

## ASTR 1020: Stars & Galaxies

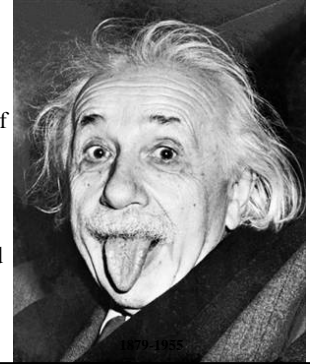
March 7, 2008

- *MasteringAstronomy* Homework on Star Death is due Mar. 10<sup>th</sup>.
- Reading: Chapter 19, sections 19.1-19.2.
- Exam 2 next Friday, March 14<sup>th</sup>. (Chapters 15.3 – 19.2).

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## Today: Dr. Einstein's Universe

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



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## Einstein in America

- A phenomenon.
- Physicist as Rock Star!

At Hopi House, Grand Canyon in 1931



Einstein at Lincoln University in 1946

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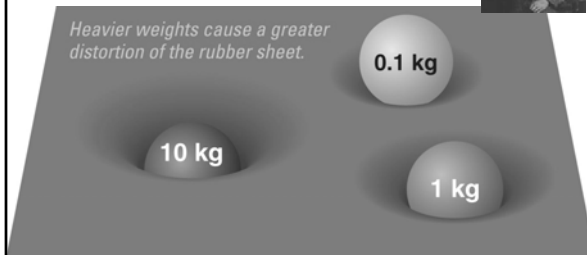
## Spacetime

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

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## Rubber Sheet Analogy

Heavier weights cause a greater distortion of the rubber sheet.

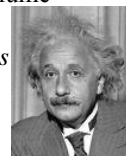


- Matter distorts spacetime in a manner analogous to how heavy weights distort a rubber sheet

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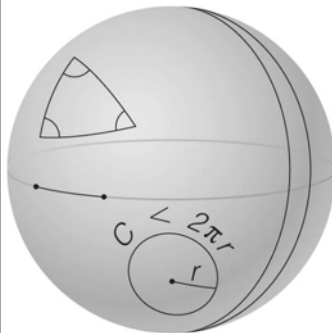
## Key Ideas of General Relativity

- 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*



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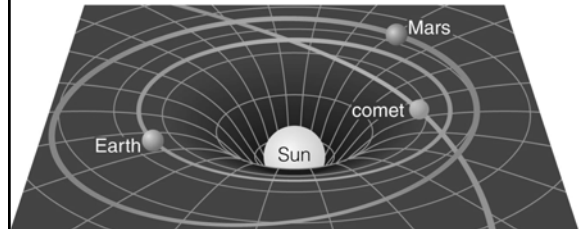
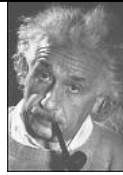
## What is curved spacetime?



- Great circle is shortest distance between two points
- Parallel lines eventually converge
- Angles of a triangle sum to  $> 180^\circ$
- Circumference of circle is  $< 2\pi r$

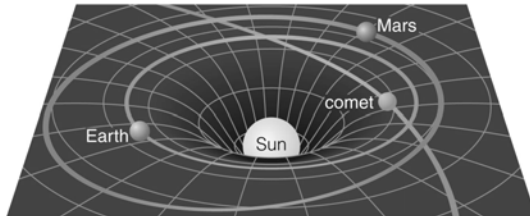
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## What is gravity?



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## Rubber Sheet Analogy



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

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**Clicker Question:** According to general relativity the presence of matter curves spacetime. That means a planet in our solar system

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

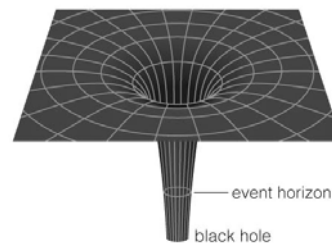
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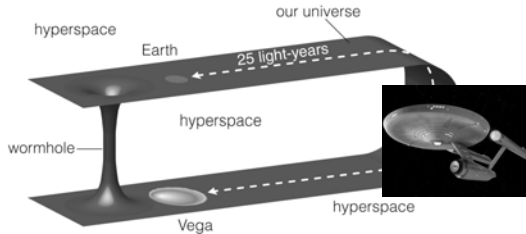
## Curvature near Black Hole



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

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## Shortcut Through Spacetime



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

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## Are Wormholes Really Possible?

- Wormholes are not explicitly prohibited by known laws of physics but there is no known way to make one
- If wormholes exist, then they can be used for time travel
- Time travel leads to paradoxes that some scientists believe should rule out the possibility of wormholes



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## Einstein: The man & husband

### Einstein's Rules for Mileva in 1914:

- Serve meals *in my room*.
- Renounce all personal relations. Don't expect any intimacy from me.
- You will stop talking to me if I request it.
- You will not belittle me in front of the children.



Albert & Mileva  
1905

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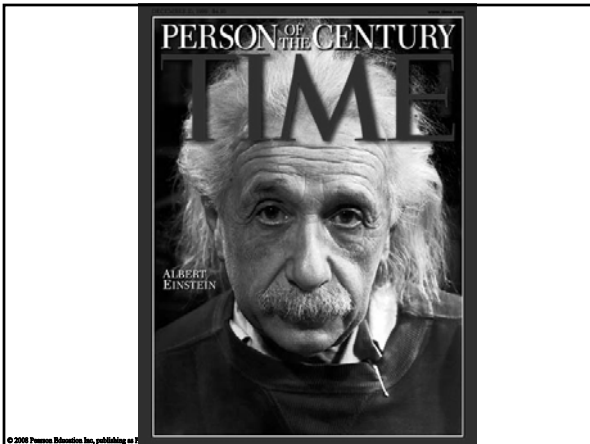
## Einstein & The Bomb

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



with Leo Szilard (1946)

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