Galaxies (AS 7007)

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Lecture 9, contents:
- Intergalactic matter
- High-z galaxies
- Evolution of galaxies
- Feedback

"Binggeli-diagram"
Absolute magnitude vs surface brightness (lum vs density)

Intergalactic matter

- Cold/neutral gas in filaments and Lya forest
- Hot gas in clusters
- Warm gas

- Missing baryons
Intergalactic matter
QSO used as lamps

QSO at z=3.173

Fig 9.12 (L. Lu, M. Rosch) 'Galaxies in the Universe' Sparke/Gallagher CUP 2007
Metallicity vs redshift

![Metallicity vs redshift graph](image)

Figure 8: Zinc abundance in QSOs from the compilation by Kobayashi et al. 2003 (black), which being together the results of several surveys (red) in visually selected QSO samples, and from the recent survey at SDSS-LSS (unselected) QSOs by Ishigaki et al. 2001 (blue). Triangles denote upper limits in QSOs whose Zn in AGN2002 has remain unknown.

Metallicity vs "scale"

![Metallicity vs scale graph](image)

Figure 9: Snapshot of the metallicity of different components of the high redshift universe. The logarithm of the metallicity is plotted relative to solar (defined by the Hy Kraft unit) against the typical linear scale of the structure for which it refers. The term "Lyman break galaxies" (LBGs) is used in a shorthand manner to refer to a more general class of actively star-forming galaxies.

Evolution of the neutral hydrogen density

![Evolution of neutral hydrogen density graph](image)

Figure 10: Mass density of neutral gas in QSOs in SDSS (plotted here as a function of redshift) and sub-sample surveys (cross). Figures adapted from Fragos et al. (2018).
Gunn-Peterson effect

As density of Lyman alpha forest clouds increase as we go to higher redshifts, we will at some point reach an epoch where the IGM is mostly neutral and the Lya forest overlap makes the QSO spectra black shortwards of Lya. This is the Gunn-Peterson effect, detected at z=6.

Hot gas in clusters

X-ray emitting through thermal bremsstrahlung

Efficient way of finding clusters

Cosmic shear

Challenging!
- Effect on each individual galaxy tiny
- Only visible through large and deep samples
Rich clusters: Virgo and Coma
irregular vs regular
(large spiral fraction) (mostly "early" types) (more relaxed)

Galaxy evolution in clusters

Butcher-Oemler effect:
Blue galaxy fraction increase with redshift
Finding distant galaxies

- Photo-z
- Spectro-z
- Colour selection (Lyman break, ERO)
- Emission line/narrow band surveys

- The problem is in contrast, many low z galaxies for each high z one
The Lyman break technique

- Same filter observes different wavelengths at different z.
- K-correction possible if spectrum known or assumed.
- Can be used for drop-out technique
- Problems for classification.

UV restframe cosmic SFR per comoving volume

- Zero redshift
- High redshift

Fig. 1: Spectral energy distribution of a star-forming galaxy at z = 3.1 is from the population synthesis model by Bruzual & Charlot (1993); the example reproduced here is for a generic blue galaxy and assumes a Salpeter IMF. The broken lines show the transmission curves of the three broadband filters used in this work, chosen specifically to detect the Lyman break at 912 Å (g, i) and G1 and the relatively continuous (green) part of the break (j, k, l). Also shown in the figure is the spectrum of the QSO Q2237-153, an optically thick Lyman break system at z = 3.57, produced the marked discrepancy over 3000 Å. Details of the QSO spectrum are given in Sec. 4.4.
Halpah luminosity function at $z=0$ and 1.5

Evolution of the UV luminosity function

Fig. 1 - The rest-frame 2000 Luminosity function. Best fitting Schechter functions are shown with solid lines. Completeness limits in each bin is shown with vertical dashed lines. We did not magnitude bins brighter than these limits when fitting Schechter functions. In each bin, we also show the best fitting Schechter function derived in the lowest magnitude bin (dashed line). This illustrates the strong evolution in the 2902 LF with redshift.

Fig. 9.12 (L. Lu, M. Rauch) Galaxies in the Universe. Sparkle/Galagher CUP 2007

LBG