# Comparison of Solar Activity During Last Two Minima on turn of Cycles Activity 22/23 and 23/24

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## ABSTRACT

The subject of our work is the review and comparison of solar activity during the last two solar minima that occurred between recent activity cycles. We use the soft X-ray global solar corona observations covering the two nine-months long time intervals in 1997/98 and 2009. Data from **RF15-I** instrument are used for the penultimate minimum. For the last unusually deep and prolonged solar activity minimum in 2009 the data from **SphinX** are used. Comparison of measurements from both experiments takes place in the overlapping energy range 2 - 15 keV. In particular we focus on the Active Region formation, evolution and flaring productivity during investigated minimum cycle phases. Summary plots, obtained from reduced observations of both X-ray instruments for the two last minima are presented.

## INSTRUMENTS DESCRIPTION

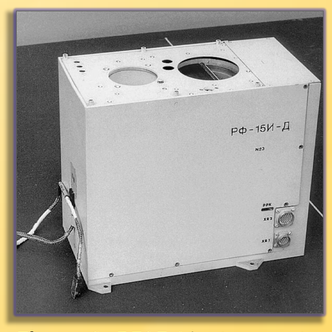


**Figure 1.** RF15-I instrument.

The **RF15-I** was soft and hard X-ray photometer-imager, which was a common project of Polish and Czech academic institutes. The instrument was launched in August 1995 onboard the Russian *INTERBALL-Tail* satellite and operated continuously till October 2000. The RF15-I performed measurements of the global solar X-ray flux using two detectors. The proportional detector nominally measured the soft X-ray solar emission in the three energy channels: 2-3 keV, 3-5 keV and 5-8 keV with 2 seconds time resolution. The scintillation detector, NaI(Tl), measured hard X-ray fluxes in five channels: 10-15-30-60-120-240 keV. In the first hard channel (h1: 10-15 keV) the data were collected simultaneously with the softer channels (each 2 seconds). In the higher energy channels (h2-h5) the data were collected every 0.125 s. if only the threshold was exceeded.


**Figure 2.** SphinX instrument.

The **SphinX** was the Polish X-ray spectrophotometer for measuring soft X-ray emission from entire solar disc in energy range between 1.2 and 15 keV. SphinX operated from February to November 2009 aboard the *CORONAS-Photon* satellite, which was launched on 30 January 2009. SphinX instrument used of four silicon PIN detectors (D1, D2, D3, D4) equipped with thin 12.7 micron thick Be entrance filters. Detectors D1, D2, D3 were designed for solar X-ray spectroscopic and photometric observations. The fourth SphinX detector D4 was used for fluorescence measurements. Such detector/aperture system was capable of measuring solar X-ray flux for coronal activity levels corresponding to the GOES class as small as 100 times below A1.0 level, through typical quiet conditions, active region emission and flares up to GOES X30 class.

## TIMES INTERVALS OF ANALYSED DATA

Two 281-days long time periods were selected for the present analysis. Both periods cover similar parts of two consecutive solar cycles minima of activity and their start times were found as equidistant to start times of respective solar cycles. The first time interval covered by RF15-I measurements consist of data from 02 July 1997 to 10 April 1998 while the second period of SphinX measurements extends from 20 February 2009 until 29 November 2009. This represents duration of active life of *CORONAS-Photon* satellite mission.

Below there are context plots (**Figure 3.**) of GOES 1-8 Å solar flux and sunspot number data showing the position of selected measurement periods within the activity cycles (see the ranges between vertical solid lines). Dashed lines indicate starts times of the 23$^{th}$ and 24$^{th}$ activity cycles.

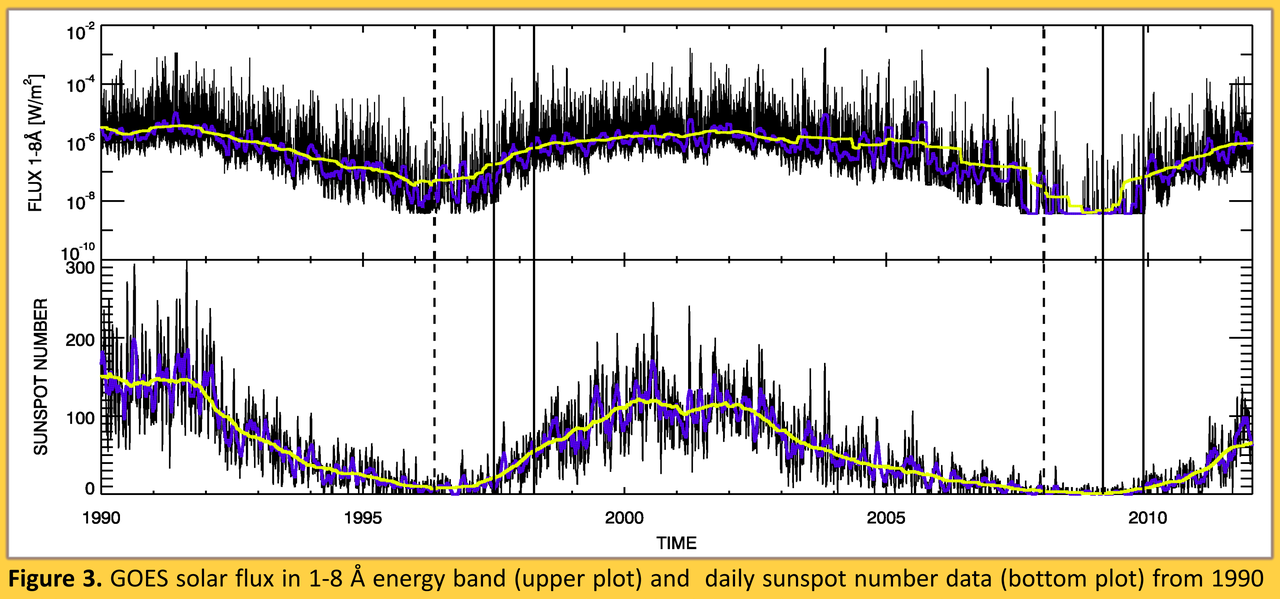


**Figure 3.** GOES solar flux in 1-8 Å energy band (upper plot) and daily sunspot number data (bottom plot) from 1990 to 2012. Monthly and yearly smoothed data are overplotted in violet and yelow respectively.

## RF15-I and SPHINX OBSERVATIONS

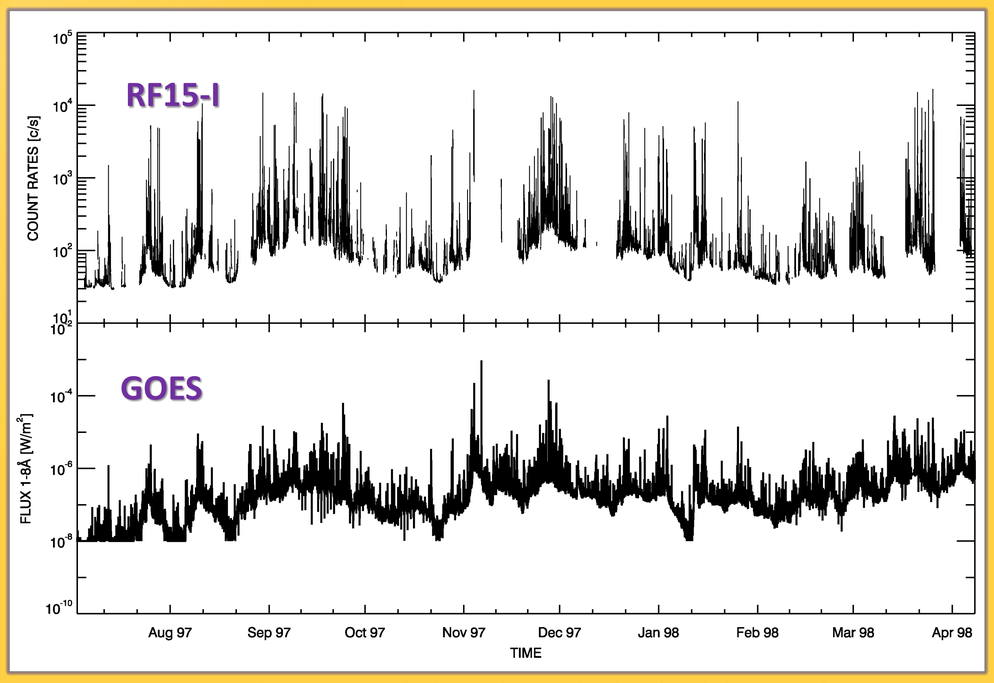


**Figure 4.** Count rates observed in soft channels and the first hard channel of RF15-I X-ray spectrometer during period from 02 July 1997 to 10 April 1998. Corresponding flux in 1-8Å range observed by GOES is shown below.

Presented light curves (**Figures 4.** and **5.**, upper plots) for RF15-I and SphinX were obtained by integrating over energy ranges 2-8 and 10-15 keV (i.e. overlapping energy ranges of the two instruments).

For the comparison, the solar flux observed by GOES in energy range 1-8Å during analysed time periods are shown as the bottom plots in **Figures 4.** and **5.** A very good qualitative agreement is evident in both cases. For the second time interval it is seen that the high SphinX sensitivity allowed for reliable measurements much below GOES detection threshold.

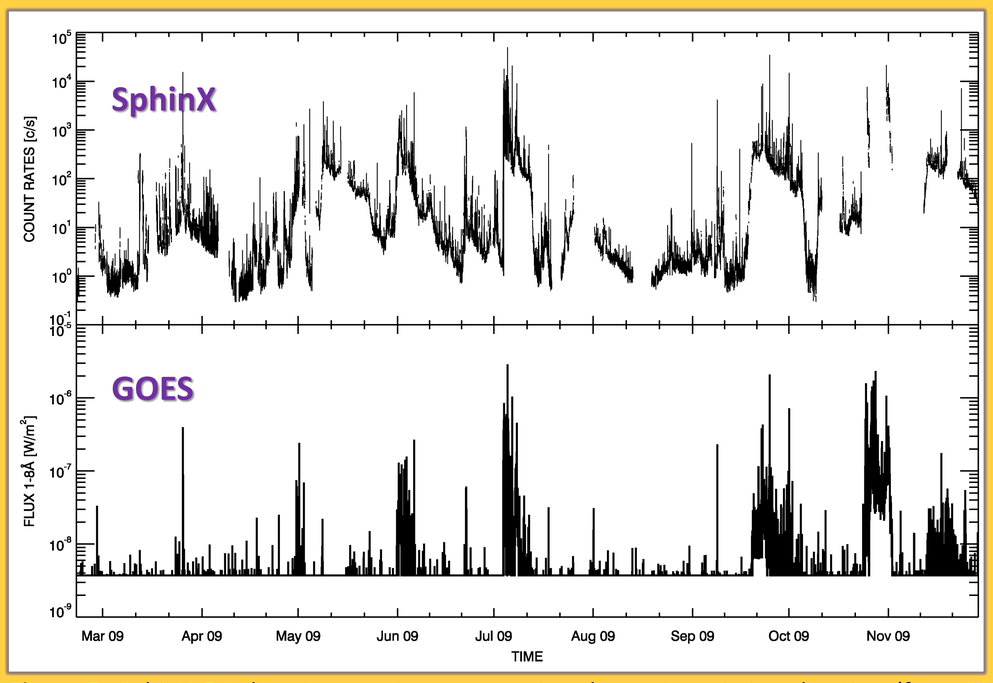


**Figure 5.** SphinX D1 detector count rates covering the entire mission duration (from 20 February to 29 November 2009) and the corresponding flux in 1-8Å range observed by GOES.

## ACTIVE REGIONS TRAJECTORIES

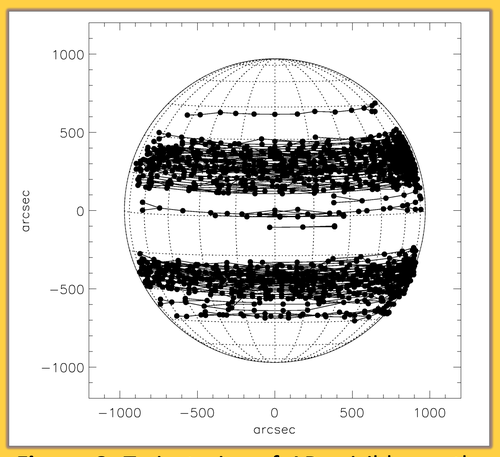


**Figure 6.** Trajectories of ARs visible on the solar disc from 02 July 1997 to 10 April 1998.

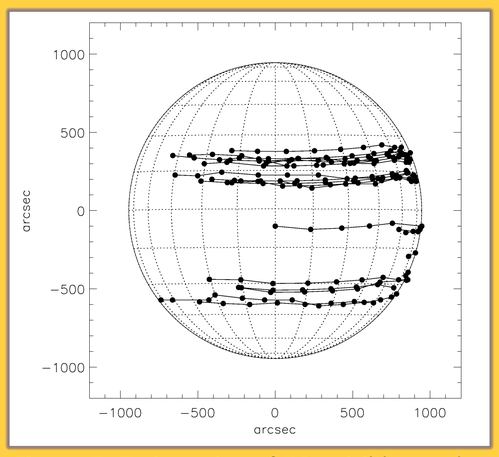


**Figure 7.** Trajectories of ARs visible on the solar disc from 20 February 2009 to 29 November 2009.

**Figures 6.** and **7.** show Active Regions trajectories on the visible solar hemisphere during analysed times periods. Times of regions emergence on solar disc were taken from Joint USAF/NOAA Solar Region Summary reports available at the website www.swpc.noaa.gov/ ftpmenu/warehouse.html.

There were 150 ARs reported for nine-month period between 02 July 1997 and 10 April 1998. For the second time period the Report quote 22 Active Regions only. This indicates that the recent activity minimum was substantially deeper than the previous.

## COMPARISON OF SOLAR CYCLES MINIMA 22/23 and 23/24

The Sun atmosphere displayed different conditions during analysed periods. In **Table 1.** we present comparison of magnetic activity features for both analysed time intervals on turn of solar cycles of activity 22/23 and 23/24. The recent minimum 23/24 turned out to be unusual quiet with a very small number of activity signatures.

| | **Minimum 22/23** 02 July 997 – 10 April 1998 | **Minimum 23/24** 20 February 2009 – 29 November 2009 |
|---|---|---|
| Number of spotless days | 16 | 210 |
| Number of flares over B1.0 GOES flares class | 1465 | 131 |
| Number of ARs on solar disc | 150 | 22 |

**Table 1.** Comparison of solar activity features for two analysed times intervals.

## PLANS

RF15-I and SphinX instruments provided X-ray spectrophotometry of solar corona during periods of the last two minima of activity. Despite a very low level of magnetic activity our instruments recorded a large number of events, much more than seen on GOES records. Our goal is preparation of the catalogue of individual events. The catalogue will contain set of information characterizing particular flares, like start, maximum and end times as well as the event amplitude, T end EM. Such database will be used in further statistical analysis of flare occurence rates for solar cycle minima.

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