Review of the XMM-Newton monitoring of the X-ray activity of SgrA*

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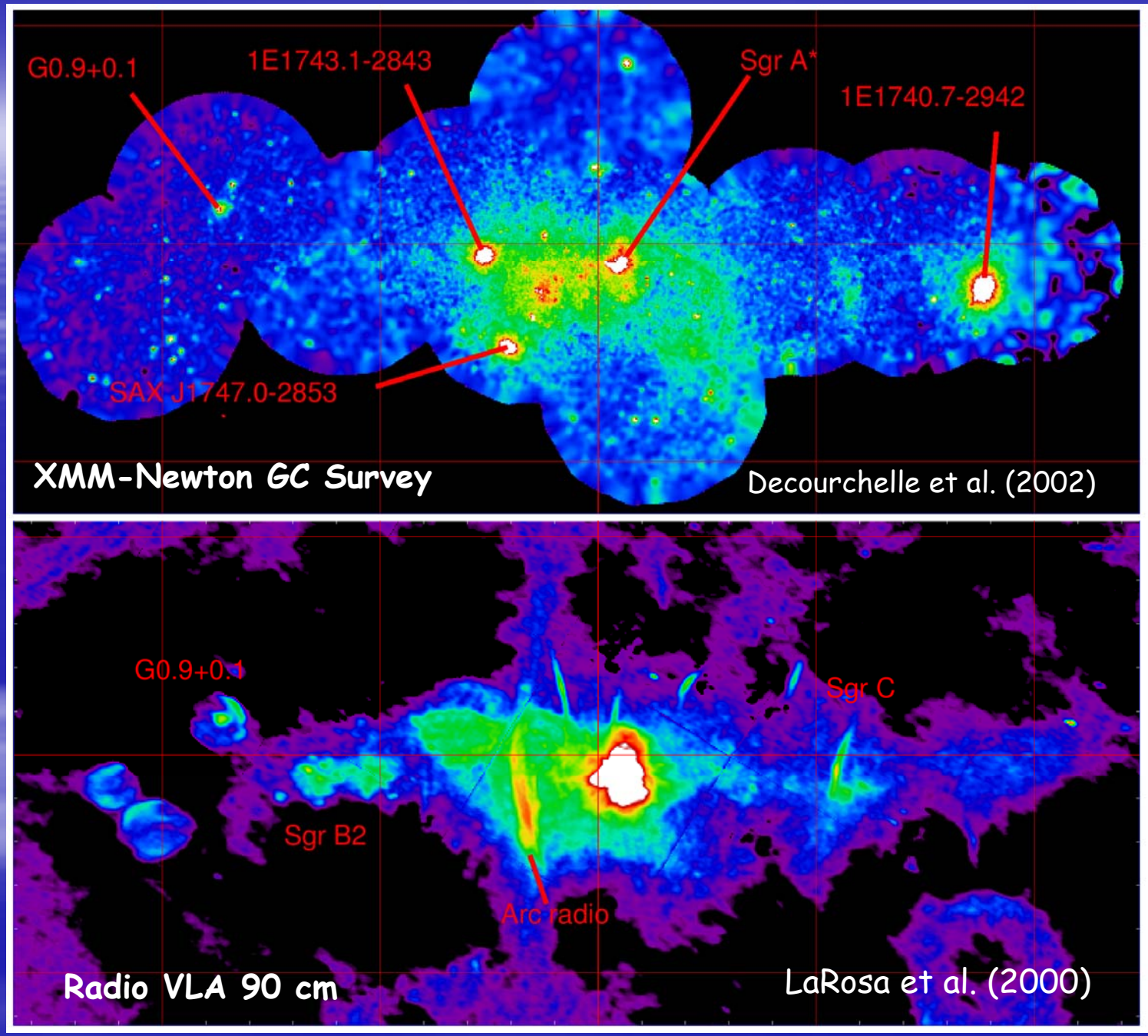

G0.9+0.1
1E1743.1-2843
Sgr A*
1E1740.7-2942
SAX J1747.0-2853
XMM-Newton GC Survey
Decourchelle et al. (2002)
G0.9+0.1
Sgr C
Sgr B2
Arc radio
Radio VLA 90 cm
LaRosa et al. (2000)

International collaboration:
XMM view of SgrA* and its close environment

+ Multi-wavelength campaigns: radio, sub-mm, mid-IR, near-IR, Gamma-rays

- *Strasbourg Observatory (France)* : D. Porquet, N. Grosso

- *CEA/Saclay (France)*: A. Goldwurm, P. Ferrando (X-rays and Gamma-rays)
  P.O. Lagage (Mid-IR)

- *MPE (Germany)*: B. Aschenbach, G. Hasinger, P. Predehl, Y. Tanaka (X-rays)
  R. Genzel (NIR)

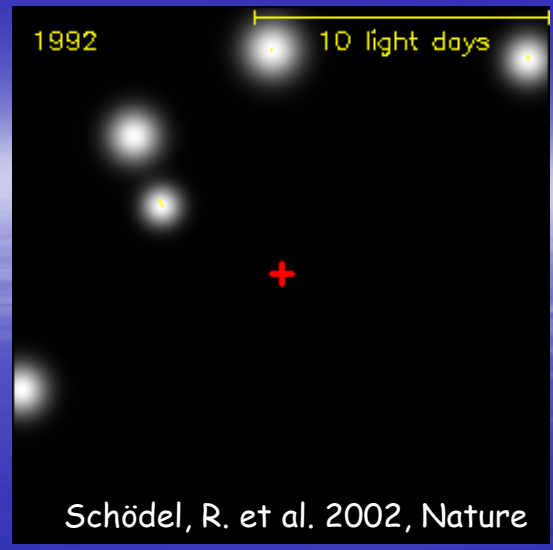
- *ESAC (Spain)*: G. Bélanger

- *Leicester (UK)*: R.S. Warwick, M. Sakano (X-rays)

- *Northwestern University (USA)*: F. Yusef-Zadeh (NIR and radio)

- *University of Arizona (USA)*: F. Melia (Theory/models)

I. Sgr A*



- **Closest Supermassive Black Hole (d ~ 8 kpc)**
  M_{BH} ~ 3-4 x 10^6 solar masses (e.g., Ghez et al. 2003, Schödel et al. 2003)

- **Bolometric luminosity: L_{bol} ~ few 10^{35} erg.s^{-1}**
  10^{-8}-10^{-9} times weaker than the Eddington luminosity
  (L_{Edd}=1.26 10^{38} $M/M_\odot$)

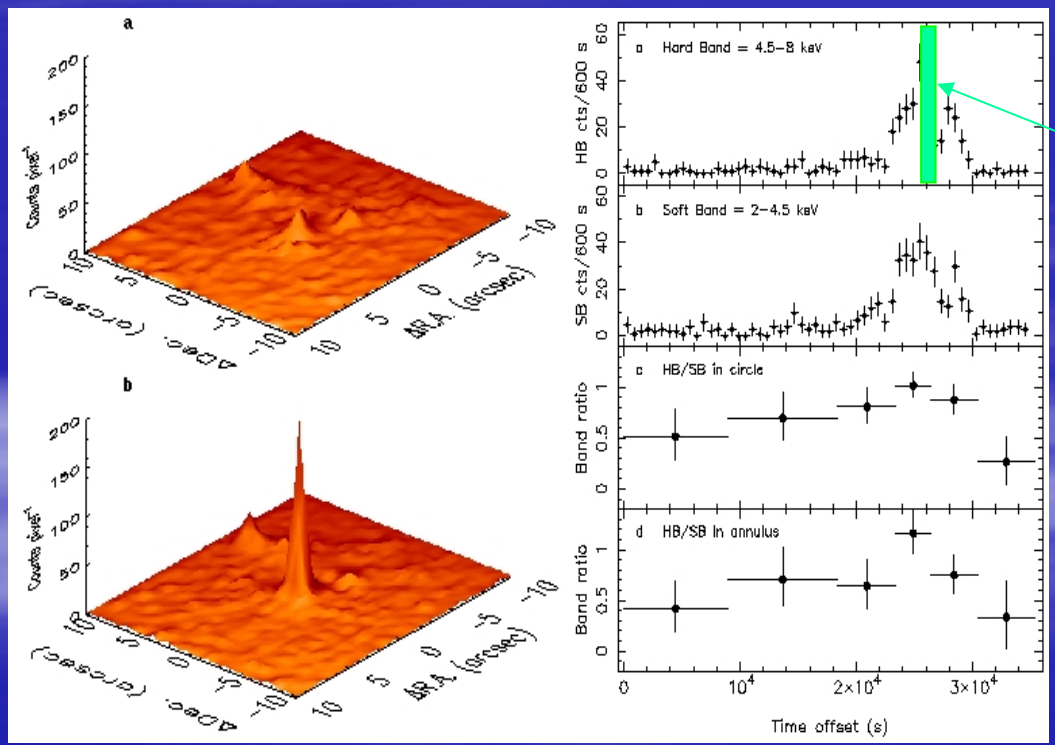
⇒ **Radiatively inefficient accretion models.**

I.1) SgrA*: X-rays

X-ray luminosity: ~ 2.4 x 10^{33} erg s^{-1} (Baganoff et al . 2003)
<< Active Galactic Nuclei (≥ 10^{42} erg s^{-1})

First detections of flares from SgrA* in X-rays:
new perspectives for the understanding of the processes at work in the Galactic nucleus

Chandra : Baganoff et al. (2001)



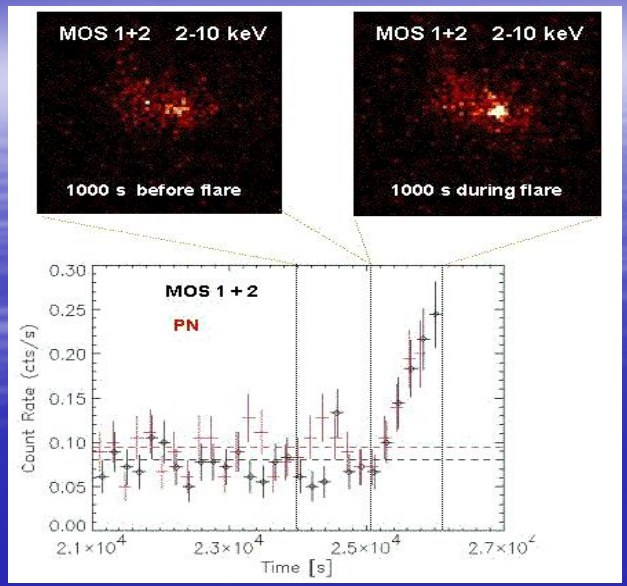
October 2000:

- Sgr A* flared by a factor 45 during about 3 hours
- The shortest time scale is 600 sec → 20 R_s.
- The spectrum hardens significantly: Γ= 1.3
  Note: Γ(quiescent) ~ 2.7

⇒ X-rays come from near the black hole (like mm-radio!).

⇒ Not consistent with simple ADAF models.

XMM detection of moderate amplitude and hard SgrA* flares



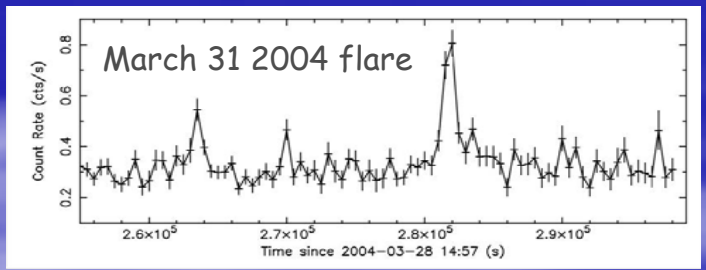
Goldwurm et al. (2003)

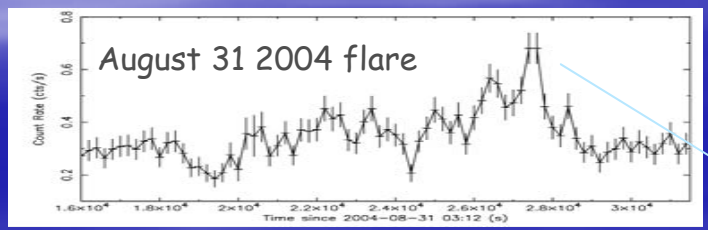
September 2001:

Occurred at the end of the PN observation: t~900s

peak/quiescent ~ at least 20-30
(L_x~ 5.4 x 10^{34} ergs/s)

Γ ~ 1.0





Bélanger et al. (2004)

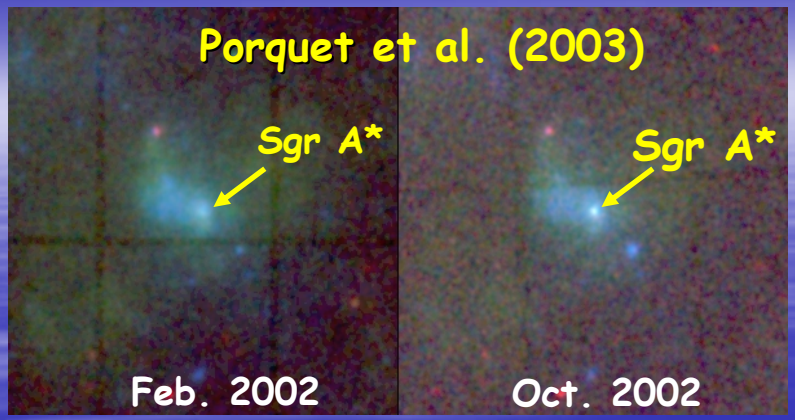
2004 XMM Large project
(AO4, ~550 ks, PI: A. Goldwurm)

2 flares with moderate amplitude:
- duration: 2500-5000s
- peak/quiescent ~ 40 (L_x~ 9 x 10^{34} ergs/s)
- Γ=1.6±0.4

+ several possible weak flares

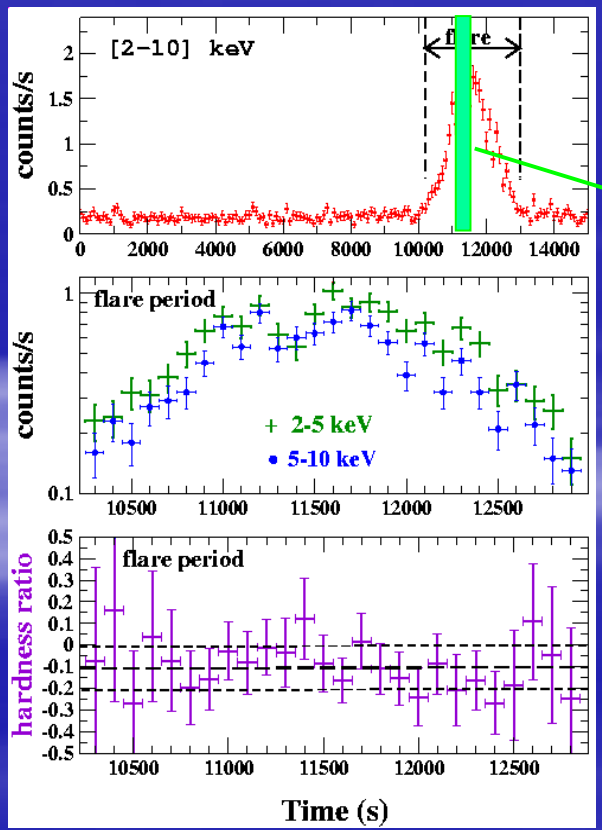
Simultaneous with a NIR flare detected with HST

The brightest and softest X-ray flare from Sgr A* (XMM-Newton)



October 3, 2002:

- duration: less than 1 hour
- amplitude: ~ 160 (peak / quiescent)
  (~ x 3-4 compared to other X-ray flares)



Peak Lum (2-10keV)= 3.6×10^{35} erg.s^{-1}

≈ Bolometric luminosity

- almost symmetrical light curve
- shortest time-scale: 200 s (3σ)

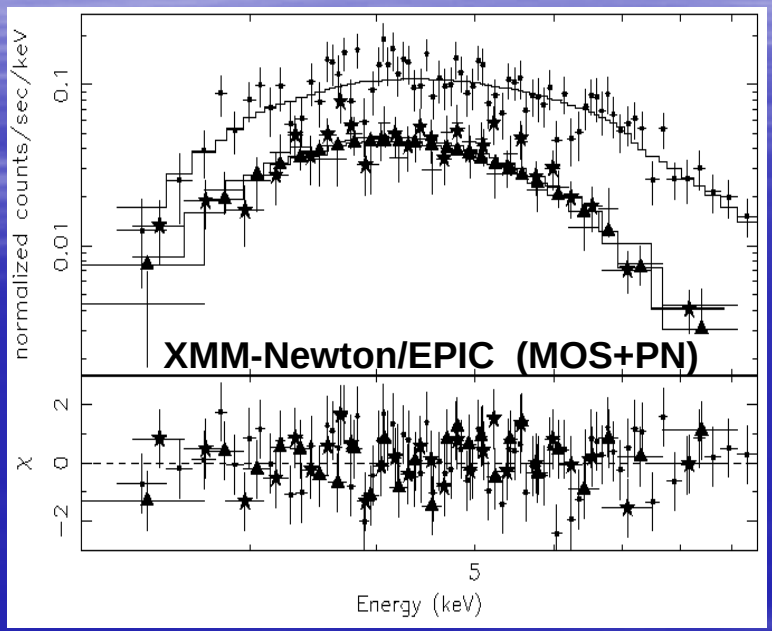
→ 7 R_s: inner central region

(R_s~ 8×10^{11} cm)

- similar soft (2-5 keV) and hard (5-10 keV) light curves.
- no significant spectral variability between the rising and decreasing phases.

X-ray spectra of the strongest Sgr A* flare

Porquet et al. (2003)



Photon spectral index :

$\Gamma = 2.5 \pm 0.3$

(XMM-PN, 10/2002)

Much softer than weaker X-ray flares
($\Gamma \sim 1.0$-1.3)

Until now two types of flares:

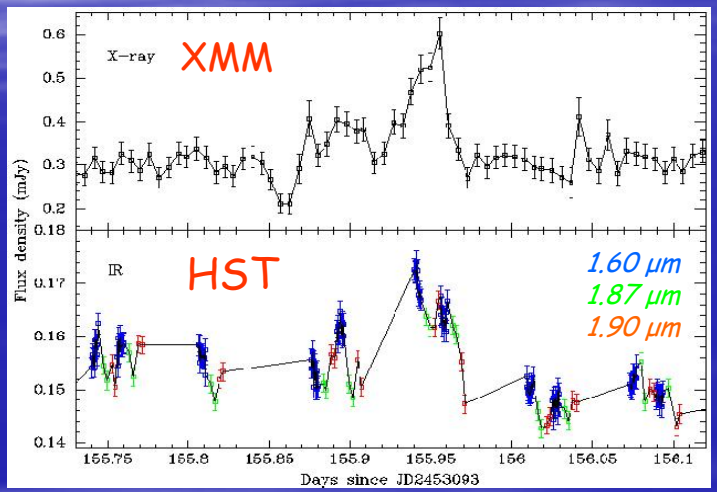
- **Moderate amplitude (× 10-40) and hard X-ray spectrum (Γ=1.0-1.5)**
- **Very Strong (× 160) amplitude and soft X-ray spectrum (Γ=2.5±0.3)**

I. 2) SgrA*: Multi-wavelength observations

Multi-wavelengths XMM AO4 GC campaign

Large Project XMM (AO4; 550ks, ~ 6 days, PI: A. Goldwurm): observations of SgrA*
2 epochs: March and September 2004 (Bélanger et al. 2005).
+ 32 HST orbits (PI: Yusef-Zadeh)

31/08/2004



Yusef-Zadeh et al. (2006)

3 bright near-IR (NIR) flares detected with HST:
* amplitudes: 10-20% increase;
* durations: 2 to 2.5 hours;
* dereddened peak fluxes ~10.9 mJy;
* flaring activity: ~30-40% of the observing time.

One simultaneous X-ray/NIR flare observed: similar morphology, similar duration with **no apparent delay.**
→ Believe to come from the same region close to the event horizon.

Not all NIR flares have (detected) X-ray counterpart (see also Eckart et al. 2004, 2006).

NIR flares: supposed to be due to Synchrotron emission.

Sub-mm photons are up-scattered (Inverse Compton Scattering) to X-ray energies by the e^- responsible for the NIR synchrotron radiation.

II. Neighbouring X-ray transient sources

X-ray binaries

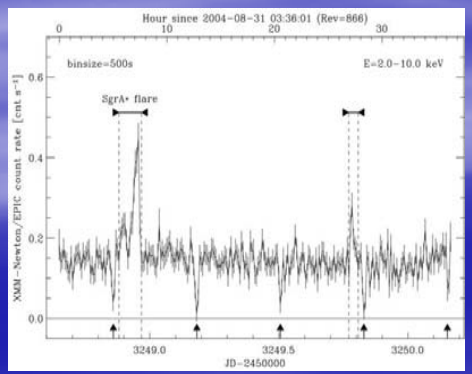
- Previous X-ray satellites (e.g., ASCA, BeppoSAX, RXTE):
  numerous bright points sources (L_x >> 10^{35} erg s-1)
  persistent or transients
  majority of Low-mass X-ray binaries containing a NS or a BH

- **Chandra and XMM-Newton with high sensitivity up to 12 keV:**
  Observation of weaker sources (~ 10^{33} - 10^{35} erg/s) with luminosities between the quiescent state and very bright outburst state.

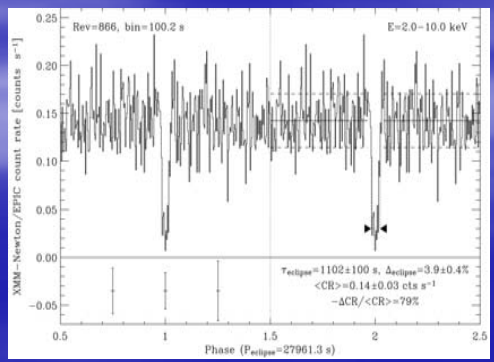
  See also the talk of C. Motch.

CXOGC J174540.0-299931: Discovery of X-ray eclipses from an X-ray binary located at only 0.1 pc from SgrA* (Porquet, Grosso et al. 2005).

light curve

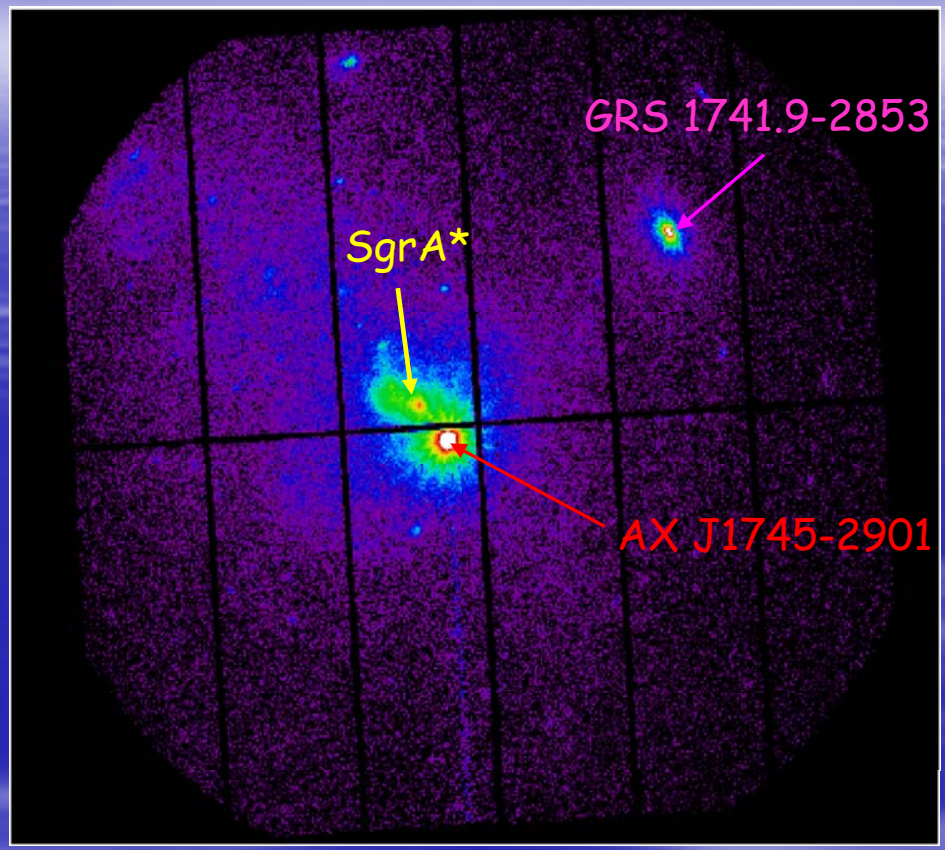


Folded light curve



X-ray eclipses with a period of ~ 7.8 h
⇒ M_2 ≤ 1.05 $M_\odot$: LMXB
⇒ M_1 ≤ 60 $M_\odot$

Last news from SgrA*: preliminary results of the April 2007 campaign (PI: D. Porquet; ~250ks)



- Long X-ray outburst (at least 7 weeks) of:

- AXJ1745-2901 (eclipsing X-ray burster): 7 deep eclipses and 1 type-1 burst observed !

- GRS1741.9-2853 (neutron star X-ray binary): 2 type-1 burst observed.

(Porquet, Grosso, Goldwurm et al. 2007a, ATEL#1058)

X-ray hiccups from SgrA*
(PI: D. Porquet; ~250ks)

- **Detection of a second strong and soft X-ray flare from SgrA* on April 4th, 2007. (Porquet et al. 2007, in prep.)**

Amplitude: ~80 → Intermediate between the two types (up to now) observed.
Duration: ~ 1 h

- **~4 weaker flares: amplitude ~20-40**

Simultaneous multi-wavelength observations with VLA, CSO, IRAM, VLT/NACO-VISIR, HST, Integral, …

⇨ Test of the Inverse Compton scattering model.

Summary:

- **2 types of SgrA* X-ray flares** (durations: ~ 1-3 h, occurrence: ~ 1 per day):
  - A majority of *faint to moderately luminous (≤ x 40) flares with hard spectrum (Γ~ 1-1.5):* *Baganoff et al. (2001), Goldwurm et al. (2003), Bélanger et al. (2005), Eckart et al. (2004,2006).*
  - *Luminous to very luminous (x 80-160) flares with soft spectrum (Γ~2.3-2.5):* *Porquet et al. (2003; 2007)*

- Multi-wavelength observations *(Eckart et al. 2004, 2006; Yusef-Zadeh et al. 2006):*

NIR and X-ray flares have similar shape with no apparent time delay.
Not all IR flares have X-ray counterpart.

Requirement for the next decade: long-term monitoring of the X-ray activity.

- Continue the monitoring of SgrA*:
  - Statistics on the X-ray flares (occurrence rate, duration, spectral index, flux) and their correlation with radio, sub-mm, and NIR.
  Bright flares are not rare but not frequent: need to observe SgrA* over long exposures.
  Enhancement or decrease of X-ray activity over decades ? (e.g., K. Koyama's talk)
  - QPO ? → BH spin and mass (Aschenbach et al. 2004; Bélanger et al. 2006)
  - Relation between SgrA* and Low-luminosity AGN ?

- Close environment: X-ray binaries (quiescent state to outburst state).

- X-ray diffuse emission (Robert Warwick's talk).

⇨ **2 × 250 ks per year needed !**