SIMULATION OF TWO INTERACTING GALAXIES NGC3395 AND NGC3396

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Abstract
In the present work the two interacting galaxies NGC3395 and NGC3396 were simulated by means of N-body simulation using Intergalactic Gravitational Motion Simulator IGMS code with 500 particles. The structure and the geometrical positions of each galaxy and their contents were found from the time before the interaction. It was also found that the interaction caused the distortion of the shape and construction of tidal tails of the galaxy NGC3395. The simulation image matches with the images of the two galaxies observed by the telescopes.

Introduction
Astronomers have studied the effects of nearby companions on galaxies and found that many of the properties of these pair galaxies could be explained through gravitational interactions and mergers of galaxy. That these interactions can have a profound effect on the participating galaxies is clear from the observational record. So, interacting galaxies, can distort each other with tides that produce tidal tails and shells of stars. When a galaxy swings past a more massive galaxy tides are severe. Interactions can be mild and may do no serious damage to the symmetry of galaxy but stronger interactions can lead to asymmetry and peculiar structure and possibly even orbit, whereas stars further from the massive galaxy follow larger, slower orbits. Such tides can distort a galaxy or even rip it apart [1][2].

After observing many interacting galaxies by telescopes, and the growth of the galaxy catalogs such as Arp catalog for peculiar galaxies, astronomer have studied by computer simulation the structure and some other properties of these galaxies named Arp galaxies who classified 338 of these interacting galaxies in the catalog [3].

Computer simulation is an important way to test the tidal origins of interacting galaxies which gives the structure of interacted galaxies in the past in which the telescopes fail to detect such events. In addition the simulation helps interpretation of the observational data in the present day. So astronomers depend on it in studying the properties of galaxies interaction. Finding the initial condition parameters in simulating interacting galaxies has a great role in studying the interaction of such systems which happened before millions of years.

The first interacting galaxy simulation was obtained by Toomer and Toomer 1972 [4] who modeled four interacting systems NGC4038/4039, M51 and NGC5195, NGC4676, and Arp 295. In the simulations it was shown how the gravitational force distorted the shapes of the galaxies and causes the tidal tails. Many researchers [5][6] simulate the interacting galaxies for investigating and
studying the properties of their components such as position, velocities and geometrical situations.

In the present work, the two interacting galaxies NGC3395 and NGC3396 (Arp270) were simulated using Intergalactic Gravitational motion simulator (IGMS) code with 500 particles. For each particle the position and velocity were found which concern the geometrical properties of the two galaxies in the past. Fig. (1) shows the interacting galaxies NGC3396 (in the top) and NGC3395 (in the bottom) observed by telescope [7].

Figure (1): Two interacting galaxies NGC3395 and NGC3396 [7].

The Simulation

In the simulation IGMS code was used for simulating the interaction between the two galaxies. The code based on Newton’s law of Universal gravitation and the simple Newtonian physics [8].

From gravitation’s law [9]:

\[
\vec{\mathcal{F}}_{ij} = \frac{G m_i m_j (\vec{x}_j - \vec{x}_i)}{\left| \vec{x}_j - \vec{x}_i \right|^3} \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (1)
\]

where \( \vec{\mathcal{F}}_{ij} \) is the mutual gravitation between \( i \) and \( j \) particles, and \( G \) is the Universal gravitation constant, \( m \) is the mass of the particles, and \( \vec{x} \) is the position.

The force acting on \( i^{th} \) particle which is the function of positions, velocities, and time can be represented as follow:

\[
\vec{F}_i = \vec{\mathcal{F}}_i (\vec{x}_j, \vec{v}_j, t) \quad j = 1, \ldots, N_p \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots (2)
\]

where \( N_p \) is the number of particles.

IGMS code calculates the motion of each particle of the two interacting galaxies. The code first selects a pair of particles, one gravitating particle and other gravitated particle. It then calculates the distance between the particles along all three axes and converts this to the resultant distance and then calculating the acceleration. The cycle repeats, cumulating all the accelerations found for each particle until all massive particles have interacted with the gravitated particle. The code then selects a new gravitated particle and repeats. When all particles have been gravitated, the time step is complete [8]. A portion of the code which solves the distance, velocity, acceleration and gravitational force of particles and of the two interacting galaxies is shown in the appendix.

In such simulations the particles are distributed in the galaxies in different distances from the center. Here for NGC3396 galaxy 150 particles are distributed in 10 rings while about 350 particles are distributed in 12 rings in NGC3395 galaxy. The gravitational force causes distortion in these distributions.

Assuming and setting the geometrical parameters successfully for the system of the two galaxies NGC3395 and NGC3396 before the interaction cause to obtain some important properties of the system at the present day such as the shape and tidal tail construction.

Table (1) represents the initial condition parameters of the NGC3395 and NGC3396 found in the present work, from which the properties of interaction can be studied.

Table 1: The initial conditions of the NGC3395 and NGC3396 galaxies assumed in the present work.

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From the table: 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. \( R_{\text{min}} \) and \( R_{\text{max}} \) are the radius of the innermost and the radius of the outermost particle rings of each galaxy. Tilt is the angle of x-z inclination of the galaxy above the x-y plane. Skew is the angle of x-y
rotation of the galaxy within the x-y plane. Distance represents the distance between the two centroids of the two galaxies at perigalacticon. Eccentricity indicates the shape of the galaxies orbit [8].

Results and Discussion

Figure (2a) shows the two galaxies at the beginning of interaction (t=0) in the x-y plane. It is clear that the NGC3396 galaxy is located in the west direction of the NGC3395 galaxy. The first galaxy is in the edge-on view, while the second is in the face-on view.

In Figure (2b) the distortion of the second galaxy appears from the positions near the first galaxy and some particles in this outer ring are affected by the attraction force between the two galaxies. With this attraction, it is shown that the first galaxy moves to the north and the second starts to incline.

Figures (2 c and d) show how the interaction causes the distortion of the shape of the second galaxies with time and also the movement of the first galaxy is continue.

In Figure (2e) the attraction force affects on all the particles of the second galaxy which causes gradual construction of tidal tail in the galaxy. The tidal tail begins to construct at (t=50 mega year, Myr.) as shown in Figure (2f).

Figure (2g) shows the construction of the tidal tails more clearly in the two positions at (t=55Myr.). Comparing this figure with Fig.1 its clear that the simulation image here matches with the telescopic image and, also it is clear from the figure that the tidal tails are severe.

Figures (2 h, i, j and k) show that the two galaxies start going far from each other, so the attraction force between them decreases with time and the tidal tails become thin and reconstruct with the disc. This case appears in Figure (2k) in which the two galaxies have no any connection with each other.

Setting the particles in rings, distortion of the shapes and the tidal tails in interaction are in agreement with simulations done by Toomer and Toomer [4].

Table (2) represents the coordinates and velocity of 100 number points in the simulation. The odd number points (1, 3, 5.....etc.) are related to NGC3396 galaxy while the even number points are related to NGC3395 galaxy.

Conclusions

1- The N-body simulation is a good way for studying the past of interacting galaxies because telescopes gave no properties of such events in the past.

2- The initial conditions of the two galaxies used in the present work indicated suitable initial conditions of the two galaxies in the past because it gives suitable image of the two galaxies compared with the telescope image.

3- The tidal tail of NGC3395 galaxy observed by telescopes and the present simulation is the result of the interaction of this galaxy with NGC3396 galaxy.

4- After many mega years the tail of galaxy will be lost if there is no any other effect on the galaxy.
Figure (2): Two interacting galaxies NGC3395 and NGC3396
Continued of Figure (2)
Continued of Figure (2)
Table (2): The position and velocities of NGC 3395 and 3396

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References


Appendix

A portion of the code which solves the distance, velocity, acceleration and gravitation force of particles of the two interacting galaxies.
void corecalc (void)
{
    //Calculates acceleration, accelerates, and moves all particles
    int p1, p2;               //particle IDs
    int galaxy;               //galaxy ID
    float dx, dy, dz;        //distance between particles along axes
    float D;                  //resultant distance between particles
    float A;                  //resultant acceleration

    for (p1 = 1; p1 <= nump; p1++)
    {
        ax[p1] = ay[p1] = az[p1] = 0;
        for (p2 = 1; p2 <= nump; p2++)
            //determine acceleration
            { if ((p1 != p2) && (m[p2] != 0))
                {
                    dx = x[p2] - x[p1];
                    dy = y[p2] - y[p1];
                    dz = z[p2] - z[p1];
                    D = sqrt(pow(dx, 2) + pow(dy, 2) + pow(dz, 2));
                    galaxy = 0;
                    if (p2 == pnucleus1) galaxy = 1; if
                        (p2 == pnucleus2) galaxy = 2;
                    if (D < grmmax[galaxy]) A = G * gm[galaxy] * (ki[galaxy] * D + kj[galaxy]) / kk[galaxy];
                    else A = G * m[p2] / pow(D, 2);
                    ax[p1] += dx * A / D;
                    ay[p1] += dy * A / D;
                    az[p1] += dz * A / D;
                }
            }
    }
    for (p1 = 1; p1 <= nump; p1++)
    {
        vx[p1] += ax[p1] * timestep;
        //accelerate
        vy[p1] += ay[p1] * timestep;
        vz[p1] += az[p1] * timestep;
        x[p1] += vx[p1] * timestep;
        //move
        y[p1] += vy[p1] * timestep;
    }
    galr = D;
    return;
}