Selection of Homework Questions

Topic 13 : Groups & Clusters

(1) Morphology Density Relation :

a. Summarise, briefly, the observational evidence that galaxy morphology depends, statistically, on environment.

b. Briefly describe the physical mechanisms which might cause this morphology--environment dependency.

c. How do galaxy-galaxy interactions differ when the duration of the encounter is significantly greater/similar/less than the orbital period within the galaxy? Identify the circumstances within galaxy clusters which would lead to these three types of interaction.

(2) Ram Pressure Stripping :

a. What is the vertical force per unit mass (i.e. acceleration) above an infinite sheet with mass surface density Σ ?

b. Unlike the disk's stars, the disk's ISM will "feel" the ram pressure exerted by a steady external wind of density ρ and perpendicular speed V. If the ISM is uniformly distributed, and is a (small) fraction α of its disk's mass, find the condition that the wind's ram pressure removes the gas from the disk. [In disk dominated galaxies, the maximum gravitational force is, in fact, just above the disk, and so if the ISM is stripped from the disk, it will be stripped from the galaxy as a whole.]

c. Imagine the milky-way galaxy falling into the Coma cluster for the first time at V ~ 1000 km/s. Near the sun, the MW disk has surface density ~75 $M_\odot$ pc^{-2} (Topic 1.3c) of which about 10% is ISM. At what ICM density (in protons/cm^3) does the ISM in the solar neighborhood get stripped? [Use psm units, recalling that 1 $M_\odot$ pc^{-3} = 40.5 $m_p cm^{-3}$].

d. Go to the ROSAT analysis of Coma by Briel et al (1992) and, after perusing their paper, look at the derived gas density profile in Figure 3 (the lower two curves show the allowed range). Using their value for H_o, at what radius would the solar neighborhood be stripped?

e. In reality, the ISM in disk galaxies is highly inhomogeneous, with clouds of higher density material embedded in a low density, high filling-factor hot phase. Give a more realistic description of how the ISM of a disk galaxy might be lost as it enters a cluster.

f. Consider one extreme: a "dense" (~10^4 H_2 molecules cm^{-3}) molecular cloud containing ~10^5 $M_\odot$ in roughly spherical form -- say, a proto-orion nebula. At what ICM density would this DMC be removed (hint: why might an updraft lift a balloon, but not a bowling ball of the same size)? Would you expect spirals entering a cluster to lose their pre-existing molecular gas?

g. In the solar neighborhood, the various ISM phases are in rough pressure balance, with pressure P/k ~ 2000 K cm^{-3} (k = Boltzmann's constant, so nT ~ 2000 K cm^{-3}). In this environment, the

DMC clouds are stable to collapse. For the MW entering Coma, express the ram pressure in units of P/k, for wind density n_{ICM} cm^{-3} and velocity V~1000 km/s. Do you think ram-pressure could trigger star formation when spirals enter a cluster at high speed?

(3) Hydrostatic Atmospheres :

Model the Coma cluster by a spherical distribution of dark matter within which galaxies and hot gas have isotropic and isothermal velocity distribution of different temperature.

a. Show that the gas and galaxy density distributions are related by: $\rho_{gas} \propto \rho_{gal}^{\beta}$ where $\beta = T_{gal}/T_{gas}$.
b. Adopting a simple formation scenario for Coma, why would you expect $\beta \sim 1$? Observations reveal $\beta \sim 0.5$. Why is this different from our simple expectations?
c. X-ray spectra suggest Coma's ICM has a temperature (kT) of 8 keV. What Kelvin temperature does this correspond to, and what is the associated galaxy velocity dispersion, σ, if $\beta = 0.5$? From Topic 8.8bii, we have for the core of an isothermal sphere: $\sigma^2 = (4\pi G/9)\, \rho_o\, r_c^2$, where r_c is the core radius. For Coma, $r_c \sim 0.5$ Mpc. What is the central density (in $M_\odot$ pc^{-3}) and core mass of Coma?
d. Adopting the cosmic ratio of dark matter to baryonic matter, and assuming all baryons are in the hot gas, what is the ICM electron density in the core of the Coma cluster. Assuming a constant density throughout the core, what is the core's total X-ray luminosity and photon flux (#/s/cm^2) at the earth (assume Coma is at 100 Mpc and all photons have energy 8 keV).
