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X–ray Observations of the Galactic Center with BeppoSAX

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Abstract

We report the results of imaging observations of the Galactic Center region obtained with the $BeppoSAX$ satellite in the ∼1-10 keV energy range. The total flux from within $\sim 2'$ from the Galactic Center corresponds to a luminosity of ∼3x10^{35} erg s^{-1}, but only about one third of this luminosity can be ascribed to Sagittarius A*, the non-thermal radio source at the dynamical center of our Galaxy. The spectrum of the diffuse emission requires a multi-temperature plasma. The softer component (kT∼0.5 keV) has a spatial distribution well correlated with the radio halo of the SgrA East shell.

1 Introduction

The region of the Galactic Center (GC) has been surveyed with several pointings of the $BeppoSAX$ MECS instrument performed in the period 1996–1998. The MECS (Boella et al. 1997) provides good imaging and spectral capabilities in the 1.3-10 keV range (angular resolution $\sim 1.2'$ at 6 keV, field of view $\sim 28'$ radius). The regular point response function of the $BeppoSAX$ grazing incidence X–ray mirrors allows an accurate analysis of the spatial morphology of this complex sky region and reduces the problem of stray light contamination from strong sources outside the field of view. This is particularly important since previous high energy observations (see, e.g., Skinner et al. 1987; Predehl & Trumper, 1994; Pavlinsky, Grebenev & Sunyaev 1994) have shown that this region of sky is particularly crowded: besides the X–ray source at the position of SgrA* (the non-thermal radio source which is believed to mark the dynamical center of our Galaxy), several bright point sources (mostly accreting binaries) are present, as well as diffuse emission extending mainly in the direction of the Galactic Plane. As shown in Fig.1, several bright X–ray sources ($L_X \gtrsim 10^{36}$ ergs s^{-1}) have been detected by $BeppoSAX$, including some recently discovered transients,

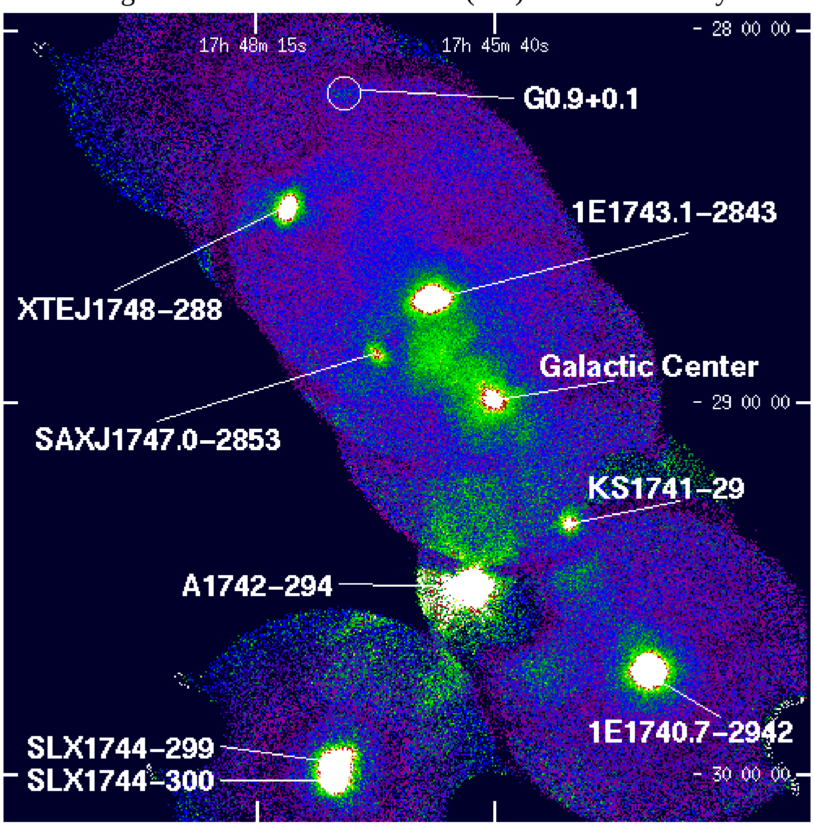

Figure 1: Exposure corrected mosaic of the MECS images of the Galactic Center region. The Galactic plane runs from top-left to bottom-right.

such as SAX J1747.0–2853 (Sidoli et al. 1998) and XTE J1748–288 (Smith et al. 1998). The properties of most of these objects are similar to those of the well known accretion powered sources found elsewhere in the Galaxy, indicating that they consist of neutron stars and black holes accreting in binary systems. A detailed account of the data analysis and results on these sources is reported by Sidoli et al. (1999).

Two fainter sources, G0.9+0.1 and G359.23–0.92 are likely associated to young, isolated neutron stars. G0.9+0.1 is a radio supernova remnant with a plerionic morphology. X–ray emission from its central part was detected with a luminosity of $\sim 10^{35}$ erg s^{-1} (Mereghetti et al. 1998). The radio source G359.23–0.92, also known as "the Mouse", belongs to the small class of radio nebulae with an axially symmetric shape which are probably formed by relativistic particles ejected from a compact object moving at high speed trough the interstellar medium. Despite being located at only $\sim 2'$ from the much brighter source SLX 1744–299, it has been detected by the MECS up to energies above 6 keV. This supports a non-thermal origin for its X–ray emission, first discovered at lower energies with ROSAT (Predehl & Kulkarni 1995).

2 The Diffuse Emission

We concentrate here on the diffuse emission from the region within $\sim 8'$ from SgrA* observed during a 100 ks long pointing performed in August 1997. This corresponds to the central part of the MECS field of view, where the spectral calibration and angular resolution of the instrument are at their best values. The emission from this region is characterized by the presence of strong emission lines, with the K-lines from iron (∼6.7 keV) and sulfur (∼2.4 keV) particularly bright. In Fig. 2 we show the surface brightness and temperature radial profiles, obtained by fitting with a single temperature thermal plasma model the counts in four concentric annular regions around the GC. Altough this spectral model cannot account for all the observed lines, it gives a reasonable description of the continuum allowing to detect a clear spectral variation: while the $\sim$ 7 keV temperature in the three external regions is almost constant, the central emission has a significantly softer emission. This can be ascribed to the presence of one (or more) point source(s) at the position of SgrA*. Based on this result, we have then analyzed the spectrum of the whole region from $2'$ to $8'$, excluding only the central part. A single temperature model is unable to reproduce all the observed features. A better fit is obtained with the sum of two thermal emission plasma models (two "MEKAL" in XSPEC), yielding $T_1 \sim 0.5$ keV and $T_2 \sim 7$ keV. In addition, a gaussian line at 6.4 keV (EW∼120 eV) is also required (see Fig. 3).

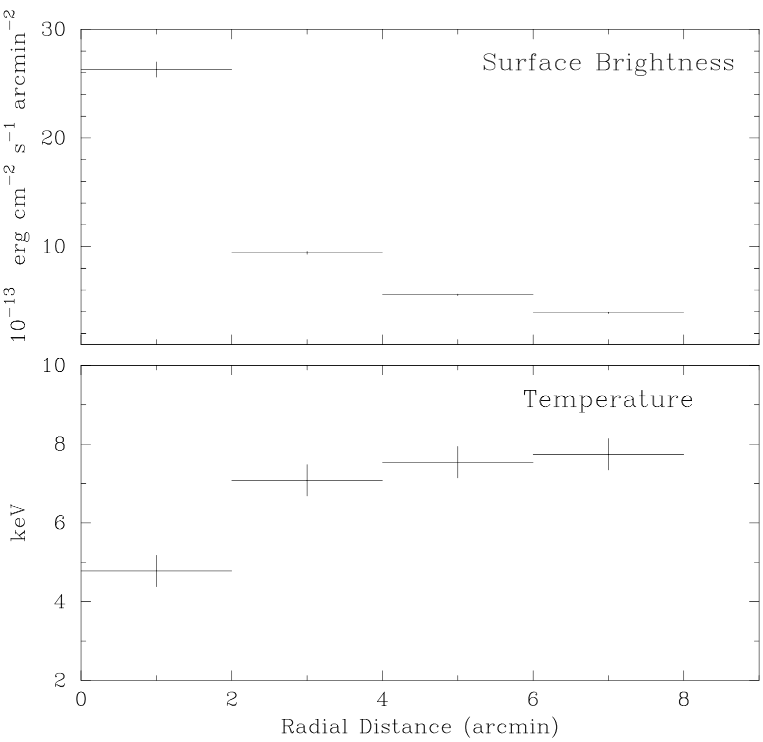

Figure 2: Surface brightness (top) and temperature (bottom) of the diffuse emission as a function of the distance from the Galactic Center.

To study the spatial distribution of the diffuse emission, we extracted images in two different energy bands. The soft (2–5 keV) and hard X-ray (5–10 keV) images show significantly different morphologies (Fig. 4). While the harder emission is boxy–shaped with the major axis oriented along the galactic plane, the softer one has a triangular shape, remarkably well correlated with the non–thermal radio emission coming from the $\sim 7'$ halo that surrounds Sgr A East (Pedlar et al. 1989). The total energy in relativistic particles estimated from

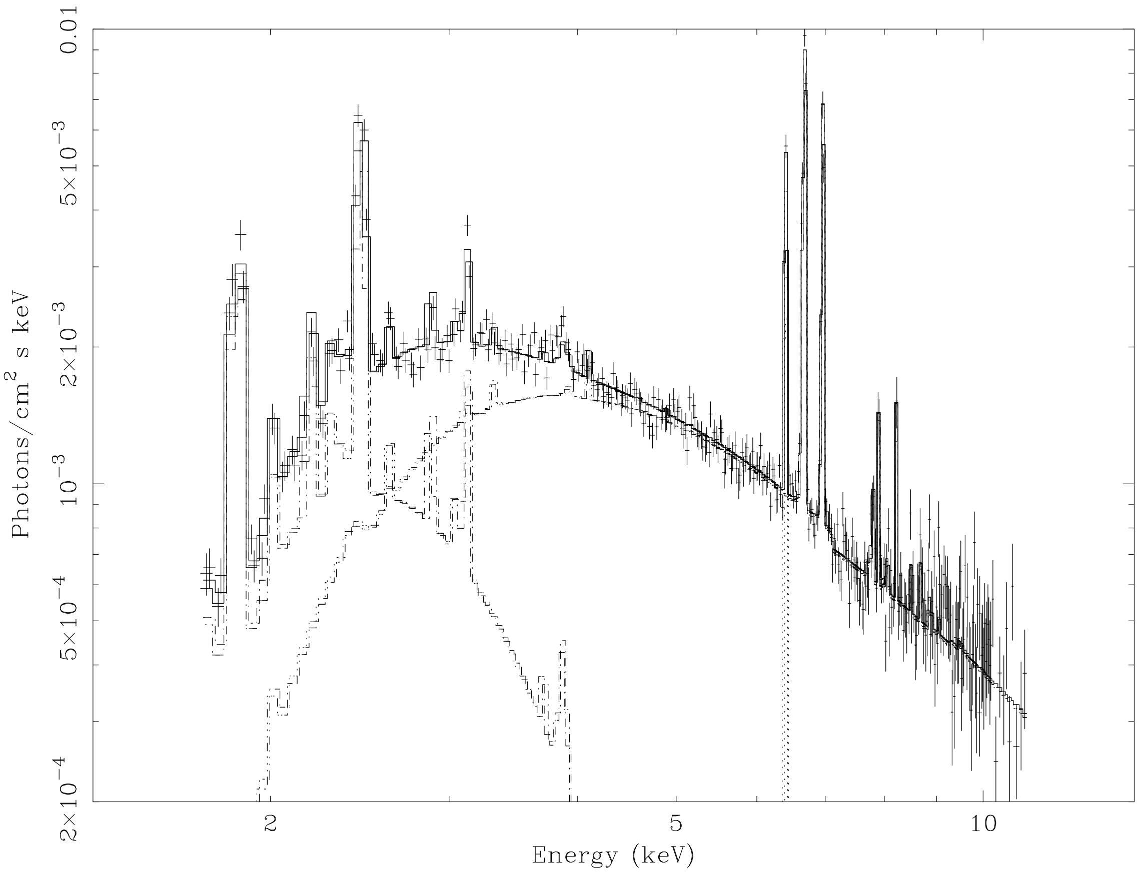

Figure 3: Spectrum of the diffuse emission fitted with two thermal models (kT$_1$ ~ 0.5 keV and ~ 7 keV).

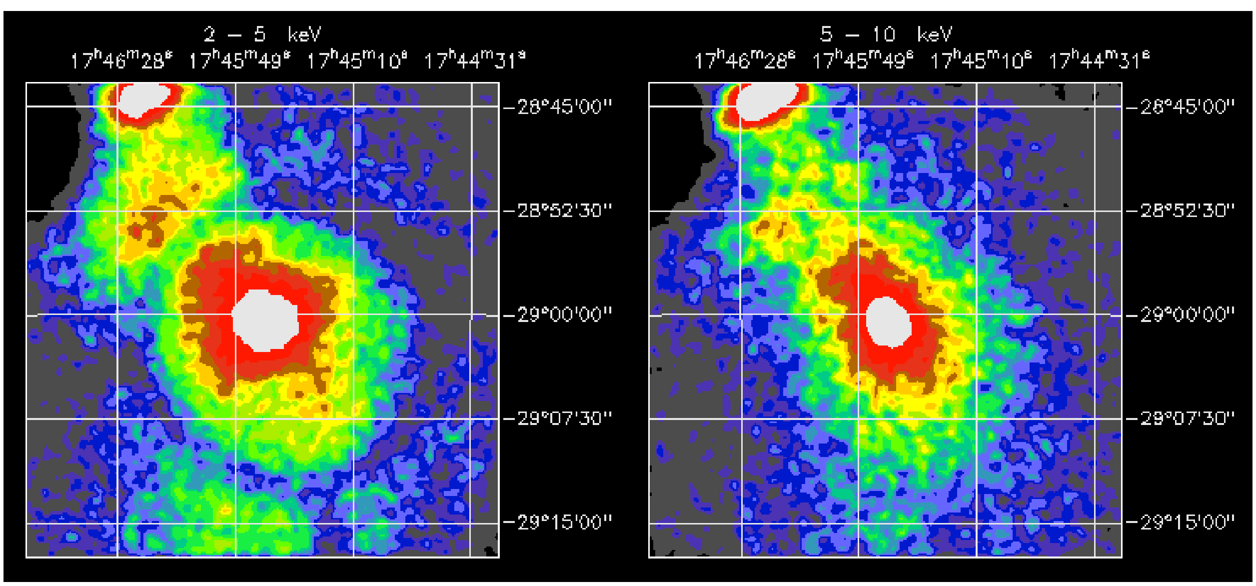

Figure 4: Images of the Galactic Center in the 2-5 keV (left) and 5-10 keV (right) energy ranges. The strong source North-East of SgrA is 1E 1743.1–2843 (Cremonesi et al. 1999). Note that the circular structure with diameter $\sim 16'$ is an artifact caused by absorption in the support ribs of the detector window.

radio observations is about $5{\times}10^{50}$ ergs s^{-1} (Pedlar et al. 1989). This value, together with the non-thermal radio spectrum and the size of $\sim$20 pc, suggests that this halo could be an evolved supernova remnant. A simple interpretation of the X–ray data could be the following: while the hard component is due to hot gas distributed along the galactic plane, the halo of SgrA East is responsible for the lower temperature plasma ($L_x \sim 5 \times 10^{35}$ ergs s^{-1}).

3 The X–ray luminosity of the Galactic Center

The presence of a supermassive black hole at the GC is supported by the studies of the mass distribution and dynamics of IR stars and streams of ionized gas seen in the radio band (Eckart & Genzel 1997). Quite surprisingly, little or no signs of activity are seen at X-ray and gamma-ray energies (Sunyaev et al. 1991, Goldwurm et al. 1994). An X-ray source consistent in position with Sgr A* has been detected practically in all the previous imaging observations, however the presence of at least four sources (Predehl & Trumper 1994, Maeda et al. 1996), and possibly more (see Sidoli et al. 1999 for details) within less than $2'$ of SgrA* makes the picture unclear. It is difficult to derive an accurate measurement of the X–ray luminosity to be ascribed to SgrA* itself, in the lack of an adequate spatial resolution. In addition, the presence of diffuse emission with a poorly known spatial distribution introduces a further complication in the background estimate. We can place a very conservative upper limit of $\sim 3 \times 10^{35}$ ergs s^{-1} to the 2–10 keV luminosity of SgrA* (corrected for the absorption, for d=8.5 kpc). This is based on the assumption that SgrA* is the only point source and that the diffuse emission at its position has the same surface brightness as measured in a concentric annular region (radius from $6'$ to $8'$). However, this is probably an overestimate of the true luminosity of SgrA* for the fact that the diffuse emission has a surface brightness distribution that increases toward the GC (see Fig. 2) and because there might be a contribution from the other point sources. A more realistic upper limit to the SgrA* luminosity can be placed if we estimate the diffuse emission at its position by estrapolating the surface brightness from the three annular regions of Fig. 2. In this case we find a luminosity of $\sim 10^{35}$ ergs s^{-1}, similar to the value obtained with ASCA (Koyama et al. 1996, Maeda et al., 1998). In any case the luminosity of SgrA* is well below the Eddington luminosity for a super–massive black hole.

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