General Relativity

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Heavier Elements

^{56}Fe + lots of neutrons and $n \rightarrow p + e^- + \bar{\nu}_e$

combine these 2 processes to **get heavy elements**

Collapsing Stars - If you increase **mass** too much, there isn't enough degeneracy pressure to resist the gravitational collapse

complete collapse → singularity (all mass M to a 'point')

predicted by Gen. Relativity!

without it, a black hole is mathematically impossible

first, special Relativity

Special Relativity

time is relative to how fast you're moving (time dilation)

$$t = \gamma t = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$$ so time "seems" to elapse slower as $\vec{v} \rightarrow c$

think of a muon (μ^-) decay time

for a muon, the lifetime is $2\,\mu s$,

for us, the lifetime **appears longer** (10's of μs)

simultaneity is not universal!

twin paradox

one twin flies on rocket at $v \approx c$

one twin is on earth

twin_{rocket} ages slower than twin_{earth}

Reason: just $\text{acceleration}_{rocket} > \text{acceleration}_{earth}$

elevator example

$9.8 m/s^2$

in an elevator falling freely, in relation to observer on ground, falling at $\vec{a} = -9.8 m/s^2$

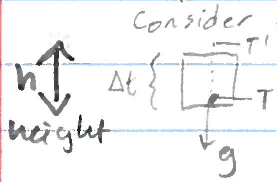
but in the elevator frame, the person is weightless!

⇒ freely falling coordinate systems are indistinguishable from inertial ones!

General Relativity

freely falling coordinate system = Inertial system

consider elevator example again



we have a light emitting diode in the elevator

$\Delta t = \frac{h}{c}$ = **travel time**

so to a person on the ground, **the top detector should see** light at a faster speed (blueshift)

change in velocity is $\Delta v = \frac{h}{c} \cdot g$ and $T' = T(1 - \frac{\Delta v}{c}) = T(1 - \frac{h}{c^2} g)$

Gen. Relativity Cont.

in inertial system no blue shift! [(in inertial = free fall system)]

BUT light is constant! There should be no change in period $T' \neq T(1-\frac{h}{c^2}g)$, $T=T'$! (for elevator frame)

what does this mean?

the moving frame is "correct", observer on ground is "incorrect"

in reality they're both right, just measure differently due to $\vec{a}$

but for observer on ground $T' = T(1-\frac{h}{c^2}g)$

and $\Delta t_{bottom}(1+\frac{h}{c^2}g) = \Delta t_{top}$

more time elapses at the top than at the bottom

or $\Delta t_{bottom} = (1+\frac{\Delta\phi}{c^2})\Delta t_{top}$ where $\Delta\phi$ is the change in gravitational potential from top to bottom

where ϕ = grav. potential = hg

correct form $\rightarrow$ so, $\Delta t_{bottom} = (1+\frac{2\phi}{c^2})^{1/2}\Delta t_{\infty}$

all well and good, but what does it mean?

if you live in a tree, your life moves faster

and if $\frac{2\phi}{c^2} \to -1$ then $\frac{2GM}{R_s c^2} = -1$

then for them, time takes FOREVER O_O

$\boxed{R_s = \frac{\sqrt{2GM}}{c}}$ = Swartzchild Radius = Event Horizon!

Schwarzschild radius