Evidence for the Accelerating Universe

1) Supernova Data: distant SN Ia are dimmer than expected by about 20–30%.

2) Cosmic Microwave Background (CMB) anisotropies: gives $\Omega_{\text{vac}}$ close to SN value. Also gives $\Omega_{\text{tot}} = 1$ to $1/2\%$ accuracy, which cannot be accounted for without dark energy.

3) Inclusion of $\Omega_{\text{vac}} \approx 0.70$ makes the age of the universe consistent with the age of the oldest stars.

★ With the 3 arguments together, the case for the accelerating universe and $\Omega_{\text{dark energy}} \approx 0.70$ has persuaded almost everyone.

★ The simplest explanation for dark energy is vacuum energy, but “quintessence” is also possible.
If infinities are cut off at the Planck scale (quantum gravity scale), then infinities become finite, but

> 120 orders of magnitude too large!

For lack of a better explanation, many cosmologists (including Steve Weinberg and yours truly) seriously discuss the possibility that the vacuum energy density is determined by “anthropic” selection effects: that is, maybe there are many types of vacuum, with different vacuum energy densities, with most ~ 120 orders of magnitude larger than ours. Maybe we live in a very low energy density vacuum because it is conducive to life.

The handwritten draft of Einstein’s retraction included the phrase “a physical significance can hardly be ascribed to them,” referring to Friedmann’s solutions, but Einstein crossed it out before submitting.

From the Wikimedia Commons. Source: PBS NOVA, Fermilab, Office of Science, United States Department of Energy, Particle Data Group.