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What Remains To Be Discovered: Mapping the Secrets of the Universe, the Origins of Life, and the Future of the Human Race

John Maddox

Free Press, New York, 1998.

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Although John Horgan's book *The End of Science* (Helix Books, 1996) is nowhere mentioned in John Maddox's *What Remains To Be Discovered*, the latter is clearly a reply to Horgan's contention that the most important scientific discoveries are behind us. Maddox summarizes many of the questions that will keep researchers busy for decades or centuries to come, and he is surely correct in saying that "the record of the past shows that novel conundrums are forever treading on the heels of those that still perplex." Maddox's book is engagingly written and clearly organized. But there are serious problems with it.

Maddox is amazingly opinionated about the directions in each field that are most and least ready for progress—a confidence in his own judgment that perhaps comes from his more than two decades as editor of *Nature*. The three parts of his book are titled Matter, Life, and Our World (the chapters of the third part are titled Thinking Machines, Mathematics, and The Avoidance of Calamity), but in this brief review I will concentrate on its discussion of physical science. I disagree with many of his predictions regarding the future of physics and astronomy. Among them:

▷ Einstein's hunch that a black hole is metaphysical (and thus intolerable) will be proved correct.

▷ By extension, the idea that the universe began in a single event, the big bang, will be found false. . . .

▷ [H]alf a century from now, cosmologists will have a much better idea of what kind of universe they are expected to explain. The once-and-for-all universe of Genesis, or of [Alan] Guth's [cosmic inflation] equivalent, is an improbable outcome.

I question whether Maddox understands enough about these subjects

to render a thoughtful opinion. Consider, for example, his description of the Big Bang:

"What was the universe like at the very beginning? It was simply a tiny bubble of space-time packed with energy. . . . But energy is equivalent to mass, which means that space-time in the nascent universe would have been tightly curved, following Einstein's theory of gravitation. . . . The result is that, one microsecond after the big bang, the observable universe would have been just 300 meters in radius . . . but would have been embedded in a much larger structure, the parts of the larger universe that are permanently beyond our ken."

Every single statement cited here is wrong, or at best misleading: The energy of relativistic particles is not gravitationally equivalent to mass. Spacetime was not curved in the early universe but perfectly (or at least nearly) flat. At one microsecond, the radius of the presently observable universe was not 300 m, the distance light covers in a microsecond, but a hundred billion times larger. The mismatch between these two scales is known as the "horizon problem" in cosmology: Since the distance light could have covered in the early universe is so small, even after taking into account the expansion of the universe, how could different regions have come to the same temperature to within about a part in 10^5 ? The only answer that has yet been found is cosmic inflation, which also solves other problems concerning the initial conditions.

To be sure, Horgan's scientific understanding appears to be no deeper than Maddox's. For example, his book says that, "Astronomers may find that the cosmic microwave background stems not from the flash of the big bang, but from some more mundane source, such as dust in our own Milky Way. . . . We humans may never see directly into the dust-obscured heart of our own galaxy, let alone into any other galaxy, but we may learn enough to raise doubts about the black hole hypothesis."

That the cosmic microwave background originates inside the Milky Way has been rather convincingly ruled out, while increasing evidence is being found for black holes. Infrared light penetrates interstellar dust, and recent infrared observations of stars orbiting very close to the center of the Milky Way have not only confirmed that a black hole is lurking there but also given a fairly precise value for its mass.

Let us hope that scientists do not leave entirely to journalists and editors the debate over the future of science!

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Galactic Astronomy

James Binney

and Michael Merrifield

Princeton U. P., Princeton, N.J.,

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James Binney and Michael Merrifield's *Galactic Astronomy* is one of the most important astronomy books of this decade. Within its nearly 800 pages it details almost every aspect of the nature and content of galaxies. Every astronomer will want to have it on his or her bookshelf as a reference work. As a textbook, however, it has severe shortcomings: many students will find it difficult and frustrating, and many instructors will find it unsatisfactory.

This is not a revision of a book of the same name by Dimitri Mihalas and Binney (W. H. Freeman, 1981); the authors describe it rather as a "replacement." What they mean by this is that they have drastically changed the point of view, aiming at the study of galaxies in general and touching on the Milky Way only as our local example. To support this aim, they have created an invaluable compendium of much of astronomy, not only detailing the facts about galaxies and the effort to understand them but also delving into related topics, such as nuclear astrophysics, radio-astronomy observations, and the physics of interstellar material.

It is this very wealth of factual detail that may render this book disappointing to teachers and students; the reader is presented with fact upon fact, but is not given the logical framework on which to hang them, a framework that would allow the facts to be remembered easily as parts of a coherent picture. Such a framework indeed exists in the form of our understanding of stellar structure, stellar evolution, and stellar populations. But these topics are not introduced until chapter 5; the properties of stars and the morphology of galaxies—introduced earlier—would have been so much more easily absorbed if the reader were first given the milieu in which so much about these topics is understood.

In a parallel way, the components of the Milky Way—disk, bulge, and halo—are held back until the tenth of the book's 11 chapters, thus passing by the possibility of interpreting corresponding components in other galaxies, rather than just cataloguing them and describing them. Strangely, interstellar material is discussed in earlier chapters, thus dividing the stellar inhabitants of chapter 10 from the material with which they share their lives. Fur-