Constructing a Template Baryonic Tully Fisher Relation

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Abstract

Here we present work done to refine the determination of a template Baryonic Tully-Fisher Relation (BTFR) using HI spectra of 196 supernova host galaxies using the L-Band receiver on the Green Bank Telescope and an archival sample of 21-cm spectra for a total sample of 320 galaxies with accurate, redshift-independent distance estimates. We are presenting updated best estimates of galaxy distances from supernovae and other methods, inclinations from the NASA/IPAC Extragalactic Database (NED) Local Volume Sample, and stellar masses from unWISE photometry. We use these newly compiled and calculated values to generate a preliminary template BTFR.

Introduction

The overall objective of this project is to reduce the scatter in the Baryonic Tully Fisher Relation (McGaugh et al. 2000) so that it can be used as a reliable redshift-independent distance indicator. To achieve this objective, we analyzed HI spectra of a sample of known supernova-host disk galaxies with established distances using data from the Green Bank Radio Telescope and archival sources.

We measure the flux of 21-cm HI profiles for these galaxies to calculate their gas mass and rotation velocity, applying corrections for inclination following the methods outlined by Masters et al. (2019). Stellar masses are derived from unWISE photometry (Lang et al. 2014) using the technique of Jarrett et al. (2023). The sum of the gas and stellar masses is the total baryonic mass of each galaxy in the sample.

The calculation of the gas and stellar mass depends on the galaxy distance. Therefore, our GBT + archival sample is selected to be galaxies that are confirmed supernova hosts with reliable distance estimates. In previous work, we used distances compiled in the Democratic Sample of Supernovae (Stahl et al. 2021).

All galaxy rotation velocities measured from the widths of the HI profiles must be corrected for inclination, measured from the ratio of the semi-minor to semi-major axis, in an optical or near infrared image.

Galaxy gas masses are proportional to the area of the HI profiles. Stellar masses can be estimated from optical or infrared photometry.

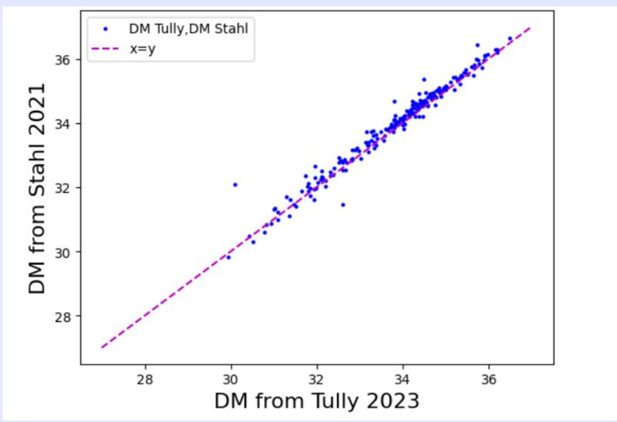
In order to reduce scatter in the BTFR, we want to have the most reliable estimates of all galaxy parameters used to calculate rotation speeds and baryonic masses.

Supernovae Based Distances

By scaling for different values of H_0 our previous distances estimates agreed reasonably well with more recent estimates from Cosmicflows-4 (Tully et al. 2023). The Cosmicflows-4 distances are a statistical combination of all of the available distance measurements of a galaxies, weighted according to reliability: Type Ia supernovae, Tully-Fisher relation, Fundamental Plane, Surface brightness fluctuations, Type II supernovae, Tip of the Red Giant branch, Cepheid Period-Luminosity relation, and geometric masers.

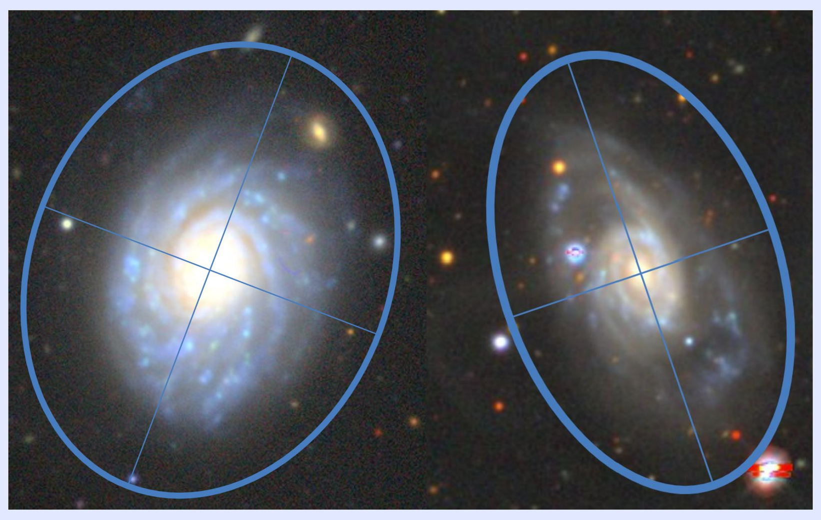
In this diagram, we compare the distance modulus from Stahl et al. 2021 to the newer estimate from Tully et al. 2023.

distance modulus is defined:
DM = m-M = 5log(d) - 5

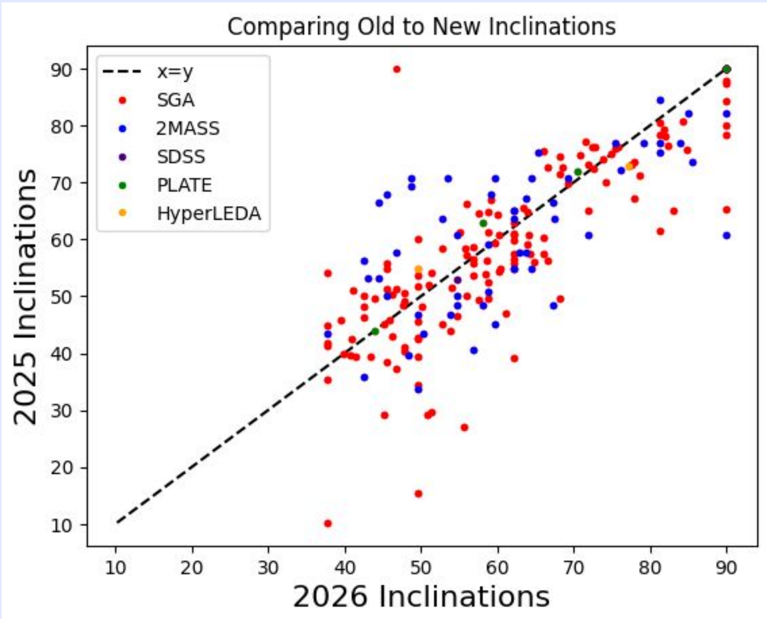


Updated Galaxy Inclinations

We used the NED Local Volume Sample (NED LVS, Cook et al. 2023) to update our ratio of the semi-minor axis to the semi-major (b/a). The NED LVS ratios come from four sources, the Siena Galaxy Atlas (Moustakas et al. 2023), the Sloan Digital Sky Survey (York et al. 2000), Two Micron All Sky Survey (Skrutskie et al. 2006), and photographic plate surveys (de Vaucouleurs et al. 1991).
In the process, nine galaxies were found to have a b/a ratio above our observation cutoff of .80. This is above the threshold needed to reliably measure galaxy rotation, thus the nine were not included in final BTFR.

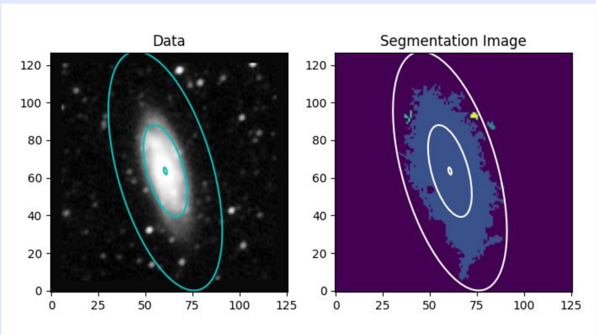


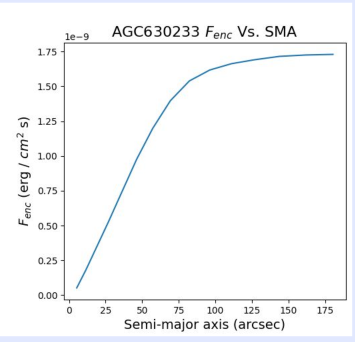
Above are two galaxies from our sample with axis ratios shown. To the right is a comparison of our new NEDLVS inclinations to previously used inclinations.



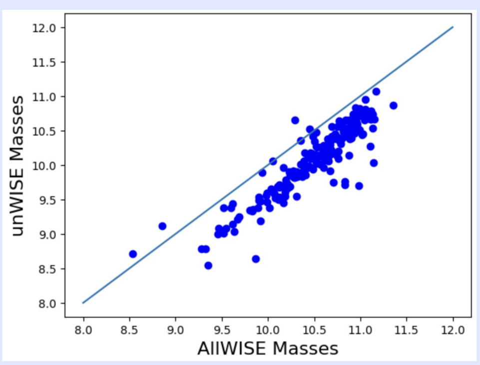
New Stellar Masses

Previously our work used values from the NED LVS (Cook et al. 2023) which relied on photometry from the W1 and W4 band of the All Wide-field Infrared Survey Explorer catalog (AllWISE). This excluded some galaxies without W4 data. Jarrett et al. (2023) gives a technique based only on the W1 band. Furthermore, we now use unblurred WISE photometry (unWISE, Lang et al. 2014) which is more optimized for galaxies than AllWISE.

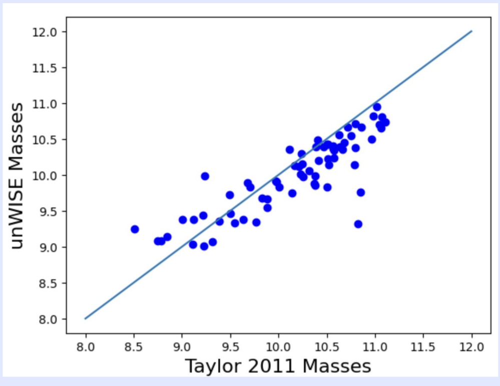




Example images from stellar mass code showing ellipses used to calculate W1 total flux and the growth curve of flux versus distance from galaxy center

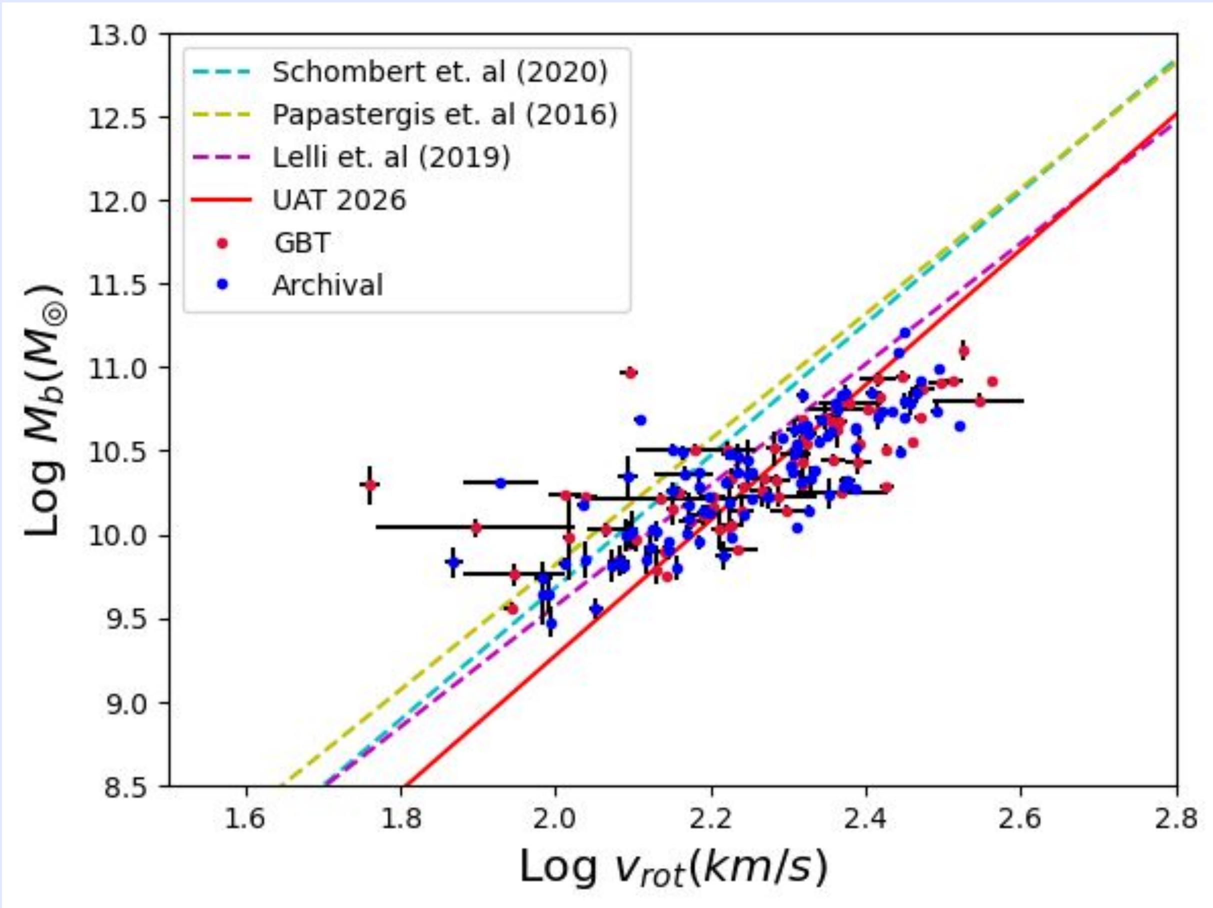


Left: figure showing difference between unWISE and AllWISE masses
Right: figure showing difference between unWISE and optical based masses (Durbala et al. 2020; Taylor et al. 2011)



BTFR Results

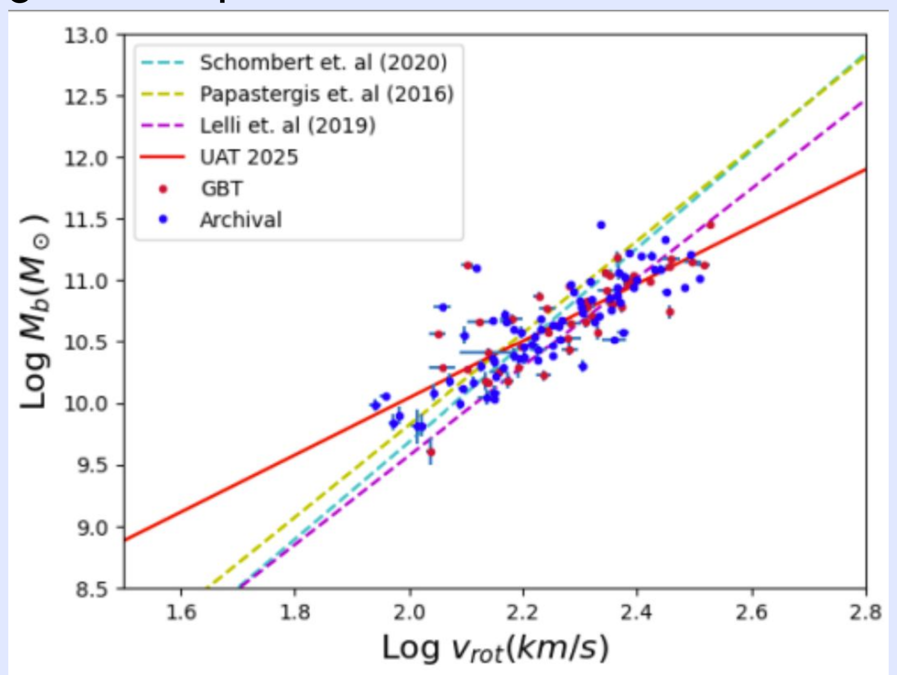
The new version of the template BTFR including our new refined galaxy parameters is shown below, along with previous studies using galaxy samples with distances estimated primarily from methods other than supernovae.



The plot above shows the resulting fit from our samples (red: GBT, blue: Archival) with the slope of 4.0486 represented by the red solid line.

Also shown are the results from:
Schombert et al. (2020) (cyan dashed line)
Papastergis et al. (2016) (green dashed line)
Lelli et al. (2019) (purple dashed line).
With slopes of 3.95, 3.75, and 3.62, respectively.

Below is the previous template BTFR. Since then our slope is more aligned with previous results.



What's Next

- Modify our model to better account for the effects of inclination of rotational velocity uncertainty.
- During the process of gathering data for our BTFR we had many non-detections which we would like to use to calculate upper limits which will be useful for studies on H1 properties in supernova host galaxies.
- Investigate outliers on our BTFR better understand the causes.
- We would also like to use PANDISC (peng et al. 2023) to model galaxies in our sample.
- We expect to use the program to identify galaxies that might have small interactions.
- Our collaboration is planning on investigating stellar formation rate in interacting galaxies
- Examine H1 properties of 'green pea' galaxies.

References: Cook D. O. et al 2023 ApJS 268 14 - Durbala, A. et al 2020 AJ 160 271 - Jarrett, T. H. et al 2023 ApJ 946 95 - Lang, D. 2014, AJ, 147, 108 Lelli, F.i et al. MN RAS 484 - Masters, K., et al. 2019, MN RAS, 484, 3267 -McGaugh, S., et al. 2000, ApJ, 533, L99 - Moustakas et al. 2023 AJ 269 1 - Peng et al 2023 ApJ 950 163 - Papastergis, E. et al. 2016 A&A 593 - Schombert, J. et al 2020 AJ 160 71 Skrutskie et al. 2006, AJ, 131, 2, - Stahl, B., et al. 2021, MN RAS, 505, 2349 -Taylor, E. et al. 2011 MN RAS 418 - Tully, R. et al 2023 ApJ 944 94 - de Vaucouleurs et al. 1991 - York et al. 2000, AJ, 120 3

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