Soft X-ray to FIR luminosities ratio in star-forming galaxies: Predictions from synthesis models

Héctor Otí Floranes & Jose Miguel Mas Hesse
LAEFF - INTA

ABSTRACT

The study of star formation in galaxies needs some basic tools, among which reliable SFR tracers are crucial ones. There exist already some calibrations for this magnitude that were obtained using different population synthesis models or that were derived relating such SFRs to luminosities at other wavelengths. We are presently revising the calibration of SFR tracers at different wavelength ranges using last generation synthesis codes. In this poster we present our preliminary analysis of the L_X to L_{FIR} ratio and compare it with the semi-empirical calibrations published in the literature.

One of the most common magnitudes used to characterize a starburst is the FIR luminosity, produced by the heated dust present in the star forming regions. The FIR luminosity is indeed a robust SFR tracer. Moreover, X-ray luminosity has been found to show a narrow correlation with FIR in these places, and therefore it has been proposed as an additional tracer of potential interest for high z galaxies, whose FIR emission is redshifted to the sub-mm radio range.

In this poster we present a preliminary analysis of the X-ray to FIR luminosities ratio obtained with the CMHK (Cerviño, Mas-Hesse & Kunth) population synthesis models, both for constant stellar formation and instantaneous bursts. The results are compared to some sample data taken from the literature and a calibration of the soft X-ray emission as an SFR tracer is obtained.

1 THE SYNTHESIS POPULATION MODELS

X-ray and FIR energies output from **CMHK synthesis population models** (Cerviño & Mas-Hesse 1994, Cerviño et al. 2002) were obtained in order to contrast them with real observational data. The main features from these models are:

• **IMF:** it follows a Salpeter profile ($\phi(m)=A\ m^{-\alpha}$), the mass varying within the range 2-120 M_{SUN}. Special care must be taken when comparing results from these models with other models which use different mass limits.

• **SFR:** extended bursts with constant star formation (**EB**) have been studied, as well as instantaneous bursts (**IB**).

• **Metallicity:** a solar metallicity is assumed in all cases.

• **Time:** we have studied short periods of intense star formation. The timescale used to study these starbursts is 30 Myr.

2 X- RAY LUMINOSITY

The **X-ray luminosity** is calculated in the 0.4-2.4 keV energy range. The sources which produce such emission are:

• Diffuse gas heated by the mechanical energy released into the ISM by stellar winds.

• Both the SNe explosions and their remnants.

These contributions are modeled by a composite Raymond-Smith thermal plasma at k_BT=0.23, 0.76 and 1.29 keV for the latter and a fixed temperature k_BT=0.5 keV for the former (Cerviño et al 2002). There is actually one free parameter ε_{eff}: the fraction of mechanical energy released that ends up heating the gas up to X-rays temperatures.

Some other X-ray radiation sources are ignored for this study:

• HMXBs: their contribution to the luminosity in this energy range is very small.

• LMXBs: they have not had time to form.

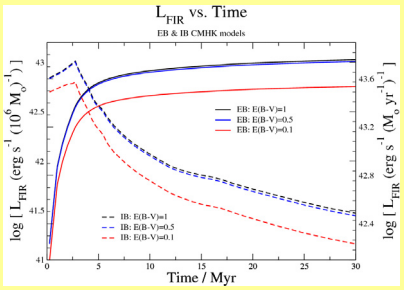
• Stellar emission: intrinsic X-ray luminosity from the stars is negligible in our case.

3 FIR LUMINOSITY

Concerning the **FIR luminosity**, a thermal equilibrium of dust is assumed, which implies all energy absorbed by dust being reemitted in the infrared range. The parameters present here are:

• **1-*f***: fraction of Lyman continuum absorbed by dust, assuming 1-*f* = 0.3.

• **E(B-V):** extinction produced by the dust. L_{FIR} saturates very rapidly for E(B-V) > 0.5, so E(B-V) = 1 can be considered an upper value and we will assume it hereafter.

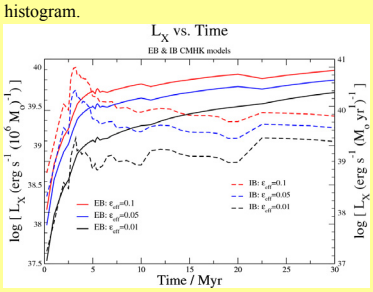


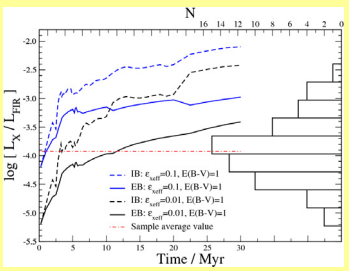
Completely obscured stars, whose radiation would be totally converted into FIR, are not considered.

Here, we show the L_{FIR} over time for both EB (scaled over SFR, right axis) and IB (scaled over the mass converted into stars, i.e. the total mass of the burst) models for various E(B-V) values. Once the most massive stars start to die, L_{FIR} decreases dramatically in the IB models. In the EB models these stars are replaced and therefore it approaches a steady state asymptotically.

4 L_{softX} AND L_{softX} TO L_{FIR} RATIO

In these graphs we present the evolution of the **X-ray luminosity** (the scaling is similar to the case of L_{FIR}) for different ε_{eff} values and the **ratio L_{softX}/L_{FIR}** of certain models which can reproduce the observational data (composed of three samples taken from the literature) represented by its total histogram.





L_{softX} in the IB models has a steeper increase at early ages whenever ε_{eff} value is assumed to be high and their L_{softX}/L_{FIR} value is about one order of magnitude larger than the ones from EB cases.

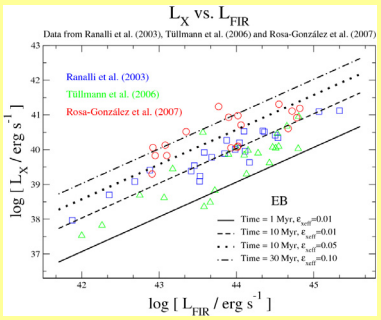
In the next section we will compare the ratios obtained with our models with those from the three observational data samples separately.

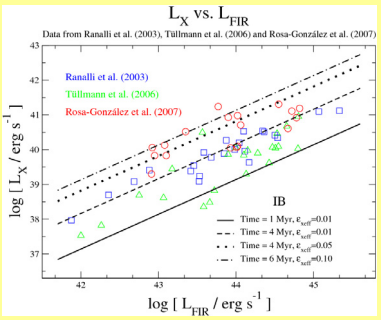
5 L_X TO FIR RATIO

Here we display the L_{softX} and L_{FIR} values from the data samples from Ranalli et al. (2003) (which we shall refer to as *Ran*), Tüllmann et al. (2006) (*Tul*) and Rosa-González et al. (2007) (*Rosag*) together with the predictions of our models for several values of ε_{eff}: 0.1, 0.05 and 0.01 at times 2, 10 and 30 Myr for EB and 2, 4 and 6 Myr for IB.

It can be seen in the plots that the observational data can be well reproduced by the synthesis models considering that the efficiency in conversion of mechanical energy is around 1-10%, a value which is consistent with previous studies. Moreover, our results show that the dispersion observed in the L_{softX} to L_{FIR} ratio can be explained as an **evolutionary effect**, i.e. using a standard value as standard SFR calibration can be misleading in some cases, and the effect of starburst evolution should be taken into account.

Therefore, we can infer from the results of our models that the sample from *Tul* is composed by younger bursts than *Ran* because early-time values tend to have a lower ratio L_{softX}/L_{FIR} - once a standard value for ε_{eff} is assumed.





N.B. 1: In order to construct our sample, we took the values from *Tul* for those sources also present in the sample of *Ran*. Also, we removed three sources from the sample from *Rosag*, which may harbour an AGN, and one whose main X-ray component comes from LMXBs.

N.B. 2: L_{softX} are measured in the 0.5-2 keV energy range for the sources from *Ran*, in 0.3-2 keV for those from *Tul* and in 0.2-2 keV for those from *Rosag*. Hence, using $L_{0.4\text{-}2.4\ keV}$ needs a correction, which given the Raymond-Smith model assumed, is negligible: $\delta(\log[L_{softX}/L_{FIR}]) < 0.05$.

L_{softX} dominates as time increases and therefore low values of ε_{eff} are needed if we want to obtain values consistent with those of the samples during the complete periods shown.

The effect of time is more acute in IB models, as can be seen

We can then extract the **calibration of SFR as a function of L_{softX}** purely from the L_{softX} values predicted by our models, which we will split into two according to the evolutionary status of the burst: evolved burst (in the asymptotic phase) and young burst (~10 Myr). Respectively,

$SFR(L_{softX})$ (M_{SUN} yr^{-1}) = $2\times10^{-41} L_{softX}$ (erg s^{-1})
$SFR(L_{softX})$ (M_{SUN} yr^{-1}) = $4\times10^{-40} L_{softX}$ (erg s^{-1})

The expression for unevolved bursts is in accordance with the empirical relation proposed by Ranalli et al. (2003) within the uncertainties of the models, once the latter is corrected for the IR range and IMF mass limits used.

Also, in the case of IB bursts we can write a similar expression for Star Formation Strength, i.e. the total mass transformed into stars since the onset of the burst:

$SFS(L_{softX})$ ($10^6 M_{SUN}$) = $5\times10^{-40} L_{softX}$ (erg s^{-1})

6 REFERENCES

• Cerviño, M. & Mas-Hesse, J. M., 1994, A&A, **284**, 749
• Cerviño, M., Mas-Hesse, J. M. & Kunth, D., 2002, A&A, **392**, 19
• Ranalli, P., Comastri, A. & Setti, G., 2003, A&A, **399**, 39
• Rosa-González, D. et al., A&A, MNRAS, **379**, 357
• Tüllmann, R. et al., 2006, A&A, **457**, 779

Address for correspondence: Héctor Otí Floranes otih@laeff.inta.es Tel: +34 91 813 11 94
Laboratorio de Astrofísica Espacial y Física Fundamental (LAEFF – INTA)
Apartado 78
28691 Villanueva de la Cañada, Madrid