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Simulation of Whirlpool Galaxy and its Companion

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Abstract

In the present work the Whirlpool galaxy and its companion are simulated using Intergalactic Gravitational Motion Simulator IGMS code. N-body method is depended in simulating 480 particles. From the simulation, it was found that the spiral shape and the arm of the whirlpool galaxy were constructed by interaction with its companion. In addition, the interaction caused the tidal bridge between the two galaxies and distorted the shape of the whirlpool galaxy to a perfect spiral galaxy. It was also found that the two galaxies started the interaction in the nearer position for hundreds million years and after that the two galaxies separate from each other.The results indicated that the simulation image matches with that observed by telescopes.

Keywords: simulation in astronomy, simulation of Whirlpool galaxy, whirlpool galaxy**.**

Introduction:

Galaxies are huge, gravitationally bound and assemblage of stars, gas, dust and dark matter. They span a wide range of size, luminosity and mass. The forms of most galaxies fall into the three main types recognized in the Hubble classification scheme, which are elliptical, spiral, and irregular galaxies.[1]

Whirlpool galaxy which is called also (M51a or NGC5194) is a perfect example of a face-on spiral galaxy discovered by Charles Messier in 1773. The name of the Whirlpool galaxy is given from drawing and descriptions made in 1845 by Lord Rosse, who saw its prominent spiral arms. They are two well-defined arms that spiral out from its relatively small central bulge. The Whirlpool galaxy was classified as an Sc galaxy in Hubble classification scheme. It has diameter 65000 light-years and masses about 5×10^{10} solar masses. It's a small fainter companion which is also called (M51b or NGC5195) lies at the end of one of the larger galaxies spiral arms. It was found by Pierrer Mechain in 1771. Tidal interaction between the two played a large part in establishing the bold spiral pattern in M51[1,2].

The astronomers believe that the spiral shapes of the Whirlpool galaxy refers to the interaction with its companion. So Halton Arp classified them as interacting galaxies which named Arp85 [3].

The whirlpool galaxy and its companion were studied depending on direct observation by the telescopes [4,5,6]. But studying the interaction of the two galaxies by simulation is necessary because it's the only way for studying the positions of the two galaxies relative with each other before and after the interaction in which the telescopes fail to observe.

The simulation is a good way for explaining the construction arms of the Whirlpool galaxy and the bridge construction between it and its companion. So many researchers simulated these two interacting galaxies [7-9].

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Figure 1 shows the telescope observation of the whirlpool galaxy and its companion which is connected with the whirlpool galaxy's arm.

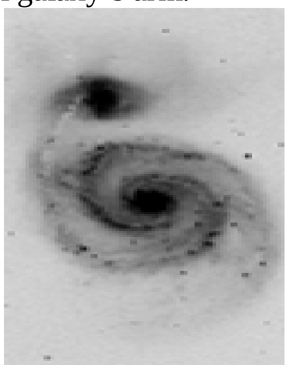


Figure 1: the whirlpool spiral galaxy and its companion [10].

In the present work, the whirlpool galaxy and its companion were simulated using Intergalactic Gravitational Motion Simulator IGMS code. N-body method is depended by simulating 480 particles at different epochs, before the interaction and after the interaction.

The simulation:

IGMS code is able to describe the interaction of two galaxies depending on N-body simulation technique. The programming language is Borland C/C^{++} 3.1 and the Newton's law of universal gravitation forms the essential base of the program, So the basic physical formulas of the code are the classical laws of motion and gravitational force which is the main force affecting the celestial bodies. The code calculates the distance between a pair of particles in three axes (x,y,z), then calculates the resultant distance between them, after that it calculates the acceleration.

The process repeats for each particle, so when all particles have been gravitated, the time step is complete.

The code calculates the distances (dx, dy, dz) between the gravitating particle and the gravitated particle as follows[11]:

```
dx = x[p2] - x[p1];
dy = y[p2] - y[p1];
dz = z[p2] - z[p1];
```

And the acceleration (a) is calculated as follows:

```
ax[p1] += dx * A / D;
ay[p1] += dy * A / D;
az[p1] += dz * A / D;
```

Where(D) is the resultant distance,(A) is the resultant acceleration , p1 and P2 are the particle 1 and the particle 2 respectively.

The velocity (v) is also calculated by the code as:

```
vx[p1]+= ax[p1] * timestep;
vy[p1] += ay[p1] * timestep;
vz[p1] += az[p1] * timestep;
```

Then the code calculates the position of the particle as bellow:

```
x[p1] += vx[p1] * timestep;
y[p1] += vy[p1] * timestep;
z[p1] += vz[p1] * timestep;
```

For simulating any two interacted galaxies it is important to assume suitable initial conditions of them before the interaction.

Therefore in the present work the initial conditions shown in table 1 represent the initial conditions of the Whirlpool galaxy and its companion.

The values of the mass and the radius of the Whirlpool galaxy and also the tilt and arguments assumed in the present work are that depended by some astronomers [2,7]. The mass of the company is assumed to be one fifth the mass of the Whirlpool galaxy [7]. The other parameters such as the distance between the galaxies before the interaction, the distribution of the particles in the rings which are 400 particles for the Whirlpool galaxy and 80 particles for the companion, the number of rings which is 10 rings for the Whirlpool galaxy and 8 rings for the companion, also the minimum radius which is 1.95kpc for the Whirlpool galaxy and 1.3kpc for its companion. And all other physical and geometrical parameters assumed in the present work were found to be suitable for simulating of the two galaxies.

Table 1: The initial conditions for the Whirlpool galaxy and its companion.

Parameters	Whirlpool galaxy	The companion
X	0.80813	5.6967
Y	-27.12319	29.36413
Z	2.22032	15.65155
Vx (km/s)	0.00894	-0.04468
Vy (km/s)	-0.00058	0.00288
Vz (km/s)	0.02455	-0.12275
Mass(M_{sun})	5×10^{10}	1×10^{10}
R_{min} (kpc)	1.95	1.3
R_{max} (kpc)	11	3.24
Distance: 17.88 kpc. Eccentricity: 0.8 Inclination: -70° Argument: -15°		

From table1: x, y and z represent the initial coordinates of each galaxy. vx, vy and vz are initial velocities of each galaxy. Mass represents the centroid mass of each galaxy. R_{min} and R_{max} are the radius of the innermost and the radius of the outermost particle rings of each galaxy.

Distance represents the distance between the two centroids of the two galaxies at perigalacticon.

Eccentricity indicates the shape of the galaxies orbit. Inclination is the angle that the orbital plane of the Whirlpool galaxy makes with the rotation plane of its companion. Argument is the rotation of the companion's orbit within its orbital plane [11].

Results and Discussion:

Figure (2a) shows two galaxies before the interaction, the big galaxy is the whirlpool galaxy and the small galaxy is its companion. The two are at the face-on view and there are no any arms or bridges between them.

In Fig.(2b) the two galaxies start interacting with each other. Some near particles of the Whirlpool galaxy were affected by the companion which are moved upward. This affection is still not strong, but in Fig (2c) the gravitational force affects strongly between them which causes the distortion in the shape of the two galaxies especially the Whirlpool galaxy. In Fig.(2d) some particles start going far from the disk of the whirlpool galaxy to construct small arm near the companion, and the distortion in the opposite part of the disk appears clearly.

Figure (2e) shows the arm elongation of the Whirlpool galaxy near the companion while in the opposite far portion of the galaxy a new arm starts construction, while the companion moves upward. In figs.2(f, g and h) the distortion of the big galaxy increases with time because of more separating of the arm in the farther part of the Whirlpool galaxy. This can be seen clearly in Fig.(2h),from which, it is shown that how the companion continues in its motion upward and the bid galaxy rotates slowly anti clock wise.

In Fig.(2i) in addition to separating the arm more than before from the bulge, the arm appears again in the northern part of the big galaxy which was unseen because of direct attraction with the companion. The upper tidal arm gradually constructs a bridge between the two galaxies which also appear in Fig.(2j).

Fig.(2k) shows the best view of the bridge construction between the two galaxies and shows how the companion now moves to behind the big galaxy. It is also clear from the figure how the farther part separated more from the bulge of the big galaxy. In addition to its rotation few degrees in anti-clock wise around its axes. The construction of arm and the bridge between the whirlpool galaxy and its companion give a perfect spiral structure to the Whirlpool.

Comparing the structure and also the situation of both galaxies with each other at 300Myr as shown in Fig.(2k) with the telescope image shown in Fig.(1), it is clear that the simulation image matches the image observed by telescope.

After that, the companion gradually moves far from the whirlpool galaxy and the bride between them becomes weak and the lower arm starts retied with the bulge as shown in Fig. (2l).

Figs.2(m, n and o) show respectively how with time the two galaxies move far from each other and the gravitational force between them decreases, while the rotation of the big galaxy continues which causes tiding the brides and the arm more and more. This can be seen in Fig. (2p) clearly in which there is no any connection between the whirlpool and its companion, and the spiral shape disappears.

From the simulation it was found that the interaction between the two galaxies for hundreds million years causes the spiral shape in the Whirlpool galaxy and makes a bridge between it and its companion. Also, it was found that how the galaxies move relative to each other and rotate.

All these results are in a good agreement with the simulation of the two galaxies by Toomer and Toomer[7], in addition of the matches of the simulation image with the image observed by telescopes[10].

Table 2 shows the positions and velocities of 80 particles of 480 particles simulated in the present work.

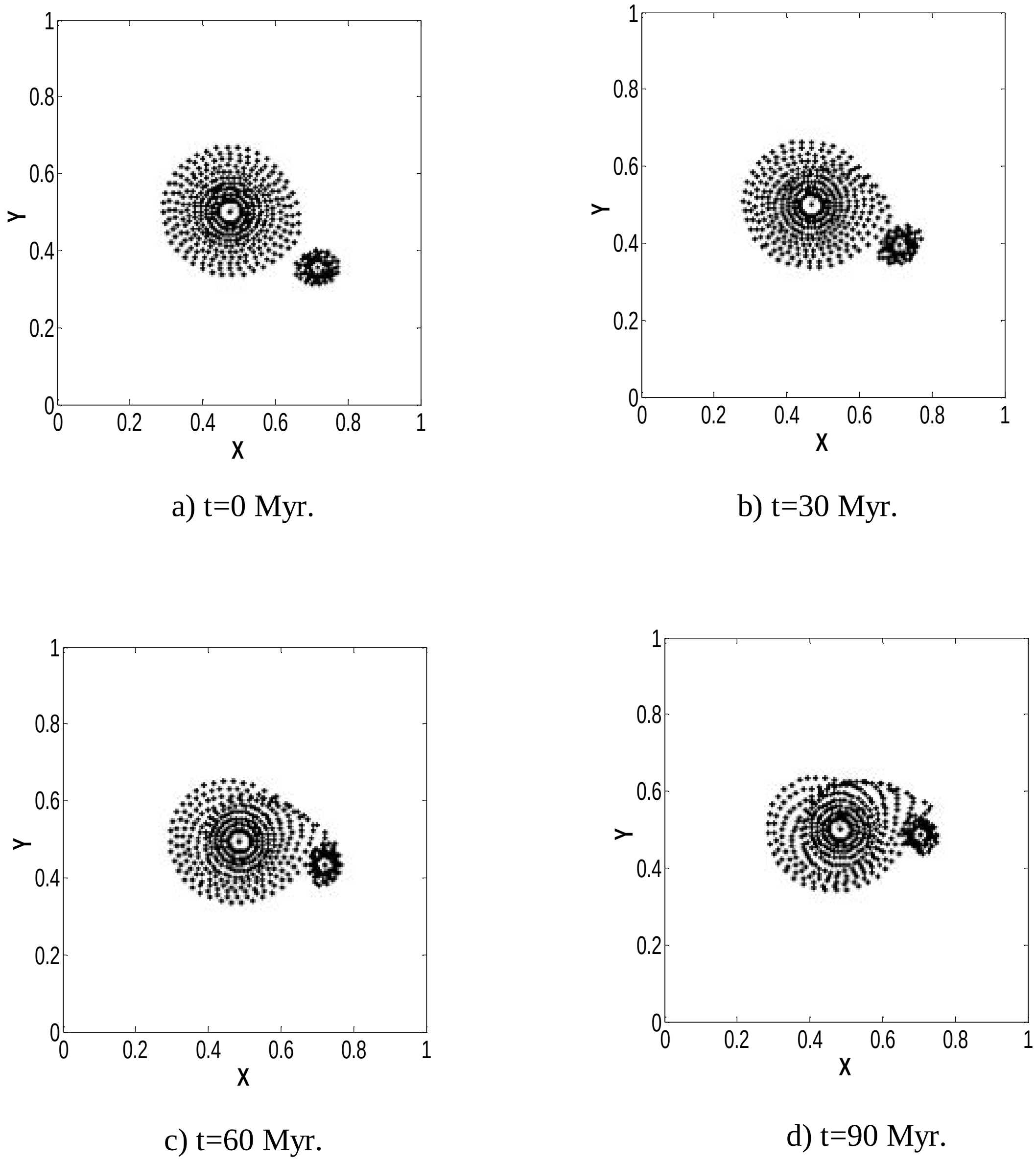
Conclusions

1- The perfect spiral structure of the Whirlpool galaxy returns to its interaction with its companion before hundreds million years.

2- The bridge between the two galaxies seen from the simulation and through the telescopes will loose because of moving the two galaxies far from each other. This process will happen if there is no any external force affecting on them.

3- The initial conditions of the two galaxies assumed and depended before the interaction in the present work found to be suitable for studying their interaction by simulation.

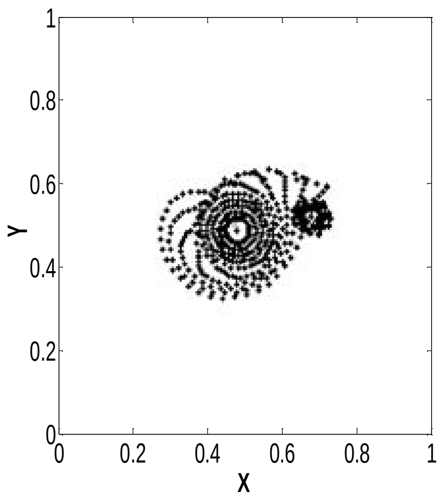
4- From the simulation, it is clear that the companion of the Whirlpool galaxy which moves continuously through the simulation can be seen behind the Whirlpool galaxy.



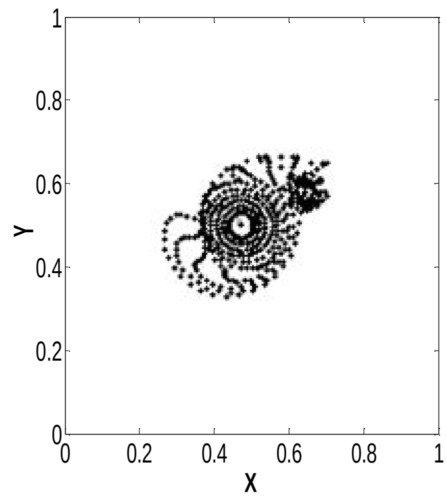
a) t=0 Myr. b) t=30 Myr.

c) t=60 Myr. d) t=90 Myr.

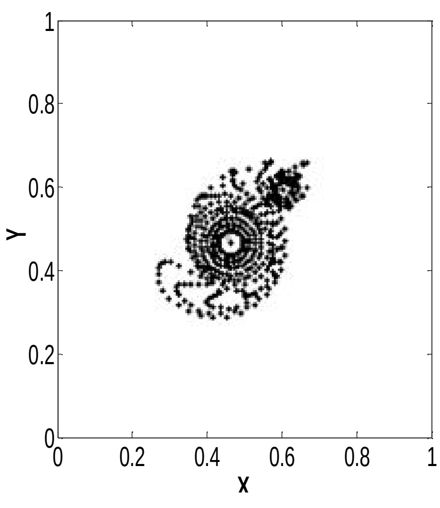
Fig.2: The interaction between the Whirlpool galaxy and its companion.



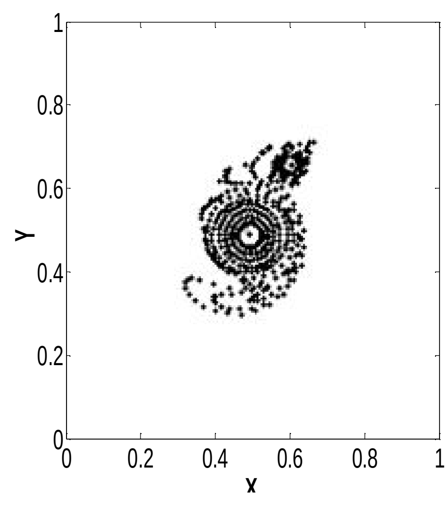
e) t=120 Myr.



f) t=150 Myr.

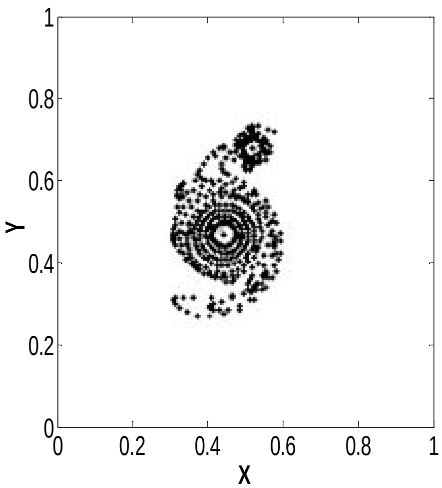


g) t=180 Myr.

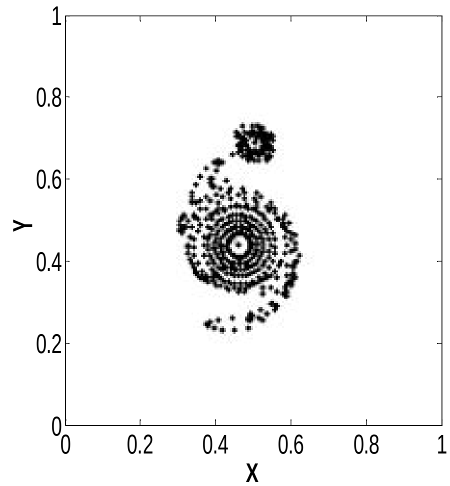


h) t=210 Myr.

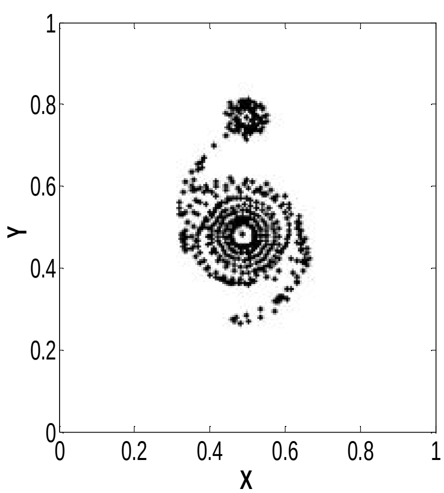
Fig.2: Continued.



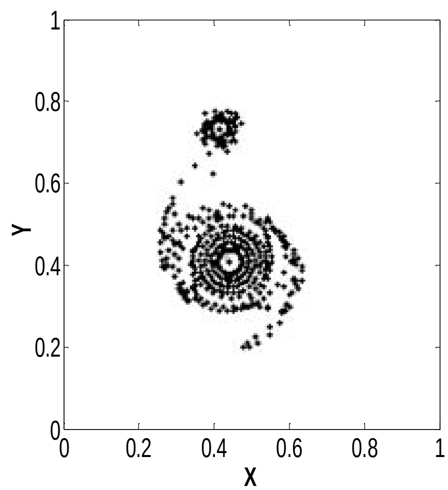
i) t=240 Myr.



j) t=270 Myr.

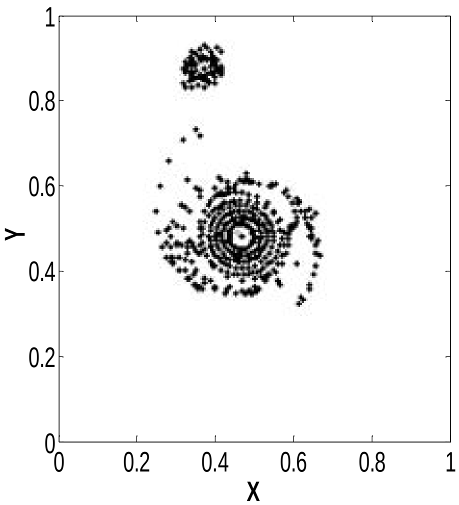


k) t=300 Myr.

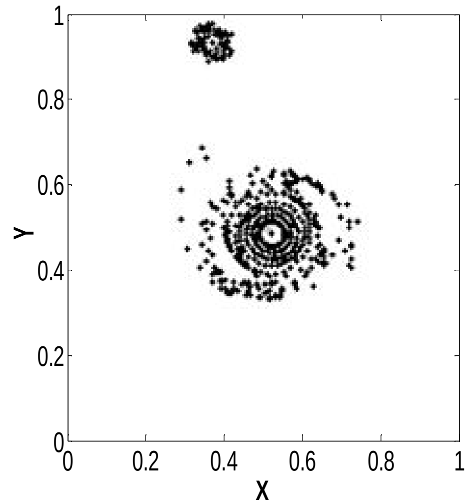


l) t=330 Myr.

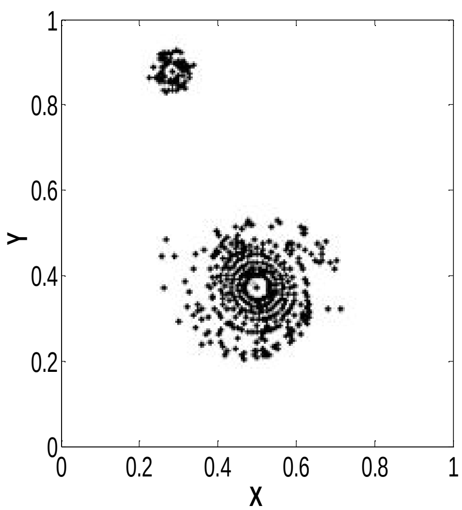
Fig.2: Continued.



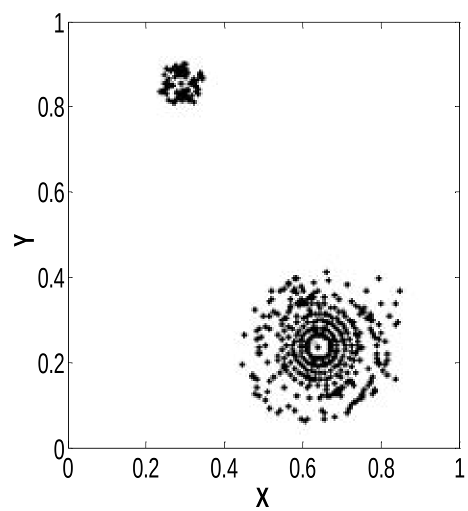
m) t=450 Myr.



n) t=500 Myr.



o) t=560 Myr.



P) t=630 Myr.

Fig.2: Continued.

Table 2 : the positions and velocities of Whirlpool galaxy and its companion

#p	x	y	z	vx	vy	vz
1	0.808	-27.123	2.22	0.0089	-0.0006	0.0246
2	5.697	29.364	15.652	-0.0447	0.0029	-0.1227
3	6.734	-26.185	2.22	-0.0432	0.3288	0.0246
4	6.514	-25.269	2.22	-0.0941	0.3166	0.0246
5	6.154	-24.399	2.22	-0.1425	0.2966	0.0246
6	5.662	-23.596	2.22	-0.1871	0.2692	0.0246
7	5.051	-22.881	2.22	-0.2269	0.2352	0.0246
8	4.335	-22.269	2.22	-0.2609	0.1954	0.0246
9	3.532	-21.777	2.22	-0.2882	0.1508	0.0246
10	2.662	-21.417	2.22	-0.3082	0.1025	0.0246
11	1.747	-21.197	2.22	-0.3204	0.0516	0.0246
12	0.808	-21.123	2.22	-0.3246	-0.0006	0.0246
13	-0.13	-21.197	2.22	-0.3204	-0.0527	0.0246
14	-1.046	-21.417	2.22	-0.3082	-0.1036	0.0246
15	-1.916	-21.777	2.22	-0.2882	-0.152	0.0246
16	-2.719	-22.269	2.22	-0.2609	-0.1966	0.0246
17	-3.435	-22.881	2.22	-0.2269	-0.2364	0.0246
18	-4.046	-23.596	2.22	-0.1871	-0.2704	0.0246
19	-4.538	-24.399	2.22	-0.1425	-0.2977	0.0246
20	-4.898	-25.269	2.22	-0.0941	-0.3177	0.0246
21	-5.118	-26.185	2.22	-0.0432	-0.33	0.0246
22	-5.192	-27.123	2.22	0.0089	-0.3341	0.0246
23	-5.118	-28.062	2.22	0.0611	-0.33	0.0246
24	-4.898	-28.977	2.22	0.112	-0.3177	0.0246
25	-4.538	-29.847	2.22	0.1603	-0.2977	0.0246
26	-4.046	-30.65	2.22	0.205	-0.2704	0.0246
27	-3.435	-31.366	2.22	0.2448	-0.2364	0.0246
28	-2.719	-31.977	2.22	0.2787	-0.1966	0.0246
29	-1.916	-32.469	2.22	0.3061	-0.152	0.0246
30	-1.046	-32.83	2.22	0.3261	-0.1036	0.0246
31	-0.13	-33.049	2.22	0.3383	-0.0528	0.0246
32	0.808	-33.123	2.22	0.3424	-0.0006	0.0246
33	1.747	-33.049	2.22	0.3383	0.0516	0.0246
34	2.662	-32.83	2.22	0.3261	0.1025	0.0246
35	3.532	-32.469	2.22	0.3061	0.1508	0.0246
36	4.335	-31.977	2.22	0.2787	0.1954	0.0246
37	5.051	-31.366	2.22	0.2448	0.2352	0.0246
38	5.662	-30.65	2.22	0.205	0.2692	0.0246
39	6.154	-29.847	2.22	0.1603	0.2966	0.0246
40	6.514	-28.977	2.22	0.112	0.3166	0.0246

#p	x	y	z	vx	vy	vz
41	6.734	-28.062	2.22	0.0611	0.3288	0.0246
42	6.808	-27.123	2.22	0.0089	0.3329	0.0246
43	9.807	-25.698	2.22	-0.0334	0.2667	0.0246
44	9.473	-24.308	2.22	-0.0747	0.2568	0.0246
45	8.926	-22.987	2.22	-0.1139	0.2406	0.0246
46	8.179	-21.768	2.22	-0.1501	0.2184	0.0246
47	7.251	-20.681	2.22	-0.1824	0.1908	0.0246
48	6.164	-19.752	2.22	-0.21	0.1585	0.0246
49	4.944	-19.005	2.22	-0.2322	0.1223	0.0246
50	3.624	-18.458	2.22	-0.2484	0.083	0.0246
51	2.233	-18.124	2.22	-0.2584	0.0418	0.0246
52	0.808	-18.012	2.22	-0.2617	-0.0006	0.0246
53	-0.617	-18.124	2.22	-0.2584	-0.0429	0.0246
54	-2.007	-18.458	2.22	-0.2484	-0.0842	0.0246
55	-3.328	-19.005	2.22	-0.2322	-0.1234	0.0246
56	-4.547	-19.752	2.22	-0.21	-0.1597	0.0246
57	-5.634	-20.681	2.22	-0.1824	-0.1919	0.0246
58	-6.563	-21.768	2.22	-0.1501	-0.2195	0.0246
59	-7.31	-22.987	2.22	-0.1139	-0.2417	0.0246
60	-7.857	-24.308	2.22	-0.0747	-0.258	0.0246
61	-8.191	-25.698	2.22	-0.0334	-0.2679	0.0246
62	-8.303	-27.123	2.22	0.0089	-0.2712	0.0246
63	-8.191	-28.548	2.22	0.0513	-0.2679	0.0246
64	-7.857	-29.939	2.22	0.0926	-0.258	0.0246
65	-7.31	-31.26	2.22	0.1318	-0.2417	0.0246
66	-6.563	-32.479	2.22	0.168	-0.2195	0.0246
67	-5.634	-33.566	2.22	0.2003	-0.1919	0.0246
68	-4.547	-34.494	2.22	0.2279	-0.1597	0.0246
69	-3.328	-35.241	2.22	0.2501	-0.1234	0.0246
70	-2.007	-35.788	2.22	0.2663	-0.0842	0.0246
71	-0.617	-36.122	2.22	0.2762	-0.0429	0.0246
72	0.808	-36.234	2.22	0.2796	-0.0006	0.0246
73	2.233	-36.122	2.22	0.2762	0.0418	0.0246
74	3.624	-35.788	2.22	0.2663	0.083	0.0246
75	4.944	-35.241	2.22	0.2501	0.1223	0.0246
76	6.163	-34.494	2.22	0.2279	0.1585	0.0246
77	7.251	-33.566	2.22	0.2003	0.1908	0.0246
78	8.179	-32.479	2.22	0.168	0.2184	0.0246
79	8.926	-31.26	2.22	0.1318	0.2406	0.0246
80	9.473	-29.939	2.22	0.0926	0.2568	0.0246

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هاوشێوەكردنی گەلەستێرەی Whirlpool لەگەڵ پاشكۆكەیدا

مەریوان ئەحمەد ڕەشید-بەشی فیزیا-كۆلێجی زانست-زانكۆی سلێمانی-هەرێمی كوردستان-عێراق

پوختە

لەم توێژینەوەیەدا هاوشێوە بوون ئەنجامدرا بۆ گەلەستێرەی Whirlpool **لەگەڵ پاشكۆكەیدا بەبەكارهینانی كۆدی هاوشێوەبوونی جوڵە كێشكردن لەنێوان گەلەستێرەكاندا** Intergalactic Gravitational Motion Simulator IGMS code **ڕێگای هاوشیوە بوونی** N-body **پشتی پێ بەسترا بۆ هاوشیوە بوونی** 480 **تەنۆلكە .**

لە هاوشیوە بوونەوەكەوە دۆزرایەوە كە شێوەی لوولپیێچی وقۆڵی گەلەستێرەی Whirlpool **دروستبوون ئەنجامی كارلێكردنی لەگەڵ پاشكۆكەیدا. زیاد لەوەش كارلێكردنەكەبووە هۆی درووستبونی پردێكی درێژ لەنێوان هەردوو گەلەستێرەكەداو شێوەی گەلەستێرەی** Whirlpool **ی تێكدا بۆ شێوەی گەلەستێرەی لولپیێچی تەواو .**

هەروەها دۆزرایەوە كە هەردوو گەلەستێرەكە دەستیان كردوە بە كارلێكردن لە نزیكترین شوێندا پێش سەدان ملێون ساڵ وپاش ئەوەش لەیەكتر دوور دەكەونەوە . ئەنجامەكان ئەوەیان دەرخست كە وێنەی هاوشێوەبوونەكە لەگەڵ ئەو وێنانەی بەتەلەسكۆب گیراون چوونیەكن.

محاكاة المجرة Whirlpool مع تابعها

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الخلاصة

في هذاالبحث تمت المحاكاة لمجرة Whirlpool مع تابعها باستخدام كود محاكاة الحركة الجذبية بين المجرات Intergalactic Gravitational Motion Simulator IGMS code . اعتمدت طريقة محاكاةN-body لمحاكاة 480 جسيماً.

لقد وجدت من المحاكاة بان الشكل الحلزوني وذراع المجرة Whirlpool تكون نتيجة للتفاعل مع تابعها . بالاضافة الى ذلك سبب التفاعل في تكوين الجسر الممتد بين المجرتين وشوه شكل المجرة Whirlpool الى مجرة حلزونية كاملة .لقد وجدت ايضا بان المجرتين بدوا التفاعل عند أقرب موقع قبل مئات الملايين من السنيين وبعد ذلك فان المجرتين تتفرقان من بعضهما البعض. أظهرت النتائج بان صورة المحاكاة مشابهة مع ما رصدت بواسطة التلسكوب.

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