

A note on the Measurement Dispersion at Low Redshift in Pantheon+ database

We considered the observational data extracted from online archives¹ on which is based *The Pantheon+ Analysis* by [Brout et al., 2022], relating to 1,701 SNIa in a wide redshift range ($0.0012 \leq z \leq 2.26$).

For redshift approximately in the range $z \leq 0.01$ or $\log z \leq -2$, the dispersion of distance measurements is particularly evident, see *Figure 1*, where the outliers are the data exceeding 3σ . Various studies have been published to suggest improvements in the processing methodologies of the *Pantheon+* database in the case of very low redshift and to reduce data dispersion; in particular:

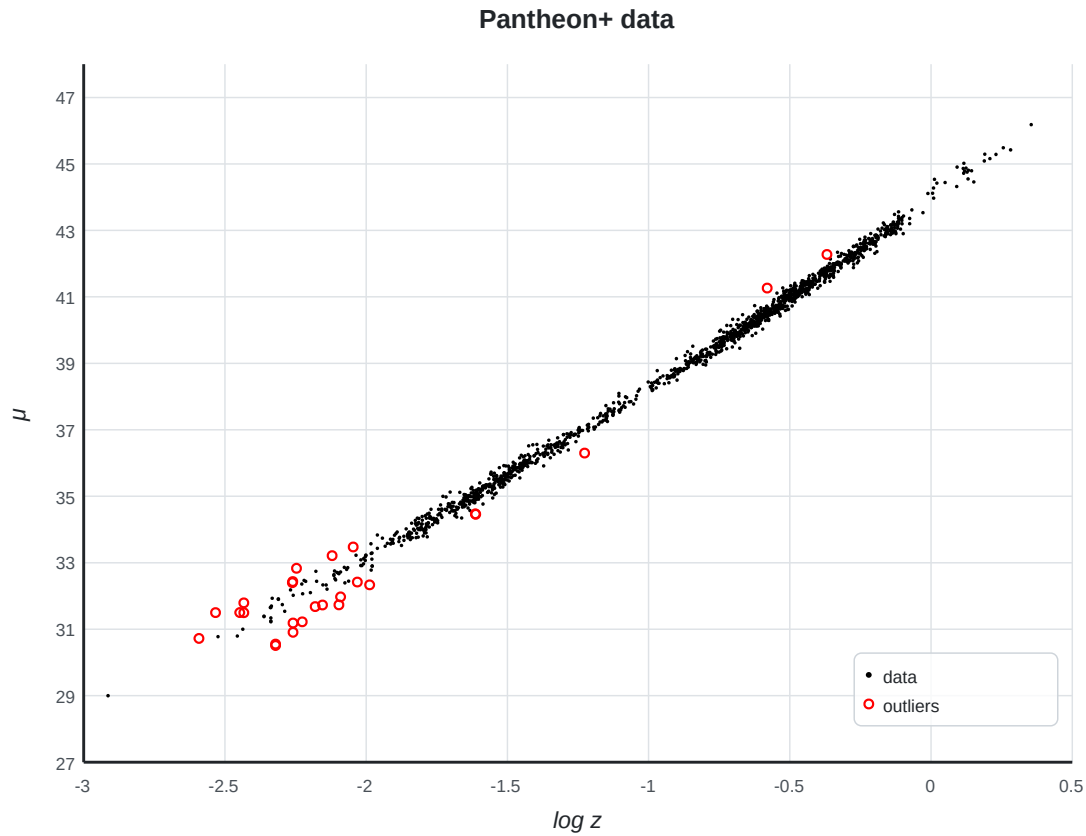
- [Peterson et al., 2022] focus on the two dominant 'motions' contributing to nearby peculiar velocities: large-scale, coherent-flow motions and small-scale motions due to gravitationally associated galaxies deemed to be in a galaxy group; they find that the optimal flow corrections derived from various local density maps significantly reduce Hubble residuals or the dispersion of distance measurements;
- [Wojtak & Hjorth, 2022] reanalyze the slopes of the colour correction in the calibration sample for SNIa standardisation, finding that the local measurement of the Hubble constant becomes dependent on the choice of SNIa reference colour, and indirectly changes the estimate of the absolute magnitude value, which can directly lead to a larger dispersion in inferred distances for the sources;
- [Perivolaropoulos & Skara, 2023] introducing the volumetric redshift scatter bias systematic and a mild signal for a change of intrinsic SNIa luminosity at about 20 Mpc; they use a likelihood model for the absolute magnitude parameter which dramatically changes the quality of fit to the *Pantheon+* sample.

Probably the dispersion of data at low redshift depends on a combination of the factors considered in the cited studies. In particular, the Phillips relation (involved in the distance modulus²), which links peak luminosity to the shape of the light curve, is particularly sensitive to peculiar effects (proper velocities, local conditions, and intrinsic variability). These at low redshift can become significant and introduce greater dispersion in the observed magnitudes and consequent calculated measurements.

¹ <https://github.com/PantheonPlusSH0ES/DataRelease>

² The distance modulus $\mu = (m - M)$ represents the difference between apparent magnitude (m) and absolute magnitude (M), and considering the distance in Mpc, is $\mu = 5 \lg(D_L) + 25 = 5 \lg(D_{URD}) + 25$; the relation with corrective parameters (SALT2 model) is $\mu = m - M + \alpha x_1 - \beta c$, where α is the coefficient that links to their luminosity the stretch of the light curves x_1 of SNIa (Phillips effect, [Phillips, 1993]) and β the coefficient that links them to color c (color correction)

Figure 1 - Pantheon+ data with outliers exceeding 3σ



References

- Brout et al., 2022 - Dillon Brout et al., *The Pantheon+ Analysis: Cosmological Constraints* (The Astrophysical Journal, Vol 938, Issue 2, id.110, 24 pp.)
- Perivolaropoulos & Skara, 2023 - Leandros Perivolaropoulos and Foteini Skara, *On the homogeneity of S_{NIa} absolute magnitude in the Pantheon+ sample* (Monthly Notices of the Royal Astronomical Society, Vol 520, pp. 5110:5125, 2023)
- Peterson et al., 2022 - Eric Peterson et al., *The Pantheon+ Analysis: Evaluating Peculiar Velocity Corrections in Cosmological Analyses with Nearby Type Ia Supernovae* (The Astrophysical Journal, 938:112, 2020)
- Phillips, 1993 - Mark Phillips, *The Absolute Magnitudes of Type IA Supernovae* (Astrophysical Journal Letters Vol 413, L105)
- Wojtak & Hjorth, 2022 - Radoslaw Wojtak and Jens Hjorth, *Intrinsic tension in the supernova sector of the local Hubble constant measurement and its implications* (The Astrophysical Journal Vol 515, 2790 , 2022)