The Galaxy luminosity function

The luminosities of galaxies span a very wide range - most luminous ellipticals are 10^7 more luminous than faintest dwarfs.

Luminosity function, $\Phi(L)$, describes the relative number of galaxies of different luminosities.

Definition: If we count galaxies in a representative volume of the Universe, $\Phi(L)dL$ is the number of galaxies with luminosities between L and L + dL.

Identical to the definition of the stellar luminosity function.

Luminosity functions are easiest to measure in clusters of galaxies, where all the galaxies have the same distance

The Schecter luminosity function

A convenient approximation to the luminosity function was suggested by Paul Schecter in 1976:

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

In this expression:

- n_* is a normalization factor which defines the overall density of galaxies (number per cubic Mpc)
- L_* is a characteristic galaxy luminosity. An L_* galaxy is a bright galaxy, roughly comparable in luminosity to the Milky Way. A galaxy with $L < 0.1\ L_*$ is a dwarf.
- α defines the `faint-end slope' of the luminosity function. α is typically negative, implying large numbers of galaxies with low luminosities.

The Schecter luminosity function

The Schecter function is:

- a fitting formula that does not distinguish between galaxy types
- as with the stellar mass function, parameters must be determined observationally:

Illustrative numbers

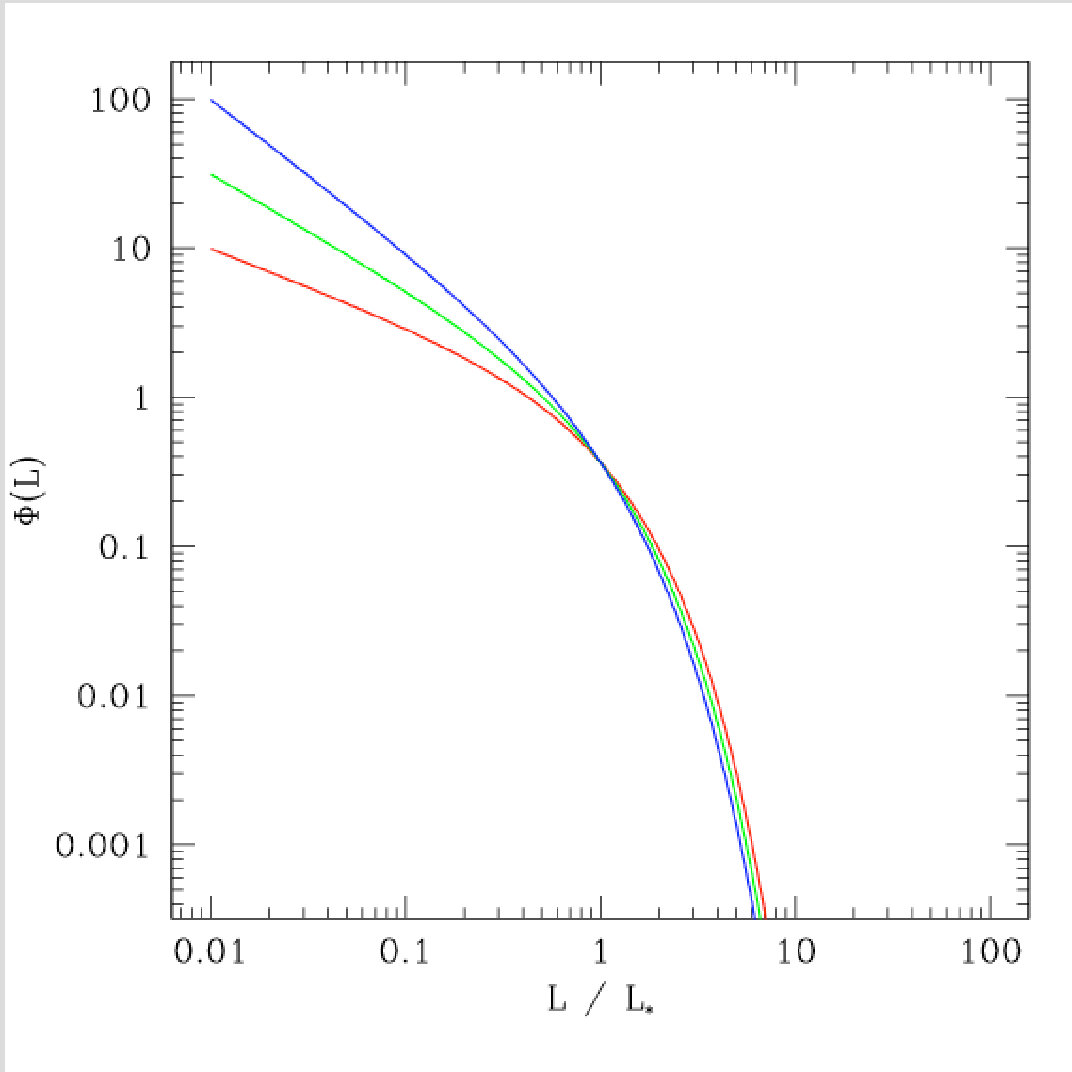
$n_* = 8 \times 10^{-3}$ Mpc^{-3} - related to mean galaxy density

$L_* = 1.4 \times 10^{10}$ L_{sun} - luminosity of galaxies that dominate light output

$\alpha = -0.7$ - lots of faint galaxies

…where $L_{sun} = 3.9 \times 10^{33}$ erg s^{-1} is the Solar luminosity.

The Schecter function plotted for different faint-end slopes, α = -0.5 (red), α = -0.75 (green), α = -1 (blue):



Properties of the Schecter luminosity function

The total number of galaxies per unit volume with luminosity greater than L is:

$$n = \int_L \phi(L)\,dL$$

This integral is not expressible in terms of elementary functions :-(

If α < -1, n diverges as L tends toward zero.
Obviously unphysical, so Schecter law must fail for very low luminosity galaxies (or have a larger alpha).

The luminosity density (units Solar luminosities per cubic Megaparsec) is given by:

$$\int_L \phi(L) L\,dL$$

Dominated by galaxies with $L \sim L_*$ for typical value of α.

Mass function of galaxies

For stars, measurements of the luminosity function can be used to derive the Initial Mass Function (IMF).

For galaxies, this is more difficult:

- Mass to light ratio (M/L) of the **stellar** population depends upon the star formation history of the galaxy.
- Image of the galaxy tells us nothing about the amount and distribution of the dark matter.

More difficult measurements are needed to try and get at the mass function of galaxies.