DUE ON FRIDAY SEPTEMBER 13, 2019 — HARDCOPY PAPER SUBMISSION ONLY

GALAXIES: PROBLEM SET 1

Problem 1: Morphological Classification [6 points]

[6 points] In class we have discussed different ways to morphologically classify galaxies. If you had to introduce a "morphological" galaxy classification scheme, how would it look like? Describe and justify your classification system.

Problem 2: Galaxy Correlations in the SDSS [30 points]

The Sloan Digital Sky Survey (SDSS) is one of the most ambitious and influential surveys in the history of astronomy. Over more than 17 years, and four phases of operations, it has taken images and spectra for over a million galaxies in the low to intermediate redshift universe. SDSS data have been released to the scientific community and the general public. Many value added products based on SDSS data are available as well. For example on the following webpage you can find catalogs with stellar masses, star formation rates (SFRs), and gas-phase metallicities. http://www.mpa-garching.mpg.de/SDSS/DR7/

a. [8 points] Plot the relation between gas-phase metallicity and stellar mass for galaxies in the SDSS and exclude the galaxies from which the relevant properties could not be measured. What physical processes could be responsible for the observed trend?

b. [8 points] It has been suggested that metallicity is not only correlated with stellar mass, but also with the SFR of a galaxy. On the webpage given above you can find SFR measurements as well. Plot the gas-phase metallicity as a function of SFR. What can you conclude from this figure?

c. [10 points] We know that stellar mass and SFR are well-correlated properties. Assess whether the SFR-metallicity relation just reflects the SFR-mass relation, or whether, independent of stellar mass, metallicity is correlated with SFR.

d. [4 points] What could be the physical explanation of this possible secondary dependence?

Problem 3: Magnitudes, Fluxes and K-corrections [34 points]

In most modern observing programs, astronomers use the AB-magnitude system to indicated the brightness of a galaxy. In this exercise we explore how to go from observed magnitude to flux densities and absolute magnitudes in the rest frame. We will use galaxy SDSS J014207.20-002941.7 (RA=25.53002947, DEC=-0.49493196). On the following webpage you can find the observed magnitudes and redshifts for all galaxies observed with SDSS Data Release 7: http://cas.sdss.org/dr7/en/tools/explore/

a. [2 points] Given the observed magnitude and redshift, what is the absolute (observed-frame) magnitude of this object in the g-band?

b. [8 points] Derive the observed flux densities (F_λ) and corresponding uncertainties in erg s^{-1} cm^{-2} $Angstrom^{-1}$ for all 5 observed bands and plot the observed broad-band spectral energy distribution (SED) of this galaxy. The filter information can be found at http://classic.sdss.org/dr7/instruments/imager/index.html#filters.

c. [4 points] Add the SDSS spectrum of the same galaxy to the figure made in b. The wavelength array information is stored in the header. Does the spectrum overlap with the broadband SED? If not, give an explanation for this offset.

d. [6 points] Show the rest-frame spectrum in comparison with the observed spectrum (both in erg s^{-1} cm^{-2} $Angstrom^{-1}$) in a new figure. Plot the g-band filter response function in the same figure, and explain your choice of response curve.

e. [10 points] As is clear from the figure made in part d, the observed and rest-frame magnitudes will be different. Use the spectrum to calculate the K-correction in the g-band. Please note that the response functions are determined for photon-counting detectors, which means you have to integrate in λF_λ or νF_ν.

f. [4 points] What is absolute rest-frame magnitude of this object in the g-band?

Problem 4: Luminosity and Mass Functions [30 points]

The Schechter luminosity function gives the number of galaxies per luminosity bin.

a. [6 points] In class we wrote the Schechter function as a function of luminosity. Derive the equivalent function in absolution magnitude M.

b. [8 points] Make the following figures, assuming the normalization is unity and taking a range in L/L_* of 10^{-2} to 10 and $\alpha = -1.5, -1.0, -0.5$.
- Log $\Phi(L)$ vs. Log L/L_*
- Log $\Phi(M)$ vs. $M - M_*$
- Log $N(> L)$ vs Log L/L_*

c. [6 points] The distribution of galaxies in terms of stellar mass can also be described by a Schechter function. However, the shape of the luminosity and mass function for the same selection of galaxies will be different. Please explain qualitatively why and how the shape changes when going from a luminosity to a mass function.

d. [10 points] Though low-mass galaxies are much more prevalent, they contain less stellar mass. Consider the stellar mass function Log $\Phi(M_S)$ vs. Log M_S/M_{S*} for $\alpha = -1.5, -1.0, -0.5$, assuming that the normalization is unity and taking a range in M_S/M_{S*} of 10^{-2} to 10. Show in what type of galaxies most of the stellar mass is locked up for the different faint-end slopes by plotting Log $M_S\,\Phi(M_S)$ vs. Log M_S/M_{S*}. (Note: these slopes are for the mass function, not the luminosity function, so do not convert with a mass-to-light ratio.)