J. Astrophys. Astr. (2008) **29,** 339–343

SphinX: A Fast *S*olar *Ph*otometer *in X*-rays

J. Sylwester[1,*], S. Kuzin[2], Yu. D. Kotov[3], F. Farnik[4] & F. Reale[5]
[1] *Space Research Center, Polish Academy of Sciences, Kopernika 11, 51-622 Wroclaw, Poland.*
[2] *P. N. Lebedev Physical Institute, Leninskij prospekt 53, 119991 Moscow, Russia.*
[3] *Moscow Engineering Physics Institute, Kashirskoe Shosse 31, 115409 Moscow, Russia.*
[4] *Astronomical Institute, Czech Academy of Sciences, Fricova 298, 251 65 Ondrejov, Czech Republic.*
[5] *INAF/Observatorio Astronomico di Palermo and University of Palermo, Palazzo dei Normanni, I-90134 Palermo, Italy.*
* *e-mail: js@cbk.pan.wroc.pl*

Abstract. The scientific goals and construction details of a new design, Polish X-ray spectrophotometer are given. It will be incorporated within the Russian TESIS X and EUV complex aboard the forthcoming *CORONAS* solar mission. SphinX (**S**olar **Ph**otometer **in X**-rays) will use PIN silicon detectors for high time resolution (0.01 s) measurements of the solar spectra of quiet and active corona in the range 0.5–15 keV. A new filter-fluorescence target concept will be employed to allow for a fast photometry of the solar X-ray flux variations in selected, well defined narrow spectral bands including the Fe XXVI and Fe XXV iron line groups.

Key words. Sun: X-rays—spectrophotometer—high time resolution.

Measurements of the X-ray variability of the Sun are of basic importance for studies of the activity, flares and the space weather. The bulk of coronal thermal plasma of temperatures between 1 MK and 50 MK contributes to the emission in the soft X-ray band. Observations of the spectral variability in the range from 0.5 keV to 15 keV provide the basis for determinations of coronal average temperature, emission measure and related thermodynamic characteristics for non-active corona and flares in particular. For more than 30 years, *GOES* X-ray ion chambers observed the Sun in two spectral bands 0.5–4 Å and 1–8 Å (3–24 keV and 1.5–12 keV respectively). These continuous measurements constitute the reference database as concerns recent solar activity observations. However, they lack the information at both the low- and high-activity conditions (below A and above X10 class). The other active solar spectrometer presently in orbit (*RHESSI*) lacks sensitivity at the lower energy end, below 3 keV. At present low activity conditions, the X-ray signal measured by *GOES* and *RHESSI* does not show-up often above the background. It is of great importance to have a possibility of taking precise measurements of the solar variability in the soft X-ray range, also during periods of very low activity. Therefore, the Wrocław Solar Physics Division Team at the Space Research Centre developed a concept of sensitive spectrophotometer **SphinX**, similar to the Indian SOXS experiment (Jain *et al.* 2005). SphinX has recently been incorporated within the TESIS complex, a part of the *CORONAS* payload. The scientific objectives of this instrument are the following:

- Investigations of quiet corona heating processes via photon arrival time–distance analysis.
- Studies of soft X-ray oscillations in the period between 1 s and 500 s.
- Search for transient ionization plasma effects which may provide a tool for determination of flaring plasma densities.
- Determination of coronal plasma composition and its variability for the following elements: Mg, Al, Si, S, Ar, Ca and Fe.
- Determination of differential emission measure (DEM) and studies of its time variability.
- Establishment of soft X-ray reference photometric standard with 5% absolute and 1% relative accuracy.
- Proof of the novel narrow-band photometry (NBF) concept.

SphinX incorporates four PIN, pure silicon, 500 μm thick detectors (AMPTEK XR-100CR) equipped with Be 12.5 μm filters. Three of them with apertures of 19.6, 0.4 and 0.078 mm^2 measure the solar X-ray fluence from events of the *GOES* class as small as 100 times below A1 level, through typical very quiet conditions, i.e., A1 level (rate: 400 cts/s in the largest aperture) up to X40 (rate: 10^5 cts/s in the smallest aperture) over 256 energy bins. The dynamic range thus covers 7 orders of magnitude with the statistical accuracy better than 1% for activity conditions above *GOES* A5.0 level (c.f. Fig. 3). Individual photon arrival times are to be measured to within 1 μs and the spectra are to be taken up to 100 times per second where statistics allow. The detectors are mounted on a thermally isolated support linked through appropriate heat pipe to the external satellite heat radiator. The detectors are by themselves Peltier-cooled. The detectors' operational temperature is expected to be below -50°C. At these temperatures, the energy resolution of the PIN detector is well below 200 eV, allowing for the solar line groups of Mg, Al, Si, S, Ar, Ca and Fe to be distinguished above the continuum emission. The in-flight calibration of the detectors gain is achieved by a special system of the input aperture shutter (see **d** and **e** in Fig. 1). This system, by the command from the SphinX computer moves the shutter sideways, closing detectors' direct solar illumination channels and exposing them to *indirect* fluorescence illumination coming from the back side of thin input transmission filters made of different materials. These three materials are fluorescing at three, precisely known, well separated in energy, monochromatic wavelengths illuminating at the same time the three detectors. The amplitude positions of the individual peaks are being determined and the on-board computer makes appropriate gain corrections if necessary. The widths of the individual peaks contain information on the energy resolution of the detectors. Depending on the intensity of the solar illumination, a secondary, pile-up peaks can be resolved, creating thus a possibility to dynamically calibrate also this effect. The calibration sequences can be run any time, and depending on the level of the solar illumination causing the input filter fluorescence, the duration of the calibration will take any time down to few seconds. After the calibration, the shutter is moved to the original position, where a direct illumination of the detectors through their respective apertures is resumed. In such gain calibration solution, the detectors have always three energy-amplitude reference points available for calibration (to the accuracy of 5–7 eV) and no radioactive sources are to be used.

The fourth detector, also connected to the heat pipe, measures instantaneous narrow-band fluxes in three wavelength bands: 1.74–2.07 Å, 2.50–3.08 Å and 7.95–9.54 Å

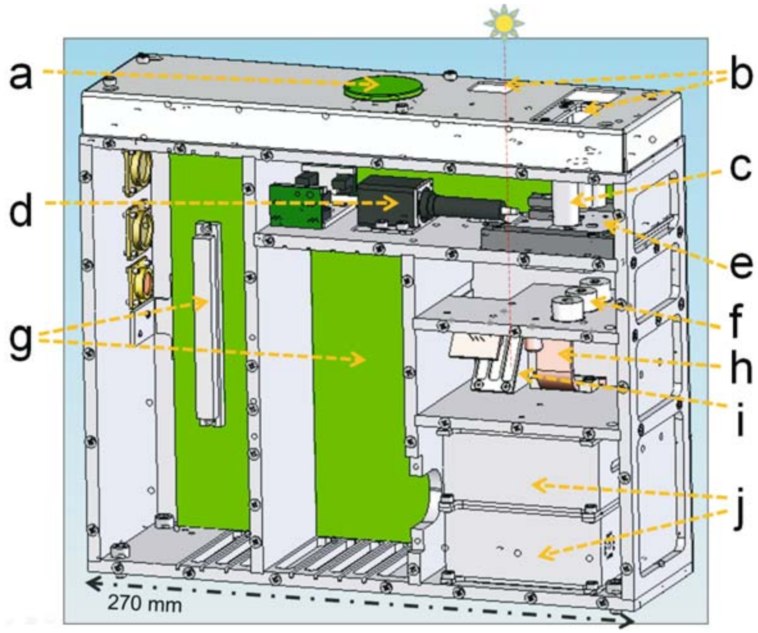

Figure 1. The design of SphinX with main components indicated: (a) alignment mirror, perpendicular to the Sun direction, (b) entrance openings covered with optical EUV stoppers – example solar ray is indicated, (c) mechanical collimators narrowing the detectors FOV to within $\pm 2.5^{\circ}$ of the Sun, (d) the shutter motor, (e) moving tray with the shutter and fluorescence calibration filters, (f) three spectrophotometric detectors, (g) electronics with microcontroller (h) cooling heat pipe, (i) three-narrow band filter-detector sections and (j) pre-amplifiers, independent for each detector. The horizontal extension is indicated at the bottom.

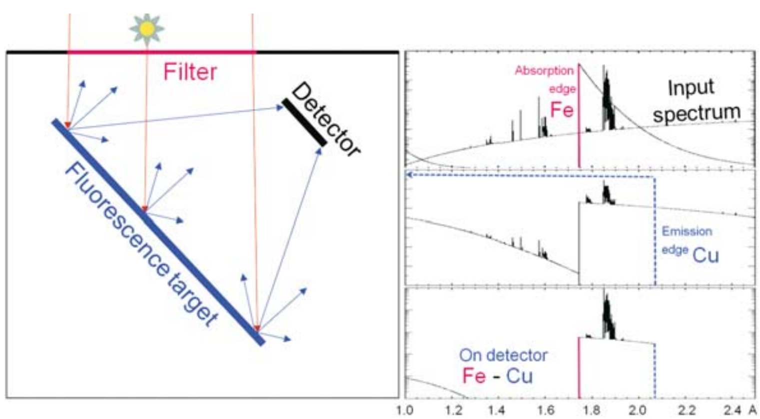

Figure 2. **(Left):** The concept of narrow band filter (NBF); **(right):** solar X-ray spectrum transmitted through the filter contains predominantly the radiation above the wavelength of specific absorption edge (middle panel). This illuminates the fluorescence target and only those wavelengths below the fluorescence excitation edge contribute to the scattered flux measured by the detector. In respect with, the system acts as the narrow-band filter with precisely defined, naturally sharp energy boundaries.

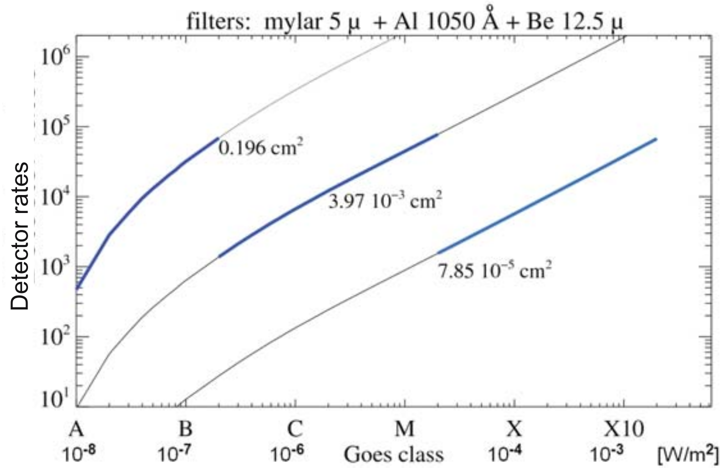

Figure 3. The expected count rates for SphinX detectors for the three apertures to be used. It is to be $\sim$ 400 cts/s at the low solar activity A1 (10^{-8} Wm^{-2}), through the largest aperture. The expected orbital background rate is $\sim$ 10 cts/s. The ranges of useful performance for each of the detectors are denoted by thicker portions on the curves. Even for events of *GOES* class X40 ($4\,10^{-3}$ Wm^{-2}), the signal will not be saturated on the smallest aperture detector.

up to hundred times per second using novel measurements concept presented in the right panel of Fig. 2. In this NBF concept, three fluorescing targets illuminate a single PIN detector. The fluorescence radiation is coming from three different pure element targets being illuminated through separate, individual selected input filters made of elements of slightly higher atomic number than their respective targets. Therefore, on the detector, the three emission peaks of different amplitudes are being instantaneously recorded. Their relative strengths depend on the shape of the solar incident spectrum in three narrow spectral bands and therefore are very sensitive to plasma temperature. We have selected the filter-target materials in order to record the portions of solar spectra containing strong emission lines of iron and magnesium. This will allow us to study transient effects, expected to be seen when emitting plasma conditions vary with time scales less than few seconds. The overall absolute calibration of the detectors has been performed using Berlin BESSY (www.bessy.de) synchrotron beams. The absolute calibration accuracy against the synchrotron beam is expected to be better than 5%. The synchrotron source has a spectrum similar to the solar one so we envisage SphinX to be the best calibrated soft X-ray spectrometer ever flown. In addition SphinX has been calibrated at several monochromatic wavelengths using the Palermo XACT facility (Barbera *et al.* 2006). The general SphinX characteristics are as follows: dimension – 270 × 70 × 220 mm, weight – 3.5 kg, power consumption – up to 15 W, 5 W average, overall data rate – more than 20 MB/24$^{\mathbf{h}}$, limited only by the on-board computer storage and telemetry resources. The instrument is equipped with its own microcomputer, reading out in-flight performance (detector temperatures, motor and shutter positions, voltages, etc.) and issuing various flare flags to its "mother" TESIS computer and to the other instrument aboard *CORONAS* satellite. Extended SphinX instrument paper is to be published in *Solar Physics* shortly.

Acknowledgements

The Polish Ministry of Education and Science grant 4 T12E 045 29 is acknowledged for financial support of the SphinX project which is being developed within the Polish Academy of Sciences and Russian Academy of Sciences bi-lateral agreement on co-operation in space research. Jarek Bąkała, Stefan Płocieniak, Marek Siarkowski and Witold Trzebiński took part in the instrument development and provided respective figures. We would like to thank the unknown referee for multiple comments which led to significant improvement of this paper.

References

Barbera, M., Candia, R., Collura, A., Di Cicca, G., Pelliciari, C., Sciortino, S., Varisco, S. 2006, *Proceedings of the SPIE*, **6266**, 62663F.

Jain, R., Dave, H., Shah, A. B., Vadher, N. M., Shah, V. M., Ubale, G. P., Manian, K. S. B., Solanki, C. M., Shah, K. J., Kumar, S., Kayasth, S. L., Patel, V. D., Trivedi, J. J., Deshpande M. R. 2005, *Solar Phys.*, **227**, 89.