It won't come to the Crunch

Celebrate our new astronomical insight into the ultimate fate of the Universe.

The Runaway Universe: The Race to Find the Future of the Cosmos
by Donald Goldsmith
Perseus: 2000. 232 pp. $25, £19.50

William H. Press

Like Lord Byron's deep and dark blue ocean, the cosmos rolls on. The cosmic expansion, as we see it relative to our own inconsequential position, proceeds at a speed of 70 kilometres per second (give or take) for every megaparsec of distance away from us. This number is the cosmologists' 'Hubble constant', its magnitude a subject of fierce dispute until the last decade, during which the likely range has so narrowed (65 to 75, say) as to make the remaining debate essentially scholastic — if no less interesting to specialists.

But is this year's Hubble constant the same as last year's? I don't mean this year's preferred measurement, but this year's actual value. Is the Universe expanding *more* or *less* rapidly this year than last year? And, if so, by how much? And can we even hope to measure what must surely be a tiny differential change?

Astonishingly, observational cosmologists are only now able to measure this effect — although there is still debate about how accurately. Even more astonishing is that the answer has turned the expectation of most theorists — not only cosmologists but also their cousins in particle and field theory — on its head.

The trick to doing the measurement is to increase the baseline: instead of comparing today's expansion with that of one year ago, compare it with that of 10^9 years ago by looking 'back in time' at very distant objects. But not just any objects will do; they must be objects with identical brethren in the here-and-now, because the differential measurement requires what amounts to a control population (astronomers refer to 'standard candles'). In just the past few years, two groups, one based at the University of California at Berkeley and the other at Harvard University, have perfected a technique for correcting the raw data from a certain kind of supernova, the 'Type Ia'. With this technique, they have created a superb control population for measuring the cosmic expansion and bringing within feasibility the measurement of its change with time.

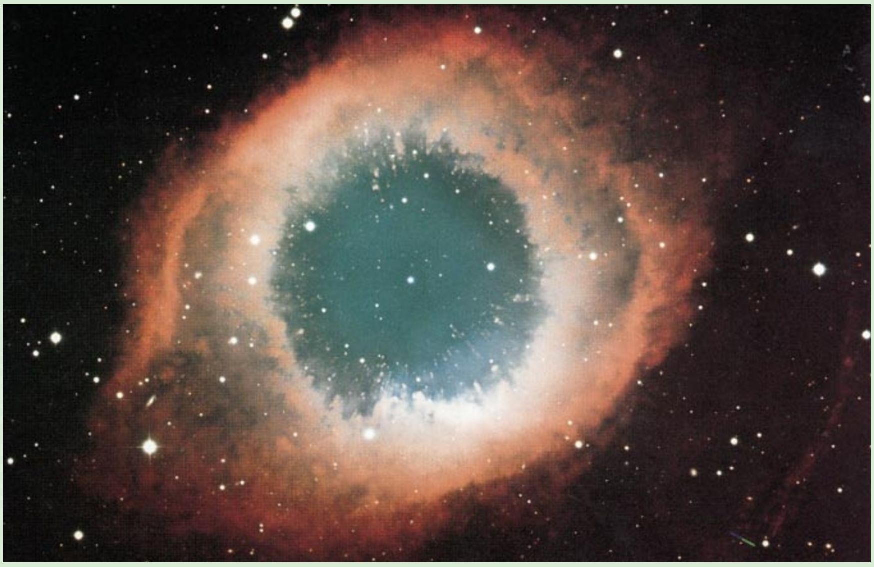
Reputable theorists all expected expansion to be slowing down. That is because gravitation is attractive, so the initial expansion of the cosmos is slowed over time by the force of gravity fighting the expansion. Until recently, the debate was always framed thus: is gravity going to win, leading to a 'Big Crunch', or is the expansion sufficiently robust that gravity will slow it only incrementally, leaving the cosmos free to 'coast' serenely to infinite expansion?

The Type Ia supernovae seem to show something much more peculiar. They do indeed indicate that the expansion is slowing, but not by as much as the known force of gravity should demand — for any plausible amount of matter. The evidence, found independently by the two groups, each with a lot of data, is that the known gravitation must be partly offset by a repulsive force (cosmologists delight in this much-repeated pun).

And so we look to the zoo of speculative repulsive forces, starting with the 'cosmological constant' invented by Einstein (and later repudiated by him), and moving to recent suggestions called 'quintessence' by their supporters (that is, a fifth essence, since physicists traditionally speak of four forces). By virtue of its seniority, although not its plausibility, the cosmological constant is given pride of place. Although now only a fractional offsetting of gravity on cosmological distances, it is destined (if it exists) to become more and more dominant with time, driving the Universe to an exponential expansion that, in a mere 10^{11} years, will drive the galaxies so far apart from one another as to make them virtually isolated sub-universes.

Hence the "runaway Universe" in the title of Donald Goldsmith's excellent exposition of these and several related matters. Goldsmith is one of the great explainers of the astronomy of our time; and an explainer's craft is of a higher order than that of a mere popularizer. In this book, the science is in no way watered down or reduced to fuzzy analogies. Rather, the author explains, carefully and precisely, in ordinary language, the entire chain of discovery and logical reasoning that underlie the broad outline given above. This makes for some pretty dense prose from time to time, and some challenging graphs to study (no equations), but the text is enlivened, mercifully, by a requisite number of scurrilous personal stories, pieces of historical context and even a good measure of plain, dry wit.

About halfway through the book, when the implications of the new supernova data are becoming weighty, the author writes:



Dwarfed by space

The Helix nebula in the constellation of Aquarius is, at 450 light-years away, the closest planetary nebula to Earth. Shown above is its central star, a very hot white dwarf. Pictures of this and many other images obtained using the world's largest telescopes, including the Hubble Space Telescope, are to be found in *Majestic Universe: Views from Here to Infinity* by Serge Brunier, translated by Storm Dunlop (Cambridge University Press, £25, $30.95). The book charts the latest advances in cosmology, and the way in which the spatial and temporal limits of the cosmos have, in the past decade, been pushed back virtually as far as the Big Bang.

"Let us pull ourselves from the slough of despond in which the implications of the new observations threaten to drown us. Rather let us lift our spirits by celebrating the new astronomical powers of insight that have brought us the latest news about the universe." A splendid idea. A few hours spent with this book is just the way to get those spirits hoisted. ■

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Magma event remembered

It is 20 years ago this month since Mount St Helens was transformed from a symmetrical cone of a mountain into a smoking crater. Its eruption killed 57 people and millions of animals, and decimated the landscape around it for hundreds of square miles. *Mount St. Helens: The Eruption and Recovery of a Volcano* by Rob Carson (Sasquatch Books, $19.95) tells the story of the event, from the preliminary, mile-high bursts of steam and ash seen throughout April, when a crater first began to open (inset, left), to the eruption itself (inset, right), its immediate aftermath, and the way in which life has slowly returned to the area.

Stopping the tectonic conveyor belt

Dynamic Earth: Plates, Plumes and Mantle Convection
by Geoffrey F. Davies
Cambridge University Press: 1999. 470 pp. £60, $90 (hbk)/£24.95, $39.95 (pbk)

David Bercovici

Geology students today are presented with the theory of plate tectonics as the grand model of how the Earth works. Centuries from now, however, it may well be viewed in the same way that we now view Kepler's laws of planetary orbits — as a set of descriptive, largely empirical rules that support a generalizable physical theory. In the case of Kepler's laws, the physical theory was Newtonian physics.

The physical theory that best accounts for plate tectonics is that of thermal convection in the mantle. In this theory, Earth's solid mantle, acting like a very viscous fluid over millions of years, loses heat as cold rock currents sink from near the surface to cool the mantle, while hot rising currents transport heat out of the mantle's deeper interior.

Convection is both elegant and universal, playing a part in everything from our cups of coffee to the interior machinations of stars. Mantle convection is thus a more fundamental theory of geology than is plate tectonics, although its presentation in most Earth-science texts is either muted or incorrect. In this regard, Geoffrey Davies' *Dynamic Earth* attempts to set the record straight: mantle convection is neither the oft-taught big wheel driving the tectonic conveyor belt nor merely small-scale circulation, unrelated to plates. As the book stresses repeatedly, the plates *are* mantle convection.

The book's underlying theme concerns the mantle's thermal boundary layers. These are relatively thin horizontal layers across which the high temperature of the mantle changes either to the colder temperatures of the atmosphere and oceans, at the upper boundary, or to the hotter temperature of the molten-iron outer core at the mantle's lower boundary. As these boundary layers retain most of the temperature contrasts of the system, they are also the primary sources of the thermal buoyancy that drives convection. The tectonic plates are thus formed from the upper thermal boundary layer, often sinking convectively along their edges in the form of cold subducting slabs which, in turn, pull the plates in their wake, hence driving plate motion. Hot mantle plumes, which cause areas of active volcanism such as occur at Hawaii and Iceland, probably emanate from the lower boundary layer.

In contrast, mid-ocean ridges, which occur in regions where plates are moving away from each other, are not pried apart by the hot upwelling currents of some giant, wheel-like convective circulation, but are pulled open passively, primarily from the force of sinking slabs. The author establishes the physical basis for this picture with clear explanations and simple equations, and uses it to explain the first-order observations, such as the surface features of the sea floor, seismic images, heat flow and mantle geochemistry.

Apart from various technical issues that I might quibble over, two philosophical problems lead me to recommend the book with caution. First, the author's presentation is quite one-sided, drawing inordinately on his own two-dimensional view of mantle convection, and only mentioning alternative ideas if he can dispatch them quickly in a few sentences. Second, he gives the impression (and even explicitly states in the introduction) that our broad understanding of mantle convection will change little beyond the views presented in the book. In science there is no progress without obsolescence, and the suggestion that little significant work remains to be done only detracts from the excitement of an active scientific field. In the end, students and instructors alike should be wary of dogmatic books that claim to be the last word on a subject.

However, despite these cautionary statements, the book is an elegant and readable exposition with a clear message of how the plates and mantle probably work. The entrance of mantle-convection theory into mainstream Earth-science education is an important cause which this book champions admirably. ■

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