PRELIMINARY STATISTICS OF DISCRETE SOURCES OBTAINED WITH THE 'MILLS CROSS'

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The statistics of the discrete sources observed in Cambridge and the interpretation given by Ryle and his colleagues constitute one of the most interesting items of recent astronomy. It is therefore of great importance to check the observational data and this can be done from the independent results being obtained in Sydney by Mills and his colleagues with the 85 Mc./s. Mills Cross. With this in mind Ryle sent me some two months ago a pre-publication account of the Cambridge work. (Now published, Ryle and Scheuer, 1955[1].) The currently available observations with the Mills Cross are not yet sufficient to give a decisive answer, but those available disagree with the Cambridge ones. Because of the importance of the subject it seems desirable to give here an interim account of these observations. The general position of the observations is discussed in a separate paper (paper 18, Pawsey). As stated there observations to date have been aimed at the study of known objects. The beam in each case was adjusted to the appropriate declination and an extended record, including the selected object in a small section, was taken. Most of these records have been examined for discrete sources and such sources listed with their intensities when sufficient records at adjacent declinations were available to delineate them. The list was restricted to sources which, within the 50′ limits of resolution of the equipment, appeared to be discrete point sources. Extended sources were neglected. This method gives an irregular coverage of the sky so that the sampling must be watched.

At the time of Ryle's letter some 550 sources had been listed over a solid angle in the sky of roughly one steradian. The region concerned included an unduly large proportion of sky adjacent to the Milky Way. For these sources the statistical distribution of flux densities is shown in the form used by Ryle by the black dots in Fig. 1. Here ρ_S is the number of sources per

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steradian with flux density greater than S. The vertical dotted line through each point shows the limits $\pm\sqrt{N}$, where N is the number of sources in the actual sample, and indicates the probable statistical error. As discussed by Ryle a uniform space density of sources should give a line of slope $-3/2$ and the straight line has this slope. It is clear that the original sample

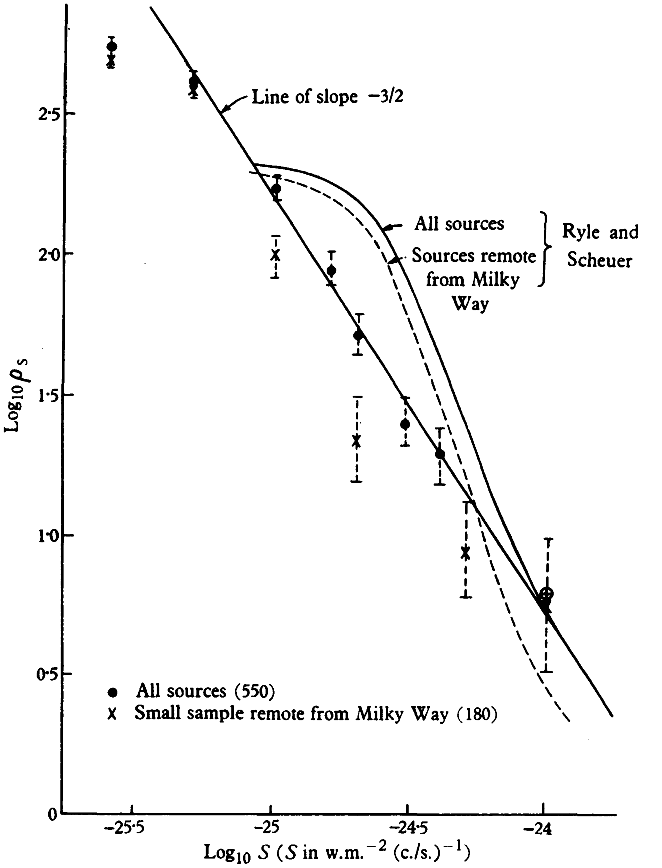

Fig. 1. Intensity distribution of first 550 discrete sources listed from 85 Mc./s. Mills Cross records. ρ_S is the number of sources per steradian with flux density greater than S. The highest intensity group, small circle, includes sources from other parts of the sky previously located by interferometers. Ryle and Scheuer's 81·5 Mc./s. distributions are shown for comparison.

showed no significant departure from the $-3/2$ distribution except for intensities less than about 5×10^{-26} w.m.$^{-2}$ (c./s.)$^{-1}$ where instrumental limitations might be expected.

In a first attempt to exclude the influence of galactic sources those sources remote from the Milky Way were selected and the resulting distribution is shown by the crosses. Unfortunately, the sample, 180 sources, is unduly small and the statistical errors great. This sample does show a suggestion of an excess of faint sources over the number expected on the uniform space density hypothesis but when the distribution is compared with those obtained by Ryle and Scheuer, which are also shown, it is seen that the excess, corresponding to the steeper slope, occurs at substantially

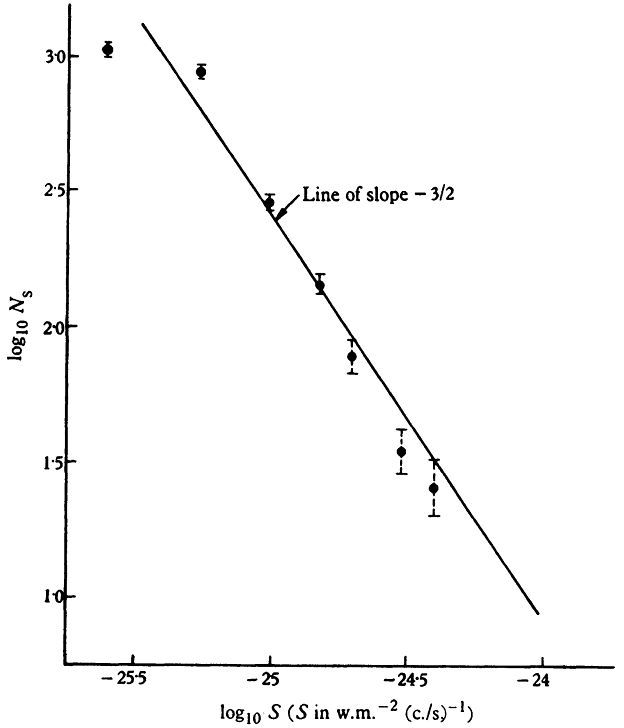

Fig. 2. Intensity distribution of first 1030 Sydney sources. N_S is the number of sources with flux density greater than S.

greater intensity in Ryle and Scheuer's case. This difference is not accounted for by the very slight difference in frequency of observations (85 and 81 Mc./s.).

In the short interval available before this symposium a considerable number of further sources were listed in regions remote from the Milky Way. This gave a total of 1030 sources in areas much less biased towards the Milky Way and the intensity distribution of these sources is shown in Fig. 2.

On considering the three Sydney curves it appears that none show a deviation from the $-3/2$ law which we can be sure is significant. There is a tendency for an increase in steepness of the curves at intensities just short of the survey limit, but we should not like at this stage to exclude possible instrumental or other extraneous effects at such intensities. The important point is that in the intensity range in which the Cambridge workers found excess steepness the Sydney results do not show such an effect. The essential difference in the results is that in the range about

$$S = 2 \times 10^{-25} \text{ w.m.}^{-2} \text{ (c./s.)}^{-1}$$

Ryle and Scheuer report two or three times as many sources despite the fact that the Sydney sensitivity limit is several times lower than theirs.

It is clear that the details of individual sources, positions, intensities and sizes, in areas common to the Cambridge and Sydney surveys, should be compared in order to elucidate the nature of the discrepancy. But this has not yet been possible because none of the detailed Cambridge information has been available to us.

There is thus a substantial disagreement between the Cambridge and the preliminary Sydney results and it seems best to withhold judgment on the most interesting interpretation put forward by Ryle and Scheuer until the Sydney observations are complete. At that stage quite definite conclusions should be reached because the pencil-beam technique used is substantially free from confusion. In the intensity range of interest for the comparison, sources stand out unambiguously as illustrated by the record of the source NGC 253 shown in Fig. 2 of paper 18 (p. 125). The flux density of this source, $S = 1{\cdot}1 \times 10^{-25}$ w.m.$^{-2}$ (c./s.)$^{-1}$ is at the lower end of the intensity range where the Cambridge and Sydney results disagree.

REFERENCE

[1] Ryle, M. and Scheuer, P. A. G. *Proc. Roy. Soc.* A, **230**, 448, 1955.

Discussion

Gold: The fact that the steepening of the slope occurs in both Ryle's and the Australian survey, in each case near the limit of the instrument but at a different level for the two methods, suggests that this is an experimental effect. In the case of Ryle's survey it is clear that weak sources with angular diameters $> 20'$ are missed near the galactic plane. A similar cut-off might have been operative at high latitudes for still weaker extended sources which are therefore perhaps missing from the lower end of Ryle's curve.

Another way in which a steepened curve could be brought about is by the erroneous judgment of intensity of some of the faint sources. When there are several sources in the beam, it might frequently occur that one is recorded of greater than the correct intensity. This would produce an increase in the

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number in one range of the curve at the expense of a proportionally much smaller decrease in a higher section of the curve. An interpretation of that sort would imply that the Cambridge survey is much more liable to such an error, and already at a higher intensity than the Australian one.

Ryle: The steepening of the slope in the Cambridge results does *not* occur near the confusion limit; the slope is significantly greater than 1·5 for an intensity of $5 \,.\, 10^{-25}$ M.K.S. units where the number of sources per beam width is about 0·06. The errors caused by confusion for such a small value of sources per beam-width is readily computed and is quite unimportant in the present case.

It is also worth mentioning that the limit of detection in the Australian survey is determined by sensitivity and not confusion; it would be a remarkable coincidence if two such entirely different factors should produce a steepening at about the same part of the curve.

The possibility of the high slope being due to extended sources has already been discussed at some length and shown to be incompatible with the Cambridge survey of low resolving power. It would also be remarkable if such an explanation could account for the similar increased slope of the Australian survey, where a much lower resolving power was used.

Bondi: I wish to make three points:

(1) The arguments given by Ryle to show that finite size and dispersion of luminosity are *separately* unable to affect the results are invalid when the two effects are considered together.

(2) Has any allowance been made for the influence of clustering?

(3) In a confusion-limited instrument like the Cambridge interferometer it is very hard to tell what the quantity designated as intensity actually measures in the case of faint sources. If this quantity contains any admixture of differentiation with respect to angular position, as is only too likely, a substantial steeping of the log N–log I curve would follow. The inverse cube law arises if half an order of angular differentiation is introduced in both directions.

Ryle: We have already discussed the effects produced by each of these possibilities independently; it is not clear why a combination of them should be any more effective in producing an increased slope of the log N–log I curve without becoming apparent on the survey of low resolving power.

Further, in connexion with Pawsey's communication, I would like to point out that a number of extended sources were found which do not appear on the main survey. Their number is too small to allow of an explanation of the increased slope in terms of partial resolution of the intense sources, but they would be sufficient to modify the slope found in a survey made with a lower resolving power such as that of Mills' aerial (50′). The discrepancy in the slopes of the two log N–log I curves ($-3{\cdot}0$ for Cambridge, and $-2{\cdot}2$ for the area containing 180 sources away from the plane in Mills' survey), may be due to such a cause.