EXTENDED HI STRUCTURES IN THE IRREGULAR GALAXY NGC 4449

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NGC 4449 is a bright (B = 9.5), nearby (4 Mpc) irregular galaxy with a high surface brightness and strong star-formation activity; for photos see Hunter and Gallagher (1989). Using the Effelsberg 100-meter dish, van Woerden et al. (1975) – and later also Bajaja et al. (1994) – found its HI distribution to extend, at the level 2×10^{19} atoms cm^{-2}, over a full degree, or ten times the D_{25} diameter. Van Woerden et al. also mentioned that the HI velocity gradient in this outer disk was opposite to that measured at Westerbork over the innermost 4 arcminutes.

With the VLA D-array, we have used a mosaic of 3 × 3 pointings to map the HI at resolutions of 1.0′ and 10 km s^{-1} over a field (FWHM) of 1° diameter (Hunter et al. 1998). The HI distribution (Fig. 1) shows the following features: 1) a bright inner body, centred on the optical galaxy and dominated by an annulus of 5 kpc diameter; 2) a symmetric elliptical – probably highly inclined – disk of 35 × 15 kpc diameter, with strong condensations at its NE and SW ends; 3) a set of narrow streamers, consisting of straight segments making abrupt angles, and containing several bright clouds. The HI mass in the inner body and elliptical disk together is 12×10^8 M$_\odot$; the streamers (about 7×10^8 M$_\odot$ of HI) are surrounded by a diffuse HI distribution, missed by the VLA interferometers but detected by the Effelsberg single-dish.

While the kinematics inside 4 kpc radius is complex, the elliptical disk outside 8 kpc radius appears to rotate at about 75 km s^{-1}, in a period of order 1 Gyr; its velocity gradient (increasing from NE to SW) is confirmed to be opposite to that in the inner body. The velocity field of the streamers is highly ordered; the velocity difference of 160 km s^{-1} (South - North), if interpreted as rotation, would imply a total mass of 10^{11} M$_\odot$ in the system; however, it is not clear that the streamers actually rotate around NGC 4449. With 100 km s^{-1} velocity. the travel time along the filament from the SW corner to the NE end would be about 1 Gyr. Velocity dispersions are about 10 km s^{-1} in the brighter parts of disk and streamers; the Northern joint and the SW crossing have broader or complex profiles. The time scale for expansion of the streamers is of order 200 Myr – unless self-gravity keeps them together.

What caused these peculiar structures? Even if the extended distribution found at Effelsberg represents delayed accumulation of primordial gas, we think the complex set of streamers must be due to external, tidal perturbations. The HI distribution is strikingly similar to that in the M81-M82-NGC3077 triplet (van der Hulst 1979, Yun et al. 1994), and three bodies may indeed be required to explain the sharp corners. The analogon of NGC 3077, at a closely corresponding position, may be provided by the gas cloud (a failed galaxy?) at the SW corner, where two filaments cross. But where is the third body? We consider several possibilities.

The nearby dwarf-irregular DDO 125, just 37′ SSW of NGC 4449, appears undisturbed and has fairly normal global properties, including 1×10^8 M$_\odot$ of HI and $M(\mathrm{HI})/L_\mathrm{B} = 0.4$. Could it once have had 8 times more gas and twice as many stars, and lost most of its gas and half of its stars over a period of 10^9 years, without looking disturbed? If spread over an area of 100×5 kpc^2, the stars would produce an almost-undetectable surface brightness of only 28 mag arcsec^{-2}. Other, major possible perturbers are at distances exceeding 4° = 300 kpc, implying timescales of order 3 Gyr, possibly too long compared to that of the streamers.

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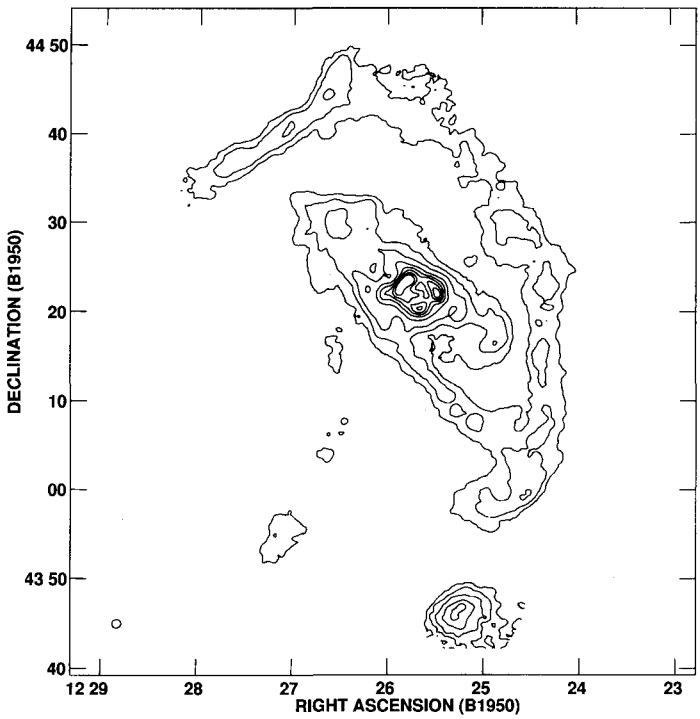

Figure 1. Distribution of HI column density; contour levels are 1, 2.5, 5, 10, 15, 20, 25 and 30 times 0.68×10^{20} atoms cm^{-2}. The ellipse at lower left is the half-maximum contour of the synthesized beam.

Or has the third body been swallowed by NGC 4449? Such a merger might have caused its current strong star formation, the counter-rotation of the inner HI, and its irregular distribution. The streamer running from the inner disk to the SW corner might then be a Toomre & Toomre (1972)-type bridge. Possible clues may come from measurement of the rotation of the inner stellar galaxy, from age analysis of its star clusters, and from a detailed study of the inner HI body and its possible interaction with the other subsystems.

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