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THREE SOLAR GAMMA-RAY FLARES OBSERVED BY YOHKOH IN AUTUMN OF 1991

M. A. Mosalam Shaltout

National Research Institute of Astronomy and Geophysics,
Helwan - Cairo - Egypt
E-mail: mamshaltout@frcu.eun.eg

ABSTRACT

The Japanese mission Yohkoh (sun-beam) observed three solar gamma-ray flares of October, November and December 1991, on the declining phase of solar cycle 22. Each flare has different spectral characteristics, strong narrow line flare, broad line flare and continuum gamma-ray flare.

The solar gamma-ray flares of October, November and December 1991 are produced from the three solar active regions NOAA/USAF 6891, 6919 and 6952 respectively. The aim of the present work is to study the general characteristics of these three active regions, and perform an evolution for the sunspots and their magnetic fields which lead to releasing highly energetic impulsive flares associated with gamma-ray emissions.

The method of cumulative summation curves for X-ray bursts and Hα flares produced from the active regions and also, cumulative summation curves for sunspots area and count number for the same active regions are applied to show any steep increase in the trend in the curves for few days prior to the γ-ray flare occurrences.

INTRODUCTION

The Yohkoh is designed to answer many questions in solar flares and coronal physics that have been raised by the highly successful Hinotori and SMM missions. The Yohkoh gamma-ray spectrometer consists of two identical BGO scintillators of 3" in diameter and 2" in thickness, and a 128-channel pulse height spectrum in the 0.3-13 MeV band is observed every 4 seconds (Yoshimori, 1991a).

Yohkoh observed solar gamma-ray flares on October 27, November 15 and December 3, 1991 on the declining phase of solar cycle 22. The October 27 flare (X 6.1/3B, S 13, E 15) was observed from 05:40 to 05:42 UT, and showed an impulsive temporal variation of gamma-ray emission. The November 15 flare (X 1.5/3B, S 13, W 19) was observed from 22:35 to 22:39 UT, and its time profile of gamma-ray emission was impulsive. The December 3 flare (X 2.2/2B, N 17, E 72) was observed from 16:35 to 16:38 UT. The gamma-ray count rate time profile was impulsive (Yoshimori, 1991b).

WORLD-WIDE OBSERVATIONS

According to "Solar Geophysical Data" provided by WDC-A for Solar-Terrestrial Physics, NOAA, Boulder, Colorado, USA, the active region NOAA/USAF 6891 produced two proton flares. The proton flux for energy > 10 MeV for the first one, 27 October γ-ray flare, was 40 pfu. The second proton flare occurred at 30 October without γ -ray emissions.

The other two active regions NOAA/USAF 6919 and 6952 did not produe protons associated with γ -ray flares of 15 November and 3 December (protons of energies > 10 MeV).

The gamma-ray flare of 27 October was associated with a microwave great burst of peak flux 3800 sfu on 10 cm wavelength, and also type II and IV Radio bursts were observed with mass ejection from the sun after gamma-ray flare occurrence. An Hα flare associated with the γ -ray flare contained two or more brilliant points, and several eruptive centers, and the flare was accompanied by a high-speed dark filament. Cosmic Ray Indices (Neutron Monitor) showed a decrease starting from 28 October 1991 at the stations Thule, Deep River, Kiel and Tokyo.

The gamma-ray flare of 15 November was associated with microwave great burst of peak flux 1000 sfu on 10 cm wavelength, and also type II radio burst was observed with mass ejection from the Sun. But no decrease in Cosmic-Ray Indices. An Hα flare associated with this gamma-ray flare, had several eruptive centers, and the flare was accompanied by a high-speed dark filament.

The gamma-ray flare of 3 December 1991 was associated with an Hα flare and several eruptive centers. The flare was associated with a microwave great burst of peak flux 1200 sfu on 10 cm wavelength. Radio bursts of type II and IV are not observed as associated phenomena with the γ -ray burst and no mass ejection from the sun was recorded.

DATA TREATMENT

The data used have been obtained from "Solar Geophysical Data" prompt and comprehensive reports of October, November and December 1991, published by NOAA, Boulder, Colorado, USA.

One of the methods for forecasting the highly energetic solar proton flares is the method of Cumulative Summation Curves (Krivsky, 1975). For this purpose we defined the following:

1. The flare parameter ΣF represents solar flares inclusive of the sub-flares observed in H-α in the world stations network "Solar-Geophysical Data", defined by the Cumulative Summation of the area of solar flares in millionths of the solar disk (MSD) which occurred in the investigated active region.

2. The X-ray burst parameter ΣX represents the Cumulative Summation of peak flux of the X-ray bursts in the 1-8 A° band in Wm^{-2} released in the investigated active region, as observed by the GOES Satellite (Solar-Geophysical Data).

3. The sunspot area parameter ΣA, is defined as the Cumulative Summation of the sunspot area of the active region in millionths of the solar hemisphere (MSH).

4. The sunspot count parameter ΣC, is defined as the Cumulative Summation of the sunspot count of the active region.

RESULTS AND DISCUSSION

The declining phase of the solar cycle 22 at 1991 showed abnormal activity, so we can conclude that 1991 is the second maximum of the cycle 22, where the first maximum is 1989. During March, June, October, November and December 1991, highly energetic solar flares are released, accompanied by gamma-ray emissions observed by the Japanese Mission Yohkoh, and the Compton Gamma-ray Observatory of NASA, USA.

Figure 1 shows the cumulative summation curves of F, X, A and C for the active region NOAA/USAF 6891, where the gamma-ray flare of 27 October 1991 was released from this region. All the curves show a steep increase prior to the γ -ray flare by three days, i.e. at 24 October. Therefore, this method can be used to predict a proton flare of gamma-ray emissions by few days. At 27 October, the sunspot group of the active region had modified Zurich class F. The maximum magnetic field strength is between 2600 and 3000 Gauss, with magnetic class BGD. The longitude extent for the sunspot group was 26°.

Figure 2 shows the cumulative summation curves of F, X, A and C for the active region NOAA/USAF 6919, where the gamma-ray flare of 15 November 1991 was released from this region. The X and F curves showed steep increase at 10 November, then increasing slowly to 15 November, the day of flare releasing. But A show continuous steep increase from 9 November till 15 November, the day of releasing the flare. Also C show steep increase from 13 November i.e. two days before the day of flare releasing. At 15 November 1991, the sunspots group of this active region had the modified Zurich class F. The Maximum magnetic field strength was between 2100 and 2500 Gauss, with magnetic class BG. The longitude extent for the sunspot group was 22°.

Figure 3 shows the cumulative summation curves for F and X for the active region NOAA/USAF 6952, where the gamma-ray flare of 3 December 1991 was released from this region. The flare was released after short time from the appearance of the active region on the eastern limb of the solar disk - for that - the method of cumulative summation can not be used. But we can see continuous increase in F and X from 2 to 8 December, then the activity became low after crossing the solar meridian.

CONCLUSION

The cumulative summation curves method can be used to predict the γ-ray flares for few days prior to their occurrence, as we used before for solar proton flare prediction (Shaltout, 1989, 1991and 1995).

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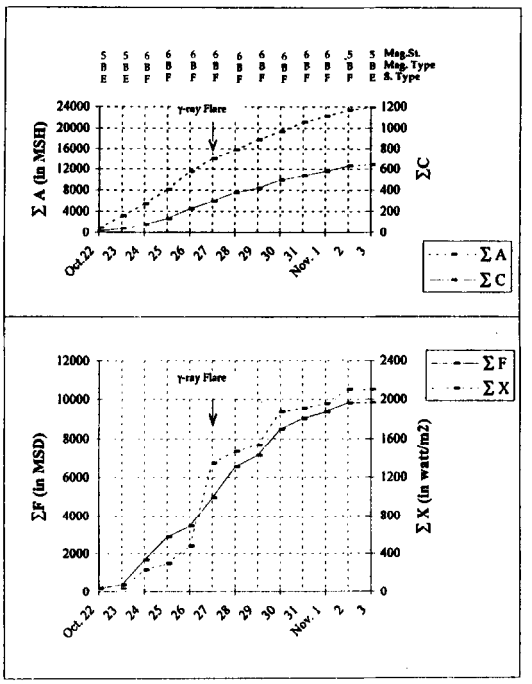

Fig. 1: The cumulative summation curves of F, X, A and C for the Solar Active Region NOAA/USAF 6891 in October - November 1991

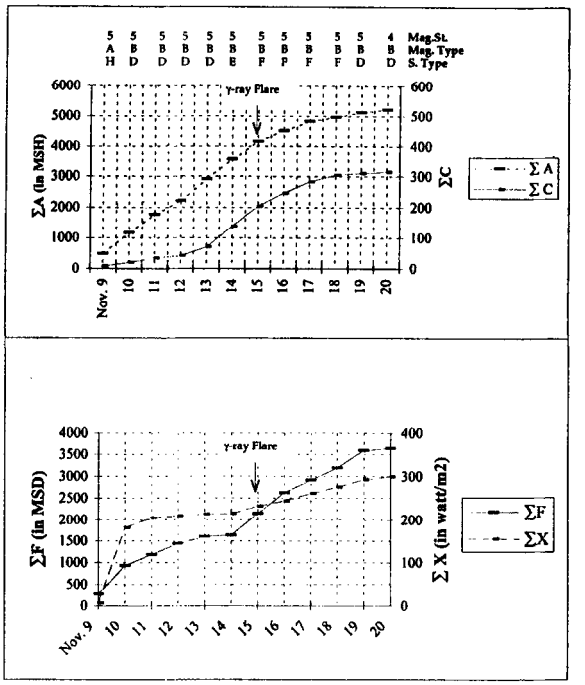

Fig. 2: The cumulative summation curves of F, X, A and C for the Solar Active Region NOAA/USAF 6919 in November 1991

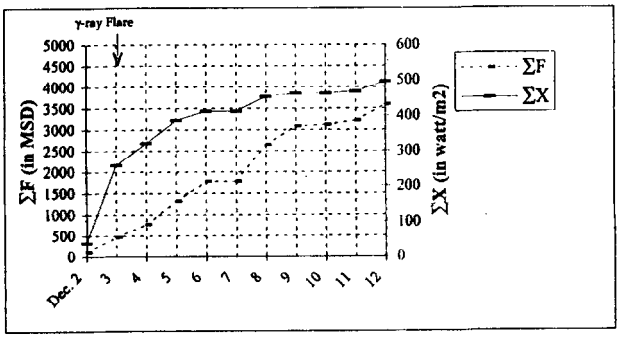

Fig. 3: The cumulative summation curves of F and X for the Solar Active Region NOAA/USAF 6952 in December 1991