A comparison of chemical and chemodynamical models

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Abstract. Representative results from a comparison of the chemical evolution of spherical collapse models without and with a intercloud medium are presented. The hot metal-rich gas distributes quickly the metals produced in supernovae throughout the galaxy, thus leading to a more homogeneous chemical evolution and flatter metallicity gradients in the gas and the stars. The stellar population is somewhat less concentrated towards the centre. The strong outflow results in a substantial loss of metals from the galaxy to its surroundings, and a lower effective yield in the galaxy.

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Chemodynamical models of galaxies (e.g. Theis et al. 1992) differ from the classical models of Larson (1969, 1973) for the dynamical and chemical evolution by taking into account the multiphase structure of the ISM. In order to understand which of the properties of Larson's models remain present in chemodynamical models, I compare spherical collapse models of either type.

Figure 1 shows results for 10^{11} $M_\odot$, with the same prescriptions as in Larson's original model (1969). The relation of gas fraction f_g and gas metallicity Z exhibits a characteristic behaviour as a function of radius: (a) the outer regions lose gas due to the streaming towards the centre. (b) the central region receives the gas from all exteriour regions where it had been enriched in metals. The metallicity may exceed that of the Simple Model. (c) as the gas in the central regions is used up, its metallicity is finally lowered by the infalling metal-poor gas.

The gas metallicities (curves in Fig. 2) develop from the initially flat profile to a strong radial metallicity gradient. In the distribution of simulated stars (circles) the strong central concentration is evident as well as a strong radial metallicity gradient.

Now let us add to such a model only one ingredient of the chemodynamical formulation: the presence of a second phase of hot gas, ejected and powered by the supernova explosions, which also carries the freshly produced metals. This intercloud medium (ICM) interacts with the cloudy medium (CM) via evaporation and condensation (cf. Köppen, Theis & Hensler, 1995, 1998).

The chemical evolution (Fig. 3) differs markedly from that of a single gas-phase model:

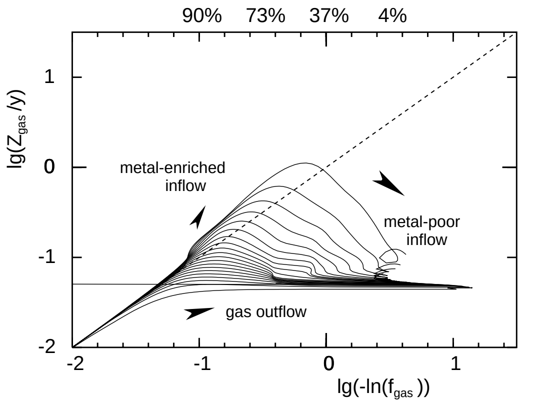

Figure 1. The evolution of gas fraction and metallicity at various radii in a spherical collapse model with a single gas phase, with the same parameters as Larson (1969). The diagonal line is the solution of the closed-box Simple Model

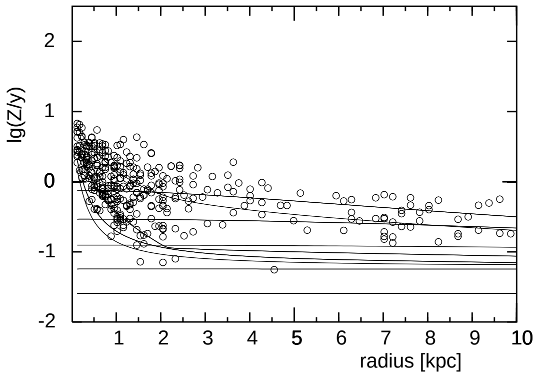

Figure 2. The evolution of the gas metallicity profile (curves) and stellar metallicities (circles indicating simulated stars) in the single gas-phase spehrical collapse model

- all regions evolve almost in the same way. The hot ICM (up to 10^8K) distributes the metals quickly (speeds up to 1000 km/s) all over the galaxy. Condensation and subsequent mixing occur preferentially in the outer regions

- the evolution follows close to that of a Simple Model with reduced yield

– eventually, the outer regions have lost all their initial CM gas due to the collapse towards the centre, and condensation dominates over the gas consumption. Metallicities reach those of the stellar ejecta

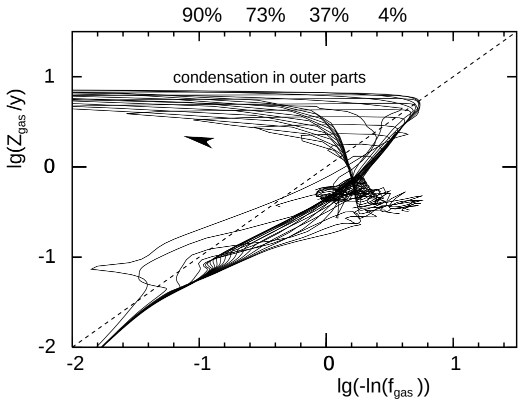

Figure 3. Same as Fig. 1, but for the chemodynamical model

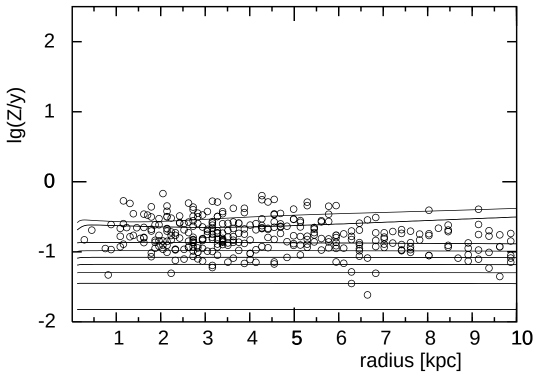

Figure 4. Same as Fig. 2, but for the chemodynamical model

The metallicity profiles of the CM gas (Fig. 4) show that the metallicity remains much more constant than in Larson's model. Because the importance of condensation increases towards the exteriour, the metallicity also increases outward. The stellar population is not as centrally concentrated as in Larson's model, and the metallicities do not exhibit a radial gradient.

Another important feature of the chemodynamical model is that the radial outflow of the hot metal-rich ICM gas leads to a significant ejection of gas mass (30% in the model shown) and of metals into intergalactic space. The distribution function for the metallicities of

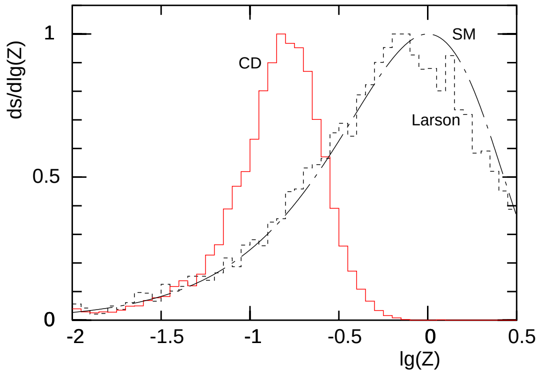

Figure 5. The distribution functions of the metallicity of long-lived stars in both models and the Simple Model (SM).

long-lived stars in Larson's model (Fig. 5) follows very closely the distribution of the Simple Model: Larson's model remains a closed–box model. The stellar population in the chemodynamical model is of lower metallicity – due to the escape of metals via the ICM – and has a more narrow distribution – more closely that of a single metallicity population.

One important finding of Larson (1969) was that if the star formation rate is assumed to depend on the gas density more steeply than with the power 1.8, the collapse of the starforming gas cloud produces a centrally peaked stellar population with the radial density profile bing very close to a deVaucouleurs profile or King model. This property is preserved in the chemodynamical models.

References

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