Properties of the Unusual Galaxy PSC 09104+4109

S.G. Kleinmann[1] and W.C. Keel[2]

ABSTRACT

The IRAS source PSC 09104+4109 is tentatively identified with a faint ($m_R \sim +19$) emission line galaxy having $z = 0.442$. Assuming this identification is correct, the total infrared luminosity of this galaxy is estimated to be 5×10^{12} L_o, among the highest for galaxies detected by IRAS. This energy is concentrated at wavelengths less than 30 μm, and is ~50 times greater than the estimated optical luminosity. The serendipitous way in which this source was found in the PSC catalog suggests that many more similar objects may be found at the lowest levels of the IRAS survey.

1. Introduction

During the startup phase of a redshift survey of sources detected at $\lambda_{obs} \sim 60$ μm in the IRAS survey, we found an object, PSC 09104+4109 (IRAS Point Source Catalog), worthy of further study both for its high luminosity and its unusual infrared spectral energy distribution. Particular interest in this IRAS source was first evoked because it was one of ten 60 μm sources, out of a list of 500 located in a slice of the sky at high galactic latitudes, that was not located near a bright ($m_{pg} < 18$) star or galaxy. Houck *et al.* (1985) showed that many such sources could be identified with distant luminous galaxies.

2. Optical Identification

In search of its optical counterpart, a deep R-band image of the region surrounding PSC09104+4109 was taken at the 2.1-m telescope of the Kitt Peak National Observatory. A cluster of faint ($m_R > 21$) sources was detected on this plate, though none brighter than $m_R \sim 22$ fell within the IRAS error box. Two brighter objects, each having $m_R \sim 19$, were found just outside the error box. One of the these (Object 1) lies near the periphery of the cluster of faint objects, while the other (Object 2) lies near its center.

The PSC position for the infrared source is listed in Table 1; its error box, as given in the Point Source Catalog, has dimensions ±11" x ±24" at P.A. 108°. The positions of the two nearby 19^{th} mag. sources, which were measured on the two-axis Grant measuring engine at NOAO, are also given in the Table; the rms error in the measurements of the system of standard stars on the plates was 0.5". The distances of each of the objects in Table 1 from the center of the IRAS error box are listed in the table in units of the positional uncertainties of the infrared source.

[1]Department of Physics and Astronomy, University of Massachusetts.
[2]Leiden Observatory.

Carol J. Lonsdale Persson (Editor)
Star Formation in Galaxies

Table 1. Positions of Sources Near IRAS PSC 09104+4109

Designation	RA (1950)	DEC (1950)	Offset From Major Axis	Offset From Minor Axis	Total Offset
PSC 09104+4109	09 10 29.8	+41 09 04			
Object 1	09 10 29.13	+41 09 22.0	1.4σ	0.5σ	1.5σ
Object 2	09 10 32.92	+41 08 52.4	$.0\sigma$	1.5σ	1.5σ

Spectra of the two red objects listed in Table 1 were obtained with the Cryogenic Camera at the 4-m telescope at Kitt Peak. These showed that the cluster-center galaxy (Object 2) had an absorption line spectrum at $z \sim 0.3$, while the object near the cluster's edge (Object 1) had a strong emission line spectrum at $z = 0.442$. By analogy with many other 60 μm sources associated with faint optical objects, we have tentatively identified IRAS 09104+4109 with Object 1. In any case, if this infrared source is extragalactic, it probably lies at $z \geq 0.2$, since less distant galaxies should have been detected on the R-band image at a level brighter than $m_R = 22$.

If $H_o = 100$ km/s/Mpc, and $q_o = 1/2$, the the total Blue luminosity is estimated to be 2×10^{10} L_o. About half of this light is due to emission lines of O[III] 5007 and 4959, Hβ and Hγ. Weak emission from He II 4686 is also observed. These lines are all narrow; Hβ has a full width at half maximum of <1000 km/s. This line width and luminosity are typical for Seyfert II galaxies.

3. Infrared Photometry

The "Add-Scan" program at IPAC was used to obtain high signal-to-noise photometry of PSC 09104+4109 in the IRAS bands. Data from 11 scans of the object were co-added, yielding significant detections in IRAS Bands 1, 2, and 3, but a low upper limit in Band 4. Flux densities derived under the assumption that the observations were made in the rest frame of a source having a spectrum $F_\nu \sim \nu^{-1}$ (as in the PSC catalog) are given in Table 2. The upper limit quoted for Band 4 corresponds to 3σ. The low ratio of flux densities, $S(100)/S(60) < 0.7$, is one of the most peculiar features of this source. In contrast, the high-redshift galaxies studied by Houck *et al.* (1985) were all found to have $S(100) \geq 2\ S(60)$. Even higher ratios are typical of normal galaxies detected by IRAS at $\lambda = 60$ μm (deJong *et al.* 1984; Soifer *et al.* 1984).

Also given in Table 2 are the corrected flux densities for a thermal source at $z = 0.442$. In this case, the flux in each band was derived by assuming that the spectrum in adjacent bands is produced by a blackbody having color temperatures 330 °K, 180 °K, and 137 °K at wavelengths 12μm to 25μm, 25μm to 60μm, and 60μm to 100μm, respectively.

Table 2. Infrared Flux Densities for PSC 09104+4109

	S(12μm)	S(25μm)	S(60μm)	S(100μm)
z=0; F=ν^{-1}	0.17±0.03	0.39±0.03	0.55±0.05	<0.39
z=0.442; F=F(BB)	0.25	0.27	0.27	<0.17

The total infrared luminosity of PSC 09104+4109 is estimated to be 5 x 10^{12} L_o, most of it emerging at $\lambda < 30$ μm. This value is nearly 3 times greater than the infrared luminosity produced by Arp 220 or Markarian 231 (for the same cosmological constants).

If the energy per octave at optical wavelengths ($0.36 < \lambda(\mu m) < 1.0$) is constant and equal to that observed in the R band, then the total infrared luminosity of PSC 09104+4109 exceeds its optical luminosity by a factor of nearly 50. This ratio is much larger than values characteristic of quasars.

4. Conclusion

The IRAS source PSC 09104+4109 has an observed infrared energy distribution which is peculiar both for stars and for galaxies, in that it peaks near λ_{obs} = 60 μm. It also exhibits a large ratio of L_{IR}/L_{opt} (~50). It is tentatively identified with an emission line galaxy having m_R ~ +19, and z = 0.442. Confirmation of this identification would show that this source is one of the most luminous objects found in the survey. Further study is required to learn the extent to which the ratio of infrared to optical luminosity can be used to distinguish the most luminous galaxies found by IRAS, and what relationship exists between PSC 09104+4109 and other classes of luminous galaxies.

Only a dozen of the 500 galaxies in the flux-limited sample from which PSC09104+4109 was drawn have been observed spectroscopically. That fact suggests that many more galaxies having such high luminosity and peculiar flux distributions may be found among the faint sources detected in the IRAS survey.

We would like to thank Don Hamilton for providing us with the spectra he obtained at the KPNO 4-m, and Judy Young who obtained the Add-Scan photometry at IPAC. This work was supported by grant # AFOSR 85-0057.

REFERENCES

DeJong, T., Clegg, P. E., Soifer, B. T., Rowan-Robinson, M., Habing, H. J., Houck, J. R., Aumann, H. H., and Raimond, E. 1984, *Ap. J. Letters*, **278**, L67.

Houck, J. R., Schneider, D. P., Danielson, G. E., Beichman, C. A., Lonsdale, C. J., Neugebauer, G., and Soifer, B. T. 1985, *Ap. J. Letters*, **290**, L5.

IRAS Point Source Catalog, 1985, Joint IRAS Science Working Group, (Washington, D.C.: U.S. Government Printing Office).

Soifer, B. T., Rowan-Robinson, M., Houck, J. R., deJong, T., Neugebauer, G., Aumann, H. H., Beichman, C. A., Boggess, N., Clegg, P. A., Emerson, J. P., Gillett, F. C., Habing, H. J., Hauser, M. G., Low, F. J., Miley, G., and Young, E. T. 1984, *Ap. J. Letters*, **278**, L71.