SHELLFLOW: The First Homogeneous All-Sky TF Survey at 6000 km s$^{-1}$

Stéphane Courteau$^1$, Jeff Willick$^2$, Michael Strauss$^3$, David Schlegel$^3$, Marc Postman$^4$

$^1$Herzberg Institute of Astrophysics, Victoria, BC

$^2$Stanford University, Department of Physics, Stanford, CA

$^3$Princeton University, Department of Astrophysical Sciences, Princeton, NJ

$^4$Space Telescope Science Institute, Baltimore, MD

Abstract. We present a new optical Tully-Fisher (TF) investigation for a complete, full-sky sample of 297 Sb–Sc spirals with redshifts between 4500 and 7000 km s$^{-1}$. The survey was specifically designed to provide uniform, well-calibrated data over both hemispheres. All previous TF surveys within the Supergalactic shell ($cz < \sim 6000$ km s$^{-1}$) have relied on matching separate data sets in the Northern and Southern hemispheres and thus cannot attain full-sky homogeneity. Analyses of the cosmological dipole and peculiar velocities based on these studies have produced contradictory claims for the amplitude of the bulk flow and whether it is generated by internal or external mass fluctuations. With Shellflow, and further zero-point calibration of existing TF data sets, we expect a high-accuracy detection of the bulk flow amplitude and an unambiguous characterization of the tidal field at 6000 km s$^{-1}$.

1 Introduction

Peculiar velocity surveys covering a fair fraction of the sky are now reaching to 6000 km s$^{-1}$ and beyond ([8], [15], [14], [8], [12], [26]) and are being interpreted as evidence for substantial flows on these scales ([4], [14], [13], [8], [18], [23]). However, the amplitude, direction, and scale of these flows remain very much in contention, with resulting uncertainties in the theoretical interpretation and implications of these measurements ([4], [23]).

Indeed, recently published conflicting results suggest that the motion of the LG is either due, or is not due, to material within 6000 km s$^{-1}$, and that IRAS galaxies either trace, or do not trace, the dark matter which gives rise to the observed peculiar velocities.

The most recent POTENT reconstruction of the MarkIII velocities ([8]) shows that the bulk velocity can be decomposed into two components arising from the mass fluctuation field within the sphere of radius $60\,h^{-1}$Mpc about the LG and a component dominated by the mass distribution outside that volume. For convenience, we refer to this boundary at $60\,h^{-1}$Mpc as the “Supergalactic shell” since it includes the main local attractors in the Supergalactic plane, the Great Attractor and Perseus-Pisces. This new analysis
shows dominant infall patterns by the GA and PP but very little bulk flow within the Supergalactic shell. The tidal component inside this volume is dominated by a flow of amplitude $370 \pm 125$ km s$^{-1}$ in the Supergalactic direction $(L, B) = (165^\circ, -10^\circ)$, which is likely generated by the external mass distribution on very large scales (see also [2], [3]). This interpretation is also supported by an increasingly large number of TF/FP investigations (based on the distribution and motion of Abell clusters) which report the detection of streaming motions of amplitudes greater than 700 km s$^{-1}$ beyond $\sim 60 h^{-1}$Mpc and away from the CMB dipole (21, 13, 26, 12). Other investigations using nearly homogeneous samples of galaxies within and outside the Supergalactic shell find motion consistent with the amplitude and direction of the CMB dipole (10). This suggests that the reflex motion of the Local Group could be explained by material contained within the Supergalactic shell.

This confusion stems, in large part, in our inability to perfectly match the many heterogeneous samples for flow studies into one self-consistent homogeneous catalogue. Much of the problem lies in the fact that, with the exception of a few surveys beyond $\sim 100 h^{-1}$Mpc (13, 26, 12), none of the surveys within the Supergalactic sphere sample the entire sky uniformly.

2 The MarkIII Catalog of Galaxy Peculiar Velocities

In an attempt to overcome this problem, two of us (JW & SC + collaborators) have recently combined the major distance-redshift surveys from both hemispheres (published before 1994) into a catalog of 3100 galaxies (26), but showed that full homogenization at the 2% level, the minimum required for a $\geq 3\sigma$ bulk flow detection at 6000 km s$^{-1}$, cannot be achieved. Due to subjective reduction techniques and varying selection criteria, fundamental uncertainties remain when trying to match greatly disparate TF datasets (24). Furthermore, a revised calibration of the MarkIII TF zero-points based on maximal agreement with the peculiar velocities predicted by the IRAS 1.2Jy redshift survey suggests a possible source of systematic error for the data sets which cover the PP cone (23). This uncertainty has not seriously affected mass density reconstructions within the Supergalactic shell (2) but it could lead to spurious estimates of the bulk flows on larger scales. A newer calibration of the Courteau/Faber catalogue of Northern spirals, not included in MarkIII, has been published (14, 15, 3) but a revision of the MarkIII catalogue is in progress (27).

3 A New All-Sky Survey: SHELLFLOW

The need to tie all existing data bases for cosmic flow studies in an unambiguous fashion is clear. To that effect, we initiated a new survey in 1996 using NOAO facilities to measure TF distances for a complete, full-sky sample of
Sb–Sc galaxies in the Supergalactic shell for which we will obtain precise and uniform photometric and spectroscopic data. This will be the first well-defined full-sky survey to sample this scale, free of uncertainties from matching heterogeneous data sets. The SFI survey of Giovanelli et al. [10] resembles ours in its scope and sky coverage, but it relies on a separate dataset ([15]) for coverage of the Southern Sky and thus cannot attain full-sky homogeneity. Our survey, on the other hand, is designed from the outset to be homogeneous to the minimum level required for unambiguous bulk flow detection at the Supergalactic shell. Because of the overlap with existing surveys at comparable depth (MarkIII + SFI), this new compilation will be of fundamental importance in tying the majority of existing data sets together in a uniform way, which will greatly increase their usefulness for global analyses of mass fluctuations in the universe.

Our sample is selected from the Optical Redshift Survey ([19]), consisting of galaxies over the whole sky with $m_B \geq 14.5$ and $|b| \geq 20^\circ$ from the UGC, ESO, and ESGC ([1]). It includes all non-interacting Sb and Sc galaxies with redshifts between 4500 and 7000 km s$^{-1}$ from the Local Group and inclinations between 45$^\circ$ and 78$^\circ$, in regions where Burstein-Heiles extinction is less than 0.3. This yields an all-sky catalog of 297 galaxies. Following the approach of [13], we use the sample itself to calibrate the distance indicator relation; this mitigates the need to tie the sample to external TF calibrators such as clusters (although it precludes measurement of a monopole term in the velocity field). Given a TF fractional distance error of 20%, the statistical uncertainty on a bulk flow from $N = 297$ galaxies at common distance $D = 6000$ km s$^{-1}$ is $\Delta D/\sqrt{N} = 70$ km s$^{-1}$. As the measured (and much contested) bulk motions on these scales are of the order of 300 km s$^{-1}$, a detection of high statistical significance is well within reach.

4 Results and Analysis

Data taking and reduction techniques follow the basic guidelines of previous optical TF surveys ([3], [21], [3], [26]). Our survey is now complete, which is essential to achieve our statistical requirements and ensure a rigorous analysis. The spectroscopy relies on measurement of H$\alpha$ rotation velocities at 2.2 disk scale lengths for the tightest TF calibration and best match to analogous 21cm line widths ([3], [23]). The photometry is based on the Kron-Cousins $V$ and $I$ systems which will allow direct matching with two largest TF field samples to date ([15], [10]). One of the key features of this study is not only its all-sky sample selection but the independent duplication of all data reductions (by at least 2, if not 3, of us). These reductions and a first flow analysis based on the Shellflow sample alone should be published soon ([3]). We also plan a more extensive analysis using the recalibrated MarkIII combined with other new catalogs not included in the original MarkIII.
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