# PSCZ *VS.* 1.2 JY VELOCITY FIELDS: A SPHERICAL HARMONICS COMPARISON

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We perform a detailed comparison of the *IRAS PSC*z and 1.2-Jy spherical harmonic coefficients of the predicted velocity fields in redshift space. The monopole terms predicted from the two surveys show some differences. Faint galaxies are responsible for this mismatch that disappears when extracting a *PSC*z subsample of galaxies with fluxes larger than 1.2-Jy. The analysis of *PSC*z dipole components confirms the same inconsistencies found by Davis, Nusser and Willick [1] between the *IRAS* 1.2-Jy gravity field and *Mark* III peculiar velocities. Shot-noise, which is greatly reduced in our *PSC*z gravity field, cannot be responsible for the observed mismatch.

## 1 Introduction

Nusser & Davis (NS)[3] show that in linear gravitational instability (GI) theory the peculiar velocity field in redshift space is irrotational and thus can be expressed in terms of a potential: $\vec{v} = -\nabla\Phi(\vec{s})$. The angular dependencies of the potential velocity field and the galaxy overdensity field [both measured in redshift space and expanded in spherical harmonics, $\Phi_{lm}(s)$ and $\hat{\delta}_{lm}(s)$, respectively] are related by a modified Poisson equation:

$$\frac{1}{s^2}\frac{d}{ds}\left(s^2\frac{d\Phi_{lm}}{ds}\right) - \frac{1}{1+\beta}\frac{l(l+1)\Phi_{lm}}{s^2} = \frac{\beta}{1+\beta}\left(\hat{\delta}_{lm} - \frac{1}{s}\frac{d\ln\phi}{d\ln s}\frac{d\Phi_{lm}}{ds}\right), \quad (1)$$

where $\phi(s)$ is the selection function and $\beta \equiv \Omega^{0.6}/b$, where $\Omega$ is the matter density and $b$ the bias of the galaxy distribution. To solve this differential equation we first compute the density field on an angular grid using cells of equal solid angle and 52 bins in redshift out to $s = 18\,000$ kms$^{-1}$.

$$1 + \hat{\delta}_j(\vec{s}_n) = \frac{1}{(2\pi)^{3/2}\sigma_{1.2n}^3}\sum_i^{N_j}\frac{1}{\phi(s_i)}\exp\left[-\frac{(\vec{s}_n - \vec{s}_i)^2}{2\sigma_{1.2n}^2}\right] \qquad (2)$$

where the sum is over all the galaxies within the catalogue $j$, $N_j$. The Gaussian smoothing width for the cell $n$ at redshift $s_n$, $\sigma_{1.2n}$, is given by $\sigma_{1.2n} = \max\{100, [\bar{n}_{1.2}\phi_{1.2}(s_n)]^{-1/3}\}$ km s$^{-1}$, where $\bar{n}_{1.2}$ and $\phi_{1.2}$ are the 1.2 Jy mean number density and selection function, respectively.

## 2 Datasets

The *IRAS PSC*z catalogue has been recently completed and contains $15\,500$ *IRAS* PSC galaxies with a 60 $\mu$m flux larger than 0.6 Jy. The average depth of this survey is $\approx 100\ h^{-1}$ Mpc. In our analysis we will restrict to the *PSC*z sub-sample of $11\,206$ galaxies within $20\,000$ km s$^{-1}$ from the Local Group. The unobserved region is modeled by the angular mask of Saunders *et al.* [4], which leaves unmasked 80% of the sky. This region is filled-in with the cloning procedure described in Branchini *et al.* (B99).[5]

The 1.2-Jy catalogue (Fisher *et al.* [6]) contains $5\,321$ *IRAS* PSC galaxies with a 60 $\mu m$ flux limit of 1.2-Jy within $20\,000$ km s$^{-1}$ of the Local Group. This catalogue has a slightly larger sky coverage of $\approx 87.6\%$ and a smaller median distance of $\approx 84\ h^{-1}$ Mpc. This catalogue is supplemented with "synthetic" objects in the ZoA and other excluded regions following the same technique.

## 3 Results, Discussion and Conclusions

We compare the line of sight peculiar velocities relative to the Local Group, $u(\vec{s}) \equiv [\vec{v}(\vec{v}) - \vec{v}_{LG}] \cdot \hat{s}$, obtained from the *IRAS PSC*z and 1.2-Jy redshift surveys gravity fields. The comparison is performed in redshift-space. To perform the decomposition in spherical harmonics coefficients we apply $\beta = 0.6$.

In Fig. 1 we display the monopole of the velocity field, $u_{00}$. In the left panel, the estimate of the velocity monopole in the 1.2-Jy (dashed line) is systematically larger than the *PSC*z one (continuous line) in the range $1\,000 < s < 8\,000$ km s$^{-1}$.

In Fig. 2 we show the three velocity dipole components of the two surveys along with the total amplitude (bottom left panel). The various dipole components exhibit good agreement, specially $u_{1,-1}$ (top right panel). Davis, Nusser and Willick (DNW)[1] find systematic discrepancies between the *Mark* III and *IRAS* 1.2-Jy–predicted flow fields, particularly a difference in the $m = -1$ component of the dipole. Estimating the velocity field from the *IRAS PSC*z catalogue allows us to understand the influence of sparse-sampling on the 1.2-Jy inferred fields. Since both dipoles are so similar, we might conclude that the discrepancies with the *Mark* III velocities do not disappear when the shot noise is reduced by a factor $\approx \sqrt{3}$, like in the *PSC*z velocity field.

Willick *et al.* applied their VELMOD machinery to compare the observed velocities of the *Mark* III galaxies with those predicted by the *IRAS* 1.2-Jy model within $s = 3\,000$ km s$^{-1}$. They found that the residuals are well
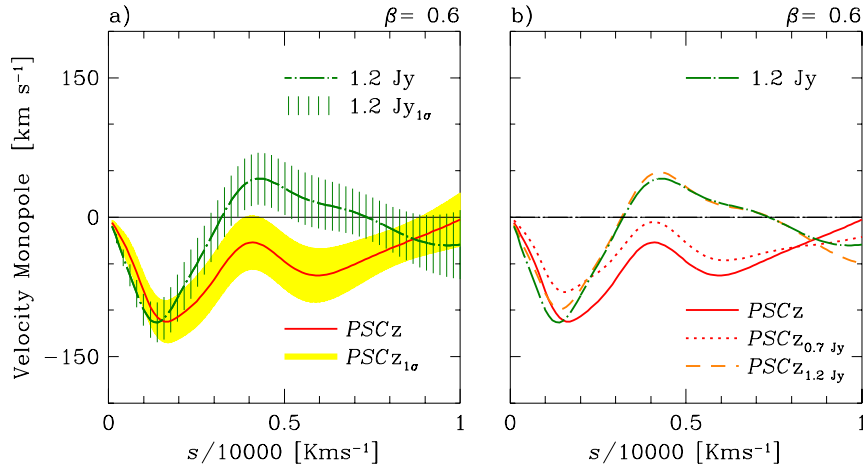
Figure 1. Monopole coefficient, $u_{00}(s)$, estimated from *PSC*z and 1.2-Jy catalogues for $\beta = 0.6$. On the two top panels dashed (thick) lines represent 1.2-Jy (*PSC*z) monopole mode of the velocity field. a) The hatched and shaded regions indicate the 1.2 Jy and *PSC*z $1-\sigma$ uncertainties, respectively. b) Dotted, dot-dashed and dashed lines represent $PSCz_{0.7}$, 1.2-Jy and $PSCz_{1.2}$, respectively.

modeled by a quadrupole with an amplitude of $\sim 3\%$ that of the Hubble flow.

In Fig. 3, the quadrupole components inferred from both *IRAS* catalogues agree quite well, except that the $m = 0, 2$ magnitudes are somewhat larger in 1.2-Jy, therefore a quadrupole mismatch between *Mark* III and the *PSC*z velocities is also to be expected. Note that when all the multipoles are considered (*i.e.* when performing a full v-v comparison) the *PSC*z and 1.2-Jy gravity fields look fully consistent (B99).[5]

In all plots, shaded and hatched regions represent 1-$\sigma$ uncertainties. These incorporate sources of errors in the velocity field: *i)* the shot-noise error due to sparse-sampling of the underlying density and velocity fields; *ii)* systematic and random errors caused by a less than perfect method of reconstruction. The uncertainties are evaluated summing in quadrature the errors due to shot-noise and filling-in procedure. We compute the shot-noise error by generating 100 bootstrap realizations of the observed distributions of *IRAS* galaxies and computing the velocity fields from these realizations. To quantify random and

systematic errors caused by the filling-in procedure we use a suite of 20 mock-catalogues that mimic the main properties of the *PSC*z and 1.2-Jy redshift surveys. A complete description of the prescription followed to quantify the velocity uncertainties can be found in Teodoro, Branchini and Frenk [8].

Where does the discrepancy between the monopoles of the *PSC*z and 1.2-Jy surveys come from? As shown in the plots, the difference is larger than that expected from the shot–noise (included in the error budget). Tadros *et al.*[9] have suggested that the *PSC*z catalogue may be incomplete for fluxes $\leq 0.7$ Jy. If true, then we would expect that the velocity monopole for the *PSC*z with a flux cut at 0.7 Jy ($PSCz_{0.7}$) would be in good agreement with the 1.2-Jy survey. The dotted line ($u_{00,PSCz_{0.7}}$) in the top panel of Fig. 1 shows shows that objects fainter than 0.7 Jy are only partially responsible for the monopole mismatch that therefore cannot be ascribed to incompleteness at low fluxes however that this is not case. It is only in cutting the *PSC*z catalogue at a flux level of 1.2 Jy that, as expected, the discrepancy disappears. This is clearly seen in the right panel of Fig. 1 in which the dashed line indicates $PSCz_{1.2}$ velocity monopole.

We conclude that a better sampled *IRAS* catalogue cannot resolve alone the mismatches between the *Mark* III peculiar velocity field and the *IRAS* predicted gravity field.

### References

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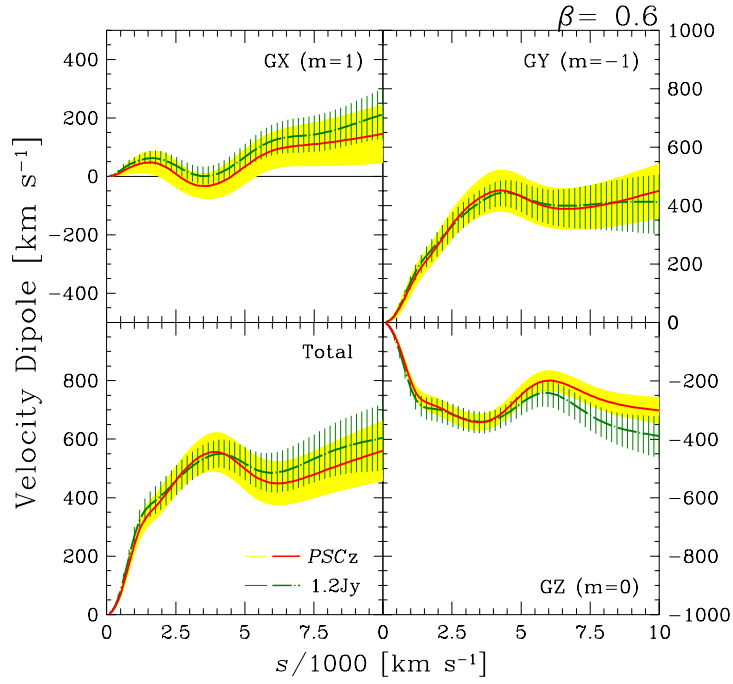8. Teodoro, L., Branchini, E. and Frenk, C.S., (in preparation)

Figure 2. The dipole coefficients, $u_{1m}(s)\{m = -1, 0, 1\}$, inferred from $PSC$z and 1.2-Jy for $\beta = 0.6$. The solid and dashed lines in the various panels represent $PSC$z and 1.2-Jy dipoles, respectively. The $GX$, $GY$, $GZ$ panels show the three Galactic components of the dipole and the bottom left is their quadrature sum. Hatched and shaded regions indicate the 1.2-Jy and $PSC$z 1–$\sigma$ uncertainty, respectively.

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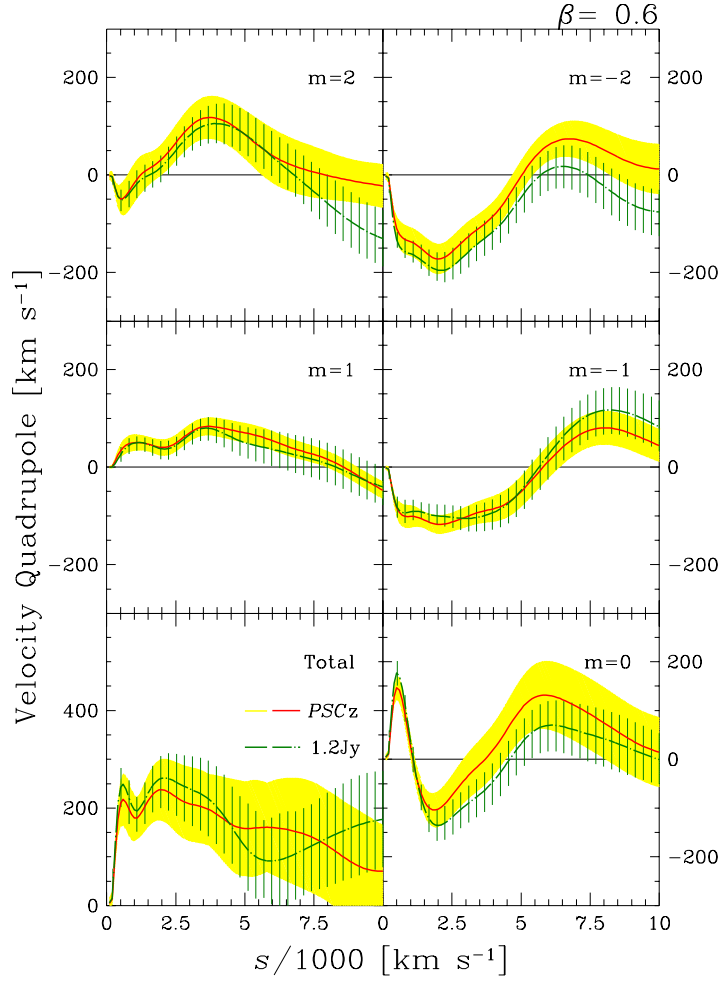
Figure 3. The quadrupole coefficients, $u_{1m}(s)\{m = -2, -1, 0, 1, 2\}$, inferred from *PSC*z and 1.2-Jy for $\beta = 0.6$. The solid and dashed lines in the various panels represent *PSC*z and 1.2-Jy quadrupoles, respectively. The $m = 0, \pm 1, \pm 2$ panels show the five Galactic components of the quadrupole and the bottom left is their quadrature sum. Hatched and shaded regions indicate the 1.2-Jy and *PSC*z 1–$\sigma$ uncertainty, respectively.