Astronomy 622 - Debate Project

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Abstract: Ω_Λ

In this abstract, I will briefly discuss one observational method for measuring Ω_Λ, also known as the cosmological parameter for vacuum energy density or colloquially "dark energy". This method depends on several observational parameters which may contain significant uncertainties.

The method involves the use of type Ia supernovae (SNe Ia) as standard candles to test different cosmological models. Higher uncertainty in the observed magnitudes of distant SNe Ia increases the degeneracy in possible cosmological models, so reducing the error bars leads to better constraints. Observations of nearby SNe Ia can be used to fine tune and reduce uncertainty in the observed magnitudes of more distant SNe Ia. Plotting a Hubble Diagram with the apparent magnitude (m) or distance modulus ($m - M$, where M is the absolute magnitude) of the SNe versus redshift (z) produces a picture of the expansion of the universe. This picture can be tested statistically against various models. In a flat universe, where $\Omega = 1$ and $k = 0$, more dramatic dimming (increasing m) of SNe Ia at high z suggests $\Omega_\Lambda > 0$.

At nearly the same time, two different groups (Perlmutter et al. 1997; Riess et al. 1998) used versions of this method to determine with a high level of confidence that indeed $\Omega_\Lambda > 0$. Perlmutter et al. compared 7 SNe Ia in the range z = 0.35 - 0.46 with a sample of 29 SNe Ia in the range z = 0.01-0.1 in order to find a "m-z relation" and from that, values of Ω_M and Ω_Λ. In their calibrations of m for the SNe, they considered factors such as light curve width (correlated with peak luminosity), stretch factor, color and spectroscopic features, correlation with the host galaxy's properties, K-corrections, and reddening. They also limited their samples by the temporal state of the SNe in order to maintain statistical uniformity. Through a statistical analysis of their resulting "m-z relation", Perlmutter et al. found an upper limit of $\Omega_\Lambda < 0.51$, with a best fit value of 0.06 (+0.28/-0.34).

Reiss et al. used a similar method, but they employed two light curve fitting methods, a broader redshift range, and a more robust exploration of the cosmological parameter space (including H_0). Their different 15 distant SNe Ia fall within a range z = 0.16 - 0.62, while their nearby sample consist of 34 SNe Ia within z = 0.08 - 0.12. They found best fit values of $\Omega_\Lambda = 0.65 \pm 0.22$ and $\Omega_\Lambda = 0.84 \pm 0.18$ depending on the light curve fitting method.

For comparison with current results, Amanullah et al. (2010) reported recently on 6 SNe Ia at $0.51 \leq z \leq 1.12$ which they combined with previous observation to find $\Omega_\Lambda = 0.726$

(+0.037/-0.040). *Note better precision!* Values like this seem to be consistent with those found from other methods, e.g. gravitational lensing statistics and analyzing the CMB.

REFERENCES

Amanullah, R., et al. 2010, Accepted to ApJ: April 9, 2010

Perlmutter, S., et al. 1997, ApJ, 483, 565

Riess, A. G., et al. 1998, AJ, 116, 1009

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