Bull. Spec. Astrophys. Obs., 1996, 39, 150–154

On the cross–identification of the IRAS–Point Source and Texas catalogs

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Received November 30, 1995; accepted December 7, 1995.

Abstract.
We present results of cross–identifications of the objects from two large catalogs, IRAS–Point Sources and Texas, in the database CATS. The list consists of 1208 pairs of sources. More than half of the IRAS sources have been identified for the first time. The resulting catalog has been cross–identified with the Green Bank 1.4 GHz catalog. Histograms of distributions of spectral indices and flux densities are presented. Spectra of some unusual radio sources are shown. Some statistical and physical selection criteria are considered.

Key words: radio sources – infrared objects – database

1. Introduction

Exploration of cosmic objects in different frequency ranges is the only way of understanding their physical nature. To find additional data, astronomers usually use the large astrophysical catalogs containing results of different kinds of observations. The most interesting things can be found in cross–identifying objects from different catalogs. The database CATS, including more than thirty main astrophysical catalogs, has been organized and relevant software has been worked out (Verkhodanov and Trushkin, 1995a, 1995b). Thus some new functions of this database could be used in search and selection of objects. We have used two catalogs, the IRAS–Point Source catalog (Beichman et al., 1988; IRAS, 1985) and the Texas preliminary 365 MHz catalog (Douglas et al., 1980; Douglas, 1987), as the largest ones in our database, to carry out cross–identification and to form an initial source identification list for subsequent investigation.

The Infrared Astronomical Satellite (IRAS) Point Sources catalog (PSC) contains data of all sky survey in four wavelength bands centered at 12, 25, 60 and 100 micron, including point source identifications with 31 catalogs of stars, galaxies, quasars, IR and radio sources. The data on 246,000 sources have been presented in this catalog.

The Texas survey of discrete radio sources north of declination -35° and stronger than 0.25 Jy at 365 MHz was carried out with the UTRAO interferometer in 1975–1980. The preliminary version of the catalog contains accurate positions, flux densities and structure models for each of approximately 65,000 sources.

A sample of objects from the IRAS Faint Sources Catalog has been partly mapped and studied by Condon and Broderick (1991). Below we use their infrared criteria of selection of galaxies.

One of the aims of the work is an attempt to detect sources with unusual spectra or ratio of infrared and radio fluxes. In the future we propose to study them with the RATAN–600 radio telescope. Part of these sources in the Galactic plane could be identified with sources from the new Galactic survey, carried out by Trushkin (1994, 1995).

We used different criteria for analysis of the Galactic plane sources.

2. Cross–identification

The main problems in identification and classification of IRAS point sources have been described by Preite–Marinez (1993). For each source from IRAS catalog the CATS database (Verkhodanov and Trushkin, 1995a, 1995b) searched for coordinates association within a radius of 120 arcsec. The resulting list we have identified through the Green Bank 1.4 GHz (GB1.4) catalog (White and Becker, 1992) to estimate spectral indices distribution.

But we have excluded 40 duplications of the Texas sources, occuring in the preliminary version of the Texas catalog because of merging nine declination strips of the survey into a joined table.

The procedure of cross–identification consisted in matching the IRAS sources to the Texas sources by seaching for their coincident positions. The position uncertainties of each object have not been taken into account because they vary from 40 to 80″ for the

IRAS coordinates. The Texas sources have a high coordinate accuracy, about 1″, but position shifts of interferometric sidelobes up to 52″ are possible in these measurements (Douglas et al., 1980). Here it is more preferable to retain any small portion of false identifications than the lost true ones. Thus we have concluded that the search radius of 120″ is acceptable for initial statistical consideration. The simple estimate of occasional coordinate coincidence probability (P) within the circle radius of 120″ for 133000 IRAS sources in the region $|b| > 10°$ is equal to 0.012, while for the rest 113000 IRAS sources in the region $|b| < 10°$ $P = 0.063$. However for identification of extended sources of the Galactic plane we have to take the radius of search larger than 1–2′. Probably a small portion of cross–identifications is occasional.

As a result we have obtained a list of 1208 sources (IRAS–Texas association or ITA catalog) after the cross–identification of the IRAS and Texas catalogs. One Texas source is associated with two different IRAS sources in the extended (6′×8′) Crab nebula. 697 of these 1208 IRAS–sources have been identified for the first time with objects from any other catalog.

In the 511 ITA sources, already identified with different sources in the initial IRAS catalog, galaxies and Milky Way radio sources dominated. There are 596 and 458 sources in the region of the Galactic plane ($|b| < 10°$and $|b| < 5.5°$, respectively).

Figure 1 displays a histogram of the number of sources vs coordinate difference radius. The occasional associations would result in a steeper increase in the numbers of sources vs radius, therefore the portion of occasional associations seems to be small.

The distributions of the number vs flux density of the ITA sources and the number vs flux density at 60 μm (excluding the upper limits value) of ITA sources is shown in Figure 2 and Figure 3.

These distributions show that most ITA sources have radio flux densities less than 5 Jy, while IR fluxes vary from tens of Jy to several thousand Jy. It has been found that the strong IR sources in the Galactic plane with the flux ratio $R = S_{IRAS}/S_{radio} > 500$, where S_{IRAS} is the flux at $60 - 100\mu m$ and S_{radio} is the flux at centimeter or decimeter wavelengths, are associated with the galactic HII regions, while non–thermal galactic sources, known as supernova remnants, have $R < 100$. (Broadbent et al., 1989).

The ITA catalog has 45 sources with $R > 500$. All of them have been identified with HII regions, which confirms the previous conclusion. For the ITA sources with $S_{60} > 100$ Jy we have examined the behaviour of S_{365} vs S_{60} as shown in Figure 4. Considerable correlation coefficient ($\gtrsim 0.6$) is presented only for the IRAS sources with $S_{60} > 500$ Jy. Usually the strong IR radiation is emitted by dust embedded in HII regions and the correlation can be due to the same source of energy. The radio continuum emission and infrared emission are proportional to the recombination rate, and for the electron temperature $T_e = 7000$ K the ratio of emissivities at $60\mu m$ and at 2.7 GHz is $\epsilon(60\mu m/\epsilon(2.7GHz) = 190f$, where f is the infrared excess, the ratio of the total IR luminosity to L_α luminosity has been found to be equal to 3–4 for typical HII regions (Broadbent et al., 1989). For optically thin HII region this ratio is almost the same, but for optically thick HII regions this ratio is still higher at 365 MHz. Using the database of astronomical catalogs it is interesting to estimate the spectral indices distribution. After the cross–identification of the ITA catalog with the 1.4 GHz Green Bank catalog, which includes spectral indices for three frequencies, we have obtained distributions of a number of sources vs two spectral indices α ($S \propto \nu^\alpha$) for the 260 identified sources (Fig.5 and Fig.6).

As we can see, both histograms show a wide peak

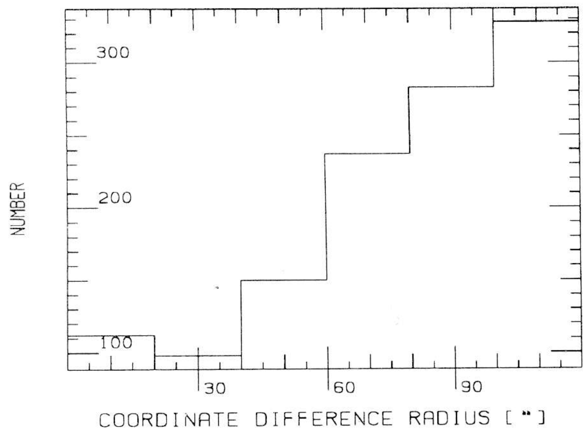

Figure 1: *Distribution of the number of sources vs IRAS–Texas coordinate difference radius*

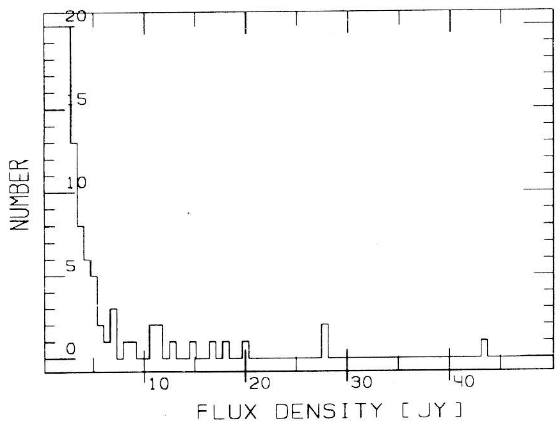

Figure 2: *Distribution of the number of sources vs flux density for Texas catalog. The maximum value 634 has been cut to 20 to change the scale.*

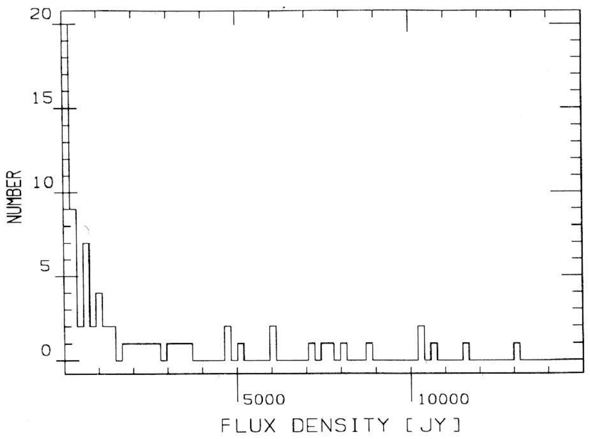

Figure 3: *Distribution of the number of sources vs flux density at 60 μm ITA catalog. The maximum value 404 has been cut to 20 to change a scale.*

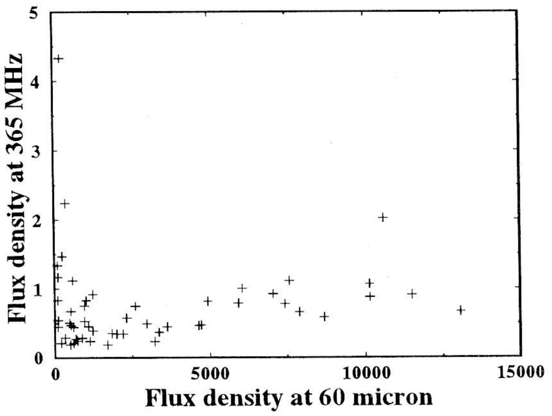

Figure 4: *Radio flux at 365 MHz vs IR flux at 60 μm for ITA sources*

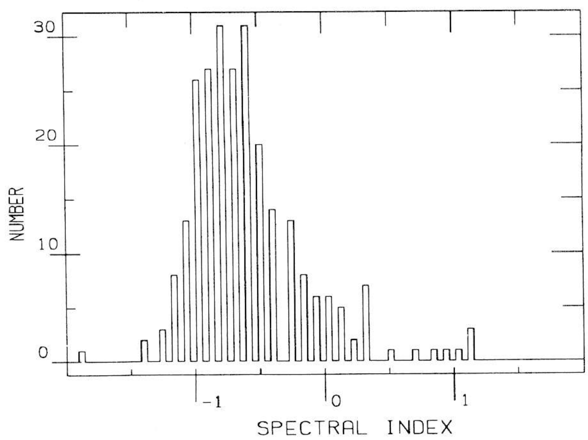

Figure 5: *Distribution of spectral indices for ITA sources at 365–1400 MHz*

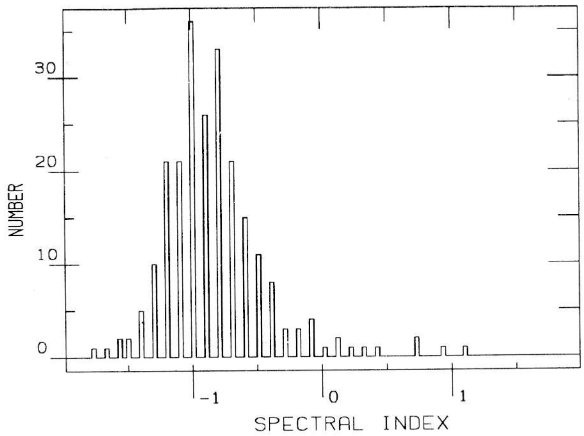

Figure 6: *Distribution of spectral indices for ITA sources at 1.4 GHz — 4.85 GHz*

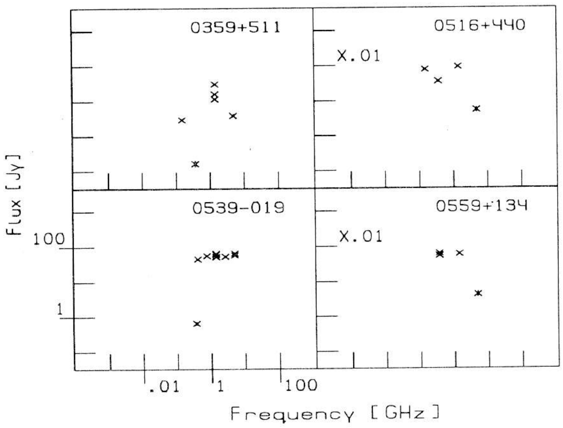

Figure 7: *Radio spectra of the unusual ITA sources*

at the spectral index $\alpha = -0.9$. Extragalactic sources, being rather normal spiral galaxies, seem to prevail in this histogram. (Table 2 from Condon, Broderick, 1991). The typical ratio of the fluxes at $60 \mu m$ and 365 MHz for these sources is equal to 50, comparing with the mean ratio being equal to 562 for the fluxes at 4850 MHz, provided that the mean spectral index is taken to be -0.9.

Another interesting thing is the existence of sources in the tails of distribution. As we can see, these sources have "peculiar" spectral indices and radio spectra. Some of these unusual radio spectra are shown in Figure 7. The source 0539–019 is an extended thermal complex W13 (NGC2024), which has been resolved with the UTRAO interferometer.

To estimate a relative portion the galactic and extragalactic sources we have calculated distributions of the number of sources versus the galactic longitude (Fig.8) and the galactic latitude (Fig.9). ITA sources are clearly seen to be concentrated towards lower latitudes and at the range of longitudes $350° < l < 50°$. The asymmetry is due to the low declination limits of

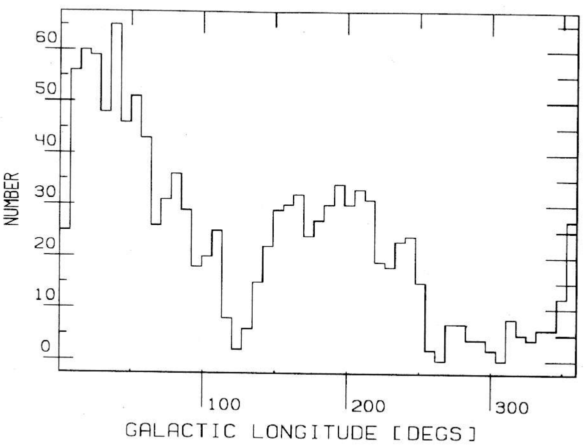

Figure 8: *Distribution of number of sources vs galactic longitude*

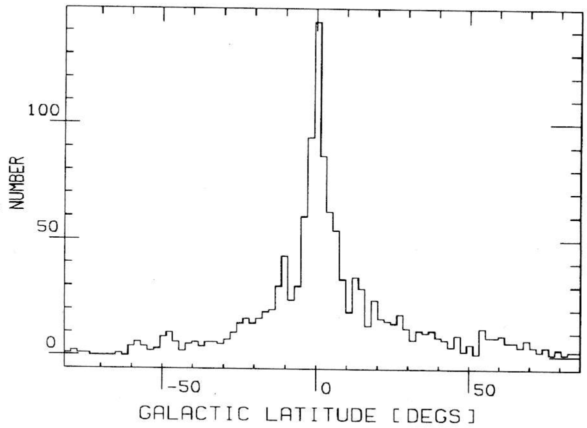

Figure 9: *Distribution of number of sources vs galactic latitude*

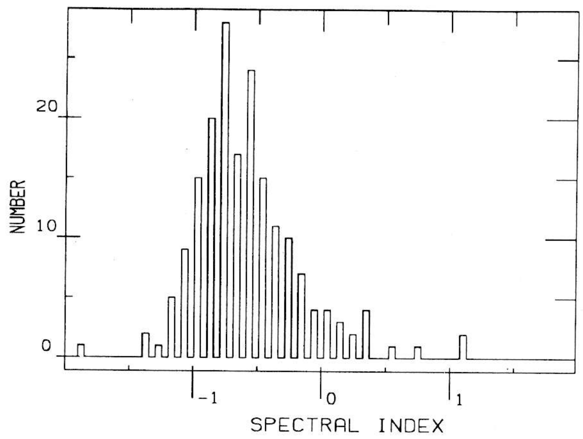

Figure 10: *Distribution of number of sources vs spectral index (365–1400MHz) for sources with* $|b| > 10^o$

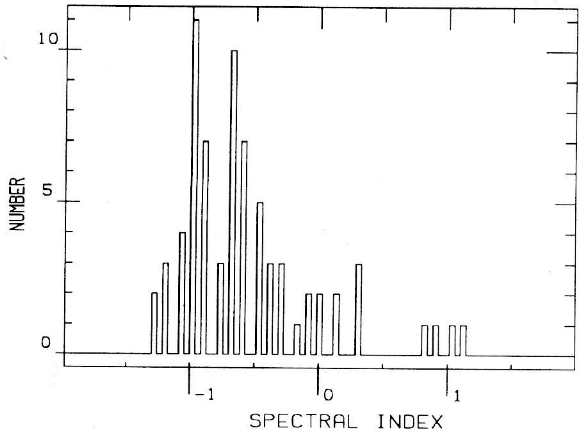

Figure 11: *Distribution of number of sources vs spectral index (365–1400MHz) for sources with* $|b| \leq 10^o$

the Texas survey. The secondary maximum is in the anticenter galactic region $l = 180°$.

Using the 1.4 GHz Green Bank data we have constructed distributions of spectral indices for sources with low and high galactic latitudes (Fig.10, 11). The portion of steep spectrum sources ($\alpha < -0.8$) in the second figure is smaller than in the first one, while the relative number of flat spectrum sources ($\alpha > -0.5$) has increased for the sample of the galactic plane sources. Obviously the thermal galactic radio sources have changed statistics in the low galactic latitude region. Some sources with inverse spectra seem to be optically thick HII regions.

The identification of the ITA and GB1.4 catalogs, where extended sources are noted, show that at least 22 sources at 1.4 GHz are extended. Only 18 sources with the flux ratio $R > 500$ have been identified with GB sources. The mean spectral index for them is equal to 0. There are 14 Markarian galaxies and 87 Zwicky galaxies among the identified ITA catalog sources. 42 objects have been found in the Veron–Veron catalog of active nuclei galaxies and QSOs.

For the identification of infrared sources with galaxies we have used the following criteria: $[\alpha(25\mu m, 60\mu m) \gtrsim +1.5]$ and $|b| > 10$ (Condon and Broderick, 1991). 138 of ITA sources satisfy these criteria. This sample has $R < 200$ and the mean value of fluxes are equal to: $S_{365} = 0.6 \pm 0.6, S_{60} = 31$ Jy. 91 ITA sources have already been identified with galaxies in the IRAS point source catalog.

Remarkable criteria of search for HII regions and planetary nebula (PN) have been proposed by Hughes and McLeod (1989) for IRAS PSC. There are 55 HII regions and only 9 PNs in the ITA catalog. It is interesting that the whole PSC has 2300 HII regions and 995 PN. Thus the latter are the fainter radio emitters at 365 MHz than the HII regions, possibly because the PNs are more compact than the HII regions while the thermal absorption is frequent for the former at the decimeter wavelengths.

The 97 ITA sources fall in the region $|l| < 17°$ and $|b| < 5.5°$ of the Galactic survey by Trushkin

(1994, 1995). All the 63 ITA sources with $S_{365} > 0.4$ Jy have been found at 3900 MHz. Normally these sources are compact with sizes $< 2'$, but 15 sources seem to be associated with extended ones. Ten bright PSC sources with $R > 500$ are bright radio sources at 3900 MHz, which have at this frequency a flux density much higher than at 365 MHz. Thus, they seem to be optically thick HII regions.

One probable source (TP1955+419) has been observed with the RATAN-600 but no signal has been registered. Analyzing the Texas data we have found that TP1955+419 is an artifact or a sidelobe of a very strong source, probably Cygnus A, in the Texas catalog.

3. Conclusion

The potentialities of the database of the astronomical catalogs have made it possible to work out a technique of cross–identification of different kinds of objects, which can be regularly used in sky survey investigation. This is the first paper demonstrating selection with the use of large Texas and IRAS–PS catalogs as one of the CATS database potentialities. The next steps of data base processing will include the estimations of probability on the base of boxes of errors for positional association.

But the most important element in search for a counterpart is to assess the identity of the physical nature of cosmic sources of different range radiation. Now it is possible to say about nature of many Texas catalog sources. Large portions of them are spiral or normal galaxies. Cross-identification of radio sources (as tracers of active energy release processes) with other cosmic objects, especially in complex Galactic regions, is a powerful method of investigation. However radio catalogs at the higher frequencies than those of the Texas catalog, which are more sensitive to extended objects radiation, are needed for cross-identification with the IRAS catalog.

Acknowledgements. Trushkin S.A. thanks the Russian Foundation of Fundamental Research for supporting this work by a grant 93–02–17086. Verkhodanov O.V. is grateful to the American Astronomical Society for financial support of this work. The authors express their thanks to S.A. Pustil'nik for the extremely valuable remarks in the course of detailed and critical review of the manuscript.

References

Beichman C.A., Neugebauer G., Habing H.J., Clegg P.E., Chester T.J.: 1988, NASA RP-1190, Infrared Astronomical Satellite (IRAS), Catalogs and Atlases, **1**, Explanatory Supplement.

Broadbent A., Haslam C.G.T., Osborne J.L.: 1989, Mon. Not. R. Astron. Soc., **237**, 381.

Condon J.J., Broderick J.J.: 1991, Astron. J., **102**, 1663.

Douglas J.N., Bash F.N., Torrence G.W., Wolf C.: 1980, Publications in Astronomy, The University of Texas, **17**.

Douglas J.N.: 1987, in: The Texas 365 MHz survey covering $-35^o \leq \delta \leq +60^o$, preliminary Ooty version (courtesy to T. Velusamy, Gopal-Krishna and H. Andernach).

Hughes V.A., McLeod G.C.: 1989, Astron. J., **97**, 786.

IRAS: 1985, IRAS point sources catalog, Joint IRAS Science Working Group.

Preite–Martinez A.: 1993, Bulletin d'Information du Centre de Donnees Astronomiques de Strasbourg, **42**, 61.

Trushkin S.A.: 1994, Prepr. SAO RAS, No. 107.

Trushkin S.A.: 1995, Astron. Asrtophys. Trans. (in press).

Verkhodanov O.V., Trushkin S.A.: 1995a, Prepr. SAO RAS, No. 106, 66.

Verkhodanov O.V., Trushkin S.A.: 1995b, in: XXVI radio astronomical Conference, Abstracts, S.-Petersburg, 252.

White R.L., Becker R.H.: 1992, Astrophys. J. Suppl. Ser., **79**, 331.