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Topic 4: Luminosity Functions

(1) The Schechter Function :

Lets evaluate some basic properties arising from the Schechter Luminosity function of galaxies. First, the function reads :

$$\Phi(L) dL = n_* \left(\frac{L}{L_*} \right)^\alpha \exp \left(-\frac{L}{L_*} \right) d \left(\frac{L}{L_*} \right)$$

1. Considering just the low luminosity galaxies $L \ll L_*$, show that for $-2 < \alpha < -1$, the total number of galaxies is infinite but the total light is not.
2. Derive an expression for the "mid-rank" galaxy luminosity, L_{mid} , such that half the light comes from galaxies with $L > L_{\text{mid}}$ and half comes from galaxies with $L < L_{\text{mid}}$. What is L_{mid} for $\alpha = -1$?
3. Transform the Schechter luminosity function expressed in L to an equivalent function expressed in M , absolute magnitude (dont just copy the formula given in B&M, but show how it comes about).
4. Using whatever computing environment you prefer, generate plots of the following related LFs :
 - (a) $\text{Log } \Phi(L)$ vs $\text{Log } L/L_*$
 - (b) $\text{Log } \Phi(M)$ vs $M - M_*$
 - (c) $\text{Log } N(>L)$ vs $\text{Log } L/L_*$
 - (d) $\text{Log } N(< M)$ vs $M - M_*$

where the second two are *cumulative* functions integrated over L or M to **brighter** galaxies. Take the normalization n_* to be unity; take the range in L/L_* to be from 10^{-2} to 10 ; and overplot lines with three values of α : -1.5 , -1.0 , -0.5 (dotted, solid, dashed). Be careful to account for the fact that graph (a) expresses Φ per unit interval of luminosity (dL), while graph (b) expresses Φ per magnitude (dM , which is an interval in $\text{Log } L$). Also, note that graphs

(c) and (d) are **not** expressed per interval, but are integrated, and so they should look the same (excluding, possibly, the direction of the x-axis).

Summarize, briefly, the various features you see in the plots and their differences.

(2) Application to the Coma Cluster :

The Coma cluster of galaxies has a luminosity function which is moderately well represented by the Schechter function, with $\alpha = -1$ and $M_{B, \star} = -19.2$ ($H_0 = 100$ km/s/Mpc). The redshift of Coma is 7000 km/s and its total luminosity is about $250 L_{\star}$.

1. How would α and $M_{B, \star}$ change if $H_0 = 50$ km/s/Mpc ?
2. What is L_{\star} (in solar luminosity units) corresponding to $M_{B, \star}$ in these two cases (use $M_{B, \odot} = 5.48$)
3. Estimate how many galaxies are brighter than L_{\star} , $0.1 L_{\star}$ and $0.01 L_{\star}$.
4. Estimate the expected luminosity of the brightest galaxy, L_1 , by setting L_1 equal to the total luminosity expected from the luminosity function in galaxies brighter than L_1 . Express L_1 in units of L_{\star} and as an apparent magnitude.

Compare the latter with the observed apparent magnitude ($B_T^{0,i}$) for the brightest Coma galaxy, NGC 4889. Comment on any difference you find between the two magnitudes.

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