Bull. Astr. Soc. India (1989) **17**, 27–34

Unidentified sources in the FIRSSE catalogue

Parag Seal *Indian Institute of Astrophysics, Bangalore 560 034*

K. Shivanandan

Hulburt Centre for Space Research, Navel Research Laboratory, Washington, DC 20375, USA

Received 1988 June 9; accepted 1989 February 5

Abstract. Thirty four sources are identified from 159 unidentified FIRSSE sources by matching the positions of the sources in different catalogues. Eigthy three sources are examined optically on the POSS-E prints. We also discuss the characteristics of 27 sources which are detected at least at three FIR wavelengths. The types of the objects are given

Key words : FIRSSE sources—IRAS sources—identification

1. Introduction

The far-infrared sky survey experiment (FIRSSE) was a rocket-borne experiment where superfluid helium was successfully used for the first time. The flight took place in 1982 January and covered 21% of the sky. The scan covered about 100° of galatic longitude along the anticentre region of the place as well as a large area of Gould belt. A total of 295 sources observed in the far-infrared region (20 μm, 27 μm, 40 μm and 93 μm) are catalogued by Price, Murdock & Shivanandan (1983 ≡ PMS). Among those 295 sources, association is given only for 136 sources and a list of 40 confirmed brighter sources is given by Price *et al.* 1983. Most of the sources are either associated with optical H II region or luminous stars embedded in dust clouds.

In the present work, out of the remaining 159 unidentified sources 117 sources are studied, using the master list of nonstellar optical astronomical objects (MLNSAO) (Dixon & Sonneborn 1980), catalogue of infrared observations (CIO) (Gezari Schmitz & Mead 1984), IRAS catalogues and atlases explanatory supplement (Beichman *et al.* 1985) and Palomer observatory sky survey red (POSS-E) prints. The remaining 42 sources detected by FIRSSE at less than three wavelengths and not observed by IRAS are not discussed here. The energy spectra and colours of 27 of these sources have also been studied for which fluxes at least at three FIR wavelengths are given.

2. Identification of sources

The positions of 117 unidentified sources are matched with the positions of the sources given in MLNSAO, CIO and IRAS PSC; and 34 of these sources are identified considering positional uncertainty of 1.5 arc min. The positions of 66 sources are matched with the positions given in IRAS PSC (Beichman *et al.* 1985) but the associations for these sources are not yet known. These 66 sources and also 17 sources, observed by FIRSSE at more than two wavelengths are optically studied using POSS-E prints. In a few cases no object is found exactly at the same position quoted by FIRSSE but objects are present in the error circle on the POSS-E prints. In a few cases the difference in positions found in FIRSSE and IRAS PSC is also more than 2 arcmin. One reason may be that some of the sources are extended, and the co-ordinates given in the catalogue the (PMS) may not be very accurate.

3. Results

Table 1 lists the beam sizes in FIRSSE and IRAS. 34 FIRSSE sources are listed in table 2, with their respective FIRSSE numbers and position (as given in the FIRSSE catalogue and IRAS PSC) and with identifications. The fluxes observed by FIRSSE and IRAS PSC are given in column 6 to 13 of table 2. An estimated dust temperature derived from

$$F = C_1 \pi^{-5} \, (e^{C_2/\lambda T} - 1)$$

(Allen 1973) is also given. For those 34 sources, already catalogued, the optical magnitudes, positions and type of objects are listed in table 3 from those catalogues. A list of 83 unidentified FIRSSE sources can be obtained from the authors.

Most of the sources observed in FIRSSE are also observed by IRAS. But some sources observed in FIRSSE in the region between 08 hrs and 23 hrs with declination —28° to +81° were not covered by IRAS. From the fluxes quoted in the tables it is clear that the fluxes observed in FIRSSE and IRAS for the same source are different. The difference is due to the difference in beam sizes used in these surveys.

Table 1. Beam sizes

FIRSSE			IRAS		
Wavelength interval μm	Effective wavelength μm	Beam size (arcmin × arcmin)	Wavelength interval μm	Effective wave-length, μm	Beam size (arcmin × arcmin)
16.7–23.4	20.3	2.5 × 10	8.5–15	12	0.75 × 4.5
23.6–30.3	27.3	2.5 × 10	19–30	25	0.75 × 4.6
34–50	40.0	4.0 × 12	40–80	60	1.5 × 4.7
65–117	93.7	5.3 × 12	83–120	100	3.0 × 5.0

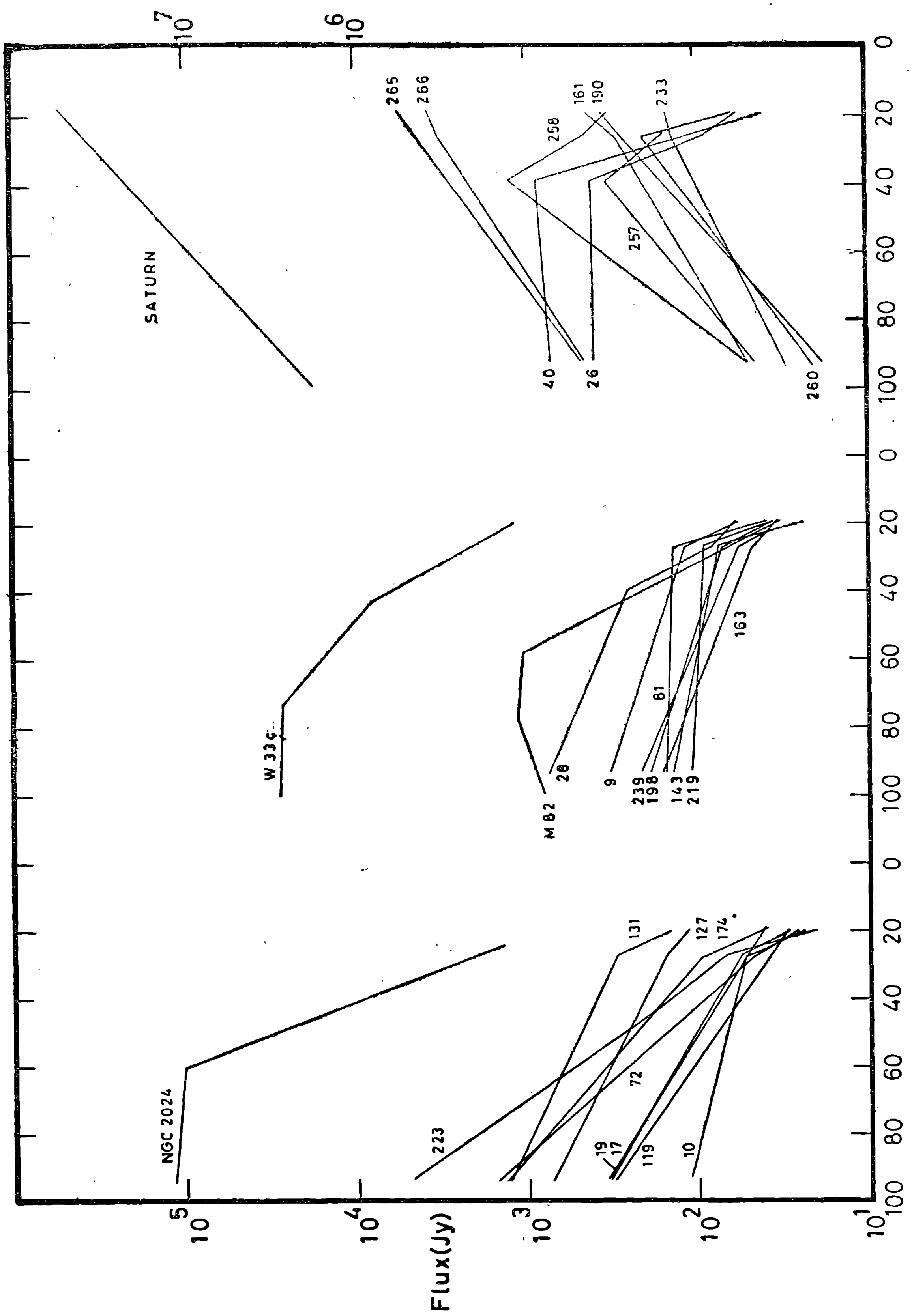

Figure 1. Far-infared spectra of unidentified sources and NGC 2024, W 33c, M 82, and Saturn.

Table 2. Identified FIRSSE sources

FIRSSE No.	FIRSSE RA(1950) h m s	FIRSSE Dec (1950) deg min	IRAS RA(1950) h m s	IRAS Dec (1950) deg min	FIRSSE FLUX (Jy) 20μ	27μ	40μ	93μ
1	2	3	4	5	6	7	8	9
14	02 04 24	+60 31.2	02 04 29.1	+60 31 43	66	138		346
15	02 13 05	+55 08.5	02 13 03.3	+55 09 12	19			49
30	02 46 02	+61 46.5	02 46 10.6	+61 47 23	76	127		342
37	03 03 37	+58 19.1	03 03 33.2	+58 19 21	299	388	612	1609
39	03 06 36	+56 38.9	03 06 26.9	+56 38 56	30	67	526	804
45	03 41 52	+23 58.4	03 41 52.8	+23 57 20	27			66
53	03 52 19	+53 43.5	03 52 23.4	+53 43 29	24			203
60	04 32 31	+51 06.7	04 32 28.7	+51 06 39	57	151	217	1474
77	05 27 26	+33 45.9	05 27 27.6	+33 45 37	39	127		390
94	05 35 11	+35 50.1	05 35 06.4	+35 49 34	24	58	307	313
95	05 35 33	+30 40.4	05 35 24.7	+30 41 11		76		354
100	05 37 41	+35 40.8	05 37 32.1	+35 40 45		393	2888	298
106	05 39 14	−01 56.6	05 39 18.1	−01 56 42	7148	14453	17000	5361
118	05 55 17	+16 31.2	05 55 20.3	+16 31 46	54	115		398
120	05 57 16	+31 56.4	05 57 18	+31 56 39	45			41
123	06 01 15	+30 29.8	06 01 21.2	+30 30 53	75	65		426
130	06 05 59	+15 41.5	06 06 01.5	+15 42 41	34			306
133	06 07 14	+21 41.8	06 06 55	+21 42 53				108
148	06 10 19	+15 23.0	06 10 23	+15 23 28	39	93		297
158	06 15 40	+23 20.7	06 15 39.4	+23 21 19	7	134		488
166	06 28 20	−09 35.3	06 28 13.8	−09 35 34	32			820
177	06 33 52	+10 50.3	06 33 56	+10 49 03	22	49		580
186	06 41 19	−01 04.8	06 41 12.5	−01 05 02	96	174		856
191	06 56 16	+03 39.1	06 56 20.3	+03 40 15	32			23
200	07 09 09	−19 44.9	07 09 05.9	−19 46 01	49	67		86
212	07 29 40	−19 14.8	07 29 35.5	−19 15 22	28	58		518
214	07 31 14	−22 03.5	07 31 11.5	−22 04 25	34	83		94
221	07 39 57	−14 36.9	07 39 59.2	−14 35 42	343	666		433
232	08 00 42	−34 23.3	08 00 39.0	−34 21 52	33			99
236	08 14 07	−35 58.4	08 14 05.7	−35 59 03				121
237	08 14 51	−35 17.8	08 14 57.4	−35 19 54				142
238	08 15 00	−35 27.1	08 14 58.2	−35 23 42				443
240	08 17 04	−21 35.1	08 17 06.9	−21 34 47	172	151		47
298	12 04 21	+17 08.8	12 04 52.6	+37 09 56				370

Some of the FIRSSE sources detected at 93 μm were not observed at all four wavelengths. 135 out of these sources emit maximum flux at 93 μm. The FIRSSE far-infrared sources may be associated with radio sources or H II regions with high radio flux. At 100 μm, the infrared sky is characterized by infrared cirrus due to emission from interstellar dust (Beichman *et al.* 1985). So there is a possibility that the fluxes at long wavelengths might be affected by cirrus contamination. Therefore sources detected by FIRSSE only at 93 μm are not considered here.

The characteristics of the 27 unidentified sources are also discussed which were observed at least at three FIR wavelengths. The energy distribution of these sources are plotted in figure 1 along with the energy distribution of active galaxy M 82 (Telesco & Harper 1982), H II regions NGC 2024 (Lemke & Low 1972) and W33c (Stier *et al.* 1984), and planet Saturn (Ward 1977). The colours of these sources

IRAS FLUXES (Jy)				Identification	Temperature (K)	Catalogue*
12μ	25μ	40μ	100μ			
10	11	12	13	14	15	16
12.07	105.78	387.56	463.22	ACK 132.00.1	83	MLNSAO
2.58	3.22	32 88	95.01	LBN 653		MLNSAO
10.22	83.66	291.10	370.89:	RAFGL 5085	92	PSC
31.04	395.82	1055.06	1297.50	RAFGL 437	72	CIO
7.46	23.09	340.32	689.85	RAFGL 5090	62	PSC
3.28	9.63	42.41:	68.87:	76131		PSC
6.15	30.84	86.75	148.84:	RAFGL 5107		PSC
12.51	131.56	649.21	642.38	RAFGL 5124	53	PSC
6.89	69.36	449.28	905.25	RAFGL 5142	69	PSC
1.18	11.52	184.25	412.87	SS 43	63	MLNSAO
1.18L	1.00L	40.25	503.52L	SS 44	49	MLNSAO
28.25	226.44	1707.93:	1635.33	MRSL 173 + 02/3	105	PSC
283.39	4746.24	7890.93:	35335.42S	IC 0434	75	MLNSAO
1.26L	63.09	420.61	525.15	RAFGL 5173	82	PSC
7.95	47.91	79.84	107.56	RAFGL 5174		PSC
6.22	22.90	345.82	648.48	CED 061	137	PSC
.75L	5.04	16.64	19.94L	MRSL 194–01/1		PSC
7.74	13.94	20.12	82.44L	ASS 51		PSC
4.67	38.28	207.59:	440.75:	RAFGL 5186	79	PSC
4.54	6.51L	5.37L	1087.09L	BFS 51	96	PSC
2.85	3.03	68.06	365.22L	LBN 1015		MLNSAO
.40L	.81	1.84L	380.69L	SG 3.082	105	MLNSAO
13.97	159.11	611.96	530.78	MIN 4706	89	MLNSAO
1.39	.31L	.40L	1.94L	114722		PSC
12.95	63.50	31.38	7.65	PK 232–04.1	103	MLNSAO
2.95	7.49	129.47	328.74	YM 36	83	MLNSAO
4.44	55.41	217.77	276.00L	RAFGL 5235	78	PSC
19.02	226.27	548.25	292.09	PK 231 + 04.2	86	MLNSAO
2.88	3.95	63.18	200.84L	369–*N	130	PSC
7.38	34.25	205.47	361.79	VHE 09A or VHE 09B		MLNSAO
.54	1.02:	1.61	11.67L	G 253.587		PSC
2.51	2.06:	52.36L	284.54:	G 253.587		PSC
119.57	139.16	38.53	10.36	RAFGL 5250	136	PSC
.62L	.27L	.65	1.25L	407109		PSC

log (F_{100}/F_{60}) versus log (F_{63}/F_{27}) are shown in figure 2, along with the colours of some known sources. F_{100}, F_{60} and F_{27} are the fluxes in Jansky at these respective wavelengths. The fluxes F_{100} and F_{60} are determined from the extrapolated energy distribution curve. The plot shows some interesting features and helps to classify the sources. It is shown very distinctly that there are different types of sources.

Studying the flux distribution and colours of the sources it, we find that the FIRSSE sources No. 9, 17, 19, 72, 119, 127, 131, 174, 223 have very steep increase in flux density after 27 μm. The compact H II regions NGC 2024 (Lemke & Low 1972) also has the similar energy distribution and colours. F 72 and F 223 have colours nearly of the same order of NGC 2024 but the fluxes emitted are much less. One reason may be that the dust coulds or H II regions surrounding the sources are cooler than NGC 2024 or less compact so the radio flux may not be high. The colours of F 119 are nearly the same as those of the Seyfert galaxy NGC

Table 3. Optical positions and magnitudes of identified FIRSSE sources

FIRSSE No.	Name	FIRSSE RA (1950) h m s	FIRSSE Dec (1950) deg min	MLNSAO catalogue RA (1950) h m s	MLNSAO catalogue Dec (1950) deg min	V mag	Type of object
14	Ack 132.00.1	02 04 24	+60 31.2	02 04 30	+60 31	—	Planetary nebula
15	LBN 653	02 13 05	+55 08.5	02 13 00	+55 10	—	Bright nebula
30	RAFGL 5086	02 46 02	+61 46.5	—	—	—	—
37	RAFGL 437	03 03 37	+58 19.1	03 03 37	+58 19 06	—	Cluster of young stars in nebulosity
39	RAFGL 5090	03 06 36	+56 38.9	—	—	—	—
45	76131	03 41 52	+23 58.4	—	—	—	—
53	RAFGL 5107	03 52 19	+53 43.5	—	—	—	—
60	RAFGL 5124	04 32 31	+57 06.7	—	—	—	—
77	RAFGL 5142	05 27 26	+33 45.9	—	—	—	—
94	SS 43	05 35 11	+35 50.1	05 35 10	+35 49	—	Diffuse galactic nebula
95	SS 44	05 35 33	+30 40.4	05 35 25	+30 39	—	Diffuse galactic nebula
100	MRSL 173102/3	05 37 41	+35 40.8	05 37 30	+35 40	—	H II region
106	IC 0434	05 39 14	−01 56.6	05 39 00	−01 54	—	H II region
118	RAFGL 5173	05 55 17	+16 31.2	—	—	—	—
120	RAFGL 5174	05 57 16	+31 56.4	—	—	—	—
123	CED 061	06 01 15	+30 29.8	06 01 19	+30 30	—	Diffuse galactic nebula
130	MRSL 194-01/1	06 05 59	+15 41.5	06 06 06	+15 49	—	H II region
133	ASS 51	06 07 14	+21 41.8	—	—	—	—
148	RAFGL 5186	06 10 19	+15 23.0	—	—	—	—
158	BFS 57	06 15 40	+23 20.7	—	—	—	—
166	LBN 1015	06 28 20	−09 35.3	06 28 00	−09 36	—	Bright nebula
177	SG 3082	06 33 52	+10 50.3	06 33 46	+10 48	—	Diffuse emission nebula
186	MIN 4706	06 41 19	−01 04.8	C6 41 14	−01 05	—	Diffuse nebula
191	114722	06 56 16	+03 39.1	—	—	—	—
200	PK 232-04.1	07 09 09	−19 44.9	07 09 06	−19 46	13.56	Planetary nebula
212	YM 36	07 29 40	−19 14.8	07 29 49	−19 18	—	Symmetric galactic nebula
214	RAFGL 5235	07 31 14	−22 03.5	—	—	—	—
221	PK 231 + 04.2	07 39 57	−14 36.9	07 39 33	−14 37	16.0	Planetary nebula
232	369-*N	08 00 42	−34 23.3	08 14 00	−35 59	—	Reflection nebula
236	VHE 09A or VHE 09B	08 14 07	−35 58.4	08 14 06	−36 00	—	—
237	G 253.587	08 14 51	−35 17.8	—	—	—	—
238	G 253.587	08 15 00	−35 27.1	—	—	—	—
240	RAFGL 5250	08 17 04	−21 35.1	—	—	—	—
268	407109	12 04 21	+17 08.8	—	—	—	—

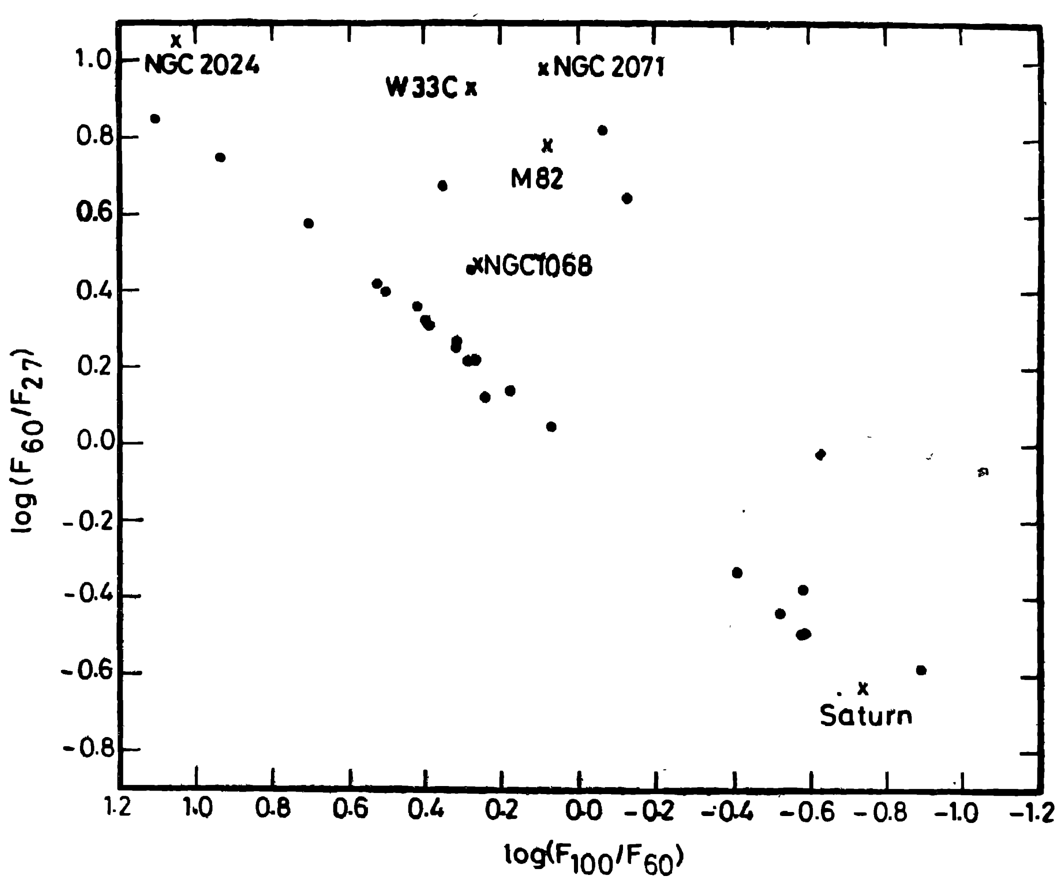

Figure 2. Colour-colour diagram of unidentified FIRSSE sources (●) along with known sources (x).

1068 (Telesco & Harper 1980). The energy distribution and colours of the FIRSSE sources No. 10, 28, 81, 143, 163, 198, 219 and 239 are similar to those of W33c (Stier *et al.* 1984), the compact core sources in H II region. FIRSSE sources No. 26 and 40 have similar energy distribution and colours like the active galaxy M 82 (Telesco & Harper 1980) and molecular cloud NGC 2071 (Harvey *et al.* 1979). The maximum radiation emitted at 40 μm is due to the reradiation from the dust heated by hot central source. For FIRSSE sources No. 161, 190, 233, 260, 265 and 266 the maximum flux is detected at about 20 μm; then there is a sharp decrease. The colours of these sources are nearly of the same order as the planet Saturn (Ward 1977) as shown in figure 2. Sources F 265 and 266 have very high flux (> 3000 Jy) at 20 μm and 27 μm. The FIRSSE sources 257 and 258 have maximum flux at 40 μm but the colours of these sources do not match with any of the known objects.

For a few cases no object is found inside the error circle on the POSS-E prints, such as F 143, 163, 260, 276 and 282. Among these the sources F 143, 163 and 360 were observed both by FIRSSE and IRAS but the region of sources F 276 and 282 was not covered by IRAS. The fluxes emitted by F 143, 163, and 260 are considerable and they are not in the galactic plane. One possibility may be that these objects are surrounded by optically thick, cool circumstellar dust, like

Becklin's object having no optical counterpart. Or an alternative explanation is, that these objects may be very distant objects or too small in size to be detected in the visible region. The sources may be galactic or extragalactic or may be even inside the solar system. Since the distances are not available and the only source of information is the FIRSSE data themselves so it is difficult to come to any conclusion about the sources. More observational work is needed to identify these sources.

4. Conclusion

The sources identified from different catalogues and POSS-E prints may be luminous stars embedded in dust cloud or ionized H II regions associated with radio sources. To study the nature of the sources further observational work is needed in the multi-wavelength regions, specially in IR and radio region.

References

Allen, C. W. (1973) *Astrophysical quantities*, Athlone Press.

Beichman, C. A., Neugebauer, G., Habing, H. J., Clegg, P. E. & Chester, T. J. (1985) *IRAS catalogs and atlases explanatory supplement*, JPL D-1855.

Dixon, R. S. & Sonneborn, G. (1980) *Master list of non-stellar optical astronomical objects*, Ohio State Univ. Press.

Gezari, D. Y., Schmitz, M. & Mead, J. M. (1984) *Catalog of infrared observations*, NASA, RP 1118.

Harvey, P. M., Campbell, M. F., Hoffman, W. F. & Thronson, H. A., Jr. (1979) *Ap. J.* **229**, 990.

Lamke, D. & Low, F. J. (1972) *Ap. J.* **177**, L 53.

Price, S. D., Murdock, T. L. & Shivanandan, K. (1983) AFGL-TR-83-0055.

Price, S. D., Shivanandan, K., Murdock, T. L. & Bowers, P. F. (1983) *Ap. J.* **275**, 125.

Stier, M. T. *et al.* (1984) *Ap. J.* **283**, 573.

Telesco, C. M. & Harper, D. A. (1980) *Ap. J.* **235**, 392.

Ward, D. B. (1977) *Icarus* **32**, 437.