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HEAVY ELEMENT ABUNDANCES AND MASSIVE STAR FORMATION

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The determination of the stellar initial mass function (IMF) remains a great challenge in astronomy. In the solar neighborhood, the IMF is reasonably well determined for stellar masses from about 0.1 $M_\odot$ to 60 $M_\odot$ (Scalo 1986). However, outside the solar neighborhood the IMF is poorly known. Among those frequently discussed arguments favoring a different IMF outside the solar neighborhood are the estimated time to consume the remaining gas in spiral galaxies, and the high rate of forming massive stars in starburst galaxies. An interesting question then is whether there may be an independent way of testing possible variations in the IMF. Indeed, the heavy elements in the interstellar medium are mostly synthesized in massive stars, so increasing, or decreasing, the fraction of massive stars naturally leads to a variation in the heavy element yield, and thus the metallicity. The observed abundance should severely constrain any deviations of the IMF from the locally determined IMF. We focus on element oxygen, which is the most abundant heavy element in the interstellar medium. Oxygen is ejected only by massive stars that can become Type II supernovae, and the oxygen abundance is therefore a sensitive function of the fraction of massive stars in the IMF. Adopting oxygen (rather than, *e.g.*, Fe) enables us to avoid uncertainties in Type I supernovae.

The ejected oxygen mass in the supernova event for a given stellar mass has been calculated for stars with solar metallicity by Arnett (1978), and more recently by Woosley and Weaver (1986), and Thielemann, Nomoto, and Hashimoto (1992). The agreement of the ejected oxygen mass for stars with masses larger than about 15 $M_\odot$ is fairly good among these authors, despite the difference in their adopted $^{12}C(\alpha,\gamma)^{16}O$ rate. There is, however, some discrepancy in the ejected oxygen mass at $m \simeq 12$ $M_\odot$, presumably due to differences in stellar structure and different treatments of the convection (overshooting) in the different supernova models. The oxygen abundance yield weighted by the IMF, however, does not differ significantly among different models. This is primarily because the ejected oxygen mass increases very rapidly with stellar mass (approximately $\propto m^4$) at $m \simeq 12 - 20$ $M_\odot$, and therefore for any reasonable IMF with a slope $x \lesssim 4$, the ejected oxygen is dominated by stars with masses $m \gtrsim 20$ $M_\odot$. We use the nucleosythesis results to calculate the oxygen yield for given IMF. We then calculate the oxygen abundance in the interstellar medium assuming instantaneous recycling of oxygen.

We found that (1) Given that the oxygen abundance in our Galaxy as well as in many normal spiral galaxies is approximately solar, there is no evidence of variations in the IMF outside the solar neighborhood. (2) Both infall and ejection of interstellar gas can change the metallicity somewhat, but they at most can change the heavy element abundance by a factor of 2 in normal spiral galaxies as long as the infall or ejection rates are proportional to the rate of star formation. Ejection can be important in dwarf galaxies where the gravitational potential wells are shallow. This may partly explain the observed low metallicities of dwarf galaxies. (3) For starburst galaxies, truncation of the IMF at large m_l results in an abundance at least an order of magnitude over the solar value. Since the available observations of the oxygen abundance suggest otherwise, a truncated IMF alone cannot explain the starburst activity. If indeed the IMF is truncated in starburst galaxies, extremely efficient mass ejection from the starburst regions has to occur in order to dilute the metallicity. This is however a non-trivial task since the ejected material would amount to many times the amount of matter existing in the starburst regions. Future observations of gas outflows in starburst galaxies should test models of a varying IMF. (4) Our method of using oxygen abundance can also be applied to extremely low-mass stars (*e.g.*, baryonic dark matter considered in galaxies) since their abundance determines the relative fraction of massive stars that can become supernovae, and thus the oxygen abundance. Clearly the slope of the IMF differs at low masses from that at high masses, therefore a useful constraint would require some knowledge of the slope of the IMF at low masses.

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