Comparing distances obtained from galaxy scaling relations with the help of group catalogues

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Abstract

Galaxy scaling relations, such as the Tully-Fisher relation and the fundamental plane can be used to derive redshift-independent distances. These two scaling relations are valid for mutually exclusive morphological galaxy types, solid group catalogues are required to compare them within galaxy clusters hosting multiple galaxies. With our investigation, we aim to better understand systematic effects between the scaling rations that may cause potential biases in peculiar motion studies.

Data for a full sky group catalogue

The dataset for our group catalogue consists of wide (coverage at least 1000 deg^2) spectroscopic surveys to obtain redshifts and positions of galaxies. The surveys we used are:

- SDSS - 1 527 251 galaxies over 9376 deg^2 (z<0.5)
- 2MRS - 43 533 galaxies over 37 540 deg^2
- 2dFGRS - 245 591 galaxies over 1500 deg^2
- 6dFGS - 84 625 galaxies over 17 046 deg^2
- CfA2 - 18 204 galaxies over 17 000 deg^2
- SSRS2 - 5 426 galaxies over 5 500 deg^2

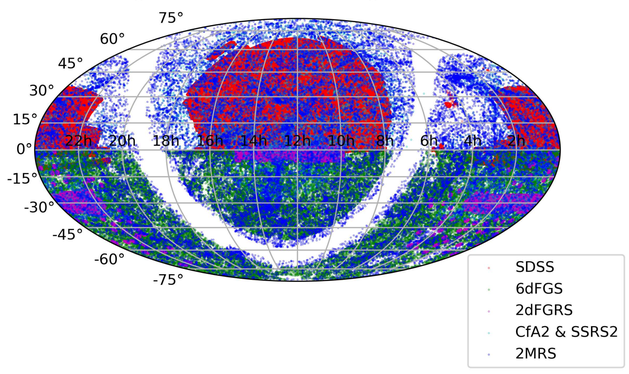

FIGURE 1: Our dataset projected on the sky.

By crossmatching the data, we found 1 757 185 unique galaxies from different surveys, which form the basis for our group catalogue.

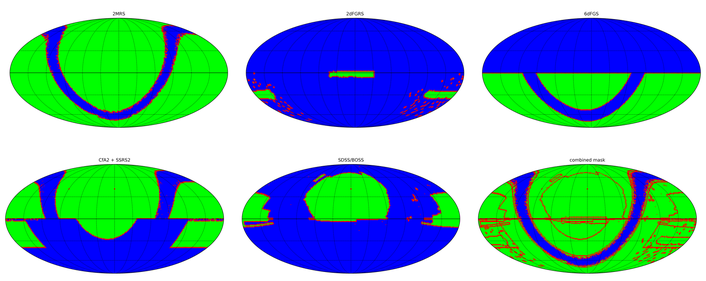

FIGURE 2: Footprints of the different surveys. The egdes (red) of the individual surveys will be marked with a flag.

FOF group finder

We use a standard FoF approach to identify groups within our combined sample. The linking lengths in each area of the sky depends on the overlap of survey footprints. We used mock catalogues based on the rerun of the Millennium simulation with WMAP7 cosmology that consider all existing combinations of footprints and the different selection criteria of the various surveys.

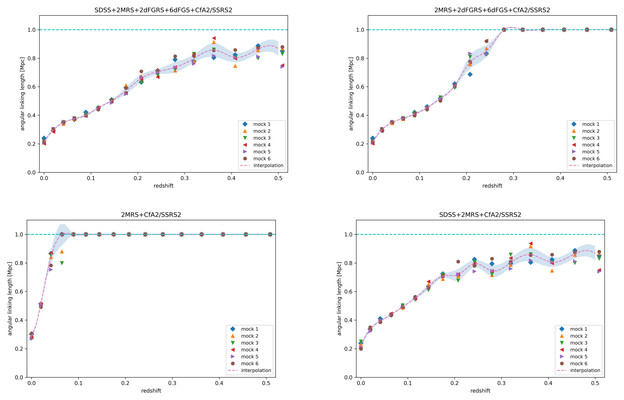

FIGURE 3: Angular linkings lengths for different combinations of footprints provided as examples for our calibrations.

MAGGIE group finder

A downside of FoF group catalogues is that they tend to be affected by interlopers. However, we can estimate the group masses from our data and use it to remove galaxies that are not bound. To this end, we adapt the MAGGIE group finder (Duarte & Mamon 2015) for our dataset. This is currently work in progress, but it will improve our comparisons in the near future.

Galaxy scaling relations

Kinematic scaling relations have been a tool to understand the nature and evolution of galaxies for many decades. The most important of these scaling relations are the Tully-Fisher relation for late-type galaxies and the fundamental plane for early-type galaxies. With the increasing number of IFU surveys, a new kinematic scaling relation following the S_K-parameter was defined recently, which is not restricted by morphological type.

The fundamental plane

The fundamental plane is an empirical relation between three global parameters of early-type galaxies: the central velocity dispersion, the effective radius in physical units, and the mean surface brightness within the effective radius. The fundamental plane can be used to obtain angular diameter distances to early-type galaxies.

$$\log_{10}(R_0) = a \cdot \log_{10}(\sigma_0) + b \cdot \mu_0 + c \qquad (1)$$

Using SDSS DR15 as our main dataset, we calibrated the fundamental plane and derived distances to over 320 000 galaxies.

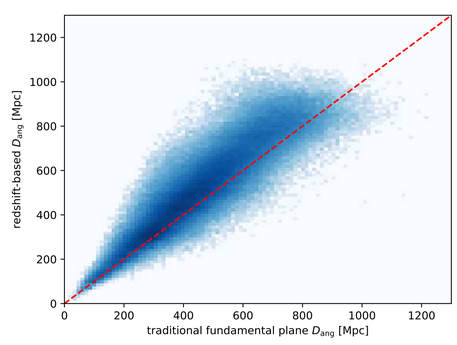

FIGURE 4: Distances to SDSS galaxies obtained by using the fundamental plane.

Tully-Fisher relation

The Tully-Fisher relation establishes a connection between the maximum rotation velocity of late-type galaxies and their absolute luminosity. Consequently, it can be used to derive luminosity distances to these galaxies.

$$L = A \cdot (v_{\max})^{\beta} \qquad (2)$$

We used the Tully-Fisher relation distances provided by NED. There are 56 124 measurements in their database, of which we find 4 481 unique galaxies (so with multiple measurements) within the SDSS footprint.

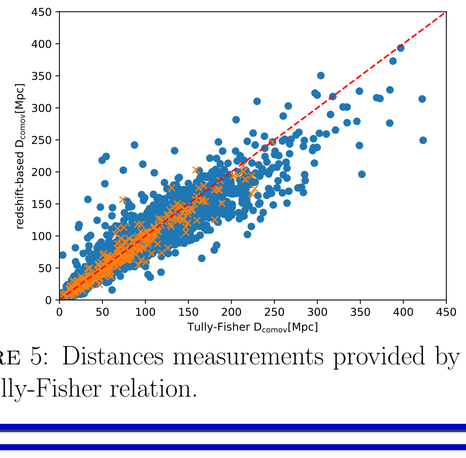

FIGURE 5: Distances measurements provided by NED using the Tully-Fisher relation.

S_K relation

The S_K relation has not been as a distance indicator yet, since the stellar mass is no directly observational quantity. In the future we will use MaNGA data for it.

$$log(M_*) = \alpha \cdot \log_{10}(S_K) + \beta \qquad (3)$$

$$S_K = \sqrt{K \cdot V_{\mathrm{rot}}^2 + \sigma^2} \qquad (4)$$

Comparison using the group catalogue

Since the Tully-Fisher relation and the fundamental plane have established applications as distance indicators a comparison between them allows us to study their systematic biases. We compare the distance measured using the different scaling relations to clusters, which were identified in our group catalogue. Although the Tully-Fisher relation and the fundamental plane target mutually exclusive types of galaxies, the group catalogue allows us to compare them since the sizes of the clusters are sufficiently small compared to the distances to these clusters. We used the median distances for our since they are less affected by interlopers. Additionally, richer clusters will provide better results because of this and the improved statistics.

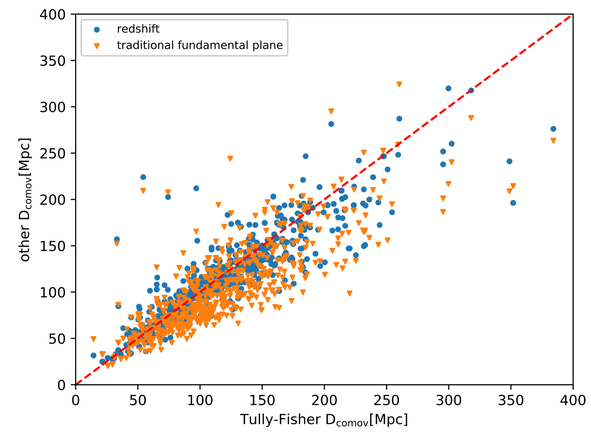

FIGURE 6: Comparison between the Tully-Fisher relation distances, redshift based distances, and fundamental plane distances for all of the 541 clusters hosting at least one early-type and one late-type galaxy.

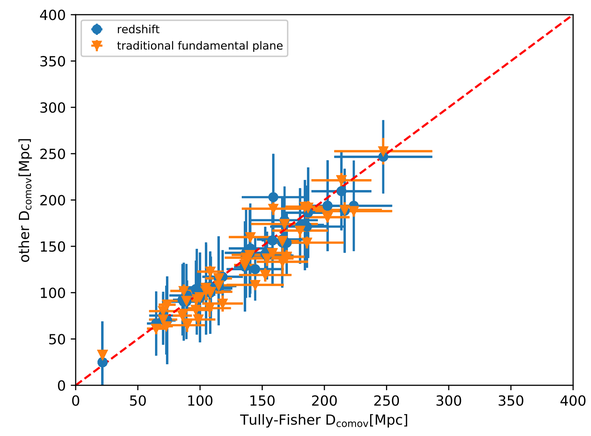

FIGURE 7: Comparison between the Tully-Fisher relation distances, redshift based distances, and fundamental plane distances for 45 rich clusters hosting at least three early-type and three late-type galaxies.

Results and Outlook

In our first approach, we primarily used the comparison between the fundamental plane and the Tully-Fisher relation as a sanity check for calibrations of the fundamental plane. So far, we could not detect any mayor systematic differences between the distances obtained from the different methods (beyond a possible normalization issue and selection effects). However, in the future we will study the deviations in greater detail as a function cluster-centric distances and also with restricted sample ranges in luminosity.

While, we have already expanded our group catalogue by including other surveys to compensate for the saturation bias in SDSS, we have not used any fundamental plane data beyond the SDSS footprint yet. We plan to include the fundamental plane distances obtained from the 6dFGS in the future, which will provide more clusters for comparison since our Tully-Fisher relation data is already full sky.

Since the S_K relation has not been adapted into a distance indicator yet, we plan to do this in the near future by replacing the stellar mass with near-infrared magnitudes. MaNGA would provide many objects within the SDSS footprint, while SAMI would allow us to study it on the Southern hemisphere. It would also allow for a more direct comparison between the other scaling relations, because the S_K relation works for all morphological types.