LYRA Validation with SOLSTICE

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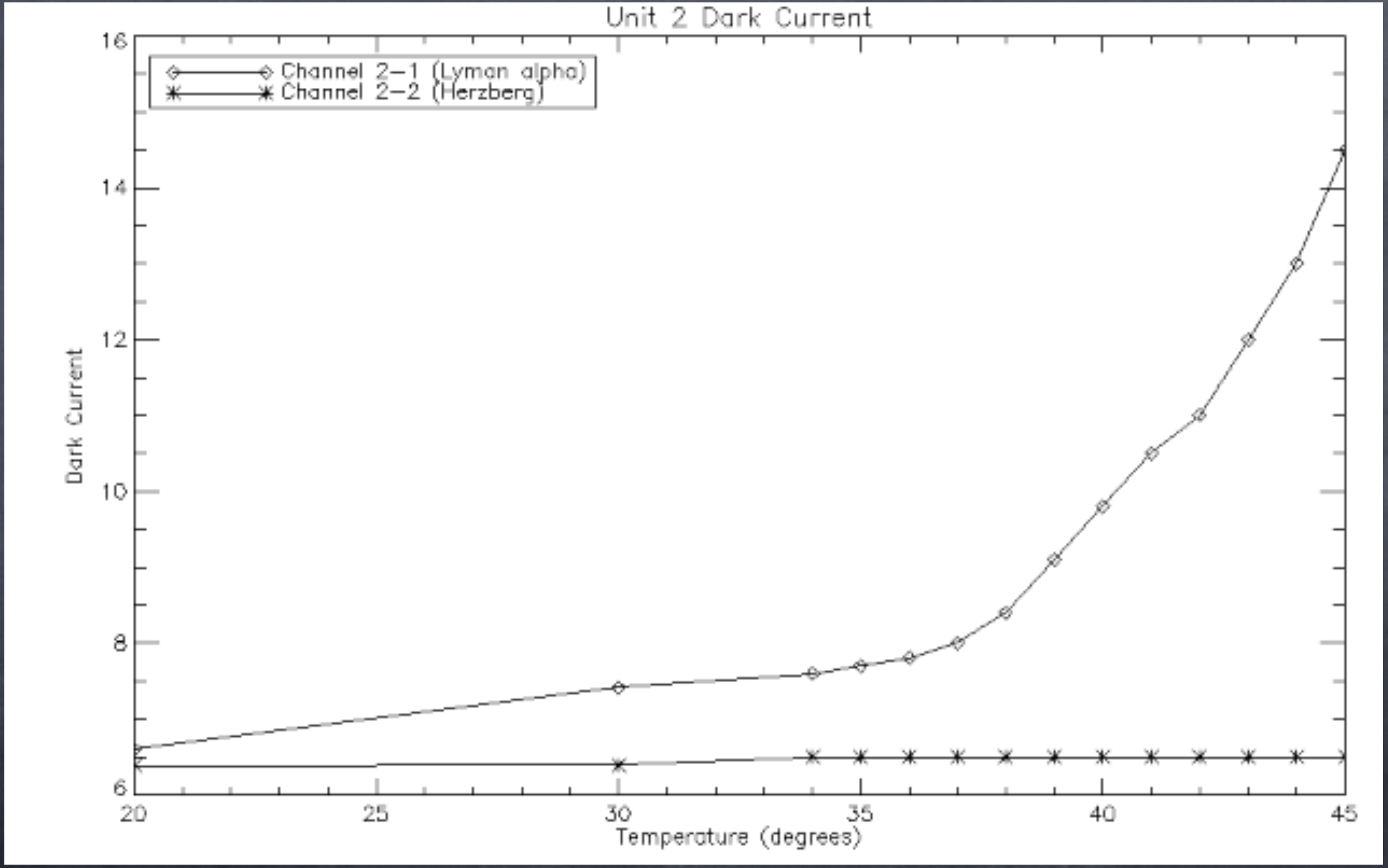
Guest Investigator Program

Goals

- Validate LYRA Channels 1 and 2
  - Thermal corrections
  - Degradation correction
  - Comparison to SOLSTICE

Dark Current and Temperature



Dark rate used in pipeline processing.

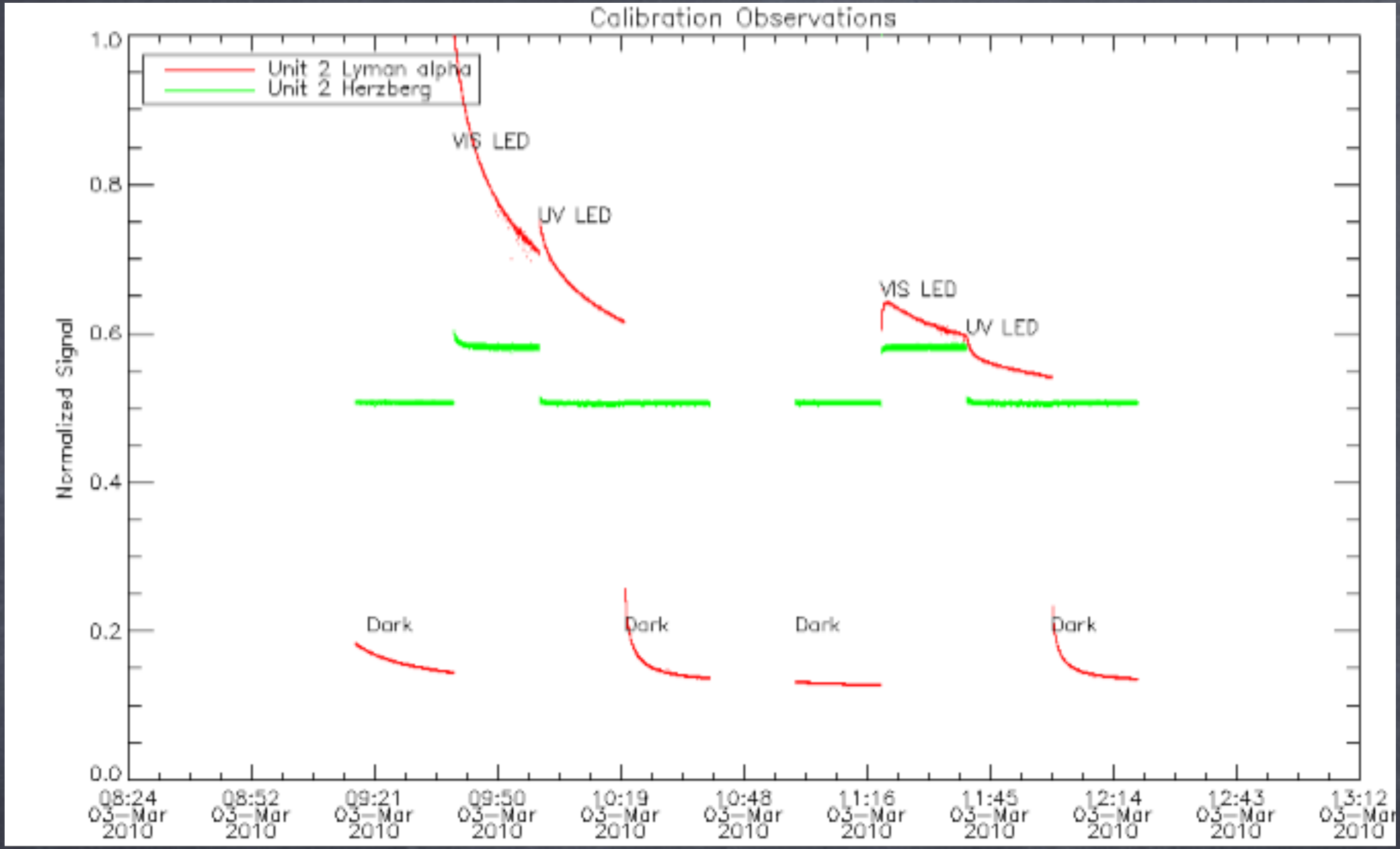
Temperature discussion with Ali

- Dark current is a function of temperature.
- Dark current increases with degradation
- Bandpass is function of temperature
- Detector “stabilization” also appears in dark current.

Detector Stabilization

- Diamond detector output can take hours to stabilize.
- Defects in crystalline structure can trap photoelectrons introducing a delay in reaching proper output level.
- Trapped electrons may take hours to leak out when signal level is reduced for dark current measurements.
- When high signal is restored, partially emptied traps refill quickly returning to stable level.
- Once traps are full, detector is responsive to signal level changes.

Calibration Observations



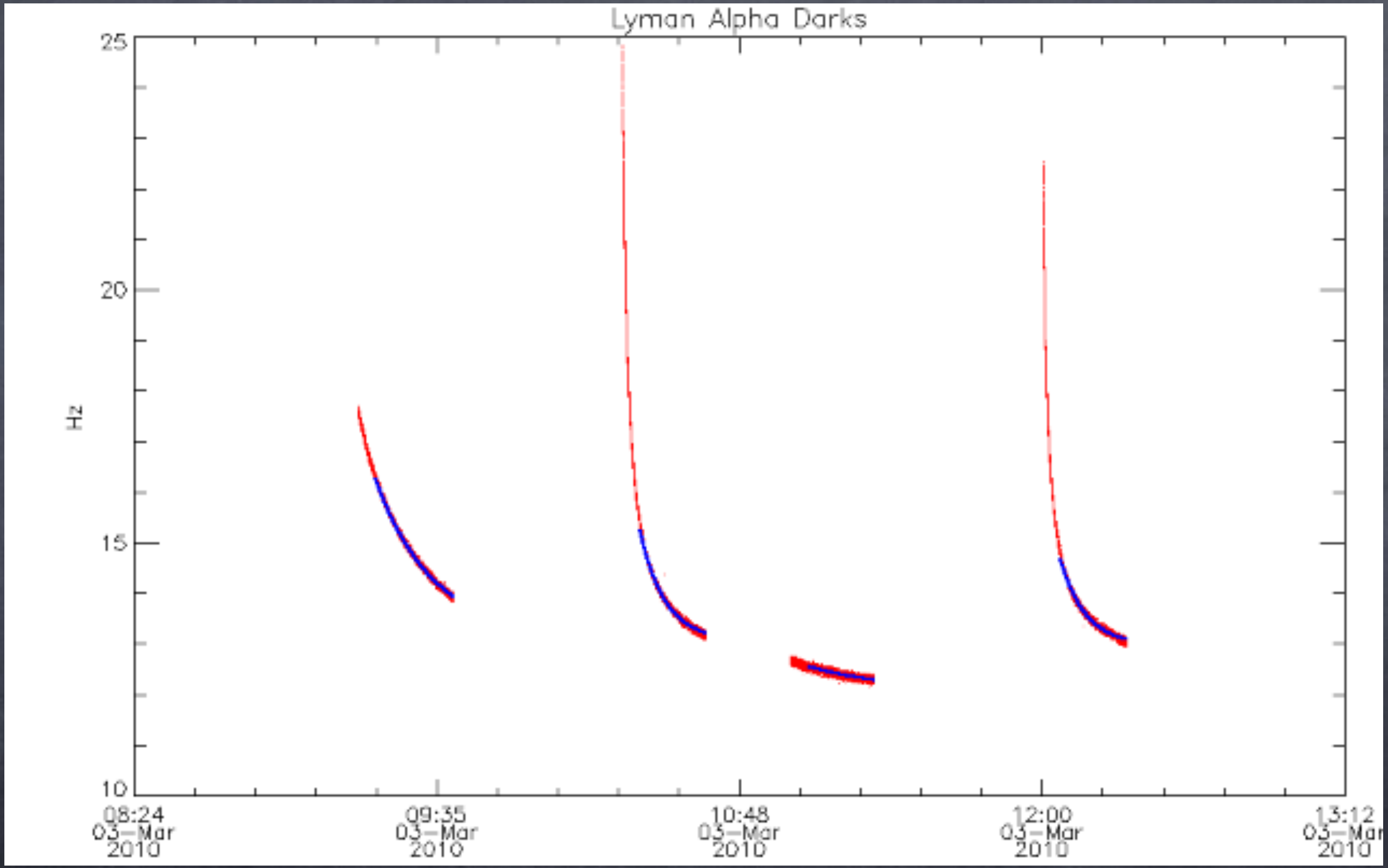
This plot shows the standard calibration observing sequence. The dark current is measured for 20 minutes, then the VIS LED is switched on for 20 minutes, then the UV LED, and finally another 20 minutes of dark current. The sequence is then repeated.

The Lyman alpha and Herzberg datasets have each been separately normalized to fit on the plot.

Analysis Strategy

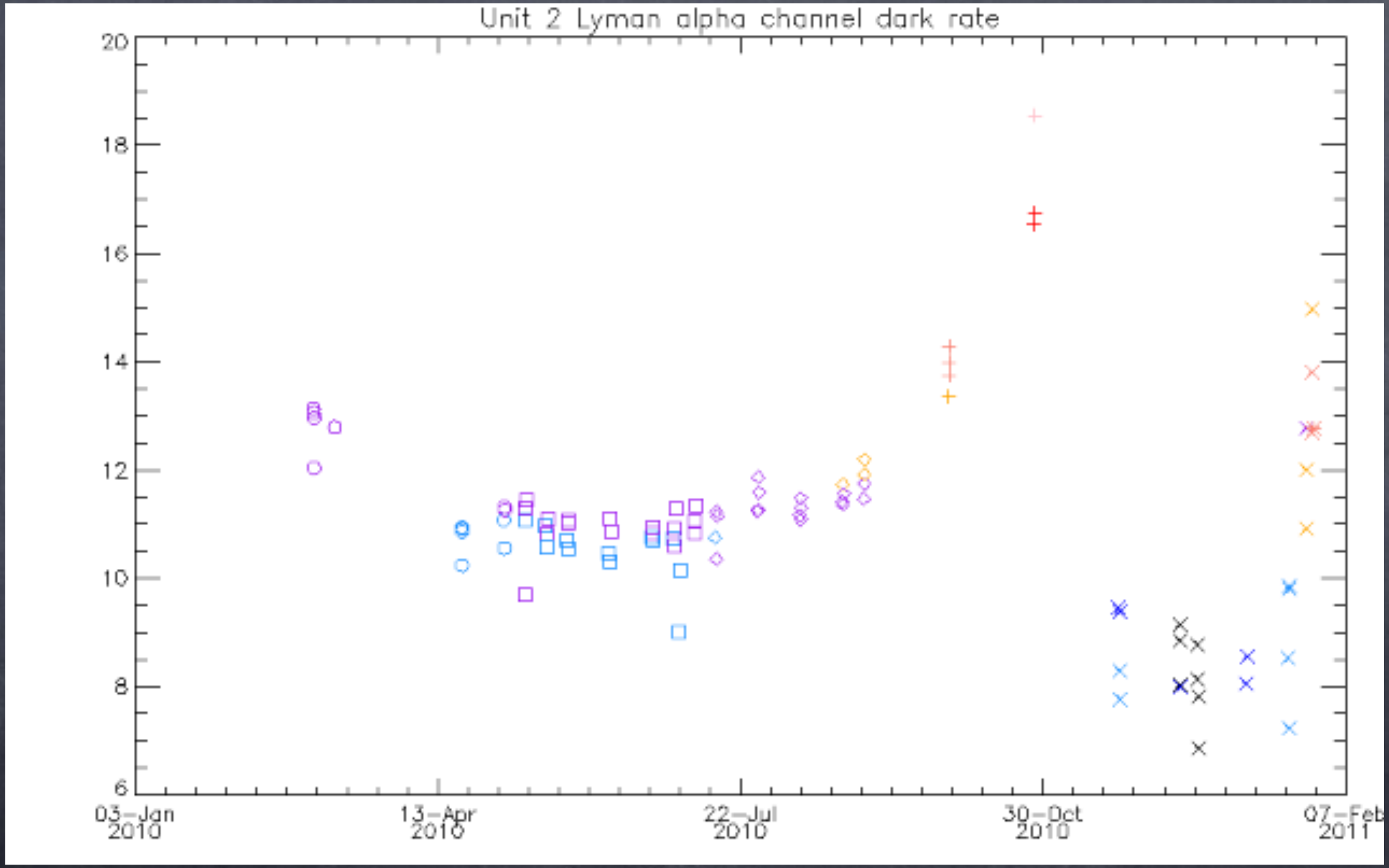
- Fit each observation with an exponential
  - C(t)=a0*exp(-a1*t)+a2
- a2 is assumed to be the value which the detector will show after stabilization.

Typical fits to dark current observations



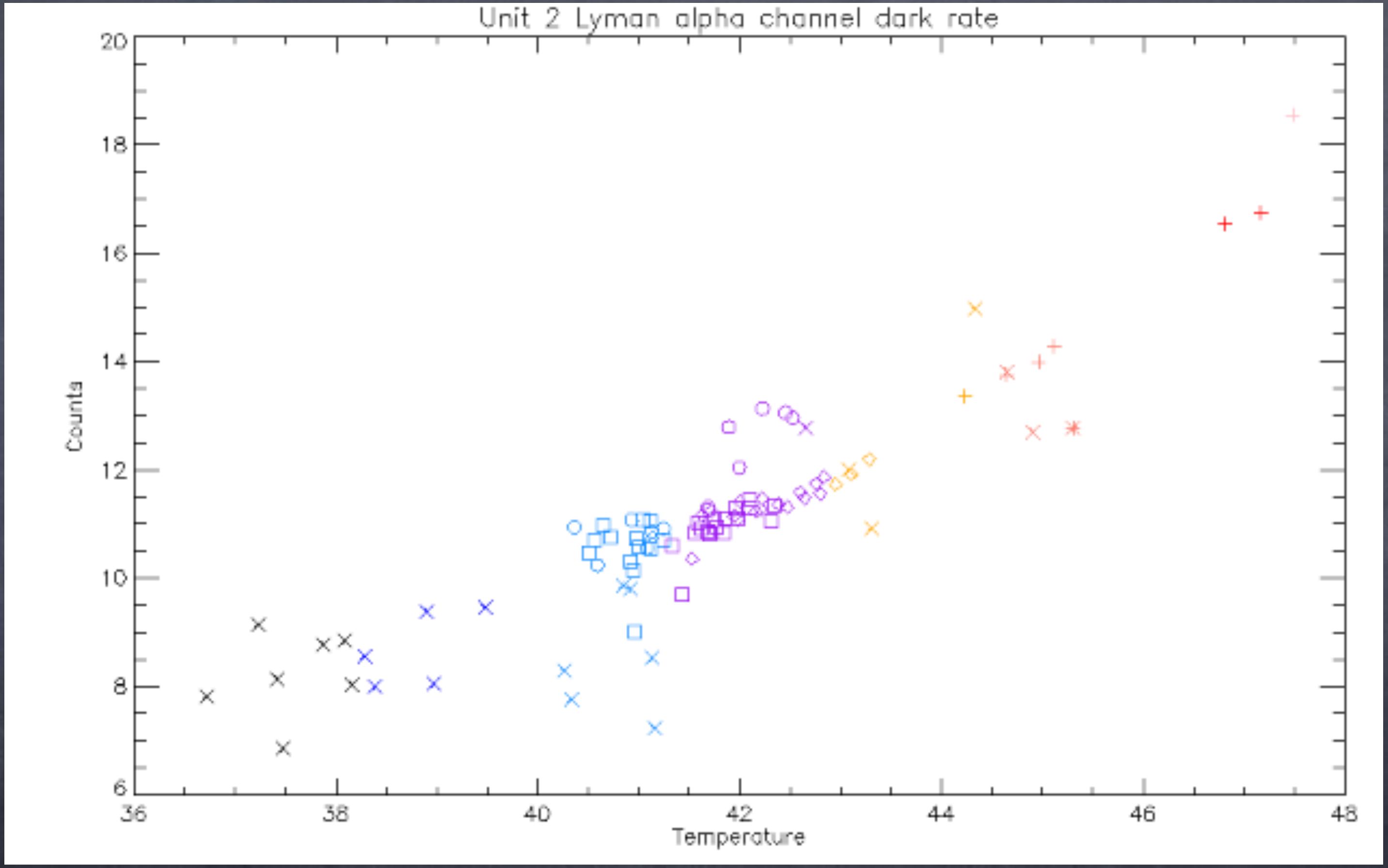
The red data points are the dark current measurements. The blue curve is the model fit used to remove the effect of stabilization.

Fits to Dark Current portion of Calibrations



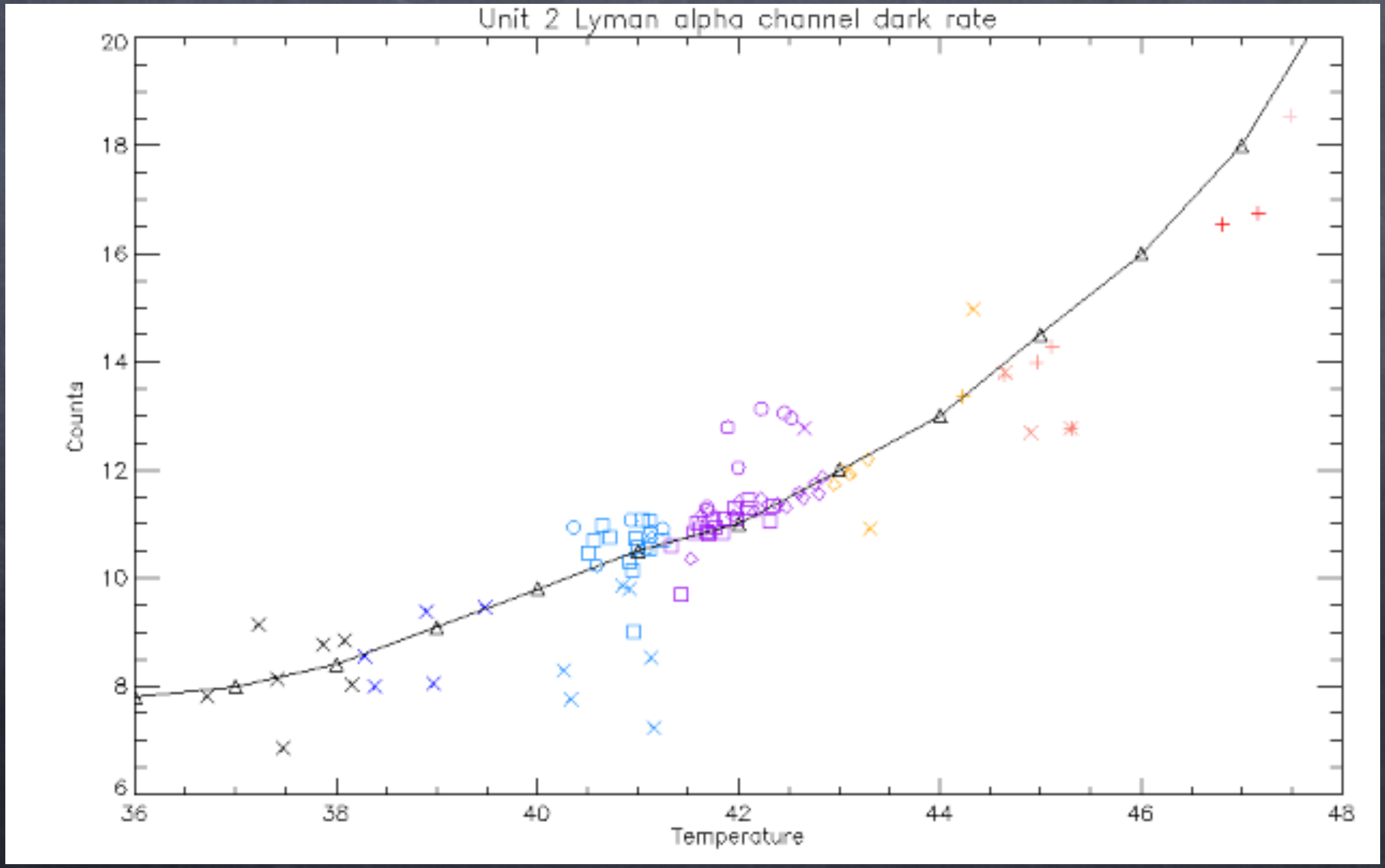
Dark current follows temperature curve.

Dark Current as a function of Temperature

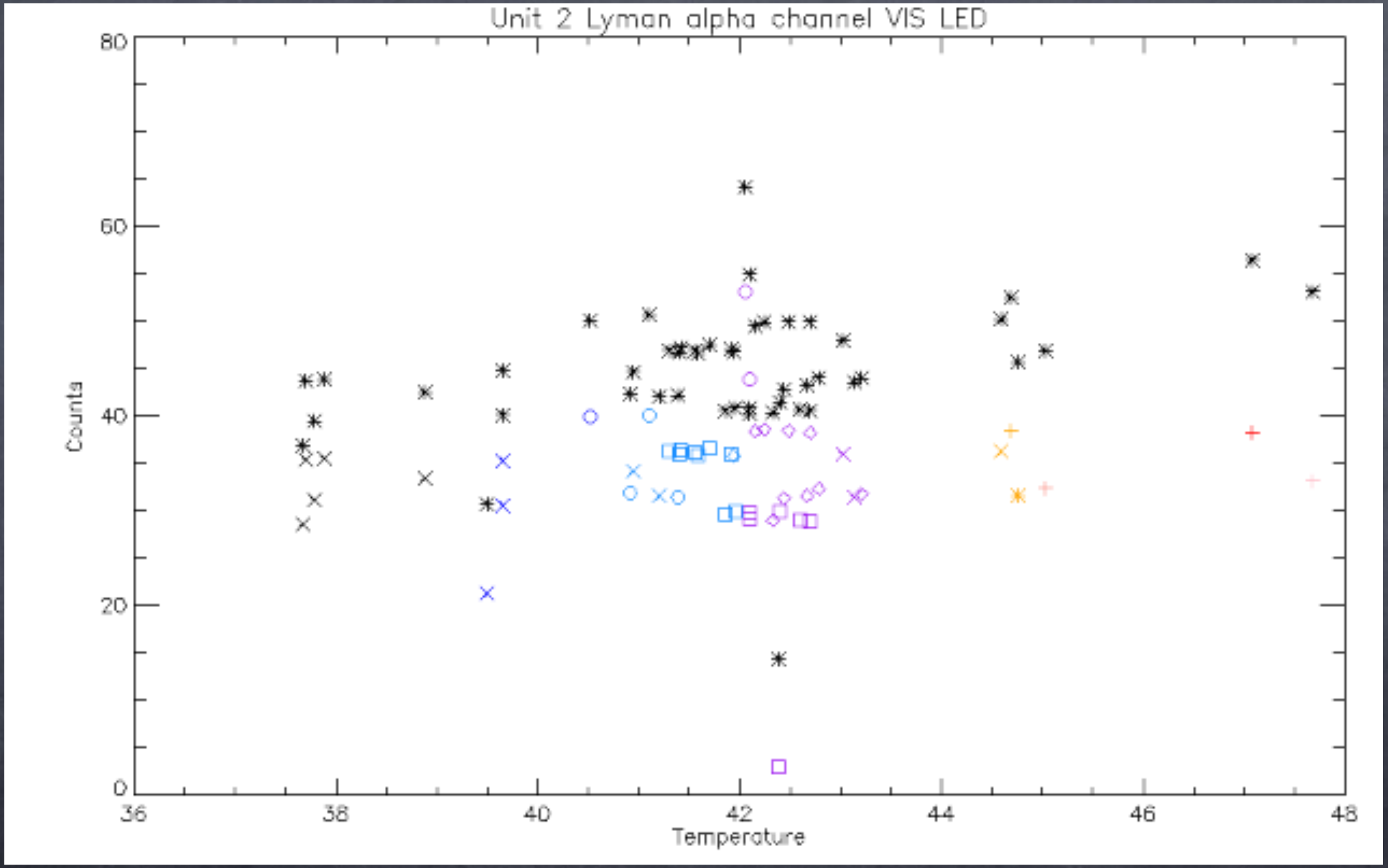


No trend with time.
Dark current should increase with detector damage.

Calibration observations agree with data from 24 Nov 2010

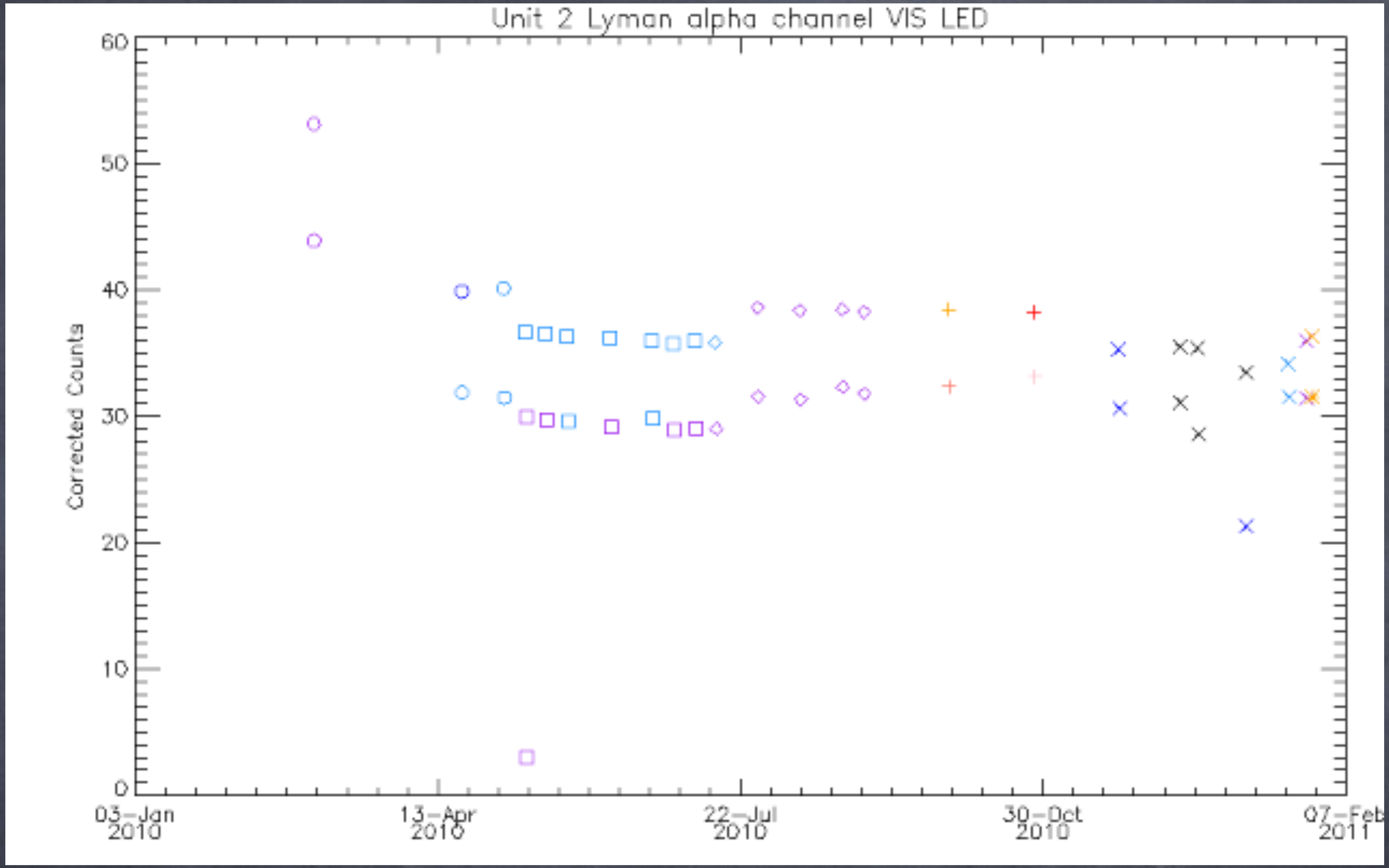


Calibration observations of VIS LED



Asterisks are uncorrected for dark current.
Colored symbols are after dark subtraction.

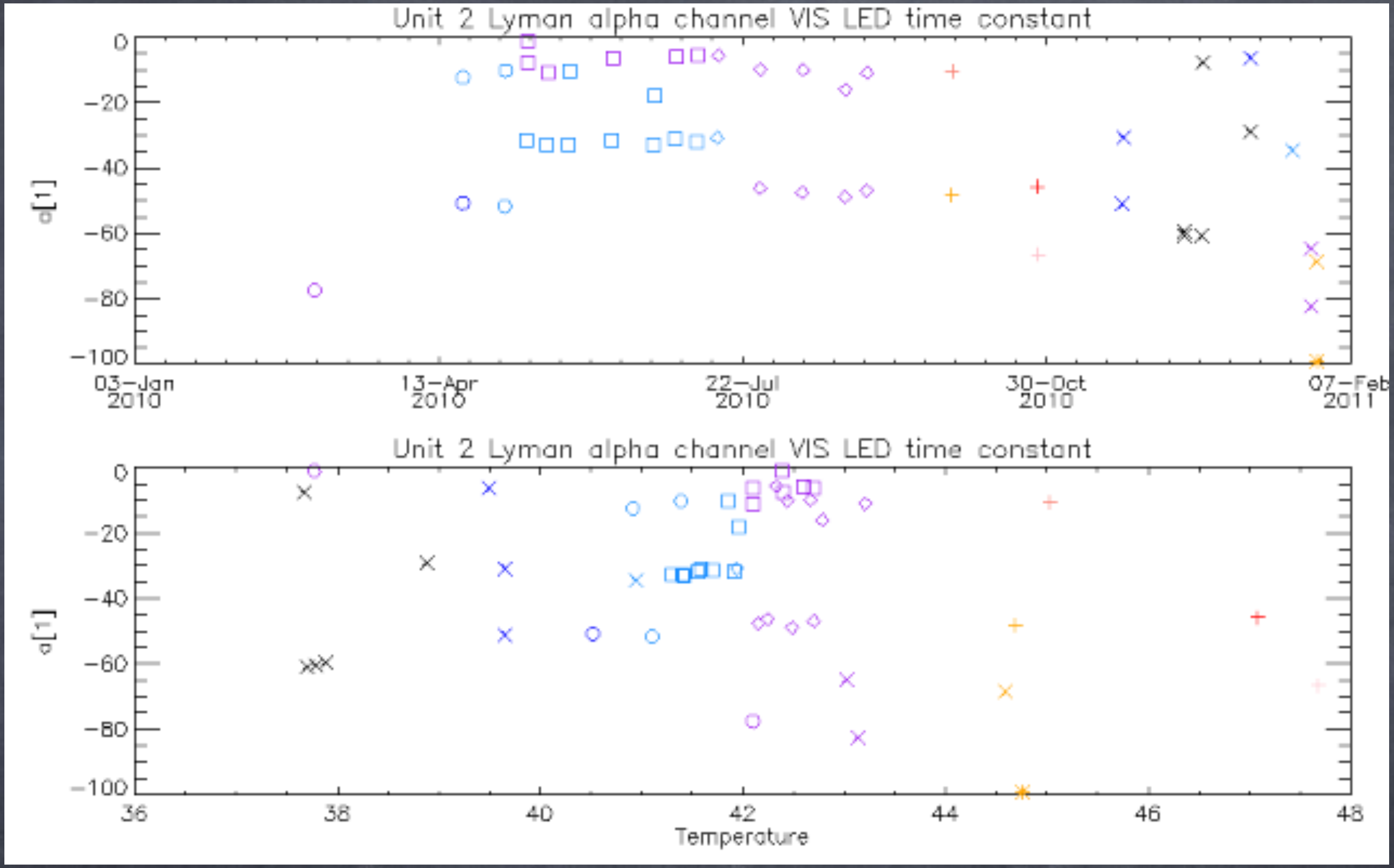
LED signal time series



Very little change of detector output when illuminated by LED over the mission.

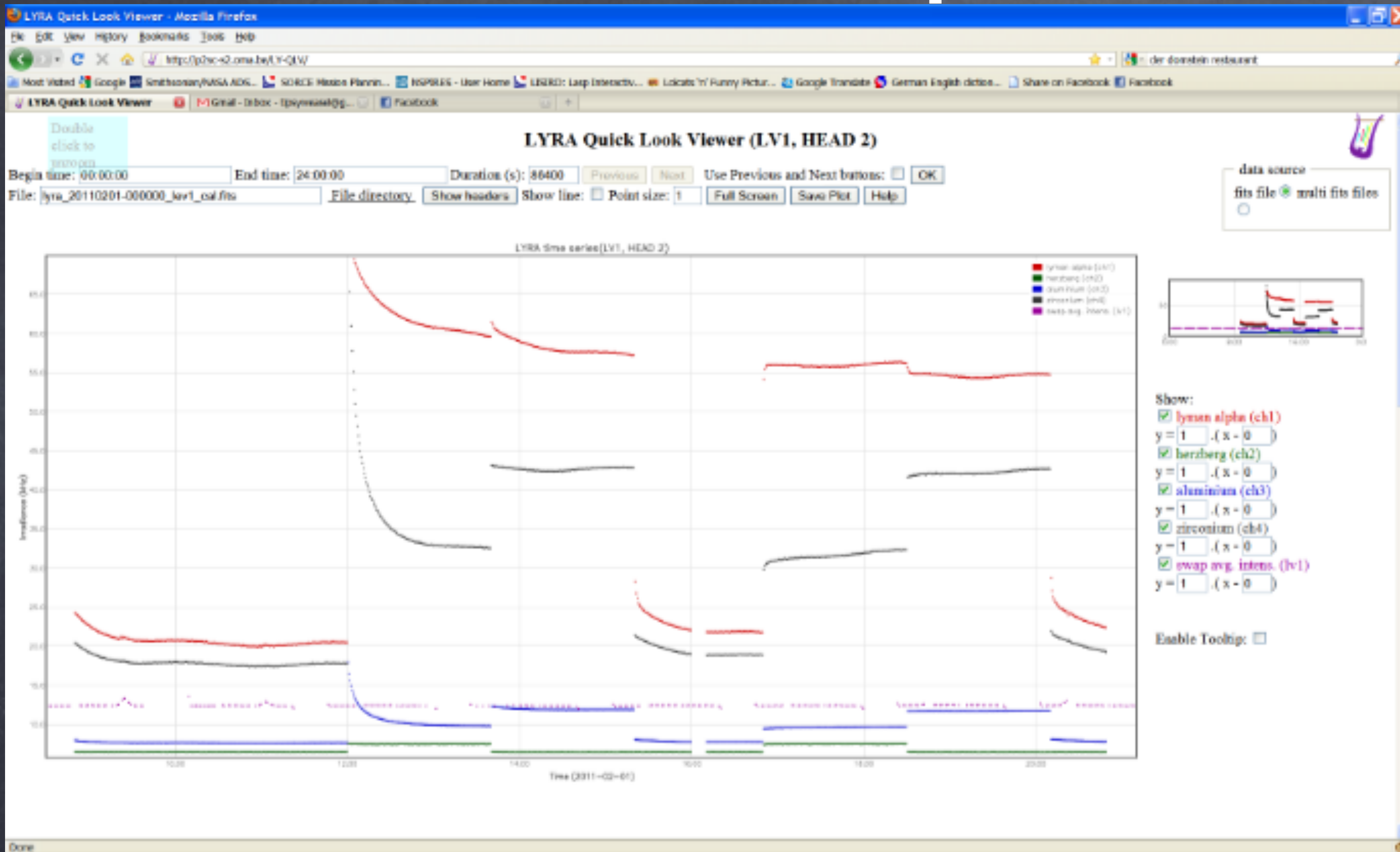
Bimodal appearance is due to systematic difference between first and second measurements during each observing sequence. This difference is not yet understood.

Stabilization time constant



There is no significant correlation between the time constant in the stabilization model with either mission day or temperature. This is a preliminary result, since there is quite a lot of scatter in the derived parameter. A more sophisticated model might show a temperature dependence.

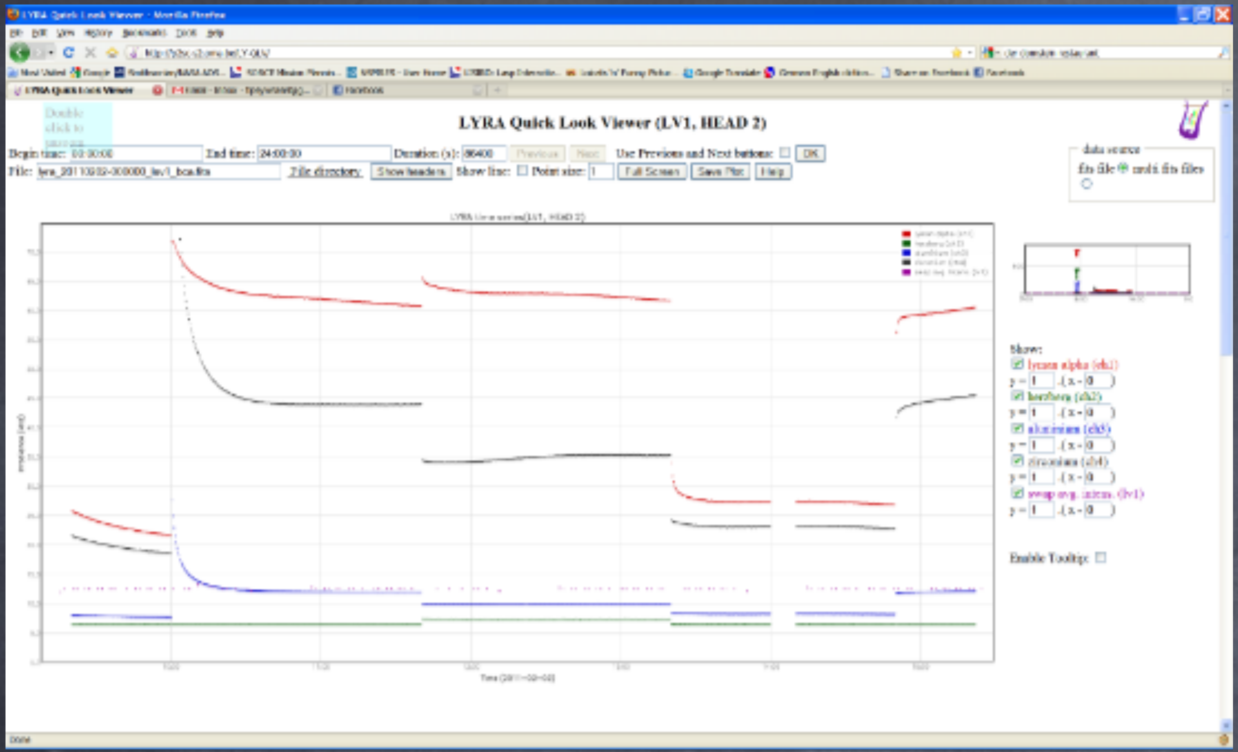
Test of trap model



If stabilization is due to traps, then after 2 hour dark exposure, traps should be empty and LED signal should be increasing asymptotically.

It’s not.

Test of LED Flash



In this calibration experiment, instead of VIS LED first then UV LED, the order was reversed. When LED is first powered on, it was thought that it flooded the detector with light, filling up the traps. The UV diode might be different.

It’s not.

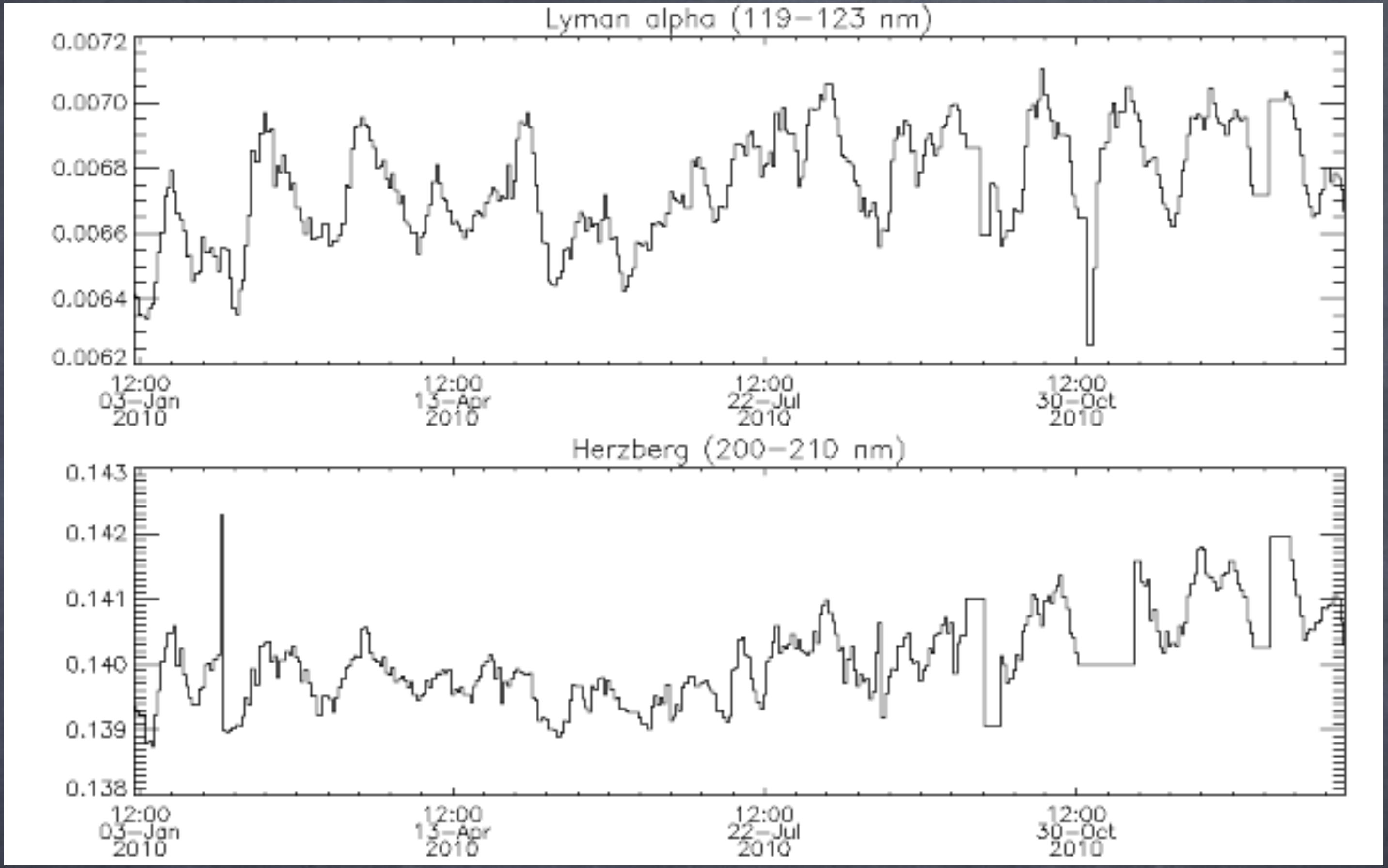
Calibration Summary

- Dark current is systematic function of temperature only, not temperature and time.
- LED signal indicates that detectors (and readout electronics) have degraded very little over the mission.
- Nearly all the degradation in the solar signal must be due to degradation of the filter transmission.

SOLSTICE Comparison

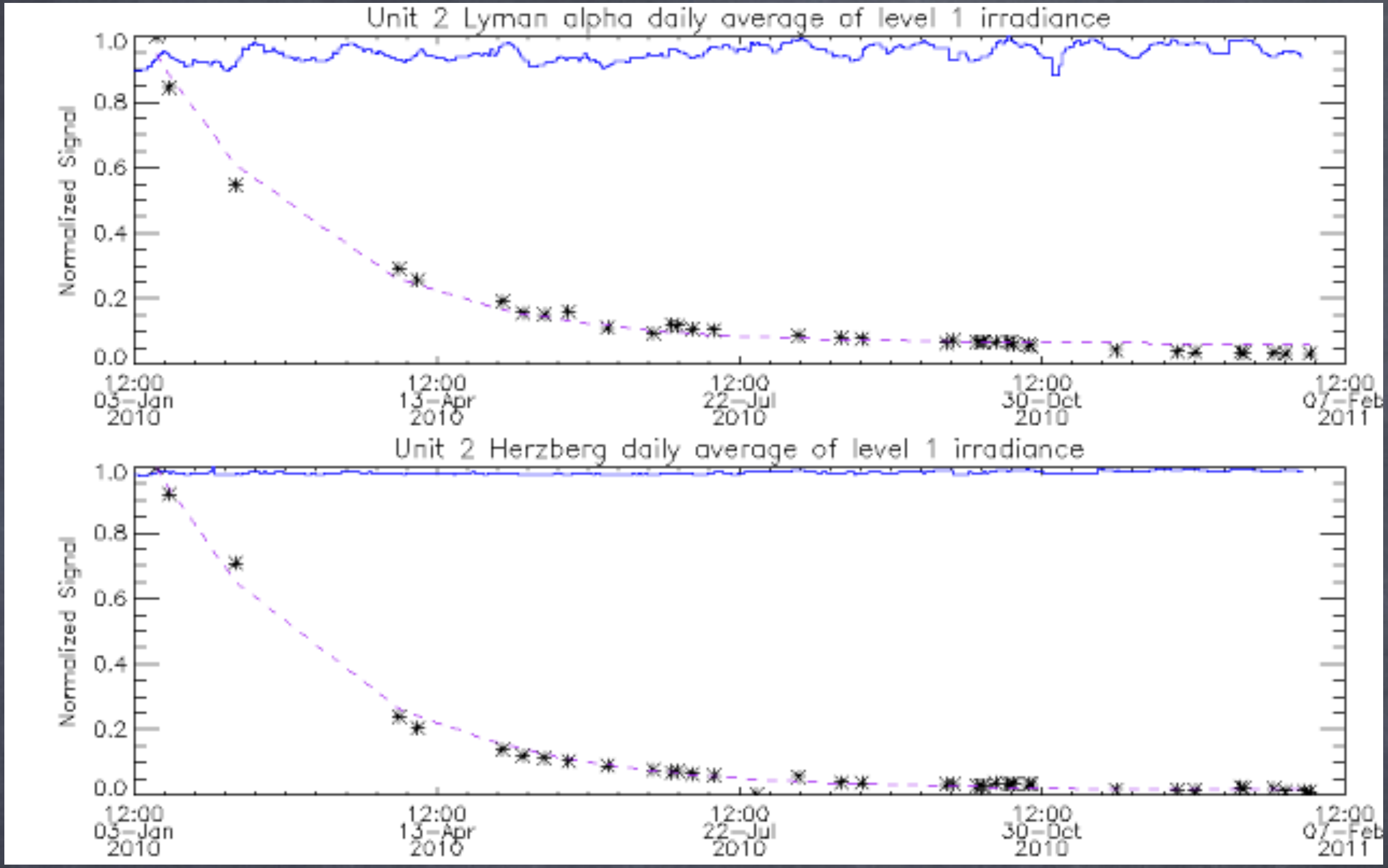
Validation of the LYRA signal using SOLSTICE data on timescales ranging from full mission to 1 minute cadence.

Solar Cycle



During the PROBA2 mission, solar rotations in the Lyman alpha channel should be approximately 10% (fractional variability) while the Herzberg channel should show variability of about 1%. Solar cycle shows a slight rise over the year in both channels.

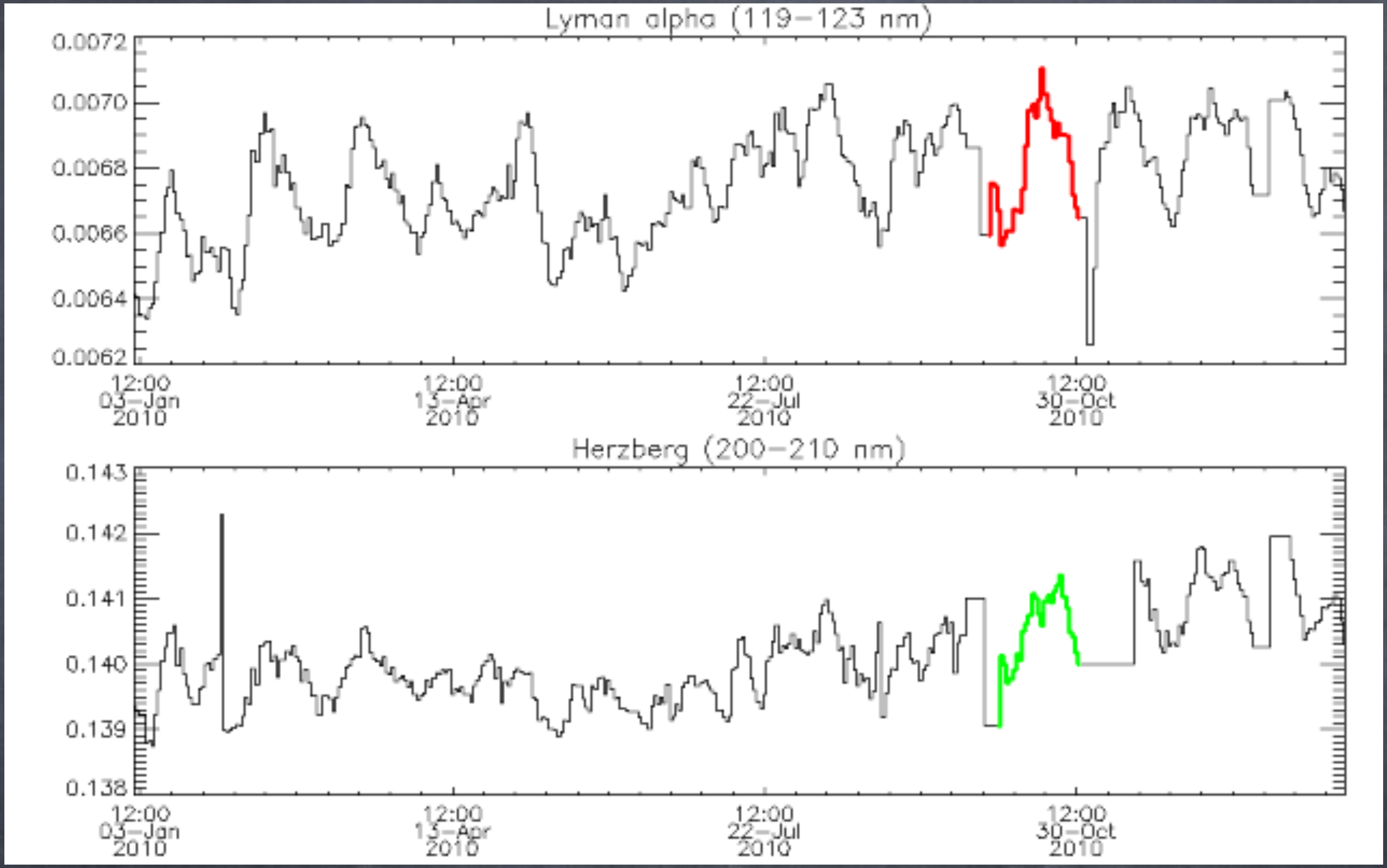
Unit 2 time series



Blue curves are SOLSTICE time series.

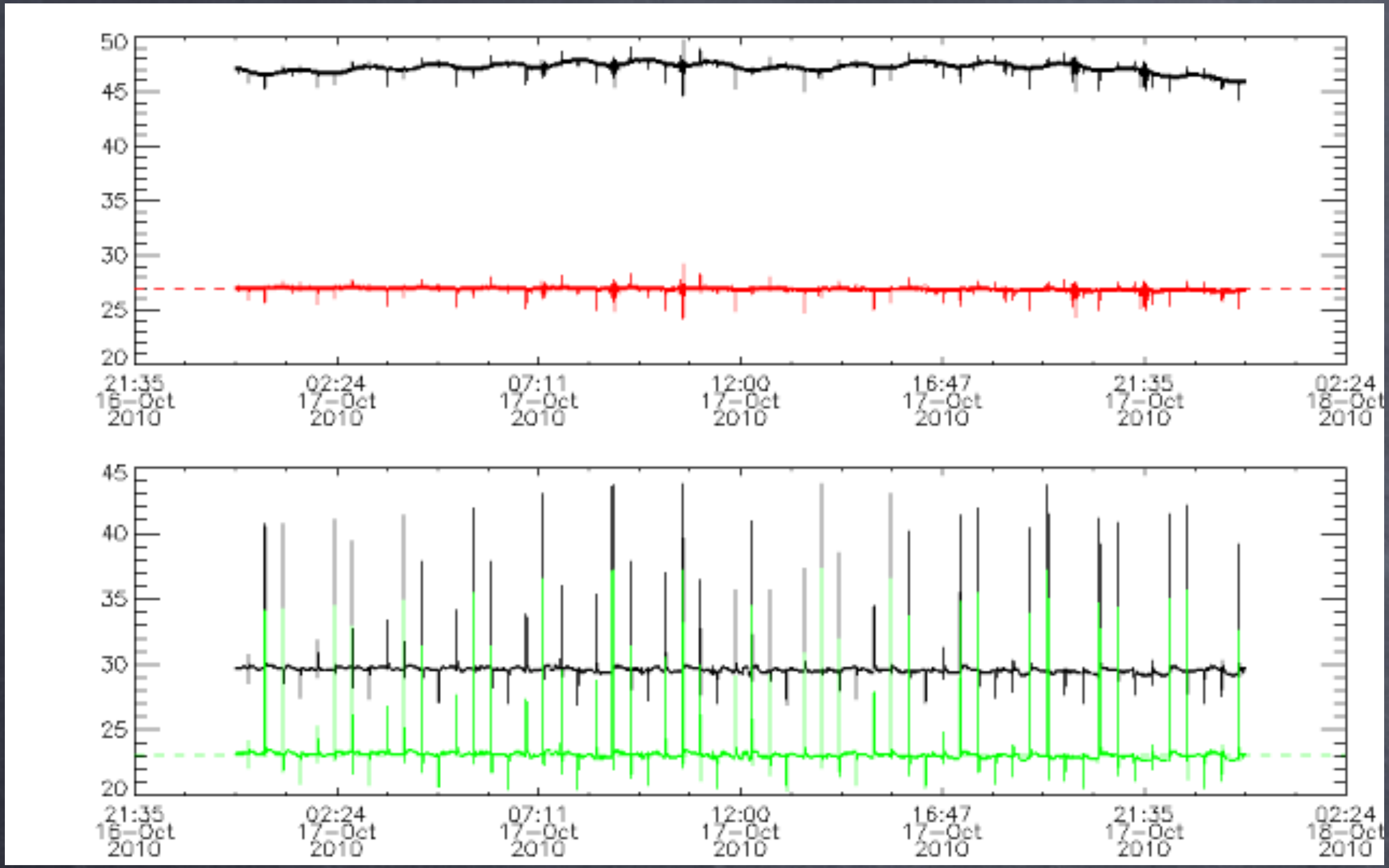
Long term degradation follows a simple exponential farily well. Once full mission has been reprocessed, this fit can be improved with more data and uncertainties estimated. Lyman alpha channel shows 99% loss of signal, Herzberg channel shows about 97% loss in level 1 irradiance compared to January 2010.

Sample Solar Rotation



The month of October 2010 was chosen because level 1 LYRA data exists, and the signature of solar activity should be strong. Earlier in 2010 there was not so much activity in the Herzberg wavelength band.

Daily Averages



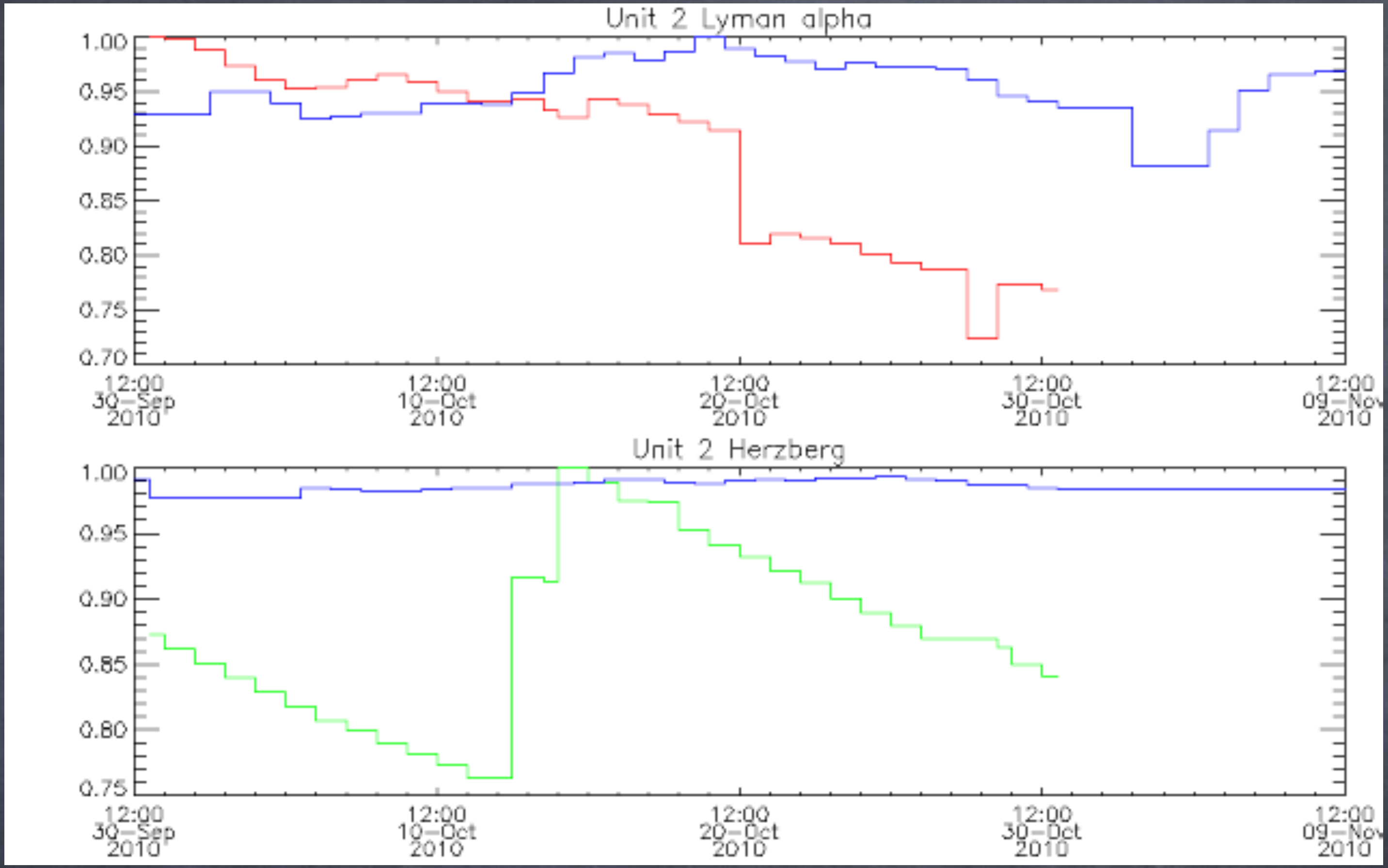
Top panel: Unit 2 Lyman alpha.
Bottom panel: Unit 2 Herzberg

Black curve is uncorrected level 1 data. Red/Green curves are after subtraction for temperature-corrected dark rate.

Dashed lines indicate median value of day's data. The median will not be influenced by the Large Angle Rotations (LAR) when the signal jumps unpredictably.

Analysis after removing LAR would be good, although currently there may not be enough pointing information in the FITS files to reliably filter out the LARs. Quaternions are only telemetered once per minute.

October 2010

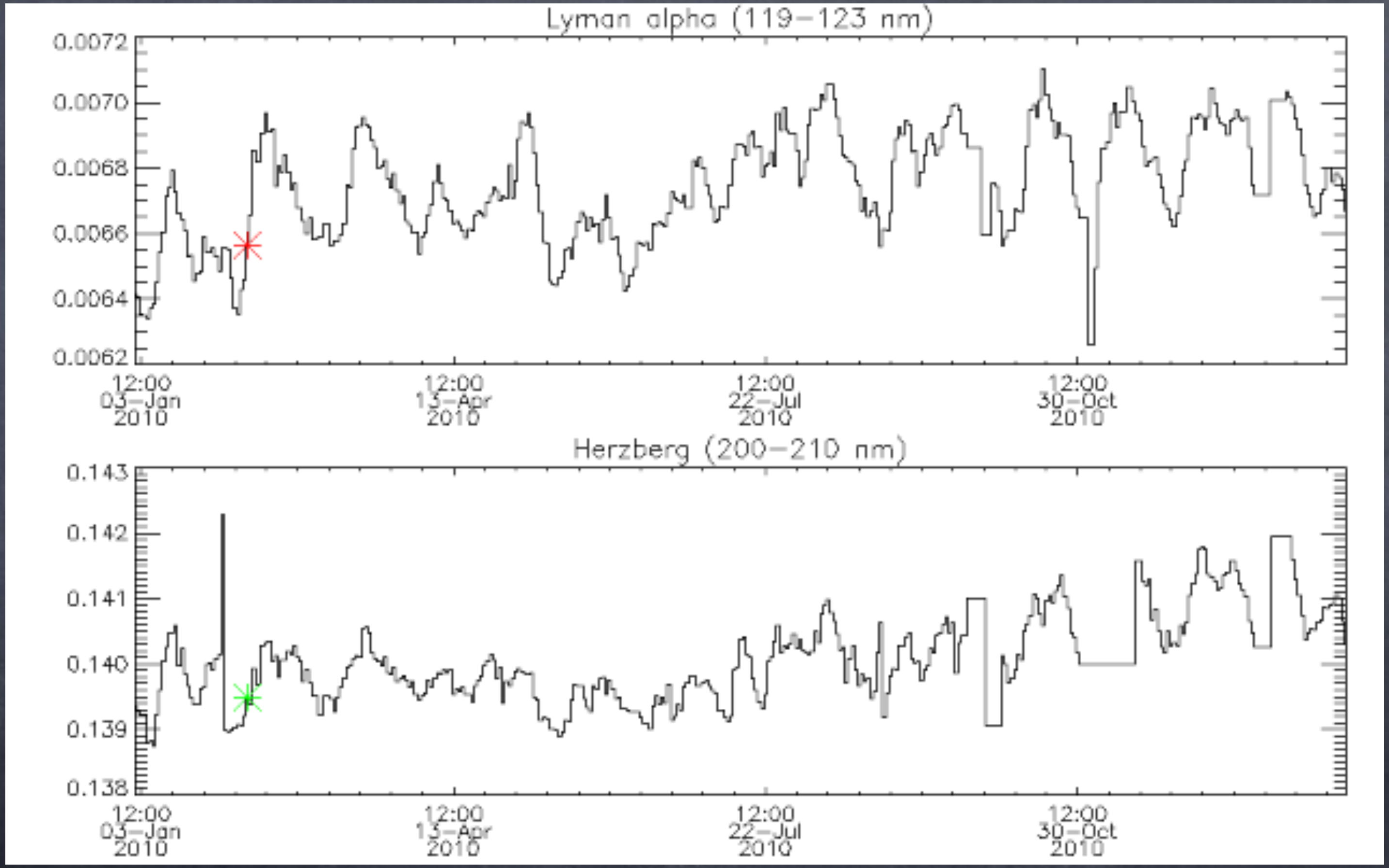


Daily median values for Lyman alpha (red) and Herzberg (green) channels. For comparison, the blue curves are the time series from SOLSTICE showing the expected magnitude of the solar variability over the month. The downward trend in each LYRA dataset could still be due to long-term degradation. I will repeat this analysis on earlier data once it has been reprocessed.

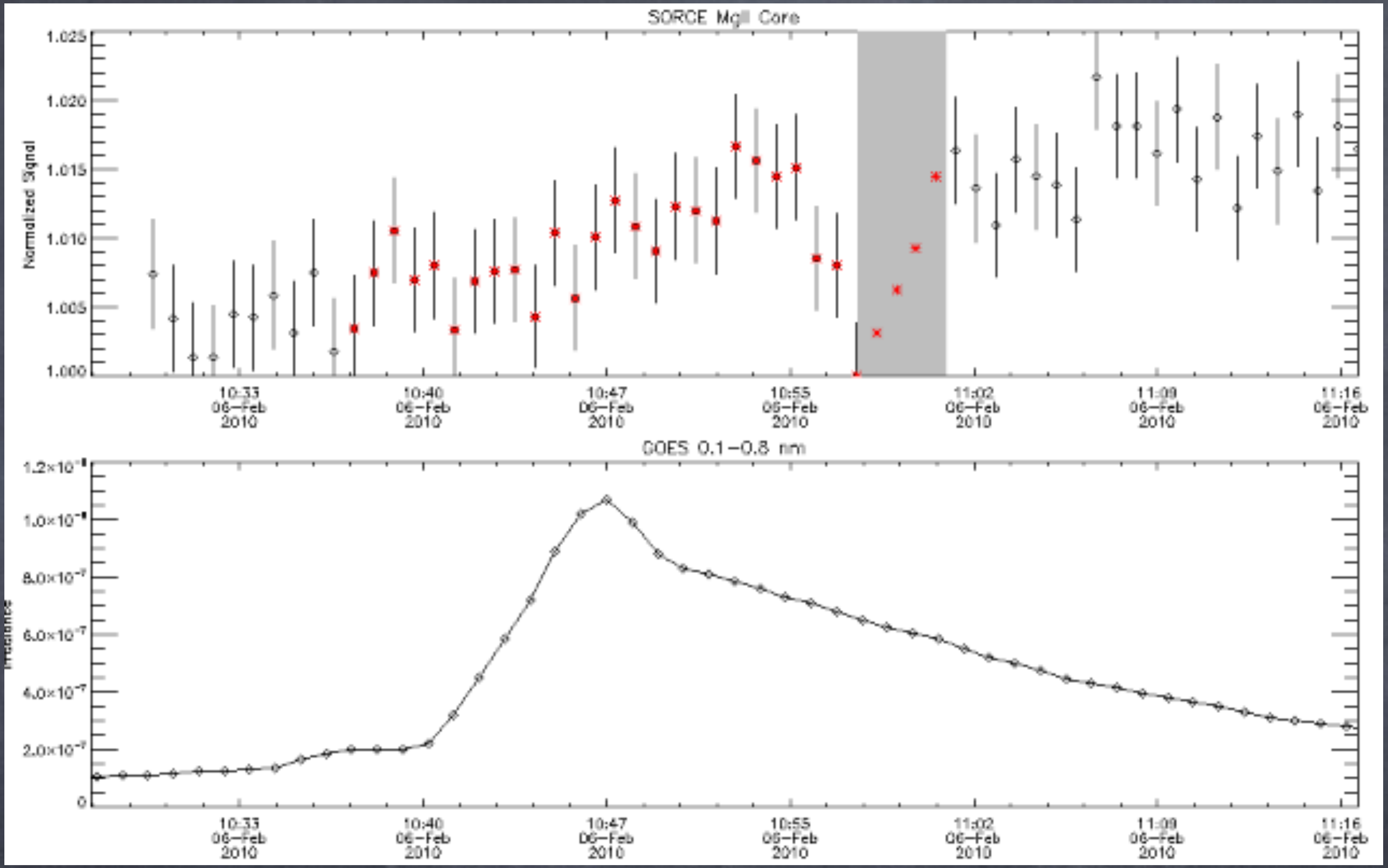
Comparison on shortest timescale

- Pick time early in LYRA mission before severe degradation.
- Choose time period within a day when SOLSTICE is in “miniscan” mode producing 1-minute cadence observations.
- Hope to see some solar variability.

6 February 2010

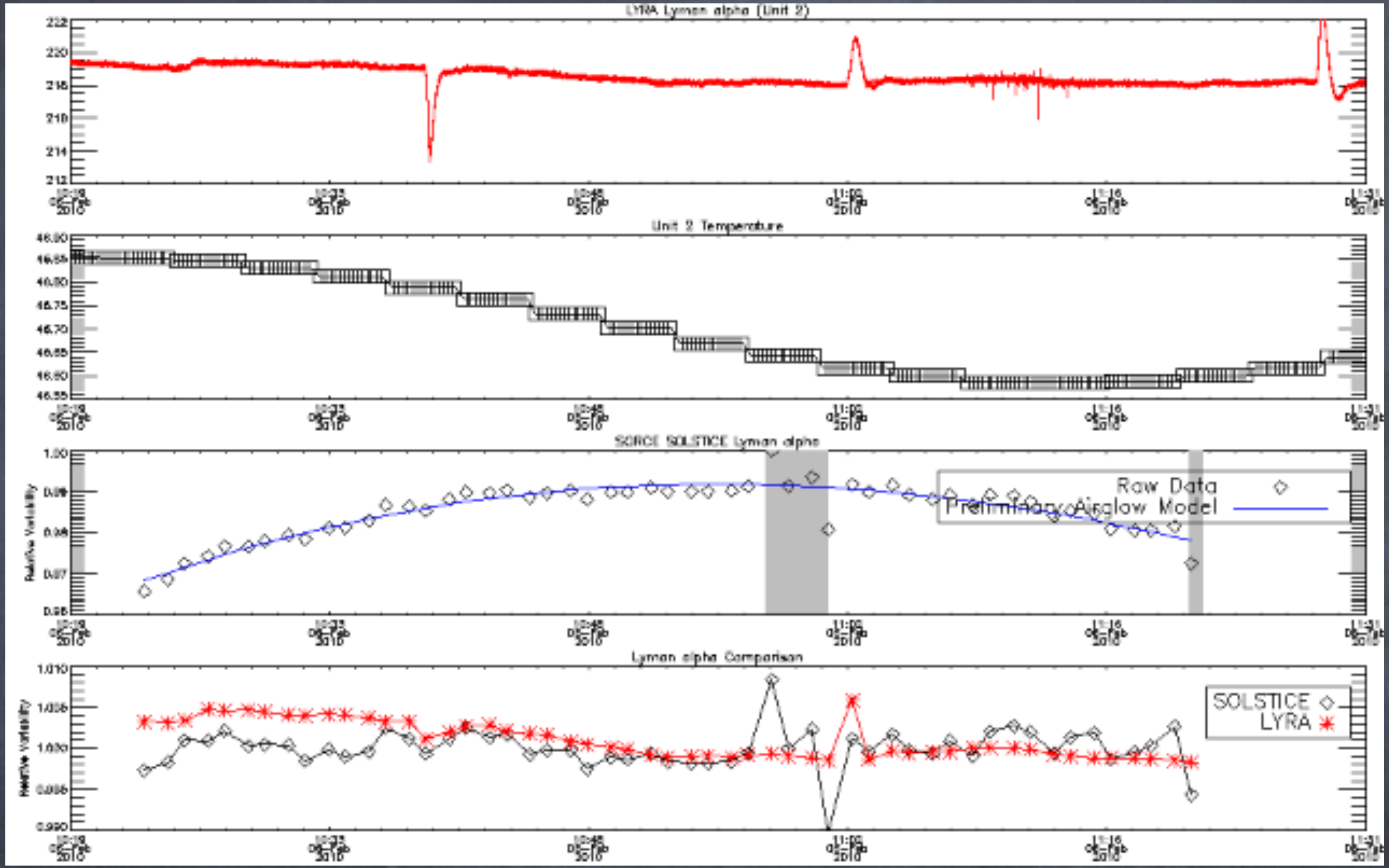


SOLSTICE MgII core



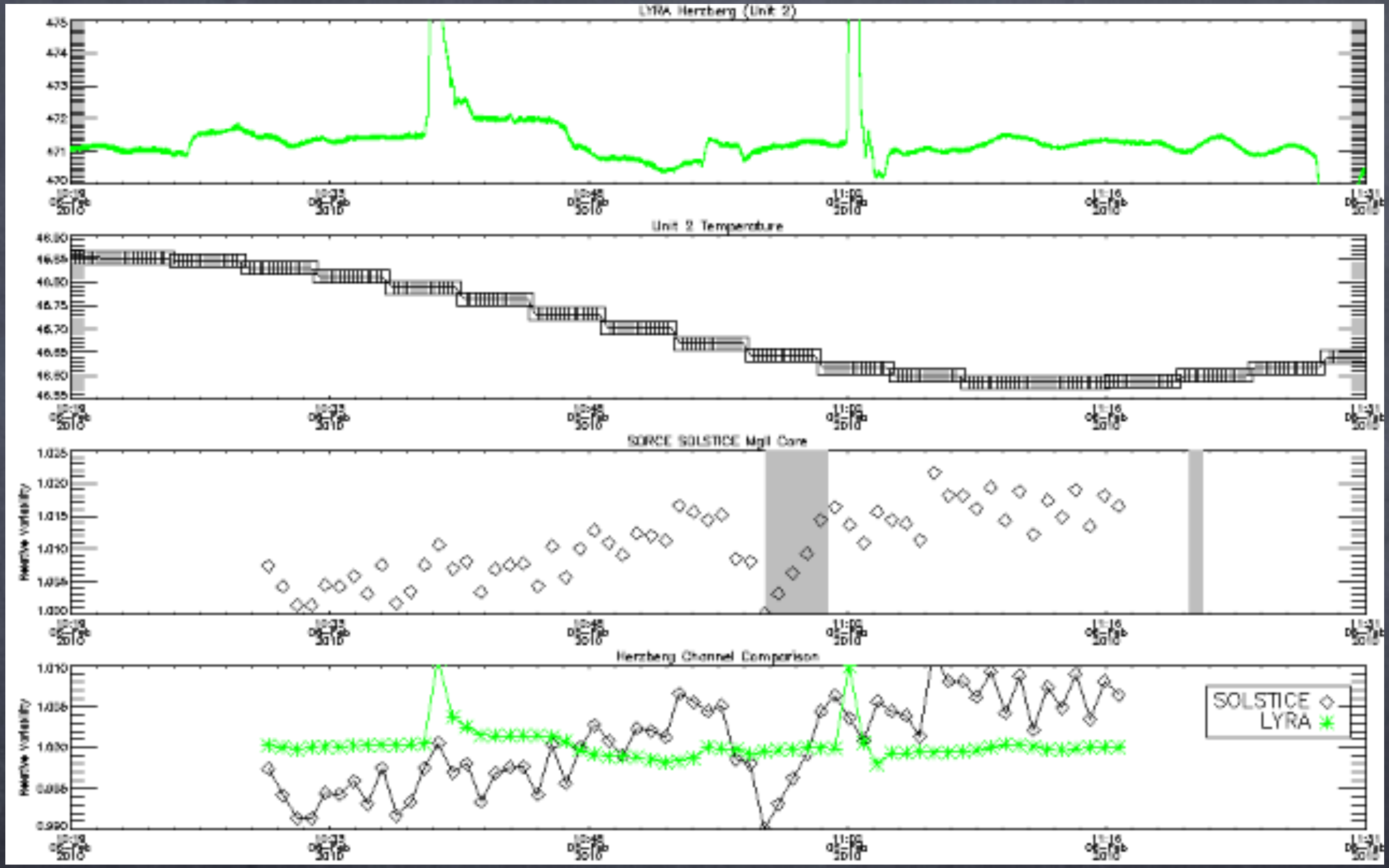
Shaded region indicates spacecraft roll maneuver. Red asterisks show when SORCE was in the SAA. The lower panel shows the GOES X-Ray flux during this time period, so it is possible that the ~1% change in the MgII cores is due to real solar activity and not an artifact. Ideally LYRA will show the same trend.

Lyman alpha 1 minute

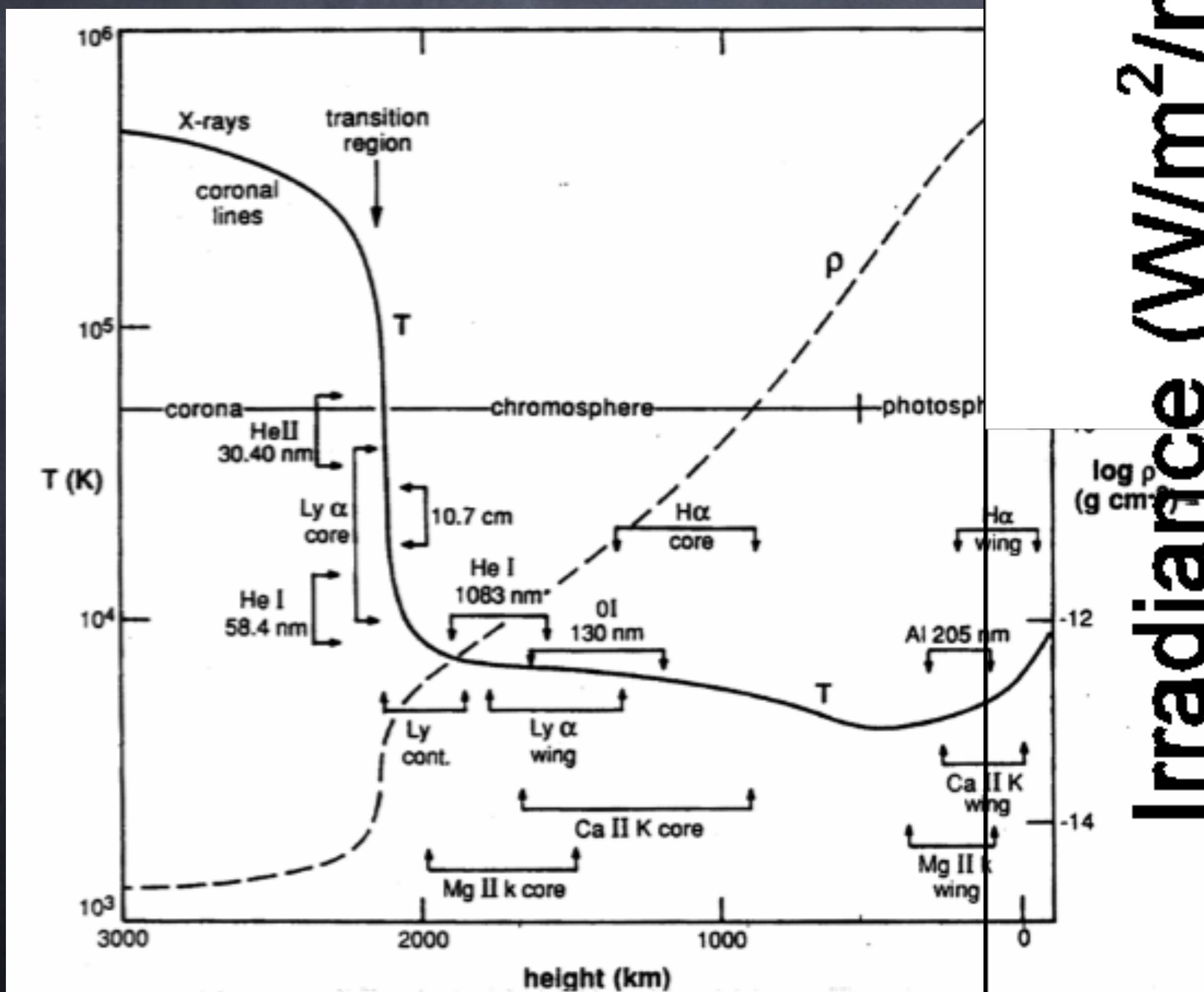


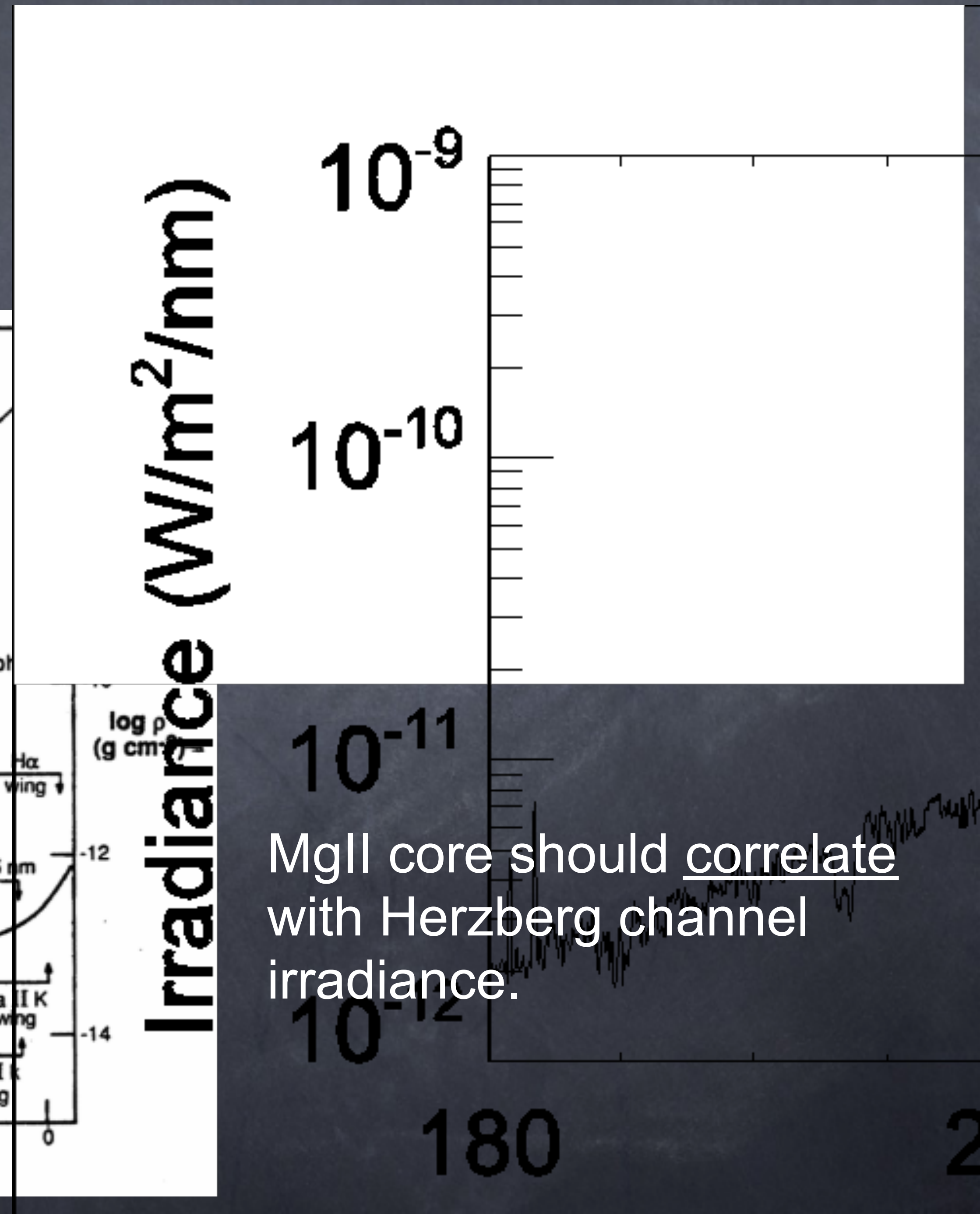
Top panel shows Lyman alpha irradiance after dark subtraction. Temperature of unit 2 is shown in 2nd panel. SOLSTICE Lyman alpha miniscans are shown by diamonds along with simple model of airglow. The shaded regions are roll maneuvers by SORCE (equivalent to LAR). The LYRA time series shows very little variability during this orbit.

Herzberg 1 minute



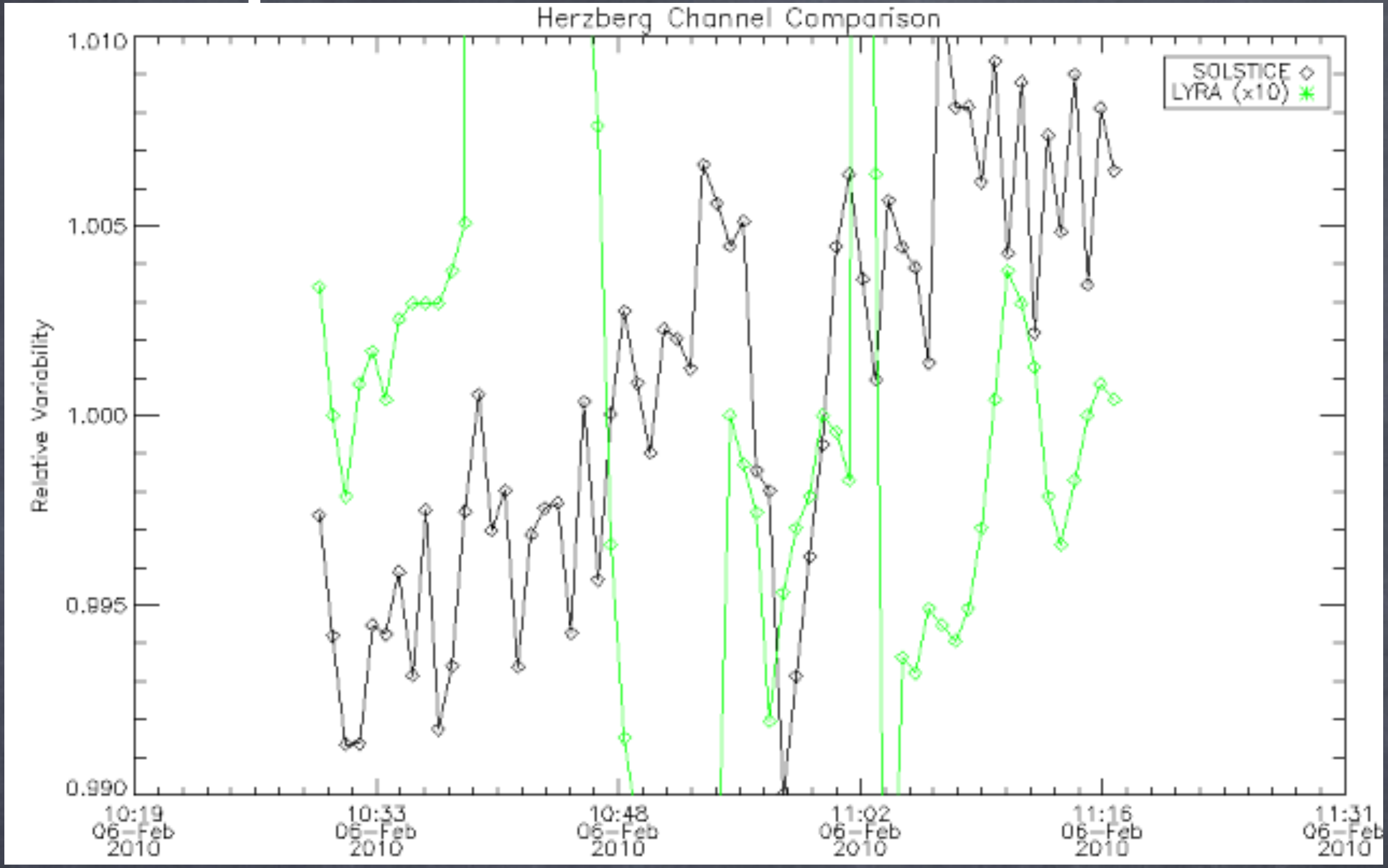
MUV Variability





MgII core should correlate with Herzberg channel irradiance.

Bandpass Normalization?



The MgII core variability should be highly correlated with the variability at 210 nm, but we must be careful about scaling factors. In this plot, the variability of the LYRA signal has been multiplied by a factor of 10. The variability of the LYRA bandpass will not necessarily be as large as the MgII cores due to differences in formation height in the solar atmosphere.

Summary of comparison to SOLSTICE

- Mission length (solar cycle) variability correction will be highly uncertain due to 99% loss of signal in Lyman alpha channel and 97% loss of signal in Herzberg channel.
- Solar Rotation timescale – artifacts due to orbit precession or pointing still dominate the signal from the Sun.
- Orbital timescale – scaling between SOLSTICE and LYRA may require more information about wavelength dependence of bandpass.

Thoughts on Guest Investigator Program

I greatly enjoyed my stay in Brussels. I definitely learned about the operation and data processing of LYRA observations, which will be essential in continuing the comparison with SOLSTICE data. In an ideal world, all the LYRA data would have been available with the latest version of the pipeline processing, but that will never be the case.

I hope that my analysis of some of the calibration data will be beneficial to the overall project. I plan to continue this analysis with early-mission LYRA data once it has been reprocessed. If there is a reasonable correlation with the SOLSTICE data, I'll write it up.

Thoughts (2)

In general, the FITS headers are complete, although having the version number in the filename and not just in the header might be useful. The biggest confusion on my part came from trying to read the older version FITS files with the same IDL code that I wrote for the new ones. That will all be solved after reprocessing.

Anik and Carlos were extremely helpful and I could not have gotten very far without them.

The entire PROBA2 team here at ROB was very friendly and made me feel at home.

Thoughts (3)

As for the structure of the G.I.P. itself, I think that it worked well for me. Since my project proposal was to help validate the data products, I probably needed to be here for an extended time like this. There's no way that I could have done this project remotely. So in this case, a month-long visit makes sense. Perhaps for other research projects a series of shorter visits might work.

I'd like to thank everyone once again for a very interesting month!

Photos