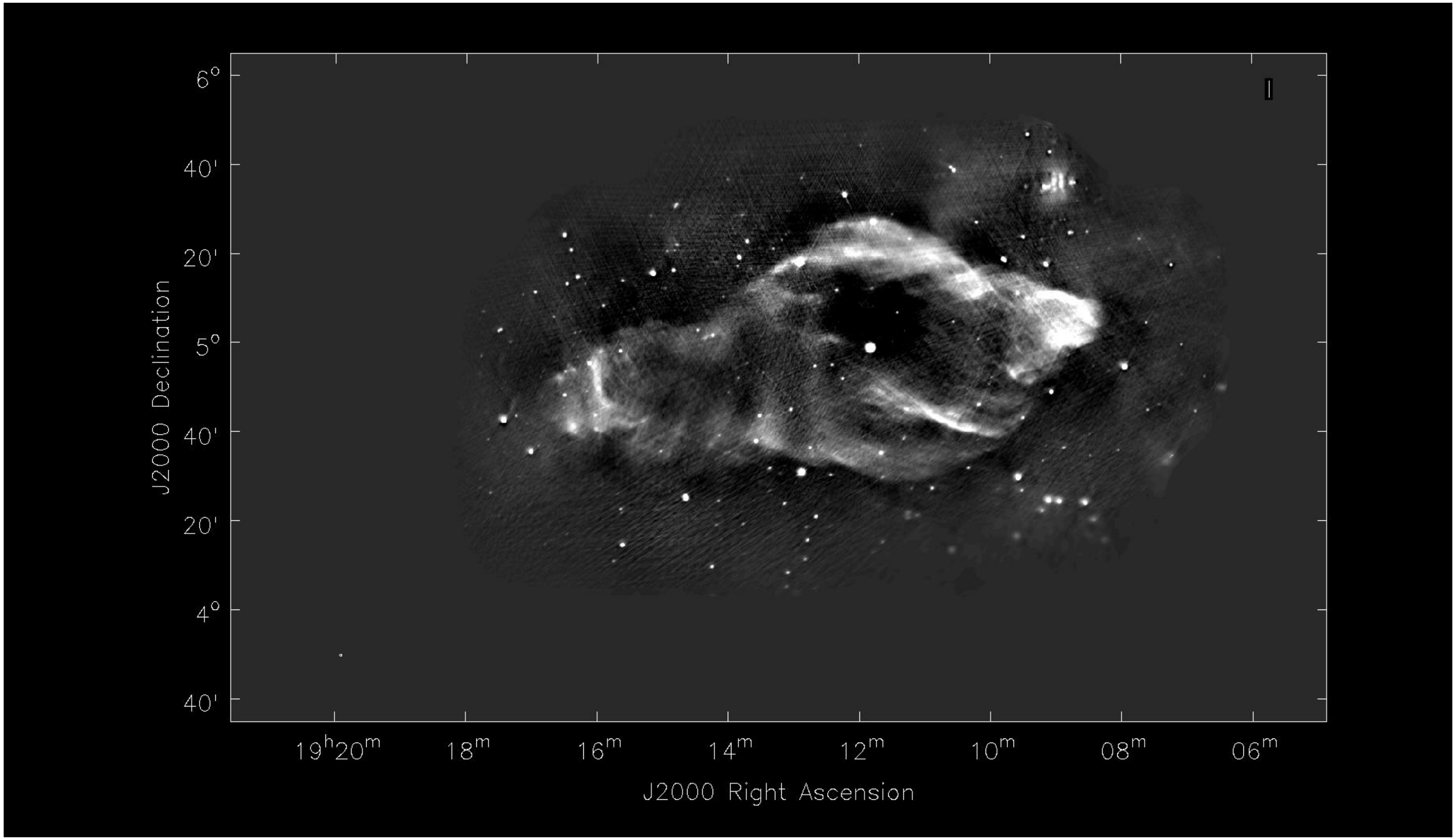
Mosaicing



6°
40'
20'
5°
40'
20'
4°
40'
J2000 Declination
19h20m
18m
16m
14m
12m
10m
08m
06m
J2000 Right Ascension

Outline

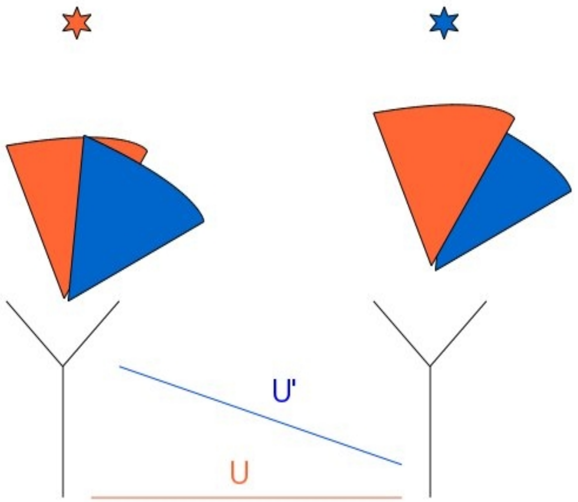
- Description of different type of mosaicing
- Details on Mosaicing by convolution (A-projection)
  - Reasons and advantages
- Limitations of different algorithms
- Some comments on Single Dish combination

Introduction

- Imaging a target larger than primary beam (pb)

$$I_m(l) = \sum_p I_p(l) \approx K(l) \sum_p W_p(l) A_p(l - l_p) I(l)$$

- Side effect: resample uv for different directions (a.k.a Ekers-Rots "*effect*")



How to mosaic

- Pointed mosaic or On The Fly (OTF) (as uniform a coverage as possible)
  - Coverage
    - Does your experiment need full sampling ?
    - Polarization may need oversampling
  - Source structure
  - Sig/Noise
  - Time allocated

Linear mosaic v/s Joint Deconvolution

- Clean Images independently then join (in casa `im.linearmosaic`)
  - Different fields do not contribute to deconvolution of a given field
  - Source in sidelobes imaged as is can be removed
- Join dirty images then clean (in casa/clean `imagermode='mosaic'`)
  - Overlap region gain from S/N and resampling of uv (better behaviour of deconvolution)
  - Source in sidelobes can create problems unless peeled (peeling of fluffy object at edge of beam is hard)

Where linear mosaic in necessary

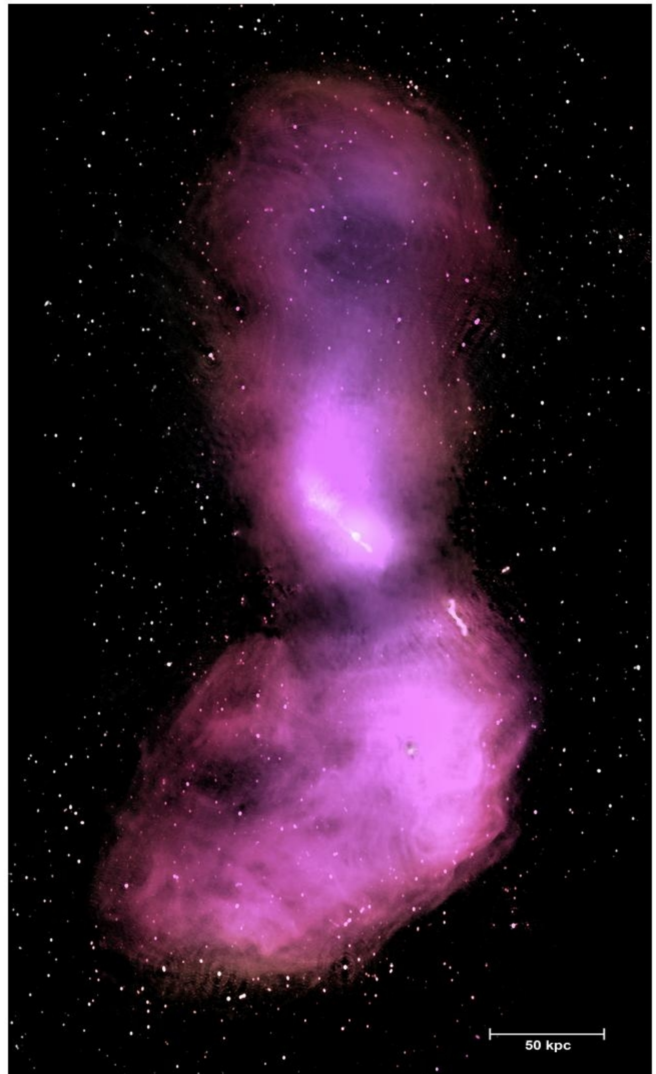


Fig. 2.— Enhanced image of Centaurus A at 1.4 GHz showing the inner lobes, the northern middle lobe (using data from Morganti et al. 1999) and the giant outer lobes.This image was created using layering techniques similar to those used by the Hubble Heritage project (http://heritage.stsci.edu), allowing a much improved visualisation of the various scale sizes and

Joint deconvolution

$$I_m(l)=\sum_p I_p(l)=K(l)\sum_p W_p(l)\,A_p(l-l_p)\,I(l)$$

- Before you do the above summation all sources in sidelobes need to be accounted for its effects in mainlobe (for each pointing)
  - UV subtraction may be necessary

- As PSF is not uniform across image CS-style deconvolution is necessary

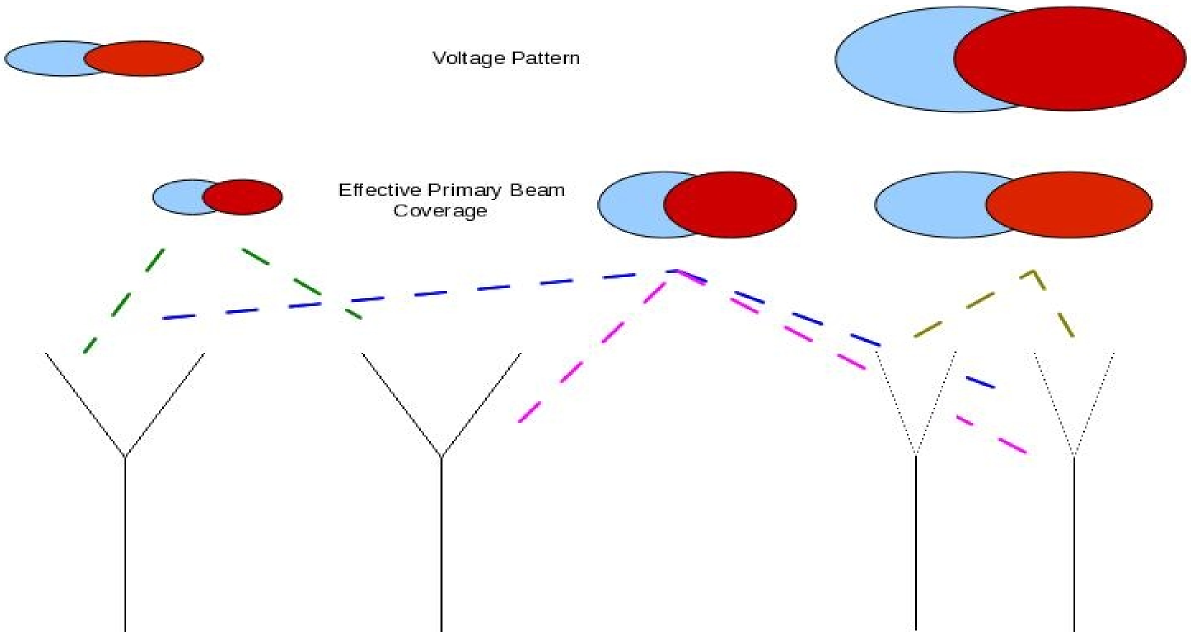
Mosaicing: Image plane v/s uv plane (A-projection)

$$I_m(l) = \frac{W(l)\sum_p \frac{A_p(l-l_p)\, I_p(l)}{\sigma_p^2}}{\sum_p \frac{A_p^2(l-l_p)}{\sigma_p^2}} = K(l)\sum_p K_p(l)\, I_p(l)$$

Ref Sault et al. (A & A 1996, 120, 375-384)

- Above summation can be achieved in image plane (in casa `ftmachine='ft'`)
- Multiplication in image plane => can be achieved by convolution in uv-plane (in casa `ftmachine='mosaic'`)

Mosaicing



Representation of a Heterogenous Interfererometry Array

Traditional/Image-plane approach to mosaic imaging

1) Mosaic independently the different effective primary beams
2) Combine the different beam mosaics with appropriate weight coverage
3) Search for clean components in combined mosaic
4) Predict what visibililities for each PB type and subtract from visibility
5) Make independent residual mosaic for each type of PB
6) Goto stage 2

Complications/Problems with traditional approach

- Traditional approach is reasonably easy except in practice mosaics are rarely “fully” uniform
- Accounting and keeping track of sensitivity and weights before combining different PB images
  - Sensitivity each PB image
    - Relative S/N when adding images
  - Relative sensitivity for each field
    - Weight image for each PB
      - For each channel
- Number of dirty images to deal with is (2 x NDishType-1)
  - Same number for weight images and PSF's
- Computation Speed for large number of fields and or frequency dependent beams
- Other directional problem leads to very complicated (tending towards impossible) and compute intensive handling/corrections

Optimal summing-mosaicing

Accounting directional signal to noise due to PB's

$$I_m(l) = K(l) \sum_p \frac{I_p(l)}{\sigma_p^2(l)} = K(l) \sum_p \frac{A_p^2(l - l_p) I(l)}{\sigma_p^2}$$

Thus before adding a given pointing to a mosaic a PB function is multiplied to observed pointing image

K(l) contains the corrections necessary to give you the “flux-correct” image for example

Mosaicing by UV-gridding

$$U_m(l) = \frac{I_m(l)}{K(l)} = \sum_p k_p A_p^2(l - l_p) I(l)$$

$$FT(U_m(l)) = V_m(u,v) = \sum_p k_p FT(A_p(l - l_p)) * FT(A_p(l - l_p) I(l))$$

$$V_m(u,v) = \sum_p k_p B_p(u,v) * V_p(u,v)$$

- Convolve every visibility point with the Fourier transform of its effective PB
- Effectively every baseline, for every time stamp and every frequency can be accounted for by the right PB
  - Heterogeneity of PB can be accounted easily
  - Also wide band mosaicing is simplified by using the right FT(PB(f))

Keeping track of your weights and relative sensitivity

or '*mosaic*' your visibility weights

- A “flux-correct” image implies accounting each primary beam (dish-diameter, frequency) contribution in each pointing
- Can easily be shown that baseline weights and K(l) are related

$$K(l) = FT^{-1}\left(\sum_p FT(A_p^2(l)) * W_{uv}\right)$$

- Thus it's equivalent to “convolve-mosaicing” the weights with

$$B_p(u,v) * B_p(u,v)$$

- The simplicity (beauty) is that the relative sensitivity of pointing-PB-baseline-frequency is automatically kept track of.

Advantages

- Order of magnitude better in imaging time
  - FFT always involved gridding by convolution in interferometry imaging
  - Only need to cache convolution functions
  - OTF mosaicing is practically feasible
- Fine granularity of correction
  - Each baseline PB and baseline can be accounted/corrected
    - Frequency, time-variations
- Fewer images to deal at any major cycle: dirty, pb-coverage correction, psf
- Extendable to other kind of calibrations and corrections (e.g. rotation asymmetric beams)

Limitations (due to PB knowledge)

- UV-mosaicing involves FFT of PB
  - Knowledge of PB is limited (edge effect)
- Sparse coverage mosaics suffer from ringing
  - Image plane mosaic may be preferred in such cases

Single-Dish addition

- Feather
  - Post imaging
  - $F(u,v) = S(u,v)f(u,v) + I(u,v)*(1 - f(u,v))$
  - Where F=FT(feathered image), S=FT(SD image), I=FT(Interferometer image), f=feathering function
- SD image as starting clean model
  - Empirically works well in most cases to recover large scale structure
  - Helps in reducing clean instabilities etc

Single Dish Addition Experimental

- Cotton-Schwab style major cycle that includes SD data and interferometer
  - Prediction stage predicts model visibilities and model SD data to be subtracted from original data
  - Weight correspondence between SD and Interferometer critical

Conclusion

- Choose your rastering pattern, coverage on your observation criteria
  - e.g polarization, overlap beam up-to where beam pol is trusted
- Choose mosaic imaging algorithm to use on knowledge of source, beam and other errors