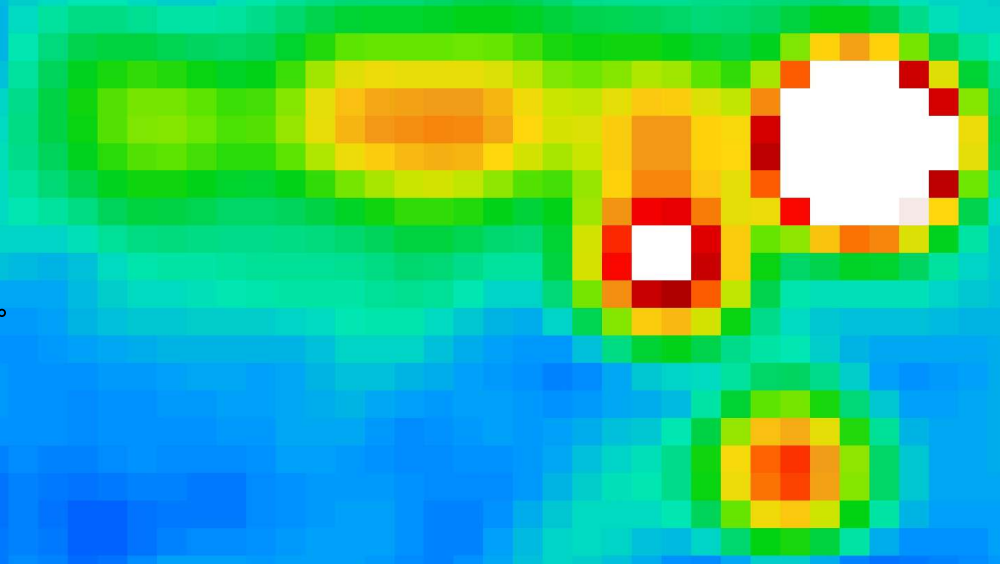
Sgr B2 - a natural Compton mirror in the Galaxy. The past activity of Sgr A*



Revnivtsev M.
Churazov E.
Sazonov S.
Sunyaev R.
Gilfanov M.

IKI, Moscow, MPA, Garching

Active Galactic Nuclei

Accreting supermassive black holes in centers of galaxies

Combined emission of AGNs gives dominant contribution to the X-ray flux near Earth

Black hole masses from ~10^6 M_{Sun} to ~10^9 M_{Sun}

Active Galactic Nuclei

Accreting supermassive black holes in centers of galaxies

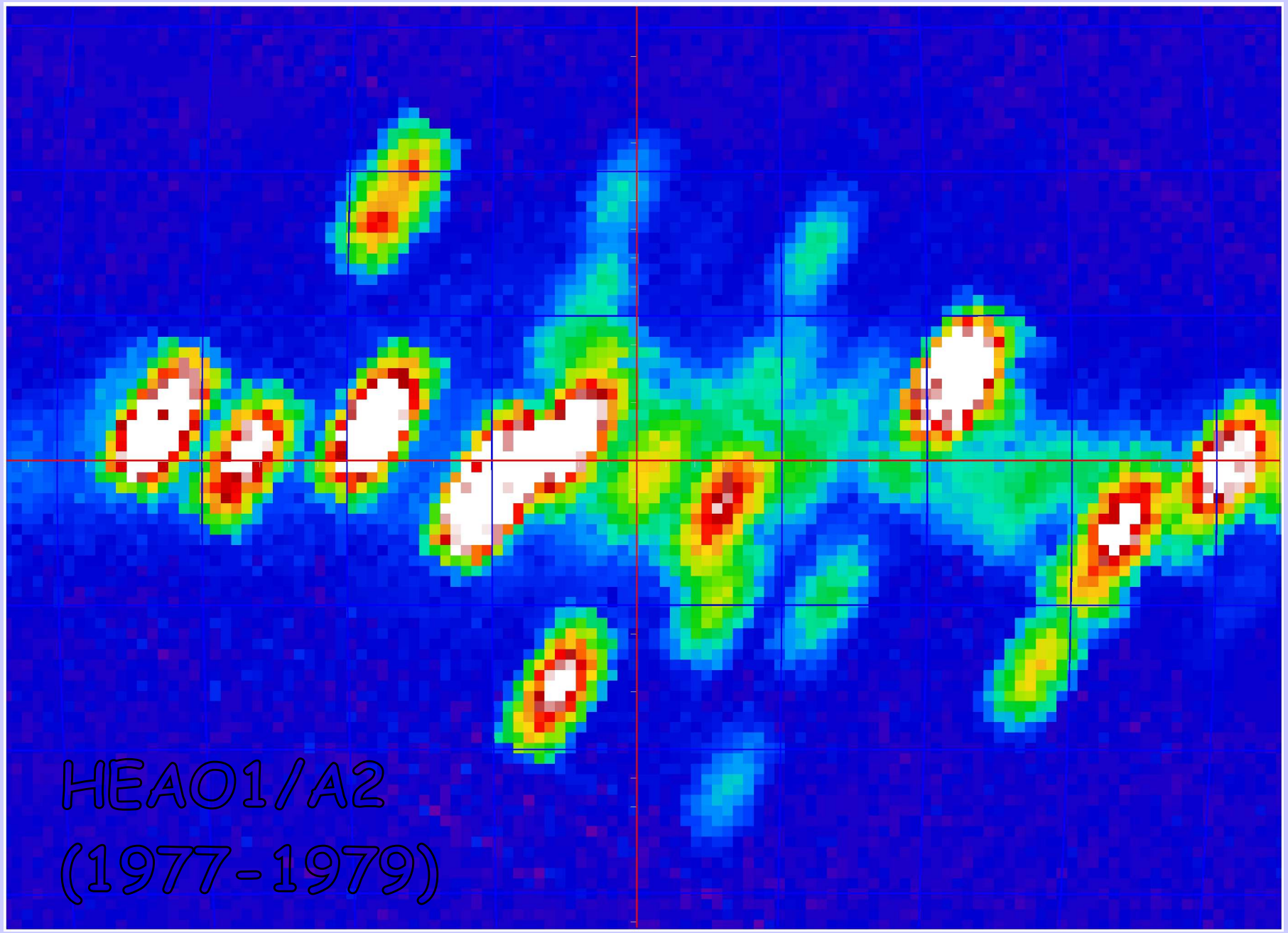
$L_{Edd} \sim 1.4 \times 10^{38}$ ergs/s for $1 M_{Sun}$ black hole

Typical AGNs with 10^{7-8} M_{Sun} have $L_x \sim 10^{42-44}$ ergs/s

Bolometric luminosity is $\sim 10^{-3}$-10^{-2} of the Eddington

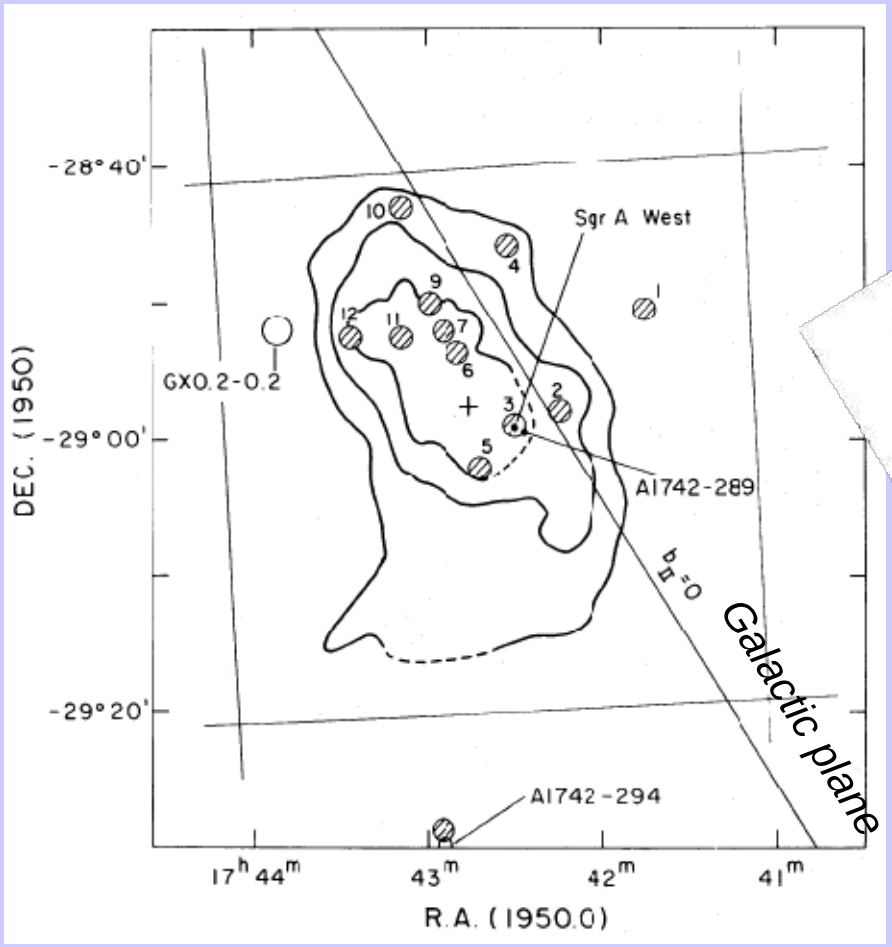
What is in the center of our Galaxy?

Galactic Center observations in X-rays



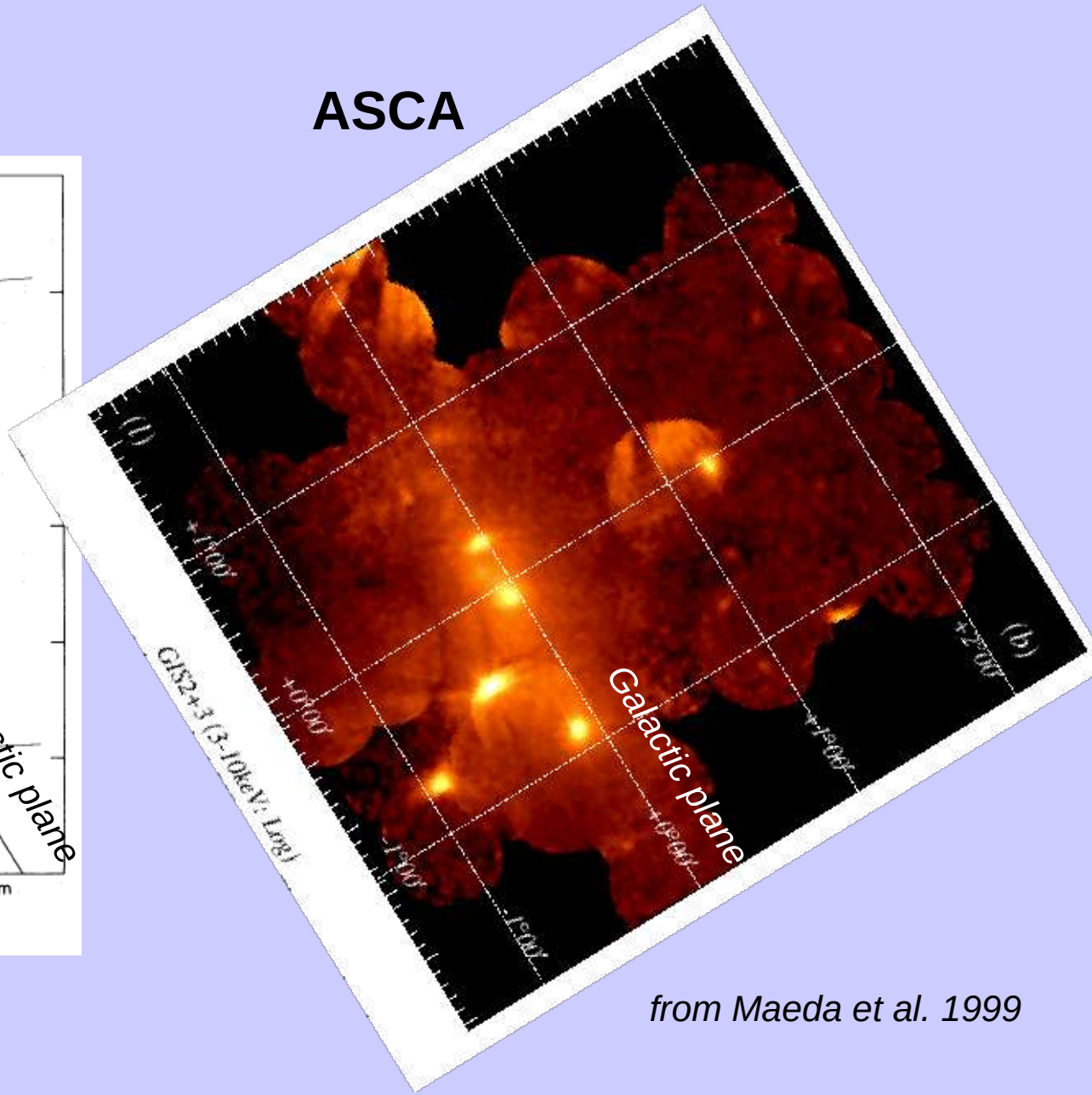
Galactic Center observations in X-rays

EINSTEIN

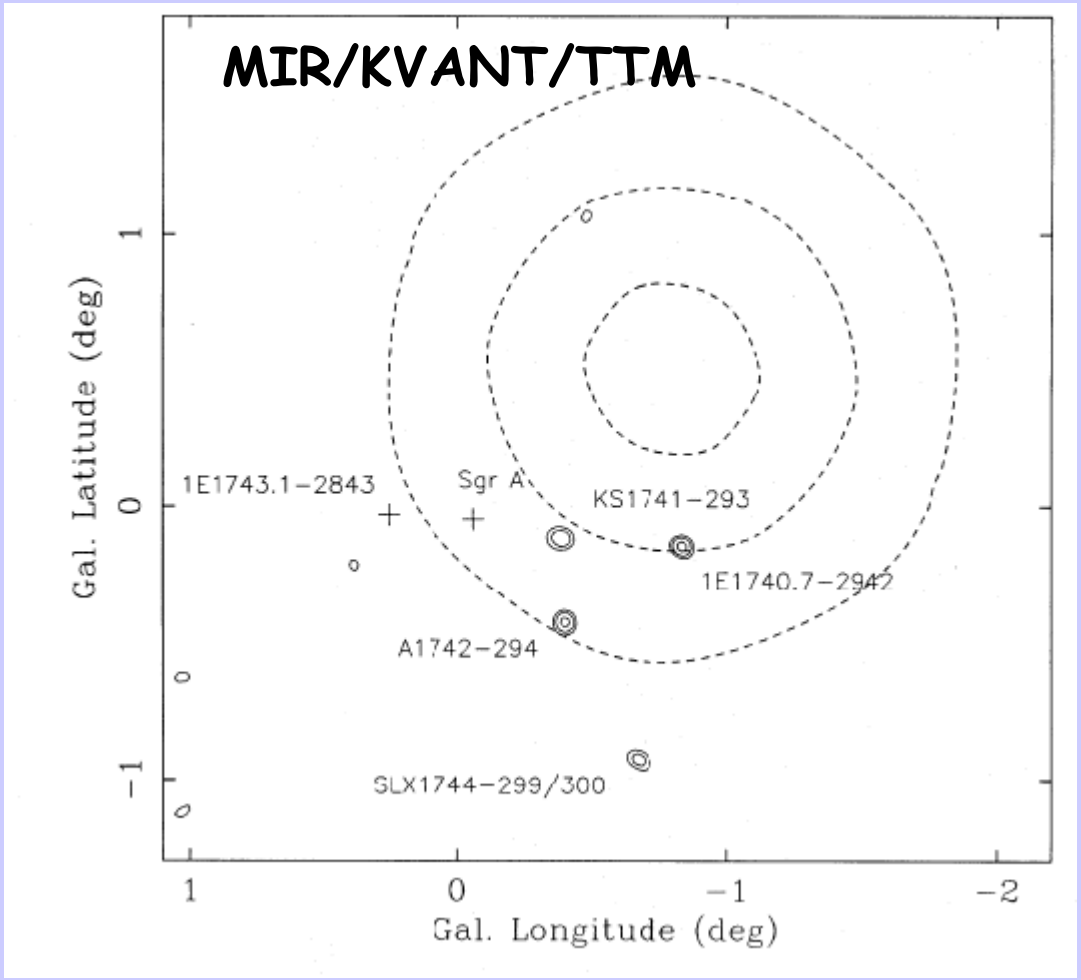


from Watson et al. 1981

ASCA

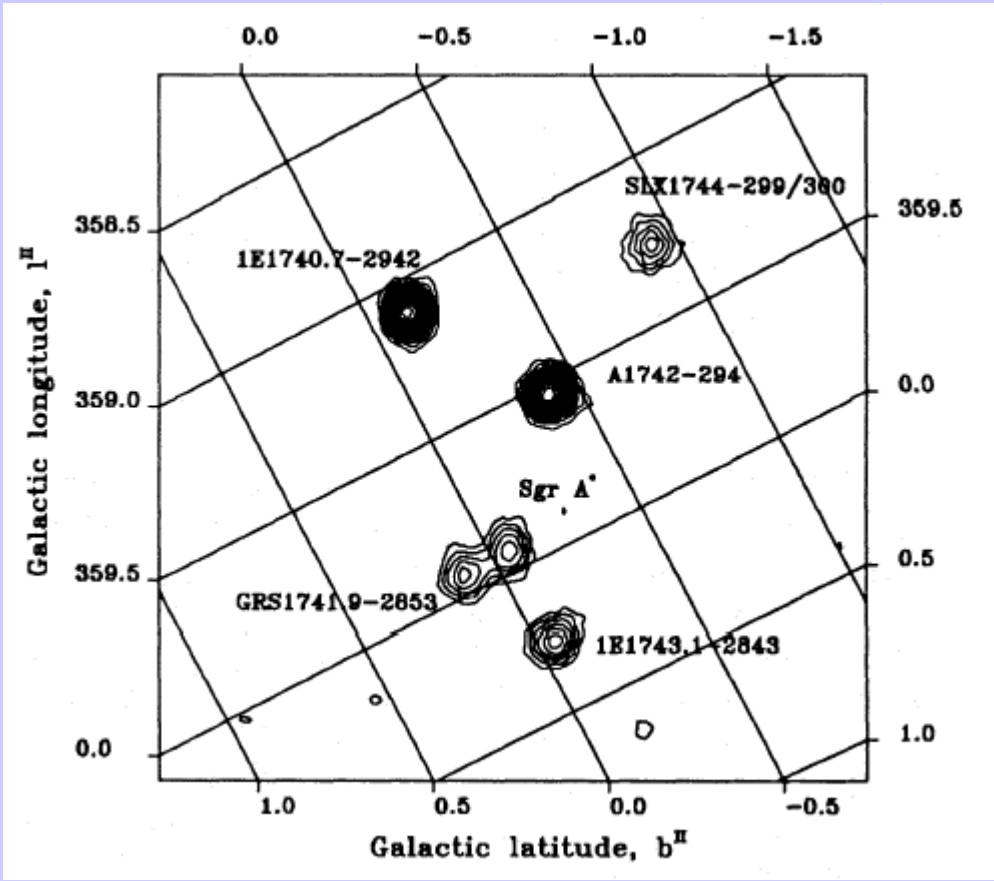


from Maeda et al. 1999



from Skinner et al. 1991

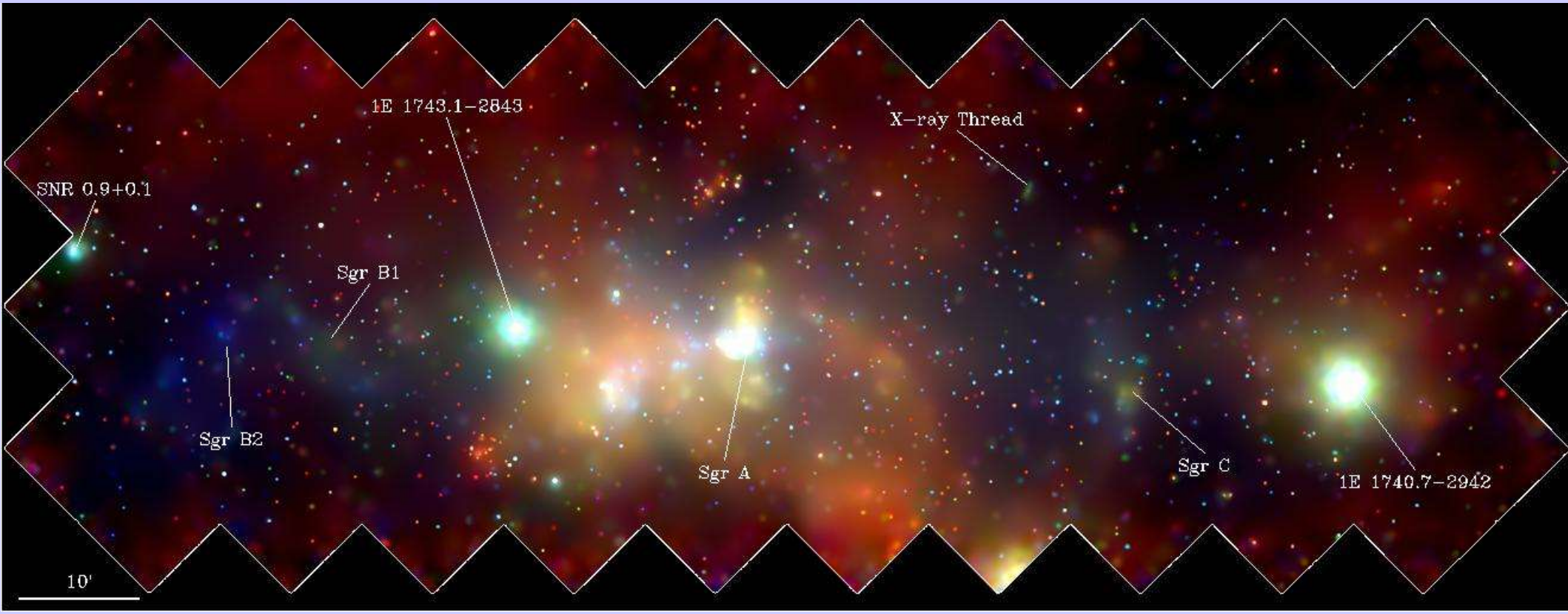
GRANAT/ART-P



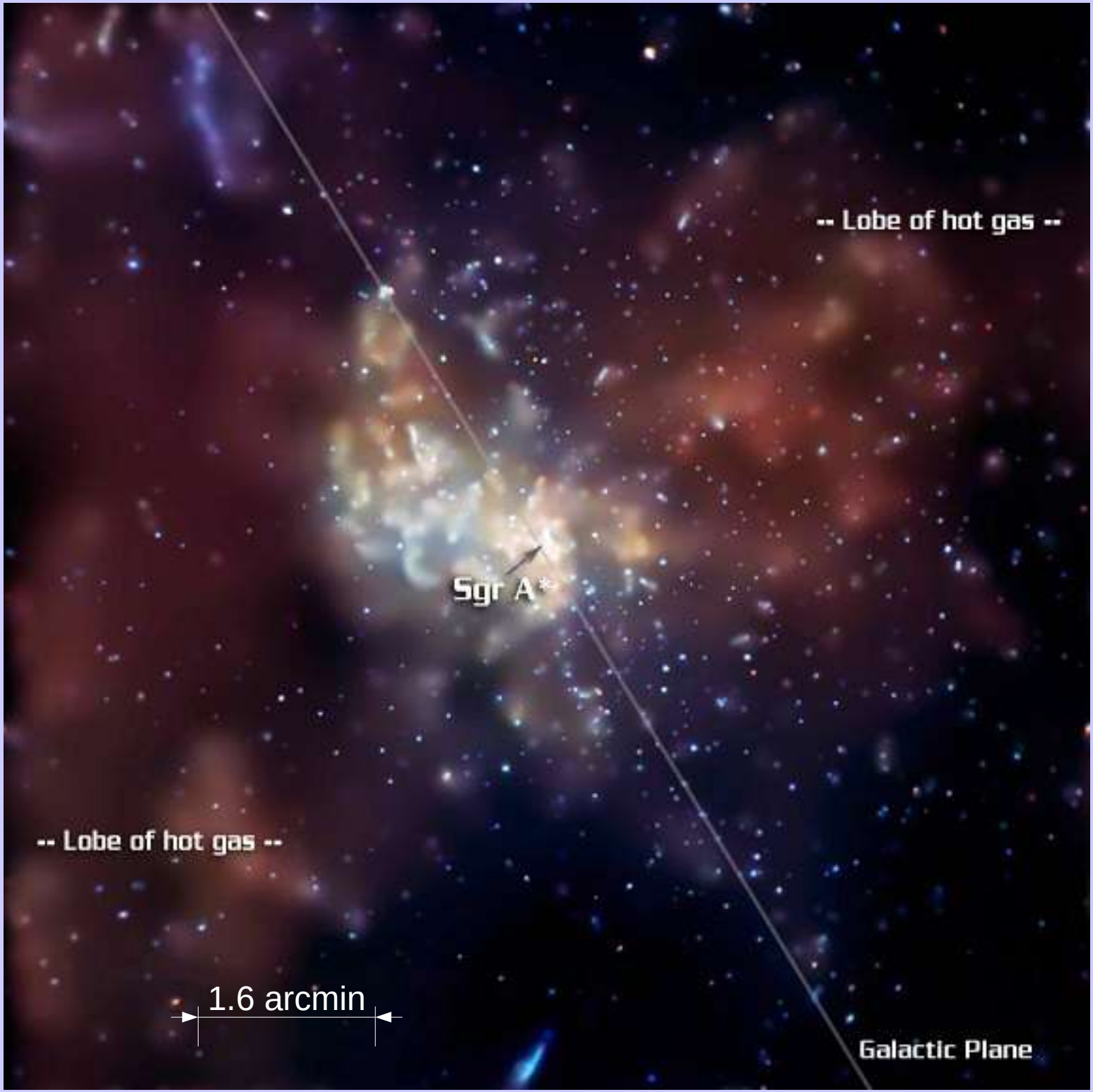
from Sunyaev et al. 1991

CHANDRA observations

from Wang et al.



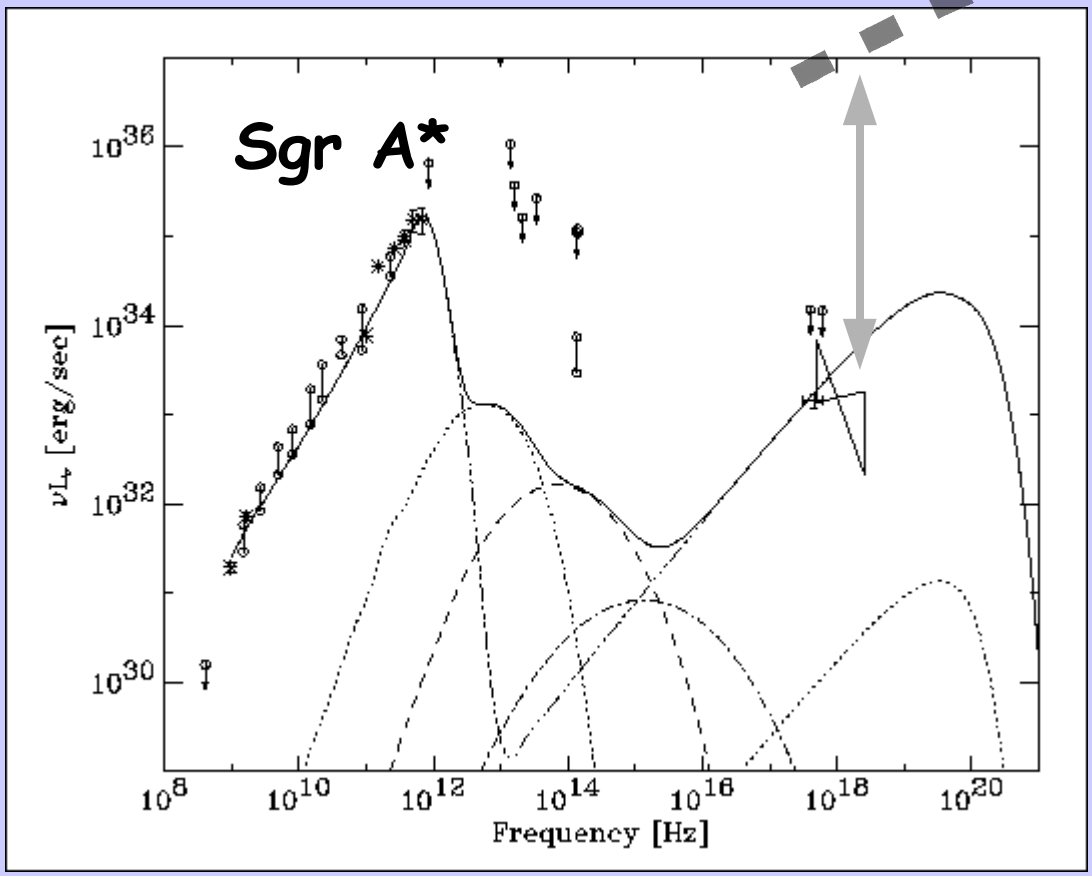
Angular resolution ~0.5 arcsec



Baganoff et al.
Muno et al.

Sgr A* L_x ~10^{33} ergs/s

1E1740.7-294

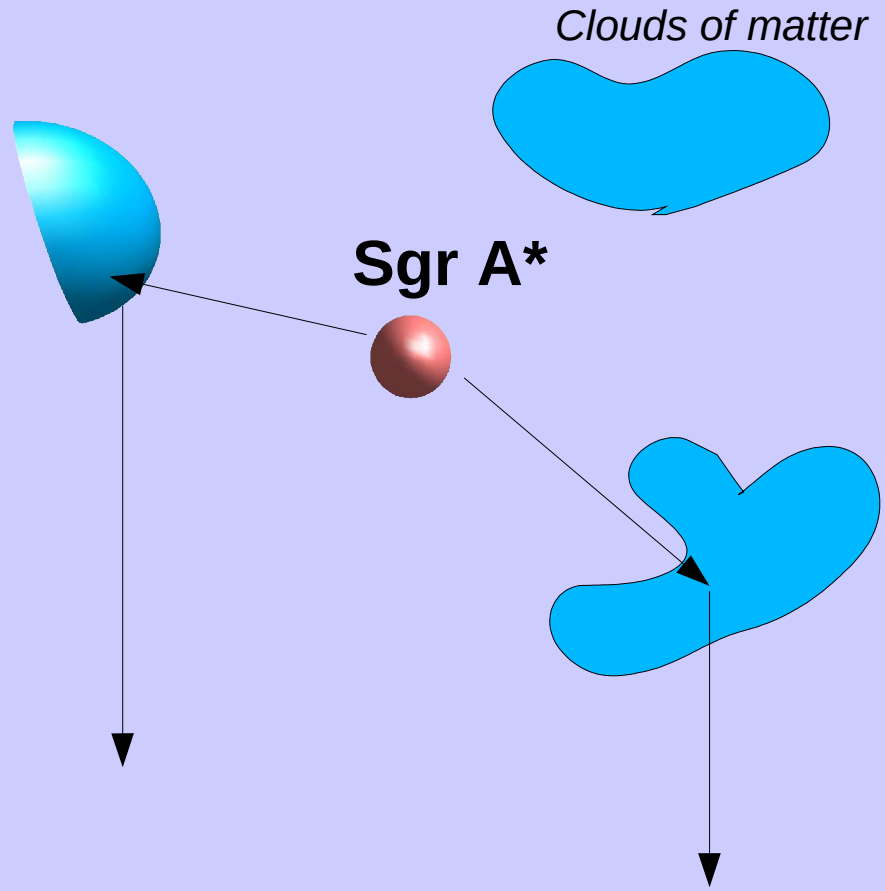


10 M_{Sun} black hole is ~10000 brighter than Sgr A* (~3 million M_{Sun})

Sgr A* is very dim. However, it is not the topic of the talk

Is it possible that Sgr A* was much brighter before?
Can such assumption be tested?

Yes, it can! Scattering of the past X-rays
(Sunyaev, Markevitch, Pavlinsky 1993)



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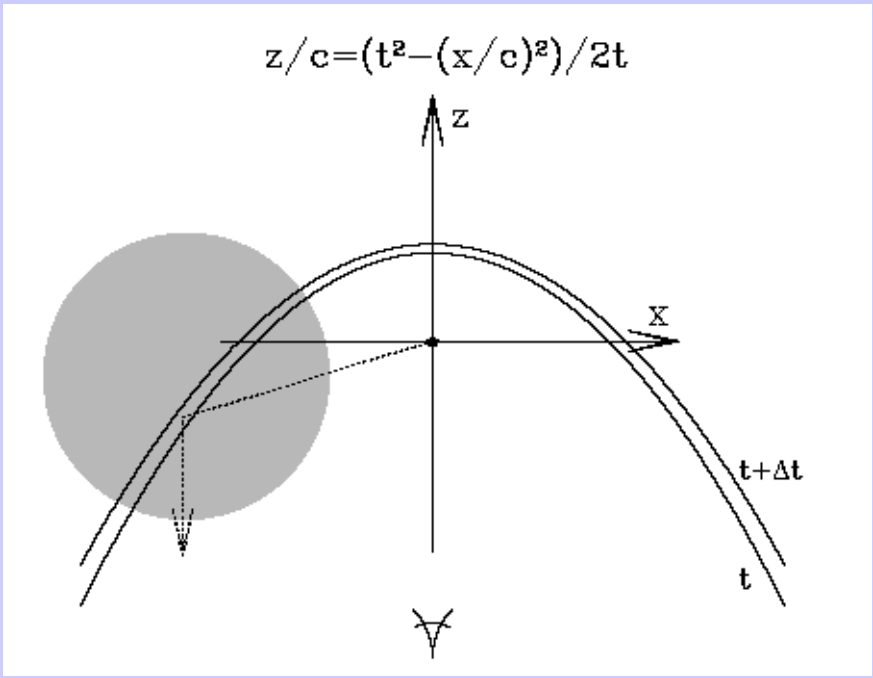
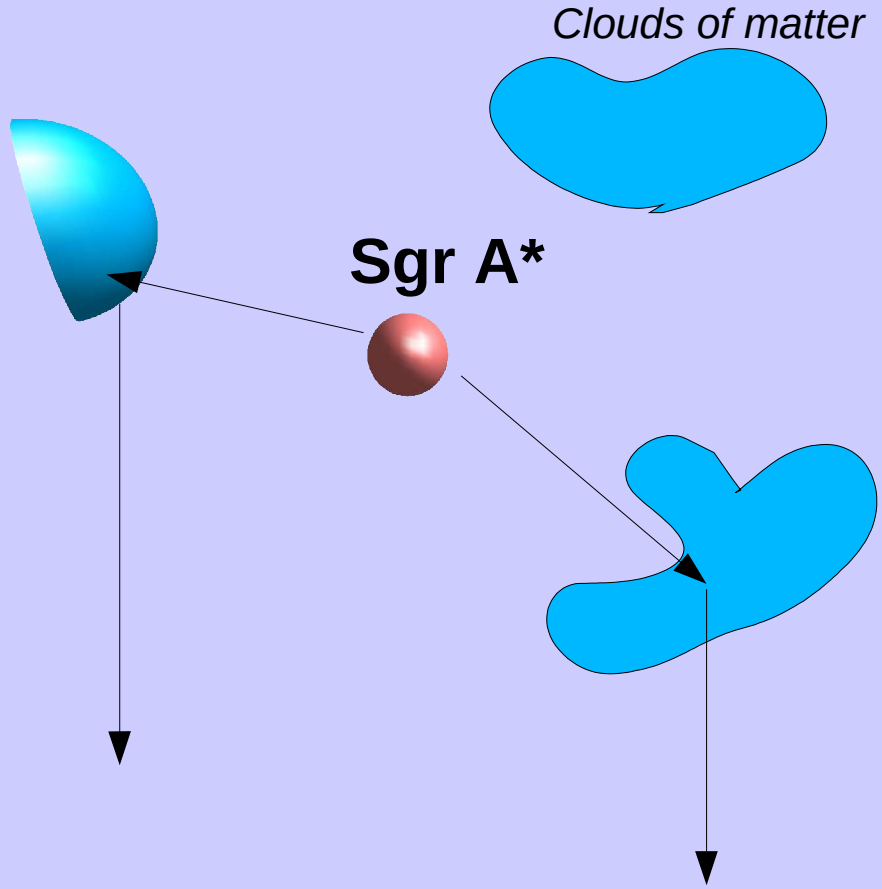
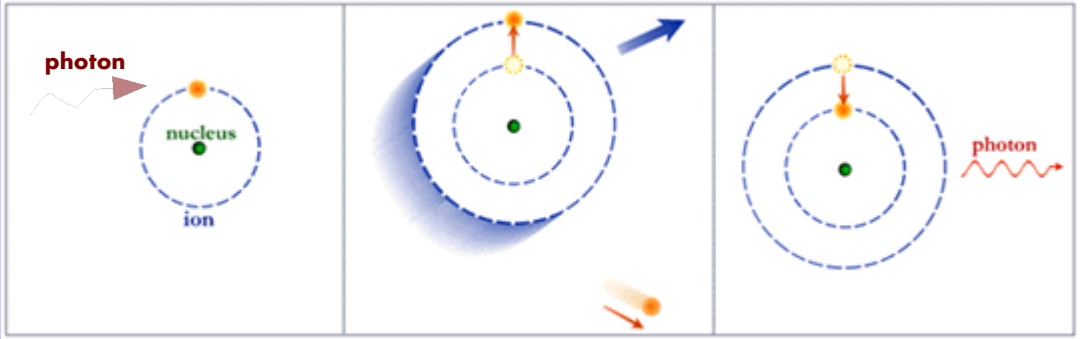
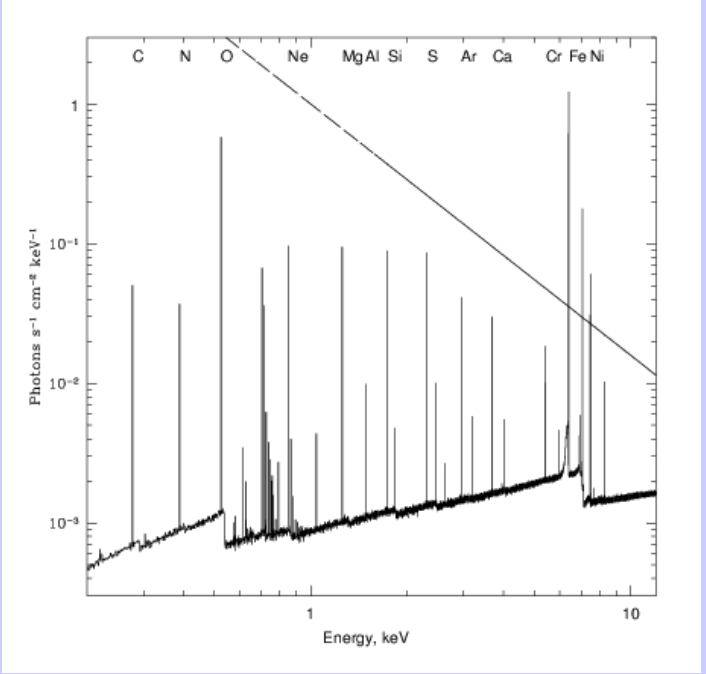


from Sunyaev & Churazov 1998



fluorescence

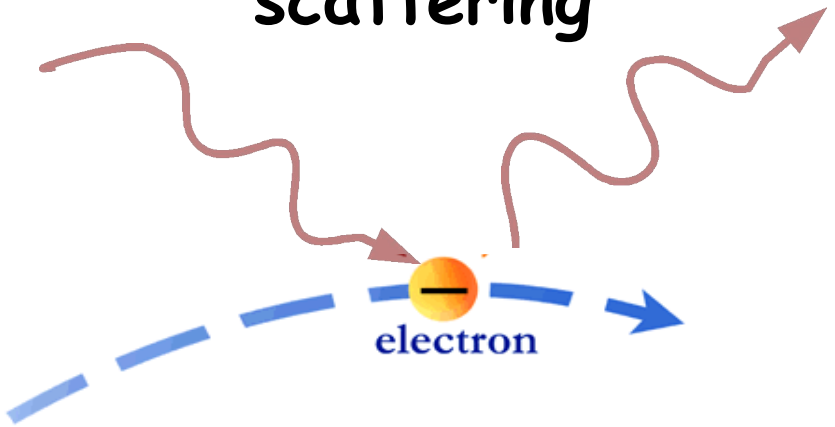


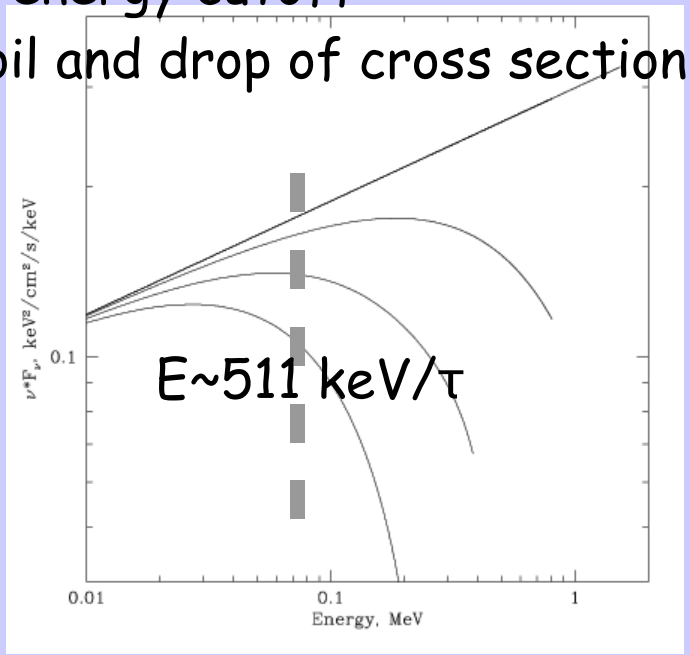


Fluorescent lines

High energy cutoff
(recoil and drop of cross section)

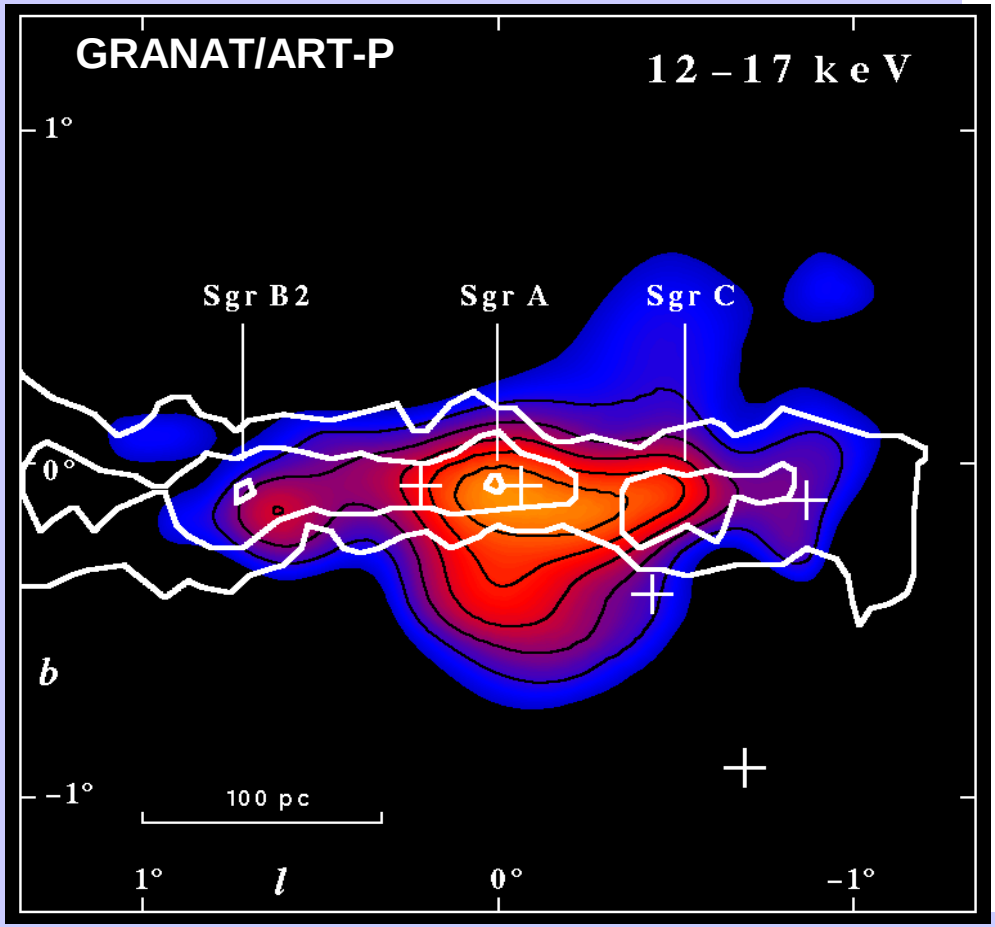
scattering





from Churazov et al. 1999

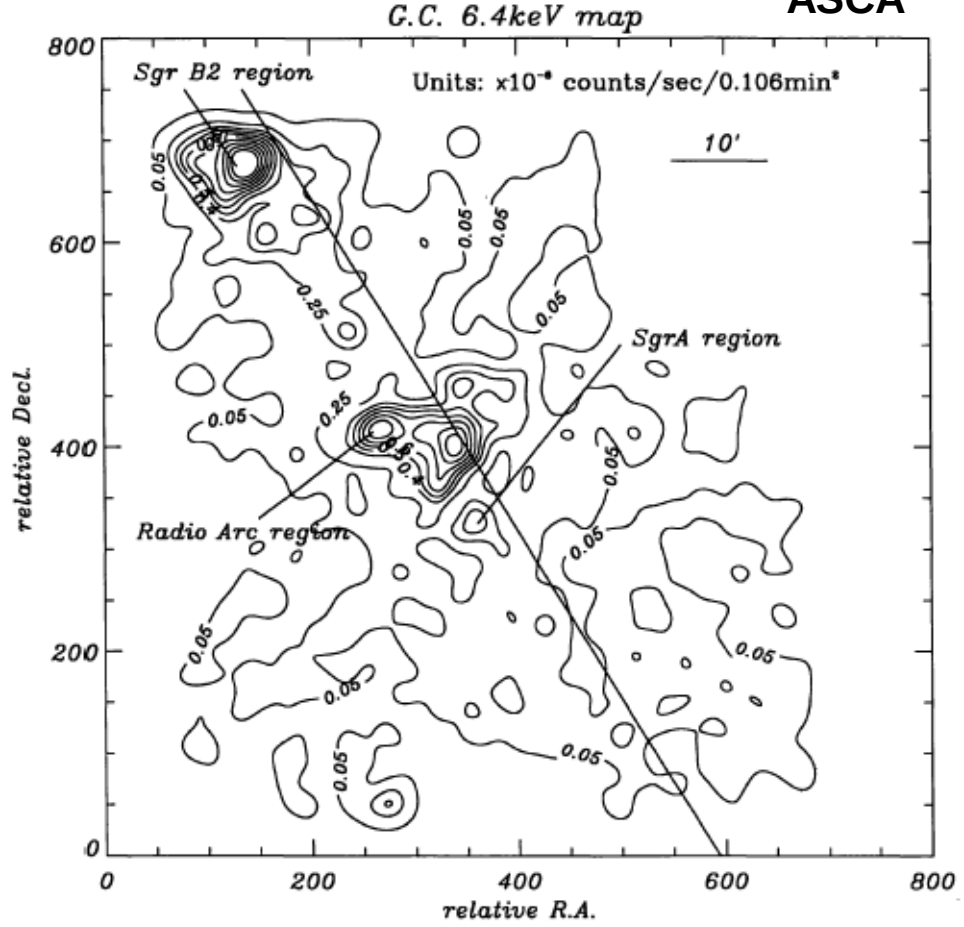
Continuum emission from molecular cloud -1993



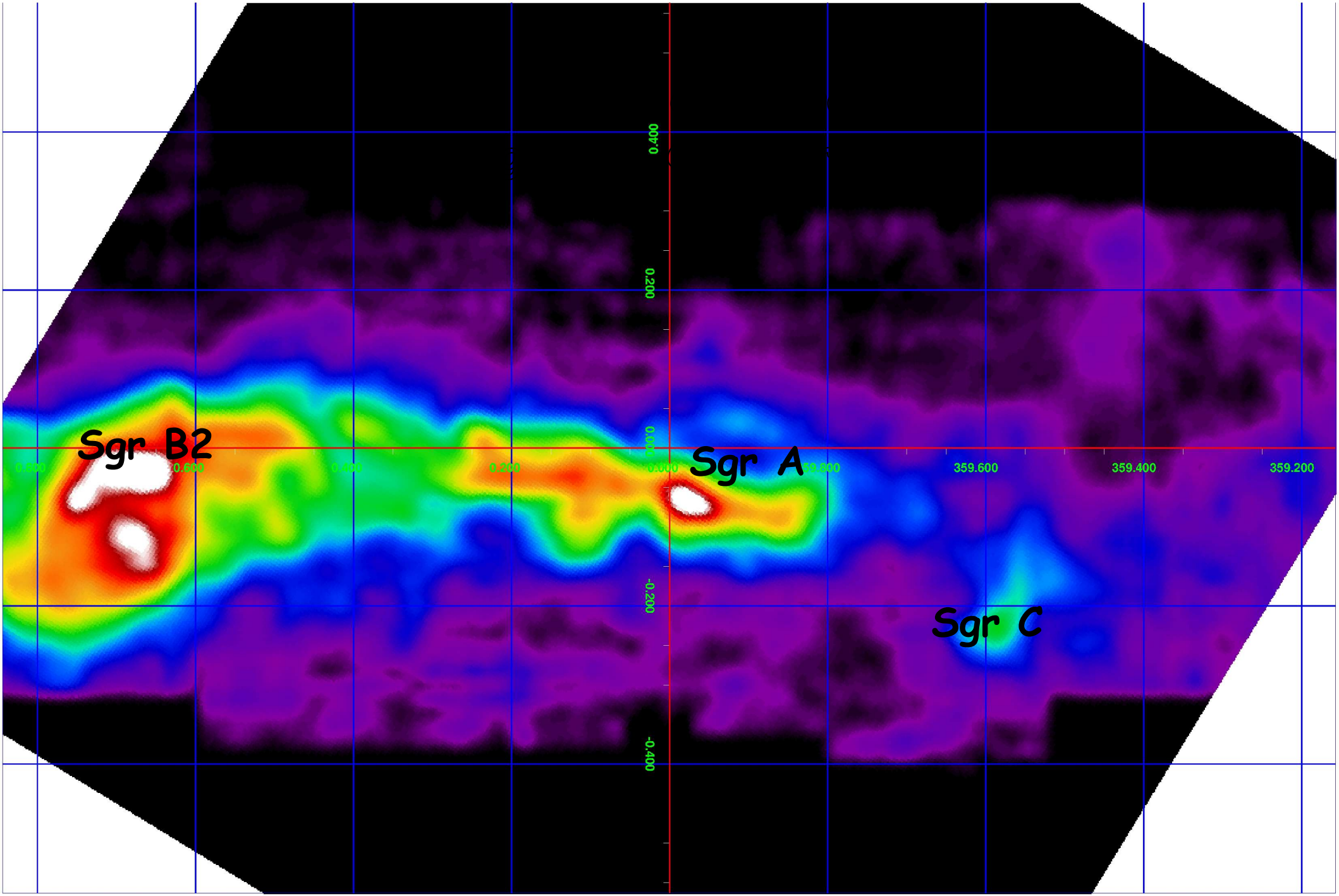
from Sunyaev, Markevitch & Pavlinsky 1993

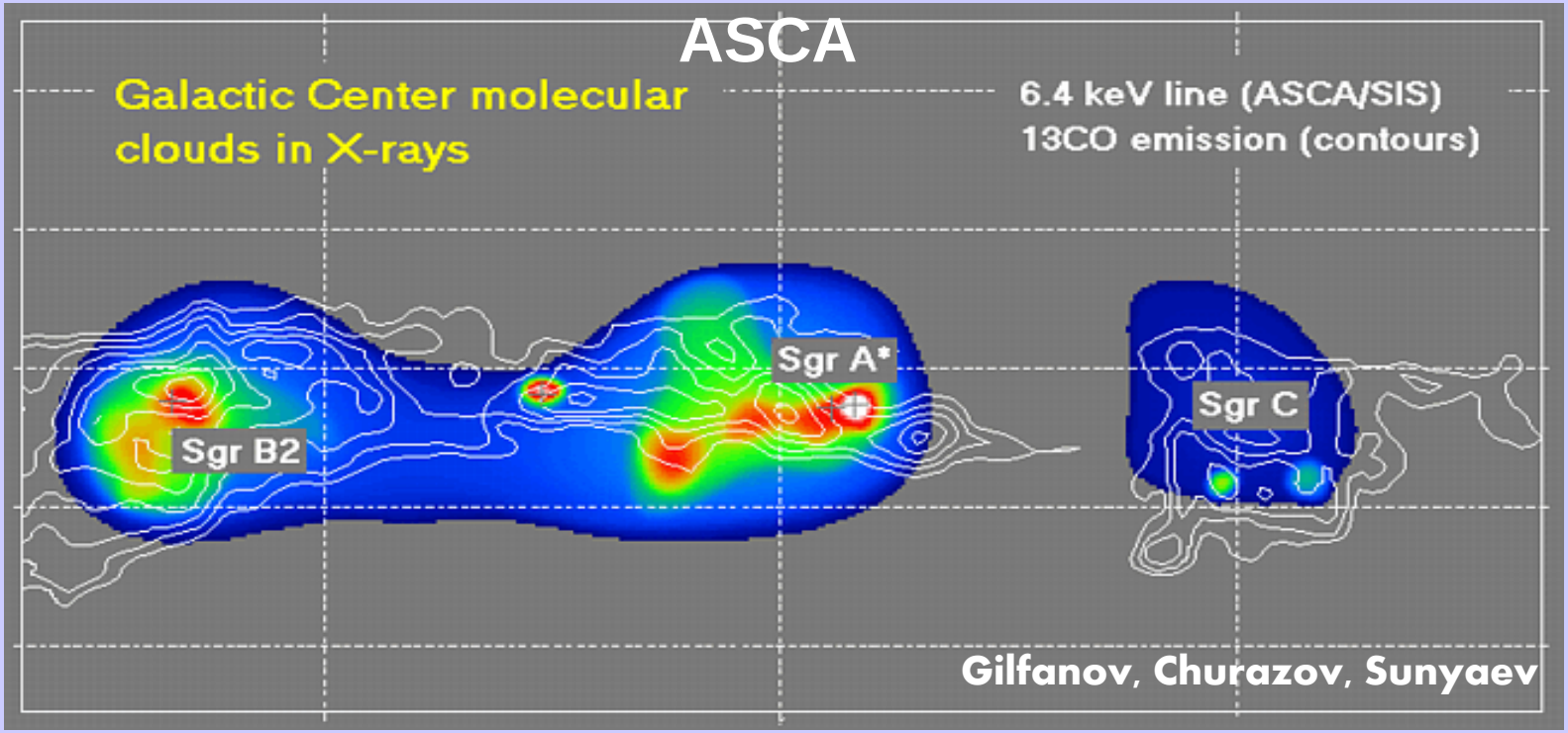
Fluorescent line emission from molecular cloud -1996

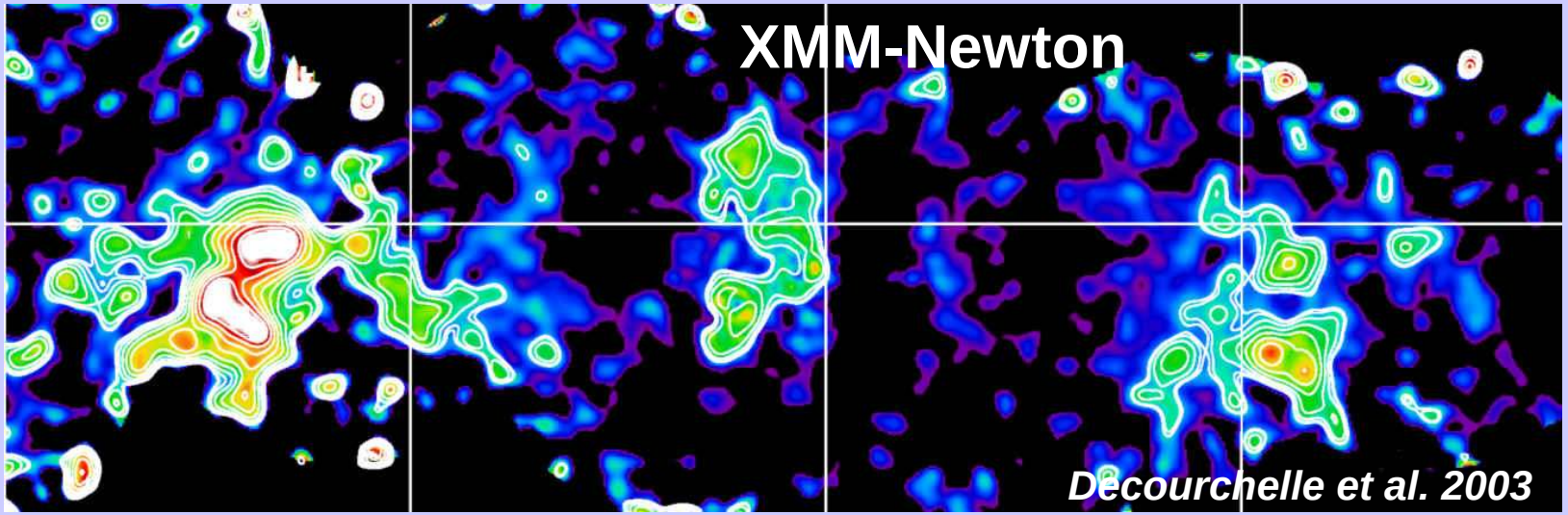
ASCA



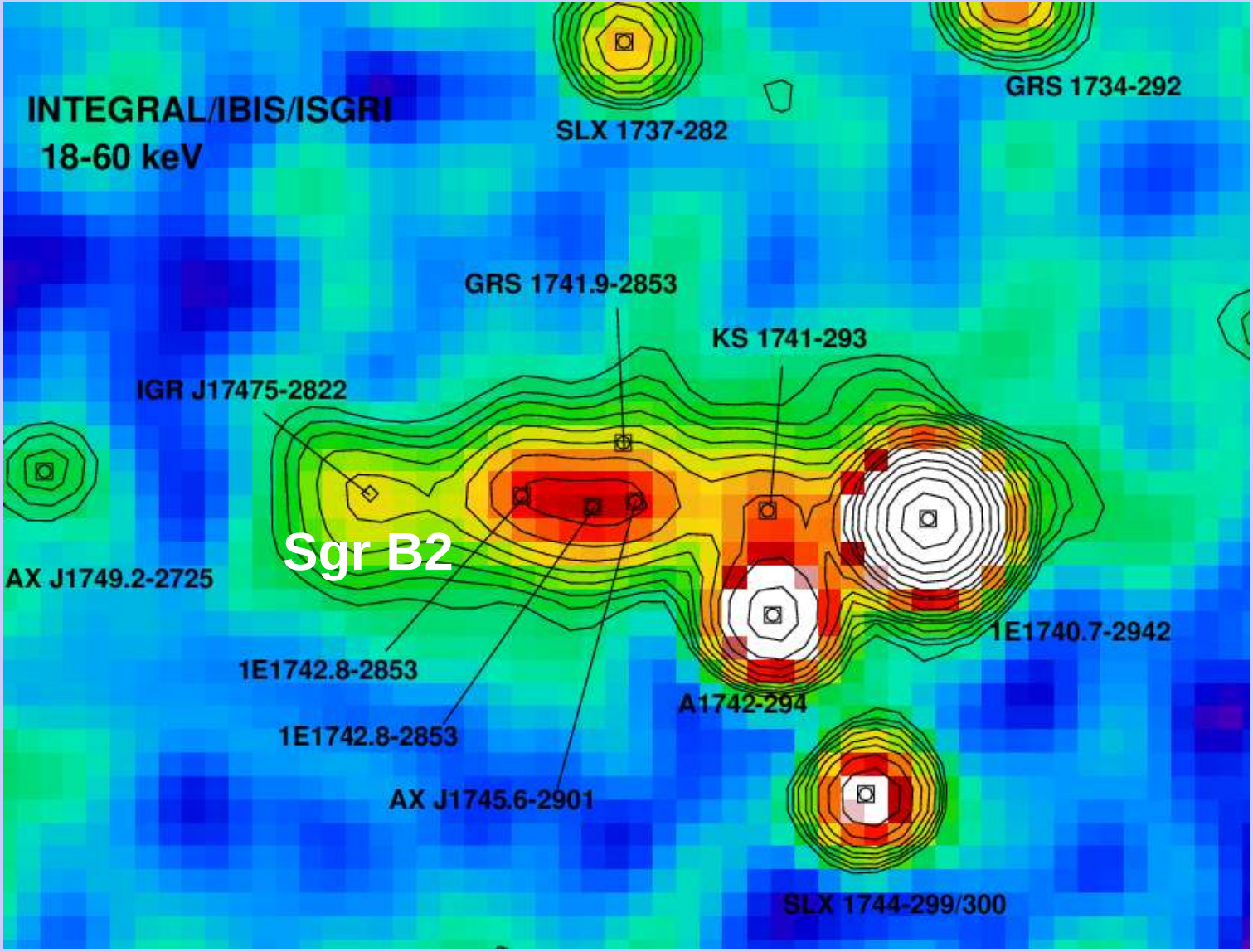
from Koyama et al. 1996


Sgr B2
Sgr A
Sgr C
0.400
0.200
0.000
-0.200
-0.400
359.600
359.400
359.200

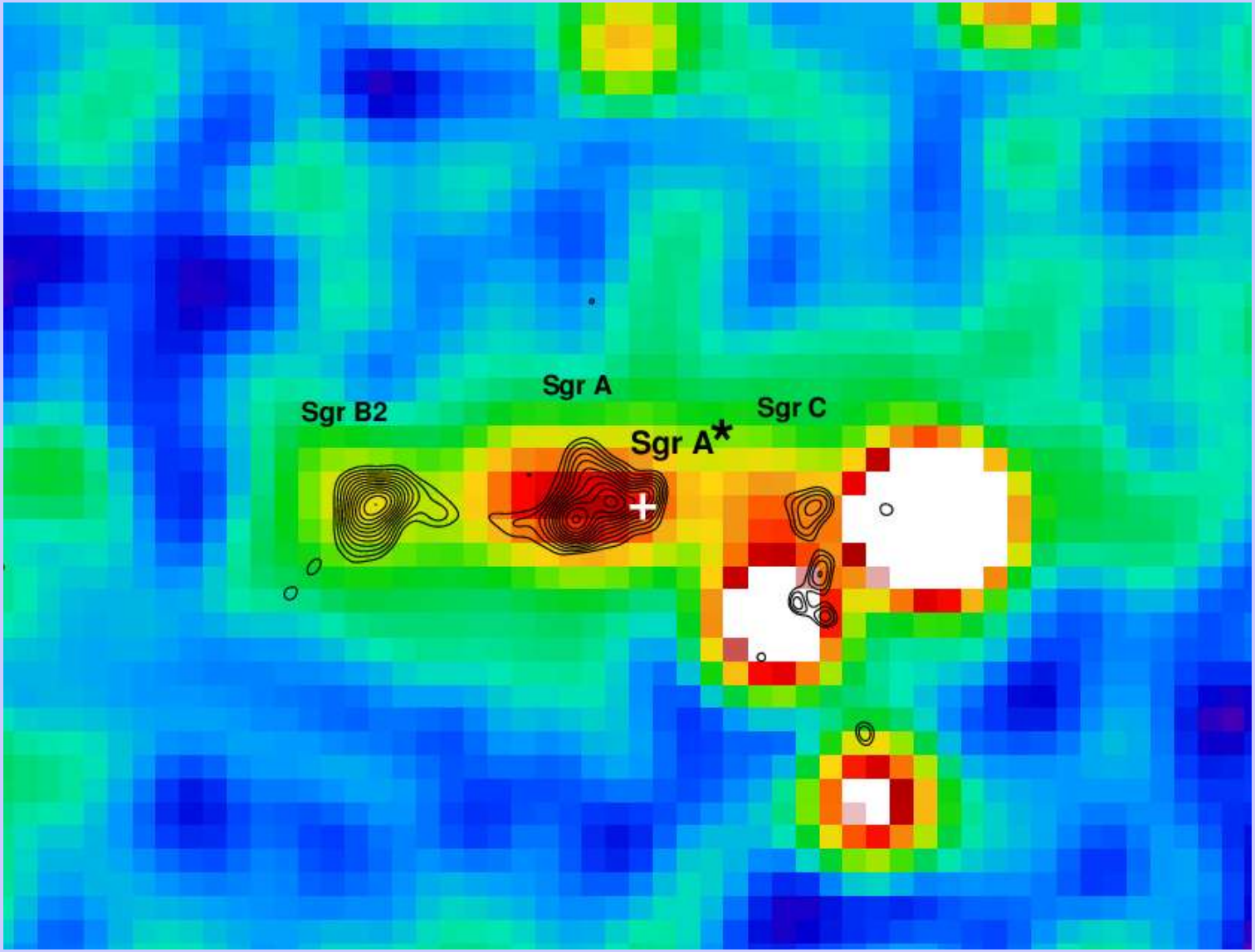

ASCA
Galactic Center molecular clouds in X-rays
6.4 keV line (ASCA/SIS)
13CO emission (contours)
Sgr A*
Sgr B2
Sgr C
Gilfanov, Churazov, Sunyaev


XMM-Newton
Decourchelle et al. 2003

Scattering of hard X-rays in Sgr B2 cloud
INTEGRAL result

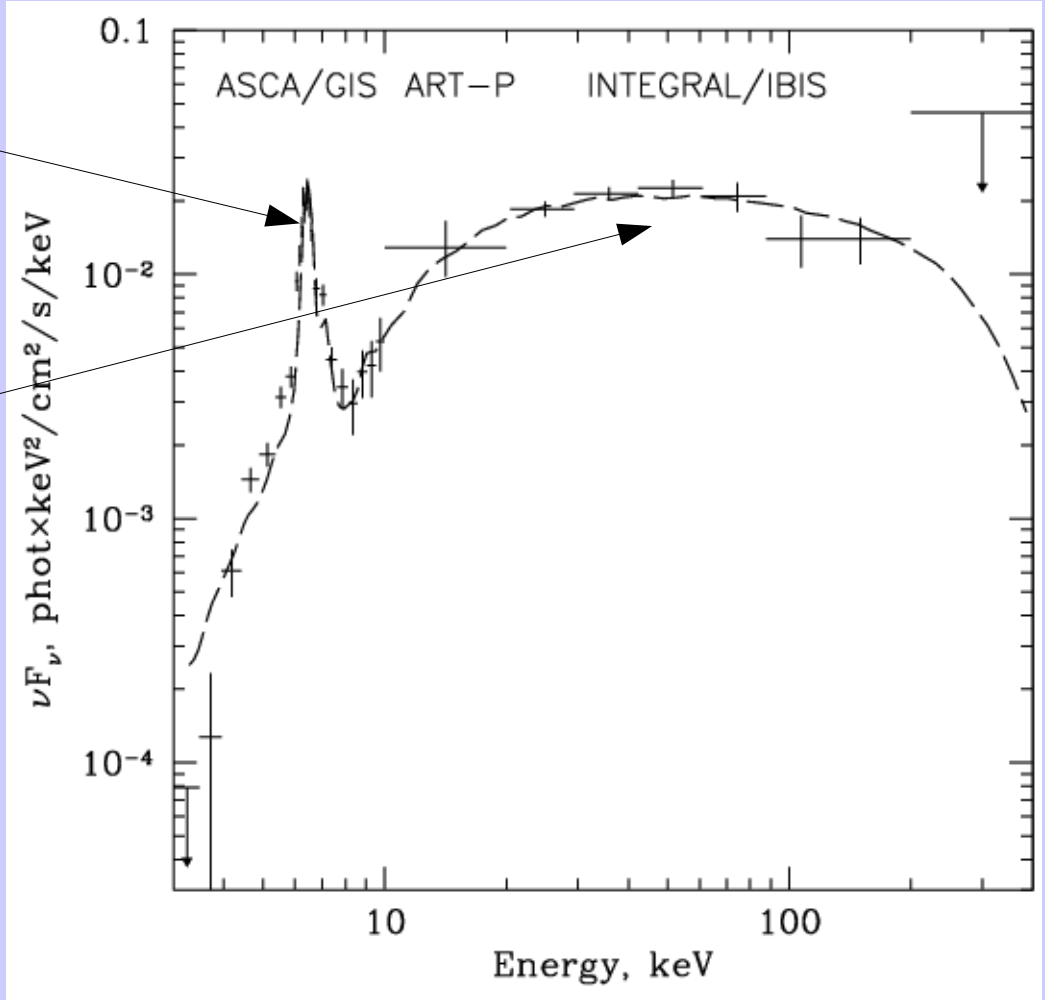


Scattering of hard X-rays in Sgr B2 cloud
INTEGRAL result



Fluorescent line

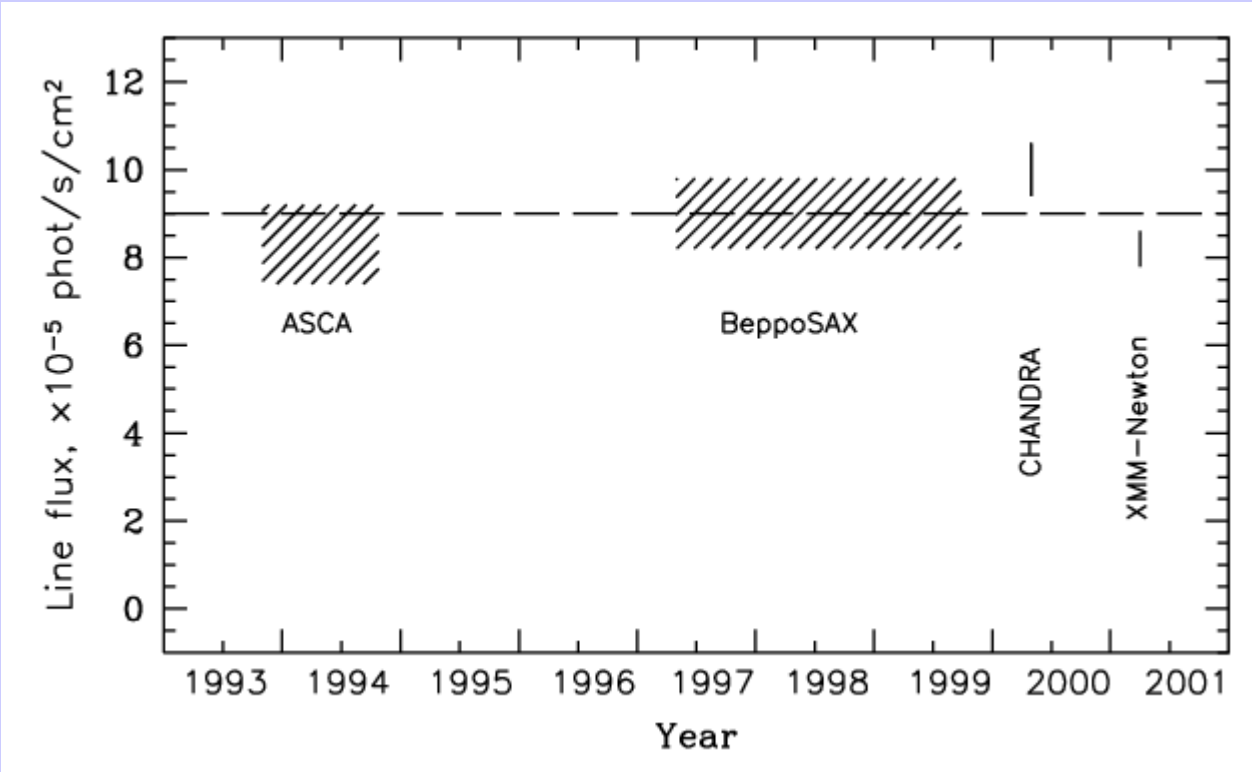
Scattered continuum



Main spectral features of Sgr B2:

1) Huge Fe K_α line (EW~2 keV)
2) Very hard X-ray continuum (up to 100 keV)
3) Possible cutoff - recoil?

What illuminates the cloud?



6.4 keV line flux is stable over ~10 years

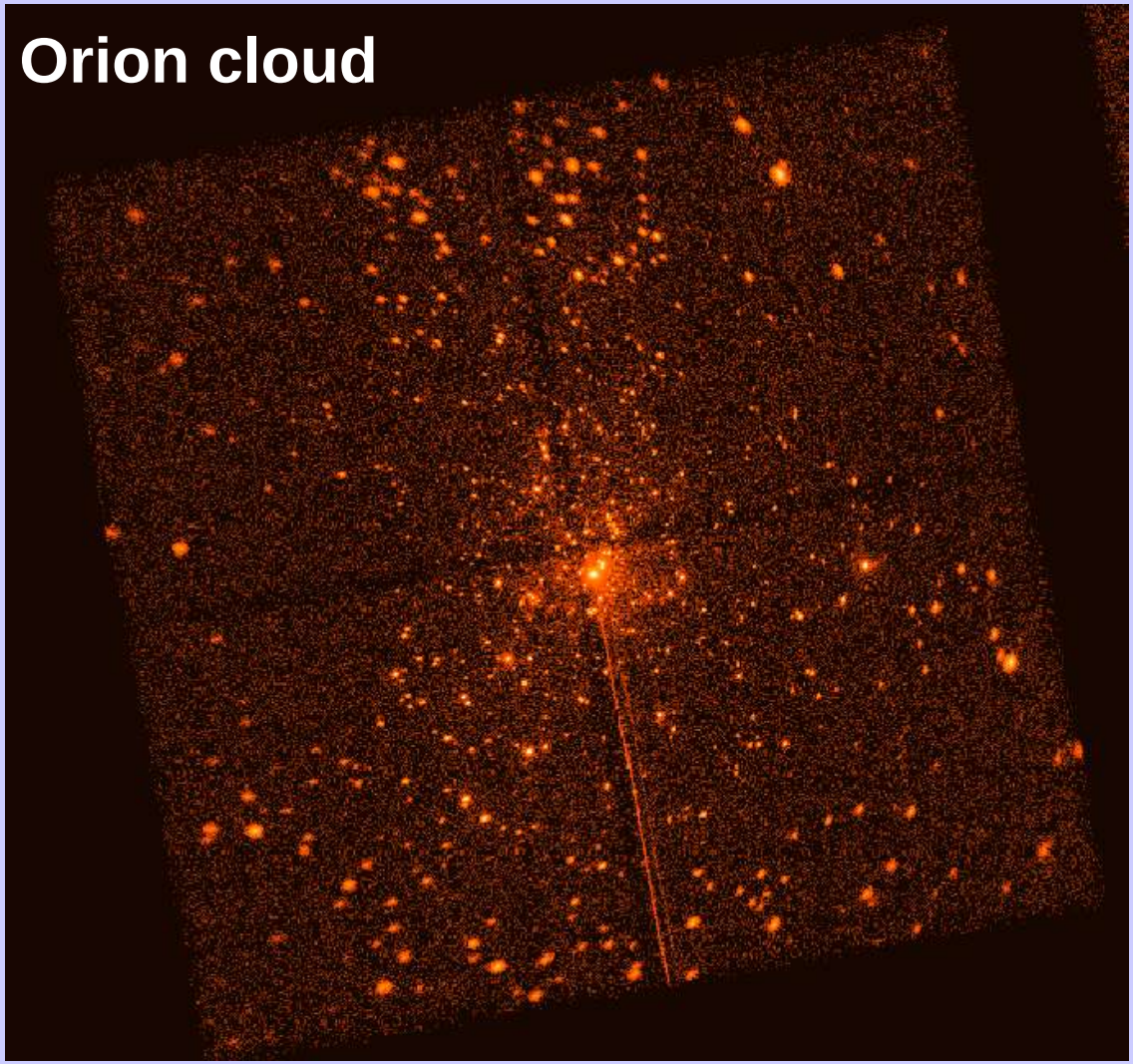
Close stellar X-ray binaries can be ruled out:

a) should be visible now

b) for any particular cloud should be personal illuminating source

- > Sgr A* long ago (~300 years)

Alternative hypothesys – internal cloud emission



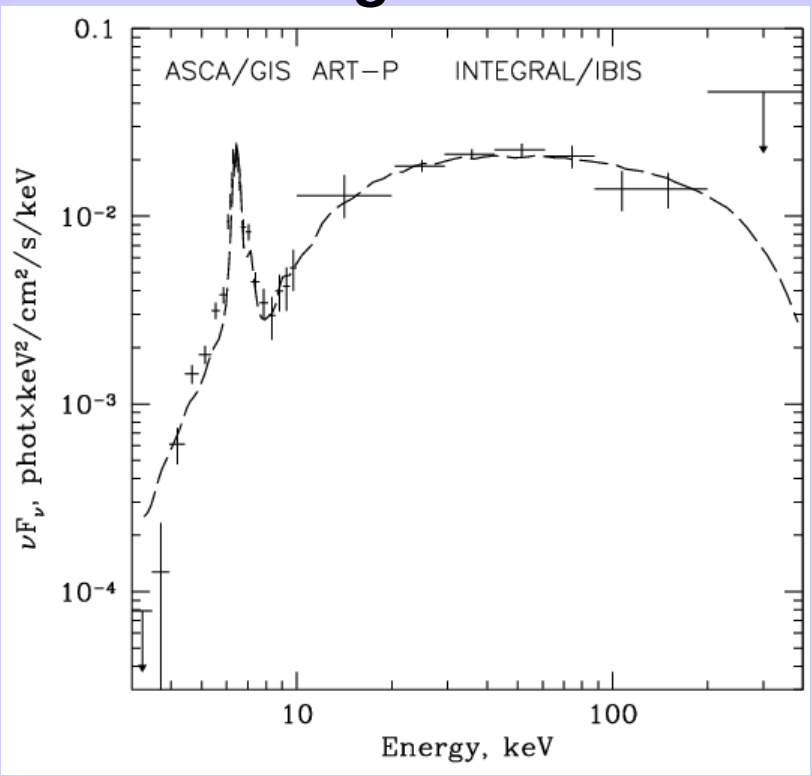
Molecular clouds
emit X-rays (YSO,PMS)

Orion $L_x \sim 10^{33}$ ergs/s
for 10^4 M_{Sun}

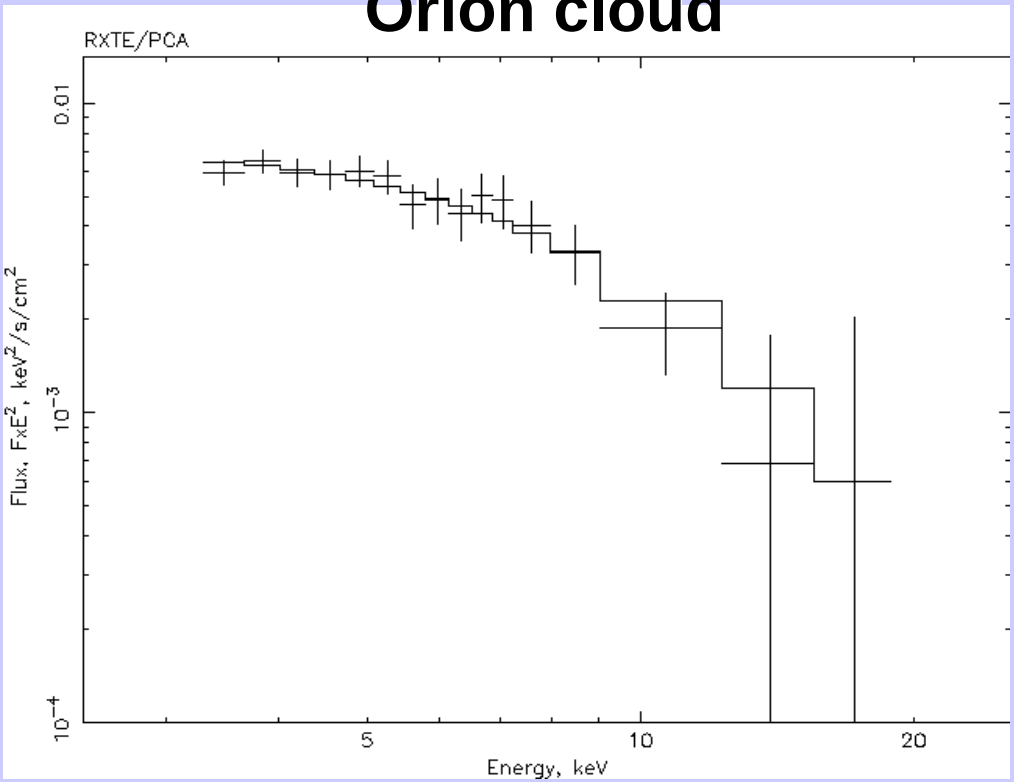
Mass of Sgr B2 is
$\sim 10^6$ M_{Sun}

Can this emission
explain Sgr B2
phenomenon?

Sgr B2



Orion cloud



1) Orion spectrum is much softer
(the same for ρ-Oph cloud, Cha clouds)
2) No strong 6.4 keV line

Alternative hypothesys – cosmic rays

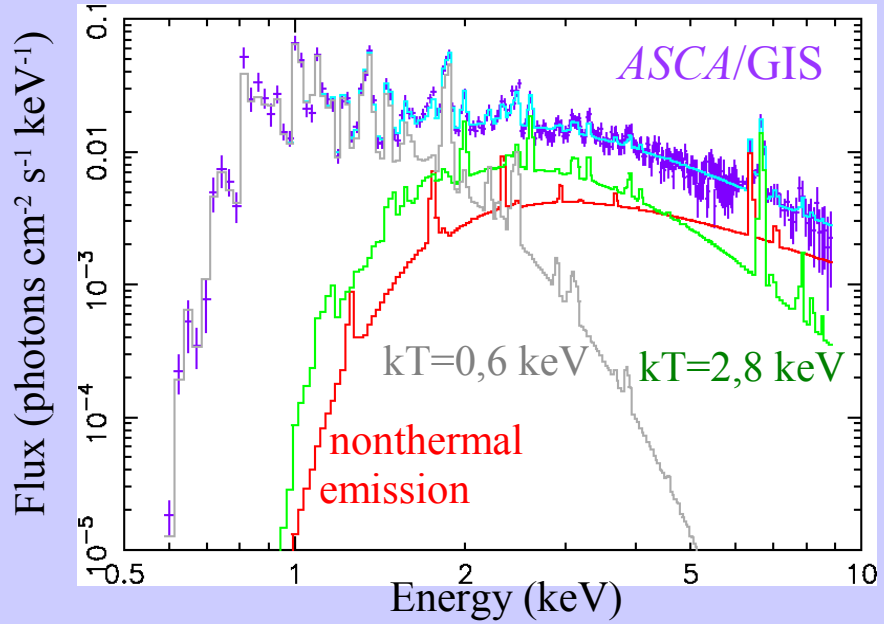
Cosmic ray ions can be ruled out (radio limits, gamma-ray limits)

Cosmic ray electrons
(should be low energy for line production)

"fluorescence" - > lines

Bremsstrahlung emission
- > hard X-ray continuum

Model is elaborated for Galactic ridge emission



Tatischeff et al. 2001

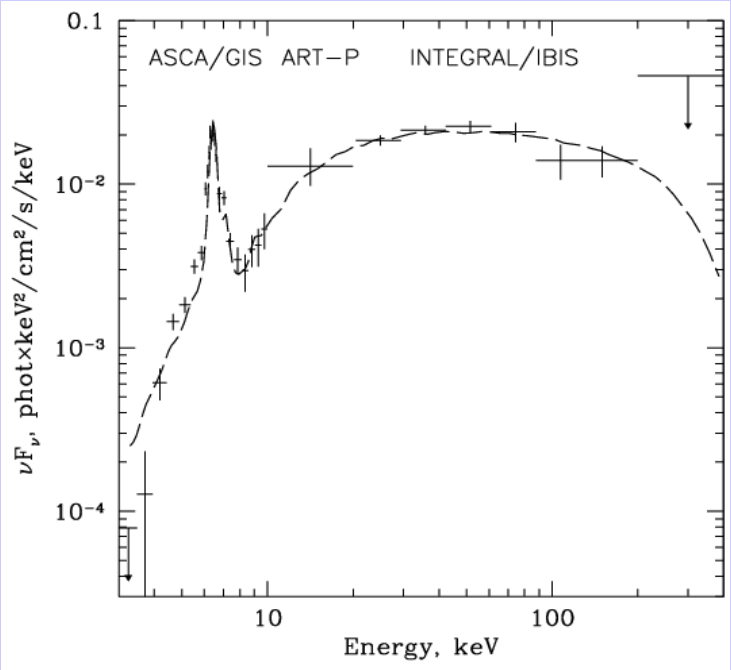
Galactic Center molecular clouds emission

1. Different clouds with different (factor of 10) optical depths have huge 6.4 keV lines (EW~1-2 keV)

2. Hard X-ray spectrum (up to 100 keV)

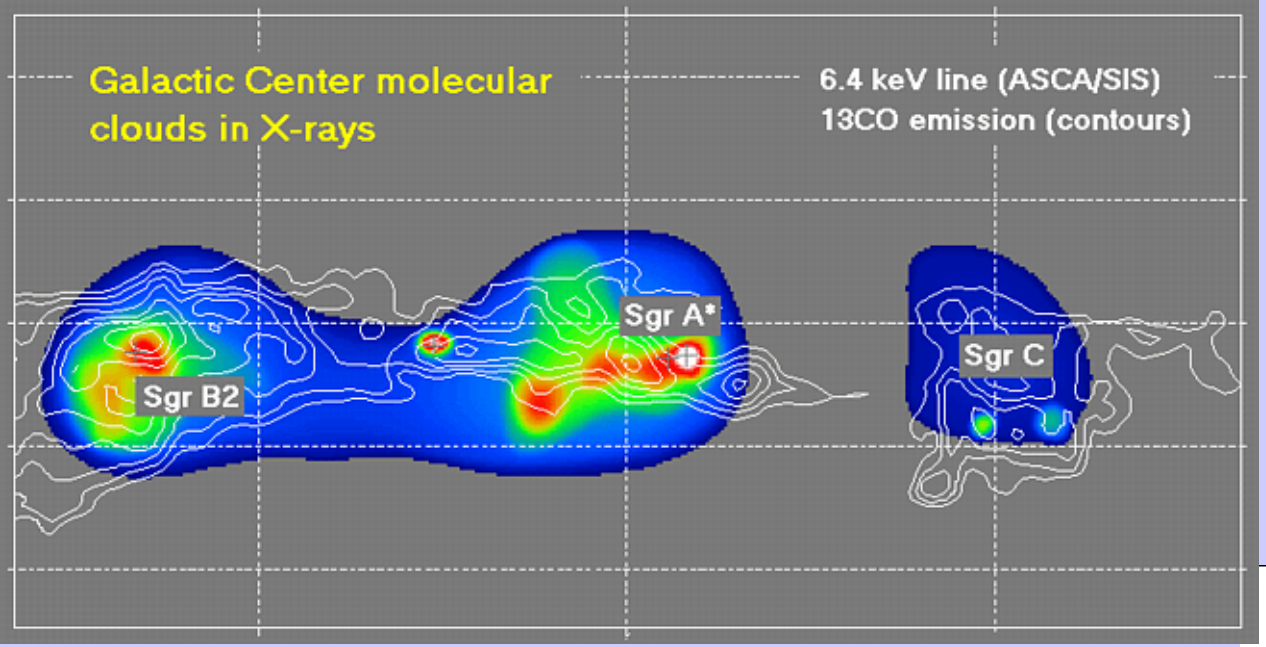
3. Emission $L_x \sim 10^{35}$ ergs/s

	Observed	Reflection	Cosmic rays
EW	~2 keV	~1 keV	~0.2-0.4 keV
Cutoff	>~100 keV	~100 keV (scattering)	any e- distr.dependent
Energy balance	10^{35} ergs/s	10^{39} ergs/s for Sgr A*	~few x10^{40} ergs/s in electrons

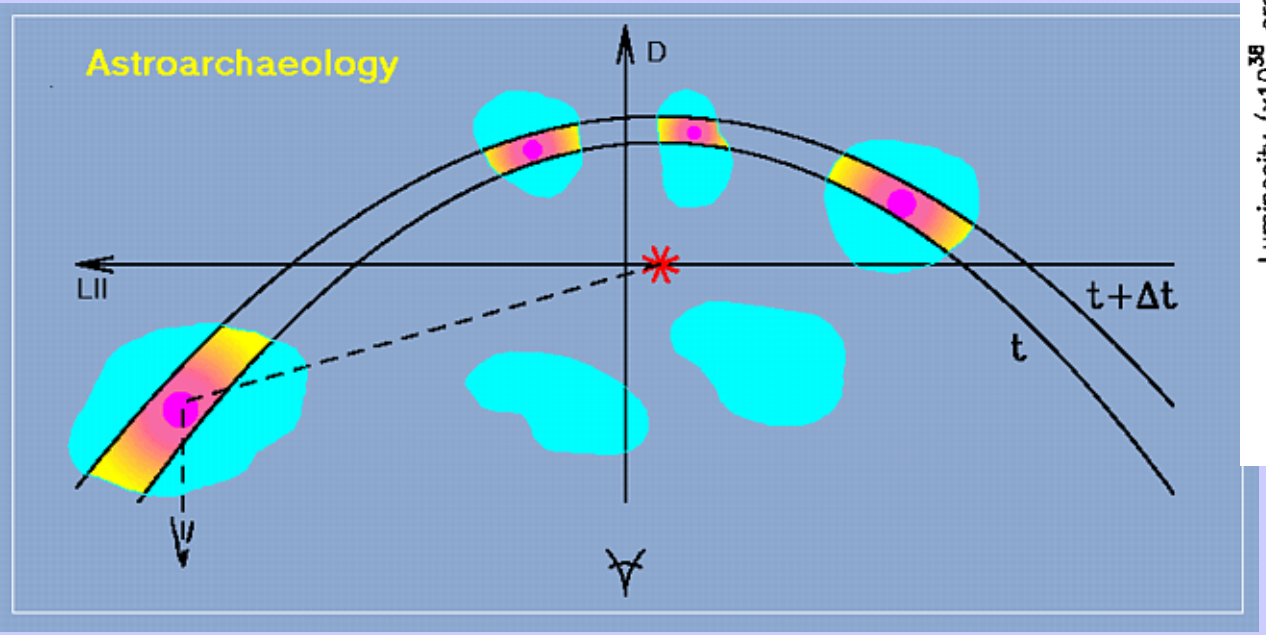


Sgr B2 cloud is optically thick for almost anything - > calorimeter

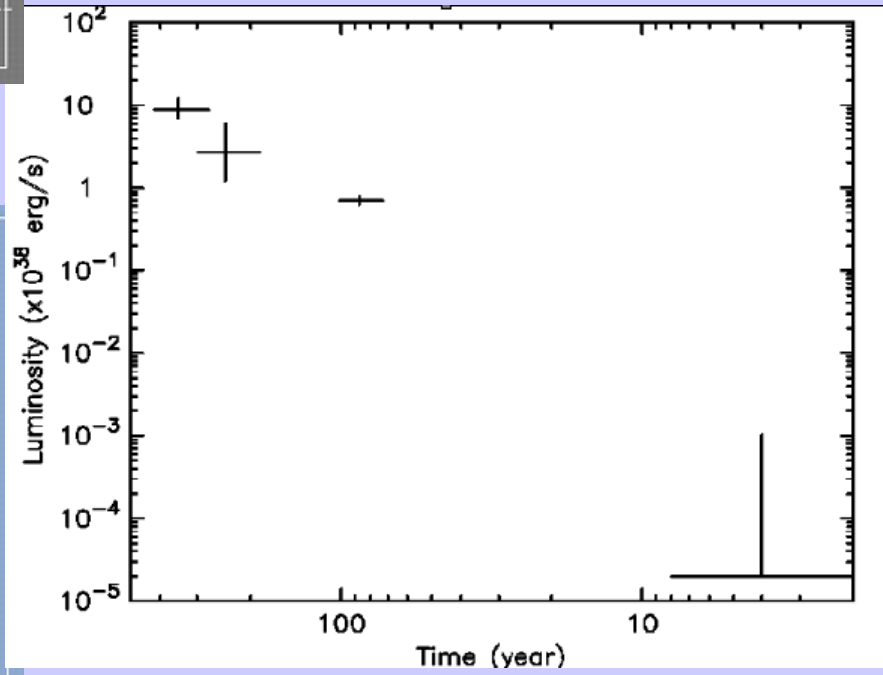
Total energy balance of Sgr B2 is ~10^{40} ergs/s. Mostly in infrared. Practically incompatible with cosmic ray electrons hypothesis



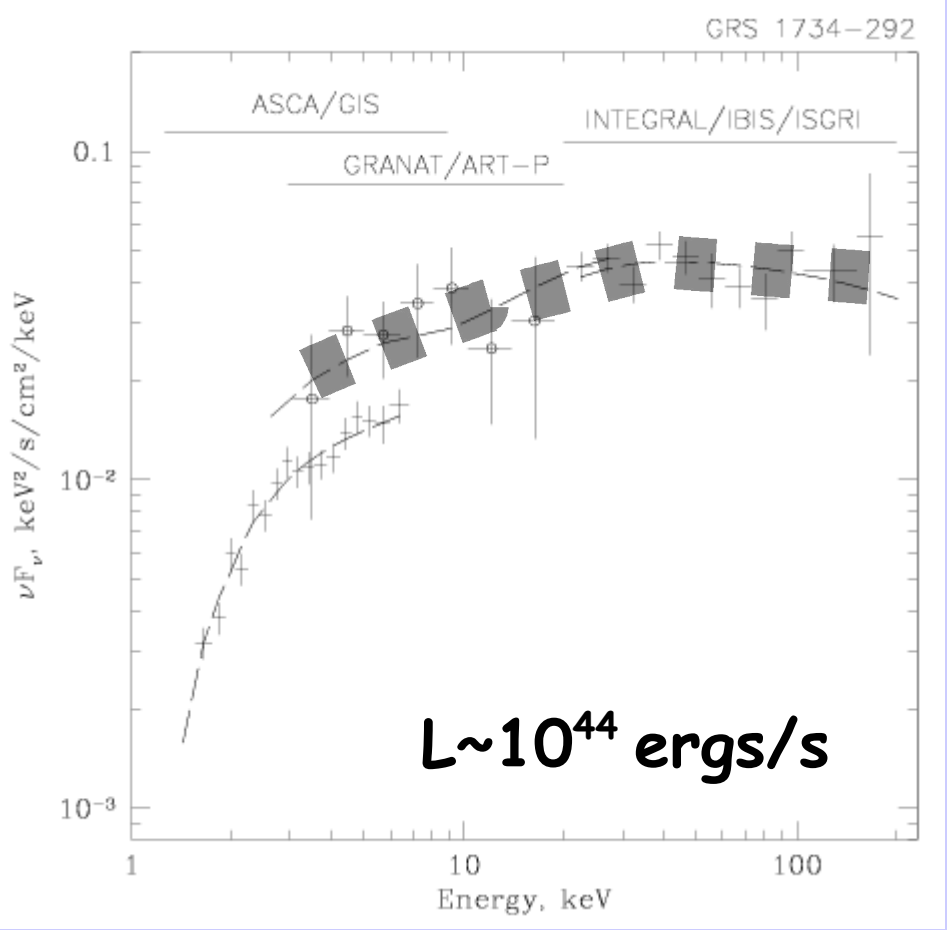
from Churazov, Gilfanov & Sunyaev 1999



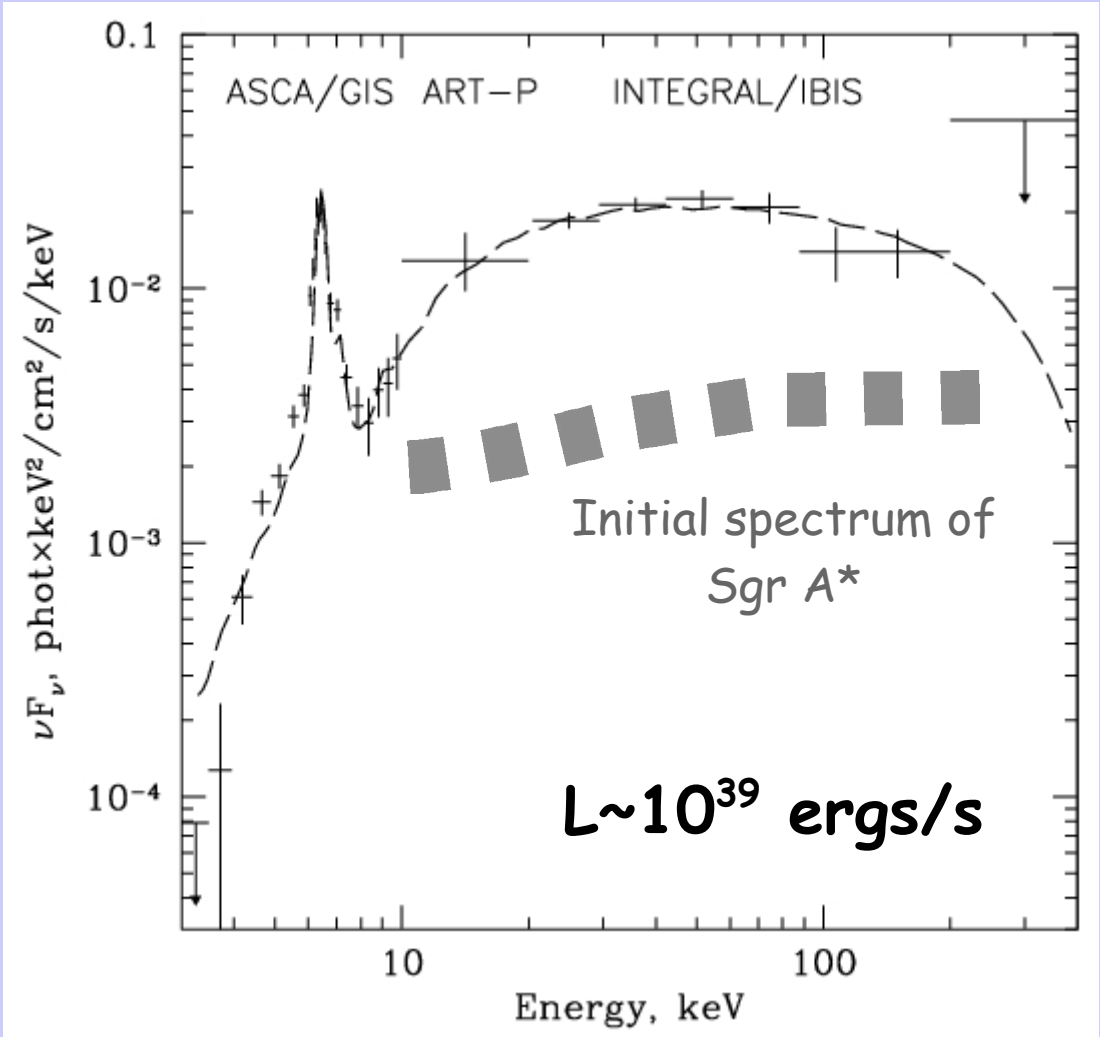
Sgr A* lightcurve



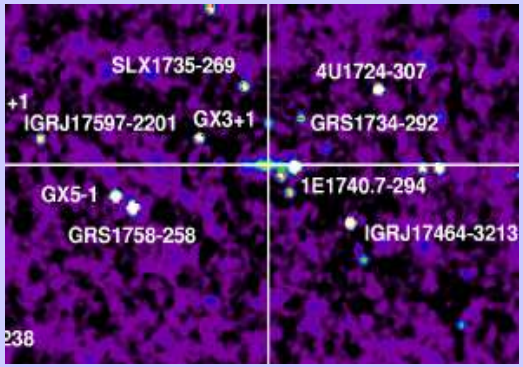
from Murakami PhD

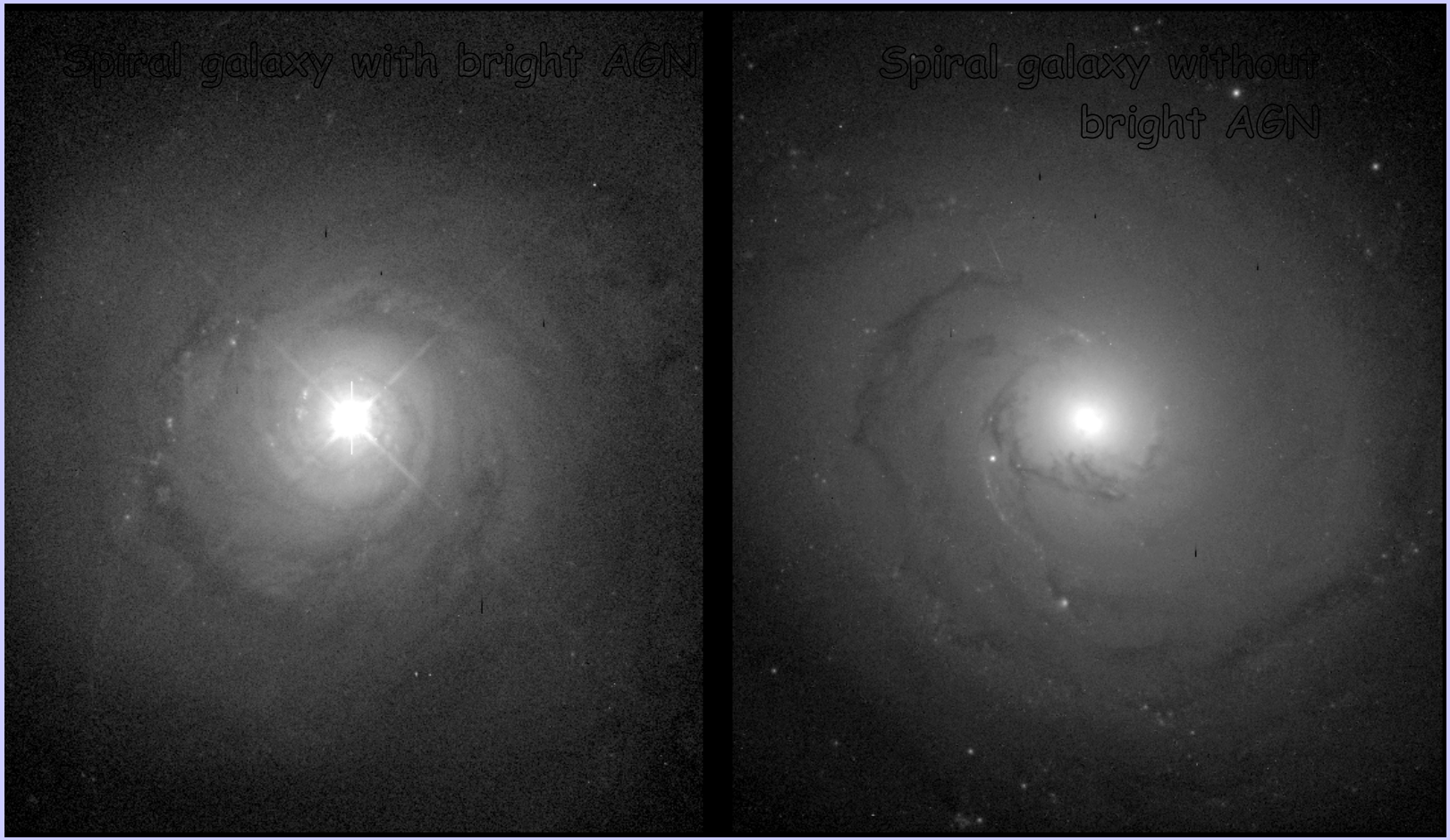


Sgr B2



Spectrum of AGN GRS 1734-292





AGNs with $L_x \sim 10^{39}$ ergs/s are indistinguishable from the host galaxies. Very fine angular resolution is needed. Not in hard X-rays now

Sgr B2 is unique case!

Summary

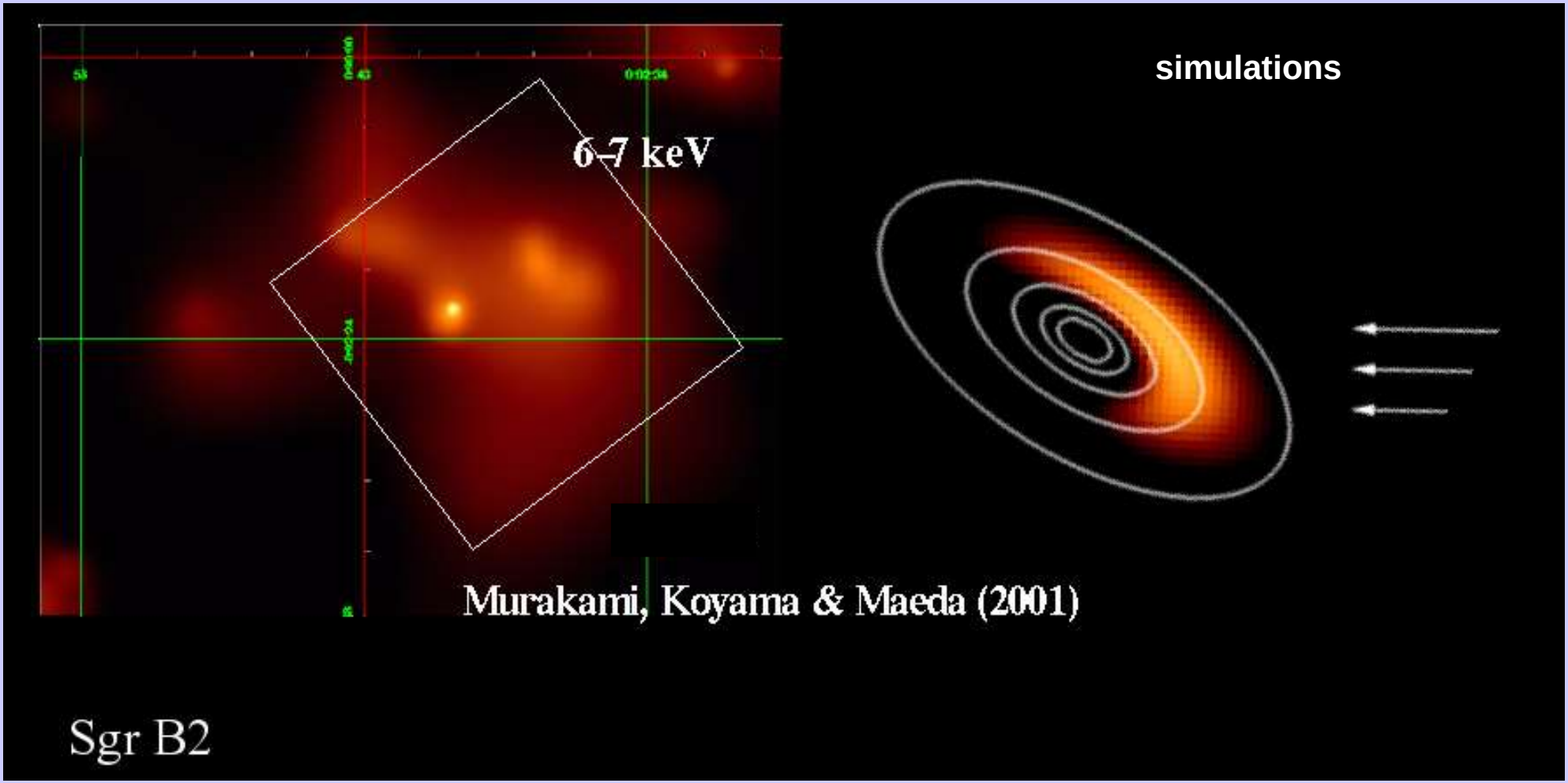
1) INTEGRAL detects hard X-ray emission from molecular cloud Sgr B2

2) Set of properties of X-ray emission of Sgr B2 allows to conclude that it is a X-ray reflection nebula. Illuminating source – Sgr A* ~300 years ago. Mass of Sgr B2 cloud is estimated

3) Shape of the spectrum of Sgr B2 allows to reconstruct the shape of the spectrum of Sgr A* when it had $L_x \sim 10^{39}$ ergs/s. Spectral shape is very similar to that of normal Seyfert galaxies.

4) This spectral measurement is absolutely unique - no curent hard X-ray instrument can do similar thing for other galaxies.

CHANDRA



Detected point X-ray sources contribute
not more than 10% to the emission of Sgr B2
(Murakami et al. 2002, Takagi et al. 2002)