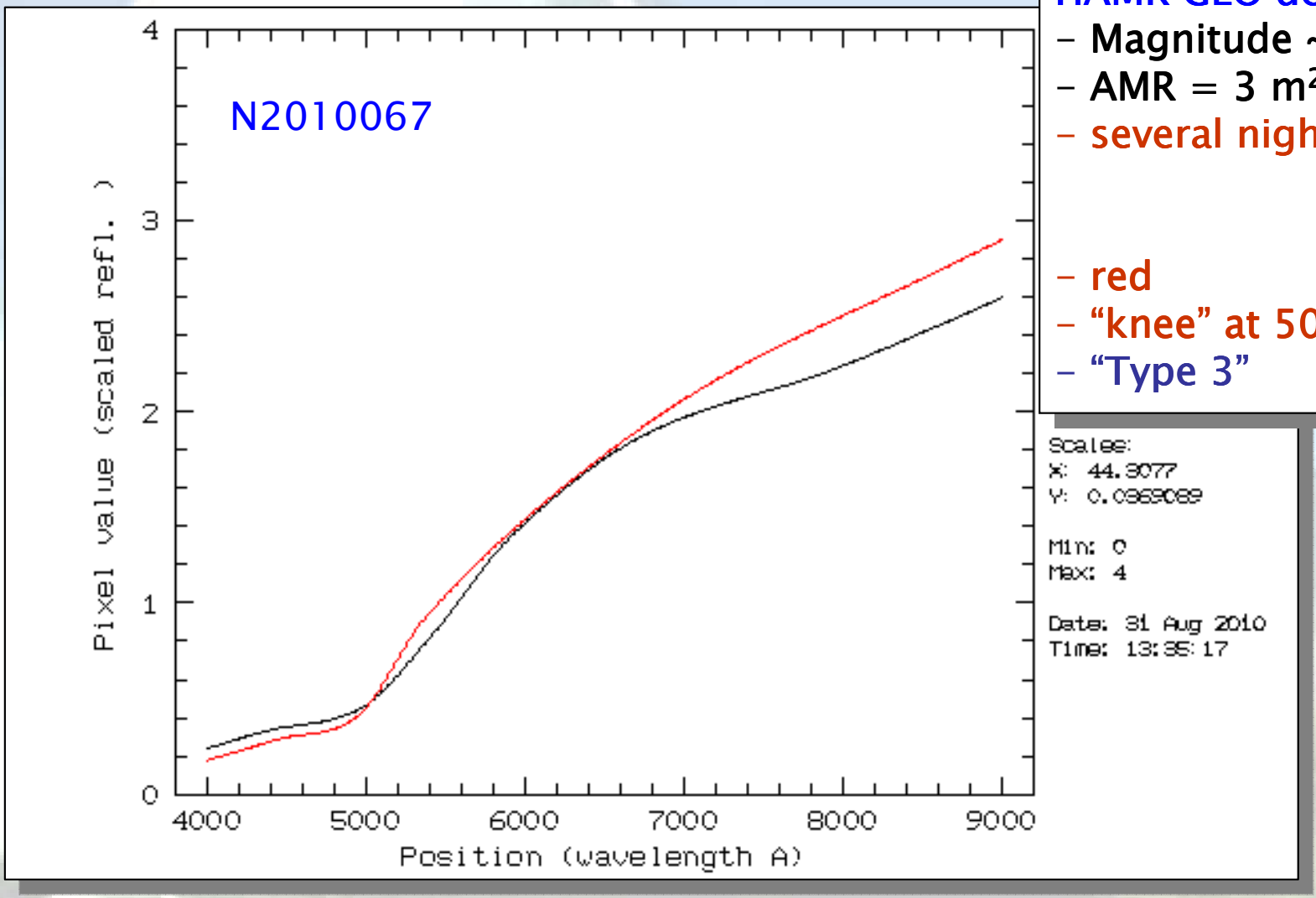
Faint HAMR GEO Debris



HAMR GEO debris
- Magnitude ~16
- AMR = 0.5 m^2/kg
- several nights

- red
- two faces?
- "Type 1"

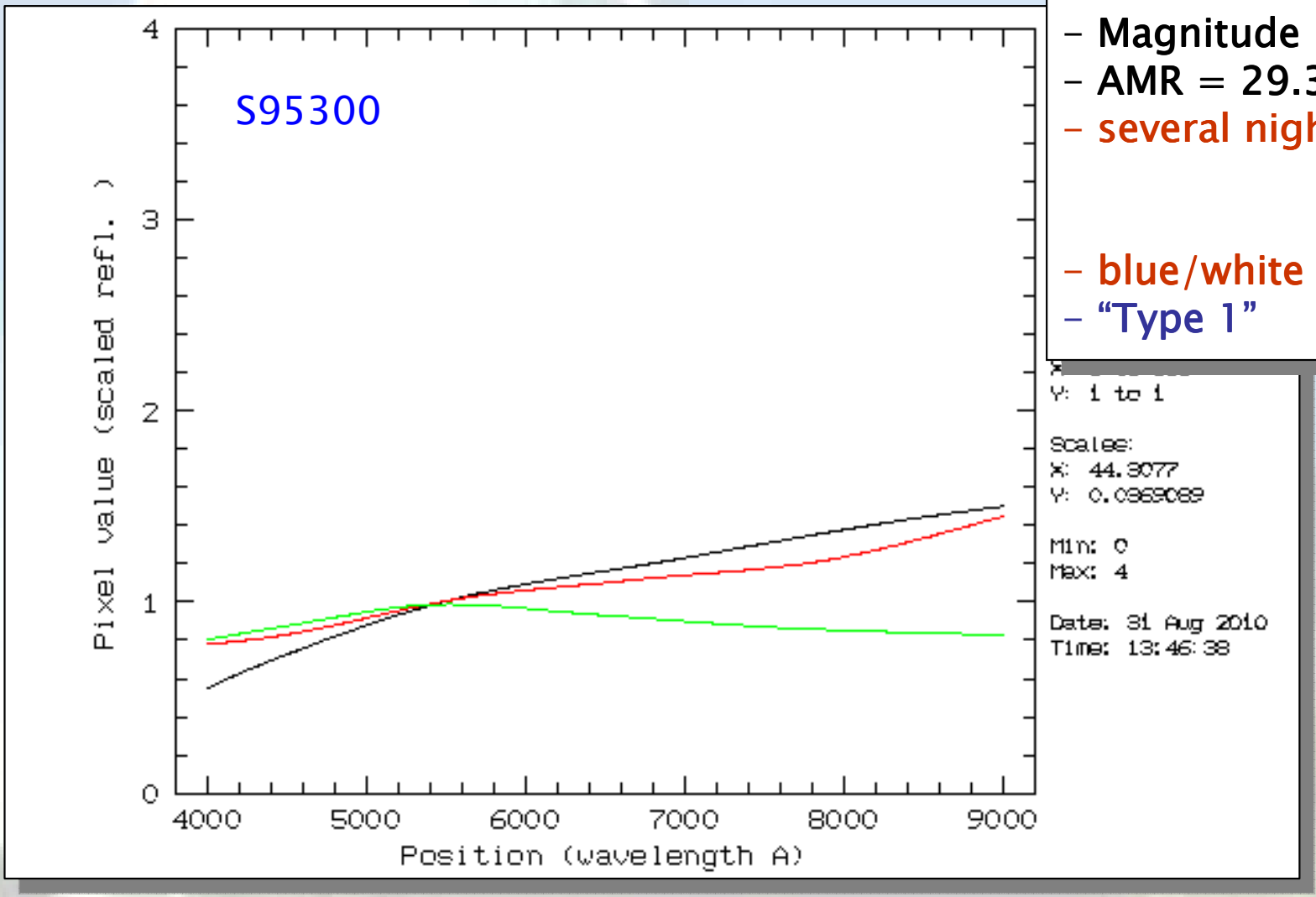
Faint HAMR GEO Debris



HAMR GEO debris
- Magnitude ~16
- AMR = 3 m^2/kg
- several nights

- red
- "knee" at 500nm
- "Type 3"

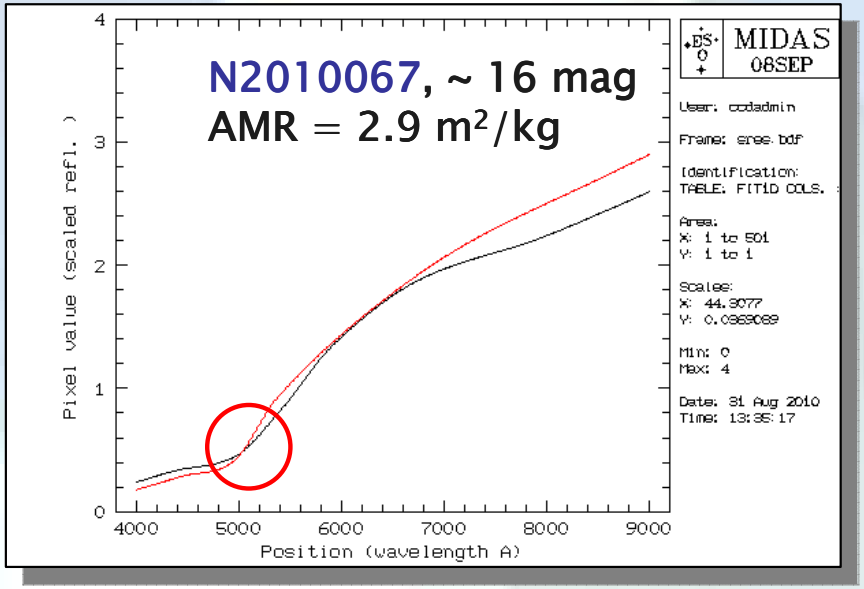
Faint HAMR GEO Debris

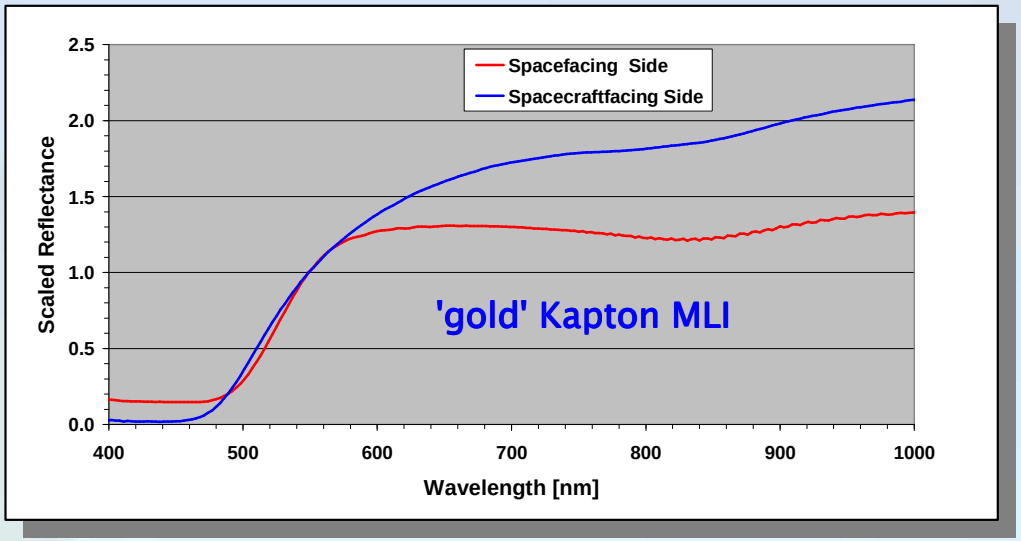


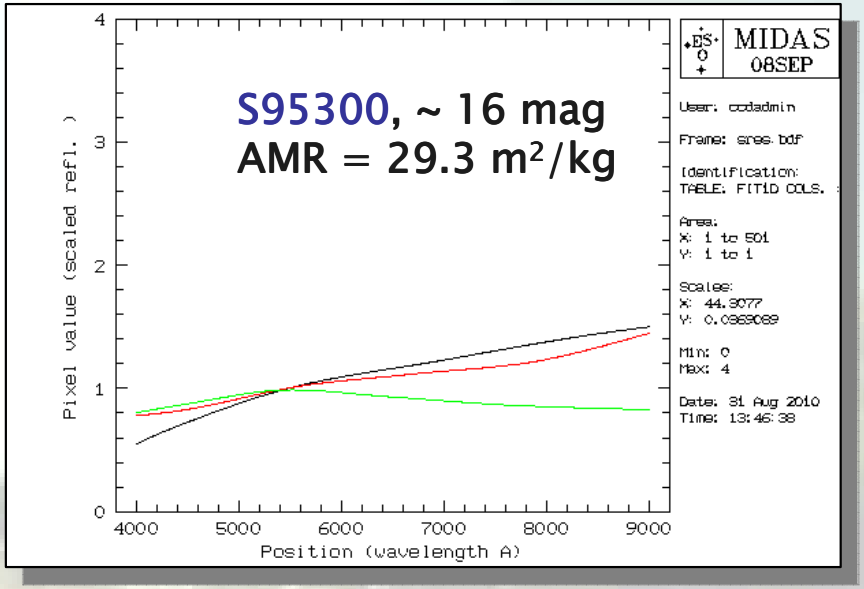
HAMR GEO debris
- Magnitude 16.3±0.8
- AMR = 29.3 m^2/kg
- several nights

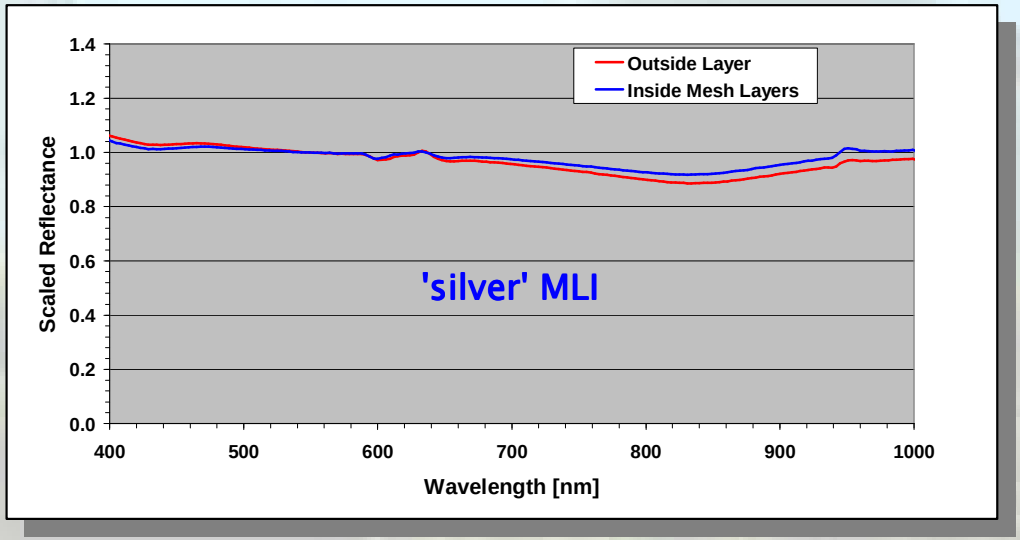
- blue/white
- "Type 1"

Comparison with Lab Spectra









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 .
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- K. Abercromby provided data on MLI.
- J. Kuusela and D. Abreu were mounting the spectrograph and taking the observations .