# Operation principles and requirements for electronics – detector system in solar X-ray instruments

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# Outline

- Introduction
- Operation modes of solar X-ray instruments
- Requirements of solar X-ray instruments
- Summary

# Introduction

- Solar Physics Division, SRC-PAS performs space experiments aimed to observations of the Sun in X-rays.

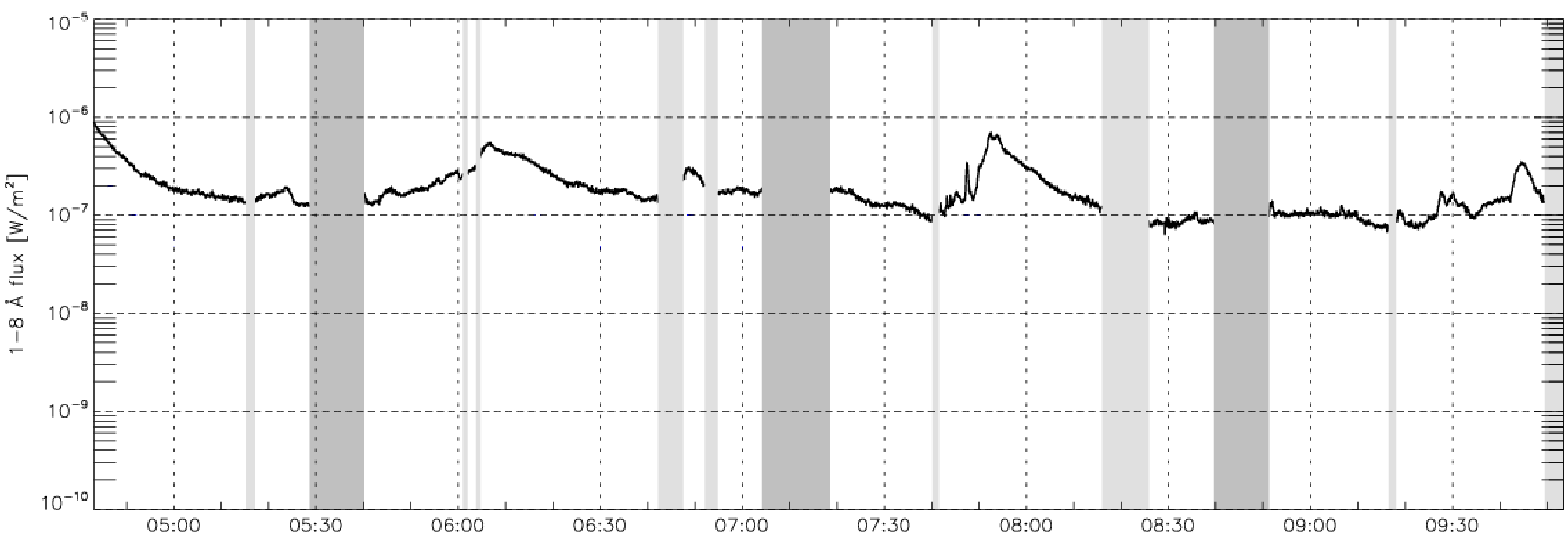
- We used solid state detectors as well as gaseous detectors in our experiments.

- We are thinking about using Micro-Pattern Gas Detectors in future experiments.

# Operation modes

**Photometer** - measurement of X-ray emission in a selected broad energy band.

- Few relatively wide energy bands.
- High energy resolution of detector is not necessary.
- Position sensitive detector is not required.
- Very high dynamics of flux intensity (photon rate can change by several orders of magnitude).



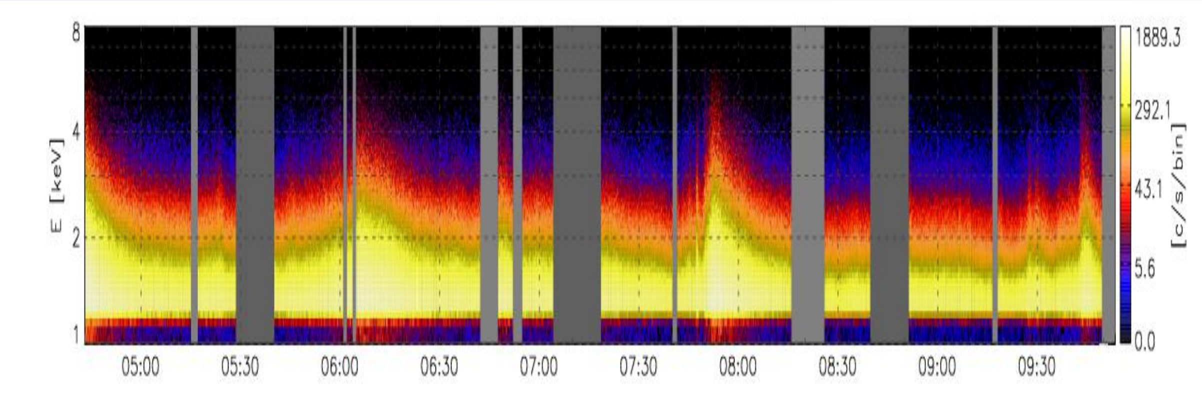
Time UT, Start time 04 Jul, 2009 04:43:05

An example of solar X-ray flux recorded by SphinX – photometric mode.

# Operation modes

**Spectrometer** - measurement of solar X-ray flux in a certain energy bands

- Lot of narrow energy bins.
- High energy resolution of detector is required.
- Position sensitive detector is not necessary.
- Very high dynamic range of flux intensity (photon rate can change by several orders of magnitude).

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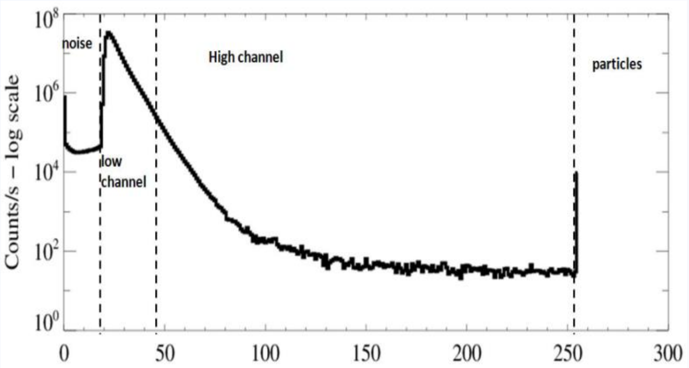
Variability of solar spectrum in time.




Energy bin

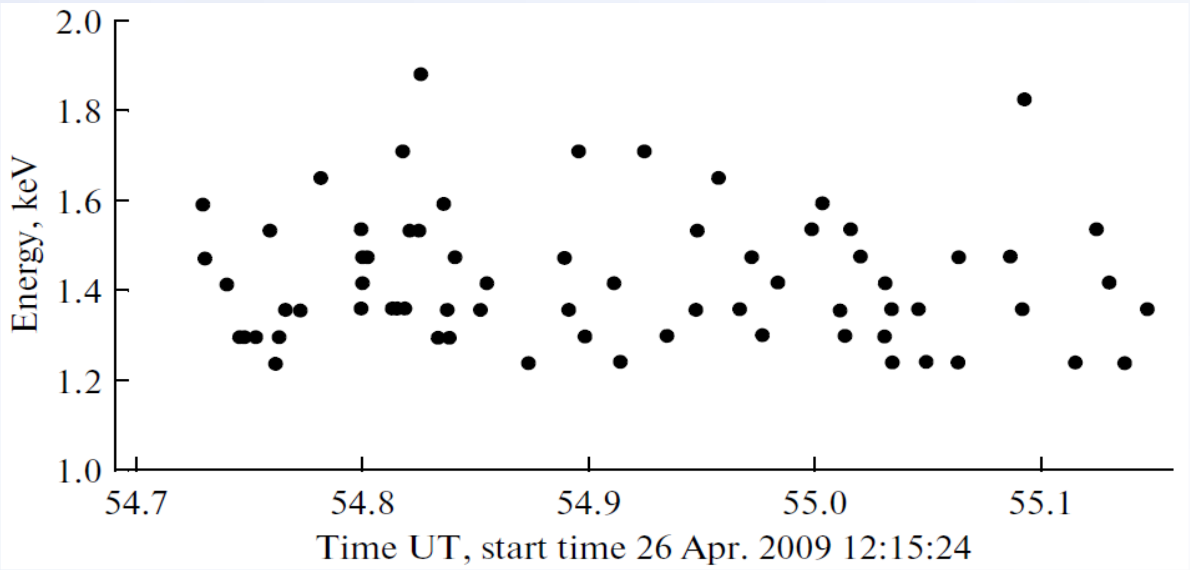
Cumulative spectrum collected from 1 to 31 May 2009.

An example of solar X-ray spectra.

# Operation modes

**Time stamping mode (detector event counting  mode)** - each detected photon is specified by its arrival time and energy (and xy(z) position if available).

- High energy resolution is required.
- Good temporal resolution is required.
- Very high dynamics of flux intensity in case of solar observations (photon rate can change by several orders of magnitude).

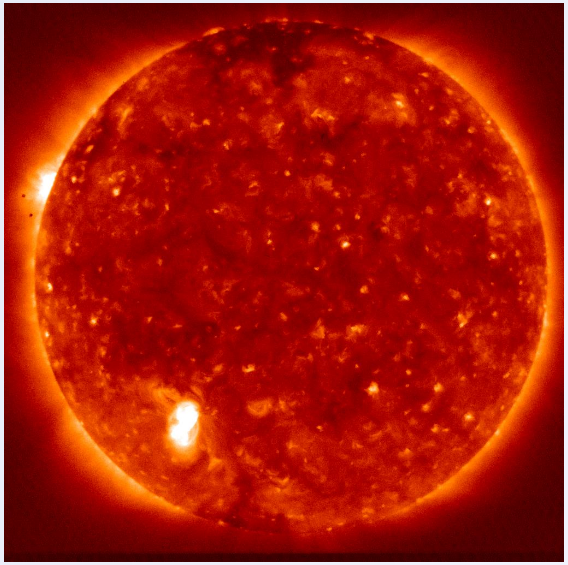


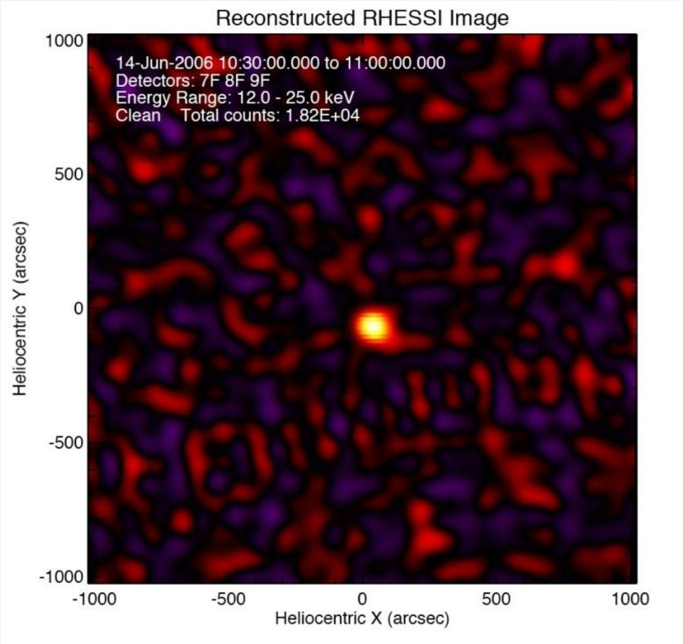

An example of time stamping data.

# Operation modes

**Imager** - provides imaging of solar disc in selected energy bands.

- High spatial resolution is an advantage.
- Position sensitive detector is desired (an exception is tomography based instrument).
- High dynamic range is preferable.






An example of the Sun image in SXR recorded by XRT (left) and reconstructed image in HXR recorded by RHESSI (right).

# Volume, mass and power

Space-born small instruments are usually severely restricted in volume, mass and power:

- Volume: typically a few cubic decimeters, strictly defined shape.
- Mass: typically a few kg.
- Power: typically a few Watts.

The limitations involve an extra effort on instrument design.

The limitations become even more severe for so-called nanosatellites – recent dynamically developing trend in satellite science.

# Radiation hardness

- Satellites operate in harsh cosmic environment and in case of solar experiments usually passes through Radiation Belts and South Atlantic Anomaly.
- Particles contributes to solar measurements.
- Particles can degrade or even damage detectors and electronics.
- Detector and electronics have to be radiation hardened.

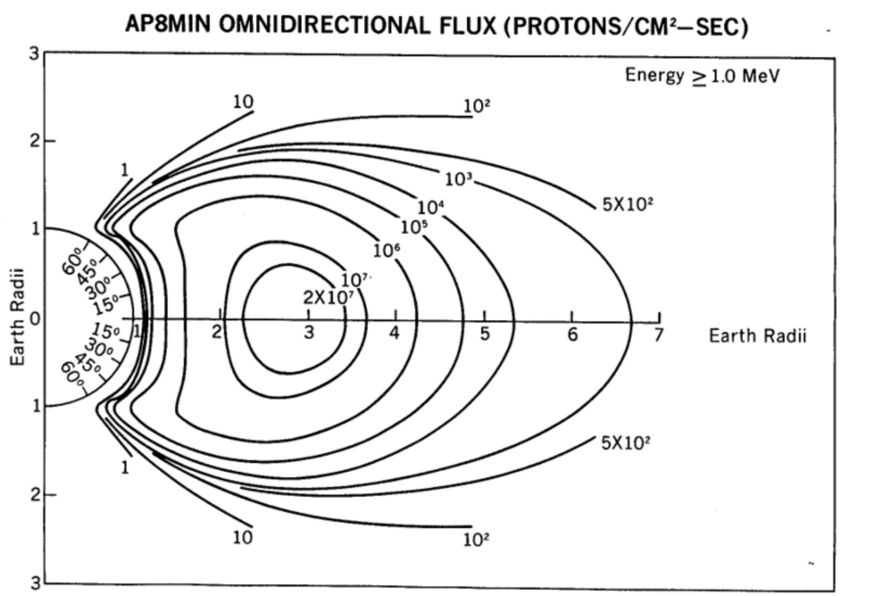
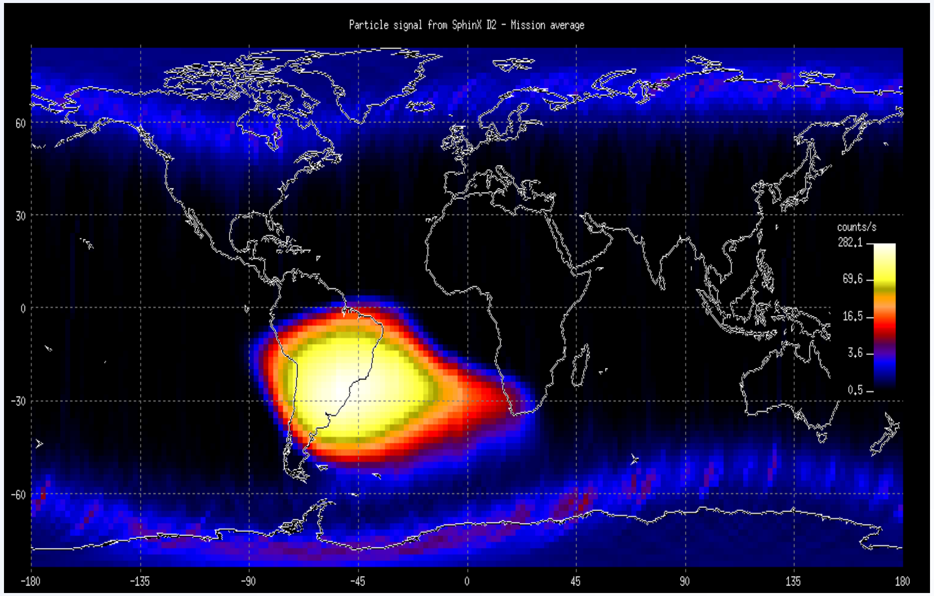



Figure 66. AP8MIN R-λ Plot of Constant Intensity Flux Contours with an Energy of ≥ 1.0 MeV




Proton flux intensity based on AP8MIN model (left), average particle count rate as seen by SphinX in 2009 during deep solar activity minimum (right).

# Stability

- Main calibration is made once before launch and cannot be performed in space.
- Stability of detector parameters within entire mission time is required.
- All parameters that may affect the detector gain (pressure, voltage) have to be monitored end collected for further data correction.
- The instrument/detector should be possibly insensitive to environment conditions, especially to temperature that may change in wide range.

# Gas operation

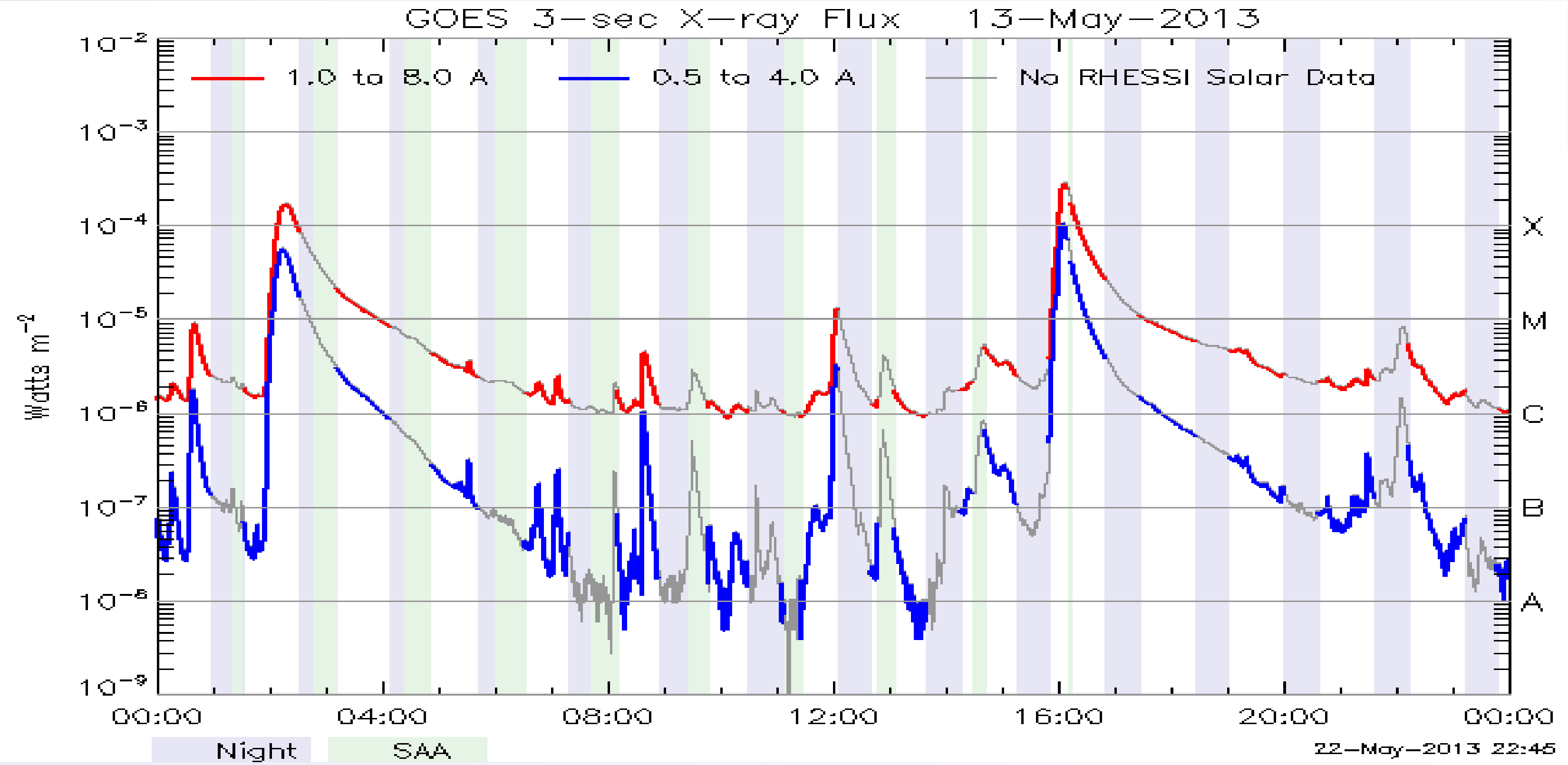
- The detector have to operate in vacuum.
- It is not desirable to flow gas through the detector and let it out (risk of incontrollable electric discharges could terminate mission).
- The detector have to operate for the nominal mission time with the same gas volume.
- There is an option for looping  larger gas amount through detector so that only a part of the entire gas supply will be exposed at a time.
- Another option is to use sealed detectors – gas will age faster.

# Temperature

- Temperature of the instrument may change in wide range.
- The detector and electronics have to be capable to operate in temperature range from -40°C to +85°C.
- The instrument should be resistant to rapid changes of temperature and high temperature gradients.

# Dynamic Range and Strong Flux

- Solar flux can change over a time scale of minutes by several orders of magnitude.
- It is difficult to cover entire dynamic range with one detector. Usually few detectors with different sensitivities are used.
- The solar integrated flux can reach $10^{10}$ photons/cm$^2$/s in excess – the detector itself and the readout electronics have to be capable to work with very high count rates.




An example of GOES data showing the dynamic range of solar X-ray flux.

# Mechanical robustness

The instrument have to withstand very strong vibrations and high acoustic shocks in wide frequency range during the rocket launch.

An example of mechanical tests performed before launch that instrument have to pass:

| TEST | Amplitude | Frequency |
|---|---|---|
| Acoustic vibrations | 122 dB – 133 dB | 35 Hz - 5 kHz |
| Acceleration | 3 g, 10 g | 10 min |
| Transports in 3 axes | 9g | 5 ms-10 ms, 120 shock/min |
| Resonance | 50 g | 10 Hz - 2 kHz |
| Vibration overload | 2 g -80 g | 10 Hz - 2.5 kHz |
| Shocks in 3 axes | 80 g | 2 ms |

# Data acquisition and telemetry

Telemetry quota is specific for given instrument – typically from few MB/day up to more than one GB/day.

On-board data handling algorithms are required to reduce amount of telemetry data (data selection, compression).

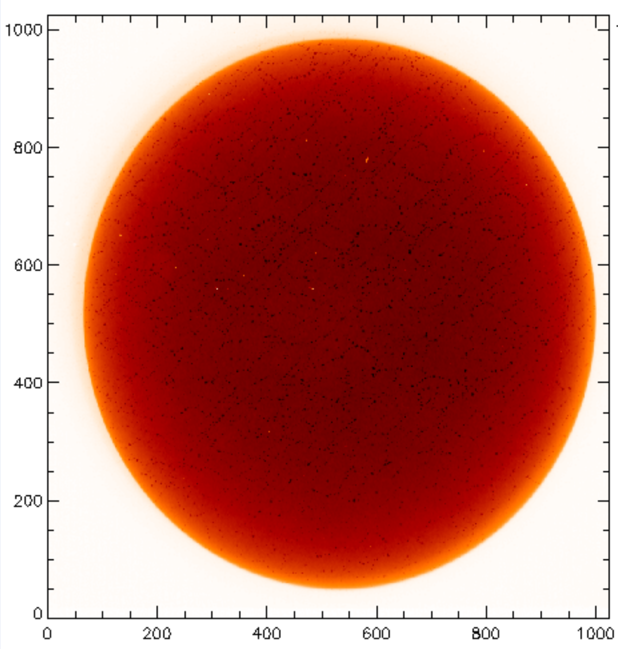
Depending on the spacecraft orbit and its visibility from the Earth by ground stations the data can be downloaded continuously or few times a day in a larger dumps.

On-board data storage is usually required.

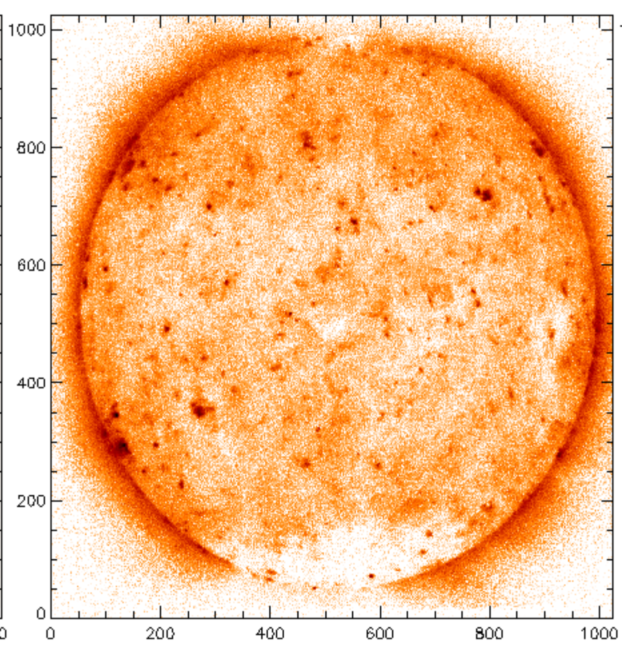
# Contamination

- Detector performance can be decreased by contamination coming from different materials used for instrument construction.
- Special care must be taken selecting the detectors material to avoid evaporating.

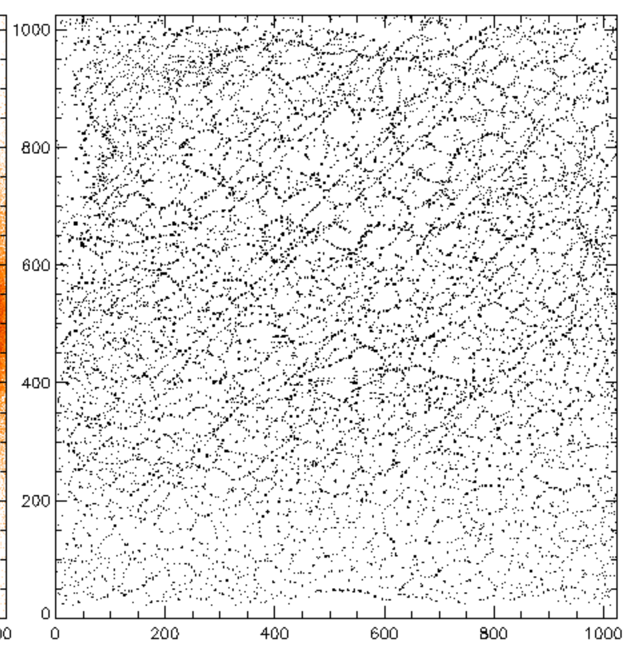
An example of XRT images:




white light image - contamination pattern is clearly seen




X-ray image - contamination pattern is invisible due to high dynamic range




extracted contamination pattern – common for both WL and X-ray images

# Summary

- Micro-Pattern Gas Detectors could be possibly used in solar space-born instruments.

- The detectors need to be adapted for space applications.

- The main challenges are:
    - detector operation in vacuum,
    - long term stability and ageing,
    - durability.

Thank you