Historical notes on the expanding universe

Michael Way, Ari Belenkiy, Harry Nussbaumer, and John Peacock

Readers' perspectives highlight vagaries of progress in science

Charles Day's article "A reporter's look at the progress of science" (PHYSICS TODAY, December 2013, page 35) provided a fascinating look at how scientific research does or doesn't stand up over time. Some cutting-edge research thought to be a shoo-in for the next big thing ended up going nowhere, while other investigations that appeared interesting but impractical turned out to be extremely useful. Two of the points Day makes at the end of the article are worth repeating:

▶ The time scale for research to bear fruit is unpredictable and often long.

▶ Because of that uncertainty, basic research is best undertaken by university (and I might add, government) labs, because the returns are just too risky for industry.

My experience on shale gas is a case in point. Back in the 1980s, I was working as a geology contractor for the US Department of Energy on the Eastern Gas Shales Project, which was attempting to develop new, domestic sources of natural gas in response to an oil embargo against the US.[1] Many different gas shales were investigated, and a great deal of effort and money were expended to develop resource assessments and new hydraulic fracturing technology to recover economical amounts of gas. Despite a few successes, most attempts were failures,[2] and the program was officially shut down in the early 1990s. In a paper I published describing some laboratory studies on shale core samples,[3] I mentioned that at least one of those formations, the Marcellus, might have significantly higher gas potential than official

estimates indicated. The results went largely unnoticed at the time because the economical extraction of shale gas was not yet possible.

Twenty-five years later, technological advances in horizontal drilling and staged hydraulic fracturing have made shale gas a significant contributor to domestic energy supplies in the US.[4] The project even got mentioned by President Obama in his 2012 State of the Union address, when he said, "It was public research dollars, over the course of 30 years, that helped develop the technologies to extract all this natural gas out of shale rock—reminding us that government support is critical in helping businesses get new energy ideas off the ground."

The president's statement reinforces another important point that Day makes in his article: The funding of short-term, targeted research at the expense of basic research could negatively affect the development of unforeseen and promising applications. How many basic research projects today, from astronomy and space to energy and the environment, are being short-changed by politicians concerned only about budget cutting and reelection? When basic research is not funded, we don't even know what it is that we don't know.

References

1. L. A. Schrider, R. L. Wise, *J. Pet. Technol.* **32**, 703 (1980).
2. A. I. Horton, *A Comparative Analysis of Stimulations in the Eastern Gas Shales*, rep. no. DOE/METC-145, US Department of Energy, Morgantown, WV (1981).
3. D. J. Soeder, *SPE Formation Eval.* **3**(1), 116 (1988).
4. D. J. Soeder, in *Advances in Natural Gas Technology*, H. A. Al-Megren, ed., InTech, Rijeka, Croatia (2012), chap. 1.

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■ **The article by Charles Day** about the outcome of scientific developments 10 years later caught my attention. Having worked in optical storage from the 1990s until my retirement a few years ago, I could closely watch the rise and decline of that industry. I would offer a

somewhat different perspective about three-dimensional storage than that presented in the article.

Ten years ago 3D optical storage still looked quite promising, in particular because it was assumed that magnetic storage would run into the so-called superparamagnetic limit. Several companies thought that with optical and magneto-optical storage, the magnetic hard disk could be overtaken in price and capacity, but most of the companies trying to develop the 3D technology went bankrupt after spending hundreds of millions of dollars. And Day's example, Call/Recall, never put a device on the market as far as I know.

My comments are not meant to disparage optical technology; developments in hard-disk storage capacity were just much faster than the optical-disk industry anticipated. At present, the storage density of hard disks is about 1 terabit per square inch (an ugly unit, but in common use), an order of magnitude higher than anticipated 10 years ago, and that density was achieved thanks to the application of clever physics. What we can learn from it: Not every good idea will make a fortune, particularly when one is fighting big companies like those in the hard-disk industry.

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The article "Measuring the Hubble constant" by Mario Livio and Adam Riess (PHYSICS TODAY, October 2013, page 41) reviewed studies of the expanding universe from the 1920s to the present. Although the history of the subject underwent considerable compression to fit the length of a magazine article, we think it may leave a misleading impression of some of the key steps to our current understanding. We therefore offer the following clarifications.

Most significantly, papers by Arthur Eddington and by Willem de Sitter

in 1930, who successfully promoted Georges Lemaître's 1927 article for the Scientific Society of Brussels, effected a paradigm shift in interpretation of extragalactic redshifts in 1930. Before then, the astronomical community was generally unaware of the existence of nonstatic cosmological solutions and did not broadly appreciate that redshifts could be thought of locally as Doppler shifts in an expanding matter distribution. Certainly, in 1929 Edwin Hubble referred only to the de Sitter solution of 1917. At the time, the relation between distance and redshift predicted in that model was generally seen purely as a manifestation of static spacetime curvature.

De Sitter's model motivated nearly all studies of the 1920s. Livio and Riess state that Knut Lundmark[1] "provided tentative, qualitative evidence for the expansion." But Lundmark's work was quantitative, and by 1925 he could state that "a rather definite correlation is shown between apparent dimensions and radial velocity, in the sense that the smaller and presumably more distant spirals have the higher velocity." That claim, however, cannot be evidence for "expansion," since neither the concept nor its theoretical justification were known to Lundmark, who was unaware of Alexander Friedmann's early 1920s papers.[2]

Livio and Riess also state that Lundmark's results "relied on the implausible assumption that all galaxies have the same diameter." But such empirical methods were common at the time. Hubble himself subsequently used galaxies as standard candles.[3] Despite considerable scatter, it is certainly plausible that fainter galaxies are more distant on average, and Lundmark was thus correct in concluding that radial velocity increased with distance.

We reiterate that Lundmark's pioneering efforts lacked any interpretation of a relation between distance and redshift in terms of expansion. As Livio and Riess indicate, the first person to treat data in that way was Lemaître in 1927. But the article should have emphasized the significance of Lemaître's work—that he had derived the predicted relation theoretically, based explicitly on the concept of an expanding universe. The details of Lemaître's derivation are given in reference 4.

At the time, Lemaître was thus in the company of a very small number of theorists who understood that cosmological models were generically nonstatic. As far as we are aware, the only workers who postulated or even knew of nonstatic solutions before Eddington's and de Sitter's public announcements were Friedmann, Yuri Krutkov, Paul Ehrenfest, Lemaître, and Albert Einstein (see the article by Ari Belenkiy, PHYSICS TODAY, October 2012, page 38). That small group of scientists hardly supports Livio and Riess's claim that "ever since the 1920s, physicists have known that we live in an expanding universe."

It is a pity that in addition to seriously undervaluing Lemaître's crucial role in establishing the concept of an expanding universe, Livio and Riess did not give greater emphasis to Slipher's achievements. Essentially the world's sole observer able to measure galaxy redshifts over 10 years, he single-handedly established that galaxies tended to be redshifted, which is the revolutionary discovery from which all else flowed. The centenary of his first radial velocity measurement was celebrated in a 2012 conference, and we encourage all those interested in the history of the subject to consult the proceedings.[5]

References

1. K. Lundmark, *Mon. Not. R. Astron. Soc.* **84**, 747 (1924); **85**, 865 (1925).
2. A. Friedmann, *Z. Phys.* **10**, 377 (1922); *Z. Phys.* **21**, 326 (1924).
3. See, for example, E. Hubble, M. L. Humason, *Astrophys. J.* **74**, 43 (1931).
4. H. Nussbaumer, L. Bieri, *Discovering the Expanding Universe*, Cambridge U. Press, New York (2009), chaps. 9 and 10.
5. M. J. Way, D. Hunter, eds., *Origins of the Expanding Universe: 1912–1932*, ASP Conference Proceedings 471, Astronomical Society of the Pacific, San Francisco (2013).

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■ **Livio and Riess reply:** The letter by Michael Way, Ari Belenkiy, Harry Nussbaumer, and John Peacock describes our article as if its intention was to review "studies of the expanding universe from the 1920s to the present." In fact, the intent was to describe current and future methods that are likely to yield values of the Hubble constant with errors not exceeding a few percent. We only provided a brief historical background to offer a context for the present work and for the recently discovered Lemaître letter. Accordingly, not only were many historical facts described very briefly or omitted altogether, but many past methods—planetary nebulae, novae, mass-loss rates from massive stars, and so on—that were not thought to have the potential to deliver the desired accuracy were not mentioned at all.

We are fully aware of the fascinating history of the subject. In fact, one of us reviewed the proceedings *Origins of the Expanding Universe*, Way and coauthors' reference 5, for the *Journal for the History of Astronomy*. There are a few excellent reviews of the history of the discovery of cosmic expansion, including Way and company's reference 4 by Nussbaumer and Lydia Bieri, which we encourage readers to seek out.

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Corrections

February 2014, page 58—In the second paragraph, the two occurrences of $\sin \alpha$ should be $\cos \alpha$.

April 2014, page 30—The equation-of-state parameter given in the first paragraph "Windows onto dark energy" should be $w_{DE} = -1.027 \pm 0.055$.

May 2014, page 17—The formula for thallium trifluoroacetate should be $Tl(CF_3COO)_3$. ■