SIMULATION OF THE INTERACTING TRIPLET M81, M82, NGC3077

N. BROUILLET (1),(2), F. COMBES (3), A. BAUDRY (1)
(1) Observatoire de Bordeaux, B.P. 89, F-33270 Floirac, France
(2) Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-5300 Bonn 1, FRG
(3) Observatoire de Meudon, F-92190 Meudon, and Ecole Normale Supérieure,
24 rue Lhomond, F-75005 Paris, France

ABSTRACT. M81 is clearly interacting with its two neighbouring galaxies M82 and NGC3077. First we simulated the deformation of the atomic gas in the triplet, using a straightforward model (restricted to the 3-body problem), in order to determine the parameters of the trajectories for the three galaxies. The resulting external tidal features satisfactorily resemble the observed HI bridges and tails. We then used a model of cloud collisions to simulate the response of the M81 molecular content. However the 3-body model parameters are not compatible with such a model. Stronger perturbations are needed in a self-consistent gas and stars simulation to produce and amplify a spiral density wave in the inner disk of M81. Preliminary tests show that a strong wave can be amplified both in the stars and gas components, the global structure bearing some resemblance with the observations. The model parameters must now be improved in the light of the most recent observational data.

1. The M81, M82, NGC3077 triplet of galaxies.

Very sensitive observations made recently with large radiotelescopes such as the IRAM 30-m or the NRO 45-m have stimulated now simulations of this nearby triplet. Observations revealed very different CO distributions indeed: a weak emission ring in the spiral arms of M81 (Brouillet et al., 1990), a very intense central emission in M82 (e.g. Nakai et al., 1987), a giant molecular complex at the center of NGC3077 (Becker et al., 1989). Tidal forces can be responsible for these unequal contents and the observed different stellar activities. The interaction is obvious (see, e.g. the HI observations of Appleton et al., 1981) and it is thought to be the origin of the spiral density wave in M81 and of the perturbations observed in M82 and NGC3077 wich are both classified as IrrII.

2. Simulation of the atomic component.

In a first approach we simulated the deformation of the atomic gas in order to determine possible trajectories for the three galaxies. The model, of the type used by Toomre and Toomre (1972), is in fact a 3-body plus a test particle model in a 3-D simulation.
There are numerous parameters acting either on the form or the intensity of the perturbation. Most of them are determined by the observations; nevertheless they are not always well-known (e.g. masses, velocities). The others result from many simulations and comparison with the HI data. We assumed here that the deformation of M82 was weak and that the observed anomalous HI has been

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torn from M81 and captured by M82 (see, e.g. Cottrell, 1977). However, this will have to be changed now with regard to newer HI data obtained with higher angular resolution (see Yun et al., this symposium).

Our best result is shown in Fig. 1. The external features, i.e. the smooth bridge between M81 and NGC3077, the NGC3077 tail, the arm towards M82, are quite satisfactorily reproduced. With respect to other simulations which considered only M81 and a companion galaxy, this result proves that we have to take into account the interaction of at least three galaxies in the group.

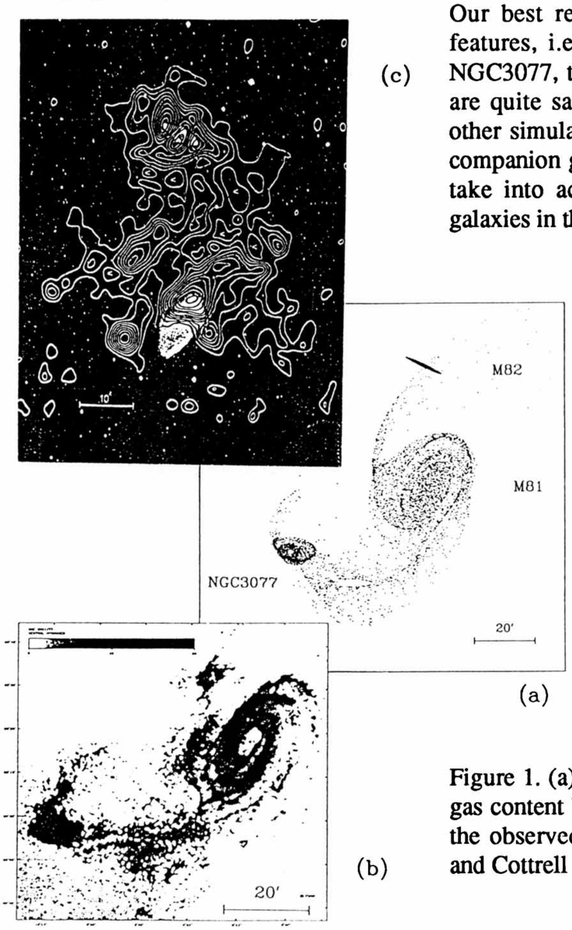

Figure 1. (a) Simulation of the deformation of the HI gas content by tidal interaction, and comparison with the observed HI maps of van der Hulst (1979), (b), and Cottrell (1977), (c).

3. Simulation of the M81 molecular component.

Our main goal was to simulate the M81 molecular content. We thus used a cloud-cloud collision model similar to that used by Combes and Gérin (1985). The clouds are considered as ballistic particles moving in the gravitational potentials of the galaxies, and the collisions lead to either a total coalescence or to 2 or 3 fragments depending on the impact parameter. The tidal forces are much less efficient in the inner part of the disk, and the passage of the two companion galaxies, with trajectories as described in section 2, induces almost no perturbation. We thus took into account the stars and gas self-gravity which can amplify even a faint perturbation in the inner disk because of the shorter rotation period.

We made a 2-D simulation with an N-body model. Solutions to our problem become now more difficult to find because of the coupling of the parameters governing the stability and the perturbation. These are the distribution of mass in the spheroidal hot component, which is linked to the rotation curve and to the morphology of the spiral wave, and the initial velocity dispersion. For the latter we chose a distribution Q(r) monotonically decreasing with the radius in order to avoid any bar instability. With the 3-body model parameters some weak spiral features only appears in the gas disk, but with a nearer perigalactic distance for M82 (tidal forces multiplied by 3 with respect to section 2), a strong m=2 wave is amplified both in the star and gas components (see Fig. 2). Furthermore this structure bears some resemblance with the observations as the gaseous disk also represents the cold atomic gas.

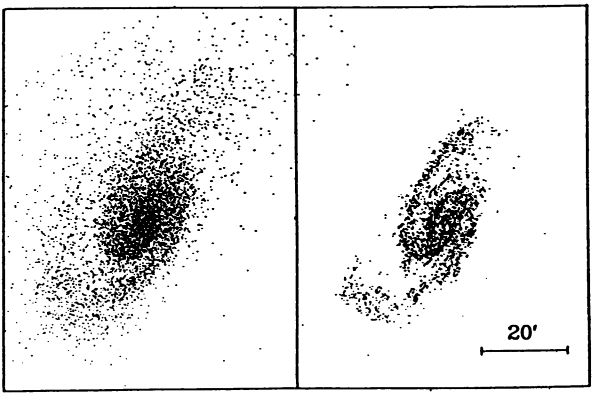

Figure 2. Plots of the stellar (left) and gaseous (right) components of M81 perturbed by M82 and NGC3077 (with self-gravity effects included).

4. Conclusion.

Our simulations show that we can now closely fit the observations and not simply produce theoretical spiral patterns. For the M81 group however, the simulation is complex and we still have to better constrain some parameters, and to include the most recent HI observational results obtained in M82.

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