Active Galactic Nuclei and Related Phenomena
IAU Symposium, Vol. 194, 1999
Yervant Terzian, Daniel Weedman, Edward Khachikian, eds.

Investigation of a New Sample of *IRAS* Galaxies

A. M.Mickaelian, S. A.Hakopian, S. K.Balayan

Byurakan Astrophysical Observatory, Byurakan 378433, Republic of Armenia. E-mail: aregmick@bao.sci.am, susanaha@bao.sci.am, bal@moon.yerphi.am

Abstract.
A new sample of some 900 faint *IRAS* galaxies will be constructed after optical identifications of all *IRAS* point sources from *PSC* and *FSC* in an area with 1 500 deg^2 at high galactic latitudes. The identifications are being made on the basis of *FBS* low-dispersion spectra, DSS images and infrared colours. Some 320 *IRAS* sources have been identified and 180 galaxies have been found. Spectral observations of these objects revealed new AGN and luminous infrared galaxies.

1. Introduction

More than 250 000 infrared point sources have been detected by the Infrared Astronomical Satellite (*IRAS*) at 12μ, 25μ, 60μ and 100μ bands. They are cataloged in the *IRAS* Point Source Catalog (*PSC*) and the *IRAS* Faint Source Catalog (FSC). Systematic cross-identifications have been made for these sources with the main available catalogs, including catalogs of bright stars, galaxies, QSOs, variable stars, planetary nebulae, late-type stars, radio sources, UVX objects, emission stars, as well as radio and other *IR* catalogs. The associations are made by coincidence (or proximity) of the coordinates (depending on the coordinate accuracy of the given catalog). These "blind" identifications result in cases, where several objects (stars, galaxies, etc.) are identified with a single IR source. Moreover, half of the *IRAS* sources remain without any identification yet and their physical nature is unknown.

2. Construction of samples and optical identification of IR sources

In order to make possible further study of the *IRAS* sources, it is necessary to identify their optical counterparts. Various samples of *IRAS* galaxies have been constructed. As it appeared, the *IRAS* galaxies make up a rather interesting population, including AGNs, luminous and ultraluminous IR galaxies, which are important for the study of star-formation phenomena.

Beginning with the first published data of the *IRAS* surveys, works on construction of various samples of *IRAS* galaxies began. Lonsdale & Helou (1985) published the catalog of known QSOs and galaxies which were associated with *IRAS* sources. On the basis of the cross-identifications the *IRAS* Bright

https://doi.org/10.1017/S007418090016190X Published online by Cambridge University Press

Galaxy Sample (*BGS*) of 330 galaxies was made up by Soifer et al (1987, 1989 and other papers). On the basis of the *IRASPSC*, Spinoglio & Malkan (1989) and on the basis of the *IRASFSC*, Rush et al (1993) have constructed a 12μ galaxy sample. Rowan-Robinson et al (1991) constructed an *IRAS* 60μ galaxy catalog, covering 82% of the sky. Strauss et al (1990) and Fisher et al (1995, and other papers of the series) on the basis of the *IRAS* data constructed a complete all-sky sample of objects brighter than 1.2 Jy at 60μ. The sample consists of 5014 objects, including 2649 galaxies. More than 20 different samples of *IRAS* galaxies are known already.

As the IR data are very useful for investigation of objects, there are many works on optical identifications of *IRAS* sources in different interested regions (e.g. star clusters), galaxy samples, etc. Some works are devoted to identifications of all the *IRAS* sources in limited regions.

There are numerous works on optical identifications of *IRAS* sources in separate regions. Johnson & Klemola (1987) investigated 56 unidentified *IRAS* point sources in the Draco cloud region. They found probable counterparts inside the error-ellipse fields, including both galaxies and stars. Sutherland et al 1991, using the APM Galaxy Survey, have generated a collection of finding charts for 4614 sources with non-stellar colors in the *IRASFSC* south of δ=-17.5° and most of them were identified with galaxies. A program of radio/IR identifications was carried out by Condon et al (1995). By the coincidence of the radio and IR coordinates for all the *FSC* sources with $F_{60} > F_{12}$ they constructed a sample of 354 probable extragalactic sources. Using the optical data these authors looked for the optical counterparts of these radio-loud FIR galaxies and QSOs.

The *OPTID* database (optical identifications for *IRAS* sources) also gives numerous possible optical counterparts for each *FSC* source (Conrow et al), but the real identifications are not made. This database is better for use in the Southern Hemisphere, as in the Northern Hemisphere, only objects with optical magnitudes $<15^m$ are given and the main part of galaxies are not included.

3. The FBS database and the program of mass-identification of IRAS sources

The largest objective prism survey is the First Byurakan Survey (*FBS*), carried out with the Byurakan 1-m Schmidt telescope and 1.5° objective prism by Markarian et al (1989). It consists of 1133 4°×4° fields and covers an area of more than 17 000 deg^2 at high galactic latitudes ($|b|$ >15°). All the Northern Hemisphere and part of the Southern Hemisphere (δ >-15°) is covered at these galactic latitudes. The dispersion is 1800Å/mm near H_γ and the spectral range is 3400-6900Å, so that one can notice some absorption and emission lines (such as Balmer lines, molecular bands, He, N_1+N_2, broad emission lines of QSOs etc.), follow the spectral distribution and compare the blue and red parts of the spectrum. These possibilities give a chance of recognition of the types of objects and their preliminary rough classification. Since 1987 surveys of blue stellar objects and red stars are being carried out on the basis of this observational material (Abrahamian et al 1990, Mickaelian 1994, and references therein).

For cosmological studies it is rather desirable to have a complete sample of optical counterparts of *IRAS* sources at high galactic latitudes. Hence, an optical identification program of all IRAS sources (mass identifications) on a large area is required. A program of mass optical identifications of IRAS sources on the basis of low-dispersion spectra is conducted for the first time since 1994 (Mickaelian 1997). The area with $+61° < \delta < +90°$ (at galactic latitudes $|b| > 15°$) was chosen with a total surface of 1 500 deg^2, where the *FBS* plates have deeper limiting magnitudes than the average. Positions of all the *IRAS* sources are examined on the *POSS* O and E charts, *FBS* plates and *DSS* images. IR colors provide additional information on the possible nature of the optical counterpart, but the latter is selected by means of recognition of the definite object, which can be an IR source. The ultimate selection of the optical counterpart is made on the basis of many parameters, including the IR colors, optical images, optical magnitudes and colors, and of course the low-dispersion spectra. These objects are not numerous among the whole stellar population, and in 90% of cases the selection is made confidently.

4. Building a new sample of IRAS galaxies

During the past 3 years, the following results have been obtained. All the unidentified *IRAS* point sources for the selected region have been extracted from the *IRASPSC* and *FSC*. They are checked for associations by the *NED* and *SIMBAD* databases. It appears that there are several known optical objects (mainly stars) near some of the selected sources. So it is an additional task to clarify why these objects have not been associated with the IRAS sources even in the updated versions of the catalogs. In all 1517 *IRASPSC* and *FSC* sources are included in the identification program.

At present optical identifications have been made for 317 IR point sources out of 341 in an area of 382 deg^2 (Mickaelian 1997, Mickaelian & Gigoyan 1998, and references therein). Optical coordinates, deviations from the *IRAS* positions are determined, V magnitudes, $B - V$ colors are estimated, and rough classification is made for all the objects. There are 133 late-type stars, 7 planetary nebulae, 8 QSO candidates, 140 galaxies, and 29 multiple galaxies and small groups among the identified optical counterparts. There is no optical counterpart near the positions of 27 sources even in the *DSS*, and taking into account their IR colors are typical for galaxies, they must be very faint galaxies in optical wavelengths. QSO candidates are selected by their low-dispersion spectra, but the QSO-like spectral distribution is approximate.

The identified galaxies can be considered as the most interesting counterparts of the IR sources. For them angular sizes and position angles are determined, morphological classification, and comments on structural and environmental anomalies, as well as on low-dispersion spectra (UV-excess, emission lines etc.) are made in addition to the above mentioned main parameters. On the basis of their low-dispersion spectra and compact structure, 21 are suspected to be Sy galaxies. 30 more have also compact and bright bulges with very faint peripheries, 2 galaxies have bright HII regions in their spiral arms, 3 have double and multiple nuclei, and *IRAS 16102+6345* has a jet-like feature. Multiple galaxies have various appearances and structures. In many cases a galaxy can

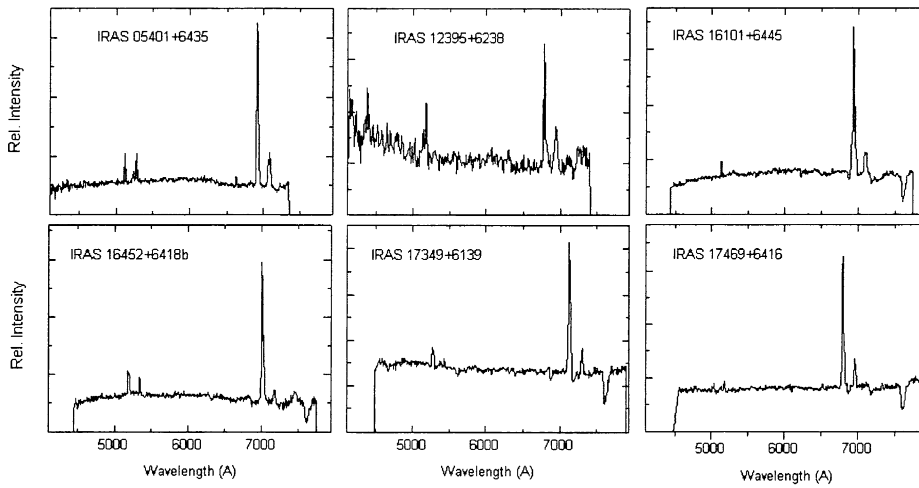

Figure 1. Slit spectra of 6 IRAS galaxies

be considered as a satellite of another, brighter one. Interaction features (tails, bridges) are present as well. Further identifications will complete the sample of *IRAS* galaxies in the region.

5. Observations and classification

The purposes of spectral observations are the investigation of spatial distribution of *IRAS* galaxies and the IR luminosity function. Besides, we will distinguish the most interesting objects (AGN, high luminosity IR galaxies, and composite spectra objects) and study them in more detail.

Observations have been made during 1997 and 1998 at the 6-m telescope of the Russian Special Astrophysical Observatory (Mickaelian et al 1998, Balayan et al 1999). The long-slit spectrograph UAGS at the prime focus with a 580×530 CCD is used (Afanasiev et al 1995). The dispersion is 5.8 Å/px and the spectral range 4000-8000ÅSpectra of 42 galaxies (including multiple ones), responsible for 33 *PSC* sources, have been obtained and reduced. Redshifts for all observed galaxies are measured, and their activity types are estimated, based mainly on well-known emission-line relations (Baldwin et al 1981, Veilleux & Osterbrock 1987). The redshifts are in the range $0.02<z<0.09$, calculated infrared luminosity is in the range $10^{10}<L_{ir}<10^{12}$. Within the scheme constructed of HII, LINER, Composite AGN and Sy2 type classes, most objects are of HII nature, 3 are LINERs and 2 are of Composite AGN nature, namely *IRAS 16118+6231* and *IRAS 12395+6238* (Veron et al 1997). Some examples of spectra of the observed objects are given in Fig. 1.

The observations and data reduction are being continued.

https://doi.org/10.1017/S007418090016190X Published online by Cambridge University Press

6. Conclusions

The optical identification program will produce a new *IRAS* galaxy sample in a region of 1 500 deg^2. It will include all *PSC* and *FSC* sources having extragalactic optical counterparts. After the fulfillment of the program of identifications, the following studies are planned:

1) study of the sample contents. In particular the availability of optical and IR (at 4 bands) data for many galaxies will help to clarify the classification principles as well (relation between IR luminosity and activity types),

2) detailed optical study (morphology: study of interactions, fine structure of central regions; and spectroscopy: determination of redshifts and activity classes) of the newly identified galaxies and groups of galaxies,

3) radio millimeter observations,

4) overall statistical study of the area, including previously identified *IRAS* sources.

5) comparison with the existing samples of *IRAS* galaxies and their statistical conclusions on space density, evolution, star-formation rate and status of the IR galaxies.

We hope to obtain the real distribution pattern of extragalactic IR sources in the local Universe. The large amount of interesting objects (active galaxies, interacting systems, QSOs) among the *IRAS* sources allow important investigations in this field, as their study brings understanding of evolutionary phenomena and processes taking place in galaxies.

Acknowledgments. A.M.Mickaelian is grateful to P.Veron for useful discussions and invitation to Observatoire de Haute-Provence, which helped to fulfill an important part of this work.

References

Abrahamian H. V., Lipovetski V. A., Stepanian J. A., 1990, Astrofizika 32, 29

Afanasiev V. L., Burenkov A. N., Vlasyuk V. V., Drabek S. U., SAO technical report 1995, V. 234

Baldwin J., Philips M., Terlevich R., 1981, PASP 93, 5

Condon J. J., Anderson E., Broderick J. J., 1995, AJ, 109, 2318

Conrow T., Lonsdale C., Evans T., Fullmer L., Moshir M., Yentis D., Wolstencroft R., MacGillivray H., Egret D., Chester T., The Faint Source Survey Optical Identification Database (OPTID), at IPAC

Fisher K. B., Huchra J. P., Strauss M. A., Davis M., Yahil A., and Schlegel D., 1995, ApJS 100, 69

Balayan S. K., Hakopian S. A., Mickaelian A. M., Burenkov A. N., 1999, Pisma v AZh, in press

Johnson H. M., Klemola A. R., 1987, ApJ S 63, 701

Lonsdale C. J., Helou G., 1985, Catalogued Quasars and Galaxies from the IRAS Survey

Markarian B. E., Lipovetski V. A., Stepanian J. A., Erastova L. K., Shapovalova A. I., 1989, Commun. Special Astrophys. Obs., 62, 5

Mickaelian A. M., Discovery and Investigation of Blue Stellar Objects of the First Byurakan Survey, Ph. D. thesis, Byurakan, 1994

Mickaelian A. M., 1997, Astrofizika 40, 1

Mickaelian A. M., Gigoyan K. S., 1998b, Astrofizika 41, in press

Mickaelian A. M., Hakopian S. A., Balayan S. K., Burenkov A. N., 1998, Pisma A.Zh., 24, 1

Osterbrock D. E., Tran H. D., Veilleux S., 1992, ApJ 389, 196

Rush B., Malkan M. A., Spinoglio L., 1993, ApJS 89, 1

Rowan-Robinson M., Saunders W., Lawrence A., Leech K., 1991, MNRAS 253, 485

Soifer B. T., Sanders D. B., Madore B. F., Neugebauer G., Danielson G. E., Elias J. H., Lonsdale C. J., Rice W. L., 1987, ApJ 320, 238

Soifer B. T., Boehmer L., Neugebauer G., Sanders D. B., 1989, AJ 98, 766

Spinoglio L., Malkan M. A., 1989, ApJ 342, 83

Strauss M. A., Davis M., Yahil A., Huchra J. P., 1990, ApJ 361, 49

Sutherland W. J., McMahon R. G., Maddox S. J., Loveday J., Saunders W., 1991, MNRAS, 248, 483

Veilleux S., Osterbrock D. E., 1987, ApJS 63, 295

Veron P., Goncalves A. C., Veron-Cetty M.-P., 1997, A&Ap 1997, 319, 52