THE CHEMICAL EVOLUTION OF THE GALACTIC HALO AND DISK

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The history of star formation in our galaxy is written in the metal abundance distributions of the stellar populations. Any star formation model is constrained by two facts. First, there was a period in the early stages of galactic evolution during which the metallicity of the gas out of which stars were being formed was significantly lower than the present epoch. Second, there is a paucity of extremely metal deficient stars in the disk of the galaxy.

To date, a large number of studies have been aimed at explaining the general problem of metallicity evolution (see reviews by Tinsley 1980, Pagel and Edmunds 1981, Twarog 1985, and references therein).

We discuss the evolution of models for star formation in galaxies with disk and halo components. Two phases for the halo (gas and stars) and three for the disk (including clouds) are used in these calculations. The star formation history is followed using nonlinear phase-coupling models which completely determine the populations of the phases as a function of time. It is shown that for a wide range of parameters, including the effects of both spontaneous and stimulated star formation and mass exchange between the spatial components of the system, the observed chemical history of the galaxy can be easily obtained. The most sensitive parameter in the detailed metallicity and star formation history for the system is the rate of return of gas to the diffuse phase due to stellar deaths. The effect of delayed return of material is also examined. In particular, the models show a rapid (1-2 Gyr) rate of increase of metals in the disk, and there is no need to invoke a variable initial mass function to explain the absence of very metal poor stars in the disk.

The Model Equations

$$\frac{ds_H}{dt} = - r_H s_H = K g_H^n$$

$$\frac{dg_H}{dt} = r'_H s_H - K' g_H^n - f g_H$$

https://doi.org/10.1017/S0074180900096832 Published online by Cambridge University Press

$$\frac{d}{dt}(Z_{H}g_{H}) = -(1 - R_{H})Z_{H}\frac{ds_{H}}{dt} + P_{H}r'_{H}s_{H} - fZ_{H}g_{H}$$

$$\frac{ds_{D}}{dt} = -r_{D}s_{D} + as_{D}c_{D} + Kg_{D}^{n} + Hc_{D}^{2} ,$$

$$\frac{dg_{D}}{dt} = r_{D}s_{D} + a's_{D}c_{D} + (H - H')c_{D}^{2} + (1 - \nu)fgH - K'g_{D}^{n},$$

$$\frac{dc_{D}}{dt} = -(a + a')s_{D}c_{D} + \mu g_{D}^{m} - H'c_{D}^{2} + \nu fgH$$

$$\frac{d}{dt}[Z_{D}(g_{D} + c_{D})] = -(1 - R_{D})Z_{D}\frac{ds_{D}}{dt} + AZ_{D}\frac{ds_{D}}{dt} + P_{D}r'_{D}s_{D} + fZ_{H}g_{H} .$$

TABLE I. Rate Coefficients for the Standard Model

Symbol Symbol	Meaning	Rate
r_H	Stellar Death Rate, halo	0.001
r'_H	Gas Return from Halo Stars	0.002
r_D	Stellar Death Rate, disk	0.001
r'_D	Gas Return Rate from Disk Stars	0.005
a	Stimulated Star Formation Rate	0.005
a'	Stimulated Cloud Destruction Rate	0.90
K	Schmidt Law for the Halo	0.50
H	Cloud-Cloud Collision Rate	0.005
H'	Cloud-Cloud Destruction Rate	0.10
n	Schmidt Law Exponent	1.5
μ	Fraction of Infall in Gas Phase	1.0
ν	Schmidt Law for the Disk	0.50
f	Infall Rate	0.05
A	Asteration Rate for Disk Stars	0.10
R_H	Remnant Mass Fraction of the Halo	0.50
R_D	Remnant Mass Fraction for the Disk	0.50
$P_{Z,H}$	Primary Metal Yield for Halo	0.002
$P_{Z,D}$	Primary Metal Yield for Disk	0.018

TABLE II. Population Fractions for Disk

Phase	10^{10} yr	1.5×10^{10} yr	Larson (1985)
Stars	0.44	0.33	0.33
Gas	0.18	0.13	0.12
Remnants	0.38	0.54	0.55

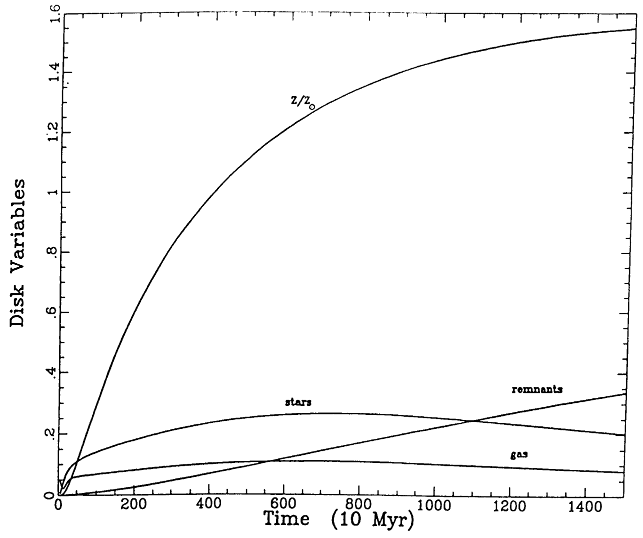

Fig. 1. Evolution of disk phases and metallicity for the standard model to 1.5×10^{10} years.

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https://doi.org/10.1017/S0074180900096832 Published online by Cambridge University Press