

Clustering of Very Luminous Infrared Galaxies and their Environment

Yu Gao

Astronomy Program, SUNY at Stony Brook

The IRAS survey reveals a class of ultraluminous infrared (IR) galaxies (ULIRGs) with IR luminosities comparable to the bolometric luminosities of quasars. The nature, origin, and evolution of ULIRGs are attracting more and more attention recently (cf. Sanders et al 1988, hereafter S88; Solomon et al 1992a; 1992b; Kormendy & Sanders 1992). Since galaxy morphology is certainly a function of environment (e.g. Postman & Geller 1984), morphological observations show that ULIRGs are interacting/merging galaxies (S88; Melnick & Mirabel 1990), and some ULIRGs might be the dust-enshrouded quasars (S88) or giant ellipticals (Solomon et al 1992a; Kormendy & Sanders 1992), the study of ULIRGs environment and large scale clustering effects should be worthwhile.

ULIRGs ($L_{IR} \geq 10^{12} L_{\odot}$; $H_0 = 75 \text{ km/s/Mpc}$ and $q_0 = 0$) and very luminous IR galaxies (VLIRGs; $L_{IR} \geq 2 \times 10^{11} L_{\odot}$) have been selected from the 2Jy IRAS redshift survey, which is complete to a redshift of 10,000 km/s and might be complete to a redshift of 30,000 km/s at high galactic latitudes (Strauss et al 1990; Yahil et al 1991). Meanwhile, a catalog of IRAS groups of galaxies has been constructed using a percolation-like algorithm. Therefore, whether ULIRGs and/or VLIRGs have a group environment can be checked immediately. Surprisingly, most VLIRGs ($\sim 90\%$) are not IRAS group members, in marked contrast to the fact that $\sim 50\%$ of IRAS galaxies are in groups of galaxies. Also, only a few percent of group member galaxies are VLIRGs and no group member galaxies are ULIRGs (see Figure 1), which is extremely different from the situation that $\sim 20\%$ of field IRAS galaxies are VLIRGs and a few percent of field IRAS galaxies are ULIRGs.

The two-point spatial correlation functions have been estimated for the some *volume-limited* subsamples of luminous IR galaxies and U/VLIRGs. Preliminary results show that there is no luminosity segregation in the correlation functions for IRAS galaxies if $L_{IR} \leq 10^{11} L_{\odot}$, which should be consistent with the conclusions of Davis et al (1988). However, for U/VLIRGs, the more IR-luminous they are, the stronger correlations they have and ULIRGs have the strongest correlations which is comparable with that of poor clusters of galaxies (Figure 2).

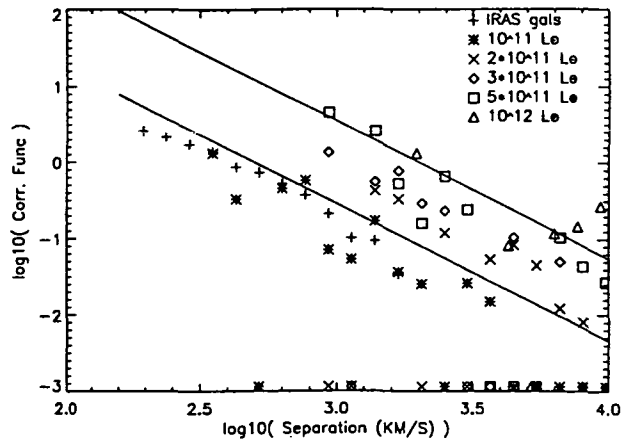
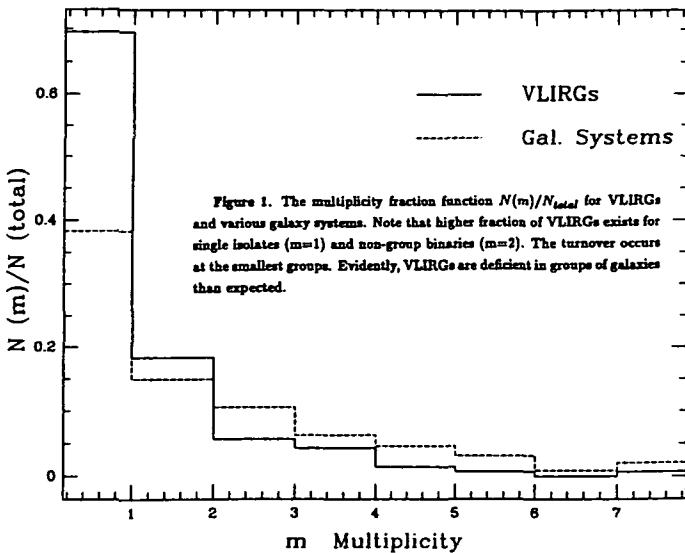


Figure 2. The correlation functions for various subsamples of IRAS galaxies as indicated by their IR luminosities. The lower and upper straight lines are the correlation functions for optical galaxies and clusters of galaxies respectively: $\xi_{opt}(r) = (\frac{r}{3500 \text{ KMS}})^{-1.6}$; $\xi_{IR}(r) = (\frac{r}{3500 \text{ KMS}})^{-1.9}$ (cf. Bahcall 1988).

Our correlation results have also been checked by selecting various subsamples within a redshift of 30,000 km/s. We can select subsamples with the same IR luminosity constraints

to check the luminosity dependence and compare the results for all the five *volume-limited* subsamples. The results are essentially the same and the conclusion of stronger clustering of more luminous VLIRGS remains unchanged.

U/VLIRGs will be the dominant population in the local universe among other objects with bolometric luminosity $L_{bol} \geq 3 \times 10^{11} L_{\odot}$. However, most of them in nearby universe are not members of clusters or groups of galaxies. Thus, the distribution of VLIRGs is avoiding the concentrations of galaxies, yet show stronger clustering effects than less luminous IRAS galaxies. Strong clustering of VLIRGs might imply their preferential location in groups as Bahcall & Chokshi (1991; 1992) suggest that the origin of the observed correlations of quasars and radio-galaxies, which is intermediate in strength between that of galaxies and of rich clusters of galaxies, is the preferential locations of quasars in small groups and of radio-galaxies in groups of galaxies of intermediate richness. According to this picture, having the same correlation amplitudes as that of groups or poor clusters of galaxies, the U/VLIRGs should have the corresponding group or cluster environments. However, most U/VLIRGs are merging galaxies and we have shown that most of them are not the members of galaxy groups now in the nearby universe. This apparent contradiction might indicate that U/VLIRGs may be the remnants of the evolution of groups of galaxies due to their advanced merging, thus losing their present properties as groups of galaxies but still have stronger correlations in spatial distribution as that of groups or clusters of galaxies. Some cosmological implications on the origin and evolution of ULIRGs and groups of galaxies might be implied.

In conclusion, there is an over population of isolated VLIRGs in the nearby universe. Most VLIRGs (especially the most luminous VLIRGs) are not members of groups of galaxies (only $\sim 10\%$ VLIRGs are in groups, whereas $\sim 50\%$ IRAS galaxies are group members) and they are deficient at small redshift of $\sim 5,000 \text{ kms}^{-1}$. However, U/VLIRGs show stronger correlation than all IRAS galaxies. The more luminous the VLIRGs are, the stronger clustering they have. The correlation strength of ULIRGs is comparable to that of poor clusters of galaxies. The U/VLIRGs' properties of stronger correlation and deficiency in galaxy groups might suggest they are probably the remnants of the evolution of groups of galaxies due to the advanced merging of member galaxies.

ACKNOWLEDGEMENTS

I thank Phil Solomon for support and suggestions. Amos Yahil is also thanked for his suggestions. I am very grateful to Michael Strauss for sending me the 2Jy IRAS redshift catalog prior to publication. I appreciate the helpful discussions with Yi-peng Jing. Finally, I wish to thank the organizers of this summer school for partial support.

REFERENCES

- Bahcall, N.A. & Chokshi, A. 1991, *Ap. J. Lett.*, **380**, L9.
Bahcall, N.A. & Chokshi, A. 1992, *Ap. J. Lett.*, **385**, L33.
Davis, M., Meiksin, A., Strauss, M.A., da Costa, L.N., & Yahil, A. 1988, *Ap. J. Lett.*, **333**, L9.
Kormendy, J. & Sanders, D.B. 1992, *Ap. J. Lett.*, **390**, L53.
Melnick, J. & Mirabel, I.F. 1990, *Astron. Astrophys.*, **231**, L19.
Postman, M. & Geller, M. 1984, *Ap. J.*, **281**, 95.
Sanders, D.B., Soifer, B.T., Elias, J.H., Madore, B.F., Matthews, K., Neugebauer, G., Scoville, N.Z. 1988, *Ap. J.*, **325**, 74. (S88)
Solomon, P.M., Downes, D. & Radford, S.J.E. 1992a, *Ap. J. Lett.*, **387**, L53.
Solomon, P.M., Radford, S.J.E. & Downes, D. 1992b, *Nature*, in press.
Strauss, M.A., Davis, M., Yahil, A., & Huchra, J.P. 1990, *Ap. J.*, **361**, 49.
Yahil, A., Strauss, M.A., Davis, M., & Huchra, J.P. 1991, *Ap. J.*, **372**, 380.