Celebrating Einstein: A Discussion about the Universe

Hubert L. Bray
Duke University

The Emily K Center
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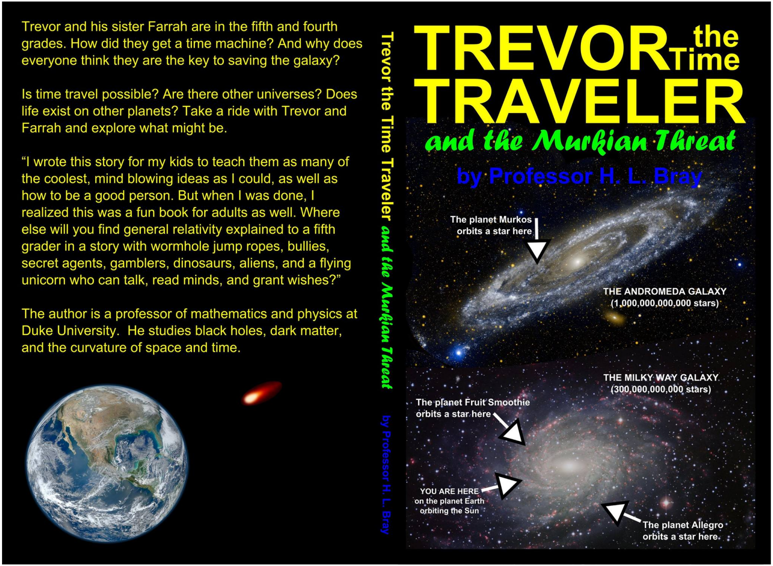
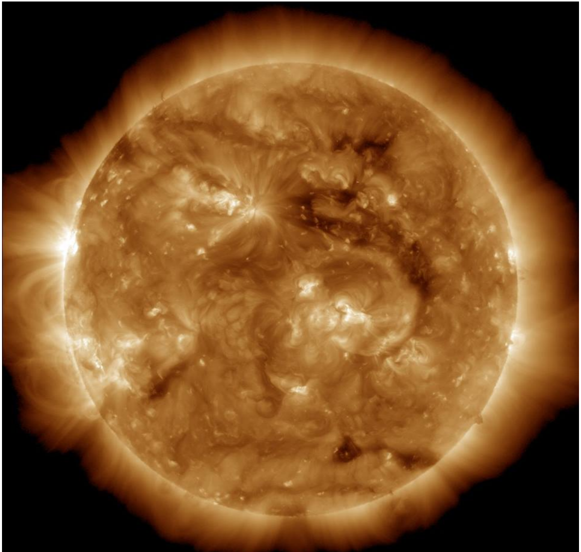
The Science behind "Trevor the Time Traveler"



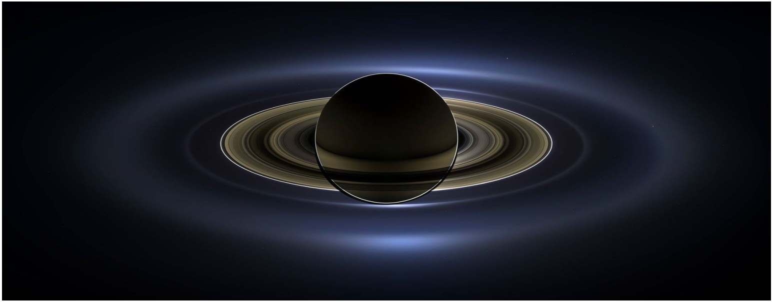
Milky Way Galaxy look-alike Galaxy NGC 6744

The Andromeda Galaxy

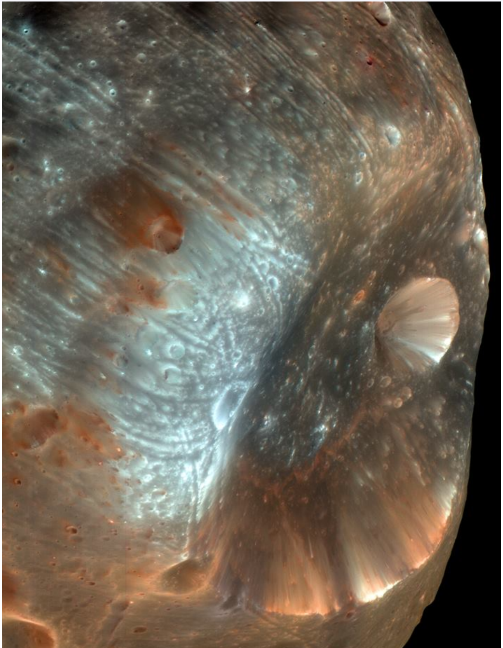
Except for hydrogen, almost all of the atoms in this room were created inside stars like our Sun that later exploded as supernovas. We are all made out of stardust.



Saturn backlit by the Sun



Stickney Crater on Phobos (the larger moon of Mars)



Phobos (the larger moon of Mars)

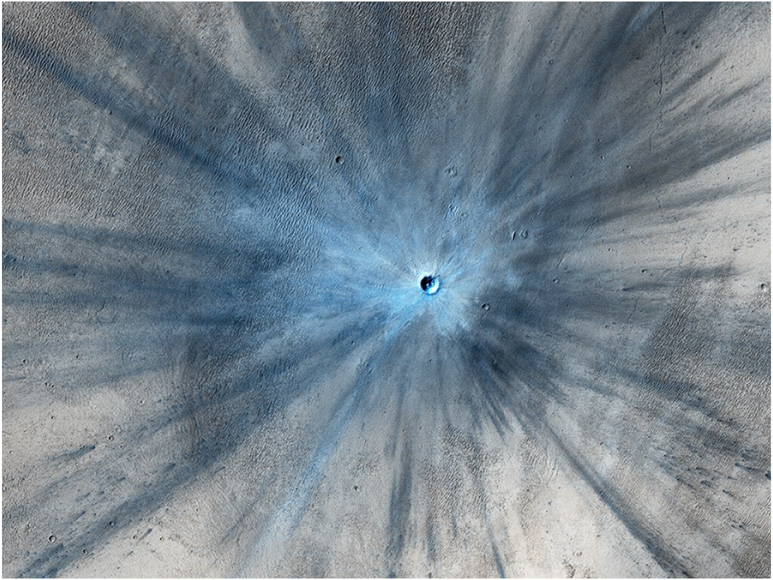
The Earth and the Moon as seen from Mars

Apollo 11 photo of the Earth from the Moon

The Earth

The Moon from the International Space Station

A New Martian Impact Crater (2010 to 2012)

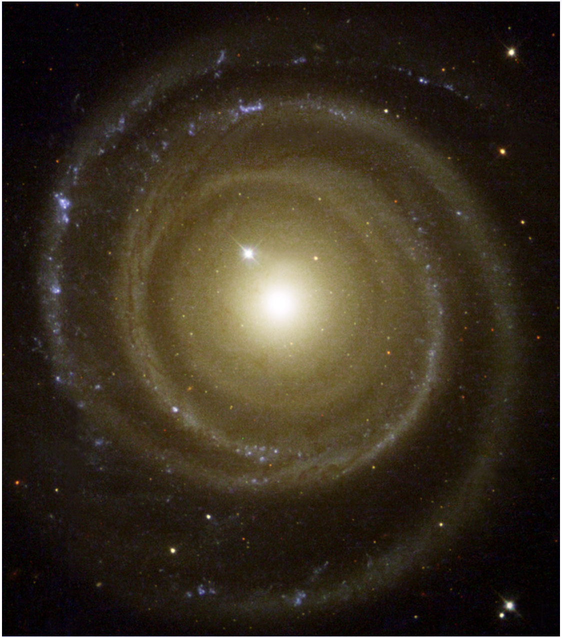


Spiral Galaxy M81

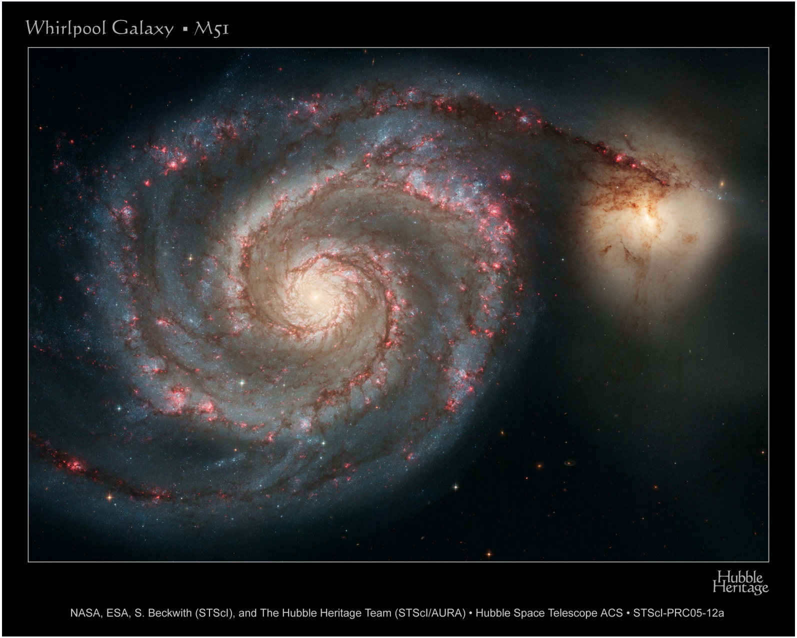
Spiral Galaxy M74

Spiral Galaxy NGC1365

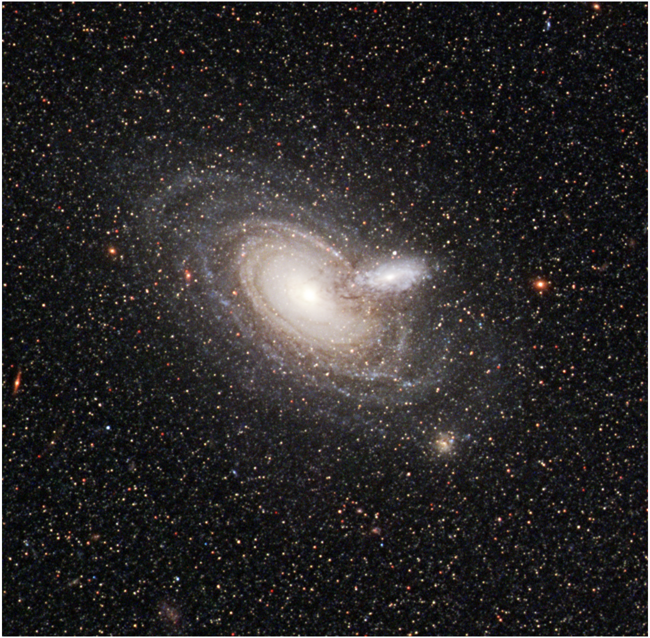
Spiral Galaxy NGC4622



Spiral Galaxy M51, the Whirlpool Galaxy



Spiral Galaxies 2MASX J00482185-2507365



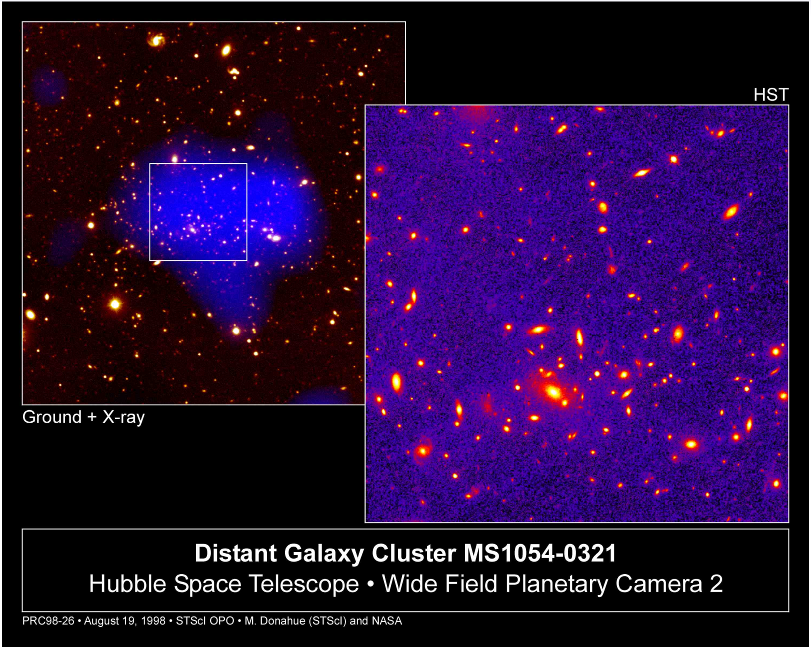
Spiral Galaxy NGC3314

Spiral Galaxies ARP274

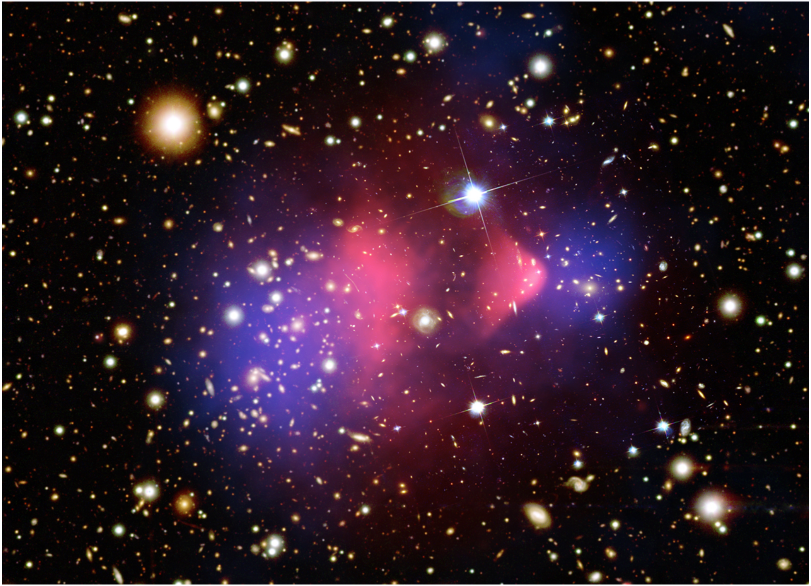
Elliptical Galaxies

Figure: Elliptical galaxies contain ellipsoidal shaped collections of stars in mostly radial orbits. Two examples are M87 (left) and NGC1132 (right).

Galaxy Cluster MS1054-0321



The Bullet Cluster



SPIRALS

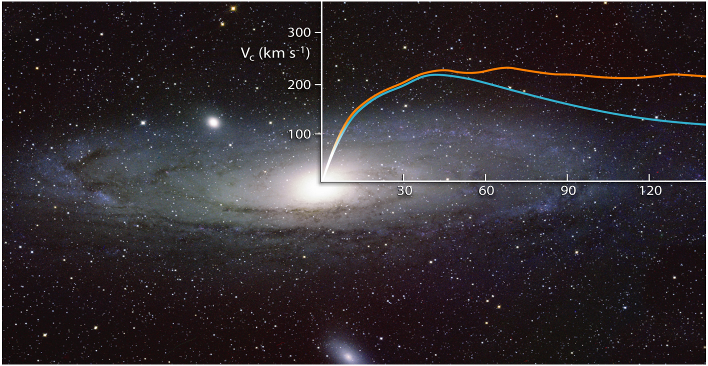
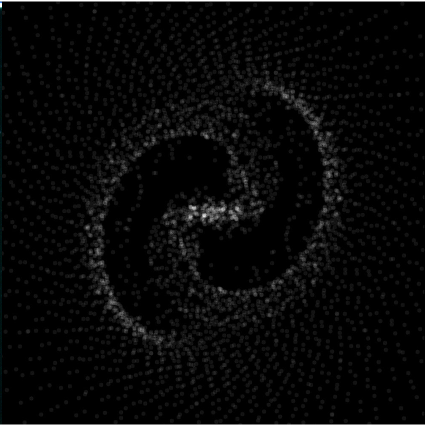


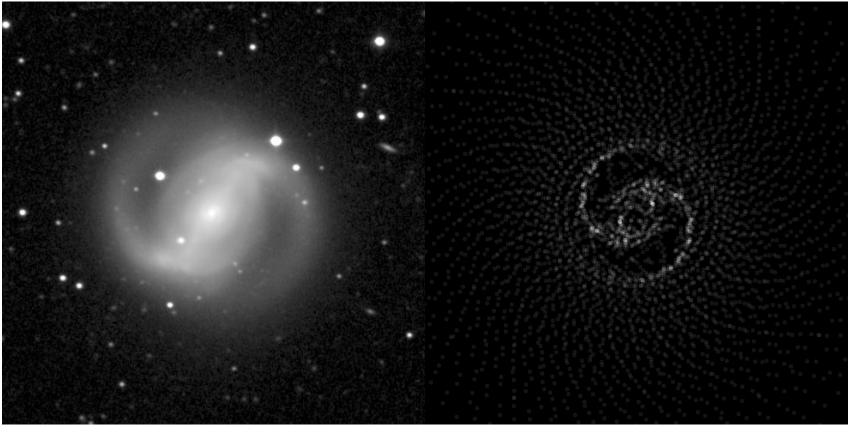
Figure: From the Dark Matter Awareness Week presentation. Presentation review at arXiv:1102.1184v1 by Paolo Salucci, Christiane Frigerio Martins, and Andrea Lapi.

Spiral Galaxy Simulation #1



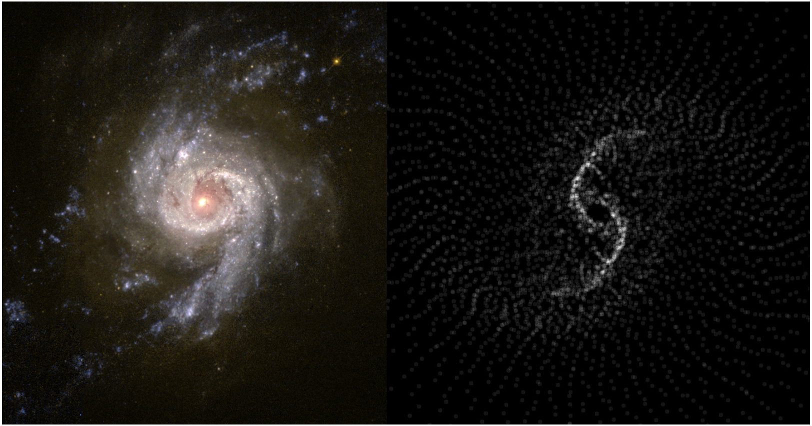
NGC1300 on the left, simulation on the right.

Spiral Galaxy Simulation #2



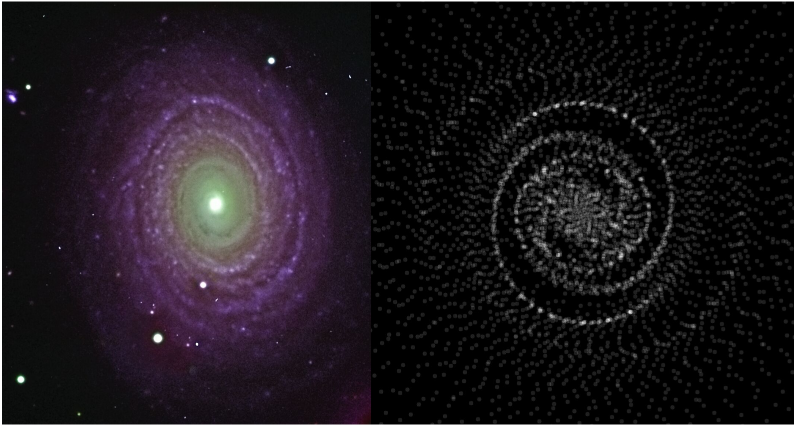
NGC4314 on the left, simulation on the right.

Spiral Galaxy Simulation #3



NGC3310 on the left, simulation on the right.

Spiral Galaxy Simulation #4

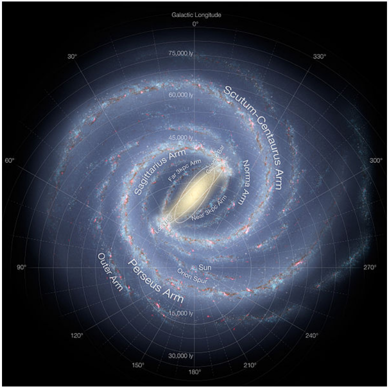


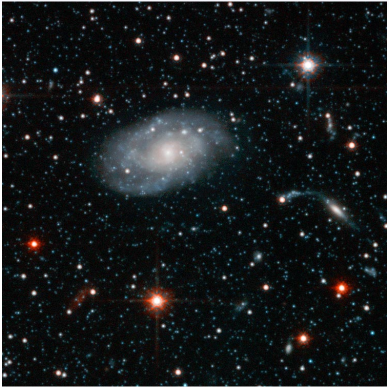
NGC488 on the left, simulation on the right.

Alien Abduction

So, if you were abducted by aliens after this lecture, how far away from Earth could they take you in your lifetime?

Alien Abduction





- The star Proxima Centauri is about 4 light years away.
- The Milky Way is about 100,000 light years in diameter.
- The Andromeda galaxy is about 2,500,000 light years away.
- The edge of the observable universe is about 45,000,000,000 light years away.

Alien Abduction

d - distance; s - time experienced by the travelers accel. at 1g

$$\frac{d}{1 \text{ light year}} = \cosh\left(\frac{s}{1 \text{ year}}\right) - 1$$

Some sample approximate values:

s (in years)	d (in light years)
0	0
1	0.5
2	3
3	9
4	25
5	75
10	10,000
15	1,500,000
20	250,000,000
25	35,000,000,000
30	5,000,000,000,000

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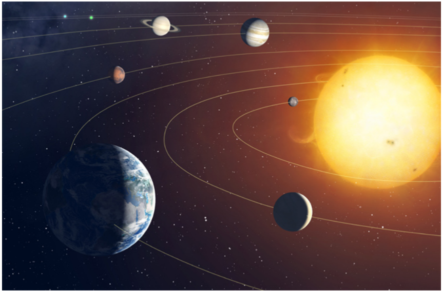
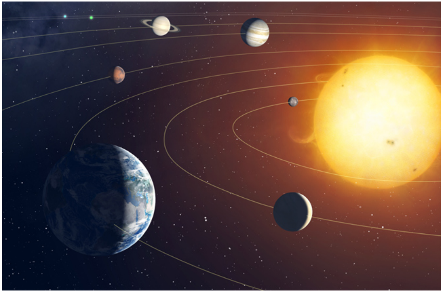
25 years to accelerate, 25 years to decelerate, and then you would be at rest, 70 billion light years from Earth!

Space Exploration and Time Travel



Meanwhile, 70 billion years have passed on the Earth.

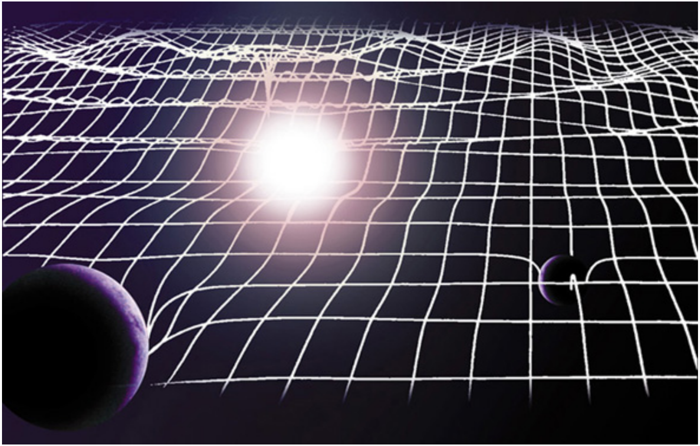
Space Exploration and Time Travel



Meanwhile, 70 billion years have passed on the Earth.

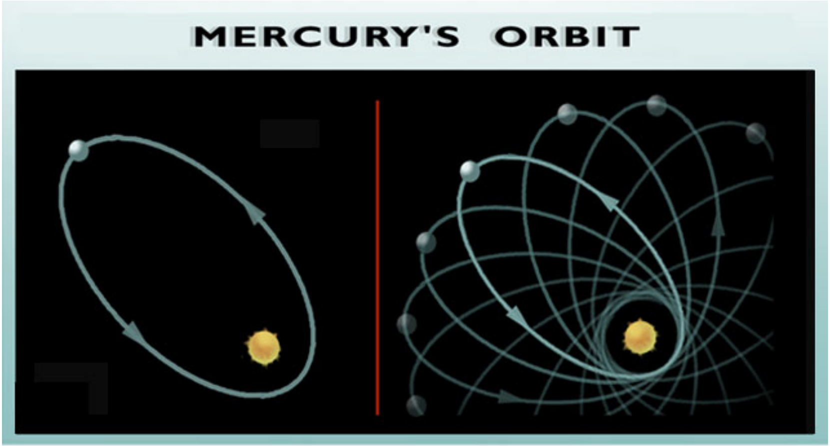
In effect, a spaceship which can accelerate at 1g for as long as you like is both a tool for space exploration and a time machine. If such spaceships exist someday, space explorers might head out in various directions and agree to meet back at Earth, 1 million or 1 billion years in the future.

Successes of General Relativity: Gravity



The Earth goes around the Sun because the mass of the Sun curves spacetime, not because of some mysterious $1/r^2$ force law assumed as an axiom without any explanation as to what the mechanism for gravity might be.

Successes of General Relativity: The Orbit of Mercury

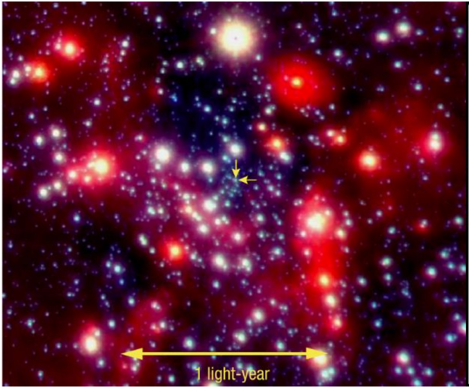


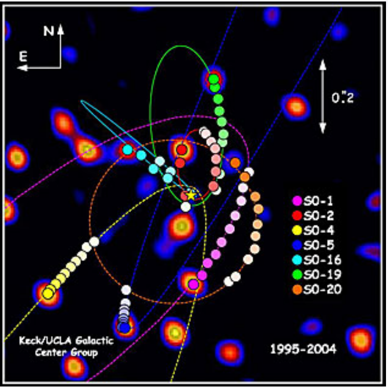
Newtonian physics predicts a precession of 1.5436° per century, not 1.5556° per century, observed since Verrier in 1859. In 1915, Einstein showed that General Relativity gets it right.

Successes of General Relativity: Black Holes

Artist's rendition of a black hole. Einstein was surprised when Schwarzschild found an exact solution to the highly nonlinear Einstein vacuum equations in 1915. Einstein spent the rest of his life believing that black holes, while existing in his theory, did not actually exist in nature. The idea seemed too radical at the time.

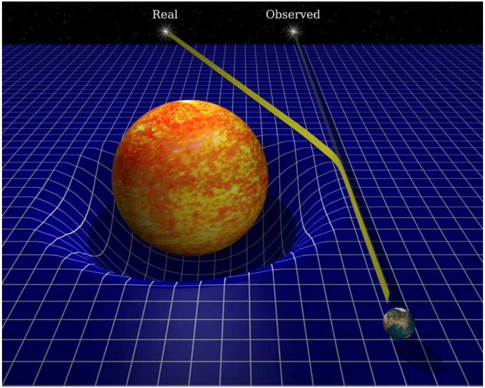
Successes of General Relativity: Black Holes

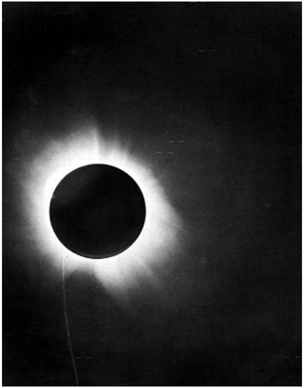




The supermassive black hole Sagittarius A* (4 million solar masses) at the center of the Milky Way Galaxy. The first black hole ever observed, Cygnus X - 1, was discovered in 1970. Today it is believed that most large galaxies have supermassive black holes at their centers.

Successes of General Relativity: Gravitational Lensing



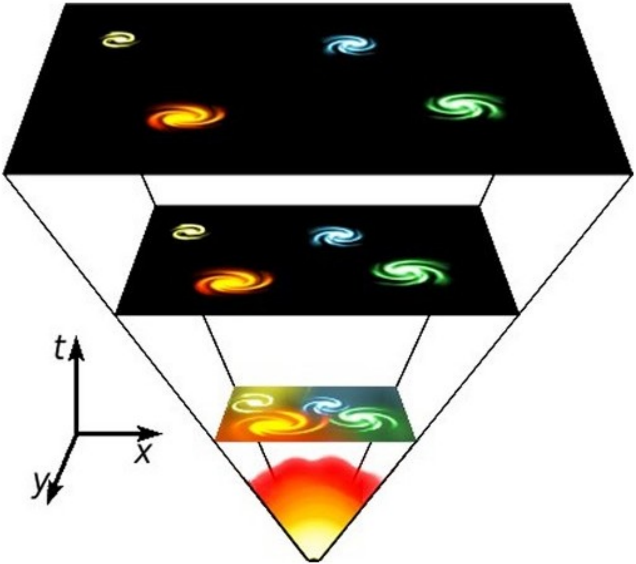


General Relativity predicts *twice* the bending angle for light that Newtonian physics predicts and agrees with observations, as observed by Eddington in 1919, on an island off the west coast of Africa during a solar eclipse.

Successes of General Relativity: Gravitational Lensing

After Eddington, Einstein becomes a celebrity, still the only scientist to receive a ticker tape parade in NYC, as he did in 1921. Still, it's not like he won the Super Bowl or anything ...

Successes of General Relativity: The Big Bang



Successes of General Relativity: The *Accelerating* Expansion of the Universe