ASTR 1040 RECITATION 8
RELATIVITY
10/24/2023

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HOUSEKEEPING

a) Sorry for delay in grading homeworks – have talked to grader about it and hope they will be in soon

b) Please submit your homeworks (on time) and make sure they are legible!

c) Will only be in AHR 4-5 next two weeks

DO PULSARS HAVE TO BE NEUTRON STARS?

Assuming a neutron star's surface can't spin faster than the speed of light, calculate a maximum possible radius of a pulsar given that they have periods measured as small as 0.001s. Using this fact, calculate **a characteristic density for a pulsar and compare to the density of a white dwarf ($\sim \mathbf{10^{10} kg/m^3}$).**

Hint: Set the centrifugal and gravitational forces at the equator equal to each other.

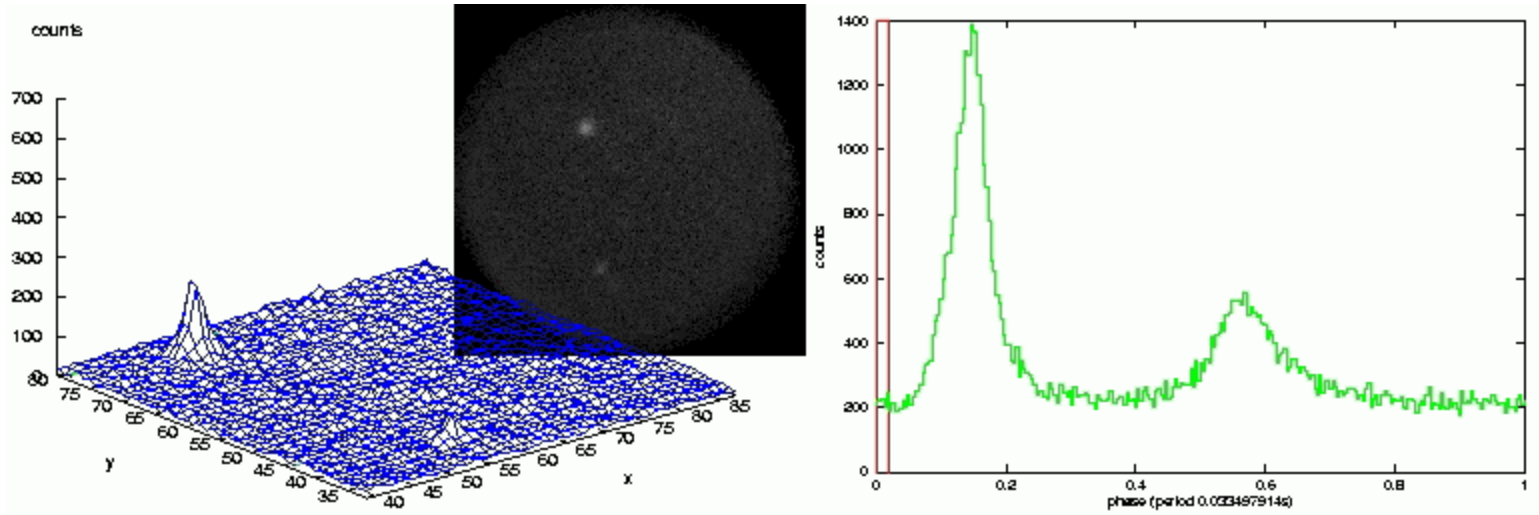
Formulae you may need:

$$v = \omega r$$

$$F_G = G\left(\frac{Mm}{r^2}\right)$$

$$F_c = m\omega^2 r$$

$$\omega = 2\pi f = \frac{2\pi}{P}$$



PRACTICE PROBLEM 1: THOUGHT EXPERIMENTS

a) I'm travelling across the galaxy (100,000 light years across as measured from Earth) in a spaceship really fast – so fast that I get some cool time dilation effects and from my perspective it only takes me 10 years to cross the entire galaxy. Did I break the speed of light?

b) There are two car accidents in New York and London at the same time according to the watches on both sets of drivers involved (who are now stationary). I'm on a flight that's halfway between New York to London on a new super fast jet with powerful cameras such that I can watch both accidents happen from the plane – from my perspective which happens first, and why?

Think about and justify your answers conceptually only, no math allowed!

MATH – THE LORENTZ FACTOR

To calculate the change in distance / time from one reference frame to another we use the **Lorentz factor**:

$$\gamma \equiv \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

Time dilation: $\Delta t' = \gamma \Delta t$

Moving frame — Rest frame

Length contraction: $\Delta x' = \frac{\Delta x}{\gamma}$

Moving frame — Rest frame (of object)

Practice problem 2:

a. If it takes me 10 years to cross the galaxy in my spaceship, but people on Earth think it took 100,000 years, what is γ? How big is the galaxy from my perspective?

b. Mark Kelly holds the record for longest consecutive time spent in space at 215 days. He lived on the ISS, which orbits the Earth at ~8,000 m/s. If you travelled in a spaceship at this speed for 215 days (from Earth's perspective) how much of a discrepancy between clocks on Earth and clocks on your spaceship would there be?

VISUALIZING SPACETIME: MINKOWSKI DIAGRAMS

How is the coordinate system defined in a Minkowski spacetime diagram? **It's relative to each observer!**

If c is the universal speed limits, photons are fastest travelling things through spacetime:

$$\frac{\Delta x}{\Delta t} = v = c \ \rightarrow \Delta x = c\Delta t$$

If everyone agrees on speed of light, they must also agree on "space time distance", i.e. for a photon:

$$c^2\Delta t^2 - \Delta x^2 = 0$$

Note: this doesn't mean they have to agree on $\boldsymbol{\Delta t}$ or $\boldsymbol{\Delta x}$!

Thus the special relativistic "distance" metric is defined in terms of light:

$$\Delta s^2 = c^2\Delta t^2 - \Delta x^2$$

Questions for you:

1. If $\Delta s^2 = 0$ for light, what does it mean for Δs^2 to be positive? Negative?
2. When looking at a spacetime diagram, how do you determine what events appear to happen at the same time and which happen at the same place?

MINKOWSKI PART 2: COMPARING FRAMES

Events that are simultaneous for one observer **are not necessarily simultaneous for any other.** Why? $\Delta t' = \gamma \Delta t$ and $\Delta x' = \frac{\Delta x}{\gamma}$ – observers **don't need to agree** on Δt and Δx, just the spacetime distance Δs!

Seeing motion through space faster = seeing motion through time slower.

Coordinate frames are related with $\tan \alpha = \frac{v}{c}$

Question: What do lines of simultaneity look like? What events are the simultaneous for every observer?