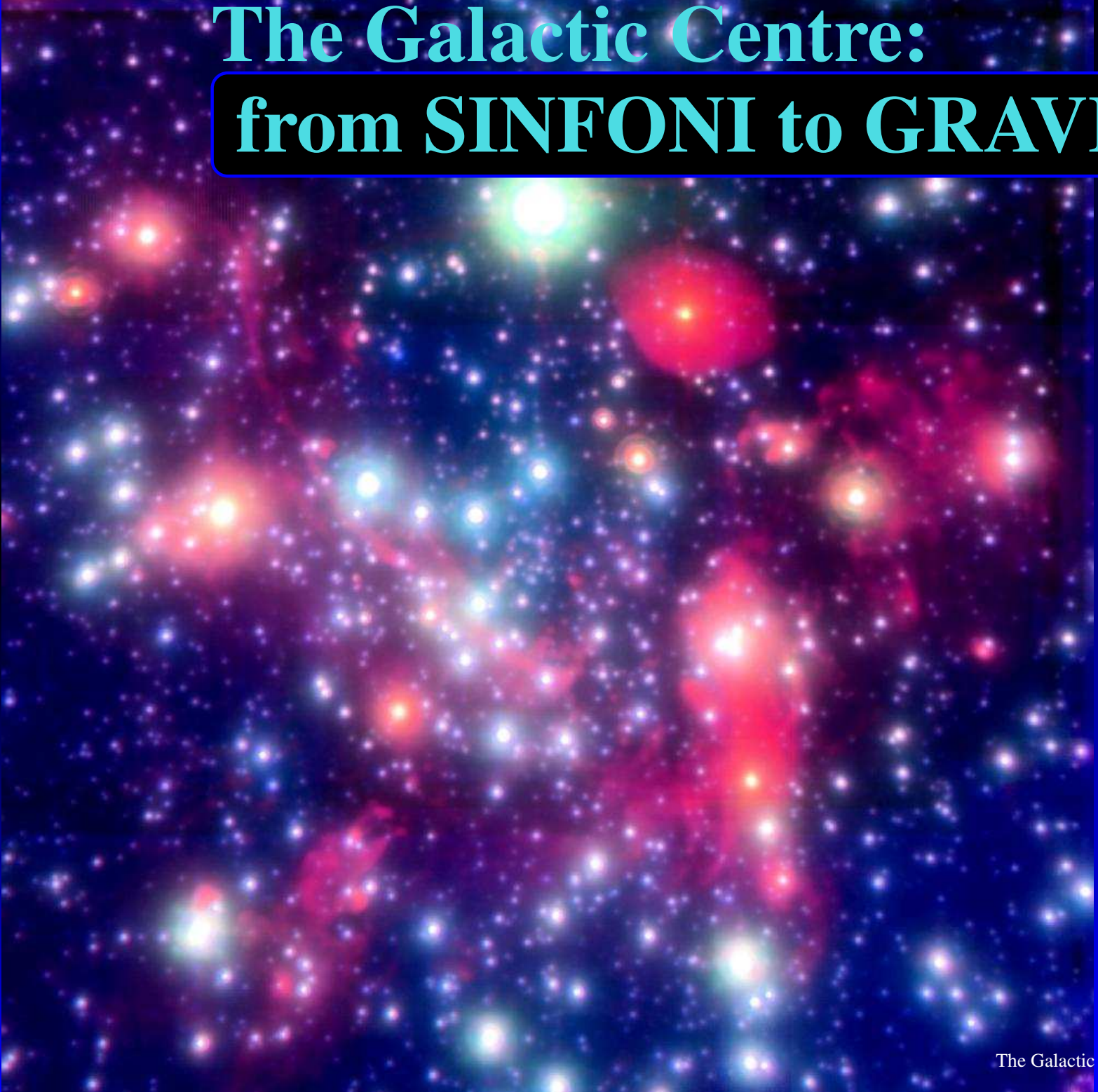

The Galactic Centre: from SINFONI to GRAVITY

Thibaut Paumard
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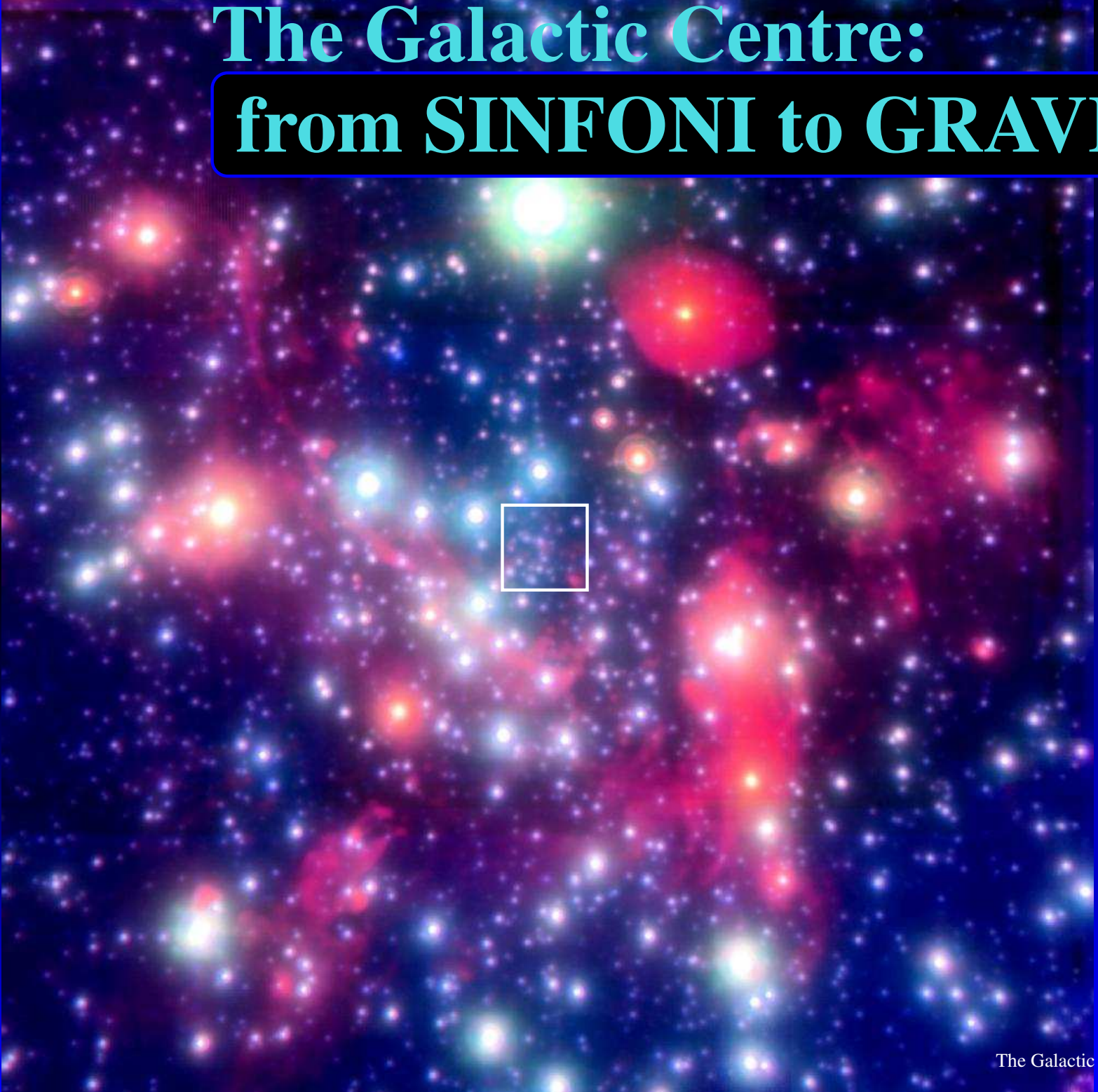

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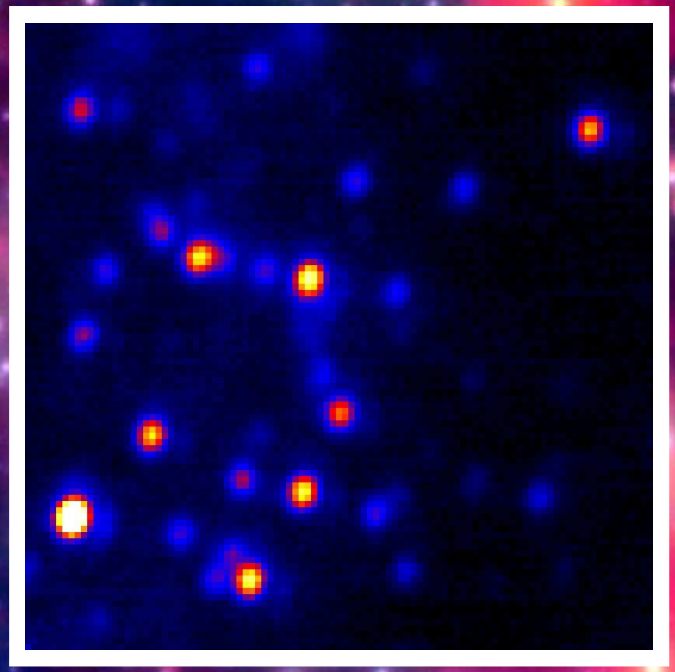

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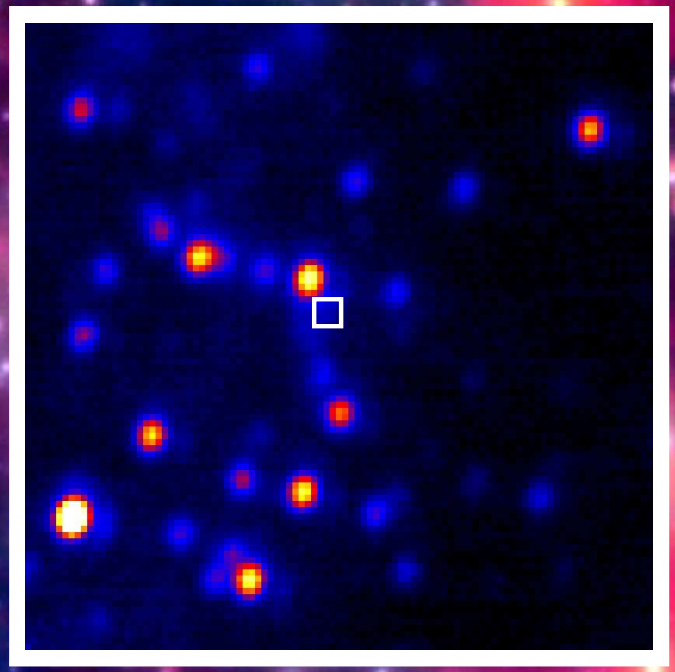

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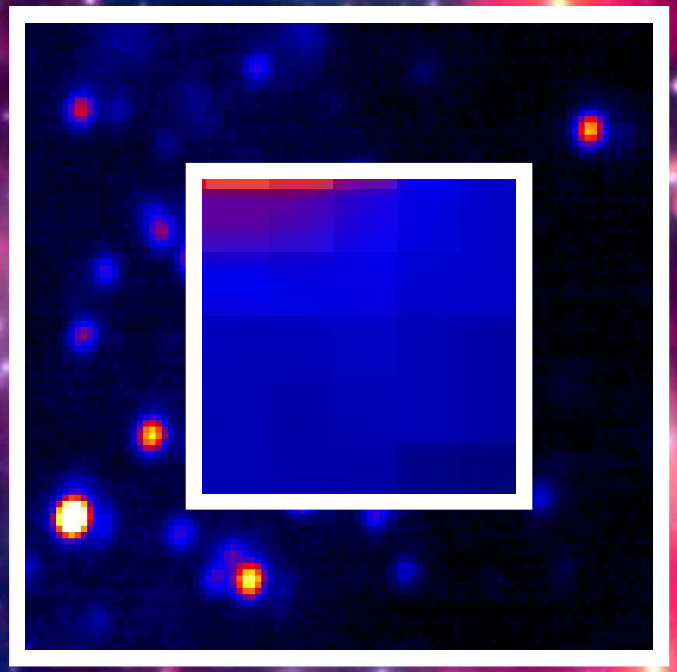

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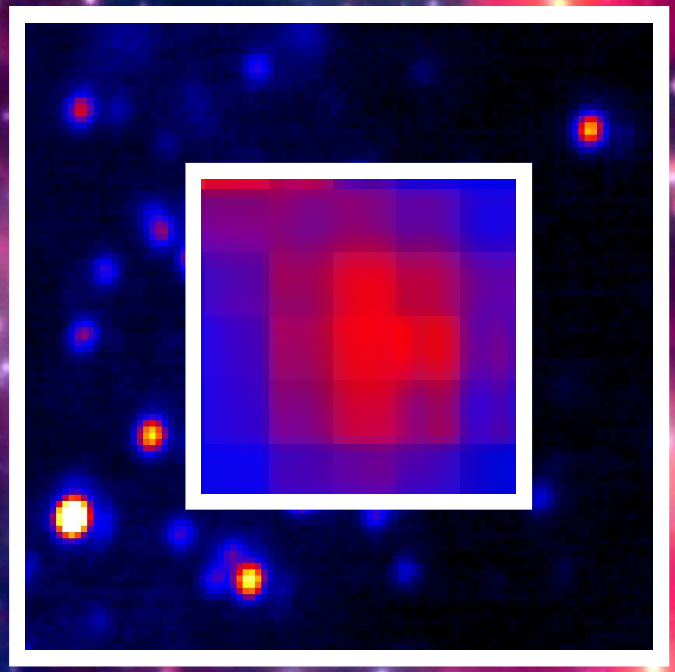

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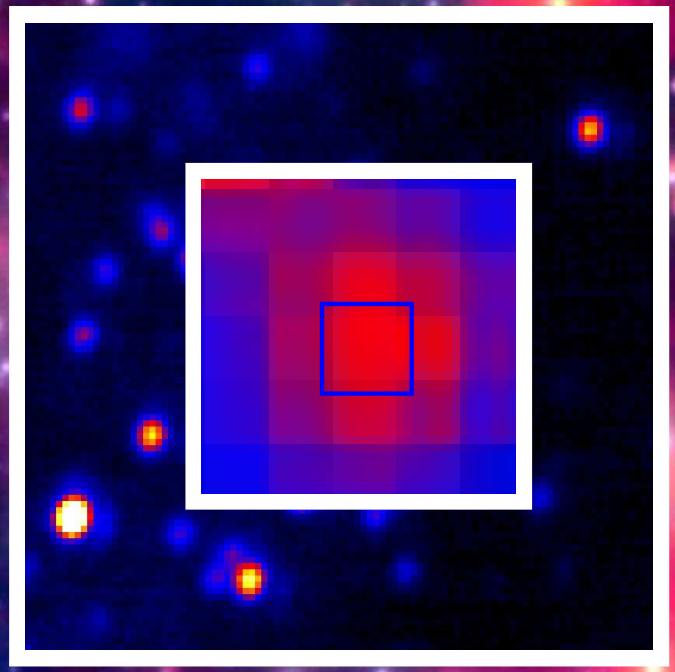

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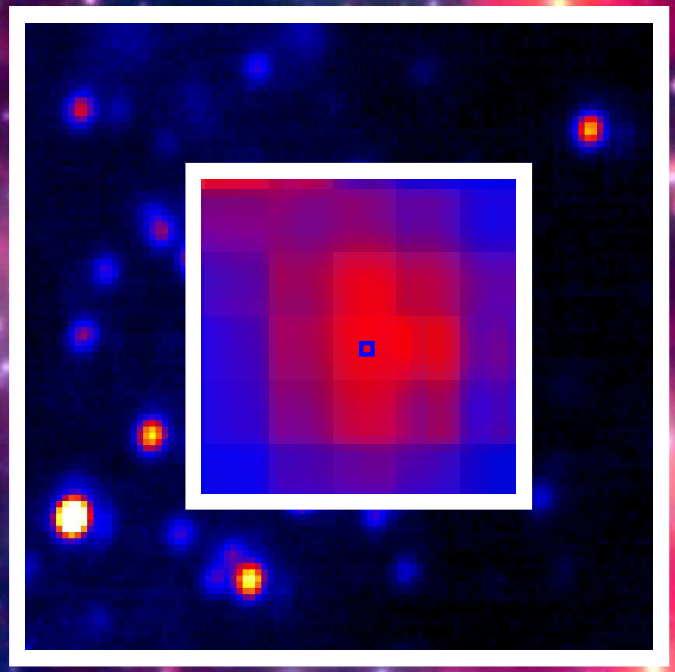

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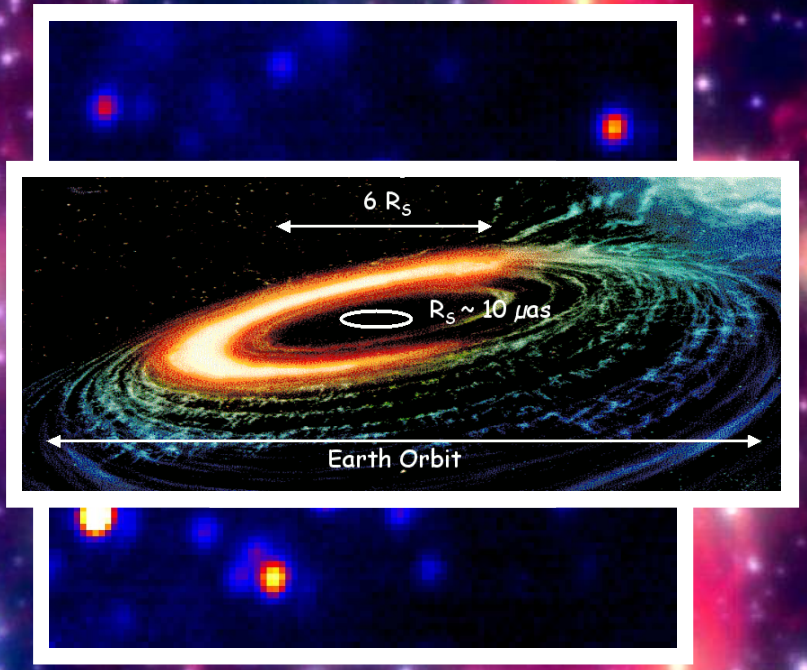

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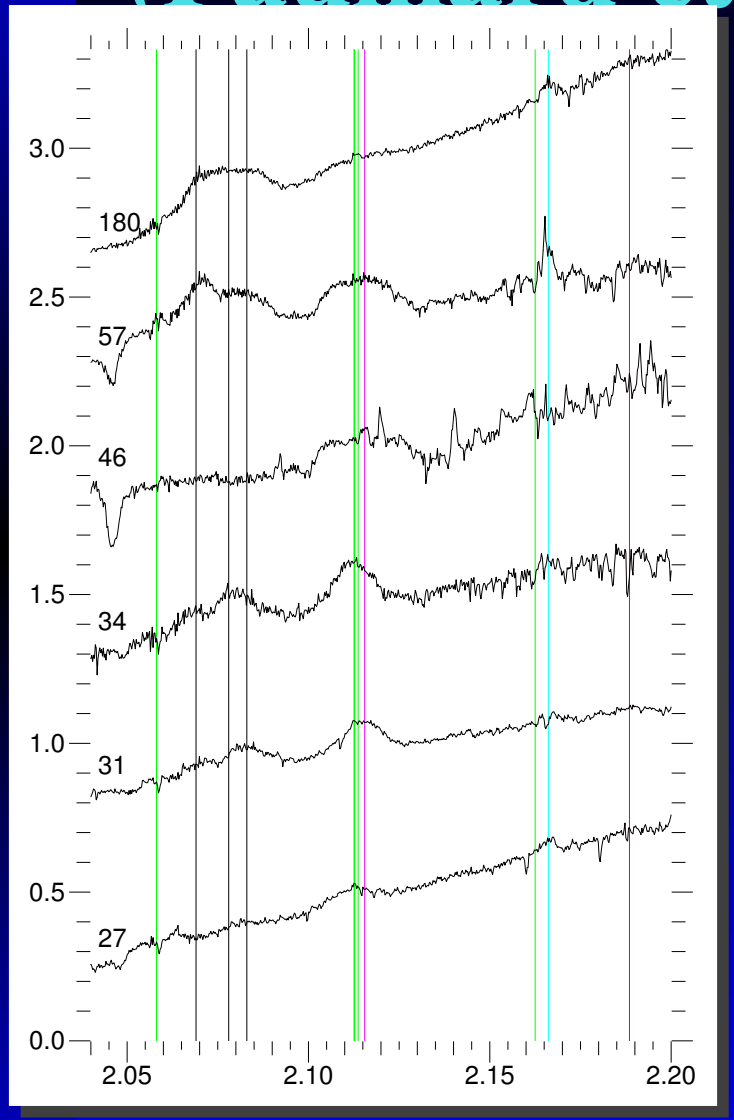
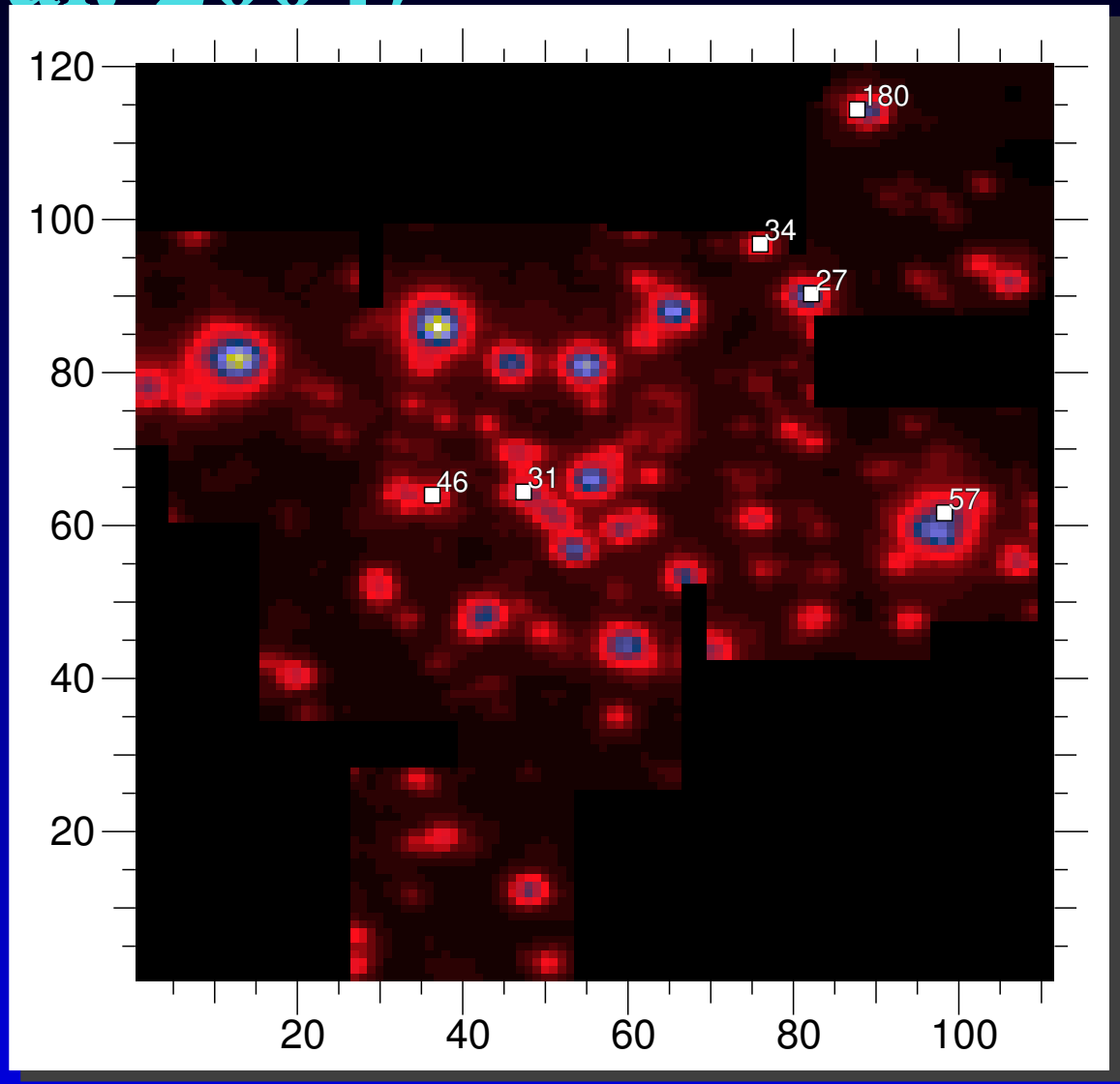
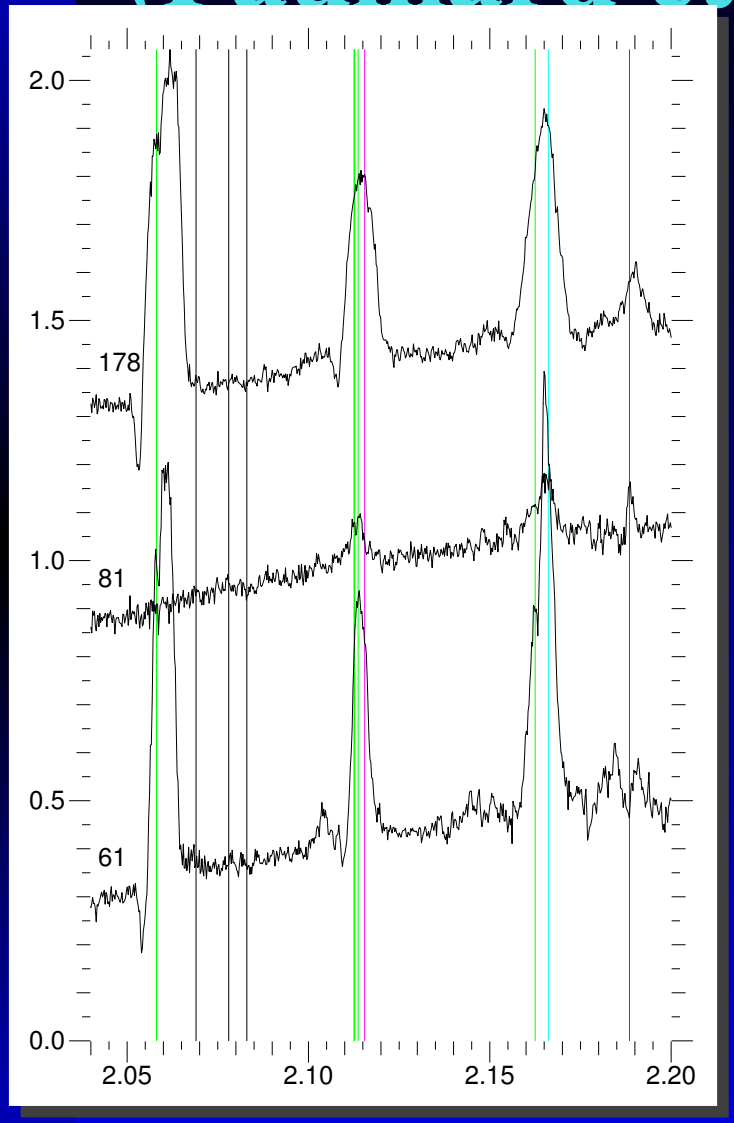
Early SPIFFI spectra... (Paumard et al. 2004)

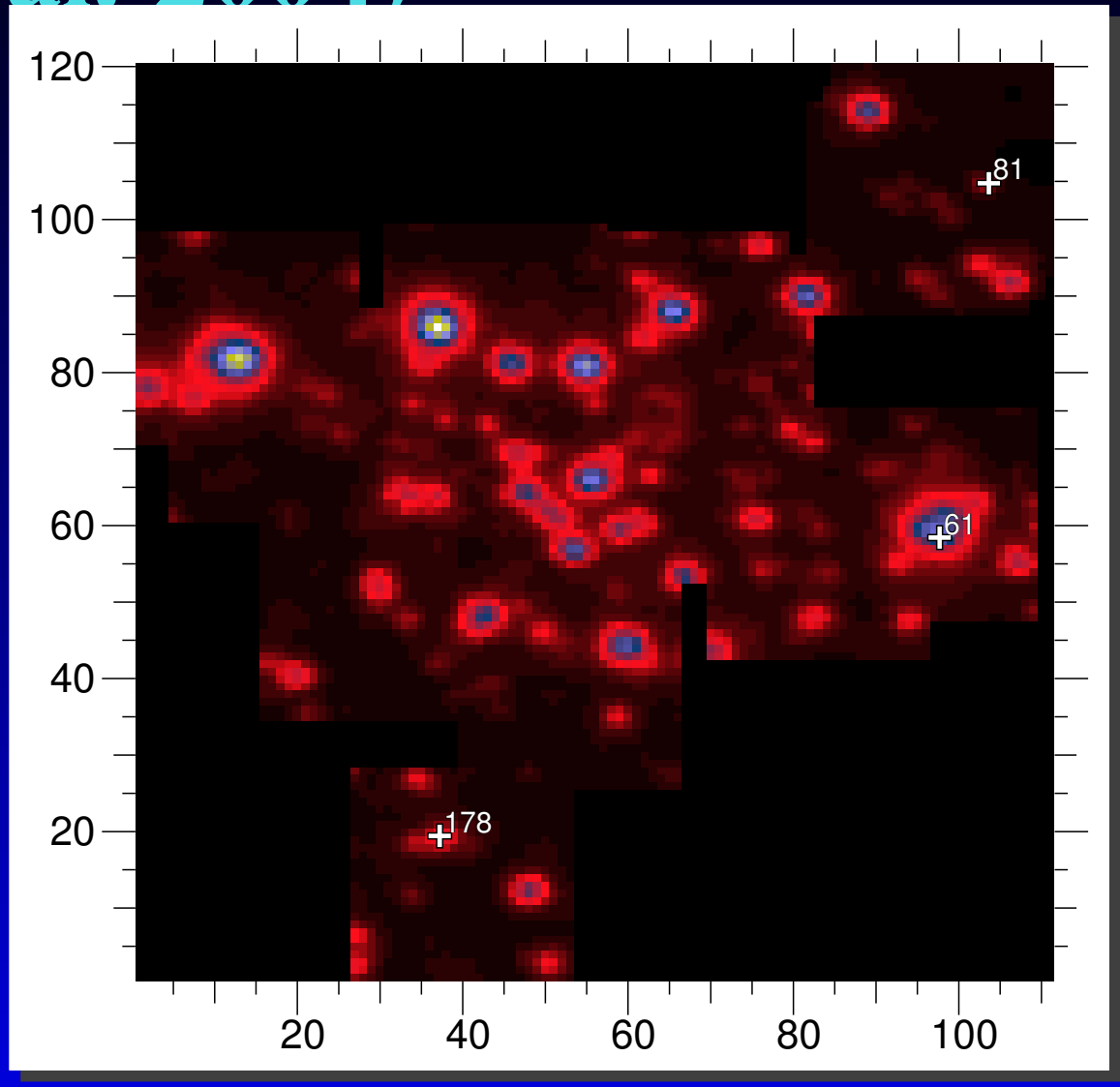




early Wolf-Rayets (broad-line stars)

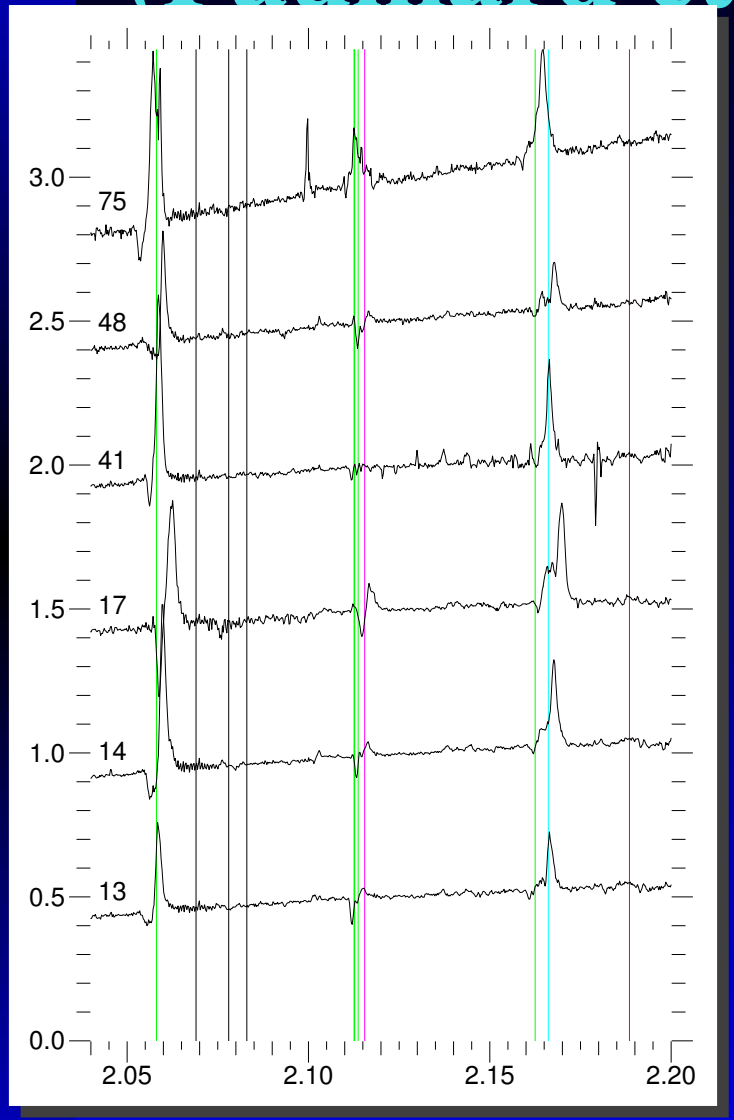
Early SPIFFI spectra... (Paumard et al. 2004)

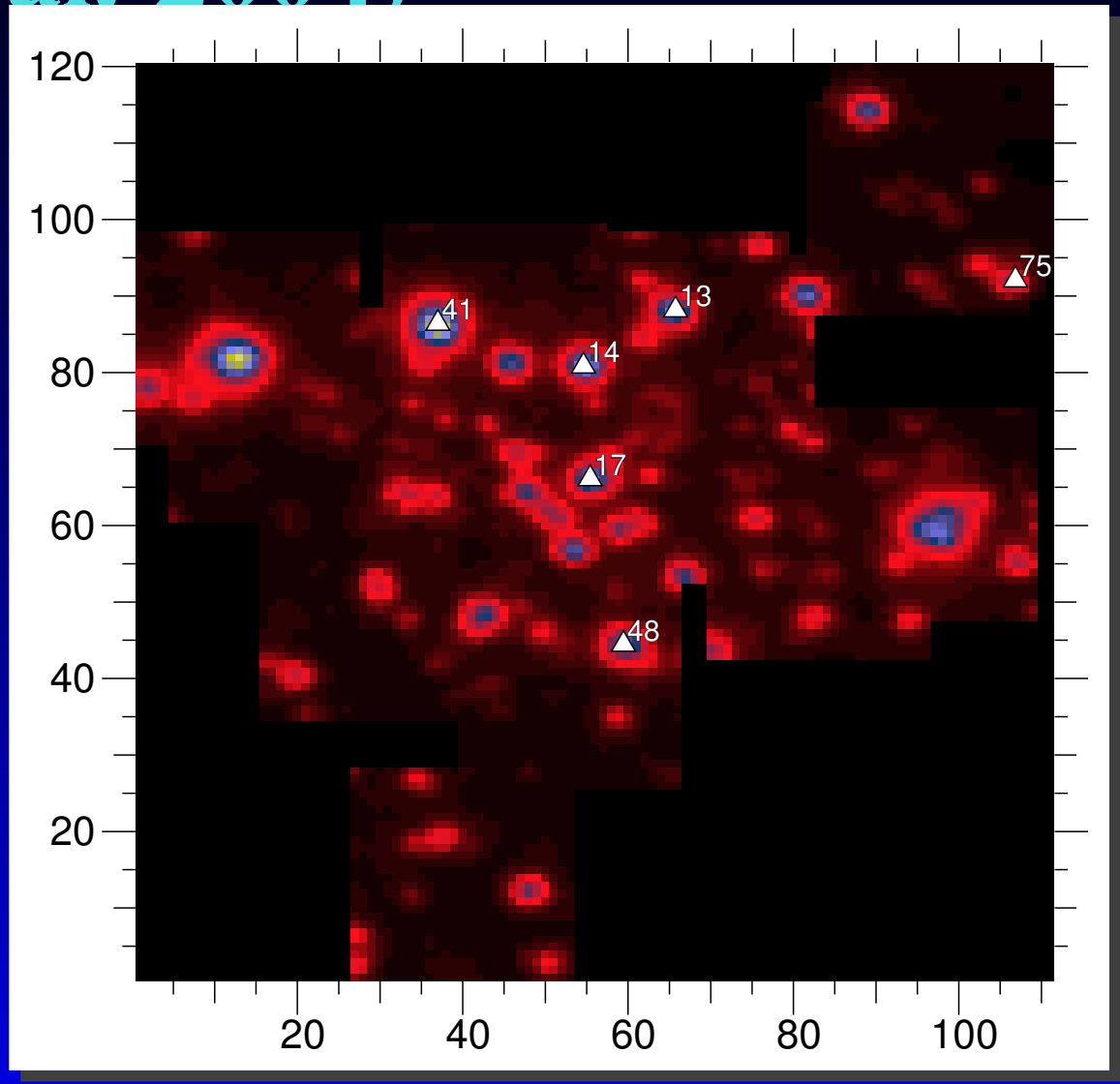




late Wolf-Rayets (broad-line stars)

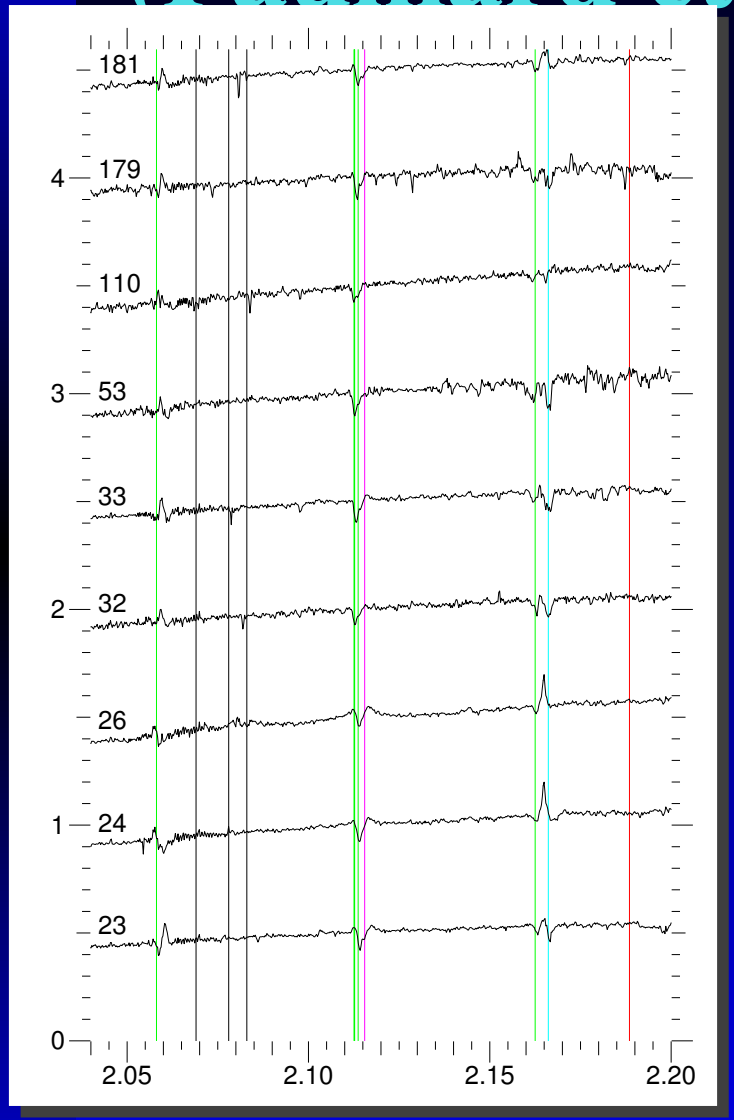
Early SPIFFI spectra... (Paumard et al. 2004)

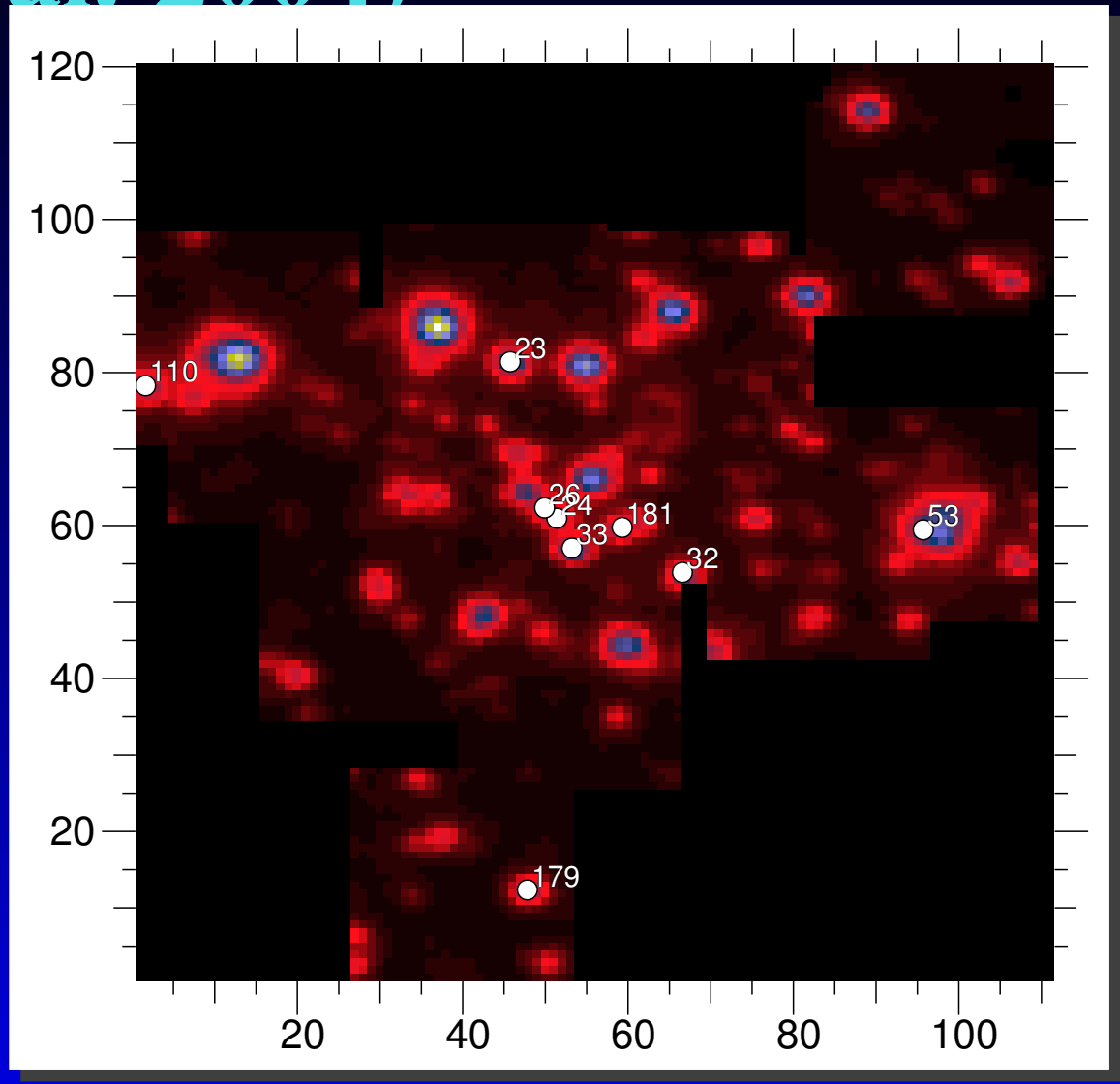




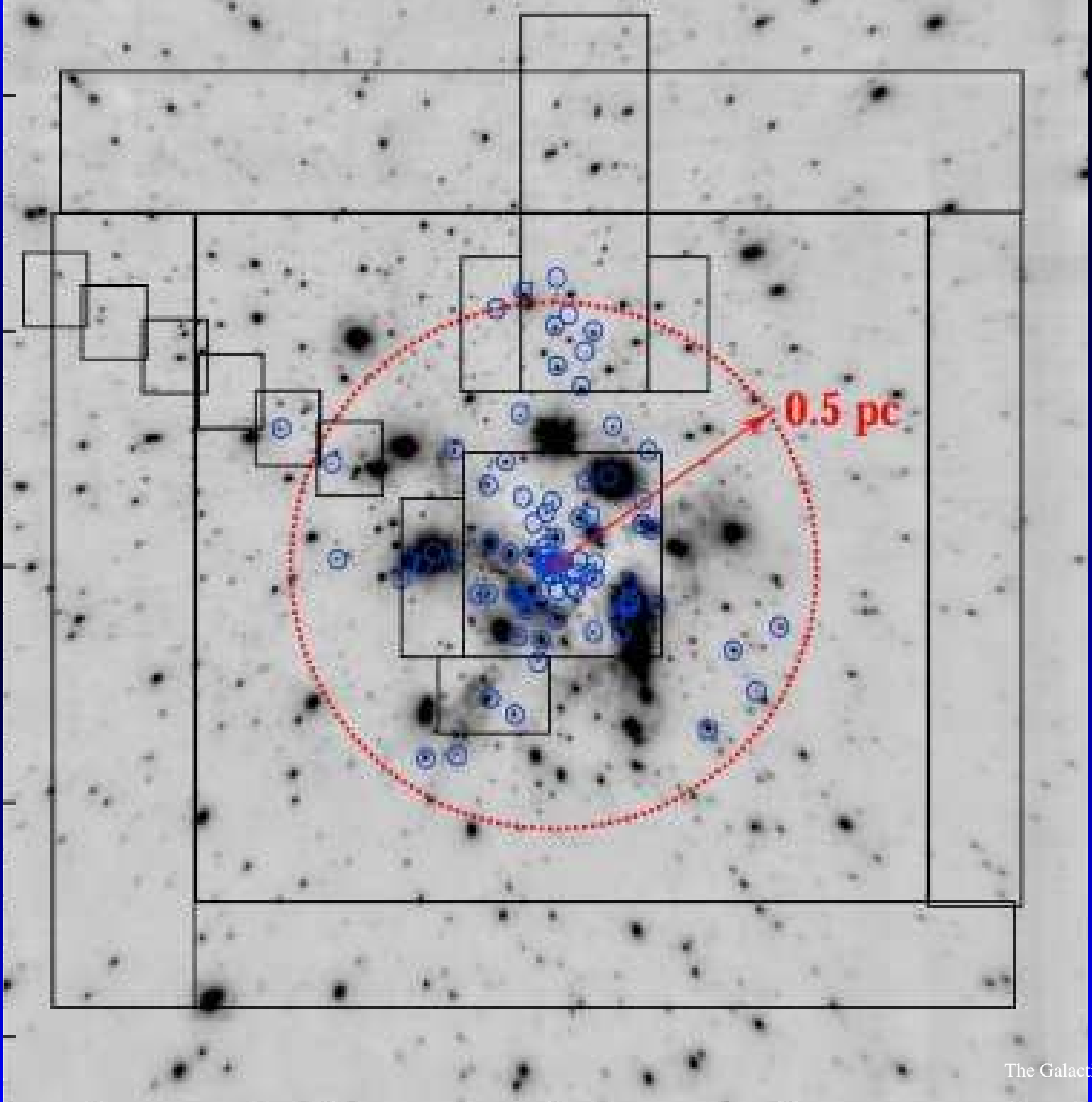
"LBVs" (narrow-line stars)

Early SPIFFI spectra... (Paumard et al. 2004)





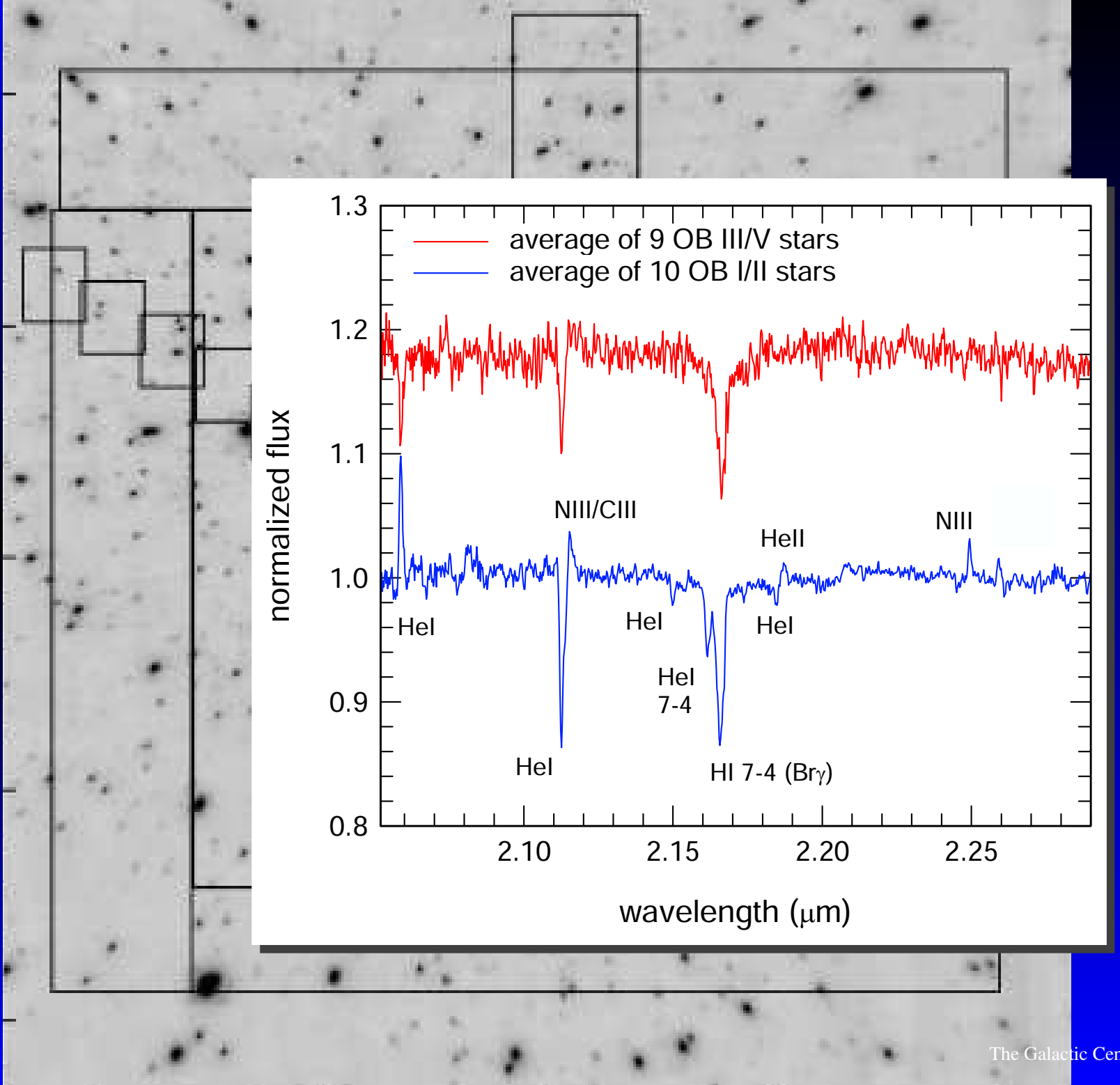
absorption line (OB) stars finally detected!



Outline of the various 2003–2005 SPIFFI/SINFONI H+K and K-band cubes superposed on an L-band NACO image

$>$ 90 early-type stars

Paumard et al. 2006 (ApJ, in press)



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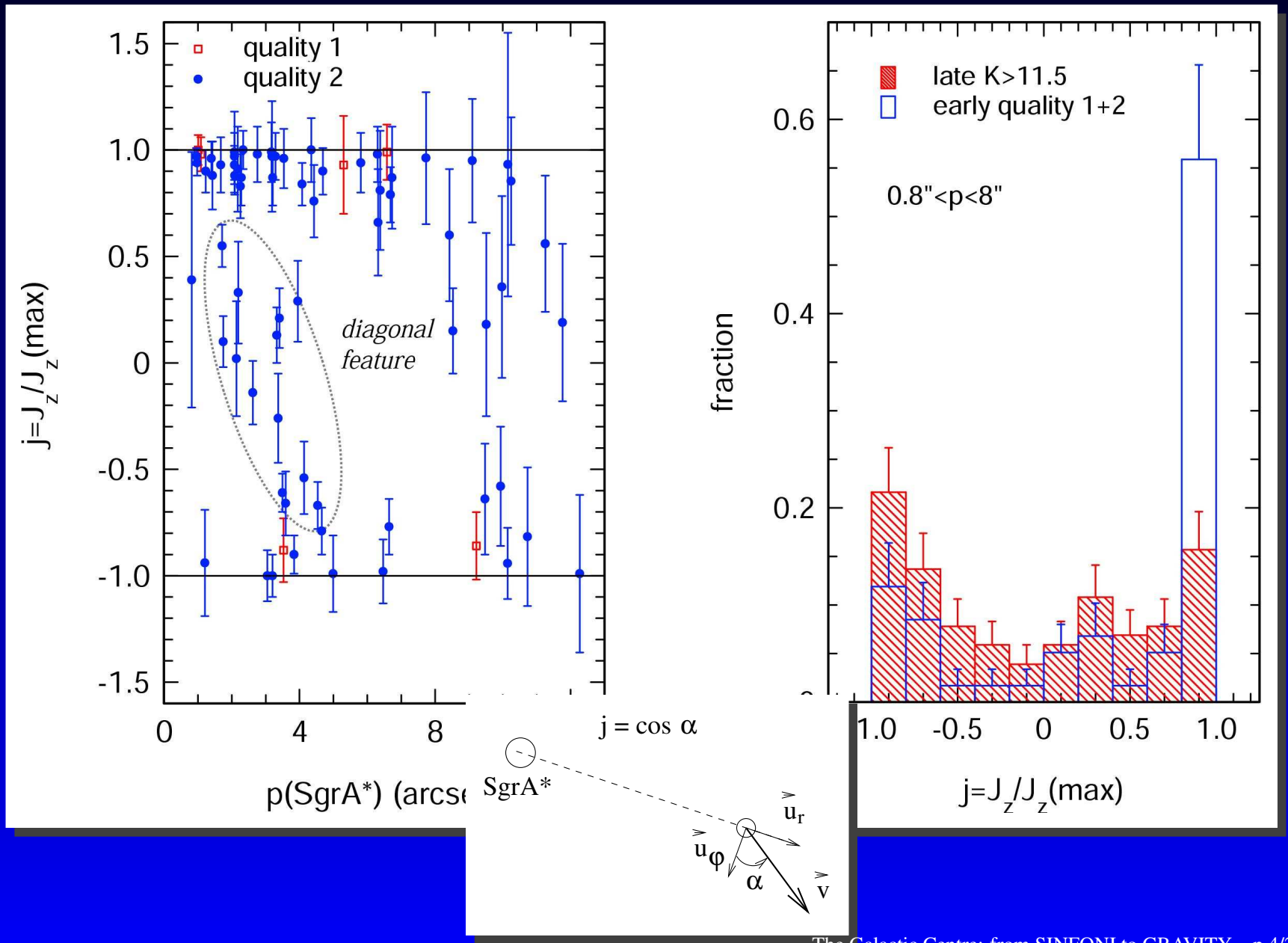
Early-type stars mostly on projected tangential orbits



The early-type stars live in two well defined disks

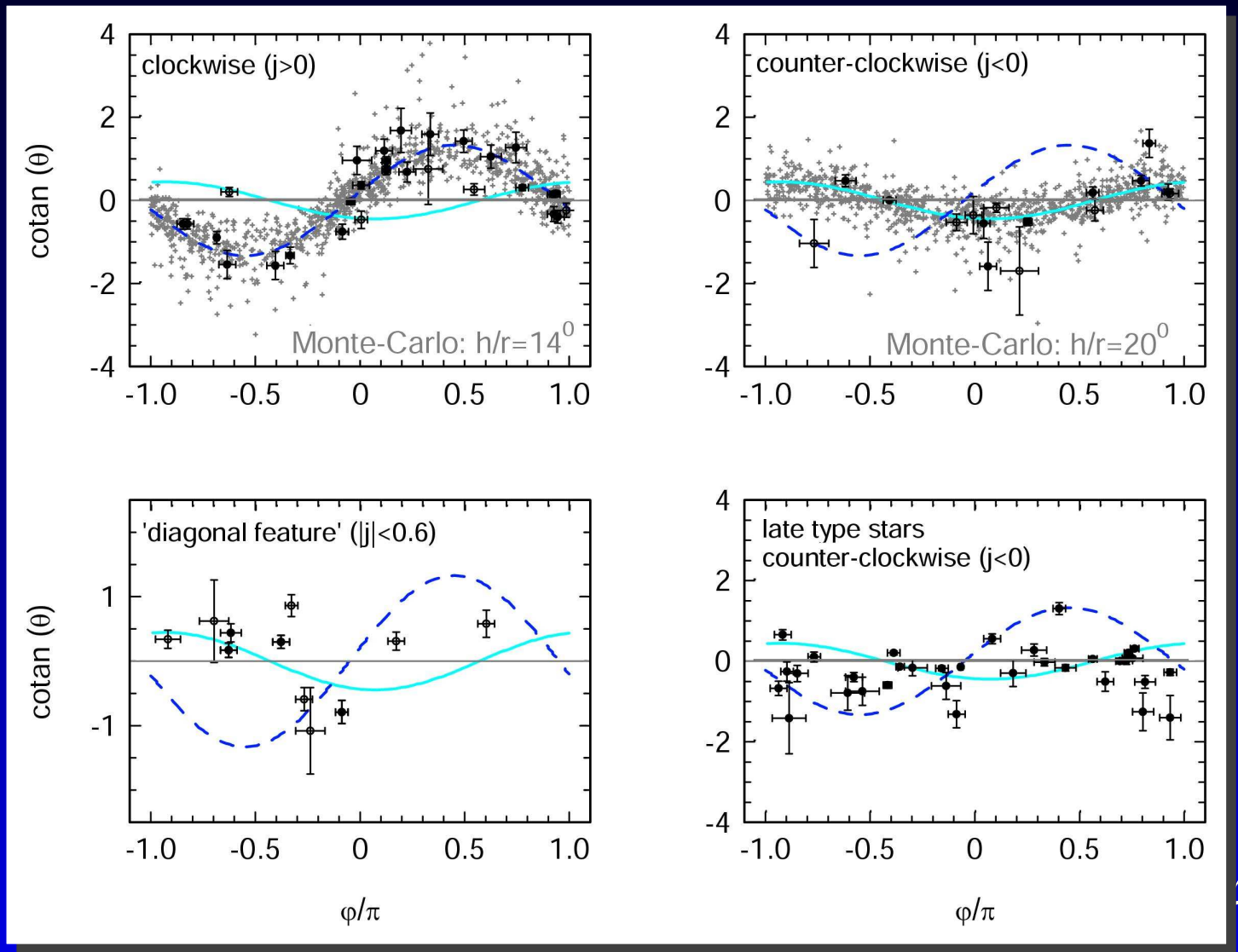
$\vec{v}_k = (v_{x,k}, v_{y,k}, v_{z,k})$
$= ||\vec{v}_k||(\sin\theta_k \cos\varphi_k, \sin\theta_k \sin\varphi_k, \cos\theta_k)$.
assume all v_k are normal to a common vector
$n = (\sin i \cos\Omega, -\sin i \sin\Omega, -\cos i)$, then

$$\begin{aligned} 0 &= \vec{n} \cdot \vec{v}_k \\ &= \sin i \cos\Omega \sin\theta_k \cos\varphi_k \\ &\quad - \sin i \sin\Omega \sin\theta_k \sin\varphi_k \\ &\quad - \cos i \cos\theta_k \end{aligned}$$

$$\sin i \sin\theta_k \cos(\Omega + \varphi_k) = \cos i \cos\theta_k$$

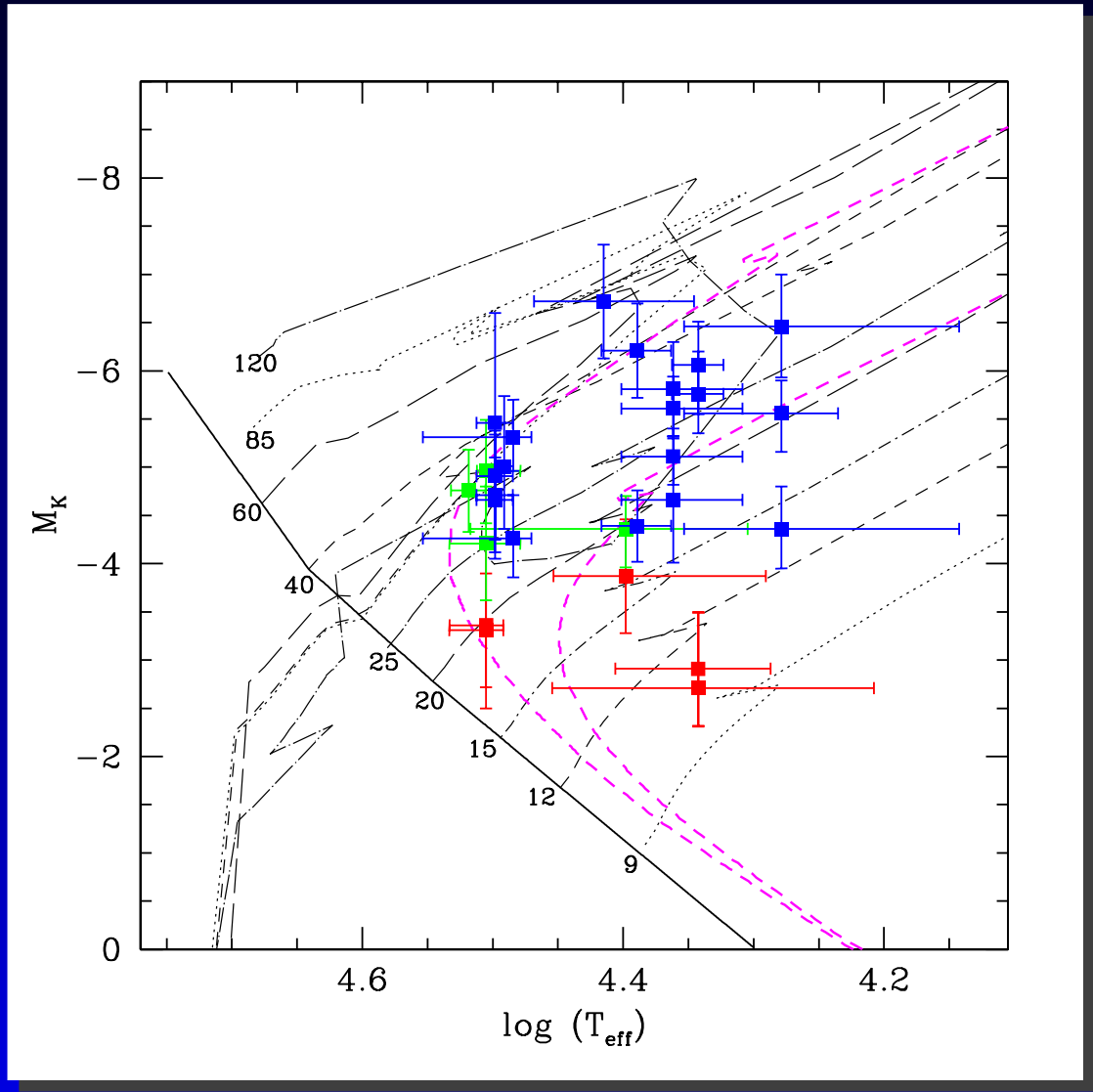
$$\operatorname{cotan}\theta_k = \tan i \cos(\Omega + \varphi_k) \; .$$

The early-type stars live in two well defined disks



$\varphi_k)$.

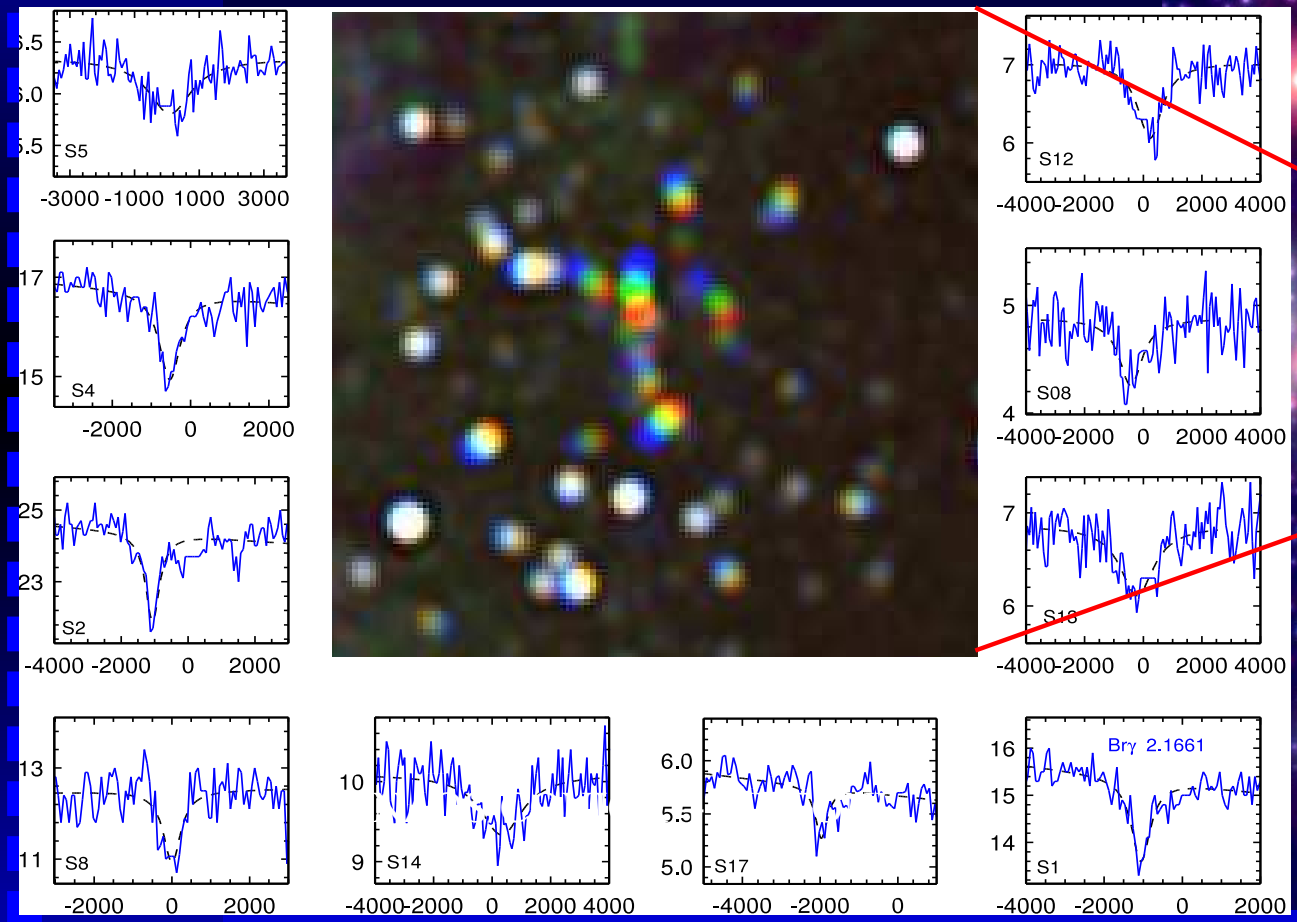
IR HR diagram: 6 ± 2 Myr old population

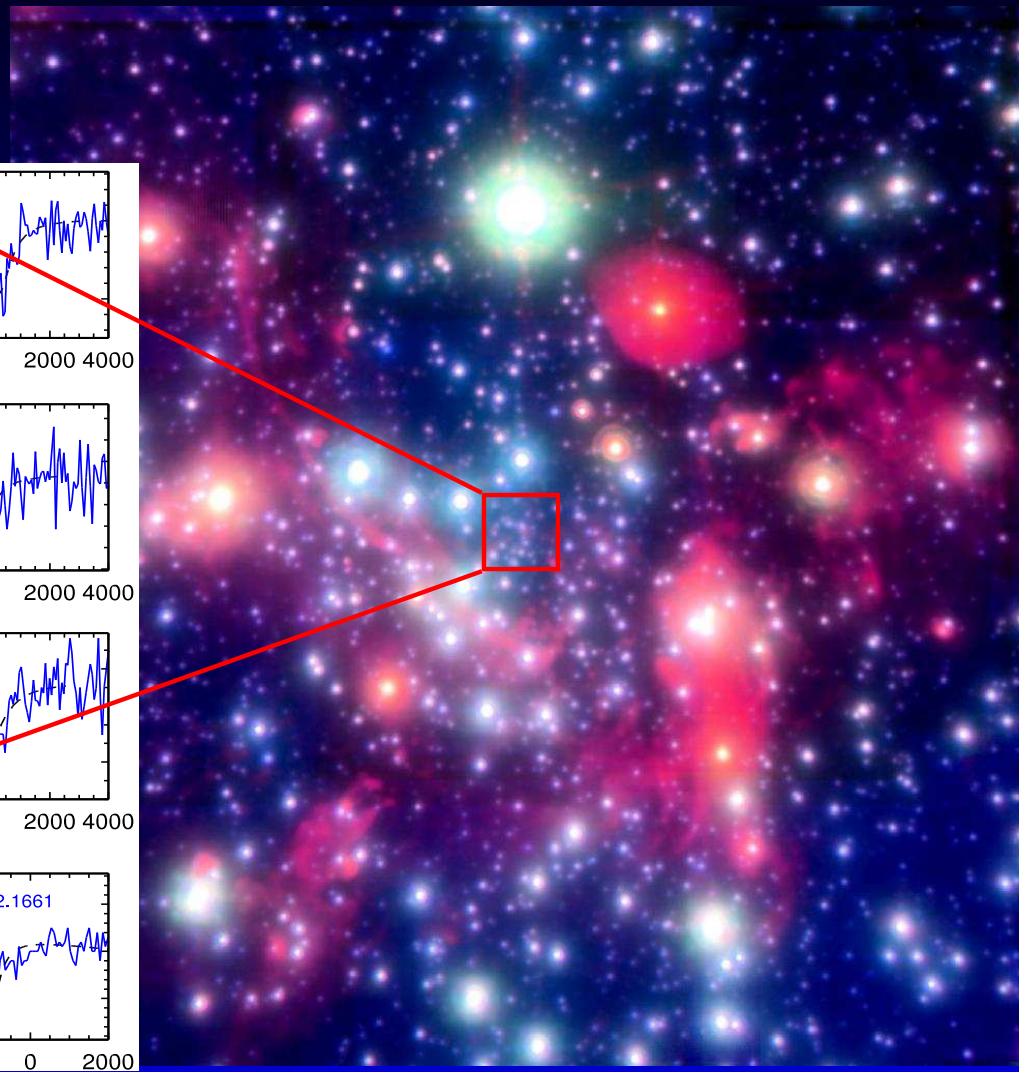


- Flat IMF;
- Total mass $< 10^4 M_\odot$;
- One disk small e, other disk large e;
- One disk contains GCIRS 13E: an extremely dense star cluster.

Star formation in an accretion disk (two, actually)

The "S-stars" are not part of any disk





(Eisenhauer et al, 2005)

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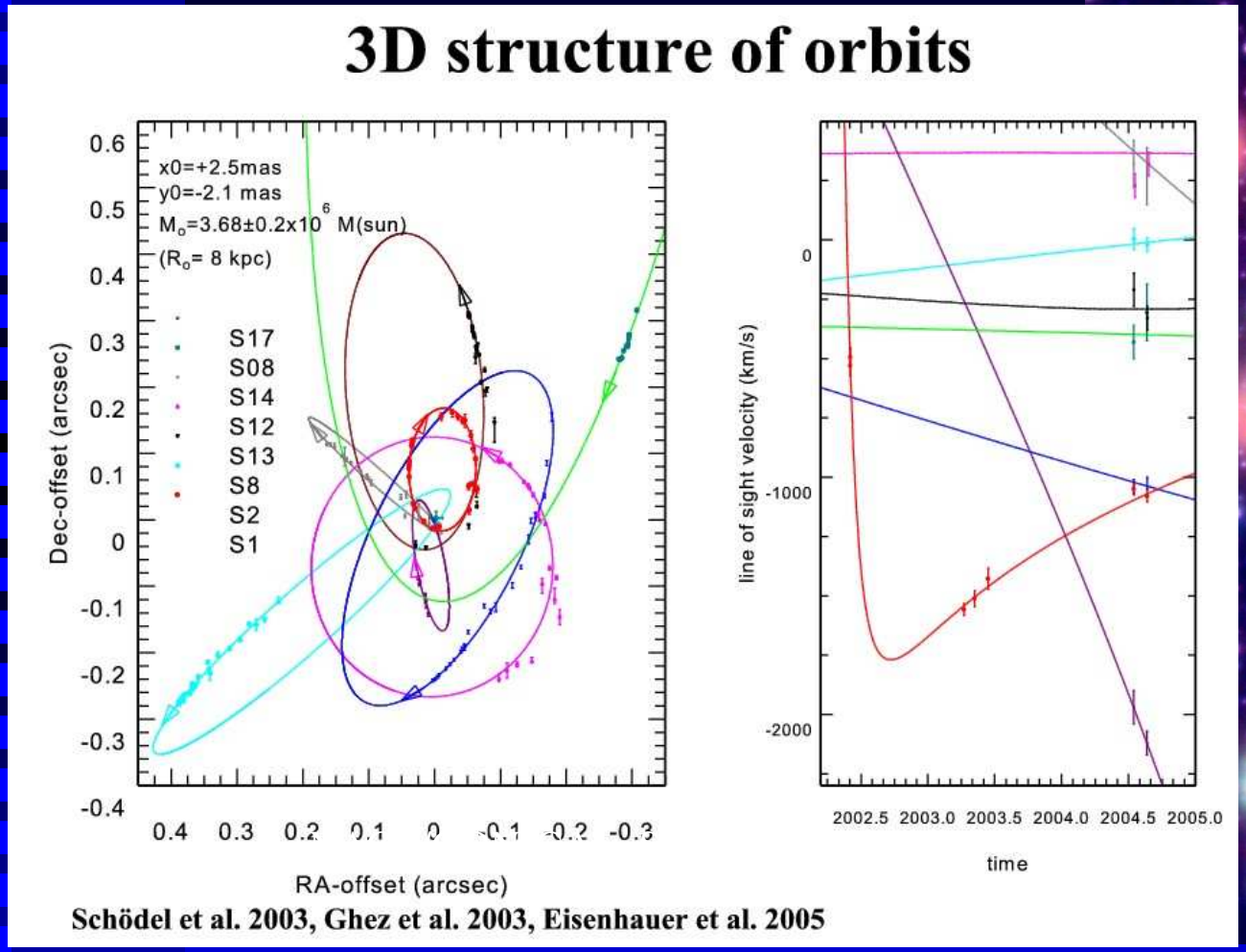
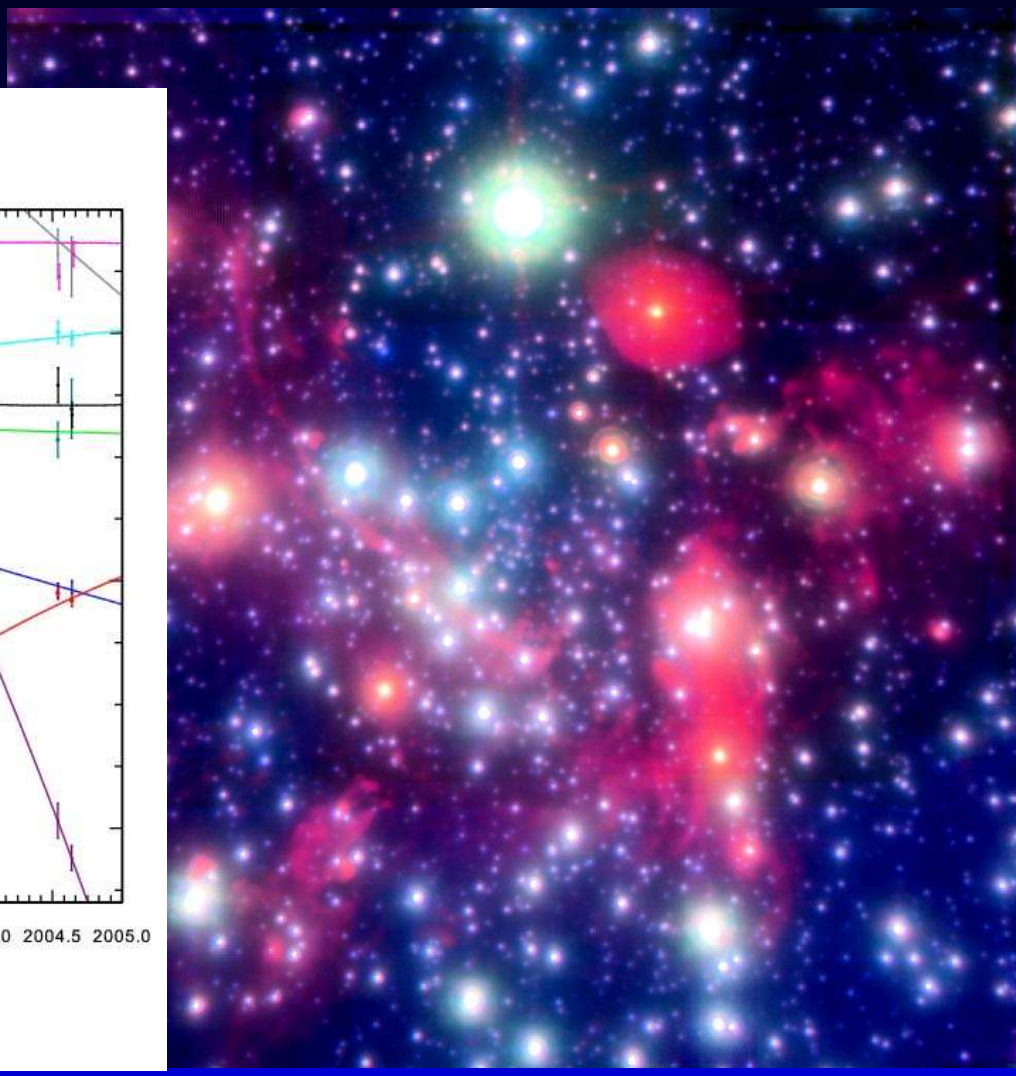
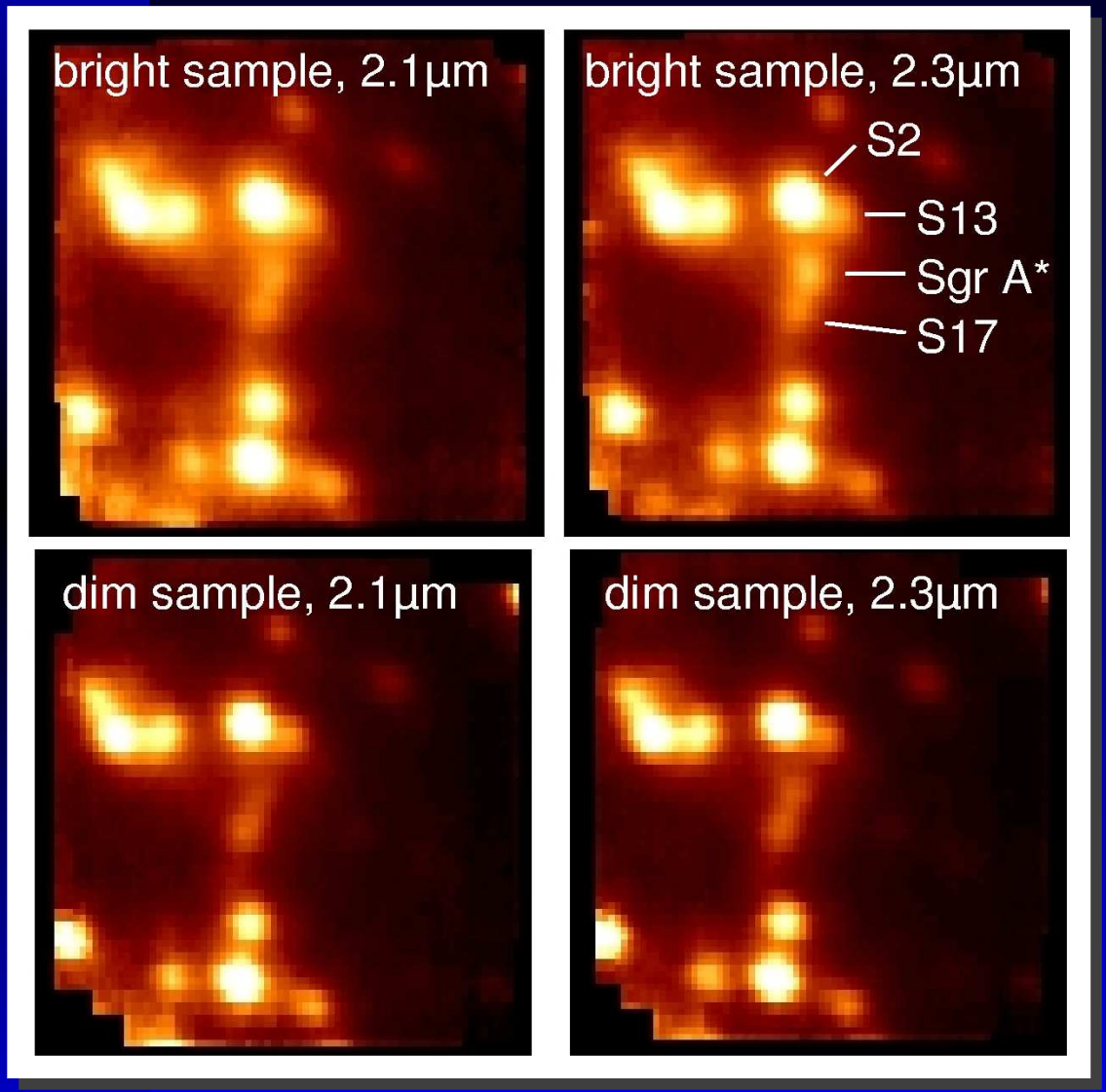




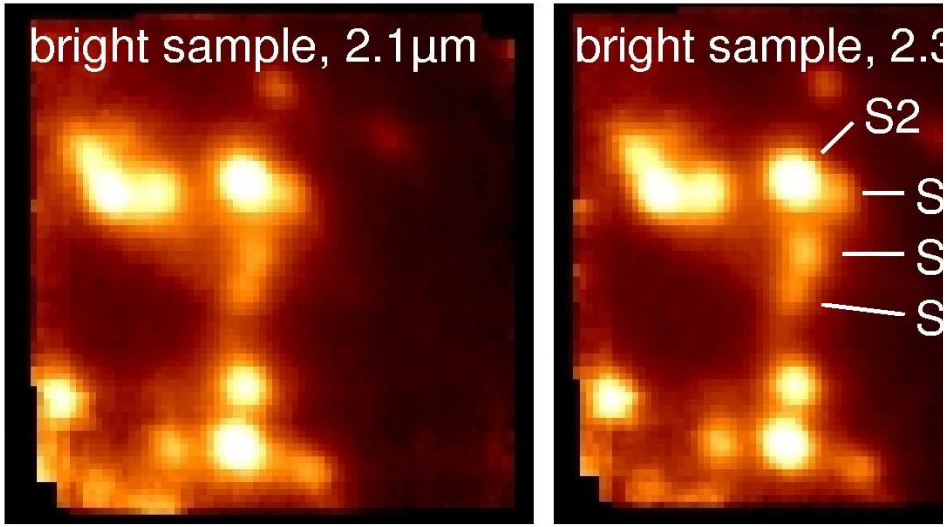
(Eisenhauer et al, 2005)

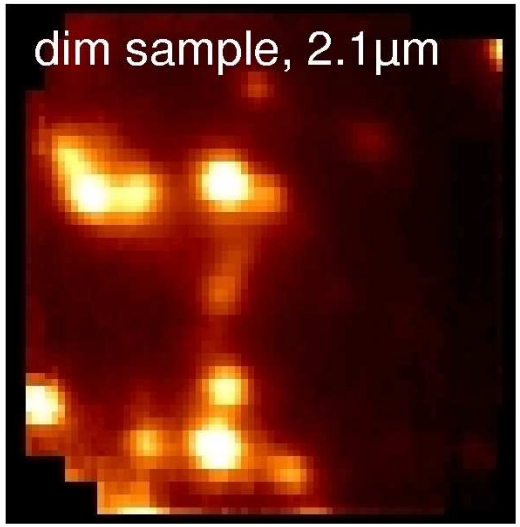
SINFONI caught a "good" flare under good seeing conditions

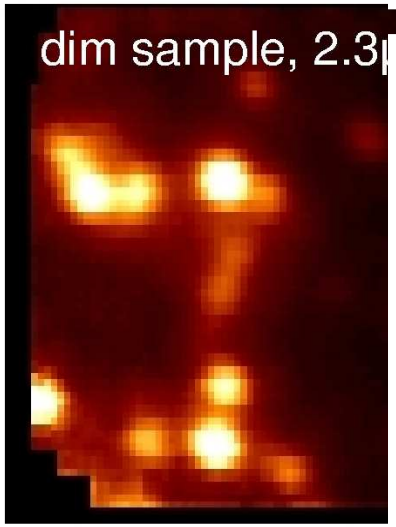


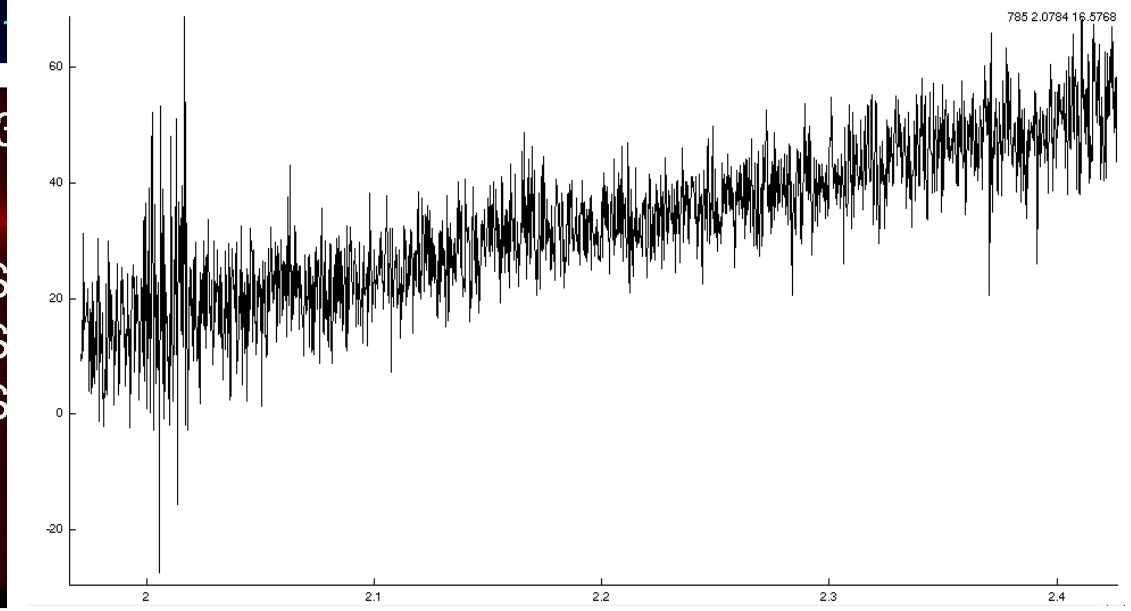
- $\simeq 4$ h;
- $0.5''$ seeing;
- coherence time: 3 ms;
- 12×5 min;
- 32×4 min;
- peak: 8 mJy;
- redder than stars.

SINFONI caught a “good” flare under good seeing conditions

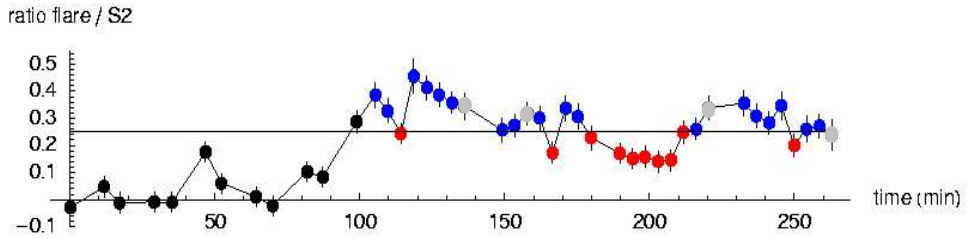






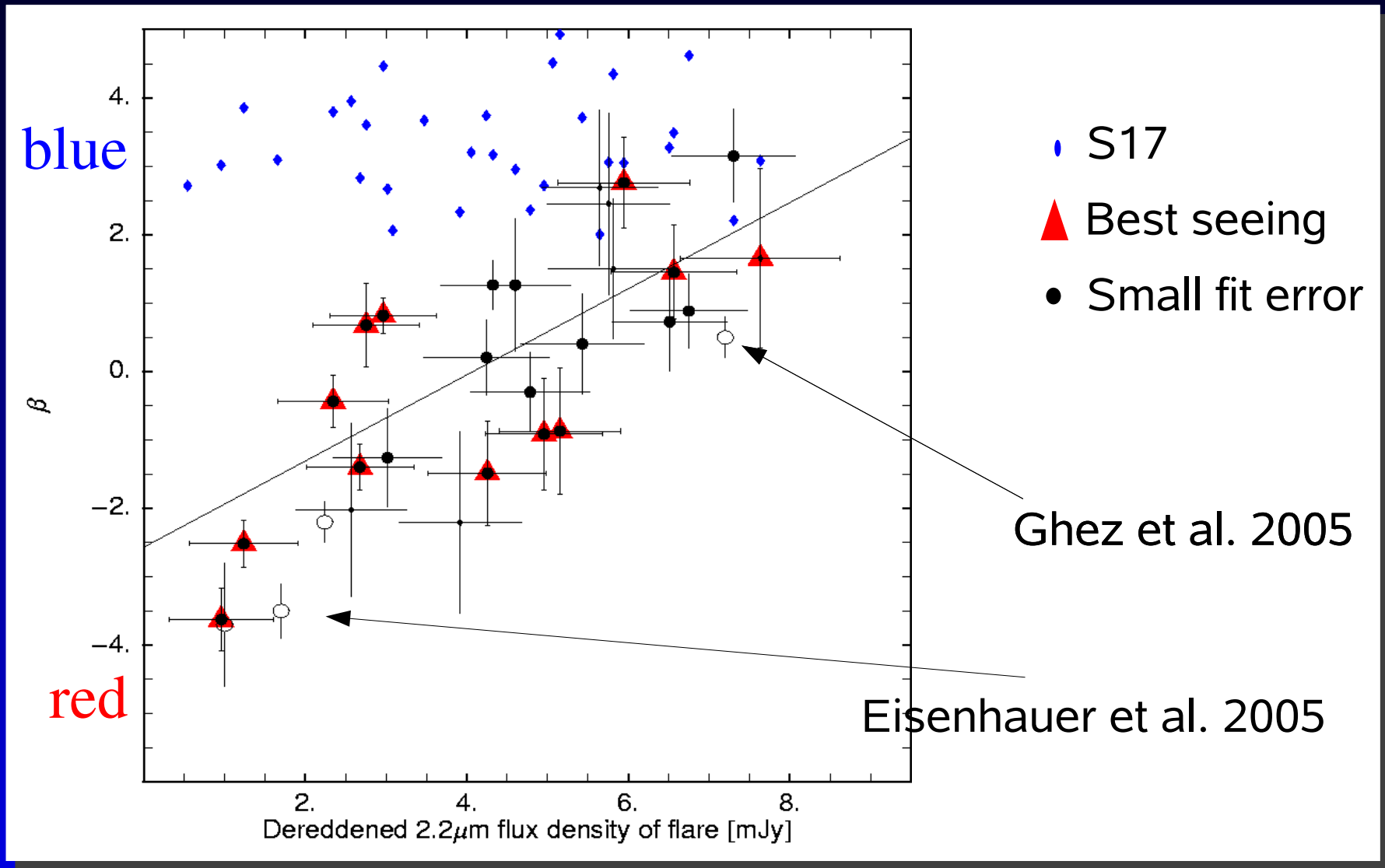


Lightcurve shows significant variations



- preflare
- bright

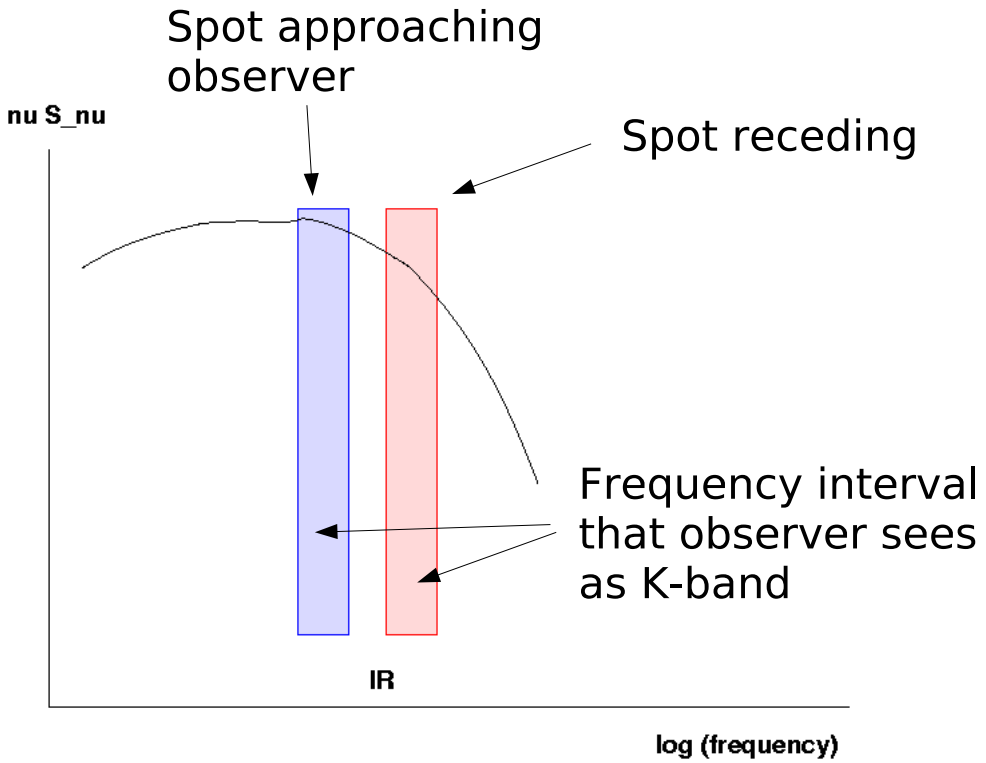
Intra-flare flux/colour correlation



Gillessen et al. 2006 (astro-ph/0511302)

Intra-flare flux/colour correlation

Concave spectrum + Doppler effect



t seeing

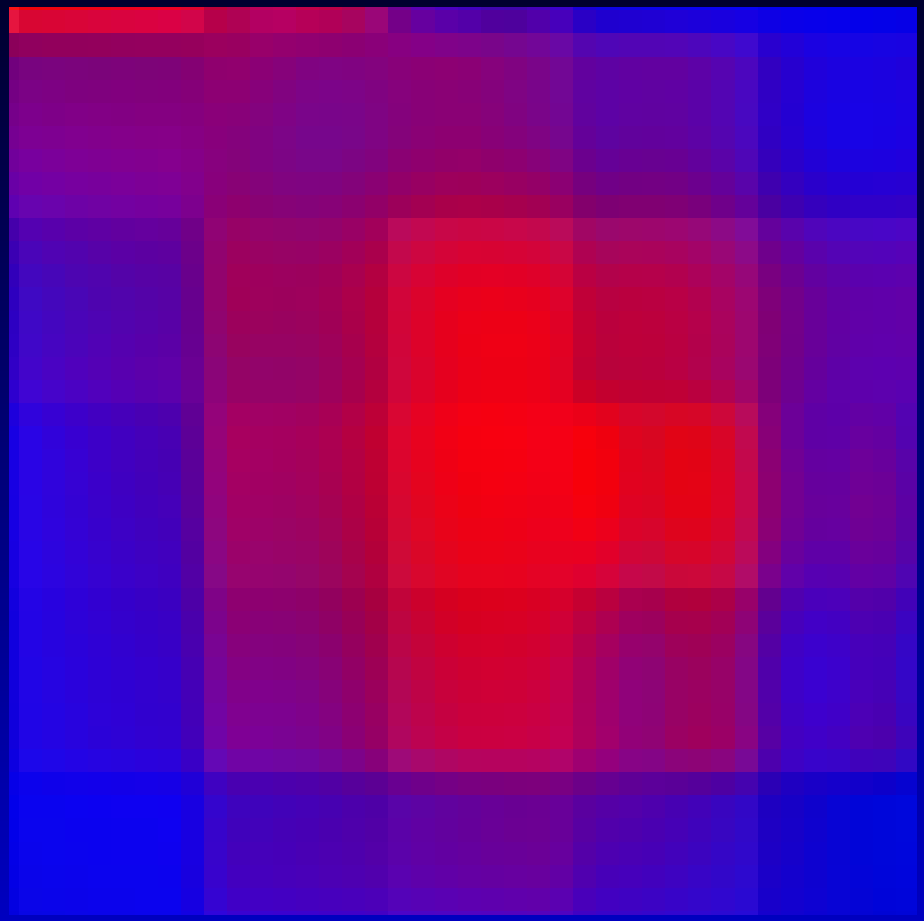
all fit error

t al. 2005

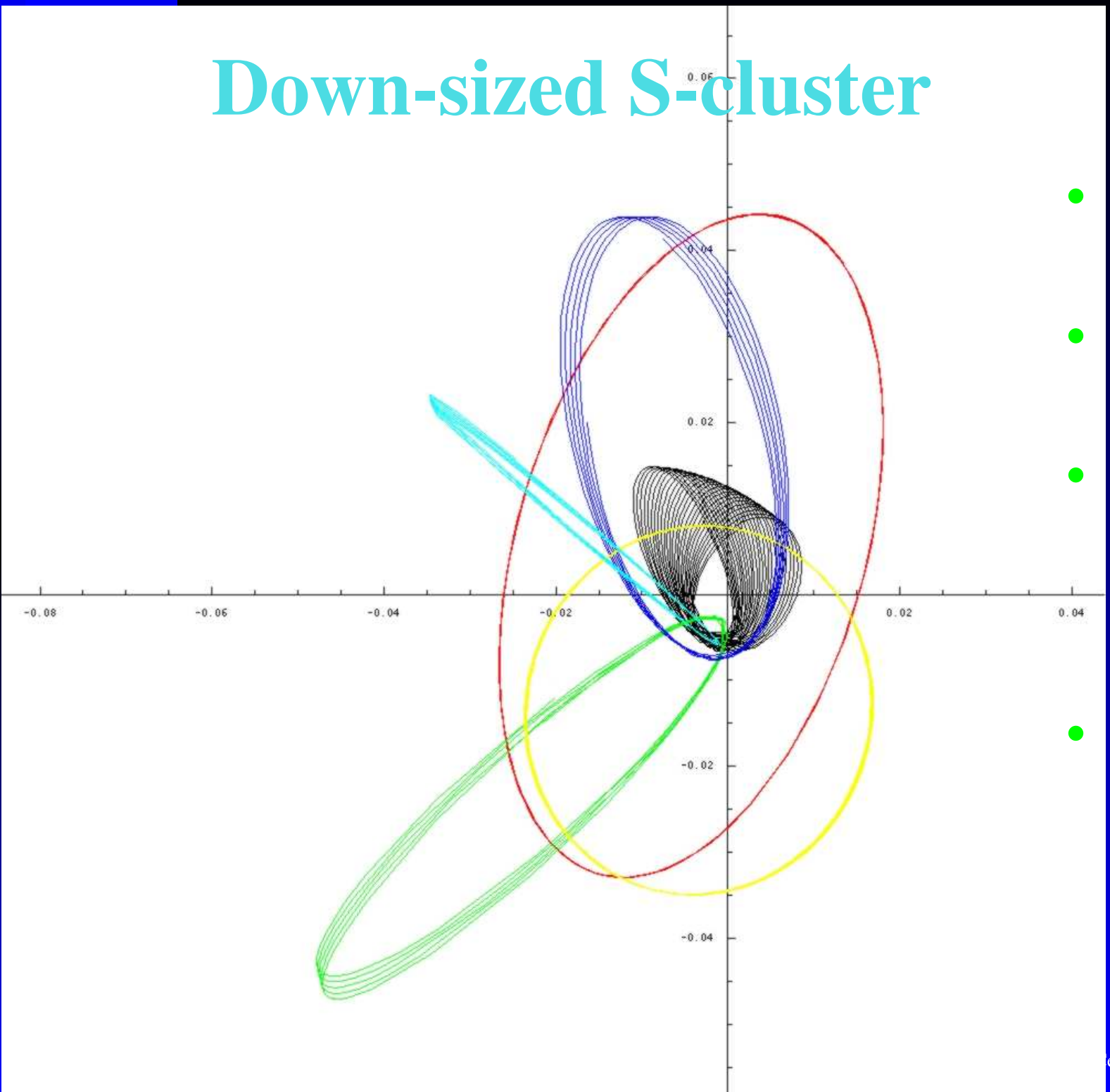
al. 2005

Gillessen et al. 2006 (astro-ph/0511302)

$25 \text{ mas} = 3000\ R_{\rm S}$

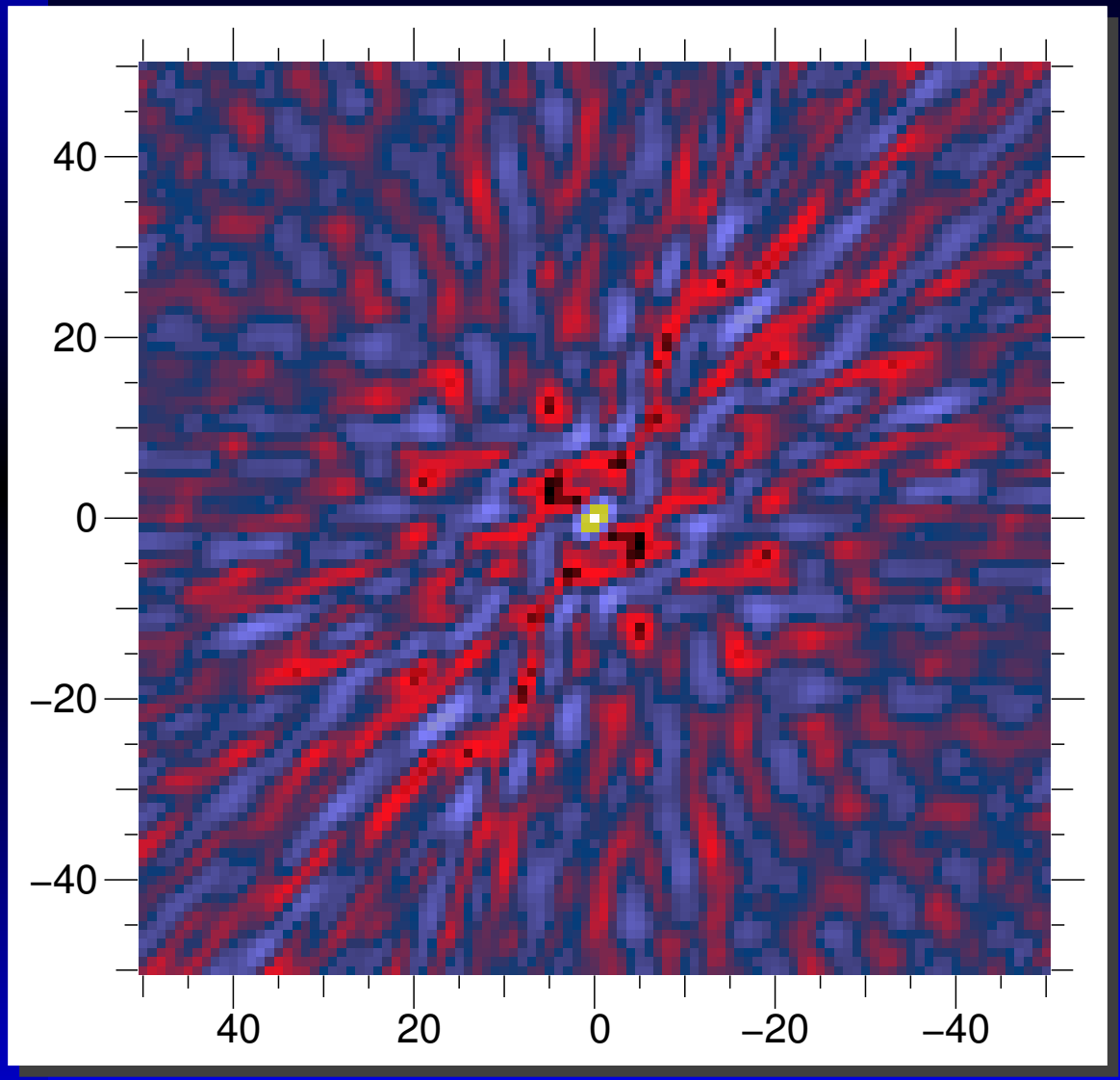


Down-sized S-cluster



- Short orbital periods ($\lesssim 1$ yr);
- fast precession (validate GR);
- probe density profile closer to SgrA* (dark matter?);
- get the mass included within $100\ R_{\rm S}$.

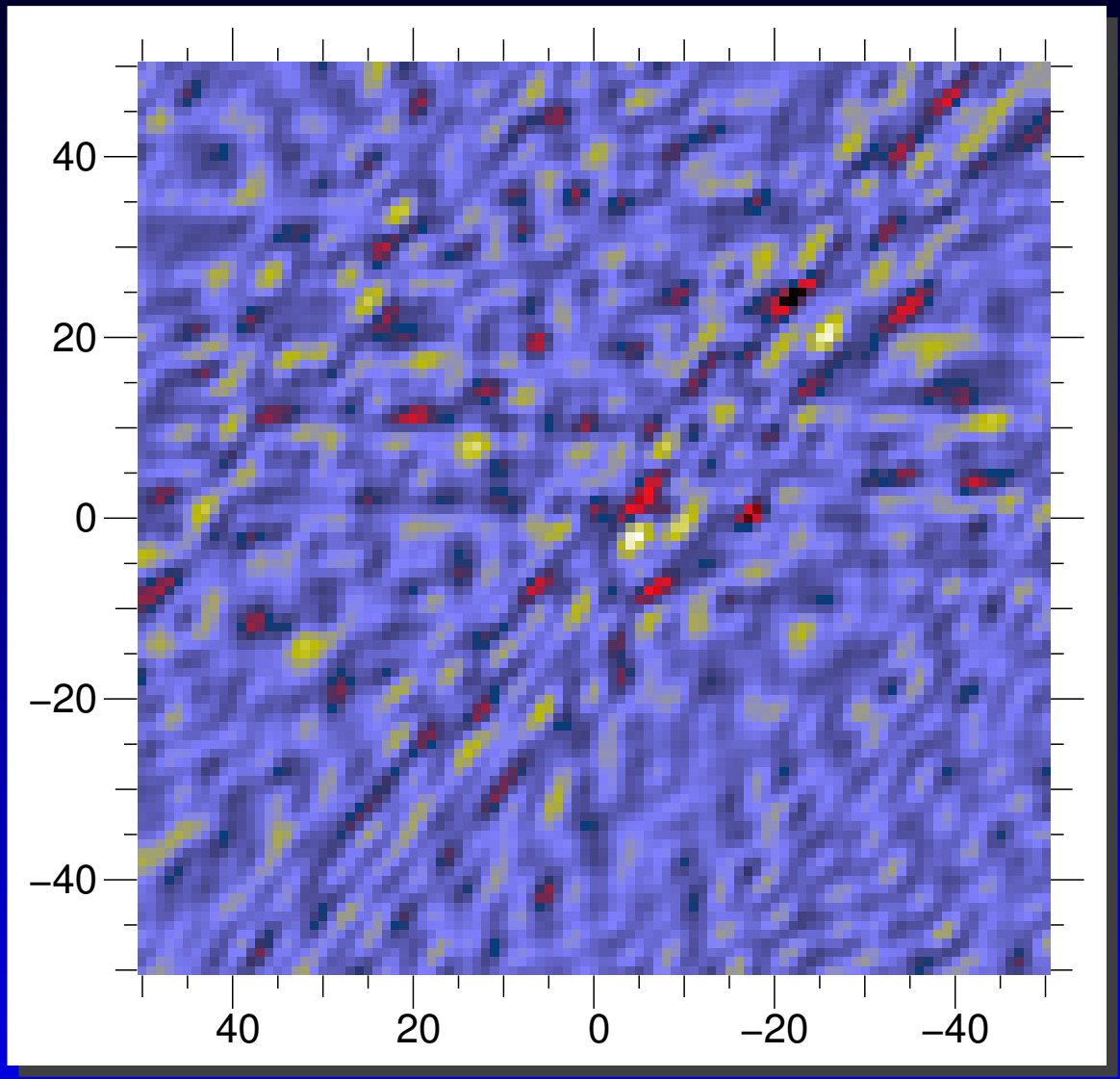
PSF: 3 (V, φ) sets, K-band, 4 UTs



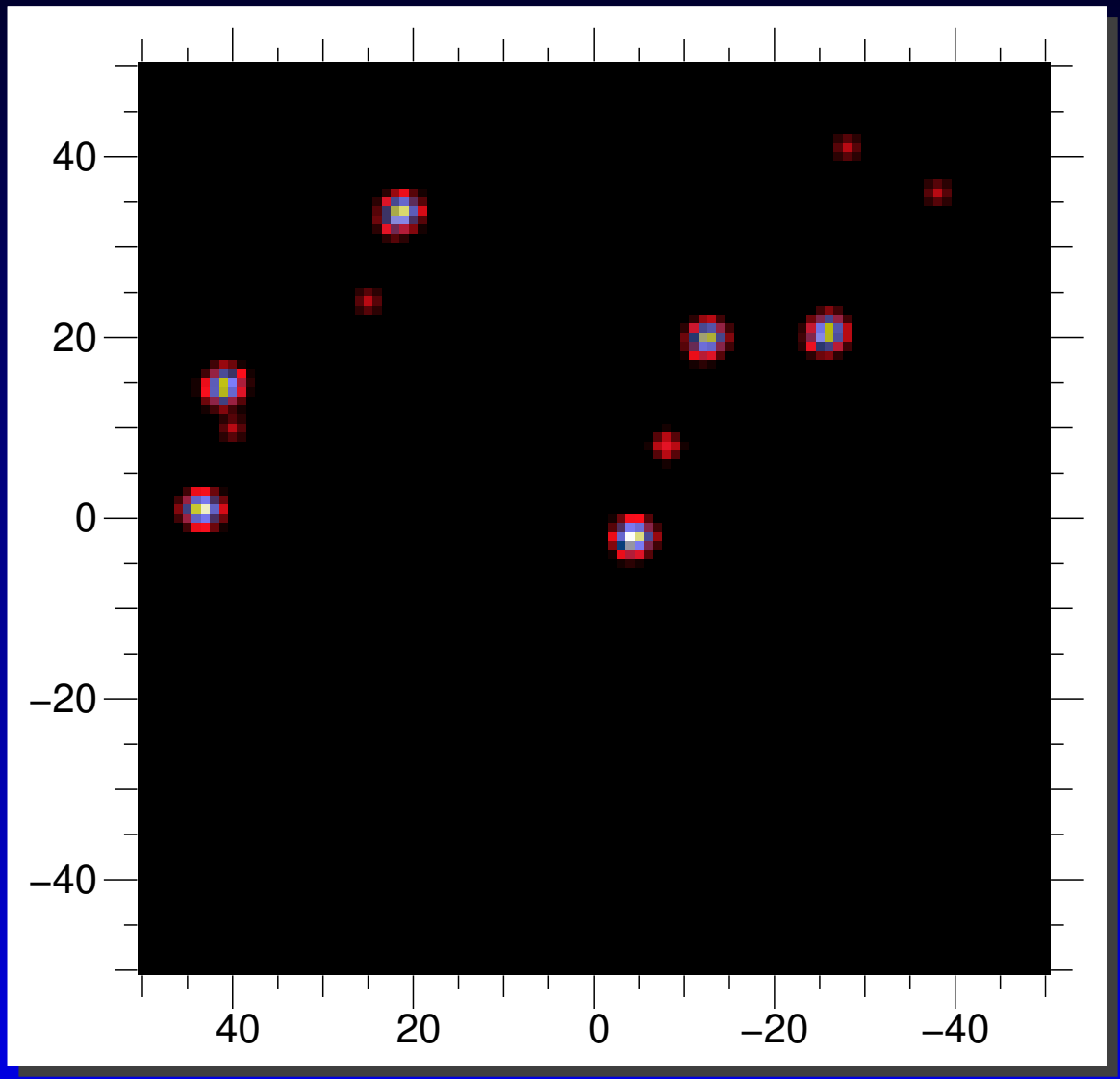
Assumed constraints:

- 3 hours per obs.;
- 5 sp. elmnts from 2.0 to 2.4 microns;
- dynamic range: $\simeq 1$ mag;
- error on visibility: 1%;
- error on phase: 2°.

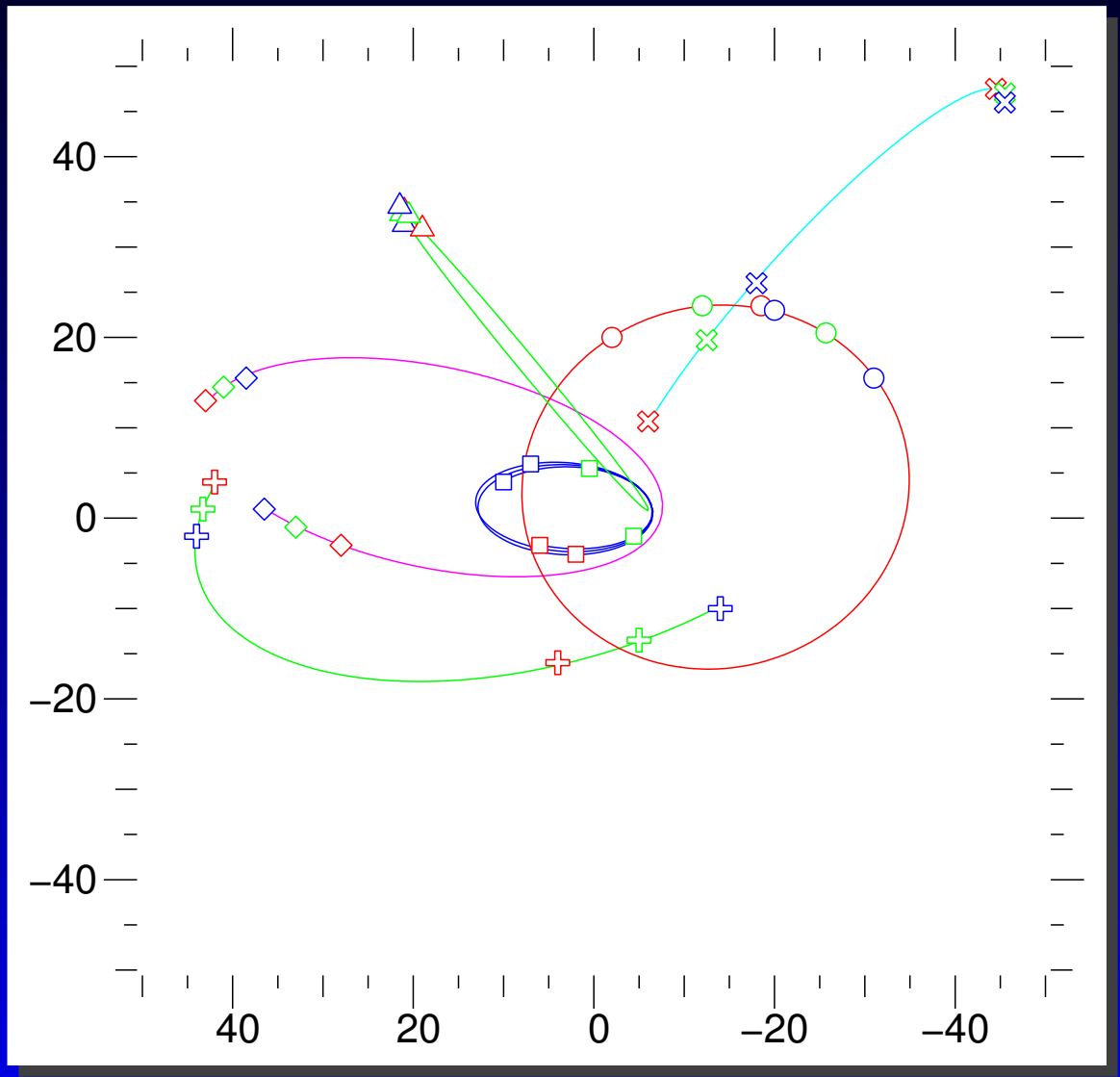
Synthesised image



Synthesised image, “cleaned”

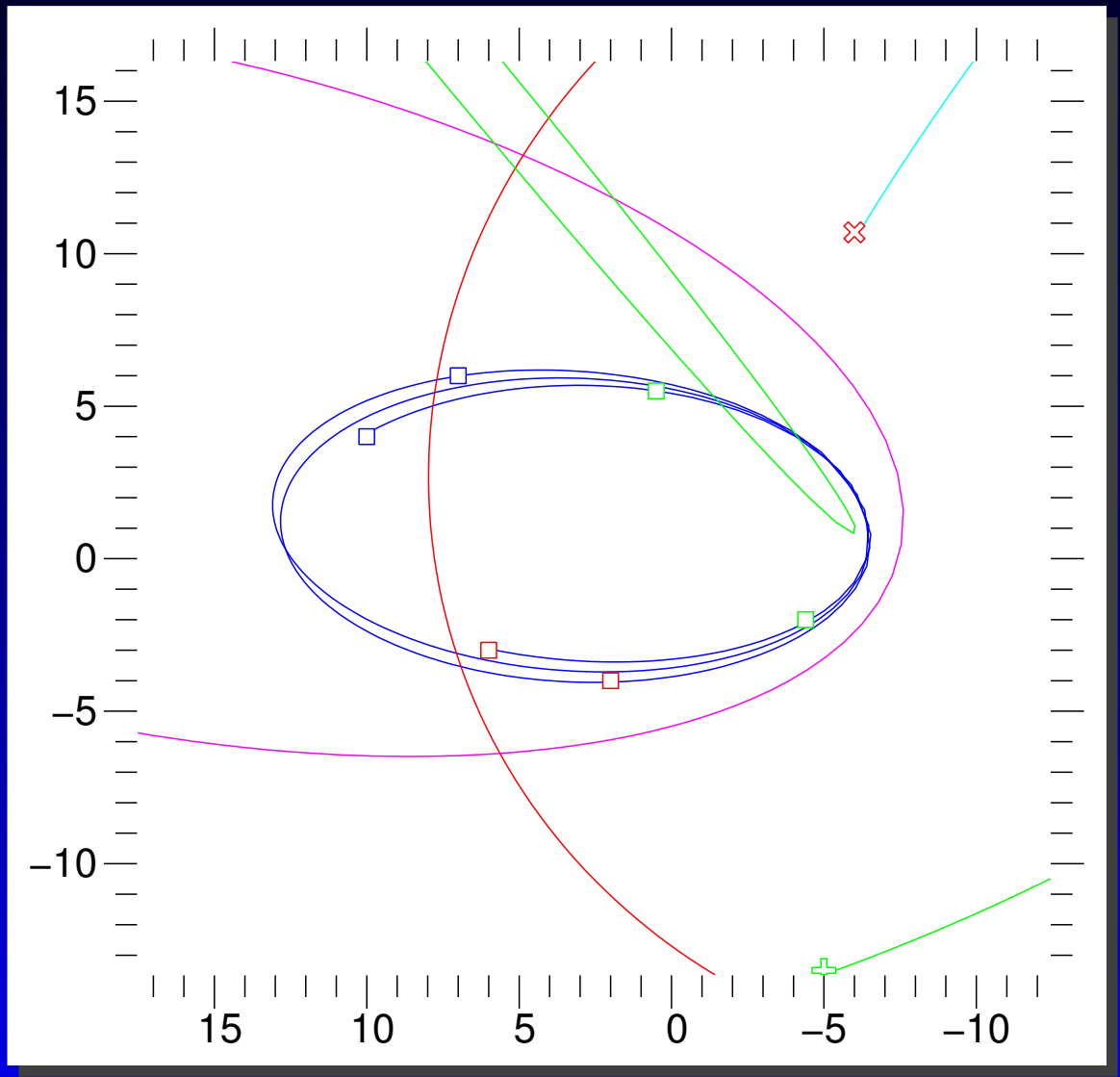


2 seasons proper motion



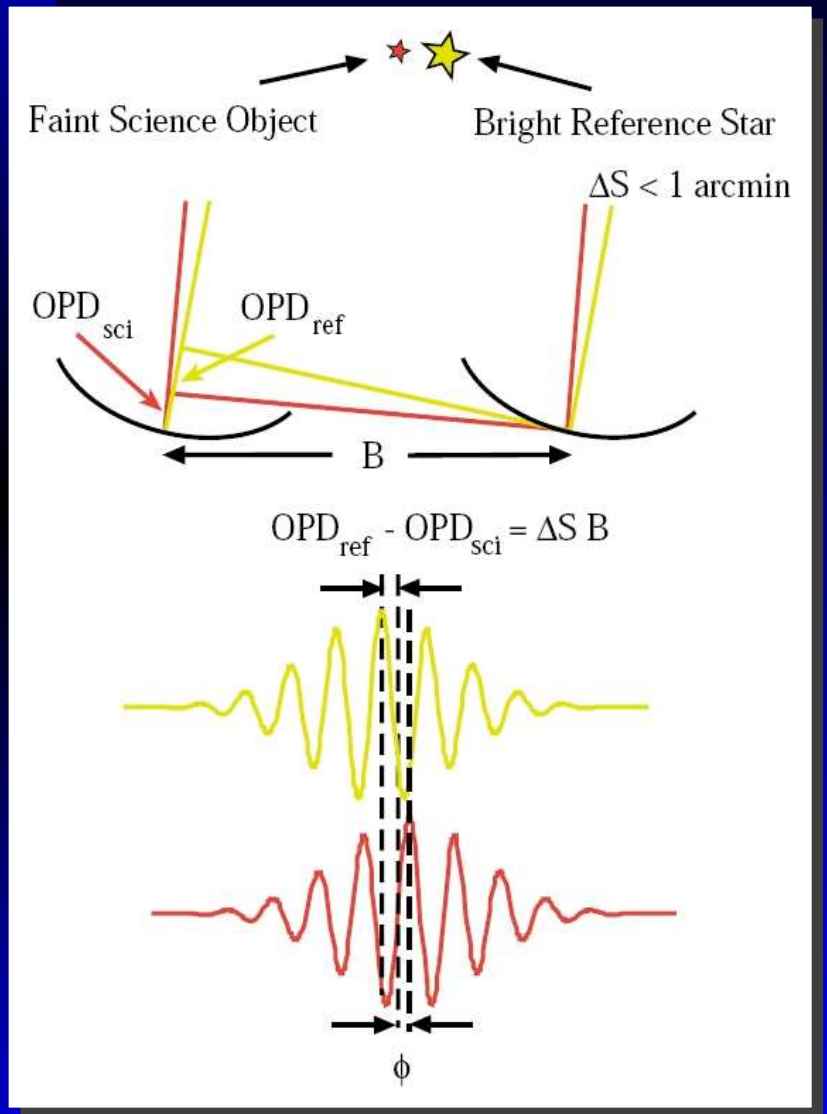
Crude measured astrometry + input orbits

2 seasons proper motion



Crude measured astrometry + input orbits

Imaging @ 1 mas, astrometry @ 10 μas



PRIMA/GRAVITY will offer astrometry with μas-accuracy:

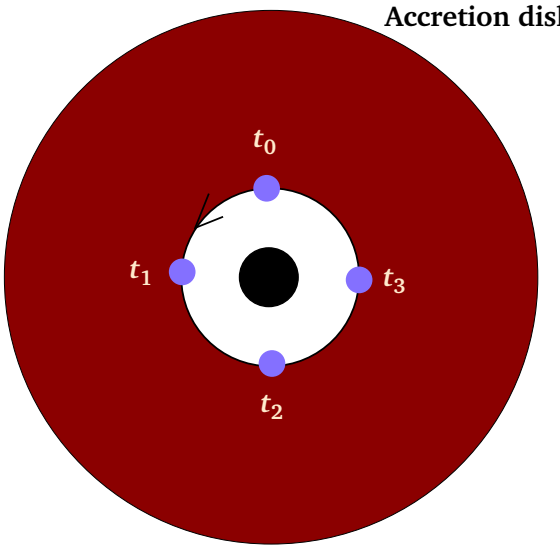
- $B = 100$-m baseline;
- reference–science objects distance: $\Theta = 1.2''$;

$\Rightarrow$ 1 R_S = 10 μas accuracy in $t = 65$ s integration time!

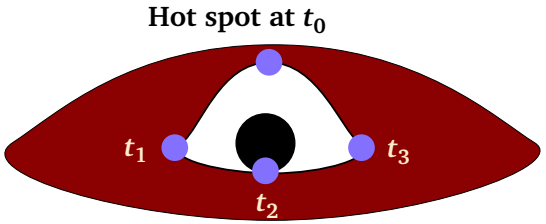
(Glindemann & Lévêque 2000)

Orbitting blob model

Hot spot on the last stable orbit



Last stable orbit seen from above

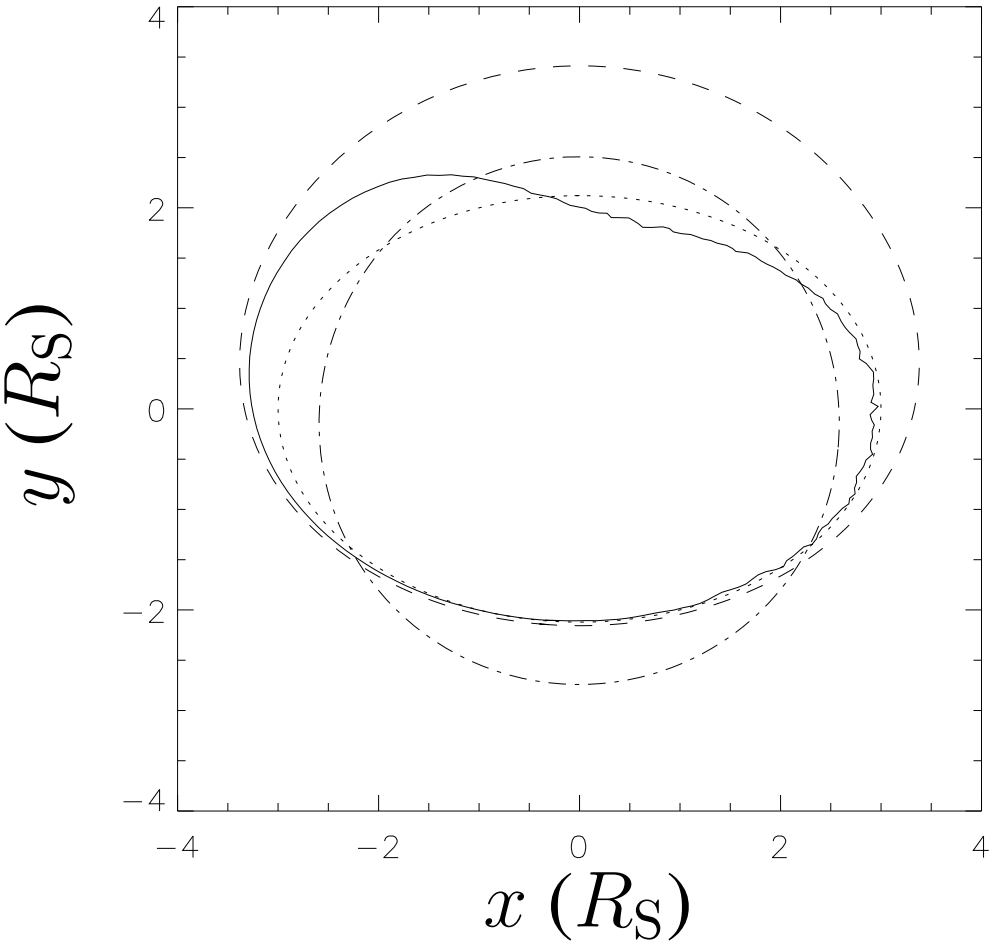


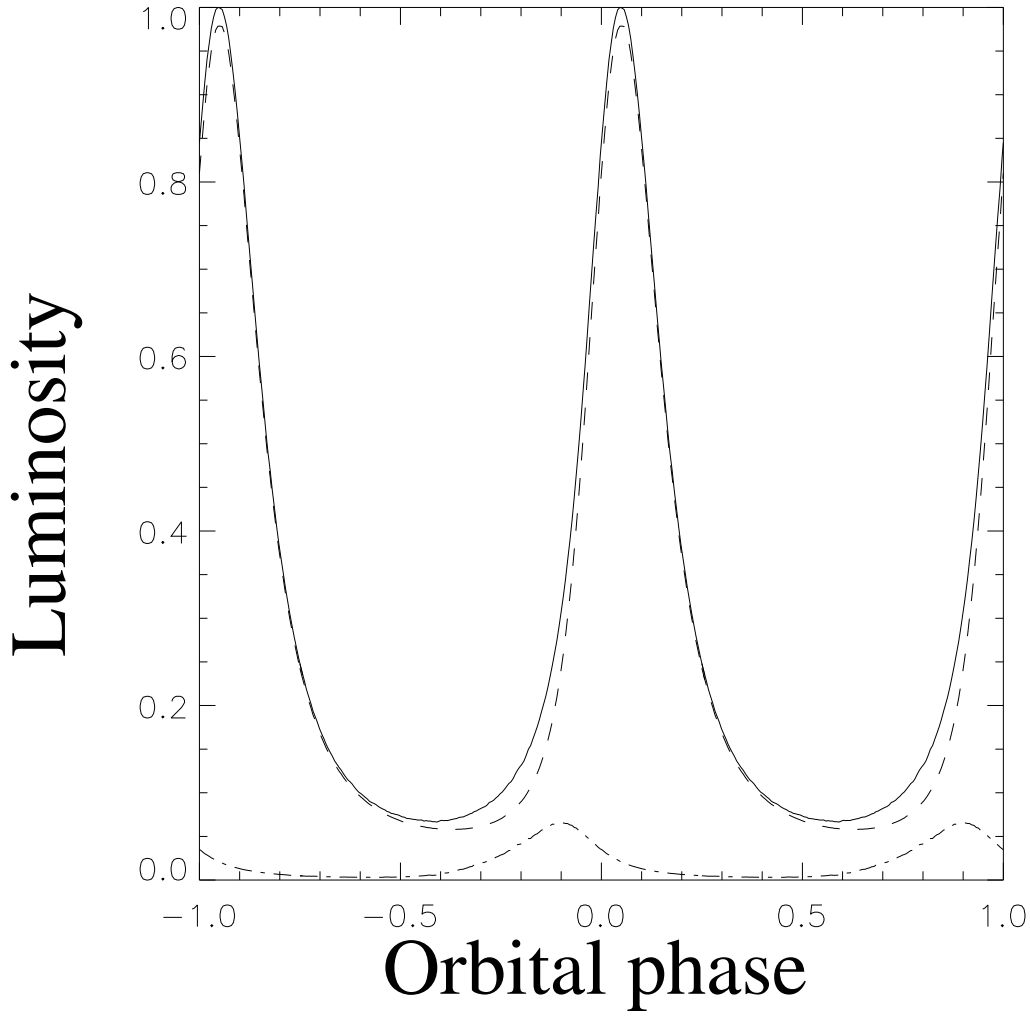
Last stable orbit seen at high inclination

Motion of the flare =
orbital motion of the clump

on average = 0

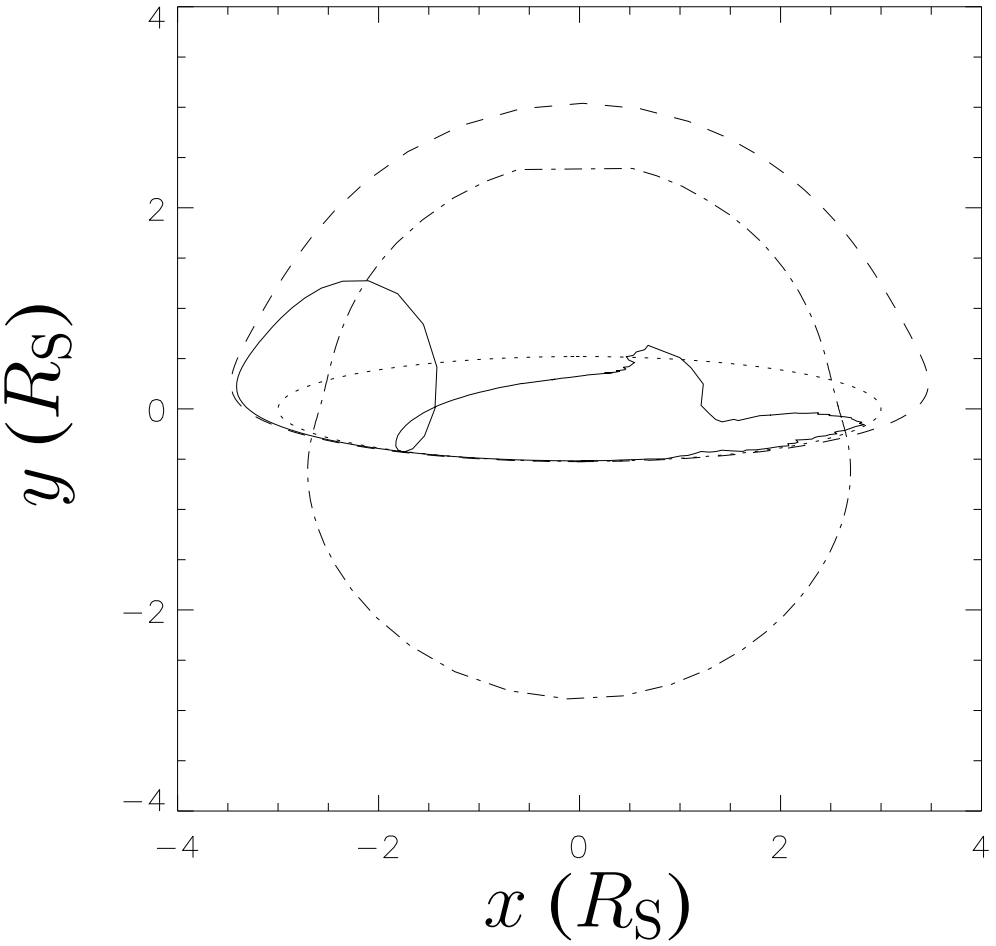
Astrometric model, $i = 45°$ $\quad \nu L_\nu \propto \nu^0$

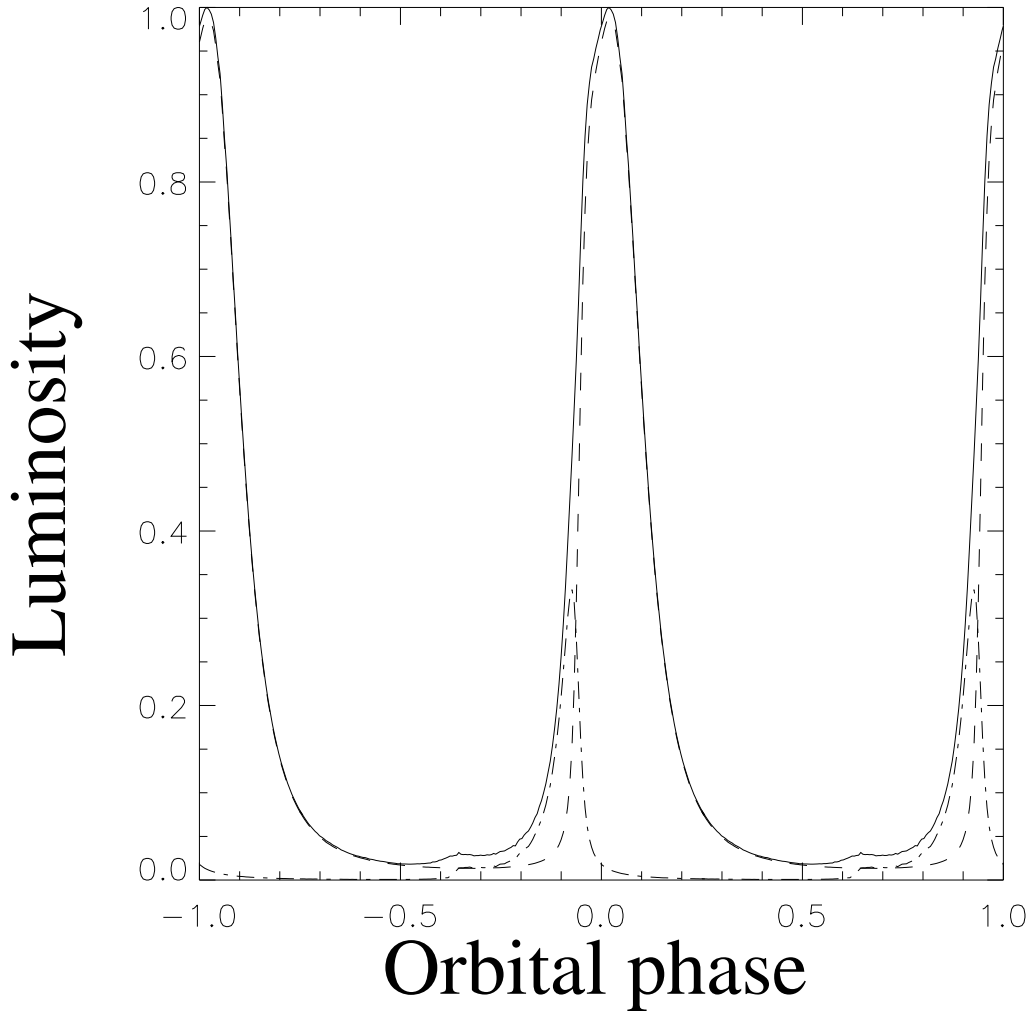




Global centroid, lensing + beaming

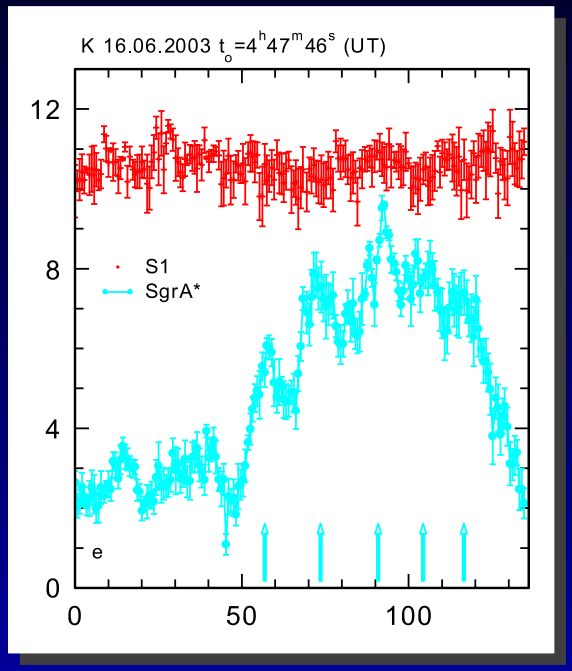
Astrometric model, $i = 80°$ $\nu L_\nu \propto \nu^0$





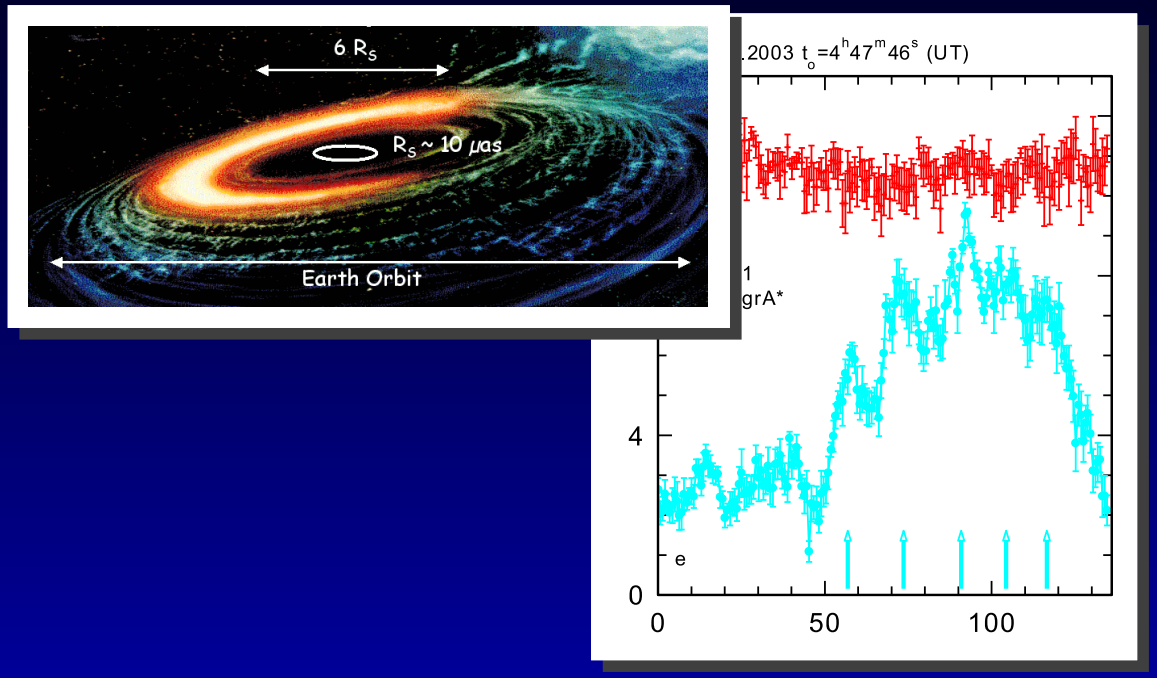
Global centroid, lensing + beaming

The light-curves don’t fit



- (Overall raise and decay;)
- low contrast;
- time-variable contrast;

The light-curves don't fit



- (Overall raise and decay;)
- low contrast;
- time-variable contrast;

$\Rightarrow$ extended component.

On flares

- 10 μas astrometry $\Rightarrow$ nature of flares;
- lightcurves of flares consistent with shearing hot spot on LSO;
- in that case, astrometry $\Rightarrow$
  - parameters of the BH;
  - physical properties of inner disk;
  - constrain "BH" size to $\lesssim$ a few $R_{\rm S}$;
  - explore a totally untested regime of gravity;
  - probe spacetime at a few $R_{\rm S}$