

Star motion around rotating black hole in the Galactic Center in real time

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Standard Model in Astrophysics

Black hole is the essential element of the Standard Model



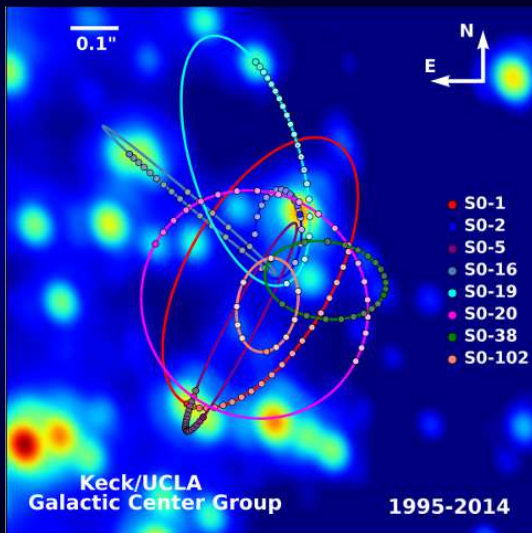
Experiment is requested for verification (falsification)
the General Relativity in the strong field limit!

The great galactographic discoveries in the XXI century



The first great galactographic discovery in the XXI century

Direct measuring the mass of the black hole SgrA* in the Galactic Center



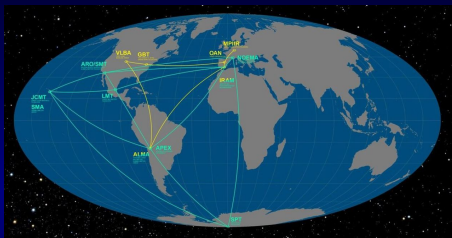
S0-102: $T = 11.5$ yrs

S0-2: $T = 16$ yrs, $M_h = (4.1 \pm 0.4)10^6 M_\odot$

The next (awaited) great galactographic discovery in the XXI century

The Event Horizon Telescope Array (EHTA) for the black hole shadow ~ 2020 yr

Submillimeter VLBI array for the Event Horizon Telescope $\rightarrow 10^{-6}''$



World EHTA stations



Submillimeter Array (ALMA)



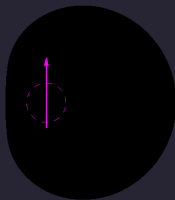
Black hole shadow (at left) and model images of Sgr A*

EHTA with 7 telescopes *Fish & Doeleman*

Crucial experiment for General Relativity verification in the strong field limit

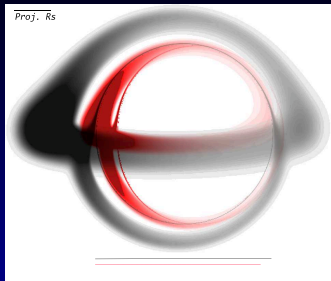
Direct evidence for existence of black holes in the Universe ~ 2020 yr

Shadow of the supermassive black hole SgrA* in the Galactic Center?

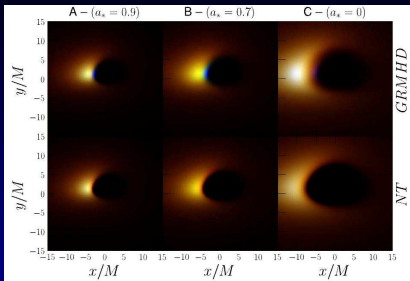


Invisible black hole horizon and visible black hole shadow

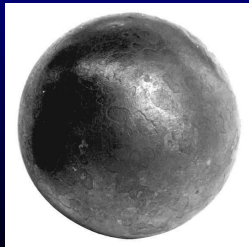
Experimental falsification of the Gravitation Theory models ~ 2020 yr



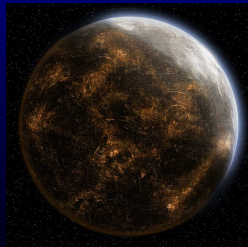
Polish disk (lon tor) $a = 0.5; 0.9$



Typhoon eye $a = 0; 0.7; 0.9$ [Zhu et al. 2012](#)



Cast-iron ball



Planet Coruscant — Capital of the Galactic Republic

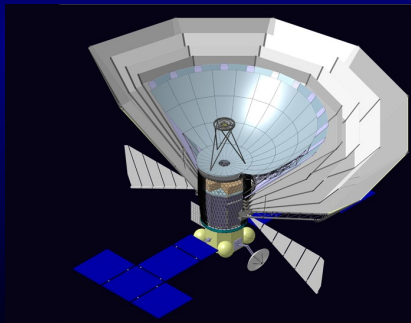
The next step. What is the Gravitation Theory?

Experimental falsification:

General Relativity, $f(R)$, C^2 , Galileon, Horndesky, extra-dim or...?

In the case of SgrA* the angular resolution $10^{-9}''$ is requested

Russian space project **Millimetron** is the most promising

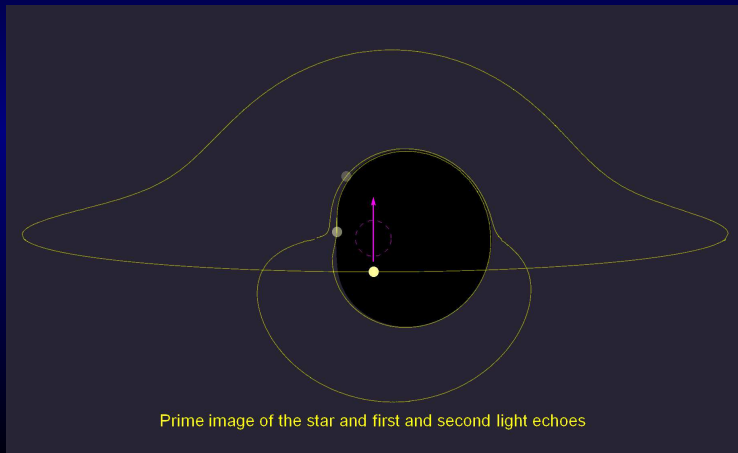


Star (probe) on the equatorial circular orbit close to SgrA* viewed by the distant telescope (Millimetron)

Orbital radius $r_s = 20 \frac{MG}{c^2} \simeq 1.24 \cdot 10^8 \text{ km} \sim 1 \text{ AU}$,

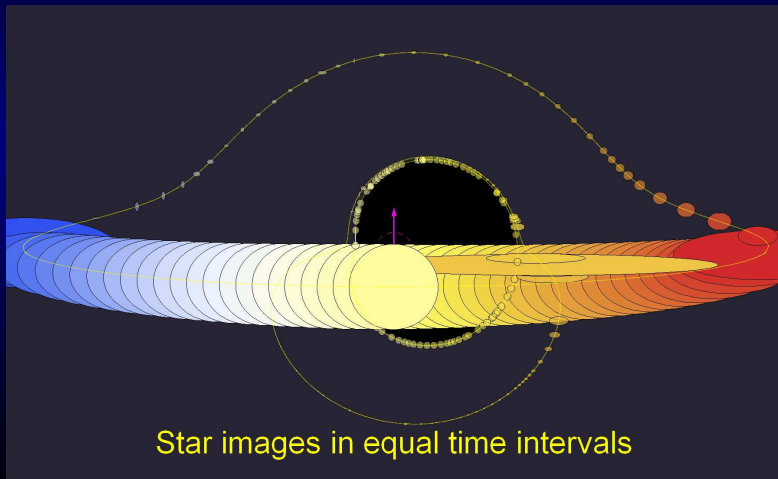
orbital period $T_s = 3.2 \text{ hrs}$, orbital velocity $v_s = 0.22c$,

black hole spin $a = 0.998$. Infinite number of instant lensed images:



Star (probe) on the equatorial circular orbit close to SgrA* viewed by the distant telescope (Millimetron)

Numerical calculations of the frequency shift (gravitational redshift and Doppler effect), gravitational lensing (deformation) of the first three star images along the circular orbit

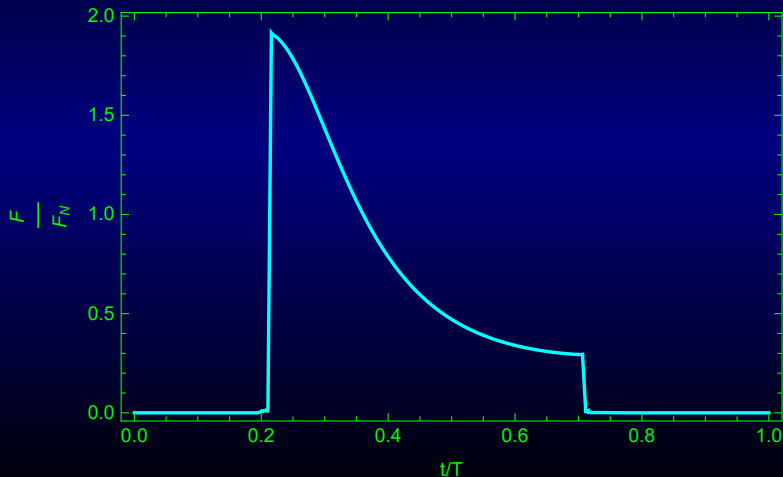


Star (probe) on the equatorial circular orbit close to SgrA*
viewed by the distant telescope (**Millimetron**):

Light curve for the prime (direct) image: $F(t)/F_N$

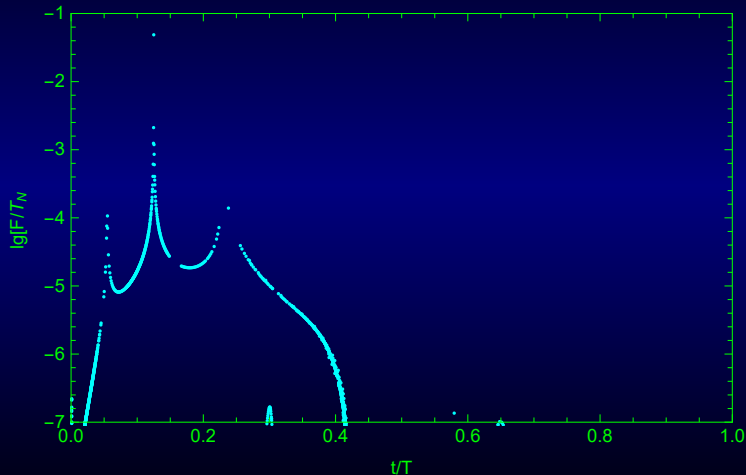
$F(t)$ — flux of energy,

F_N — Newtonian flux of energy



Star (probe) on the equatorial circular orbit close to SgrA* viewed by the distant telescope (Millimetron)

Light curve for the first light echo: $F(t)/F_N$

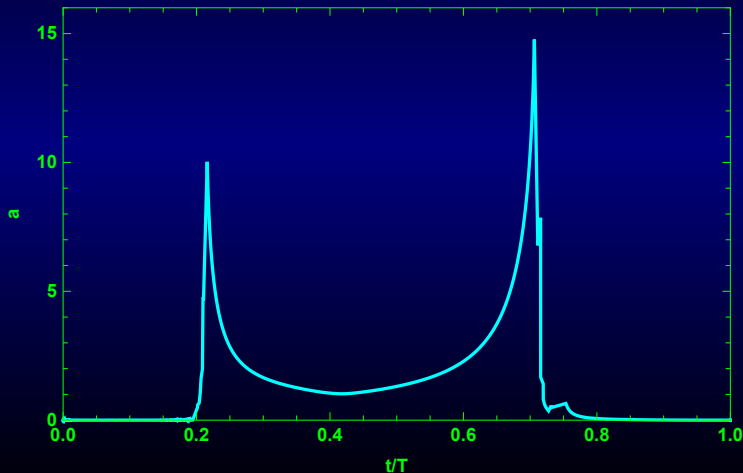


Star (probe) on the equatorial circular orbit close to SgrA*
viewed by the distant telescope (**Millimetron**):

Semiaxis $a(t)$ for the prime (direct) image

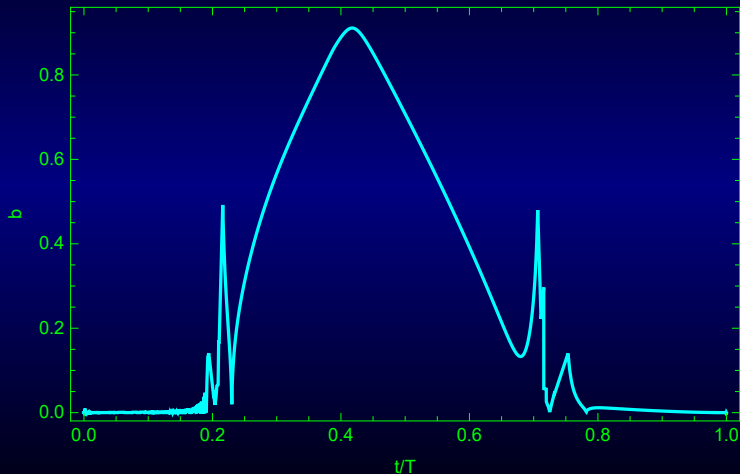
$F(t)$ — flux of energy,

F_N — Newtonian flux of energy



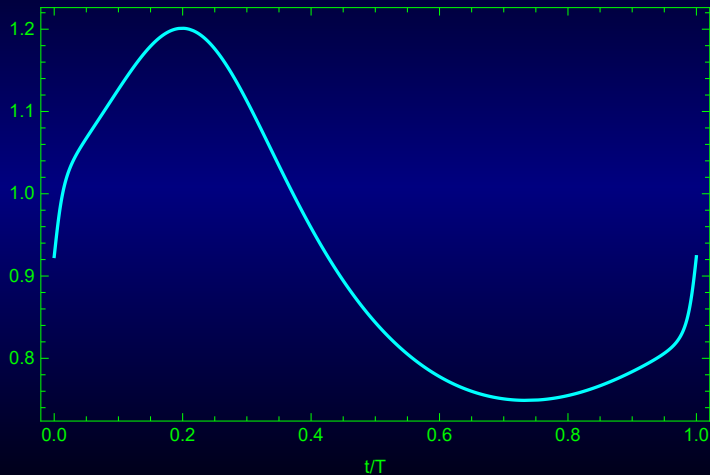
Star (probe) on the equatorial circular orbit close to SgrA*
viewed by the distant telescope (**Millimetron**)

Semimajor axis $b(t)$ for the prime (direct) image



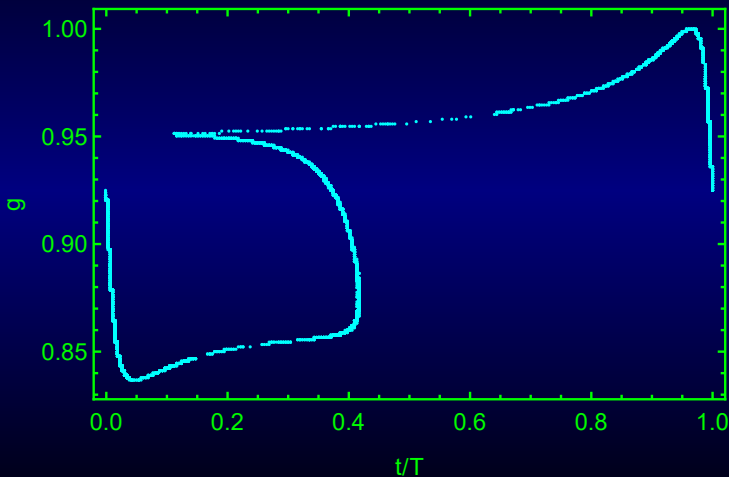
Star (probe) on the equatorial circular orbit close to SgrA* viewed by the distant telescope (Millimetron)

Frequency shift $g(t)$ for the prime (direct) image



Star (probe) on the equatorial circular orbit close to SgrA*
viewed by the distant telescope (Millimetron)

Frequency shift $g(t)$ for the first light echo image

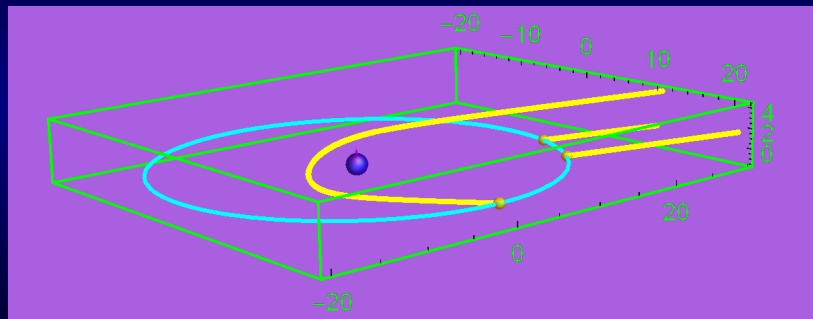


3D photon trajectories

Prime image: no intersections of equatorial plane

First light echo: one intersection of equatorial plane

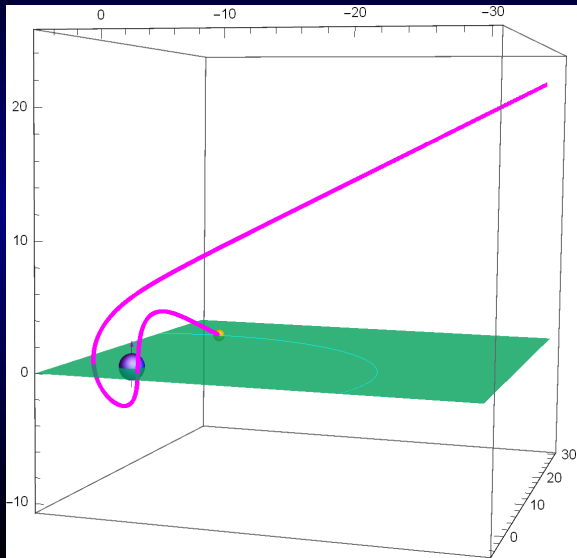
$$\lambda = -6.9, \quad q = 1.74, \quad r_{\min} = 4.64$$



3D photon trajectory

Second light echo: two intersections of equatorial plane

$$\lambda = -1.78, \quad q = 5.2, \quad r_{\min} = 3.11$$



The objective of “The Event Horizon Telescope” project is to resolve the shadow of the supermassive black hole in the Galactic Center in the year 2020.

It would be the first experimental attempt for direct black hole identification and first verification of the General Relativity in the strong field limit.

There is a chance to find a star moving on the relativistic orbit close to this black hole.

We made the animated numerical model of the gravitational lensing of a star (probe) moving around rotating Kerr black hole in the Galactic Center.

Thanks to all!