The luminosity function of galaxies in halos:
from satellites to clusters.

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The faint-end of the galaxy luminosity function in galaxies systems

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We studied the galaxy luminosity function in low mass systems of hosts with satellite galaxies. For this purpose, we used the main spectroscopic galaxy sample from the fourth data release of the Sloan Digital Sky Survey (SDSS) to identify satellite galaxies around bright hosts. We used a statistical background subtraction method to compute the galaxy luminosity function in an ensemble of nearly 3000 fields centered in hosts. We found that the faint-end slope of the galaxy luminosity function is $\alpha \sim -1.8$ in the full sample, and remarkably step in subsamples of early type hosts. We found also an upturn signature approximately at $M_r \sim -18+5log(h)$ depending on the host properties and the photometric band. We performed the same analisys on bright isolated galaxies, where the abundance of faint satellites is lower, and compared the results with that obtained in clusters of galaxies.

INTRODUCTION

The galaxy luminosity function (LF) is the abundance of galaxies as a function of their luminosity per unit volume. The shape of the galaxy LF is an important issue in the semianalitic models of galaxy formation because their origin is closely related with the physical proceses involved in the galaxy formation and evolution. Evolutionary processes give rise to changes in the luminosity of galaxies, and therefore, changes in the galaxy LF may be expected in galaxy asociations where these processes take place. The study of the galaxy LF in different environments is helpfull in understanding the mechanisms responsible of the changes in the properties of the populations of galaxies. The universality of the galaxy LF is not well understood, partly because of the limitations in the amount of available data wich do not allows to obtain a galaxy LF with statistical significance, and because of the different samples used. Several methods have been developed to calculate the galaxy LF, in some of them it necesary to calculate the luminosity of a galaxy, in order to determine their absolute magnitude, and hence a distance estimator is needed. The commonest indicator of distance is the cosmological redshift, wich is available only if the galaxy is brighter than the limiting magnitude of the spectroscopic sample. For this reason, the study of the galaxy LF faint-end is difficult to be carried out and limited to samples of nearby galaxies.

On the other hand, the great amount of data from the current galaxy catalogues make possible statistical studies. Spectroscopic samples are flux-limited, but can be combined with the photometric samples and, with some simple asumptions, can be used to obtain the distributions of magnitudes and colors of large samples of faint galaxies.

SAMPLE

The Sloan Digital Sky Survey (SDSS) will cover on completion almost one quarter of the sky, with spectroscopic information of approximately 10000 galaxies and quasars (Stoughton et al., 2002) This survey provides also accurate photometric information in 5 bands, u, g, r, i, z (Fukugita et al., 1996) and spectroscopy of objects brighter than $r = 17.77$ with a completitude greater than 99% and a mean redshit of 0.104 (Strauss et al., 2002).

We identified host-satellite systems using the main galaxy sample in the fourth release of the SDSS. This sample contains 190589 galaxies in the redshift range between 0.02 and 0.1, covering a sky area of 4783 square degrees. Galaxies brighter than $M_r = -18$ without any spectroscopic companion brighter than $M_r = -17$ within $1000\, h^{-1} Kpc$ of projected distance and $1000\, Km/s$ of velocity difference, are considered primary galaxies.

The satellites are at least 2 magnitudes fainter than their hosts, and lie at a maximum projected distance of $500\, h^{-1}\, Kpc$. The velocity diferences between the host galaxy and their satellites are lesser than $500\, Km/s$. We found 2736 hosts (4.3% of the primaries) with 5466 satellites (1.99 spectroscopic satellites per host), and 59836 isolated galaxies.

We used all galaxies up to a magnitude of 22.22 in the r band, within $600\, h^{-1} Kpc$ from the host galaxies. This full photometric sample comprises nearly 8 million galaxies in the fields of hosts.

In this poster we show the results obtained from the fields centered in hosts galaxies, and some first results from the isolated central galaxies sample.

METHOD

It can be assumed that galaxies in clusters and groups lie in overdensity regions of finite extent embedded into a uniform field of background and foreground galaxies. Taking this into account, the number of galaxies in a cluster region can be compared with the number of galaxies in the background to obtain the excess counts. We used this statistical method to obtain the excess of galaxy counts around haloes with a central bright host galaxy with respect to the assumed uniform distribution of galaxies in the background and foreground. We present here the galaxy luminosity function as the number of galaxies asociated to a given set of haloes, per unit absolute magnitude. This background subtraction technique allows us to obtain the number of galaxies in a given aparent magnitude bin and in the neighboring region of central bright galaxies, in excess with respect to the number of galaxies in the background. An inner ring ranging from 15 Kpc h^{-1} to 40 Kpc h^{-1} was used. We choose a local background to account for large scale fluctuations in the number density of galaxies, but far away from the central galaxy to ensure that this is not associated with the background galaxies. According to the density profiles, we used a conservative minimum radial distance of 200 Kpc h^{-1} and covering an area of 20 times the area of the inner ring.

Under the same assuptions, the absolute magnitudes of the excess galaxies are calculated as if the satellites stand at the redshift of their corresponding hosts.

RESULTS: GALAXY LUMINOSITY FUNCTION

In order to determine the group physical extent in projected sky we calculated the density of galaxies as a function of the distance to the central galaxy. We found the presence of an overdensity region confined to a tight ring around the central galaxy. It can be seen (fig. 1) that the overdensity is present up to approximately 50 Kpc from the central bright galaxy.

We enclosed the inner ring between $15\,h^{-1}Kpc$ and $40\,h^{-1}$Kpc of projected distance, using a simple flat cosmological model and a Hubble parameter equal to $100\,Mpc^{-1}$Km/s. The background is obtained from a second ring, $200\,h^{-1}$Kpc far away from the host, and with an area 20 times the area of the inner ring. The galaxy counts of the external ring were properly normalized to calculate the excess counts.

We used this local instead of a global background to take into account global fluctuations of the galaxy density in the neighboring regions of the central galaxies. The number of galaxies per unit area in the inner rings is tipically $\simeq 2.03$ galaxies/Kpc^2/host in the hosts sample, with a maximum luminosity corresponding to $r = 22.2$, out of wich approximately 0.77 galaxies/Kpc^2/host are in excess with respect to the local background. The distribution of magnitudes in the hosts sample is calculated with nearly 4000 galaxy counts. The faint-end slope of the galaxy LF is surprisingly high. Since a single Schechter function is not enough to fit the observed distribution of galaxy absolute magnitudes, we chose a double Schechter function to fit independently the bright-end and the faint-end of the galaxy magnitude distribution. The magnitude cut is arbitrarily set to $M_u = -18$. In order to estimate the errors in the determination of the Schechter function parameters, we performed the fits moving the magnitude cut so that the corresponding bin is shifted one unit. In fig. 3 we show the resulting galaxy LF for the whole sample of galaxies in the fields of host bright galaxies in the 5 bands.

CONCLUSIONS

We have determined the shape of the luminosity function of satellite galaxies around bright hosts in the fourth release of the SDSS. The statistical technique of background subtraction used allows us to obtain a reliable determination of the best fit parameters of the Schechter functions to the observed data. The fitted functions in the bright-end are consistent with the ones found in the literature, in the same luminosity range (e.g., Blanton et al., 2005). The faint-end shows a step slope of nearly -1.8 up to a magnitude of -15.18 in a volume limited sample extending up to $z = 0.1$. This slope is in agreement with the galaxy luminosity function faint-end obtained in denser environments like groups (Gonzalez et al., 2005) and massive clusters (Popesso et al., 2005, A&A in press). These results sugest that in gravitationally bound systems the population of faint galaxies is very important, indenpendently of the mass of the system. On the other hand, the faint-end slope of the LF of field galaxies is of the order $\alpha \geq -1.3$ acording to Blanton et al., indicating that the step slope of the faint-end may be characteristic of systems of galaxies but not of field galaxies.

REFERENCES

Adelman-McCarthy J., et al. 2005, astro-ph/0507711

Blanton et al., 2005, ApJ, 631, 208

Fukugita et al. 1996, AJ, 11, 1748

Gonzalez et al., A&A, in press (astro-ph/0507144)

Popesso et al., 2005, A&A in press, astro-ph/0410011

Stoughton C., et al. 2002, AJ, 123, 485

Strauss M., et al. 2002, AJ, 124, 1810

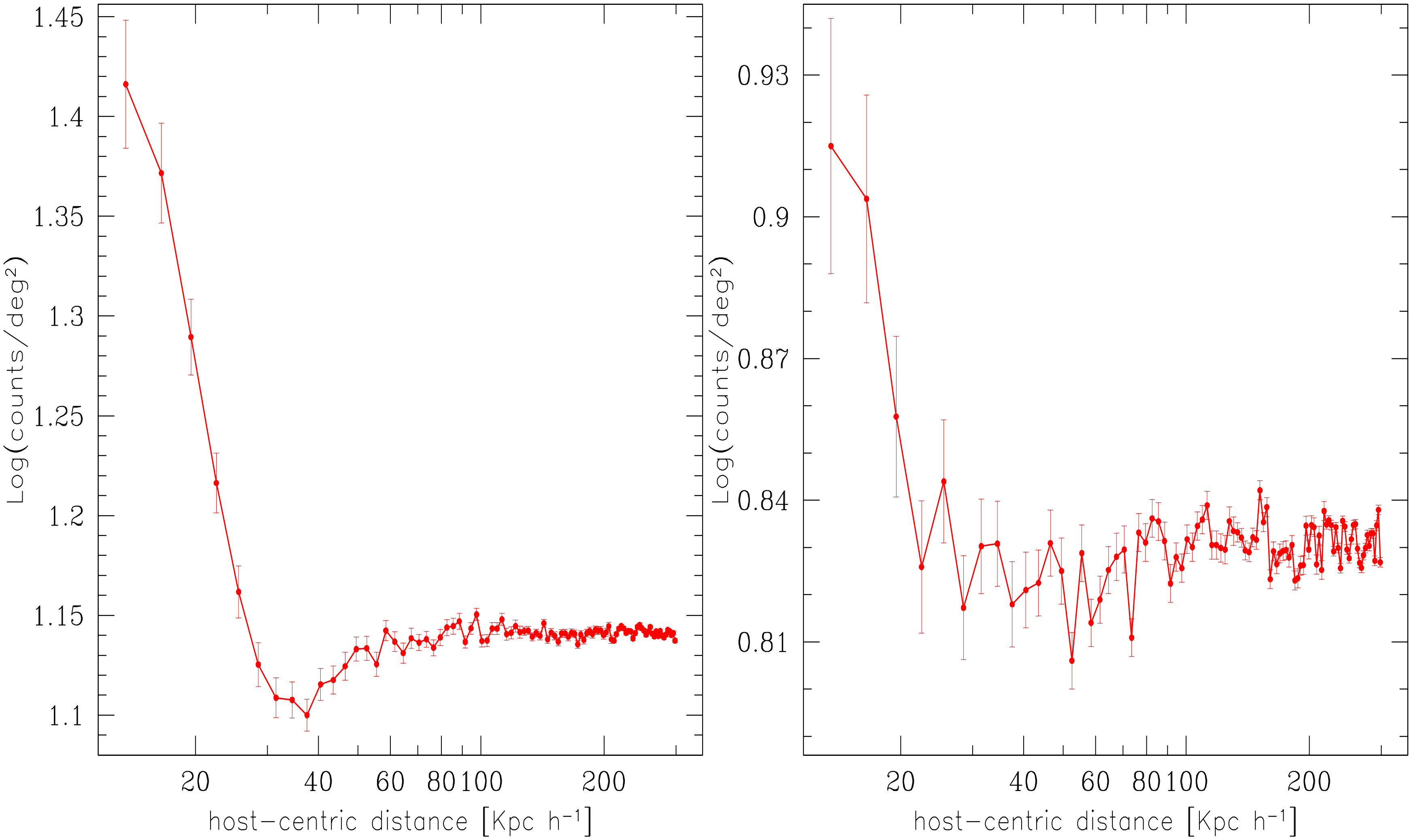


Fig. 1.- Radial density profile of photometric galaxies in the fields of hosts galaxies (i.e., with spectroscopic satellites, left) and isolated galaxies (right). It can be apreciated that the signal is stronger in the case of photometric fields centered in bright galaxies with spectroscopic satellites. This suggest that the presence of bright satellites is accompanied by faint satellites. It is also interesting the fact that satellites are tight accumulated near the host galaxy. In both cases the inner ring extends from 15Kpc up to 40Kpc.

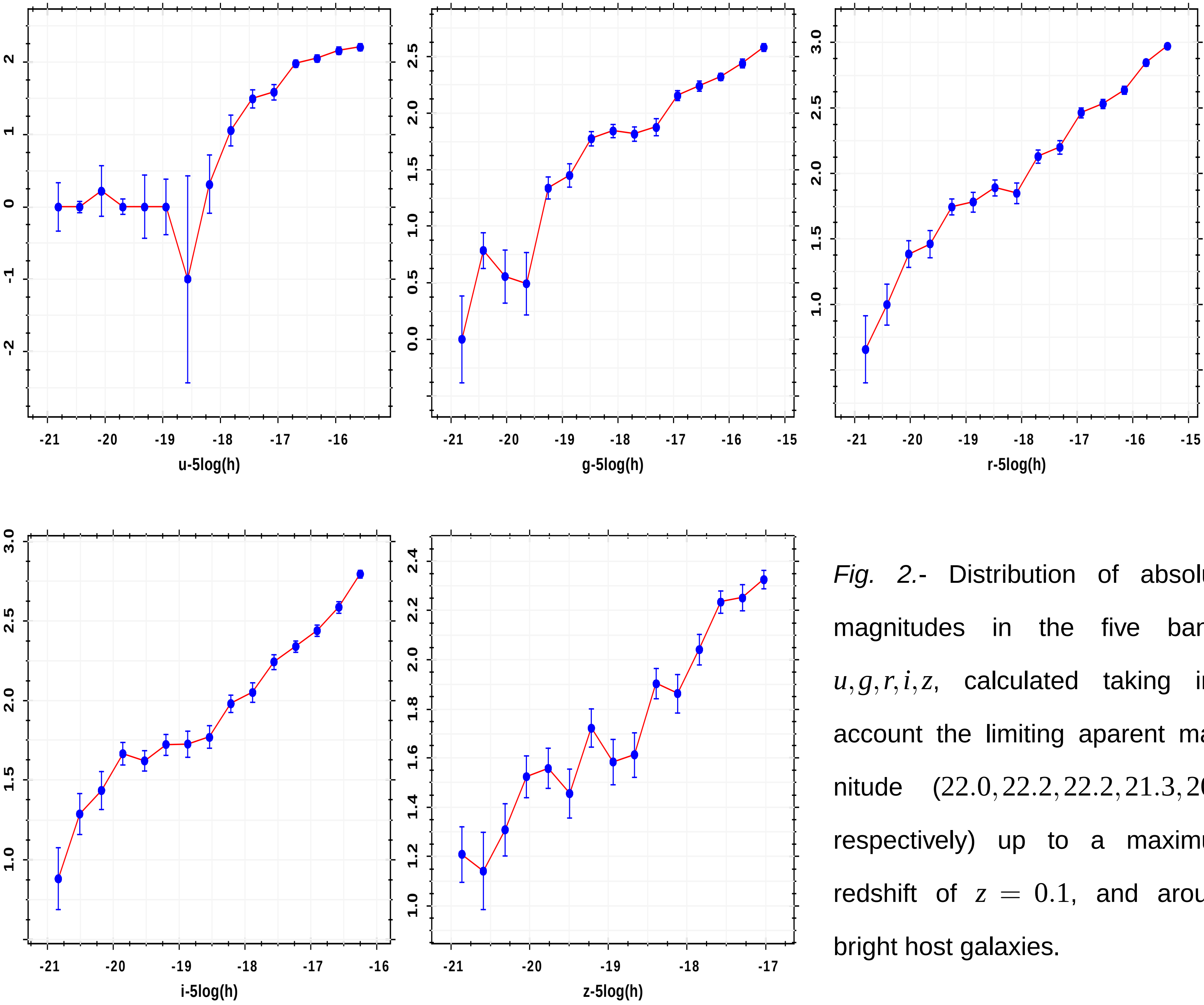
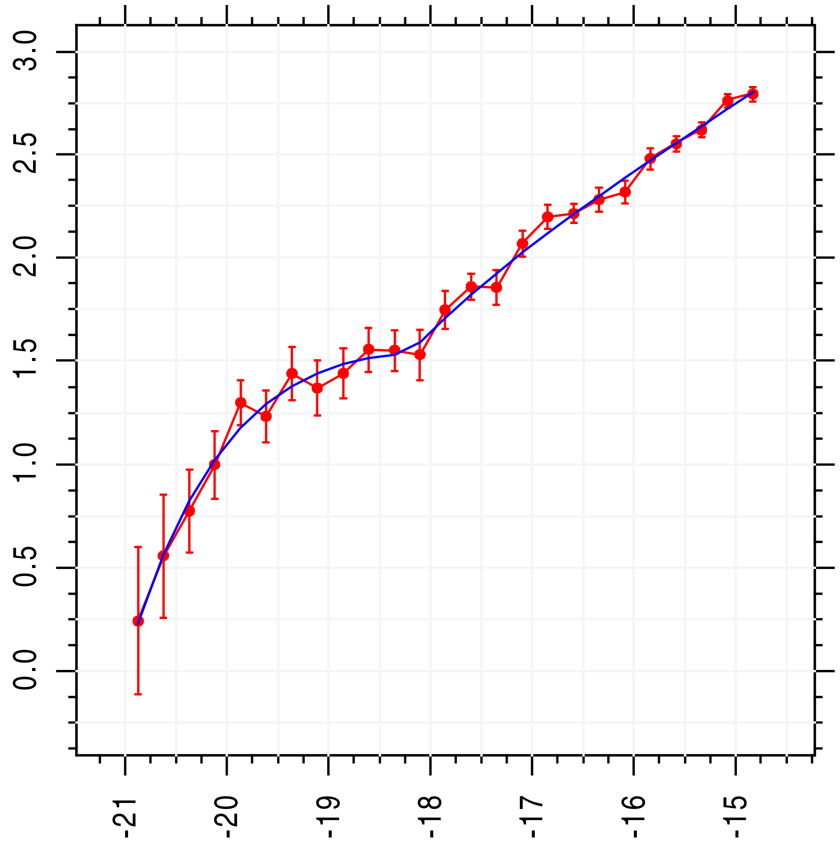


Fig. 2.- Distribution of absolute magnitudes in the five bands u, g, r, i, z, calculated taking into account the limiting aparent magnitude $(22.0, 22.2, 22.2, 21.3, 20.5$ respectively) up to a maximum redshift of $z = 0.1$, and around bright host galaxies.



restriction	Schechter function fits			
	bright end		faint end	
	M^*	α	M^*	α
isolated	-20.5	-0.5 ± 0.1	-18.2	-1.4 ± 0.3
hosts	-20.4	-1.5 ± 0.1	-23.65	-1.8 ± 0.1
$M_r < -18$	-19.3	-0.8 ± 0.1	-21.9	-1.9 ± 0.2
$M_r > -18$	-20.3	-1.3 ± 0.2	-18.1	-0.6 ± 0.3
$g - r > 0.75$	-19.7	-1.2 ± 0.2	-22.5	-1.9 ± 0.2
$g - r < 0.75$	-20.4	-1.6 ± 0.2	-19.4	-1.5 ± 0.2

Fig. 3.- Dependence of the galaxy LF on the properties of the host galaxy. The bootstrap errors are showed in each bin. Errors in the parameters correspond to the 1σ curves in the likelihood fuction. Errors in M^* are of the order of 0.2 in the bright end and 0.5 in the faint end, due to the small number of points used in the fit. Only the first line in the table corresponds to the isolated central galaxy sample, while the other correspond to the fields around host galaxies. The figure shows the fit for the full sample of galaxies in the fields of hosts.