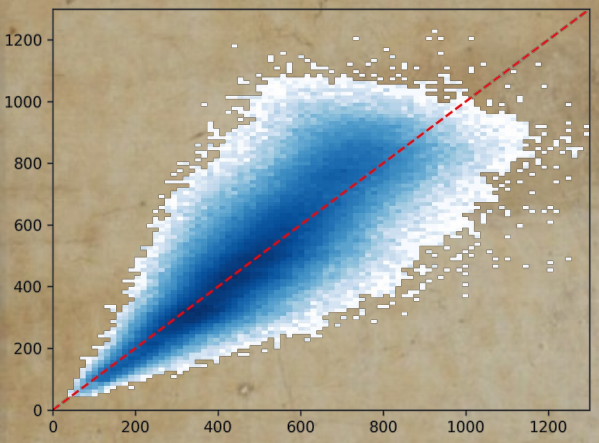
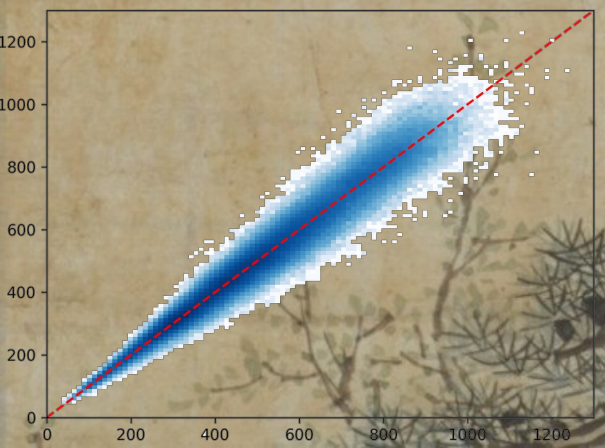
Peculiar velocities derived from the Fundamental Plane

by

Christoph Saulder

KIAS KOREA INSTITUTE FOR ADVANCED STUDY





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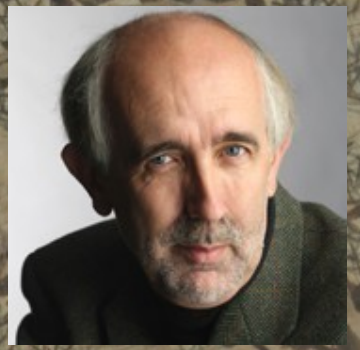
Collaborators

NED

- Christoph Saulder (KIAS)
- Ian Steer (NED)
- Owain Snaith (KIAS)
- Changbom Park (KIAS)
- Barry F. Madore (NED)



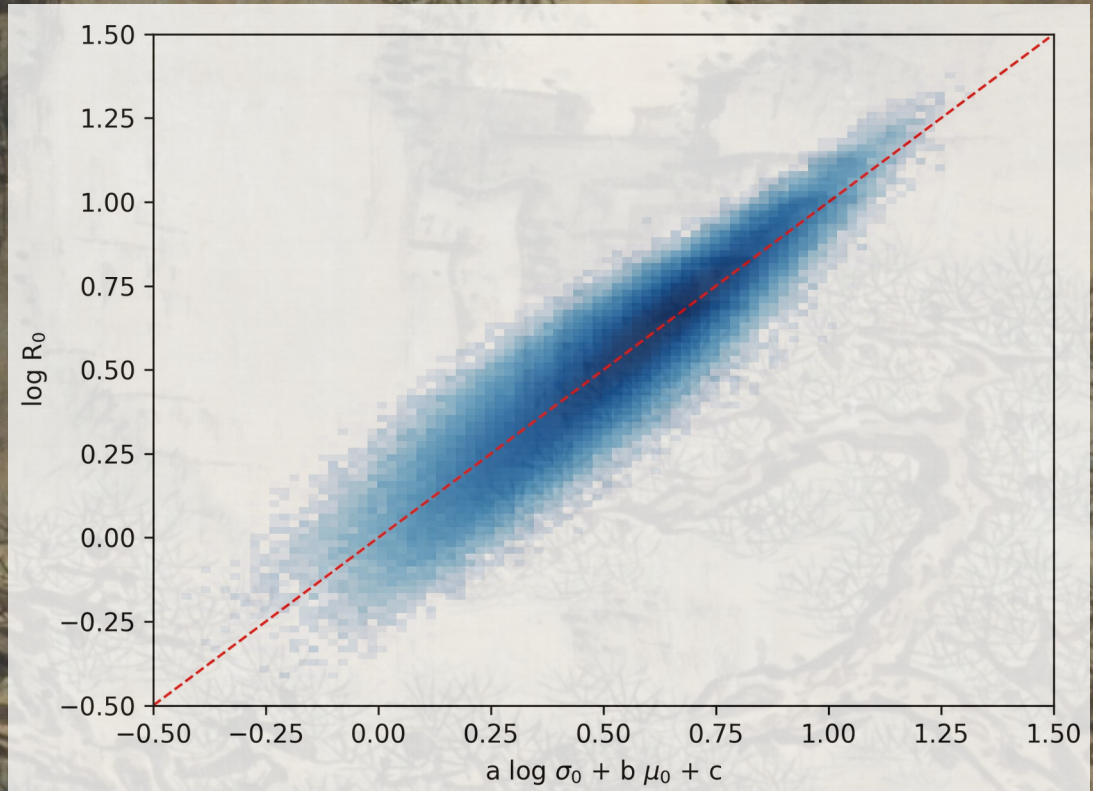
The traditional fundamental plane

- Empirical distance indicator for early-type galaxies:

$$\log(R_0) = a \log(\sigma_0) + b\,\mu_0 + c$$

- ~20% accuracy

- Assuming:
  - luminosity-independent M/L ratios for ETG
  - virial equilibrium
- a=2, b=0.4, but in reality a~1, b~0.3



Central velocity dispersion data is rare

- Central velocity dispersions are obtained by fibre spectroscopy
- Large samples of good quality data are rare:
  - 6dFGS follow-up (6dFGSv)
  - SDSS/BOSS
  - Taipan Survey (ongoing)
- SDSS/BOSS provides the by far largest sample (and also the photometric data)

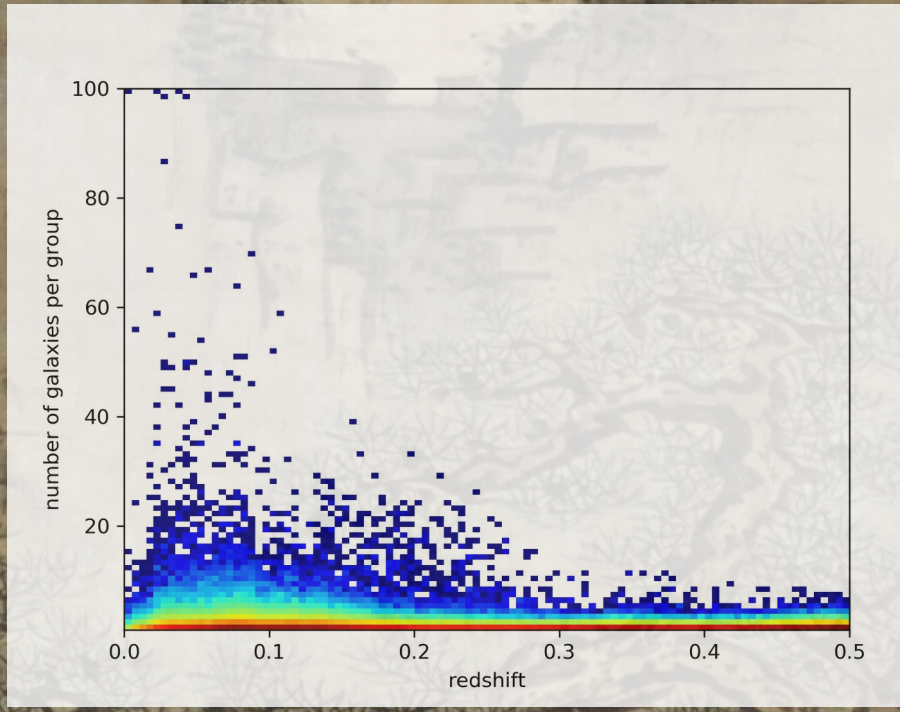
The largest sample of fundamental plane data

- Notable previous (large) calibrations:
  - Bernardi+ 2003: ~8 000 ETG in SDSS
  - Hyde&Bernardi 2009: ~46 500 ETG in SDSS
  - La Barbera+ 2010: ~4 500 ETG in SDSS
  - Magoulas+ 2012 & Campbell +2014: ~9 000 ETG in 6dFGS
  - Saulder+ 2013: ~93 000 ETG in SDSS
  - Saulder+ 2015&2016: ~119 000 ETG in SDSS

- NOW: ~280 000 early-type galaxies identified in SDSS DR 14 (including BOSS)

Group catalogue

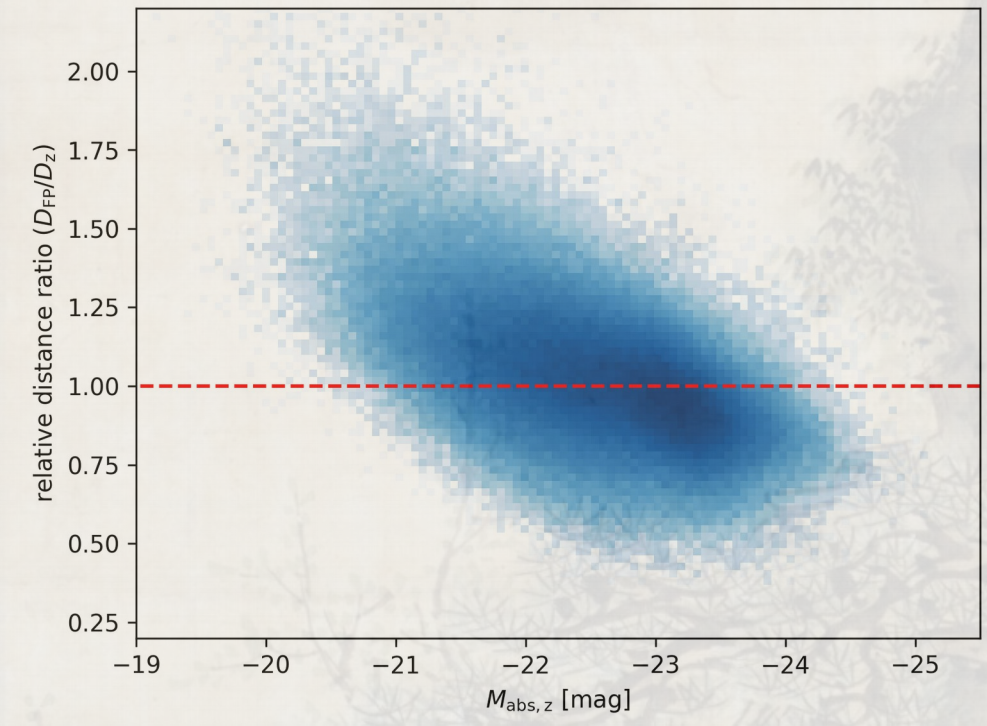
- Combined SDSS/BOSS Friends-of-Friends group catalogue up to z=0.5
- 2MRS included to compensate for the saturation BIAS of SDSS spectroscopy
- Linking lengths calibrated used mock catalogues based on the WMAP7 re-run of the Millennium simulation

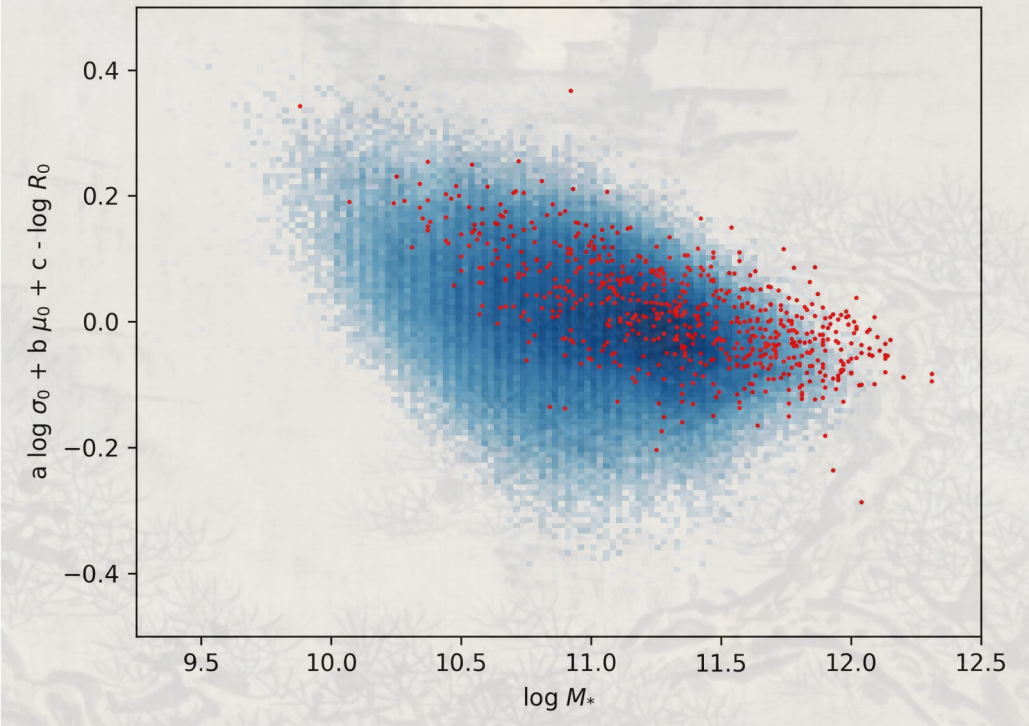


- Collapsing the “finger of God” effect for clusters
- Improving FP distance estimates to groups hosting several ETG
- Comparing FP-distances to Tully-Fisher relation distances

Problematic biases

- Strong dependence on absolute magnitude → stellar mass dependence (very clear with MaNGA)
- Assumption that M/L is luminosity independent is wrong → more than just a tilt
- Serious issue for magnitude limited surveys

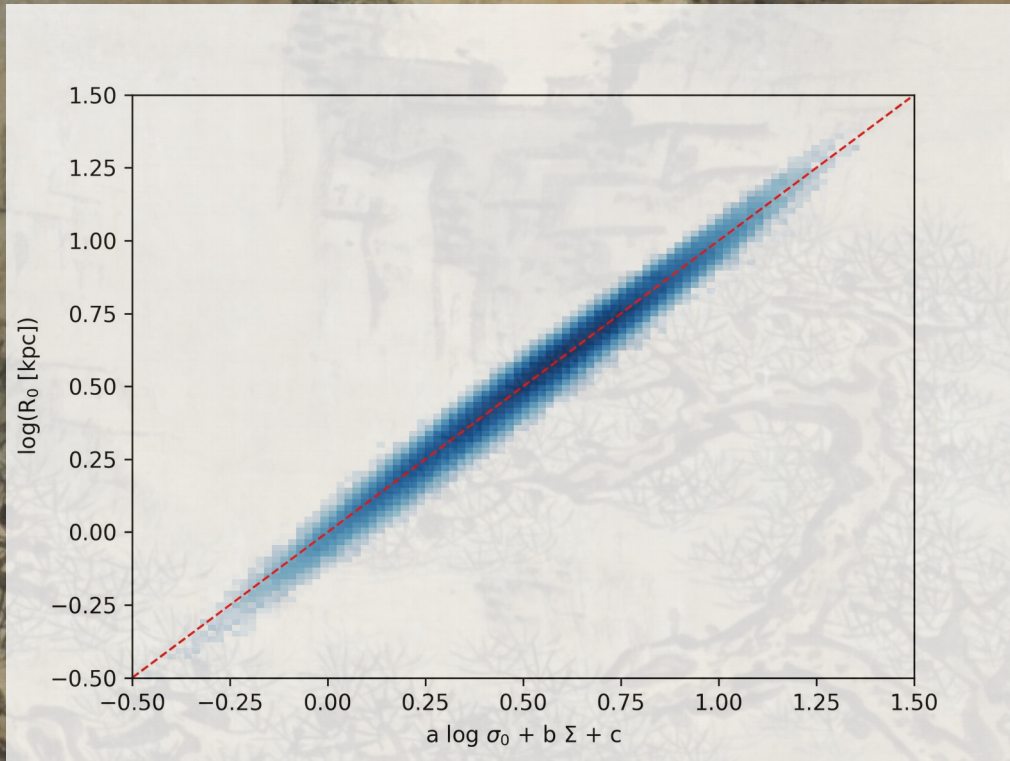




The stellar mass fundamental plane

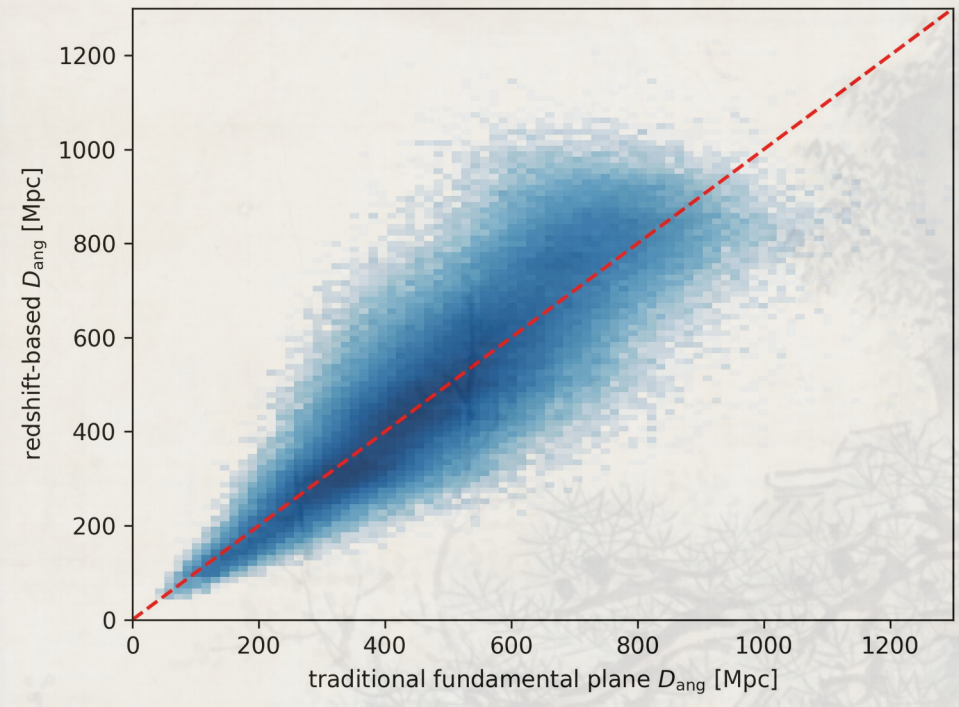
- Discussed in Hyde&Bernardi+2009, but not used to its full potential (as a distance estimator):
  $\log(R_0) = a \log(\sigma_0) + b \log(\Sigma) + c$
  with $\log(\Sigma) = \log(M_*) + m_{abs} - \mu_0 = \log(M_*/L) - \mu_0 + k$

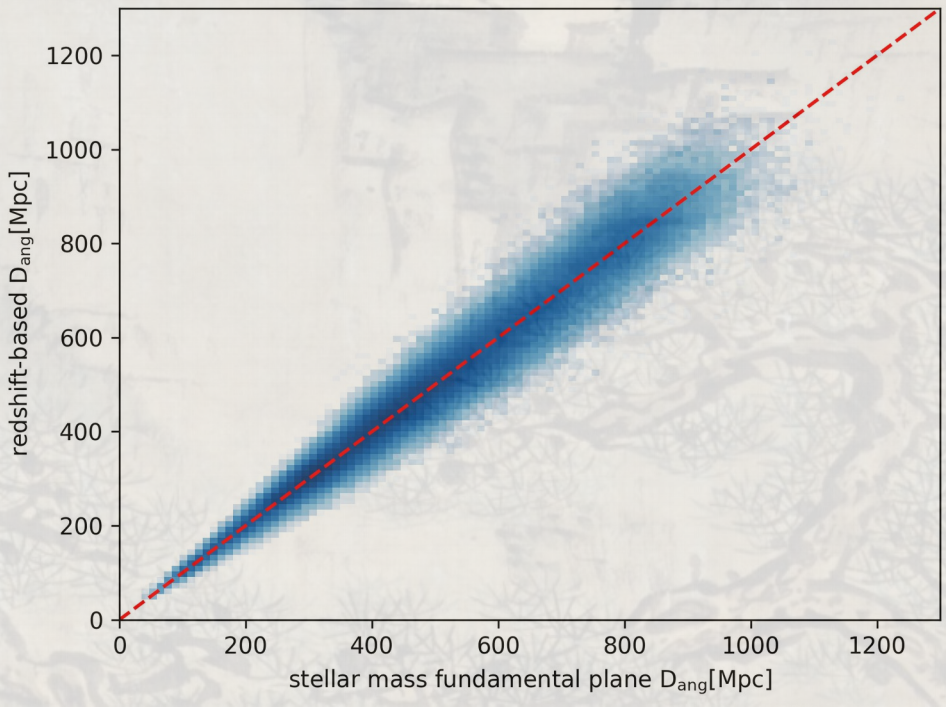
- Has a hidden redshift dependence (M_* and m_{abs})
- Tempered by using their combination: M_*/L
- Trading biases and gains



Improvement in distance measurements

- Group catalogue improves average accuracy by 0.5%
- Traditional FP: 19.8% accuracy on average
- Stellar mass FP: 7.7% (stat.) + 0.8% (sys.)



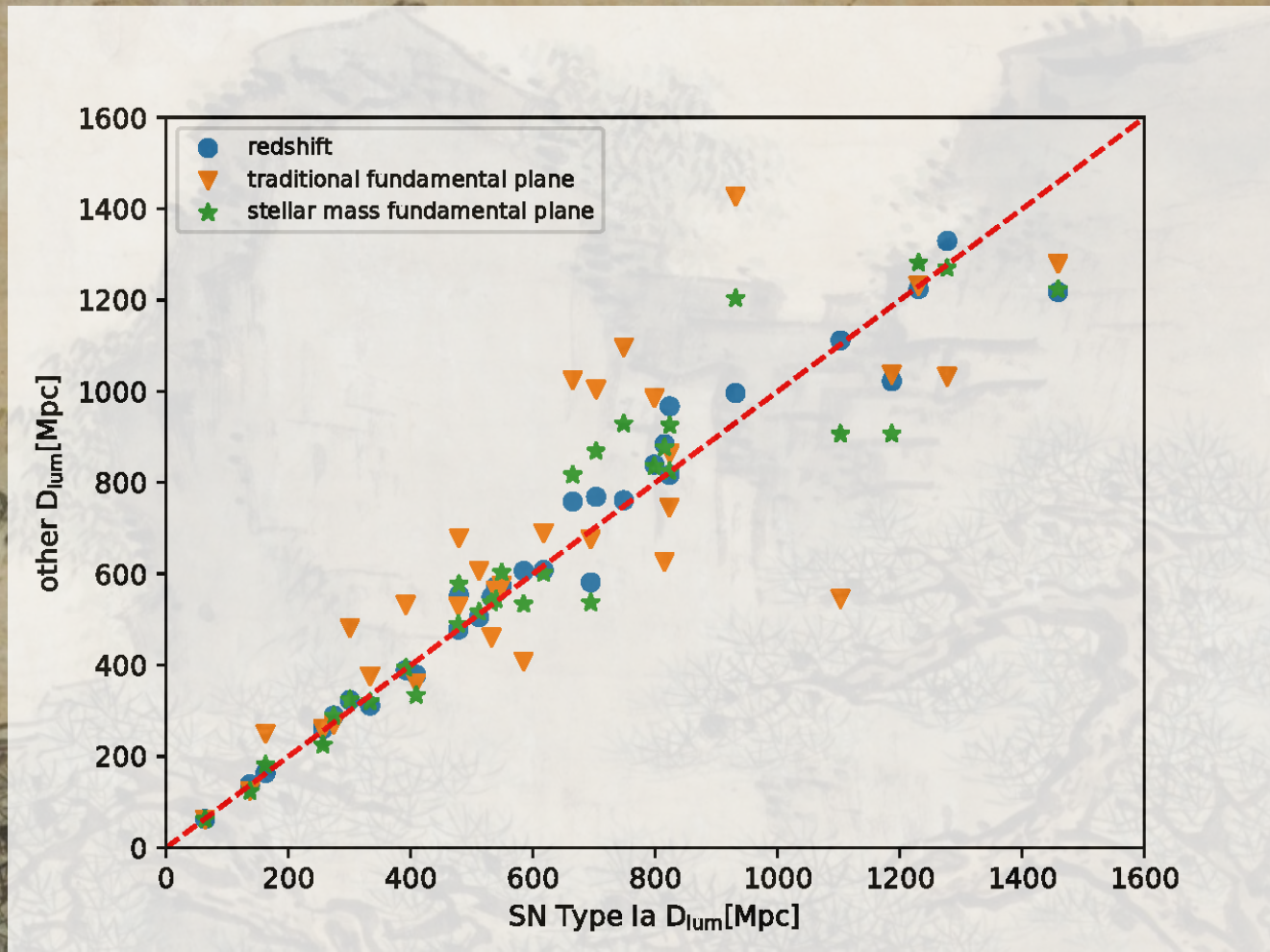


Comparison to SN Type Ia distances

- Using 740 SN Type Ia distances (Betoule+2014)
- 31 SN are located within our sample of ETG

- Scatter Sni Ia vs.
  - Redshifts: 8.1%
  - Trad. FP: 28.9%
  - SM. FP: 14.9%

- Results are not as clear as expected, but small sample

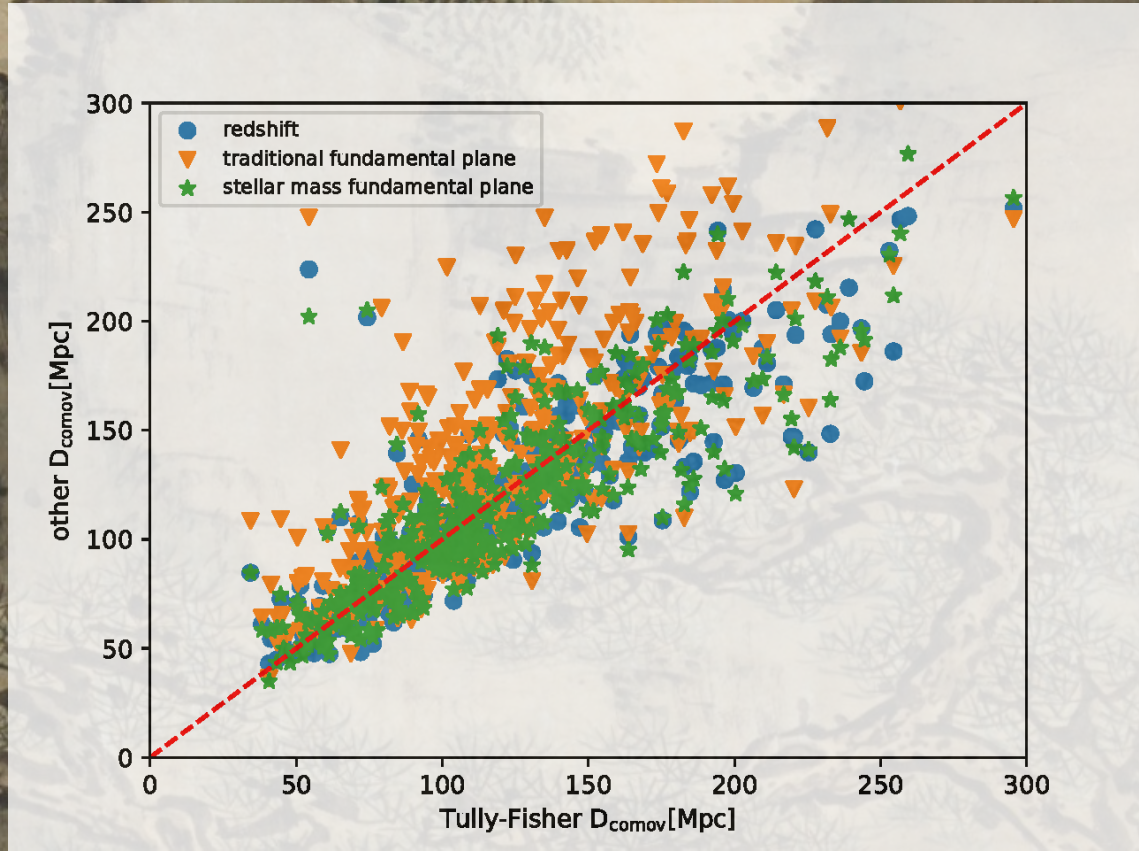


Comparison to the Tully-Fisher relation distances

- Our group catalogue allows for a comparison of FP distances and TF-relation distances (from NED)
- 397 groups have at least 1 FP and 1 TF galaxy

- Scatter Tully-Fisher vs.
  - Redshifts: 22.2%
  - Trad. FP: 39.5%
  - SM. FP: 22.6%

- Systematic bias of Trad FP
- Interlopers may affect these results

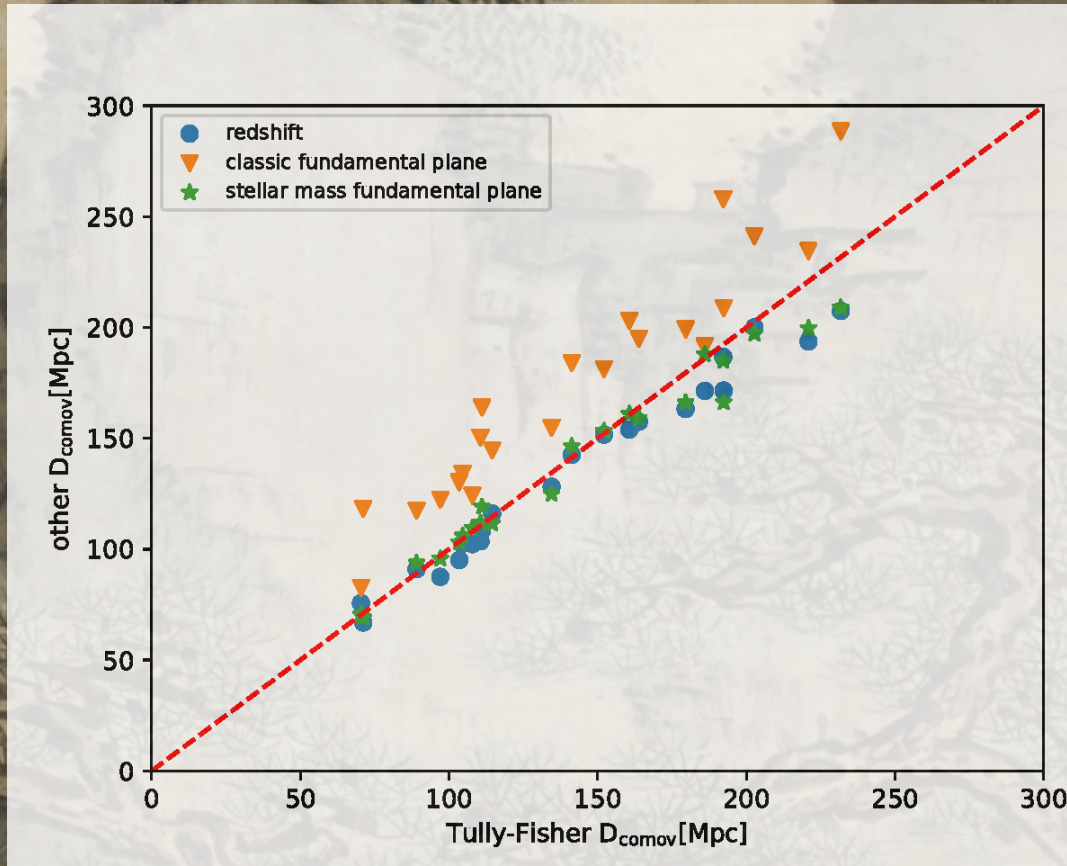


Selecting rich clusters for a better comparison

- Selecting a sub-sample of rich clusters:
  at least 3 FP galaxies and at least 3 TF galaxies
- 22 clusters found

- Scatter Tully-Fisher vs.
  - Redshifts: 6.1%
  - Trad. FP: 27.3%
  - SM. FP: 4.6%

- SM FP agrees better with TF distance than with redshift distances



Peculiar velocities

- Self-consistent set of (mostly) redshift-independent distances
- Redshifts for the same objects
- → peculiar velocities

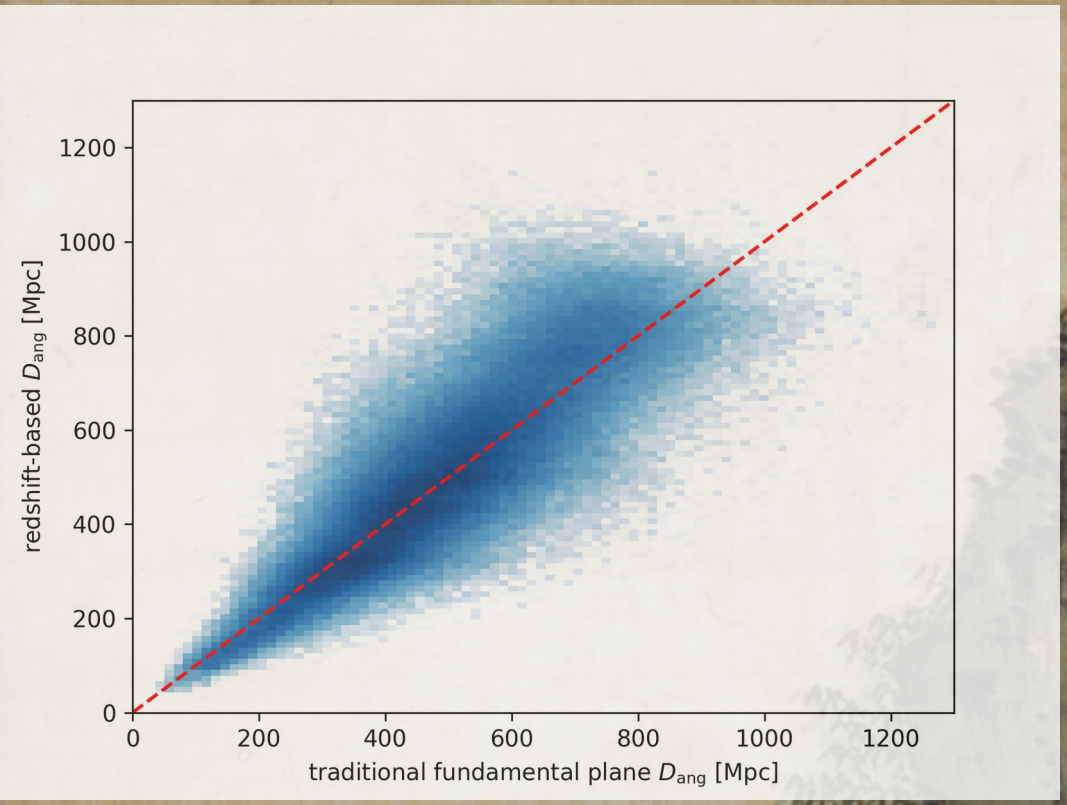
- Quality selection (we will focus on clusters, because they provide more solid distances)
- Take care of systematics (difficult)

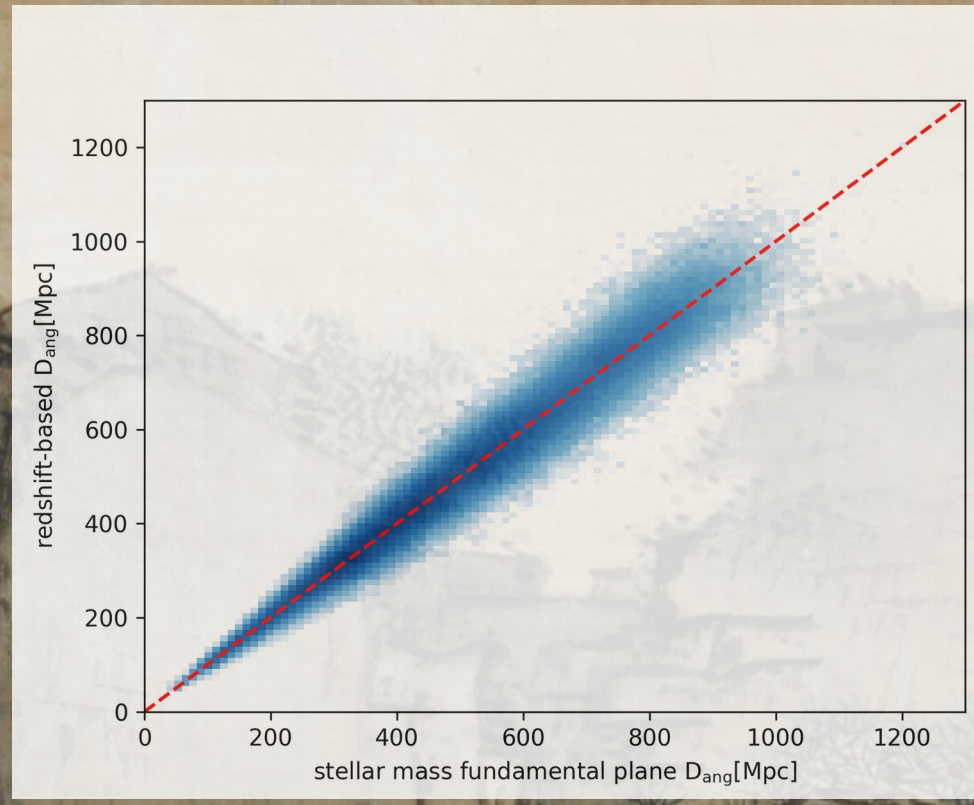
- Long-term goal: study momentum power spectrum and the β parameter
- Work in progress

Summary

- Largest sample of fundamental plane distances (~280 000 galaxies)
- Updated combined SDSS/BOSS/2MRS group catalogue up to z=0.5 (>1 000 000 groups)
- Traditional fundamental plane is biased
- Stellar mass fundamental plane provides notably better distances: 7.7% accuracy
- Good agreement of the SM FP distances with Tully-Fisher distances from NED
- Peculiar motions are work in progress
- **Paper (Saulder+) is about to be submitted**

ANY QUESTIONS?



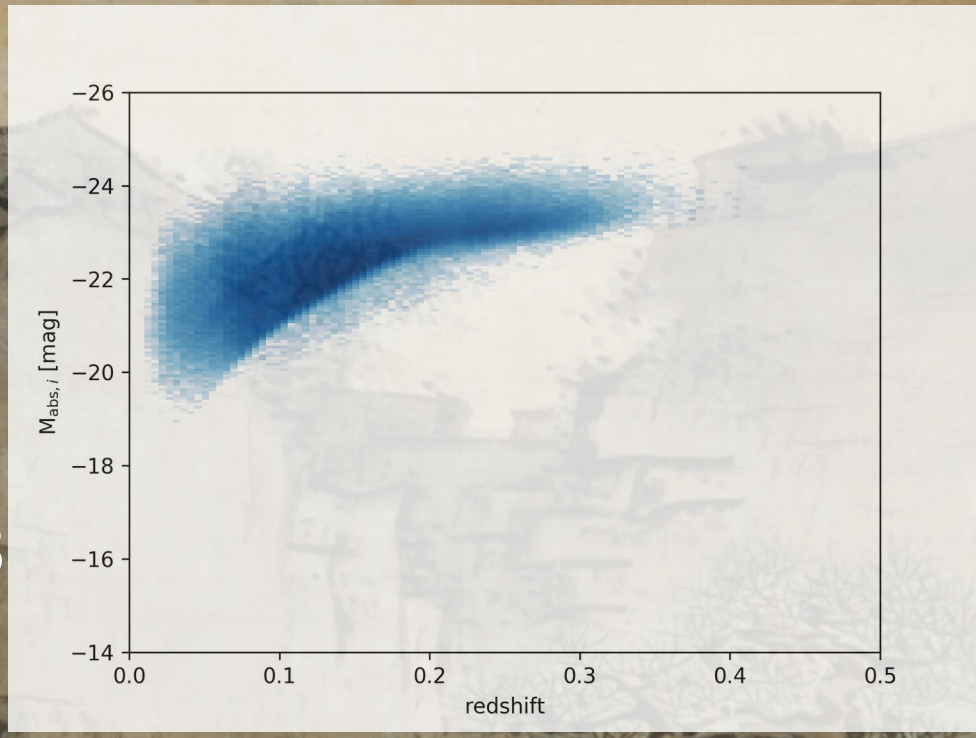


감사합니다 !

ADDITIONAL SLIDES FOR POSSIBLE QUESTIONS

Dataset for fundamental plane calibrations

- ~280 000 early-type galaxies from SDSS DR14

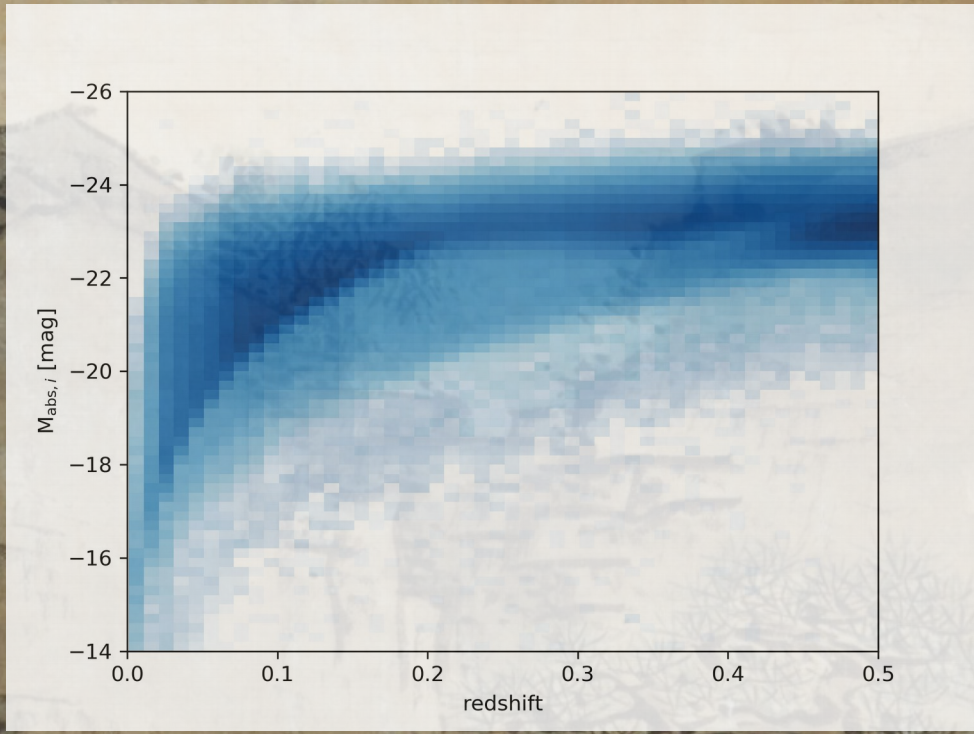


- Axis ratio < 0.7
- (g-r) colour > 0.65 mag
- g>r>i>z (the redder, the brighter)
- De Vaucoleur profiles more likely than exponential profile
- De Vaucoleur fitting fraction > 0.8

- Within 3-σ of the red sequence
- Corrected central velocity dispersion ∈ [100 km/s, 420 km/s]
- Absolute magnitude ∈ [-19 mag, -25.5 mag]
- Log(R0/kpc) ∈ [-0.5 dex, 1.5 dex]
- Corrected (g-r) colour < 2.5 mag

Dataset for group catalogue

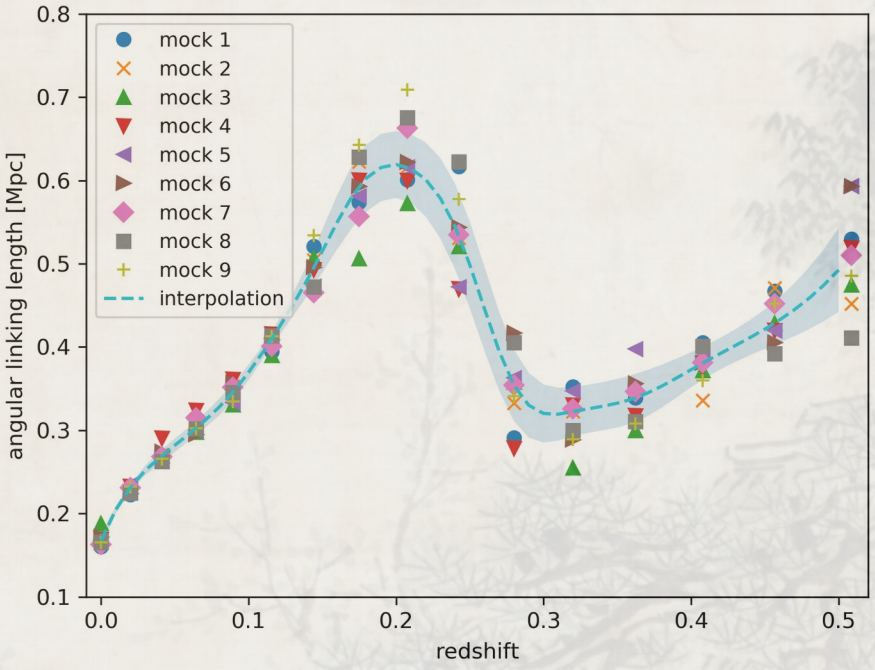
- All Galaxies and QSO with spectroscopic redshifts in SDSS DR14
  - SDSS main galaxy sample
  - SDSS LRG sample (low and high z)
  - BOSS low z sample
  - CMASS sample

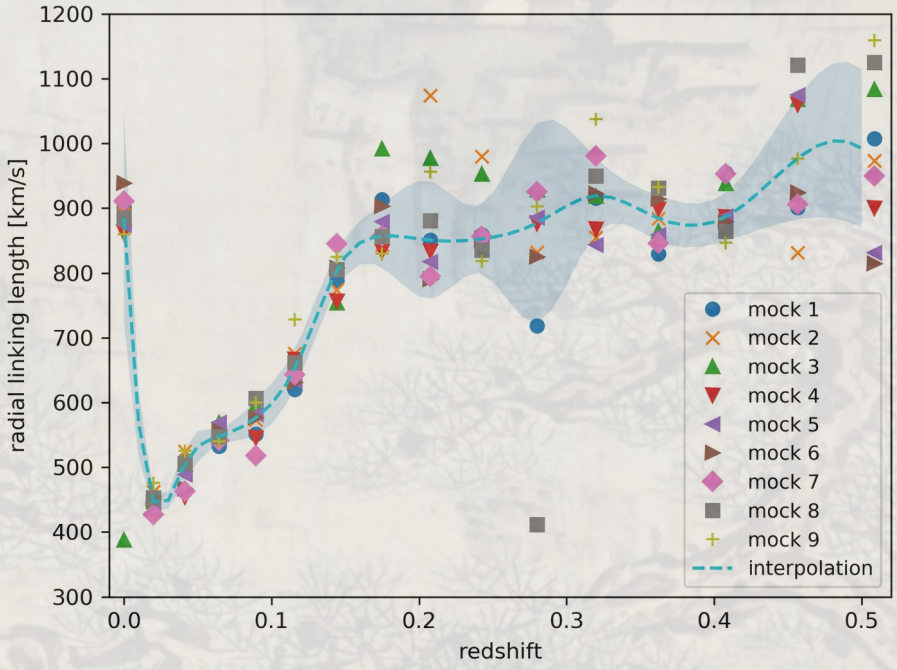


- All galaxies 2MRS within 1 degree of the SDSS DR14 spectroscopic footprint
- 1 269 405 objects as the basis for our group catalogue

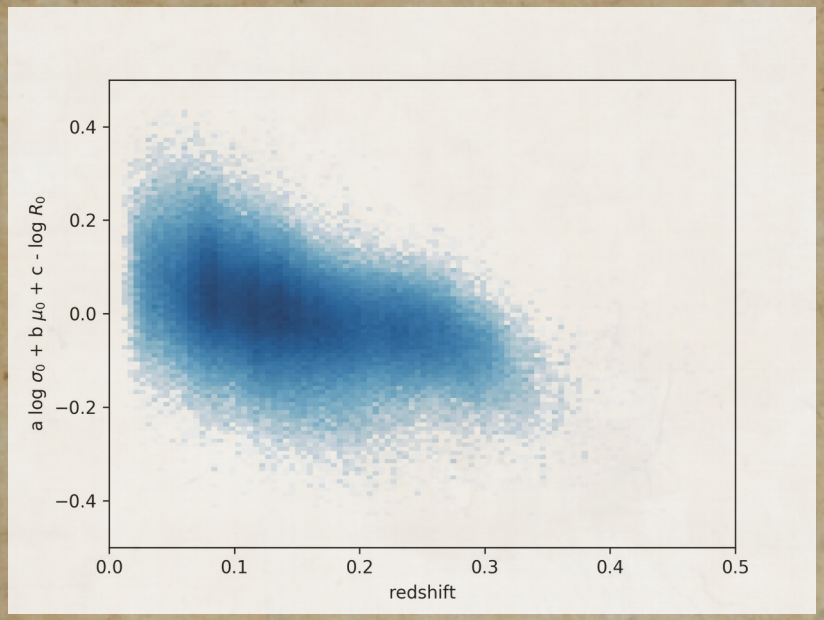
Linking length calibration

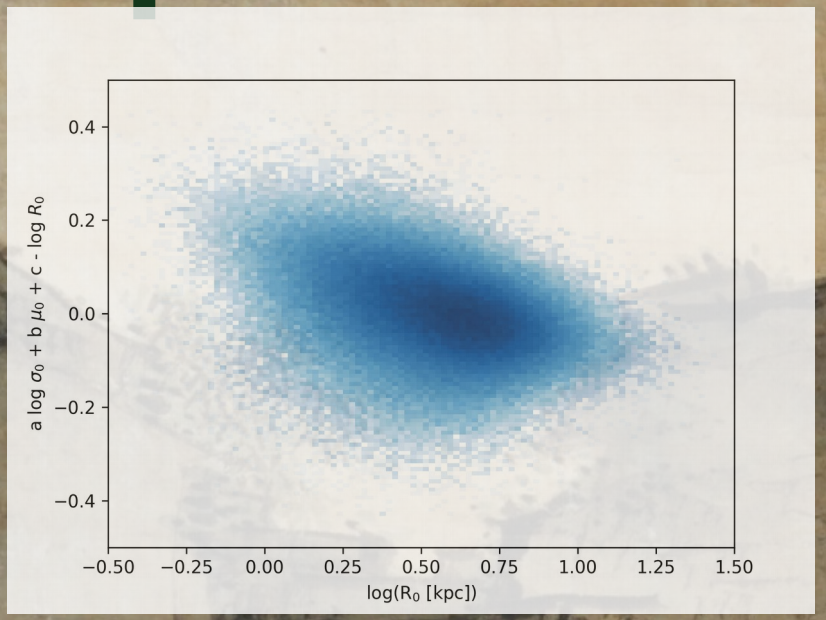
- Mock catalogues based on the WMAP7 rerun of the Millennium simulation
- Optimized for each redshift bin using the method of Robotham+2011

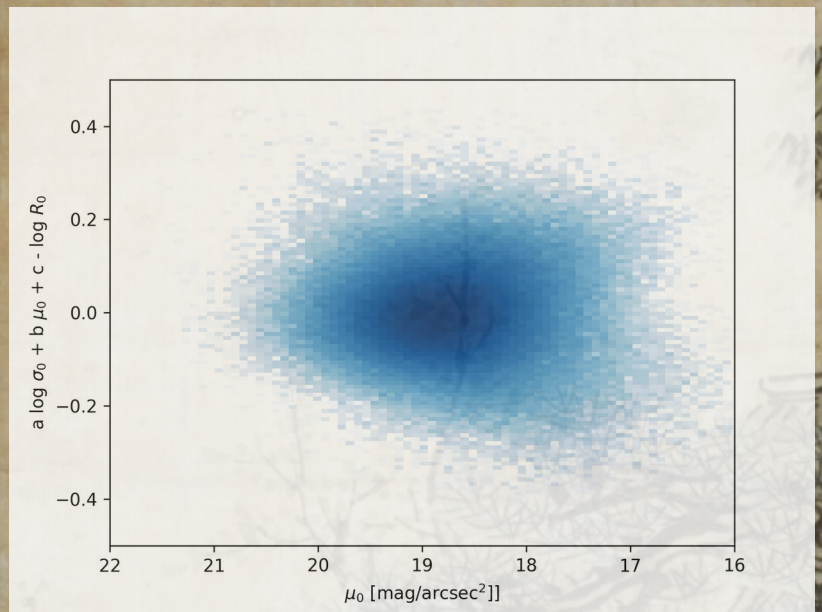


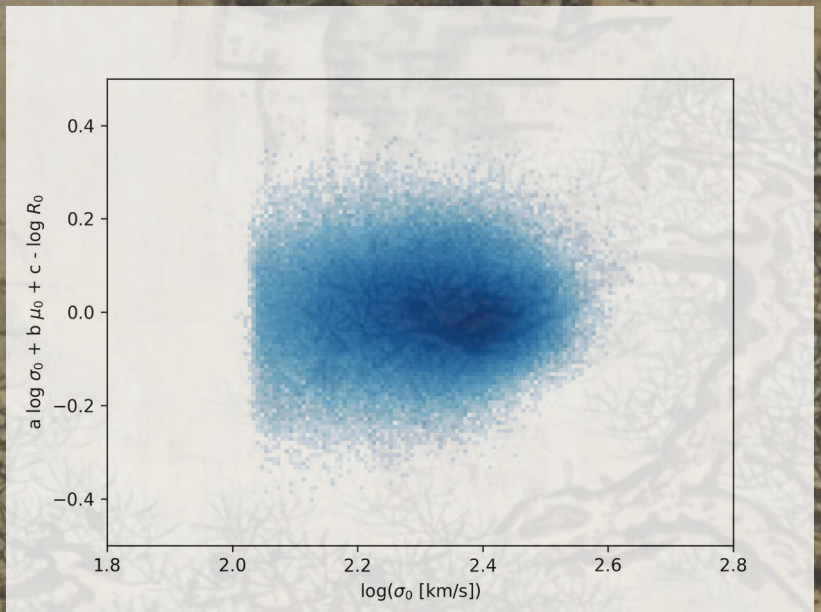


Residuals of the traditional fundamental plane

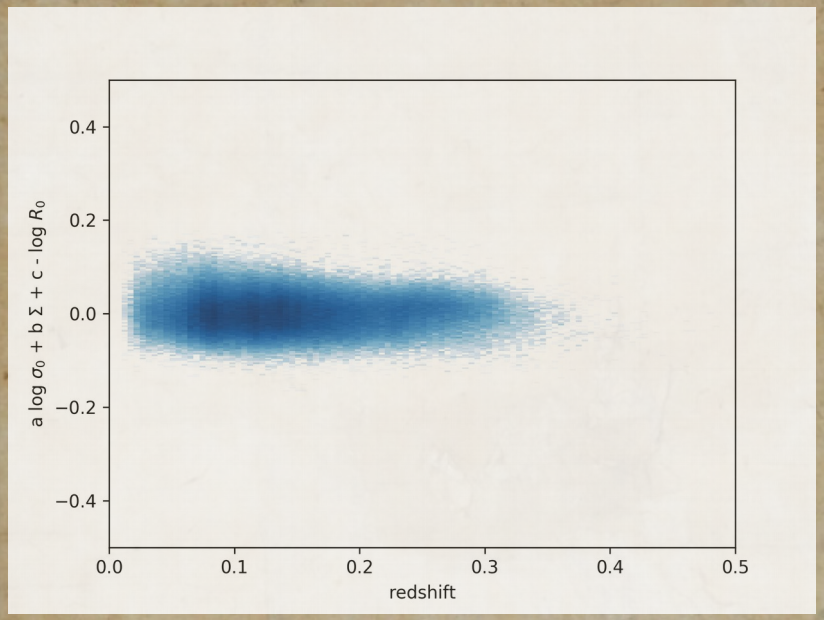


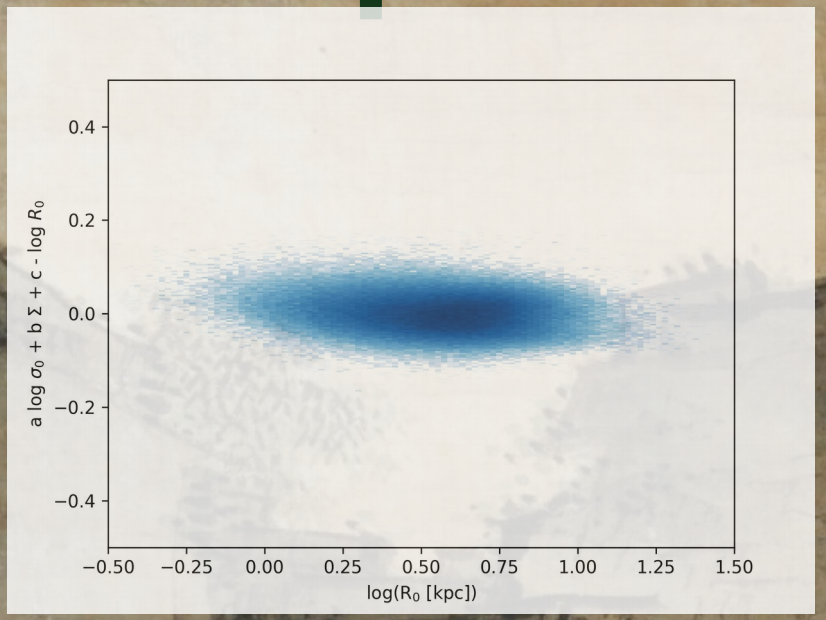


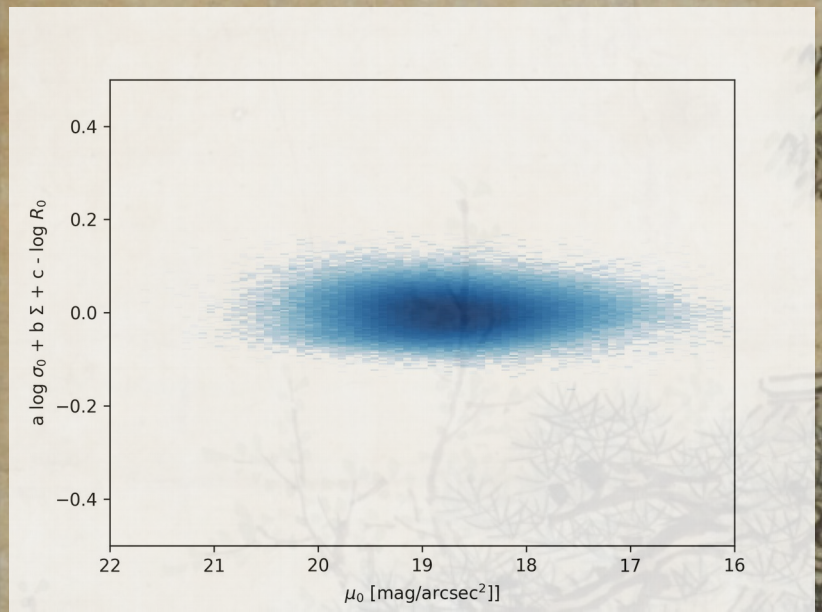


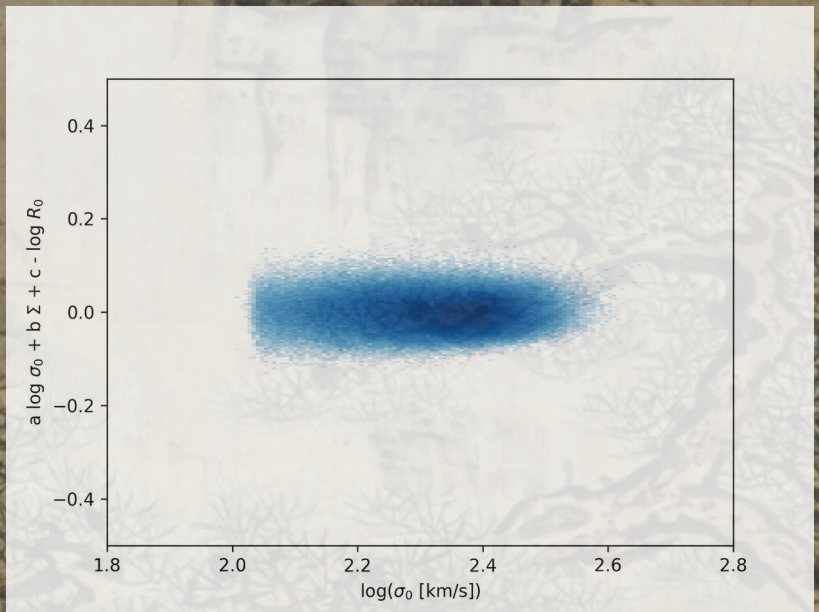


Residuals of the stellar mass fundamental plane



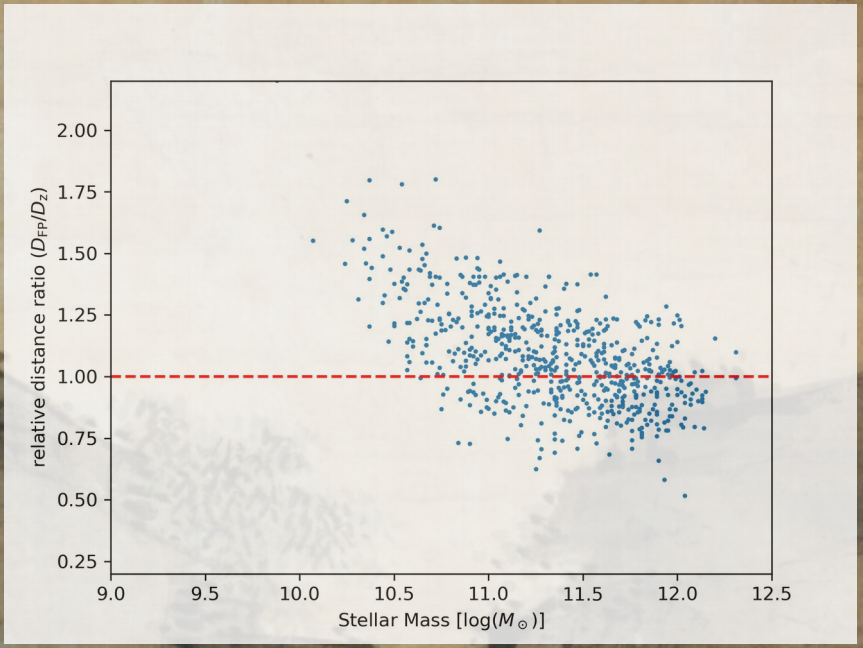


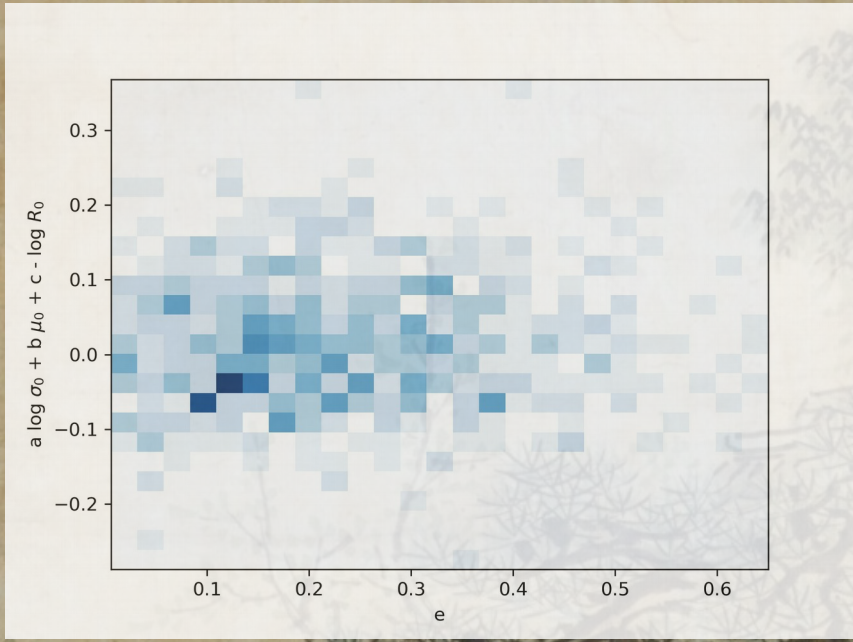


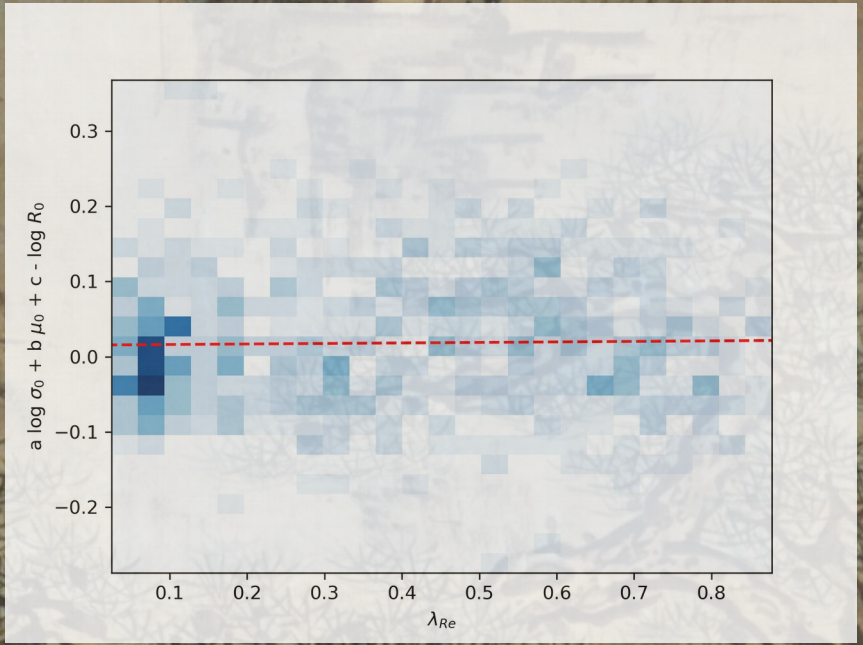


MaNGA data and residuals

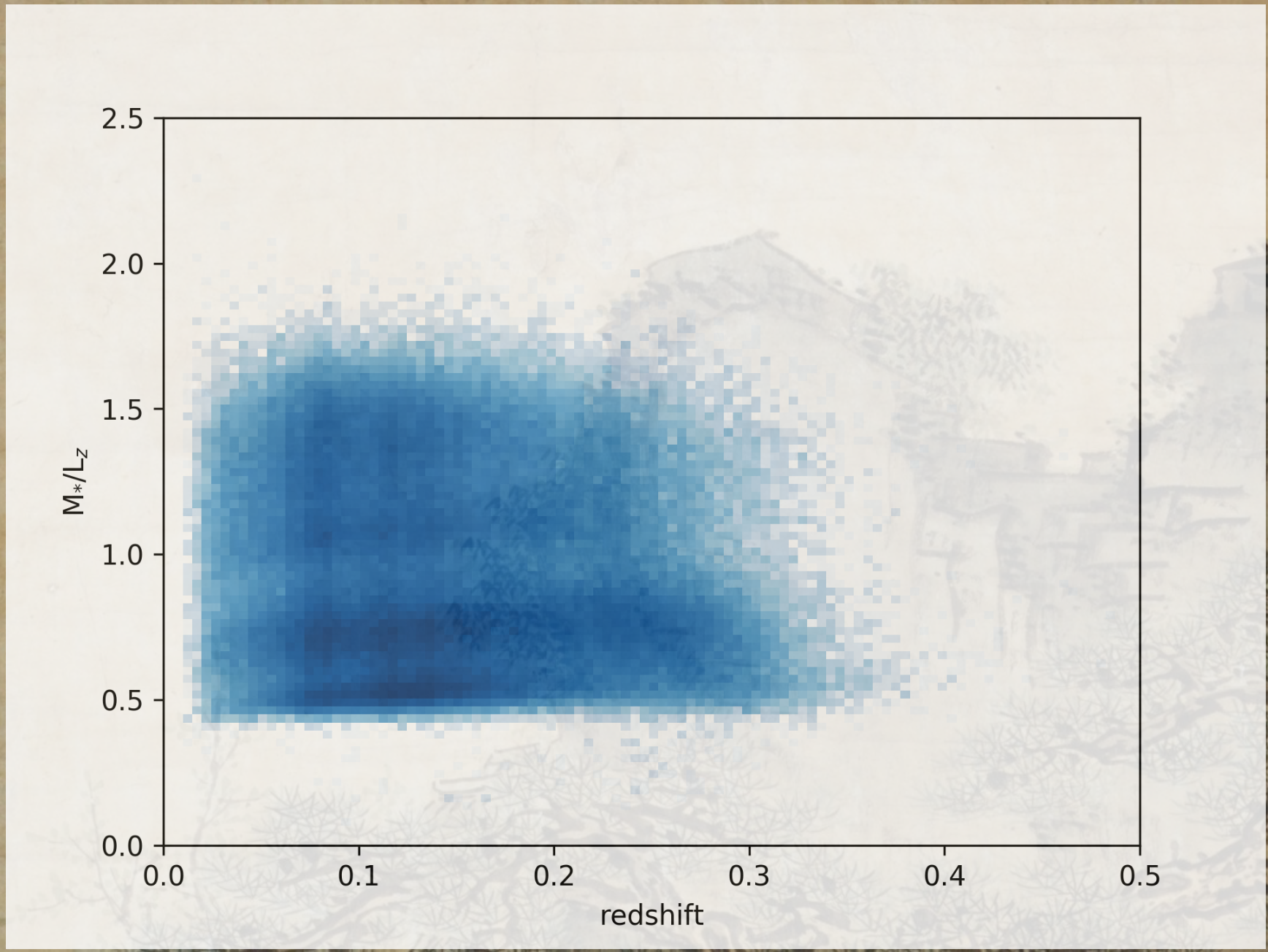
- For the traditional FP
  - Strong trend with stellar mass
  - No correlation with the rotation parameter λ_{Re} or the ellipticity e





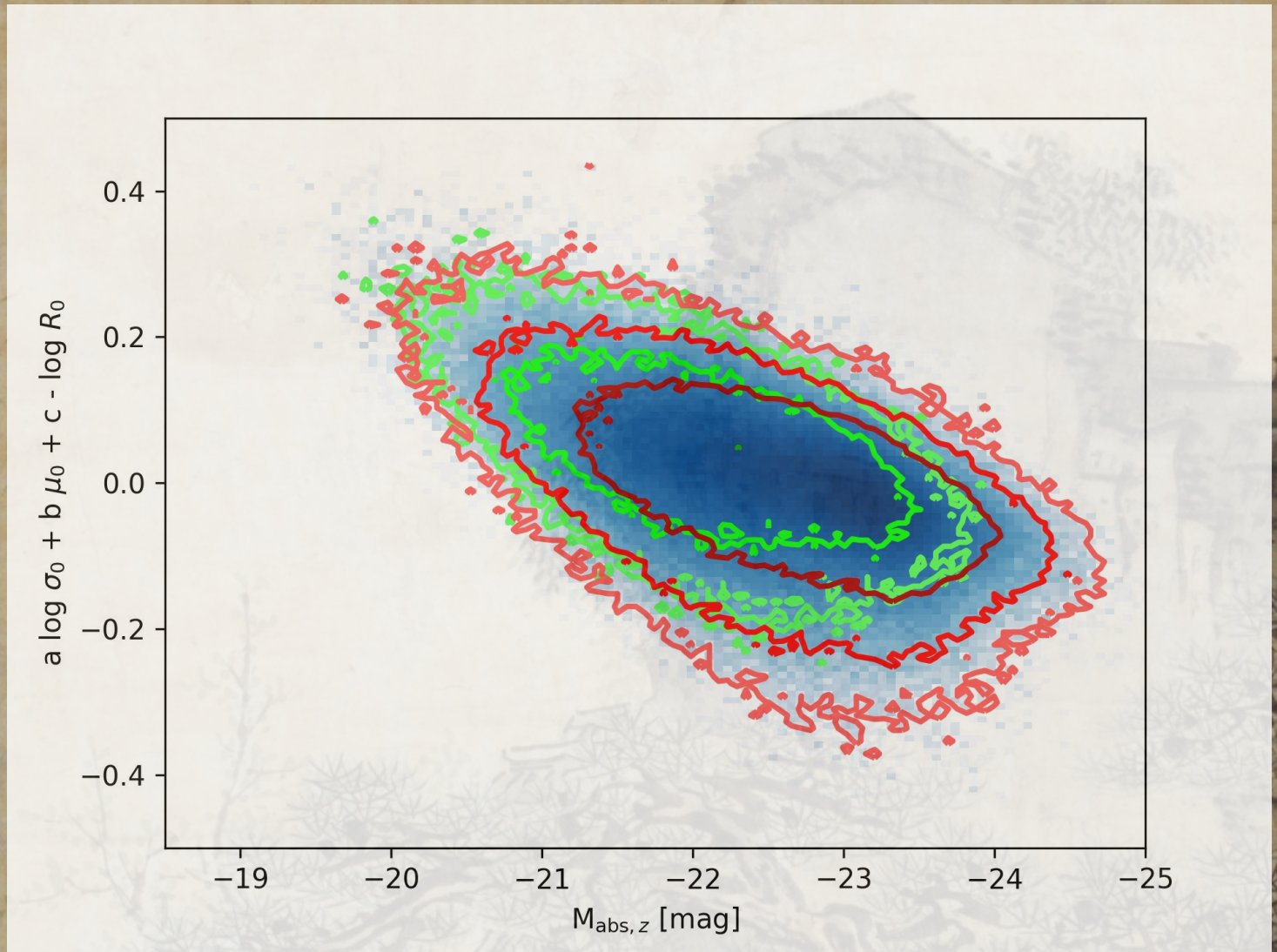


Stellar mass to light ratio



Environmental effects

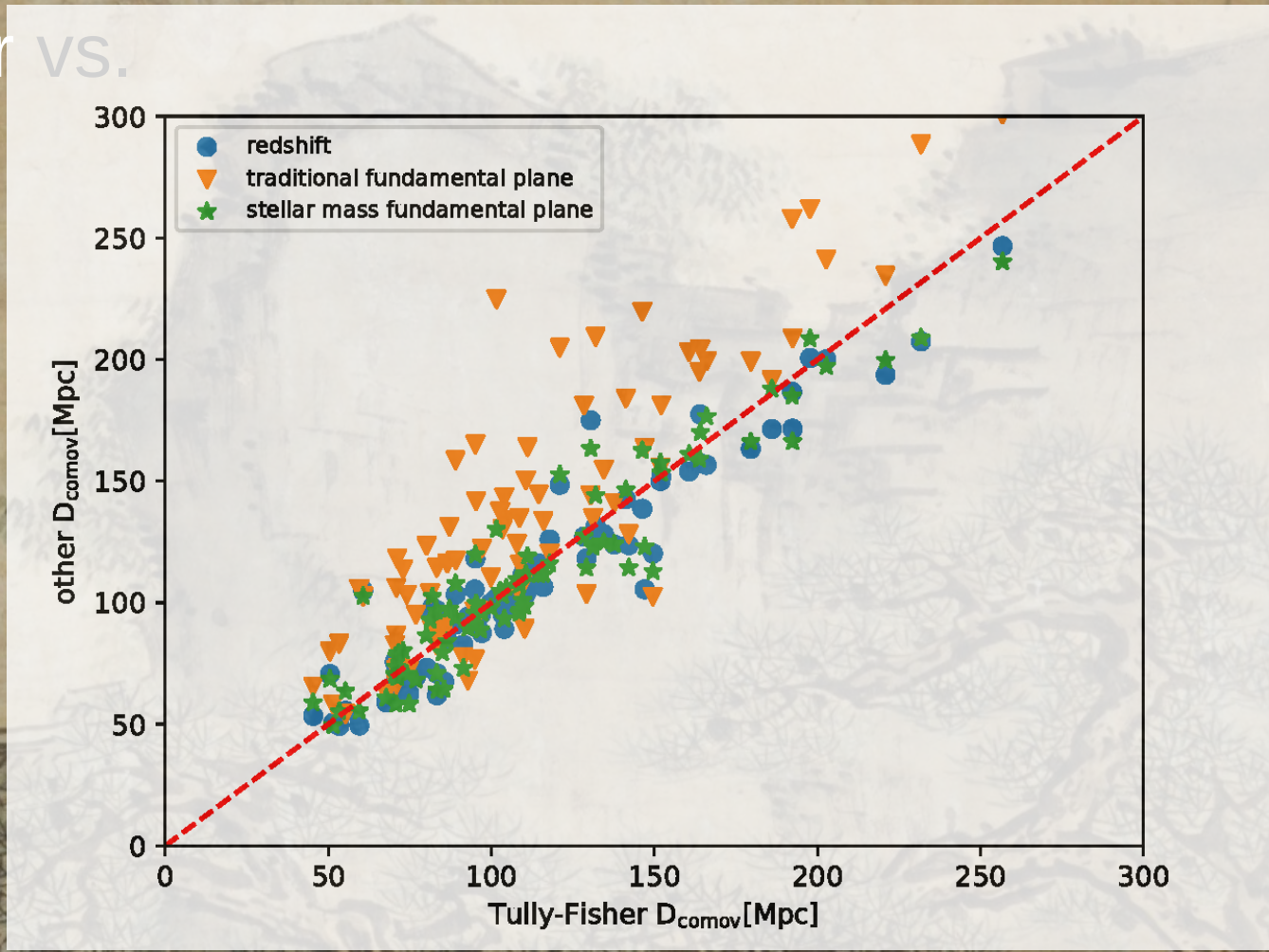
- Centrals are off-set from satellites,
  but they are also systematically brighter



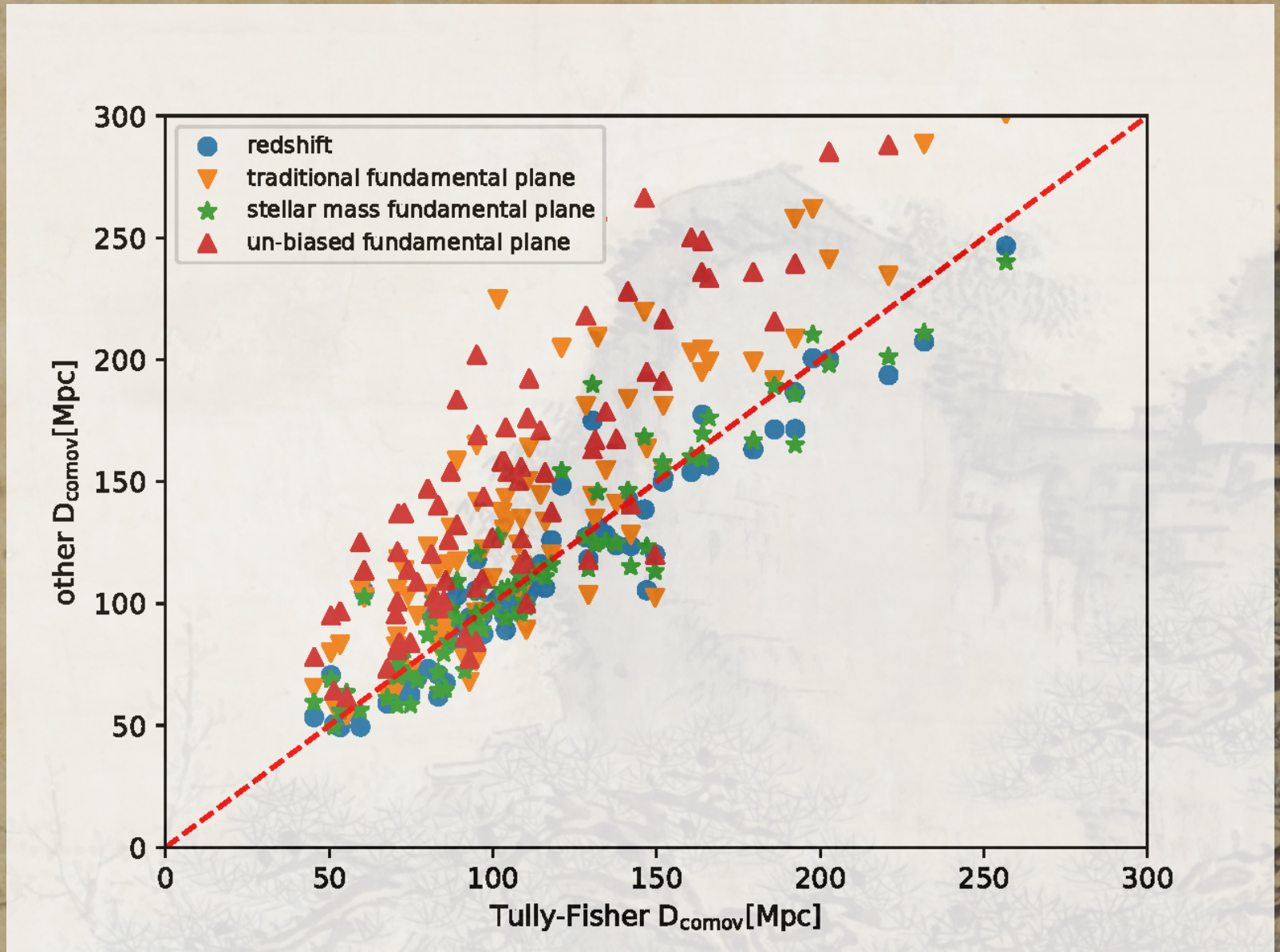
Tully-Fisher vs. others

- 2 or more TF galaxies and at least 1 FP galaxy
- 84 groups

- Scatter Tully-Fisher vs.
  - Redshifts: 12.0%
  - Trad. FP: 33.3%
  - SM. FP: 13.2%



Malmquist bias correction vs. Tully-Fisher relation



The complete picture

- Painting of a gathering of scholars
- Anonymous painter
- Joseon dynasty
- National Museum of Korea
- https://www.museum.go.kr/site/eng/relic/search/view?relicId=1012

N/A

Sorry, but I haven’t prepared a slide for this specific question.