The sub-maximality of galaxy disks

Thomas Martinsson[1], Marc Verheijen[1], Kyle Westfall[1], Matthew Bershady[2], Dave Andersen[3], Rob Swaters[4]

[1] Kapteyn Astronomical Institute, Groningen, The Netherlands; [2] University of Wisconsin, Madison, USA;
[3] NRC Herzberg Institute of Astrophysics, Victoria, Canada; [4] NOAO, Tuscon, USA

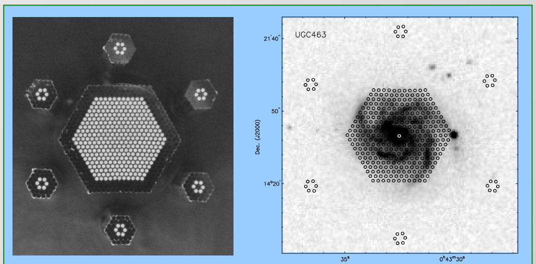
contact: martinsson@astro.rug.nl

Introduction:

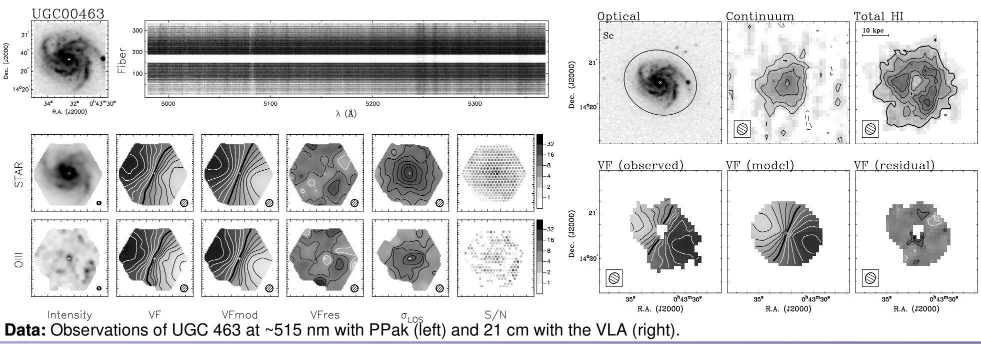
One of the main goals of the DiskMass Survey (Bershady et al. 2010a) is to break the so-called "disk-halo degeneracy", which has hampered rotation-curve mass decompositions of spiral galaxies for a long time. The often used "maximum-disk hypothesis" (van Albada & Sancisi 1986) circumvents this problem by assuming a maximum contribution from the baryons to the total mass content of the galaxy, but still remains unproven. From our stellar and gas kinematical observations of nearly face-on spiral galaxies, we break this degeneracy using the equation $\sigma_z = \sqrt{\pi G k h_z \Sigma_{dyn}}$, which directly relates the disk mass surface density (Σ_{dyn}) to the vertical velocity dispersion of the disk stars (σ_z). This poster presents some main results from a sample of 30 galaxies observed with the IFU PPak, to appear in the PhD thesis of T. Martinsson.

Conclusions:

(1) The vertical velocity dispersion (σ_z) follows a well-defined exponential radial decline, expected for constant M/L and thickness of the disk.
(2) A tight linear relation exists between the central velocity dispersion of the disk stars ($\sigma_{z,0}$) and the maximum rotation speed (V_{max}).
(3) The radial HI mass surface density (Σ_{HI}) profile is surprisingly well fitted by a Gaussian function.
(4) Our rotation-curve mass decompositions contradict the maximum-disk hyphothesis, showing that the intermediate-to-late-type galaxies in our sample have sub-maximal disks.

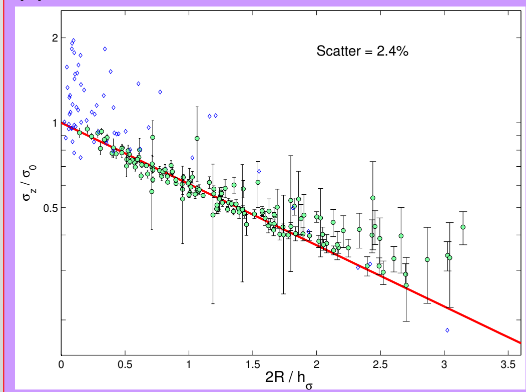


PPak: Left: The fiber-based PPak IFU, developed for the DiskMass Survey (Verheijen et al. 2004), has a large field of view, with 331 science fibers and 36 sky fibers. Right: The PPak fiber-footprint overlaid on top of UGC 463, one of the galaxies in our sample.



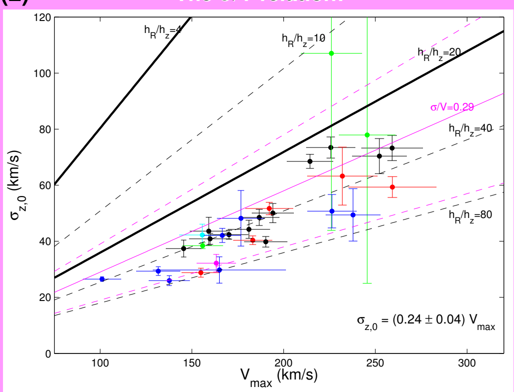
Data: Observations of UGC 463 at ~515 nm with PPak (left) and 21 cm with the VLA (right).

(1) Exponential decline of σ_z:



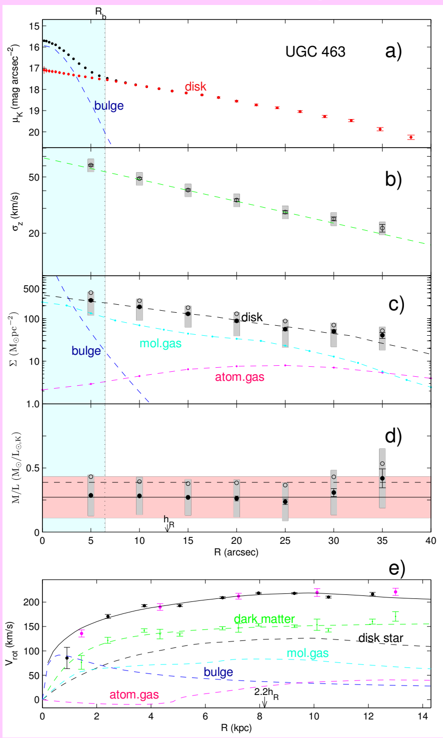
Stellar velocity dispersions from all 30 galaxies, azimuthally averaged in 5" wide rings, as a function of radius. The smaller, blue symbols indicate measurements within the "bulge" radius (see figure to the right). The thick line shows the exponential function fitted to individual fiber measurements for every galaxy separately. Clearly, σ_z is well described by an exponential decline out to at least $h_\sigma \sim 2h_R$, consistent with a constant M/L and thickness of the disk.

(2) The σ/V relation:



Linear relation between the central vertical velocity dispersion of the stars in the disk ($\sigma_{z,0}$) and the maximum rotational speed (V_{max}). We find $\sigma_{z,0} = (0.24 \pm 0.04)\ V_{max}$, which can be compared to $\sigma_{z,0} = (0.29 \pm 0.10)\ V_{max}$ found by Bottema (1993). With the assumption that disks are maximal, self-gravitating, exponential, and of constant M/L, we find that all but one galaxy have a disk more oblate than any observed edge-on galaxy (Kregel et al. 2002; observed range indicated with the two thick black lines). This result indicates that the disks are sub-maximal.

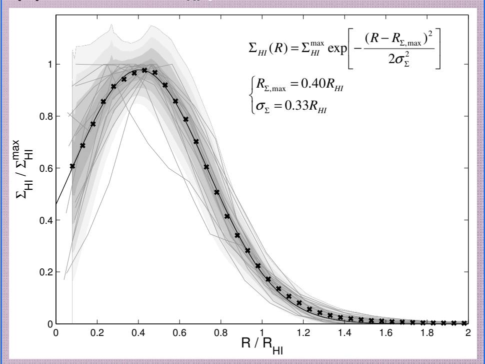
Rotation-Curve Mass Decomposition:



Radial profiles illustrating the mass decomposition of an observed rotation curve. The light-blue shaded area, seen in the first four figures, indicates the "bulge" region, delimited by the radius (R_b) where the bulge contributes 10% of the K-band emission. Data within R_b have been excluded from any analysis. The figures above provide: **(a)** The K-band surface brightness profile. Red points show the surface brightness of the disk, after subtracting the bulge. **(b)** Azimuthally averaged measurements of σ_z, where the dashed green line shows the exponential fit. **(c)** Mass surface densities measurements. Open circles show Σ_{dyn} calculated from σ_z above, using the equation in the Introduction. Filled circles provide the disk stellar mass surface density ($\Sigma_{disk,*}$), after subtracting the bulge and gas components from Σ_{dyn}. The dashed black line shows $\Sigma_{disk,*}$, assuming the mean M/L in panel d. **(d)** K-band mass-to-light ratios measurement using $\Sigma_{disk,*}$ and μ_K. Solid line indicate mean stellar M/L. **(e)** Rotation-curve mass decomposition: Observed rotation curve (black and magenta filled circles), decomposed into different mass components.

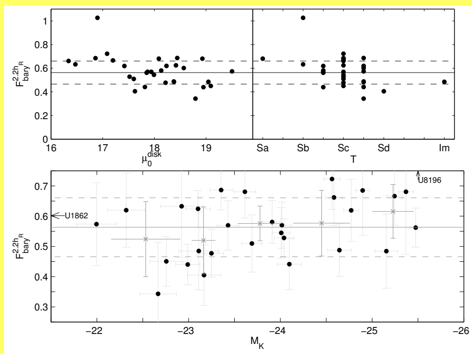
Note that the dark matter dominates over the stellar disk at all radii.

(3) The radial Σ_{HI} profile – A Gaussian:



Radial Σ_{HI} profiles of individual galaxies plotted as grey lines. Black crosses show averaged normalized Σ_{HI}, with the gray scale covering two times the standard deviation. The black solid line shows the best-fitted Gaussian profile.

(4) Sub-maximal disks:



Ratio of baryonic rotation speed to total rotation speed (F_{bary}), measured at $2.2h_R$, versus central disk surface brightness (top left), morphological type (top right), and absolute K-band magnitude (bottom). Black dots show measurements of the individual galaxies, gray errorbars show the average and scatter of radial binned subsamples. The average F_{bary}=0.56 ± 0.10, with a weak trend of larger F_{bary} for more luminous galaxies.

References:
Bershady et al., 2010a, ApJ, 716, 198
Bershady et al., 2010b, ApJ, 716, 234
Bottema, 1993, A&A, 275, 16
Kregel et al., 2002, MNRAS, 334, 646
van Albada & Sancisi, 1986, RSPTA, 320, 447
Verheijen et al., 2004, AN, 325, 151