

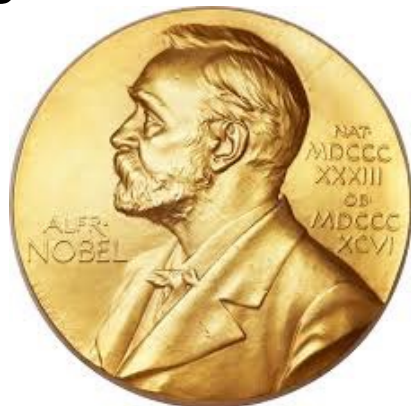
Amikor egy szupernagy tömegű fekete lyuk nem elég

Gabányi Krisztina (ELTE TTK Csillagászati Tanszék, MTA-ELTE
Extragalaktikus Asztrofizika Kutatócsoport, Csillagászati és
Földtudományi Központ Konkoly-Thege Miklós Csillagászati Intézet)



Nobel Media. Ill. Niklas Elmehed.

2020 – Fizikai Nobel-díj



- Roger Penrose, Reinhard Genzel és Andrea Ghez
- „A fekete lyukak elméleti kutatásának megalapozásáért és Tejútrendszer középpontjában található szupernagy tömegű fekete lyuk létezésének bizonyításáért tanulmányozásáért”

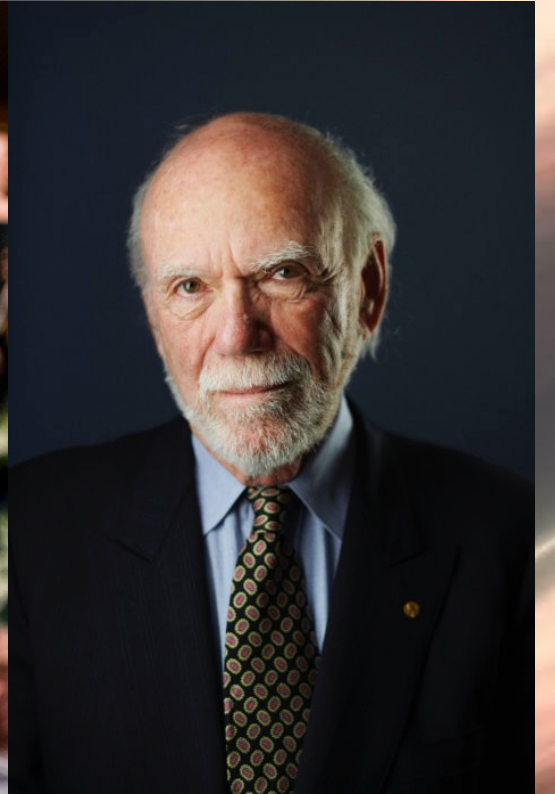
Event Horizon Telescope

6,5 milliárd naptömegű
fekete lyuk



Mérés: 2017 április

Publikáció: 2019 április

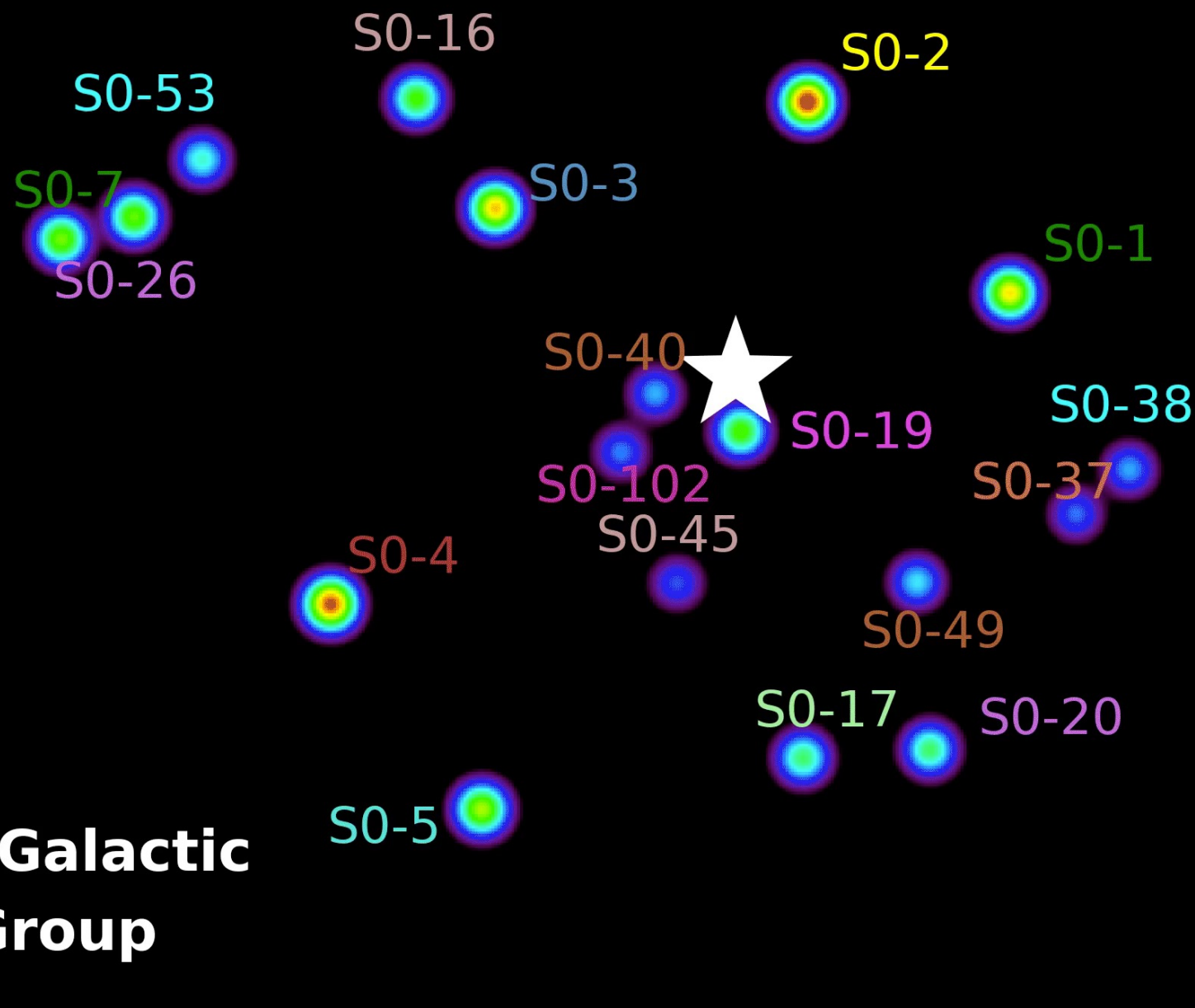


*Interstellar – film (2014)
Kip Thorne – executive producer*

S2 periódusa: ~ 16 év

SgrA*-tól való legkisebb távolsága: 17 fényóra

1995.5



0.1"



S0-30

**Keck/UCLA Galactic
Center Group**

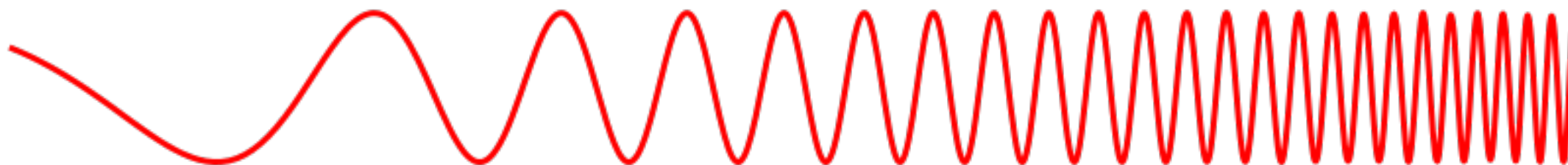
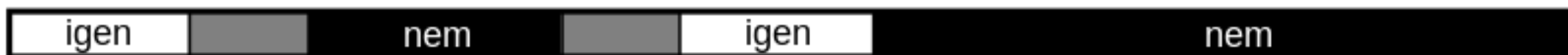


ESO

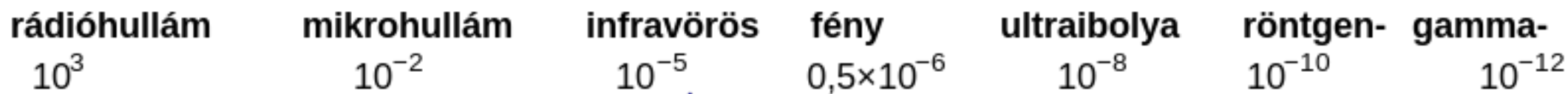
Áthatol a csillagközi anyagon?



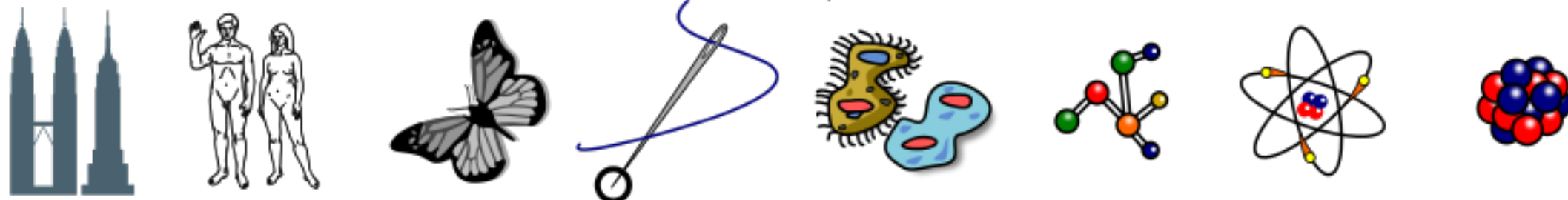
Átengedi a Föld légköre?



Hullámtartomány
Hullámhossz (m)

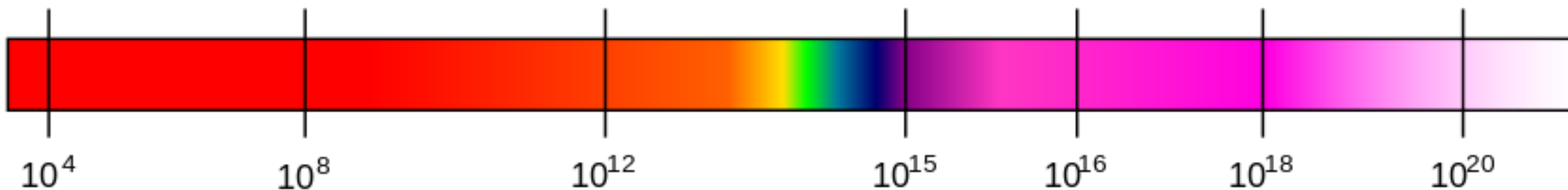


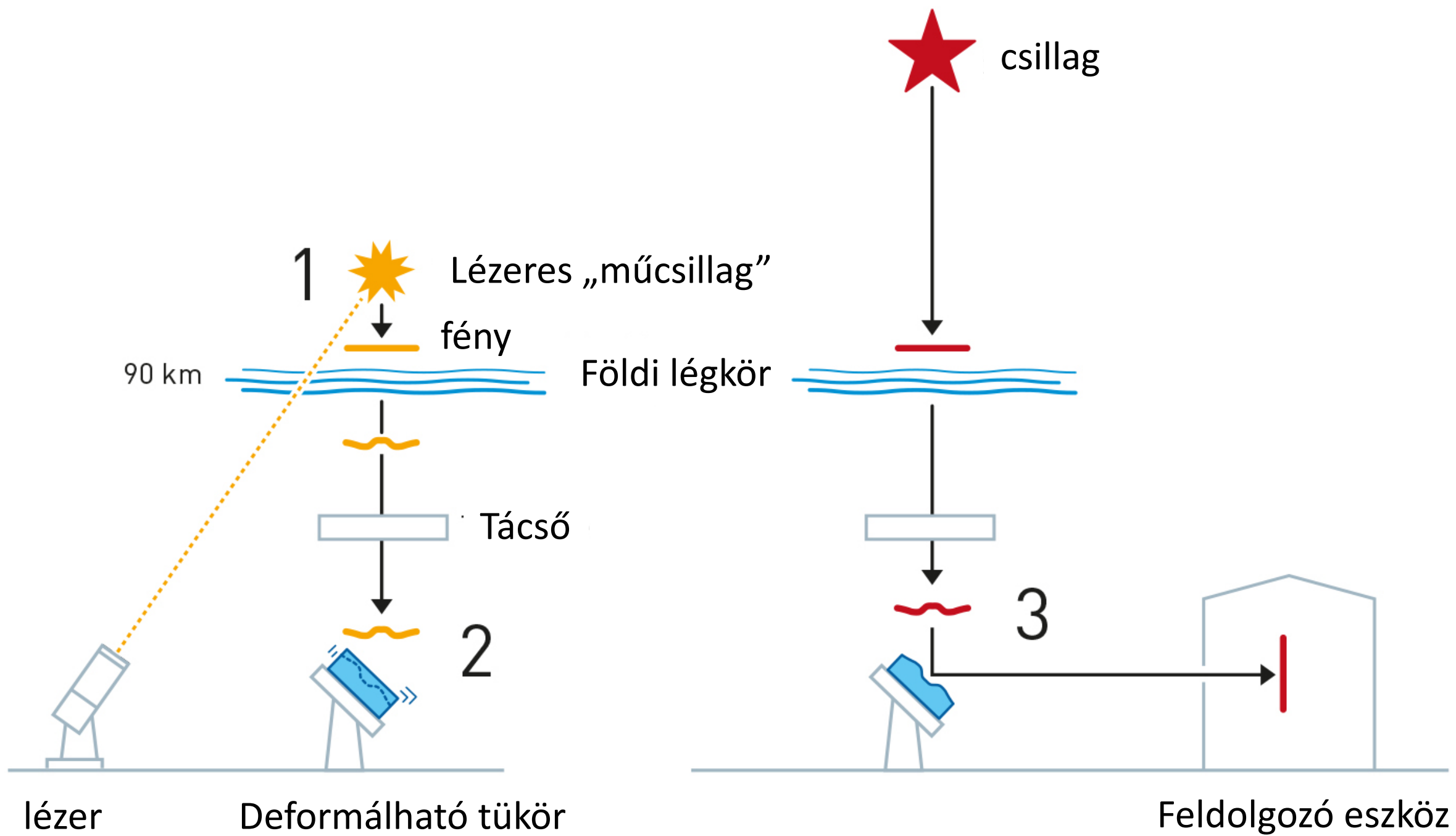
A hullámhossz nagyságrendje

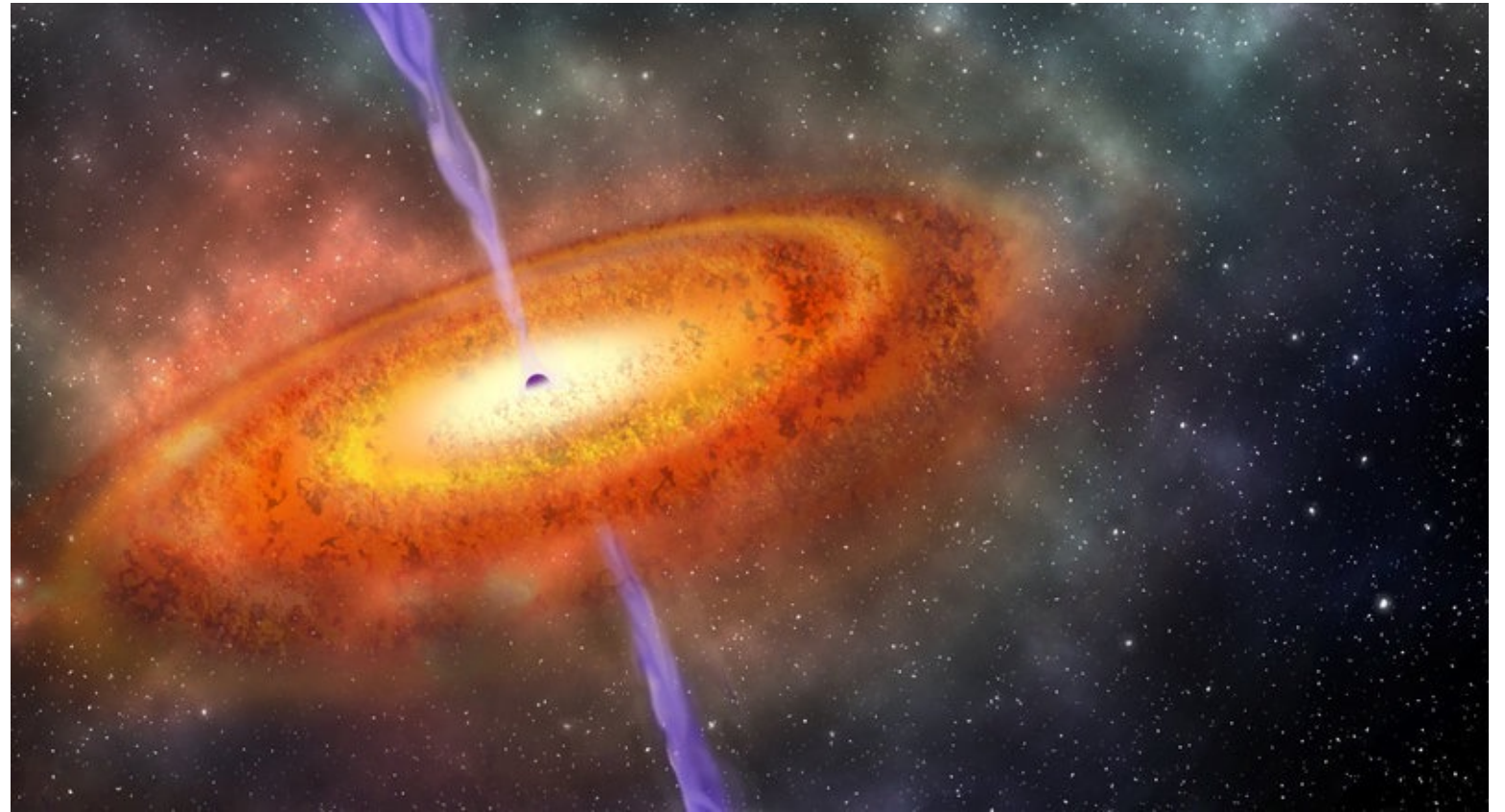
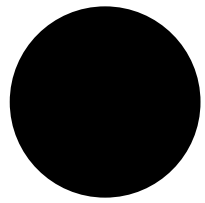


épületek	ember	pillangó	tűhegy	egysejtű	molekula	atom	atommag
----------	-------	----------	--------	----------	----------	------	---------

Frekvencia (Hz)







Antenna galaxisok– 45 millió fényév távolságra



Hubble Űrtávcső

Földi felvétel



<https://www.youtube.com/watch?v=C0XNyTp5brM>

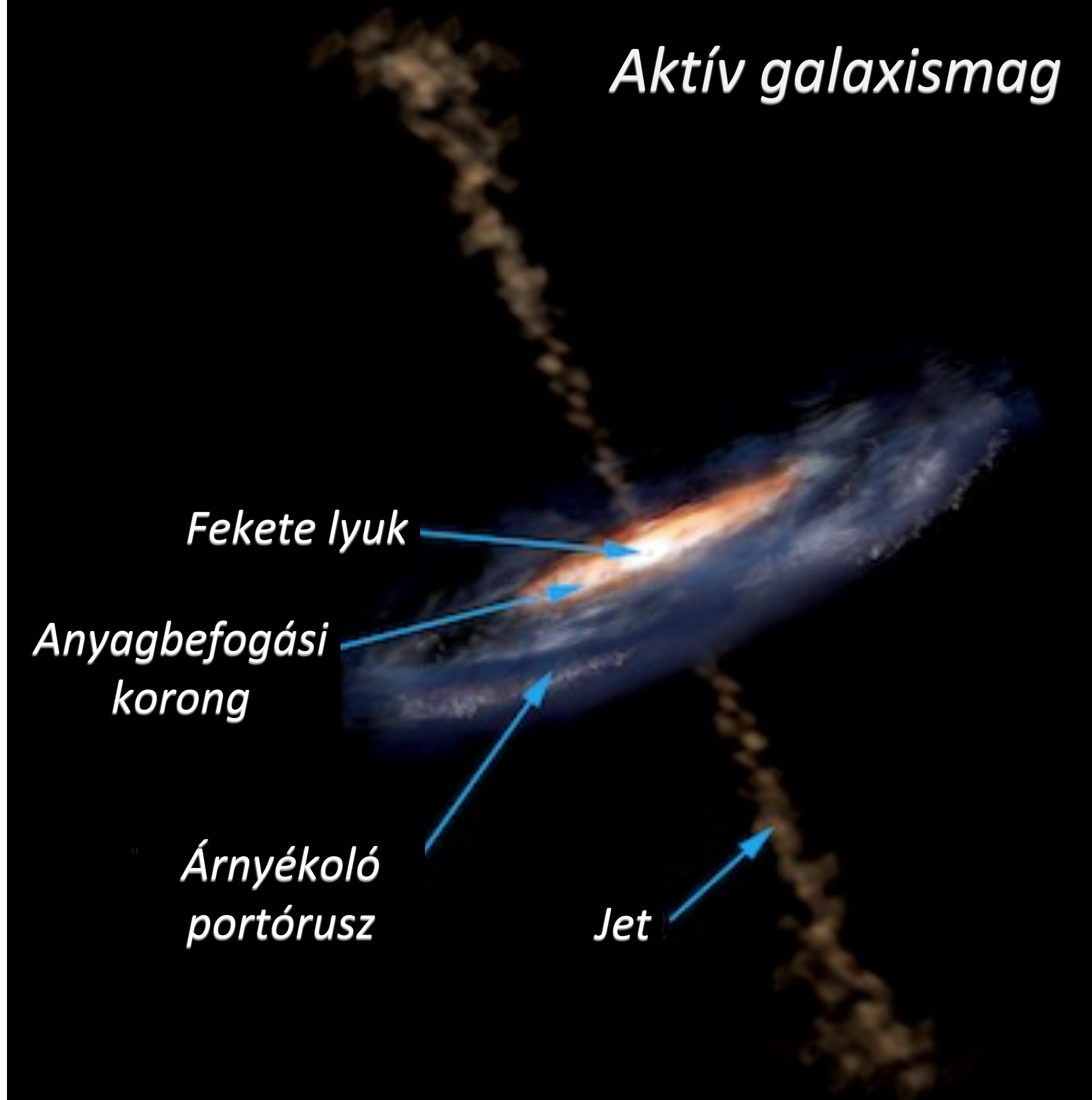
Aktív galaxismag

Fekete lyuk

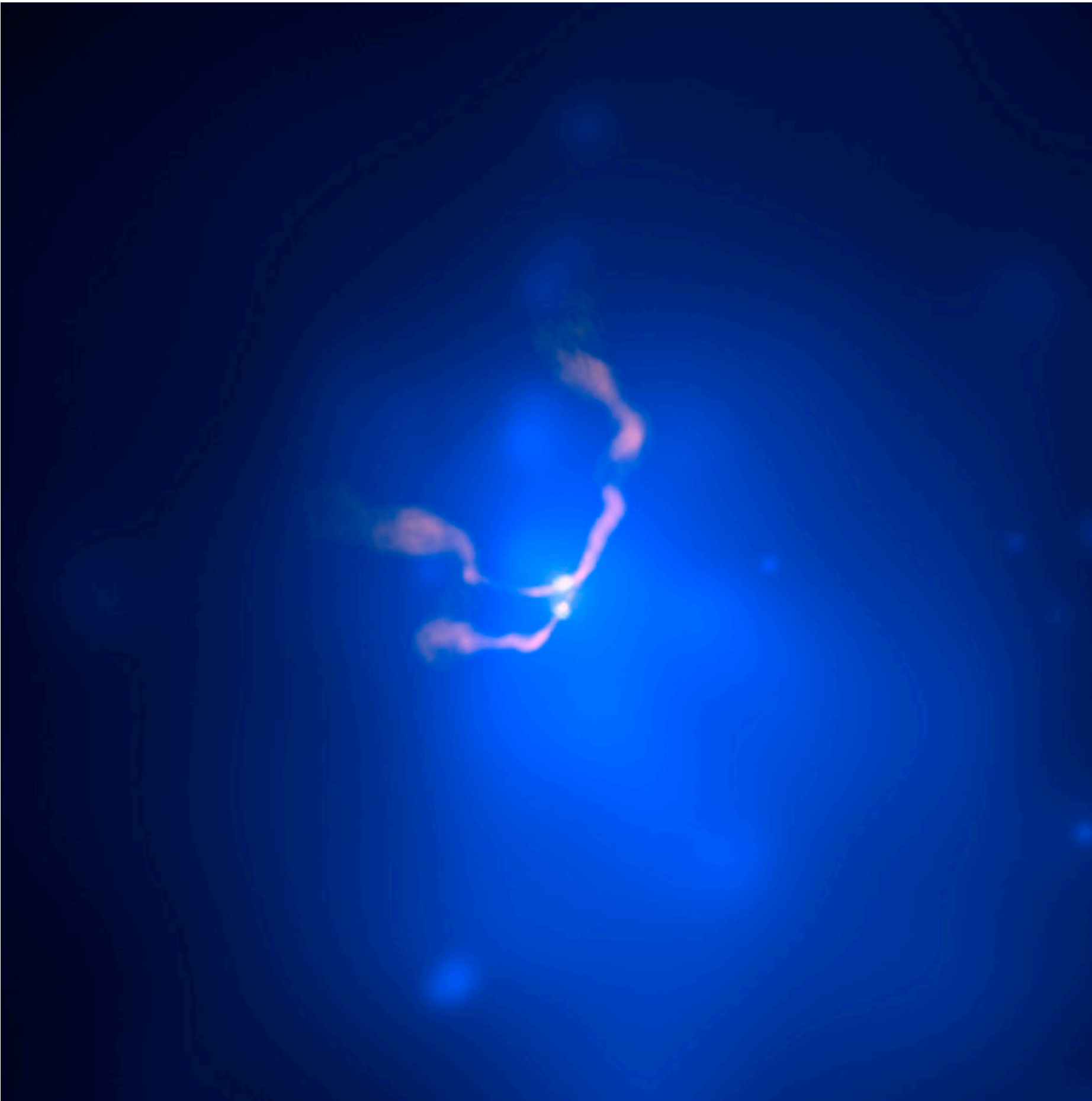
*Anyagbefogási
korong*

*Árnyékoló
portórusz*

Jet



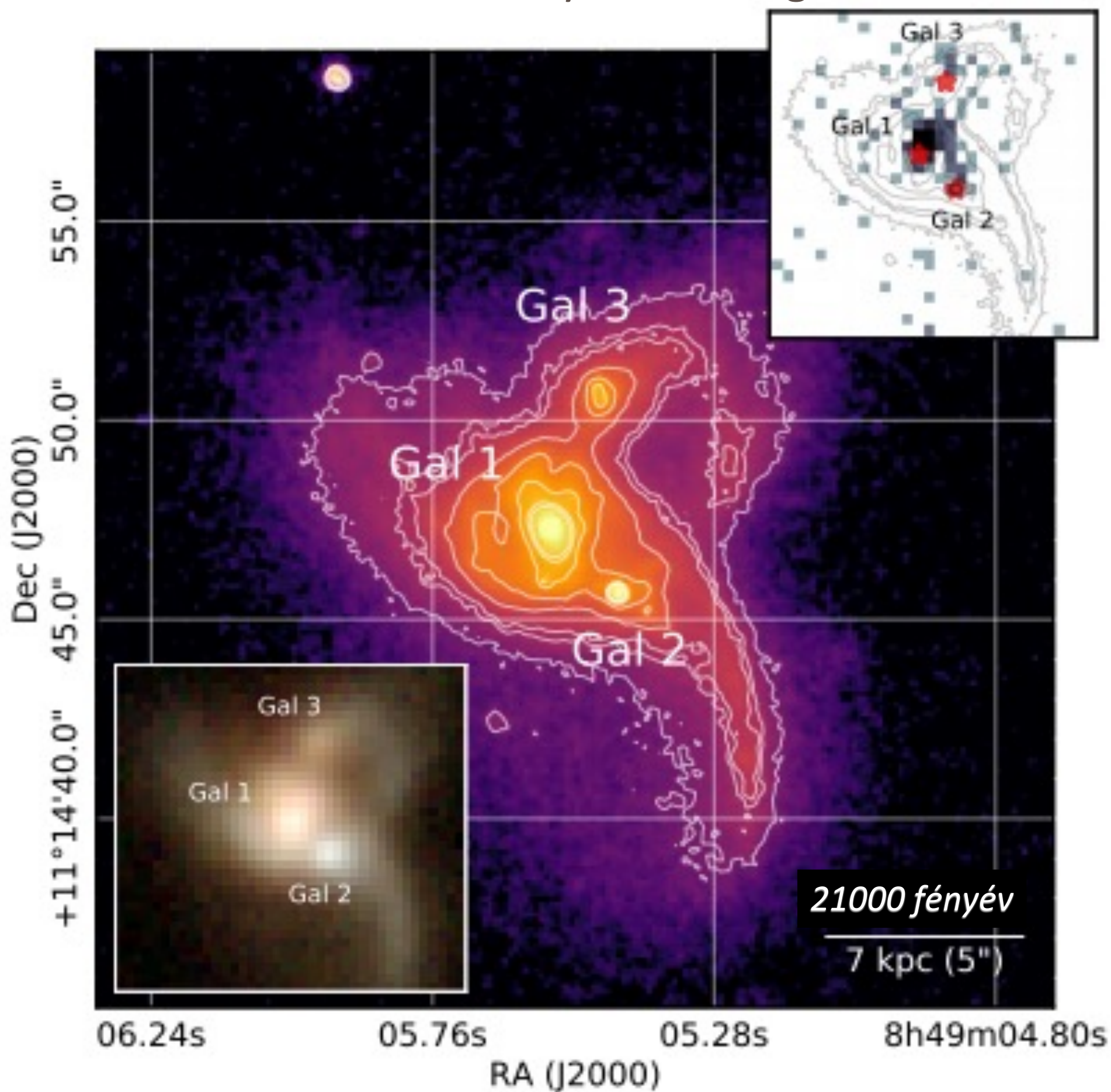
3C 75 – 300 millió fényév távolságra



Rádió, röntgen

*Két fekete lyuk távolsága:
25 000 fényév*

J0849+1114 - 1 milliárd fényév távolságra



Röntgen

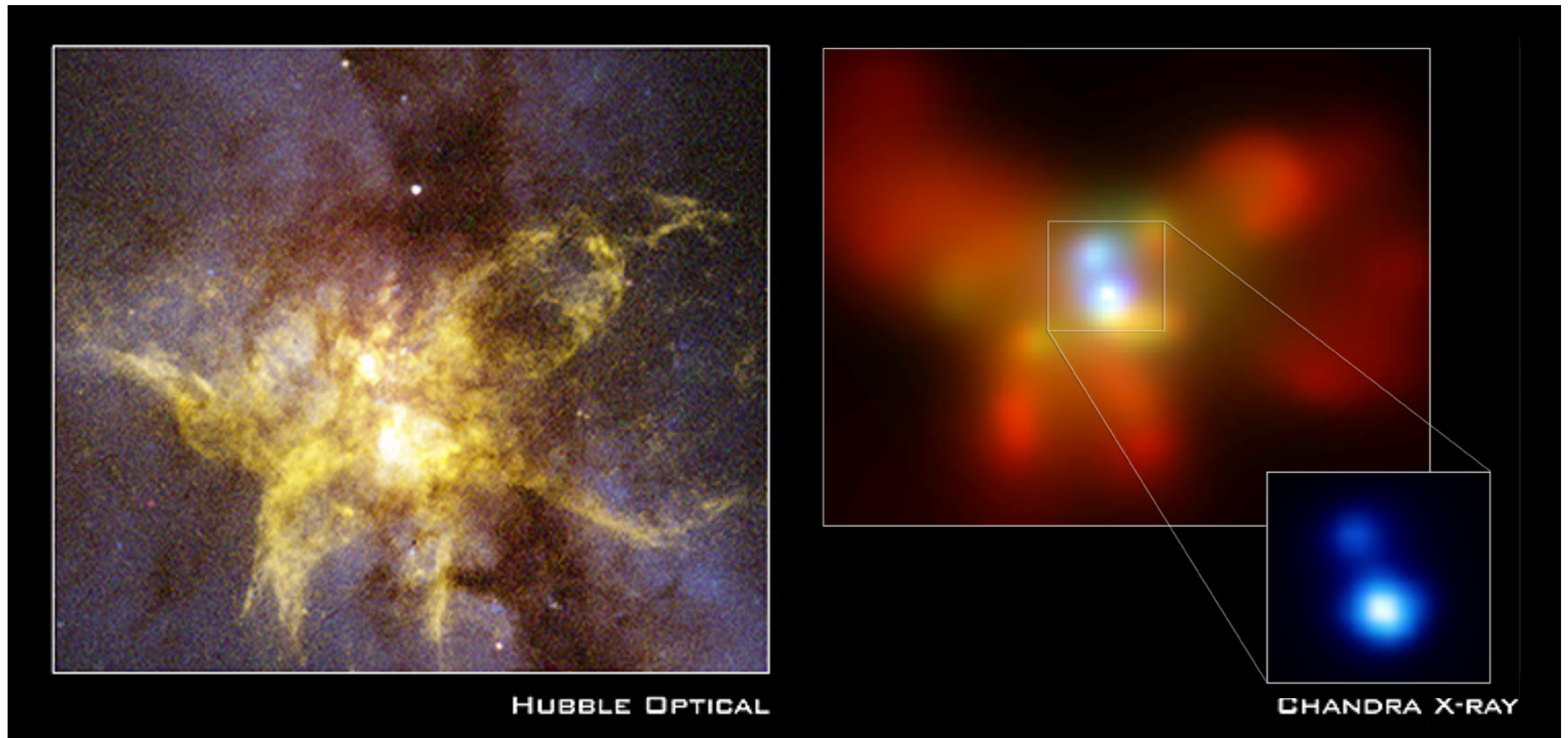
Optikai

21000 fényév

7 kpc (5")

NGC 6240 – 400 millió fényév távolságra

Két szupernagy tömegű fekete lyuk 3000 fényévre egymástól

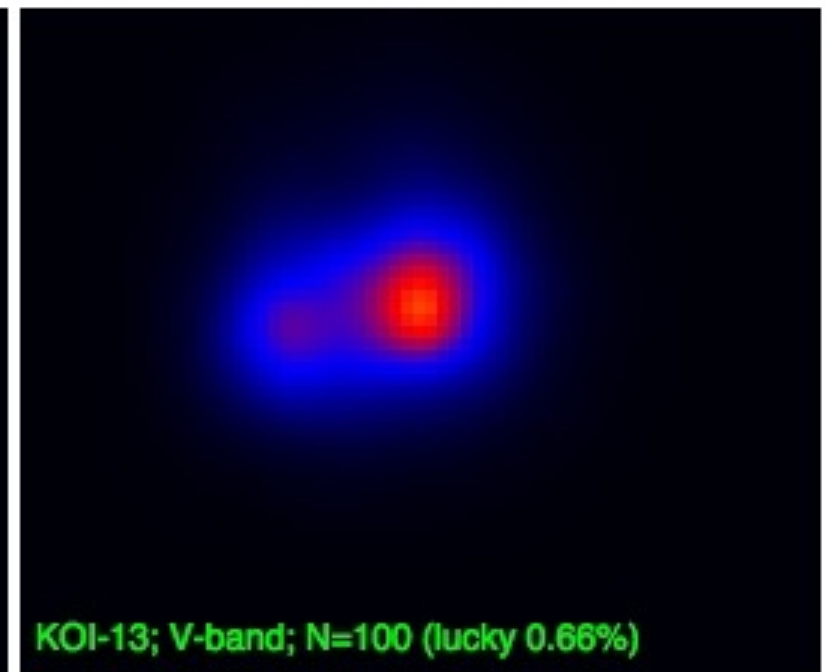
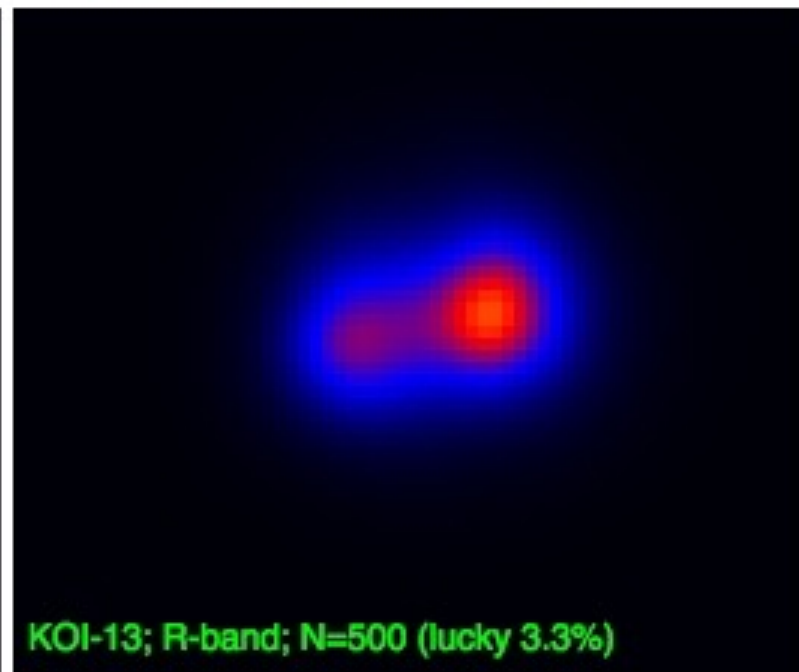
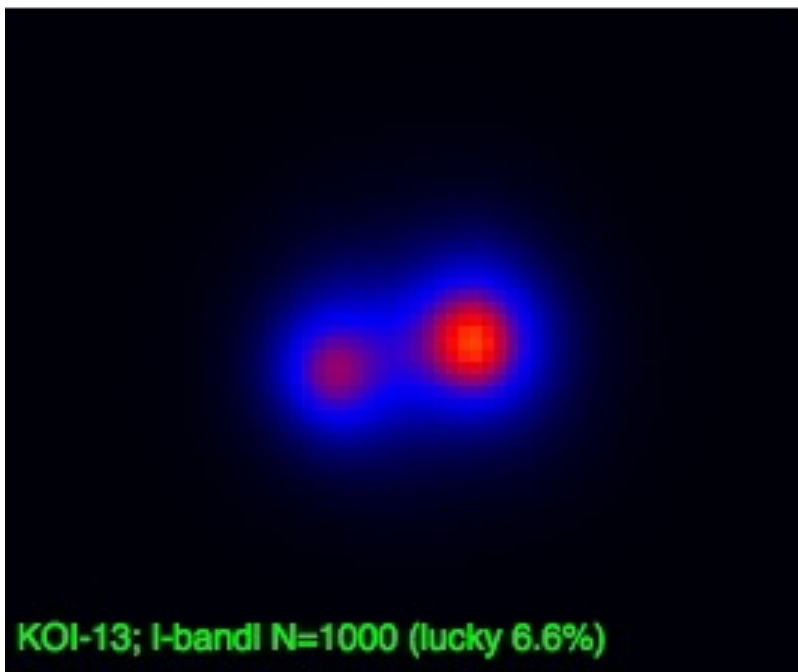
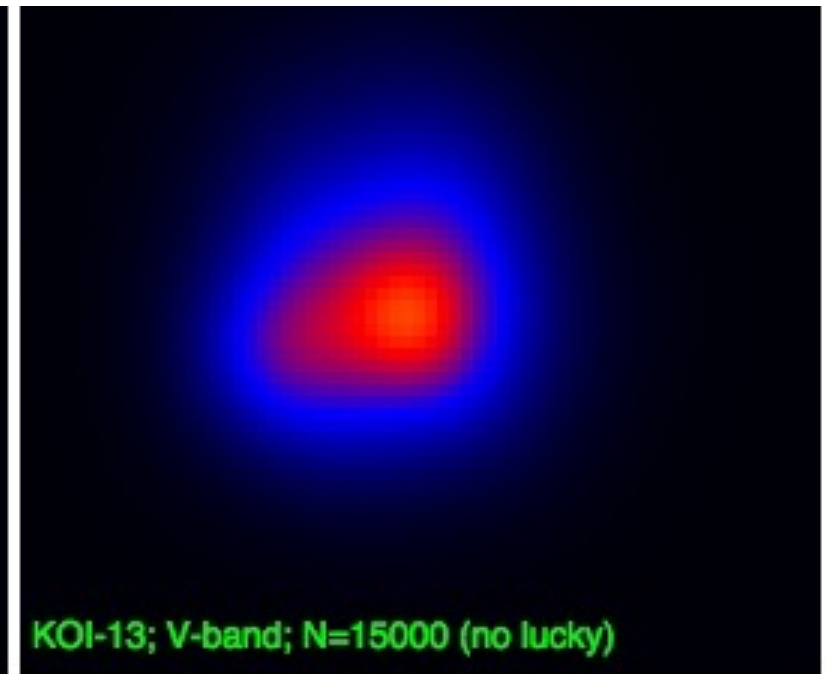
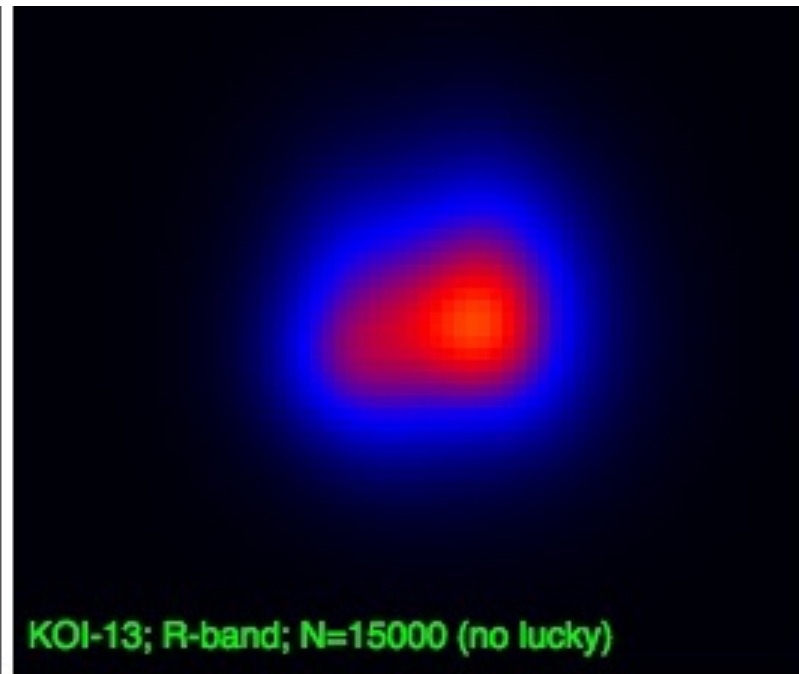
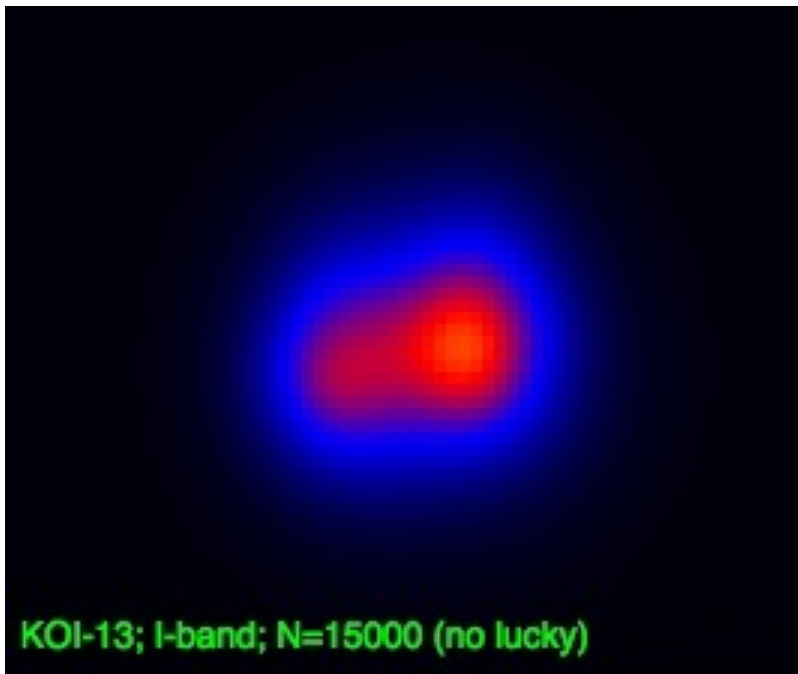


Felbontóképesség

$$\theta \sim \frac{\lambda}{D}$$

hullámhossz

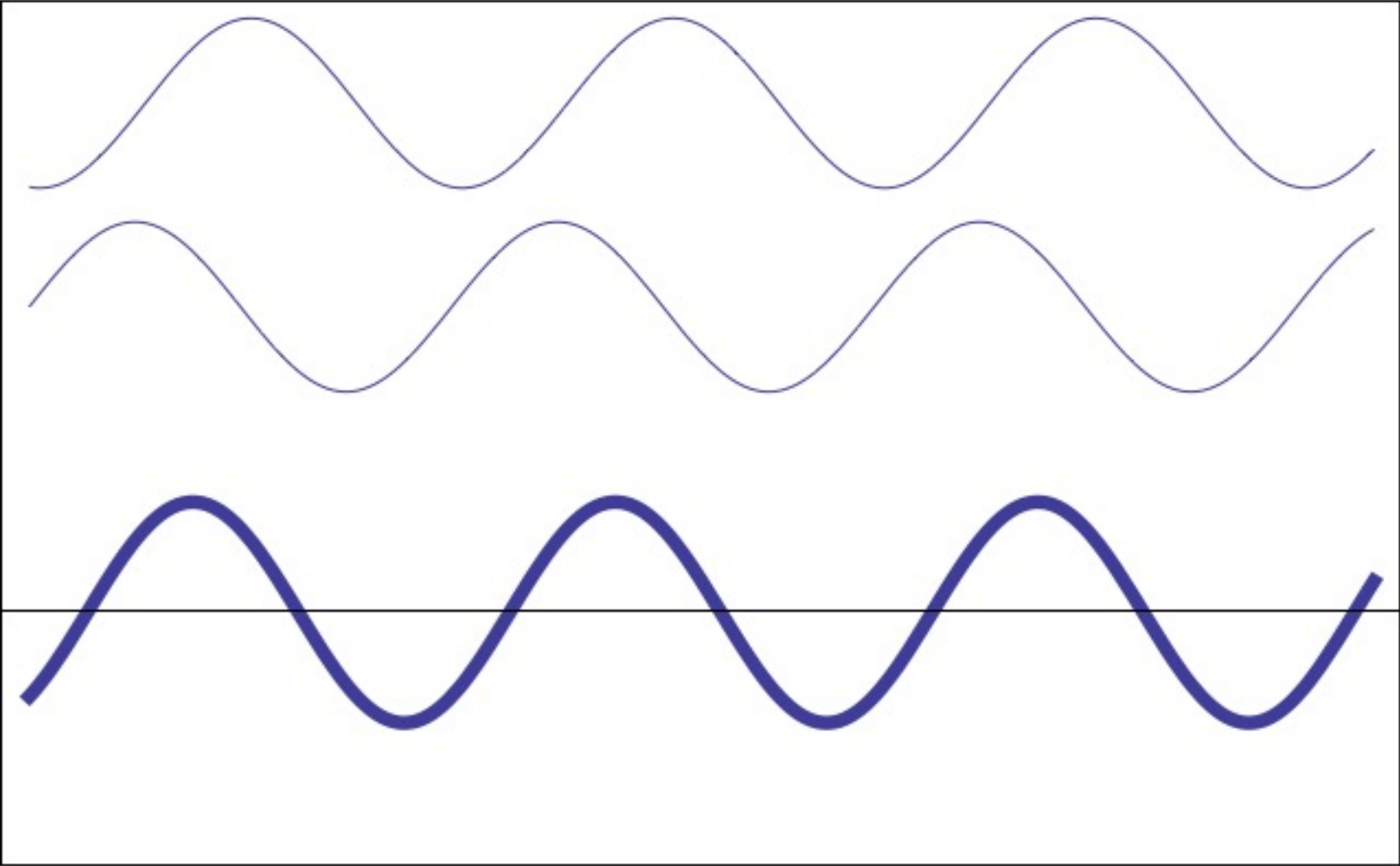
átmérő



Interferometria

$$\text{Szögfelbontás} \sim \frac{\text{hullámhossz}}{\text{bázisvonalhossz}}$$





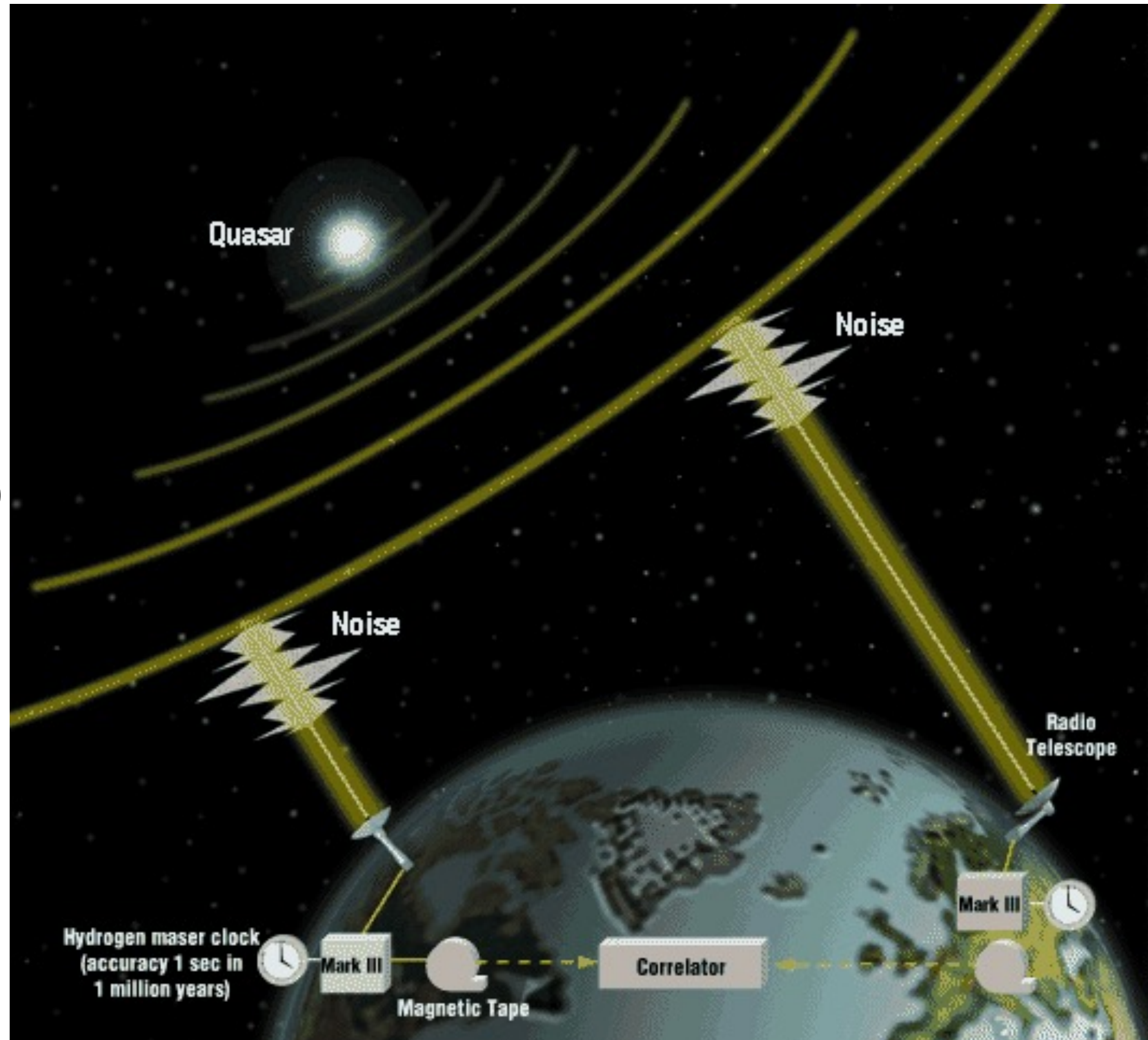
Nagyon hosszú bázisvonalú interferometria

Very Long Baseline Interferometry

$$\theta \sim \frac{\lambda}{b}$$

Hosszabb bázisvonal (b)
⇒ finomabb
szögfelbontás

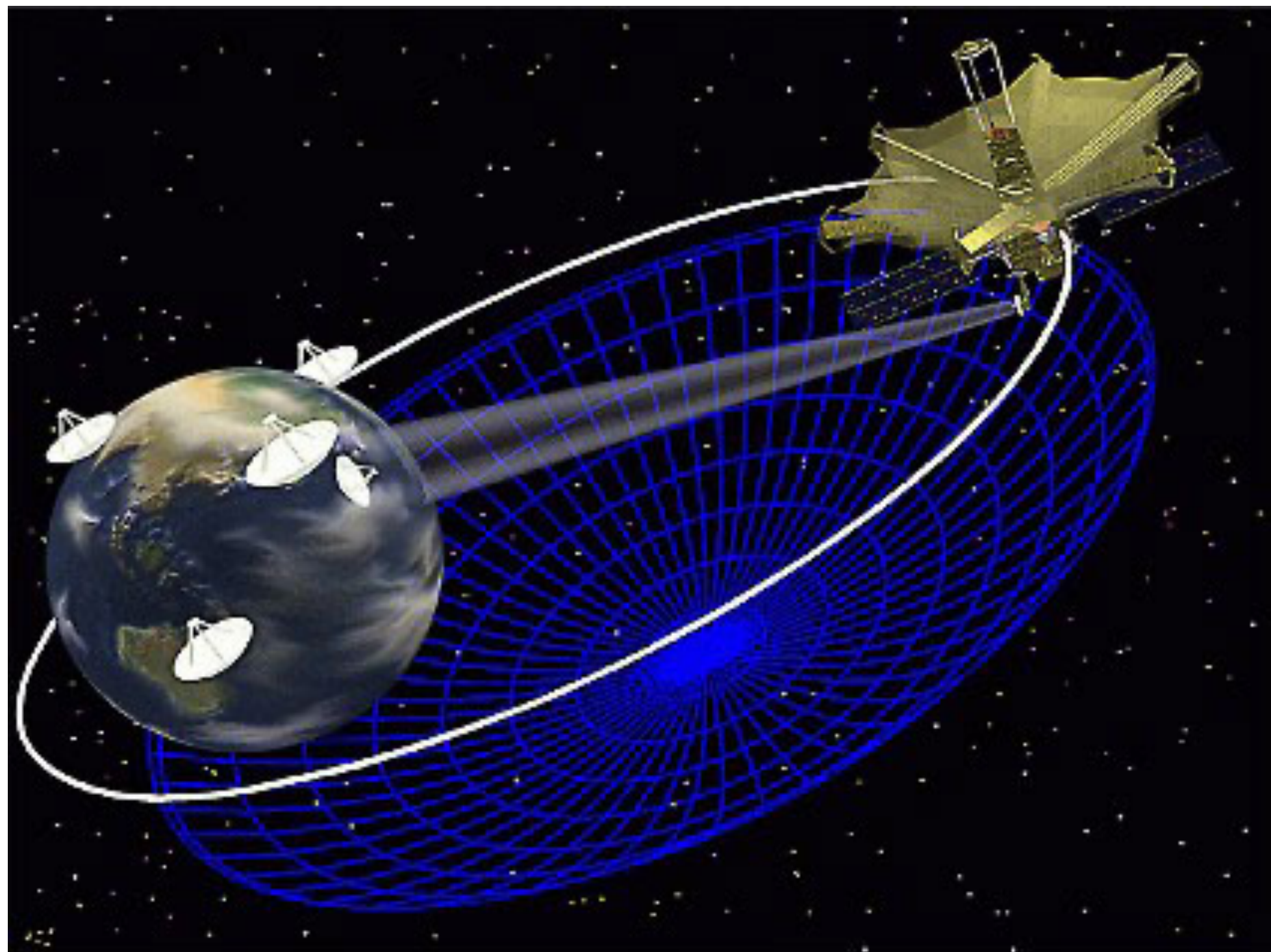
Rövidebb hullámhossz
(λ) ⇒ finomabb
szögfelbontás



Űr-VLBI – HALCA - はるか

1997-2005

Földtávolpont: 21400 km



Ūr-VLBI - RadioAstron

2011-2019

Russia's RadioAstron space observatory

The RadioAstron observatory with an unprecedented high resolution capability will make it possible to observe remote objects in space

Parabolic antenna

- Diameter: 10 meters
- Comprises 27 carbon-plastic "petals"

Broad-beam antennas

Focal module

This is the first Russian orbital radio telescope

It will study:

- Galaxy nuclei
- Black holes
- Neutron stars
- Interstellar plasma clouds
- The Earth's gravitational field
- And many other objects and phenomena in the Universe

Ordered by: Federal Space Agency

Chief contractor: Lavochkin Research and Production Association

Scientific equipment developed by: Astro Space Center of the Russian Academy of Sciences' Lebedev Physics Institute

The RadioAstron observatory was launched on July 18, 2011.

Active service life: At least five years

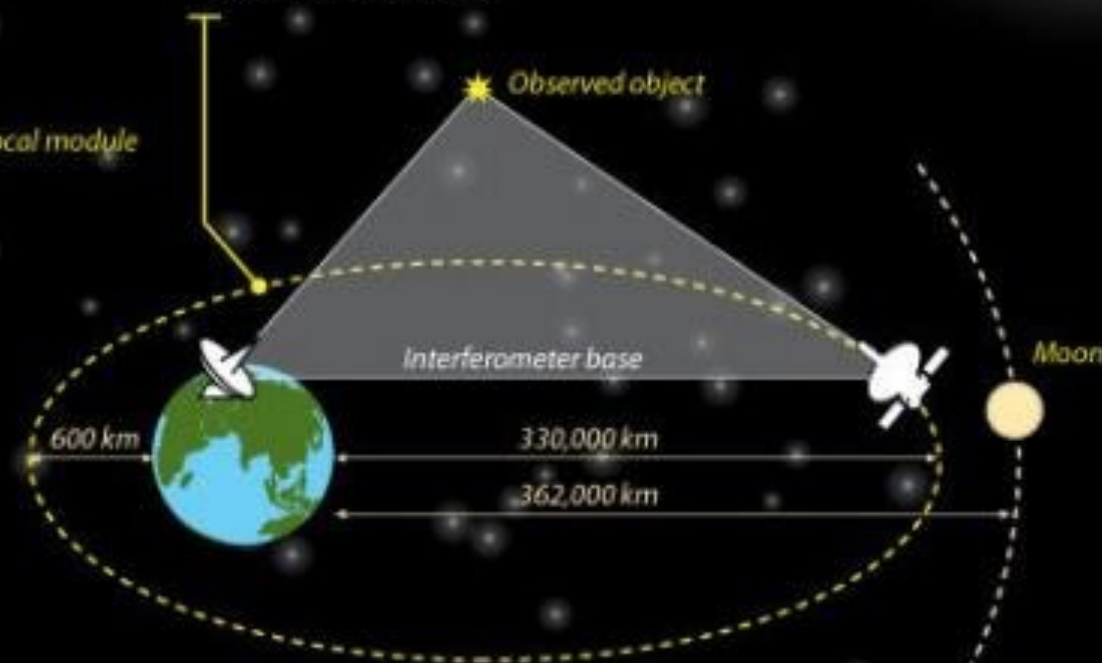
Navigator service module

High-capacity radio facility

Solar batteries

Highly elliptical orbit

- Apogee: 330,000 kilometers
- Perigee: 600 km
- Orbital period: 8.2 days



The RadioAstron observatory will operate with an international network of ground-based radio telescopes. This huge ground- and space-based telescope system, also called an interferometer, will provide the finest angular resolution.

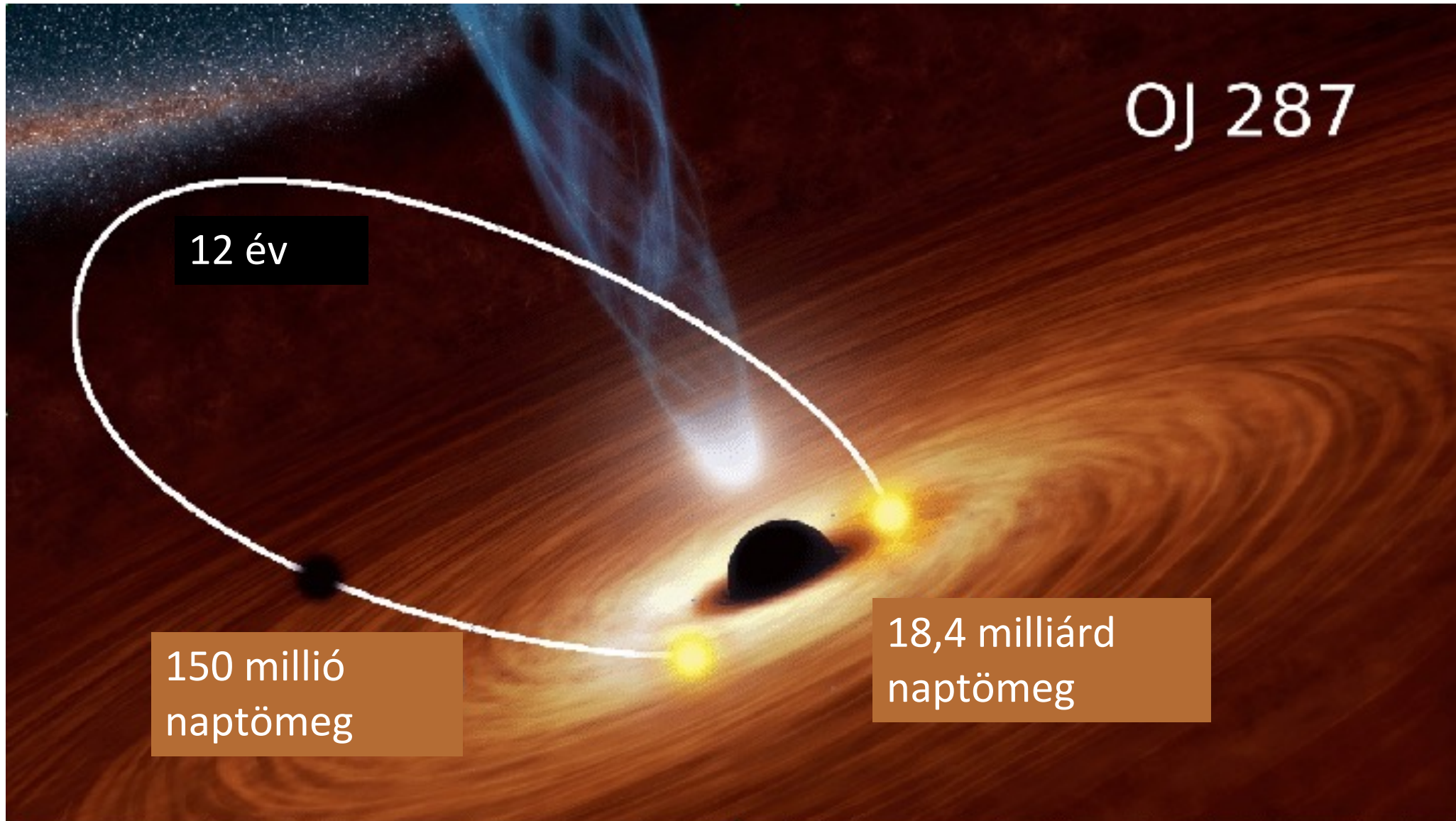
This will make it possible to obtain images of remote objects with a resolution exceeding that of NASA's Hubble orbital telescope a thousand times over

OJ 287

12 év

150 millió
naptömeg

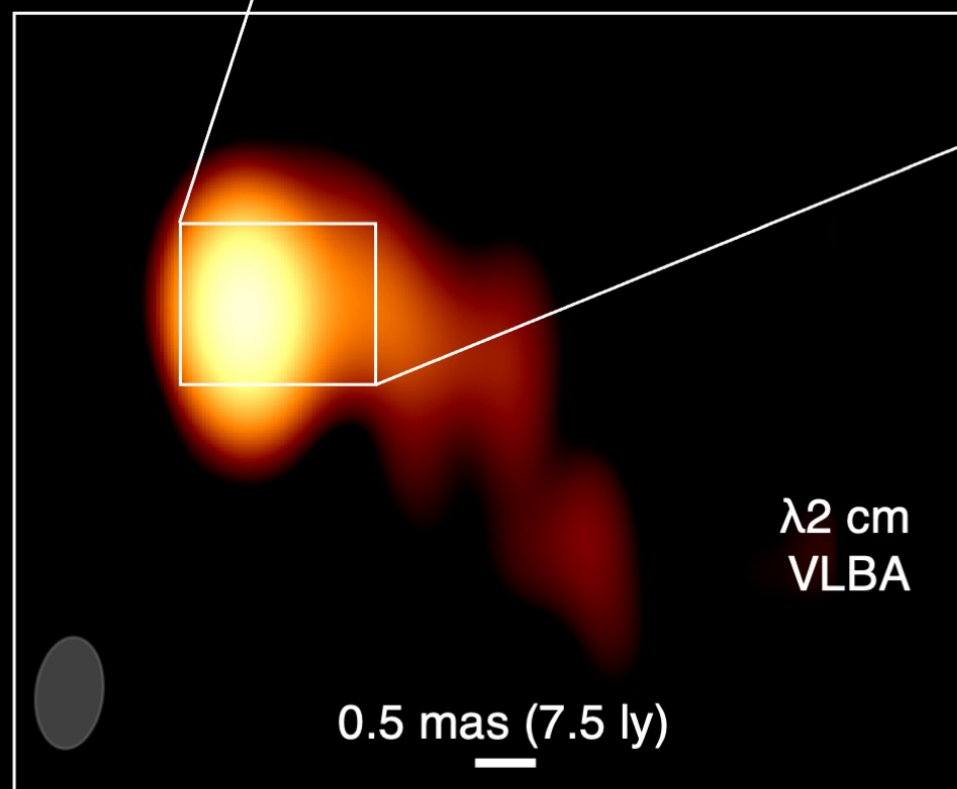
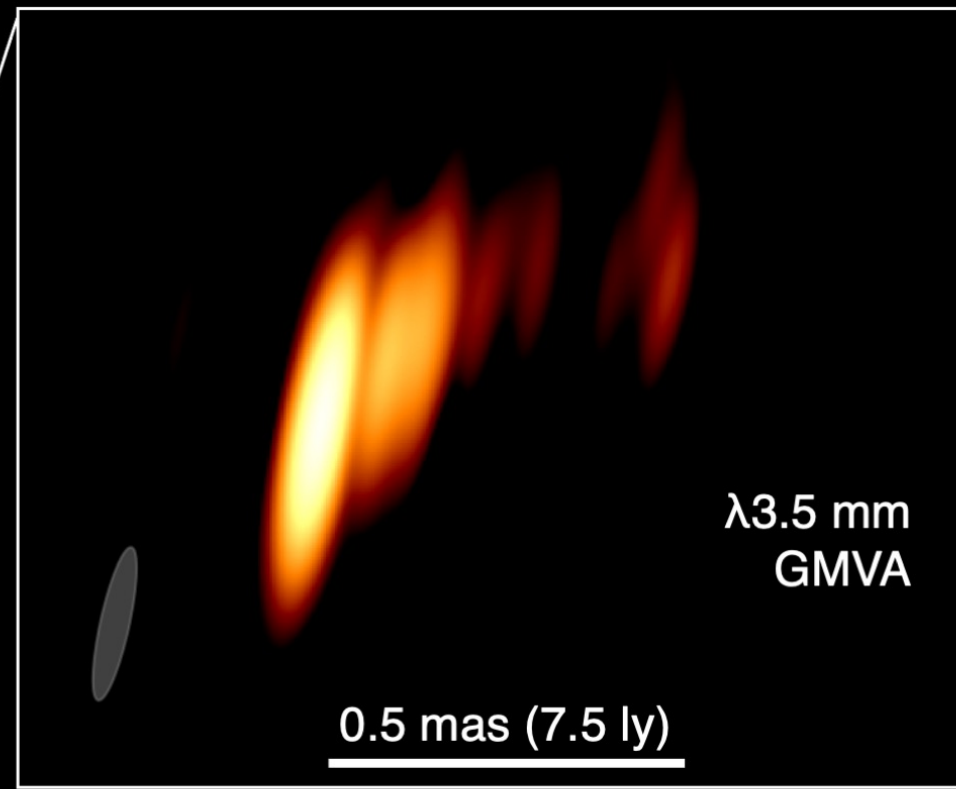
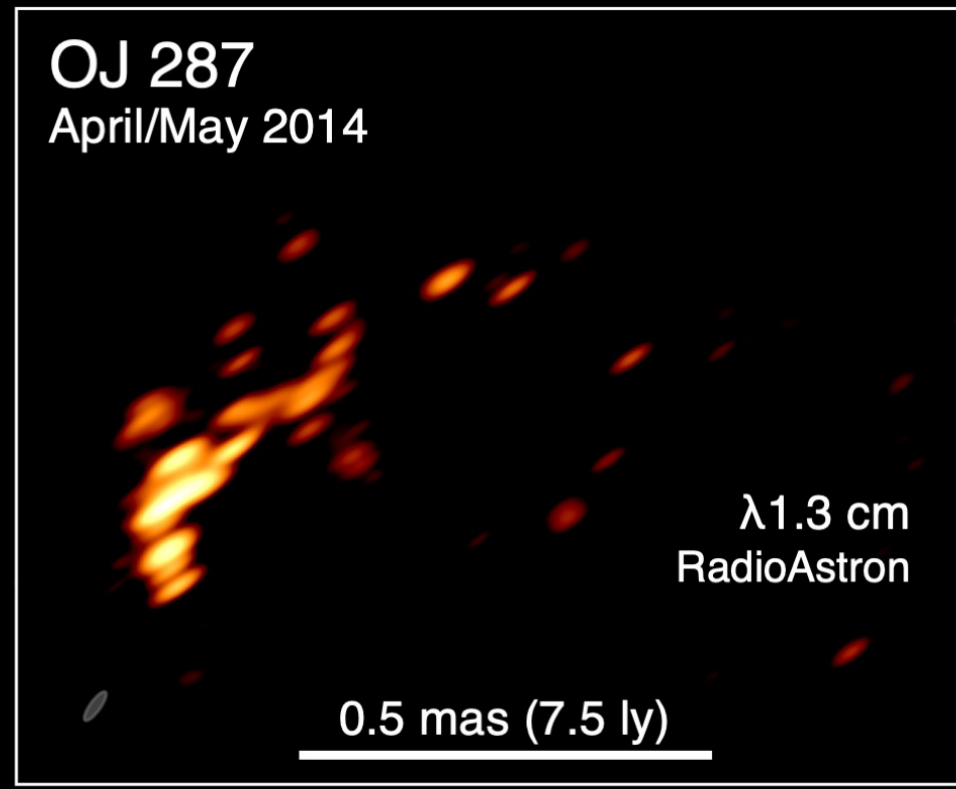
18,4 milliárd
naptömeg





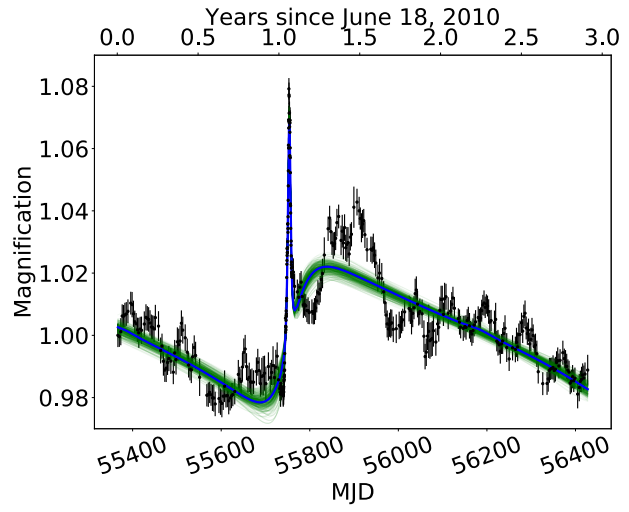


OJ 287
April/May 2014



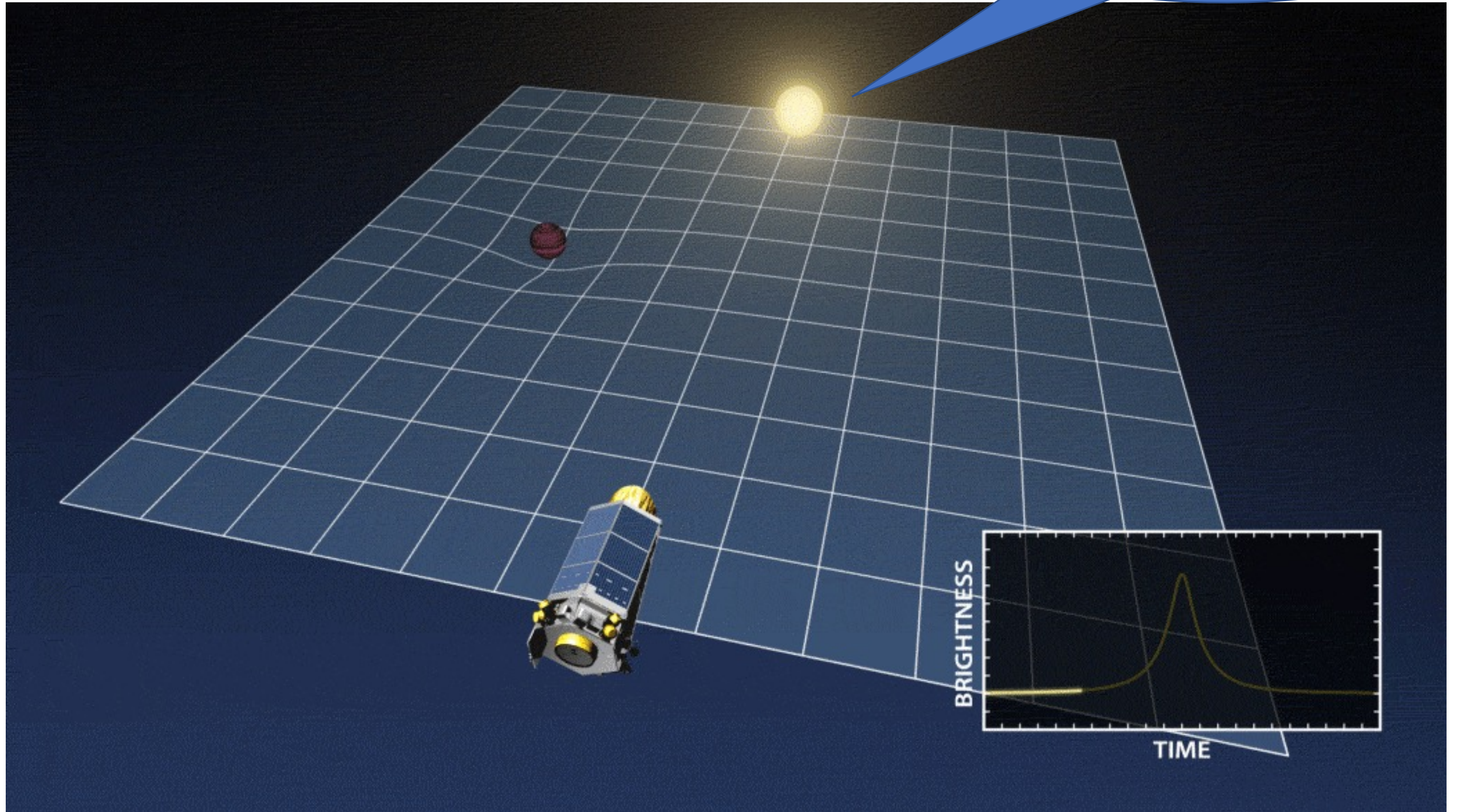
Collage: Eduardo Ros (MPIfR)

© Gómez, Traianou,
Krichbaum, et al., The
Astrophysical Journal
(2022)



Gravitációs lencsézés

Aktív galaxismag



The Gravitational Wave Spectrum

Sources

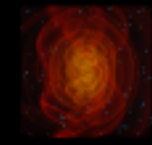
Detectors



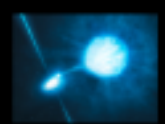
Big Bang



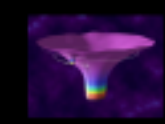
Supermassive Black Hole Binary Merger



Compact Binary Inspiral & Merger



Extreme Mass-Ratio Inspirals



Pulsars, Supernovae



age of the universe

Wave Period

years

hours

seconds

milliseconds

10^{-16}

10^{-14}

10^{-12}

10^{-10}

10^{-8}

10^{-6}

10^{-4}

10^{-2}

1

10^2

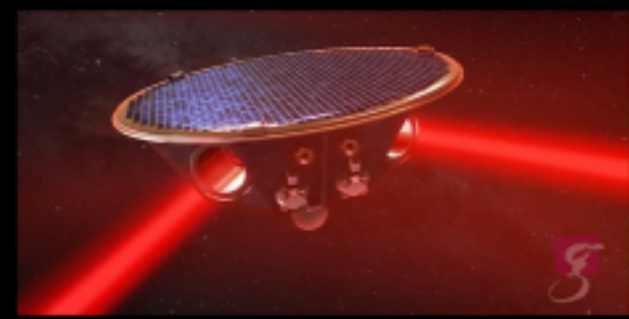
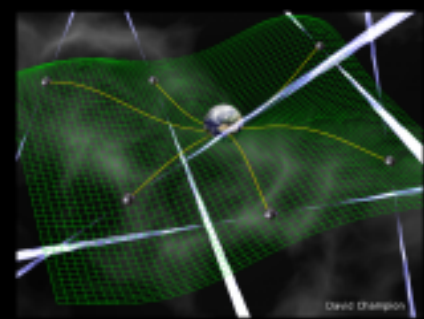
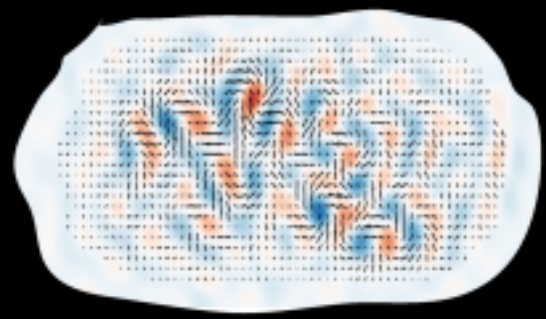
Wave Frequency

CMB Polarization

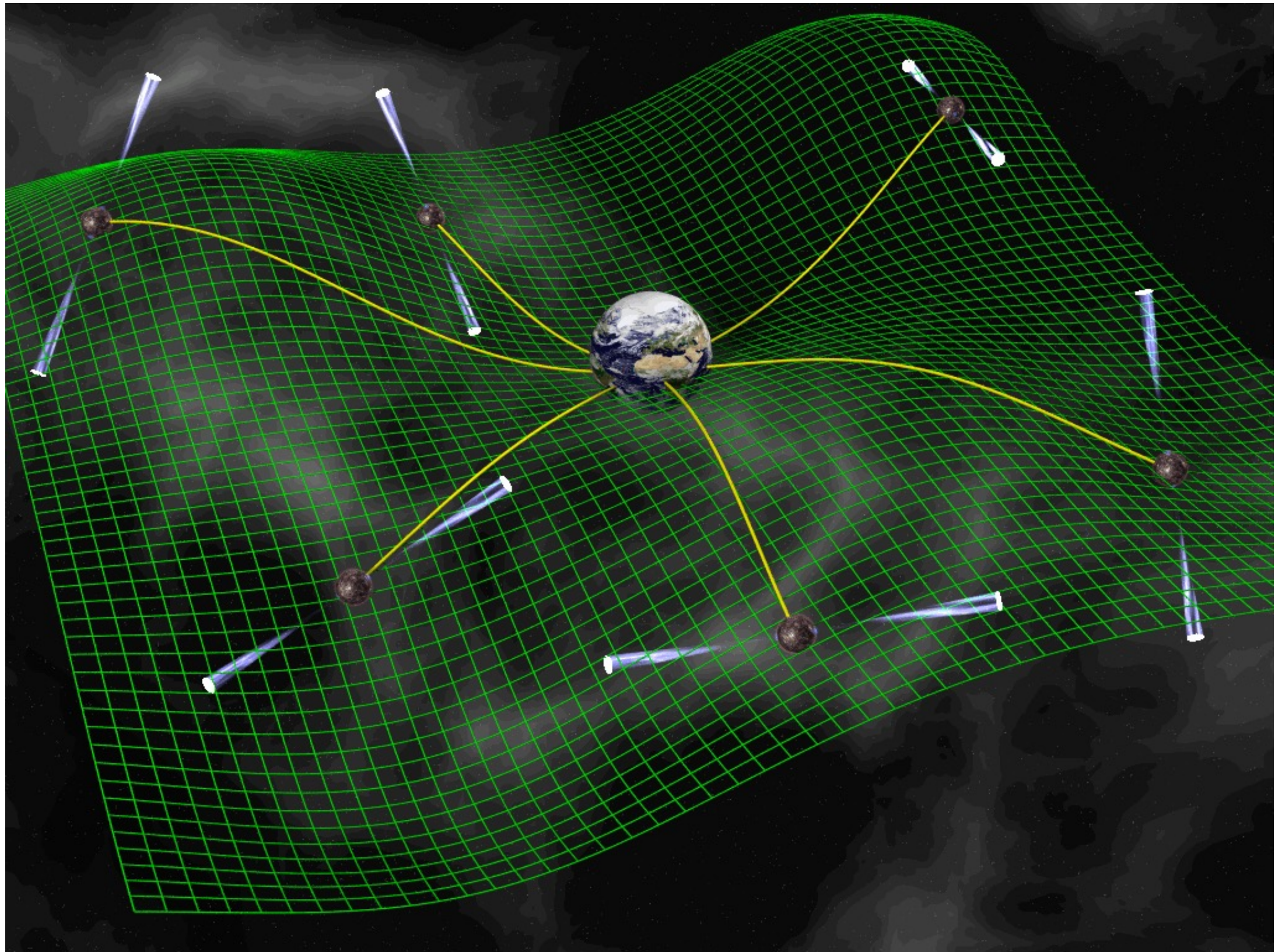
Radio Pulsar Timing Arrays

Space-based interferometers

Terrestrial interferometers



Pulsar Timing Array



e-LISA

Lézer interferometer 2,5 millió km karhosszúsággal

