*The Galactic Center: Feeding and Feedback in a Normal Galactic Nucleus*
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# On the past activity of Sgr A*

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**Abstract.** Recent X-ray emission events in the Galactic center would be expected to generate an X-ray reflection response within the surrounding clouds of the central molecular zone, in the Galactic disk and even, if powerful enough, in clouds outside our Galaxy. We review here the current constraints on Sgr A*'s past activity obtained through this method, with particular emphasis on the strong evidence that has been gathered for multiple X-ray flashes during the past few hundred years.

**Keywords.** ISM: reflection nebulae — Galaxy: center — X-rays: ISM — surveys — radiation mechanisms: nonthermal

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## 1. The current phase of Sgr A*

Sgr A*, the supermassive black hole (BH) at the center of the Milky Way, is known to be extremely faint, with a bolometric radiation measured to be about 8 orders of magnitude lower than the Eddington luminosity for its estimated mass, $M_{BH} = 4.4 \times 10^6 M_\odot$ (Ghez *et al.* 2008; Gillessen *et al.* 2009). This Eddington fraction is even lower than the one typically observed for the quiescent luminosity of transient X-ray binaries (Garcia *et al.* 2001). Since the birth of radio and X-ray astronomy, the Galactic center (GC) supermassive BH has been observed to be in this low-luminosity state. A major progress was the discovery that Sgr A* displays flares in X-rays (Baganoff *et al.* 2001; Goldwurm *et al.* 2003) and near-infrared (Genzel *et al.* 2003), during which the X-ray intensity increases, from the typical quiescent value, by factors as large as hundreds (Nowak *et al.* 2012; Neilsen *et al.* 2013). However, even during these events, Sgr A*'s luminosity still remains extremely low. *Are we witnessing the typical and only state of Sgr A*, or is this a temporary condition? Has Sgr A* experienced much brighter periods in the past?*

## 2. A transient phase of Sgr A*? Clues from the surrounding material

The mass accretion rate toward Sgr A* is observed to decrease by many orders of magnitude moving closer to the supermassive BH (see Genzel *et al.* 2010 for a review). It goes from $\dot{M} \sim 10^{-2}$ $M_\odot$ yr$^{-1}$ at tens or hundreds of parsecs from Sgr A*, to $\dot{M} \sim$ few $10^{-6}$ $M_\odot$ yr$^{-1}$ at the Bondi radius, and declines even further ($\sim 10^{-7} - 10^{-9}$ $M_\odot$ yr$^{-1}$) down at the inner accretion radius (see Table III of Genzel *et al.* 2010). This dramatic fall in the mass accretion rate is expected to be, at least in part, a consequence of either star formation, or outflows (e.g. in the form of winds and/or of jets; Fender *et al.* 2004; Proga *et al.* 2000; Ponti *et al.* 2012) or magnetic forces (e.g. Eatough *et al.* 2013) that progressively attenuate the accretion flow toward Sgr A*. Whether such mechanisms are sufficiently efficient to channel away enough material to guarantee that Sgr A* is persistently in a state of starvation is still an open issue. Alternatively, the drop of the accretion rate could be the result of an episodic feeding of Sgr A*, with the supermassive BH being nowadays close to the floor of an inactive phase. In such a scenario, the feeble accretion flow observed today could be the result of a previous bright active phase that interrupted the accretion flow (various ideas have been proposed, see e.g. Morris *et al.* 1999 for the proposition of a cyclic mechanism which would control the growth of the BH and its feedback to the surrounding medium).

## 3. Reflection: a tool to study the recent X-ray activity of Sgr A*

The densest and most massive molecular clouds in the Galaxy (forming the so-called central molecular zone, CMZ; Morris & Serabyn 1996) are placed within a few hundred parsecs from Sgr A*, providing us with a tool to constrain the past X-ray activity in the GC (see e.g. Sunyaev & Churazov 1998). It is in fact expected that a bright X-ray flash, emitted in the GC during the past few hundred years, would still be traveling within the CMZ and produce a reflection component (composed of emission lines, the most intense of which would be the Fe K$\alpha$ line, and a hard X-ray continuum) when illuminating a molecular cloud (see Ponti *et al.* 2013 for a review). This scenario was first proposed to explain the extended and diffuse hard X-ray emission coincident with the distribution of molecular clouds (Sunyaev *et al.* 1993). These authors suggested that the observed hard X-ray emission could be the signature of a reflection component. If so, an intense Fe K$\alpha$ line (with $\sim 1$ keV equivalent width) should have been present. Three years later, *ASCA* observations confirmed the presence of such fluorescent line emission from the same clouds (Koyama *et al.* 1996).

### 3.1. *The XMM view of the Fe K$\alpha$ emission from the CMZ*

The upper panel of Figure 1 shows the RGB image of the Fe K emission from the CMZ. This image is the mosaic of all 106 *XMM* observations pointed within 1° from Sgr A* (see Ponti *et al.* 2014 for more details and Soldi *et al.* 2014). The Fe K$\alpha$ emission shows a patchy distribution correlated with the distribution of molecular clouds, traced here through the $N_2H^+$ $J = (1-0)$ emission (see lower panel of Figure 1). In fact the superposition of Fe K$\alpha$ and $N_2H^+$ emissions shows that all the brightest Fe K$\alpha$ emitting regions coincide with massive molecular complexes. However, not all massive molecular complexes are Fe K$\alpha$ emitters (e.g., the 20 and 50 km s$^{-1}$ clouds). This is compatible with the reflection scenario which predicts that a past flare from Sgr A* would currently illuminate only part of the clouds of the CMZ. Interestingly, weak but significant Fe K$\alpha$ emission is observed to be produced even in clouds with weak $N_2H^+$ emissions†.

### 3.2. *The Fe K$\alpha$ emission from Sgr B2 and the X-ray flash hypothesis*

Up to about a decade ago, Sgr B2, the densest and most massive molecular cloud of the Galaxy, was the most luminous cloud in Fe K$\alpha$ line of the Milky Way. For this reason it has been widely used as a prototype to test the various emission models. Using *ASCA* and *INTEGRAL* data, Revnivtsev *et al.* (2004) showed that Sgr B2's spectrum was consistent with a reflection spectrum characterized by a hard X-ray continuum (with a Compton hump) and a huge Fe K$\alpha$ line with an equivalent width of $\sim 2$ keV. The observed large

† For example, in correspondence with the Fe K$\alpha$ active clouds close to the Arches cluster (G0.103-0.069), Paschen-$\alpha$ emission is observed (Tatischeff *et al.* 2012), suggesting that material is photo-ionized by the stars of the Arches cluster.

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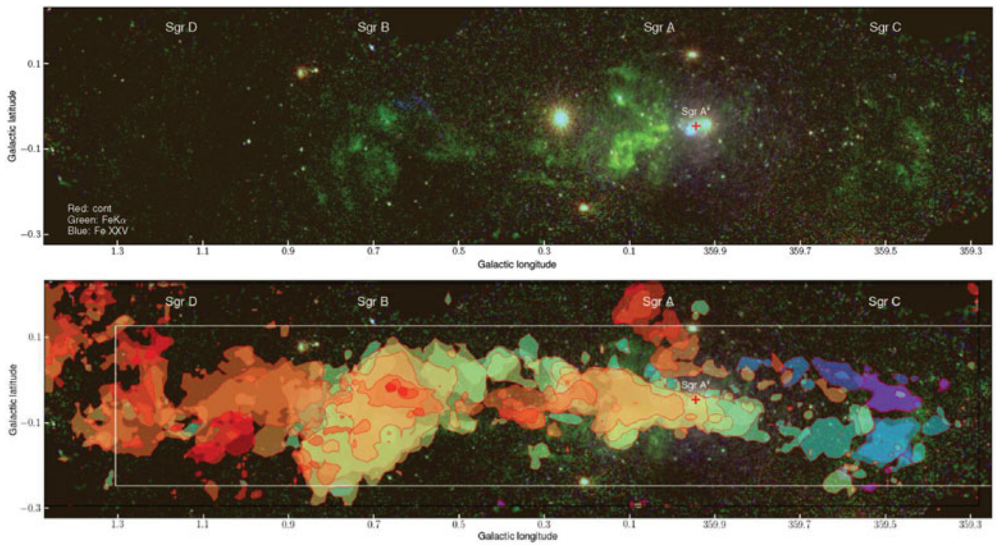


**Figure 1. Upper panel:** RGB image of the Fe K emission from the CMZ: in red the continuum emission red-ward of the Fe K$\alpha$ line (5−6.1 keV), in green the integrated Fe K$\alpha$ intensity (6.3−6.5 keV) and in blue the FeXXV line emission (6.62 − 6.8 keV) are shown. **Lower panel:** Molecular matter distribution as derived by $N_2H^+$ $J = (1-0)$ emission, superimposed onto the Fe K emission map. The Mopra $N_2H^+$ data-cube (Jones *et al.* 2012) was divided into $\sim 10$ km s$^{-1}$ slices and the contours delimiting the regions with peak brightness higher than $T_A^* > 0.15$ K (see Jones *et al.* 2012). The emission from each individual $N_2H^+$ slice is shown with a different color (with rainbow color scale) in order to emphasize the different line of sight velocities of the various molecular complexes (spanning velocities from $v = -75$ in blue to $v = +85$ km s$^{-1}$ in red). As pointed out by Molinari *et al.* (2011), the cloud's velocity field suggests the presence of an elliptical and twisted ring of clouds. The white rectangle indicates the region where we computed the Fe K$\alpha$ emission profile (Figure 3). [A COLOR VERSION IS AVAILABLE ONLINE.]

Fe K$\alpha$ luminosity implied that the source of the flash of X-rays had a luminosity of $L_{2-200\mathrm{keV}} \sim 10^{39}$ erg s$^{-1}$ for more than a decade (Revnivtsev *et al.* 2004). Such a large luminosity allowed the authors to discard X-ray binaries as a possible source (assuming an external illumination scenario) and leaves Sgr A* as the only viable source. Moreover, the spectrum of Sgr B2 is not unique. Studies of other molecular cores showed very similar X-ray spectra, dominated by an intense Fe K$\alpha$ line (plus the associated K$\beta$ emission) with a typical equivalent width of $\sim 1$ keV, a hard X-ray emission and a prominent Fe K edge (see Koyama *et al.* 2007; Terrier *et al.* 2010; Ponti *et al.* 2010; Nobukawa *et al.* 2010; Capelli *et al.* 2011).

Further support for the scenario of an X-ray flash produced by a compact accreting source (thus expected to be highly variable) came with the detection of variability in the Fe K$\alpha$ emission. Both Muno *et al.* (2007) and Inui *et al.* (2009; see also Koyama *et al.* 2008) observed signs of variability in the Fe K$\alpha$ emission from the Sgr A and Sgr B complexes, respectively. The hard X-ray light curve of Sgr B2 (obtained through analysis of the *INTEGRAL* data) confirmed the decrease observed in the Fe K$\alpha$ band (Inui *et al.* 2009), with a measured drop of the reflection flux by a factor of 2.5 − 3 between 2000 and 2009 (Terrier *et al.* 2010). Subsequent *Suzaku* and *Chandra* observations confirmed this trend, extending the decrease further in time, with a drop of a factor of $\sim 5$ and $\sim 10$, respectively (Nobukawa *et al.* 2011; Terrier *et al.* in prep). We have thus witnessed a rapid switching off of the X-ray emission from Sgr B2. This happens on a timescale comparable to the light-crossing time of its core, suggesting, once again, an external illumination as the excitation mechanism.

### 3.3. *Alternatives to the X-ray flash: the cosmic ray scenarios*

Reflection of an X-ray flash is not the only way to produce an Fe K$\alpha$ emission and a hard continuum from molecular clouds. Interaction between cosmic rays (either electrons, protons or ions) and the molecular cloud material (Yusef-Zadeh *et al.* 2002; 2007; 2013; Dogiel *et al.* 2009; 2011; Tatischeff *et al.* 2003; 2012) or supernova ejecta and clouds (Bykov 2003) can also induce Fe K$\alpha$ and hard X-ray continuum emissions. For example, the interaction between the cosmic ray protons produced in the shock created by the supersonic motion of the Arches cluster with the surrounding molecular material can explain the Fe K$\alpha$ emission produced in the region around the Arches cluster (Tatischeff *et al.* 2012; see also Krivonos *et al.* 2014a,b). Moreover, it is not excluded that cosmic rays might produce a constant background of Fe K$\alpha$ emission (Uchiyama *et al.* 2013) as diffuse as the entire CMZ† (Yusef-Zadeh *et al.* 2013; but see Dogiel *et al.* 2013).

We point out that the fast variability observed in many molecular clouds disfavors a cosmic ray origin. In fact, emission induced by cosmic ray protons or ions is expected to be constant on century time-scales. Cosmic ray electrons might be special in this respect. In fact, under certain conditions, cosmic ray electrons could produce variable Fe K$\alpha$ emission on time-scales as short as few years (see Yusef-Zadeh *et al.* 2013). However, the very low efficiency for Fe K$\alpha$ line production implies very large luminosities in cosmic ray electrons (Dogiel *et al.* 2013) and due to the long diffusion time, such emission has to be localized very close to the source of electrons. Moreover, only if very high iron overabundances are invoked ($\sim 3-5$ times Solar), can cosmic ray electrons barely produce the observed line equivalent widths of typically $\sim 0.8-2$ keV.

### 3.4. *Superluminal echoes as evidence for external irradiation*

Important evidence for reflection of an X-ray flash produced by an external source comes from the observation of superluminal echoes. Under particular conditions of the source-reflector-observer geometry, light echoes can appear superluminal. This phenomenon was predicted by Sunyaev & Churazov (1998) and observed thanks to an *XMM* monitoring campaign of the Sgr A complex lasting about a decade (Ponti *et al.* 2010). The echo has been observed to have an apparent speed in excess of 3 times the speed of light, therefore ruling out cosmic ray models and internal sources as alternatives to external illumination (Ponti *et al.* 2010). A recent study of all the *Chandra* observations of the same molecular complex confirmed the superluminal propagation of the echo (Clavel *et al.* 2013). Moreover, the echo was observed to propagate radially away from Sgr A* (Ponti *et al.* 2010; Clavel *et al.* 2013), thus reinforcing the association of Sgr A* (or an unknown source very close to the GC) as the possible source of the X-ray flash.

## 4. Reconstructing the recent light curve of Sgr A*

Figure 2 shows an attempt to reconstruct the past activity of Sgr A*. At present Sgr A* spends most of its time in quiescence at an X-ray luminosity of $L \sim 10^{33}$ erg s$^{-1}$ with about one flare per day lasting $\sim 1-3$ hours. These flares can reach luminosities up to $L_X \sim 10^{35}$ erg s$^{-1}$ (Neilsen *et al.* 2013). Past X-ray observations show no signs of more luminous or intense activity during the past 15 – 20 years. On the other hand, the Fe K$\alpha$

† If that were the case, then part of Sgr B2's Fe K$\alpha$ emission would be produced by cosmic rays. Therefore, a constant residual Fe K$\alpha$ component should be manifested as soon as the X-ray echo that has been illuminating Sgr B2 has completely passed beyond the cloud.

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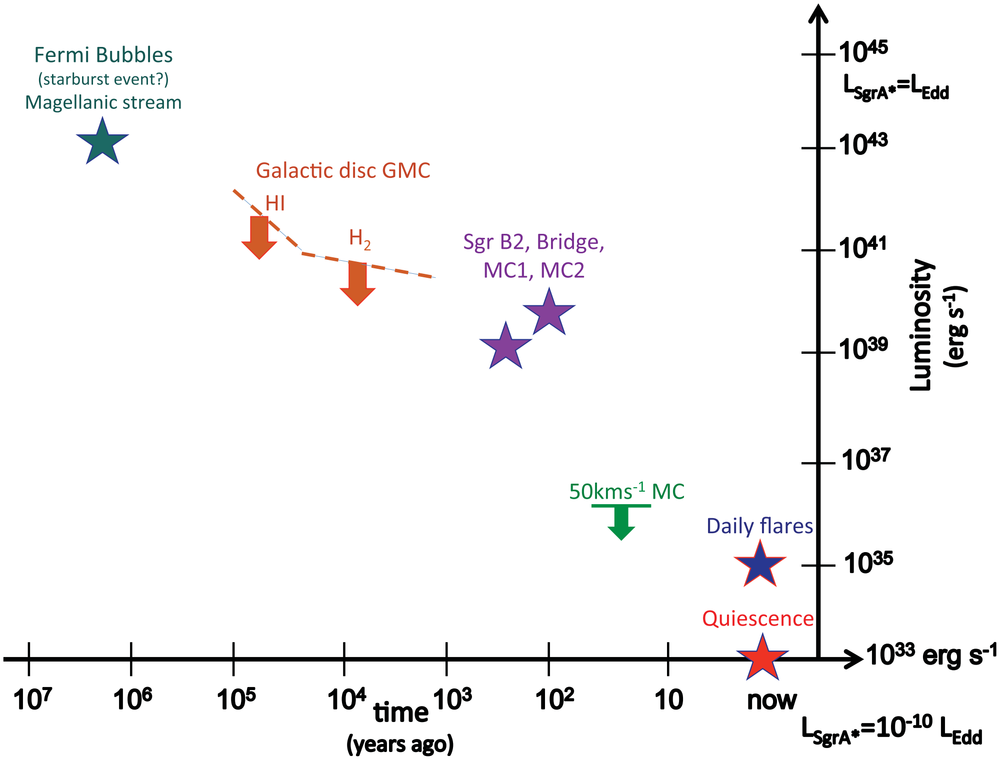


**Figure 2.** Constraints on Sgr A*'s past activity, for the last ten million years.
[A COLOR VERSION IS AVAILABLE ONLINE.]

and hard X-ray emissions from the molecular clouds in the CMZ suggest that Sgr A* was $\sim 4-6$ orders of magnitude brighter than observed today, at least for a brief period of time, within the past few centuries (Revnivtsev *et al.* 2004; Terrier *et al.* 2010; Ponti *et al.* 2010; Capelli *et al.* 2012; Ryu *et al.* 2013; Clavel *et al.* 2013). The Fe K$\alpha$ intensity (or its corresponding upper limit) of individual clouds can give stringent constraints on Sgr A*'s past activity if the cloud's line of sight distances to the supermassive BH are known. In fact, a simple relation (see Sunyaev & Churazov 1998) connects the intensity of the reflection emission ($I_{\mathrm{FeK}\alpha}$, the Fe K$\alpha$ intensity), the cloud column density ($N_{\mathrm{H}}$, which can be estimated using molecular line emission), the areal size of the cloud ($A$) and the luminosity ($L$) of the illuminating source, once the source-to-cloud distance ($d$) is known:

$$L \propto \frac{d^2 \times I_{\mathrm{FeK}\alpha}}{A \times N_{\mathrm{H}}}.$$

Unfortunately, the line of sight position is known for only a few clouds. For instance, the 50 km s$^{-1}$ is thought to be located a few tens of parsecs behind Sgr A*† (Coil *et al.* 2000; Ferrière 2012). Since, no intense Fe K$\alpha$ emission is observed from this cloud, we can place an upper limit $L_{\mathrm{Sgr\,A*}} \leqslant 8 \times 10^{35}$ erg s$^{-1}$ for the mean luminosity of Sgr A*

† The 50 km s$^{-1}$ cloud is observed to be interacting with Sgr A East shell (Serabyn *et al.* 1992; Jackson *et al.* 1993), which is located primarily behind Sgr A*. Indeed the minispiral surrounding Sgr A* is observed in absorption against Sgr A East spectra (Yusef-Zadeh *et al.* 1987; Pedlar *et al.* 1989).

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during the past 50 – 80 years (Ponti *et al.* 2010)†. We also have a measurement of the position of Sgr B2 compared to Sgr A* (parallax measurements, assuming it is in circular orbit around Sgr A*; Reid *et al.* 2009). Thus, knowing the other parameters of the cloud, we can determine that Sgr A*'s luminosity was $L \sim 1.5 - 5 \times 10^{39}$ erg s$^{-1}$, and started to fade $\sim$ 100 years ago (Terrier *et al.* 2010).

### 4.1. *Methods to estimate line-of-sight distances to clouds*

The precise reconstruction of Sgr A*'s past activity has been limited by the poorly constrained line-of-sight distances of most of the clouds. A significant effort has been recently undertaken to try to solve this problem. Under the assumption that the soft X-ray plasma is uniformly distributed within the CMZ, Ryu *et al.* (2009; 2013) measured the X-ray absorption toward several molecular clumps in the Sgr B and Sgr C complexes, thus providing constraints on their line of sight distances‡. Thereby, the authors estimate that Sgr A*'s luminosity was roughly constant ($\sim 1 - 4 \times 10^{39}$ erg s$^{-1}$, with few peaks) during the past 500 years, showing a sharp drop starting $\sim$ 100 years ago. Alternatively, Capelli *et al.* (2012) used the equivalent width of the Fe K$\alpha$ line to derive the source-cloud-observer angle and therefore the line of sight distance. Indeed the reflection continuum, dominated by Compton scattering, has a strong (1+cos$\theta$) angular dependence, in the optical thin limit, while the Fe K$\alpha$ emission is isotropic. As a consequence, the Fe K$\alpha$ equivalent width depends on the system geometry. Applying this method to several clouds of the Sgr A complex, under the assumption that all clouds have the same iron abundance, Capelli *et al.* (2012) provided further constraints on the luminosity decay, suggesting that the luminosity of Sgr A* was several $10^{39}$ erg s$^{-1}$ about 140 – 160 years ago, then decreased to $10^{37-38}$ erg s$^{-1}$ about 80 – 130 years ago and to less than $10^{36}$ erg s$^{-1}$ in the past 60 years. A third method would consist of considering global dynamical models for the general three dimensional distribution of the CMZ. For instance, Molinari *et al.* (2011) suggested that the clouds of the CMZ might be distributed along a twisted elliptical ring. The line of sight velocities of the different clumps in the ring support this interpretation (e.g. see lower panel of Figure 1), indicating that the majority of the CMZ clouds might be undergoing orderly orbits along the twisted ring (the $x_2$ orbits; Contopulous 1980). Despite the disagreement in the inferred location of some clouds (such as the Sgr B2 and the 50 km s$^{-1}$ clouds) with the one derived by Molinari *et al.* (2011)¶, the general picture appears convincing. In fact, it agrees with the expectation of what the gas dynamics should be in the presence of a potential well dominated by the stellar bar at the GC.

### 4.2. *Match between the twisted ring and the Fe K$\alpha$ emission*

Under the assumption that: i) the clouds are distributed primarily in such a twisted ring; and that ii) they reflect a past echo from a source inside the ring; we expect (because of the low luminosity of Sgr A* over the past few decades) to observe the clouds at small projected distances and in front of Sgr A* to have negligible Fe K$\alpha$ emission, while the Fe K$\alpha$ active clouds should be concentrated either at larger projected distances or behind the GC. If that is the case, we also expect that only some specific parts of the twisted ring will be illuminated.

† We point out that this luminosity corresponds to the Sgr A* luminosity averaged over about a decade, corresponding to the light crossing time of the cloud. Shorter flares with higher luminosities but smaller fluences are clearly possible.

‡ Under their assumptions, no or maximum absorption is expected if the respective clouds are placed in the near or far end of the CMZ, respectively.

¶ A new model extending further East, and therefore locating Sgr B2 in front of Sgr A* has just been proposed (see Bally *et al.* 2013).

In agreement with this picture, Figure 1 shows that almost no Fe K$\alpha$ emission is observed from the two parts of the twisted ring thought to be placed in front of Sgr A*. Besides, many clouds at high projected distance (e.g. in the Sgr B and Sgr C complexes) are Fe K active. In particular, an almost continuous branch of Fe K$\alpha$ active clouds runs between the Sgr A and Sgr B complexes, along the same location where the back side of the molecular ring is located. Interestingly, these clouds seem to belong to two complexes that are running almost parallel just south of 1E1743.1−2843 and appear as two thin structures $\sim$ 20 pc long and only $\sim$ 4 pc wide. These clouds might belong to two different sets of $x_2$ orbits. The West branch of the twisted ring, located behind Sgr A*, shows weaker Fe K$\alpha$ emission (see Figure 1). This might be partly due to the lower column density of the clouds in that region. Despite this, we detect for the first time Fe K$\alpha$ emission just North West of Sgr A*, very close to the BH.

### 4.3. *The characteristics of past flare(s)*

The variable, sometimes superluminal, Fe K$\alpha$ emission from the CMZ clouds produces a compelling case for the existence of a bright ($L \sim 10^{39}$ erg s$^{-1}$) source in the GC (most probably Sgr A*), a few centuries ago (see Figure 2). However, the detailed character of this source's active phase is still an open question. *Did the flare last for several centuries with minor luminosity fluctuations around $L \sim 10^{39}$ erg s$^{-1}$, such as observed in AGN? Or was the active phase made of several distinct episodes? What is the time-scale of the flares?*

The time-scale of variation of the reflected Fe K$\alpha$ emission from a molecular cloud depends on the convolution of the light curve of the illuminating source with the transfer function of the cloud (introducing a smoothing of the order of the light crossing time of the cloud). In agreement with these simple considerations, it is observed that larger clouds vary on longer time-scales than smaller ones and, in particular, that their halving time is comparable to the light crossing time of their nucleus (Muno *et al.* 2007; Terrier *et al.* 2010; Ponti *et al.* 2010). This indicates that the intrinsic luminosity variations of the source are shorter than the cloud light crossing times. To characterize rapid source variations it is therefore required to monitor the smallest possible molecular clumps. With this aim, Clavel *et al.* (2013) analyzed all the *Chandra* observations pointed at the Sgr A complex and discovered two types of variations, characterized by two different time-scales, in molecular clumps having similar compact sizes. Several clumps showed variations up to a factor $5-10$ in less than 2 years. Other clumps showed slower linear variations lasting about a decade. The different light curves appear to reflect two different events, the transfer functions being similar for clumps of similar sizes. Whether these large amplitude variations (up to a factor $\sim$ 10) are large flares superimposed upon a long-lasting period of increased activity (such as generally observed in AGN; McHardy *et al.* 2006; Ponti *et al.* 2012; Soldi *et al.* 2013) or whether they are really distinct and independent outbursts, with variations of $\sim 4-5$ orders of magnitude in luminosity (from the quiescent level up to $L \sim$ few$10^{39}$ erg s$^{-1}$) in few years, is still an open question.

Figure 3 shows the profile of the Fe K$\alpha$ emission, integrated between $l$ = 1.5 and $l = 359.275°$ and $b = 0.166$ and $b = -0.3°$ during the 2001 and 2012 *XMM* scans of the CMZ. Both in the Sgr A, Sgr B and Sgr C complexes we observe drops of factors of several in 11 years, consistent with the inference that the Sgr A* light curve dropped off significantly in the last century.

## 5. The flare(s) origin and possible different sources

*What is the origin of such a large luminosity variation?* Such an exceptional luminosity could be an extreme event produced by the same process that generates the present day

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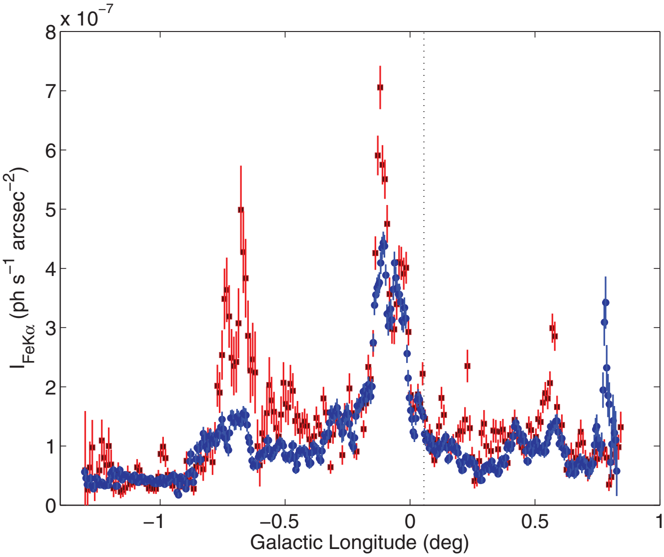


**Figure 3.** Fe K$\alpha$ profile of the 2001 (red squares) and 2012 (blue circles) *XMM* (EPIC-pn) scans of the CMZ. The dotted line indicate Sgr A*'s position. [A color version is available online.]

activity of Sgr A*. Through Monte Carlo simulations, it has been shown that accretion of colliding stellar winds can produce pockets of cold gas that, accreting onto Sgr A*, could explain its current flaring activity (Cuadra *et al.* 2008). The creation of larger pockets is rare, but possible. It is plausible that, on time-scales of centuries, some clumps with low angular momentum and massive enough to generate flares with luminosities of $\sim 10^{38} - 10^{39}$ erg s$^{-1}$ could be created (Cuadra *et al.* 2008). Alternatively a flare could have been produced by a partial tidal disruption of a star by Sgr A* (Yu *et al.* 2011). Another scenario invokes collisions between clumps of molecular matter to reduce their angular momentum, ultimately bringing material close to the BH horizon, and, in this way, enhancing accretion (Czerny *et al.* 2013). Zubovas *et al.* (2012) considered the consequences of planets being gravitationally disrupted and thus producing flares with L$\sim 10^{41}$ erg s$^{-1}$ for a few decades.

Alternatively the X-ray flash could have been produced by a different X-ray source, located close to Sgr A*. Several candidates have been proposed. A young magnetar (SGR J1745−2900) has recently been discovered at only $\sim 2.4''$ from Sgr A* (Rea *et al.* 2013). Such a source might have undergone a giant flare in the past few centuries. If, indeed, it experienced an event as bright as the brightest ever observed from a magnetar (SGR 1806−20; Hurley *et al.* 2005; Frederiks *et al.* 2007), it could explain part of the reflected emission from the CMZ. However, such an event would not explain the large fluence implied by the Sgr B2 emission and can hardly be reconciled with the 10-year duration of the MC1 event (Clavel *et al.* 2013). Alternatively, the interaction between the shock created by the supernova explosion that produced the Sgr A East remnant and the 50 km s$^{-1}$ cloud could have created an extended-duration X-ray flash, perhaps with considerable substructure (Fryer *et al.* 2006) able to explain part of the Fe K$\alpha$ emission (although it would require large energetics in low energy cosmic rays). Another obvious alternative are X-ray binaries. As discussed above, the high luminosity implied by the Sgr B2 emission excludes the possibility that *all* the Fe K$\alpha$ emission could be due to X-ray binaries. On the other hand, *part* of the Fe K$\alpha$ emission must be induced by X-ray binaries (if close

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enough to a molecular cloud). In fact, reflected emission induced by an X-ray binary has already been observed in the GC (Muno *et al.* 2005).

## 6. Evidence for earlier activity

The light-crossing time of the CMZ ($\sim 10^3$ yr) places a time constraint on past Sgr A* activity with the method described above. *Is it possible to constrain Sgr A*'s history even further back in time?* Cramphorn & Sunyaev (2002) used the giant molecular clouds in the Galaxy to extend such studies to previous events. These authors placed upper limits to Sgr A*'s luminosity down to about $8 \times 10^{40}$ erg s$^{-1}$ for several periods within the past $4 \times 10^4$ years (see Figure 2). At earlier times the limits are less tight, with $L_{\rm Sgr\,A*} \sim 10^{41} - 10^{42}$ erg s$^{-1}$. Due to the non-homogeneous cloud distribution in the Galactic disk, unconstrained periods lasting as long as $\sim 3 \times 10^3$ years could have happened in the past $\sim 4 \times 10^4$ yr. These authors extended this study even further, to the HI gas in the Galactic disk. In this way, they ruled out a long term X-ray active phase, at $\sim 0.01$ Eddington, ending less that $\sim 10^5$ years ago.

To extend this study further back in time, other tracers of BH activity are required. The so-called Fermi bubbles (Su & Finkbeiner 2012) are two gigantic features extending up to $\sim 10$ kpc, originating from the GC and evident as extended $\gamma$-ray emission (with approximately uniform surface brightness and sharp edges), as well as at other wavelengths. Several mechanisms could have created the bubbles, e.g., enhanced star formation, dark matter, AGN activity. If these bubbles had been inflated by an active phase of Sgr A*, then their estimated energy content would be of the order of $\sim 10^{55}$ erg (Bland-Hawthorn & Cohen 2003; Su *et al.* 2010), with the active phase occurring a few $10^6$ years ago. The Fermi bubbles thus suggest that a few $10^6$ years ago Sgr A* might have been an AGN, looking very much like a typical Seyfert galaxy. We expect that such an event should have had a profound impact on the surrounding material, with consequences that might still be measurable today. Recently Bland-Hawthorn *et al.* (2013) discussed the possibility that enhanced H$\alpha$ emission in the Magellanic Stream could have been induced by the same Seyfert-like episode at the origin of the Fermi bubbles. In particular, the authors inferred a luminosity during this phase of about 0.03 to 0.3 Eddington. The accretion disk that fueled the Seyfert-like accretion event could have been the nursery where the young stars of the nuclear stellar cluster could have formed (Nayakshin *et al.* 2007; thus explaining the "paradox of youth" Ghez *et al.* 2003). This accretion phase could be linked to the minispiral and the truncated circumnuclear disk (thought to have either a transient origin or be the product of an energetic disruption of a stable disk; Martin *et al.* 2012; Requena-Torres *et al.* 2012; Zhao *et al.* 1995; Mills *et al.* 2013).

We point out that, during such an event, the GC would have appeared as an AGN to an observer outside the Milky Way. In those conditions the circumnuclear disk and the rest of the CMZ would have appeared as the torus of such AGN (Ponti *et al.* 2013).

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