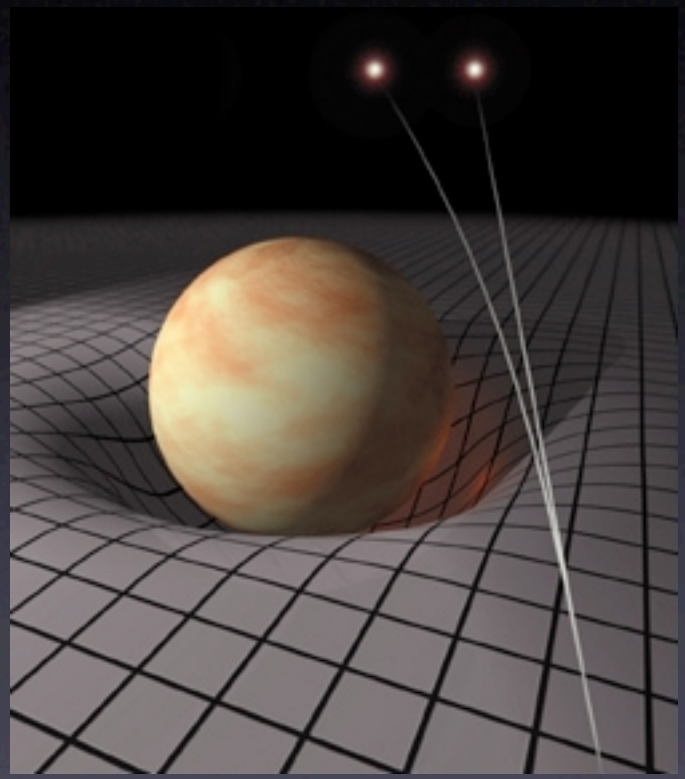
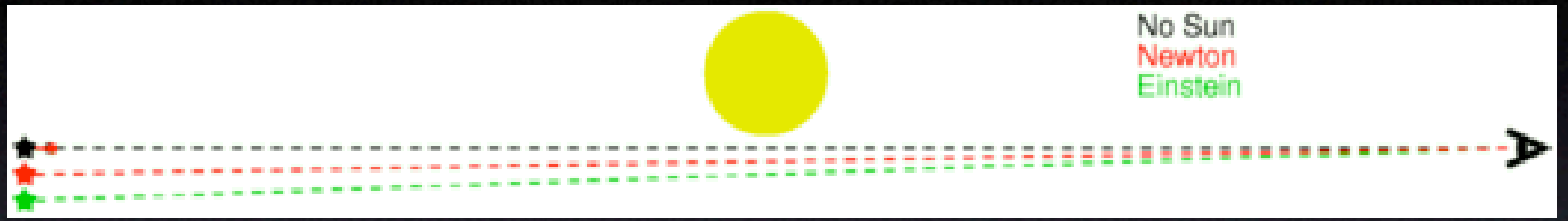
General Relativity



Lecture 2: Specific Predictions and Tests of GR

2.1 Light Bending

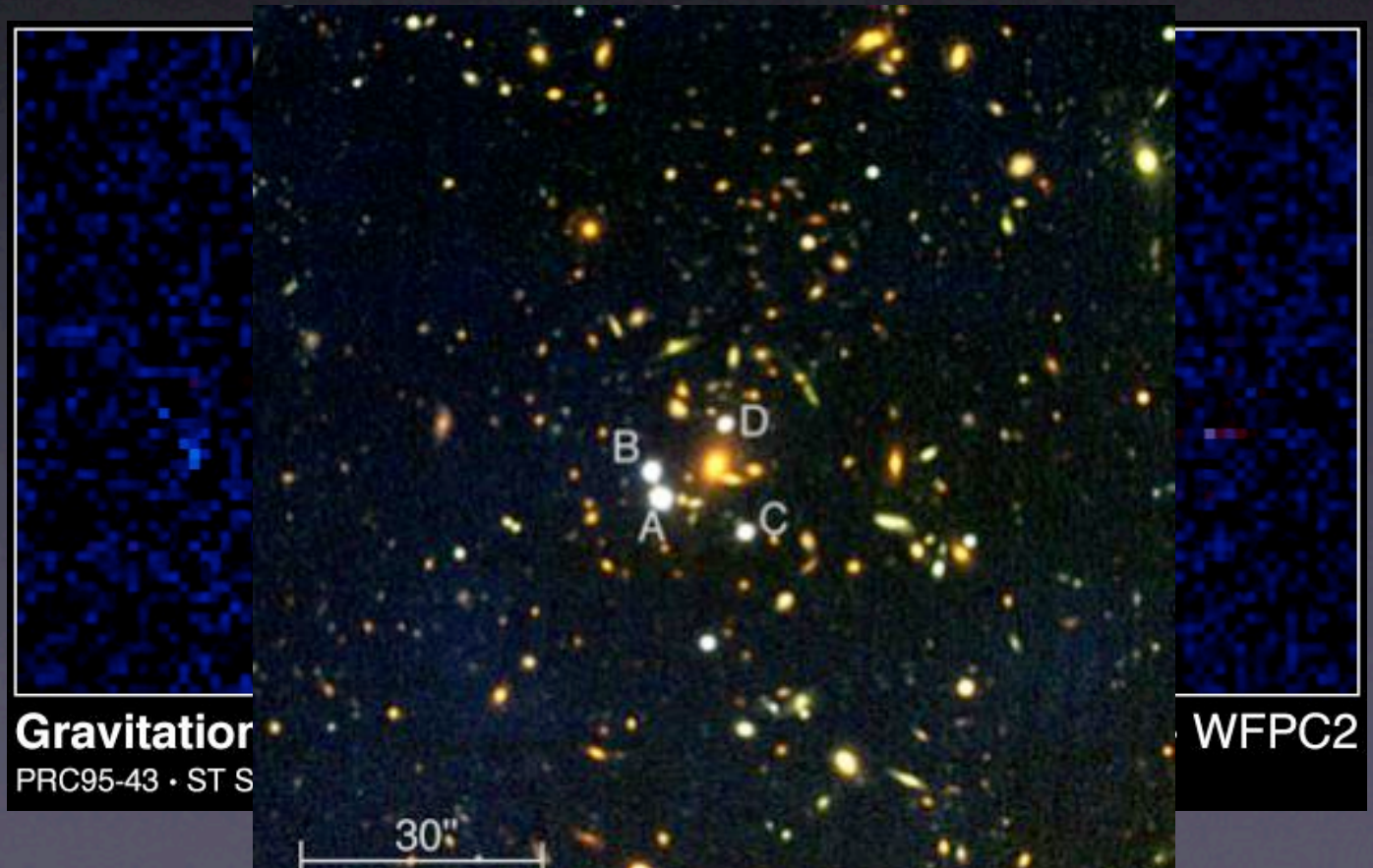


- first GR prediction; tested by Sir Arthur Eddington: starlight from Hyades cluster measured near Solar limb during 1919 eclipse

$$\delta \simeq \frac{4GM}{Dc^2} \simeq 1.75 \text{ arcseconds}$$

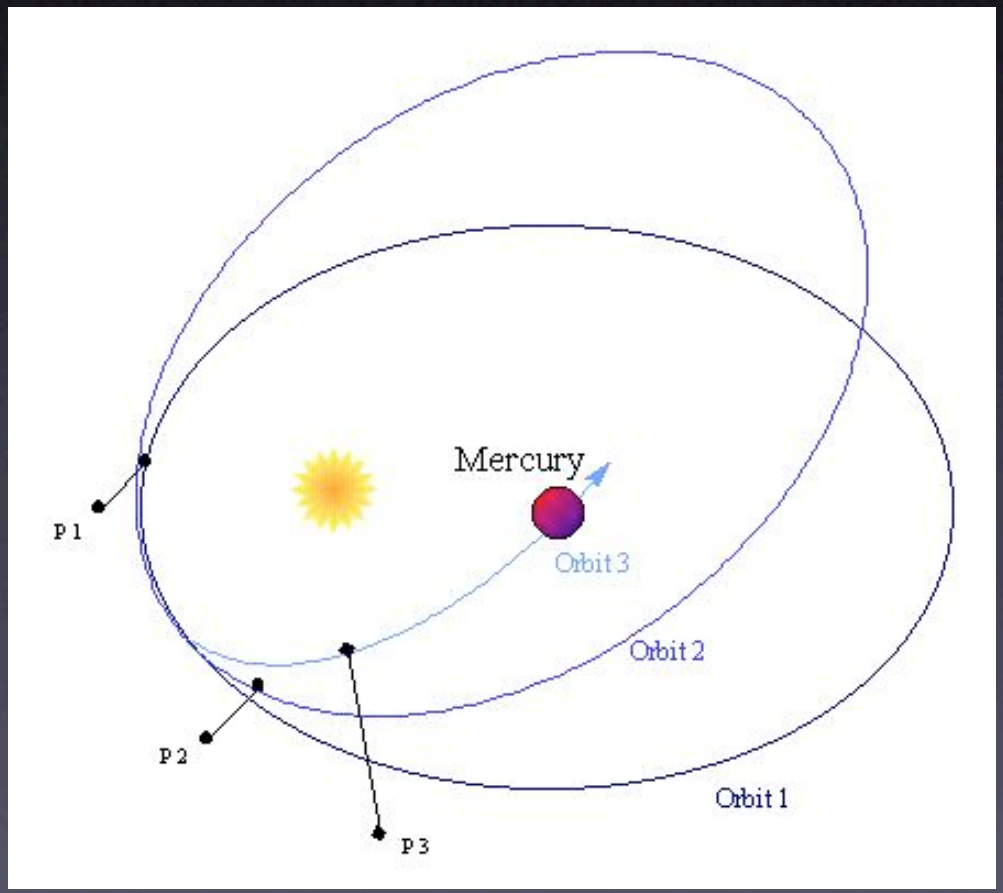
2.1 Light Bending
(aka gravitational lensing)

- naturally, light bending is more pronounced for larger concentrations of mass and more intense radiation fields:



2.2 Mercury's Perihelion Advance

- Mercury's closest approach (perihelion) advances with each orbit around the Sun



Observed perihelion advance:
574" per century

Predicted Newtonian advance
(due to other planets):
531" per century

43" discrepancy precisely accounted for by GR (i.e. spacetime distortion)

2.3 Gravitational Time Dilation

- as viewed by a distant observer, clocks tick slower in a strong gravitational field: (i.e. more time has lapsed between any 2 events)

  time interval = lapse factor x proper time interval

$$\boxed{T = \Gamma T_0} \qquad \text{where} \qquad \Gamma = \left(1 - \frac{2GM}{rc^2}\right)^{-1/2}$$

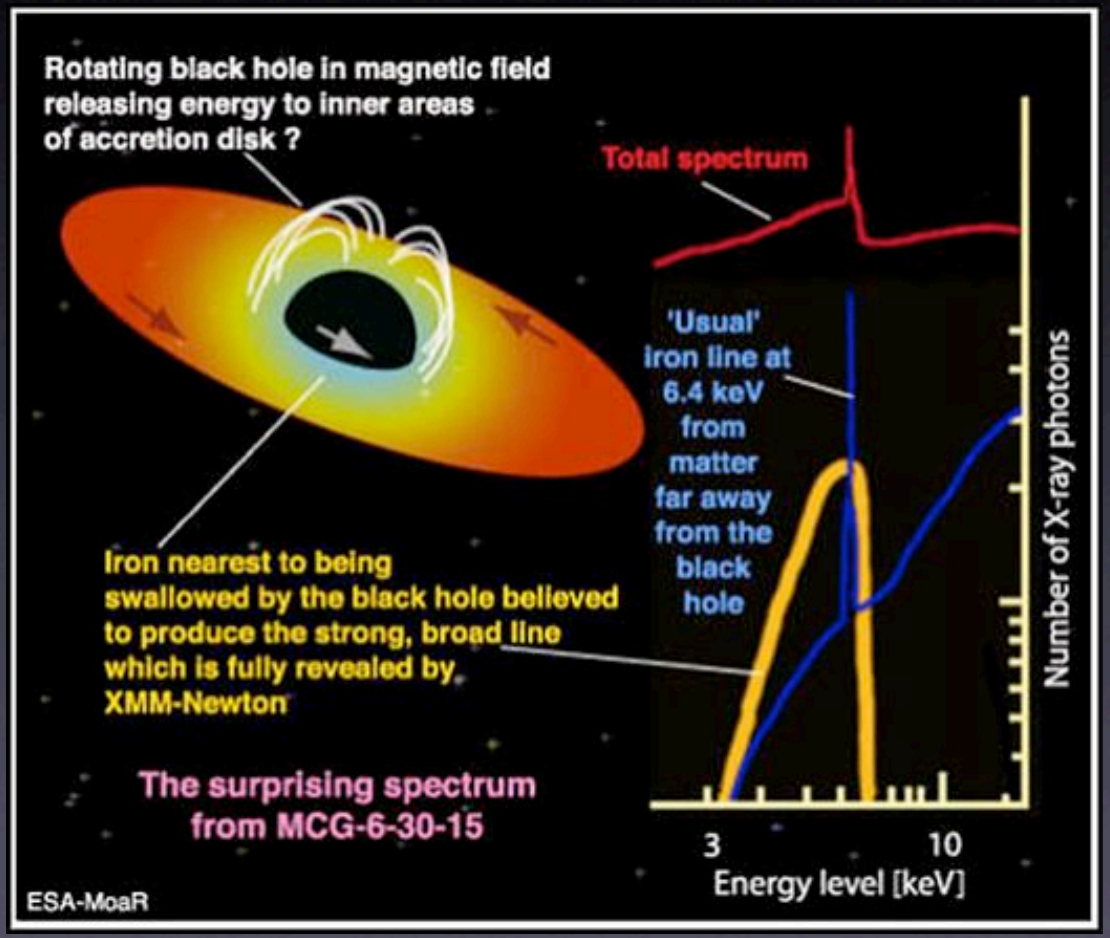
- proper time interval is different for 2 observers at different locations r
- prediction confirmed with spectacular precision by timing measurements from binary pulsars (e.g. PSR 1913+16

2.4 Gravitational Redshift

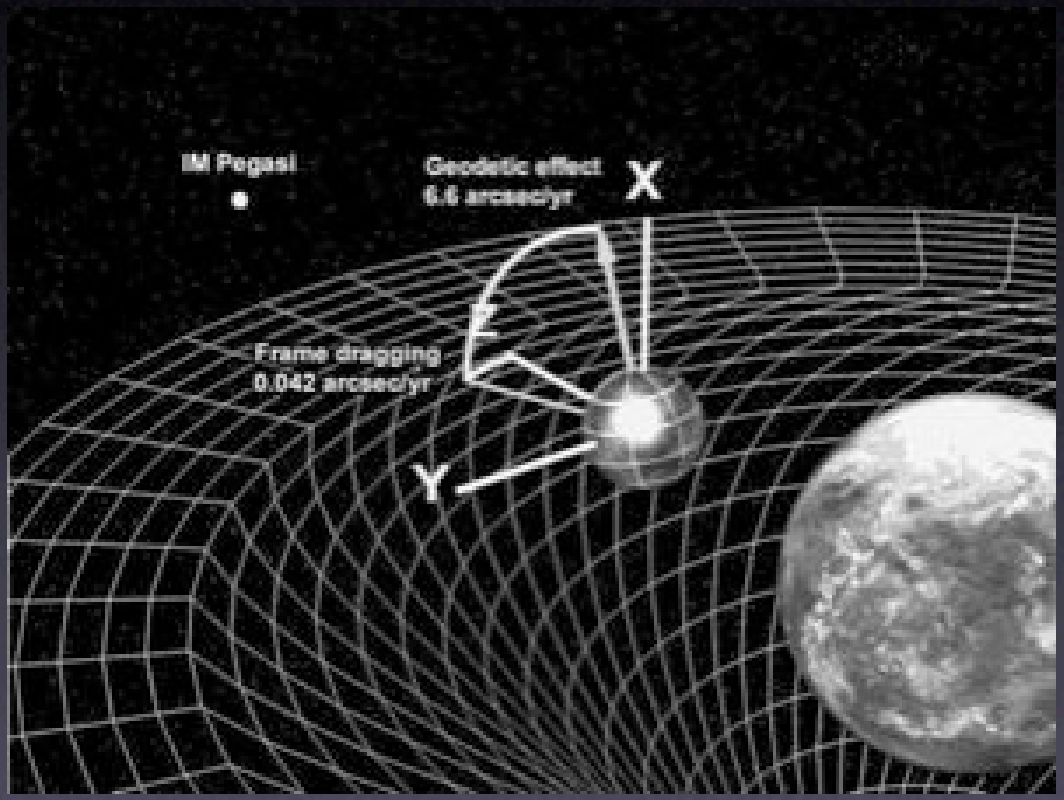
- time dilation implies the period corresponding to the wavelength of light also appears longer to a distant observer

- photons lose a factor of $1 + z_g$ in energy in climbing out of a strong gravitational potential from r to infinity, where

$$z_g = \Gamma - 1 \simeq \frac{GM}{rc^2}$$

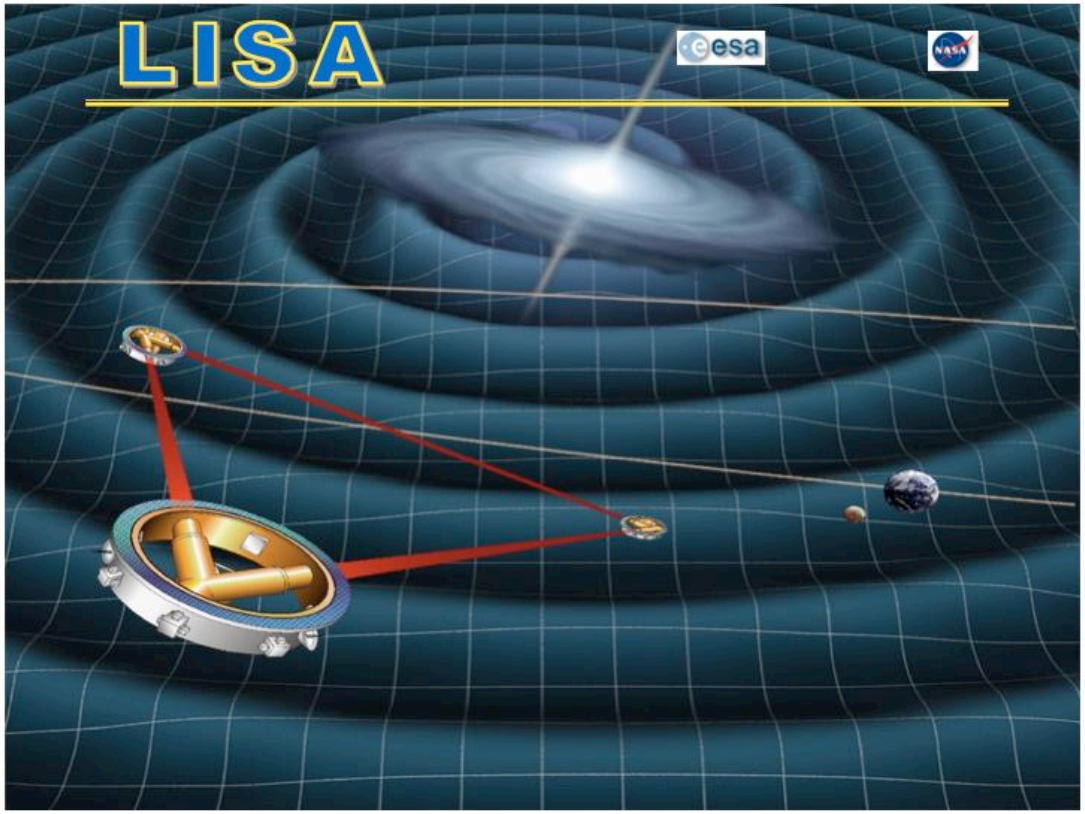


2.5 Frame Dragging
(Lense-Thirring Precession)



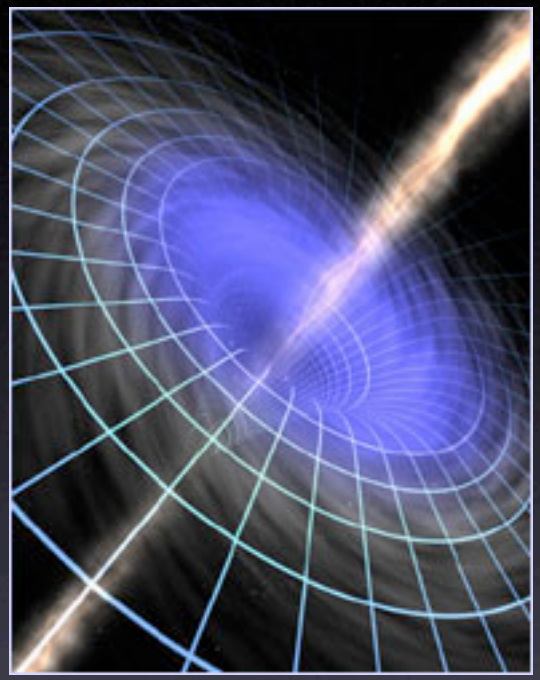
- a small rotating mass residing in the gravitaional field of a more massive object will experience a spin precession as it gets dragged around with distorted spacetime
- the Gravity Probe B experiment is currently in orbit taking measurements to test this prediction for Earth

2.6 Gravity Waves



- GR predicts spacetime ripples will propagate as wave-like disturbances
- gravity waves are believed to arise from events such as coalescing binaries (e.g. PSR 1913+16
- several international programs are now underway to measure gravity waves, but the predicted amplitudes are extremely small

2.7 Black Holes



- the existence of countless numbers of black holes is implicitly predicted by Schwarzschild's solution to the field equations for a point mass in vacuo
- today, there is overwhelming observational evidence that black holes exist both as the endpoints of stellar evolution and also at the centres of galaxies