The Zeldovich Universe: Genesis and Growth of the Cosmic Web
Proceedings IAU Symposium No. 308, 2014
R. van de Weygaert, S. Shandarin, E. Saar & J. Einasto, eds.

doi:10.1017/S1743921316010073

Cosmological parameters from the comparison of peculiar velocities with predictions from the 2M++ density field

Michael J. Hudson[1,2], **Jonathan Carrick,**[1] **Stephen J. Turnbull**[1] **and Guilhem Lavaux,**[1,2,3,4,5]

[1]Department of Physics & Astronomy, University of Waterloo, Waterloo, ON, N2L 3G1, Canada
[2]Perimeter Institute for Theoretical Physics, 31 Caroline St. N., Waterloo, ON, N2L 2Y5, Canada
[3]CNRS, UMR7095, Institut d'Astrophysique de Paris, F-75014, Paris, France
[4]Sorbonne Universités, UPMC Univ Paris 06, UMR7095, Institut d'Astrophysique de Paris, F-75014, Paris, France
[5]Canadian Institute for Theoretical Astrophysics, University of Toronto, 60 St. George Street, Toronto, ON M5S 1A7, Canada
email: mjhudson@uwaterloo.ca

Abstract. Using redshifts from the 2M++ redshift compilation, we reconstruct the density of galaxies within 200 h^{-1}Mpc, and compare the predicted peculiar velocities Tully-Fisher and SNe peculiar velocities. The comparison yields a best-fit value of $\beta^* \equiv \Omega_{\rm m}^{0.55}/b^* = 0.431 \pm 0.021$, suggesting $\Omega_{\rm m}^{0.55}\sigma_{8,\rm lin} = 0.401 \pm 0.024$, in good agreement with other probes. The predicted peculiar velocity of the Local Group from sources within the 2M++ volume is 540 ± 40 km s^{-1}, towards $l = 268^\circ \pm 4^\circ$, $b = 38^\circ \pm 6^\circ$, which is misaligned by only 10° with the Cosmic Microwave Background dipole. To account for sources outside the 2M++ volume, we fit simultaneously for β^* and an external bulk flow in our analysis. The external bulk flow has a velocity of 159 ± 23 km s^{-1} towards $l = 304^\circ \pm 11^\circ$, $b = 6^\circ \pm 13^\circ$.

Keywords. galaxies: distances and redshifts, large-scale structure of universe, cosmological parameters, dark matter

1. Introduction

The comparison between density and velocity fields allows one to measure two important cosmological parameters. The first is $\beta^* \equiv \Omega_{\rm m}^{0.55}/b^*$, where b^* is the bias of L^* galaxies. With a measurement of σ_8^*, the L^* galaxy density fluctuation in an 8 h^{-1}Mpc sphere, this can be converted into $\Omega_{\rm m}^{0.55}\sigma_{8,\rm lin}$. The second parameter is the contribution to the large-scale flow arising from matter beyond the limits of the density field, $V_{\rm ext}$. This is sensitive to the growth rate and matter power spectrum and on very large scales. In this contribution, we summarize results from Carrick et al. (2015). We refer the reader to that paper for full technical details.

2. 2M++ Density Field

The reconstructed galaxy density field is based on the 2M++ redshift compilation (Lavaux & Hudson 2011), which in turn is based on the 2MRS redshift survey(Huchra et al. 2012), the 6dF galaxy redshift survey (Jones et al. 2009) and the Sloan Digital Sky Survey (Abazajian et al. 2009). We correct for selection effects using the usual methods. An iterative method is used to obtain the reconstructed real-space positions of galaxies,

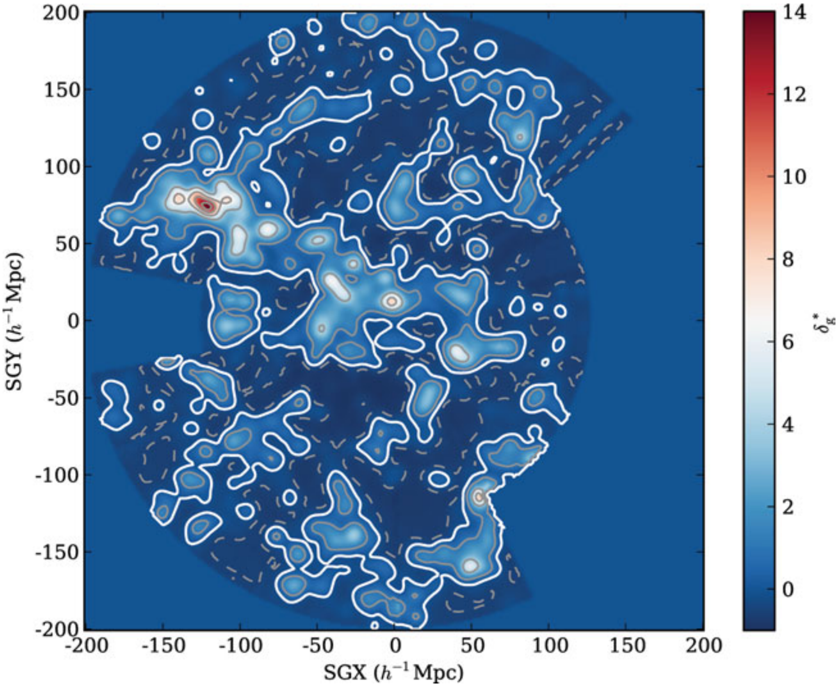

Figure 1. The Supergalactic Plane (SGZ= 0) of the 2M++ luminosity-weighted galaxy density contrast field, reconstructed with $\beta^* = 0.43$ smoothed with a Gaussian kernel of radius 4 h^{-1}Mpc. The dashed contour is $\delta_g^* = -0.5$, the bold white contour is $\delta_g^* = 0$, and successive contours thereafter increase from 1 upwards in steps of 3. The Galactic plane runs roughly along the SGY= 0 axis. The Shapley Concentration is located at (SGX, SGY) $\simeq$ (-125, 75) h^{-1}Mpc, the Virgo Supercluster directly above the LG, the Hydra-Centaurus Supercluster at (-40, 20) h^{-1}Mpc, and the Perseus-Pisces Supercluster is at (40, -30) h^{-1}Mpc. (Reproduced from Fig. 4 of "Cosmological parameters from the comparison of peculiar velocities with predictions from the 2M++ density field," , Carrick et al., MNRAS, 450, 317).

after having smoothed the density field with a Gaussian of width 4 h^{-1}Mpc. In the Appendices of Carrick et al. (2015), we show via N-body simulations that this method yields unbiased predicted peculiar velocities with a scatter of 140 km s^{-1}. Fig. 1 shows the supergalactic plane of the 2M++ galaxy density field.

We find no evidence of a large-scale underdensity within the 2M++, consistent with the results of Böhringer et al. (2015).

3. Comparison with Tully-Fisher and SNe Peculiar Velocity Data

We then compare the predicted peculiar velocities from 2M++ with peculiar velocity data from SFI++ (Springob et al. 2007, Tully-Fisher) and the "First Amendment" supernova sample (Turnbull et al. 2012). We use several methods to make the comparison: a direct method including a correction for inhomogeneous Malmquist bias, and in the case of the TF data, an inverse "VELMOD" method . We find these methods give consistent results, within the uncertainties. The best fitting β^* is 0.431 ± 0.021 with $V_{\rm ext} = 159 \pm 23$ km s^{-1} towards $l = 304° \pm 11°$, $b = 6° \pm 13°$.

When combined with a measurement of $\sigma^*_{8,\rm g}$, β^* can be used to constrain the degenerate parameter combination $f\sigma_8 = \beta^*\sigma^*_{8,\rm g}$. From 2M++, we use counts in cells within radial shells and obtain the value $\sigma^*_{8,\rm g} = 0.99 \pm 0.04$. The product of the growth factor and

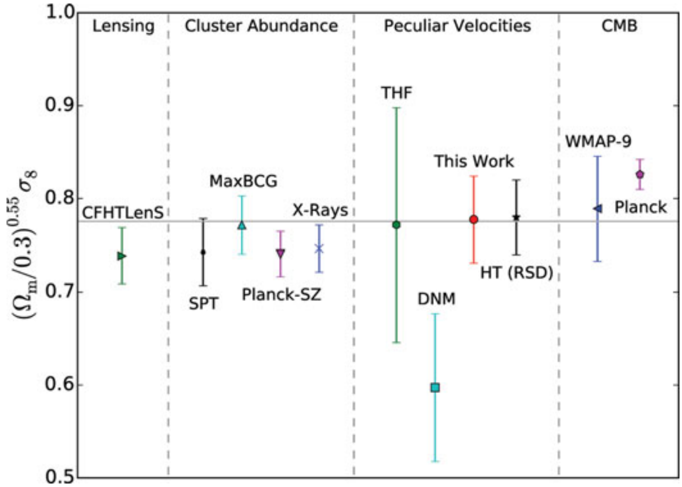

Figure 2. Comparison of $f\sigma_{8,\mathrm{lin}}$ measured results. Values plotted above derived from weak-lensing (Kilbinger et al. 2013, CFHTLenS) and cluster abundances [Reichardt et al. (2013, SPT), Rozo et al. (2010, MaxBCG), Planck Collaboration et al. (2013, Planck-SZ), Vikhlinin et al. (2009, X-rays)] have assumed a value of $\Omega_m = 0.3$ in mapping constraints to $\Omega_m^{0.55}\sigma_8$. Results obtained through previous analyses of measured peculiar velocities are also shown [Turnbull et al. (2012, THF), Davis et al. (2011, DNM)], as well as from redshift space distortions (Hudson & Turnbull 2012, HT). CMB results are from WMAP9 and the Planck Collaboration (2015) . The horizontal line is the error-weighted mean of all values ($f\sigma_8 = 0.400 \pm 0.005$), shown here for reference. (Reproduced from Fig. 8 of "Cosmological parameters from the comparison of peculiar velocities with predictions from the 2M++ density field," , Carrick et al., MNRAS, 450, 317).

non-linear σ_8 is thus $f\sigma_8 = 0.427 \pm 0.026$. We convert our non-linear value of σ_8 to a linearized value and obtain the constraint $f\sigma_{8,\mathrm{lin}} = 0.401 \pm 0.024$.

Our value of $f\sigma_{8,\mathrm{lin}} = 0.40 \pm 0.02$ is in good agreement with those obtained using the same methodology, such as Turnbull et al. (2012) (0.40 ± 0.07), Pike & Hudson (2005) (0.44 ± 0.06). It is, however, in slight tension with the result of Davis et al. (2011) who found 0.31 ± 0.04. We have also compared our value $f\sigma_{8,\mathrm{lin}}$ to constraints placed on a degenerate combination of Ω_m and σ_8 through independent means. In particular, our value is in excellent agreement with a different peculiar velocity probe, namely measurements of $f(z)\sigma_8(z)$ at different redshifts via redshift space distortions, which yield a best-fit value of $f\sigma_8 = 0.40 \pm 0.02$ (Hudson & Turnbull 2012). Fig. 2 shows a comparison between measurements of $f\sigma_{8,\mathrm{lin}}$ by several different techniques. There is some tension between some results *e.g.* Kilbinger et al. (2013) and Planck-SZ (Planck Collaboration et al. 2013) versus Planck CMB temperature (Planck Collaboration et al. 2015). The peculiar velocity result presented here is consistent with all of these values.

4. The Large Scale Velocity Field

The value of V_{ext} is consistent with previous results on a similar scale (Turnbull et al. 2012), who found 150 ± 43 km s^{-1} towards $l = 345°$, $b = 8°$ from a comparison of the A1 SNe with the PSCz reconstruction(Branchini et al. 1999).

It is interesting to compare the predicted bulk flow in a 50 h^{-1}Mpc Gaussian window with observations. The 2M++ velocity model predicts a flow of 227 ± 25 km s^{-1} towards $l = 293°$, $b = 14°$, an amplitude consistent with the cosmic variance expected in ΛCDM. This is smaller than the value of 407 ± 81 km s^{-1} towards $l = 287°$, $b = 8°$ found by Watkins et al. (2009), and 292 ± 27 km s^{-1} towards $l = 297°$, $b = 7°$ by Hong et al. (2014)

 https://doi.org/10.1017/S1743921316010073

but consistent with the 249 ± 76 km s^{-1} towards $l = 319°$, $b = 7°$ found by Turnbull et al. (2012).

5. Conclusions

By comparing the 2M++ density field with observational peculiar velocity data sets, we obtain a value of $f\sigma_{8,\mathrm{lin}}$ is consistent with previous measurements from RSD. It lies between the lower values from small-scale probes such as weak gravitational lensing and the slightly higher values predicted by Planck (Planck Collaboration et al. 2015).

The residual bulk flow, i.e. the contribution to the bulk flow due to sources outside the 2M++ volume, V_{ext}, is significantly different from zero, indicating that we have not yet resolved all of the sources of the LG's motion.

The resulting 2M++ density and peculiar velocity fields obtained from this analysis are made available at `cosmicflows.uwaterloo.ca` and `cosmicflows.iap.fr`

References

Abazajian, K. N. *et al.*, 2009, *ApJS*, 182, 543
Böhringer, H., Chon, G., Bristow, M., & Collins, C. A., 2015, *A&A*, 574, A26
Branchini, E. *et al.*, 1999, *MNRAS*, 308, 1
Carrick, J., Turnbull, S. J., Lavaux, G., & Hudson, M. J., 2015, *MNRAS*, 450, 317
Davis, M., Nusser, A., Masters, K. L., Springob, C., Huchra, J. P., & Lemson, G., 2011, *MNRAS*, 413, 2906
Hong, T. *et al.*, 2014, *MNRAS*, 445, 402
Huchra, J. P. *et al.*, 2012, *ApJS*, 199, 26
Hudson, M. J. & Turnbull S. J., 2012, *ApJL*, 751, L30
Jones, D. H. *et al.*, 2009, *MNRAS*, 399, 683
Kilbinger, M., Fu, L., Heymans, C., Simpson, F., Benjamin, J., Erben, & T., Harnois-Deraps, 2013, *MNRAS*, 430, 735
Lavaux, G. & Hudson, M. J., 2011, *MNRAS*, 416, 2840
Pike, R. W. & Hudson, M. J., 2005, *ApJ*, 635, 11
Planck Collaboration *et al.*, 2013, ArXiv e-prints
Planck Collaboration *et al.*, 2015, ArXiv e-prints
Reichardt, C. L. *et al.*, 2013, *ApJ*, 763, 127
Rozo, E. *et al.*, 2010, *ApJ*, 708, 645
Springob, C. M., Masters, K. L., Haynes, M. P., Giovanelli, R., & Marinoni, C., 2007, *ApJS*, 172, 599
Turnbull, S. J., Hudson, M. J., Feldman, H. A., Hicken, M., Kirshner, R. P., & Watkins, R., 2012, *MNRAS*, 420, 447
Vikhlinin, A. *et al.*, 2009, *ApJ*, 692, 1060
Watkins, R., Feldman, H. A., & Hudson, M. J., 2009, *MNRAS*, 392, 743