Infrared Line Emission in the Interacting Region of Arp 244
(the Antennae): Colliding Molecular Cloud Complexes?

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Introduction & Background

The Antennae (NGC 4038/4039, Arp 244, VV245) are a nearby (~22 Mpc) infrared-luminous pair of interacting galaxies. Using N-body numerical simulations Toomre & Toomre (1972) succeeded in generating the long tidal tails seen in optical/H I images of the galaxies (van der Hulst 1979). The strongest emission in both the radio continuum (Hummel & van der Hulst 1986) and the CO(1-0) line (Stanford et al. 1990; Wilson et al. 2000; Lee et al. 2001), and also the mid-infrared emission (12-17 µm, Mirabel et al. 1998) occurs in the interaction (overlap) region to the west and between the two nuclei, especially in its southern dense clouds. The ratio of [Ne III] and [Ne II] mid-infrared lines indicates that stars as massive as 60 M☉ are present there (e.g. Mirabel et al. 1998).

Scientific Justification

Using the BIMA Array with a 7.8”x6.6” beam Lee et al.(2001) have found that there are two kinematically distinct molecular cloud complexes separated by ~100 km/s in the southern part of the overlap region (see below), corresponding roughly to the clouds SGMC #4 and SGMC #5 found by Wilson et al.(2000). It seems likely that each of these is associated with one of the interacting galaxies. Because their relative positions along the line of sight are unknown, it is unclear if the complexes are approaching or moving away from each other. This relative position will affect the mechanisms of star formation significantly, either by collisions of giant molecular clouds or by other embedded physical parameters.

Possible explanations for blueshifted hydrogen lines (relative to blueshifted molecular cloud complexes):

• The ionized gas lies close to the front surface of the blueshifted molecular cloud complex and is largely accelerated outward and toward the observer.

• The stars with which the ionized gas is associated have a different velocity distribution than the molecular cloud.

• Basically, no redshifted hydrogen lines are detected, i.e. hydrogen emissions are emanated from blueshifted giant molecular cloud complexes.

• The visual extinction derived from the ratio of hydrogen lines is much smaller than the one estimated from CO column density (6 compared to 20).

Summary of discussions

We have obtained velocity-resolved spectra of three infrared hydrogen recombination lines, covering a wide range of wavelengths, in the interaction region of the Antennae galaxies, where millimeter CO observations have revealed two distinct clouds of gas with widely different radial velocities. Using an empirical extinction formula, standard recombination line ratios, and the standard gas-to-dust conversion factor, we infer that the two molecular clouds currently are moving away from each other. This is contrary to the conventional expectation of cloud collisions leading to starburst activities (e.g. Wilson et al.2000).

Reference