RevMexAA (Serie de Conferencias), **9**, 283–285 (2000)

Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco

X-RAY EMISSION FROM STAR FORMING GALAXIES

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RESUMEN

En este trabajo hemos complementado nuestros modelos de síntesis evolutiva, que abarcan desde ondas de radio a rayos X, con códigos de fotoionización para investigar los efectos de la emisión X de galaxias "starburst" en las líneas de emisión del óptico.

ABSTRACT

In this work, we have linked our evolutionary synthesis models, covering the entire spectral range from radio to X-rays, with photoioniztion codes in order to investigate the effects of the X-ray emission from starburst galaxies on the optical emission lines.

Key Words: **GALAXIES: STARBURST — GALAXIES: STELLAR CONTENT — X-RAYS: GALAXIES**

1. EVOLUTIVE SYNTHESIS MODELS

Our models, which include the evolution of single and binary stars, have been discussed elsewhere (Cerviño & Mas-Hesse 1994, hereafter CMH; and Cerviño & Mas-Hesse 2000), and we refer the reader to them for more details. Here we present the predictions corresponding to the emission line spectra when the X-ray continuum is taken into account in photoionization models. The complete set of models can be found at the web address `http://laeff.esa.es/~mcs/model`.

The main feature of our work is the inclusion of the X-ray domain (up to 20 keV) in the multiwavelength energy distribution. The basic components of the X-ray emission included in the code are:

- *Mechanical energy* released by SN and stellar winds in the ISM, which is partially reprocessed to thermal soft X-rays.

- *Supernova remnants*, which have been assumed to generate two components with a composite Raymond-Smith spectrum.

- *High mass X-ray binaries*, with circular orbits (i.e., giant or supergiant stars) and stellar wind accretion onto a compact object, producing hard black body emission.

The most important parameter for the X-ray emission is the efficiency of the conversion of the kinetic energy to X-rays. This parameter is basically undetermined, although it must be correlated with the evolution of the ISM in a star forming region. Figure 1 shows the evolution of the number of ionizing photons, Q, in the energy ranges from 1.8 − 4 Ryg and 4 − 20 Ryg. The effect of different efficiencies for the conversion of kinetic energy is very important in the 4 − 20 Ryg region of the ionizing continua.

Our models assume that the spectra from WR stars are similar to an O V star with the corresponding spectral type (or O3 V star for the hotter WR in the synthetic cluster). More realistic treatments can found in the works of Stasińska and Luridiana et al. in these proceedings. Also, we do not take into account the effects of shocks in the ISM.

[1] Supported by an ESA fellowship.

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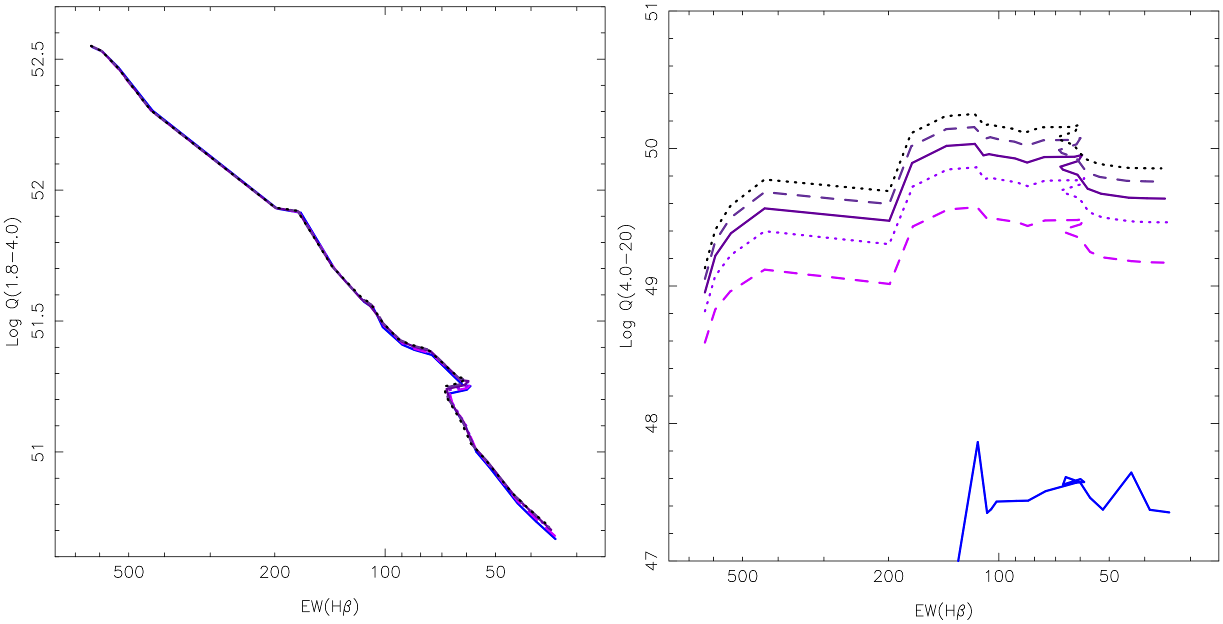

Fig. 1. Evolution of the ionizing continuum in different energy ranges. Lower solid line: including only the SNR contribution. Upper dotted line: assuming 100% of kinetic energy released in X-rays.

The resulting spectra have been used as input to the photoionization code *CLOUDY* (by Ferland) in order to obtain their influence on the emission lines of the optical spectra. We assume a very simple geometry (spherical radiation bounded clouds with constant density, $\log n_H = 1.5$).

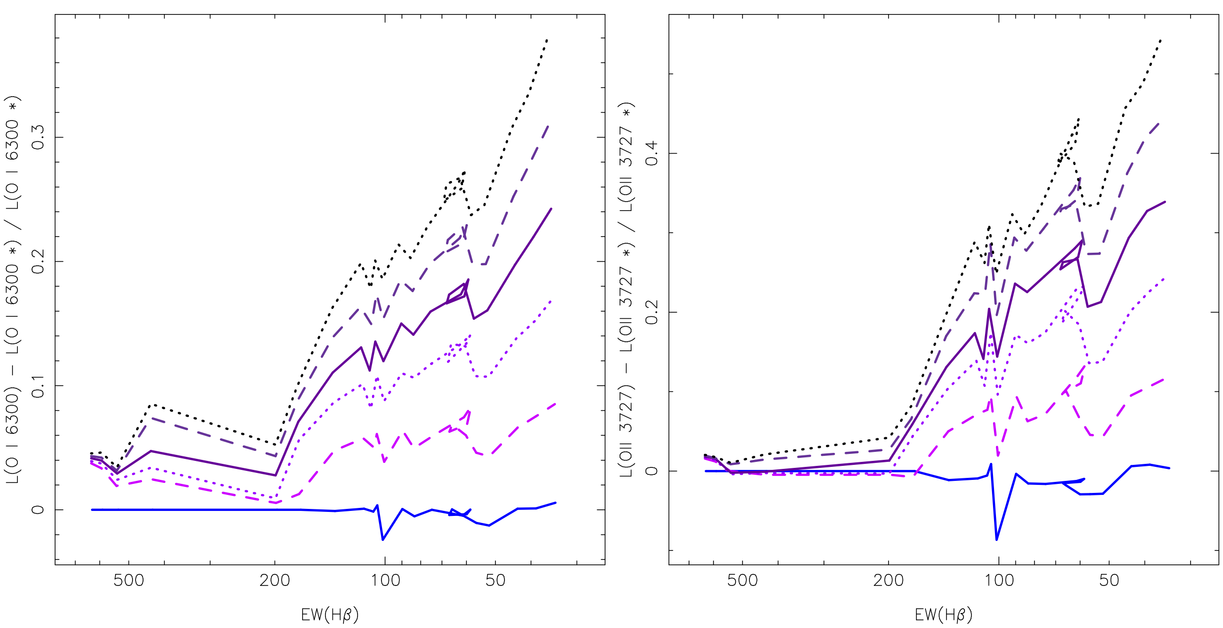

Fig. 2. Evolution of the variation of some nebular lines for different amounts of kinetic energy converted into X-rays. Symbols as Figure 1.

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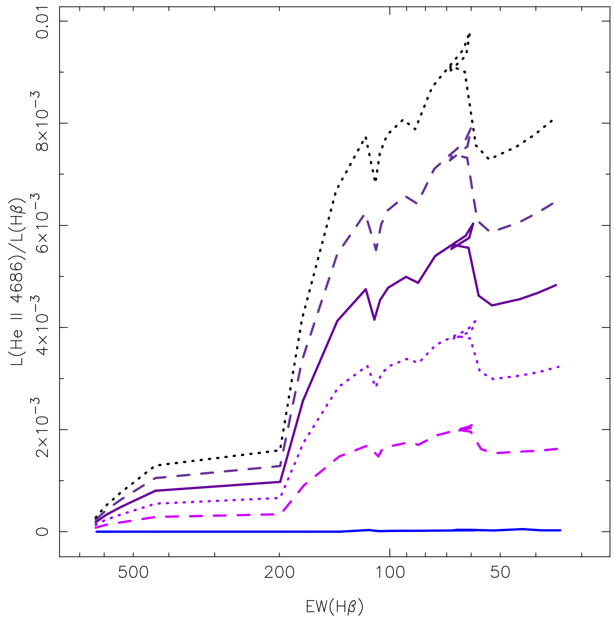

Fig. 3. Evolution of the variation the ratio L(He II 4686 Å) vs. $L(H\beta)$ for different amounts of kinetic energy converted into X-rays. Symbols as Figure 1.

2. THE EFFECTS ON THE EMISSION LINES

As far as binary systems are important only for ages higher than 5 Myrs (or EW(Hβ) lower than 50 Å), due to the production of WR stars and renewed massive stars that will provide the cluster with ionizing photons (see CMH for more details), we have only performed the analysis during the first 5 Myrs when the ionizing effects from X-rays are more important. Figure 2 shows the effect of X-rays on some emission lines (say O I 6300 Å and O II 3727 Å as an example). We compare the results from models without X-rays, and models when SNR (lower solid line) have different fractions of kinetic energy conversion. The inclusion of X-rays has a significant influence on these lines (about 30%).

Figure 3 shows the variation of the ratio L(He II 4686 Å) vs. $L(H\beta)$. The Helium line is strongly influenced by the X-ray emission, and the ratio increasses by more than a factor of 10 at ages above 5 Myrs. Assuming a high efficiency in the reprocessing of mechanical energy into soft X-rays, it is possible to reproduce the observational values of $L(HeII)/L(H\beta)$. We conclude that this additional component of the ionizing flux, together with the ionizing emission from WR stars (Schaerer & Vacca 1998), may be responsible for the relatively large $L(HeII)/L(H\beta)$ values observed in several starburst galaxies.

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