COLISIONES FRONTALES ENTRE GALAXIAS ESFERICAS

SPHERICAL GALAXY COLLISIONS. HEAD-ON ENCOUNTERS

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RESUMEN: En este trabajo investigamos encuentros frontales entre galaxias esféricas de igual masa por medio de experimentos N-cuerpos. Los cambios en energía interna y orbital correlacionan bien con la inversa de la velocidad relativa en el momento de máximo acercamiento V_p. Las galaxias siempre ganan energía en los encuentros, pero se encuentra que su velocidad rms se ve disminuída por efecto del encuentro, lo que significa que la energía extra se invierte en expandir la galaxia más que en aumentar su energía cinética. Las galaxias caen en órbitas ligadas y se fusionan si V_p es menor que $2.75\sigma_p$, donde σ_p es la velocidad rms en el momento de máximo acercamiento. Los experimentos cubren un amplio rango en V_p, desde colisiones casi en la frontera de la fusión hasta $V_p = 17.0 \sigma_p$. Dos modelos diferentes de galaxias se usaron en los experimentos, difiriendo entre ellos principalmente en su distribución de velocidades (en un modelo predominan las órbitas radiales mientras que en el otro las tangenciales). Sus perfiles de densidad son, sin embargo, similares, y no se ven profundamente alterados por los encuentros. Una comparación hecha con los resultados obtenidos de aplicar la aproximación impulso a nuestros modelos muestra diferencias sistemáticas muy importantes en el caso de las colisiones más violentas (se observan discrepancias de hasta un 100%). A pesar de que la aproximación impulso no da resultados adecuados, es todavía posible derivar algunas correlaciones que permiten describir los cambios en energía interna en términos de V_{p1} e independientemente del modelo usado. El intercambio de masa entre las galaxias participantes del evento es casi nulo en todos los casos. En la segunda parte de este trabajo discutimos los resultados obtenidos en la simulación de encuentros tándem. Estos no muestran una diferencia sistemática con los otros experimentos, lo que refuerza la idea de que los resultados de una colisión frontal (al menos en cuanto a energía interna se refiere), son independientes de modelo de galaxia particular usado. Esto sugiere que, si el tiempo entre colisiones sufridas por una galaxia en un cúmulo es suficientemente largo como para recuperar un estado de equilibrio luego de cada encuentro individual, la evolución de una galaxia en tales vecindades podría ser descripta por la suma de eventos estocásticamente distribuidos.

ABSTRACT: We investigate low-velocity, highly interpenetrating ("hard") head-on encounters between equal mass spherical galaxies by means of full N-body simulations. We compute the energy changes (both orbital and internal) caused by the collisions, and find that they correlate well with the collision strength (the perturber mass-weighted inverse of the relative velocity at closest approach, M_p/V_p). Galaxies always gain energy in the encounters, but their rms velocity decreases after the collision, extra-energy being used to expand the galaxy rather than increasing its kinetic energy. The galaxies fall into bound

orbits and merge rapidly if $V_p < 2.75\sigma_p$, where σ_p is the rms velocity of the galaxy at maximum overlapping. The experiments cover a wide range of collision strengths, from nearly merging collisions to $V_p \sim 17.0\ \sigma_p$. Two different galaxy models have been used throughout the experiments, differing mainly on their velocity distribution; ISO model, whose core particles are in isotropic orbits while halo ones follow predominantly radial orbits, and CIRC model, in which most of the kinetic energy resides on tangential velocity components. Their density profiles are, however, similar, and are not strongly altered after the collisions. A comparison of the correlations found with the predictions of the impulsive aproximation shows large systematic departures for most "hard" encounters. For interpenetrating encounters, impulse results are strongly dependent on how mass is distributed in the perturber while the dependence on the type of orbit which predominates in the target galaxy is much smaller. Small changes in the radial scale length of the perturber cause large variations in impulsive results. However, these latter always show a defined steeper dependence on V_p/σ_p than the simulations do. All models behave similarly regarding to fractional internal energy gain $\Delta U/U_o$, while mass and orbital energy losses ($\Delta M/M_o$ and $\Delta E/E_o$, respectively) are found to depend somewhat on the internal velocity distribution of the colliding galaxies. In spite of the failure of impulse approximation to describe the results of the simulations, it is possible to derive simple scaling laws to describe internal energy gain in terms of the impact velocity V_p, irrespective of the model used. When the collision is simultaed using a single "rigid" perturber (i.e. an extended mass model), we find that all fractional change estimates (both in energy and mass) predicted in the impulse approximation approach do not agree with simulation results either. Mass exchange between the colliding galaxies is negligible for head-on collisions, provided they do not merge. Mass loss computation involves large uncertainties because of the relatively small number of bodies used in each experiment (~ 250-500 per galaxy), and specially because escapers are always those initially in high-energy orbits, the worst sampled region of binding energy space for such a number of particles. However, we present a simple model which allows to calculate fractional mass losses depending only on the binding energy distribution of the initial galaxy and on the impact velocity. Tandem encounters are also simulated, and do not show systematic differences with the results found for initial galaxies. Yet, the galaxy after the encounter differs significantly from its former structure. It becomes larger (R_h and R_9, the radius containing half and 90 per cent of the mass, respectively, are always larger than their original values), less bound (Δ U is always positive), and better mixed (i.e. its energy distribution is flattened because of the encounter; if the original distribution were already flat, its form is not significantly altered exception made for the global secular drift to less bound orbits). Therefore, although "hard" collisions may produce large structural changes in the galaxies participating of the event, the effect of cumulative encounters (as experimented by a galaxy in a cluster) may still be described by the sum of stochastically distributed individual events since higher-velocity more-eccentric collisions are expected to produce always less damage on the intervening galaxies.