Detailed Mitigation of Photo-Electron Noise in the Dual Electron Spectrometers on MMS with Respect to Solar Activity

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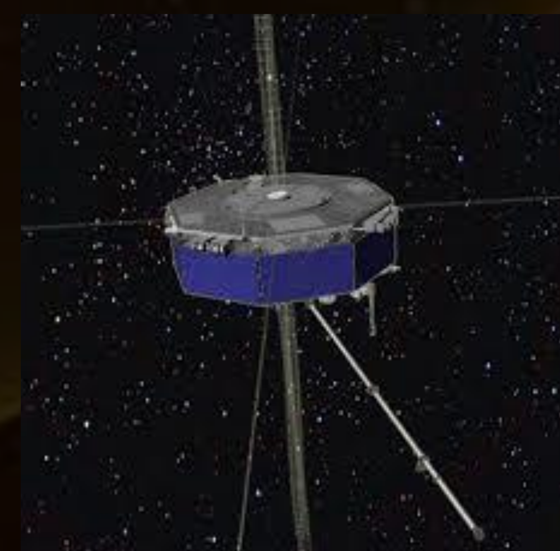
Introduction

MMS is a formation of four satellites in high earth orbit designed to study a fundamental plasma process called magnetic reconnection. To do this, it carries plasma, electric field, and magnetic field instruments. MMS has been in flight for 4 years (2015 launch).

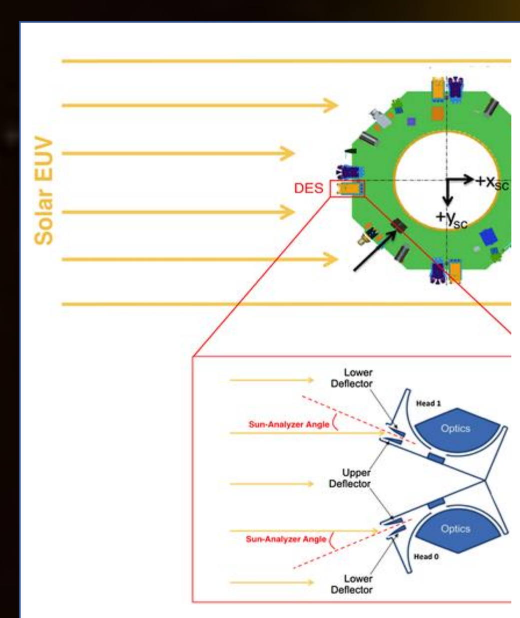


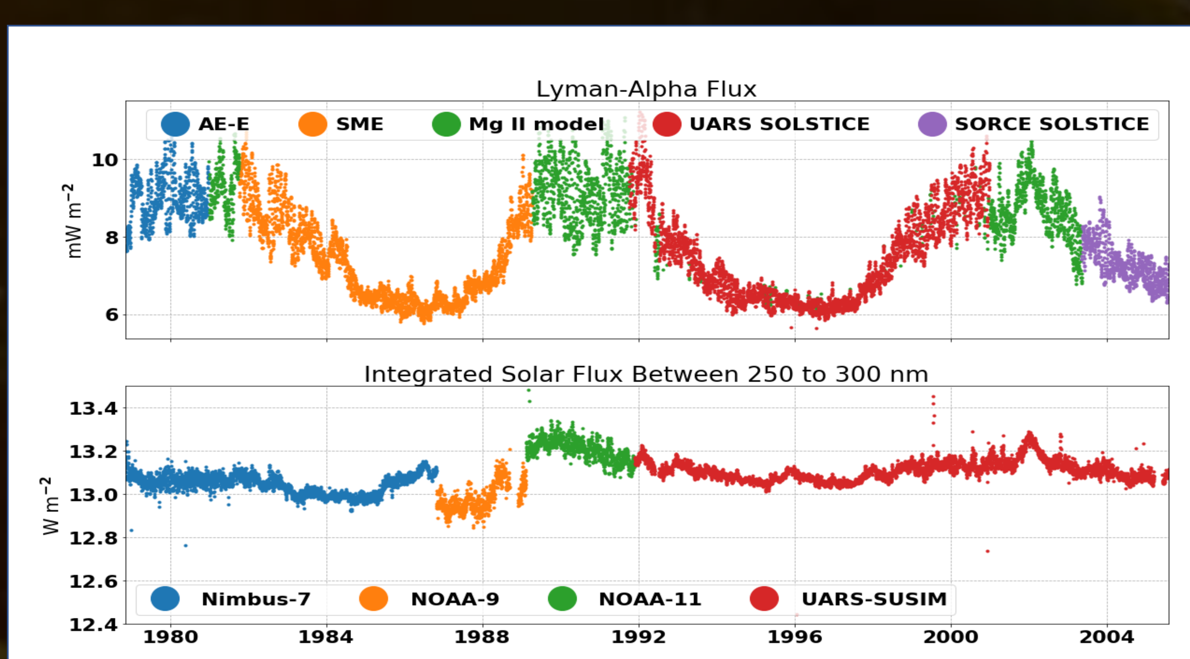
Dual Electron Spectrometer (DES)

The dual electron spectrometer is a critical plasma instrument on the MMS spacecraft that counts and tags electrons with their direction, in turn measuring 3-D velocity distribution functions.

Photo-electric Noise Source

The DES instrument is susceptible to a noise source caused by detection of electrons generated inside the instrument from the photo-electric effect (Gershman et al, 2016). Through this process, electrons are ejected from the surface by solar EUV photons and detected by the instrument as if they were from the environment. The generation rate of these photo-electrons is expected to be proportional to the intensity of incident radiation.





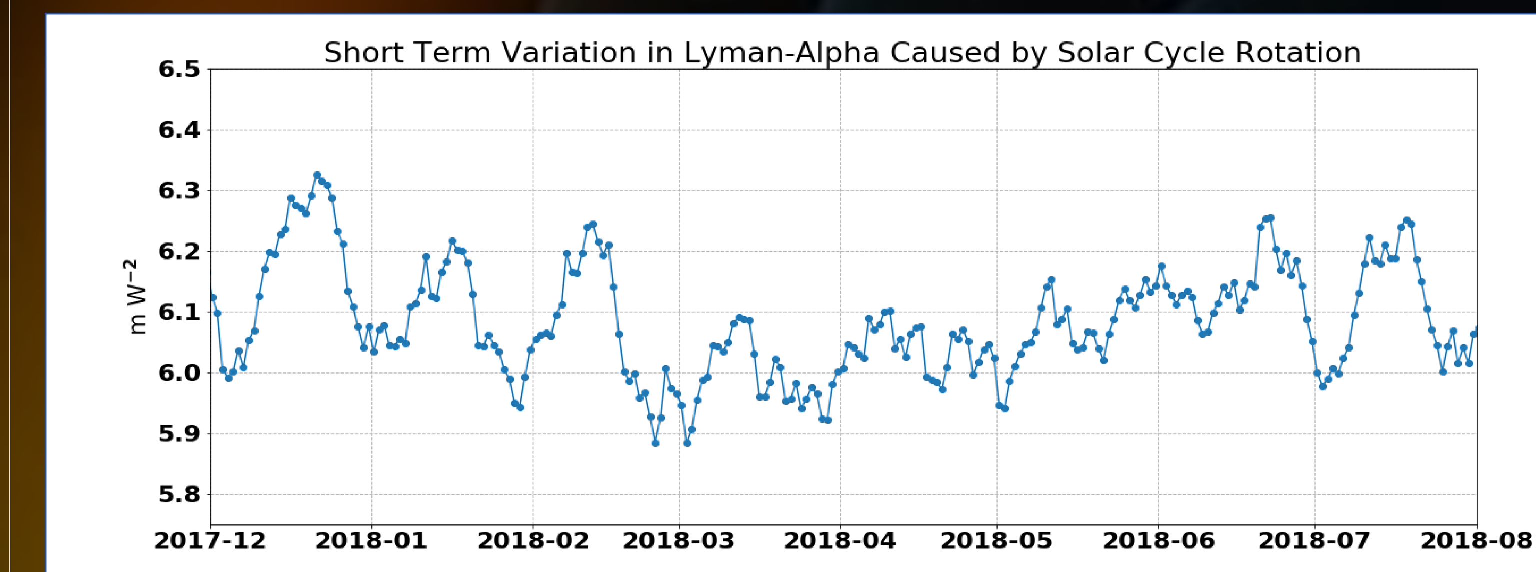
Solar Cycle Variations in the Lyman-Alpha (121.6 nm) and integrated 250 to 300 nm band. The difference in intensity at the shorter wavelengths is much more pronounced than in the 250 to 300 nm UV range.

Solar Cycle Variations in EUV

While longer UV to visible output from the sun stays constant, there is long-term variability at shorter wavelengths over the course of a solar cycle, as shown in the Lyman-alpha emission line (121.6 nm) time history from 1980 – 2004. The difference between the low and the high is about a factor of 2.

Solar Rotation Variations in EUV

There is also variation in the solar EUV output over the course of a solar rotation (24.5 days). The factor is about 1.75.



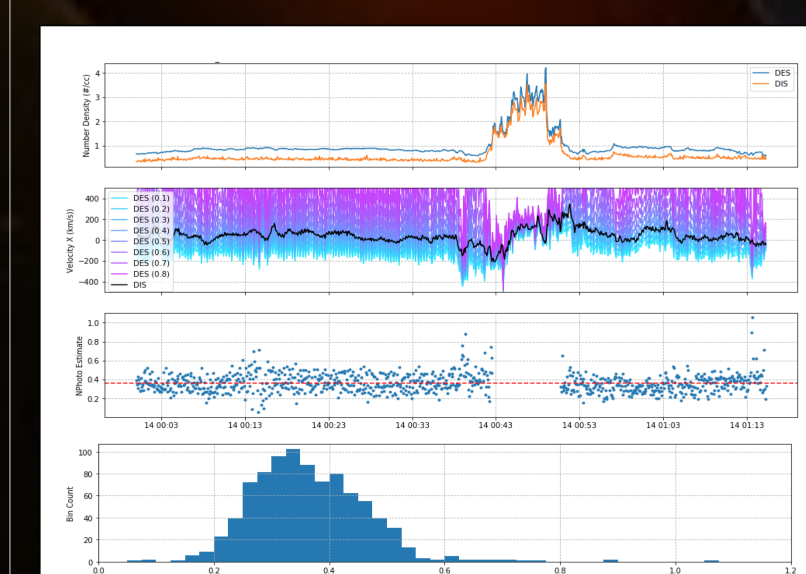
Solar Rotation Variation in the Lyman-Alpha (121.6 nm) Flux as Measured from SORCE/SOLSTICE

Estimating the Photo-Electron Level

These EUV-generated photo-electrons originate on the surfaces facing the sun. As an additive population to the phase space distribution observed by DES, they bias the derived bulk electron velocity towards the sun facing direction.

In regions of the magnetosphere where the current density ***J*** is zero, the electron bulk velocity vector and the ion bulk velocity vector are approximately equal. Using this principle, we calculated a scalar quantity n_{photo} that captures the photo-electron level. This variable is defined in terms of background subtraction.

When subtracting a normalized background photo-electron velocity distribution from the raw DES velocity distribution, the background velocity distribution must be scaled to account for the variation in EUV. The scalar quantity n_{photo} is defined as the required scaling to produce an electron bulk velocity matching the ion bulk velocity.



Estimates of the photo-electron level (nphoto) over the course of 2-hours. Estimates are fairly consistent within this interval and become stronger when averaged.

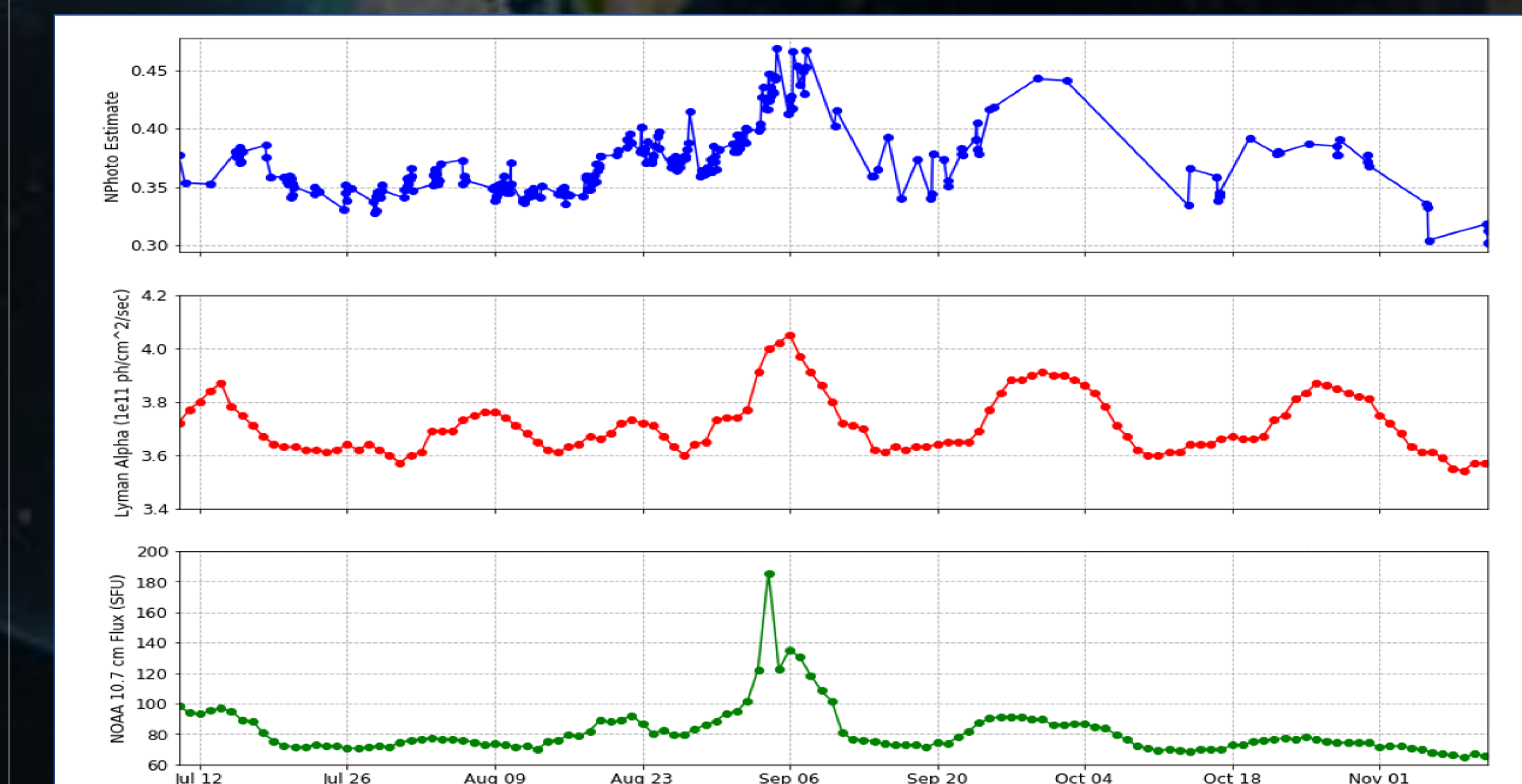
The multi-colored lines are the electron bulk velocities (DES) with varying levels of photo-electron subtraction.

$$\hat{f}_{\text{measured}} = f_{\text{true}} + n_{photo} * f_{\text{photo}}$$

Correlating Noise Level with Solar Activity Proxies

Using the estimated photo-electron level, we compared this to two metrics for solar activity: the 121.6 nm flux as measured by TIMED/SEE, and the 10.7 cm Flux delivered by the NOAA Space Weather Prediction Center.

Correlating these variables show a level of agreement confirming the cause/effect of solar EUV output on the noise source predicted in the left portion of this poster.



Zoomed in comparison of n_{photo} estimate with two proxies for Integrated Solar UV: Lyman-Alpha (121.6 nm) and the 10.7 cm Radio Flux. The three, especially the n_{photo} estimate and the Lyman-alpha observation, show a strong correlation with each other.

Conclusion

This analysis supports an understanding of the physics of the instrument noise source not previously understood and justifies correcting the data by adjusting the background subtraction as frequently as a day. Using proxy variables for integrated UV such as Lyman-alpha, we can track the photo-electron level by its true nature. In the event of another noise sources appearing on the instrument, we can rule out attribution to photo-electrons by observing such proxies. In addition, through this newly understood correlation we can make predictions about the photo-electron level years into the future and estimated levels before launch.

Acknowledgements

This research was supported by the NASA Magnetospheric Multiscale Mission under the Fast Plasma Instrument (FPI) operations project.