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Abstract

Full Text

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A PRACTICAL CRITERION OF THE STATIONARITY OR NONSTATIONARITY OF FINITE SELF-GRAVITATING STELLAR SYSTEMS

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The probable passage of various stellar systems through an initial stage of a diffuse state with effective mutual collisions of the elements composing them ([1]), and the allowance for gravitational perturbations from large-scale structural inhomogeneities ([2]), provide physical grounds for establishing, generally speaking, stationarity (or mixing ([3])) in stellar systems left to themselves for a sufficiently long time.

Let us consider the following practical criterion for the applicability or inapplicability of a stationary model to one or another real stellar system. Let δ be the mean density of the system. Then at a distance r from its center of mass the "circular velocity" of bodies within the system is of the order

$$v_0 = \sqrt{\frac{4}{3}\pi G\delta}\, r, \tag{1}$$

and the period of revolution

$$P_0 = \frac{2\pi r}{v_0} = \sqrt{\frac{3\pi}{G\delta}}. \tag{2}$$

On the other hand, by the virial theorem, applicable to stationary and linearly nonstationary systems ([4], [5]), the root-mean-square velocity of stars in the system relative to its center of mass is expressed in terms of its mass M and mean radius $\bar{r}$ as follows:

$$\sqrt{\overline{v^2}} = \sqrt{\frac{1}{2}\frac{GM}{\bar{r}}}, \tag{3}$$

i.e., the period of oscillation along the mean diameter of the system $2\bar{r}$ is of the order

$$P_1 = \frac{4\bar{r}}{\sqrt{\overline{v^2}}} = \sqrt{\frac{32\bar{r}^3}{GM}} = \sqrt{\frac{24}{\pi G\delta}} \simeq P_0 \simeq \frac{3}{\sqrt{G\delta}}. \quad (4)$$

Consequently, the period

$$P = \sqrt{\frac{3}{\sqrt{G\delta}}} \quad (5)$$

characterizes the time of substantial displacement of bodies within the system (a kind of time of one-time mixing). Any finite cosmic system at some time arose from something and in this sense has a definite age T. If $T \ll P$, then the system could hardly have had time to come

into a stationary state. Conversely, if $T \gg P$, then during the lifetime of the system each of the bodies composing it has repeatedly moved through the region accessible to it, and on average the entire system at any given moment should naturally be regarded, at least in a first approximation, as stationary.

This criterion:

$$\begin{aligned} T \ll P \quad & \text{for nonstationary systems,} \\ T \gg P \quad & \text{for stationary systems} \end{aligned} \quad (6)$$

is in good agreement with the astronomical data given in Table 1, which require no special explanation.

Table 1

	Dilute O-associations	Open clusters, type O	Open clusters, types B and A	Globular star clusters	Galaxy	Metagalaxy
δ, g/cm^3	10^{-23} ([6,4])	10^{-22} ([7])	10^{-22} ([7])	$4 \cdot 10^{-22}$ ([8–11])	10^{-24} ([12])	$\ll 10^{-27}$ ([13–16])
P, years	10^8	$4 \cdot 10^7$	$4 \cdot 10^7$	$2 \cdot 10^7$	$4 \cdot 10^8$	$\geq 10^{10}$
T, years	10^7 ([17,4])	10^7 ([18])	10^9 ([18])	$5 \cdot 10^9$ ([19])	$5 \cdot 10^9$ ([19])	$5 \cdot 10^9$ ([19])
According to criterion (6)	Nonstationary	Nonstationary	Stationary	Stationary	Stationary	Nonstationary

	Dilute O-associations	Open clusters, type O	Open clusters, types B and A	Globular star clusters	Galaxy	Metagalaxy
Direct indications	Expansion ([6,20–25]), disintegration ([26,4])	Expansion ([27,4]), disintegration ([18])	Practical absence of hyperbolic velocities, applicability of stationary models ([18,11,12,28,29])	Practical absence of hyperbolic velocities, applicability of stationary models ([18,11,12,28,29])	Practical absence of hyperbolic velocities, applicability of stationary models ([18,11,12,28,29])	Redshift (recession of galaxies) ([30])

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Note: Figure translations are in progress. See original paper for figures.