

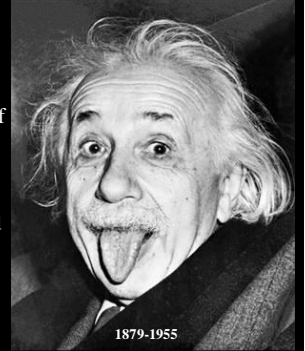
ASTR 1020: Stars & Galaxies

October 16, 2013

- *Mastering Astronomy* Homework on **Lives of Stars** is due Friday, Oct. 18.
- Reading: Chapter 6.
- Extra credit SBO observing session on Thursday, Oct. 17 at 7:30 pm.

Today: Dr. Einstein's Universe

- Einstein comes to America in 1933.
- The General Theory of Relativity (and Gravity).
- Black holes.
- Einstein: The man and the politician.



Einstein in America

- A phenomenon.
- Physicist as Rock Star!

At Hopi House, Grand Canyon in 1931



Einstein at Lincoln University in 1946

Spacetime

- Special relativity showed that space and time are not absolute.
- Instead they are inextricably linked in a four-dimensional combination called **spacetime**.

Rubber Sheet Analogy

Heavier weights cause a greater distortion of the rubber sheet.

10 kg

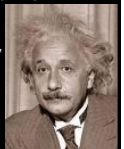
0.1 kg

1 kg

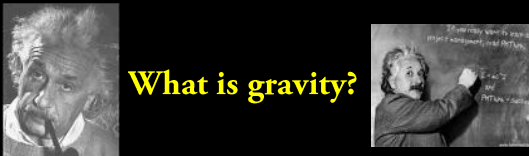
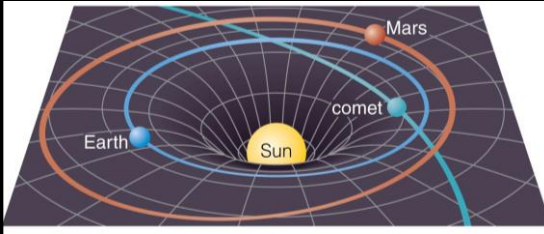
- Matter distorts spacetime in a manner analogous to how heavy weights distort a rubber sheet

Key Ideas of General Relativity

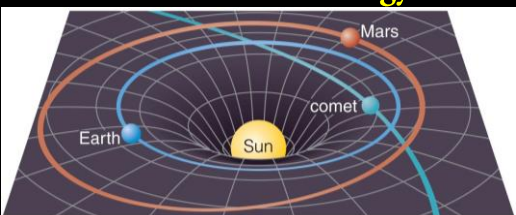
- Gravity arises from distortions of spacetime
- Time runs slowly in gravitational fields
- *Black holes* can exist in spacetime
- The universe may have no boundaries and no center but may still have finite volume
- Rapid changes in the motion of large masses can cause *gravitational waves*



What is gravity?

Rubber Sheet Analogy



- Mass of Sun curves spacetime
 - Free-falling objects near Sun follow curved paths
 - Circles near Sun have circumference $< 2\pi r$

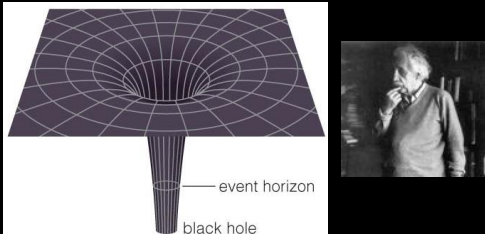
Clicker Question: According to General Relativity, the presence of matter curves spacetime. That means a planet in our solar system

- a) Feels a force of gravity coming from the sun
- b) Moves *as if* there was a force coming from the sun
- c) Experiences “free fall” or free movement by moving in a curved orbit
- d) None of the above
- e) b and c

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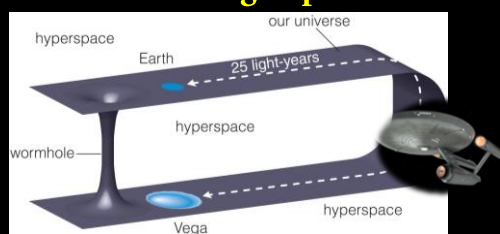
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Curvature near Black Hole



- Continued shrinkage of Sun would eventually make curvature so great that it would be like a bottomless pit in spacetime: a *black hole*

Shortcut Through Spacetime



- Some mathematical solutions of the equations of general relativity allow for shortcuts called *wormholes* that are tunnels through *hyperspace*

Einstein & The Bomb

- $E=mc^2$ is the basis behind the nuclear bomb.
- Einstein wrote to President Roosevelt in 1939 that an atomic weapon was possible.



with Leo Szilard (1946)

