INITIAL MASS FUNCTION AND GALACTIC CHEMICAL EVOLUTION MODELS

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Abstract

In this contribution we focus on results from chemical evolution models for the solar neighbourhood obtained by varying the IMF. Results for galaxies of different morphological type are discussed as well. They argue against a universal IMF independent of star forming conditions.

Introduction

Galactic chemical evolution (GCE) models are useful tools to understand how galaxies form and evolve. In particular, abundance and abundance ratio trends can be read as records of different evolutionary histories and interpreted in terms of the different time scales on which different objects evolve (Matteucci and François 1989; Wheeler et al. 1989). Unfortunately, dealing with very complex and poorly known mechanisms such as mass accretion, star formation and stellar feedback, brings with it the need for many assumptions and parameters. As a consequence, GCE models are by no means unique (Tosi 1988). Therefore, it is worthwhile quantifying the uncertainties of GCE predictions arising from different treatments of the physical processes involved with structure formation and evolution. Here we concentrate on uncertainties due to different assumptions on the stellar IMF. By comparing the model predictions with the available data, we show that particular IMF slopes can be ruled out in the Galaxy, whilst a “standard” solar neigh-
bourhood IMF is not suitable to describe the high metallicities observed in ellipticals.

1. The IMF in the solar neighbourhood

The most widely used functional form for the IMF is an extension of the “original mass function” proposed by Salpeter (1955) to the whole stellar mass range, \( \varphi(m) \propto m^{-1.35} \) for \( 0.1 \leq m/M_\odot \leq 100 \). Besides this, multi-slope expressions (Tinsley 1980; Scalo 1986; Kroupa et al. 1993; Scalo 1998) and a lognormal form for the low-mass part of the IMF (\( m \leq 1 M_\odot \); Chabrier 2003) are considered here. In the latter case, for the 1–100 \( M_\odot \) stellar mass range we adopt a power-law form with an exponent \( x = 1.7 \).

In Fig. 1 we show the fractional masses falling in specific mass ranges according to different IMF choices, for one single stellar generation. An example of what one gets when integrating over the Galactic lifetime, i.e. over many stellar generations, is given in Fig. 2, where we display the predicted behaviour of \([O/Fe]\) vs \([Fe/H]\) for all the IMFs listed above. We choose oxygen because of its well understood nucleosynthetic origin (François et al. 2004) and because the very high-quality data available for solar neighbourhood stars (Meléndez and Barbuy 2002) allow for a very meaningful comparison between model predictions and observations. Although theoretical errors of the order of 0.2–0.3 dex can be associated to model predictions owing to the uncertainties in the actual

*Figure 1.* Fractional mass (y axis) falling in each given mass range (x axis) according to different IMF choices, for one single stellar generation.
Figure 2. $\text{[O/Fe]}$ vs $\text{[Fe/H]}$ in the solar neighbourhood as predicted by models adopting different IMFs (short-dashed line: Salpeter 1955; dotted line: Tinsley 1980; solid line: Scalo 1986; long-dashed line: Kroupa et al. 1993; dot-short-dashed line: Scalo 1998; dot-long-dashed line: Chabrier 2003). Data are mean $\text{[O/Fe]}$ from $\text{[O I]}$ lines in 0.2 dex metallicity bins (circles) and $\text{[O/Fe]}$ values from infrared OH lines (stars; Meléndez and Barbuy 2002).

IMF form, it is apparent that both Salpeter’s and Scalo’s (1998) IMFs overproduce oxygen for most of the Galactic lifetime. Generally, models assuming Salpeter’s, Tinsley’s or Scalo’s (1998) IMFs are found to predict far too high global metal abundances ($Z_\odot \sim 0.024$–0.033), especially if the most recent measurement of this quantity in the Sun is taken into account ($Z_\odot = 0.0126$; Asplund et al. 2004). The Scalo (1998) IMF also leads to overproduce $^3\text{He}$ from the time of solar birth up to now, due to its high percentage of 1–2 $M_\odot$ stars (see Fig. 1). On the contrary, the remaining IMFs all guarantee a good agreement between the model predictions and the data (see Romano et al. 2004 for details).

Therefore, from simple GCE arguments we conclude that the IMF of field stars in the solar neighbourhood must contain less massive stars than the Salpeter one. An extrapolation of the Salpeter law to the high-mass domain is not suitable to explain the solar neighbourhood properties. This is not surprising; indeed, the Salpeter slope of $x = 1.35$ was originally derived for stars less massive than 10 $M_\odot$.

2. The IMF in external galaxies

The observational properties of dwarf galaxies are better explained by assuming a Salpeter-like stellar mass spectrum. This is true for both
dwarf spheroidals (Lanfranchi and Matteucci 2003) and late-type dwarf
galaxies (Romano, Tosi and Matteucci in preparation). On the other
hand, the chemo-photometric properties of massive ellipticals at both
low and high redshifts are better explained with an IMF slightly flatter
than Salpeter’s. In their pioneering work, Arimoto and Yoshii (1987)
showed that an IMF with a power index smaller than Salpeter,
\( \varphi(m) \propto m^{-0.95} \) for \( 0.05 \leq m/M_\odot \leq 60 \), gives an excellent fit to the observed
colors of giant elliptical galaxies. We find that the chemo-photometric
properties of local and high-redshift massive spheroids are well repro-
duced with an IMF slope even more similar to Salpeter’s, i.e. \( \varphi(m) \propto m^{-1.25} \) for \( m > 1 M_\odot \) (Romano et al. 2002).

In conclusions, our GCE models give us hints for (small) IMF vari-
aitions with star forming conditions. Further studies have been presented
at this workshop which seem to confirm our findings, from both a theo-
retical (e.g. C. Chiosi; P. Kroupa; L. Portinari, these proceedings) and
an observational (e.g. S. Lucatello, these proceedings) point of view.

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