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Visible Light Spectroscopy of GEO Debris^{1,2}

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Our goal is to understand the physical characteristics of debris at geosynchronous orbit (GEO). Our approach is to compare the observed reflectance as a function of wavelength with laboratory measurements of typical spacecraft surfaces to understand what the materials are likely to be. Because debris could be irregular in shape and tumbling at an unknown rate, rapid simultaneous measurements over a range of wavelengths are required. Acquiring spectra of optically faint objects with short exposure times to minimize these effects requires a large telescope.

We describe optical spectroscopy obtained during 12-14 March 2012 with the IMACS imaging spectrograph on the 6.5-m 'Walter Baade' Magellan telescope at Las Campanas Observatory in Chile. When used in f/2 imaging mode for acquisition, this instrument has a field of view of 30 arc-minutes in diameter. After acquisition and centering of a GEO object, a 2.5 arc-second wide slit and a grism are moved into the beam for spectroscopy. We used a 200 l/mm grism blazed at 660 nm for wavelength coverage in the 500-900 nm region. Typical exposure times for spectra were 15-30 seconds.

Spectra were obtained for five objects in the GEO regime listed as debris in the US Space Command public catalog, and one high area to mass ratio GEO object. In addition spectra were obtained of three cataloged IDCSP (Initial Defense Communications Satellite Program) satellites with known initial properties just below the GEO regime. All spectra were calibrated using white dwarf flux standards and solar analog stars.

We will describe our experiences using Magellan, a telescope never used previously for orbital debris spectroscopy, and our initial results.

1. This work is supported by NASA's Orbital Debris Program Office, Johnson Space Center, Houston, Texas, USA.
2. This paper includes data gathered with the 6.5 meter Magellan Telescopes located at Las Campanas Observatory, Chile.



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Spectroscopy

- **Goal – visible light (4000 – 8000 Angstrom) spectroscopy of GEO debris for comparison with laboratory spectra of actual spacecraft materials.**
- **What are the possible surfaces seen at GEO?**
- **Simultaneous wavelength coverage.**
- **Using imaging spectrographs on Magellan 6.5-m telescopes. Large telescopes in excellent seeing – short exposure times. Important if irregularly shaped object tumbling.**



6.5-m Magellan Telescopes

Las Campanas Observatory, Chile

Baade – imaging & spectroscopy

Clay - spectroscopy

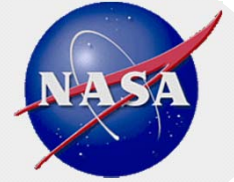


Collaboration of Carnegie Institution, University of Arizona, Harvard University, University of Michigan, and Massachusetts Institute of Technology.



Spectroscopy at Magellan

- **March 2012 – first attempts with Baade telescope.**
 - IMACS – Inamori Magellan Areal Camera and Spectrograph.
 - 30 arc-minute diameter field of view for acquisition.
 - 3 nights.
 - Spectra acquired of 6 GEO debris pieces (1 high area to mass) and 3 IDCSP satellites.
 - Reductions in progress.
- **May 2012 – Clay telescope.**
 - LDSS3: Low Dispersion Survey Spectrograph (Version 3) designed for cosmology.
 - 8.3 arc-minute diameter acquisition field of view.
 - 5 arc-second wide slit.
 - Two half nights.
 - Spectra of 5 cataloged GEO debris pieces plus 1 IDCSP object.
 - Exposure time 30 seconds/spectra.
 - Preliminary results from one half-night reported here.



LDSS3 on Clay Telescope

- **Sampling – 2 Angstroms/pixel. Smoothed spectrum yield 10 A resolution.**
- **30 second exposures.**
- **Spectra divided by spectra of solar analog star (SF1615 – James Webb Space Telescope (JWST) standard).**
- **Normalized to 1 in 7500-8000 Angstrom region.**
- **Primary technical challenge – blind non-sidereal tracking to keep object in 5 arc-second wide slit.**



Targets

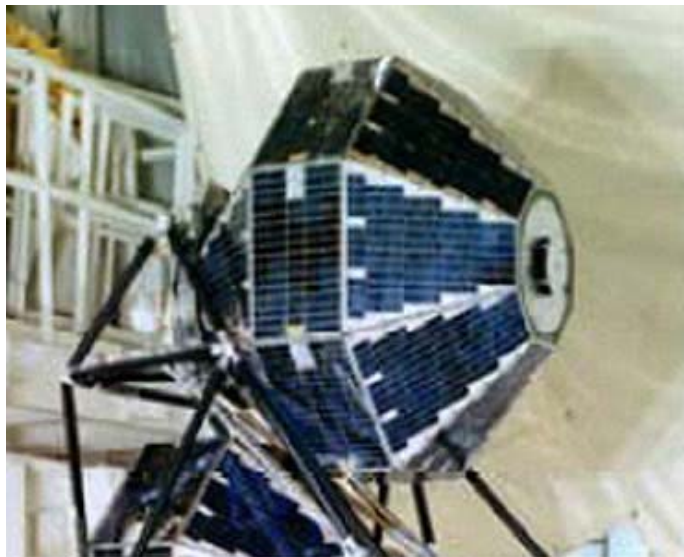
- **GEO or near GEO objects with recent TLEs selected from public catalog.**
- **Objects visible from Chile during May 2012 run:**

SSN	Launch Year	Description
02655	1967	IDCSP
12996	1977	EKRAN 2 DEB
13753	1976	LES 8,9/SOL 11A,B DEB
25000	1968	TITAN TRANSTAGE DEB
29014	1977	EKRAN 2 DEB
29106	2005	MSG 2 DEB (COOLER COVER)



Two objects of known launch characteristics

02655 IDCSP 15 1967-003H



USAF

Initial Defense Communications Satellite Program
26 sided polygons of solar cells, 86 cm diameter

29106 MSG 2 Cooler cover 2005-049E

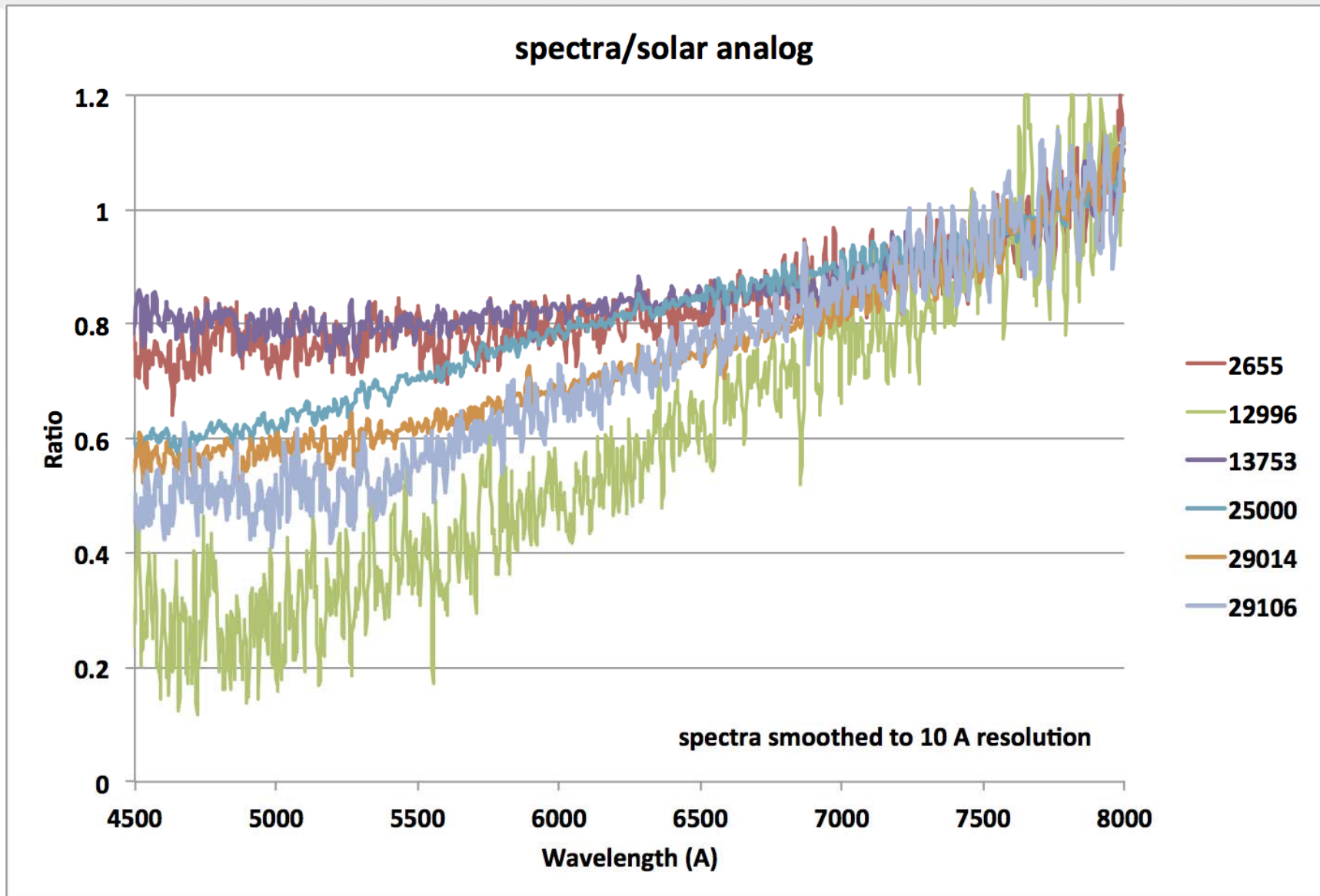


1.9 meter² area

Source: Jah and Kelecyc IAC 2010

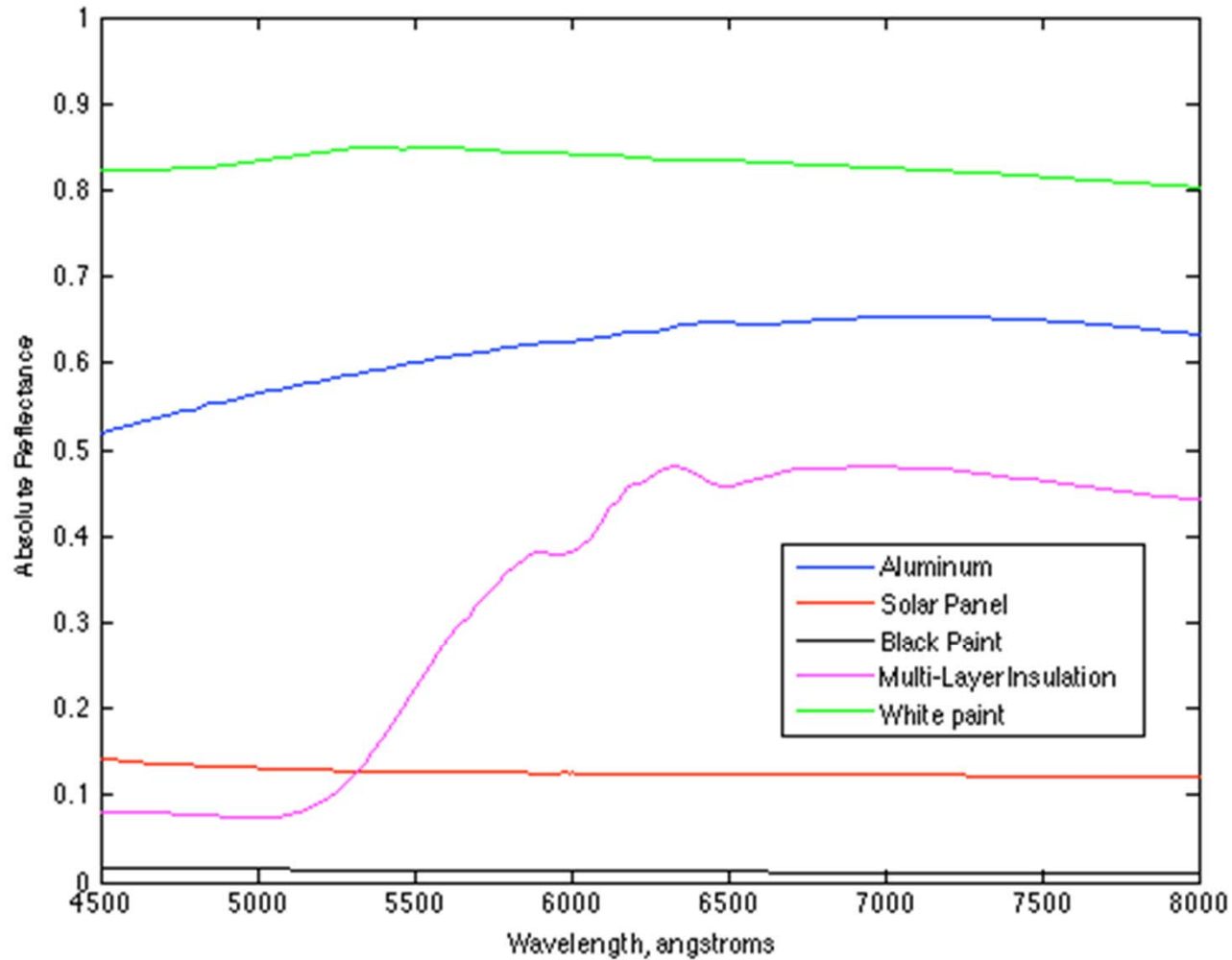


Summary of Observations



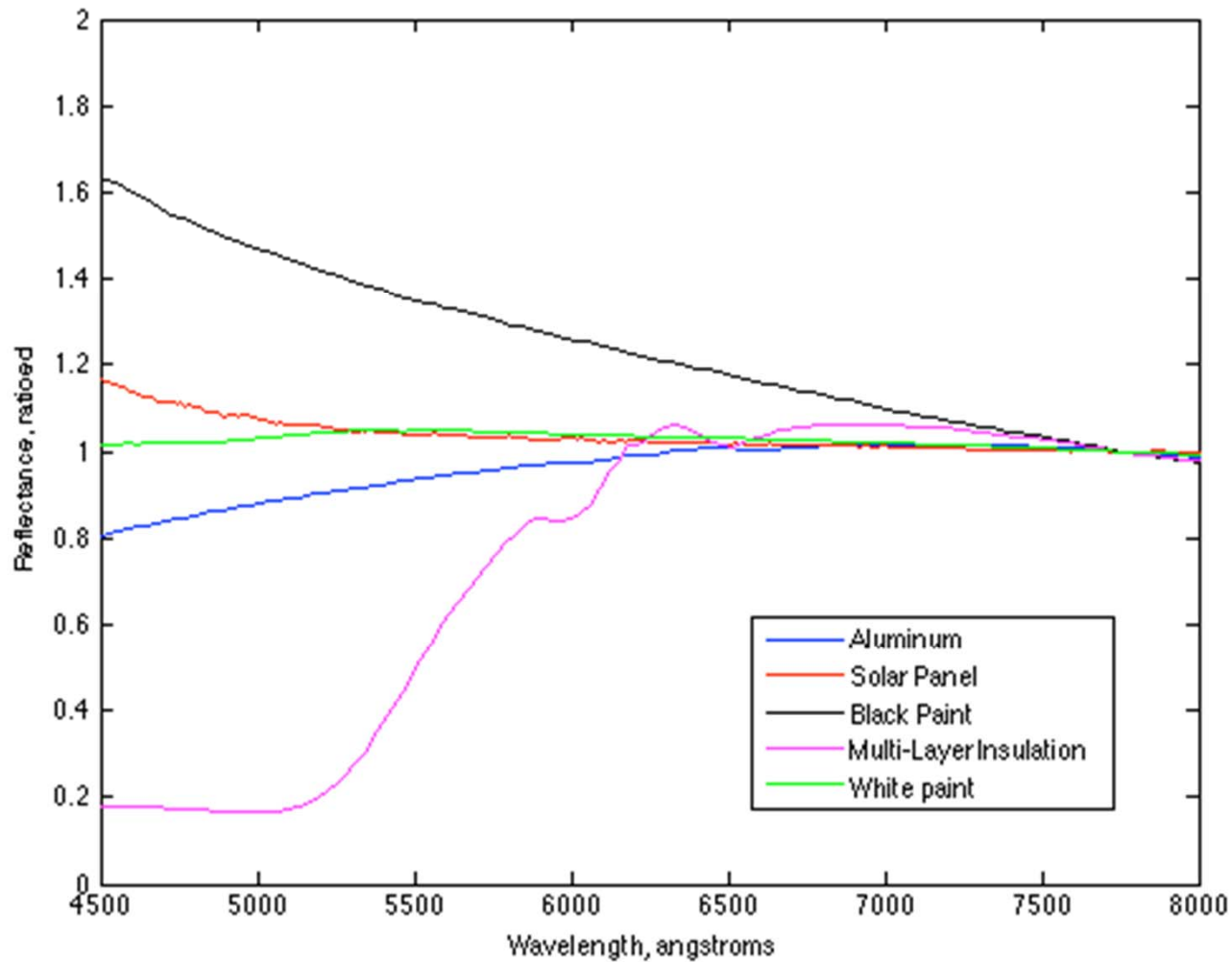


Laboratory Measurements



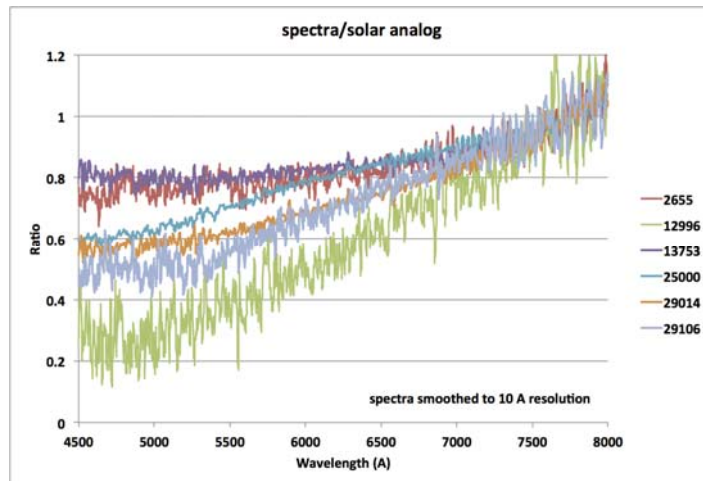


Laboratory Measurements normalized to 7500-8000 Angstroms

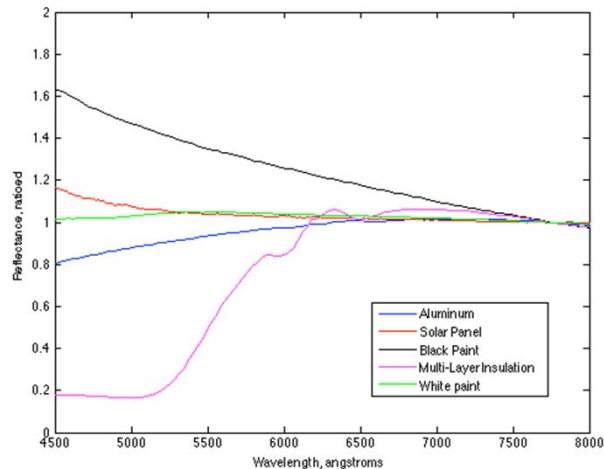




Interpretation of Observations

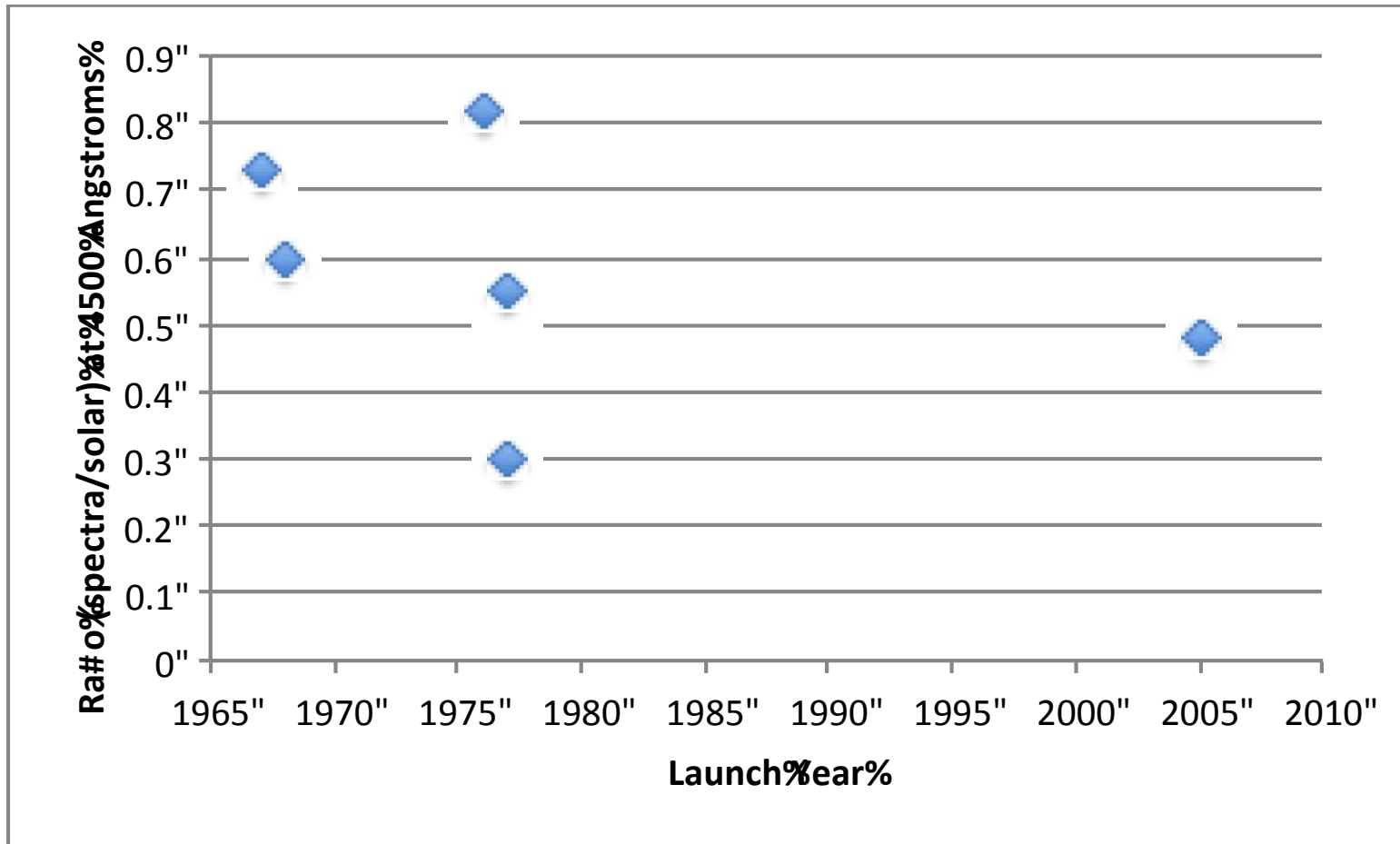


- All observations show positive slope from blue to red.
- 2655 IDCSP and 13753 LES 8,9/SOL 11A,B DEB have flattest response.
- 12996 EKTRAN 2 DEB has greatest slope.
- 2 pieces of EKTRAN 2 DEB (12996 and 29014) have different slopes.
- With exception of two flat response objects (2655 and 13753), no obviously good fit to any laboratory measurements.



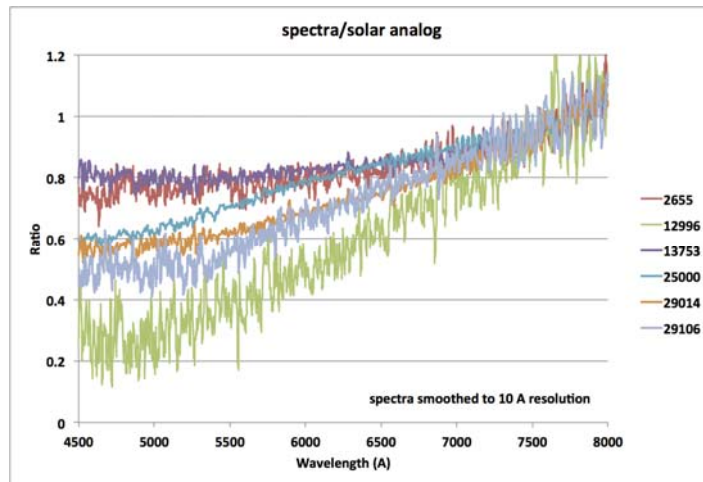


No Dependence on Launch Year

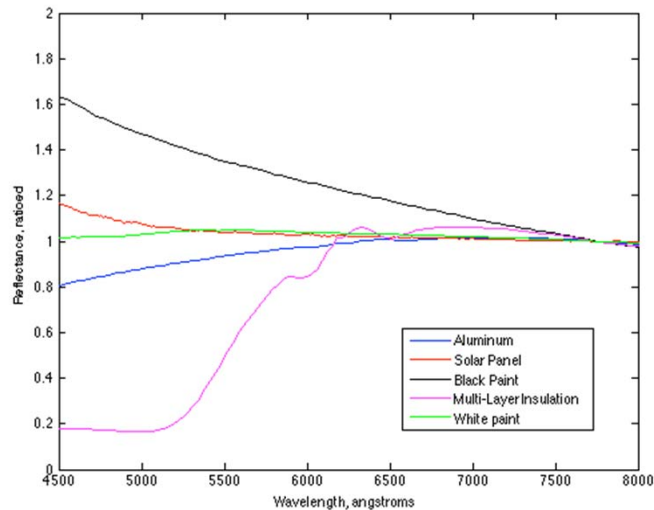




Conclusions



- 2655 (IDCSP with solar cells) and 13753 (LES 8,9/SOL 11A,B DEB) have flat response and compare well with laboratory measurements with exception of turn up near 7000 Angstroms.



- **Mystery - none of other objects compare well with laboratory measurements. Why?**
 - Debris could be rapidly tumbling (faster than 30 second exposure time). Multiple surfaces presented to observer.
 - Space weathering?
 - Errors in observing and/or reduction?
 - ????