Python Code for Mitigating Malmquist and Eddington Biases in Latent-Inclination Regression of the Tully-Fisher Relation

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This software repository provides the Python functions and a Jupyter notebook that implement the latent-variable bias-mitigating inference methods for the Tully-Fisher Relation. The methods are described in Fu (2025), titled "Mitigating Malmquist and Eddington Biases in Latent-Inclination Regression of the Tully-Fisher Relation", submitted to AAS Journals (eJP submission ID: ApJ AAS64459). A preprint of the paper is available at https://arxiv.org/abs/2504.10589.

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README.md ⌄

Mitigating Malmquist and Eddington Biases in Latent-Inclination Regression of the Tully-Fisher Relation

Summary

The Tully-Fisher relation (TFR) is an empirical correlation between luminosities and rotation velocities of disk galaxies. Since rotation velocity can be measured independent of distance, this correlation allows astronomers to use disk galaxies as *standardizable candles* for distance measurements. Once the correlation is calibrated using

importance to observational cosmology.

Although the TFR is often described as a linear correlation in logarithmic scales, the inference of its slope and intercept is not a simple linear regression problem, because of several important differences:

- The dependent variable (luminosity or mass) is a combination of two observables - the apparent magnitude and the luminosity distance from redshift.
- The independent variable (maximum rotation velocity) requires deprojecting the apparent HI line width to the edge-on perspective. So it requires estimating the inclination angle of the disk relative to the line-of-sight.
- There are measurement errors involved in all four observables, and there are intrinsic scatters in both axes.

Because of these characteristics, precise and unbiased inference of the TFR is hindered by one major source of measurement error (**inclination angle**) and two major statistical biases:

- **The Distance-Dependent Malmquist Bias in Luminosity** due to (1) the separation of magnitude limit and luminosity limit in a sample covering a range of distances, and (2) the measurement errors and the intrinsic scatter in luminosity.
- **The Generalized Eddington Bias in Luminosity** due to (1) non-uniform distributions of galaxies in rotation velocity, and (2) the measurement errors and the intrinsic scatter in rotation velocity.

These problems are not readily handled by previous methods such as the Gaussian-mixture dual-scatter method by Kelly (2007) and the maximum likelihood method of Willick (1994) and Willick et al. (1997). Both methods require the line widths to be individually corrected by the uncertain inclination angle, so low-inclination galaxies ($i < 45$ deg) must be excluded to avoid the most problematic corrections. In addition, the former cannot mitigate the distance-dependent Malmquist bias because distance is not separated from magnitude, and the latter cannot mitigate the

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simu2fit.ipynb

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TFR_likefun.py

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Additional details

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Is supplement to

Publication: arXiv:2504.10589 (arXiv)

▾ Software

Repository URL ↗

https://github.com/fuhaiastro/TFR_biases

Programming language ↗

Python, Jupyter Notebook

Development Status ↗

Active

Versions

Version v1.0   Jul 23, 2025

10.5281/zenodo.16378199

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