Synthesis Imaging Workshop

Introduction

R. D. Ekers

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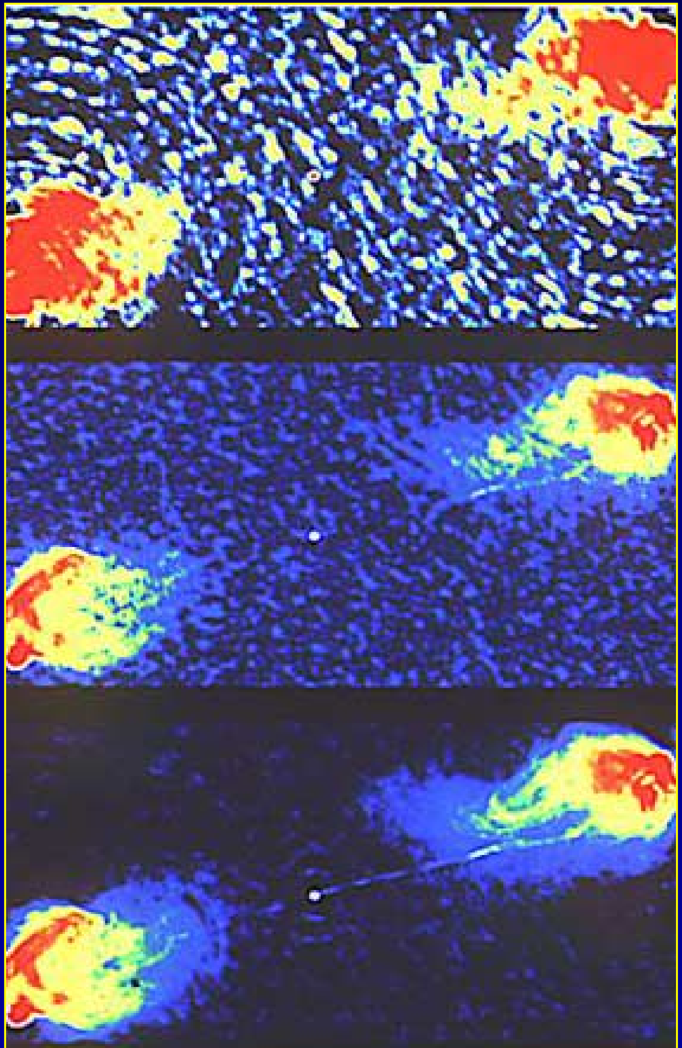
WHY?

- Importance in radio astronomy
  - ATCA, VLA, WSRT, DRAO, MERLIN, BIMA, IRAM...
  - VLBA, JIVE, VSOP, APT
  - ALMA, LOFAR, SKA

Cygnus A



- Raw data
  - VLA continuum
- Deconvolution
  - correcting for gaps between telescopes
- Self Calibration
  - adaptive optics

WHY?

- Importance in radio astronomy
  – ATCA, VLA, WSRT, DRAO, MERLIN, BIMA, IRAM...
  – VLBA, JIVE, VSOP, APT
  – ALMA, LOFAR, SKA
- AT as a National Facility
  ✓ easy to use
  ✘ don’t know what you are doing
- Cross fertilization
- Doing the best science

Indirect Imaging Applications

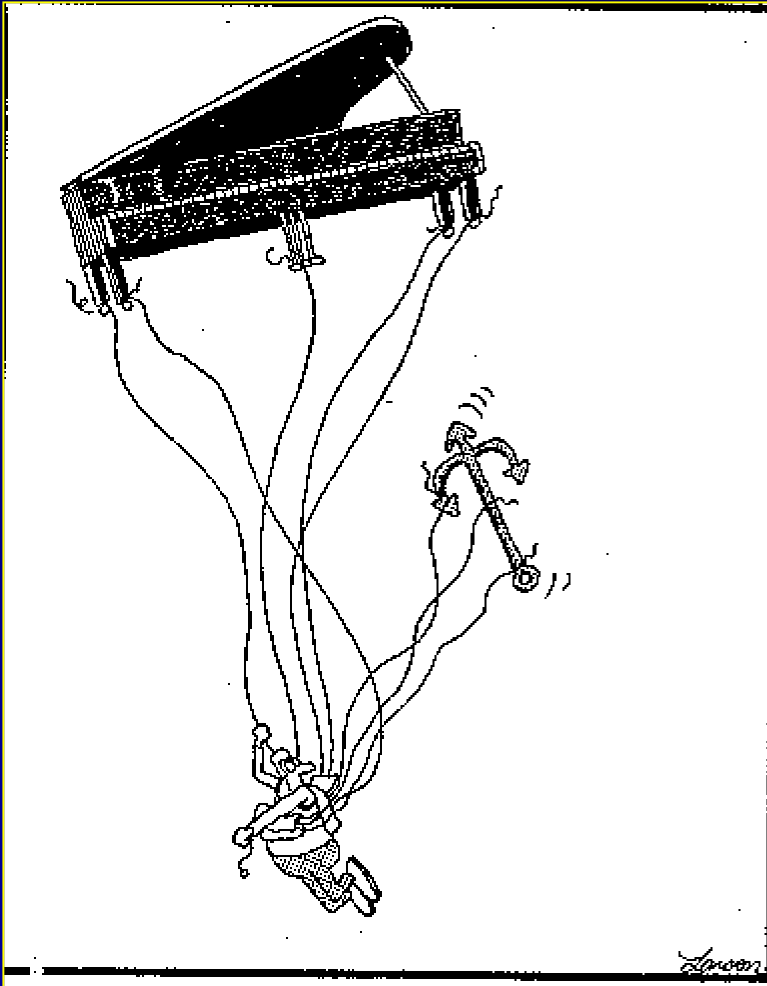
- Interferometry
  - radio, optical, IR, space...
- Aperture synthesis
  - Earth rotation, SAR, X-ray crystallography
- Axial tomography (CAT)
  - NMR, Ultrasound, PET
- Seismology
- Fourier filtering, pattern recognition
- Adaptive optics, speckle

Doing the best science

- The telescope as an analytic tool
  - how to use it
  - integrity of results
- Making discoveries
  - discoveries are driven by instrumental developments
  - recognising the unexpected phenomenon
  - discriminate against errors

HOW ?

- Don't Panic!
  - Many entrance levels



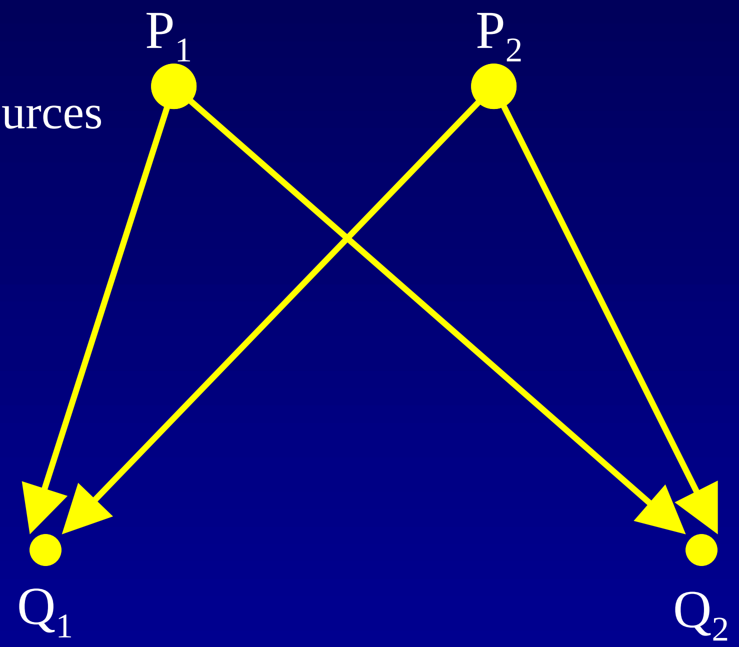
Murray didn't feel the first pangs of real panic until he pulled the emergency cord.

Basic concepts

- Importance of analogies for physical insight
- Different ways to look at a synthesis telescope
  - Engineers model
    - Telescope beam patterns…
  - Physicist model
    - Sampling the spatial coherence function
    - Barry Clark *Synthesiing Image ch 1*
    - Born & Wolf *Physical Optics*

Spatial Coherence

P_1 & P_2
spatially incoherent sources



At distant points Q_1 & Q_2
The field is partially coherent

van Cittert-Zernike theorem

The spatial coherence function is the Fourier Transform of the brightness distribution

Analogy with single dish

- Big mirror decomposition
- Reverse the process to understand imaging with a mirror

Storing visibilities

- Schematic of data flow {VLA data path overview}

Hologram analogy

Explanation via interference

- Time Life *Computers & the Cosmos*

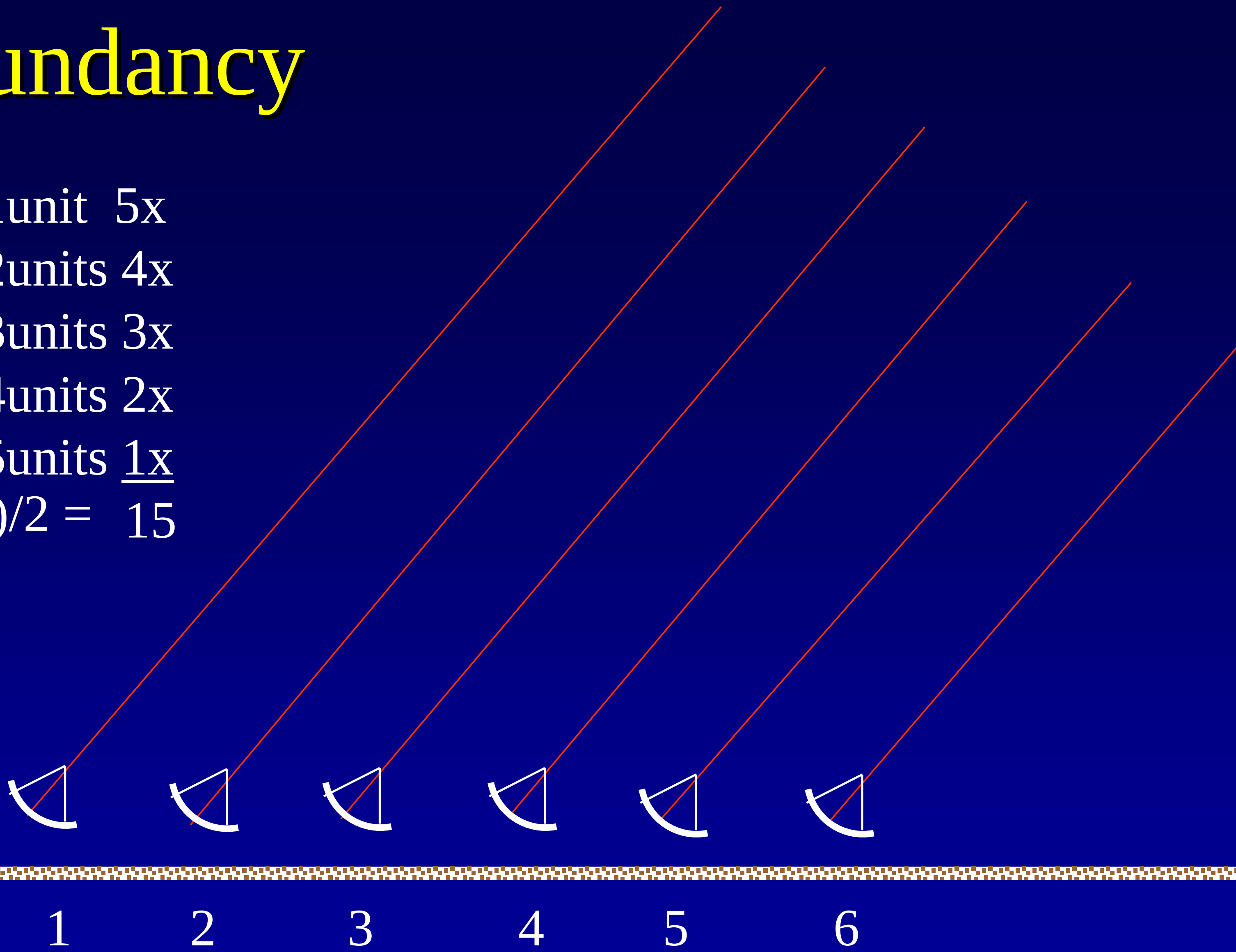
Filling the aperture

- Aperture synthesis
  - measure correlations sequentially
  - earth rotation synthesis
  - store correlations for later use
- Redundant spacings
  - some interferometer spacings twice
- Non-redundant aperture
- Unfilled aperture
  - some spacings missing

Redundancy

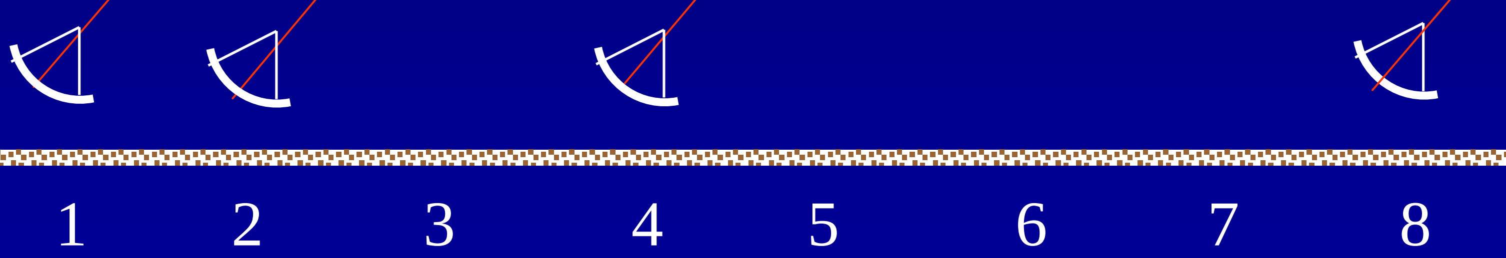
1unit 5x
2units 4x
3units 3x
4units 2x
5units 1x

n(n-1)/2 = 15



Non Redundant

1unit 1x
2units 1x
3units 1x
4units 1x
5units 0x
6units 1x
7units 1x
etc



Optical v Radio imaging

- Radio measures coherence and computes image
- Optical converts a highly redundant coherence function to an image and detects it
- Penalties for “cheating”
  - Dynamic range limited
  - advantage of redundant spacings and filled apertures
  - Harder to control errors, but can control errors
- Easy to reimage
  - too easy?

Terminology

RADIO		OPTICAL
Antenna, dish	⇔	Telescope, element
Sidelobes	⇔	Diffraction pattern
Near sidelobes	⇔	Airy rings
Feed legs	⇔	Spider
Aperture blockage	⇔	Vignetting
Dirty beam	⇔	Point Spread Function (PSF)
Primary beam	⇔	Field of View

Terminology

RADIO		OPTICAL
Map	⇔	Image
Source	⇔	Object
Image plane	⇔	Image plane
Aperture plane	⇔	Pupil plane
UV plane	⇔	Fourier plan
Aperture	⇔	Entrance pupil
UV coverage	⇔	Modulation transfer function

Terminology

RADIO		OPTICAL
Dynamic range	⇔	Contrast
Phased array	⇔	Beam combiner
Correlator	⇔	?
Receiver	⇔	Detector
Taper	⇔	Apodise
Self calibration	⇔	Wavefront sensing (Adaptive optics)

Analogies

RADIO		OPTICAL
grating responses	⇔	aliased orders
primary beam direction	⇔	grating blaze angle
UV (visibility) plane	⇔	hologram
bandwidth smearing	⇔	chromatic aberration
local oscillator	⇔	reference beam