A New Observational and Numerical Study of Tidal Interactions in M81-M82-NGC3077 system

M. S. Yun, P. T. P. Ho (Harvard-Smithsonian), N. Brouillet (Bordeaux), K. Y. Lo (Illinois)

A nearby system of interacting galaxies M81-M82-NGC3077 triplet (D=3.3 Mpc; Freeman & Madore 1988) has been studied using multi-wavelength observations and numerical simulations to obtain a comprehensive understanding on the dynamics and the consequences of tidal interactions in a group environment. The VLA 12-field mosaic HI observations of $2^\circ \times 1.^\circ5$ region have revealed a vast array of HI filaments which suggests that the severity and extent of tidal disruptions far exceed the previous estimates. A tidal remnant of the former HI disk of M82 extending up to 30 kpc (in projection) is identified for the first time, and the pervasive effects of the tidal disruption are traced into the inner disk by optical and CO observations, including a kinematic trace of a large scale bar potential (Yun, Ho, & Lo 1992). The HI disk of M81 is traced out to 40 kpc in radius, and a large scale ($l \sim 20$ kpc) velocity anomaly ("High Velocity Trough"), which may be a remnant of a gaseous collision, is found within the disk of M81. The large HI bridge between M81 and NGC 3077 (van der Hulst 1979) is also found to extend $\gtrsim 50$ kpc further, bending around NGC 3077, toward M82. The total HI detected in this experiment, $5.6 \times 10^9\ M_\odot$, represents the majority of the single-dish flux (Appleton, Davies, & Stephenson 1981) and suggests that the bulk of HI found in the region belongs to the three galaxies and the tidal filaments.

The impact and details of the tidal interactions have been further examined through the use of numerical techniques. The "restricted 3-body" approach was used to simulate the observed distribution of tidal HI streamers connecting the three galaxies, and the success of the simulation is further strengthened by the accurate predictions on the gas kinematics. As suspected from the observations, all of the HI bridges (or streamers) are found to be tidally produced. The majority of the HI gas surrounding M82 is identified to be the tidally disrupted HI disk of M82 itself, contrary to the previous suggestions of tidally captured gas from M81 (e.g., Cottrell 1977). The South Tidal Bridge between M81 and NGC 3077 is identified as a tidal arm originating from M81 while the North Tidal Bridge between NGC 3077 and M82 is found to be the tidally disrupted HI disk ($\sim 10^9\ M_\odot$) of NGC 3077. The latter conclusion is highly unusual since NGC 3077 is currently an apparent early type galaxy (Barbieri, Bertola, & di Tullio 1974; Price & Gullixson 1989), and additional studies are in progress to further explore this unusual discovery.

The high degree of success achieved by the restricted 3-body calculations is quite surprising since neither self-gravity nor hydrodynamics are included in the modeling, and this may suggest that the role of self-gravity and hydrodynamical effects in tidal interactions may not be so important. On the other hand, there are some curious details that seem improbable, such as the tidal disruption of NGC 3077 which appears to have occurred only during the most recent passage by M81 while they are modelled as a bound pair ($e = 0.7$). Our full N-body study of tidal orbit

decay suggests that NGC 3077 may have undergone a tidal capture by M81 from a more eccentric orbit, and the 3-body simulation may be interpreted as a short term tracing of the tidal interactions and the evolution of tidal remnants immediately following the capture. The shortness of the time scale involved in the simulation, 3×10^8 years, is consistent with this explanation and may also explain the apparently insignificant role of hydrodynamical effects in shaping the tidal remnants. The main difference of this simulation from the previous ones is that the masses of the galaxies and the sizes of the disks are larger at least by a factor of two. The use of numerical studies such as this may also be useful in determining the physical quantities of the systems under study. Since the mass, length (or distance), and velocity (or time) scales are linked by gravity in such tidal interactions, an independent determination of mass and velocity scales may lead to the determination of the distance to the system, for example.

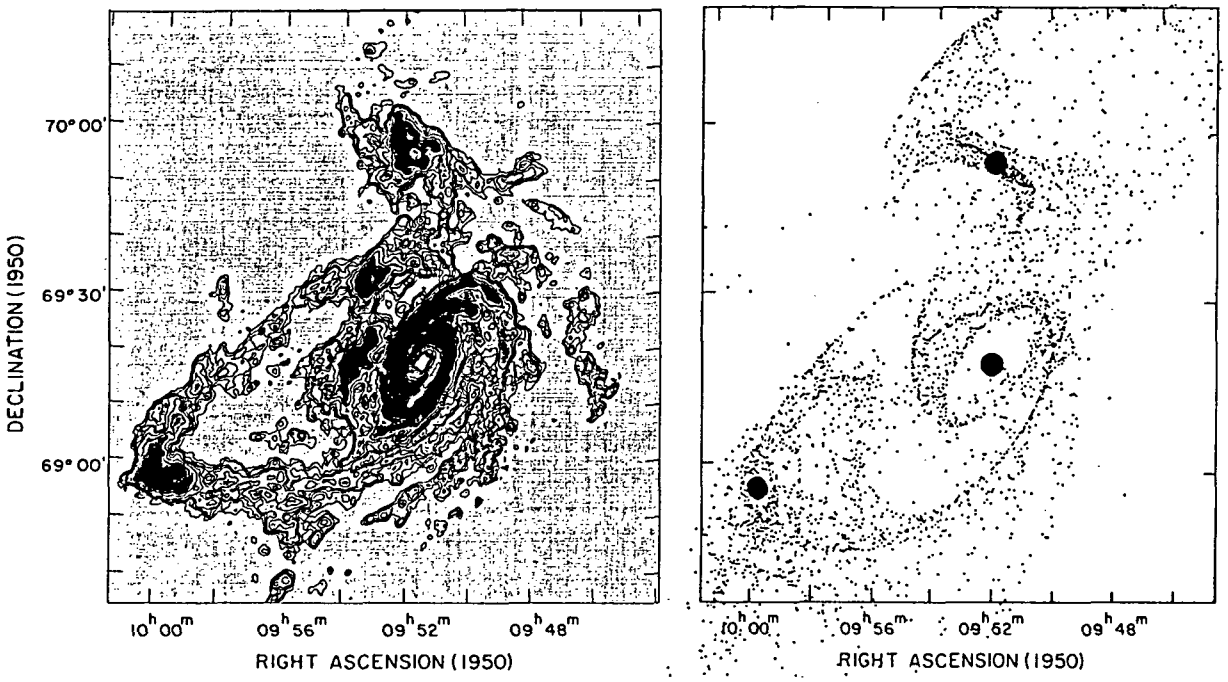

Figure 1. The 12-field VLA HI mosaic of the M81-M82-NGC3077 system (left) is compared with the result of the restricted 3-body simulation (right). The lowest contour for the HI map corresponds to the column density of 2.7×10^{19} cm^{-2}, and the contours increase in multiples of 1, 2, 3, 4, 6, 10, 15, 25, and 40.

References

Appleton, P. N., Davies, R. D., and Stenphenson, R. J. 1981, MNRAS, 195, 327
Barbieri, C., Bertola, F., and di Tullio, G. 1974, A&A, 35, 463
Cottrell, G. A. 1977, MNRAS, 178, 577
Freeman, W. L., and Madore, B. F. 1988, ApJL, 332, L63
Price, J. S., and Gullixson, C. A. 1989, ApJ, 337, 658
van der Hulst, J. M. 1979, A&A, 75, 97
Yun, M. S., Ho, P. T. P., and Lo, K. Y. 1992, ApJL, submitted