The SuperMassive Black Hole at the Galactic Center

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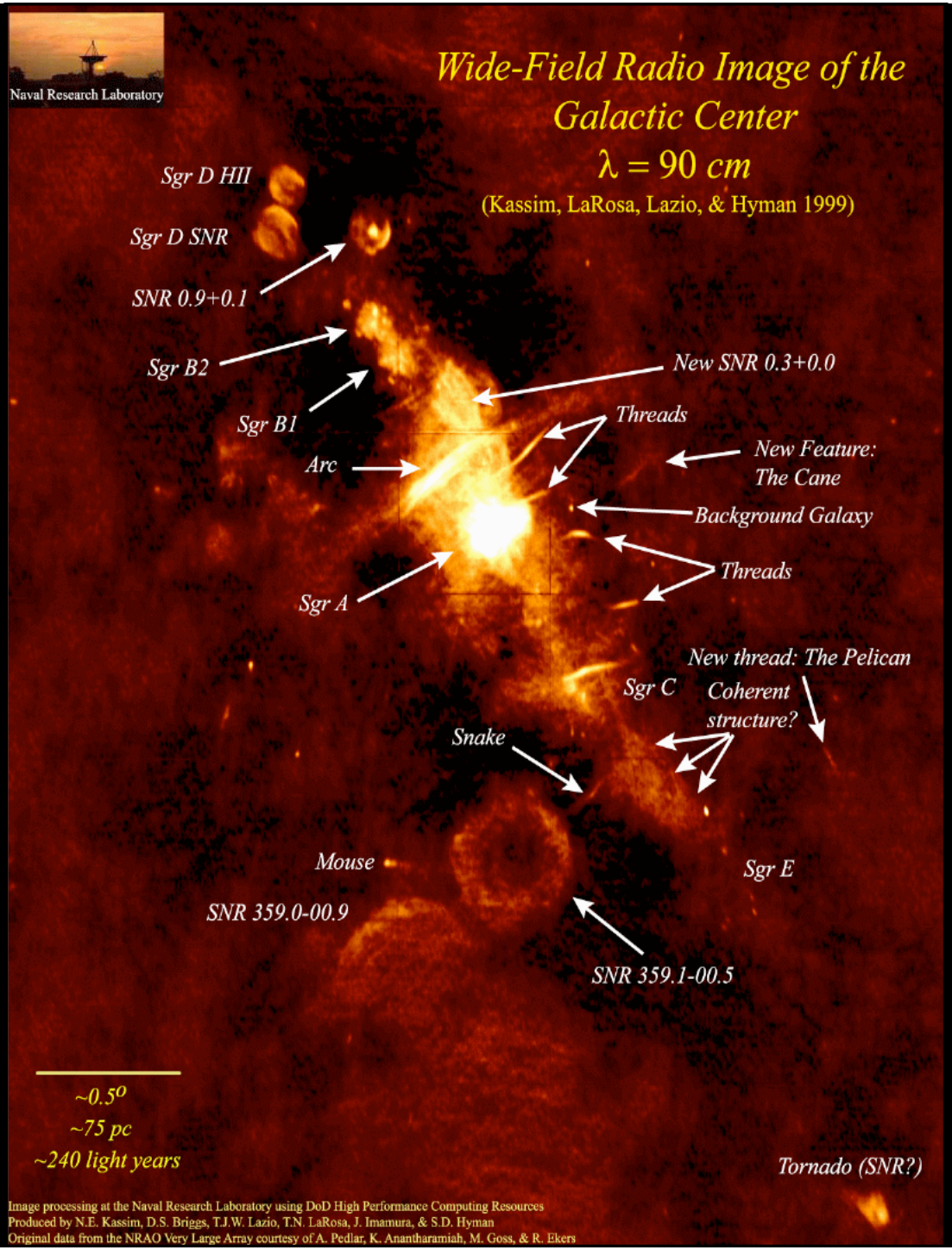
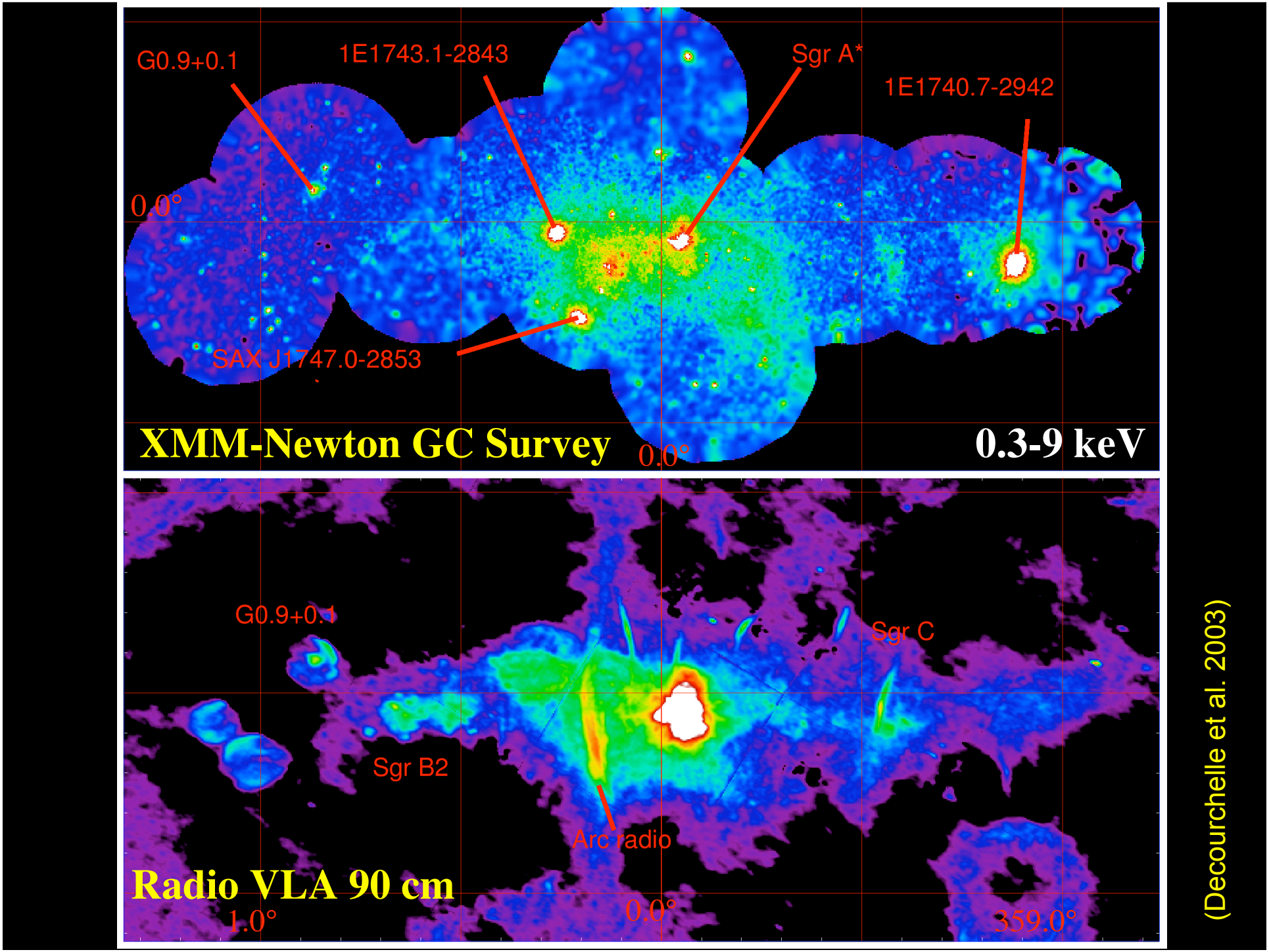
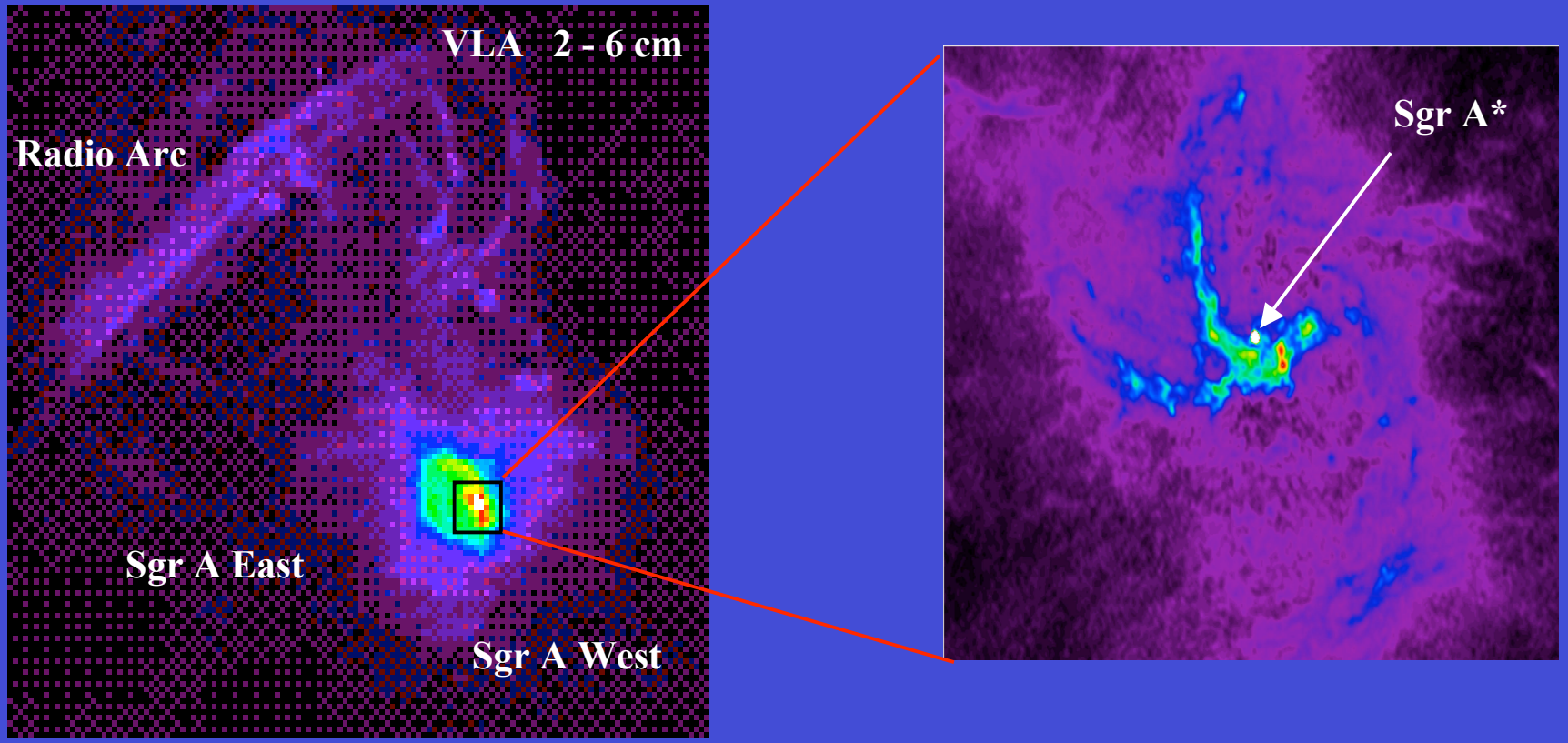
- The Galactic Center Region
- Sgr A*: radiative signature of the galactic SMBH
- High energy emission from Sgr A*
- Flaring activity of Sgr A*
- Recent INTEGRAL results
- Accretion / Jet Models for Sgr A*
- Perspectives with SIMBOL X

Atelier SIMBOL X – 11-12 March 2004 CNES Paris, France


Naval Research Laboratory
Wide-Field Radio Image of the Galactic Center
λ = 90 cm
(Kassim, LaRosa, Lazio, & Hyman 1999)
Sgr D HII
Sgr D SNR
SNR 0.9+0.1
Sgr B2
Sgr B1
Arc
New SNR 0.3+0.0
Threads
New Feature: The Cane
Background Galaxy
Threads
Sgr A
New thread: The Pelican
Sgr C
Coherent structure?
Snake
Mouse
SNR 359.0-00.9
Sgr E
SNR 359.1-00.5
~0.5°
~75 pc
~240 light years
Tornado (SNR?)
Image processing at the Naval Research Laboratory using DoD High Performance Computing Resources
Produced by N.E. Kassim, D.S. Briggs, T.J.W. Lazio, T.N. LaRosa, J. Imamura, & S.D. Hyman
Original data from the NRAO Very Large Array courtesy of A. Pedlar, K. Anantharamiah, M. Goss, & R. Ekers


G0.9+0.1
1E1743.1-2843
Sgr A*
1E1740.7-2942
0.0°
SAX J1747.0-2853
XMM-Newton GC Survey
0.0°
0.3-9 keV
G0.9+0.1
Sgr C
Sgr B2
Arc radio
Radio VLA 90 cm
1.0°
0.0°
359.0°
(Decourchelle et al. 2003)

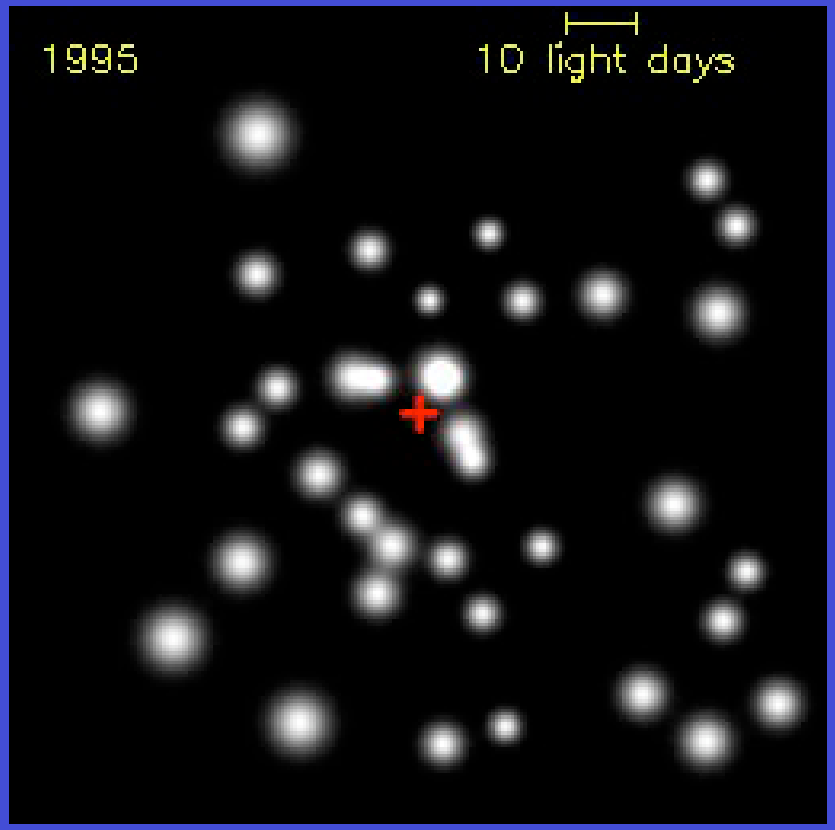
The Sgr A complex and Sgr A*



- **Sgr A*: a bright (1 Jy), variable, compact synchrotron radio source**
- **Flat spectrum, sub-mm bump linearly polarized**
- **Coincide** (< 10 mas) with cluster dynamical center. **Proper motion** < 15 km s^{-1}
- **Radio size** 0.1 mas < 1 AU (15 R_S for a BH of 3 10^6 $M_\odot$)

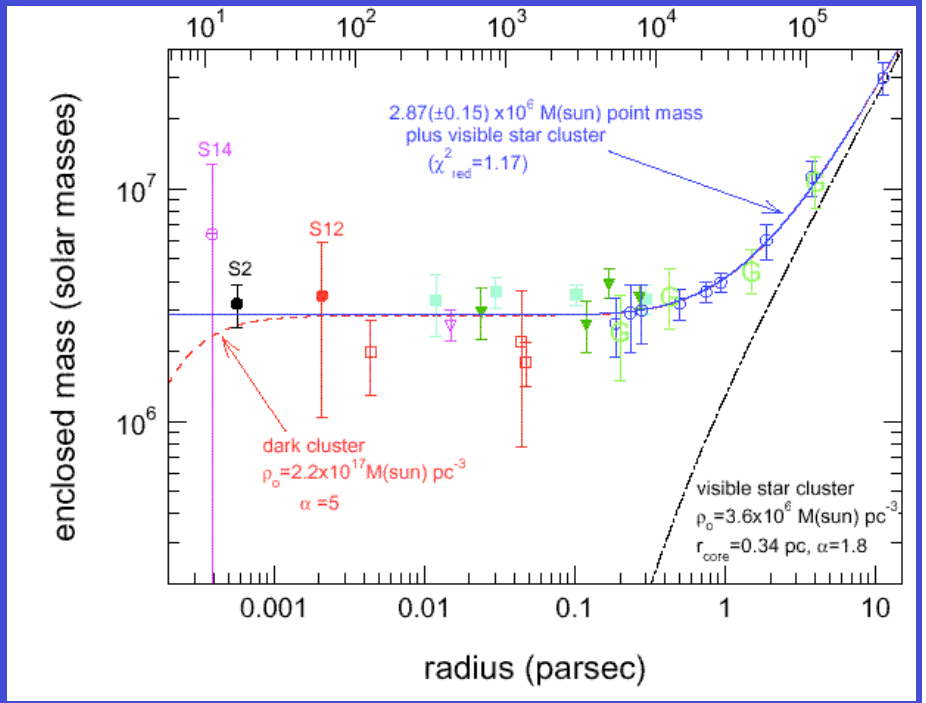
DISCOVERED 30 yr ago (Balick & Brown 1974) PREDICTED in 1971 (Lynden-Bell & Rees)

Sgr A*: the GN Massive Black Hole



NIR adaptive optics at VLT & Keck

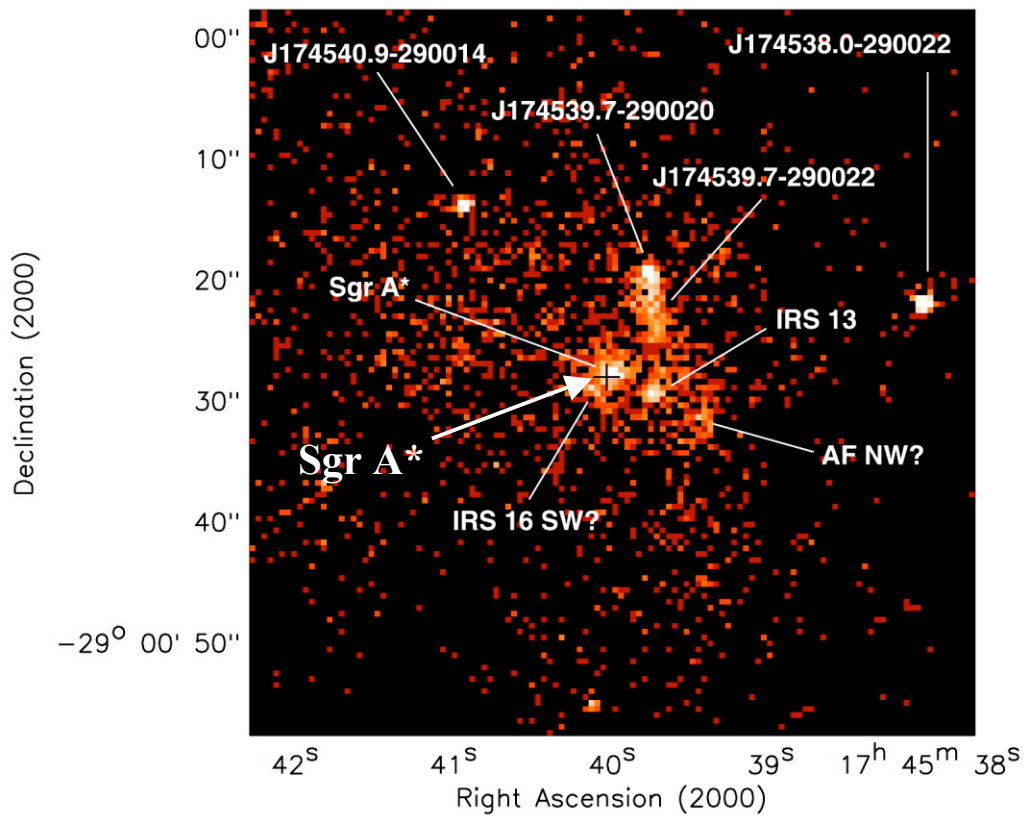
- Proper motions of the stars of the central cluster
- Orbital parameters of the closest star **S2** to the GC:
  P 15.2 yr, V 5000 km s^{-1}
- Dynamical center in **Sgr A***

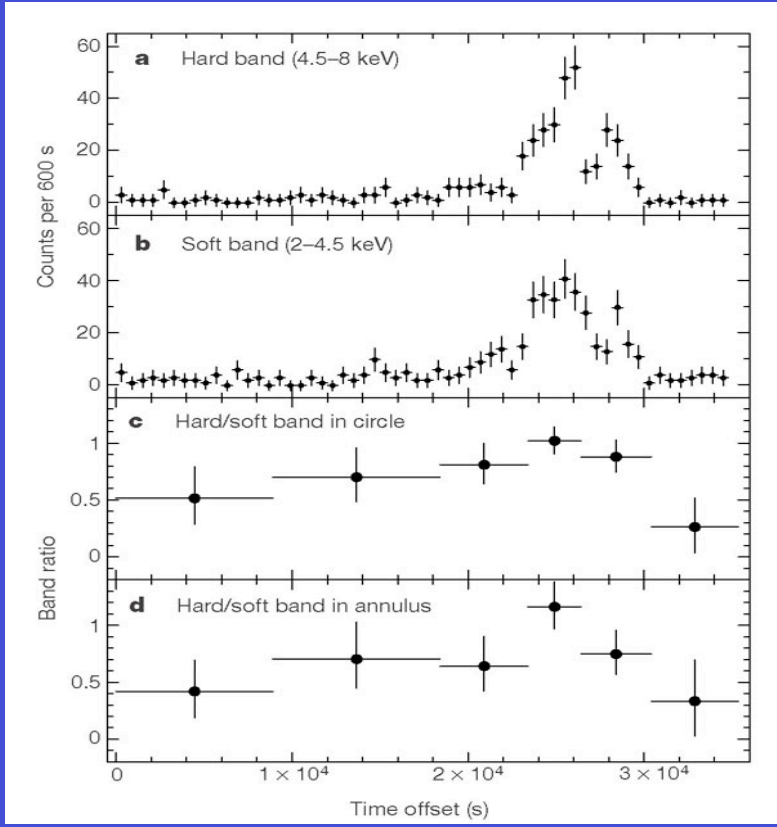


- Enclosed Dark Mass 3 10^6 $M_\odot$
  within 124 AU = 17 l. h. 2000 R_S
- **A SUPER MASSIVE BLACK HOLE**

(Schoedel et al '02, Genzel et al '03, Ghez et al '03)

Chandra Observations of Sgr A*

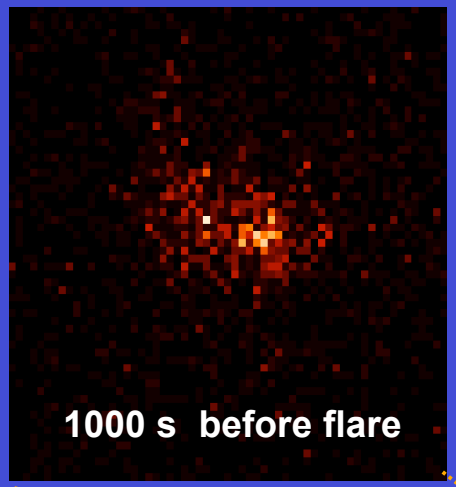


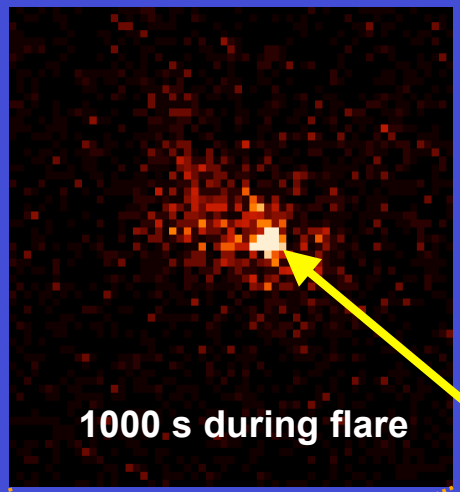


- **Sgr A* weak persistent emission:**
  L_X(2-10 keV) ≈ 2 10^{33} erg s^{-1}
  soft power law (Γ ≈ - 2.7)
  partly extended (≈ 1")
  (Baganoff et al. 2003)

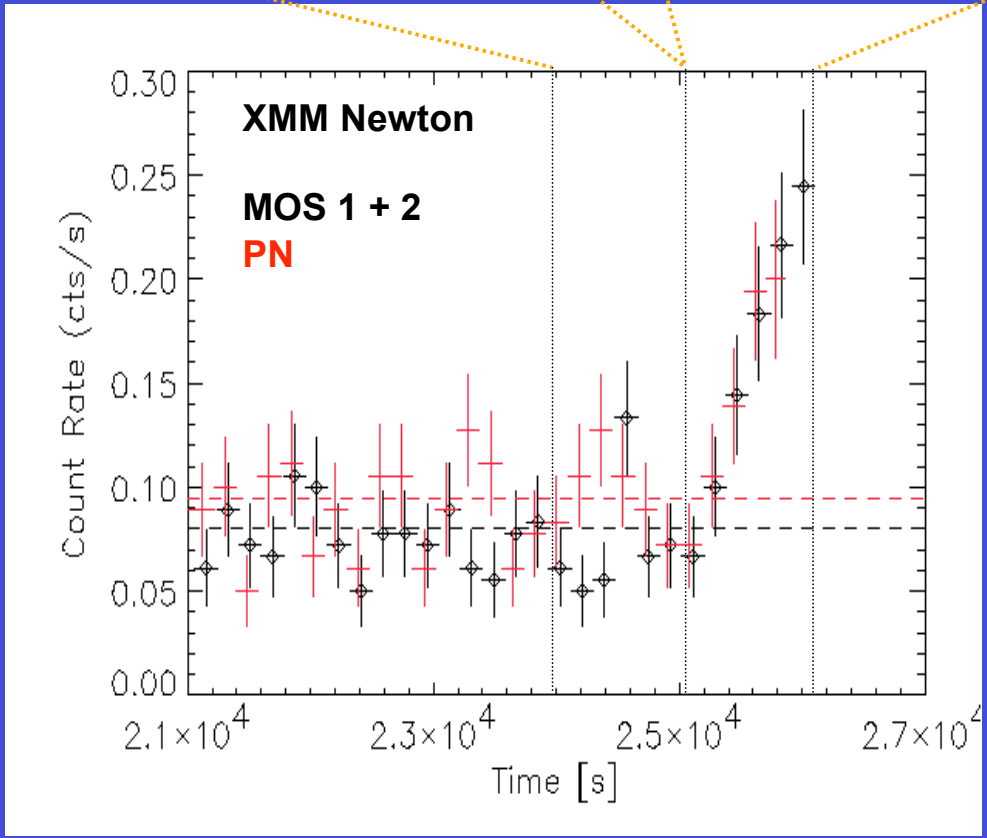
- **Sgr A* bright X-ray Flares :**
  short duration ~ 3 hr
  L_{peak} (2-10 keV) ≈ 10^{35} erg s^{-1}
  hard power law (Γ ≈ - 1.3)
  (Baganoff et al. 2001)

XMM-NEWTON Detection of a Sgr A* X-Ray Flare





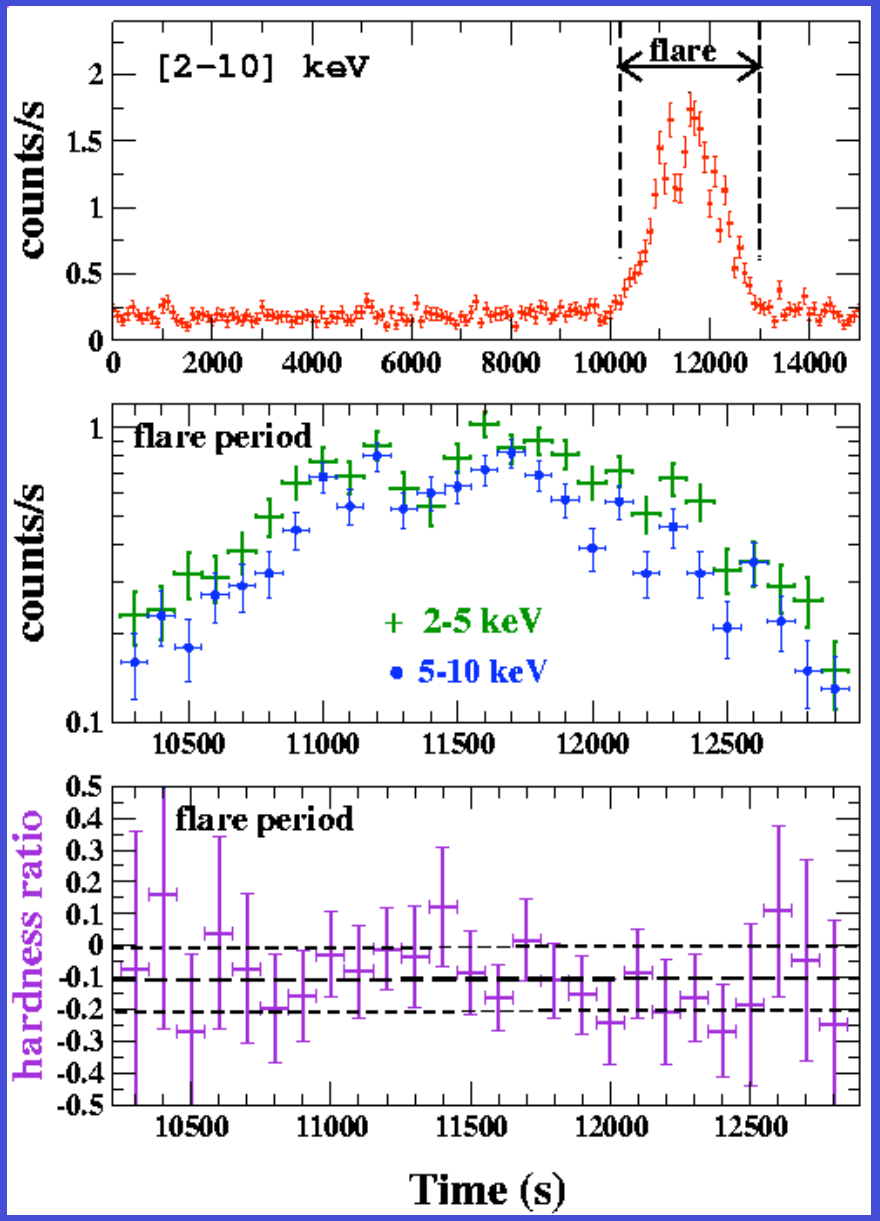
Sgr A*

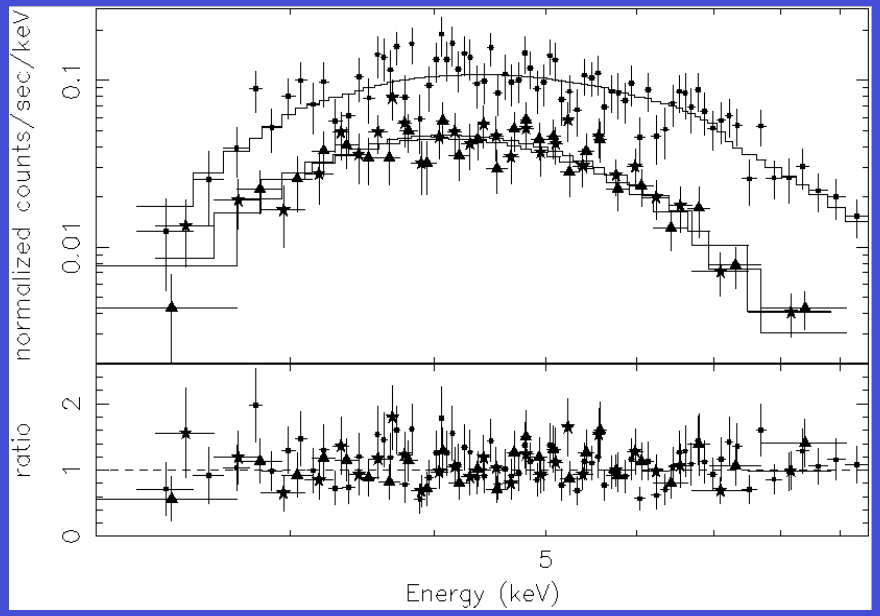


- New flare on Sep 2001
- Peak L_X (2-10 keV) ~ 5 10^{34} erg s^{-1}
- Hard spectrum ($\Gamma \sim 1$)
- No spectral variations

(Goldwurm et al. 2003)

The Brightest Sgr A* X-Ray Flare



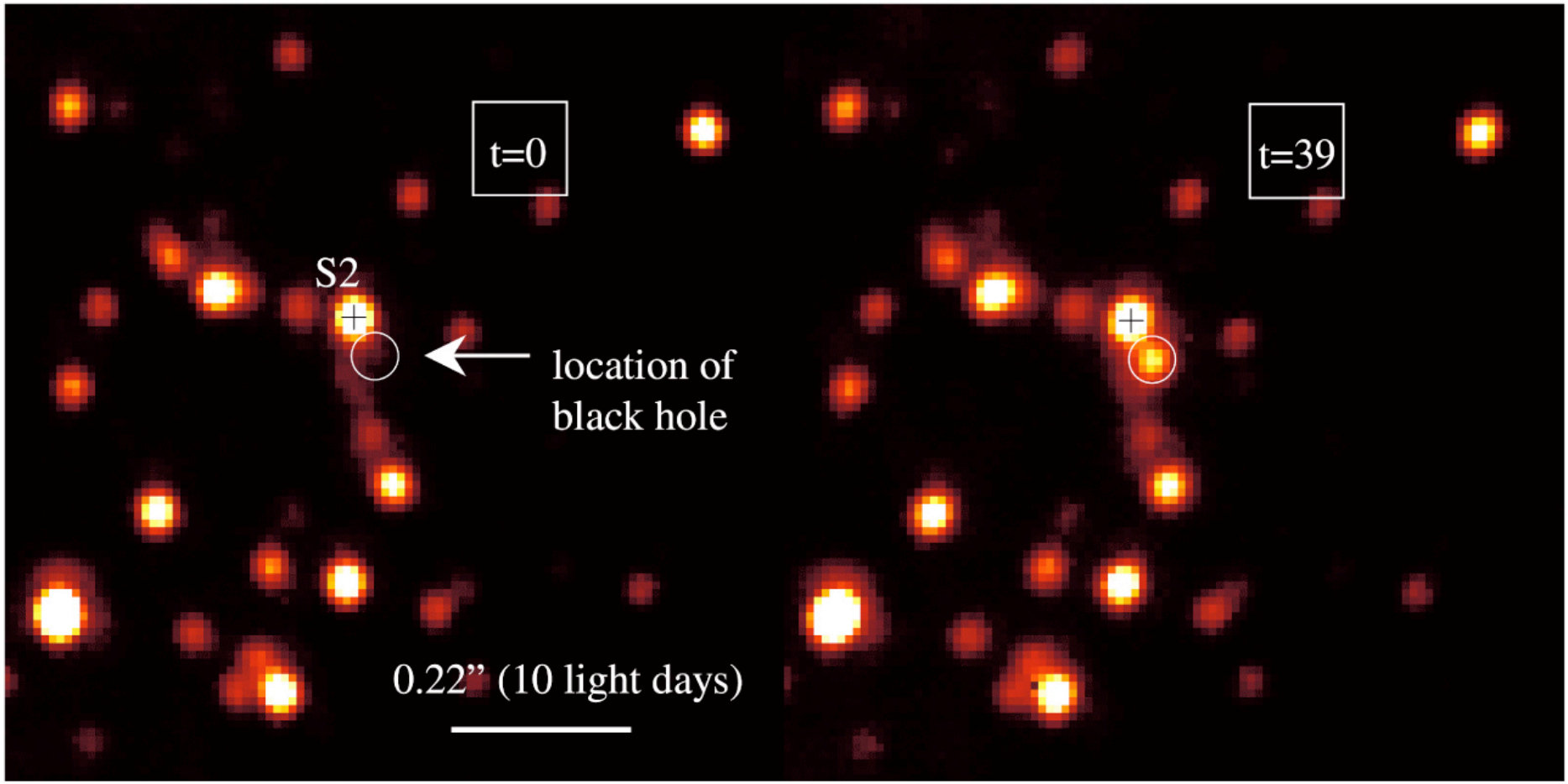


Detected with XMM-Newton in Oct 2002

- Peak L_X (2-10 keV) ≈ 3.6 10^{35} erg s^{-1}
- L increase > 180, Duration ≈ 2.7 ks
- Soft spectrum (Γ ≈ 2.5 ± 0.3)
- No spectral variations, No Fe lines
- Changes on scales of 200 s
  => emitting region size of ≈ 10 R_S

(Porquet et al. 2003)

The Sgr A* Near-IR Flares

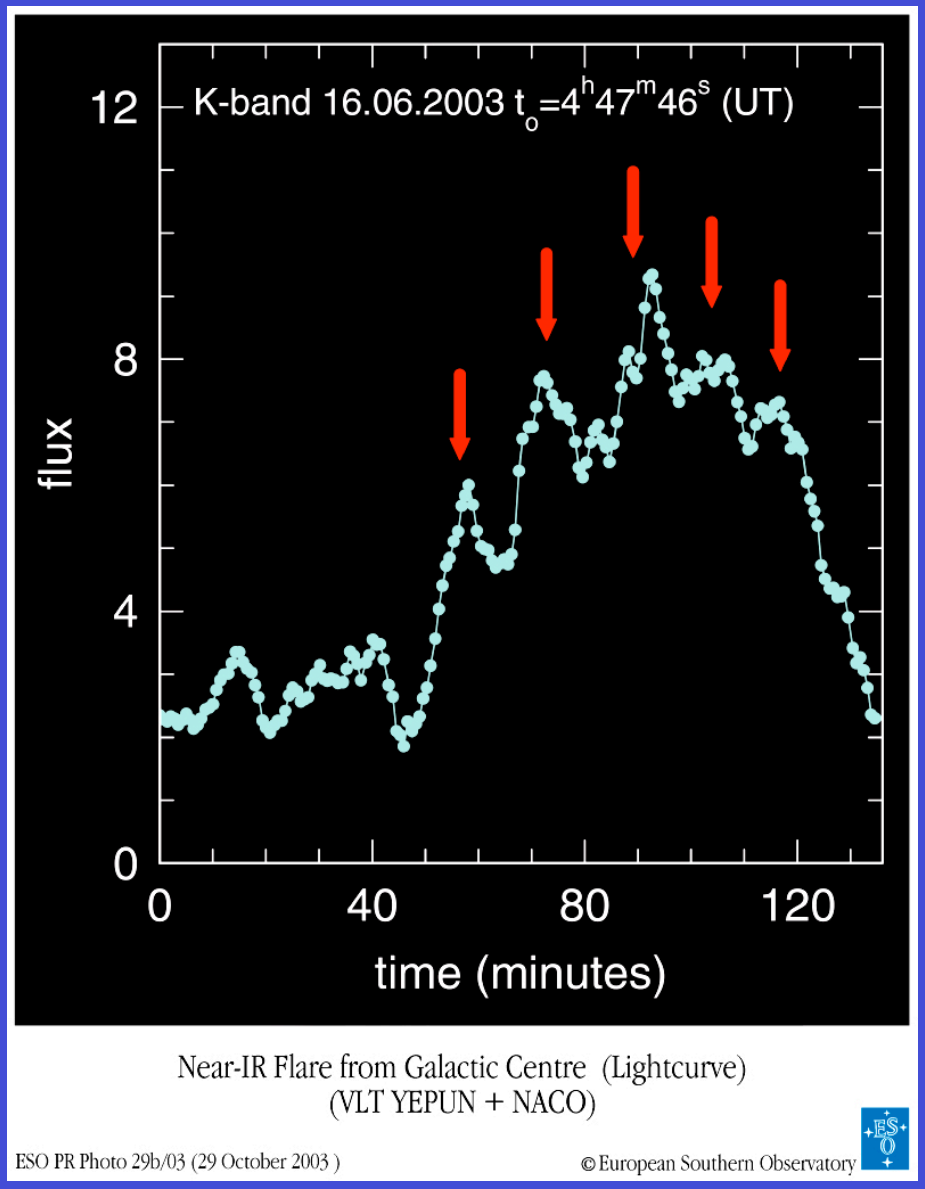


Near-IR Flare from Galactic Centre (VLT YEPUN + NACO)

ESO PR Photo 29a/03 (29 October 2003)

(Genzel et al. 2003)

Periodicity in the NIR flares Sgr A*: BH spin ?



Near-IR Flare from Galactic Centre (Lightcurve)
(VLT YEPUN + NACO)

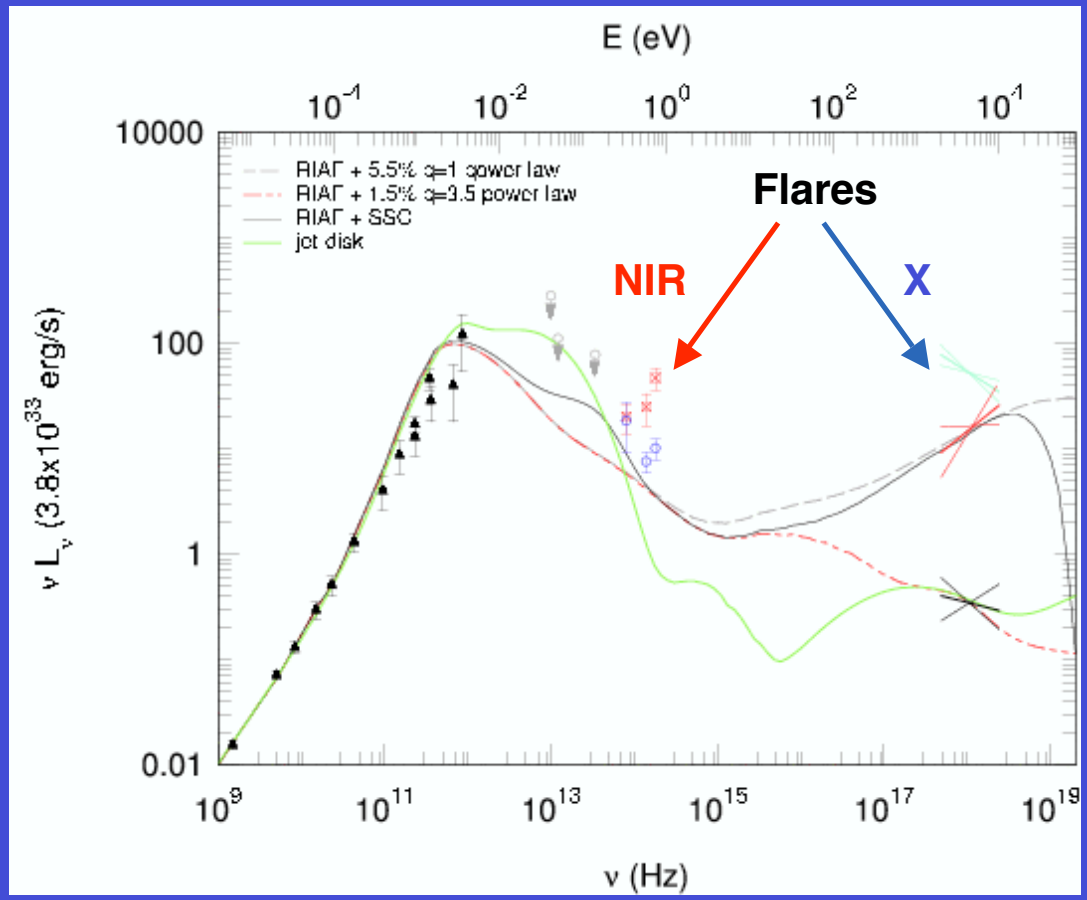
ESO PR Photo 29b/03 (29 October 2003)

- **Discovery of 17 min periodicity in the NIR flares**
- **For a 3.6 10^6 $M_\odot$ Schwarzschild BH the keplerian period at the LSO is 27 min**
- **The QPO imply that Sgr A* is a Kerr BH with spin of a = $J/(GM/c^2) = 0.52 \pm 0.1$?**

  (Genzel et al. 2003 Nat)
- **Recent time analysis of the data of the X-ray Flares have shown presence of similar periodicities (Lense-Thirring ?)**

  (Aschenbach et al. 2004)

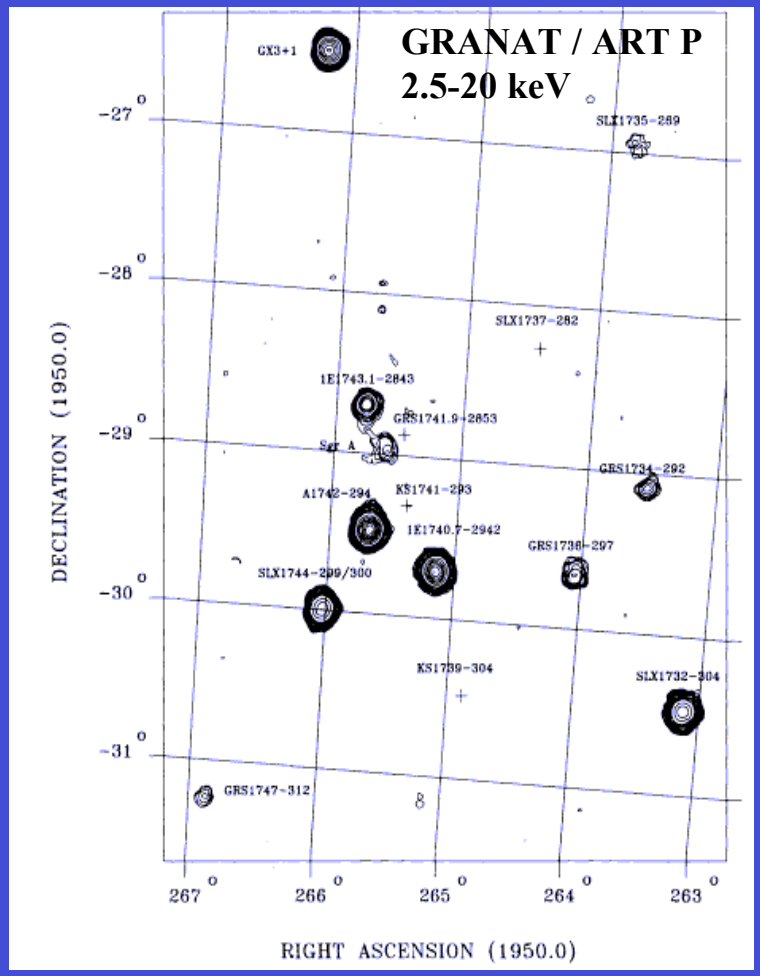
NIR flares Sgr A*: non-thermal model

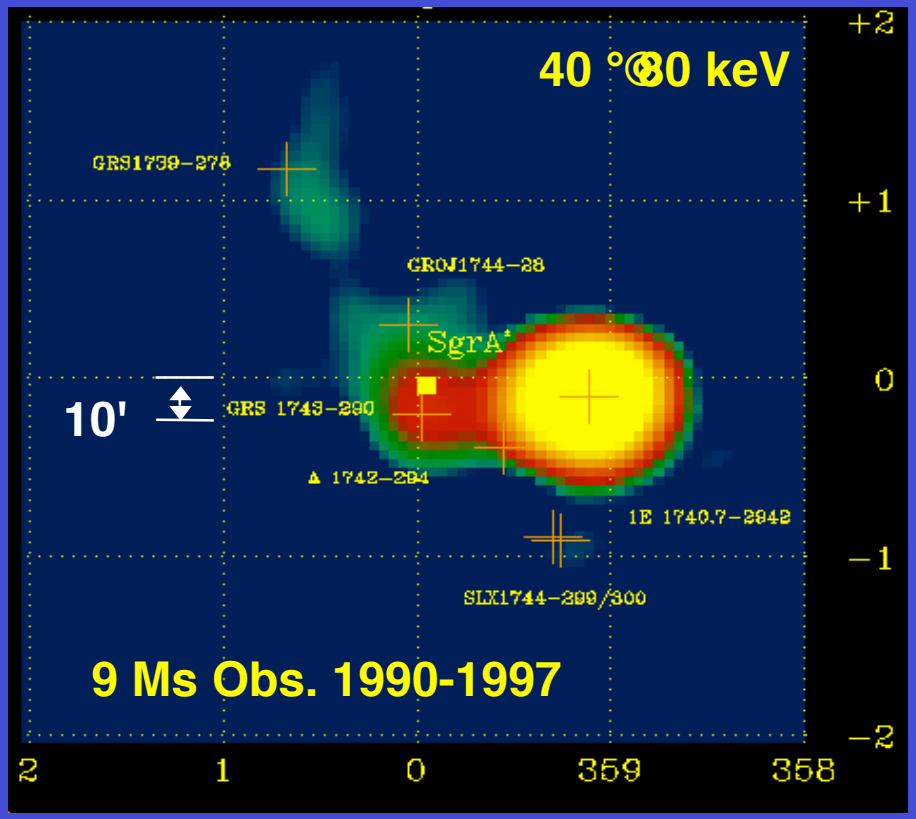


(Genzel et al. 2003)

- NIR flares have time-scales similar to X-ray flares (but more frequent)
- NIR Emission also comes from very close to the BH
- Models strongly constrained. Non-thermal component needed
- An important energy range to explore: the hard X-rays/gamma-rays

Hard X-rays & Gamma-Rays from GN





SL2/XRT and **ART-P** detected Sgr A at L_X(3-20 keV) ≈ 0.5-1 10^{36} erg s^{-1}

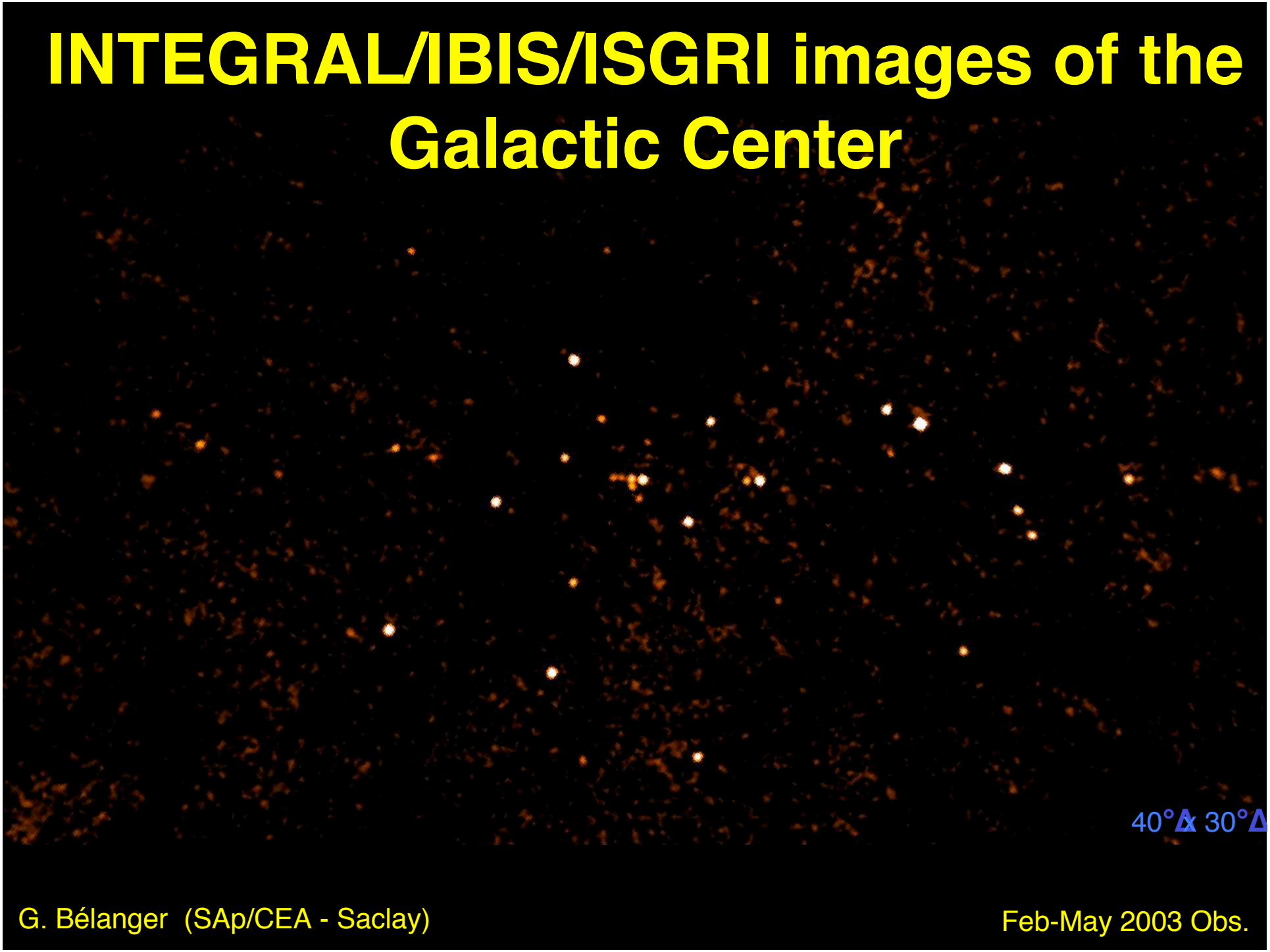
(Skinner et al 87, Pavlinsky et al 94, Sunyaev 94)

SIGMA / GRANAT discovered a closeby source and set upper limits to Sgr A* γ-ray emission:

$L_{(30 - 300\ keV)} < 1.2\ 10^{36}$ erg s^{-1}

(Goldwurm et al. 1994, Goldoni et al. 1999)

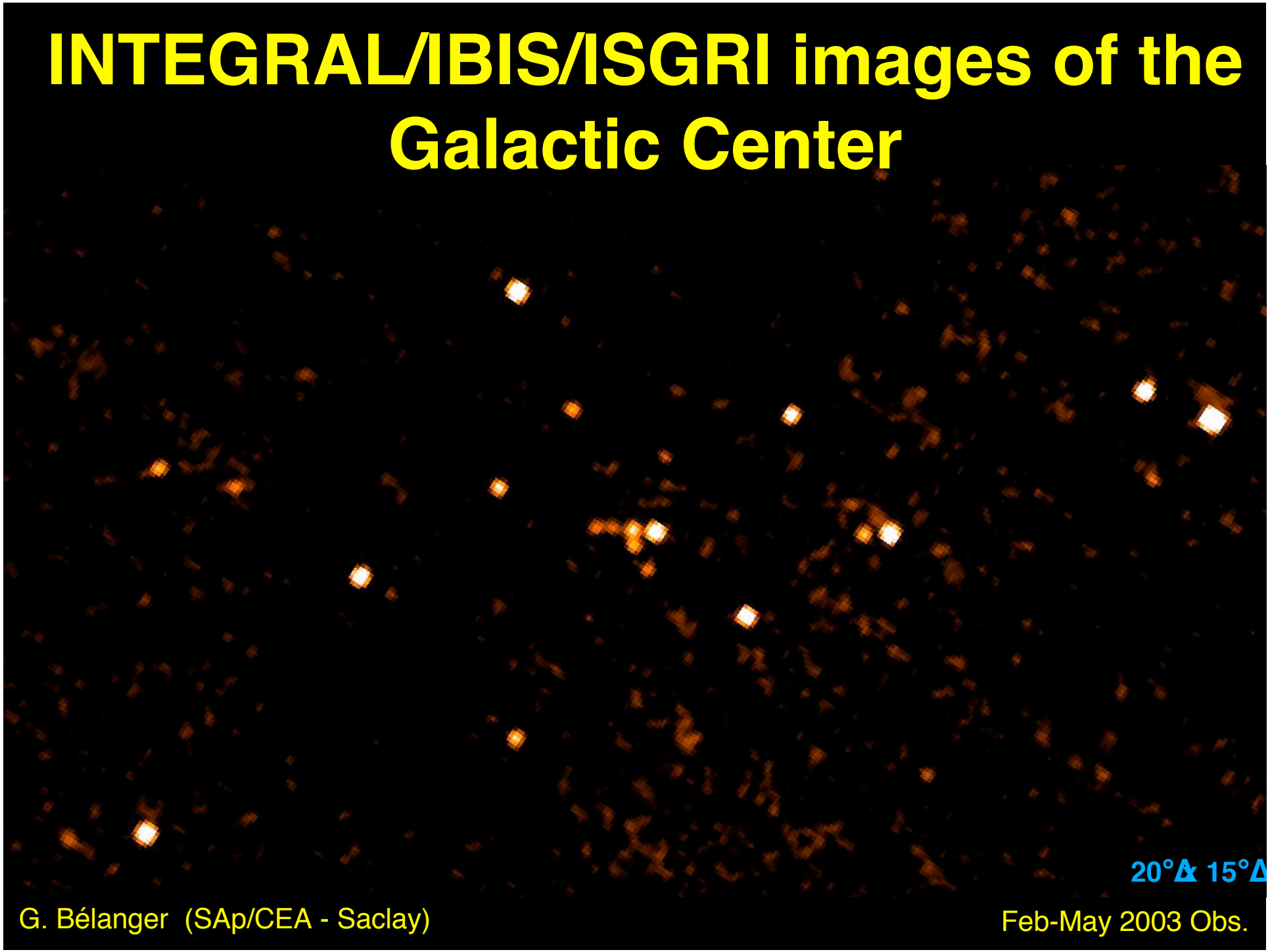
INTEGRAL/IBIS/ISGRI images of the Galactic Center



G. Bélanger (SAp/CEA - Saclay)

Feb-May 2003 Obs.

INTEGRAL/IBIS/ISGRI images of the Galactic Center



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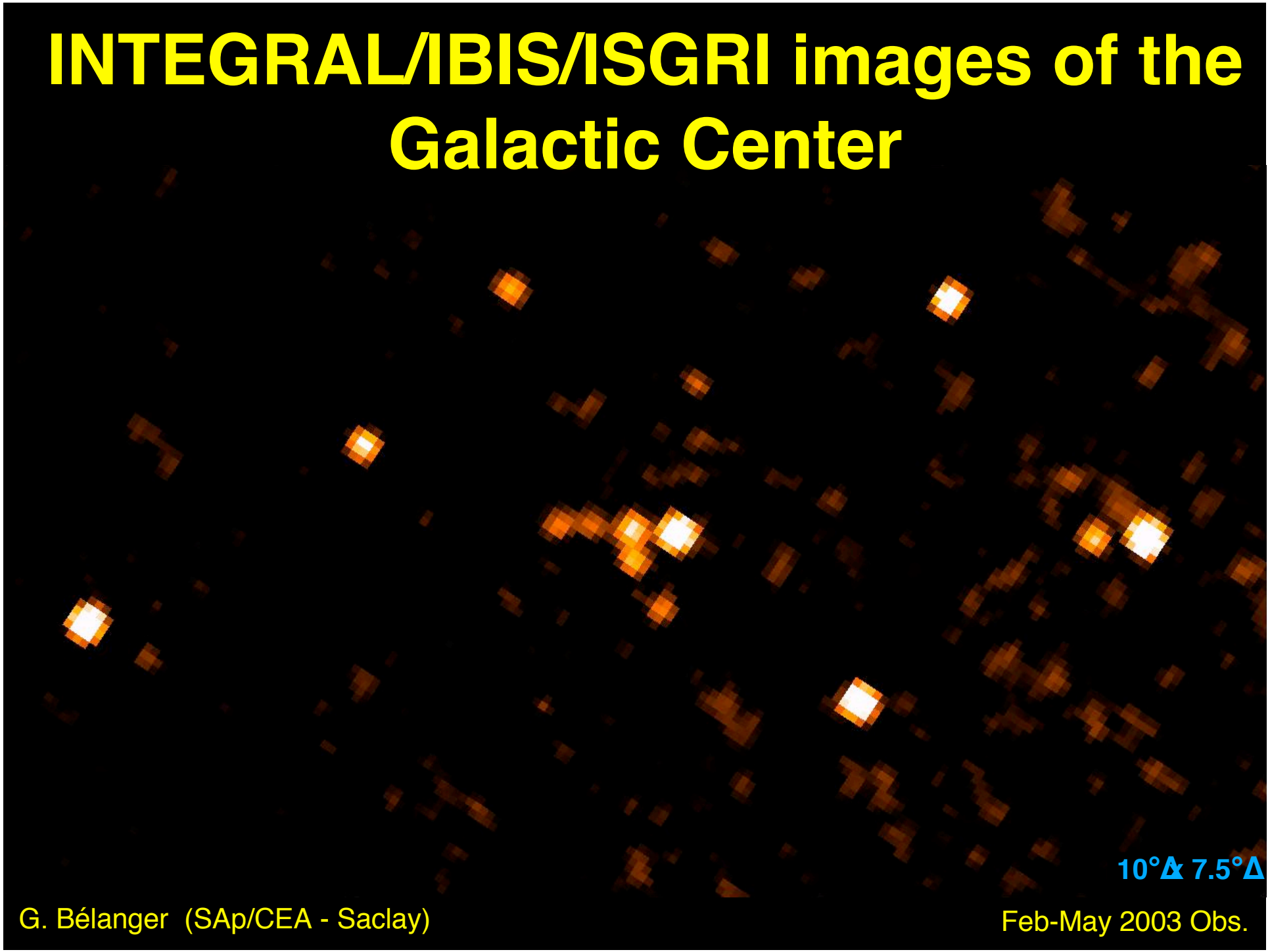

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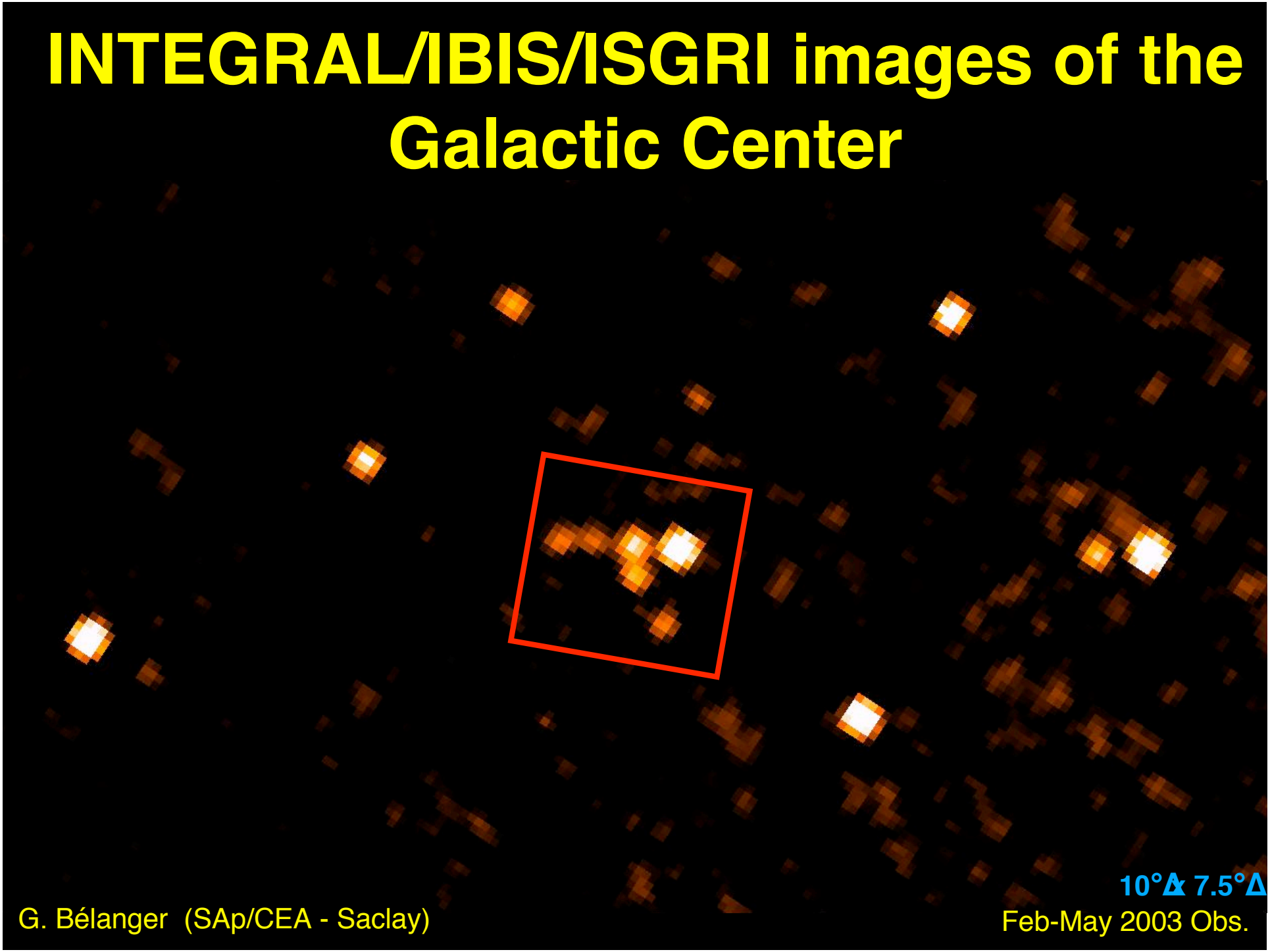
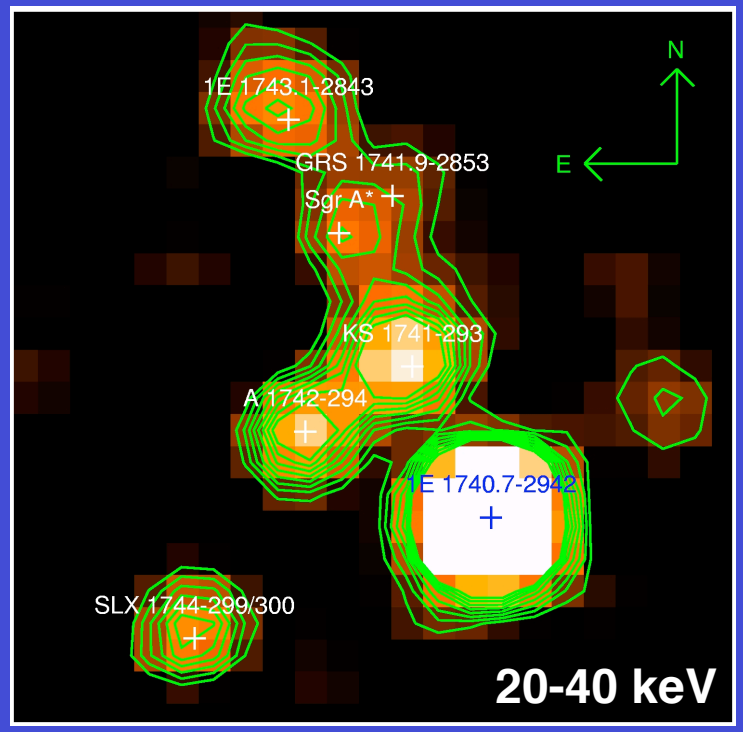
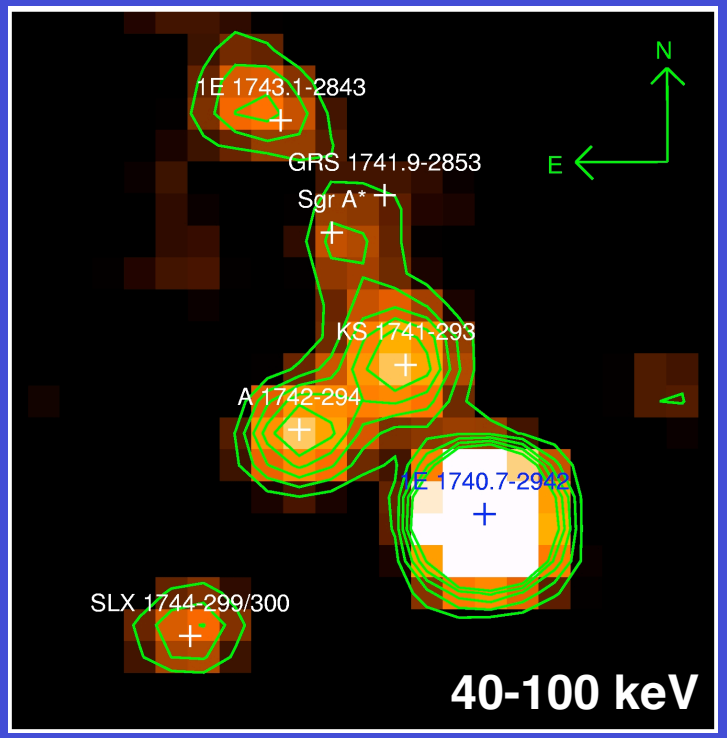


INTEGRAL IBIS / ISGRI Images of the Nuclear Region





- **Feb - May 2003 Observations** (Eff. Exp. ~ 800 ks)
- Six known high-energy sources in the central 2° □ 2° of the Galaxy
- A significant excess (8.7 _) at ~ 1' from Sgr A* (4.7 _ in 40-100 keV)
- Flux 20-100 keV □ 3-5 mCrab

(Bélanger et al. 2004, ApJ)

Nature of the INTEGRAL source in Sgr A region

- The INTEGRAL source is not compatible with known high energy (> 10 keV) sources of the region (the closest are GRS 1743-290 at 9' and GRS 1741.9-2853 at 10')

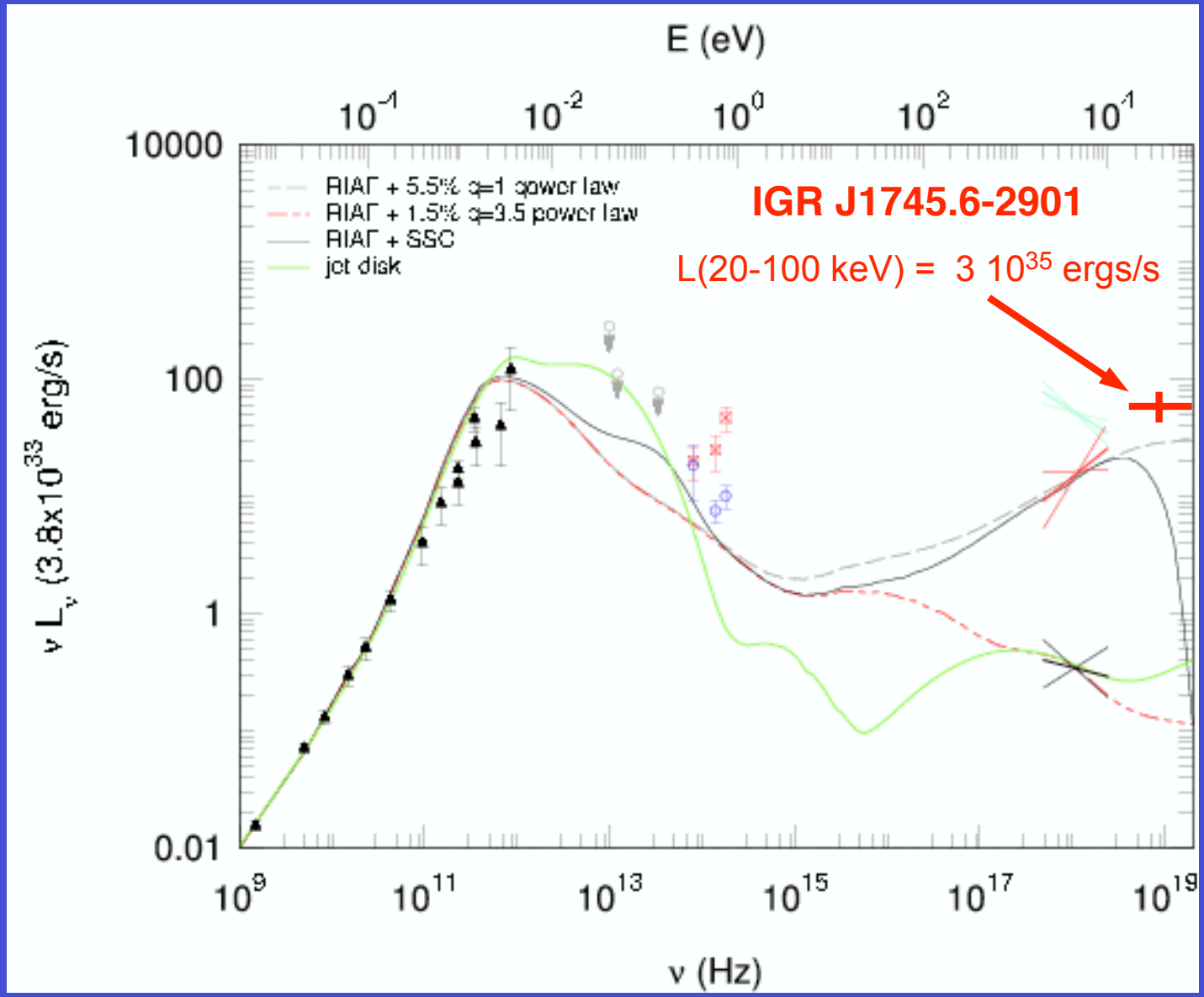
- It is not associated to non-thermal structures of the region (Radio Arc, Radio/X NTF) proposed as possible HE sources.

- It cannot be explained by the extrapolation of the (point/diffuse) X-ray emission within 10' from Sgr A* as measured by XMM, SAX, Chandra. The thermal plasma with kT □ 8 keV would give ~ 1 mC in 20-40 keV and < 0.1 mC in 40-100 keV

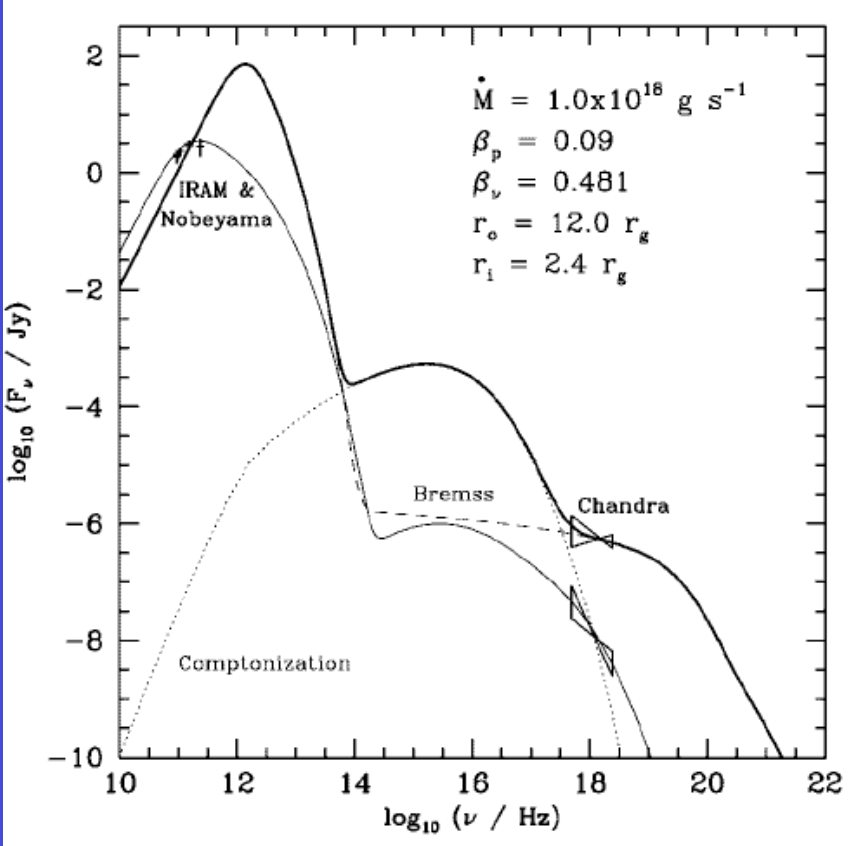
- Several Chandra sources are present in the error box but they are weak and soft. However a strong and hard X-ray transient was observed by ASCA AX1745.6-2901 at only 1.3' from Sgr A*. It was suggested to be the counterpart of the SL2 and ART P sources.

A new (unidentified) INTEGRAL source : IGR J1745.6-2901 which **cannot be unambiguously identified with Sgr A***

If IGR J1745.6-2901 is associated to Sgr A*

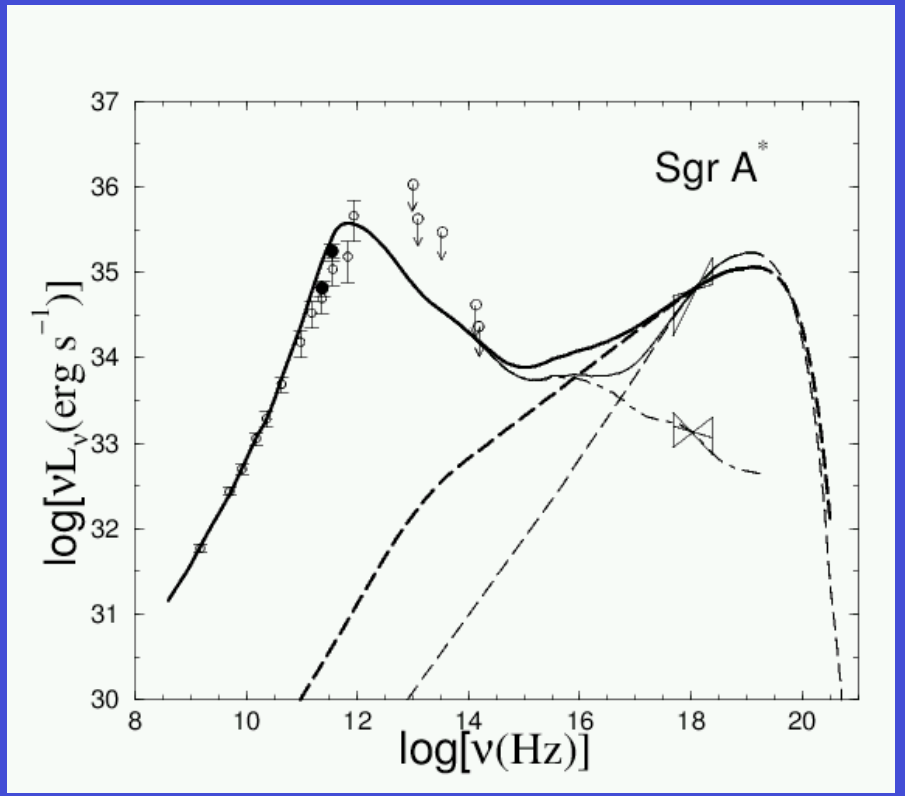


Accretion Models & …



Hot magnetized keplerian disk Model for Sgr A* (Bremm flare)

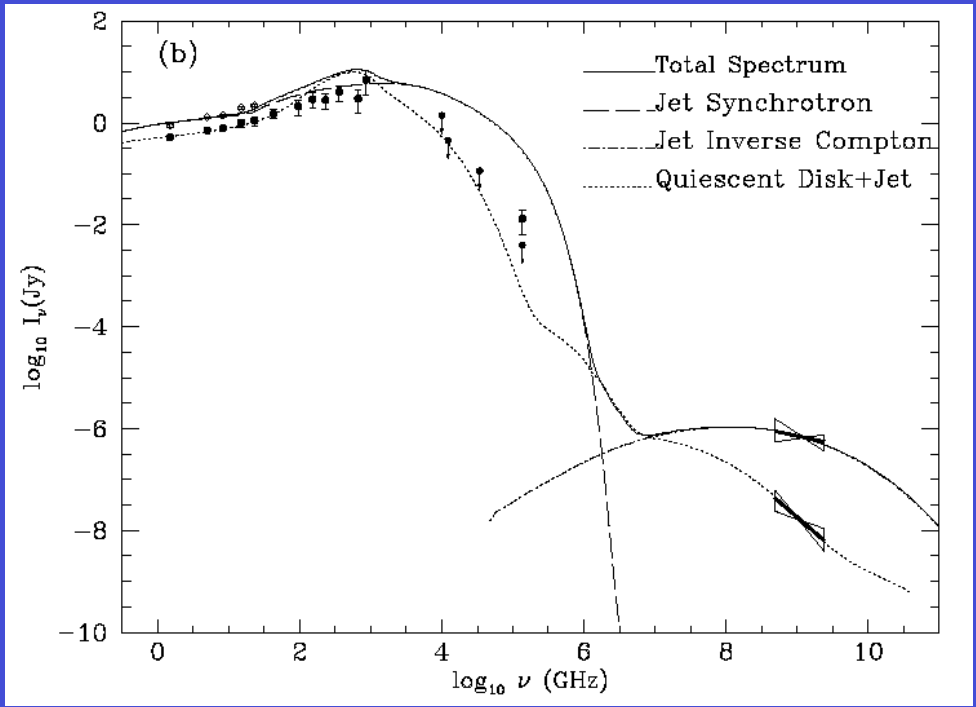
(Liu & Melia, 2002)



Radiative Inefficient Accretion Model for Sgr A* with non-thermal component (synch fl)

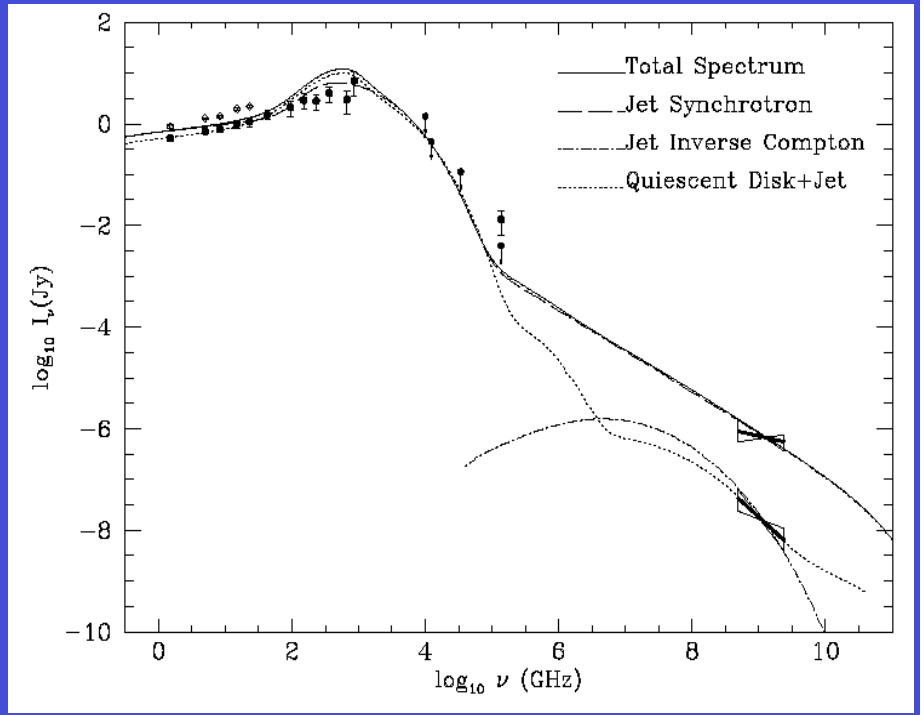
(Yuan et al. 2003)

…. Jet Models for Sgr A*



Compact Jet Model for Sgr A* with SSC X-ray Flare

(Markoff et al. 2002, Yuan et al. 2002)



Compact Jet Model for Sgr A* with thin synchrotron X-ray flare

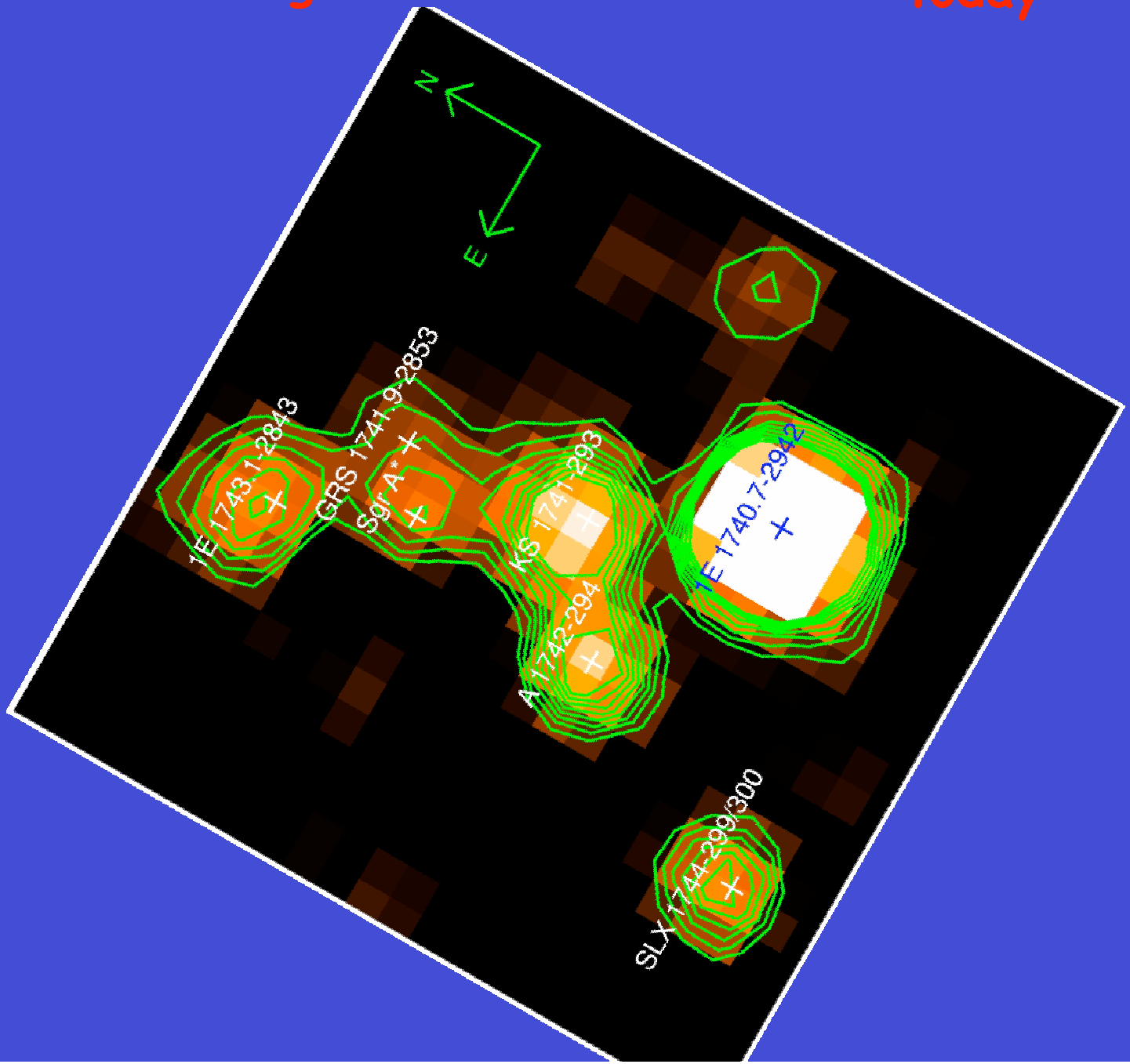
(Markoff et al. 2002, Yuan et al. 2002)

Planned 2004 Multi-_ Campaign on Sgr A*

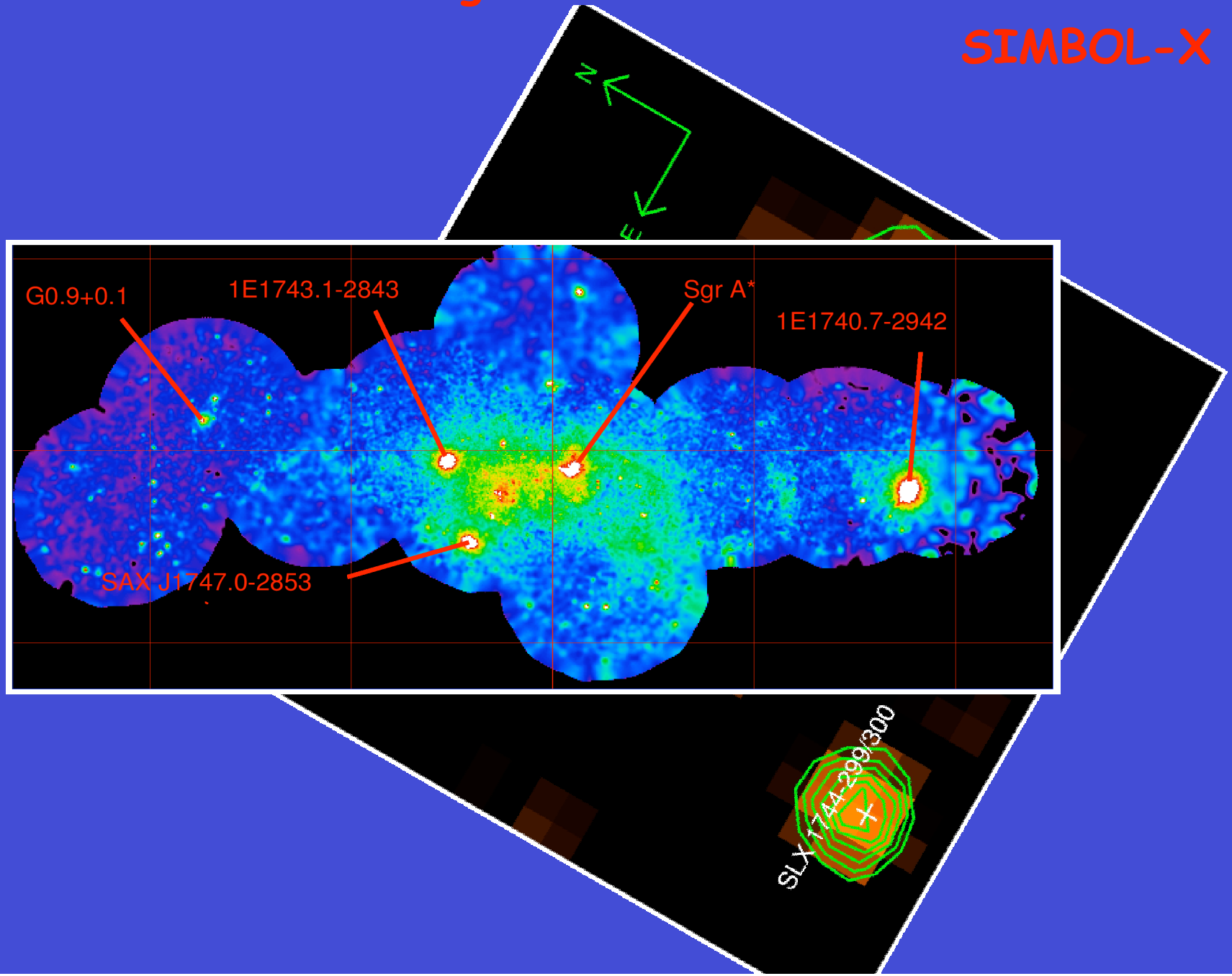
WAVELENGTH	TELESCOPE	Status
VHE Gamma-ray	HESS	Planned
Hard X-rays/_-rays	**INTEGRAL**	**Planned (300 □ 2 ks)**
X-rays	**XMM/Newton**	**Planned (260 □ 2 ks)**
NIR	VLT, HST/NICMOS	Planned, proposed
Sub-mm	CSO, SMA	Planned, proposed
Mm	BIMA, NRO	Planned, proposed
Radio	ATCA, VLA, GMRT	Planned, proposed

The central degree at > 20 keV

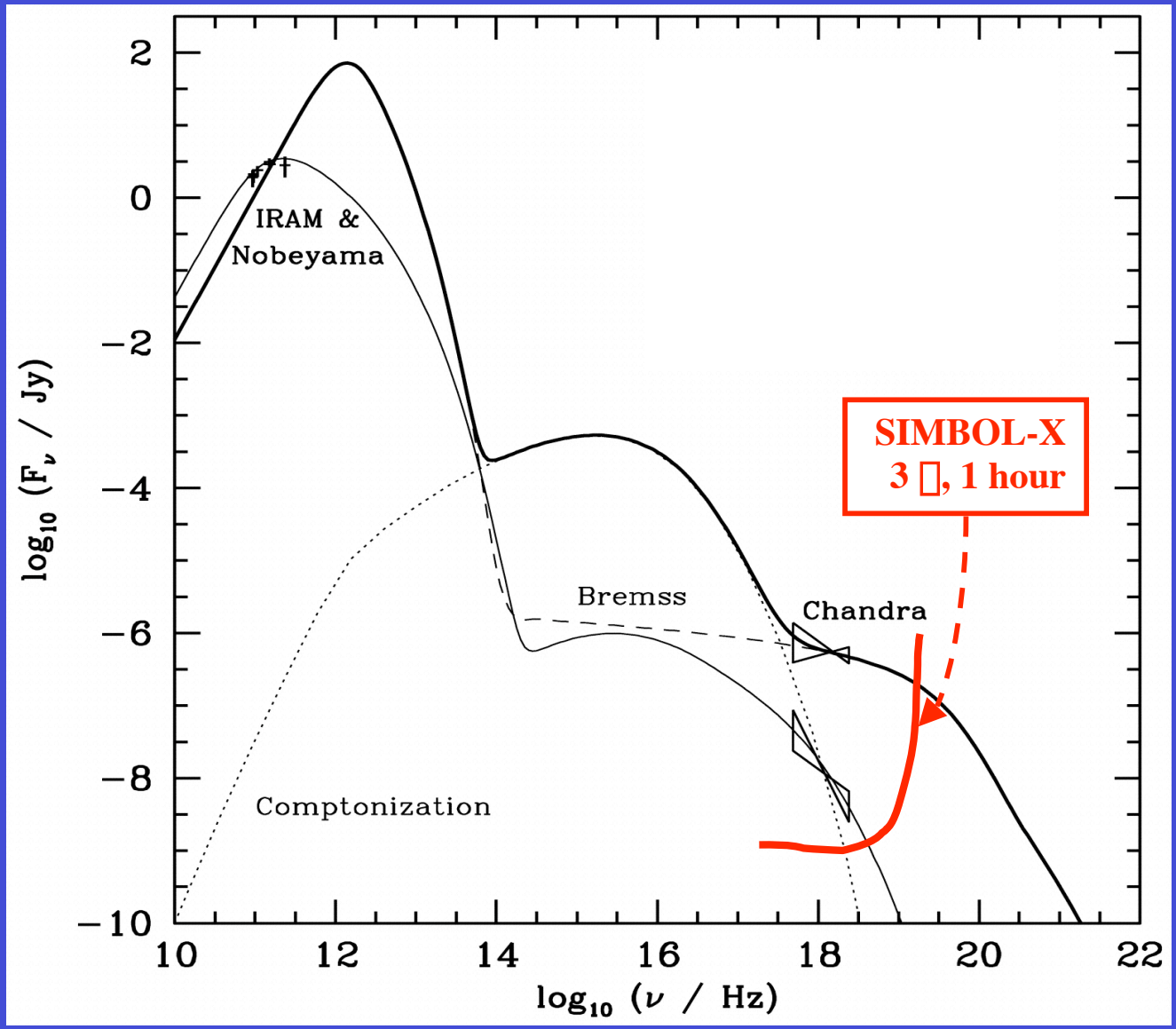
today



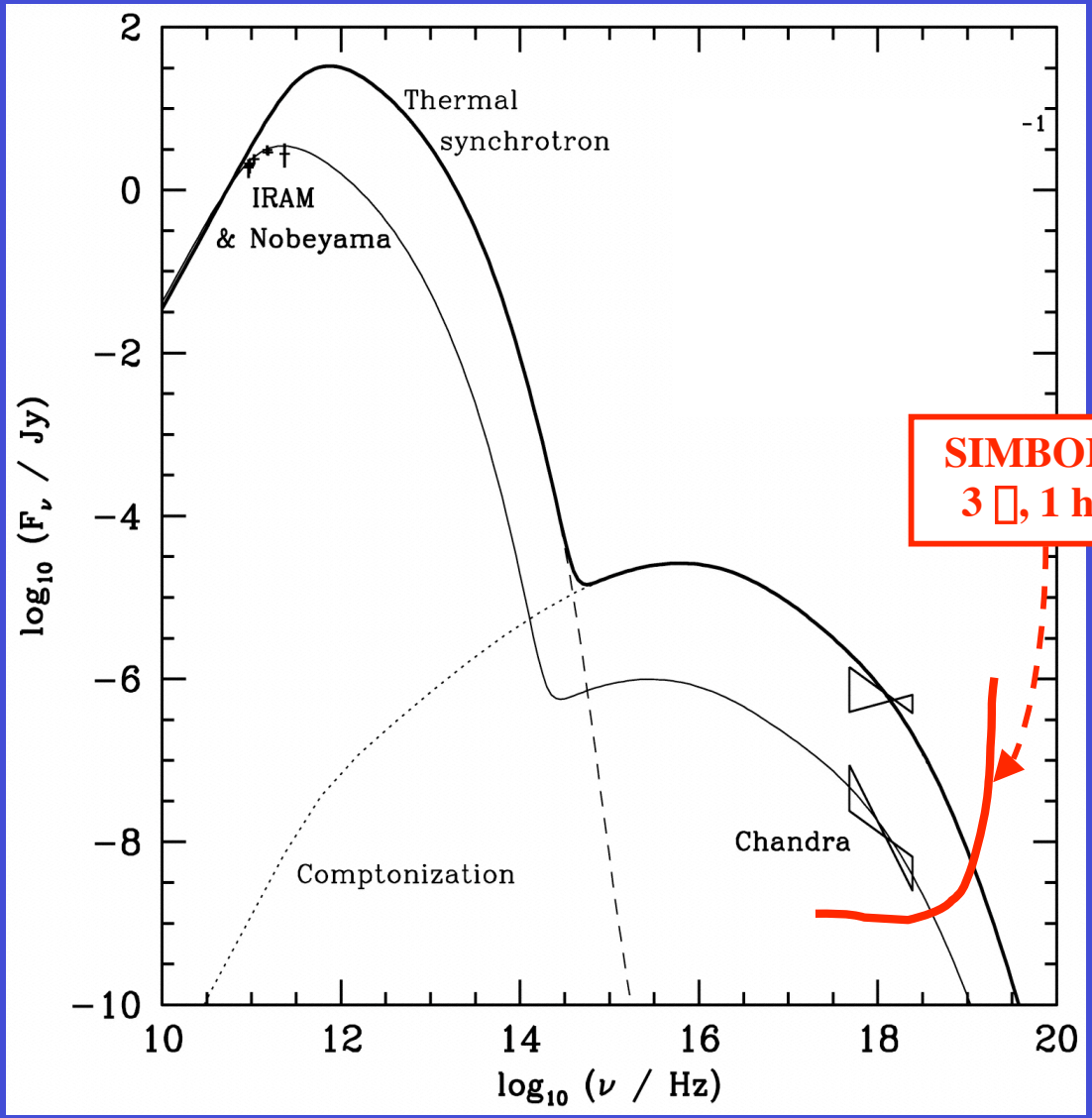
The central degree at > 20 keV in 2011 with SIMBOL-X



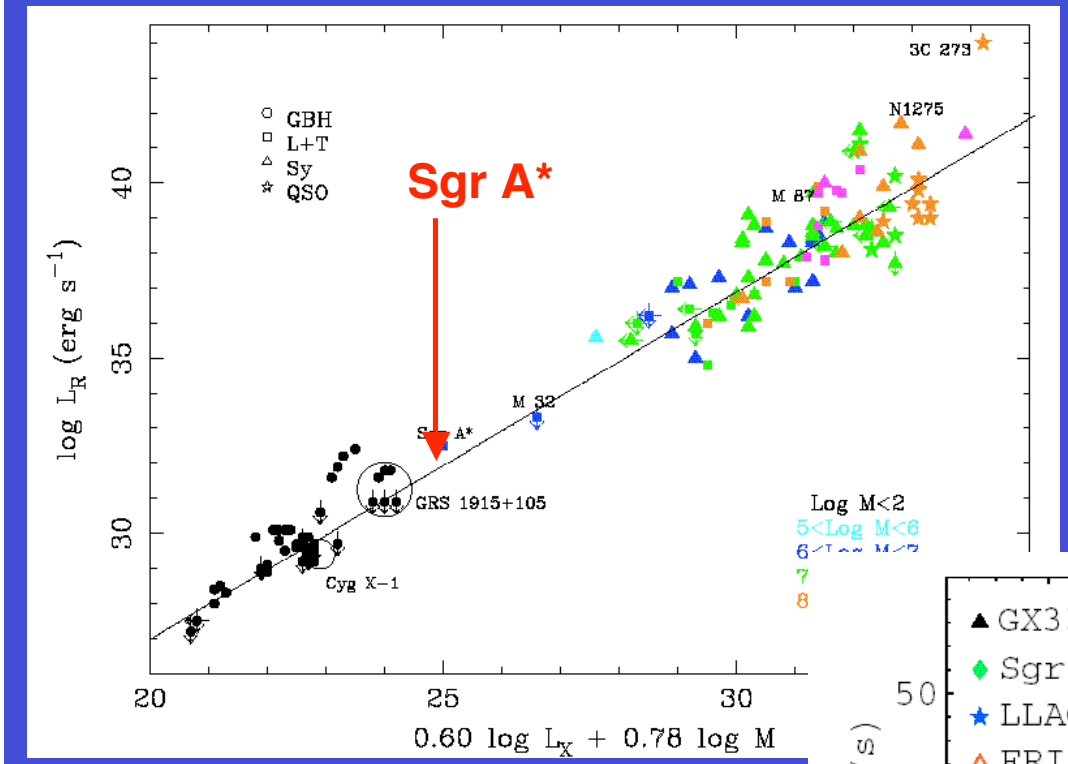
Perspectives with SIMBOL X



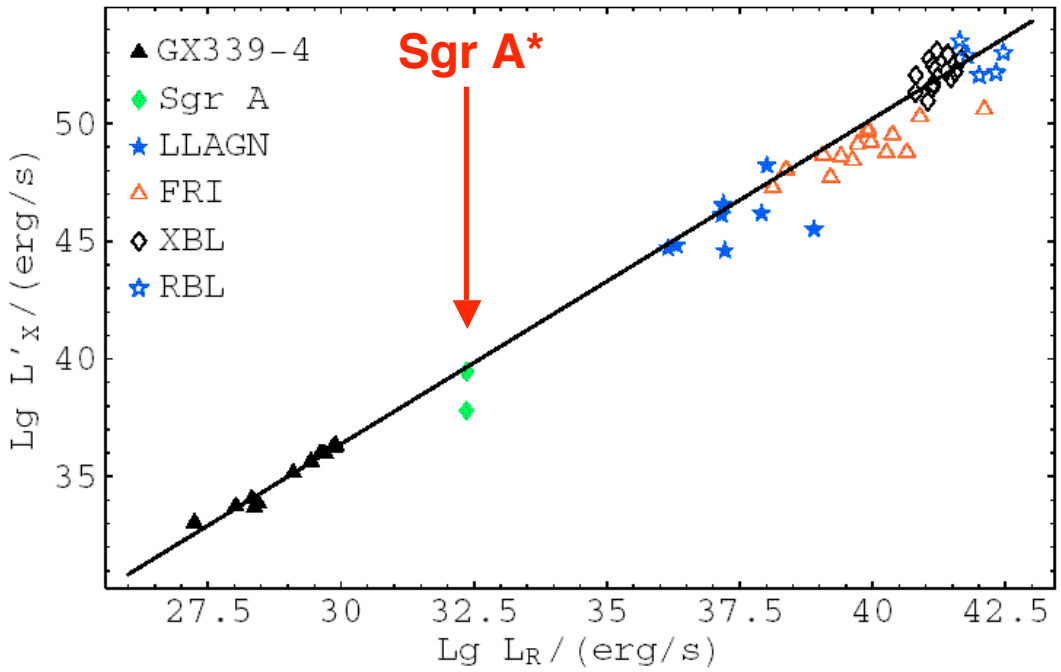
Perspectives with SIMBOL X



L_x – L_R correlation in accreting BH ?



- The nucleus of our Galaxy links stellar mass black hole systems to AGNs
- Understanding Sgr A* will provide deep insight in accretion/ejection processes at work in compact objects



- E.g. Sgr A* shares with AGN and BH XRB the correlation law found between L_X and L_R
- General correlation after proper object mass scaling

(Gallo et al. 03, Falcke et al. 04)