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### On the origin of galaxy chains

O. A. Zheleznyak <sup>a</sup>

<sup>a</sup> Uman Teachers' Training College, Uman, Ukraine

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## SHORT NOTE

# ON THE ORIGIN OF GALAXY CHAINS

O. A. ZHELEZNYAK

*Uman Teachers' Training College, 258900 Uman, Ukraine*

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We propose the hypothesis that galaxy chains are a result of disintegration of a rotating self-gravitating toroidal body.

KEY WORDS Chains, galaxies.

A chain of galaxies typically contain several galaxies and have diverse spatial configurations. According to photometry, the mean color of these galaxies is  $\langle B - V \rangle \approx 0.4$  and  $\langle U - B \rangle \approx -0.4$ , which is very close to that of irregular galaxies (Metlov, 1979). The average size of a chain ( $l$ ) is approximately 30 kpc. Observations imply a physical connection between the galaxies forming a chain and the average velocity ( $v$ ) difference between the components of a chain is 250 km/s ( $\Delta v \approx 250$  km/s). This can be explained by rotation around a common center (Vorontsov–Velyaminov, 1979). In some cases, a galaxy belonging to a chain exhibits a strong deviation in velocity from other chain members.

In this paper, the hypothesis of a common origin of the galaxies forming a chain is proposed. The main idea is that the chains are a result of the disintegration of a rotating self-gravitating toroidal body. The gravitational instability leads to the concentration of the matter on one side of the toroidal body resulting in an asymmetric configuration which looks like a knot-shaped biscuit. Further matter compression gives origin to new galaxies and a galaxy chain.

The mass distribution asymmetry affects the redistribution of the angular momentum and one of the galaxies can receive a much larger velocity with respect to the chain centre than other galaxies.

Using the conservation of energy, we can demonstrate that this is possible. The total mechanical energy of a self-gravitating toroidal body is equal to the total energy of the chain:

$$\frac{1}{2}\dot{I}_r\omega_r^2 + \Pi_r \approx T_c + \Pi_c, \quad (1)$$

where

$\dot{I}_r = M_r(R^2 + \frac{3}{4}a^2)$  is the moment of inertia of the toroidal body,

$\Pi_r \approx -\frac{GM_r^2}{2\pi R} \ln \frac{8R}{a}$  is the gravitational energy of thin toroidal body,

$M_r$  is the mass of the toroidal body,

$\omega_r$  is its angular velocity,

$R$  and  $a$  are the larger and smaller torus radii, respectively, and  $T_c$  and  $\Pi_c$  are the kinetic and potential energy of the chain.

The potential energy of the chain is given by

$$\Pi_c = -\frac{G}{2} \sum_{i=1}^n \sum_{j=1}^n \frac{m_i m_j}{r_{ij}} \quad (i \neq j),$$

where  $m_i$  and  $m_j$  are the galactic masses and  $r_{ij}$  is the distance between the galaxies. Consider four galaxies of the same mass  $m$  which have been formed from the "knot-shaped biscuit" located at distance  $R$  from the center of mass of other galaxies in the torus. The latter are separated by distance  $\lambda$  corresponding to the critical wave-length for gravitational instability. Eq. (1) then takes the form

$$M_r(R^2 + \frac{3}{4}a^2)\omega_r^2 - \frac{GM_r^2}{\pi R} \ln \frac{8R}{a} \approx 3m(\Delta v)^2 + mv_4^2 - \frac{Gm^2}{R} \left(1 + \frac{5R}{2\lambda} + \frac{2R^2}{R^2 - \lambda^2}\right).$$

Taking into account that  $\omega_r \approx \Delta v/R$ , we find

$$\gamma = \frac{v_4}{\Delta v} \approx \left[ \frac{M_r}{m} \left(1 + \frac{3}{4} \frac{a^2}{R^2}\right) + \frac{Gm}{(\Delta v)^2 R} \left(1 + \frac{5R}{2\lambda} + \frac{2R^2}{R^2 - \lambda^2}\right) - 3 + \frac{GM_r^2}{\pi R m (\Delta v)^2} \ln \frac{a}{8R} \right]^{1/2}. \quad (2)$$

Thus,  $\gamma \approx (2 + 3)$  for the following typical values of relevant parameters:  $\Delta v \approx 250$  km/s,  $m \approx 10^{11} M_\odot$ ,  $R \approx l/2 \approx 15$  kpc,  $a \approx \lambda \approx 3$  kpc and  $M_r = 4m$ .

From the physical point of view, effect discussed above is due to a partial transformation of torodial bodies the gravitational energy of the toroidal body into the kinetic energy of the galaxies.

I am grateful to Professor A. D. Chernin for useful discussion.

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