



Figure 1 | Averaging the Universe. These three curves represent the same distribution of matter on three different averaging scales. The blue curve shows considerable detail; the pink one is averaged on a medium scale to show the overall inhomogeneity; and the red one is averaged on a very large scale to show the uniform cosmological average. The effective general-relativistic field equations describing the behaviour of the Universe will be different at each of these scales; the essential question in assessing the role of inhomogeneities is how the averaging of the small-scale terms adds up to affect the dynamics of the large-scale averaged depiction.

But local inhomogeneities also affect cosmological observations of distant sources, which are sensitive to focusing effects on the emitted light caused by changes to the local gravitational field¹⁰. Averaged over all sources, the focusing of null geodesics — the paths followed through space-time by massless particles such as photons — agrees when a lumpy, small-scale model is averaged to attain a smooth, large-scale model. But for individual sources, a correction will be required depending on whether the light rays from the observed object traverse mainly voids or matter before reaching us. The observational effects of lumps should be determined using an averaging process based on the paths taken by light¹¹, rather than just by averaging over space. This might significantly change the apparent luminosity of distant objects, but the result will depend on the details of how matter is distributed — which is not well enough known to give a definite answer.

A new dimension to this discussion comes from David Wiltshire and others^{2,3}, and from Teppo Mattsson⁴, who argue that in analysing the observations one should take into account the dominance of large-scale voids in the Universe and the way that local pockets of higher density are tied into the expanding Universe. By going back to the roots of general relativity, Wiltshire considers how measurements of space-time in a smoothed model and in a small-scale model that takes voids into account are related. It seems that our interpretation of observations is crucially affected by the differences between the two. The magnitude of the effect may be sufficient to significantly affect the acceleration that the supernova observations seemingly demand; indeed, some claim it can explain it away fully^{3,4}. But this point of view is disputed⁵, and needs to be evaluated carefully in light of a realistic view of the nature of local inhomogeneities in the real Universe.

An alternative to locally inhomogeneous

models that might provide an explanation of the acceleration observations is large-scale inhomogeneity — a breakdown of the copernican assumption on the Hubble scale (the scale of the visible Universe)⁶. The observed acceleration and data from NASA's WMAP satellite, which is probing anisotropies in the cosmic microwave background (the radiation left over from the Big Bang), can be explained by assuming that we are near the centre of a Hubble-scale inhomogeneity of anomalously low density in a Universe that is spherically symmetrical⁷. Testing the existence of the requisite spatial inhomogeneity is difficult with observations of galaxies or other sources, because their evolution over time is unknown, but is in principle possible¹² using the anisotropies or the spectrum of the cosmic microwave background. But such tests are dependent on models of matter–radiation interactions.

Spatial homogeneity is one of the foundations of standard cosmology, so any chance to check those foundations observationally should be welcomed with open arms. Further tests are being proposed¹³, but they depend on models of gravity or matter. A potentially substantial step forward is provided by Clarkson *et al.*⁸. They show that a simple observation of the copernican principle that is independent of any theory of gravity or model for dark energy is possible through redshift and area–distance observations of distant galaxies.

As the supernova observations are analysed further, a pivotal question is what physical properties are acceptable for any proposed dark-energy solution. Despite what some adventurous workers propose, we perhaps need to query any violation of energy conditions that implies the existence of negative kinetic-energy terms, as indicated by some analyses¹⁴. It may be that such observations are trying to tell us that there is something fundamentally wrong in our assumptions; and that the acceleration



50 YEARS AGO

In these days when the output of scientific literature challenges the ability of the worker in even the most specialized fields to keep himself informed about current research, news of the publication of yet another scientific journal must sometimes be received with mixed feelings. This will not, however, prevent geologists from wishing success to the Geological Society of Egypt, which in 1957 published the first number of the *Egyptian Journal of Geology*, which is to be produced in the future twice-yearly.

From *Nature* 15 March 1958.

100 YEARS AGO

The Diseases of Animals. By Nelson S. Mayo — This work, which purports to be one of popular advice on the care and common ailments of farm animals, is written entirely from the American point of view, and deals with American methods principally, in most distinctly American orthography. It cannot be doubted that its usefulness to the British rural public, not less than the pleasure of reading it, are considerably lessened thereby. It is decidedly irritating to readers on this side of the Atlantic to see such abominations as “sulfur,” “esophagus,” “sulfate,” “mold,” and others of a similar kind. There is, nevertheless, a good deal of useful and practical information on the care of animals and farm stock which the farmer would do well to know, no matter in what part of the world he carries on his occupation ... So far as this country is concerned, there is still room for a good up-to-date popular scientific work which will give the farmer such simple knowledge of the breeding, accidents, and diseases of his animals as will show him the occasion and the wisdom of consulting the skilled veterinarian.

From *Nature* 12 March 1908.

50 & 100 YEARS AGO