SOLAR AND STELLAR FLARE OBSERVATIONS USING WATCH

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Astract

The Danish experiment WATCH (Wide Angle Telescope for Cosmic Hard X-rays) is to be flown on board the Soviet satellite GRANAT in middle of 1989. The performence characteristics of the WATCH instrument is described. It is estimated that WATCH can detect about 100 solar hard X-ray bursts per day. WATCH can also detect about 40 energetic stellar soft X-ray flares, similar to the fast transient X-ray emissions detected by the Ariel V satellite.

Introduction.

All sky X-ray monitors have made two important contributions to X-ray astronomy: signalling the onset of transient phenomena and the study of long term variability in the bright galactic X-ray sources (Holt and Priedhorsky,1987). The all sky X-ray monitors flown up to now (eg. Vela 5B and Ariel V SSI) had limited energy range (< 20 keV) and duty cycle (<0.01). Therefore, only a limited parameter space in time scale (>hours), energy (< 20 keV) and sensitivity (> 5 m Crab for one day) have been explored upto now. The importance of extending these parameters can be realized from the fact that omni-directional detectors of modest sensitivity like the Vela 5A have opened up a new branch of astronomy, namely the gamma ray burst astronomy.

The WATCH detectors (Lund,1981) have extended energy range (6 keV to 180 keV), complete sky coverage at all time scales and single station localisation capacity for bright sources. Hence they are ideally suited for (1) real-time alarm for X-ray transients, (2) continuous monitoring of bright X-ray sources for long term variability, (3) single station localisation for gamma-ray bursts and (4) exploring new phenomena in the hard X-ray energy range with time scales of a few minutes. Further, WATCH detectors can also detect solar hard X-ray bursts and bright stellar X-ray flares. Here we describe the characteristics of the WATCH instruements and discuss the capabilities of studying solar and stellar flares.

2. Instrumentation.

The WATCH detector is a Rotation Modulation Collimator (RMC) with single modulation grid and two interleaved grids of X-ray detectors. The detector consists of a circular mosaic of NaI (Tl) and CsI (Na) crystals, viewed by a single photomultiplier tube. A modulation grid made of bars of Tantalum, Tin and Copper, is mounted 5 cm above the crystal surface. The crystal and the modulation grids are rotating at a rate of about 60 rpm.

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The X rays incident on each type of detectors are recognised electronically by their decay time characteristics. An λ ray source generates a periodic "chirp" in the count rate in each type of detector called the modulation pattern which is uniquely dependent on the X-ray source position. The total count rate in both the detectors, however, will not be modulated and hence can be used to decouple the effect of source intensity variation on the modulation patterns. Though the pitch angle of the modulations is 2.86°, bright sources can be localized correct to a few arc-minutes.

The opening angle of the detector is 73° (4.4 steradian). Four identical units will be mounted on the Soviet satellite GRANAT, giving complete sky coverage. The total effective area of the detector, averaged over the whole sky, is shown in Fig. 1, as a function of energy. The effective area of the CsI crystal is lower for X-ray energies less than about 70 keV because of a dead layer developing on the crystal surface. It can be seen from the figure that the effective area is > 25 cm^2 for X-ray energies between 20 keV and 110 keV; and > 10 cm^2 for X-ray energies between 6 keV and 180 keV. The detector characteristics, along with the details of the GRANAT satellite is given in Table 1.

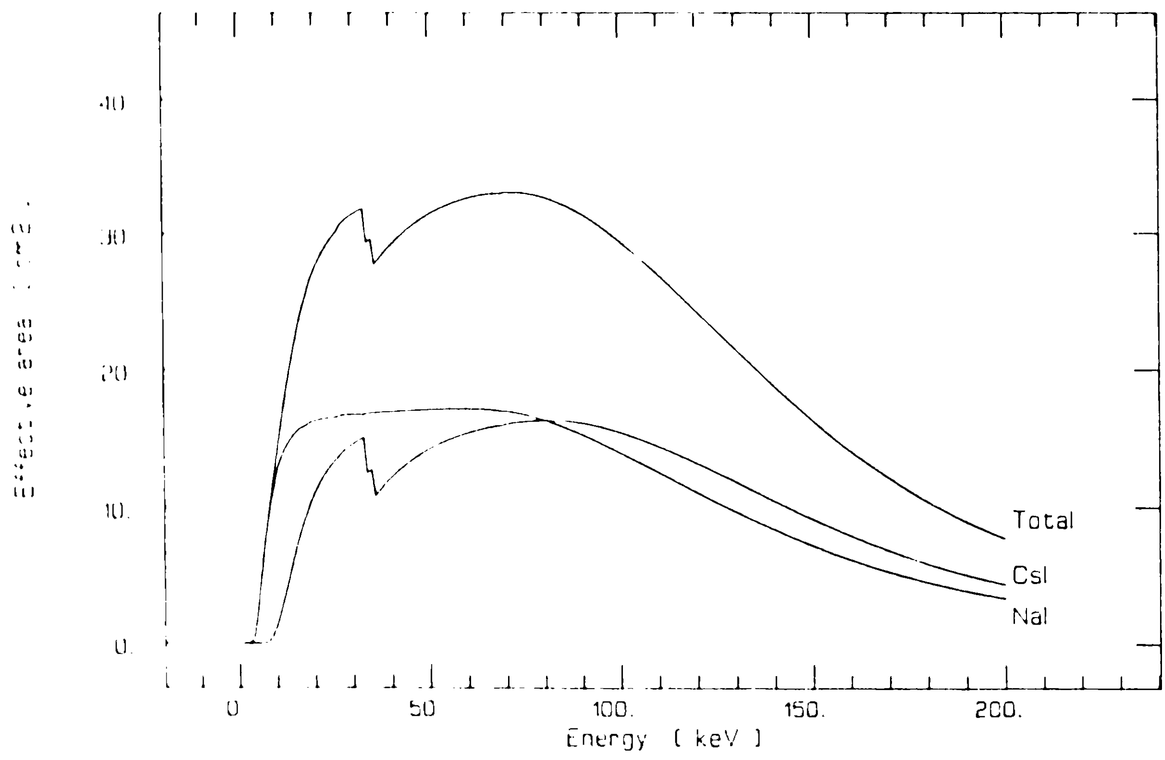

Fig.1. The effective area of the WATCH detectors, averaged over the whole sky, as a function of energy.

Table 1. WATCH instrument details.

1. Detectors:

Efective area	:	30 cm^2
Energy range	:	6 keV to 180 keV
Energy resolution	:	30 % at 60 keV
Angular resolution	:	5 arcminutes.
Expected background	:	400 counts per second.
Sensitivity	:	20 mCrabs (for 1 day integration) 10^{-7} ergs/cm^2 (for gamma-ray bursts)
Time resolution	:	100 μs (triggered events) 4 s (count rates in two energy bands) 512 s (modulation patterns)

2. Other details:

Launch	:	≈ July 1989 (Four WATCH detectors on board the Soviet satellite GRANAT)
Satellite orbit	:	Eccentric (2000 km - 200000 km) 51° inclination 96 hour period.
Life time	:	> 1 year
Telemetry	:	once every 24 hours.

3. Solar hard X-ray bursts.

From the number distribution of solar hard X-ray bursts given by Lin et al (1984), we estimate that WATCH should detect about 100 solar hard X-ray bursts per day during the next solar maximum. This estimate is based on a assumed power law specral index of -5, duration 5 seconds and low energy cutoff at 10 keV (see Lin et al.). We find these assumptions to be consistent with the detection of 15 - 25 solar hard X-ray bursts per day by the HXRBS of SMM (Dennis et.al., 1988), which has much higher low energy cutoff (25 keV).

The much larger data base of solar hard X-ray bursts is useful to confirm the flare periodicity reported by Bai(1987). Further, the modest positional information (≈ 5 arcminutes) is useful to identify the solar hard X-ray bursts with the associated H_α flares, which in turn can be used to search for active longitude belts (Bai, 1988).

Lin et. al. also estimate that the average rate of energy deposition by greater than 20 keV electrons from all the bursts above a threshold of 10^{-2} (cm^2 s keV)$^{-1}$ is about 10^{24} ergs s^{-1}. The contribution to this energy input from bursts of lower threshold, can be estimated from measuring the integrated hard X-ray flux from the Sun. The WATCH detectors can measure the integrated hard X-ray flux from the Sun correct to 0.5 dex in one day. If the total hard X-ray flux is comparable to the solar coronal emission (10^{27} ergs s^{-1}), it will be an independent support to the recent suggestion by Parker (1988) that the solar corona is powered by "nanoflares".

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4. Stellar soft X ray flares.

Stellar soft X ray flares of the type detected by focussing X-ray instruments like the Finstein Observatory (Haisch, 1983), are too weak for detection by the WATCH detectors because of low energy threshold (6 keV). The fast transient X ray (FTX) emissions detected by the Ariel V satellite (Pye and McHardy, 1983) are of more energetic type and about 60 % of these FTX events are identified with stars (Rao and Vahia, 1987). Pye and McHardy have estimated that an isotropic detector should detect about 120 FTX per year above the SSI threshold of 8 SSI counts per sec. WATCH should detect about 40 FTX per year above 10 σ (a 5 keV thermal spectral shape is assumed). WATCH has considerably better localisation capability (a few arcminutes) compared to the Ariel V detectors (a few degrees) and hence unambiguous stellar identification sholud be possible. The WATCH detector also has high time resolution gamma ray burst detection capacity, which should clarify the intriguing connection between the gamma-ray bursts and FTX sources, as indicated by the two associations given in Pye and McHardy (1983).

On the other hand, the HEAO A - 1 fast transient search (Connors et al., 1986) identified 8 FTX sources and 6 of them are likely to be associated with flare stars. Connors et al, however, estimate that an isotropic detector should detect more than 10^4 FTX per year above the threshold of 6 mCrabs. This corresponds to an event rate of more than 240 per year for the WATCH detectors, above a threshold of 10 σ. This is considerably higher than the Ariel V FTX event rate and this difference can be explained from the fact that Ariel V SSI instrument had a time resolution of 90 minutes, whereas the HEAO A-1 FTX events had a time duration of less than 1000 s. The WATCH detectors, being sensitive to all time scales, should be able to distinguish and classify the two types of FTX events. Further, detection of soft X ray flares by an isotropic detectors, should lead to the discovery of many new RS CVn type of binaries, which cannot be identified photometrically because of their unfavourable orbital inclinations.

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