THE EFFECT OF STELLAR MASS ON KINEMATICAL AGE DETERMINATION

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It is believed that kinematical characteristics of a group of stars, as the velocity dispersion or the lag in rotation, change systematically with time. This kinematical evolution is widely used for the determination of stellar ages. In particular, velocity dispersion should increase with time owing to irregular galactic force field. A classical formula for the increase of stellar velocity ν with the age τ

$$\nu = \nu_o(1 + \gamma\tau)^{1/3} \tag{1}$$

has been derived by Spitzer and Schwarzschild (1953) on the assumption of a gravitational action of supposed massive interstellar clouds (10^5-10^6 M_o) on stellar motions. This mechanism, as well as some others, e.g. violent relaxation proposed by Lynden Bell (1967) work independently of stellar masses because of the great mass ratio of interacting bodies. The interactions between individual stars which should produce mass effects in stellar motions, working towards the equipartition of energy, seemed to be insignificant owing to great distances between the stars. The relaxation time for these interactions is of the order of 10^{14} years, as has been shown by Chandrasekhar (1942).

Yet, since it is known that stars are formed in aggregates - associations or clusters - for which the relaxation time is of the order of their age (10^7 years for open clusters and 10^9 for globulars) it is to be expected that stars leave their parent aggregates with some degree of exchange of energy, when the aggregate merges into the general galactic field. Consequently, the velocity dispersion should be to some extent dependent on the mass of stars, being larger for lower mass stars at the same age level (Iwanowska, 1958). It is not easy, however, to check this effect because of a strong correlation existing between the age and mass of stars, as follows from the stellar evolution considerations. This is the case for normal main-sequence stars for which one

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might consider the increase of the dispersion along the sequence as a result of either an increase of age, or a decrease of mass, or both factors acting together. For this last case I should like to propose a generalization of the Spitzer-Schwarzschild formula adding a mass factor :

$$\sigma^2 = \sigma_o^2(M_\odot/M)^\alpha(1+\gamma\tau)^{2/3} \tag{2}$$

where the exponent α indicating the degree of "maxwellization" of stellar motions is contained between 0 (no mass effect) and 1 (full maxwellization). σ_o means the initial velocity dispersion of stars of one solar mass, intercepted by the general galactic field, τ is the time elapsed since then up to now.

It is not possible to determine distinctively α and γ from velocity dispersions of stars whose masses are correlated with their ages, as is the case for most of main sequence stars (another problem of hidden mass!). We have to look for mass effects in the motions of either young low mass stars or old high mass ones. Such objects seem to exist in our Galaxy, dMe stars representing the first case, some giants approaching probably the other one. The difficulty lies, however, in our poor knowledge of masses of these stars and still more of their ages. Nevertheless, it seems to be worthwhile to attempt a solution at the present level of information.

I have compiled (Table I and Fig. 1) bona fide most reliable data for different stellar species of population I, namely mass values taken mostly from Allen (1973), age estimations taken mostly from evolutionary tracks of stars calculated by Iben (1967), using half-life time for stars on the main sequence, and velocity dispersions taken from Allen (1973) or Parenago (1954) for early type stars, or from determinations made in Torun for later type ones. These last values have been obtained for different stellar species in the course of determining statistical population indices and are supposed to represent pure population I data. Mean velocity dispersion in one coordinate is being used throughout, namely

$$\sigma^2 = \frac{1}{3}(\sigma_u^2 + \sigma_v^2 + \sigma_w^2)$$

Taking equation (2) in the form

$$\sigma^3 = \sigma_o^3(M_o/M)^{\frac{3}{2}\alpha}(1+\gamma\tau)$$

I have first determined graphically σ_o and γ drawing a straight line through the most certain point d(F,G,K) with solar mass and age values and a fictitious point weighted between young star points to correspond to one solar mass. This straight line represents the equation (2) for

Table I : Basic data

Stellar species	Mass $M/M_{\odot}$	Age τ (10^8 yrs)	Dispersion σ (km s^{-1})	Ref. for σ
Bo	18.0	0.04	8.7	
B6	5.0	0.3	10.0	
Ao	3.0	1.0	11.7	
A6	2.0	3.0	15.0	
Cepheids	7.2	0.6	12.0	1
d(F,G,K)	1.0	45.0	26.7	2
dMe	0.3	5.0	18.9	3
late dMe*)	0.2	6.0	19.2	4

*) dM5e and later

References for σ : 1 - T. Boenigk, Bull. Astron. Obs. Torun, No 44 1968 ; 2 - R. Głebocki, ibidem, No 41, 1967 ; 3 - W. Iwanowska, ibidem, No 49, 1972 ; 4 - W. Iwanowska, in press.

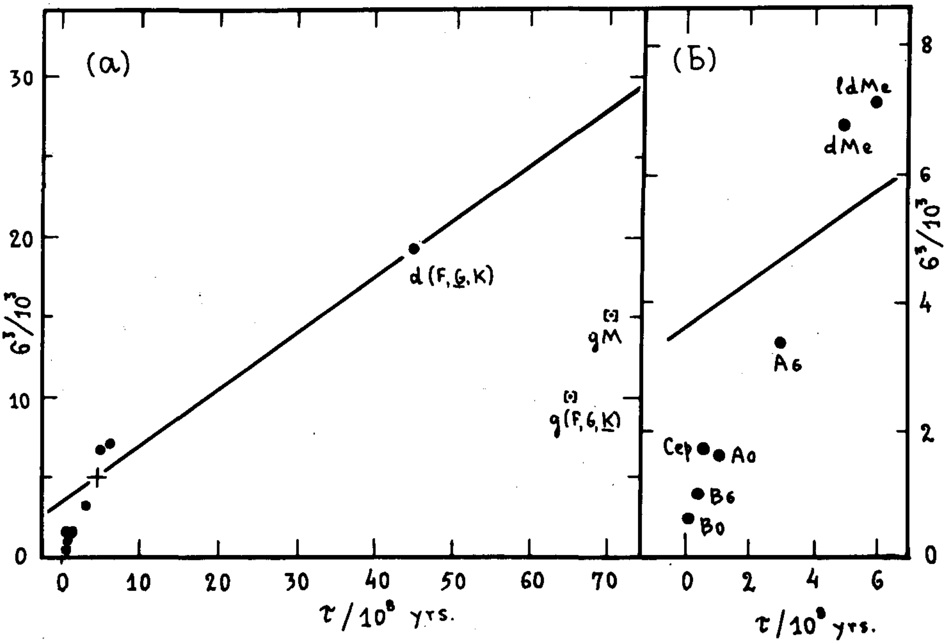

Fig. 1 : a) Observed (σ^3,τ) relation ; b) Enlarged part of it.

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stars of one solar mass. Then α-values have been found for individual points according to the equation (2) with σ_o and γ already known. Mean α was taken finally. In my first solution no cepheids have been used, but late type giants were included with the ages close to 7x10 years, as assigned by Wielen (1973) to "old" giants. The results were

$$\sigma_o = 15 \text{ km s}^{-1}, \ \gamma = 1.1\text{x}10^{-9}, \ \alpha = 0.40 \pm 0.04.$$

Since evolutionary tracks converge to the region of giants from a very wide range of stellar ages covering more than two orders of magnitude, it is difficult indeed to derive a reliable mean age for them. Therefore, I have performed a second solution based on the data given in Table I with no late type giants. The new parameter values are

$$\sigma_o = 15 \text{ km s}^{-1}, \ \gamma = 1.0\text{x}10^{-9}, \ \alpha = 0.33 \pm 0.07$$

concordant with the former ones within one mean error value. The new α-value has been determined from very young stars (see Fig. 1b). For this age and mass range following empirical formula occurs to fit very well

$$\sigma^3 = \sigma_o^3(1 + \gamma\tau) - a \log(M/M_\odot) \qquad (3)$$

with a = 2.77 $\pm$ 0.39 x 10^3. Of course, one cannot take these figures too seriously, since possible systematic errors in age, mass and dispersion determinations are not known. Nevertheless, the obtained results are in favour of the significance of stellar masses for their motions in our Galaxy. This fact, if real, has also some consequences on the chemical evolution of the Galaxy, when massive stars, main producers of heavy elements are more concentrated towards the galactic plane and center because of the lower velocity dispersions. This fact alone should produce a composition gradient.

It is also clear that our solutions cannot be applied with the same parameter values to population II stars. If the galactic halo consists of stars ejected from the disc and those formed in the halo - in globular clusters or in extragalactic aggregates - a composite formula seems to be appropriate for halo stars containing two terms at least :

$$\sigma^2 = \sigma_o'^2(M_\odot/M)^{\alpha'}(1 + \gamma'\tau)^{2/3} + \sigma_o''^2(M_\odot/M)^{\alpha''}(1 + \gamma''\tau)^{2/3} \qquad (4)$$

The first term may have parameter values close to those of population I, while for the second term one should expect a σ_o'' value of the order of 100 km s^{-1} and a negative value for γ''.

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