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ИЗДАТЕЛЬСТВО АКАДЕМИИ НАУК ВЕНГРИИ

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The properties of Sco X-1 X-ray source have been studied in the energy interval 16—111 keV using balloon-borne X-ray detectors. The X-ray telescope consisted of a NaI(Tl) crystal with an area of 97.3 cm^2 and 4 mm thick surrounded by cylindrical active and passive collimators with a field of view of 18.6° FWHM. The telescope was mounted on an orienting platform with its axis at 31° to the zenith and it scanned an annulus in the sky in each rotation. The balloon flight was made from Hyderabad (lat. 17.6° N and long. 78.5° E) India, on April 16, 1969. The data obtained from this flight were combined with those from the earlier flights on April 28, 1968 and December 22, 1968 using the same instrument. It is found that in the energy interval 16—111 KeV, the spectrum can be represented either (i) by the exponential form $N(E)\mathrm{d}E = (K/E)e^{-E/E_0}\mathrm{d}E$ with $E_0 = 5$ keV, in the energy range 15—40 keV, and $E_0 \approx 30$ keV in the 40—110 keV range, or (ii) by a power spectrum of the form $N(E)\mathrm{d}E = C.E^{-\alpha}$, where $\alpha = 4.5 \pm 0.5$ over the entire energy range. The flux in the energy interval 16—47 keV was found to be almost steady for a period of one hour on April 16, 1969. The results from other X-ray sources will be presented later.

In this paper we present briefly the results of our observations of Sco X-1 X-ray source in the energy interval 16–111 keV. These observations were made with an X-ray telescope in a balloon flight on April 16, 1969 from Hyderabad, India (lat. 17.6° N, long. 78.5° E). The balloon which was launched at 0009 hrs (I.S.T.) on April 16, 1969 (1839 hrs U.T. April 15, 1969) reached the ceiling altitude of 4.5 g cm^{-2} of residual atmosphere at 0215 hrs and floated at nearly constant altitude of 4.5 ± 0.2 g cm^{-2} for 4.4 hrs until cut down at 0637 hrs. The analysis of the data obtained during one hour at ceiling altitude has been completed and is presented here. Further analysis is in progress and the results will be reported later. The data obtained in this flight have been compared with some of the results obtained in the earlier flights on April 28, 1968 and December 22, 1968 from the same location and using the same instrument, and some characteristic properties of the X-ray source have been studied.

The X-ray telescope consisted of a NaI(Tl) crystal of 97.3 cm^2 area and 4 mm thick coupled to a 5″ photomultiplier. The crystal was surrounded by both active and passive collimators. The active collimator was a cylindrical plastics scintillator and the passive collimator was composed of cylindrical shieldings of lead, tin and copper. The FWHM of the telescope was 18.6°. The pulses from the NaI crystal were sorted into nine continuous channels extending from 7–131 keV. All the information was recorded on photographic film. An Am^{241} source came in the field of view of the telescope once in every 15 min for about 30 sec and provided in-flight calibration of the detector at 16.5 and 59.8 keV. It was found that the detector performance remained steady during the entire period of the balloon flight.

The axis of the telescope was kept inclined at a fixed angle of 31° to the zenith and the telescope was mounted on an oriented platform. The orienter had been programmed to look at 18 successive azimuths separated by 20°, for a period of 1 min in each position, so that the entire 360° of azimuth was to be covered in a cycle of 18 min and the procedure repeated during the period of the balloon flight. However, owing to the malfunction of a relay, the driving motor rotated the telescope in azimuth at nearly uniform speed during the entire flight instead of orienting it in specified directions. A pair of crossed flux gate magnetometers provided the information on the aspect of the telescope continuously. Also the aspect information in digitized form was available once in 8.2 sec. Therefore, the data for the entire flight period can be analysed satisfactorily.

The entire instrument including the orienting platform was enclosed in a pressurised aluminium gondola having a top thickness of 0.22 g cm^{-2}.

Sco X-1

The data of Sco X-1 obtained from 0254 hrs to 0353 hrs I.S.T. on April 16, 1969 is reported here. The meridian transit of Sco X-1 on that day was at 0254 hrs I.S.T. at a zenith angle of 32° and the efficiency of the telescope for Sco X-1 at this time was as high as 95%. The angle between Sco X-1 and the telescope axis was computed taking into account the drift of the balloon in longitude, and the efficiency of the telescope for Sco X-1 was calculated during this one hour period of observation. It was found that Sco X-1 was in the field of view of the telescope for 23% of the time and the effective exposure time of Sco X-1 with 100% efficiency was 341 sec. The background counting rate was obtained from the counts collected during the time

Table 1

Energy spectrum and intensity of Sco X-1 on April 16, 1969

Energy band (keV)	Mean energy (keV)	Excess counts	Equivalent exposure at 100% efficiency (sec)	Attenuation factor*	Flux	
					Photons/cm² sec keV	KeV/cm² sec keV
16— 25.5	20.75	198± 56	341	55.6	$(3.49\pm1.10)\times10^{-2}$	$(7.25\pm2.04)\times10^{-1}$
25.5— 37.0	31.3	294± 70	341	5.72	$(4.59\pm1.10)\times10^{-3}$	$(1.44\pm0.34)\times10^{-1}$
37.0— 47.0	42.0	112± 64	341	3.43	$(1.16\pm0.66)\times10^{-3}$	$(4.87\pm2.76)\times10^{-2}$
47.0— 67.5	57.3	157± 89	341	2.82	$(6.54\pm3.70)\times10^{-4}$	$(3.75\pm2.12)\times10^{-2}$
67.5—111.0	90.3	67±137	341	2.35	$(1.10\pm2.24)\times10^{-4}$	$(9.93\pm20.3)\times10^{-3}$

* This includes the attenuation in 0.22 g cm^{-2} of aluminium in the gondola and in the atmospheric thickness along the telescope axis.

when no known sources were in the field of view of the telescope. The excess counts due to Sco X-1 were obtained by subtracting background counting rate measured during the same period of observation. The relevant data are summarised in Table 1, showing the fluxes of Sco X-1 in six energy bands extending from 16 to 111 keV. It is seen that a positive signal from Sco X-1 is obtained in all the energy bands.

The fluxes shown in Table 1 are uncorrected for escape probability of iodine K X-rays and also for efficiency and resolution of the detector. This correction for our detector is small and amounts to about 10%, as calculated for our earlier flight data. The correction will be taken into account in the final analysis of the data.

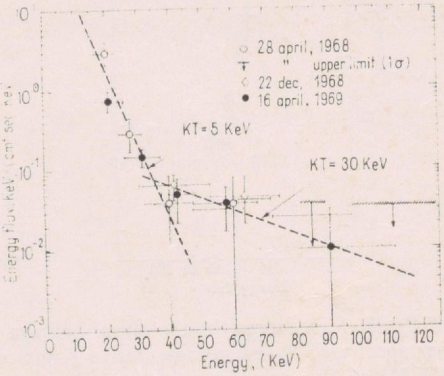

Fig. 1. Energy spectrum of Sco X-1 measured in three balloon flights from Hyderabad, India on April 28, 1968, December 22, 1968 and April 16, 1969. The lines corresponding to exponential spectra with $E_0 = 5$ keV and $E_0 = 30$ keV are shown for comparison

The energy fluxes of Sco X-1 measured in energy interval 16–111 keV on April 16, 1969 are plotted in Fig. 1. In the same figure we have shown the data obtained by us with the same detector on April 28, 1968 and on December 22, 1968 during the period of steady flux [1]. The intensities measured during these three periods are in good agreement with one another. It is seen in Fig. 1 that the spectrum of Sco X-1, if represented by an exponential spectrum of the form $N(E)\mathrm{d}E = (K/E)\mathrm{e}^{-E/E_0}\,\mathrm{d}E$ cannot be represented by a single value of E_0 in the entire energy interval of 16–110 keV. In the energy interval 15–40 KeV, E_0 is 5 keV. This corresponds to the temperature $T = 5.8 \times 10^7$ °K if the emission is due to thin hot plasma. In the high energy interval of 45–110 keV range, the value of E_0 is much larger, ~30 keV, and the corresponding temperature would be much higher. Similar results were obtained recently by Buselli et al. [2]. We expect to determine the intensity at 90 keV more precisely when the analysis of all the data of the April 16, 1969 flight is completed and this should enable us to determine the value of E_0 more accurately for the high energy range.

In Fig. 2 we have plotted our data of *photon fluxes* in log-log scale. This shows that the spectrum of Sco X-1 in the energy interval 15–110 keV can be represented by a power law spectrum $N(E) \sim E^{-\alpha}$, where $\alpha = 4.5 \pm 0.5$. For comparison the fluxes measured in the energy range 2–15 keV by Chodil et al. [3] and Bradt et al. [4]

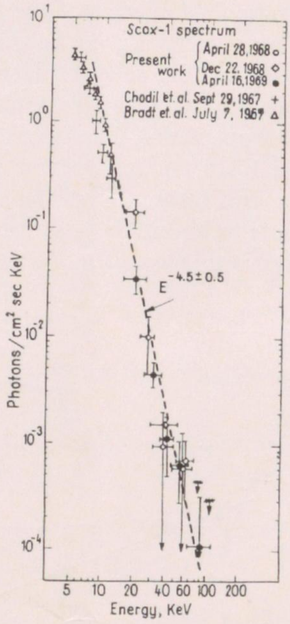

Fig. 2. Photon spectrum of Sco X-1 measured in the three balloon flights from Hyderabad plotted in the form of power spectrum. A few representative points of CHODIL et al. [3] and BRADT et al. [4] at low energies are shown for comparison

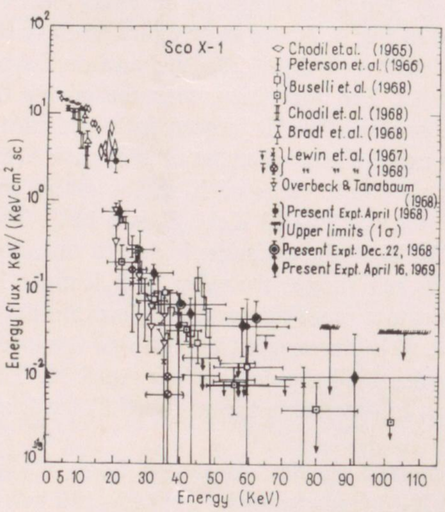

Fig. 3. X-ray intensities of Sco X-1 measured in the three balloon flights from Hyderabad together with available spectral information on Sco X-1

are shown in Fig. 2. It is seen that it may be possible to fit a single power law spectrum for Sco X-1 in the energy range 8 – 110 keV. At lower energies, however, the rocket results indicate a flatter spectrum.

A comparison of the data obtained by us in three balloon flights, with the available spectral data on Sco X-1 is shown in Fig. 3. It is seen that although there is general agreement, the absolute fluxes at a given energy interval may differ by a factor of 2 – 3, indicating the possible time variation of Sco X-1 intensity [1 – 8].

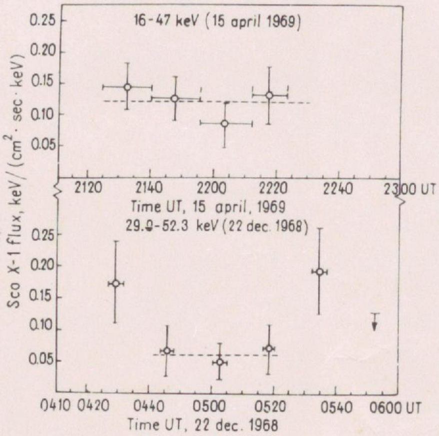

Fig. 4. Time variation of the intensity of Sco X-1 in 16—47 keV band on April 16, 1969 and 30—52 keV band on December 22, 1968

In order to study whether there was any short term variation of intensity of Sco X-1, we have plotted in Fig. 4 the Sco X-1 intensity in the energy band 16 – 47 keV as a function of time for the first one hour of observation. It is seen that the intensity in this band remained essentially the same during this period. For comparison we have shown the intensity changes measured on December 22, 1968 [5], when there was a drop of the intensity by a factor of 3 during a period of 15 min to a steady level lasting for about 45 min followed by sharp rise by a factor of 3 and a decrease again.

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