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The 2MASS Tully–Fisher Survey: Mapping the mass in the Universe

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Abstract. The 2MASS Tully–Fisher Survey (2MTF) aims to measure Tully–Fisher (TF) distances for all bright, inclined spirals in the 2MASS Redshift Survey (2MRS) using high-quality HI widths and 2MASS photometry. Compared with previous peculiar-velocity surveys, the 2MTF survey provides more accurate width measurements and more uniform sky coverage, combining observations with the *Green Bank, Arecibo*, and *Parkes* telescopes. With this new redshift-independent distance database, we will significantly improve our understanding of the mass distribution in the local Universe.

Keywords. galaxies: distances and redshifts, galaxies: spiral, catalogs, surveys

1. Introduction

The Tully–Fisher relation is an empirical relation between the luminosity and rotation velocity of spiral galaxies (Tully & Fisher 1977). As a secondary distance indicator, the Tully–Fisher relation is a good tool for measuring the redshift-independent distances to local spiral galaxies. With these distances, we can calculate the peculiar-velocity field, which in turn allows us to trace the mass distribution in the local Universe.

In the last few decades, a number of Tully–Fisher surveys have been conducted, including those described in Giovanelli *et al.* (1997b), Springob *et al.* (2007), and Tully *et al.* (2008), which are typically limited by source selection criteria and sky coverage. For instance, the SFI++ survey (Springob *et al.* 2007), which is the largest Tully–Fisher survey to date, was selected optically in the I band and only covers Galactic latitudes down to $|b| = 15°$. This sky coverage is a significant limitation to measuring an all-sky peculiar-velocity field, especially in the Zone of Avoidance (ZoA; the part of the sky which is difficult to observe because of dust and source crowding in our own Galaxy).

Thus, a new all-sky Tully–Fisher survey with uniform source selection and sky coverage is needed for the study of the local peculiar-velocity field. This new survey will improve our model of the mass distribution of the local Universe.

2. 2MASS Tully–Fisher Survey

The 2MASS Tully–Fisher Survey (2MTF), which is based on a source list selected from the 2 Micron All-Sky Survey (2MASS), will provide better statistics and more even sky coverage than previous surveys, in particular greatly reducing the impact of the ZoA. This survey will make use of existing high-quality rotation widths, new HI widths, and 2MASS photometry to measure Tully–Fisher distances for all bright, inclined spirals in the 2MASS Redshift Survey (2MRS; Huchra *et al.* 2012).

2.1. *Source selection*

To minimize the errors in the final Tully–Fisher distances, we selected only bright and highly inclined galaxies from the 2MRS with limits of $K_s = 11.25$ mag, $cz < 10,000$ km s^{-1}, and axial ratios $b/a < 0.5$. The target sample contains approximately 6000 galaxies and covers more than 90% of the whole sky, where the missing 10% is due to obscuration by the Milky Way; 35% of these galaxies have rotation width measurements for Tully–Fisher distances already available from the literature, but based on very uneven sky coverage. Fig. 1 shows the distribution of the 6000 target galaxies.

2.2. *Current Data Status*

Our new HI line observations contain ∼1300 galaxies that were observed at high velocity resolution with the *Green Bank Telescope* (*GBT*) and the *Parkes Telescope* between February 2006 and February 2012. When complete in 2012, the Arecibo Legacy Fast ALFA survey (ALFALFA; Giovanelli *et al.* 2005) will also provide high velocity-resolution widths for all HI-rich galaxies in the high-Galactic-latitude Arecibo sky.

2.2.1. *New Observations with the GBT and Parkes Telescope*

In the northern sky ($\delta > -40°$), we observed some 1000 galaxies using the *GBT* in the 2006A, 2006B, and 2006C semesters. Observations were done in position-switched

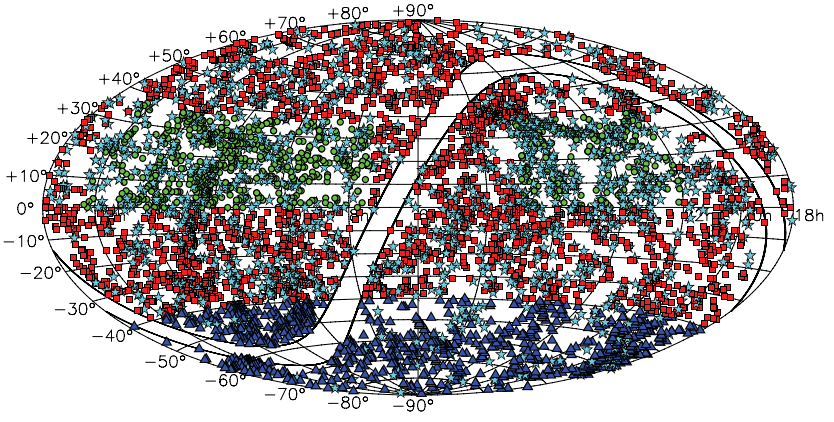

Figure 1. Distribution of the 6000 2MTF target galaxies. The red squares indicate galaxies observed with the *GBT*, galaxies observed at Parkes are plotted as blue triangles, the green circles show the ALFALFA galaxies, and the cyan stars are galaxies with archival data. The thick lines trace the Galactic latitudes $b = +5°$ and $b = -5°$.

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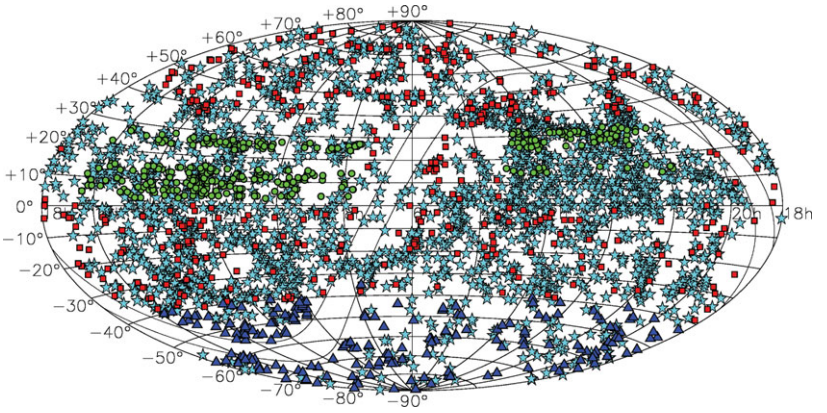

Figure 2. Distribution of the final sample of 3000 2MTF galaxies (pending the addition of the remaining ALFALFA galaxies). All symbols have the same meaning as in Fig. 1

mode, always in pairs of 5 min ON/OFF with a 12.5 MHz bandwidth and 8192 channels. In the sky south of −40°, 305 galaxies which meet our selection criteria were considered observable from Parkes without confusion. In six semesters (06OCTS, 07APRS, 07OCTS, 08APRS, 08OCTS and 11OCTS) at Parkes, we observed all of these 305 galaxies using the 20 cm multi-beam receiver in beam-switching mode, with a bandwidth of 8 MHz and 1024 spectral channels.

To obtain the smallest possible errors in Tully–Fisher distances, we have to minimize the error (less than 10%) in the measurements of rotation widths. We require signal-to-noise ratios > 10 to measure the widths to better than 10%. From these new observed HI lines, we obtained 386 high-quality HI width measurements from *GBT* data, and we also obtained 152 high-quality HI spectra at Parkes.

2.2.2. ALFALFA *40% Data*

ALFALFA is a large, blind HI survey being undertaken with the *Arecibo telescope*. It covers the high-Galactic-latitude Arecibo sky, and will be completed in late 2012. More than 30,000 extragalactic HI sources will be detected by ALFALFA with redshifts up to $z \sim 0.06$; 40% of the ALFALFA data ($\sim 15,900$ HI sources) were published by Haynes *et al.* (2011). After cross-matching with our 2MTF target sample, we found 357 useful widths for our Tully–Fisher calculations. We still await the full data release, so that we may complete our sample.

2.2.3. *Archived Data*

The archived HI widths are mainly from the SFI++ database (Springob *et al.* 2005). In addition to the SFI++ data, we also selected HI widths from more than 10 additional catalogs in the literature. Approximately 2000 archived HI data sources matched our 2MTF target sample, and 1800 widths have accuracies of better than 10%.

Our final sample (pending the addition of the remaining ALFALFA galaxies) includes roughly 3000 useful HI widths in total, which are uniformly distributed. This includes all of the newly observed galaxies, the ALFALFA 40% data, and the archival data. The spectroscopic data will be published and made available online shortly. The data release and analysis papers are also in preparation (Masters *et al.*, in prep.; Hong *et al.*, in prep.). Fig. 2 shows the sky distribution of the final 2MTF sample, and Fig. 3 shows the histograms of the galaxies' central velocities and HI widths.

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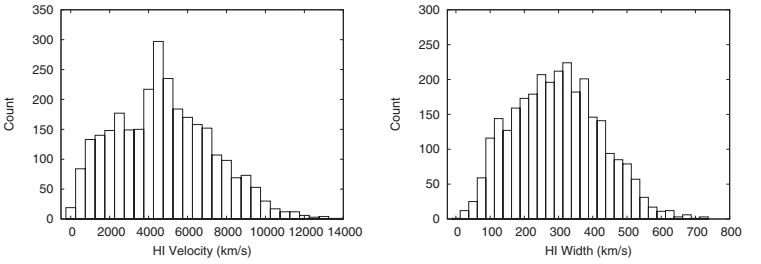

Figure 3. Central-velocity and HI width histograms of the final 2MTF sample.

2.3. *New Near-infrared Tully–Fisher Template*

A universal Tully–Fisher calibration in the near-infrared bands is very important for the 2MTF project. Masters *et al.* (2008) constructed a new Tully–Fisher template in the 2MASS J, H, and K bands using the 'basket of clusters' method (Giovanelli *et al.* 1997a), based on a sample containing 888 galaxies in 33 clusters.

Masters *et al.* (2008) also split the full sample into three subsamples divided by galaxy morphology, and determined that the Tully–Fisher relation depends on galaxy morphology in all three 2MASS bands, with later-type galaxies having a steeper Tully–Fisher slope and a fainter zero point than earlier-type galaxies (see Masters *et al.* 2008; their fig. 4).

Masters *et al.* (2008) corrected the final relation to that for Sc-type galaxies, and this relation will be used as the universal template for the 2MTF calculations.

3. Conclusion

The 2MTF project is an all-sky Tully–Fisher survey. It will measure Tully–Fisher distances of all bright, highly inclined galaxies in the local Universe. Compared with previous Tully–Fisher surveys, the 2MTF project provides more even sky coverage and a smaller 'Zone of Avoidance,' and will be a better sample for measuring the peculiar-velocity field in the local Universe. The final 2MTF sample contains approximately 3000 high-quality HI widths, all selected from the 2MASS Redshift Survey. The sample is composed of three parts, the newly observed HI widths by our group using the *GBT* and *Parkes* telescope, the ALFALFA HI widths, and archived high-quality HI widths from the literature. A new calibration of the near-infrared Tully–Fisher relation has been derived and published. The 2MTF project will help us to study and understand the peculiar-velocity field in the local Universe. Using the 2MTF data, we will provide better constraints on the local bulk flow, dipole motion, and mass distribution.

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