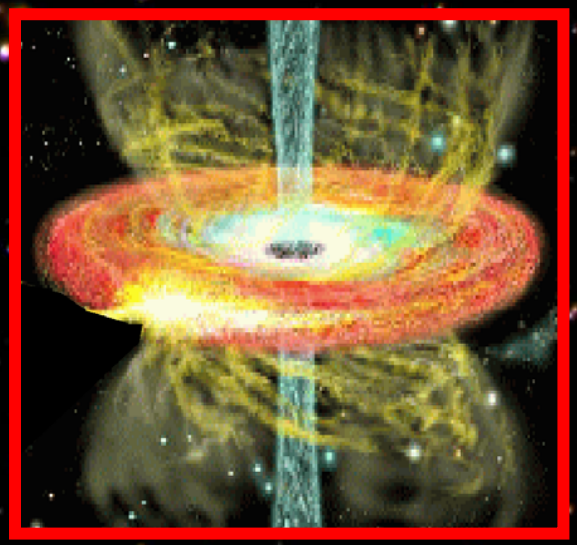
The NIR/X-ray Variable Source SgrA* and its Immediate Environment

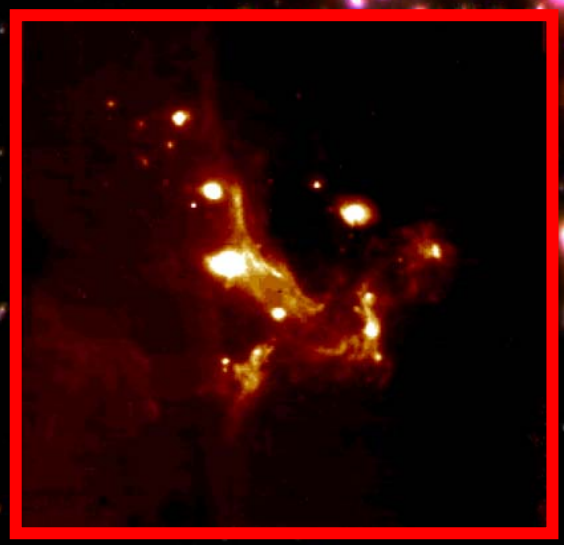
The Paradoxes of Massive Black Holes: A Case Study in the Milky Way
Kavli Institute for Theoretical Physics, April 14-16, 2005

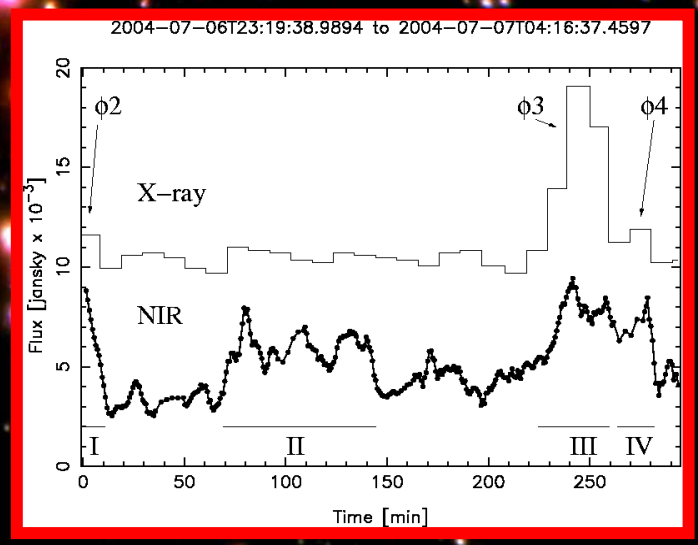
Andreas Eckart

I.Physikalisches Institut der Universität zu Köln

F.K.Baganoff, R. Schödel, M. Morris, T. Viehmann,
M.W. Bautz, W.N. Brandt, G.P.Garmire, R.Genzel, T. Ott,
G.R. Ricker, C. Straubmeier, G.C. Bower, J.E. Goldston







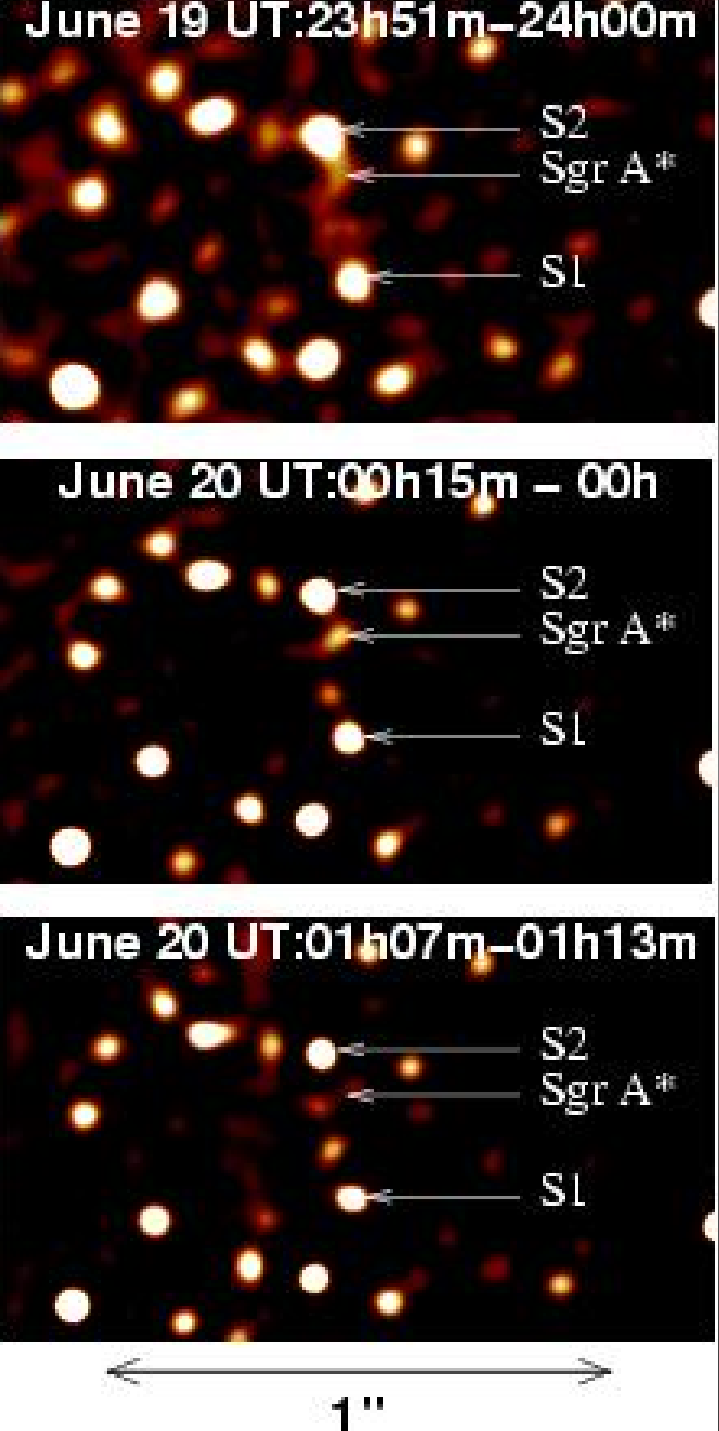
Content of presentation:

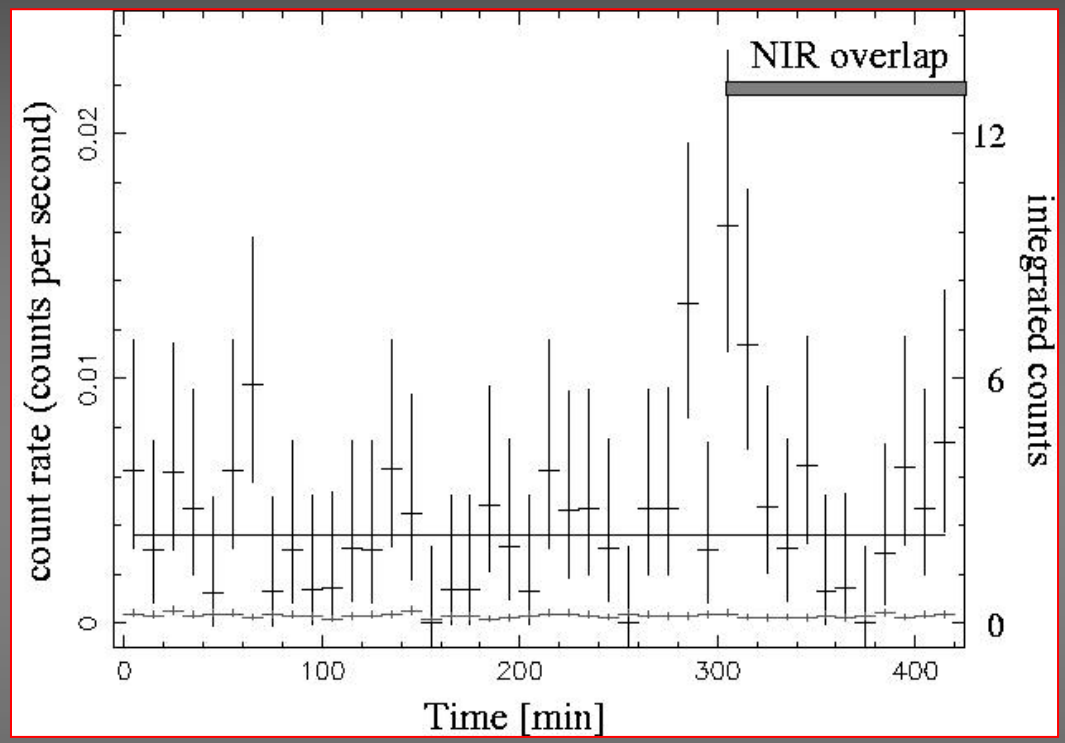
- VLT/Chandra flares 2003
- VLT/Chandra flares 2004
- Simultaneous HKL/X-ray quiescent emission 2004
- MIR/NIR emission towards SgrA*
- Simple SSC models
- Flare statistics

*Simultaneous NIR / X-ray Measurements of Sgr A**

2003

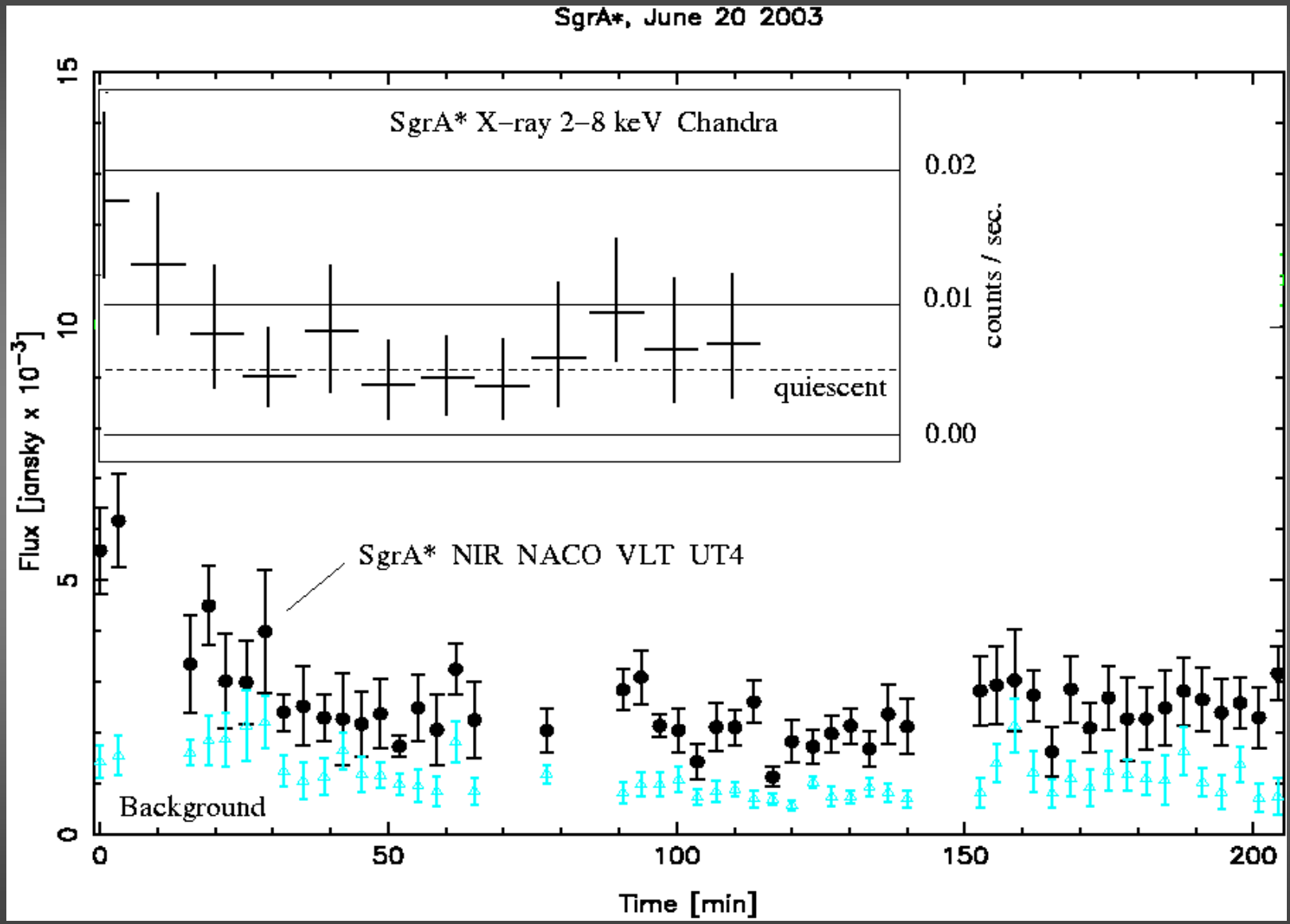
Simultaneous NIR/X-ray Observations





Eckart, Baganoff, Morris, Bautz, Brandt, Garmire, Genzel, Ott, Ricker, Straubmeier, Viehmann, Schödel, Bower, and Goldston 2004 A&A 427, 1

SgrA*: First Simultaneous K-band/X-ray Observations



Eckart et al. 2004

NACO/VLT June 20, 2003

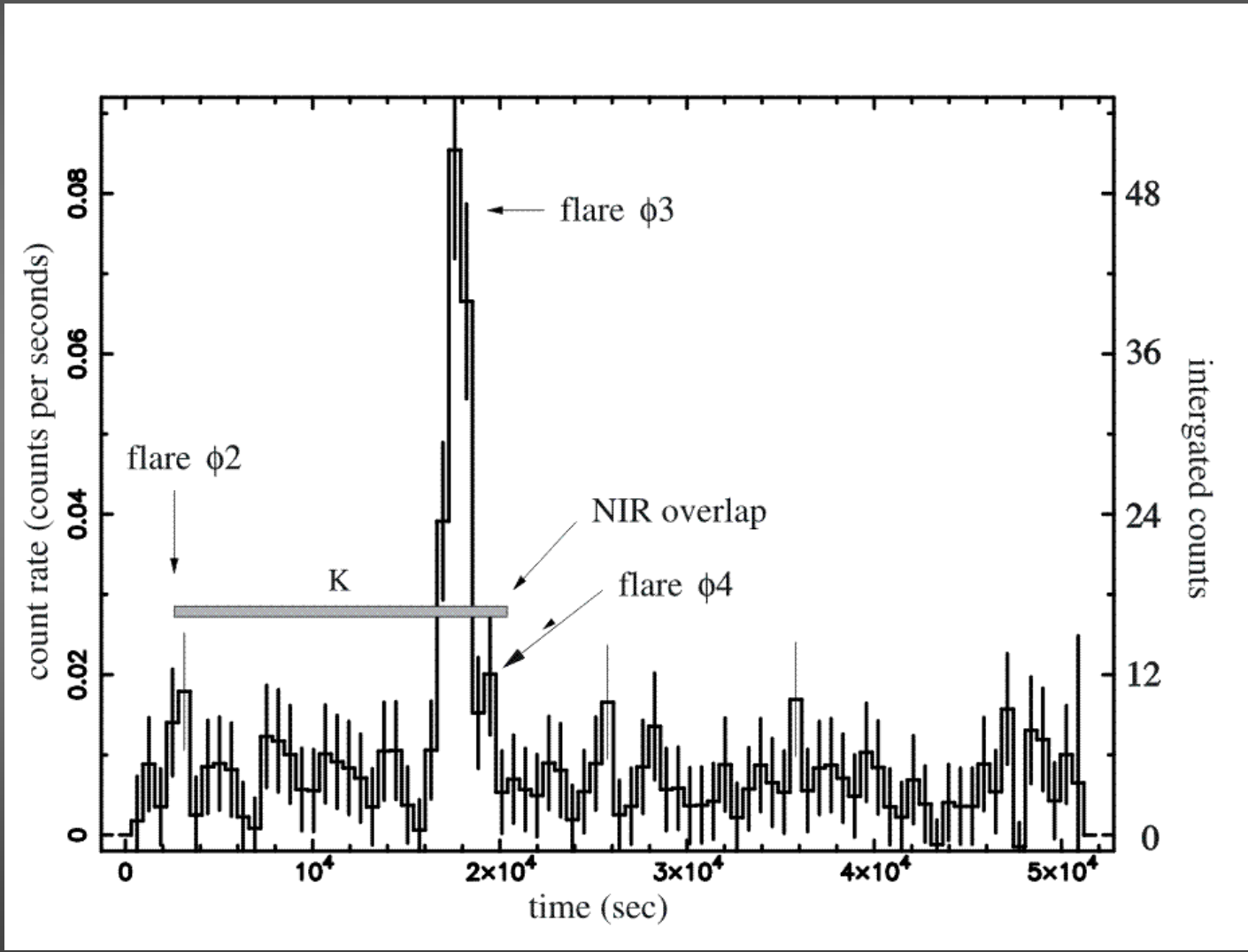
*Simultaneous NIR / X-ray Measurements of Sgr A**

2004

2004 Observing LOG

Telescope	Instrument	Energy/λ	UT Start Time	UT Stop Time
Chandra	ACIS-I	2-8 keV	05 JUL 2004 22:38:26	06 JUL 2004 12:56:59
Chandra	ACIS-I	2-8 keV	06 JUL 2004 22:35:12	07 JUL 2004 12:53:45
1 VLT UT 4	NACO	1.7 μm	06 JUL 2004 02:47:11	06 JUL 2004 03:26:48
2 VLT UT 4	NACO	2.2 μm	06 JUL 2004 03:48:53	06 JUL 2004 07:05:59
3 VLT UT 4	NACO	3.8 μm	06 JUL 2004 07:17:10	06 JUL 2004 08:42:52
4 VLT UT 4	NACO	2.2 μm	06 JUL 2004 23:19:39	07 JUL 2004 04:16:37
5 VLT UT 4	NACO	3.8 μm	08 JUL 2004 23:54:48	08 JUL 2004 00:45:44
6 VLT UT 4	NACO	2.2 μm	08 JUL 2004 00:53:32	08 JUL 2004 06:53:46

SgrA*: Simultaneous NIR/X-ray Observations



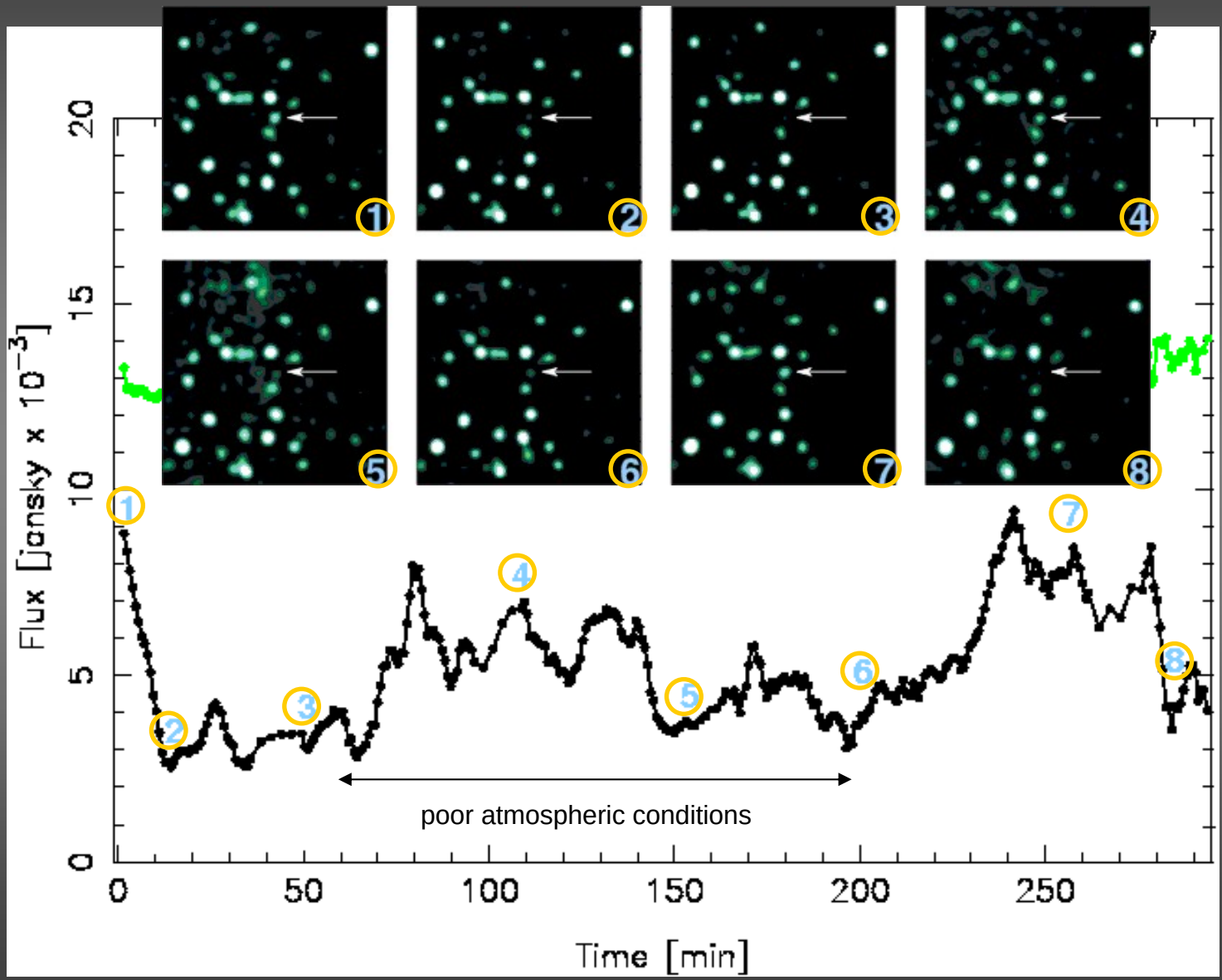
CHANDRA 7 july 2004

Eckart et al. 2005, in preparation

SgrA*: Simultaneous NIR/X-ray Observations

Comparison with imges demonstrates the variability shown in the lightcure.

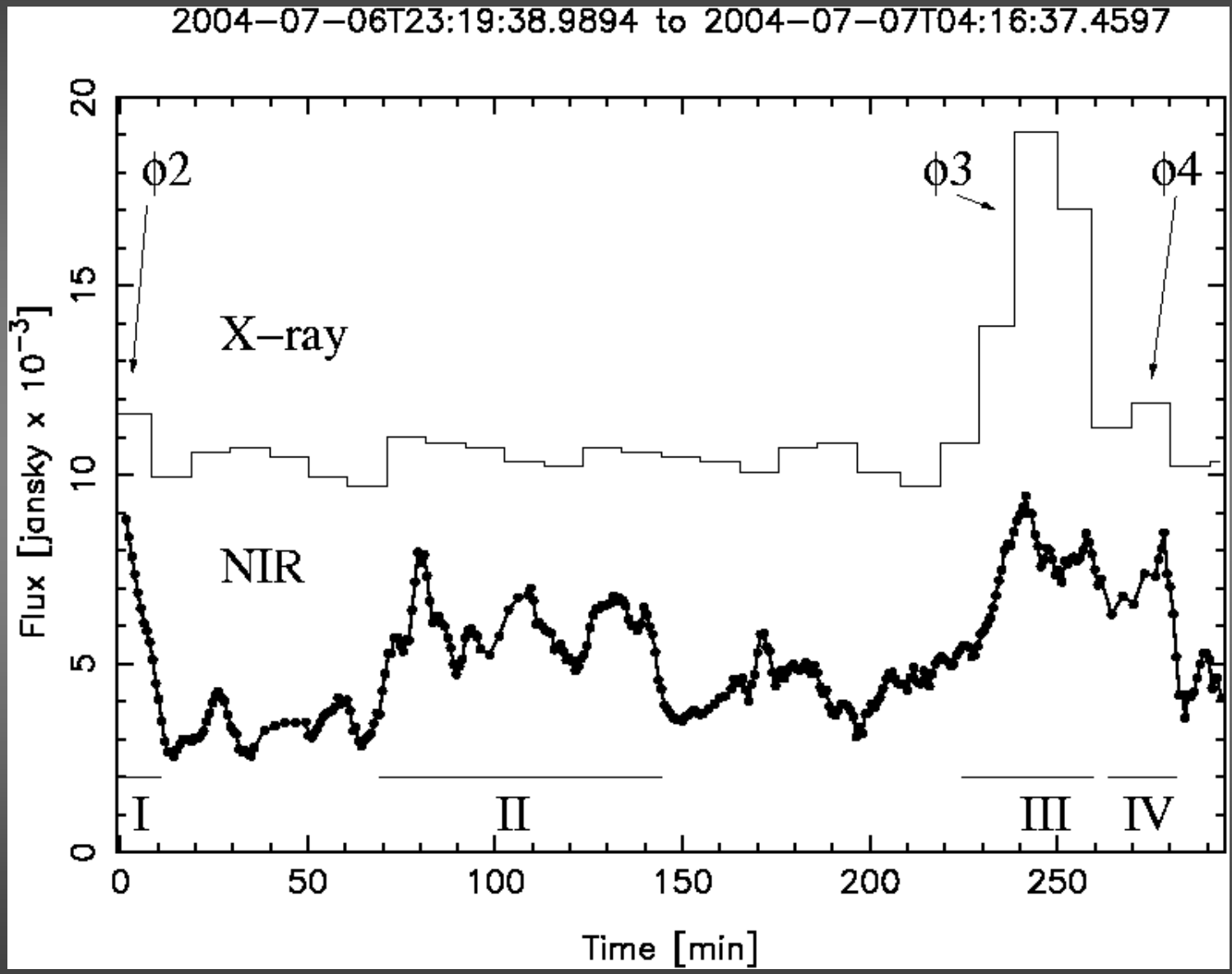
Flare emission originates to within <10mas form the position of SgrA*



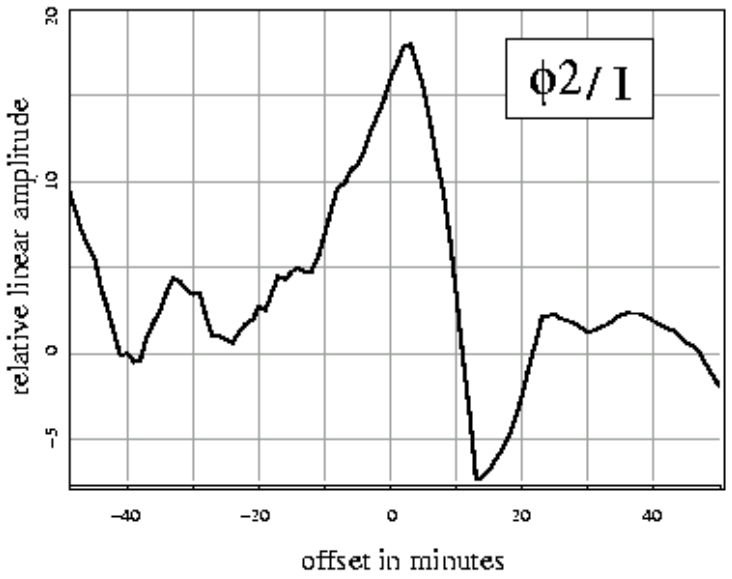
NACO/VLT / July 2004

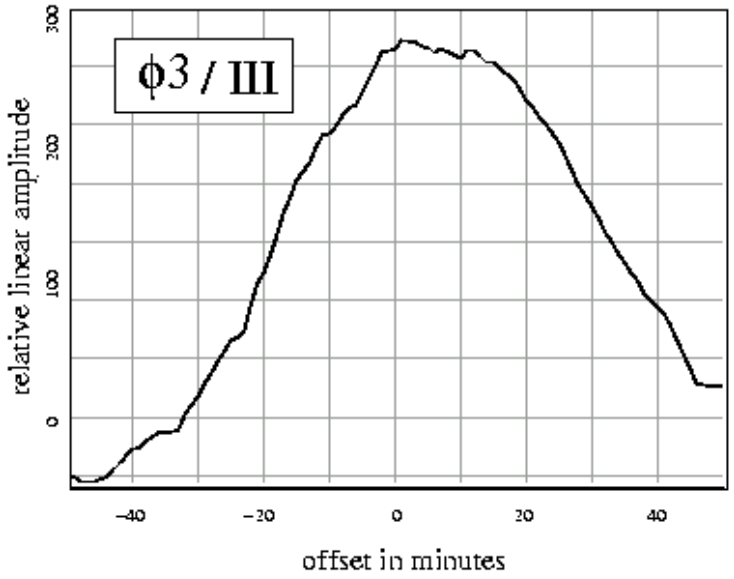
Eckart et al. 2005, in preparation

Simultaneous Flare Emission



Cross-Correlation of Simultaneous NIR/X-ray Flares

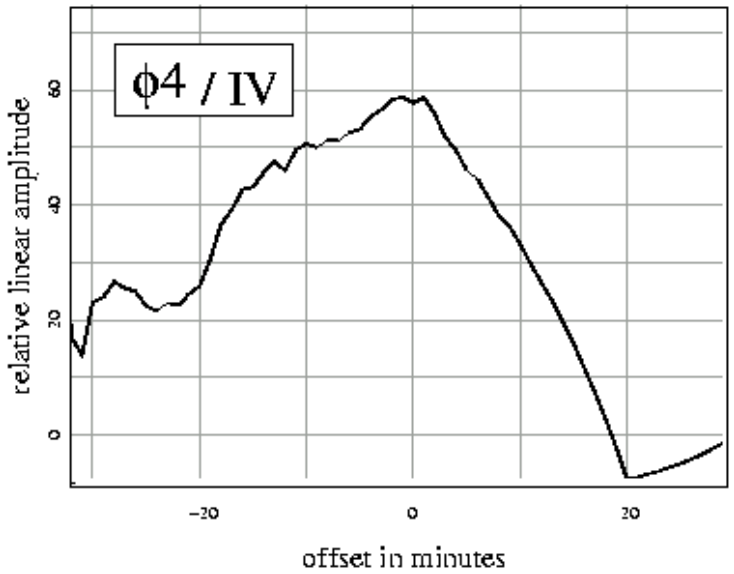




ϕ2/I and ϕ4/IV are dominated by a decaying flank; ϕ3/III is domainated by a rising flare flank.

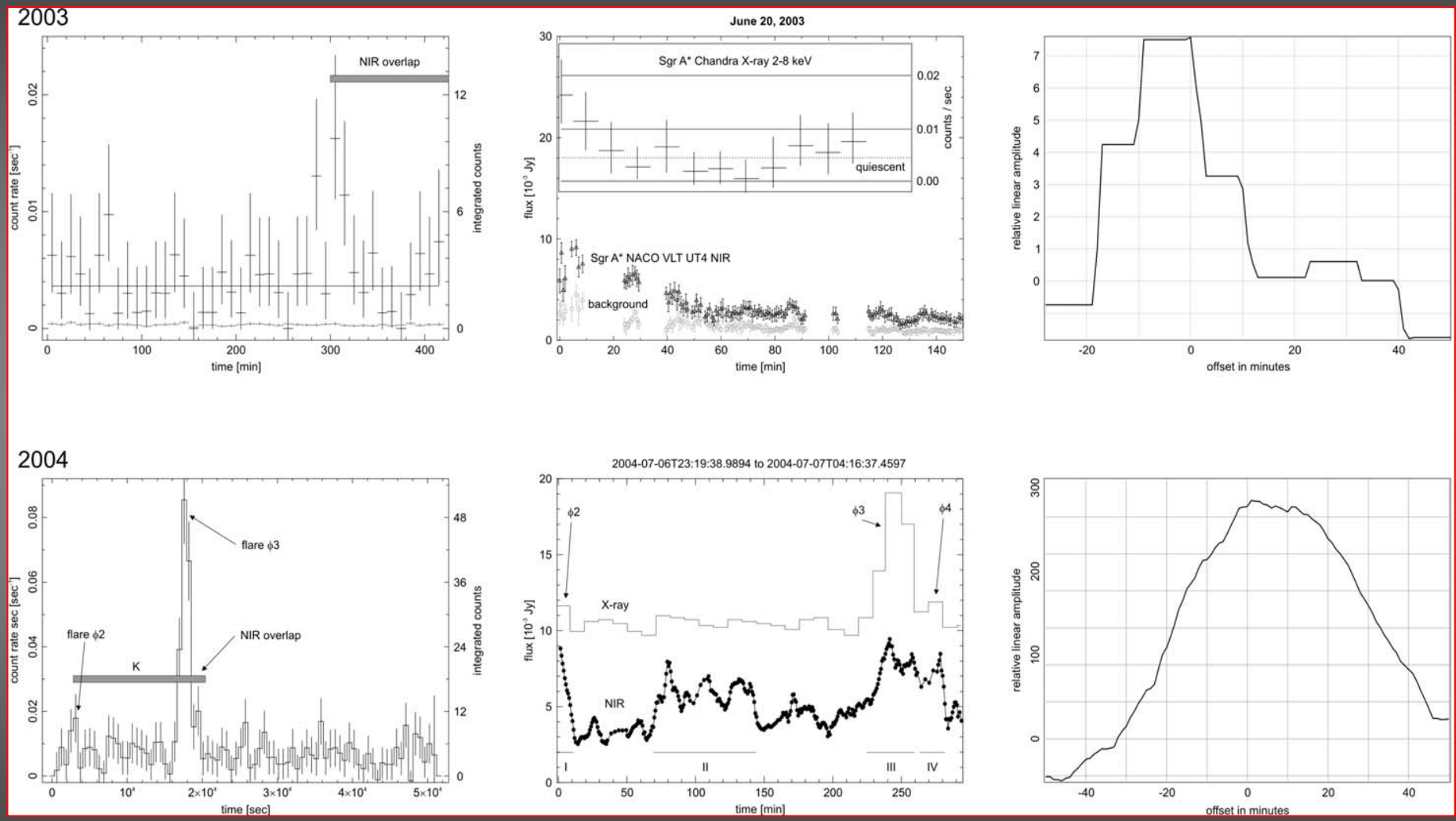
Time lags are less <10-15 minutes

NIR and X-ray flares are well correlated.



IQ-state subtracted

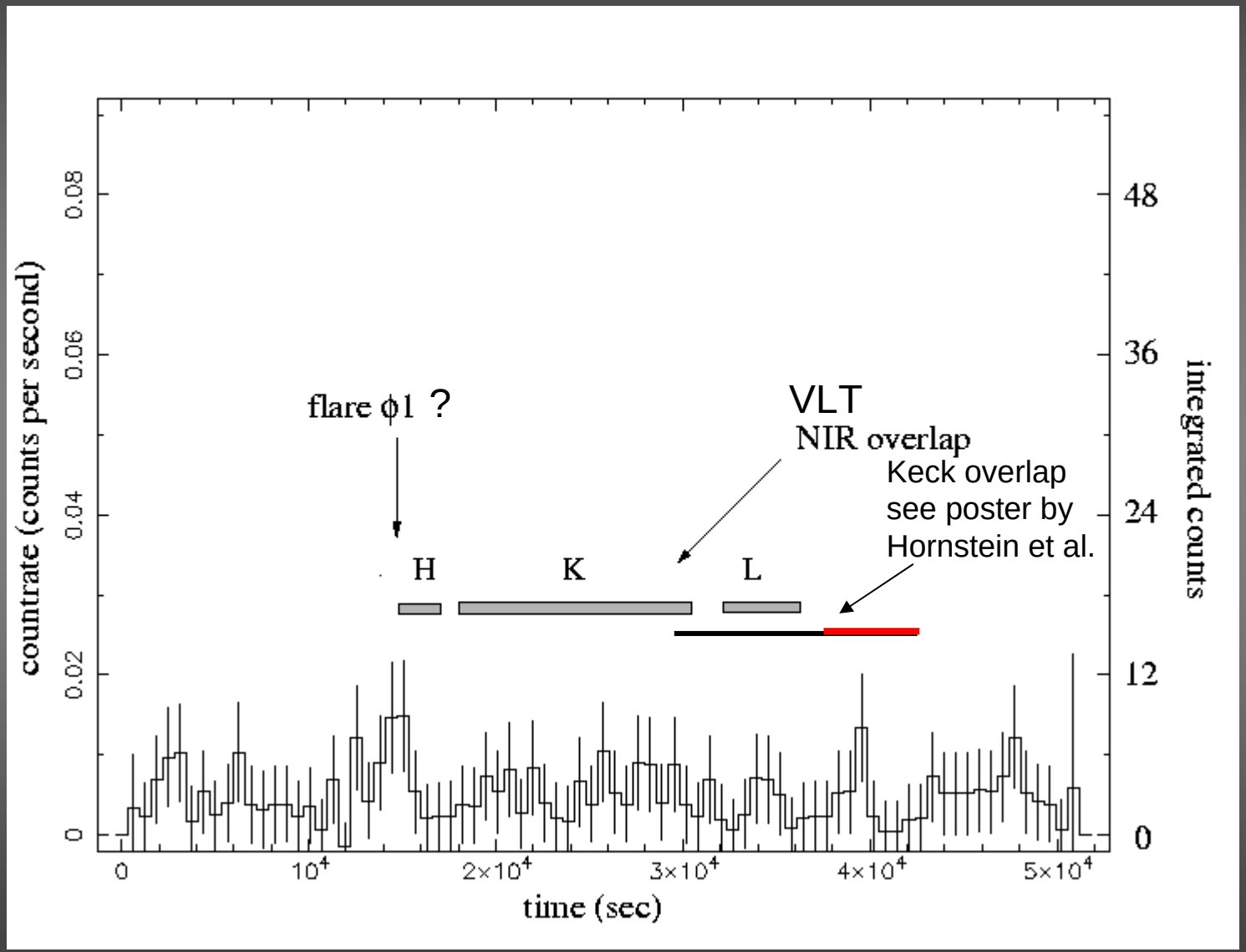
Simultaneous rising and falling of X-ray/NIR flares



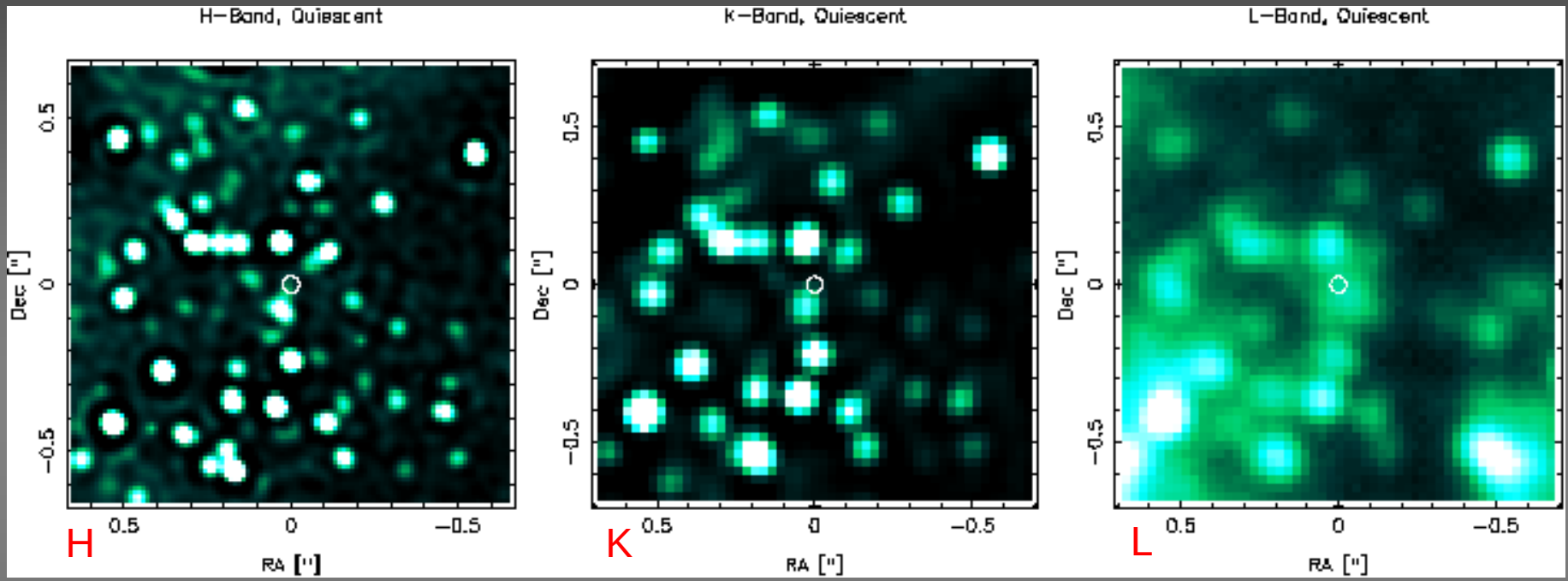
Simultaneous NIR / X-ray Measurements of Sgr A in its Quiescent State*

2004

Quasi-simultaneous NIR/X-ray quiescent state observations



Quasi-simultaneous NIR/X-ray quiescent state observations

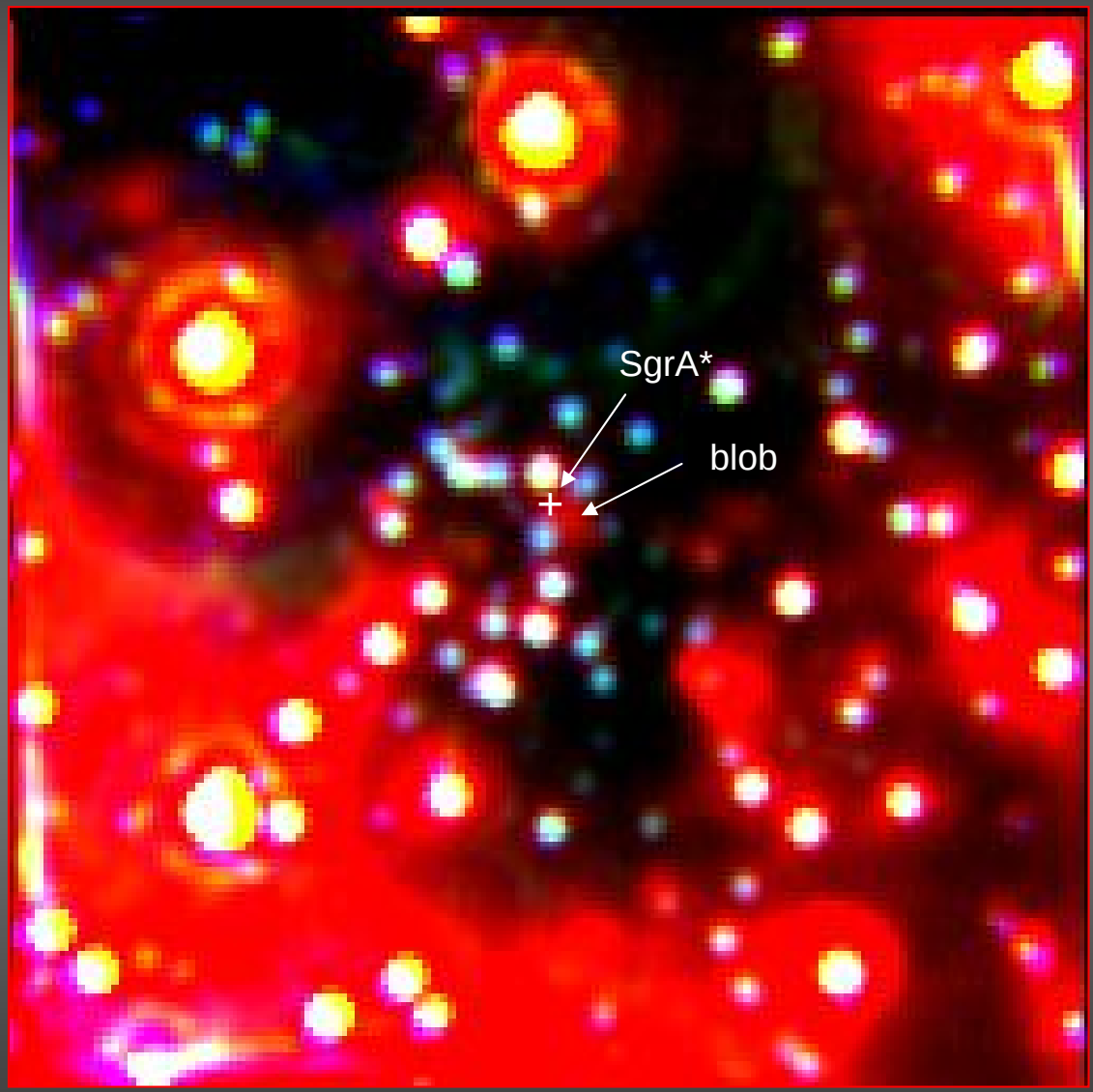


Integration times: 40 min H-band <3mJy
100 min K-band < 3mJy
80 min L-band <23mJy
6 July 2004

white circle marks
position of SgrA*

NIR/MIR spectral energy distribution from the central arcsecond

Detection of a Dust Component along the Line of Sight towards SgrA*



5“x5“

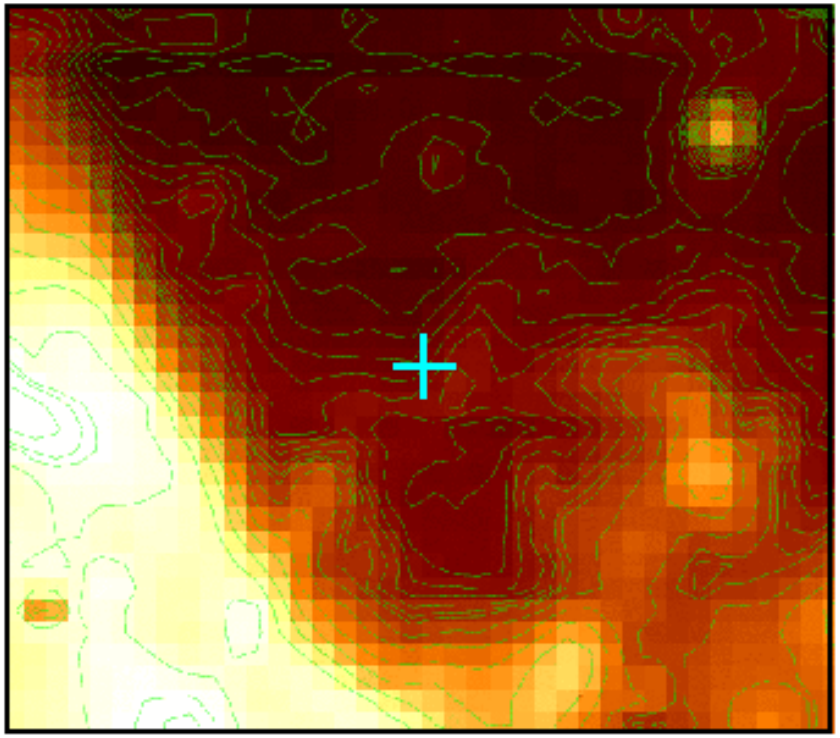
HKL multi-color image of the central 2.6“x2.6“ taken with NACO. L-band is in red.

Fore-/Backgrond dust component 26mas west of SgrA*
~1000 AU at 8 kpc
(see also Ghez et al. 2004)

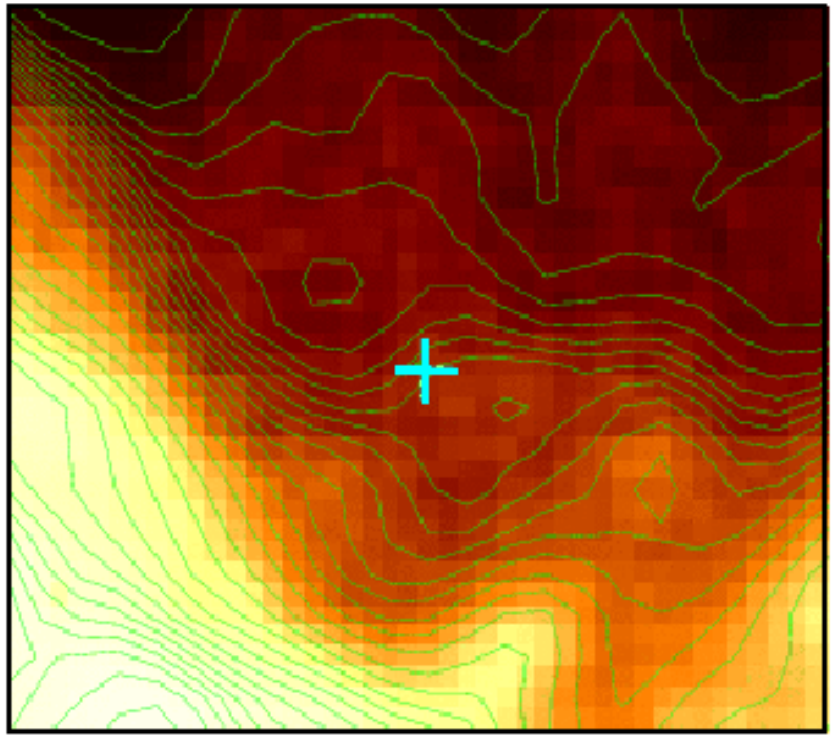
High angular reslution required in the MIR!!

Several of those dust blobs are seen across the field

VISIR VLT Observations



8.6 μm

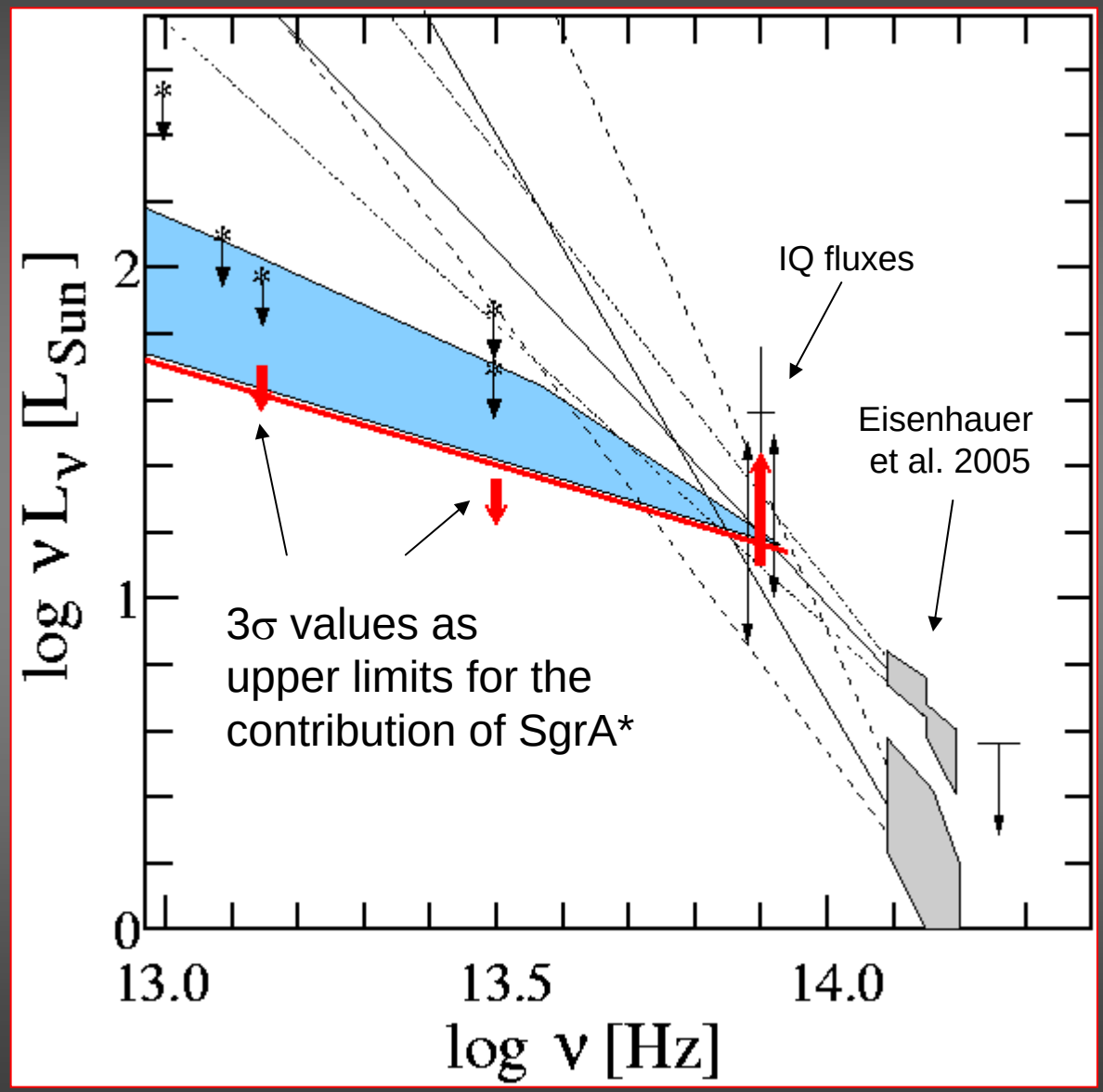


19.5 μm

field of view: 5.0“x4.4“
cross marks position of SgrA*

positional uncertainty +-0.2“
positioning via IRS3, 7, 21, 10W and in addition at 8.6 mm IRS 9, 6E, and 29

MIR Fluxes



The emission at 8.6μm and 19.5μm is dominated by dust

spiral ratio

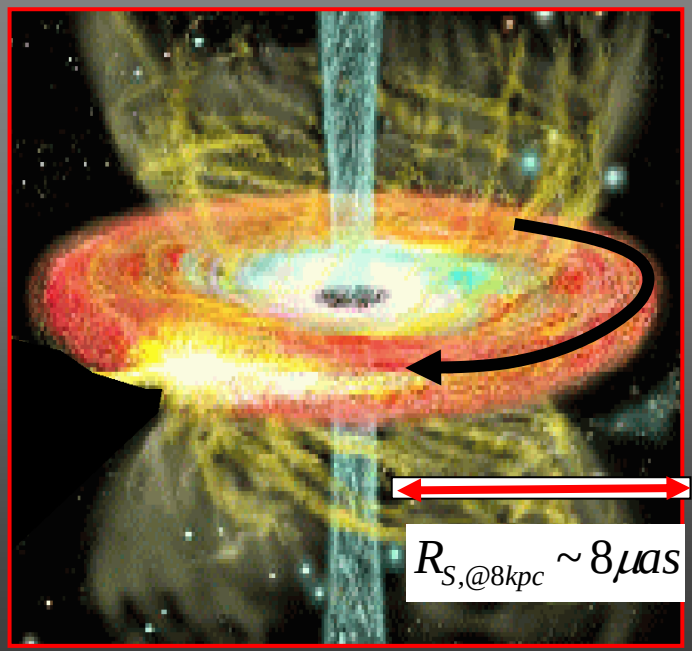
$S_{3.8} \rightarrow S_{8.6}$

$S_{19.5} / S_{8.6}$ = spiral ratio

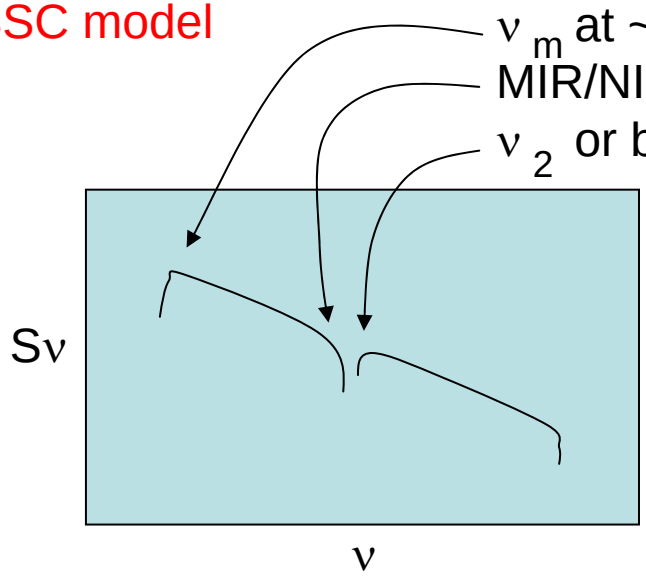
A simple SSC Model with a Synchrotron Spectrum Truncated in the MIR/NIR

Table of Exemplary Models

	S_{NIR} synchr. (mJy)	S_{NIR} SSC (mJy)	S_{X-ray} (nJy)	B (G)	$\nu_{max,obs}$ (GHz)	$S_{max,obs}$ (Jy)	size (μas)	$\alpha_{NIR/X-ray}$
IQ1	0.8	2.0	<18	17	820	3.9	7.9	1.3
IQ2	-	3.0	<27	5	820	7.7	8.1	1.3
IQ3	2.0	0.02	<15	38	1500	0.33	1.5	0.8
F1	(18) 4	1.13	65	68	1640	11.5	8.5	1.1
F2	(73) 5	0.3	240	59	1640	10.5	8.5	0.8



SSC model



$\gamma_e \sim 10^3$

$\Gamma = 1.2 - 2.0$

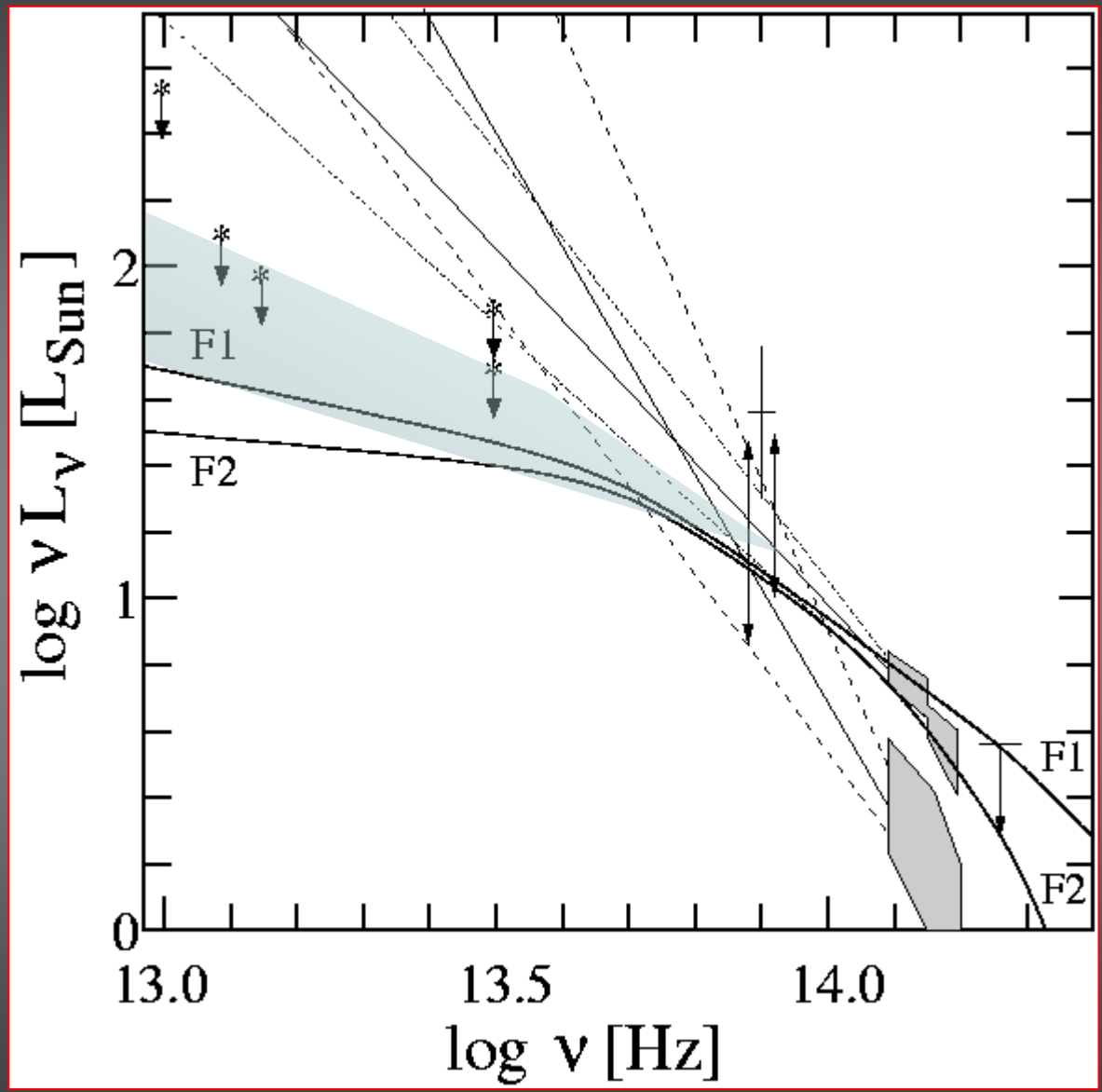
$\delta = 1.3 - 2.0$

$(\phi = 10^o - 45^o)$

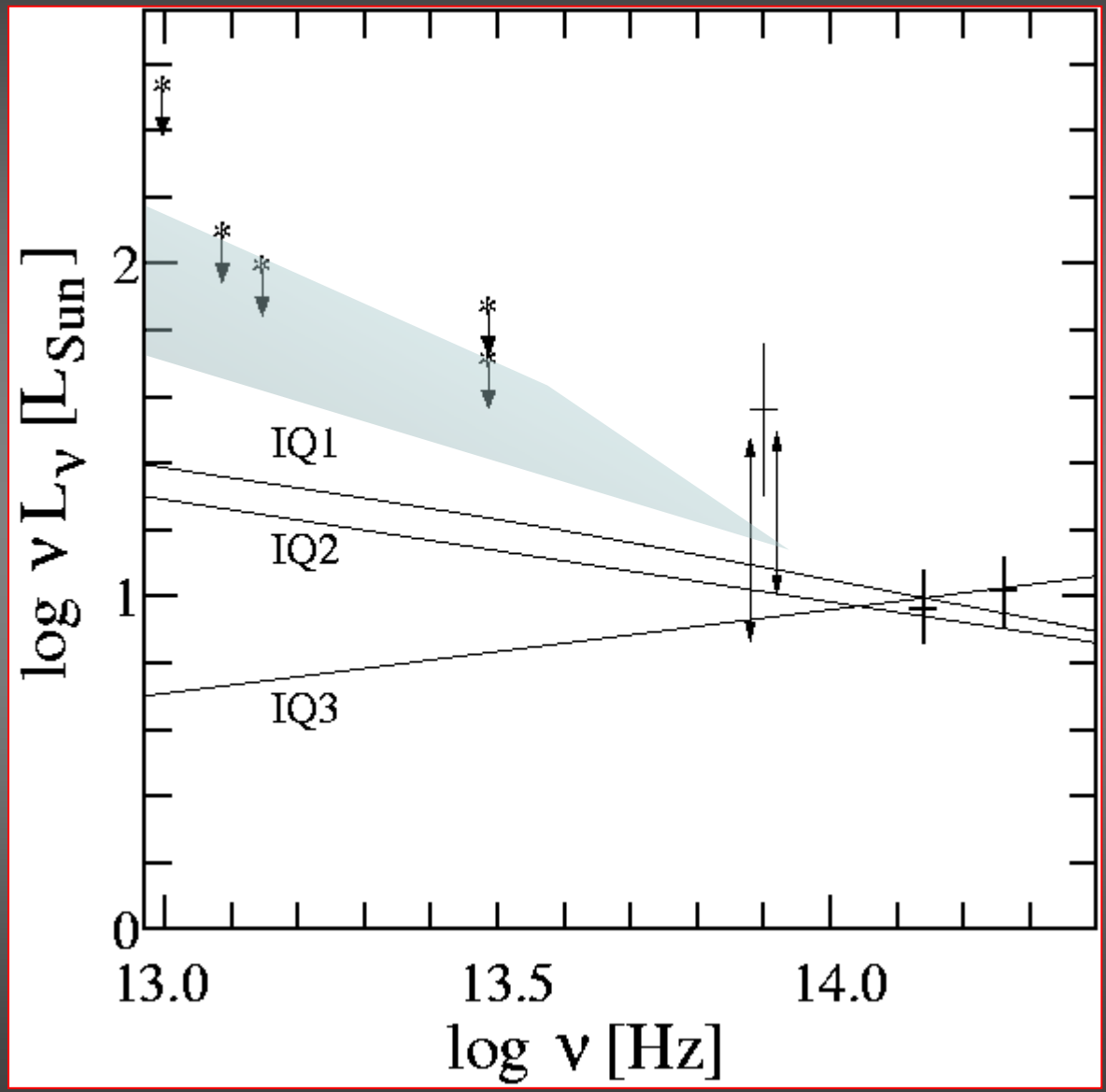
Simultaneous weak flare models

Cutoff may shift towards shorter wavelength: NIR flare spectral index may be flatter

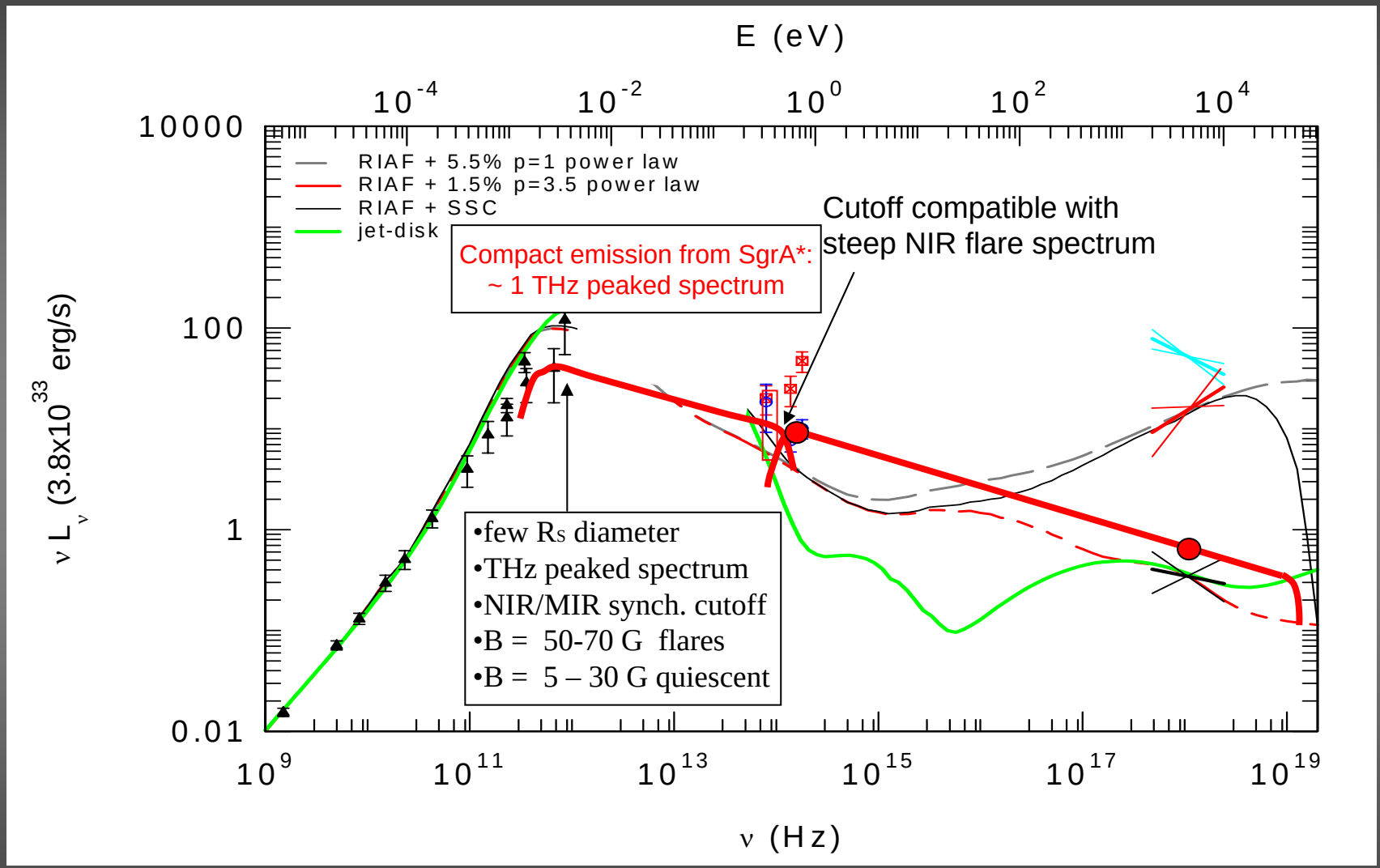
Model consistent with low upper limits in the MIR



NIR/X-ray quiescent state models



First simultaneous weak flare and models



Radio: Zhao, Falcke, Bower, Aitken, et al. 1999-2003
X-ray: Baganoff et al. 2001, 2003, Goldwurm et al. 2003, Porquet et al. 2003,
NIR: Genzel et al. 2003, Ghez et al. 2003
models: Markoff, Falcke, Liu, Melia, Narayan, Quataert, Yuan et al. 1999-2001
SSC model after Marscher (1983) and Gould (1979)

Data and model
Eckart, Baganoff, Morris et al. 2005

NIR/MIR flare activity reflects variations in the electron energy spectrum

i.e. position of MIR/NIR cutoff and intensity of synchrotron and SSC components

What is the distribution of flare intensities in the NIR?

NIR Flare Rate

Results by Hornstein and Viehmann scaled to 100 min.

The results of the 2005 session are in agreement with a K-band flare rate of

$$4 \pm 2 \quad flares / day$$

Assumtion:

- characteristic flare length

$$\kappa_0 \sim 100 \pm 30 \,\mathrm{min}$$

- The NIR emission of SgrA* can be described by consecutive flares of that characteristic length

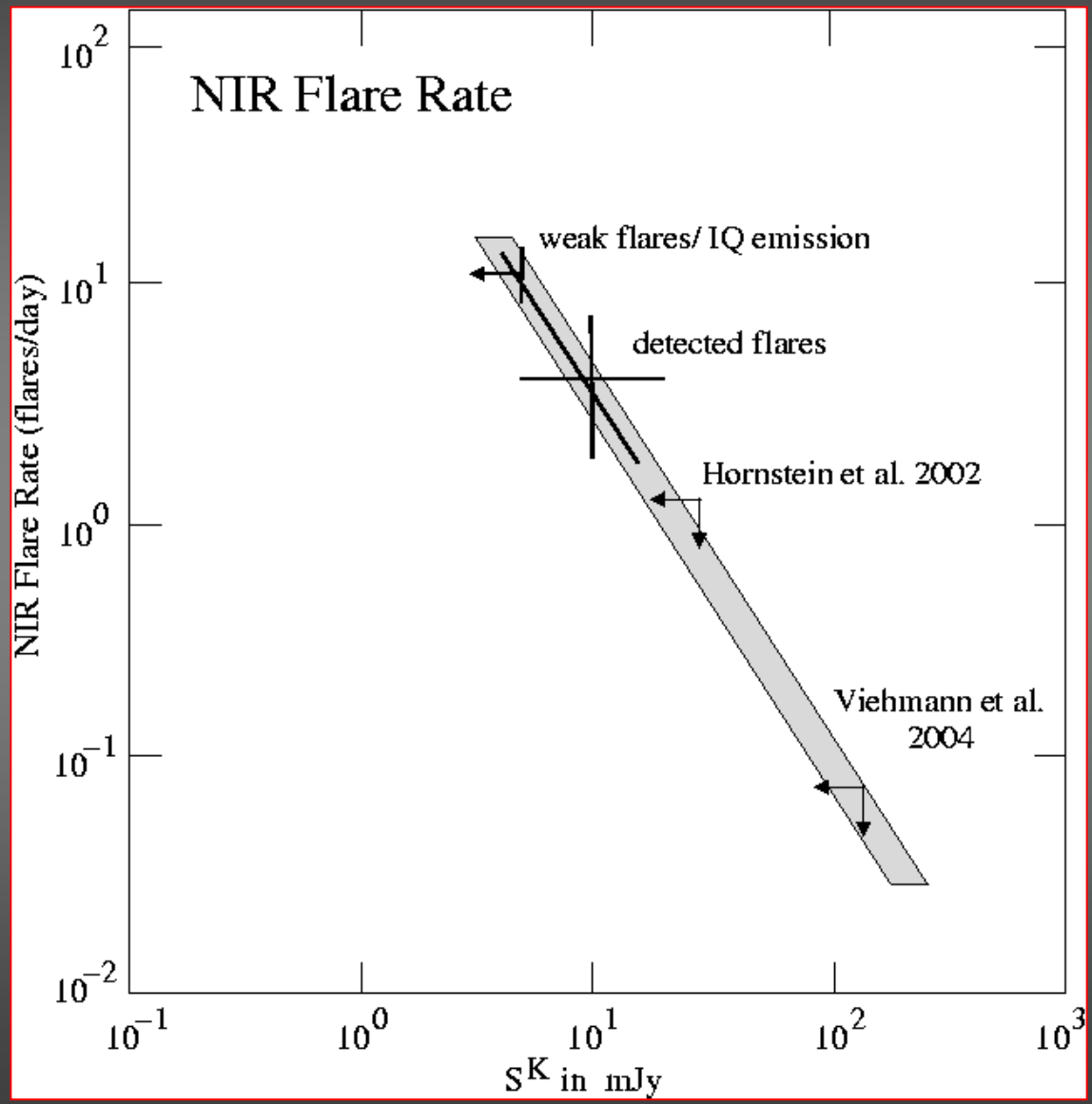
Finding:

Flare rates and limits lie on a $\varsigma = -1.4 \pm 0.2$ power-law

$$N(A) = \kappa_0 A^{-\varsigma} \kappa_1 \kappa_2$$

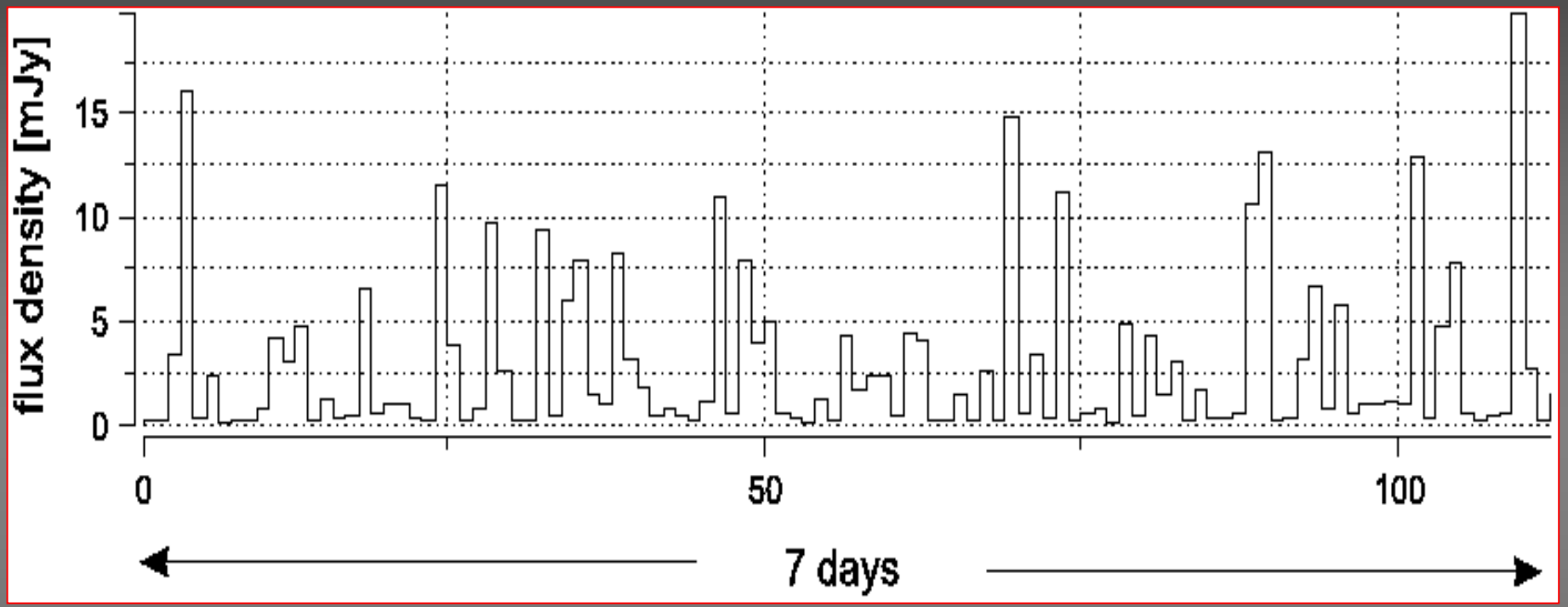
$$\kappa_1 = \exp(-A / A_{high})$$

$$\kappa_2 = \exp(-A_{low} / A)$$



value of ζ is independent on value for κ_0

Simulation of SgrA* NIR flare activity



Simulation of the NIR flare activity assuming a characteristic flare length of 100 minutes, a typical flare flux of 10-20 mJy, and a power-law dependency with a power-law index of $\zeta \sim -1.4$

Simultaneous Observations of NIR/X-ray Flares

- **Position within < 10 mas from Sgr A***
- **Time lag NIR-to-X-ray $\leq$ ~10-15 min $\Rightarrow$ same electron population**
- **NIR and X-ray sources are identical**
- **NIR: Synchrotron and SSC emission, flare rate is higher in the NIR**
- **Indications for related activity at mm-wavelengths**

Eckart et al., 2004, A&A; Eckart et al., 2005, in preparation

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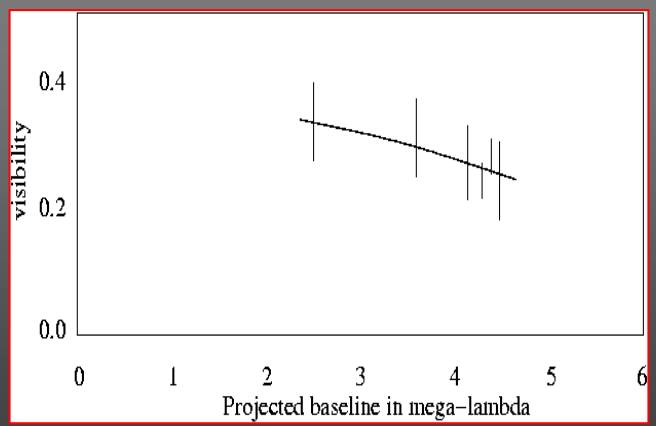
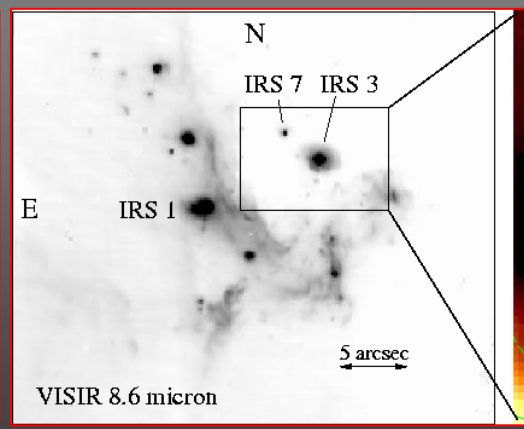
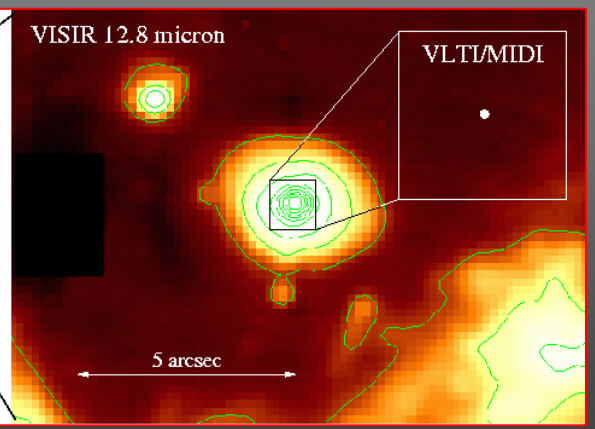
- Nelly Mouawad - Extended mass disribution around SgrA*
- Jihane Moultaka - L-band observations of the ISM towards IRS3/IRS13
- Rainer Schödel - Structure of the central stellar cluster
  - On the possibility of an IMBH in the IRS13 complex

Please see also latest ESO Messanger:
J.-U.Pott et al. : The brightest compact MIR source at the GC
VLTI Interferometric observations of IRS3







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GC06
18-22 April 2006
Bad Honnef,Germany

(on the river Rhein, just south of Köln/Bonn)

End