The Field Disk Galaxy Population between $z=1$ and Today

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We focus on field disk galaxies at $0<z<1$: cosmologically significant look-back times, but less frequent violent interactions than at $z>1$.

Some of the questions to be addressed:

• **What does the Tully-Fisher relation up to $z\sim 1$ look like?**

• **How do the sizes of disk galaxies evolve?**

• **How do their stellar population properties evolve as a function of time and DM Halo mass?**
Our Sample

261 galaxies observed with VLT/FORS in the FORS Deep Field and William Herschel Deep Field (~100h in total).

2.5h to 10h integration time per object.

Slits aligned with major axes to get rotation velocity as function of radius → rotation curve, maximum rotation velocity $V_{\text{max}}$, total mass etc.

Additional HST/ACS imaging for derivation of disk inclination angle, disk scale length etc. Bulge-disk decomposition with GALFIT (Peng 2002)
1. Assume an intrinsic $V_{\text{rot}}(r)$

2. Simulate *intrinsic* 2-D rotation velocity field

3. Weight with exponential surface brightness profile (in direction of dispersion)

4. Convolve with Point Spread Function

Example of simulated rotation velocity field (solid lines: »iso-velocity« zones)
Synthetic Rotation Curves

5. Extraction from velocity field according to slit position & slit width (1 arcsec) ⇒ synthetic rotation curve

6. Fit to observed rotation curve yields *intrinsic* $V_{\text{max}}$
Results from $V_{\text{max}}$-Derivation

238 (out of 261) galaxies with spectroscopic redshifts

98 objects (41%) rejected from kinematic analysis due to kinematic perturbations, low S/N, solid-body etc.

→ 140 galaxies with determined $V_{\text{max}}$

in the redshift range $0.05 < z < 0.97$, $\langle z \rangle = 0.43$,
look-back time $0.6 \text{ Gyr} < t_1 < 7.6 \text{ Gyr}$, $\langle t_1 \rangle = 4.5 \text{ Gyr}$
for $H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$
B-band Tully-Fisher diagram: local compared to \( z \approx 0.5 \)
B-band Tully-Fisher diagram: local compared to $z \approx 0.5$

HQ rotation curves, low morphological asymmetry $A < 0.25$ (44 galaxies)
Distant sample TF scatter $\sigma_{TF}=1.05$ mag ($\sim 2 \times$ local value).
Average brightening $\Delta M_B = -0.68$ mag by $z \approx 0.5$

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B-Band TF offsets as a function of redshift
B-Band TF offsets as a function of redshift

squares: median in 3 z-bins
B-Band TF offsets as a function of redshift

squares: median in 3 z-bins
Velocity-size relation: local vs. $z \approx 0.5$
Disk sizes at given $V_{\text{max}}$ mildly decrease towards higher redshifts.

Offsets $\Delta \log r_d$ from local $V_{\text{max}}$-$r_d$ relation
Dashed/dotted: local relation & 3$\sigma$ scatter
Disk Sizes

Disk sizes at given $V_{\text{max}}$ mildly decrease towards higher redshifts.

Offsets $\Delta\log r_d$ from local $V_{\text{max}}-r_d$ relation
Dashed/dotted: local relation & $3\sigma$ scatter
Filled squares: median values in 3 redshift bins
Disk sizes at given $V_{\text{max}}$ mildly decrease towards higher redshifts

Offsets $\Delta \log r_d$ from local $V_{\text{max}}$-$r_d$ relation
Dashed/dotted: local relation & 3σ scatter
Filled squares: median values in 3 redshift bins
Single-zone models fitted to observed optical+NIR colors from deep imaging.
Four free parameters:
- formation redshift $z_{\text{FOR}}$
- SF timescale $\tau_1$
- enrichment timescale $\tau_2$
- intrinsic reddening E(B-V)

Best-fit models indicate downsizing. Possibly a combined effect of SN feedback and UV background (e.g. Governato+2009)

Instrinsic dust reddening

\[ E(B-V) \]

\[ \log M_s/M_\odot \]

→ mass-dependency similar to local spirals (e.g. Tully+1998)
Summary

• Spectra of 261 disk galaxies at $0.1 < z < 1.0$ taken

• 140 rotation curves usable for derivation of $V_{\text{max}}$

• Distant disks more luminous than local counterparts (Tully-Fisher offset $\Delta M_B = -0.7$ mag at $z \approx 0.5$)

• Evidence for disk growth (by $\sim 60\%$ since $z=1$ at fixed $V_{\text{max}}$)

• Stellar populations evolve according to downsizing scenario
Thanks a lot to all collaborators! In alphabetical order:


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Examples of rotation curves from our sample
B-Band TF offsets as a function of redshift

squares: median in 3 z-bins
Stellar mass fractions

![Stellar mass fractions graph]

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Best-fit model timescales for low- and high mass disks

New Data

15 massive spiral galaxies with significant bulge components at \( z \approx 0.4 \) (PI A.Böhm). 10 hrs on target with VLT/FORS2

Main aims:

- Determine bulge velocity dispersion \( \sigma_v \)

- Construct distant \( \sigma_v - V_{\text{max}} \) relation: evidence for bulge mass evolution?

- Mass decomposition of rotation curves into DM Halo, disk and bulge

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