Atomic Hydrogen in the Disturbed Edge-on Galaxy NGC 4631

Richard J. Rand and J. M. van der Hulst
Kapteyn Astronomical Institute, Univ. of Groningen

Abstract. We present WSRT HI observations of the nearby, disturbed, edge-on galaxy NGC 4631. A low-resolution (45"x87") map shows previously unknown tidal debris at large distances from the plane, and two dwarf companions. A high-resolution (12"x22") map reveals a very disturbed gas layer in NGC 4631, with a wealth of small-scale structure. The most striking discovery is a supershell in the eastern half of the disk with a diameter of about 3 kpc, a mass of $\sim 10^8$ $M_\odot$ and a tentative expansion velocity of 45 km s^{-1}. If the expansion is real, the energy which must have been injected by supernovae to explain the shell's current parameters is roughly 4×10^{55} erg! Such a high energy requirement suggests an alternative formation mechanism, such as a collision with a small companion.

Introduction and Observations. NGC 4631 is a nearby (D=7.5 Mpc), nearly edge-on ($i = 85°$) galaxy which has a dwarf elliptical companion, NGC 4627, at about 3' NW of the nucleus, and an edge-on companion, NGC 4656, at about 30' to the SW. The system affords one of the best opportunities to see how interactions can disturb the gaseous layers of a galaxy. Previous WSRT observations (Weliachew, Sancisi & Guélin 1978), at a resolution of 48"x89", revealed a complex distribution of HI emission, with four long (20 to 50 kpc) spurs of gas protruding out of the warped main gas layer of the galaxy. Recent Hα observations by Rand, Kulkarni & Hester (1992) revealed a bright, thick, disturbed disk of ionized gas with much structure, patchy emission, and a few loops up to 1.5 kpc from the plane. There is also a 3–4 kpc diameter disturbance in the disk which, in projection, appears roughly circular. The interaction is presumably the cause of the strong star formation in NGC 4631 and the disturbances to its disk.

These results prompted several questions about the small-scale structure of the HI emission. How do the tidal features connect to the main disk? Do the disturbances in the ionized gas have HI counterparts? How disturbed is the gas layer in general? To address these issues, we mapped the system at the full resolution (12"x22") of the WSRT. A low-resolution (45"x87") map was also produced from this data set. Here we present some of the preliminary results.

Results and Discussion. The low-resolution map is not presented here but the results are briefly summarized. In addition to the four spurs found by Weliachew et al., very faint tidal debris can be seen extending in a large arc from Spur 3 (see Weliachew et al. for identifications), first to the north-east, then bending to the south. Also, two new compact sources have been detected. Both have optical counterparts on the Palomar Sky Survey, one catalogued (MCG+06-28-022), one not. The catalogued source lies about 30 kpc east-south-east of NGC 4631, has an HI mass of 2×10^7 $M_\odot$, and a velocity of $V_{hel} \approx 900$ km s^{-1}. The other source lies at about 50 kpc west-north-west of NGC 4631, has an HI mass of 5×10^7 $M_\odot$, and a velocity of $V_{hel} \approx 765$ km s^{-1}.

The high-resolution map reveals a wealth of substructure in the disk of NGC 4631, with many high-velocity and high-z features. Most striking is the discovery of a nearly complete supershell in the eastern half of the disk, with a diameter of 3 kpc and a mass of $\sim 10^8$ $M_\odot$, which is coincident with the circular feature in the *ionized* gas layer mentioned above (Figure 1). There is tentative kinematic evidence for expansion at 45 km s^{-1}. If the expansion is real, the kinetic energy is about 3×10^{54} erg, and the energy which must have been injected by supernovae to explain its current parameters is about 3×10^{55} erg, or the equivalent of 30,000 supernovae! The new ROSAT image of NGC 4631 (Walterbos, this volume) shows that there is an X-ray source near the center of the shell. The large energy requirement implies an unprecedentedly rich OB association for a galactic disk. Therefore, other formation mechanisms, such as a collision with a small companion, should not be ruled out. One clue as to its origin would be an association with the footprint of one of the four extraplanar spurs, but the evidence for such a connection is weak. How the shell formed therefore remains a matter of uncertainty.

References

Rand, R. J., Kulkarni, S. R., & Hester, J. J. 1992, ApJ, in press

Weliachew, L., Sancisi, R., & Guélin 1978, A&A, 65, 37

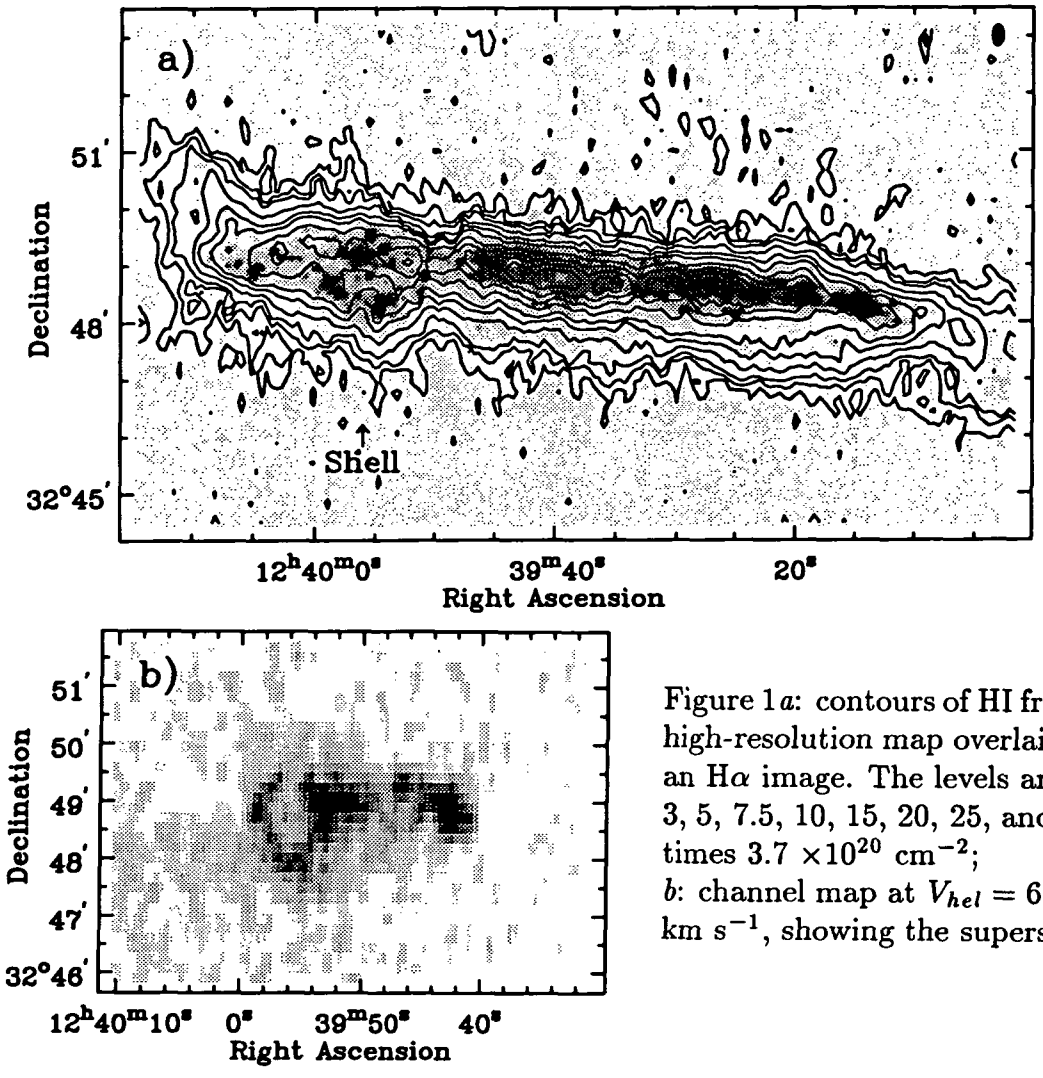

Figure 1*a*: contours of HI from the high-resolution map overlaid on an Hα image. The levels are 1, 2 3, 5, 7.5, 10, 15, 20, 25, and 30 times 3.7 $\times 10^{20}$ cm^{-2};
b: channel map at $V_{hel} = 675$ km s^{-1}, showing the supershell.