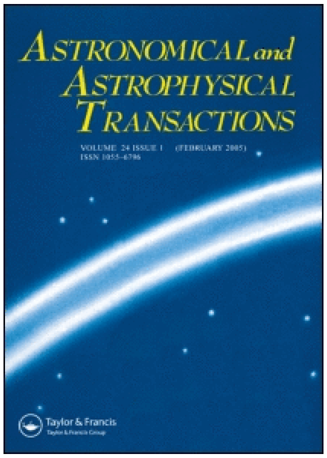

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I. Sattarov [a]; A. S. Hojaev [a]; C. T. Sherdonov [a]; O. V. Ladenkov [a]
[a] Ulugh Beg Astronomical Institute of Uzbek Academy of Sciences, Tashkent, Uzbekistan

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RELATION OF THE X-RAY BRIGHT POINT NUMBER TO THE X-RAY BACKGROUND ON THE SUN

I. SATTAROV, A. S. HOJAEV, C. T. SHERDONOV, and O. V. LADENKOV

Ulugh Beg Astronomical Institute of Uzbek Academy of Sciences, Astronomicheskaya, 33, Tashkent, 700052, Uzbekistan

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The relation of the X-ray bright point number to the intensity of X-ray background is studied on the basis of satellite observations. The daily X-ray bright point number for the time interval 1991-1999 was inferred from YOHKOH Soft X-ray telescope data. It was found that the X-ray bright point number is indeed anti-correlated with the solar activity indices as was found from SKYLAB data a little earlier. At the same time the X-ray bright point number is anti-correlated with the intensity of the X-ray background from GOES data. The high degree of anti-correlation of the number of XBPs with the X-ray background data inspires the assumption that the number of XBPs slightly alters during the solar cycle. It was shown that the maximum number of XBPs strongly depends on the X-ray background level: the lower the level, the greater the number.

KEY WORDS Sun – X-ray, Sun – bright points, solar activity

1 INTRODUCTION

Point-like X-ray emitting features were firstly observed on the rocket X-ray telescope image scans in 1969 (Vaiana *et al.*, 1970). Typically they appear as spots of 30″ diameter with a 5″-10″ bright core associated with small bipolar magnetic features and are found at essentially all solar latitudes (Krieger *et al.*, 1971). Preliminary analysis of photographs from the S-054 X-ray telescope aboard Skylab has shown that the X-ray bright points (XBPs) have a statistical distribution of lifetimes with a mean of eight hours (Golub *et al.*, 1974). The number of XBPs that live 2–48 hours is at least ten times greater than the number of those living more than 48 hours. Features with a lifetime of two days or less have a very broad latitude distribution whereas nearly all longer lived features are found within ±30° of the equator (Golub *et al.*, 1976). XBPs are usually identified as small, short-lived and rapidly evolving bipolar magnetic features (Harvey *et al.*, 1975).

Davis *et al.* (1977) and Golub *et al.* (1979) have shown that the frequency of occurrence of coronal bright points, namely XBPs, is periodic and varies out of phase with the sunspot number. The phase difference is close to 180°, i.e. these two quantities appear to be anti-correlated. This result was based upon X-ray observations made during the Skylab mission as well as during six sounding rocket flights covering the period 1970–78. Later on the observations were supplemented by data obtained during two flights in 1978 and 1981. Newly obtained data are consistent with the above-mentioned conclusion (Davis, 1983). These results were interpreted as an oscillator in wavenumber space with relatively small variations in the average total rate of flux emergence (Golub *et al.*, 1979). On the one hand, the observational data, on the base of which the result was found, were obtained by different telescopes and, on the other, the data have abruptness in the range. It seems that the XBP relation to the solar activity should be studied on the basis of homogeneous long scale range (about one solar activity cycle) data obtained with the same telescope, such as the YOHKOH soft X-ray telescope which was launched in 1991 and is operating still. Since 1993 the YOHKOH data have been accessible to the scientific community. Our study is based on the YOHKOH data. What problems are there with XBPs, to our mind? Foremost at present, the place and significance of XBPs in the solar activity isn't clearly known. Is there really an anti-correlation between the XBPs and sunspot numbers? Golub *et al.* (1979) concluded that the inverse correlation of the XBP number with the sunspot number is not attributable to 'visibility' effects. Below the results of our study of the relation of the YOHKOH XBP number to other solar activity indices is presented. The 'visibility' effects are discussed.

2 DATA AND ANALYSES

On the daily soft X-ray images from YOHKOH published in the Solar-Geophysical Data (SGD Prompt Report for 1993–1998) we have counted the number of XBPs for the time interval from January 1993 until December 1998. This interval covers descending and ascending phases of solar activity with a minimum of activity in the middle of this interval. It is a very suitable interval for the statistical study of XBPs and their relation to the different solar activity indices, when there are a few active regions and a lot of XBPs on the Sun.

We have used the smoothing utilities and the correlational analysis method given in the IDL 4.0.1 software (see description of the method, for instance, in Neter *et al.*, 1988)

For the correlational analysis of the number of XBPs we used the international relative sunspot numbers (RSN from the SGD) as was done earlier by other authors (Golub *et al.*, 1979); Davis (1984).

It is known that the sunspot is located on solar surface but XBPs are observed in the solar corona, i.e. sunspots and XBPs belong to different layers of the solar atmosphere with different physical conditions. Both sunspots and XBPs have a magnetic nature but they display different magnetic phenomena. So we have used also preliminary GOES satellite Daily X-ray Background data, which means the X-

Table 1. Correlation parameters for data of the 22–23rd cycles.

Correlated data	*Coefficients of correlation*		
	All data	*1st half*	*2nd half*
XBPs/X-ray background	−0.82	−0.77	−0.93
XBPs/Wolf's number	−0.76	−0.69	−0.85
X-ray background/Wolf's number	0.91	0.93	0.91

ray flux in Wm^{-2} (SGD, Comprehensive Reports, 1993–1998) for the correlational analysis. These data have shown 11-year variations in the sunspots number.

Both the daily background data and the daily XBP numbers are hard fluctuating temporal sequences. So we smoothed the data over a 30 day period. The smoothed sunspot, XBP numbers and background data are reproduced in Figure 1. As one can see in Figure 1 there is a high degree of correlation between the sunspot numbers and background data. The coefficient of the correlation between them is equal to 0.91 (see Table 1). Both the sunspot numbers and background data are anti-correlated with the number of XBPs. Thus the anti-correlation coefficient between the number of XBPs and background data (0.82) is more than that of between the number of XBPs and sunspots (0.76). Such a coefficient for the ascending (1996–1998) phase of the solar cycle is a bit larger (0.93) than for the descending (1991–1996) phase (0.77).

The X-ray radiation of the Sun is of special interest near the minimum of the solar activity. At the minimum the background data drop to their minimal value (10^{-8} Wm^{-2}) and the number of XBPs achieves its maximal value ($\sim$ 40). The time interval between June 1995 and April 1997 is characterized (see Figure 1) by a great number of XBPs. For this interval the coefficient is equal to 0.78.

3 DISCUSSION AND CONCLUSIONS

The coefficient of anti-correlation between the XBP number and the background data is more than that of between the number of XBPs and RSN. If the number of XBPs is related with the solar activity it has to be connected with the activity of the X-ray component. Indeed, in Figure 1 one can see that within the time interval from July 1995 (near the 900th day in Figure 1) to August 1997 (near the 1700th day in Figure 1), which involves the activity minimum, the number of XBPs is twice that outside this interval. During this period the background data on average are more than 10 times smaller than outside it. On passing from the boundary of the interval to both sides the level of the background at first quickly increases but soon slows. The number of XBPs shows the same behaviour as the background data but with opposite sign. Contrary to the variation of the background data by 10 times which took place in March 1994 (near the 400th day in Figure 1), the variation of number of XBPs is by about 1.1 times only. Therefore variations of the X-ray

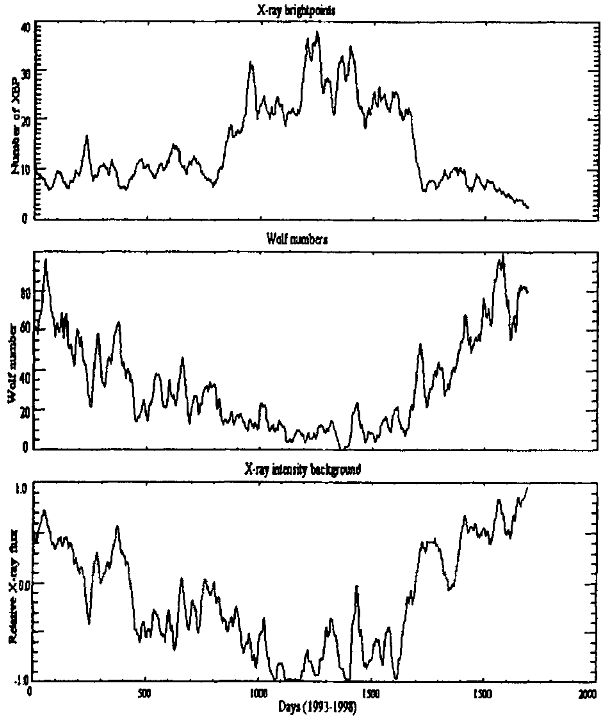

Figure 1 Plots of the smoothed X-ray intensity background, Wolf's and XBPs numbers from top to bottom, respectively.

background have no effect on the number of XBPs. It seems that the background variations change the conditions of the XBP visibility. The number of weak XBPs which were observed at the background fluxes near 10^{-8} Wm^{-2} is 2.5 times greater than that observed during higher fluxes (near 5×10^{-7} Wm^{-2}). Good visibility of XBPs occurred for fluxes $\leq 10^{-8}$ Wm^{-2}.

A high degree of anti-correlation of the XBP number with the X-ray background data, which means the existence of a dependence between the number of XBPs and this background level, probably suggests that the number of XBPs alters within a small range along the solar cycle. The visibility of XBPs varies as the X-ray background changes. The maximum number of XBPs is observed for an X-ray background flux $\leq 10^{-8}$ Wm^{-2}. We will continue investigation of the nature of the XBPs.

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