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A Possible Origin of the Mass–Metallicity Relation of Galaxies

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Abstract. Previous attempts to explain the observed mass–metallicity relation of galaxies invoked selective outflows that need to be tuned to the particular cases.

Here we demonstrate that the simple concept of a star-formation history (SFH) dependent galaxy-wide integrated galactic initial stellar mass function (the IGIMF) can easily and naturally explain the mass–metallicity relation.

The idea relies on the simple fact that stars form in clusters. So to construct the IGIMF one needs to add all the stellar IMFs in the clusters formed in one epoch. The SFH enters because a galaxy with a high SFR can form more-massive clusters than a galaxy with a low SFR. Dwarf galaxies therefore have, per unit stellar mass formed, far fewer if any supernovae of type II than massive galaxies.

This work rests on the recent paper by Köppen, Weidner & Kroupa (2007).

Keywords. stars: luminosity function, mass function – ISM: abundances – ISM: evolution – galaxies: abundances – galaxies: evolution – galaxies: ISM

1. The Variable IMF

In Kroupa & Weidner (2003) and Weidner & Kroupa (2005) it has been shown that the formation of stars predominantly in clusters has a profound influence on the IGIMF of all stars in a galaxy. The masses of young, embedded star clusters also follow a power-law distribution, the embedded cluster mass function (ECMF). Furthermore, the clusters limit the mass of the most-massive star in them (Weidner & Kroupa, 2004). But the IGIMF depends not only on the ECMF but also on the star formation history of a galaxy. Weidner, Kroupa & Larsen (2004) derive a relation between the current SFR and the maximum mass of a cluster in a galaxy. Alltogether the IGIMF has the following shape,

$$\xi_{\rm IGIMF}(m, {\rm SFR}(t)) = \int_{M_{\rm ecl,min}}^{M_{\rm ecl,max}({\rm SFR}(t))} \xi(m \leqslant m_{\rm max}(M_{\rm ecl}))\, \xi_{\rm ecl}(M_{\rm ecl})\, dM_{\rm ecl}. \qquad (1.1)$$

2. Conclusions

Fig. 1 shows the results of a chemical evolution model calculation with the IGIMF. For details on the models and a larger series of models see Köppen *et al.* (2007).

- The idea of a SFR-dependent IGIMF provides a most attractive way to explain

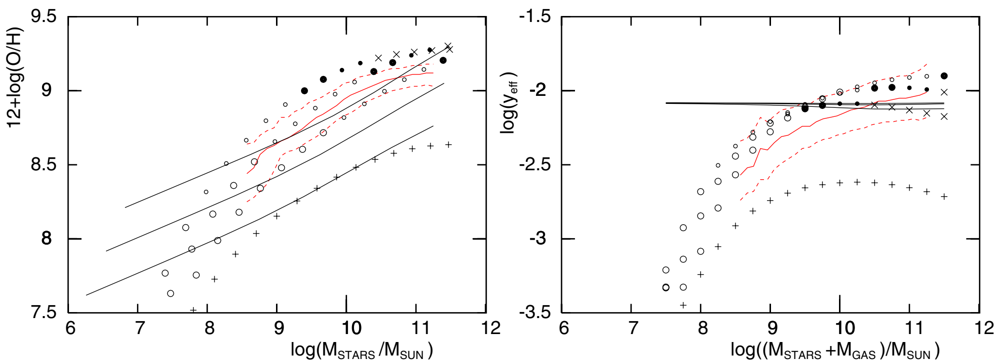

Figure 1. *Left Panel*: The relation between oxygen abundance and stellar mass of galaxies. Dashed lines indicate the 16, 50, and 84 percentiles of the observed metallicity distribution by Tremonti et al. (2004). The symbols are results from closed-box models with an exponentially decreasing infall of primordial gas and with a star formation rate depending on the galactic mass. See Köppen et al. (2007) for details of the models. The full curves refer to models computed with a constant Salpeter IMF. *Right panel*: The relation between the effective O yields and the total galactic mass: dashed lines indicate the 16, 50, and 84 percentiles of the observed distribution by Tremonti *et al.* (2004). The symbols denote the same sequences of closed box models as in the *left panel*.

the observed relation between metallicity and galactic mass as well as the one between effective yield and galactic mass.

• The main effect at work is the lowering of the effective upper mass limit of stars for low star-formation rates, which reduces the number of supernovae of type II.

• The closed box model as well as the models with monotonically decreasing infall provide a remarkable match to the observed median mass–metallicity relation.

• This is in strong contrast to models with a constant IMF.

• By combining the effects of gas outflows and a variable IGIMF a steeper mass–metallicity relation would be achieved than the ones produced by either process alone.

• The results predict higher metallicities and higher oxygen yields for galaxies with strongly fluctuating star formation histories.

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