

Galaxies & Large-scale structure

The CMB & the homogeneous and isotropic universe

- Clusters of galaxies
- Galaxies at high redshifts
- 2-pt correlation functions

- Probing the matter distribution using weak lensing
- The CMB, Measuring cosmological parameters
- The mass and energy content of the universe

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University of Rochester

cD galaxies

A2261-BCG



Galaxy cluster mass

Estimated from the virial theorem:

$$M = A \frac{\sigma_{\text{los}}^2 R_{\text{cl}}}{G} \sim 10^{15} M_{\odot}/h$$

where

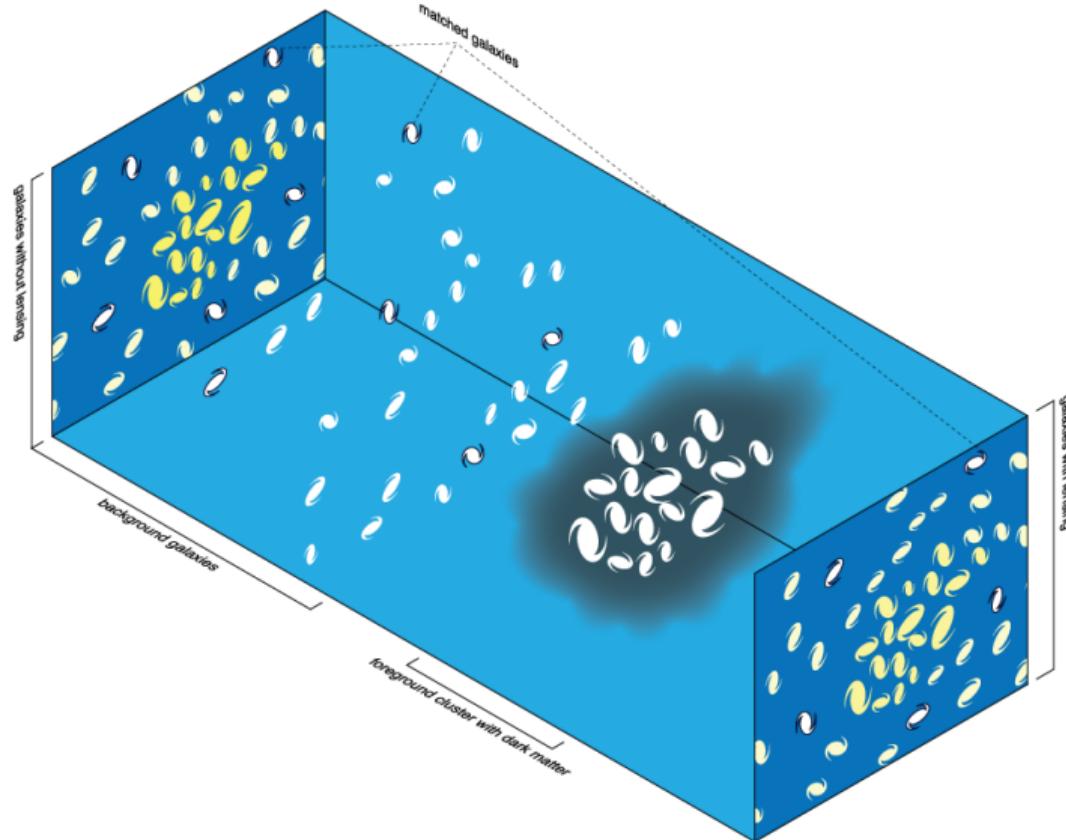
R_{cl} \equiv cluster radius

A depends on density profile and definition of R_{cl}

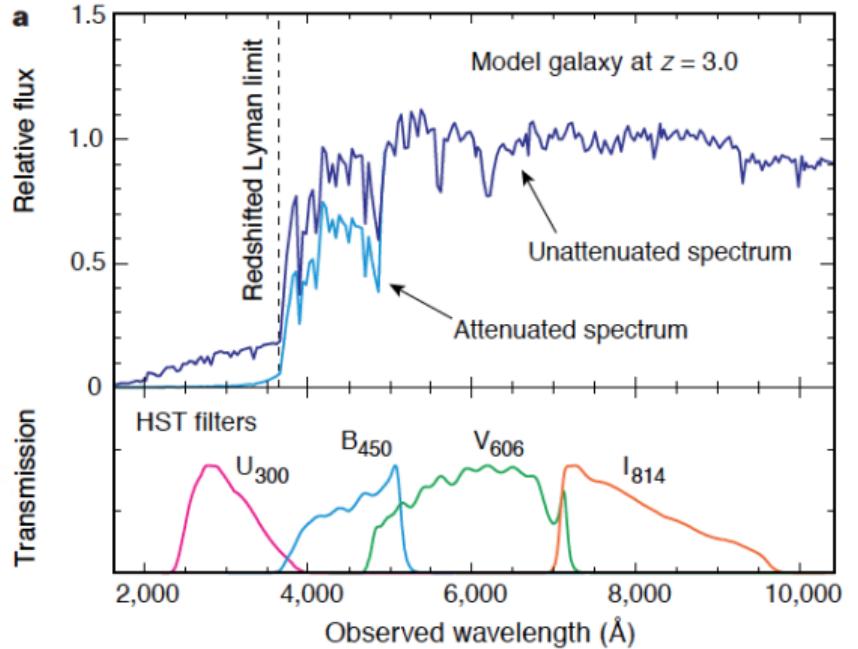
Resulting mass-to-light ratio:

$$\left(\frac{M}{L_B} \right)_{\text{cl}} \sim 350h \left(\frac{M_{\odot}}{L_{\odot}} \right)_B$$

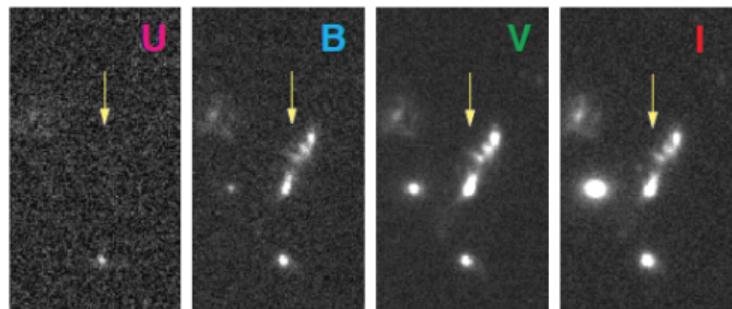
Gravitational lensing



Lyman-break galaxies



b



Star formation rate through time

Measure total gas mass converted into stars per unit time per unit volume at redshift z :

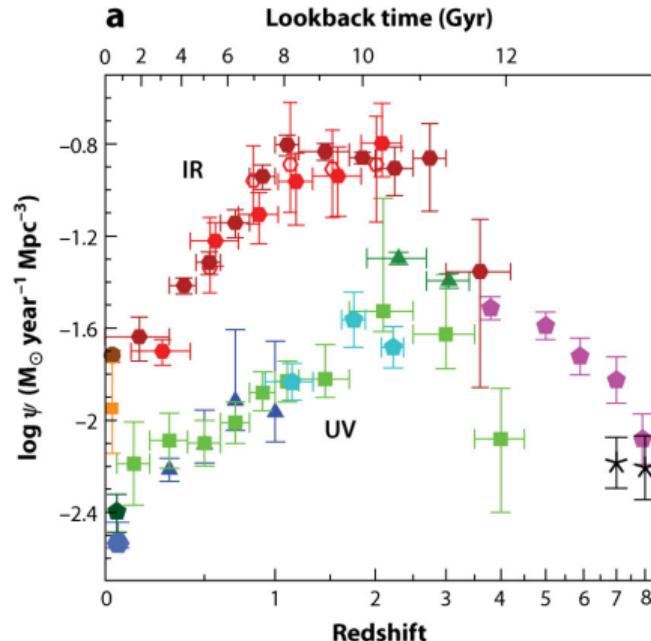
$$\begin{aligned}\dot{\rho}_*(z) &= \int d\dot{M}_* \dot{M}_* \int P(\dot{M}_*|L, z) \phi(L, z) dL \\ &= \int \langle \dot{M}_* \rangle(L, z) \phi(L, z) dL\end{aligned}$$

where

$P(\dot{M}_*|L, z) d\dot{M}_*$ ≡ probability for galaxy with luminosity L at redshift z to have SFR in range $(\dot{M}_*, \dot{M}_* + d\dot{M}_*)$

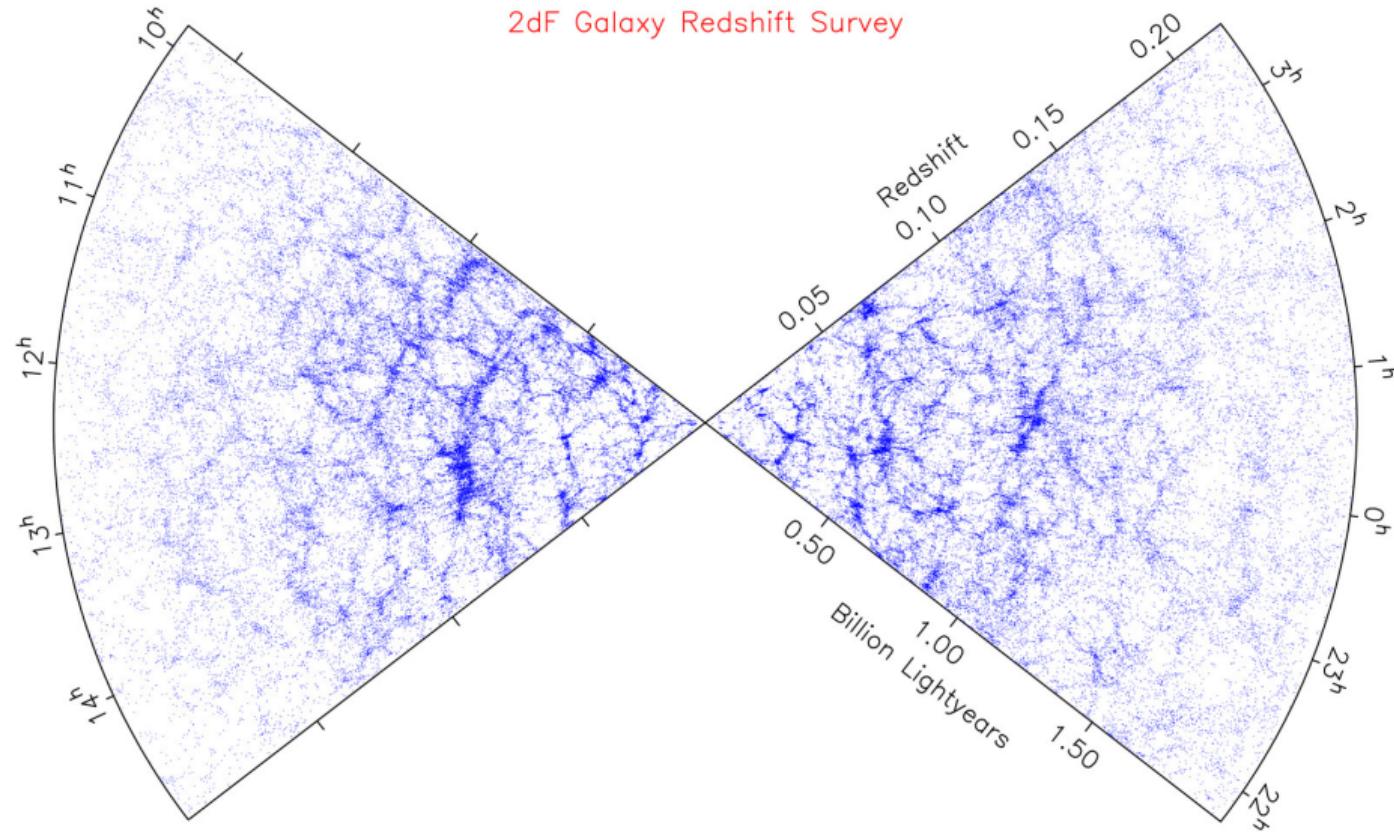
$\langle \dot{M}_* \rangle(L, z)$ ≡ mean SFR for galaxies with luminosity L at redshift z

$\phi(L, z)$ ≡ luminosity function



 Madau P, Dickinson M. 2014.
Annu. Rev. Astron. Astrophys. 52:415–86

The cosmic web



2-point correlation function

$$\xi(r) = \frac{DD(r)\Delta r}{RR(r)\Delta r} - 1$$

where

$DD(r)\Delta r \equiv$ number of galaxy pairs with separation $r \pm \frac{\Delta r}{2}$

$RR(r)\Delta r \equiv$ number of randomly-distributed galaxy pairs with separations $r \pm \frac{\Delta r}{2}$

On small scales ($r \lesssim 10 \text{ Mpc}/h$),

$\xi(r) = \left(\frac{r}{r_0}\right)^{-\gamma}$, where $\gamma \sim 1.8$ and $r_0 \sim 5 \text{ Mpc}/h$.

