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COSMOLOGICAL PARAMETERS AND EVOLUTION OF THE GALAXY LUMINOSITY FUNCTION

by

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ABSTRACT

We discuss the relationship between the observed distribution of discrete sources of a flux limited sample, the luminosity function of these sources, and the cosmological model. We stress that some assumptions about the form and evolution of the luminosity function must be made in order to determine the cosmological parameters from the observed distribution of sources. We present a method to test the validity of these assumptions using the observations. We show how, using higher moments of the observed distribution, one can determine, independently of the cosmological model, all parameters of the luminosity function except those describing evolution of the density and the luminosity of the luminosity function. We apply these methods to the sample of ~ 1000 galaxies recently used by Loh and Spillar to determine a value of the cosmological density parameter $\Omega \approx 1$. We show that the assumptions made by Loh and Spillar about the luminosity function are inconsistent with the data, and that a self-consistent treatment of the data indicates a lower value of $\Omega \approx 0.2$ and a flatter luminosity function. It should be noted, however, that incompleteness in the sample could cause a flattening of the luminosity function and lower the calculated value of Ω and that uncertainty in the values of these parameters due to random fluctuations is large.

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I. INTRODUCTION

The use of redshift–magnitude (or flux) data of discrete sources such as galaxies or quasars for the determination of cosmological parameters has proven difficult because of large dispersion in the absolute magnitudes (or luminosities) of these objects and possible evolution of their luminosities or other intrinsic parameters. Dispersion merely complicates the simple classical tests for standard candles (e.g., Petrosian, 1974), but as stressed in this work, the presence of evolution of the luminosity of standard candles, or the evolution of the parameters of the luminosity function of non-standard candles, makes simultaneous determination of such evolution and the cosmological parameters impossible. Assumptions based on theory or other observations not related to redshift–flux data are required.

Recently, Loh and Spillar (1986a) have measured redshifts and monochromatic fluxes of about one thousand galaxies extending to redshifts $z \approx 1$. In a second paper (Loh and Spillar 1986b, hereafter LS) they claim that this data indicate a value for the density parameter, $\Omega = .9 \pm .3$ (for cosmological constant $\Lambda = 0$). This is an important result especially since it disagrees with all other recent estimates of the contribution to Ω from visible and dark matter (which indicate $\Omega < .4$), but it agrees with the required value of $\Omega = 1$ for the inflationary model.

As mentioned above, such analyses require some assumptions. In this work we examine the assumptions made by LS in order to determine the reliability of their results. Bachall and Tremaine (1988) have criticized these assumptions based on theoretical estimates of the rates of accretion, galaxy mergers, and differential evolution of various galaxy classes. Our approach, on the other hand, is based purely upon the observed data. We test the reliability of the assumptions made by LS using only their data, and without any other assumptions or theoretical estimates.

Our general procedure is described in section II. The results of the application of this procedure to the LS data and the tests of the consistency of their assumptions are described in section III. Section IV summarizes our results and conclusions which are that the uncertainties in the various parameters are larger than assumed or determined by LS and a value of Ω lower than that claimed by LS is more consistent with the data.

II. GENERAL EQUATIONS

The observed distribution, $n(l, z)$, of non-standard candles in the redshift–flux plane contains information about the cosmological parameters, which we denote as Ω_i, as well as information about the luminosity function and its evolution, $\Psi(L, z)$, where L is the absolute luminosity of the sources, assumed here to be greater that some minimum luminosity, L_{min}. The bolometric (or k–corrected monochromatic) flux and luminosity, and the two distributions are related via

$$L = 4\pi d_l^2(\Omega_i, z)\, l\,, \tag{1}$$

$$n(l, z)\, dl\, dz = V'(\Omega_i, z)\Psi(L, z)\, dL\, dz\,, \tag{2}$$

where d_l is the luminosity distance and V' is the derivative of the comoving volume with respect to redshift (e.g., Weinberg 1972).

Without loss of generality, we can write the luminosity function as

$$\Psi(L, z)\, dL = \rho(z) f(L/L_*, \alpha_1, \alpha_2, \ldots)\, dL/L_*\,, \tag{3}$$

with the normalization

$$\int_{x_{min}}^{\infty} f(x, \alpha_i)\, dx = 1\,, \tag{4}$$

where $x_{min} = L_{min}/L_*$, so that $\rho(z)$ is the comoving density evolution (or number of sources within a specified comoving volume, V), and L_* is a luminosity scale. In general, ρ, L_*, and the parameters α_i may vary with redshift. However, if α_i are constant, then the luminosity function retains its shape and $L_*(z)$ describes the identical luminosity evolution of all objects.

It is well known that in most cases of practical importance, a distribution function can be completely specified by its moments about any arbitrary point (Kendall, 1970). Knowledge of the moments of a distribution function, therefore, is equivalent to knowledge of distribution function itself, and in theory, any calculations involving the distribution function can be performed equally well with the moments of the distribution.

For a sample of sources with fluxes $l > l_o$, the $n^{\rm th}$ flux moment in the redshift interval δz, defined as $\delta \mathrm{M}_n = \int_{l_o}^{\infty} (l/l_o)^n n(l,z)\, dl\, \delta z$, can be written as

$$\delta \mathrm{M}_n = \rho V' \delta z\, \mathrm{G}_n(\Omega_i, \alpha_i, z)\,, \tag{5}$$

where

$$\mathrm{G}_n = x_o^{-n} \int_{x_o}^{\infty} x^n f(x, \alpha_i)\, dx\,, \tag{6}$$

and

$$x_o(\Omega_i, z) = \begin{cases} 4\pi d_l^2 l_o/\mathrm{L}_*, & \mathrm{L} \geq \mathrm{L}_{min} \\ x_{min}, & \mathrm{L} < \mathrm{L}_{min} \end{cases} . \tag{7}$$

We note that for our chioce of L_{min} for the data to be discussed in section III, x_o is given by the first of the expressions in equation (7).

If we parameterize the luminosity function with n parameters, $(\rho, \mathrm{L}_*, \alpha_i)$, then in principle, the first n moments may be used to solve for these parameters. Note, however, that the parameters ρ and L_* always occur in the combinations $\rho V'$ and L_*/d_l^2, and therefore these parameters may not be determined independently from the cosmological model. Information about the cosmology is needed to obtain these parameters, or alternatively, if we know the values of these parameters and their variation with redshift independently, we can determine the values of the cosmological parameters. Clearly, if the value of any parameter is chosen incorrectly, then the remaining parameters calculated by the method of moments should be considered suspect.

The Number-Flux Test

Loh and Spillar (1986) apply the above test to their sample of ~ 1000 field galaxies using the first two moments of the distribution, and assuming a two parameter Schechter function for the galaxy luminosity function:

$$f(\mathrm{L}, z)\, d\mathrm{L}/\mathrm{L}_* = \frac{(\mathrm{L}/\mathrm{L}_*)^{\alpha} \exp(-\mathrm{L}/\mathrm{L}_*)\, (d\mathrm{L}/\mathrm{L}_*)}{\Gamma(\alpha+1, x_{min})}\,, \tag{8}$$

where Γ represents the incomplete gamma function. This form has been shown to fit well to the locally ($z < .1$) observed galaxy luminosity function (e.g., Felten 1985) and LS assume local values of the parameters, derived from the analyses of Kirshner, Oemler, and Schechter (1979) and Kirshner, *et al* (1983), of $\alpha = -1.25$, and $\Phi^* = \rho/\Gamma(\alpha+1, x_{min}) = 1.23\times10^{-2}\,\mathrm{h}^{-3}\mathrm{Mpc}^{-3}$ where h is the hubble constant in units of 100 Km sec^{-1} Mpc^{-1}. We note, however, that recent analyses have found different values for the these parameters. Efstathiou, Ellis, and Peterson (1988) for example, find the range of $-0.92 < \alpha < -1.72$, depending on the survey analyzed, and a best estimate of $\alpha = -1.07 \pm .05$. For certain galaxy types they find values as high as $\alpha = -0.48$.

LS assume that the slope, α, is independent of redshift up to $z \sim 1$ which means that the luminosity function undergoes density evolution if ρ (or Φ^*) varies with redshift, and luminosity evolution if L_* varies with redshift. With this assumption, only the zeroth and first moments – the total number of sources, $\delta\mathrm{N}$, and total flux, $\delta\mathrm{F}$ – are needed:

$$\delta\mathrm{N} = \delta z \rho V' \,\Gamma(\alpha+1, x_o)/\Gamma(\alpha+1, x_{min})\,, \tag{9}$$

$$\delta\mathrm{F} = \frac{\delta z \rho V'}{x_o}\,\Gamma(\alpha+2, x_o)/\Gamma(\alpha+1, x_{min})\,. \tag{10}$$

LS introduce the quantity $\mathrm{C}_1 = \delta\mathrm{F}/\delta\mathrm{N} = \Gamma(\alpha+2, x_o)/x_o\Gamma(\alpha+1, x_o)$ for the ratio of average flux to the limiting flux, l_o. The right hand side depends only on x_o, and in principle can be solved for x_o from the observed values of C_1. With x_o known, the quantities $\rho V'$ and L_*/d_l^2 may be found from equations (7) and (9). One further assumption on the form of either $\rho(z)$ or $\mathrm{L}_*(z)$ is necessary to separate the evolution of the luminosity function from cosmological evolution. For example, in the case of pure luminosity evolution, $\rho =$ constant, and after the determination of $x_o(z)$, equation (9) can be used to solve for the cosmological parameters, Ω_i. Equation (7) may then be used to solve for the luminosity evolution, $\mathrm{L}_*(z)$. For pure density evolution, on the other hand, $\mathrm{L}_* =$ constant, and one uses equation (7) and the values of x_o to find the cosmological parameters and equation (9) to find the density evolution, $\rho(z)$. We note that, a priori, any form of either $\rho(z)$ or

$L_*(z)$ could be assumed with correspondingly different values found for Ω. LS assume the case of pure luminosity evolution and find $\Omega = 0.9 \pm 0.3$ for cosmological constant $\Lambda = 0$.

This result is only as reliable as the assumptions which are very restrictive and have been criticized by Bachall and Tremaine (1988) who show, for example, that differential evolution between spirals and ellipticals could have caused LS to find a value of $\Omega = 1$ in an $\Omega = 0$ universe. This demonstrates that the values of the cosmological parameters calculated by this method are sensitive to the evolutionary form chosen for the luminosity function, and information contained in the sample must be used to determine this evolution. We use two different methods to determine the reliability of the LS results, both based purely on the properties of their observed sample.

III. ANALYSIS OF THE LS DATA

In this section we first examine the self-consistency of the LS procedure and then describe the use of higher moments of the observed distribution as a refinement of this procedure. We use the data set kindly made available to us by Dr. Loh which is a set of apparent magnitudes and redshift of galaxies complete to an apparent magnitude of 22. In the following, we shall be dealing with redshift bins of $\delta z = 0.2$. This is sufficiently narrow that for our purposes here we can ignore the differential k-corrections across each bin and use the data directly. However, to determine the of evolution of $L_*(z)$ more accurately than is possible with the present data, these corrections must be included. Our results on α and Ω are independent of such refinements.

i) Testing the Assumptions

As described above, LS assume a Schechter function undergoing pure luminosity evolution ($\alpha = -1.25$, $\rho = \text{const.}$) to determine a value for Ω (assuming $\Lambda = 0$). Their procedure also gives $L_*(z)$, although they do not explicitly calculate it. We find that within the observational uncertainties, L_* can be assumed constant. On the other hand, given the value of Ω obtained by LS, we can determine the luminosity function and its evolution using a non-parametric method (Petrosian, 1986). This method gives the cumulative luminosity function, $\Phi(\mathrm{L}, z) = \int_{\mathrm{L}}^{\infty} \Psi(\mathrm{L}', z)\, d\mathrm{L}'$ and the cumulative density function, $\sigma(z) = \int_0^z \rho(z) V'(z)\, dz$ as functions of redshift. We have carried out this treatment of the LS data assuming $\Omega = 1$ (close to their derived value) for four different redshift bins. The resulting cumulative luminosity functions are shown in figure 1. In order to test the validity of the LS assumptions, one can fit these distributions to integrals of Schechter functions with varying the slope, α, and characteristic luminosity, L_*. Equivalently, one can carry out the test by fitting to the observed cumulative counts the function

$$\mathrm{N}(>\mathrm{L}, z) = \int_{\mathrm{L}}^{\infty} \Psi(\mathrm{L}', z)\, \delta V(\mathrm{L}', z)\, d\mathrm{L}' , \tag{11}$$

where $\delta V(\mathrm{L}, z) = V(z_{\mathrm{L}}) - V(z - \frac{\delta z}{2})$ and $z_{\mathrm{L}} = z + \frac{\delta z}{2}$ for $\mathrm{L} \geq \mathrm{L}_z \equiv 4\pi l_o d_l^2(z + \frac{\delta z}{2}, \Omega)$ or is found from $d_l = (\mathrm{L}/4\pi l_o)^{\frac{1}{2}}$ for $\mathrm{L} < \mathrm{L}_z$. The error and confidence regoin analysis is more straightforward for the second method and consequently we use this method in our fitting procedure. The best chisquare fits form this method and the 90% confidence regions, determined by Monte Carlo simulation, are shown in the insets of figure 1, and the best fit parameters are plotted as a function of redshift in figure 2. It is evident that the best fit values of α are inconsistent with the value of $\alpha = -1.25$ assumed by LS. Furthermore, for $z \geq .3$, the slope and characteristic luminosity seem to be constant to within random errors, $\alpha \approx -0.2$ and $\mathrm{L}_* \approx 5.0 \times 10^9\, \mathrm{h}^{-2} \mathrm{L}_\odot$.

With $\mathrm{L}_*(z)$ known, we may now use the non-parametric method to construct the cumulative density function, $\sigma(z)$, from the data. The result is shown in figure 3 where we plot σ as a function of comoving volume (not redshift). We also plot a straight line expected for constant comoving density $(\rho = \text{const.}, \sigma(V) \propto V)$. The deviation from constant density is not statistically significant.

As we shall see below, a lower value of Ω may be a more likely result. Consequently, we have repeated the above analysis for $\Omega = 0.5$ and $\Omega = 0.0$. The results for the $\Omega = 0.0$ case are also plotted in figures 2 and 3. Again, we find α and L_* to be constant above

$z = 0.3$, and $\sigma(V) \propto V$. In this case, however, the deviation of $\sigma(V)$ from the constant comoving density line is less significant than for $\Omega = 1$, although no firm conclusions can be reached from this.

We conclude from the above discussion that the results found by LS are not consistent with their assumption of constant slope, α, and normalization, Φ^*. To further demonstrate this fact, we show in table I the values of $\rho V'$ for the redshift bin $0.3 < z < 0.5$ for different subsamples of the data determined by assuming different limiting fluxes l_o (or magnitudes, m_o), which means different values of the parameter x_o. We expect $\rho V'$ to be independent of x_o (see equation 9) as is the case for the best fit $\alpha = -0.2$ found above and not for $\alpha = -1.25$ assumed by LS. Because of this variation, the value of Ω calculated in the redshift-number test with $\alpha = -1.25$ is sensitive to the values of x_o chosen for each redshift bin and can vary by as much as 100% for different choices of m_o. The best fit α produces no such variation in $\rho V'$ and we are able to include the dimmest objects, and hence the largest number of them in the redshift-number test, while encountering no ambiguity in the calculated value of Ω.

ii) Self-Consistent Method

We also test the assumptions made by LS using higher moments of the distribution. For example, the value of the slope, α can be obtained together with L_* directly from the data using the second moment. In addition to the average flux, $\mathrm{C}_1 = \delta\mathrm{M}_1/\delta\mathrm{M}_0 = \delta\mathrm{F}/\delta\mathrm{N}$, we calculate the *rms* flux (in units of limiting flux), $\mathrm{C}_2 = (\delta\mathrm{M}_2/\delta\mathrm{M}_0)^{1/2} = \left(\mathrm{G}_2(x_o)/\mathrm{G}_0(x_o)\right)^{1/2}$. Using these two relations, we can calculate for each redshift bin the values of both α and x_o (instead of just x_o from C_1 with an assumed value of α as done by LS). Table II gives the results of this procedure obtained numerically. It is evident that the data does not warrant the assumption of constant α; the value of α increases with z, and for $z > 0.4$, it is larger than -1.25. This is in agreement with the results of the fitting procedure described above.

Because the values of the higher moments become increasingly sensitive to random fluctuations in the data, it is usually best to restrict the analysis to the first few moments of the luminosity function and to determine the remaining parameters by other means. Consequently, the values of α given in table II should be considered as rough estimates.

iii) Cosmological Parameters

Clearly, the value of Ω derived by LS is suspect. Using the larger value $\alpha = -0.2$, we obtain a lower value for Ω. To show this, we carry out the test using only the first moment in the redshift range $0.3 < z < 0.9$ by evaluating Ω for various assumed values of α and no evolution in the number of galaxies, ρ =constant. In order to avoid possible uncertainty caused by incompleteness in the data toward the lower fluxes, we perform this determination for three different limiting fluxes (or limiting apparent magnitudes m_o = 21.0, 21.5, and 22.0). The results plotted as curves of α *vs.* Ω are shown in figure 4 (filled triangles, squares, and circles, respectively) together with the best fit values of α obtained above (open circles). It can be seen that the three α *vs.* Ω curves, each derived using different values of x_o, converge for $\alpha \sim -0.2$, indicating that this is the correct value of slope, and that Ω is less sensitive to α for the curves with higher values of x_o. The intersection of these curves with the best fit α curve (obtained for various assumed values of Ω) gives the self-consistent values, $\alpha = -0.2$ and $\Omega = 0.2$, but with large possible errors.

IV. SUMMARY AND CONCLUSIONS

We have discussed the relationship between the observed distribution of a magnitude limited sample of discrete sources in the redshift-flux plane, the evolution of the luminosity function of the sources, and the cosmological model. We emphasize that some assumptions about the shape and evolution of the luminosity function are necessary before we can derive the cosmological parameters from this relationship. For example, in the simplest case of a luminosity function of invariant shape undergoing density and/or luminosity evolution, knowledge of one of these evolutions is required before the number-redshift or flux-redshift distribution can be used to determine the other evolution and the cosmological model.

Loh and Spillar, assuming the local values for the parameters of the luminosity function (a Schechter function) and only pure luminosity evolution, derive a large value for the density parameter ($\Omega = 1$ for $\Lambda = 0$).

We have shown how the method of LS can be generalized for a more complete analysis of the data and we describe two procedures for testing the validity of such a determination of the cosmological parameters. The first method checks for consistency of the assumptions with the final results. Given the cosmological model derived by LS ($\Omega = 1$), we use a non-parametric method to determine the form of the luminosity function and the density evolution. While we find that the absence of density evolution (as assumed by LS) is consistent with the data, the exponent α of the luminosity function is larger ($\alpha \sim -0.2$) for $z > .3$ than the local value ($\alpha = -1.25$) assumed by LS. With this larger value of α we find $\Omega \approx 0.2$

With the second method we use one more moment of the observed distribution to determine the value of the exponent, α, explicitly independent of Ω. Again, we find a larger α, ranging from -0.5 to $+0.1$, but with larger error bars because random errors tend to increase with higher moments.

We conclude, therefore, that the large value of Ω derived by LS is not consistent with their data, and that the exponent, α undergoes rapid evolution from the local value of -1.25 to -0.2 in the redshift range 0 to 0.4. This is perhaps unexpected based on conventional ideas of galaxy evolution, and we have sought other explanations for the high values of α at high redshift. First of all it should be noted that the error bars are large and our calculated values of α are not strictly inconsistent with the new determinations of slope by Efstathiou, *et al.* (1988). Another possibility is that the data are not complete to the limiting magnitude claimed by LS. A large incompleteness at lower fluxes (higher magnitudes) would reduce the observed number of low luminosity galaxies resulting in a flatter luminosity function or a larger α. This, of course would not validate the high value of Ω found by LS. It would mean that both the high value of Ω and the high value of α

are suspect.

There is some evidence, however, against the arguments that high α and low Ω are the result of simple incompleteness in the LS data. First, the effect of incompleteness should increase with increasing redshift and therefore, the value of α should increase monotonically. This is not what is observed. Secondly, we have tested the incompleteness hypothesis by repeating the above analysis using subsamples (with magnitudes less than 21.5 and 21.0) of the original sample with a limit of 22 magnitude. As shown in figure 4, while the value of Ω derived using the smaller local value of α ($= -1.25$) changes with limiting magnitude, it remains essentially constant for the larger values of α. Thus, we conclude that incompleteness, unless it is more complicated than a simple undercounting objects above a certain magnitude, does not effect our derived values of $\alpha \approx -0.2$ and $\Omega \approx 0.2$. We stress, however, that the error bars are large and more data is needed for a reliable determination of both the cosmological parameters and the parameters of the luminosity function. If the data are accurate and α does indeed vary as shown above, then this will have important consequences for deep galaxy counts.

We wish to thank Dr. Loh for providing the detailed data used in this analysis and Dr. Wagoner for useful discussions. This work was supported by NASA grants NCC 2-322 and NGR 05-020-668.

Table I

Variation of $\Phi^* V'$ with x_o for $0.3 < z < 0.5$

		$\alpha = -1.25$		$\alpha = -.2$	
C_1	N	x_o	$\Phi^* V'$ ($\times 10^2$)	x_o	$\Phi^* V'$ ($\times 10^2$)
5.29	177	0.06	2.72	0.20	10.67
3.83	158	0.11	3.39	0.31	10.35
2.83	126	0.22	4.41	0.49	10.20
2.18	92	0.41	5.79	0.77	10.24
1.74	52	0.78	8.84	1.25	10.69

Table II

Solutions to x_o and α from second moment test

z	N	C_1	C_2	x_o	α
0.25	104	8.58	16.33	.026	−1.24
0.40	177	5.29	7.27	.153	−0.52
0.60	157	2.92	3.47	.556	0.13
0.80	98	2.19	2.49	.839	−0.01

REFERENCES

Bachall, S. R., and Tremaine, S. 1988, *Ap. J. (letters)*, **326**, L1

Efstathiou, G., Ellis, R. S., Peterson, B. A. 1988, *Ap. J.*, **232**, 431

Felten, J. E. 1985, *Commts. Astrophys.*, **11**, 53

Kendall, E. 1970, *Introductory Mathematical Statistics* (New York: John Wiley and Sons), p. 87

Kirshner, R. P., Oemler, A., and Schechter, P. L. 1979, *Astron. J.* **84** 951

Kirshner, R. P., Oemler, A., Schechter, P.L., and Shectman, S. A. 1983, *A. J.*, **88**, 1285

Loh, E. D., and Spillar, E. J. 1986a, *Ap. J.*, **303**, 154

Loh, E. D., and Spillar, E. J. 1986b, *Ap. J. (Letters)*, **307**, L1 (LS)

Petrosian, V. 1974, *Ap. J.*, **188**, 443

Petrosian, V. 1985, in *Structure and Evolution of Active Galactic Nuclei*, ed. G. Giuricin (Dordrecht [Netherlands]: Reidel), p. 353.

Weinberg, S. 1972, *Gravitation and Cosmology* (New York: John Wiley and sons), p. 453

Figure Captions

Fig. 1 – Nonparametric cumulative luminosity functions, $\Phi(>L)$, for the Loh and Spillar data at four different redshifts for $\Omega = 1$ and Hubble constant $H_0 = 100$ Km sec^{-1} Mpc^{-1}. Insets: χ^2 contours (90% confidence) for characteristic luminosity, L_*, and slope, α, of the Schechter functions fit to the data. Filled circles indicate best fit values. Note that at low redshifts the sample includes more low luminosity objects and the fitting procedure is more sensitive to the slope, α, while at higher redshifts it samples the exponential tail of the distribution and the procedure is more sensitive to L_*. Note, also, that for the redshift bin $0.2 < z < 0.3$, the Schechter function is not a good fit. This could be due to random fluctuations or contamination by stars in the low redshift bin.

Fig. 2 – Variation with redshift of the characteristic luminosity, L_*, and slope, α, of the Schechter luminosity function fitted to the Loh and Spillar data for $H_o = 100$ Km sec^{-1} Mpc^{-1}. Best χ^2 fit and 90% confidence intervals are shown for $\Omega = 1$ (filled circles). Best fit L_* are also shown for $\Omega = 0$ (open circles). Best fit α for $\Omega = 0$ are almost identical to those for $\Omega = 1$. The error bars on the local values of α and L_* indicate the range of various determinations. Note that the local value of L_* refers to a rest frame wavelength of about 400 nm while values of L_* at higher redshifts refer to luminosities at observed 800 nm. Correction due to these differences will be smaller than the indicated error bars. The large error bar at $z = 0.25$ is reflective of poor fit to Schechter function refered to in figure 1.

Fig. 3 – Nonparametric cumulative density functions, $\sigma(V)$, *vs.* comoving volume for $0.3 < z < 0.9$. Straight lines indicate constant comoving density. $V_{min} = V(z = 0.3)$. Note that the vertical scale is arbitrary and that $\Omega = 0$ shows better consistency with no evolution than the $\Omega = 1$ model.

Fig. 4 – Best fit values of slope, α, (derived from the values in figure 2) for assumed value of Ω and for $z > 0.3$ (open circles), and solutions for Ω (closed symbols) from the number-flux test for various assumed values of α and for three different values of limiting flux, $m_o = 21.0$, 21.5, and 22.0 (triangles, squares, and circles, respectively). Two typical error bars are shown. Note that the value of Ω calculated by the number-flux test is strongly dependent upon the choice of α and m_o for $\alpha \sim -1.25$. The intersection of these curves gives the self-consistent values of $\alpha = -0.2$ and $\Omega = 0.2$. Note however that because of large error bars, $-0.9 < \alpha < 0.5$ and $0 < \Omega < 0.8$ are possible solutions.

ADDRESSES

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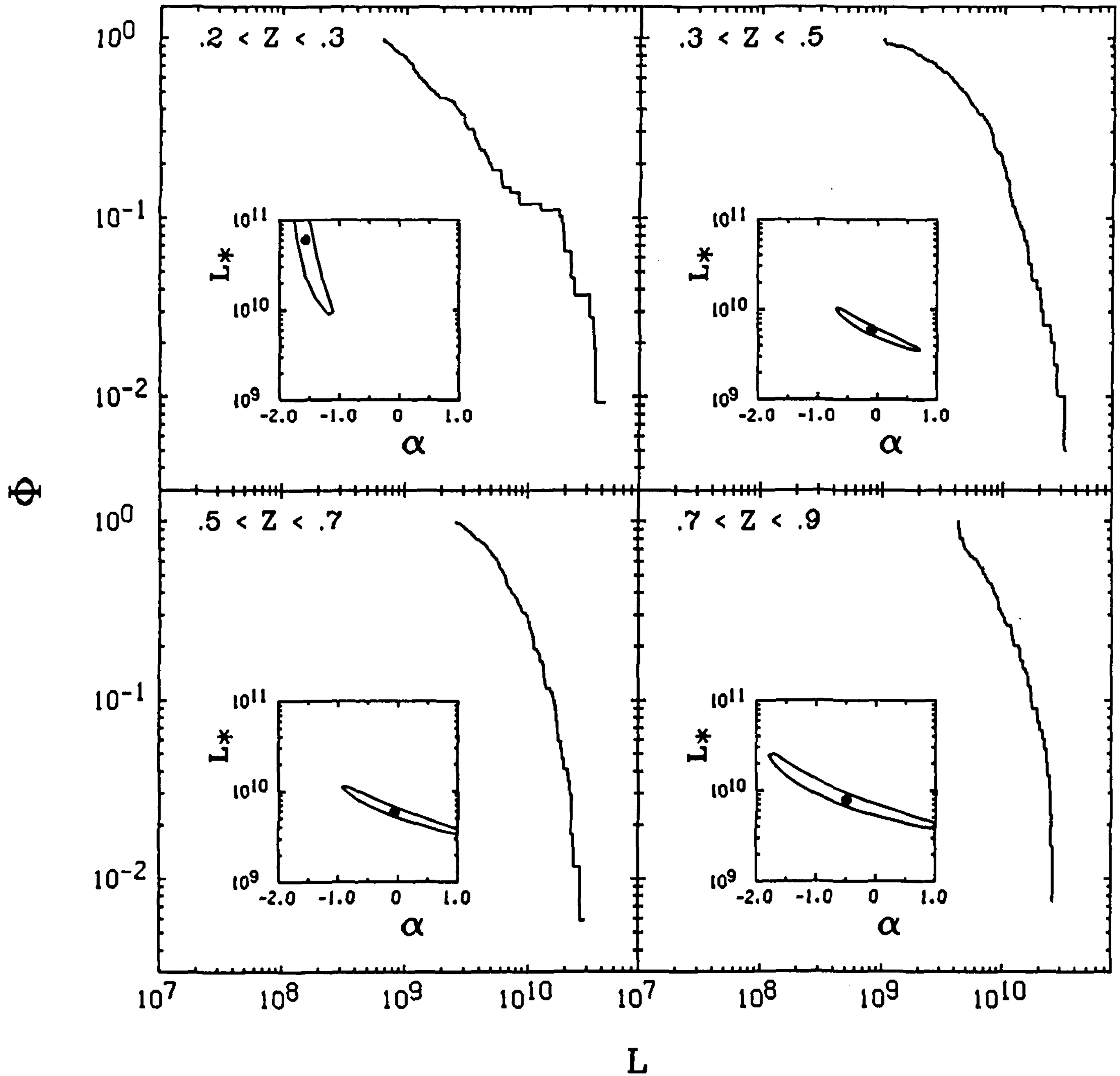


.2 < Z < .3
.3 < Z < .5
.5 < Z < .7
.7 < Z < .9
10^0
10^{-1}
10^{-2}
Φ
L*
10^{11}
10^{10}
10^9
-2.0
-1.0
0
1.0
α
10^7
10^8
10^9
10^{10}
L

FIGURE 1

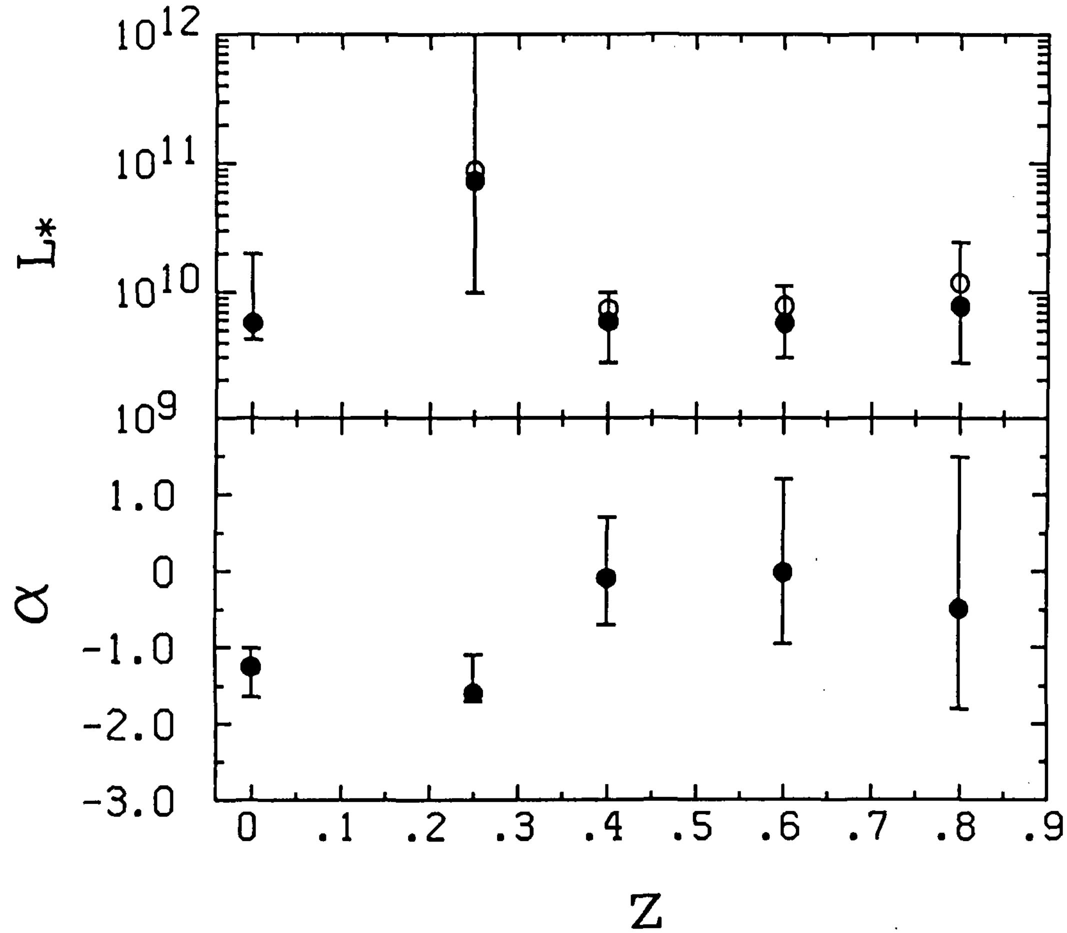
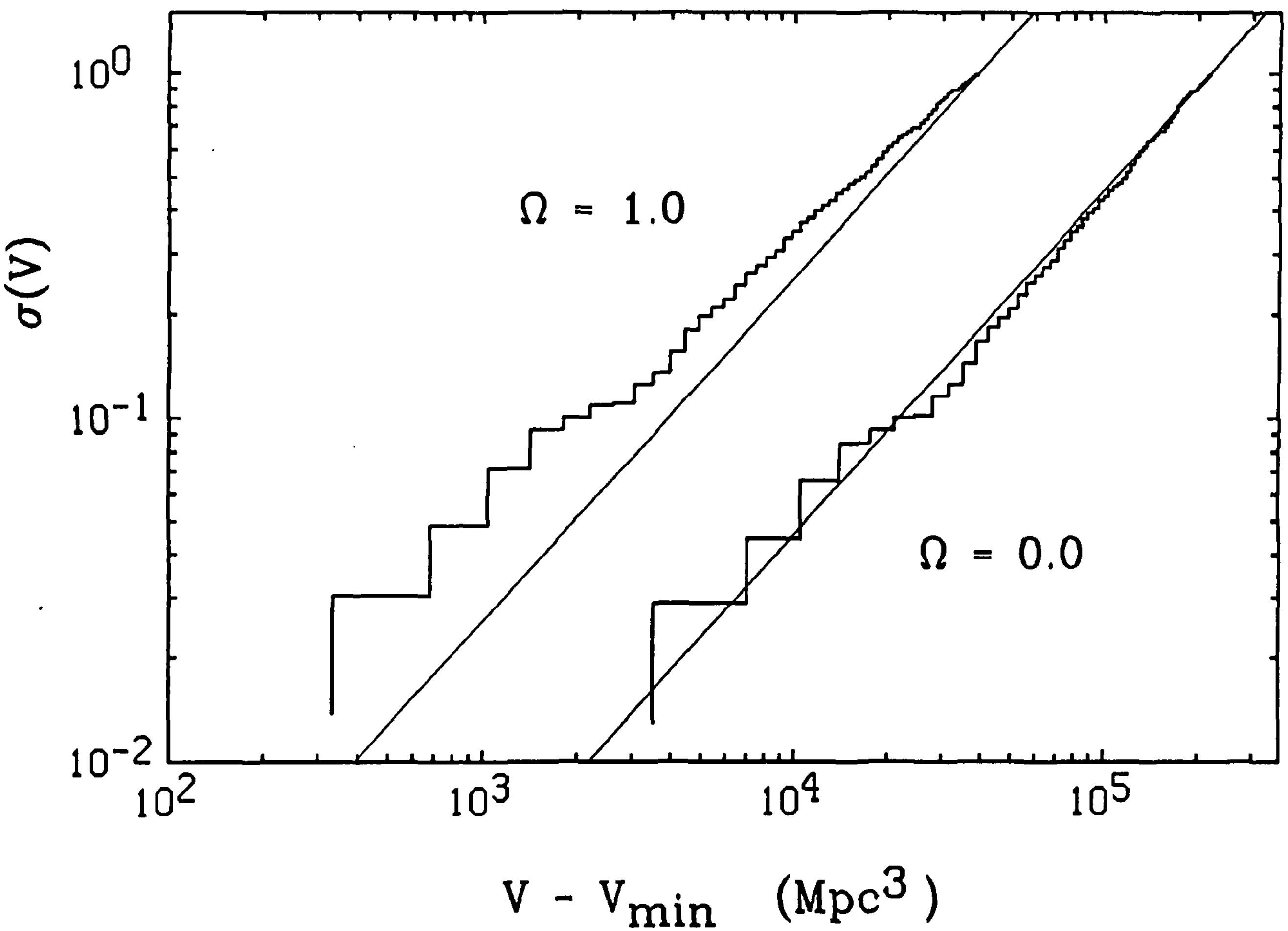


FIGURE 2



10^0
10^{-1}
10^{-2}
$\sigma(V)$
$\Omega = 1.0$
$\Omega = 0.0$
10^2
10^3
10^4
10^5
$V - V_{min}$ (Mpc^3)

FIGURE 3

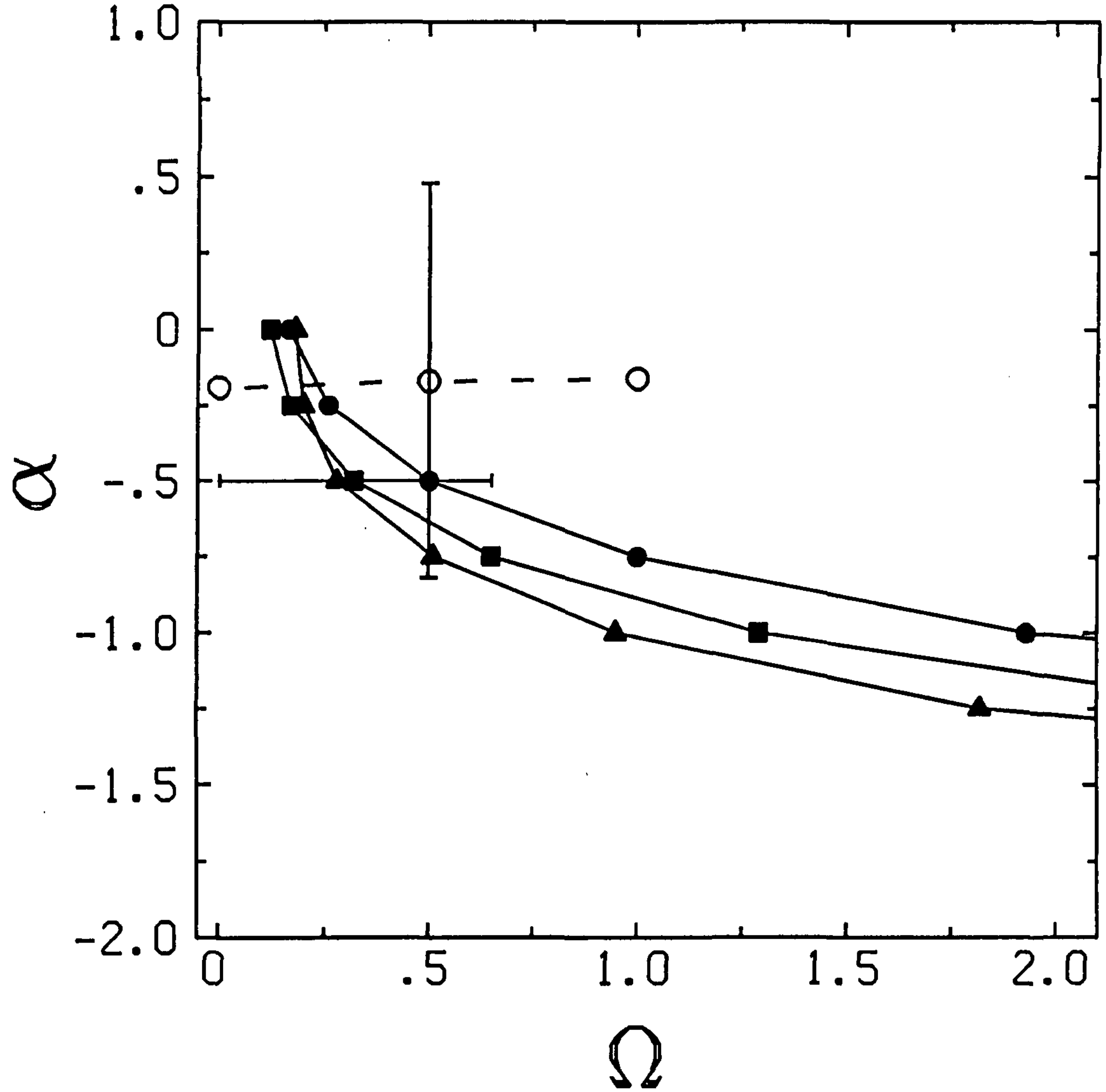


FIGURE 4

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