THE FIR EMISSION AND [CII] IN LINERS

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Abstract

LINERs galaxies have been considered as the low level end of the family of Active Galactic Nuclei (AGNs). But a lack of consensus does still exist on the nature of these galaxies. Some of them show clear evidences for an AGN nature whereas data at different frequencies seem to support an Starburst origin as the responsible of their observed properties.

The general properties at FIR of LINERs have not been properly studied. Among the LINERs reported in the multifrequency catalogue by Carrillo, Masegosa et al. (1999) 335 have been observed with IRAS. In this paper we present a preliminary analysis of these data. The most relevant result obtained so far is that the 12 microns emission is associated with the cold disk dust emission. The ISO database have been used to search for all the LINERs observed with the Long Wavelength Spectrograph looking for C^+ detections. In 27 galaxies out of the 69 LINERs observed with ISO the [CII]λ 158 μm has been measured. The main conclussion from this analysis is that C^+ is not related to the recent star formation events but instead it seems to be associated to the PDRs in giant molecular clouds.

Key words: Galaxies: star formation: activity: LINERs – Missions: FIRST

1. Introduction

Within the framework on Active Galactic Nuclei (AGNs), LINERs are not well understood systems and still some controversial aspects on their nature need to be solved. Since their discovery by Heckman (1980) who pointed out their possible relation to Seyfert-like galaxies, a large amount of work has been devoted to analize the origin of their nuclear spectrum. The most popular interpretation is that shock heating mechanism is the main source of the ionization observed. But the discovery of broad emission lines in some of them (Filippenko and Halpern 1984) lead to suggest photoionization by a power law in a high density medium. After the work by Filippenko and Terlevich (1992) pointing out that LINER spectrum can be produced by stellar photoionization, a strong debate started again between the shock and photoionization explanations.

New data from HST (Maoz et al. 1998) have increased our knowledge into their physical nature. Their UV spectra seem to be more consistent with the starburst explanation than with a non-thermal nature. Also the lack of detection of UV source on most of the objects searched for, casts doubt about the AGN nature of most LINERs. Different explanations have been explored like an obscured AGN (Ho 1999), a duty cycle line variability in the UV source (Eracleous, Livio and Binette 1995) or soft X-ray ionization from an AGN (Binette et al. 1996). It is worthwhile pointing out that most of the work developed so far has been concentrated on optical selected samples. In particular the nature of the LINERs selected galaxies among the IR high luminosity galaxies ($\sim$ 38%) studied on Kim's thesis has been overlooked. Their results (Kim et al. 1995; Kim and Sanders 1998; Veilleux et al. 1999) suggest that the nature of the ionization mechanism is of stellar origin and/or shock heated but not strong evidences seem to support an AGN nature.

Due to all this controversial aspects and the importance of these systems for galaxy evolution studies (between 20-30% of the spiral nuclei have LINER characterictics) we started a project on these rather enigmatic objects. A multifrequency catalogue of all the known LINERs has been already published (Carrillo, Masegosa et al. 1999). ISO observations on a large amount of LINERs offer the oportunity to tackle with most of the open questions. Here we repport the IR properties from IRAS bands and the preliminary analysis of C^+ line on all the LINERs observed by ISO.

2. Infrared Properties of LINERs galaxies

Among the 496 data in the Carrillo et al. recopilation, 335 LINERs were detected with the IRAS satelite. Figures 1 and 2 show the relations between the main IRAS bands normalized to the total IR luminosity (as calculated by Kim and Sanders 1998). The most remarkable result from such analysis is the excelent correlation found between L_{12}/L_{IR} and L_{60}/L_{IR} ratios (Fig. 1). No correlation has been found between L_{12}/L_{IR} and both L_{25}/L_{IR} or L_{100}/L_{IR}. L_{25}/L_{IR} and L_{60}/L_{IR} seem to be well correlated also with L_{100}/L_{IR} (see Fig. 2). In Figure 3 the correlations between 25/100 and 12/60 against 60/100 are

Proc. Symposium *'The Promise of the Herschel Space Observatory'* 12–15 December 2000, Toledo, Spain
ESA SP-460, July 2001, eds. G.L. Pilbratt, J. Cernicharo, A.M. Heras, T. Prusti, & R. Harris

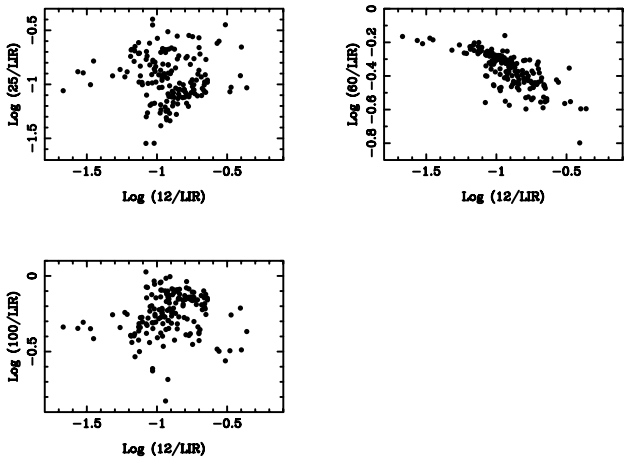

Figure 1. Correlations between normalized IRAS fluxes at 25, 60 and 100μm and the normalized flux at 12μm for the LINERs sample in Carrillo, Masegosa et al. 1999.

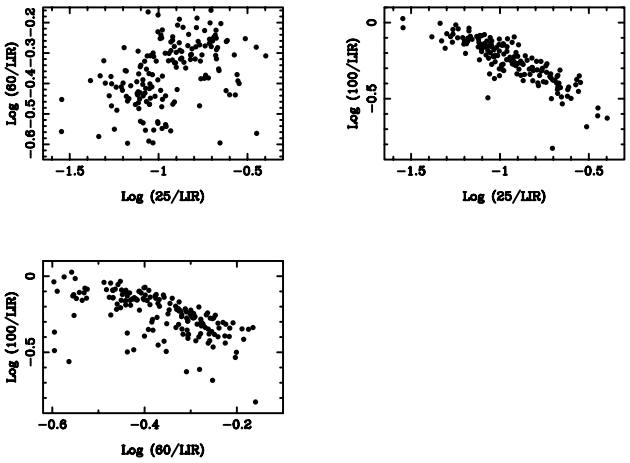

Figure 2. Correlations between normalized IRAS fluxes at 60 and 100μm versus the normalized flux at 25μm, and between the normalized fluxes at 100 versus 60μm, for the LINERs sample in Carrillo, Masegosa et al. 1999.

presented. The large majority of the data show a 25/100 ratio typical of non very active phenomenon, overlapping with systems in which the actual process of star formation in the galaxy is not in a very active phase (Dultzin-Hacyan, Masegosa and Moles 1990).

In this paper we only discuss data for which the complementary ISO information has been obtained (see next Section). A full analysis will be presented in a separate paper (Masegosa et al. 2001, in preparation). Three galaxies (NGC 1052, NGC 4278 and IC 1459) present very large values, typical of what it has been found in Seyfert galaxies (Dultzin-Hacyan, Moles and Masegosa 1988). Taken a typical value for normal (non-active) spiral galaxies between 0.025 and 0.04, only 4 galaxies present such low values (NGC 7217, NGC 6286, NGC 5005 and NGC 4651). Therefore the first conclusion from the IR properties of LINERs is that the bulk of the FIR emission is produced by a star formation process. Only for 3 objects out of 27 we found clear evidences for an AGN origin for the emission at 25μm. The estimated dust temperatures for the galaxies are between 20 and 50 K. This result is compatible with the classical diagram FIR/B vs 60/100. LINERs tend to fill the region determined for the normal galaxies with a slight overlap with Star Forming Galaxies.

A more striking result is the tight correlation between 12/60 and 60/100 ratio (the correlation coefficient amounts to 0.78 with an rms for the residuals of 0.07). An enhancement in the 12/60 ratio is observed when 60/100 decreases. Since the origin of the 60μm flux is attributed to the starburst component and 100μm to the cold dust associated with the cirrus component coming from the extended disks, then it appears that 12μm becomes more important when the starburst component decreases. 12μm emission has been attributed as due to the emission of PAH molecules; then it appears that PAH and cold dust should be spatially correlated. This result is at variance with what has been claimed that PAH appears in strong radiation fields (Thuan et al. 1999).

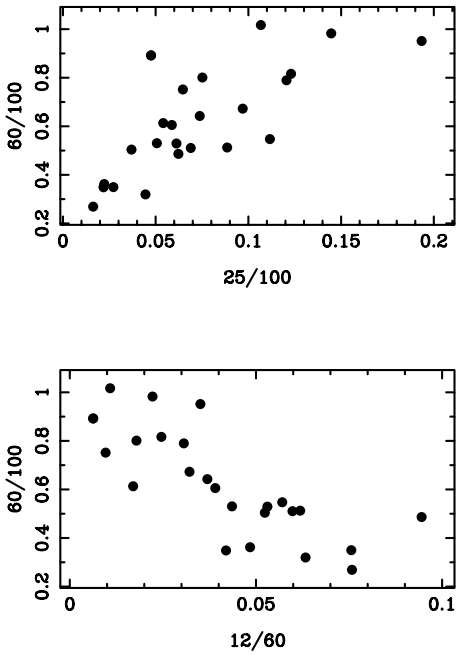

Figure 3. Correlations between IRAS colors for the LINERs with ISO data on [CII].

3. The origin of [CII]

By using as starting point the recopilation sample by Carrillo, Masegosa et al. (1999), we have selected all the galaxies observed by ISO, using the archive data. Among the 479 objects searched for, 158 have been observed with the different instrumental ISO capabilities. From them only 78

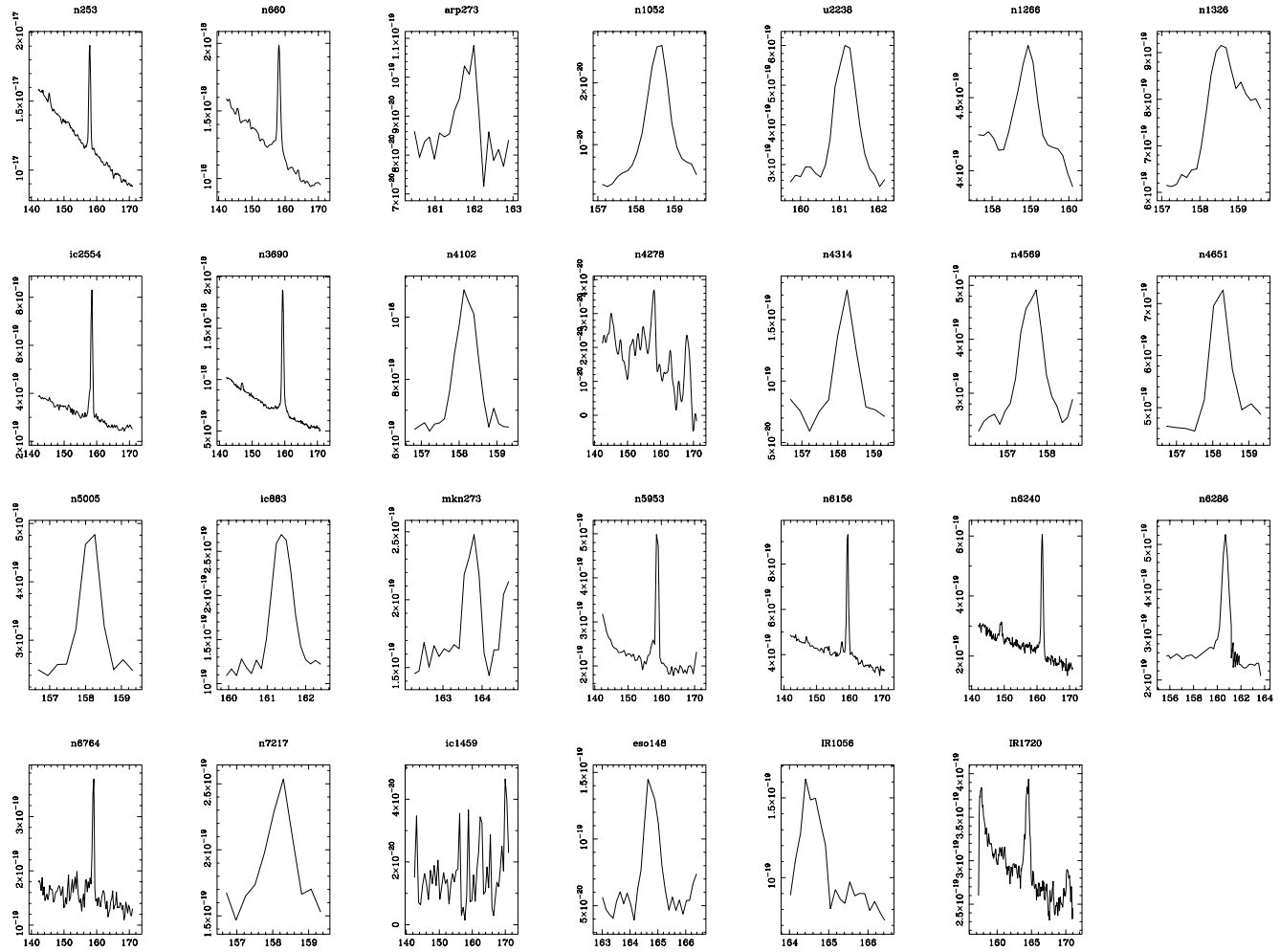

Figure 4. Spectra showing the [CII]158μm emission line for the 27 LINERs in Carrillo, Masegosa et al. 1999 with such information available in ISO archive data. The flux in W cm^{-2} is represented as a function of λ in μm.

have spectral information obtained with the LWS and/or SWS. Here we only report the data taken with the LWS (Clegg et al. 1996). 27 out of 69 present good data for the [CII]λ 157μm line. Figure 4 shows the measured [CII] line for these objects.

The C^+ luminosity has been normalized to the total IR luminosity and for LINERs represents a 0.3% at most of the total IR luminosity for these galaxies, very close to the values quoted by Stacey et al. (1991) and Malhotra et al. (1997) for normal spiral galaxies. The most interesting result obtained (see Figure 5) is that it is only related to the 12μm emission. Therefore [CII] is not associated to very intense regions of star formation, instead it should appear to be related to regions where PAH molecules come from. These regions are broadly accepted to be responsible for the 12μm emission observed with IRAS. This result appears to be in good agreement with the recent finding by Helou et al. (2000) applying a new normalization of the Malhotra et al. (1997) diagram to the Aromatic Feature Emission. On the other hand the lack of any type of correlation with the nuclear Hα emission supports the view that [CII] is not associated with strong recent starbursts.

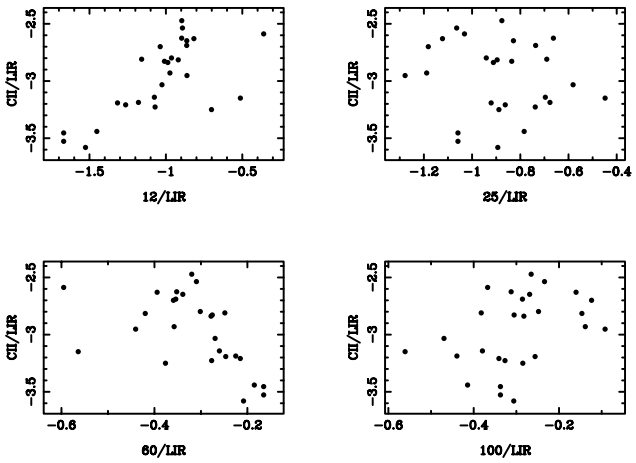

Figure 5. Correlations between [CII] flux and IRAS fluxes (normalized to the total FIR emission).

In Figure 6 we present the [CII]/IR ratio against CO/IR ratio for the 17 galaxies with CO observations reported in the literature. A clear trend is detected between both quantities, supporting the hypothesis that [CII] comes from the PDR associated to giant molecular clouds in LINERs. Higher spatial resolution would be desirable to disantangle the origin of [CII] in various types of galaxies. The lack of spatial resolution of LWS allows only to speculate on the nature of [CII] in galaxies hosting different types of activity (Bergvall et al. 2000; Masegosa et al. 2001, in preparation) but not definite conclusions can be drawn based on these data.

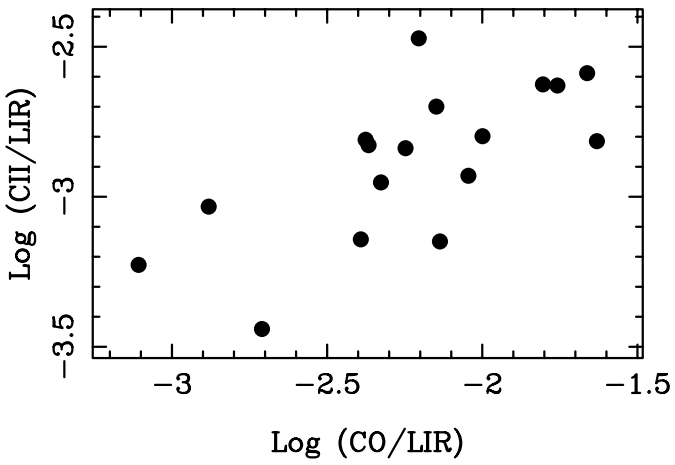

Figure 6. [CII] versus CO luminosities (normalized to the total IR luminosity) for the 17 LINERs galaxies with such data in our sample.

Acknowledgements

I.M. and J.M. acknowledge financial support from the Spanish Ministerio de Educación y Cultura (ESP98-1351) and Junta de Andalucía TIC-114. This paper is based on observations with ISO, an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA. The ISO Spectral Analysis Package (ISAP) is a joint development by the LWS and SWS Instrument Teams and Data Centers. Contributing institutes are CESR, IAS, IPAC, MPE, RAL and SRON.

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