Synthesis Imaging in Radio Astronomy
Reading Note

Renkun Kuang

September 19, 2019

Contents

Preface

The Summer School on Synthesis Imaging held in Socorro, New Mexico from June 17 to June 23, 1998 was the sixth in a series held approximately every three years. This Volume contains the edited texts of lectures from the series, and succeeds the previous collection from the Third Synthesis Imaging Summer School published in 1989. It is intended for **serious students of synthesis imaging and image processing.**

Purpose of the course

The NRAO operates two of the world's most powerful synthesis radio telescopes, the Very Large Array (VLA) and the Very Long Baseline Array (VLBA), a synthesis tele- scope.
(Now in 2019, there are three telescopes, including ALMA, https://public.nrao.edu/)
The major goal of this course, like that of its predecessors beginning in 1982 was to **inform potential users of these two synthesis telescopes about the principles of these instruments' operation, about subtleties of data acquisition, calibration and processing with such instruments, and about techniques for obtaining the best results from them.**

As such, the course is aimed first at radio astronomers who need synthesis techniques and instruments for their research. Get practical experience of synthesis imaging, Fourier methods and coherence. Many of the exciting developments in data processing that have made synthesis telescopes so powerful. We therefore have set out to **discuss the subject as fully as necessary for those who**

wish to use the NRAO's radio synthesis instruments for their own research. Our goal is to **discuss the subject in enough detail that the student can appreciate both the strengths and limitations of the synthesis technique**, and so begin to evaluate how much, or how little, credence to give individual synthesis images. **To exploit an instrument fully for frontier research, the user must understand it thoroughly enough to distinguish unexpected instrumental errors from unexpected discoveries about the cosmos. A firm understanding of synthesis instruments involves understanding their operating principles (and the assumptions that underlie them), their hardware and the algorithms and software used in the data reduction.** All these topics are covered here.

Although synthesis imaging is a specialized skill even within radio astronomy, it is grounded in mathematical and physical principles that have applications in other fields. Interpret images made by synthesis telescopes. It may also interest researchers who **use Fourier methods or deconvolution techniques for imaging in physics, medicine, remote sensing, seismology or radar.**

Subject matter

The first segment of the course contains sixteen lectures that describe the fundamentals of synthesis imaging and which could be read as a stand-alone course by the beginning student. The second segment consists of seventeen lectures on more advanced and specialized topics.

NRAO lore

AIPS
https://public.nrao.edu/
The on-line bibliographic Abstract Service of the Astrophysics Data System at Harvard University.

This book is dedicated to the memory of Daniel S. Briggs. Dan was killed in a skydiving accident near Chicago just a few weeks after the summer school. Dan was an enthusiastic teacher and researcher who will be sorely missed. His 'Robust' weighting scheme has become the standard for synthesis imaging. At the summer school he gave an excellent lecture on imaging and deconvolution (see Lectures 7 and 8 of this volume contributed by Dan and collaborators). He entered thoroughly into the spirit of the summer school — attending all the lectures and interacting

with many of the participants. Dan also influenced the style of this book by making many helpful suggestions. We are in his debt.

Chapter 1

Coherence in Radio Astronomy

In this lecture the **main principles of synthesis imaging are derived.**

1.1 Introduction

A survey of the derivation of the main principles of synthesis imaging, and the assumptions that go into them. This is because a substantial number of the lectures to follow will discuss the problems which arise when these assumptions are violated under the conditions of the observation the astronomer wants to make. At the same time, I will cast this introduction into the terminology of modern optics, in an attempt to stay abreast of current fashions in physics.

Some reference books, e.g. The alternate viewpoint on radio interferometers, from the perspective of the electrical engineers who originally developed them, is explicated in Swenson & Mathur (1968).
The interferometer in radio astronomy, IEEE, 1968

other:
SparseRI: A Compressed Sensing Framework for Aperture Synthesis Imaging in Radio Astronomy
The Sensitivity of Synthetic Aperture Radiometers for Remote Sensing Applications From Space
Basics of Interferometer, PPT