ASTRON

Netherlands Institute for Radio Astronomy

Update on beams

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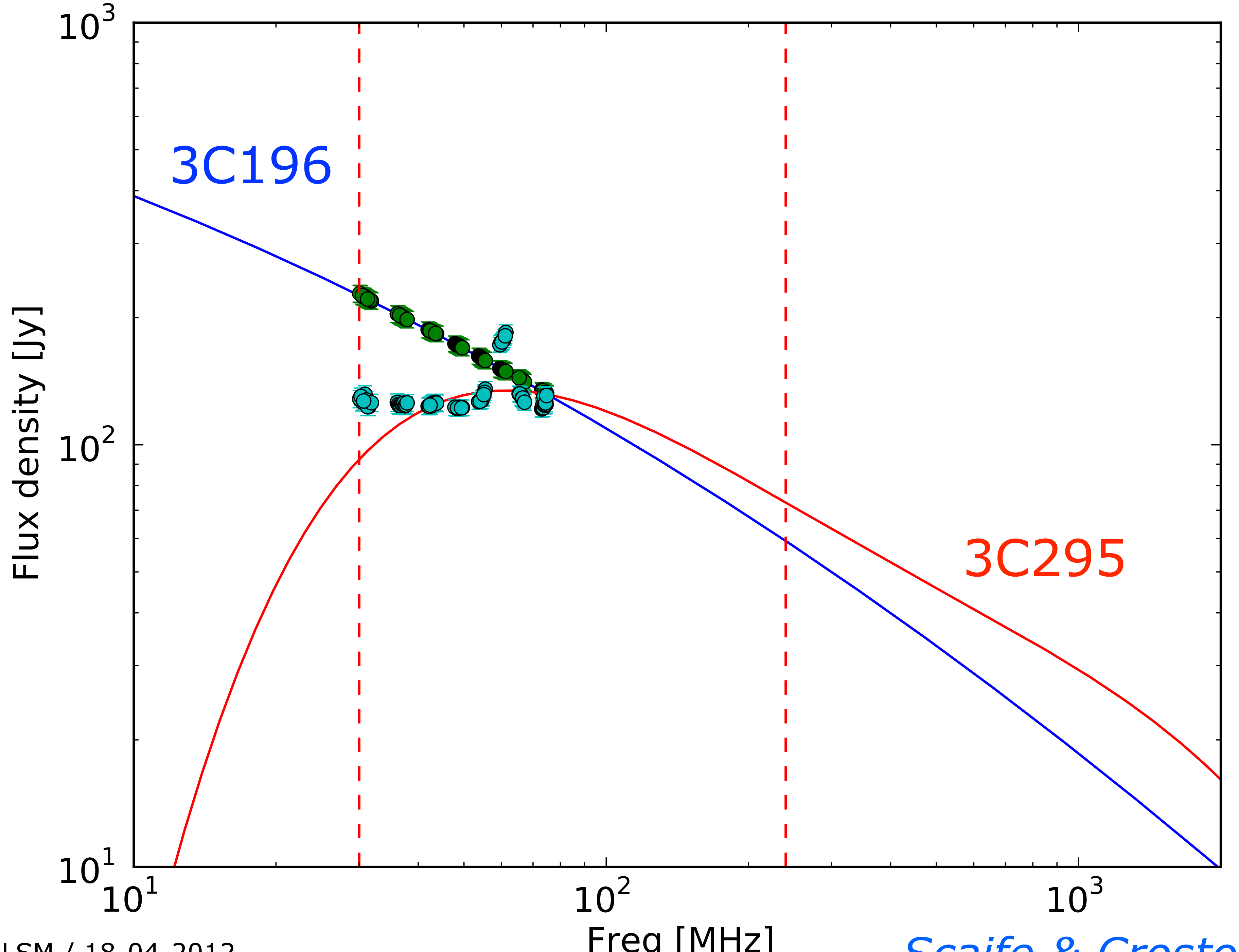
ASTRON is part of the Netherlands Organisation for Scientific Research (NWO)

LOFAR

Element beam tests ongoing ....

- Can two calibrators (observed simultaneously in LBA) calibrate each other? Test done with 3C196 and 3C295 (after demixing)
- So far indicating a problem with the element beam model ..... ?



Scaife & Croston

Beam mapping review

- 15x15 pointing grids centered on CygA
  - Observed so far: HBA_DUAL (1x) and LBA_INNER (3x)
  - Processing steps calibrate all pointings in direction of CygA; interpret gain amplitudes as (*voltage*) beam in that direction
- Range of frequencies intended to sample MSSS bands
- Gives excellent discrimination between well-behaved stations and others (mispointings and “squashed” beams)
- Can be done with short observations and quick processing
- Previously shown to give good match between observed beam patterns and prediction of beam model, for well behaved stations

Antenna patterns

- For a uniformly illuminated aperture, expect the beam pattern to behave like

$$F(u) = \frac{J_1(\pi D u)}{u}$$

- This case has
  FWHM = 1.02 λ/D

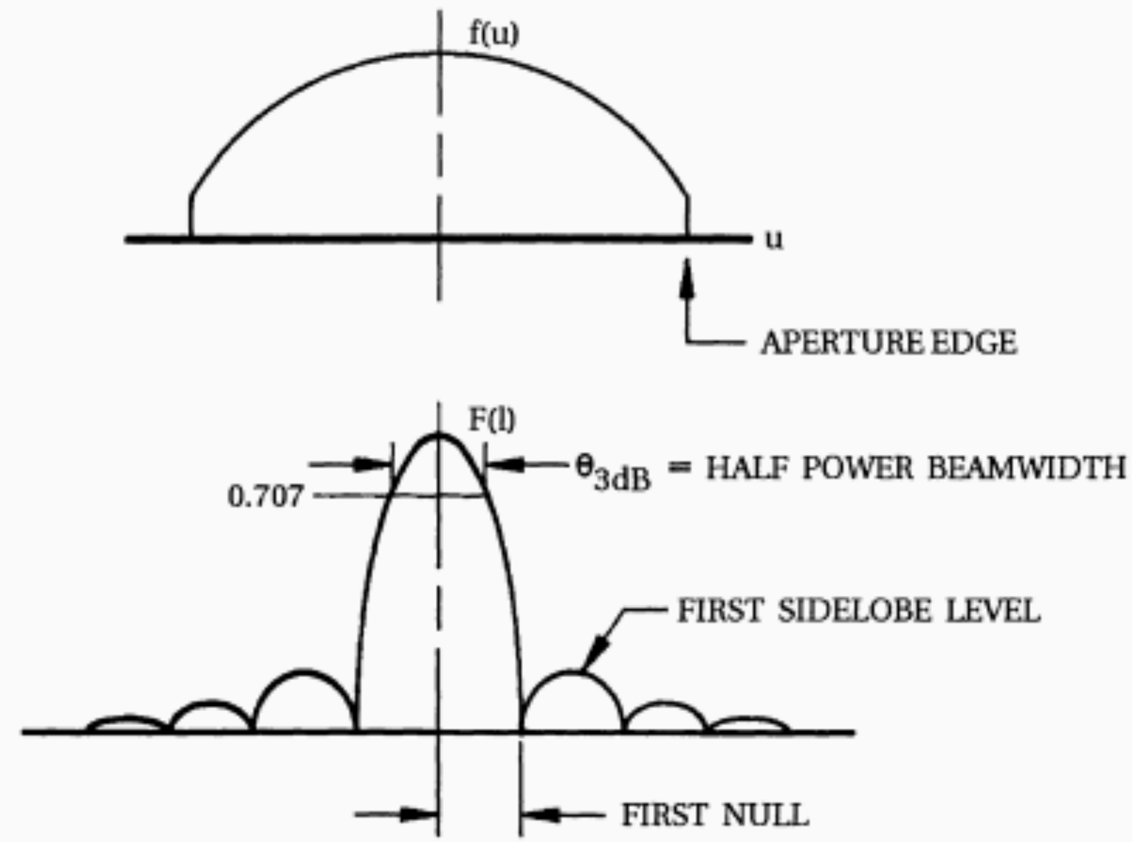


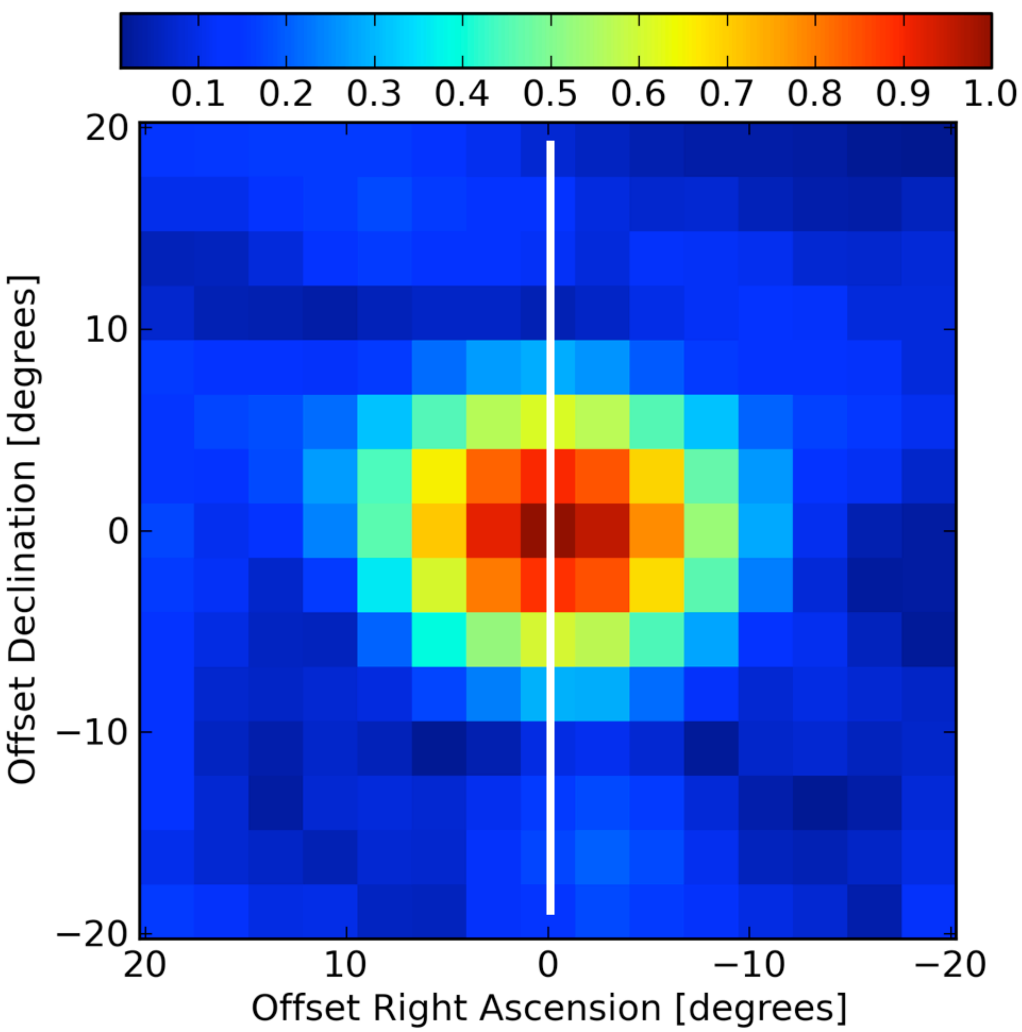
Figure 3–3. The Fourier transform relationship between an antenna aperture distribution and its far-field radiation pattern. The form of the aperture distribution, $f(u)$, and the radiation pattern, $F(l)$, are shown for a one-dimensional example. In general both quantities are complex. Only the amplitudes are shown here.

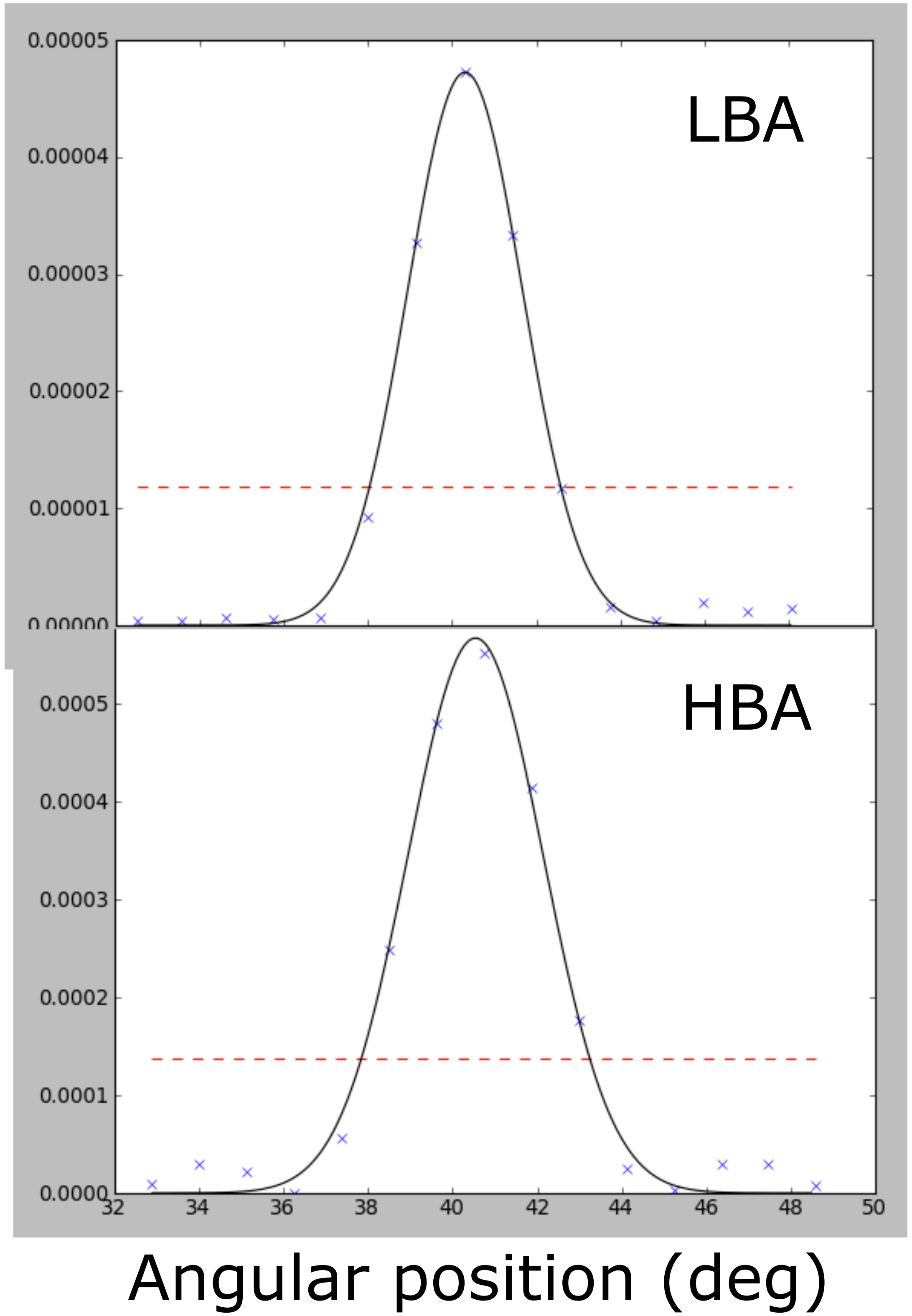
The form of $f(u,v)$ for an antenna is determined by the way in which the antenna feed illuminates the aperture. In general, the more that $f(u,v)$ is tapered at the edge of the aperture, the lower will be the aperture efficiency and the sidelobes and the broader the main beam. Tabulations of a wide variety of $f(u,v)$, and their $F(l,m)$, can be found in antenna textbooks (Hansen 1964, p. 66; Rudge *et al.* 1982, Table 1.2). For example, the VLA antennas are designed to have uniform illumination ($f(u,v)$ = constant) over the whole aperture, except where the aperture is blocked by the subreflector and its support struts. In this case, for a circularly symmetric aperture of diameter D, $F(u) = J_1(\pi D u)/u$, which has the properties: first sidelobe level = −17.6 dB, half power beamwidth = $1.02\lambda/D$, and position of first null = $1.22\lambda/D$. These are in good agreement with measured beam parameters for the VLA 25-meter diameter reflector, except for the first sidelobe level, which is modified by aperture blockage as shown in Figure 3–8.

Napier (1999)

Determining beam FWHM

- FWHM determined in LBA & HBA (both for CS004) using Gaussian fit to station beam, using points above 25% of the peak, e.g.:





Beam widths

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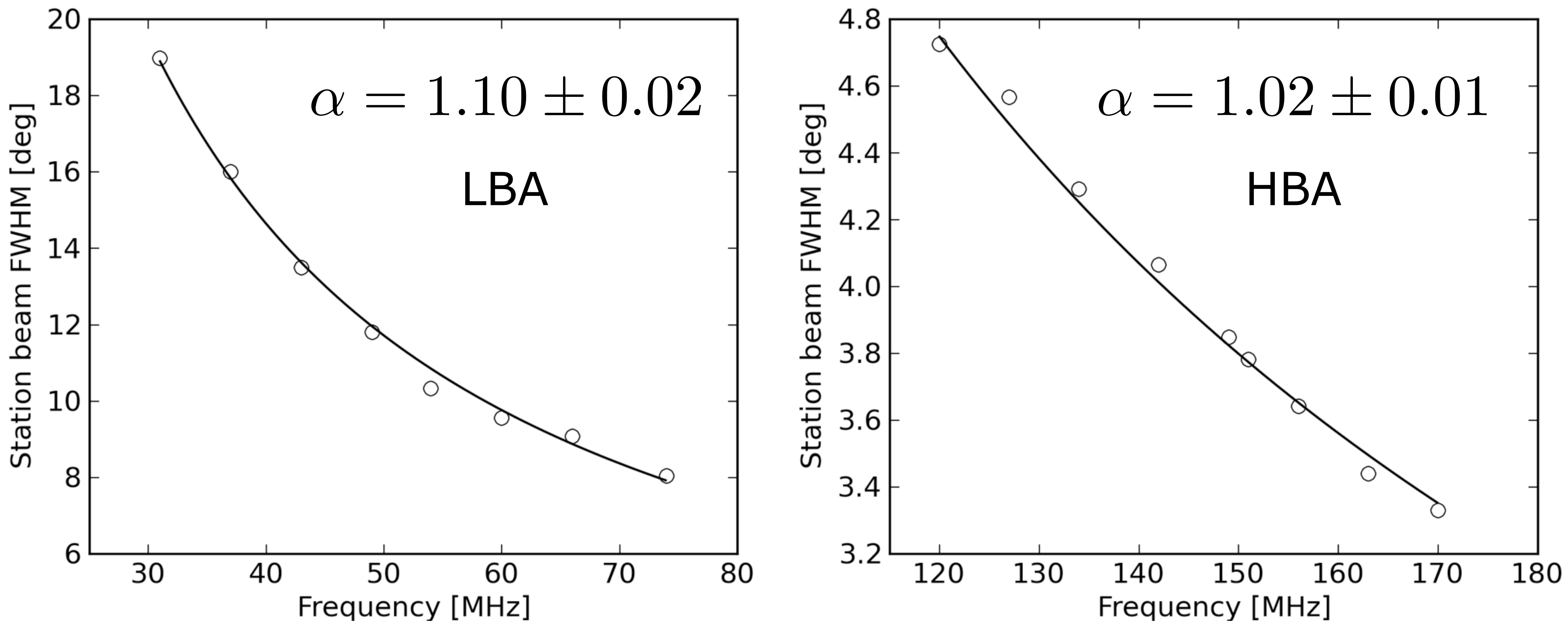
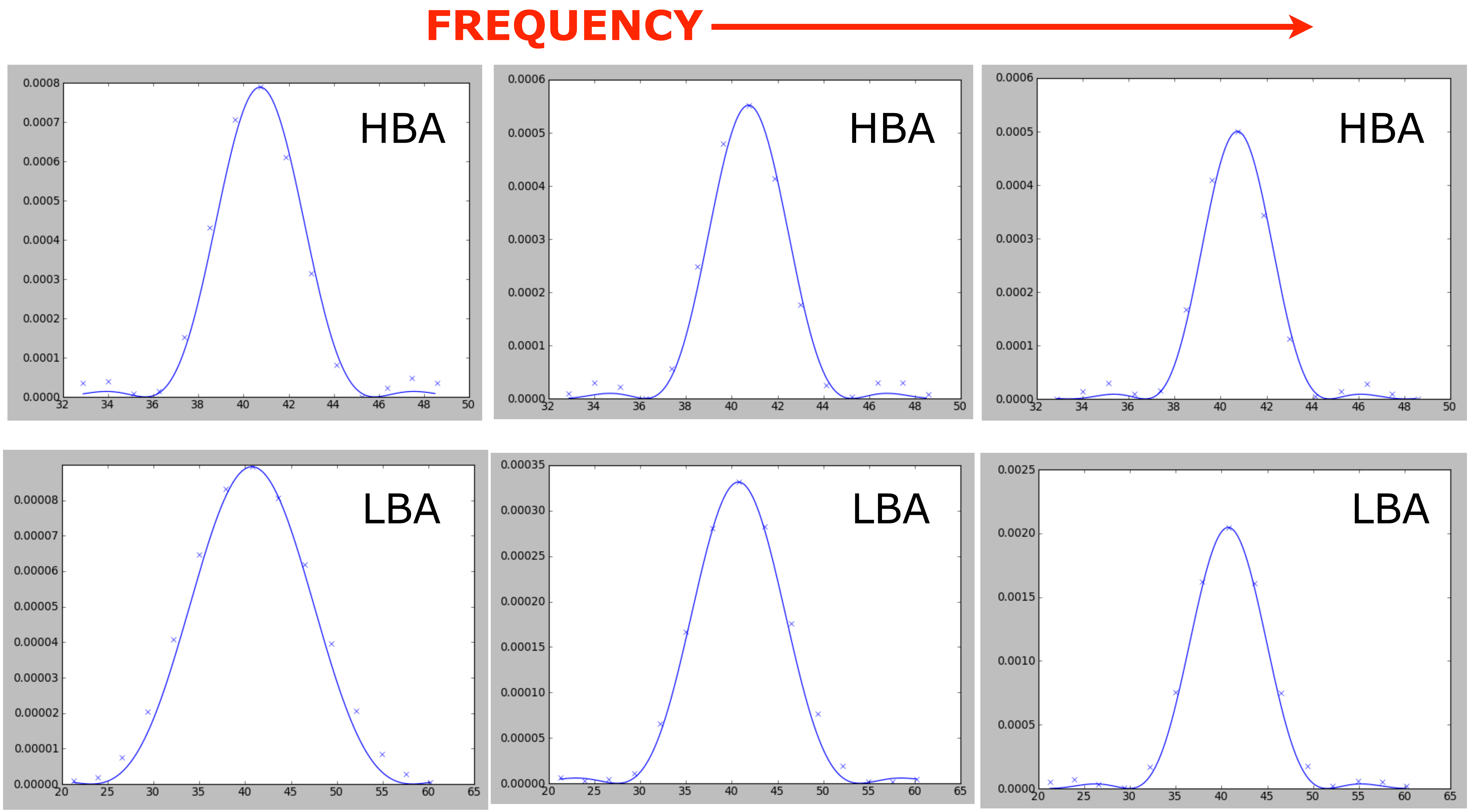
- Variation of beam width expected to follow $\mathrm{FWHM} = \alpha \frac{\lambda}{D}$
- Value of α is ~1.3 for tapered 25m dish, what is it for LOFAR?
- Fitted run of FWHM vs λ using functional form above
    - error on scale factor estimated using variance of (FWHM/(λ/D))



Analytic form of the beam

- Using Bessel-sinc function (prediction only), a good match to the beams is found (though the sidelobe levels are too low for HBA)



Conclusions and future work

- Element beam problems? - Further investigation underway.
- Beam mapping not only good for qualitative analysis
- Beam FWHM follows expected trend with wavelength and diameter
  - HBA: scaling factor appropriate for perfectly illuminated "dish"
  - LBA: scaling factor for slightly tapered "dish"
- Beam shapes seem to follow Bessel sinc functions to first order
  - More stations need to be analysed
  - Cannot be completely correct, but what are the limitations?
  - LBA_OUTER ????
  - Can analytic beam shapes be used for quick and dirty calibration/imaging?

Beam polarization degree?

- Only determined so far for CS004, needs further investigation