

Celebrating Einstein: A Discussion about the Universe

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The Emily K Center
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The Science behind “Trevor the Time Traveler”

Trevor and his sister Farrah are in the fifth and fourth grades. How did they get a time machine? And why does everyone think they are the key to saving the galaxy?

Is time travel possible? Are there other universes? Does life exist on other planets? Take a ride with Trevor and Farrah and explore what might be.

“I wrote this story for my kids to teach them as many of the coolest, mind blowing ideas as I could, as well as how to be a good person. But when I was done, I realized this was a fun book for adults as well. Where else will you find general relativity explained to a fifth grader in a story with wormhole jump ropes, bullies, secret agents, gamblers, dinosaurs, aliens, and a flying unicorn who can talk, read minds, and grant wishes?”

The author is a professor of mathematics and physics at Duke University. He studies black holes, dark matter, and the curvature of space and time.



Trevor the Time Traveler and the Murkian Threat

by Professor H. L. Bray

TREVOR^{the} TRAVELER and the Murkian Threat

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The planet Murkos
orbits a star here

THE ANDROMEDA GALAXY
(1,000,000,000,000 stars)

THE MILKY WAY GALAXY
(300,000,000,000 stars)

The planet Fruit Smoothie
orbits a star here

YOU ARE HERE
on the planet Earth
orbiting the Sun

The planet Allegro
orbits a star here.

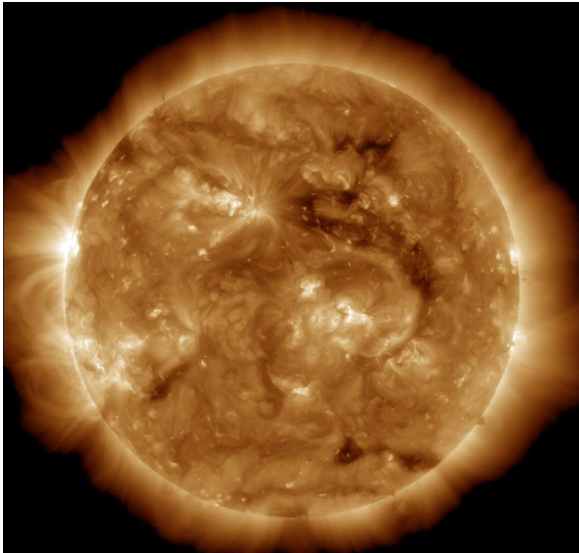
Milky Way Galaxy look-alike Galaxy NGC 6744



The Andromeda Galaxy



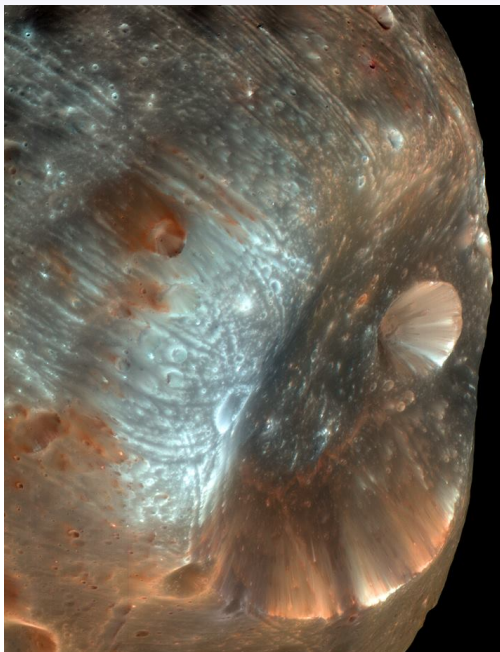
Except for hydrogen, almost all of the atoms in this room were created inside stars like our Sun that later exploded as supernovas. We are all made out of stardust.



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 M74



Hubble
Heritage

Spiral Galaxy NGC1365



Spiral Galaxy NGC4622



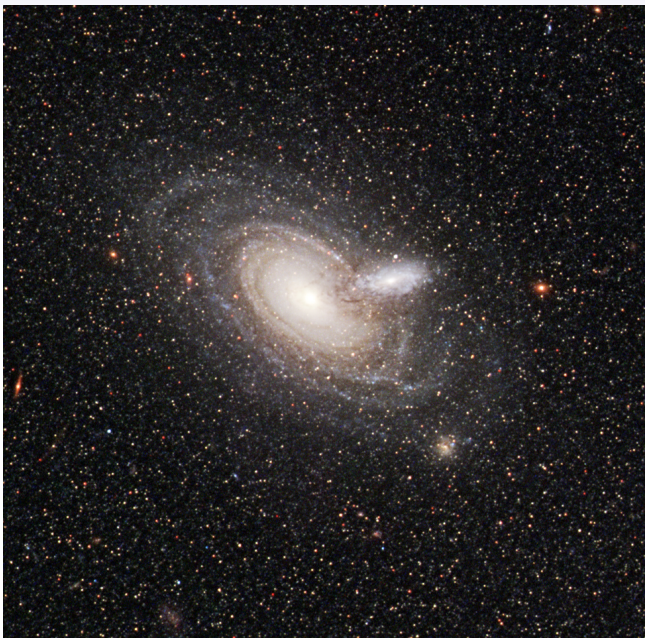
Spiral Galaxy M51, the Whirlpool Galaxy

Whirlpool Galaxy • M51



Hubble
Heritage

Spiral Galaxies 2MASX J00482185-2507365



Spiral Galaxy NGC3314



Spiral Galaxies ARP274

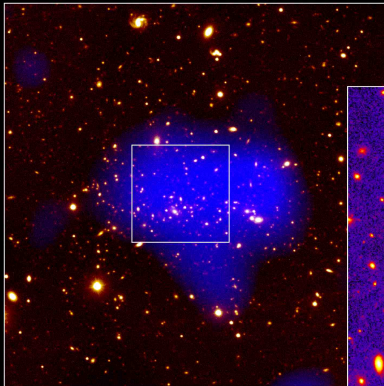


Elliptical Galaxies

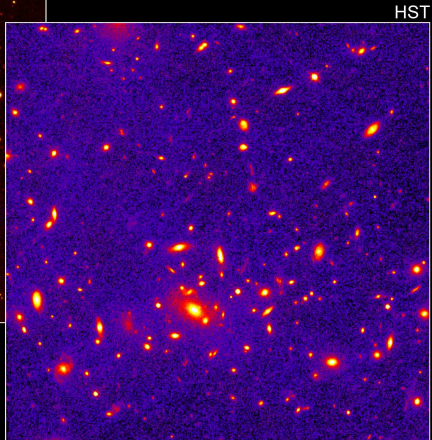


Figure: Elliptical galaxies contain ellipsoidal shaped collections of stars in mostly radial orbits. Two examples are M87 (left) and NGC1132 (right).

Galaxy Cluster MS1054-0321



Ground + X-ray



Distant Galaxy Cluster MS1054-0321
Hubble Space Telescope • Wide Field Planetary Camera 2

The Bullet Cluster



SPIRALS

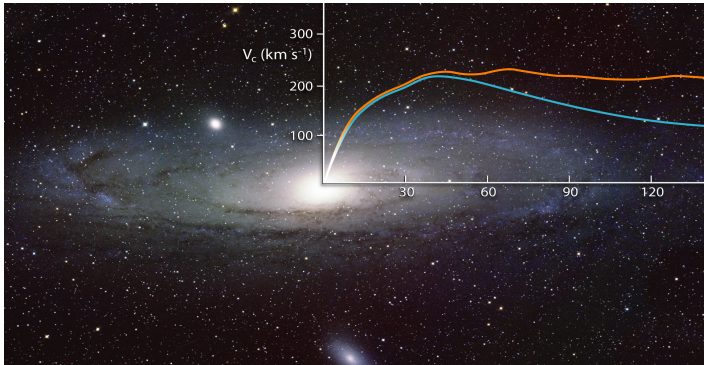
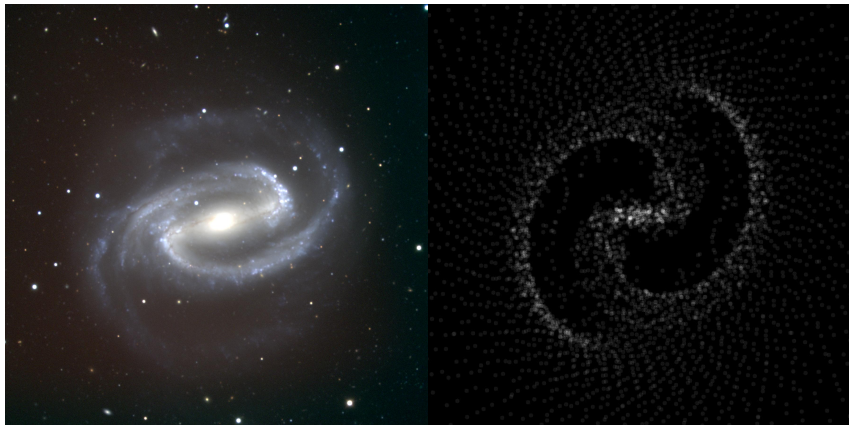


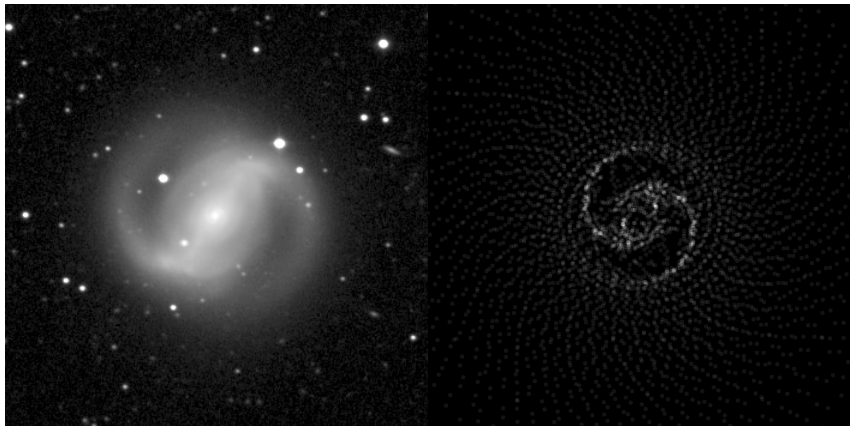
Figure: From the Dark Matter Awareness Week presentation. Presentation review at arXiv:1102.1184v1 by Paolo Salucci, Christiane Frigerio Martins, and Andrea Lapi.

Spiral Galaxy Simulation #1



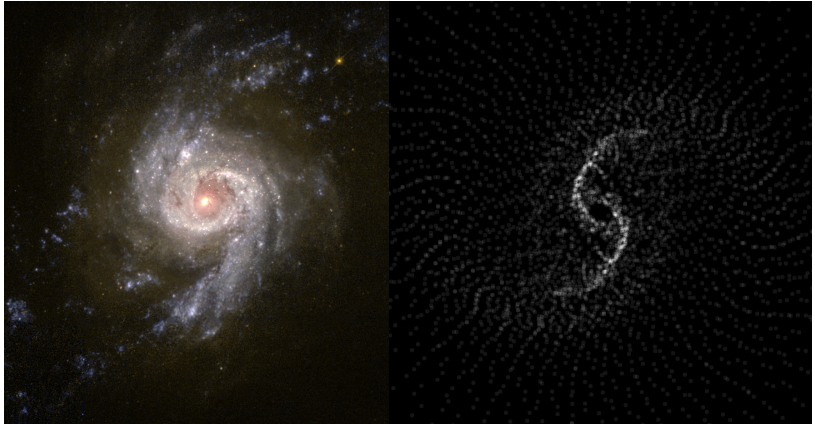
NGC1300 on the left, simulation on the right.

Spiral Galaxy Simulation #2



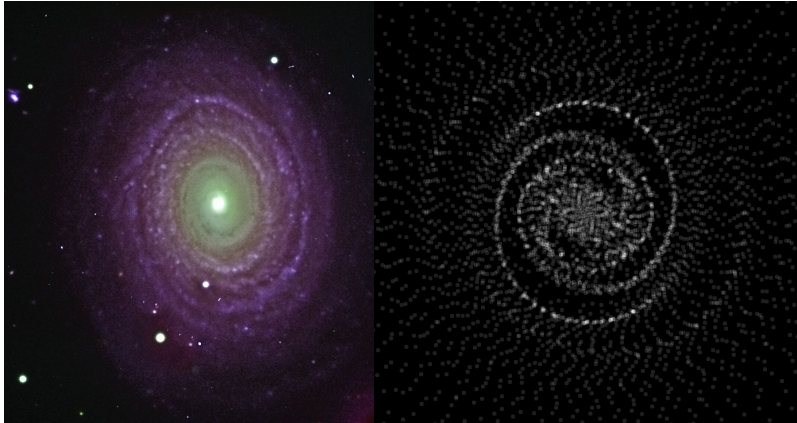
NGC4314 on the left, simulation on the right.

Spiral Galaxy Simulation #3



NGC3310 on the left, simulation on the right.

Spiral Galaxy Simulation #4



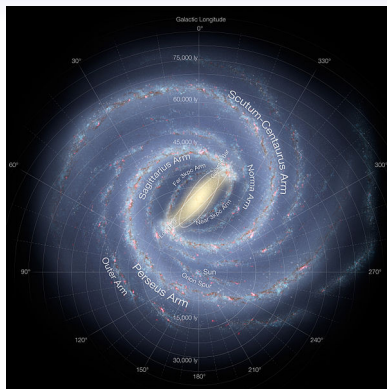
NGC488 on the left, simulation on the right.

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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Alien Abduction



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Practically anywhere, if you eat right and exercise!

Alien Abduction

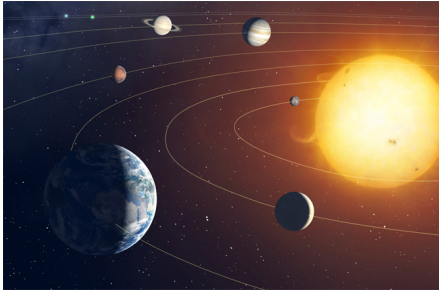


So, if you were abducted by aliens after this lecture, how far away from Earth could they take you in your lifetime?

Practically anywhere, if you eat right and exercise!

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.

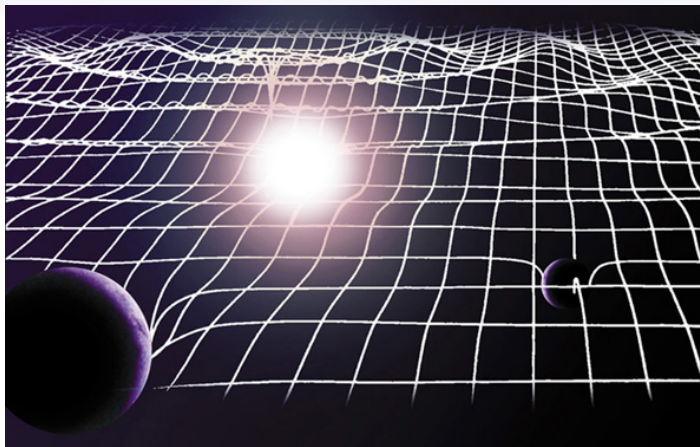
Space Exploration and Time Travel



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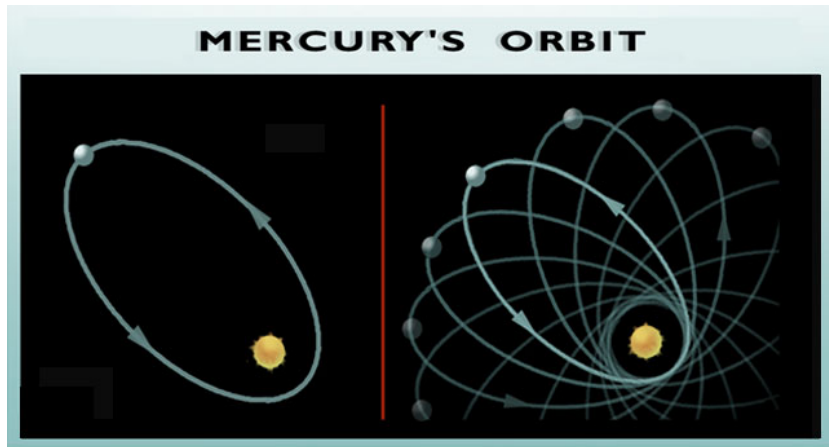
In effect, a spaceship which can accelerate at $1g$ for as long as you like is both a tool for space exploration and a time machine. If such spaceships exist someday, space explorers might head out in various directions and agree to meet back at Earth, 1 million or 1 billion years in the future.

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



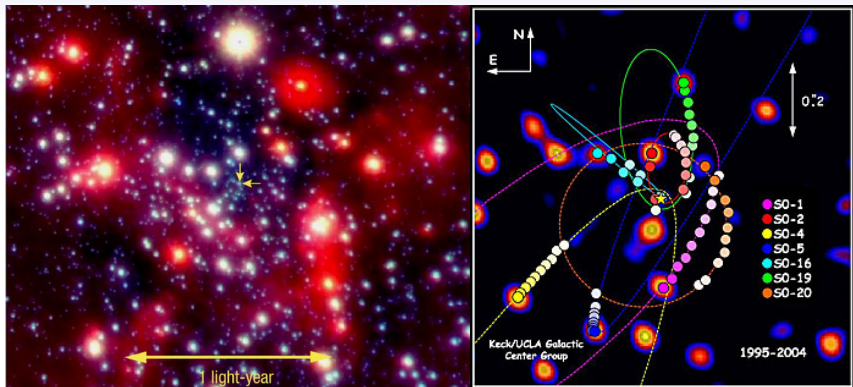
Newtonian physics predicts a precession of 1.5436° per century, not 1.5556° per century, observed since Verrier in 1859. In 1915, Einstein showed that General Relativity gets it right.

Successes of General Relativity: Black Holes



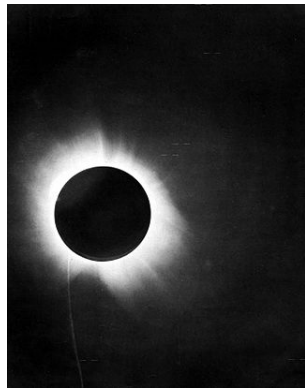
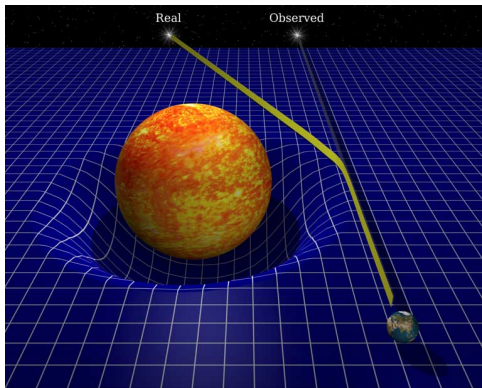
Artist's rendition of a black hole. Einstein was surprised when Schwarzschild found an exact solution to the highly nonlinear Einstein vacuum equations in 1915. Einstein spent the rest of his life believing that black holes, while existing in his theory, did not actually exist in nature. The idea seemed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



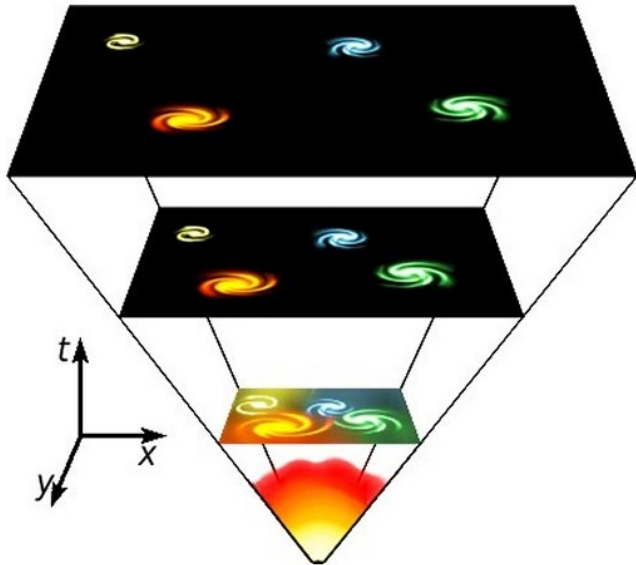
General Relativity predicts *twice* the bending angle for light that Newtonian physics predicts and agrees with observations, as observed by Eddington in 1919, on an island off the west coast of Africa during a solar eclipse.

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

