More muddle over the Hubble constant

A new calculation makes it likely that Type 1a supernovae will be more useful standard candles for estimating the distance scale of the Universe, but discordance is unlikely to be banished soon.

CONFLICT and confusion about the value of the Hubble constant continue. For many years, it has been a source of acute embarrassment to cosmologists that there appear to be two distinct and discordant ranges in which observational estimates lie. On the one hand, there are values lying in the region of 50 $\text{km s}^{-1}\,\text{Mpc}^{-1}$, on the other, there is a cluster of estimates almost twice as large, in the region of 80 $\text{km s}^{-1}\,\text{Mpc}^{-1}$. (In these expressions, 'Mpc' stands for the non-SI unit megaparsec, which is a million parsecs or nearly 3 million light-years.)

The discordance is important because the Hubble constant, which is literally a measure of the rate at which the expansion velocity increases with increasing separation between our Galaxy and another, also sets the physical scale for the Universe and therefore, by inference, its age. The smaller values of the Hubble constant suggest a greater age, certainly more than 15 billion years. The larger values suggest a smaller age, perhaps 10 billion years or less.

Notoriously, the smaller ages for the Universe raise problems, at least for those who believe that the modelling of stellar structure has become a precise art-form. For it is well known that some globular clusters in our Galaxy contain stars whose age is estimated to exceed 12 billion years, and which may be as great as 16 billion years. That belief is plainly at variance with the larger estimates of the Hubble constant.

That conflict was sharpened just under a year ago, with the publication of two estimates of the Hubble constant based on observations of the variable stars called Cepheid variables in galaxies of the Virgo cluster (M. J. Pierce *et al. Nature* **371**, 385; 1994 and W. L.Freedman et al. *Nature* **371**, 757; 1994). Both measurements, based on stars in different members of the Virgo cluster, gave values for the Hubble constant in the upper range. On that basis, there seemed little doubt about the supposed conflict between the age of the Universe and that of the oldest stars in our Galaxy.

But the argument is far from being settled. For one thing, last year's results depend on arguments for telling the placing of the galaxies in which Cepheid variables were observed in relation to the cluster as a whole. That is one important source of uncertainty. Another is the difficulty of interpreting the variations of the observed brightness of the distant galaxies from which periods of oscillation must be derived.

Luckily, the second set of observations last year derived from the Hubble Telescope. The hope must be that there are more and even better observations to come. In short, the wait for a definitive answer to the question whether there is a conflict between the age of the Universe and that of the oldest known stars may not be long.

Yet the research network keeps generating numbers at the other end of the bimodal spectrum of the Hubble constant. The latest is due to a group of physicists at the University of Oklahoma and is interesting for its own sake as well as for the support it offers those who would like the talk of conflict to go away (P. Nugent *et al. Phys. Rev. Lett.* **75**, 394–397; 1995). What Nugent and his colleagues have done is to take the handful of high-quality observations of Type 1a supernova explosions and to calculate their absolute luminosity.

If the description is in any way relevant to the explosion of a star, a Type 1a supernova explosion is an almost well-ordered happening. The total energy output of the event reaches a maximum in two to three weeks, after which it decays with half-lives corresponding to the radioactive decay times of ^{56}Ni and ^{56}Co of 8.8 days and 111 days respectively.

While there is still apparently room for argument about the kinds of stars that blow up in this way, one favoured explanation is that such a supernova is formed from a white dwarf which is part of a binary system, and which accretes enough material from its companion to spring into life again. Because at least the core of a white dwarf is degenerate in the sense of quantum mechanics, the gravitational forces at the surface will be considerable, the accreted matter will be greatly compressed and thermonuclear reactions may be ignited in shells of material near or even at the surface, involving elements even heavier than helium, carbon for example. The supernova explosion takes the form of the ejection of a shell of matter. Whether or not these explosions are capable of generating elements heavier than iron is an open question, but there is no doubt that iron is one of the end products.

The essence of what Nugent and his colleagues attempt is to calculate the link between the maximum luminosity of a supernova and the time between the initial explosion and maximum brightness in two different ways. First, they tackle the transport of radiation and matter in a stellar atmosphere thrown off by the initial explosion (which is not child's play, but a relativistic problem). On that view, the length of time to maximum brightness is a rapidly increasing function of the amount of energy released in the explosion, which is what would be expected; modest explosions would quickly fizzle out.

Then they work through the consequences of supposing that the expansion of the atmosphere is driven by the successive radioactive decay of ^{56}Ni and ^{56}Co into ^{56}Fe. These processes are supposed to deposit their energy in the exploded atmophere of the star directly. At 1.1 MeV for the decay of a nickel nucleus, simple arithmetic shows that there is enough energy to keep even a supernova glowing provided that the amount of nickel is a substantial fraction of the mass of the Sun.

The outcome is of general interest. If radioactive elements play the part foreseen for them, the time to maximum brightness for all Type 1a supernove must lie between 15 and 20 days. By the authors' account, the agreement between these predictions and the behaviour of the known and well-observed supernovae of this type is as good as can be expected. The crucial point, for cosmologists, is that the same methods make it possible to calculate the absolute luminosity of a particular supernova at its peak, so providing the 'standard candle' required for fixing distances in the Universe.

The practical difficulties are nevertheless serious. Supernovae of this type do not occur every day, and then only in distant galaxies. Telling how long it takes for an explosion to reach its peak is usually a matter of searching through other people's chance observations to find when the explosion happened. Even so, there seems little doubt that the new argument will help to make a tricky class of observations more tractable.

But, of necessity, there is little chance that the muddle about the value of the Hubble constant will melt away as a result. And, sadly, the prospect that there will quickly be a dramatic increase of the distance over which people can observe these and other standard candles is not bright. A stroke of luck might put things right, but that cannot be prearranged. The pity is that while the discordance persists, cosmologists will not know which way to turn on questions like the reality of the Big Bang.

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