Detectability of Cosmic Dark Flow in the Type Ia Supernova Redshift-Distance Relation

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We have re-analyzed [1] the detectability of large scale dark flow (or local bulk flow) with respect to the CMB background based upon the redshift-distance relation for Type Ia supernovae (SN Ia). If a universal CMB dipole exists it would be exceedingly interesting. Such apparent large scale motion could provide a probe into the instants before cosmic inflation, either as a remnant of multiple field inflation, pre-inflation fluctuations entering the horizon [2], or a remnant of the birth of the universe out of the mini-superspace of SUSY vacua in the M-theory landscape. Such possibilities lead to a remnant dipole curvature in the present expanding universe that would appear as coherent velocity flow relative to the frame of the cosmic microwave background . Hence, this has been dubbed [3] "cosmic dark flow."

We made two independent analyses: one based upon identifying the three Cartesian velocity components; and the other based upon the cosine dependence of the deviation from Hubble flow on the sky. We applied these analyses to the Union2.1 SN Ia data [4] and to the *SDSS*-II supernova survey [5]. For both methods, results for low redshift, $z < 0.05$, are consistent with previous searches. We find a local bulk flow of $v_{\rm bf} \sim 300\,{\rm km\,s^{-1}}$ in the direction of $(l, b) \sim (270, 35)°$. However, the search for a dark flow at $z > 0.05$ is inconclusive. The reason that the dark flow is difficult to detect for $z > 0.05$ can be traced to the large errors in the determined distance moduli of the SN Ia data. For a fixed error in the distance modulus, the actual error in the velocity increases with redshift.

Figure 1 from [1] illustrates the result of simulating surveys that accumulate SNIa events at redshift bins with $\Delta z = z/3$ centered at $z = 0.05$, 0.1, and 0.3. The intersection of the horizontal dashed line with the curves indicates the number of supernovae in Union2.1 low redshift sample.

Based upon simulated data sets, we deduce that the difficulty in detecting a dark flow at high redshifts arises mostly from the observational error in the distance modulus. Thus, even if it exists, a dark flow is not detectable at large redshift with current SN Ia data sets. We estimate that a detection would require both significant sky coverage of SN Ia out to $z = 0.3$ and a reduction in the effective distance modulus error from 0.2 mag to < 0.02 mag. We estimate that a greatly expanded data sample of $\sim 10^4$ SN Ia might detect a dark flow as small as $300\,{\rm km\,s^{-1}}$ out to $z = 0.3$ even with a distance modulus error of 0.2 mag. This may be achievable in a next generation large survey like *LSST*.

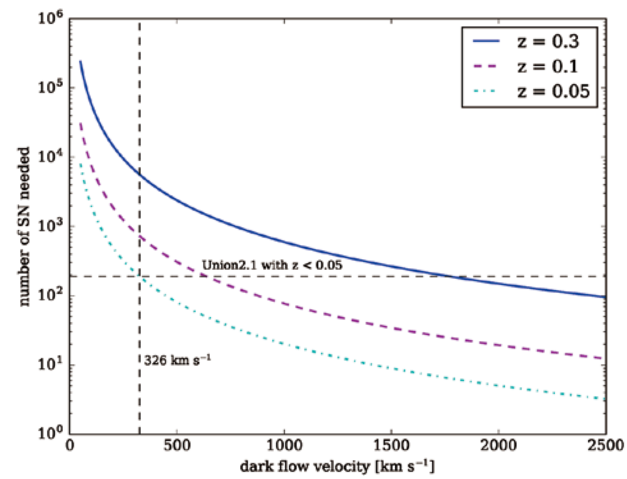

Figure 1: Illustration of the number of SN Ia required for a 3σ detection in redshift bins centered at $z = 0.05$ (dot-dashed line), $z = 0.1$ (thick dashed line), or $z = 0.3$ (thick solid line). The vertical dashed line denotes a bulk flow velocity of $326\,{\rm km\,s^{-1}}$ as inferred in our analysis of the low redshift Union2.1 sample. The intersection of this line with the lower $z = 0.05$ curve suggests that a flow was detectable in the low redshift Union2.1 sample. The intersection of this line with the upper curve, however, indicates that to detect a dark flow in at $z = 0.3$ the one needs $N > 4582$ SN Ia events.

References

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