The highest resolution full disc EUV corona image

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1) Introduction

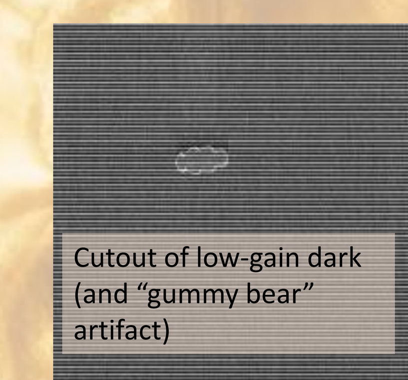
On March 7 2022 with Solar Orbiter at a distance of 0.50 AU to the Sun and crossing the Sun and Earth line, the Extreme Ultraviolet Imager (EUI) with its High Resolution Imager in EUV (HRI-EUV, 17.4 nm) created a 25-panel mosaic of exposures covering the entire disc of the Sun.

Here we discuss some of the challenges of calibrating this HRI-EUV data when creating the highest resolution full-disc solar corona image in Extreme Ultraviolet light ever.

3) Calibrating

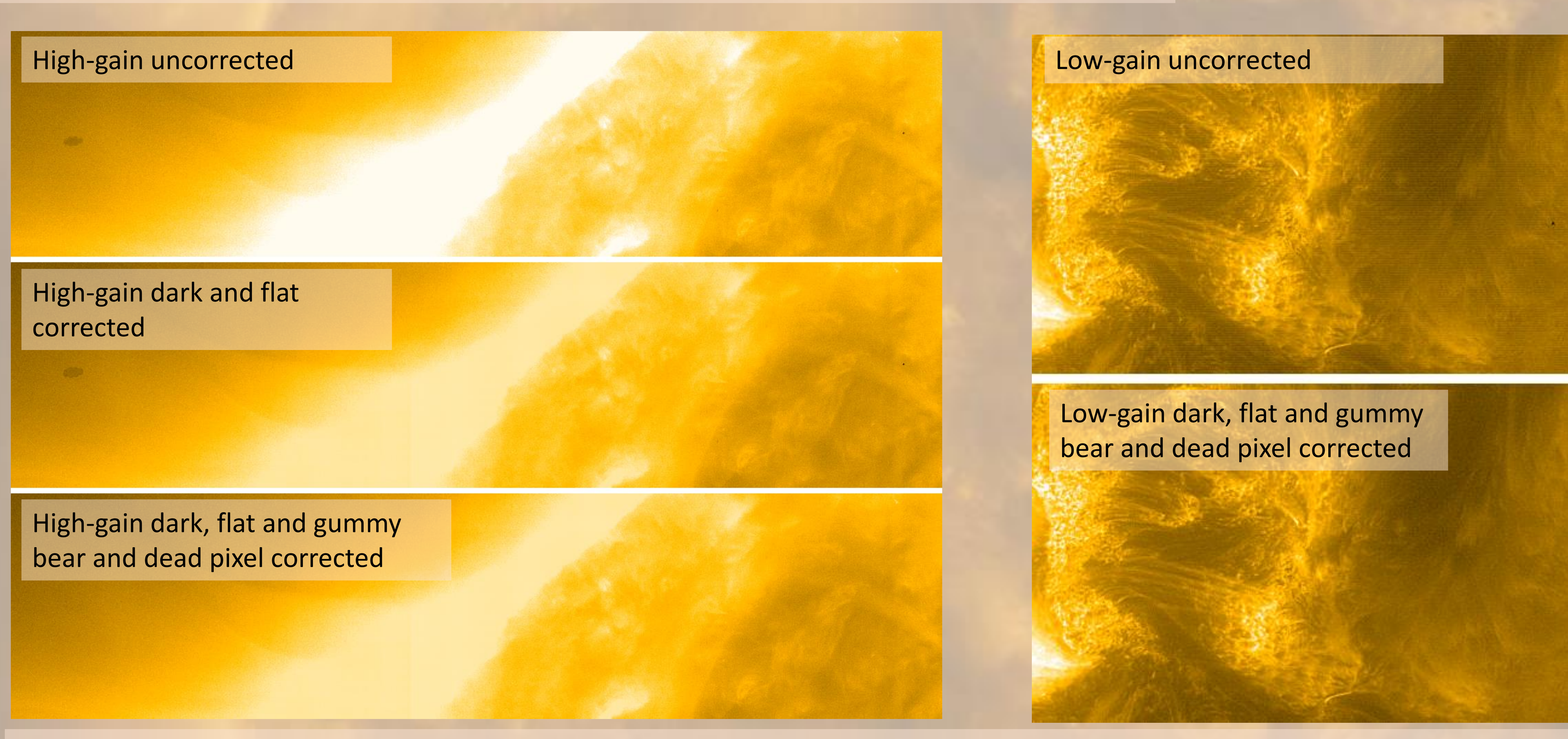
The images are calibrated on ground using dark and flat images. For the low-gain images, however, the existing dark frame is clipped, resulting in an undercorrection of the images. To improve on this, a (repeating) 4-column correction map was applied to remove this biggest component of the bias signal. The image to the right shows a cut-out of the clipped low-gain dark image surrounding a 'gummy bear' shaped artifact. Below that a high-gain flat image showing a wavy pattern and the stitching line in the middle of the detectors. The flat correction is not yet applied when combining gains onboard, but a similar 4-column correction is applied onboard.

The gummy bear artifact is not (completely) removed by the dark or flat field correction, and is often still visible in the calibrated level 2 data.



Cutout of low-gain dark (and "gummy bear" artifact)

High-gain flat

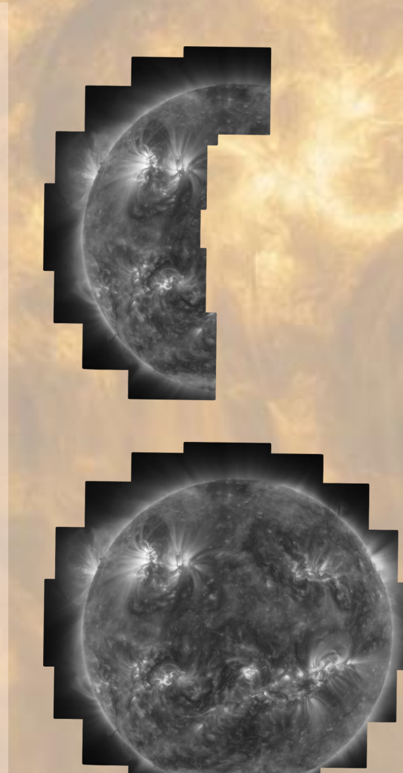


Above: The calibration steps visualized for the high-gain (left) and low-gain (right) images. The gummy bear artifact was removed by multiplying the intensity of the pixels inside the gummy bear by a correction factor calculated from the ratio of the median intensity of pixel values inside the gummy bear and the median intensity of pixel values just surrounding the gummy bear. The low-gain images clearly show the eliminated 4-column pattern.

5) Creating the Mosaic

The calibrated images were aligned using pointing information available in the FITS header of the image files. The images were then manually combined and merged over a region of ~50 pixels using photo editing software. The relatively large overlap between panels allowed us to merge mostly in less dynamic areas of the Sun, avoiding seam-like artifacts caused by slight misalignments or changing views (in horizontal direction the neighbouring panels are taken almost 1 hour apart!).

The HRI-EUV mosaic was placed on top of an (averaged) FSI 174 image taken during the same times. The contrast of the mosaic image was slightly enhanced, and a custom color map was applied for dramatic effect. The resulting mosaic measures over 9000 x 9000 pixels, and is displayed in the panel at the far right.



6) Conclusions

The HRI-EUV mosaic calibration exercise resulted in the highest resolution full disc EUV corona image ever. The mosaic was produced in first instance for outreach purposes (e.g., it was used in the successful* ESA press release of May 2022, and will furthermore be displayed on a 5.8 x 5.8 meter canvas during the Open Door Days of the Royal Observatory of Belgium on September 24-25, 2022), but some science use and multi-instrument cross-calibration can also be anticipated after the calibration procedure has been further refined and implemented in the EUI calibration software.

An interactive version of the mosaic can be found here:
https://www.sidc.be/EUI/pictures/20220307_hrieuv_mosaic/

See also the EUI Jupyter Notebook 4 of the the Data Processing tutorial (Friday Sep. 15, 2022)

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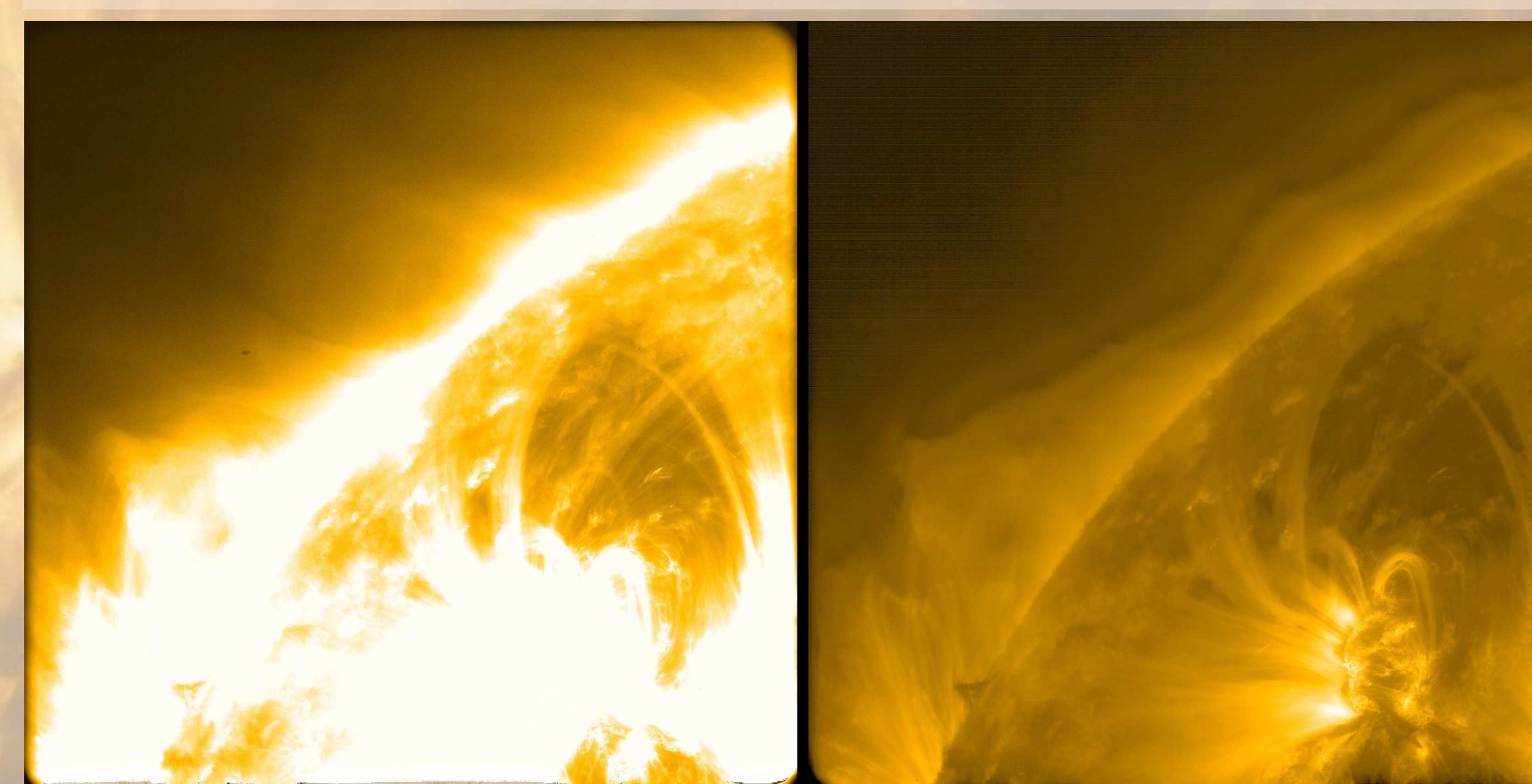
* Crashing our webserver

2) Dataset

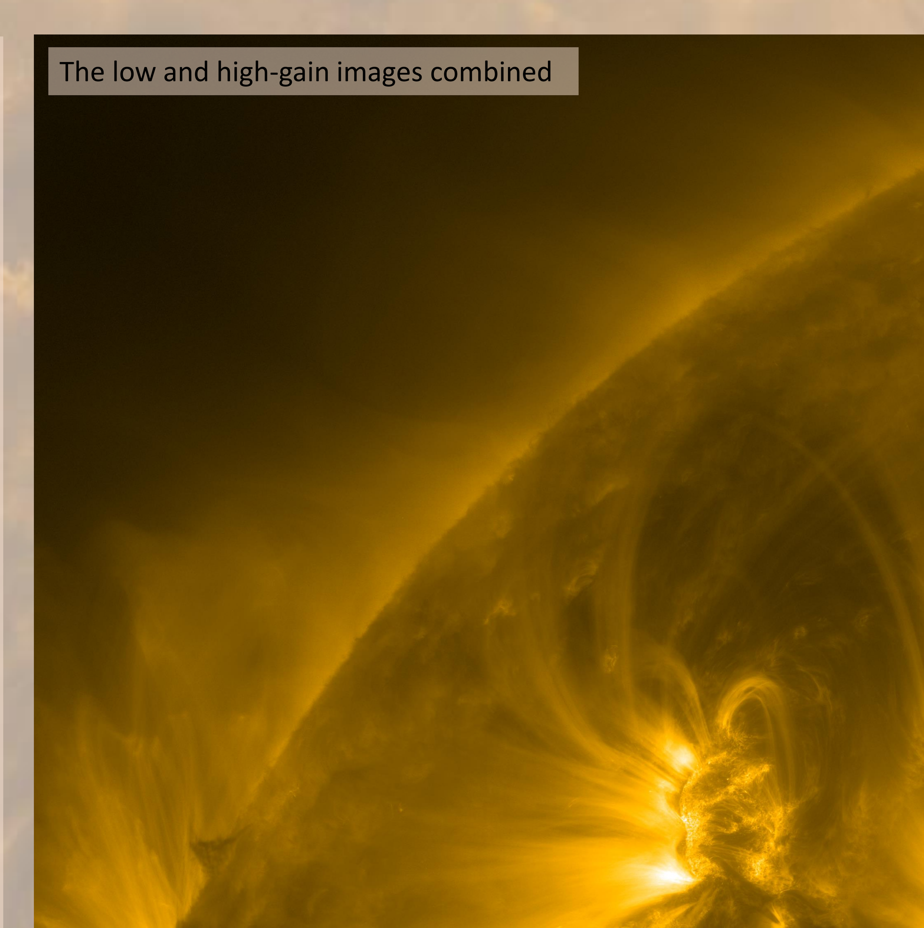
The HRI-EUV instrument was taking pairs of high and low-gain images every 30 seconds, resulting in 9 high-quality lossily compressed (2 bpp) image pairs per pointing position. In total 25 panels were imaged over 4 hours 35 minutes. The HRI-EUV instrument is capable of creating combined gain high dynamic range images onboard, however, this functionality is not working perfectly and is incompatible with the larger than normal field of view (2368^2 vs 2048^2 pixels).



Left: high-gain only HRI-EUV image, showing large parts of the Sun over-exposed, but good signal in the fainter parts of the images. The dark lines at the bottom are detector artifacts and are in fact showing some low-gain pixels. Right: low-gain only HRI-EUV image. There are no longer over-exposed pixels, but the image shows several ringing artifacts in darker areas of the image.

4) Combining gains

The low and high-gain images are automatically scaled such that the intensity levels are matching. To avoid bias from the lower-quality dimmer areas of the low-gain images, this process is performed by looking at the intensity of those pixels where the high-gain image is almost saturated. This intensity is compared to the intensity of the matching low-gain pixels. The resulting gain factor is not quite uniform throughout the field of view, resulting in a (slight) visible mismatch when the over-exposed high-gain pixels are replaced by the scaled low-gain pixels.



The low and high-gain images combined