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Stability of Hickson Groups of Galaxies

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Abstract

In this work we have used the Viril theorem to investigate the dynamical stability of Hickson compact groups of galaxies. The average luminous mass of the galaxies member is approximately 1.3 $\times 0^{11}$ $M_\odot$ and average total luminous mass of group is approximately 4.6 $\times 0^{11}$ $M_\odot$. The virial theorem has used to estimate the virial mass. The average Virial mass of group of galaxies is approximately 6.3 $\times 0^{13}$ $M_\odot$ This is attributed to the presence of large amount of dark matter which is more than 90% in this group. Hickson compact groups of galaxies are unstable system due to the virial to luminous masses ratio.

Key Words: Galaxies, compact groups, luminosity, masses.

1. Introduction

The most common structures in the universe are systems of galaxies and are treated to be as the building blocks of the universe. Galaxies occur in a wide variety of systems ranging from single galaxies through pairs, small groups to rich clusters of galaxies. Most galaxies are neither completely isolated nor in rich clusters, but instead are found in galaxy groups that contain only a handful of members, thanks to gravity. The dynamical evolution of gravitationally bound groups of galaxies should account for some of the objects seen in the universe. There is little consensus on the nature of compact groups of galaxies. They are relatively small, dense, isolated system, containing typically three or more members, with very low median projected intergalactic separation. The compact group formation could act on the majority of galaxies in the immediate surrounding of the group: as a suggestion, large potential wells of dark matter form first. All galaxies in the area of these wells would fall in producing a compact group before finally merging. The extent of such potential wells would have to be considerably large than the extent of the present Hickson compact groups. A numerical simulation of the merging of compact groups shows that the process may result in the formation of bright elliptical galaxies. If the compact groups are interpreted as transit phases in the dynamical evaluation of looser groups, the merger remnants they leave behind exemplify galaxy formation at the present epoch. X-ray observation is most suitable to investigate the potential well by revealing the extension of the gas surrounding the group. Therefore they are extremely useful in elucidating the nature and dynamical state of these objects and should allow discriminating between the various compact group formation scenarios given by[1]. The Virial mass necessary to bind a group was larger than the luminous mass. The problem which has still not found a definite answer is the dynamical instability of large galaxy aggregates has always been demonstrated by assuming that if they were stable they should obey the virial theorem. Early studies of stability of the galaxy groups show that the virial mass necessary to bind a group was larger than the visible mass by a factor of 50, [2]. The aim of the present work is to show how the stability of some Hickson compact groups of galaxies can be described as defined earlier by [3]. We have used the virial theorem to check if these groups are stable or not.

2. Optical, Visible, Mass of Groups

The data of some Hickson compact groups of galaxies which have been compiled from [4–6], are reinvestigated in the present study. In general all member galaxies are of known radial velocities [4]. It is now clear that many galaxies emit a large fraction of their radiation at other wavelengths, especially radio and infrared. The luminosity of our sample have been calculated from the absolute magnitude relation:

$$L/L_{\Theta} = 0.4 \times (m_{\Theta} - m_g)10". \tag{1}$$

Here, L is the galaxy luminously, $L_{\odot}$ is the luminosity of the sun, m_g is the magnitude of galaxies and $m_{\odot}$ is the magnitude of the sun, the magnitudes of galaxies have been used [7]. The visible mass of individual galaxies in Hickson compact groups has been obtained from adopted mass to light ratio. The mass to luminosity ratio in Hickson compact groups are somewhat lower than for relatively isolated galaxies [8]. We have assumed that the mass to light ratio 9 – 13 for spiral galaxies, 10 for elliptical galaxies and 3 for irregular galaxies [9].

The estimated average luminous mass of galaxies members is $\sim 1.3 \times 0^{11} M_{\odot}$. The total luminous mass of the groups is calculated by taking the summation of the individual masses of the galaxy members and is roughly $\sim 4.6 \times 0^{11}\ M_{\odot}$.

3. Stability of the Groups

The gravitationally bound system is in Equilibrium State if its total energy is equal to zero. So, one half of the time averaged potential energy is equal the kinetic energy according to the Virial theorem. The Virial mass of Hickson compact groups of galaxies using the Virial theorem is determined. To approach the problem we start with the equation of Virial theorem given by

$$e2T = U \tag{2}$$

It applies to a wide variety of systems, from an ideal gas to a cluster of galaxies, [10].

The kinetic energy of relaxed group of galaxies is given by

$$T = \frac{3}{2} \sum_i m_i v_i^2, \tag{3}$$

where T is the kinetic energy of the group. m_i and ν_i are the mass and radial velocity of group members with respect to the center of the group [11].

The Potential energy is given by:

$$-U = \frac{2G}{p\pi} \sum_i \sum_j \frac{m_i m_j}{r_{ij}}, \tag{4}$$

where, U is the potential energy of the group. m_i , m_j are the masses of group members [11], G is the gravitational constant, and r_{ij} is the 3-D real distance between the center of a galaxy m_i and the center of a galaxy m_j [11]. For instance, consider the masses of the galaxy members m_i to calculate the gravitational force of the system in a unit of mass, which is generated by the gravitational attraction of a distribution of m_i, since the force is conservative by the potential.

The total Virial mass of groups is approximately given by [2] as,

$$m_{vt} = -2\frac{T}{U}m_L, \tag{5}$$

where m_{vt} is the total Virial mass of group, m_L is the total luminance mass of the group. The Virial mass of Hickson compact groups have been determined.

We study the stability of Hickson compact groups of galaxies by applying the Virial theorem and define therefore S ratio ($S = M_{virial}/M_{visible}$) of the Virial to the Visible masses of the group. If the Virial theorem is fulfilled, it must hold ($S \sim 1$). For stability it would be a sufficient condition if ($0 < S < 2$) [2]. In this work we accept the S more than 10 times is a stable group.

The calculations of visible and virial masses of Hickson compact groups of galaxies in unit of solar mass and the ***S*** ratio are listed in Table 1. The Virial theorem is due to fact that mass to luminosity ratios used are global values and are subject to some uncertainty.

An alternative explanation that Hickson compact groups of galaxies are bound supporting the hypothesis of the presence of large amounts of dark matter in these groups. This is supported by the fact that the average mass of a member as deduced using the mass to luminosity ratio is approximately $1.3 \times 10^{11} M_{\odot}$, and the average total luminous mass of a group is approximately $4.6 \times 0^{11} M_{\odot}$. The average Virial mass (average dynamical mass of group) ranges up to $6.3 \times 10^{13} M_{\odot}$. This can be attributed to presence of large amounts of dark matter in Hickson compact groups of galaxies. This makes nearly a value more than 90% of the whole of mass of groups are dark matters. [4], found that the average Virial mass is $5.5 \times 10^{13} M_{\odot}$ and suggested that the presence of more than 85 % of dark matter. So the systems of groups are bounded by dark matter not by luminous matter.

The ***S*** ratio for Hickson compact groups of galaxies has been calculated with the mean value 99.7. The variation of ***S*** values could be two times lower or two times higher than the adopted values. In addition to the effect of random errors in ***S***, there are several sources of systematic errors which could affect the results. Probably the mass of galaxies or the mass of certain type of galaxies is a matter of doubt. This leads to an overestimate of the ***S*** values.

4. Conclusion

The mass to luminosity relation for each morphological type is used to derive the galaxies luminous masses, since the luminosity of the members is previously estimated. The result show that the average luminous mass of the members of the Hickson compact groups is approximately 1.3×10^{11}, $M_{\odot}$ and the estimated average total luminous mass of the groups is approximately $4.6 \times 10^{11} M_{\odot}$. The average dynamical group's masses range up to $6.3 \times 10^{13} M_{\odot}$. This is attributed to the presence of large amount of dark matter in Hickson compact groups. [4] concluded that average dynamical groups masses range up to $5.5 \times 10^{13} M_{\odot}$ and he found that more than 85 % of the mass in compact groups could be non luminous mass (dark matter). These results have been used to test the stability of Hickson compact groups through the virile theorem. It can be seen that the ratio (***S***) of Virial masses to luminous masses is in average about 99.7, in all groups the ***S*** ratio is more than 2, dark matter not by luminous matter bound the system of groups. This means that these groups are not stable for the luminous mass and may be the unstability of these groups leads to the collapse of these systems and increase the galaxies merging. Some groups are in dynamical equilibrium and physically bounded groups with general mode of stability.

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Table 1. the Virial to luminosity mass ratios for Hickson compact groups. Column 1 is The groups number, column (2) is the luminous mass, column (3) is the Virial mass And column (4) is the S ratio.

G. N	M_L (10^{11}) $M_\odot$	M_v (10^{13}) $M_\odot$	$S = (M_L/M_V)$
1	4.353	6.5	149.3223
4	6.063	7.91	130.4635
5	6.57	1.81	27.54947
6	5.148	7.07	137.3349
7	5.259	6.59	125.309
8	15.71	5.29	33.67282
12	5.91	2.04	34.51777
13	7.942	3.66	46.08411
15	5.858	2.39	40.79891
16	4.975	1.49	29.94975
19	1.155	1.3	112.5541
20	2.649	1.21	45.67761
21	9.045	13	143.7258
23	1.823	1.85	101.4811
24	3.384	8.18	241.7258
25	3.415	1.7	49.78038
26	1.7277	4.5	260.4619
30	5.034	6.93	137.6639
32	10.89	4.49	41.23049
35	10.406	3.1	29.79051
37	6.66	5.87	88.13814
39	4.472	1.39	31.08229
40	5.888	1.83	31.08016
43	3.658	2.64	72.17059
44	1.838	1.19	64.74429
45	1.0105	2.9	286.9866
46	1.359	3.23	237.6748
47	4.16	1.39	33.41346
49	1.2497	1.96	156.8376
56	3.766	1.72	45.6718
57	12.881	4.66	36.17732
58	9.353	3.29	35.17588
59	1.244	2.5	200.9646
60	12.01	4.7	39.13405
62	2.581	1.04	40.29446
65	26.5	81.03	305.7736
66	9.369	5.54	59.13118
67	10.476	2.24	21.38221
68	5.143	3.4	66.10927
69	3.814	8.7	228.107
74	9.83	28.65	291.4547
75	7.993	12.2	152.6336
76	9.453	14.5	153.3905
79	1.7984	1.04	57.82918
80	2.366	1.09	46.06932
82	8.919	5.28	59.19946
83	4.444	5.06	113.8614
84	12.384	22.25	179.6673
87	5.212	1.28	24.55871
88	9.031	2.88	31.89016
89	4.506	2.14	47.49223
90	3.546	1.171	33.02312
91	9.442	17.57	186.0835
93	7.151	12.56	175.6398
94	13.059	4.25	32.54461
95	6.52	2.14	32.82209
96	7.0676	5.2	73.57519
97	4.86	1.89	38.88889
99	8.091	3.41	42.145591

References

[1] Geller J. Diaferio and M. Ramella, *AJ.*, **107(2)**, (1994), 868.

[2] J. Materne, and G. A. Tammann, *A&A*, **37**, (1974), 383.

[3] P. Hickson, *ApJ*, **255**, (1982), 382.

[4] P. Hickson, G. John P. de Oliveira, and G. Palumbo, *AJ*, **399**, (1992), 353.

[5] Prandoni, A. Iovino, H. T. MacGillivray, *AJ*, **107**, **(**1994), 1235P.

[6] Elizabeth Barton, Margaret Geller, Massimo Ramella, Ronald O. Marzke, L. Nicolaci da Costa, *AJ*, **112**, (1996), 871B.

[7] C. Mendes de Oliveira and P. Hickson, *Ap J*, **380**, (1991), 30.

[8] L. Giuseppe, Giovani Busarello, Hilmar Lorenz, Gotthard Richter, Simone Zaggia, *A&A*, **282**, (1994), 418L.

[9] J. Sersec, *Extragalactic Astronomy*, ed. Springer, (Heidelberg, 1982) P. 330.

[10] D. Ostlie, W. Bradley, An Introduction to Modern Stellar Astrophysics, Benjamin Cummings, ISBN 0-201-59880-9, 610.

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