Bull. Astr. Soc. India (2005) **33**, 11–18

Studies on H_α and SXR flares in relation to Type III metric bursts

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Received 15 June 2004; accepted 27 January 2005

Abstract. A study was made on H_α and SXR flares in relation to Type III metric bursts. The interrelationship between H_α and SXR flares was examined by grouping the events into two categories, (i) the events associated with Type III metric bursts, and (ii) those not associated with Type III metric bursts. Important results obtained are: (a) the drift rate of Type III bursts increases with the increase of integrated intensity of H_α-flares, (b) the intensity of SXR flares increases with the increase of intensity of H_α flares, this increase becomes steeper in the presence of Type III bursts, (c) the SXR flare intensity decreases with the increase of asymmetry in duration of H_α flares, this sort of decrease is also steeper in the presence of Type III bursts.

Keywords : SXR bursts, Type III metric bursts

1. Introduction

All flares seen in H_α generally produce a brightening in soft x-rays (Thomas and Teske, 1971). Although H_α and soft x-ray (SXR) flares have roughly similar time profiles, the SXR flares are characterised by a fast rise and much slower decay. Datlowe et al. (1974) reported that both the H_α and SXR emission start and peak at about the same time. Thomas and Teske (1971) found the SXR burst to start and peak by about 2 minutes earlier than that of the H_α flare. But according to Falciani et al. (1977) it starts by 2 minutes later. So an investigation about the interconnection between H_α and SXR flares is an important aspect, as they are interlinked to each other in respect of their evolution.

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Again, among the metric bursts Type III bursts which are characterised by a short duration and very fast frequency drift from high to low frequencies, generally have predominant occurrences in the solar atmosphere. But statistical analysis shows that about 70% of Type III bursts occur without any event classified as a flare or subflare in the optical region (Kuiper, 1973). Hence, the presence or absence of Type III metric bursts may influence the interrelationship betwen H_α and SXR flares.

In the present paper we have reported this interconnection between H_α and SXR flares by dividing the events in two classes: the events associated with Type III bursts and the events not associated with Type III bursts.

2. Data collection and method of analysis

Data of Type III radio bursts, H_α flares, and SXR flares were collected from Solar Geophysical Data bulletins published by NOAA, U.S. Department of Commerce. These events were observed during the period (1998-1999) by the different solar observatories distributed all over the globe. Only those data of a particular observatory were included in the present analysis, which had definite reports of the upper and lower frequencies of Type III radio emission. But although SGD gives different types of these bursts like, III B, III N, III G, III GG etc; we have taken them as a single category known to be Type III because of dearth of data in separate classes. As the frequency of observation of Type III metric bursts sweeps linearly with time (Melendez et al. 1999), we have found out the drift rate D of Type III bursts with the help of the following relation:

$$D = \frac{\Delta f}{\Delta t} = \frac{f_{\max} - f_{\min}}{d} \tag{1}$$

where $f_{\max}$ and $f_{\min}$ represent the upper and lower limits of the frequency at which the radio emission takes place and 'd' gives the duration of a burst. In this connection it is to be noted that the drift rate defined in this manner gives its average value.

The integrated intensity I_f as introduced by Sawyer (1967) giving the energy output of a H_α flare was calculated by using the following formula which takes into consideration of all factors, such as, duration, area, luminosity etc. of a flare, all expressed in terms of the flare area.

$$I_f = 7.6 A_s^2 \tag{2}$$

where A_s is the measured area in square degrees. Hence, the unit of I_f would be in (square degree)^2.

We have defined another variable A to be known as asymmetry by using the following relation:

$$A = \frac{r}{d} \tag{3}$$

where r represents the rise time (the time interval between maximum and starting phases) and d is the total duration of a flare. We have calculated the values of A for both H_α flares and SXR bursts and designated these variables as A_α and A_x respectively. The smaller values of 'A' (a larger asymmetry) give a prolonged energy release as it was defined by Dennis and Zarro (1993). In this connection it is to be noted that the asymmetry as defined here is not identical with impulsiveness as used by Pearson et al. (1989), which gives the growth rate of the energy input in flares.

At first the SXR flares were associated with H_α flares in which almost cent percent association was observed. These events are said to be correlated with each other when their starting times do not differ from each other by ±5 min. After this, the metric Type III radio bursts were correlated with the SXR associated H_α flares in the same manner as stated above. But it was examined that there were no metric bursts at all for a large number of cases. Hence, the analysis was carried out by dividing the data into two groups, one with metric bursts associated, and, the other without metric bursts association. Again, among the different types of metric bursts only Type III was found to be predominant. Hence, the analysis is confined to Type III metric bursts only.

3. Results

The drift rate as calculated by applying the above equation (1) is found to obey power law with an exponent nearly equal to 2.2 (Fig. 1) which is similar to that of $\frac{df}{dt} = 0.001$ $f^{1.84}$ as pointed out in McLean and Labrum (1985). Next the drift rate, D, of Type III bursts is related with the integrated intensity, I_f, of the respective H_α flares. The variation is shown in Figure 1 in which the correlation coefficient is found to be 0.72. The least square fit between these two variables is given by,

$$I_f = 0.735 + 0.008D \tag{1}$$

where the terms have the usual meaning as stated earlier. It appears from this relationship that with the increase of drift rate of Type III bursts, the H_α flare intensity increases in a linear way. Highly energetic H_α flares produce Type III metric bursts of greater drift rates.

In figure 3(a) logarithmic values of SXR flare intensity is plotted against H_α flare intensity for the cases in which there is no Type III burst association. The correlation coefficient is high which is of the order of 0.8. The best fit equation is given by

$$LogI_x = -2.823 + 0.044I_f \tag{2}$$

where I_x is the intensity of SXR flares in ergs cm^{-2} sec^{-1}. But in case of the events which are associated with Type III bursts, the correlation is slightly less, of the order of 0.6, as shown in Figure 3(b). The equation connecting SXR flare intensity and H_α flare intensity is similar to above, but with different slope and intercept.

$$LogI_x = -2.776 + 0.07I_f. \tag{3}$$

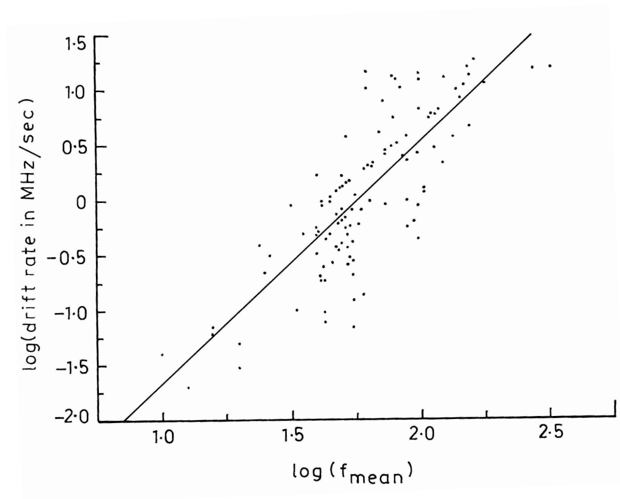

Figure 1. Straight line showing the variation of drift rate with mean frequency (f_{mean}) of Type III bursts.

The slope of the line is greater than that in the previous case. This implies that SXR flares become more energetic, which these flares are associated with Type III metric bursts simultaneously.

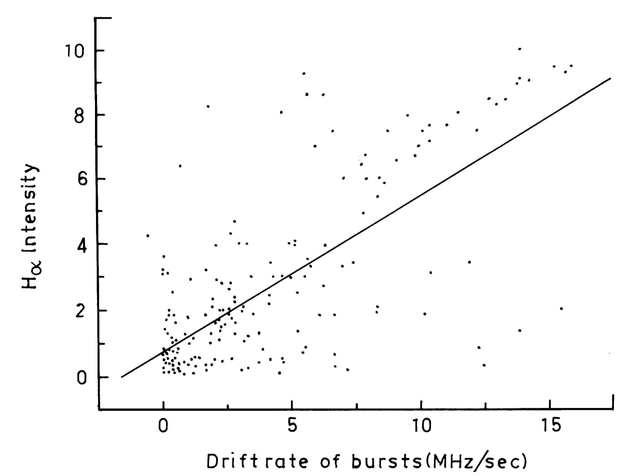

Figure 2. Straight line showing the variation of integrated intensity of H_α flares against the drift rate of Type III bursts.

In the next phase of work the variation of SXR flare intensity with the asymmetry

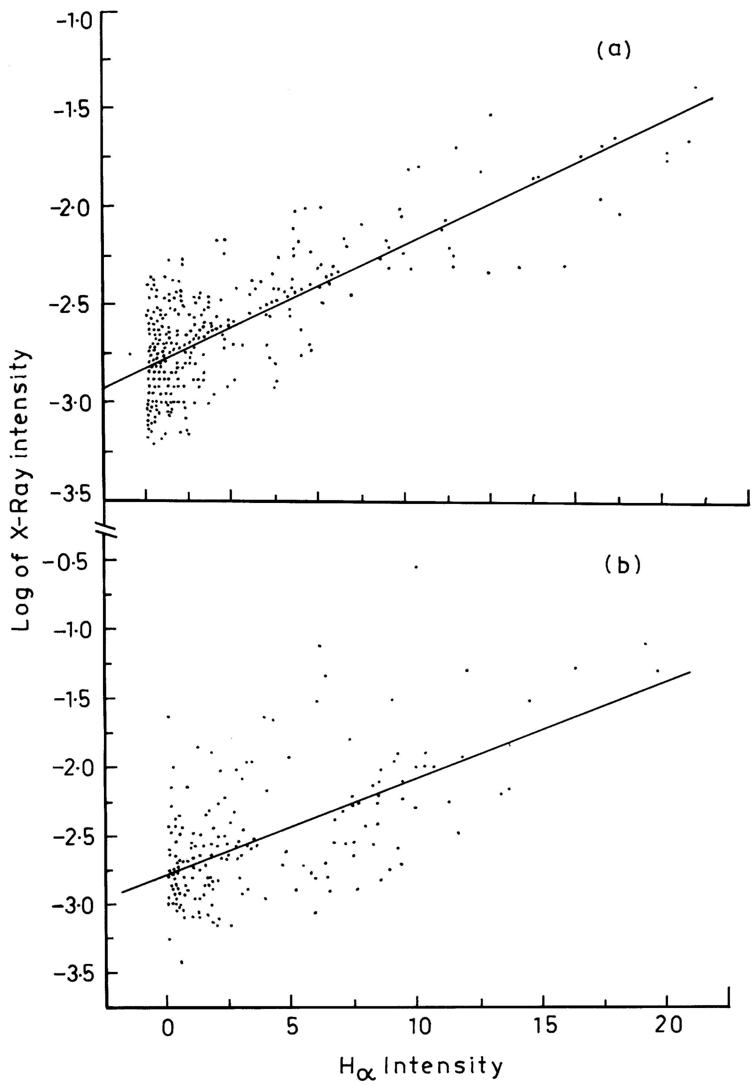

Figure 3. Plot of SXR flare intensity against H_α flare intensity (a) for the events associated with Type III bursts and (b) for the events not associated with Type III bursts.

of H_α flares is studied. The intensity of SXR flares is plotted against asymmetry as shown in Figure 4(a) and 4(b). Figure 4 gives this dependence for the cases in which there is no Type III bursts, whereas, Figure 5 is for the cases in which Type III bursts occur simultaneously. Very poor correlation (of the order of -0.14) is observed for the first group events, but a strong correlation (of the order of -0.61) is found for the second

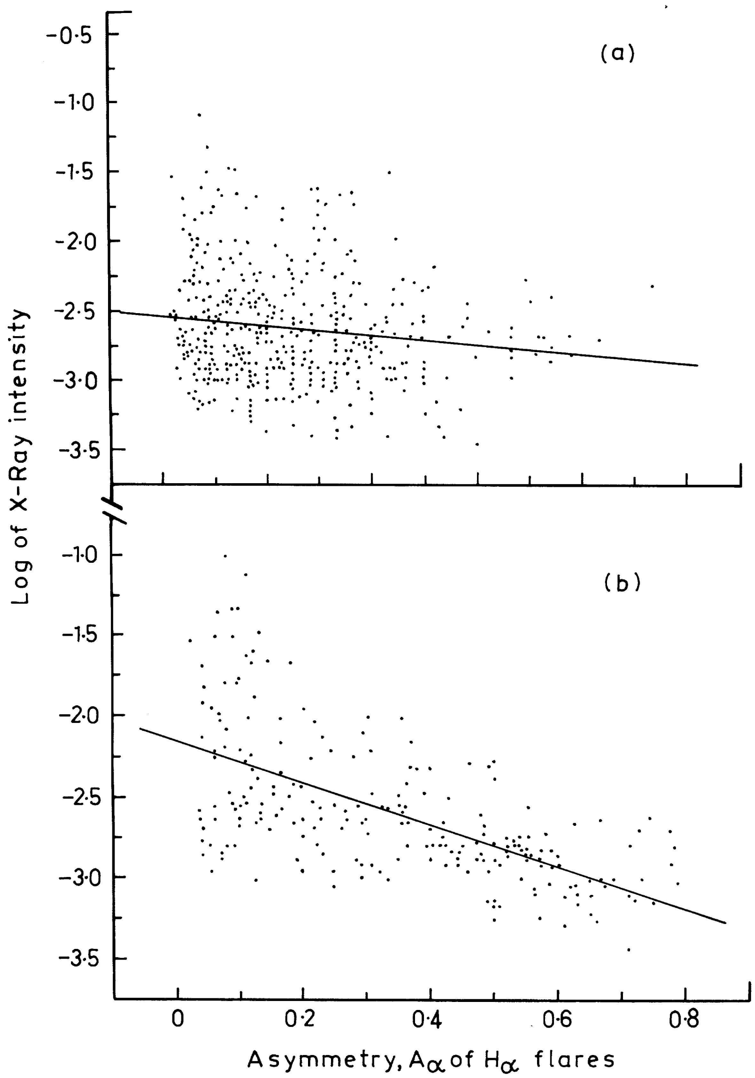

Figure 4. SXR flare intensity is plotted against the asymmetry in H_α flares (a) in which Type III bursts are associated and (b) in which Type III bursts are not associated.

group of events. The equations connecting the SXR intensity and asymmetry in H_α flares are given as follows:

$$\log I_x = -2.54 - 0.36A_\alpha \text{ (in absence of Type III bursts).} \tag{4}$$

$$\log I_x = -2.16 - 1.28A_\alpha \text{ (in presence of Type III bursts).} \tag{5}$$

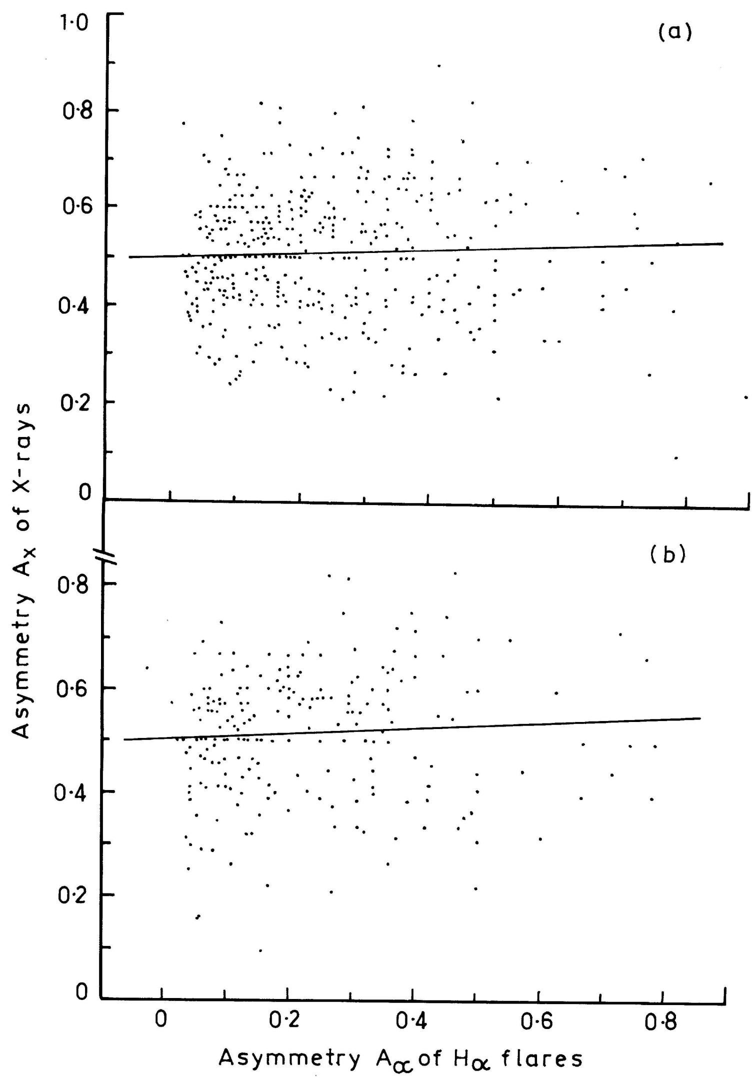

Figure 5. Plot showing the variation of the asymmetry in SXR flares against the asymmetry in H_α flares (a) in the presence of Type III bursts and (b) in the absence of Type III bursts.

In both the cases the SXR intensity is examined to decrease with the increase of asymmetry in duration of H_α flares. But this decrease is much steeper in case of the events which are associated with Type III metric bursts. Moreover, the correlation is also found to be higher in this case.

At last the asymmetry of SXR flares, A_x, is plotted against the asymmetry, A_α of

H_α flares. The asymmetry in duration of SXR flares is found to be independent of the asymmetry in duration of H_α flares. Very poor correlation (of the order of 0.08) is found to exist for the cases (i) without Type III bursts, (Figure 5(a)) and (ii) with Type III bursts' association (Figure 5(b)). The equations connecting the aforesaid variables are given by

$$A_x = 0.5 + 0.053 A_\alpha \text{ (without Type III)} \tag{6}$$

$$A_x = 0.5 + 0.063 A_\alpha \text{ (with Type III).} \tag{7}$$

4. Discussion

The drift rate of Type III metric bursts is found to increase linearly with the increase of H_α flare intensity. Higher drift rate means faster movement of the agent that excites plasma oscillations of gradually diminising frequency, as the stream passes through coronal plasma of progressively decreasing electron density. The intensity of x-ray flare increases exponentially with the increase of integrated intensity of H_α flares. This dependence becomes more strong in the presence of Type III bursts. As the integrated intensity of H_α-flares increases, a large number of electrons are accelerated; and take part in Type III emission. The fast moving stream causes plasma condensation, heating the ambient medium which causes soft x-ray emission by free-free emissions. Moreover, SXR intensity decreases with the increase of asymmetry of H_α-flares. The larger values of 'A' (a smaller asymmetry) give faster energy release in H_α-flares, which leads to lesser values of SXR intensity. As the energy release in H_α flares takes place quickly, the electrons do not get sufficient time to become thermalised due to which thermal free-free emissions causing soft x-rays can take place.

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