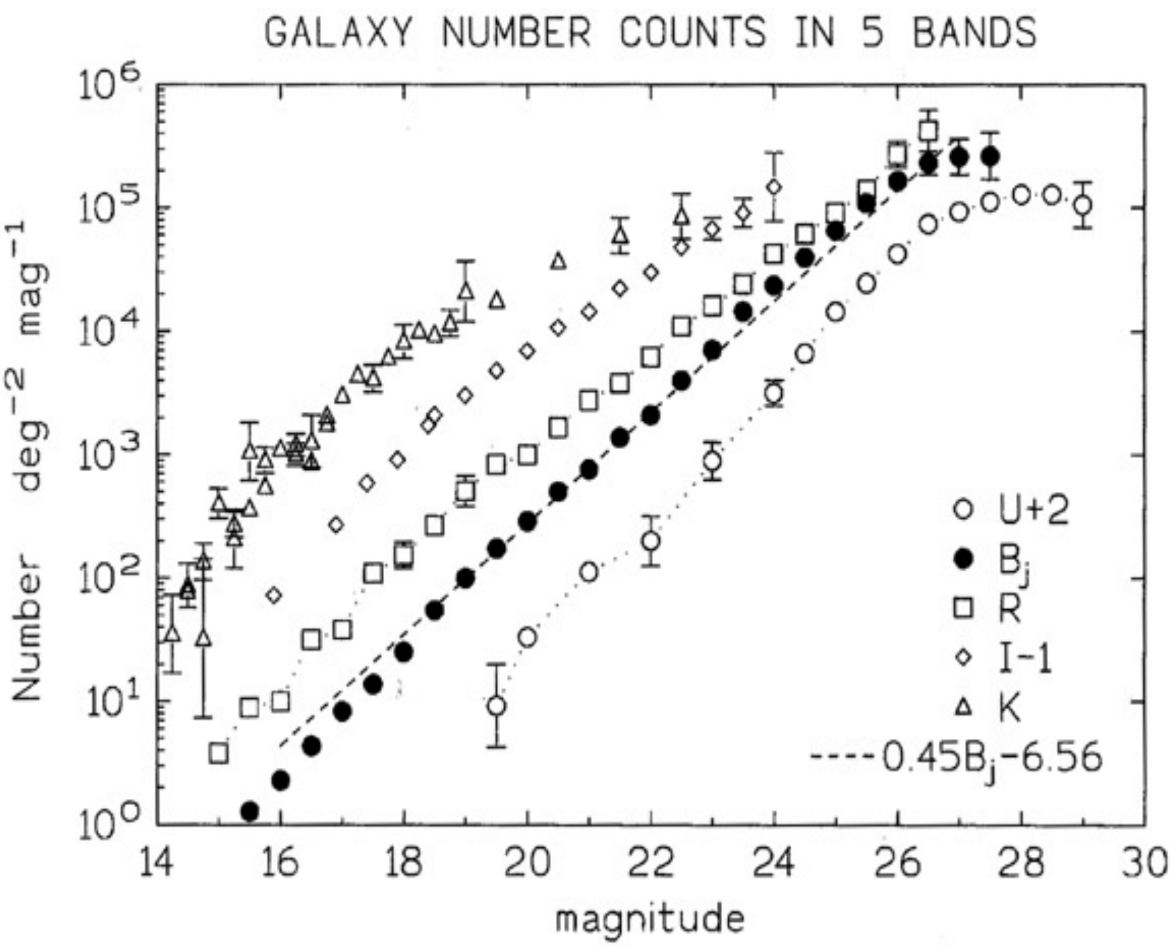
Source Counts:
A Proxy for the Volume-Redshift Test

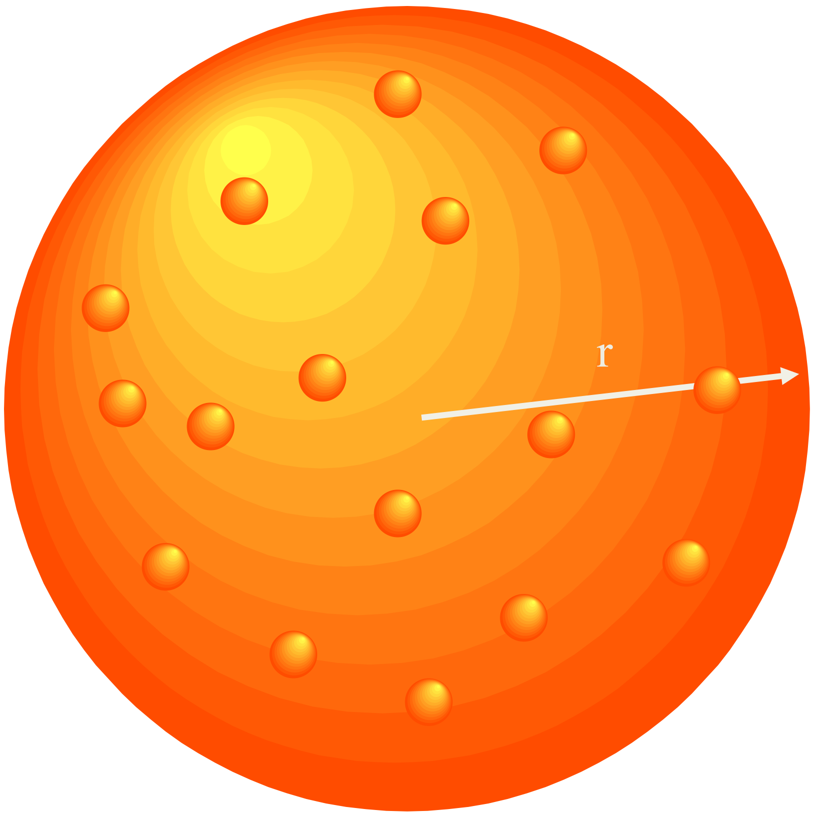


The Number Counts

- Essentially a volume vs. redshift test in disguise; use luminosity distance as a proxy for redshifts
- If one can measure lots of reshifts (expensive!), one could also do a more direct test of source counts per unit comoving volume, as a *f(z)*
- Usually assume that the comoving number density of sources being counted is non-evolving (aha!)
- In radio astronomy, done as a source counts as a function of limiting flux; in optical-IR astronomy, as galaxy counts as a *f*(magnitude)
- Nowadays, the evolution effect, flux limits, etc., are included in modeling predicted counts, which are then compared with the observations

Euclidean Number Counts

Assume a class of objects with luminosities L, which down to some limiting flux f are visible out to a distance r. Then, the observed number N is:



$$N \propto V \qquad V \propto r^3 \qquad \Rightarrow N \propto r^3$$

Since the flux f follows the inverse square law,

$$f \propto \frac{1}{r^2}$$

$$r^3 \propto f^{-3/2}$$

Thus we have: $\boxed{N \propto f^{-3/2}}$

Euclidean Number Counts

We can generalize this to multiple populations of sources, e.g., sources with different intrinsic luminosities. They all behave in the same way:

$$N = N_{0,1} f^{-3/2} + N_{0,2} f^{-3/2} + \cdots$$

So again:

$$N = f^{-3/2} \sum N_{0,i}$$

To get the ***differential counts*** (e.g., per unit magnitude):

$$\frac{dN}{df} \propto -\frac{3}{2} f^{-5/2}$$

Since

$$d \ln N = -\frac{3}{2} d \ln f$$

we get:

$$\boxed{\frac{d \ln N}{d \ln f} = -\frac{3}{2}}$$

Cosmological Number Counts

In relativistic cosmological models, the volume element is generally:

$$dV = \frac{R^3 r^2 dr d\varphi}{\left(1 - kr^2\right)^{1/2}}$$

So the count of sources out to some distance r_0 is:

$$N = \int n dV = \int n_0 R_0^3 \frac{r^2 dr d\varphi}{\left(1 - kr^2\right)^{1/2}} = 4\pi n_0 R_0^3 \int_0^{r_0} \frac{r^2 dr}{\left(1 - kr^2\right)^{1/2}}$$

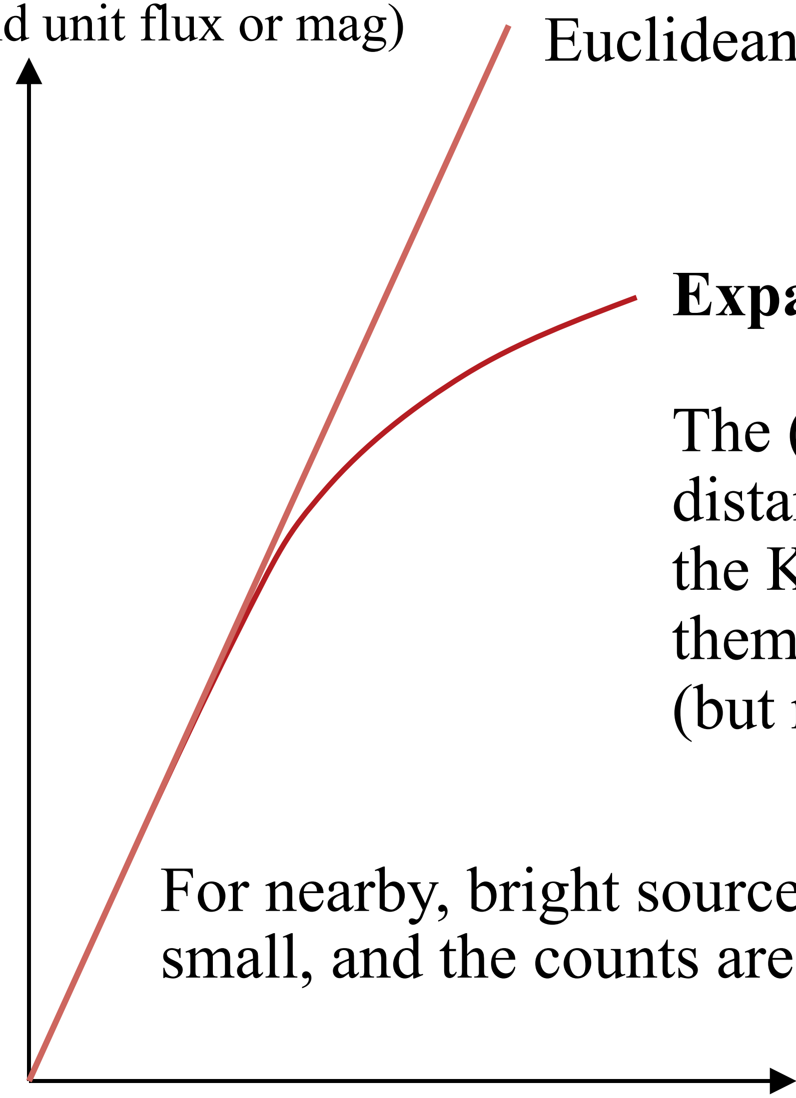
Since their fluxes are: $f = L / (4\, \pi\, D_L^{\,2})$

➞ Both N and f depend on cosmology!

As it turns out, all matter-dominated, P = 0 models have

$$\frac{d \ln N}{d \ln f} > -\frac{3}{2}$$

Source Counts: The Effect of the Expansion

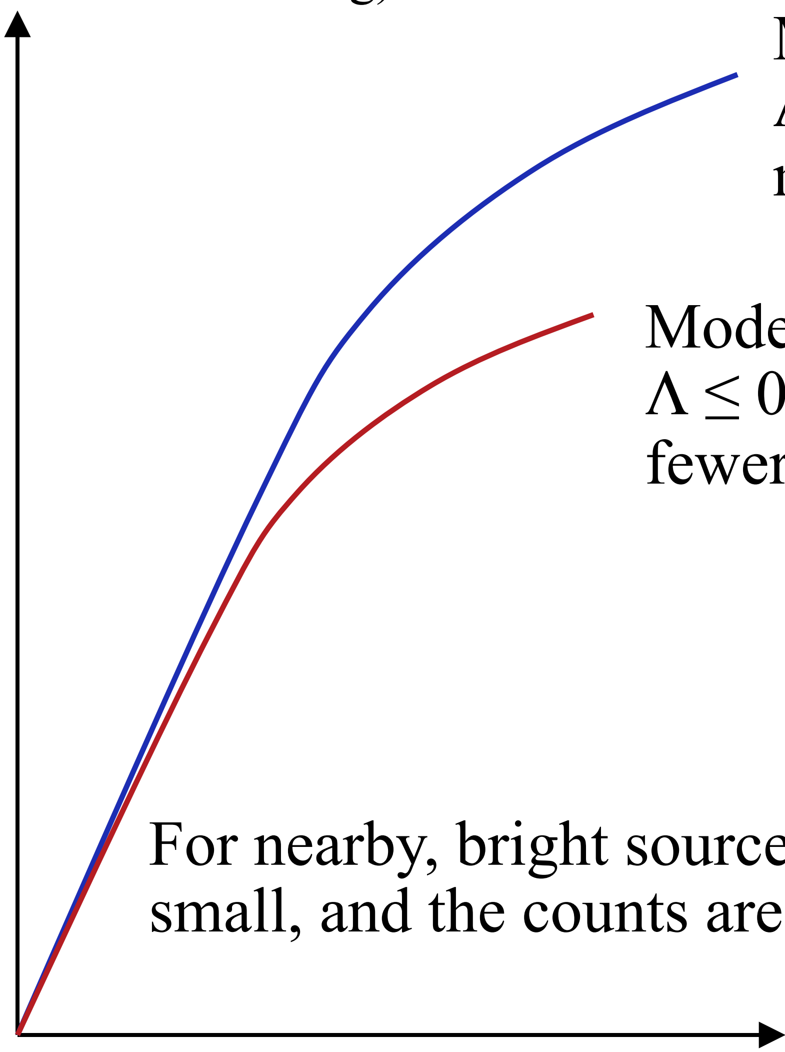


The $(1+z)^2$ factor in D_L makes more distant sources fainter, and the K-correction also tends to make them dimmer (but not always - e.g., in sub-mm)

For nearby, bright sources, these effects are small, and the counts are close to Euclidean

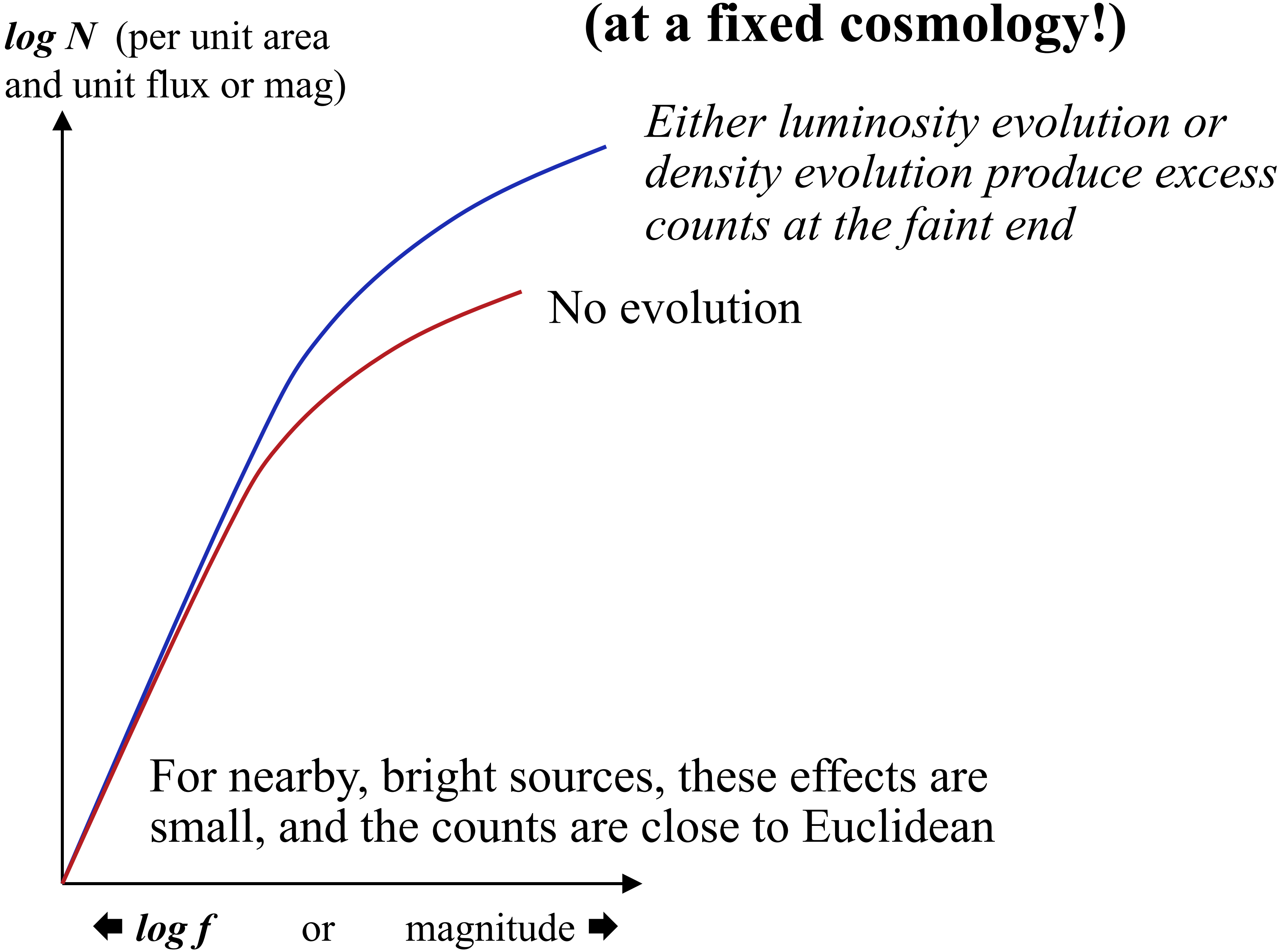
Source Counts: The Effect of Cosmology

(with no evolution!)



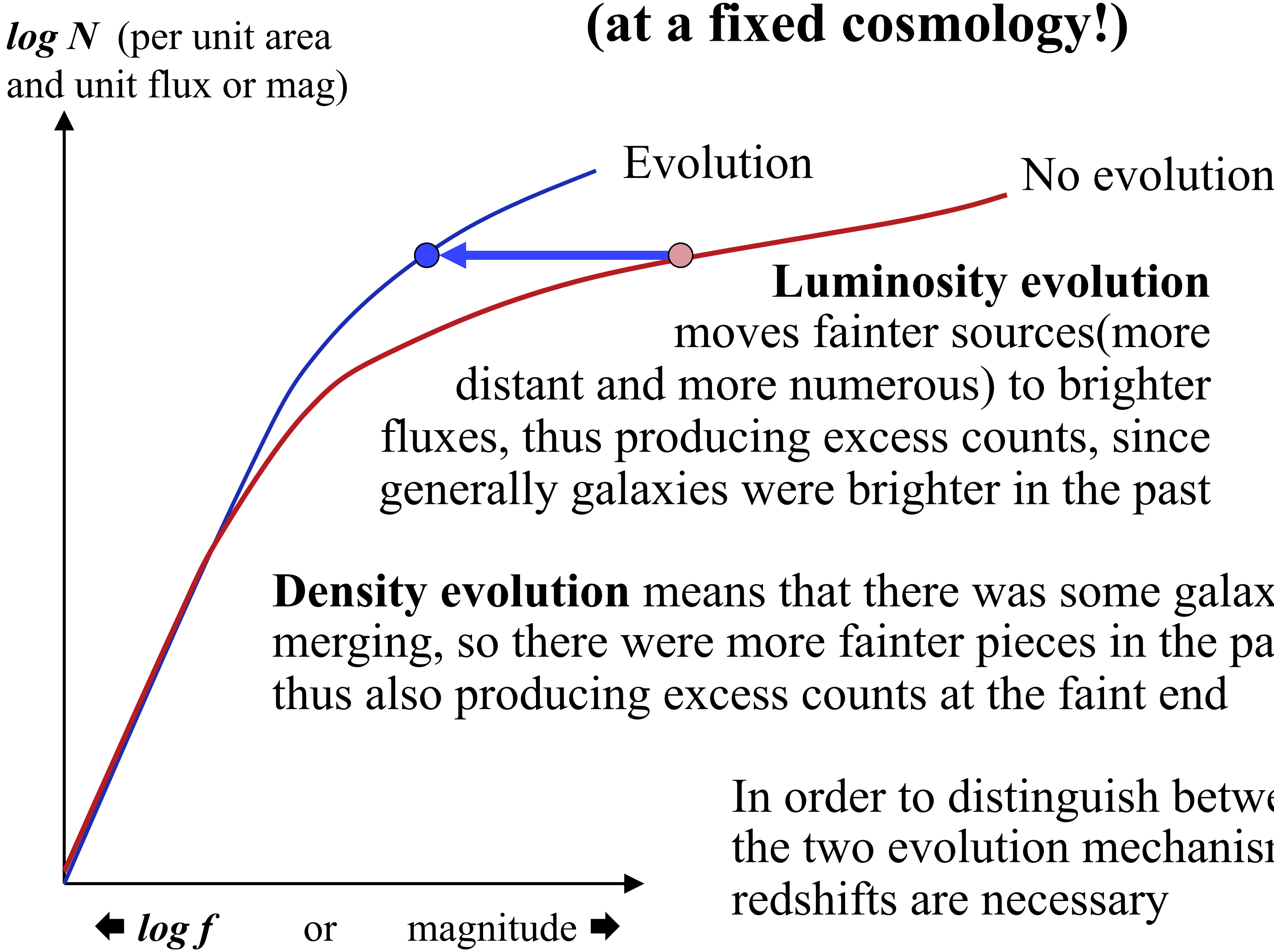
Source Counts: The Effect of Evolution

(at a fixed cosmology!)



Source Counts: The Effect of Evolution

(at a fixed cosmology!)



Luminosity evolution moves fainter sources(more distant and more numerous) to brighter fluxes, thus producing excess counts, since generally galaxies were brighter in the past

Density evolution means that there was some galaxy merging, so there were more fainter pieces in the past, thus also producing excess counts at the faint end

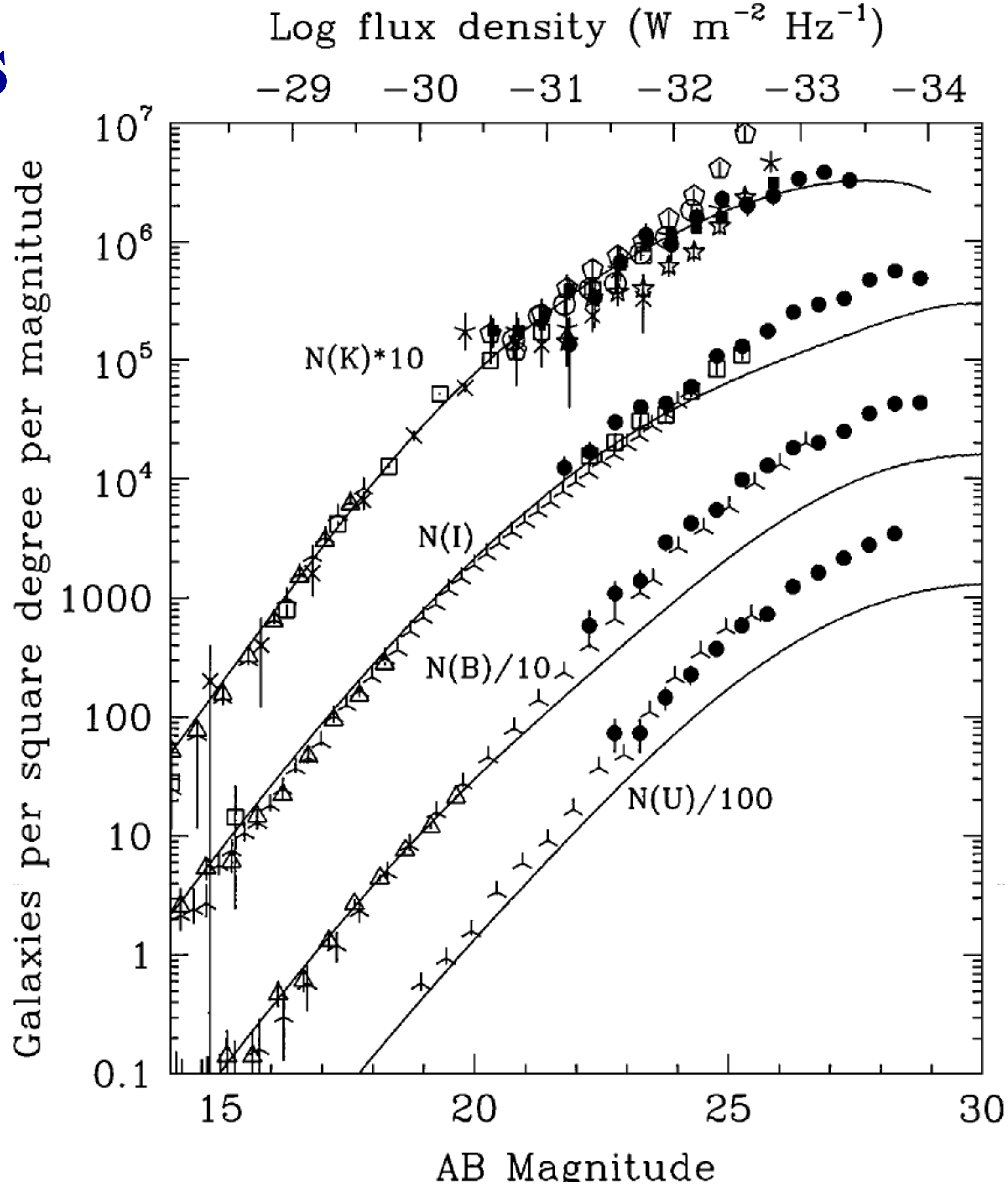
In order to distinguish between the two evolution mechanisms, redshifts are necessary

Galaxy Counts in Practice

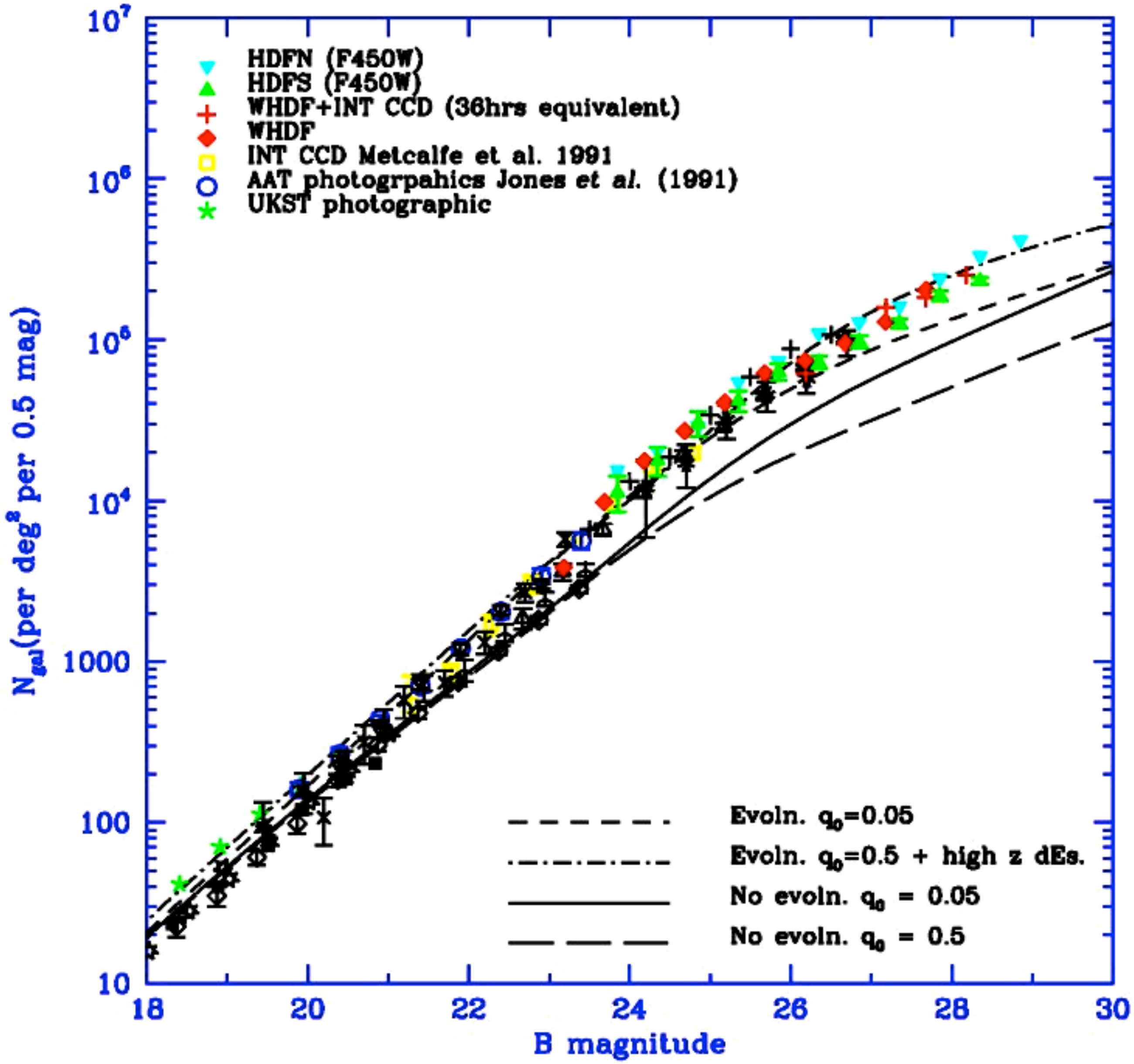
The deepest galaxy counts to date come from HST deep and ultra-deep observations, reaching down to ~ 29th mag

All show excess over the no-evolution models, and more in the bluer bands

The extrapolated total count is ~ 10^{11} galaxies over the entire sky



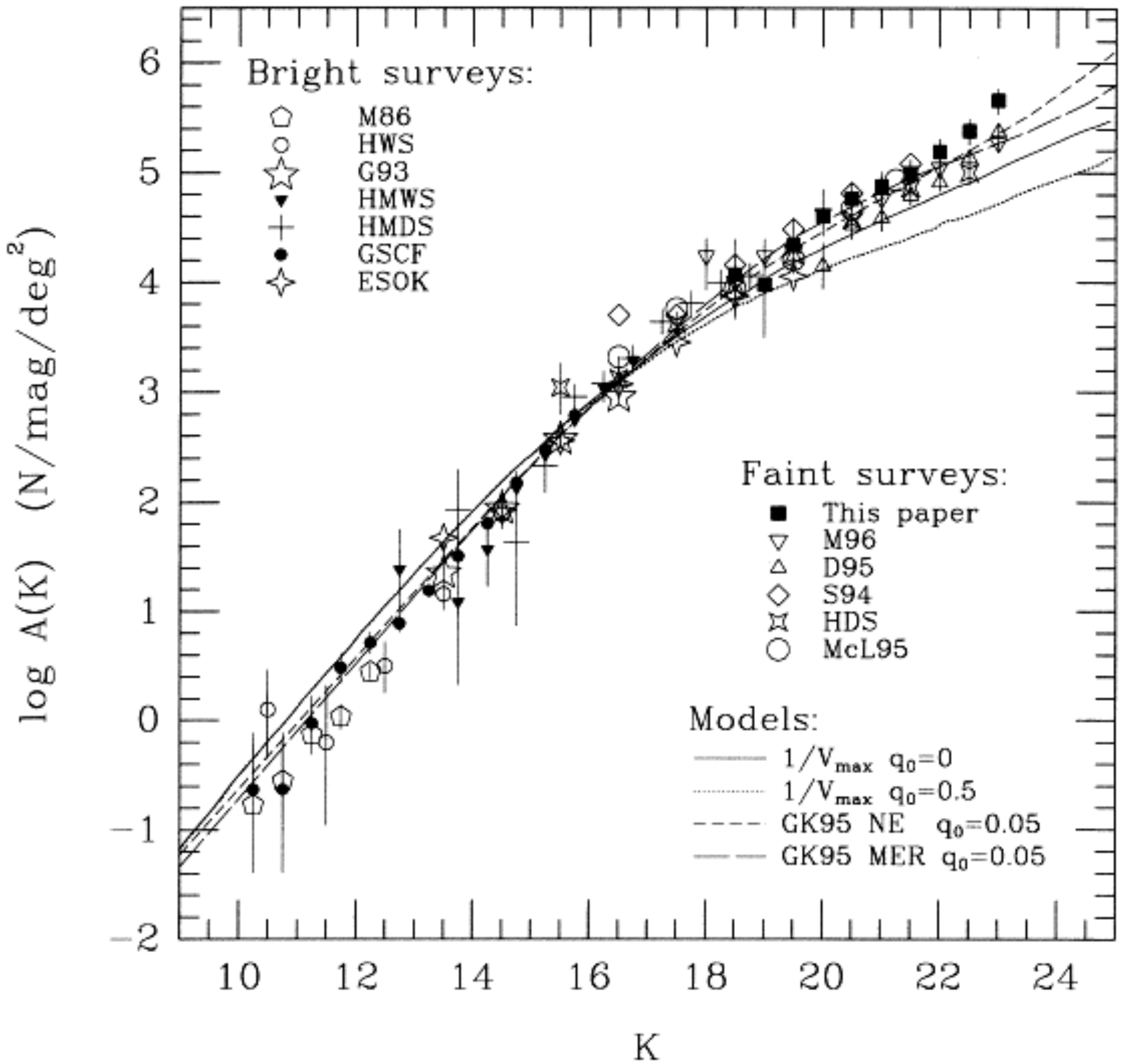
Galaxy Counts in Practice



Observed counts demand some evolution, and favor larger volume (i.e., low Ω_m, $\Omega_\Lambda > 0$) cosmological models

We expect the evolution effects to be stronger in the bluer bands, since they probe UV continua of massive, luminous, short-lived stars

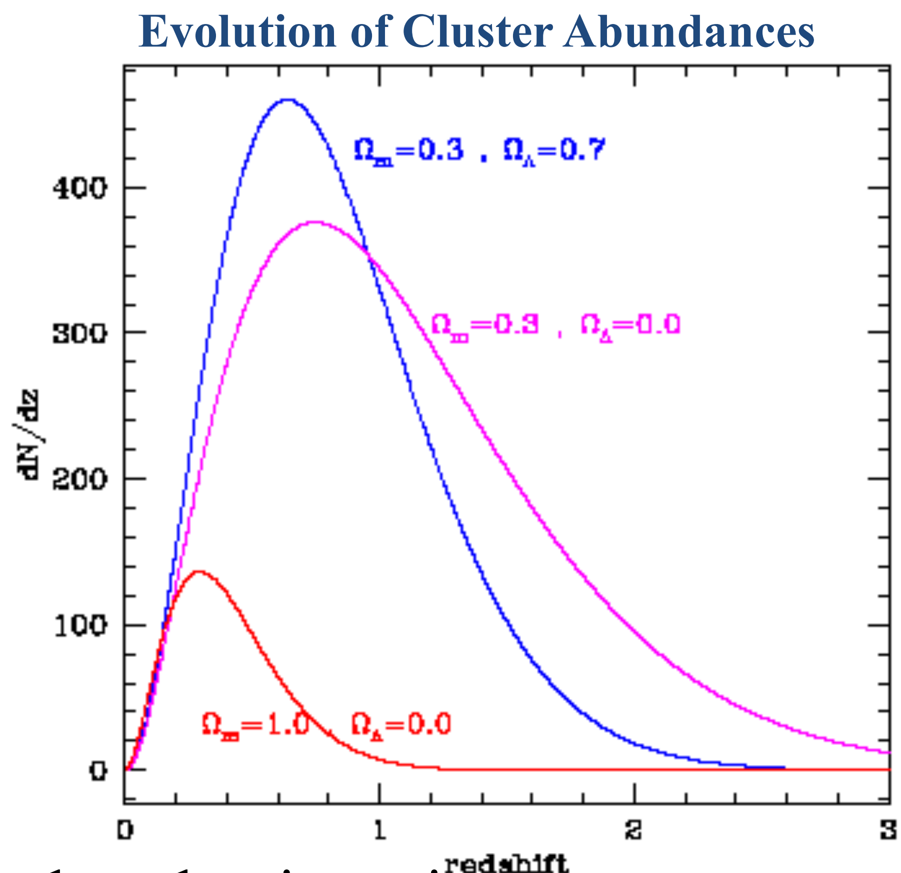
Galaxy Counts in Practice



These effects are less prominent, but still present in the near-IR bands, where the effects of unobscured star formation should be less strong, as the light is dominated by the older, slowly evolving red giants

Abundance of Rich Galaxy Clusters

- Given the number density of nearby clusters, we can calculate how many distant clusters we expect to see
- In a high density universe, clusters are just forming now, and we don't expect to find any distant ones
- In a low density universe, clusters began forming long ago, and we expect to find many distant ones



- Evolution of cluster abundances:
  – Structures grow more slowly in a low density universe, so we expect to see less evolution when we probe to large distances
  – Expected number in survey grows because volume probed within a particular spot on the sky increases rapidly with distance

Next:
The Cosmic Concordance