# SHORT-LIVED SOLAR BURST SPECTRAL COMPONENT AT f $\gtrsim$ 100 GHz

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## ABSTRACT

A new kind of burst emission component was discovered, exhibiting fast and distinct pulses (~60 ms durations), with spectral peak emission at f $\gtrsim$ 100 GHz, and onset time coincident to hard X-rays to within $\lesssim$128 ms. These features pose serious constraints for the interpretation using current models. One suggestion assumes the f $\gtrsim$ 100 GHz pulse emission by synchrotron mechanism of electrons accelerated to ultrarelativistic energies. The hard X-rays originate from inverse-Compton scattering of the electrons on the synchrotron photons. Several crucial observational tests are needed for the understanding of the phenomenon, requiring high sensitivity and high-time resolution (~1 ms) simultaneous to high-spatial resolution (<0.1 arc s) at f $\gtrsim$ 100 GHz and hard X-rays.

## DISCUSSION

An extraordinary solar burst was observed on 21 May 1984, 1326:20 UT, with high sensitivity and time resolution using the Itapetinga 14-m antenna, at 30 GHz and 90 GHz, and at hard X-rays (>25 keV) by the HXRBS experiment onboard SMM (Kaufmann et al., 1985a). The event is shown and described in Figure 1. The spectrum derived for the Structure A of this event is shown in Figure 2, clearly suggesting an emission component towards millimeter (or sub-millimeter) waves only. The existence of such a burst emission component was, in fact, already suggested in the past, although the data were obtained with very poor time resolution. In Figure 3, spectra of various bursts obtained in the past, by different authors, do suggest either a "flattening" or a rise towards higher frequencies. Therefore, the occurrence of an emission component in the mm to sub-mm range of frequencies might be common to many solar flares.

The basic diagnostics of the 21 May 1984 burst can be summarized as follows:

– Maximum emission frequency $\gtrsim 10^{11}$ Hz

– Timescale ~30 ms (60 ms durations)

– Several packets of distinct pulses. Large relative amplitude ($\Delta F/F$) ~ 60%. Much larger than the usual "ripple" (~1%) found at f < 100 GHz.

– Hard X-rays (>25 keV) onset coincident to $\lesssim$100 ms.

– "Delays" or lack of time correlation at lower frequencies (<100 GHz) with respect to hard X-rays, do not exist at $\gtrsim$100 GHz.

The 21 May 1984 burst-observed emission (for Structure A, Figure 1) in the radio and hard X-ray ranges is shown as thick solid lines in Figure 4, which also includes the typical fluxes reported for white-light flares (Neidig and Cliver, 1983). Several tentative spectral fits, based on different energy loss mechanisms, are indicated in the figure and described in its caption.

All the loss processes, spectra are shown in Figure 4, imply timescales considerably larger than the observed ones (60 ms). If hard X-rays are produced by bremsstrahlung, the short timescales observed require ambient plasma densities of the order of $10^{15}$ $cm^{-3}$, which are quite too high. Therefore, another loss process might be acting in order to account for the short lifetime of the pulses observed. One possibility is to assume the effectiveness of inverse-Compton (I.C.) scattering, reducing the electron energies in short timescales, and originating the observed hard X-rays. This possibility was already considered in the past (Shklovsky, 1964). One interpretation was recently suggested to explain the features of the 21 May 1984 event (Kaufmann et al., 1985b). The pulses are attributed to primary accelerators located somewhere in an unstable loop, producing "instantaneously" a population of ultrarelativistic electrons which constitute a self-absorbed synchrotron source inside which the I.C. quenching on the source photons originate the hard X-ray photons. Equating the synchrotron and I.C. conditions, the model predicts the observed fluxes at radio and at hard X-rays, and accounts for the small timescales observed, which are shown in Figure 4. The predicted Synchrotron 1 spectrum peaks in the infrared ($\sim 10^{13}$ Hz), and implies electrons accelerated to $\gtrsim 100$ MeV energies, in magnetic fields ranging from 100 to 1000 G. A similar mechanism spectrum has been proposed by Stein and Ney (1963) to explain white-light flare (WLF) continuum emission.

According to this interpretation (Kaufmann et al., 1985b), the pulse sources are very short-lived ($\sim 60$ ms), very small ($\lesssim 10^7$ cm), and exhibiting high apparent brightness temperatures ($\gtrsim 10^{10}$ K). As these sources vanish, the electrons decay into lower energy levels and might still be able to produce the better-known longer-lasting emissions at microwaves and X-rays.

Alternative interpretations might be considered by placing the primary accelerator sources deep into the chromosphere, in a very high ambient plasma atmosphere. This new physical situation needs further investigations. One attempt is currently in progress reconciling it with the burst impulsive phase description recently proposed by de Jager (1985).

*Acknowledgments.* This research was partially supported by Brazilian research agency FINEP. One of the authors (PK) is a Guest Investigator on SMM.

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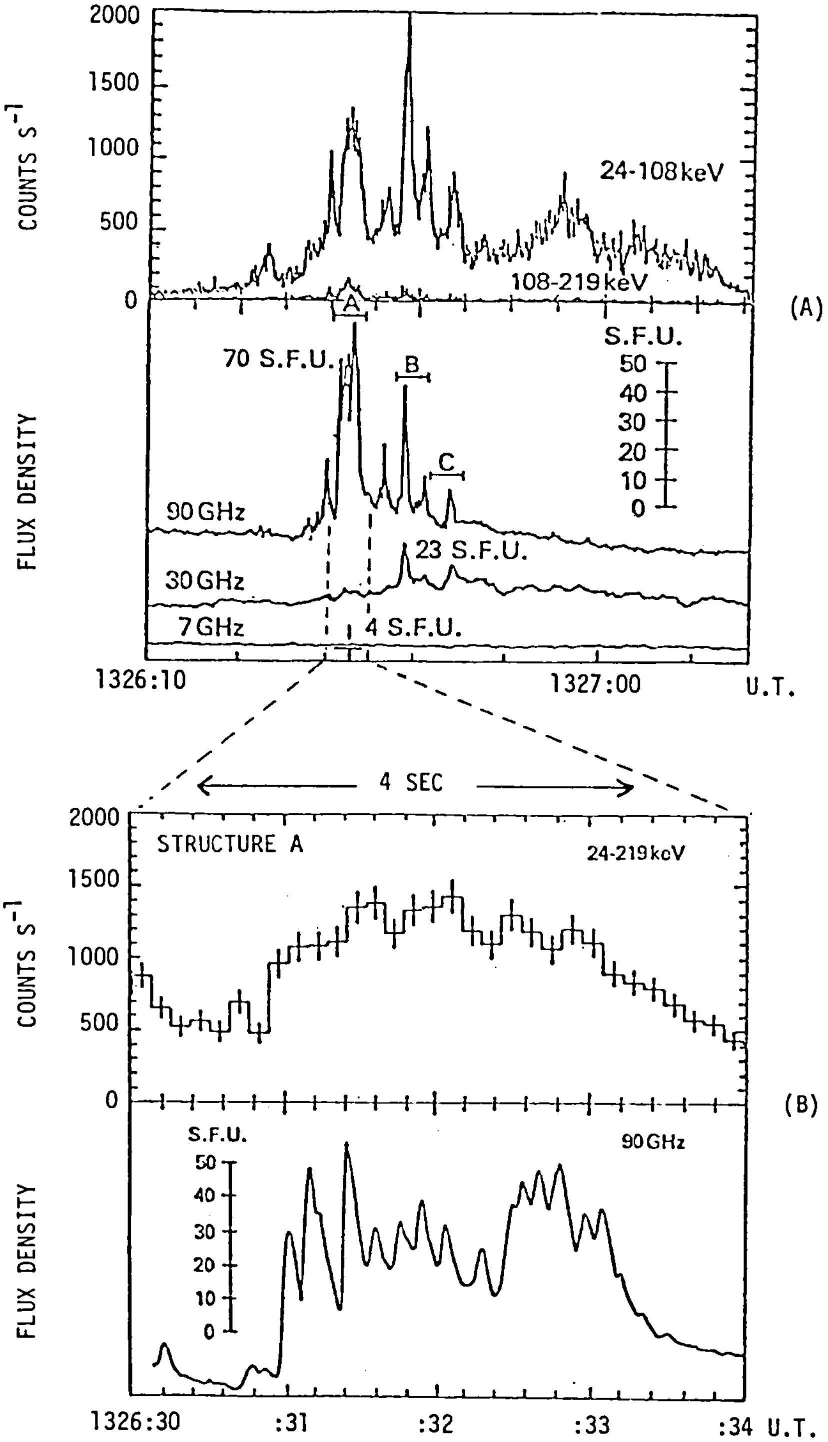



Figure 1. The solar burst of 21 May 1984 is shown in compressed timescale (A), with two hard X-ray energy ranges at the top, and 90 GHz, 30 GHz, and 7 GHz at the bottom. All hard X-ray burst structures correlate in time very well with the 90-GHz emission, but not well for lower frequencies emissions. The major Structure A is time expanded in (B), with hard X-ray (24 to 219 keV) data at the top, restricted to 128-ms time resolution, and 90-GHz data at the bottom, displayed with 10-ms time constant. The structure consists in a packet of distinct pulses, repeating at about 7 Hz. The e-folding rise time of a pulse is about 30 ms. The hard X-ray onset is coincident to the 90-GHz onset by less than 128 ms.

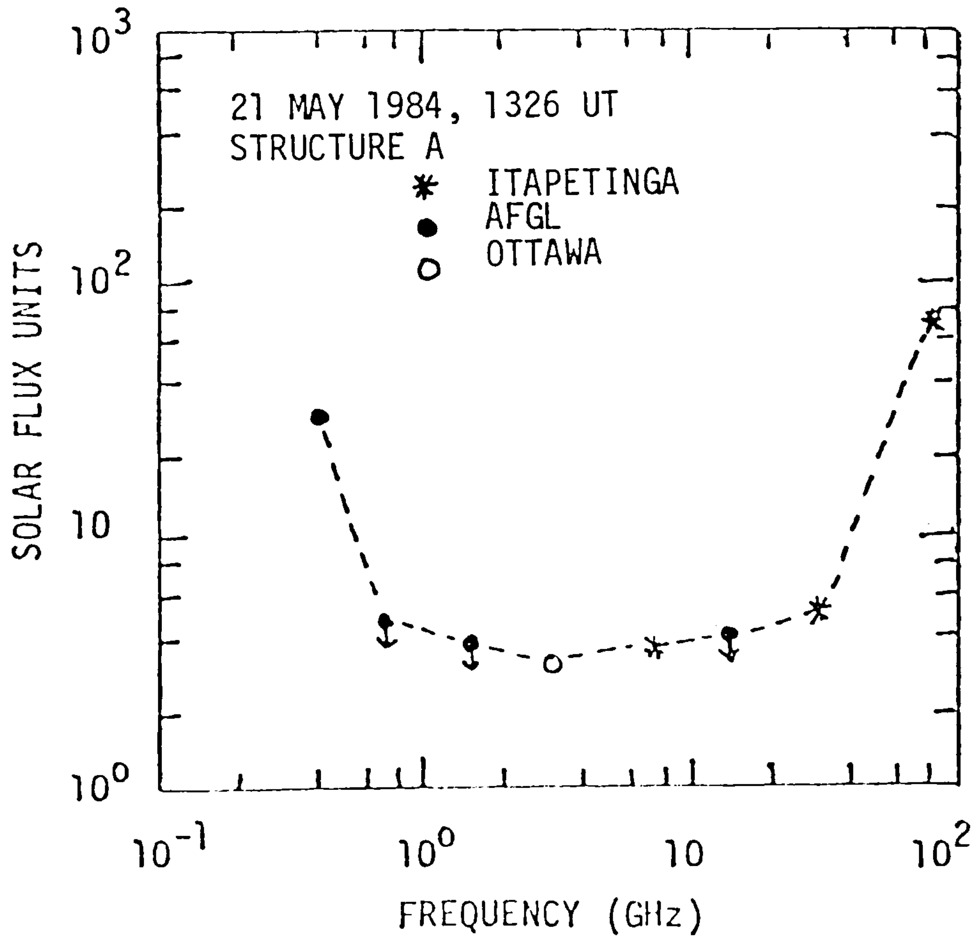
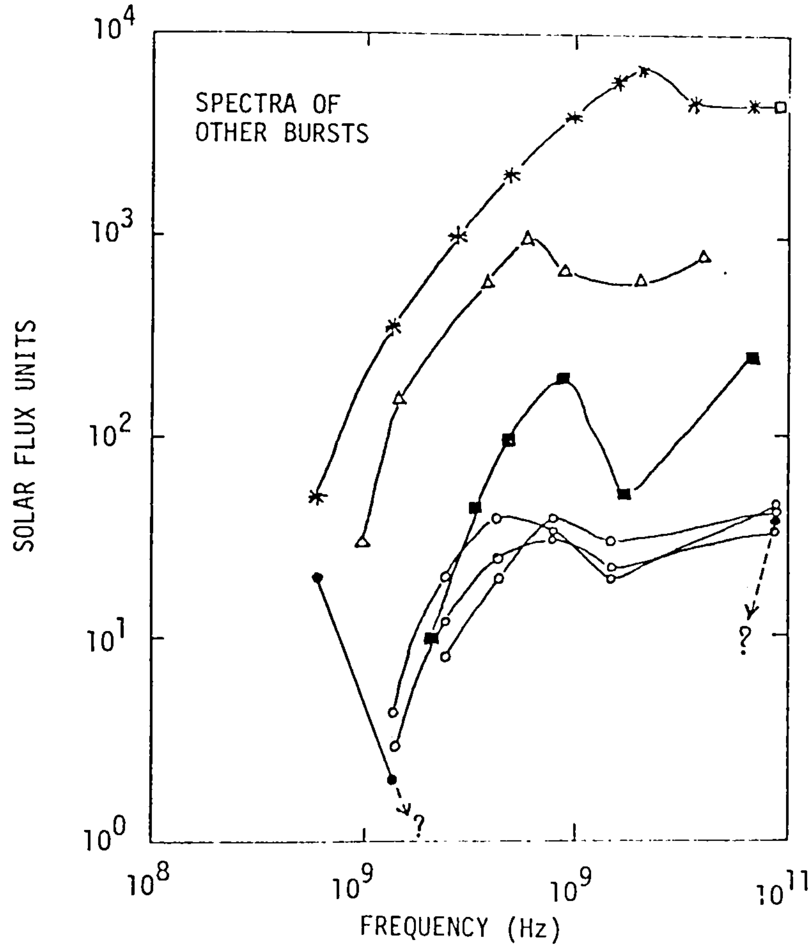



Figure 2. The observed spectrum of Structure A of 21 May 1984 solar burst (Figure 1). The existence of a burst emission component peaking somewhere at $f \gtrsim 100$ GHz is clearly evidenced.




$*$ CROOM (1970)
□ COGDELL (1972)
○ SHIMABUKURO (1972)
● SHIMABUKURO (1970)
■ AKABANE ET AL. (1973)
△ ZIRIN AND TANAKA (1973)

Figure 3. Spectra of various solar bursts obtained in the past by various authors, with symbols and names quoted at the bottom. They confirm that the occurrence of a burst emission component in the mm to sub-mm range of frequencies is common to many flares. One of these spectra (Shimabukuro, 1970) is possibly very similar to the spectrum of the event studied here (Figure 2).

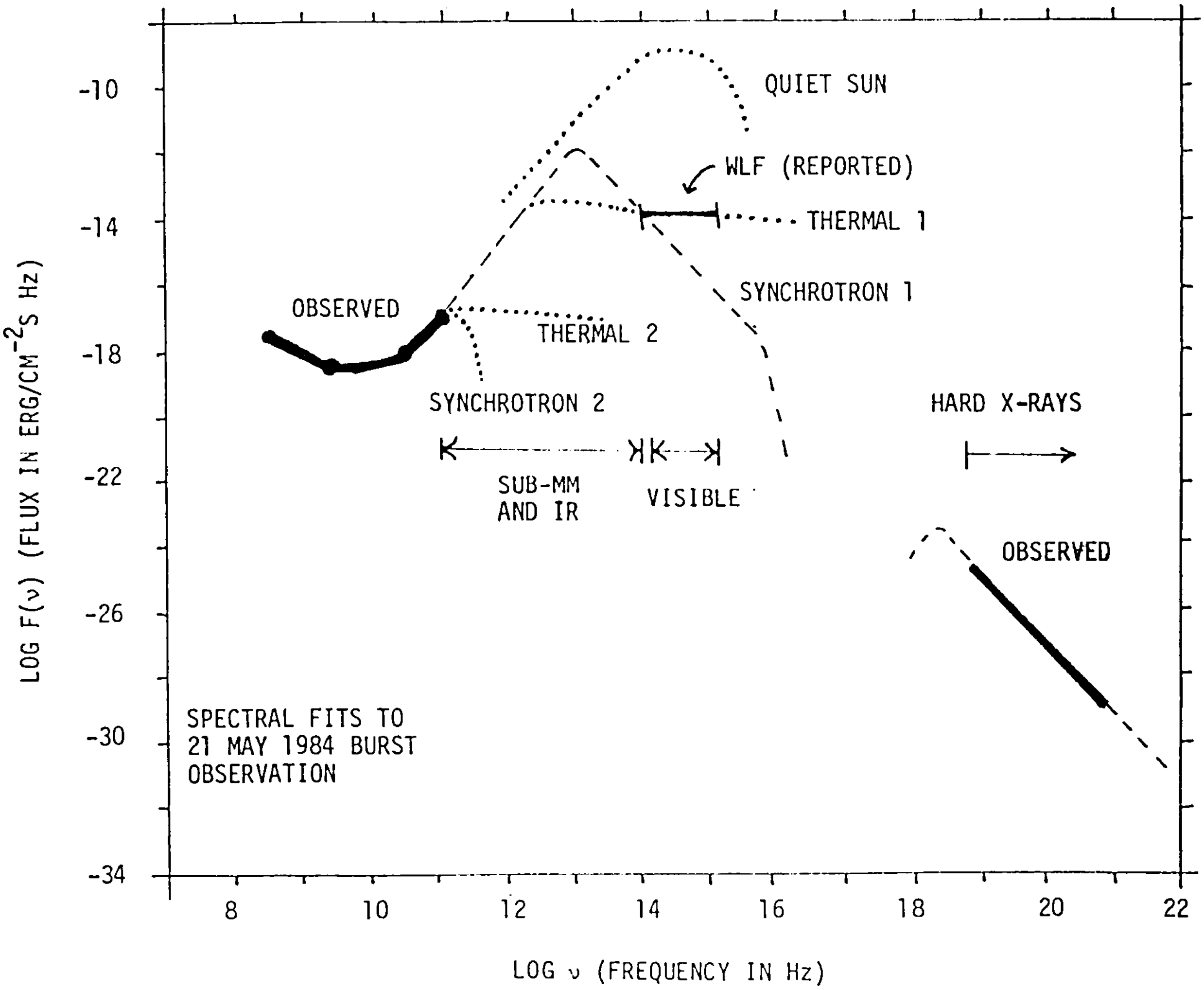



Figure 4. A radio-hard X-ray range spectral display, showing the observed emissions of 21 May 1984 solar burst (Structure A, Figure 1), and the typical fluxes reported for white-light flares (Neidig and Cliver, 1983). The tentative spectral fits (points' lines) are: Thermal 1: a thermal component with turnover frequency somewhere in the sub-mm or far infrared range of frequencies, fitting white-light flare reported fluxes (Ohki and Hudson, 1975); Thermal 2: a thermal component with turnover frequency at about 100 GHz (Shimabukuro, 1970); and Synchrotron 2: losses by electrons with relativistic energies, with emission spectrum peaking at about 100 GHz (implying in electrons energies 7 MeV in a 500 Gauss magnetic field). The Synchrotron 1 plot in dashed line, peaking in the infrared, is a model prediction for a synchrotron/inverse-Compton mechanism (implying electrons' energies ~100 MeV in a 500 Gauss field) (Kaufmann et al., 1985b). The quiet-Sun blackbody spectrum is shown at the top.