Summary of the Stray Light Study 2014
– measurements for correcting X-ray images –

2-September, 2014 by Aki Takeda
1. Introduction

9-May-2012: Ti-poly image blurring noticed.

First noticed in June as sudden rise of G-band intensity.

(cf: PPT file by DeLuca, McCauley, et al. 22-Jun-2012)
Our current understanding of the phenomena:

- caused by an XRT pre-filter failure (pinhole).
- visible stray light contaminating X-ray images.
- Yohkoh/SXT suffered the same failure in 1993, so presumably, corrected by the same method as SXT.

Use terminator images for correction.
- Take image with X-ray filter during Day to Night (or N to D) transition of the spacecraft.
- X-ray component is completely absorbed by the atmosphere while passing through the long optical path.
- Visible light component starts to decay some time after the extinction of the X-ray.
- There exists a short period of time (~30 sec for SXT) when the visible light component is purely detected through the X-ray filter (→ stray light image).
Difference between XRT and SXT cases:

<table>
<thead>
<tr>
<th></th>
<th>XRT</th>
<th>SXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbit</td>
<td>Sun synchronous</td>
<td>Low inclined (31 deg.)</td>
</tr>
<tr>
<td>Eclipse season</td>
<td>May to mid-August</td>
<td>All year</td>
</tr>
<tr>
<td>Twilight frequency</td>
<td>Every ~98 min. (2014.8)</td>
<td>Every ~97 min. (1997.9)</td>
</tr>
<tr>
<td>Twilight (D to N) duration</td>
<td>5 to 10 min.</td>
<td>Typically 100 sec.</td>
</tr>
<tr>
<td>Data acquisition window</td>
<td>1 to 3 min.</td>
<td>Typically 20 sec.</td>
</tr>
</tbody>
</table>

- XRT stray light images can be taken only during limited months. However,
- the condition of data acquisition for each twilight event is better in XRT than SXT.
2. XRT Stray light measurement – 2014.

2.1. Basic structure of observing programs:

(1) Full-Sun images before twilight (1024x1024, with the relevant filter, with multiple exposures, use synoptic obs., if available). These are Images to be corrected.

(2) Monitor images for light curve (256x256, in G-band and Ti-poly, centered on AR or bright structures, every 10 seconds, from 30 sec before the twilight to ~30 sec after entering the night). Important to be sure the stray light images were taken at the right timing.

(3) Stray light image (1024x1024, with the relevant filter, DPCM, every ~60 sec, starting a few minutes after the twilight through the night entry).
## 2.2 Dates of measurement and purposes

<table>
<thead>
<tr>
<th>Timeline No.</th>
<th>Date &amp; Time (UT)</th>
<th>Purposes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2014/05/06 17:40</td>
<td>Collect Light Curve, Ti-poly (250 msec) at Disk Center</td>
</tr>
<tr>
<td>2</td>
<td>2014/05/15 18:20</td>
<td>LC, Ti-poly (1.41 sec) &amp; Al-mesh (707 msec) at DC</td>
</tr>
<tr>
<td>3</td>
<td>2014/05/27 20:30</td>
<td>LC, Al-poly (1.00 sec) &amp; C-poly (1.41 sec) at DC</td>
</tr>
<tr>
<td>4</td>
<td>2014/07/03 18:30</td>
<td>LC, Ti-poly (1.41 sec) &amp; Thin-Be (2.83 sec) at DC</td>
</tr>
<tr>
<td>5</td>
<td>2014/07/30 18:30</td>
<td>LC, Med-Al (32 sec) at DC</td>
</tr>
<tr>
<td>6</td>
<td>2014/07/31 15:49</td>
<td>LC, Med-Be (24 sec) at DC</td>
</tr>
<tr>
<td></td>
<td>2014/07/31 17:27</td>
<td>LC, Thick-Al (64 sec) at DC</td>
</tr>
<tr>
<td></td>
<td>2014/08/01 16:26</td>
<td>LC, Thick-Be (64 sec) at DC</td>
</tr>
<tr>
<td>7</td>
<td>2014/08/08 18:56</td>
<td>LC, Ti-poly (4.00 sec) &amp; C-poly (4.00 sec) at N-pole</td>
</tr>
<tr>
<td></td>
<td>2014/08/08 20:40</td>
<td>LC, Ti-poly (1.41 sec) &amp; C-poly (1.41 sec) at E-limb</td>
</tr>
<tr>
<td></td>
<td>2014/08/08 22:30</td>
<td>LC, Ti-poly (4.00 sec) &amp; C-poly (4.00 sec) at S-pole</td>
</tr>
</tbody>
</table>
3. Results

(1) Out of 9 X-ray analysis filters, significant visible stray-light components were detected only with the Ti-poly and C-poly filters.

- Ti-poly (at DC pointing) [XRT20140515_182503.4.fits]
- C-poly (at DC pointing) [XRT20140527_204601.0.fits]
(2) Stray-light images consist of 3 components:

- Solar disk component (brightest). Ti-poly disk is 2.5 times brighter than C-poly's.
- Dark component (weakest contribution). Rapid changing periodic stripes similar to those found in dark frames.

(3) At the polar- and limb-pointings, stray-light images are different most significantly in the solar disk component.
Stray-light images at N-pole, E-limb, and S-pole pointings.

- **Ti-poly**
  - XRT20140808_191124.0.fits
  - XRT20140808_205020.5.fits
  - XRT20140808_222905.4.fits

- **C-poly**
  - XRT20140808_191137.1.fits
  - XRT20140808_205031.0.fits
  - XRT20140808_222918.5.fits
(4) Stray-light images are good for quantitative correction of X-ray coronal images taken closely in time with and at the same pointing as the stray-light image.

[Things to consider to correct other images]

- Pointing of the stray-light image needs to be the same as the image to be corrected.

- Long term variation of the stray-light intensity. (Stray-light in May-2014 is approximately twice the level in May-2012.)

- Reproducibility of the pointing. (Seasonal change of the offset between Hinode and XRT, typically 10 to 30 arcsec.)
Examples of image correction (top: before corr., bottom: after corr.)