Title: ***Cosmic Discovery***
Author: M. Harwit
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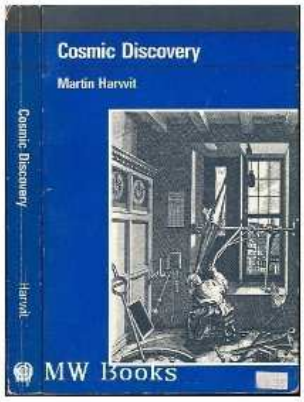
Reviewer: Whitham D. Reeve



Cosmic Discovery is the first book I have read that systematically describes the mechanics of scientific discovery. But that is only a small part of the story. It also describes the many important accidental discoveries that resulted from work unrelated to the discovery itself. This book makes it clear that the majority of important astronomical discoveries were made by outsiders who were neither trained as astronomers nor looking for astronomical phenomena. It also makes clear that advances in astrophysics did not come about as a result of theoretical insight and that further advances do not require the building of bigger and bigger optical telescopes (as is commonly claimed by many astrophysicists).

The first and second radio astronomers ever, Karl Jansky and Grote Reber, were not astronomers or even trained in astronomy – they were radio men. Cosmic microwave background radiation was accidentally discovered by terrestrial radio communications researchers trying to find excess noise in an antenna system and they did it before a group that was purposefully looking for it. There are many more examples given in the book, and not all of them are discoveries made through radio astronomy. Indeed, before World War II there was only one radio astronomy discovery – the "Electrical Disturbances Apparently of Extraterrestrial Origin" first detected by Karl Jansky in 1931 [Jansky].

Cosmology is the study of the origin and evolution of the universe. At the time this book was written and continuing through today, most progress in cosmology resulted from the use of improved technology. With few exceptions, cosmological theories are driven by surprises in measurements and most of these are made with new equipment. At first, all the new equipment came from systems that were developed during World War II and then surplused when it ended. Later, new equipment was purpose-built and most recently much of it has been specifically designed for and flown on spacecraft. The technology used in research has changed and improved immensely since ***Cosmic Discovery*** was written and presumably a lot more is understood about the universe but many questions remain unanswered. So, no, we are not there yet.

Cosmic Discovery gives both the big picture and many of the little pictures. The book has only five chapters but each is comprehensive: 1 – *The Search*; 2 – *Discoveries*; 3 – *Observation*; 4 – *Detection, Recognition and Classification of Cosmic Phenomena*; and 5 – *The Fringes of Legitimacy – The Need for Enlightened Planning*. It also has two appendices – *The Number of Undetected Species* and *Information, Capacity, and Information Rates*. At the end, just before the Index, are 12 pages of references listed by preface, chapter and appendix. The index is quite unique in that it actually is a glossary + index in which many words and phrases point to a page and also are defined. I found myself reading the index.

This book is not an artificial account written for the casual reader; it is serious and well researched, but it is easy to read and well-illustrated with charts and images (all black-white), and it certainly is well within reach of the casual reader. Chapter 2 – *Discoveries* is about 100 pages long and is especially enlightening and interesting. There are 43 sections in chapter 2, one for each type of major discovery from 1798 up to about 1984 including who, what, when, where, how and why. It is interesting to note that none of these discoveries followed the same or even similar path and there almost always was a major detachment in time between the discovery and the theory explaining it. The discoveries are summarized in tabular form in Chapter 5 – *The Fringes of Legitimacy*. Chapter 5 also tries to teach us that we have much to learn from past successes and failures. It touches on the military and commercial influences as well as the contributions by non-astronomers, all of which are important ingredients to discovery. Without them we would not even be close to where we are now – in contrast to the more recent but revisionist ***A Single Sky*** written by Munns and reviewed by me in the January-February 2014 issue of Radio Astronomy [Reeve].

The author likes to list things out including seven common traits in the major discoveries, and these are worth repeating here:

1. *The most important observational discoveries result from substantial technological innovation in observational astronomy;*
2. *Once a powerful new technique is applied in astronomy, the most profound discoveries follow with little delay;*
3. *A novel instrument soon exhausts its capacity for discovery;*
4. *New cosmic phenomena frequently are discovered by physicists and engineers or by other researchers originally trained outside astronomy;*
5. *Many of the discoveries of new phenomena involved use of equipment originally designed for military use;*
6. *The instruments used in a the discovery of new phenomena often have been constructed by the observer and used exclusively by him;*
7. *Observational discoveries of new phenomena frequently occur by chance – they combine a measure of luck with the will to pursue and understand an unexpected finding.*

In the early days of scientific discovery, just about everything was learned through visible light – the light was the carrier by which the information was transported across the universe. ***Cosmic Discovery*** tells us that in 1984, there were five known carriers, or channels, of information through which we learn about the universe: Electromagnetic waves (gamma- and x-rays through radio); cosmic ray particles (highly energetic electrons, protons and heavier nuclei); solid bodies (meteors and meteorites); neutrinos and antineutrinos; and gravitational waves. There is no mention in this book of so-called dark energy or dark matter, which I suppose also could be called channels of information by their absence of direct detection and measurement.

We are told in ***Cosmic Discovery*** that in the United States all astronomy research takes place at national centers. This should be no surprise; however, up to the time the book was written, not a single one of the 43 major cosmic discoveries mentioned above were originally at a national center. But apparently they are trying.

All research in the United States (and the world) is government funded one way or another and scientific goals, funding agency and the scientist's motivations are not always aligned. The author spends a fair amount of time offering his opinions on how future research should be conducted and, therefore, how taxpayer's money should

be spent. Everyone has their own ideas about this, and the author has some good ones. On the other hand, it is human nature to use lofty goals as justification for spending other people's money even though it is a paycheck that really matters. Many of the large radio astronomy projects being undertaken as I write this review grew from seeds planted about the time ***Cosmic Discovery*** was written 30 years ago.

Much contemporary research is centered on confirmation of the various theories of cosmology (for example, the Big Bang theory) and Einstein's theory of relativity. In a way, each confirmation is a new discovery. Except in these cases, the theory came first. Many early discoveries came first and theory came second so it is easy to conclude there is no single best method, process or path.

What characterizes an astronomical observation? ***Cosmic Discovery*** provides a laundry list with seven items:

1. Type of carrier (or information channel)
2. Wavelength or energy of the carrier
3. Angular resolution of the observing instrument
4. Spectral resolution of the observing instrument
5. Time resolution of the observing instrument
6. Polarization, if any
7. Time and date and direction observed

When we, as amateur radio astronomers, undertake our own observations, we most likely are limited by our apparatus. The angular, spectral and time resolution of our observations may be extremely broad. We may be using only one linearly polarized antenna with low directivity and, thus, cannot derive any polarization or direction information at all. Also, it is well known that data time and date stamping is problematic in amateur radio astronomy. After collecting the data, all we know is the type of information channel (radio), wavelength (frequency) and relative intensity. But serious amateurs do not simply throw up their hands and complain to congress, which would be a total waste of time anyway. Instead, they start at the top of the laundry list and work their way down, improving each line item as best they can. Thus, ***Cosmic Discovery*** not only entertains and enlightens us but also helps us get our own non-government funded observatories in order.

In conclusion, this is a very good book and it will not break the bank. I first heard about it from the director of the NRAO Operations Center in Socorro, New Mexico during a talk he gave to a group of us at the *Radio Astronomy at the Frontiers of Astrophysics* short course in 2011. He said the book served as inspiration for him to pursue the path he followed into radio astronomy. I took that as a good recommendation and after reading the book agree that ***Cosmic Discovery*** is inspiring.

Readers of this review might be interested that Physics Today magazine interviewed the author; see the October 2014 issue:
http://scitation.aip.org/content/aip/magazine/physicstoday/news/10.1063/PT.5.3015?utm_medium=email&utm_source=Physics+Today&utm_campaign=4838684_Physics+Today%3a+The+week+in+Physics+6-10+October&dm_i=1Y69,2VPJW,HPI212,AFJ1Q,1

[Jansky] Jansky, K., *Electrical Disturbances Apparently of Extraterrestrial Origin*, Proceedings of the Institute of Radio Engineers, Vol. 21, No. 10, pg 1387–1398, Oct. 1933

[Reeve] Reeve, W. Book Review of *A Single Sky: How an International Community Forged the Science of Radio Astronomy*, Society of Radio Amateur Astronomers, Radio Astronomy, January-February 2014

Reviewer - Whitham Reeve has been a director of SARA and presently is a contributing editor for the SARA journal, *Radio Astronomy*. He worked as an engineer and engineering firm owner/operator in the airline and telecommunications industries for more than 40 years and has lived in Anchorage, Alaska his entire life.