Adaptive Aperture Synthesis

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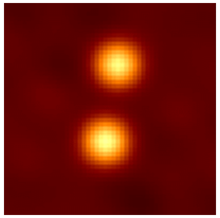
Optical Aperture Synthesis (OAS)

- Terrestrial applications

- Astronomical applications



COAST image of close binary star, Capella. The separation of 1/20 arcsecond can be resolved though OAS.

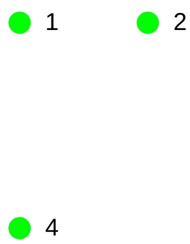
$$\phi_{a,b} = k\left(\xi_{a,b}\beta + l_a - l_b\right) + \psi_{a,b}$$

Benefits:
Increased resolution

Drawbacks:
Sidelobes

Calibration

- Model building approaches



- Redundant Spacings Calibration (RSC)
  - Sampling same frequency should yield identical answer, any difference is due to phase errors.

$$\psi'_{a,b} = \psi_{a,b} + k\xi_{a,b} \cdot \beta$$

$N(N-1)/2 + N$ Unknowns

$N(N-1)/2$ Measurements

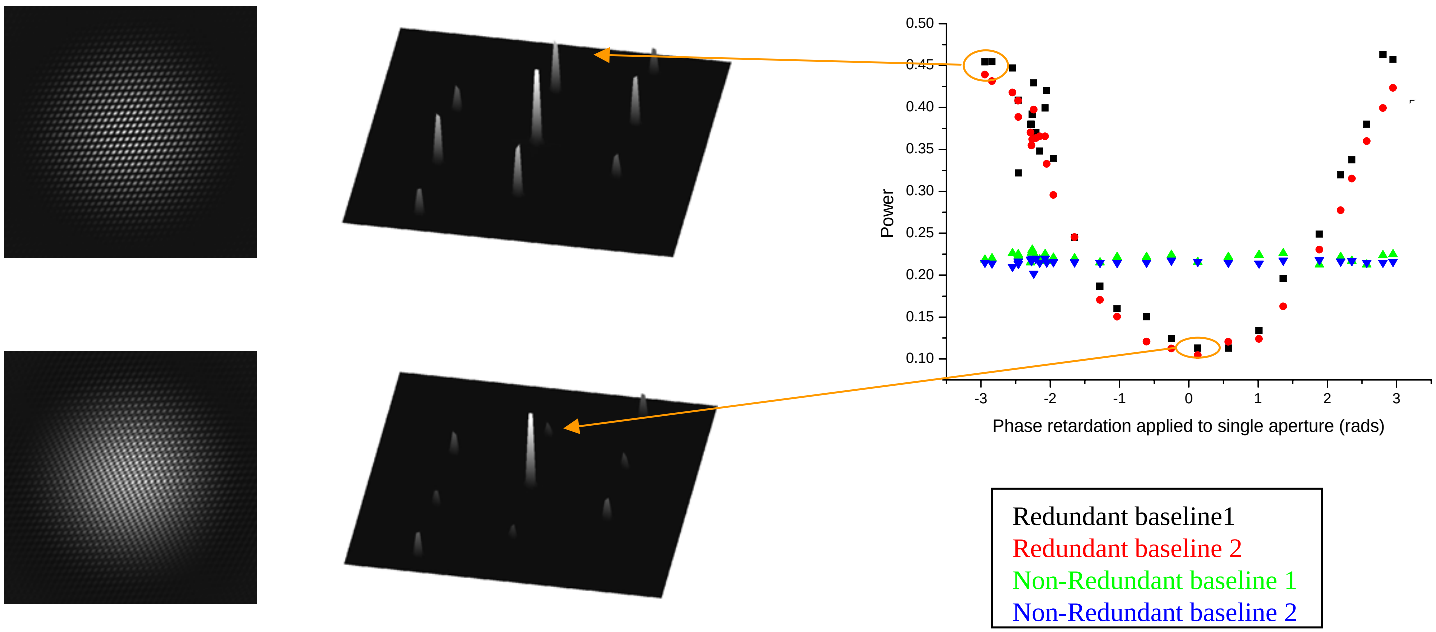
3 disposable parameters define a plane

$N-3$ Redundant baseline measurements

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & -1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & -1 & 0 & 0 & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} \psi'_{1,2} \\ \psi'_{1,3} \\ \psi'_{1,4} \\ \psi'_{2,3} \\ \psi'_{2,4} \\ \psi'_{3,4} \\ kl_1 \\ kl_2 \\ kl_3 \\ kl_4 \end{pmatrix} = \begin{pmatrix} \phi_{1,2} \\ \phi_{1,3} \\ \phi_{1,4} \\ \phi_{2,3} \\ \phi_{2,4} \\ \phi_{3,4} \\ 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Solve for object phases by robust matrix inversion

Adaptive Correction



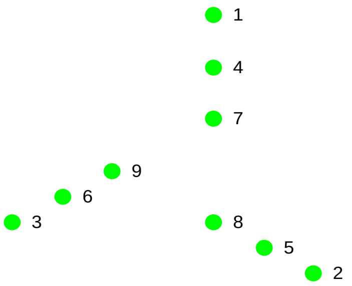
By Parseval's theorem, improving visibility increases image sharpness

Adaptive correction

- Knowledge of interaction between aperture phases and visibilities required
- Phase sequencing
  - Likely to need iterative solution in all but simplest arrays
- True multivariate optimisation:
  - Iterative but all phases converge to solution simultaneously

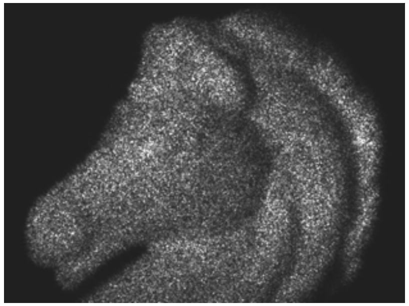
Design

Array design considerations:

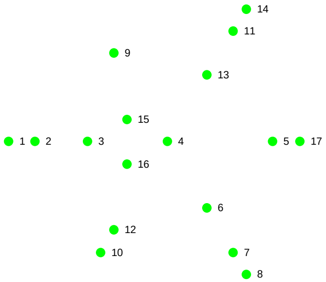


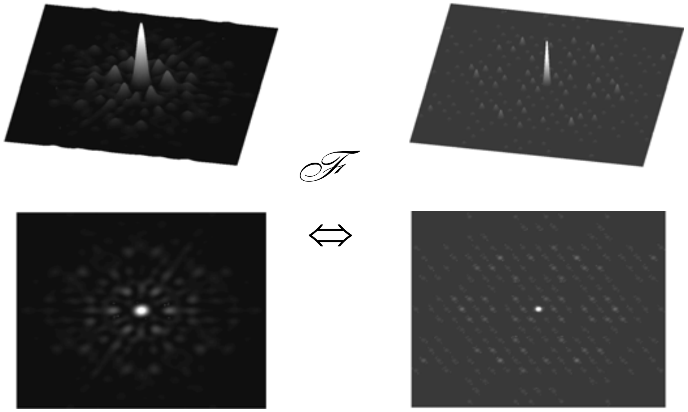
- **Full rank**
  - N-3 Redundant baselines
- **Good frequency coverage**
  - Efficient space filling array
  - More apertures
- **Low sidelobe levels**
  - Null steering
  - Decrease periodicity
- **Numerical stability and conditioning**
  - Choice of disposable parameters for robust phase plane (orthogonal vectors)
  - Fewer apertures
  - Calibrate long baselines with short ones to improve SNR.

Image reconstruction

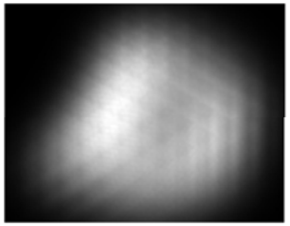


Filled aperture

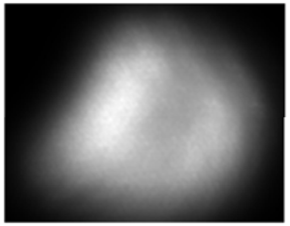




PSF Autocorrelation



9 Apertures



17 Apertures

Relationship to A.O.

- Determine phase errors
  - Matrix inversion
  - Wavefront correction
- Image sharpness criteria
  - Real time adaption from frequency space
- Both work through redundancy

Acknowledgements

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