The correlation of the optical and radio core emission with the isotropic H$\alpha$ emission constrains the core bulk Lorentz factor assuming a relativistic jet origin for the radio and optical emission. For a continuous jet, bulk Lorentz factors 2–5 are inferred, somewhat smaller than the bulk Lorentz factors required by the BL Lac-FRI unification schemes. If the core emission is dominated by a jet component, this discrepancy could be reconciled by a two-layer jet with a fast moving spine surrounded by a slower outer layer (e.g., Sol, Pelletier, & Asseo 1989; Laing & Bridle 2002). If the radio and optical core emission are indeed inner jet synchrotron emission, then their strong correlation with H$\alpha$ core emission implies either a direct link between jet luminosity and gas excitation power even on these very small scales, possibly via jet-gas interactions, or a close relation between AGN photo-ionizing power and jet radiative (and possibly kinetic) power (e.g., Baum & Heckman 1989). Lastly, we find that radio, optical and H$\alpha$ core luminosities of elliptical LINER-type AGNs with and without kiloparsec-scale radio jets appear to have similar relations. The results suggest (i) the engines in the two types producing the cores might be similar and (ii) the core radio emission in ellipticals without large-scale radio jets may be produced by small-scale jets. The clue to what distinguishes sources with and without large-scale radio jets has yet to be identified.

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VLA Observations of the “Integral Sign” Galaxy

The “Integral Sign” galaxy (UGC 3697) is a nearby Sd spiral that exhibits a dramatic “S”-shaped warp in its stellar disk (Figure 1). Although a mild degree of bending or twisting is observed in the outer gas disks of the majority of spiral galaxies, warping of the stellar disk is typically less pronounced, and warps of the amplitude seen in UGC 3697 are rare. This implies UGC 3697 may be in a rather unstable and short-lived dynamical state. UGC 3697 is further intriguing in that in spite of its significant distortion, its stellar disk appears remarkably thin. Moreover, unlike most spiral galaxies viewed edge-on, it shows no obvious dust lane and no hint of a spheroid component. In these ways, the appearance of UGC 3697 is reminiscent of the flattest and dynamically coldest Sd galaxies—the so-called “superthins” (Goad & Roberts 1981).

Superthins appear to be among the least evolved disk galaxies in the local universe. They typically exhibit quiescent, gas-rich disks with low metallicities and minimal signs of dynamical heating (e.g., Bergvall & Rönnback 1995; Matthews et al. 1999). They also appear to be highly dark-matter dominated. An example of a prototypical superthin spiral is UGC 7321 (Matthews et al. 1999). As summarized in Table 1, UGC 7321 and UGC 3697 share a number of similar global physical properties, including their sizes, neutral hydrogen contents, scale heights, and peak rotational velocities. However, UGC 3697 has a blue luminosity ~5 times higher than UGC 7321 and a far-infrared luminosity ~23 times greater. Combined, these traits strongly suggest that UGC 3697 may have once been a quiescent superthin that has only recently begun a transformation as the result of a tidal interaction or minor merger. Indeed, UGC 3697 is part of a small galaxy group that includes the peculiar elliptical UGC 3714, as well as several dwarf galaxies. Catching

<table>
<thead>
<tr>
<th></th>
<th>UGC 3697</th>
<th>UGC 7321</th>
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<tr>
<td>$D$ (Mpc)</td>
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<td>$V_{rot}$ (km s$^{-1}$)</td>
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<tr>
<td>$M_{HI}$ ($\times 10^9 M_\odot$)</td>
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<td>1.1</td>
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<tr>
<td>$L_B$ ($\times 10^9 L_\odot$)</td>
<td>3.5</td>
<td>1.0</td>
</tr>
<tr>
<td>$L_{FIR}$ ($\times 10^9 L_\odot$)</td>
<td>1.8</td>
<td>0.079</td>
</tr>
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a superthin in the act of being perturbed is of considerable interest, as it can show how these seemingly fragile disks respond to environmental influences.

In order to further explore the environment of UGC 3697 and assess how it has affected the neutral gas (HI) distribution and kinematics of this galaxy, we have observed UGC 3697 in the HI 21-cm line using the VLA in its CS configuration. We obtained a total of 12 hours of on-source data, reaching a 3σ limiting column density of \( \sim 2 \times 10^{19} \) cm\(^{-2}\) per channel with a velocity resolution of 5.2 km s\(^{-1}\) and a spatial resolution of \( \sim 19'' \).

As seen in the total HI intensity image in Figure 2, our VLA observations reveal a pronounced gaseous warp in UGC 3697. Overall, the HI distribution traces the shape of the stellar warp, but it also exhibits additional twists and extensions. On the eastern side of the galaxy, we find gas concentrated along the midplane as well as a wide swath of more diffuse emission sweeping below the plane. In our optical image in Figure 1, this region is faintly delineated by a very blue population of stars.

One surprise revealed by our VLA data is that unlike in normal edge-on spirals, the brightest HI concentration in UGC 3697 is not found near the central regions of the galaxy, but rather along its western edge, where we detect a bright, extended blob of emission in the galaxy midplane. A network of long, curved filaments of gas, \( \sim 3–7 \) kpc in extent, also protrude from the northern edge of the disk near this location. Neither these filaments nor the bright mid-plane clump have any obvious optical counterpart.

In Figure 3 we show the HI velocity field for UGC 3697 and its environs. Not surprisingly, the velocity field of UGC 3697 itself appears highly distorted owing to the strong warping of the disk. These data also confirm the presence of several gas-rich neighbors, only one of which was a previously catalogued member of the UGC 3697 group (UGC 3714). Although it is the brightest visual companion of UGC 3697, UGC 3714 is only a weak HI source and exhibits little rotation. In contrast, the brightest two HI companions in Figure 3 appear only as extremely faint smudges on the Digitized Sky Survey. We also have detected a previously uncatalogued dwarf very close to the eastern tip of the disk of UGC 3697. A rotational signature in this dwarf is evident from our data, and in Figure 1 we see a faint optical counterpart \( \sim 10'' \) across, with \( L_B \sim 8.5 \times 10^6 \) L\(_{\odot}\).

What can these new data tell us about the evolutionary history of UGC 3697? One hypothesis for the origin of galactic warps is that they are triggered by tidal interaction. Since a fairly massive object is required to trigger a warp purely via tidal effects, the most likely culprit would appear to be UGC 3714, at a projected distance of 39 kpc from UGC 3697. Assuming a typical internal group velocity, it is feasible that UGC 3697 and UGC 3714 may have had a close encounter \( \sim 10^8 \) yr ago. This timescale is roughly consistent with the ages of the HII regions of UGC 3697 inferred by Márquez & del Olmo (1991). However, a problem with this scenario is that the disk of UGC 3697 lacks...
the signatures of dynamical heating (thickening) expected from such an event (e.g., Reshetnikov & Combes 1997). Moreover, to the limiting sensitivity of our present data, UGC 3697 does not show any gaseous bridges or arcs linking it with UGC 3714 or any of its other neighbors.

Several pieces of evidence in our new VLA data suggest a new, alternate possibility for the origin of the warp of UGC 3697. Examination of our individual HI channel maps reveals that the bright blob of gas seen along the midplane in Figure 2 does not follow the same ordered rotation as the underlying disk—i.e., its mean radial velocity deviates from the adjacent material. The total amount of gas in this “anomalous” component is \( \approx 2 \times 10^8 \, M_\odot \). This is comparable to the HI mass of a typical dwarf irregular galaxy, suggesting that a dwarf may have recently either plummeeted into the disk of UGC 3697, or been stripped of the bulk of its gas during a close fly-by. Such an event would be expected to trigger inflows of gas toward the central regions of the galaxy (Hernquist & Mihos 1995) and may account for the enhanced 21-cm radio continuum emission we detect within the central kpc of UGC 3697. The faint dwarf seen near the eastern edge of UGC 3697 could be the stripped core of this intruder.

Independent of the origin of the strong warping of the disk of UGC 3697, the question remains what will be the ultimate fate of this system. If a \( \sim 10^8 \, M_\odot \) satellite has indeed been accreted, the late stages of this process are expected to excite vertical instabilities in the disk (Sellwood et al. 1998), hence the “superthin” disk of UGC 3697 may soon begin to buckle and thicken. The outcome could be a transformation into something resembling typical Magellanic spirals, which have substantially thicker disks and less regular and symmetric structure, but often very similar masses, sizes, HI contents, and luminosities to UGC 3697. Since galaxy interactions and mergers were far more common in the past, our results hint that other superthin disks residing in rich environments may have already been similarly transformed, helping to account for the puzzle of the diverse array of disk morphologies seen within a similar range of physical parameter space at the end of the Hubble sequence—from quiescent superthins to star-bursting Magellanic systems.

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References
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Figure 3. HI velocity fields of UGC 3697 and several neighboring members of the UGC 3697 group.