On the relative orientation of binary galaxies.

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Abstract. The projected directions of the rotation axes of interacting binary disk galaxies tend to align orthogonal to each other. Sofue (1992) has suggested that this could be due to shorter merger times for galaxies with parallel spins. We show by means of N-body simulations that this suggestion is correct.

1. Introduction

The relative orientation of galaxy spins with the orbital spin in interacting binary systems has been examined by Sofue (1992). He found that the projected directions of the rotation axes tend to align orthogonal to each other. He suggested that this could be explained in the case that paired galaxies with parallel spins have already merged, while those with the orthogonal spin axes are still in the process. So, systems with a “Tri-Axial” angular momentum distribution should have longer lifetimes. This assumes an scenario where both galaxies are formed altogether and the plane of the orbit lies near the planes of the galaxies.

It is know that the tidal disturbance on a galactic disc due to a companion is strongest in the case of prograde. Thus, binary systems where the spins of the galaxies are parallel to the orbital spin would suffer strong couplings and will merge very fast (Keel 1991). So, the chance for survival of this kind of system would be small. Even when one galaxy has an anti-parallel spin, the galaxy which have the spin parallel to the orbital spin will “see” the other galaxy in a direct (prograde) orbit and the chance for an anti-spin pair to survive a merger is also small. In this scenario, the “more stable” pair, i.e., the system which will take a longer time to merge is a “tri-axial” one, where neither the galaxies spins nor the orbital spin are aligned.

We will show that the merging time certainly depends on the orientation of galaxy spins, but it could also exist a dependence on the energy of the orbit and on the time of first pericenter passage. In this work, we perform a series of binary disk galaxy interactions to check the validity of the “Tri-Axial” hypothesis.
2. Simulations

All the simulations were performed with the TREECODE (Barnes and Hut 1986). The parameters for the evolution were a tolerance parameter \( \theta = 0.7 \), a softening equal to 0.06666 and a time step equal to 0.025. With these parameters the total energy is conserved better than 0.05%. The units of length and time are 3 kpc and \( 10^7 \) years respectively, and we take \( G = 1 \). Using this normalization the unit of mass is \( 6 \times 10^{10} M_\odot \).

Each galaxy is formed by an halo and a disk. The spherical system is a truncated Plummer model while the disk follows a truncated Kuzmin/Toomre law in the radial direction and is an isothermal sheet vertically, with constant vertical scale thickness. Each model galaxy consists of 40000 equal mass particles and the halo mass ratio is set to \( M_D/M_H = 1/3 \). This value and the values of the Toomre (1964) \( Q \) parameter are selected in order to prevent the possible formation of bars in the disks (Athanassoula and Sellwood 1986). Table I shows more details on the parameters of each galaxy: \( N_H \) and \( N_D \) are the number of the particles in each component, \( M_H \) and \( M_D \) their masses, \( b_H \) and \( b_D \) the radial scale lengths and \( R_{cut_H} \) and \( R_{cut_D} \) the truncation radius. For the case of the disk \( z_0 \) represents the vertical scale length.

| Table 1. Model parameters. |
|-----------------------------|
| Halo | \( N_H \) | \( M_H \) | \( b_H \) | \( R_{cut_H} \) | Disk | \( N_D \) | \( M_D \) | \( b_D \) | \( R_{cut_D} \) | \( z_0 \) |
|-----|--------|--------|--------|-------------|------|--------|--------|--------|-------------|--------|
| 30000 | 1.5 | 5.0 | 10.0 | 10000 | 0.5 | 1.0 | 5.0 | 0.1 |

The binary galaxy systems are set as follows. First, we shifted the isolated galaxy model in the \( Y \)-axis. Galaxy 1 is always placed at \( Y = -11 \) and Galaxy 2 at \( Y = +11 \) in simulation units. In this way the halos do not overlap initially. Their relative speeds are such that the galaxies are initially in a parabolic orbit with radius of pericenter \( R_p = 6 \) and lie in the \( X-Y \) plane (in other words, the orbital spin is always pointing in the \( Z \) direction). \( X_\pm Z_\pm \) means that the spin of the galaxy lies in the \( X-Z \) plane forming an angle of 45° (+) or 135° (−) with the \( X \)-axis. In Table II we list the spin orientation of each galaxy of our simulations.

| Table 2. Spin of the galaxies. |
|-------------------------------|
|                               | O1 | O2 | O3 | O4 | O5 | O6 | O7 | O8 |
| Galaxy 1                      | \( Z_+ \) | \( Z_+ \) | \( Z_+ \) | \( Z_- \) | \( Z_+ \) | \( X_+ Z_+ \) | \( X_+ Z_+ \) | \( X_- \) |
| Galaxy 2                      | \( Z_+ \) | \( Z_+ \) | \( Z_- \) | \( X_- \) | \( X_+ \) | \( X_- Z_+ \) | \( X_- Z_+ \) | \( Y_+ \) |
| Orbit                          | \( Z_+ \) | \( Z_- \) | \( Z_+ \) | \( Z_+ \) | \( Z_+ \) | \( Z_- \) | \( Z_- \) | \( Z_+ \) |

3. Preliminary results

In Figure 1, we plot for all orientations listed in Table 2, the relative distance between the mass center of the disks as a function of time, computed with the bounded particles. We can see that there is a clear dependence of the merging time on the galaxy orientation, in the sense suggested by Sofue (1992), the
tri-axial systems lasting longer time. For the simulations O1, O3, and O8, we also performed parabolic encounters with pericenter $R_p = 12$ and also circular encounters. In the case of parabolic orbits with the greatest pericenters the galaxies did not merge within 15 Gy. In the case of circular orbits, both galaxies merge as in the parabolic encounters with small pericenter. There are only small differences of the merging times with respect to the case of parabolic encounters.

During the merging of both galaxies some particles are lost, specially in the cases of direct encounters. In the case of perpendicular orientations or bigger spin differences the fraction of loose particles is very small (less than 1%). For parallel spins the fraction of particles lost amounts to 4% while in the case of spin difference of 45° the amount is the 3%. We also note that in direct interactions the discs loose their particles at the first passage, while for the other orientations the small fraction of particles is lost at the moment of the merging.

References

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