Lecture 10: The luminosity distribution of galaxies

- How many galaxies are there?
- How do we calculate this?
- How do we represent it?
- What’s the implication for:
  - The luminosity density
  - The matter density
- Some example calculations

The Luminosity distribution

- We want to know how many galaxies of each type and luminosity are contained within a representative volume.

\[ N = \frac{\text{Number}}{\text{Mpc}^3} \text{ in an interval of } dM \]

This is the luminosity distribution
The Space Density of Galaxies

- Galaxies are known to range in B luminosity: -22 to -8 mags (i.e., \(x \times 400,000\) in L)
- We want to know the number per dM per cubic Mpc.

\[
\log(\text{Number}/dM/\text{Mpc}^3)
\]

Absolute Magnitude

How do we get these LDs?

- Typically via a large apparent magnitude limited redshift survey
- For \(z > 0.01\), \(V_H \gg V_{pec}\), therefore redshifts convert to distance.

1988 APM/MSSO \(~2000\)
1994 CFRS1&2 \(~8000\)
1997 LCRS \(~25000\)
1999 ESP \(~30000\)
2002 2dFGRS \(~250,000\)
2007 SDSS \(~1,000,000\)

But how do we convert a magnitude limited distribution to a volume limited distribution.
AAT 2dF fibre positioner allows for simultaneous measurement of up to 400 redshifts:
2dFGRS Results

Redshift distribution

Raw data from a z survey

N(z)

N(M)

N(obs)
How do we get these LDs?

- To get the volume limited distribution requires a volume correction as at fixed \( m \) we see more luminous objects over large distances (volumes).

\[
i.e., d \propto 10^{-0.2M} \propto L^{\frac{1}{2}}
\]

But the volume over which galaxy is seen is:

\[
V \propto d^3 \propto 10^{-0.6M} \propto L^{\frac{3}{2}}
\]

\[
\therefore NdM \propto \frac{N(\text{obs})}{10^{-0.6M}} \propto \frac{N(\text{obs})}{L^{\frac{3}{2}}}dM
\]

In practice we have to take into consideration expanding non-euclidean space-time (i.e., \( V = f(n(d, \text{Cosmology})) \))

- hopefully this is now a plot of the real distribution of galaxies, showing what fraction are intrinsically luminous or of low luminosity
  - if we haven’t missed any galaxies, e.g. types with few spectral lines to measure, very dusty ones...
The Galaxy Luminosity Function

- No consensus
  - \( x^2 \) uncertainty at \( M_* \)
  - \( M > -16 \) unknown

- SDSS & 2dFGRS:
  - SDSS1 resolved
  - SDSS2 puzzling

- ESP & 2dFGRS OK

- LG best insight ? (~50 galaxies)
Problems

• Selection bias
  – Its much easier to get spectra (redshifts) for very old or very young galaxies (strong lines).
  – Easier to measure redshifts for concentrated galaxies (LSBG bias)
  – Galaxy clustering and cosmic variance
  – Volume correction very large at faint M
  – Volume surveyed very small at faint M

Poor Statistics at the faint-end

Lower M limit is set by combination of m limit and z min. I.e., set z > 0.013 for analysis to be robust to peculiar velocities
E.g., What is the ration of volume surveyed for galaxies with $M$ and $M+5$?

\[ V \propto 10^{-0.6M} \]

\[ \frac{V_1}{V_2} \propto 10^{-0.6(M_1-M_2-5)} = 1000 \]

- Hence galaxies with $M_1$ are seen over a volume 1000x larger than those with $M_1+5$.
- Therefore if the true LD is flat (i.e., $N(M)dM=constant$) we will see 1000 $M_1$ galaxies for every $M_1+5$ galaxy.
- This places a fundamental limit on how far down the LD we can probe.
- i.e., for 1 million galaxies (i.e., SDSS) we expect 1:1 million MW +10mag galaxies (i.e., -9.8)
- Impossible to quantify the dwarf population? O. Lopez-Cruz
- Not quite, cosmology helps but diminishing the number of giant galaxies beyond a certain distance.
Illustration: Galaxies of equal luminosity $B=16$

Illustration: Galaxies of equal luminosity $B=18$
Morphological LDs