The Galaxy Population

Luminosity & Stellar mass
Halo mass & Star formation history

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Galaxy distributions

In general, we can mathematically describe the distribution of a galaxy population as

$$dn = \phi(G_1, G_2, \ldots)\, dG_1\, dG_2 \ldots$$

In astrophysics, our goal is to observationally determine ϕ and understand the origin of its form from physical principles.

Because galaxies form and evolve within dark matter halos, the properties of the galaxy population are linked to the properties of the dark matter halo population.

We can write the distribution function of galaxies with a property G_i as

$$P(G_i) = \int P(G_i|H_i)P(H_i)\, dH_i$$

For example, the luminosity function

$$\phi(L) = \int \Phi(L|M)n(M)\, dM$$

Centrals v. satellites

When studying the galaxy population, we often need to consider central galaxies separate from the satellite galaxies.

Central galaxies are located at the potential minima of their halo, and they formed with their halo.

Satellite galaxies are central galaxies within their own halo, but their halos have become incorporated into another (much larger) halo.

A central galaxy's properties should be strongly correlated with its halo properties, since they formed together. We would not expect a similar correlation between a satellite galaxy and the larger halo that it is in. For satellites,

$$P_s(G_i|H_i) = \iint P(G_i|G_a)P_c(G_a|H_a)P(H_a|H_i)\, dH_a\, dG_a$$

Galaxy luminosity function

The galaxy luminosity function, $\phi(L)$, is defined so that

$$dn(L) = \phi(L)\, dL$$

To construct the luminosity function from a magnitude-limited survey, the number counts need to be normalized by the volume within which a galaxy of a given luminosity can be observed.

Magnitude-limited surveys

A **magnitude-limited survey** contains all galaxies within some patch of the sky that have apparent magnitudes brighter than some $m_{\rm lim}$.

Recall that

$$M = m - 5\log\left(\frac{d_L(z)}{\rm Mpc}\right) - 25 - K(z)$$

By definition,

$$2.5\log\left(\frac{L}{L_\odot}\right) = M_\odot - M$$

In a magnitude-limited sample, a galaxy with luminosity L will only be part of the survey if it is within the maximum luminosity distance $d_{\rm max}$ (corresponding to $z_{\rm max}$) where

$$5\log\left(\frac{d_{\rm max}(L)}{\rm Mpc}\right) = m_{\rm lim} - M_\odot - 25 + 2.5\log\left(\frac{L}{L_\odot}\right) - K(z_{\rm max})$$

Magnitude-limited surveys

For a magnitude-limited sample, within some solid angle Ω, we expect that the number of galaxies with luminosity L to be

$$dN = \phi(L) V_{\text{max}}(L)\, dL$$

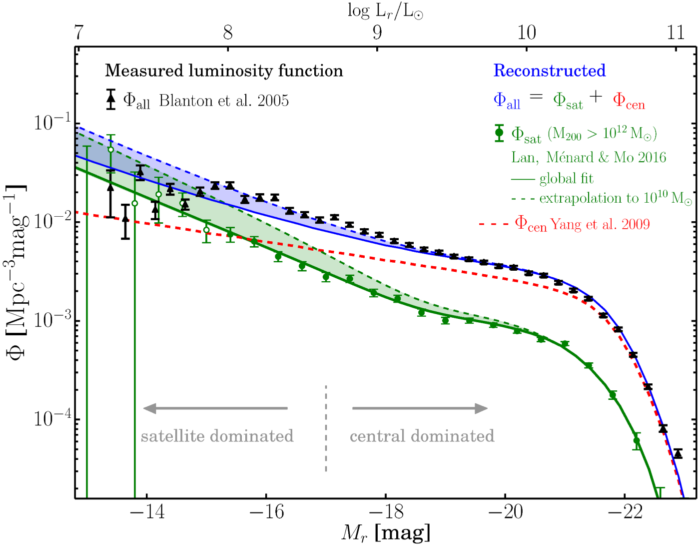
so that

$$\phi(L)\, dL = \frac{dN}{V_{\text{max}}(L)} = \sum_i \frac{1}{V_{\text{max}}(L_i)}$$

Normally, we represent the luminosity function by the Schechter function,

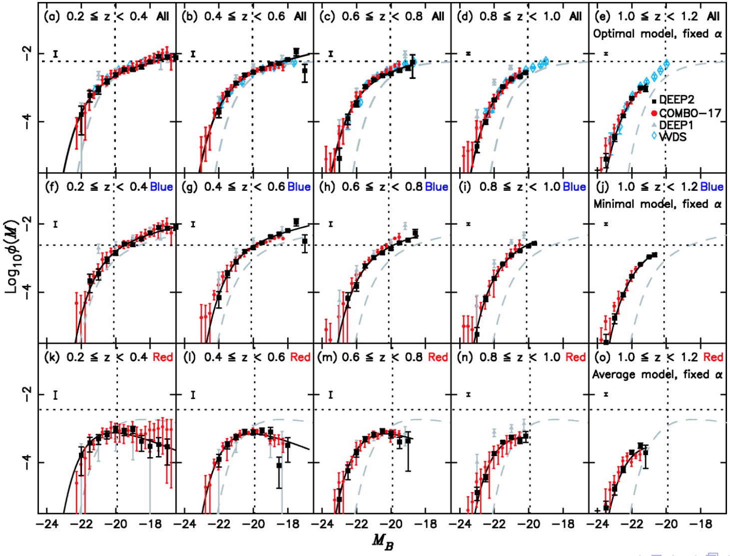
$$\phi(L)\, dL = \phi^* \left(\frac{L}{L_*} \right)^{\alpha} e^{-L/L_*} \frac{dL}{L_*}$$

Observed luminosity function

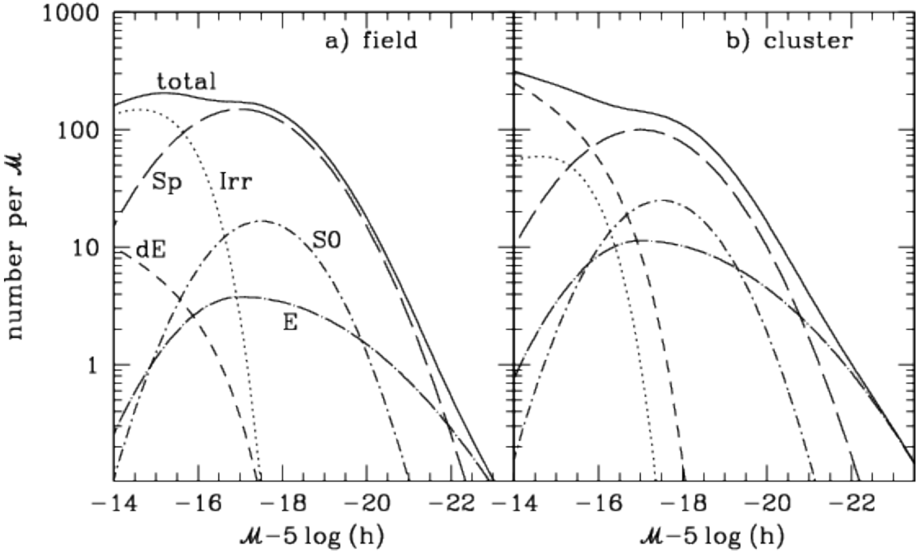


Lan, Ménard, & Mo (2016)

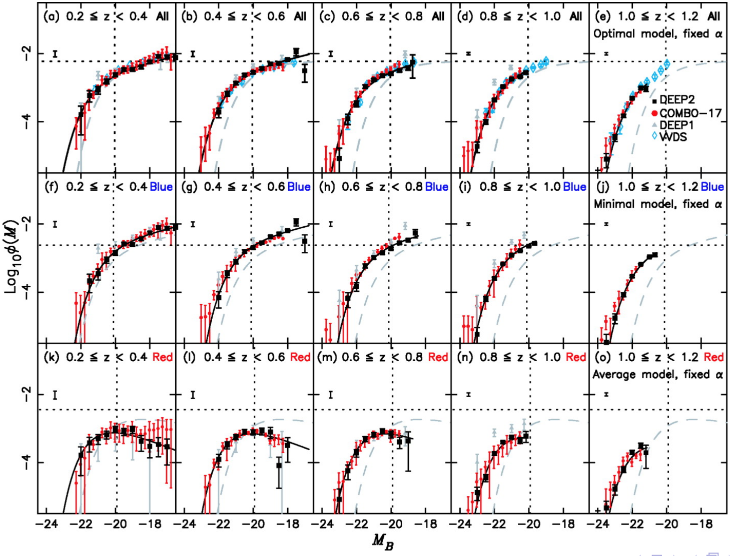
Dependence of luminosity function on galaxy color



Dependence of luminosity function on galaxy morphology



Redshift evolution of the luminosity function



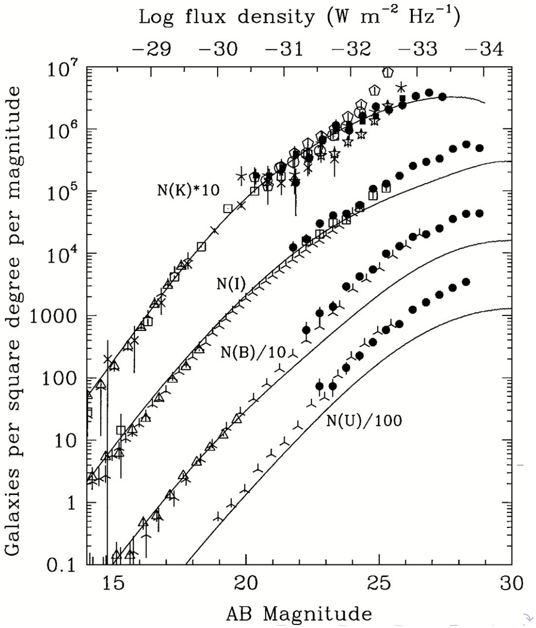
Counting galaxies

Define the number count, $\mathcal{N}(m)$, as the number of galaxies per unit apparent magnitude per unit solid angle:

$$d^2N(m) = \mathcal{N}(m)\, dm\, d\Omega$$

For a non-evolving population in a non-expanding Euclidian space,

$$N(< m) \propto f_m^{-3/2} \propto 10^{0.6m}$$



Cosmic star formation history