Dig in the RHESSI catalogue.

What we can say about HXR emission along one solar cycle and how we can use it for future instruments?

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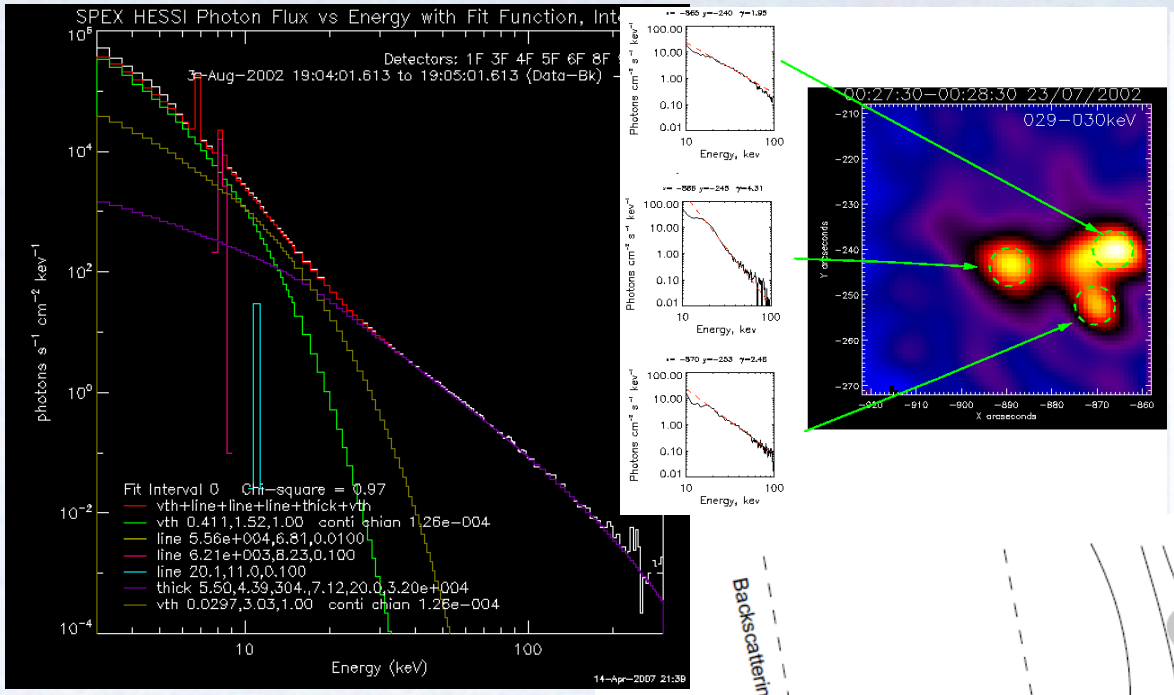
Solar Hard X-Ray radiation



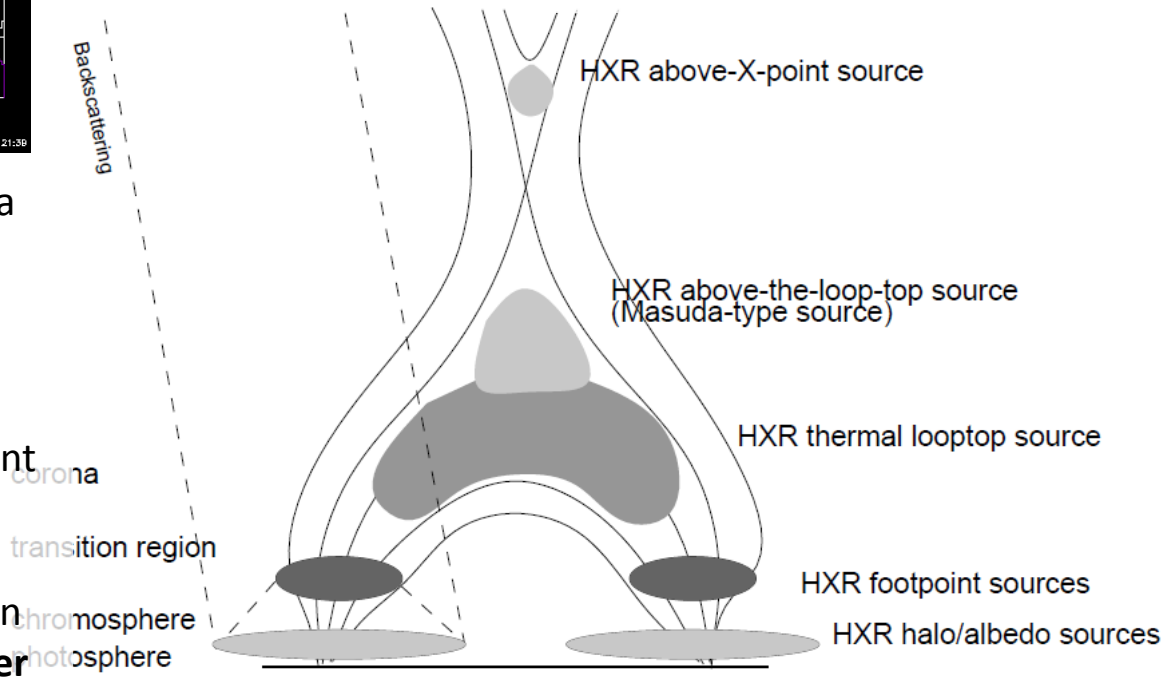
Observations reveal at least five (or four) types of HXR sources:

- above-X-point
- above-the-loop-top
- thermal loop top
- foot point
- halo/albedo

Spatially unresolved HXR spectrum is a mixture of several sources of various parameters.

Therefore, next step in understanding HXRs is **imaging spectroscopy** – present instruments allow for this.

We can not improve angular resolution thus we need to put observatory **closer to the Sun.**

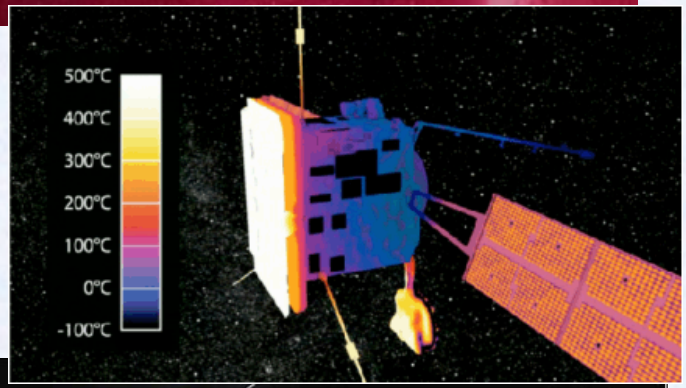


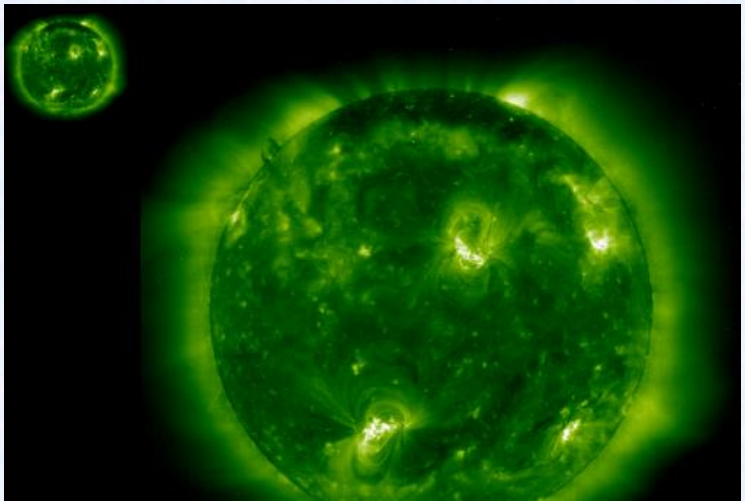
Aschwanden 2005, „Physics of the Solar Corona”

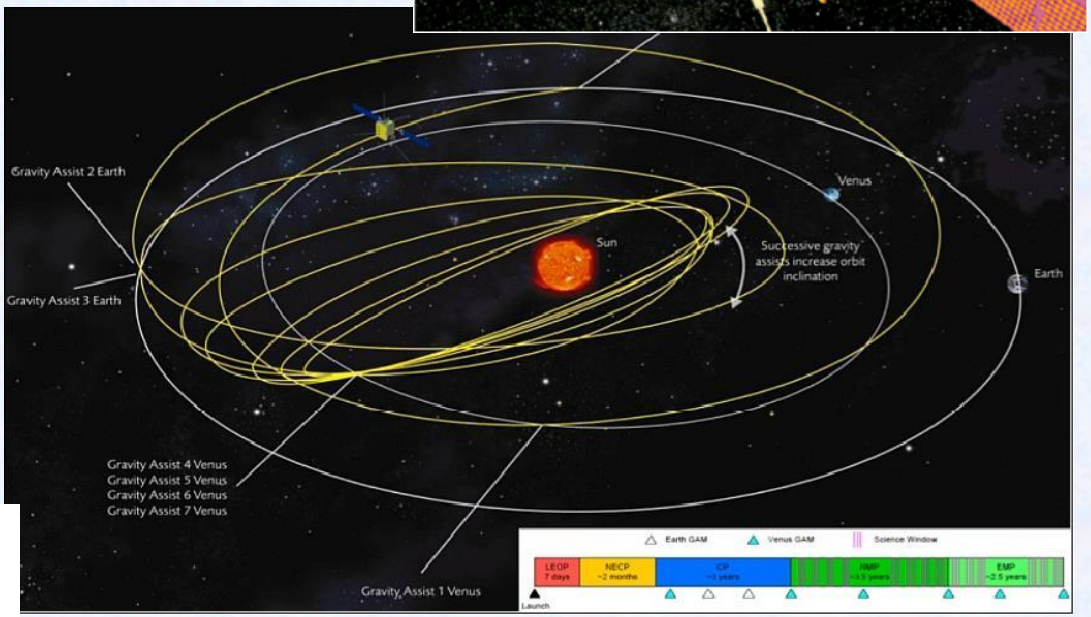
Solar Orbiter

Launch: July 2017, Cape Canaveral Air Force Station, Florida

Cruise phase: Day 101 – Venus flyby (4000 km), Day 597 & 1328 – Earth flyby (700 km), Day 1497 - close (300 km) Venus flyby
Summer 2021 – first science orbit

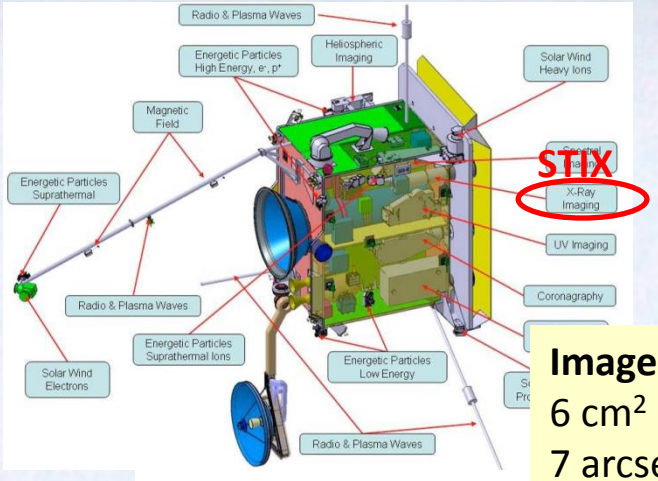






To improve spatial resolution with unchanged angular resolution.

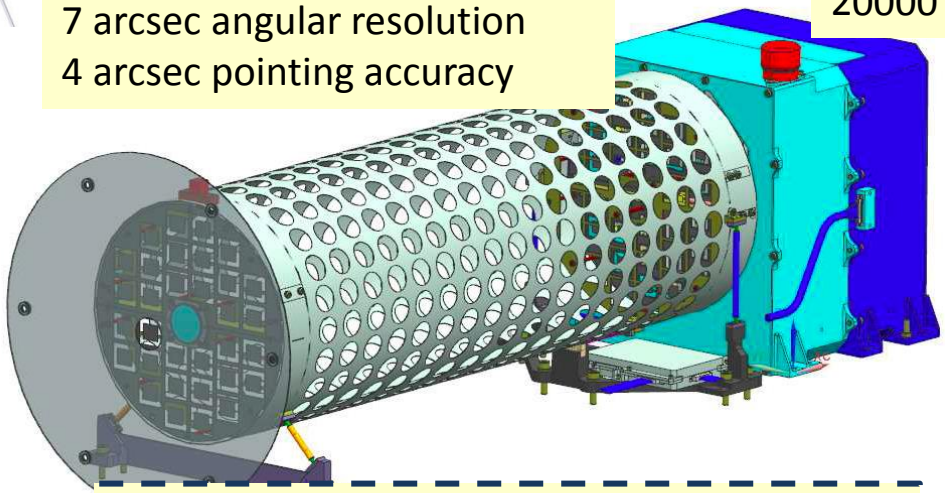
Spectrometer/Telescope for Imaging X-rays (STIX)

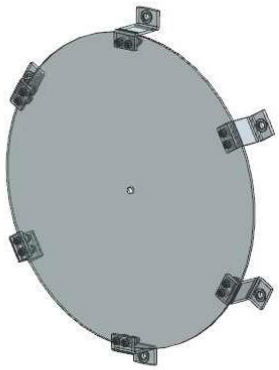


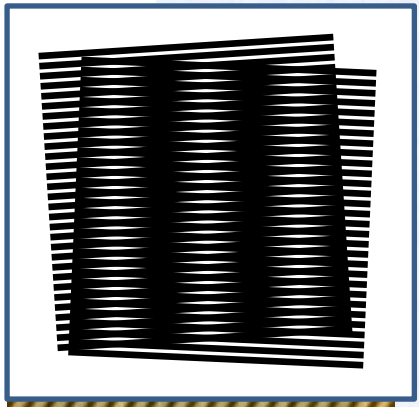
3 independent subsystems to reach scientific requirements.

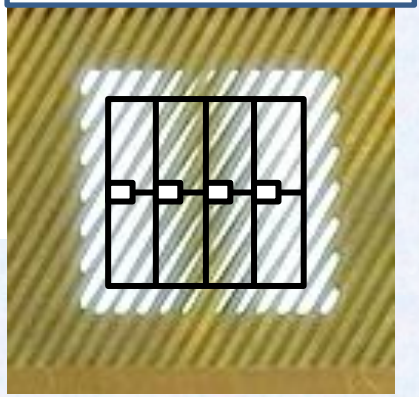
Detector Electronics Module
50% efficiency at 100 keV
1 keV FWHM at 6 keV
15 keV FWHM at 150 keV
20000 cts/s /cm^2

Imager
6 cm^2 effective area
7 arcsec angular resolution
4 arcsec pointing accuracy





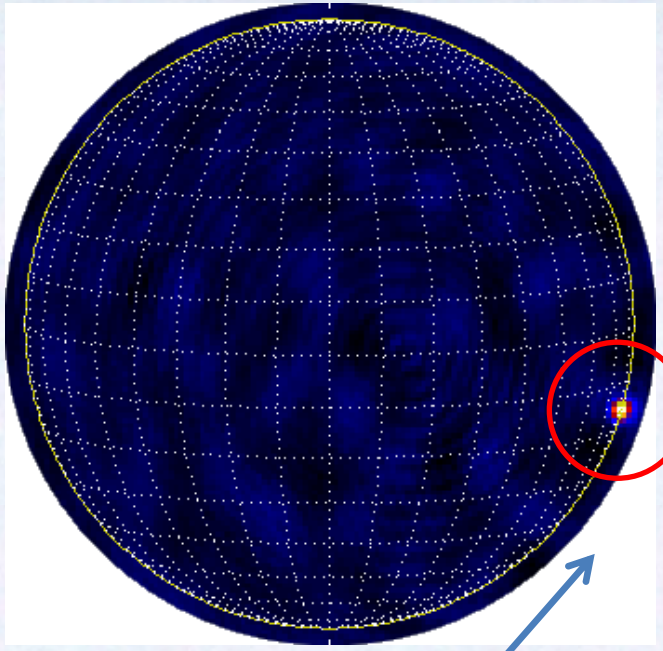


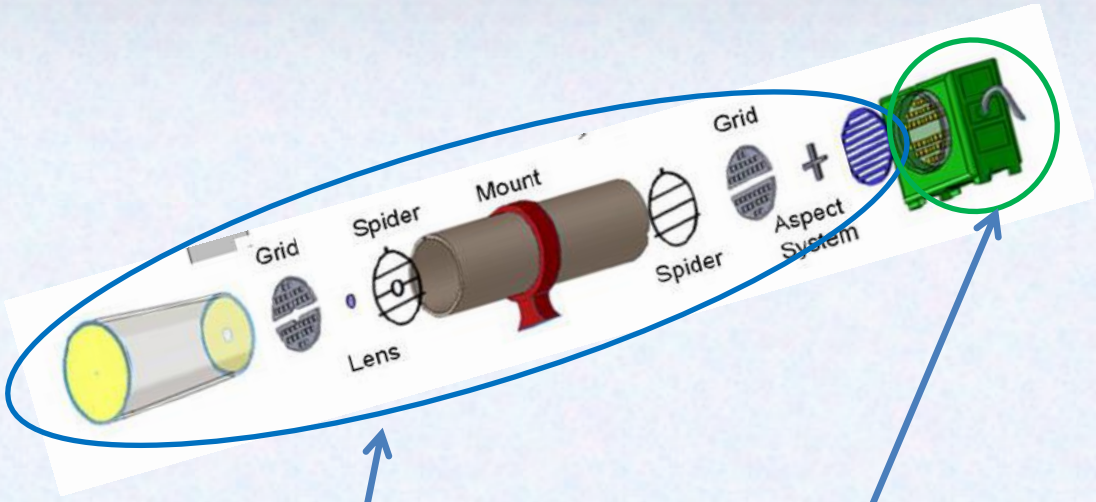


75 cm long, 22 cm large (w/o windows)
7 kg mass
??? W electrical power during flares
700 bps telemetry rate
Temperatures from –25°C to +620°C

X-ray windows
4 keV low-energy threshold
4% transmission variation

Detector System Simulator





- entrance window
- production of secondary particles
- grids transmission
- interaction in detector crystal

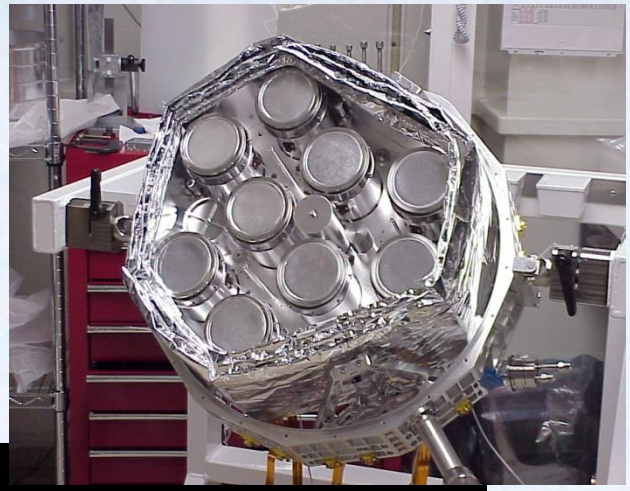
to simulate different sources
(intensity, morfology, time evolution)
-> photon seed population for other modules of simulation package

software – hardware
Detector Simulation System (DSS)

We need to perform parametrization of real HXR emission sources for creating photon seed population which will be used for simulations of detectors, IDPU, aging effects etc.

RHESSI

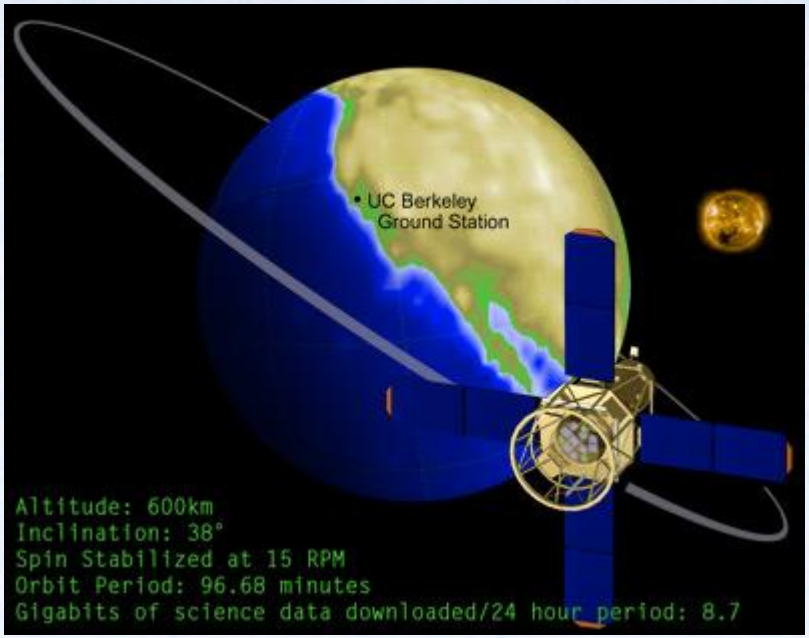
- Launched 5-Feb-2002 r.
- Initial orbit: 600 km circular, 38°
- Planned for 2 years + 3 years of extended mission



- 12+ years of observations
- More than 66 800 orbits
- More than 90 000 flares (7 TB of data)
- Present altitude: 534 x 517 km
- First possible reentry: 2018 (expected: 2023)

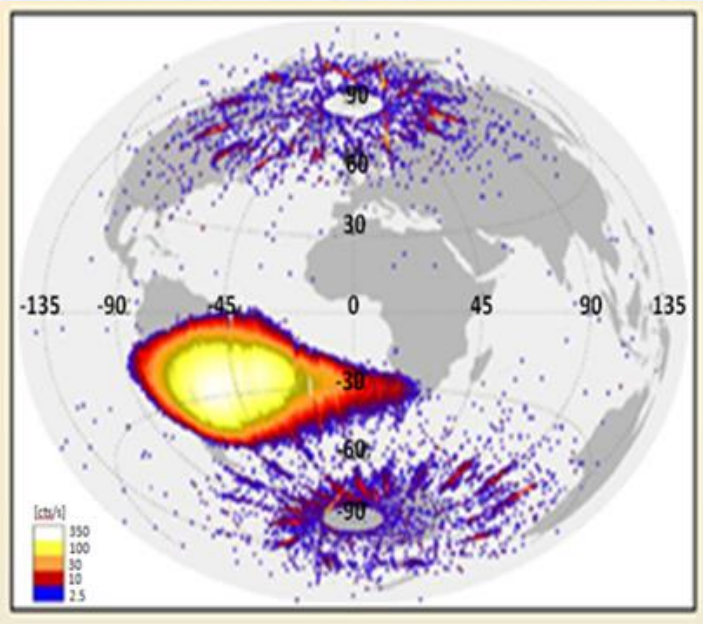
- All subsystems performing well
- Continous rise of detectors temperature (from 75 K to 115 K) due to decreasing efficency of cooling system. 150 K will not be reached before 2018
- Systematical decrease of detectors performance due to aging (sensitivity, resolution, noise)
- Annealing performed two months ago.
- No visible changes in grids orientation.

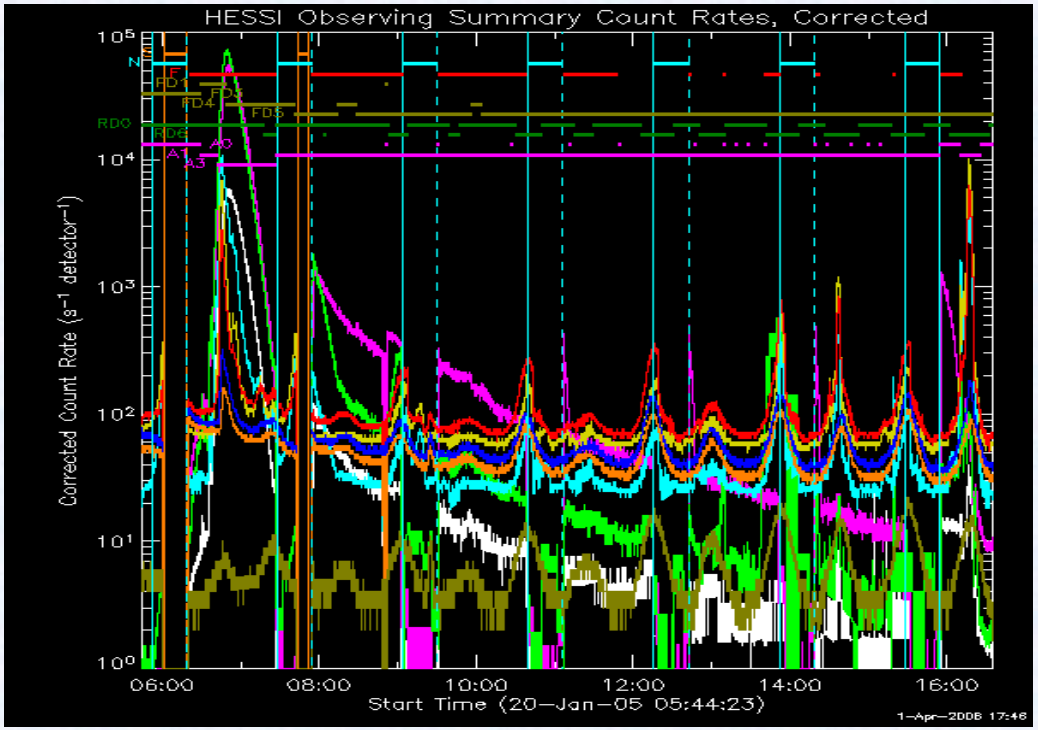
RHESSI



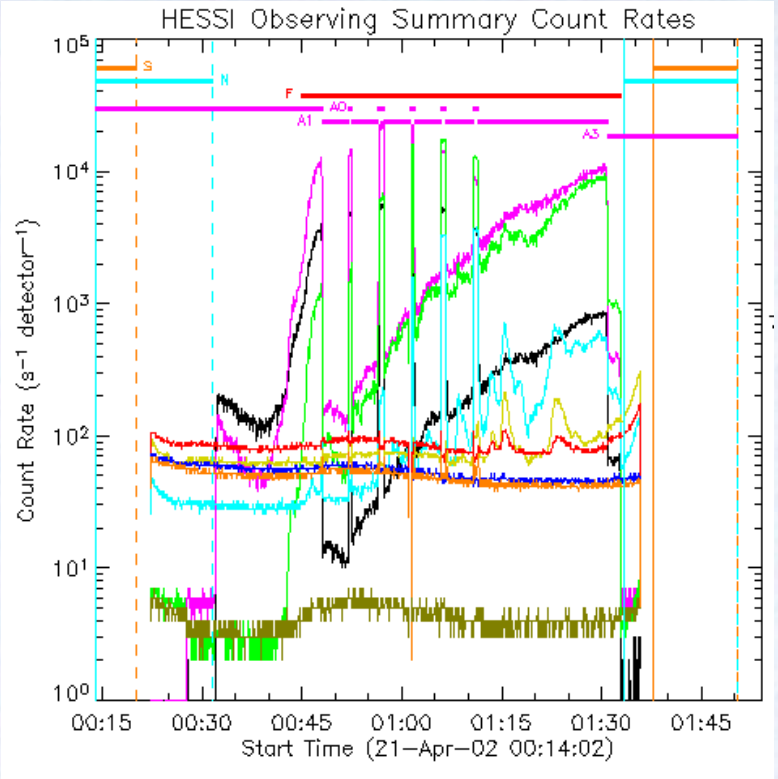
The orbit is inclined (38°) – passages through radiation belts and South Atlantic Anomaly (SAA)

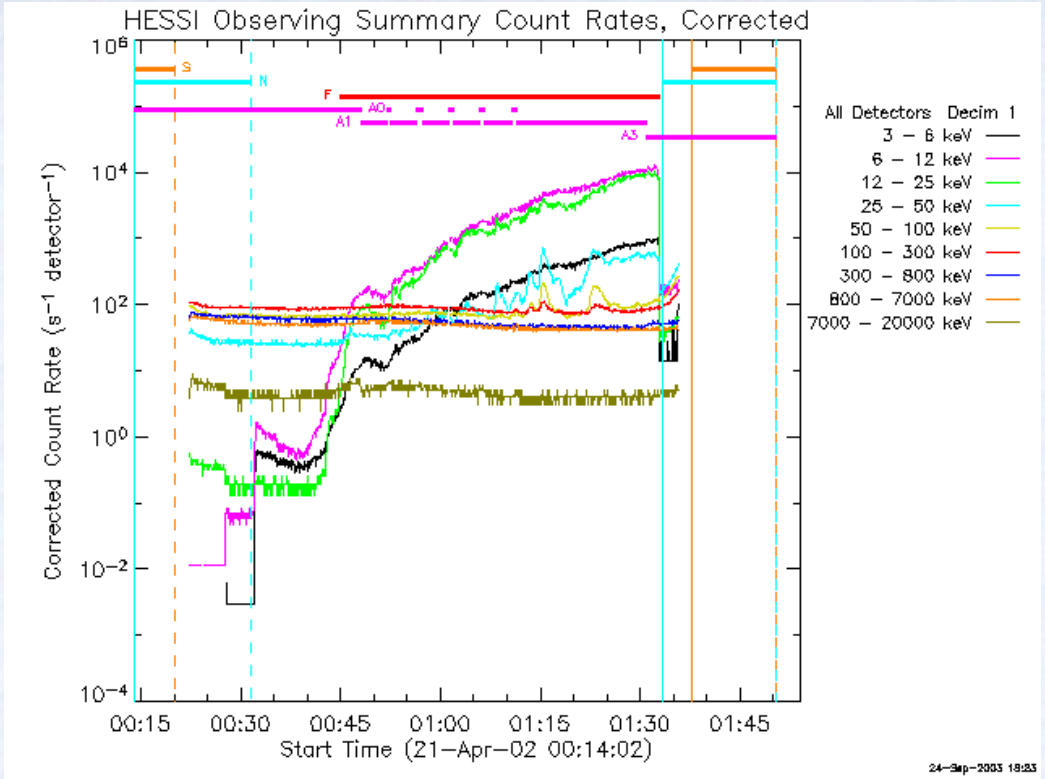
There is no shielding of the instruments – many artifacts in light curves (particles, gamma ray bursts etc.) which impede automatic recognition of solar flares.





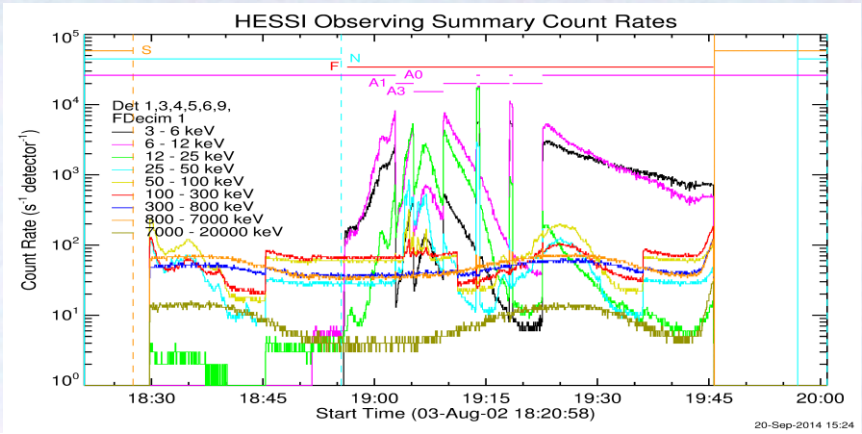
RHESSI quicklook light curves

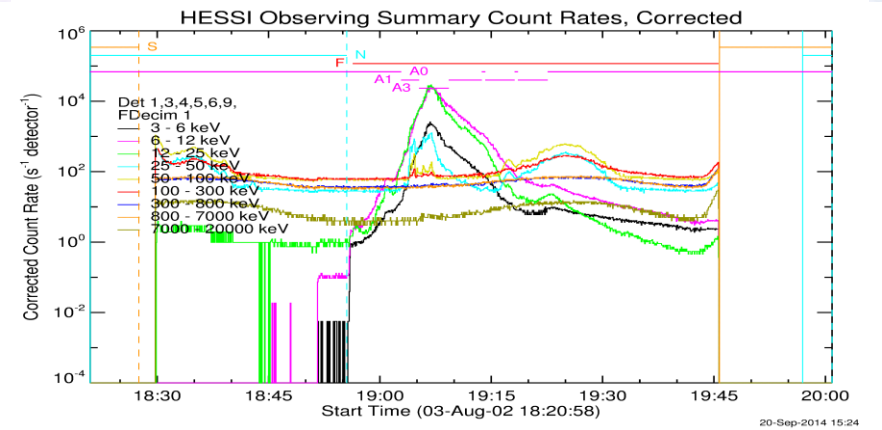


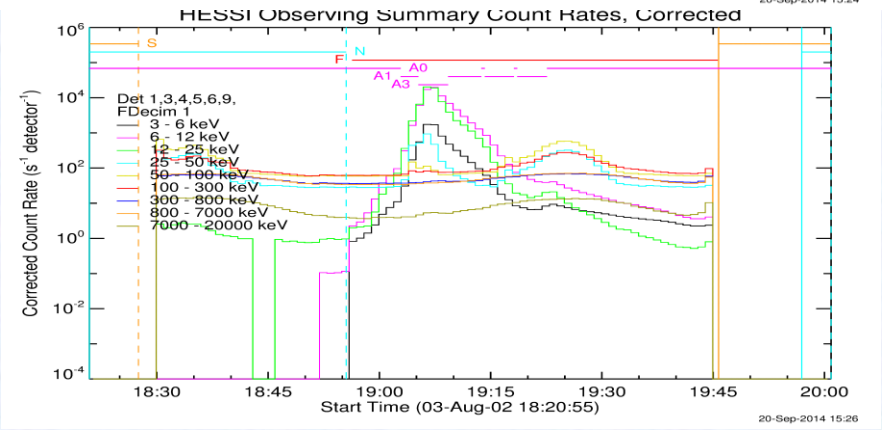


- one of RHESSI quicklook products, prepared directly from Level0 data, no decimation and livetime correction
- corrections attempt to remove the effects of attenuator and decimation state changes
- 4-second resolution count rates averaged over all nine detectors
- shown in nine standard energy bands covering the range 3 to 20000 keV
- on that basis the RHESSI flare list is prepared

RHESSI flare list





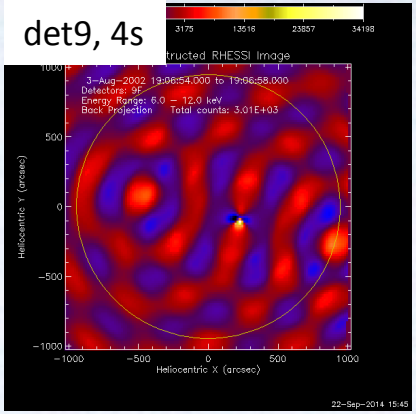


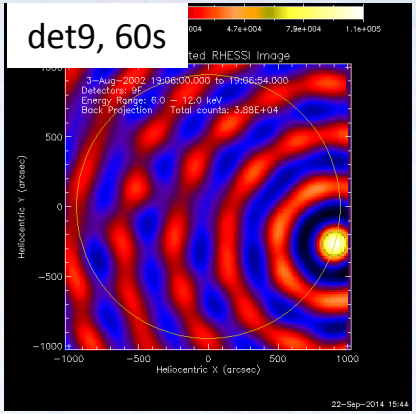
The flare list is obtained by comparing the observing „corrected” count rate in the 6 to 12 keV energy band to a threshold obtained using a 60 second running average.

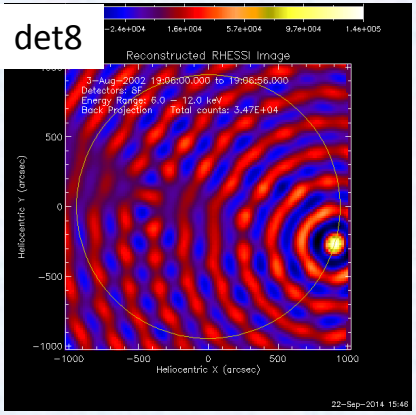
A flare candidate is flagged as a possible solar flare if the ratio of the count rate in **the front detectors to total count rate is 3 sigma above** its own background level (also determined using a 60 second running average).

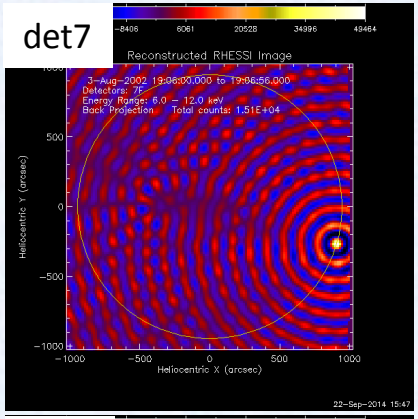
Even with the front - total ratio test, particle precipitation events can be confused with flares. The candidate is only confirmed as a solar flare **if a valid position is found** in the 6 to 12 keV energy band.

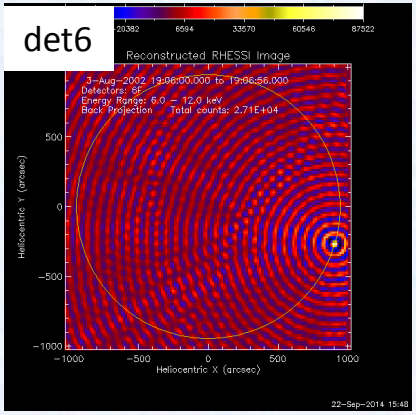
RHESSI flare list

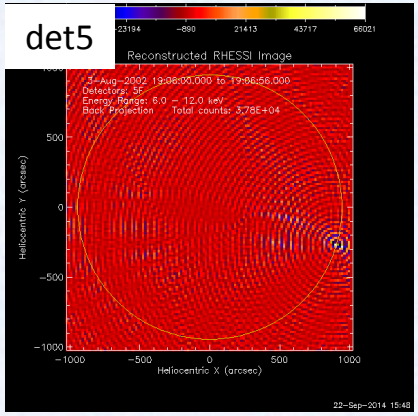












The process of flare position founding uses 128x128 images for collimators 5, 6, 7, 8, 9:

1. Using 16 arcsecond pixels, make a 128x128 backprojection map using subcollimator 9
2. Excluding any pixel within FWHM of the rotation center, determine the location of the brightest pixel.
3. Repeat steps 1 and 2 for subcollimators 8,7,6 and 5
4. Determine XY0 as median of found brightest pixels
5. Select those map peaks that are within a radial distance, R, from XY0 where R is the FWHM of subcollimator 9.
6. If there are fewer than 3 maps satisfying this condition, the algorithm fails.
7. Otherwise, determine the average, X,Y of the selected map peaks. This is the result.

Once a position is found, then the process attempts to find a position in higher energy bands, the highest energy band found to have a valid position is recorded in the flare list.

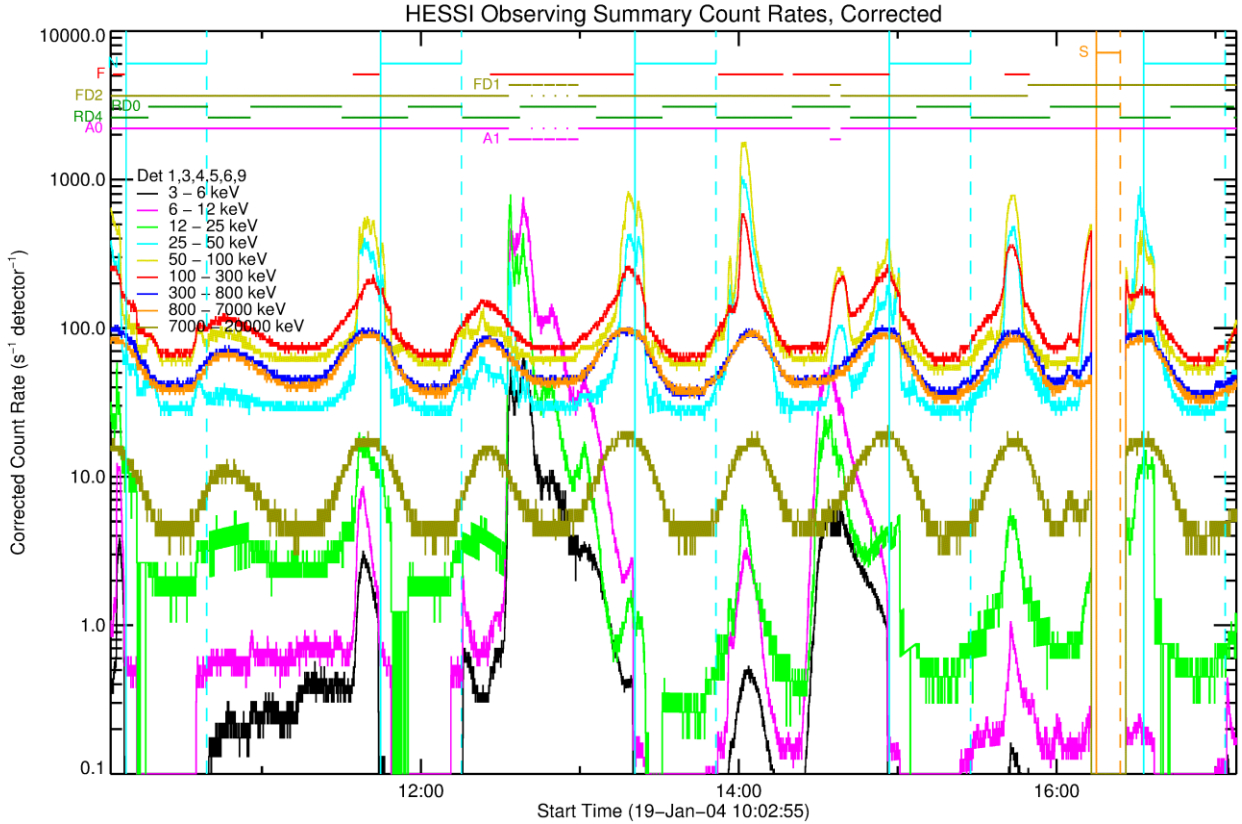
Looking into RHESSI flare list

```
HESSI Flare List  (generated 22-Sep-2014 16:05)

Total # flares: 96168  Time range: 12-Feb-2002 21:29:56.000 - 17-Sep-2014 01:35:04.000

2 flares found that meet the following requirements:
Id_number Limits: 2021213 to 2021230

    Flare     Start time        Peak      End      Dur   Peak     Total      Energy X Pos Y Pos Radial   AR    Flags
                                                    s     c/s    Counts        keV  asec  asec   asec

  2021213 12-Feb-2002 21:29:56 21:33:38 21:41:48   712    136    167304      12-25   592  -358    692    0  A1 P1
  2021228 12-Feb-2002 21:44:08 21:45:06 21:48:56   288      7      9504       6-12   604  -341    694 9811  A1 P1 PE Q1

Notes:
  Note that only events with non-zero position and energy range not equal to 3-6 keV are confirmed as solar sources.
  Events which have no position and show up mostly in the front detectors, but were not able to be imaged
    are flagged as "PS".
  Events which do not have valid position are only confirmed to be non-solar if the NS flag is set.
  Peak Rate:  peak counts/second in energy range 6-12 keV, averaged over active collimators, including background.
  Total Counts:  counts in energy range 6-12 keV integrated over duration of flare summed over all subcollimators,
    including background.
  Energy:  the highest energy band in which the flare was observed.
  Radial Distance:  distance from Sun center
  Quality Codes: Qn, where n is the total number of data gap, SAA, particle, eclipse or decimation flags set for event.
    n ranges from 0 to 11.  Use care when analyzing the data when the quality is not zero.

Flare Flag Codes:
  a0 - In attenuator state 0 (None) sometime during flare
  a1 - In attenuator state 1 (Thin) sometime during flare
  a2 - In attenuator state 2 (Thick) sometime during flare
  a3 - In attenuator state 3 (Both) sometime during flare
  An - Attenuator state (0=None, 1=Thin, 2=Thick, 3=Both) at peak of flare
  DF - Front segment counts were decimated sometime during flare
  DR - Rear segment counts were decimated sometime during flare
  ED - Spacecraft eclipse (night) sometime during flare
  EE - Flare ended in spacecraft eclipse (night)
  ES - Flare started in spacecraft eclipse (night)
  FE - Flare ongoing at end of file
  FR - In Fast Rate Mode
  FS - Flare ongoing at start of file
  GD - Data gap during flare
  GE - Flare ended in data gap
  GS - Flare started in data gap
  MR - Spacecraft in high-latitude zone during flare
  NS - Non-solar event
  PE - Particle event: Particles are present
  PS - Possible Solar Flare; in front detectors, but no position
  Pn - Position Quality: P0 = Position is NOT valid, P1 = Position is valid
  Qn - Data Quality: Q0 = Highest Quality, Q11 = Lowest Quality
  SD - Spacecraft was in SAA sometime during flare
  SE - Flare ended when spacecraft was in SAA
  SS - Flare started when spacecraft was in SAA
```

List may be generated in several ways: command line, RHESSI GUI, txt file from RHESSI site etc.

RHESSI flare list

Flare	Start time	Peak	End	Dur s	Peak c/s	Total Counts	Energy keV	X Pos asec	Y Pos asec	Radial asec	AR	Flags
4011937	19-Jan-2004	10:03:52	10:05:22	10:08:12	260	160	114312	12-25	-51	-200	207	540	A0 DF DR P1 PE Q3
4011927	19-Jan-2004	11:34:24	11:38:14	11:44:20	596	112	188832	6-12	-19	-197	198	540	A0 DF DR P1 PE Q3
4011914	19-Jan-2004	12:26:08	12:38:38	12:45:32	1164	752	1599060	25-50	-6	-185	185	540	a0 A1 DF DR P1 Q2
4011991	19-Jan-2004	12:45:32	12:49:22	12:58:32	780	144	392142	12-25	7	-193	193	540	a0 A1 DF P1 Q1
4011966	19-Jan-2004	12:58:32	13:01:42	13:16:44	1092	45	124245	12-25	5	-193	193	540	A0 a1 DF DR P1 PE Q3
4011967	19-Jan-2004	13:16:44	13:19:22	13:20:20	216	3	2882	6-12	-109	-242	266	0	A0 DF DR P1 PE Q3
4011939	19-Jan-2004	13:52:16	14:02:58	14:16:44	1468	3	9192	6-12	-118	-264	290	0	A0 DF DR P1 PE Q3
4011916	19-Jan-2004	14:20:24	14:34:38	14:56:52	2188	56	198148	6-12	-102	-261	280	543	a0 A1 DF DR EE P1 PE Q4
4011928	19-Jan-2004	15:40:20	15:42:42	15:49:52	572	69	108356	6-12	62	-189	199	540	A0 DF DR P1 PE Q3
4011930	19-Jan-2004	17:19:32	17:22:30	17:28:44	552	120	211344	3-6	0	0	0	0	A0 DR PE PS Q2



corrected live curve

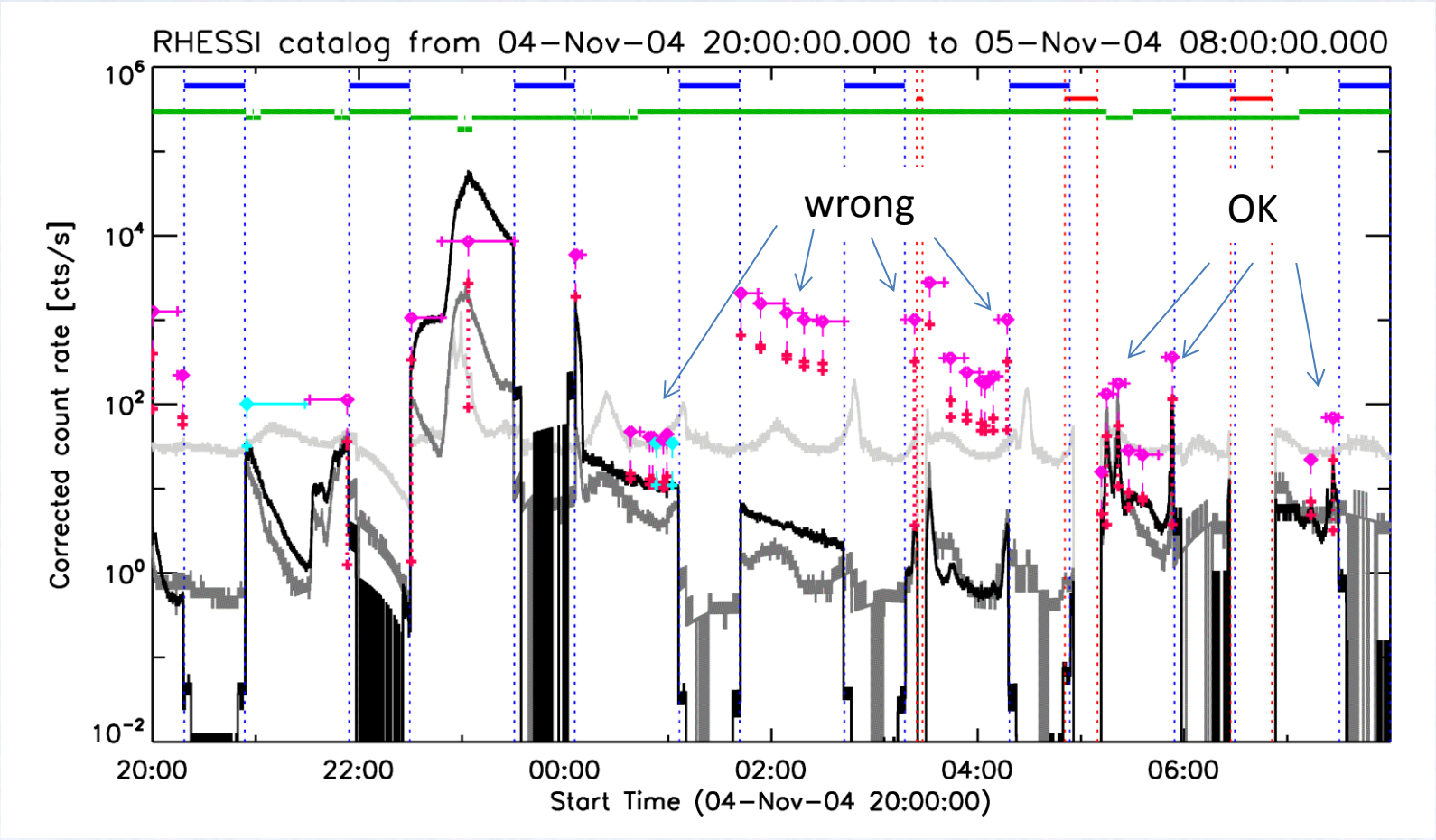
dominated by particle events which are sometimes recognized as flares

Looking into RHESSI flare list

Please note:
(http://hesperia.gsfc.nasa.gov/rhessi2/home/data-access/rhessi-data/flare-list/)

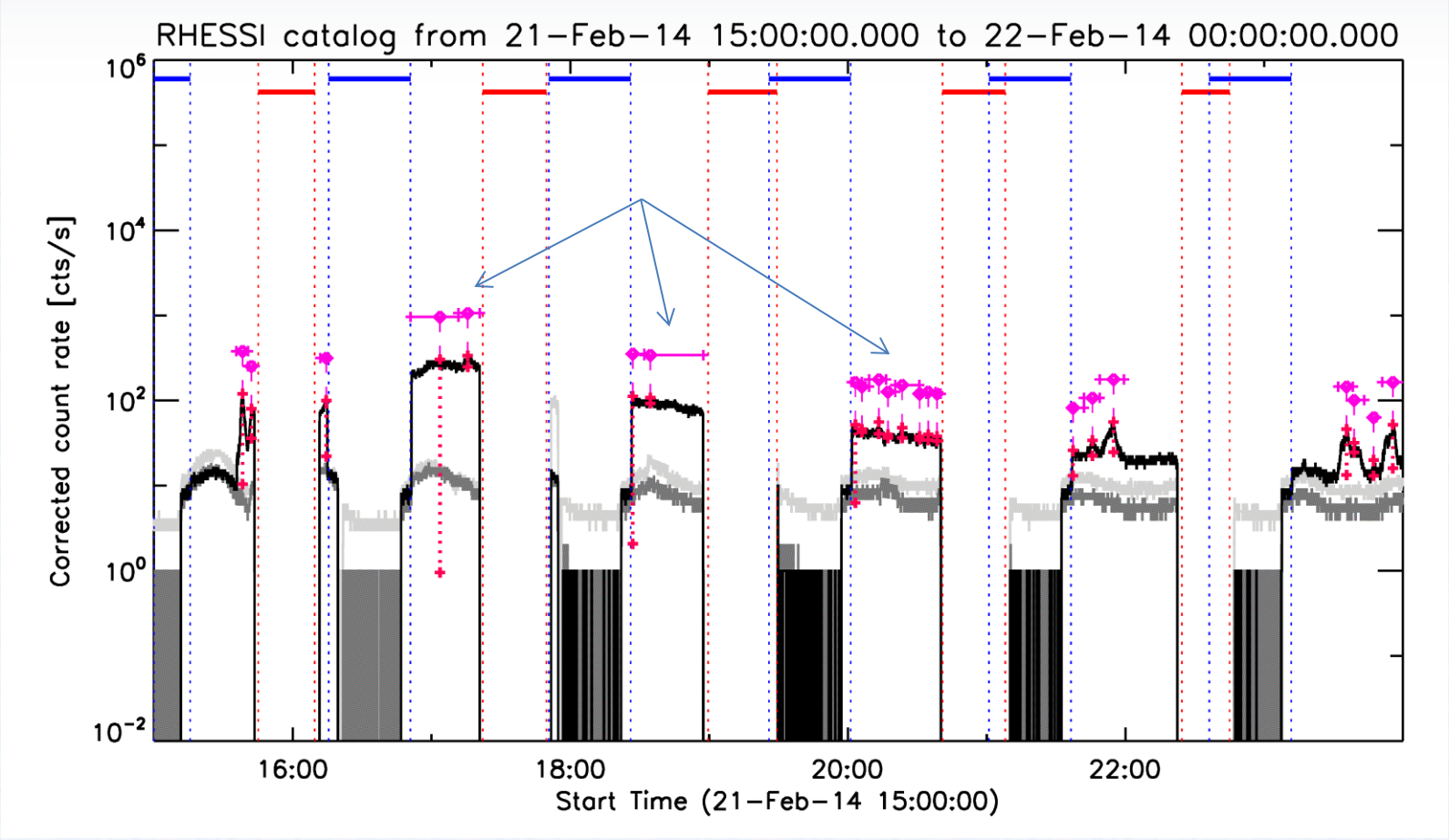
- Only events with non-zero position and energy range above 3 to 6 keV are confirmed as solar sources.
- The flare catalog is occasionally reprocessed (e.g. on September 10, 2010 to include ~24,000 microflares by using the 6 to 12 keV instead of the 12 to 25 keV band), so the start/end times for specific flares may change, and the number of flares on any day may change.
- ***Be careful*** when performing statistical studies of the RHESSI solar flares because flares are listed as multiple flares when interrupted by night, SAA, or gaps.
- Observing summary count rates are not corrected for dead time and pulse pileup effects. Note that the corrections are approximate, and ***should not be used in any quantitative analysis.***

RHESSI flare list



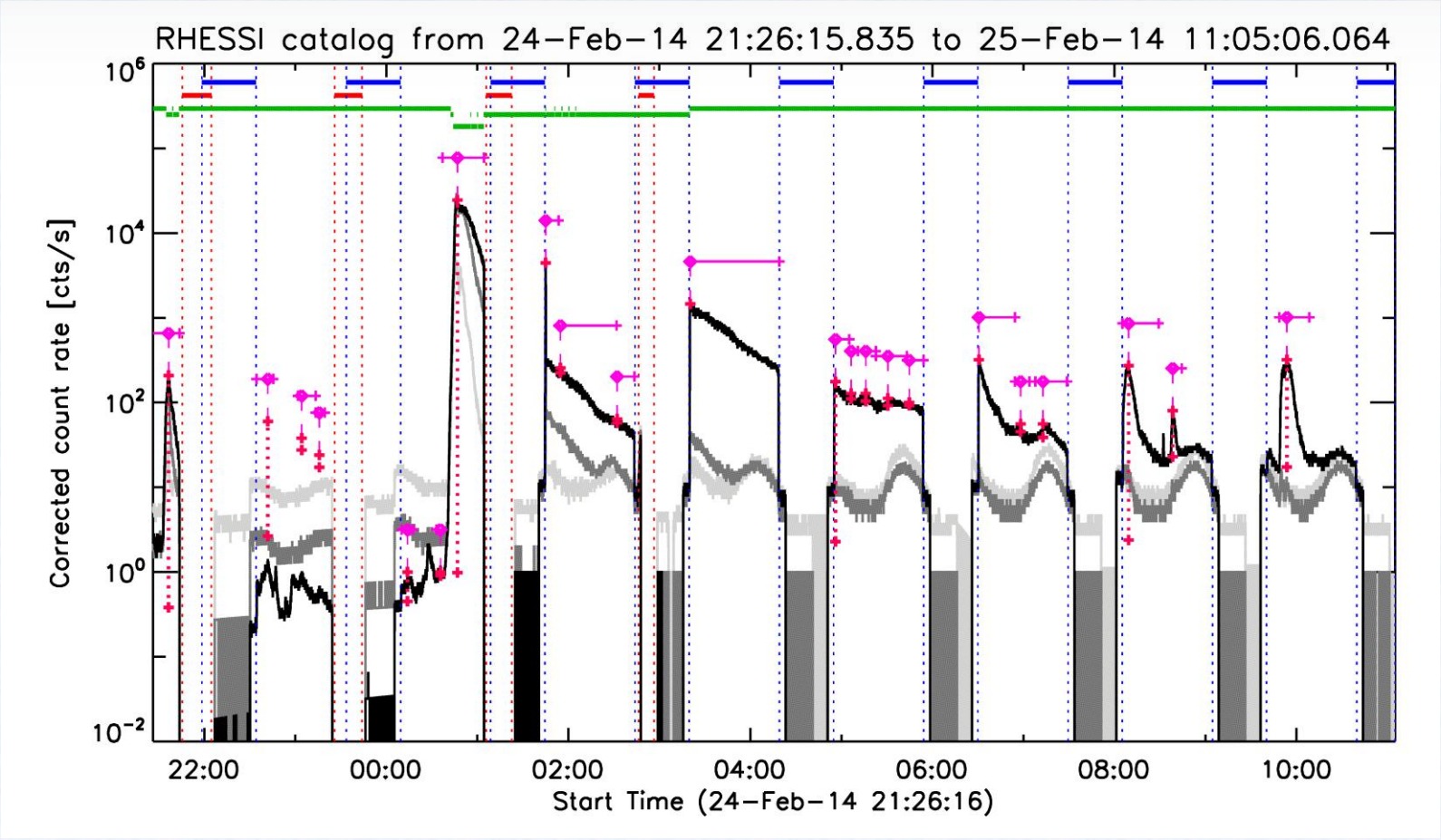
- light blue points – non-solar events
- large fraction of light curves/catalog events is poorly corrected for attenuator

RHESSI flare list



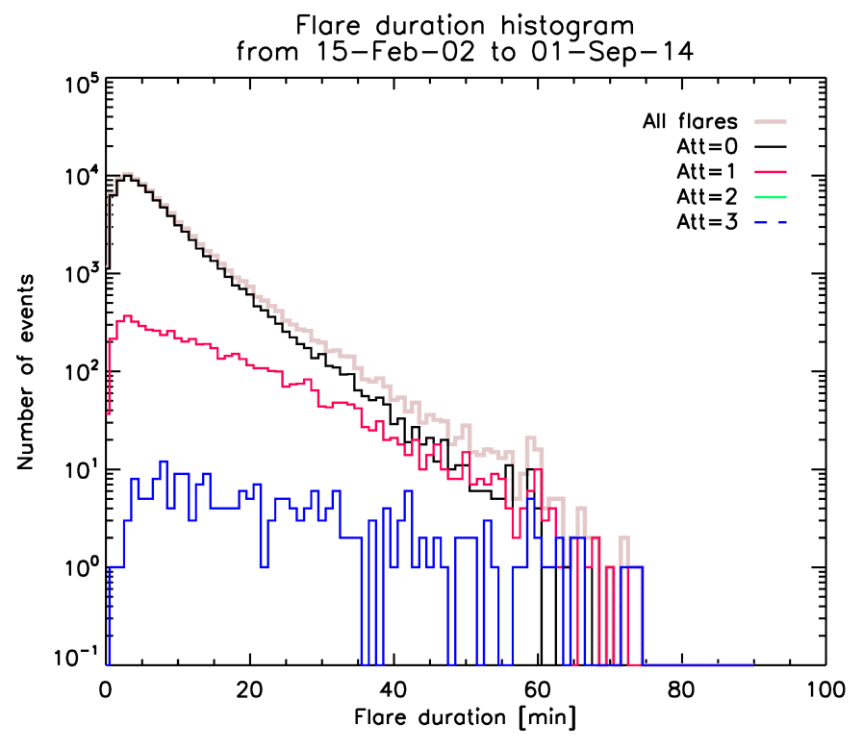
- long duration events are split into many short flares

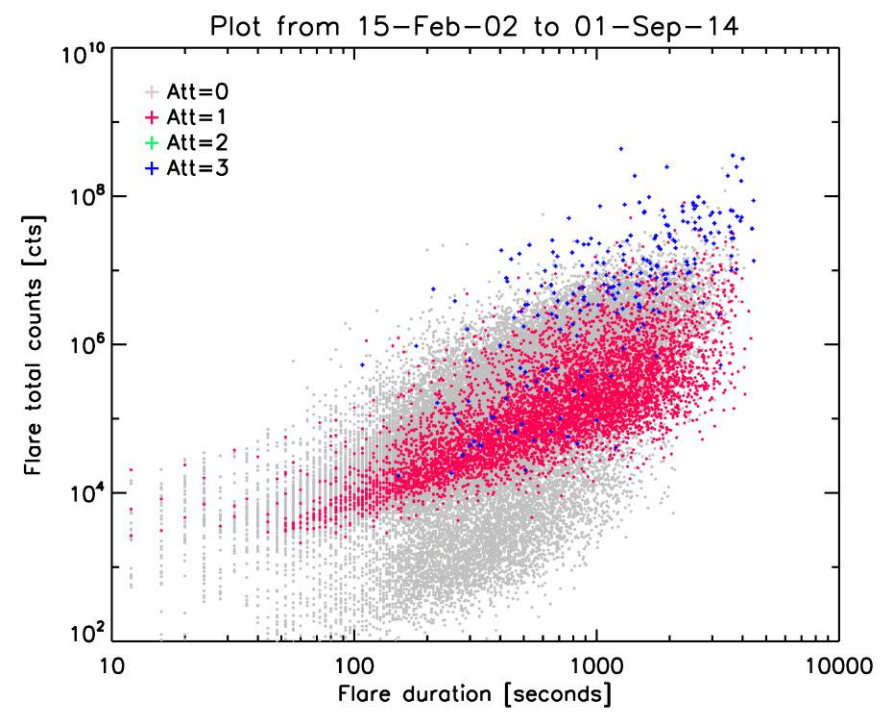
RHESSI flare list



- Another example of LDE. Attenuator changes not well resolved. Each orbit on decay phase is treated as separate flare.

Flare duration



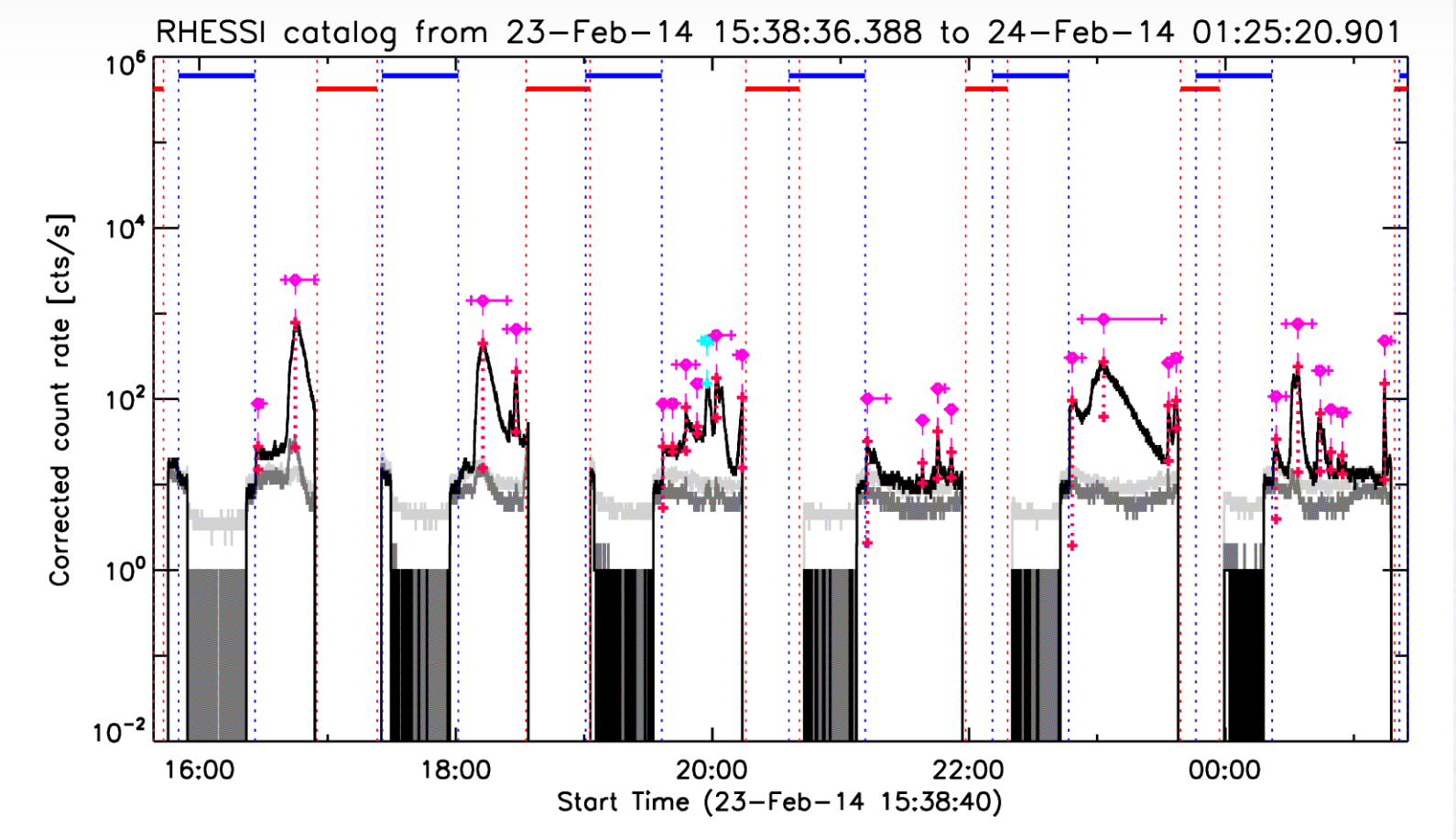


Distribution of flare duration is strongly affected by data gaps, lack of LDE recognition etc.

Improvement of the algorithm is needed, but distribution gives enough information for STIX simulations.

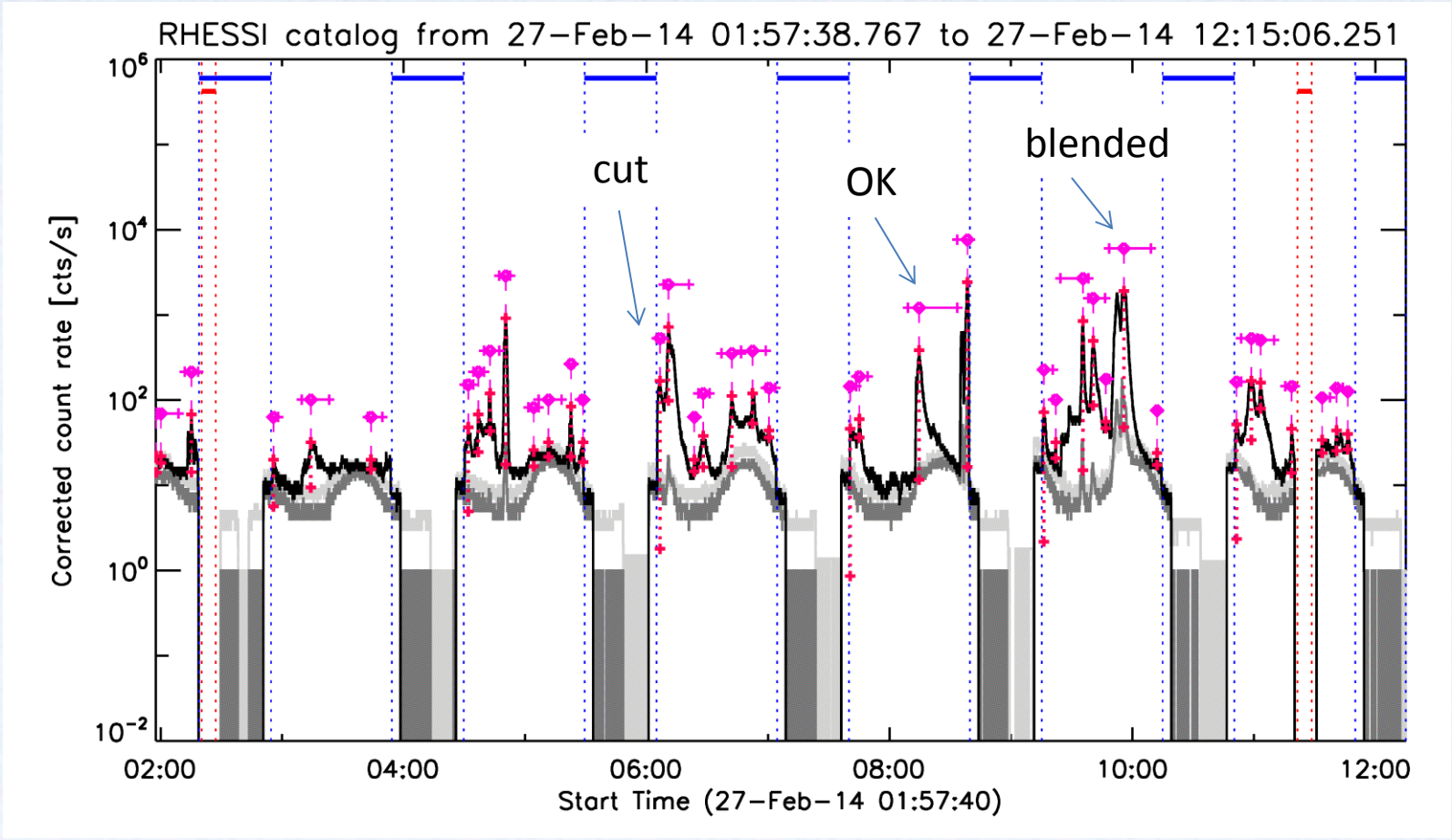
Both, total counts and duration, are affected by problems discussed, but still there is a numerous group of events with well resolved observational characteristics.

RHESSI flare list



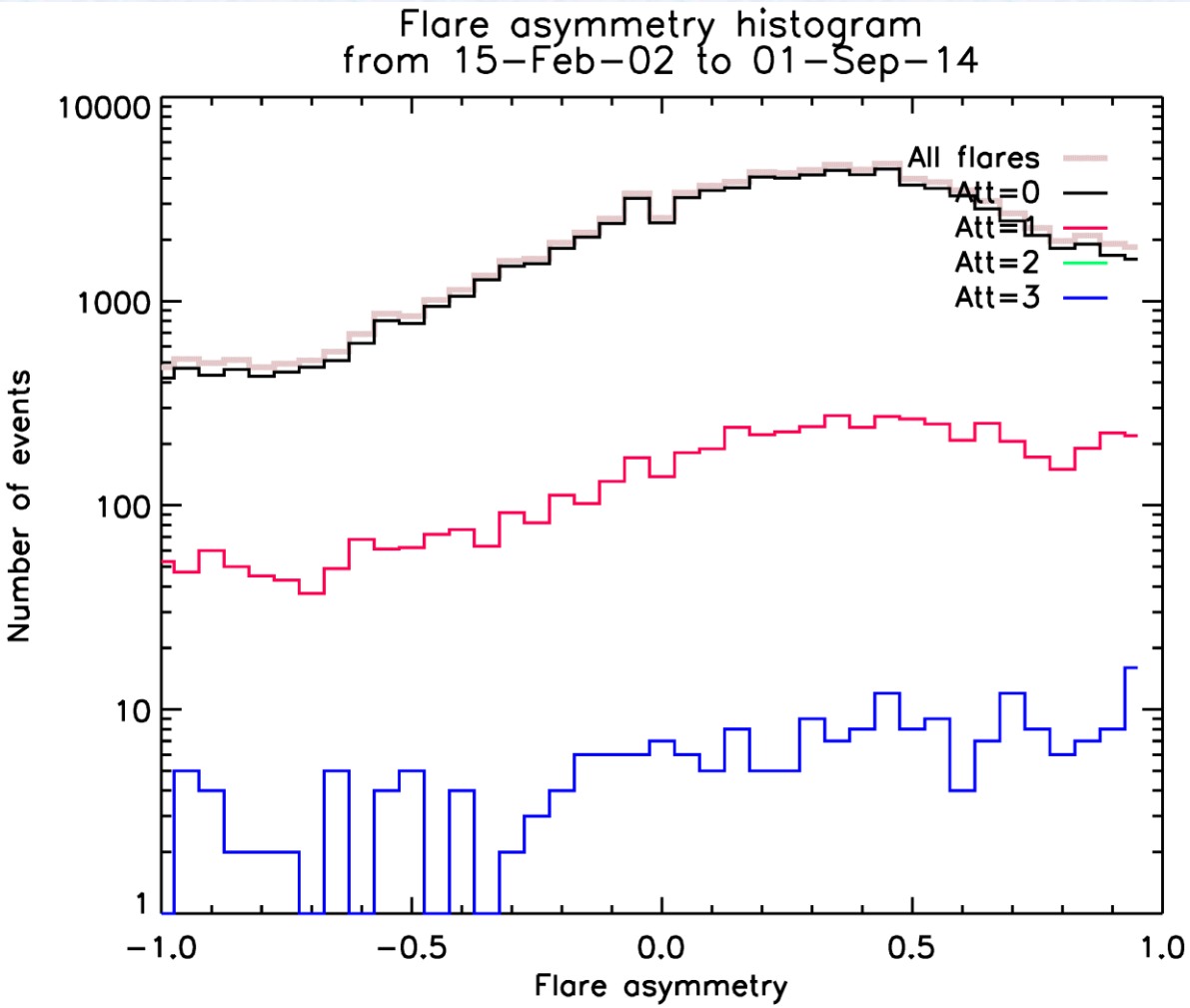
- a good example

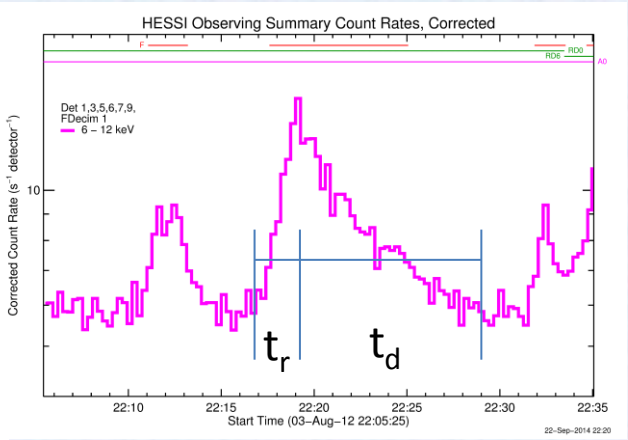
RHESSI flare list – small flares



- Small flares are most suitable for statistical analysis – low count rates
- We tried to look into temporal characteristics of small, short flares because they may be very usefull for constructing sequences of background or low activity periods

Short flares time profiles



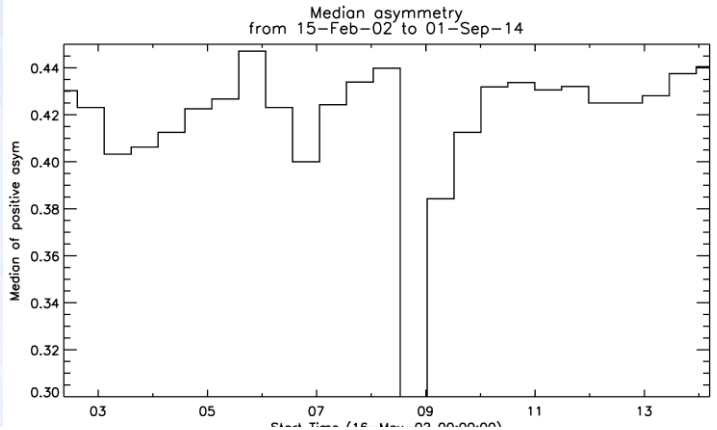


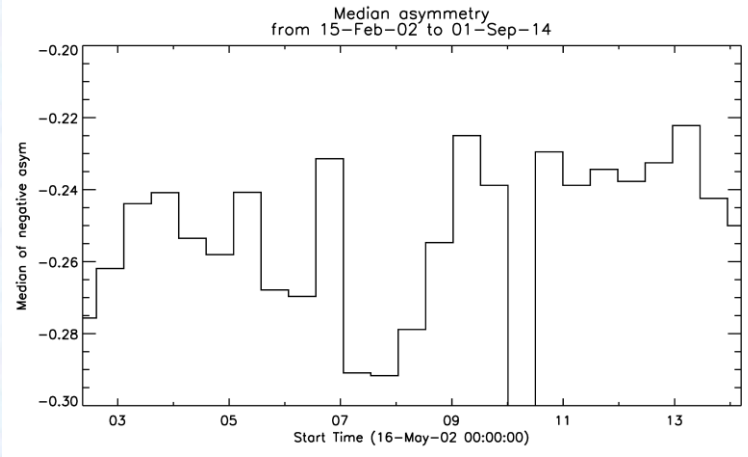
$$A = \frac{t_{delay} - t_{rise}}{t_{delay} + t_{rise}}$$

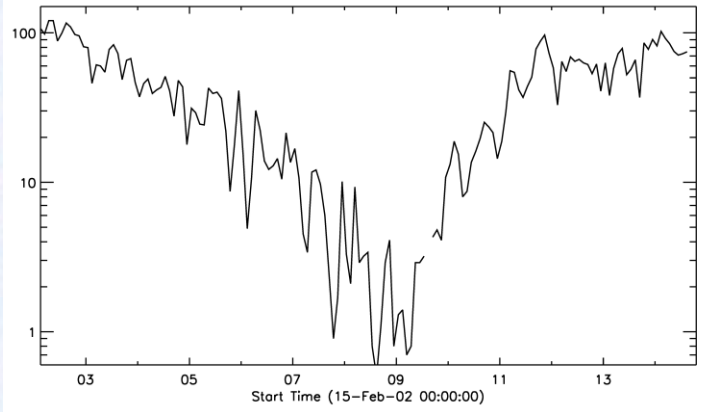
Positive asymmetry is expected.

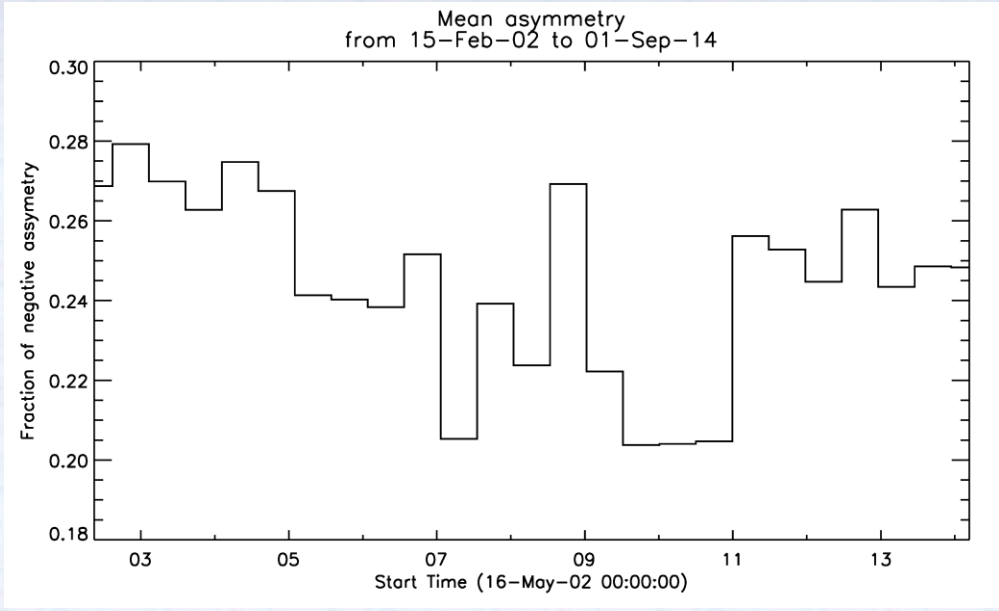
Negative numbers are related with cutted and blended events, mainly

Short flares time profiles







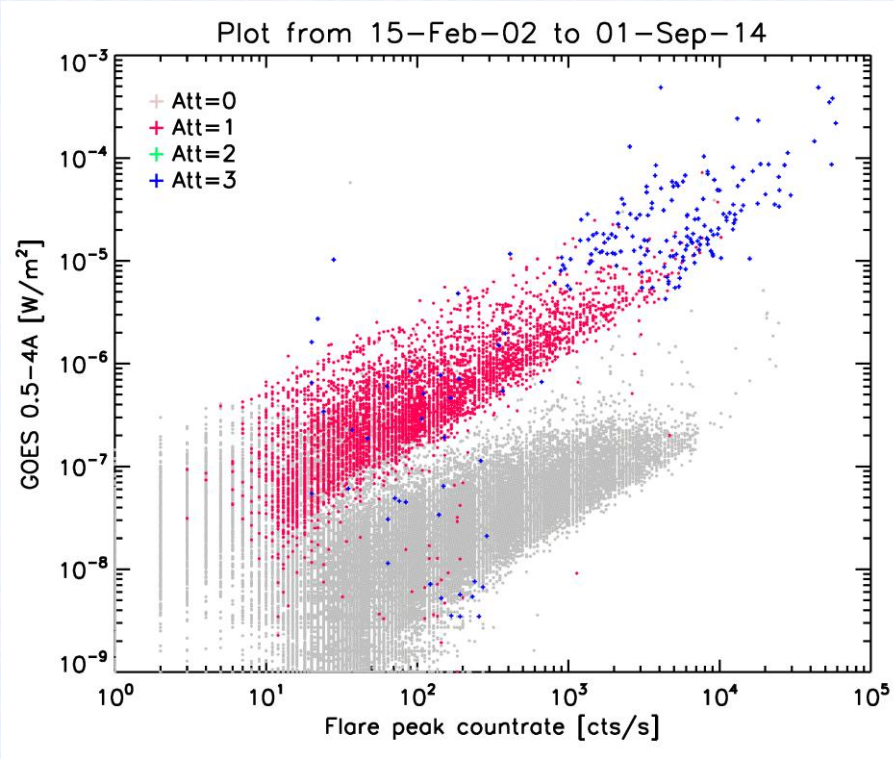


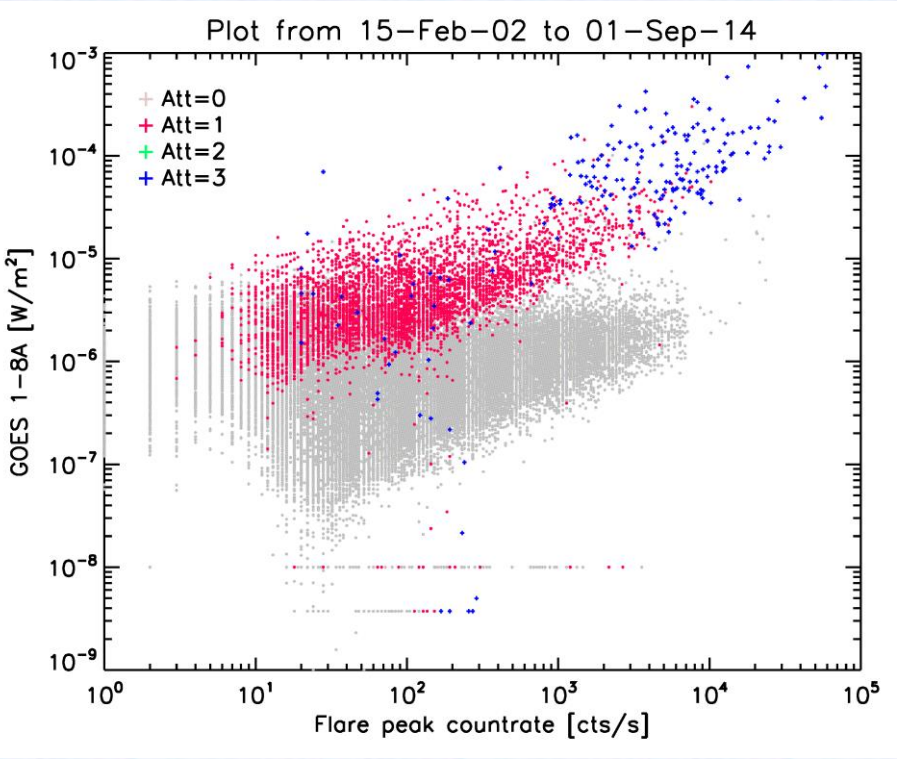
There is almost no important modulation of small flares profile with solar activity.

Negative asymmetry is observed more often during high solar activity – blending

Small flares characteristics will be used for „construction” of time profiles of background or quiet Sun emission. Data from Polish spectrophotometer SphinX will be used also.

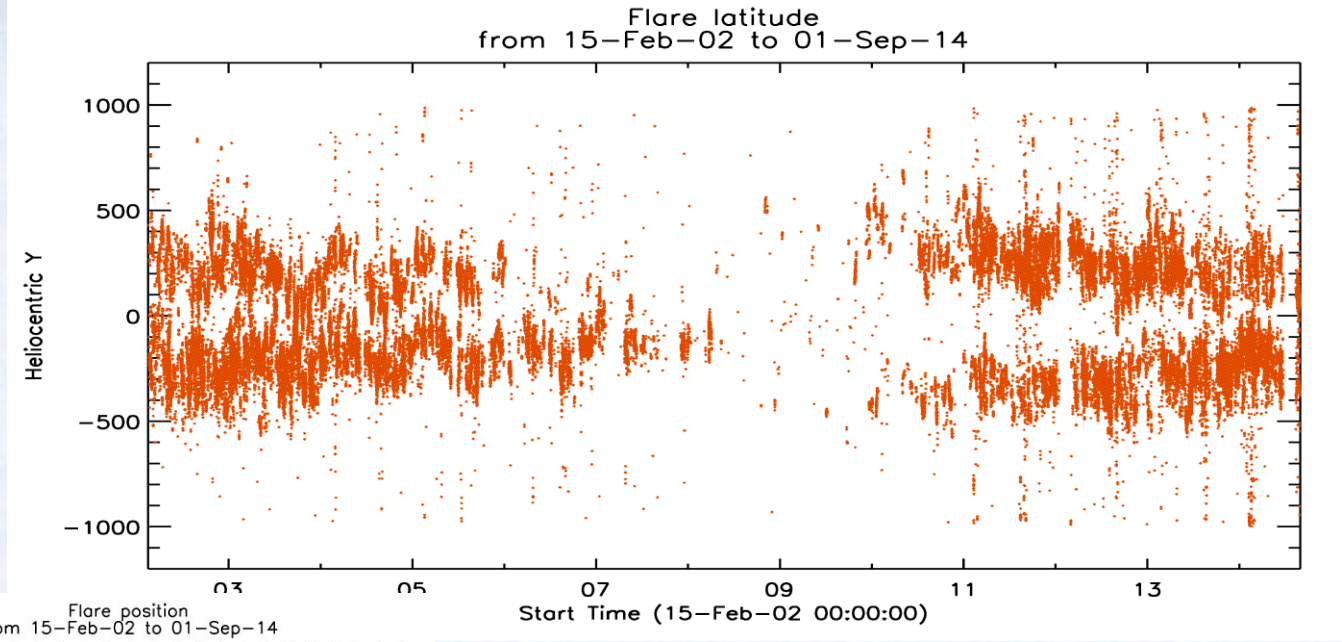
GOES-RHESSI (flare list)

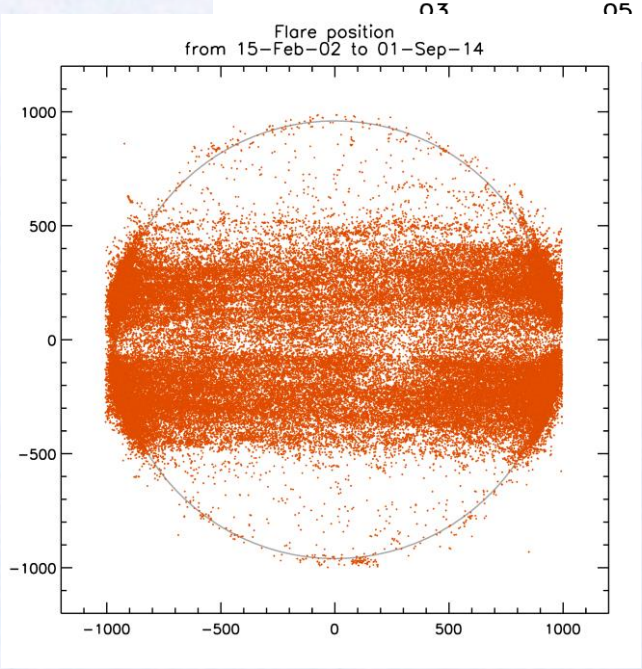




Wrong correction for attenuator presence is clear.
GOES data may be used for improvement of this part of catalogue.

12+ years, positions



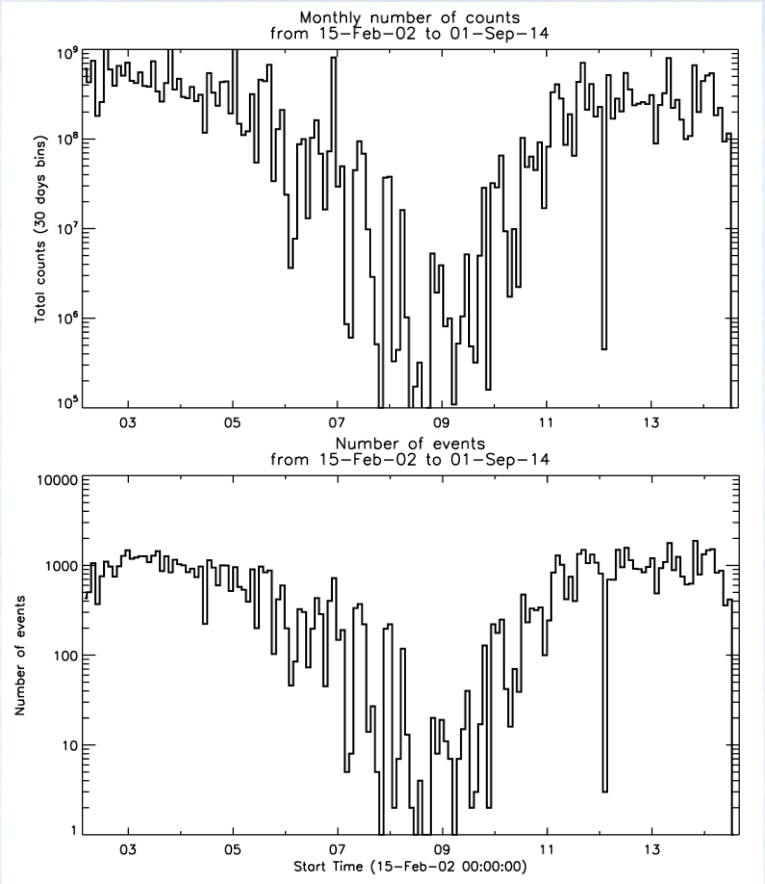


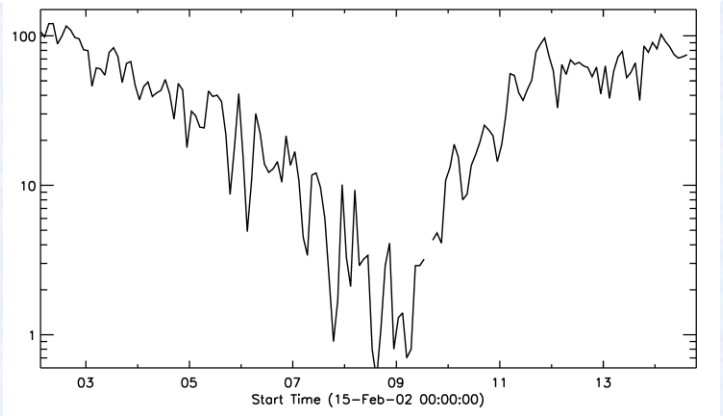
„Hole” close to the rotation axis

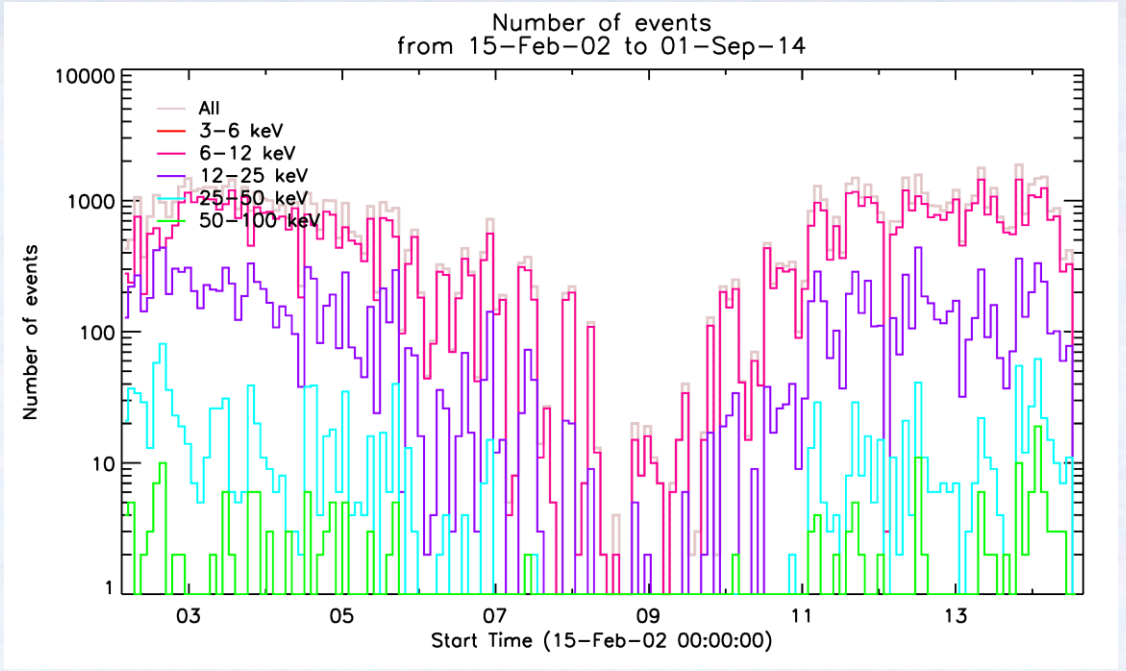
Mapping of flares should be reprocessed – sharp cut close to equator

It will remove correlation between non-solar events and solar activity

12+ years



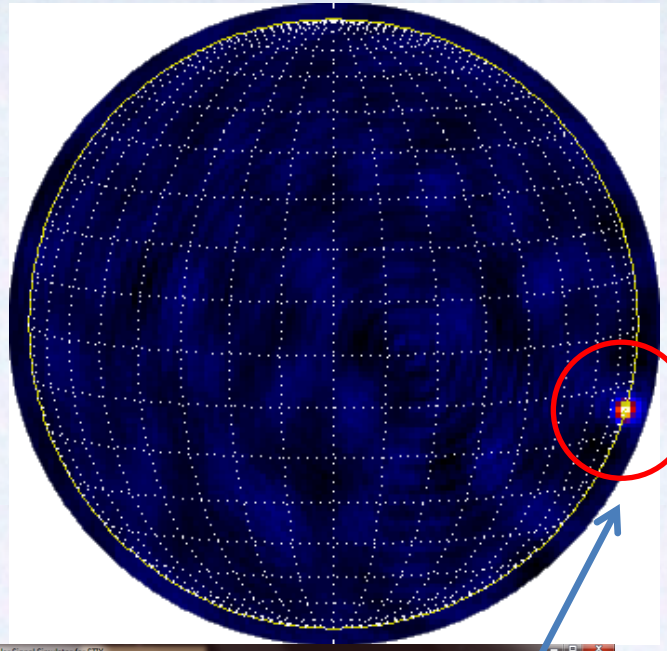


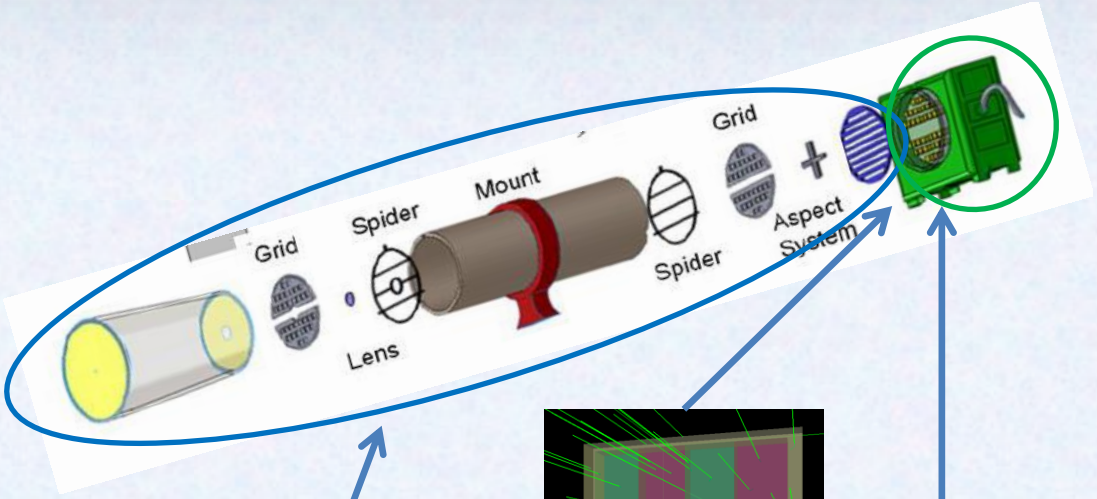


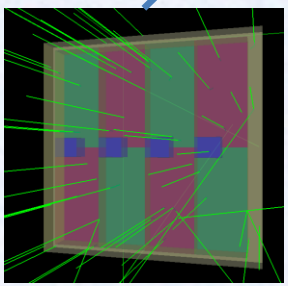
Important for simulations of STIX behaviour in various phases of solar cycle.

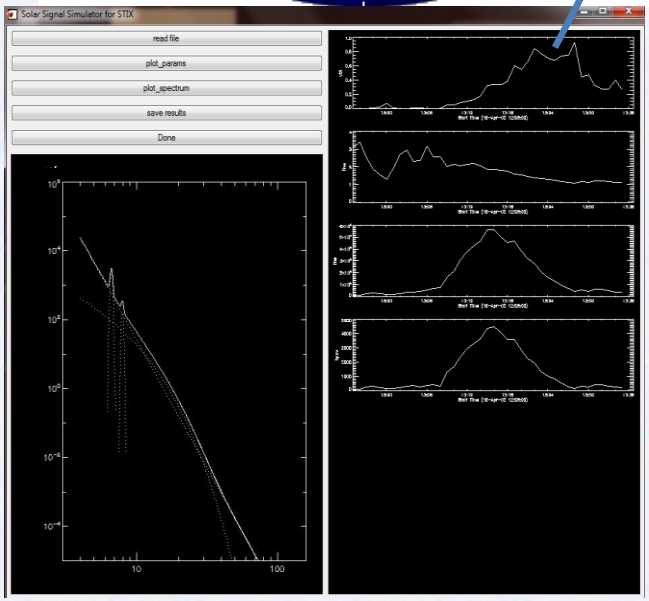
Similar analysis of SEP occurence will be used for calculation of detectors aging effects.

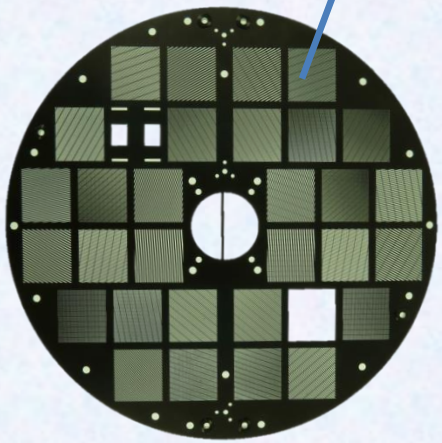
STIX simulations











December 2014 – all subsystems will be ready for integration and first run.

SUMMARY

- RHESSI catalogue still needs several improvements like filtering long (>one orbit) events, larger field of view for selecting non-solar events
- Correlation with GOES may be used to improve correction for attenuators.
- With several improvements RHESSI flare list may contain information for statistical analysis.
- Frequency distributions of flares parameters may be used for constructing artificial sequences of flares. For STIX we are able to handle one sequence lasting up to 200 hours.
- Developed simulation system will be very usefull during cruise phase and scientific orbits.