Whispers from the Cosmos:
Listening to Gravity's Hidden Message

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Storyline

- Early ideas about gravity
- Gravity in your basement
- Gravitational astronomy
- Whispers from the Cosmos
Reminder
The Laws of Nature
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- Nature could behave in three distinct ways
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- Everything we see around us follow patterns and rules
- We call these patterns **the Laws of Nature** some of which we have discovered.
Newtonian Gravity

- **Universal Law of Gravitation** was discovered by Isaac Newton.

- It says that the gravitational force:
  - acts between **any two objects**
  - is larger for **larger masses**
  - decreases as the **separation** between masses increases

- Successfully predicts orbits of planets in the solar system (Kepler’s Laws)

- **Gravity binds the Cosmos and makes it all go!**
The Magic of Gravity

• Newton’s great epiphany was **all objects experience gravity**

• How do we know this?

• We can **prove it by experiment!**
  But we have 2 problems
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  • Gravity is WEAK
  • The Earth is HUGE (a trillion-trillion times more massive than common everyday objects)
Cavendish Experiment

• In 1797 Henry Cavendish built a **torsion balance**

• Earth pulls on both little masses, so they turn freely on the thread due to weak forces

• This was one of the first **high precision** measures of Nature’s fundamental character
Science in the Kitchen
Science in the Kitchen
Science in the Kitchen
Science in the Basement
Science in the Basement

- I can build **my own** Cavendish experiment in the basement using stuff lying around the kitchen.
High Precision Gravity
High Precision Gravity
High Precision Gravity

- The force in this experiment is **120,000,000,000** times smaller than the force the Earth holds me down with. *Sticks, string, and some brains.*
Seeing the Cosmos with Gravity

- We can tell a lot about an object from its gravity

- What it’s made of, how dense it is, what shape it is...

- Wouldn’t it be great if we could probe the Cosmos, not with light, but with gravity?

- Gravity is weak, but with clever technology, we can deal with it!
LISA (Laser Interferometer Space Antenna)
Building LISA
Ripples in the Fabric of the Cosmos

- When mass moves, the gravitational field changes
- The changes in the gravitational field travel outward at the speed of light – a mental picture of what we call **gravitational waves**
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The changes in the gravitational field travel outward at the speed of light – a mental picture of what we call **gravitational waves**.
Ripples in the Fabric of the Cosmos
The Gravitational Wave Cosmos
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Gravitational waves **encode astrophysical information**!

They aren't good for making pretty pictures. :-(

The Waveform Zoo
The Songs of Gravity

10 Msun Black Hole + 10,000 Msun Black Hole
circular orbits

10 Msun Black Hole + 10,000 Msun Black Hole
eccentric orbits
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Wonder, mysteries and grandeur

- Gravitational astronomy offers us endless new mysteries and fantastic new vistas.

- It challenges our **ingenuity and creativity**, and inspires us to **explore and understand**, not just gravity, but ourselves and our place in the Cosmos.