

SWAP AT 2.5 YEARS: A PERFORMANCE ANALYSIS

Dan Seaton, Bogdan Nicula, & David Berghmans
Royal Observatory of Belgium

and

Jean-Philippe Halain
Centre Spatial de Liege

In Orbit Degradation of Solar & Space Weather Instruments

Solar-Terrestrial Center for Excellence ☀ Brussels, Belgium ☀ May 3, 2012



A BRIEF INTRODUCTION TO PROBA2 & SWAP



Movie: ESA

PROBA2 LAUNCH

November 2, 2009, 01:50:51 UTC ☀ Plesetsk, Russia



SPACECRAFT SEPARATION

November 2, 2009, 04:50:06 UTC ☀ 725 km altitude



ESA'S PROBA2 PROGRAM

Project for **O**n-**B**oard **A**utonomy



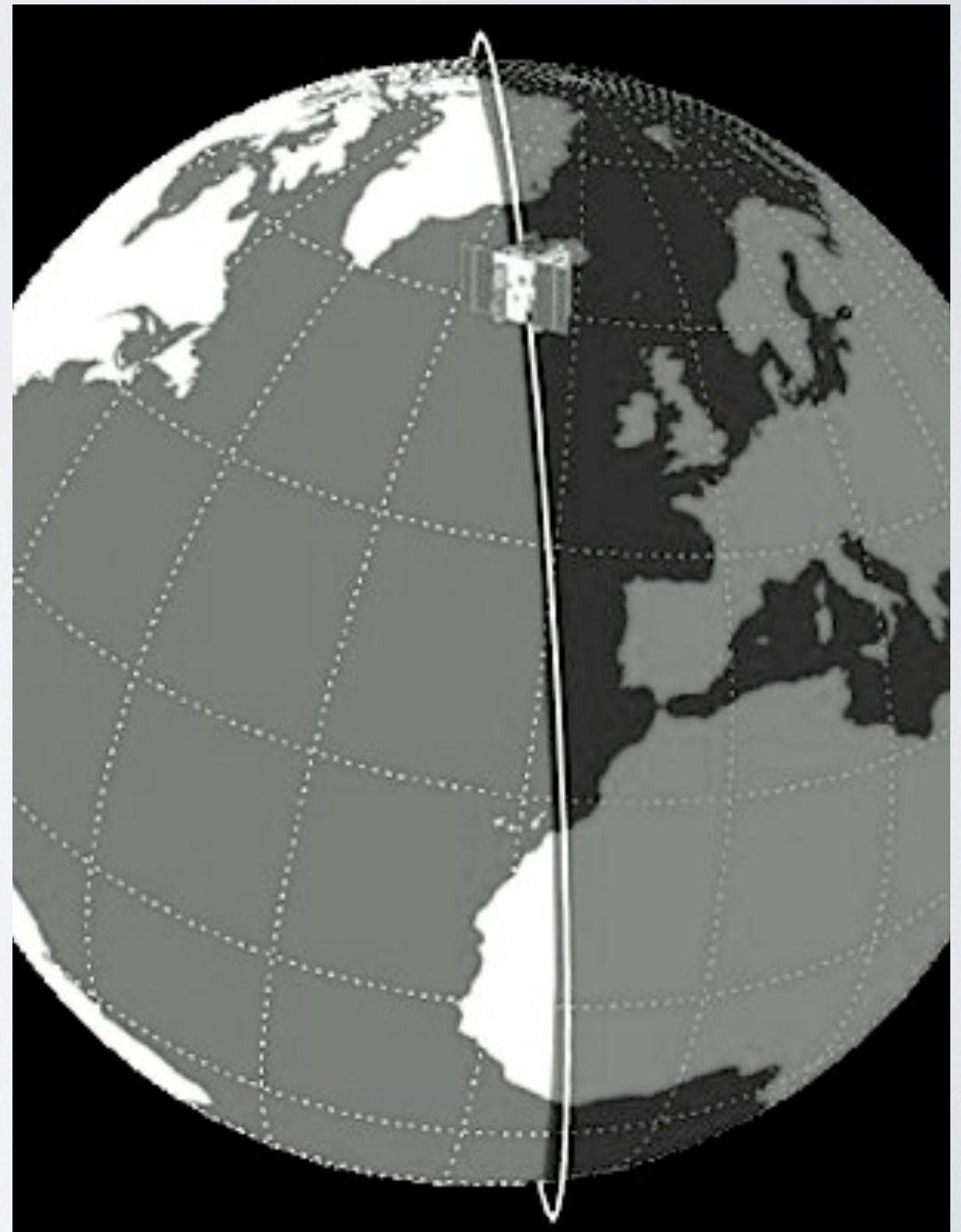
ESA'S PROBA2 PROGRAM

4 science instruments: SWAP, LYRA, TPMU, DSLP
17 platform technology experiments

ORBIT

Polar Sun-Synchronous

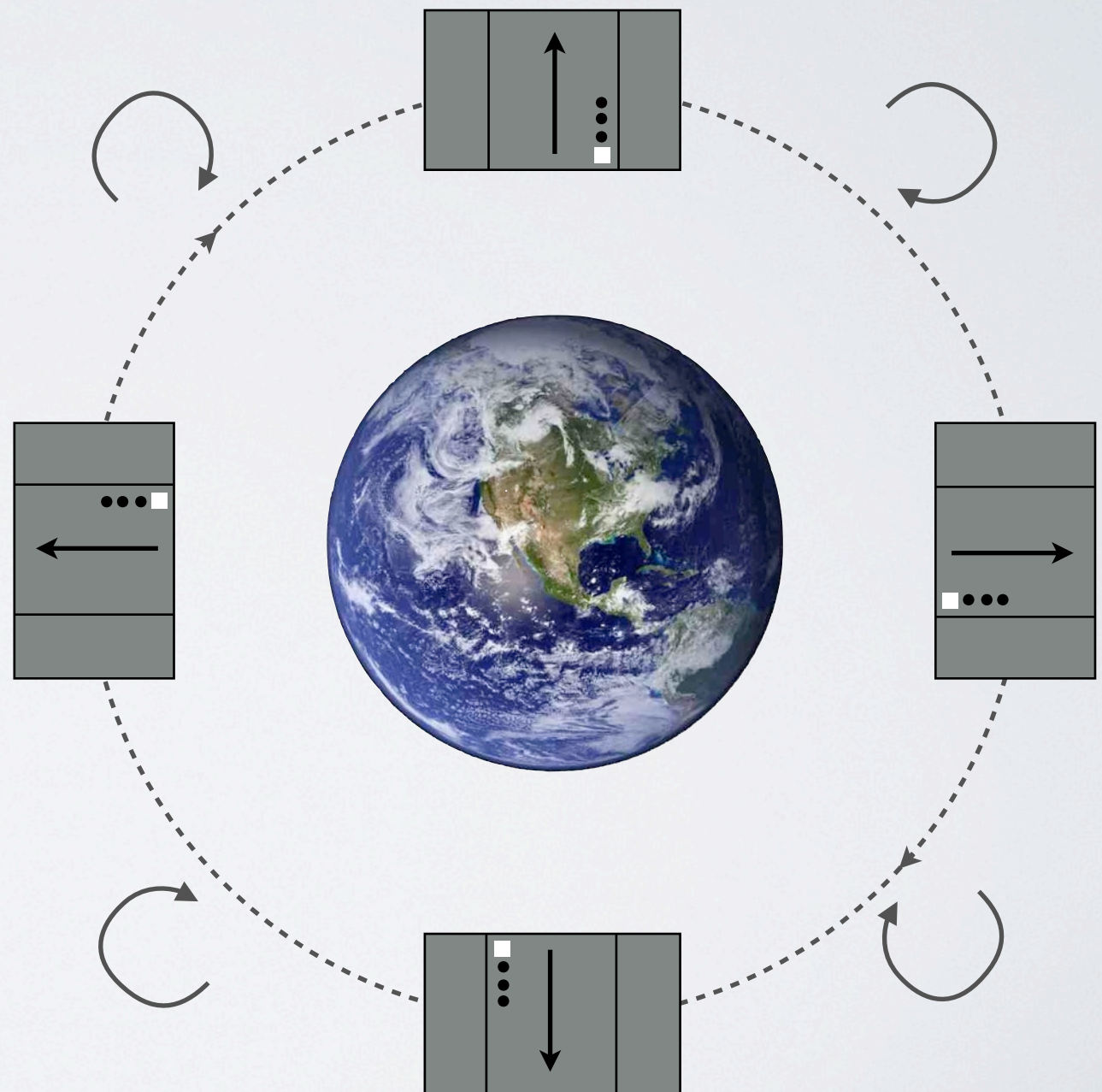
725 km altitude



ORBIT

≈ 100 minute period

Large Angle Rotations
every 25 minutes



ORBIT

Eclipse season:

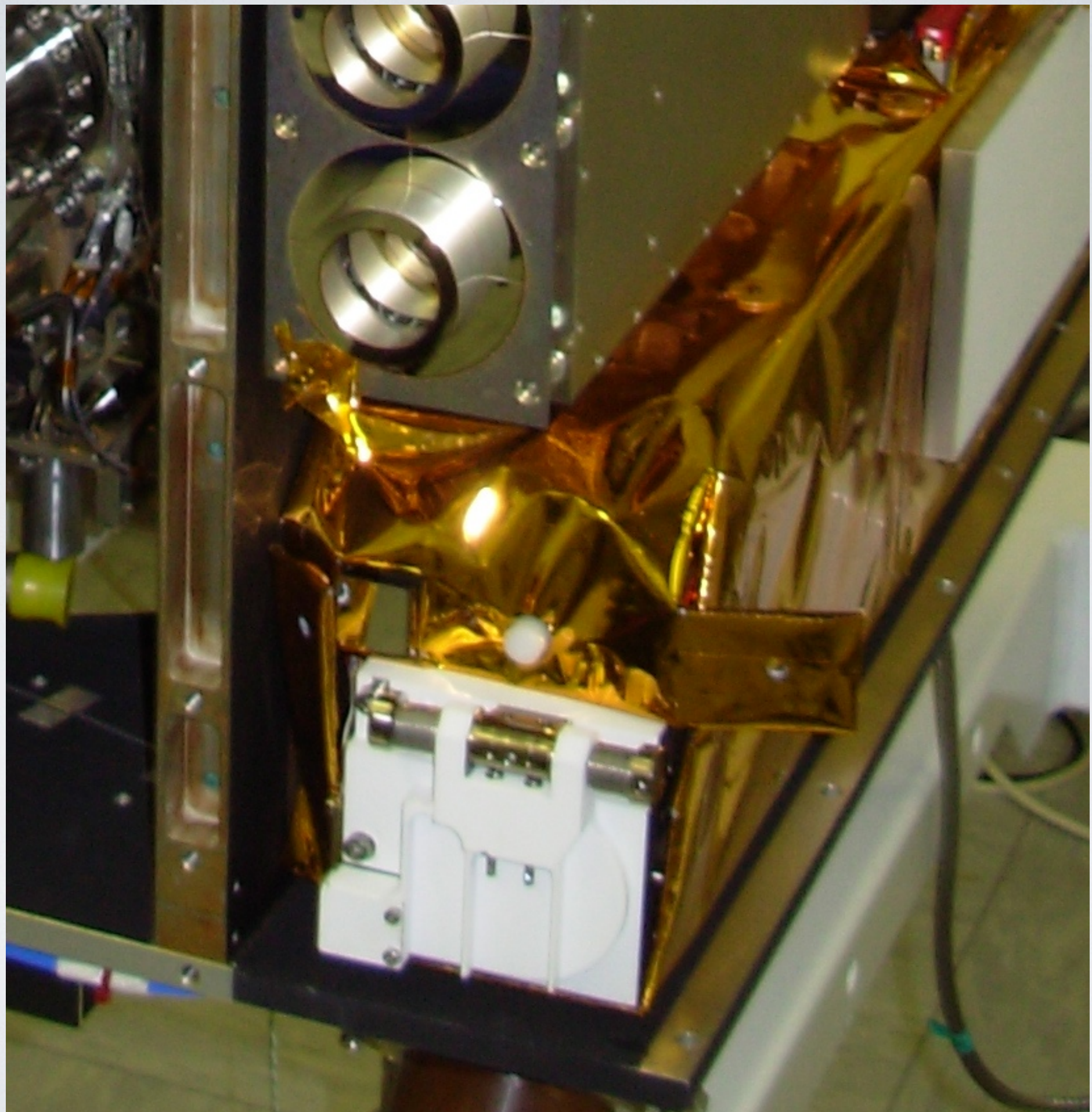
- Visible: November-January
- EUV: Slightly longer
- Maximum duration 18 min per orbit visible eclipse

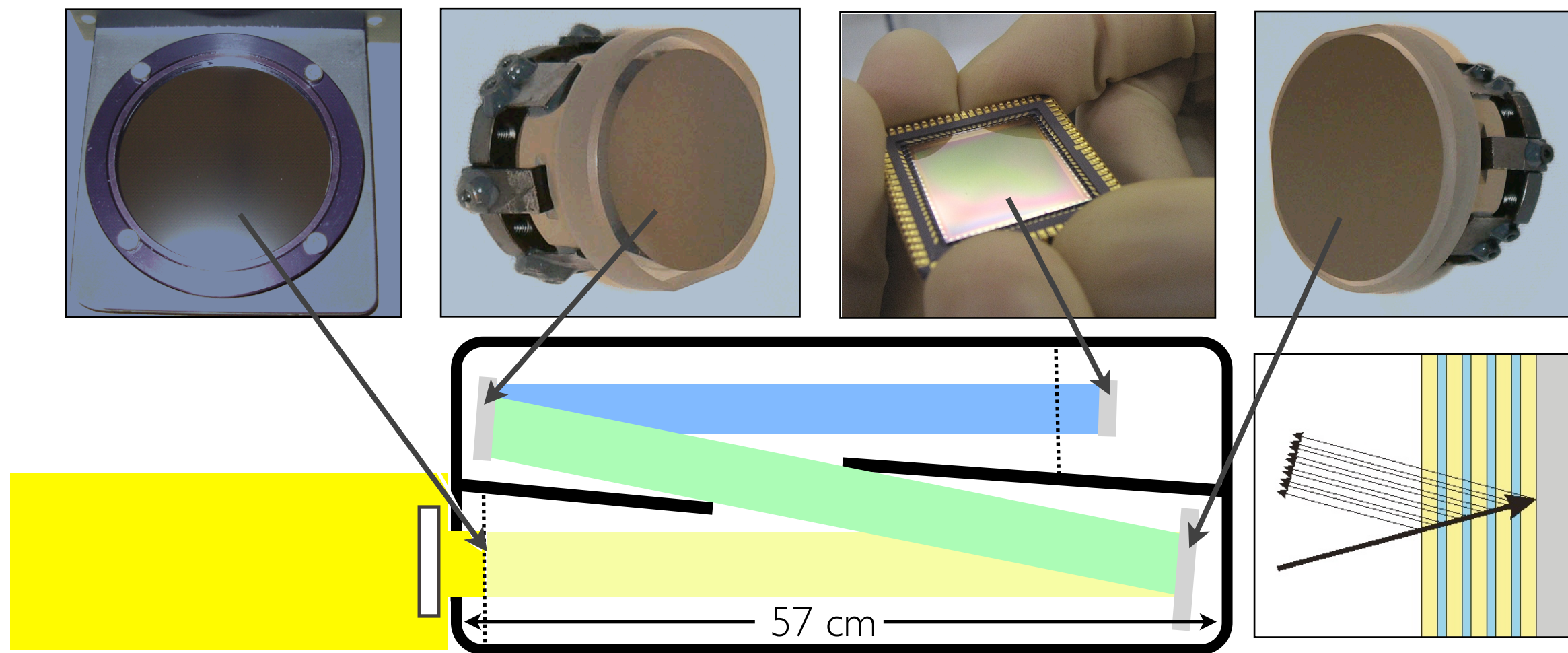




PROBA2 INSTRUMENTATION

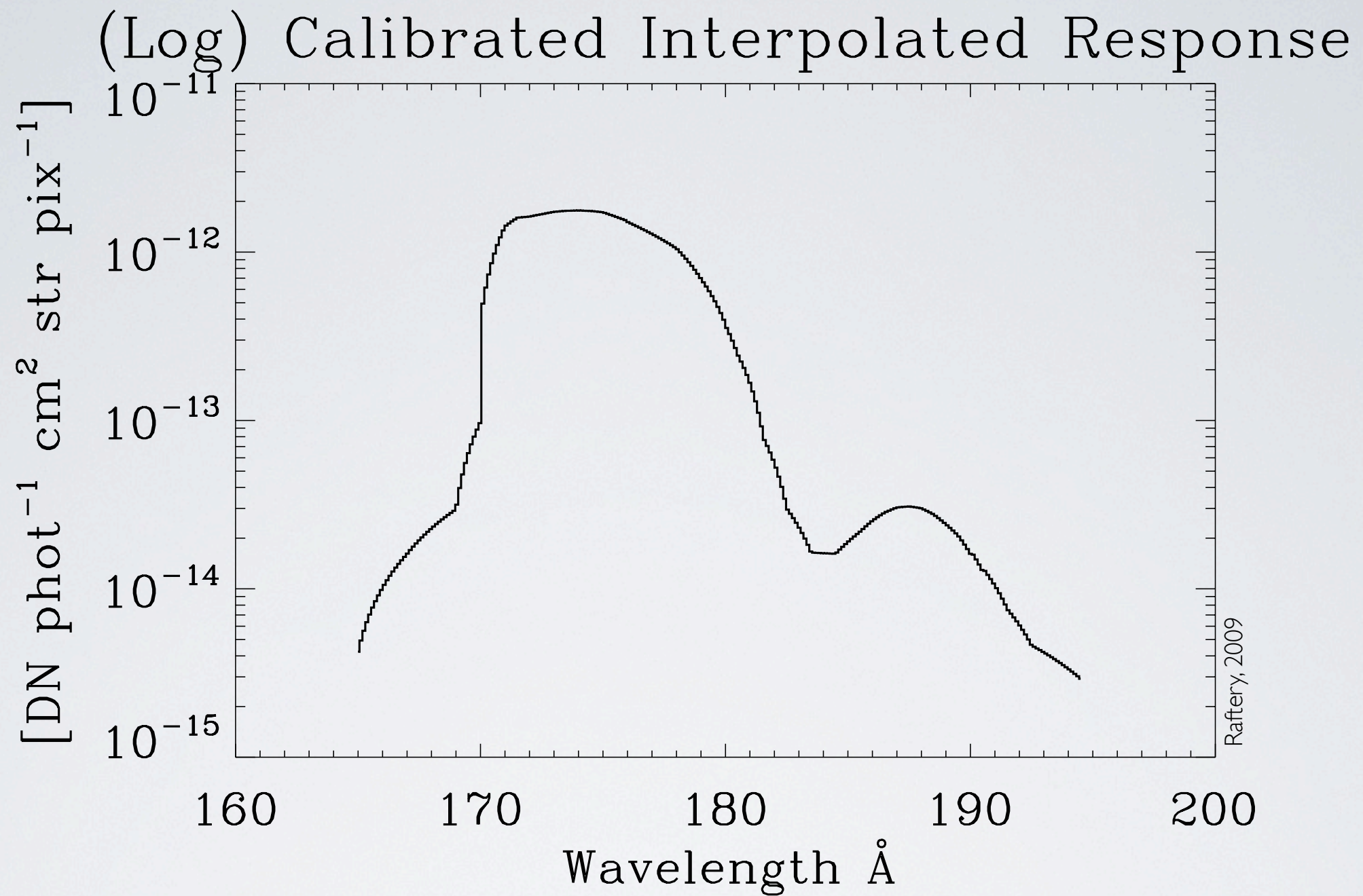
Sun **W**atcher with **A**ctive Pixel System & Image **P**rocessing





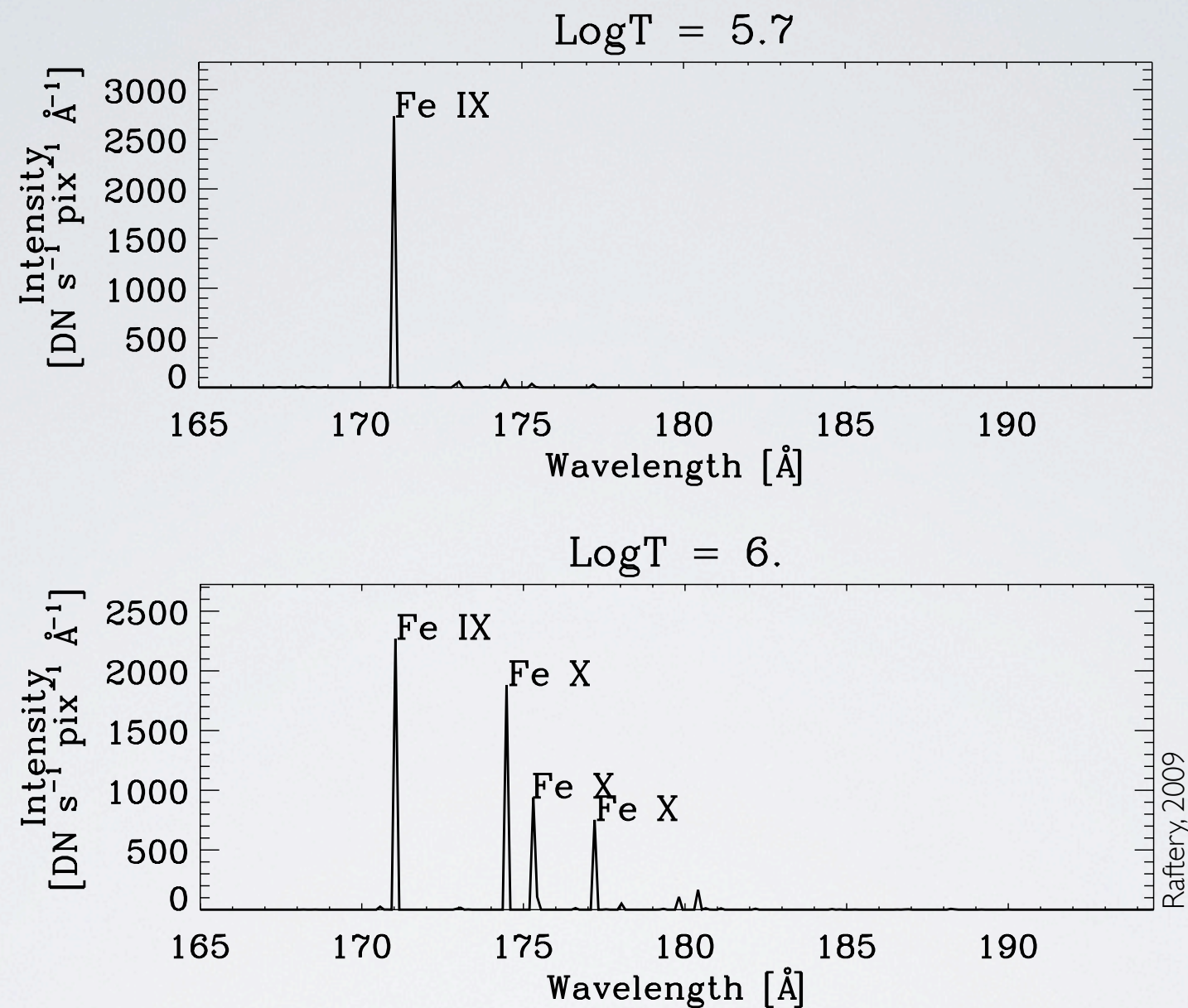
OPTICAL PATH

Off-Axis Ritchey-Chrétien Scheme



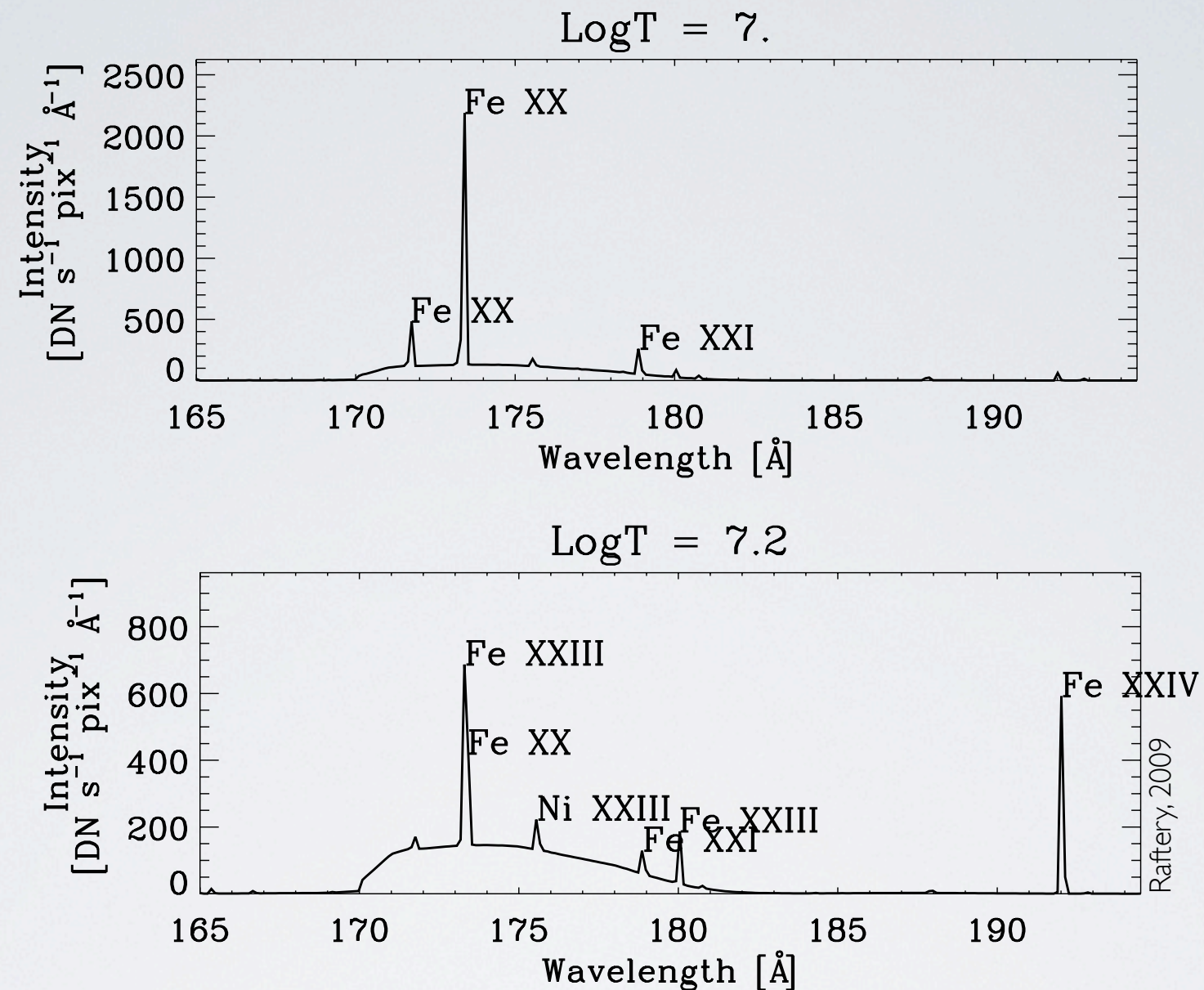
SPECTRAL RESPONSE

Measured with Synchrotron Beam at BESSY



SPECTRAL RESPONSE

Transmitted Lines at Selected Temperatures

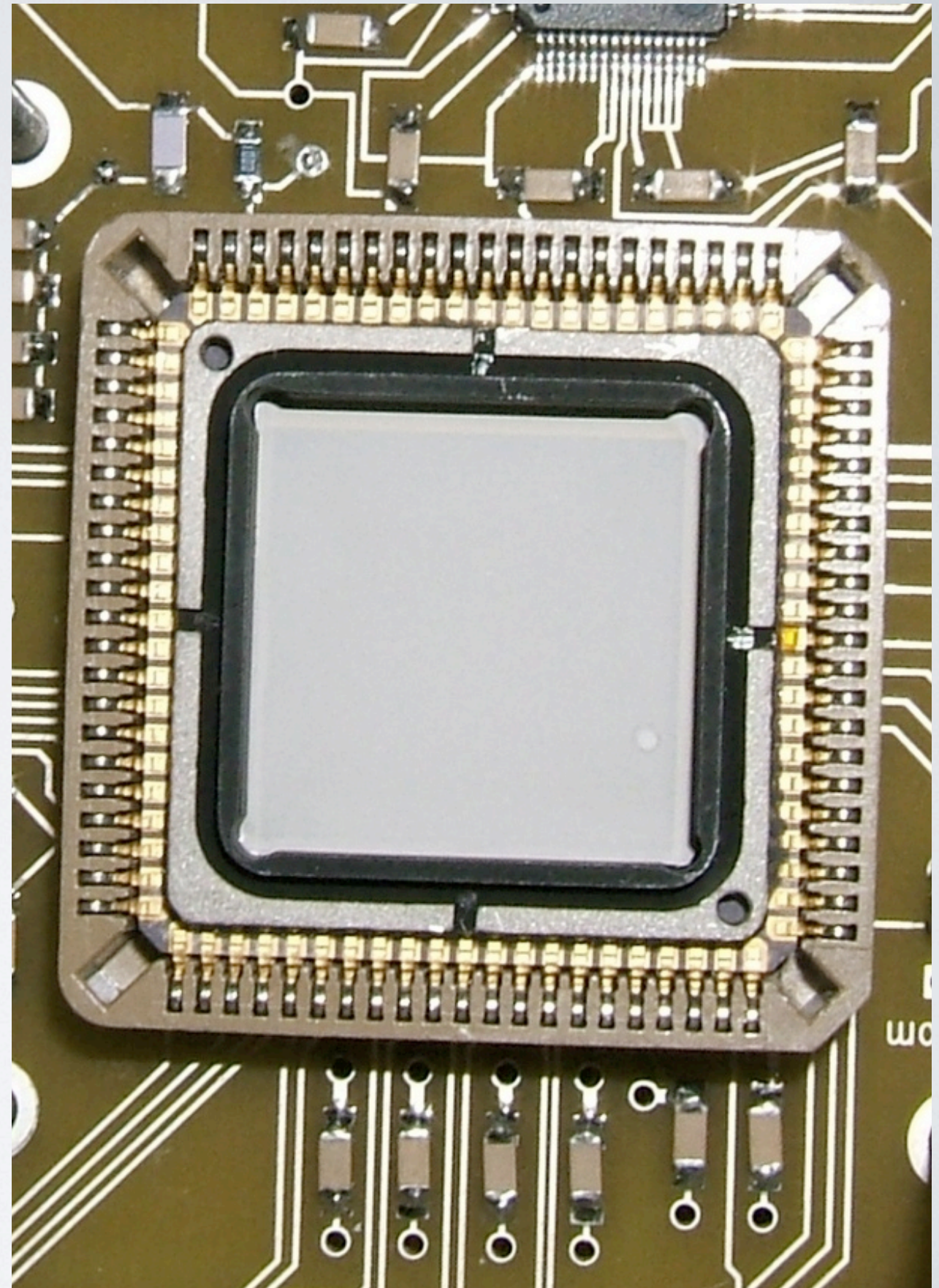


SPECTRAL RESPONSE

Transmitted Lines at Selected Temperatures

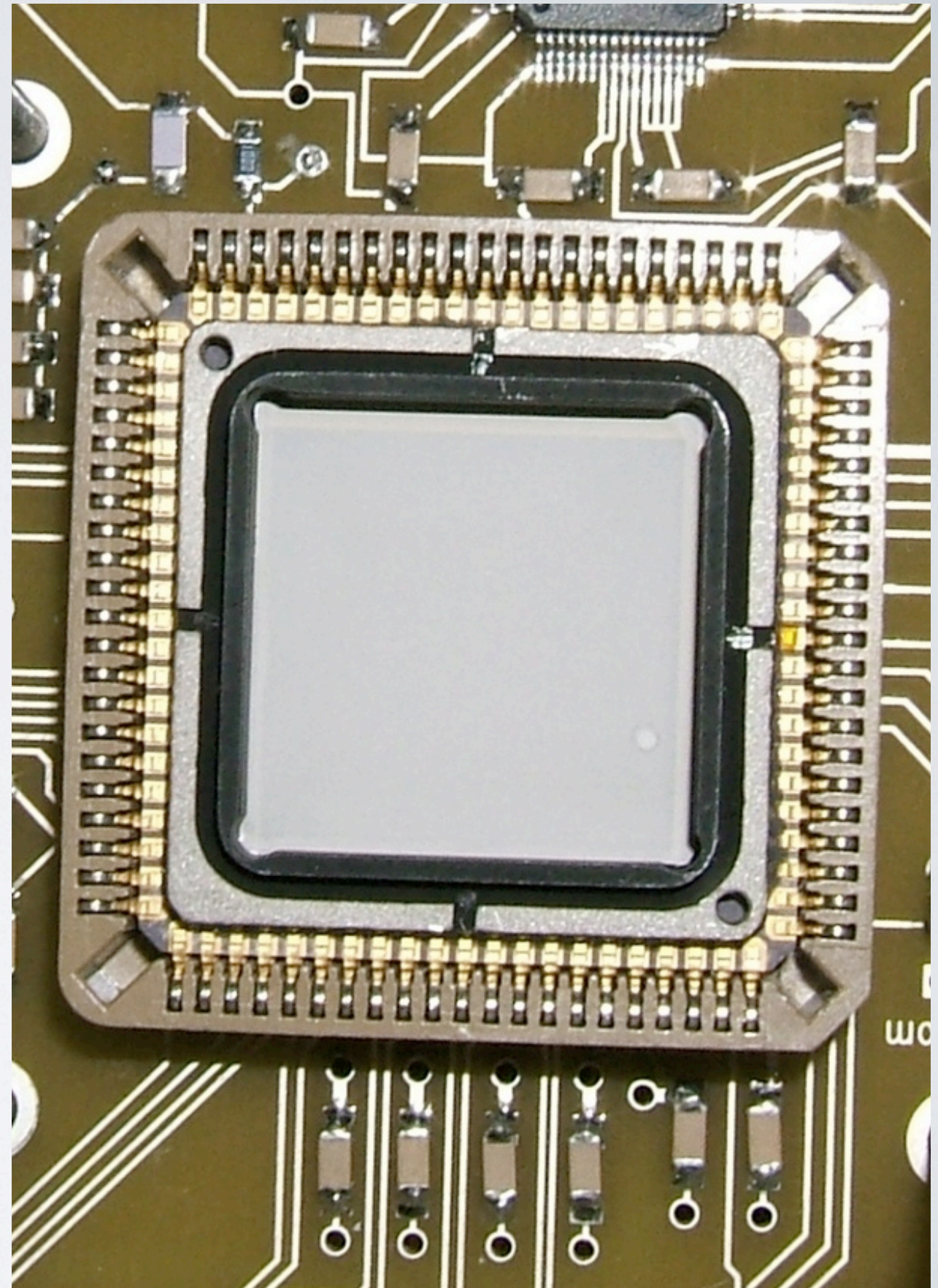
CMOS APS DETECTOR

1024×1024 Pixels



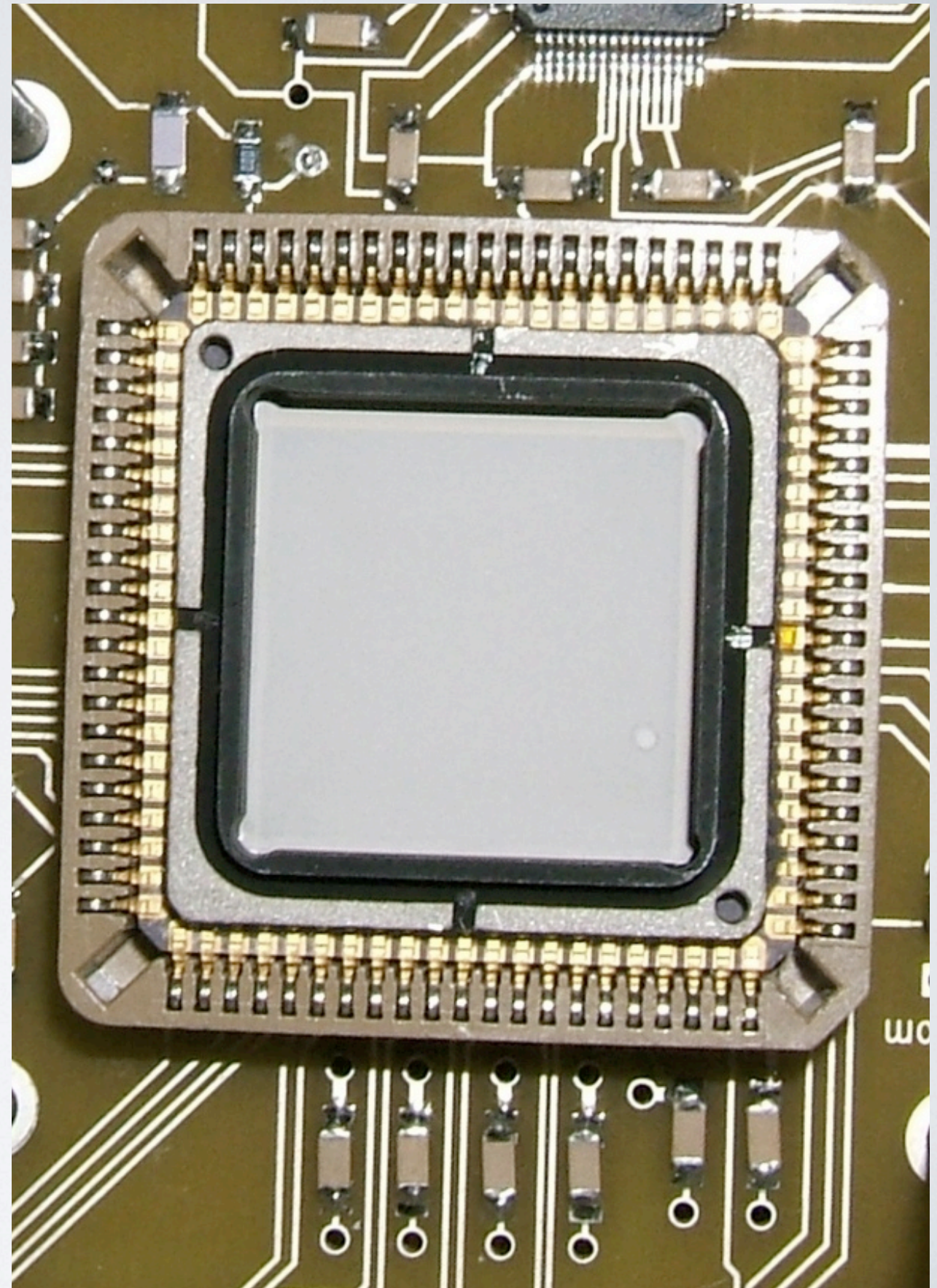
CMOS APS DETECTOR

Low power consumption



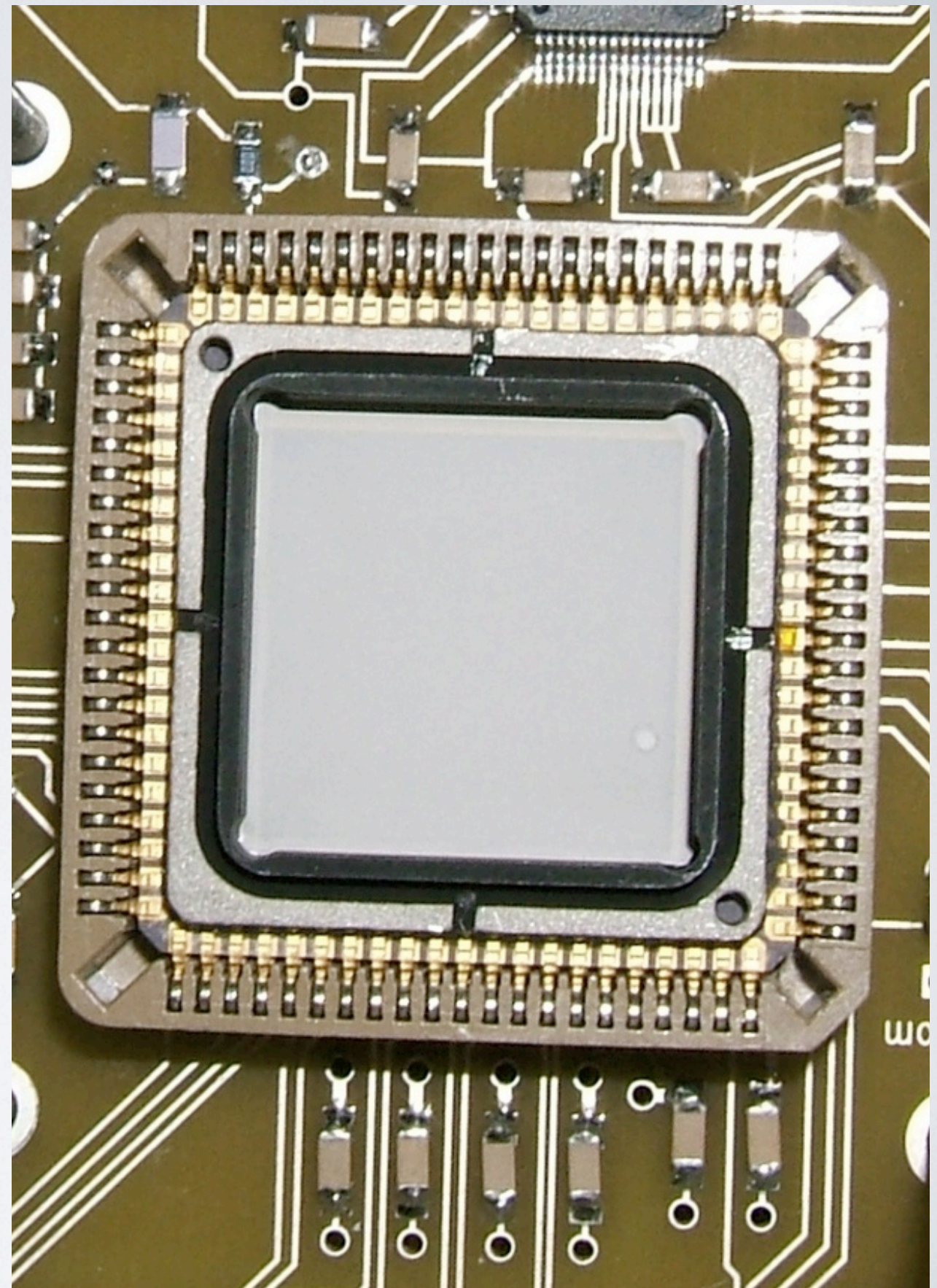
CMOS APS DETECTOR

P43 coating for EUV sensitivity



CMOS APS DETECTOR

First CMOS for solar physics
in orbit

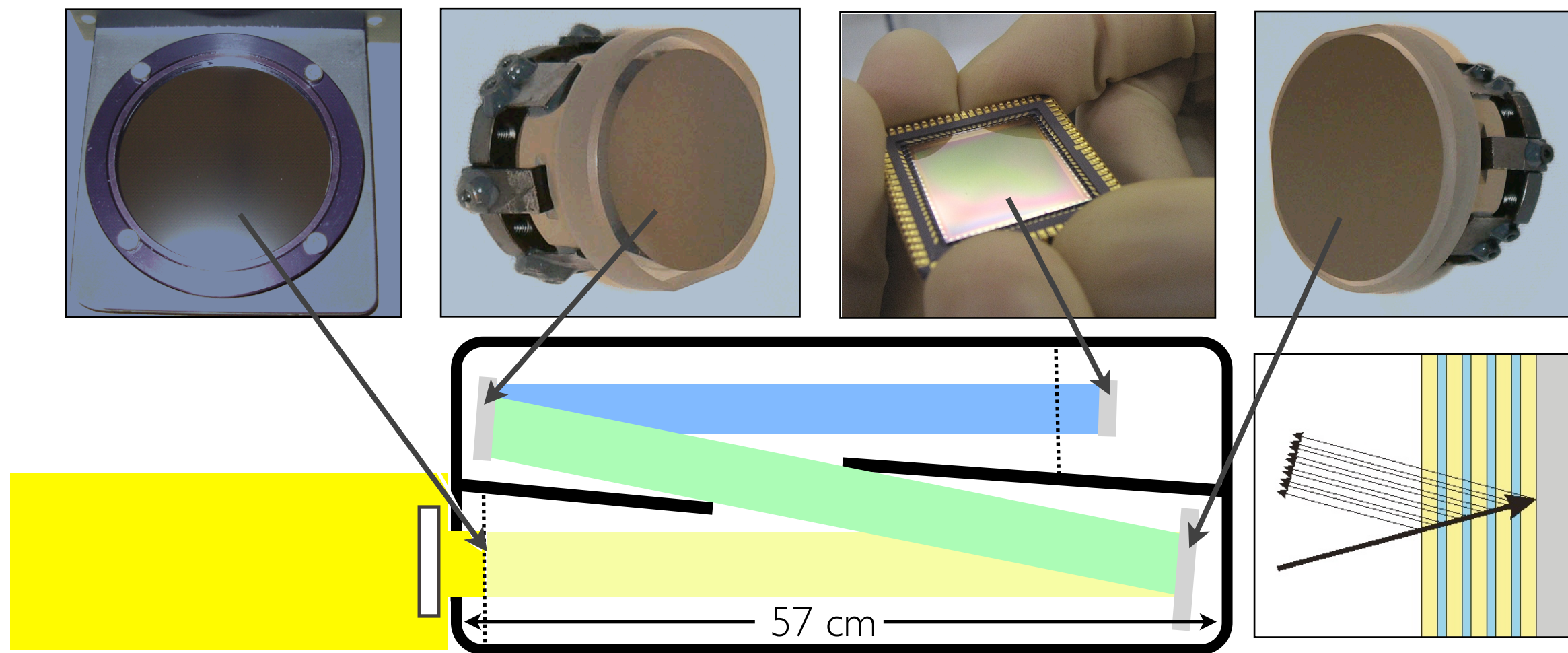


DEGRADATION

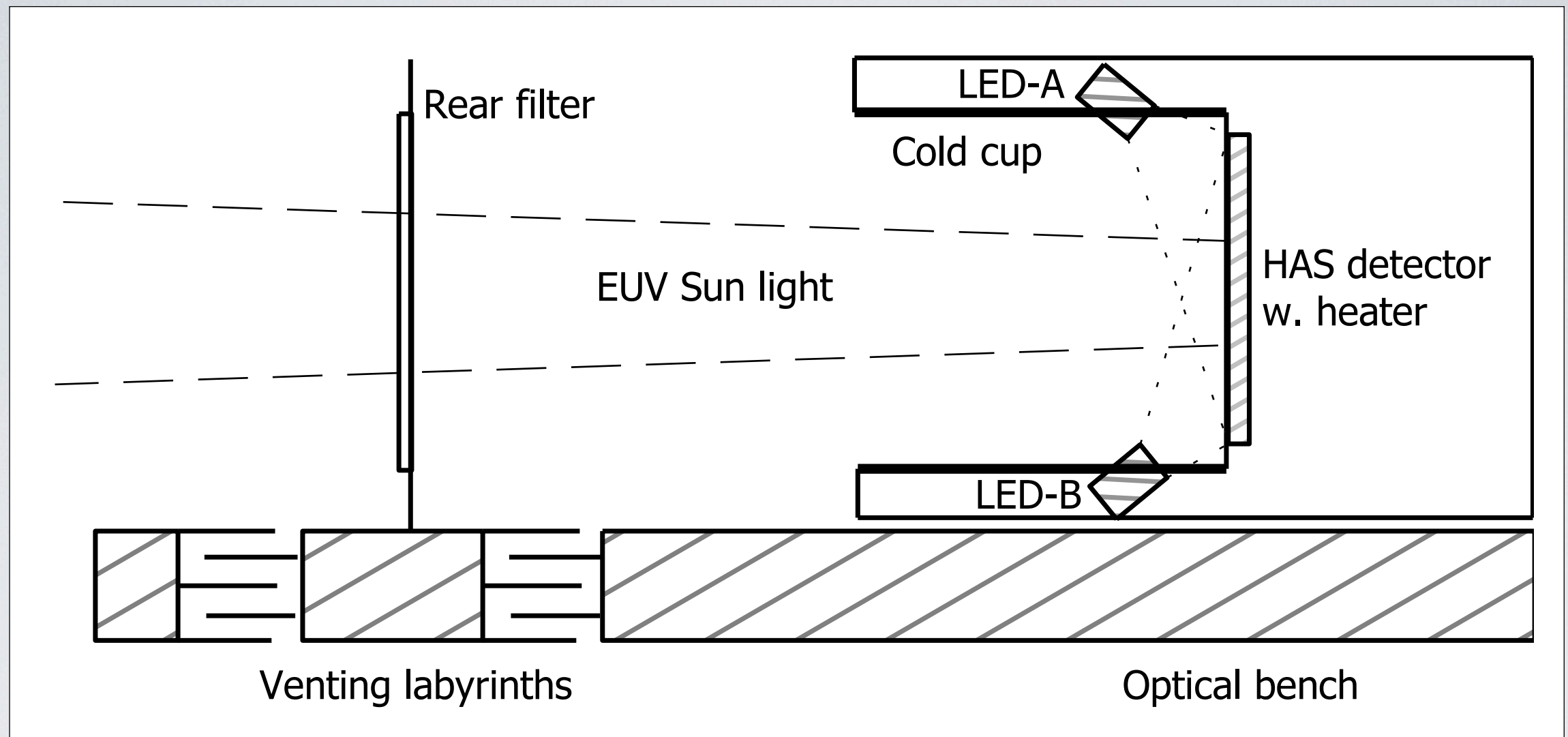
THREE TYPES OF DEGRADATION

- I. Optical Degradation
- II. Detector Degradation
- III. Spatially-Dependent Degradation

I. OPTICAL DEGRADATION

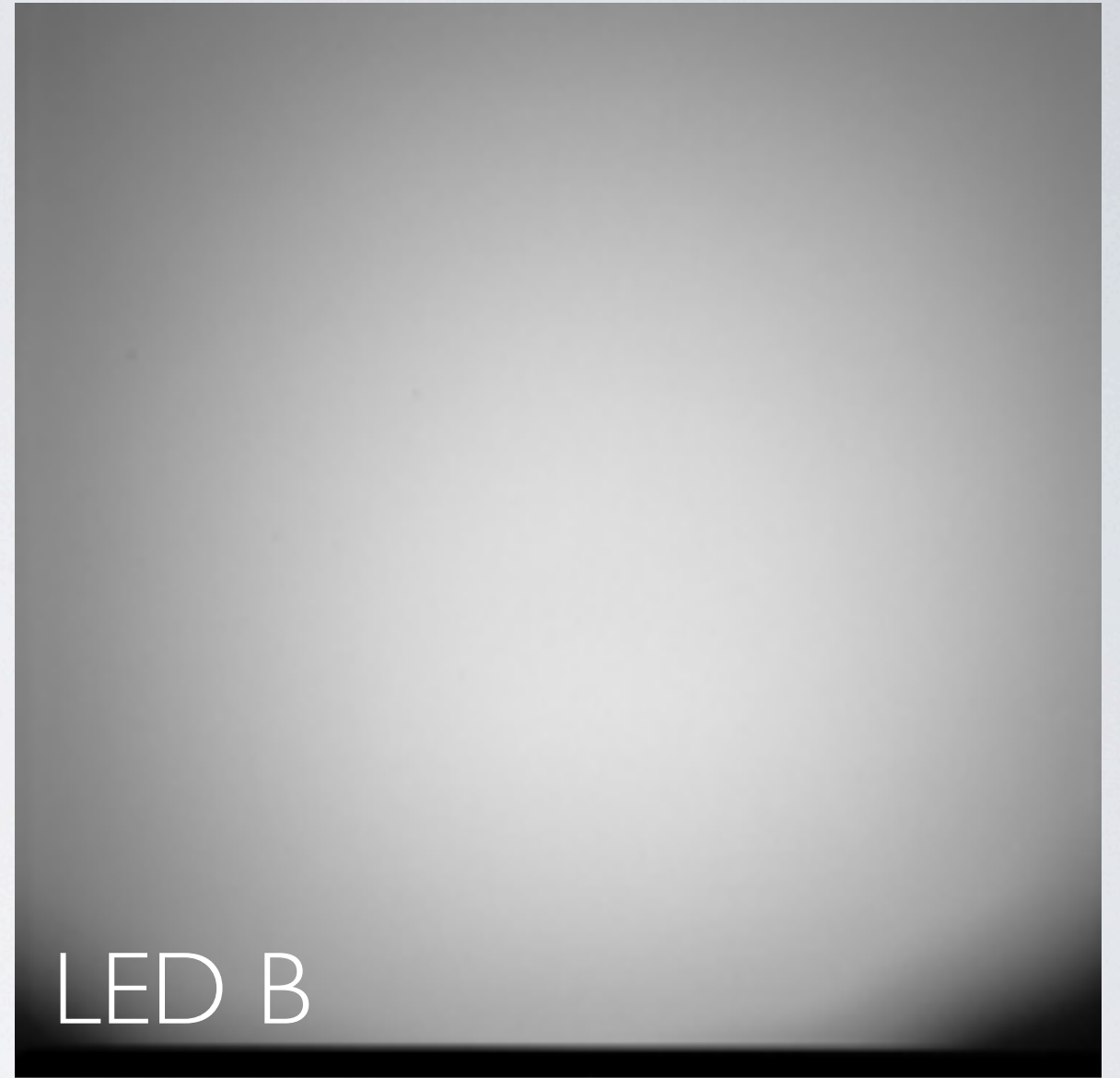
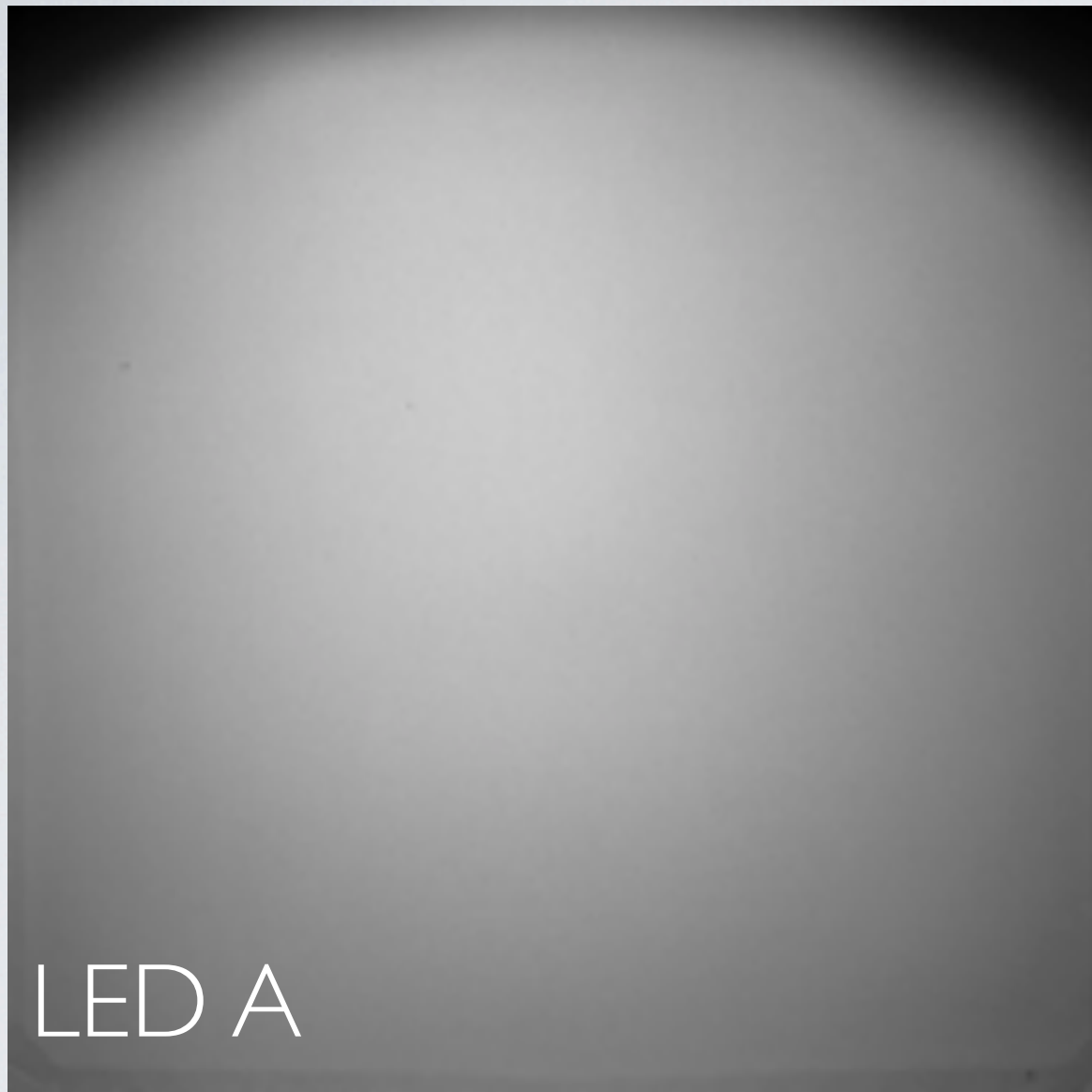


OPTICAL DEGRADATION

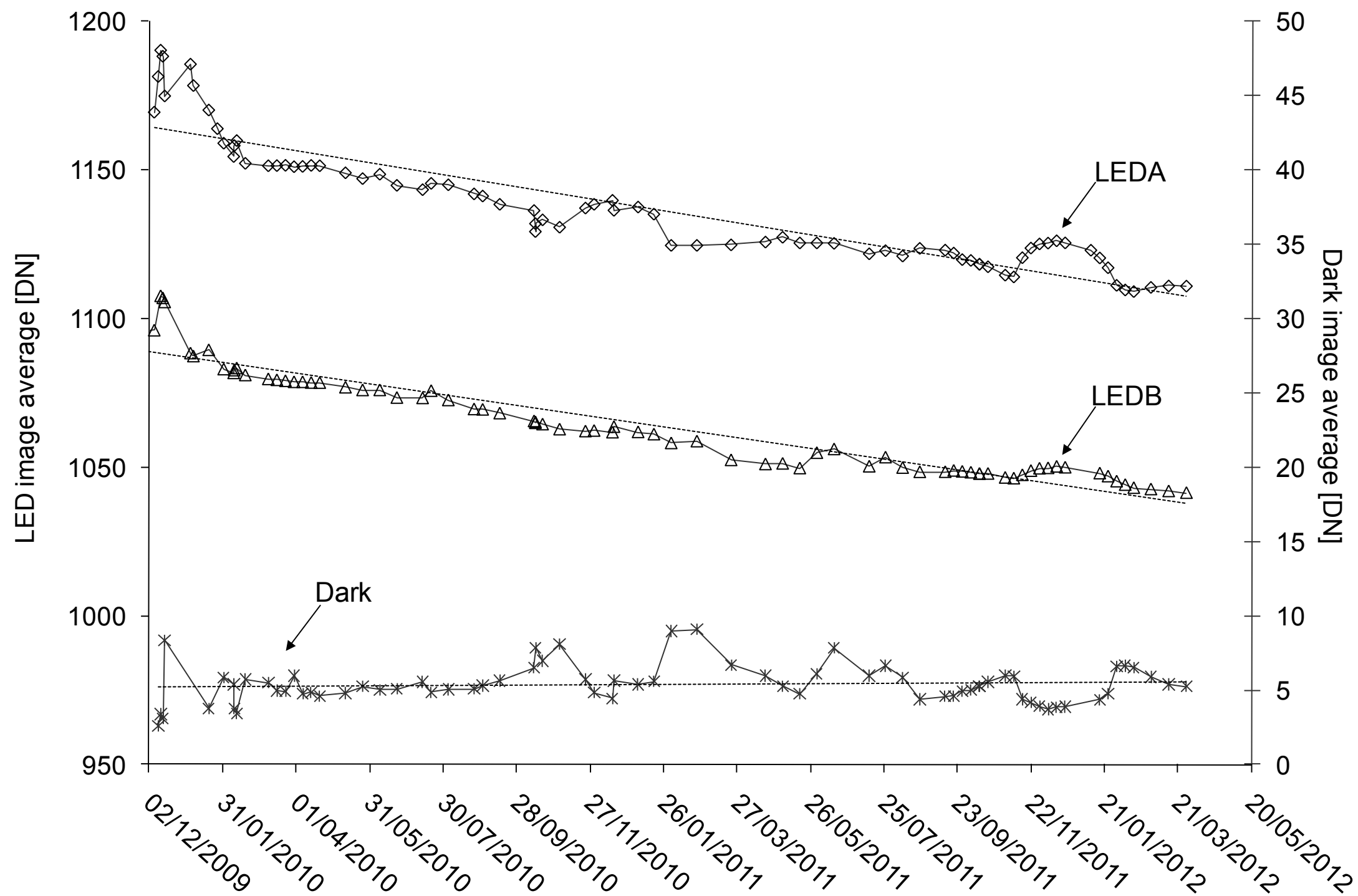


FOCAL PLANE ASSEMBLY

Two LEDs for Calibration



LED IMAGES



LED BRIGHTNESS EVOLUTION

PROBLEM I!

Cannot decouple changes in LEDs
from changes in SWAP itself.

PROBLEM 2!

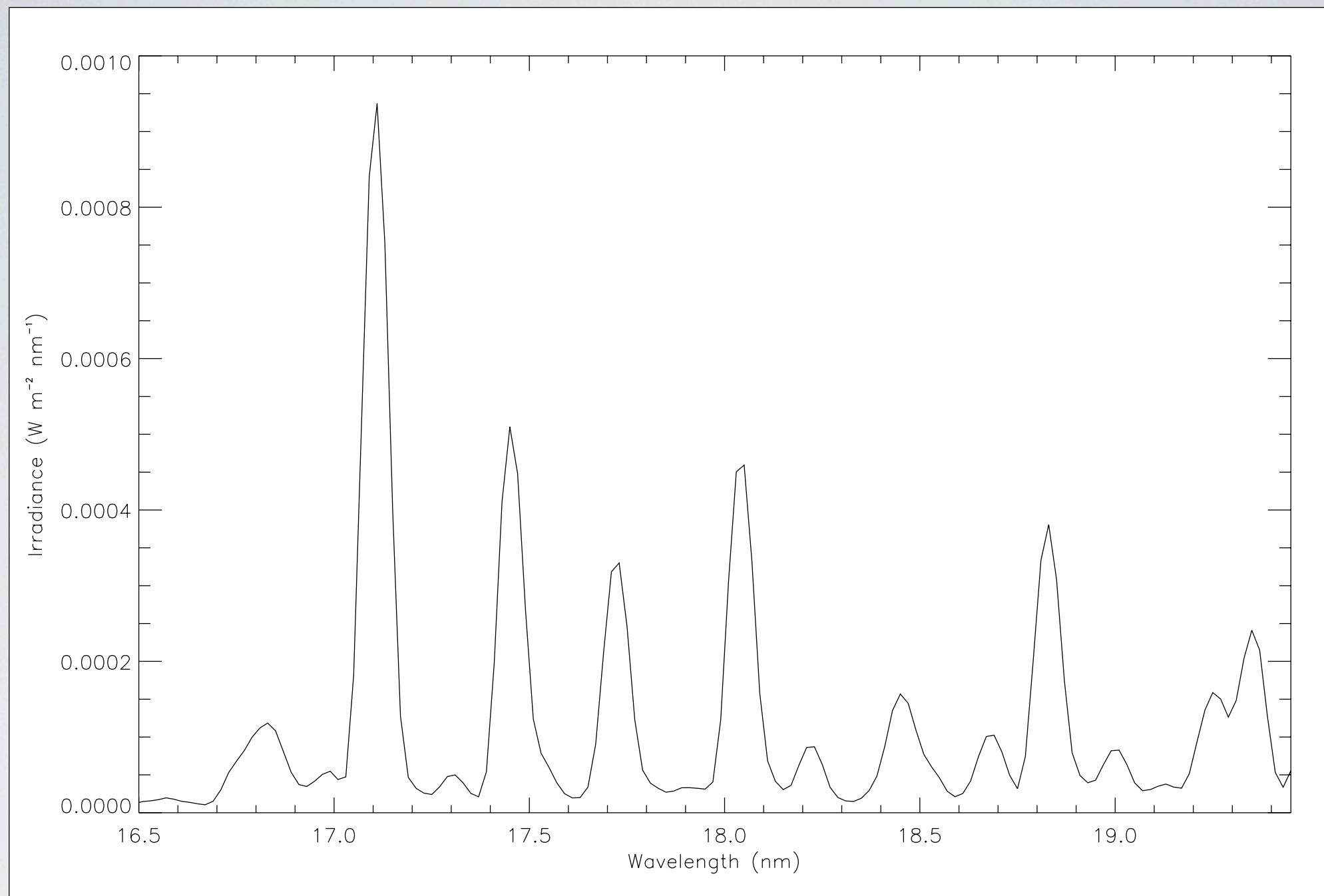
LEDs do not interact with any of the optical elements we would like to test.

SOLUTION

Use an external light source for this test.

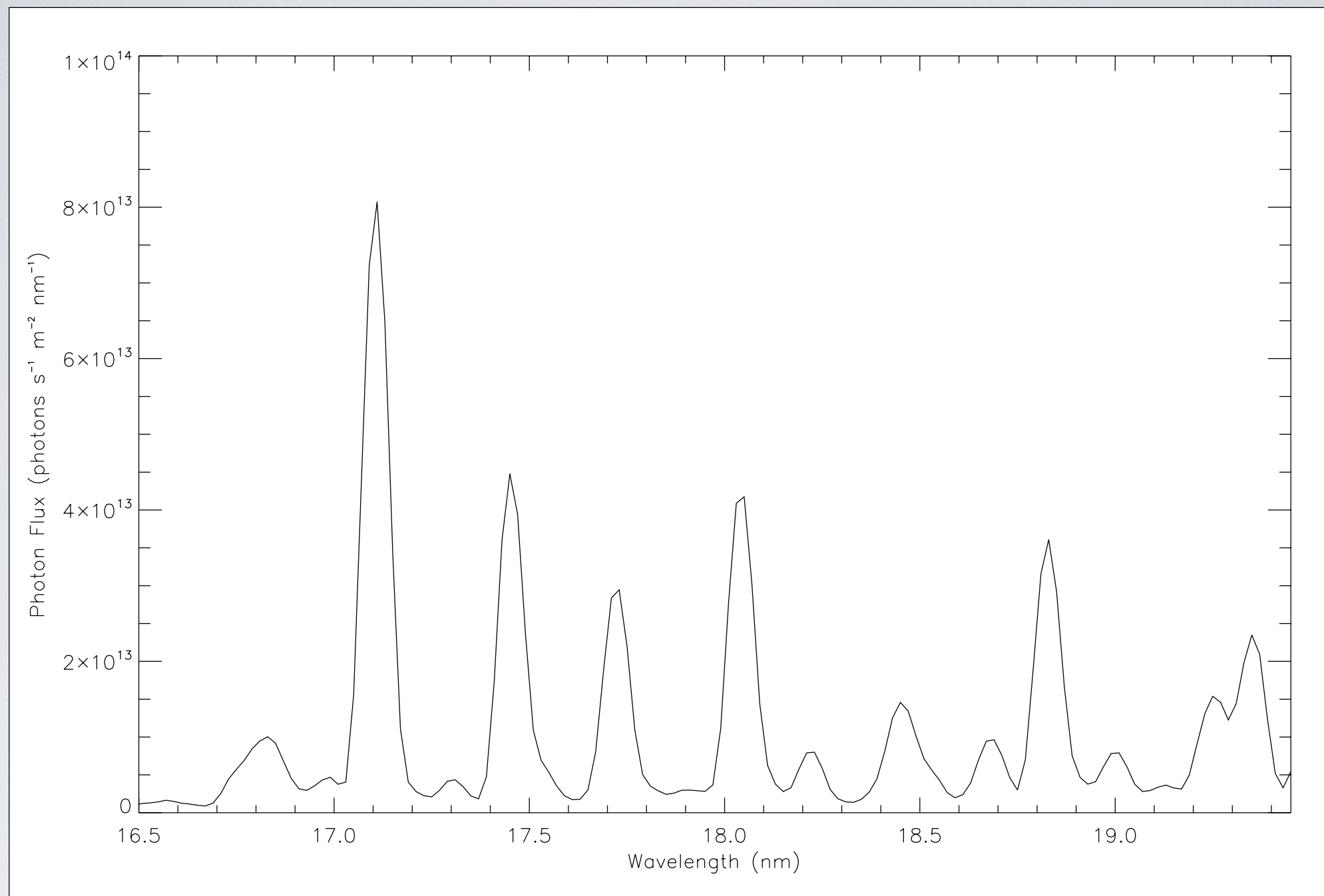
YET ANOTHER PROBLEM!

The only EUV source available to SWAP is the sun, which also evolves in time.



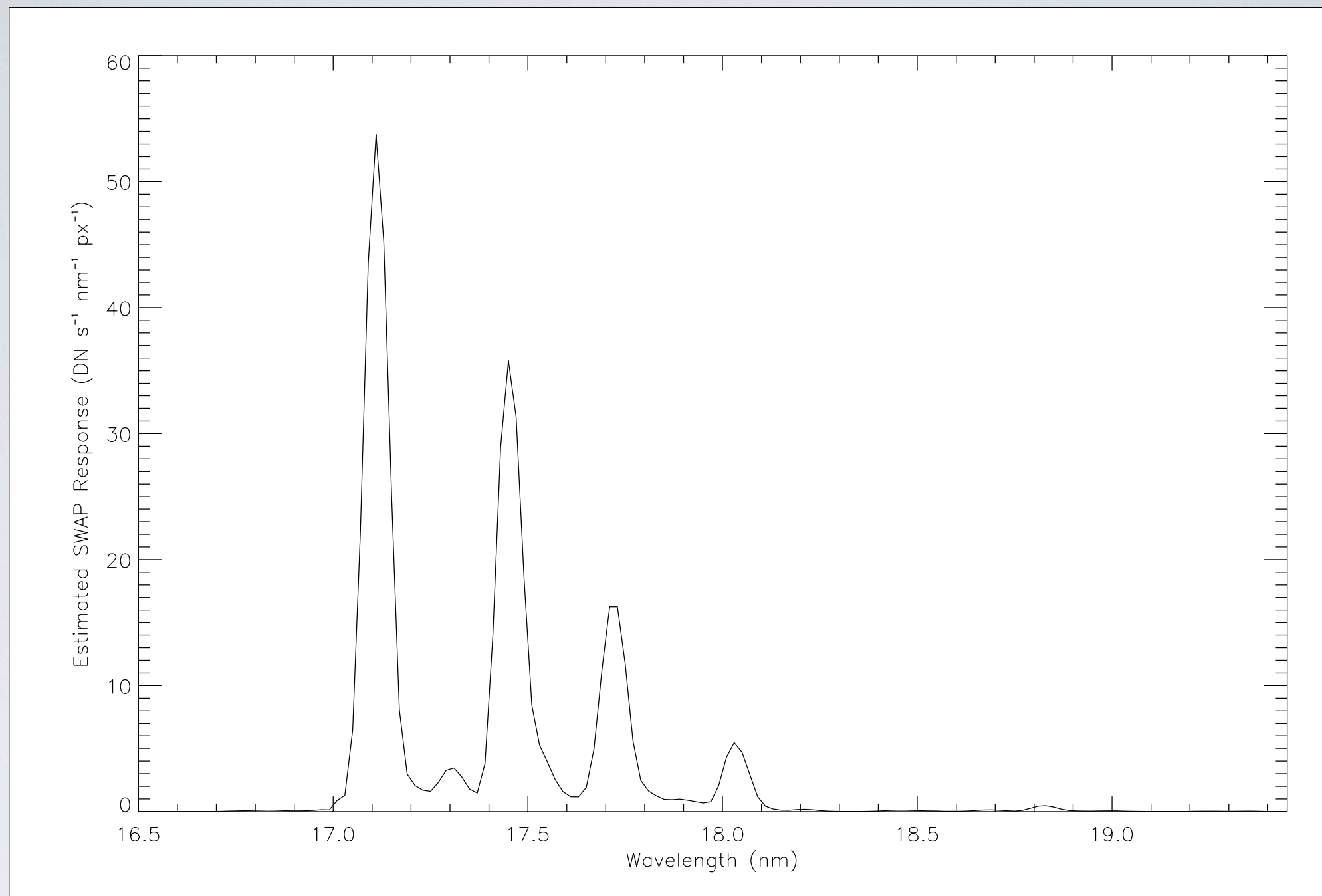
SOLAR IRRADIANCE

EVE Irradiance near SWAP Bandpass



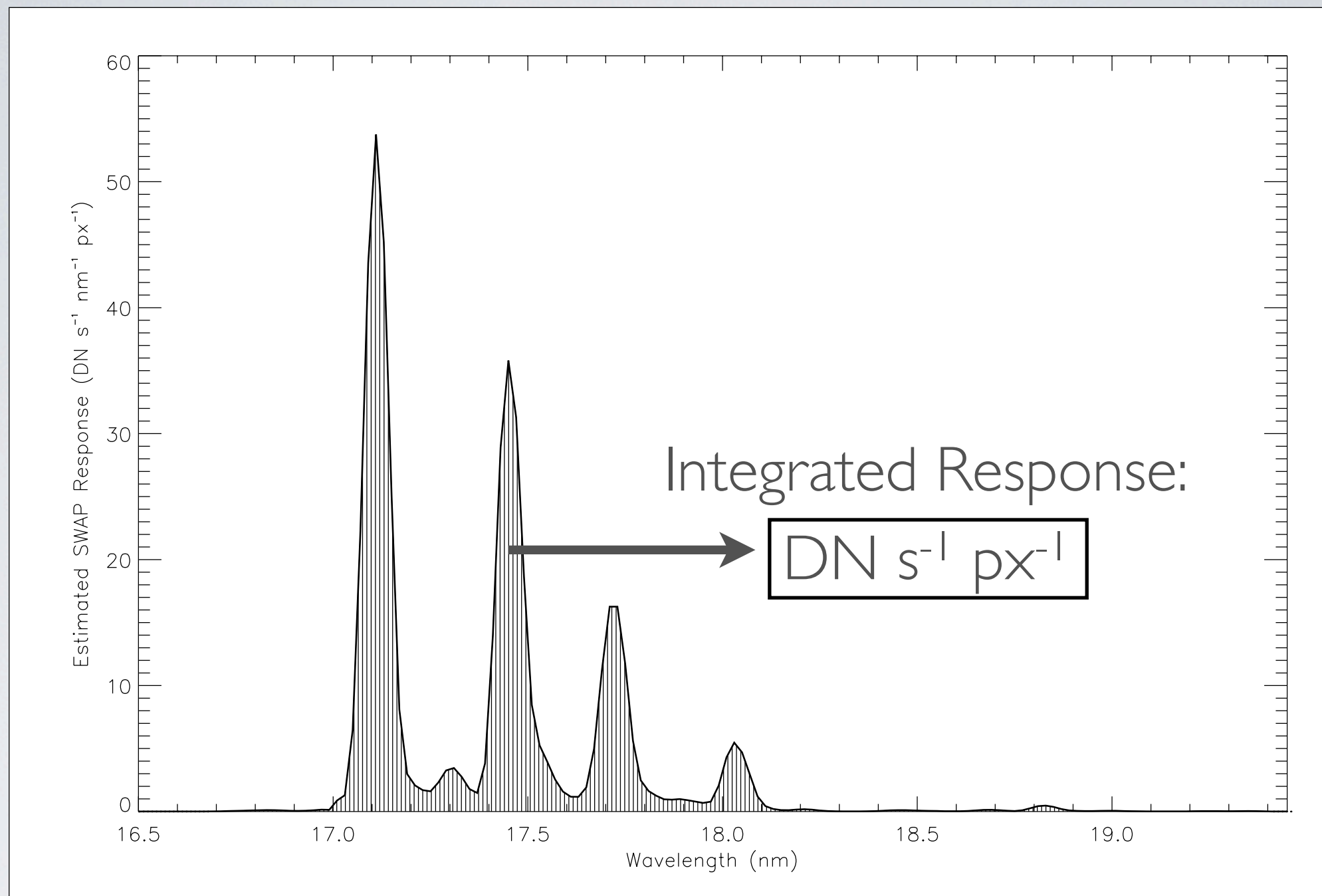
PHOTON FLUX

Photons s⁻¹ m⁻² nm⁻¹



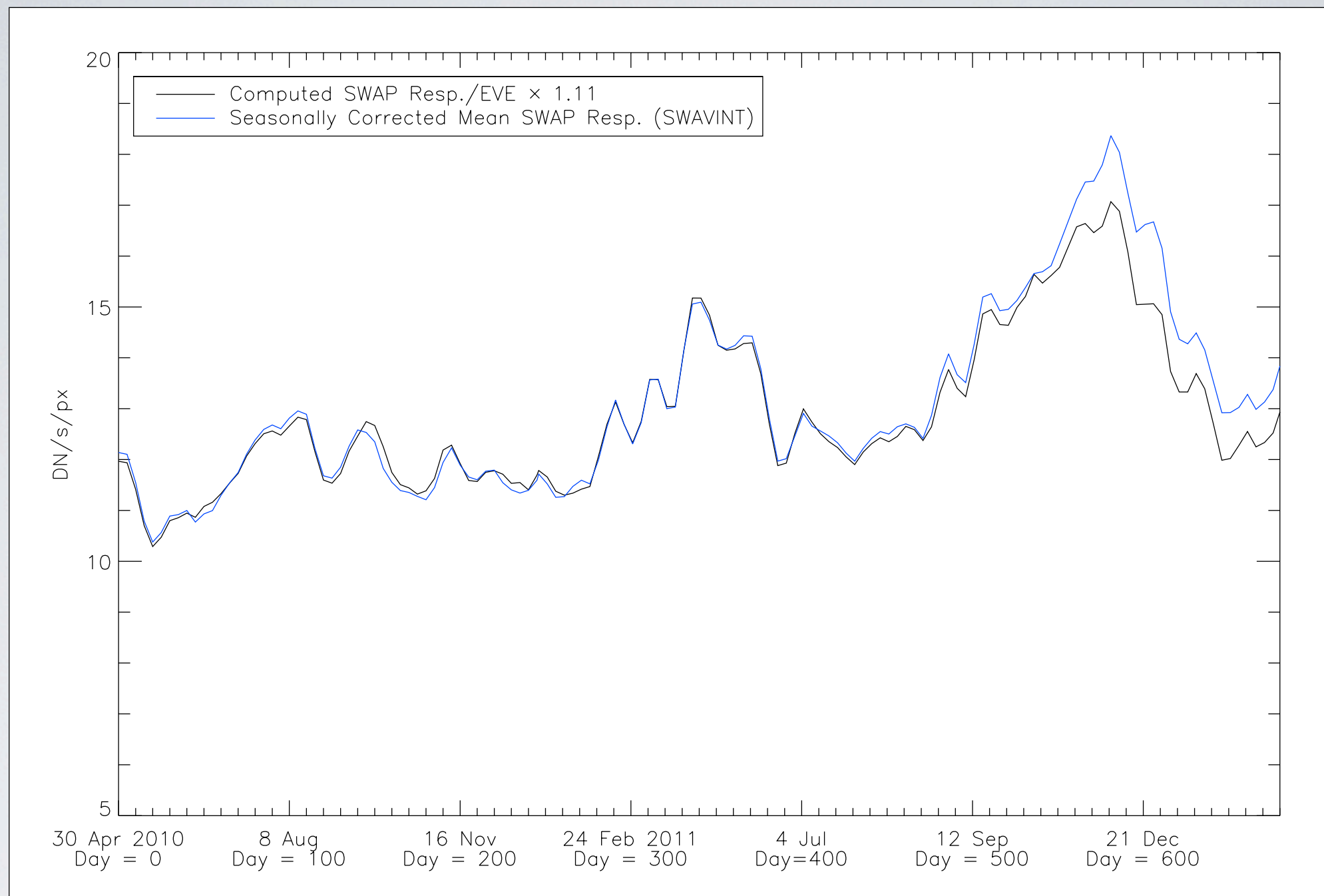
ESTIMATED SWAP RESPONSE

Photon flux modulated by SWAP bandpass



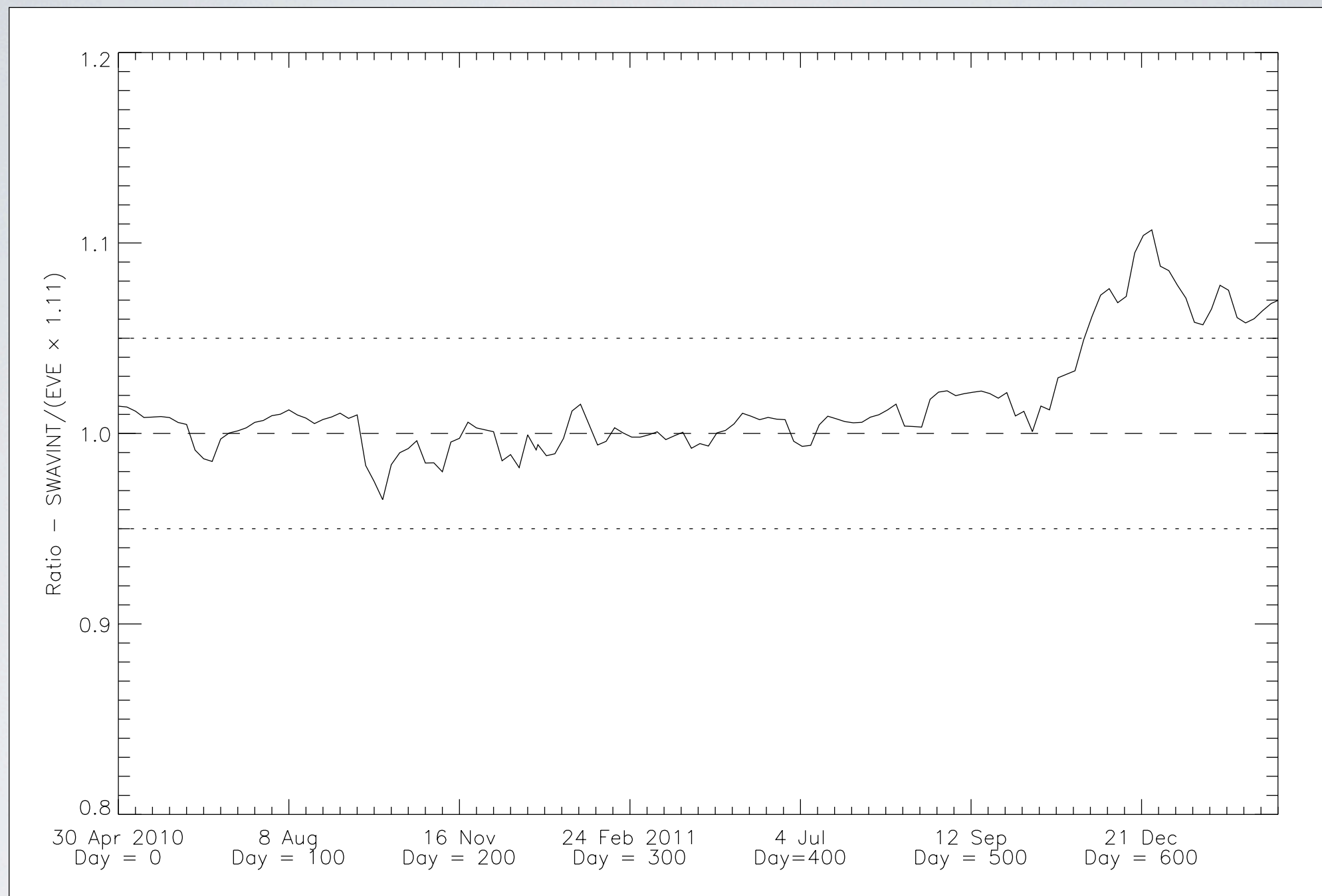
ESTIMATED SWAP RESPONSE

Photon flux modulated by SWAP bandpass



IRRADIANCE EVOLUTION

SWAP (Blue) vs. EVE (Black)



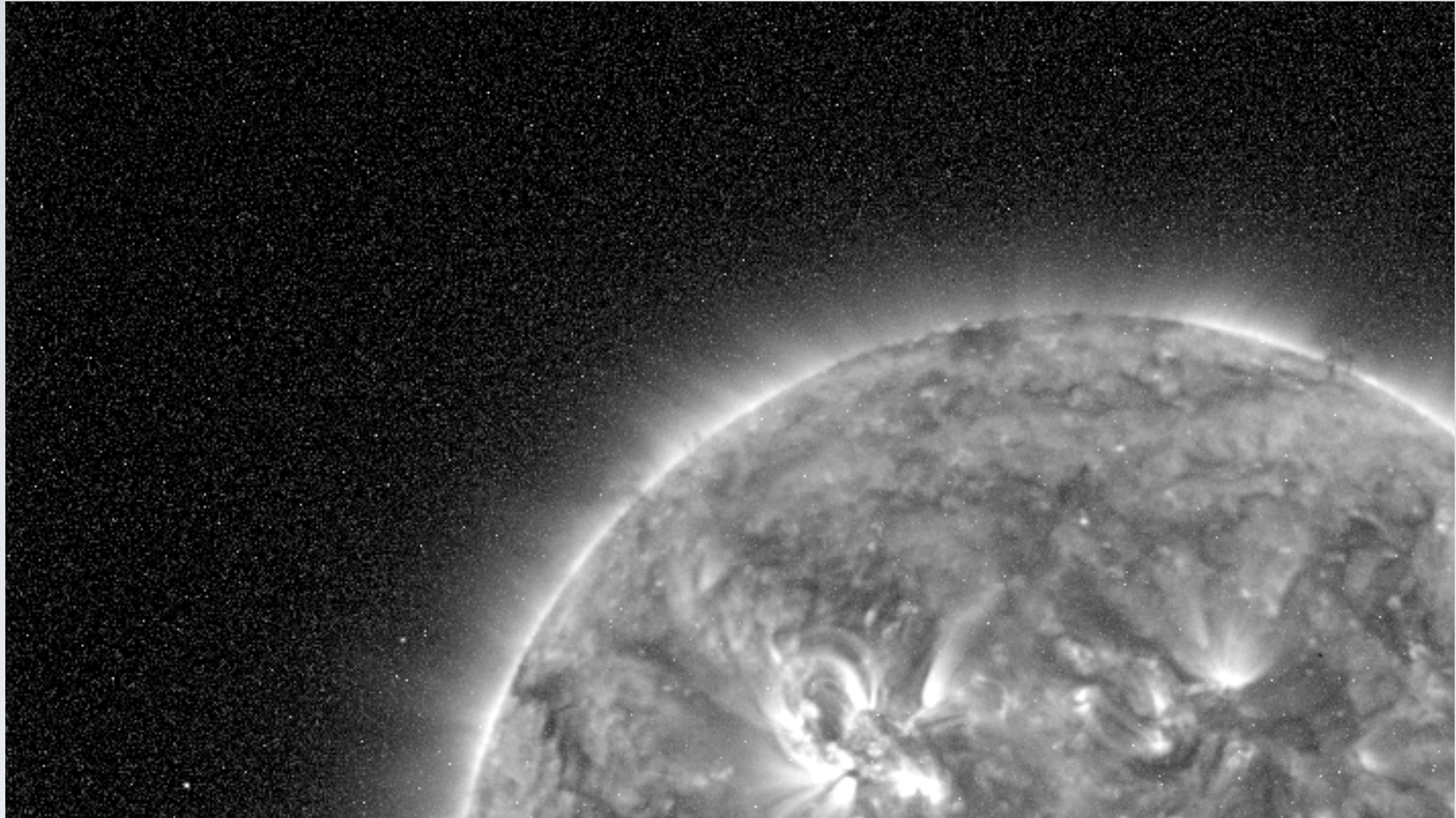
IRRADIANCE EVOLUTION

SWAP (Blue) vs. EVE (Black)

OPTICAL DEGRADATION

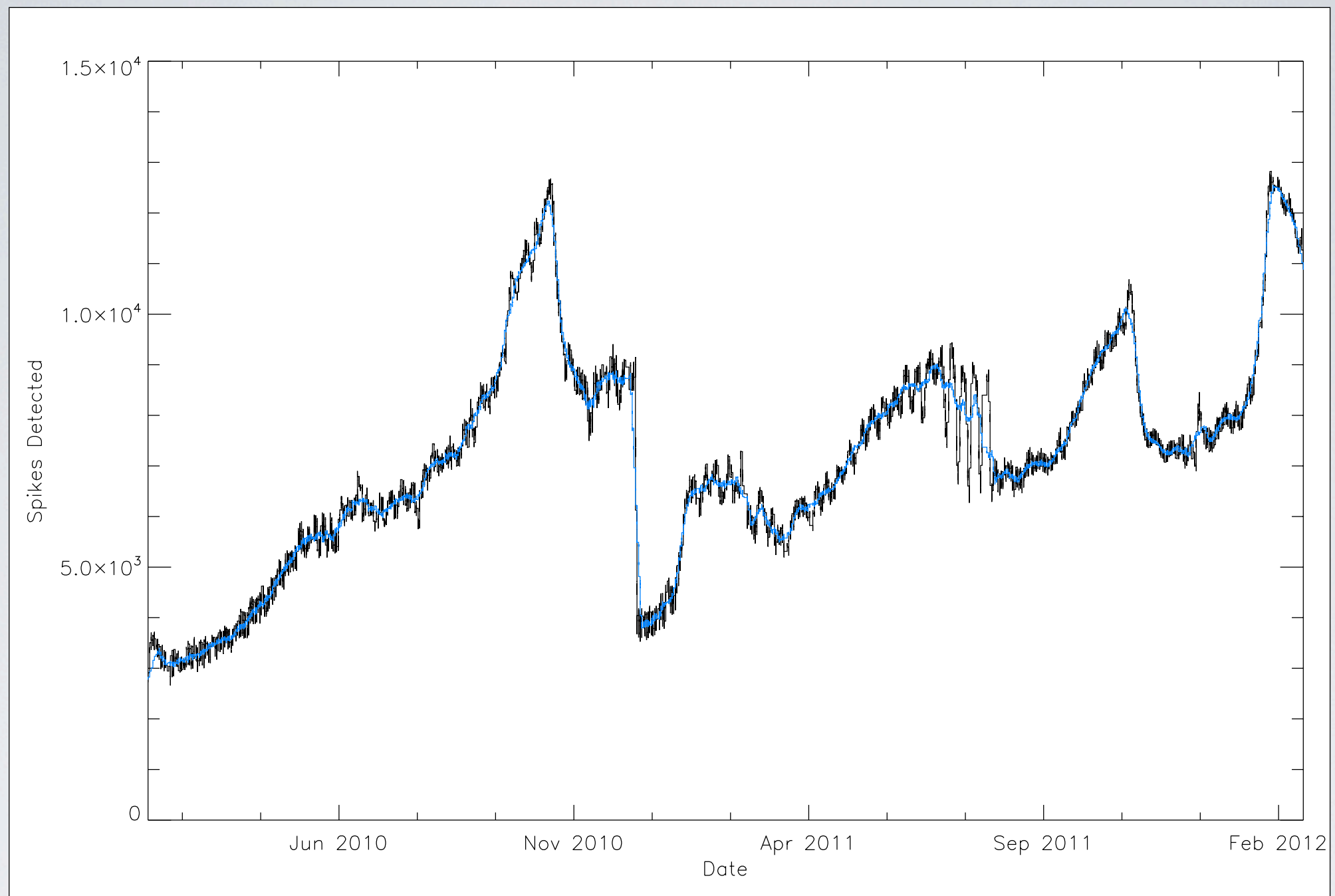
- SWAP optical path response is apparently not degrading
- EVE response may be degrading or changing
- More concrete conclusions are difficult—deep discussion with EVE team still needed

II. DETECTOR DEGRADATION



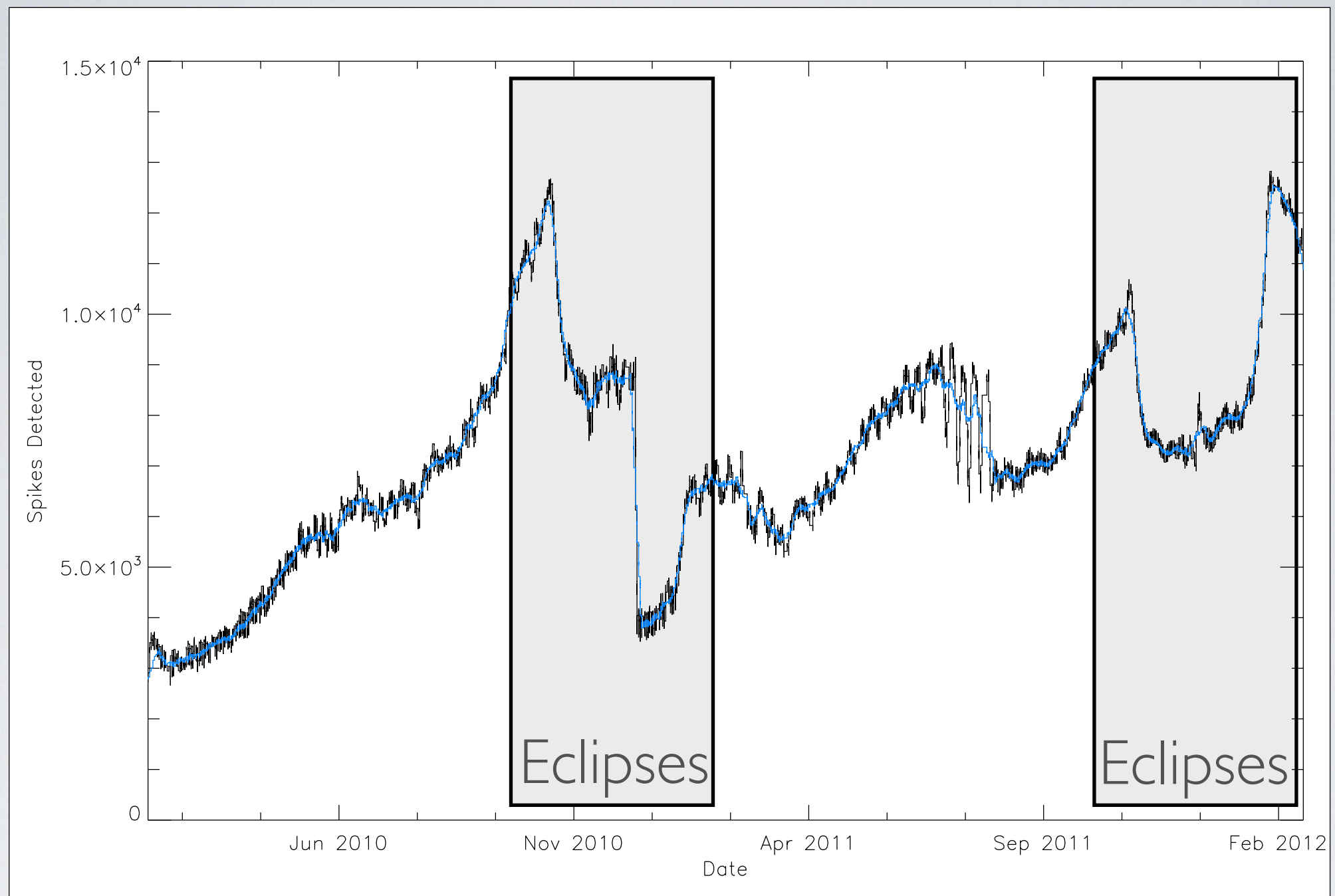
SWAP LEVEL-0 IMAGE

Bright pixels are removed during image calibration



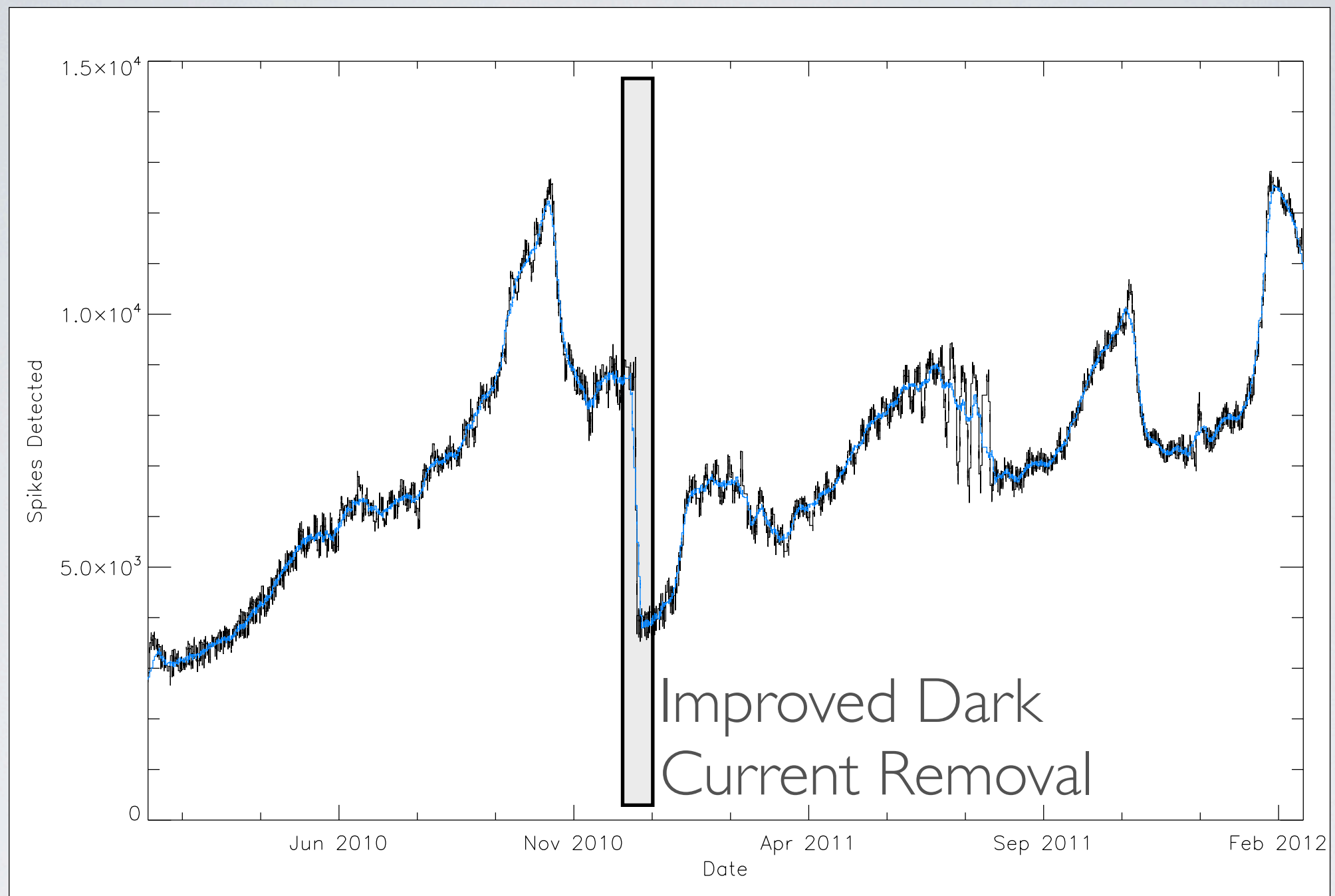
HOT PIXEL DETECTIONS

Rate of detections in nominal SWAP data images



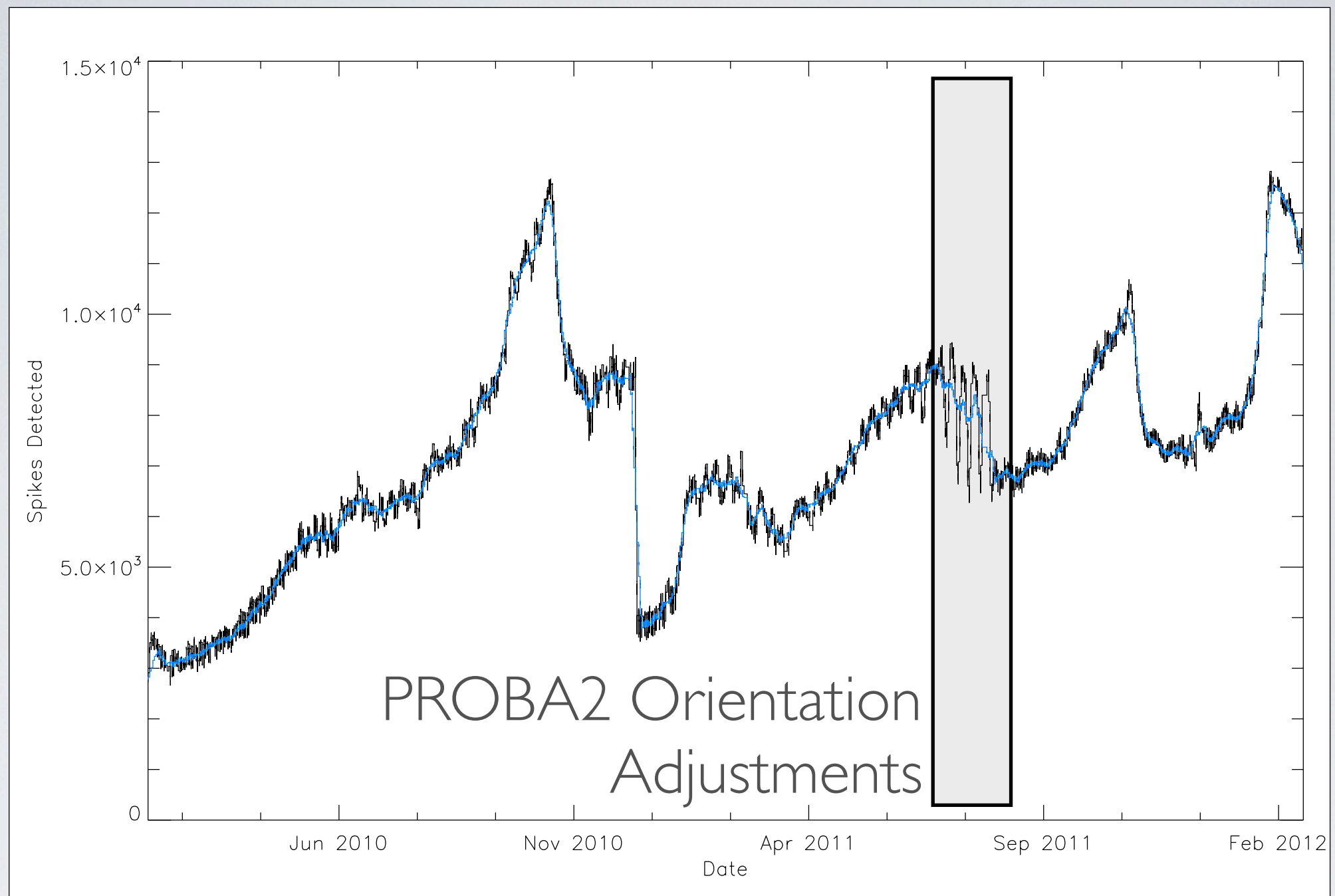
HOT PIXEL DETECTIONS

Rate of detections in nominal SWAP data images



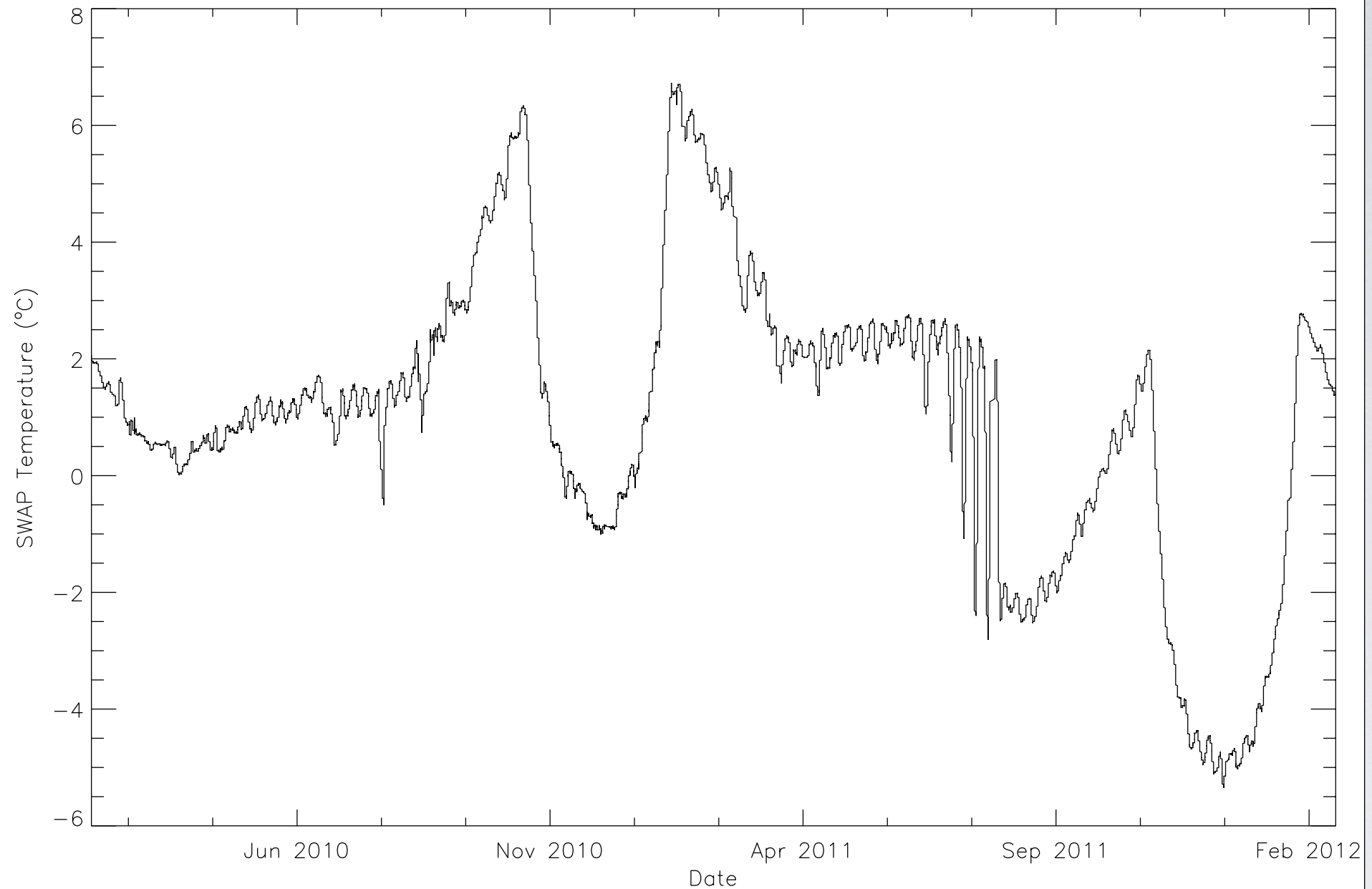
HOT PIXEL DETECTIONS

Rate of detections in nominal SWAP data images



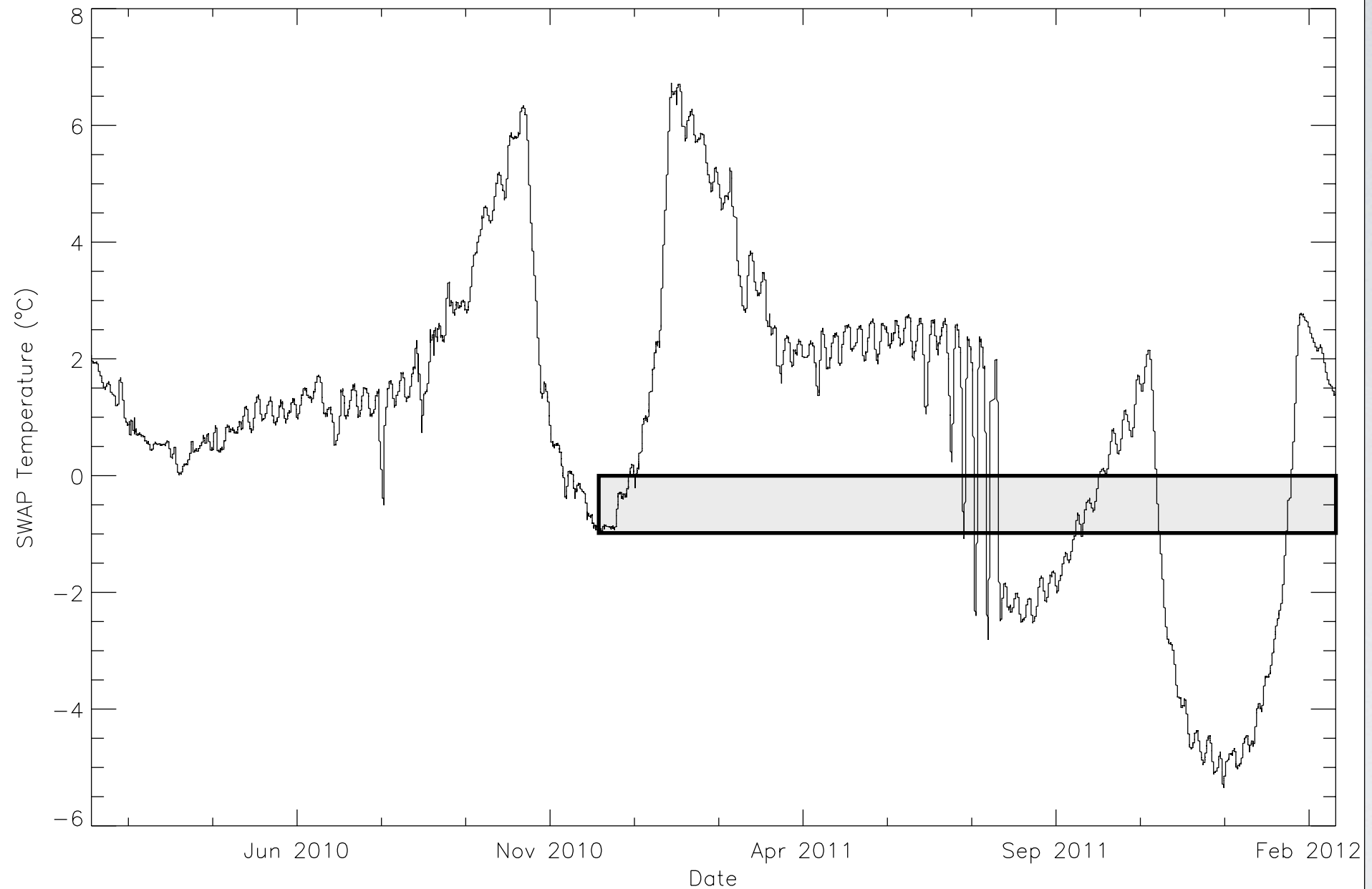
HOT PIXEL DETECTIONS

Rate of detections in nominal SWAP data images



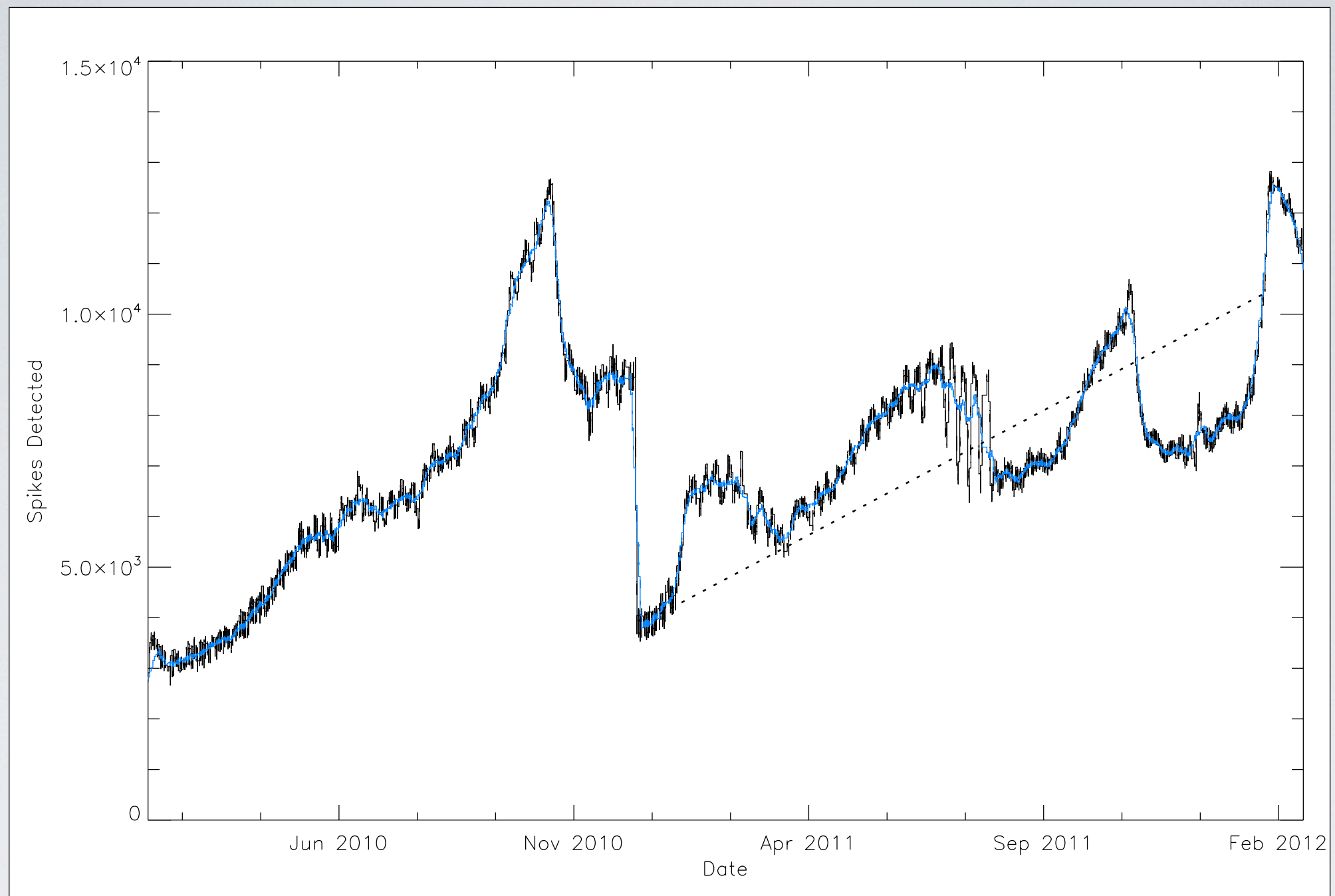
DETECTOR TEMPERATURE

Isolate periods of similar temperature



DETECTOR TEMPERATURE

Isolate periods of similar temperature



HOT PIXEL DETECTIONS

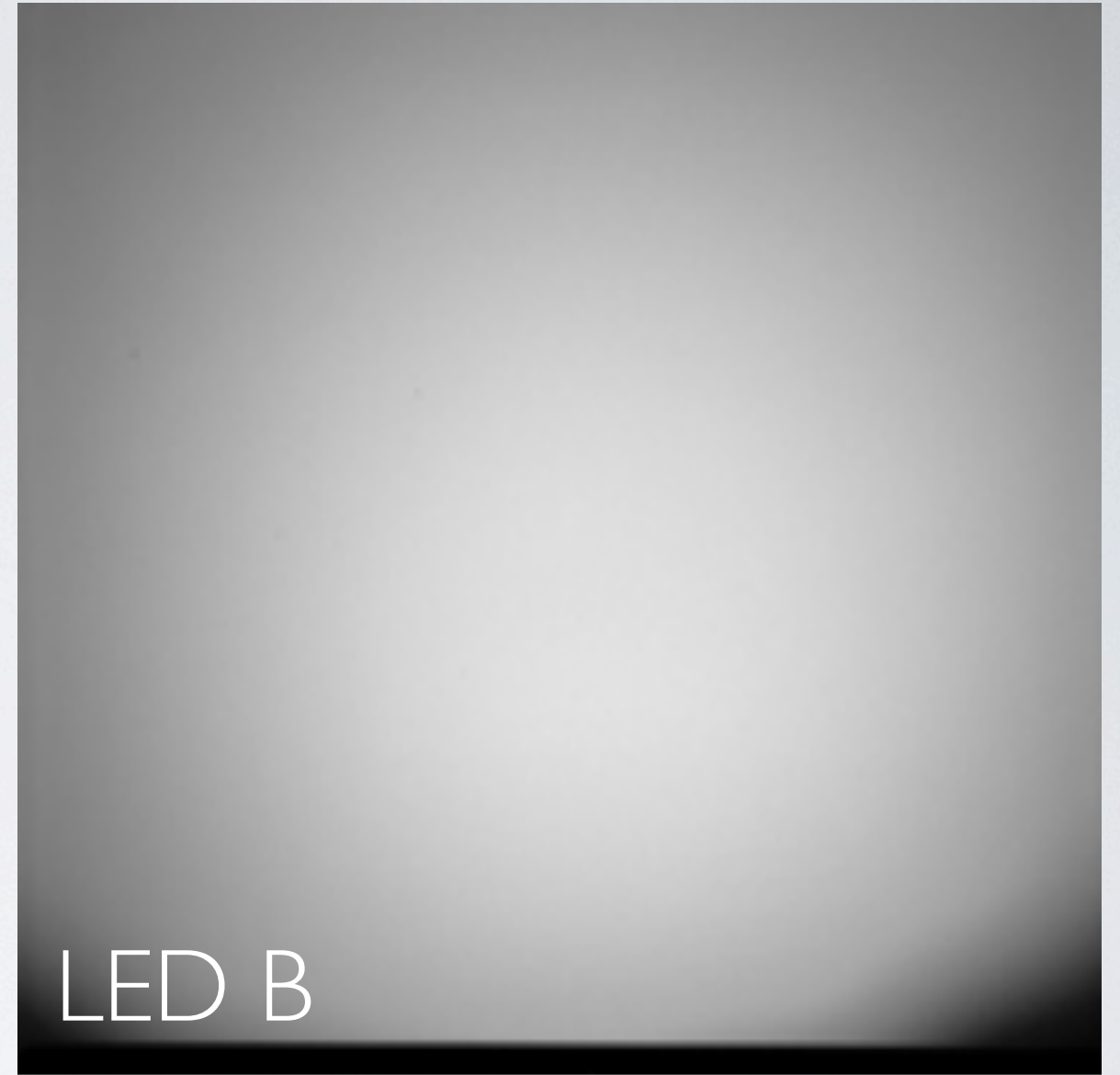
Slope = 16.7

Rate of Increase ≈ 6100 per year

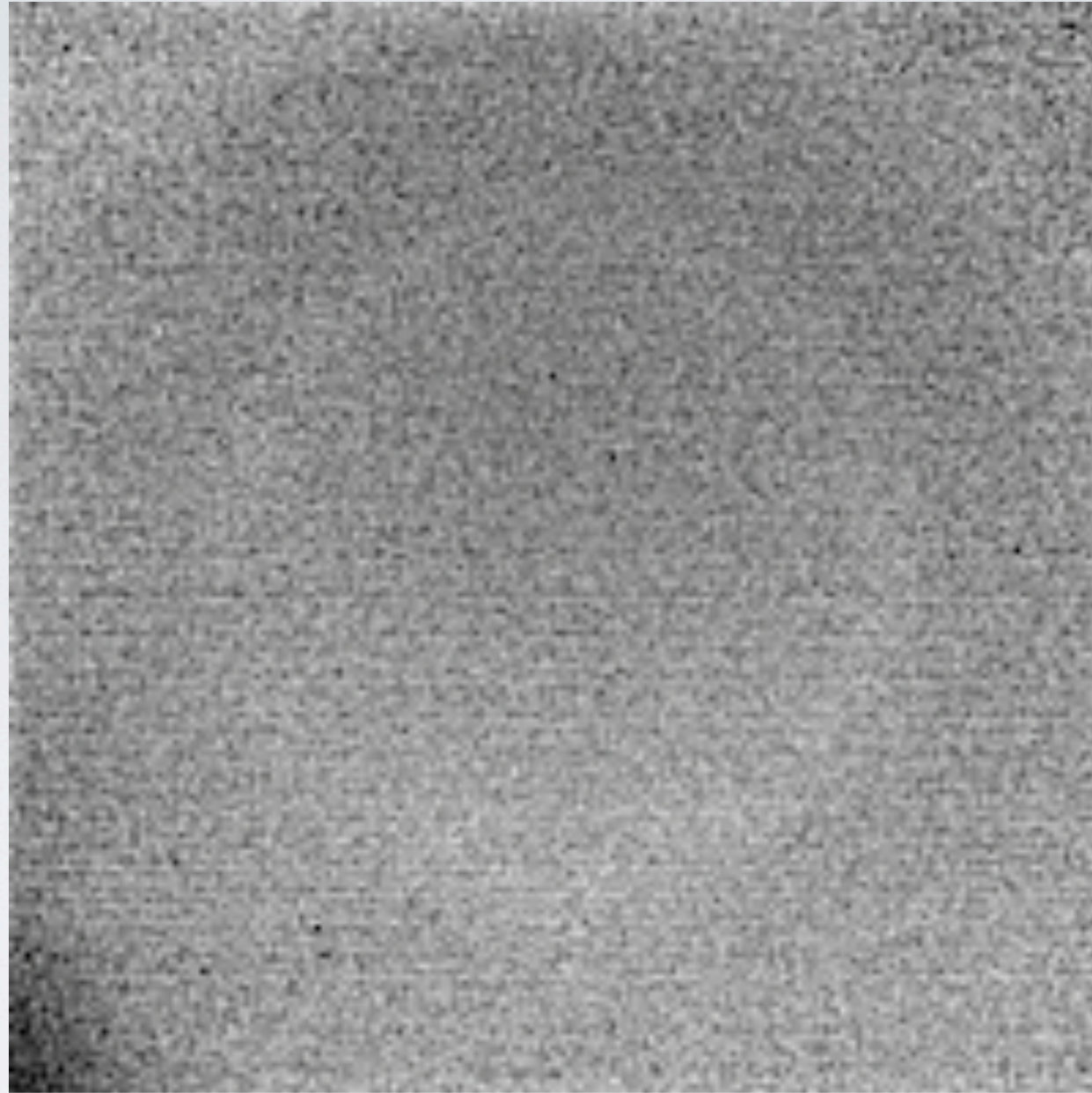
DETECTOR DEGRADATION

- Not all new spike detections are malfunctions
- Spikes are strongly related to evolution of dark current
- Spikes are also related to changes in calibration scheme
- **Detector is degrading at significantly less than 0.5% per year**

III. SPATIALLY-DEPENDENT DEGRADATION



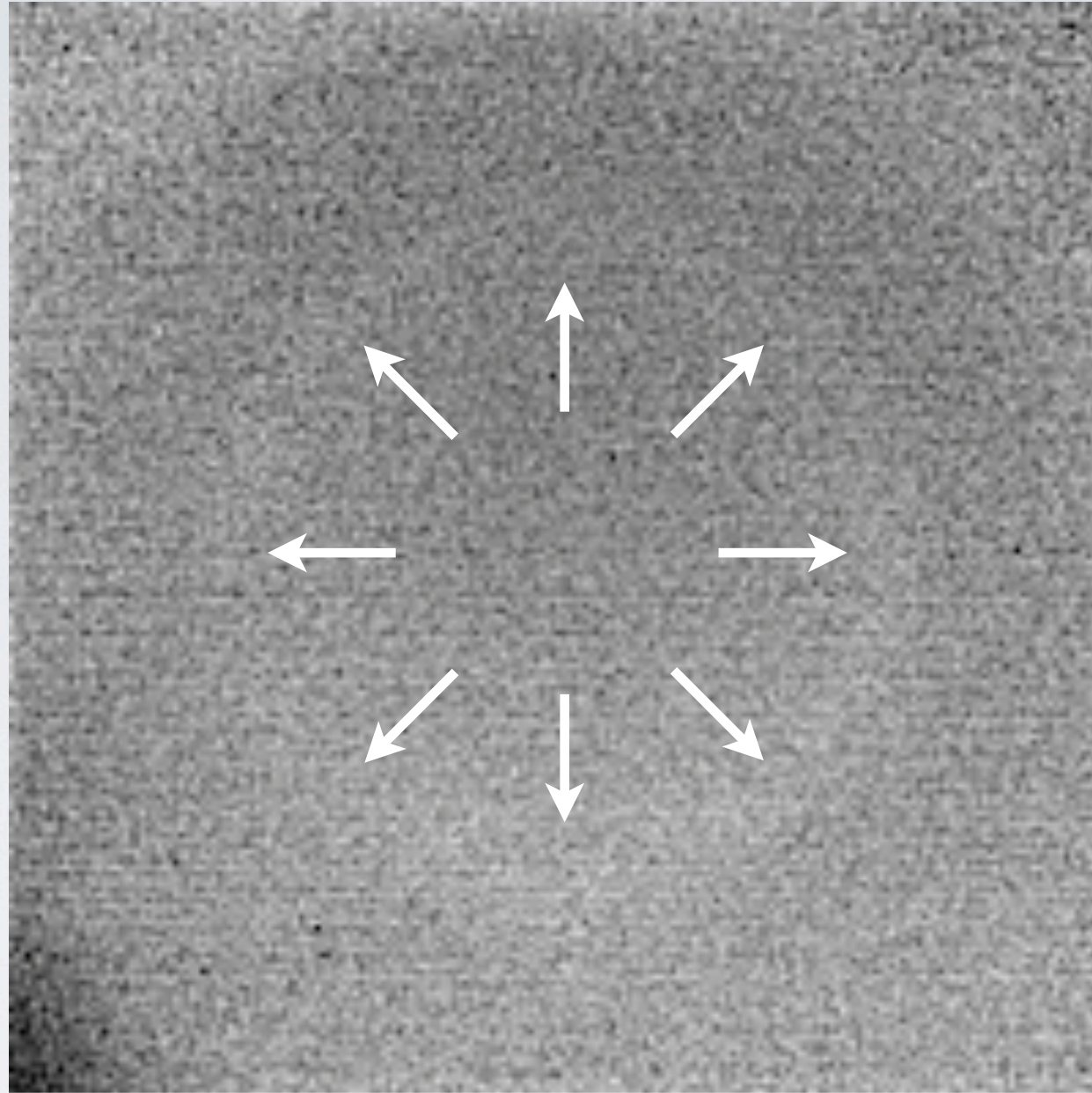
LED IMAGES



LED IMAGE RATIO

Image 1: April 2010

Image 2: Feb 2012



LED IMAGE RATIO

Image 1: April 2010

Image 2: Feb 2012

RING CHARACTERISTICS

- Decrease is $\approx 0.1\%$ of local LED image brightness
- Not seen in EUV images of the sun

POSSIBLE CAUSES

- Coating aging due to EUV exposure
- Change in response of detector
- Visible-opaque contaminant on detector/coating

CONCLUDING QUESTION:

Has SWAP degraded during its two-year mission?

No^{*}.

No^{*}.

*To within measurable limits for nominal images.