The Galaxy Population

Star formation history
Environmental dependence & Simulations

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The galaxy luminosity function

To see the explicit relationship between halo mass and luminosity, we can write the galaxy luminosity function as

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

The mass function of the halos can be approximated by the Press-Schechter function,

$$n(M)\,dM = \frac{\bar{\rho}}{M} f_{\rm PS} \left[\frac{\sigma(M^*)}{\sigma(M)}\right] \frac{dM}{M}$$

where

$$f_{\rm PS} = \sqrt{\frac{2}{\pi}} \left(1 + \frac{n}{3}\right) x^{(n+3)/6} \exp\left[-\frac{1}{2} x^{(n+3)/3}\right]$$

and $x \equiv M/M^*$ with $n \sim 2$.

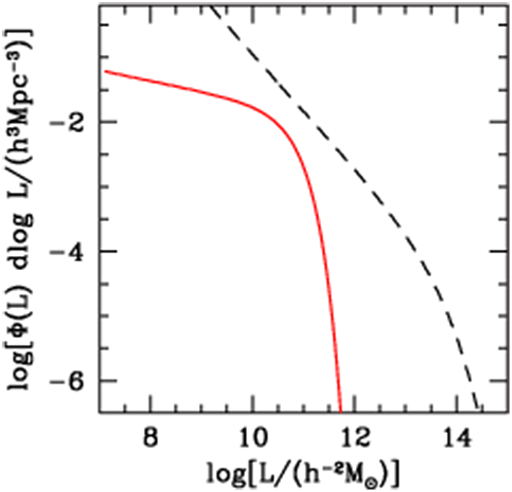
Relating the halo mass to the luminosity

It is simplest to assume that the total luminosity of a galaxy is directly proportional to its halo mass,

$$L = \frac{\varepsilon_{\rm SF}}{\Upsilon_*} M_{\rm baryon}$$

As seen on the right, $\varepsilon_{\rm SF} = \Upsilon_* = 1$ (black dashed line) predicts higher luminosities at all halo masses than what is observed (red solid line), so $\varepsilon_{\rm SF}/\Upsilon_* \ll 1$.

In addition, the shape does not match, so the halo mass must depend on $\varepsilon_{\rm SF}$ and/or Υ_*.

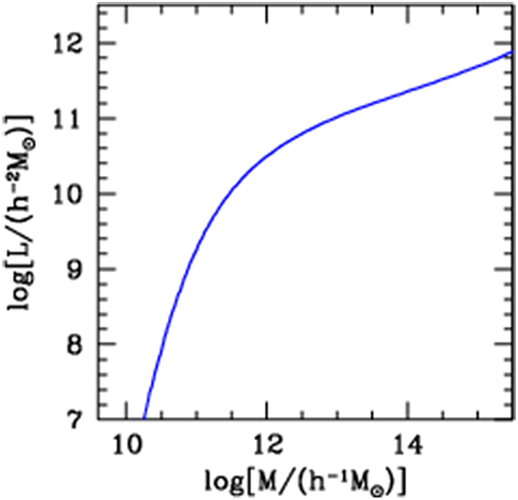


Relating the halo mass to the luminosity

The blue curve on the right is the result of matching the observed number densities $n(M)$ and $n(L)$ assuming a monotonic relationship between L and M.

$$\frac{\varepsilon_{\rm SF}}{\Upsilon_*} \propto \frac{L}{M} \propto M$$

$\varepsilon_{\rm SF}/\Upsilon_*$ is largest at $\sim 10^{12}$ Mpc$/h$.



Luminosity function of central galaxies

We can approximate the average number of galaxies with luminosity L in a halo of mass M as

$$\Phi(L|M) = \delta[L - L_c(M)]$$

Assuming that

$$L_c = L_0 \frac{X_L^\beta}{1 + X_L^{\beta-\gamma}}$$

with $0 < \gamma < \beta$, $X_L \equiv M/M_L$, and

$$L_c \propto \begin{cases} M^\beta & \text{for } M \ll M_L \\ M^\gamma & \text{for } M \gg M_L \end{cases}$$

Luminosity function of central galaxies

We find that the luminosity function for central galaxies is

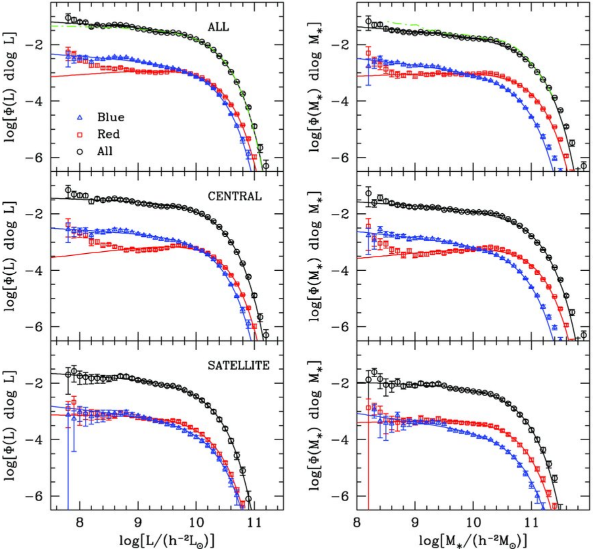
$$L\phi_c(L) = \frac{\bar{\rho}}{\eta M^*}\sqrt{\frac{2}{\pi}}\left(1+\frac{n}{3}\right)\left(\frac{L}{L^*_\eta}\right)^{(n-3)/6\eta} \exp\left[-\frac{1}{2}\left(\frac{L}{L^*_\eta}\right)^{(n+3)/3\eta}\right]$$

where $L^*_\eta = L_0(M^*/M_L)^\eta$ and

$$\eta = \begin{cases} \beta & \text{for } M \ll M_L \\ \gamma & \text{for } M \gg M_L \end{cases}$$

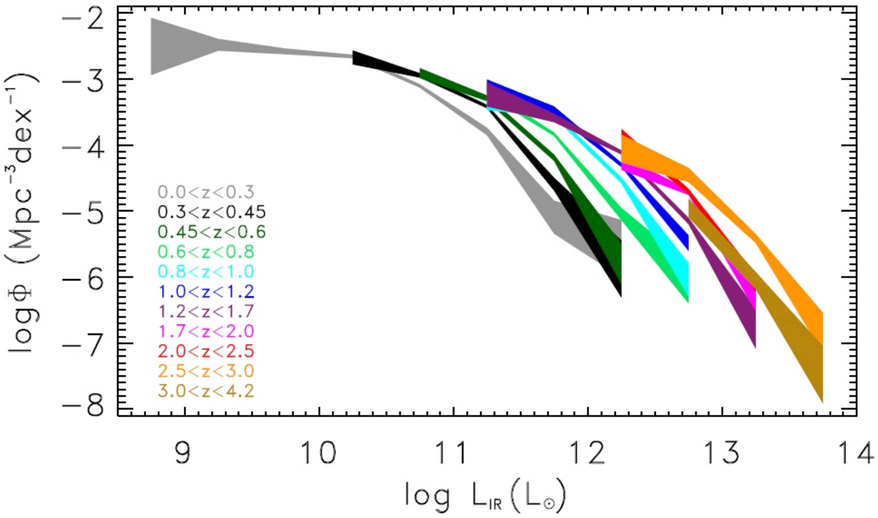
For $n = -2$, the faint-end slope is then predicted to be $\alpha \sim -1 - 5/6\beta$.

Luminosity function of central galaxies



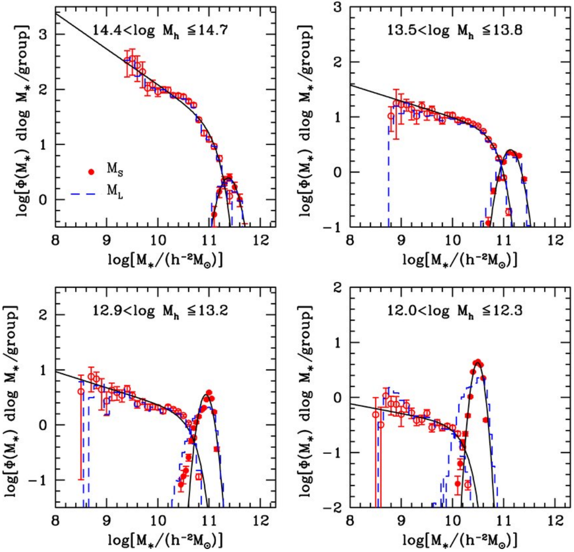
Yang et al. (2009)

Redshift evolution of the luminosity function



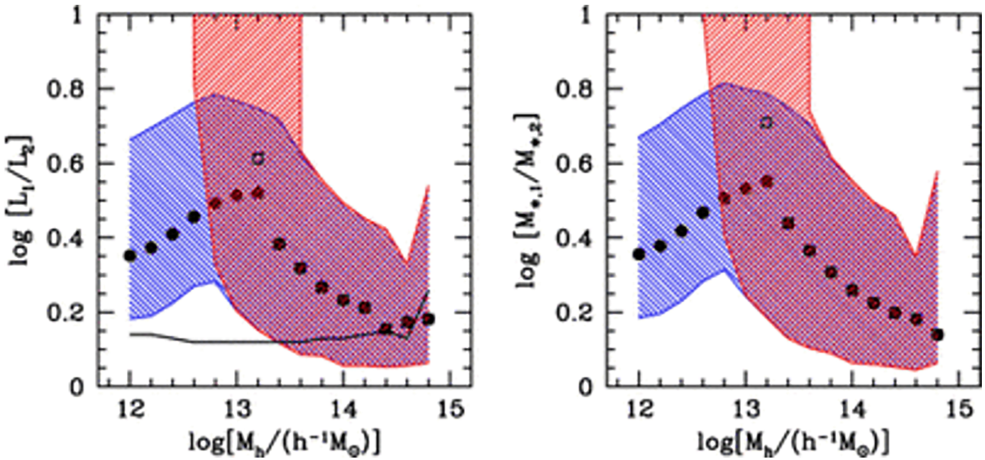
Gruppioni et al. (2013)

Luminosity function of satellite galaxies



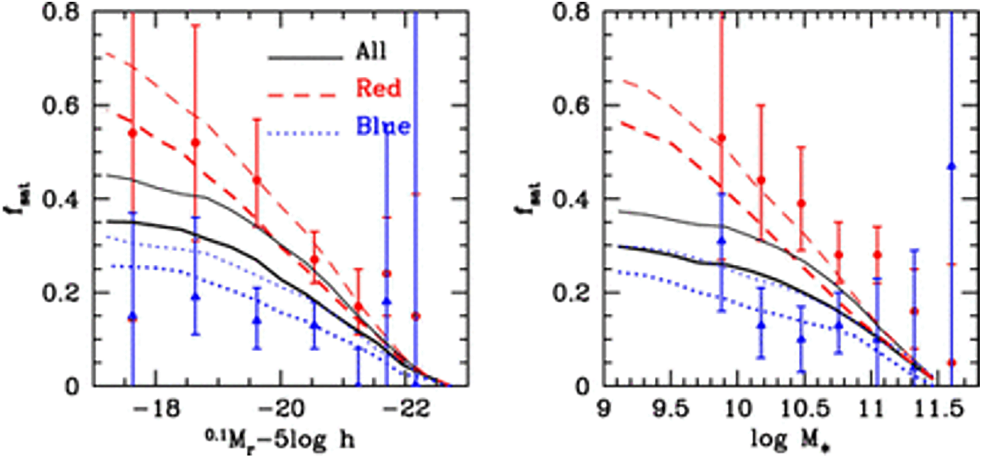
Yang et al. (2009)

The luminosity gap



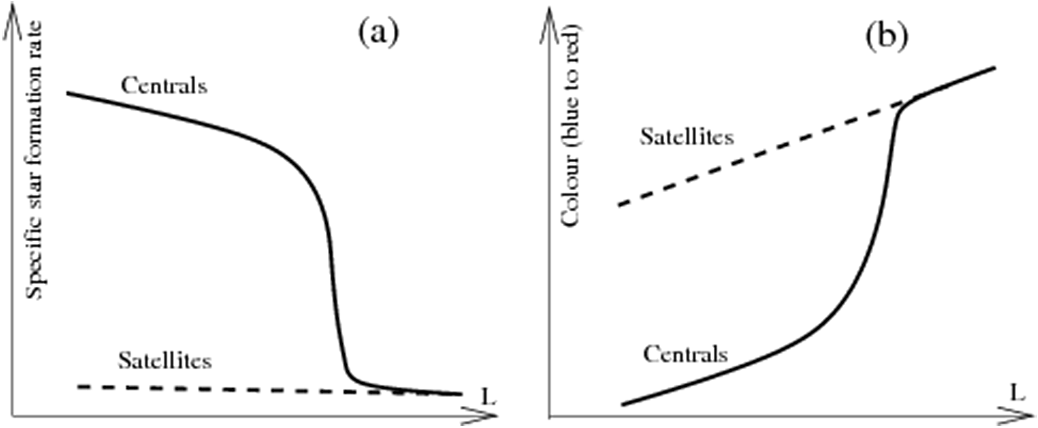
Yang et al. (2008)

The fraction of satellite galaxies

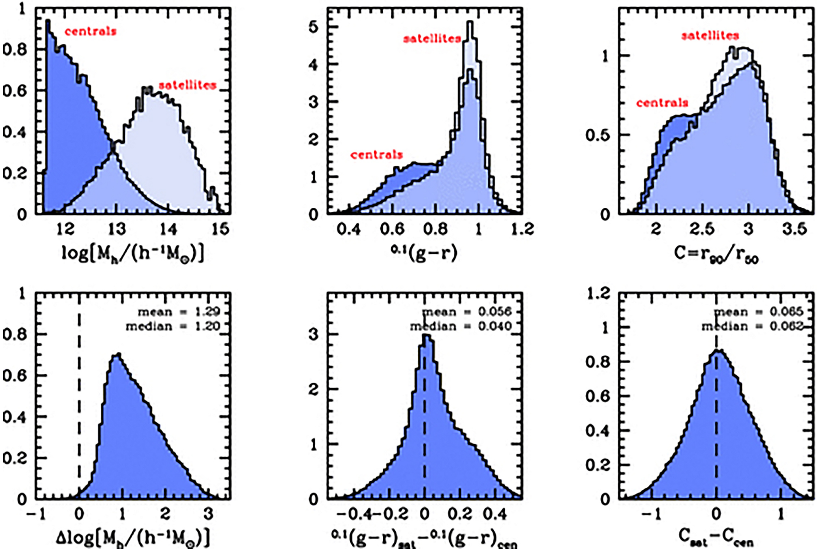


Yang et al. (2008)

sSFR and color as functions of luminosity

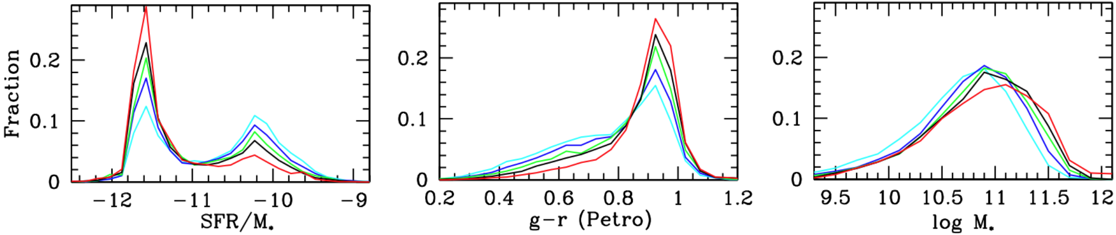


Differences between centrals and satellites



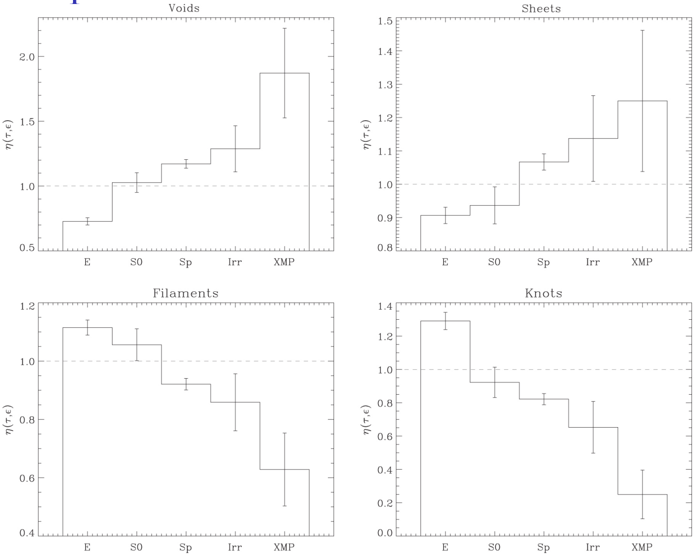
van den Bosch et al. (2008)

Environmental dependence



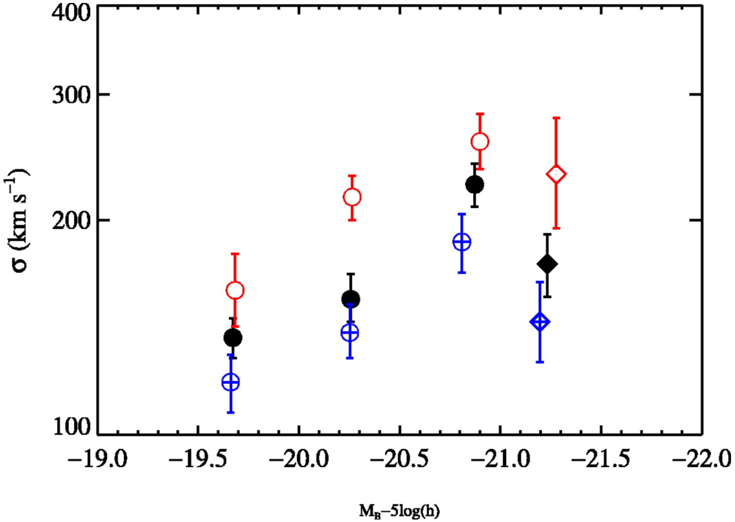
Kauffmann et al (2004) - Colors correspond to galaxy density: red being the highest, and cyan being the lowest.

Environmental dependence



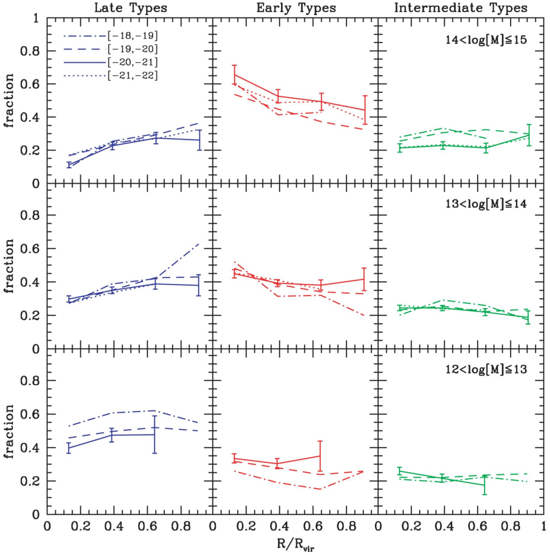
Filho et al. (2015)

Central galaxies on small scales



Conroy et al. (2007)

Satellite galaxies on small scales



Weinmann et al. (2006)

Effects on large scales