Tutorial Schedule

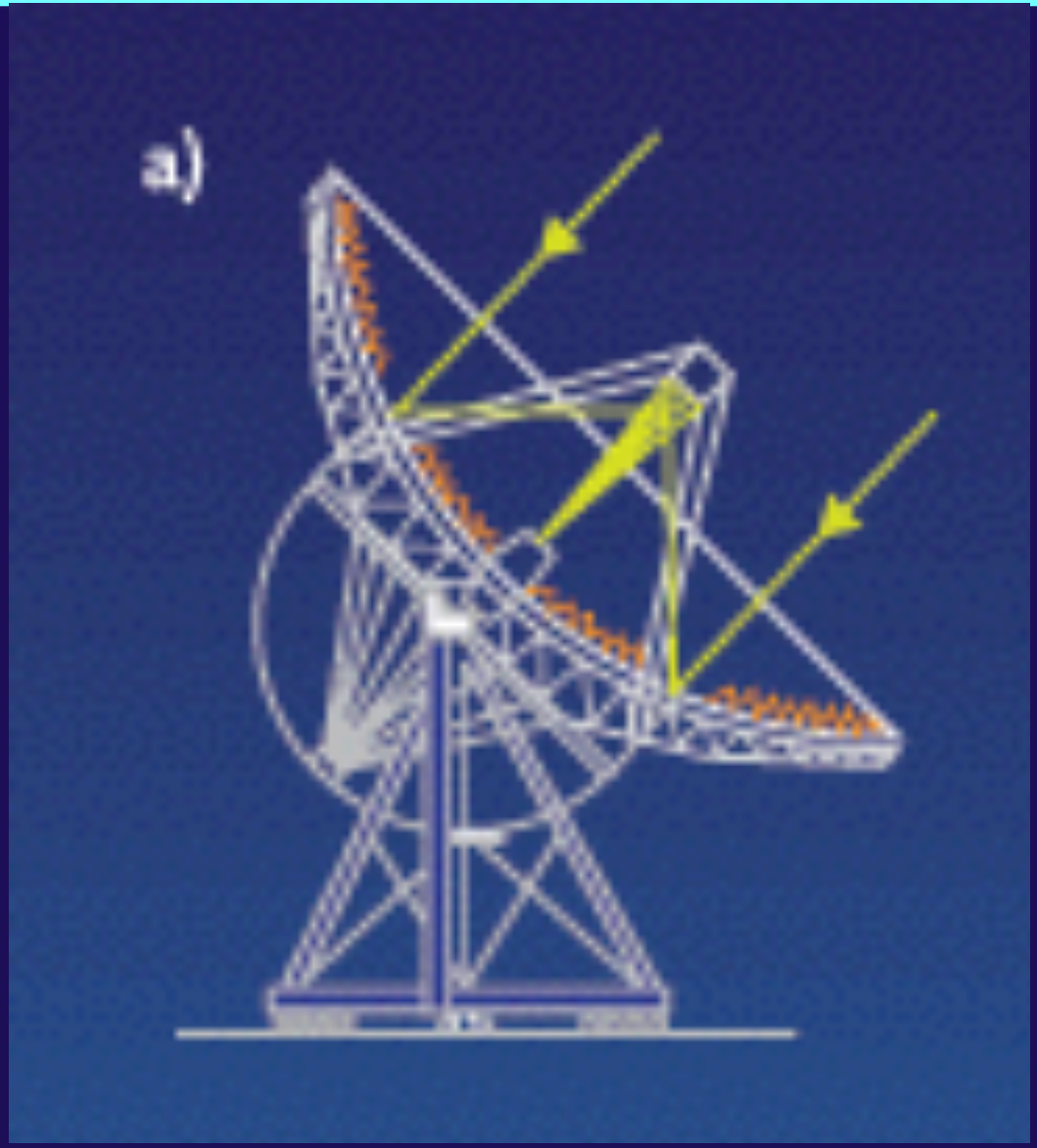
19 October 2015

Start at 10:00 am - Introduction to **CASA** for ALMA, EVLA, and GMRT data-reduction

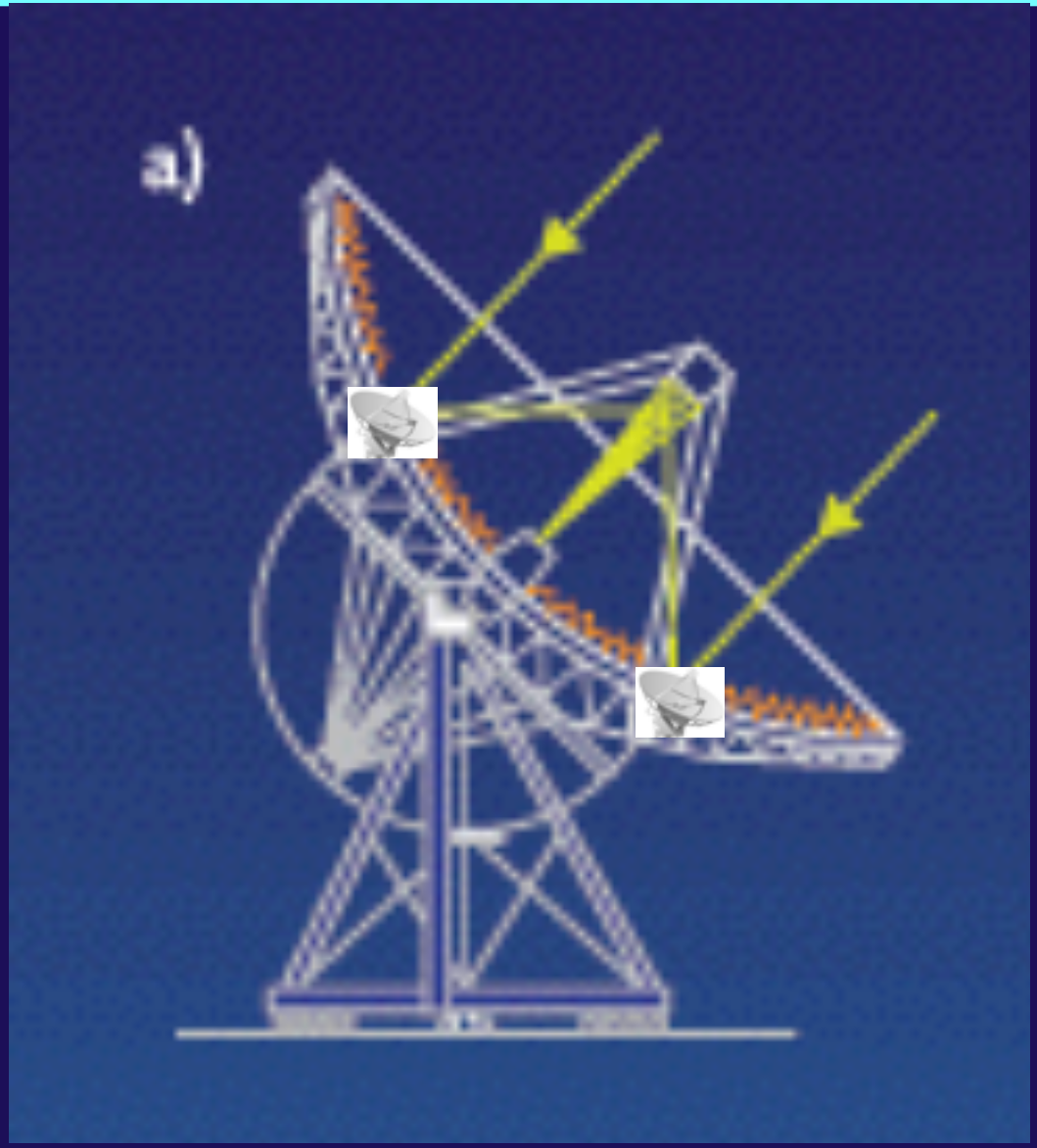
Instructors:

- D. Lal (NCRA-TIFR)
- P. Muralimohan (IIA)
- R. Khatun (IIA)

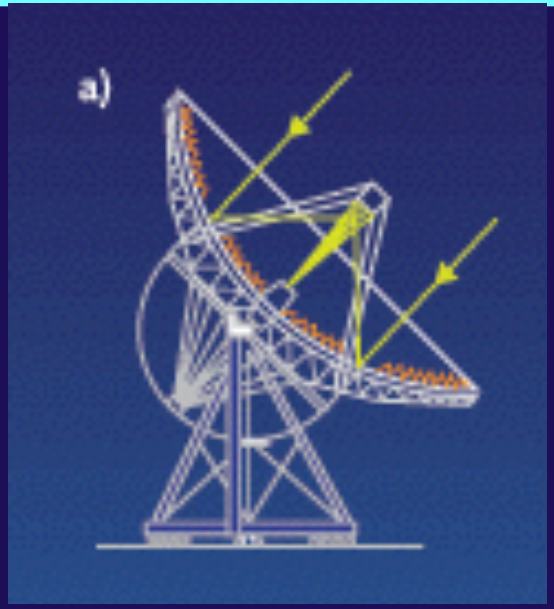
Radio telescope/dish



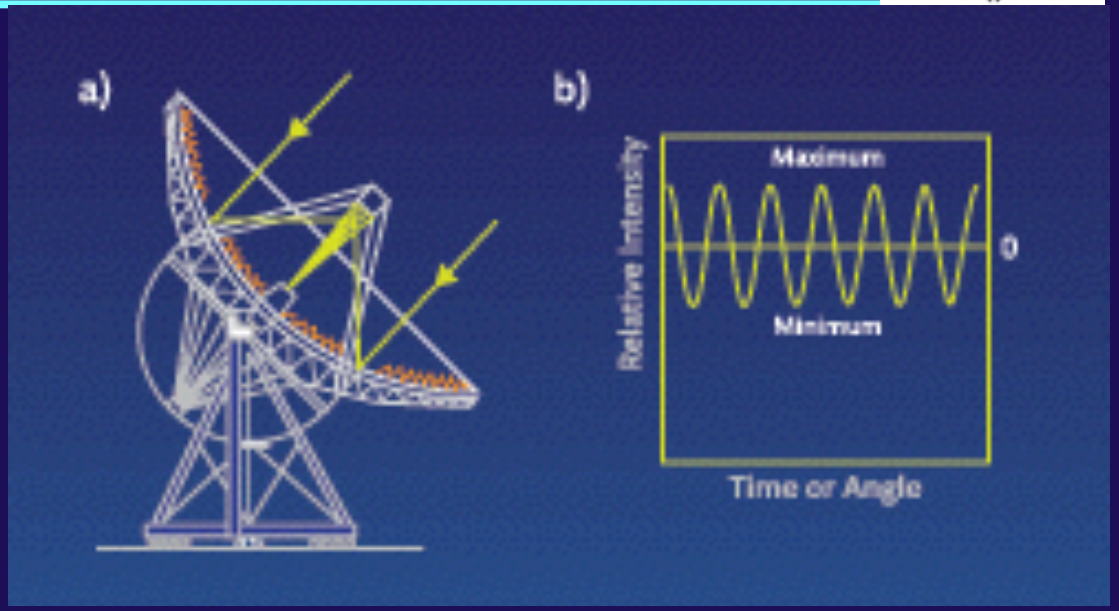
Radio telescope/dish



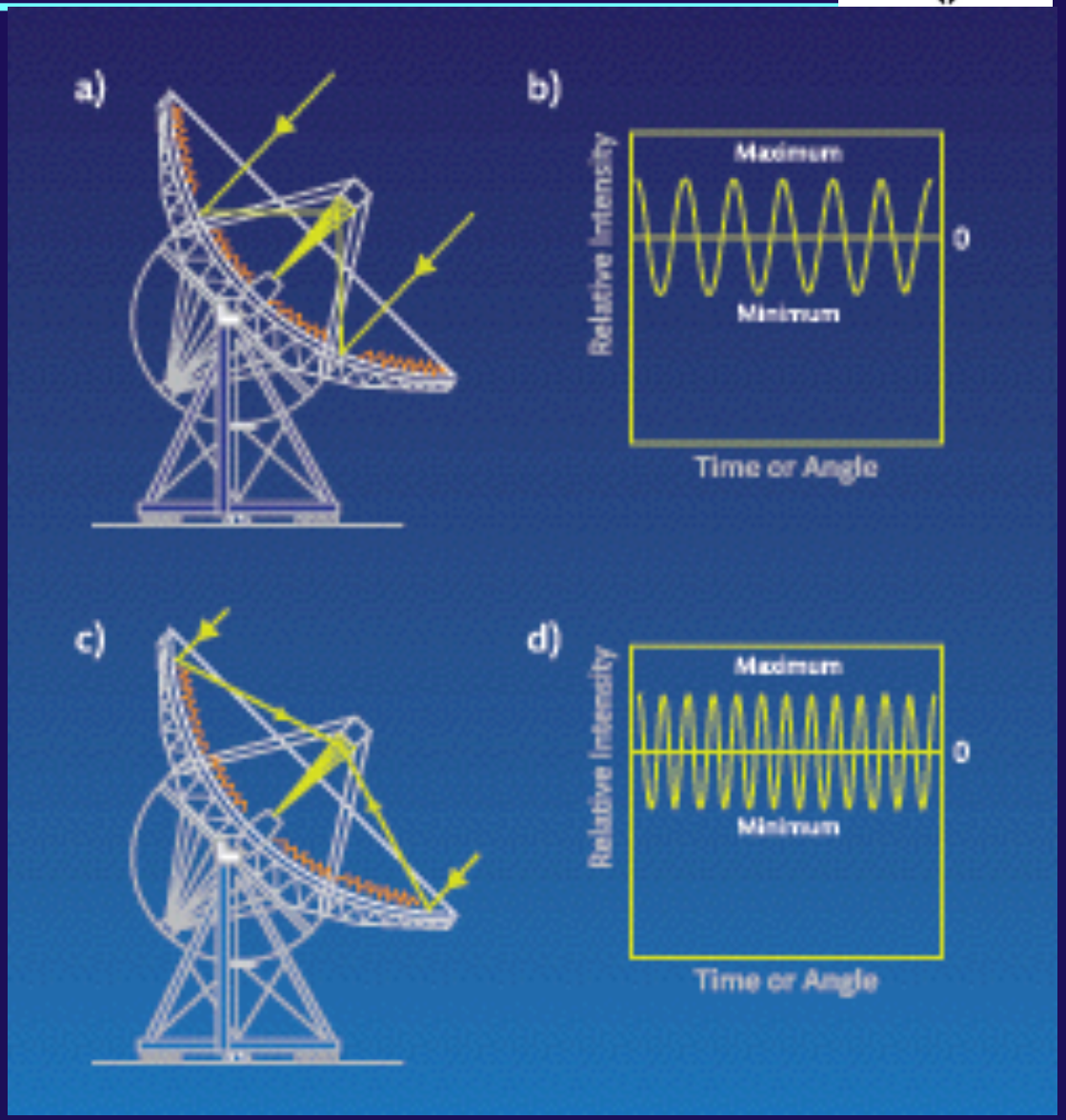
Radio telescope/dish



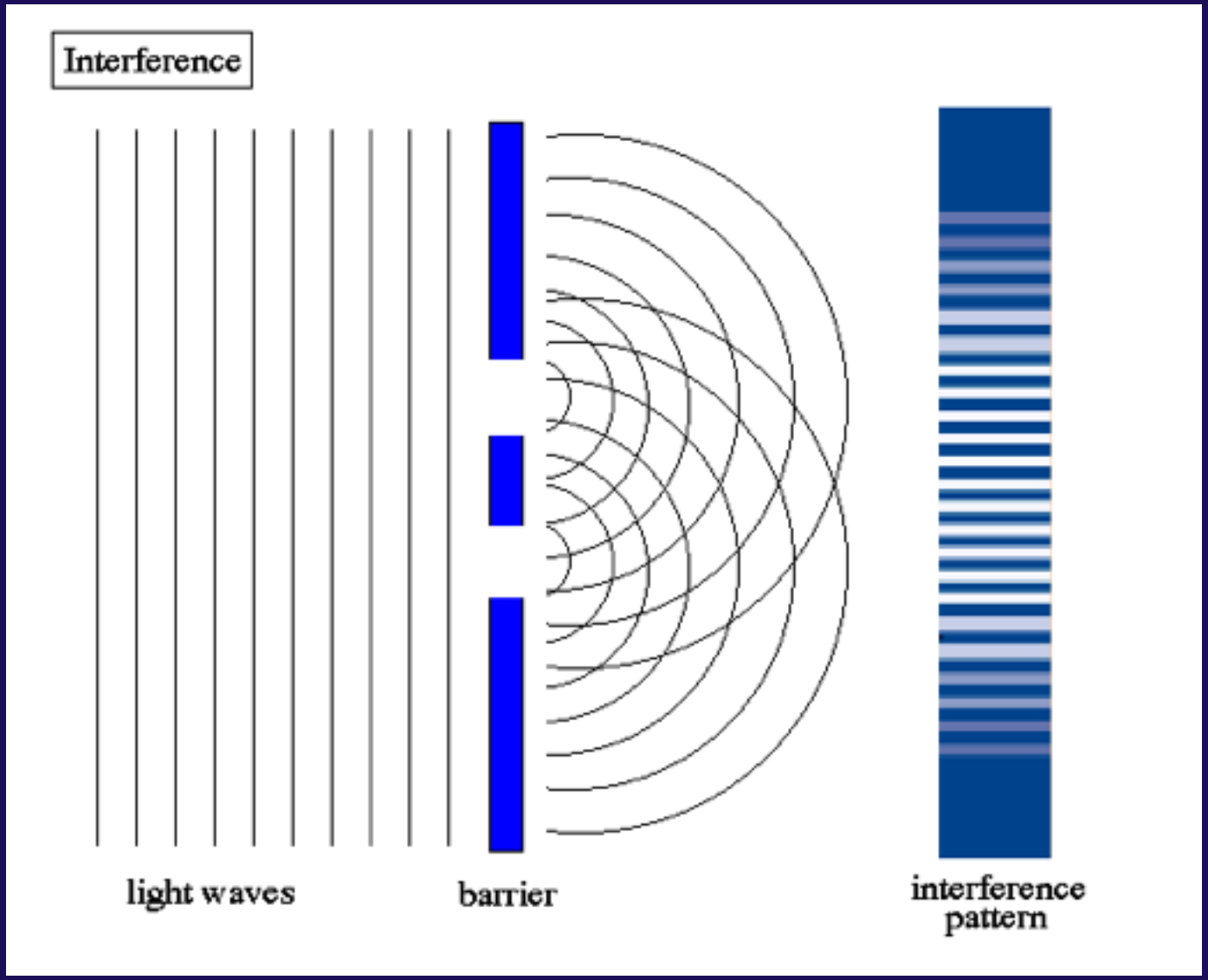
Radio interferometry



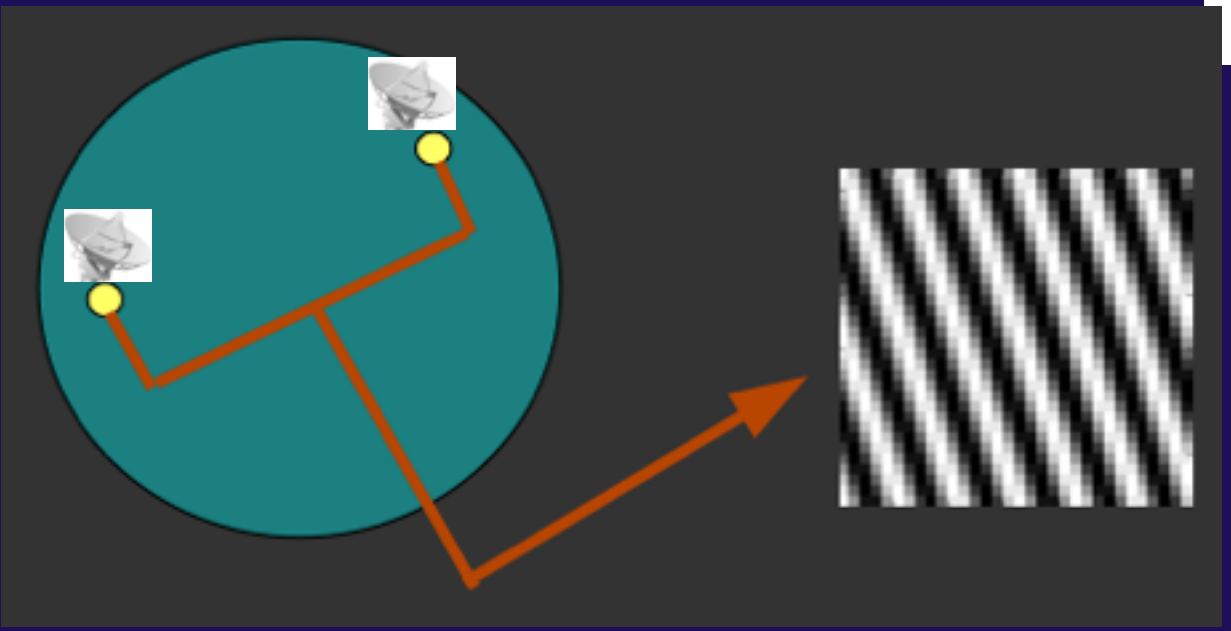
Radio interferometry

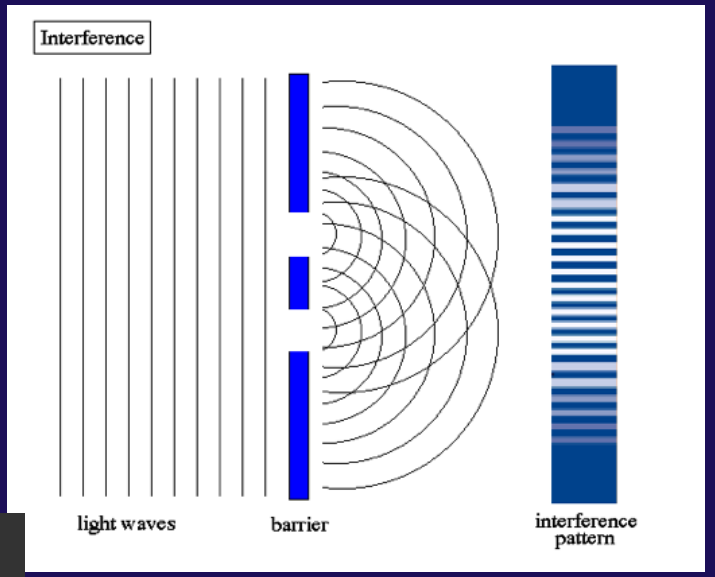


Young's Double-slit Expt

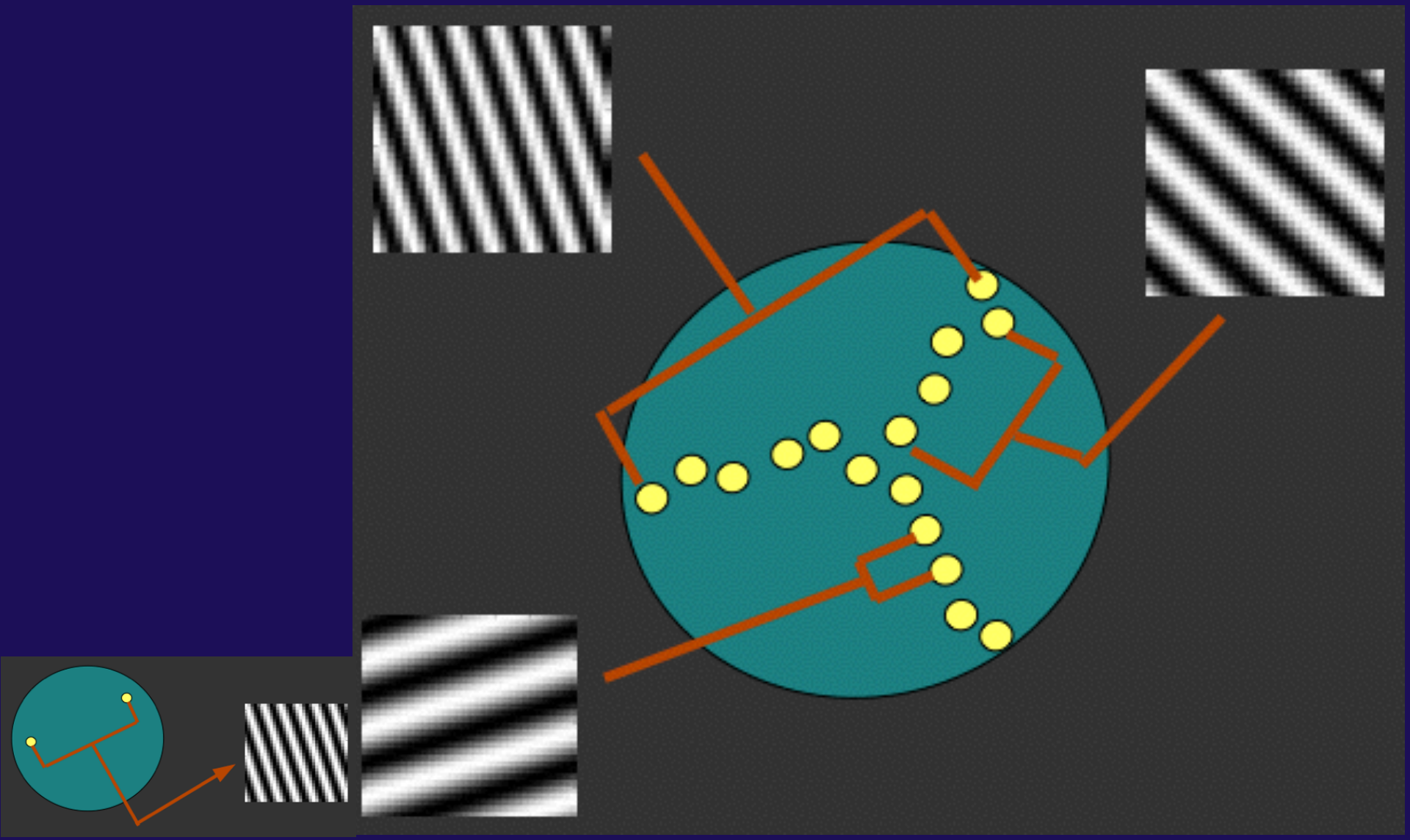


Young's Double-slit Expt

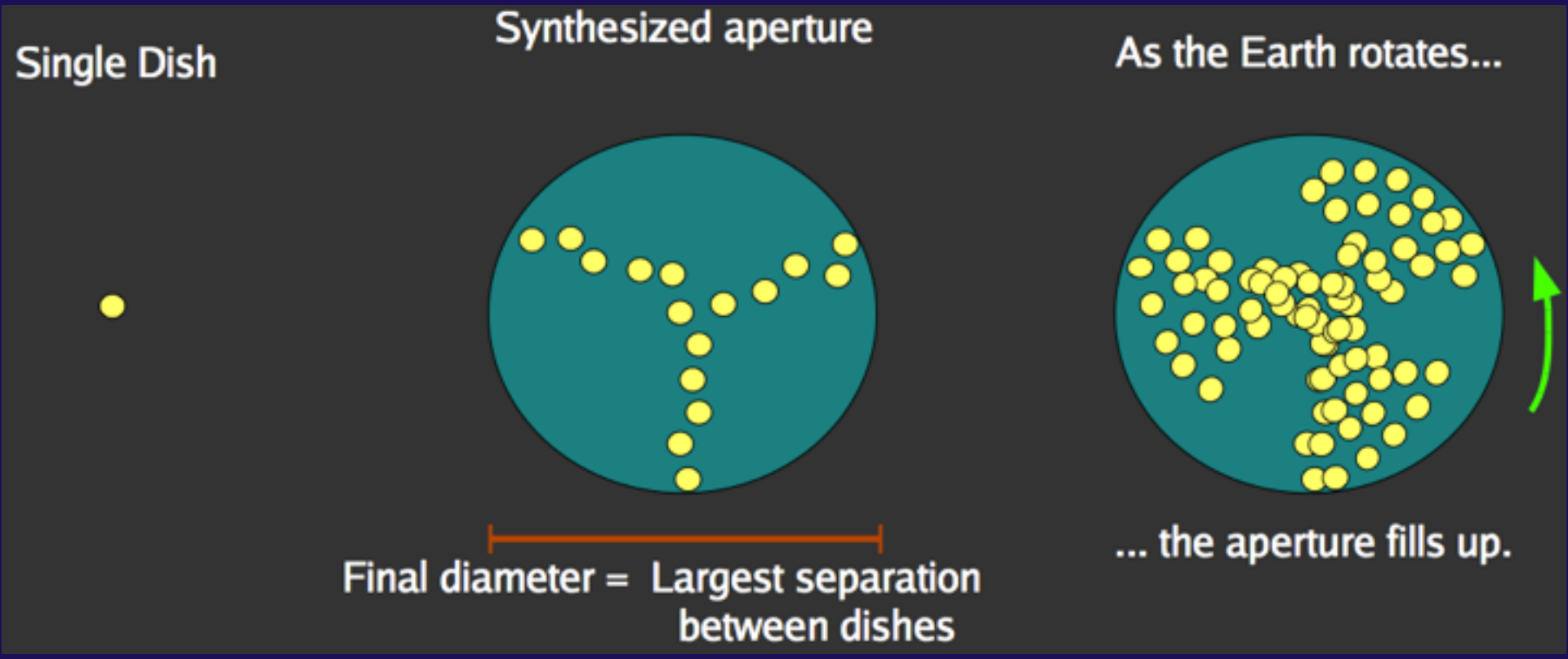




Fourier synthesis

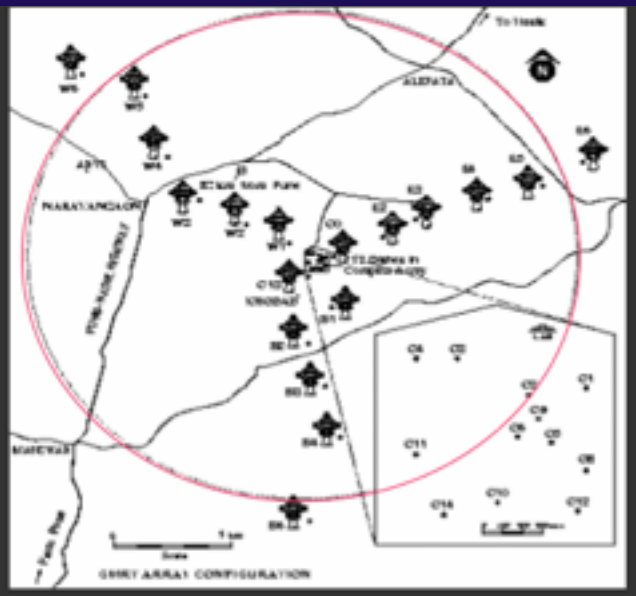


Fourier synthesis



Earth rotation aperture synthesis

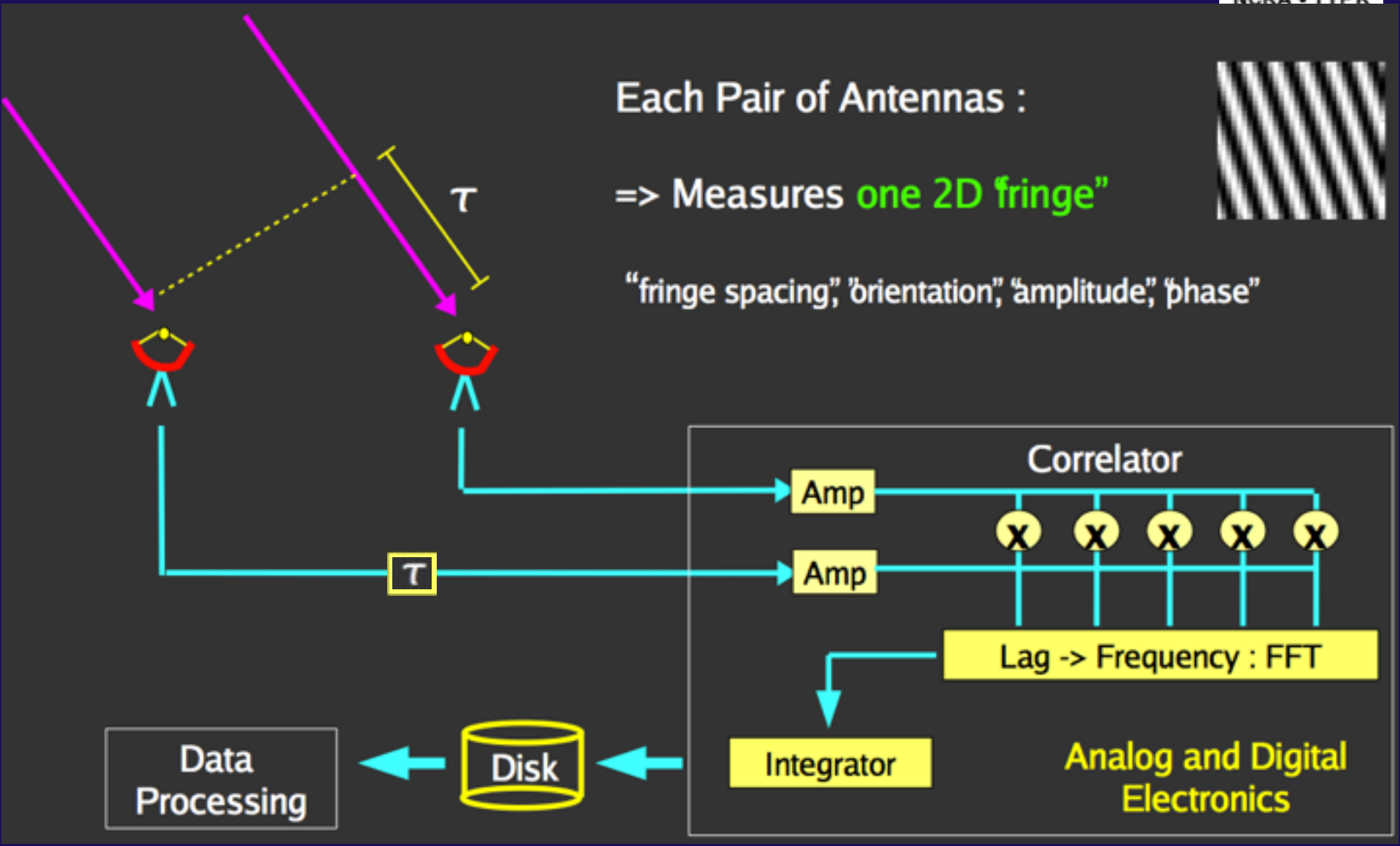
Very Large Array



Giant Meterwave Radio Telescope

... this is called 'Aperture Synthesis '

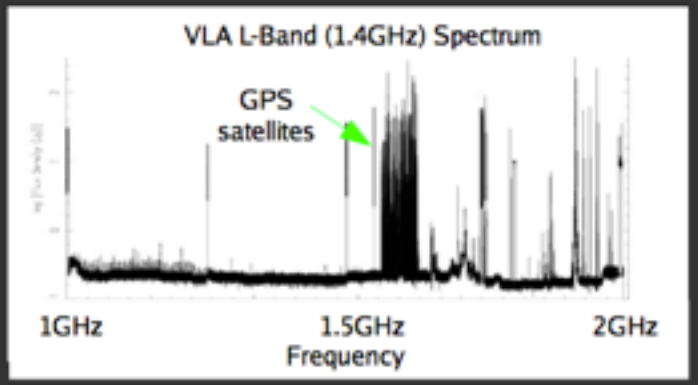
Signal processing



Data processing

(1) Editing :

Some data are corrupted by man-made signals
=> Need to identify and remove bad data

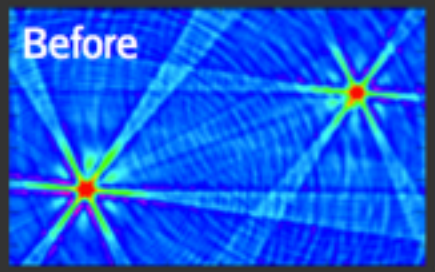


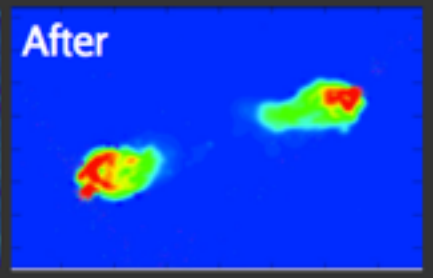
(2) Calibration :

Fourier Optics applies only under ideal conditions
=> Need to model instrumental effects and apply corrections.

(3) Image Reconstruction :

Only some Fourier terms are measured.
=> Need to estimate the others...





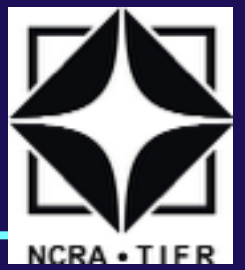
CASA: Data analyses

- Importing GMRT data into CASA
  Flexible Image Transport System (FITS)
  UVFITS (understood by AIPS, MIRIAD)

- ***importuvfits***
  input – UVFITS data file
  output – Measurement Set (MS)
  understood by CASA

- ***Listobs***
  - Which sources, how many scans
  - Observing frequency, time and duration
  - Frequency and time resolution
  - Array coordinates

CASA: Loading and viewing



plotuv -useful for plotting u-v coverage

plotxy – line plots, fairly general, useful for scripting

plotms – interactive general purpose and versatile, cannot be scripted yet (4.1.0)

viewer (casaviewer) – gray scale/waterfall plots

Examining/exploring the data

CASA: Loading and viewing

U-v coverage

Azimuth vs Elevation

Time series (time vs amp, phase)

Bandshape (freq. vs amp, phase)

Data selection syntax

Range: X~Y

Time: YYYY/MM/DD/HH:MM:SS

Time range: Time1~Time2

Antenna: 1~3 = 1,2,3

11,12,15

Baseline: ANT1 (OPERATOR) ANT2

& - only cross-correlations

&& - both auto and cross corr.

&&& - only auto corr.

CASA: Loading and viewing

Specification	Meaning
ANT	Select only cross-correlation baselines between all the antennas in ANT and *all* other available antennas
ANT&	Select only cross-correlation baselines between antennas in ANT only
ANT1 & ANT2	Select only cross-correlation baselines between antennas in ANT1 and ANT2
ANT&&	Select cross- *and* auto-correlation baselines between all the antennas in ANT only
ANT&&*	Select cross- *and* auto-correlation baselines between all the antennas in ANT and *all* other available antennas
ANT1 && ANT2	Select cross- *and* auto-correlation baselines between antennas in ANT1 and ANT2
ANT&&&	Select *only* auto-correlation baselines for antennas in ANT
!ANT	Excludes all baselines involving antennas in ANT. ANT can be any of the above expressions
ANT1 ; !ANT2	ANT1 and ANT2 can be any of the above expressions. This selects only cross-correlation baselines between all the antennas in ANT1 and *all* other available antennas **except** those involving antennas in ANT2.

Data selection syntax

CASA: FLAGging

Weeding out the bad data

- Antennas
- Scans
- Time stamps
- Spectral channels
- Baselines
- Radio Frequency Inteference (RFI)

CASA: FLAGging

- Science, but also an ART
- Astronomical sources – smoothly varying across physically sensible parameters (time, frequency, uv) (*exceptions – variable sources and spectral lines*)

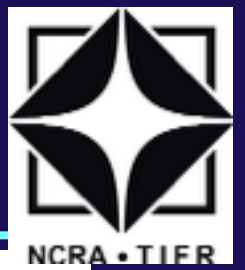
Signals which jump in time, frequency

Signals which change with instrumental boundaries – antennas, baselines, scans, spectral channels, ...

The first (and sometimes) the last integration times in every scan

Any exceptionally short scans!

CASA: FLAGging



Amplitudes easiest to catch big issues with

Phases are usually much more sensitive to noise and errors, but looking at phases really works only for high SNR data sets

For identifying what to flag (+ some flagging)

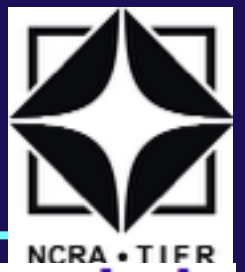
plotms

viewer (casaviewer)

For actual flagging

Tflagdata

CASA: CALIBration



CASA trick

tget <taskname> - will fill in the <keyword>=<value> pairs from the last execution of this task

G_i's are a function of both frequency and time

Key Assumption - Calibration can be separated into frequency and time dependent parts.

Bandpass calibration – Calibration of the frequency dependent part of G_i's

Approach – use a strong source with no spectral lines in the band of interest.

bandpass - 3C286

Calibration

CASA: CALIBration

3C223.1_240MHz.MS

- Spw='0:0~22'
- Spw='0:44~63'
- Antenna='1'; timerange='22:37:48~25:10:08'
- Antenna='3'; timerange='23:40:33~25:14:53'

Flagging

Structure of a MS

- THREE data columns
  - Observed data $V_{ij}(obs)$
  - Corrected data $G^{-1}_{i}\, G^{-1*}_{j}\, V_{ij}(obs)$
  - Model data $V_{ij}(model)$

Approach – observe a source of known strength,

Primary Flux calibrators - 3C48, 3C286, 3C147

setjy

CASA: STEPs

Gain calibration – Calibration of time dependent part of G_i's.

Objective

Approach – Use a strong source known to be non-variable over the time scale of observations

gaincal – 3C286

Flux calibration

setjy on the primary flux calibrator(s)

- Do it on one flux calibrator at a time
- Also known as amplitude calibration

Bandpass calibration

bandpass on the primary flux calibrators(s)

- To remove the variations in the gains across the band
- Can be done on both the flux calibrators in a single run
- Will create a 'caltable', you choose the name

CASA: STEPs

NCRA • TIFR

Applycal -

plotms, viewer – plot and compare 'data', 'model', 'corrected' data and 'residual' columns to examine and understand what flux calibration has done.

Calibration

- Clearcal
- Tflagdata (scan='2')
- Setjy (field='0'; field='3')
- Bandpass (only flux calibrators)
  - Plotcal to verify
- Gaincal (on flux and phase calibrators)
  - Plotcal to verify
- Fluxscale (to get the flux of phase cal 8.88+/- 0.13 Jy)

Plotcal to verify

Plotting

plotcal – plots antenna based solutions

Channel no. Vs amp/phase

CASA: STEPs

- Applycal (to the entire dataset)
- Clean – image a calibrator source
  - Examine the PSF
  - Examine the Image

```
#  setjy :: Fills the model column with the
   visibilities of a calibrator
vis         = '3C223.1_240MHz_FLAGGED.MS'
field       =         '0'
usescratch          =       True


REPEAT WITH field='3'
```

setjy

CASA: STEPs

```
vis          = '3C223.1_240MHz_FLAGGED.MS'
caltable= '3C223.1_240MHz_FLAGGED.BPASS'
Field        = '0,3'
Refant       = '10'
```

bandpass

```
vis          = '3C223.1_240MHz_FLAGGED.MS'
caltable= '3C223.1_240MHz_FLAGGED.GCAL'
Field        = '0,1,3'
Refant       = '10'
Calmode    = 'ap'
```

gaincal

CASA: STEPs

NCRA • TIFR

```
vis          = '3C223.1_240MHz_FLAGGED.MS'
caltable  ='3C223.1_240MHz_FLAGGED.GCAL'
Fluxtable='3C223.1_240MHz_FLAGGED.FLUX'
Reference = '0,3'
Transfer = '1'
incremental=False
```

fluxscale

```
vis       = '3C223.1_240MHz_FLAGGED.MS'
field     = ''
Gaintable=['3C223.1_240MHz_FLAGGED.BPAS
  S','3C223.1_240MHz_FLAGGED.FLUX']
```

applycal

Approach: AIPS/CASA

Exiting data:

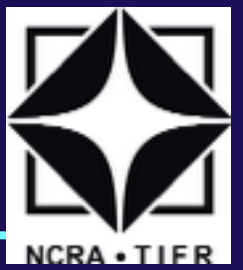
- AIPS
- CASA

Imaging:

- CASA
- AIPS

…

Acknowledgements



key papers:

http://www.aoc.nrao.edu/~rurvashi/HTMLfiles/Research.html#TALKS

http://www.aoc.nrao.edu/~sbhatnag/

Synthesis imaging summer school notes/lectures:

http://ncra.tifr.res.in/ncra/ncra1/students/External%20students/ras-2015

https://science.nrao.edu/science/meetings/2014/14th-synthesis-imaging-workshop

Urvashi R.V., Divya Oberoi, Nissim Kanekar, Ruta Kale,

Students and postdoctoral-students,

…