Galaxy evolution in deep photometric surveys

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1) Objectives

In this work we attempt to establish the statistical basis for the study of the evolution of galaxy populations in the universe under different environments, through the analysis of the luminosity function (LF) of galaxies calculated on deep photometric catalogues with only photometric information. The main aim of this work is to test the reliability of estimating the galaxy LF calculated by using photometric redshifts ($\mathbf{z_{photo}}$) as distance estimator. We analysed the effectiveness of different methods to recover the LF by comparing with the results obtained using spectroscopic information.

2) Methodology

To perform the statistical tests, we used a mock galaxy catalogue constructed by Zandivarez et al (2014) [1] from the Millennium I simulation [2] plus a semianalytical model of galaxy formation [3].

We adopted as a test tool a mock catalogue that mimics the main properties of the future photometric catalogue Javalambre Physics of the Accelerating Universe Astrophysical Survey (J-PAS).

J-PAS will cover at least 8000 $\mathbf{deg^2}$, using an unprecedented system of 56 narrow band filters and 5 broad band in the optical (Figure 1). The mock catalogue constructed for the future J-PAS by Zandivarez et al. 2014 [1] provides us a sample of synthetic galaxies with all the properties needed to study the problems involved in the determination of the luminosity function, not only at the present, but also its evolution in time.

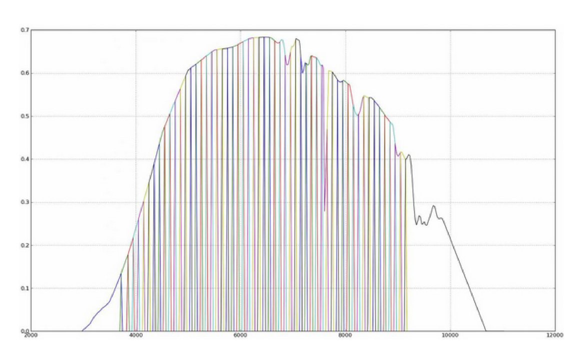

Figure 1: J-PAS photometric narrow bands.

The volume limited sample with absolute magnitudes brighter than $\mathbf{-16.4}$ contained in the selected light-cone, comprises **6756097** galaxies up to $\mathbf{z \sim 1.5}$ within a solid angle of **17.6** $\mathbf{deg^2}$. The final spectroscopic mock catalogue comprises **793559** galaxies with $\mathbf{i_{SDSS} \leq 23}$ in the selected light-cone. In Figure 2 we show an illustration of the spatial galaxy distribution as a function of redshifts (upper panel) and the redshift distribution of galaxies (lower panel).

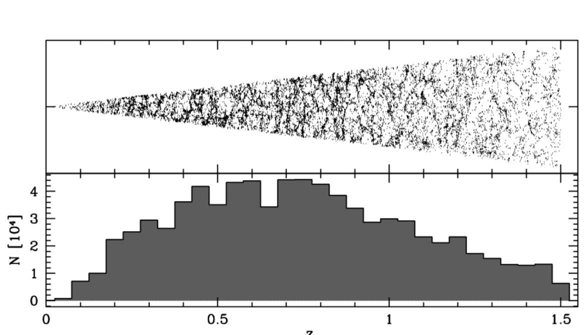

Figure 2: **Upper panel:**: Spatial distribution of the mock galaxies as a function of redshifts.
Lower panel:Redshift distribution of galaxies with $\mathbf{i_{SDSS} \leq 23}$ in the selected light-cone with an angular coverage of $\mathbf{17.6\ deg^2}$.

3) LF: Spectroscopic Estimator

The C-Method [4] was simplified and developed by Choloniewski 1987 [5] in order to compute simultaneously the shape of the LF ($\varphi\mathbf{(M)}$) and its normalisation.
This method measures the value $\mathbf{C(M)}$ (Figure 3) which represents the total number of galaxies brighter than M which could have been observed if their magnitudes were M. Using a simple recursive relation for ψ_{i+1}, we can estimate the LF, $\phi\mathbf{(M)}$.

$$\psi_{i+1} = \psi_i (C_i + 1)/C_{i+1}$$

$$\phi(M) = \frac{\sum_i^{M_i} \psi_i \sum_{j=1}^{N} d_j}{V \Delta M}$$

where V is the volume of the sample, and the summation of $\mathbf{d_j}$ depends on ψ_i and $\mathbf{C_i}$.

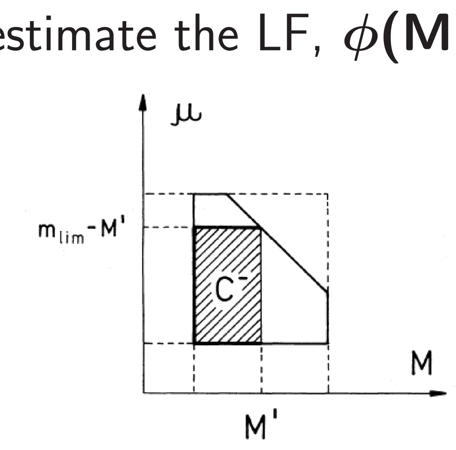

Figure 3: $\mathbf{C(M)}$ value in the M-μ space.

4) LF: Photometric Estimator I

With the advent of photometric surveys, the C-method has been modified to obtain the value of C using photometric redshifts. In the Subbarao et al. (1996) [6] method, each galaxy is now represented as a Gaussian distribution in redshift. Thus, we obtained a continuous function in absolute magnitude $\mathbf{C(M)}$.

$$C(M) = 0.5 \sum_i \mathrm{erfc}\left(\frac{z^*(m_i, M) - z_i}{\sigma_i}\right) - \mathrm{erfc}\left(\frac{z^*(m_{lim}, M) - z_i}{\sigma_i}\right)$$

$$\phi(M) = A \exp\left\{\int_{-\infty}^{M} \frac{dX}{C}\right\} \frac{dX}{C}$$

where X(M) is the first term of C(M).

5) LF: Photometric Estimator II

Comparing spectroscopic and photometric information of the mock galaxies, Zandivarez et al 2014 [1] have shown that a Lorentzian probability distribution function performs better than a Gaussian function to quantify the distributions of the differences between the photometric and spectroscopic redshifts for J-PAS. Hence, we also modified the equations to take into account a Lorentzian error distributions, i.e. we adopted

$$C(M) = \frac{1}{\pi} \sum_i \arctan\left(\frac{z_i - z^*(m_i, M)}{\sigma_i}\right) - \arctan\left(\frac{z_i - z^*(m_{lim}, M)}{\sigma_i}\right)$$

As in the Gaussian case, X(M) is the first term of C(M). We used the same formula to compute $\phi\mathbf{(M)}$.

6) Results

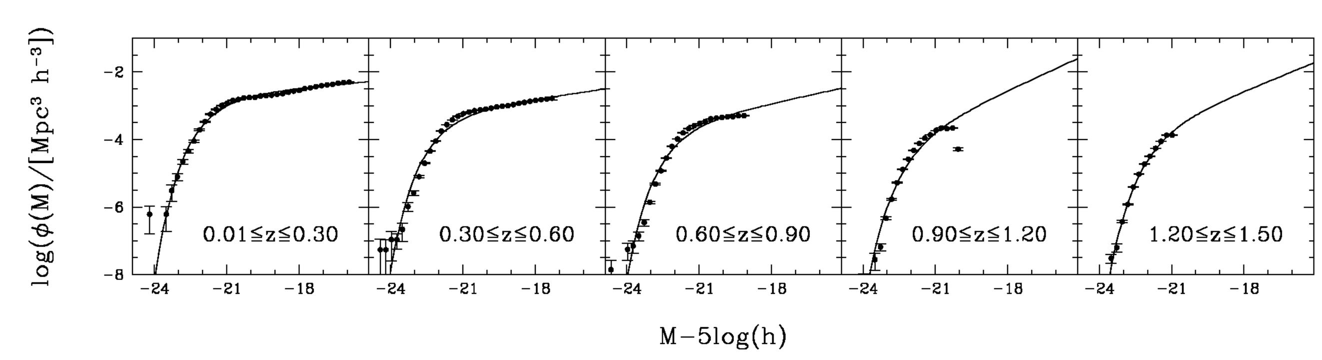

Figure 4: LF of simulated galaxies estimated with the spectroscopic C-Method [5] in different redshift ranges. The errors were estimated using the bootstrap resampling technique. The solid line shows the fit performed using a Schechter function.

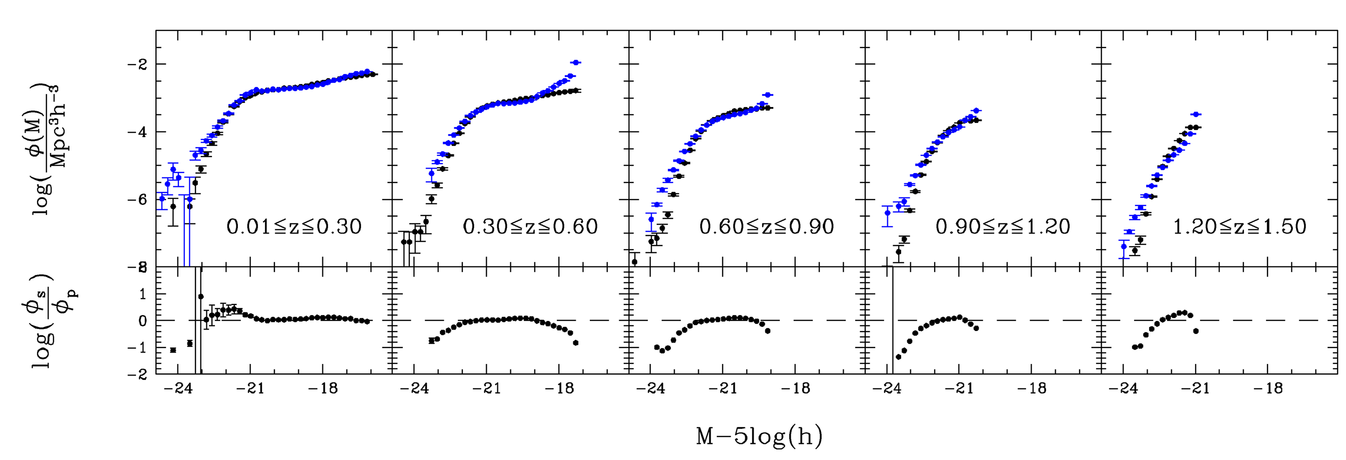

Figure 5: *Upper Panel*: LF of simulated galaxies estimated with the photometric C-Method [6] in different redshift ranges (red dots). For comparison, we also show the LF estimated using spectroscopic information (black dots). The errors were estimated using the bootstrap resampling technique. *Lower Panel*: Ratio between the photometric and spectroscopic LFs. Error bars are computed by error propagation.

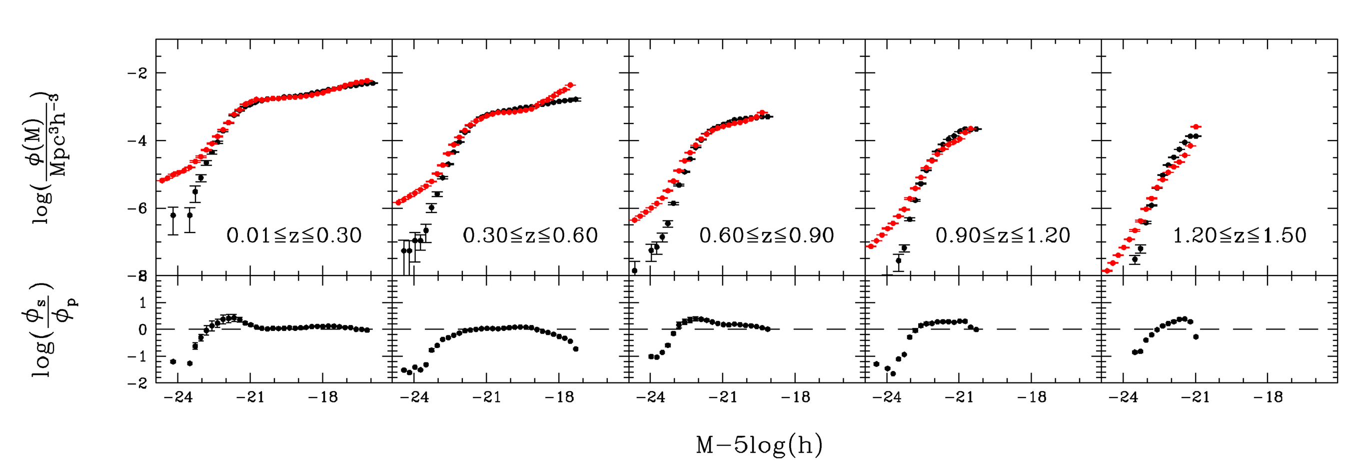

Figure 6: *Upper Panel*: The same as the previous figure but using the modified photometric C-Method using a Lorentzian error distribution.

7) Conclusions

- From the comparison between the estimations of the LF using spectroscopic and photometric redshifts we observe a good agreement in a given range of absolute magnitudes, depending on the redshift range under analysis (mainly around the position of the characteristic absolute magnitude).
- In general, the LF obtained using photometric redshifts usually is overestimated in the bright end of the absolute magnitude range.
- Using a Gaussian error distribution produces very noisy determinations in the bright end of the LF, while a Lorentzian error distribution actually improves the determination in those bins, producing a smooth LF in a wider range.

8) References

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