WIDE-FIELD J- AND K-BAND GALAXY COUNTS IN THE ELAIS FIELDS

P. Vaisanen1,2, E. V. Tollestrup1, S. P. Willner1, and M. Cohen3,4

Accepted to the Astrophysical Journal

ABSTRACT

New near-infrared galaxy counts in the J and K bands are presented over a total area of 0.70 and 0.97 degrees, respectively. The limiting magnitudes of the deepest regions are 19.5 in J and 18.0 in K. At J > 16 and K > 15 our J and K-band counts number counts agree well with existing surveys provided all data are corrected to a common magnitude scale. There are real differences from field to field, and the ELAIS N1 and N2 fields show an overdensity of J < 16, K < 15 galaxies. The slopes of log N(m)/dm are ~ 0.40 to 0.45 at 15 < K < 18 and 16 < J < 19.5. Our counts favor galaxy models with a high normalization of the local luminosity function and without strong evolution.

Subject headings: surveys – galaxies: photometry — galaxies: evolution — infrared: galaxies – cosmology: observations

1. INTRODUCTION

Counting galaxies as a function of magnitude has established itself as a powerful way to study galaxy evolution. This is especially true in the near-infrared, where K-corrections are smaller and dust extinction of less importance than in the visible. There have been numerous K-band galaxy surveys for over a decade now. These have shown the pitfalls of deriving any definite evolutionary conclusions from a single wavelength: e.g. the excess of faint galaxies seen especially in blue bands (see Ellis 1997 for a comprehensive review) is not nearly as severe in K-band. Another near-infrared waveband, the 1.25μm J-band, is now added to the available data. Bershady et al. (1998) and Saracco et al. (1999) have published deep J-counts, and there are preliminary wide field DENIS-J (Mamon 1998) and 2MASS-counts (Skrutskie 1999) available at J < 16. Ultra-deep HST NICMOS counts are also available in J and H bands (Thompson et al. 1999, Yan et al. 1998, Teplitz et al. 1998). The only intermediate magnitude J-counts to date are those of Teplitz et al. (1999); our survey covers a slightly shallower magnitude range but has a sky coverage 15 times as large.

The range of magnitudes, J = 12.5–19.5, in the present survey is too bright to be of direct interest to cosmology and high redshift galaxy evolution studies. However, modeling of the faintest counts to study the evolution of distant galaxy populations heavily relies on accurate normalization of the models at brighter magnitudes. Indeed, the normalization is often left as a free parameter, signifying that the local galaxy population is still quite uncertain. The bright and medium counts are thus instrumental in the studies of both the local galaxy population and the evolving properties of galaxies with large look-back times.

Our survey fields are within the European Large Area ISO-Survey (ELAIS) regions (see Oliver et al. 2000). ELAIS fields will be heavily studied in wavelengths ranging from X-rays to radio bands, with much of the scientific interest lying in high-redshift, dust-obscured star formation, AGN, and ultraluminous infrared sources. Our observations were done as part of NIR followup for the ELAIS project. This paper presents our galaxy counts and compares them to some available data and models.

We also address the question of whether this field, selected because of its low 100 μm emission, is a representative sample of the extragalactic sky. The discussion of individual objects relating to ISO-sources will be presented elsewhere.

2. OBSERVATIONS AND DATA

All the observations were carried out using the STELIRCam instrument (Tollestrup & Willner 2000) mounted on the 1.2-m telescope of Fred Lawrence Whipple Observatory on Mt. Hopkins. The camera contains two InSb detector arrays with 256x256 format, which view the same field simultaneously through different filters. Our J and K-band images were taken during a total of 16 nights in 1997 April and June and 1998 April. During the 1997 June run the J-array was unavailable, resulting in larger coverage in K-band in our survey. The 1.2˝ pixel scale was used for all observations, and the seeing varied between 1.8 and 2.3”. Each frame was a 60-second integration, typically consisting of 6 co-adds. A 5 by 5 dither pattern was used resulting in a 25 minute integration time per pointing. Data reduction followed a commonly-used sequence of linearizing, sky-subtracting, flattening, and then co-adding the frames. Cosmic rays were also removed in the process. The partially overlapping 25 min pointings were then mosaiced together to produce the final images. Near-infrared standard stars used to calibrate the data were taken from Elias et al. (1982). We estimate the calibration on the instrumental system (Barr filters) to be accurate to 0.04 mag.

The survey consists of two areas located in the ELAIS N1 and N2 regions. The central coordinates are (α, δ) = (16h 09m 00s, 54°40’00”) and 16h 36m 00s, 41°06’00” (J2000), respectively. The galactic latitudes for N1 and N2 are b = 45.0° and 42.3°. During the first run we mostly took data around ISO-detections. Later we filled in the gaps, but coverage of the N1 field remains fairly non-uniform. The total areas observed are 0.70 degrees in J and 0.97 degrees in K-band, less than half of the ELAIS N1 and N2 areas, which comprise > 2 degrees.

We used the SExtractor v2.0.18 package (Bertin & Arnouts...
1996) for the source detection and photometry. At the deepest regions of our maps (see Table I for the areas) the noise background level corresponds to $J = 23.0$ mag/arcsec$^2$ and $K = 21.3$ mag/arcsec$^2$ in $J$ and $K$, respectively.

SExtractor computed object magnitudes in several ways: isophotal, various fixed apertures, and a composite referred to as “BEST-magnitudes.” The BEST-magnitude is usually the Kron-magnitude (see Bertin & Arnouts 1996; Kron 1980), which is photometry in an elliptical aperture with shape determined by the shape of the detected object and size chosen to include almost all the object’s flux. However, in very crowded regions the BEST-magnitude is the isophotal magnitude instead. In our data, this happens with fewer than 5% of detections. Based on our simulations using different detection parameters, corrections, tests on sub-fields, etc., the BEST-magnitude is the most robust. It does not need aperture corrections, and thus there is no need to account for differences in flux measurements due to object profiles and sizes. Corrections for the differing seeing conditions during many observing nights are also rendered unimportant. (There is an input parameter in SExtractor for a Gaussian convolution used for detection of objects, but it does not affect photometry. Simulations showed that the range of seeing observed had $< 5\%$ effects on numbers of detections even at the faintest levels.)

Fig. 1 shows the results of one of our simulations. At each magnitude bin, $10^5$ objects were placed individually on the real data frames and extracted in exactly the same way as the final source catalog. The simulations shown here are all for galaxies, both disk and elliptical, because they best show the complications in photometric measuring techniques. The aperture magnitudes lose a significant amount of flux when measuring bright, extended galaxies. Even large $17''$ apertures typically underestimate the brightness of $K \approx 13$ galaxies by nearly 0.2 mag. Small apertures, while being more robust at faint levels, need very large (and often uncertain due to e.g. seeing effects) corrections to total magnitudes at the bright levels. The pure isophotal magnitudes underestimate the flux at all magnitudes, especially near the detection limit. The faint point sources are also a problem with large apertures. While generally point sources behave much better with all magnitude scales (typically flux losses of $\approx 0.1$ mag), the corrections to total are very different for them, complicating the task of placing the whole survey on a consistent magnitude scale. The BEST-magnitudes, in contrast, remain very robust over the whole range of magnitudes and object types, and no corrections are needed.

Fig. 1 also shows that all the magnitude systems used in the simulations significantly overestimate the flux at the faintest level. This upturn happens at $\sim 30 – 50\%$ completeness limit and thus does not affect our final catalog. (In the case shown, the catalog cutoff would have been the $K = 17.25$ bin, although the deepest parts go down to bins at $J = 19.25, K = 17.75$.) On the other hand, all commonly used magnitude measuring systems suffer biases against low surface brightness objects (Dalcanton 1997), and ours is no exception.

We have compared the BEST-magnitude number counts against all the mentioned measuring techniques (along with appropriate corrections). All the differences remain at less than 10% down to the catalog limit ($J = 19.5, K = 18.0$). The final uncertainties are larger than this, so though the BEST magnitude is adopted for all subsequent discussion, the results would be about the same for aperture or isophotal magnitudes.

3. Number Counts

3.1. Completeness corrections

The noise of our mosaics is non-uniform owing to using frames from three different runs, with different sky conditions, and to varying exposure times from dithering and overlapping frames. We thus counted the objects in different bins according to the depth of regions in the final images. (See Bershady et al. 1998 for a similar approach.)

Completeness corrections were calculated using Monte Carlo simulations. As mentioned in the previous section, simulated sources were randomly placed onto our real data frames and extracted in the same way as the final catalog of sources. This gave the completeness levels as a function of magnitude for the depth reached in each region of the survey. Fig. 2 shows an example of completeness levels in the deep regions of the $J$-images using point sources and galaxy profiles. The simulation results gave a matrix of input/output magnitudes. This matrix contains not only incompleteness at a given magnitude level but also the amount of “bin-jumping”, i.e., sources being found at another flux level than their intrinsic magnitude. The original counts can be calculated by inverting the matrix using the observed counts. (See e.g. Moustakas et al. 1997, Minezaki et al. 1998.) We also have a powerful internal check for the completeness corrections: the corrected counts from the shallow regions of our map should be consistent with the observed counts from the deepest depth bins. As an example, Fig. 3 shows a case where the N2 $J$-band counts from the deepest area of the map are plotted with counts from a shallower region. The completeness-corrected shallow counts do indeed match the deeper data.

Completeness simulations were done with real data frames, so the corrections include the effect of confusion, overlapping of sources. Depending on object morphology, the completeness limit would have been overestimated by 0.25 – 0.4 magnitudes if source-free noise frames had been used in the simulations.

3.2. Star/galaxy separation

Separation of stars and galaxies was done in different ways for different magnitude ranges. For the brightest objects, stars and galaxies were easily separated by eye with the SExtractor CLASS parameter used as a check.

At magnitudes $J > 15.5, K > 14.0$, the spatial resolution of our infrared images is not good enough for morphological separation of stars from galaxies to be secure. Down to 1.5 magnitudes fainter than these limits, we used a combination of visible classifications and visible and infrared colors to classify each object as star or galaxy. Visible data came from the APS-

5The prescription for computing Kron-magnitudes is, first, the second order moments of the object profile are used to define a bivariate Gaussian profile with mean standard deviation $\sigma_{G0}$. An elliptical aperture whose elongation $\epsilon$ and position angle are defined by these moments is scaled to $6\sigma_{G0}$. Next, within this aperture the first moment is computed:

$$r_1 = \frac{\Sigma J(r)}{\Sigma J(r)}.$$

Finally, the elliptical aperture used in actual photometry is defined by the axes $\epsilon r_1$ and $kr_1/\epsilon$. Additionally, the smallest accessible aperture size is set to $3\sigma_{G0}$ to avoid erroneously small apertures in the lowest S/N regions. To arrive at a balance of systematic and random errors, a value $k \approx 2$ is usually used. We used $k = 3$ which we found for our undersampled data to minimize the fraction of lost flux while still not increasing errors significantly.
catalog\(^6\) (Pennington et al. 1993), which lists magnitudes derived from Palomar Observatory Sky Survey images. Two sets of color-color plots were used for both \(J\) and \(K\) sources to decrease uncertainties: \(B−R\) vs. \(B−K\) and \(R−K\) and \(B−R\) vs. \(B−J\) and \(R−J\). Fig. 3 shows the resulting \(B−R\) vs. \(R−K\) plot for sources brighter than \(K=15.5\), which is slightly worse than the other color-color separation for the \(K\)-band. We show this to compare to equivalent plots by Saracco et al. (1997); their Fig. 3) and McCracken et al. (2000). Saracco et al. found this classifier to fail – stars and galaxies completely overlap each other. It seems as if their galaxies are missing \(K\)-band flux. The reason remains unclear, since they use exactly the same aperture for optical and NIR bands. Their aperture is quite small, though, only 5\('\).

Our plot, in contrast, shows ‘total’ magnitudes, which can be criticized by claiming that they introduce different samplings of source profiles in different bands. However, we find consistent results whether using either of the two sets of color-color plots, the APS-classification (which is morphological in nature), or our eye-ballling/SExtractor classification. In any case, we are not trying to produce exact color-color tracks for stars and galaxies here, only to separate them, and for that purpose our magnitudes and those of the APS-catalog seem to be very well suited.\(^7\)

In the faintest bin where the color method was used (\(J = 16.75, K = 15.25\)), the fraction of \(J\) or \(K\) sources that do not have APS-correspondents is \(\approx 15\%\). The intrinsically reddest galaxies are the first to be missing from the APS-list, but with our data it is impossible to quantify exactly the proportions of non-matched stars and galaxies. As the correction is small, we simply divided the unidentified sources between stars and galaxies, taking 2/3 to be galaxies in this bin and half to be galaxies in brighter bins. Even if all the missing sources were classified as galaxies, the change in number counts would still be well within the uncertainties of the final galaxy counts.

Beyond \(J > 17, K > 15.5\), the number of missing sources grows rapidly. Instead of attempting classification of individual objects, we subtracted a model (Cohen 1994) of the Galactic point source foreground from the total counts to give the galaxy counts. Fig. 4 shows the resulting \(J\)-band star counts in the N2 field. The scatter is small and is similar in the N1 field and in the \(K\)-band. The SKY model counts (Cohen 1994) used to derive galaxy counts for the faintest magnitudes (\(J > 17, K > 15.5\)) are also shown in Fig. 4. The model counts were computed specifically for our two fields but were scaled by a factor of 0.9 in order to better fit the star counts in the faintest bins where direct separation worked. The same model has previously been applied to galaxy counts by Minezaki et al. (1998) and by Hall et al. (1998). The latter authors found a precedent for one field (Q0736-063) with a chance under-density in foreground star counts compared with SKY. As is seen, the SKY model fits our star counts very well.

### 3.3. Count results and their uncertainties

Table 1 and Figures 5 and 6 show our final galaxy counts. The error bars are calculated from Poisson statistics (Gehrels 1986). In addition, an uncertainty derived from the different star/galaxy classifications and an assumed 10\% uncertainty of the SKY model are included at bright and faint magnitudes, respectively. In the four faintest bins an estimated uncertainty of the completeness corrections is also included.

The uncertainty from galaxy-galaxy correlations is negligible. Calculating equation 5 of Huang et al. (1997) with our survey characteristics shows that at most (at the faintest magnitude), the contribution from galaxy-galaxy correlations starts to approach 50\% of the Poisson uncertainties, which in turn are small compared to our completeness correction uncertainties at these magnitudes. As noted by Huang et al. (1997), uncertainties due to large scale structures such as rich clusters and voids are poorly known and hard to quantify. Indeed, these might well be a major reason for surprisingly varying results in galaxy counts (Section 4.1).

The effect of systematic magnitude errors (\(\sim 0.05\) mag) on the final number counts can be estimated from equation 7 of Huang et al. (1997). The uncertainty remains below Poisson uncertainties in our counts until \(K = 17\) and after that well below completeness-related uncertainties. Photometric errors can change the counts only in the horizontal direction, but random errors can affect also the log N slope. As seen in Fig. 4, photometric uncertainties increase from 0.02 at \(K = 12\) to 0.5 mag at \(K = 17.5\). Using Huang’s equation 9 and a slope of 0.5 (Section 5), this translates to an error of \(\approx 0.01\) in the slope, which is smaller than our derived 0.03 \(\pm\) uncertainty in the slope fitting. In any case, this effect resulting from galaxies jumping from bin to bin (and preferentially to a brighter magnitude bin near the detection limit) is corrected for in our completeness correction method.

Even if all corrections and the uneven depth of our map were ignored, the derived counts would not change significantly until the faintest two or three bins. Treating the varying noise areas in detail and modeling the bin-jumping gives us confidence to present the corrected counts all the way to \(J = 19.5\) and \(K = 18\).

### 4. Comparison with other data

In \(K\)-band there have been numerous surveys for over a decade. Figure 5 shows a compilation of available \(K\) surveys at magnitude ranges similar to ours. Our counts appear clearly at magnitude \(K = 15\). (At \(K < 13\) the statistical significance is small, but at \(13 < K < 15\) the difference is \(> 3\sigma\).) There is a factor of \(\approx 1.4\) difference at \(15 < K < 17\); the most significant differences are with the Huang et al. (1997) and Gardner et al. (1996) surveys due to their large areas (\(\sim 10\) degrees\(^2\)). Non-uniform sky coverage is unlikely to explain the effect. N2 was covered very uniformly, while N1 was not, and \(K\) more uniformly than \(J\), yet we see similar counts in both regions and bands.

There are two classes of explanation for the systematic differences. The ELAIS fields may have galaxy populations that differ from those in other survey fields, or different surveys may have used different magnitude scales. The latter would imply a 0.2-0.3 mag difference in the fainter flux levels and 0.5 mag and more at \(K < 15\). The following sections discuss each possibility.

#### 4.1. Galaxy Clusters and Local Overdensity

Known galaxy clusters have a modest effect on our number counts. The N2 region contains two galaxy clusters, Abell 2211 and 2213. Both are of richness 1, approximately 15\('\) in diameter, and lie at a redshift of \(z \approx 0.15\). A ‘typical’ cluster member

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\(^6\)The Automated Plate Scanner (APS) databases are supported by the National Science Foundation, the National Aeronautics and Space Administration, and the University of Minnesota and are available at [http://aps.umn.edu](http://aps.umn.edu).

\(^7\)When available, using \(B−I\) vs. \(I−K\) (eg. Huang et al. 1997) will do an even better job in separating stars and galaxies.
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is expected to have $R \approx 18$, $J \approx 16$, and $K \approx 15$. We estimated the effect of these clusters on the counts by excluding the areas around them (16" diameter) and recalculating the galaxy counts in N2. Compared to the original counts, we find correction factors ranging from 0.77 to 0.97 between $J=14.25$ and 18.25, the largest correction being at $J = 15.25$ as expected. In $K$, the corrections are somewhat smaller (the $K$ sky coverage being larger) averaging a factor of $\sim 0.9$ between $K=13.75$ to 16.75. The largest correction is 0.80 at $K = 14.75$. The cluster-corrected counts are tabulated in Table 1 and shown in Figs. 6 and 7.

The N1 field has a cluster (Abell 2168) near the edge of the region. It lies at $z \approx 0.06$ and thus covers a larger area on the sky. Whether some of its members (expected brightnesses $K < 13$) are part of our N1 field is impossible to determine with the available data. In any case the statistics are poor at $J < 15$ and $K < 14$, and we did not attempt corrections. The same holds for a nearby cluster (Abell 2197; $z \approx 0.03$) 1° west of N2. If there is contamination from this cluster, it would only be at $J \approx 12$, $K \approx 11$.

The effect of field selection on prior counts cannot be ignored either. Many surveys purposely avoid regions near clusters of galaxies. While this is understandable not to contaminate ‘field galaxy’ counts, it may bias the counts to voids and otherwise selectively underdense regions. Most significantly, the largest surveys to date, Gardner et al. (1996) and Huang et al. (1997; hereafter the Hawaii survey) both avoided clusters.

In order to try to quantify the effects of field selection, we extracted blue magnitudes of galaxies from the fields of selected $K$-surveys. Fig. 8 shows the blue (O plate) APS-galaxy counts in the fields of the Hawaii survey, Gardner et al. (1996), Szokoly et al. (1998), and Kümmel & Wagner (2000), along with APS-counts in the regions of the present survey. All these surveys have > 0.6 degrees$^2$ sky coverage. The APS-counts are consistent with prior $B$-band counts in the fields of Gardner et al. (1996; using an approximate $m_B - B = 0.15$ color taken from Humphreys et al. 1991).

In the range $B=18–20$, which roughly corresponds to $K=14–16$, the N2 region shows an excess by a factor of 1.1–1.3 compared to the other survey regions (including N1). This excess in N2 is explained by the clusters discussed above. The correction factors can be obtained from Table 1.

The fields of the Hawaii survey (Huang et al. 1997) show systematically lower blue counts compared to other survey regions by a factor of about 1.3. This survey contained numerous subfields (including the areas of Glazebrook et al. 1994 counts), of which we could examine 75%. (The SB area was not available in the APS-catalog.) There were large field-to-field variations, as pointed out by Huang et al. (1997). The lower amplitude of the Hawaii $K$-survey thus seems to be a result of a systematic underdensity at their survey regions, and we adopt a factor of 1.3 correction to the Hawaii $K$-counts. In fact, Huang et al. interpret their counts (mainly the slope) as pointing towards a large local void.

The blue counts of the other large survey region (Gardner et al. 1996) are at the same level as in our (corrected) fields. The authors have excluded a region around an unspecified cluster, and thus the extracted APS-counts from these fields are possibly slightly higher than the corresponding optical survey of Gardner et al. (1996). There is a difference between their two fields, NGP and NEP; the NEP-field showed higher counts than the NGP field, even though the cluster mentioned above is in the NGP field (Baugh et al. 1996). Thus the known cluster cannot explain the difference between fields.

The other two surveys (Kümmel & Wagner 2000, Szokoly et al. 1998), though smaller, show blue counts consistent with those in our regions and those of Gardner et al. (1996).

All the above evidence shows that it is practically impossible to define a pure ‘field galaxy’ population when sky coverage is of the order of a square degree. There always are clusters, bright or faint, rich or poor, in or just outside the field. One can avoid the bright clusters, but never all the fainter ones, so one necessarily expects a somewhat biased sample. A search using NED$^8$ at the regions of the relatively uniform $K$-surveys in the literature produced rich Abell clusters within 1° of nearly every field center. More distant ($z \approx 0.5$) rich clusters are expected to be numerous inside a 1 sq. degree field (see e.g. Lidman & Peterson 1996). For example, the SC field of Glazebrook et al. (1994) and Huang et al. (1997) has a rich Abell cluster just outside the field, but more than 10 fainter galaxy clusters closer to the field center (NED, Lidman & Peterson 1996). The best one can do is to estimate the magnitude of the effect of either having clusters in field, or the effect of avoiding them. Some surveys (Saracco et al. 1997, Ferreras et al. 1999) consist of tens of small, random sub-fields. In cases like these, it is easier to quantify the field-to-field variations and, in fact, Saracco et al. (1997) find their systematically low counts to be consistent with field-to-field count fluctuations. On the other hand, it is harder to accurately estimate the effective covered area due to large fraction of edges in the images.

In summary, there is a small (∼ 10%) overdensity due to rich galaxy clusters in our N2 field. There is likewise a systematic underdensity of galaxies in some of the Hawaii fields. Additionally, there are nearby clusters outside both of our fields, which might affect the brightest ($J < 14$, $K < 13$) counts.

4.2. Aperture corrections

As mentioned above, the difference between our counts and the others could also be that magnitude scales are not directly comparable resulting in discrepancies in the horizontal scale of the log N - mag plot. We discuss this in the spirit that all magnitudes should be total, since ultimately we wish to compare data with models of galaxy populations which implicitly assume total luminosities for the galaxies. For the reverse train of thought we refer the reader to an enlightening work by Yoshii (1993), which models the photometric selection effects to enable comparison of galaxy models with raw counts acquired with a given magnitude measuring method.

The Glazebrook et al. (1994) counts have been measured for the most part with 4" apertures. Such an aperture is very small for galaxies in $13 < K < 16$ range and results in large corrections. The authors present a correction to physical, redshift dependent, $20 h^{-1}$ kpc apertures (Glazebrook et al. 1995); the corrections range from $-1.0$ mag to $-0.1$ mag at $z = 1.0$, typically being $-0.3$ to $-0.5$ mag around $K = 15$. Based on our simulations, we brightened their counts by an additional $-0.4$ mag at $K=14–16$, and by $-0.5$ and $-0.3$ at bins brighter and fainter than this range, respectively. Though the Glazebrook et al. counts still remain somewhat lower than ours, the correction brings them within 2σ. Fig. 14 plots these and other counts discussed below in their ‘corrected’ form.

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$^8$The NASA/IPAC Extragalactic Database (NED) is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.
The Teplitz et al. (1999) counts are based on very small aperture magnitudes (∼ 2 ″), and we expect corrections of at least −0.5 mag at K = 14 decreasing to −0.2 mag at K > 16.5. These corrections make their counts somewhat brighter (or higher) than our counts, though still consistent. The data of Gardner et al. (1993), Ferreras et al. (1999), and the K > 16.5 bins of Kümmel & Wagner (2000) are also fixed aperture magnitudes. The apertures range from 6 ″ to 8 ″. Based on our simulations (see Fig. 1), even the 10 ″ aperture underestimates the total flux of galaxies by ∼ 0.4 − 0.2 mag between K = 14 − 17. We corrected the Gardner et al. (1993) data by −0.4, −0.3, −0.2, and −0.1 mag at bins K < 14.5, 14.5 < K < 16, 16 < K < 17.5, and K > 17.5. The Ferreras et al. (1999) bins at K = 14.5, K = 15−17, and K = 17.5 were corrected by −0.4, −0.3, and −0.2 mags, respectively. Finally, the K > 16.5 data of Kümmel & Wagner (2000) were corrected by −0.2 mag.

Gardner et al. (1996) used 10 ″ apertures, but the results were corrected to "total" magnitudes using I-band growth curves. However, the corrections and the equivalent aperture for the total magnitude are not available.

Saracco et al. (1997) and Minezaki et al. (1998), as well as Kümmel & Wagner (2000) in the brighter part of their magnitude range, use FOCAS 'total magnitudes' (Jarvis & Tyson 1981). All these authors note that the FOCAS magnitudes tend to underestimate faint source fluxes (see also Thompson et al. 1999). The latter two groups thus apply additional corrections: −0.06 to −0.25 mag at 17.5 < K < 19 (Saracco et al. 1997) and ∼ −0.1 mag (Minezaki et al. 1998). The Saracco et al. (1997) counts lie below the bulk of other data, and the other two are also fainter than our data by ∼ 0.3 mag. We have not explored FOCAS photometry and thus cannot quantify the exact differences involved here; simple isophotal photometry, which the FOCAS total magnitudes are based on, clearly underestimate the flux, as noted before (see Fig. 1 and also Saracco et al. 1999).

Huang et al. (1997) measure their magnitudes in 8 ″ apertures, but correct them to 20 ″ using curves of growth. The corrections for galaxies are fairly large, ranging from −0.55 to −0.2 mag, consistent with the results of our simulations. At K < 13, Huang et al. use isophotal magnitudes for galaxies, which underestimate the total flux by 0.05 mag according to our simulations. Comparing the 20 ″ fixed apertures to our BEST-magnitude, we still find evidence of small 0.05−0.1 mag difference at 14 < K < 17, part of which can also be due to a small overestimation of flux with BEST-magnitudes (Fig. 1). The cluster-corrected Hawaii counts are consistent with ours. (See Section 3.1, without the factor of 1.3 correction due to underdensity, their counts would lie below ours with ∼ 3σ significance.)

The counts of Szokoly et al. (1998) are the only ones which use exactly the same magnitude scale as we do. Their counts also lie below ours with a difference of ∼ 0.3 mag at K > 15 (or a factor of about 1.3 in number), though they are not more than 1.5σ away from our counts.

Of the presently available counts the most consistent with ours without corrections over the whole measured magnitude range are those of Jenkins & Reid (1991). Considering the observational technique, these counts are quite different in nature from the other counts. They are a result of statistical evaluation of the K-band background fluctuations in random patches of sky. The method has been widely used in radio and x-ray source counts (e.g. Condon 1974, Scheuer 1974) and should in principle be free of all the uncertainties arising from incompleteness in detecting and measuring fluxes of individual sources. Moreover, Jenkins & Reid (1991) do not purposely avoid clusters of galaxies, while many of the other surveys do just that.

Fig. 1 compiles those counts which had directly comparable magnitude systems or for which we have adequate information to make a magnitude correction. Only those surveys using small apertures (Gardner et al. 1993, Glazebrook et al. 1994, Ferreras et al. 1999, Teplitz et al. 1999, and Kümmel & Wagner 2000 at K > 16.5) were corrected. Jenkins & Reid (1991), the Hawaii counts, and Szokoly et al. (1998) do not need photometric corrections compared to our counts. Most of the other surveys used FOCAS 'total' magnitudes and we lack data to make a quantitative correction to the Kron-type magnitudes. Though not plotted here for consistency, Saracco et al. (1997) and Minezaki et al. (1998) made corrections using their own simulations. Also Gardner et al. (1996) applied unspecified corrections to their aperture magnitudes. After correction, all of the counts are consistent for K > 15.

There is much less data to compare with in the J-band (Fig. 1). The bright galaxy overdensity in both N1 and N2 is clearly seen also in J-band compared to DENIS counts. At fainter J-magnitudes, our counts are in unison with the published Teplitz et al. (1999) counts and also connect very well with the deeper counts of Bershad et al. (1998). The most recent J-counts (Saracco et al. 1999) are consistent within the uncertainties, though they are clearly lower than e.g. the Teplitz et al. (1999) counts beyond our magnitude range. The counts of Teplitz et al. (1999) were measured with small (∼ 2 ″) apertures, and after magnitude correction we would expect them to be somewhat brighter than our data, as the corresponding K-data.

The Saracco et al. (1999) survey was measured with a 2.5 ″ aperture. Though the magnitude range is deeper than ours and small apertures are thus justified, the size of aperture still might result in some flux-loss even with the fixed −0.25 mag aperture correction applied. Moreover, the field was centered on the NTT deep field, which possibly is biased against 'bright' (J ∼ 19 mag here) objects.

Bershad et al. (1998) also determined magnitudes using small ∼ 2 ″ apertures, but the measurements were dynamically corrected to total magnitudes using the size of the object, in much the same manner as the Kron magnitudes we used. Our counts thus lie in the middle of the available J > 16 data.

In summary, the differences among different sets of K-counts at K > 15 mag are partially due to differences in magnitude scales. After appropriate aperture and clustering corrections, our J > 16, K > 15 galaxy counts agree with those in the literature. Our bright (K < 15, J < 16) counts are still higher than most other data by a factor of up to 2. This is probably due to a real overdensity of bright field galaxies in our survey regions as compared to other regions. There are nearby clusters outside our fields, but it is hard to see how they could increase the counts by as much as a factor of two.

5. COMPARISON WITH MODELS

Models incorporating cosmology and galaxy evolution should be able to explain both the number counts themselves and the slope of the number counts with magnitude. Though a rigorous modeling of galaxy evolution and galaxy populations requires knowledge of redshift distributions, it is nonetheless informative to calculate how predictions from standard parameterizations of the local luminosity function (LF) fit our final NIR counts.
In a non-evolving model, the slope and amplitude of the counts are dependant on the LF and the K-correction. The latter depends on galaxy types and SEDs of galaxies, but these differences are small in the NIR. For a given LF, different cosmologies have negligible effect on the counts in the bright range we consider. Thus the only significant parameters are the local luminosity function and luminosity evolution, which steepens the slope, \( d \log N/dm \), at our magnitude range.

To be sure we are not affected by the bright galaxy excess in our fields, we examine ranges \( J=16.5–19.5 \) and \( K=15.5–18.0 \). All slopes, unless otherwise stated, will refer to these magnitude ranges. Our \( J \) counts show well determined slopes of \( 0.40 \pm 0.01 \) and \( 0.38 \pm 0.02 \) in N1 and N2, respectively (errors are \( 1 \sigma \) uncertainties of the fitted gradient). In the \( K \)-band we measure slopes of \( 0.41 \pm 0.02 \) and \( 0.45 \pm 0.03 \). The cluster correction in N2 steepened the slope slightly: without the correction, the \( K \)-slope would have been \( 0.43 \pm 0.02 \). Other recent counts, eg. Szokoly et al. (1998), Minezaki et al. (1998), and Kümmel & Wagner (2000), give similar values for the slopes in \( K \). These are significantly shallower than the steep \( 0.65–0.70 \) slopes at \( K<16 \) found in the Hawaii survey and by Gardner et al. (1996), even after taking into account the magnitude range difference. To explain the steep slope of the Hawaii survey, Huang et al. (1997) invoked a significant under-density of galaxies in the local universe at very large scales of over \( 300h^{-1}\) Mpc. Our data do not show evidence for this local hole scenario.

To model the counts, we first adopt the largest to-date NIR LF determination, Gardner et al. (1997; hereafter Gardner LF), as the baseline model \( (M_L = -24.6 \text{ mag, } \alpha = -0.9, \varphi = 2.1 \times 10^{-3} \text{ Mpc}^{-3}, \text{ with } H_0 = 50 \text{ km/s/Mpc}) \). We also use make use of Gardner’s (1998) galaxy number counts software and use a basic parameter set found in the same paper, which includes six types of passively evolving galaxies with a galaxy mix from Gardner et al. (1997). The Gardner LF with pure luminosity evolution results in a slope of \( 0.46 \) in \( J \)-band and \( 0.48 \) in \( K \)-band. No-evolution models give shallower slopes of \( 0.41 \) and \( 0.44 \), respectively. For reference, this same non-evolving model gives a slope of 0.60 at \( K=10–15 \), and 0.53 at \( K=13–18 \).

The non-evolving Gardner LF model best fits both our \( J \) and \( K \) slopes, though the evolving slopes are within the \( \sim 3\sigma \) confidence limits. To see how model dependent the slopes are, we calculated the relevant slopes for other observed LF’s. Mobasher et al. (1993), Cowie et al. (1996), Szokoly et al. (1998), and Loveday (2000) LF’s result in similar slopes as the Gardner LF, while the Glazebrook et al. (1995) LF gives slightly steeper slopes: 0.52 for the evolving model in \( K \). Clearly, LF’s resulting in steeper slopes than this would be ruled out by more than \( 3\sigma \) level by our counts.

Examining both the slope and the amplitude of the counts (see Figs. 1 and 2), the baseline model underpredicts our \( J \) and the \( K \) counts by more than \( 3\sigma \) at \( 13 < K < 17 \). This is easily understood, however, since the Gardner LF determination acquired the number density \( \varphi \) by fitting the counts of Gardner et al. (1996) and Huang et al. (1997). These counts were seen (Sections 4.1 and 4.3) to be lower than ours. A factor of 1.5 higher value for the normalization \( \varphi \) in the Gardner LF Schecter parameterization would give an excellent fit to our NIR counts.

In fact, the two most recent \( K \)-band LF determinations (Szokoly et al. 1998, Loveday 2000) give direct observational support for LF’s resulting in a higher amplitude of number counts. (Both determined \( \varphi \) by maximizing the likelihood of their Schecter parameters from their galaxy sample rather than fitting any given number count.) While the exact value of number density \( \varphi \) remains poorly constrained by all present surveys, the best-fit values of both Szokoly et al. (1998) and Loveday (2000) produce excellent fits to our counts and have the same factor of 1.5 higher amplitude at \( K<17 \) compared to the baseline model. Fig. 1 and 2 show predicted counts calculated from the Szokoly et al. (1998) LF \((M_L^K = -25.1 \text{ mag, } \alpha = -1.3, \text{ and } \varphi = 1.5 \times 10^{-3} \text{ Mpc}^{-3}) \). This LF includes significantly more faint galaxies than the baseline model but also more \( > L^* \) galaxies.

The predicted counts from this LF, as well as that of Loveday (2000), are consistent with the fainter counts in both NIR bands when evolution is included.

By giving more freedom to LF parameters, it is possible to construct a realistic counts model which produces the shallow slope \( (\sim 0.4) \) of our NIR counts even with evolution included, along with the correct amplitude, and a fit to the faintest counts. Bershady et al. (1998) show counts from their observationally based \( 1/V_{max} \) simulations. We fitted a model to their \( q_0 = 0 \) curve \((M_L^K = -26.1, \alpha = -1.3, \text{ and } \varphi = 5.0 \times 10^{-4} \text{ Mpc}^{-3} \) gave a good fit) and added luminosity evolution. This LF has greater numbers of luminous galaxies than previously discussed LF’s and also has more faint galaxies than the baseline model (though not as many as the Szokoly et al. 1998 LF). While the fit to our own counts is convincing, the LF seems to overpredict the preliminary DENIS counts.

As noted before, redshift distributions are essential in constraining the models more accurately, e.g. to separate particular evolutionary models and different LF’s producing similar number counts. There has been substantial progress in defining IR-selected \( N(z) \)-samples (e.g. Cowie et al. 1996). The ELAIS regions are currently being followed-up with redshift-surveys, as well as multi-color imaging surveys; there will thus be much improvement in the breadth of useful data in the near future. We are in the process of getting our \( J \)-coverage on par with the \( K \) survey, and will also defer the discussion of \( J-K \) color distributions to a follow-up work.

In summary, non-evolving or passively evolving galaxy models best fit our NIR galaxy number count data. Models with stronger evolution or large local voids (which both result in steeper slopes) are ruled out by more than \( 3\sigma \) confidence. The data favor local luminosity functions with relatively large populations of faint galaxies and those that produce a high normalization of mid-range NIR counts.

6. SUMMARY

Our \( J \) and \( K \)-band galaxy counts in two ELAIS fields (N1,N2) represent the largest areas to date in the ranges \( 15 < J < 19.5 \) and \( 16 < K < 18 \). The \( J \)-band counts are the first wide field galaxy counts at this magnitude range. For \( J>16 \), \( K>15 \), the data are consistent with existing surveys provided significant magnitude scale corrections and large-scale structure effects are taken into account. In particular, the N2 region has a 10% overdensity of galaxies due to rich clusters. The fields of the large Hawaii survey (Huang et al. 1997) seem to have a systematic underdensity of about a factor of 1.3, which explains their counts without the need for a local void.

At \( J<16 \) and \( K<15 \), the counts in the ELAIS fields are higher than previous results by up to a factor of two. This is probably due to a real overdensity of field galaxies in the regions, although nearby large galaxy clusters outside the fields may affect the very brightest magnitude bins. This overdensity needs to be taken into account when interpreting results of surveys in other wavelengths in these regions.
Our galaxy counts favor a high normalization of the local LF. The slope of the counts, $d \log N / dm \approx 0.40 - 0.45$, together with the amplitude of the counts at $K=15–18$ and $J=16–19$ are best fit by minimally evolving galaxy models and luminosity functions having relatively large numbers of faint galaxies.

We thank Gary Mamon for providing DENIS counts and Matthew Bershady for providing his J-counts and models. We also wish to thank the referee and Kalevi Mattila for constructive criticism and useful suggestions. PV acknowledges support from the Smithsonian Institution, the Academy of Finland, and the Finnish Cultural Foundation.

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## Table 1
Differential galaxy counts

| mag  | N1raw | N  | Nlow | Nup  | A  | C  | N2raw | N  | Nlow | Nhigh | Ncc  | A  | C  |
|------|-------|----|------|------|----|----|-------|----|------|--------|------|----|----|
|      | Nraw  | low| up  | A    | C  |    | Nraw  | low| up  | high  | cc  |    |    |
| J-band |      |    |     |      |    |    |      |    |     |        |    |    |    |
| 12.75 | 1     | 10 | 0   | 35   | 0.201 | 1.000 | 7     | 27 | 10   | 44    | 0.497 | 1.000 |
| 13.25 | 1     | 8  | 0   | 31   | 0.201 | 1.000 | 5     | 21 | 10   | 32    | 0.497 | 1.000 |
| 13.75 | 0     | 4  | 0   | 23   | 0.201 | 1.000 | 5     | 20 | 0    | 43    | 0.497 | 1.000 |
| 14.25 | 4     | 40 | 11  | 78   | 0.201 | 1.000 | 11    | 44 | 15   | 74    | 0.497 | 1.000 |
| 14.75 | 6     | 64 | 38  | 103  | 0.201 | 1.000 | 14    | 57 | 30   | 83    | 0.497 | 1.000 |
| 15.25 | 18    | 176| 111 | 249  | 0.201 | 1.000 | 27    | 109| 57   | 160   | 0.497 | 1.000 |
| 15.75 | 26    | 258| 163 | 329  | 0.201 | 1.000 | 79    | 319| 279  | 359   | 0.497 | 1.000 |
| 16.25 | 24    | 237| 177 | 305  | 0.201 | 1.000 | 104   | 418| 366  | 470   | 0.497 | 1.000 |
| 16.75 | 68    | 676| 507 | 846  | 0.201 | 1.000 | 163   | 656| 525  | 787   | 0.497 | 1.000 |
| 17.25 | 113   | 1053| 915| 1190 | 0.201 | 1.006 | 226   | 874| 743  | 1004  | 0.497 | 1.039 |
| 17.75 | 154   | 1734| 1508| 1960 | 0.201 | 0.885 | 356   | 1609| 1377 | 1841  | 0.497 | 0.891 |
| 18.25 | 192   | 2475| 2146| 2804 | 0.201 | 0.772 | 419   | 2083| 1759 | 2406  | 0.497 | 0.809 |
| 18.75 | 244   | 4611| 3780| 5443 | 0.142 | 0.747 | 486   | 3091| 2566 | 3615  | 0.417 | 0.754 |
| 19.25 | 136   | 6694| 5260| 8128 | 0.062 | 0.657 | 390   | 5149| 3955 | 6343  | 0.292 | 0.519 |

| K-band |      |    |     |      |    |    |      |    |     |        |    |    |    |
|        |      |    |     |      |    |    |      |    |     |        |    |    |    |
| 11.25  | 0     | 1  | 0   | 12   | 0.325 | 1.000 | 1     | 4  | 0    | 12    | 0.645 | 1.000 |
| 11.75  | 4     | 22 | 2   | 41   | 0.325 | 1.000 | 3     | 10 | 5    | 20    | 0.645 | 1.000 |
| 12.25  | 4     | 22 | 0   | 43   | 0.325 | 1.000 | 8     | 26 | 12   | 42    | 0.645 | 1.000 |
| 12.75  | 2     | 11 | 0   | 31   | 0.325 | 1.000 | 7     | 23 | 8    | 40    | 0.645 | 1.000 |
| 13.25  | 10    | 59 | 22  | 97   | 0.325 | 1.000 | 7     | 21 | 13   | 33    | 0.645 | 1.000 |
| 13.75  | 15    | 89 | 56  | 122  | 0.325 | 1.000 | 32    | 99 | 70   | 131   | 0.645 | 1.000 |
| 14.25  | 30    | 183| 143 | 223  | 0.325 | 1.000 | 61    | 190| 163  | 217   | 168   | 0.645 | 1.000 |
| 14.75  | 41    | 249| 203 | 295  | 0.325 | 1.000 | 101   | 313| 276  | 351   | 251   | 0.645 | 1.000 |
| 15.25  | 87    | 459| 376 | 541  | 0.325 | 1.173 | 204   | 638| 572  | 703   | 542   | 0.645 | 0.991 |
| 15.75  | 168   | 997| 894 | 1100 | 0.325 | 1.036 | 311   | 917| 842  | 993   | 807   | 0.645 | 1.051 |
| 16.25  | 238   | 1621| 1476| 1765 | 0.325 | 0.905 | 475   | 1516| 1394 | 1638  | 1417  | 0.645 | 0.972 |
| 16.75  | 315   | 2889| 2356| 3422 | 0.325 | 0.670 | 689   | 2593| 2082 | 3103  | 0.645 | 0.824 |
| 17.25  | 301   | 4720| 3987| 5453 | 0.230 | 0.554 | 719   | 3576| 3017 | 4136  | 0.595 | 0.676 |
| 17.75  | 167   | 6260| 4519| 8001 | 0.122 | 0.436 | 529   | 7019| 5457 | 8580  | 0.458 | 0.329 |

- **a** actual number of galaxies counted
- **b** corrected counts in units of $N/mag/deg^2$
- **c** lower limit on corrected counts
- **d** upper limit on corrected counts
- **e** approximate survey area for this bin in square degrees
- **f** approximate completeness for this bin
- **g** corrected galaxy counts after removing objects near clusters for N2 region

Note: Areas and completeness levels are approximations. The exact values are determined in four separate image depth bins, whereas only the global, averaged, values are shown here for comparative purposes.
FIG. 1.— Input minus output magnitude with different magnitude measuring systems for simulated objects with galaxy profiles. The error bars are the standard deviation of fluxes of the detected sources. They are similar in all data sets and are plotted for only one set for clarity. These results are from Monte Carlo simulations where $\sim 10^4$ sources in each bin were randomly placed in the deepest 25% of the K-band maps. Images were generated by IRAF's 'MKOBJECTS' package and have random inclinations. The BEST-magnitudes refer to SExtractor output, which essentially uses the Kron-magnitude (see text) to measure the flux. In this case, the lowest bin in our catalog would be the one at $K=17.25$ mag.
Fig. 2.— Completeness levels from the photometric simulations. Here the fraction of detected sources in the deeper parts of $J$ maps are shown for different object classes. Point sources (solid line) are detected to nearly 0.5 magnitudes fainter levels than normal galaxy profiles (dashed and dot-dash lines). The results shown here use a simple definition for a ‘detection’: the extracted source was found within 1.5″ of the input source and had a flux within ±4σ of the extracted spread of fluxes in the bin. For the point source case a result using an additional requirement for detection (dotted line) is also shown: the extracted flux had to be within ±0.25 mag of input flux. This definition would allow a crude completeness correction, but both of these definitions overlook the issue of the derived magnitudes for sources that are extracted but not within 0.25 mag of the correct flux. For a better completeness correction, curves such as these are not enough. One also needs the information on where the rest of the original sources of the bin are extracted (‘bin-jumping’). This information is included in the Monte Carlo results.
Fig. 3.—$J$-band total counts in two different depth-bins of the N2 area. The squares show raw counts from the deepest $\sim 30\%$ of the map, and the diamonds are from the second shallowest of the four different depth-bins ($\sim 25\%$ of total area). The solid curve shows the shallower counts after the completeness correction is applied. Although the last point on the curve seems consistent, it has an effective correction factor of about 7 and in practice is not included in our catalog. The corrected curve lies below the original raw count at some points because of bin-jumping effects: many faint sources have erroneously been detected at the bin, and the correction moves them back to their intrinsic, fainter bin. The total (summed over the four depth bins) N2 $J$-band raw and corrected counts are shown in Fig. 4.
Fig. 4.— Observed $J$-band star counts in the N2 field. Squares show an average from different methods of classifying stars versus galaxies: eye-balling, using the APS morphological classification, and two different sets of color-color plots. Color 1 refers to $B − R$ vs. $B − J$ and color 2 to $B − R$ vs. $R − J$. The solid curve shows the SKY-model (Cohen 1994) prediction for this field including the factor of 0.9 normalization. The total counts, stars plus galaxies, are also shown as raw (dashed) and completeness-corrected (dotted).
Fig. 5.— An example of the color-color classification for the $K < 15.5$ sources. Objects separate into two groups in the $B - R / R - K$ plane, although at the red end there is more overlap. The classification is very consistent, however, with the morphological classification of the APS-catalog: the crosses are galaxies and dots stellar sources. ‘$B$’ and ‘$R$’ in this plot actually mean the POSS-plate blue (O) and red (E) magnitudes. For the color-correction see e.g. Humphreys et al. (1991).
Fig. 6.— Differential $J$-band galaxy counts. The counts are tabulated in Table 1. For counts in the N2 region the open symbols show the effect of the cluster correction, discussed in Section 4.1. Error bars include the Poisson component and estimated completeness correction uncertainties. The N1 and N2 points are offset by 0.03 and –0.03 mag, respectively, for clarity.
Fig. 7.— Differential $K$-band galaxy counts. Open symbols show the cluster corrected counts, and the points are offset by $\pm 0.03$ mag, as in the previous figure.
Near-Infrared Galaxy Counts

Fig. 8.—$K$-band galaxy counts (solid symbols) along with other available data at similar magnitude ranges. All other data are plotted as published. Our counts show an excess compared to others, especially at bright magnitudes. The comparison is split into two panels for clarity only; there is no underlying difference between the two sets. To see the relative significance of the different counts, the approximate sky coverages (in degrees$^2$) of the surveys are given in parentheses. The preliminary DENIS counts are a sample from all-southern-sky counts (Mamon 1998). HWS, HMWS, and HMDS are from Gardner et al. (1993). The rest of the surveys are: Jenkins & Reid (1991), Glazebrook et al. (1994), Gardner et al. (1996), Huang et al. (1997), Saracco et al. (1997), Minezaki et al. (1998), Szokoly et al. (1998), Ferreras et al. (1999), Teplitz et al. (1999), and K"ummel & Wagner (2000).
FIG. 9.— Blue ($m_{pg} \approx B + 0.15$) galaxy counts extracted from the APS-catalog (O plate). Counts are shown at locations of selected large $K$-band surveys, including our N1 and N2 fields. Counts at the areas of Huang et al. (1997) seem to have a systematic undensity of a factor $\sim 1.3$ compared to median counts. Error bars for the Huang et al. (1997) counts show the field-to-field variation. The ELAIS N2 has an overdensity of about 10%. These results are consistent with the $K$-band counts. The APS-based counts are not completeness corrected in any way, and the incompleteness is expected to be significant at $B > 20$. 

**APS counts**

- N1
- N2
- Gardner 96
- Huang 97
- Szokoly 98
- Kuemmel 00
- B-data; Gard96
Fig. 10.— Comparison of $K$ surveys that have magnitude systems directly comparable to ours plus those for which we were able to estimate a magnitude correction. The latter are plotted in their corrected form. Data here are a subset of those in Fig. [1]. The ‘Gardner93’ label now contains the HWS, HMWS, and HMDS data. Most error bars are omitted for clarity. The Hawaii survey (Huang et al. 1997) is corrected for its systematic underdensity of galaxies, and our N2 counts are corrected for their small overdensity (Section 4.1, Figure 9), but otherwise there are no field corrections. The $K > 15$ counts are all consistent. At brighter magnitudes, while our statistics are poor, we seem to have an overdensity of galaxies.
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Fig. 11.— Differential $J$-band galaxy counts. Our data are shown as solid symbols, circles for N1 and squares for N2 (cluster corrected). Counts of Bershady et al. (1998, triangles), Teplitz et al. (1999, open circles), and Saracco et al. (1999, crossed) are shown, along with preliminary counts from DENIS (Mamon 1998, diamonds). Teplitz et al. (1999) counts are the only ones done at a similar magnitude range, and their survey area is indicated in parentheses. All points are plotted as published. We would expect aperture corrections to make the Teplitz et al. (1999) counts $\sim 0.2$ to 0.5 mag brighter. Thus our counts would lie between them and the Saracco et al. (1999) counts, while being most consistent with the Bershady et al. (1998) data. There are several models plotted, all of which have luminosity evolution included. The lines labeled 'G' show model counts using the LF of Gardner et al. (1997), while 'S' is for Szokoly et al. (1998) LF, which has more faint galaxies. A model with a cosmological constant ($\lambda_0 = 0.8$) is shown as the dashed curve. The dash-dot line ('B') shows a model where the local LF parameters were chosen to fit an empirical simulation from Bershady et al. (1998; $1/V_{max}, \theta_0 = 0$) after which luminosity evolution was added.
Differential $K$-band galaxy counts. Our data are shown as solid symbols, circles for N1 and squares for N2 (cluster corrected). Preliminary counts from DENIS (Mamon 1998) are shown as triangles. Bright and medium deep counts are plotted here as open circles without separating them; the same data-set are shown individually in Fig. 10. The deep counts are shown separately. At $16 < K < 20$ the points below other data are those of Saracco et al. (1997, 1999); see discussion therein for possible reasons for the underdensity. Other deep survey data are from: Soifer et al. (1994), Djorgovski et al. (1995), McLeod et al. (1995), Moustakas et al. (1997), Saracco et al. (1997; ESOKS1), and Bershady et al. (1998). Following Bershady et al. (1998), the Djorgovski et al. (1995) data are corrected by -0.5 mag, all other deep data are plotted as published. The same models as in the previous $J$-band counts figure are overplotted.