# Constraints on the Birth of the Universe and Origin of Cosmic Dark Flow

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This paper [1] reviewed several constraints on new physics in the early universe including resonant particle creation [2] and Supersymmetry motivated inflation in the M-theory landscape leading to a cosmic dark flow. Such dark flow is the result of quantum entanglement with a neighboring universe that persists during inflation [1]. This residual curvature would appear as a bulk motion of the universe with respect the the CMB frame corrected for motion with respect to the cosmic dipole moment.

We summarized [1] recent constraints on the dark (or bulk) flow velocity based upon a new analysis of the deviations from Hubble flow in the SNIa redshift-distance relation. We made two analyses: one identifying the three dimensional Cartesian velocity components; the other analyzing the cosine dependence on the sky of the deviation from Hubble flow. Fits were for $z < 0.05$ and $z > 0.05$ using both the Union2.1 [3] and SDSS-II [4,5] supernova surveys. We also studied [1] simulated data in which a bulk flow was imposed to determine whether the difficulty in detecting a bulk flow at high redshift is due to uncertainty in the redshift-distance relation, confusion with peculiar velocities, or the absence of a bulk flow. We found [1] a bulk flow velocity of $270 \pm 30\,\mathrm{km\,s^{-1}}$ in the direction $(l, b) = (295 \pm 30, 10 \pm 5)°$ in the Cartesian analysis, while the cosine analysis gave $325 \pm 50\,\mathrm{km\,s^{-1}}$ in the direction $(l, b) = (276 \pm 15, 37 \pm 3)°$, consistent with previous analyses. In the redshift bin $z > 0.05$, however, we found [1] only marginal evidence for a bulk flow velocity. We also found that the SDSS-II supernova data set has insufficient sky coverage to provide a meaningful result.

Galaxies in which a SN Ia has occurred provide, perhaps, the best alternative ([1] and refs therein) because their distances are better determined. However there are fewer data available. There has been a wide variety in the attempts to find a bulk flow in SN Ia data sets. Our study [1] differed from that of the previous analyses in several key aspects. We made an independent analysis based upon two different approaches and two separate data sets. We utilized a MCMC fit to the three Cartesian components of bulk flow velocity rather than the velocity magnitude in galactic coordinates. This approach had better stability near the Galactic pole. We then also analyzed the same data by searching for a deviation from Hubble flow with a $\cos\theta$ angular dependance on the sky. These studies established the robustness of these two complementary techniques for identifying the magnitude and direction of the bulk flow and confirmed previous detections of a bulk flow out to at least $z = 0.05$.

Having established the viability of the methods adopted, we then applied them for the first time to the large sample of (~ 1000) galactic redshifts and SN Ia distances from the *SDSS*-II survey [4,5]. However, we found that the analysis of the *SDSS*-II data was severely limited by the paucity of data in the direction of the cosmic dipole moment. We establish [1] that there is a detectable bulk flow at low redshifts, but at best a marginal detection for high redshifts.

From simulated data sets, we deduced [1] that the current uncertainty at high redshifts arises mostly from the current error in the distance modulus. We estimated [1] that with a sample like the Union2.1 data set, a detection would require both significant sky coverage of SNIa out to $z = 0.3$ and a distance modulus error reduction from 0.2 to $\leq 0.02$ mag. However, a greatly expanded data set of $3 \times 10^4$ events might detect a bulk flow even with a typical distance modulus error of 0.2 mag as may be achievable with the next generation of large surveys like LSST.

## References

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