UNIVERSITY OF WARSAW

Astronomical Observatory

FACULTY OF PHYSICS
WARSAW UNIVERSITY

Astrometry with VLTI and GRAVITY

9th OPTICON Gaia Science Alerts workshop

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UNIVERSITY OF WARSAW

Content

1. Introduction to VLTI;
2. VLTI capabilities;
3. Very narrow angle Astrometry;
4. GRAVITY instrument and capabilities;
5. Astronomical applications with GRAVITY.

Introduction to VLTI

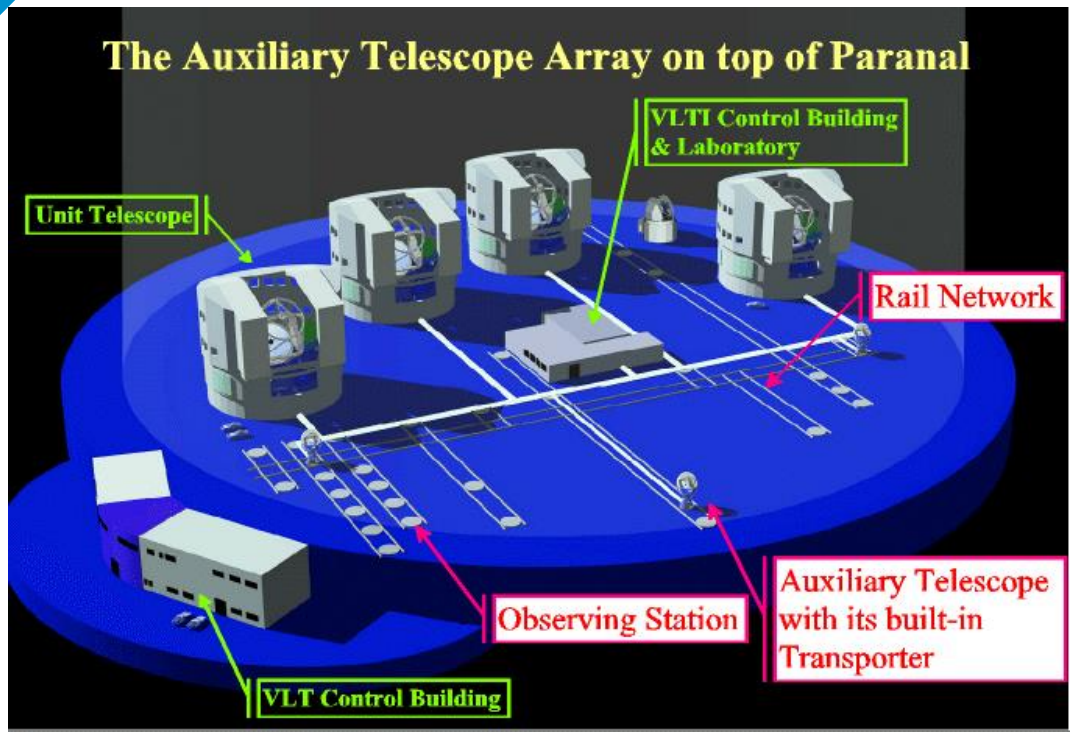


Fig. 1. The Very Large Telescopes (VLT) [1]

- First unit telescope was built in 1998;
- Consist of 4 8.2 m diameter Unit Telescopes (UTs) + optical instruments, 4 1.8 m diameter Auxiliary Telescopes (ATs);

VLTI Instruments:

Current:

- GRAVITY;
- PIONIER;
- AMBER.

Under Construction:

- MATISSE.

Closed:

- PRIMA;
- MIDI;
- VINCI.

1. *THE VLTI AUXILIARY TELESCOPES: ESO* [interactive]. 2018 [viewed 23/09/2018]. Website: http://certificate.ulo.ucl.ac.uk/modules/year_one/www.eso.org/projects/vlti/AT/index_at.html

VLTI capabilities

- Operates at visible and Infrared wavelengths (300 nm – 20 μm);
- Angular resolution approximately 0.001 arc-second;
- Angular resolution for single telescope mode is about 0.05 arc-second;
- VLTI has baselines from 8 to 200m;
- Can make a “25x25” pixels images;
- It requires at least 625 visibilities (u,v points).

1. *THE VLTI AUXILIARY TELESCOPES: ESO* [interactive]. 2018 [viewed 23/09/2018]. Website: http://certificate.ulo.ucl.ac.uk/modules/year_one/www.eso.org/projects/vlti/AT/index_at.html

Very narrow angle Astrometry

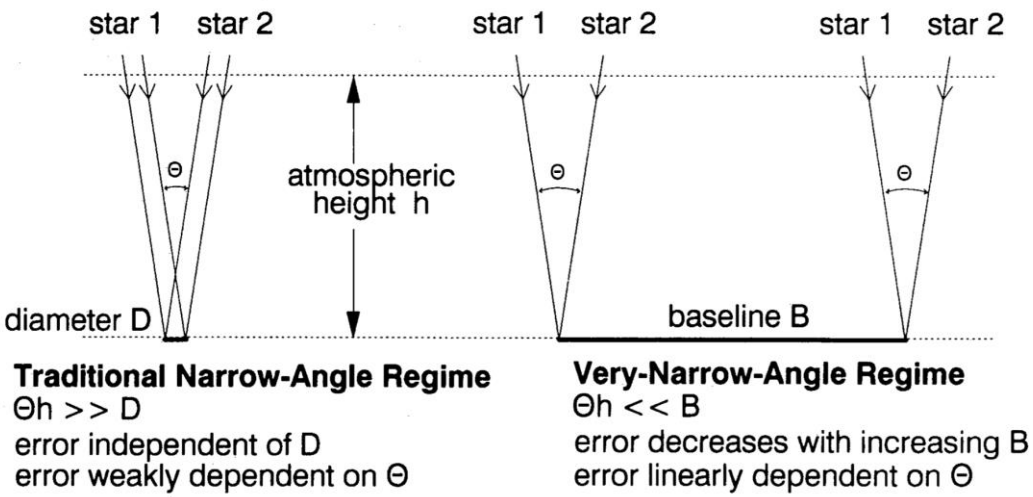


Fig. 2. Traditional and Very narrow angle astrometry [2]

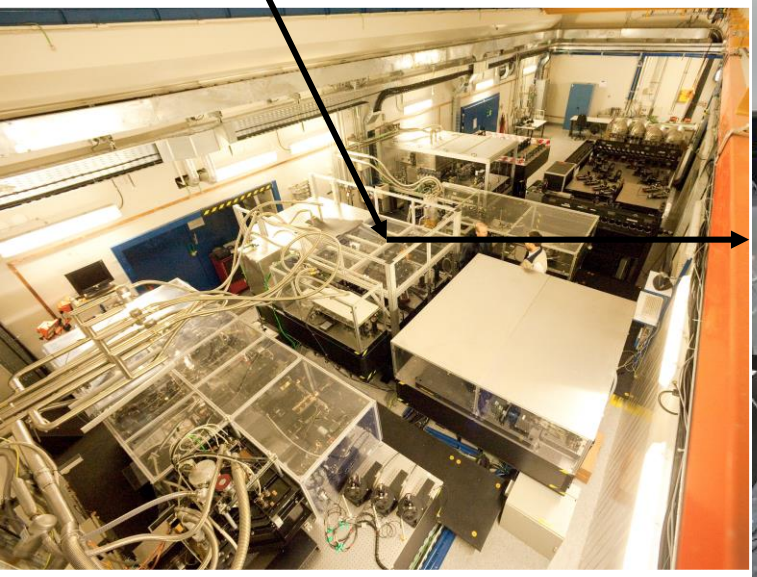
Very narrow angle regime: relative astrometric error δ x improves with baseline B and reference star position θ

$$\delta x = \frac{\theta}{B^{2/3}} \quad (1)$$

Narrow angle astrometry requires to monitor the angular distance between the target and a few reference stars.

2. SHAO, M. and M. M. COLAVITA. Long-baseline Optical and Infrared Stellar Interferometry. *Annual Review of Astronomy and Astrophysics.* 1992, vol. 30, pp. 457-498. Doi: 10.1146/annurev.aa.30.090192.002325

GRAVITY



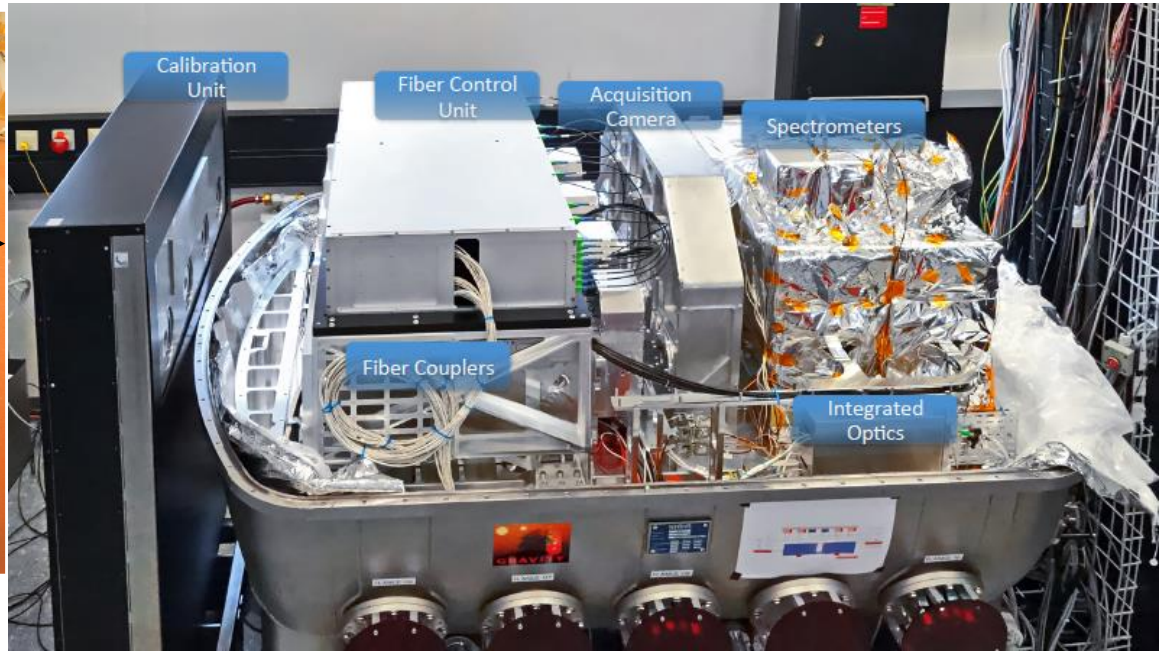
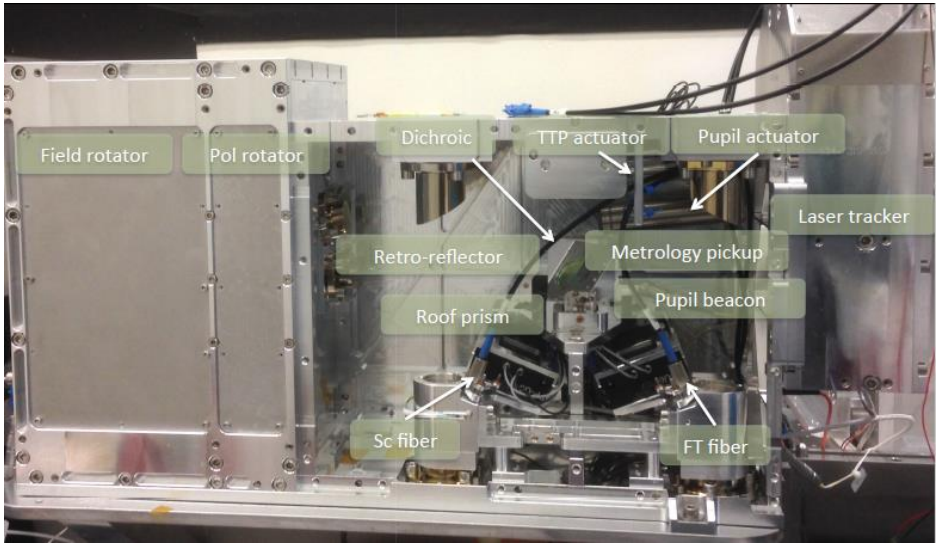
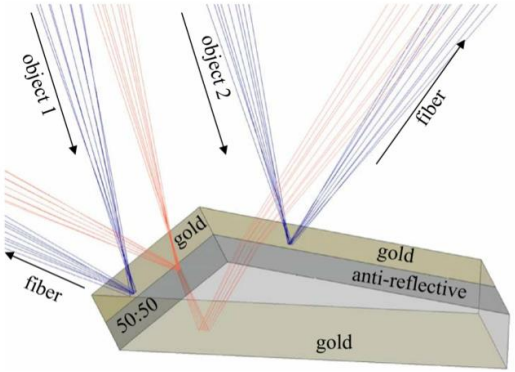


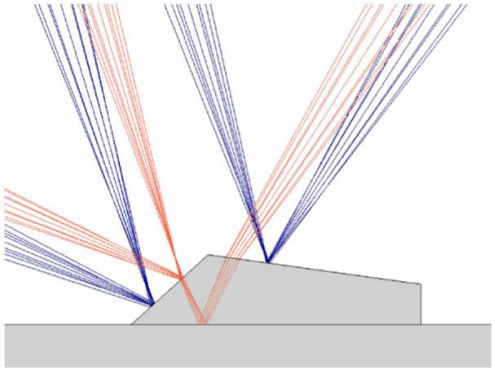
Fig. 3. GRAVITY [3]

3. *GRAVITY: ESO* [Interactive]. 2018 [viewed 23/09/2018]. Wesbite: http://www.eso.org/sci/facilities/paranal/instrume-nts/gravity/in-st.html

GRAVITY (Fiber coupler)







Stabilization of the beam:

- For perfect tilt correction;
- For simultaneous tilt error.

Credits: Oliver Pfuhl slides (9th VLTI Summer school, Lisbon, Portugal). Website: http://www.jmmc.fr/twiki/bin/view/Jmmc/VltiSchool2018/SchoolLectures

GRAVITY capabilities

- Two independent interferometers (fringe-tracker and science channel);
- Interferometry with four telescopes;
- Control-loops to track fringes;
- Single-field and dual-field mode;
- Polarization split/combined modes;
- Three spectral resolutions (20, 500, 4000);
- Instrument contained in cryostat to mitigate thermal background and provide ultra-high stability;
- Allows measurement of inclination;
- Direct measurement of planet mass;
- Allows to infer alignment of planets with rotation axis, companions, disks, other planets;
- Probes parameter space between transits/ rad vel & direct imaging.

Credits: Oliver Pfuhl slides (9th VLTI Summer school, Lisbon, Portugal). Website: http://www.jmmc.fr/twiki/bin/view/Jmmc/VltiSchool2018/SchoolLectures

Astronomical applications with GRAVITY

Young Stellar Objects

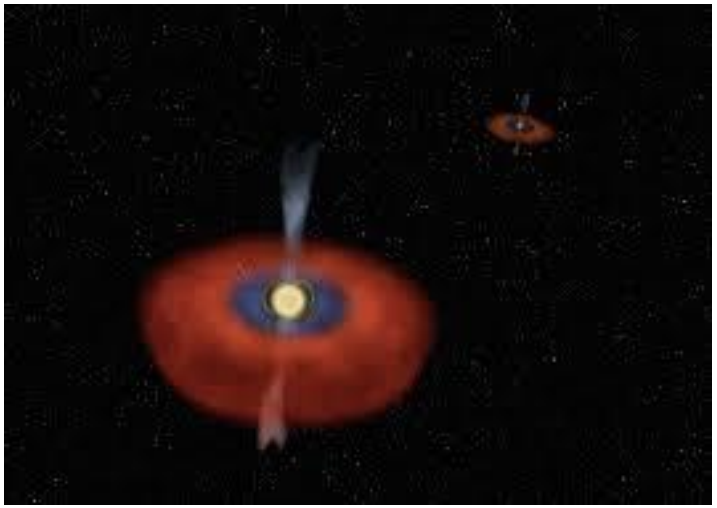


Fig. 4. Star SCra N [4]

Stellar orbits at Supper massive Black Holes

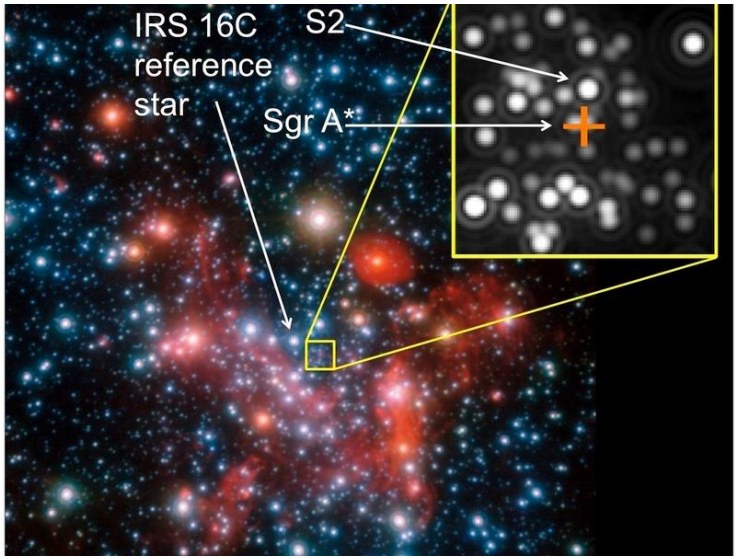


Fig. 5. Black Hole Sgr A* [5]

4. The Messenger. ESO, 2017, no. 170. Doi: 10.18727/0722-6691/5047.
5. *SUCCESSFUL FIRST OBSERVATIONS OF GALACTIC CENTRE WITH GRAVITY: ESO* [interactive]. 2016 [viewed 25/09/2018] Website: https://www.eso.org/public/news/eso1622/

Microlensed Images

TCP J0507+2447

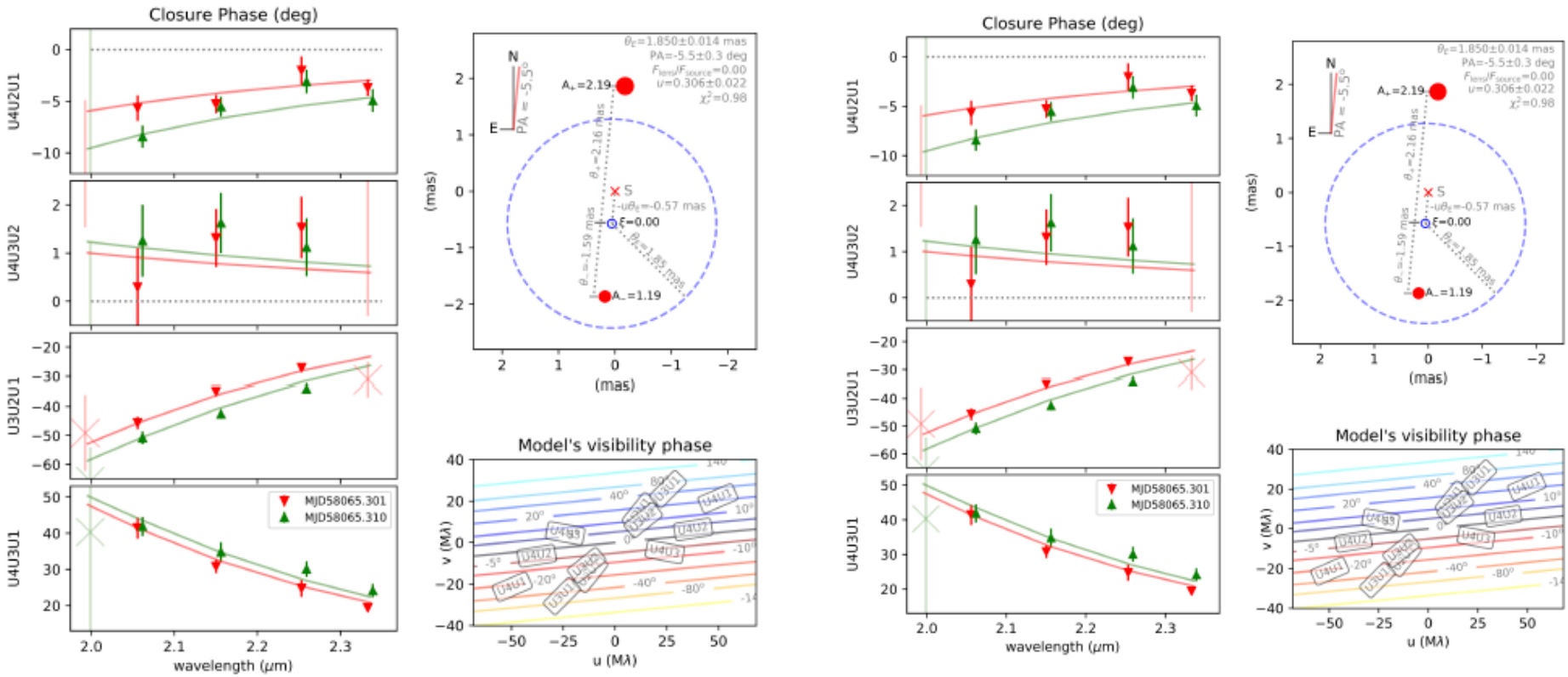
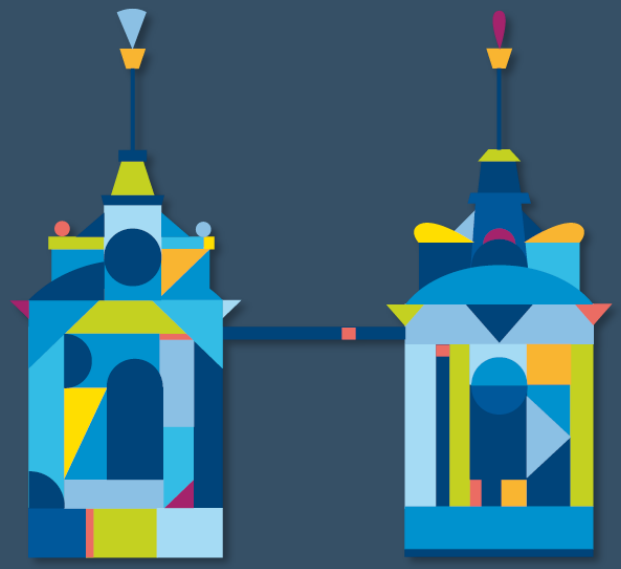


Fig. 6. VLTI model: a) with no lens light, b) with a luminous lens [6]

6. DONG, Subo, et al. First resolution of Microlensed images. arXiv:1809.08243.



Thank You for Your Attention!

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