NUMBER COUNTS OF GALAXIES TO B = 25*

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ABSTRACT. Results are presented of counts of galaxies over the apparent magnitude range $21 \leq B \leq 25$, which have been obtained at the 6-meter telescope using McMullan's electronographic camera. These data do not indicate evidence for rapid luminosity evolution of galaxies. It is noted that the faintest galaxies, on the whole, have bluish color and a small correlation function amplitude.

Counts of faint galaxies at large telescopes make it possible to investigate a luminosity evolution of galaxies. The most valid information derives from counts log N(m), which are performed in different colors simultaneously. A determination of the amplitude and the time-scale of the luminosity evolution of galaxies must be treated, obviously, as a necessary prelude to the precise determination of the cosmological deceleration parameter, q_o.

The first counts of galaxies fainter than 23rd magnitude were carried out by Karachentsev and Kopylov (1977) and by Kron (1978). The fundamental work of Kron contains a detailed analysis of theoretical and observational aspects of the problem of counting galaxies. There is an appreciable disagreement, however, between the data of these authors in the sense that the counts of Kron show a relative number excess, log N(B = 23.5) ≃ 0.4. To understand the reason for this disagreement, we have undertaken new observations, the results of which are presented here.

Observations were made in Selected Area 57 (1950: $\alpha = 13^h05^m.8$; $\delta = +29°35'$) near the north galactic pole with deep photoelectric standards. This is one of the two fields investigated by Kron. On April 30, 1979, the author obtained films of the field in three colors (B, V, and R) with McMullan's electronographic camera installed in the 6-meter telescope cage. The camera has a high-quantum-efficiency photocathode

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of 44 mm diameter. The linearity of the system response, a wide dynamic range, and its low noise make the electronographic camera a valuable instrument for a photometry of extremely faint objects. The electronograms were obtained from a 35-minute exposure in each color, with a mean seeing of 1".8. The films have sky background densities of 0.6, 1.2, and 1.4 in B, V, and R, respectively.

At present, we restrict ourselves to photometry of the field in the blue color only. In an area of 30 (arc minutes)^2 were about 400 objects to B = 25. Stars and galaxies are distinguished reliably to B = 23. Among the faint images, stars contribute no more than 10%. The numbers of galaxies in the field, and their number per square degree, brighter than apparent magnitude B are presented in Table 1 over the range 21 ≤ B ≤ 25.

Table 1. Galaxy Counts in SA 57

m_B	Number in the field	log N(m) per degree
21.0	6	2.85:
21.5	12	3.15
22.0	17	3.30
22.5	28	3.52
23.0	47	3.74
23.5	98	4.06
24.0	166	4.29
24.5	240	4.45
25.0	380	4.65
26.2:	930	5.05:

The small-scale noise of the electronogram is rather low, amounting to 0.5% of the sky background at 1 (arc sec)^2, or about 3 times smaller than IIIa-J emulsion noise (Kron 1978). For the given noise level a galaxy of the 25th apparent magnitude has a signal-to-noise ratio, S/N = 3, with a typical image square of about 10 arc sec^2.

At a still lower detection level, down to S/N ≃ 1, or B = 26.2, there are also visible extremely faint images; their log number is given in the last line of Table 1. The reliability of this last entry is certainly rather poor, because, on the one hand, an unknown fraction of the galaxies could have been missed, and on the other, the grain noise introduces some false images. This estimation needs confirmation by repeated plates of the field.

Recently, data on number-magnitude counts of faint galaxies have been enriched by new work (Peterson et al. 1979, Tyson and Jarvis 1979). A summary of the deep counts is presented in Figure 1. The differential counts by Kron and by Peterson et al. have been transformed into integral ones and normalized at B = 20-21. Note that both counts have been

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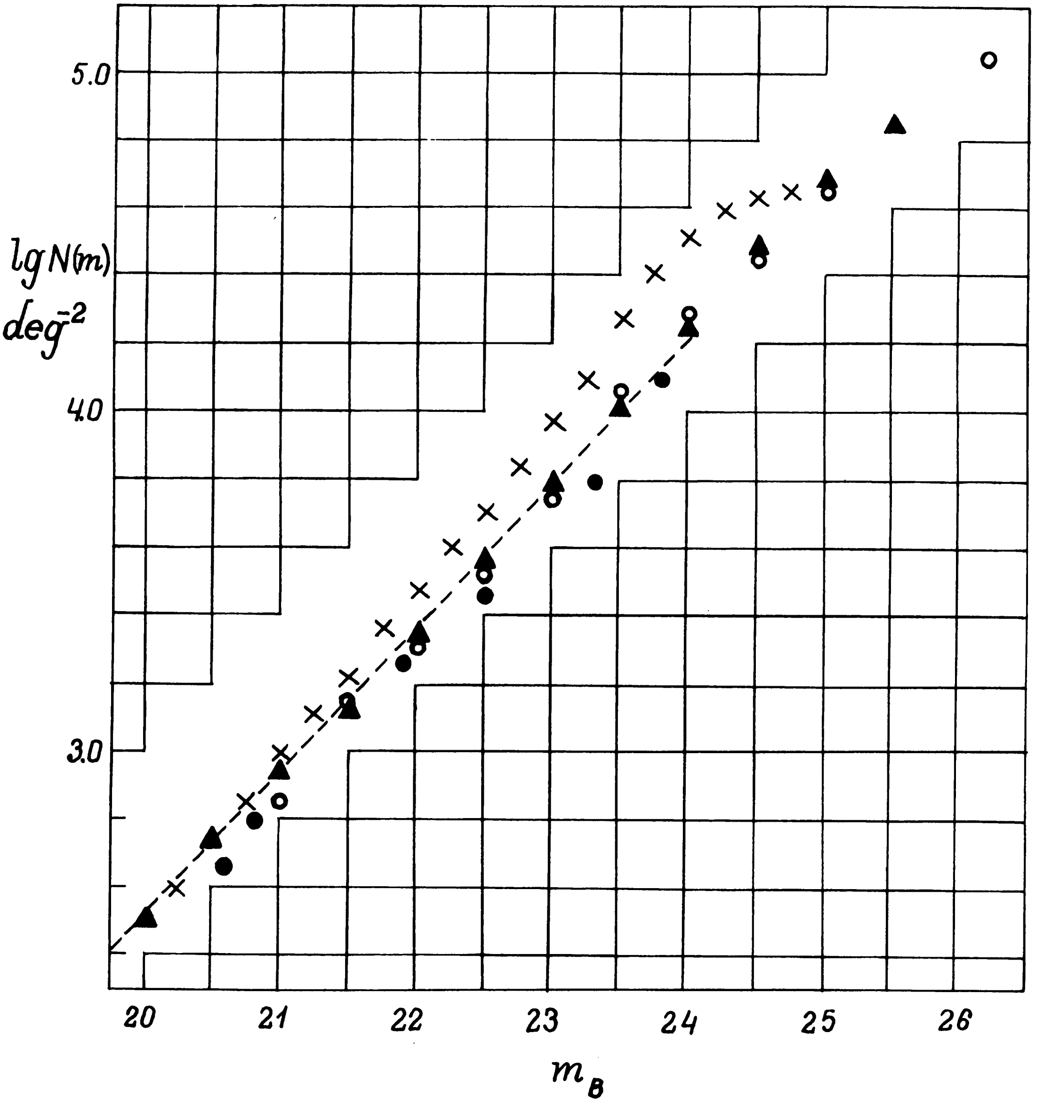

Figure 1. Integral number of galaxies per square degree brighter than apparent magnitude m_B. The data by different authors are indicated by the symbols: dots -- Karachentsev and Kopylov (1977); open circles -- the present paper; crosses -- Kron (1978); triangles -- Peterson et al. (1979); dashed line -- Tyson and Jarvis (1979). A 45° line in the figure corresponds to the expected number distribution slope for the case of no luminosity evolution.

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carried out in the J system. Transformation from J to B requires a correction of about + $0^m.2$, which is slightly dependent on the mean color of galaxies over the magnitude range under consideration.

As seen in Figure 1, our new counts show slightly more galaxies than our previous ones. This may be caused by an underestimation of the light of faint outlying parts of galaxies in our former counts, which were made mostly on IIa-0 plates. Nevertheless, a significant difference exists between our present counts and those of Kron. The discrepancy is at a maximum near B = 24. The humpbacked shape of log N(m)-relation by Kron, which is interpreted by him as due to evolution, is not consistent with the present data. Considering also the data of other authors, we suggest that the excess of faint galaxies in Kron's counts may be due to his specific reduction procedures and/or selection of faint images.

The simulation of measurement errors and selection effects is a rather difficult task, the principal difficulty being the lack of advance knowledge of the shape of the log N(m) curve for extremely faint magnitudes. A bias in log N(m) is quite sensitive to the emulsion contrast γ, together with the seeing factor. In our experience, the linearity ($\gamma = 1$) and the small noise of electronograms minimizes the role of systematic measurement errors near the detection threshold.

The results of our counts of galaxies agree with the data of the Anglo-Australian group (Peterson et al. 1979). It is interesting that the agreement extends beyond B = 24.5, which is the completeness limit of the counts by Peterson et al. (1979). The last points in Figure 1 do not deviate strongly from the linear relation, log N(m) = constant + 0.41 m, founded by Tyson and Jarvis (1979). This excellent agreement of independent observers' data, obtained under different conditions, provides hope of obtaining a reliable basis for theoretical analysis of evolution effects.

Note that counts near B = 25-26 correspond to galaxies whose redshifts reach or exceed z = 1. Therefore, the statistics of QSO absorption lines may provide an independent confirmation of the counts, if intervening galaxies cause the absorption lines.

In the field investigated we do not find a large variation in the surface density of galaxies. The amplitude of two-point correlation function, $w(\Theta) \lesssim 0.04$, at scales of Θ = 10" to 60". Assuming that our sample is 10 times deeper than the survey by Shane and Wirtanen, we estimate the value of $w(\Theta)$ by using the scaling method of Groth and Peebles (1977). The amplitude of w (60") agrees satisfactorily with the expected one; however, the observed w (10") is 2-3 times lower than the calculated value. This may mean that small-scale clustering of galaxies ($\lesssim$ 100 kpc) has not developed yet at z = 1. Another explanation could be a selection of galaxies according to their colors, because blue spiral galaxies, with a lower space concentration, are more easily visible at large distances than elliptical galaxies. A larger sample of galaxies is needed to check this result.

Even a passing glance on the electronograms confirms Kron's conclusion that remote galaxies are predominantly blue. Most faint groups are more distinct on the blue plates than in the visual or red ones. The relative numbers of galaxies to the film limit in B, V, R are in the ratios $N(B \leq 25.0): N(V \leq 24.5): N(R \leq 23.5) = 1:0.79:0.76$. Our measurements of a dozen galaxies with $\langle B + V\rangle/2 \simeq 23$ give the mean colors $\langle B - V\rangle = +0.52 \pm 0.08$ and $\langle B - R\rangle = +1.04 \pm 0.24$.

Considering the preliminary character of the present photometric data, we shall not discuss evolutionary effects in detail here. We do note, however, that there is good agreement among different authors on the expected slope of the curve, $\alpha = d \log N/dm$, which has been calculated under the assumption of no luminosity evolution, over the range of 21-24 mag; namely: $\alpha = 0.39$ (Karachentsev and Kopylov 1977); $\alpha = 0.39$ (Kron 1978); and $\alpha = 0.42$ (Peterson et al. 1979). The observed data points are only a little steeper than the mean slope $\alpha = 0.40$ (the diagonal in Figure 1). A moderate effect of galaxy evolution probably exists. However, it is necessary to know the precise energy distribution in the ultraviolet for a large sample of galaxies of different morphological types before we can confidently interpret a small excess of faint galaxies as a product of galaxy evolution.

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