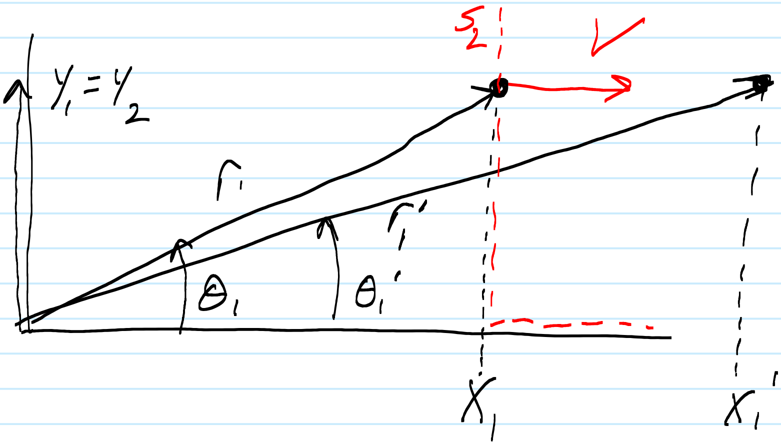
Doppler---The source is moving a speed v---and may emit light in all directions, so some of it is reaching "us"--the observer.

Emission of Light — consider motion of the source — NOT LIGHT



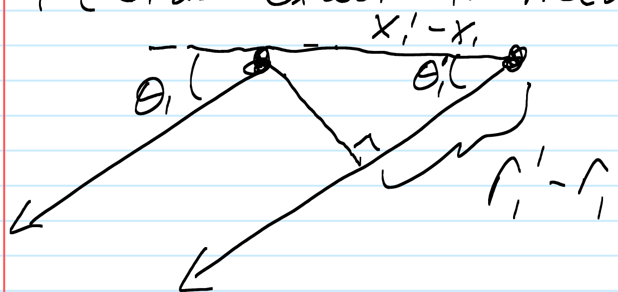
$$T_0 = t_2' - t_2$$

frame S_2 moves with particle

$$\gamma_0 = \frac{1}{T_0}$$

Note the use of PRIME here is for the second event. Event first, unprimed. Event second--primed. So T_o is really a "Delta T" and is what we would all measure of the object (emitter) were sitting still.

We will approximate — the distance the atom travels is << distance to the observer.
(can do exact if needed)



rays are ≈ // so $\theta_1' \sim \theta_1$

I see the atom/emitter travel from an initial position x_1 to the next emission x_1'

The time between emissions in the rest frame of the emitter is $T_o = t'_2 - t_2$

The Doppler shifted time period between events received in frame 1 --- IS NOT SIMPLY THE TRANSFORMS OF THESE NUMBERS.....NOT $t'_1 - t_1$ ------The second emission must travel extra distance too--and this matters.

We will also assume that the two rays of light heading back to the observer are headed in a parallel direction. That is θ_1' and θ_1 are the same (ish) . This approx can be done exactly---but is really good approx as long as the distance moved by emitter is small during the time.

In frame 1 what do I observe happening?
I see a particle at the $x_2=0$, ~~and the~~ particle has a (is a) clock--ticking. I see reverse transformed time t_2

$$t_1 = \gamma(t_2 + 0)$$

Likewise Later

$$t_1' = \gamma t_2'$$

I receive signal, but it takes time to get to me r/c...

$$t_{1\,\text{Received}} = t_1 + r_1/c$$

$$t'_{1\,\text{Received}} = t_1' + r_1'/c$$

It is the difference in receiving the two pulses of light that I measure as "The time period in my reference frame". We want to see how it relates back to T_o

$$T = t'_{\text{Received}} - t_{\text{Received}}$$

$$T = \left(t_1' + r_1'/c\right) - \left(t_1 + r_1/c\right)$$

$$= t_1' - t_1 + (r_1' - r_1)/c$$

$$= \gamma(t_2' - t_2) + (r_1' - r_1)/c$$

geometry from figure

$$= \gamma T_0 + \underbrace{(x_1' - x_1)}_{\underbrace{v(t_1' - t_1)}_{v\gamma T_0}} \cos\theta_1 / c$$

$t_2' - t_2 = T_0$

$t_1' = \gamma t_2'$
$t_1 = \gamma t_2$

$$= \gamma T_0 + v\gamma T_0 \cos\theta_1 / c$$

$$= T_0 \gamma \left(1 + \frac{v}{c} \cos\theta_1\right)$$

or more typically

$$\nu = \frac{\nu_0}{\gamma\left(1 + v/c \cos\theta_1\right)}$$

θ_1: observed angle in S_1

freq $= 1/T$

We defined angle here in this derivation to be---stand at origin. Particle is at some position moving in direction positive x axis. The angle is the angle between how I point to the particle--and the particles motion (which was assumed as + x axis here). If I head toward a stationary object---it looks like it is moving toward me. The angle in that case would be more like 180 degrees than zero.

Comments and questions regarding Doppler effect:

- When an emitter moves toward me (higher frequency), away (lower)---but what if the emitter is crossing 90^{o}---is there still a Doppler shift? (TRANSVERSE OR 2ND ORDER DOPPLER EFFECT)
- Does this all reduce back to normal stuff (no gamma's) when v<<c ?   (DO IT)
- I believe that the best techniques for exoplanet detection using Doppler shift in starlight due to planet tugging on star--causing wiggle---is about better than 1.00m/s difference in speed due to Doppler (remember the speed of light).
- https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/#/1

OK-watch out for those intergalactic traffic lights.