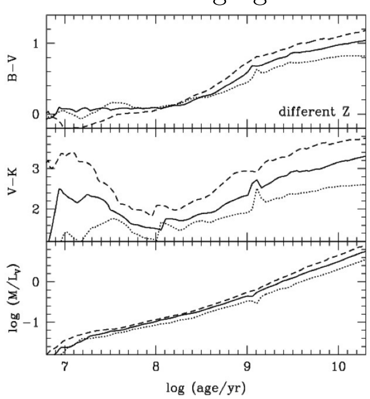
Galaxies: Structure, Dynamics, and Evolution
Problem Set 6
Instructor: Dr. Bouwens

Here is problem set #6. The entire problem set will be due before noon on Tuesday, December 6, 2016.

1. The mass estimates from Kauffmann rely to a large extent on the absorption line indices $D_n(4000)$ and $H\delta$. These are independent of extinction and reddening by dust. Why do Kauffmann et al. still need an estimate of the extinction to estimate the stellar mass of the galaxies?

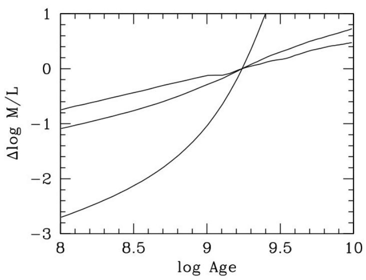
2. Evolution of the mass-to-light ratio.

(a) The mass-to-light ratio is roughly a power-law with time. Measure by hand the coefficient α for the mass-to-light ratio $M/L = t^{\alpha}$ for the V band from the following figure shown in lecture (choose the middle line):



(b) The $B - V$ and $V - K$ color of a SSP (simple stellar population) depend more or less linearly on $\log t$ for ages about 10^8 years. Determine this dependence from the figure shown above (take the middle line again). Use the result to derive the coefficient α for the mass-to-light ratio dependence on time for the B band and the K band.

(c) Use the following figure (also shown in lecture) to derive α for the U-band (the U band curve is the steepest one):



3. (a) Assume that the time dependence of the mass-to-light ratio derived in problem #2 for all t below 10^{10} years. The equations above were derived for single burst stellar populations. Now assume a population with constant star formation. Calculate the evolution of the M/L ratio with time T for the U, B, V and K band. Do this by calculating the light from a populations formed at a time interval t, $t + dt$, and then integrating from $t = 0$ to $t = T$, where T varies from 1 to 10 Gyr. The only thing we care about is the dependence of the M/L ratio with time, not the absolute value of the M/L ratio.

(b) Use the results obtained in (a) to derive the dependence of the $U - B$, $B - V$, and $V - K$ colors with time. Compare these numbers to the time dependence of the same colors for an SSP.

4. We have seen that the typical stellar mass of galaxies in the universe is around $10^{10.6}\,M_\odot$. Find in the literature estimates for the stellar mass of the Milky Way, and the Andromeda galaxy. Give the references from which you lifted the values. How much mass is in the bulge of the Milky Way ? How do these values compare to the typical mass ?

5. The number density of galaxies is about 0.008 h^3 Mpc^3. The correlation length r_0 is $5.2h^{-1}$ Mpc.

a) Why does the density and the correlation length depend on h ($= H_0/$ (100 km/s/Mpc))

b) The correlation function gives the relative excess of galaxies at a given radius. Calculate the integrated correlation function, i.e., the excess from within a radius smaller than r.

c) Now combine this with the average number density to estimate the radius r within which each galaxy has on average 1 neighbor.

d) What would this radius be if the galaxies are not correlated?

6. Use an actual stellar population code to predict spectra. Start early, as it may take you a day to complete this problem. Only 2 simulations run simultaneously on their site and often take one hour.

(a) Go to the website http://www.stsci.edu/science/starburst99/docs/parameters.html. You will run a simulation to calculate how the spectrum of a galaxy would change, if all the stars formed at the same time. You will mostly use the default parameters. For the metallicity and tracks, select Padova Orig, with a metallicity of 0.004. Change the metallicity of the high-resolution spectrum to 0.008. Change the last grid point to 10000 $\times 10^6$ yr and select logarithmic steps. Choose 100 time steps. For the output files, select 7: Spectrum and 9: Colors. Run the Simulation, wait for the results, and download them. Plot the spectrum at $\sim 10^7$ years, $\sim 10^8$ years, $\sim 10^9$ years, and $\sim 10^{10}$ years. The simulation may take an 1 hour or longer, depending on how many other simulations are in the queue.

(b) Use the absolute magnitude M_V and $V - I$ color to determine how the absolute magnitude of a galaxy in the I-band varies with time, if it forms all of its star at some fixed time in the past. Plot the M_I versus log_{10}time, from 10^6 to 10^{10} years. Given this relationship, how would we expect the mass-to-light of this galaxy to vary with time in the I band? Specifically, can you express the evolution of the mass-to-light as a power-law t^α? How does it compare with the formula derived in class assuming that the light from a galaxy is dominated by red-giant stars and adopting a Salpeter IMF?

7. An important assumption in the analysis of unresolved stellar population is that of a universal initial mass function. What would be the impact if this assumption were not true? Consider two cases: the first being a Salpeter IMF with cut-offs at 0.1 $M_\odot$ and 100 $M_\odot$ and the second being a Salpeter IMF with cut-offs at 0.1 $M_\odot$ and 1 $M_\odot$.

(a) Assume that a galaxy formed stars acording to the two IMFs described. Very qualitatively, what would the SEDs of galaxies look like like 10 Myr later and 11 Gyr later? How similar are the SEDs of galaxies in the two cases at the later time?

(b) How do the SEDs of galaxies evolve in the case of the first IMF vs. the second IMF? How accurately could one determine the time since the instantaneous burst of star formation in the two cases?

(c) Let's suppose that the true IMF of a galaxy corresponded to the second case, but let's suppose one assumed it was the first case. How might it impact one's estimates of the total mass locked up in stars based on the observed SED? How might it impact one's estimates on the total metals ejected as a result of supernovae in the formed stars? Describe each case.