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Hα and FUV luminosities from a stochastically formed stellar population

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Abstract. It has been observed that the ratio of Hα to FUV luminosity ($L_{H\alpha}/L_{FUV}$) is lower in low surface brightness galaxies. This behaviour has been attributed to systematic variations of the upper mass end and/or the slope of the Initial Mass Function (IMF) (Meurer *et al.* (2009) and Lee *et al.* (2009)). However these hypotheses do not explain the observed scatter in luminosity ratio ($L_{H\alpha}/L_{FUV}$). We present a model for the total $L_{H\alpha}$ and L_{FUV} luminosity arising from a randomly populated IMF following the Salpeter power law and the clustering law of Oey & Clarke (2007).

Keywords. methods: numerical, stars: mass function, galaxies: star clusters.

1. Method Description

We assume that the star formation process occurs in individual associations of variable size, following an universal power-law distribution (Lamb *et al.* 2010) and that in each association of stars, the stellar population is distributed with a Salpeter IMF. In order to allow stochastic fluctuacions around distributions, we assume that each association forms stars on five generations or bursts (Parravano *et al.* 2003). We use the following empirical clustering law to calculate the size by association:

$$n(N)dN \propto N^{-\beta}dN \tag{1.1}$$

where N is the number of high-mass stars (m $> 8M_{\odot}$), n(N) dN is the number of associations in the range N to N + dN and β is the power law index. With this equation we calculate the number of high-mass stars per association Parravano *et al.* (2003).

$$N^{\beta-1} = \frac{N_{h,l}^{\beta-1}}{1 - x\left(1 - \left(\frac{N_{h,l}}{N_{h,u}}\right)^{\beta-1}\right)} \tag{1.2}$$

where $N_{h,l}$ and $N_{h,u}$ are the minimum and maximum number of stars of an association respectively. In this work, x is a random number between 0 and 1, $N_{h,l} = 1$, $N_{h,l} = 6\times10^4$ and $\beta = 2$. The mass of each star in the association is calculated as:

$$m_i = \left[\mu_i^{-\Gamma} - x_i\left(\mu_i^{-\Gamma} - \mu_{i-1}^{-\Gamma}\right)\right]^{-1/\Gamma} \tag{1.3}$$

with

$$\mu_i = \frac{m_u}{\left[\frac{i\phi_u}{N/5}\left(\frac{m_u}{m_h}\right)^{\Gamma} + 1\right]^{1/\Gamma}} \tag{1.4}$$

where $\Gamma = 1.35$ for the IMF Salpeter, m_u is the upper mass end ($m_u = 120M_\odot$) of the IMF, m_h is the limit for high-mass stars ($m_h = 8M_\odot$) and again x is a random number between 0 and 1.

We use the number of ionizing photons (Nio) and FUV luminosity provided by Gustavo Bruzual (private communication) corresponding to the Charlot & Bruzual (2007) models with the Padova tracks at solar metallicity. We calculate the corresponding $L_{H\alpha}$ using $L_{H\alpha}$=1.36×10^{-12} Nio (erg/s) (Osterbrock 1989).

To calculate the total $H\alpha$ and FUV luminosities of a galaxy, we use, as free parameter, the number of associations formed per million year (Association Formation Rate, AFR) and add the contribution of each star through its lifetime. We follow the evolution of these quantities during a simulation time of $4{\times}10^9 yr$ in order to assure that results are statistically reliable.

2. Results

The results of our simulation are shown in Fig. 1. In this figure, each panel corresponds to a different AFR (labelled in the figure). In the left panel AFR = 0.1 Myr^{-1} and in the right panel AFR = $4000 Myr^{-1}$, that corresponding to a star formation rate of 1.7 $\times 10^{-4} M_\odot yr^{-1}$ and $5.7 M_\odot yr^{-1}$, respectively.

We can observe that:

• L_{FUV} shows a smoother distribution than $L_{H\alpha}$. This is due to stars with $8M_\odot < m < 40M_\odot$ that contribute a longer time to L_{FUV} than to $L_{H\alpha}$.

• The ratio $L_{H\alpha}/L_{FUV}$ is greater in the higher AFR regime (bottom panels) and the corresponding fluctuations, measured as the standard deviation of the $L_{H\alpha}/L_{FUV}$, are lower for higher AFR.

In figure 2 we compare the results of our model with a sampled of observed galaxies. We are able to explain both, the scatter and the change of slope observed in the $L_{H\alpha}$-L_{FUV} relation for $L_{H\alpha} < 1 \times 10^{38}$(erg/s). These results are similar to those published by

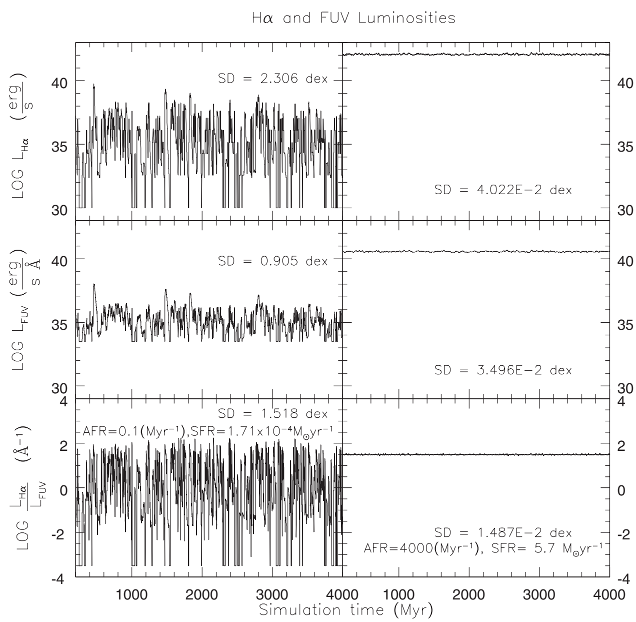

Figure 1. $L_{H\alpha}$, L_{FUV} and $L_{H\alpha}/L_{FUV}$ ratio for different AFR, with their fluctuations.

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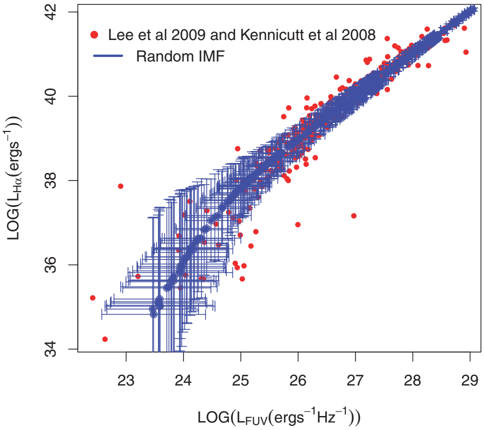

Figure 2. The squares shows the observed galaxies: We have compiled 330 galaxies from Lee *et al.* (2009) in the bands FUV and Hα luminosity from Kennicutt *et al.* (2008). The corrections for internal absorption were made as indicated in Lee *et al.* (2009). The points and errors bars respectively show average values and their fluctuations, measured as the standard deviation in our simulation.

Fumagalli *et al.* (2011), who use a slightly different model, where a distinction between the mass of the stars that contribute to the ionizing and non ionizing luminosity is assumed.

3. Conclusion

Our model, in which the IMF and clustering law for high mass stars are stochastically sampled, is able to reproduce the observed $L_{H\alpha}$-L_{FUV} trend in star forming galaxies of different brightness. It is not necessary to invoke a non-universal IMF in order to explain the $L_{H\alpha}$-L_{FUV} observed.

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