Computer Assignment 2

Deadline for the report: **27-10-2023 17:00h**
Upload your report in Assignments on Brightspace

The goal of this assignment is to learn to compute a galaxy stellar mass function (GSMF) starting from a galaxy catalogue with redshift and stellar mass information. There are different methods to compute the GSMF. Here we will focus only on the simplest technique, the so-called $1/V_{\rm max}$ method, which is explained in detail below. This method involves the galaxy count in different stellar mass bins and the computation of the galaxy comoving number density (per unit of cosmic volume) and per unit of logarithmic stellar mass (dex) in each bin.

In this assignment you should compute the GSMF in the redshift bin $z = 2 - 3$.

Your delivery for this assignment should consist of:

- a report of maximum 3 pages (with font size 11 points), summarizing what you did and presenting your plot of the requested GSMF (including both the $1/V_{\rm max}$ points and the Schechter function). Please also state how many galaxies you have in each stellar mass bin of your computed GSMF. Discuss qualitatively : what is the functional form of the obtained plot? Is this what you expect and, if not, why?
- a printout of your computational code(s) to perform the GSMF $1/V_{\rm max}$ calculation (with all the steps). You can use any computational language of your choice.

The steps for this assignment are as follows:

1. Consider the CANDELS GOODS-South galaxy catalogue publicly available at:
https://archive.stsci.edu/missions/hlsp/candels/goods-s/catalogs/v1/
Select the catalogue named:
"hlsp_candels_hst_wfc3_goodss_santini_v1_mass_cat.txt"
and download also the corresponding readme file
"hlsp_candels_hst_wfc3_goodss_santini_v1_readme.txt" for reference.
As you will see, the downloaded catalogue has multiple columns. You will only need: source ID (first column named "Seq"); H_mag; PhotFlag; StarFlag; AGNFlag; zbest; M_med.
2. Clean the catalogue, such that you keep only normal galaxies, with good photometry, in the redshift bin of interest, i.e. $z = 2 - 3$. For this,

use the information in the columns PhotFlag; StarFlag and AGNFlag and zbest. In addition, consider an H-band magnitude limited catalogue at $H = 27$ mag, i.e. you should only keep galaxies with H_mag< 27. For all the galaxies in your clean catalogue keep the H_mag, redshift (zbest) and stellar mass (M_med) information. We will assume that the catalogue is 100% complete up to $H = 27$ mag, which means that we will ignore any necessary completeness correction in the galaxy counting.

3. Once you have a clean catalogue, convert all the stellar mass values in the M_med column into a logarithmic form, i.e. consider $\log_{10}$(M_med). Then bin all your data in stellar mass from $\log_{10}$(M_med)=8.0 to 11.8. The recommended step for the binning is 0.2 dex (constant for simplicity), but you can adapt this value to your consideration, provided that you have at least 10 galaxies in each stellar mass bin, and that you end up with at least 12 stellar mass bins.

4. In principle, to compute the galaxy comoving number density in each stellar mass bin, you simply need to count your galaxies and divide this number by the comoving volume sampled by the CANDELS GOODS-South survey at $z = 2 - 3$. To compute this volume consider that the area of the survey is $\sim 180\,\mathrm{arcmin}^2$. However, the effective volume probed by galaxies which are close to the limiting magnitude might be smaller than the redshift bin volume (because they would not be in the catalogue any more once they are fainter than the limiting magnitude). So each galaxy has to be weighed by a factor $V_{z_{\rm bin}}/V_{z_{\rm max}}$ before counting it for the computation of the comoving number density. The following steps explain how you should compute $z_{\rm max}$ for each source.

5. For each galaxy compute the flux density f_ν associated with its H-band magnitude. Then, always assuming that the stellar mass is M_med, recompute the H-band magnitude that this same galaxy would hypothetically have in different redshift steps between zbest and the maximum redshift of the bin (which is $z = 3$ in this exercise). Consider all redshifts between zbest and $z = 3$ with steps dz=0.1. For simplicity, just assume that $f_\nu(z_1)/f_\nu(z_2) \approx [(1 + z_1)\, d_L^2(z_2)]/[(1 + z_2)\, d_L^2(z_1)]$, i.e. we ignore any necessary k-correction.

6. Identify if there is a redshift at which you reach the catalogue limiting magnitude H=27 mag: this is $z_{\rm max}$ for that galaxy. If the galaxy were still brighter than H=27 mag by redshift $z = 3$, then simply take $V_{z_{\rm max}}$=$V_{z_{\rm bin}}$, i.e. the correction factor described above in point 4 would be 1. If the catalogue limiting magnitude H=27 mag is reached at $z < 3$, then compute the galaxy $V_{z_{\rm max}}$, which is the comoving volume of the Universe between $z = 2$ (lower limit of the redshift bin) and $z_{\rm max}$, with the corresponding area of the galaxy

survey under study. Of course, $V_{z_{\rm max}} \leq V_{z_{\rm bin}}$, so that the correction factor for each galaxy described in step 4 will be ≥ 1. Provide a list with the number of galaxies in each bin after applying the $V_{z_{\rm max}}$ correction.

7. With the correct weight factor for each galaxy, perform the comoving number density calculation explained in point 4 (for each stellar mass bin). Remember to divide each of these values by the size of your stellar mass bin (e.g. 0.2 dex) to make sure that you obtain the GSMF in the right units, which should be $\mathrm{Mpc}^{-3}\,\mathrm{dex}^{-1}$.

8. Compute error bars for each of your $1/V_{\rm max}$ data points, only considering Poisson errors.

Note: to compute comoving volumes, assume a flat cosmology with $H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_{\rm M} = 0.3$ and $\Omega_\Lambda = 0.7$.