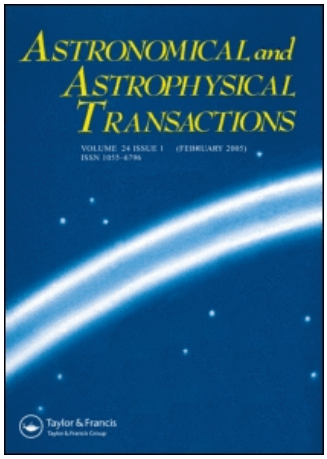

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T. B. Omarov [a]
[a] Astrophysical Institute, Alma-Ata, Kazakhstan

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ON THE ASTRONOMICAL APPLICATIONS OF THE DYNAMICS OF HIERARCHICAL SYSTEMS†

T. B. OMAROV

Astrophysical Institute, Alma-Ata 480068, Kazakhstan

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An equation for the formation time of galaxy clusters in a self-organizing Universe of the critical density is obtained using the method of dynamics of hierarchical systems. It is shown that the value of this time predetermines, in a certain sense, the violent relaxation time.

KEY WORDS Celestial mechanics, stellar dynamics – galaxy clusters: violent relaxation

Any self-organizing system has a hierarchical structure [1]. There are reasons to believe that galaxy clusters form a hierarchical level in the self-organizing Universe [2, 3]. These subunits of the Metagalaxy expanding according to the Hubble law as systems of gravitating bodies, generally, are not in equilibrium initially [4]. It is known that the dynamical activity of hierarchical systems at some given level can be investigated by considering processes at the lower levels as boundary conditions and those at the upper levels, as a constant [3]. In the case of the Metagalaxy with the critical density $\delta = 1/6\pi Gt^2$, such an approach to the behavior of galaxy clusters leads to the equation containing their formation time T:

$$\begin{aligned} U + 2h &\simeq 4/3(U_0 + 2h) - 1/6(\dot{U}_0 T) - (14(U_0 + 2h) - 2\dot{U}_0 T)t/T \\ &+ (27(U_0 + 2h) - 9/2(\dot{U}_0 T))(t/T)^2 - (40/3(U_0 + 2h) \\ &- 8/3(\dot{U}_0 T))(t/T)^3, \end{aligned} \tag{1}$$

where t is the cosmogonical time, $(-U)$ is the potential energy, h is the energy integral, U_0 and $\dot{U}_0$ are the values of U and dU/dt for $t = T$, respectively. In this equation for non-equilibrium conditions of galaxy clusters (in the corresponding practical sense $U(t)+2h \neq 0$), the time interval is considered such that the condition $t - T < T$ is simultaneously fulfilled.

It is believed that an efficient mechanism of the relaxation acts in galaxy clusters associated with a considerable non-regularity of the initial mass and velocity

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distributions [3]. In equation (1) under a dominant effect of such a process on the time behavior of the quantity $U + 2h$, we can neglect the initial rate of its variation. Correspondingly, we have

$$U + 2h \simeq (U_0 + 2h)(4/3 - 14(t/T) + 27(t/T)^2 - 40/3(t/T)^3), \tag{2}$$

putting

$$\dot{U}_0/(U_0 + 2h) \ll 5/T. \tag{3}$$

For the root $t/T > 1$ of the equation

$$4/3 - 14(t/T) + 27(t/T)^2 - 40/3(t/T)^3 = 0, \tag{4}$$

we find $1.24 < t/T < 1.25$. Consequently, in the self-organizing hierarchical Universe with the critical density, the time τ for reaching the virial equilibrium in galaxy clusters is predetermined by the formation epoch of these gravitating systems as follows:

$$\tau \simeq (1/4)T. \tag{5}$$

The condition (3) under $T = 4\tau$ naturally means that, in the violent relaxation process, the average value of the variation rate of the non-equilibrium parameter $U + 2h$ strongly exceeds its initial value

$$|\dot{U}_0| \ll |U_0 + 2h|/\tau. \tag{6}$$

Relation (5) can be used, in particular, for the determination of the formation epoch of galaxy clusters as non-equilibrium systems of gravitating masses, according to the estimates of the violent relaxation time of these objects.

References

1. Nicolis, J. C. (1986) *Dynamics of Hierarchical Systems*, Springer-Verlag, Berlin-Heidelberg
2. Haken, H. (1983) *Advanced Synergetics*, Springer-Verlag, Berlin-Heidlberg.
3. Saslaw, W. C. (1987) *Gravitational Physics of Stellar and Galactic Systems*, Cambridge University Press, Cambridge.
4. Ostriker, J. P. (1978) *The Large Scale Structure of the Universe*, M. S. Longair and J. Einasto (eds.), IAU Symp. No. 63, Reidel Publ., p. 393.