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GAMMA-RAY OBSERVATIONS OF SN1987A

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ABSTRACT. We present gamma-ray observations of SN1987A in the energy range from 150 keV to 1 MeV carried out on June 19, 1988, on-board a stratospheric balloon with two NaI(Tl) detectors (600 cm^2 total area). The telescope incorporated a passive collimator and was mounted on a stabilized platform which allowed observations with a pointing accuracy of approximately 2^o in azimuth. The flight altitude was about 5.5 mb and the total observation time was 6 hours, divided between source and background. The 2 σ upper limits for the continuum are 2.45×10^{-5} and 5.42×10^{-6} photons cm^{-2} s^{-1} keV^{-1} in the 0.15 to 0.30 MeV and 0.30 to 1.00 MeV energy bands, respectively.

RESUMO. Apresentam-se observações da SN1987A na faixa de raios gama no intervalo de 150 keV a 1 MeV, feitas em 19 de junho de 1988 a bordo de um balão estratosférico utilizando-se dois detectores de NaI(Tl) (600 cm^2 de área total). O telescópio, provido de um colimador passivo, foi montado sobre uma plataforma estabilizada com precisão azimutal da ordem de 2^o. A altitude média do vôo foi de 5,5 mbar e o tempo total de observação foi de cerca de 6 horas, dividido entre a fonte e o ruído de fundo atmosférico. Os limites superiores (2 σ) para o contínuo são $2{,}45 \times 10^{-5}$ e $5{,}42 \times 10^{-6}$ fótons cm^{-2} s^{-1} keV^{-1} nas bandas de 0,15 a 0,30 MeV e de 0,30 a 1,00 MeV, respectivamente.

Key words: GAMMA-RAY — STARS-SUPERNOVAE

I. INTRODUCTION

The supernova SN1987A in the Large Magellanic Cloud is one of the major astrophysical events of this century. It was discovered on February 23, 1987 (Shelton 1987) and its progenitor is Sk -69 202, a blue supergiant with luminosity of $2\text{-}5 \times 10^{38}$ erg/s. It is an uncommon supernova: its progenitor was a blue supergiant about 3 magnitudes dimmer at optical maximum and its spectral evolution was quite faster than normal type II supernovae (Hillebrandt et al. 1987). This type of supernova is quite rare in irregular galaxies such as LMC, and perhaps its metallicity can explain the light curve. Calculations made by some authors (Woosley et al. 1987; Chan and Lingenfelter 1987; Pinto and Woosley 1988; Gehrels et al. 1988) indicate that the light curve in the optical maximum and thereafter has been powered by the energy liberated during radioactive decay of Co^{56}. SN1987A also made it possible for the first time to detect a non-solar neutrino emission from the explosion of a stellar object.

The MIR-KVANT observatory (Sunyaev et al. 1987) and the X-ray satellite GINGA (Dotani et al. 1987) reported, respectively in August and early September 1987, hard X-ray detection roughly coincident with the gamma-ray observation by SMM (Matz et al. 1988). Some balloon experiments (Sandie et al. 1988; Cook et al. 1988; Mahoney et al. 1988; Ubertini et al. 1989; Teegarden et al. 1989) have made measurements of gamma-ray lines and continuum. The currently accepted idea for the antecipation of the high energy emission is the mixing of Ni^{56} and Co^{56} in the outer hydrogen-rich layers by some kind of instability - probably a Rayleigh-

Taylor process (Pinto and Woosley 1988, and references therein). The experiments detected X and gamma-ray continuum, due to comptonization of line gamma rays, and the 847 keV and 1238 keV gamma rays from Co^{56} decay.

There is a strong possibility that a neutron star has been formed during the explosion. This hypothesis has gained great support with the confirmation of the neutrino observations and with the Kristian et al. (1989) reports on observation of submillisecond optical pulsations in January, 1989.

II. THE EXPERIMENT

The block diagram of the experiment is shown in Figure 1. The telescope employed two 8" diameter x 3" thick NaI (TI) crystals with approximate area of 600 cm^2. A 3 mm thick lead honeycomb structure in front of the crystals defined a field of view of 25° (FWHM) for incident photons from supernova below 500 keV. Additionally, the detectors were surrounded by similar lead shielding to prevent leakage of photons from the sides and bottom.

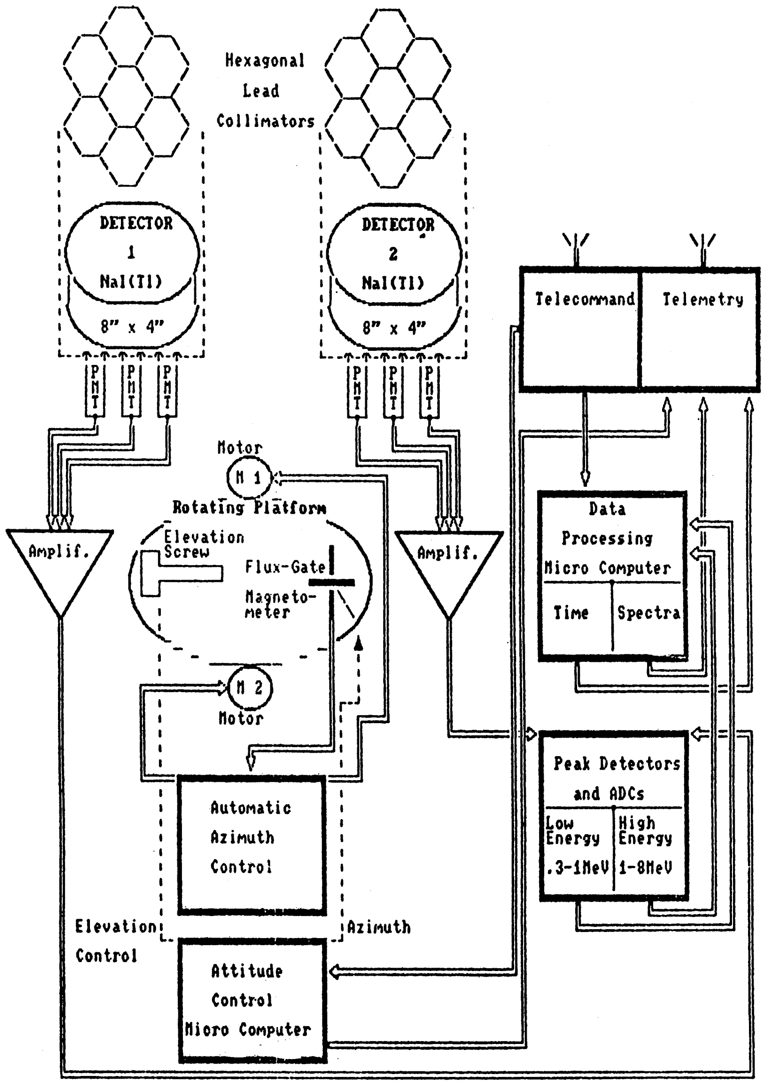

Fig. 1. Block diagram of the experiment.

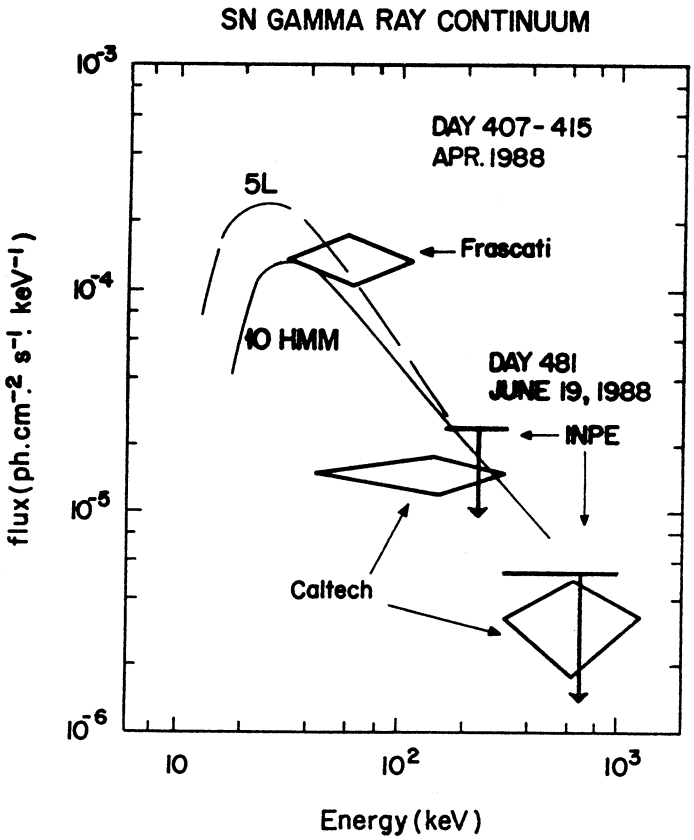

Fig. 2. Measurements of the gamma-ray continuum from SN1987A compared with models 10HMM and 5L (adapted from Gehrels et al. 1988).

The on-board data processing consisted of integral counts and spectral analysis. The energy loss events in the two crystals are separated into three nominal bands of 0.15 to 0.30 MeV, 0.30 to 1.00 MeV and 1.00 to 8.00 MeV to provide integral count rates. These permitted flux evaluation of the continuum and dead time correction of the pulse height analysers. The same events of each detector in these energy ranges were subjected to pulse height analysis by a pair of 256 channel analysers.

The detector system was mounted on an alt-azi platform with gimbal system to stabilize and orient the telescope axis in azimuthal direction with an accuracy better than 2°. The orientation was stabilized by a flux-gate magnetometer using the geomagnetic field. Two magnetometers provided the azimuthal direction calibration. The telescope zenith angle movements were performed by a mechanical lever. The flight program involved alternate viewing of the supernova and background by the telescope for periods of 24 minutes and 12 minutes respectively. An on-board microprocessor with command from ground controlled the view direction of the telescope both in azimuth and elevation.

The data of the experiment and housekeeping information were sent to ground by FM-FM telemetry system.

III. BALLOON FLIGHT AND RESULTS

The experiment was flown on June 19, 1988, from Birigüi (50° 20'W and 21° 20'S) at 10:15 UT and had a float of ~ 6 hours at an average altitude of ~ 5.5 mbar, with a stratospheric balloon of 80.000 m^3 capacity. This permitted ~ 4 hours of monitoring of supernova and 2 hours of background. The balloon flight trajectory was obtained by an OMEGA navigation system.

The post-flight data analysis involved in the first phase, balloon telescope attitude position by the use of magnetic sensor data, magnetic declination corrections and ground calibration. Once the attitude positions are ascertained, the relevant detector information was analysed for flux contribution due to Supernova and background. The results employed the two lower integral count rate bands comprising data between 150 keV to 1 MeV energy. The photon flux in these bands were corrected for efficiency, telescope response and atmospheric attenuation. For the analysis of Supernova contribution only portions of data with telescope response above 80% were employed. The low altitude of the balloon flight coupled with the high zenith angle of the supernova and lack of active anticoincidence, permitted us provide the upper limits for the flux of the SN1987A.

The observed 2σ upper limits for the continuum are 2.45×10^{-5} and 5.42×10^{-6} photons cm^{-2} s^{-1} keV^{-1} in the energy channels 0.15 to 0.3 MeV and 0.3 to 1.0 MeV respectively. In Figure 2, the upper limits for the supernova fluxes are shown along with the results obtained by Caltech (Cook et al. 1988) and Frascati (Ubertini et al. 1989) groups with experiments performed two months earlier. Our values are consistent with these experimental values and are in agreement with the spectral calculations based on 10HMM (Pinto and Woosley 1988a) and 5L (Pinto and Woosley 1988b) models of material mixing in ejecta.

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