SOUTHERN STUDIES OF LUMINOUS INFRARED GALAXIES

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ABSTRACT. The results from optical and radio studies of a flux limited sample of luminous infrared galaxies in the Southern Hemisphere are reported. The detailed study of the nearest (z ≤ 0.13) ultraluminous infrared galaxies ($L_{ir} \geq 10^{12} L_{\odot}$) show that these are mergers of giant gas-rich systems with critical separations of 10 kpc. Merging of gas-rich galaxies enhance molecular cloud formation, as well as the infrared luminosity per nucleon of interstellar gas.

1. Selection of Bright IRAS galaxies

Luminous infrared galaxies were selected from two IRAS flux limited samples of galaxies. First, from an extension to $\delta \leq -20°$ and $| b | \leq 30°$ by Egami et al., of the IRAS Bright Galaxy Sample previously compiled by Soifer et al. (1987). The redshifts of this extended sample were obtained at Hawaii, the 2.2 m argentine telescope, or kindly provided by Strauss (1989). This extended sample of $\sim$ 600 Bright IRAS Galaxies covers 85% of the sky and contains most of the extragalactic sources with IRAS 60μm flux densities greater than 5.4 Jy that are located beyond 5 degrees from the galactic equator. The second sample comes from an on-going deeper redshift survey by Strauss et al. (1990) of IRAS sources with 60μm flux densities greater than 2.5 Jy.

2. Morphology of Ultraluminous Infrared Galaxies

The optical morphology of ultraluminous infrared galaxies has recently been a subject of controversy. Sanders et al. (1988) obtained low resolution images of 10 ultraluminous infrared galaxies with the Palomar 1.5 m telescope, concluding that nearly all ultraluminous infrared galaxies are strongly interacting merger systems. On the other hand, from images of a sample of luminous IRAS galaxies in the North Polar Cap obtained at La Palma, Lawrence et al. (1989) concluded that although galaxy interaction may be a common causal factor in luminous IR activity, it is far from being the ubiquitous factor as suggested by Sanders et al. (1988).

In this context, Melnick and Mirabel (1990) obtained New Technology Telescope (NTT) images of 16 southern ultraluminous infrared galaxies ($L_{ir} \geq 10^{12} L_{\odot}$ for H_o = 75 km $s^{-1} Mpc^{-1}$) at z $\leq$ 0.13. The excellent quality of the NTT optics and the good seeing conditions on La Silla were fully exploited to reveal possible faint morphological features in the images of these galaxies. Melnick and Mirabel (1990) found that all the objects of this nearby sample of southern

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ultraluminous galaxies show the features that Toomre and Toomre (1972) identified as resulting from gravity in strongly interacting merger systems. Tails, wisps and double nuclei are apparent in all galaxies at $cz \leq 25{,}000$ km s^{-1}. However, the faint extended features that are characteristic of tidal interactions become less ostensible at $cz \geq 25{,}000$ km s^{-1}, and only the brighter, distorted main bodies of the galaxies remain easily visible. From this Melnick and Mirabel (1990) concluded that in the images of luminous infrared galaxies the faint extended features provoked during galaxy-galaxy collisions may become blurred at higher redshifts.

The difficulty for the detection of tidal features in systems at high redshifts is not only a matter of detector sensitivity, but also of angular resolution. A typical seeing of 1 arcsec projected on a galaxy that is at a redshift $z = 0.2$ corresponds to a length of $\sim$ 4 kpc. This implies that the short counter tails present in evolved merger systems (e.g. Mrk 231, Arp 220) may be difficult to resolve at redshifts $z \geq 0.2$. It is then possible that Lawrence et al. (1989) identified a lower proportion of interacting galaxies because among their sample of galaxies there are several objects with redshifts $z \geq 0.1$, whereas Sanders et al. (1988) only imaged ultraluminous infrared galaxies at $z \leq 0.1$. A not so relevant, but nevertheless contributing factor in the clarification of the controversy on morphology is the fact that Sanders et al. (1988) use $H_o = 75$ km s^{-1} Mpc^{-1}, whereas Lawrence et al. (1989) use $H_o = 50$ km s^{-1} Mpc^{-1}. This introduces a factor of 2 difference in the definition of the intrinsic infrared luminosity of the sample galaxies.

Another important result found by Melnick and Mirabel (1990) is the existence of a critical separation of about 10 kpc between the colliding galaxies of their sample. In other words, advanced merging seems to be a necessary condition for the greatly enhanced infrared luminosity. This close approach is observed even in systems that have developed spectacular bridges and antennae. The best example is IRAS 19254-7245, a system of colliding galaxies with the two nuclei 10 kpc apart, that shows remarkable narrow and elongated tails over a total extent of 400 kpc. Bright spots along the tidal remnants suggest the possibility of localized bursts of star formation at distances in the range of 50-150 kpc from the main bodies of the merging galaxies.

3. The molecular and atomic gas content of Luminous Infrared Galaxies

Mirabel et al. (1990) conducted with SEST a CO (1-0) survey of luminous infrared galaxies in the Southern Hemisphere. They found that these galaxies are extremely abundant in molecular gas, with total masses of H_2 in the range of 0.6-6 x $10^{10} M_{\odot}$, namely 2-20 times the mass of molecular gas in the Milky Way. The infrared luminosities per nucleon of interstellar gas $L_{ir}/M(H_2)$ are in the range of 10-80 $L_{\odot}/M_{\odot}$. This is 5-40 times the global value of this ratio in the Galaxy averaged over the whole disk. The the optical morphology and large masses of molecular gas found among the ultraluminous infrared galaxies suggests that these are mergers of giant galaxies extremely rich in gas.

Dynamical interactions are likely to have implications beyond purely morphological effects. Mirabel and Sanders (1989) have shown that the overall ratio of molecular to atomic gas in luminous infrared galaxies increases with the far-infrared excess, f_{ir}/f_b. Among the galaxies with the higher infrared excesses there are systems with strikingly small atomic mass fractions, where less than 15% of the total mass of interstellar gas is in atomic form. Mirabel and Sanders (1989) have speculated that this relative depletion of HI in galaxies with large infrared excess may be primarily due to an enhancement of molecular cloud formation during galaxy-galaxy mergers. In merger-induced shocks, as a consequence of the large amounts of interstellar gas driven toward the central regions, there may be an increase of the rate of conversion of HI into H_2. Although the H_2 that was present before cloud-cloud collisions will be initially dissociated by shocks of velocity $\sim$ 100 km s^{-1}, the large amounts of centrally concentrated molecular gas found by

Scoville et al. (1986) and Planesas et al. (1990) in advanced merger systems are an indication of very efficient mechanisms for the formation of H_2.

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