SIGMA OBSERVATIONS OF THE GALACTIC CENTRE

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ABSTRACT

After the first year of performance of SIGMA, more than 390 hours of data on the Galactic Centre region have been recorded. This survey establishes the extremely variable nature of this region. During a period of 6 months, 3 sources have dominated successively: 1E 1740.7-2942, GRS 1758-258, GX1+4. Concerning the two first sources, their spectral shape and their variability suggest to include them in the list of the black hole candidates.

1. INTRODUCTION

The idea of a massive black hole in the Galactic Center (GC), was supported by the presence of the compact radio source Sgr A*, the kinematics of the nearby neutral gas, and the detection, during the 70-80 th, of a gamma-ray continuum emission with a power law spectrum similar to AGN's spectra [1]. The discovery, near the GC, of a time-variable 511 keV electron-positron annihilation radiation, appeared as an additional black hole argument [2]. But in contrast with the X-ray band (between 1 and 30 keV), where many sources have been identified in the GC region [3], earlier observations in the gamma-ray domain, with poor angular resolution, have assembled a confused picture. The location and the nature of gamma-ray sources, especially the 511 keV source, were ambiguous.

2. OBSERVATIONS

SIGMA is a French coded-aperture telescope on board the Soviet GRANAT space observatory, sensitive to radiation at energies from 35 keV to 1.3 MeV. The instrument features a Uniformly Redundant Array mask and a NaI scintillation camera to image a 4.7° x 4.3° full sensitivity field of view with ~ 15'-20' angular resolution (partial modulation is recorded from a much wider field of view whose total width is 11.5°x 10.9° at 50% sensitivity) [4].

During the first year of performance, 26 observations pointed towards the GC have been performed. Up to now, from the 390 hours of recorded data, 5 sources have been clearly

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detected: the Einstein source 1E 1740.7-2942 [5], the newly discovered source GRS 1758-258 [6], the globular cluster Terzan 2 [7], the pulsar GX1 + 4 [8], and the transient source KS1731-258 [9]. The most surprising result obtained from the SIGMA images is the strong variability of the GC region. As shown in Fig.1 three sources have successively dominated this region.

The first image recorded in Spring, 1990, shows a strong source identified with 1E 1740.7-2942 and a newly discovered weaker source called GRS 1758-258. Observations of September-October, 1990, confirmed this state: 1E 1740.7-2942 and GRS 1758-258 have been in spring and fall 1990 the only permanent galactic center sources detected.

The second image, recorded in February, 1991, shows the surprising *disappearance of the Einstein source.* The region is dominated by GRS 1758-258.

In the third image, recorded in April, 1991, the brightest source is now GX1 + 4. 1E 1740.7-2942 is still below the SIGMA detection limit and GRS 1758-258 is detected at the same flux level as the flux detected in spring and fall 1990. Note that no bright emission is detected from the dynamic centre of the Galaxy.

It is clear now that in a region of $10^{\circ} \times 10^{\circ}$, centered on the GC, sources are extremely variable. A spectrum integrated on this region during fall 1990 is not comparable with a spectrum of the same region integrated during winter 1991, for the simple reason that recorded photons have not the same origin. Thanks to the coded aperture technique we are able to identify and to study each of these sources separately. Two of them are singled out for original behavior: 1E 1740.7-2942 and GRS 1758-258.

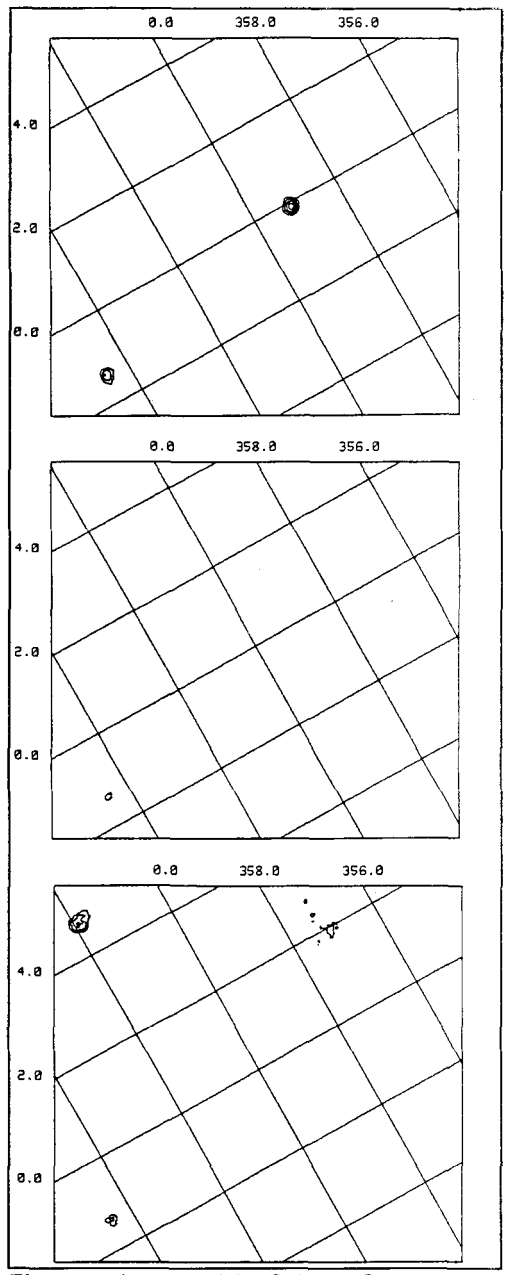

Figure 1: Images of the Galactic Centre region from 40 to 110 keV. From top to bottom: Spring 90, Winter 91, Spring 91. Contour levels are drawn every 0.10 cts/s starting at 0.25.

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3. UNUSUAL SOFT GAMMA-RAY SOURCES: 1E 1740.7-2942 and GRS 1758-258

GRS 1758-258 is a new source detected by SIGMA in the 35-120 keV energy band at the level of 10 standard deviations, while no hard radiation was detected from GX5-1. G.Skinner reexamined the data from the Spacelab2 coded mask telescope (XRT), from the TTM coded mask telescope on board MIR-KVANT and from EXOSAT and has found the presence of the source in all three cases [10]. The position of the source in all these experiments agree well with our position and is: alpha = 269.525° and delta = -25.747° in 1950.0 coordinates (90% error circle radius: 0.75 arcmin). Due to the proximity of GRS 1758-258 to GX5-1 (separated by 40'), the observations of GX5-1 in soft gamma-rays with collimated instruments, most probably measured the hard emission from GRS 1758-258.

The light curve of GRS 1758-258 is shown in Fig 2. The source flux appears stable during spring and fall 1990, but a decrease of 10% is observed during the winter 1991. The mean spectrum over the year is better fitted by a comptonized disk model [11] than by a simple power law, with a temperature of the disk kT = 37 (28:54) keV, a Thomson optical depth $\tau = 1.4$ (0.8:2.3), and the flux at 100 keV $F_{100} = 4.4\ (4.0{:}4.9).10^{-5}$ ph/s/cm^2/keV. Contrary to usual X-ray sources, the GRS spectrum is very weak in the X-ray domain, probably due to absorption, and becomes one of the strongest of the Galaxy in the Sigma domain.

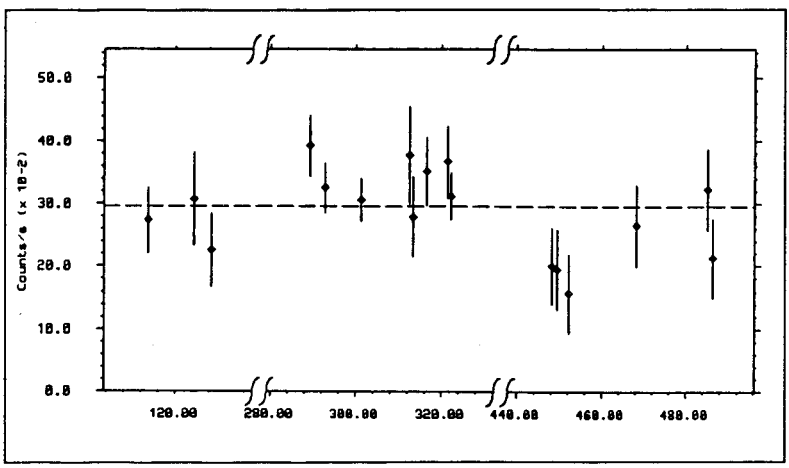

Figure 2: Light curve of GRS 1758-258 from 40 to 110 keV. The days are represented in Julian day - 2447862 (date of the launch).

The light curve of 1E 1740.7-2942 is shown in Fig 3. During spring and fall 1990, the Einstein source was the brightest source of the GC region in the soft gamma ray domain and its luminosity and spectral shape were nearly constant. The averaged spectrum collected during these observations shows clearly a steepening above 150 keV and is better fitted by a comptonized disk model [11] than by a simple power law, with a temperature of the disk kT = 45 (34:76) keV, a Thomson optical depth $\tau = 1.1$ (0.5:1.7), and a flux at 100 keV $F_{100} = 6.7\ (6.0{:}7.4).10^{-5}$ ph/s/cm^2/keV. This "standard state" spectrum is very similar to the Cyg X-1 spectrum recorded by SIGMA in 1990 [12]. Assuming that the Einstein source is at the distance of the GC (8.5 kpc), the brightness of both sources in their "standard state" are

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remarkably close at 2-4 10^{37} ergs/s.

On October, 13-14, 1990 (arrow in Fig 3), SIGMA detected a hardening of the 1E 1740.7-2942 spectrum. During all this session (4.5 10^4s useful time), the source spectrum was found to exhibit a spectacular unexpected structure, above 200 keV up to 700 keV [13]. The total duration of this feature can be estimated between a minimum of 18 hours and a maximum of 70 hours. These values limit the dimension of the source to few a 10^{15}cm. Note that in comparison with the "standard state", the 40-200 keV luminosity didn't decrease. It seems then unlikely, that such a change was related to redistribution of the released energy over the spectrum, as observed for Cyg X-1 during transition between gamma1 and gamma3 states. On the other hand this strong bump may be related to electron-positron annihilation. If we suppose that the observed spectrum is the sum of the "standard state" spectrum and a gaussian feature, the following parameters are obtained: center at 404 (370:530) keV and width (FWHM) 101 (23:350) keV. The relation of 1E 1740.7-2942 with the variable narrow 511 keV line observed toward the GC by the collimated experiments is still unclear. The feature observed by SIGMA is much broader, at lower energy, and lasted at most a few days while the narrow 511 keV line was observed during several years. However, 1E 1742.7-2942 remains the best candidate for identification of this line, since it is the only source detected above 300 keV near the GC.

The last set of observations performed in February-March 1991 [14], revealed that the source entered a low state with a luminosity at the level of 20-25% of the averaged luminosity observed in the "standard state". Clearly, we are faced with a new long-term low-state of the source.

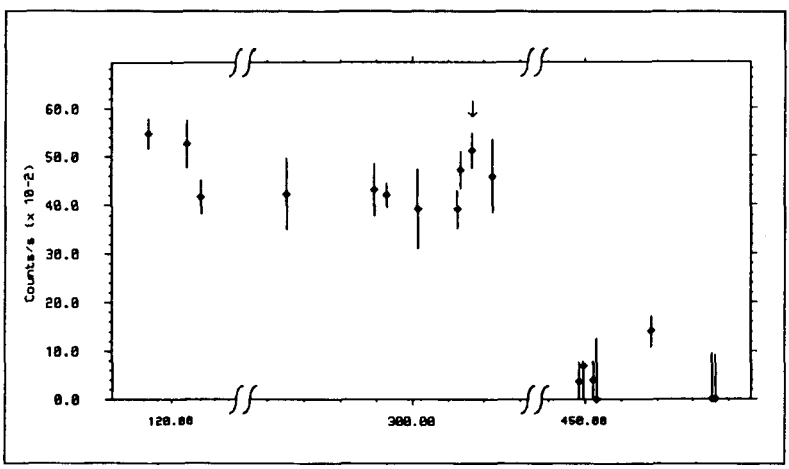

Figure 3: Light curve of 1E 1740.7-2942 from 40 to 110 keV. The days are represented in Julian day - 2447862 (date of the launch).

Both sources 1E 1740.7-2942 and GRS 1758-258 present similar characteristics: variabilities; a low X-ray flux; and a high energy tail. The flux variability seems to indicate that these sources are more likely accreting objects than Crab-like sources. The presence of a high energy tail is well explained in the framework of Comptonized model with a high temperature of electron plasma [11]. Heating of the plasma is due to accretion and cooling to comptonization by X-ray photons. The presence of a neutron star, instead of a blackhole, does

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not allow the electron plasma to reach high temperatures, as soft photons reradiated by the neutron star surface increase the cooling term [15]. In consequence no high energy tail is expected. Thus spectral shape of these two sources could be the signature of accreting black holes.

4. CONCLUSION

In the soft gamma-ray regime, the emission of the galactic centre is strongly variable. Between fall 1990 and winter 1991, 3 sources have successively dominated this region: 1E 1740.7-2942, GRS 1758-258, GX1+4.

Concerning the source 1E 1740.7-2942: the shape of the spectrum in its "normal state" is similar to the spectrum of Cyg X-1. The strong variability of the source flux indicates that this is more likely an acreting object than a Crab-like source. The discovery of a strong bump in the spectrum at high energies, probably related to electron positron annihilation, implies that this source is a candidate for identification of the narrow 511 keV line.

Concerning the source GRS1758-258: the shape of the mean spectrum is also similar to the spectrum of Cyg X-1 and this source seems to be also variable.

These last remarks suggest to include these two sources in the list of galactic black hole candidates.

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