GAS IN MERGING GALAXIES

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SUMMARY

We present observations of the neutral hydrogen, ionized hydrogen, and starlight of galaxies chosen from the "Toomre Sequence" of merging galaxies (Toomre, 1977, in "The Evolution of Galaxies and Stellar Populations"). This sequence is meant to represent the progressive stages of the merger of two disk galaxies into a single elliptical-like remnant. The galaxies in this study span the full range of this sequence.

The stars and atomic gas are very differently distributed, with the stars more widely distributed at early stages, and the gas much more widely distributed at later stages. Large quantities of neutral gas are sent to large radii ($\gtrsim$100 h^{-1}kpc), and still persist even after the central remnant has relaxed to an $r^{1/4}$ light profile.

There are a few times $10^9 M_\odot\, h^{-2}$ of both molecular and atomic gas in each of these systems. Throughout the different stages, about half of the total gas mass lies within the galaxies' optical bodies. The fraction of this mass that is in neutral hydrogen drops rapidly in the later stage mergers, suggesting that atomic gas is processed into molecular gas, stars, and hot gas during the merger and resulting star burst.

Star formation occurs at all stages of the interaction, both within the tails and in the central bodies. In the early stages, the Hα shows many arcs and plumes. In the late stages, there are large H II regions in the tails which are associated with large quantities of neutral hydrogen. There is always a very good correlation between optical, Hα, and H I peaks, with $N_{HI} \gtrsim 3\times10^{20}$cm^{-2} at the location of the H II regions in the tails.

TRENDS

Early Stages: Arp 295 (fig. 1a), NGC 4676="The Mice" (fig. 1b).
Selection: Clearly separated disks bodies; Connecting luminous bridge; Tails or counterarms reaching a few optical diameters (D_{opt}) in length.
Optical: Fainter, thicker optical "plumes" out to several D_{opt}. More widely distributed than H I. **Hα:** Found mostly in main bodies, with loops and plumes, especially along the minor axis (see Arp 295 north, NGC 4676 north). Almost no Hα found in bridges. Hα clumps in tails. **H I:** Confined to bodies and brighter tidal features. Less extended than optical. Reaches a few times D_{opt}. $N_{HI}\gtrsim3\times10^{20}$cm^{-2} at regions with optical and Hα clumps. We note that the break in the tail of NGC 4676 south and subsequent clump in H I is very similar to the H I morphology of NGC 4038/9 = "The Antennae" (Mahoney, van der Hulst, and Burke, in preparation). The later has a very blue dwarf at the end of the arm, whereas in NGC 4676S we find several H II regions.

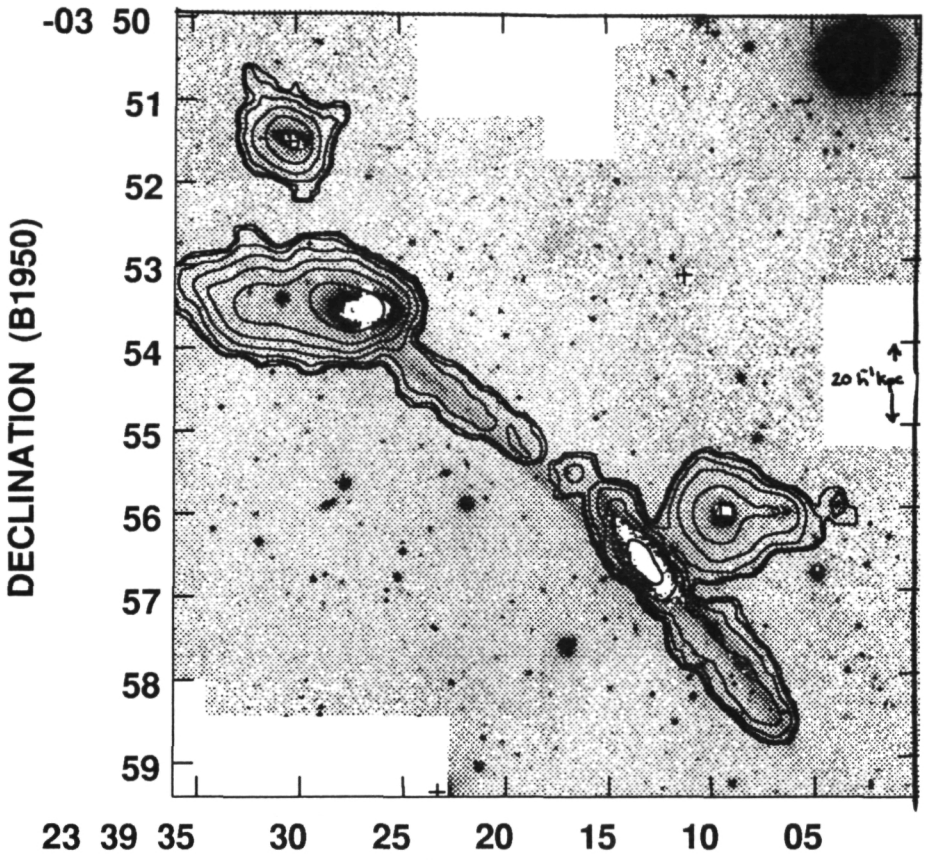
Middle Stages: NGC 520 + UGC 957 system (fig. 1c).
Selection: Distinct optical bulges embedded in a common luminous envelope; Long, luminous tails. (Note: NGC 4038/9, referenced above, and NGC 3256 and NGC 1467 (English, in preparation) also fall in this category and have similar data available).
Optical: Optical tails end long before H I. Sharp optical cutoffs. Extremely IR luminous. **Hα:** Again, find most Hα in the bodies, with plumes and loops and emission along the minor axis. Also in the regions between the two bulges. Still seen in clumps in tails. **H I:** Gaseous arm is much, much longer than the optical features, with a total H I cross-section 20 times the optical. Central H I absorption. H I minimum along the minor axis, possibly related to the Hα plumes. Column densities $\gtrsim4\times10^{20}$cm^{-2} at regions with optical and Hα clumps (southern tail, at location of UGC 957).

Late Stages: NGC 3921 (fig. 1d), NGC 7252 (fig. 1e).

Selection: Two tails, but only one body. $r^{1/4}$ luminosity profile in the remnant.
Optical: Long, fainter tails, several times D_{opt} in length, which end abruptly. Many loops and shells surrounding the remnant body. **Hα:** The ionized gas in the central remnant is much more smoothly distributed than in the earlier stages, though there are still many knots. There is either Hα or blue colours at the base or spine of the tails. The end of the optical tails coincides with a bright H II region in each of these systems. **H I:** Most, if not all, of the neutral hydrogen is in the tails (the gas which appears near the central regions

can be kinematically associated with the outer regions). Central regions H I poor, CO rich. The end of the optical tails, with the H II regions, have large neutral gas enhancements, with $N_{HI} \gtrsim 4 \times 10^{20} cm^{-2}$. The gaseous tails, however, extend up to twice as far as the optical tails beyond these points.

fig 1a: Arp295
early stage



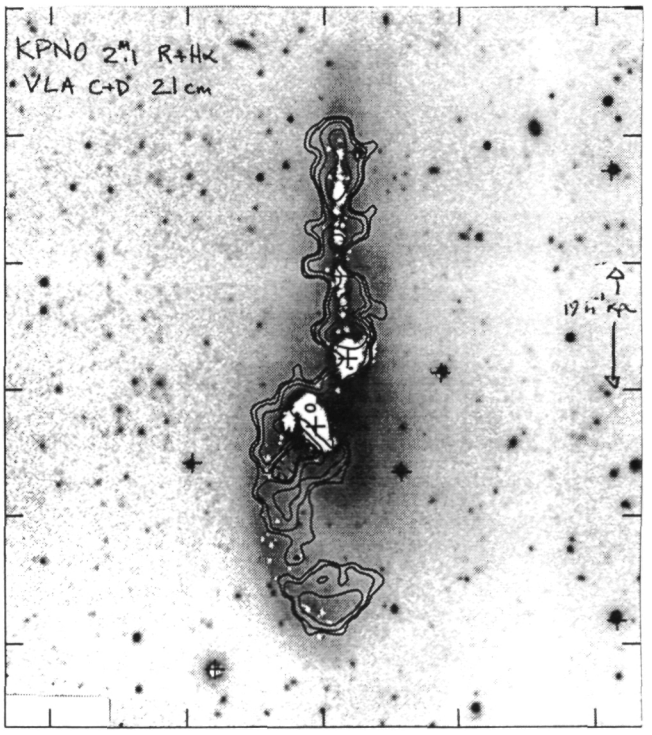


Figure 1 a-e: The 5 interacting systems: Arp 295, NGC 4676, NGC 520, NGC 3921, and NGC 7252. The greyscale shows the deep *KPNO* and *CTIO* broad band *R* images delineating the faint stellar structures, the white shows *KPNO* narrow band Hα imagery, and the contours show *VLA* C+D array observations of the neutral hydrogen. N_{HI} contours are drawn at the following levels, in intervals of $10^{19} cm^{-2}$: 1a,b: (5,10,20,40,80,160); 1c: (2,4,8,16,32); 1d-e: (5,10,15,20,25,30,40).

fig 1b
NGC4676
early stage

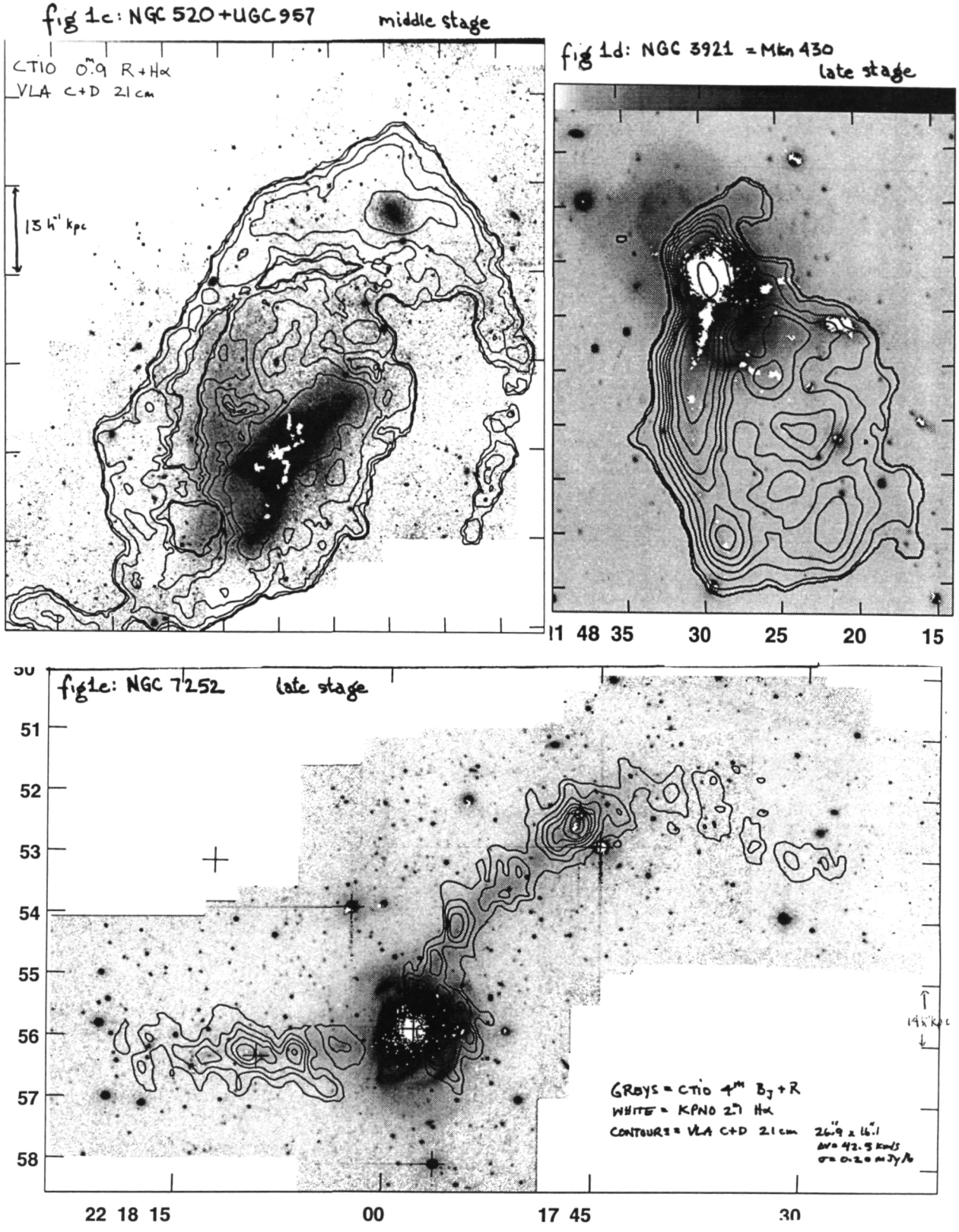


fig 1c: NGC 520+UGC 957
middle stage
CTIO 0.9 R+Hα
VLA C+D 21 cm
13 h⁻¹ kpc
fig 1d: NGC 3921 = Mkn 430
late stage
11 48 35
30
25
20
15
fig 1e: NGC 7252
late stage
50
51
52
53
54
55
56
57
58
22 18 15
00
17 45
30
GRays = CTIO 4m Bj+R
WHITE = KPNO 2.1 Hα
CONTOURS = VLA C+D 21 cm
26.9 x 16.1
ΔV = 42.3 kms
σ = 0.20 mJy/b