The major directions of my work to date have been: structure and kinematics of distant field galaxies (described in my statement of research interests); optical and radio observations and fluid dynamical modeling of the gas velocity fields of barred galaxies, using this data to break the degeneracy between disk and dark halo mass in rotation curve fitting; fluid dynamical modeling to simulate gas kinematics in the bar of the Milky Way; and Fabry-Perot observations of faint, diffuse Hα emission from H I clouds in the Galactic halo.

1. Structure and Dynamics of Barred Galaxies from 2-D Observations and Modeling

Many disk galaxies have large-scale stellar bars; 30% of disk galaxies classified from blue images have bars (Sellwood & Wilkinson 1993), while in the near-IR and IR "hidden bars" are revealed and the percentage is 70% in the K-band (Mulchaey & Regan 1997). Studying the structure and dynamics of barred galaxies is necessary to understand the influence bars can have on the structure and evolution of disk galaxies. However, it requires more intensive effort than for axisymmetric galaxies, since the simplifying assumptions of axial symmetry and circular orbits no longer hold: 2-D observed velocity fields and 2-D fluid dynamical simulations are required to model the flow of the gas emission-line tracers.

Bars drive angular momentum transfer in disks and feed gas to the inner regions of galaxies, and are associated with formation of stars and super star clusters in circumnuclear rings and spirals, thought to form at inner Lindblad resonances (see *e.g.*Barth *et al.* 1995; Maoz *et al.* 1996; Carollo *et al.* 1997). The presence of an ILR may cut off fueling of a central engine (Mulchaey & Regan 1997). Bars can cause strong secular evolution of disks – gas consumption and bulge building – and may destroy themselves by driving mass to the center (Norman *et al.* 1996). Whether bulges predate disks or are built by secular evolution is an open and active question (*e.g.*Norman *et al.* 1996; Renzini 1999). Although it is presumed that there is a link between the gas flows in barred galaxies and the distribution and amount of star formation in bars, the necessary kinematic data (especially 2-D velocity fields with high spatial resolution) exist for few barred galaxies.

Barred galaxies can also yield information about galactic structure which is inaccessible in axisymmetric galaxies. In an axisymmetric galaxy there is a degeneracy between stellar disk and halo contributions to the rotation curve, which prevents us from determining the stellar M/L and the dark halo scale density and radius (the "maximum disk" problem, van Albada *et al.* 1985). This creates a paradoxical situation: disk galaxy rotation curves are our best evidence for dark halos on galaxy scales, but have not yielded useful limits on the structure of dark halos.

In barred galaxies, the degeneracy is lifted: the noncircular streaming motions are sensitive to the mass of the bar. By comparing models to observed velocity fields, we can measure the stellar M/L and hence the disk contribution to the rotation curve, revealing the dark matter contribution and the radial density profile of the dark halo.

We have now carried out this program of disk-halo separation for a typical barred galaxy, NGC 4123 (Weiner *et al.* 2001a,d). We obtained a 2-D velocity field of the galaxy using the Rutgers Fabry-Perot at the CTIO 4-m to observe the Hα line. This velocity field has resolution $\sim 1.5''$, and shows the non-circular streaming motions and shocks in the bar. We obtained an H I velocity field using the VLA to determine the rotation curve at large radii, where the dark matter halo must dominate the mass.

We used I-band 2-D surface photometry to generate mass models, which include the stellar component of the galaxy, the gas, and a dark halo. We then ran many fluid dynamical models to simulate the gas flow in these model potentials, for a range of values of stellar M/L and bar pattern speed, and compared the simulated velocity fields to the observed Fabry-Perot velocity field. Only models with a high disk M/L_I of 2–2.5, and a fast bar rotation speed, can match the data.

We concluded that the stellar disk of NGC 4123 is 85–100% of the maximum mass, and dominates the rotation curve to well outside the optical radius of the galaxy. The dark halo is not very centrally concentrated, with a large core radius and a characteristic density which is 2–4 times lower than predicted by cosmological simulations with CDM or ΛCDM-type initial conditions (Bullock *et al.*2001).

This result, together with studies which suggest that dwarf and LSB galaxies have less concentrated halos, indicates that although dark matter is necessary on galaxy scales, it does not behave as expected from CDM-type models. However, these models lead to galaxy formation scenarios with many attractive features (*e.g.*Dalcanton *et al.* 1997, Mo *et al.* 1998). The resolution of these discrepancies requires a systematic study of the distribution of dark matter in galaxy halos, by modeling galaxies over a range of velocity width and surface brightness. I have now collected the necessary Fabry-Perot data for several nearby barred galaxies.

2. The Properties of the Bar of the Milky Way

In a related project, I have applied fluid dynamical modeling of gas flows to study the bar of our own Galaxy (Weiner & Sellwood 1999). There is now a fairly strong consensus that the Milky Way has a bar (*e.g.* Blitz *et al.* 1993, Fux 1999), but parameters such as its size, alignment with respect to the Sun, and pattern speed are difficult to determine, due to the edge-on geometry and high extinction. Kinematics are always the best measure of a mass distribution, but in the Galaxy, the projection effects can make their interpretation difficult.

As in the NGC 4123 program, we attempt to construct a gas-flow model which can match kinematic data, in this case the H I longitude-velocity ($l - V$) diagram toward the Galactic center. The presence of gas at “forbidden” velocities in the $l - V$ diagram has long been seen as evidence for non-axisymmetric structure in the Galaxy (*e.g.* Liszt & Burton 1980). We attempted to find a bar model which could reproduce the shape of the outer envelope of the H I $l - V$ diagram. The shape of this outer envelope has been used to derive the inner rotation curve of the Milky Way, leading to a rotation curve with a sharp rise and puzzlingly quick decline at small radius under the assumption of circular orbits (see Liszt 1992).

By running gas-flow simulations in 51 different model potentials and projecting them as seen from the Sun, we constructed a bar model for the center of the Milky Way which matches the outer envelope of the H I $l - V$ diagram fairly closely. The model explains the presence of gas in the forbidden quadrants of the $l - V$ diagram. It also shows that the rise-and-decline in the Milky Way rotation curve is a spurious effect caused by the assumption of circular orbits. The model bar has a semimajor axis of 3.6 kpc, is aligned at an angle of $\sim 30°$ to the Sun–Galactic center line, and rotates quickly, with corotation at 1.2 times the semimajor axis. In the future, the technique will be used to test models for the Galactic bar such as those derived from COBE photometry (*e.g.* Dwek *et al.* 1995), with the aim of producing a model which satisfies both photometric and kinematic constraints.

3. Faint Hα Emission from the Magellanic Stream and High Velocity Clouds

I have used Fabry-Perot instruments at CTIO and Las Campanas to search for faint, diffuse Hα emission from neutral hydrogen clouds associated with our Galaxy and the Magellanic Clouds, (Weiner, Vogel, & Williams 2001b,c). These H I clouds have not been detected optically, apart from a few clouds with detections of interstellar absorption lines against background sources. A Fabry-Perot is ideal for searches for faint diffuse emission lines due to its high spectral resolution and large collecting area, much larger than possible with slit spectrographs.

We have discovered Hα emission from the leading edges of three of the subclouds of the Magellanic Stream, which trails behind the LMC/SMC system (Weiner & Williams 1996). The emission is strongest on the leading edges of the subclouds, with intensity 200 – 1200 milli-Rayleighs (mR),[1]. equal to emission measures of 0.5 – 1 cm^{-6} pc. Away from the leading edges, the emission declines in intensity, to < 40 mR. A possible explanation for this emission and its association with cloud leading edges is that it is caused by ram pressure on the Magellanic Stream clouds as they move through tenuous, hot coronal gas in the Galactic halo, some 40–50 kpc above the Galactic plane, with perhaps $n_{\rm H} \sim 10^{-4}$ cm^{-3} at $\sim 10^6$ K.

We have also searched for Hα emission from high-velocity clouds of neutral hydrogen outside the Galactic disk. The HVCs are H I clouds with $|V_{LSR}| > 90$ km s^{-1}, often found at high latitude and inconsistent with Galactic rotation. Their distances are largely unknown, apart from two clouds which show absorption against halo stars and are at < 5 and 4-10 kpc. These two clouds also have detections of Hα emission, of 90-200 mR (Tufte *et al.* 1998).

The nature and origin of HVCs remain controversial (see review by Wakker & van Woerden 1997). The most favored models for HVCs are: Galactic fountain models (*e.g.* Shapiro & Field 1976; Houck & Bregman 1990) in which the HVCs are recycled disk gas which is blown out in superbubbles, cools and falls back to the disk; and accretion models, in which the HVCs are gas accreting onto the Galaxy, possibly from satellites in the outer Galactic halo or even from the Local Group (*e.g.* Blitz *et al.* 1999). The models predict greatly different distances: in Galactic fountain models, the HVCs are a few kpc above the disk, while in the recent Local Group model of Blitz *et al.* (1999), the HVCs are at hundreds of kpc. Since the gas mass in HVCs goes as distance squared, the implications for accretion of gas onto the Galaxy are radically different.

In a campaign begun at CTIO and continued at Las Campanas, we observed 20 HVCs. We find a range of Hα intensities. A few clouds have strong (for HVCs) emission of 120-1000 mR, comparable to the emission of 90-200 mR that Tufte *et al.* (1998) detected from the two large HVCs with known distances. However, many of the HVCs we observed are very faint, with Hα emission of $40 - 80$ mR.

The faintness of these HVCs suggests that they are farther away than the bright HVCs. The Hα emission is most likely caused by photoionization from UV light leaking out of the Galactic plane. We constructed a model of the ionizing radiation field emergent from the Galactic disk and normalized it to produce the correct Hα intensities for the two HVCs with known distance brackets and Hα fluxes. Our observations of the Hα flux from an HVC can then be used to place the clouds within the model and obtain the distances. We find that our faint HVCs are at distances 20–60 kpc, much too far to be part of a Galactic fountain, but too close to be associated with the Local Group.

[1] 1000 mR = 1 Rayleigh = 10^6 photons cm^{-2} s^{-1} into 4π, or 5.6×10^{-18} erg cm^{-2} s^{-1} arcsec^{-2}.

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