Measuring Galaxy Disk Mass with the SparsePak Integral Field Unit on WIYN

Marc Verheijen[1], Matthew Bershady[1], and David Andersen[2]

[1] University of Wisconsin, Madison WI 53706, USA
[2] Max Planck Institute for Astronomy, Heidelberg, Germany

We present first results from the commissioning data of the SparsePak Integral Field Unit on the WIYN telescope. SparsePak is a bundle of 82 fibers, arranged in a sparsely filled, 76×77 arcsec hexagonal grid. It pipes light from one of the Nysmith foci to the Bench Spectrograph. See http://www.astro.wisc.edu/˜mab/research/sparsepak and Bershady et al. (2002a) for more details. The fibers are each 5 arcsec in diameter and are thus suitable to obtain spectroscopy on extended objects of lower surface brightness such as galaxy disks. In fact, SparsePak was purposely developed to measure stellar kinematics and velocity dispersions in disk galaxies with the ultimate goal of constraining the surface densities and masses of stellar disks. Such a measurement is crucial to improve our understanding of the principal dynamical components in disk galaxies from rotation curve decompositions.

As part of the SparsePak commissioning program we observed several galaxies, one of which was NGC 3982, a blue and very high surface brightness galaxy with $\mu_0^{\rm obs}$(B)=19.3 mag/arcsec^2 and B−K′=3.4 (Tully et al. 1996). It was mapped in three spectral regions; around 5130Å(MgI), 6680Å(Hα) and 8660Å(CaII-triplet) with FWHM spectral resolutions of 24, 16 and 37 km/s respectively. About 3 dozen template stars with a range in $T_{\rm eff}$ and surface gravity were observed as well by drifting them across many fibers.

Three pointings were taken in the Hα line to fill the hexagonal grid. This yielded a contiguous Hα velocity field of very high signal-to-noise. Fitting a tilted-ring model to this velocity field yielded a kinematic inclination of 26±2 degrees, consistent with the isophotal ellipticity, and an Hα rotation curve at 5 arcsec resolution which supplements a low resolution HI rotation curve.

Stellar absorption line observations were taken with a single SparsePak pointing, aimed at measuring the vertical velocity dispersion of the stars. Here we focus on the stellar velocity dispersions measured from the deepest CaII line. In the inner regions of the galaxy, the signal-to-noise in the spectra of individual fibers is high enough to determine the line centroids and to construct a stellar velocity field. Comparison of the Hα and stellar velocity fields clearly shows the effects of asymmetric drift inside 1.5 disk scale lengths h_R. Outside this radius the asymmetric drift approaches zero.

The layout of the fibers and the near face-on orientation of the galaxy allows for azimuthal averaging of 6, 6, 6, 12 and 18 fibers in 5 annuli to improve the signal-to-noise in the CaII absorption line in the outer regions of the galaxy.

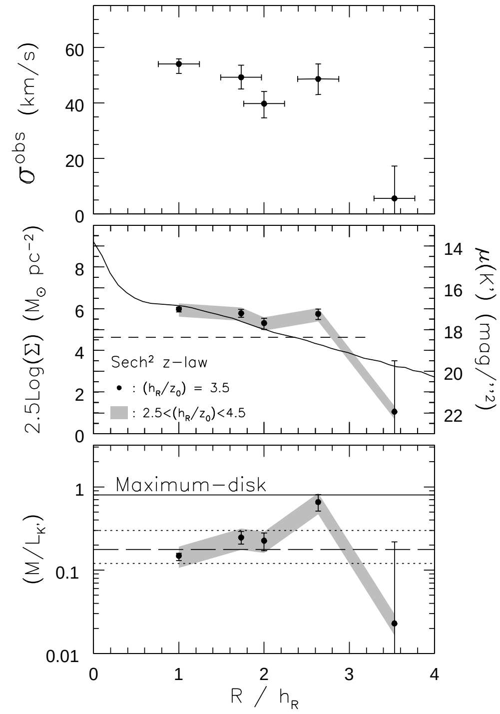

Fig. 1. Upper panel: Azimuthally averaged stellar velocity dispersions corrected for instrumental and tem–plate broadening. Horizontal bars indicate the radial bin widths. Note the sudden drop beyond 3 disk scale lengths. Middle panel: The points indicate the inferred mass surface density for an isothermal vertical density profile and a range of scale heights. The solid line shows the radial K' surface brightness profile. Bottom panel: derived M/L of the disk in the K' band. The solid line shows the maximum value allowed by the rotation curve. The dashed lines indicate the weighted radial average value and the dotted lines relate to the dotted lines in the right panel of Figure 2.

The outermost annulus, with 18 fibers, has a radius of 3.5 h_R. Before averaging, the projected rotational velocities were taken out, using the centroids of the high signal-to-noise Hα lines. Stellar velocity dispersions were determined by convolving the spectrum of a K0.5-III template star with a Gaussian of varying FWHM and finding the best match to the azimuthally avaraged galaxy spectra.

The results are summarized in Figure 1 and in Bershady et al. (2002b). The plotted velocity dispersions are the σ of the convolution Gaussian. No corrections were applied for contributions from the projected radial and tangential velocity dispersion components which are estimated to contribute less than 13%. The measured velocity dispersion is fairly constant with radius except for the outermost point where a significantly lower velocity dispersion is observed. Assuming an isothermal (sech^2) vertical density profile, a mass surface density can be derived for a variety of scale heights based on results from recent work by Kregel et al. (2002). This mass surface density includes any non-stellar component in the disk and is a factor $\sim$3.5 higher than the surface density of the Milky Way in the solar neighborhood (Kuijken & Gilmore 1991), indicated by the short dashed line in the middle panel. Given the K$'$ luminosity profile, the mass-to-light ratio of the disk can be computed as a function of radius. A weighted radial average of $(M/L_{K'})$=0.18 is used in a rotation curve decomposition shown in Figure 2 which implies a substantially ($\sim$ 25%) sub-maximum, yet very high SB disk.

This work was supported by NSF grant AST-9970780.

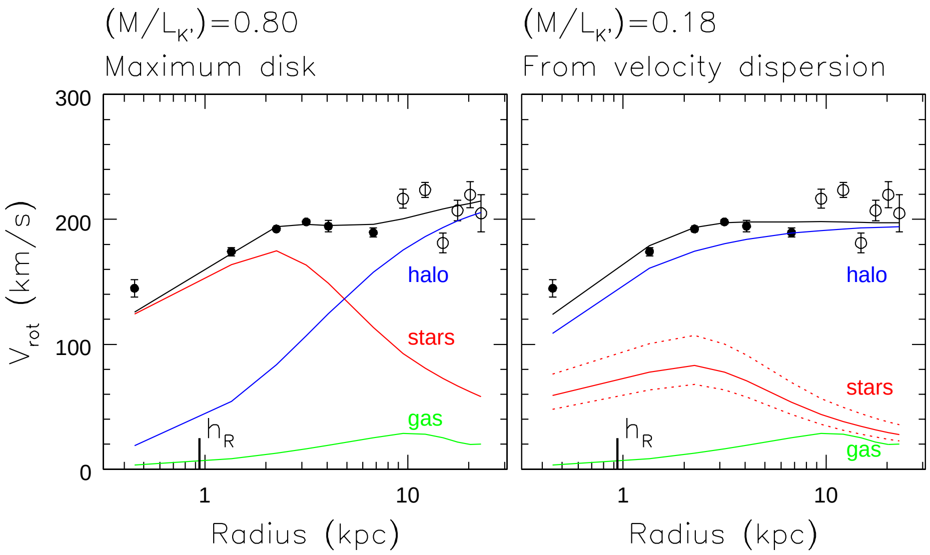

Fig. 2. Rotation curve decompositions for NGC 3982. Solid points are from SparsePak, open points are from HI measurements. Left panel: maximum-disk decomposition which implies a stellar mass-to-light ratio of 0.80 in the K′ band. Right panel: rotation curve decomposition with a disk M/L of 0.18 based on the stellar velocity dispersion measurement of SparsePak. This suggests that NGC 3982 has a strongly sub-maximum disk. This is surprising given the fact that the stellar disk has a very short scale length and and extremely high surface brightness.

References

1. M.A. Bershady, D.R. Andersen, J. Harker, M.A.W. Verheijen, L.W. Ramsey 2002a, PASP, in preparation
2. M.A. Bershady, D.R. Andersen and M.A.W. Verheijen 2002b, in *D*isks of Galaxies: Kinematics, Dynamics and Perturbations, eds. L. Athanassoula, I. Puerari, ASP Conference Series, in press
3. K. Kuijken and G. Gilmore 1991, Ap.J., 367, L9
4. M. Kregel, P.C. van der Kruit and R. de Grijs 2002, MNRAS, in press
5. R.B. Tully, M.A.W. Verheijen, M.J. Pierce, J.-S. Huang, R.J. Wainscoat 1996, A.J., 112, 2471