An X-ray survey of the Central Molecular Zone: variability of the Fe Kα emission line

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The origin of the Fe Kα emission

The Fe Kα line at 6.4 keV and its associated continuum emission observed throughout the Central Molecular Zone (CMZ) have been interpreted as due to the interaction of low-energy cosmic rays with molecular matter through inverse bremsstrahlung emission and ionization by sub-relativistic electrons (Yusef-Zadeh et al. 2007), protons (Dogiel et al. 2009) or ions (Tatischeff et al. 2012). The observations of Fe Kα line flux variability in different regions (Sgr B2, Inui et al. 2009, Terrier et al. 2010, 2013; Sgr A, Muno et al. 2007, Ponti et al. 2010, Clavel et al. 2013) rule out this scenario in many places of the CMZ, since the expected energy loss of particles is too slow to account for the observed rapid variability, and rather favor a reflection origin. In fact, a bright, but now extinct hard X-ray source, likely Sgr A*, could have illuminated the CMZ clouds which in turn produced delayed emission through Compton scattering and K-shell photo-ionization of iron (Sunyaev & Churazov 1998). The analysis of this emission is therefore fundamental to reconstruct the much more active past of Sgr A*.

The XMM-Newton view of the CMZ

From 2000 to 2012, more than 100 observations have been performed by XMM-Newton within the central degree around Sgr A*. In particular, two full scans of the CMZ have been carried out in 2000-2001 and more recently in 2012 (Fig. 1). In order to follow the propagation of the reflected emission through the central 200 pc of our Galaxy, we have systematically analyzed the 13 years of XMM-Newton data. Images have been produced selecting events in a narrow band centered at 6.4 keV (ΔE = 160 eV) for all the EPIC instruments, and the contribution from the continuum emission estimated and subtracted (assuming a power law spectrum with photon index Γ=2 and absorbed by $N_H = 7\times10^{22}$ cm^{-2}). Large scale mosaic images of observations performed within 5 main time periods (Fig. 2) have been produced, and a finer time resolution (few months to one year) is used for specific regions depending on the data availability.

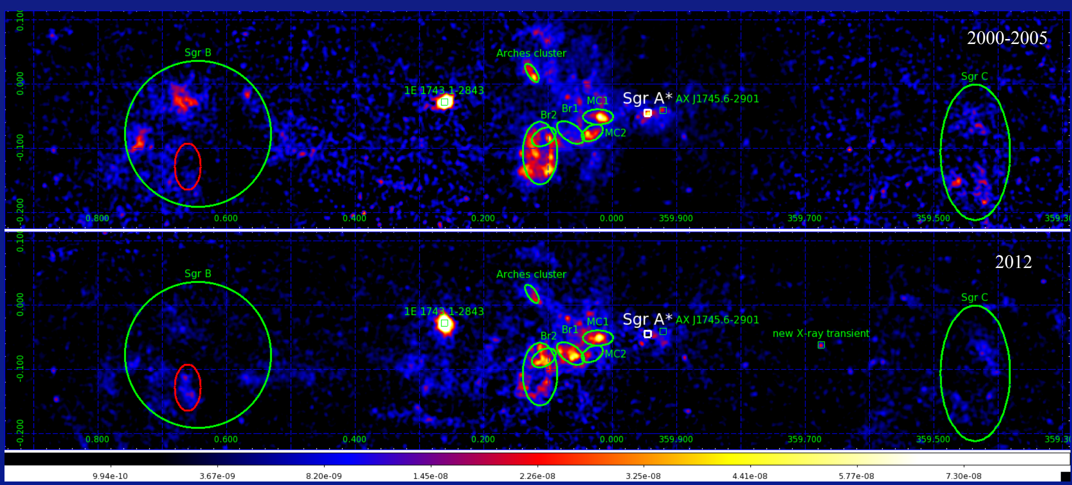

Fig. 1 (above) – Background- and continuum-subtracted intensity maps of the inner Galactic centre region measured by XMM-Newton at 6.4 keV at two different epochs (maps in units of ph/cm2/s/pixel, with 2.5 arcsec pixel size and to which a Gaussian smoothing with a kernel radius of 7 pixels has been applied). Some of the Fe Kα bright molecular complexes are indicated with ellipses or circles, while the positions of some bright point sources are marked with squares. A new X-ray transient has been detected during the 2012 survey.

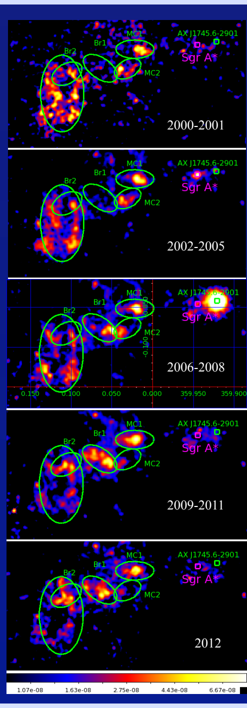

Fig. 2 (right) – Zoom into the Sgr A region as observed by XMM-Newton at 6.4 keV in 5 periods during the last 13 years (maps in units of ph/cm2/s/pixel, with 2.5 arcsec pixel size and to which a Gaussian smoothing with a kernel radius of 5 pixels has been applied). The propagation of the emission away from Sgr A* can be observed within the MC and Br clouds (see also G. Ponti and M. Clavel presentations during this conference).

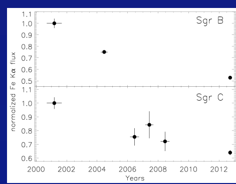

Fig. 3 (above) – Sgr B (top) and Sgr C (bottom) Fe Kα light curve during the XMM-Newton observations. The fluxes have been computed integrating over the large regions indicated in green in Fig. 1, and have been normalized to the flux level of the 2000-2001 observation. A global decrease is observed for these molecular regions. In particular for Sgr C, this supports a reflection origin for the observed variable emission.

First results

Preliminary results indicate a significant decrease of the total 6.4 keV emission in the CMZ. This can be clearly observed on a large global scale in the Sgr B molecular complex (Figs. 1 and 3), even though some specific sub-regions appear to have brightened, as for example the G0.65-0.14 region (red ellipse in Fig. 1), or the horizontal filamentary structure at the south-east of Sgr A. We report here for the first time a significant variation of the Fe Kα emission in the Sgr C complex (Fig. 3), by a factor of two down to the arcminute scale. Previously only a low significant 8% variation in just one region of the complex had been reported (Ryu et al. 2013). Our result would indeed favor the reflection scenario over a cosmic ray origin for the Sgr C sub-regions where such variations are observed. In the Sgr A region, the propagation of the emission away from Sgr A* (within the regions labeled MC and Br in Fig. 2) is continuing, consistently with the echo moving through the Galactic centre and fading, as previously reported by Ponti et al. (2010) and Clavel et al. (2013). Important additional hints to the nature and duration of the past event(s) responsible for the observed emission will be provided by the estimate of the percentage of molecular gas that has emitted at 6.4 keV within the past years of observations across the whole CMZ, and how that percentage has varied.

References

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