

THREE COSMOLGICAL REMARKS

In traditional societies the remarks of seniors were prized, for their memories often spanned events rare enough to have remained unseen by most yet frequent enough to offer eventual challenges to all. Even here among friends who are self-styled cosmological “old radicals”, I think I am the senior.

But I am not persuaded that astronomy, for all its antiquity, ought to share the values of traditional societies. Orbital radiometers and CCDs are not very old; it is the news that is our meat, if not our bread and butter. I will therefore tell three small stories old and new.

1. One true old tale: (I suppose its effect is to praise famous men.) In the spring of 1937 I was an eager and naive graduate student under Robert Oppenheimer at Berkeley. It was Niels Bohr himself who held forth there for several evenings in a lecture series of considerable depth, though aimed at a wide university audience. His topic was fundamental physics, in particular the quantum theory and its applications, One question from the audience remains in my mind for the prescience of Bohr’s answer, a guide to my own views ever since.

The questioner asked for Bohr’s opinion of the cosmological theories of the day, the universes of LeMaitre, de Sitter, Milne and others, none of them much beyond a powerful but purely geometrical stage. Bohr’s answer came firmly though not quickly. He replied that he felt it premature to form cosmological judgments. Two great relevant domains of physics would allow real progress towards the grand questions of origins and endings only if they were taken together.

On the one hand they were the relativistic ideas of universal space-time-gravity; on the other, the nature of the fundamental particles of physics. Until these two domains should interact in some observable physical context, no sound advance could be made. In 1937 no such context had yet been recognized. The question was still premature.

That context was first dimly seen at the end of WWII by George Gamow, and by now this symposium, and every one like it is largely concerned with physical cosmology, some evolving space-time chockfull of particles known and surmised, and what they might or might not have done. We have the right context and within it much admirable data, especially from COBE, though not yet many firm answers.

2. That context is of course the early and not-so-early universe, mainly before plasma recombination, but with a long tail into the present, for instance the form of the Hubble flow and the amount and kind of dark matter. Our Symposium 168 opened with redshifts and went soon to COBE and its current ground-based augmentation.

For me it is obligatory to weigh COBE very highly, since its astonishing precision is unmatched anywhere else in cosmology. That the large-angle microwave isotropy—a neat dipole convincingly removed—is as good as 5 or 10 ppm, that the spectrum is so astonishingly Planckian, its polarization so tiny, its energy density so high—these are rock-solid results. They predispose me to any theory that makes them the natural outcome of fundamental processes, and so avoids the ubiquitous astrophysical realities, all the plausible imperfections, clustering, clumping, motions, alignments, relaxation times, local gravitational potential wells, and all the rest. The inflation idea sets them all aside by a simple process, over many orders of magnitude. That seems to me the source of its appeal. It gets first things right first. Evidently that is not yet a proof, but only the promise of an understanding of simplicity.

3). I want to add another name beside Bohr's, that of a colleague who might have been here, Sir Fred Hoyle. His direct contributions are not exceeded by those of any theorist in cosmology since Einstein. Why, it was he who even gave the name to our Symposium: "Examining the Big Bang..." Fred formed that phrase on the air in 1950 in a rather derisory mood. Yet it has stuck firmly not only among us, the happy few astronomers, but far, far beyond our IAU, to the comic strips, even into everyday slang.

I believe The Big Bang has become a term of dangerous ambiguity. Here in our Symposium 168 it is used over and over again to name all the properties we have strong evidence for: the universal spatial expansion with its dilution of matter and radiation density, long evolution, and an outrush of much uniformity at high speed. But that was not the original thrust of the term, and by far it is *not* what even well-informed science journalists, not to mention their viewers and readers, now understand by it.

Of course The Big Bang does in fact entail all those fine observable processes. We like that part. But most of those who watch us and hear us use the term freely don't really care so much about observable physical processes, grand as they are. What the term means to them—and it meant this to Hoyle too—was something singular. To Hoyle it was a true singularity of the equations of the field theory, to most others a truly singular event, a metaphysical event without a physical cause. Most outsiders would still agree with that reading.

But now we insiders usually attach the same name to quite reasonable if extraordinary *consequences* of an initial expansion of a small parcel of matter and field, not to the singular point itself. I submit that makes for real trouble.

For I do not think we have any evidence one way or another of any singularity. The popular inflation scenario imagines a region before inflation that was non-singular and fully covered by the Einstein equation. The quasi-steady state alternative, for one, postulates a C-field present, to give some sort of causal action-like account of what came before. Certainly the true singularity, The Big Bang, is not at all excluded. It might be there, just before the delta-t moment of the inflation. Who knows?

But no longer is a Big Bang out of nothing the direct extrapolation of what we see and reckon from physics. It is now only one postulate open to theorists, and not one to be expected in every theoretical account.

Symposium 168 quite properly did not much discuss *The Bang*, and I much wish we hadn't labelled all the rest of what we do in cosmology by the powerful old phrase. If we do not find a more careful way of talking—and I concede it isn't easy—I fear that Sir Fred will have had the last word with his witticism. That is one victory I doubt that he wants!

The public will continue to think that we see the First Uncaused, right there in the black-body intensity variations. Surely that inference cannot content us, even those who hold what is certainly possible, but equally certainly not proved, that the Big Bang came only just before the time horizon for the first inflation. We owe to the public appreciation of modern cosmology a clearing up of our ambiguous use of Hoyle's infectious metaphor.

An expository invention is badly needed, or at least repeated brief clarifications by the many who write on these matters—for instance, in the coming preface to Symposium 168!