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# The spatial and temporal evolution of gas and heavy elements in the galaxy

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In this thesis we have studied the evolution of gas and iron in the Galaxy. Before modelling the chemical evolution of the Galaxy, we have looked into some important constraints and inputs to evolution models.

We have first derived the age-metallicity relation (AMR) of stars at the solar neighbourhood by combining the observed history of the star formation rate of Soderblom *et al.* (1991) and the metallicity distribution of stars of Pagel (1989). The AMR thus derived is almost linear on a logarithmic metallicity scale after the first two Gyrs, although there is a small, almost periodic variation on this trend. We have also corrected the data of Soderblom *et al.* (1991) for the increase of the scale heights of stars with age to find the actual variation of the star formation rate per unit area of the disc. We find that this correction makes the observed star formation history consistent with a nearly constant star formation rate (Rana & Basu 1992).

The initial mass function (IMF) of stars has been calculated after taking into account one important factor—the presence of unresolved multiple stars. It is seen that once unresolved multiple stars are taken into account, very little or no non-baryonic dark matter is needed to account for the dynamical mass of the Galactic disc at the solar neighbourhood. The multiplicity corrected present day mass function (PDMF) gives a stellar mass density of $41.3^{+13.8}_{-10.3}$ $M_{\odot}\mathrm{pc}^{-2}$ as opposed to only $32.7^{+10.8}_{-8.7}$ $M_{\odot}\mathrm{pc}^{-2}$ given by the PDMF not corrected for the effects of stellar multiplicity. We have calculated the IMF from the PDMF using number of star formation rates (SFR) of the form $\psi \propto \exp(-t/\tau)$, where $\psi$ is the SFR and $\tau$ the decay constant of the star formation rate. We find that the neutron star and white dwarf formation rates restrict $(1/\tau)$ to the range $-0.1 - 0.1$ Gyr$^{-1}$. The IMF calculated from the multiplicity corrected PDMF with a constant star formation rate has a slope of $-1.7$ in the mass range $0.6\ M_{\odot} \lesssim m \lesssim 100\ M_{\odot}$, which is steeper than the Salpeter slope of $-1.35$ (Basu & Rana 1992a,b).

One of the most common assumptions of chemical evolution models is that at any given time the inter-stellar medium (ISM) is chemically homogeneous. We find that relaxing this condition allows a better reproduction of the metallicity distribution of low mass stars. We also find that this also helps in improving the G-dwarf problem, *i.e.*, the fact that there seems to be fewer very low-metallicity G-dwarfs than is predicted by simple models of galactic chemical evolution. We also find that if we apply a scale height correction to the observed metallicity distribution of G-dwarfs, none of the conventional models can reproduce the shape of the curve very well. However, the fits are better if the ISM is assumed to be chemically inhomogeneous (Basu & Rana 1992c).

We have investigated the chemical evolution of the galaxy with the star formation rate assumed to be nearly constant with time. If the Galactic disc has evolved as a closed system, it is found that the observational constraints at the solar neighbourhood and the rest of the Galactic disc can be satisfied if the star formation rate varies as the $\sigma_g^{\alpha}Z^{\beta}$, with $\alpha = 1.15 \pm 0.05$ and $\beta = 1.25 \pm 0.05$ where $\sigma_g$ is the surface mass density of gas and $Z$ the metallicity. This model has only two free parameters $\alpha$ and $\beta$. The other parameters of the model like the returned fraction are calculated from the IMF which was derived using the adopted star formation rate. This model gives good fits to the observational data on the history of the star formation rate, the AMR, the G-dwarf metallicity distribution and the formation rate of white dwarfs. The star formation rate is nearly constant, with the ratio of the past average SFR to the present SFR being $1.2 \pm 0.3$. The fits to the Galactic data on the radial distribution of the surface density of gas, the radial metallicity gradient and the radial variation of the current SFR are also reasonable. The adopted star formation rate with $\alpha = 1.15$ and $\beta = 1.25$ is consistent with one proportional to some power of the surface density of molecular hydrogen. Such a SFR implies that stars form at the rate of around 3.5 $M_{\odot}\mathrm{pc}^{-2}$ in the solar neighbourhood today. The yield of iron calculated from this model is 0.57 $Z_{\odot}$, which can be obtained from the IMF if the mass range of the progenitors of type II supernovae is around 9.5 ± 10 $M_{\odot}$ to 50 $M_{\odot}$ (Basu & Rana 1992b, 1993).

We have also considered some models which allow infall of gas on to the Galactic disc. We have tried to constrain the time-scale of gas infall on to the disc using the observed G-dwarf metallicity distribution function and the observed age metallicity relation in conjunction with the multiplicity corrected PDMF in the solar neighbourhood. It is seen that the time scale of infall can be constrained to be between 2 and 4.5 Gyr. The predicted rate of infall today at the solar neighbourhood is only about 10% of the rate at which mass is being locked up into stars. We also find that if star formation in the disc is assumed to begin as soon as the disc begins to form, models with a constant rate of infall fail to reproduce solar neighbourhood observations (Basu 1993).

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