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LUMINOUS INFRARED GALAXIES: AGN OR STARBURSTS?

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RESUMEN

Se llevó a cabo una inspección espectroscópica de una muestra de más de 200 galaxias IRAS. Se clasificaron cuidadosamente los espectros de los núcleos de estas galaxias como "semejante a región H II" o "semejante a NAG" usando un gran número de diagnósticos de cocientes de líneas corregidos por las líneas de absorción estelar subyacente. Confirmamos que tanto la fracción de galaxias luminosas infrarrojas ("GLIs") con espectros semejantes a NAG y la fracción de galaxias Seyfert entre los objectos semejantes a NAG aumentan con la luminosidad infrarroja. Por otro lado, la fracción de objetos similares a LINERs, es relativamente constante $\sim$ 25%. El origen de la emisión de las líneas algunas veces es una función de la distancia al núcleo. Con base en los cocientes de la líneas de emisión y las intensidades de las líneas de absorción, la actividad de formación estelar circunnuclear parece ser común entre GLIs, independientemente del tipo de espectro nuclear. La información sobre el ancho de las líneas sugiere que hay vientos nucleares a gran escala en muchos de estos objetos y que son un medio eficiente para deshacerse del material oscurecedor en la región nuclear. Con base en sus líneas de emisión, líneas de absorción y propiedades morfológicas, las GLI Seyfert parecen estar en un estado de evolución más avanzado que las GLI semejantes a regiones H II.

ABSTRACT

A spectroscopic survey of a sample of more than 200 IRAS galaxies was carried out. Great care was taken in classifying the nuclear spectra of these galaxies as "H II region-like" or "AGN-like" using a large number of line-ratio diagnostics corrected for the underlying stellar absorption features. We confirm that both the fraction of luminous infrared galaxies ("LIGs") with AGN-like spectra and the fraction of Seyferts among the AGN-like objects increase with infrared luminosity. The fraction of LINER-like objects, on the other hand, is relatively constant at $\sim$ 25%. The origin of the line emission sometimes is a function of the distance from the nucleus. Based on the emission-line ratios and the strengths of the absorption features, circumnuclear starburst activity appears to be common among LIGs, regardless of their nuclear spectral types. Line width information suggests that large-scale nuclear winds are present in many of these objects and are an efficient way of getting rid of the obscuring material in the nuclear region. Based on their emission-line, absorption-line, and morphological properties, Seyfert LIGs appear to be at a more advanced stage of evolution than H II region-like LIGs.

Key words: **GALAXIES: NUCLEI — GALAXIES: SEYFERT — GALAXIES: STELLAR CONTENT — INFRARED: GALAXIES**

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1. INTRODUCTION

Prior to the launch of the Infrared Astronomical Satellite (IRAS), only a few galaxies were known to be luminous in the infrared domain. Since then, however, the IRAS survey has revealed that an important fraction of extragalactic objects emit the bulk of their radiation at far-infrared wavelengths (Houck et al. 1984; Soifer et al. 1984). In fact, above $\log(L/L_\odot) \sim 11$, this class of galaxies becomes the dominant extragalactic population in the local universe, exceeding even the space densities of optically selected quasars at comparable bolometric luminosity (Soifer et al. 1989). Luminous infrared galaxies (LIGs) may therefore provide important clues to the process of galaxy formation and the origin of nuclear activity in galaxies.

Perhaps the most important question regarding LIGs is the nature of their energy source. Scenarios involving intense star formation (e.g., Condon et al. 1991), dust-enshrouded active galactic nuclei (AGN; e.g. Sanders et al. 1988), and galaxy–galaxy collisions (Harwitt et al. 1987) have been suggested to explain the large luminosity of the brighter sources. Optical studies generally address this question by attempting to determine the main source of ionization of the line-emitting gas in LIGs and the role of galaxy interaction in triggering the large infrared luminosities of these objects (cf. review by Heckman 1991). The distinction between the source of the infrared radiation in these galaxies and the source of ionization of their line-emitting gas is important to emphasize here as the former is believed to be deeply embedded in the core of these objects and is therefore invisible at optical wavelengths (and possibly up to 25 μm [Condon et al. 1991]). Optical studies infer the nature of the energy source by assuming that the physical characteristics of the circumnuclear gas and underlying stellar population are good probes of the central energy source. This is also the approach that we will follow in the present study.

A major limitation of previous optical studies has been the small size of their samples or the limited number of line and continuum diagnostics used in their analysis. In an attempt to remedy to this situation we have carried out a spectroscopic survey of a large sample of IRAS galaxies. Long-slit Palomar 5-m spectra covering at least 3750 – 8000 Å (sometimes up to $\sim$ 1 μm) at a resolution of about 10 Å were obtained of more than 200 infrared galaxies. A constant linear aperture of 2 kpc was used to extract the nuclear spectra from these data and therefore minimize aperture-related effects. Long-slit information could be extracted from twenty-three of these galaxies (hereafter called the long-slit subsample). The results are presented in §2. We discuss the implications of these results in §3, where we address the nature of the energy sources in luminous infrared galaxies and discuss possible scenarios to explain the data. Finally, the main conclusions are summarized in §4

2. RESULTS

2.1. Spectral Classification

In contrast to many previous studies, we attempted to use all of the diagnostic tools known to be efficient at differentiating between the various ionization mechanisms (Baldwin, Phillips, & Terlevich 1981; Veilleux & Osterbrock 1987; Osterbrock, Tran, & Veilleux 1992 and references therein). All of the line ratios used in this analysis were corrected for reddening (cf §2.2) and the presence for underlying stellar absorption. We find a clear tendency for the more luminous objects to have AGN-like line ratios and for these objects to be more Seyfert-like (Table 1). In contrast, LINER-like galaxies contribute 20 – 25% of the LIG population, regardless of the infrared luminosity.

Figure 1 shows that most of the objects in the long-slit subsample have line ratios which do not change significantly with the size of the aperture. There are a few exceptions, however. The most noteworthy examples are ZW453.062, NGC 5953, NGC 7679, NGC 1204, and 2055-42 (labelled 1 through 5 in Fig. 1). The line ratios of the first three objects are AGN-like in the nucleus but are H II region-like in the circumnuclear gas. This behavior can be understood if there is a circumnuclear starburst which dilutes the AGN-like emission from the nucleus of these objects. Dilution effects of this sort may explain (at least in part) the smaller fraction of AGN-like LIGs found in fainter IRAS surveys (Leech et al. 1989). In these studies, the ultraluminous infrared galaxies are typically three times more distant than objects in our sample, so the aperture includes more of the circumnuclear (presumably H II region-like) emission than in the more nearby objects. This result emphasizes the fact that a constant *linear-size* aperture is crucial when classifying the nuclear spectra of LIGs using emission-line ratio diagnostics.

On the other hand, the line ratios in the nuclei of NGC 1204 and 2055-42 are typical of starburst galaxies but become LINER-like at larger distances from the nucleus. A similar effect is observed in M82 (e.g., Heckman, Armus, & Miley 1990 [HAM90]). This type of ionization structure can be explained in the context of a

upernovae-driven wind model in which the circumnuclear gas is either collisionally ionized by strong shocks aused by the interaction of the outflowing nuclear gas with the ambient material or is photoionized by the hermal ionizing continuum produced by the starburst itself.

Table 1. Nuclear Spectral Types

	10 – 10.99	11 – 11.99	12 – 12.99
	log ($L_{ir}/L_{\odot}$)		
No. of Objects	44	92	20
H II region-like	70 %	60 %	45 %
AGN-like	30 %	40 %	55 %
(Sey 1 + 2)/AGN-like	23 %	35 %	64 %
LINER-like	23 %	26 %	20 %

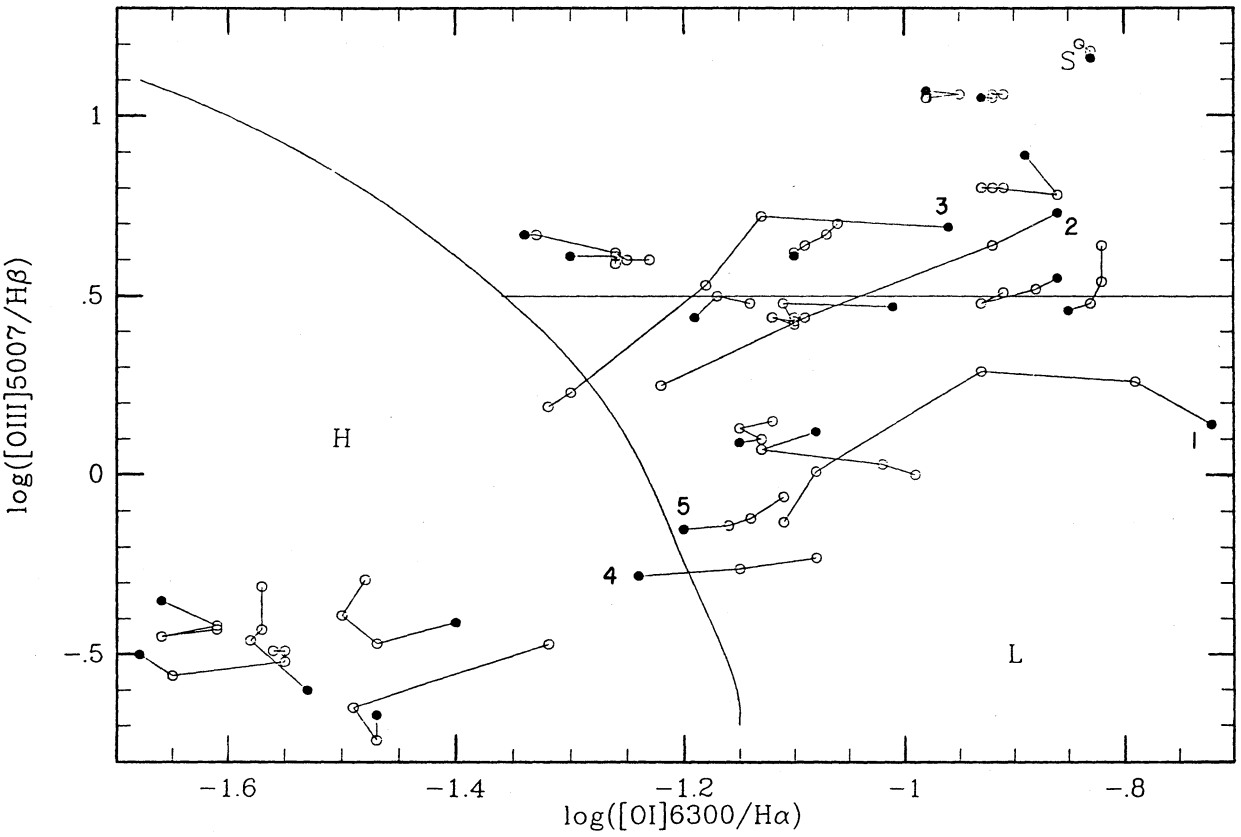

Fig. 1. Effects of the aperture size on the [O III] λ5007/Hβ versus [O I] λ6300/Hα line-ratio diagram. The ocations of the H II region-like, LINER-like, and Seyfert-like line ratios are indicated by the labels "H", "L", ınd "S", respectively. The filled circles represent the line ratios of the unresolved nuclei. The size of the aperture ncreases along the segments connecting the filled circle to the other circles.

2.2. Dust Content

The primary dust indicator used in the present investigation is the emission-line Balmer decrement. The amount of reddening measured in the nuclei of LIGs was found to be at least twice as large as in optically-selected Seyfert and H II region-like galaxies, confirming the importance of dust in the infrared-selected objects. There is a tendency for Seyfert LIGs to be less reddened than H II region-like and LINER-like LIGs. Irrespective of their infrared luminosities, the amount of reddening in the objects in the long-slit subsample generally decreases outward from the nucleus. This high degree of dust concentration is consistent with the compact distribution of molecular gas in many of these luminous infrared galaxies (e.g., Scoville et al. 1991). Interestingly, inverted reddening profiles in which the reddening in the center of the galaxy is less than outside of the nucleus occur more frequently among AGN-like objects than in H II region-like galaxies.

2.3. Density and Temperature

The average [S II] density in the nuclei of Seyfert 2 LIGs is significantly larger than in H II region-like galaxies, while LINER-like objects have intermediate values. Complex density variations are observed in all of the objects in the long-slit subsample. However, there is a weak trend for lower densities to be found at larger distances from the nucleus. The radial density *profiles* of AGN-like galaxies were not found to be different from those measured in H II region-like objects apart from the generally higher normalization factor mentioned above.

The [O III] $\lambda5007/\lambda4363$ temperature could be determined (estimated) in the nuclei of three (eight) H II region-like galaxies, eight (ten) Seyfert 2 galaxies, but in none of the LINER-like objects. These temperatures were found to be consistent with photoionization either by stars (for the galaxies classified as H II region-like) or by an active nucleus (for the Seyfert 2 LIGs). A study of the temperature gradients could be carried out for only two galaxies: the Seyfert 2 galaxy NGC 7679 and the H II/LINER-like galaxy IR2222-08. The temperatures measured in this second object were found to be considerably higher than in the Seyfert 2 galaxy, suggesting that shock ionization may be important in IR2222-08. The clear tendency in this object to measure higher temperatures at larger distances from the nucleus also suggests that shock ionization gradually becomes the dominant ionization process in the outer parts of the line-emitting region. A similar, though less significant positive temperature gradient is also observed in NGC 7679.

2.4. Kinematics

The [O III] $\lambda5007$ line was selected for line width measurements because it is strong in most LIGs and free of any nearby emission lines or absorption features (in contrast to Hα). The line widths do not correlate with infrared luminosity, but the average line width of both Seyfert and LINER-like LIGs is about twice the average line width of H II region-like LIGs (300 km s^{-1} versus 140 km s^{-1}). The spatial variations of the [O III] line widths were also examined in a dozen objects. The most remarkable result of this analysis is the general tendency for the line widths to reach a maximum *outside* of the nucleus. The highly non-Gaussian profiles found at intermediate radii in a number of these galaxies suggest that the larger line widths observed outside of the nucleus are produced by organized, large-scale bulk motion rather than by chaotic, turbulent motion. We speculate that the broad profiles outside of the nucleus are produced by (unresolved) line splitting where two or more emission-line components having different velocities are present. The broad profiles outside the nucleus of these objects are therefore interpreted as being the kinematic signature of large-scale bipolar outflows from the nucleus.

2.5. Stellar Population

The strength of the Mg Ib absorption feature is a good indicator of the presence of an old ($\gtrsim 10^9$ yr) stellar population. The median equivalent width of detected Mg Ib features in our sample of galaxies is ~ 1.3 Å, with the AGN-like galaxies (especially the LINER-like LIGs) having a stronger Mg Ib feature than the H II region-like objects. This result may imply that the stellar population in H II region-like LIGs is younger than in the AGN-like nuclei. However, all of these equivalent widths are considerably smaller than the equivalent widths observed in non-active spiral galaxies. Dilution of the old-star continuum by a featureless continuum produced by an AGN or by hot, young stars can explain this result. Measurements of this feature in the circumnuclear region indicate that Mg Ib remains faint outside of the nucleus. This result suggests that the

ource of dilution of the old stellar continuum is extended and, consequently, that circumnuclear starbursts are mportant contributors to the optical continuum in most of the objects in our subsample. Another explanation s that we are seeing the red supergiant phase of spatially extended, young starbursts (age $\sim 10^7$ yr). In this cenario, there is no need for an underlying old stellar population because the weak Mg Ib absorption feature s entirely produced by the red supergiants (Bica, Alloin, & Schmidt 1990).

The behavior of the Ca II triplet $\lambda\lambda$8498, 8542, 8662 also supports the existence of extended starburst ctivity in the few objects in which we could measure this feature. Complex, non-monotonic variations of the $H\beta$ absorption feature are observed in many objects of our sample. However, essentially all LIGs with Seyfert pectral characteristics present $H\beta$ equivalent widths which are smaller in the nucleus than in the circumnuclear egion. This is the strongest evidence from absorption line data that a featureless AGN continuum may be contributing to the optical continuum in the nuclei of Seyfert LIGs. The fact that the LINER-like LIGs in our sample do not show this behavior suggests that AGN continuum emission is not a major contributor to the optical continuum of these objects. This last statement is based on a few objects so it is uncertain.

2.6. Radio Data

The effects of dust extinction in LIGs were further investigated by comparing the 20-cm continuum fluxes to reddening-corrected $H\alpha$ fluxes for most of the objects in our sample. We found that the radio-$H\alpha$ ratio is two orders of magnitude larger than the thermal value expected from a 10 000 K extinction-free gas, with LINER-like objects showing the larger excesses. The large values of this ratio are probably due to a combination of two effects: (1) most likely, the amount of reddening determined from optical emission lines are underestimates of the actual amount of dust, and (2) non-thermal radio processes associated with supernova explosions and their remnants, shock ionization, or directly related to the central AGN are present in the cores of these objects. One or both of these effects is affecting LINER-like objects more than the other LIGs.

2.7. Morphology

As in previous studies, we find a strong correlation between infrared luminosity and the phase of the merger. A weaker but significant correlation is also observed between spectral types and interaction class in the sense that AGN-like objects and especially Seyfert 2 galaxies are more advanced merger systems than H II region-like objects. This result is to be expected since the proportions of AGN-like objects and Seyfert 2 galaxies increase with infrared luminosity. We also searched for any variations in the [O III] λ5007 line widths as a function of the stage of interaction. No significant trend was observed. Finally, we calculated the average equivalent width of the $H\alpha$ emission line as a function of the interaction phase, and found a clear tendency for more advanced mergers to have larger equivalent widths. A similar result was obtained by Keel et al. (1985) in an optically-selected sample of galaxies.

3. DISCUSSION

3.1. Energy Sources

An important distinction should first be made between the source of energy responsible for ionizing the line-emitting gas in LIGs (thereafter called the source of ionization) and the source of energy powering the quasar-like bolometric luminosities and violent outflows observed in some of these objects. It can be shown that the fraction of the total energy produced by LIGs which is used in ionizing the line-emitting gas observed at optical wavelengths is relatively small ($\lesssim 10\%$). In the present section, we will first address the issue of the nature of the ionization source in LIGs and then attempt to provide further constraints on the more difficult question of the origin of the large bolometric luminosity in these objects.

There is very little question that the main source of ionization in LIGs with H II region-like spectra is photoionization by hot O – B stars. The debate has centered in the past on the ionization process in AGN-like objects and more particularly the galaxies with LINER-like spectra. A considerable amount of work over the last ten years has been devoted to this issue (see Heckman 1987 and Filippenko 1989 for reviews). The nebulae of most LIGs are entities which are morphologically irregular as a result of galactic encounters and/or the interaction of nuclear outflowing gas with the circumnuclear region. LINER-like emission associated with shock ionization is a natural consequence of such violent processes. In this scenario, the kinetic energy involved in the large relative gas motion is efficiently thermalized via shocks, producing very hot ($T \sim 10^6 - 10^7$ K) gas at

the interface of the interaction. LINER-like emission is produced in the 10^4 – 10^5 K post-shock gas or in gas photoionized by dilute bremmstrahlung radiation emitted by the hot gas phase. In either case, the LINER-like emission is expected to be produced from a region which is spatially extended, as was indeed observed in many of the nearby LIGs of our sample and in the sample of HAM90. Moreover, LINER-like emission was found to be particularly frequent in advanced mergers and in objects with broad emission-line profiles. The high values of 20-cm to Hα flux ratio in LINER-like LIGs can be explained in the context of shock ionization through an abundant production of relativistic electrons. However, the complex radial variations of the line ratios and strengths of the stellar absorption features described in §2 strongly suggest that both photoionization and shock ionization are taking place in many of these objects. Indeed, based on energy arguments, HAM90 have shown that shock ionization cannot be responsible for *all* of the line emission in LIGs.

Seyfert-like emission is considerably more difficult to produce from shock ionization than LINER-like emission as a very restrictive range of shock conditions are needed to produce such high-excitation spectrum (e.g., Binette, Dopita, & Tuohy 1985; Innes 1992). Shock ionization is thus unlikely to be the dominant ionization process in Seyfert-like LIGs. Photoionization by a genuine AGN or by a cluster of unusually hot stars ("warmers"; Phases 2 and 3 in the scenario of Terlevich 1992) appear equally capable of producing the line emission in these objects.

The importance of starbursts in LIGs can be estimated by comparing the predictions of the starburst model with some of the results from our sample. We choose this method of reasoning rather than comparing our results with the predictions of the AGN model because we feel that the relationship between the various energy regimes of star formation (radio versus infrared versus optical) is better understood than in AGN. The ratio of the continuum luminosity at λ = 4860 Å, L(4861), to the infrared luminosity was calculated for all the objects in our sample. The continuum luminosity was defined as P(4861) × 4861 where P(4861) is the monochromatic power of the continuum at 4861 Å corrected for reddening using the emission-line Balmer decrement. We find that the average values of log $L(4861)/L_{ir}$ for H II region-like, LINER-like, and Seyfert-like galaxies are all about the same (-0.74, -0.82, and -0.70, respectively) but that the scatter among Seyfert-like LIGs is nearly twice as large as among the other two classes of objects. These results suggest that the source of continuum in some of these Seyfert galaxies is different from H II region-like and LINER-like LIGs, and that most LINER-like LIGs are more directly related to the H II region-like objects than to the Seyfert galaxies (as suggested above). Based on the results of Rice et al. (1988) and others, $L_{ir}/L_{bol} \gtrsim 0.5$ and therefore the continuum luminosity, L(4861), is $\sim$ 5% of the bolometric luminosity. This ratio can be compared with the theoretical predictions of Wise (1985) in the case of a young (10^6 – 10^7 yr) starbursting stellar population: $L(4861)/L_{bol} \sim 10 - 20\%$. Thus, we find that up to 50% of the bolometric luminosity of the LIGs in our sample could be powered by the starburst if all of the optical continuum is indeed produced by young stars. Note that underestimates in the reddening corrections of the optical continuum would increase this value. On the other hand, the infrared luminosity of some of the Seyfert-like LIGs may be less than 50% of the total bolometric luminosity, and part of the optical continuum may be produced by an old stellar population or, in some Seyfert LIGs, a power-law AGN continuum.

In the "pure" starburst model, the infrared, radio, and Hα luminosities are measures of the star formation rates in the galaxies. The star formation rates derived from these methods are 0.1 – 500 $M_\odot$ yr^{-1}, where the larger values correspond to the ultraluminous infrared galaxies. In these objects, the entire interstellar medium would be transformed into massive stars in only $\sim 10^8$ yr. These results suggest that an AGN is responsible for at least some of the energy produced in the core of the more luminous infrared galaxies.

3.2. Evidence for Outflows in Luminous Infrared Galaxies

There is strong evidence that violent outflow is present in at least some of the objects in our sample. Nuclear line widths larger than 600 km s^{-1} are frequently observed in LIGs. Most of the objects presenting such broad profiles have an AGN-like emission-line spectrum. Line widths of this magnitude cannot be easily explained by smearing of a normal rotation curve across the nuclear aperture or broadening effects related to the nuclear stellar velocity dispersion. A non-gravitational origin to the broad profiles is favored. Other, perhaps more convincing evidence for non-gravitational motion in the LIGs of our sample comes from the presence of broader profiles outside of the nucleus in most of the galaxies. These results suggest that some of the line-emitting gas in these galaxies is being accelerated outward. This outflowing component is likely to interact with the ambient material of the host galaxy or with the slow-moving gas of a previous outflow event; extended LINER-like emission might result from this interaction. The positive temperature gradient found in the two galaxies with [O III] λ4363 strong enough to be measured outside of the nucleus also supports the possibility that shock

onization is important outside of the nucleus of some of these objects. Finally, the presence of inverted dust profiles in a few of these objects is also consistent with the scenario in which the dust in the nuclear region of these objects has been ejected in a violent outflow event along with the gas component. Note, however, that such nuclear dust deficit can also be explained by dust *destruction* in the nucleus or by complex optical depth effects (Leech et al. 1989; Keel 1992).

3.3. Origin and Evolution

The results from the present study emphasize once again the importance of galactic interactions in LIGs. Previous studies have also found that the nuclear concentration of the molecular gas and the infrared luminosity per unit H_2 mass is larger for the more luminous objects and the more advanced merger systems (e.g., Sanders, Scoville, & Soifer 1991). N-body simulations show that such a high nuclear concentration of molecular gas is a natural consequence of the merger of two late-type spiral galaxies (e.g., Barnes & Hernquist 1991). However, these models have difficulties predicting the subsequent evolution of this gas concentration. Star formation (not included in the N-body simulations) is undoubtedly important in the central region of the merger. Such a nuclear starburst may disrupt the gas phase of the merger through deposition of a large amount of mechanical energy by supernovae and stellar winds. On the other hand, if the gas concentration becomes sufficiently dense to be self-gravitating, fragmentation and instability can lead to further radial inflow. In these circumstances, the physical conditions become favorable to the formation of a central massive black hole (MBH) or to the fueling of a pre-existing black hole. An active nucleus results, further disrupting the surrounding gas through its intense radiation field, x-ray heated wind, and possible radio jets (Begelman, McKee, & Shields 1983; Begelman, Blandford, & Rees 1984).

The high frequency of AGN-like galaxies among advanced merger systems is indeed consistent with the formation of an active nucleus in LIGs. On the other hand, the presence of AGN-like galaxies in loosely interacting systems suggests that the formation of a MBH may precede the *present* phase of merger formation in at least a few systems. However, this scenario does not exclude the possibility that the preexisting MBH was formed at an earlier epoch by a galaxy encounter. Tidal forces induced by the present galaxy interaction may be responsible for reactivating these black holes before the final merger phase.

A few other results support an evolutionary sequence in which H II region-like LIGs evolve into AGN/QSOs: (1) The amount of dust derived from the emission-line Balmer decrement is observed to be smaller in the nucleus of Seyfert LIGs than in H II region-like objects. Nearly all the objects which present a larger dust content outside of the nucleus than in the nucleus have AGN-like optical spectra. Although the optical method used in the present study is likely to underestimate the actual dust content of these galaxies (Leech et al. 1989; Keel 1992), this result is consistent with Seyfert LIGs being at a more advanced stage of dust destruction than H II region-like galaxies. (2) Another indication that AGN-like LIGs may be at a more advanced stage of evolution than H II region-like LIGs is the presence of stronger Mg Ib and Hβ absorption features in the first class of objects. These features indicate that the optical continuum of AGN-like LIGs is produced in part by an old (10^8 – 10^9 yr) stellar population which is either not present in H II region-like LIGs or is being swamped by a younger starburst. Note, however, that this effect is stronger among AGN-like LIGs with LINER characteristics. These objects were found to have a larger dust content that any other classes of LIGs (§2.2), and may not be powered by a genuine AGN (§3.1). Differences in the strength of the absorption features may thus be an indication of the time elapsed since the last starburst rather than the stage of dust destruction in the nucleus.

4. SUMMARY

A spectroscopic survey of a sample of more than 200 IRAS galaxies was carried out. Great care was taken in classifying the nuclear spectra of all these galaxies as "HII region-like" or "AGN-like" using a large number of line-ratio diagnostics corrected for the underlying stellar absorption features. We find that AGN-like galaxies are more common among the more luminous infrared galaxies, and that the fraction of Seyferts among the AGN-like objects also increases with infrared luminosity. In contrast, the fraction of LINER-like objects remains relatively constant at $\sim$ 25 %. The ionization mechanism responsible for the line emission sometimes changes with distance from the nucleus. The emission-line, absorption-line, and continuum properties of the gas outside of the nuclei of LIGs strongly suggest that circumnuclear starburst activity is common among LIGs, regardless of their nuclear spectral types.

The [O III] profiles of both Seyfert and LINER-like LIGs were found to be considerably broader on average than the H II region-like objects. We find that most of the galaxies in which we could determine the radial

variations of the [O III] line widths present broader profiles in the circumnuclear region than at the nucleus. These results suggest that large-scale nuclear winds are common in these objects and are an efficient way of getting rid of the obscuring material in the nuclear region. The spatially extended LINER-like emission observed in many of these objects may be due to shock ionization resulting from the interaction of the wind-accelerated gas and the ambient gas. The nuclear regions of Seyfert LIGs was found to be somewhat less dusty than in H II region-like objects. Although the dust distribution generally is concentrated towards the nucleus, inverted dust profiles in which the nucleus appears less dusty than the circumnuclear region are observed more frequently among AGN-like LIGs. Galaxies with Seyfert emission lines may therefore be at a more advanced stage of dust destruction/expulsion than H II region-like LIGs. The slightly stronger Hβ and Mg Ib absorption features found in the nuclei of AGN-like objects may also indicate that these objects are at a more advanced stage of evolution than H II region-like LIGs. Further support for this scenario comes from the fact that AGN-like objects are found more frequently in advanced mergers than H II region-like galaxies. However, this last result may be a luminosity effect rather than an effect related to the dominant nuclear source of ionization.

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