How can we test the General Relativity with the future astrometric data of GRAVITY ?

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Advisors
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GPhys's day, June 6th 2015

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OUTLINE

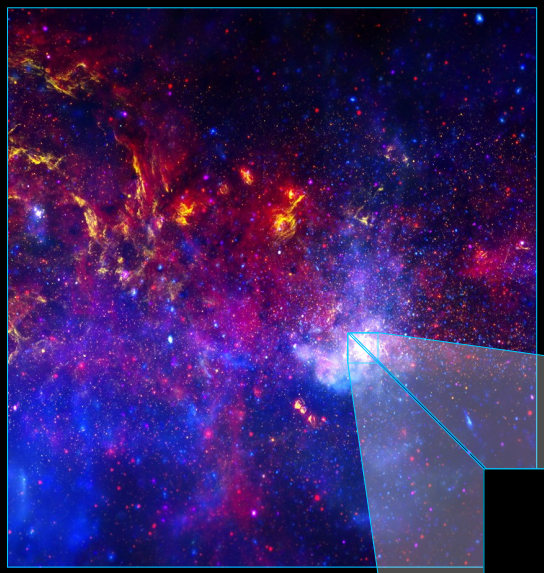
1. By studing the Galactic Center

2. By using GRAVITY

3. By building an apparent relativistic orbits model

4. By getting an accurate model

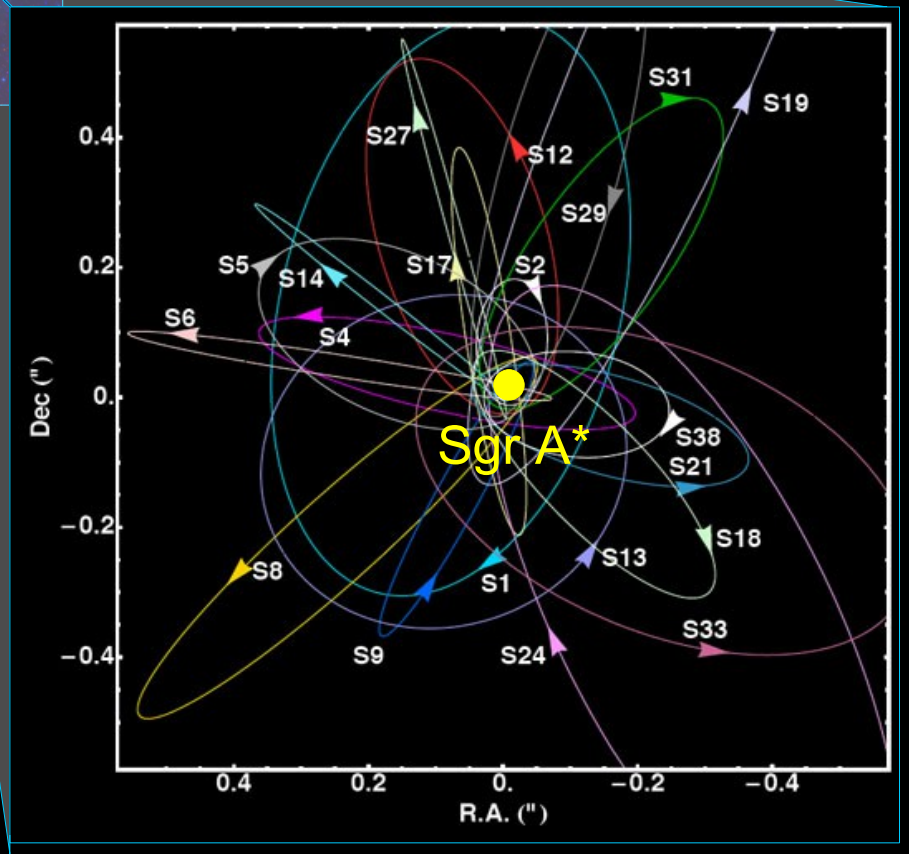
1. By studing the Galactic Center



S cluster → S2 Orbit

$M_0 = 4.31 \pm 0.6 \times 10^6 M_\odot$

0.5"



Gillessen S., et al.
ApJ, 692, 1075
(2009)

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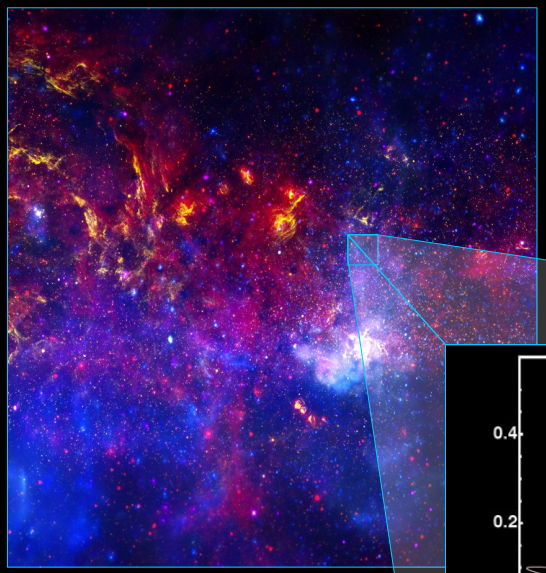

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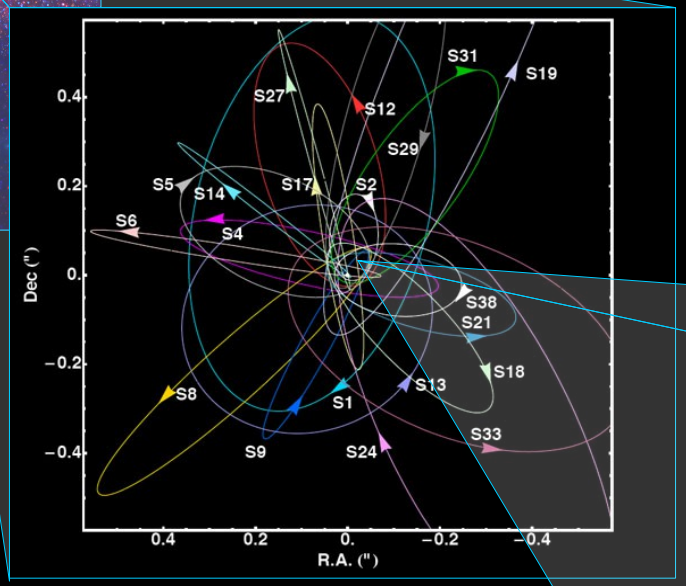

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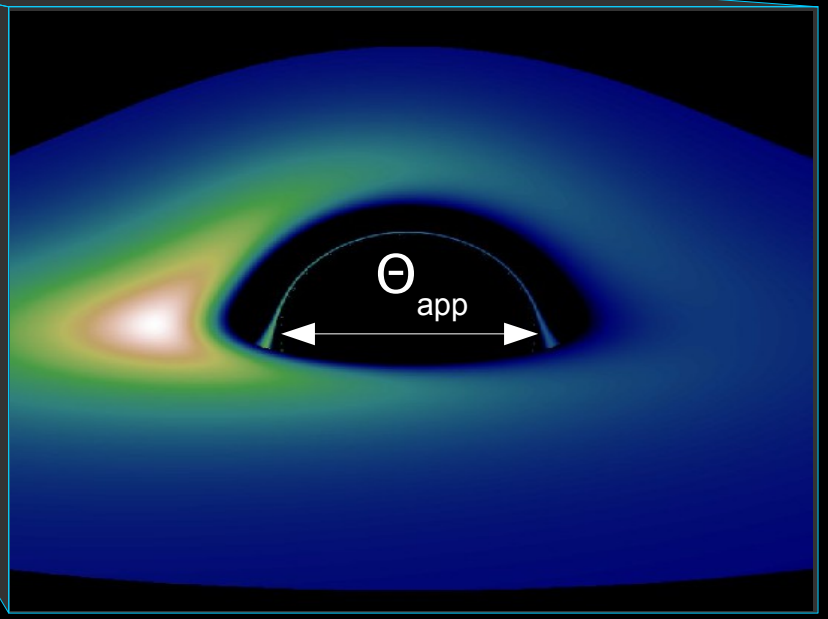
(2009)

Apparent size of a Schwarzschild black hole seen from Earth (D ≈ 8 kpc): $\Theta_{app} \approx 53$ μas

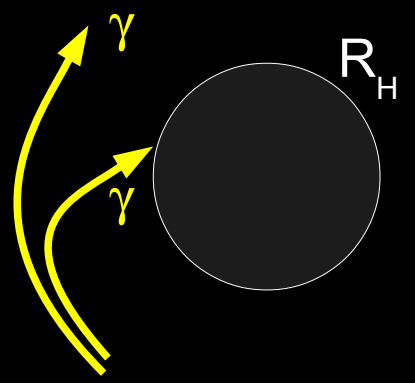
Biggest balck hole !



GYOTO image of an accretion disk around a Schwarzschild black hole

1. By studing the Galactic Center

a) Is there a supermassive black hole at the center of our Galaxy ?
→ Is there an event horizon ?



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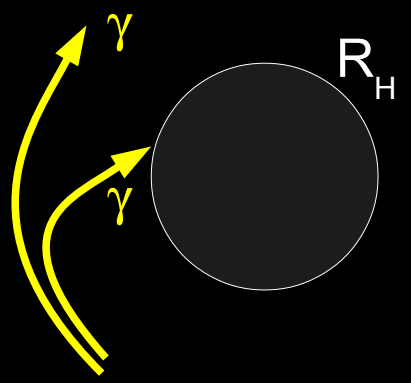
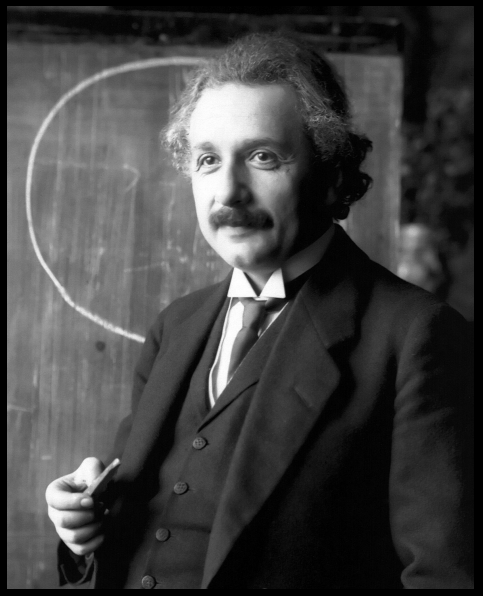


b) Is there a black hole described by the General Relativity in the Galactic Center ?



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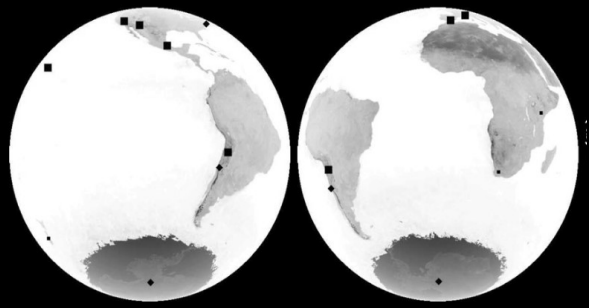
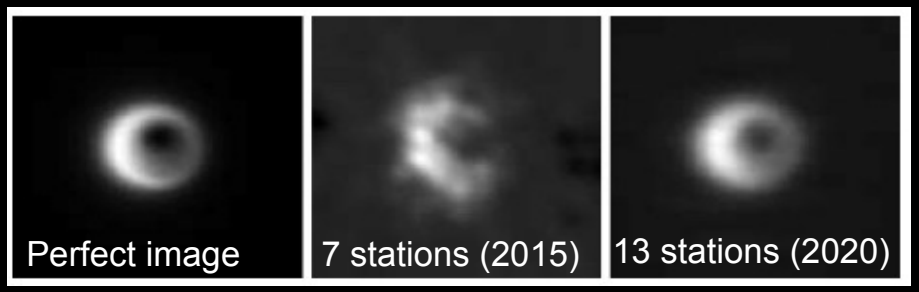
a) Is there a supermassive black hole at the center of our Galaxy ?

EHT (Event Horizon Telescope)
Interferometer
VLBI : 13 stations



Radio → image of Sgr A*

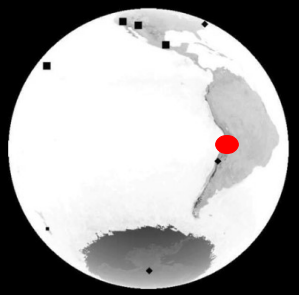


Simulation with a=0 and i=30°

Fish & Doeleman, Proc. IAU Symp 261 (2010)

b) Is there a black hole described by the General Relativity in the Galactic Center ?

GRAVITY
Interferometer
VLTI : 4 telescopes

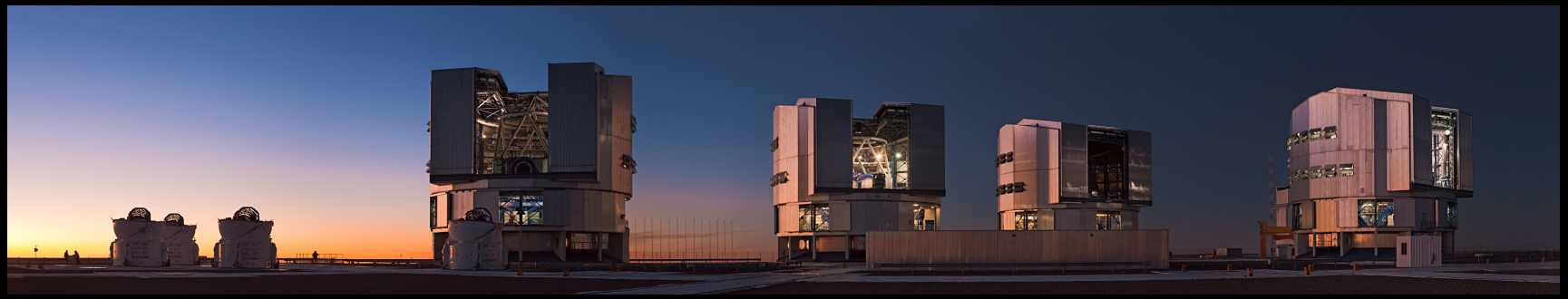


Infrared → stars

Comparison of the orbits of stars close to Sgr A* observed with GRAVITY and those obtained with the General Relativity

2. By using GRAVITY

Interferometer of 4 telescopes working in the K band (2-2.4 µm)



Angular resolution : 4 mas
Research field of view : 2"
Modes : Imaging et Astrometric
Scientific field of view: 60 mas

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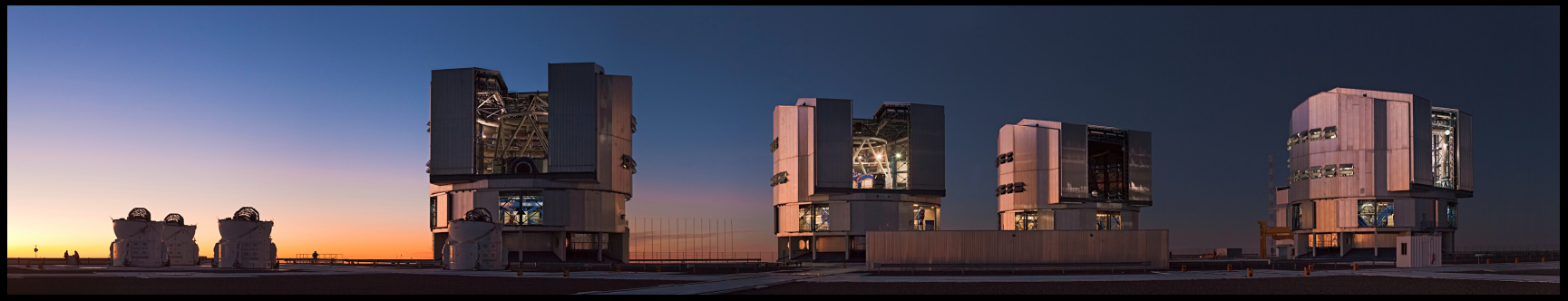
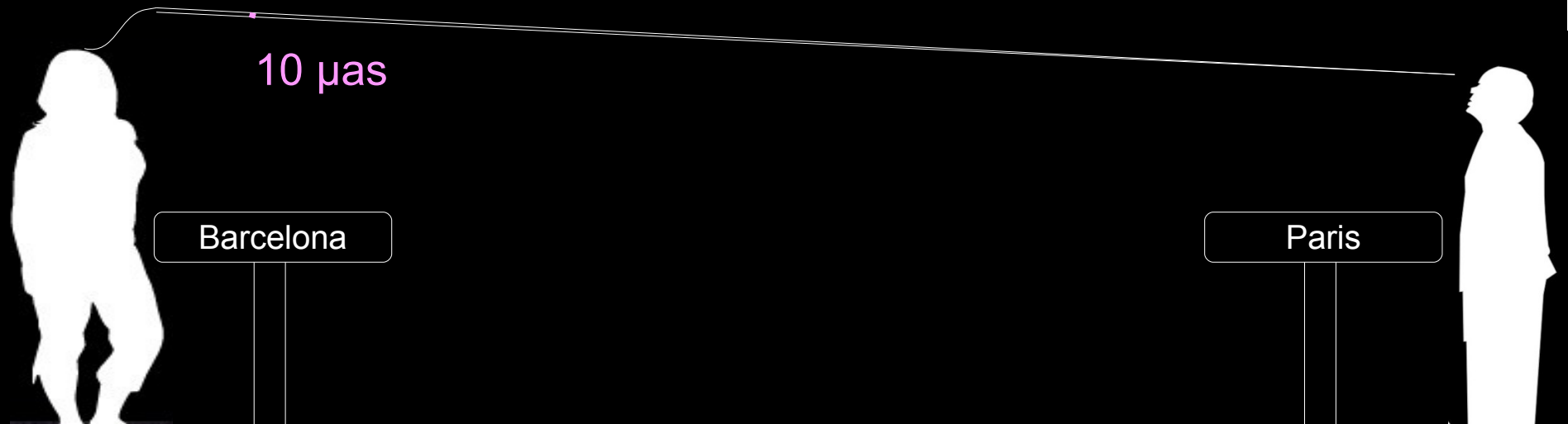
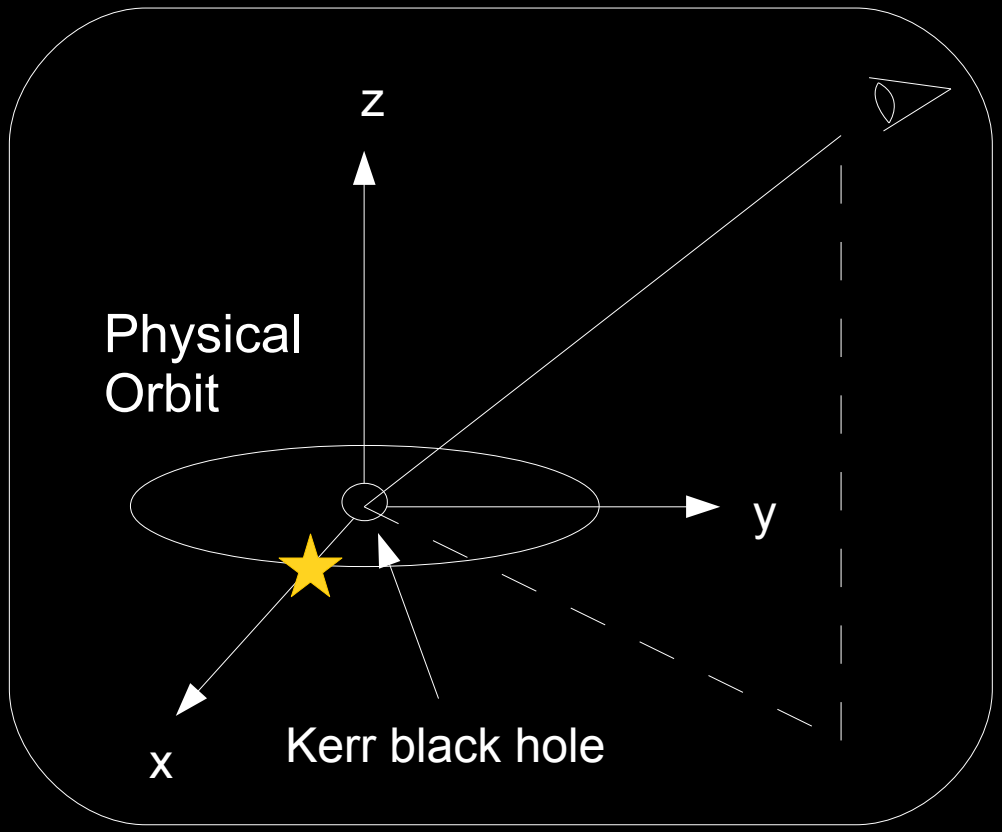


Angular resolution : 4 mas
Research field of view : 2"
Modes : Imaging et Astrometric
Scientific field of view: 60 mas
Astrometric accuracy : 10 µas (< 53 µas)



3. By building an apparent relativistic orbits model



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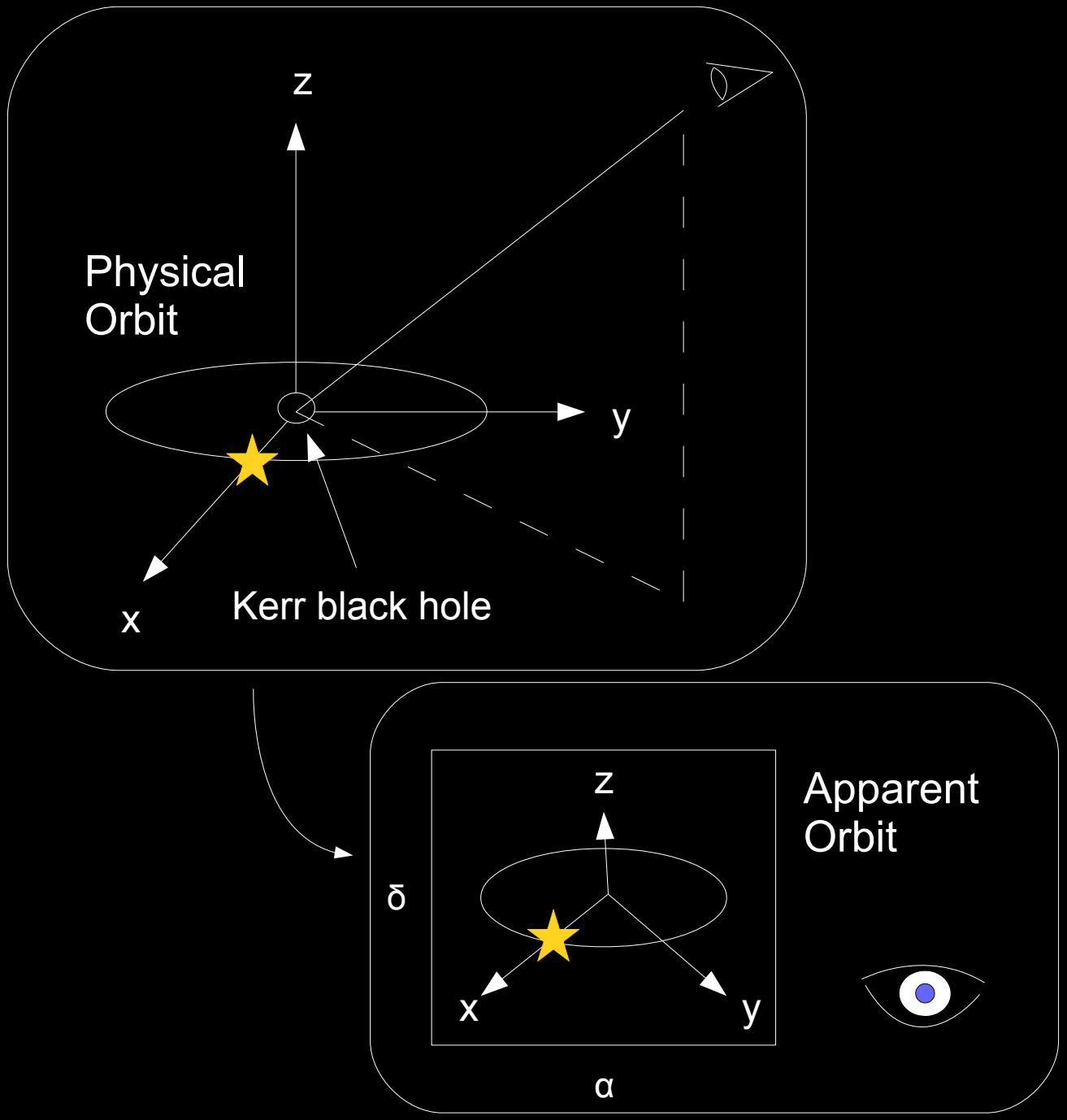

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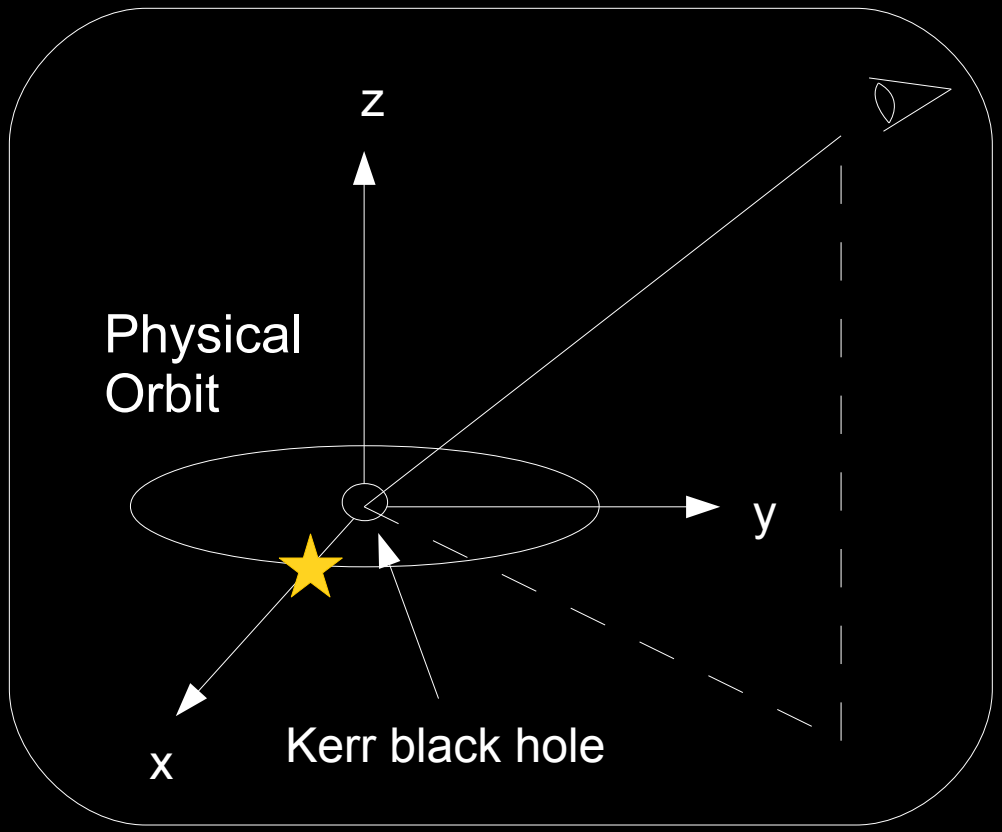

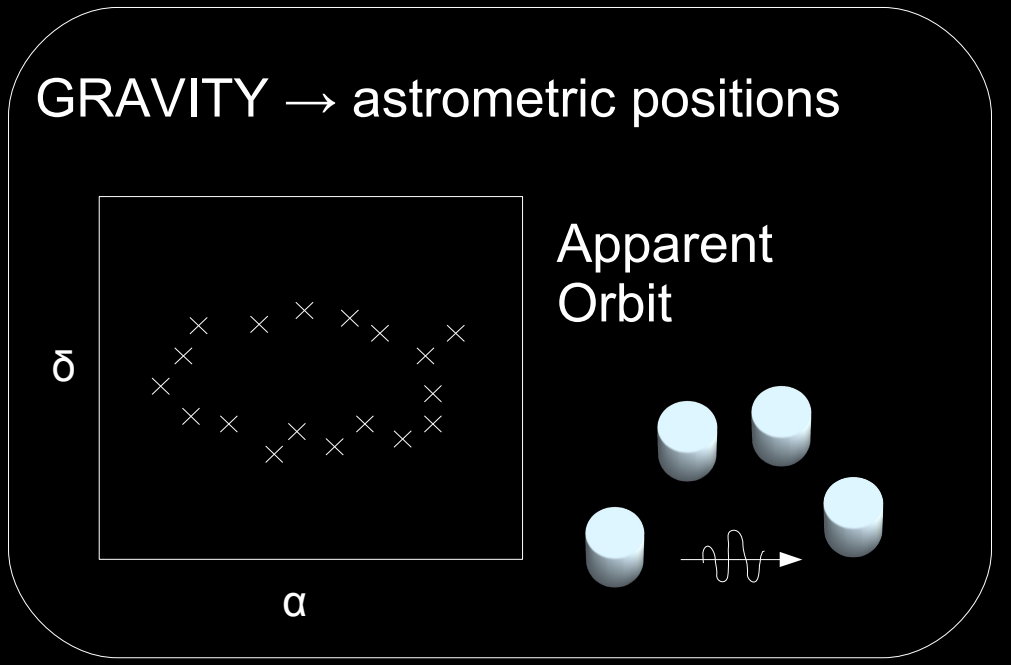

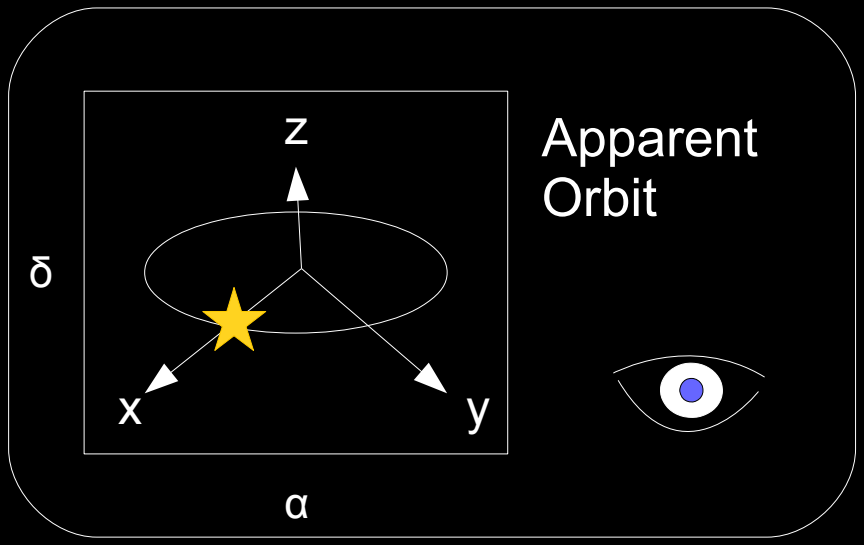

Fit
(M, a, D, i, ...)

3. By building an apparent relativistic orbits model

Take into account several effects :

→ time delay

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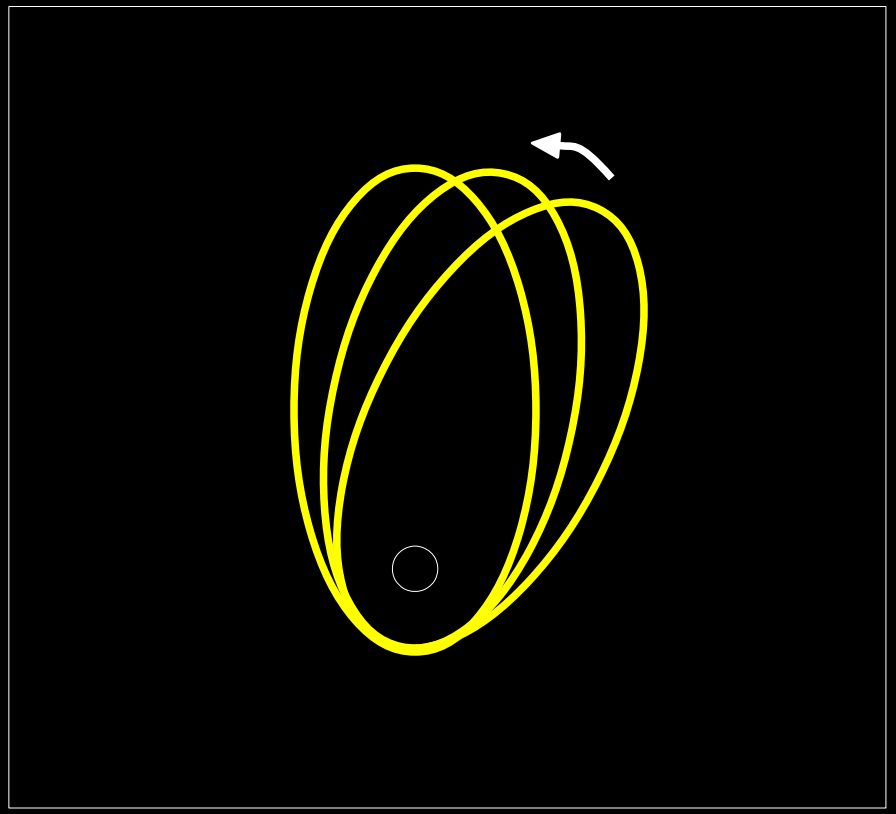
→ pericenter advance



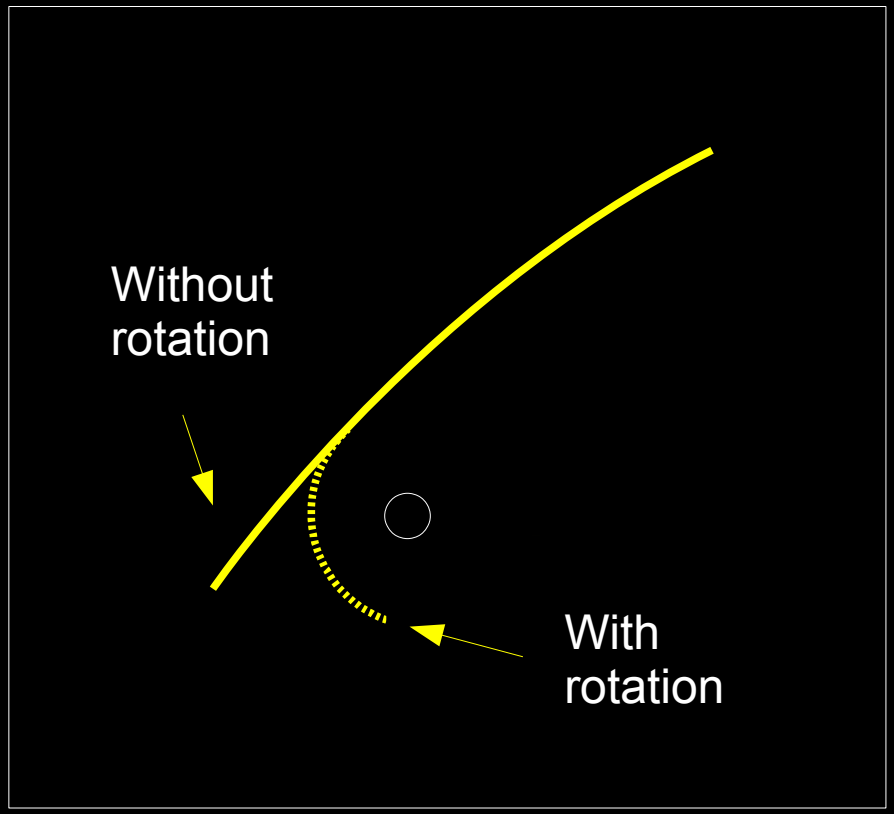
3. By building an apparent relativistic orbits model

Take into account several effects :

→ time delay

→ pericenter advance

→ Lense-Thirring effect



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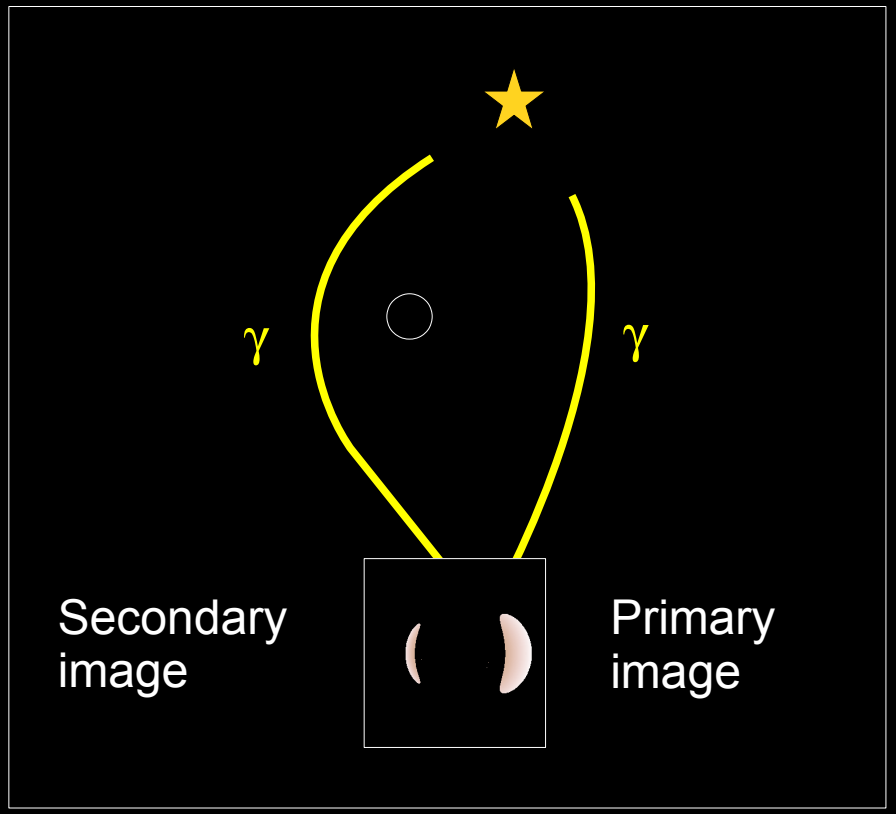
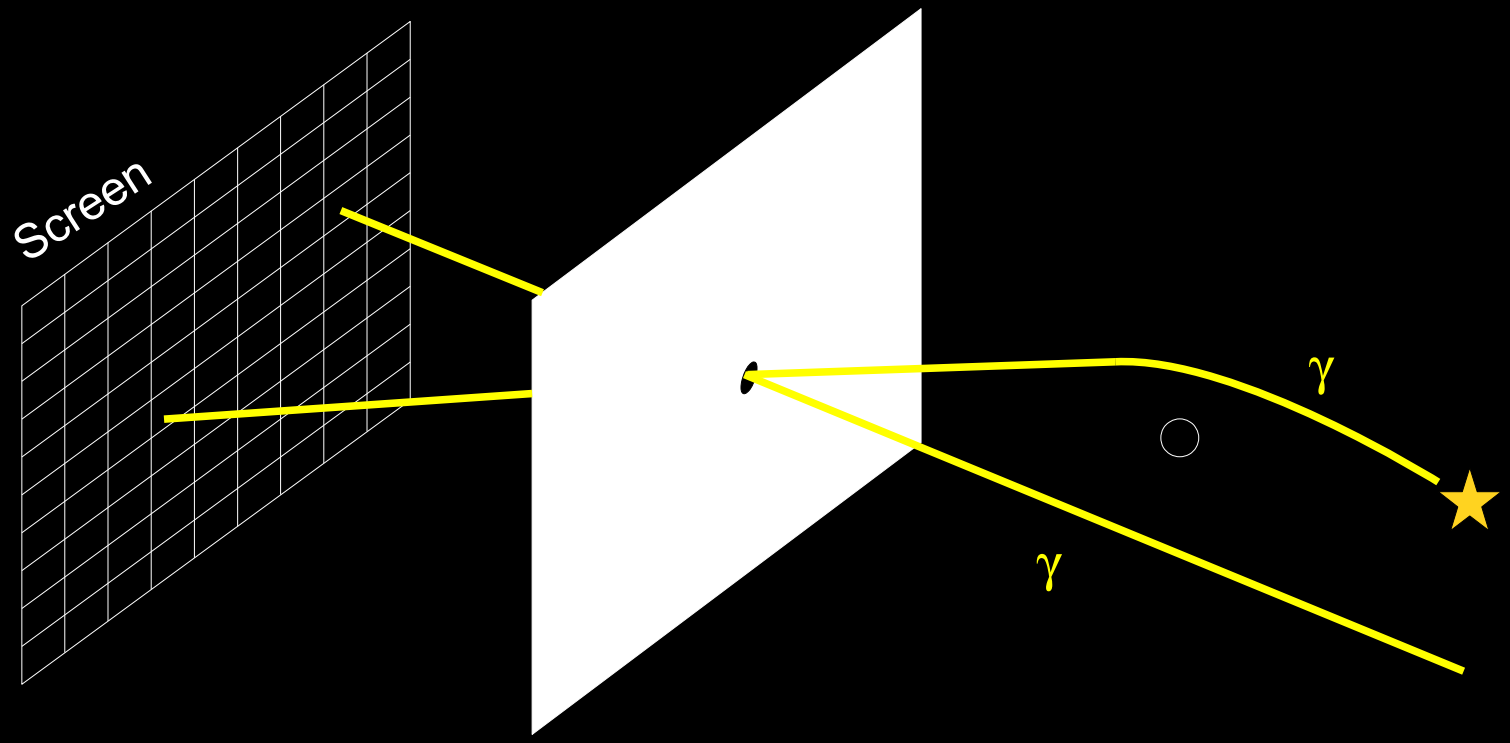
Take into account several effects :

→ time delay
→ pericenter advance
→ Lense-Thirring effect
→ lens effects

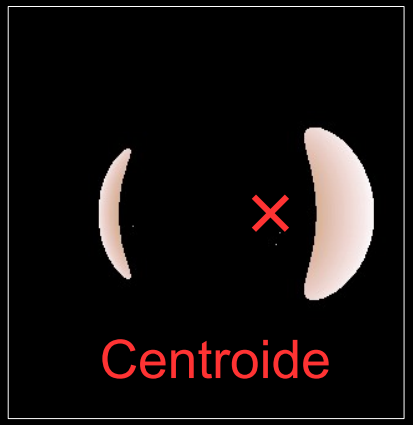


3. By building an apparent relativistic orbits model

GYOTO : ray-tracing code developed by Vincent et al. (2011)



Apparent positions with GYOTO :



4. By getting an accurate model

Accuracy of the future model << 10 μas → ≤ 1μas

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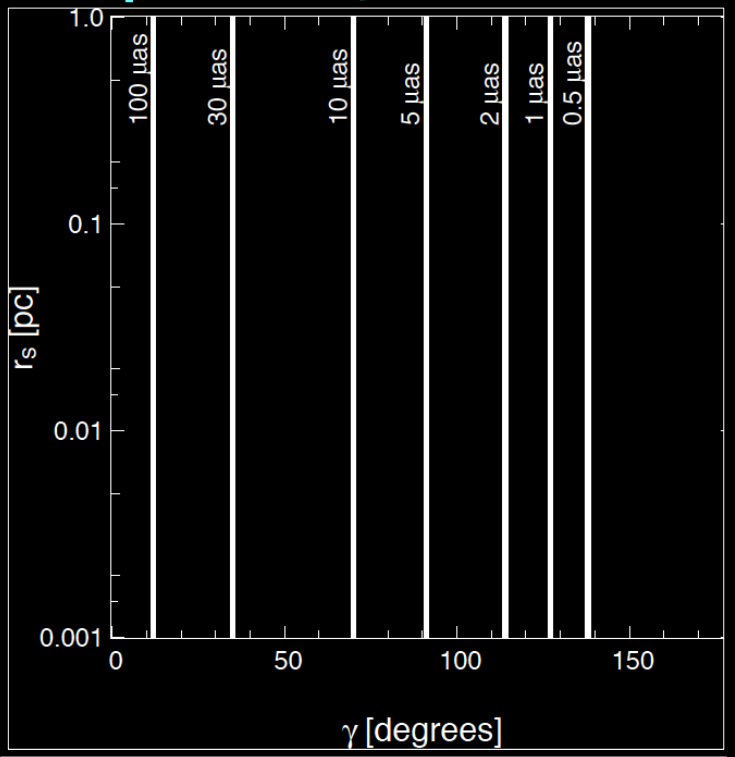
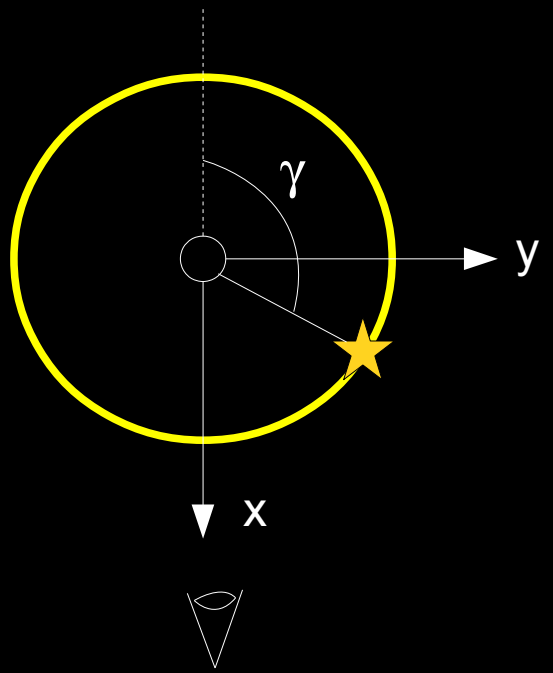
Accuracy of the future model << 10 μas → ≤ 1μas
- take into account the lens effects

Bozza & Mancini (2012)



Astrometric shift of the primary image



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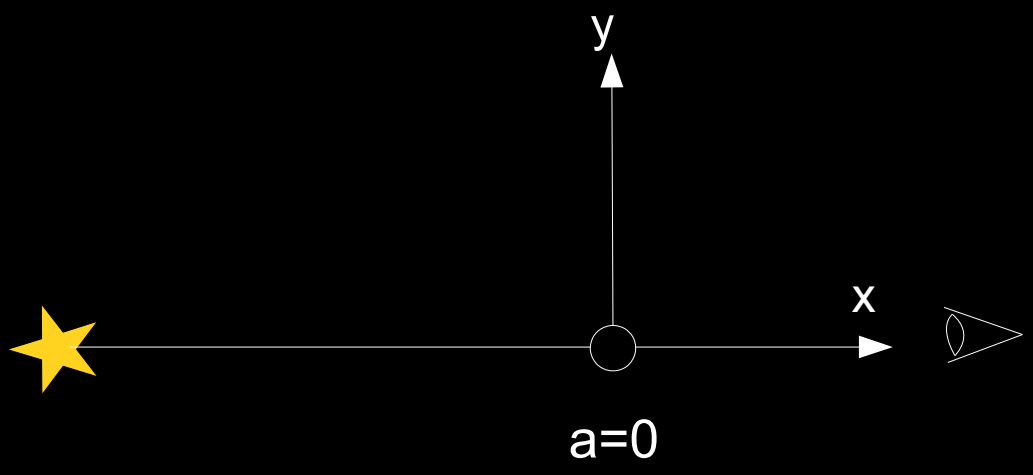
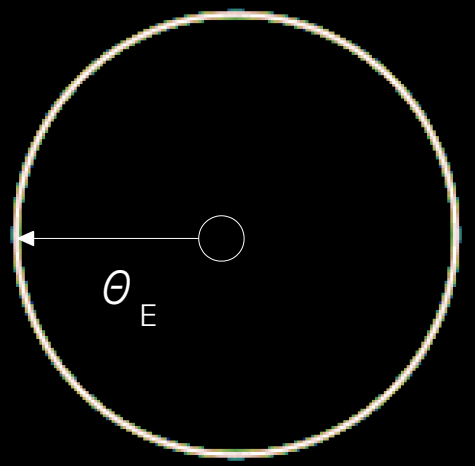
<u>Weak field regime :</u>
comparaison of GYOTO with analytical formulas developed by Sereno et al. (2008)
<u>For instance :</u> Einstein ring radius





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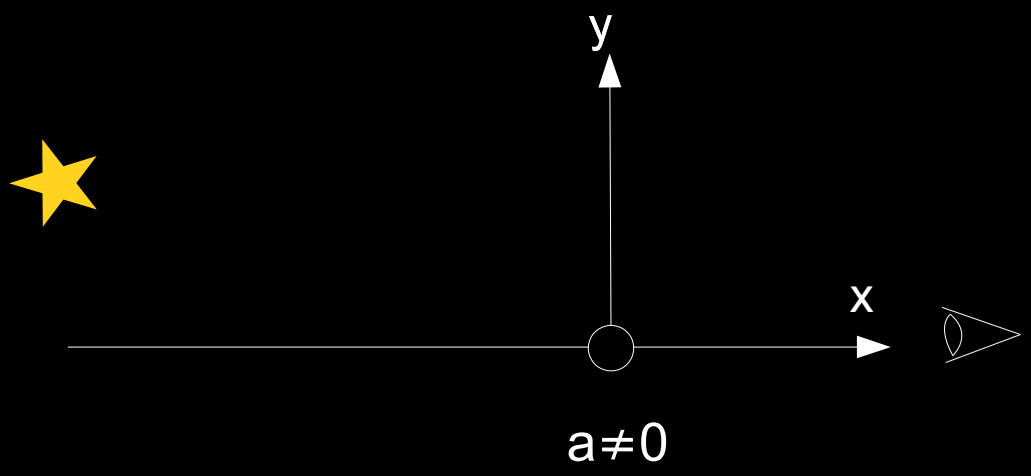

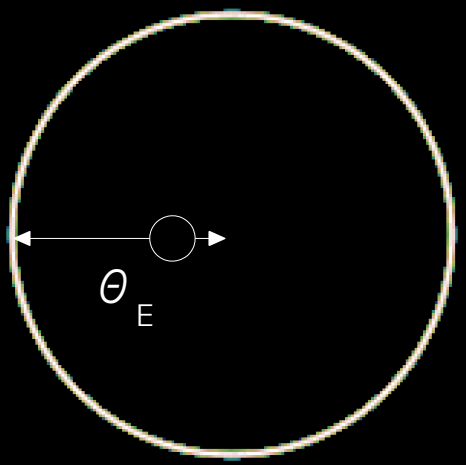

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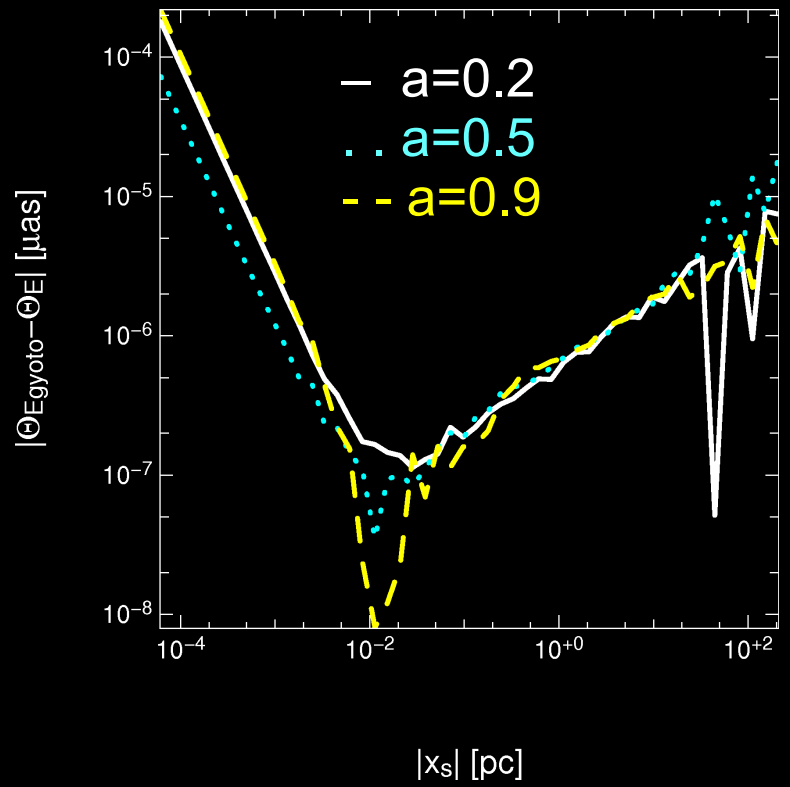

$|\Theta_{Egyoto} - \Theta_E| < 10^{-3}$ μas

$\Delta\Theta_E < 10^{-3}$ μas

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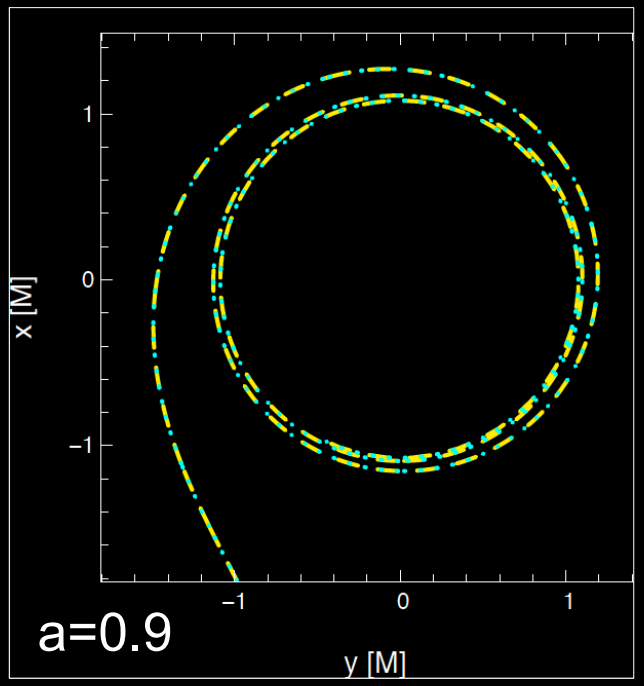
<u>Strong field regime:</u>
comparaison of GYOTO with a semi-analytical ray-tracing code, GeoKerr, developed by Dexter et al. (2009)



. . GYOTO
- - GeoKerr

δx, δy < 10^{-3} μas

Summury

How can we test the General Relativity with the future astrometric data of GRAVITY ?

By building an apparent relativistic orbits model with GYOTO :

→ importance of lens effetcs

→ GYOTO is valid and accurate

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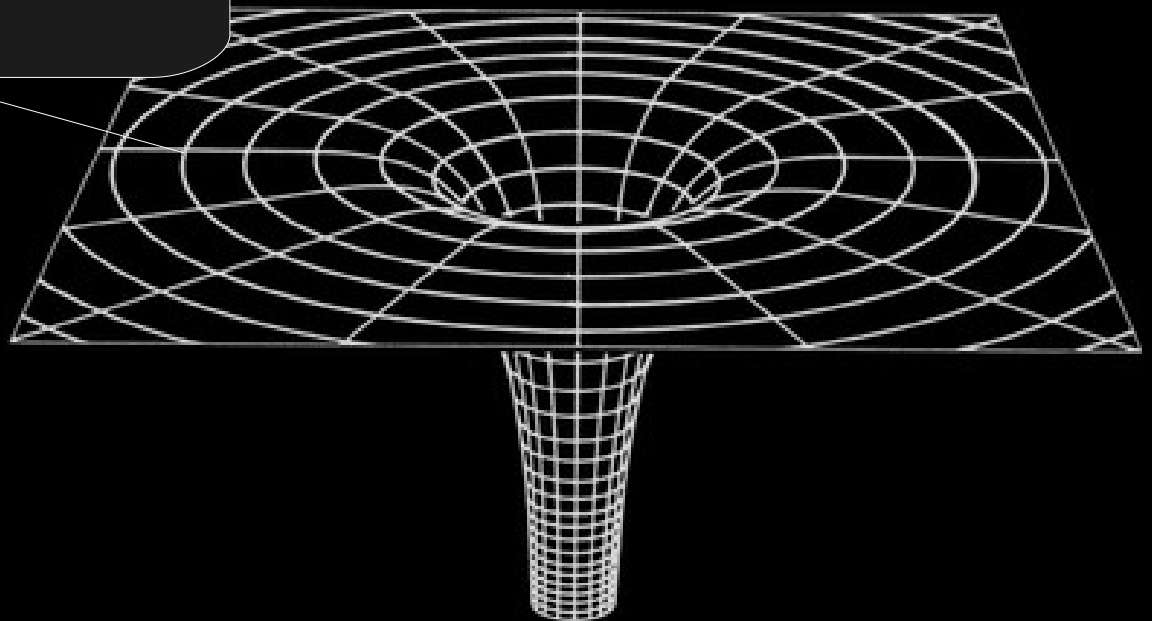
Implement the model

→ computing time of GYOTO images too long



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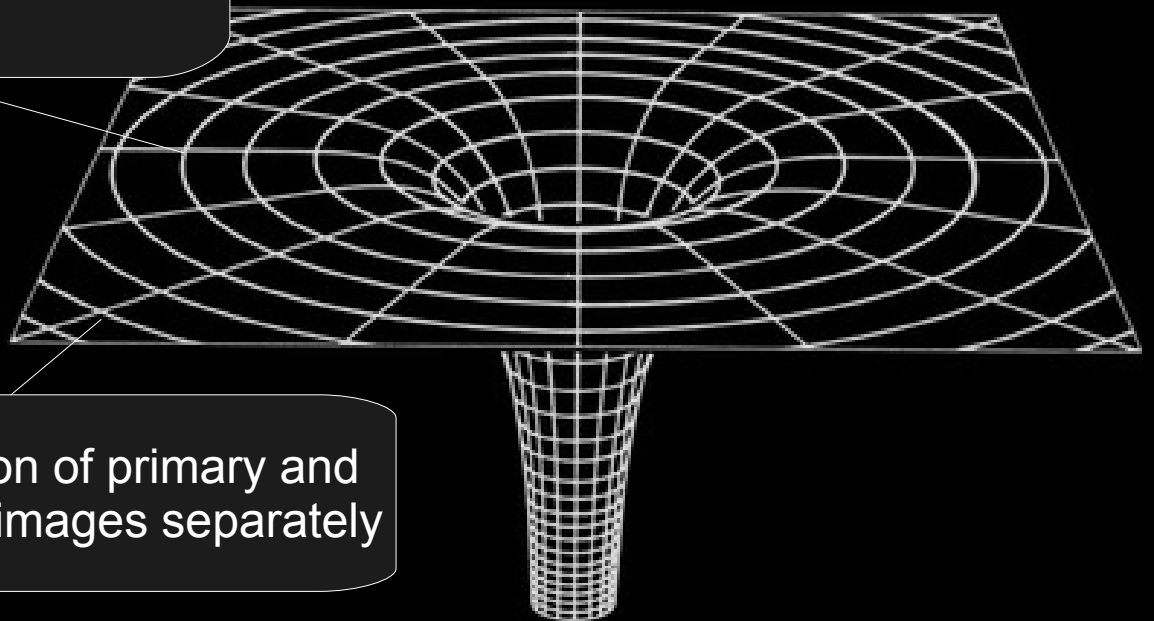

Computation of primary and secondary images separately

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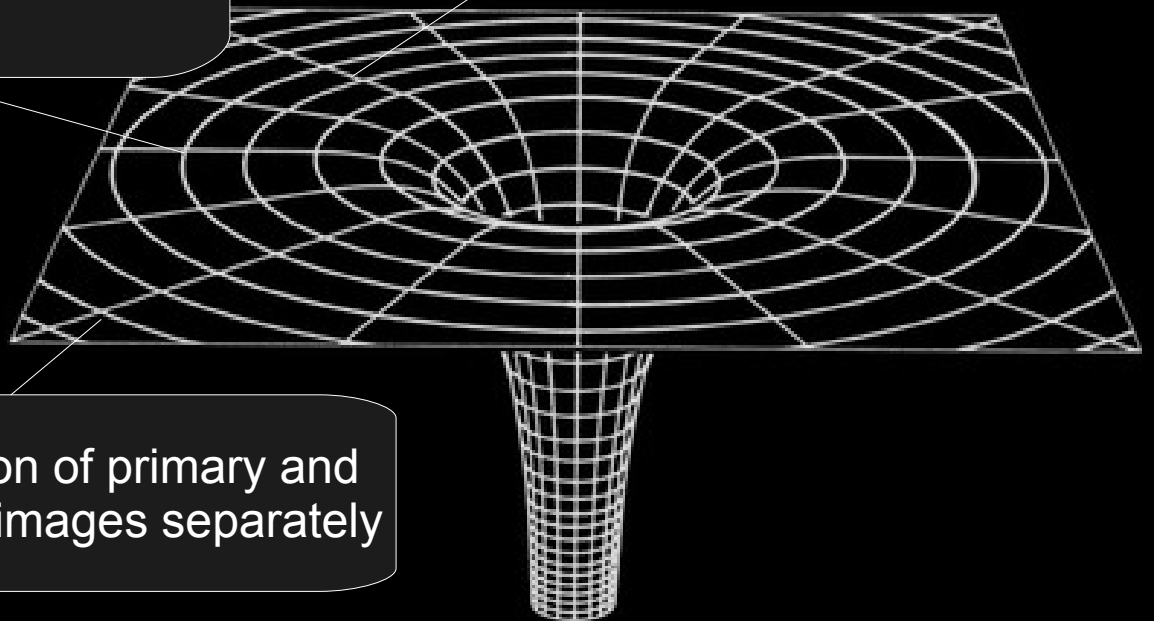
MPI



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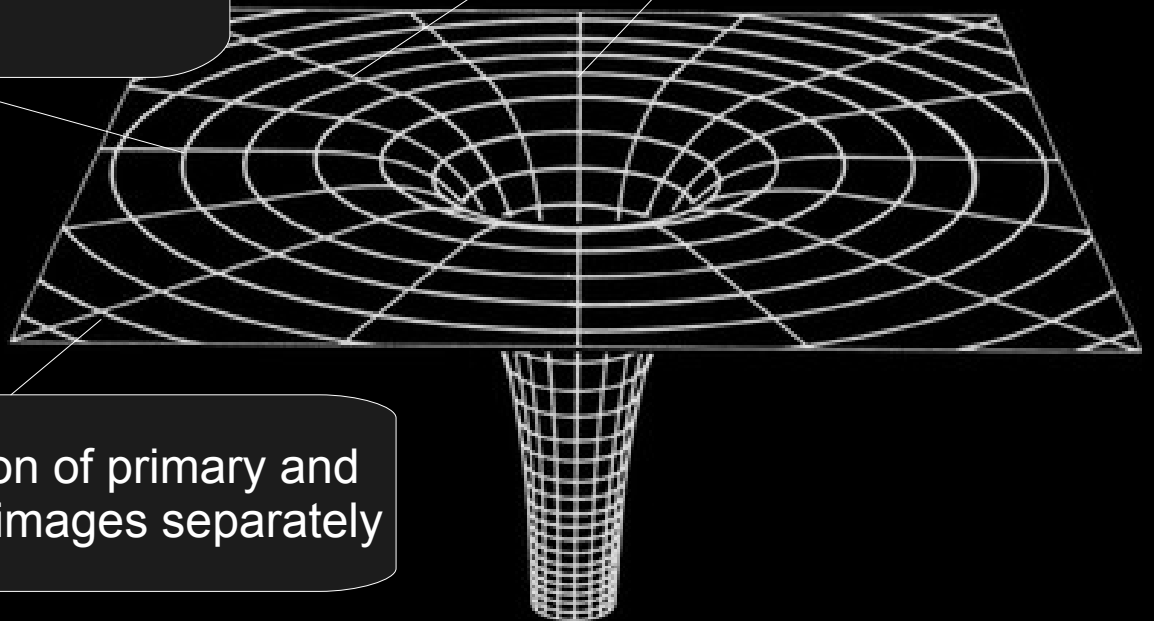

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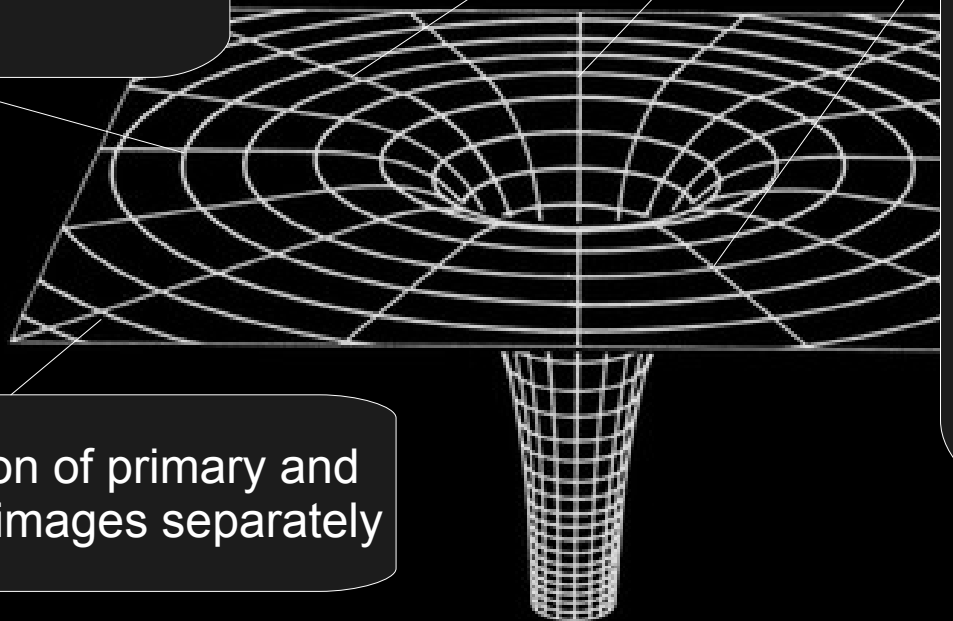

1. influence of secondary images of S stars on the future GRAVITY data

2. influence of the Solar System on GRAVITY data (Christophe Le Poncin-Lafitte, Aurélien Hees)

Computation of primary and secondary images separately