

Is There a Ring Around Milky Way?

J J RAWAL

Nehru Planetarium, Nehru Centre, Worli, Bombay 400 018

Received 5 September 1981; revised received 15 May 1982

The resonance theory among the members of Magellanic Plane Group of Local Group of Galaxies is discussed. In this it is assumed that our Milky Way Galaxy lies at the centre of such a system and that the members of the system revolve around it. It is shown that the inner members of the Magellanic Plane Group must have been forming a ring structure around the Milky Way.

1 Introduction

Resonance theory in planetary system states that if n_1, n_2, n_3 ($n_i = 2\pi/T_i$, T_i being the corresponding orbital period, $n_1 > n_2 > n_3$), denote the mean motions of three secondaries going around a primary (orbits assumed circular and coplanar), then a necessary condition for the frequent occurrence of mirror configuration^{1,2} is

$$\alpha n_1 - (\alpha + \beta)n_2 + \beta n_3 = 0 \quad \dots (1)$$

where α and β are small positive integers. It follows from Eq. (1) that in a reference frame revolving with the mean motion of any one of the three secondaries, the relative mean motions n'_i of the other two are commensurate, and that in a frame I (that of the innermost secondary), we have $n'_2 = n_1 - n_2$ and $n'_3 = n_1 - n_3$ and the ratio of these relative mean motions is given as follows.

$$n'_2/n'_3 = (n_2 - n_1)/(n_3 - n_1) = \beta/(\beta + \alpha) \quad \dots (2)$$

In terms of revolution periods, Eq. (2) becomes

$$n'_2/n'_3 = (T_2 - T_1)T_3/(T_3 - T_1)T_2 = \beta/(\beta + \alpha) \quad \dots (3)$$

For a stable three-body resonance, the relative mean motion ratio (RMMR) [Eq. (3)] has the value 2/3. This case is called Laplace's resonance relation and three successive orbits following this relation represent stable motion.

Here, we apply and discuss the resonance theory among the members of the Magellanic Plane Group (MPG) of the Local Group of Galaxies as they are nearly coplanar³. In this we assume that our Milky Way Galaxy lies at the centre of such a system and that the members of the system revolve around it.

2 Is there a Ring Around Milky Way?

Kunkel³ has given a list of twelve stellar systems which are the members of the MPG. As we are taking the radius of the Milky Way to be 50 kpc (Ref. 4) in our

discussion, we consider those members of the MPG which lie beyond 50 kpc. It has been verified that the general features and results of the present discussion remain the same whether we use the distances of the stellar systems from the galactic centre or from the sun. In the application of Kepler's third law to find the revolution periods of the stellar systems under consideration, we take the mass of the Milky Way to be $5 \times 10^{11} M_\odot$ (Fujimoto⁵ adopts the mass of the Milky Way to be $1.2 \times 10^{11} M_\odot$).

The application of RMMR to the successive members of the MPG under consideration yields the values presented in Table 1.

With the help of RMMR, the possibility of a ring structure around our Galaxy has been investigated theoretically. For this, we hypothesize that an object (dwarf Galaxy, cluster or a ring) exists between the Milky Way and the Large Magellanic Cloud (LMC). We denote this hypothetical object by HILMCO (hypothetical intra-Large Magellanic Cloud object). We assume that the successive triad HILMCO, LMC and SMC (Small Magellanic Cloud) has for its RMMR the value 2/3, i.e. it is assumed that the resonance among the members of the successive triad is stable as is the case with the first triad of Table 1. Then applying Eq. (3), we know the orbital period T_1 of the HILMCO and hence its distance. The repeated application of this idea will give us all the stable resonant orbits within the orbit of LMC. With the mass and radius assumed above for our Galaxy, we do not find any such orbit within the orbit of LMC even if we take RMMR to be 1/2.

We now find Roche limit of our Galaxy and try to see whether it helps us to infer a ring structure around our Galaxy. Roche limit is the distance around the primary (here Milky Way), on entering which a secondary (here a satellite stellar system) gets disrupted into fragments by tidal forces; alternatively, that the matter within this

Table 1—Resonance in the Triads of Successive Members of the MPG under Consideration

Triad	RMMR [$\beta/(\beta + \alpha)$]
{ LMC SMC Ursa Minor	2/3
{ SMC Ursa Minor Draco	1/2
{ Ursa Minor Draco Pal 4	2/3
{ Draco Pal 4 Carina	1/4
{ Pal 4 Carina Leo I	4/5

distance would not get condensed into a satellite-stellar system, and is given by

$$r_R = 2.46 (\rho_p / \rho_s)^{1/3} \times R_p \quad \dots (4)$$

where, ρ_p is the mean density of the primary, ρ_s is the mean density of the secondary and R_p is the radius of the primary. We take the radius of our Milky Way to be 50 kpc. Therefore, to arrive at the Roche limit, r_R , of our Galaxy, one requires a knowledge of the ratio ρ_p / ρ_s .

Kurth⁶ has discussed the following idealized stability criterion

$$\bar{\rho} > 2\rho \quad \dots (5)$$

where $\bar{\rho}$ is the mean density of a spherically symmetric cluster and ρ is the density of the sphere about the galactic centre having the centre of the cluster on its surface, and being uniformly filled with the total mass of the Galaxy. Therefore, for a disrupting cluster, we should have the condition

$$\bar{\rho} \leq 2\rho \quad \dots (6)$$

We assume that this condition remains valid not only for a cluster but also for any satellite-stellar system. Under this condition taking the critical value of $\rho/\bar{\rho}$ ($=\rho_p/\rho_s$) given by the relation (6) to be 1/2 we find the Roche limit of our Galaxy to be ~ 100 kpc. Therefore, all satellite-stellar systems of our Galaxy lying within the distance of ~ 100 kpc and fulfilling the condition (6)

on $\rho/\bar{\rho}$, are under disruption and must have been forming a ring structure around our Galaxy. In fact, such satellite-stellar systems may be considered to be the parts of the ring structure around our Galaxy.

If the mass and the radius of our Galaxy are 10-15% less than what we have assumed above, we get one orbit within the orbit of LMC which, of course, lies within the Roche limit, and without giving different picture may be interpreted to be the part of the ring structure along with other inner members of MPG.

In this context, it is interesting to note that a southern sky survey of HI (neutral hydrogen) by Mathewson *et al.*⁷ in the velocity range -340 to 380 km sec⁻¹ has shown that a long filament of HI extends from the region between the Magellanic Clouds down to the south galactic pole and connects with the long HI filament discovered by Wannier and Wrixon⁸. Hodge⁹ showed that the small galaxy in Ursa Minor is larger than its tidal limit even if our Galaxy has no halo. Hodge and Michie¹⁰ have suggested that it is being tidally disrupted. Lynden-Bell¹¹ shows that the Draco object is also elongated and suggests that these objects might be the debris of a Greater Magellanic Galaxy which was progressively disrupted by the tidal forces of our Galaxy. All these studies tend to suggest the existence of a ring structure around our Galaxy.

Acknowledgement

The author thanks Prof. J V Narlikar, Prof. S M Chitre and Dr S Ramadurai of the Tata Institute of Fundamental Research, Bombay, for helpful discussions and useful suggestions. The author is also grateful to the referees for their critical comments and helpful suggestions.

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