Доклади на Българската академия на науките
Comptes rendus de L' Academie Bulgare des Sciences
Tome 45, №8, 1992

ASTRONOMIE

STAR FORMATION IN KARACHENTSEV'S DOUBLE GALAXIES

G. T. Petrov, V. A. Mineva

(Submitted by Academician K. Serafimov on April 17, 1992)

The pairs of galaxies arc the simplest systems of galaxies. It is of great interest to study such systems because of the different rates of evolution, gravitation and star bursts effects. There is strong evidence that double galaxies were born together and the evolution in the future elapsed via parallel ways.

IRAS all-sky survey covered > 96% of the sky at 12, 25,60 and 100 mkm. Roughly 11500 galaxies and quasars have been detected with positional accuracy arc. sec in 1 sigma. The vast majority of the extragalactic objects detected in the IRAS survey are late-type spirals. Elliptical and lenticular galaxies are rarely detected. A review of IRAS data of extragalactic objects has been given by Soifer et al. [1].

We began an investigation of star formation in different types of galaxies — HSBG. Arakclian and Markarian galaxies using the IRAS data. The pairs of galaxies are the only reason to look for some differences in the star formation of the components of the same system. As a beginning we have chosen Karachentsev's pairs of galaxies [2]. The Karachentsev list contains 603 pairs altogether.

For our future investigations we adopted, for the Hubble constant H = 75 km/sec.Mpc, the blue flux to be proportional to nuF (4400)

(1) Lg Fbl = -7.43- m/2.5 [watt/sqr.m]

and

(2) Ffir = 1.26E-llx(2.58xS60+Sl00)

(3) F_{tot}=*1.75E-llx(12.66xS12H 5xS25+2.55xS60+1.0l XS100) according to [3] and [4], respectively, where *F* —in [erg/sqr.cm*sec].

(4) Lg L = 53.28+2LgVhel + Lg *F* [watt].

Table 1 presents the median, average values and standard deviations for some basical parameters characterizing Karachentsev galaxies. The basic optical data were taken from Appendix 1 of K a r a **c** h e n **t** s e v [5]. All the objects had been compared by the coordinates, magnitudes, radial velocities and cross-references with the IRAS sources from [8 1. As a result 384 galaxies (32%) were found to be IRAS sources. We shall mention that 32% of Arakelian, 40% of Markarian and 53% of HSB galaxies are included in IRAS sources.

It should be pointed out that the galaxies in pairs emit more energy in the far infrared than in the optical region of the spectrum. As pointed out by W y n n-W i l l i a m s [6], most of the energy emitted by newly born stars still in their cocoons will be reradiatcd in the infrared. The IRAS data should be specially valuable to study the characteristics of star formation. Far-infrared luminosities are a measure of the current star formation rates and dust plays the role of frequency converter that absorbs the short wavelengths photons emitted by newly formed massive stars and then reemits the energy at longer wavelengths [7].

Table 1

Median and average values for the basic parameters of Karachentsev's double galaxies

Z	LgLbι	LgL_{ir}	Rir/bl	F60/100	F25/60	T60/100	A1(100/60)	A1(60/25)	Md60
M 0.0183	43.48	43.68	0.49	–0.37	–0.04	40.3	–1.70	–1.50	5.30
X 0.019	43.43	43.60	0.17	–0.38	–0.09	40.7	–1.72	–1.49	5.23
σ 0.010	0.48	0.66	0.41	0.16	0.22	6.3	0.74	0.78	0.66

Following Rowan-Robinson [8] far-infrared (10 —1000 mkm**)** radiation **can** be expected from a normal spiral galaxy due to a variety of mechanisms:

1. Dust in the interstellar neutral hydrogen clouds illuminated by a general interstellar radiation field;
2. Dust in the surface layers of molecular clouds heated by the interstellar radiation field and in addition by young OB-associations recently formed from the cloud complex;
3. Dust in the vicinity of the protostars and newly formed stars embedded in the molecular clouds;
4. Circumstellar dust shells with high optical depth around the late type stars. OH —IR masers and young planetary nebulae.

The classical Fig. 2 from the paper of de J o n g et al. [9] presents the region occupied by the bright spirals on the diagram S60/S100 —$Lg(F_{ir}/F_{bl})$**.** The correlation between the two parameters made the authors propose a simple two components model to explain the observed IR fluxes —the cold one from the diffuse matter, and the warm from the neighbor of young stars. The difference for KarG is the lack of correlation (in contrary to the case of normal spirals).

Similar distribution was found by Pe r s s o n et al. [8] for the galaxies from Upsala General Catalog of Galaxies. They explain this by supposing that the biggest part of the far infrared emission comes from the diffuse interstellar dust heated by the interstellar radiation field. An alternative possibility is the strong reddening changed the real ratio [10].

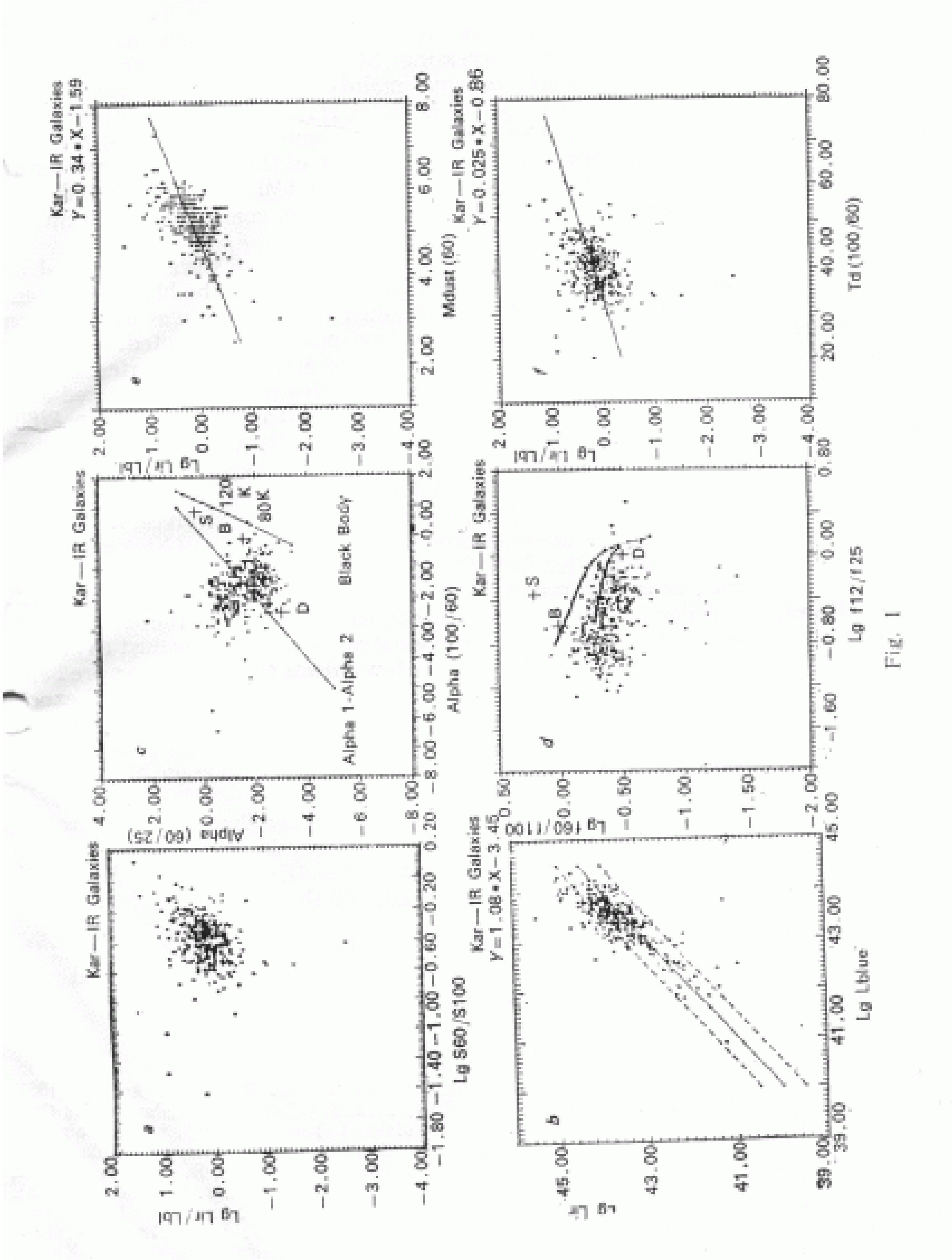
The lack of correlation between L_{ir}/L_{bl} and S60/S100 shows that the simple two component models do not work for KarG. De Jong and Brink [8] have proposed a variant of such model including the ratio L_{warm}/L_{cold}. Accepting that Tcold=16K and Twarm=60K and different ratios *Lw/Lc*. they could describe much of the observational properties of the IR sources.

H e l o u [11] proposes a two-component model for the optically thin matter based on the flux ratios F(12/25) —F(60/100) —Fig. le. The advantage here is in using all IRAS data. His model itself is the line "H" in Fig. I: above this line most of the IR fluxes are due to star formation. The KarG occupied a large part of the diagrams and it can be seen that only few of them need quite strong radiation to explain their situation above line "Y". That is why, in the future, we do not need to use the three-component model of Rowan-Robinson [8], marked by crosses as "Disk", "starBurst" and "Seyfert".

A similar analysis is proposed by S e k i g u c h i [12] using a mixture of two Black Body examples with temperature Tcold = 30 K. Fig. *b* —Al(100.60) —A1(60.25) shows the lines of constant Alpha and different temperatures of Black Body radiation. The model of Rowan-Robinson is marked, too (see above).

Having fluxes and luminosities in the IR and Blue we could evaluate the SFR in $[M_o/year]$ —Galagher and Hunter [8]:

(5) $dM_{fir}/dt = 2.5$ E —10 x Delta/beta x L_{ir}.



Because of the uncertainties of Delta and Beta we could use their approximate evaluations presented as the regions of constant (between the lines), increasing (above lines) and decreasing (below lines) star formation rate in the figure. Fig. \d presents the same relation Lg L_{bl} —Lg L_{ir} for KarG. The three lines mark the regions with constant, decreasing and increasing SFR. Note that here Lbl is in the Johnson's B-system. The KarG occupy mainly the region of constant and increasing star formation. Following de Jong et al. [7] if IR-fluxes are mainly from the newly formed O-stars with time live ca. 1E+7 years, luminosities — lE+4 Lo and masses 1E +10 M_o, then in average ca. 2-3 solar masses of the interstellar matter are converted every year in young stars. Taking into account IMF, we can conclude thai about 20-30 M_c annuary are converted in young stars —i.e. comparable with SFR in the normal S-galaxies.

Using infrared excess index CI = Fir/Fbl as a convenient measure of infrared activity, we can conclude that the higher IR activity corresponds to the higher dust temperature. In Fig. 1f we present such relation, the dust temperature was defined from the F(60)/F(100) flux ratio and n=0 grain absorption model was adopted. The mean dust temperature is close to 41 K — similar to HSB and Markarian Galaxies.

As it was mentioned above, we suppose the IR radiation is due to the heated dust. The mass of the radiated dust is determined by using the dust temperature from F(60)/ F(100) flux ratio because of rapidly decreasing dust emissivity with the temperature.

For optically thin matter the dust mass is determined as

(6) $M_{dust}(\lambda) = 4\pi Rg^2 \times F(\lambda)/(4\pi B_\lambda(T_d) \times K(\lambda))$,

where *Rg* is the distance to the galaxy, *F(λ)* is the observed flux at given λ, T_d is the dust temperature and K(λ) is the mass absorption coefficient

(7) $K(\lambda) = Q(\lambda)/(4/3) \times \alpha \times \rho$ **[cm*/g];** $Q(\lambda) \sim \lambda^{-n}$.

Adopting the Drain and Lee model for dust mixture of graphite and silicate particles with radius α = 10 mkm and density ρ = 2 g/cm, absorption efficiency of the dust proportional to M_{dust} (i. e. n = 1) and /C(60)^250 cnrVg, we evaluated the mass of the dust to be from 10^5 to 10^7 M_o with average value 2 X 10^5 M_o. Only in few objects the dust masses are below or above these limits. In Fig. 1*c* we present the relation of M_{dust} from infrared excess.

Studying the infrared fluxes from IRAS as an example of Karachentsev doule galaxies, we could conclude that:

1. The IR KarG are a sample of the normal galaxies with an average higher IR lu
minosities — < Lg Lir> 43.60;
2. We could expect an increasing or constant SER rather than a decreasing one.
This could be explained with the influence of the neighbor in the pair;
3. To detect IR fluxes from the KarG it has to have lE+3 to lE+8 M_o dust in
these galaxies. For the arbitrary amount gas/dust ca. 100 this leads as to the **1E+5 -**
1E+10 M_o gas;
4. Star formation activity in Karachentsev's double galaxies is lower than in the
Arakelian, HSBG or Markarian ones and is similar to the SFR in bright spiral gala-
xies in Virgo.

REFERENCES

[1] Soifer, B. T., J. R. Houck, G. Neugbauer. Ann. Rev. A & Ap, 25, 1987, 187. [2] Karachentsev, I. D. Contr. SAO UdSSR, 7, 1972, 3. [3] Catalogued Galaxies and Quasars Observed in the IRAS Survey. edition. Jet Propulsion Laboratory, 1989. [4] Belfort et al. A & Ap. **176,** 1987, I. [5] Karachηtsv, I. D. In: Double Galaxies, Moscow, Nauka, 1987. [6] Wynn-WilIiams, C. Ann. Rev. A & Ap., 20, 1982, 587. [7] Stein, S., B. Soiier. Ibid., 21, 1983, 177. [8] Star Formation in Galaxies, NASA CP —2466, 1987 (Ed. C. J. Lonsdale Persson),
[9] De Jong, T., P. E. Clegg, B. T. Soifer, M. Rowan-Robinson, H. J. Habiηg, J. R. Houck, H. H. Aumann, E. Raimond. Ap. J. Let., **278,** 1984, L67.
[10] Dennefeld, M. et al. In: Star Forming Dwarf Galaxies and Related Objects (Eds G. Kunth. T. Thuan and J. Van) 1986, 351. [11] Helou, G. Ap. J. Let., **311,** 1986, L33. [12] Sekiguchι, K. Ap. J., **316,** 1987, 145.

Department of Astronomy Bulgarian Academy of Sciences 1000 Sofia, Bulgaria