Mosaic(k)ing

ATNF Synthesis Workshop

Erwin de Blok

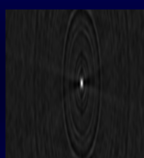
Overview

- Why mosaicking?
- Different Approaches
- Mosaicking in Practice
- Mosaicking at ATCA

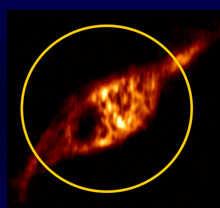
Why Mosaicing?

- Source larger than primary beam: $\theta > \lambda/D$
  - not limited by primary beam size
- Source structure at large scales: $\theta > \lambda/b_{min}$
  - better uv coverage

Single Pointing



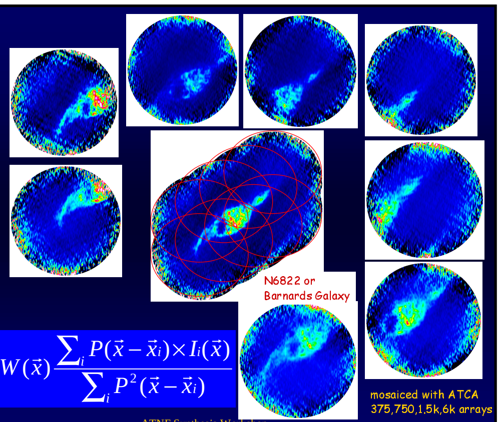
*



$$I(\vec{x}) = D(\vec{x}) * (P(\vec{x}) \times S(\vec{x})) + \sigma(\vec{x})$$

Mosaicing: Individual Approach

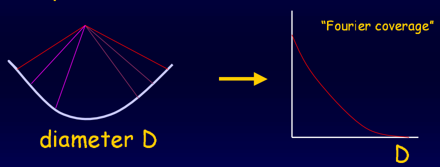
- Observe single pointings
- Reduce them separately
- "Stitch" images together
- Disadvantages:
  - Deconvolution non-linear (cleaning bowl)
  - Overlap regions noisy (primary beam shape)
  - Expensive in observing time
  - Does not use all uv information
- OK for high-res where source << field



$$M(\vec{x}) = W(\vec{x}) \frac{\sum_i P(\vec{x}-\vec{x}_i) \times I_i(\vec{x})}{\sum_i P^2(\vec{x}-\vec{x}_i)}$$

The Special Stuff: Ekers & Rots (1979)

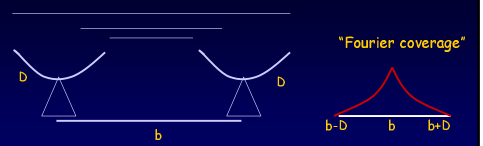
- Single dish consists of many sub-interferometers



- Single pointing cannot recover information: one visibility, many "interferometers"
- More pointings (e.g. scanning) can: image

Ekers & Rots Trick 2

- An interferometer does not just measure baseline b
- It measures spacings between b-D and b+D

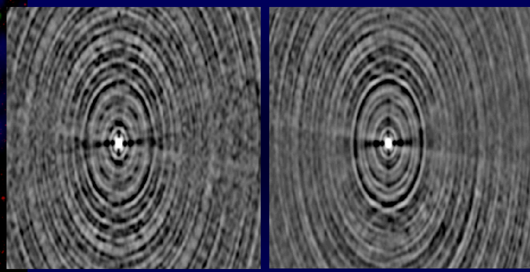


Ekers & Rots 3

- Again, one pointing cannot recover this information (individual approach)
- Many pointing together can recover this "extra" coverage (joint approach)

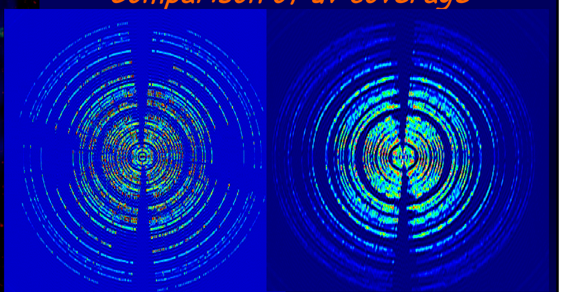
⇒ **Use all uv data from all pointings simultaneously: better uv-coverage, better beam, better image**

Comparison of beams



Individual Joint

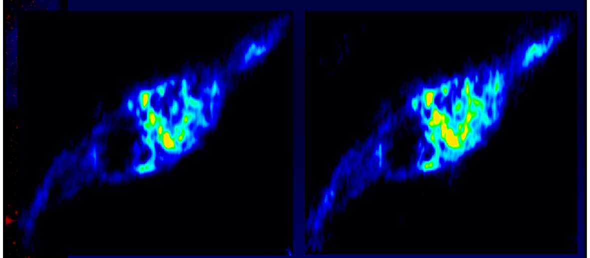
Comparison of uv coverage



Individual both radial (extra uv coverage) and azimuthal (adjacent pointings) improvement Joint

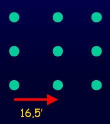
Mosaicing differences

individual joint

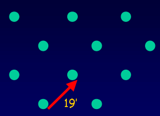


Mosaicing Grid

- Rectangular grid
  - Nyquist sampling $\theta = \lambda/2D$
  - = 16.5' at 21cm at ATCA



- Hexagonal grid
  - Nyquist sampling $\theta = (2/\sqrt{3})\,\lambda/2D$
  - = 19.0' at 21cm at ATCA
  - Solid angle coverage better



Drive times

- For short drives: $t=2(s/a)^{1/2}$
- $a=400$ deg/min^2
- so for 0.5 degree drive, t = 4.3 sec

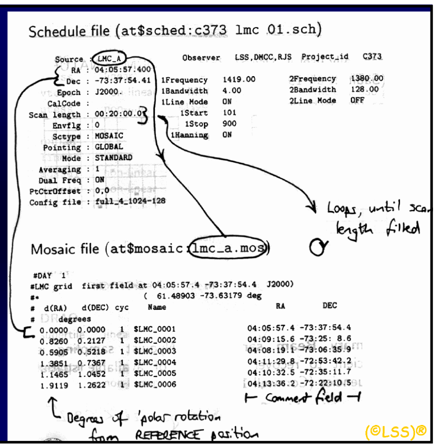
ATNF Synthesis Workshop

Complete uv sampling

- One baseline measures region in uv plane with size 2D
- At transit, time between independent points is $\tau=(86400/2\pi)(2D/L)$ sec where D=diameter, L=longest baseline
- Nyquist sampling for N pointings: dwell time is $\tau/2N$ sec
- E.g. 375m: 13.4 min. 750m: 6.7 min

ATNF Synthesis Workshop

Sched files


Schedule file (at$sched:c373 lmc 01.sch)

```
     Source : LMC_A                Observer   LSS,DMCC,RJS  Project_id   C373
         RA : 04:05:57.400
        Dec : -73:37:54.41   1Frequency    1419.00        2Frequency   1380.00
      Epoch : J2000.         1Bandwidth    4.00           2Bandwidth   128.00
    CalCode :                1Line Mode    ON             2Line Mode   OFF
Scan length : 00:20:00.0         1Start    101
     Envflg : 0                   1Stop    900
     Sctype : MOSAIC           1Hanning    ON
   Pointing : GLOBAL
       Mode : STANDARD
  Averaging : 1
  Dual Freq : ON
PtCtrOffset : 0,0
Config file : full_4_1024-128
```

Mosaic file (at$mosaic:lmc_a.mos)

```
#DAY  1
#LMC grid  first field at 04:05:57.4 -73:37:54.4  J2000)
#*                        (  61.48903 -73.63179 deg
#  d(RA)   d(DEC) cyc    Name                        RA         DEC
#  degrees
  0.0000  0.0000   1  $LMC_0001              04:05:57.4 -73:37:54.4
  0.8260  0.2127   1  $LMC_0002              04:09:15.6 -73:25: 8.6
  0.5905  0.5218   1  $LMC_0003              04:08:19.1 -73:06:35.9
  1.3851  0.7367   1  $LMC_0004              04:11:29.8 -72:53:42.2
  1.1465  1.0452   1  $LMC_0005              04:10:32.5 -72:35:11.7
  1.9119  1.2622   1  $LMC_0006              04:13:36.2 -72:22:10.5
```

Mosaicking with MIRIAD

- Linear mosaic with LINMOS (after CLEAN/RESTOR on indiv pointings)
- MIRIAD has multi-source capability: no need to split files
- Making cubes: use INVERT with option=mosaic
- Deconvolving: Maximum entropy MOSMEM or cleaning with MOSSDI
- Restoring with RESTOR

Other mosaicing software

- Classic AIPS:
  - LTESS (linear)
  - VTESS, UTESS (non-linear)
- AIPS++
  - part of IMAGER tool
  - has MEM and clean variations
  - also has "mosaicwizard"

Summary

- Mosaicing is essential for widefield imaging
- Mosaicing is easy
- Use individual approach for high angular resolution observations where b >> D: minimize primary beam errors
- Use joint approach where b ≈ D: extra uv information

Literature

- Ekers & Rots (1979), IAU Coll 49, 61
- Cornwell (1988), A&A, 202, 316
- Cornwell, Holdaway & Uson (1993), A&A, 271, 697
- Sault, Staveley-Smith, Brouw (1996), A&A Sup, 120, 375
- Holdaway (1998), ASP Conf 180, Ch. 20
- Sault & Killeen, Miriad manual, Ch. 21