Determination of the Photometric Calibration and Large-Scale Flatfield of the STEREO HI-2 Cameras.

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The Problem

- Two separate but linked questions:
  - To derive scaling factors to convert HI-2 counting rates to physical units (B_{sun}, S10, W/m^2).
    - Including any time variation.
  - To determine the large scale flat field correction.
- Has been done for HI-1 (Bewsher *et al.*, *Sol. Phys.* **264**, 433 [2010]).
  - Similar approach for HI-2 was not successful.

A new approach?

- HI-2 has a much larger FoV, and also a larger PSF (in pixels as well as arcminutes).
- As a result of this:
  - Stars of a given magnitude are closer together in relation to the PSF size, so confusion is a much bigger problem.
  - This means that the method of using fixed annuli to determine stellar brightnesses failed.
- Must devise:
  - a new way to measure stellar brightness and
  - new criteria for star selection.

Sample

- Needs to exclude:
  - Faint stars that are confused.
  - Bright stars that are partially saturated.
  - Variable stars, and others that cannot be readily characterized.
- Used Yale Bright Star Catalogue, and select:
  - 2.0 < V < 5.5
  - Not variable or double
  - Has spectral class that matches a spectrum in Pickles (*PASP* , **110**, 863 [1998]).
- Gave a list of 575 stars.
- Other criteria can be applied on the fly.

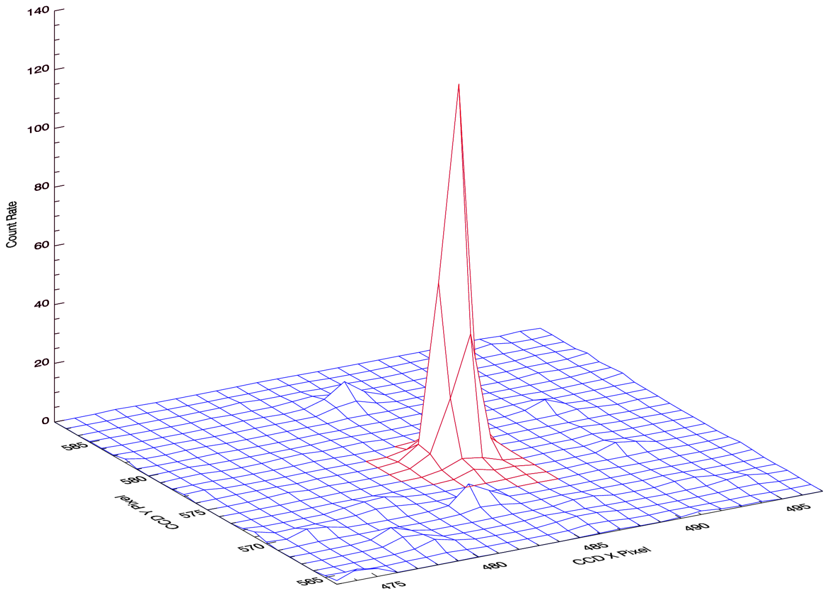
Stellar Brightness

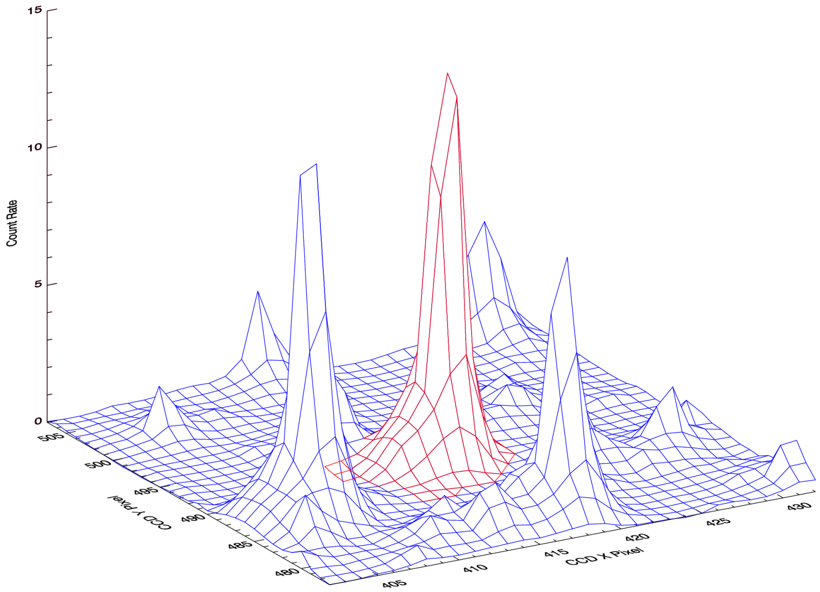
- Need to find a way of separating stars from background and determining both.
- Annuli already shown not to work.
- Fitting PSFs across the FoV failed as the PSF is significantly dependent on the brightness of the star as well as the location in the FoV.

Stellar Brightness (2)

- New definition:
  - Find peak nearest to catalogue position.
  - Mark region > 1/3 that count rate.
  - Find centroid.
  - Numerically compute radial gradient from centroid
  - Define star to be central region + region with -ve gradient.
  - Background is median of the rest of the ROI.

Stellar Brightness (3)

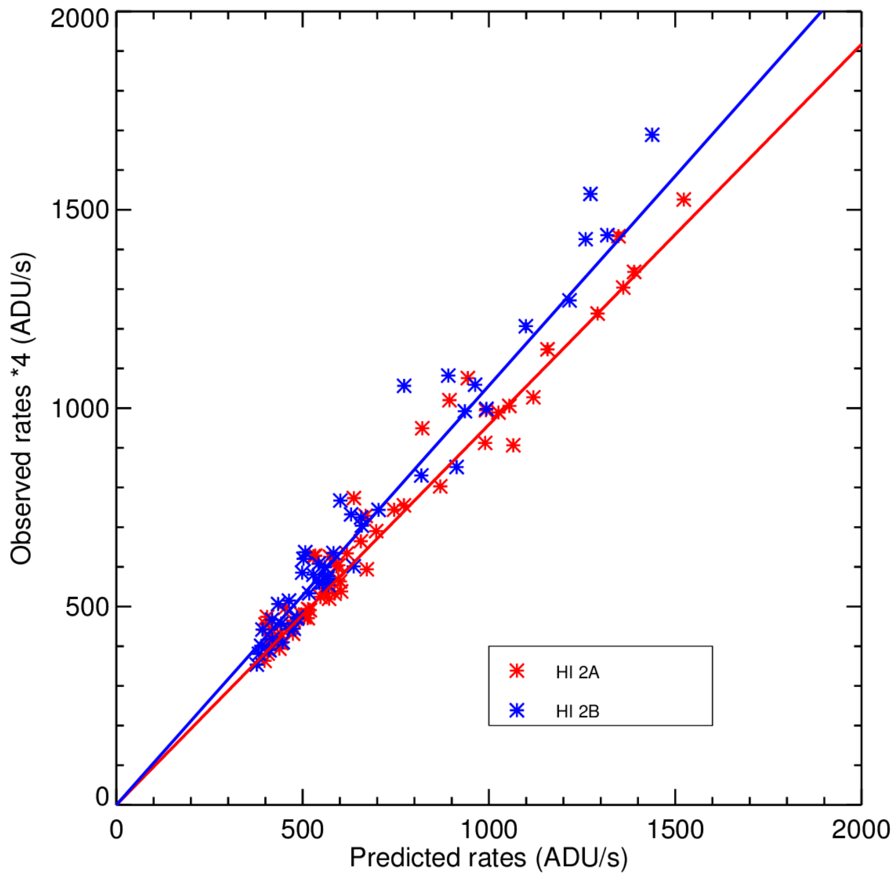




Measurements

- Define a “core” region 100 image bins (200 CCD pixels) in radius.
- For each star passing through that region measure its count rate in every science image and compute median count rate and interquartile range.
- Compare with count rate predicted by passing the star's spectrum through the HI-2 spectral response.
- Use an L1 norm fitting as the deviations are dominated by systematic rather than random deviations.

Result

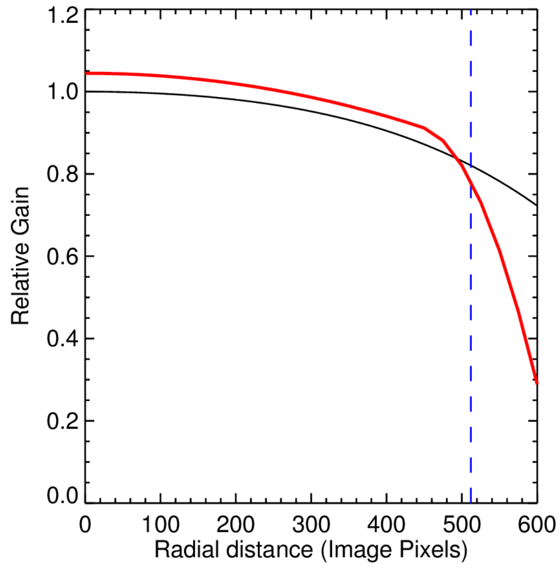


- Find HI-2A has slightly lower response, 0.959±0.01 times pre-launch values.
- HI-2B has somewhat higher, 1.057±0.02 times pre-launch.
- No major changes with time or spectral type, or location within the central region.

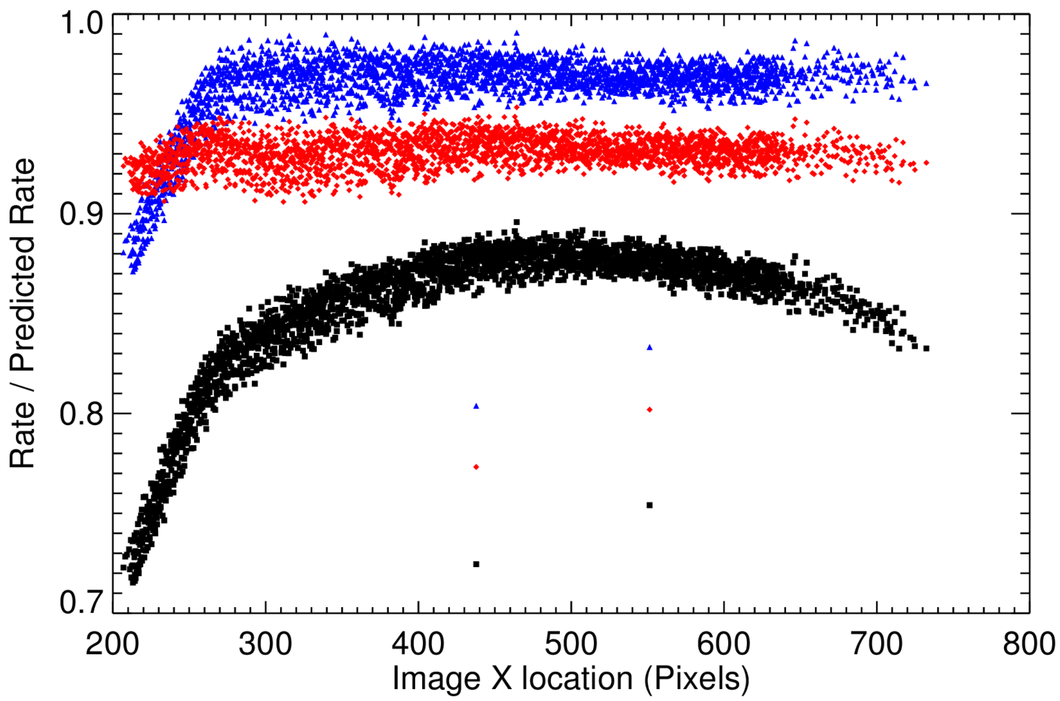
Large-Scale Flat Field

- Clear from tracking stars across the HI-2 FoV that there is a fall-off of response near the edge relative to pre-launch FF.
- For HI-2A can fit all the measurements as a function of radial distance from CCD centre.
- Pre-launch was of the form: $FF(r)=1+a_1r^2 + a_2r^4$.
  - To accommodate the vignetting we use:
    $FF(r) = a_0 + a_1r^2 + a_2r^4 + a_3\max(r-a_4,0)^2$.
  - $FF(r) \approx 1.04 - 6.42\times10^{-7} r^2 - 7.32\times10^{-14} r^4 - 2.25\times10^{-5} \max(r-448.8,0)^2$.
    - Where r is measured in science image bins.
- HI-2B is consistent with this, but too few stars are well-behaved across the whole field to get a proper fit.

The fit & η-Nor



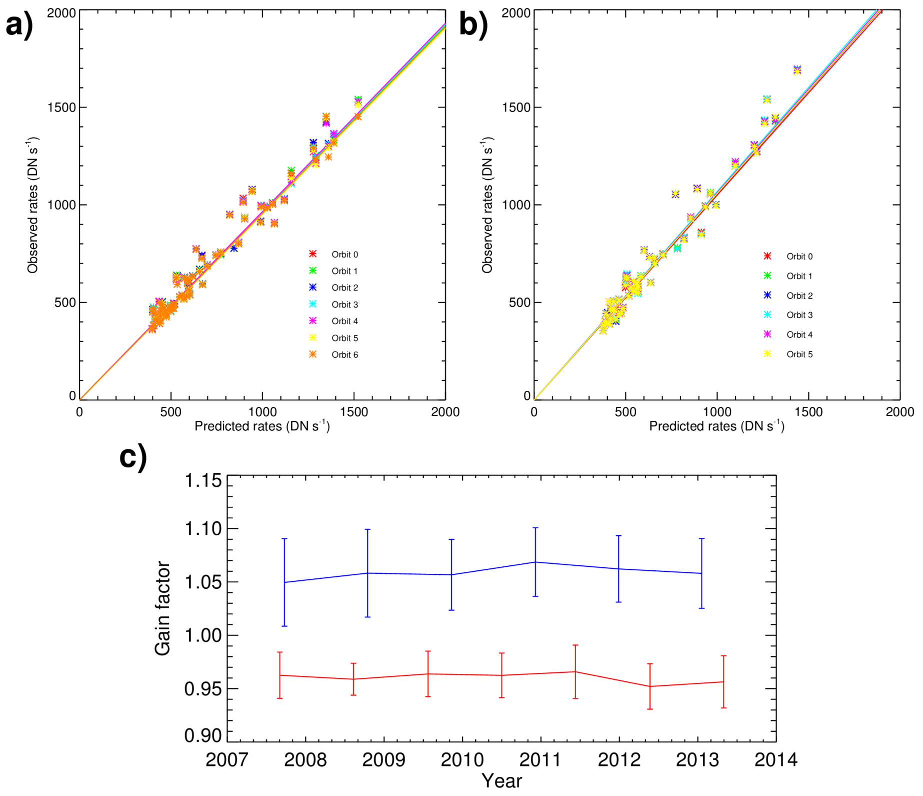
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
100
200
300
400
500
600
Relative Gain
Radial distance (Image Pixels)



1.0
0.9
0.8
0.7
200
300
400
500
600
700
800
Rate / Predicted Rate
Image X location (Pixels)

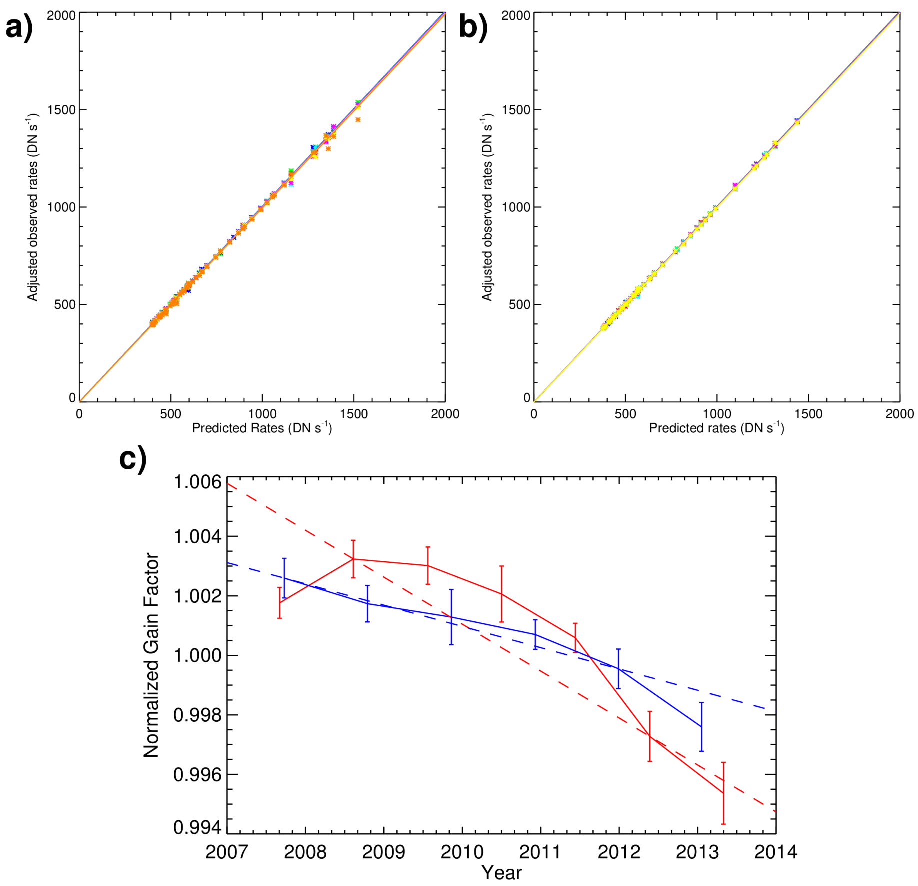
Time variation

- Other major question to address is the extent of detector degradation.
- From the raw data, grouped by STEREO orbit, this looks to be small.
- Also clear that each star has variation small compared with its deviation from the trend.



Time variation (2)

- If we remove that star-to-star variation we are left with a much tighter correlation and a clear trend.
- For HI-2A, the degradation is about 0.16% per year.
- For HI-2B it is about 0.07% per year.
- Both are significantly slower than other comparable instrumental degradations.



Summary

- Now have a usable calibration for both HI-2 instruments.
  - Corrections are comparatively small, so no drastic reinterpretation will be needed.
- Also large-scale flat field for HI-2A.
  - Pre-launch values are again good for most of the FoV, but significant vignetting near the edges.
- Large PSF of HI-2B means that flat field can't be independently determined, but it looks to be consistent with HI-2A.

Summary (2)

- The degradation of the detectors is slow compared with other instruments such as LASCO-C3 and SMEI.
  - The analysis published for HI-1 (Bewsher *et al.*, *Sol. Phys.*, **276**, 491 [2012]) would not have detected a similar degradation rate.