Progress Towards Understanding the Degradation and Performance Characteristics of the PROBA2- LYRA Instrument

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Abstract

The Large Yield Radiometer, LYRA is a solar radiometer on the ESA PROBA2 spacecraft launched November 2, 2009. LYRA has been designed to provide measurements of the solar XUV to MUV (soft X-ray to middle ultraviolet) region of the solar spectrum. The LYRA instrument observes in four broad spectral channels, from soft X-ray to UV, chosen for their relevance to solar physics and space weather. Each of the four channels has the capability of acquiring irradiance measurements at a nominal cadence of 20 Hz, but can be increased to 100 Hz. Each of the four channels has suffered from significant degradation almost immediately after launch. The degradation observed in the LYRA channels is detrimental to the potential science. Preliminary work has shown that the most likely cause of the observed degradation is contaminant buildup on the filters at the front of the instrument.

In this work, we present initial results of our investigation into the performance characteristics and observed degradation. We have developed and will present results from our three-step approach: 1. Develop models for each LYRA channel using measured calibrations and instrument design parameters, 2. Use the models to estimate the sensitivity changes due to possible degradation sources (thickness and composition), and 3. Evaluate corrected sensor performance by comparing the measured data with independent measurements from currently operating instruments.

Measured LYRA Degradation

The LYRA radiometer on the ESA PROBA2 spacecraft comprises three separate channels each measuring in four spectral bands to assess new technology for making such measurements[1]. As well as providing technology demonstration of wide band-gap detectors, the data collected by LYRA have proved to be very useful for real-time space weather monitoring, and the very high cadence of measurements have allowed studies of, for instance, quasi periodic oscillations in flares, that can lead to better understanding of the physics of the flaring plasma[2].

The degradation of the main observing unit can be tracked by comparing the measured irradiances to those obtained by the other units that are only exposed to the Sun rarely, and unfortunately, the main LYRA photometers show significant degradation that progresses with solar exposure[3].

Degradation Model

The degradation of solar viewing instruments is often ascribed to the buildup of contaminants (often hydrocarbons) that are unavoidably introduced during the instrument and spacecraft build and test. These contaminants can find their way into the optical system, and especially if they are on the front (solar viewing) element can by polymerized onto the surface, and reduce the transmission of the system. A recent review of observed degradation and processes is given by BenMousser et al.[3].

The degradation of the LYRA primary channels has been calculated by Ingolf Dammash for the 200th day (July 24, 2010) since PROBA2 first light[3]. The degradation is determined by comparing the measurement made by the primary channels with those of a backup channel that has not had significant solar exposure.

In order to take into account the solar spectral shape under the broad-bandpass of the LYRA channels we used the WHI reference spectrum[4] from March 25–March 29, 2008. We used this composite solar spectrum rather than creating a new one as the 10.7 cm radio flux (F10.7) on July 24, 2010 was 85, and that for the reference spectrum was 83.8, so the solar spectra should be similar.

Examining the as-built assembly documents for the LYRA cover mechanism, both a silicone RTV and epoxy were identified as possible sources of contaminants, so a two-component (C and Si) contamination model was used.

Tabulated atomic property values — atomic scattering factors[5], refractive indices[6], and mass energy-absorption coefficients[7] — are available to cover the wavelength range covered by LYRA. The deposition of carbon contamination is in the form of graphitic carbon(see for example[8]), and so those properties have been used.

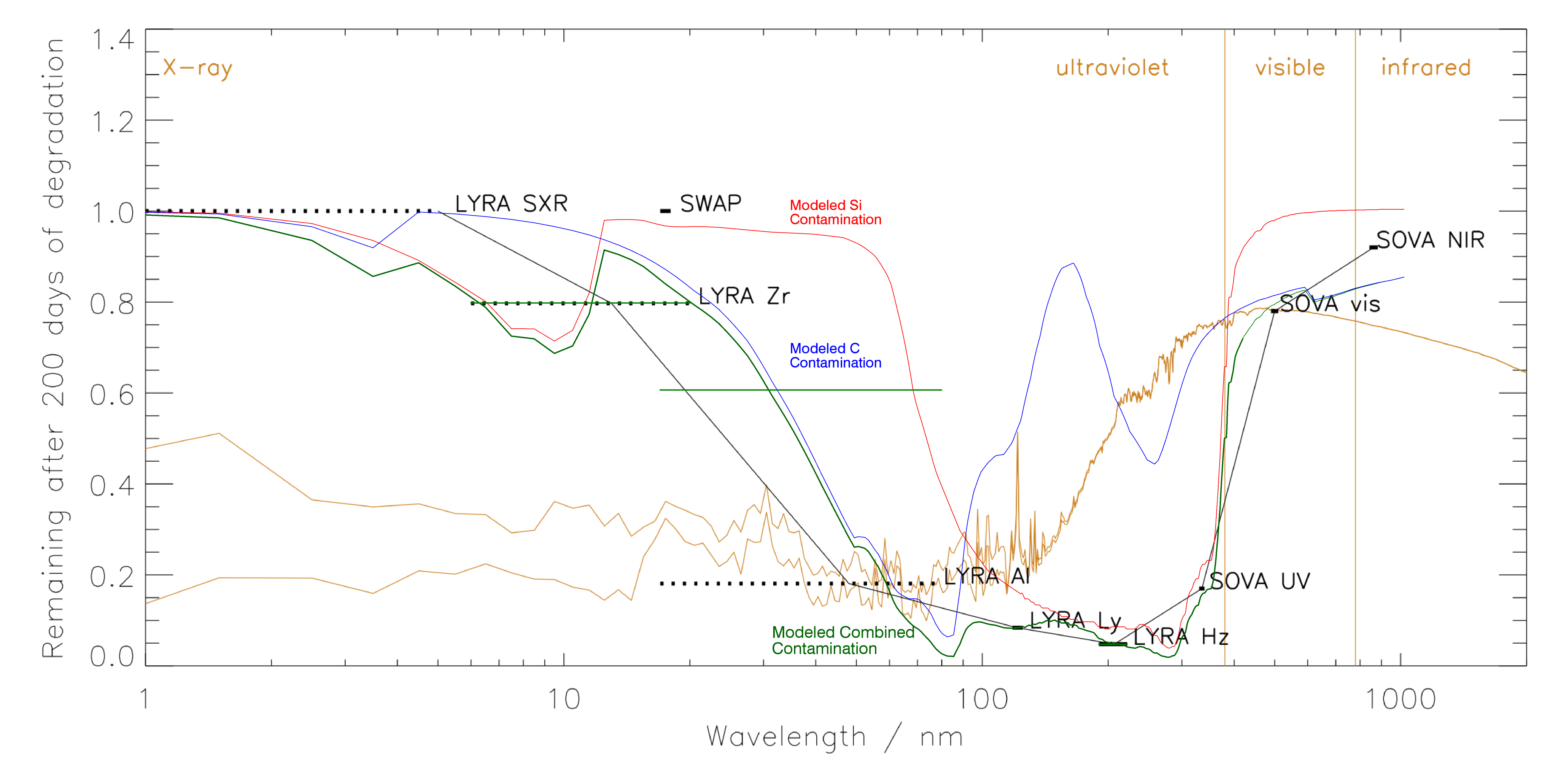
The only variable used in the fit was the thickness of the C and Si layers. The result are shown in the figure, and the calculated contaminante thicknesses are: C 13.3 nm and Si 12.6 nm.

Future Work

We plan to look at the progression of the degradation of all the LYRA channels, especially during the early part of the mission when the degradation rate will be fastest. As the contaminants have wavelength dependent attenuation the effective bandpass of the broad EUV channels changes, so once the contaminate thickness has been determined the effective bandpass can be calculated and the corrected irradiance calculated based on an EUV spectrum from SDO-EVE or TIMED-SEE (for instance).

We will look at the time history of the degradation of the backup channel by repeating the analysis for the backup unit and see whether the degradations (especially for the Al channel) follow the same evolution.

Measured and Modeled LYRA Degradation



Conclusions

We have proposed a model that explains the degradation in terms of contamination of the photometers with carbon and silicon. Sources for both these species have been identified in the LYRA cover mechanisms. This simple two-component model fits the observed degradation very well for all but the “Al” channel, that shows significantly more degradation than predicted by the model.

The assumption made in this analysis is that the layer thickness of contaminants is the same for all channels. The example of the SDO-EVE degradation in the MEGS-A Slit 1 and Slit 2[3] has demonstrated that this is not the case, again with the Al filter showing significantly more degradation than the Zr filter. We do not have an explanation for this at the moment but a couple of possible explainations have been proposed: The temperature of the Sun-viewing filters may be significantly different, and hence the contaminant residence times very different; the secondary electron emission from the filter materials may be very different, and hence polymerization rates will be different[8].

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