

IRIS Flat Fields

Flat fielding of images acquired with IRIS CCDs is required to remove the effects of:

- vignetting,
- the semi-regular laser anneal pattern visible at the 5-10\% level in CCD images,
- potential dose accumulation burn-in,
- dust and artifacts on the slit and detector,
- the intensity pattern due to irregularities in the slit width (spectrograph).

1. Slit-Jaw Flat Fields

Method:

Flat fields for the slit-jaw imagers are constructed using the technique presented in Chae (2004) which makes use of relatively shifted solar images in order to extract the stationary flat field pattern of the instrument from the moving solar scene. For this implementation we have selected a Reuleaux triangle dither pattern of 30 arcsec containing 15 pointings for the FUV filters. This way the dither can be accomplished on the short timescale of the solar chromosphere. A larger dither pattern is required to properly account for the large vignetting pattern due to the Solc filter mask and instead we use a 70 arcsec pattern with 30 pointings. The results of 3 dither sequences are combined to produce the final flat field. Regions of bright but quiet plage provide sufficient counts for the FUV. The filters with high contrast (FUV + NUV core) are taken with the telescope out of focus so a more uniform coverage of the CCD is possible, while images for the lower contrast NUV wing and glass filters are taken in focus to ensure the granulation pattern of the quiet Sun can be accurately extracted.

The Chae method significantly decreases the amount of time spent obtaining flat field images. Each wavelength of the SJI uses different optics, causing a change in the vignette pattern, in addition the CCD has a slightly different gain response at each wavelength, necessitating the use separate flat fields for each filter. Using the Chae method only 15 x 3 flats are necessary for each filter, whereas an averaging method might take hundreds of images to sufficiently smooth over the solar structure.

The fiducial marks in the spectra and the slit in the SJI images are important for calibration and are therefore seamlessly removed by replacing the pixels around each with the pre-launch flat field images obtained using a mercury lamp filtered to 2537 Å.

Results:

2. Spectrograph Flat Fields

Method:

The spectrograph flat fields are produced by extracting the spectral profile from spectrograph images which have been sufficiently averaged. The emission lines of the FUV and the Mg II line cores show high contrast features and non-uniform line profiles, even in the quiet Sun. A spectrum which is spatially smooth and spectrally uniform is obtained by taking a coarse raster of the disk center quiet Sun, during which the telescope is defocused and slewed during the exposures to provide additional smoothing, then the images in the sequence are averaged together. At least 200 images are required to build a good intermediate flat field.

To extract the spectral profile the intermediate flat field is up-sampled by padding the Fourier transform of the image. This image is warped using the geometry correction determined for each spectral window to make the spectral and fiducial lines straight with respect to the grid of pixels. Averages are taken along the spatial and spectral dimension. These averages are reversed through the geometry correction, resampled back down to the original image size, and divided from the original spectrum to produce the final flat field. The spatial flat field (average along the spectral dimension) is reserved so that it can be shifted and applied to properly compensate for slight thermal shifts of the spectrum on the detector.

Exposure times of 15 seconds are used for each individual image for both the NUV and FUV flat field observations. For the FUV spectra, this ensures that the bright lines have enough signal, however the faint lines and continuum do not rise above the level of the read noise.

Results:

FUV Background:

Attempts to flat field the FUV spectra have currently been stifled by the presence of a smooth stray light background. This background does not contain the CCD annealing pattern which is present at blue and UV wavelengths, indicating that it may be a red or infrared light leak, which would penetrate more deeply into the CCD. A gain of 5.6±0.2 photons/DN has been measured for the stray background in long exposures taken off the solar limb which is comparable with the gain measured with the blue LEDs and consistent with the statistics expected for visible or infrared photons. Analysis of the off-limb data from the other channels of IRIS does not indicate a similar stray component. The background must be characterized and removed before the FUV spectrograph flat fields can be properly determined or applied.

References

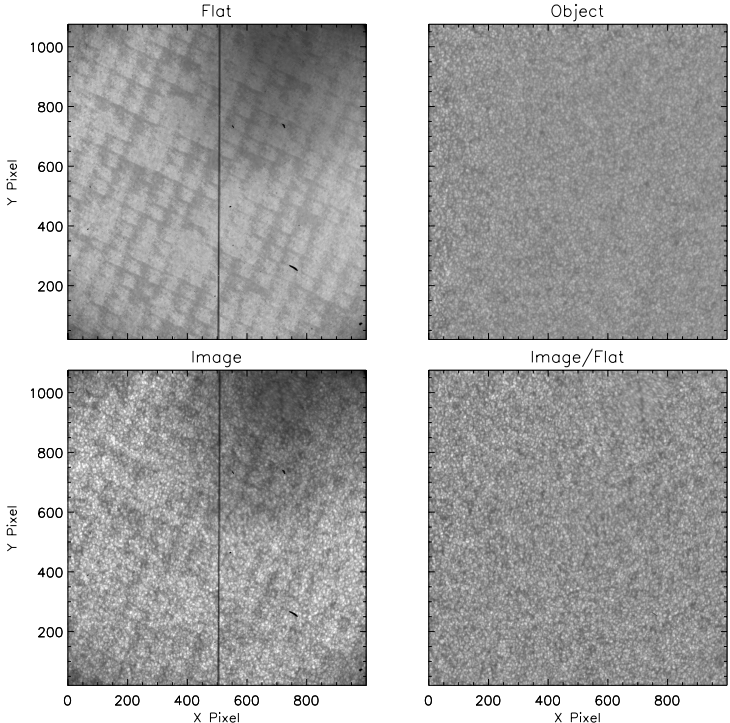


Figure 1. Results from the Chae method using the 2832 slit-jaw.

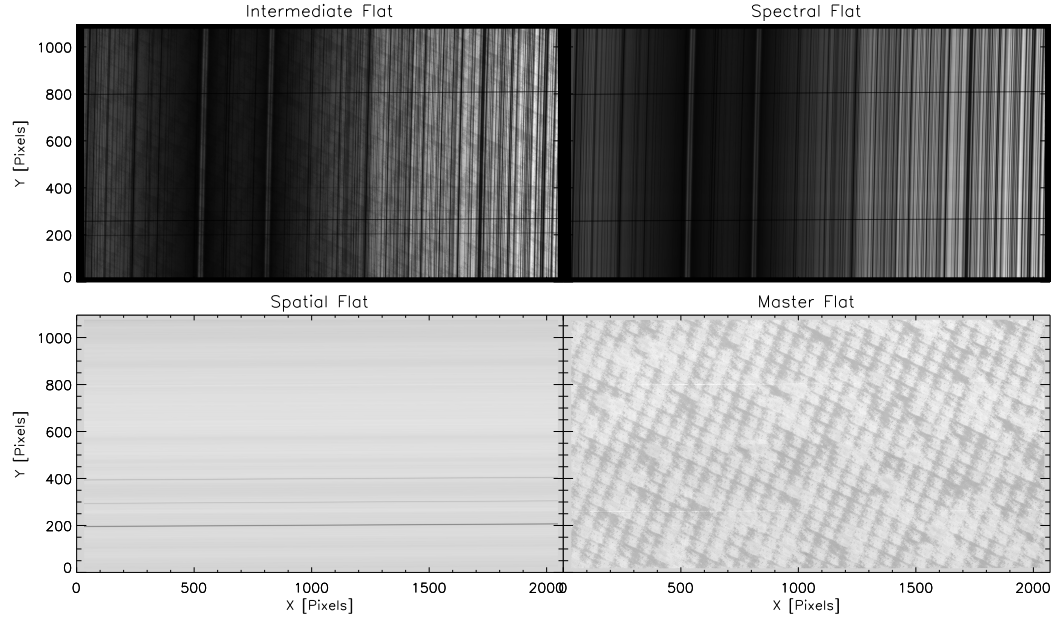


Figure 2. Sequence of flat field analysis for the NUV spectrograph.

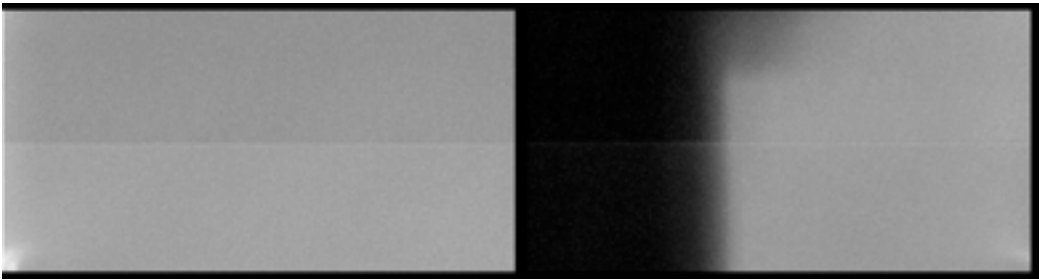


Figure 3. The average FUV spectrograph image from off-limb pointings.

Figure 4. The best fit solution of the average background level in the FUV when the SJI 2793 Å filter was present, fitted using a smoothed 2D limb-darkening function.

