Study of ISM tracers in galaxies

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Abstract. We collected data for two samples of normal and interacting galaxies for a total of 2953 galaxies having fluxes in one or more of the following wavebands: FIR, 21 cm line, CO(1-0) lines and soft X-ray. The large set of data obtained allowed us to revisit some of the already known relations between the different tracers of the interstellar medium (ISM), such as the link between the FIR flux and the CO line emission, the relation between X-ray emission and the blue or FIR luminosity. The relation lacking from observations for early-type galaxies has been discussed and explained in detail in the frame of a suitable theoretical model, obtained by coupling chemo-dynamical N-body simulations with a dusty spectrophotometric code of population synthesis.

1. Introduction

Some relationships between the various phases of the interstellar gas and between gas, dust, and stars have been studied since many years, such as the one between CO and far-infrared (FIR); on the other side some relations, connected with X-ray emission, have been studied only recently. Using data presented in the literature and our catalogues of normal and interacting galaxies (Bettoni et al. 2003; Casasola et al. 2004), we have collected data on fluxes in the 60, 100 µm, CO(1-0) lines, and in the soft X-ray band. This set of data allowed us to study and extend the relations between different tracers of the ISM in galaxies of various morphological types (from E to Irr), with different type of interaction (perturbed or normal galaxy) and activity (Seyfert 1, Seyfert 2, or Liners), as described in the following.

2. Cold gas and warm dust

Several authors (Sanders & Mirabel 1985; Solomon & Sage 1988; Bregman et al. 1992) found that the global galaxy luminosity derived from CO(1-0) line is directly related with the flux at 100 µm. The large set of data we used allowed us to more clearly redefine this relationship, and in particular we found that the relation, first obtained by Bregman et al. (1992) for early type galaxies, is also valid for late type galaxies. This link derives from the excitation of gas clouds by the currently forming stars and by the warming of the dust in the galaxy.
3. X-ray component

It is known that a proportionality exists between $L_X$ produced by discrete sources and $L_B$, the blue luminosity of the whole galaxy: late-type galaxies have a global X-ray luminosity directly proportional to $L_B$, while early-type systems are dominated by emission produced by hot diffuse gas, and their $L_X$ is proportional to the square power of the blue luminosity, as discussed by Beuing et al. (1999). For this reason, we studied the early and late-type galaxies separately.

Late-type galaxies In late-type galaxies (t$>$Sb) our data show the existence of a linear relation between soft X-ray fluxes and other indicators of recent and current star formation (B and FIR luminosity respectively). Fabbiano et al. (1992) have interpreted the link between B and X-ray luminosity in late type galaxies as due to the contribution of discrete X-ray sources, whose number is proportional to the quantity of already formed stars. The X-ray emission is also produced by HII regions, where there is an ongoing vigorous star formation, and its contribution appears more evident in FIR light and may explain the existence of the linear relation between $L_X$ and $L_{FIR}$.

Early-type galaxies Considering the relations involving X-ray emission for the early-type galaxies, the previous correlations become less evident, in particular between $L_X$ and $L_{FIR}$. To understand this apparent disagreement, we used recent chemo-dynamical models (see Piovan et al. 2006) coupled with dusty evolutionary population synthesis. The luminosities derived by the models seem to confirm our hypothesis about a connection between the exhaustion of the star formation and the “migration” of the early type galaxies toward lower $L_{FIR}$, moving the galaxy representative points above the linear relation in the $L_X$ vs $L_{FIR}$ diagram. In most of early-type galaxies of our sample, the mechanism of IR emission is no longer strictly related to the ongoing star formation and to the reprocessing of the radiation in the dense regions where new stars are born. The FIR emission therefore comes most likely from circumstellar dusty shells around AGB stars and from an interstellar diffuse medium due to the outflow of dusty gas from AGB and RGB stars.

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