SIGNATURES OF GALAXY INTERACTIONS

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ABSTRACT. We demonstrate some peculiar features that can be taken as signs of interaction between galaxies. The features are sharp edged one armed spirals and two-component density and/or velocity structure. We give a kinematical explanation of the first arm and show typical velocities in this arm.

1. Introduction - an example from a numerical simulation

1.1. The motivation for the present investigation was the frequent appearance of some peculiar shapes in the transient stage of simulations of interacting galaxies. Fig. 1 shows results from a numerical experiment of a perturbing mass passing by a galaxy on an in-plane, parabolic orbit. We can see how first a single arm (a) with a very sharp edge is formed followed by a second symmetric counterarm (b). However, the story does not end there. The second arm is followed by a third arm (c), parallel to the second, which has a different velocity structure as can be seen in the last frame (d) where the third arm crashes through the second arm.

1.2. The signature we will deal with here is the sharp edge of Fig. 1a and the associated area which is totally void of material. The double arm structure is discussed in a recent paper by Elmegreen et. al. (1990).

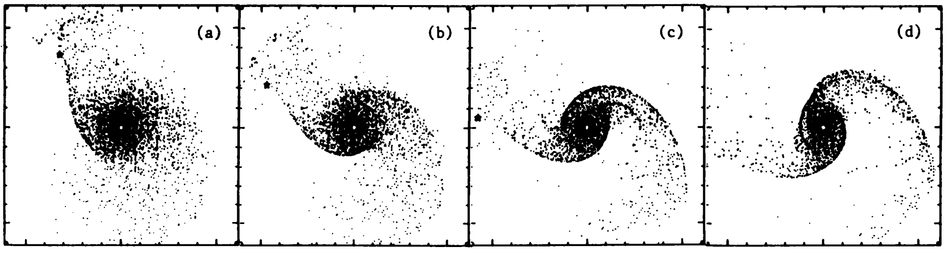

Figure 1: Peculiar features seen in numerical simulations: (a) The first arm with its sharp edge is created, (b) the symmetric counterarm is formed, (c) a third arm produce double arm structure, (d) the third arm has a differend velocity structure which makes it crash in to the second arm.

F. Combes and F. Casoli (eds.), Dynamics of Galaxies and Their Molecular Cloud Distributions, 357–359.

2. A kinematical explanation of the first arm

2.1. We simplify the problem to a case where we can study it semi-analytically by taking the limit of no selfgravitation and a perturbation that is instantaneous in time (impulse approximation). At least for the first arm, this does not change the form of the arm much, as can be seen in fig. 2.

2.2 Using the impulse approximation and the epicyclic approximation for the orbits the evolution of the disc can thus be followed analytically. We have previously argued (Donner et. al. 1990, Sundelius et. al. 1990) that the most prominent features can be identified with caustics, where the Jacobian of the transformation from initial to current positions vanishes, corresponding to a fold in the disc.

2.3. A further argument that it is the same mechanism that is responsible for the formation of the first arms in fig. 2 is displayed in fig. 3: for the cases of no selfgravity+impulsive perturbation and selfgravity+continous perturbation, we have followed the particles in the first arm backwards in time. The positions of the particles in the first case agree with the analytical results. Following the particles of the arm in the selfgravitating case with a continous disturber returns the particles to approximately those same positions, and that at the time when the perturbation has its maximum, i.e. the time when we would try to approximate its effect with an impulse!

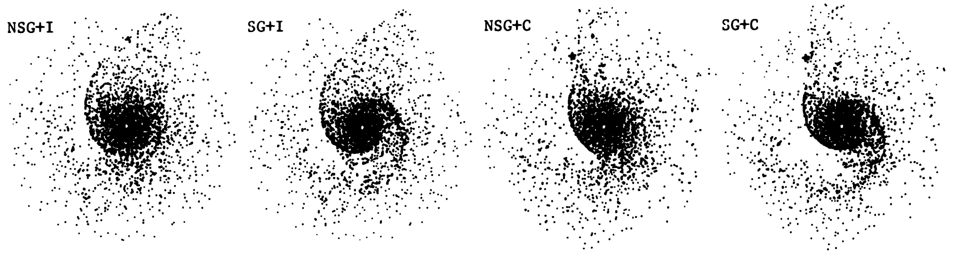

Figure 2: The first arm formed with different conditions, SG=Self Gravity, NSG=No SG, I=Impulse perturbation, C=Continous perturbation (i.e. realistic orbit).

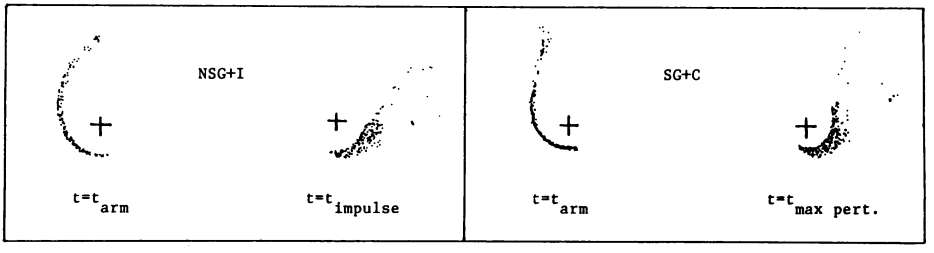

Figure 3: Particles that constitute the arm at different times for the first and last case of fig. 2. t_{arm} is the time when the particles actually make up the arm, t_{imp} is the time of the impulse perturbation, $t_{max\ pert.}$ is the time of max. perturbation for the continous perturbation.

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3. Velocities

3.1. We have examined the velocities of the first arm for a range of interactions (cf. the poster contribution by Donner et. al. in these proceedings). The velocities are generally very similar for this whole range, i.e. there is a only a weak dependence on the orbital parameters for the one disc we have considered. The functional form of the velocities can be understood from the kinematical explanation above.

3.2. Fig. 4 shows velocities and epicycle phases of the particles in the first arm of Fig. 1c. The radial (a) and peculiar tangential (b) velocities of this arm are good examples of the general behaviour in the survey mentionend in the previous paragraph. (c) shows the epicyclic phase in the arm. The regular behaviour in the arm can be understood from the impulse approximantion and the epicyclic approximation: particles start with similar phase $\beta=\beta_0$. Time evolution in the epicycle approximation means $\beta=\beta_0+\kappa t$. Because the epicyclic frequency, κ, increases toward the center, the regular behavior of (c) follows. (d) shows the epicyclic phase for all particles in the entire disc, there are indeed sharp edges in more than position coordinates only!

3.3. Apart from the usual problems (one observed coordinate, orientation w.r.t. the observer, unknown circular rotation curves) with using velocities for extracting information about the disc dynamics we mention the consequence of Liouville's theorem on any study of collisionless systems: when we try to see the velocity structure of a part of the disc we might try to identify a feature that will enable us to compare to other objects. In identifying a feature we usually look for an overdensity in position space - conservation of phase-space density means that the corresponding velocity structure will be dispersed, the sharper the feature, the larger the scatter in velocity.

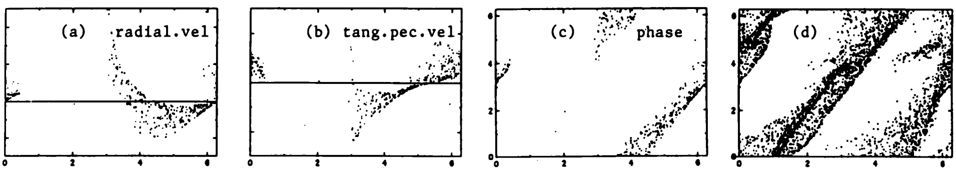

Figure 4: Velocity measures of the particles in the first (lower) arm in the simulation in fig 1c, all as a function of azimuthal angle. (a) is radial velocity, (b) peculiar tangential velocity, (c) is the epicyclic phase. (d) shows the epicyclic phase for all particles in the disc.

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