ACTIVE GALACTIC NUCLEI FROM THE EXTENDED EINSTEIN MEDIUM SURVEY

I.M. Gioia[1,2], T. Maccacaro[1,2], R.E. Schild[1], A. Wolter[1], J.T. Stocke[3], S.L. Morris[4], I.J. Danziger[5].

1) Center for Astrophysics, Cambridge, MA
2) Istituto di Radioastronomia, Bologna, Italy
3) University of Colorado, Boulder, CO
4) Steward Observatory, Tucson, AZ
5) ESO, Garching bei Munich, FRG

ABSTRACT. This paper presents a progress report on a major extension of the Einstein Observatory Medium Sensitivity Survey (MSS). The results obtained from the survey are briefly summarized, particular emphasis is given to the Active Galactic Nuclei (AGN) and BL Lac objects of the MSS. The basic properties of these classes of extragalactic objects are presented and discussed.

1. INTRODUCTION

The Medium Survey is a collaboration among the Center for Astrophysics, the Steward Observatory of the University of Arizona, the University of Colorado and the European Southern Observatory. The survey consists of X-ray sources serendipitously discovered with the Imaging Proportional Counter (IPC) on board the Einstein Observatory (Giacconi et al. 1979), in the energy range 0.3-3.5 keV, at intermediate fluxes between the UHURU/Ariel V limit and the Einstein Deep Survey limit, namely in the flux range between 10^{-11} and 10^{-13} ergs cm^{-2} s^{-1} (see Maccacaro et al. 1982, for a complete description of the survey). The published MSS contains 112 sources selected in 345 IPC fields, covering 90 square degrees of sky. The optical identification (Stocke et al. 1983, Gioia et al. 1984) of all the sources allowed us to extract complete samples of astronomical objects for detailed statistical studies. Some of the main results obtained from the analysis of the extragalactic samples in the original MSS will be reviewed.

2. RESULTS FROM PREVIOUS WORK

The LogN-LogS relation for the extragalactic sample has been found to be consistent with that predicted by the euclidean model (slope α = 1.45±0.12). Gioia et al. (1984) have shown that this result is actually the sum of two different contributions given by AGN and clusters of galaxies. In particular the AGN LogN-LogS curve has a slope steeper than 1.5, corresponding to the fact that they are an

E. Ye. Khachikian et al. (eds.), Observational Evidence of Activity in Galaxies, 329–335.

https://doi.org/10.1017/S0074180900155329 Published online by Cambridge University Press

evolving class of object (Maccacaro, Gioia and Stocke, 1984), while the LogN-LogS curve for clusters of galaxies shows a slope flatter than the euclidean value. No flattening is evident at the low flux end of the AGN LogN-LogS relation. The number of BL Lacs, not included in our working definition of AGN, is too small (5) to allow us to attempt a detailed statistical study of their properties. Their paucity, however, is significant and it has been used by Maccacaro et al. (1984) to show, under the hypothesis of isotropic emission, that BL Lac objects do not evolve, or at least not as strongly as AGN. Figure 1 shows the integral LogN-LogS curves for the total extragalactic sample, the AGN and the BL Lac samples.

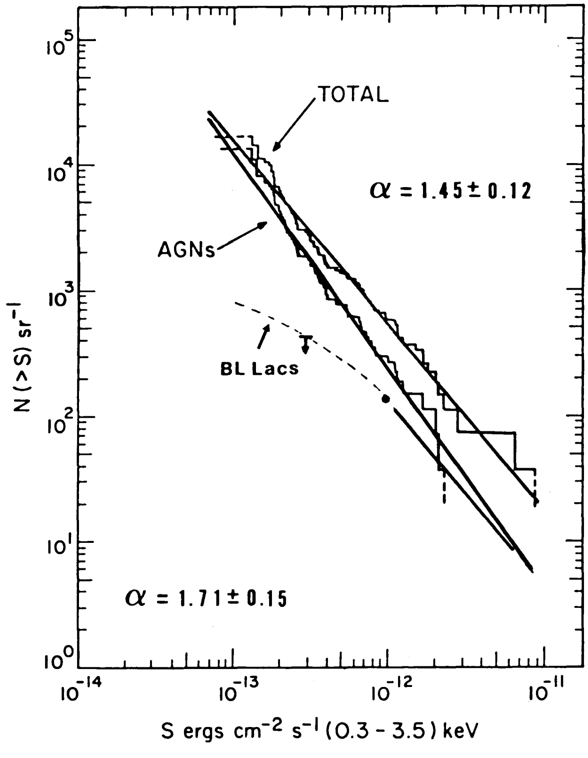

Figure 1. The integral Log N (>S) - Log S relation for the extragalactic X-ray sources (adapted from Gioia et al. 1984 and Maccacaro et al. 1984).

Maccacaro, Gioia and Stocke (1984) have studied the distribution in space of the X-ray selected AGN and found that this distribution is strongly non-uniform. Within the framework of a pure luminosity evolution model of the form $Lx = Lx(z=0)e^{Cz/(1+z)}$, a best fit value of 4.85 for the evolution parameter C has been derived. In the same framework of a pure luminosity evolution, the AGN luminosity function is not appropriately represented by a single power law. A significant flattening occurs at low luminosities ($Lx(z=0) < 2x10^{25}$ ergs s^{-1} Hz^{-1}). This flattening is hardly quantifiable given the limited statistics.

https://doi.org/10.1017/S0074180900155329 Published online by Cambridge University Press

3. OPEN QUESTIONS

A number of questions still remain unanswered and need more investigation:

1) The low-luminosity flattening of the AGN luminosity function is poorly determined.
2) At present it is not possible to discriminate between different evolution models (e.g. Pure Luminosity Evolution, Pure Density Evolution or Luminosity Dependent Evolution). One has to assume a model and then constrain the parameters which describe it.
3) The study of the AGN X-ray luminosity function and its cosmological evolution provides the most powerful tool to compute the AGN contribution to the diffuse X-ray background. A very accurate determination of the luminosity function and of the cosmological evolution are obviously needed.
4) The BL Lac number counts, although poorly determined, are significantly different from the AGN number counts. This has important and, as yet, not completely understood implications for the relationship between these two classes of objects.

This is why we have undertaken such a large program to extend the Survey. Greatly improved statistics will help to solve most, even if not all, of the open problems.

4. FINAL UPDATE

Over the last two years we have been working to extend the Medium Survey by analyzing new IPC fields. The gathering of the X-ray data has been completed only recently. The identification process and the collection of information at other wavelengths, such as the radio or the infrared bands, is still underway. It will probably take two more years to identify spectroscopically all the X-ray sources in the extended survey.

We have analyzed 1439 IPC images covering 780 square degrees of the high galactic latitude sky and we have discovered 836 serendipitous X-ray sources, of which 403 have been already identified spectroscopically. Of these, 171 are AGN and 16 are BL Lacs or BL Lac candidates. Upon completion of the optical identification program the AGN sample will consist of about 400 objects, while the BL Lacs should number about 30. This means that we now have about 7.5 times as many objects as were in previously published samples (see Maccacaro et al. 1982, Stocke et al. 1983, Gioia et al. 1984).

5. BASIC PROPERTIES OF THE AGN AND BL LAC SAMPLES

In what follows the basic properties of the sources already

https://doi.org/10.1017/S0074180900155329 Published online by Cambridge University Press

identified with AGN and BL Lacs are shown. However, since only half of the sources have been identified up to now, the properties of these identified subsamples are biased in favor of the apparently brighter objects, or in favor of objects which are active also at other wavelenghts.

Figure 2 shows the apparent m_v distribution which spans the range 14.5 to 20.5 with an average value of 17.6. (Darker shaded areas in Figures 2, 3, 4 and 5 represent the corresponding distributions for the published sample). Only a few more objects are expected at the bright end of the m_v distribution. At the faint end, on the other hand, the true m_v distribution may substantially exceed that shown in Figure 2, because these objects are harder to identify.

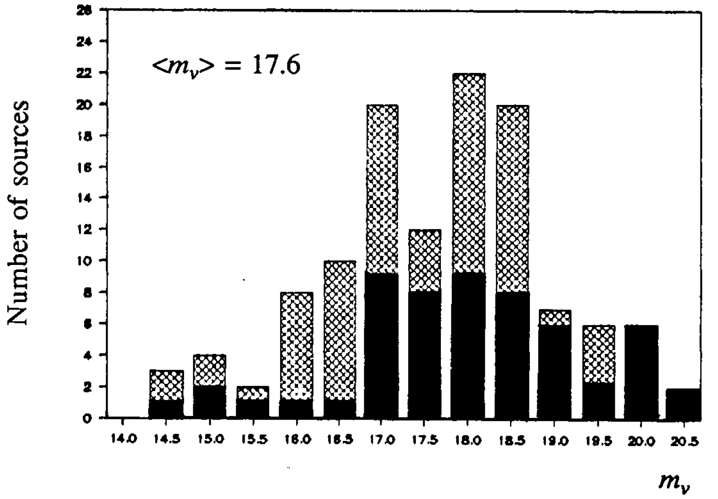

Figure 2. Apparent magnitude distribution for X-ray selected AGN.

The well known distribution of redshifts of X-ray selected AGN (see Gioia and Maccacaro, 1983, and references therein for a more thorough discussion) weighted towards low z ($<z> = 0.4$) is shown in Figure 3. However in the extended MSS survey there are already 18 AGN with z > 1, with approximately 40 expected in the entire sample upon completion of the identification program. Therefore the extended MSS, with a larger dynamical range in redshift, will provide a better sample for studying AGN evolution.

Optical absolute magnitudes are in the range -19 to -31 with an average magnitude M_v = -23.7 (see Figure 4). Besides low redshift objects, the X-ray selection favors also the detection of low-luminosity AGN. It is important to study the evolution properties of this type of object and compare them with the properties of high luminosity quasars selected by other means (radio or optical) in order to fill in important gaps in our understanding of the AGN phenomenon.

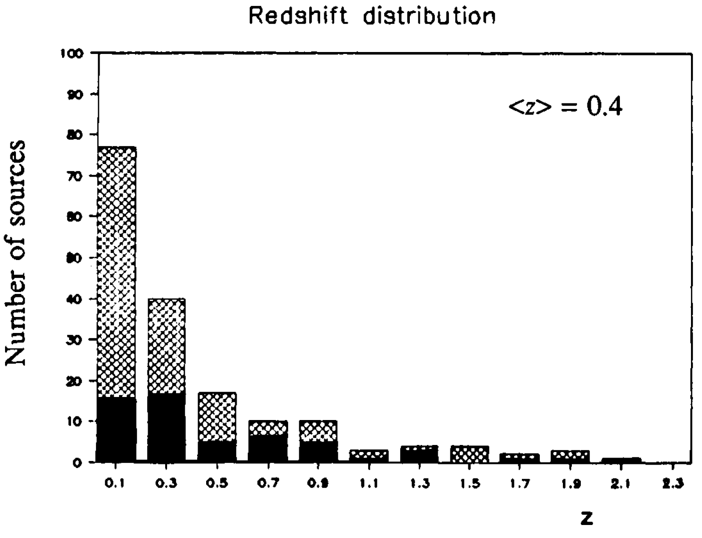

Figure 3. Redshift distributions for X-ray selected AGN.

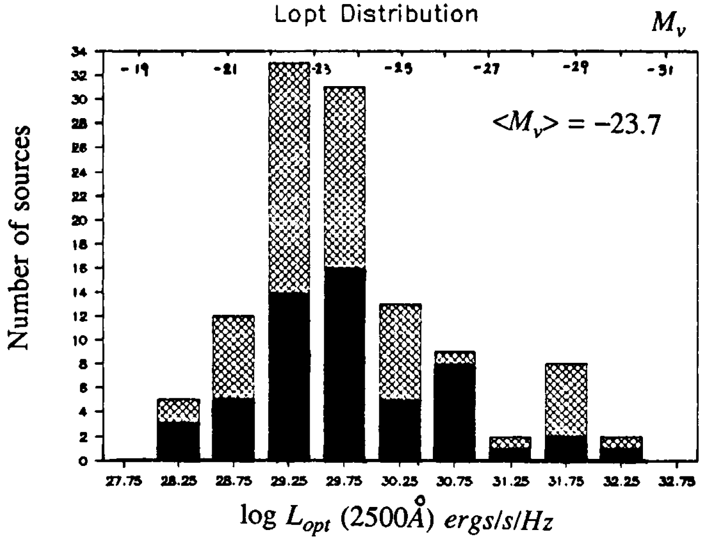

Figure 4. Absolute magnitude distribution for X-ray selected AGN.

As expected from the fact that they are X-ray selected, the MSS AGN are strong X-ray emitters with luminosities in the range 10^{42} - 10^{47} ergs s^{-1}. Figure 5 shows the X-ray luminosity distribution which has an average value of log Lx = 44.3.

https://doi.org/10.1017/S0074180900155329 Published online by Cambridge University Press

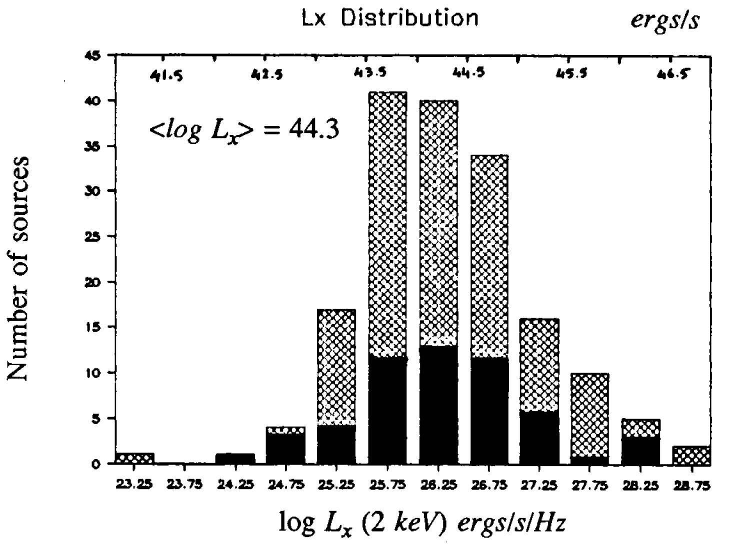

Figure 5. Monochromatic X-ray luminosity distribution of X-ray selected AGN.

6. CONCLUSIONS

The identification process and the gathering of information at other wavelengths is underway. About 300 MSS sources have already been observed with the VLA at 6 cm: most of the new BL Lacs have been identified by means of radio observations. Cross correlation is being done with other catalogues, like the IRAS catalogue. For all the sources three color CCD photometry will be available. When the identification process of the MSS is completed, the increased statistics will enable us to answer most of the open questions.

We thank J. Schwarz for a careful reading of the manuscript. This work has received partial financial support from NASA Contract NAS8-30751, NASA Grant NAG-8442 and from the Smithsonian Scholarly Studies Program Grant SS48-8-84.

REFERENCES

Giacconi, R., et al. 1979, Ap.J. Letters, 234, L1.
Gioia, I.M. and Maccacaro, T., 1983, in Proceedings of the 24th Liege Astrophysical Colloquium Quasars and Gravitational Lenses (Liege: Institut d' Astrophysique), pag.63.
Gioia, I.M., Maccacaro, T., Schild, R.E., Stocke, J.T., Liebert, J.W., Danziger, I.J., Kunth, D. and Lub, J., 1984, Ap.J., 283, 495.
Maccacaro, T., et al., 1982, Ap.J., 253, 504.
Maccacaro, T., Gioia, I.M. and Stocke, J.T., 1984, Ap.J., 283, 486.
Maccacaro, T., Gioia, I.M., Maccagni, D. and Stocke, J.T., 1984, Ap.J. Letters, 284, L23.
Stocke, J.T., Liebert, J.W., Gioia, I.M., Griffiths, R.E., Maccacaro, T., Danziger, I.J., Kunth, D. and Lub, J., 1983, Ap.J., 273, 458.

DISCUSSION

GURVITS: What is the part of QSOs in your survey? Is there a special track at QSOs in the "log N-log S" plane?

GIOIA: We do not distinguish quasars from Seyfert galaxies in our definition of AGN (Active Galactic Nuclei). The AGN log N-Log S I have shown comprises both kinds of objects.

WILSON: Your log N vs log S for BL LACS is very strange and may indeed imply something remarkable about their space distribution. Have you considered as an alternative interpretation that the deficiency at low X-ray fluxes may be made up by apparently relatively normal galaxies? In other words could the effect be connected with the difficulty of recognizing a weak BL LAC nucleus in a normal galaxy?

GIOIA: The X-ray selected BL LAC objects are characterized by a very high fx/fv (x-ray to visual flux ratio). However, even if we are unable to recognize a weak BL Lac nucleus in an otherwise normal galaxy, the number of X-ray selected galaxies in the Medium Survey is so small (only 3 galaxies our of 112 sources) that this possibility is very unlikely.