## 4/06/05 *Test 3 this Friday.*

Review session Thursday, 5PM, RLM 15.216B. Office hours or make appointment.

Wheeler on travel Monday, film on time travel. Watch for Kip Thorne, Igor Novikov, Stephen Hawking, Quantum Gravity.

News: Shuttle launch may be delayed past May 15. Photo of extrasolar planet? Partial eclipse of Sun Friday 4:17 to 5:59. Maximum at 5:10, 26% in Austin. Solar telescope image on 13th floor RLM.





Pic of the day:

Star cluster in Scorpius

Black holes and Time (Section 5.2)

If a clock moves away from an observer it ticks more slowly.

If a clock is deep in a gravity well it ticks more slowly according to an observer at large distance where gravity is absent.

Both effects if you drop a "clock" into a black hole and watch it fall in from a safe distance where gravity is weak (flat 3D space).

What does it mean to fall? Rather deep and strange phenomenon! Drop things, fall at same rate...

## Falling to Einstein

According to Einstein - curved space around gravitating objects "flows" inward - *inward escalator*.

If object floats with *no force* in space (free fall), it will move toward the center of gravitation

⇒ falling - all objects respond to same curvature, have the same acceleration

Like water down a drain - sit still in water, but go down the drain.

Must exert force to resist, to avoid free fall, to avoid the flow of space inward toward the center of the gravitating object.



Volunteer finds herself rapidly falling through event horizon, noodleized, dies

Distant observer sees Doppler and gravitational redshifts Received photons get longer, longer wavelength Time between photons gets longer and longer Infinite time for last photon emitted just as volunteer reaches the event horizon

 $\Rightarrow$ Distant observer never sees volunteer cross the horizon

 $\Rightarrow$ *Photons get undetectable, very long wavelength, most of the time is between photons - absolutely black - why black holes are black.* 

## Black Hole Evaporation Hawking Radiation § 6

Quantum Fuzzy Event Horizon

vacuum "boils" with creation/annihilation of particles/antiparticles easiest to make photon = anti-photon (no mass)

but also  $e^- e^+$ ,  $p^+ p^-$ , neutron anti-neutron, neutrino anti-neutrino

## At event horizon - position of event horizon and of particles is *quantum uncertain*

One particle in pair can be swallowed, other escapes - carries mass, energy - pure quantum effect.

Black holes are not just one-way affairs, with quantum effects they will lose mass and energy