

Stars & galaxies, multiple-choice questions

$[M_{\odot} = 1.989 \times 10^{30} \text{ kg}, m_p = 1.67 \times 10^{-27} \text{ kg}, k_B = 1.38 \times 10^{-23} \text{ J K}^{-1},$
 $1 \text{ pc} = 3.09 \times 10^{16} \text{ m}, G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}]$

Problem 1.

The mass of the Andromeda galaxy is dominated by a dark halo with density profile $\rho(r) \propto 1/r^2$, mass $M = 2.0 \times 10^{12} M_{\odot}$, and extent $r_{\star} = 200 \text{ kpc}$.

1. The circular velocity at distance $r = 300 \text{ kpc}$ is

- (a) 170 km s^{-1}
- (b) 207 km s^{-1}
- (c) 220 km s^{-1}

2. The circular velocity at $r = 100 \text{ kpc}$ is

- (a) 170 km s^{-1}
- (b) 207 km s^{-1}
- (c) 293 km s^{-1}

3. The galaxy in addition has a uniform density bulge with mass $M_b = 2.0 \times 10^{10} M_{\odot}$ and radius $r_b = 4.0 \text{ kpc}$. Combining dark halo and bulge, the circular velocity at $r = 2.0 \text{ kpc}$ is

- (a) 73 km s^{-1}
- (b) 207 km s^{-1}
- (c) 220 km s^{-1}

4. Compute the equivalent of Oort's constant A at $r = 2 \text{ kpc}$ from the centre of Andromeda (using its halo and bulge parameters from above).

- (a) $14.4 \text{ km s}^{-1} \text{ kpc}^{-1}$
- (b) $48.9 \text{ km s}^{-1} \text{ kpc}^{-1}$
- (c) $55.0 \text{ km s}^{-1} \text{ kpc}^{-1}$

Problem 2.

Doppler motions show that the line-of-sight velocity dispersion of galaxies in a cluster of galaxies is $\sigma_{1D} = 800 \text{ km s}^{-1}$.

1. Assuming isotropic orbits, the 3D velocity dispersion, σ_{3D} , is
 - (a) 800 km s^{-1}
 - (b) 1386 km s^{-1}
 - (c) 2400 km s^{-1}
2. The cluster's radius $R = 0.5 \text{ Mpc}$. The virial mass of the cluster is
 - (a) $M = 7.4 \times 10^{13} M_{\odot}$.
 - (b) $M = 2.2 \times 10^{14} M_{\odot}$.
 - (c) $M = 6.7 \times 10^{14} M_{\odot}$.
3. Another cluster has mass $M = 1.0 \times 10^{15} M_{\odot}$ and radius $R = 1.0 \text{ Mpc}$. Compute its virial temperature T , assuming pure hydrogen gas. (The binding energy of the hydrogen atom is 13.6 eV .)
 - (a) $T = 1.7 \times 10^8 \text{ K}$ and the gas is mostly ionised
 - (b) $T = 3.5 \times 10^8 \text{ K}$ and the gas is mostly ionised
 - (c) $T = 1.7 \times 10^8 \text{ K}$ and the gas is mostly neutral
 - (d) $T = 3.5 \times 10^8 \text{ K}$ and the gas is mostly neutral
4. Compute the 1D velocity dispersion, σ_{1D} , of galaxies in this cluster. Use this to compute the cluster's crossing time, $t_{\text{cr}} = R/\sigma_{1D}$.
 - (a) $t_{\text{cr}} = 470 \text{ Myr}$
 - (b) $t_{\text{cr}} = 820 \text{ Myr}$
 - (c) $t_{\text{cr}} = 1200 \text{ Myr}$