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ISOLATED PAIRS OF SPIRAL GALAXIES - A STATISTICAL STUDY OF FAR INFRARED AND MICROWAVE CHARACTERISTICS

by

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Abstract A statistical study of the far infrared and microwave ($\lambda 6.3cm$) luminosities of a sample of isolated pairs of spiral galaxies and a comparison sample of non-interacting galaxies selected from the lists given by Wunderlich and Klein (1991) does not reveal any significant difference between the two samples.

Key words : *Galaxies : Interacting spiral Galaxies - star burst - infrared & Microwave characteristics*



1. Introduction

Studies in the infrared reveal aspects of star formation in galaxies (Rowan - Robinson 1991) and galaxy interactions are believed to be responsible for enhancing the rates of star formation and for triggering bursts of star formation (Keel 1991). Presence of a companion galaxy and merging systems are characterised by very high rates of star formation and 'star burst' activity (Keel 1991). Sanders et al.(1986) infer that the majority of the most luminous IRAS galaxies with far infrared luminosities greater than $10^{11}L_{\odot}$ appear to be strongly interacting systems and those with the highest $^{L}{}_{FIR}/M(H_2)$ ratios are mergers or close contact pairs. According to de Jong (1986) the fraction of interacting systems among infrared galaxies is significantly higher than among local field galaxies which suggests that (distant) encounters between galaxies may play an important role in triggering bursts of star-formation.

Lonsdale, Persson and Matthews (1984) have observed that, on average, the $10\mu m$ luminosities of interacting galaxies are higher than those of non-interacting galaxies. This observation is in conformity with the conclusion of Cutri and Mc Alary (1985) that a population of nuclei with extremely luminous $10\mu m$ emission is unique to the interacting sample.

However, Cutri and Mc Alary (1985) also state that comparisons with suitable control samples indicate that at least 50% of the galaxies in interacting pairs have infrared properties no different from those of non-interacting galaxies and remark that it will be just as important to understand why interactions do not always induce activity. Also, Keel and Van Soest (1992), based on a study of the pairing properties of Markarian starburst galaxies using optical and far infrared data, do not find any clear differences in the global character of starformation between isolated and paired Markarian systems. In view of these disparate results it seemed of interest to make a statistical study of the far infrared and $\lambda 6.3cm$ radio continuum luminosities of interacting and non-interacting spirals which have been compiled by Wunderlich and Klein (1991) to enable a comprehensive discussion of the radio-FIR relation of interacting and non-interacting spirals.

2. Data for the Statistical Study

a) Interacting Spirals

Wunderlich and Klein (1991) list 36 pairs of interacting galaxies. For compiling this list they used the "catalogue of isolated pairs of galaxies in the northern hemisphere" (Karachentsev 1972). In compiling this list they picked the objects by searching the Palomar Sky survey charts and applied to all galaxies appearing to form a pair criteria for isolation as well as apparent photographic magnitude and differences in

radial velocities of the galaxies in the pair. They have also restricted the choice to a limited range of right ascensions.

b) Comparison Sample

They list 37 isolated spirals as comparison sample which is part of the sample given by Hummel (1980). In selecting this sample they have used certain brightness criteria while restricting to certain limiting right ascensions and declinations. They have carefully excluded all those galaxies which are noted as members of pairs or groups by others.

c) Data for the present study

For our statistical study we have used the data from Wunderlich and Klein's (1991) Table 8 giving the far infrared and monochromatic radio luminosities for the isolated pairs of galaxies and Table 9 for the comparison sample. From these two tables we have picked out objects which are almost at the same distance, the difference being $\leq 1Mpc$ and for which definite values of far infrared luminosities and the luminosities of the cold component of dust are tabulated. On this basis we have obtained a data sample of 11 pairs of almost equidistant interacting and comparison objects. The average distance and the absolute photographic magnitude of the interacting and comparison sample are approximately the same. These 11 pairs are listed in Table 1 below along with the distances.

TABLE 1

List of interacting and non-interacting galaxies and their distances.

S. No.	Interacting galaxies Non-interacting	Distance D Mpc.
1	K 218	3.1
	N 1560	2.6
2	K 133	3.8
	N6503	4.2
3	K40	6.7
	N7640	7.7
4	K 110	16.9
	N 7217	16.5
5	K 210	17.4
	N7814	17.2
6	K 195	23.8
	N 6643	23.1
7	K 216	24.6

	N 2712	25.1	
8	K 132	31.8	
	N2701	32.3	
9	K186	35.0	
	N1169	35.0	
10	K 165	56.2	
	N1961	55.4	
11	K68	58.9	
	N2942	58.8	
	MEAN	25.29	(Interacting)
		25.26	(Non-Interacting)

Statistical Analysis and Results

We have obtained the far infrared luminosity of the warm dust component in each object by subtracting the luminosity of the cold component from the total luminosity in the FIR given in Tables 8 and 9 by Wunderlich and Klein (1991). The luminosity of the warm dust component is the result of the heating of the dust particles by recently formed massive (OB) stars and is therefore indicative of the recent OB star formation rate. Many studies have also established the high correlation between the total microwave and far infrared emission of spiral galaxies suggesting that the young massive stars are causally linked to the radio continuum.

In order to find out how the far infrared characteristics compare between the sample of interacting (i.e. isolated pairs of) galaxies and the comparison sample (of non-interacting) galaxies we have subjected their warm component luminosities to statistical tests. Applying the rank U test of Mann - Whitney (Chase and Brown 1986) we are led to reject the hypothesis that the two samples are from different populations at the 5% level of significance. Also, since the sample sizes $n_1 = n_2 > 10$ the distribution of U is approximately normal and using the corresponding test statistic we arrive at the same conclusion with the same level of significance. The Wilcoxon signed rank test (Chase and Brown 1986) also confirmed this conclusion.

A similar analysis performed on the cold component luminosities for the two samples also leads to the same conclusion.

We subjected the monochromatic microwave ($\lambda = 6.3cm$) luminosities of the interacting and companion samples to Statistical analysis. In five of the interacting samples and four of the comparison samples only upper limits to the microwave

luminosities are given by Wunderlich and Klein (1991). Hence, as treated by Cutri and Mc Alary (1985) for censored data with upper limits, we carried out the Gehan two-sample test (Eddington 1987). This again, as one would expect because of the tight correlation between radio and FIR luminosities, showed that the distributions of the two samples are not different.

4. Conclusion

Statistical analyses of samples of interacting and non-interacting spiral galaxies selected from the lists given by Wunderlich and Klein (1991) suggest that the far infrared characteristics of these samples of spiral galaxies do not differ significantly. This result seems to be in accordance with the observation of Cutri and Mc Alary (1985) that at least 50% of the galaxies in interacting pairs have infrared properties no different from those of non-interacting galaxies and also with the conclusion of Keel and Van Soest (1992) that they are unable to identify any clear differences in the global character of star formation between isolated and paired Markarian systems.

It may also be noted that the FIR luminosities of the warm dust component in the samples in our study are $\leq 10^{11} L_{\odot}$ and according to Sanders et al. (1986) only those with far infrared luminosities $> 10^{11} L_{\odot}$ are strongly interacting systems.

If it is established that the far infrared properties of some interacting spiral galaxies are not significantly different from non-interacting spiral galaxies it is possible that, irrespective of the triggering mechanism, the resulting starburst loses memory of it and the same kind of objects are produced as suggested by Campos-Aguilar and Moles (1991) for blue compact dwarf galaxies. Keel and van Soest (1992) have also noted that they are unable to identify any clear differences in the global character of star formation between isolated and paired Markarian systems and remark that interactions can apparently trigger bursts of star formation but exercise little influence on their properties once triggering has occurred.

It would be interesting to identify the physical parameters which distinguish those isolated pairs of galaxies that differ in their far infrared and microwave characteristics from the non-interacting galaxies and those isolated pairs that do not reveal any differences.

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References

Campos-Aguilar, A. & Moles, M. (1991) Astr. Ap. 241, 358.

Chase, W. & Brown, F. (1986) General Statistics, John Wiley & Sons, ch. 14.

Cutri, Roe M. & Mc Alary, Christopher W. (1985) Ap. J. 296, 90.

de Jong, T. in 'spectral Evolution of Galaxies' (Eds : C. Chiosi & A. Renzini) Reidel p. 111.

Eddington, E.S. (1987) Ramdomization Tests, Marcel Dekker, Inc. Ch. 11.

Hummel, E. (1980) Astr. Ap. Suppl. Ser. 41, 151.

Karachentsev, I.D. (1972) Comm. Spl. Ap. obs. USSR. 7,1.

Keel W.C. (1991) in 'Dynamics of Galaxies and Their Molecular Cloud Distributions' (Eds: F. Combes & F. Casoli) Kluwer : Dordrecht p. 243.

Keel, W.C. & Van Soest, E.T.M. (1992) Astr. Ap. Suppl. ser. 94, 553.

Lonsdale, C.J., Persson, S.E. & Matthews, K. (1984) Ap. J. 287, 1009.

Rowan - Robinson, M. (1991) in 'Dynamics of Galaxies and Their Molecular Cloud Distributions' (Eds : F. Combes & F. Casoli) Kluwer : Dordrecht p. 211.

Sanders, D.B. et al. (1986) Ap. J. 305, L 45.

Wunderlich, E. & Klein, U. (1991) Astr. Ap. Suppl. Ser. 87, 247.