# Andromeda & Milky Way galaxies in free fall towards each other

***IF*** initial mutual velocity $= 0$ m/s (both radial and orbital velocity).

(Andromeda actually has a radial velocity towards us of rougly 300 km/s, but we hardly know its lateral velocity, so it might well be that we are revolving our common barycentre).

We consider the resulting bull's eye trajectory to be a degenerate elliptical orbit $[a < \infty,\ b = 0 \Rightarrow e = 1]$ from apoapsis to periapsis according to Kepler's laws, where the reduced mass $\mu = Mm/(M+m)$ "orbits" the $M+m$ barycentre and we calculate half the orbital period.

Kepler's 3rd law: $\omega^2 a^3 = GM_{\text{tot}} \therefore \omega = \sqrt{\dfrac{GM_{\text{tot}}}{a^3}}$

we have: $a = \dfrac{R}{2} \therefore a^3 = \dfrac{R^3}{2^2 2}$

$$\omega = \frac{2\pi}{T} \therefore T = \frac{2\pi}{\omega} = 2\pi \cdot \sqrt{\frac{a^3}{GM_{\text{tot}}}} = \frac{2\pi}{2} \cdot \sqrt{\frac{R^3}{2GM_{\text{tot}}}}$$

hence, the *free fall time* (½orbit) is: $\boldsymbol{t_{\text{ff}}} = \dfrac{T}{2} = \boldsymbol{\dfrac{\pi}{2} \cdot \sqrt{\dfrac{R^3}{2GM_{\text{tot}}}}}$

<u>We have:</u>

$R \approx 2.54 \times 10^6$ ly $\approx 2.403 \times 10^{22}$ m

$G \approx 6.67430 \times 10^{-11}$ N·m²/kg²

$M_{\text{MW}} \approx 1.15 \times 10^{12} M_\odot$

$M_{\text{Andr}} \approx 1.5 \times 10^{12} M_\odot$

$M_\odot \approx 1.98847 \times 10^{30}$ kg

$M_{\text{tot}} = M_{\text{MW}} + M_{\text{Andr}} \approx 5.27 \times 10^{42}$ kg

<u>yielding:</u>

$$\boldsymbol{t_{\text{ff}} \approx 2.21 \times 10^{17}\ \text{s} \approx 6.99 \times 10^9\ \text{yr} \approx 0.508 t_{\text{H}}}$$

At the aforementioned speed of 300 km/s (wrongly assuming it constant), it would take $2.403 \times 10^{22}$ m / 300 km/s $\approx 2.54 \times 10^9$ yr $\approx 0.184 t_{\text{H}}$ .

Andromeda is our nearest neighbour spiral galaxy.
On the cosmic scale, it is *very* close to us
and yet our kiss (starting with zero velocity) would have to bide

**seven billion years, half the age of the universe!**

***Intergalactic gravitation*** is

**GIGANTICALLY** small.

Yes, it's astronomically small, negligible for most purposes.

## We see this fleet need no beat and neatly meet & the speed be:

(of course it's a one-dimensional head-on collision and we calculate in the barycentric frame!)

conservation of energy: $E_{\text{kin,tot}} = \frac{1}{2} M_A v_A^2 + \frac{1}{2} M_{MW} v_{MW}^2 = \frac{G M_A M_{MW}}{R} = E_{\text{pot}}$

conservation of momentum: $\frac{v_A}{v_{MW}} = \frac{M_{MW}}{M_A}$ (using absolute values)

hence: $v_{MW} = v_A \frac{M_A}{M_{MW}} \therefore v_{MW}^2 = v_A^2 \frac{M_A^2}{M_{MW}^2}$

therefore: $\frac{1}{2} M_A v_A^2 + \frac{1}{2} M_{MW} v_A^2 \frac{M_A^2}{M_{MW}^2} = \frac{G M_A M_{MW}}{R}$

i.e.: $v_A^2 M_A \left(1 + \frac{M_A}{M_{MW}}\right) = \frac{2 G M_A M_{MW}}{R}$

yielding: $v_A = \sqrt{\frac{2 G M_A M_{MW}}{R M_A \left(1 + \frac{M_A}{M_{MW}}\right)}} = \sqrt{\frac{2 G M_{MW}^2}{R (M_A + M_{MW})}} = M_{MW} \sqrt{\frac{2G}{R (M_A + M_{MW})}}$

and: $v_{MW} = v_A \frac{M_A}{M_{MW}} = M_A \sqrt{\frac{2G}{R (M_A + M_{MW})}}$

which results in: $\boldsymbol{v_{\text{coll}}} = (M_A + M_{MW}) \sqrt{\frac{2G}{R (M_A + M_{MW})}} = \sqrt{\frac{\boldsymbol{2G(M_A + M_{MW})}}{\boldsymbol{R}}}$

**This renders:** **~171 km/s**

Cf.: $\sim$200 km/s $< v_{\odot,\text{MW}} <$ $\sim$250 km/s

Dividing the sum of their radii by this velocity
yields the **maximum duration of this collision**:

we find: $R_{MW} \approx 52850$ ly (Google as of 2024-03-26)
and: $R_A \approx 110000$ ly (sic)
so: $R_{\text{tot}} \approx 162850$ ly $\approx 1.54 \times 10^{21}$ m

**yielding:** $\boldsymbol{\Delta t_{\text{coll}} < \sim 285}$ **million years.**

How many stars will collide? See http://henk-reints.nl/astro/HR-Galaxy-star-collision.pdf.

Now assume the sun's orbital period around the galactic centre (~240 Ma)
equals the rotation period of the entire **Milky Way**. Then the latter has **revolved**
not more than a mere 13.77 Ga / 240 Ma $\approx$ **57 times since the big bang.**

*Ceci n'est pas la galaxie d'Andromède, ni la Voie lactée.*

  