Converting Hα luminosities to SFRs

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Introduction

Because massive stars have short life times the number of currently existing massive stars determines the actual massive star formation rate. The number of massive stars is commonly obtained from the integrated Hα luminosity of the target galaxy, after correcting for extinction and NII emission. If the fraction of massive star formation of the total star formation is known then the meassured integrated Hα luminosity of a galaxy can be converted in its current SFR.
Combining an initial mass function (IMF) with stellar evolution models a linear relation between the SFR and the produced Hα luminosity can be constructed (Kennicutt 1994). Originally used for normal disk galaxies such a linear relation has also been applied on dwarf irregular galaxies (Skillman et al. 2003).
But the integrated galaxial initial mass function (IGIMF), counting all newly formed stars in all young star clusters together, is much steeper in the high-mass star regime than the underlying canonical IMF (Weidner & Kroupa 2005) and SFRs are therefore underestimated.

IGIMF

Within a star formation epoch of δt=10 Myr (Weidner & Kroupa 2005) an ensemble of star clusters forms. The cluster masses are distributed according to the embedded cluster mass function (ECMF). The upper mass limit of the ECMF scales with the actual SFR (Weidner, Kroupa & Larsen 2004). The distribution of stellar masses in each star cluster follows a constant canonical IMF the upper mass limit of which is determined by the total cluster mass (Weidner & Kroupa 2004). The IGIMF, $\xi_{\rm IGIMF}(m)$, is then calculated by integrating over the cluster mass function, $\xi_{\rm ecl}(M_{\rm ecl})$, multiplied with the stellar IMF in each individual cluster, $\xi_{M{\rm ecl}}(m)$,

$$\xi_{\rm IGIMF}(m) = \int_{M_{\rm ecl,min}}^{M_{\rm ecl,max}(SFR)} \xi_{M{\rm ecl}}(m)\, \xi_{\rm ecl}(M_{\rm ecl})\, {\rm d}M_{\rm ecl} \quad . \qquad (1)$$

To be consistent with Weidner & Kroupa (2005) we explore four different IGIMF-models: the so-called Standard scenario, one model to maximise and two models to minimise the IGIMF-effect. Both functions, the ECMF and the underlying canonical IMF, have multi-power law forms ($m^{-\beta_i}$ and $m^{-\alpha_i}$, Tab. 1). The normalised IGIMFs in the standard scenario are plotted in Fig. 1 for different actual SFRs.

Tab. 1: Slopes and mass limits of the IMF and ECMF for four IGIMF-models

Parameter	Standard	Minimal-1	Minimal-2	Maximal
$m_1/M_\odot$	0.08	0.08	0.08	0.08
α_1	1.30	1.30	1.30	1.30
$m_2/M_\odot$	0.5	0.5	0.5	0.5
α_2	2.35	2.35	2.35	2.35
$m_3/M_\odot$	1.0	1.0	1.0	1.0
α_3	2.35	2.35	2.35	2.7
$M_1/M_\odot$	5	5	-	5
β_1	2.35	1.0	-	2.35
$M_2/M_\odot$	50	50	50	50
β_2	2.35	2.0	2.0	2.35

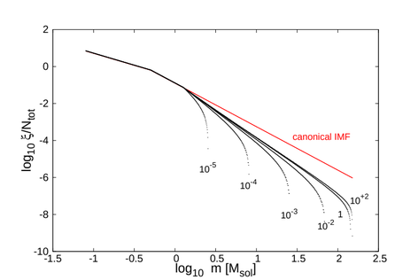

Fig. 1: Normalised IGIMFs in the standard scenario for different SFRs: 100, 1, 10^{-2}, 10^{-3}, 10^{-4} and 10^{-5} M$_\odot$ yr^{-1} compared with a canonical IMF with slopes -1.3 ($0.08 \le m/{\rm M}_\odot \le 0.5$) and 2.35 ($0.5 \le m/{\rm M}_\odot \le m_{\rm max}$).

SFR-Hα-relation

The Hα luminosities are obtained by integrating the product of the IGIMF and the number of ionising photons within the star formation epoch δt over the full stellar mass spectrum and dividing the result by δt. The resulting relation between the SFR and the produced Hα luminosity is plotted in Fig. 2. To explore the full effect of the IGIMF we compare with two *classical* models, where the IGIMF is identical to the IMF but using the same stellar models: a canonical IMF, and a Salpeter IMF with a slope of 2.35 between 0.1 and 100 M$_\odot$ on which the widely used *classical* relation

$${\rm SFR} \,/\, {\rm M}_\odot\, {\rm yr}^{-1} = L_{\rm H\alpha} \,/\, 1.26 \cdot 10^{41}\ {\rm erg\ s}^{-1} \qquad (2)$$

by Kennicutt et al. (1994) is based.

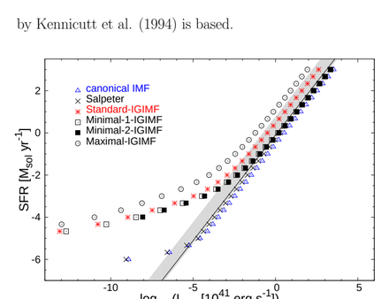

Fig. 2: Relations between the SFR and the produced Hα luminosity for four different IGIMF-models and two classical models, in which the Igimf is identical to the IMF, the full range of linear relations by Kennicutt et. al (1994, gray shaded area) and the widely used relation (Eqn. 2, solid line).

Note that the IGIMF notion implies SFRs for low Hα luminosities that are orders of magnitude higher than predicted by the Kennicutt relation (Eqn. 2) and is independent of the explicit choice of the IGIMF model.

dIrr galaxies

Applying our SFR-L$_{\rm H\alpha}$ relation on the observed Hα-luminosities of the Sculptor dwarf irregular galaxies (Skillman et al. 2003) the SFRs (Fig. 3) and related parameters such as the gas depletion time scale (Fig. 4) change dramatically.

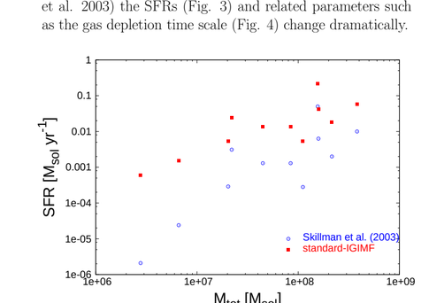

Fig. 3: Derived SFRs of the Sculptor dIrrs based on the standard scenario and based on Eqn. 2 (Skillman et al. 2003).

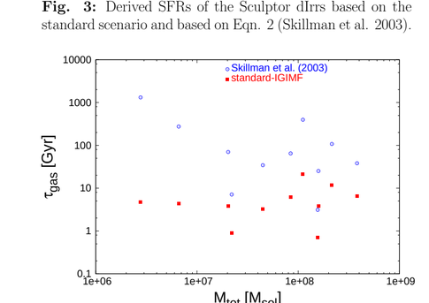

Fig. 3: Derived gas depletion times of the Sculptor dIrrs based on the standard scenario and calculated from SFRs based on Eqn. 2 (Skillman et al. 2003).

References

Kennicutt, Jr., R. C., Tamblyn, P. and Congdon, C. E., 1994, *ApJ*, **435**, 22
Skillman, E. D. and Côté, S. and Miller, B. W., 2003, *AJ*, **125**, 593
Weidner, C. and Kroupa, P., 2004, *MNRAS*, **348**, 187
Weidner, C. and Kroupa, P., 2005, *ApJ*, **625**, 754
Weidner, C. and Kroupa, P. and Larsen, S. S., 2004, *MNRAS*, **350**, 1503

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