The X-ray properties of luminous infrared galaxies and their contribution to the X-ray background

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Abstract. We present a study of the sample of luminous infrared galaxies (LIGs, \( L_{\text{IR}} > 10^{11} L_\odot \)) observed in the hard (2-10 keV) X rays. The main results are: 1) most LIGs are powered both by AGN and starburst activity; 2) the AGNs in our sample are absorbed in the infrared by a lower \( N_H \) than in the X-rays or, alternatively, the dust-to-gas ratio is lower than galactic; 3) the study of a subsample of sources observed in the 20-200 keV band indicates that most of the AGNs hosted by the LIGs are heavily obscured up to 100 keV and, therefore, their contribution to the X-ray background must be small.

1 Introduction

The Luminous Infrared Galaxies (LIGs) are a class of objects characterized by high infrared luminosities (\( L_{\text{IR}} > 10^{11} \) erg s\(^{-1}\)). Both AGNs and starbursts can power LIGs, but the relative contribution of these two energy sources to the bolometric luminosity is still unclear.

X-ray observations in the hard (2-10 keV) band can be a powerful tool to unveil the AGN emission in the LIGs and to estimate its contribution to the total luminosity. It is at present impossible to analyze a representative LIGs sample in the 2-10 keV band, because the hard X-ray observations performed up to now are strongly biased in favor of AGN-dominated sources. Nevertheless, a significant number of IR-selected LIGs with X-ray observations is now available both in the literature and in public archives, and therefore a comparison between the X-ray properties of AGN-dominated and IR-selected LIGs is possible. We collected the data of all the luminous infrared galaxies observed so far in hard X-rays and studied their X-ray emission and the correlation between their X-ray and infrared properties.

2 X–ray and IR properties of the sample

The X-ray properties of our sample of objects are very heterogeneous both in terms of brightness and spectral shape. Most of the objects optically classified as type 1 Sys or QSOs are characterized by bright X-ray emission (relative to the IR luminosity) and their X-ray spectrum does not show indications for significant
cold absorption. A significant fraction of the narrow line AGNs are also relatively bright in the X-rays and their spectrum is characterized by a photoelectric cutoff ascribed to Compton thin absorbing gas ($N_H < 10^{24}\text{cm}^{-2}$). The remaining objects optically classified as AGNs are very weak in the X-rays. This can be due to the intrinsic weakness of the AGN component or to an absorbing column density higher than $10^{24}\text{cm}^{-2}$ (Compton thick AGNs). Finally, a few objects are optically classified as starbursts and are all very weak in the X rays. In Fig. 1 we plot the X/IR flux ratio versus the infrared colour defined as $C_{\text{IR}} = 2 \times \frac{f_{25}}{f_{60}}$, where $f_{25}$ and $f_{60}$ are the flux densities at 25 $\mu$m and at 60$\mu$m. A clear correlation is apparent in Fig. 1: type 1 AGNs are preferentially in the high X/IR ratio and warm infrared colour part of the diagram. Moving towards lower 25/60$\mu$m ratios we find lower X/IR ratios and an increasing fraction of obscured AGNs at first, and of starbursts afterwards.
A simple model in agreement with this correlation is shown in Fig. 2: starting from a “pure Seyfert 1” point, at the top-right corner in the plot, the oblique rightmost (light) line gives the expected location of AGN-dominated objects, with an increasing X-ray absorbing column density moving toward the bottom. The dotted (dark) curves give different degrees of mixing of starburst and AGN, with the AGN contribution lowering moving to the left.

In this model the absorption suffered by the IR radiation is only a small fraction of that inferred from the X-ray column density by assuming a standard dust-to-gas ratio. Indeed, we find that there is no way to explain the correlation if we assume that (1) the same amount of material obscures both the X-rays and the infrared and that (2) the dust-to-gas ratio is galactic. This is because if none out of the two hypothesis above are relaxed, the absorbed model gives a pure-AGN curve that is almost horizontal, because the IR colour decreases too fast with respect to the X/IR flux ratio. A simple explanation for the difference between the absorption in the IR and in the X-rays can be the following: if the density in the circumnuclear torus decreases radially, the X-rays, emitted in the very central region, are much more absorbed than the 25µm radiation, emitted by the warm dust located along the inner face of the torus, far from the plane of the accretion disk.

Besides the optical classification, the simple picture depicted above is sup-
ported by additional pieces of evidence: 1) broad lines in the polarized spectrum or in the near IR are found only in type 2 objects with warm IR colour, that, according to our model, are the AGN-dominated LIGs; 2) the large majority of the IR-cold sources have steep (starburst-like) X-ray indices while IR-warm sources have flatter (AGN-like) indices. For a more detailed discussion about these issues, we remind to a forthcoming paper [3].

3 The 20-200 keV emission of LIGs

Our sample includes a subsample of 13 sources optically classified as type 2 AGNs and observed by BeppoSAX up to 200 keV. 6 out of the 11 sources that are Compton–thick in the 2-10 keV range are completely absorbed also in the 10 to 200 keV band, therefore implying a column density \( N_H > 10^{25} \text{ cm}^{-2} \). Only two of the 11 Compton thick sources have an excess in the 15-100 keV range, while for the remaining three the hard 15-100 keV X-ray emission is unconstrained. The shortage of objects with \( 10^{23} \text{ cm}^{-2} < N_H < 10^{25} \text{ cm}^{-2} \) already pointed out in a sample of optically selected Seyfert 2s [2], would have important consequences in the synthesis models of the X-ray background, since this class of Sy2 should contribute significantly to the XRB in the 10 keV to 200 keV band, where most of the XRB energy is emitted. These models are by and large successful in synthesizing the XRB from the contributions of individual AGNs; they must however include a dominant contribution from absorbed, type 2 AGNs, which up to now have been observed only at low redshifts and low luminosities. Assuming that type 1 and type 2 AGNs evolve in the same way (as predicted by unified models), the zero-th order extrapolation has to face several discrepancies, and could be cured only by adding extra type 2 sources at intermediate or high redshifts [1]. It has been proposed that LIGs could be the required additional sources, thanks to their high luminosity and high spatial density. However, our work indicates that even those sources in which the presence of a luminous AGN is strongly supported by several optical and IR indicators, are on average very dim in the hard X-rays up to 100 keV, because of heavy obscuration. Therefore, the contribution of this class of sources to the XRB is negligible.

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References

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