Echoes of the past outbursts of Sgr A* to be revealed with X-ray polarimetry

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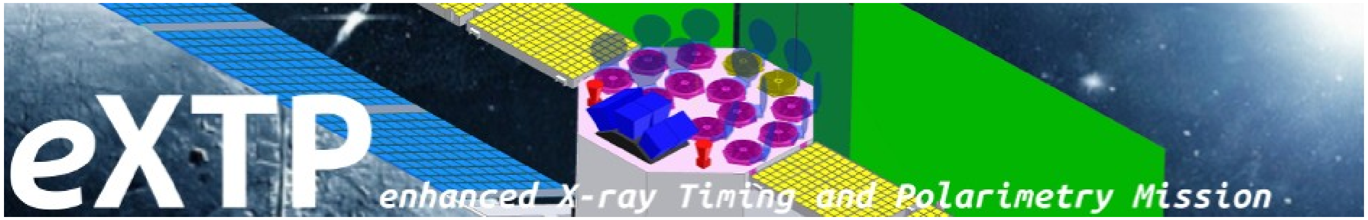


The Galactic center

Picture :

- FoV of the picture ~ 1.5 x 2.5 degrees
- Mid-IR image from the Midcourse Space Experiment satellite

Curiculum vitae :

- Coordinates first established by Harlow Shapley in 1918:
  RA 17h45m40.04s, Dec −29° 00' 28.1'' (J2000 epoch)
- 8.33 ± 0.35 kpc (~27 ± 1 kly) (distance)
- Invisible in optical, ultraviolet and very soft X-rays due to interstellar dust
- Collection of vast cosmic dust clouds, bright star clusters, swirling rings of gas, and even a supermassive black hole (Sgr A*)

The intriguing case of Sgr A*

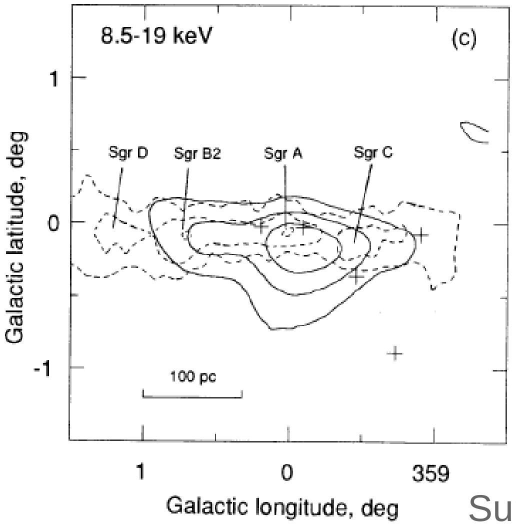
Sgr A* has a very low accretion rate:

About 10^{-8} $M_{sol}.y^{-1}$ near the event horizon (Baganoff et al. 2003)

resulting in X-ray luminosity of the order 2×10^{33} $erg.s^{-1}$ (Baganoff et al. 2001; Quataert 2002)

In comparison, 10^{7} - 10^{8} M_{sol} black holes in Seyfert 1 AGN accrete 0.01 - 0.2 $M_{sol}.y^{-1}$

(Meyer-Hofmeister & Meyer 2010)

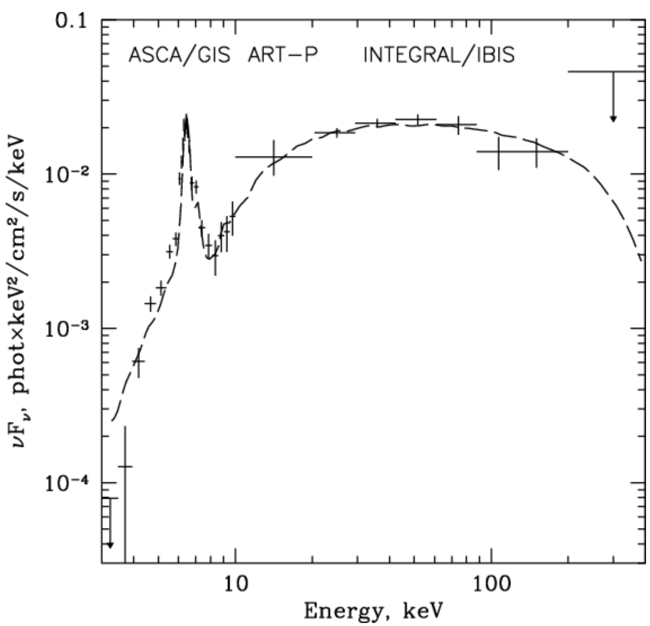


Sunyaev et al. (1993)

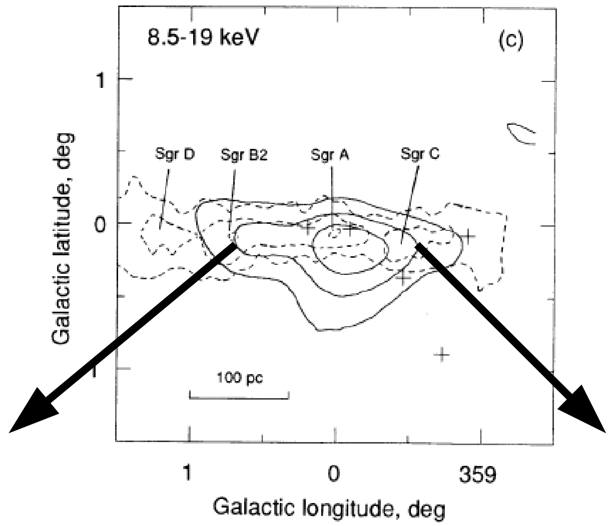
Such quiescence is in disagreement with several past X-ray observations of the Eastern and Western molecular clouds

(Sunyaev et al. 1993)
(Koyama et al. 1996)

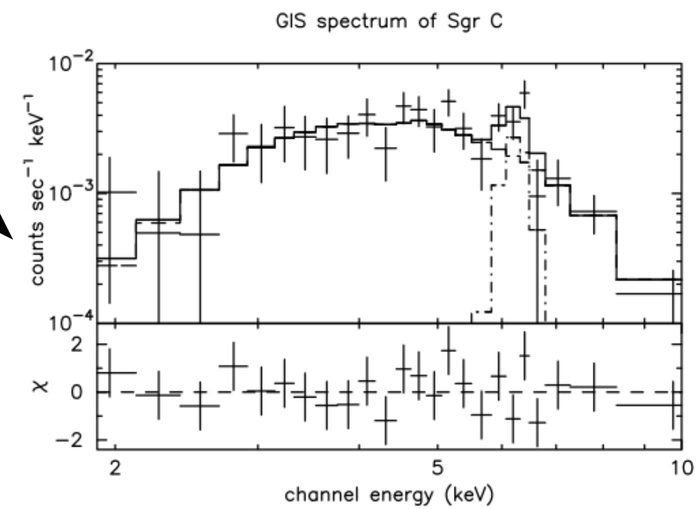
Past reflection?



Koyama et al. (1996) / Terrier et al. (2010)



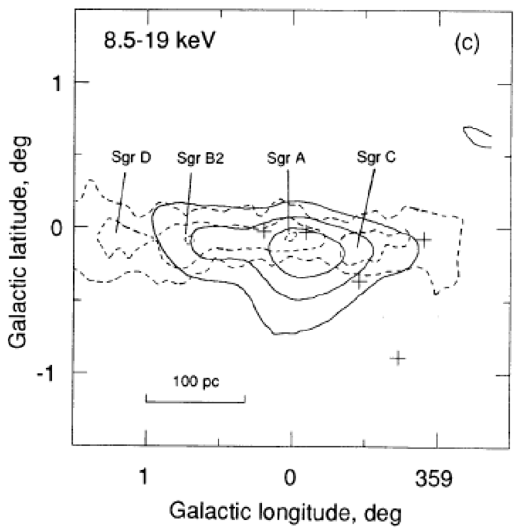
Sunyaev et al. (1993)



Murakami et al. (2001)

Pure reflection spectra ($L_X \sim 10^{35}$ erg.s^{-1}) … but no nearby sources bright enough!

Past reflection?



Sunyaev et al. (1993)

A geometrical solution:

Sgr B2 and Sgr C are reflection nebulae, shining the reprocessed emission from a past Sgr A* outburst ($L_X > 10^{39}$ erg.s^{-1})

Sunyaev & Churazov (1998)
Murakami et al. (2000)

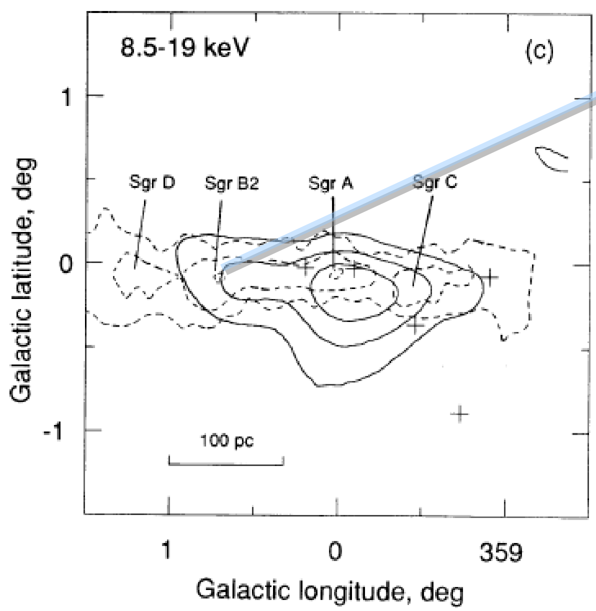
→ past flaring period of Sgr A*
(Sgr A* would have been active ~400 years ago and again about 100 years ago)

Inui et al. (2009)
Ponti et al. (2010)

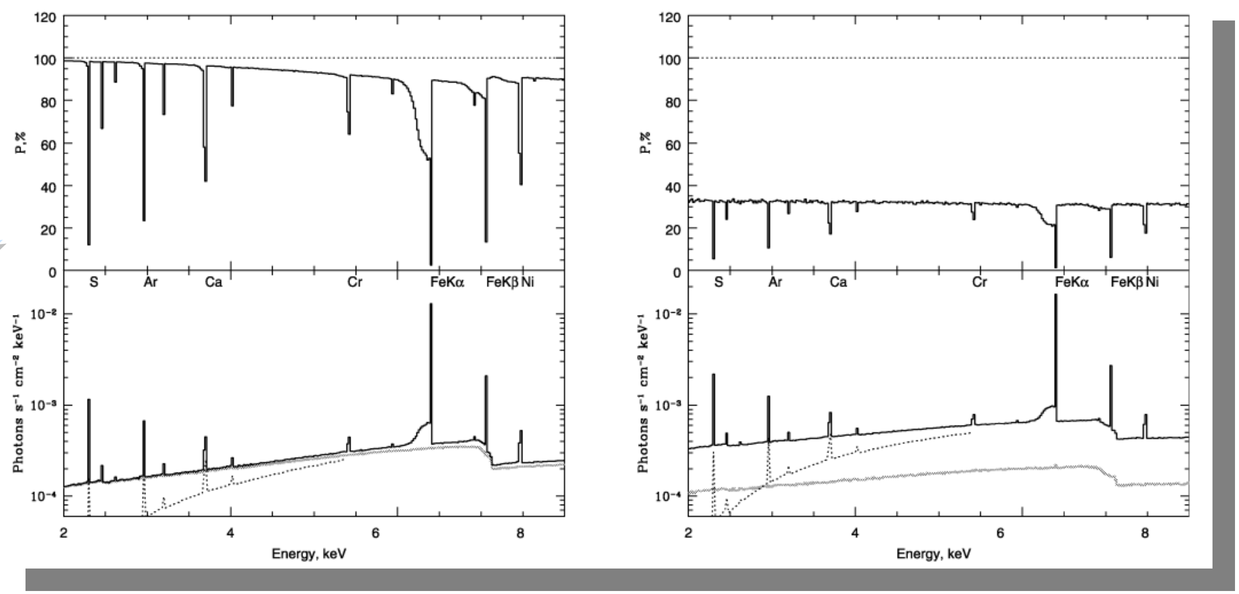
The estimated duration of the flare depends on the spatial location of the reflector
Cannot be properly constrained using X-ray spectroscopy or timing analyses

Soft X-ray polarimetry results

Polarization resulting from scattering on a single molecular cloud



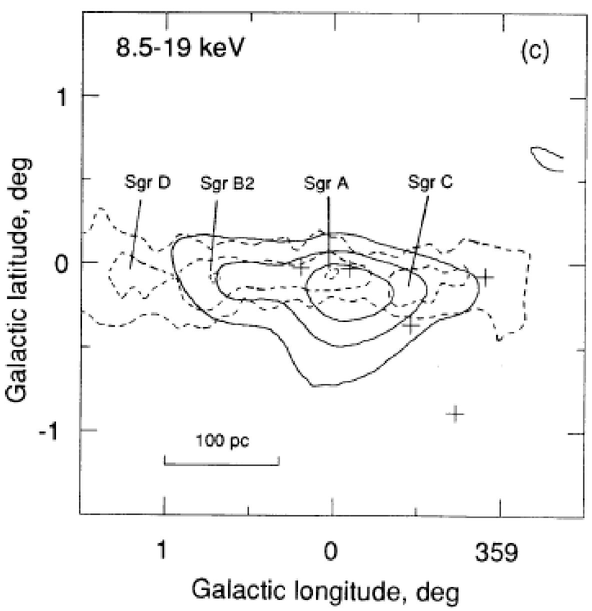
Sunyaev et al. (1993)



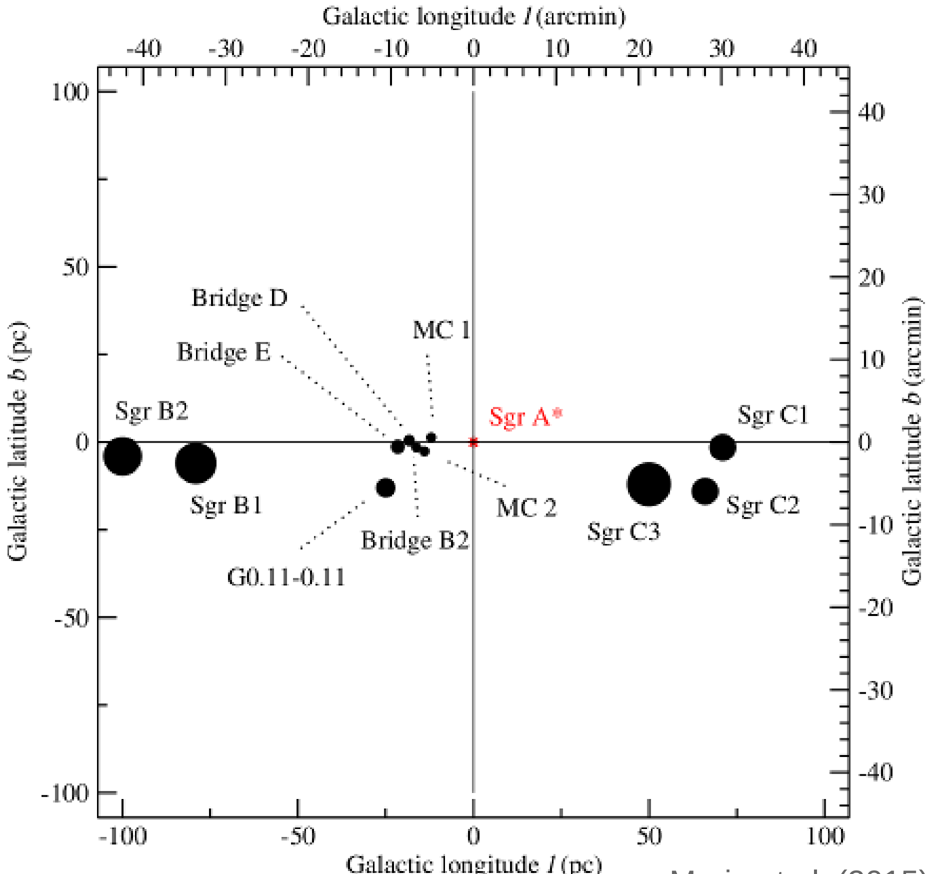
Churazov, Sunyaev & Sazonov (2002)

Soft X-ray polarimetry results

Polarization resulting from scattering
on a collection of 11 X-ray reflection nebulae



Sunyaev et al. (1993)



Marin et al. (2015)

Soft X-ray polarimetry results

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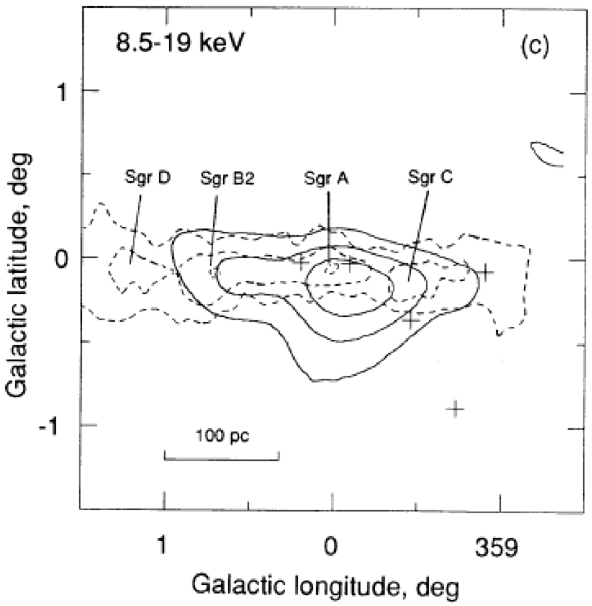
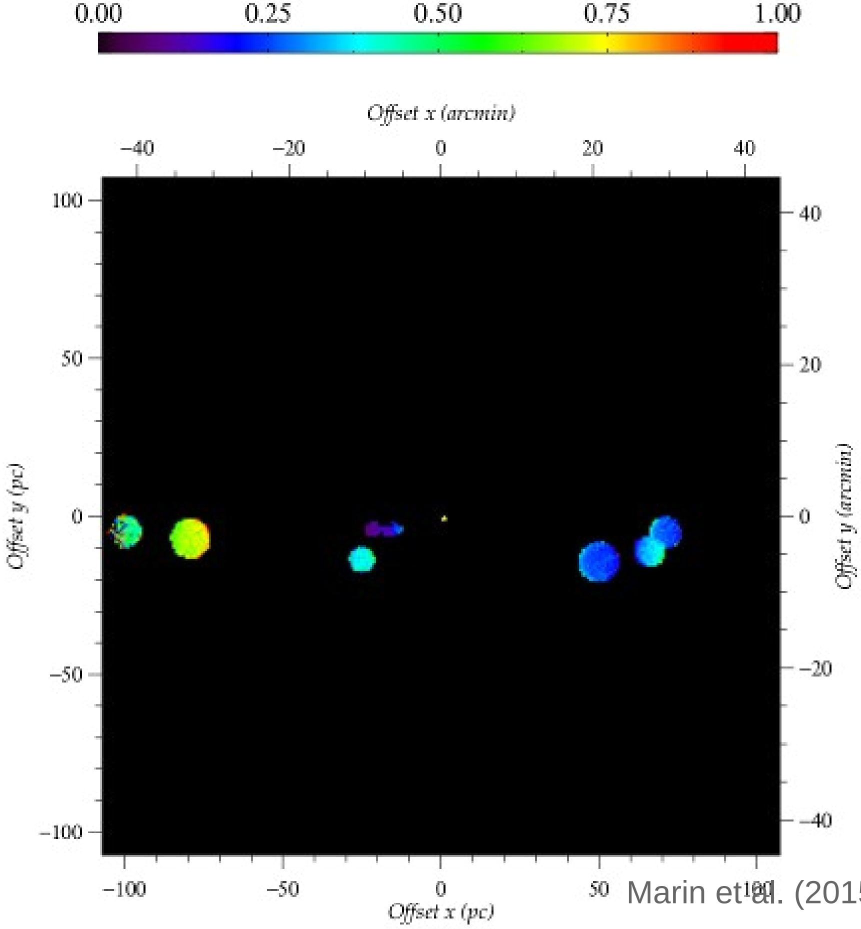


Sunyaev et al. (1993)



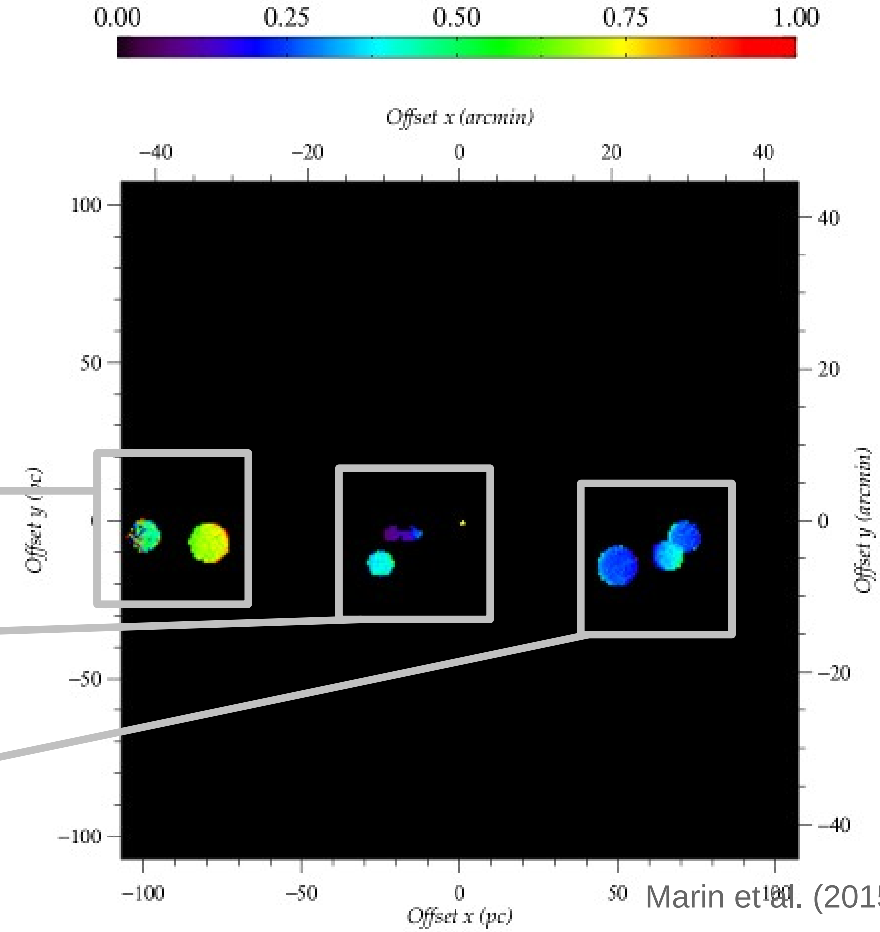
Marin et al. (2015)

Soft X-ray polarimetry results

Polarization resulting from scattering
on a collection of 11 X-ray reflection nebulae

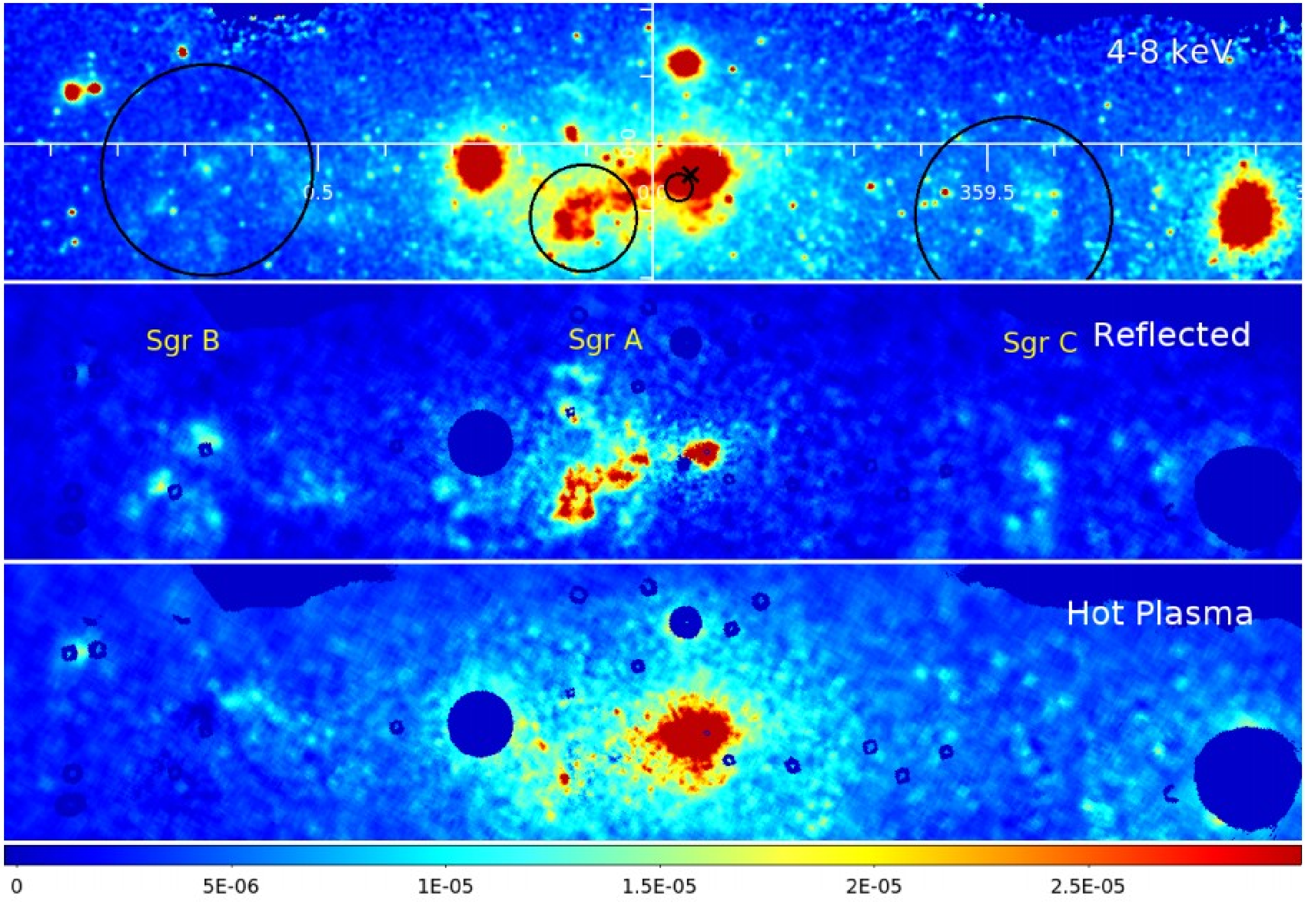
Boxes = eXTP field of view (12 arcmin)

Molecular cloud	P (%)	ψ (°)
Sgr B2	65.0	88.3
Sgr B1	76.9	84.4
G0.11-0.11	55.8	61.6
Bridge E	12.7	67.9
Bridge D	0.1	74.2
Bridge B2	15.8	77.8
MC2	25.8	73.8
MC1	0.1	77.5
Sgr C3	32.9	106.4
Sgr C2	34.9	99.1
Sgr C1	31.1	94.6



Marin et al. (2015)

Accounting for GC plasma emission



Churazov et al.
(2016, submitted)

Accounting for GC plasma emission

→ Spectral decomposition (Ryu et al. 2009, 2013)

Combination of the plasma contribution and the emission due to the reflection of the external source radiation

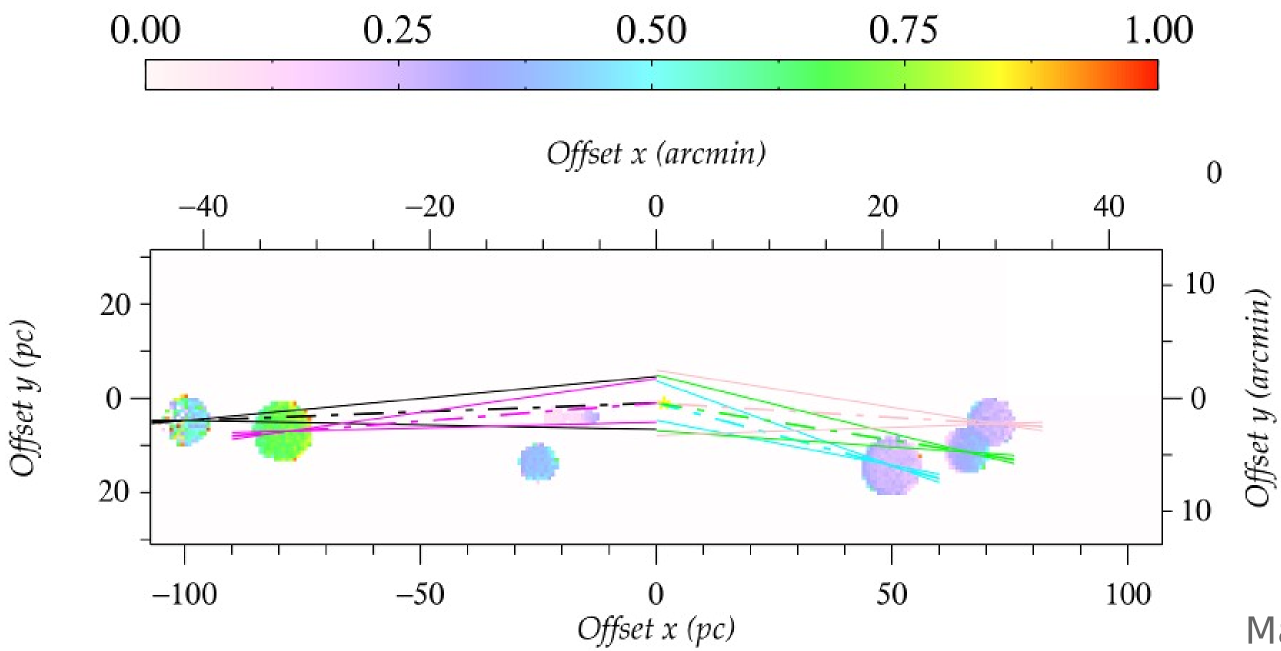
Molecular cloud	P (%)	ψ (°)	f_R (%)	$P_{exp.}$ (%)	$P_{detect.}$ (%)	$\psi_{detect.}$ (°)
Sgr B2	65.0	88.3	70.0	45.5	57.4 ± 4.4	83.3 ± 3.4
Sgr B1	76.9	84.4	52.6	40.5	40.4 ± 3.9	80.3 ± 3.3
G0.11-0.11	55.8	61.6	–	–	–	–
Bridge E	12.7	67.9	–	–	–	–
Bridge D	0.1	74.[illegible]	–	–	–	–
Bridge B2	15.8	77.8	–	–	–	–
MC2	25.8	73.8	–	–	–	–
MC1	0.1	77.5	–	–	–	–
Sgr C3	32.9	106.4	50.7	16.7	15.5 ± 2.4	109.0 ± 4.5
Sgr C2	34.9	99.1	63.0	22.0	17.9 ± 3.8	99.1 ± 5.6
Sgr C1	31.1	94.6	60.2	18.7	23.1 ± 3.3	98.1 ± 6.0

Dilution factor

Marin et al. (2015)

Pinpoiting the emission source

If molecular clouds are echoing a past flare of Sgr A* → high soft X-ray polarization is expected with electric vector perpendicular to the line connecting the two sources

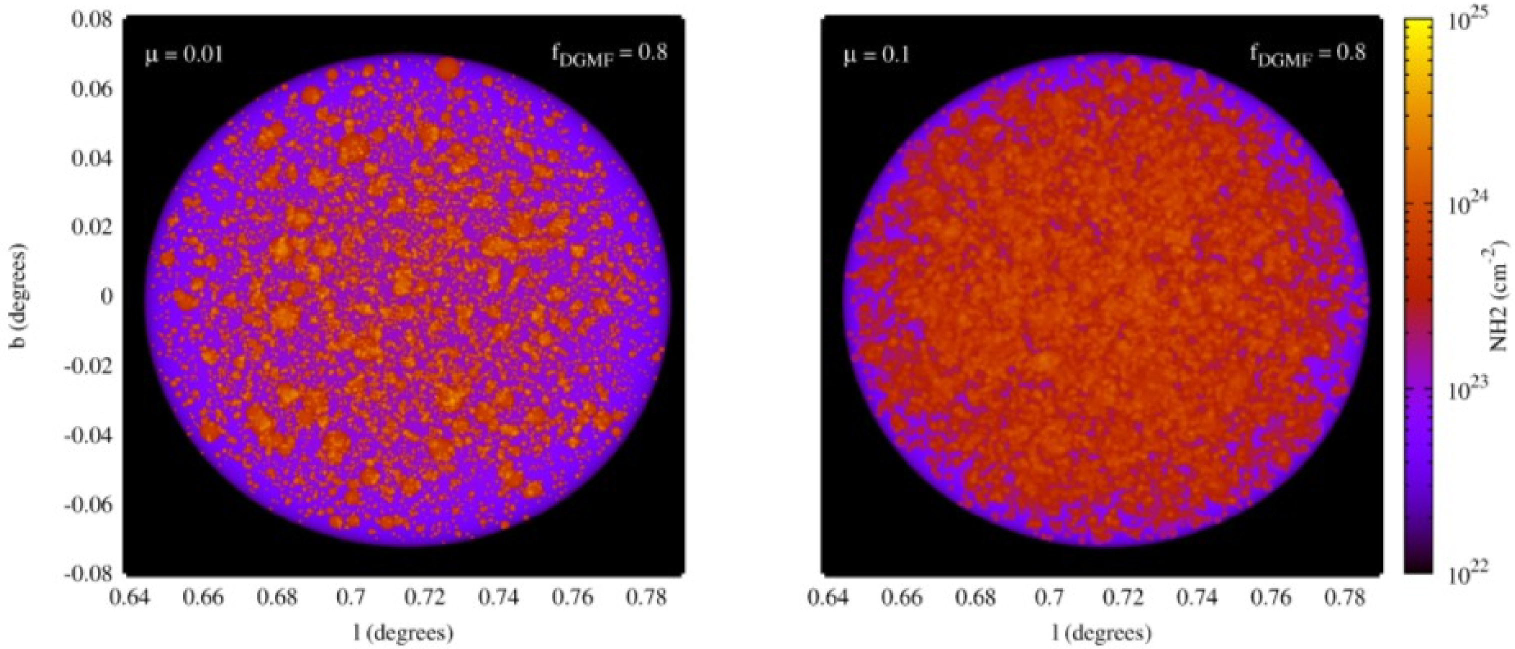


Marin et al. (2015)

Using the imaging capability of eXTP

Fragmented clouds ?

→ the case of Sgr B2



Molaro et al. (2016)

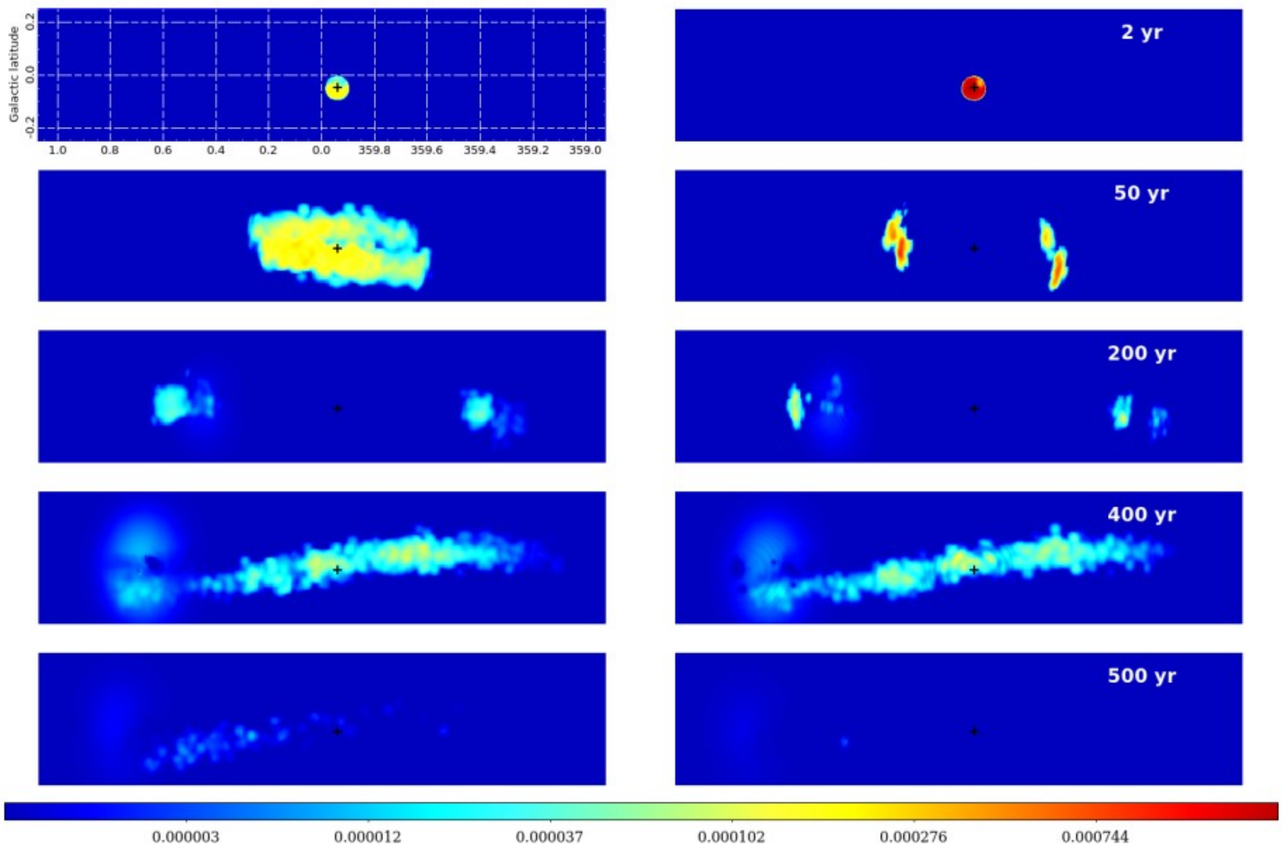
Using the imaging capability of eXTP

Time evolution of a flare seen with the polarized flux

Reflected component flux as a function of time. Single outburst

Left panel = 50 yr long outburst
Right panel = 5 yr long outburst

Luminosity of the central source is 10x larger for the 5 yr outburst, to provide the same fluence as for the longer outburst



Churazov et al. (2016, submitted)

Conclusions

X-ray polarimetry can probe the complex environment of the GC
+ it can prove or reject the AGN history of Sgr A*

The 3D localisation of the reflection nebulae with respect to Sgr A* can be fixed by measuring the degree of polarization
+ help to define the correct light-curve of its flare

eXTP polarization mapping possible if the GC plasma emission is taken into account (duration to be properly determined)

Polarization imaging is the strength of a future mission such as eXTP

X-ray polarization may distinguish between the two scenarios explaining the power-law continuum and the 6.4 keV iron feature (flaring / low-energy CR electrons)