# WHI Working Group 2A:
# Quantifying the Quiet Sun / Irradiance for Solar Cycle Minimum
# (Version 2)

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# Whole Heliosphere Interval (WHI) 2008

- Whole Heliosphere Interval is an international coordinated observing and modeling effort to characterize the 3-dimensional interconnected solar-heliospheric-planetary system.
- Period is March 20, 2008 to April 16, 2008
  - Solar Carrington Rotation 2068
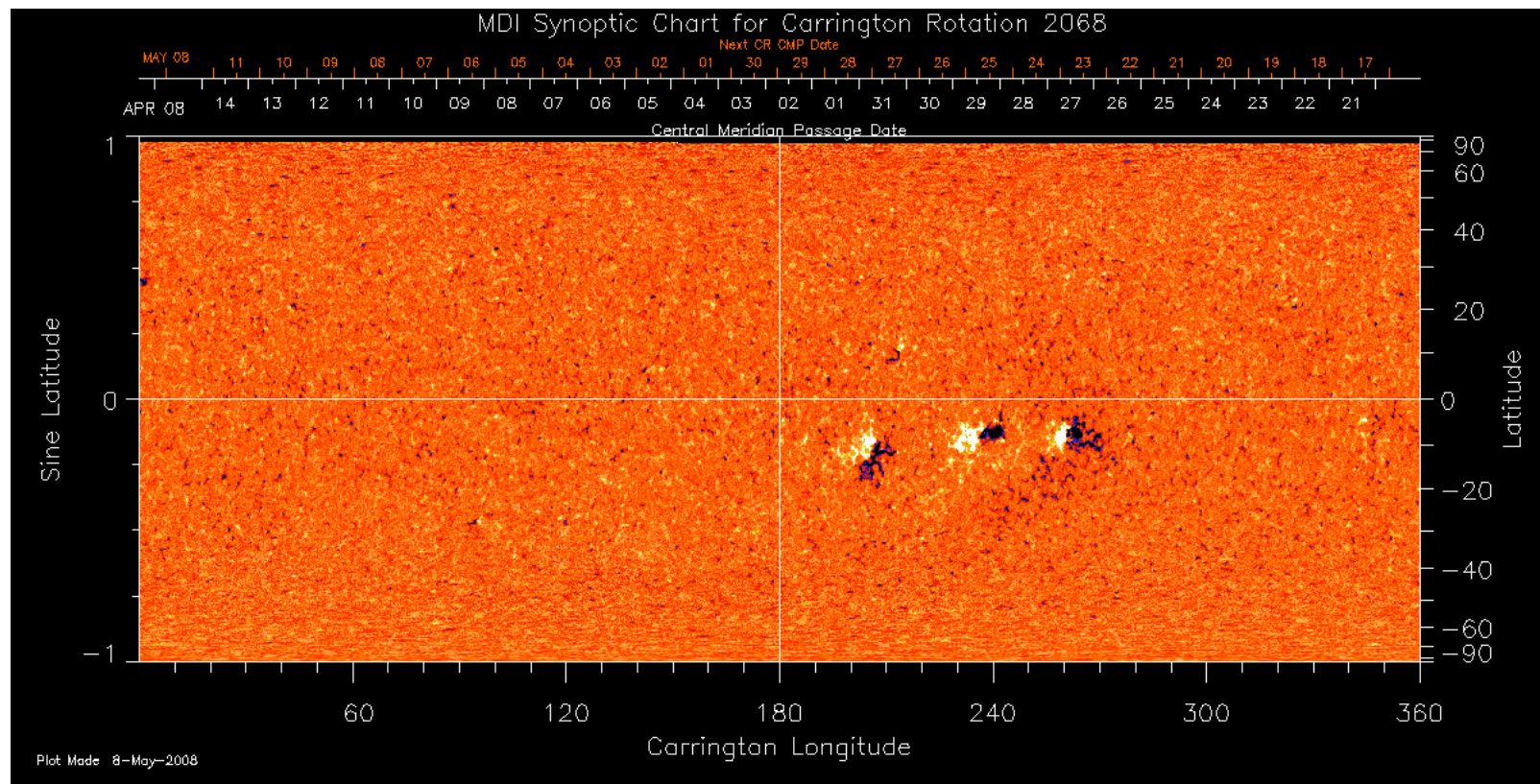
# Quantifying the Quiet Sun

- **WHI period of April 10-16, 2008 chosen for the quiet Sun interval**
  - Perhaps not solar cycle minimum, but it did turn out to be quiet solar conditions
  - Additional goal is to compare to Whole Sun Month (WSM, 1996) results (Thur PM discussion)
- **Quiet Sun – Scott McIntosh leading**
  - Conditions / references / results from many solar imagers
    - SOHO – SUMER, CDS, EIT  (part of WSM 1996 study)
    - Hinode - SOT, XRT     TRACE      STEREO  SECCHI, EUVI
- **Solar Cycle Minimum Irradiance – Tom Woods leading**
  - TIMED SEE, SORCE, Rocket EVE, SOHO SEM, SBUV

# Solar Cycle Minimum Yet?

**Sunspot Number (SSN)**
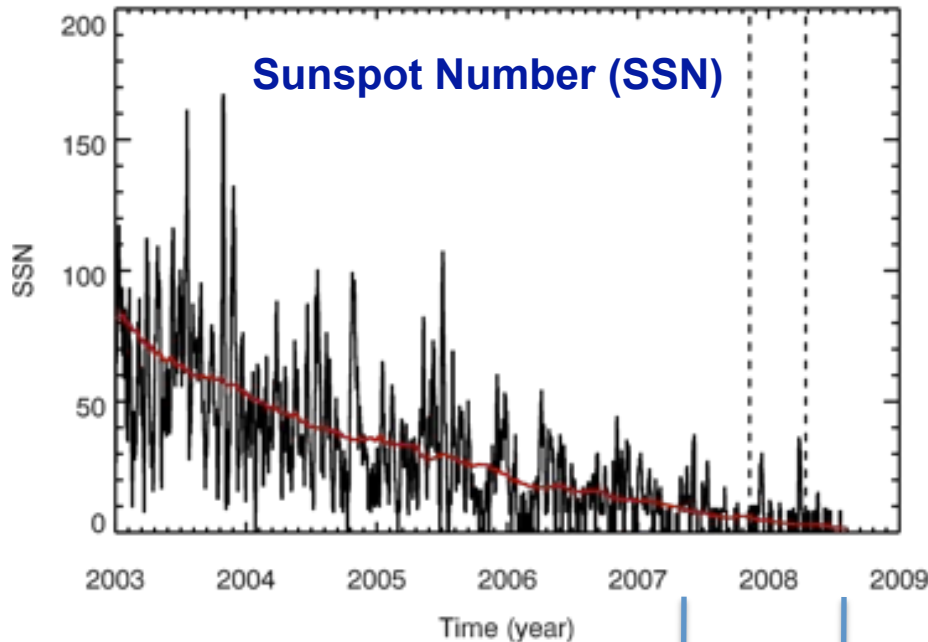
- Standard definition of "solar cycle minimum" is the minimum in SSN smoothed over 1-year
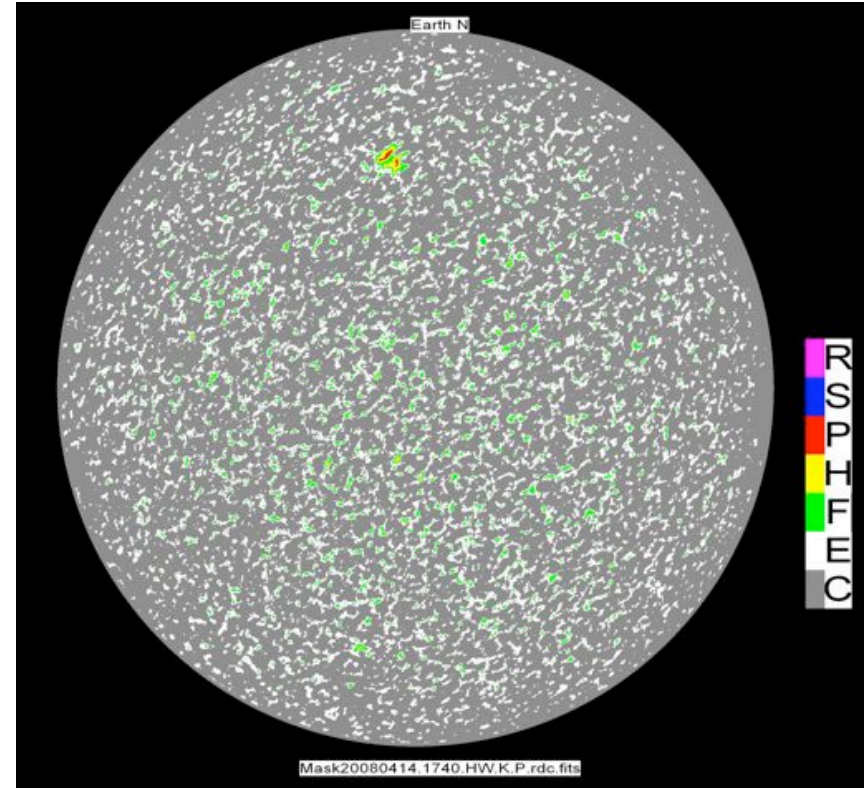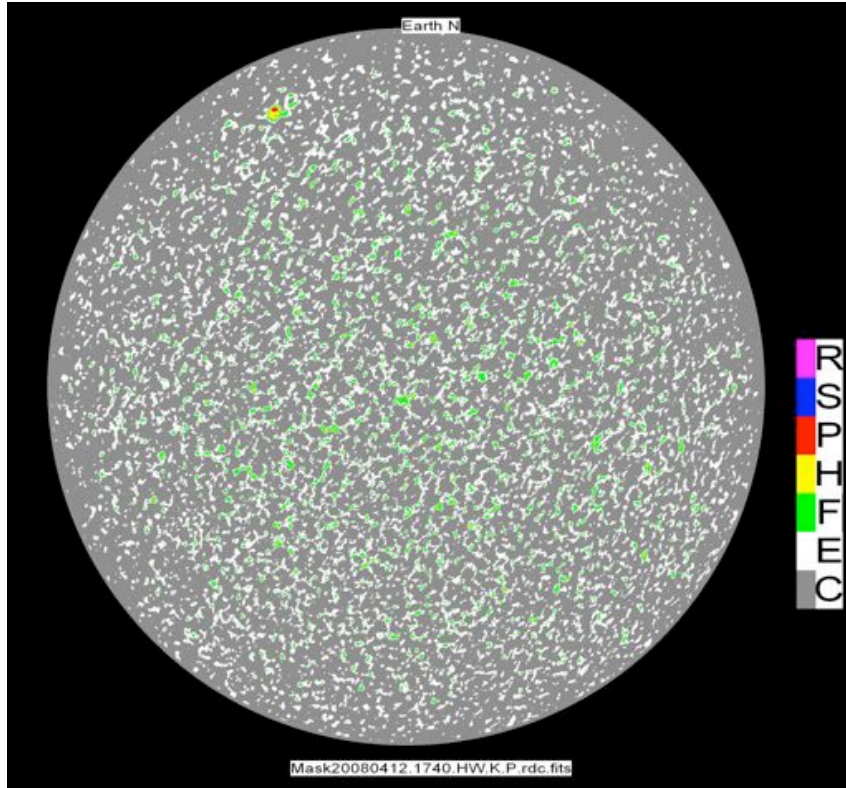
- <SSN> minimum level ~ 0-5

Candidate Minimum Conditions
Nov 2007        Apr 2008        Future
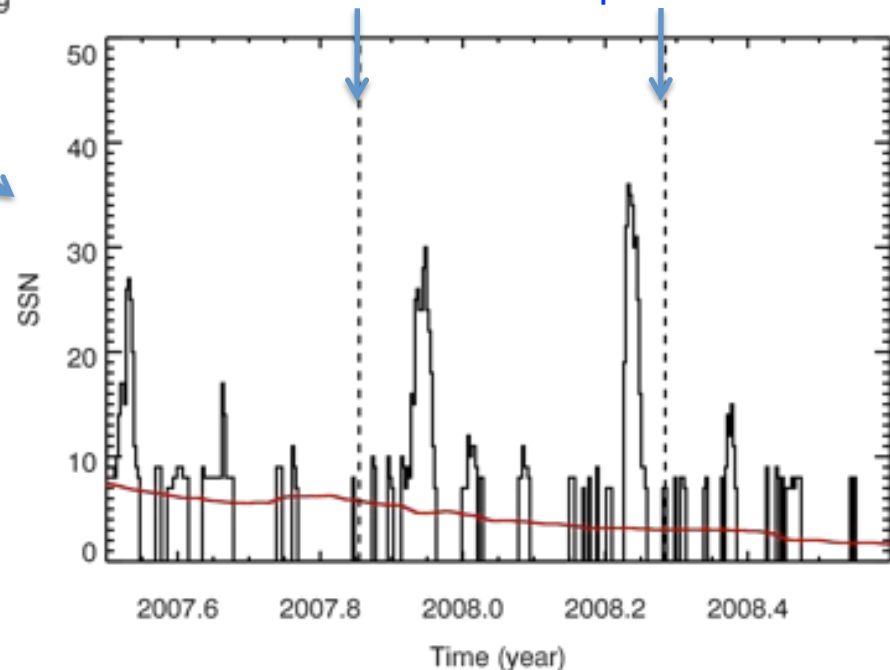
- **Not seen minimum yet !**

- however minimum will not be obvious until **6 months** after the event …

# PSPT Images Used to Identify Solar Features

April 12-14 were very quiet days



| Day | Features areas (relative to solar disk area) | | | | | | | |
|-----|---------|--------|--------|---------|----------|-----------|-----------|-----------|
|     | A       | B      | D      | F       | H        | P         | S         | R         |
| 2008/04/12 | 0.07283 | 0.7051 | 0.1971 | 0.02365 | 0.001226 | 6.09e-005 | 3.669e-006 | 1.834e-005 |
| 2008/04/14 | 0.06446 | 0.7234 | 0.1916 | 0.01921 | 0.001110 | 0.0001519 | 4.046e-006 | 1.839e-005 |

# Solar Activity During WHI April 10-16, 2008 QS Interval

- **PSPT images are used to generate feature areas**

- **Moderate solar activity in late March**

- **Very low solar activity during April 10-16**
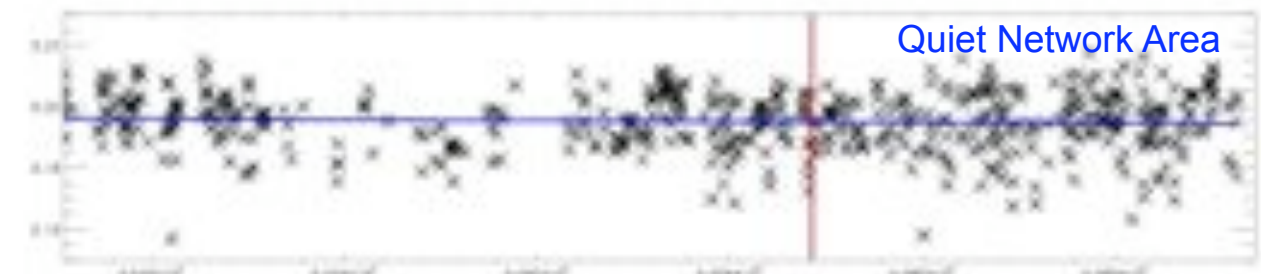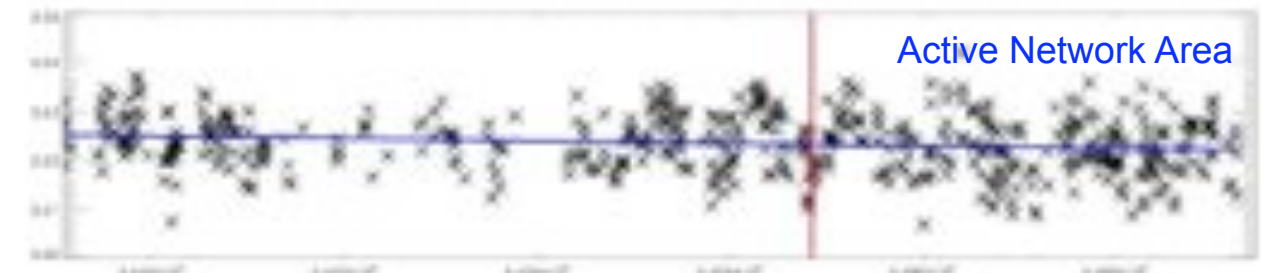
# Solar Irradiance Data Sets

- **TIMED Solar EUV Experiment (SEE)**
  - XPS: 0.1-27 nm, $\Delta\lambda \sim 8$ nm
  - EGS: 27-194 nm, $\Delta\lambda \sim 0.4$ nm
- **Solar Radiation and Climate Experiment (SORCE)**
  - XPS – same as on TIMED SEE
  - SOLSTICE: 115-308 nm, $\Delta\lambda \sim 0.1$ nm
  - SIM: 200-2400 nm, $\lambda/\Delta\lambda \sim 30$
  - TIM: total solar irradiance (TSI)
- **SOHO Solar EUV Monitor (SEM)**
  - 26-34 nm and zeroth order 0-50 nm
- **SDO EUV Variability Experiment (EVE)**
  - Rocket EVE: 6-105 nm, $\Delta\lambda \sim 0.1$ nm
  - Suborbital rocket launched 14 April 08
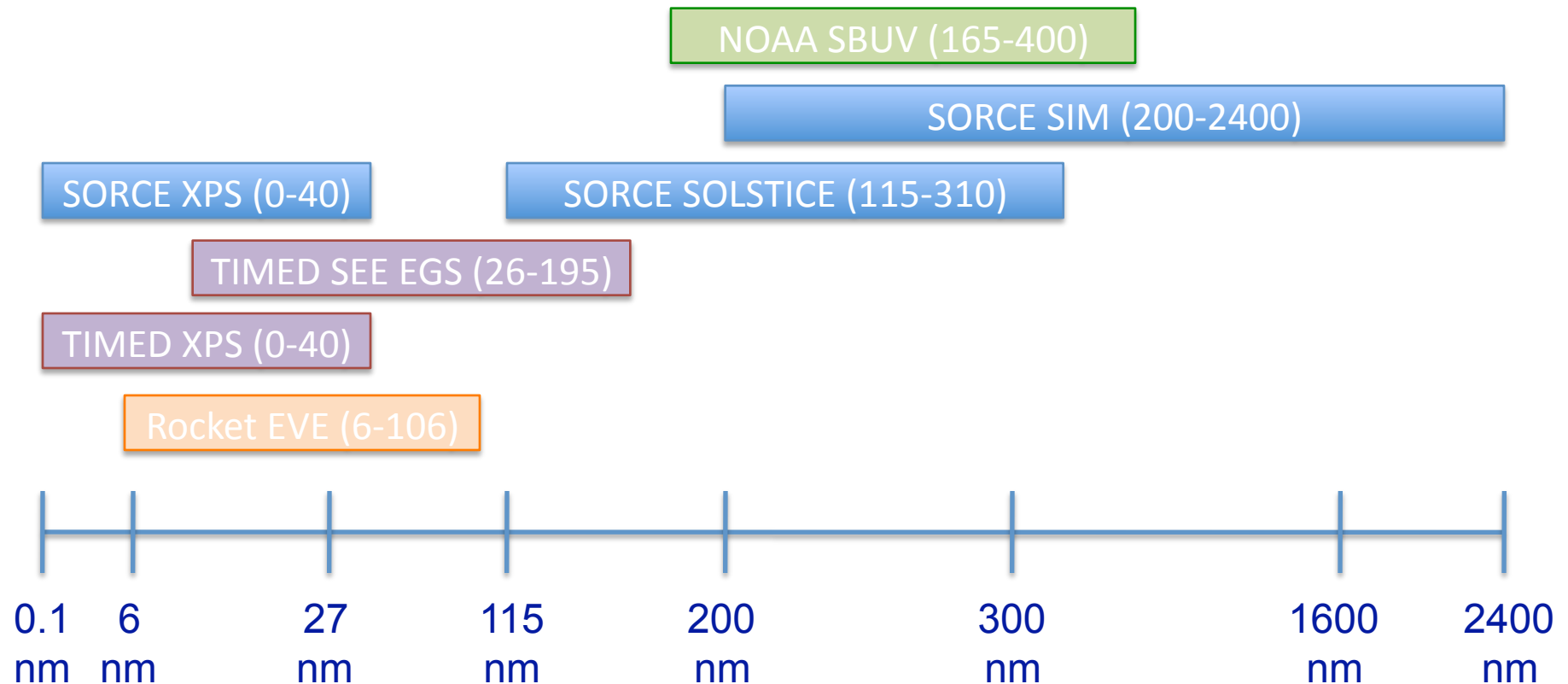- **NOAA SBUV: 200-400 nm**

# Two Spectra to Prepare for WHI Interval

- **"Quiet Sun" (solar cycle minimum) Reference Spectrum**
  - WHI Quiet Sun dates of Apr 10-16 (Rocket 14-Apr-2008)

- **"Active" Reference Spectra**
  - "Sunspot" active spectrum:  March 25 – March 29
  - "Faculae" active spectrum:  March 30 – April 4

- **Compare these new results to model and previous reference spectra**
  - Models:  SRPM, NRLEUV, VUV2002
  - Reference Spectra:  Thuillier (ATLAS 1&3), ASTM-E490
    - ATLAS-3 Reference Spectrum:
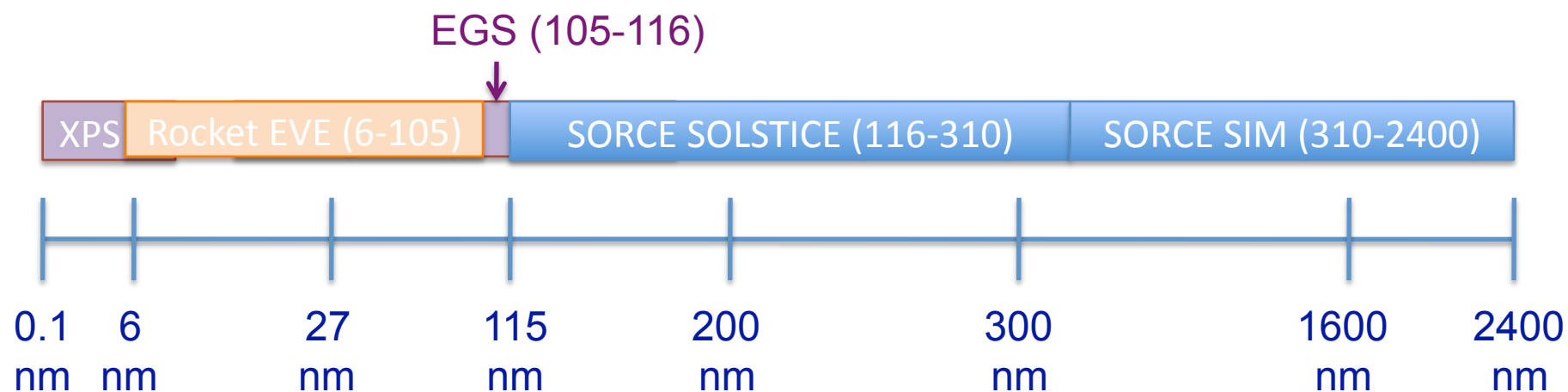      - May 1997 rocket measurement  for < 119 nm
      - March 1995 UARS and ATLAS-3 observations for > 119 nm

# Spectral Distributions for WHI Irradiance Sets

- **How to combine?**
  - consider accuracy, spectral resolution, degradation, etc.
  - select wavelength boundaries or averages ?



NOAA SBUV (165-400)

SORCE SIM (200-2400)

SORCE XPS (0-40)

SORCE SOLSTICE (115-310)

TIMED SEE EGS (26-195)

TIMED XPS (0-40)

Rocket EVE (6-106)

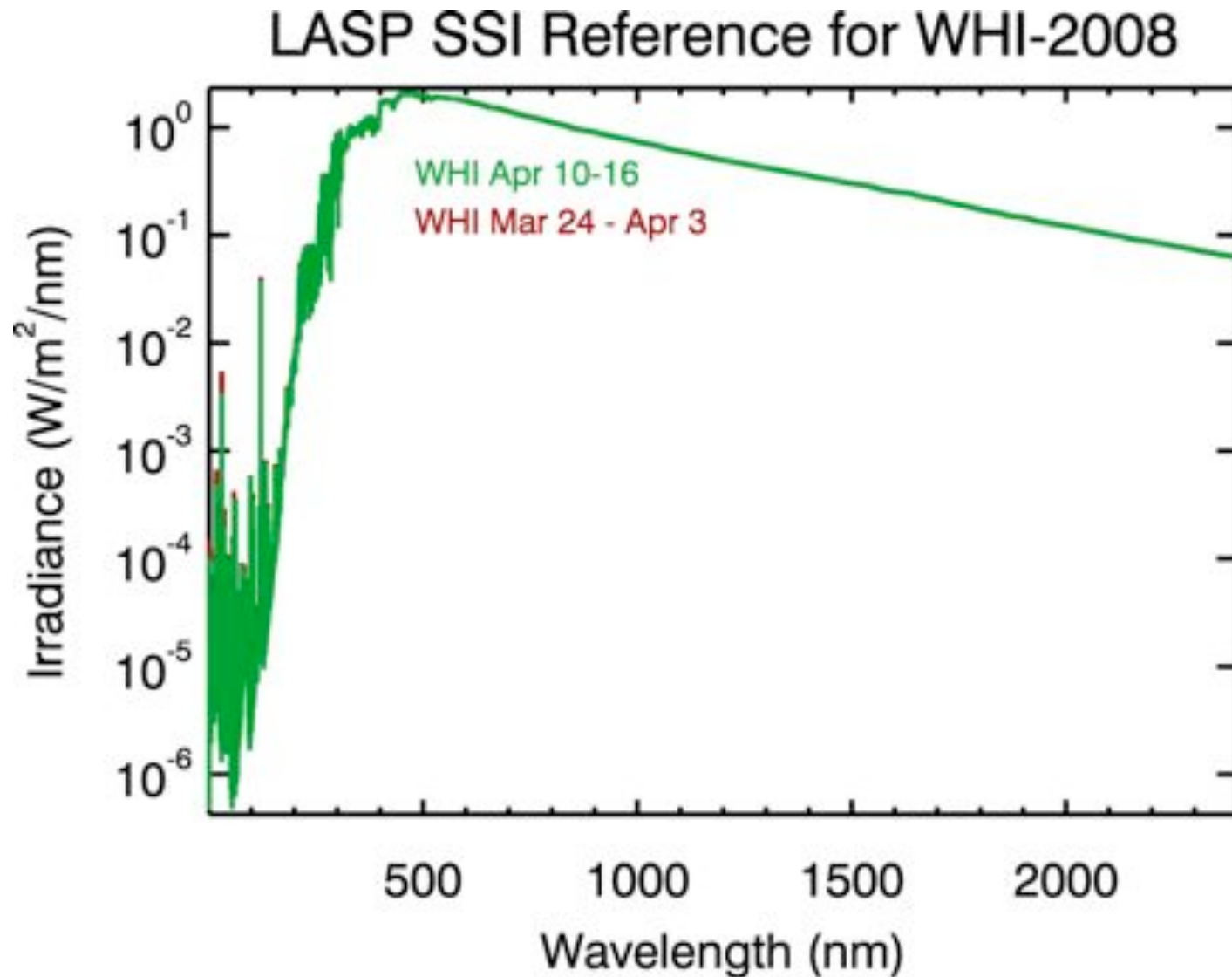| 0.1 nm | 6 nm | 27 nm | 115 nm | 200 nm | 300 nm | 1600 nm | 2400 nm |

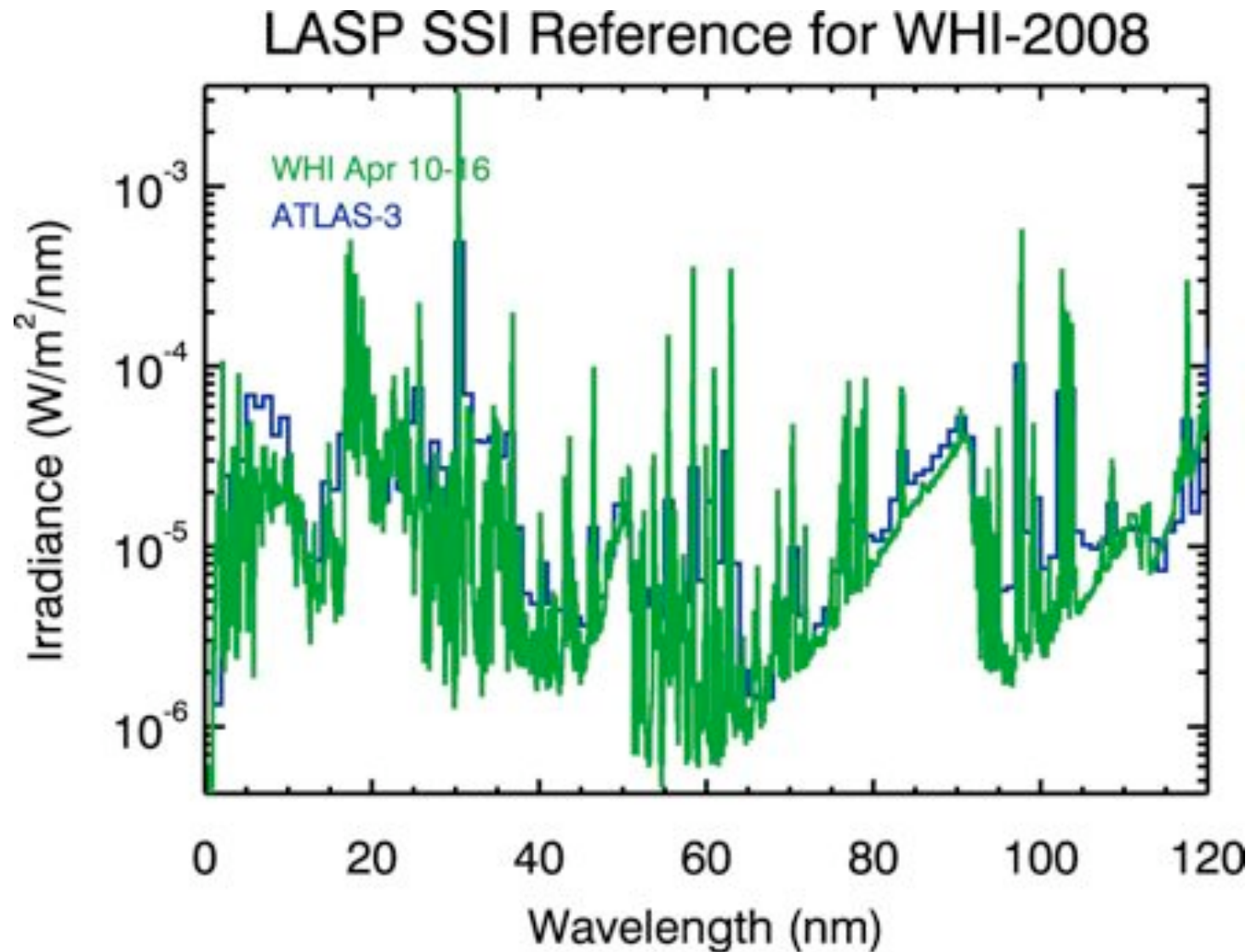# Solution for Reference Spectra (version 1&2)

- **Spectral Intervals / Resolution**
  - 0.1-nm intervals on 0.05-nm centers
  - Note that SIM instrument resolution (above 310 nm) is much less than 0.1-nm
- **Selected Wavelength Intervals**
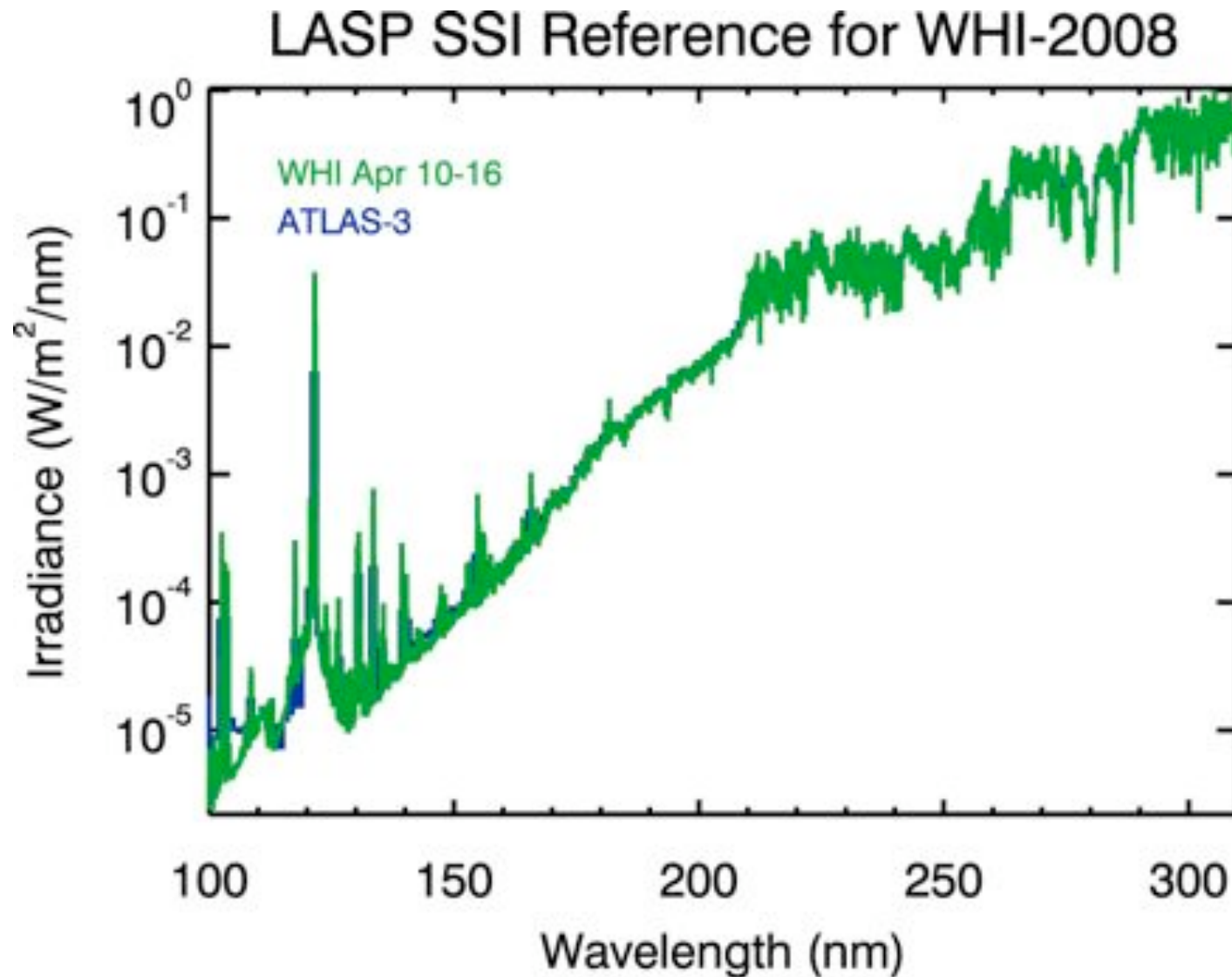  - Did have to fill 113-116 nm (no measurements)

EGS (105-116)

| XPS | Rocket EVE (6-105) | SORCE SOLSTICE (116-310) | SORCE SIM (310-2400) |

0.1 nm   6 nm   27 nm   115 nm   200 nm   300 nm   1600 nm   2400 nm

# WHI Solar Irradiance – Full Range 0-2400 nm



LASP SSI Reference for WHI-2008

WHI Apr 10-16
WHI Mar 24 - Apr 3

# WHI Solar Irradiance: Rocket EVE & SEE



LASP SSI Reference for WHI-2008

# WHI Solar Irradiance: SORCE SOLSTICE



LASP SSI Reference for WHI-2008
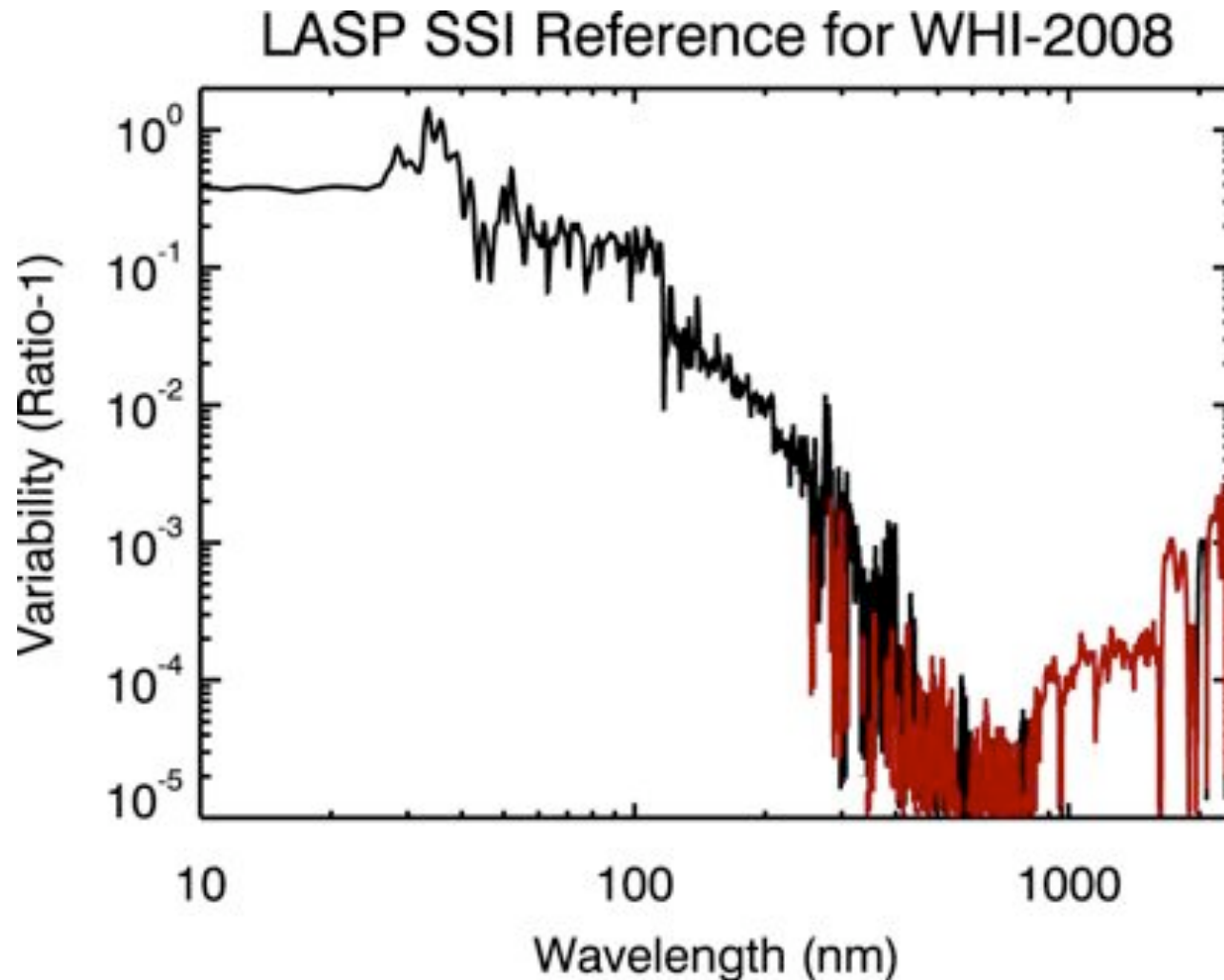
# WHI Solar Irradiance: SORCE SIM



LASP SSI Reference for WHI-2008
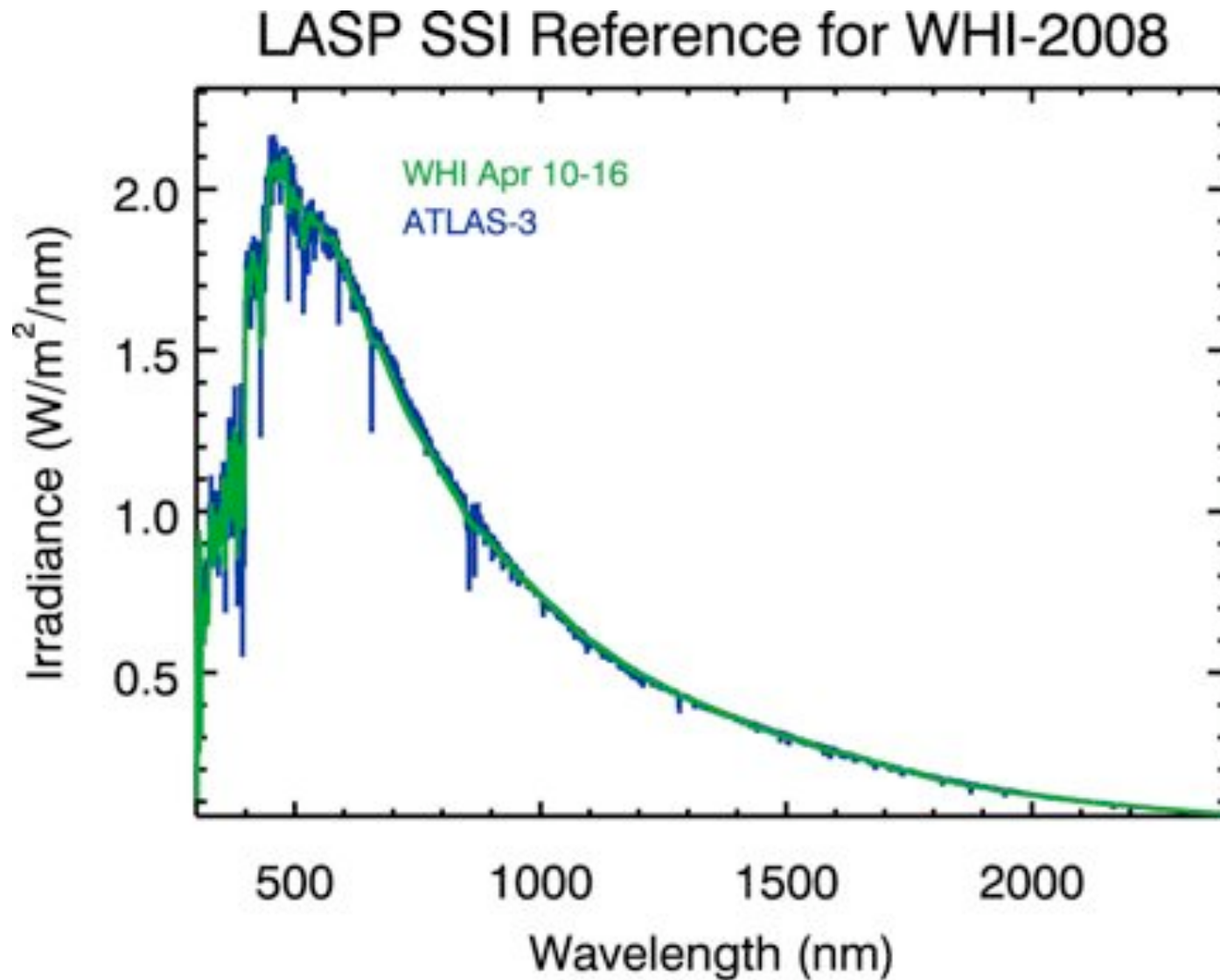
# WHI Solar Irradiance: Solar Variability

- **Average of the active spectrum to minimum spectrum**
  - Red represents negative variability (sunspot darkening)



LASP SSI Reference for WHI-2008

# WHI & Atlas-3 Comparison: EUV

- EUV range in Atlas-3 is actually based on May 1997 rocket measurement and old AE-E (EUV81) variability. Expect accuracy for Atlas-3 EUV to be ~50%
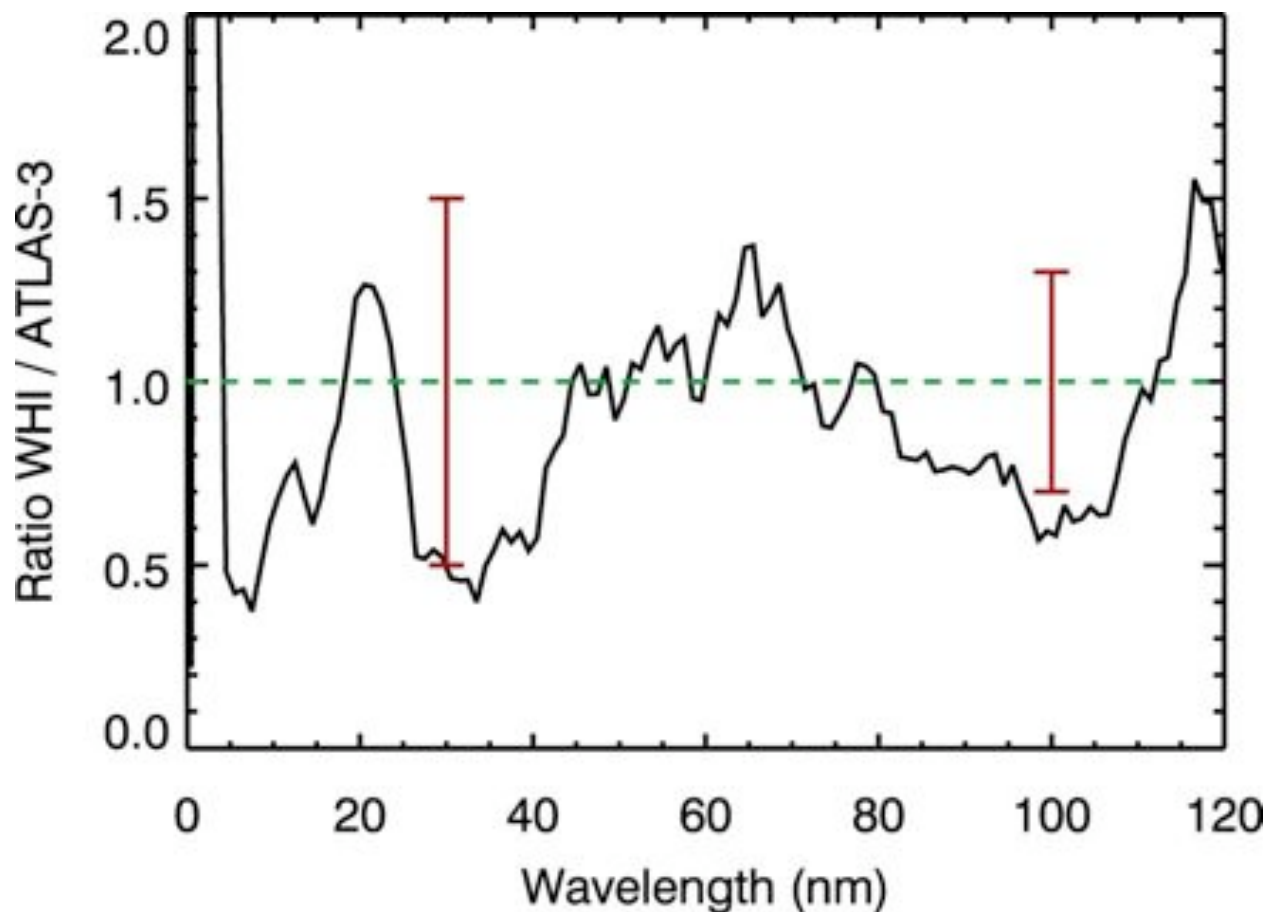
# WHI & Atlas-3 Comparison: FUV-MUV-NUV

- FUV-MUV-NUV range in Atlas-3 is based on UARS SOLSTICE and UARS SUSIM, and validated with Atlas SUSIM, SOLSPEC, SBUV observations
- **These results are from March 1995 (not solar cycle minimum)**
- Accuracy / validation at 3-10% [Woods et al., JGR, 1996]
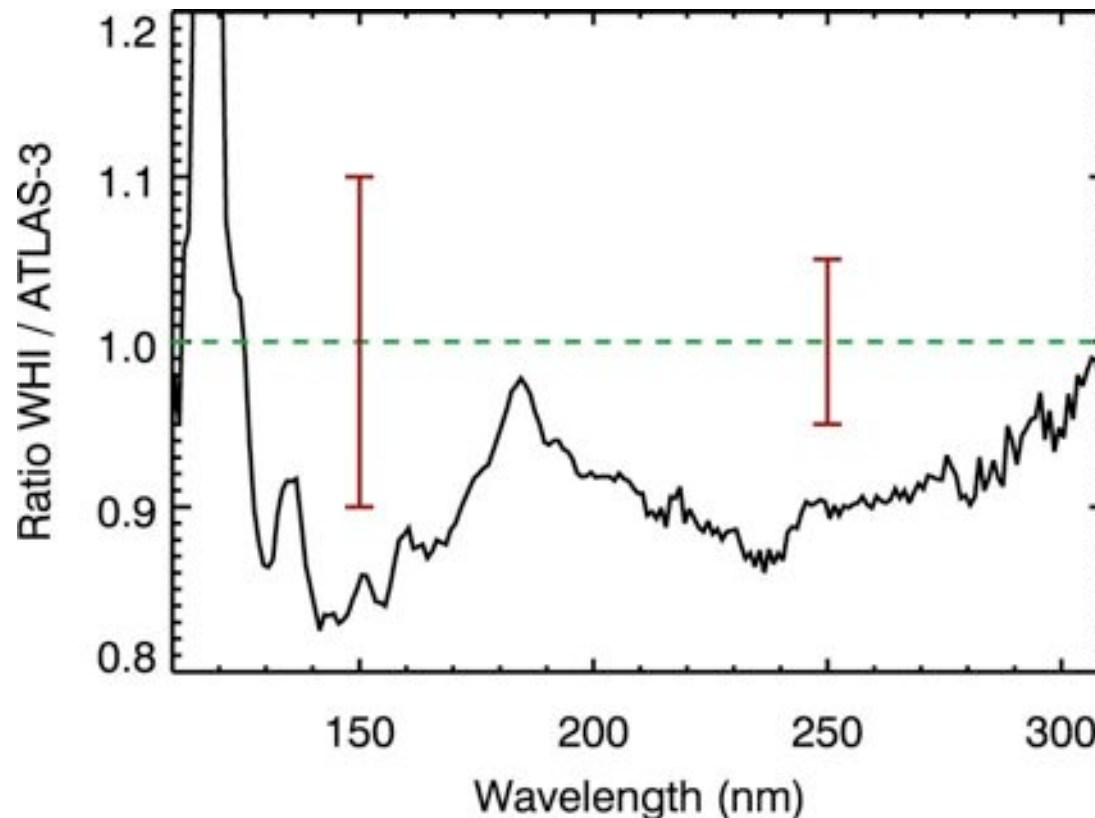
# WHI & Atlas-3 Comparison: Visible & NIR

- Atlas-3 Visible and NIR results are from Atlas SOLSPEC
- Expected accuracy of ~2%
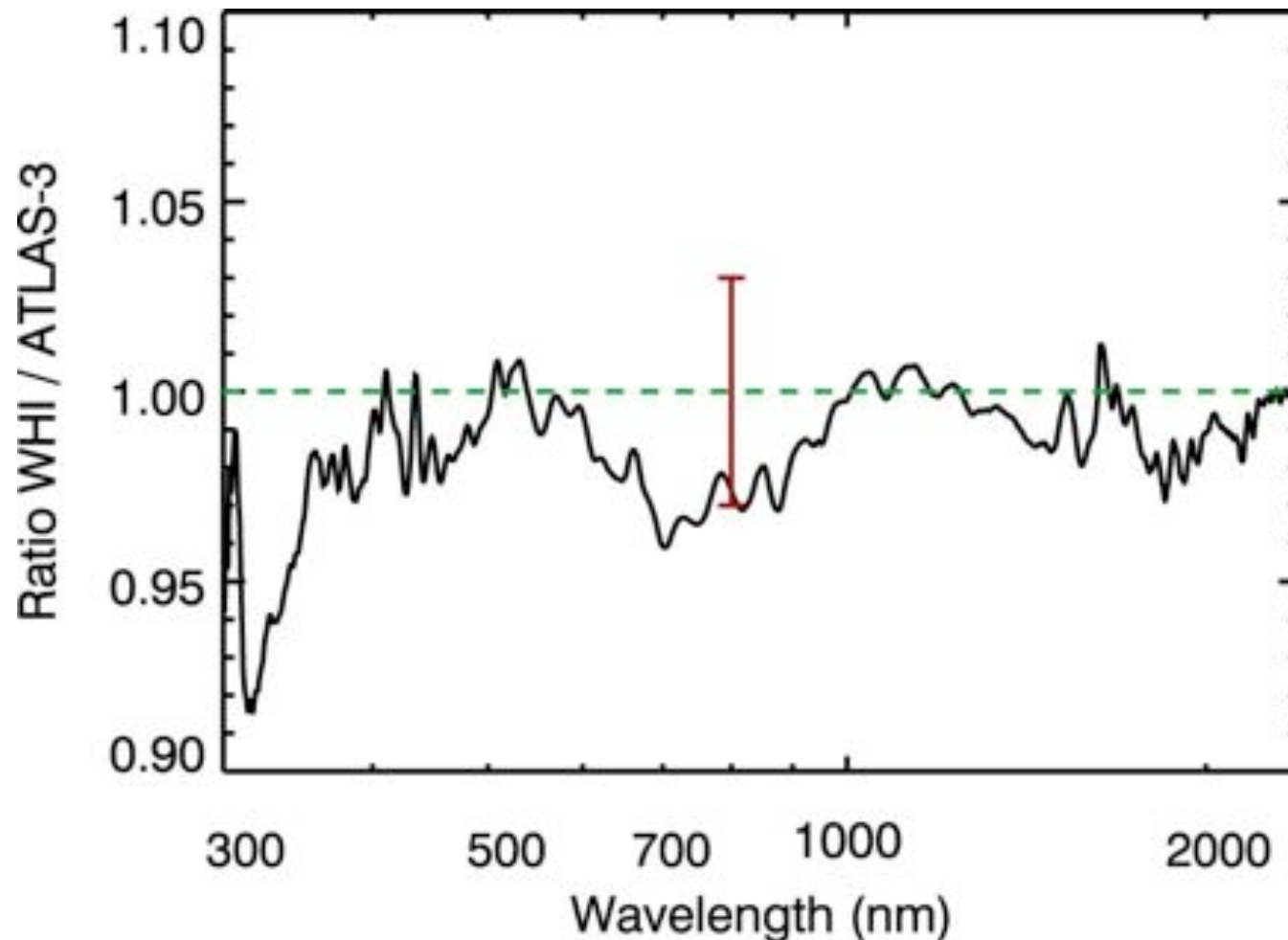
# WHI Solar Irradiance Files

- **ref_solar_irradiance_whi-2008_ver2.dat**
  - text data file – see header information for more details
- **IDL code : plot_whi_ref.pro**
  - supporting code: read_dat.pro, setplot.pro, rainbow.pro
  - supporting files: atlas3_1-nm.dat, vuv2002_whi-2008.dat
- **plots (subdirectory, graphics are in JPEG format)**
  - Spectra plots:
    - whi_ref_both, whi_ref_0-120nm, whi_ref_100-310nm, whi_ref_300-2400nm
  - Solar variability (ratio Mar / Apr – 1.0)
    - whi_ref_variability   (red = negative changes, sunspot blocking)
  - Comparison to ATLAS-3 (ratio WHI Apr / ATLAS-3)
    - whi_ref_ratio_atlas3, whi_ref_ratio_atlas3_0-120nm, whi_ref_ratio_atlas3_120-310nm, whi_ref_ratio_atlas3_300-2400nm

http://lasp.colorado.edu/lisird/    and   http://ihy2007.org/WHI/