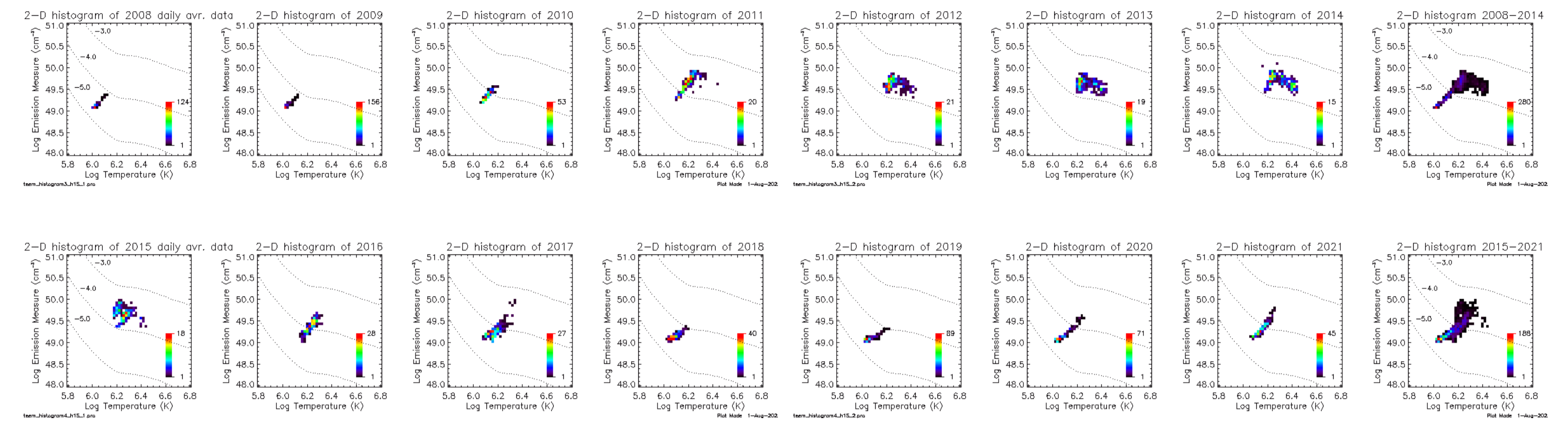
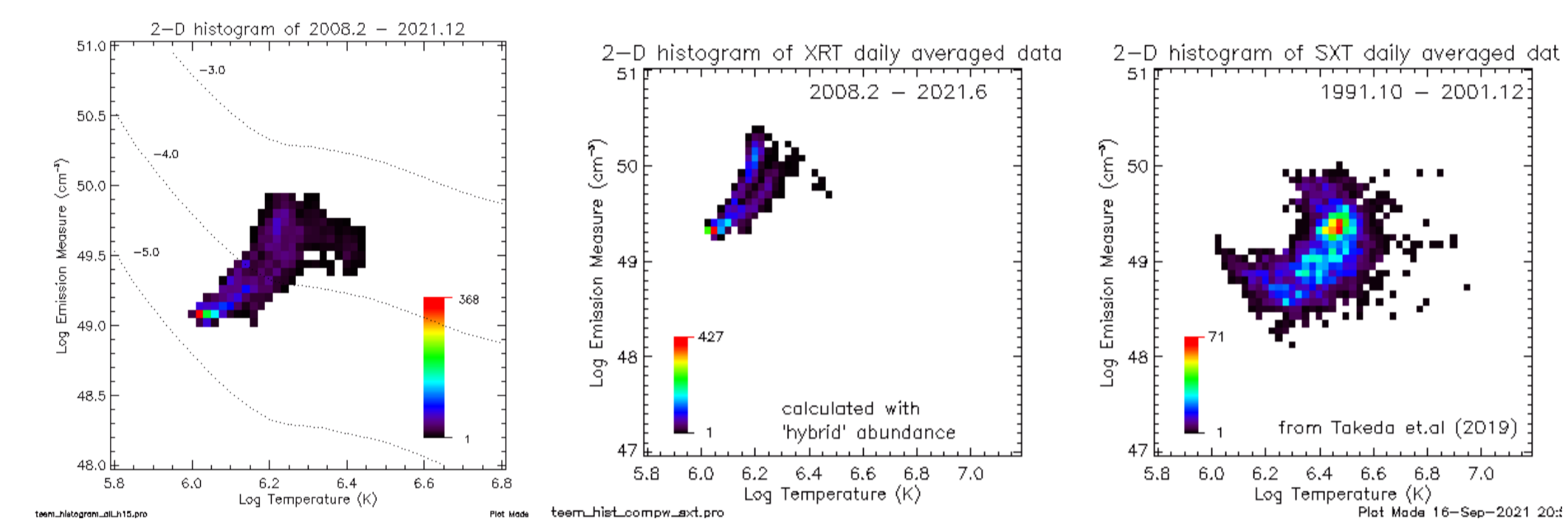


**Fig. 1:** Top: Daily averaged filter-ratio temperatures derived from the full-Sun integrated signals (red line) of the thin-Al and Al/Mg/Mn filter pairs of Yohkoh/SXT. The blue and green lines were calculated using the integrated signals of Northern- and Southern-hemispheric corona, respectively. Middle: Daily averaged filter-ratio emission measures associated with the temperatures in the above. Bottom: Soft X-ray irradiance calculated for the wavelength range of 5-60Å.



**Fig. 2.1:** 2-D histograms of daily averaged filter-ratio temperatures and emission measures from the full-Sun integrated signals, for the year 2008 to 2021. The bin size of the histogram along the Te- and EM-axes in log scale is 0.025 (K) and 0.075 ( $\text{cm}^{-3}$ ) respectively. The dot curves indicate the pairs of Te and EM that gives the same irradiance values; -3.0, -4.0 and -5.0  $\text{W/m}^2$  (in log scale), respectively from upper-right to lower-left in each plot.



**Fig. 2.2:** Left: 2-D histograms of XRT filter-ratio temperatures and emission measures for the whole available years (2008-2021) calculated assuming coronal elemental abundance by Feldman 1992. Middle: XRT Te-EM histogram calculated assuming hybrid elemental abundance by Schmelz et al 2011. Right: Corresponding 2-D histogram obtained by Yohkoh/SXT (based on the hybrid abundance).

## Summary

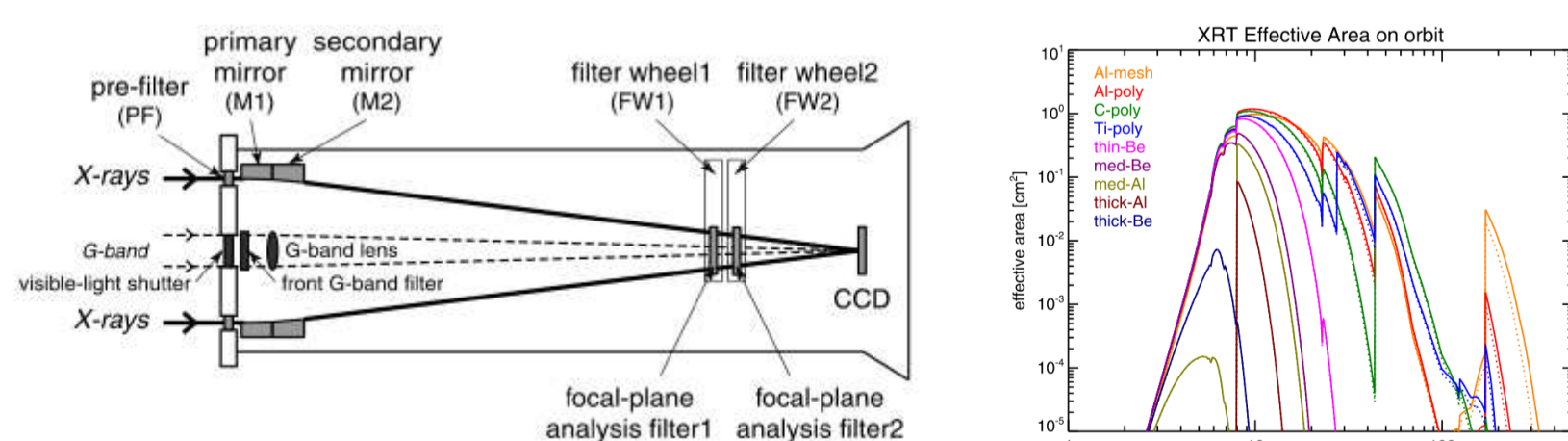
The X-ray Telescope(XRT) on board the Hinode satellite(in operation since late 2006) has been taking soft X-ray images of the Sun with multiple broadband filters. Using the data from its synoptic full-Sun observing program, the full-Sun averaged filter-ratio temperature(Te) and emission measure(EM) are obtained, and from which mission-long solar X-ray irradiance is derived, in theory. However, in reality, the correcting the effect of instrumental failure or aging is crucially important to derive the reliable results over the whole mission period.

We will show the mission-long variation of coronal Te, EM and irradiance (5-60Å) based on the most recent method of correction: considering the effect of XRT pre-filter failure and taking the contamination layer developed on the X-ray analysis filters into account. The results will be compared with those from other instruments, like GOES/XRS, Yohkoh/SXT and MinXSS1/X123.

## 1. Hinode/XRT and the SCIA

Hinode (Japanese word for 'sunrise') is a Japan/US/UK mission for high-energy solar physics (2006-present). See Fig. 3.

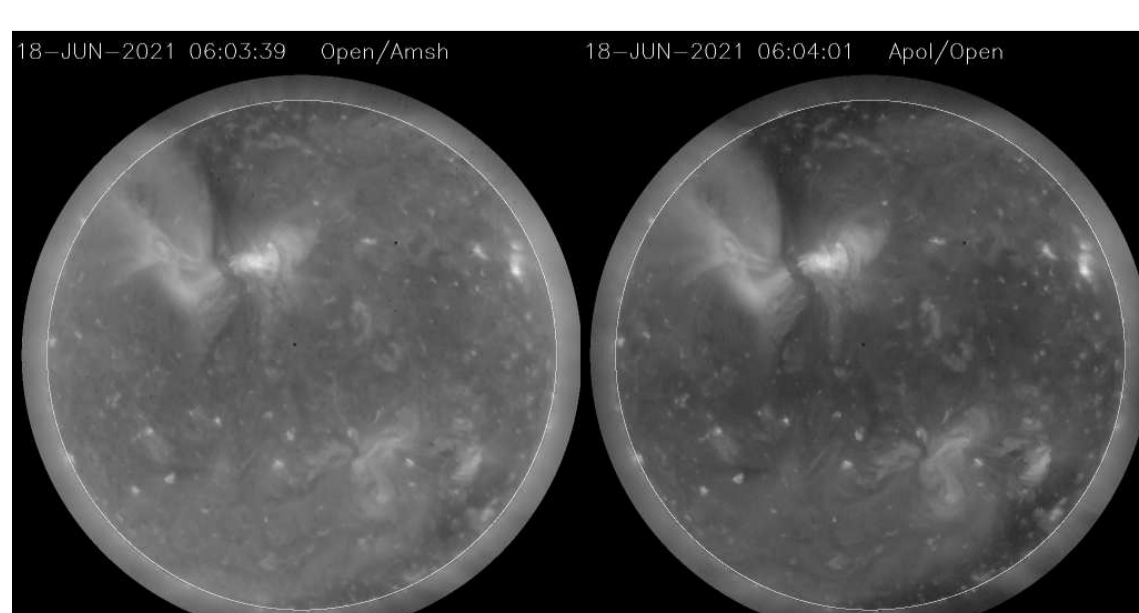
- XRT is a grazing incidence telescope on-board the Hinode satellite to form X-ray images in the 6 – 200Å range on a 2048x2048 CCD. The field of view is 2040x2040 arcsec.
- Full-Sun observations by XRT are mainly through the synoptic program that typically runs twice daily, using short/medium/long exposure times, which are later processed into a single composite image to increase the intensity dynamic range. These products are accessible from XRT Synoptic Composite Image Archive (SCIA) located at Montana State University.  
<http://solar.physics.montana.edu/HINODE/XRT/SCIA>



**Fig. 3:** Hinode/XRT assembly and spectral response of X-ray analysis filters (from Narukage et al., 2011).

## 2. Data processing

Using XRT full-Sun composite images, soft X-ray irradiance was derived with the following steps.



**Fig. 4:** Example of Al-mesh and Al-poly image pair. The area outside 1.1Rs are masked.

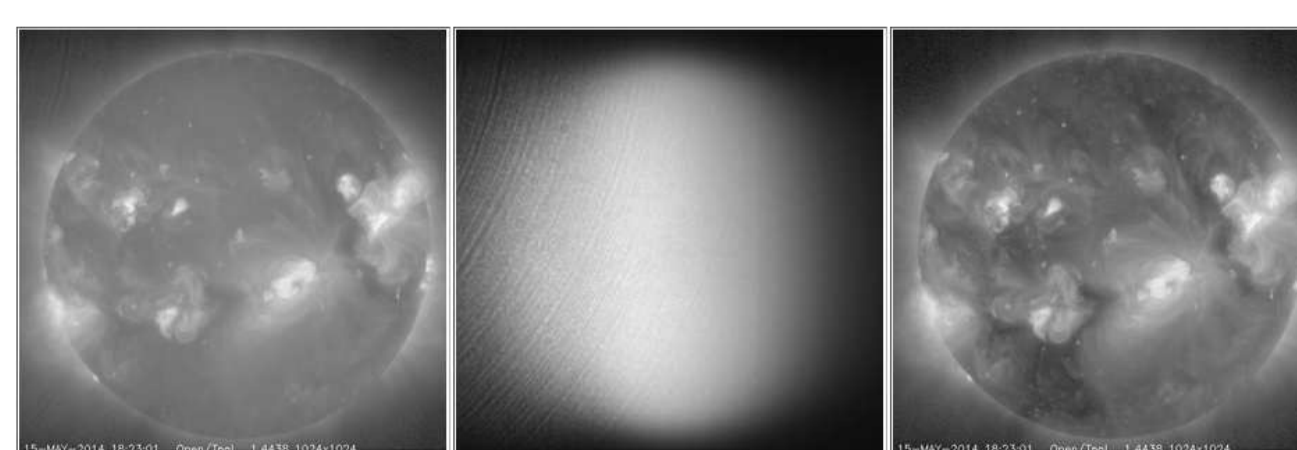
1. Find pairs of Al-mesh and Ti-poly filter images for the period 2008.2 through 2015.6, taken close in time (< 10 min. apart) and review for quality check. For the period after 2015.6, Al-mesh and Al-poly pairs was used.
2. Collect coronal intensities within 1.1Rs to obtain full-sun integrated signal pairs from each pair of images. See Fig.4.
3. Derive filter-ratio temperature and emission measure from each signal pairs
4. Isothermal coronal spectra is calculated from the derived temperatures and emission measures, using CHIANTI atomic DB and software (ver. 10.0).
5. Integrate obtained spectrum over XRT's effective spectral range (5-60Å) to derive coronal irradiance in the unit of  $\text{W/m}^2$ .

## 3. New Calibration

### 3.1 Correction of visible stray light component

Visible stray light contamination is caused by a crack developed on the XRT's pre-filter (multiple events experienced). The correction takes the following two steps:

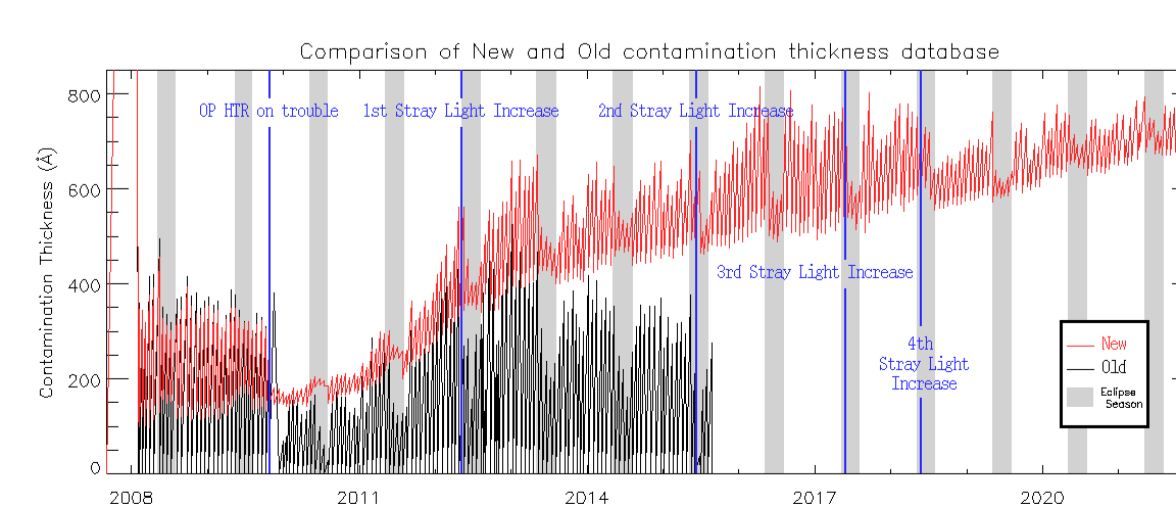
1. Subtract visible light component from the X-ray images. See Fig.5. (this part is NOT new!)
2. Modify XRT's effective area function due to the open area of the pre-filter. From the G-band stray light data analysis, we estimated the open area fractions for each event (Table 1), and incorporated them into the effective area functions.



**Fig. 5:** Example of stray light correction of Ti-poly image. Left: before stray light subtraction. Middle: visible stray light pattern. Right: stray light subtracted image.

event	date	open fraction
1st	9-May-2012	0.1%
2nd	14-Jun-2015	3.3%
3rd	27-May-2017	7.5%
4th	29-May-2018	9.9%
(5th)	8-Jun-2022	???

**Table 1:** Estimated open area fraction of XRT pre-filter.

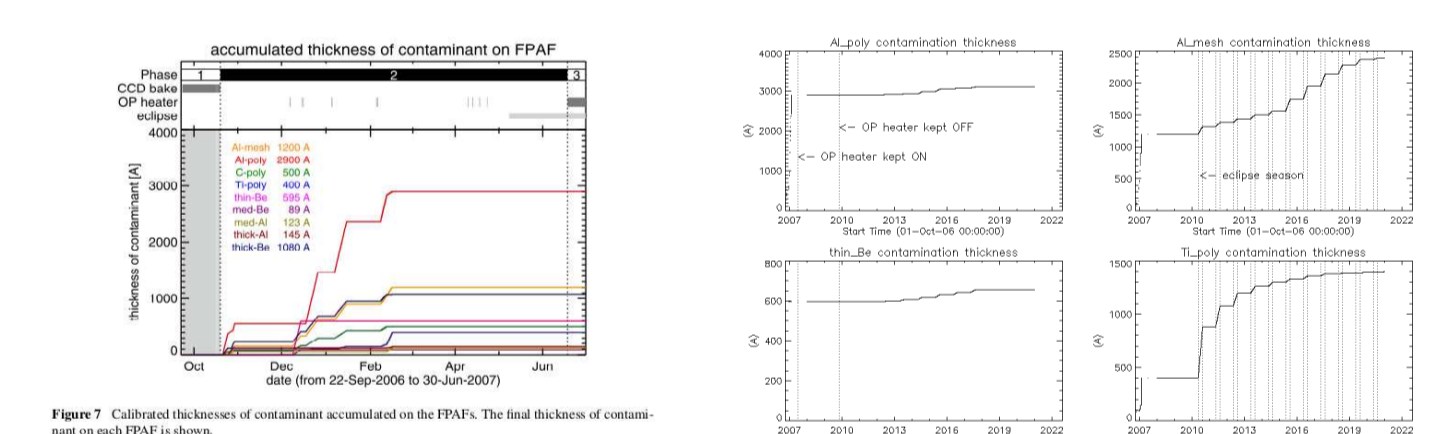


**Fig. 6:** Thickness of contaminant layer on CCD by Narukage et al 2011 (black) and modified values by K. Yoshimura (red).

## 3.2 Reconsidering contamination on X-ray filters

There is a growth of contaminant layers on CCD and X-ray analysis filters. It is considered to be caused by the evaporation of some material used in the telescope. The contamination on CCD was initially modeled by Narukage et al (2011), but modified since 2017 to allow the existence of the residual layer (by K. Yoshimura).

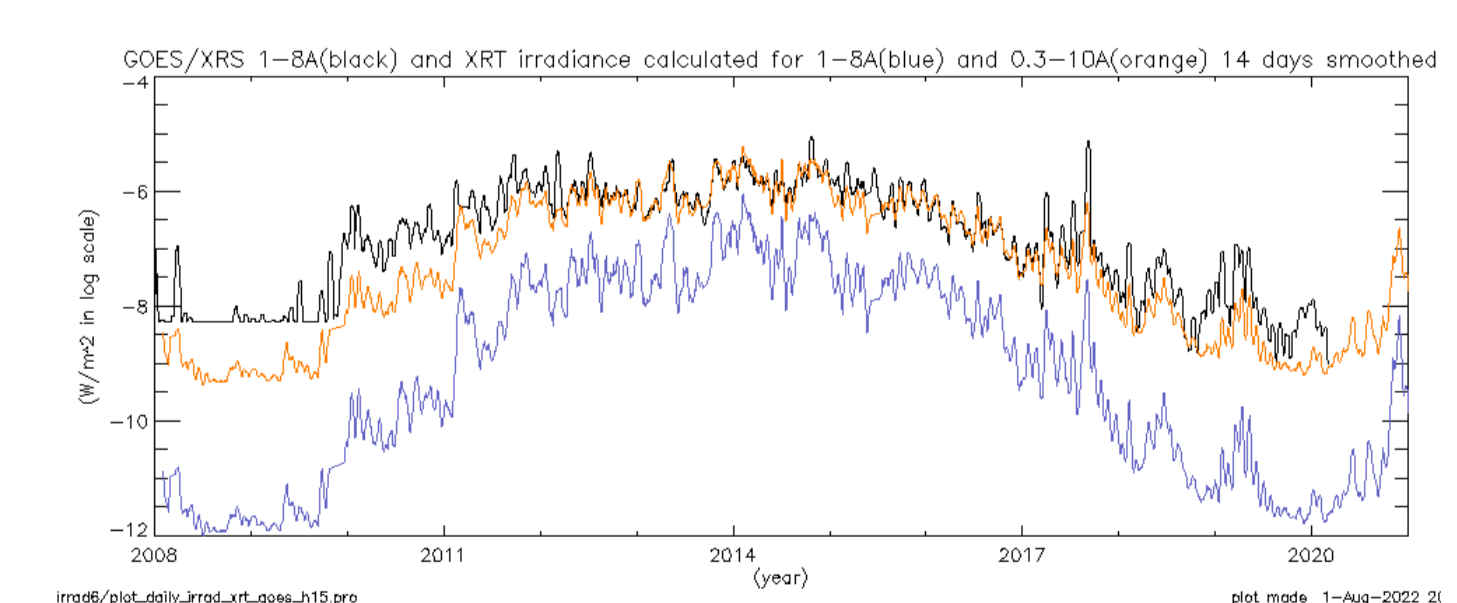
The thickness of contamination layer on the X-ray filters was investigated by Narukage et al (2011) until 2007. However, additional growth of the contaminant layer is naturally expected after the XRT Operational Heater was permanently turned off in 2010. We determined the amount of additional contaminant so that it provides natural curve of irradiance evolution.



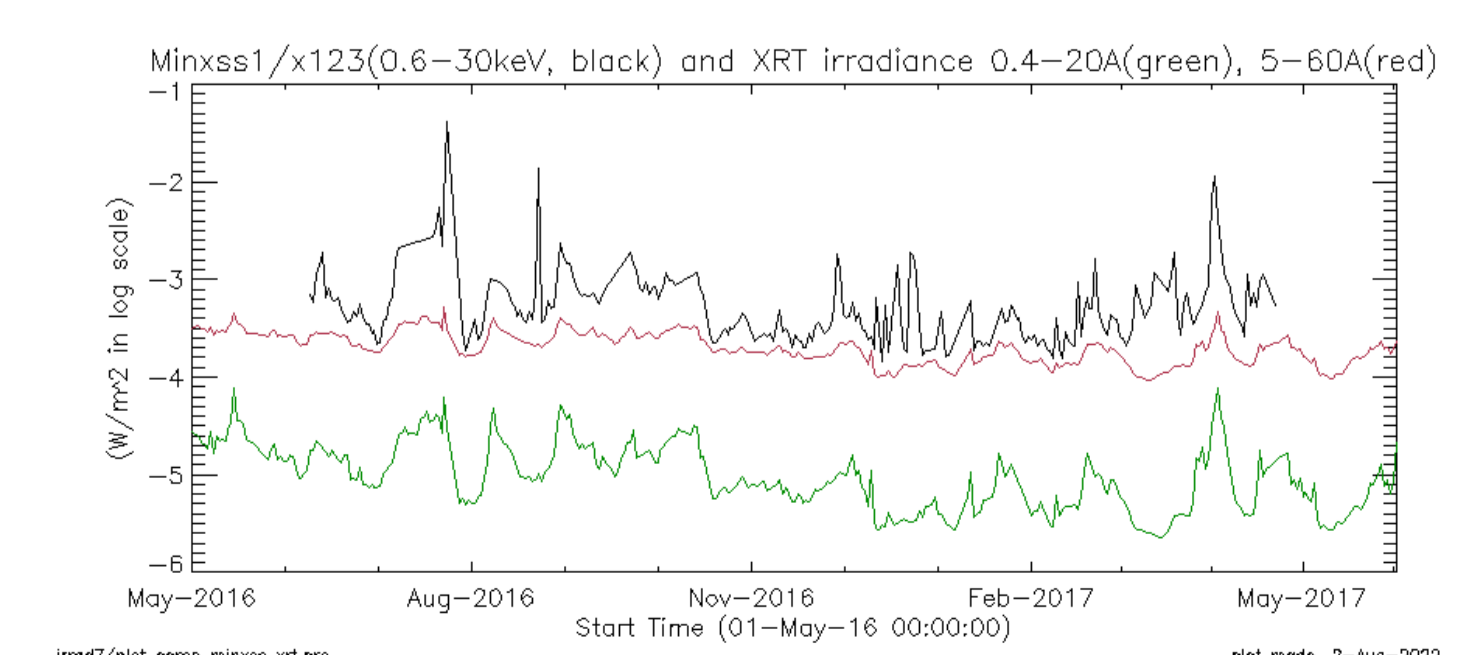
**Fig. 7:** Left: Thickness of contaminant layer on X-ray filters by Narukage et al 2011. Right plots: Newly adopted X-ray filter contamination layer thickness.

## 4. Some Results

- XRT irradiance calculated for the 5-60Å range, filter-ratio temperature and emission measure are and plotted in Fig. 1.
- From the obtained temperatures and emission measures, yearly 2-D histograms were created and then compared with the results with Yohkoh/SXT (1991-2001). See Figures 2.1 and 2.2.
- XRT irradiance calculated for 1-8Å range was compared with the GOES/XRS 1-8Å flux. See Fig. 8.
- XRT irradiance calculated for 0.4-20Å was compared with the MinXSS/X123 observation in 0.6-30keV range. See Fig. 9.



**Fig. 8:** Comparison of GOES/XRS 1-8Å flux and XRT irradiance calculated for 1-8Å and 0.3-10Å wavelength ranges.



**Fig. 9:** Comparison of MinXSS1/X123 0.6-30 keV and XRT irradiance calculated for 0.4-20Å and 5-60Å wavelength ranges.