High Energy Emission from the Galactic Center

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Abstract. The Center of our Galaxy has been observed with high energy instruments since the very beginning of the X-ray and gamma-ray astronomy space programs to search for the high energy radiation from the nearest super-massive black hole, now associated to the peculiar radio source Sgr A\textsuperscript{*}. In the recent years, with the launch of Chandra, XMM-Newton and INTEGRAL and with the start of the operations of the ground-based VHE observatory HESS, this quest has led to some fundamental discoveries with the detection of flaring activity from Sgr A\textsuperscript{*} and of several other high energy point-like and diffuse sources in the region. I will review, after an introductory summary of historical developments, the recent results in the field with particular attention to the findings related to Sgr A\textsuperscript{*} and the observations of the INTEGRAL observatory.

1. Introduction

The Galactic Center (GC) is a very dense and complex sky region of approximately 600 pc size (∼4° in projection) where a number of interesting high-energy phenomena take place. Located at about 8 kpc distance it hosts the nearest super massive black hole (SMBH) to the sun, surrounded by a variety of objects that interact with each other. The high energy processes generated in this extreme environment are possibly common to other galactic nuclei, and therefore, given its proximity, it represents a unique laboratory for modern astronomy. Totally obscured in the optical wavelengths by the Galactic plane dust, the GC is mainly observed from radio to infrared (IR) and again at high energies. Some important results have been recently obtained with the new generation of X-ray and gamma-ray observatories: Chandra, XMM-Newton, INTEGRAL and HESS. After a short introduction on the characteristics of the Galactic Center (see also [42, 43, 27, 41]) I will review the historical developments of high energy observations of this peculiar region and will summarize some of the recent results.

The radio images of the GC obtained with the VLA at 90 cm [32] show all the complexity of the central few square degrees of the Milky Way (Fig. 1). This region indeed contains ∼10% of the galactic interstellar molecular gas, concentrated in the dense giant molecular clouds (MC) like Sgr B, Sgr C and those of the Sgr A radio and molecular complex. Shell-like supernova remnants (SNR) (e.g. G 359.1-005) heat the interstellar matter with their expanding shells which in some cases appear to be interacting with the molecular clouds. While several other non-thermal filaments demonstrate the presence of accelerated particles spiraling the strong (∼1 mG) magnetic fields of the region (like the large structure known as the radio arc), other structures have thermal radio spectra and are in fact HII regions ionized by close-by, hot, and young star clusters. The central 30 pc are dominated by the Sgr A complex, formed by a few MCs (M-0.02-0.07, M-0.13-0.06) an expanding SNR, Sgr A East, and a central HII region...
surrounding the bright compact radio source Sgr A\(^*\), the radio manifestation of the central SMBH. Sgr A East is a non-thermal radio source composed of diffuse emission of triangular shape and an inner oval shell (3\(^{\prime}\) \times 4\(^{\prime}\), or 7 pc \times 9 pc) centered about 50\(^{\prime}\) (\(\approx 2\) pc) west of Sgr A\(^*\). The shell appears to be expanding, compressing the molecular cloud M-0.02-0.07 and probably creating the string of 4 HII regions and the OH masers observed around the shell. The first estimates of shell energy were well above the typical release of a SN, and it was proposed that Sgr A East was the result of 40 SN or of the explosive tidal disruption of a star by the SMBH. In the inner regions, a molecular ring rotates rapidly around the compact source Sgr A\(^*\), and appears to join onto a thermal diffuse nebula, Sgr A West, with the characteristic shape of a minispiral that is also centered on Sgr A\(^*\). Sgr A West is ionized by a cluster of hot young and massive stars, centered at about 2\(^{\prime}\) from Sgr A\(^*\) and known as the IRS 16 cluster. Some of these stars emit powerful stellar winds which interact with the surrounding medium and must feed the SMBH.

While the dynamics of matter at radial distances > 2 pc are dominated by the central core of the Galactic Bulge star cluster, the large velocities of gas and stars observed in the innermost regions imply the presence of a massive black hole. Adaptive optics NIR measurements of the velocities and proper motions of the brightest and closest stars to Sgr A\(^*\) (the so called "central star cluster"), made with the NTT, the VLT and the Keck over the last 10-15 yr, have provided precise orbital parameters for several of them [57, 20, 24]). The derived parameters imply the presence of a dark mass of 3-4 \(10^6\) M\(_{\odot}\) enclosed within a radius < 100 AU. Only a SMBH can explain such densities. The dynamical center of the central star cluster is coincident (within 10 mas) with the bright (\(\approx 1\) Jy), compact, variable, synchrotron (flat power law spectrum) radio source Sgr A\(^*\). Since its discovery 30 years ago [7], it has been considered the counterpart of the massive black hole of the Galaxy. The source is linearly polarized at sub-mm frequencies, where the spectrum also presents a bump indicating that the emission becomes optically thin. The proper motion of Sgr A\(^*\) is < 20 km s\(^{-1}\) and its size, measured at frequencies of 3 mm where the interstellar scattering is small, is of the order of 0.1-0.3 mas, about 15-20 R\(_{S}\), where R\(_{S}\) = \(\frac{2GM}{c^2}\) \(\approx 10^{12}\) cm = 0.06 AU is the Schwarzschild radius for a 3.5 \(10^6\) M\(_{\odot}\) BH.

![Figure 1. The VLA radio image (2.5\(^{\circ}\) \times 1.5\(^{\circ}\)) at 90 cm of the Galactic Center region, in galactic coordinates with grid lines separated by 0.5\(^{\circ}\) and the 20-40 keV INTEGRAL/IBIS contours (see Fig. 4) [10].](image-url)
2. The quest for the high energy emission from Sgr A*

The first detections of high energy emission from the GC direction obtained in the 1970-1980 seemed to support the presence of a SMBH at the center of the Milky Way, predicted first by Lynden Bell and Rees in 1971 [36] and suggested by the discovery of Sgr A* of Balick and Brown in 1974 [7]. However as the resolution and sensitivity of the high energy telescopes improved it was realized that the Galactic SMBH itself was actually very weak. Proctor et al. (1978) [53] presented the picture of the known X-ray emission from the GC at the eve of the launch of the HEAO II satellite, the Einstein Observatory. The Galactic Center X-ray source (GCX-1) detected by Uhuru in 1970 was already attributed to a composition of several sources, some of which variables, but whose positions were known with error boxes of typical sizes of 0.1° - 0.5°.

The first soft X-ray (< 4 keV) images with arcmin resolution were obtained only with the Einstein observatory in 1979 [60] and showed that the central 20' of the Galaxy were dominated by diffuse emission and several weak point-like sources one of which associated to the Sgr A* complex. The latter was resolved in 3 weaker sources with Rosat [52] and this set an upper limit of only 10^{34} erg s^{-1} to the soft X-ray luminosity of the nucleus. On the other hand the BH could still shine in hard X-rays or even at 511 keV, the positron-electron annihilation line, since important fluxes were observed from the general direction of the GC since the early 70s at these energies. After all, BH binaries like Cyg X-1 often emit the bulk of their accretion luminosity at > 100 keV. However in the 1990s observations in hard X-rays (3-30 keV) with XRT/SL2 [58] and with ART-P/GRANAT [49] and then in soft gamma rays (30-1000 keV) with SIGMA/GRANAT [26, 27] showed that the GC hard X-rays were rather due to the peculiar hard source 1E 1740.7-2942, a BH X-ray binary and microquasar located at > 100 pc away from the center, and that Sgr A* also was under-luminous at these energies. The SIGMA telescope also set upper limits on the presence of a point-like source of 511 keV line [38] while in those same years OSSE/CGRO showed that the bulk of the 511 keV line emission was not variable but rather diffuse and extended over the whole Galactic bulge [54]. The pre-Chandra/XMM and pre-INTEGRAL/HESS era ended with the detection of a GC gamma-ray source at energies > 100 MeV with EGRET/CGRO [40]. This source is now positioned slightly away from the nucleus (∼ 0.2°) [30] but it could still be linked to Sgr A*.

These high energy results set the total Sgr A* bolometric luminosity to less than (0.5 - 1) 10^{37} erg s^{-1} [27, 47] and prompted the development of new accretion models where the radiative efficiency is very low. The most popular were those named Advection Dominated Accretion Flows (ADAF) which assume that the energy exchange between protons and electrons is inefficient and electron temperature remains well below the virial temperature reached by the protons. Energy is therefore advected into the BH before being released as radiation [47]. These models have been used for other BH accreting systems with sub-Eddington accretion rates. They predict very low efficiencies, but very hard X-ray spectra extending to the gamma-ray bands.

A new era of high energy astronomy was opened with the launch of Chandra and XMM-Newton (1999) X-rays observatories, the launch of the gamma-ray mission INTEGRAL (2002) and the start of operations of the HESS Atmospheric Cherenkov ground telescope (2003) for very high energy (VHE) gamma-rays.

3. The Galactic Center in the X-ray band

In the 2-10 keV X-ray band the GC has been deeply monitored by Chandra and XMM-Newton in the recent years. The emission is dominated by few bright, sometimes transient, X-ray binaries probably not associated with the GC (e.g. 1E 1740.7–2942, 1E 1743.1–2843, etc.). However, the region also contains a large population of weak point-like persistent and transient sources, distributed as the old stellar population of the Galactic Bulge cluster. However the visible point sources can account only for 10% of the total emission, the rest being produced by diffuse emission with 3 distinct components, a soft thermal one (kT ∼ 1 keV), probably due to SNR
heated gas, a hot (kT ∼8 keV) possibly thermal component and a non-thermal one characterized by a strong 6.4 keV line (the fluorescent line of neutral or weakly ionized iron). Several SNR, non-thermal filaments and star clusters are also detected. The central 20 pc emission is dominated by the thermal emission from Sgr A East, while Sgr A* itself appears very weak.

3.1. Quiescence and flaring activity of Sgr A*
As mentioned above, a SMBH surrounded by dense environment is an ideal system to generate accretion powered X-ray emission, but it was quickly realized that the Galactic SMBH is very weak, even in the hard X-ray domain (where BH binaries in hard state emit the bulk of their accretion luminosity) [26, 27]. The total (from radio to X-rays) Sgr A* luminosity amounts to less than 5 × 10^{36} \text{ erg s}^{-1}, i.e. some 10^{-8} times the Eddington luminosity (L_E) of a 3.5 × 10^6 M_☉ BH. Since the IRS16 stellar winds are supposed to feed the BH at a rate of few 10^{-4} M_☉ yr^{-1} (but see [17] for an update on this issue) which implies accretion luminosities of 0.02 L_E, this led to the development of theories of very inefficient accretion flows (e.g. Bondi models and ADAF models) [41, 47]. The Chandra observatory in 1999, with its unprecedented angular resolution of 0.5″ confirmed the very low X-ray luminosity of Sgr A* (2 × 10^{33} \text{ erg s}^{-1} in the 2-10 keV band) but measured a steep spectrum (photon index \alpha \sim 2.5), not compatible with the ADAF thermal bremsstrahlung models ([6]). One year later Chandra made the dramatic discovery of a powerful X-ray flare from Sgr A*. During this event, of a total duration of 3 hr, the flux increased by a factor 50 to reach luminosities of 10^{35} \text{ erg s}^{-1} and displayed a hard spectral slope (\alpha \sim 1.3) [5]. XMM-Newton confirmed the presence of such bright, hard flares from Sgr A* [28] and discovered the most powerful one with an increase factor of 200 and, this time, a significantly steeper spectrum (\alpha \sim 2.5) [50] (see Fig. 2). The flare duration (few hours) and the observed short-time-scale variations (200 s) indicate that the X-ray emission is produced within 20 R_☉. This cannot be accounted for by the standard ADAF model (for which the bulk of the X-ray emission is produced from the whole accretion flow starting at the accretion radius), so several other models are now considered where non-thermal emission plays a major role. The Liu and Melia picture [33, 34] assumes that after a Bondi-like flow with sub-equipartition magnetic field, the accreted matter circularizes in a small, very hot, highly-magnetized Keplerian disk where quasi-relativistic electrons produce synchrotron radiation in the sub-mm band and, by inverse Compton, the steep X-ray spectrum. Flares can be produced either by sudden increase in accretion rate or rapid release of magnetic energy, and the two different X-ray spectral slopes can be explained. Markoff et al. [39] locate the main energy release at the base of a relativistic jet rather than in the accretion disk. Substantial modification of ADAF models (inclusion of outflows, convection and non-thermal component) were also considered [61] to explain the Sgr A* X-ray flares. The different models can account for the observed spectral shapes, but they predict different correlations between sub-mm, NIR and X-ray fluxes. Simultaneous observations of Sgr A* flares at different frequencies could strongly constrain the models, and therefore several multiwavelength campaigns on Sgr A* have been performed in the recent years (see section 3.4).

3.2. The diffuse X-ray emission
The Chandra and XMM-Newton surveys of the GC have also provided several new results on the diffuse X-ray emission. The first one is the confirmation that the central few hundred parsecs are permeated by a hard diffuse emission peaked towards the center and extending along the plane, as observed by previous instruments and in particular by ASCA [31]. Continuum and line spectra of this emission [48, 44] (and in particular the strong 6.7 and 6.9 keV lines of ionized iron) seem to indicate that it is thermal with a temperature of about 8 keV. Such a hot plasma cannot be confined in the region by the gravitational potential, it would escape in < 4 × 10^4 yr and its origin is therefore still unexplained (but see [13]). Chandra detected more than 2000
Figure 2. XMM-Newton Sgr A∗ X-ray flare detections. Top: MOS 2-10 keV images (5′ size) before and during the 2001 Sep flare [28]. Bot: PN light curve of the brightest flare [50].

FIGURE 3. Simultaneous HST near-IR (top: blue for 1.60 μm, green for 1.87 μm and red for 1.90 μm) and XMM X-ray (bottom) light curves during the 2004 Aug 31st Sgr A∗ flare. Units are flux density (mJy) for NIR and count rates for X-ray curves [63].

point-like weak sources in the central 17′ × 17′, and in spite of the fact that the cumulative spectrum of these sources is very similar to the one of the hot component, this population cannot explain more than 10% of the diffuse emission. Muno and collaborators [44] argued that since the spatial distribution of the diffuse component is not compatible with the one expected from point sources the hot diffuse component cannot be given by the cumulative effect of weak unresolved point-like sources. On the other hand, some features (the continuum is sometimes associated to the 6.4 keV line rather than the 6.7 keV one) are difficult to reconcile with a pure thermal nature, so a few authors have proposed a non-thermal origin for this component, i.e., cosmic ray interaction with the ISM [59, 62], or the effect of SN ejecta in dense gas regions [14]. Indeed the other distinct component of the GC diffuse emission is the 6.4 keV line of neutral weakly-ionized iron which has a different morphology than the 6.7 keV line, a very large equivalent width and is certainly due to non-thermal processes, such as reprocessing of external high energy radiation or cosmic ray interactions within dense molecular clouds.

3.3. Sgr B2 and Sgr A East

The 6.4 keV image of the region shows a very strong peak at the position of the Sgr B2 giant MC. This was interpreted as fluorescent line due to scattering of hard X-ray emission coming from an external source, possibly Sgr A∗ itself [31, 46]. A strong transient outburst of hard X-rays from the SMBH occurred some 300 yr ago could have traveled the distance to Sgr B2, illuminating the dense cloud and generating the Fe line and the hard X-ray emission. Indeed hard (> 10 keV) X-ray emission from Sgr B was initially detected with the GRANAT/ART-P, and now clearly observed up to 200 keV with INTEGRAL [55].

The recent X-ray observations of the Sgr A complex have demonstrated that the bright X-ray source Sgr A East is a mixed morphology SNR, where the non-thermal radio shell surrounds a centrally peaked thermal X-ray emission [37]. The X-ray plasma has 2 components, one at 1 keV and the other at 4 keV [56]. High abundances in the center of the source indicate that part of the emission is due to heated SN ejecta. However the X-ray data show now that Sgr A East,
apart from the high plasma temperature and from expanding into a very dense medium, is not
an exceptional SNR. It appears to be the product of a typical SN II or a SN Ia occurred about
10^4 yr ago. Assuming a certain distance of the SN from Sgr A*, the shell of swept up ISM could
have reached the SMBH feeding it and triggering a Sgr A* outburst of hard emission, later
reflected by Sgr B2 [37]. As mentioned before, this interpretation remains controversial, the
main problem being that other 6.4 keV peaks observed with XMM-Newton and related to MCs
cannot be due to the same outburst event unless very special geometries and distance scales
between the MCs of the region are assumed.

3.4. Recent results on Sgr A* flares: NIR / X-ray detections and modulation

The years 2003 and 2004 have seen several new developments in the domain. In particular a
series of large multiwavelength campaigns have been performed in order to obtain simultaneous
broad-band measurements of the variable emission from Sgr A*. One of them was carried out
in 2004 and was based on a XMM-Newton approved large project (≈ 550ks) for the X-ray
monitoring of Sgr A* with half the observation performed at the end March and the other half
at the end of August. This program involved radio (VLA, ATCA), sub-mm (CSO, SMT, NMA,
BIMA), NIR (VLT, HST) and gamma-ray (INTEGRAL, HESS) observatories. Although not
all planned observations could be realized and simultaneous coverage was limited, the campaign
was highly successful with the detection of two new bright (factor 40 increase) X-ray flares with
XMM-Newton [9], several NIR flares with the HST (one of which simultaneous to an X-ray
one) and radio and sub-mm variability at various levels [63]. One of the 2 X-ray flares (31st
August) was particularly long (~ 10 ks) and some interesting time variability analysis could be
performed. A bright X-ray and radio transient at 3" from the SMBH was also detected and
studied during this program [51]. In this respect it has to be mentioned that several transients
in the GC region have been discovered and studied with XMM and Chandra and that these
studies have provided evidence of an intriguing overabundance of such sources in the central pc
of the Galaxy [45].

These campaigns were motivated by the fact that already in 2003 it was revealed using the
VLT [22] and then the Keck [24] observatories that Sgr A* also flares in the NIR band. The NIR
flares are more frequent (several per day) than the X-ray ones (~ 1 per day) and their steep
non-thermal spectra extending in the MIR domain [20, 23, 15] confirm that synchrotron is the
dominant radiation mechanism. The IR observations also provided the spectacular evidence that
the emission appears modulated with a period of 17 min [22]. If such a period is associated to
the last stable orbit of an accretion disk then the timescale implies that the SMBH is rotating at
50% of the maximum allowed spin. Revisiting X-ray flare variability Aschebach et al. [4] found a
set of possible quasi periodic oscillations (QPO) in the power spectra. These periods appeared to
correspond to the characteristic frequencies (Keplerian, vertical and radial epicyclic oscillations
and Lense-Thirring precession) of a disk orbiting around a BH with maximum spin. A more
detailed timing analysis of the X-ray data, however, has been recently presented by Bélanger et
al. (2006b) [11] [12]. These authors found in the Sgr A* 10 ks X-ray flare of 31st August 2004 a
very significant QPO at 22.2 min (1330 s). Again this period is shorter than the period at the
LSO for a Schwarzschild BH and it implies, if associated to stable orbits, a Kerr BH with spin
parameter a ~ 0.2 or higher. These authors also re-analyzed the previous XMM data and found
no evidence for the other modulations reported previously. Although these results are extremely
exciting they need to be confirmed by other significant measurements. Firm detections of QPO
from Sgr A* with periods in the range 15-30 min would certainly favor the accretion disk models
(vs. jet models) and would provide strong constraints on the mass and spin of the GC SMBH.

The first flare simultaneously observed in IR and X-rays was detected using Chandra and the
VLT [18]. The flare was however very weak and no clear light curve and spectral shape could be
derived from the X-ray data. A much brighter event was observed simultaneously with XMM and
the HST during our large 2004 multiwavelength campaign on Sgr A* mentioned above [63]. The 31st August X-ray flare could indeed be observed with the NICMOS camera of the HST (Fig. 3) at frequencies between 1.6 and 1.9 μm (Fig. 3). The simultaneous NIR and X-ray flares were very similar in shape and the lack of significant time lags indicate that the same population of particles must produce the 2 components. The synchrotron cooling time for producing X-rays in the typical 10 G magnetic field of the accretion flow is much shorter (< 1 min) than the duration of flares, so the X-rays are most probably produced by inverse Compton of sub-mm photons off transiently-accelerated electrons that generate the NIR emission via the synchrotron mechanism [63]. The different spectral slopes of flares could be caused by a varying electron distribution or magnetic field [63, 35]. Similar results were derived from other simultaneous detections of X-ray and NIR flares with Chandra and the VLT [19]. The main efforts are now directed to the simultaneous measurement of spectra over a broad band (from sub-mm to X-rays), since such data would provide information about the particle distribution, magnetic fields, and sizes of the emitting region [35]. Indeed, as for X-rays, NIR flares have been observed with both blue and red spectral slopes and the presence of a flux-slope correlation (the more intense the harder) even within a single event was recently reported [25], although this result has not been firmly confirmed. The detection of a sub-mm flare coincident with a NIR flare, also obtained during our 2004 campaign, could imply that emission decay is not due to synchrotron cooling (since for sub-mm photons cooling time is longer than for NIR) but rather to adiabatic expansion, which may indicate plasma outflows [63]. The inverse Compton emission responsible for the X-rays could also extend to the gamma-ray regime depending on the electron distribution and magnetic field. We therefore searched for simultaneous flares using the INTEGRAL observatory.

Figure 4. INTEGRAL/IBIS 20-30 keV image of the Galactic Center from the 2003-2004 survey, in galactic coordinates with grid lines separated by 0.5°. Contours mark iso-significance linearly-spaced levels from 9.5 to 75 σ [10].

Figure 5. Broad band XMM/INTEGRAL spectrum of IGR J17456–2901 where the 1-10 keV spectrum was obtained from XMM data of the region within 8′ from Sgr A*. The best fit model is an absorbed 2 temperature plasma with kT ≈ 1.0 (red) and 6.6 keV (green) plus a broken power-law of indexes 1.5 and 3.2 with break energy at 27 keV (blue) [10].

4. The Galactic Center in gamma-rays
The INTEGRAL observatory monitored, with the IBIS/ISGRI telescope, the GC region for more than 4.7 Ms of effective exposure between 2003 and 2004, obtaining the most precise images of the GC ever collected in the 20-600 keV band [8, 29, 10]. In addition to the bright X-ray binaries, INTEGRAL detected a faint and persistent high energy emission coming from the very center of the Galaxy (Fig. 4), compatible with a pointlike source located (within the 1′ error radius) at the Sgr A* position. Due to the IBIS angular resolution (∼ 13′ FWHM) this...
source (IGR J17456–2901) cannot be clearly associated to the SMBH or to other objects of the dense central region. The lack of variability and of a bright discrete X-ray counterpart suggests that it is rather a diffuse emission concentrated in the inner central 10-20 pc of the Galaxy. The INTEGRAL spectrum was compared to the 1-10 keV one obtained from XMM-Newton (partly simultaneous) data integrating over the region of the IBIS point spread function [10]. The normalizations of the spectra match well (Fig. 5), but the thermal plasma with kT of 6 keV used to model the bulk of the X-ray diffuse emission cannot explain the data at > 20 keV, and neither can the contributions of the transient point sources seen by Chandra or XMM in 2003 and 2004. A non-thermal component extending up to 120-200 keV with spectral slope of photon index 3 is clearly present and its origin is still unexplained. Simultaneous XMM-INTEGRAL observations performed during the 2004 campaign are not conclusive on the possible detection with INTEGRAL of the Sgr A* X-ray flares since the 2 events were observed with XMM during the INTEGRAL passage into the radiation belts, when the instruments did not recorded data. However, even if the Sgr A* X-ray flares extend to > 20 keV with their hard slope, they are too infrequent to fully account for the central gamma-ray source.

In addition, INTEGRAL observed constant hard emission, from Sgr B2 (IGR J17475-2822 in Fig. 4). This supports the hypothesis that the iron emission from Sgr B2 is a reflection nebula generated by a large eruption of Sgr A* that occurred 300 years ago [55].

IGR J17456–2901 on the other hand could be linked to the VHE gamma-ray emission observed by several Atmospheric Cherenkov Detectors. HESS, the most sensitive and precise of them, reported the presence of a TeV source centered within 1’ from Sgr A* [1]. The source is constant and displays power-law spectrum extending from 300 GeV up to 10 TeV. This emission cannot be explained by heavy dark matter particle annihilation and is probably due to interactions of particles accelerated at very high energies. Recently [2] the HESS collaboration also reported TeV diffuse emission closely correlated to the giant molecular clouds of the Galactic Center region. The spectrum and distribution of this emission are consistent with the idea that the central source accelerated in a recent past the hadrons now interacting with the molecular gas. However the mechanism and site of acceleration, the expanding shell of the Sgr A East SNR [16] or the regions close to the SMBH horizon [3], have not yet been identified. The EGRET source observed between 50 MeV and 10 GeV (3EG J1746–2852) located at 0.2° from Sgr A* [40, 30] seems too far to be the 1 GeV counterpart for the INTEGRAL and the HESS sources, but in this complex region the EGRET data are not conclusive. Gamma-ray emission from the GC has now been clearly detected but its origin and nature are not yet fully understood.

5. Conclusions
The Chandra, XMM-Newton, INTEGRAL and HESS monitoring of the GC will continue in the coming months and years, hopefully coupled to NIR, sub-mm and radio observing programs. These programs will possibly settle the issue of periodicities in the X-ray flares and will provide measurements of the broad band spectra of the Sgr A* flares. In the near future GLAST will probably unveil the mystery of the EGRET source at the GC and the next generation of ACD detectors will map the region at TeV energies with increased precision. To solve the puzzle of the hard X-ray emission and to fully understand the several items still open will however necessitate focusing instruments in this energy domain such as Simbol–X, which is expected to fly at the beginning of the next decade [21].

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