OPTICAL LIGHTNINGS AS A BACKGROUND IN SEARCHES FOR COSMIC X-AND GAMMA-RAY BURSTS THROUGH ATMOSPHERIC FLUORESCENCE

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ABSTRACT

A photomultiplier system has been exposed to the night-sky at Gulmarg (India) during 1972-1977 to search for cosmic X-and γ-ray bursts of time-scale $\lesssim$ 1 mS through the atmospheric fluorescence technique. Lightning events detected on several days are found to exhibit an anomalously wide spectral distribution and in several cases match the expected temporal and spectral characteristics of the atmospheric fluorescent pulses. This constitutes a serious interference in an unambiguous identification of fluorescent events of cosmic origin by the scintillation technique.

INTRODUCTION: Several experiments have been carried out so far to detect short time-scale ($\lesssim$ 1 mS) cosmic X-and γ-ray bursts through the atmospheric fluorescence process (1-3). Optical emissions from lightnings are known to constitute a serious transient background in these searches, because of comparable time-scales and an occasional duplication in the pulse profiles observed in the two processes (2). Although genuine lightning pulses can, in principle, be distinguished by recording the associated atmospheric field variations simultaneously, such a distinction becomes difficult in many cases because of the different sensitivities of the optical and the electric field channels. Barasch (4) and Ogelman and Bertsch (1) have proposed possible methods of distinction based on the expected differences in the optical spectra of the atmospheric fluorescence radiation and the lightning discharges: Whileas the fluorescence spectrum in the visible region is largely restricted to N_2^+ emissions in the wavelength region λ = 3400-4300 A° (references 1,2), the optical spectrum of lightnings comprises several atomic-line and molecular-band features superimposed on a strong continuum extending between λ = 3800-6900 A° (references 4,5). The proposal by Ogelman and Bertsch (1) employs two spectral channels: one, called Violet or V-channel, responds preferentially to the fluorescent spectrum (λ= 3400-4300 A°)and the second channel, called yellow or Y-channel, transmits mainly wavelengths between 4300-5500 A°, which overlap a sizeable portion of the lightning continuum but contain no major N_2^+ fluorescent bands. It is argued by the authors that, the ratio of the signal amplitudes in the V- to Y-channels, (A_V/A_Y), being appreciably less for a lightning event than for a fluorescent pulse, may afford a method of distinction between the two processes. However, we report here that a sizeable number of lightning events, identified on the basis of the associated variations in the atmospheric electric field, have A_V/A_Y ratios which lie outside the range expected for lightning events and thereby render difficult an unambiguous selection of fluorescent pulses of cosmic origin.

<u>EXPERIMENTAL DETAILS</u>: The atmospheric fluorescence detector at Gulmarg (3) essentially comprises three, 12" photomultipliers, (EMI 9545B), which are covered with broad band optical filters and view the sky on clear, moonless nights in a cone of 60^0 semivertical angle. Two photomultipliers, referred to as V-channels, respond preferentially to wavelengths $\lambda \lesssim 4200$ A^o and the third, designated as Y-channel, has a lower cut-off at $\lambda \sim 4500$ A^o. The system is operated in a prompt-coincidence mode, a trigger pulse being generated whenever the out-puts of the V-channels are coincident within ~ 10 μS. The signals from the optical channels are displayed on a Cathode Ray Oscilloscope alongwith the corresponding response in a lightning channel, (L-channel), which monitors short-term variations in the atmospheric electric field (6) . The oscilloscope traces and the event time, derived from an ovened-quartz clock, are subsequently photographed by an open-shutter, 35 mm camera.

The threshold photon flux of the optical channels is estimated to be $\sim 10^{-5}$ erg cm^{-2} S^{-1} and the detection range of the L-channel is 50 Km for a typical return-stroke (6,7). The three optical channels are regularly calibrated with an LED-lamp pulser and it is ensured that their overall gains always remain within 20% of one another.

<u>ANALYSIS AND RESULTS</u>: It has been shown elsewhere (8) that, for the Gulmarg system, the spectral index $A_V/A_Y = 5 \pm 1$ for the atmospheric fluorescence radiation, when due consideration is given to the atmospheric extinction as well as to the transmission and spectral characteristics of the photomultiplier detectors and the optical filters. On the other hand, for the flat spectrum of optical lightnings as given by Connor (5), the corresponding range of values for A_V/A_Y should be $\lesssim 3$ with a peak at ~ 1. These values include modifications that may be introduced in the detected lightning spectrum on account of Rayleigh and Mie scatterings. In order to examine the degree to which the lightning events conform to this expected behaviour, a sample of $\sim 11,000$ events, recorded at Gulmarg, was selected on the basis of their non-zero response in the lightning - channel and their peak amplitudes measured in V-and Y-channels. Fig. 1a gives a typical example of the lightning event belonging to this sample.

Based on the observed daily distribution of A_V/A_Y ratios, lightning days can be divided into samples 'A' and 'B' (see Figs. 2a and 3a). Sample A, comprising 37% of the total lightning days considered (60 days), comes close to the behaviour expected on the basis of the Connor's observations of the lightning spectrum (5). Here, out of a total of 6755 events, 96.2% lightnings contribute to $A_V/A_Y < 4$ as against only 3.8% with a value $\gtrsim 4$ for this parameter. On the contrary, A_V/A_Y ratio distribution for the lightning events of sample B (Fig. 3a) is much broader, with a value $\geqslant$ 4 found in $\sim$25% cases. This constitutes a significant departure from the expected behaviour of lightning events and cannot be accounted for in terms of the atmospheric scattering alone.

Figs. 2(b) and 3(b) give the distribution of the spectral index A_V/A_Y for events with no output in the lightning channel ($A_L \sim 0$) and recorded on sample A and sample B lightning days respectively. A remarkable parrallelism is evident with the corresponding A_V/A_Y distributions of the lightning events (Fig. 2a and 3a respectively). Moreover, for both the distributions represented by Figs. 2b and 3b, and comprising 362 and 846 events respectively, about 10% events have $A_V/A_Y > 4$ and $\sim$ 8% events have a value for this ratio which falls in the interval 5±1, as expected for the genuine atmospheric flucrescent pulses. However, on account of the correlations referred to above, including the observation that these events have been recorded on lightning-active days, it is more reasonable to conclude that most of the events having $A_V/A_Y = 5\pm1$ and $A_L \sim 0$ are actually lightnings which could not be picked up by the L-channel, either because the discharges were intrinscally weaker or their sources were too distant. Out of a total of 96 events thus left out (Fig. 1b represents a typical case), it is possible that some may indeed be genuine fluorescent pulses. But unless it can be established directly with the help of multi-station coincidence observations, it is appropriate to ignore such ambiguous cases while considering the Gulmarg data alone. It is thus evident that the spectral index A_V/A_Y is not always a reliable parameter in resolving fluorescent pulses from the lightning background.

If the lightning events constituting Fig. 3b are indeed distant ones, while the events in Fig. 3a occur relatively nearby, the remarkably similar shapes of the two curves suggests that the broadening of A_V/A_Y distribution cannot be attributed to differential atmospheric scattering in the two cases but may imply that the lightning source spectrum itself is different for sample B days compared with that of sample A days. Furthermore, the close correspondence between Figs. 3a and 3b, especially in the case of secondary peaks, indicates an inherent structure in the lightning source spectrum of sample B days in contrast with the flat spectrum observed by Connor (sample A days and reference 5).

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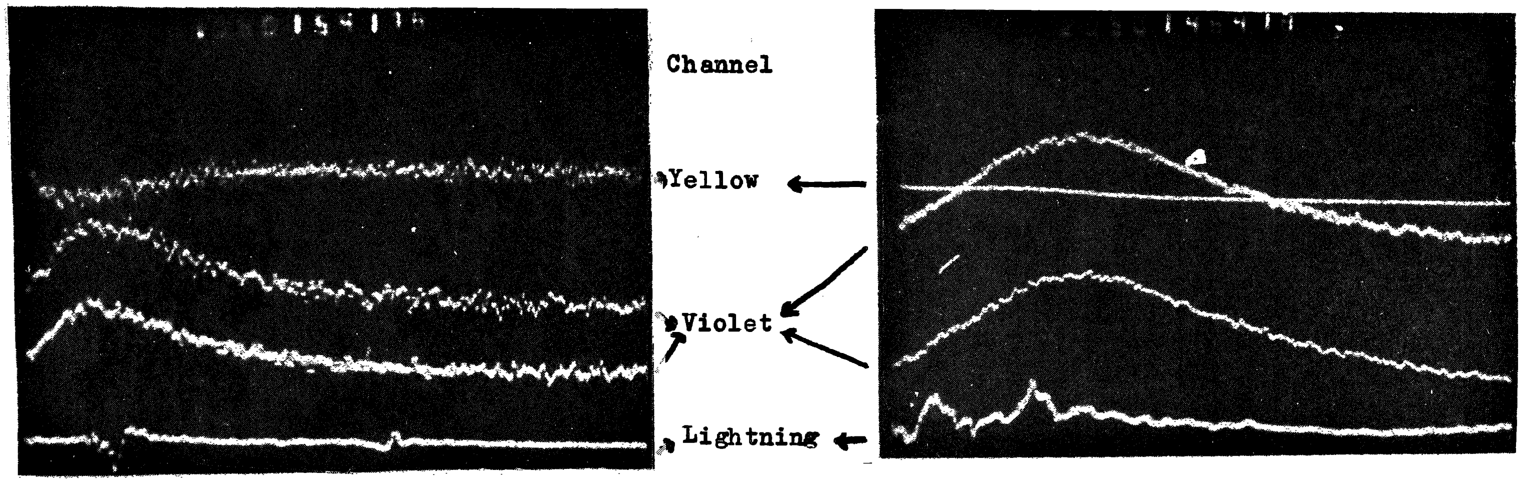

Fig. 1a

Fig. 1b

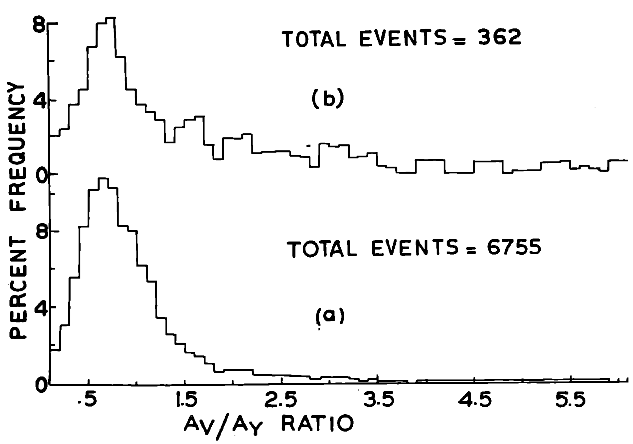

Fig. 2

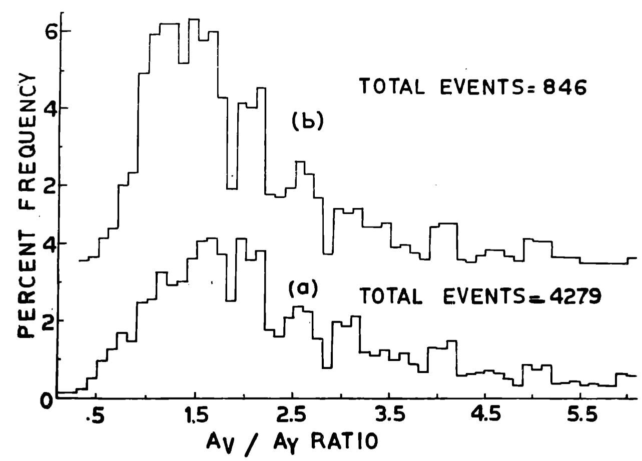

Fig. 3