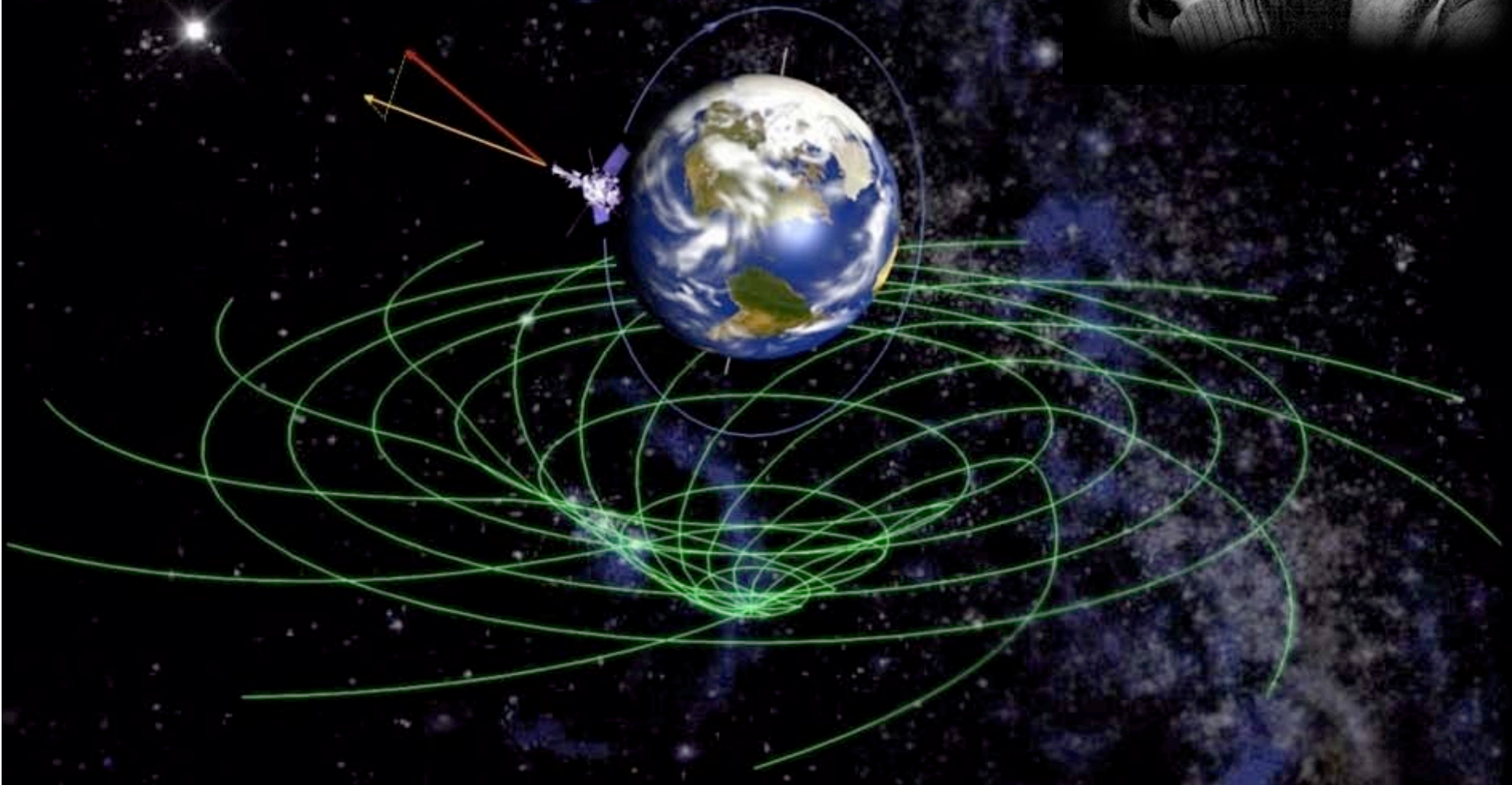
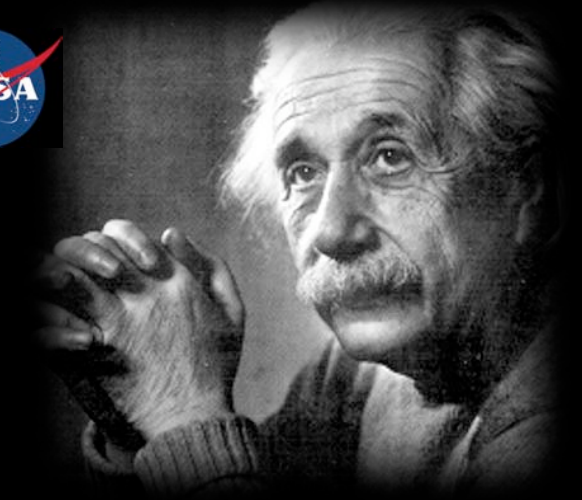


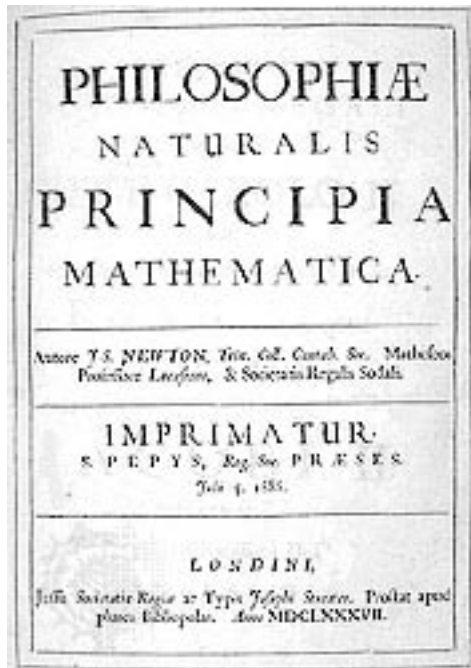
Gravity Probe B



Testing Einstein's Universe



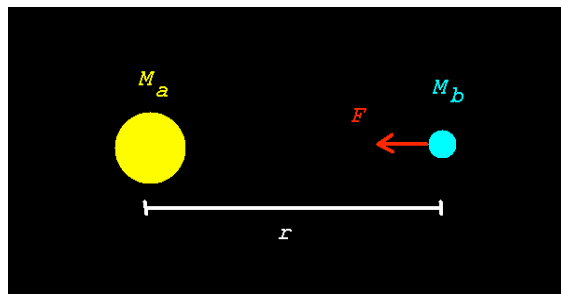
STORY 1:
What is Einstein's
“curved spacetime”?



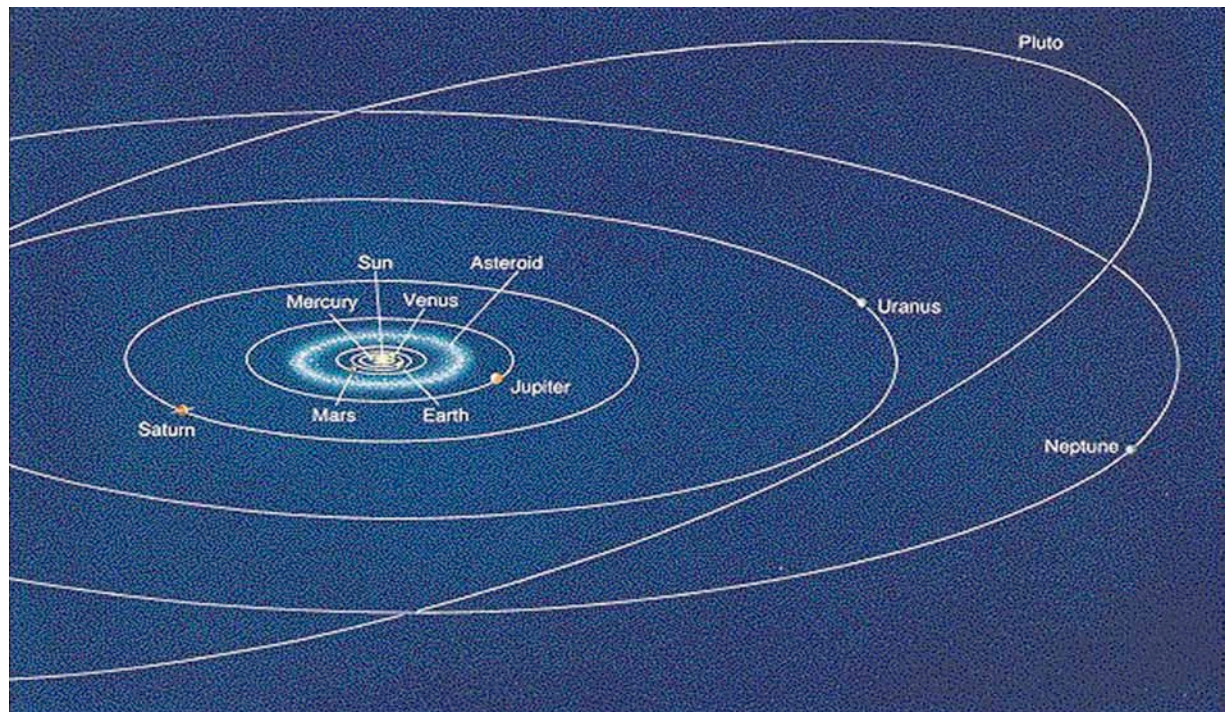
Newton's Inference

In the Principia (1687), Newton states:

“there is a power of gravity pertaining to all bodies, proportional to the ... quantities of matter which they contain.”



$$F = G \frac{M_a M_b}{r^2}$$

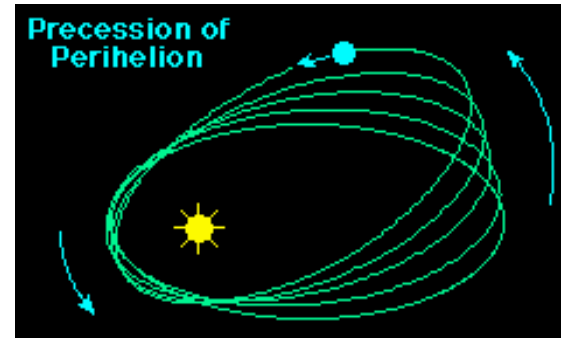


Why Wonder @ Gravity?

1) Mercury's "extra" precession

Newton - 531 arcsecs

Actual - 574 arcsecs



2) No such thing as coincidence

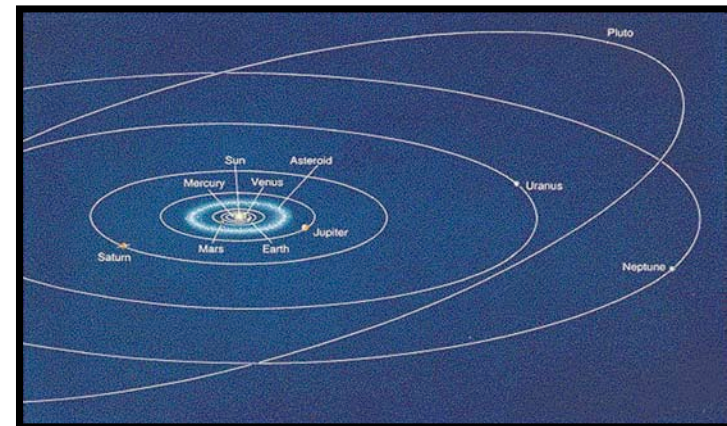
Balance b/w inertia~acceleration

3) How fast is gravity?

“instant propagation” (Newton)

or

“delayed information” (Einstein)



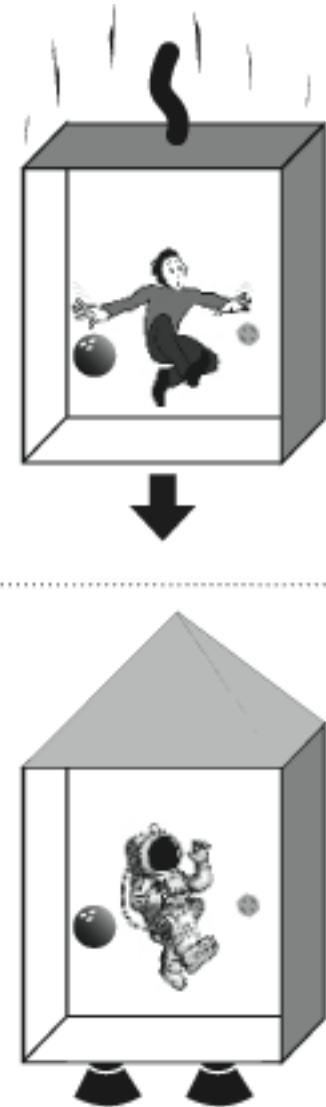
An Alternative Explanation

Say the magic word “*gedanken*” and we can make gravity disappear...

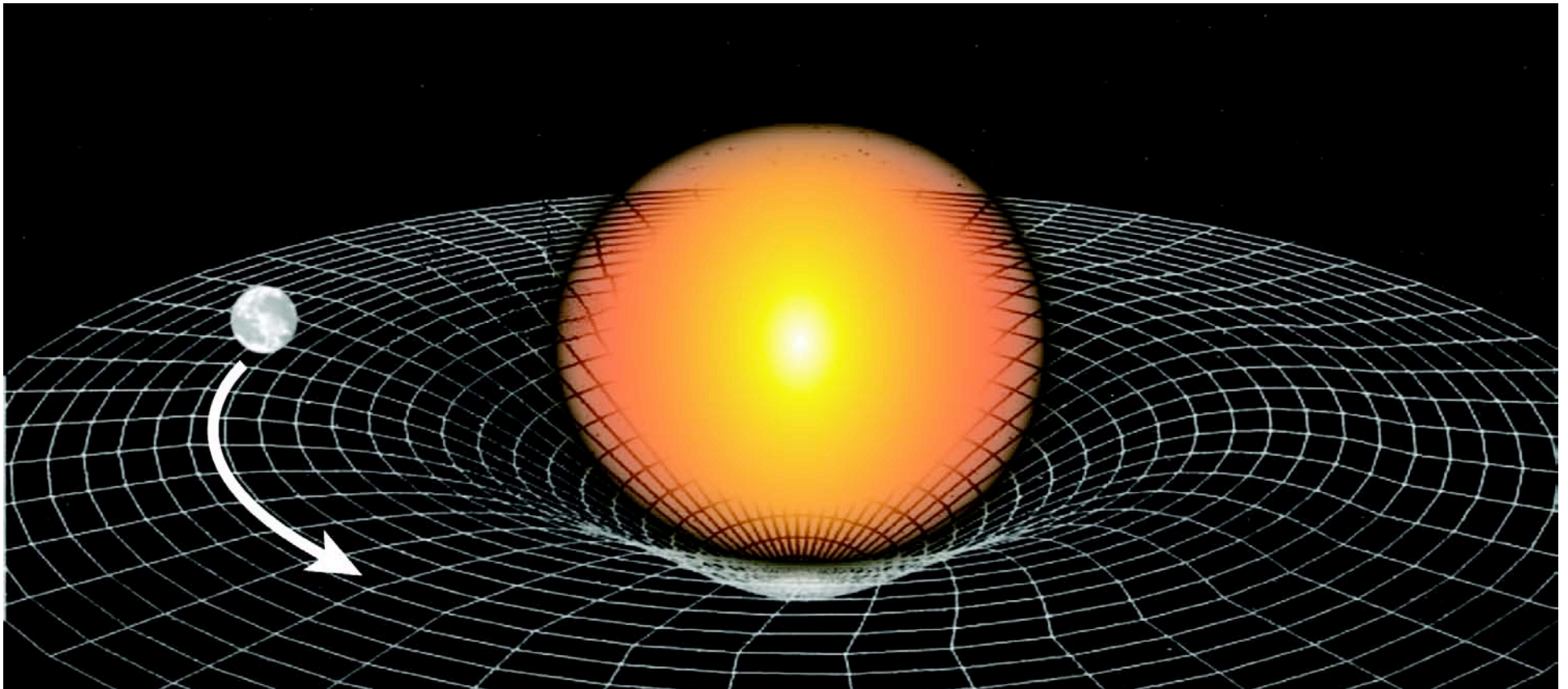
Step back and recognize that “gravity” is not a force, but an experience. It is a collection of observed actions and behaviors and a set of personal experiences. The role of science is to provide a theory to coherently explain what is behind all these observations and experiences.

Newton provided one explanation -- a propagating force inherent in mass.

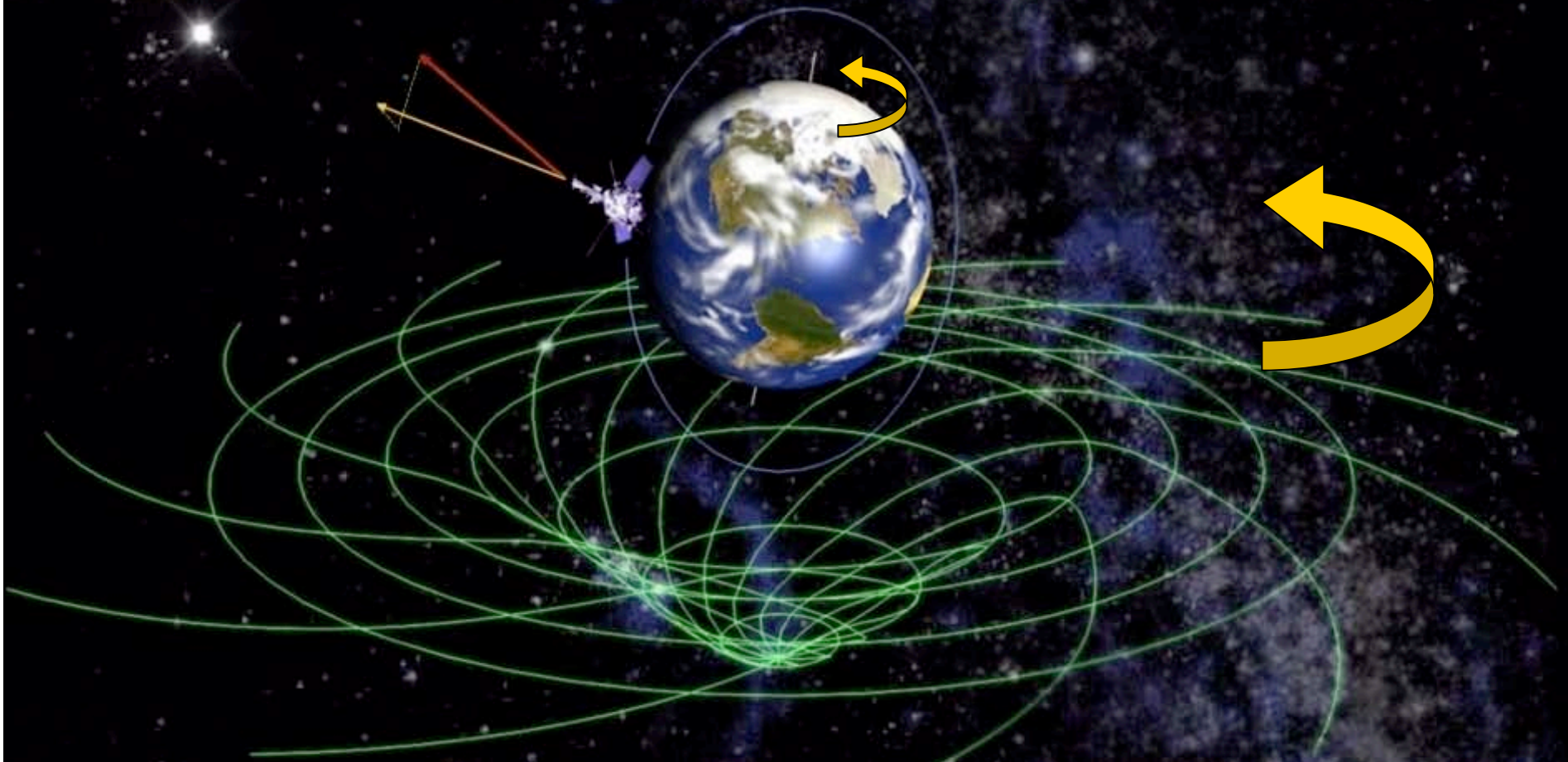
Einstein provided an alternative explanation -- mass follows the curvature of spacetime.



Matter follows the structure of spacetime.
Where spacetime is curved by a mass, other
masses will follow that curve.



What is frame-dragging?



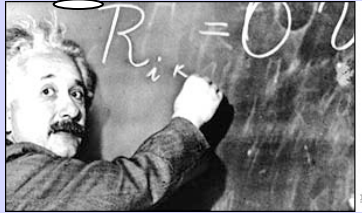
A rotating mass “drags” spacetime around it

STORY 2:

What is Gravity Probe B?

How does it work?

Einstein's General Relativity 1916



Yes, spacetime must be curved to produce orbital paths and equivalent accelerations...

Leonard Schiff 1960

Forty years later, Leonard Schiff and colleagues propose the “relativity gyroscope experiment” to test Einstein’s theory



GP-B has four requirements:

1. Build a perfect straight line that can orbit the Earth stably.
2. Align it with a distant star.
3. Protect it from all forces, except for “gravity” (or curved spacetime).
4. Watch it very carefully for one year.

**1) Build a perfect straight line
that can orbit the Earth stably.**

We have four requirements:

1. Build a perfect straight line that can orbit the Earth stably.
2. Align it with a distant star.
3. Protect it from all forces, except for "gravity" (or curved spacetime).
4. Watch it very carefully for one year.

A GYROSCOPE

a gyroscope's spin axis maintains its orientation as long as it is spinning



What makes a perfect gyroscope?

**sphericity
+
homogeneity = balance**

World's Best Gyroscope

*“roundest object ever made”
Guinness Book of World Records*



Material Fused quartz spheres, coated with niobium metal

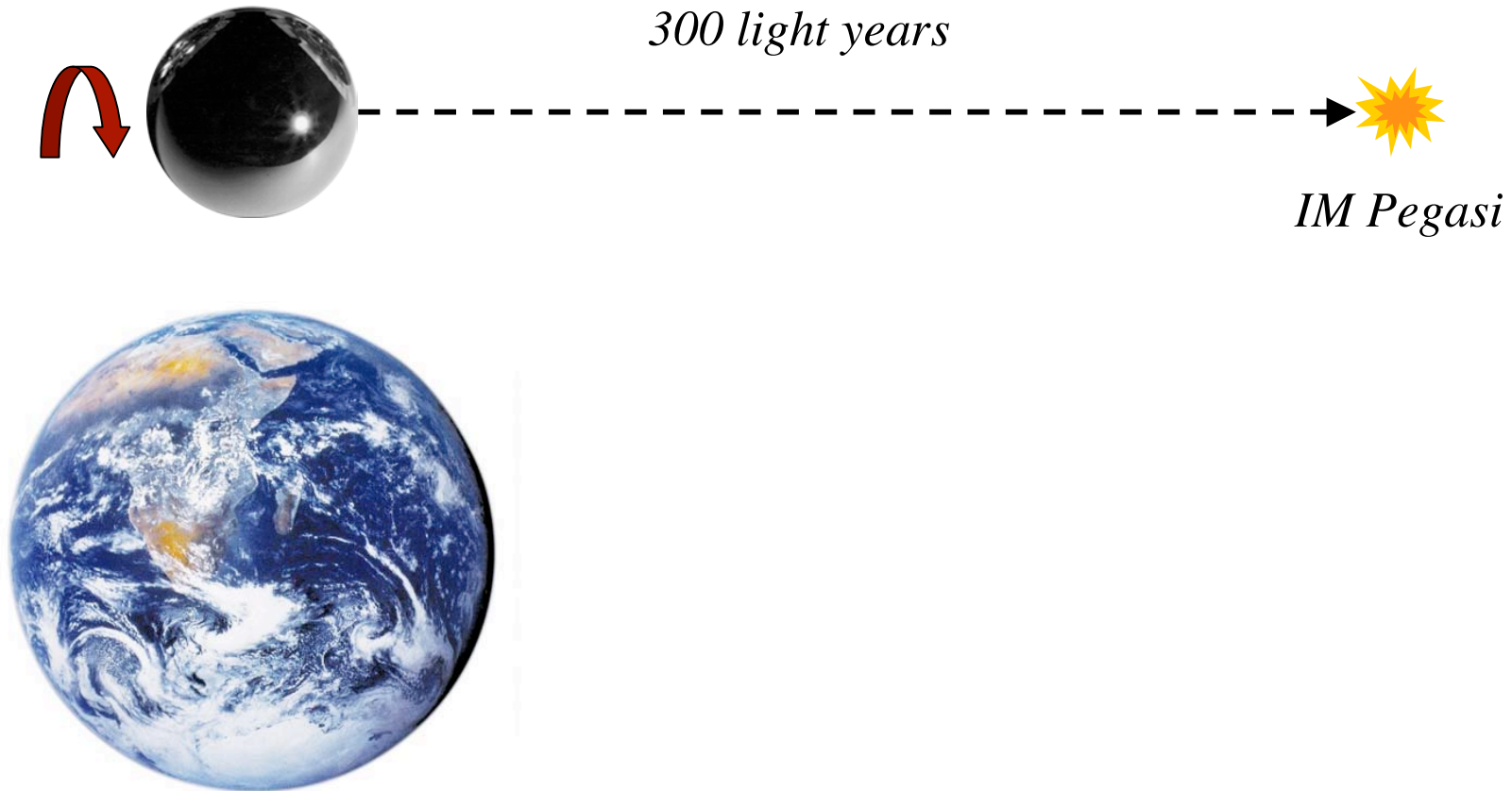
Sphericity < 0.3 millionths of an inch (40 atomic layers)

Homogeneity < 2 parts per million

2) Align it with a distant star.

We have four requirements:

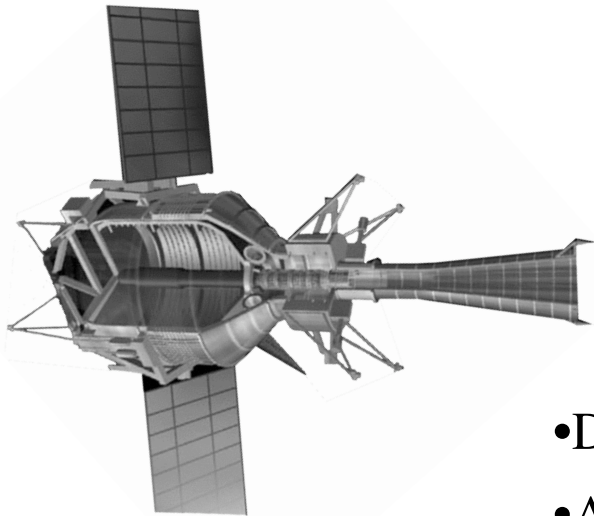
1. Build a perfect straight line that can orbit the Earth stably.
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3. Protect it from all forces, except for “gravity” (or curved spacetime).
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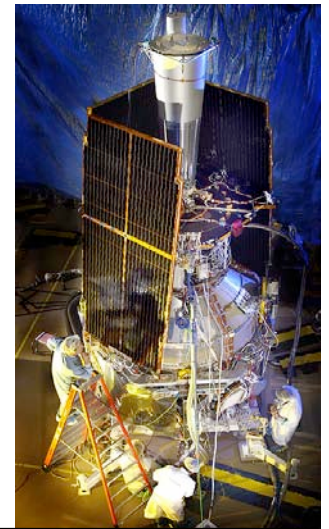
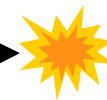
3) Protect from all forces... except “gravity”

We have four requirements:

1. Build a perfect straight line that can orbit the Earth stably.
2. Align it with a distant star.
3. Protect it from all forces, except for “gravity” (or curved spacetime).
4. Watch it very carefully for one year.



- Dust
- Atmospheric “wavetops”
- Heat
- Magnetic field

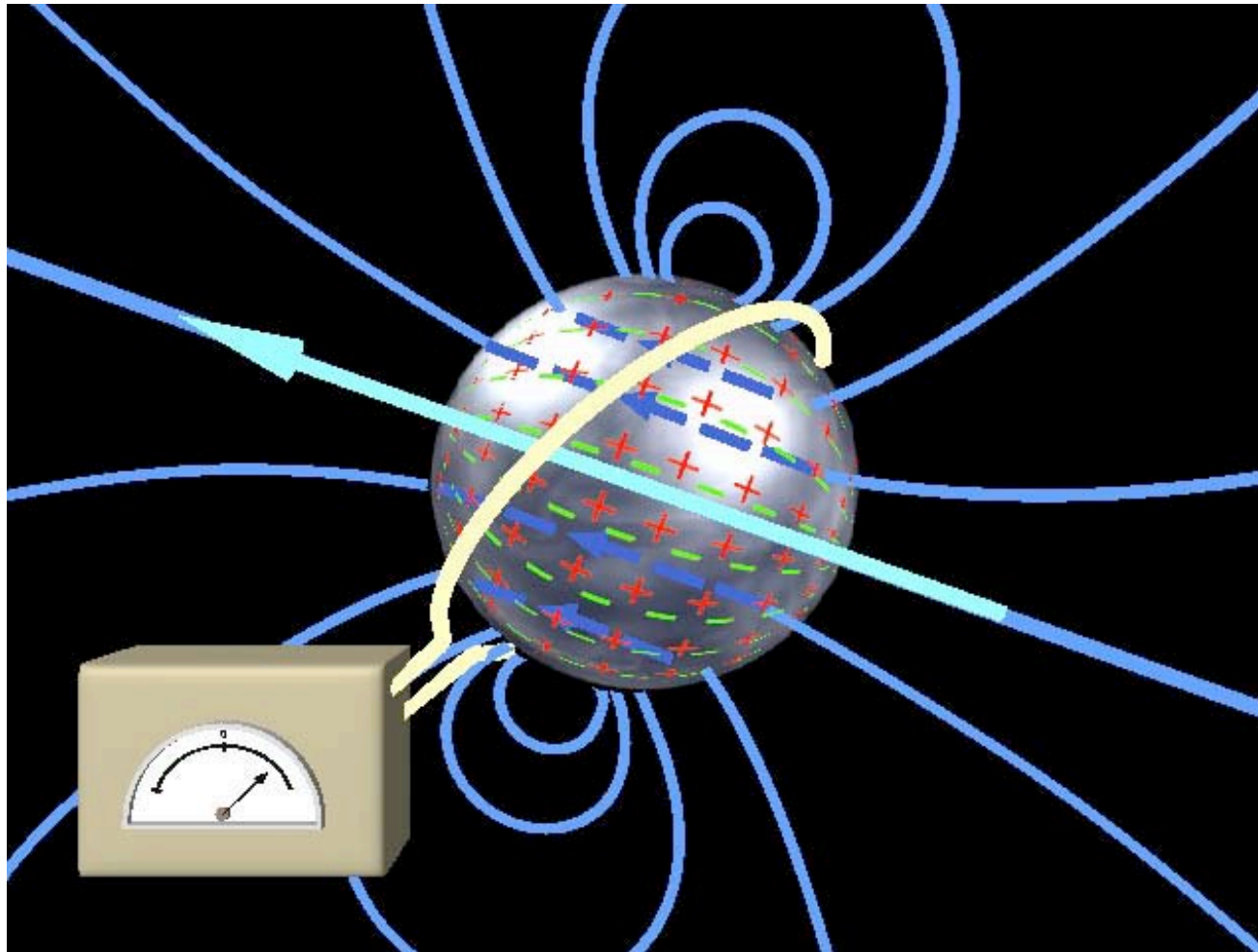


- Weakest thrusters ever!
- Supercooled helium (2K)
- Lead bags

4) Watch very carefully for one year

We have four requirements:

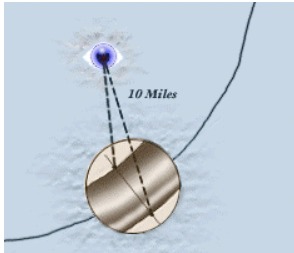
1. Build a perfect straight line that can orbit the Earth stably.
2. Align it with a distant star.
3. Protect it from all forces, except for “gravity” (or curved spacetime).
4. Watch it very carefully for one year.



Superconducting metal generates magnetic field when spinning

Must sense any tilt in spin axis > 0.5 milliarcseconds
(~ 2 ten-millionths of a single degree)

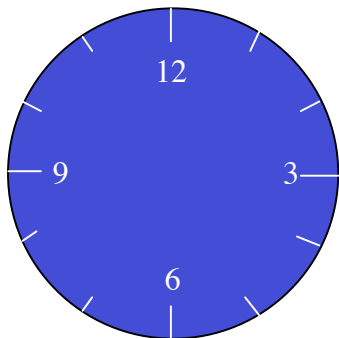
EQUIVALENT TO...



...measuring the width of a human hair (~ 100 microns) from 25 miles!



...measuring Lincoln's head on a US penny from 3,000 miles
(*San Francisco to New York*)!



...spotting an angle 50 million times smaller than a single minute
on a clock face!

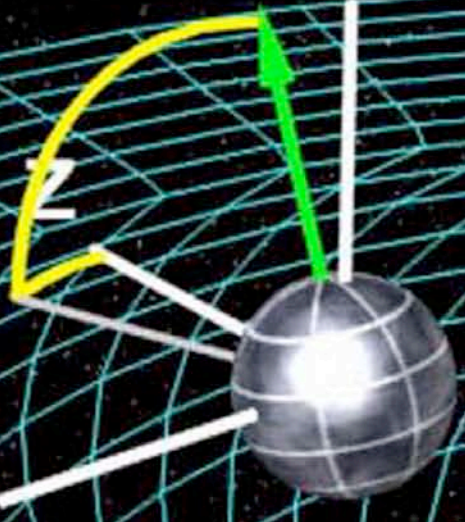
IM Pegasi



Geodetic effect
6.6 arcsec/yr

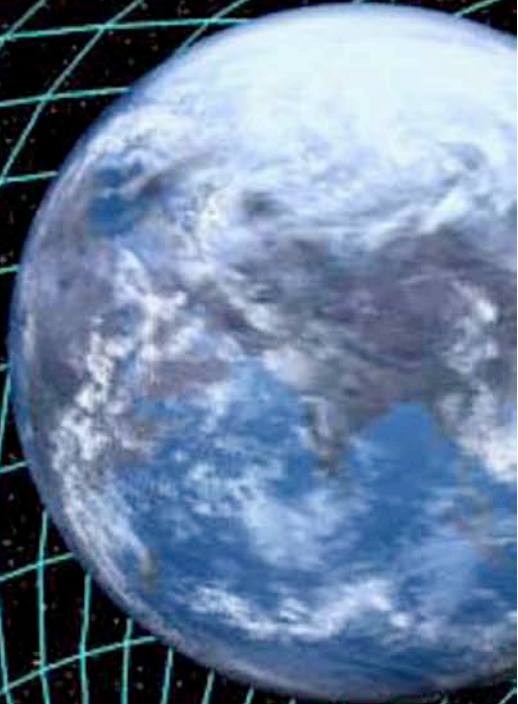
X

Frame dragging
0.041 arcsec/yr

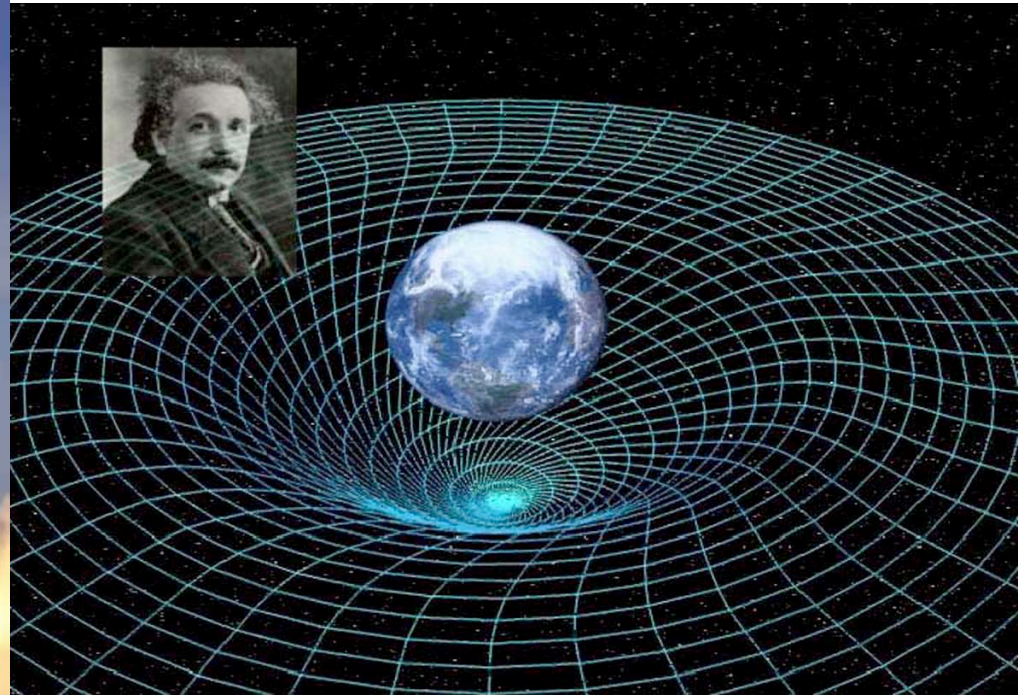


Y

Z



Was Einstein
right?



Find out in 2006...