Our Black Hole

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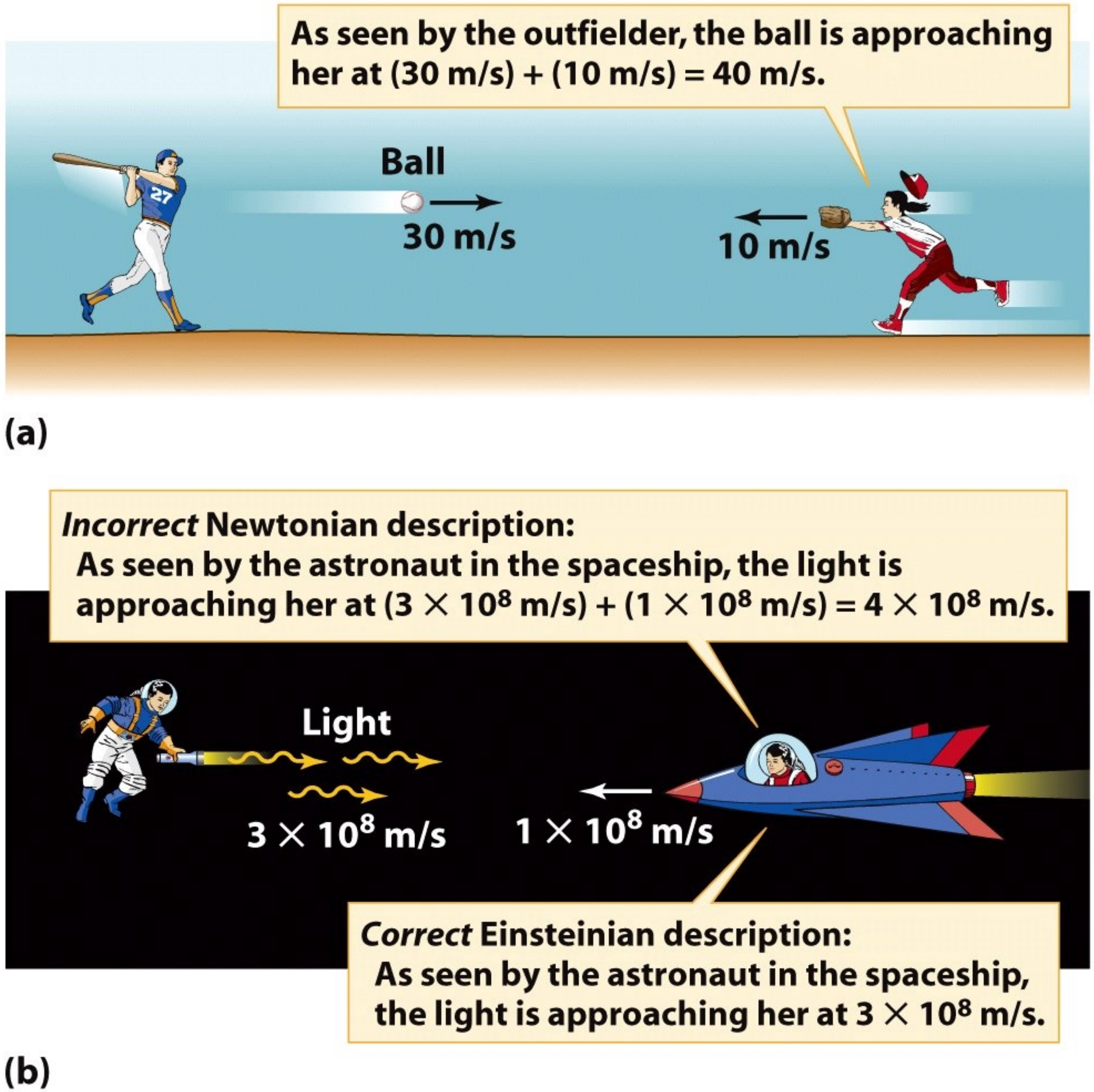


Figure 22-1
Universe, Eighth Edition

The curvature of space-time

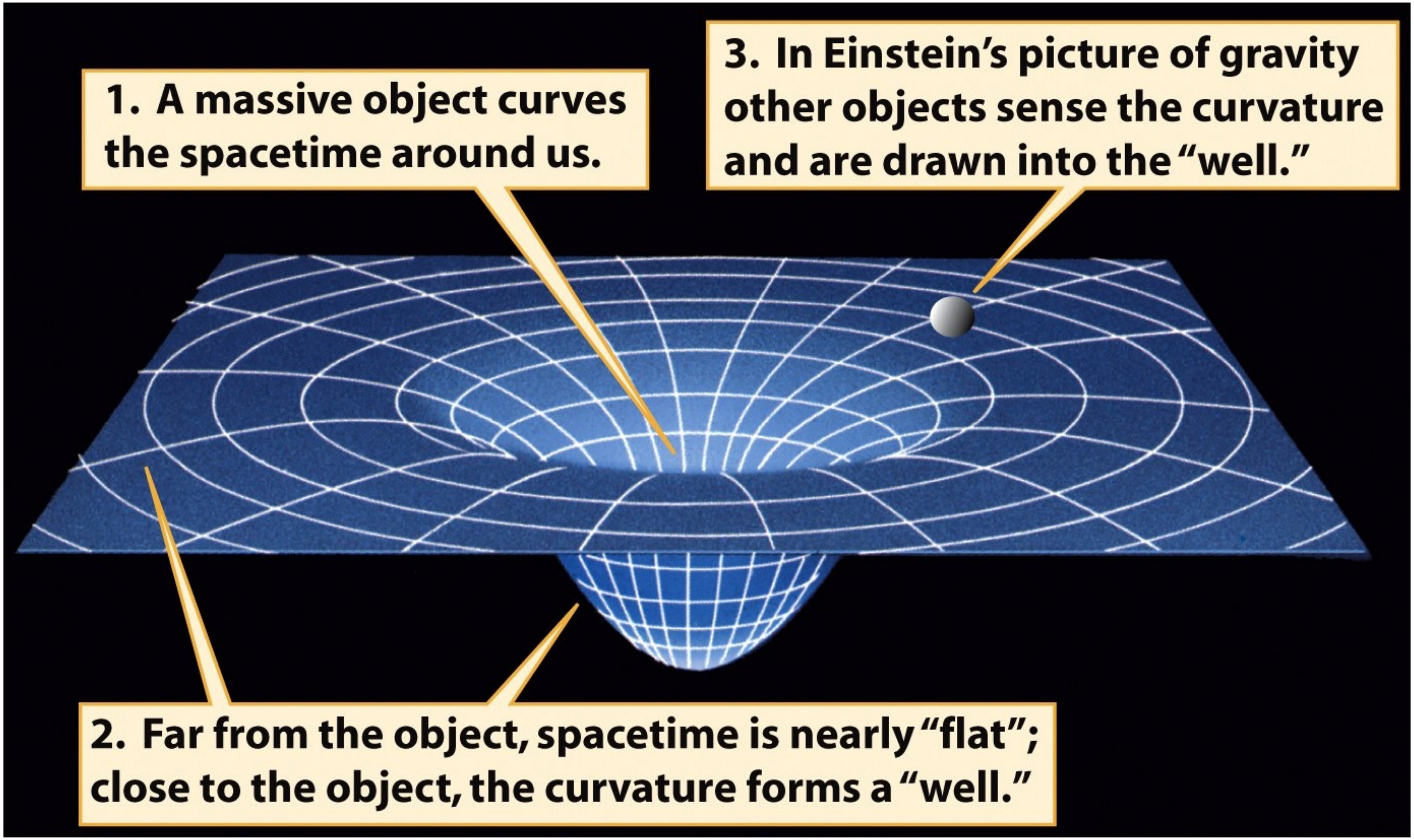


Figure 22-4
Universe, Eighth Edition

Deflection of light

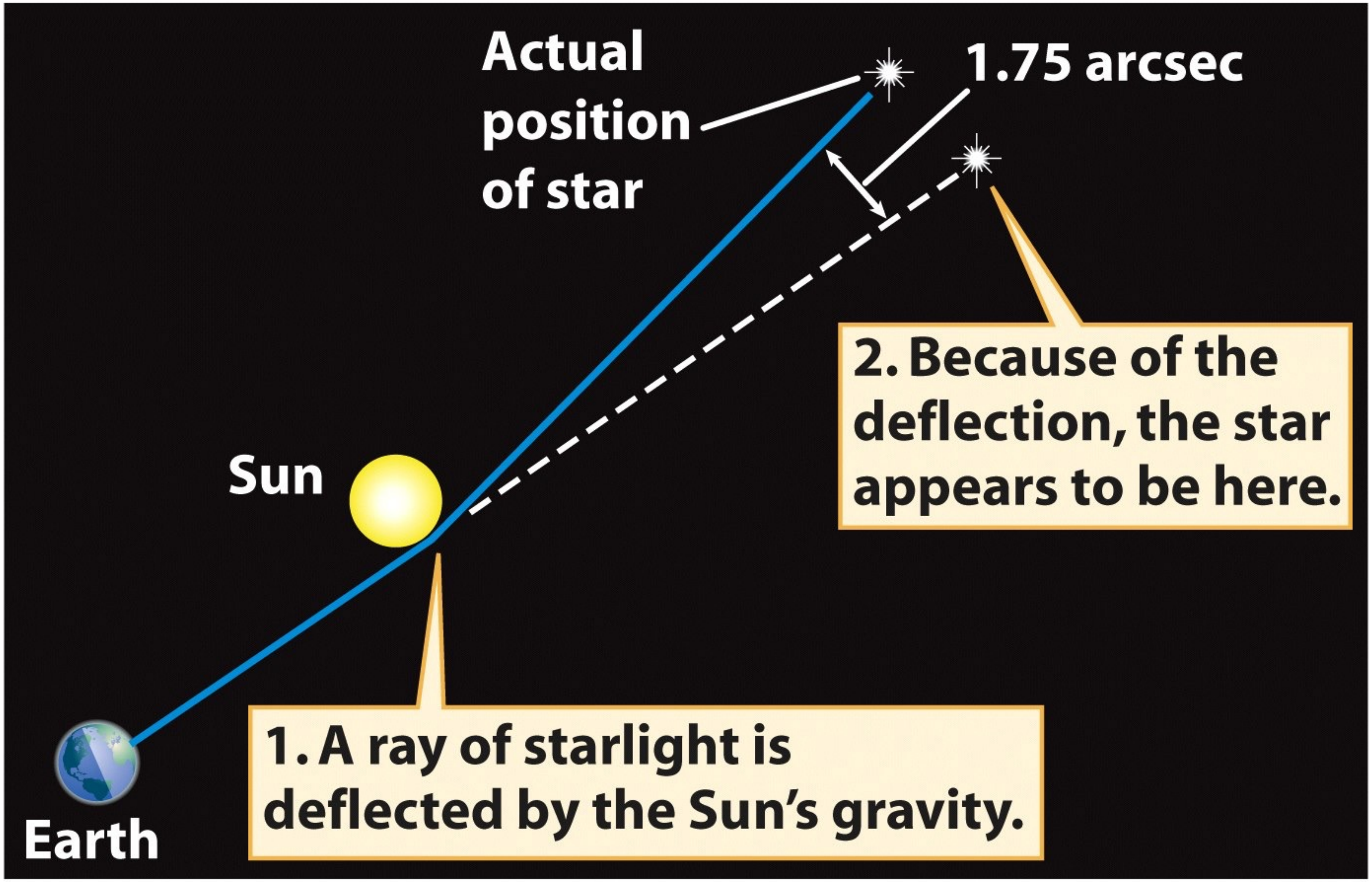
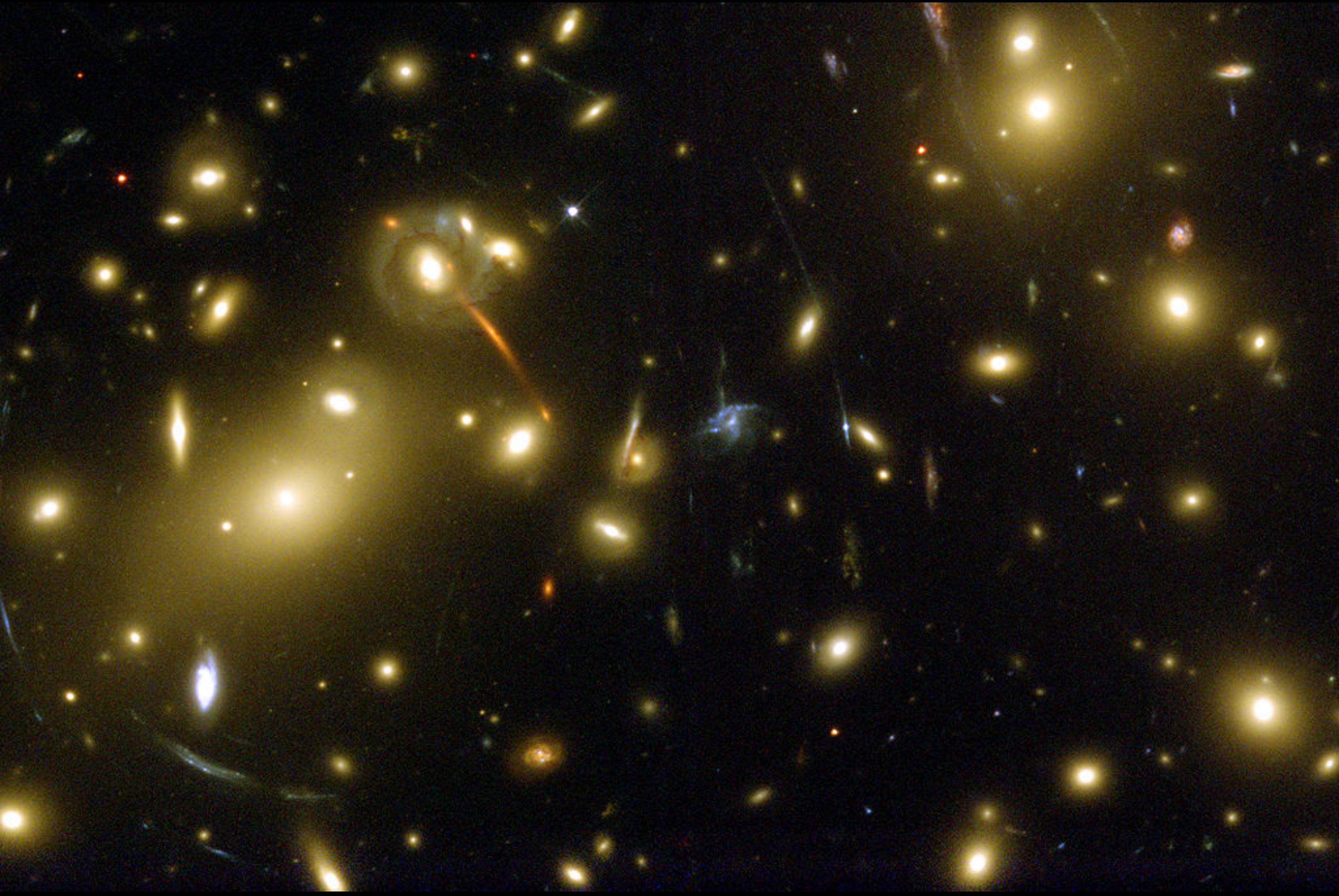


Figure 22-5
Universe, Eighth Edition



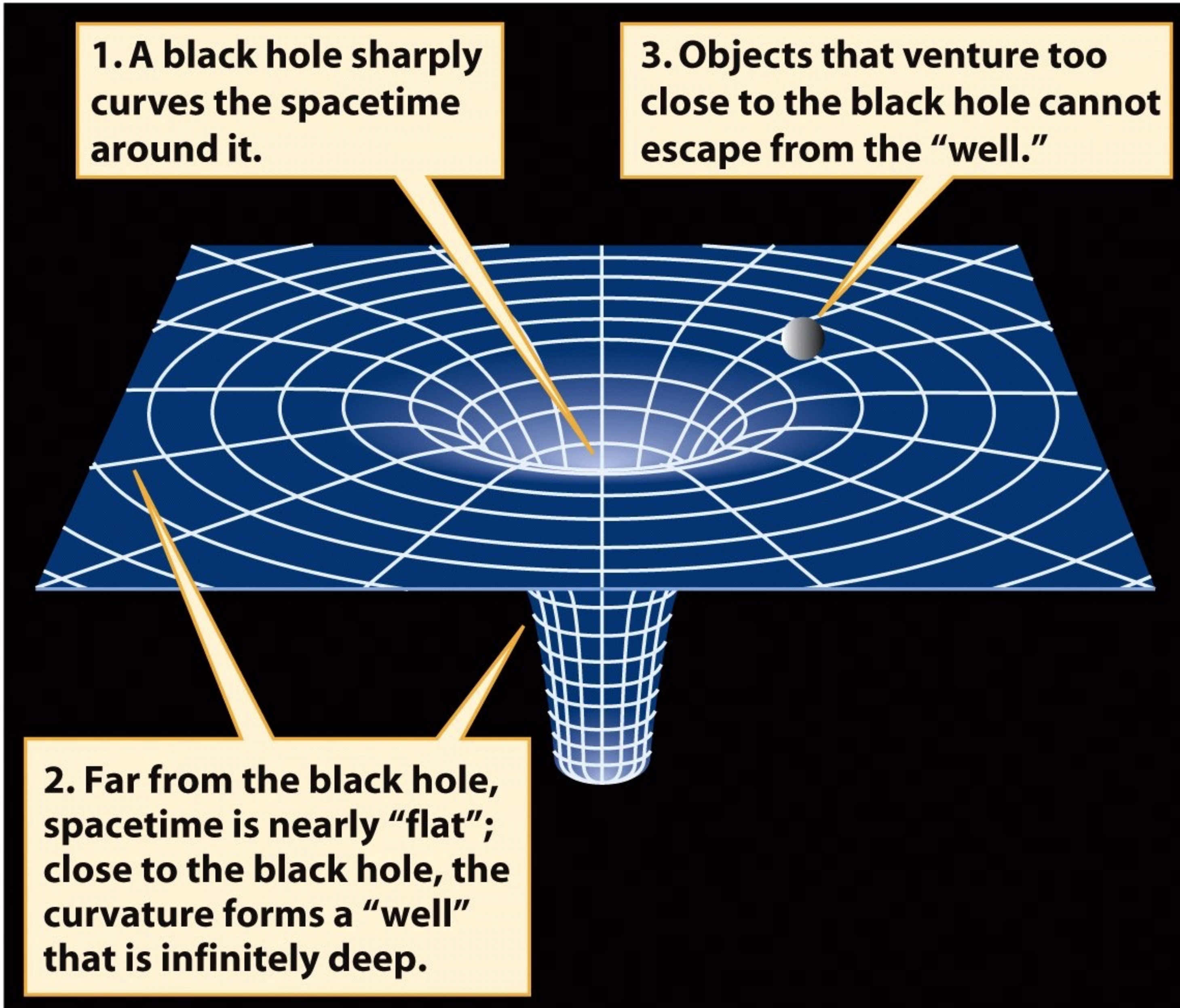
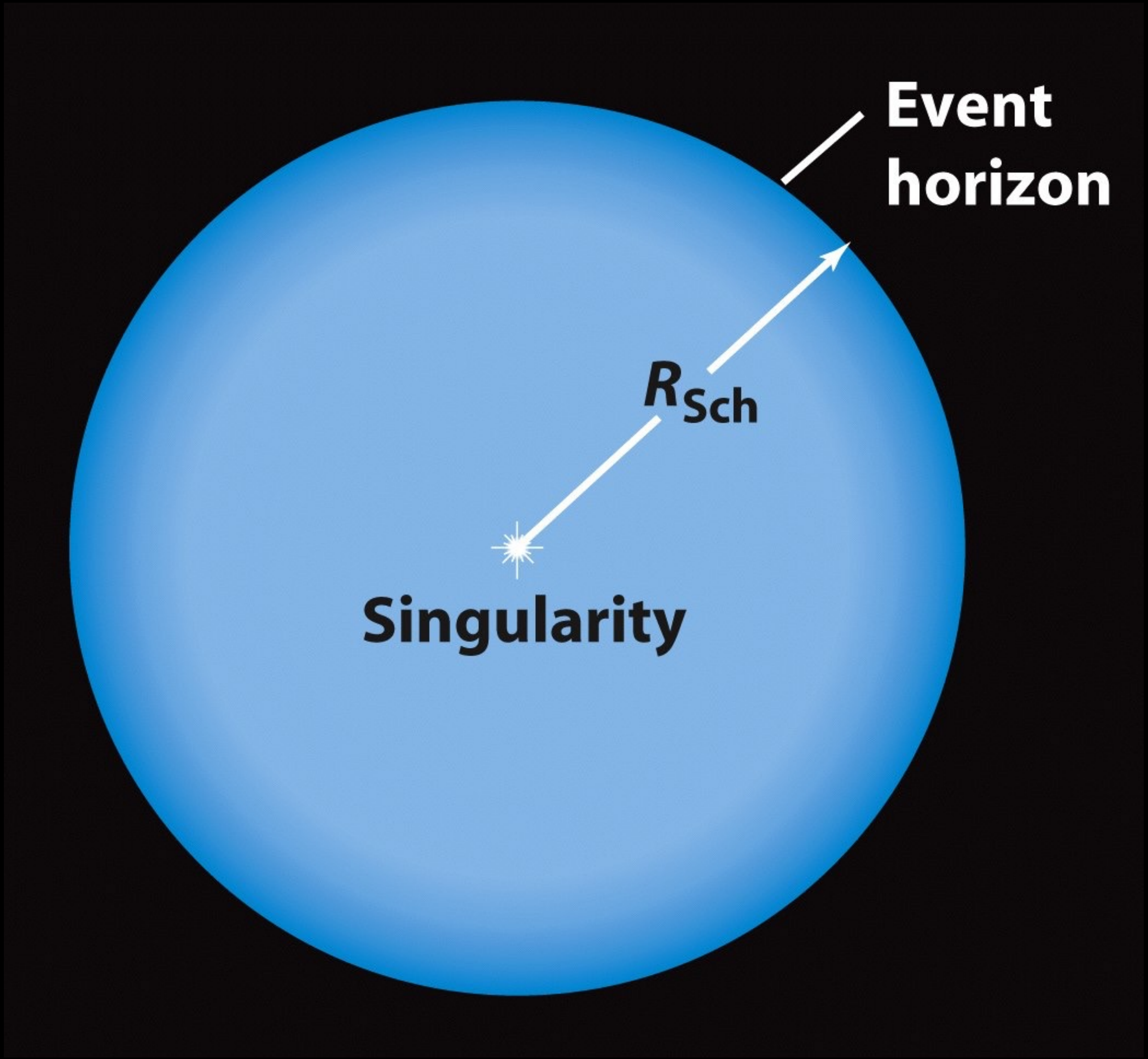


Figure 22-9
Universe, Eighth Edition


Event
horizon
R_{Sch}
Singularity

Escape velocity

$$E_{\mathrm{kinetic}} + E_{\mathrm{potential}} = 0$$

$$\frac{1}{2}mv^2 - \frac{GmM}{r} = 0$$

$$\frac{1}{2}mv^2 = \frac{GmM}{r}$$

$$v_{\mathrm{escape}} = \sqrt{\frac{2GM}{r}}$$

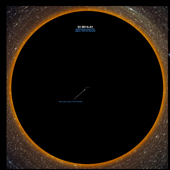
The radius of a black hole

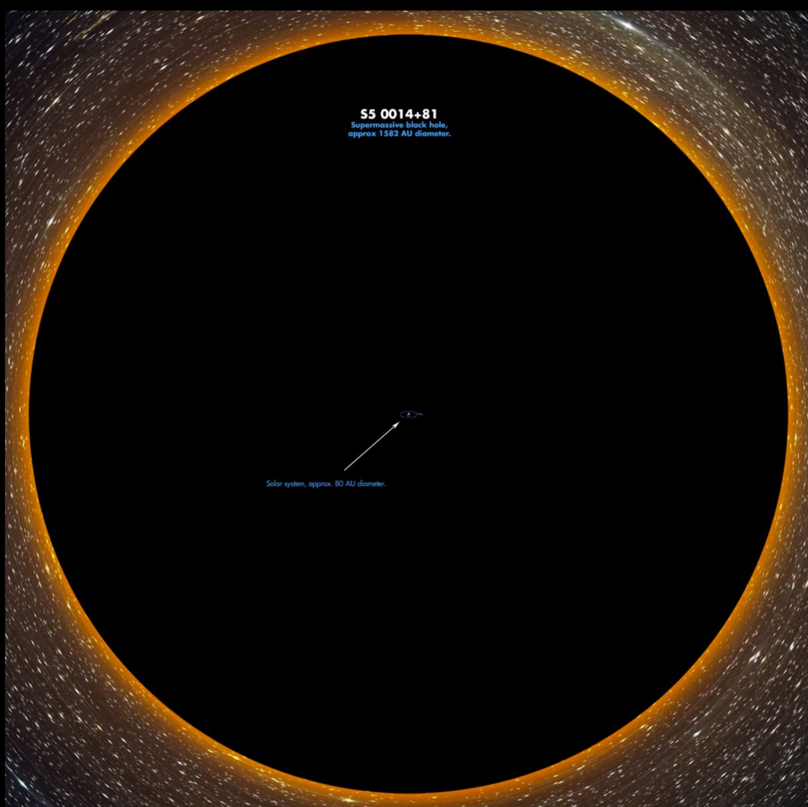
$$v_{\mathrm{escape}} = c$$

$$c = \sqrt{\frac{2GM}{R}}$$

$$\boxed{R = \frac{2GM}{c^2}}$$

The larger the black hole, the smaller the gravity at its Event Horizon!





$$R = \frac{2GM}{c^2}$$

$$g = \frac{GM}{R^2} = \frac{c^4}{4GM}$$

Falling into a black hole

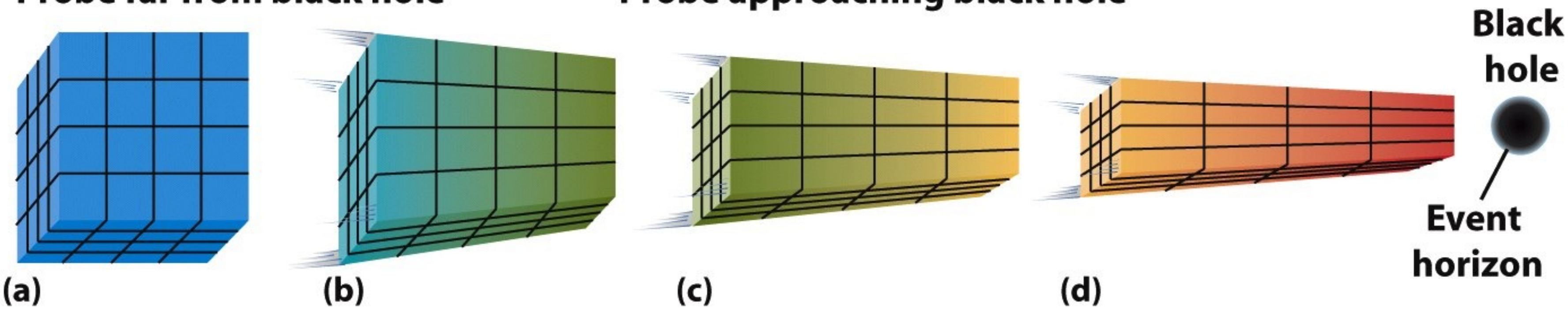
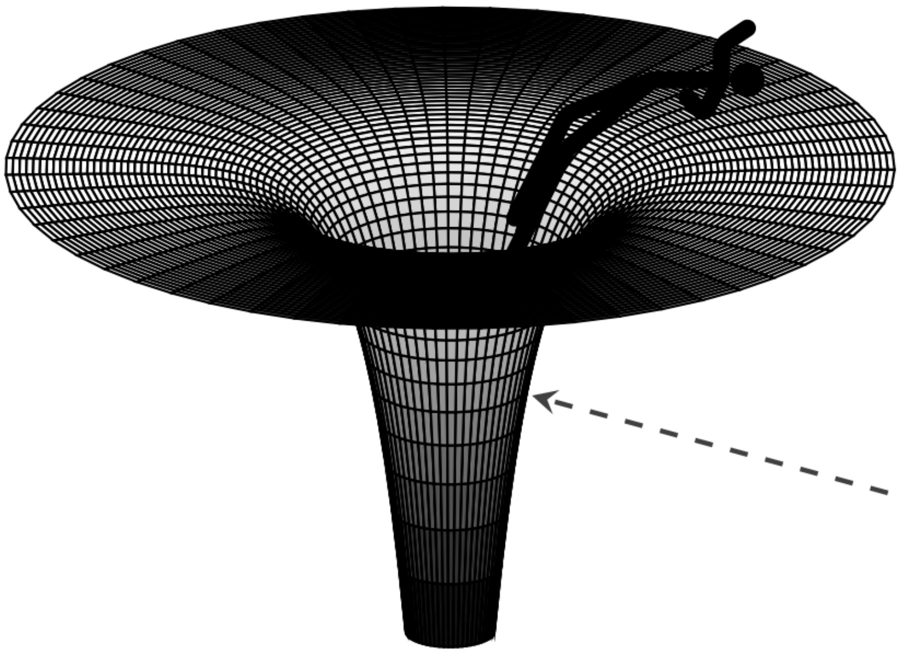


Figure 22-22
Universe, Eighth Edition

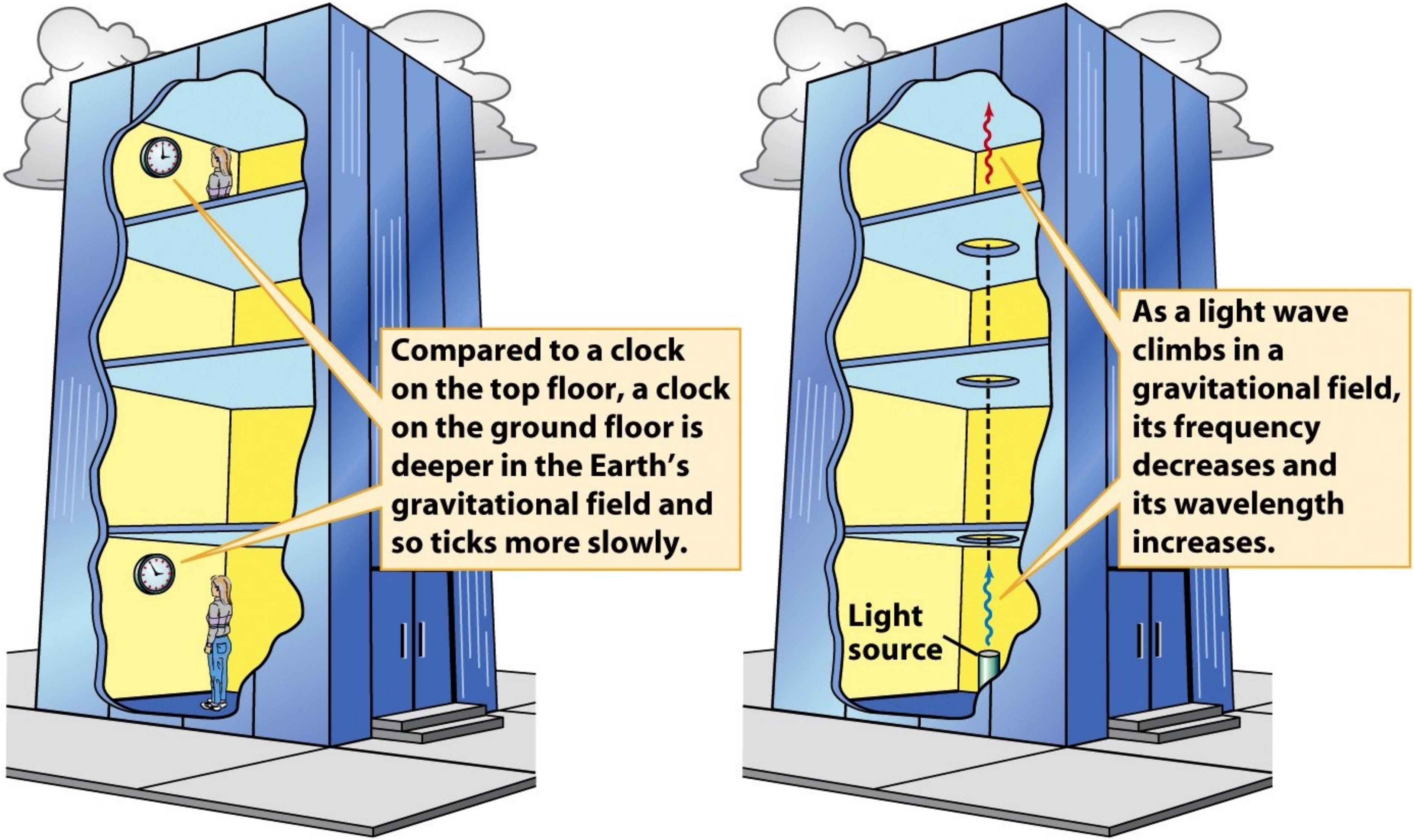
Falling into a black hole

$$ds^2 = -\left(1 - \frac{2GM}{c^2 r}\right) dt^2 + \left(1 - \frac{2GM}{c^2 r}\right)^{-1} dr^2 + r^2 d\Omega^2$$



$$|\Delta F_{grav}| = \frac{2GMmd}{r_0^3}$$

$$r_{Horizon} = \frac{2GM}{c^2}$$



(a) The gravitational slowing of time **(b) The gravitational redshift**

Figure 22-7
Universe, Eighth Edition

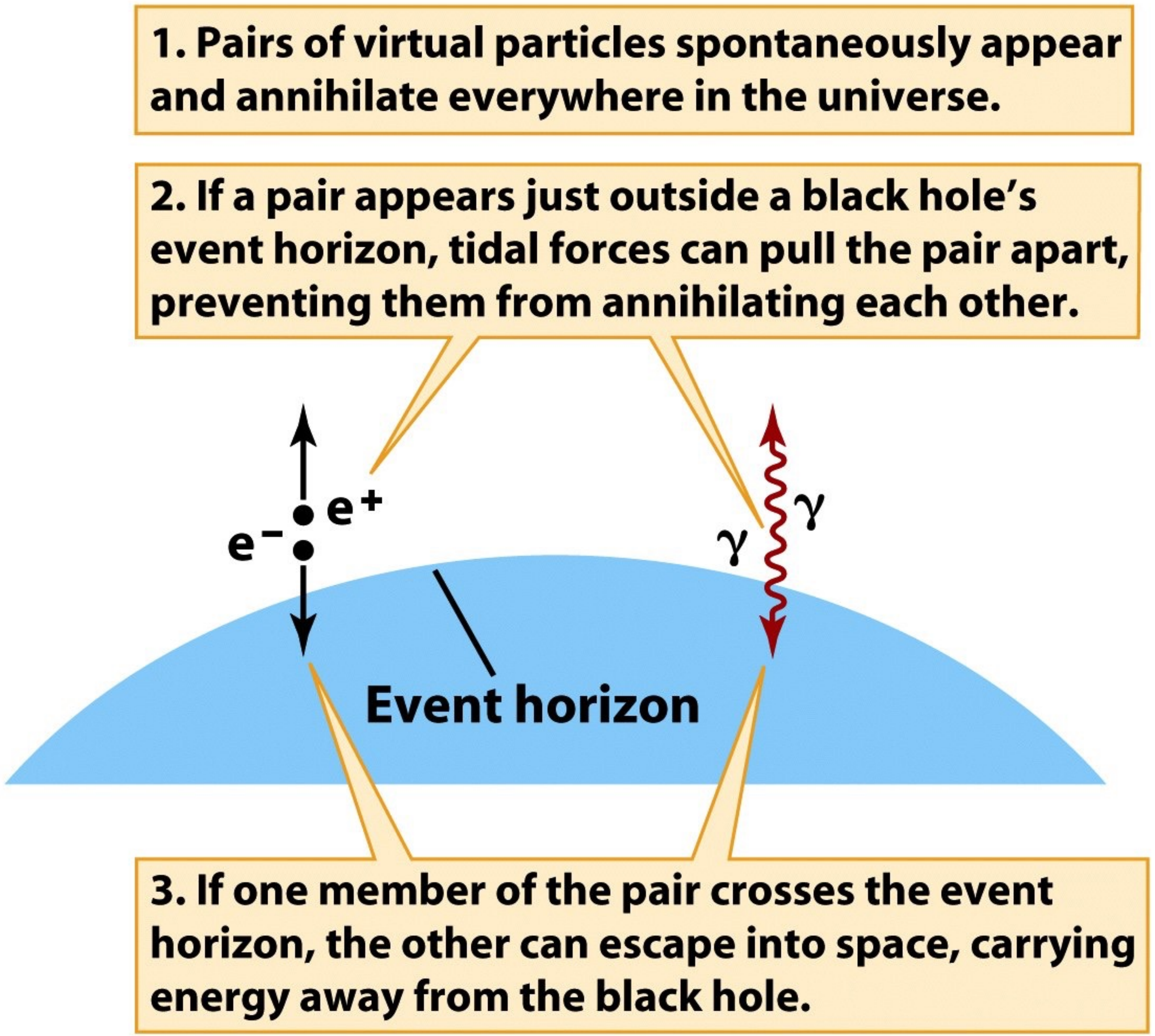
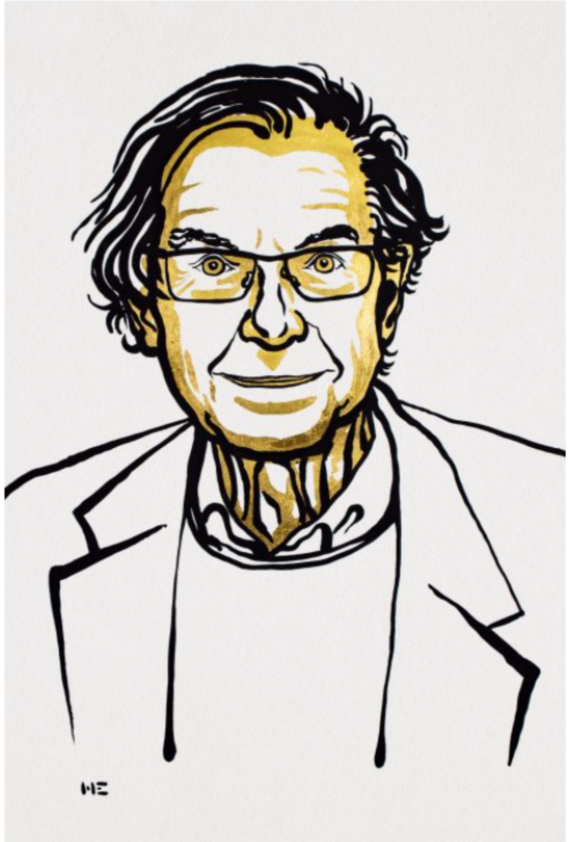


Figure 22-23
Universe, Eighth Edition

The Milky Way

The Nobel Prize in Physics 2020



Ill. Niklas Elmehed. © Nobel Media.

Roger Penrose

Prize share: 1/2

Ill. Niklas Elmehed. © Nobel Media.

Reinhard Genzel

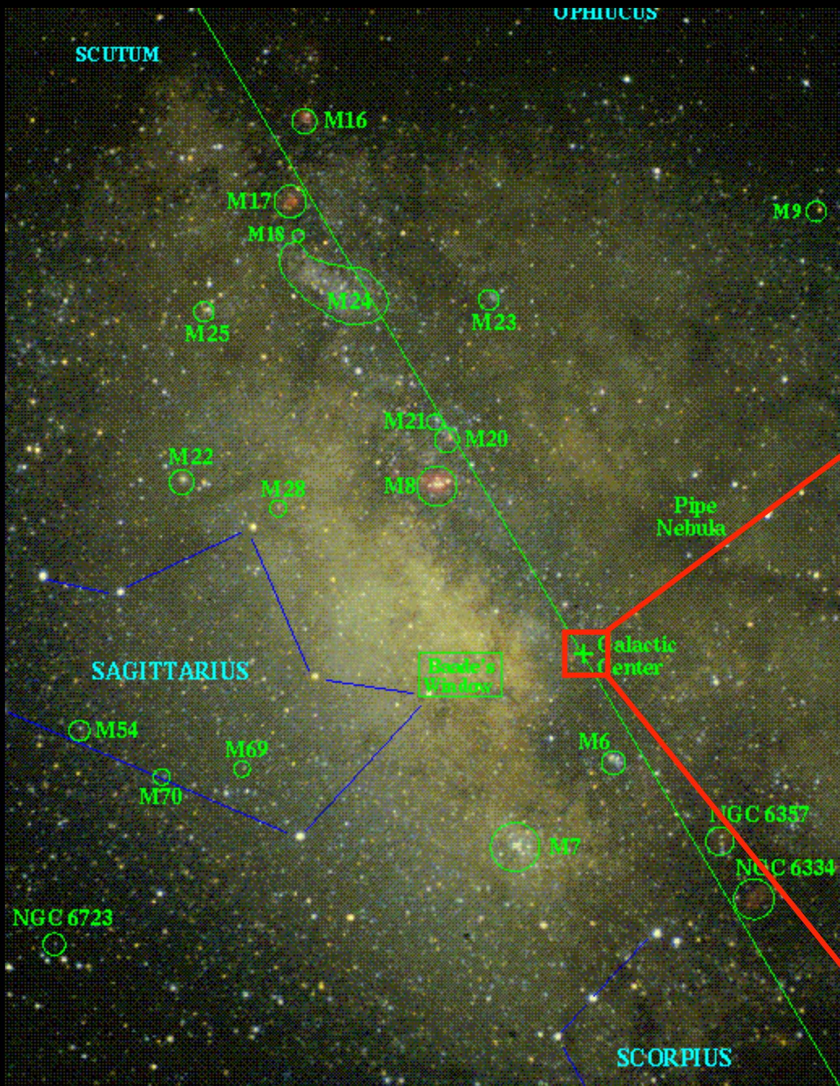
Prize share: 1/4

Ill. Niklas Elmehed. © Nobel Media.

Andrea Ghez

Prize share: 1/4

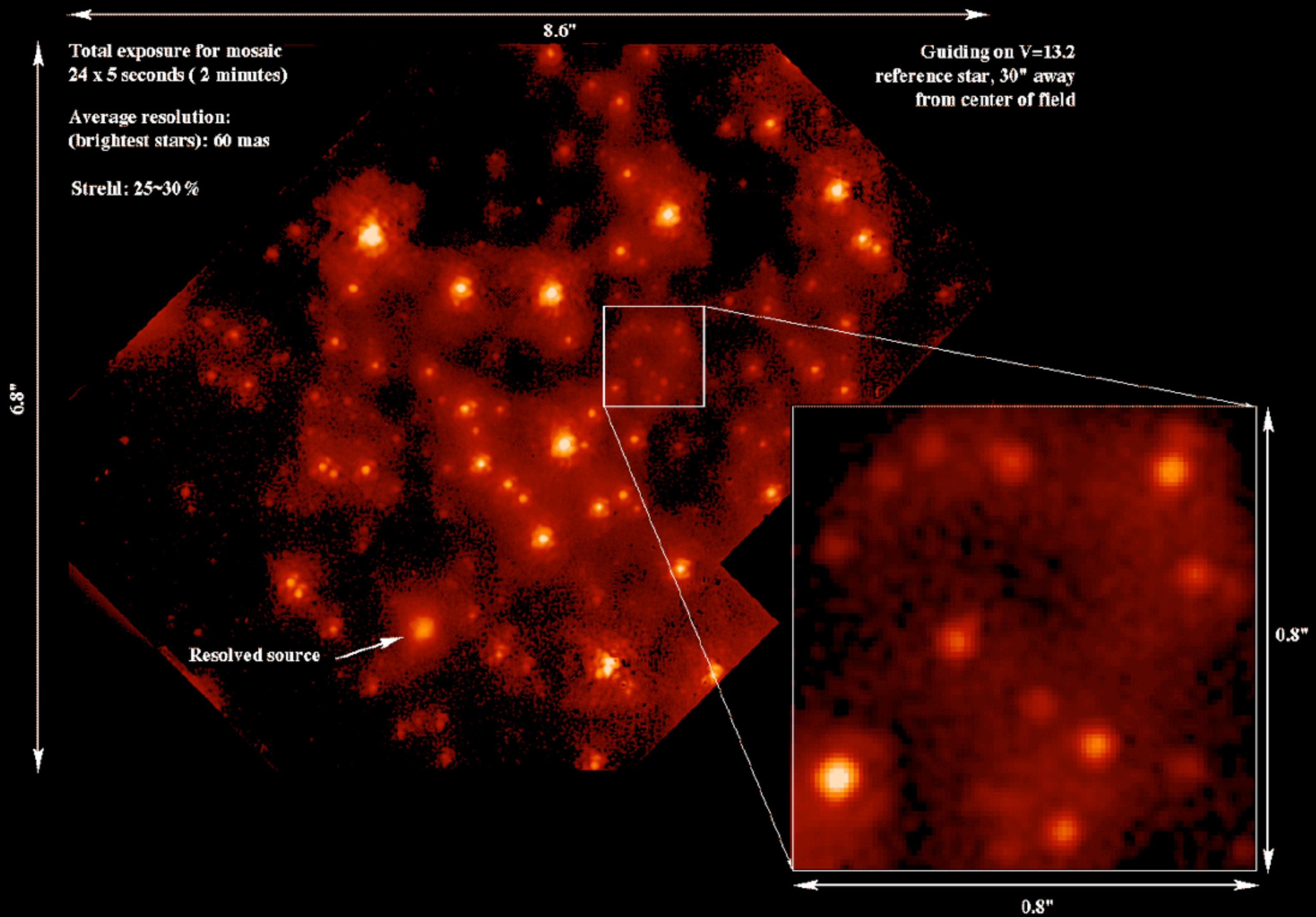
The centre of our Galaxy



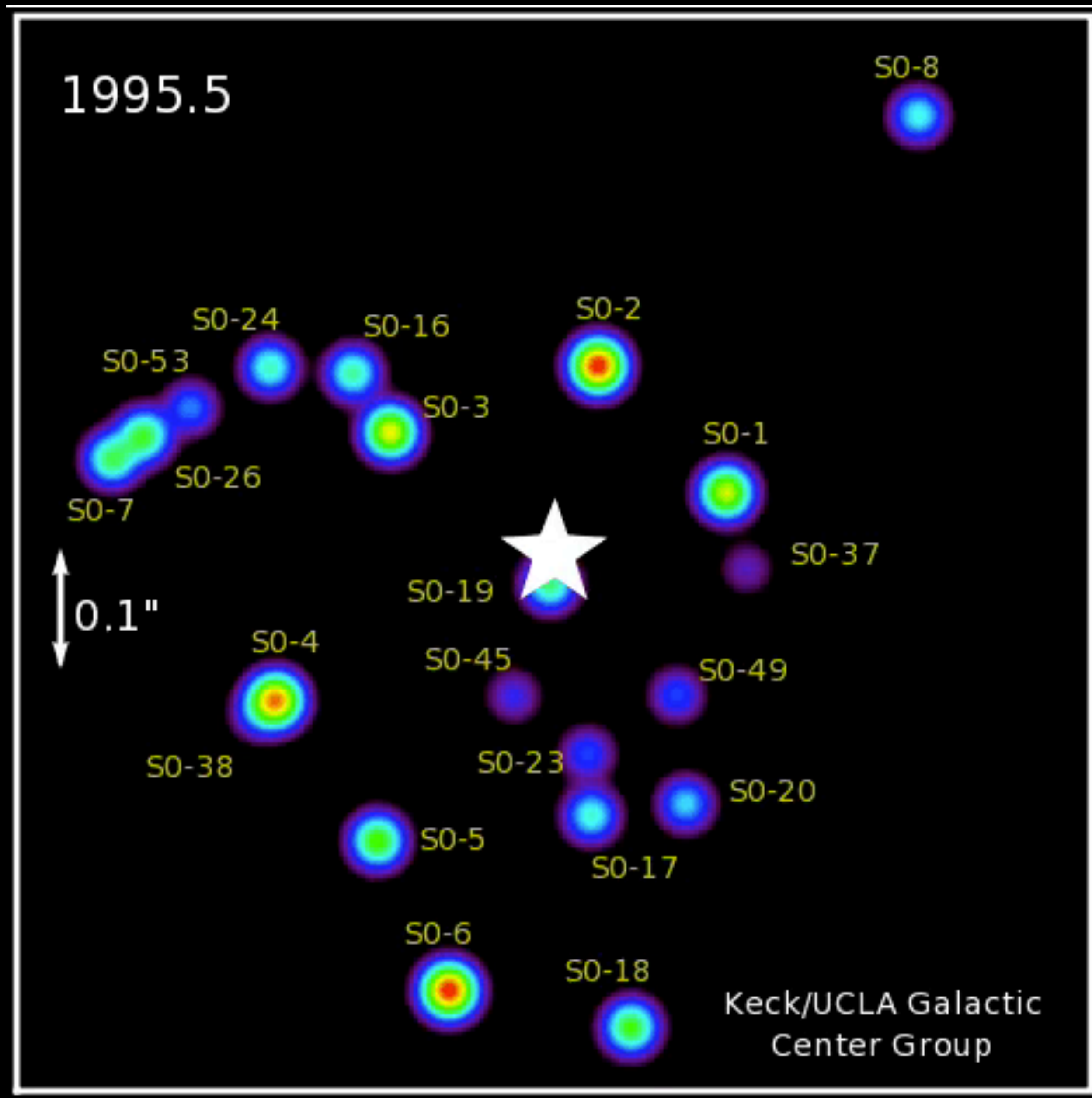
- 10 by 15 degrees
- View to centre blocked by dust
- Baade's window is dust free

0.5 x 0.5 deg in IR (NOAO)

Zooming in…

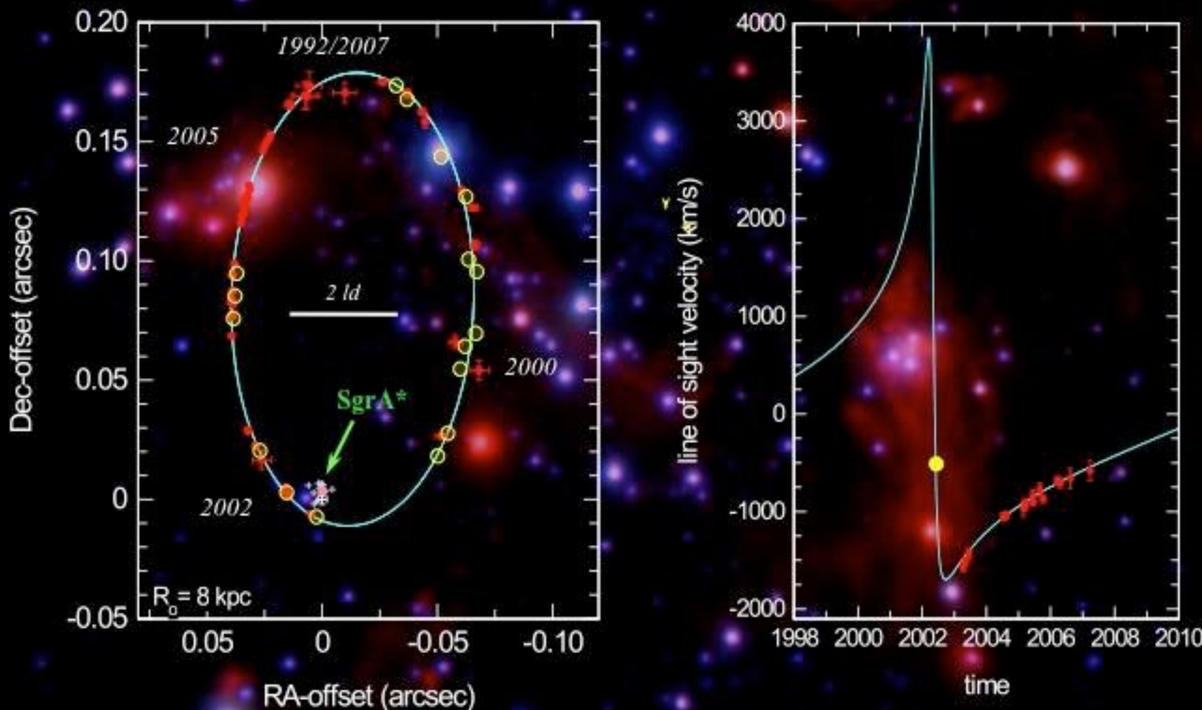


8.6"
Total exposure for mosaic
24 x 5 seconds (2 minutes)
Average resolution:
(brightest stars): 60 mas
Strehl: 25~30 %
Guiding on V=13.2
reference star, 30" away
from center of field
6.8"
Resolved source
0.8"
0.8"


1995.5
S0-8
S0-24
S0-16
S0-2
S0-53
S0-3
S0-1
S0-26
S0-7
S0-37
S0-19
0.1"
S0-4
S0-45
S0-49
S0-38
S0-23
S0-20
S0-5
S0-17
S0-6
S0-18
Keck/UCLA Galactic
Center Group

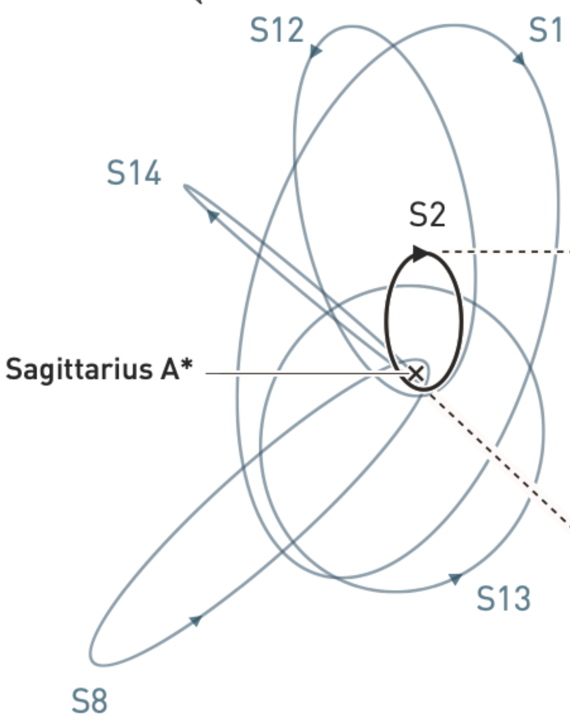
15 years of tracking stellar orbits

MPE (VLT)
Univ. California Los Angeles (Keck)

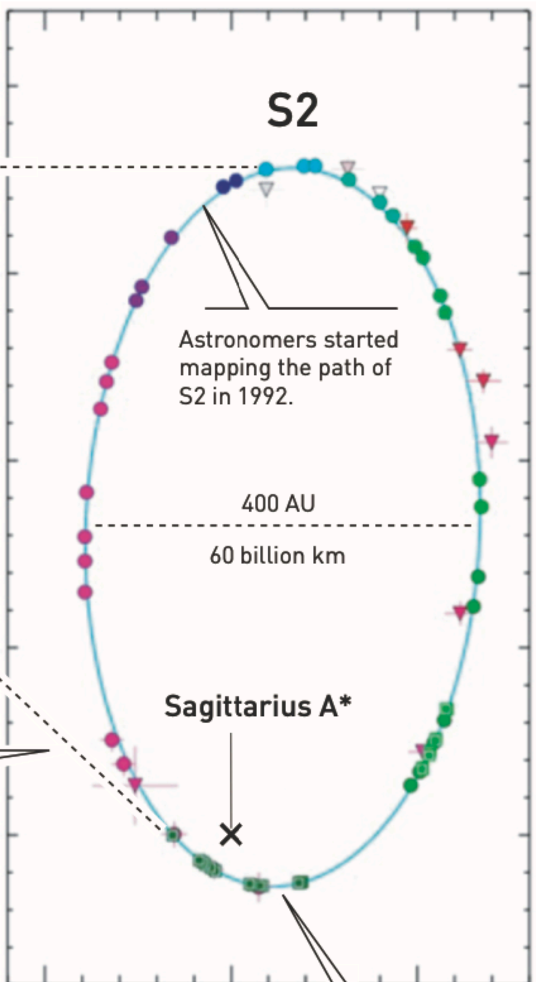


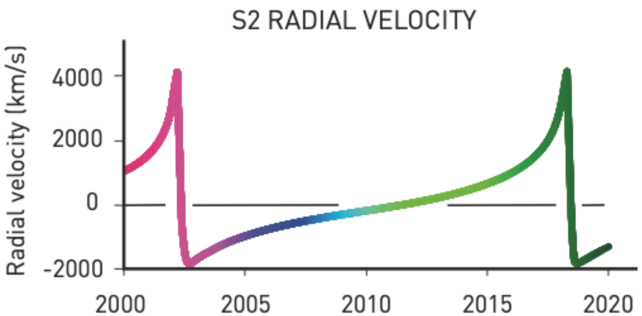
Schödel et al. 2002, 2003, Ghez et al. 2003, 2005, Eisenhauer et al. 2003, 2005, Gillessen et al. 2007

Some of the measured orbits of stars close to Sagittarius A* at the centre of the Milky Way.



Astronomers were able to map an entire orbit of less than 16 years for one of the stars, S2 (or S-02). The closest it came to Sagittarius A* was about 17 light hours (more than 10,000 million kilometres).

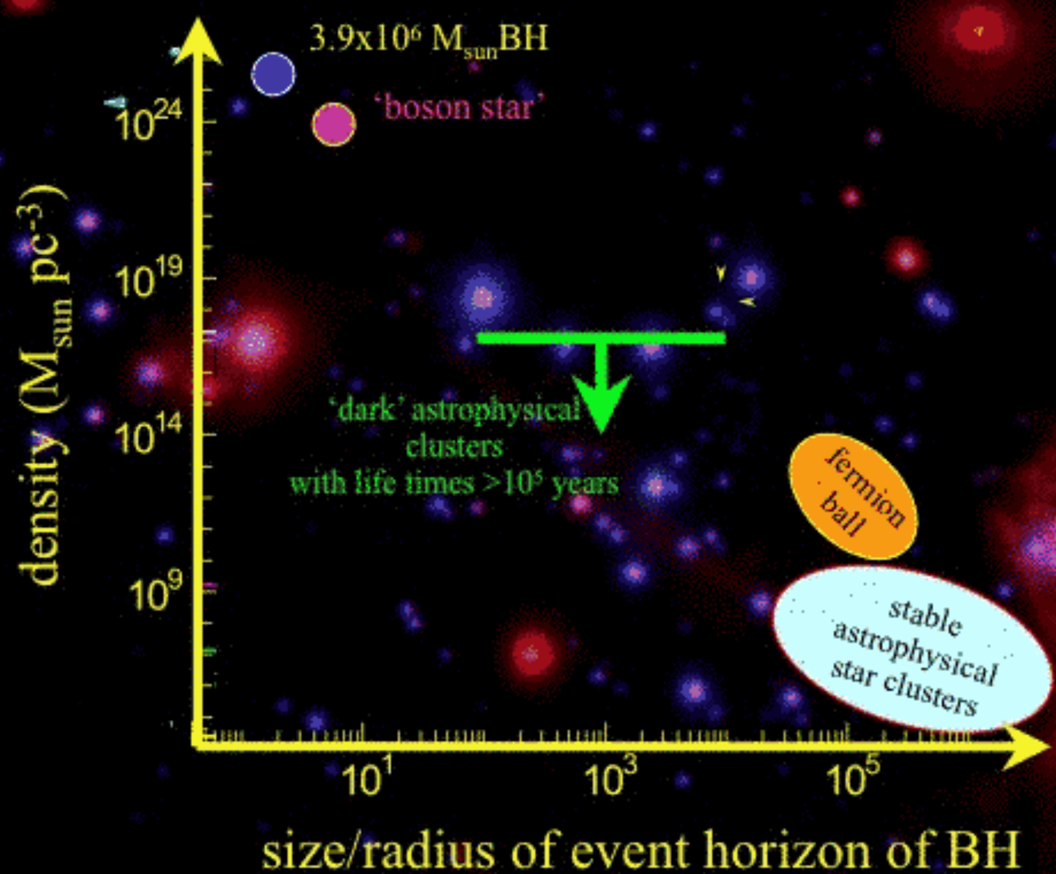




The S2 star's radial velocity increases as it approaches Sagittarius A* and decreases as it moves away along its elliptical orbit. Radial velocity is the component of the star's velocity that is in our line of sight.

Closest to Sagittarius A* (in 2002 and 2018), S2 reaches its maximum velocity of 7 000 km/s.

Is SgrA* a black hole ?



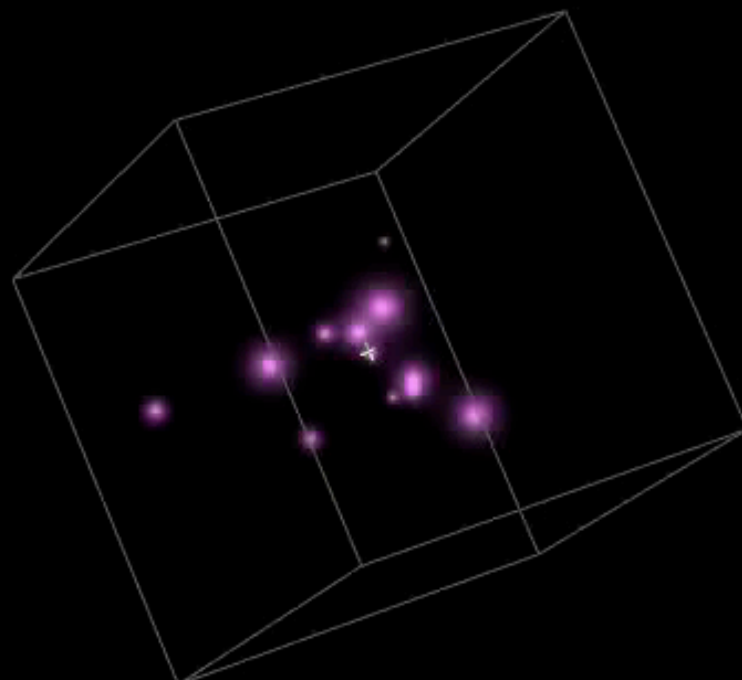
Genzel et al

Is SgrA a black hole ?*

Genzel et al

Year: 1995.0

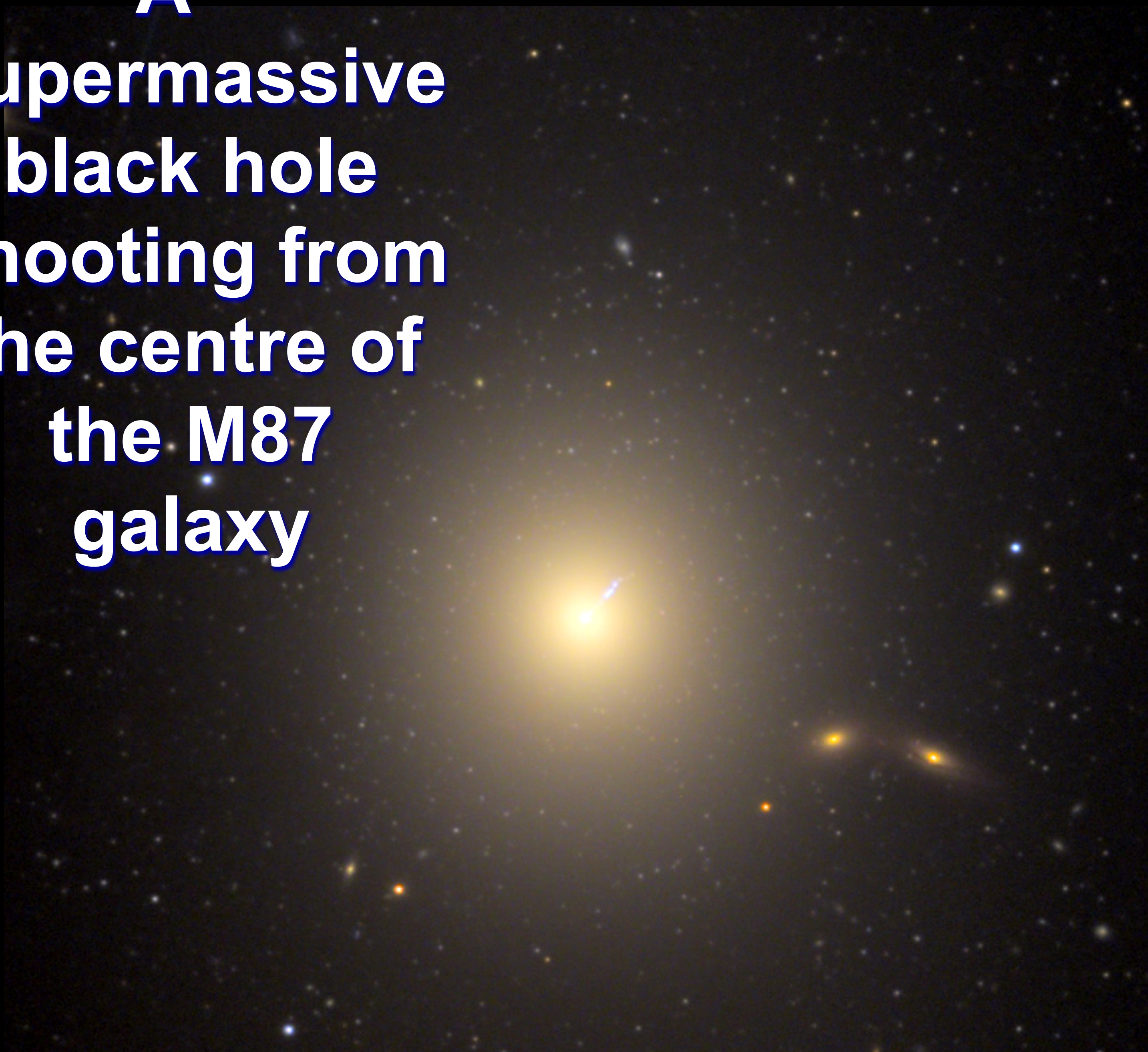
The Acceleration of Stars Orbiting
the Milky Way's Central Black Hole



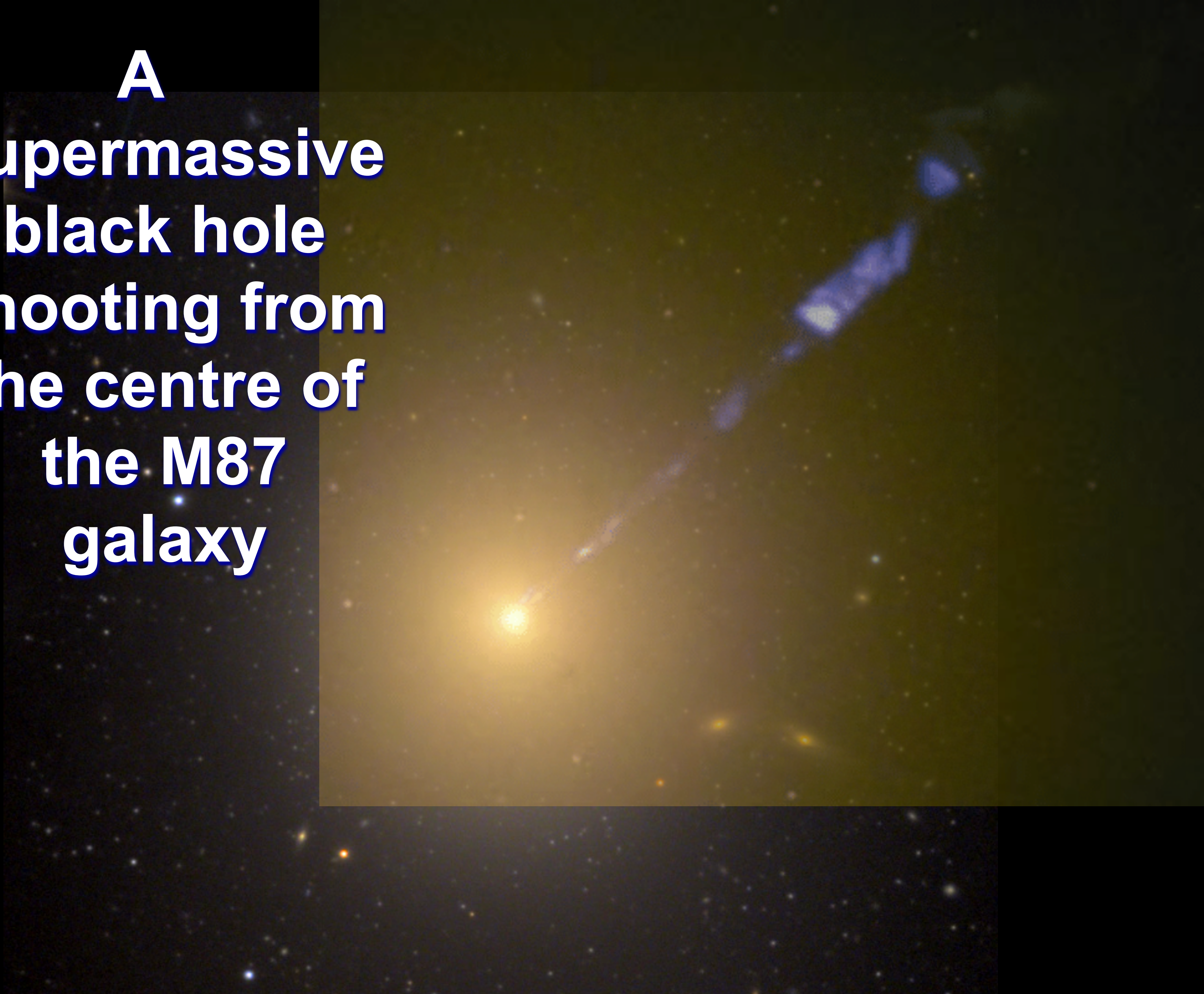
Data: Andrea Ghez, Jessica Lu (UCLA)
Visualization: Dinoj Surendran, Randy Landsberg,
Mark SubbaRao (UChicago / Adler / KICP)

UCLA/Keck Galactic Center Group

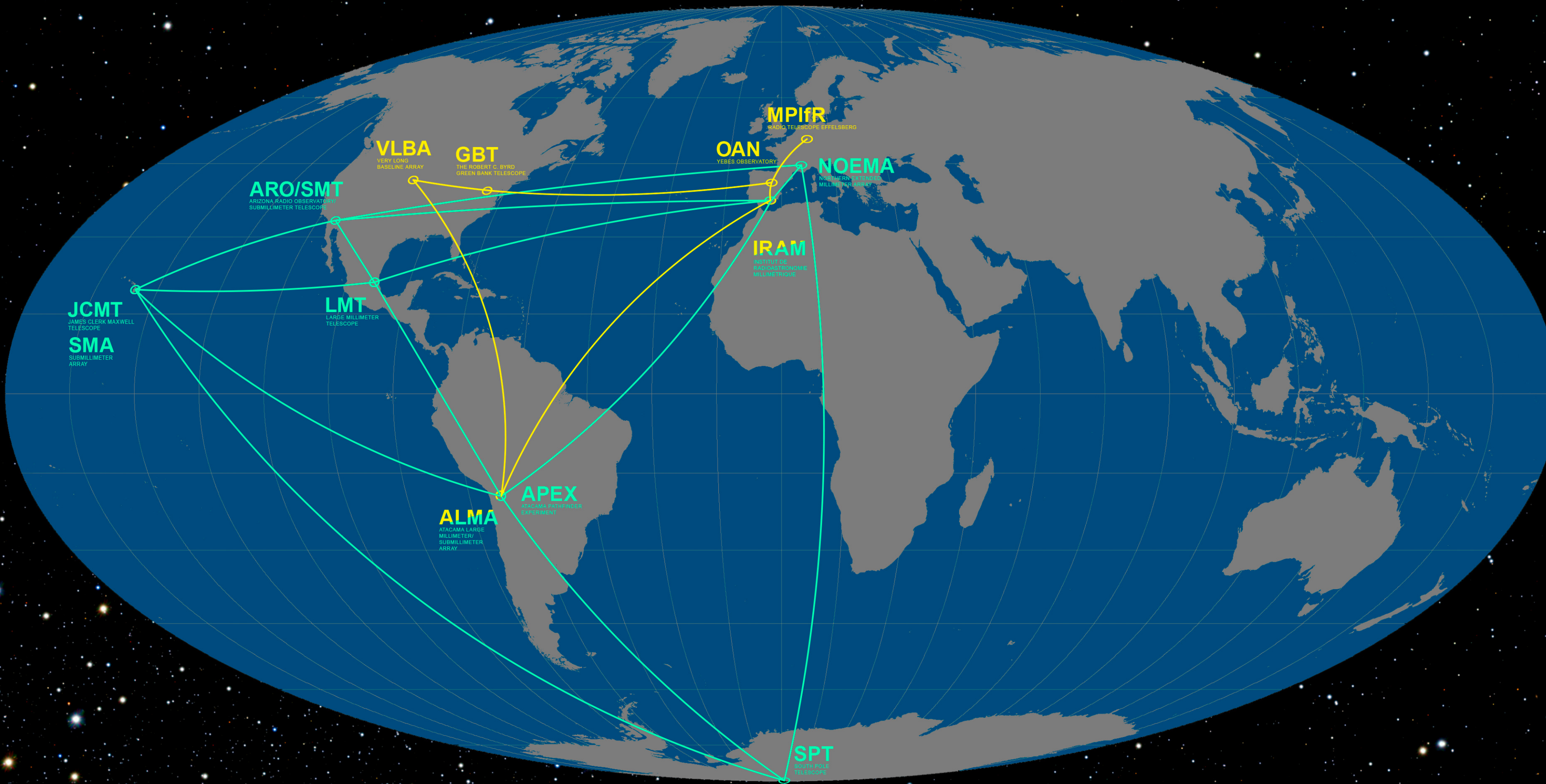
A supermassive black hole shooting from the centre of the M87 galaxy



A supermassive black hole shooting from the centre of the M87 galaxy



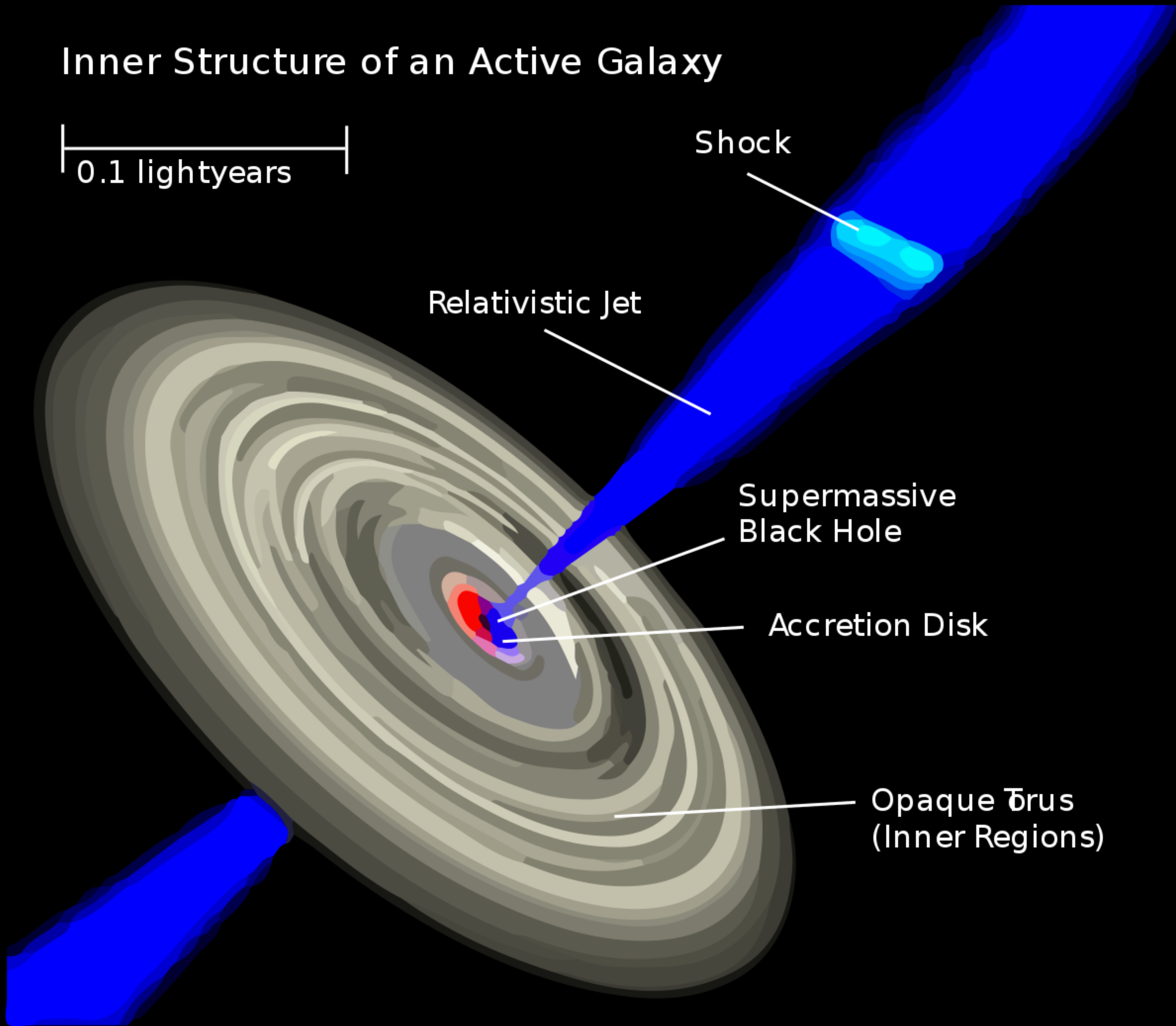
The Event Horizon Telescope



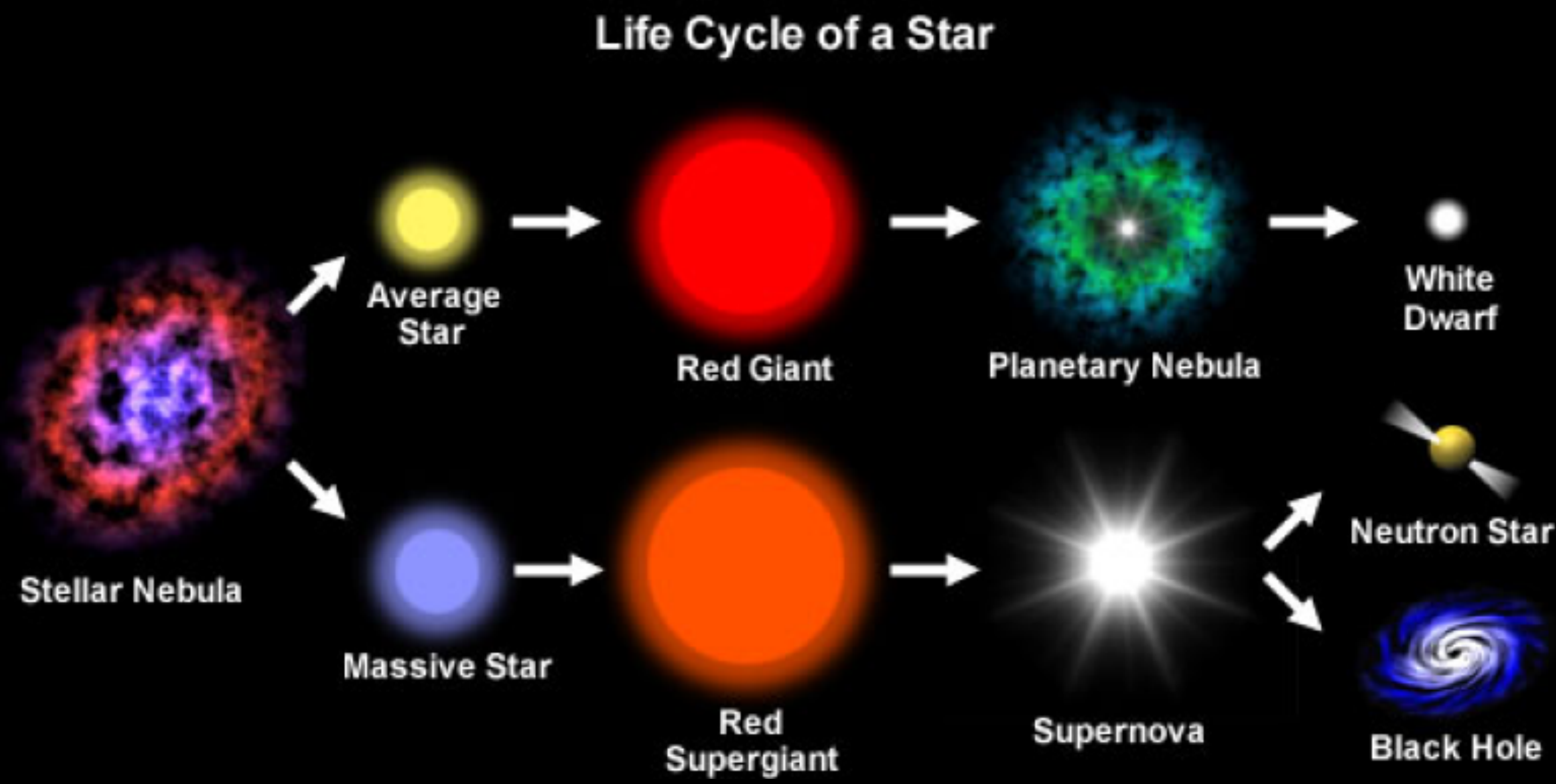
The first ‘image’ of a black hole

Supermassive black holes

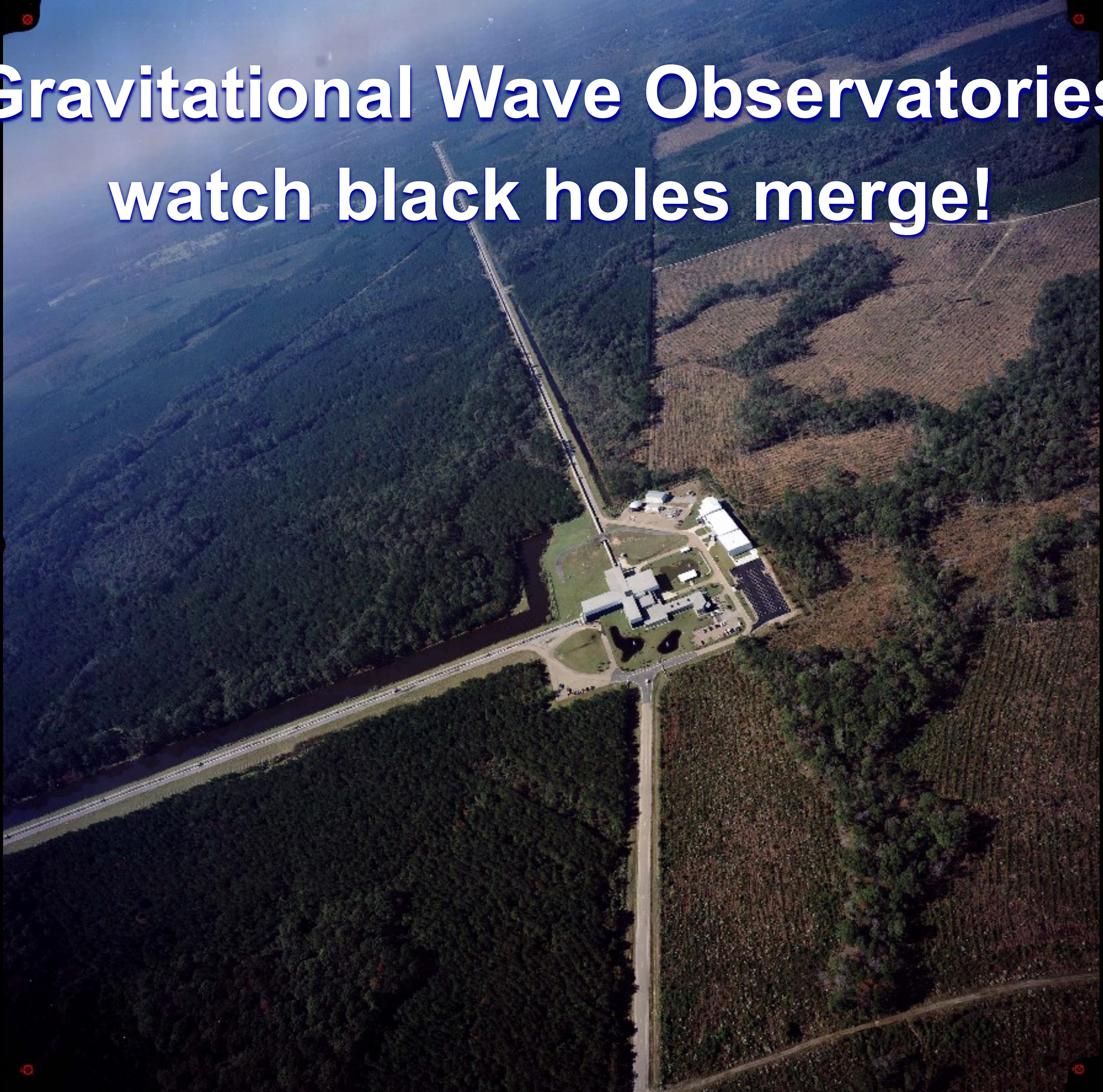
Inner Structure of an Active Galaxy



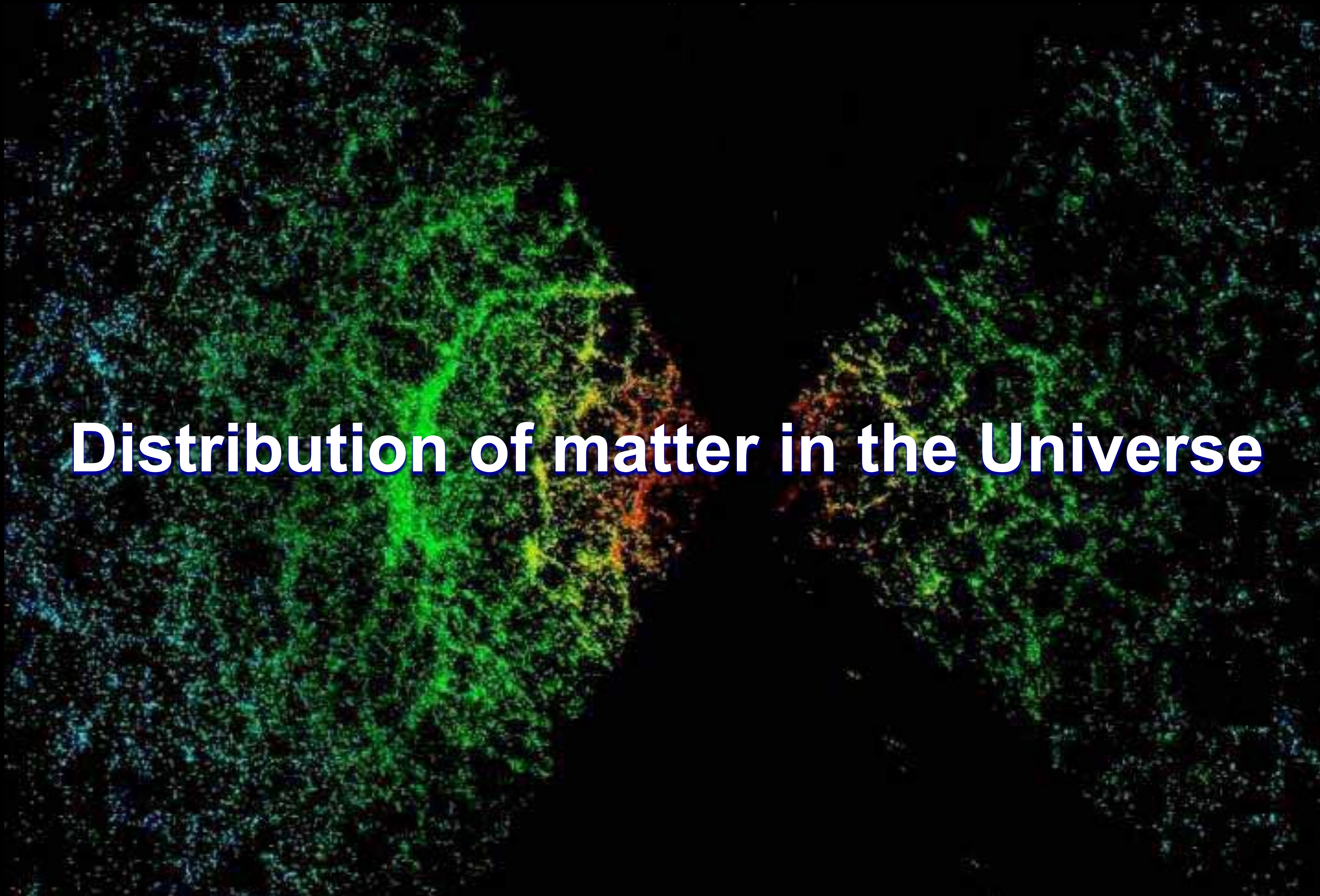
Some stars end up as black holes



Exploding stars leave black holes behind


Gravitational Wave Observatories
watch black holes merge!

Distribution of matter in the Universe



Distribution of matter in the Universe

Primordial black holes may form the mysterious Dark Matter!