# Introductory Astronomy

Week 6: Relativity and Black Holes

Clip 11: GR in Astronomy

First Results

- Bound (negative energy) Newtonian orbits are closed. After a period motion repeats

- Perturbations modify this. Mercury orbit precesses 1.5°/century

- Planetary contributions explain all but 43"

- Einstein uses effective potential to find relativistic deviation 43"
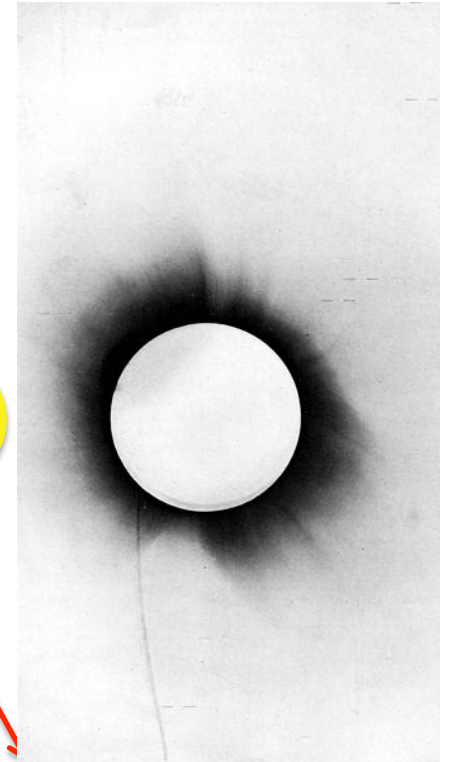
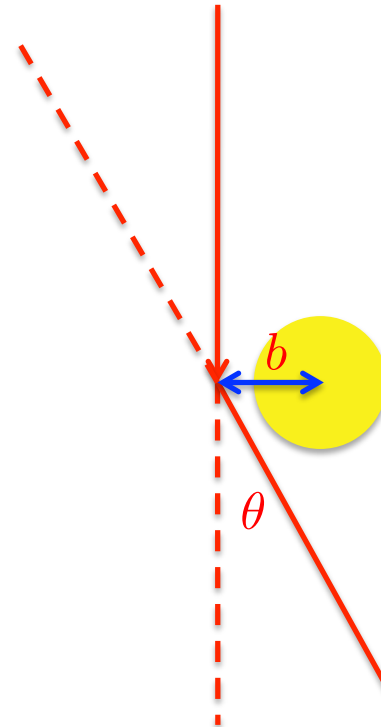- GR essential in close binaries!
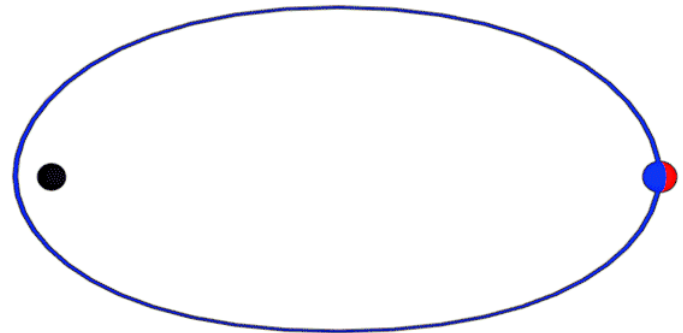
Gravity Probe B Precision

- Measured deviation from **Newtonian** predictions due to **curved geometry** and Earth **rotation**
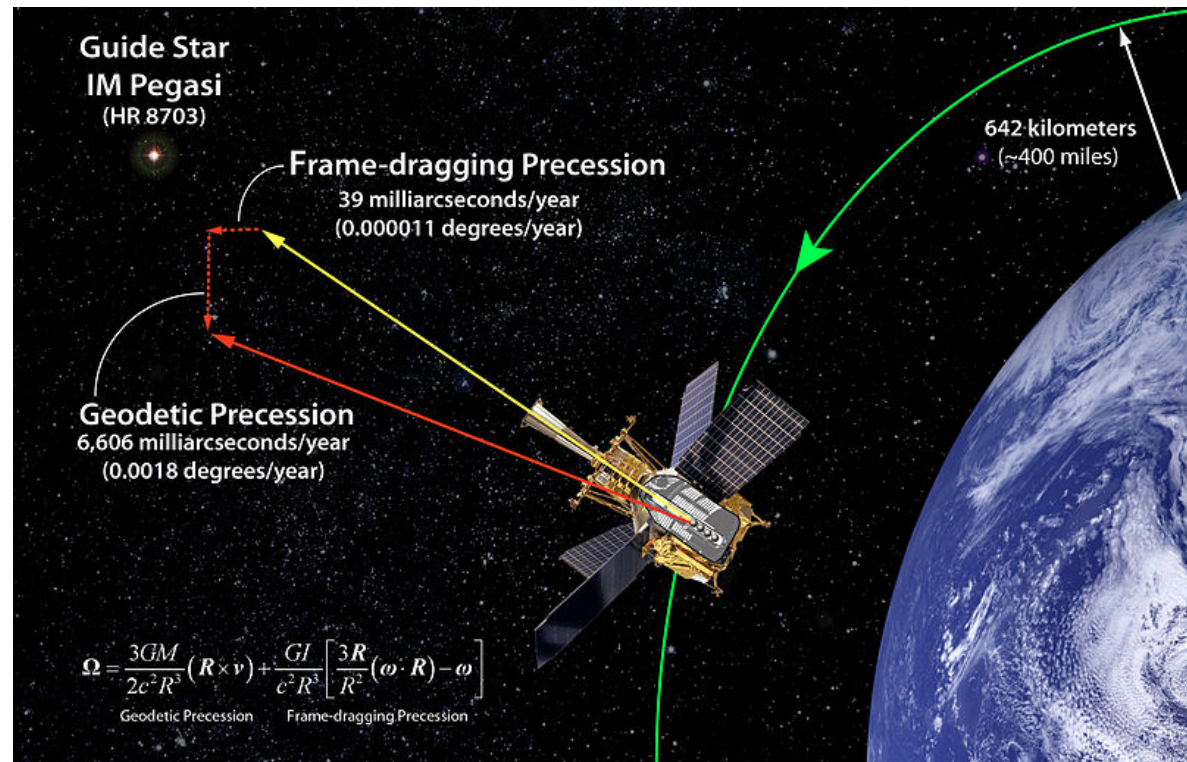
Light Deflection

- Does Gravity act on light?

- Equivalence principle or mass-energy equivalence: yes

- Full GR calculation: $\theta = \dfrac{4GM}{rc^2}$

- Eddington 1919 eclipse measures deflection by Sun

Gravitational Lensing

- Massive objects in line of sight act as lenses
- Use this to see dimmest objects
- Use lensing to learn about the lens:
  - Exoplanet detection
  - Dark Matter detection

Binary Pulsar PSR1913+16

- In Aquila at $6400\,\mathrm{pc}$

- Millisecond pulsar with period $59\,\mathrm{ms}$

- Periodic pulse delay with period $7.8\,\mathrm{h}$

- Binary of two neutron stars of mass $1.5 M_\odot$ and $a = 2.8 R_\odot$

- System is very eccentric (perturbed by SN?) with periastron $1.1 R_\odot$

- Perfect lab to study GR

- Pulse delay exhibits Doppler effect as well as gravitational redshift

- Precession of perihelion measured – agrees with GR

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Gravitational Waves

- As neutron stars orbit GR predicts they will lose energy to gravitational waves

- Rate of period decrease consistent with GR

- In $2.5 \times 10^8 \, \mathrm{yr}$ merge
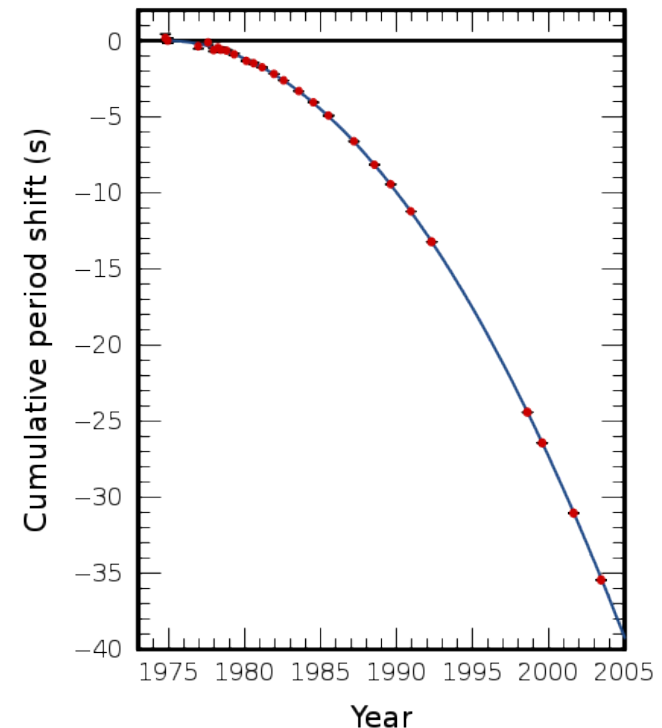
Can We See Them?

- Gravitational wave detectors like LIGO expect to find evidence of violent neutron star mergers by detecting change in length of 3km laser by fm

Credits

- Precessing ellipse: Wikimedia Commons/ Anynobody http://en.wikipedia.org/wiki/ File:Newtonianvseinsteinianorbits.gif

- Abel 370: NASA, ESA, and the Hubble SM4 ERO Team & ST-ECF http://apod.nasa.gov/apod/ap090921.html

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