MEGS-B CCD Degradation and Revised Operation Plan

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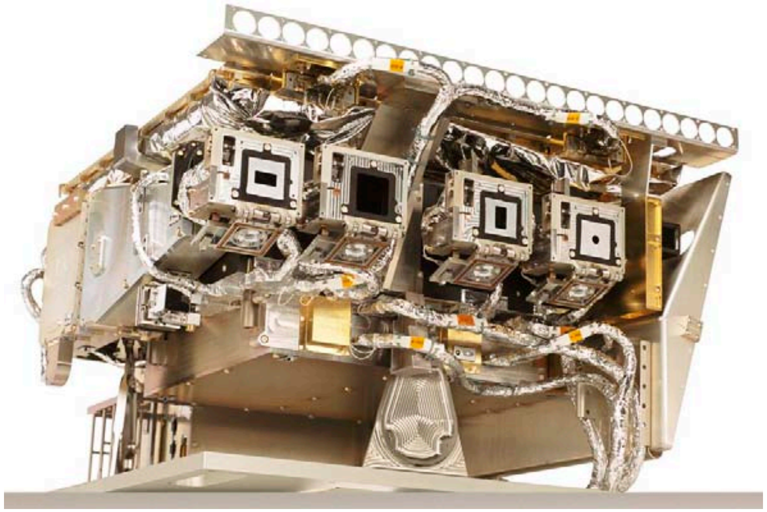
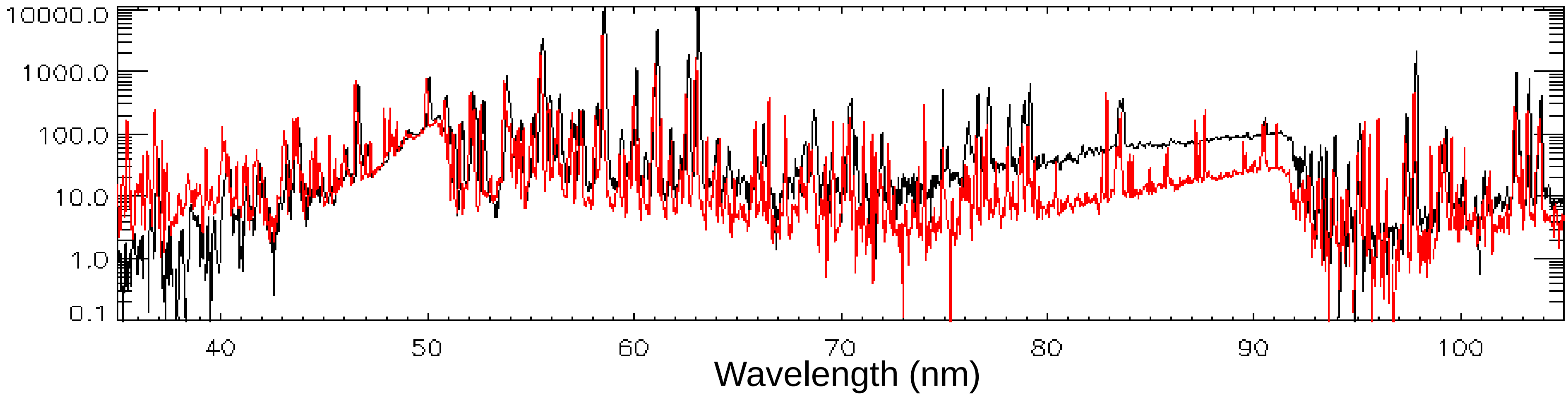


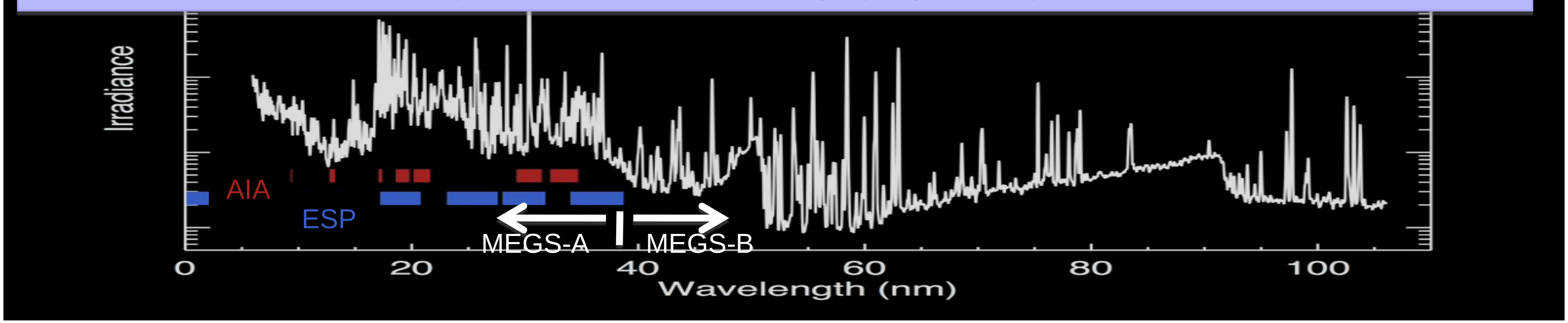
SDO EVE Instrument

MEGS-B has initial degradation at $\lambda > 70$ nm

- **MEGS-B Actual Signal (Red) is lower than Expected Signal (Black)**
  - Most notably for wavelengths longer than 70 nm and at bright solar lines.
  - Planning fewer MEGS-B solar observations to reduce its degradation rate.



Despite degradation, MEGS-B is making the best-ever solar EUV irradiance measurement. Note that EVE meets Level 1 requirements (measure 18 emission lines with 0.1-nm resolution, 25% accuracy, and 20-sec cadence) by operating either MEGS-A or B alone.

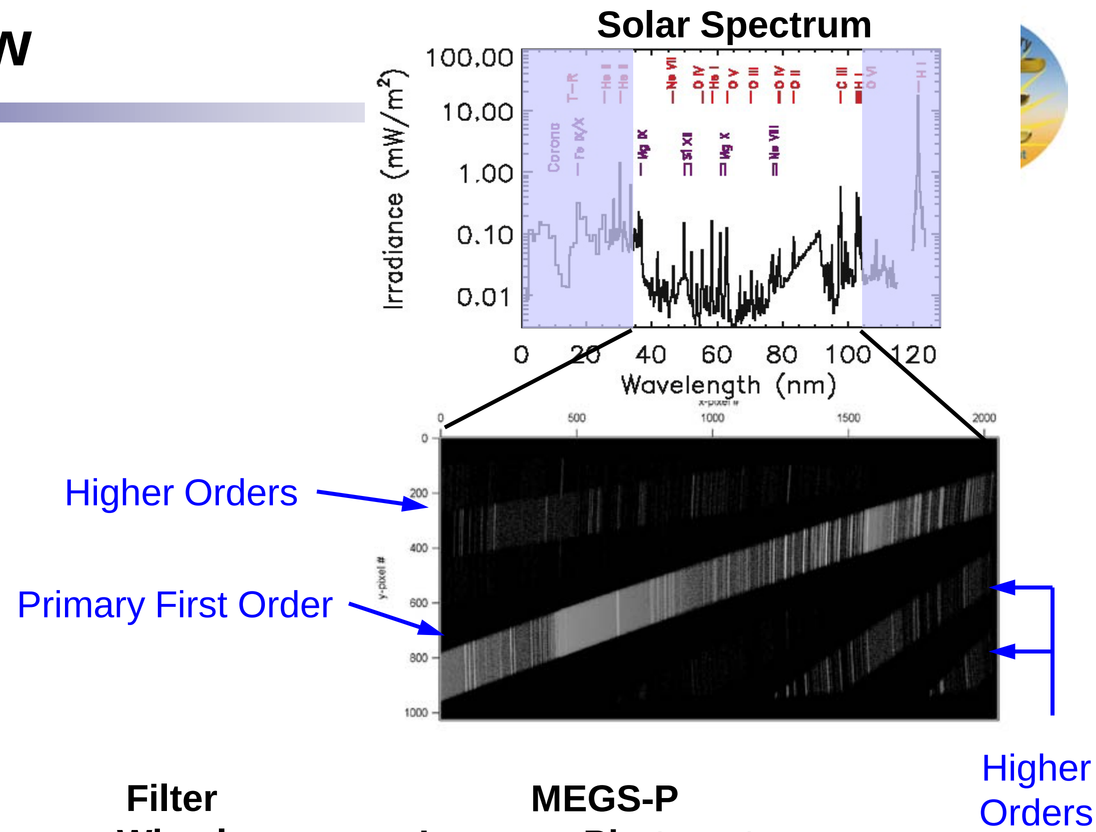


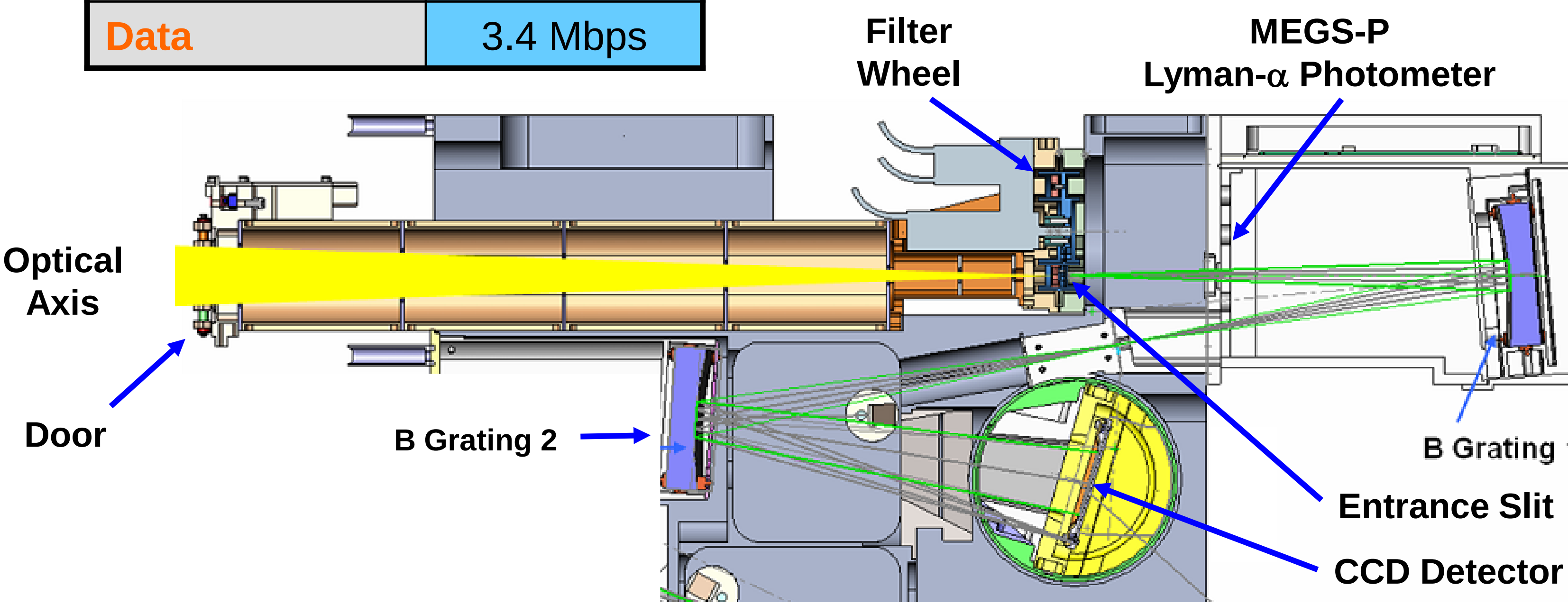
EVE Status

- **Started normal operations (24/7) on May 1, 2010**
- **First calibration rocket completed successfully (5/3/2010)**
  - Little, if any, initial degradation for MEGS-A, MEGS-P, SAM, and ESP
  - Larger than expected degradation for MEGS-B
    - Two phases of degradation:
      1. Initial degradation seen for first light: affects mostly 70-105 nm range
      2. CCD Burn-in of bright solar lines: effects seen in daily flatfield LED calibrations
    - From analysis and on-orbit tests, the cause appears to be mostly CCD charging
      1. Initial charging is possibly due to longer-than-expected stay in GTO or unknown charging prior to launch
      2. CCD burn-in is due to exposure to solar radiation (on top of initial charging)
      3. CCD bake-out helps with solar radiation burn-in but not with initial degradation
- **EVE MEGS revised observation plan**
  - EVE Level 1 science requirement specifies measurement of 18 emission lines. EVE was designed so that only MEGS-A or MEGS-B is required to operate continuously to meet comprehensive success criteria.
  - MEGS-A, SAM, ESP will run with 10-sec cadence (24/7) for flare monitoring.
  - MEGS-B revised plan includes 5-min observations once per hour to support space weather operations (I/T modeling). For supporting solar physics (flare) research, MEGS-B has a 3-hour block of solar observations each day and also can plan a 24-hour flare campaign about once per month.

MEGS-B Overview

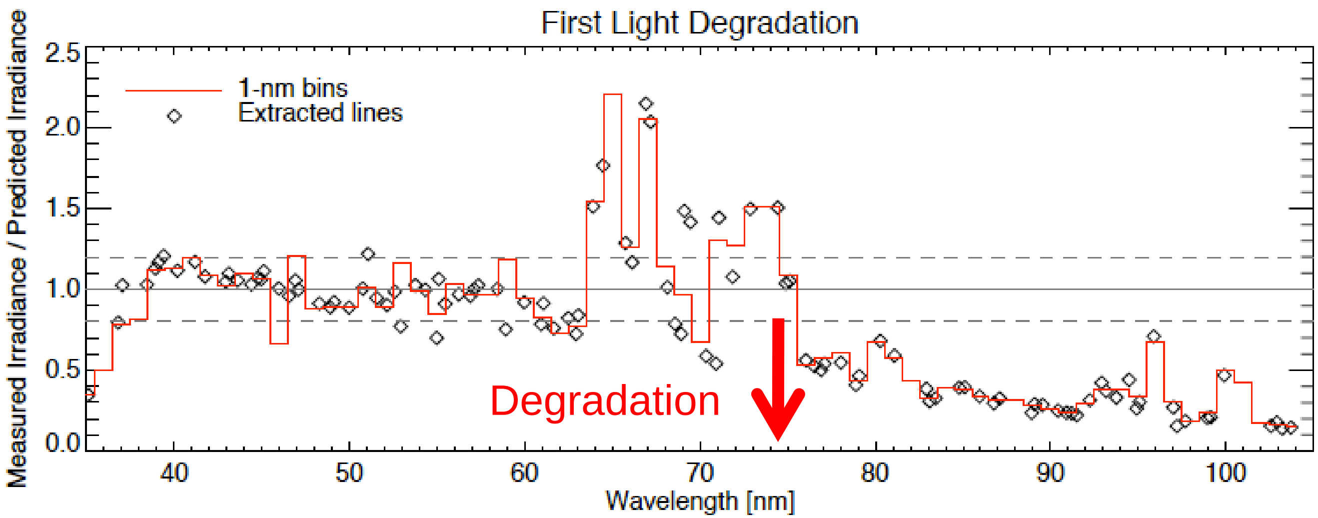
λ Range	34 - 105 nm
Δλ Resolution	0.1 nm
Time Cadence	10 sec
Field of View	±2°
Aperture Door	One-shot
Filter Wheel	5 positions
CCD Detector	1024 x 2048
Power	11 W
Data	3.4 Mbps



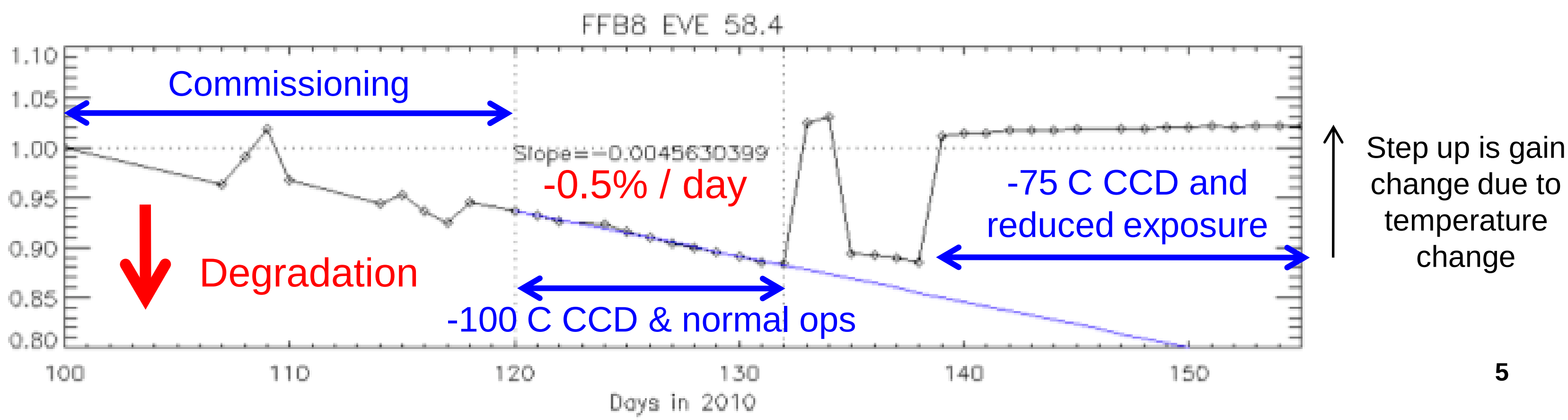


Two Phases of MEGS-B Degradation

- **First Light Degradation**
  - Solar signal smaller than expected in 70-105 nm range

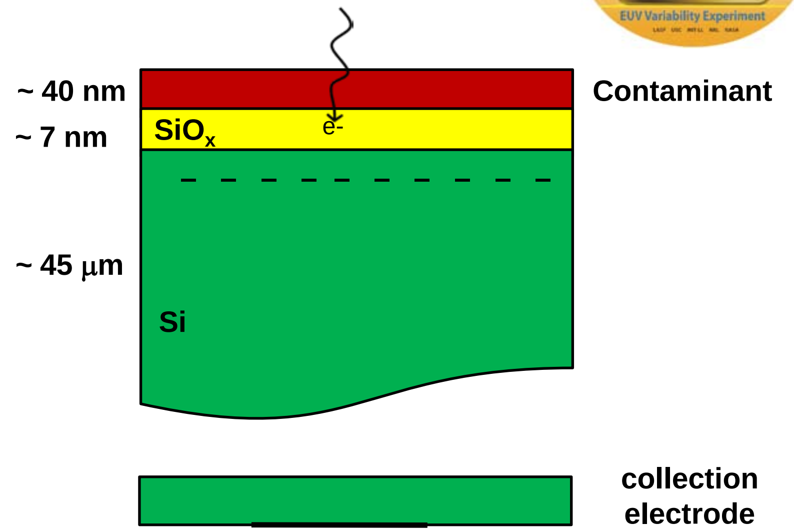


- **Burn-in of bright solar lines into CCD since first light**
  - Burn-in seen in both flat-field (FF) LED images and for solar observations

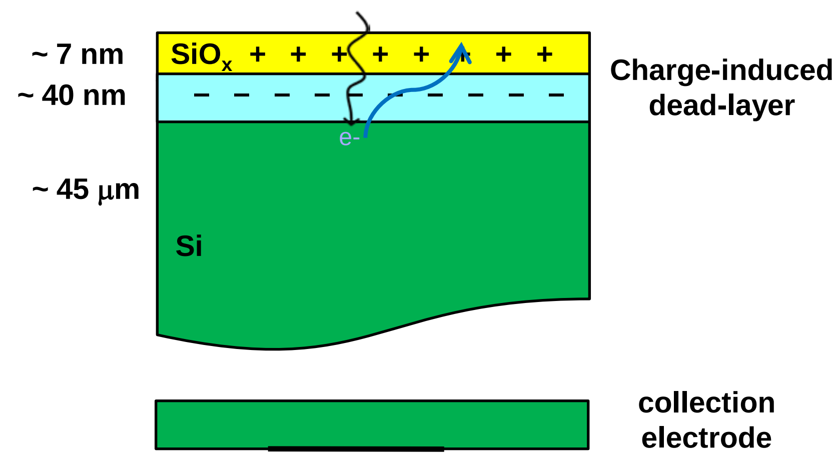


Possible Degradation Scenarios

- **Contamination Since Calibration**
  - Degradation amount suggests about 20 nm of contaminant on CCD or gratings. Pre-flight monitoring indicates less than 10 nm.
  - Possible sources from EVE itself, purge gas, propulsion.
  - Mitigation: bake-out CCD



- **CCD Charging**
  - Top layer (SiOx and/or contaminant) can charge up and create Si dead layer inside CCD.
  - Possible sources for charging by protons during GTO and by solar EUV. Could also be charging from purge gas, but unlikely.
  - Mitigation: apply higher voltage across CCD (not option for MEGS)



- **Combination of Both Options**

Symptoms of Different Mechanisms

First Light Degradation

- **Contamination:**
  - Likely to be a nearly <u>uniform</u> contamination layer across device
    - Implies spatial independence of QE reduction for given λ
  - Will charge faster for constant flux than does a clean device
    - Charging proportional to the depth of the absorber
  - <u>QE may improve with temperature</u>
    - Due to boil-off of material

First Light Degradation

Burn-in at bright solar lines

- **Charging:**
  - Until implanted charge is overcome, QE is independent of back surface charging
  - Once implanted charge is overcome, QE is dependent upon back surface charging
  - <u>Completely localized possible; QE reduced only in areas of charging</u>
    - Charge mobility is low
    - If QE reduction is spatially uniform, implies charging mechanism is spatially uniform
  - QE reduction is expected to be temperature <u>independent</u>

Radiation Dose in GTO versus GEO

- **Dose rate is expected to be 3-7 times worse during GTO than while in GEO.**
- **MEGS-P showed factor of 7 higher background level while in GTO**

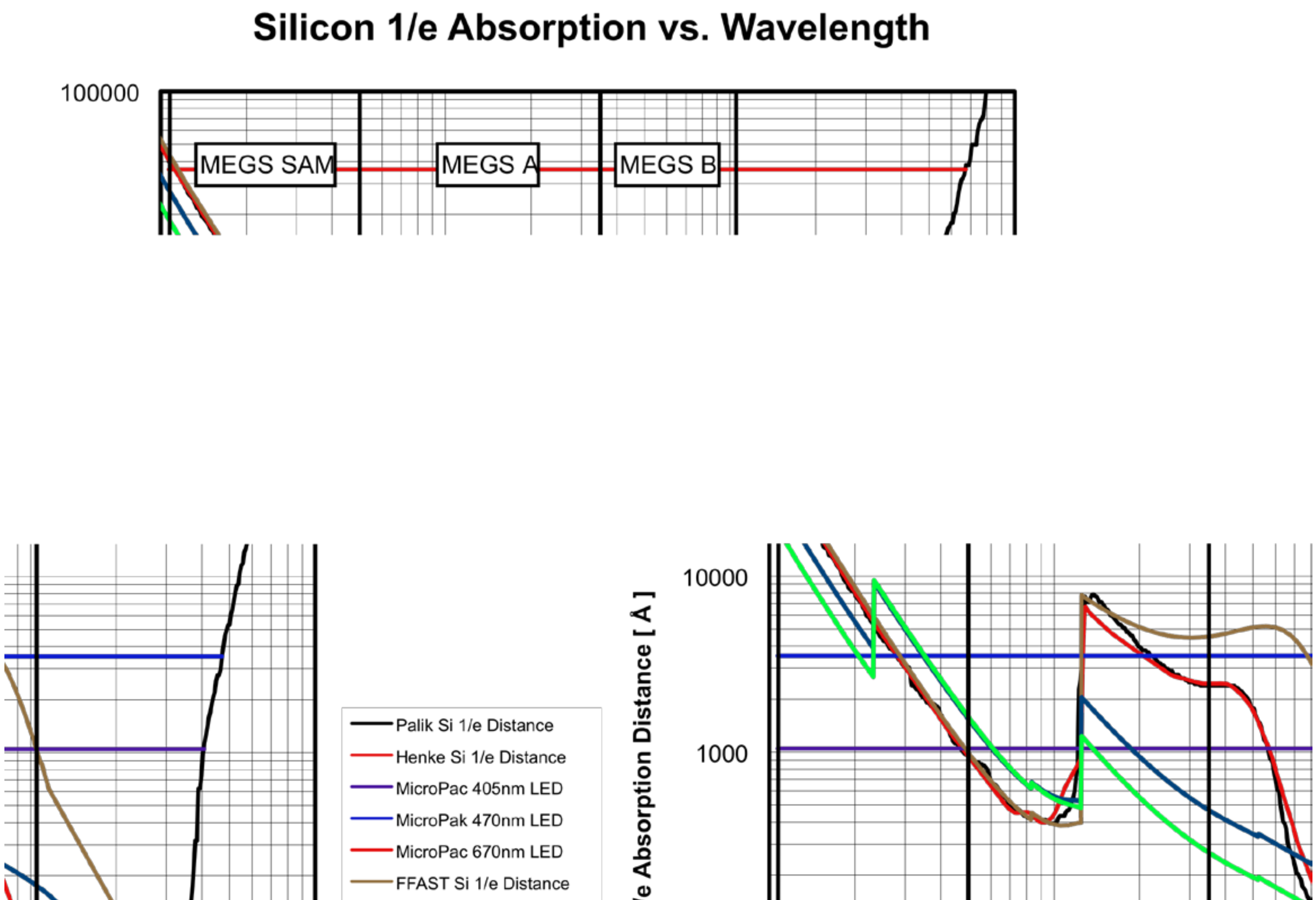
- GTO: 1000-36000 km
- Shield Dose for 20 mm Al is 1.7 kRad / year
  - 28% Bremstrahlung
  - 6% Solar Protons
  - 65% Trapped Protons
- TID (MeV) from Mulassis with 10 mm Al shielding
  - 3×10^4 Trapped Electrons
  - 3×10^3 Solar Protons
  - 4×10^4 Trapped Protons

- GEO: 36000 km circular
- Shield Dose for 20 mm Al is 0.52 kRad / year
  - 65% Bremstrahlung
  - 35% Solar Protons
  - 0% Trapped Protons
- TID (MeV) from Mulassis with 10 mm Al shielding
  - small Trapped Electrons
  - 1×10^4 Solar Protons
  - small Trapped Protons

SDO was in GTO longer than planned so higher Dose than planned.

CCD (Si) Absorption Curve

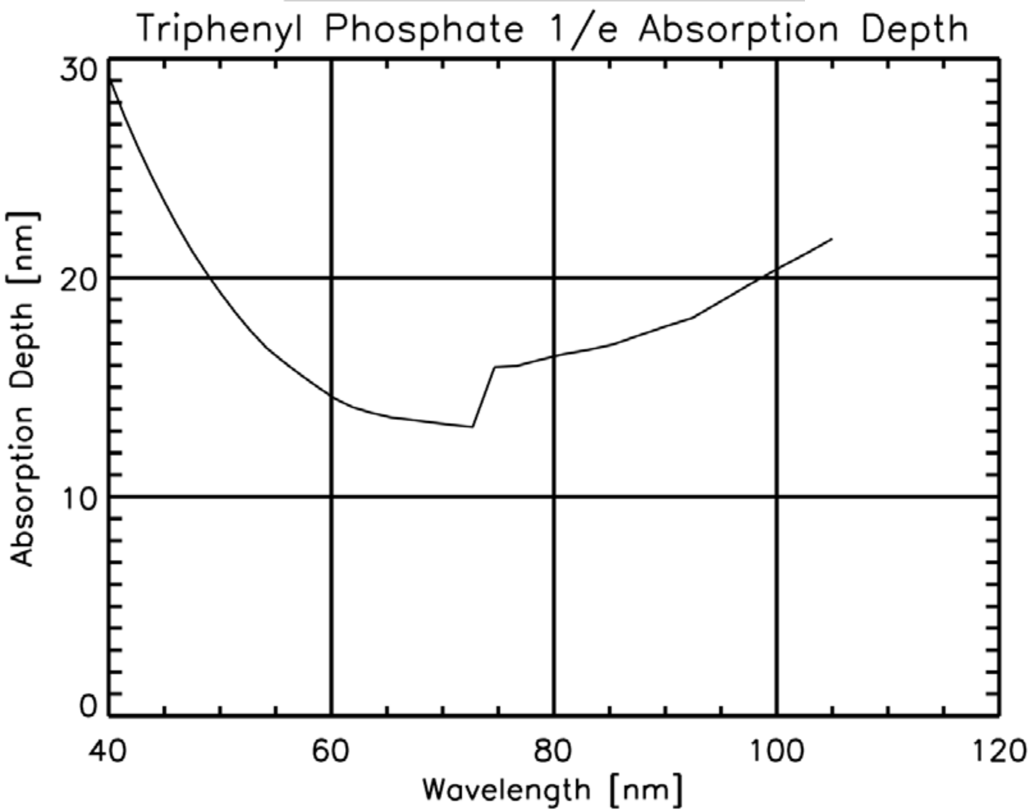
- Blue LED is intended for MEGS-A CCD comparisons
- Violet LED is intended for MEGS-B CCD comparisons

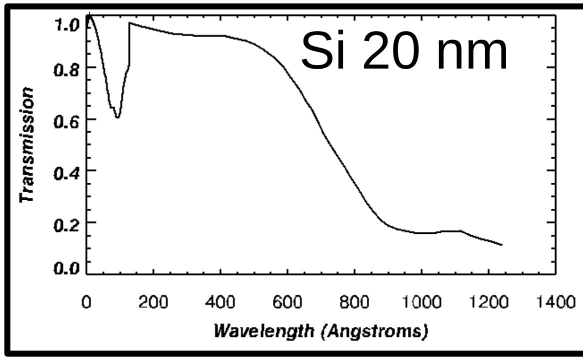


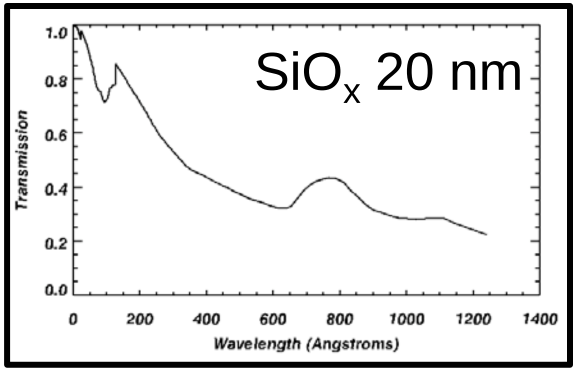
Contaminant Absorption Curves

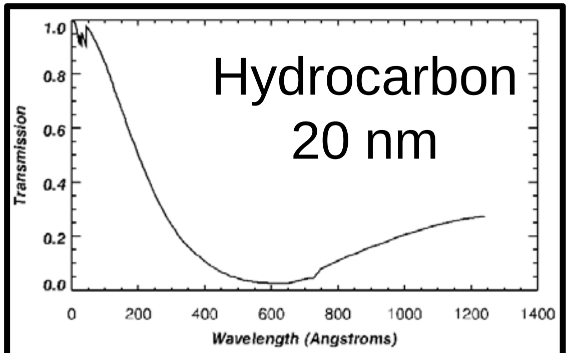
- **First Light Degradation curve looks more like Si**
  - however, don't see 5-12 nm (50-120 Å) notch for MEGS-A
  - so other type of contaminant is also considered
  - or MEGS-A CCD might not be charged as much

Hydrocarbon Example



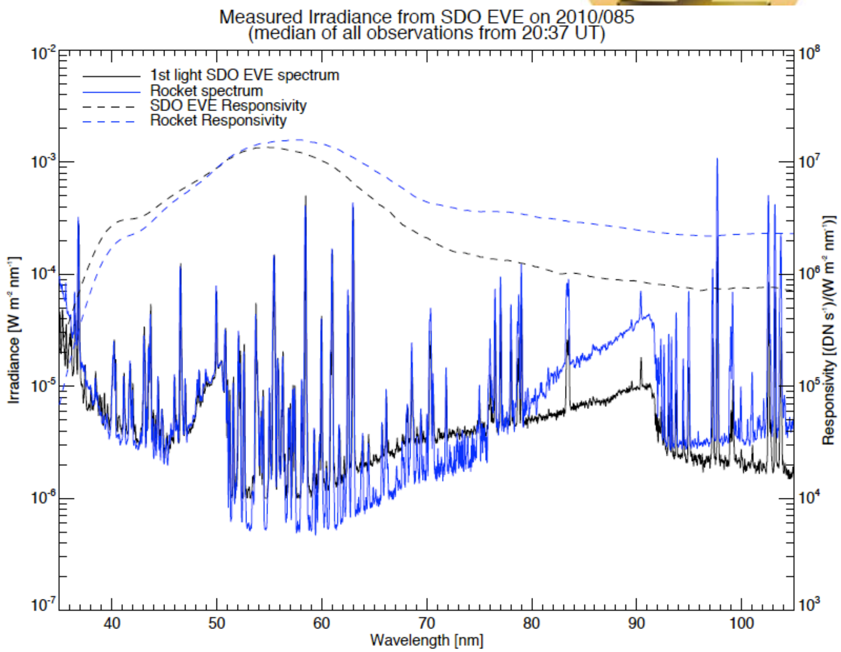


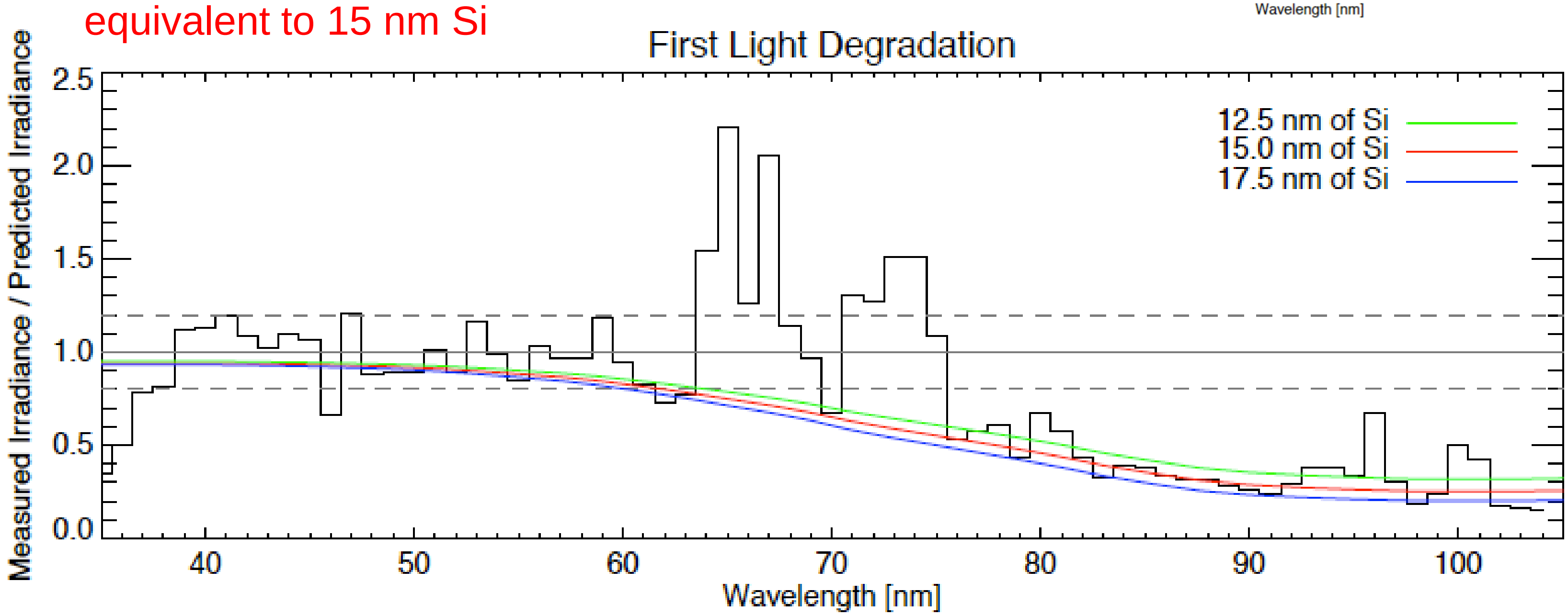




Degradation Seen in First Light Spectrum

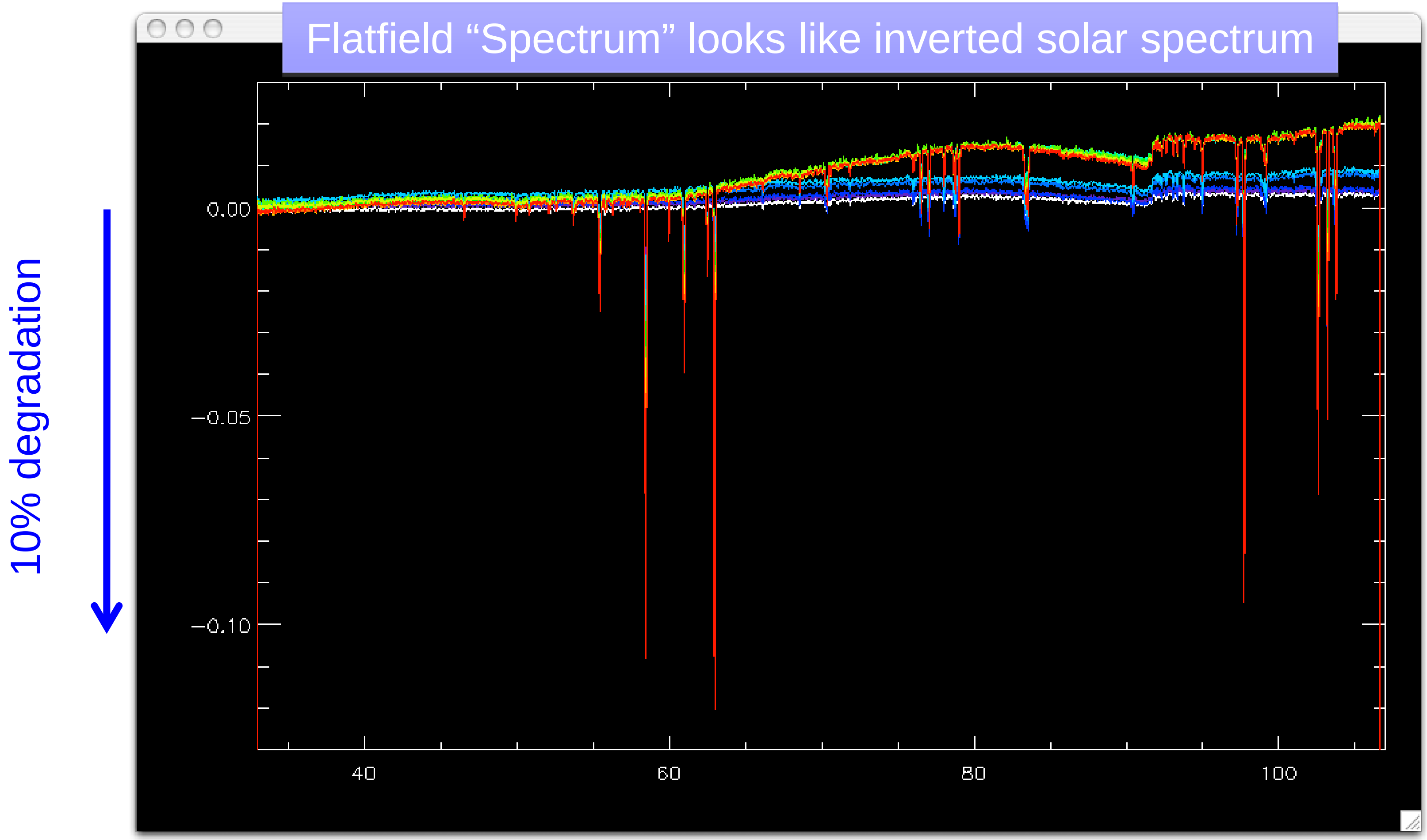
- **First minute of solar observations indicate significant decrease in sensitivity from what was expected with SURF calibrations**
- **Ratio includes correction for solar variability from DOY 085 to 123 (rocket day) by using TIMED SEE data**
  - Subtracting dark level impacts background so ratio is better where bright lines are
  - Si dead-layer model suggests charging equivalent to 15 nm Si



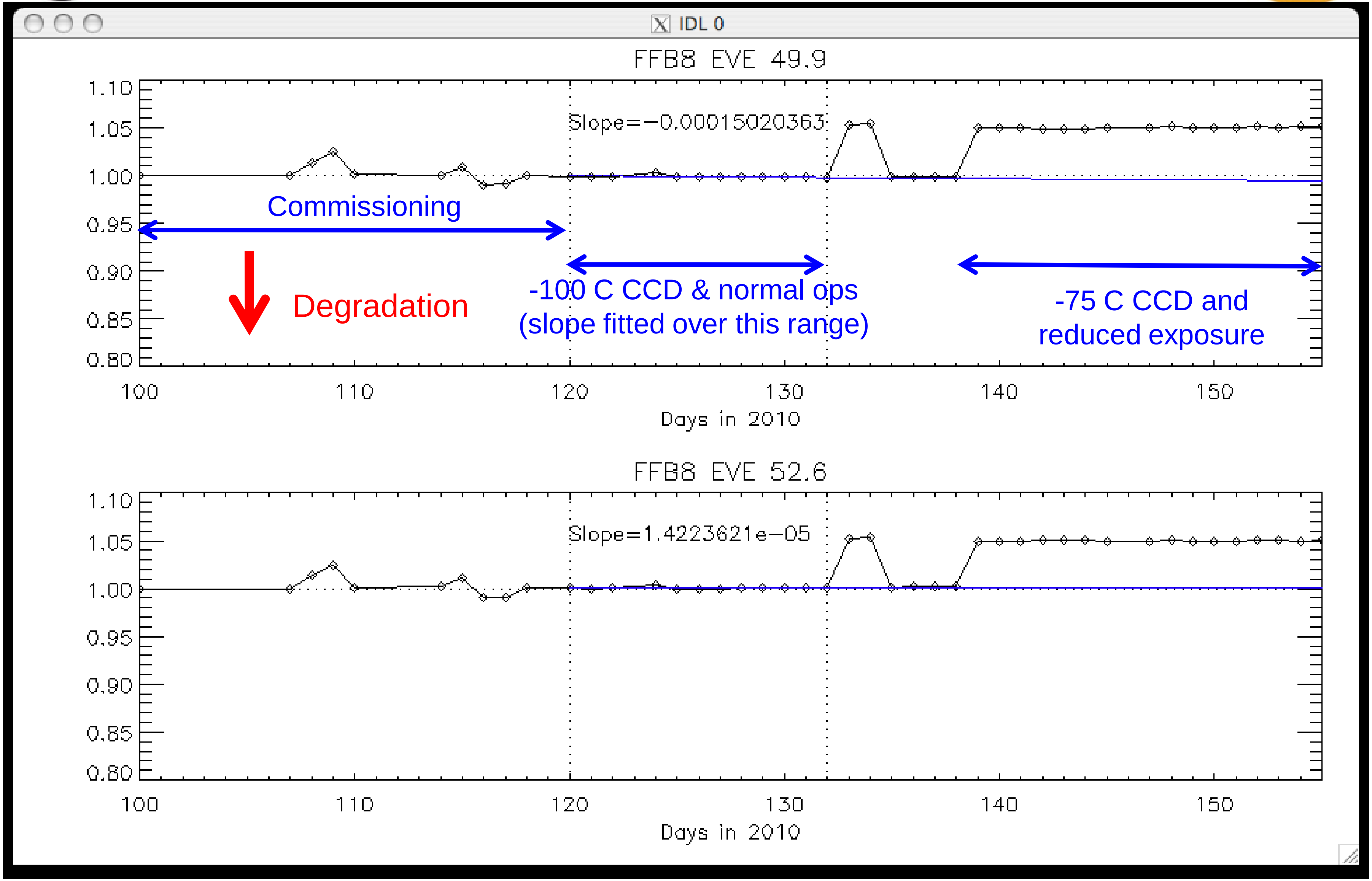


CCD Burn-in Seen for Bright Solar Lines

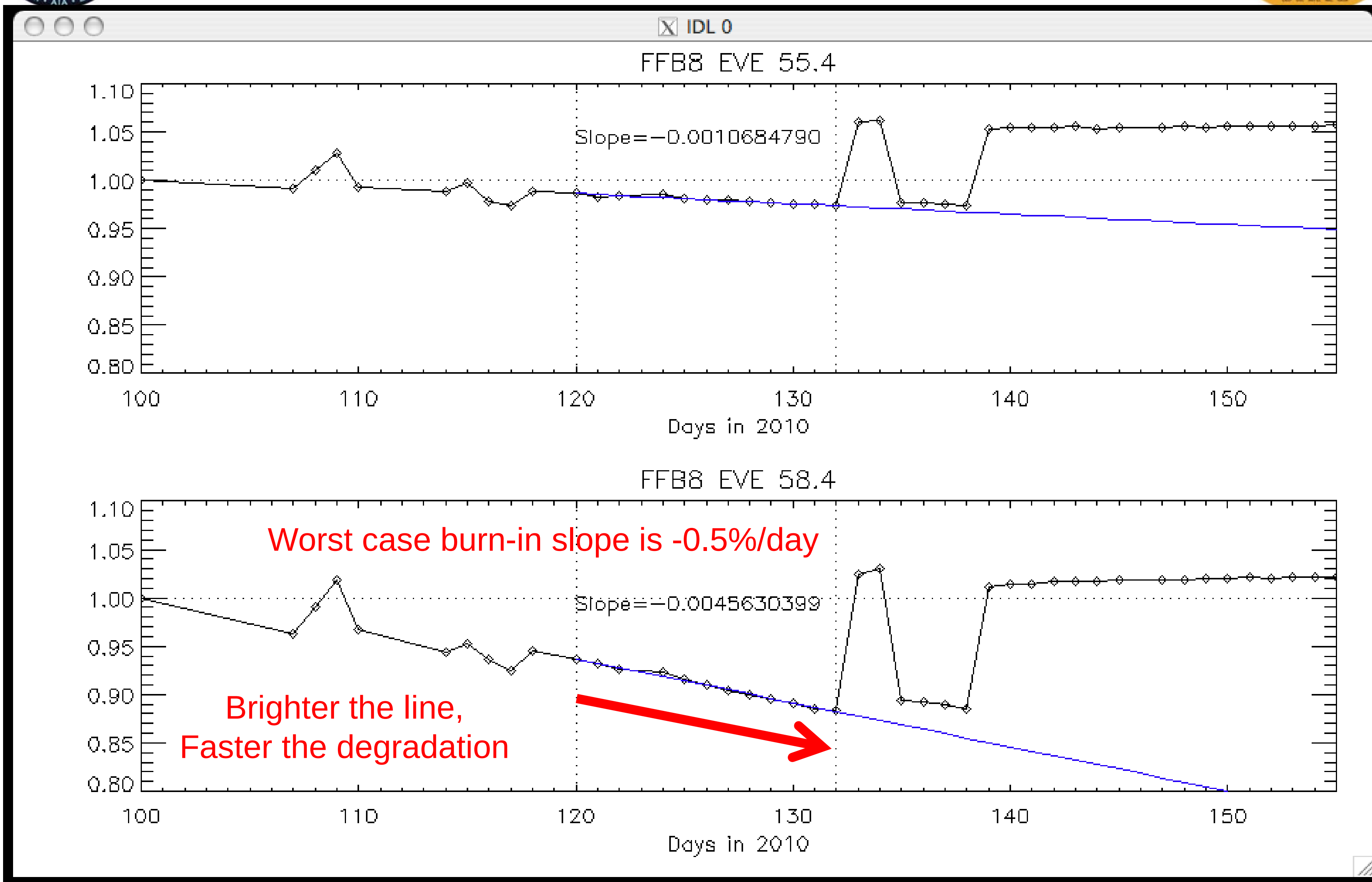
- **CCD Burn-in is best seen in the flatfield LED images that show darker regions where there are bright solar lines**



Blue LED: Example with no degradation



Blue LED: Example of Burn-In

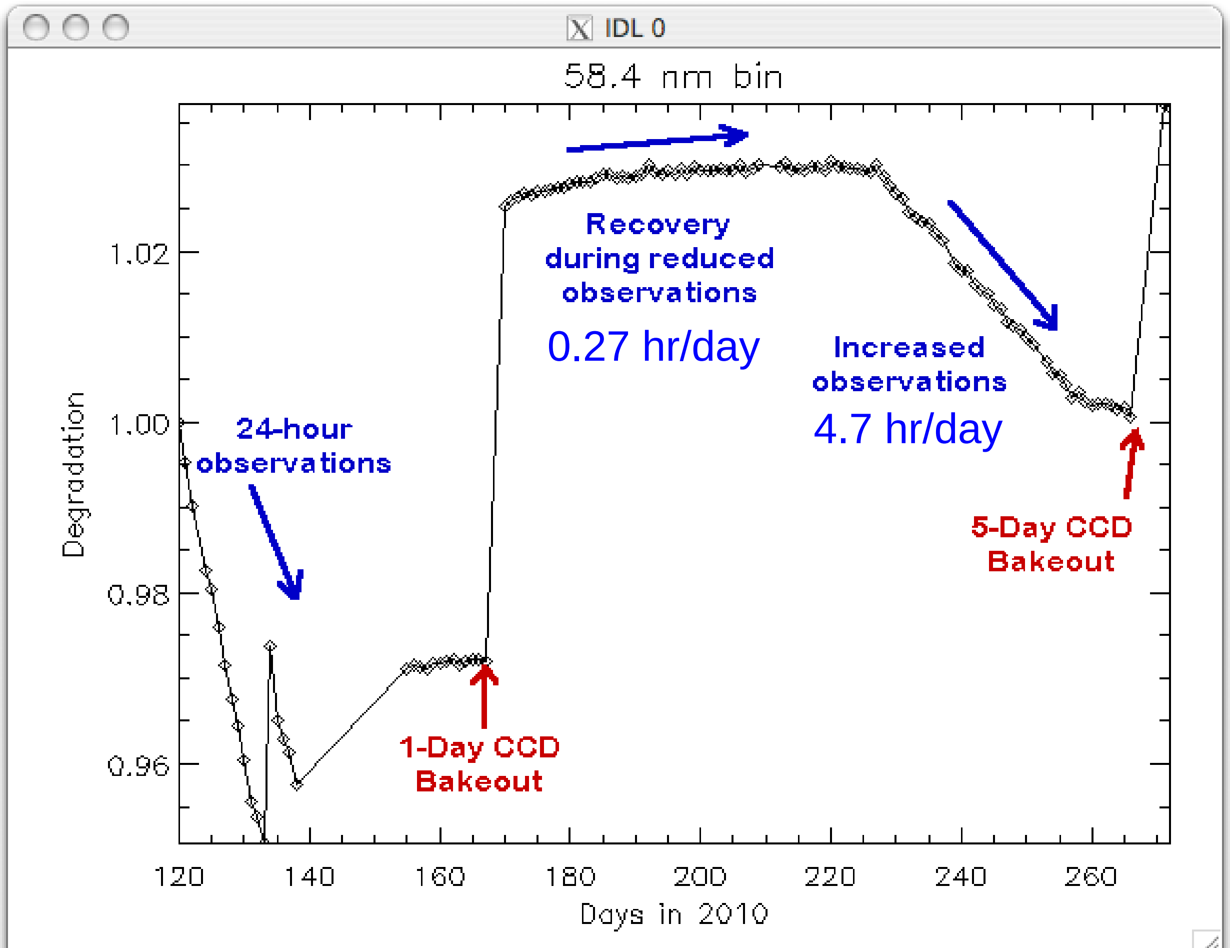


Mitigation Options: Results and Plans

- **Bake-out CCD to drive off contaminants**
  - Original design allows for regular bakeouts of CCDs
  - CCDs had bake-out at +15 °C for 36-hours: showed minor recovery
  - Conclude that degradation is not due to contamination
    - Consist with MEGS-P and other channels not showing degradation and that initial degradation spectral profile can only be fit with Si layer
    - This implies MEGS-B degradation is mainly due to charging on CCD. We don't have any other on-orbit mitigation options for CCD charging.
- **Change operations to reduce MEGS-B degradation rate**
  - Only use MEGS-B for limited measurements
    - MEGS-P is part of MEGS-B, so MEGS-P operations also get changed.
    - MEGS-B revised plan includes 5-min observations once per hour to support space weather operations (I/T modeling). For supporting solar physics (flare) research, MEGS-B has a 3-hour block of solar observations each day and also can plan a 24-hour flare campaign about once per month.
  - Other EVE Channels (MEGS-A, MEGS-SAM, ESP) remain in planned operations mode (24/7, high-cadence)
  - These plans still meet EVE Level 1 requirements (measure 18 solar lines at 0.1-nm resolution, 25% accuracy, and 20-sec cadence).

CCD Bake-outs Help to Mitigate Degradation

- **Bake-out of CCD helped remove burn-in effects.**
  - a 1-day bake appears as good as 5-day bake
- **May have CCD bake-outs twice per year (during eclipse season)**



He I 58.4 nm line degrades the fastest

Summary of MEGS-B Degradation

- **Initial degradation detected at first light**
  - Degradation consistent with extra Si dead-layer of about 15 nm (due to CCD charging since final calibration)
  - Mostly impacts 70-105 nm range for MEGS-B.
    - Measurement precision for 35-70 nm is not impacted. The precision for the 70-105 nm range can be recovered by averaging 1-5 minutes of data.
  - Calibration rocket provides the correction for this initial degradation

- **CCD Burn-in for bright solar lines**
  - The brightest solar line indicates 0.5% per day degradation when operating 24/7.
  - Most of the MEGS-B range is not showing this burn-in effect, just the few bright emission lines and the hydrogen continuum near 90 nm.
  - Slight recovery seen when operating with daily 16-min solar observations.
  - CCD bake-out provided recovery for burn-in effect but not for initial degradation
  - Daily flatfield lamp (LEDs) measurements provide correction for burn-in effects

Note that MEGS-A did not have any initial degradation but has some slight burn-in for its brightest solar line (He II 30.4 nm).