# Demonstrating the Causation of Gravity for Subluminal Velocities

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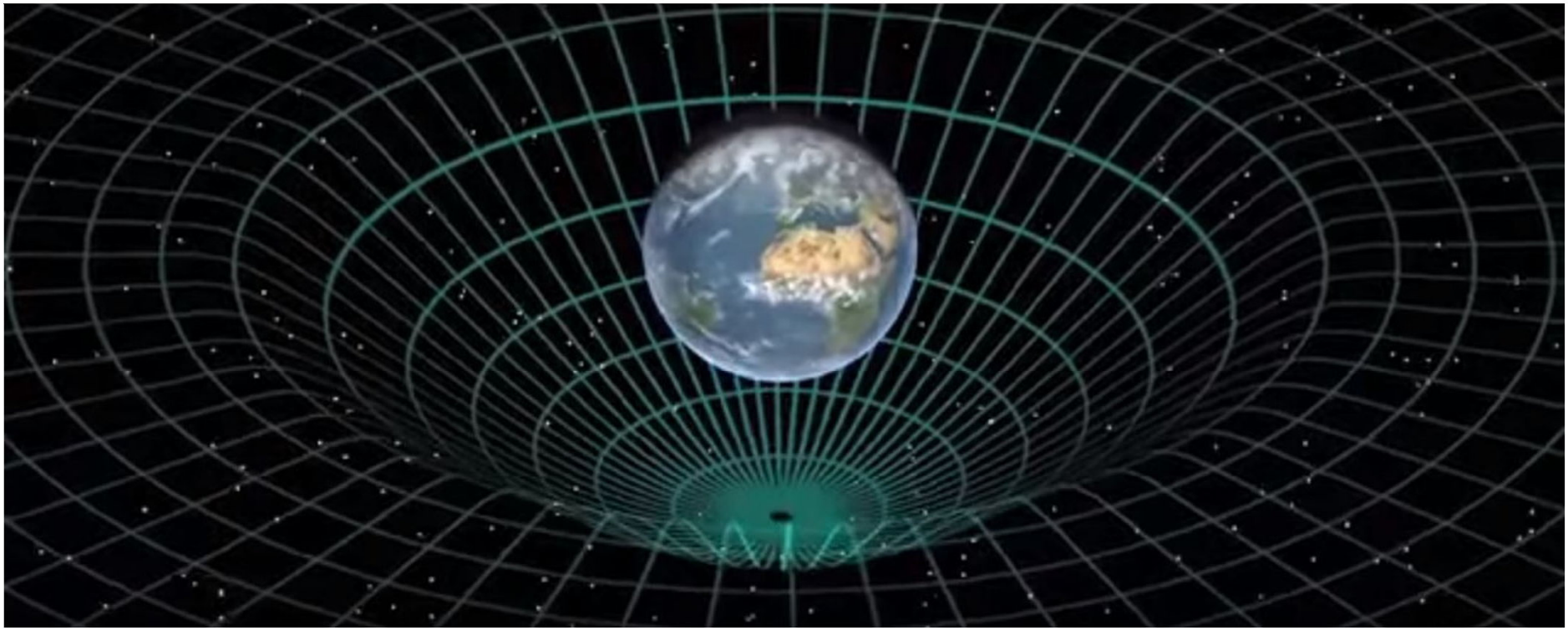
# Demonstrating the Causation of Gravity for Subluminal Velocities

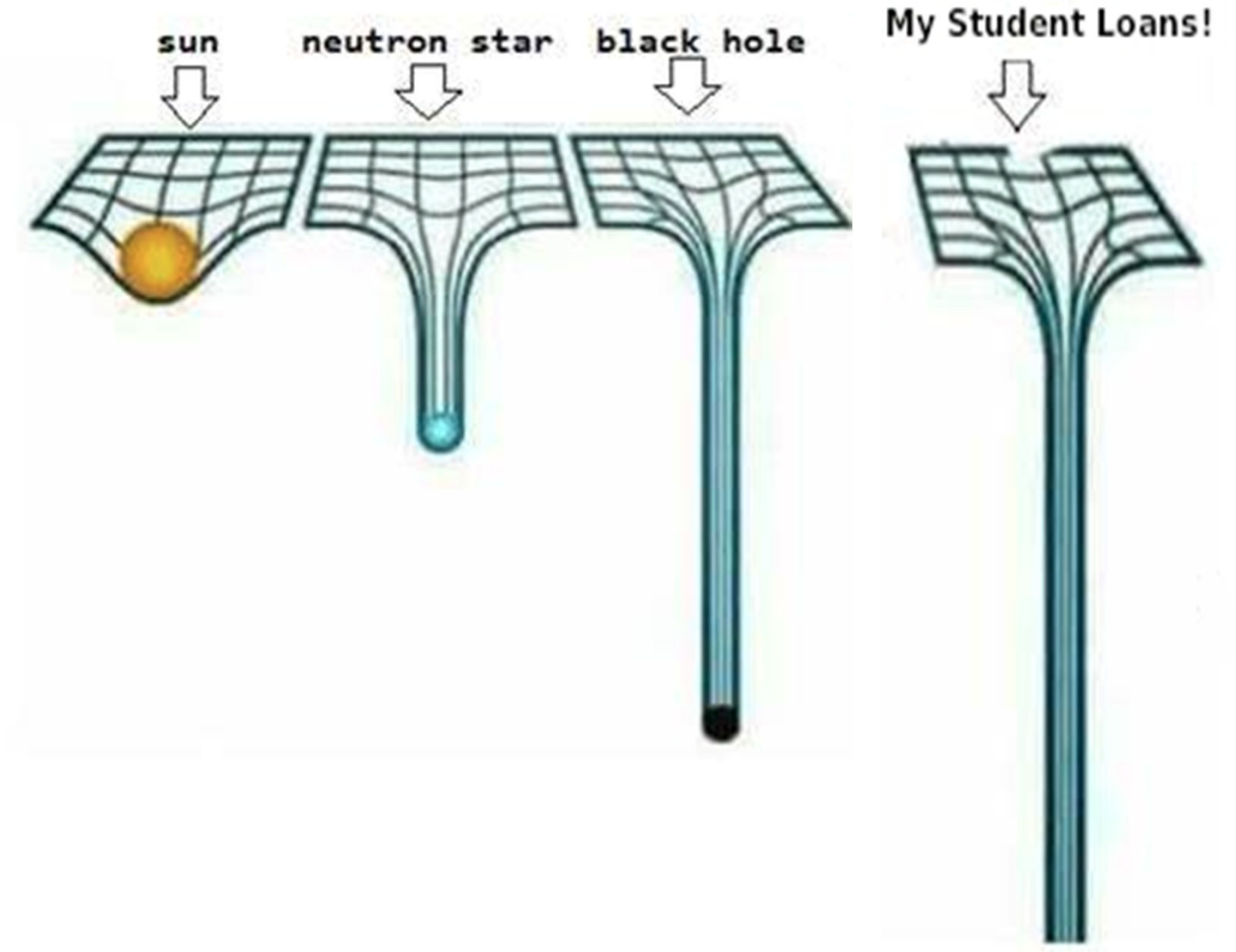
- Subluminal Velocities?
- v << c
- AKA, Human Speeds!
- Weak, Static Gravity
- What causes the Gravity we experience as humans?

# Einstein's Field Equation

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

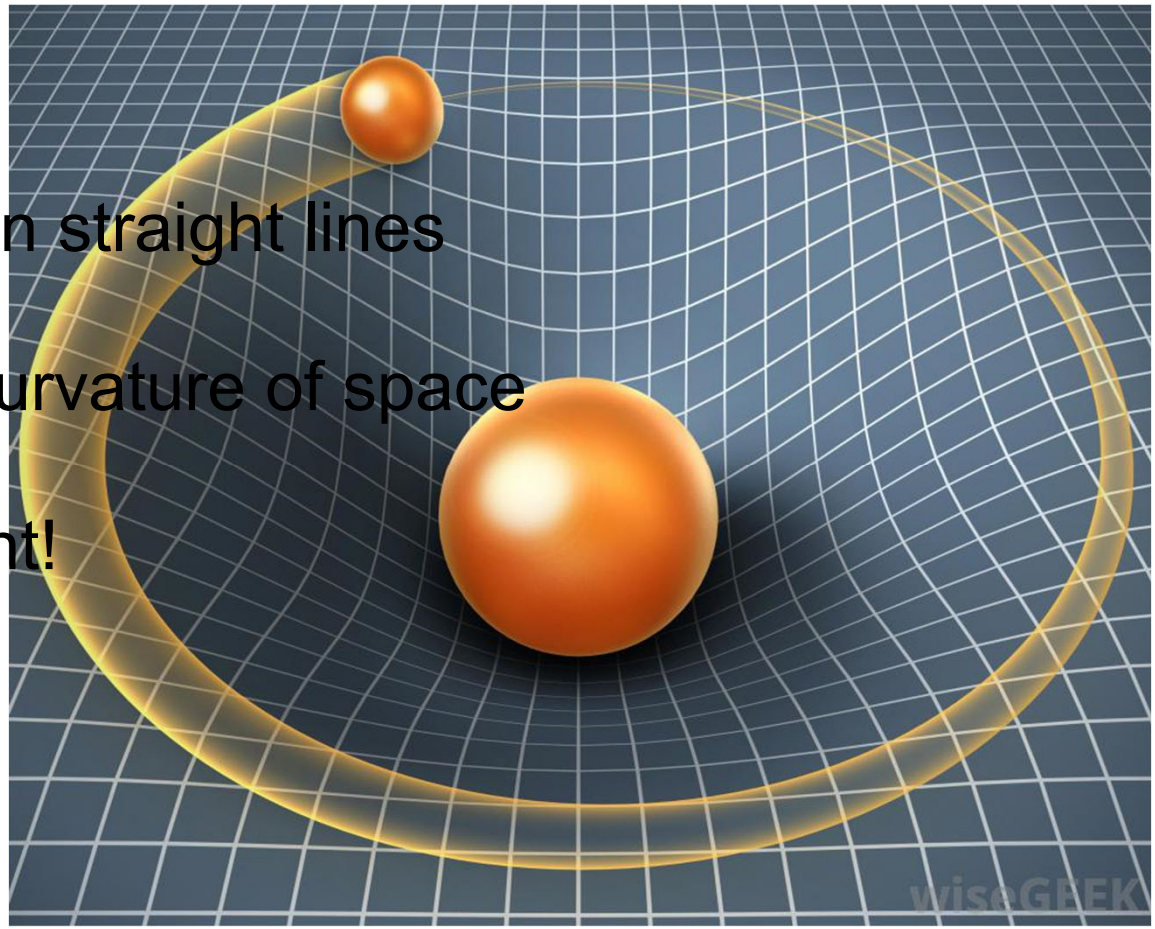


# Scale of the Most Massive Objects in the Universe

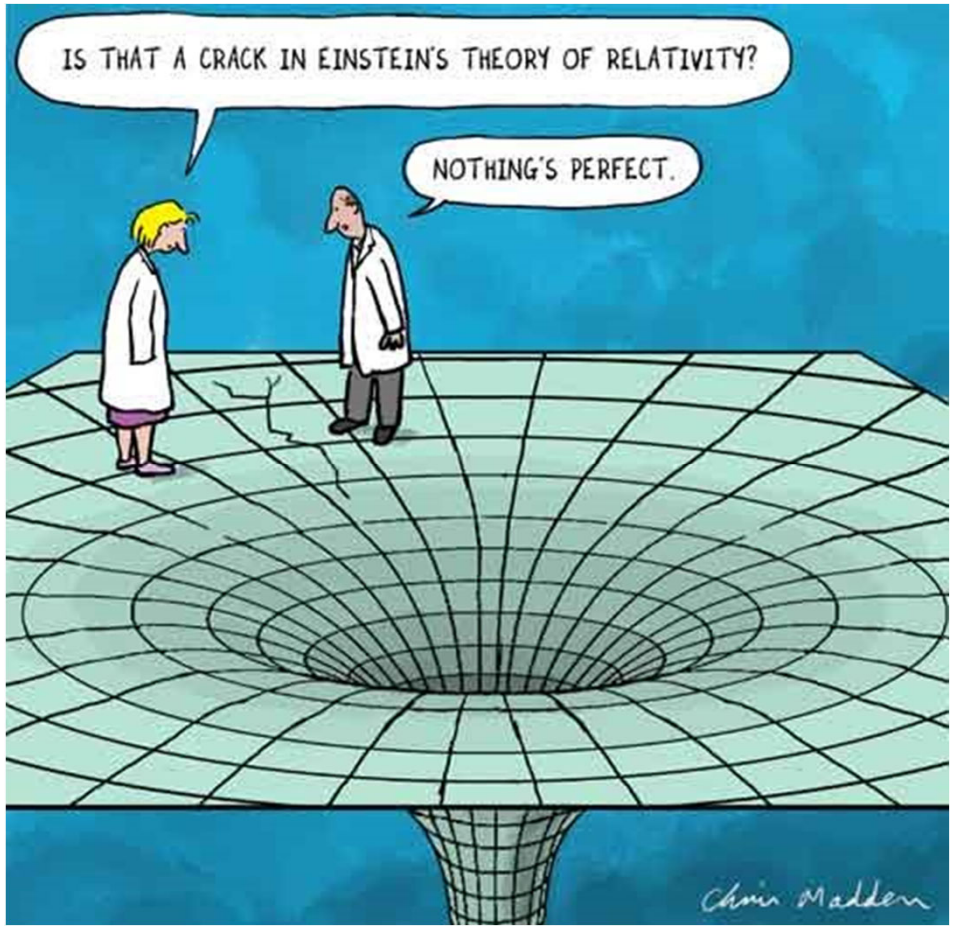


# The Rubber Sheet Model

- Mass curves space
- Orbiting objects traveling in straight lines
- Straight Lines follow the curvature of space
- WAIT! Something isn't right!



# What do you mean, something's not right!?




- Common Misconception Confounded by:
- The Truth is more complicated
- We don't feel like explaining it to you!
- But I will…
- Its SPACETIME!
- Not Space and Time…
- However...
- Mathematically Separable
- Schwarzchild Solution
- At the speed of light, the curvature of space ha
- We don't move at the speed of light!
- At human velocities, in weak, static gravity…
- Space is FLAT!!!
- No, not the EARTH… SPACE is Flat!
- So… What causes the Gravity we experience a

# Miscon of rubber sheet

# Let's do some MATH!!!

- Starting with the E.F.E.
-
$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- What is the metric in this room?
  - Weak, static gravity with slow velocity...

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu} \qquad |h_{\mu\nu}| << 1$$

# Metric in the room

- Geodesic Equation

$$\frac{d^2x^\alpha}{d\tau^2} + \Gamma^\alpha_{\mu\nu}\frac{dx^\mu}{d\tau}\frac{dx^\nu}{d\tau} = 0$$

- 4-velocity

$$u^\lambda = \begin{pmatrix} \gamma c \\ \gamma u_x \\ \gamma u_y \\ \gamma u_z \end{pmatrix} \rightarrow \begin{pmatrix} c \\ 0 \\ 0 \\ 0 \end{pmatrix} \quad , where\ \gamma = \frac{1}{\sqrt{1-\frac{u^2}{c^2}}} \rightarrow 1,\ |\vec{u}| << c$$

$$therefore\ \mu, \nu = 0,\ d\tau = \frac{dt}{\gamma} \Rightarrow d\tau = dt$$

# 4 velocity

$$\frac{d^2x^\alpha}{dt^2} + \Gamma^\alpha_{00}c^2 = 0$$

$$\Gamma^\alpha_{00} = -\frac{1}{2}g^{\alpha\sigma}h_{00,\sigma} = -\frac{1}{2}\eta^{\alpha\sigma}h_{00,\sigma}$$

- There's no gravity in x or y, only z, so...

$$\alpha = 3,\ \eta^{\alpha\sigma} = \delta_{\alpha\sigma},\ \alpha = \sigma,\ \eta^{33} = 1$$

$$\frac{d^2z}{dt^2} - \frac{1}{2}h_{00,3}c^2 = 0$$

$$\frac{d^2z}{dt^2} = \frac{1}{2}\frac{\partial h_{00}}{\partial z}c^2, \qquad \frac{d^2z}{dt^2} = -g$$

$$h_{00} = -\frac{2gz}{c^2},\ h_{11} = h_{22} = h_{33} = 0$$

Recall...

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

$$g_{00} = -\left(1 + \frac{2gz}{c^2}\right),\ g_{11} = g_{22} = g_{33} = 1$$

# Shwartzchild solution for metric in the room

# Schwarzchild Metric

- Derived in the trenches of WWI… LITERALLY!

$$ds^2 = g_{00}c^2dt^2 + g_{11}dx^2 + g_{22}dy^2 + g_{33}dz^2$$

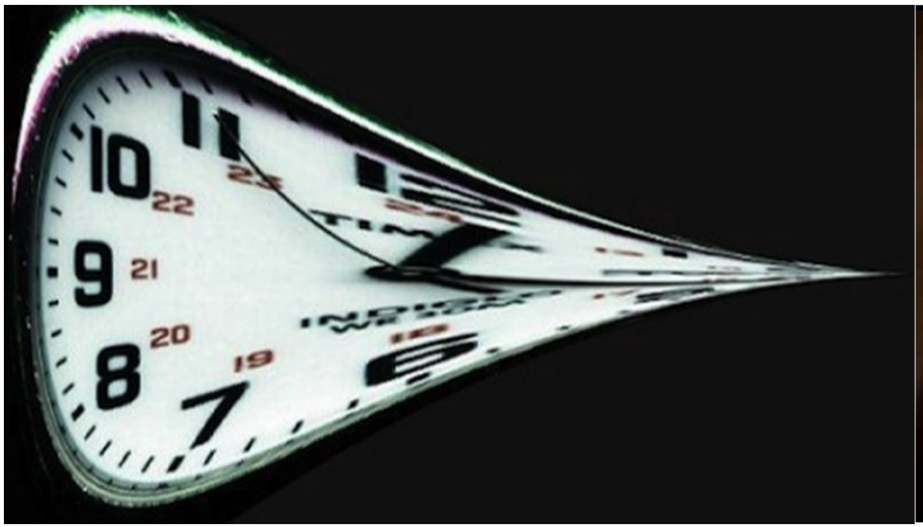
- The Metric in the room...

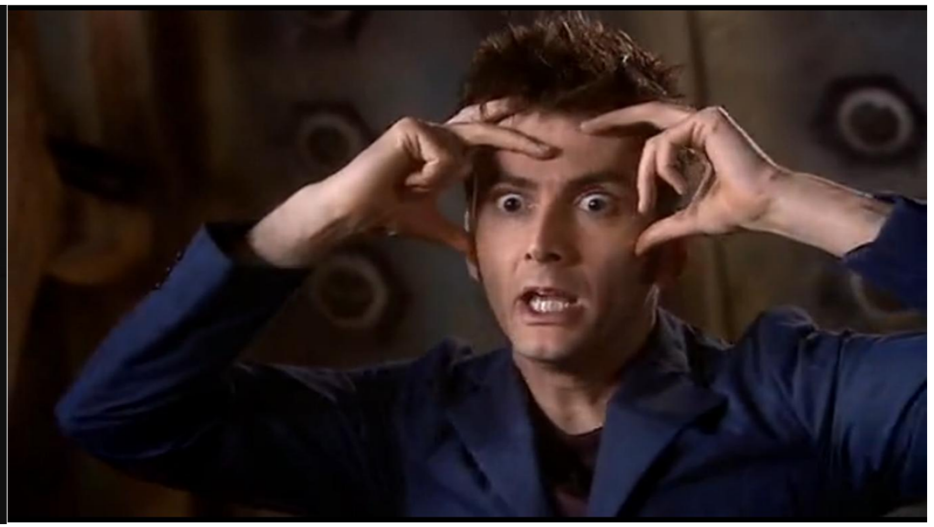
$$ds^2 = -\left(1 + \frac{2gz}{c^2}\right)c^2dt^2 + dx^2 + dy^2 + dz^2$$

$$ds^2 = -\left(1 + \frac{2gz}{c^2}\right) c^2 dt^2 + dx^2 + dy^2 + dz^2$$

Space Is FLAT!!

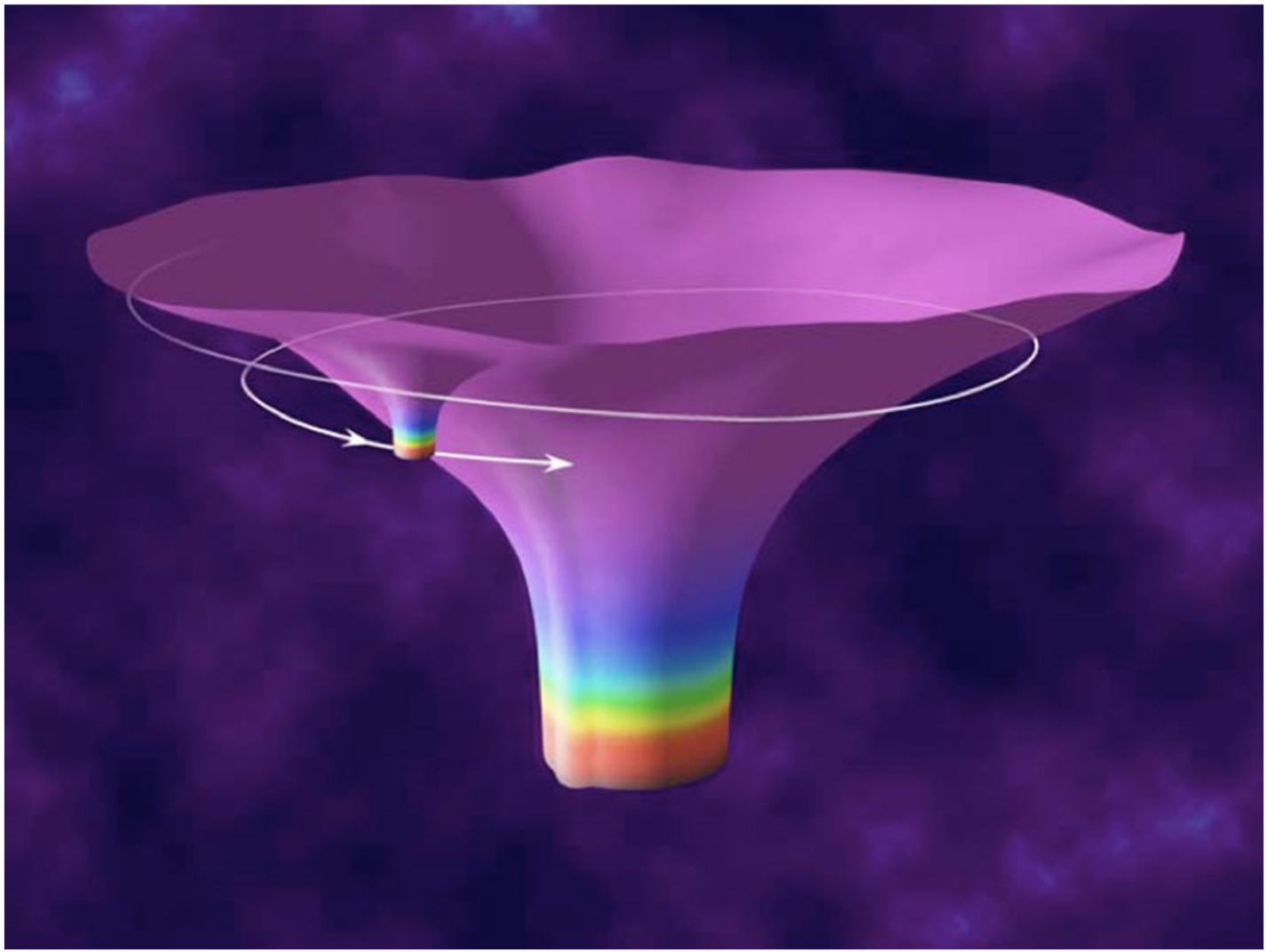
- The warping of time is what causes the gravity we experience!
NOT CURVED SPACE!!!





# Its the warping of time!!!

Kip Thorne’s Modified Rubber Sheet Model. Color represents warping of time.



# diagrams

# Let's Punch and Crunch!

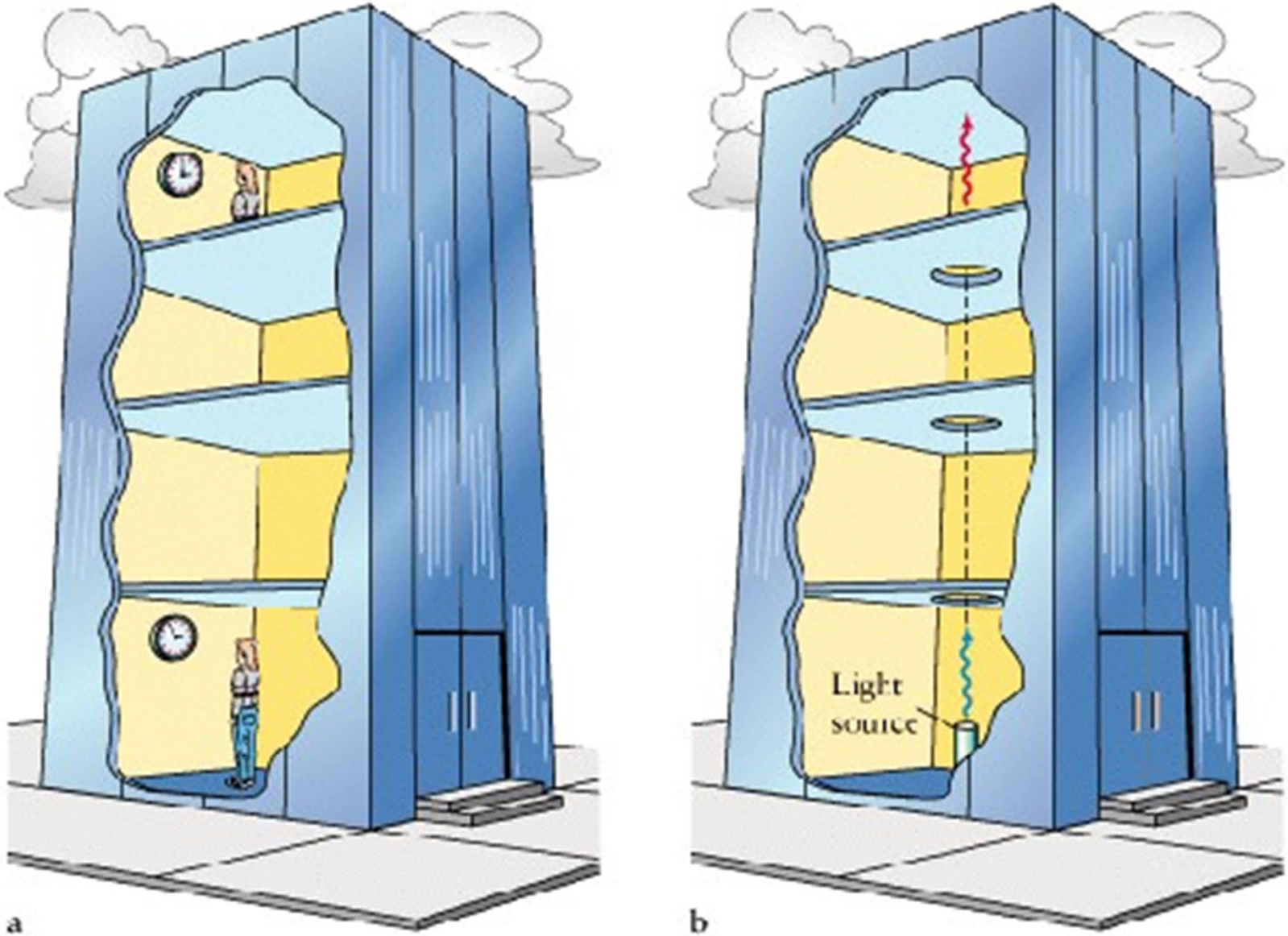
$$h = 10m,\ g \approx 10m/s^2,\ c = 3 \times 10^8 m/s,\ t_{floor} = 1s$$

$$\begin{aligned} d\tau &= \sqrt{1 + \frac{2gh}{c^2}}\, dt \\ (t_{cieling}) &= \sqrt{1 + \frac{2gh}{c^2}}\, (t_{floor}) \\ &= \sqrt{1 + \frac{200}{10^{17}}} \\ &= (1 + 10^{-15})s \end{aligned}$$

+ 1 femtosecond

# Experimental Evidence

- Pound – Rebka, 1960
  - Havard University's Jefferson Tower
  - h = 22.5 m
  - Using Mossbauer Effect
  - Measured $gh/c^2 \sim 2.5 \times 10^{-15}$


Light
source
a
b

# Reference expiremental proof

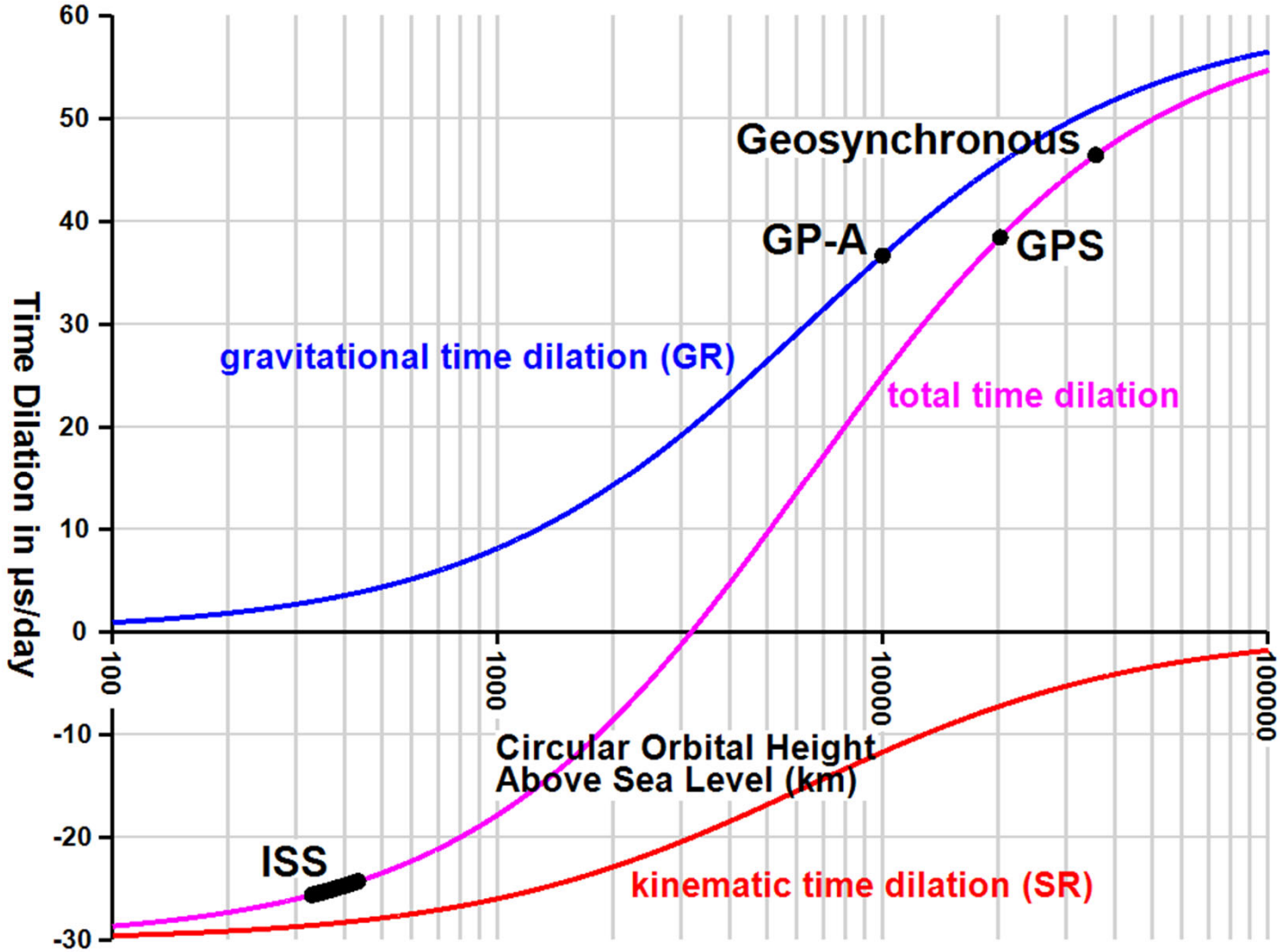
# Global Positioning System

- GPS is designed to compensate for Relativity
  - - 8 ns per day for SR
  - + 46 ns per day for GR
  - Total + 38 ns per day
  - If not, your Nav would accumulate more than 14 km discrepancy every day…
  - In 1 week, the GPS would be off by ~61 miles!

# How far is that!?

- Salem, Ma
- Worcester, Ma
- New London, Ct
- Montauk, Long Island, Ny
- In the Atlantic Ocean, off the coast of Cape Cod!

# Orbital Compensation GR/SR



# GPS comp

# Conclusion!

- At human Velocities, Space is FLAT!
  - Earth is still not flat…
- Spacetime is separable, Mathematically
  - Using the Schwarzchild Metric
- A second at 10 m up is 1 fentosecond faster than on the ground
- The cause of Gravity we feel as humans is the warping of time!
- Einstein was wicked smaht!

# conclusion

- Take away!

# Citations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