VELOCITY FIELDS FROM IRAS–PSCZ SURVEY

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ABSTRACT.
We present a self–consistent nonparametric model of the cosmic velocity field based on the spatial distribution of IRAS galaxies in the recently completed all–sky PSCz redshift survey. The dense sampling of PSCz galaxies allows us to infer peculiar velocities field up to large distances with unprecedented high resolution.
The most streaking feature of the PSCz model velocity field isa coherent large–scale streaming motion along the Perseus Pisces, Local Supercluster, Great Attractor and Shapley Concentration baseline, with no evidence for a backinfall into the Great Attractor region. Instead, material behind and around the Great Attractor is inferred to be streaming towards the Shapley Concentration.
A likelihood analysis that uses the information available on bulk velocities, cosmological dipoles and local shear has been performed to measure $\beta$. We have obtained $\beta = 0.6^{+0.22}_{-0.15} (1–\sigma)$, in agreement with other recent determinations.

1 Introduction

The Gravitational Instability picture and the Linear Biasing hypothesis provide us with a theoretical framework in which galaxy peculiar velocities are related to the inhomogeneities of the underlying mass density field, $\delta_m$. On large scales, where Linear Theory applies, the relation is remarkably simple and one can compute peculiar velocities directly from the galaxy distribution. The resulting velocity field is fully specified by the $\beta = \frac{f_{100}}{f_{60}}$ parameter, where $b$ is the bias parameter that linearly relates the inhomogeneities in the galaxy distribution to the underlying mass density field. Comparing the model velocities with the observed ones allows one to check the plausibility of the adopted theoretical scenario and to constrain the $\beta$ parameter. Here we present a new model for the velocity field predicted from the PSCz survey that we compare with existing peculiar velocity catalogues.

2 The PSCz Galaxy Survey

Large sky coverage is the basic requirement to model peculiar velocities from a redshift survey. The dataset used in this work is the recently completed PSCz redshift survey described in detail by Saunders et al. (1998) and briefly summarized here. The main catalogue contains some 15,500 IRAS PSC galaxies with $60 \mu$m flux, $f_{60}$, or greater. To avoid cirrus contamination only PSC objects with $f_{100} < 4f_{60}$ were selected. Stars were excluded by requiring that $f_{60} > 0.5f_{25}$. For our purposes, one of the most important properties of the PSCz catalogue is its large sky coverage. The only excluded regions are two thin strips in ecliptic longitude that were not observed by the IRAS satellite, the Magellanic clouds, and the area in the galactic plane where the B–band extinction exceeds 2 magnitudes. Overall, the PSCz catalogue covers $\sim 84\%$ of the sky. It is worth stressing that the survey is deeper and the galaxy sampling is denser that in any previous all–sky cata-
Figure 1. Distribution of IRAS PSC galaxies vs. redshift. The upper and the lower, shaded histograms represent the distribution of PSCz and 1.2Jy. galaxies, respectively. The curves show the expected counts as a function of distance estimated from the selection functions. The heavy line at the bottom shows the predicted distance distribution of Abell/ACO clusters. The labels give the total number of objects in each sample.

3 Building Velocity Models

Systematic errors are a major concern when modeling, measuring and comparing peculiar velocities. In the modeling phase we keep systematics under control by using three independent techniques that predict velocities from the galaxy distribution in redshift space:

1) A particle–based iterative method similar to that introduced by Yahil et al (1991), which predict the peculiar velocity of the PSCz galaxies at their real space positions.

2) A similar iterative algorithm in which, however, densities and velocities are computed onto a regular grid.

3) The Spherical Harmonics expansion technique introduced by Nusser and Davis (1994) in which the velocity field is predicted at any points in the redshift space.

All these methods assume linear or quasi–linear theory and therefore require some degree of smoothing.

Random and systematic errors for the three model velocity fields have been evaluated using a suite of mock PSCz catalogues extracted from the N–body simulations by Cole et al. (1997).

4 A Cosmographic Tour

The depth and sampling frequency of the PSCz dataset allow a reliable
Figure 2. PSC\(z\) density and velocity fields within 120 \(h^{-1}\) Mpc on a slice through the Supergalactic plane. Continuous lines represent positive isodensity contours drawn with a spacing of \(\Delta \delta_m = 0.5\). The thick line sets the 0 overdensity level. Negative contours are drawn with a dashed line. The amplitude of the velocity vectors, obtained for \(\beta = 1\), is on an arbitrary scale.

A map of the density and velocity fields to be constructed within a sphere around us of 120 \(h^{-1}\) Mpc. Figure 2 shows the PSC\(z\) model density and velocity fields smoothed with a 6 \(h^{-1}\) Mpc Gaussian filter in a slice through the Supergalactic plane.

The Local Supercluster, cluster at (SGX, SGY) = (−2.5, 11.5), is connected to the prominent Hydra–Centaurus supercluster at (SGX, SGY) = (−35, 20). Together with the Pavo–Indus–Telescopium supercluster [(SGX, SGY) = (−40, −15)], the latter makes up the well-known Coma cluster. The Virgo cluster appears as a peak at (SGX, SGY) = (0, 75). The Perseus–Pisces supercluster is at (SGX, SGY) = (45, −20) and its northern extension is visible at [(SGX, SGY) = (45, 20)]. The Cetus Wall may be seen as an elongated structure around (SGX, SGY) = (15, −50). Finally, the Shapley Concentration starts appearing towards the edges at [(SGX, SGY) = (−90, 60)]. The Sculptor void is the largest underdense region at [(SGX, SGY) = (−20, −45)], almost matched in size by the void centered at [(SGX, SGY) = (70, 50)].

The local velocity field implied by the density field is dominated by the large infall patterns towards the Great Attractor, Perseus–Pisces and Coma. A striking feature is the large-scale coherence of the velocity field, apparent as a long ridge between Cetus and Perseus–Pisces and as a
The large-scale flow along the Perseus–Pisces (North), Virgo, Great Attractor, Shapley Concentration baseline. Note that a firm prediction of the PSCz data is the lack of prominent back-infall onto the Great Attractor region.

5 The Bulk Flow

The bulk velocity represents one of the simplest low-order statistics that, in principle, can be estimated observationally and which has a theoretical counterpart. Measuring and modeling the bulk flow within a given volume, however, is prone to random and systematic uncertainties. Both errors have been estimated using the mock PSCz catalogues. Figure 3 we compare our theoretical predictions to various observational measurements. On the left-hand side we show the amplitude of the bulk velocity (lower plot) and of its SGY component (upper plot). The strip delimited by the dashed lines represents the model prediction and its 1-σ uncertainties. Filled triangles are taken from Dekel et al. (1998) and represent the bulk flow from the Mark III catalogue (Willick et al. 1997), measured using a POTENT–smoothing technique. A similar method has been applied by Eldar et al. (1998) on the SFI catalogue (Giovanelli et al. 1997). Their result is displayed with filled square. The open triangle shows the bulk flow obtained by considering the sample of SNe Ia (Riess et al. 1995). The open square displays the result by Lauer and Postman (1994). The right-hand side of the figure shows the direction in the sky of the various bulk flows. The filled circle represents the PSCz prediction. The direction of the CMB dipole is plotted for reference and is represented by an
asterisk in the centre of the figure. The bulk flow predicted using PSC\_z agrees well, both in amplitude and directions, with all the experimental determinations but, perhaps not surprisingly, disagrees with the result obtained by Lauer and Postman. Comparing predicted and measured bulk flow allows one to measure $\beta$. As indicated in the figure, we find $\beta \simeq 0.75$ with, however, a large error of $\sim 50\%$.

6 Estimating $\beta$

Predicted peculiar velocities can be compared to the observed ones to estimate $\beta$. This exercise, however, is potentially prone to systematic biases that need to be corrected for. We have performed a likelihood analysis, similar to that introduced by Strauss et al. (1992), in which such a comparison can be performed that automatically accounts for random and systematic errors in a statistical fashion. The observational quantities we consider are: the velocity of the Local Group measured from the CMB dipole ($v_{LG} = 625 \pm 25$ km s$^{-1}$ from the 4 years COBE data of Lineweaver et al. (1996)), the bulk flow measured from the Mark III catalogue by Dekel et al. (1998) and the evidence of a small “shear” ($|v_s| < 200$ km s$^{-1}$) indicating that the local flow is remarkably cold (see van de Weygaert this volume). The theoretical quantities, predicted from the distribution of PSC\_z galaxies, are: the acceleration at the position of the Local Group and the cumulative bulk flow in spheres of increasing radius. Under the hypothesis that all the quantities mentioned above are Gaussian random fields and assuming a prior model for the underlying cosmology it is possible to obtain an analytic expression for their joint probability distribution. Maximizing the distribution with respect to the free cosmological parameters allows one to estimate $\beta$. We have obtained that $\beta = 0.6^{+0.25}_{-0.15} (1-\sigma)$. Along with the constraints that this analysis sets on the other parameters, we conclude that a universe with high $\Omega_m$ is less favourite by observations.

Other techniques of constraining $\beta$ involve point–by–point velocity comparisons. Because of its dense sampling and low shot noise errors the PSC\_z velocities can be reliably modeled out to large distances and then compared with objects capable of tracing the large scale dynamics, such as clusters of galaxies. A velocity–velocity comparison of this type has been recently performed using the PSC\_z model velocity field and the SMAC catalogue of clusters’ velocities and is described by Hudson et al. in this volume.

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