KINEMATICAL AND CHEMICAL EVOLUTION OF THE GALACTIC DISK

Cedric G. Lacey and S. Michael Fall
Institute of Astronomy, Cambridge, England

We have calculated models for the kinematical and chemical evolution of the Galactic disk that include the infall of metal-free gas and the stochastic acceleration of disk stars. Our models are similar in some respects to those of Chiosi (1980) and Vader & de Jong (1981), but the results are compared with a greater variety of observational data. A complete description of this work will appear shortly in Monthly Notices of the Royal Astronomical Society.

The evolution of the stars, gas and heavy elements is treated in the approximation of instantaneous recycling, with a constant yield y and returned fraction R, and with no exchange of material between different galactocentric radii. The rate of infall of gas per unit area is assumed to vary as

$$f(r, t) \propto \exp(-\alpha r - t/t_f) \tag{1}$$

so as to give an exponential profile for the surface density. Following Schmidt (1959), the star-formation rate is assumed to vary as a power of the volume density of the gas; thus

$$(1 - R)\ \psi = C(\mu_g/H_g)^n\ H_g \tag{2}$$

where μ_g is the surface density of the gas layer, H_g is its half-thickness and ψ is the star-formation rate per unit area. We calculated models with n = 1, 3/2, 2 and adjusted the parameters t_f and C.

The stars are born with a small velocity dispersion comparable to that of the gas and are then accelerated by the irregular gravitational field of "clumps" in the disk. The evolution of the vertical velocity dispersion σ_s is represented by a phenomenological equation of the form proposed by Wielen (1977), with the additional assumption that the coefficient of diffusion in velocity space has the same time-dependence as the star-formation rate, thus:

$$d\sigma_s^{\,q}/dt = \beta d\mu_s/dt\ , \tag{3}$$

H. van Woerden et al. (eds.), The Milky Way Galaxy, 597–599.

https://doi.org/10.1017/S0074180900243222 Published online by Cambridge University Press

Table 1. Input parameters for best-fit models

n	t_f	C	q	β	σ_{SO}
1	5.5	0.5	2	14	2
3/2	3.5	1.1	2	17	2
2	2.0	2.1	5/2	85	3

Units : t_f in Gy, C in $(M_\odot pc^{-3})^{1-n}$ Gy^{-1}
β in $(km\ s^{-1})^q (M_\odot pc^{-2})^{-1}$, σ_{SO} in km s^{-1}

Table 2. Output parameters for best-fit models

n	y	$\overline{\psi}/\psi_1$	$(1-R)\psi_1$	f_1
1	0.015	2.1	2.9	1.9
3/2	0.014	3.9	1.6	0.8
2	0.012	8.6	0.7	0.1

Units : ψ_1 & f_1 in $M_\odot$ pc^{-2} Gy^{-1}

where μ_S is the surface density of the stars and q and β are parameters to be determined. This is reasonable if the perturbing clumps are giant molecular clouds and perhaps also if they are spiral wavelets.

Models for the solar neighbourhood were compared with observations of the present gas density and the age-metallicity, number-metallicity and velocity dispersion-age relations for disk stars. For each value of n there is a best-fit model providing a good fit to all of these data. The input parameters of these models are given in Table 1 and some of the output parameters in Table 2 (in which the subscript "1" denotes the present value and a bar the time-average value). The n = 2 model is probably ruled out by its large value of $\overline{\psi}/\psi_1$, but the n = 1 and n = 3/2 models are consistent with the observational constraint $0.5 \lesssim \overline{\psi}/\psi_1 \lesssim 4$.

We also calculated the variation of properties with galactocentric radius for models with the same values of the parameters as fit the solar neighbourhood best. These models reproduce the approximate constancy of the stellar scale height with radius observed in edge-on galaxies, and the n = 1 and n = 3/2 models were consistent with the observed radial variation of gas density and star-formation rate. However, none of the models gave an abundance gradient as large as that observed. We are at present working on models with radial gas flows in an attempt to resolve this problem.

REFERENCES

Chiosi, C.: 1980, Astron. Astrophys. 83, p. 206
Schmidt, M.: 1959, Astrophys. J. 129, p. 243
Vader, J.P., and de Jong, T.: 1981, Astron. Astrophys. 100, p. 124
Wielen, R.: 1977, Astron. Astrophys. 60, p. 263

DISCUSSION

J.V. Villumsen: Your best value for q in equation (3) is about 2, while your analytical calculation of scattering (your paper in section III.2 of this Symposium) gives you q = 4. How do you reconcile those values?

Lacey: The value q = 2 was obtained by fitting the predictions of the model, including the phenomenological equation (3), to Wielen's (1977) observational data on the relation between vertical velocity dispersion and age. The mechanism of scattering by clouds with negligible random motions, which predicts q = 4 (c.f. eqn (4) of my paper in Sect. III.2), is thus not consistent with Wielen's data unless the product $N_c M_c^2$ has declined with time more rapidly than the star-formation rate.

R.W. Hilditch: A general observational remark. There is now plenty of evidence for the existence of main-sequence B, A stars and G, K giants with apparently normal, solar-type abundances at several kiloparsecs from the galactic plane. I refer to the work of Tobin and Kilkenny; Rodgers, Harding and Sadler; Hill, Hilditch and Barnes; and Hartkopf and Yoss.

T.M. Bania : I would like to comment on the possible uncertainty in our understanding of the evolution of low-mass stars, which contribute substantially to the chemical evolution of the ISM when their envelopes become fully convective at the base of the red-giant branch. Recently Bob Rood, Tom Wilson and myself have surveyed the Galaxy to determine the He abundance in giant HII regions. The most striking result is that the He abundance in W3, which is located beyond the solar circle, is at least seven times the proto-solar value whereas the He abundance in M17, an inner-Galaxy source, is solar or less. This is exactly opposite in sense to the observed C and He being produced in low-mass stars and slowly accumulating during the main-sequence phase into a zone of enhanced abundance near the mass fraction 0.3 - 0.4. If the C gets mixed to the surface and expelled, so should the He, and these species ought to show the same radial abundance gradient in the Galaxy. Thus something funny is going on in these sources, and our standard assumptions regarding the rate of enrichment from low-mass (and high-mass?) stars should be examined critically.

https://doi.org/10.1017/S0074180900243222 Published online by Cambridge University Press

In the Aula of Groningen University, A. Blaauw presents descendants of J.C. Kapteyn with copies of "Sterrenkijken bekeken", a booklet about the history of Groningen astronomy. CFD