STUDIES OF FAINT FIELD GALAXIES

Richard S. Ellis
Durham University
England

Although claims are often made that photometric surveys of faint field galaxies reveal evidence for evolution over recent epochs ($z<0.6$), it has not yet been possible to select a single evolutionary model from comparisons with the data. Magnitude counts are sensitive to evolution but the data is well-mixed in distance because of the width of the luminosity function (LF). Colours can narrow the possibilities but the effects of redshift and morphology can only be separated using many passbands.

The conclusions of Koo's(1981) UJFN analysis do not differ significantly from that of Kron (1978) who used counts in J and F. Moreover the data can be fitted without recourse to evolution if the LF is strongly dependent upon colour/morphology. The adjustment necessary to eliminate evolution in this way is rather extreme but it highlights two ways in which we can make further progress in this important subject.

Firstly, uncertainties in intepreting faint data reflect those in local galaxy parameters (Ellis 1980). One remedy is to derive statistical information on nearby galaxies from local redshift surveys. Here I discuss results based on the AAT redshift survey (Peterson et al 1982) which comprises 5 Schmidt fields to J = 16.7 i.e. well beyond local inhomogeneities. Secondly, the difficulties in resolving the many possibilities encountered with faint photometry could be resolved with redshifts. To obtain redshift distributions for faint samples is now feasible via multi-object spectroscopy. At intermediate magnitudes ($J\sim20$) such distributions test the faint end of the galaxy LF; at faint magnitudes ($J\sim22$) they offer a direct evolutionary test.

The AAT redshift survey reveals two important points. Firstly, the LF normalisation is lower than previous estimates - as might be expected if local effects were important in other surveys. Figure 1 shows that the AAT survey counts together with deeper Schmidt counts are well-fitted by a model incorporating no evolution, K-terms reviewed by Ellis(1982) and a morphological variation of the LF defined by the AAT redshift data. The Kirschner et al(1978,KOS) counts have been transformed by photometering their SP3 field in our system; their counts show a northern normalisation significantly higher than the AAT value. The effect of the low value (60% lower also than that adopted by Koo and co-workers) is to strengthen the

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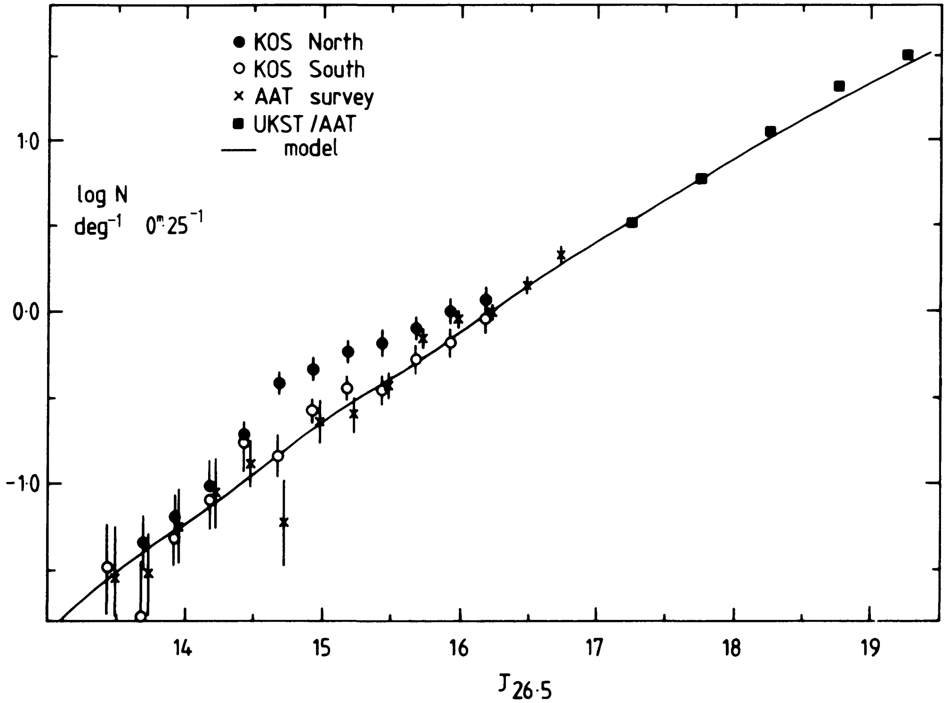

Figure 1: Differential galaxy counts transformed to the J (IIIa-J+Schott GG385) system at an isophote of 26.5 mag/sq arcsec. The model assumes the AAT survey LF, K-terms from Ellis(1982) and no evolution. Note the high normalisation for the northern KOS data.

evolution needed at faint magnitudes. Whilst it is possible that the areas covered by the AAT survey are anomalous, this seems unlikely given the volumes sampled, the uniformity of the counts from field to field and the agreement between the count slope and that expected for a homogeneously distributed sample. The results also show the importance of obtaining well-calibrated photometry in the deeper non-evolving region 17< J <19.

The AAT survey also shows (Figure 2) that the LF over all types does not vary significantly from one sample to another provided each sample is analysed in the same way. The parameters reported by Huchra (this symposium) for the CfA survey LF are also close to those in Figure 2. It appears that M^* is known to within $\pm$ 0.1m and α to within $\pm$ 0.15; the effect of these uncertainties on faint galaxy predictions is small. The remaining problem here is the morphological/colour variation in the LF, specifically for late types whose K-terms are small and for which M^* may be very faint. Kron (1982) mentions 13 galaxies with B<18.9 and U-B<-0.35 for which $\langle M \rangle = -17.5$ (H_o=100) whereas the latest class in the AAT survey, Sdm/Irr with U-B$\sim$-0.15, gives $\langle M \rangle = -18.9$. Larger or deeper surveys should resolve this question.

Simple considerations show that the redshift distribution of 2-300 galaxies at J$\sim$22 should test evolution of the form discussed by Bruzual (1980) and Tinsley(1978). The long integrations necessary to determine

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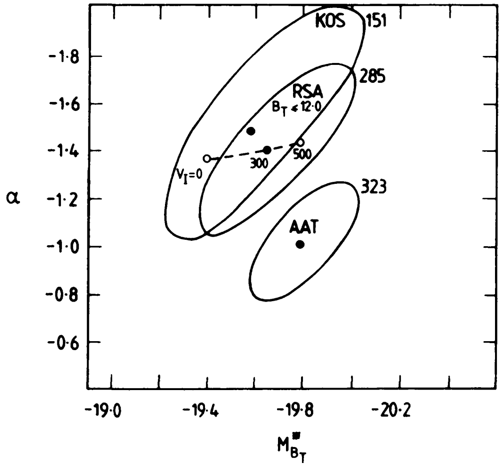

Figure 2: 1σ error contours for Schechter LF parameters determined for various redshift catalogues (H_0=100) after Efstathiou et al 1982. The Revised Shapley Ames (RSA) results are sensitive to the Virgo infall velocity as indicated (km/sec). The sample size is indicated alongside each contour.

the redshift of a faint galaxy has led to searches for quick approximate alternatives to direct spectroscopy. At present there seems to be no generally accepted alternative. Colours have been considered by various groups; infrared colours are somewhat better than visible ones because, for modest redshifts they should not depend on morphology. However the current i-r/redshift relation for optically-selected galaxies shows much scatter for z>0.3 although the average is close to that expected for no evolution (Ellis and Allen 1982). The situation may be better than current data imply because, of necessity, the relationship is derived using cluster members where visible and i-r anomalies are often found. The optical colour-z relation for clusters(Kristian et al 1978) is not easy to reconcile with the field colour-z tests performed by Koo. Since the i-r method would be very efficient if imaging were possible, it is important to continue studying the i-r colour/redshift relation using <u>field</u> galaxies. The combination of i-r and optical colours allows, in principle, the separation of morphology and redshift. With 47 optically-selected galaxies Ellis and Allen were unable to find any high z objects with rest-frame s.e.ds like elliptical galaxies.

Projects using genuine spectroscopy of faint field galaxies presently involve only small (∿50) samples but should provide an impressive impact on the subject over the next 2 years. Turner(1980) has obtained redshifts for 58 galaxies with J∿19-21 and Gunn(1982) has claimed that the redshift distribution does not agree at all well with model predictions. However, as Koo(1981) remarks, the sample is <u>not</u> a random subset of a complete photometrically-defined sample and the magnitude distribution peaks near J=20 but extends beyond J=21. The selection criteria assumed by Gunn, viz <J>=20, may well be inappropriate for the sample; as an example, if we assume the sample <u>is</u> complete to J=21 then the redshift distribution is in fair agreement with a no evolution model based on the AAT survey parameters.

I have begun a survey using the AAT multi-object spectrograph (Ellis et al 1982) which currently reaches J=21.2; spectra of 50 galaxies have been secured and provisional redshifts for 20 do not indicate any serious discrepancy with the AAT survey-based no evolution prediction. The only

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results on fainter galaxies where evolution might be observed in small samples are those of Koo(this symposium); at $J\sim22.5$ the redshifts of 54 galaxies indicate mild evolution although, at present, the sample is biased to those galaxies with strong, easily detectable, features including emission lines.

This raises the general difficulty of determining the redshift of a galaxy whose morphology and redshift is not known a priori. The wavelength range over which familiar features are recognisable is limited by the detector and sky and is crucially important in the red. At faint magnitudes where $z\sim1$ galaxies might occasionally be expected, it must be demonstrated convincingly that such a redshift could have been measured successfully before claiming the absence of high z objects is significant. This is an important point because, with multi-object facilities, there may a reluctance to go back and clean up individual failures.

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DISCUSSION

Segal: Non-parametric analyses by an optimal statistical technique or large low-redshift galaxy samples due to de Vaucouleurs (1979), Visvanathan (1979), and the revised Shapley-Ames catalog show a very good fit by the Lundmark quadratic law and corresponding discrepancies from the Hubble law. Such discrepancies have a systematic redshift dependence convolved with the Lundmark law luminosity function, and so appear as evolution within the framework of the Friedmann cosmology. Is there any special reason to doubt that the evolution you describe may originate in this way and that physically there is no evolution?

Ellis: It is certainly true that the discrepancy between the Friedmann predictions and the observations is conventionally explained as luminosity evolution with little reason other than the expected changes in the stellar populations from considerations of the H-R diagram in our own galaxy. I will say, however, that the accumulation of large well-defined redshift samples at various magnitude limits will help clarify the non-Friedmann possibilities. Those data will be available to you at the earliest opportunity.

Kiang: Does your result of no evidence for evolution not support the high value of $q_o(+1)$, consistently found by Sandage and co-workers from the Hubble diagram of cluster galaxies, assuming no evolution?

Ellis: The no-evolution model implied by the AAT survey fits only the faint data to $J \sim 21.5$, or equivalently $z \lesssim 0.3$; thereafter, mild evolution is required. Since the Hubble diagram data covers a wider redshift range, evolutionary corrections would be necessary before deriving q_o. In a recent review (Ellis 1982), I was unable to reconcile the evolution implied by the field counts with that indicated on the Hubble diagram, assuming q_o is small (as local dynamical arguments imply). However, this was partly because the published Hubble diagrams are not in agreement with one another. Furthermore, one might question whether the giant ellipticals in rich clusters evolve in the way expected for normal early-type galaxies.

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