❖ The Tully-Fisher relation for early-type galaxies

❖ Bluedisk: HI-rich spiral galaxies

M. den Heijer (AIfA, MPIfR), G. Józsa (ASTRON), J. Kerp (AIfA), G. Kauffmann (MPA), T. Oosterloo (ASTRON), P. Serra (CSIRO), J. Wang (MPA) et al.

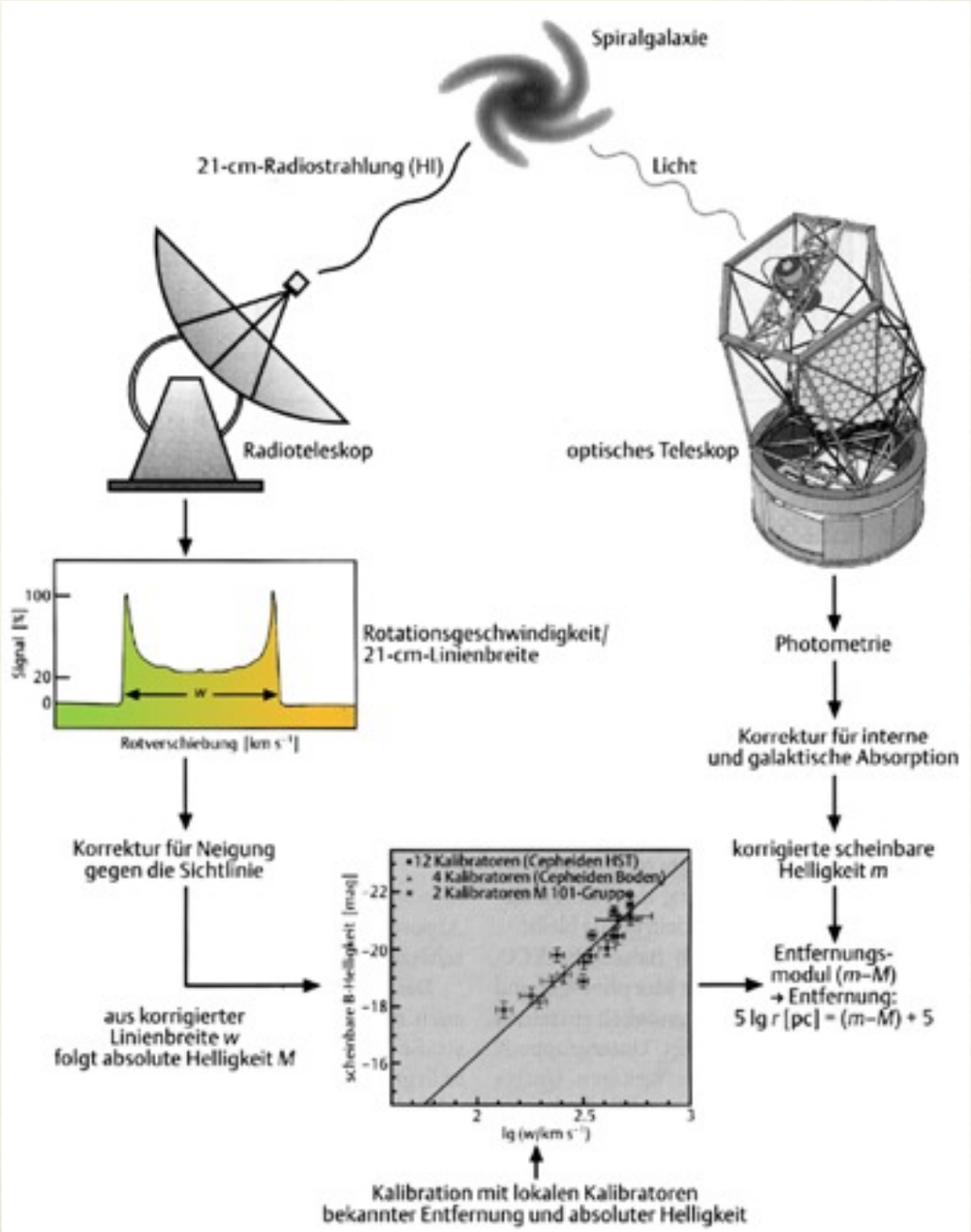
YERAC Bielefeld 30.9.2013

Overview

- **Tully-Fisher** (TFR) for **early-type galaxies** (ETGs):
  - Project within the ATLAS3D project (Cappellari, 2011).
    - Multi-wavelength survey of 260 nearby (D ≲ 40 Mpc) ETGs + semi-analytical modeling.
    - Goal: study formation & evolution of ETGs.
- **Bluedisk** (G. Kauffmann):
  - Multi-wavelength survey of 50 nearby (D ≳ 100 Mpc) **HI-rich spiral galaxies.**
  - Goal: study accretion of gas by galaxies.
  - Status: paper I (Wang 2013): published, paper II (Wang) and paper III (Milan): in progress.

Tully-Fisher for ETGs

- TFR: correlation between HI line width and K-band magnitude → proxies for **dynamical mass** and **stellar mass (DM halo, stellar component)**.
- Baryonic TFR: HI line width vs. **baryonic (stellar+gas) mass**. Important constraint galaxy formation models + test for modified gravity.



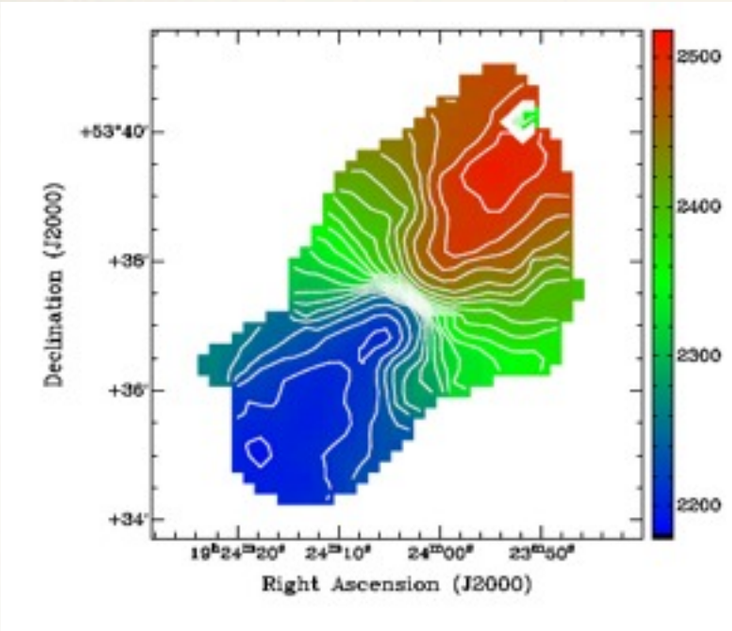
http://pluslucis.univie.ac.at

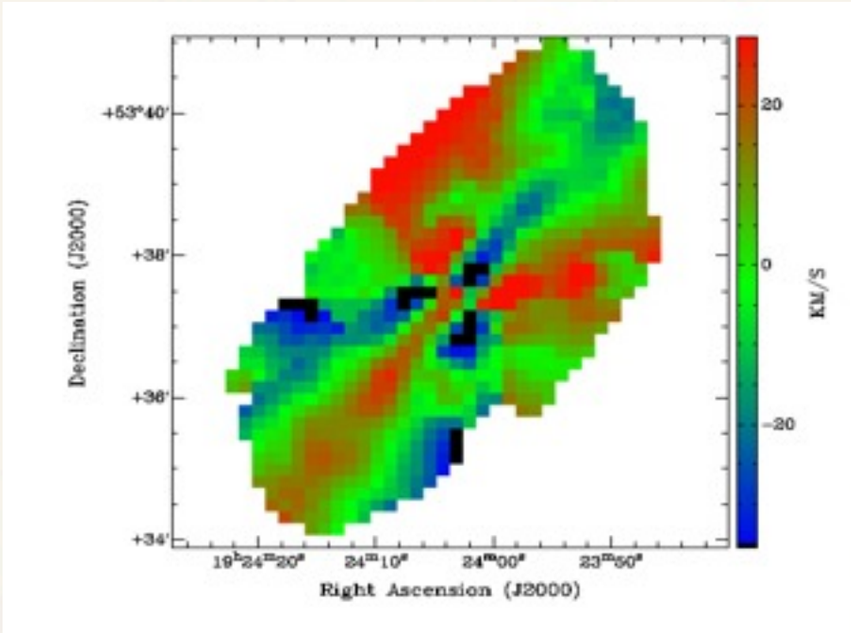
Tully-Fisher for ETGs: Sample

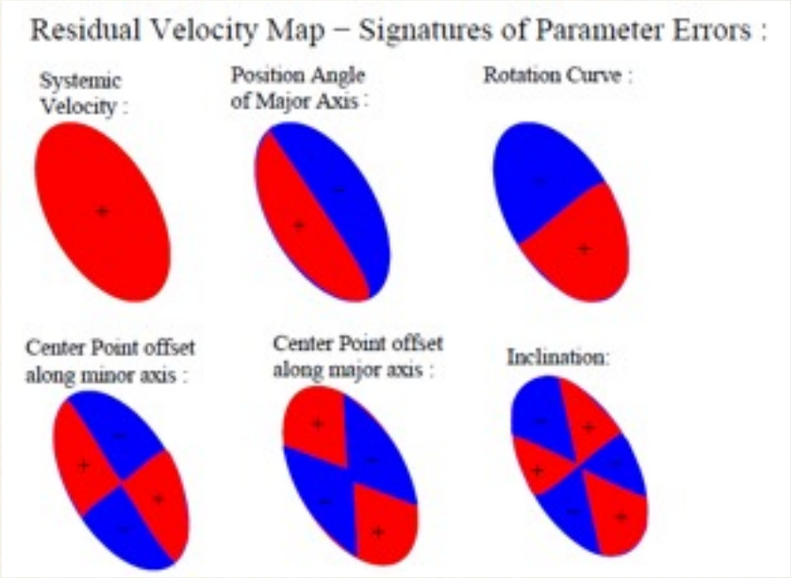
- D < 42 Mpc, M*K* < -21.5 mag
- From the detected 53 ETGs in HI (S0 and E, Serra et al. 2012), we selected 16 in which rotation dominates over random motions and which have a resolved HI-disk. Use deep WSRT HI data to model the kinematics.
- Stellar mass is derived using M/L from stellar kinematics (JAM, Cappellari et al. 2008) and star formation histories (SFH, Cappellari et al. 2013).
- Crucial: rotation velocity **inclination correction**...

Tully-Fisher for ETGs - Methods

- Analysis of HI velocity fields (rotation curves instead of W): tilted-rings, study residual patterns with harmonic decomposition.
- a(3)-amplitude ~ inclination error, b(1) & b(3): radial motions.





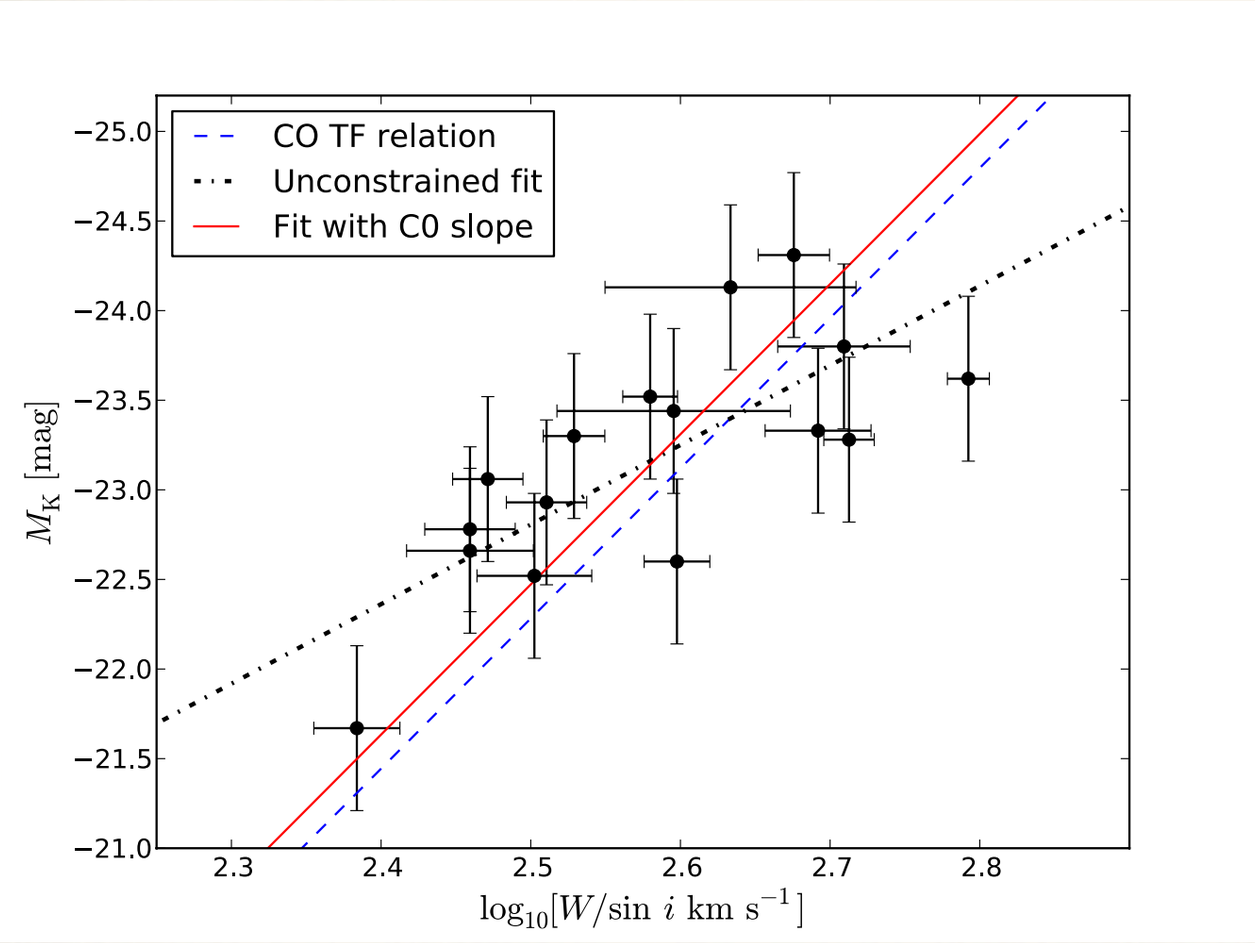


Warner, 1973

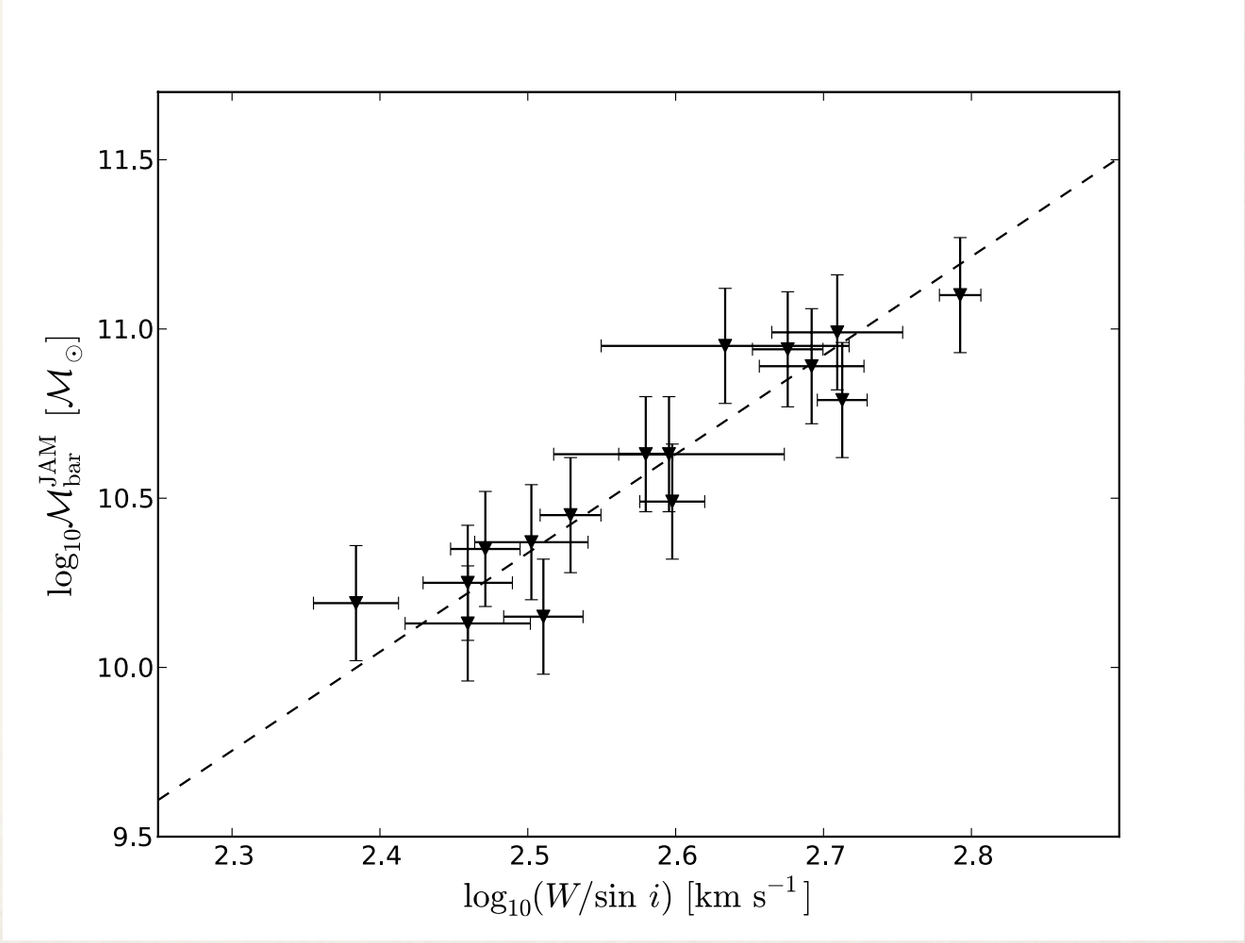
$$v(x,y) = a(0) + \sum_{k=1}^{fitdeg} a(k) \cdot \cos(k \cdot \theta) + b(k) \cdot \sin(k \cdot \theta)$$

Tully-Fisher for ETGs - Results

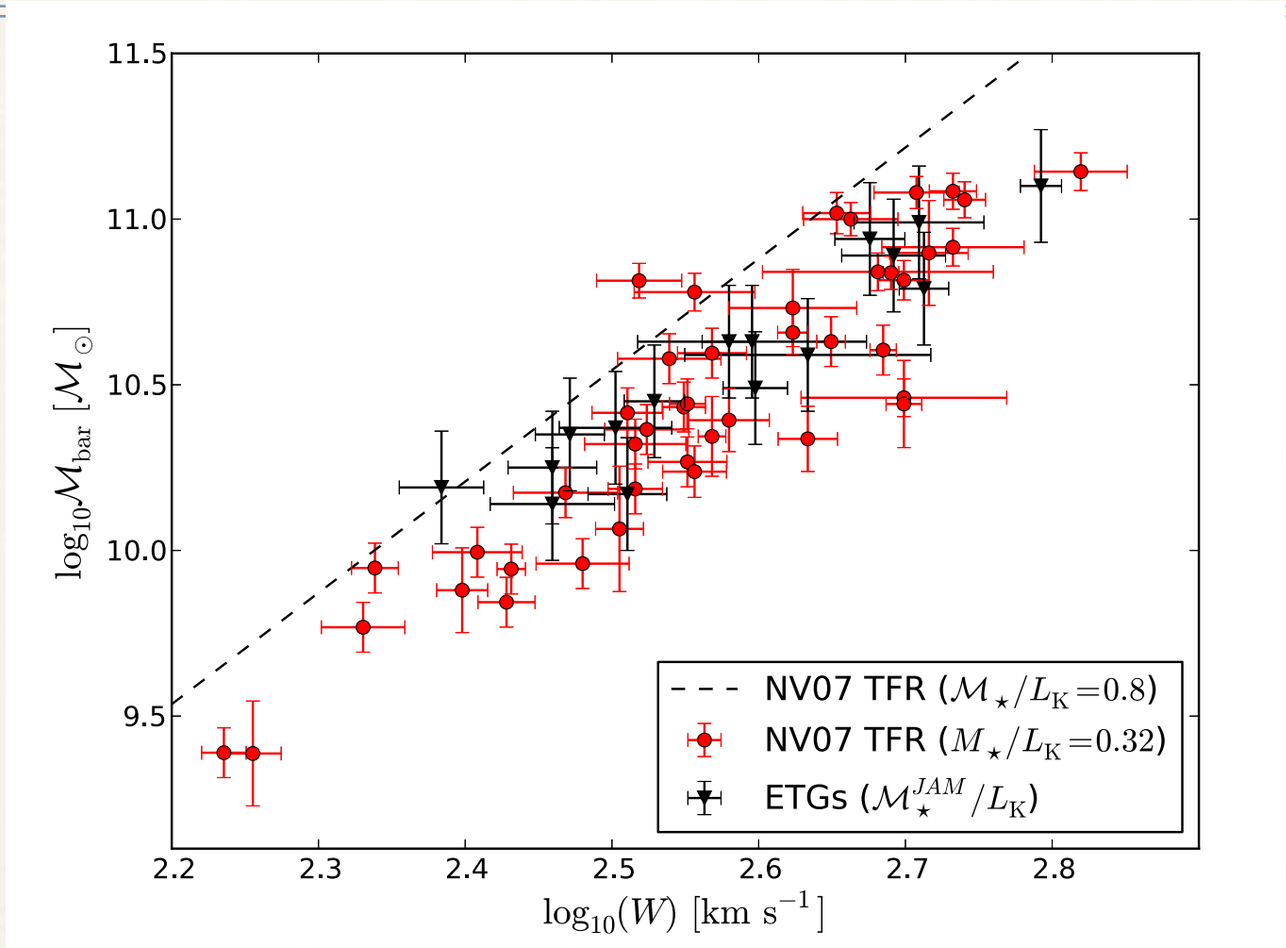
K-band (NIR) TFR



Baryonic TFR (JAM, R-band)



Tully-Fisher for ETGs - Results

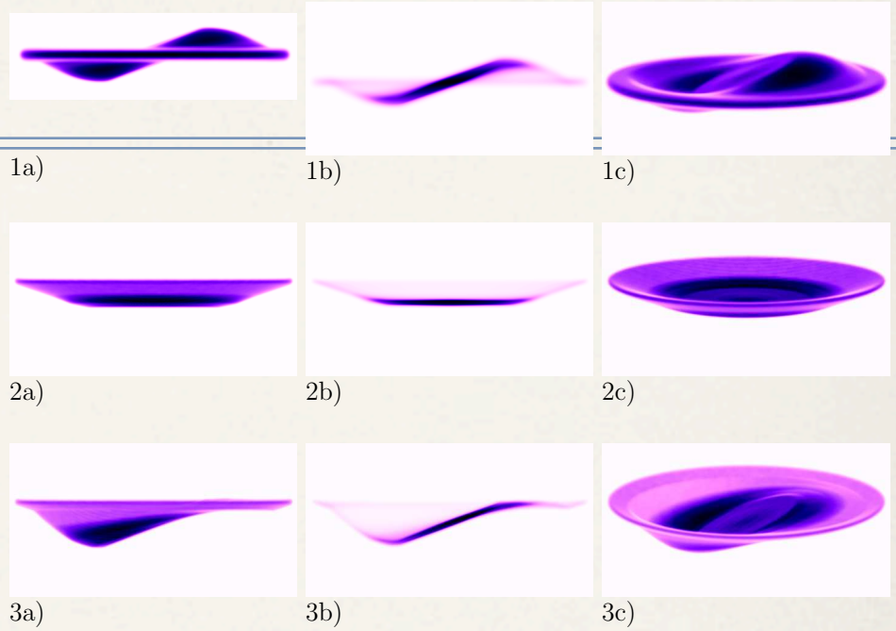


- Shows that M/L in K-band is smaller than 0.8 (max. disk) for the spirals, confirms Martinsson et al. (2013).
- Possible explanation: Tonini (2010), improved stellar population models show increased TP AGB-star contribution to K-band luminosity.

Tully-Fisher for ETGs - Results

- Using M/L from stellar kinematics yields tightest BTFR, offset from spiral relation → suggests structural **M/L variations** amongst ETGs.
- BTFR is better defined than K-band TFR.
- Possible alternative explanation for offset from spirals: smaller size of ETGs.
- Comparison with ATLAS3D CO TFR ⇒ the rotation curves stay flat.
- Baryonic-/K-band TFR **shallower** than established relations for spirals. Elliptical orbits?

Bluedisk - Introduction



- Neutral gas **accretion rate** MW / M31 type galaxies:

  ~ 0.7 M☉ /yr (Richter, 2012).

- **Star formation rate** (SFR): factor 3-5 higher.

- Cooling of hot X-ray coronae not enough to explain SFR.

- Indirect evidence for gas accretion:

  - Warps, lopsided HI-disks,

  - extra-planar gas in local spirals (NGC 891).

Józsa 2005

ESO

Bluedisk - Introduction

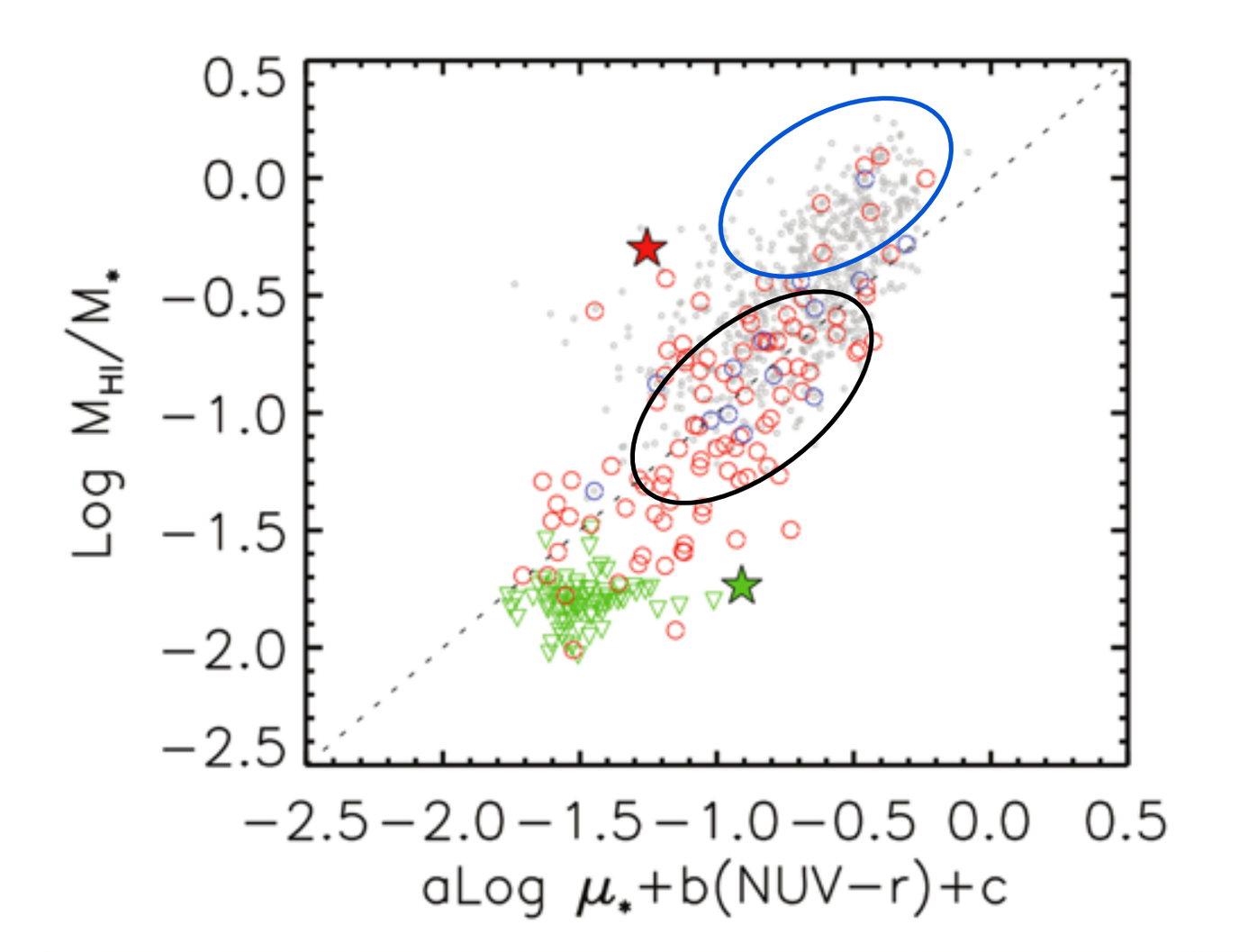
- Catinella et al. (2010): **atomic gas** content correlates with **UV-r colours** and **stellar surface mass densities**, however:

- > 10% of the galaxies have an excess HI content,

- have metal-poor ionised gas in their disks,

- and are **bluer/younger** (Wang 2011).

  ⇒ Indirect evidence of **gas accretion.**



Bluedisk - Introduction

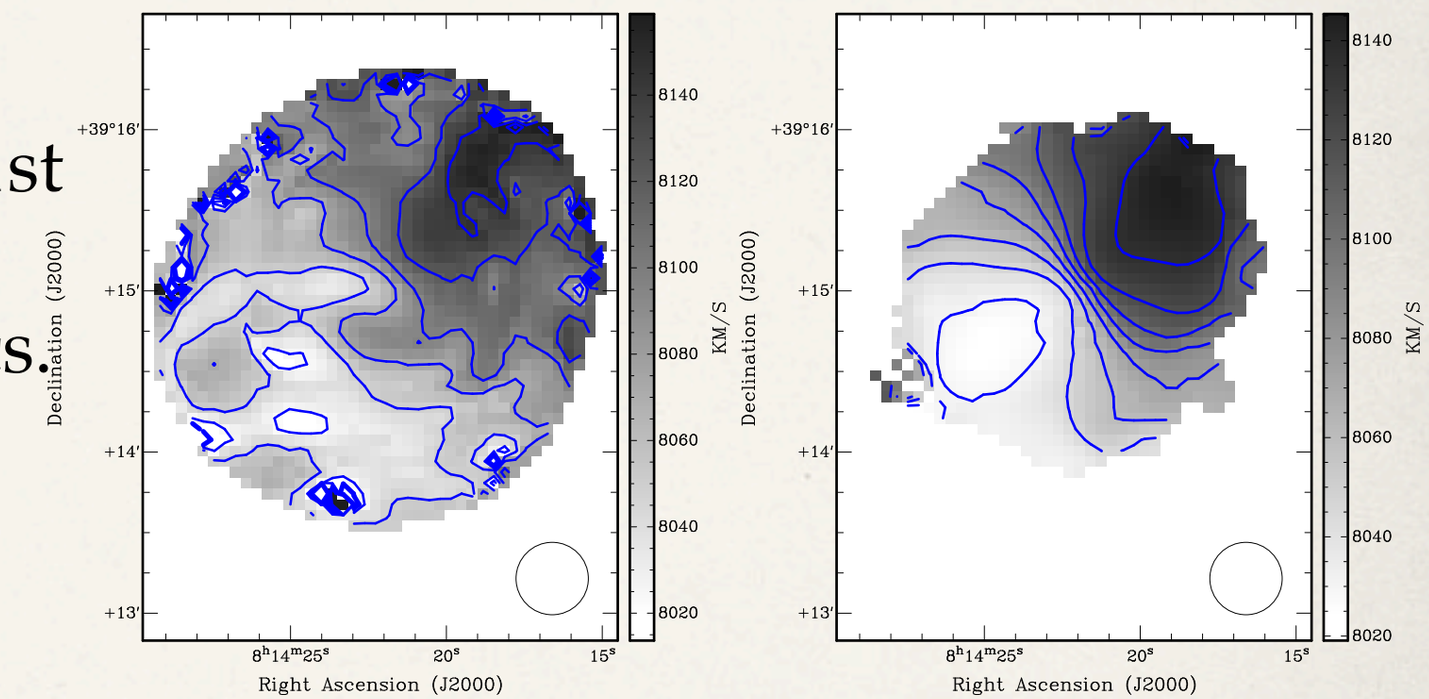
- WSRT HI observations of 25 gas-rich galaxies and 25 control galaxies matched in stellar mass, size, inclination, z.
- Paper I (Wang et al., 2013): morphology. Results:
  - HI-rich galaxies lie on the same **HI mass vs. HI size** relation,
  - they have larger **HI size/optical sizes**,
  - appear clumpy than normal spirals, but...
  - they are **not more asymmetric** and are **not more disturbed.**
- Points at a scenario where hot gas in the hot corona shock-heated gas cools and condenses onto the disk rather than the accretion of cold gas.

Bluedisk HI kinematics - Goals

- Do the HI-rich galaxies have kinematics different from the normal spirals?
  - Do they have larger **radial motions**?
  - Are they more kinematically **lopsided**?
  - Do the **rotation curves** look different? → V_{asymp} from HI, inner part from long-slit spectroscopy and CO.

Bluedisk kinematics - Methods

- Tools: velocity fields.
- However, distances >100 Mpc, beam-smearing is an issue → 1st moment velocity fields do not represent galactic dynamics.
- Improvement: Gauss-Hermite velocity fields.



- SKA pathfinder, Apertif etc. → Soon, many galaxies will be observed at comparable distance; how to quickly analyse kinematics?

Bluedisk kinematics - Results

- Systematical inspection of data cubes: gas-rich galaxies have more symmetric warps, but are not more lopsided or asymmetrically warped.
- Quantitative analysis: Tilted-ring fitting, asymmetry measures.

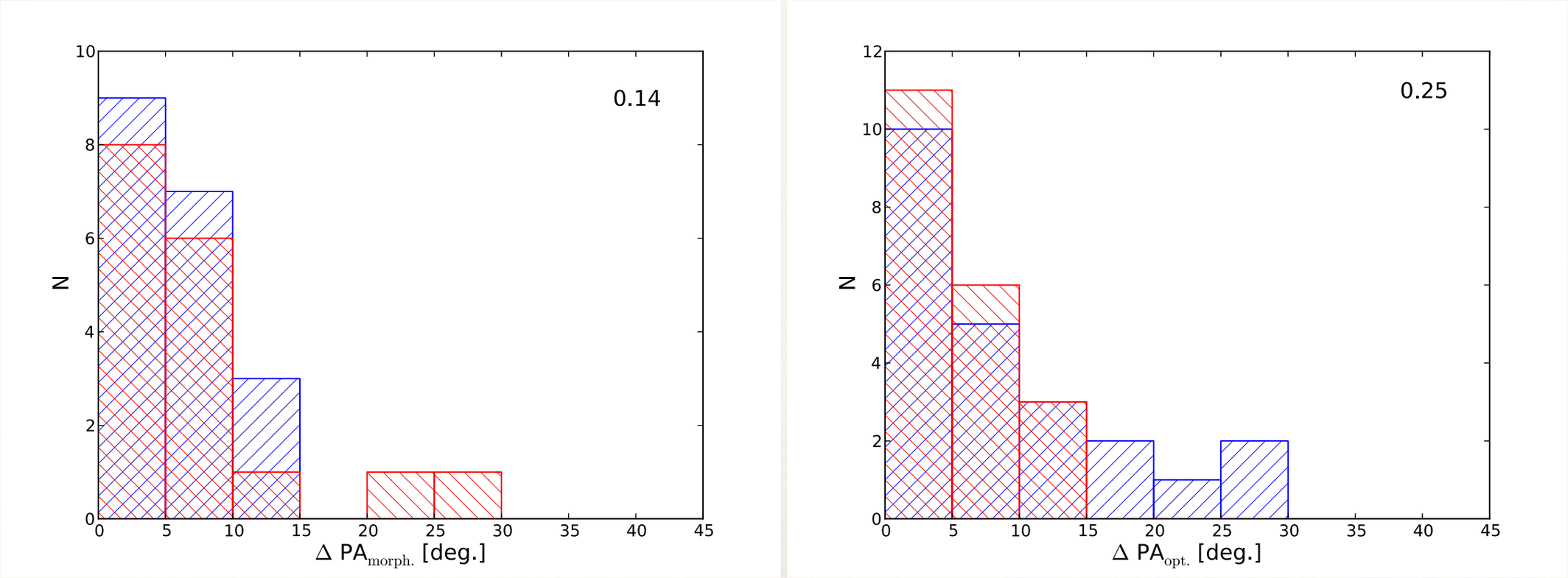
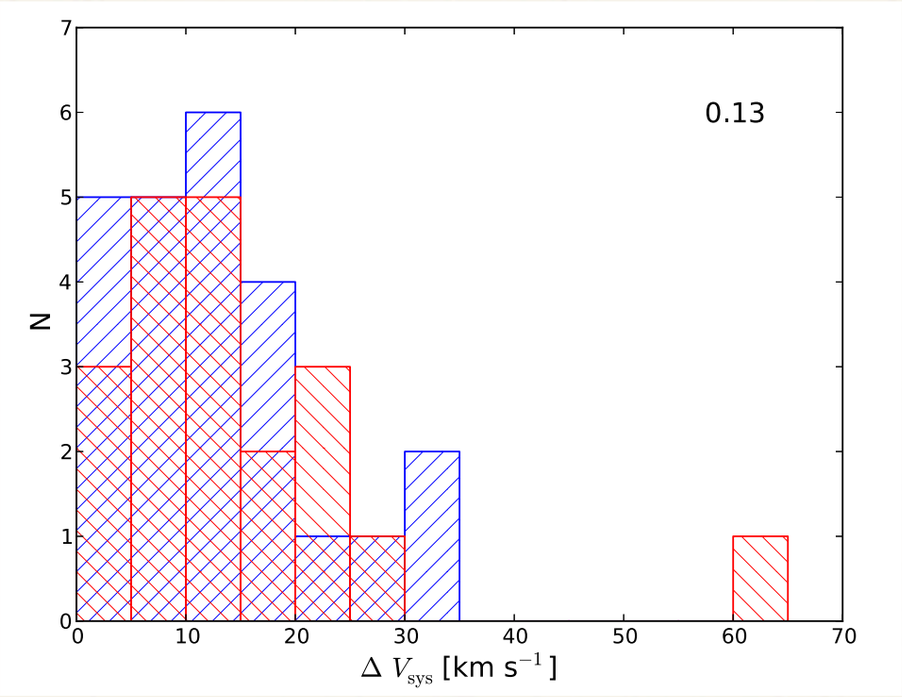
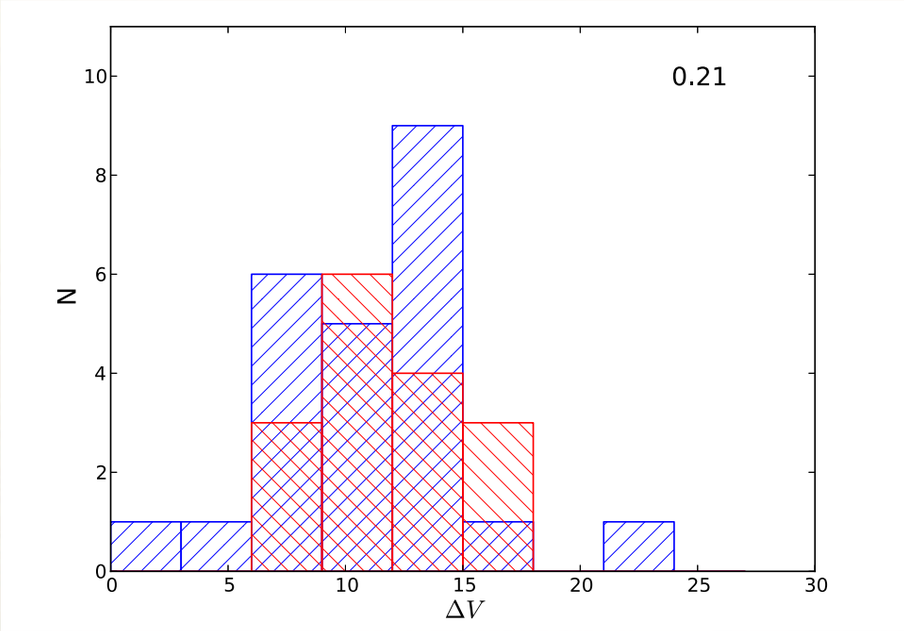
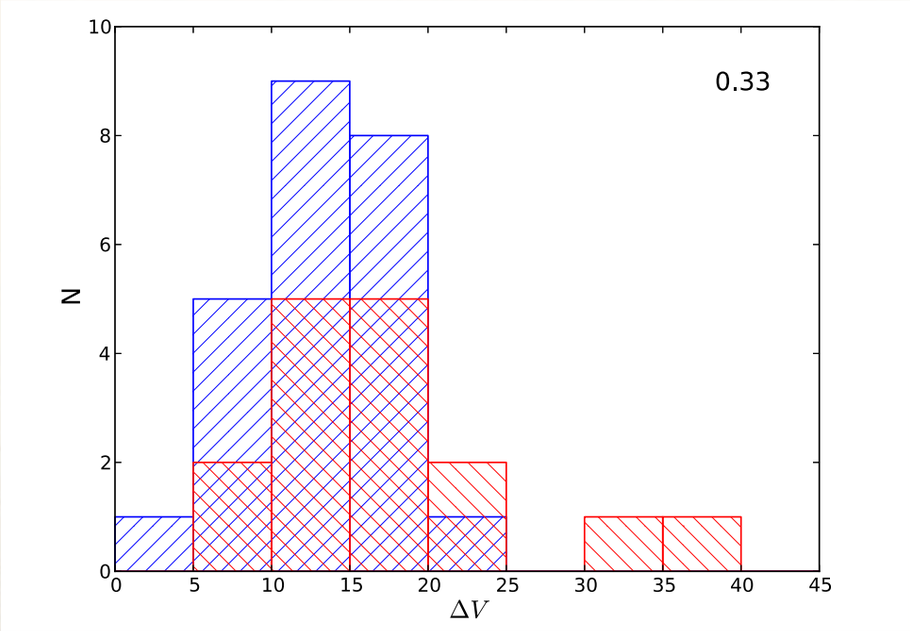


Figure 2. Left: difference between the kinematical and the morphological H I PA. Right: difference between the kinematical H I PA and the optical PA.

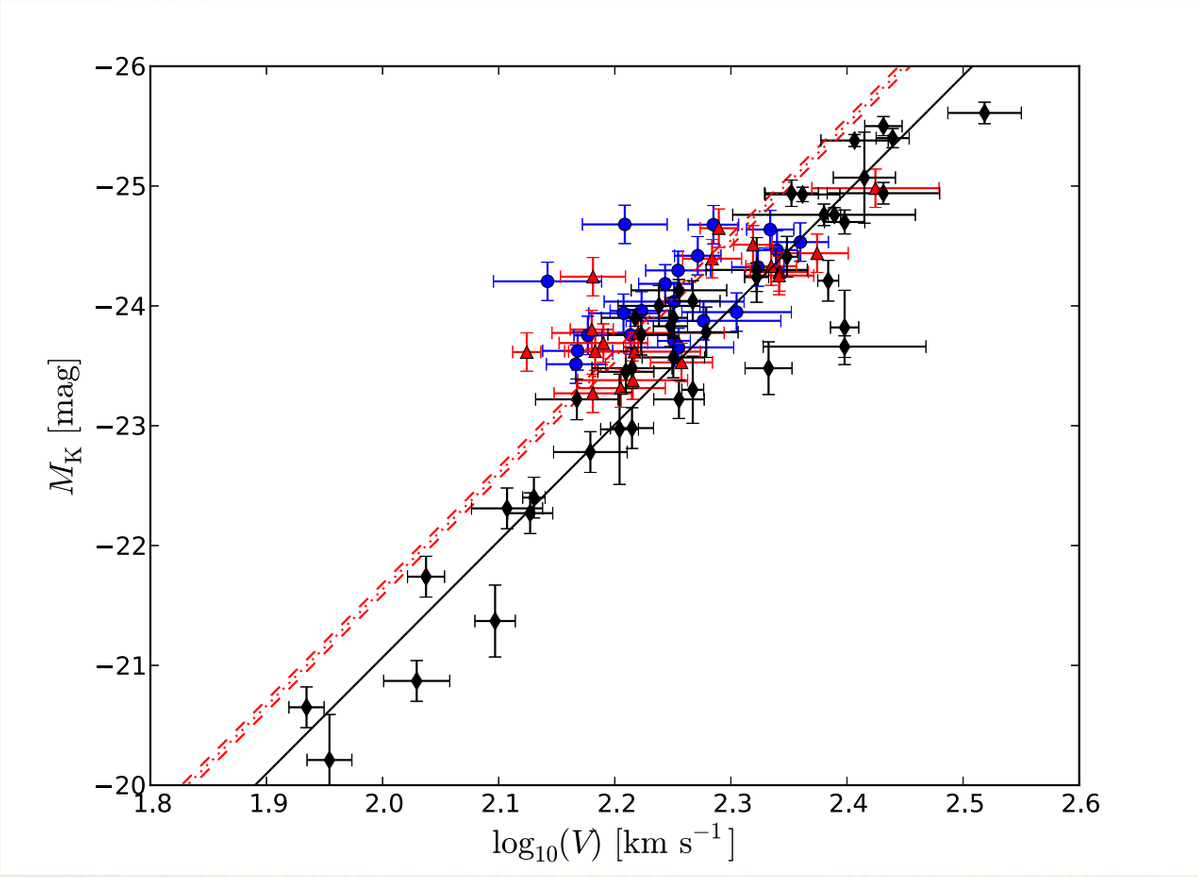
Bluedisk kinematics - Results

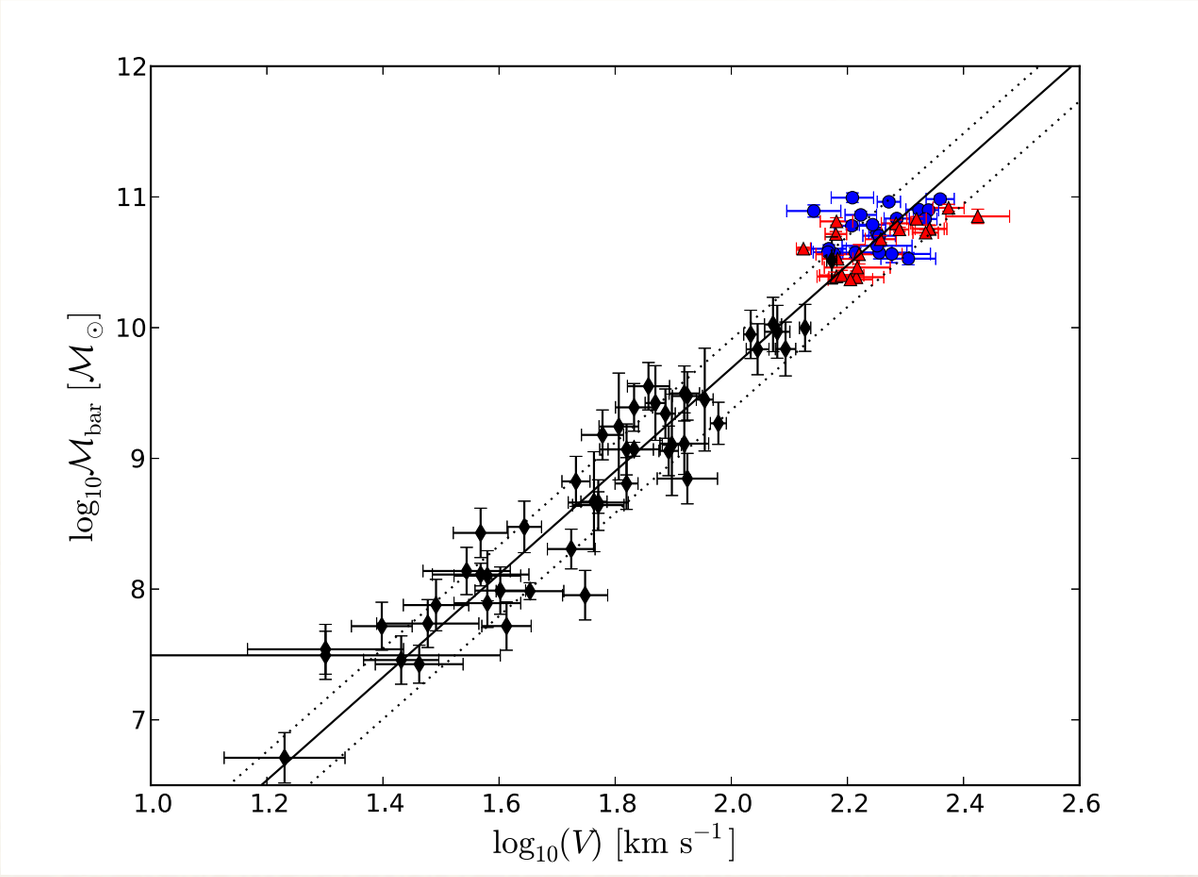






Bluedisk kinematics - Results

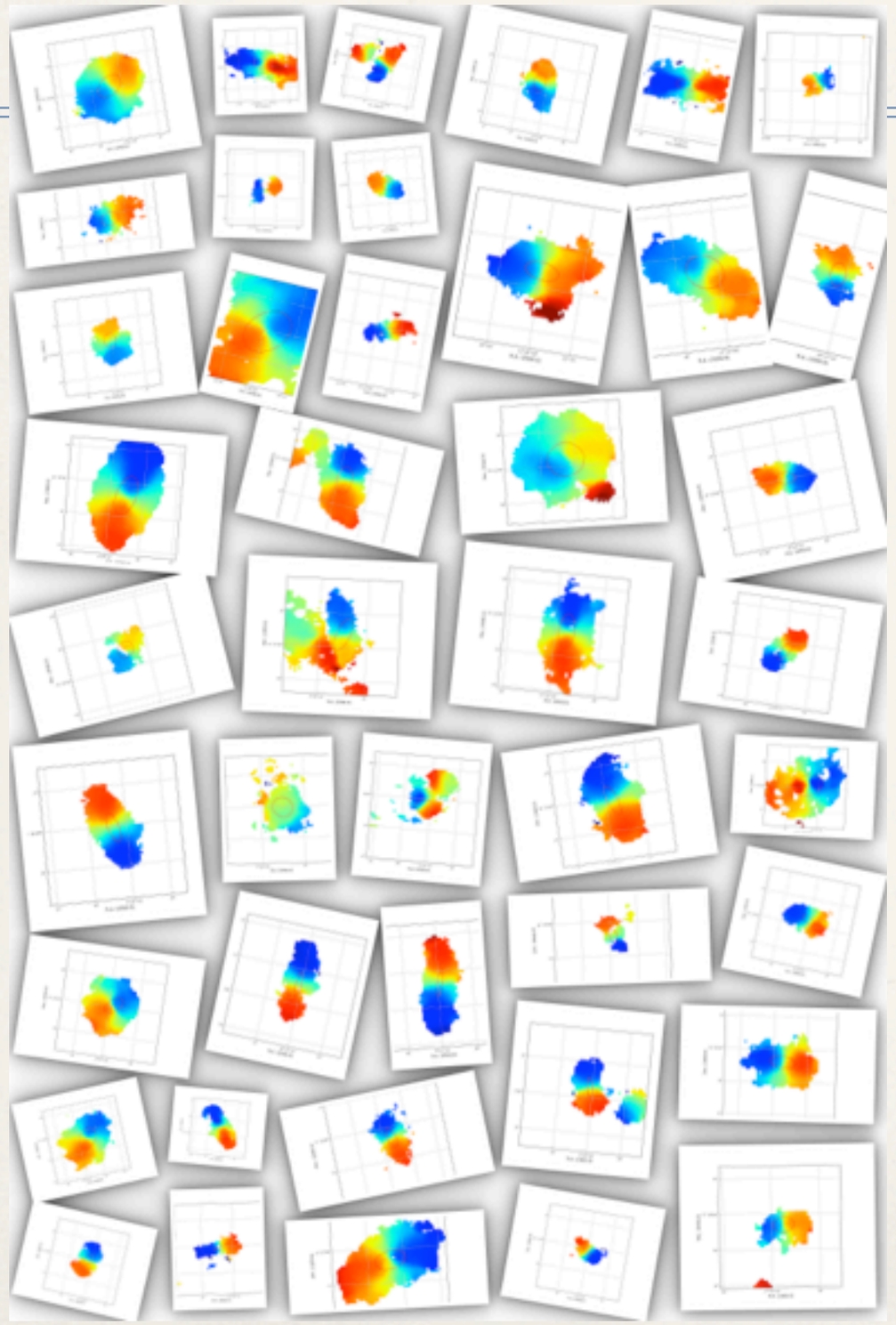


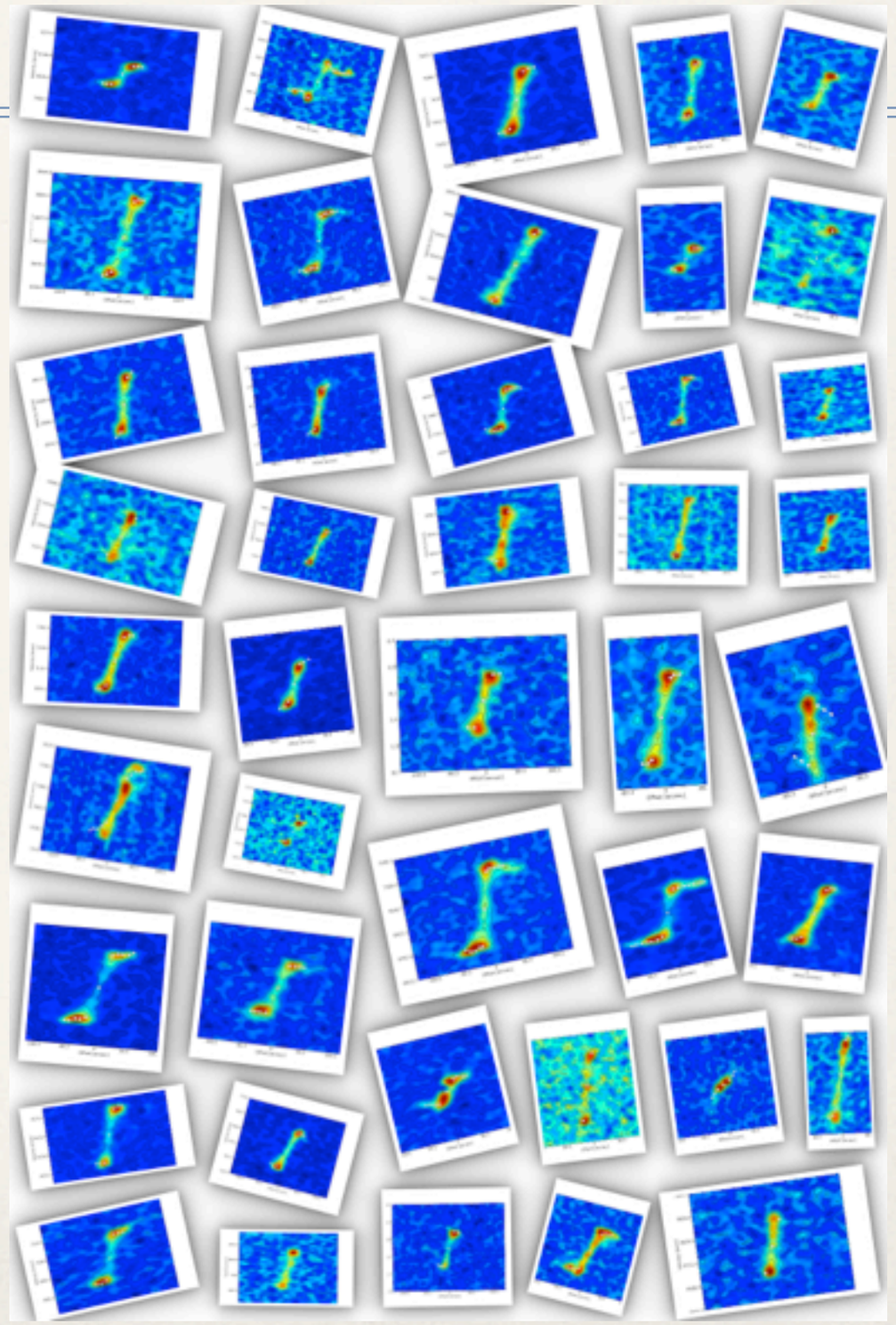


Bluedisk kinematics - Results

- Quantitative asymmetry analysis:
  - Beam-smearing makes tilted-ring fits to velocity fields difficult. Future work: fit to data cube.
  - gas-rich galaxies are not more asymmetric.
- It appears that the gas-rich galaxies are **not** more disturbed → smooth accretion from the ambient medium rather than episodic accretion.

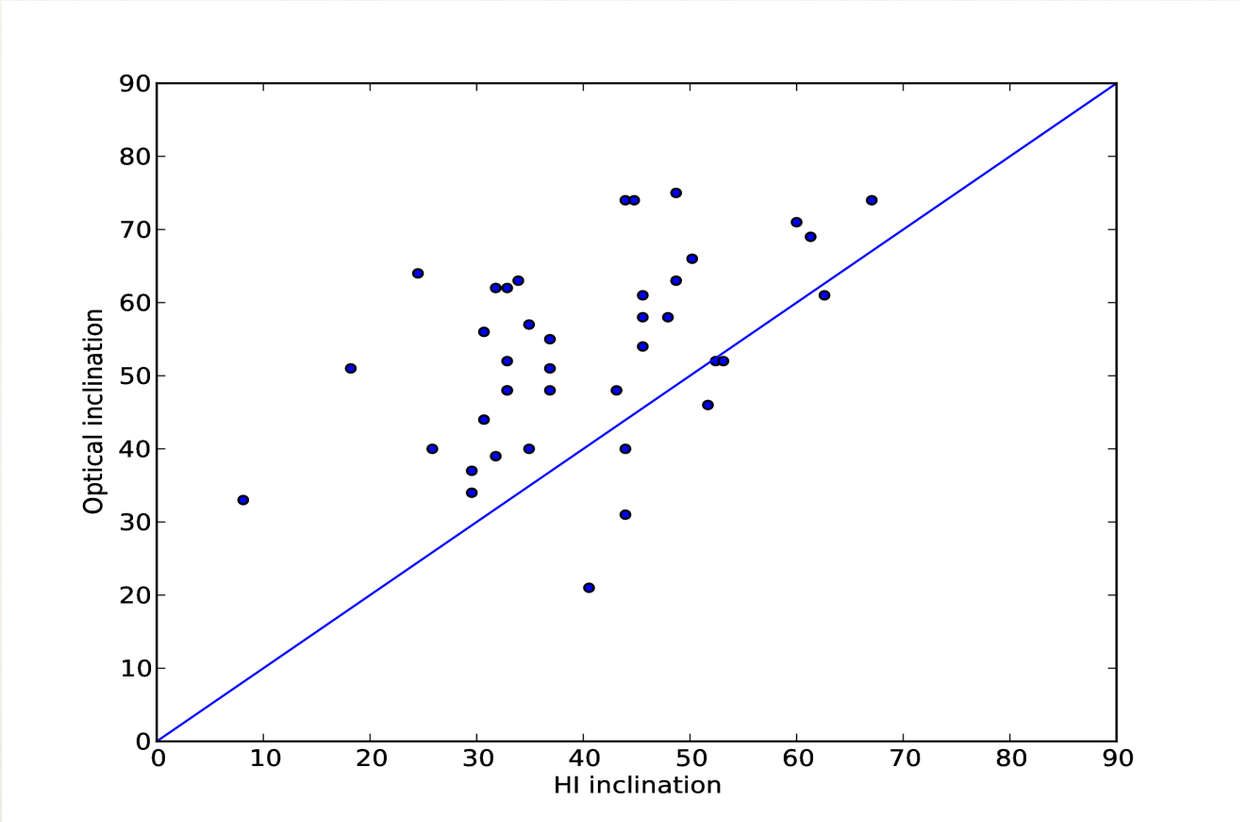
Thank you!





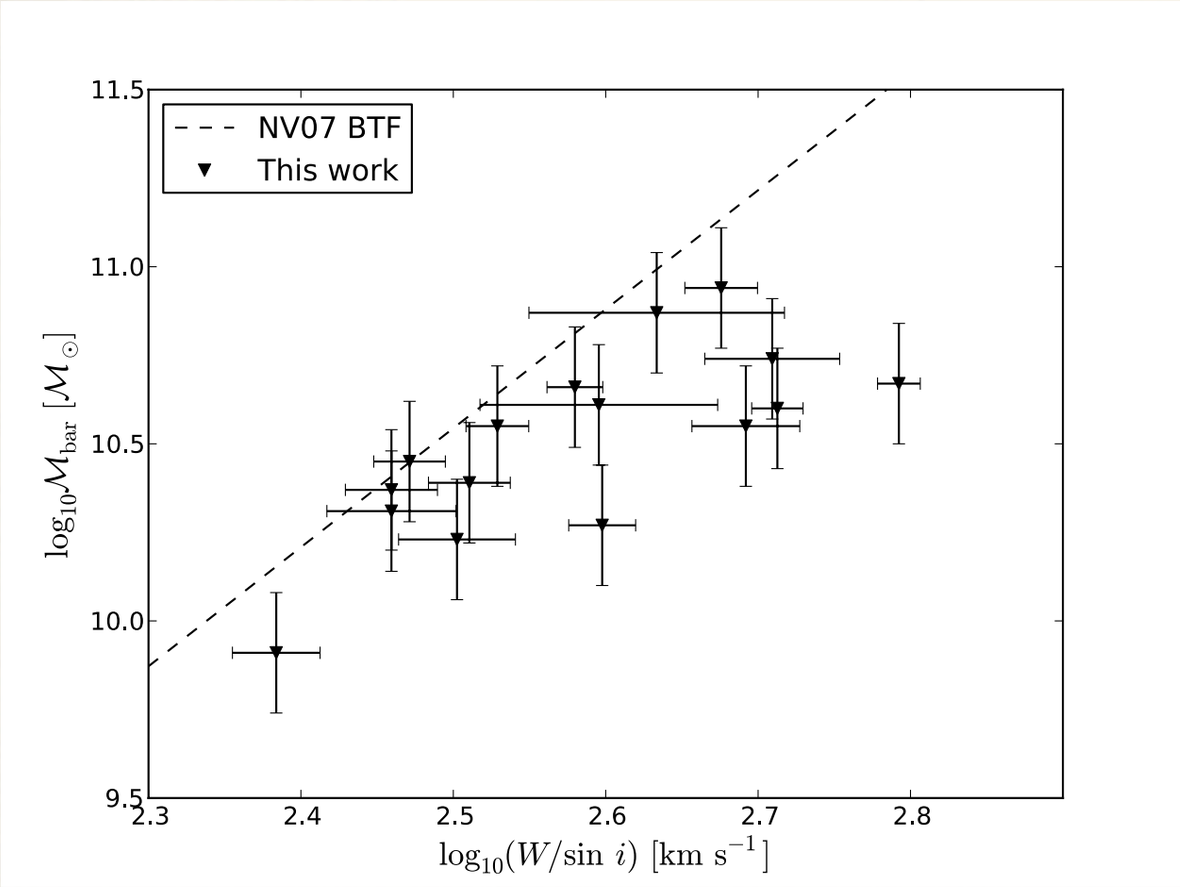
Bluedisk kinematics - Methods

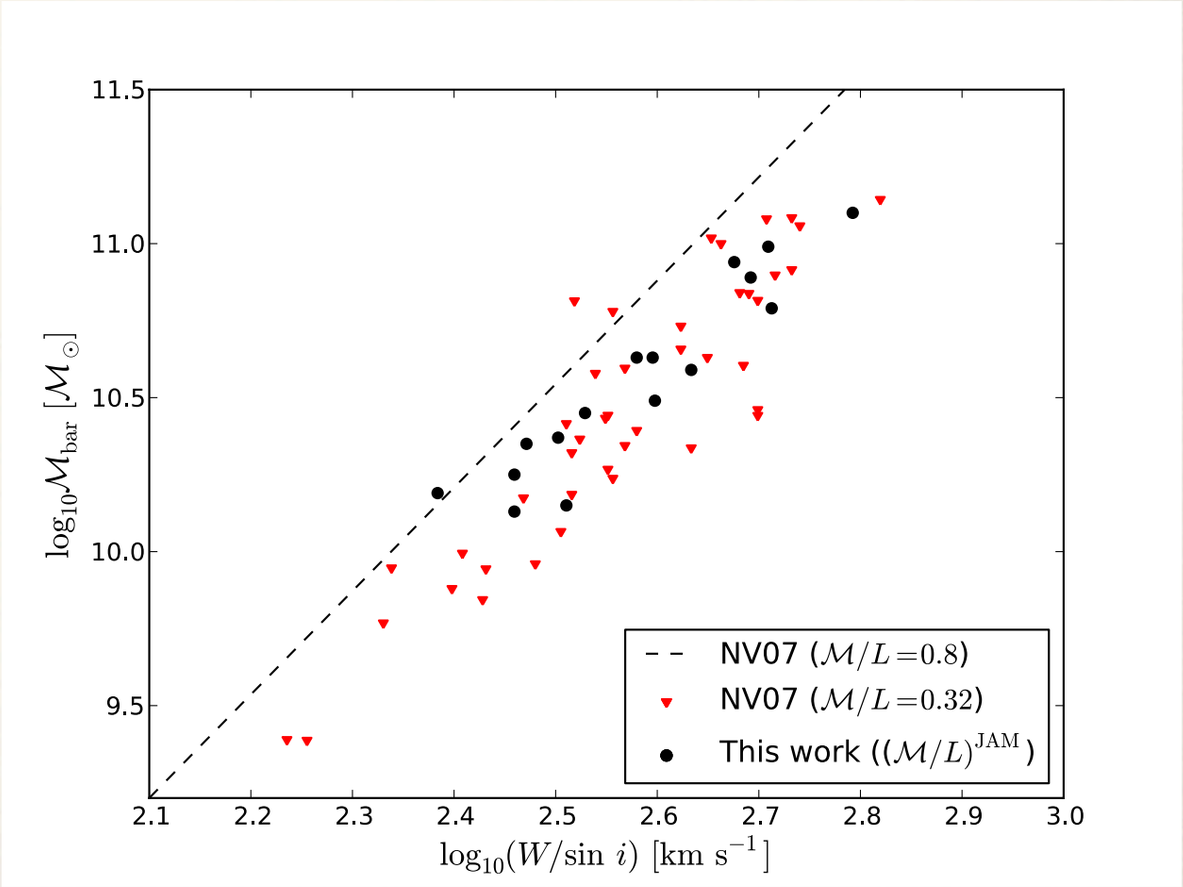
- Problem: beam-smearing effect due to limited WSRT resolution: ~13″ → semi-minor axes are stretched.
- → No inclination can be recovered from the HI kinematics.



Tully-Fisher for ETGs - Results

- Comparison with the spiral BTFR (fixed M/L) from Noordermeer & Verheijen (2007).





Atlas3D & Tully-Fisher for ETGs

- ATLAS3D-comb: alternative galaxy classification, based on bulge-to-disk stellar kinematics.
- Selected 16 galaxies where rotation dominates over random motions and which have a resolved HI-disk (mostly S0 and late type E). Use deep WSRT HI data to study their TFR.