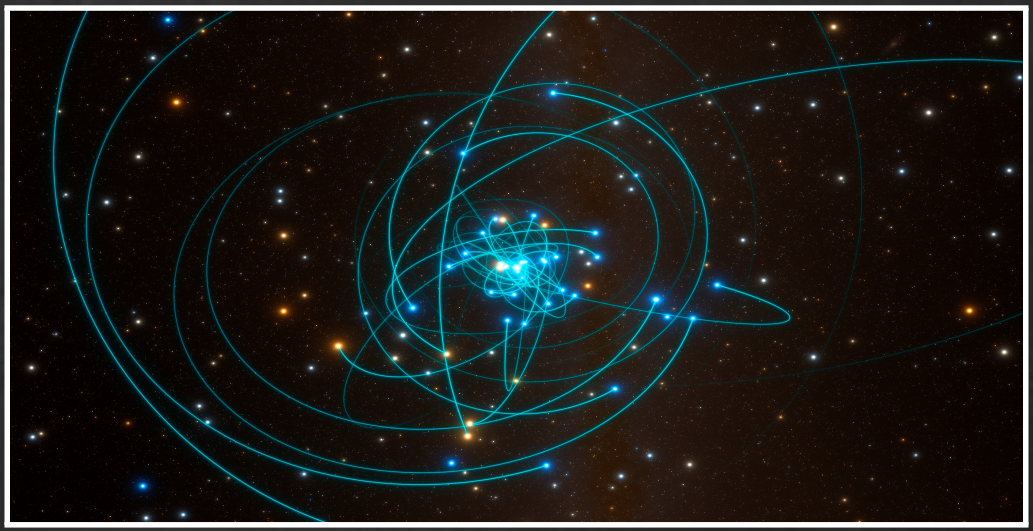
EPS Conference on Gravitation

GRAVITY: General Relativity in the Galactic Centre



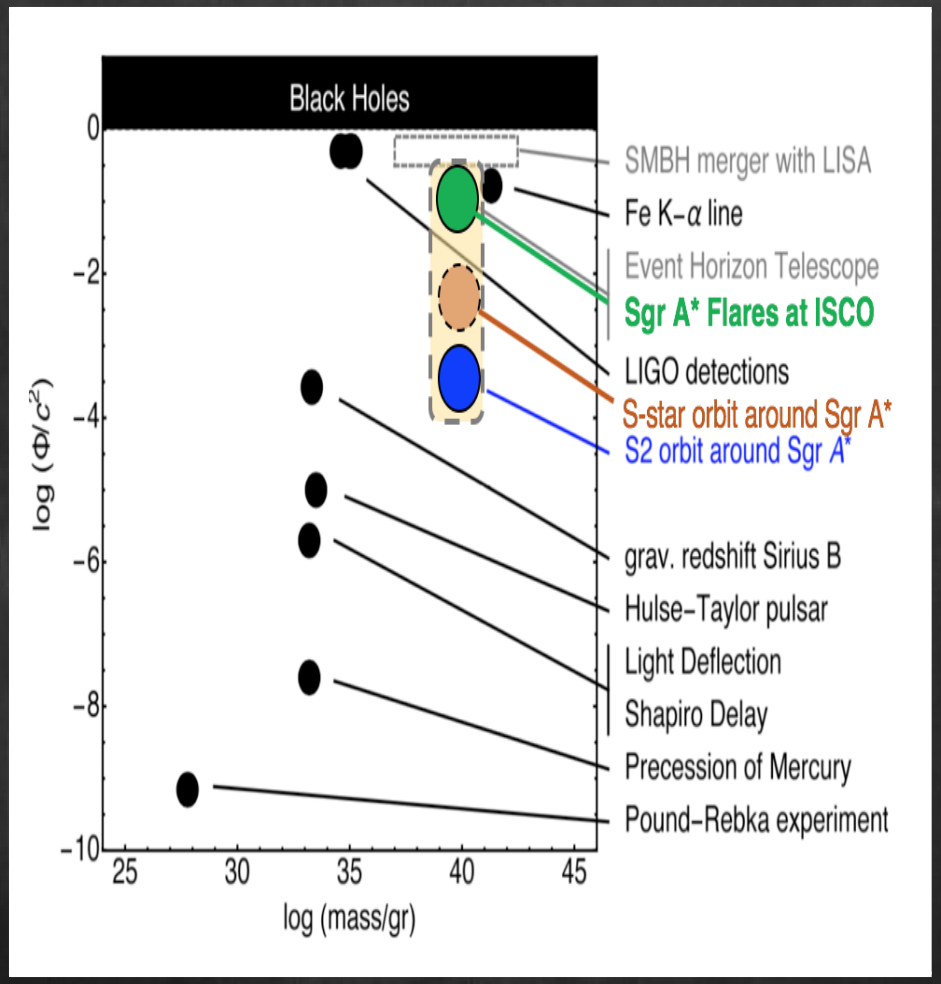
Odele Straub

MPI for Extraterrestrial Physics

Overview: research of gravity

WEAK	STRONG	
very weak field	∼∼∼ strong curvature ∼∼∼	
Lab, Earth	stationary	dynamical
Cosmology	XRB - NS, BH	mergers - NS, BH
weak field	∼∼∼ weak curvature ∼∼∼	
Solar system	AGN, SgrA*	EMRI
ms radio pulsars		

Tests of gravity



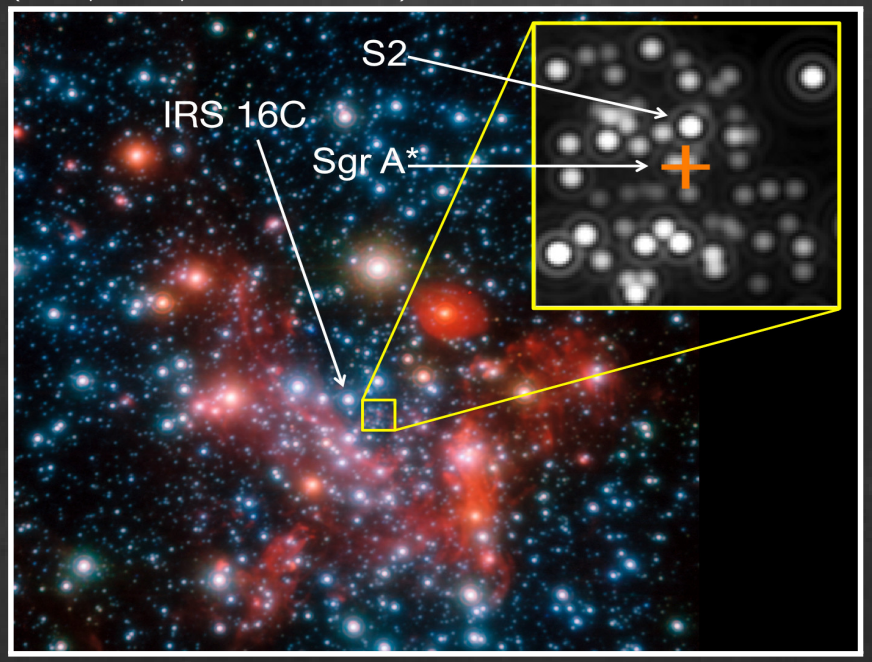
(after Psaltis 2008)

Einstein Equivalence Principle:

- ⋆ Weak EEP: universality of free fall ($m_i = m_g$)
- ⋆ *Local Position Invariance* of non-grav. measurements
- ⋆ Strong EEP: local Lorentz invariance (rotation, boost $\rightarrow$ physics is SR)
- ⋆ Falsifiability: Test alternative theories of gravity !

How to do GR in the GC?

(ESO/MPE/Gillessen et al)



(NASA/CXC/Amherst College/Haggard et al)

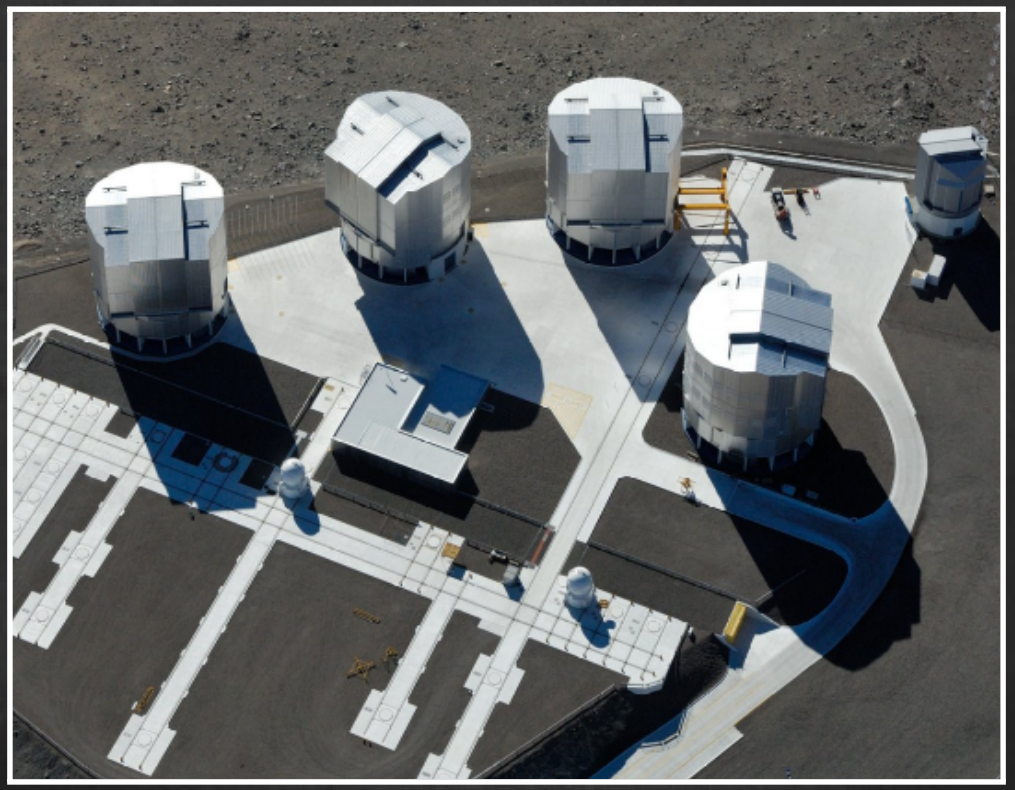
- ⋆ Sgr A*: biggest BH in the sky (d $\approx 53\mu$as for $a_* = 0$).
- ⋆ We want μas-astrometry on nearby stars and flares.

Requirements to test GR in the GC

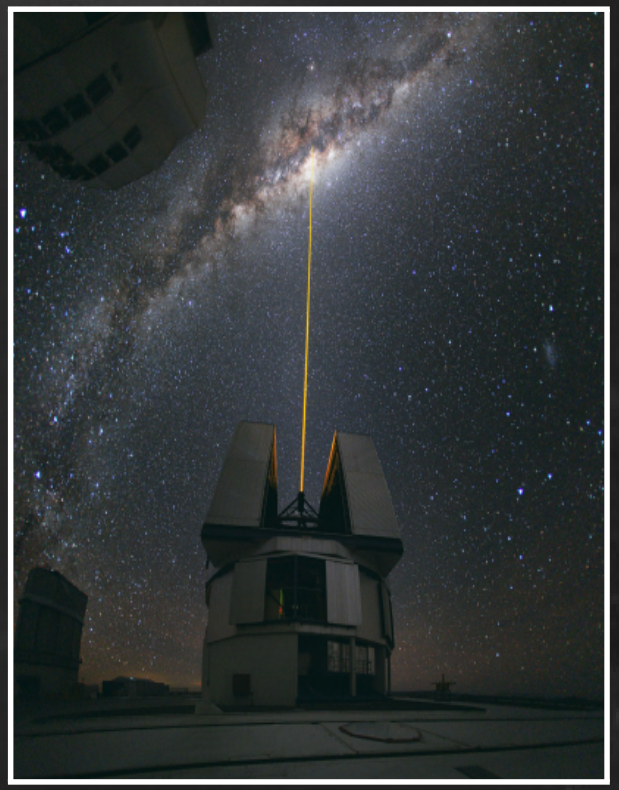
Which sizes are we talking about?
Microarcsecond astrometry,
i.e. like seeing a 1 Euro coin on the surface of the Moon

Requirements to test GR in the GC

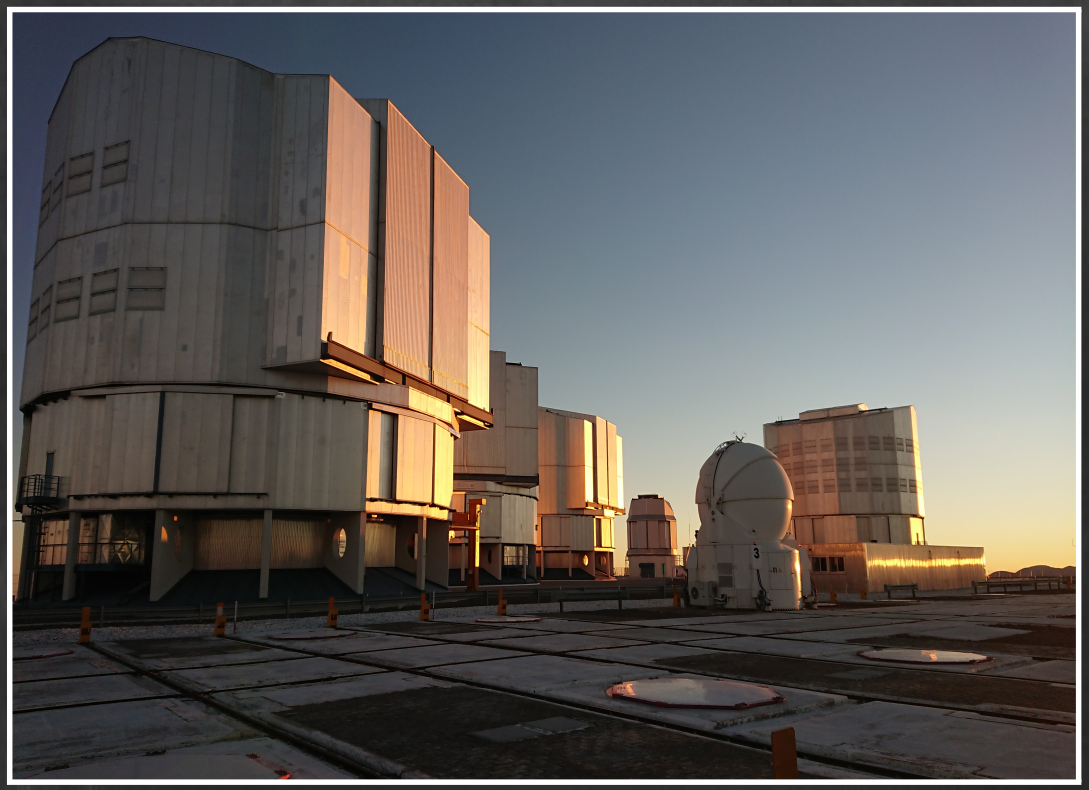
We need a really big telescope
and adaptive optics (correct atmospheric distortions)



(ESO)



What is GRAVITY?

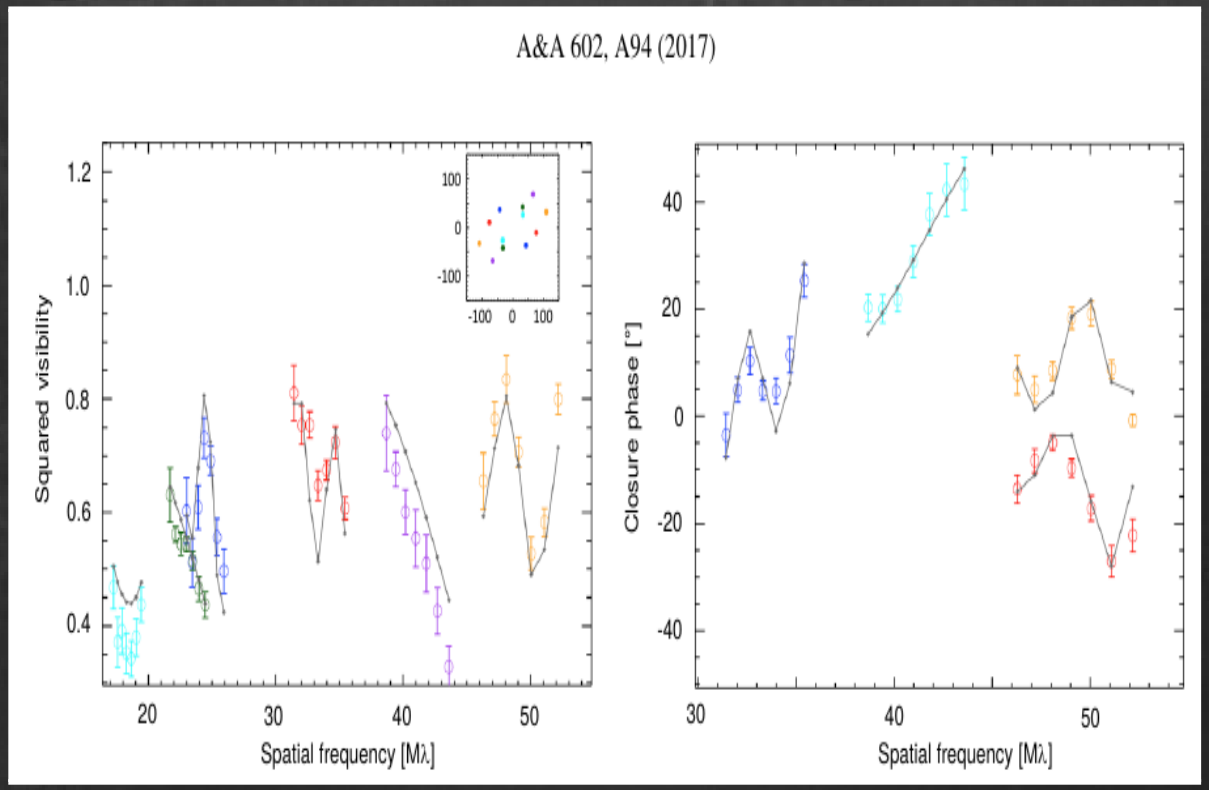


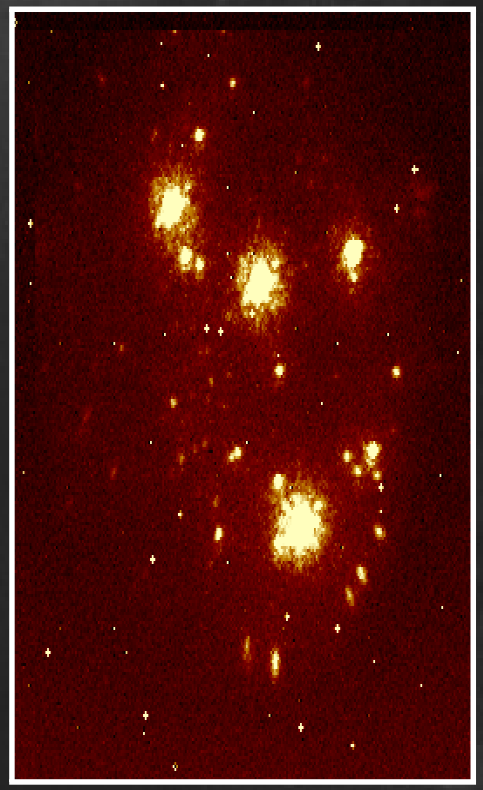
UTs (8.2m, AO) & ATs (1.8m no AO)

Interferometer at the VLT in Chile. Combines light of 4 telescopes. Spatial resolution of an equivalent telescope up to 130m in diameter. Works in the K-band, 2.0-2.4 μm.

(03/05/2018)

Visibility & phase: Sgr A*



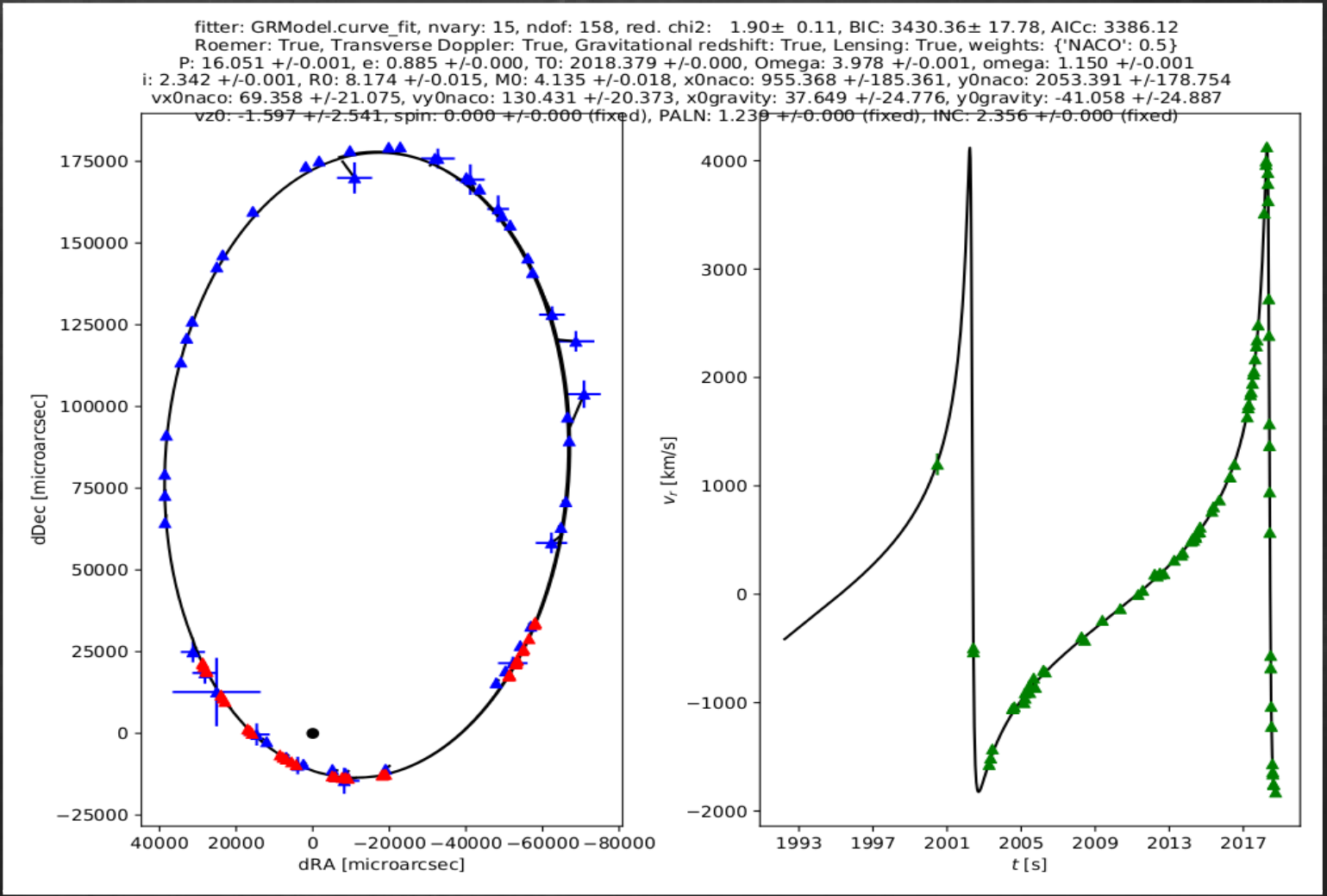


(GRAVITY, First Light paper, 2017) (H-band, UT1 acquisition camera, 07/08/2017)

Results (separation, fluxes) derived from fitting binary model to SgrA* - S2.

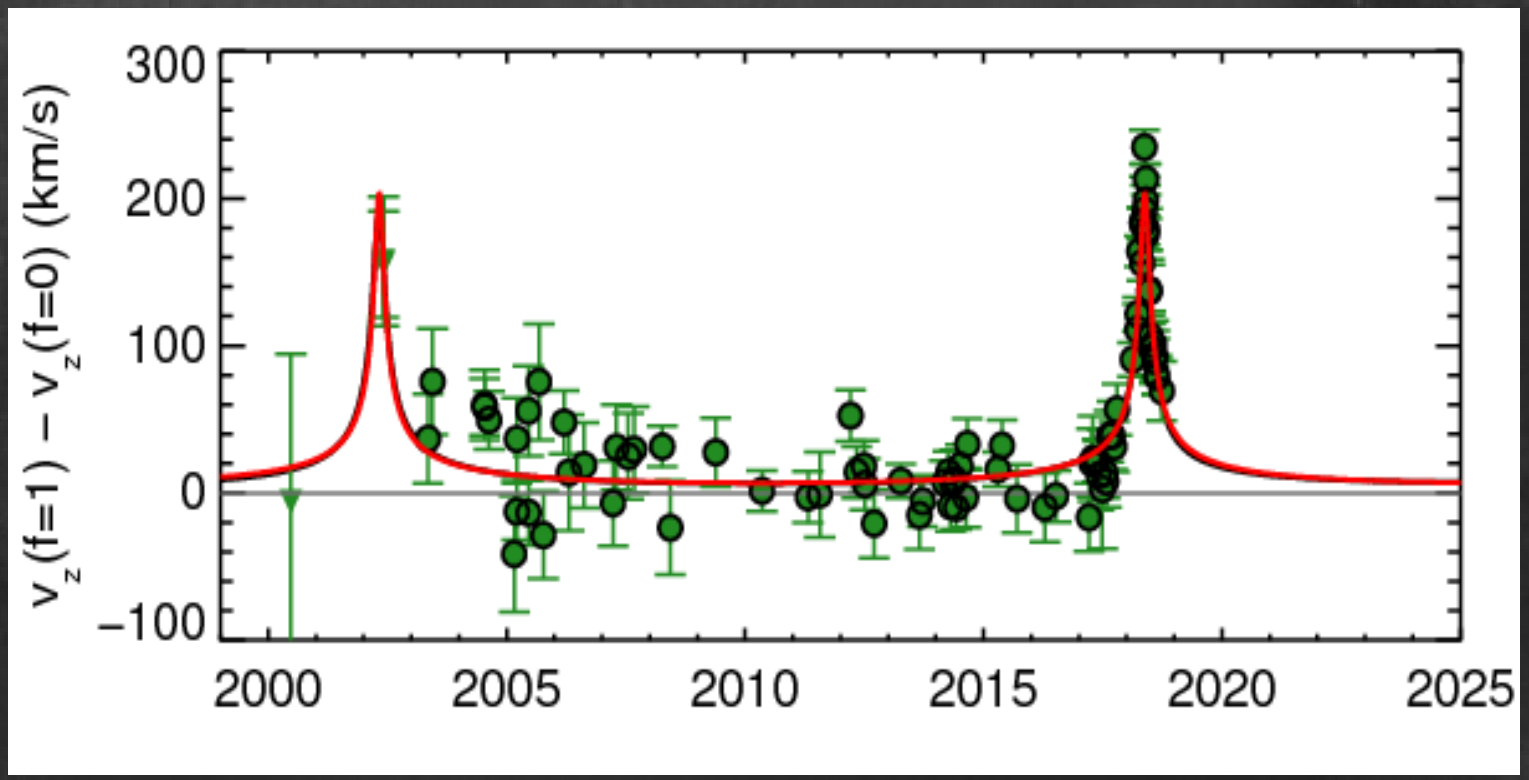
1. S2 orbit: position & velocity

(GRmodel fit - GYOTO ray-tracing code, public)



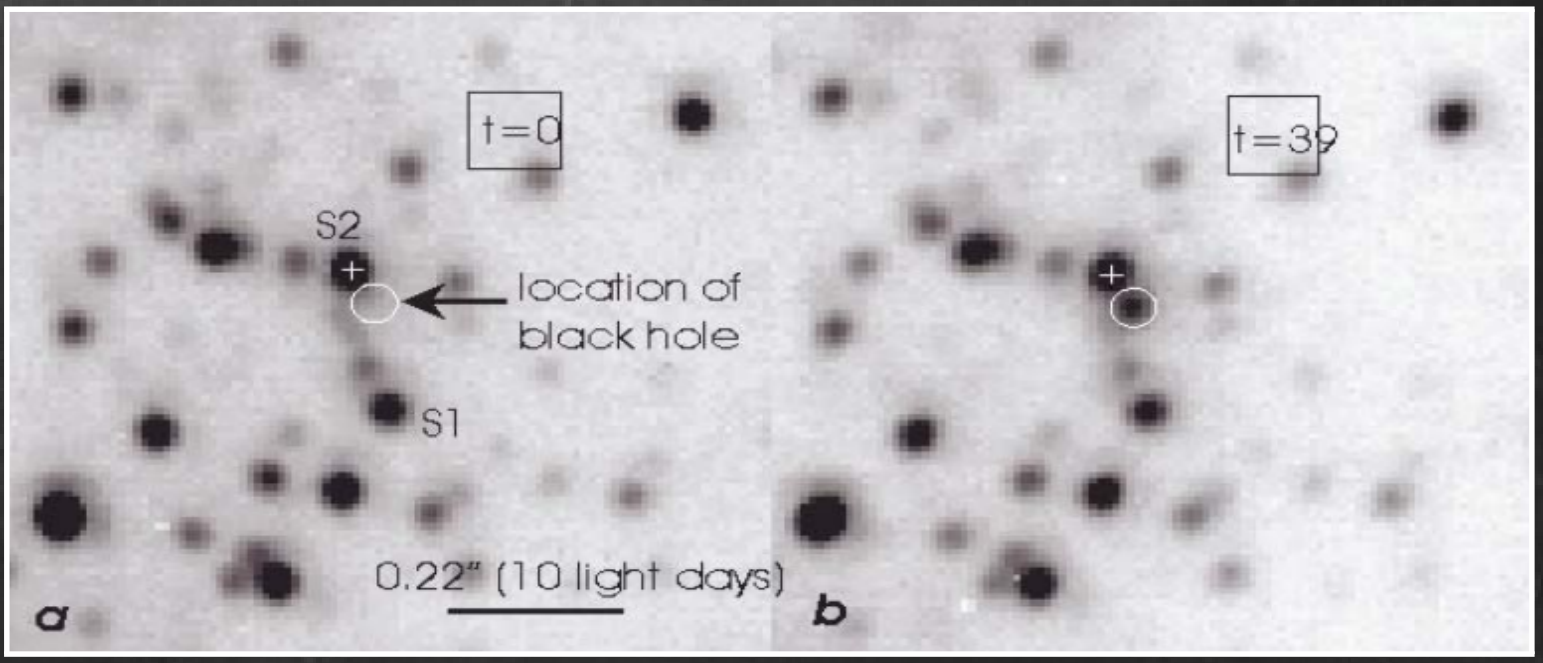
GRAVITY+NACO+SINFONI data

1. S2 orbit: Gravitational redshift



We subtract $V_{obs} - V_{Kepler}$ (green) and get
* NOT zero at the pericentre
* instead curve fits GR (red curve)

2. Sgr A* flares



(Genzel et al, 2003)

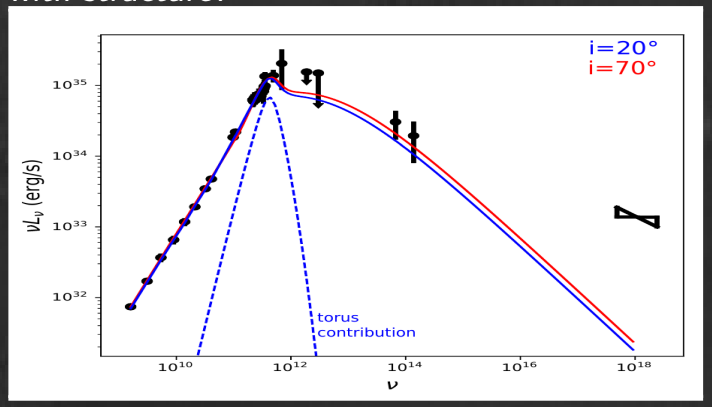
- ⋆ Flares are recurrent bursts of radiations in the IR & X-ray
- ⋆ models: inefficient flow with hot spot, jet, or red noise...
- ⋆ Why is this interesting? - variability (ca 40min) corresponds to near ISCO (strong gravity regime)

2. Sgr A* flares

Competing scenarios with evidence:

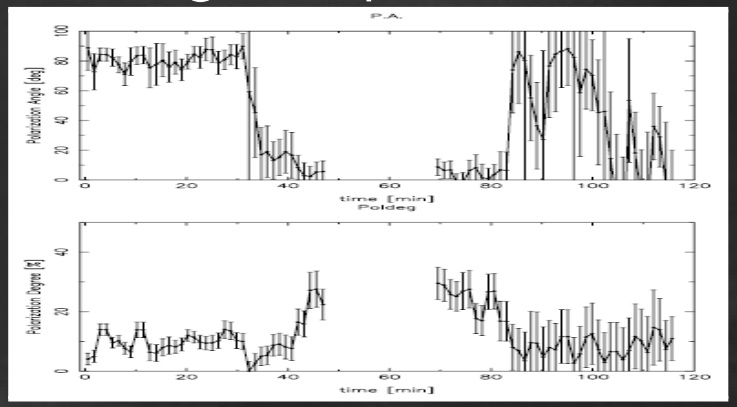
- ⋆ Jet

with structure?



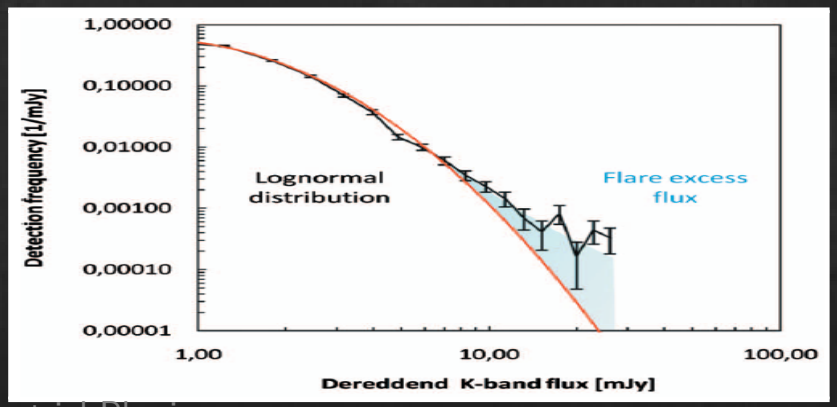
(stationary case, e.g. Vincent+2019)

- ⋆ Orbiting hot spot



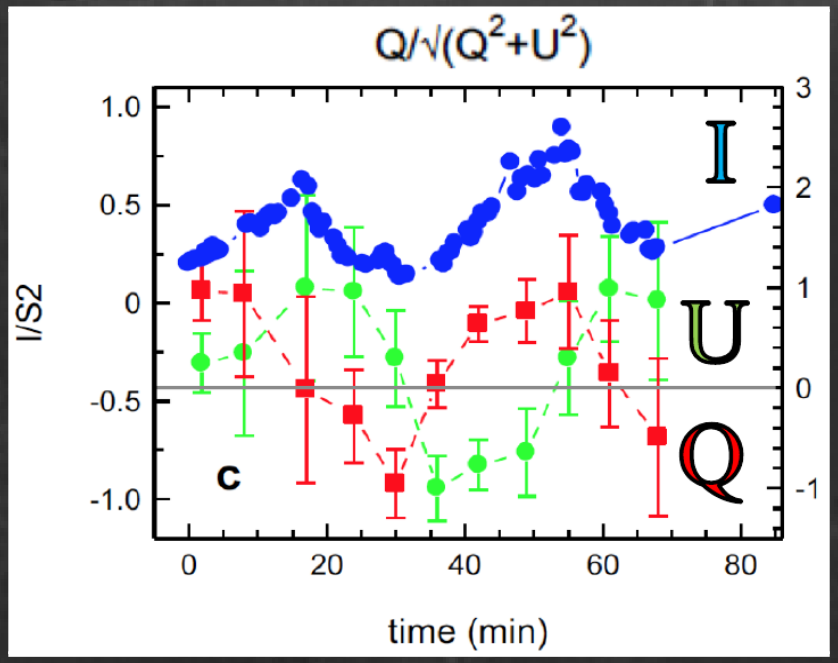
radio polarization (e.g. Trippe et al. 2007)

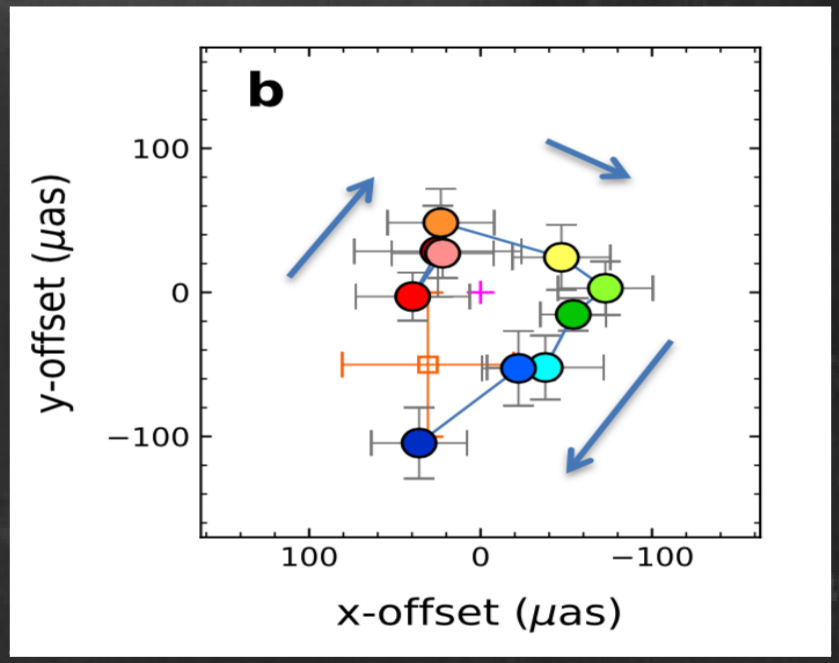
- ⋆ Statistical fluctuations



(log-normal flux, GRAVITY)

2. Sgr A* flares: polarized flux

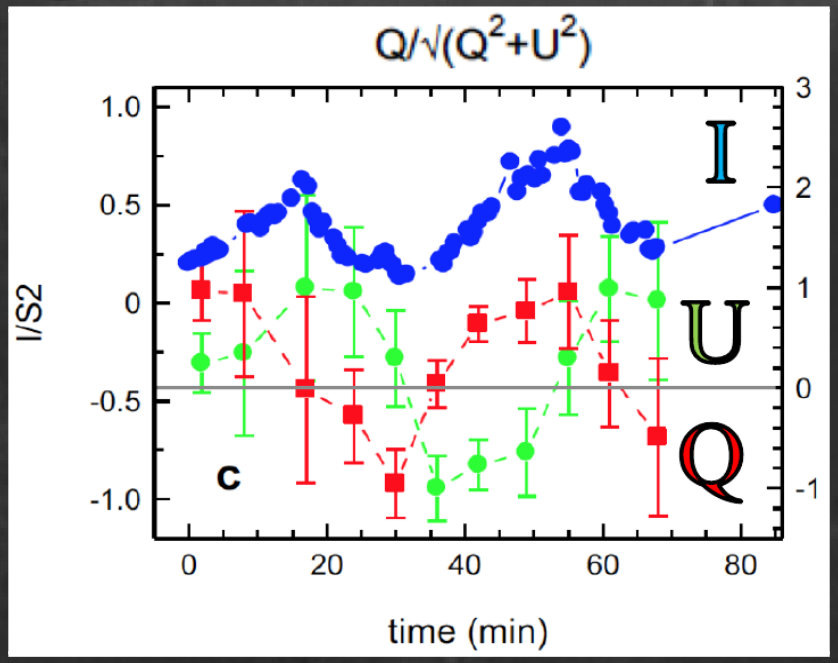


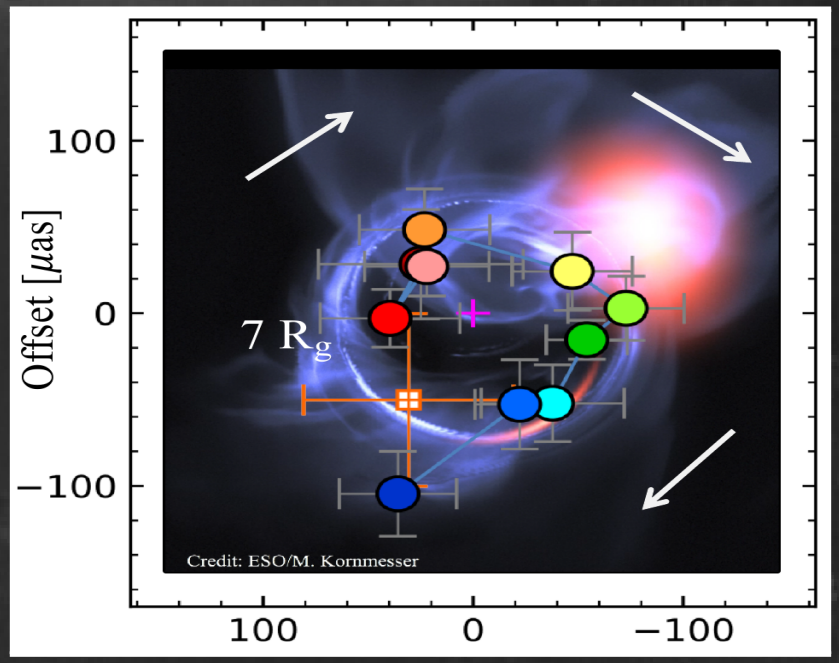


(GRAVITY 2018a,b)

Continuous positional and polarization changes consistent with a circular orbit at 6-10 Rg and a period of 30-65min, seen nearly face-on (or... face-on jet)

2. Sgr A* flares: polarized flux



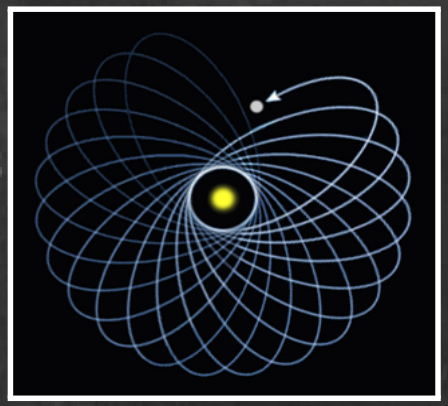


(GRAVITY 2018a,b)

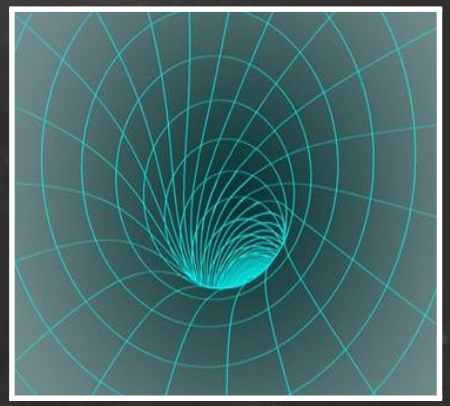
Continuous positional and polarization changes consistent with a circular orbit at 6-10 Rg and a period of 30-65min, seen nearly face-on (or... face-on jet)

Outlook: GC Laboratory

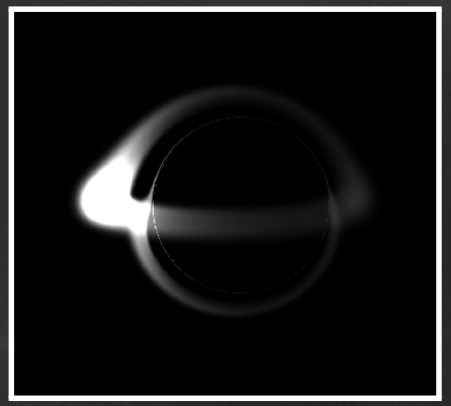
Understanding our home, the Milky Way, is the key to understanding the Universe.



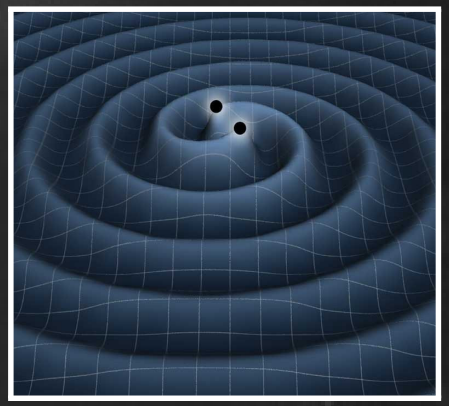
Pericenter advance of S2 orbit (GRAVITY)



BH spin via frame-dragging effect on (inner) stellar orbits (GRAVITY+)



BH silhouette (EHT)



GW mergers in the GC, EMRIs (LISA)

The GRAVITY collaboration

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Acknowledgements: Institutes

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8 ESO, Garching, Germany
9 ESO, Santiago, Chile
10 Observatoire de Genève, Université de Genève, Versoix, Switzerland
11 Onera - The French Aerospace Lab, Châtillon, France
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15 Sterrewacht Leiden, Leiden University, Leiden, The Netherlands
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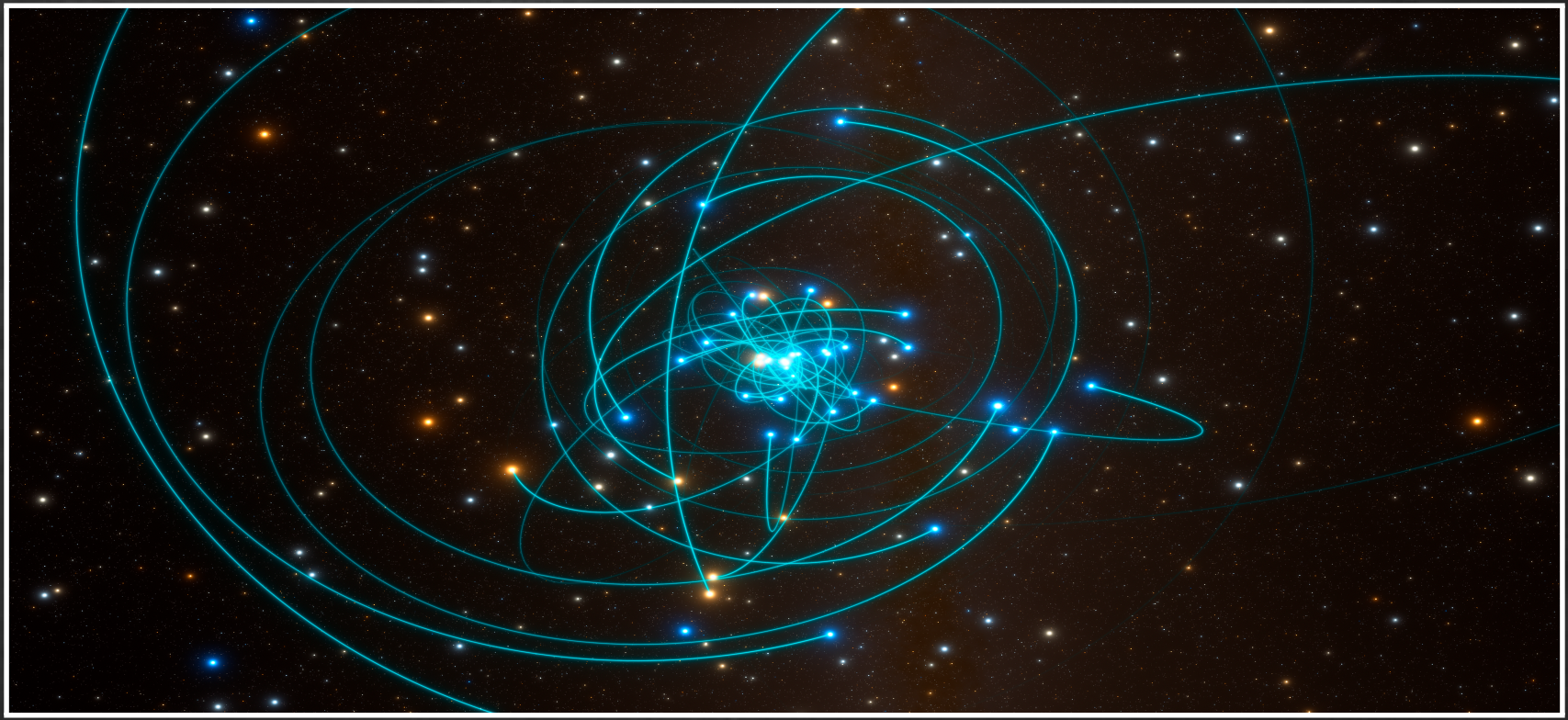
The end



(ESO)