STAR BURST ACTIVITY IN HIGH SURFACE BRIGHTNESS GALAXIES

(Letter to the Editor)

G. T. PETROV

Dept. of Astronomy, Bulgarian Academy of Sciences, Sofia, Bulgaria

(Received 13 May, 1988)

Abstract. High surface brightness galaxies are also galaxies with high star-forming activity. About a half of them omit, on the average, twice as much energy in the IR than in the blue. The rates of star formation are 10–30 times higher than those in normal galaxies. On average 100–300 solar masses gas are converted into stars every year and 10–30 are massive stars.

1. Introduction

Recently Petrov (1986) published a list of 47 new high surface brightness galaxies in the Nilson (1973) system of diameters. The criteria for their choice was as in Arakelian (1975): namely, surface brightness $\overline{B} \geq 22m_p$ angl. s^{-2}, where $\overline{B}$ is defined by

$$\overline{B} = m_p - 0.25 \operatorname{cosec} I\, b^{\mathrm{II}}\, I + 2.5 \log\left(3.14\ \frac{D \times d}{4}\right) + 0.22D/d + 0.73\,.$$

Petrov (1986) showed that with the Nilson's system of diameters this criteria is more stringent – only 24% of all 193 Arakelian galaxies included in the UCGC aare HSBG in the Nilson system. In spite of the galaxies are relatively bright (only two are with $m_p > 14.5$) they are insufficiently studied. For about 20 of them it was taken spectra with dispersion 50 A mm^{-1} on the 2-m telescope of the National Astronomical Observatory in Rozhen, Bulgaria. The results will be published at a later time.

The IRAS data allow as to make a general study of the star burst activity in this type of galaxies.

2. The Results

Out of total 47 HSBG in the *Catalogue of Galaxies and Quasars* detected in the IRAS Sky Survey, 1985 are included 25 (53%) objects. This is comparable with the percentage of the active galactic nuclei with the far-infrared fluxes from the IRAS (58%), and is more significant than those for the Sy 1G, LINERs and Markarian galaxies (ca. 40%) or Akn G (32%). Only this fact is an evidence for the higher star burst activity in this galaxies.

In Table I we present accordingly the number of the object (Petrov, 1986), the magnitude m_p in the Zwicky system, the redshift z, the densities of the IR fluxes at 12,

Astrophysics and Space Science **151** (1989) 169–175.

TABLE I

Far-infrared characteristics of high surface brightness galaxies

No.	m_p	z	S_{12}	S_{25}	S_{60}	S_{100}	$\log S_{12/25}$	$\log S_{60/100}$	$\log L_{\rm FIR}$	$\log L_B$	$\log CI_{\rm FIR}$
602	14.0	0.090	0.54	1.26	2.13	2.43	−0.37	−0.06	45.05	45.19	0.14
604	13.5	0.009	0.25*L*	0.29:	1.84	3.53	−0.06	−0.28	43.28	43.24	−0.04
605	13.7		0.48	0.82	8.00	13.06	−0.23	−0.21			0.65
606	14.1		0.36*L*	0.27*L*	0.69	1.06:	0.12	−0.19			−0.27
607	14.1		0.25	0.25	0.93	2.41	0.0	−0.41			−0.12
608	14.5	0.029	0.26*L*	0.25*L*	0.71	1.39	0.02	−0.29	44.87	44.82	−0.05
609	14.0		0.38*L*	0.25*L*	0.84	1.97	0.18	−0.37			−0.14
610	14.2		0.25*L*	0.26*L*	1.37	3.01	−0.02	−0.34			0.14
611	13.9		0.25*L*	0.25*L*	0.87	2.08	0.0	−0.38			−0.17
615	14.3	0.031	0.25*L*	0.25*L*	1.27	2.51	0.0	−0.30	43.99	44.11	0.12
617	13.4		0.25*L*	0.27:	1.54	2.94	−0.03	−0.28			−0.15
618	14.1	0.011	0.26*L*	0.25*L*	0.89	1.30	−0.02	−0.16	43.19	43.03	−0.16
619	13.2		0.25*L*	0.25*L*	1.74	3.02	0.0	−0.24			−0.20
620	13.3		0.25*L*	0.25*L*	1.45	2.37	0.0	−0.21			−0.26
622	14.2		0.80*L*	0.25*L*	0.55	0.97	0.51	−0.25			−0.30
623	14?		0.77	7.16	8.44	4.30	−0.97	+0.29			0.65
624	14.3	0.035	0.25*L*	0.28	1.86	3.30	−0.05	−0.25	44.10	44.36	0.26
627	14.2		0.26*L*	0.25*L*	0.56	1.09	0.02	−0.29			−0.28
628	13.5		0.31	0.54	4.37	8.28	−0.24	−0.28			0.33
630	14.4	0.050	0.25*L*	0.25	0.40:	5.39*L*	0.0	−1.13	44.38	44.59	0.21
632	14.5		0.25*L*	0.25*L*	1.04	1.72	0.0	−0.22			0.08
639	14.3	0.0615	0.29*L*	0.45:	0.52	1.00*L*	−0.19	−0.28	44.60	44.32	−0.28
641	14.3	0.031	0.49*L*	0.39*L*	2.70	4.00	0.10	−0.17	44.00	44.39	0.39
642/3	14.0		0.25*L*	0.31:	1.44	2.58	−0.09	−0.25			0.03

25, 60, and 100 mkm in Jy, the temperature indices $S_{12/25}$ and $S_{60/100}$, the luminosities in the far-infrared $L_{\rm FIR}$ and in the blue L_B in erg s^{-1} and the infrared excess index $CI_{\rm FIR} = F_{\rm FIR}/F_B$.

According to the calibration of the IRAS data (see *Catalogued Galaxies*, 1985) $F_{\rm FIR} = 1.26 \times 10^{-14}(2.58S_{60} + S_{100})$ W m^{-2} and $L = 4\pi d^2 F$, where d is the distance to the galaxy. The luminosities and the fluxes F in the B-region are determined by Zwicky's magnitudes without the corrections proposed by Sasano (1985). Following Houck *et al.* (1984) $\log F_B = -7.54 - m_p/2.5$ W m^{-2}. With this calibration the fluxed in B are about 5 times higher than those determined by the standard reaction of the B-filter (see Soifer *et al.*, 1987).

It is seen fro the data in Table I that far-infrared luminosities are $L_{\rm FIR} = 10^{43}$–10^{45} erg s^{-1}. It is the same for the luminosities in the blue. A total of 11 (44%) objects emit more energy in the far-infrared than in the blue. For two objects (Nos. 604 and 608) $F_{\rm FIR} \approx F_B$ – i.e., about the half of the HSBG have FIR fluxes comparable or higher than the blue ones.

Figure 1 present the 'two-colour' diagram $\log S_{60/100} - \log S_{12/25}$ for the 25 HSBG with measured IR fluxes. The straight lines restrict the region of the 'normal' galaxies,

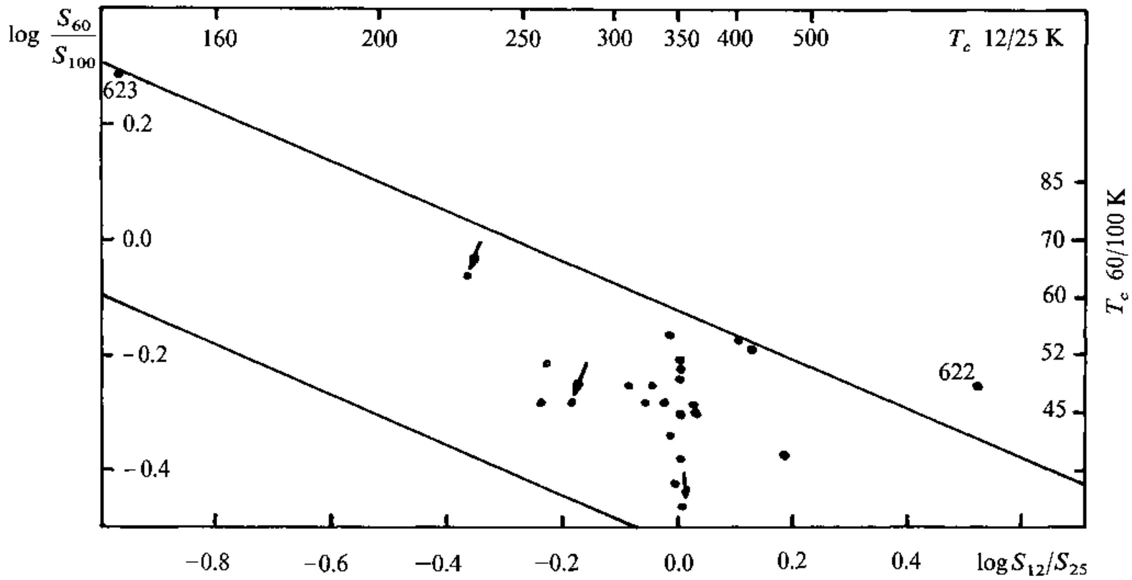

Fig. 1. Plot of log S_{60}/S_{100} vs log S_{12}/S_{25} for the high surface brightness galaxies. The straight lines restrict the region occupied by 'normal' galaxies (Helou, 1986). The Seyfert galaxies are marked with arrows. The vertical arrow indicated that galaxy No. 630 is far below the dot.

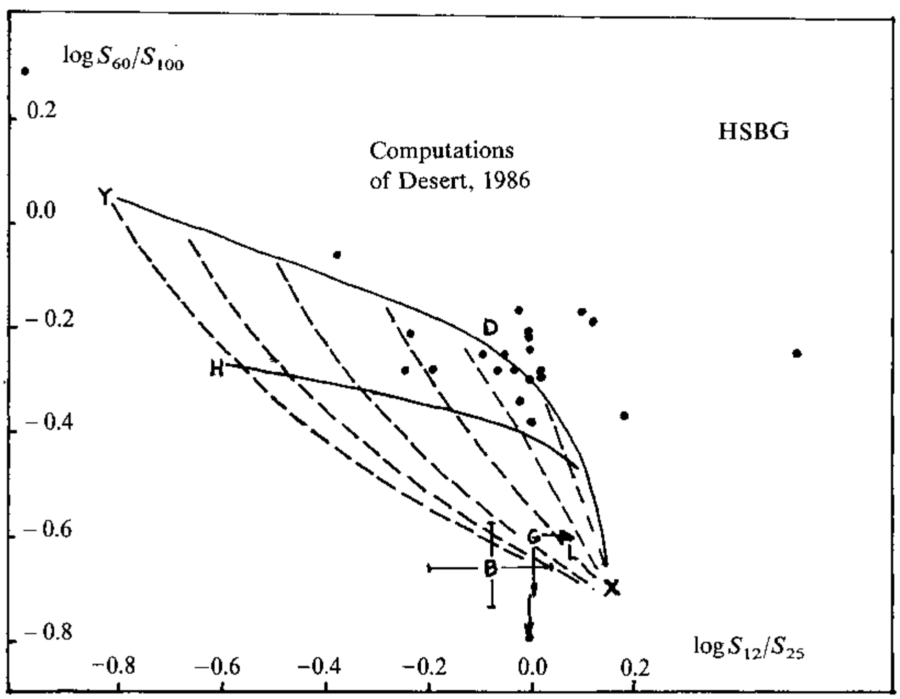

Fig. 1a. A comparison of the observing colour temperature indices with the theoretical computations of Desert (1986). B, L, and G marked the cirus data for the Galaxy. The galaxies above the H-line on the diagram probably due their IR fluxes to the burst of star formation.

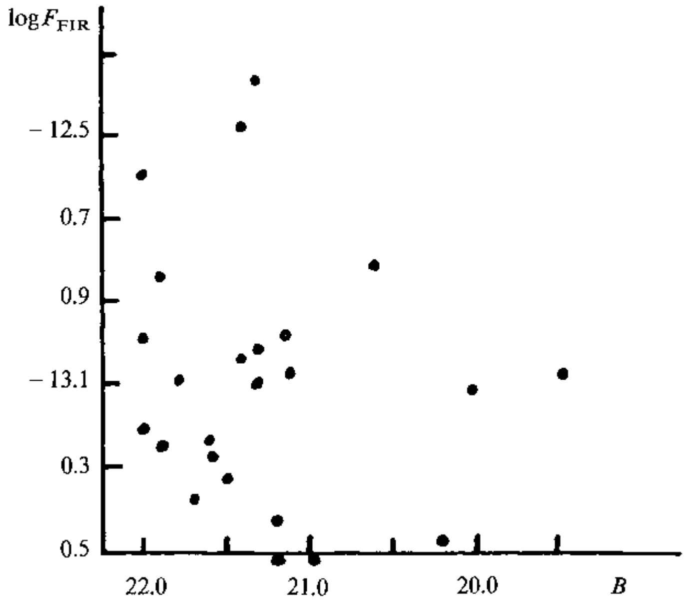

Fig. 2. Plot of logF_{FIR} vs surface brightness $\bar{B}$ for the HSBG.

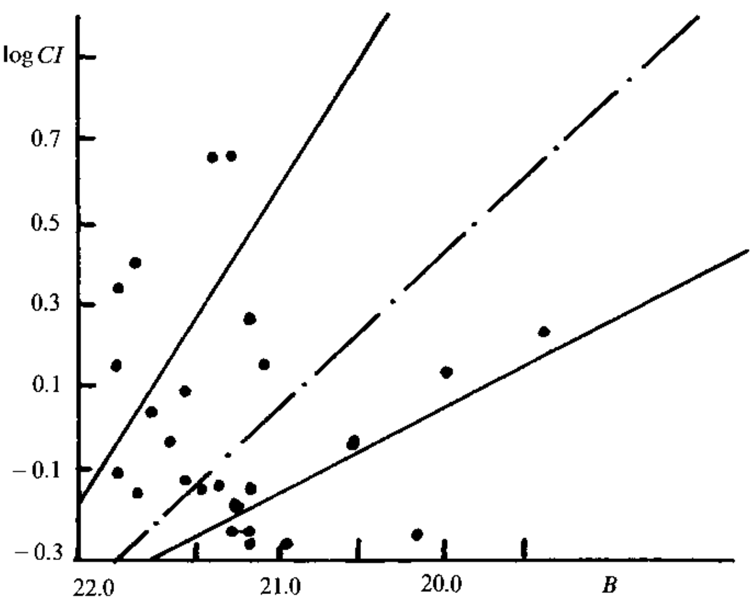

Fig. 3. Plot of logCI_{FIR} vs $\bar{B}$ for the HSBG. The dashed line separate conditionally the galaxies with $L_B < L_{FIR}$ and with $\bar{B} = 21.5 m_p$/angl. s^{-2}. The straight lines arc carry out by the least-square method.

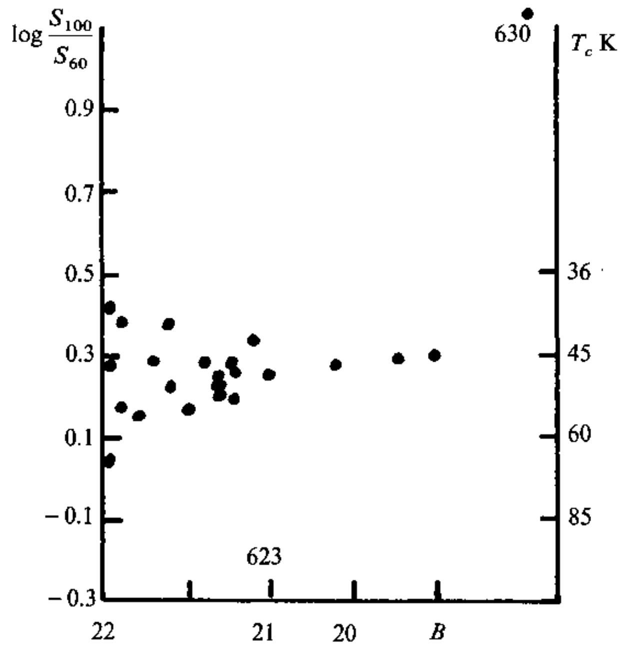

Fig. 4. Plot of $\log S_{100}/S_{60}$ vs $\bar{B}$ for the HSBG. When the surface brightness increase the dust temperature 100/60 asymptotically approach to 45 K.

studied by Helou (1986). The temperatures are as in Soifer *et al.* (1987). As it is seen, two objects are declined from the main group – Nos. 622 and 630.

The galaxy 622 is warmer and because of his place on the diagram where the objects with lower star-forming are placed, possibly there is an additional source of heating of the dust.

The galaxy 630 is a compact Zwicky galaxy (VII Zw 768) and radiogalaxy 3C 371. Its dust temperature 60/100 is only 25–27 K and in the same time it emits 1.5 times more in the IR than in the blue. In the light of the two-component model of de Jong *et al.* (1984) and of the calculations of Desert (1986) it follows that the IR flux is connected with the cold disc component. This is contrary to the fact that, as a group, the compact galaxies included only the warm component and set the upper limits for the $CI_{\rm FIR}$n and the dust temperature (Petrov, 1988). Because of this, probably an alternative explanation is that the IR flux is from a non-thermal nuclear source as in the three-component model of Soifer *et al.* (1987).

The galaxy 623 is characterized with higher rates of star formation in comparison with other galaxies. It is in the upper left corner of the diagram. We know only that it is a peculiar object and, as Petrov (1988) has shown, the peculiar galaxies are, on the average, more active in the IR.

There are two Seyfert galaxies amongst HSBG – No. 602 = I ZW 1 and No. 639 = II Zw 136. They are marked with arrows; and as it is seen, they are not ejected from other galaxies.

Figures 2, 3, and 4 show the relations of the far-infrared fluxes $F_{\rm FIR}$, far-infrared indices $CI_{\rm FIR}$, and colour indices $S_{100/60}$ from the surface brightness $\bar{B}$. It is difficult to say something definite for the first one – may be there is no relation. On Figure 3 the region is conditional separate on the two parts with the dashed line – one mainly contain the objects with $L_B > L_{\rm FIR}$ and higher surface brightness ($\bar{B} \geq 21.5 m_p$/angl. s^{-2}), and secondly the other ones. The first group objects satisfy a common relation $\log CI_{\rm FIR} = 3.74–0.19\bar{B}$ with very high correlation coefficient $r = -0.75$. The second group shows a weak relation with $r = -0.39$.

The temperature index $S_{100/60}$ – if we exclude the two galaxies mentioned above – asymptotically approaches 45 K dust temperature as the surface brightness is increasing. Probably this is the characteristic dust temperature for this class of objects.

A comparison of the IRAS data with the theoretical conclusions of Desert (1986) it is seen that the IR fluxes in the HSBG are due of higher star burst activity (all objects without No. 630 lie above the 'H'line of his Figure 2). If we (following de Jong *et al.*, 1984) assume that the IR emission in the HSBG is re-radiated from dust radiation of O-stars with masses of ca. 10 m_0, luminosities $\sim 10^4 L_0$ and time of life $\sim 10^7$ years, for the average infrared luminosity $\bar{L}_{\rm FIR} = 3.2 \times 10^{44}$ erg s^{-1} it is necessity every year about 100–300 solar masses gas to be converted in the stars and about 10 to 30 of them to be a massive stars.

3. Conclusions

The IRAS data for the HSBG testify that these are galaxies with high star-forming activity. The main conclusions are:

(a) More than 50% of the HSBG have measured IR fluxes. About a half of them emit, on the average, twice as much energy in the IR than in the blue.

(b) The galaxies with $L_B > L_{\rm FIR}$ and relatively higher surface brightness satisfy a general relation $\log F_{\rm FIR} - \bar{B}$.

(c) With the increasing of the surface brightness the dust temperature 100/60 asymptotically approaches 45 K.

(d) The rates of star formation are 10–30 times higher than those in normal galaxies. On average 100–300 solar masses gas are converted into stars every year and about 10–30 are massive stars.

Acknowledgement

The author is thankful to the Director of the Max-Planck Institute of Astronomy, Heidelberg, for the hospitality during his stay in Heidelberg.

References

Arakelian, M. A.: 1975, *Contr. Bjurakan Obs.* **47**, 3.
Catalogued Galaxies and Quasars detected in the IRAS Survey: 1985.
De Jong, T., Clegg, P., Soifer, B., Rowan-Robinson, M., and Habing, H.: 1984, *Astrophys. J.* **278**, L67.
Desert, F. X.: 1986, in F. Israel (ed.), *Light on Dark Matter*, D. Reidel Publ. Co., Dordrecht, Holland.
Fasano, G.: 1985, *Astron. Astrophys. Suppl.* **60**, 285.
Helou, G.: 1986, *Astrophys. J.* **311**, L33.
Houck, J., Soifer, B., Neugebauer, G., Beichmann, C., and Auman, H.: 1984, *Astrophys. J.* **278**, L63.
Nilson, P.: 1973, *Uppsala General Catalogue of Galaxies*, Uppsala.
Petrov, G. T.: 1986, *Astrophys. Space Sci.* **124**, 407.
Petrov, G. T.: 1988, (in press).
Soifer, B., Houck, J., and Neugebauer, G.: 1987, *Ann. Rev. Astron. Astrophys.* **25**, 187.