The luminosity function:

A short introduction

Things to know:

- LF definition
- Ways to derive the LF from galaxy surveys
- Recent/future results

Definition:

- Comoving number density of galaxies with luminosity [L,L+dL].

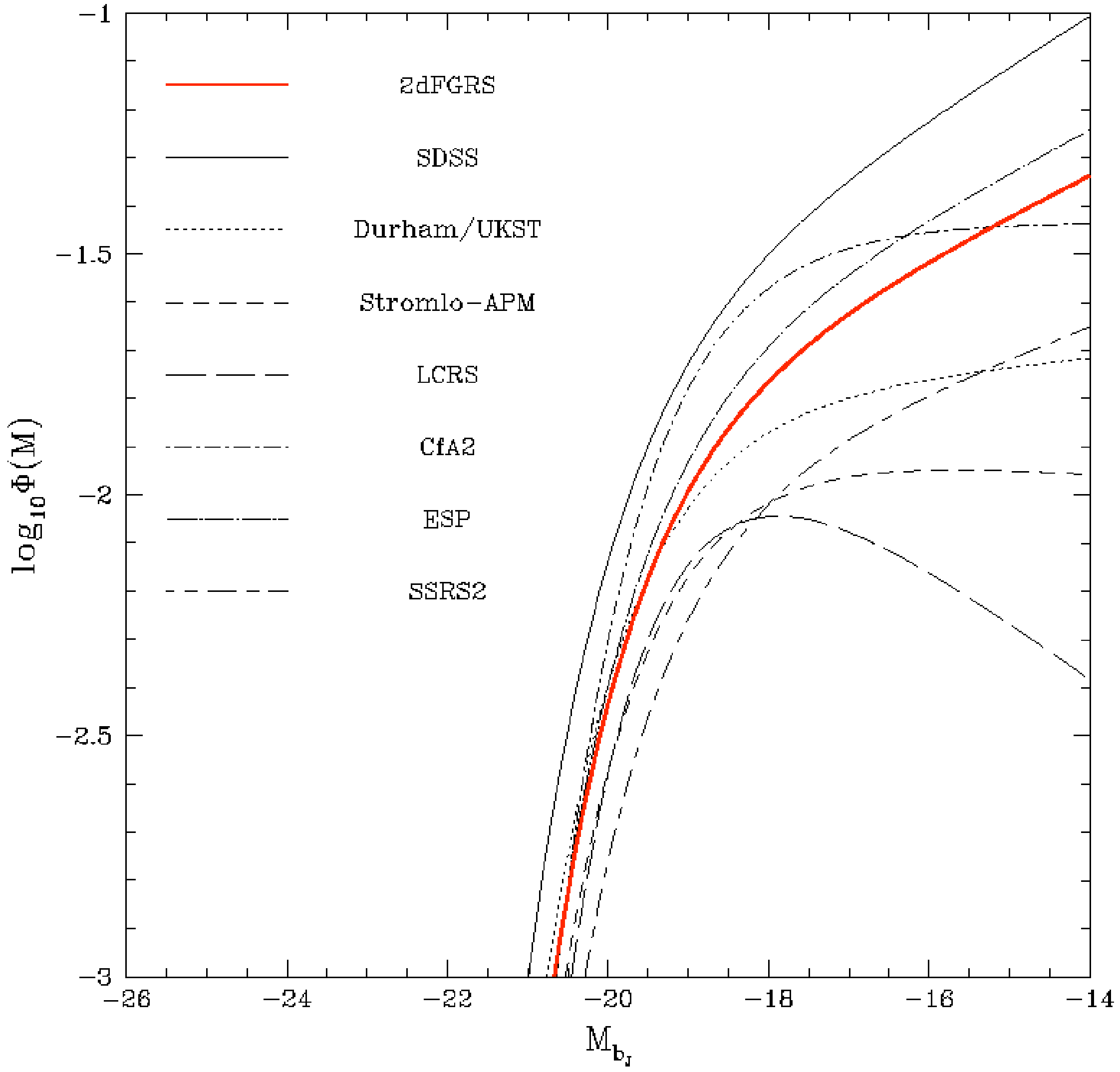
$$dN = \phi(L)\, dL\, dV$$

Applications:

- Describe selection fn of survey.
- De-project angular correlation fn.
- Constrain models of galaxy formation.
- Quantitative probe of evolution.

An old Snapshot:

- Very messy…
- Most are Schechter fn's, but all different.
- Looks bad, but now much better: Limited by systematic effects (e.g. galaxy selection, magnitude definition, surface brightness etc)



Methods of calculation:

$$M = m - 25 - 5\log_{10}(d_L) - k(z)$$

LF is just the number density of galaxies…
… so just have to count the number of galaxies
… and divide by the observable volume of each one
… simple.

Only complication is the magnitude limits of the survey

- $1/V_{max}$ (move the galaxy, out of fashion)

  Move the galaxy forwards and backwards in redshift, to find the maximum volume it could have inhabited and still been observed.

- Maximum likelihood (change its brightness, in fashion)

  At a fixed redshift, what is the range of luminosities, L, that a galaxy could have - and still be observed… need to assume a form for the LF.

Continued…

Maximum likelihood method for magnitude-limited survey:

$$p_i \equiv p(M_i \,|\, z_i) = \phi(M_i) \Big/ \int_{M_{\min}(z_i)}^{M_{\max}(z_i)} \phi(M)\, dM \;,$$

$$\begin{Bmatrix} M_{\min}(z_i) \\ M_{\max}(z_i) \end{Bmatrix} = \begin{Bmatrix} m_{\min,i} \\ m_{\max,i} \end{Bmatrix} - 25 - 5 \log d_{Li} - k(z_i) \;.$$

$$\mathscr{L} = p(M_1, \ldots, M_N \,|\, z_1, \ldots, z_N) = \prod_{i=1}^{N} p_i \;,$$

Need to know what $\phi(M)$ looks like.

Note: Must determine
Normalization independently

Continued…

Two options: 1) Use Schechter fn $\phi(L)$ (STY 1979)
2) Use a step-wise $\phi(L)$ (EEP 1988)

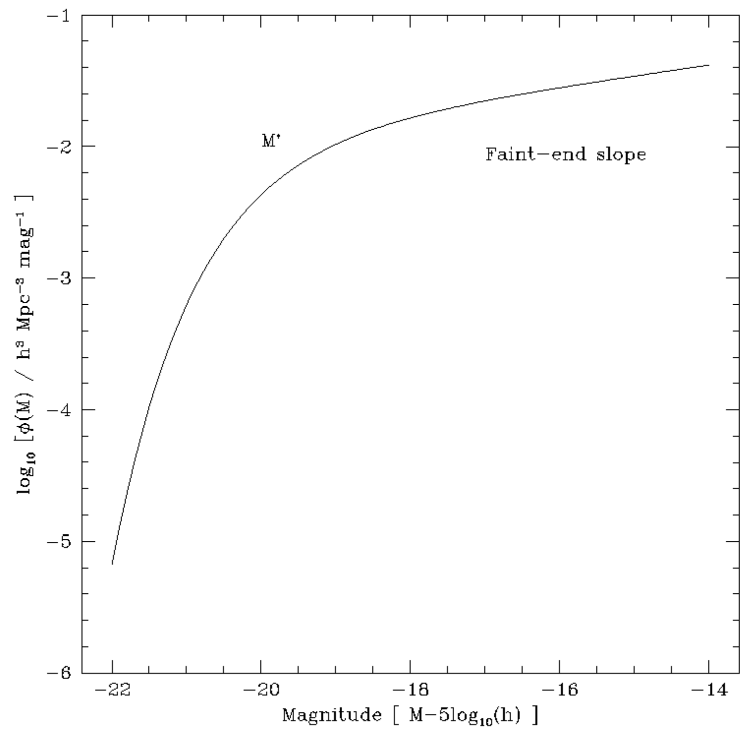
Combination of both is best!

Schechter fn (1976) is pretty good:

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

$$\frac{L}{L^*} = 10^{0.4(M^* - M)} \ ,$$

M_* = characteristic magnitude
α = faint-end slope
ϕ_* = number density (isn't in max.like)



$$\phi(M)dM = 0.4\ln(10)\phi^* 10^{0.4(M^* - M)(\alpha+1)} \exp[-10^{0.4(M^* - M)}]dM \ .$$

Normalisation of the LF:

- Normalisation cancels out in maximum likelihood
- Must be determined independently through number counts.

$$N(m, m+\Delta m) = \Omega_{\rm eff} \int_{r_c(z_{\rm min})}^{r_c(z_{\rm max})} r_c^2 [\int_{L_1(z)}^{L_2(z)} \phi(L) dL] dr_c \ .$$

Typical parameters:

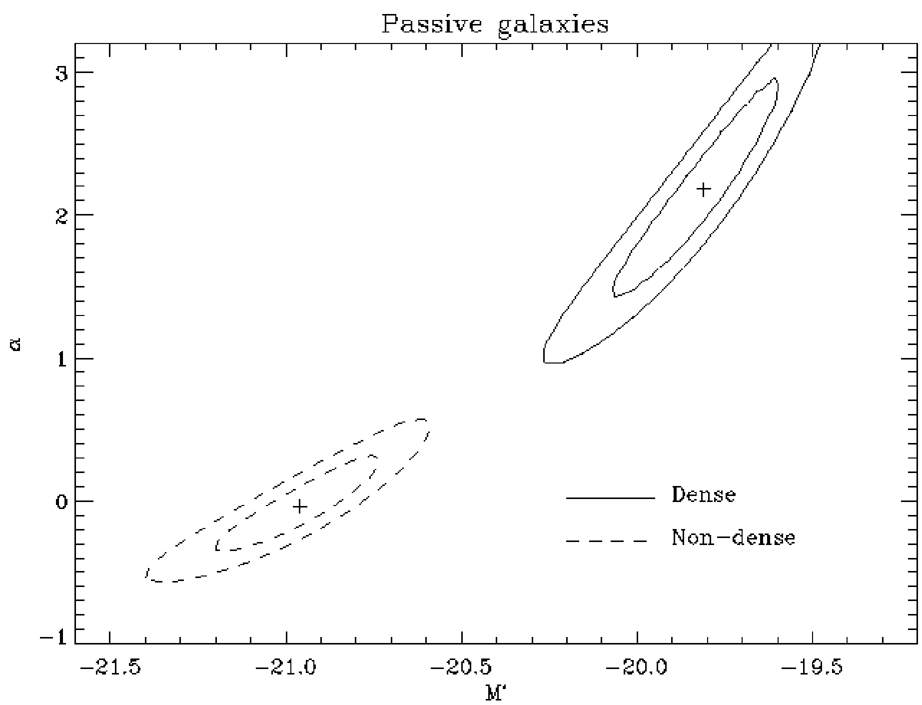
Typical numbers at $z = 0$: (NB: These are highly correlated!)

$M_* - 5\log(h)$	-19.7 (B) -20.8 (R) -23.1 (K)
α	(-0.9, -1.2)
ϕ_*	$1.5\times10^{-2}\ h^{-3}\ \mathrm{Mpc}^{-3}$

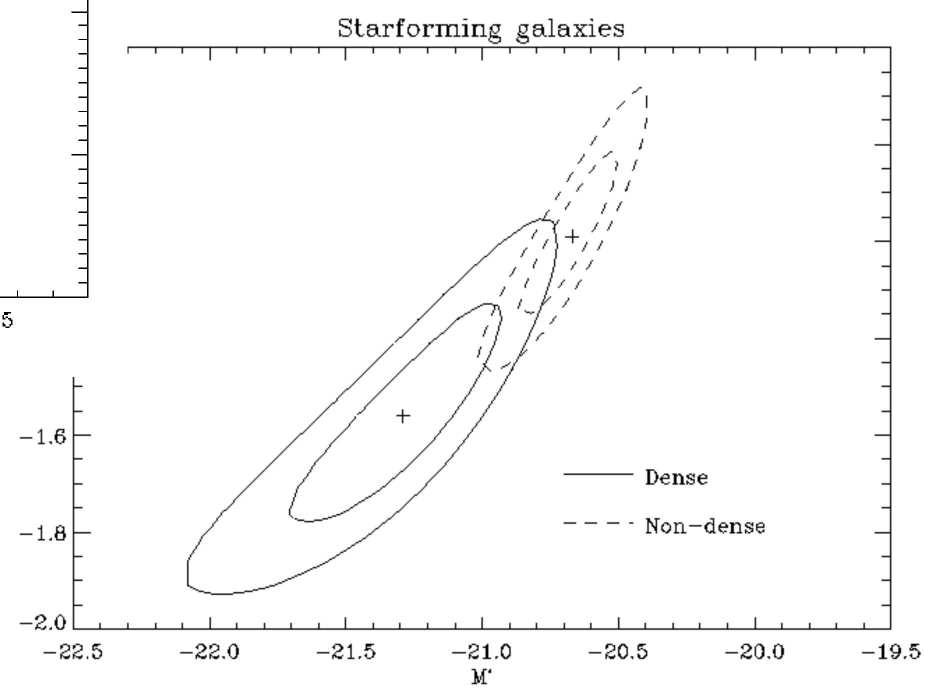
Most recent calculations at $z = 0$.

Look at: Norberg et al. (2001), MNRAS, 336, 907
Blanton et al. (2001), AJ, 121, 2358
Bell et al. (2003), astro-ph/0303394

Correlations:



Normalisation determined independently of M_* and □ but still correlated.



Schechter parameters are correlated.

Other properties:

- The number density of galaxies whose luminosities exceed L is,

$$= \int_L^{\infty} \phi(L) dL = \phi^* \int_{(L/L^*)}^{\infty} \left(\frac{L}{L^*}\right)^{\alpha} e^{-L/L^*} d\left(\frac{L}{L^*}\right) = \phi^* \Gamma(\alpha + 1, L/L^*),$$

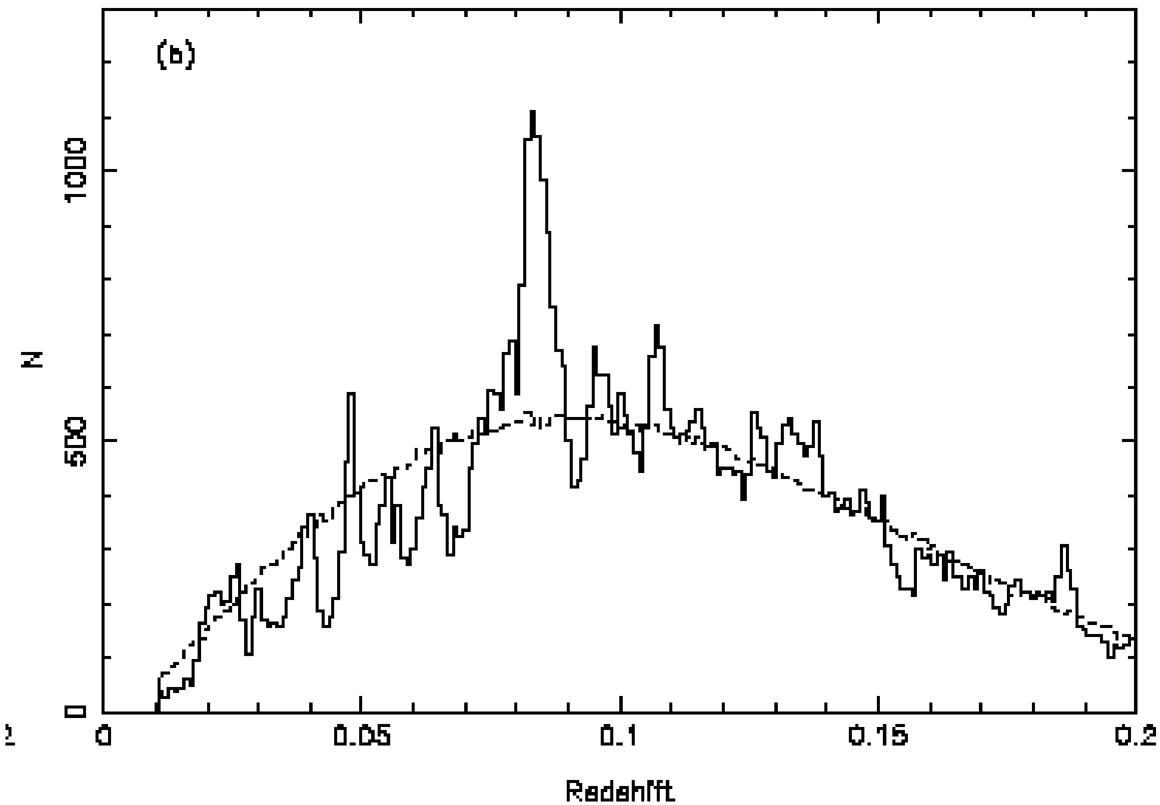
- The luminosity density of galaxies whose luminosities exceed L is,

$$= \int_L^{\infty} L\phi(L) dL = \phi^* L^* \int_{(L/L^*)}^{\infty} \left(\frac{L}{L^*}\right)^{\alpha+1} e^{-L/L^*} d\left(\frac{L}{L^*}\right) = \phi^* L^* \Gamma(\alpha + 2, L/L^*),$$

Selection function:

Probability of observing a galaxy at redshift, z

$$S(z) = \int_{\max[M_{\min}(z), M_1]}^{\min[M_{\max}(z), M_2]} \phi_{\rm obs}(M)dM \Big/ \int_{M_1}^{M_2} \phi(M)dM \ ,$$



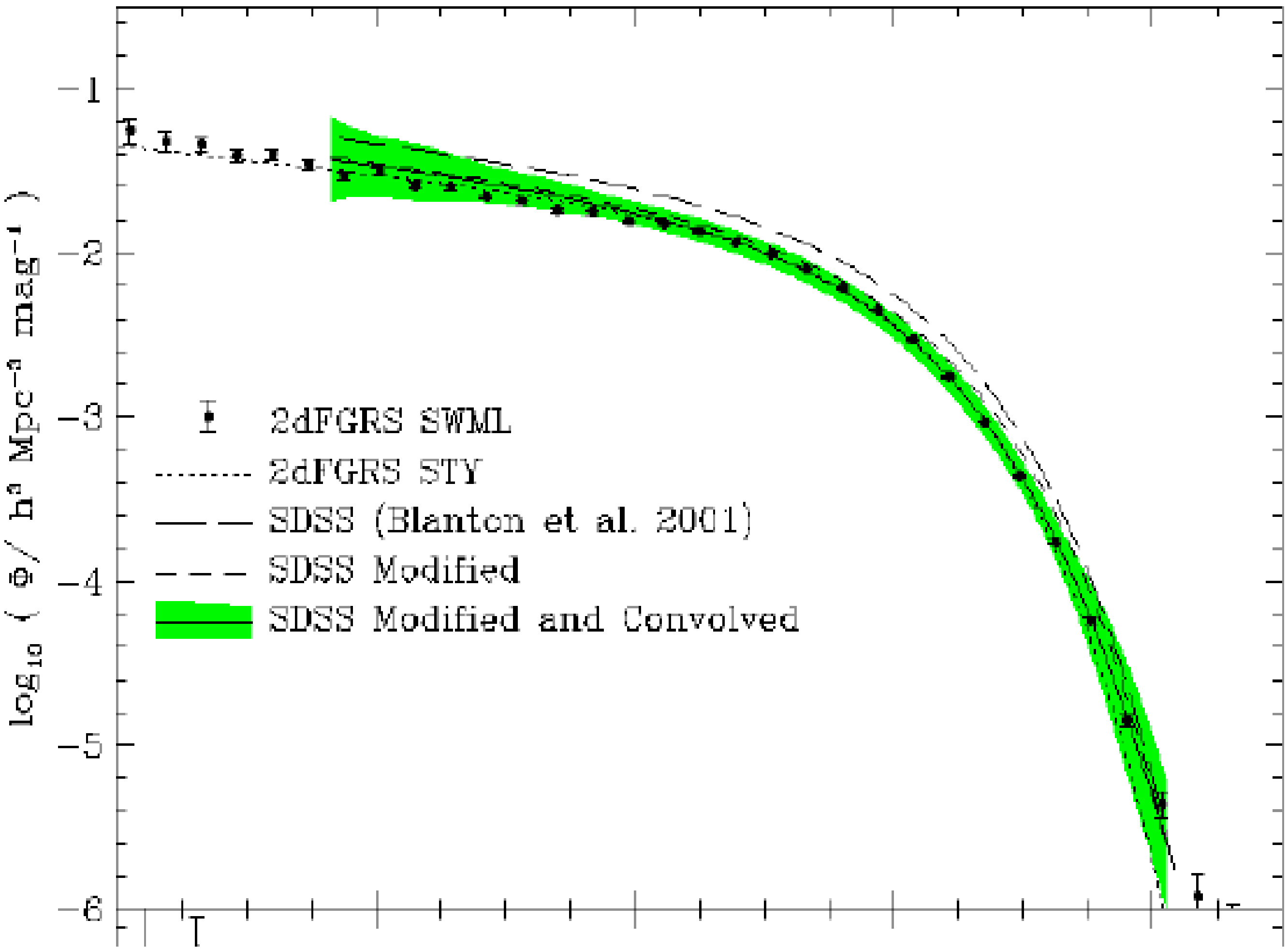
Magnitudes:

- Bolometric flux difficult. Instead measure the flux in a given wavelength bandpass. Note this also determines the selection of galaxies…

2dFGRS	b_J	Norberg et al (2001)
SDSS	u,g,r,i,z	Blanton et al. (2001)
2MASS	J,H,K	Bell et al. (2003) Cole et al. (2001)
LCRS	Rc	Lin et al. (1998)
COMBO17	Lots..	Wolf et al. (2003)

Current state-of-the-art:

z = 0, optical LF



See Norberg et al., astro-ph/0111011 for a detailed comparison between 2dFGRS and SDSS, including color transformations.

Other properties:

- LF varies with type of galaxy (e.g. Madgwick et al. Using 2dFGRS)

  Morphology, spectral type and color. Spiral / star-forming / blue galaxies are fainter

- LF may vary with environment (e.g. Driver & de Propris, astro-ph/0212520)

  Evidence is sketchy…

- LF varies with redshift (e.g. Lilly et al. Using CFRS)

  Evolution appears to be very pronounced.
  At $z = 1$, M_* may be 1 mag brighter?
  Number density evolution depends on type

In the very near future…

- DEEP2 (UC + Caltech)
- VLT-VIRMOS (Europeans)
- Both will probe evolution all the way from

  $z = 0$ to $z \sim 1.5$