Ay 124 Winter 2016 – HOMEWORK #5

Due Friday, March 4, 2016 by 5pm, in Denise's mailbox in 249 Cahill

Problem 1 *Toomre's Q*

The famous "Toomre Criterion" (also known as "Toomre's Q") for the local stability of a differentially rotating thin disk (of gas or stars – the criteria are nearly identical) to axisymmetric perturbations is described in §6.2.3 of Binney and Tremaine (beginning on p. 494 in the 2008 edition). Compute Toomre's Q for stars in a Milky Way-like disk with a scale length $R_s \simeq 3$ kpc, and disk velocity dispersion. At what galactocentric radius would you predict the stellar disk would becomes Toomre unstable? What is wavelength of the "most-unstable" mode? How does the result change for a MW-like gaseous disk, and for the young stars that form from it? How would the answer change if you were to consider a gaseous disk whose surface density is entirely dominated by gas (i.e., $\Sigma_{\rm gas} >> \Sigma_{\rm stars}$ as might be found in a very young galaxy beginning its star-forming life)?

Problem 2 – *Galaxy Mergers*

Consider the local universe, filled with galaxies whose luminosity function is well-described by a Schechter function with characteristic density Φ^*, characteristic luminosity L^*, and slope $\alpha \approx -1.0$ (you may adopt reasonable numerical values for these parameters). Assume that the mean relative velocity of galaxies is 300 km s^{-1}, and that a significant collision between galaxies occurs when they pass each other with impact parameter < 100 kpc.

a) Estimate the mean time between galaxy collisions in the present-day universe.

b) Explain (multiple) reasons why your estimate in a) significantly under-estimates the true incidence rate of collisions. Use a back-of-the-envelope approach to estimate a more reasonable collision timescale. In your thinking, you may want to consider that 1) galaxies are not randomly distributed in space, but clustered, where the excess probability over random of finding another galaxy within a distance r is $\xi(r) = (r/r_0)^{-1.8}$, with $r_0 \simeq 7$ Mpc and 2) the mean distance between galaxies at redshift z was smaller by the factor $(1 + z)$.

c) Assume that galaxies involved in collisions (as defined above) begin the process of merging, and that the merger time is given approximately by the timescale for violent relaxation of the dynamical system including the two galaxies. Explain how you might calculate the expected fraction of all galaxies that would be observed to be *in the process of merging* at a given time? How would you expect that fraction to change with increasing redshift?

Problem 3- *Spectral Synthesis*

Download the spectrum of the galaxy NGC 3512 and the stellar spectra of O7, B3, A1, G1, K4 main sequence stars ("V" for the luminosity class), plus the spectra of G5 and K4 giants (luminosity class "III") from the class website under Homework #5. The data files are all ascii format, with column 1 as wavelength and column 2 as f_λ in arbitrary units. Using the data analysis package of your choice, construct a linear least-squares program that solves for the linear combination of the stellar spectra that best-reproduces the observed galaxy spectrum.

a) Report what fractions (or limits on fractions) of the various spectral types you find. Plot your fit result and the observed galaxy spectrum, and comment on any spectral regions that are not well-reproduced by your population synthesis spectrum.

b) Can you distinguish replacement of a given fraction of main sequence K stars from that of K giant stars? Given the fractions, standard initial mass functions, and qualitative features of stellar evolution, which do you think is actually the more reasonable choice: main sequence or K giants?