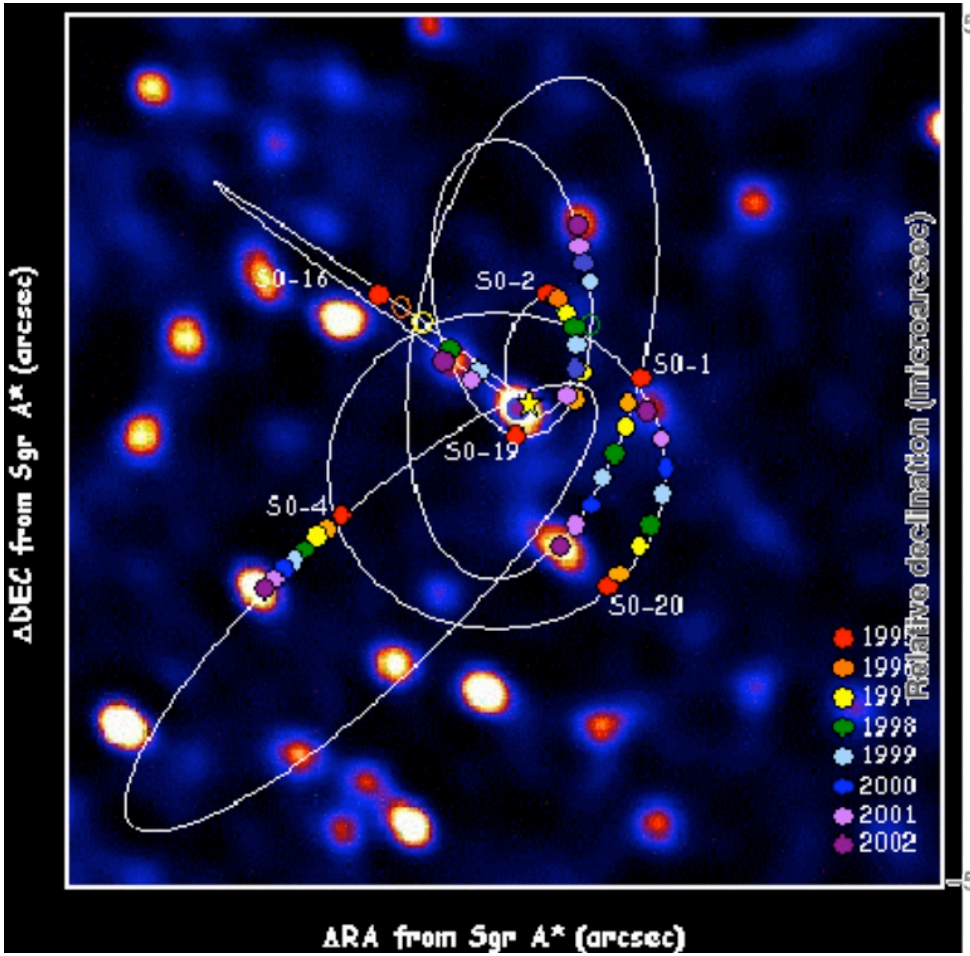
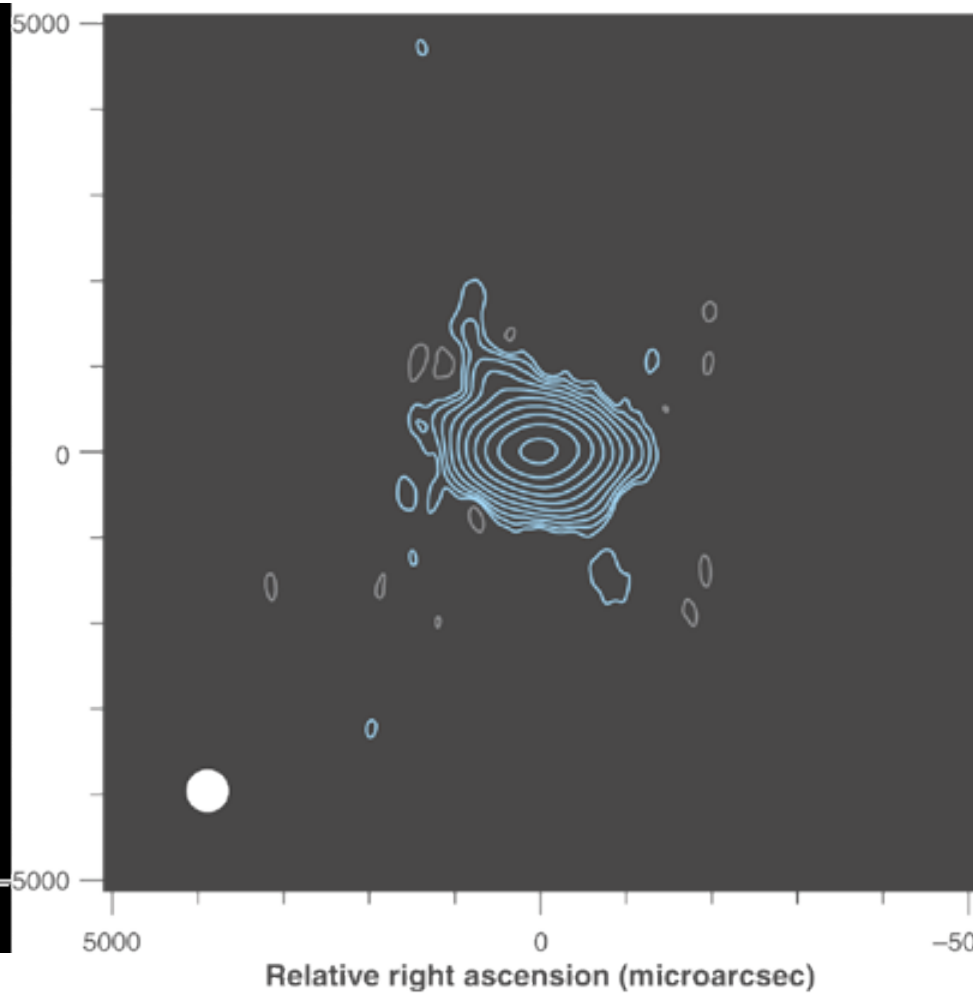




Infrared Image

- Deduced mass from six stellar orbits
- $3.7+/-0.2 \times 10^6\ M_{sun}$
- Enclosed within 45 AU
- Density $8 \times 10^{16}\ M_{sun}\ pc^{-3}$

(Ghez et al. 2005)

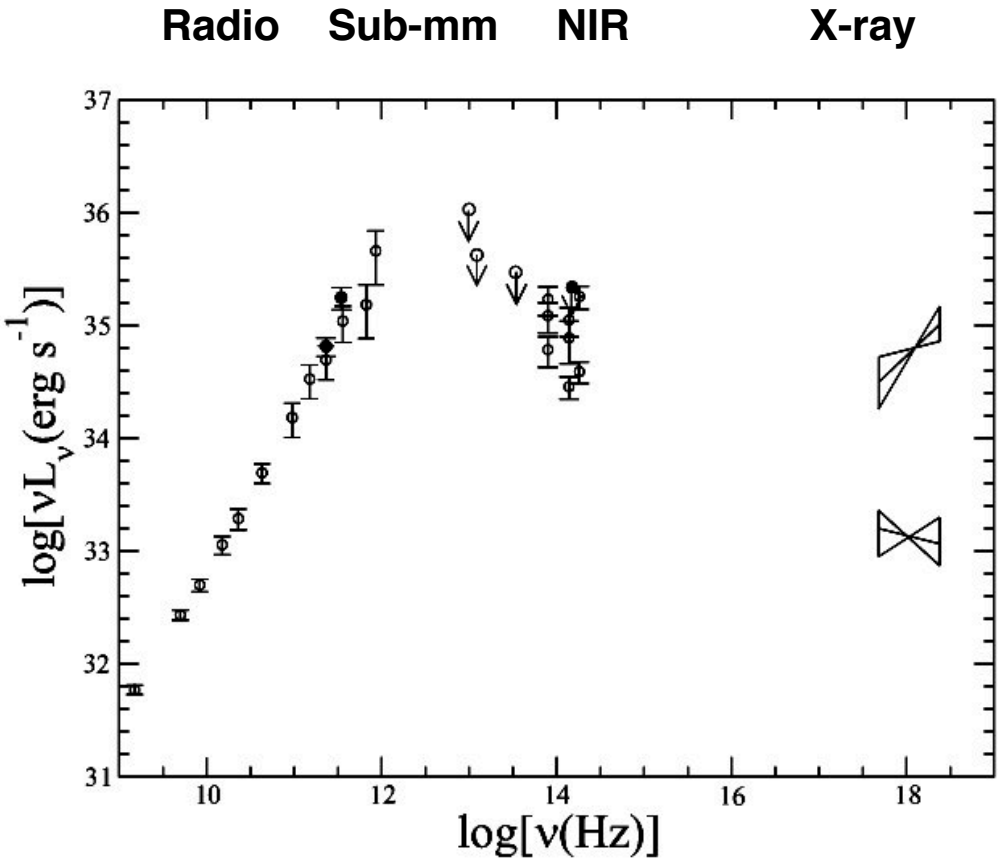
Radio Image

- Discovered in 1974
- Size < 1AU (Bower et al. 2004)
- Proper motion:
  - > 10% of the dynamical mass (Reid & Brunthaler 2004)
  - Stellar density $10^{22}\ M_{sun}\ pc^{-3}$
- Massive black hole

Spectrum of Sgr A*

- Extremely faint
- Optically thin and thick regime
- Peak in sub-mm
- Variability detected in almost all wavelengths

- Phenomenological question:
  - Is the variability correlated?
    - Will it address the emission mechanism?



Outline

- Light curves in NIR, X-rays wavelengths
- Cross correlation: NIR vs X-ray/γ–ray
- Explain the X-ray /soft γ-ray emission by ICS
- Power spectrum of NIR emission

- Nonthermal filaments

Multi-wavelength Observations of Sgr A*
(Other Non-thermal Sources in the Galactic Center)

F. Yusef-Zadeh

X-Ray
(XMM)
- G. Belanger
- A. Goldwurm
- F. Melia
- B. Warwick

Radio
(VLA+ATCA)
- D. Roberts
- G. Bower

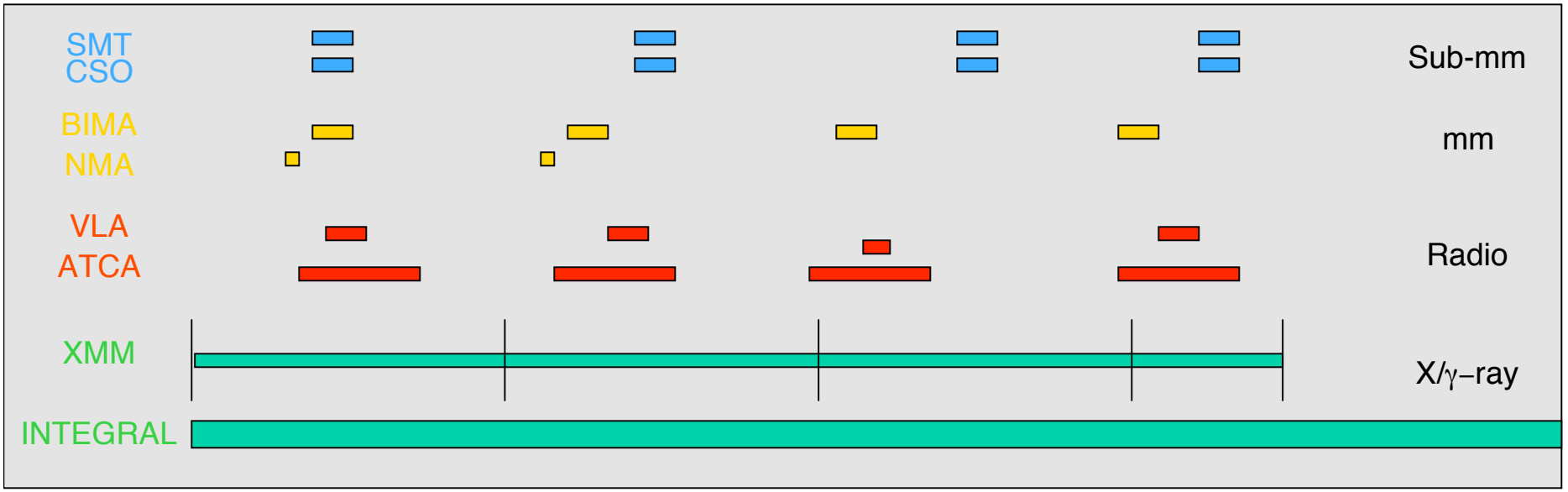
Near-IR
(HST)
- H. Bushhouse
- C. Heinke
- M. Wardle
- S. Shapiro
- A, Goldwurm

Sub-millimeter
(CSO, SMT)
- D. Dowel
- B. Vila Vilaro
- L. Kirby

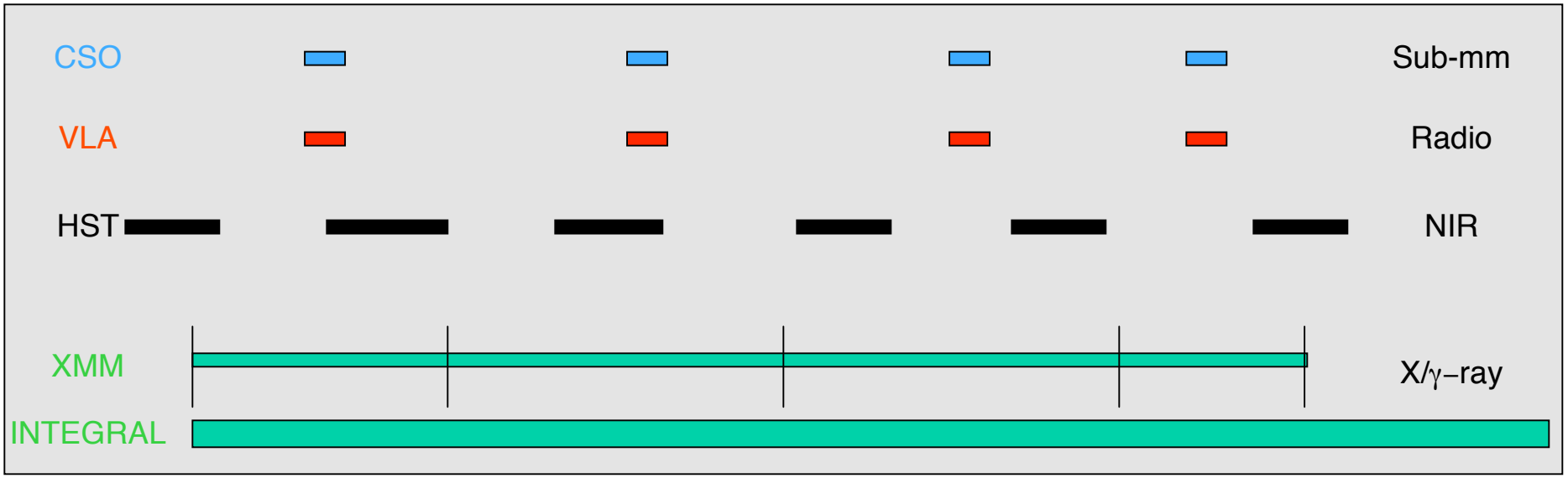
Soft γ-Ray
(INTEGRAL)
- G. Belanger
- A. Goldwurm
- M. Renaud
- R. Terrier
- F. Melia
- N. Lund
- J. Paul
- G. Skinner

Two Epochs of Observations of SgrA* in 2004

March Campaign

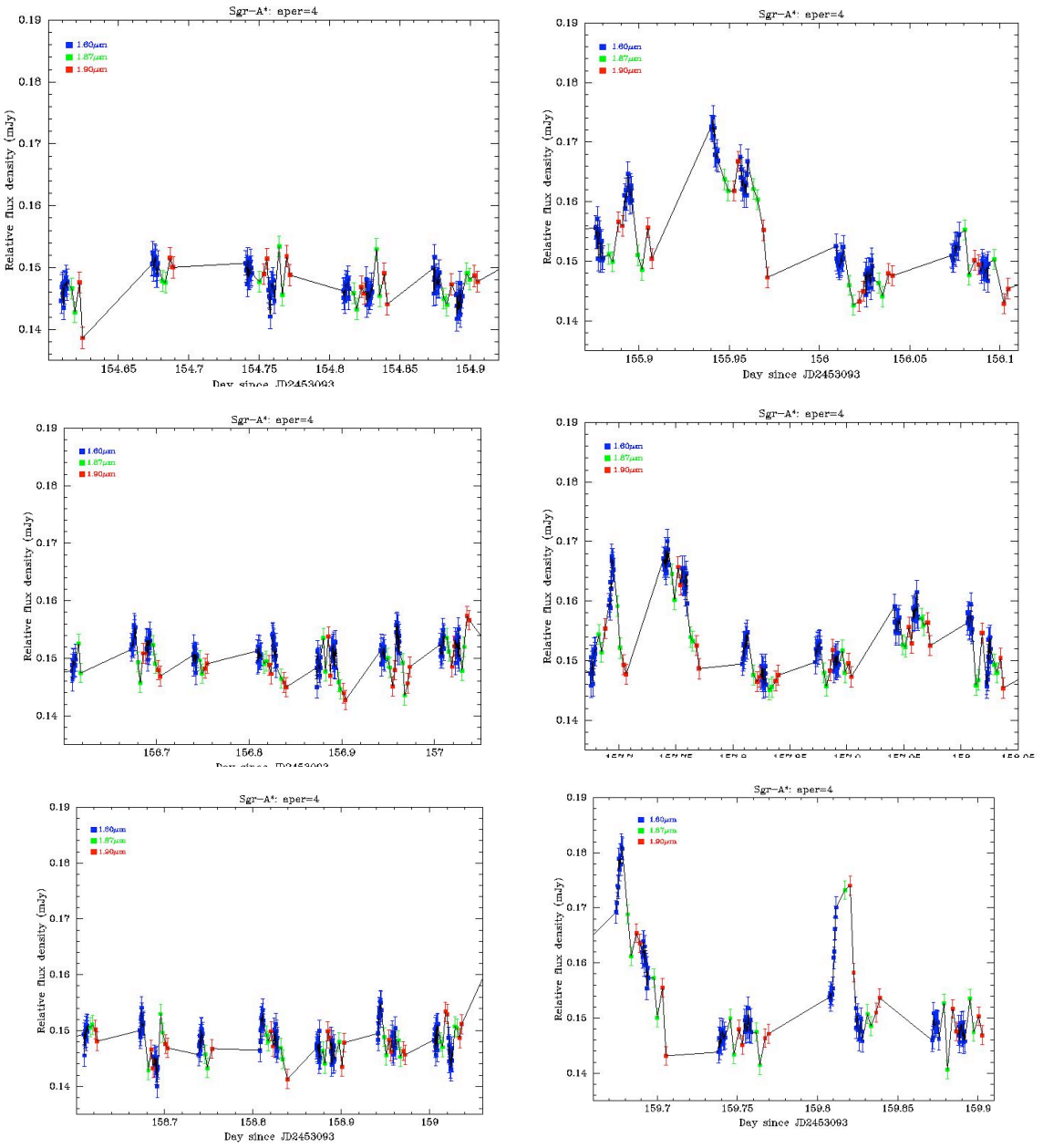


September Campaign

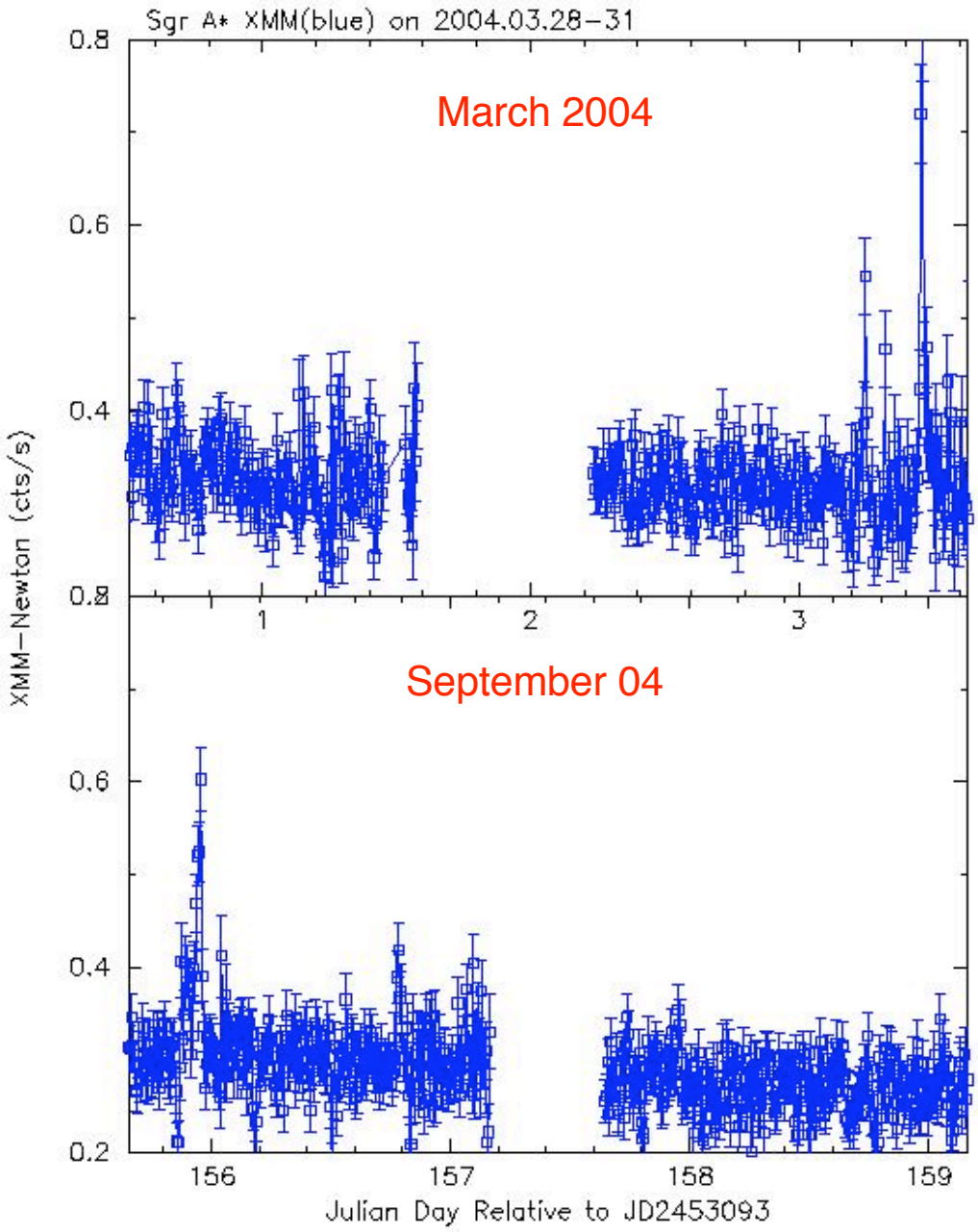


NIR variability in 1.6, 1.87 (Paα line), 1.9μm

- NIR Light Curves of SgrA* (blue, red, green)
- **Amp**: 10 % to 25% or 3 to 5 times the quiescent flux (11-14 mJy)
- **Duration**: multiple peaks, lasting from 20 minutes to hours
- **Flare activity**: overall fraction of activity is about 30-40% of the observed time (background 8.9 mJy)
- **Spectrum:** Unknown

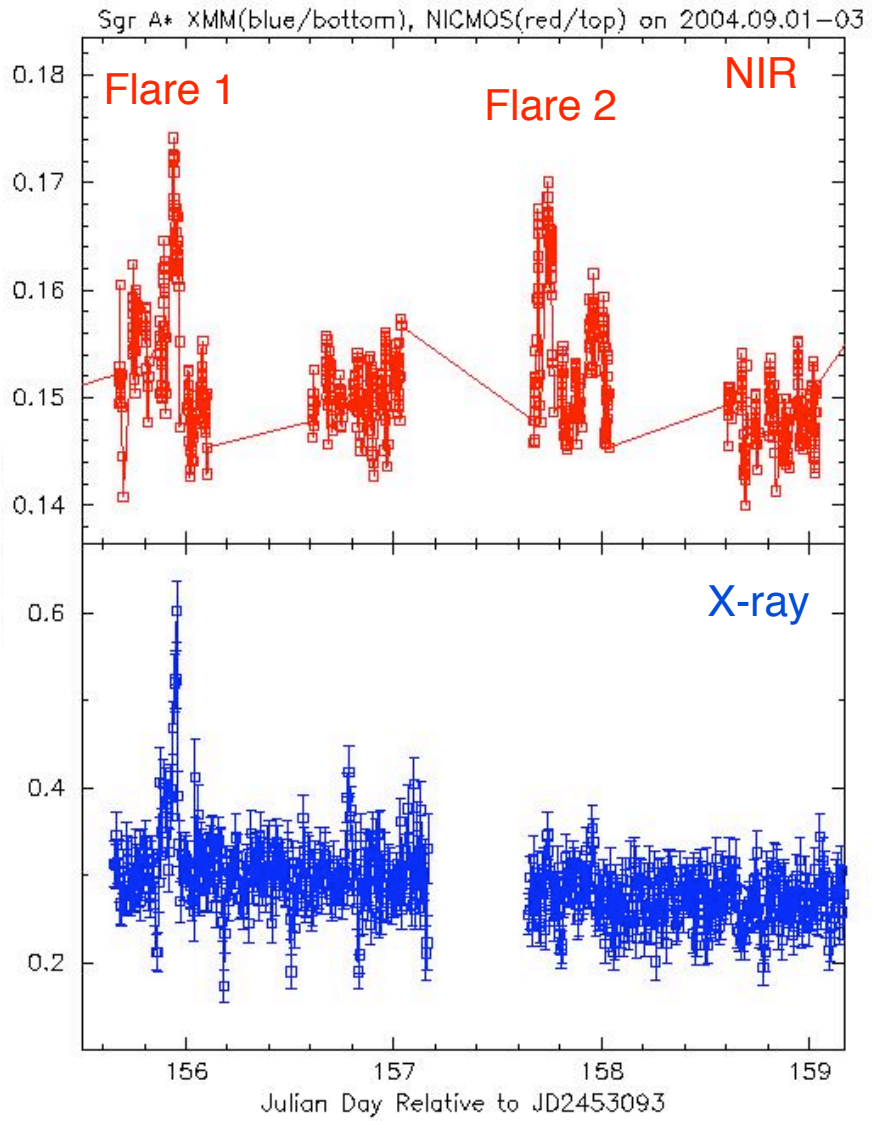


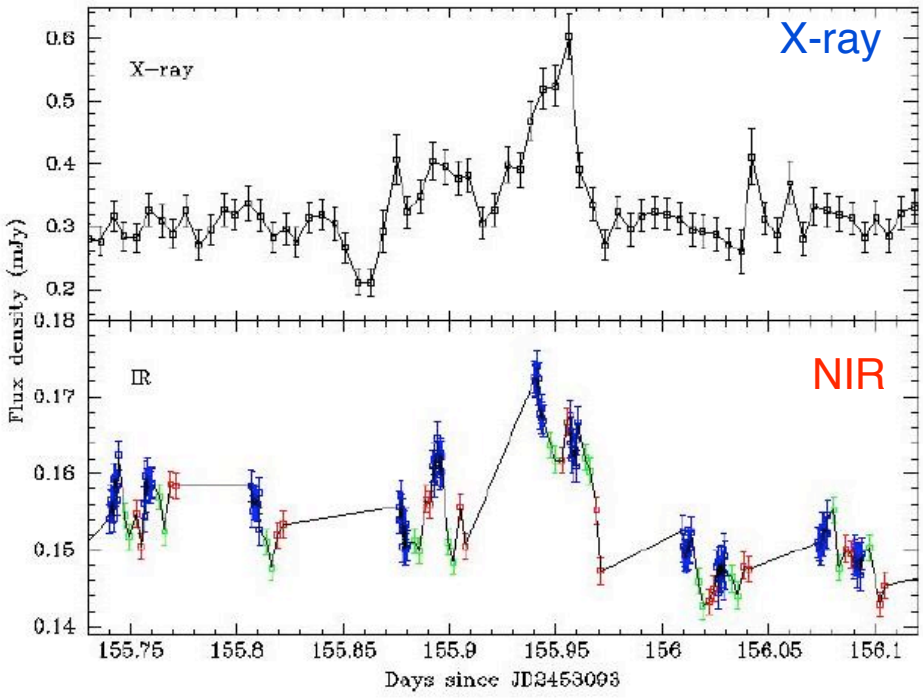
- X-ray Light Curves of Sgr A* (2-10 keV)
- **Amp**: 35 times the quiescent X-ray flux
- **Duration**: multiple peaks, lasting from 10 minutes to 3 hours
- **Spectrum:**
  - Power-law with α = 0.6+/0.5
  - L(2-10 keV)=7.7 x10^{35} erg/s
- **Flare activity**: Two clusters of flares in one weak



Belanger et al. 2005a

NIR (1.6-1.9μm) vs. X-Ray (September Campaign)





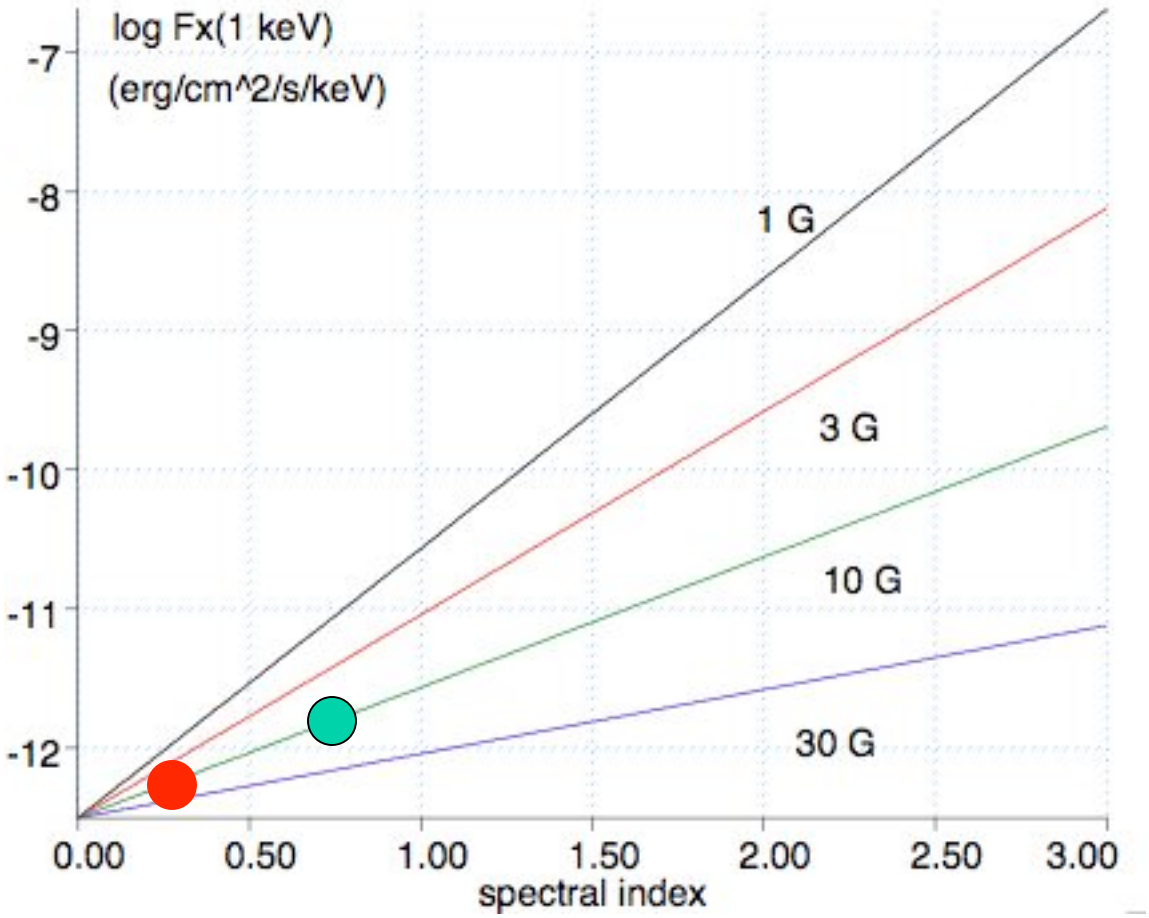
No time delay

Simultaneous X-ray and NIR flare

- NIR due to Synchrotron: τ_{nir}= 40min, Beq=10G, E_e=1.1 GeV
- X-Rays due to Synchrotron: τ_{nir}=1min, B=10G, E_e=10 GeV
- X-Rays due to ICS: diameter=10R_{sch}, $F_{850\mu m}$=4Jy, E_e=1GeV
- $E_{predict}$=2x10^{-12} erg/cm2/s/keV, E_{obs}=1.2x10^{-12} erg/cm2/s/keV

NIR Flares with and without X-ray Counterparts

- The softer (steeper) the particle spectrum, the higher the X-ray flux
- The harder (flatter) the particle spectrum, the weaker the X-ray emission



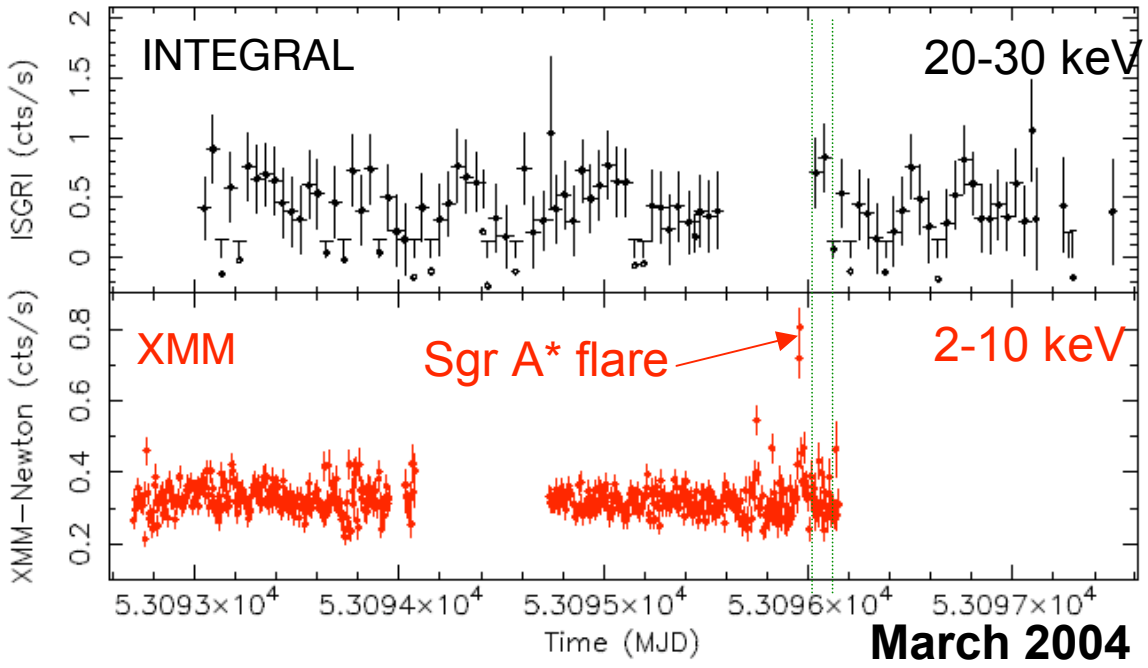
X-ray Flux as a function of spectral index

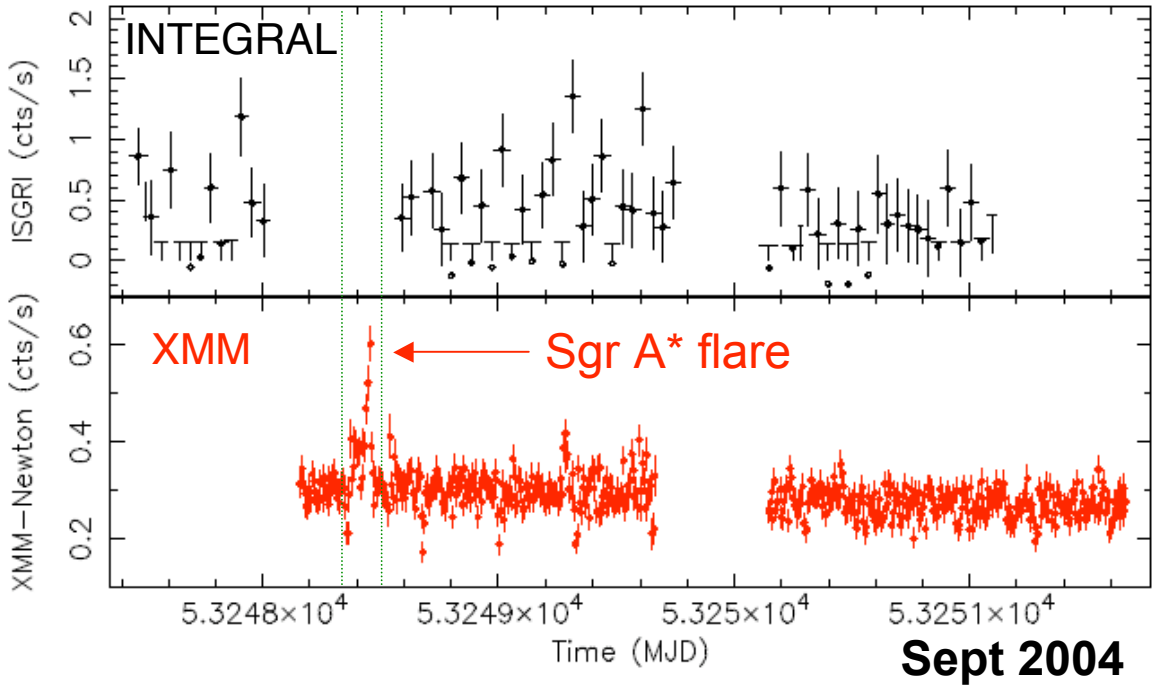
Flare 1

Flare 2

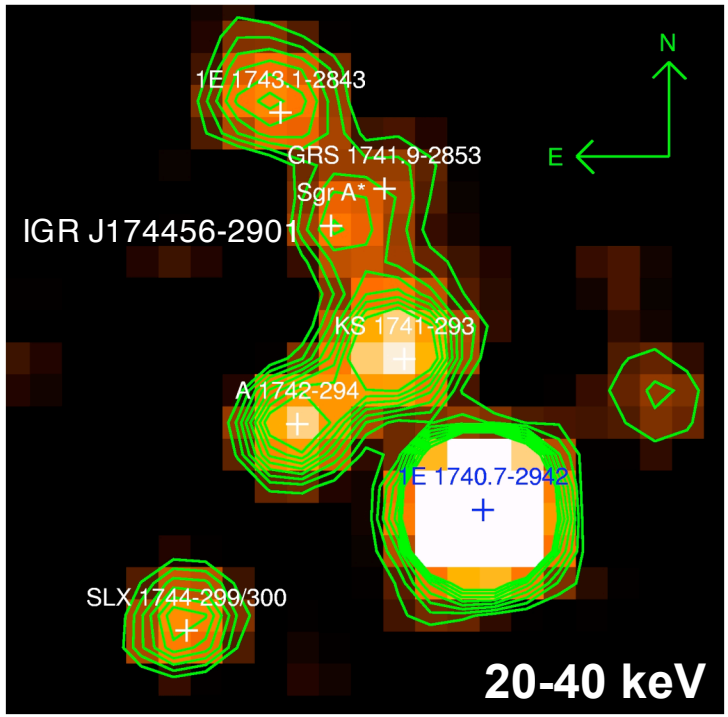
INTEGRAL and XMM Variability

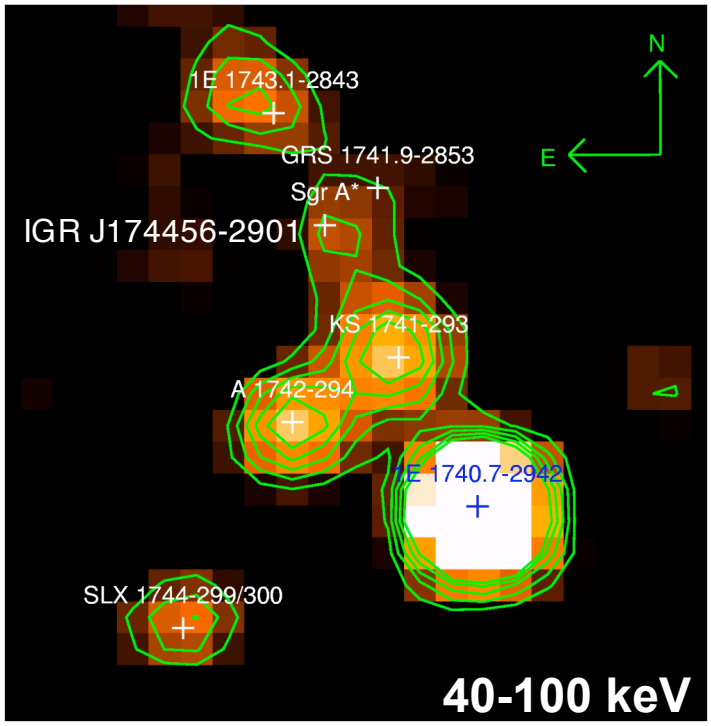
- INTEGRAL:
  - 20-30 keV light curve of IGR J17456-290
- Cross Correlation
  - During the 2 bright SgrA* flares seen with XMM INTEGRAL was in the radiation belts (Belanger et al. 2005b)





First IBIS / ISGRI Images of the Galactic Center

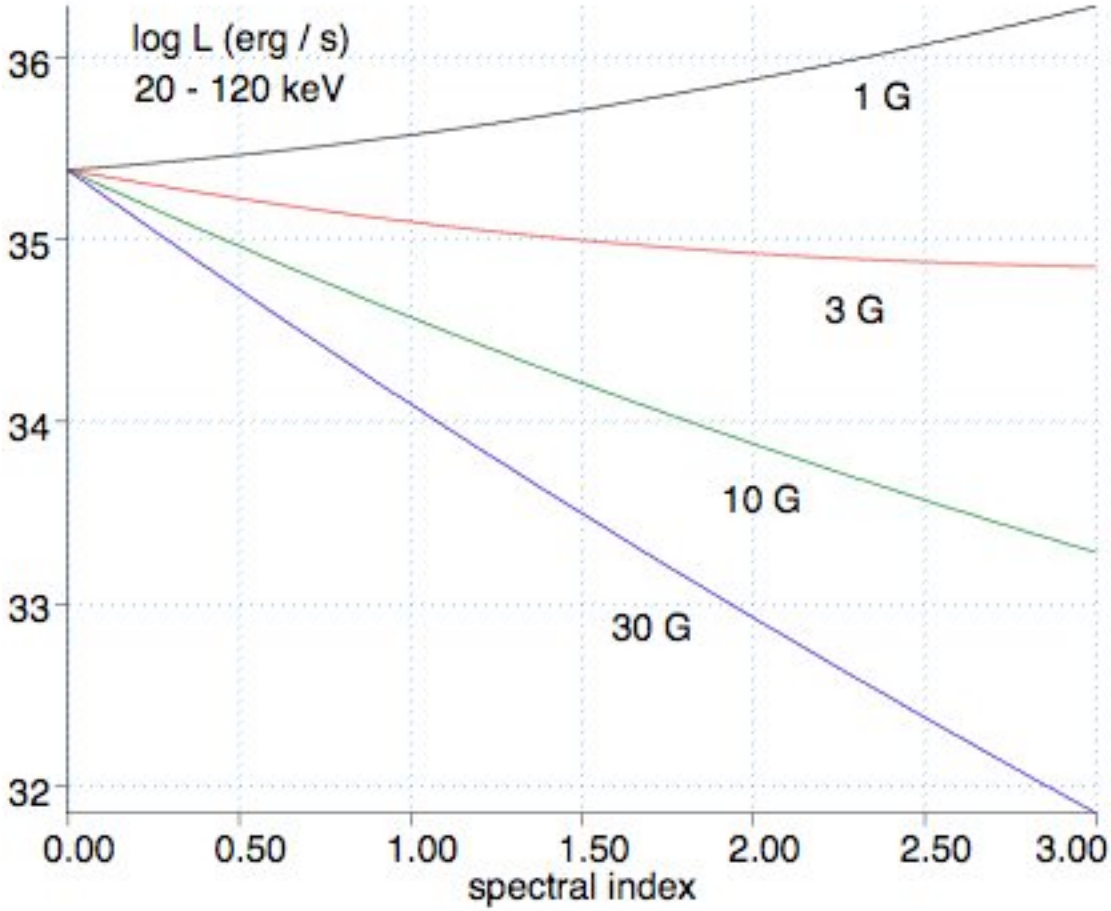




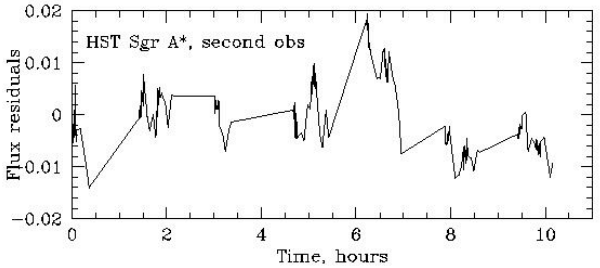
- Six known high-energy sources in the central 2 ° × 2° of the Galaxy
- Detection of IGR J1746-290 coincident with Sgr A*
- A significant excess (8.7 σ) at ~ 1' from Sgr A* (4.7 σ in 40-100 keV)
- Power-law α = 2.04 +/- 0.98 and L(20-120 keV) = 4.8 10^{35} erg/s

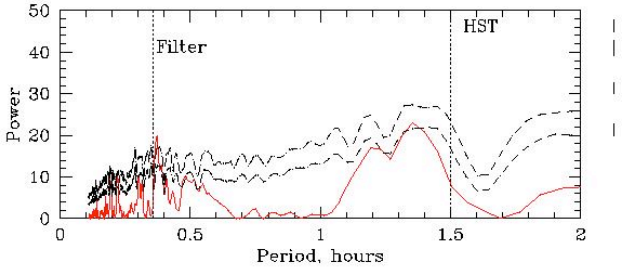
Soft γ–ray Flux as a function of spectral index

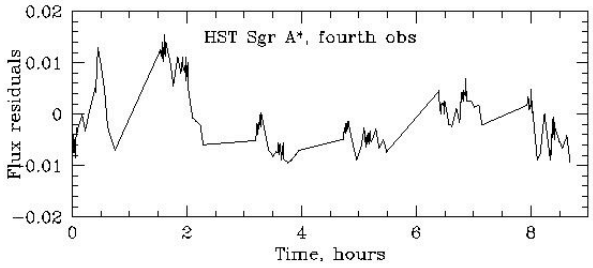
- The spectral index in NIR ranges ~ 2-4
- The population of particles producing NIR emission can explain the soft γ-ray emission

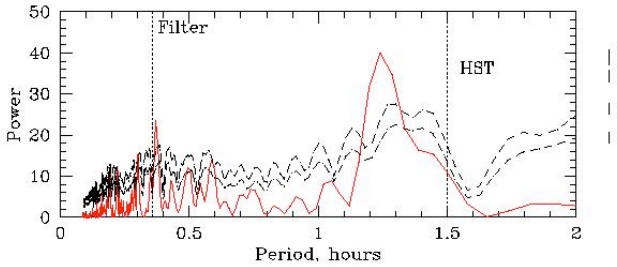


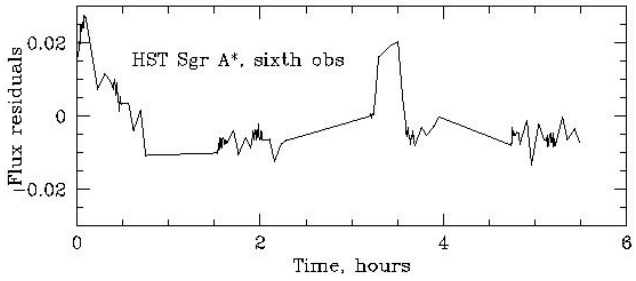
- Lomb-Scargle periodogram searches for periodicity
- Monte Carlo simulation of red noise – $P(f) \sim f^{-1}$ – using the observed statistics
- Significant power with a period of ~ 1.3h and ~ 30min
- a/M=0
  - $(r/M)_{orbit} = 6R_{sch}$
  - The same scale size as the region of the seed photons for ICS

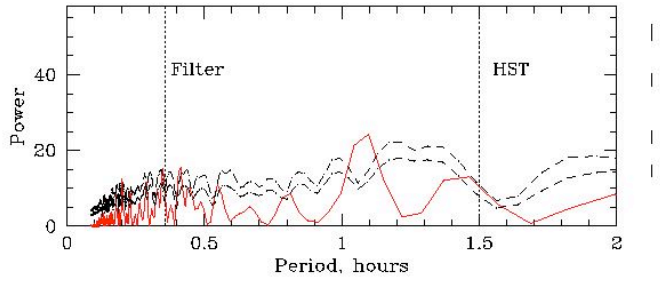


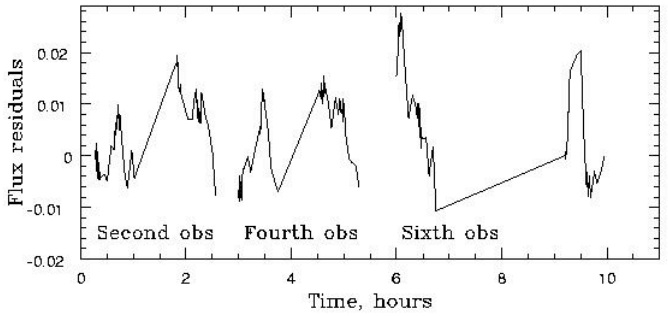


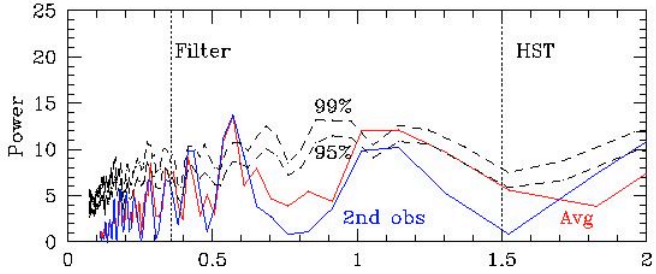






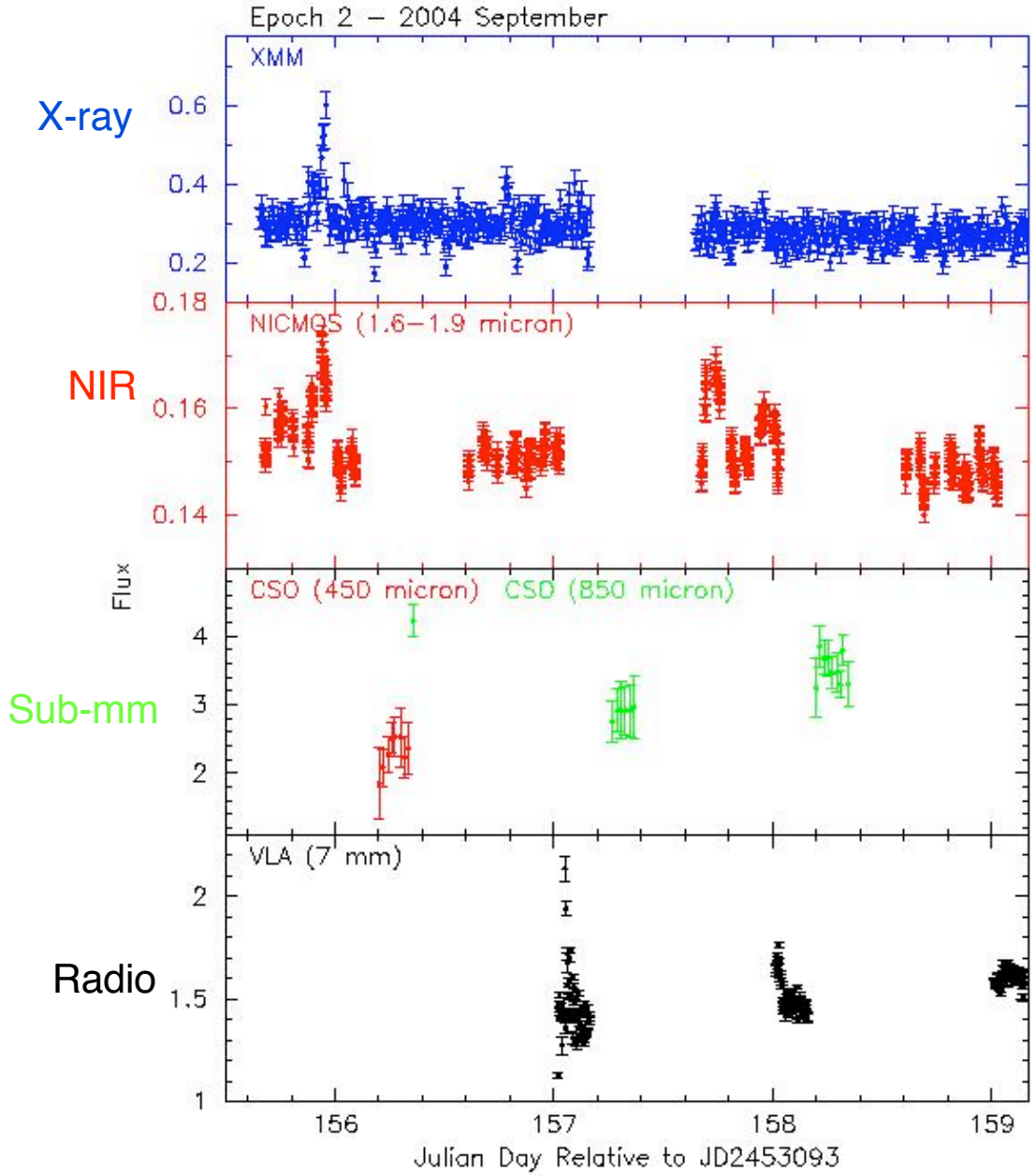




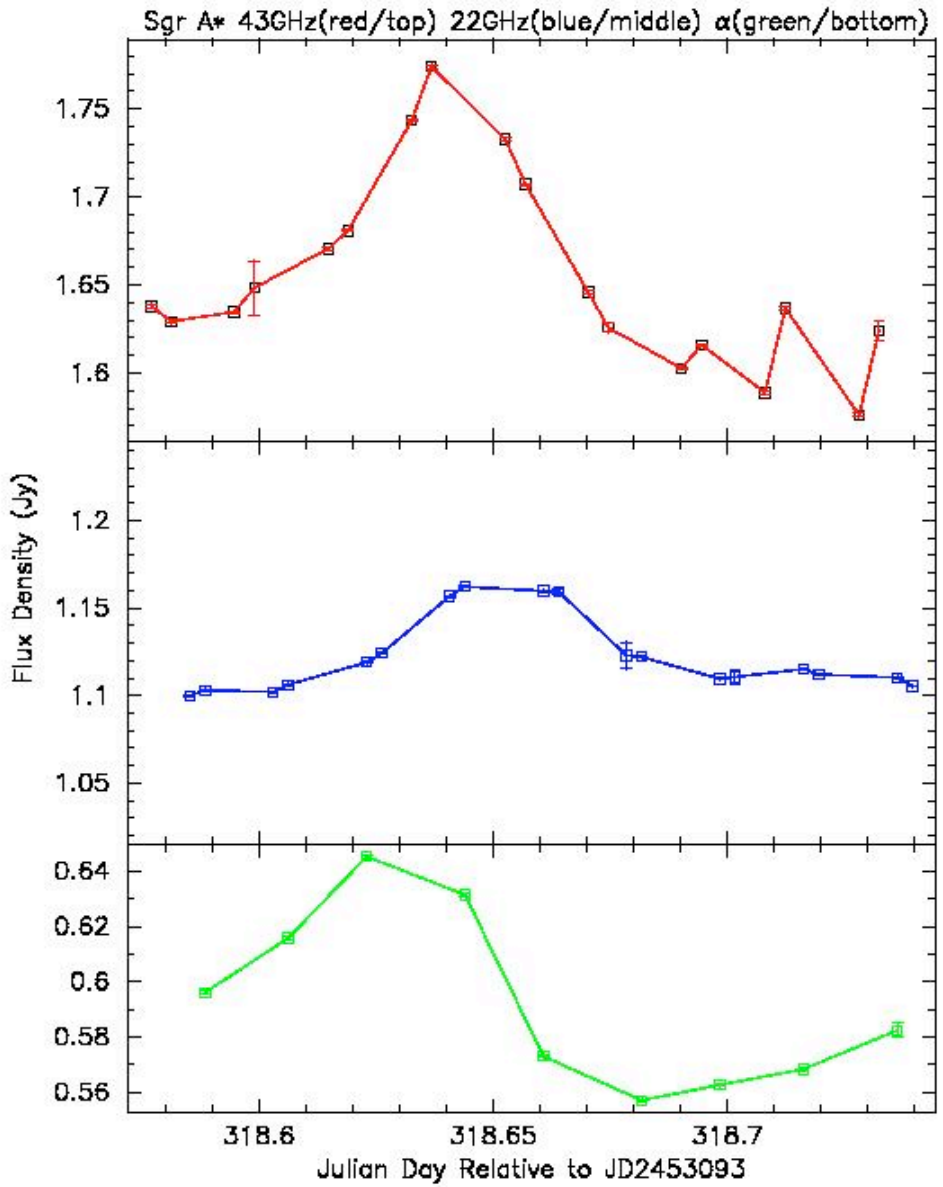


Radio (7mm) vs X-ray (March Campaign)

- Lag time between X-ray/NIR flare and sub-mm peak 4-5 hours
- Time delay between X-ray/NIR and radio peak is one day
- An expanding synchrotron source in an optically thick medium
- As the electrons cool, the synchrotron self-absorption frequency moves to longer wavelengths
- Delay as a function of frequency expected



Radio Time Lags Between 7mm and 13mm



Conclusions

- Flare correlation: simultaneous vs delayed
- Correlation between a near-IR and X-ray/soft γ–ray flare: the same population of particles can explain
- An expanding synchrotron self-absorbed blob: outflow
- Evidence for a NIR flare with quasi-periodic 1-1.3h and 30min behavior
- The flow always fluctuates even in its quiescent phase:
  - ICS may account for steady X-ray/γ-ray source