Astrophysics

Cepheids and cosmic distance

from David A. Hanes

OBSERVATIONAL cosmologists await with excitement the launch of the Hubble Space Telescope, which bids fair to revolutionize our view of the extragalactic Universe and, in so doing, eventually to resolve the vexed question of the correct cosmic distance scale. Nevertheless, despite optimistic predictions that the whole problem will be resolved in the course of a few days' observations (Maddox, *J. News and Views Nature* 313, 347; 1985), answers seem likely to require years of observation and analysis. This is especially the case as much of the attention has centred on the projected study of cepheid variable stars, long an indispensable tool of observational cosmologists but so far undetectable in any but the nearest galaxies.

But now, B. Madore and W. Freedman (*Astron. J.* 90, 1104; 1985) have taken a fresh look at the problem and have devised new efficient procedures which eliminate much of the tedium that has so far seemed unavoidable in the study of cepheids. Given the extremely high costs of operating the Space Telescope, the savings are of great practical importance, offering the promise of a swifter result that will contribute to the resolution of a long-standing controversy.

Cepheid variable stars are in some respects excellent distance indicators. They are intrinsically luminous and thus can be detected in remote galaxies; they draw attention to themselves by varying regularly in brightness with periods which range from a few days to a few hundred days; and they obey a well-defined period-luminosity law, with the intrinsically bright cepheids varying more slowly than their less luminous brethren. Their use is straightforward in principle. Repeated observations reveal the variability and allow the delineation of the light curve, whence comes a secure mean apparent luminosity and the period. The latter implies an absolute luminosity, once the period-luminosity law has been calibrated by nearby cepheids of known distance.

Erratum

Apologies are due to our readers and to Ira Herskowitz for an unfortunate typographical error in his article "Yeast as the universal cell" (22 August, page 678). The first sentence of the fourth paragraph should have read: "The yeast spindle is a tripartite structure, consisting of microtubules that join at one end of the centromere (the yeast version of the kinetochore of the chromosome) and at the other end to the microtubule organizing centre, the spindle pole body (analogous to the centrosome)". In the published article 'centrosome' appeared as 'centromere', thus exacerbating the terminological confusion the author was trying to clarify.

and the difference between apparent and absolute luminosity yields the distance.

Practice is more difficult. Historically, cepheids have most often been studied through the use of blue-sensitive photographic plates, which assists detection because cepheid amplitudes are largest at short wavelengths. Moreover, photographic plates can be made uniform on large scales, and are thus ideal for survey work in nearby galaxies (although they lack the sensitivity of modern electronic detectors). But each cepheid must be well studied throughout its cycle, and hundreds of long-exposure plates may be needed to delineate the light curves; thus some programmes have taken decades to complete (Sandage, A.R. *Astrophys. J.* 166, 13; 1971). Principally for this reason, extragalactic cepheids have been studied in only a few nearby galaxies. Given the small field of view of the Space Telescope and other urgent demands on it, a repetition of such programmes is neither practicable nor desirable.

Madore and his co-workers (*IAU Colloq.* 82; 1985) have already nicely simplified one aspect of the use of cepheids, by relying on the fact that, at red and near-infrared wavelength, cepheids vary with only small amplitude. Thus a single infrared 'snapshot' of a cepheid allows a precise distance estimate, provided of course that the period is already known. Moreover, the effects of interstellar obscuration and different stellar heavy element abundance are reduced at the longer wavelengths, so that certain systematic errors may be eliminated. Even so, in as yet unexplored galaxies, the need to carry out long-term surveys both to identify the cepheids and to determine their periods seems to be one of the prices which must be paid.

Or so it appeared until Madore and Freedman's most recent investigation. The question they posed was this: how can one determine the period of a cepheid without many observations at various phases? Their use of a simple analogy aids understanding their conclusion. Imagine an idealized case in which all cepheids have the same amplitude in astronomical magnitudes (relative luminosity). Suppose further that the light curve of a cepheid is a pure saw-tooth function; that is, each cepheid declines linearly in magnitude over its full period, then instantly brightens back to maximum luminosity. In this picture, long-period cepheids have slower decline rates than do short-period cepheids; moreover, a pair of brightness measurements only days apart should yield the period by a simple inversion.

Real cepheids, of course, are not so

obliging. Their amplitudes are not all the same. Moreover, while their light curves are generally not sinusoidal, neither are they perfectly saw-toothed; and it is the lower-amplitude cepheids that have the more nearly sinusoidal behaviour. One complication therefore is that a pair of randomly placed observations may straddle the turnover in the light curve or fall on the rising branch, so that the derived period is quite incorrect. However, Madore and Freedman show that, by happy coincidence, some of these effects cancel out or can be unambiguously taken into account; they predict that a large fraction of the detected cepheids will yield adequately precise periods from a single pair of brightness measurements.

There are some other complications. Although cepheids are likely to be in the majority, any star field will include variable stars of different kinds, for which the treatment is quite invalid and misleading. Moreover, any particular cepheid may have a binary companion diluting its light. But Madore and Freedman show that only slight extensions of the proposed methods — the use of several rather than two spaced observations at a few wavelengths — will resolve most of these difficulties.

Indeed Madore and Freedman describe encouraging simulated experiments in which they analysed pairs of observations separated by six or seven days, randomly drawn from the massive compilations of the photometry of the well-studied cepheid variables in the Small Magellanic Cloud, the nearest external galaxy outside the Milky Way. These observations yield reliable periods for the predicted fraction of the cepheids and produce a quite reasonable period-luminosity relationship. Although the sample is restricted, without interloping variables of other kinds, the results lend impressive support to the proposed techniques. Madore and Freedman next plan to study nearby galaxies with ground-based telescopes to quantify the accuracy attainable in actual observations.

Will these efficient techniques alone

100 years ago

THE NEW STAR IN ANDROMEDA

WE have received the following important communication from Lord Rosse:

SINCE my communication of September 8 our books have been searched for information on the past history of the nucleus of the Andromeda nebula. I subjoin in full the entries bearing upon the question whether the "new star" is now seen for the first time, or is a variable now shining out with abnormal brilliancy. The latter would appear to be the case. The nebula was frequently observed in past years with the 6-foot reflector and measures made. These measures being too few in number for a proper survey of the nebula, publication was postponed in 1878, and the details of configuration of the nebulosity have not appeared such as to merit a monograph. ROSSE

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