33-120
Science & Science Fiction

This week – First Major Question:

What is the nature of space and time?

Today…

Finish “Modern Physics”

Begin “Future Physics”

Wormholes and Time Travel into the Past

- **Problem 2 due today, Sept. 15**
  - **Time Dilation on ISS** (details on Canvas)
- **Spacetime Team Project next Monday, 9/18**
  - **Einstein's *Principle of Equivalence***
  - **No lecture – gather data for project**
  - **Team assignments on Canvas**
  - **Pick up equipment this week or Mon.**
  - **Results due on Wed. Sept. 20**

Announcements for Friday, Sept. 15

- **Exploration Paper 1** due Friday, Sept. 22
  - Your choice of topics on **Space & Time**
  - Min. 75% original writing (“Turnitin”)
  - DO NOT use generative AI to write
  - Minimum 2 full pages of text
  - At least one reference
  - One Submission Only (don’t rush)
  - Details on Canvas

Coming Attractions…

Can a black hole be used for time travel?

What happens to the fabric of *spacetime* when two black holes meet in space?

Is something like a *Star Trek* "warp drive" hypothetically possible?

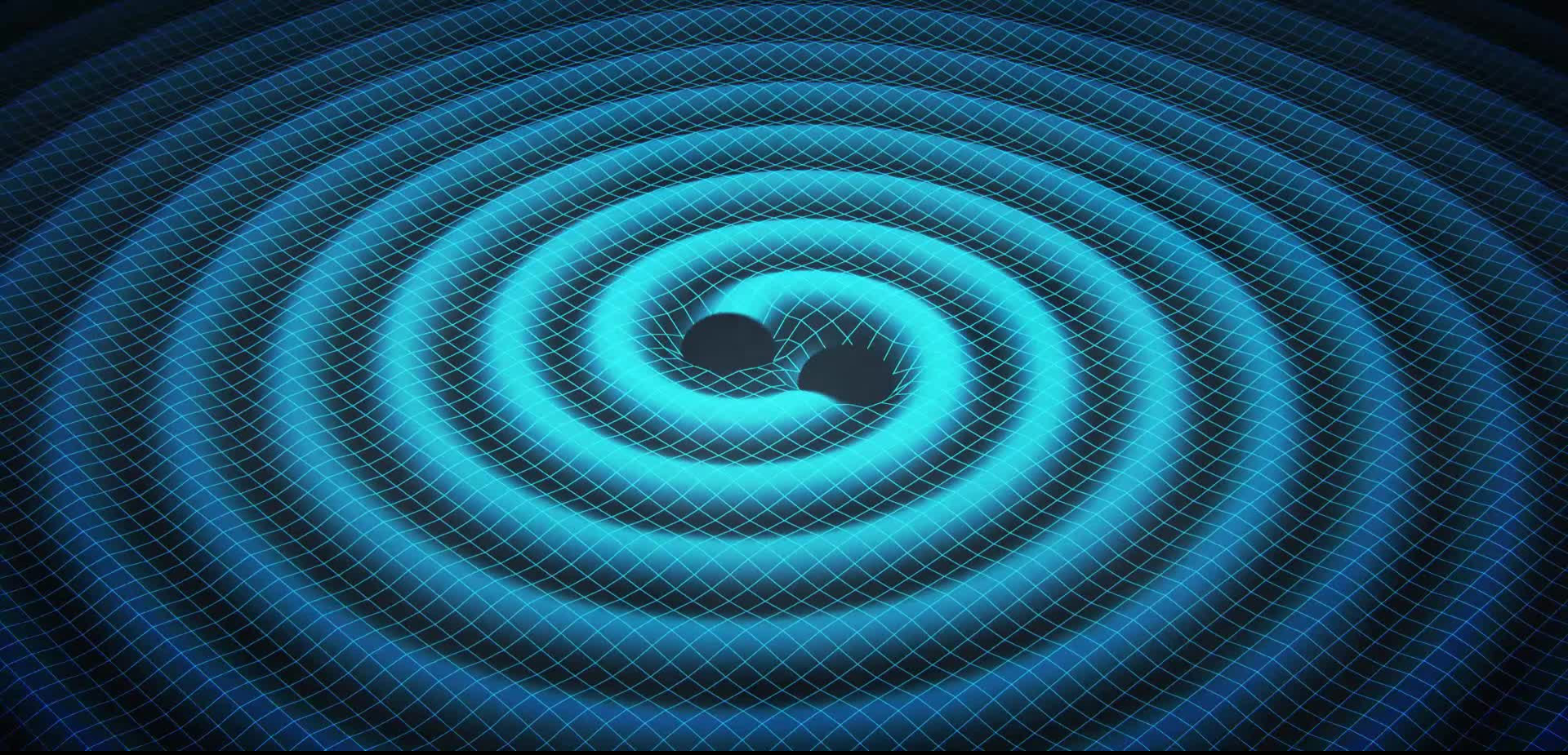
Last time…
Black Holes and Time Travel, Gravitational Waves, Warp Drive

- **Gravitational Time Dilation:**

$$t_r = t_\infty \sqrt{1 - \frac{2Gm}{rc^2}}$$

  - t_r = time at some distance r from a mass m
  - t_∞= normal time (infinitely far from the distortion)
  - hours near black hole = years back on Earth

General Relativity:
Clocks run more slowly when closer to large mass.
(allows for time travel into the <u>future</u>)



https://www.extremetech.com/extreme/222852-what-are-gravitational-waves-and-where-does-physics-go-from-here-now-that-weve-found-them

Gravitational Waves…
Ripples of distortion in spacetime

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- **Timeline for Gravitational Waves:**
  - **Predicted by Einstein's General Theory of Relativity (published 1916; written 1915)**
  - **First detected by LIGO (September 2015)**
  - **LIGO collaboration convinced results were real (December 2015)**
  - **Paper delivered to PRL (21 Jan 2016)**
  - **Press release + publication (11 Feb 2016)**
  - **Nobel Prize (Weiss, Barish, Thorne) 2017**

Gravitational Waves:
The big physics announcement of 2016

Special Relativity: $E=mc^2$

Equivalence of Energy and Mass

General Relativity:

Fabric of spacetime distorted by large mass

The basic idea of warp drive:
Not just Sci-Fi but a hypothetical possibility!

Curvature of Spacetime = **Configuration of Matter and Energy**

“Space tells matter how to move.”
“Matter tells space how to curve.”

The basic idea of warp drive:
Not just Sci-Fi but a hypothetical possibility!

The warp drive: hyper-fast travel within general relativity

Miguel Alcubiere

Department of Physics and Astronomy, University of Wales

Class. Quantum Grav. **11** (1994)

Warp Drive:

Travel globally faster than light, but not locally.

Not just Sci-Fi but a hypothetical possibility!

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Recap:

Newton and Classical Physics…

- 3-D Space and (1-D) Time are separate, independent concepts
- Gravity acts instantaneously over arbitrary distance

Major Question 1:
What is the Nature of Space and Time?
Part 1 Classical Physics

Recap:

Einstein and Modern Physics…

- *Spacetime*: 4-D "fabric"
- Perception of space and time depend on relative motion
- Clocks run slow at high speed

Major Question 1:
What is the Nature of Space and Time?
Part 2 Modern Physics

Recap:

Einstein and Modern Physics…

- Speed of light constant for all
- Nothing travels faster than light
- Only massless particles can travel at the speed of light

Major Question 1:
What is the Nature of Space and Time?
Part 2 Modern Physics

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Recap:

Einstein and Modern Physics…

- Gravity is result of distorted *spacetime* near a large mass
- Clocks run slow when close to large mass

Major Question 1:
What is the Nature of Space and Time?
Part 2 Modern Physics

Recap:

Einstein and Modern Physics…

- Predicted Gravitational Waves (1915)
- LIGO: first direct measurement of Gravitational Waves (2015)

Major Question 1:
What is the Nature of Space and Time?
Part 2 Modern Physics

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Recap:

Einstein and Modern Physics…

- Time travel into the *future* is possible! (in both SR & GR)
- Time travel into the *past* is NOT possible.

Major Question 1:
What is the Nature of Space and Time?
Part 2 Modern Physics

“Future Physics”

- Wormholes
- Quantum gravity
- Time travel into the past?
- The Multiverse Hypothesis

Major Question 1:
What is the Nature of Space and Time?
Part 3 “Future Physics”

What is a *wormhole?*

Hypothetical shortcut through spacetime

Quantum-scale phenomenon

Highly unstable

Where did the concept originate?

“Future Physics”
Wormholes

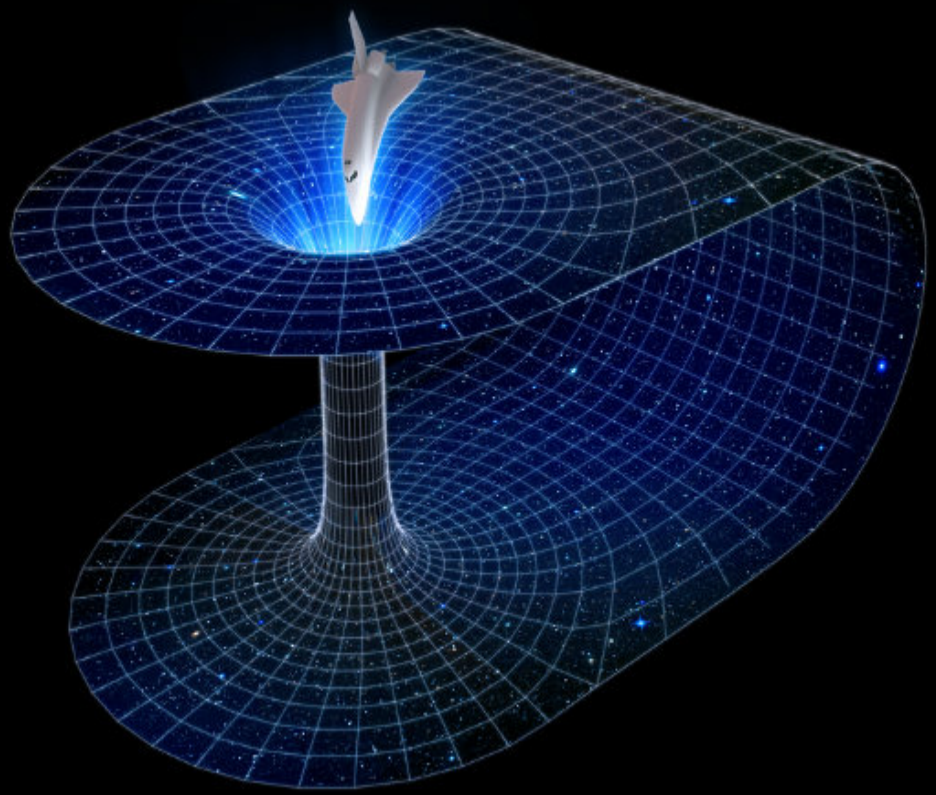
What does spacetime look like at the quantum scale?

No longer Einstein's continuous 4-D "fabric"

More like a "quantum foam"

Bubbles and wormholes

"Future Physics"
Wormholes



http://space-engine.wikia.com/wiki/Wormhole

- Shortcut through spacetime
- Existence is <u>hypothetical</u>
- Quantum-scale; highly unstable
- Enormous energy needed to keep one open long enough to be useful

Properties of Wormholes

Contact

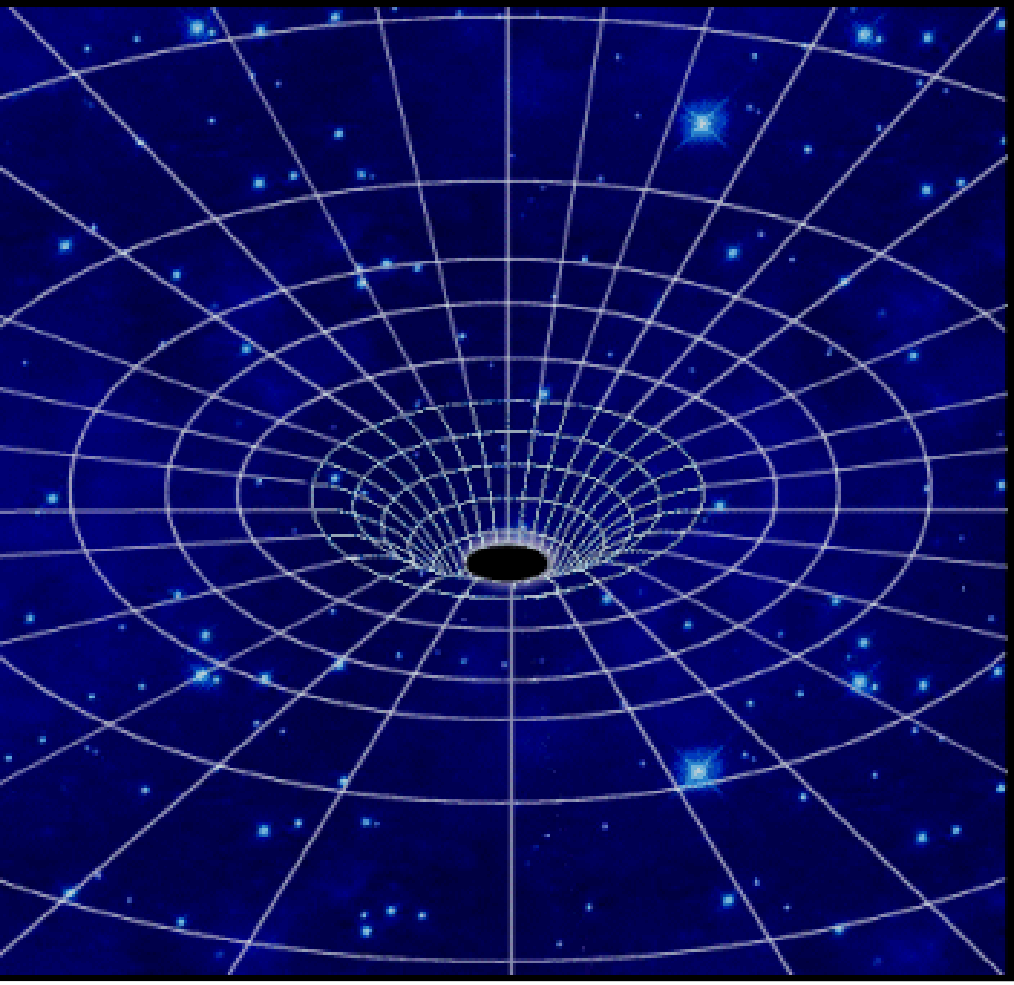
Written by Carl Sagan (1985)

Radio astronomer detects transmission from extraterrestrial intelligence

What would it take to go and visit them?

Author consults an expert for suggestion

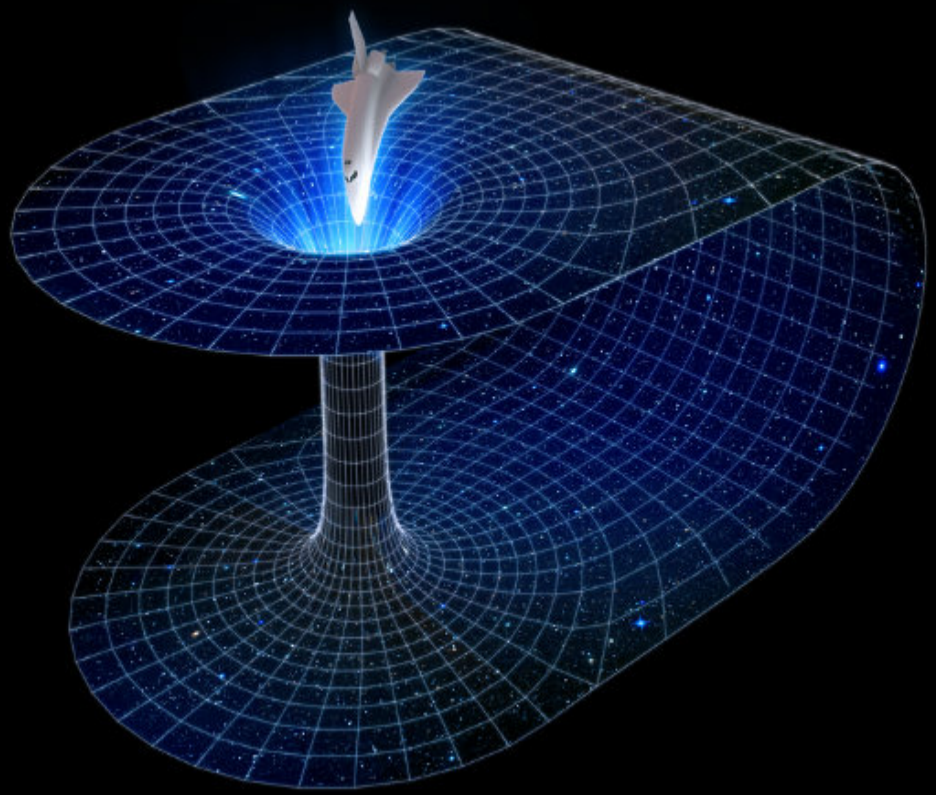
Carl Sagan, Kip Thorne and "CONTACT"



Why not use a black hole?

- Gravitationally completely collapsed object
- Event horizon: point of no return, beyond which not even light can escape
- If you go into a black hole you don’t come out somewhere else.
- You die!

Sagan’s original idea:
Can we use a black hole?



http://space-engine.wikia.com/wiki/Wormhole

- **Shortcut through spacetime**
- **Existence is <u>hypothetical</u>**
- **Quantum-scale; highly unstable**
- **Enormous energy needed to keep one open long enough to be useful**

Kip Thorne's alternative suggestion:
Use a *wormhole*.

Contact

Directed by Robert Zemeckis

Warner Brothers (1997)

Giant machine opens wormhole to distant part of galaxy

Jumper

Directed by Doug Liman

20th Century Fox (2008)

Given what you know about wormholes, what is your opinion about the technology in this scene?

Contact

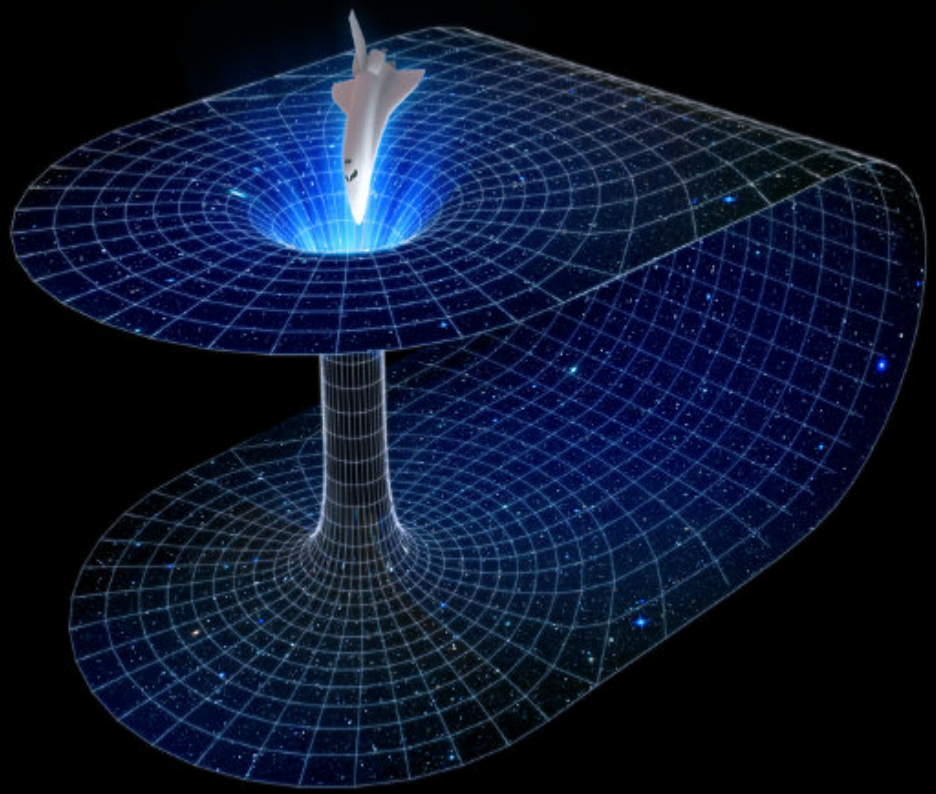
Written by Carl Sagan (1985)

Introduced the concept of a *wormhole* as a shortcut through space into popular culture

But Einstein says spacetime is a 4-D "fabric"

Could a wormhole be used for time travel?

Carl Sagan, Kip Thorne and "CONTACT": unexpected implications of wormholes



http://space-engine.wikia.com/wiki/Wormhole

Hypothetically, YES!

- Shortcut through spacetime (not just through space!)

Could a wormhole be used as a time machine?

Star Trek
“The City on the Edge of Forever”

Written by Harlan Ellison

Paramount (1967)

Could a wormhole be used for time travel?

Next time…
Wormholes and time travel;
Other possibilities for time travel;
"Future Physics" (continued)

Barry Luokkala

Teaching Professor of Physics

Carnegie Mellon University