Construction of a SORCE-based Solar Spectral Irradiance (SSI) Record for Input into Chemistry Climate Models

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With special thanks to Mark Rast (LASP, CU) and Ilaria Ermolli (Rome Observatory) for providing PSPT solar images

Project Goals

Goal 1: ***Solar Spectral Irradiance (SSI) input for Chemistry Climate Models (CCM)***

- **Produce a daily SSI composite spectral record suitable for CCM transient studies over Solar Cycle 23 and 24.**
- **This record mostly based on observed irradiance of SORCE SIM and SOLSTICE**

Goal 2: ***Extend wavelength coverage and gap fill record for daily coverage***

- **CCM's requires very broad wavelength coverage (110-100,000 nm), compliance of the integrated spectrum with the TSI, and uncertainty estimates**
- **Record extended in wavelength and gap-filled in time with SRPM**
- **Image preparation in progress**

Goal 3: ***In-depth comparison of SORCE observations with Fontenla et al. (2011 & 2015) Solar Radiation Physical Model (SRPMv2)***

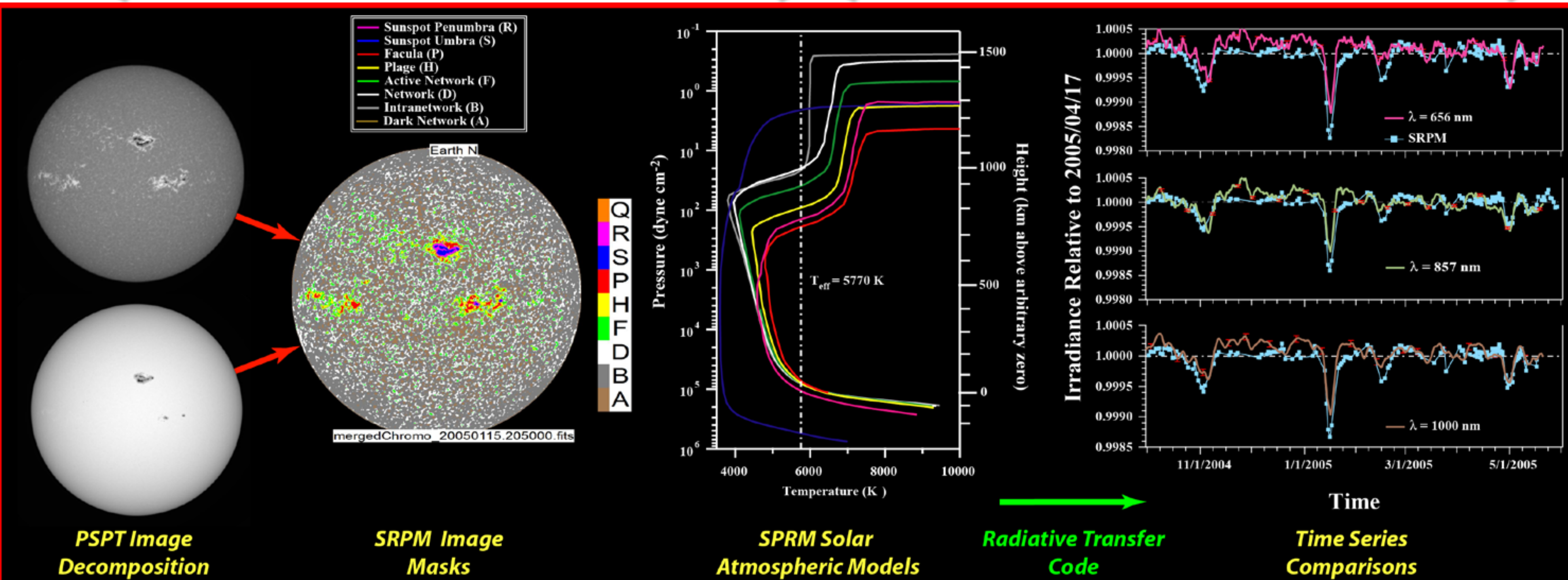
SIST Progress Report, Year 1 Activities

1. Archive PSPT images and masks from Rome Observatory (OAR) and Mauna Loa Solar Observatory (MLSO)
2. Extend record back to the year 2001 (Solar Cycle 23 max)
3. Perform SRPM image processing
4. Reconcile and study differences in image processing between the two observatories
5. Execute SRPM spectral synthesis 200-10,000nm
6. Convolve and re-sample SRPM spectra to reproduce SIM observations

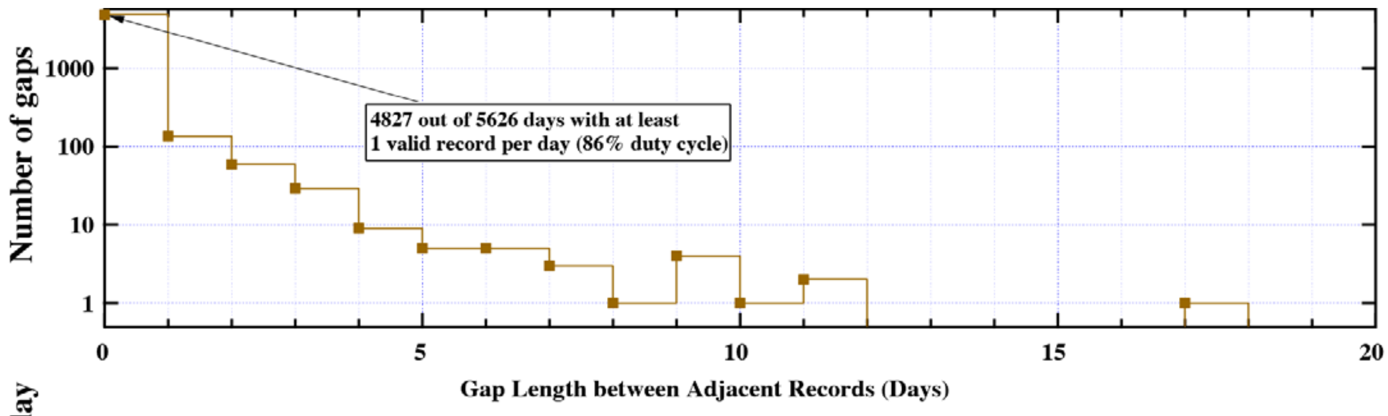
SRPM spectral synthesis overview

- **SRPM combines solar feature areas with physics-based solar atmospheric spectral models at high spectral resolution to compute the emergent intensity spectrum**
- **This project will use images from 2 sources:**
  - Rome PSPT (courtesy of Ilaria Ermolli, Rome Observatory)
  - Mauna Loa PSPT (courtesy of Mark Rast, Mauna Loa Solar Observatory, MLSO)

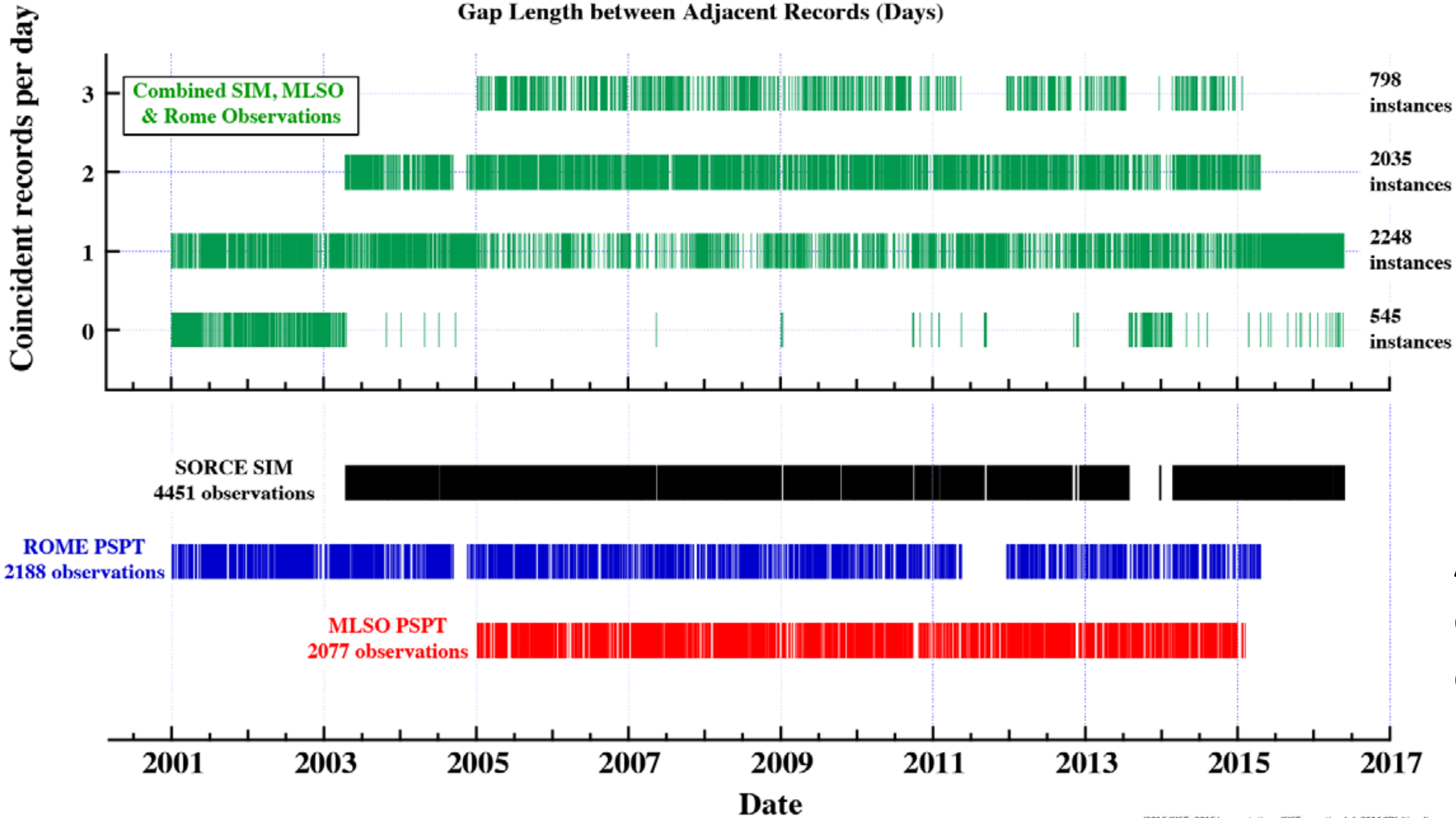
2015-2016 ⟷ **2016-2017**



Activities 1 & 2: Archive PSPT images, extend record to 2001

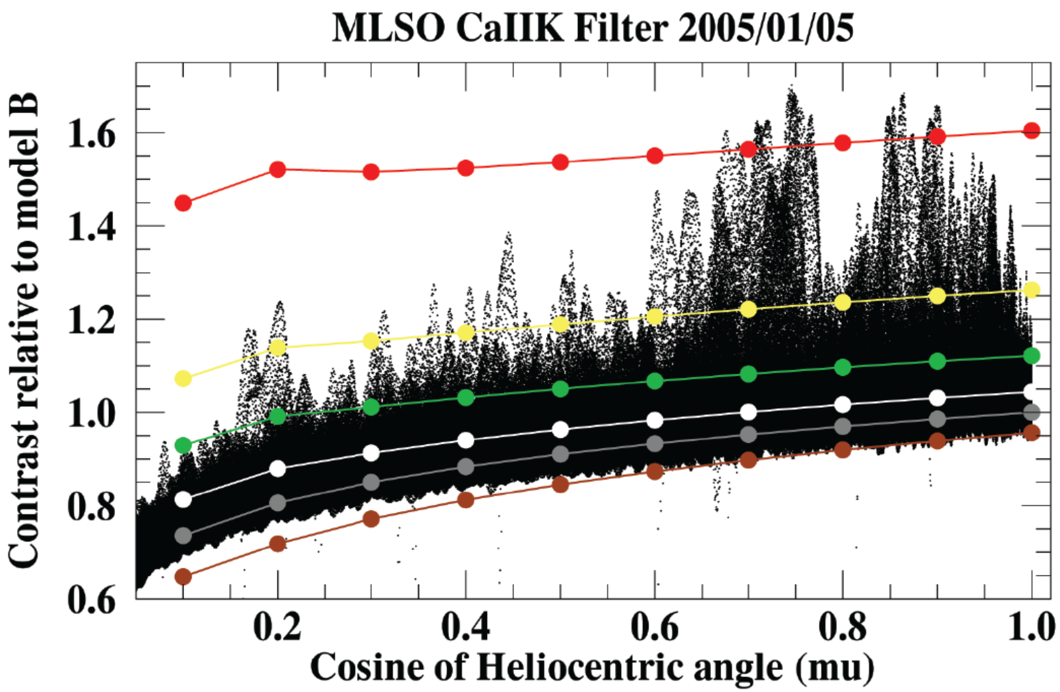


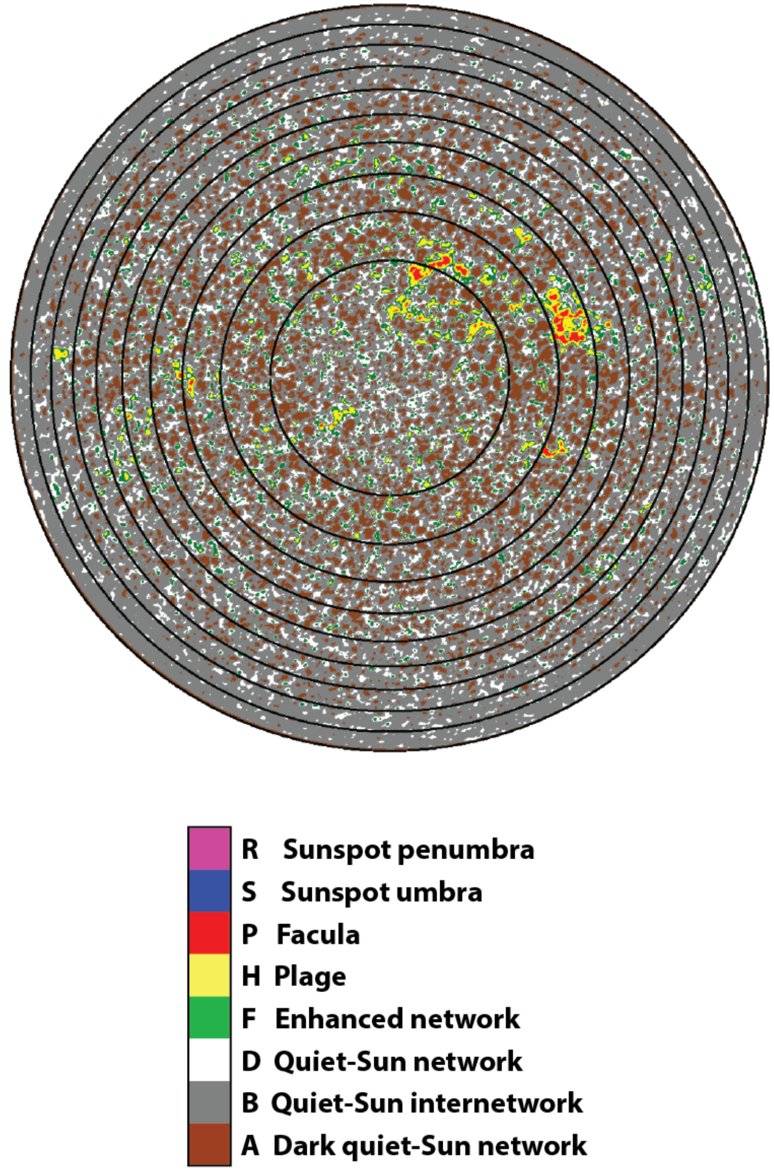
When limited to the SORCE era, about 98% of the data has at least one observation per day



After 2011 SERFS data can be used (based on AIA images)

Activity 3: Perform SRPM image processing





$$\bar{I}_{m,\mu}(\lambda_0) = \int I_{m,\mu}(\lambda_0)\Phi(\lambda - \lambda_0)\, d\lambda$$

- $I_{m,\mu}$ = The m[th] model intensity.
- $\Phi(\lambda)$ = Instrument bandpass profile.
- μ = $\cos(\theta)$, θ=heliocentric angle.

$$I_a = \frac{\sum_{n=1}^{All\ Pixels} I_{m_n,\mu_n}}{Number\ of\ Pixels}$$

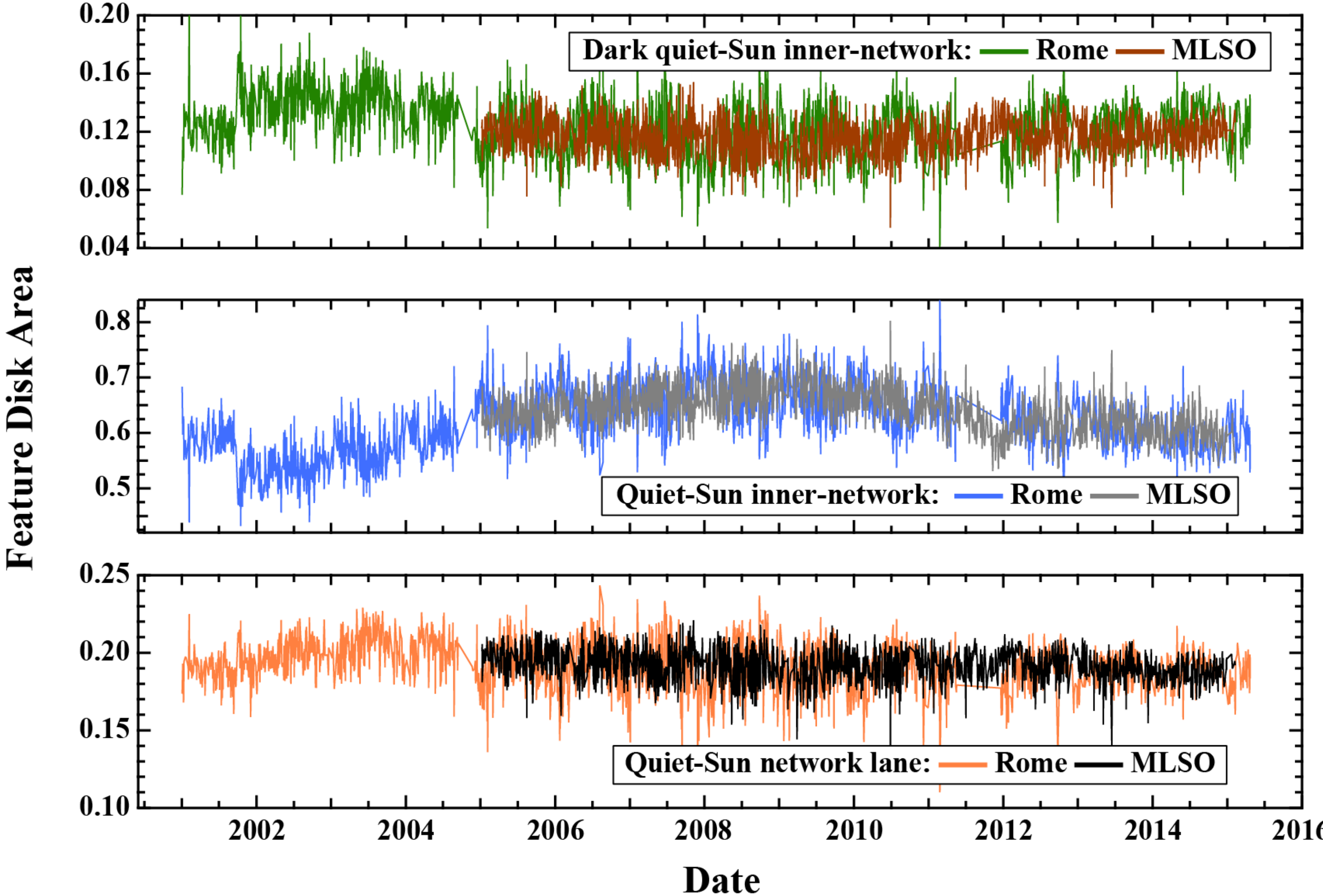
- I_a = Average disk intensity found from spline interpolation to account for CLV and normalized to total number of pixels.

$$R = \Omega_{Sun} I_a$$

- R = Irradiance calculated at 1 AU.
- Ω_{Sun} = Solid angle subtended by solar disk.

…/2015/SIST_2015/presentations/SIST_meetingJuly2016/Illustrator/allimg_vs_mu.ai

Activity 4: Compare Rome & MLSO PSPT



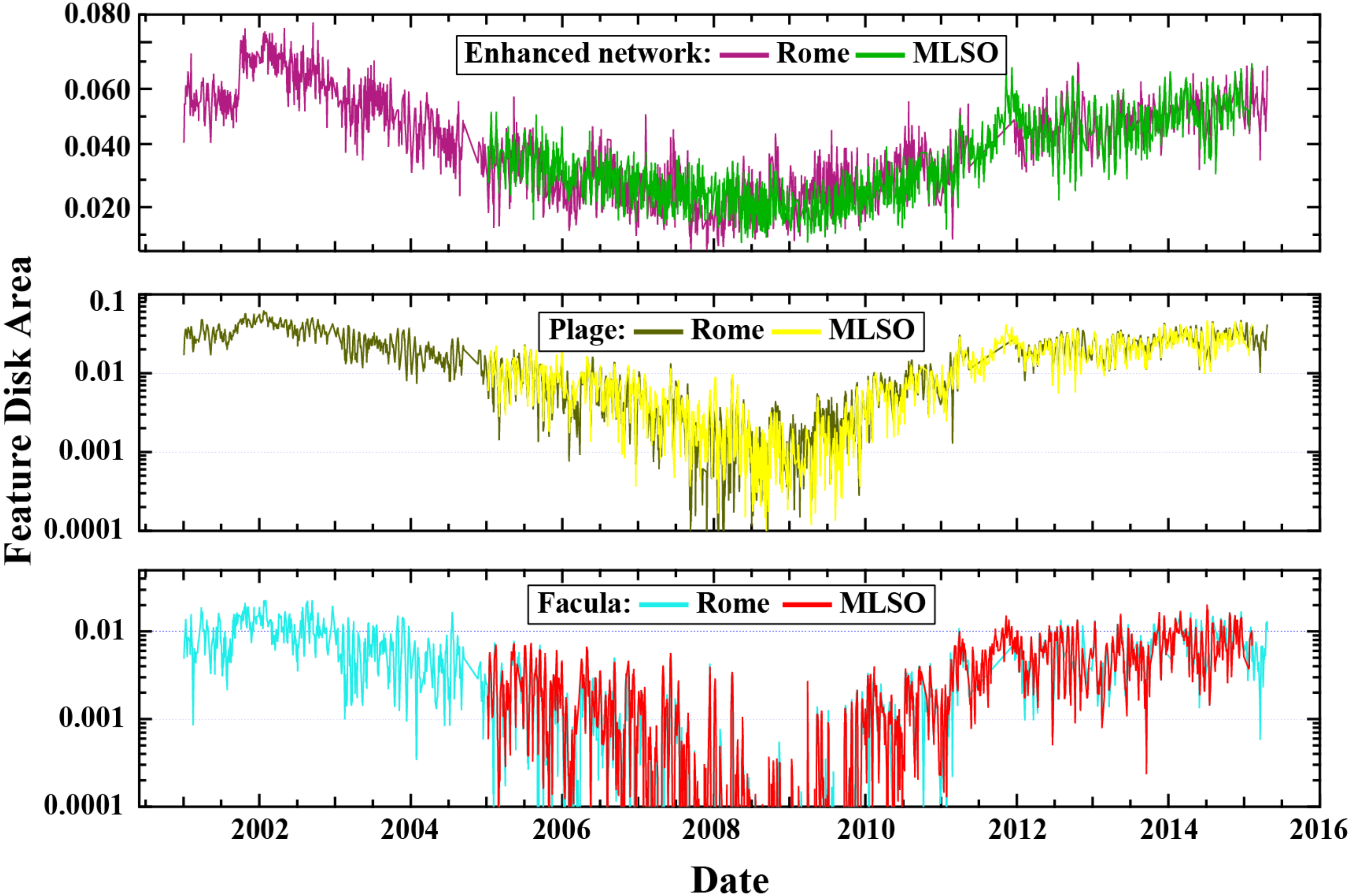
1 AU Phase Lag
42 days

38 days

28 days

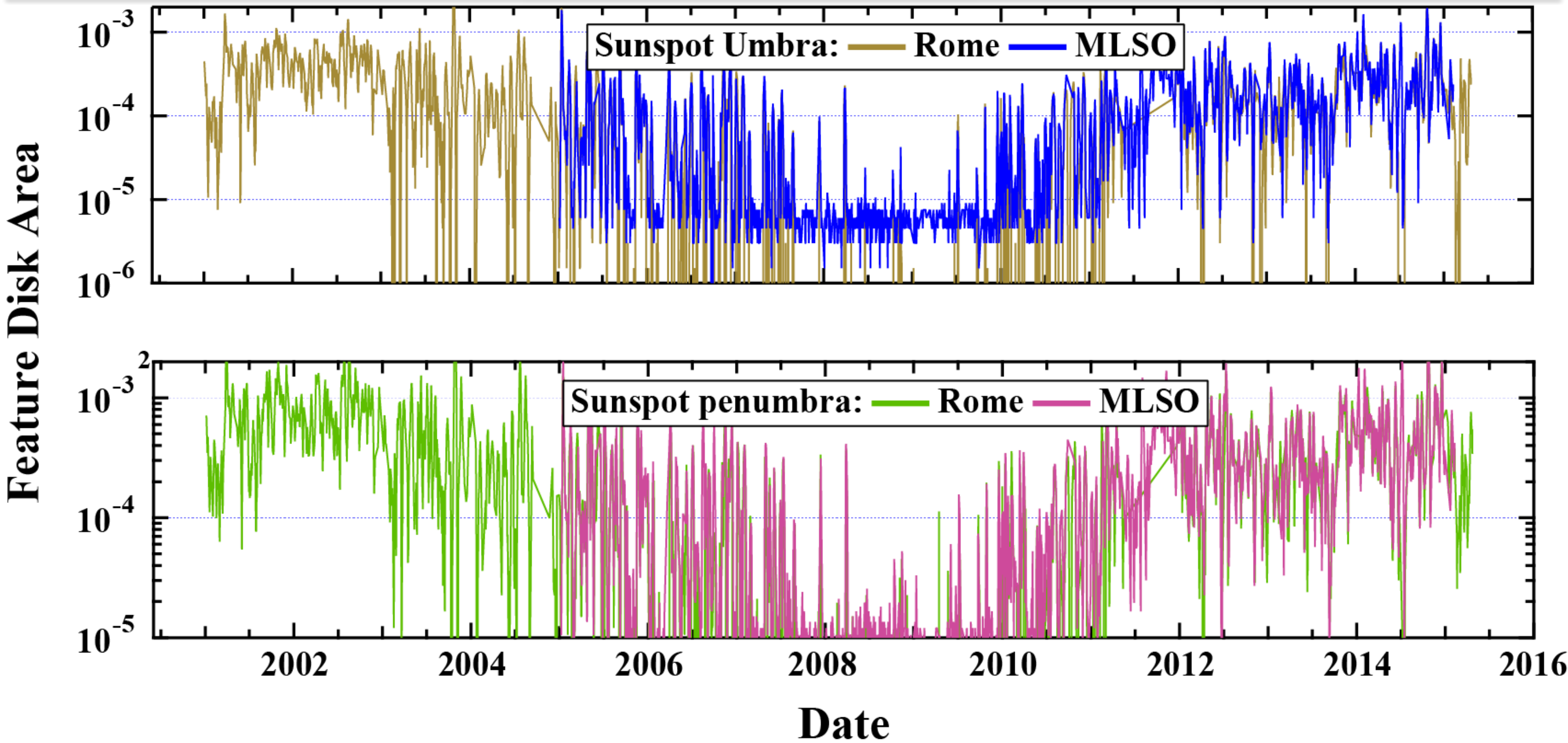
Small quasi-annual oscillation in quiet-Sun data – presumably due to slight defocus in telescope (?); problem less apparent in MLSO data; not coherent with 1 AU

Activity 4: Compare Rome & MLSO PSPT



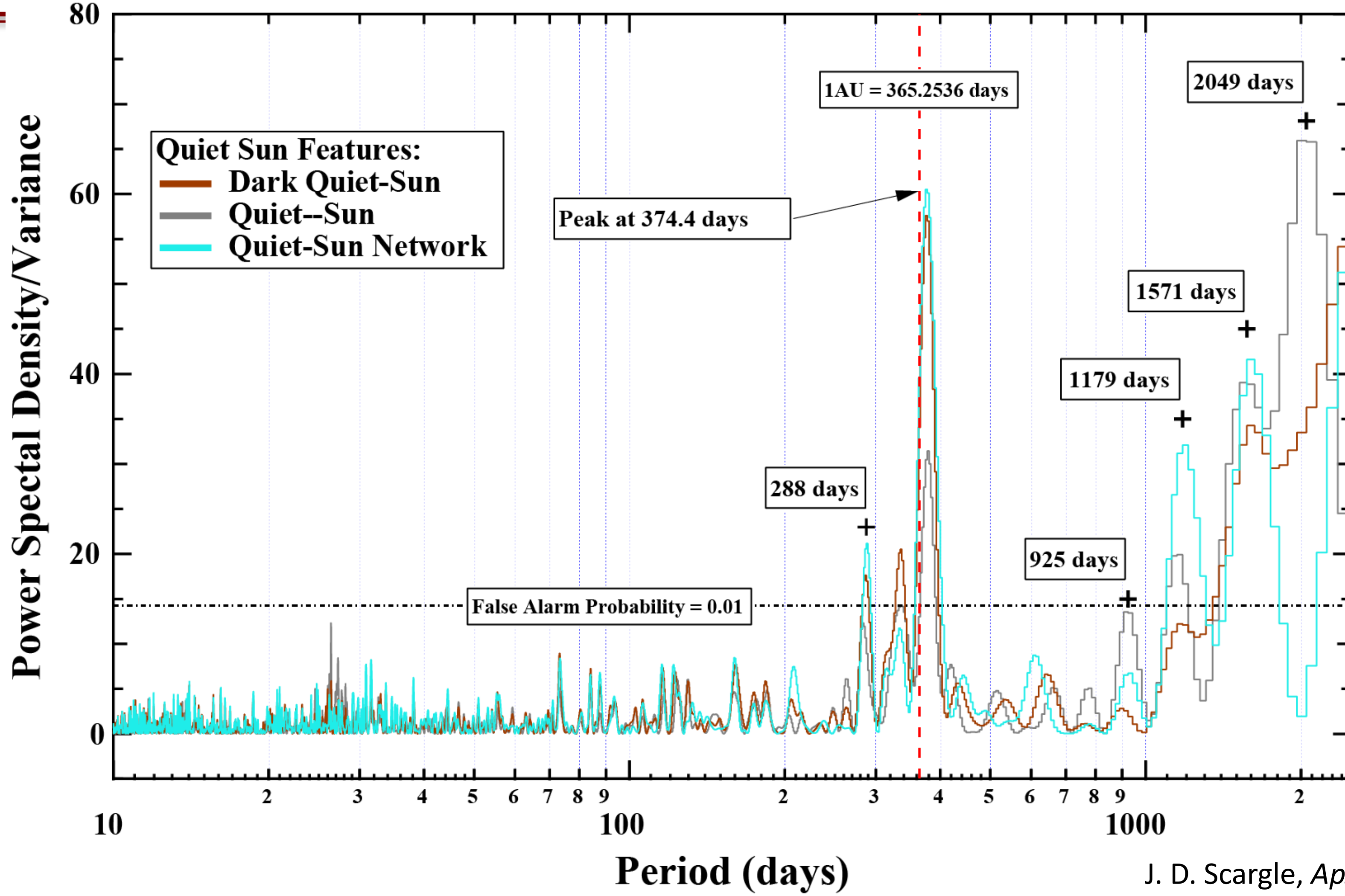
- Generally good agreement for bright active regions.
- Solar max: Facula + Plage ~80% Enhanced network, Solar min: ~6%

Activity 4: Compare Rome & MLSO PSPT



- **Dead pixels in MLSO leave a persistent sunspot area of ~8x10^{-6} making an irradiance offset of <0.0008 Wm^{-2}nm^{-1} in the MLSO data. Will correct MLSO irradiance to match Rome value in the combined data set.**

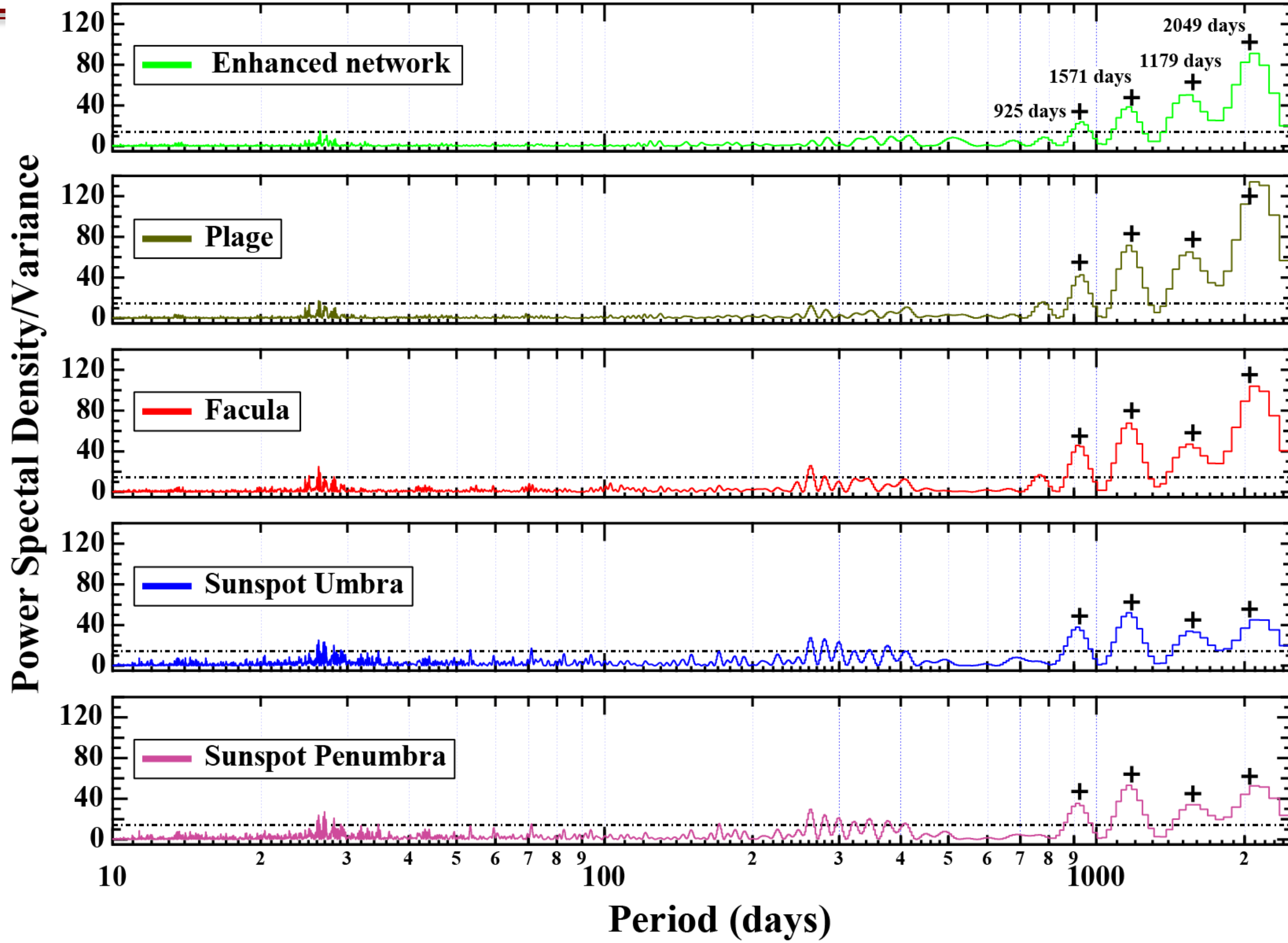
Feature Spectral Power Density – Quiet-Sun



J. D. Scargle, *ApJ*, **263**, 1982

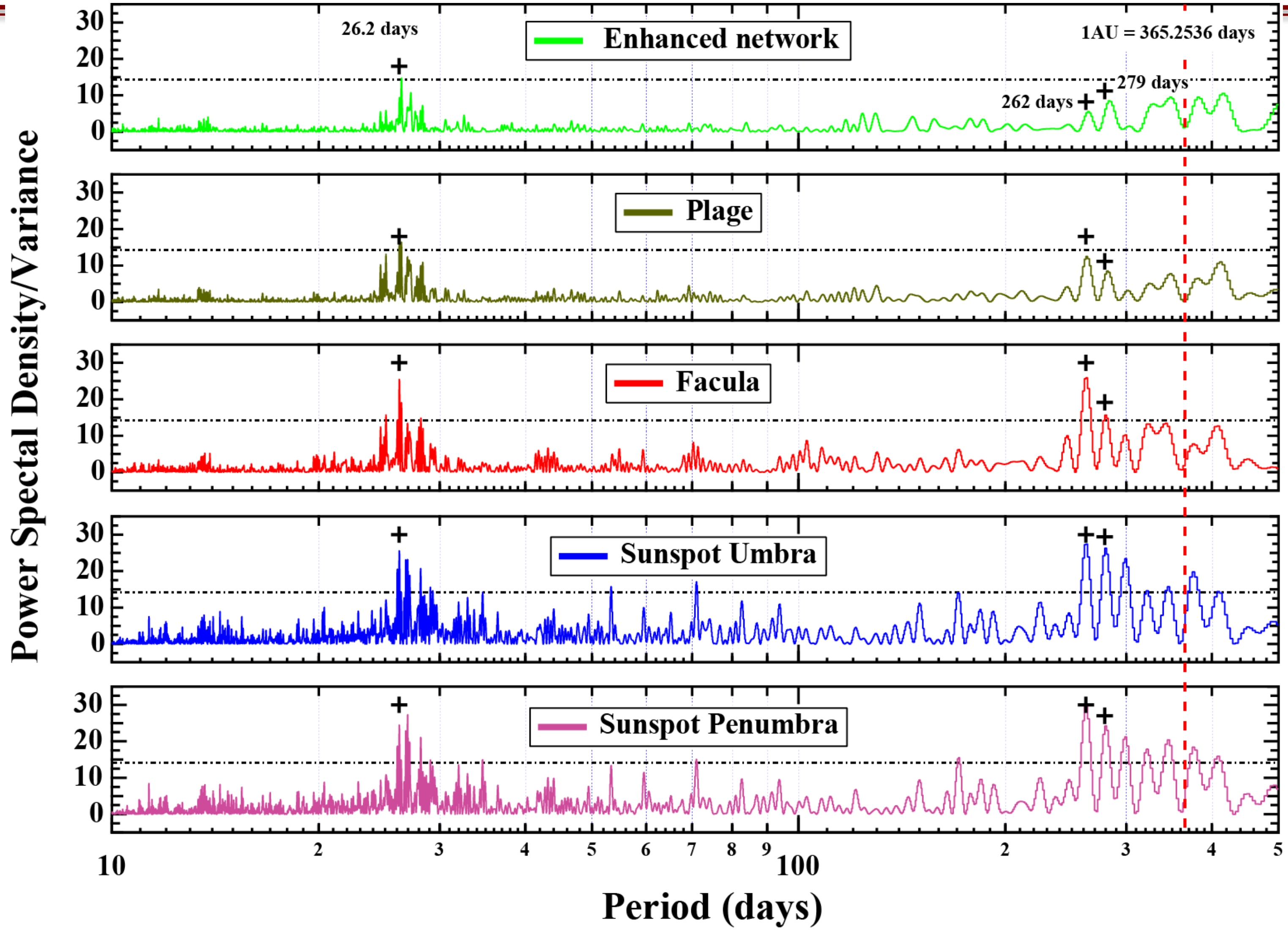
- **Significant power content at 374 days for all three quiet-Sun features**
  - **Different from 1 AU and not phase-locked to 1 AU, a solar oscillation mode???**
- **Significant power at 288 days for all three features**

Feature Spectral Power Density – Active regions



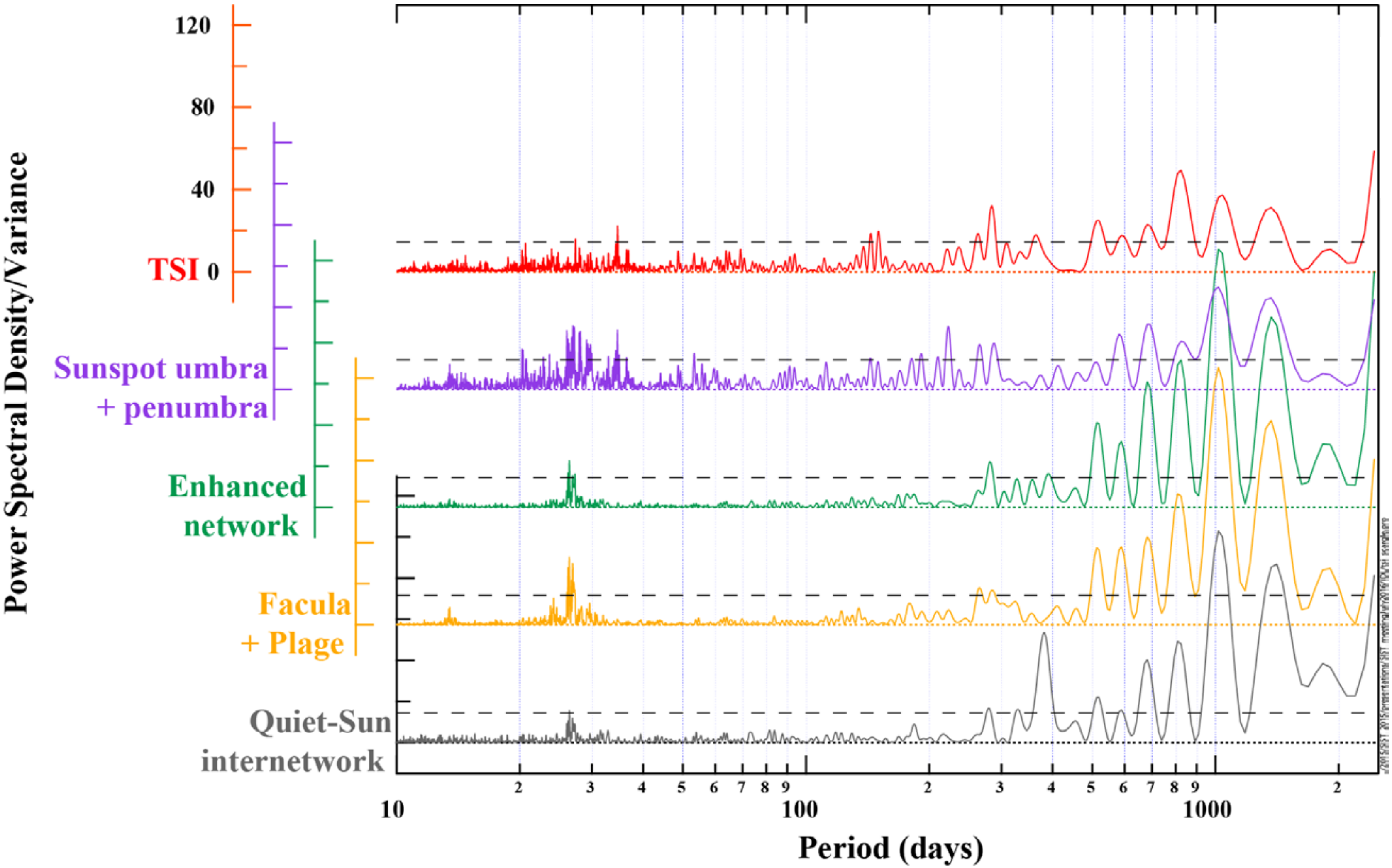
- **Same long-period components present in active region power spectra as quiet-Sun but with small shifts**

Feature Spectral Power Density – Active regions



- In high frequency regime (i.e. short periods) ~27 rotational period evident and significant for all active region components. A second grouping appears at about 262 dayS with highest significance for sunspots and facula.

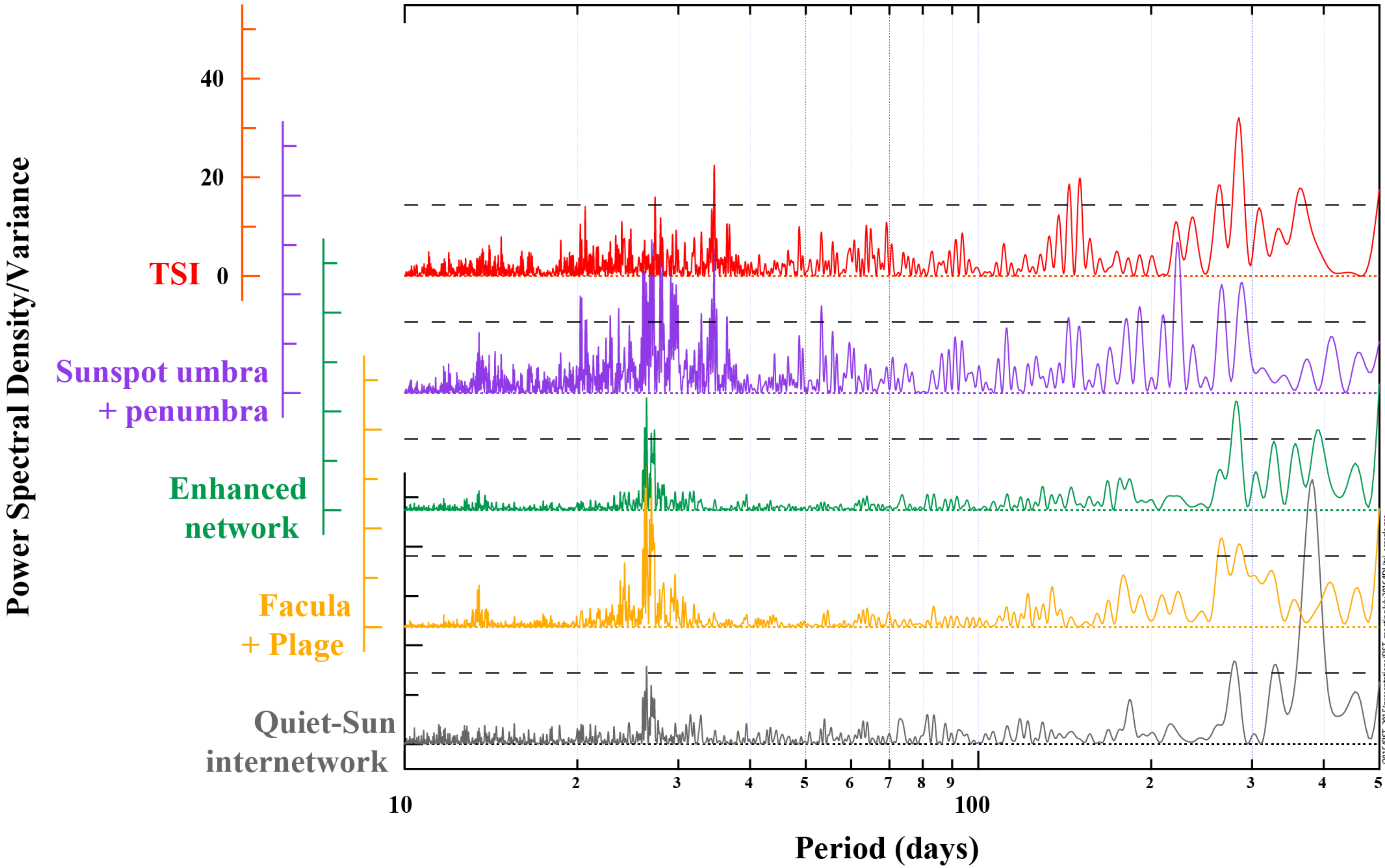
Feature Spectral Power Density – Relative to TSI



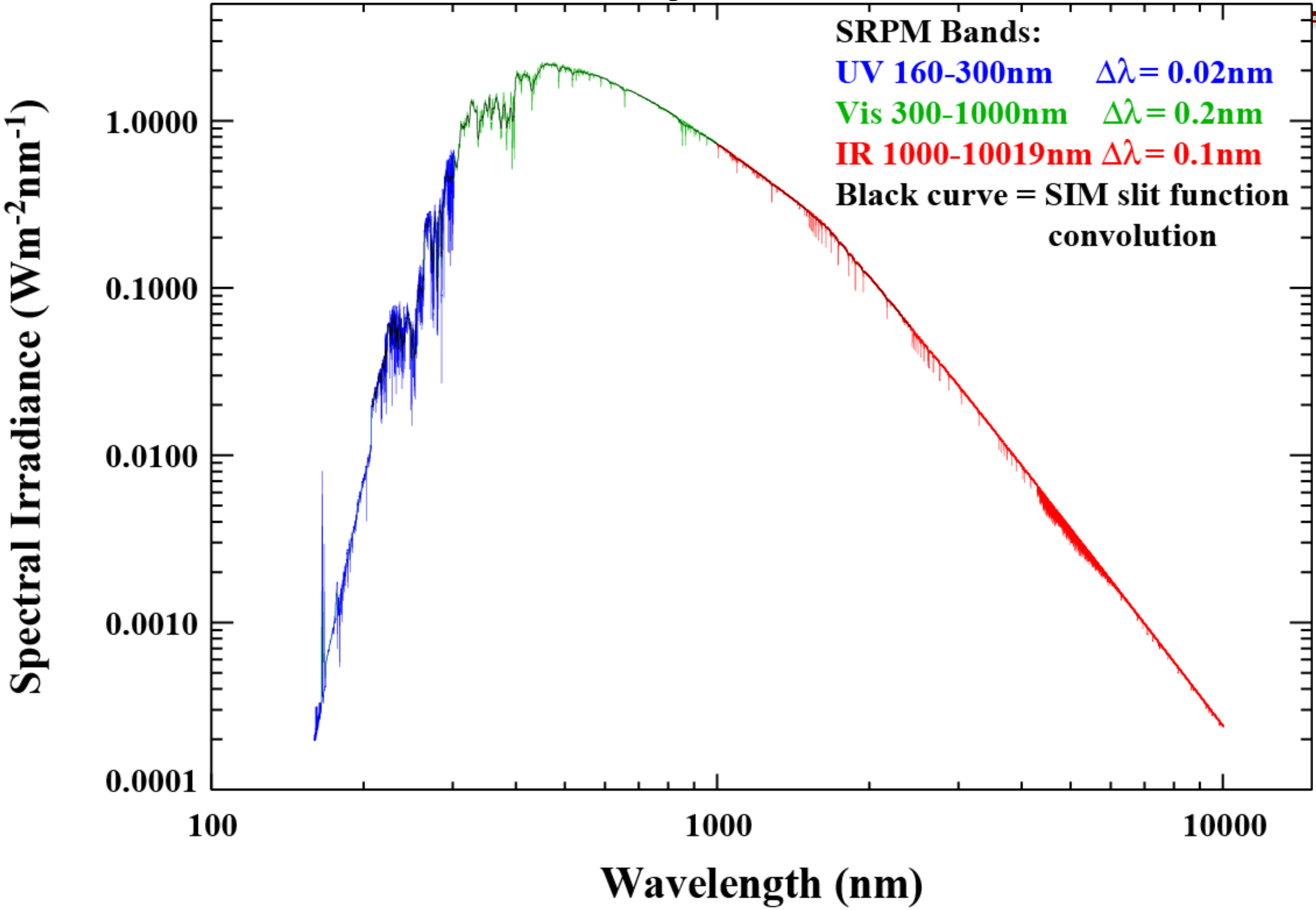
All common days

- **The eight PSPT feature areas combine to reproduce the frequency content of the TSI therefore the image analysis faithfully represents which solar structures contribute to the solar variability**

Feature Spectral Power Density – Relative to TSI

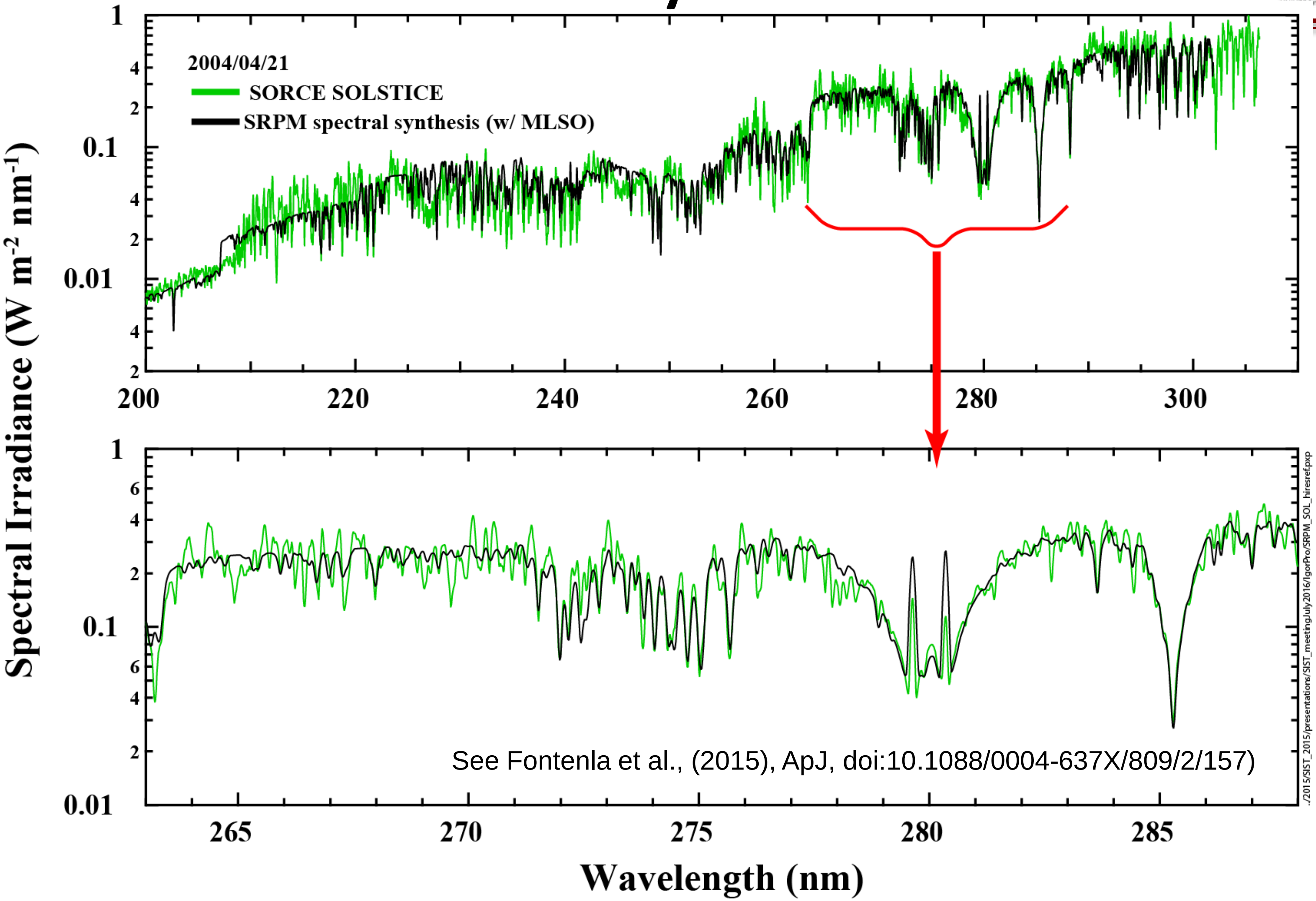


Activities 4 & 5: SRPM synthesis & convolution



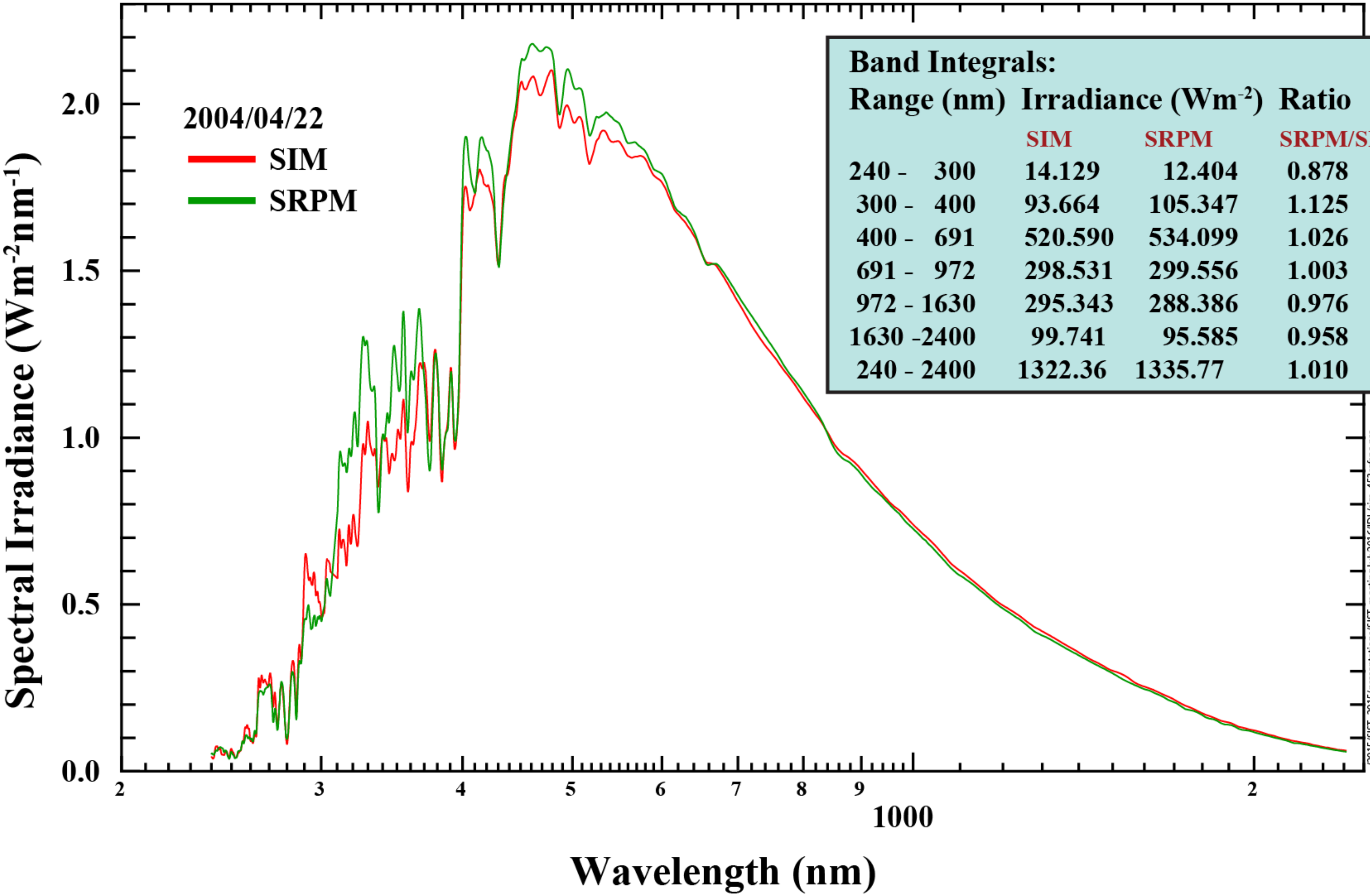
- **Completed spectral synthesis for full MLSO & Rome image records**
- **Completed convolution and interpolation of SRPM spectra to SORCE SIM resolution and sampling – ready for direct comparison.**
- **UV<160 nm and infrared >10000 nm still pending**

Activities 4 & 5: SRPM synthesis & convolution



- **Significant improvements in the MUV by identifying and including sources of 'missing' opacity.**
- **Improved agreement with SOLSTICE 0.1 nm**

Activities 4 & 5: SRPM synthesis & convolution



Band Integrals:

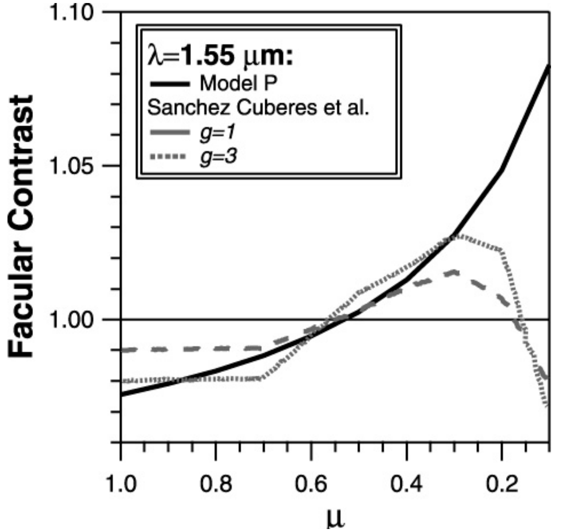
Range (nm)	Irradiance (Wm^{-2}) SIM	Irradiance (Wm^{-2}) SRPM	Ratio SRPM/SIM
240 - 300	14.129	12.404	0.878
300 - 400	93.664	105.347	1.125
400 - 691	520.590	534.099	1.026
691 - 972	298.531	299.556	1.003
972 - 1630	295.343	288.386	0.976
1630 -2400	99.741	95.585	0.958
240 - 2400	1322.36	1335.77	1.010

Summary 2015-2016/Actions 2016-2017

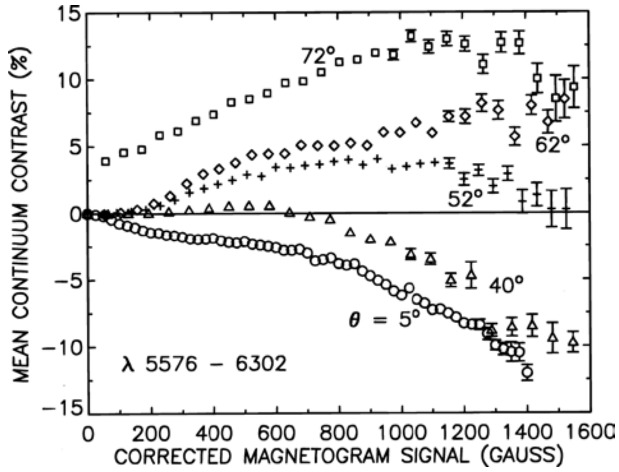
1. **Completed tasks:**
    1. **Accumulating, curating, and refining PSPT image library complete.**
    2. **Comparative analysis of coincident ROME and MLSO PSPT images complete. Records can be combined into a single record that now spans 2001/01 to 2015/04.**
    3. **SRPM spectral synthesis completed from 160-10,000nm. Higher resolution data convolved and re-sampled to match standard wavelength spacing.**
2. **Activities for 2016-2017:**
    1. **Detailed SRPM comparisons with SORCE SIM and SOLSTICE data will be conducted.**
    2. **Filling in critical gaps in the PSPT record will continue on a lower priority basis in 2016-2017.**
    3. **Acquire SRPM data for 100-160nm and develop a product for the 10,000-100,000nm portion of the spectrum**
    4. **Three publications are planned for 2017 (PSPT analysis, SORCE/SRPM comparison, Version 23 SIM findings and corrections)**

Observations Supporting SIM Trends

LASP
LABORATORY FOR ATMOSPHERIC AND SPACE PHYSICS
UNIVERSITY OF COLORADO AT BOULDER

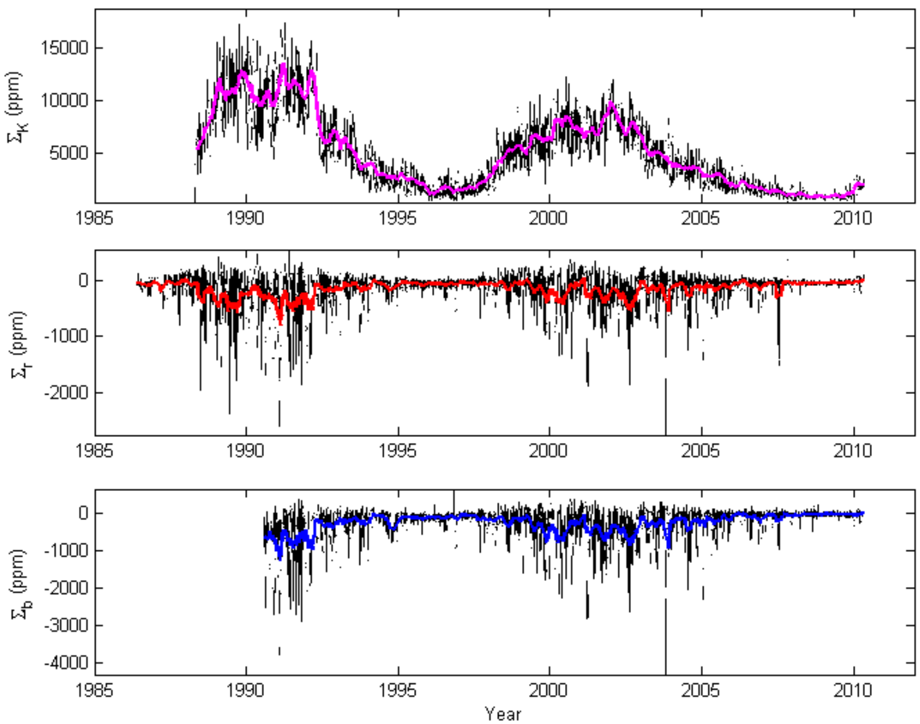


Sanchez Cuberes et al., ApJ,2002



Topka et al., ApJ 1997

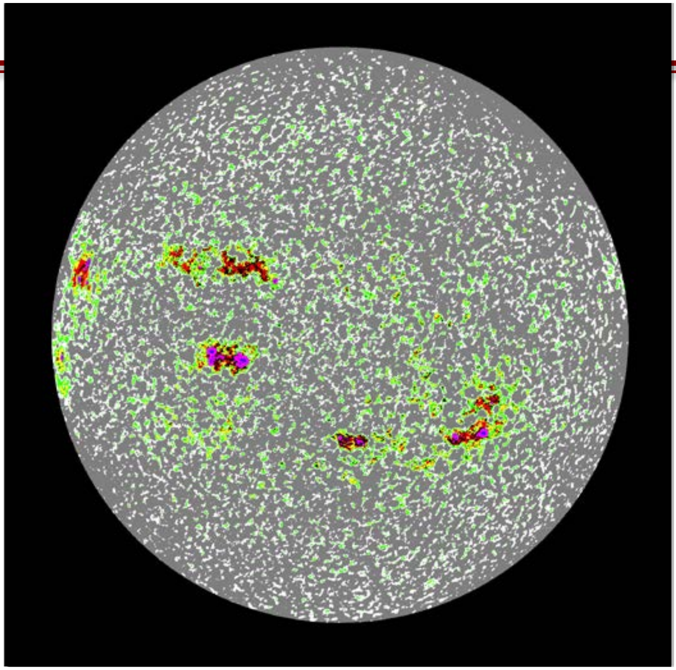
Features contrast varies with wavelength and heliocentric angle and corresponds to the slope of T vs P

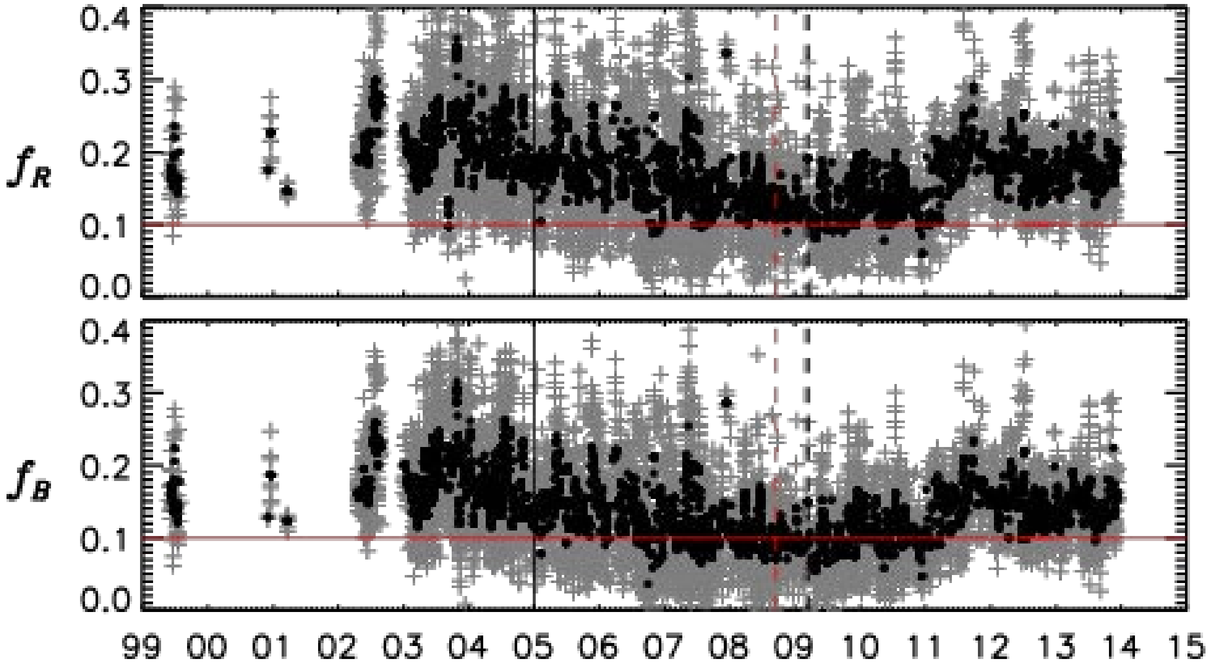


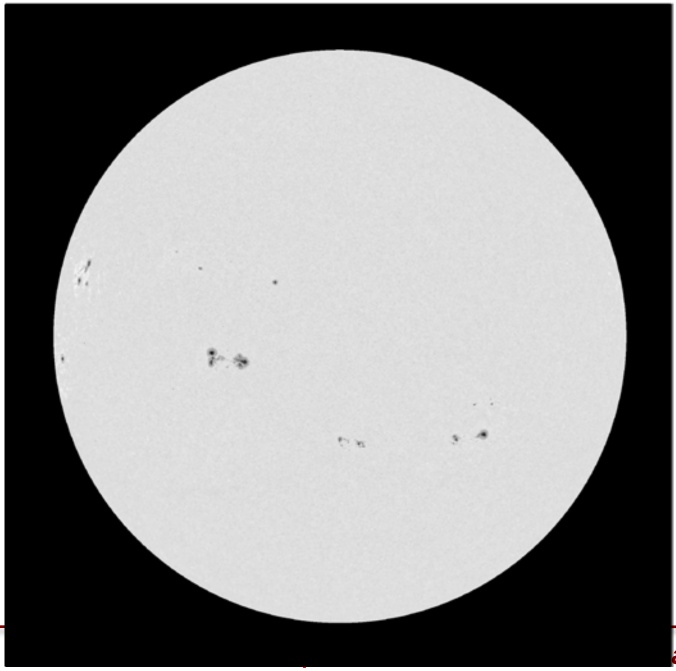
The photometric sums exhibit similar temporal patterns: they are negatively correlated with solar activity, with strong short-term variability and weak solar-cycle variability.

Preminger et al.., ApJ,2011

PSPT observations of Facula

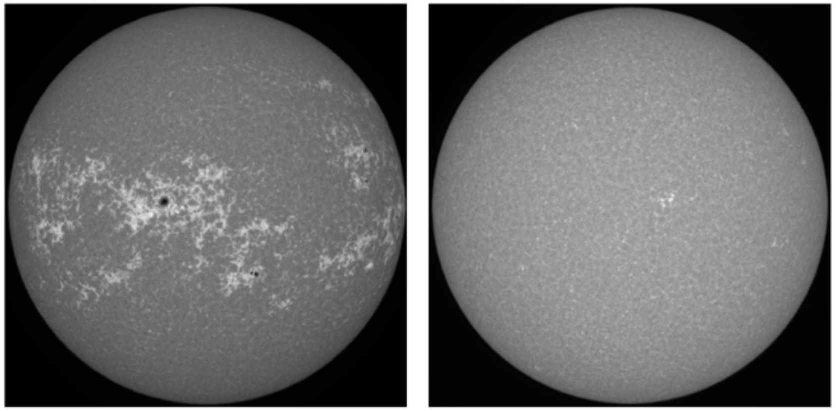


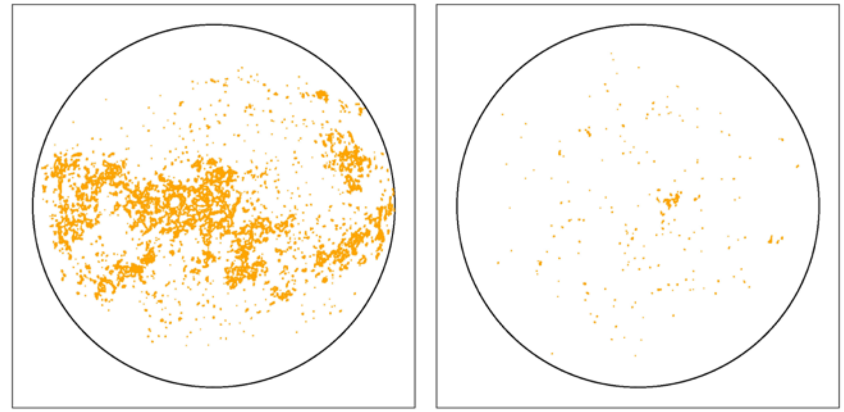




- Some Facula and plage have negative contrast at red continuum wavelengths
- The fraction of dark Facula decreases into SC23 minimum and increases into rising phase of SC24

Feature Disk Filling

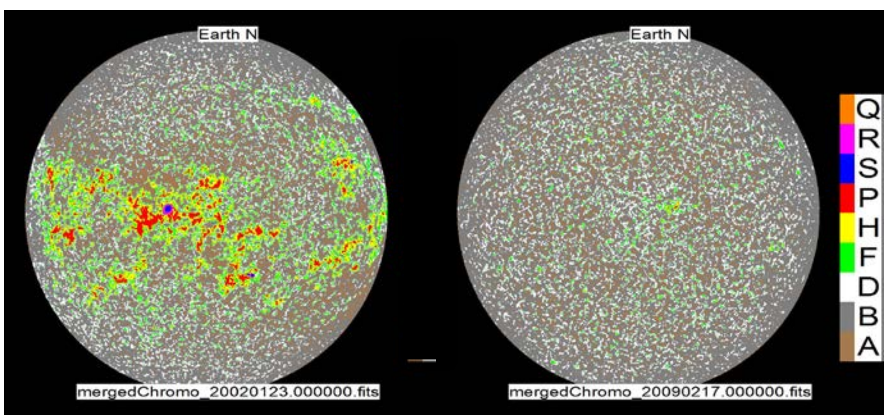


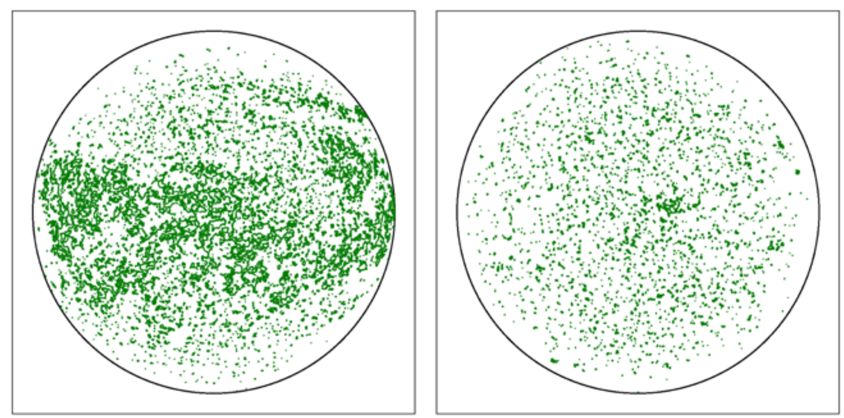


PSPT Ca K II

2002/01/23 & 2009/02/17

Model H (plage)





SRPM Masks

Model F (active network)