Single-dish spectral-line observing

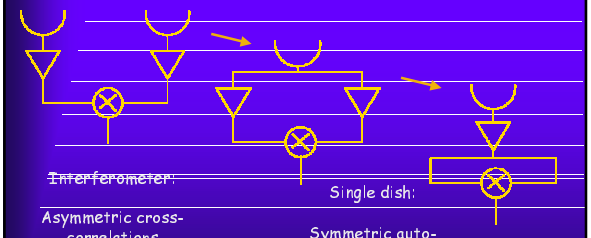
Lister Staveley-Smith, ATNF

- Why use a single-dish?
- Analogy with interferometer
- Demonstration - bandpass calibration
- Multiple beams
- Imaging & calibration

Why use a single-dish?

- Provide zero-spacing ⇒ total flux density ($\int I_D d\Omega = 0$ for interferometer)
- Provides structure with $\theta > \lambda / B_{min}$, where B_{min}=30 m for ATCA ⇒ complementary to interferometer
- Sensitivity (often larger diameter, more beams, better receivers)
- Simplicity (beams formed in hardware)

Single-dish/interferometer analogy -I



Interferometer:

Asymmetric cross-correlations

$C_{ij}(\tau) \neq C_{ij}(-\tau)$

⇔

Complex visibilities V(ν)

Single dish:

Symmetric auto-correlations

⇔

Real visibilities

Single-dish/interferometer analogy -II

source ground

Let Voltage $A(t)=A_{src}(t)+A_{atmos}(t)+A_{grnd}(t)+A_{rx}(t)$

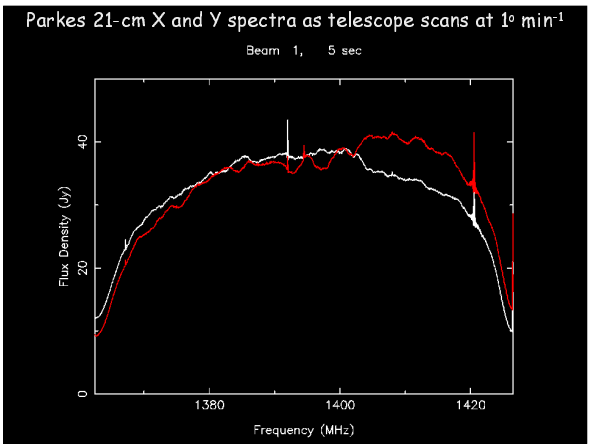
atmosphere receiver

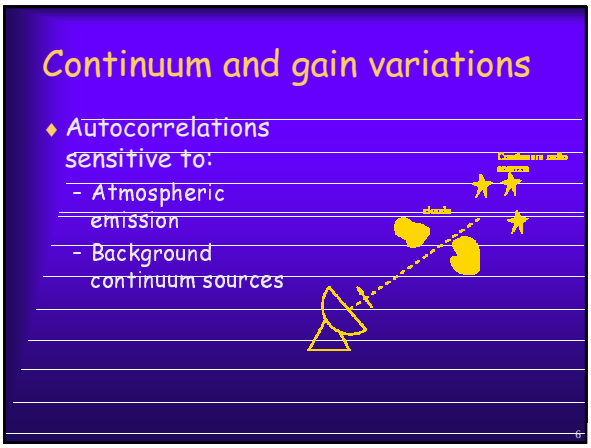
- Interferometer:

$C_{ij} = \langle A_1(t)A_2(t) \rangle = \langle A_{1,src}(t)A_{2,src}(t) \rangle$

- Single dish ($A_1=A_2$):

$C = \langle A(t)A(t) \rangle = \langle A^2_{src}(t) \rangle + \langle A^2_{atmos}(t) \rangle + \langle A^2_{grnd}(t) \rangle + \langle A^2_{rx}(t) \rangle$


Parkes 21-cm X and Y spectra as telescope scans at 1° min-1
Beam 1, 5 sec
Flux Density (Jy)
0
20
40
1380
1400
1420
Frequency (MHz)


Continuum and gain variations
Autocorrelations sensitive to:
- Atmospheric emission
- Background continuum sources
clouds
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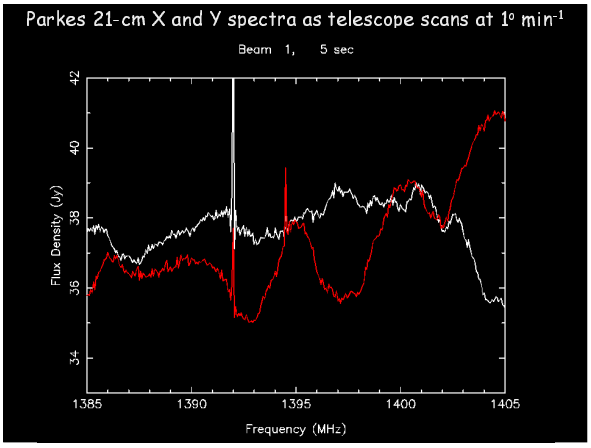
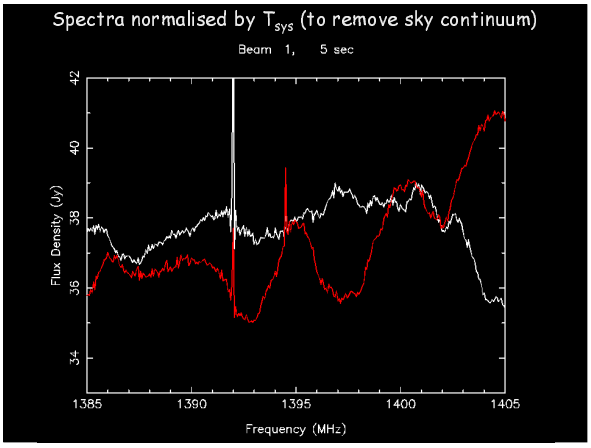
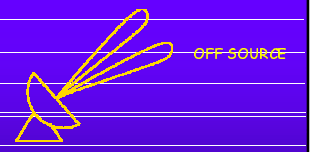

Parkes 21-cm X and Y spectra as telescope scans at 1° min-1
Beam 1, 5 sec
Flux Density (Jy)
34
36
38
40
42
1385
1390
1395
1400
1405
Frequency (MHz)


Spectra normalised by Tsys (to remove sky continuum)
Beam 1, 5 sec
Flux Density (Jy)
34
36
38
40
42
1385
1390
1395
1400
1405
Frequency (MHz)

Bandpass calibration techniques for compact obects



- Position switching
  - Calibrate using a nearby off-source position
- Beam switching
  - Calibrate using an off-source beam
  - (needs symmetric beams)

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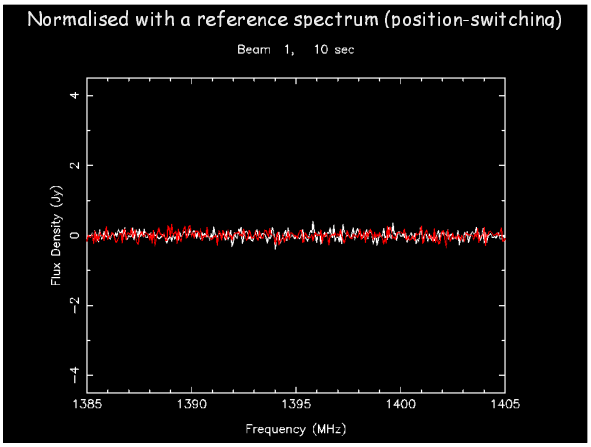
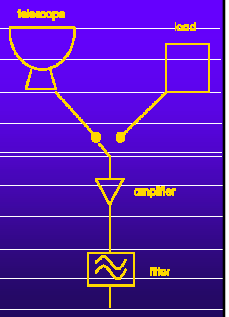


Bandpass calibration techniques for extended objects



- Frequency switching
  - Change 1st local oscillator so spectral line moves
- Load switching
  - Switch to a cold load (e.g. Penzias & Wilson)
- Noise adding

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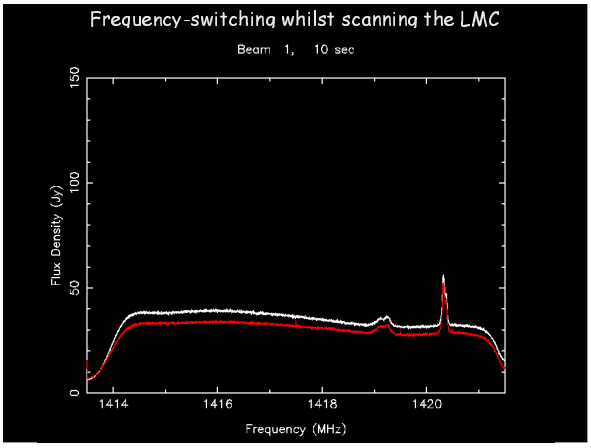
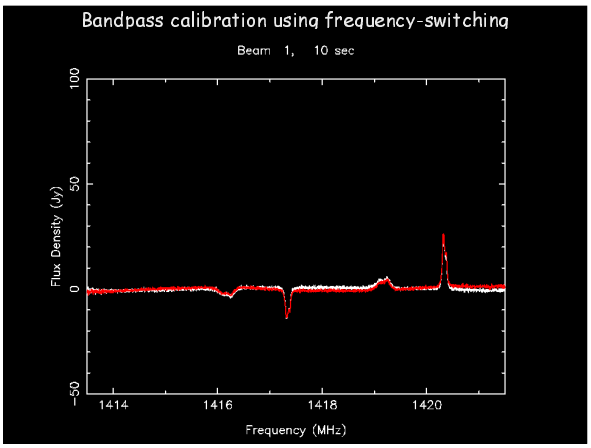
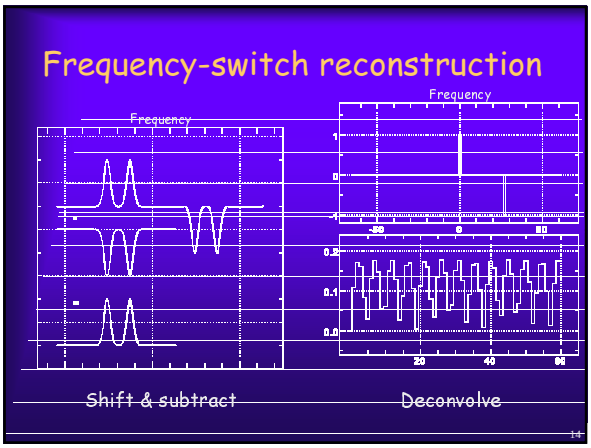



Bandpass calibration using frequency-switching
Beam 1, 10 sec
Flux Density (Jy)
100
50
0
-50
1414
1416
1418
1420
Frequency (MHz)


Frequency-switch reconstruction
Frequency
Frequency
Shift & subtract
Deconvolve
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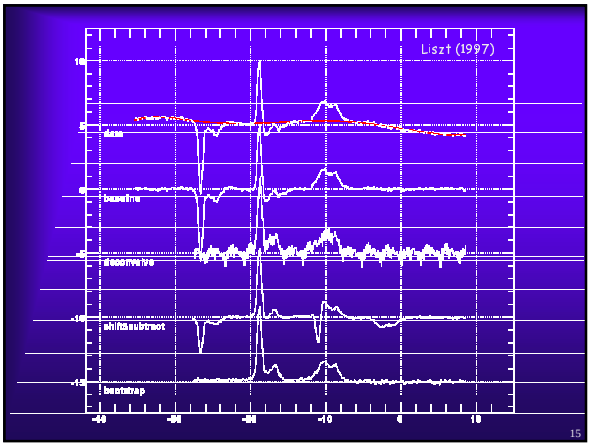
Liszt (1997)
data
baseline
deconvolve
shift and difference
bootstrap
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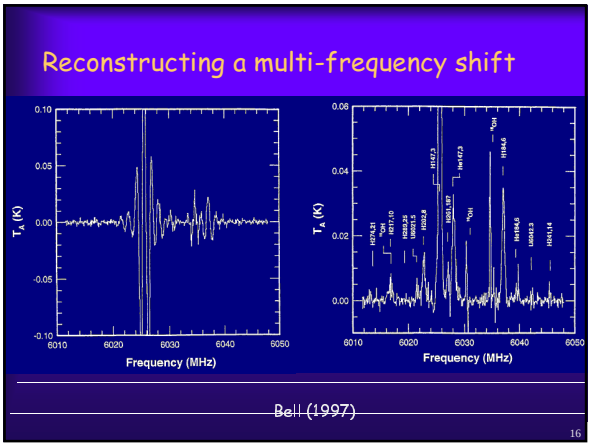
Reconstructing a multi-frequency shift
T_A (K)
Frequency (MHz)
Bell (1997)
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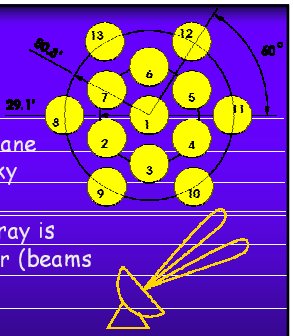
Multiple beams



- Many beams in focal plane ⇒ faster imaging of sky
- A typical multibeam array is NOT an interferometer (beams don't overlap)
- An *n*-beam array is equivalent to *n* single dishes pointing in *n* different locations

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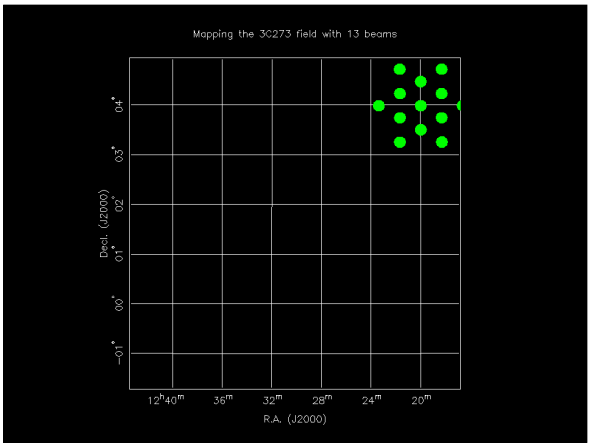
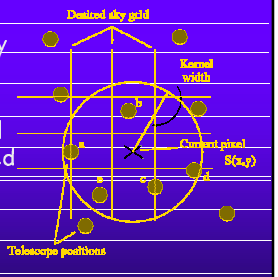


Imaging

- Sky will not be regularly sampled, so Fourier interpolation not useful
- Interpolation in general not useful if PSF allowed to vary
- Generally prefer to convolve data onto a regular grid



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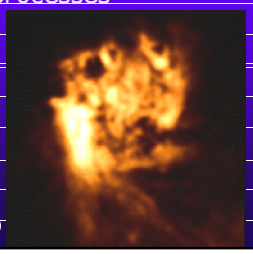
Calibration - I

- If you want to accurately calibrate your images, image the calibrator so that it goes through same processes



LMC in HI
(Parkes multibeam)

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Calibration - II

- To accurately calibrate an extended source, use an extended calibrator (e.g. S8, S9 for 21-cm images) as beams, in general, are not Gaussian