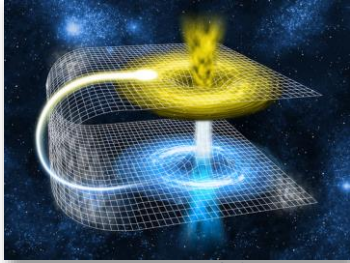


Today's Class: Einstein and Interstellar Travel

- Final paper due on December 7.
- Reading: Sections 13.1-13.2 in Cosmic Perspective.
- Complete FCQs by Dec. 2.



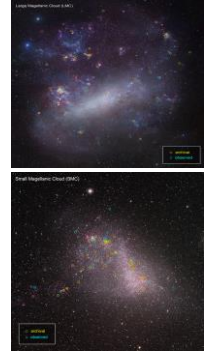
Astronomy 2020 – Space Astronomy & Exploration

1

Hubble Launches Large Ultraviolet-Light Survey of Nearby Stars

presented by Emily Casson

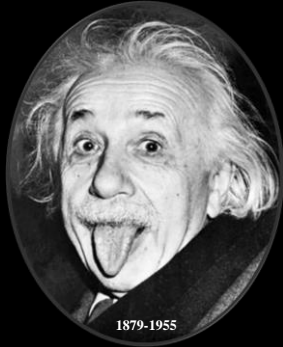
- As of November 5, 2020, the Hubble Space Telescope has been tasked with the largest observing program of its career.
- It is called the ULYSSES Program and for the next couple of years, Hubble will observe nearby stars in Ultraviolet Light, as many young and massive stars emit a lot of UV light.
- Ulysses stands for Ultraviolet Legacy Library of Young Stars as Essential Standards
- It will observe the young stars in our galaxy which will give us a better understanding of what our Sun was like in the first few million years of its existence.
- And also observe older, massive stars in four nearby galaxies- The Large Magellanic Cloud, The Small Magellanic Cloud, Sextans A, and NGC 3109 informing us on their radiation and how that affects their evolution and star forming regions and galaxies.
- Observing and creating a data bank of spectra for these stars which will provide information on their composition, temperature, velocity, density, etc.
- **Question:** Do you think this Ulysses Program is an effective and valuable use of Hubble's Last remaining years of relevancy or before its mission ends?



2

Today's Class

- Einstein comes to America in 1933.
- The General Theory of Relativity (and Gravity) published in 1915.
- Black holes & worm holes.
- Einstein: The man and the politician.



3

Einstein in America

- A phenomenon.
- Physicist as Rock Star!

At Hopi House, Grand Canyon in 1931



Einstein at Lincoln University in 1946

4

Einstein in America



5

Spacetime

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

6

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

7

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*

8

Detection of Gravitational Waves

Colliding Neutron Stars

Laser Interferometer Gravitation-Wave Observatory (LIGO)

2017 Nobel Prize in Physics

9

What is gravity?

10

Rubber Sheet Analogy

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

11

Einstein's Relativity

12

Class Exercise: 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

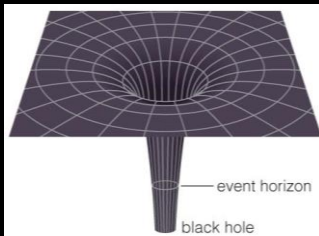
13

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

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14

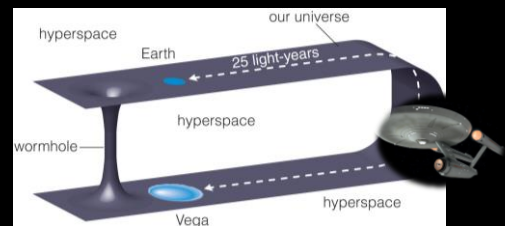
Curvature near Black Hole



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

15

Shortcut Through Spacetime



- Some mathematical solutions of the equations of general relativity allow for shortcuts called *worm holes* that are tunnels through *hypertime*

16

Interstellar Travel via Wormholes?



17

Einstein & The Bomb

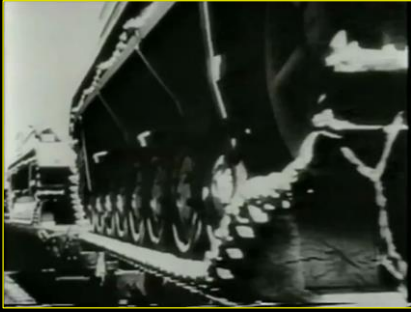
- $E=mc^2$ is the basis behind the nuclear bomb.
- Einstein wrote to President Roosevelt in 1939 that an atomic weapon was possible.



with Leo Szilard (1946)

18

Einstein & The Bomb



19

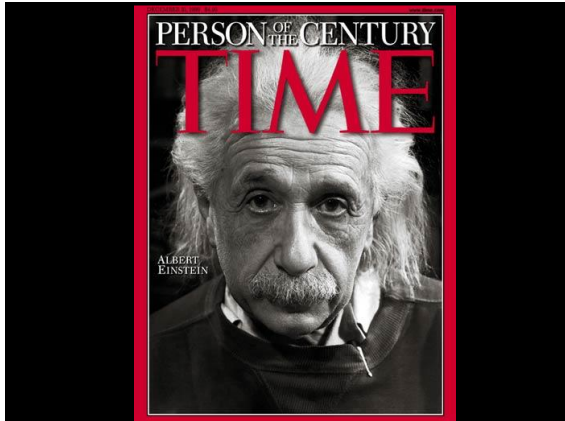
Einstein & The Bomb

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20



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