Solar space-born instruments and detectors for X-ray observations of the solar corona.

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ABSTRACT: X-ray observations of the solar corona have been undertaken in Solar Physics Division of Space Research Centre of the Polish Academy of Sciences (SRC-PAS) in Wroclaw, Poland for more than four decades. A review of SRC-PAS satellite solar experiments and their measurements is shown with a particular focus on the latest ones. Various types of gaseous and solid state detectors used in space X-ray instrumentation are discussed. Possible applications of Micro Pattern Gaseous Detectors in further space experiments for solar X-ray observations are outlined.

BACKGORUND: Investigations of the solar radiation in short wavelengths began in the mid of 20th century. The first solar X-ray experiments were launched into space on sounding rockets. Today majority of solar space experiments are operating on satellite platforms. Sounding rockets are still in use however as test beds for new experimental concepts. List of mor important satellites for observation of the Sun in Extreme Ultraviolet (EUV) and X-rays is shown in Table 1. Orbits of selected solar satellites experiments are plotted in Figure 1.

Table1: Solar X-ray satellites that operated in the last two decades

SATELITE	RHESSI	CORONAS-Photon	KORONAS-F	KORONAS-I	SDO	PROBA2	TRACE	Yohkoh	Hinode	GOES 15	GOES-14	GOES-13	GOES-10	ISS
ID	27370	33504	26873	23019	36395	36037	25280	21694	29479	36411	35491	29155	24786	25544
Launch Date:	2002-02-05	2009-01-30	2001-07-31	1994-03-02	2010-02-11	2009-11-02	1998-04-02	1991-08-30	2006-09-22	2010-03-04	2009-06-27	2006-05-24	1997-04-25	1998-11-20
Mission end:	-	2009-12-01	2003-05	-	-	-	2010-06-21	-	-	-	-	-	2009-12-02	-
Launch Vehicle:	Pegasus XL	Tsiklon-3	Tsiklon-3	Tsiklon-3	Atlas V	Rokot	Pegasus XL	M-3SII	ISAS MV	Delta IV	Delta IV	Delta IV	Atlas-Centaur	Proton-K
Launch Site:	CC	PLR	PLR	PLR	CC	PLR	VAFB	USCJ	USCJ	CC	CC	CC	CC	Tyuratam
Mass [kg]:	230.0	1900	2260	2160	270.0		250.0	390.0	700.0	3,238	3,133		2109.0	31 100
Nominal Power [W]:	414.0				1540.0		200.0	200.0	500.0	2300	2300	2300.0	2105	
Funding Agency:	NASA	MEPHI	RSA	RSA	NASA	ESA	NASA	ISAS, NASA	ISAS, NASA	NASA	NOAA	NOAA	NOAA	RSA, NASA

MEPHI - Moscow Engineering Physics Institute (Russia), RSA - Russian Space Agency (Russia), ISAS - Institute of Space and Aeronautical Science, U of Tokyo (Japan), NASA - National Aeronautics and Space Administration (US), NOAA - National Oceanic and Atmospheric Administration (US), ESA - European Space Agency. CC - Cape Canaveral (US), PLR – Plesetsk (Russia), VAFB - Vandenberg AFB (US), USCJ - Uchinoura Space Center (Japan).

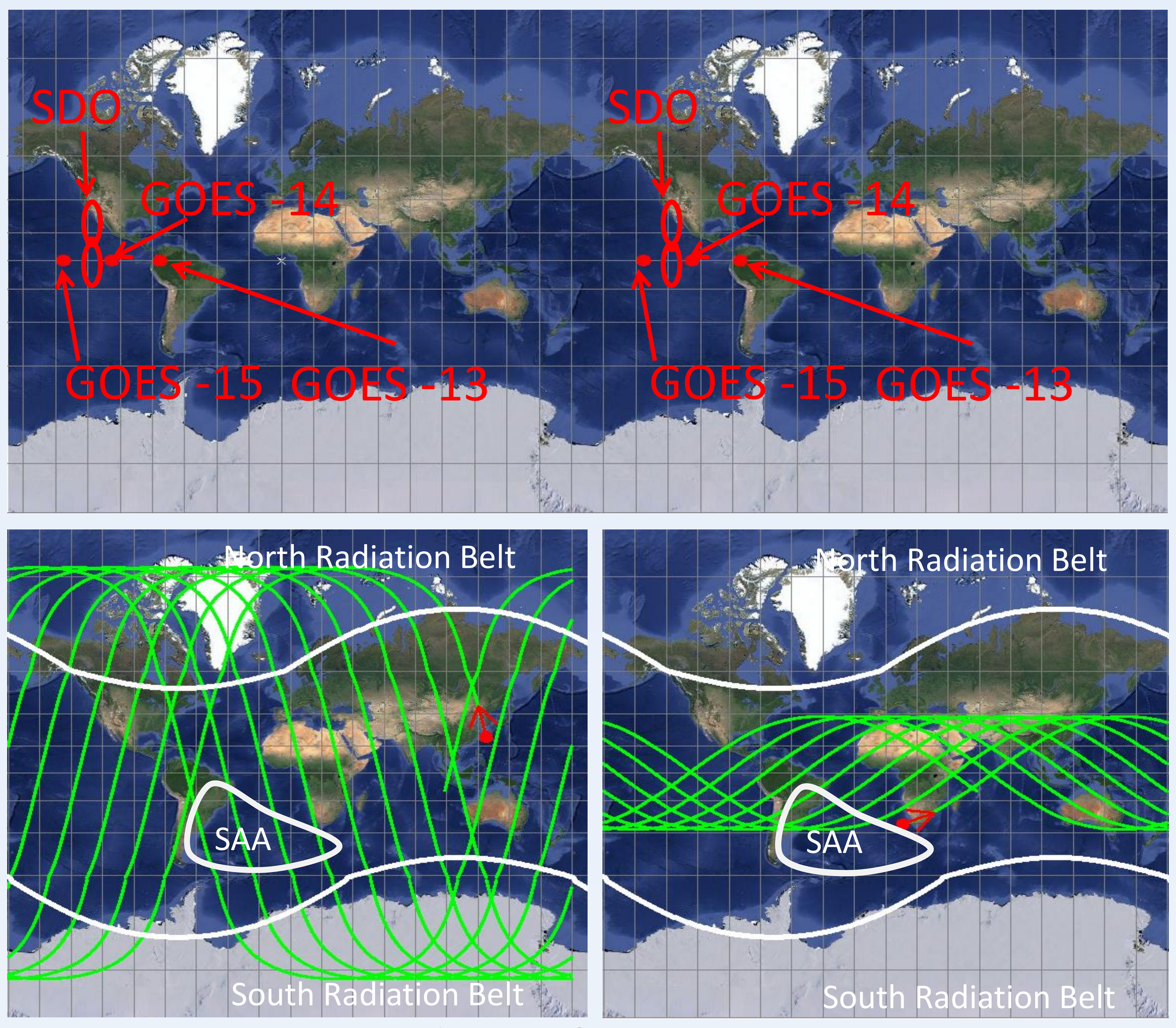

Figure 1. TOP: Orbits of SDO, GOES-15, GOES-14, GOES-13 satellites. Bottom-left: orbit of Hinode satellite. Bottom-right orbit of RHESSI spacecraft.

WHY STUDY THE SUN IN X-RAYS: Solar X-ray emission comes from the upper, ver hot (MK temperatures), layer of the Sun's atmosphere – the corona. The question why solar corona is so hot, in comparison to the solar surface (6000K), remains unanswered and is one of the most important questions in modern solar physics. Thus any X-ray solar data can be used in cutting edge science concerning coronal heating. Solar X-ray measurements are also very important in studies of trigering, evolution and spectorscopy (Figure 2)of solar flares - the most energetic events in the Solar System. Analysis of X-ray solar corona also allows for testing theories and improving models of soalr chemical composition, and plasma ionisation equlibriums.

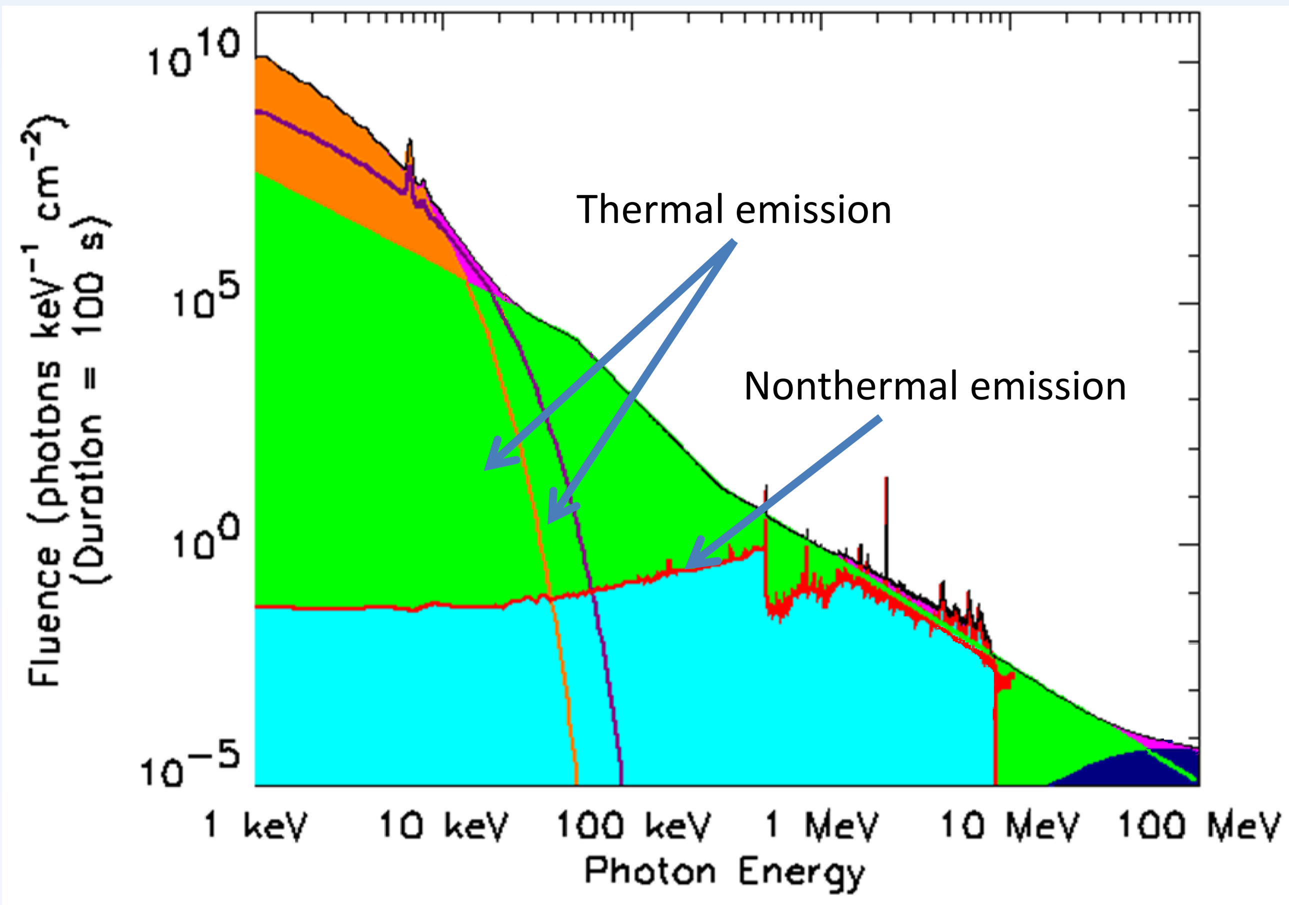

Figure 2. Composite solar flare spectrum.

Source: http://hesperia.gsfc.nasa.gov/rhessi2/home/mission/science/overview-of-solar-flares/

WROCLAW SOLAR X-RAY GROUP: The Wroclaw group was founded in 1970 and yet in 1970 first Polish space experiment took place. It was X-ray spectroheliograph with a set of pin-hole cameras launched on sounding rocket. Since that time the group activity has been focused on construction of the instrumentation providing the imaging and spectroscopy of the hot coronal plasmas. The scientific core of the group also is involved in analysis and interpretation of data obtained from experiments. Constructed in Wroclaw rocket and satellite payloads were mainly equipped with pin-hole cameras, telescopes, photometers, spectrometers and the collimators – all intended to take observations of the solar corona in the X-ray. Some of the more recent Wrocław experiments are shown in Figure 3, 4 and 5. Today the Wrocaw group constitutes one of the Divisions (Solar Physics) of Space Research Centre, Polish Academy of Sciences.

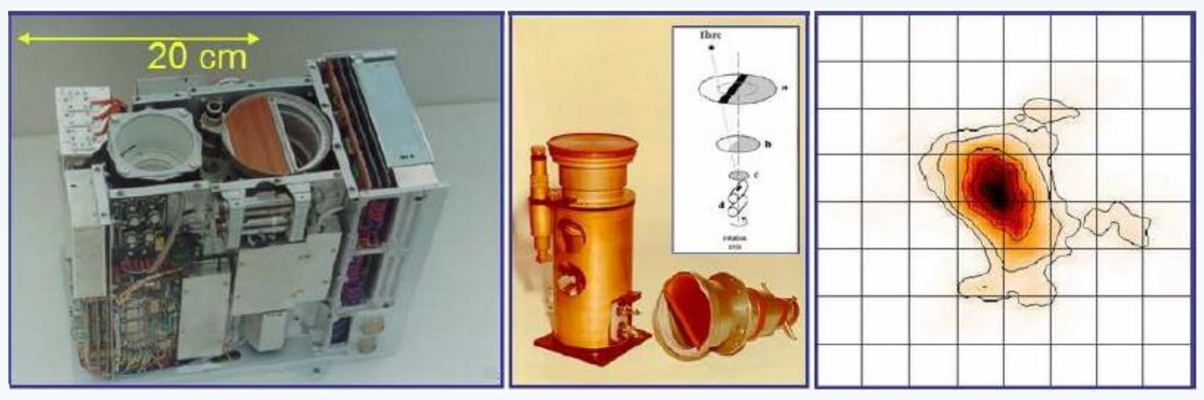

Figure 3: Left: RF15-I soft X-ray Photometer-Imager flown on INTERBALL-Tail mission. Center: Imager assembly of RF15-I, Right image obtained from RF15-I (grid is 50×50 arcsec).

SOLAR X-RAY INSTRUMENTS AND DETECTORS: Solar EUV and X-ray instruments can be roughly divided into the following types: **photometers, spectrometers, polarimeters, imagers**. Preferably the instruments for space mission should be light, compact in size, have low power consumption (~1W/kg) and could operate in large temperature range. In addition they should be mechanically robust to sustain severe launch conditions. Space-born instrumentation also should be capable of operating in harsh cosmic environment where it is exposed to different types of radiation including interactions with energetic particles, mainly electrons and protons.

Recent solar mission use mainly solid state detectors. GOES satellite are still operated using ion chambers. For imaging experiments usually detectors with spatial resolution are necessary. Exceptions to that are instruments based on tomography technique, such as RHESSI for instance, where detectors without spatial resolutions are used. Typically detector sensitive volume is made from silicon but CdTe and germanium detectors are also in use. Most of the sensors used are in space are CCDs and PIN-diodes. APSC sensor has been recently flown on PROBA2 mission. Silicon drift Detectors (SDDs) are considered for further experiments in Wroclaw group. Recently Wrocław team is also looking for detectors that could operate in soft/hard **X-ray energy range, have spatial resolution, distinguish photon signal from charged particle events, and could measure polarization. Recent state-ot-the-art MPGD detectors would be ideally suited for that purposes.**

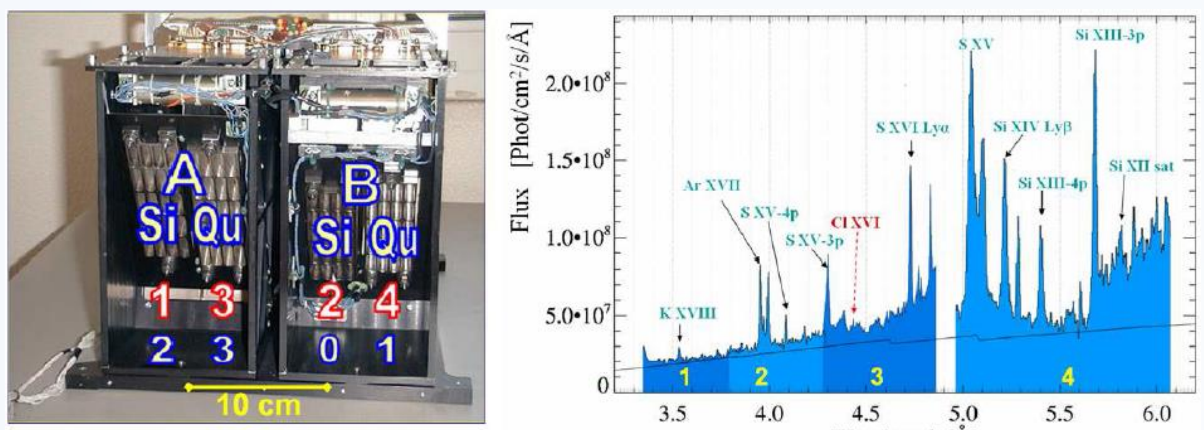

Figure 4: RESIK brag-cristal spectrometer flown on CORONAS-F satellite. Right: High resolution spectra from RESIK.

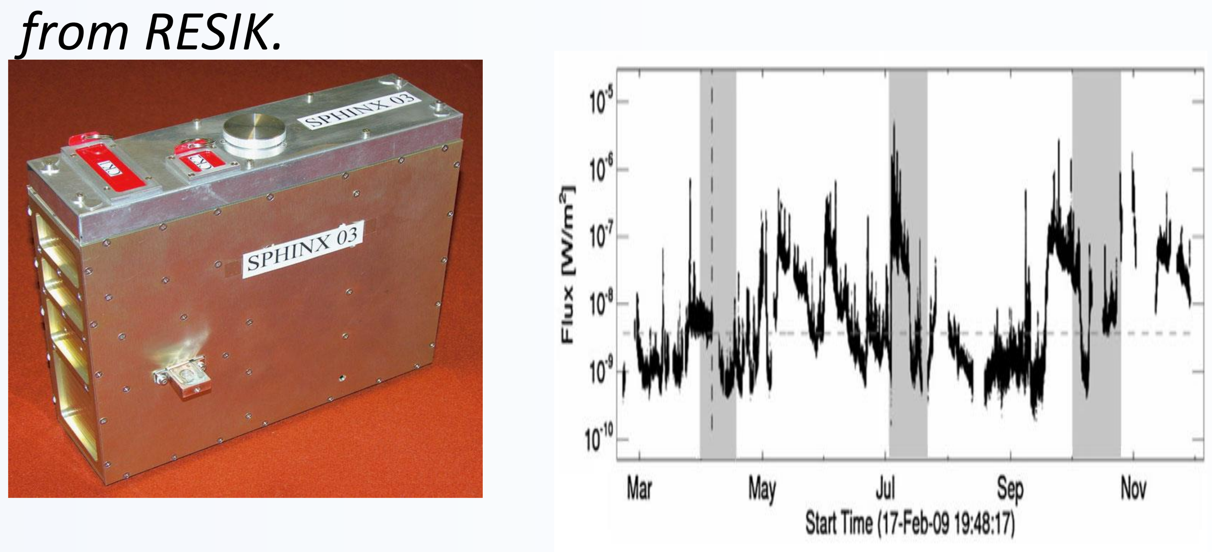

Figure 5: Solar Photometer in X-Rays SphinX. SphinX was launched on CORONAS-Photon satellite. Right: SphinX mission long lightcurve showing solar activity changes during deep minimum in 2009 .

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