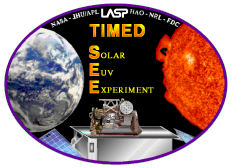
XPS Calibrations



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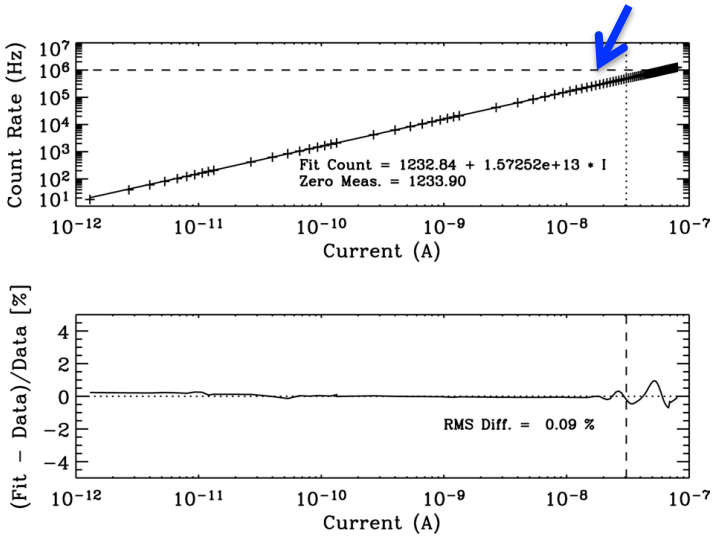
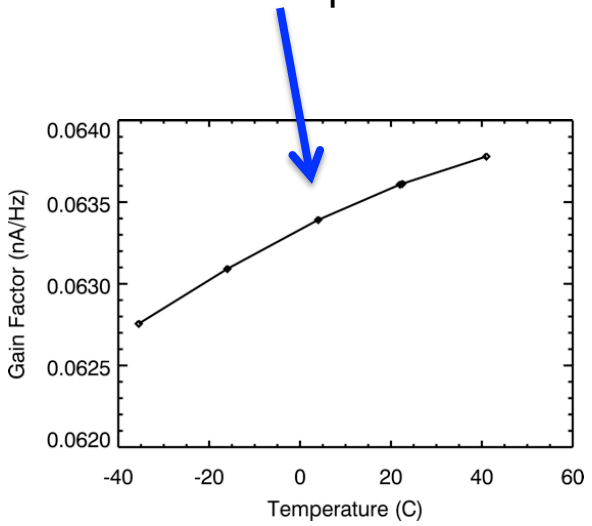
XPS Calibration Overview

➢ Pre-flight Calibrations

- Selection of filter diodes without pinholes
- Responsivity calibrations (PTB BESSY, NIST SURF-III) with 5-15% accuracy
- Electronics gain calibration: linearity check and as function of temperature



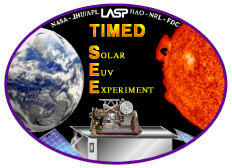


➢ In-flight Calibrations

- Rocket underflight calibrations using prototype XPS (about once per year)
  - NIST SURF-III used for the rocket XPS calibrations
- Redundant channel calibrations (initially once a day, now once a month on SORCE)

XPS Diode Calibration History

- TIMED XPS diodes calibrated at PTB BESSY in 1998 (Frank Scholze)
  - reference diode used with monochromator and synchrotron source
  - calibrations are between 1 and 25 nm
  - TIMED launched in Dec. 2001
- SORCE XPS diodes calibrated at NIST SURF-III in 2001 (Rob Vest)
  - reference diode used with monochromator and synchrotron source (BL-9)
  - calibrations are between 5 and 50 nm
  - SORCE launched in Jan. 2003
- Rocket XPS diodes calibrated at NIST SURF-III in 2003 (Tom Woods)
  - direct use of synchrotron source (BL-2) with multiple beam energies
  - calibrations are over all wavelengths, but results primarily over the 0-34 nm range
  - Annual underflight calibration rockets: Feb. 2002, Aug. 2003; next: Oct. 2004
- TIMED SEE Version 7+ data and SORCE XPS Version 5+ data are based on the 2003 rocket XPS calibration



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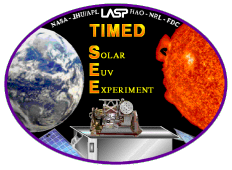
Two Batches of Diodes Calibrated

Batch 1 (1998-TIMED)

Filter Coating	Thickness (Å) Specification	Thickness (Å) from BL-2
Ti - C	5000 / 500	3875 / 500
Ti-Zr-Au	200/2000/1000	-
Ti-Pd	2000 / 1000	1628 / 791
Al-Sc-C	2000/1000/500	-
Al-Nb-C	2500/500/500	2089/392/473
Al-Cr	2000 / 1000	-
Al-Mn	2000 / 1000	-

Batch 2 (2000-SORCE)

Filter Coating	Thickness (Å) Specification	Thickness (Å) from BL-2
Used Batch #1 Ti-C		
Ti-Mo-Au	400/2000/1000	452/1113/741
Ti-Mo-Si-C	400/2000/1000/500	341/1313/1035/461
Al-Sc-C	2700/500/500	1791/500/250
Used Batch #1 Al-Nb-C		
Al-Cr	2700 / 1000	1750 / 1114
Al-Mn	2700 / 1000	1750 / 1447



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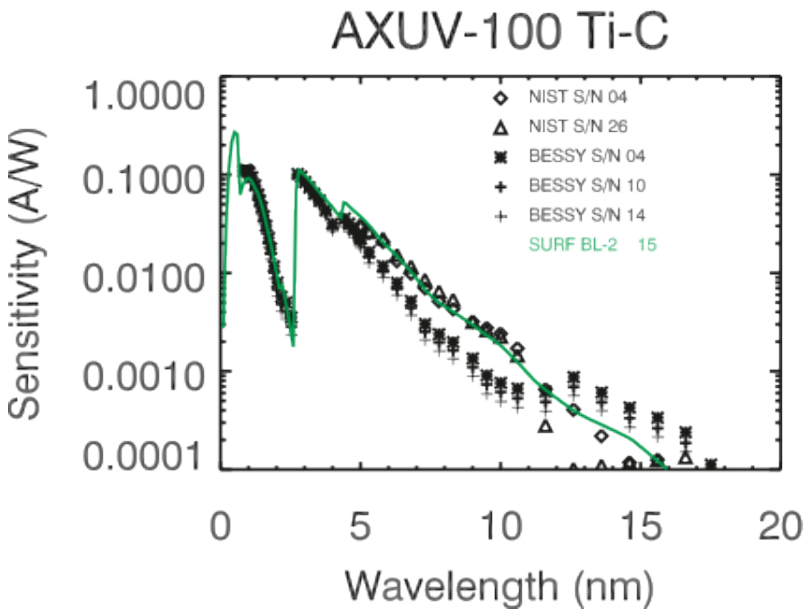
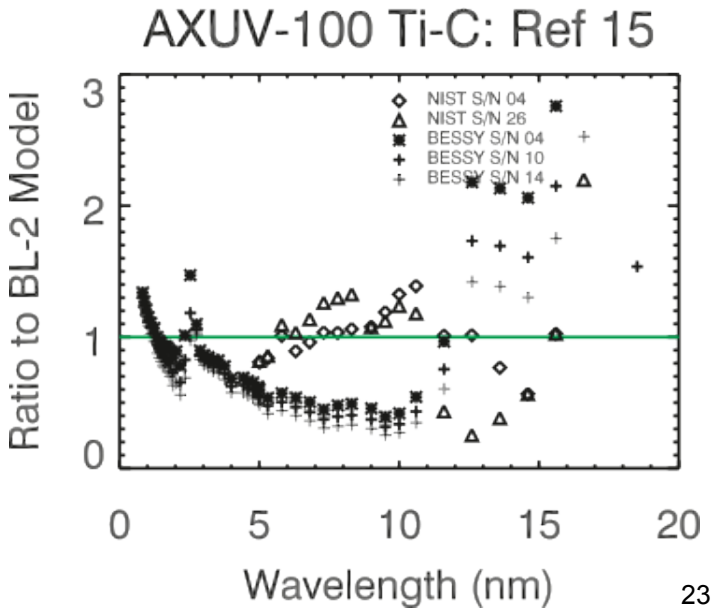
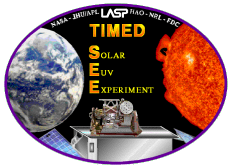
Ti-C Photodiode Calibration

- All Ti-C diodes are from Batch 1 and are expected to be similar
- Factor of 2 differences at some wavelengths
  - BESSY has good agreement < 4 nm, lower 4-12 nm, higher >12 nm
  - SURF BL-9 and BL-2 results agree







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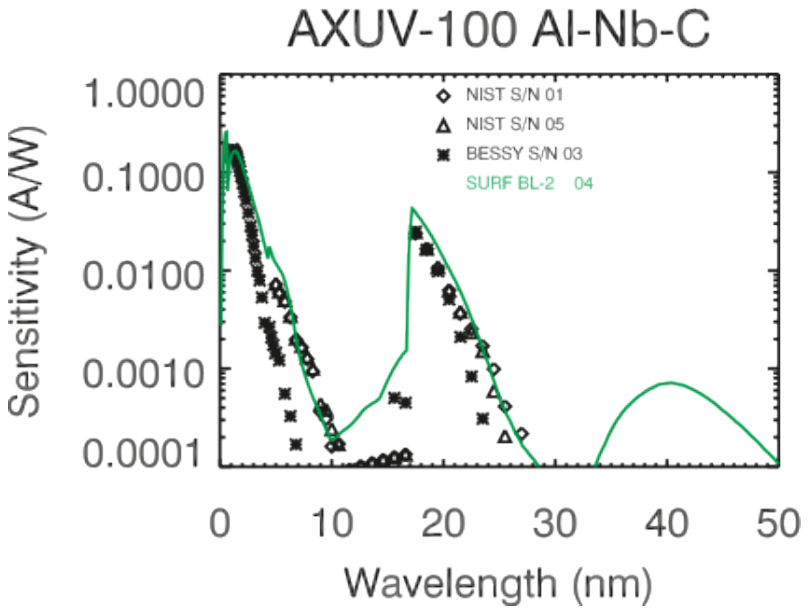
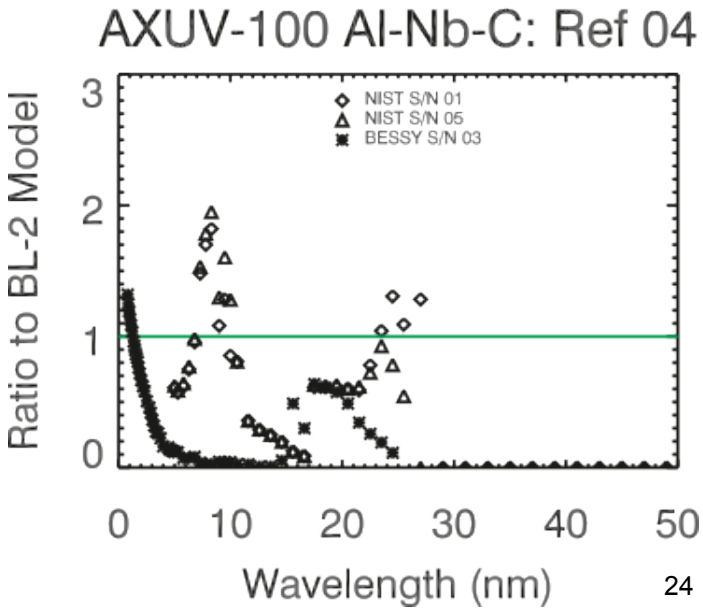
Al-Nb-C Photodiode Calibration

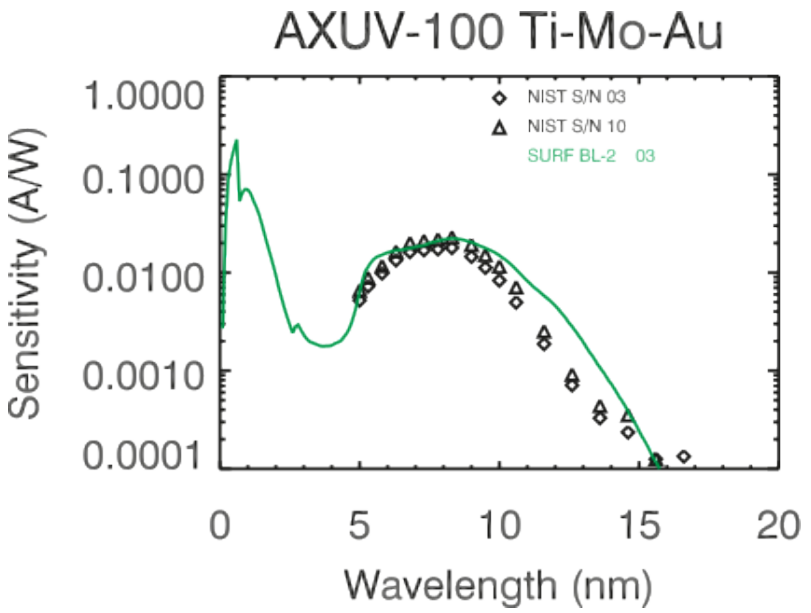
- All Al-Nb-C diodes are from Batch 1 and are expected to be similar
- Large differences at some wavelengths
  - BESSY has good agreement < 3 nm, lower 3-17 nm and >21 nm
  - SURF BL-9 and BL-2 results agree < 10 nm and > 23 nm
  - SURF BL-2 is higher 17-21 nm

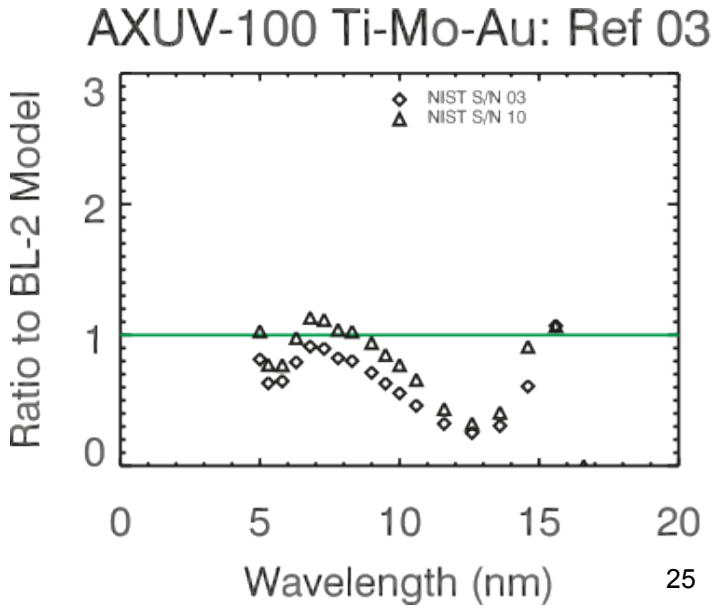




Ti-Mo-Au Photodiode Calibration

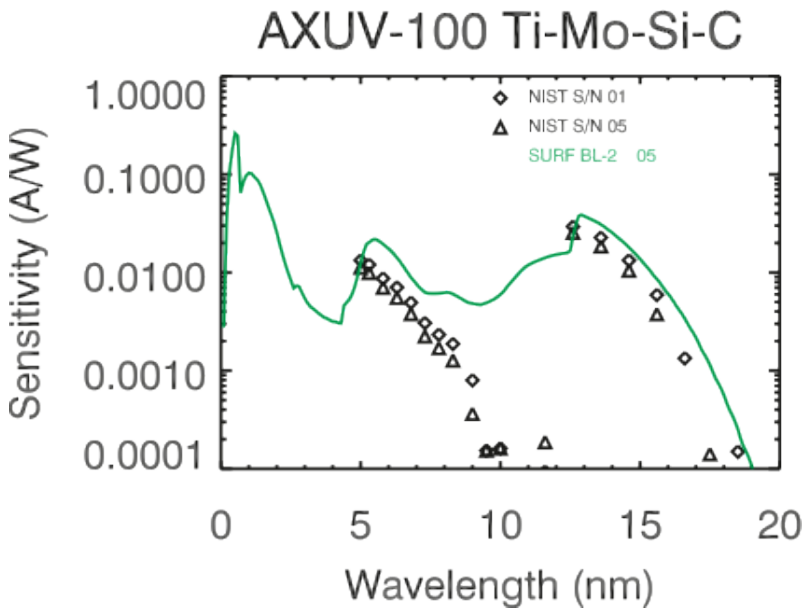
- Ti-Mo-Au diodes are from Batch 2 and are expected to be similar
- None of these diodes were calibrated at BESSY
- Good agreement between SURF BL-9 and BL-2 results
  - BL-2 result is higher 10-14 nm

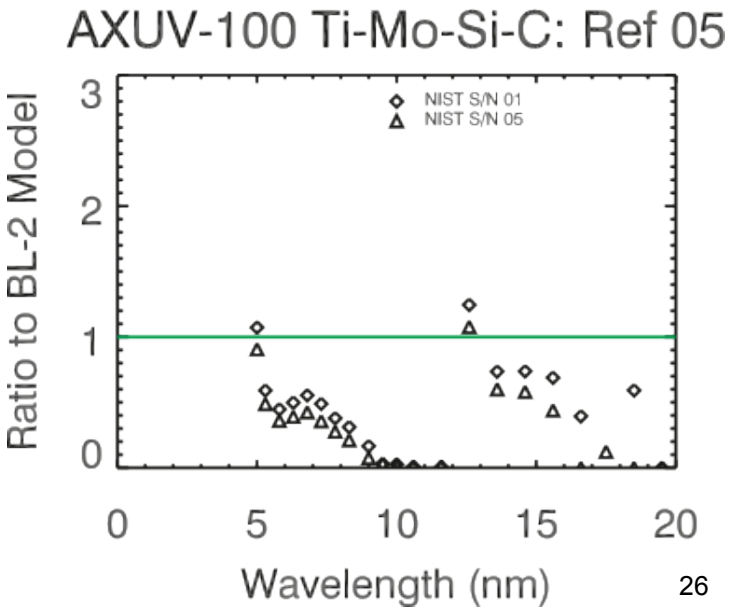




Ti-Mo-Si-C Photodiode Calibration

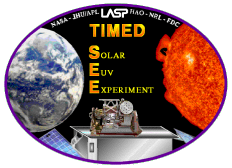
- Ti-Mo-Si-C diodes are from Batch 2 and are expected to be similar
- None of these diodes were calibrated at BESSY
- BL-2 results are higher than SURF BL-9 results





Summary of Comparisons

- Generalization of Differences
  - BESSY is lower in the 3-10 nm range: exceptions are the Ti-Pd and Ti-Zr-Au diodes
  - SURF BL-2 method is higher in the 17-35 nm range
- Possible Causes for Differences
  - Photodiode sensitivity could change with time, e.g. filter oxidation
    - Rocket XPS calibrated on SURF BL-2 in May 2003 and Jan. 2004 showed no degradation
    - Photodiodes stable now, but could have changed early in life
  - SURF BL-2 method has larger errors at longer wavelengths (>17 nm) because sensitivity is much lower than peak sensitivity at short wavelength
  - Filter transmission model (Henke material constants) could have wavelength dependent errors and would affect SURF BL-2 results
  - BESSY and SURF BL-9 monochromator corrections for scattered light and higher orders are possibly more problematic where the sensitivity is low (orders of magnitude weaker than peak sensitivity)



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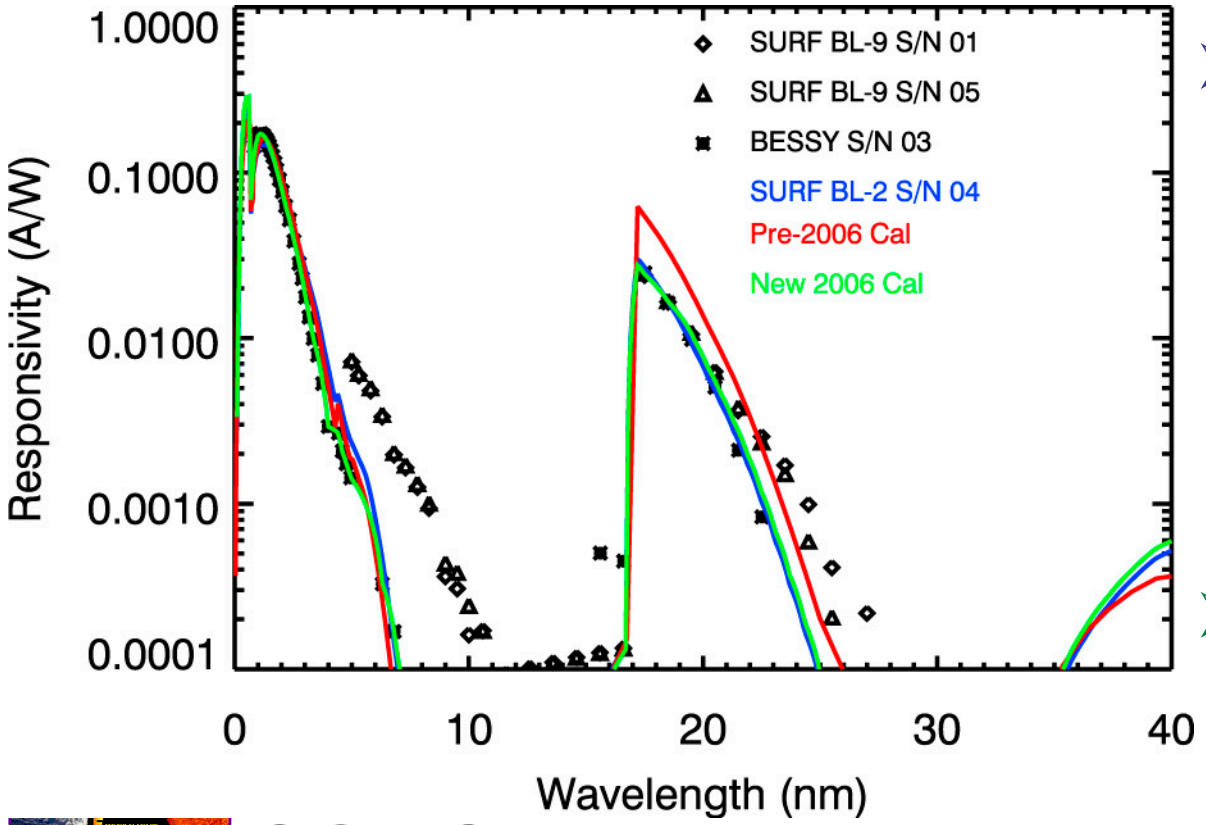
Average is Used for XPS Data Processing

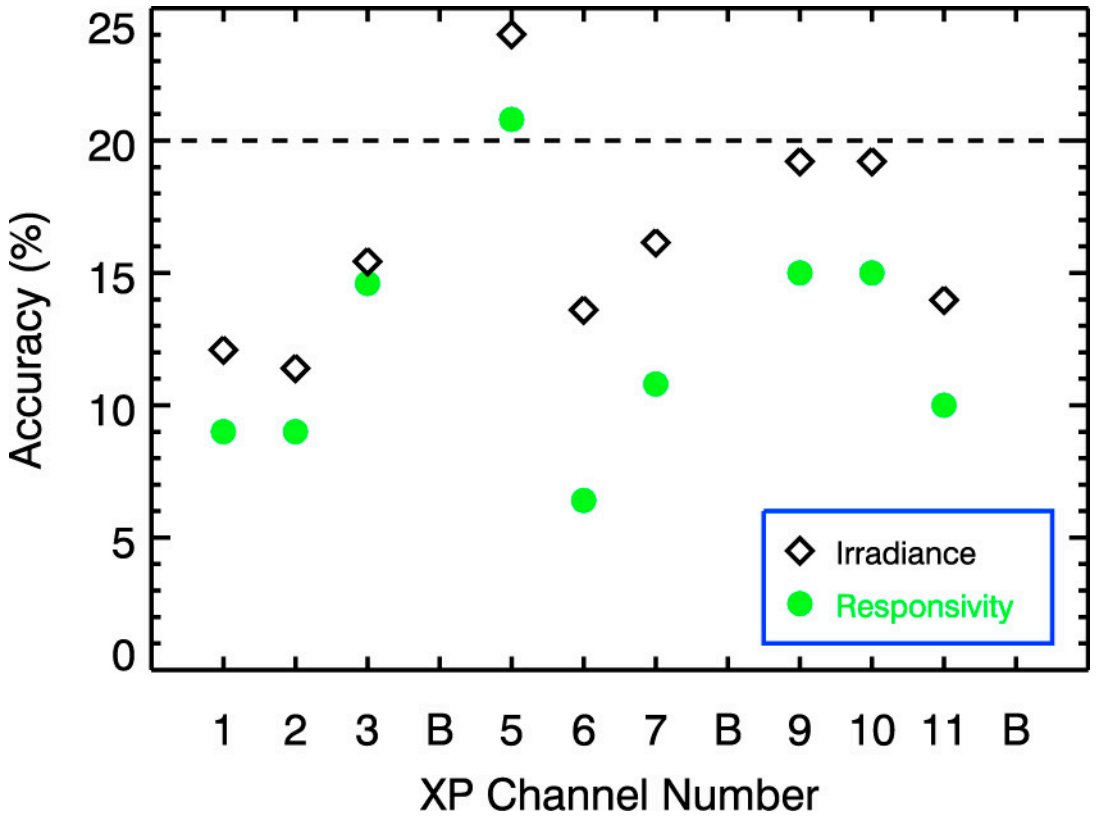
- XPS has three different pre-flight calibrations
  - NIST SURF BL-9 (monochromator + reference detector)
  - PTB BESSY (monochromator + reference detector)
  - NIST SURF BL-2 (direct synchrotron source: primary std)



- Updated XPS calibration in 2006 by merging best of these results
  - Previously used single calibration set in data processing
- Example shown for XP#5 (Al/Nb/C)

Irradiance Accuracy is about 15%

- Reponsivity accuracy is primary contribution to irradiance accuracy
- XP#1, #2, and #7 are used in XPS Level 4 processing
- XP#5 and #10 have higher than expected visible light signals and are not included in the public XPS data products



Bandpass (nm)	XP Channel
0.1-7	1, 2
7-17	6, 7
17-25	3, 5
25-37	9, 10
121-122	11

TIMED SEE

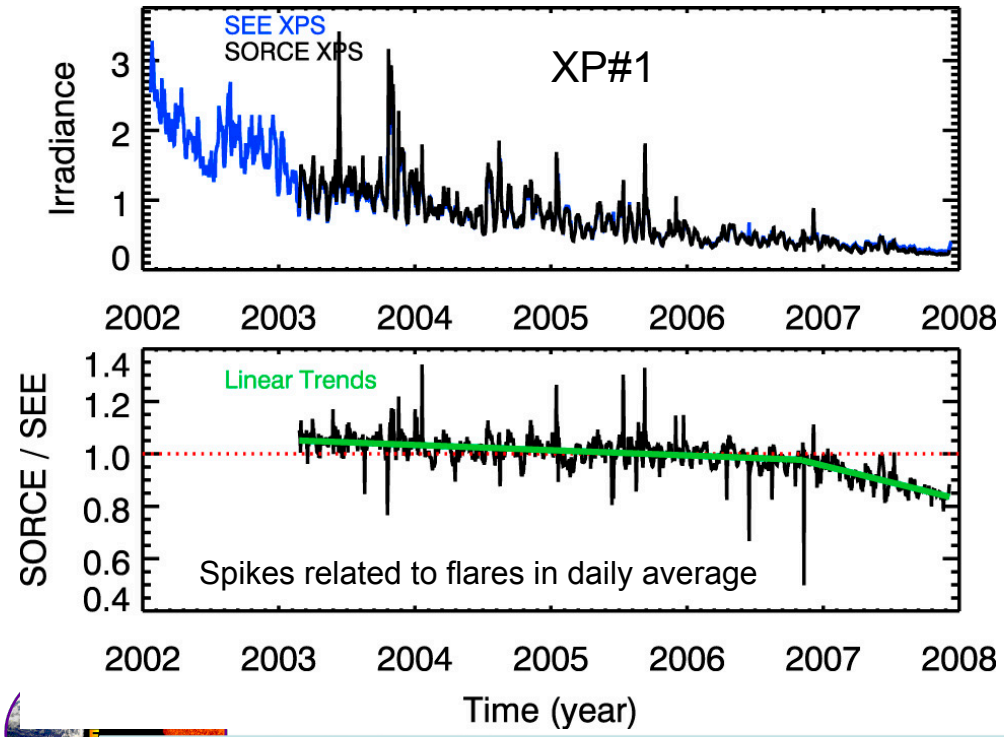
SORCE

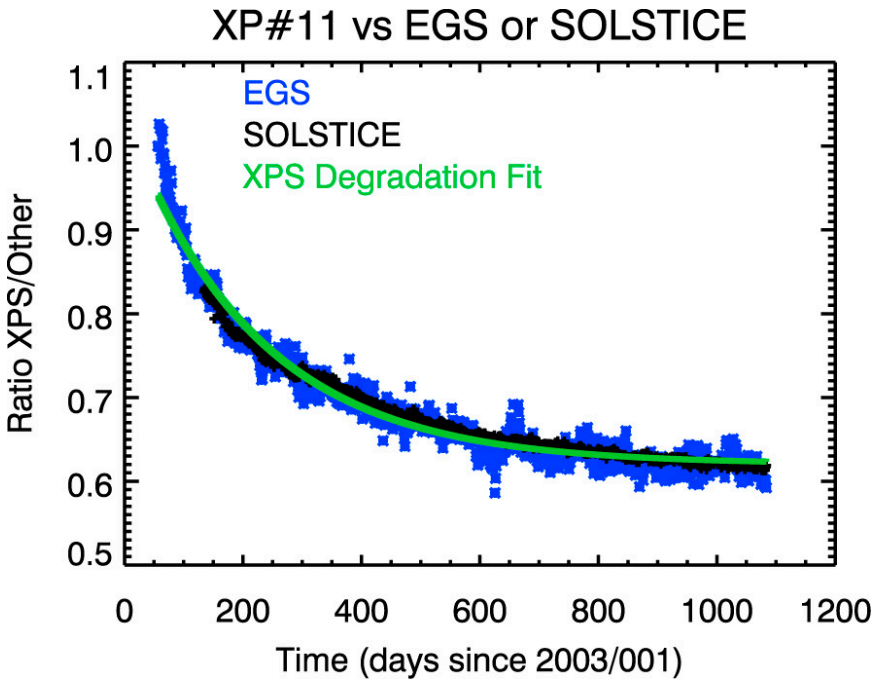
SORCE XPS Degradation Results

- Degradation tracked in-flight by using weekly on-board redundant channel calibrations, overlapping measurements by TIMED SEE and SORCE SOLSTICE, and annual calibration rocket flights
- Degradation Results (note goal is 1%/year for σ_{LT}):

Small for XUV channels before 2007
Moderate after 2007 (higher exposure rate)
σ_{LT} = 1.1%/5 yr = 0.2%/yr

Moderate for Ly-α filter (XP#11)
Exponential decay down to 0.62
σ_{LT} = 4.5%/3 yr = 1.5%/yr

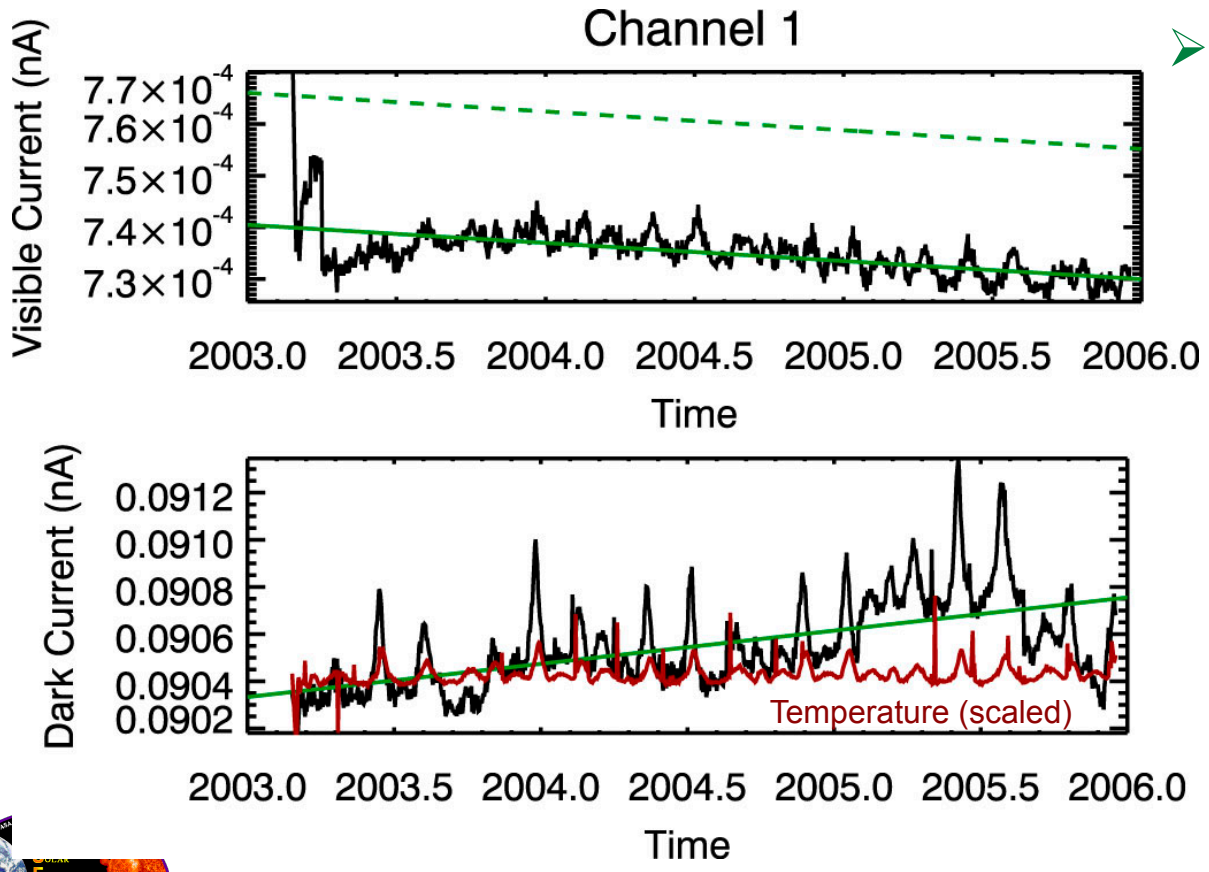




Due to its low duty cycle (3%), TIMED SEE XP#1 has had no degradation.

Additional In-flight Calibrations (trending)

- Visible Light Trend: Small time and temperature dependency
- Dark (background) Trend: Small time and temperature dependency



- Example shown for XP#1 (Ti/C)

Visible Light Current
- Time trend of 0.1%/year
- Temp. trend very small

Dark Current
- Time trend of 0.2%/year
- Temp. trend of 0.1%/°C

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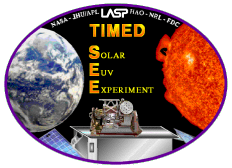
Summary of XPS Calibrations

- The differences between BESSY, SURF BL-9, and SURF BL-2 are still not fully understood

- The XP#1 (0.1-7 nm) channels on both TIMED SEE and SORCE are the primary references for XPS
  - Best agreement for different BESSY and SURF calibrations
  - Has shown no degradation over 10 years for TIMED SEE XP#1
  - Has only single band and so is not very sensitive to spectral changes (such as flares)
  - Is used for scaling CHIANTI spectra for Level 4 product
  - Scales very well with the GOES XRS (X-ray) and thus is useful as proxy for the solar X-ray



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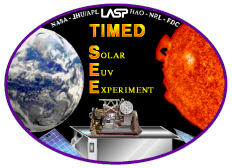
XPS Comparisons to SDO EVE



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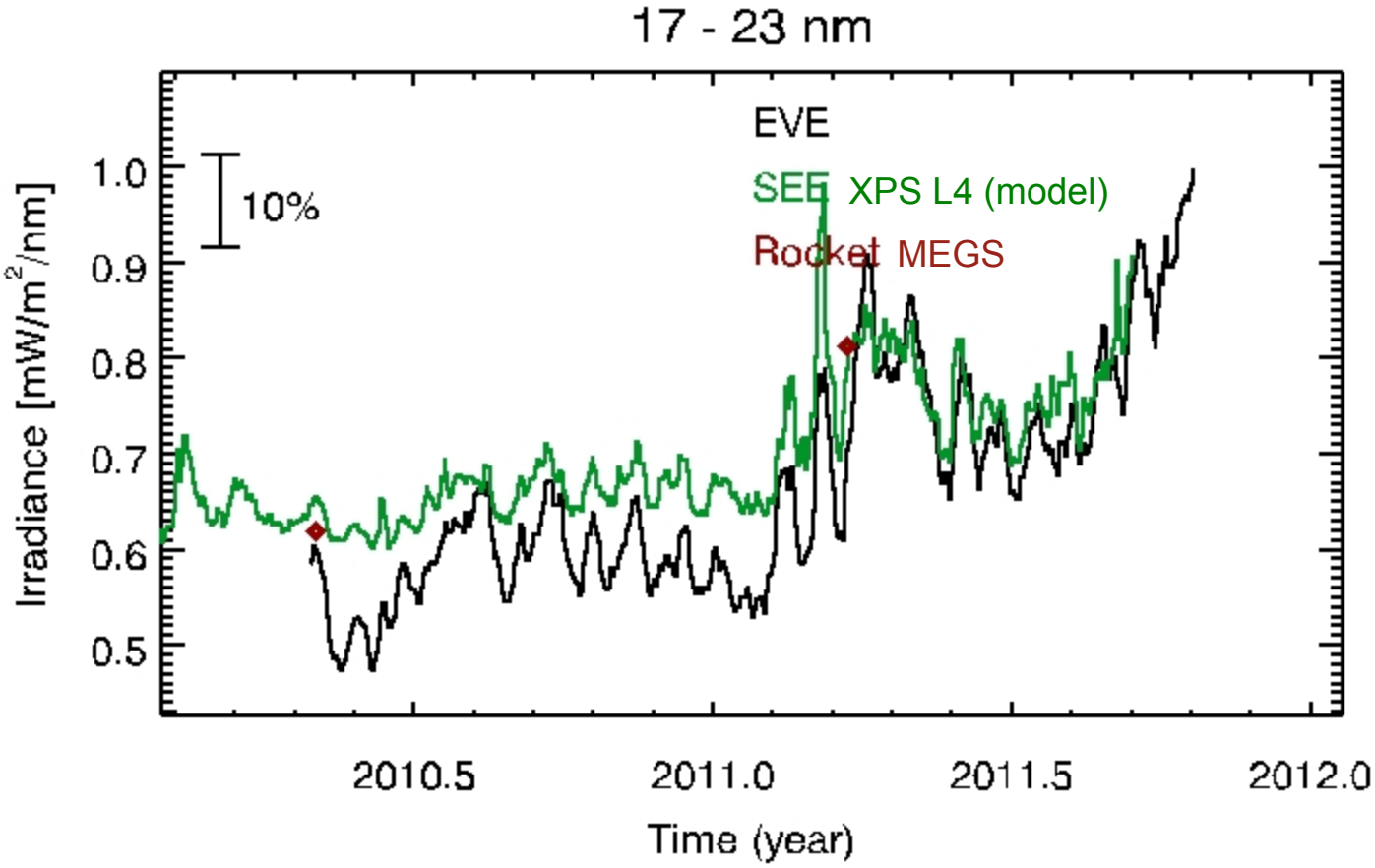
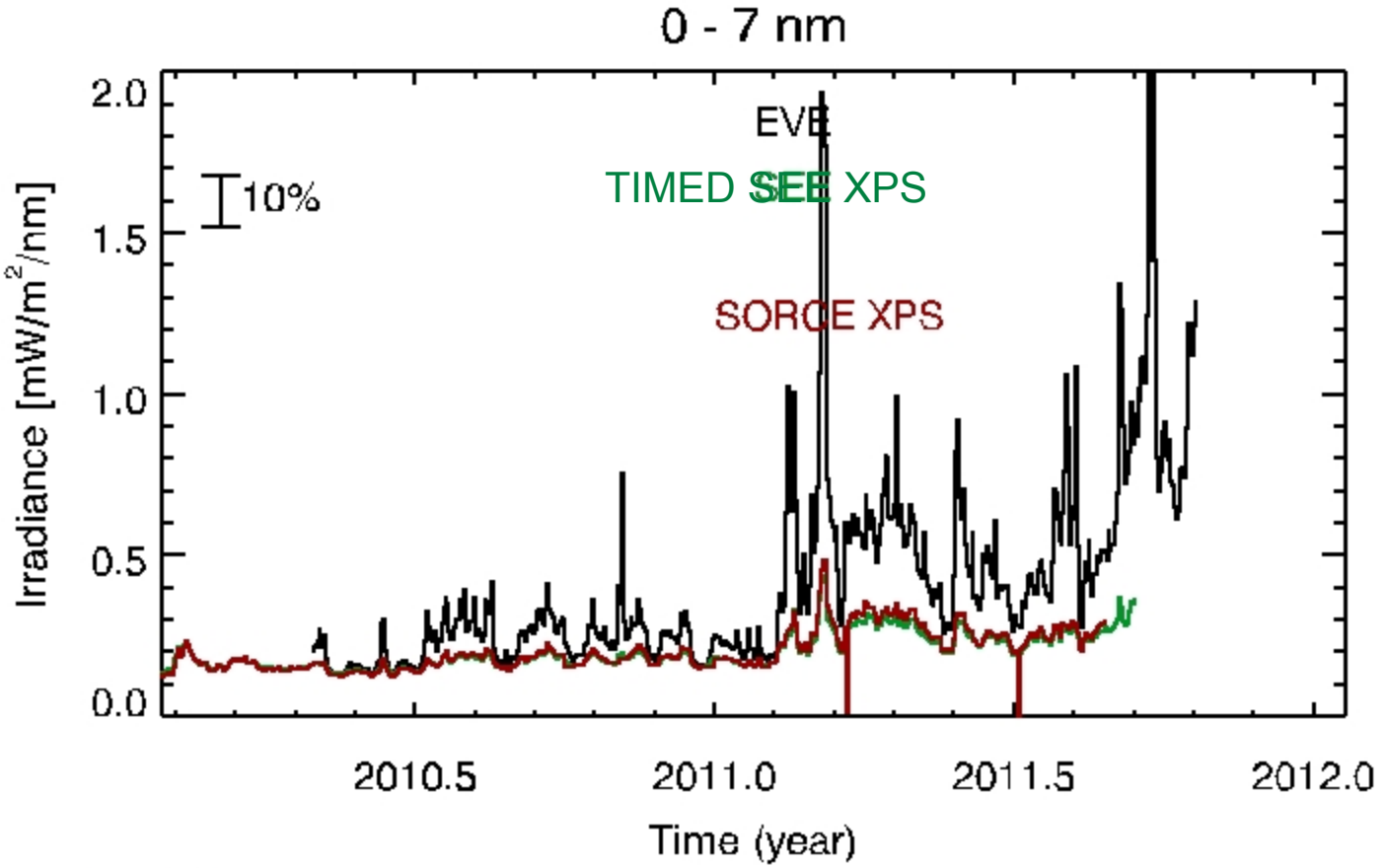
XPS compared to SDO EVE MEGS

- XPS Level 4 spectral model has reasonable good agreement with the EVE MEGS spectra when XPS Level 4 is integrated over broad bands



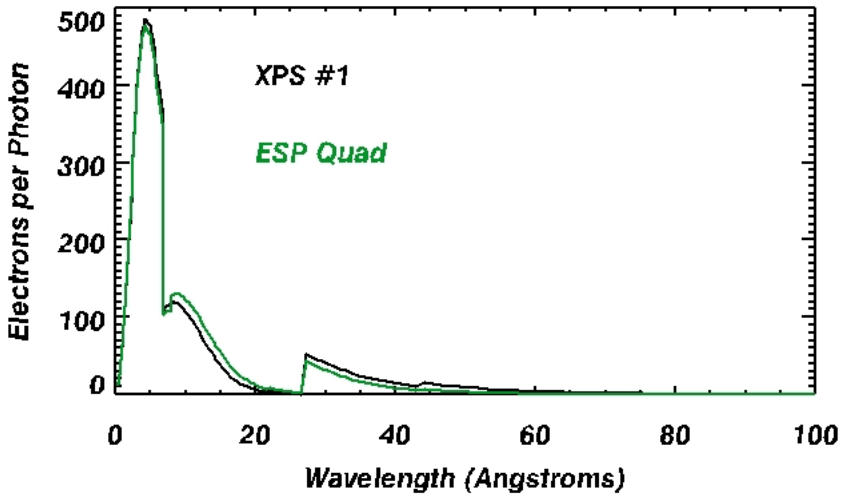
XPS compared to SDO EVE ESP Quad

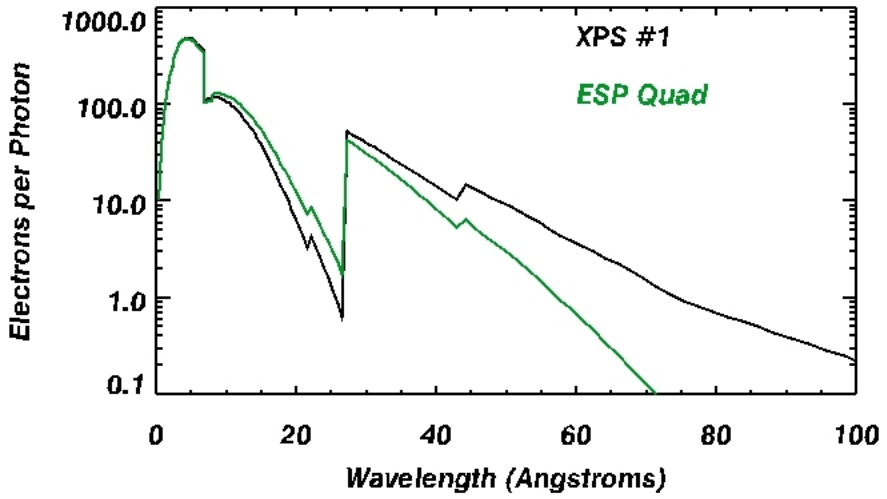
- XPS and ESP Quad agree for lower levels of solar rotation but not for the peaks - this might mean a difference in effective bandpass ???
- TIMED SEE XPS (3% duty cycle) and SORCE XPS (70% duty cycle) agree, so XPS – ESP difference is not expected to be a difference if including flares



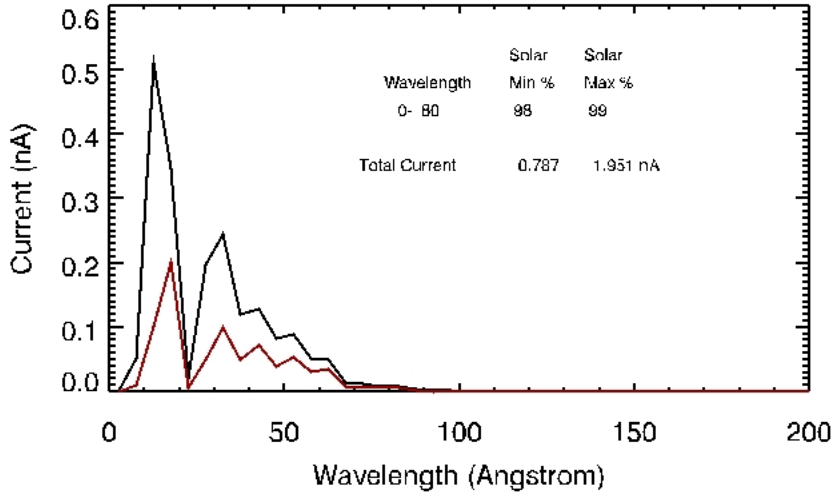
What are the spectral bands for XPS & ESP?

- XPS #1 = Ti/C (3875 / 500 Å) ESP Quad = Al/Ti/C (1500/2840/380 Å)





XPS#1: “auto band” = 0-80 Å



ESP-Quad:”auto band” = 0-60 Å