known Shubnikov–de Haas effect (attributable to a different quantum effect). These are also periodic in inverse magnetic field and the period $\Delta(1/B)$ provides an accurate means of measuring the electron density N_s and Fermi wavelength λ_F of the 2DEG: $\Delta(1/B) = 2e/hN_s = e\lambda_F^2/h\pi$.

The two West German groups use a similar theoretical model, based on quantum mechanical perturbation theory, to explain the magneto-oscillations. An analysis by Beenakker[8] based on classical mechanics gives a similar result. He shows that the centre of the cyclotron orbit drifts along the direction of the gate stripes when the 'resonance' condition given by the equation is satisfied. This drift motion of the electrons arises from the combined action of forces due to the magnetic field and the electric field of the superlattice. Off resonance, the orbit centre drift is negligible. ☐

L. Eaves is in the Department of Physics, Nottingham University, Nottingham NG7 2RD, UK.

COSMOLOGY

Explosive assault on Ω

Robert P. Kirshner

THE explosive effect of supernova 1987A on astrophysics vividly reminds us that supernova explosions mark the violent demise of stars, generate 10^{53} erg blasts of neutrinos, forge the elements out of which astronomers and telescopes are made, and produce (perhaps) violently spinning neutron stars. But what are they good for? On page 523 of this issue[1], an international collaboration including workers from Denmark, Australia and the United Kingdom report heroic work to discover and study the most distant supernova yet: an object at an apparent visible-band magnitude of 22.05 — near the limits of detection — in a cluster of galaxies at redshift $z = 0.31$. The authors suggest that using distant supernovae as standard candles with 10^6 times the luminosity of Cepheid variables will allow us to measure the global geometry of space, and to determine the cosmological density parameter Ω.

The technique is straightforward, but tedious. Using the 1.5-m Danish telescope at La Silla, Chile, the Danish part of the team have monitored 60 clusters in the redshift interval $0.2 < z < 0.5$ over a period of two years. Each month, for nine months of the year, they obtain 1-hour CCD (charge-coupled device) exposures and immediately compare the current frame with previous data to look for the subtle brightening that a supernova makes in the image of a distant galaxy. The group has already had one success[2], detecting an object that might be a type II supernova in a cluster at $z = 0.28$, but the current report is more revealing because a spectrum of this faint new object has been obtained at the Anglo-Australian Telescope.

The spectrum is important, because there are several types of supernovae, and they are sorted by their spectra. The type I supernovae are those with no hydrogen present, in contrast to the type II (such as SN1987A) in which hydrogen is a conspicuous feature. In recent years, it has become clear[3–5] that the type I objects must be further divided into two classes — type Ia, which show a distinct absorption attributed to Si II at a wavelength of 6,150 Å, and type Ib which lack that feature. This difference is not a mere spectroscopic detail, but is correlated with different energy output at optical, infrared and radio frequencies and probably reflects different stellar progenitors for the two types. The distant supernova measured last August has a noisy spectrum because it is so faint, and it is superposed on the light of the galaxy that contained its progenitor, but the spectrum looks remarkably like those of type Ia supernovae nearer us, once the effects of the redshift are taken into account.

The cosmological use of the type Ia objects hinges on their homogeneity[6]. The theoretical reason is that the events are likely to arise from the subsonic thermonuclear burning of carbon–oxygen white dwarfs exactly at the Chandrasekhar mass — those only just stable against gravitational collapse. Such a distinct and well-defined process may be expected to lead to a well-defined light output. The empirical reason is that a carefully selected set of good observations for type Ia supernovae shows a small (less than 0.2 mag) scatter in the magnitude at maximum[7,8].

With such a small intrinsic scatter, the measurement of distant supernovae of this type can lead to a measure of the cosmological density Ω by the classical methods of the redshift–magnitude diagram. In euclidean space, the brightness of a distant standard candle drops off as the square of the distance, but gravitational space curvature induced by the presence of matter can produce measurable deviations from this relation. It is this prospect that Norgaard-Nielsen *et al.* hold out in this issue[1]. The apparent magnitude for a type Ia object at $z = 0.3$ differs by 0.16 mag between $\Omega = 0.0$ and the Ω = exactly 1.0 so beloved of inflation theorists (Ω is normalized to the critical density needed to halt, eventually, the Universe's expansion). If the scatter in the observations is of the same order, then in a few years, observations of a handful of supernovae in distant clusters might begin to narrow the allowed range of Ω. The advantage of this approach is that the type Ia events being observed in distant clusters may be the same events as we can observe nearby: if that is exactly true, then no corrections for evolution need to be applied.

Although it is appealing to think that supernovae might lead us out of an age of ignorance and belief into an era of measurement and understanding, two observational issues need to be carefully studied before too much faith is placed in this promising approach. First, the homogeneity of the type Ia events is a matter of observation, not of faith, and there are recent spectroscopic clues that show small, but real, differences among members of this class[9]. If there is a corresponding photometric variation, then the task of determining the difference between $\Omega = 0$ and $\Omega = 1$ from the Hubble diagram may move from the formidable to the insuperable.

Second, we need to build confidence that the supernovae observed at high redshift are really the same as the supernovae observed nearby. Although the spectrum and the light curve obtained for the supernova at $z = 0.31$ resemble those of nearby supernovae, some subtle selection effect may make the supernovae found in distant clusters a little different from the local sample. A cautious way to approach this problem is to populate the Hubble diagram at intermediate redshift from $z = 0.03$ to $z = 0.3$, and to provide empirical evidence that type Ia supernovae remain superlative standard candles from our own Galaxy out to the edge of the observable Universe. The authors of the article in this issue[1] suggest that because the sought-for effect would be larger at $z = 0.5$, the best course is to press on to the highest possible redshift. However, another approach might be to shore up our knowledge of supernovae from the local neighbourhood through intermediate redshift to be certain that any observed effect comes from space curvature and not from a changing population of supernovae. ☐

Robert P. Kirshner is at the Harvard–Smithsonian Center for Astrophysics, Cambridge, Massachusetts 02138, USA.

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