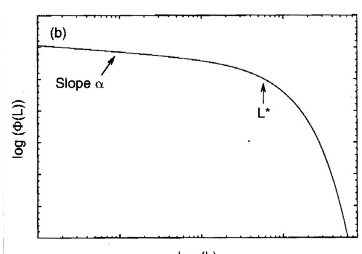
Astro 358/Spring 2012

Galaxies and the Universe

Figures + Tables for Lecture 7
(Th Feb 9)

Galaxy Luminosity Functions

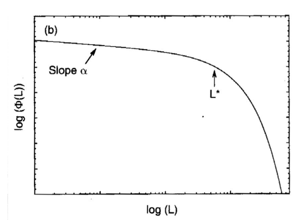
Schechter Luminosity Function



(Fig 3.31 EAC)

- Generic feature of the Schechter luminosity function of galaxies
  Log(Phi(L)) → rises at fainter L for L<L*,
  → drops sharply at L > some characteristic L*
- Schechter functions are a good fit to luminosity functions of galaxies in the field

Schechter Luminosity Function as function of Log(L) versus M_B



(Fig 3.31 EAC)

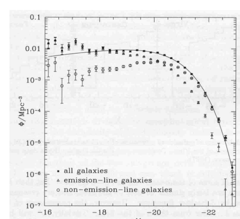


Figure 4.12 Luminosity function as derived from the Las Campanas Redshift Survey, together with the Schechter function that best fits the data at points brighter than $M = -17.5$ (with parameters $\alpha = -0.70 \pm 0.05$ and $M_R^* = -20.29 \pm 0.02 + 5 \log h$.) The component luminosity functions of emission-line and non-emission-line galaxies in the survey are also shown. [After Lin *et al.* (1996) from data kindly provided by H. Lin]

(Fig 4.12 GU)

Schechter LF is shown as a solid line in both figures.
LHS Fig : For x-axis= log(L), in regime L<L*, Phi rises at fainter L if α< 0
RHS Fig: For x-axis =M_R, in regime M_R >M_R^* Phi rises at fainter M_R rises if α< -1.
Here α = -0.7

Fitting a Schecter Luminosity Function to Field Galaxies

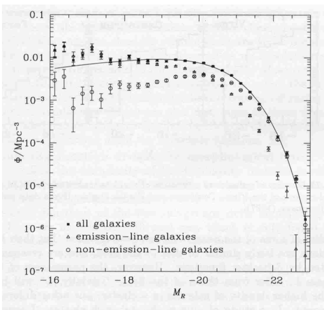
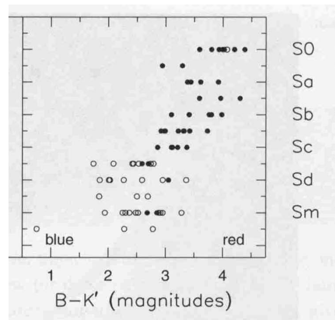


Figure 4.12 Luminosity function as derived from the Las Campanas Redshift Survey, together with the Schechter function that best fits the data at points brighter than $M = -17.5$ (with parameters $\alpha = -0.70 \pm 0.05$ and $M_R^* = -20.29 \pm 0.02 + 5 \log h$.) The component luminosity functions of emission-line and non-emission-line galaxies in the survey are also shown. [After Lin *et al.* (1996) from data kindly provided by H. Lin] (GU)

1) When fitting a Schechter LF (SLF) to data, the derived slope α of the faint-end of the LF is highly sensitive to the luminosity of fainter galaxies included in the fit.

Example: In the figure, using bright galaxies only gives a best-fit SLF with α~-0.7, shown as a solid line. This SLF under-predicts the no of faint galaxies detected.

Characteristic Luminosity L* of SLF in near-IR versus optical data



Typical B-K color of Sa to Sc~. 3 to 4.5 mag
Expect M_K* in luminosiy function to be brighter than M_B*

A Schecter LF is not a good fit to LF of galaxies in clusters

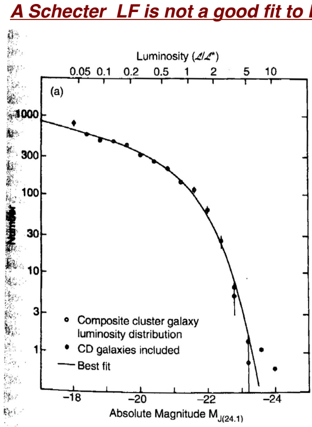


Fig. 3.31. Left panel: galaxy luminosity function as obtained from 13 clusters of galaxies. For the solid circles, cD galaxies have also been included. Upper panel: a schematic plot of the Schechter function

Cluster LF: Schechter LF only fits roughly the overall shape of the cluster LF but fails to account for cD galaxies at the very bright end (L>10L*).

(EAC)

Centers of very rich galaxy clusters show a cD galaxy

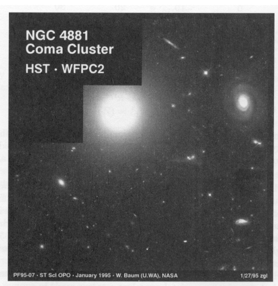


Figure 4.29 The cD NGC 4881 is located near the center of the Coma cluster and is surrounded by a swarm of much less luminous galaxies. [Figure courtesy of STScI]

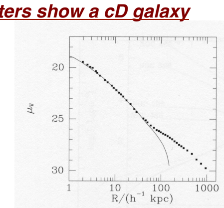


Figure 4.28 The surface-brightness profile of the cD galaxy that lies at the center of the cluster Abell 1413 (points). The line shows the $R^{1/4}$-law that best fits the inner points. [From data kindly provided by J. Schombert based on the work of Oemler (1976).]

Acc. to Schechter LF (SLF), no of galaxies with L>10 L* (e.g., cD galaxies) are ~inexistent
→ SLF fails in center of very rich clusters, such as Coma , whose center contains a cD galaxy

Table 3.1. Characteristic values for elliptical galaxies. D_{25} denotes the diameter at which the surface brightness has decreased to 25 B-mag/arcsec^2, S_N is the "specific frequency", a measure for the number of globular clusters in relation to the visual luminosity (see (3.13)), and M/L is the mass-to-light ratio in Solar units (the values of this table are taken from the book by Carroll & Ostlie, 1996)

	S0	cD	E	dE	dSph	BCD
M_B	−17 to −22	−22 to −25	−15 to −23	−13 to −19	−8 to −15	−14 to −17
$M(M_\odot)$	10^{10} to 10^{12}	10^{13} to 10^{14}	10^{8} to 10^{13}	10^{7} to 10^{9}	10^{7} to 10^{8}	$\sim 10^{9}$
D_{25} (kpc)	10–100	300–1000	1–200	1–10	0.1–0.5	< 3
$\langle M/L_B \rangle$	~ 10	> 100	10–100	1–10	5–100	0.1–10
$\langle S_N \rangle$	~ 5	~ 15	~ 5	4.8 ± 1.0	–	–

Luminosity, mass, and size of cD galaxy >> Elliptical galaxy

A Schecter LF is not a good fit to LF of galaxies in clusters

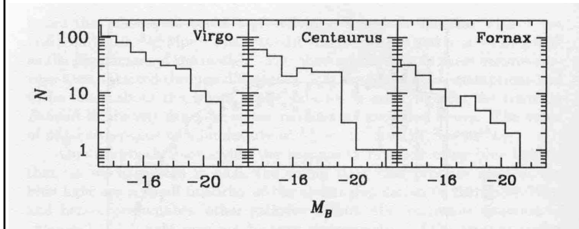


Figure 4.13 Number of galaxies as a function of absolute magnitude [$\propto \Phi(M)$] found in the central regions of the Virgo, Centaurus and Fornax clusters [From data published in Jerjen & Tammann (1997)]

Schechter LF only fits roughly the overall shape of the cluster LF (with a steep slope alpha=-1.3) but fails to fit the detailed shape (e.g. "bump" at M(B) = -16 + 5 log h)

Morphology-density relation seen in LF of individual galaxy types

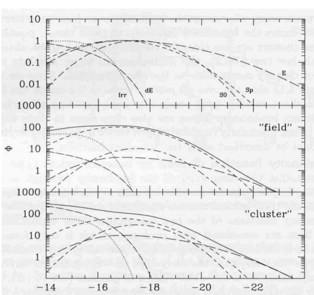


Figure 4.14 Luminosity functions for galaxies of various morphological types. The top panel shows The separate functions at arbitrary normalization, while the lower panels show approximately how these components combine to produce the total luminosity function in the field and in clusters.

1) MDR for bright galaxies

The frequency of (E+S0) galaxies relative to spiral galaxies is much higher in high density environments (e.g., galaxy clusters) than in low density environments (e.g., field)

Frequency of E+S0:Sp
= 40%+50% :10% in cluster
= 10%+10%: 80% in field

2) MDR for Faint galaxies

The frequency of dE relative to dIrr
= higher in cluster than in field

3) The MDR is reflected in the LF of the cluster vs LF of field, when the overall LF of the cluster is decomposed into the LF for different galaxy types (E, S0, Sp, Irr, dE): See fig 4.14.

Morphology-density relation seen in LF of individual galaxy types

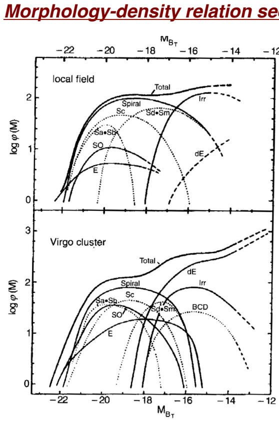


Fig. 3.32. The luminosity function for different Hubble types of field galaxies (top) and galaxies in the Virgo Cluster of galaxies (bottom). Dashed curves denote extrapolations. In contrast to Fig. 3.31, the more luminous galaxies are plotted towards the left. The Schechter luminosity function of the total galaxy distribution is compiled from the sum of the luminosity distributions of individual galaxy types that all deviate significantly from the Schechter function. One can see that in clusters the major contribution at faint magnitudes comes from the dwarf ellipticals (dEs), and that at the bright end ellipticals and S0's contribute much more strongly to the luminosity function than they do in the field. This trend is even more prominent in regular clusters of galaxies

(Fig 3.32 EAC)

Morphology-density relation illustrated by images of clusters

In the core of galaxy clusters, such as the Abell 1689 cluster, E/S0 dominate over spirals

Spirals are visible only in the outskirt of the cluster and in the field

Core of Abell 1689 cluster

Morphology-density relation illustrated by images of clusters

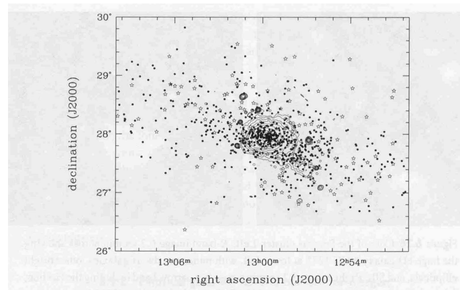


Figure 6.25 Coma cluster: solid dots show elliptical galaxies; open stars are spirals. Contours show the intensity of X-rays: the diffuse emission is from hot cluster gas; the point sources are distant active galaxies – M. van Haarlem.

Coma = nearest, rich, regular cluster, at a distance of ~100 Mpc

MDR: Early type galaxies (E/S0) dominate over spirals in the core of the Coma cluster