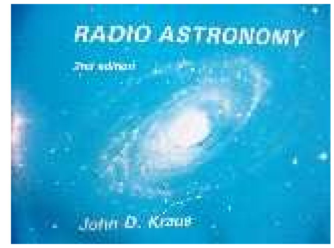

Title: ***Radio Astronomy, 2nd Ed.***
Author: J. Kraus
Publisher: Cygnus-Quasar Books
ISBN: 1-882484-00-2
Date published: 1986
Length: 721 pages + 22 pages in two indices (see text)
Status: In print
Availability: New spiral-bound softcover available for 50 USD from Radio-Sky Publishing; used spiral-bound softcover available for 42 USD from Amazon.com, used hardcover available from online book sellers for about the same price
Reviewers: Whitham D. Reeve and Wolfgang Herrmann

Radio Astronomy by John D. Kraus probably is mentioned more often than any other book when radio astronomers, especially practitioners, discuss the technical aspects of their endeavors. ***Radio Astronomy*** originally was published by McGraw-Hill Book Company in 1966 and last updated by the author in 1986 (the author died in 2004). The Cygnus-Quasar edition of this book reviewed here is a reprint of the 1986 version and was published in November 2005. It includes a 62-page hand-written solutions manual corresponding to the questions at the end of each chapter (the solutions manual is not included in hardbound editions of the book). John Kraus also wrote an excellent antenna engineering book [Kraus88], along with several other books for technical and popular audiences. One of them, ***Big Ear Two***, was reviewed by Reeve in 2011 [Kraus95]. A comprehensive list of Kraus's publications can be found at {NRAO}.

Why review a book that last was updated over 30 years ago? We review this book now because it still is relevant today and to our knowledge no in-depth review of it has ever been written. ***Radio Astronomy*** provides well-written introductory material concerning physics and electromagnetics, which have not changed since it was published. Some terminology obviously has been refined since 1986 (for example, gravity waves vs gravitational waves) but differences usually are clear from the context. Many discoveries have been made since Kraus last updated his book not only with terrestrial radio telescopes but on a huge scale with purpose-built space probes and spacecraft, which were not nearly as ubiquitous in the 1980s as now.

The parts of the book that are out-of-date do not detract from its present-day usefulness. Radio astronomers, both amateur and professional, always are searching for good books to help them understand, and we believe no other book does such good job. Anyone interested in the technical aspects of radio astronomy should have it on their bookshelf. ***Radio Astronomy*** rightfully deserves the often-seen descriptive terms "classic text" and "bible of radio astronomy". A reader with knowledge of integral calculus will obtain the most benefit from this book.

The author stated in the first edition of ***Radio Astronomy*** "*the aim of this book is to bring together a balanced selection and treatment of (radio astronomy) topics that is elementary enough to serve as an introduction to radio astronomy yet is sufficiently detailed to be useful as a teaching text and reference work*". The second edition, to which this review applies, brings into the discussion the numerous new developments over the intervening years between 1966 and 1986 including advancements in receivers and antennas as well as the number of radio sources discovered during that time.

The Cygnus-Quasar edition has two original book pages printed side-by-side on each paper page so it is not as thick as the original book but is about twice is wide. The book still is pretty hefty. The page count given at the beginning of this review is based on the original pages. The spiral binding of the Cygnus-Quasar edition allows it to lie flat when open, making it easier to use as a working reference than a thick, hard-bound book. Most readers will not go through the book from front-to-back but will go directly to a chapter or section of interest. The possible exceptions are the first several chapters, which together form an excellent introduction to radio astronomy and should be read in sequence by beginning radio astronomers.

John Kraus was not only a highly competent physicist, he also was a highly competent writer. He wrote in plain language, which makes his works easily accessible by technical and non-technical readers alike. ***Radio Astronomy*** has over 400 illustrations, all black-white and well reproduced in the Cygnus-Quasar edition. Captions are actually useful and are supported by the text. There are 1000 equations and 300 problems. Two very nice features of this book are that the author has paid close attention to units of measure and has listed all symbols and abbreviations in the front-papers – both add to overall usability and readability. Kraus makes it clear in the *Preface* that he relied on many other people for some individual chapters and a lot of data. He did a great job of editing those contributions for consistency throughout.

The book consists of twelve chapters and seven appendices. The seven initial chapters cover introductory astronomy and radio astronomy fundamentals, radio wave polarization and propagation, and radio telescope antenna and receiver design. These are followed by a group of three chapters discussing celestial radio sources – those within our solar system and Milky Way galaxy, pulsars and then extragalactic radio sources. ***Radio Astronomy*** is one of few books on the subject that discusses solar system radio sources. The last two chapters cover radio surveys and the search for extraterrestrial intelligence (SETI). Kraus was heavily involved and a pioneer in SETI. The appendices include lists of radio sources, radio astronomy frequency allocations, antenna beamwidth and sidelobe details and coordinate conversions. There is a name index of people involved in radio astronomy and a conventional subject index. The subject index is well-done, useful and indicative of good textbooks published during the author's era.

Chapter 1, *Introduction*, spends a few pages defining radio astronomy as a subset of *photon astronomy*, which encompasses the full electromagnetic spectrum including radio, infrared, optical, ultraviolet, x-ray and gamma ray radiation. Both passive and active techniques are considered. Passive astronomy involves only receivers, which receive the emissions from celestial radio sources. Active astronomy uses radar methods, which use both a transmitter and receiver. Kraus points out that radar methods are limited to the solar system because of the time delays and huge roundtrip free space propagation losses. This chapter also provides a quite decent but necessarily brief history of early radio astronomy up to about 1950. The author describes the works of Karl Jansky and then Grote Reber followed by the work of other early pioneers. The General References for this chapter list many of the original books by these pioneers as well as other introductory references written through the early 1960s. Many of these are recommended reading not only for their historical perspective and content but also because they are easier to understand than many more modern books.

In chapter 2, *General Astronomy Fundamentals*, the author provides "*topics forming an essential background*", which includes a description of our solar system. Some of the material here is outdated. For example, the listing of planets and their moons has changed – Pluto was kicked off the list a few years ago, leaving eight planets to ***Radio Astronomy***'s nine. Kraus mentions that six planets have 31 known natural satellites; by 2016 the number had grown to 171 moons. The book has a good description of our galaxy, the Milky Way, and compares it to other nearby galaxies with an introductory discussion of both their optical and radio characteristics. Kraus provides an interesting diagrammatic representation of the universe in six steps showing first the Earth-Moon System and progressing outward to the Universe as a whole. Included here and of interest to both optical and radio astronomers are the coordinate systems used in astronomy. There are many, many such systems, and many of those have highly specific purposes, but Kraus covers the most commonly used: Horizon system, Equatorial coordinates, Ecliptic coordinates and Galactic coordinates. Many other topics are covered in chapter 2 including the (crazy) stellar magnitudes.

Radio Astronomy Fundamentals is the title of chapter 3, and this is the first chapter that actually talks about the radio part of radio astronomy. This chapter has 123 equations in 47 pages and includes some basic examples of their use. The problems at the end of the chapter (and the solutions in the Cygnus-Quasar edition) cover the Wien displacement law, brightness and antenna pattern-brightness distribution. The topics in this chapter cover a lot of ground. Each topic is only briefly discussed and there are no derivations based on first principles. Kraus provides references for more detailed study, and many of them can be obtained cheaply on the used book market. Even though it is only an overview, chapter 3 is well worth studying by anyone interested in radio astronomy.

The polarization of radio waves reveals useful information about the emission source. For example, a celestial radio source that produces circular polarization will use a different process than a source that produces random polarization. Radio wave polarization is a simple subject when viewed from the narrow perspective of the linear polarization produced or received by a single dipole antenna. However, linear polarization is only a limiting condition of the more general elliptical polarization. Circular polarization is another limiting condition. When random and partial polarization are taken into account, the overall subject is quite complex. Chapter 4, *Wave Polarization*, covers this subject in 24 pages, so it is only a very brief overview. Discussions include the polarization ellipse, the Poincaré Sphere, Stokes parameters and the matrix representation of an antenna's response. Any meaningful level of polarization discussion includes trigonometry, and this chapter is no exception. The last topic covered in this chapter is polarization measurements, which makes this book unique compared to many other books on radio astronomy.

Radio wave propagation is another complex but important subject, which the author covers in chapter 5, *Wave-Propagation Fundamentals*. Electromagnetic propagation from a source millions of light-years away to an observer on Earth is no easy job, either conceptually or practically. These radio waves pass through and are corrupted by intervening intergalactic, interstellar and interplanetary gas clouds to say nothing of Earth's ionosphere. The received power on Earth is exceedingly small. These phenomena are discussed in a scant 24 pages. Kraus starts with Maxwell's equations, a traditional treatment that provides the basis for anything having to do with electromagnetics, but he quickly moves on to their practical aspects.

After studying the first five chapters in detail, the reader is now ready to learn about *Radio-Telescope Antennas* in chapter 6. This chapter is about 128 pages and includes the operation of adding, multiplying and other types of interferometers involving two antennas. Also covered is 2-dimensional aperture synthesis involving more than two antennas. Of interest to users of parabolic dish reflector antennas is a section on off-axis operation, effective aperture and surface irregularities. Kraus provides a quick overview of antenna types used at major radio observatories around the world during his time. Although this mostly is of historical interest, a surprising number of the radio telescopes (or at least their mechanical structures) are still in service today. Amateur radio astronomers might be inspired by Kraus's own humble beginnings with 250 MHz helical antennas of his own design because they are relatively easy to build (helical antennas are described in technical detail in [Kraus88]). Chapter 6 includes 36 problems at the end, some simple and some not so simple.

Logically following the chapter on antennas is chapter 7, *Radio-Telescope Receivers*. This chapter was written for the book by Martti Tiuri and Antti Räisänen. It has 75 pages and a lot of basic information. Some of the techniques described here would be considered obsolete or low performance in modern professional radio astronomy (for example, the diode vacuum tube noise generator) but, nevertheless, almost everything still is applicable. Kraus initially used electromechanical chart recorders at the receiver backend but these eventually gave way to computers and teletype machines and then digital signal processing as electronic technology progressed. Digital signal processing was in its early stages when ***Radio Astronomy*** was last updated and only a 1-bit digital autocorrelator is discussed.

Chapter 7 discusses the many types of receivers specifically developed for radio astronomy including Dicke receiver, Graham's receiver, Dicke receiver with gain modulation for balancing, null balancing Dicke receiver, simple (adding) interferometer receiver, interferometer with correlation receiver, phase-switched receiver and correlation receiver. These are outgrowths of the simple total power receiver and are meant to overcome its limitations or improve its performance. Each has a unique sensitivity constant that is used in the ideal radiometer equation. The chapter discusses measurement of receiver noise temperature, an extremely important characteristic of any radio telescope. The chapter includes so much fundamental radio astronomy receiver information that it should not be skipped by anyone serious about their work or hobby. Readers of Kraus's books will readily notice he leans toward practical considerations wherever possible, and even though he did not write this chapter, it follows his style.

Chapter 8 is the most comprehensive chapter of the book encompassing 136 pages. It is titled *The Radio Sky, Spectra, the Solar System and Our Galaxy*. As the author states in his introduction to the chapter it is intended as a "*summary ... of some of the principal observational results of radio astronomy*". This can safely be considered as an understatement as a very substantial range is covered in great detail. The chapter starts with a description of the radio sky as seen at various frequencies and covers the detection of the 3 K cosmic microwave background radiation. Then the spectra of different sources are discussed covering thermal and non-thermal sources, followed by a description of ionized hydrogen. Some more in-depth background of synchrotron radiation is given subsequently; this section may require a bit more than average mathematical skills. After this overview, the chapter continues to describe specific sources.

As already pointed out this book covers the sun and its radio characteristics in great detail, a total of about 20 pages are devoted to this subject. This is followed by some considerations related to the moon and major planets. The most important part of it and of specific interest to amateurs is the comprehensive coverage of Jupiter and one of its moons Io. After having covered our solar system, the chapter reaches farther out into our galaxy and describes the two types of the most important continuum sources, supernova remnants and star forming (HII) regions. The famous hydrogen line emission at 21 cm is covered next, starting with the history of its discovery. The implications of the observed Doppler shift structure for the analysis of the Milky Way structure is pointed out, and an example for absorption lines is provided. Other interstellar molecular lines are described, including a table of the wealth of molecules that were already observed at the time of the publication of the book. A brief section deals with radio recombination lines. The chapter finishes with the galactic center and some variable sources.

Chapter 9 deals with *Pulsars*. It starts with the history of the discovery of pulsars and then continues in a somewhat unusual sequence. Rather than explaining the origin of the pulsar radiation the author prefers to deal with some aspects of the propagation characteristics (dispersion) first, continuing with pulsar fluxes. The section on pulsar surveys can be considered outdated by today's standards, but the section on spectra and spin down of pulsars is still up to date. The high stability of the pulsar rotation is highlighted with their application as standard clocks. Then the author covers another important aspect of the effects of interstellar matter on propagation, scintillation. What would have been expected earlier in the chapter, i.e. the origin of the pulsar radiation is covered next before the chapter finishes with binary systems and the indirect detection of gravitational waves due to the observation of such systems. We find this chapter a bit "unsorted". While all important aspects are covered, re-ordering would have helped in understanding the interesting pulsar subject. This deficiency however can be overcome by choosing a different sequence while reading this chapter.

Having covered all major aspects of our galaxy by now, it is time to reach out farther into space with Chapter 10, *Extragalactic Radio Astronomy*. The author compares various types of extragalactic radio sources with galactic sources demonstrating the enormous powers involved. At the time of the publication of this book it was not known that different extragalactic sources are actually of the same nature and differ only in their orientation towards the observer. This is one of the few subjects where one notices that the book was published some time ago. As a result of this, the discussion of various radio galaxies is a bit split up within the chapter. Of specific interest to the amateur may be the explanation of the Andromeda galaxy as the observation of the hydrogen emission from this galaxy is within the realm of possibilities of the ambitious amateur. Two subjects in this chapter may be quite involved: The explanation of the 10^{12} K limit and the superluminal expansion. Here it is helpful that the author give a number of examples for his calculation. The chapter finishes with some cosmological considerations.

Chapter 11 covers the subject of *Radio Surveys*. It gives a comprehensive overview of the surveys which were available at the time of writing. Even though in the meantime more surveys have been performed, these later ones are typically of a more specialized nature. The surveys covered are therefore still important today and in particular the amateur will benefit. Obviously the coverage of John Krauss' own survey, the Ohio survey, is covered in more detail including a description of the processing techniques.

SETI is the headline of the last chapter 12 which explains the rationale of such a search and which frequencies of observations have been chosen. The parameters of the possible distance where a detectable signal can be expected are explained, again using a practical example. The chapter finishes with the searches that had been done in the past.

The appendices consist of a list of radio sources (quite helpful for the amateur) referencing the various surveys, a Messier list, the frequency allocations for radio astronomy, examples for beam width and side lobes for various apertures and a precession chart and graphical conversion chart from equatorial to galactic coordinates. The latter two may not be so useful today as good software tools are readily available.

In conclusion this still is an excellent book with only very few things to criticize. It can be considered as the number one choice for anyone who wants to get serious with radio astronomy.

Citations:

[Kraus88] Kraus, J., Antennas, 2nd Ed., McGraw-Hill Book Co., 1988

[Kraus95] Kraus, J., *Big Ear Two - Listening for Other-Worlds*, Cygnus-Quasar Books, 1995 (a review of this book appears in the April-May 2011 issue of *Radio Astronomy*)

{NRAO} http://www.nrao.edu/archives/Kraus/kraus_bibliography.shtml

Reviewer - Whitham Reeve 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. Contact: whitreeve@gmail.com

Reviewer – Wolfgang Herrmann is the president of the "Astropeiler Stockert e.V." He received his PhD in Physics from the University of Bonn. He has spent most of his professional career in the telecommunication industry. At retirement age, he now enjoys learning as much as possible about radio astronomy, doing observations and improving the instrument. Contact: messbetrieb@astropeiler.de

Radio astronomy has led to substantial increases in astronomical knowledge, particularly with the discovery of several classes of new objects, including pulsars, quasars, and radio galaxies. This is because radio astronomy allows us to see things that are not detectable in optical astronomy. Such objects represent some of the most extreme and energetic physical processes in the universe. Radio astronomy is a subfield of astronomy that studies celestial objects at radio frequencies. The first detection of radio waves from an astronomical object was in 1932, when Karl Jansky at Bell Telephone Laboratories observed radiation coming from the Milky Way. Subsequent observations have identified a number of different sources of radio emission. These include stars and galaxies, as well as entirely new classes of objects, such as radio galaxies, quasars, pulsars, and masers. The discovery of The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. Founded in 1956, the NRAO provides state-of-the-art radio telescope facilities for use by the international scientific community. NRAO telescopes are open to all astronomers regardless of institutional or national affiliation.

What do we Learn From Radio Astronomy? Radio astronomy has changed the way we view the Universe and dramatically increased our knowledge of it. Traditional optical astronomy is great for studying objects such as stars and galaxies that emit a lot of visible light. Individual stars, however, are normally only weak emitters of radio waves. We detect radio waves from our Sun only because it is so close although its radio emissions can play havoc with radio communications on Earth when a solar storm erupts. Radio Astronomy. 795 likes Â· 5 talking about this. Radio Astronomy is a down-to-Earth dialogue between UW Madison astronomers exploring the latest in...Â On Saturday, a meteor blazed a path over Madison! On today's show, Zach and Kendall will talk about what meteors are, why they light up the sky, and what we can learn from them. Tune into WORT 89.9FM at ~6:35CT tonight! Radio Astronomy. 12 November 2019 Â·. Radio astronomy is a subfield of astronomy that studies celestial objects at radio frequencies. The first detection of radio waves from an astronomical object was in 1932, when Karl Jansky at Bell Telephone Laboratories observed radiation coming from the Milky Way. Subsequent observations have identified a number of different sources of radio emission. These include stars and galaxies, as well as entirely new classes of objects, such as radio galaxies, quasars, pulsars, and masers. The discovery of