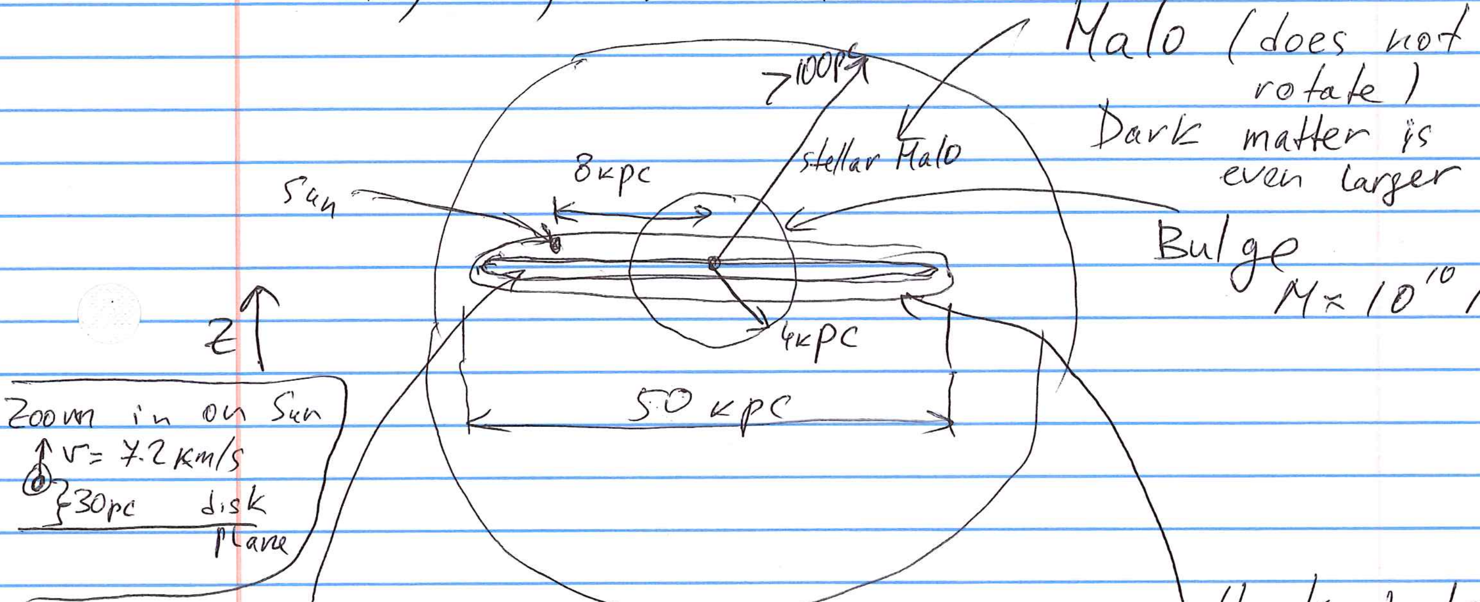
Lecture 35.

* Milky Way Galaxy
* Oscillations around disk
* Rotation curves and Dark matter requirement

Milky way Galaxy (Our home)

Note: all stars we can see with naked eye (or even telescopes) our ~~...~~ stars from our galaxy. Other galaxies appear as "nebular" i.e. stars are not resolved.

Milky way side view



thin disk => $M \approx 6 \cdot 10^{10} M_\odot$
≈ 90pc in Z

young stars

thick disk
$M \approx (0.2 \div 0.4) \cdot 10^{10} M_\odot$
$Z \approx 1$kpc, older stars

~~Total mass~~ $= 8 \cdot 10^{10} M_\odot$ luminos mass (disks, bulge, halo)

Total mass $\approx 190 \cdot 10^{10} M_\odot$ ← huge errorbars see table 24.1

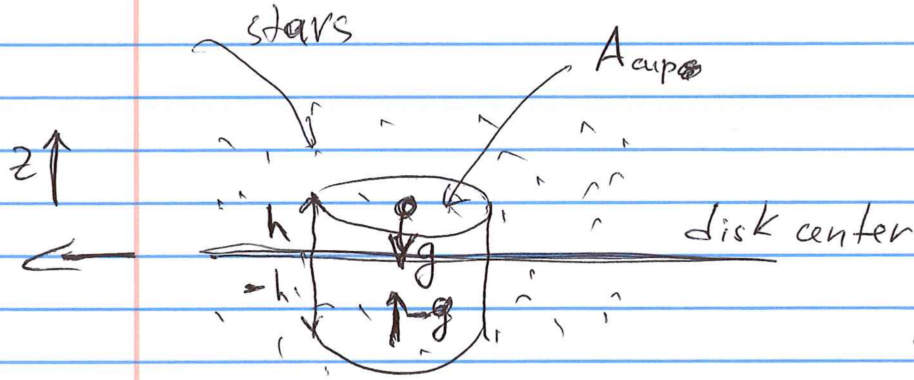
i.e. most of the Mass is Dark Matter

some could be white/red dwarf which are not very luminos

↳ WIMP – weakly interracting massive particles

MACHO – massive compact halo object
↳ observed transient due to G. lensing

Sun oscillations around ~~disk~~ and within disk
↑ or any other star



→ almost like a plane

$z \simeq 50\,pc$
whole disk $\varnothing \simeq 50\,kpc$

$$\frac{z}{\varnothing} \simeq 10^{-3}$$

Gauss law for charges — same charges repel

$$\oint_{\text{closed area}} \vec{E}\, d\vec{A} = \oplus k_e 4\pi \underbrace{\sum_i q_i}_{\text{Enclosed charge}}$$

Similarly for mass (since Gravity and Coulomb force $\sim 1/r^2$)

gravity attractive ⇒ masses attract each other

$$\oint \vec{g}\, dA = \ominus 4\pi G \circ M_{inside}$$

no flux through sides due to symmetry

$$-2g \circ A_{cup} = -4\pi G M$$

$$= -4\pi G \cdot 2h \circ A_{cup} \circ \rho$$

$$g = |\vec{g}| = 4\pi G h \rho$$

$$\ddot{\vec{r}} = \vec{g}$$

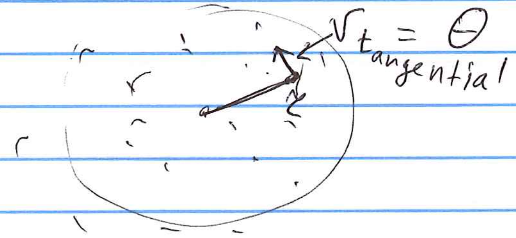
$$\ddot{h} = -(4\pi G \rho h) \Rightarrow h = A \circ e^{i\omega t} \quad \boxed{\omega = \sqrt{4\pi G \rho}}$$

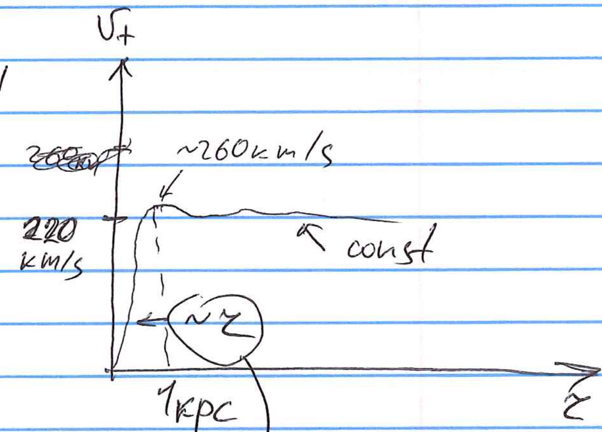
$$\rho = 0.15\, M_\odot/pc^3 \Rightarrow \boxed{P_{osc} \simeq 7 \cdot 10^7 \text{ years}}$$

Rotation curve

Top view

in the book





recall that circular orbital speed

$$\frac{mv^2}{r} = G\frac{M_r m}{r^2}$$

$$\boxed{M_r = \frac{v^2 r}{G}}$$

rigid body like

$$v_t = \omega r$$

$$M_r = \frac{(\omega r)^2 r}{G}$$

$$\frac{dM_r}{dr} = \underbrace{4\pi \rho(r) r^2}_{\text{sphericall shell}} = \frac{3\omega^2 r^2}{G}$$

$$\Rightarrow \boxed{\rho(r) = \frac{3}{4\pi}\frac{\omega^2}{G} = \text{const}}$$

at center region

Outside central region

$$\frac{dM_r}{dr} = \underbrace{\frac{v^2}{G}}_{\text{const}} = 4\pi r^2 \rho$$

$$\boxed{\rho = \frac{1}{4\pi r^2}\frac{v^2}{G}} \sim \frac{1}{r^2}$$

but Luminos Mass have density which scales as $\sim 1/\rho^{3.5}$ $\Longrightarrow$ $\boxed{\text{Dark Matter is needed}}$ to compensate