

This is the last class of PHY132S

**“Pick up the tempo just a little
and take it on home
The singer ain’t singing and the
drummer’s been draggin’ too long
Time’ll take care of itself, so just
leave time alone
So pick up the tempo just a little
and take it on home”
-- Willie Nelson**

1

Announcement

- I am preparing a summary of the theories of relativity
- A link will appear in the Relativity page of the portal when it is ready

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Last Time

- The General Theory of Relativity (1916)
 - Three pieces used by Einstein in building the theory
 1. Geometry is Physics (Riemann)
 2. Inertia *here* is due to mass *there* (Mach)
 3. Acceleration is equivalent to gravitation (Einstein)
 - But only locally
 - Einstein’s Synthesis

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Today

- Predictions of the General Theory
 - Gravitational Time Dilation
 - Stellar Aberration
 - Advance of the Perihelion of Mercury
 - Gravity Waves
 - Black Holes
 - Expanding Universe
- Problems with the theory

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Einstein: "For an observer in free fall off the roof of his house, there exists for him during his fall no gravity."

Assume there is no air resistance. Is such an observer in an *inertial reference frame*?

A. Yes

B. No



But only locally

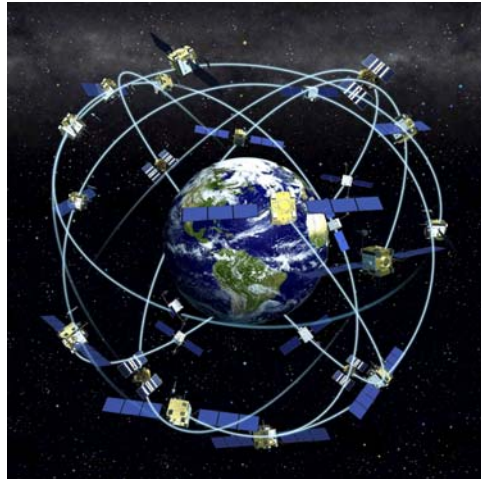
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Predictions of General Relativity and Experimental Tests of the Predictions

1. Clocks in gravitational fields run slowly
 - Confirmed

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GPS



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Stellar Aberration

Apparent Position



Distant Star



Sun

Earth



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Predictions of General Relativity and Experimental Tests of the Predictions

1. Clocks in gravitational fields run slowly
 - Confirmed
2. Stellar Aberration
 - Confirmed

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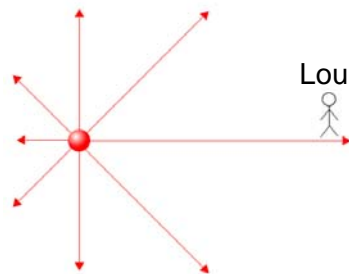
Predictions of General Relativity and Experimental Tests of the Predictions

1. Clocks in gravitational fields run slowly
 - Confirmed
2. Stellar Aberration
 - Confirmed
3. Advance of Perihelion of Mercury
 - Confirmed within large errors

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We suddenly move the electric charge

Does the electric field
for Lou immediately
change?



A. Yes

B. No

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Laser Interferometer Gravitational Wave Observatory (LIGO)



Hanford Washington



Livingston Louisiana

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Predictions of General Relativity and Experimental Tests of the Predictions

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4. Gravity Waves
 - Experiments are under way

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When a Star Runs Out of Fuel

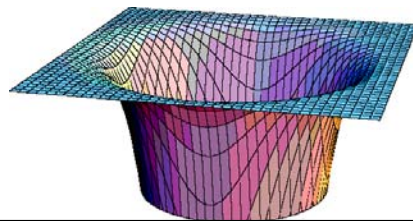
- $M < 1.2 M_{\text{Sun}}$
 - Spinning ball of dead slag: “white dwarf”
 - Density $\sim 1 \text{ tonne / cm}^3$ Radius $\sim 5000 \text{ km}$
- $1.2 M_{\text{Sun}} < M < 3 M_{\text{Sun}}$
 - Protons and electrons fused into neutrons: “neutron star”
 - Density $\sim 10^6 \text{ tonnes / cm}^3$ Radius $\sim 10 \text{ km}$
- $M > 3 M_{\text{Sun}}$
 - Neutrons crushed out of existence. A hole is punched in the fabric of spacetime
 - “Black hole”
 - Density infinite Radius zero

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Black Hole

Embedding Diagram

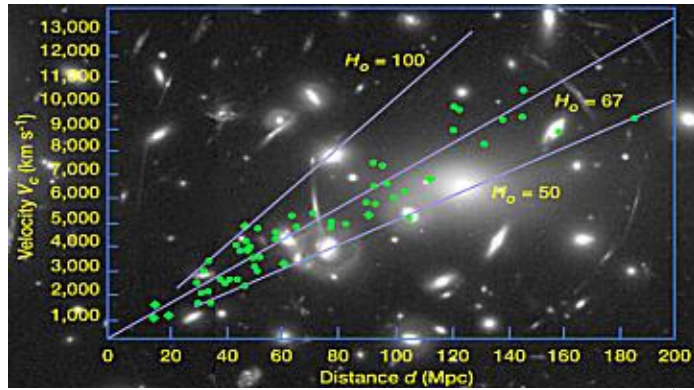


Predictions of General Relativity and Experimental Tests of the Predictions

1. Clocks in gravitational fields run slowly
 - Confirmed
2. Stellar Aberration
 - Confirmed
3. Advance of Perihelion of Mercury
 - Confirmed within large errors
4. Gravity Waves
 - Experiments are under way
5. Black Holes
 - Excellent candidates known

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Modern Hubble Data

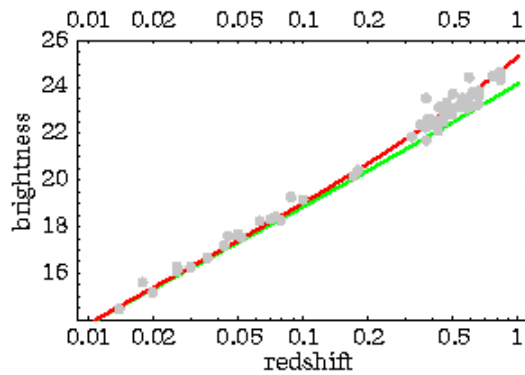


Predictions of General Relativity and Experimental Tests of the Predictions

1. Clocks in gravitational fields run slowly: confirmed
2. Stellar Aberration: confirmed
3. Advance of Perihelion of Mercury: confirmed within large errors
4. Gravity Waves: experiments under way
5. Black Holes: excellent candidates known
6. Expanding Universe
 - Confirmed

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Perlmutter et al. (1998)



Finally ...

Best of luck on your Exams

And have a fabulous Summer!

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