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

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Introduction: solar X-ray instruments (see parallel poster „Solar space-born instruments and detectors for X-ray observations of the solar corona") use various types of detectors operating in energy range of soft X-ray (up to several keV) or hard X-ray (up to ~100 keV). Commonly used are solid state detectors (Si, Ge, CdTe) and gaseous detectors. Depending on instrument type (photometer, spectrometer, imager, etc.) the design requires to optimize different parameters such as: energy resolution, spatial resolution or fast readout. In order to improve the instrument performance indirect methods are used like Fourier imaging (RHESSI) or Bragg spectrometry (RESIK). The general requirements for MPGD detectors as detectors in space-born solar X-ray instruments are described.

Operation modes of solar X-ray instruments

Depending on used detectors and operation modes, the X-ray instruments can provide different types of data. For the instruments without spatial resolution which observe overall solar emission from entire solar disc the most basic is **photometric mode** providing light curve of solar x-ray flux in fixed energy range (Figure 1). In **Spectral mode** the instrument measures solar X-ray flux in a certain energy bands providing the spectrum as histogram of intensity density vs energy/wavelength (example is given in Figure 2). The key parameter for this mode is energy resolution. In case of direct energy measurements using gaseous or solid state detectors, the resolution is limited to that offered by the used detector.

In **Time stamping mode (detector event counting mode)** each detected photon is specified by its arrival time and energy (Figure 3). Both photometric and spectral data can be reconstructed based on the time stamping data. Unlike the above described modes an **imager** feature spatial resolution which provides imaging of solar disc in selected energy bands. Usually for EUV and SXR range the instruments use direct imaging with CCDs (Figure 4 left) or APSs. For HXR indirect Fourier imaging technique is commonly used, thus position sensitive detectors are not required (Figure 4 right).

General requirements for space-born instruments

Volume, mass and power - There are severe restrictions on volume, mass and power budget for the instruments. Typically the instruments must fit in a few cubic decimeters with a mass of few kg. The power consumption is limited to few Watts.

Radiation hardness - The instruments operate in harsh cosmic environment, especially while crossing Radiation Belts or South Atlantic Anomaly (Figure 5). The particles (mainly electrons and protons) may contribute to measurements and cause detector degradation.

Stability - Measuring X-ray flux requires very good stability of detector parameters within entire mission time (long-term stability, ageing). Main calibration is made once before launch and cannot be performed in space. However a simple on-board calibrations are possible during the mission. The instrument/detector should be possibly insensitive to environment conditions, especially to temperature that may change in wide range.

Gas operation - One can imagine three basic gas **operation** methods for gaseous detectors in space experiment. Detectors can be sealed and always the same gas volume will be exposed to incident radiation. In sealed detectors gas will age with time and change the detector gain. Another method is to loop larger gas amount through detector so that only a part of the entire gas supply will be exposed at a time. The third method is to flow gas through the detector and let it out. This solution however could produce a cloud of gas around the satellite and increase the risk of incontrollable electric discharges which could terminate the mission.

Strong Flux - Solar experiments receive very strong flux in comparison to other space experiments – stellar for instance. The solar irradiance can reach 10^{10} photons/cm^2/s in excess. Thus detector itself and the readout electronics have to be optimized to work with high counting rates.

Dynamic Range - Solar flux can change, over a time scale of minutes, by several orders of magnitude. None of the detectors flown in recent space experiments were capable to deal with such high flux variability. They typically saturated at highest flux level and were insensitive for lowest fluxes. Multi-detector assemblies with sensors of different sensitivities can be employed to measure solar flux in its entire variability range.

Mechanical robustness - The instrument must withstand very strong vibrations and high acoustic shocks in wide frequency range during the rocket launch.

Data acquisition and telemetry – The telemetry quote is specific for each solar instrument and can range from few MB/day up to more than one GB/day. Depending on the spacecraft orbit and its visibility from the Earth by ground telemetry stations the data can be downloaded continuously or few times a day in a larger dumps. Therefore the instrument electronics should be capable of storing large data volume produced by detector in on-board memory storage.

Contamination – The detector performance can be decreased by contamination coming from different materials used for instrument construction (Figure 6). Therefore it is important to take care of selection of detector construction materials that not evaporate in vacuum and do not contaminate the entire satellite systems.

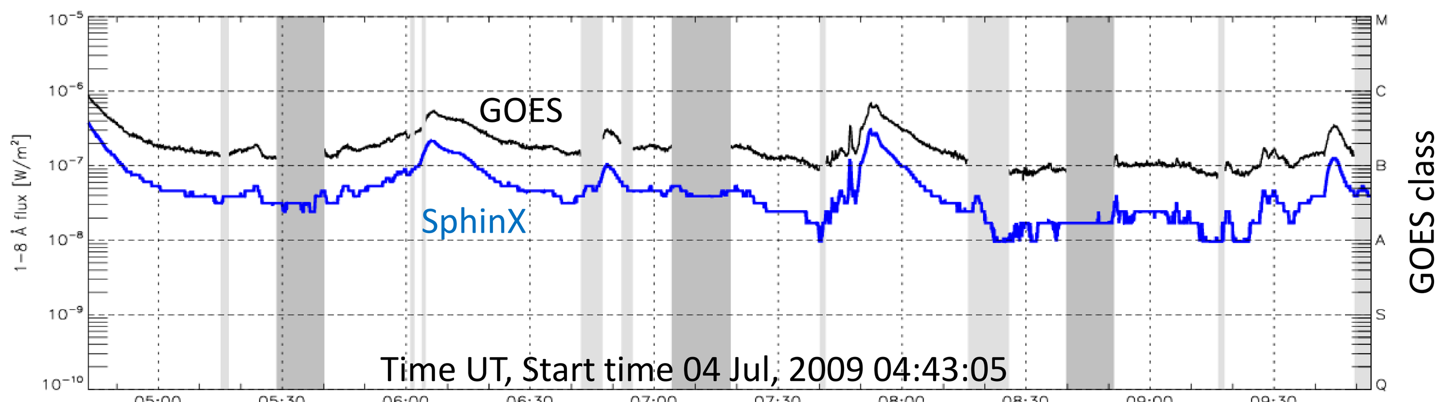

Figure 1. An example of photometric data recorded by SphinX (black) and GOES (blue).

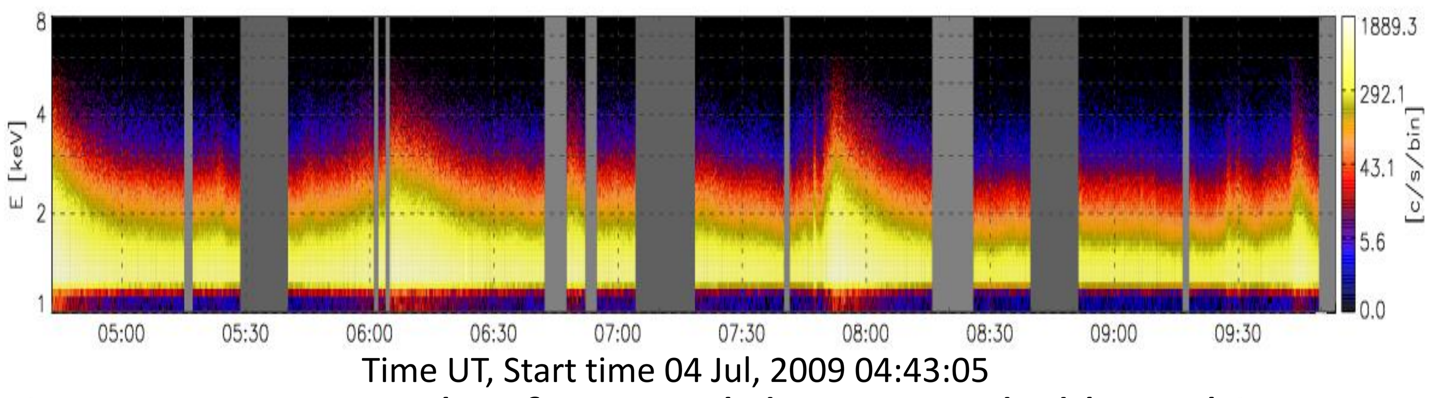

Figure 2. An example of spectral data recorded by SphinX.

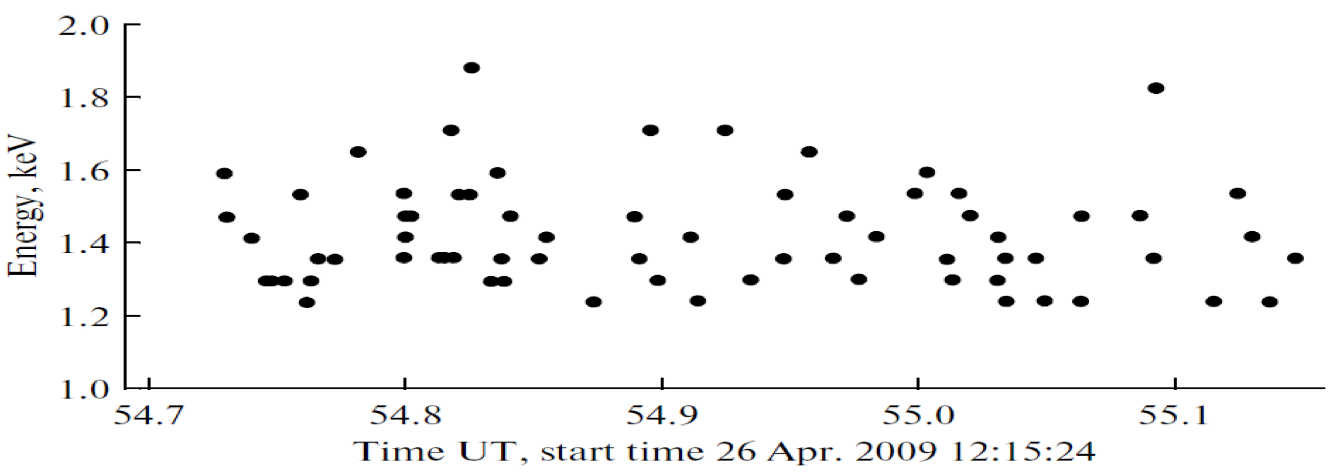

Figure 3. Left: An example of time stamping data recorded by SphinX.

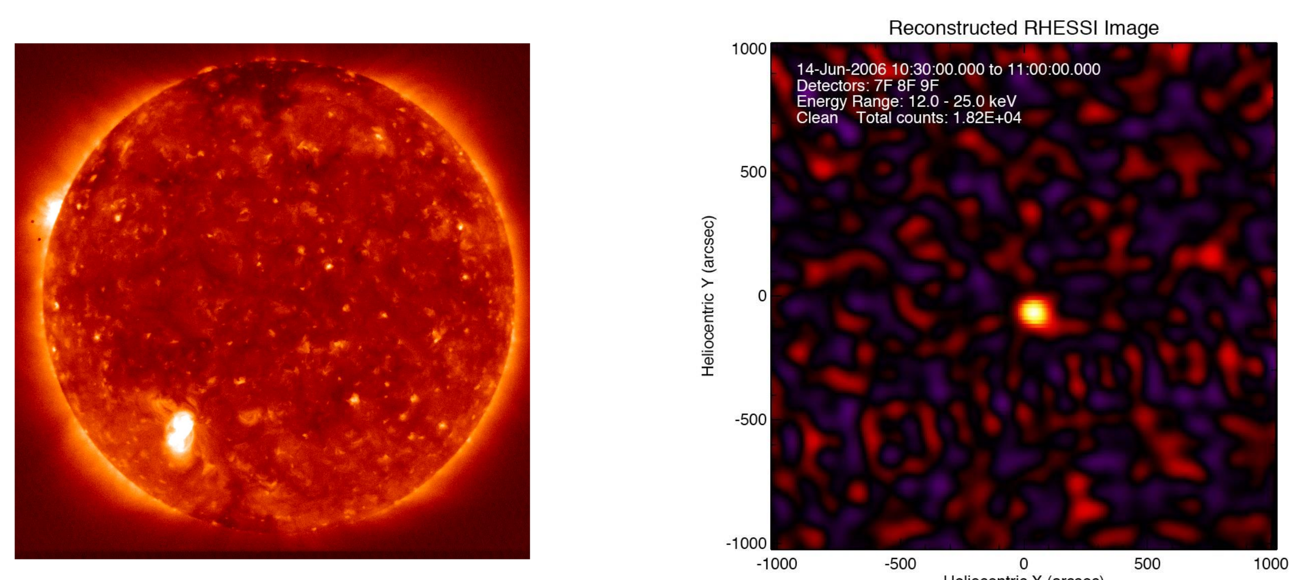

Figure 4. Left: an example of the Sun image in SXR recorded by XRT, right: an example of reconstructed image in HXR recorded by RHESSI.

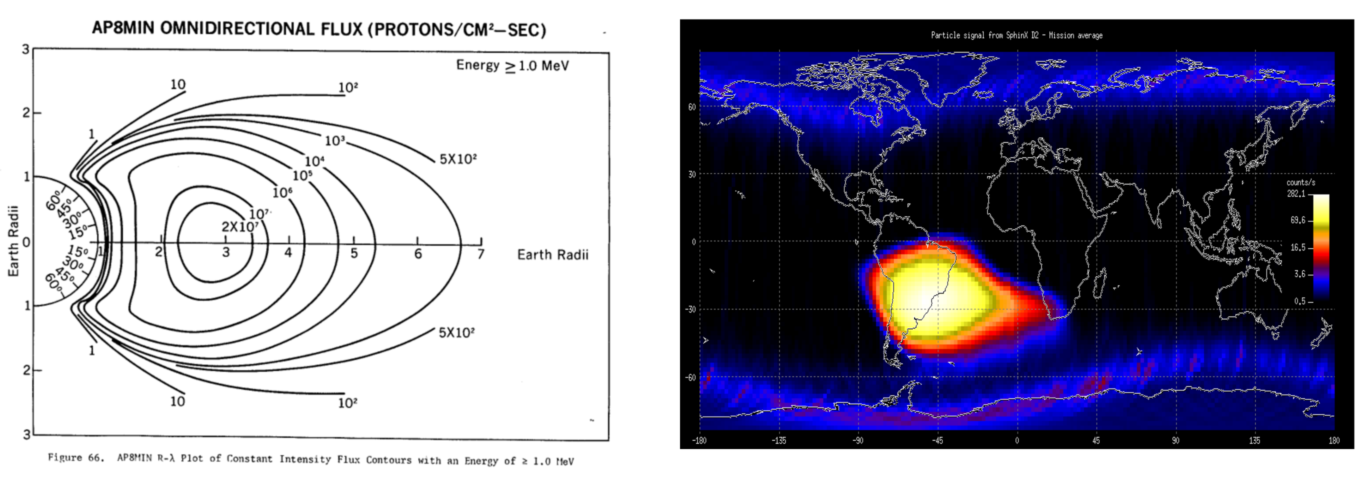

Figure 5. Left: proton flux intensity based on AP8MIN model, left: average particle count rate as seen by SphinX in 2009 during deep solar activity minimum.

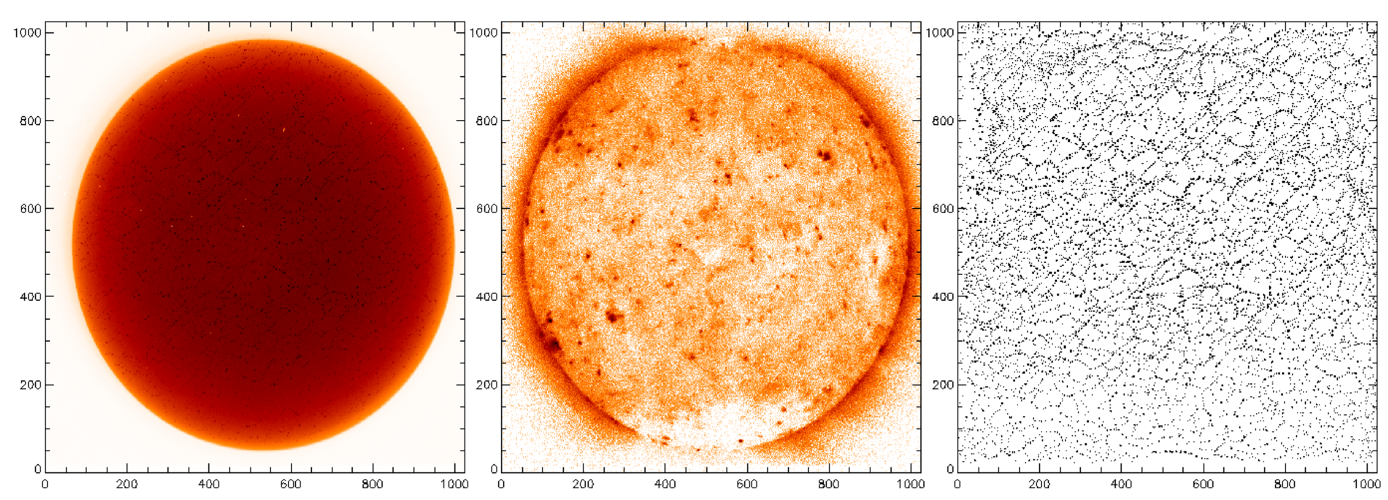

Figure 6. An example of XRT images - left: white light image - the contamination pattern is clearly seen, center: X-ray image - contamination pattern is invisible due to high dynamic range, right: extracted contamination pattern – common for both WL and X-ray images.