Tianlai dish array configuration

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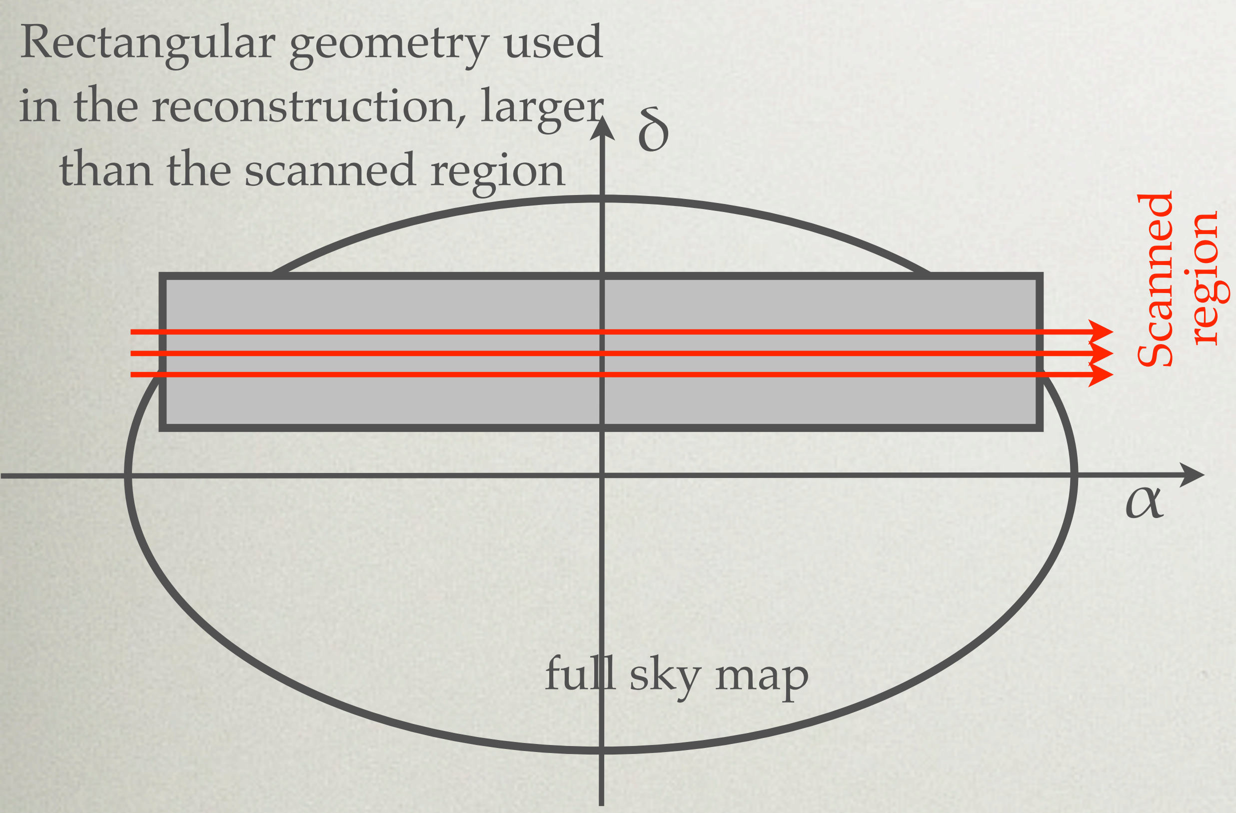
- Comparison of several configurations for the Tianlai 16-dish array, and survey strategy
- Based on work being done by Jiao Zhang
- Computation of reconstructed beams from visibilities, Transfer function and noise power spectrum
- Assume transit mode operation, with several scans along the declination, and complete beam knowledge
- assume stationary white noise for the visibilities as a function of time $V_{ij}(t) \dashrightarrow V_{ij}(\alpha)$

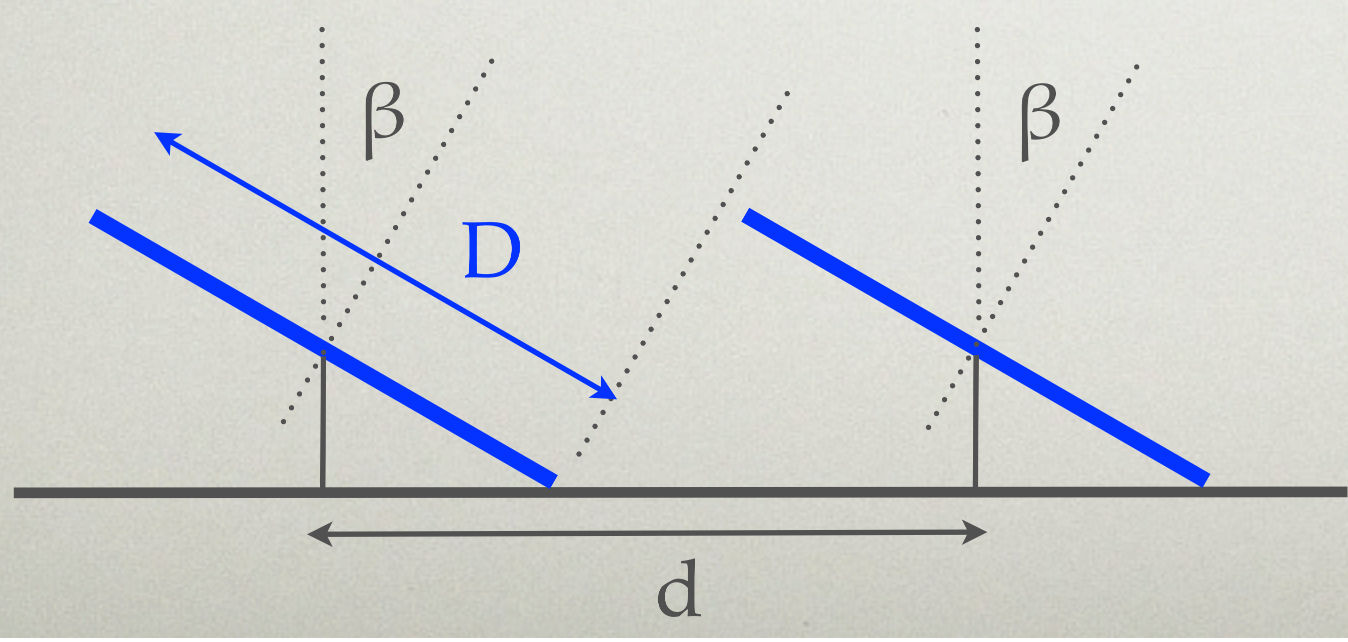
$$
\begin{aligned}
\text{Sky} &: \quad \alpha \;\; (\text{RA, East} - \text{West, EW}) \\
& \quad\;\; \delta \;\; (\text{DEC, North} - \text{South, NS}) \\
\text{Fourier} &: \quad (\alpha, \delta) \longrightarrow (u, v) \\
\text{Sky} &: \quad I(\alpha, \beta) \longrightarrow F(u, v) \\
\text{Visibilities} &: \quad V_{ij}(\alpha) \rightarrow \tilde{V_{ij}}(u)
\end{aligned}
$$



$$
\begin{aligned}
\left(\tilde{V_{ij}}(u)\right) &= [A_u] \times (F_u(v)) + (n) \\
\left(\hat{F}_u(v)\right) &= [B_u] \times \left(\tilde{V_{ij}}(u)\right) \\
\left\{\hat{F}_u(v)\right\} &\rightarrow \hat{F}(u, v) \\
\hat{F}(u, v) &\rightarrow \hat{F}_W(u, v) = \hat{F}(u, v) \times W(u, v) \\
\hat{F}_W(u, v) &\longrightarrow \hat{I}(\alpha, \delta) \qquad (\text{FFT})
\end{aligned}
$$

Configurations

- 16=4x4   D=6 m dishes, $D_{eff}=\eta D=5.4$ m, base spacing d=7 m
- maximum N_B = 8x17=136 baselines
- (a) regular array, 28x28 m^2 , N_B =25 baselines
- (b) circular, 1+6+9, ~32x32 m^2 , N_B =101 baselines
- (c) irregular, 2+3+5+4+2, ~32x32 m^2 , N_B =84 baselines
- 9 scans : $\delta = \{0, \pm 1.5^\circ, \pm 3^\circ, \pm 4.5^\circ, \pm 6^\circ\}$

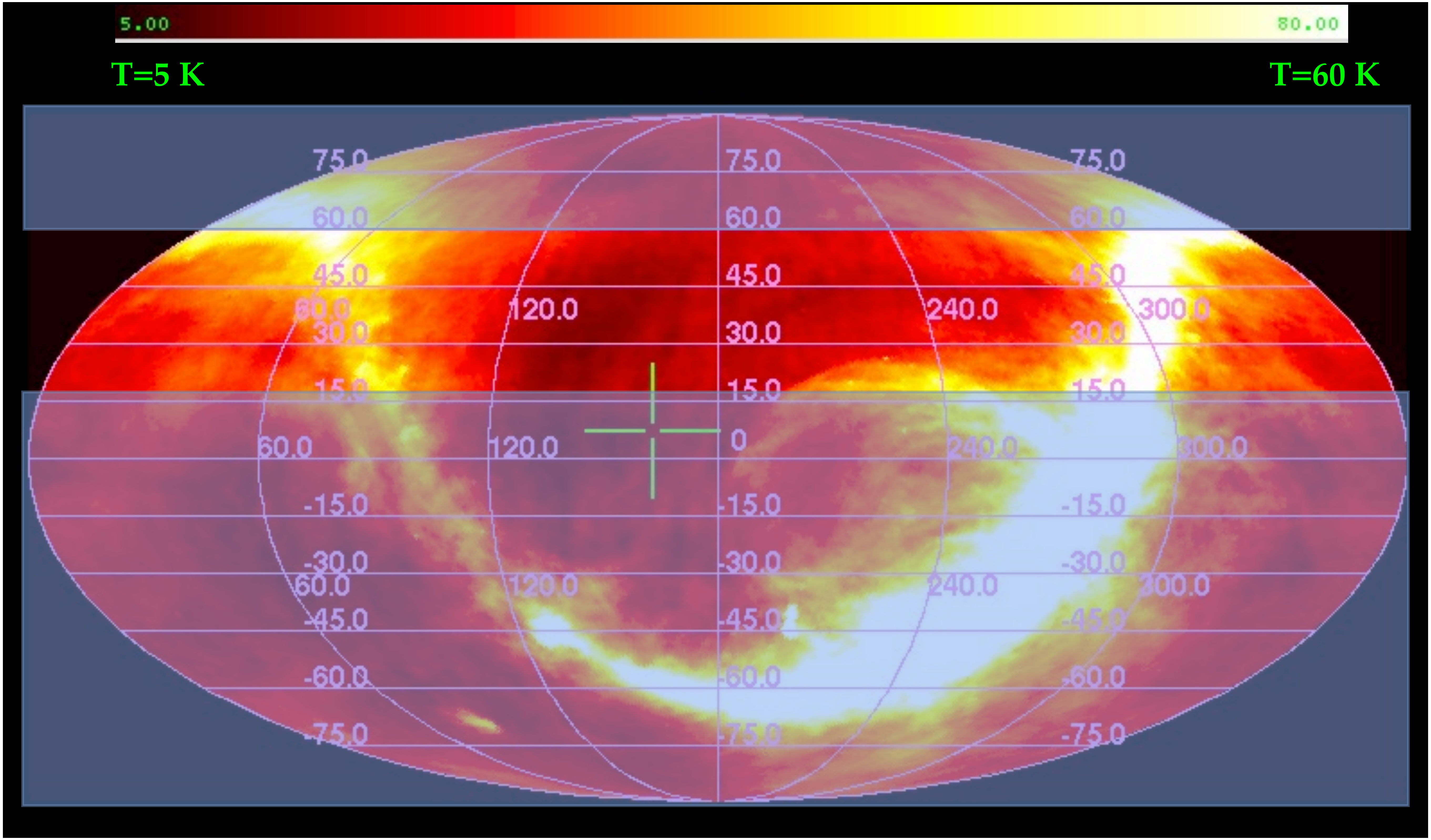


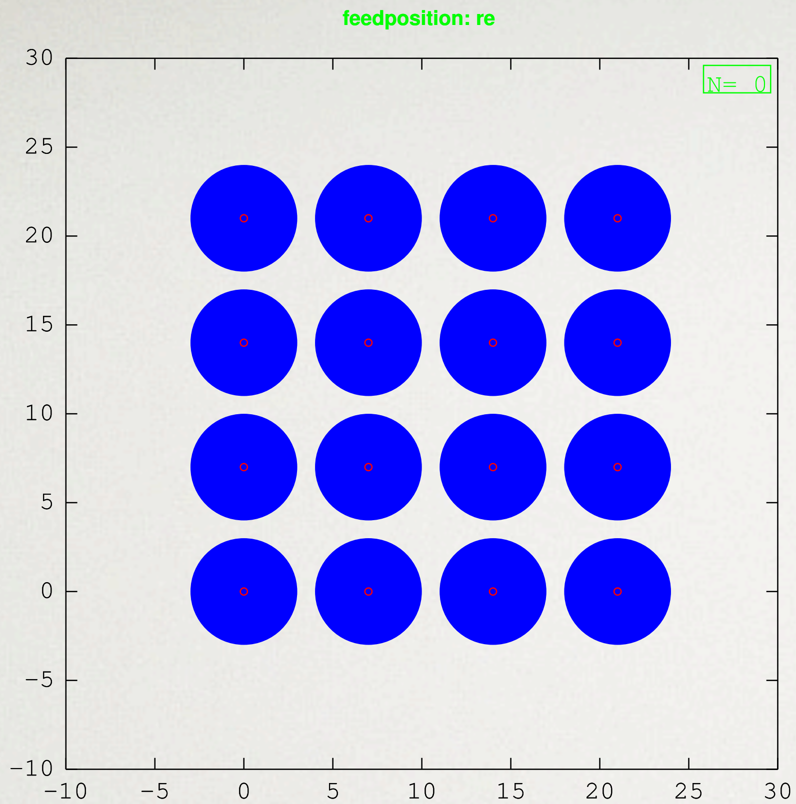
$$d \simeq \frac{D}{\cos(\beta_{max})}$$

$$D = 6\,\mathrm{m}, d = 7\,\mathrm{m}$$

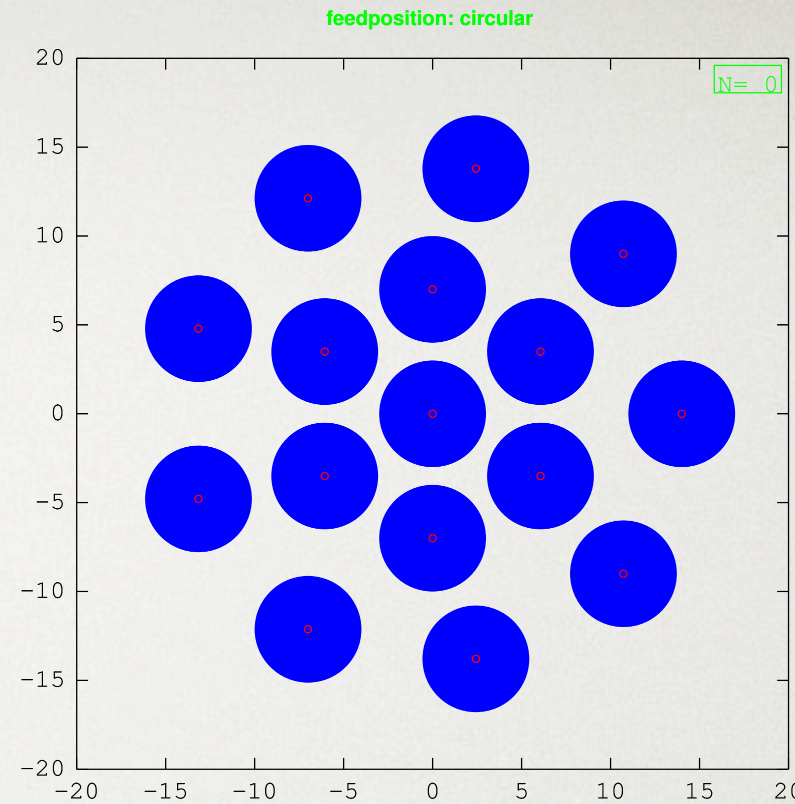
$$\beta_{max} \simeq 30^\circ$$

Synchrotron map @ 400 MHz - Eq. Coordinates (ra,dec)
Tianlai-16dish accessible sky region
(45 N ± 25 deg) → 20 < δ < 60 in Xinjiang (45 N)

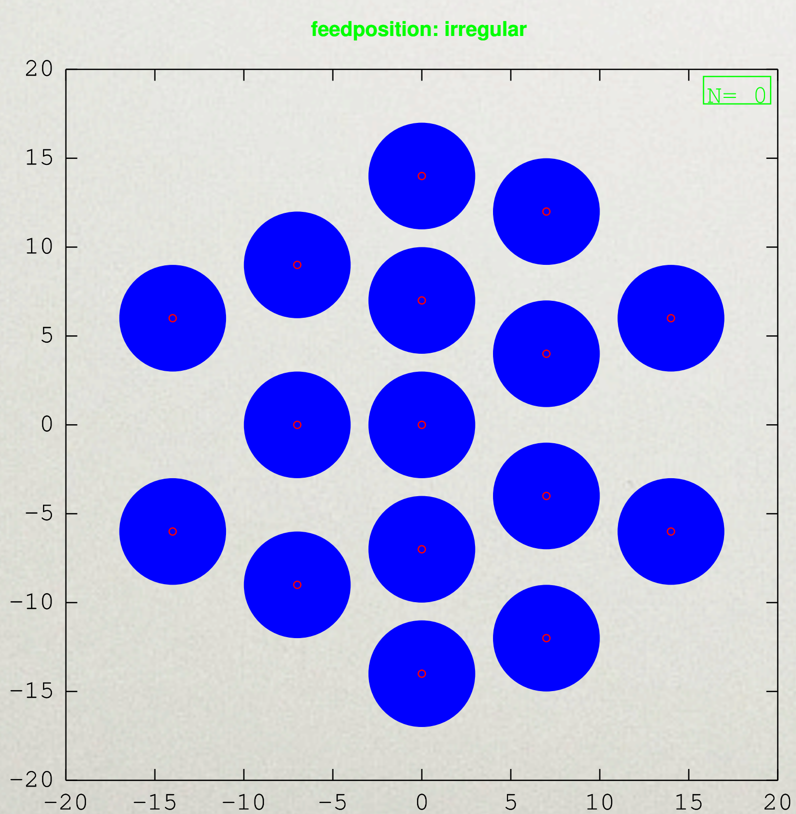




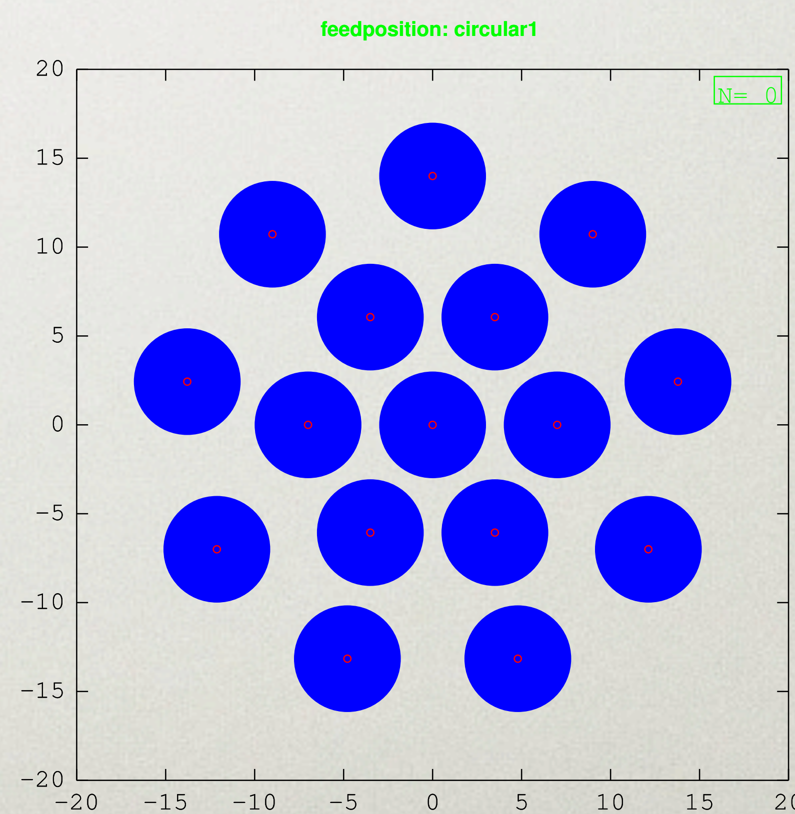
(a) regular



(b) circular



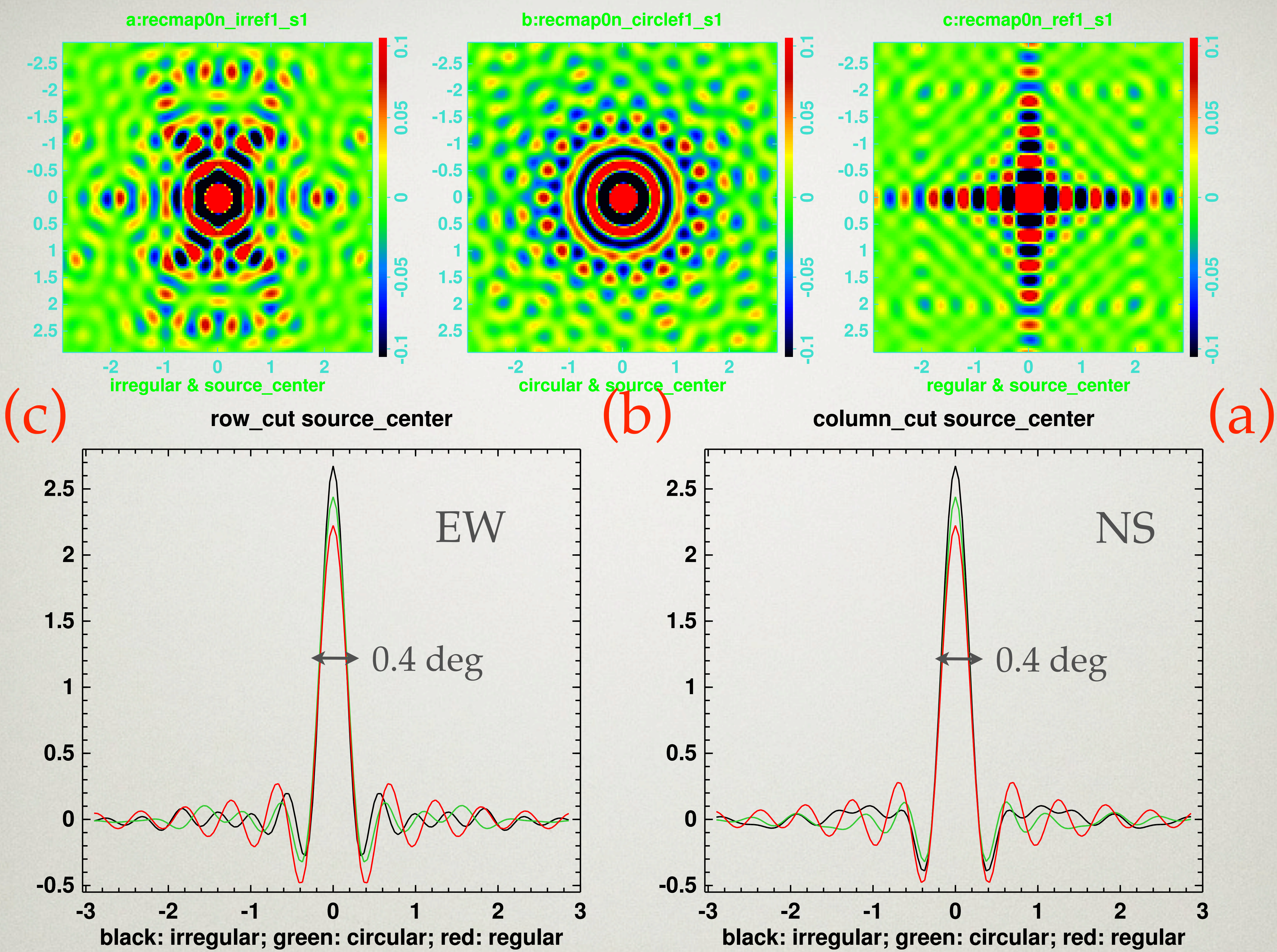
(c) irrgular



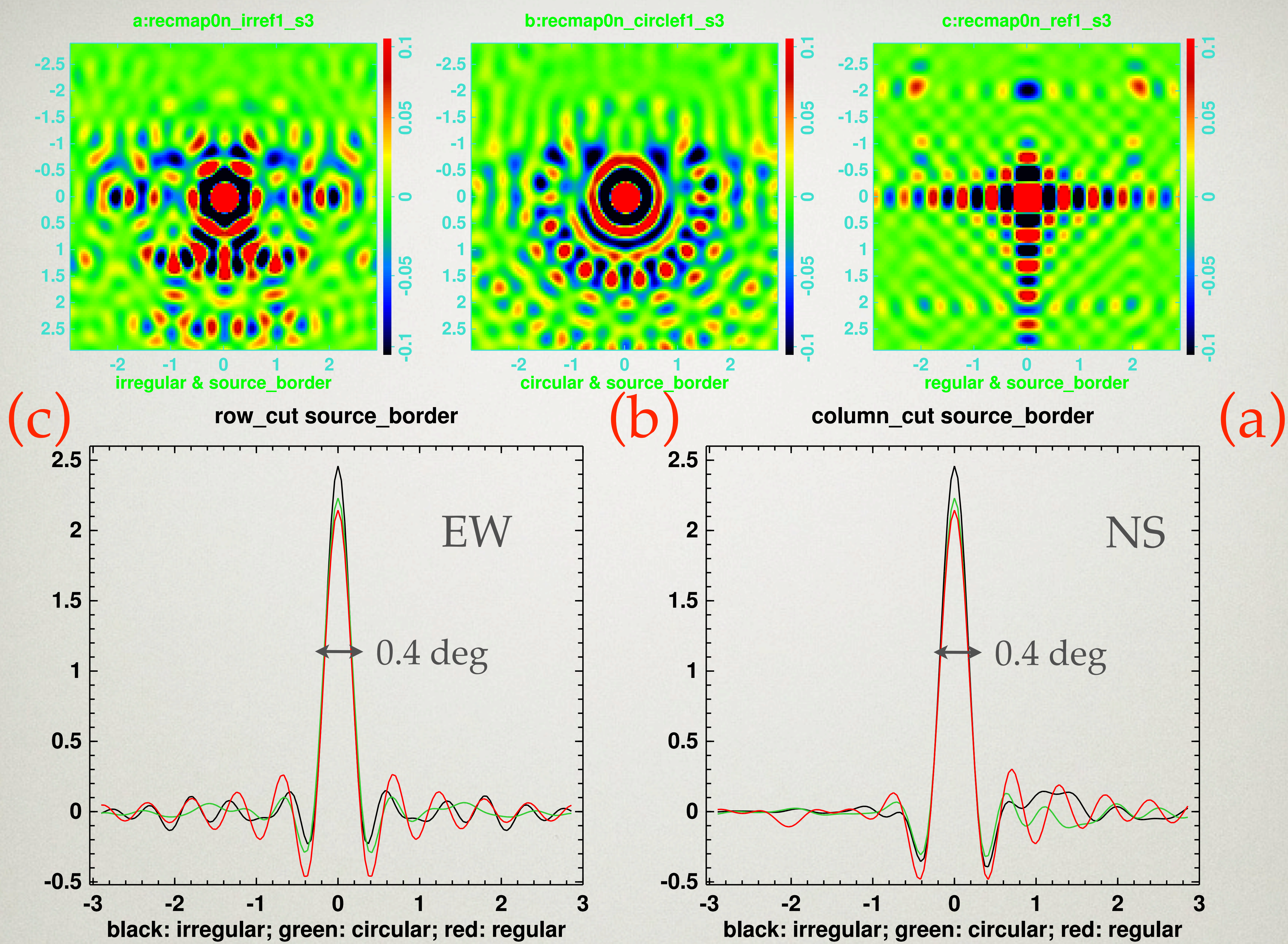
(d) circular–rotated

Beam shapes

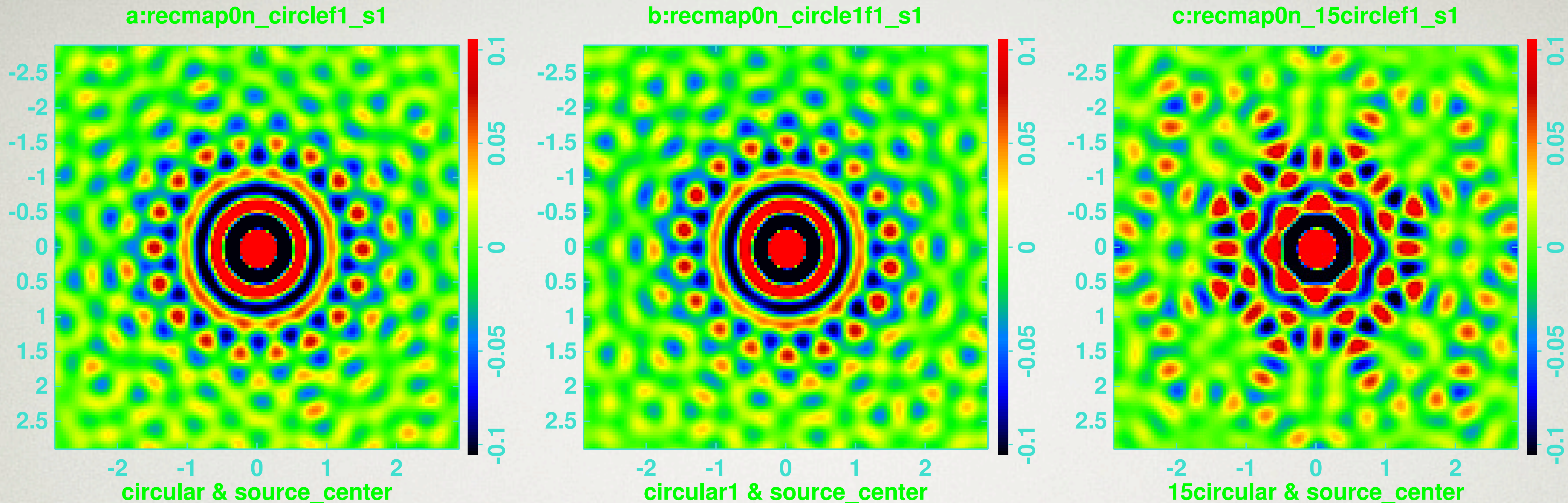
- Compute the reconstructed from the visibilities (without noise) for an input map with point sources at different declination
- The beam (response to a point source) depends on declination, but not on RA
- beam before and after applying weights on the (u,v) plane (cut/weight based on the computed noise covariance matrix, application of a frequency independent global beam)

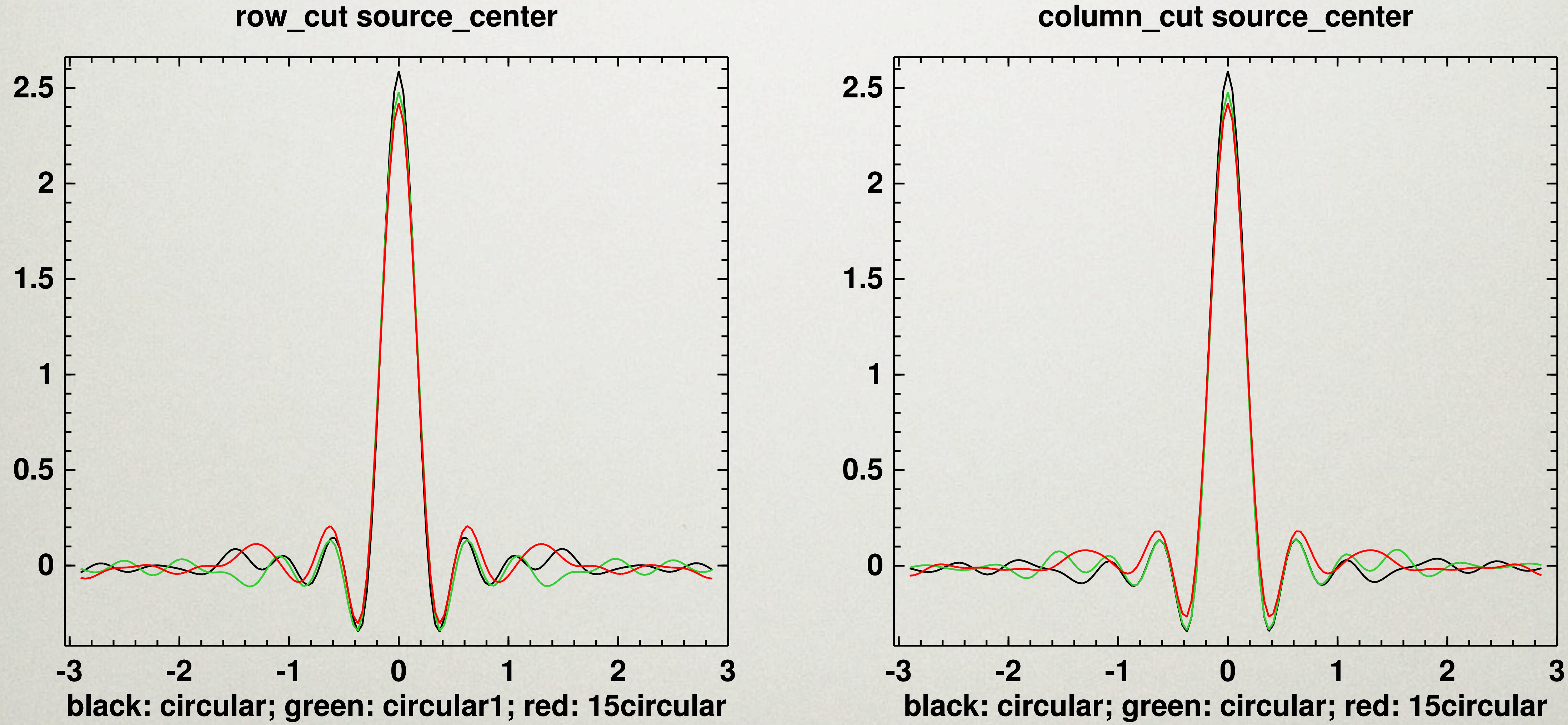


Beam at center (in δ) - 1200 MHz



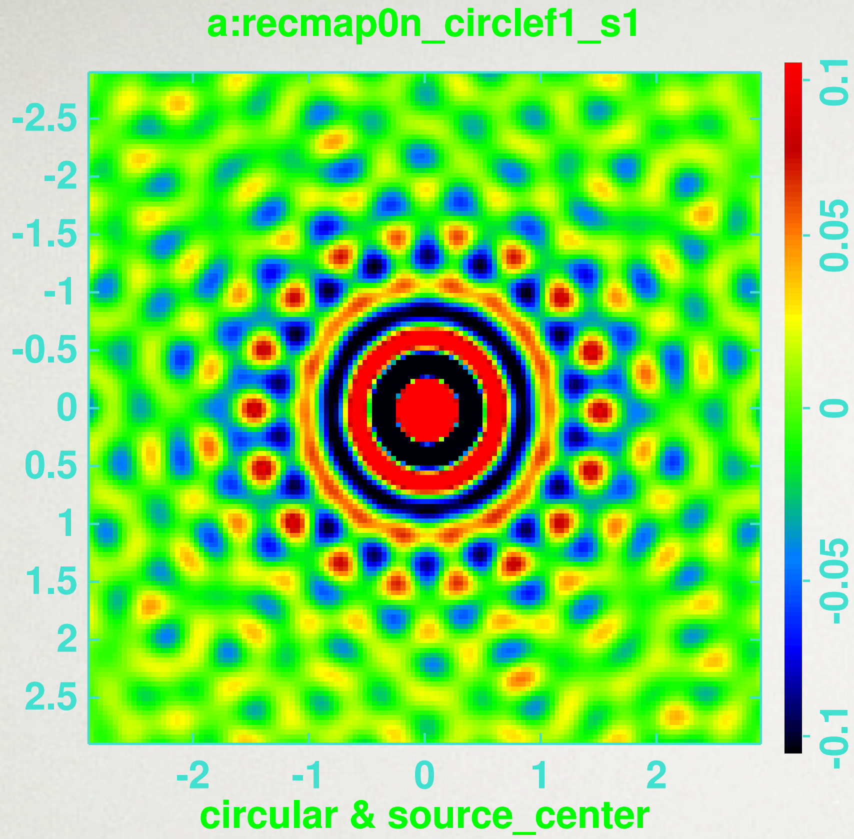
Beam at the edge (in δ) - 1200 MHz

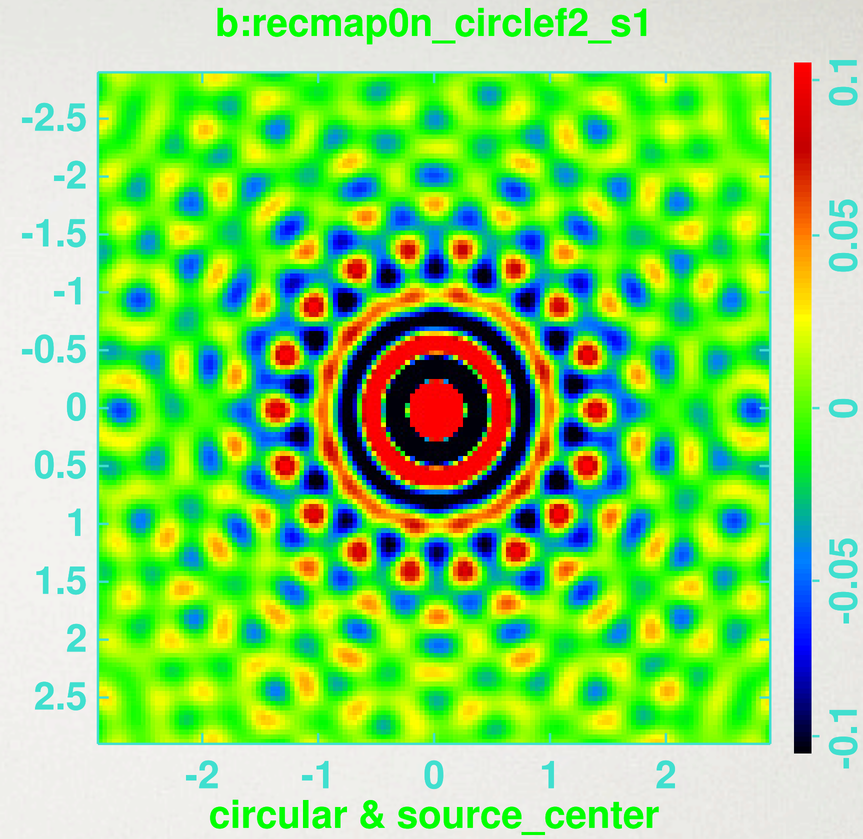




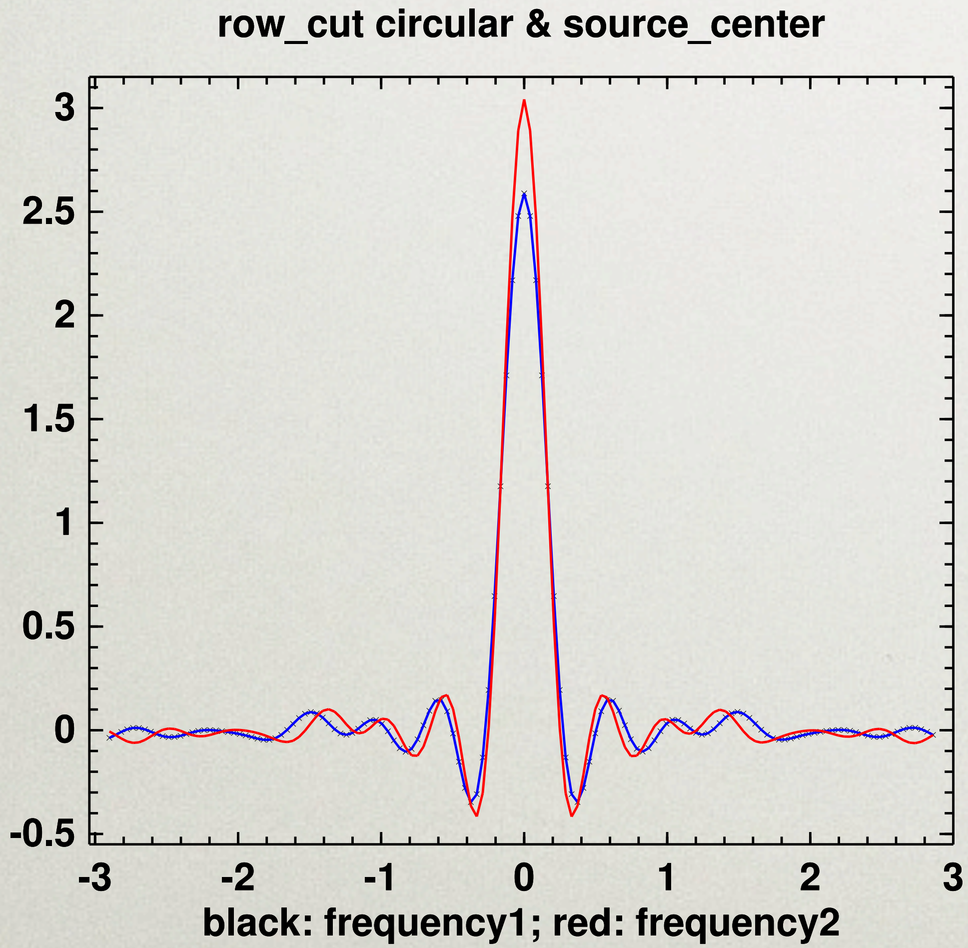
Beam at center for 2 16-dish circular configurations and one 15-dish circular

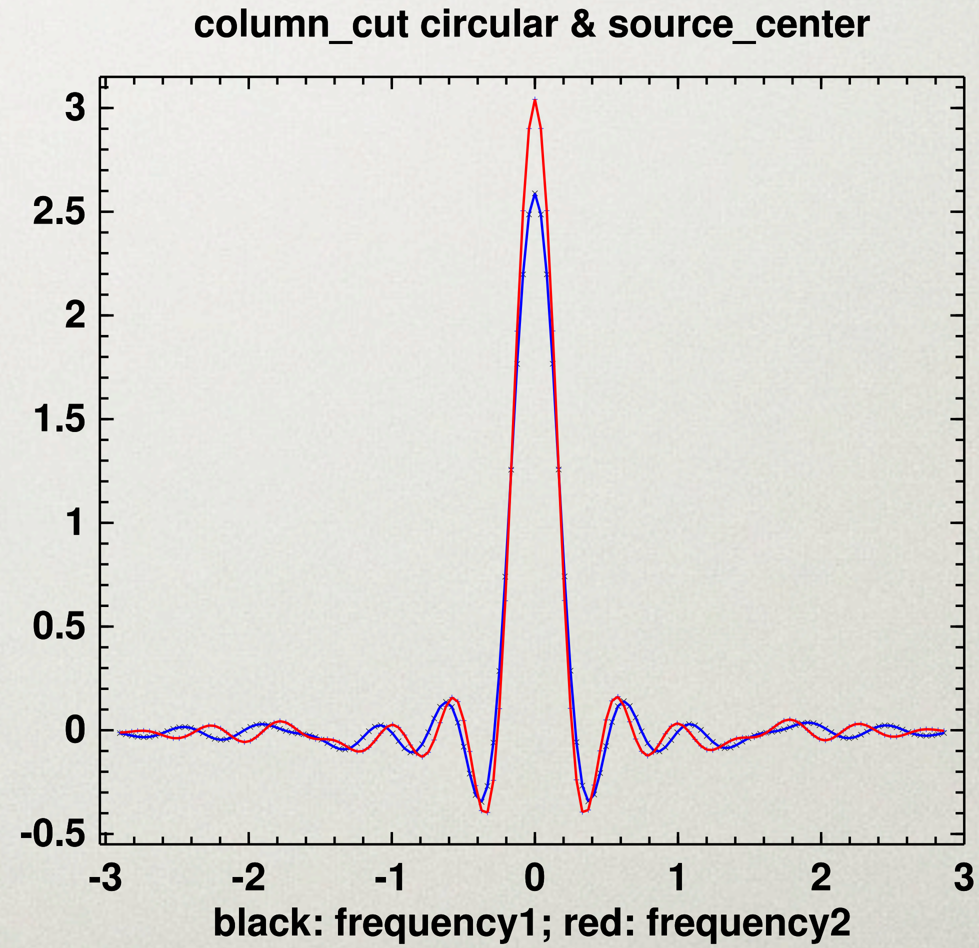
1200 MHz





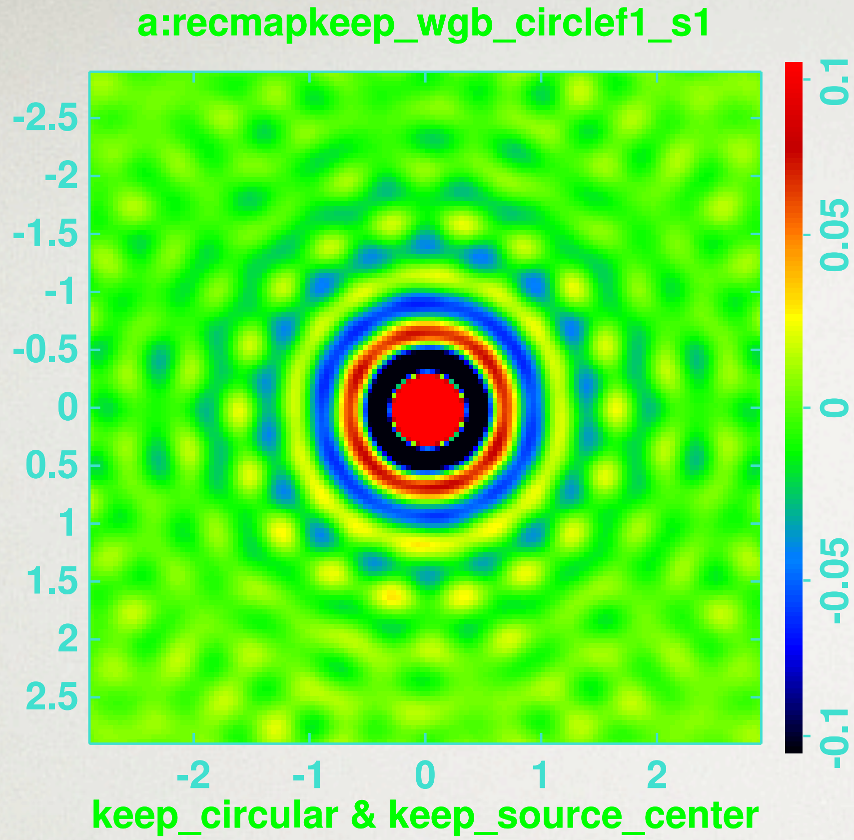
1300 MHz

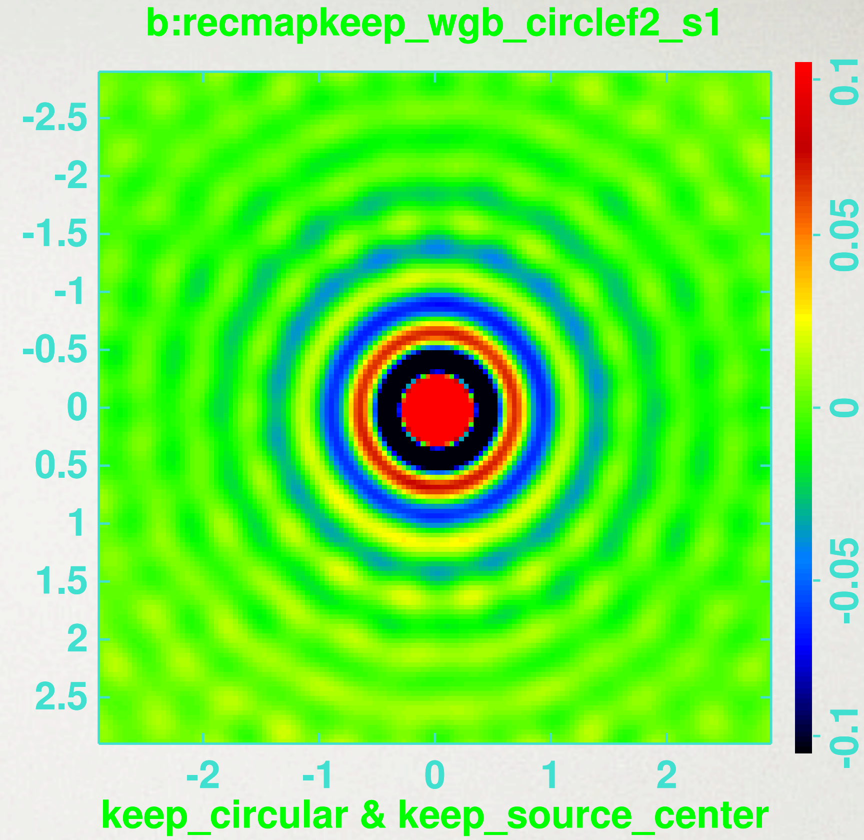




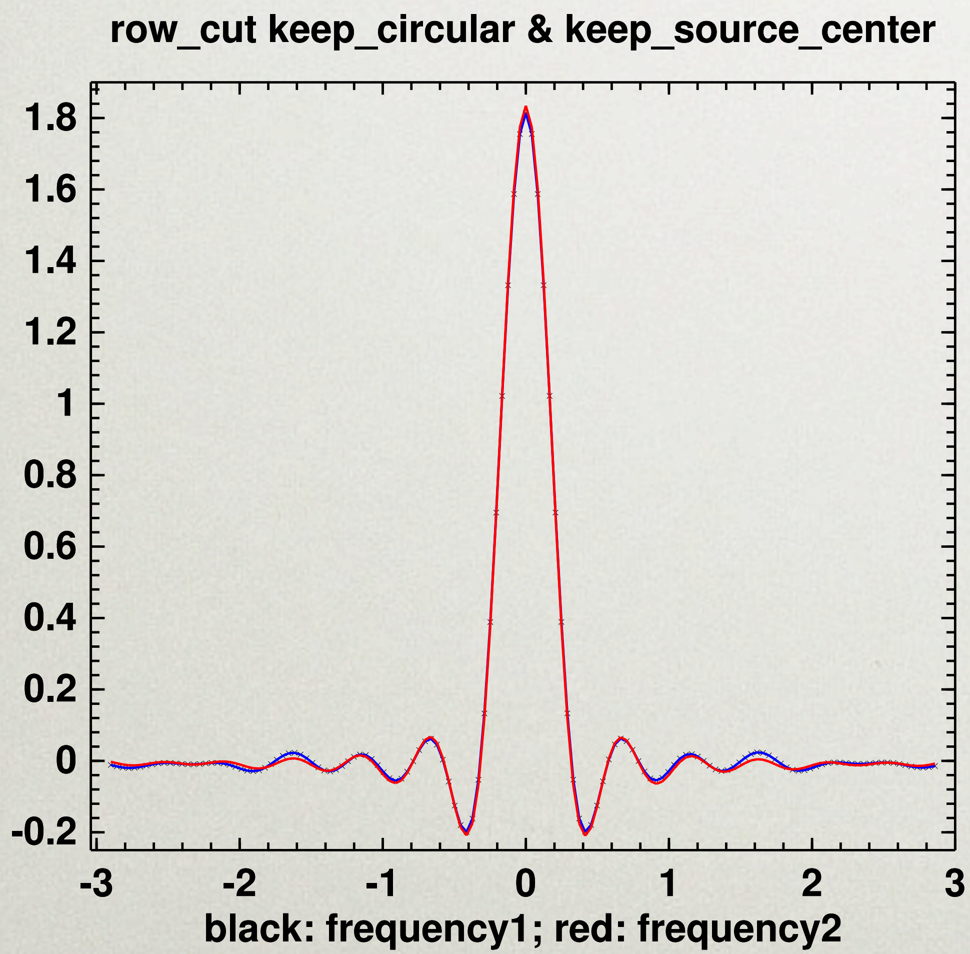
Beam frequency dependency - circular configuration (b) - 1200 MHz, 1300 MHz

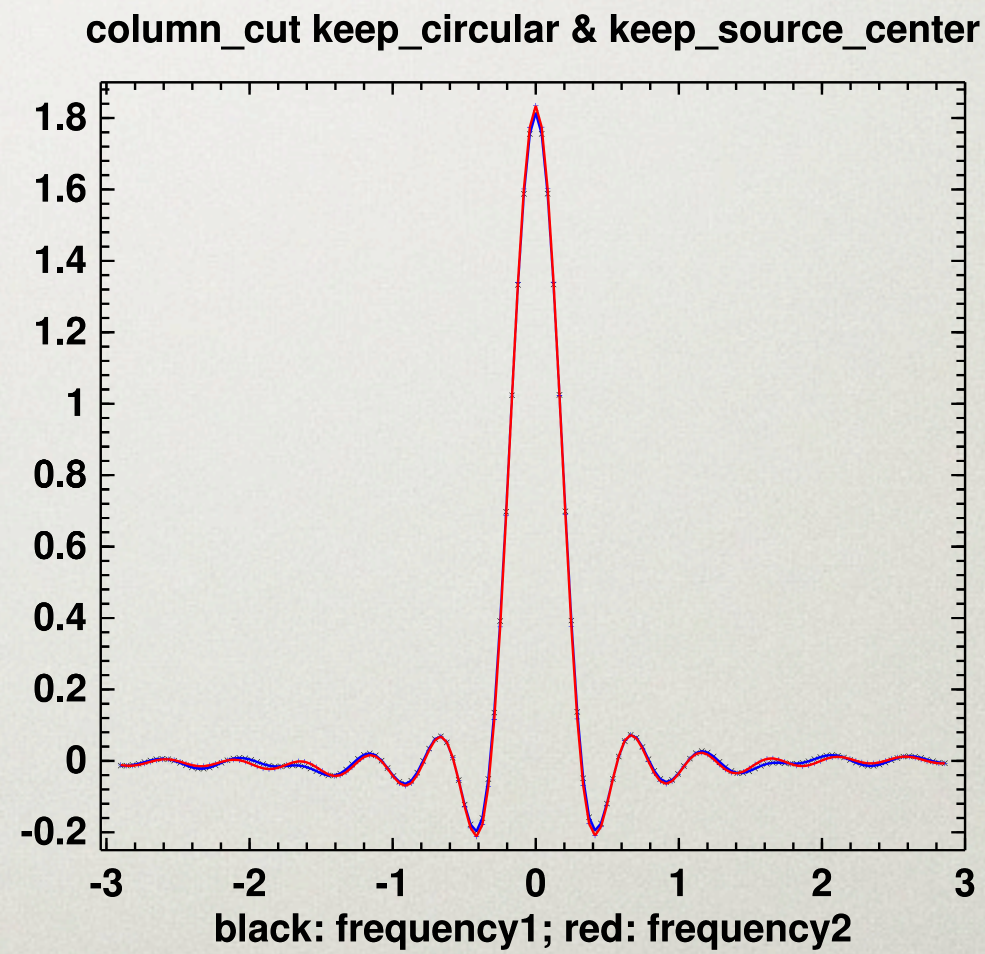
1200 MHz



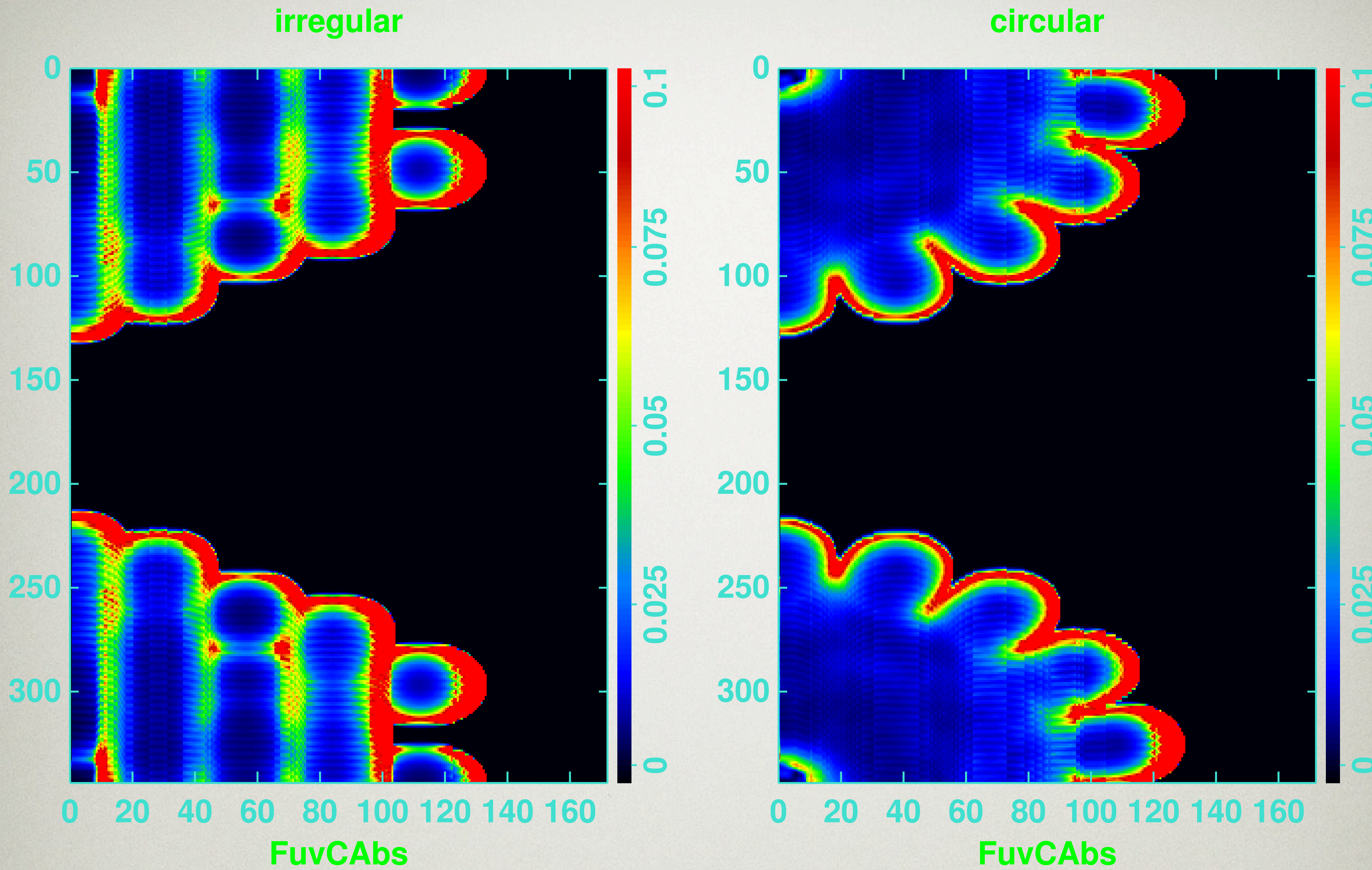


1300 MHz





Applying a global weight function - circular configuration (b) - 1200 MHz, 1300 MHz

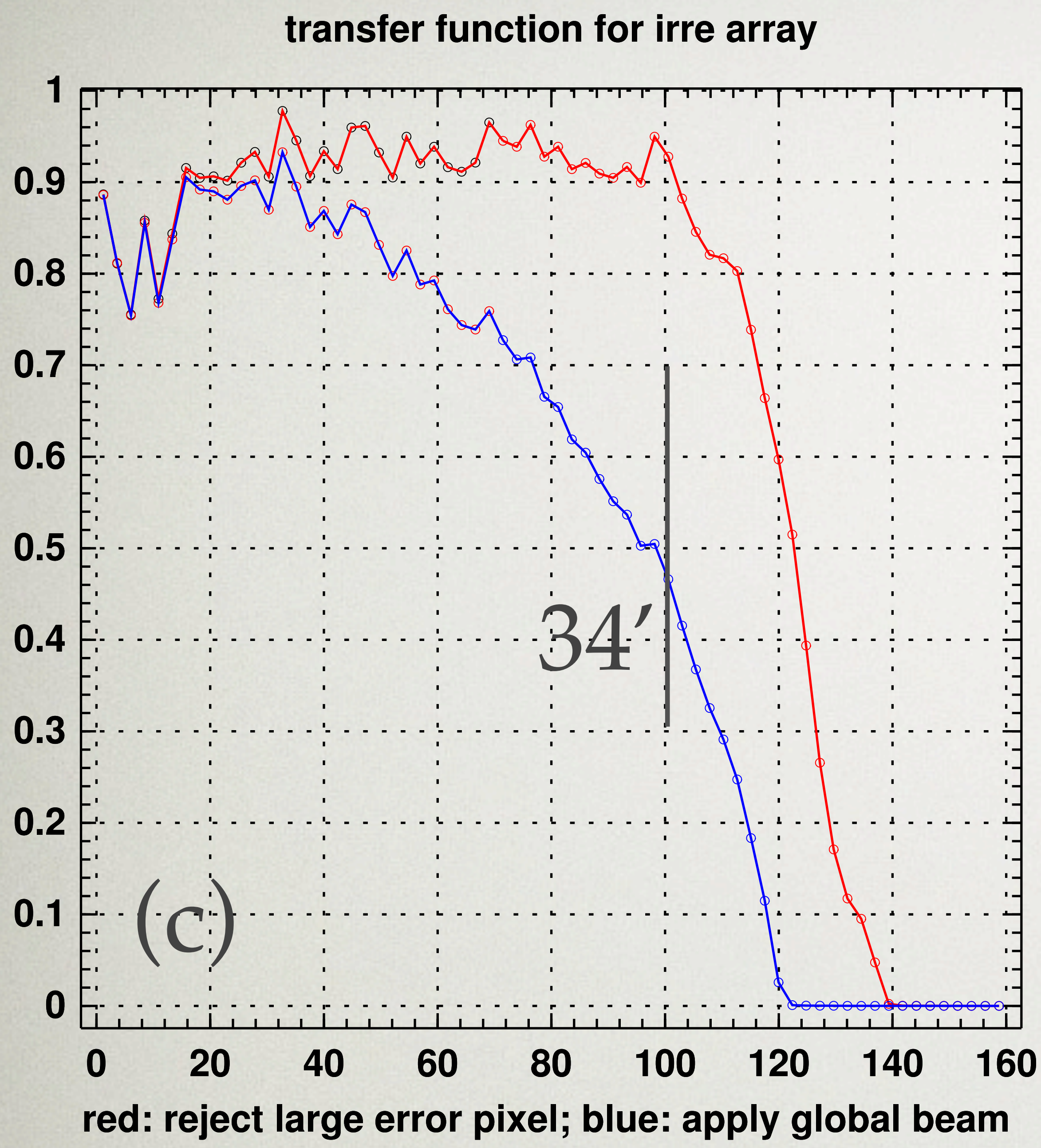


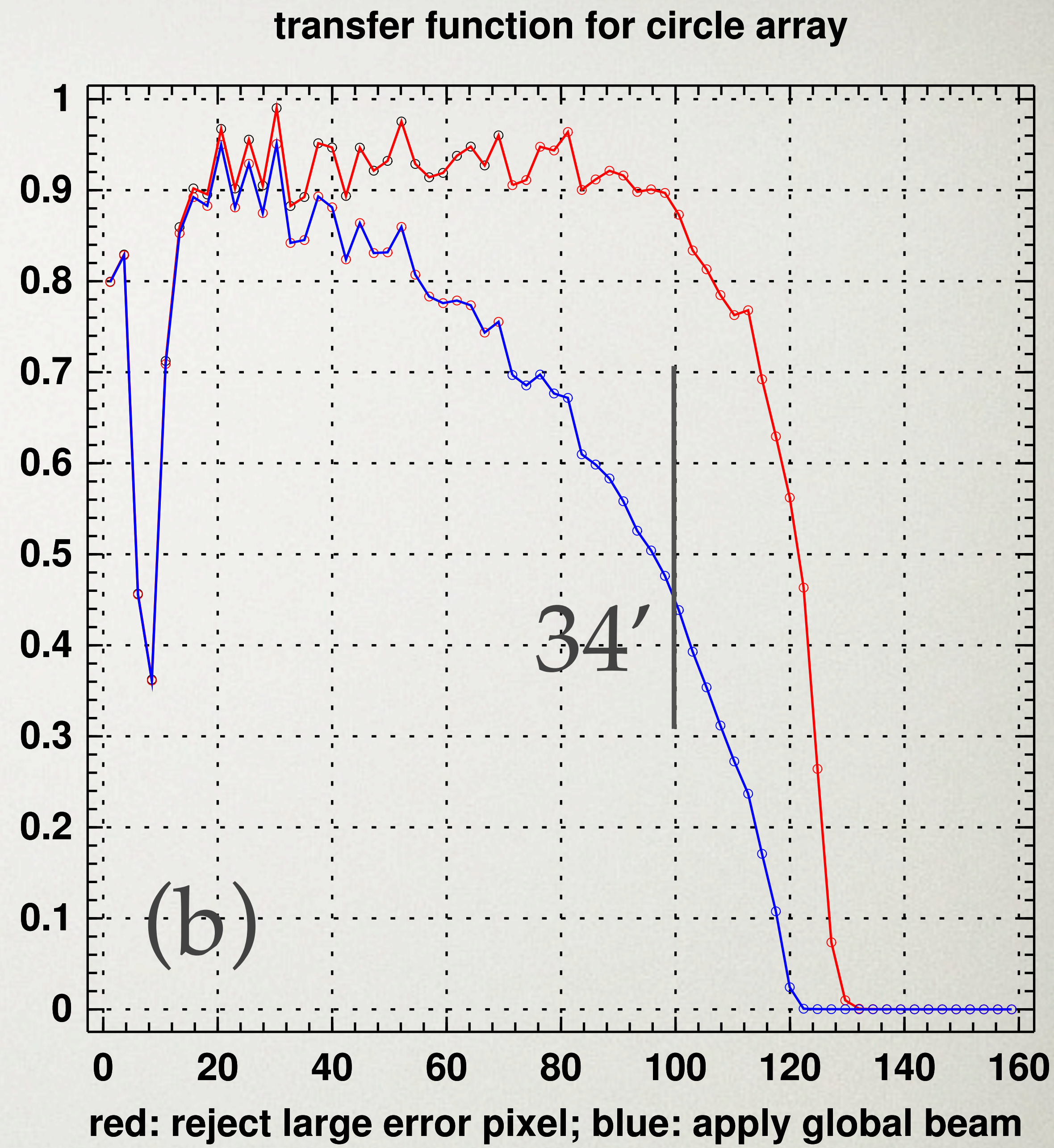
Diagonal of the error covariance matrix for configurations (b),(c)

Transfer function and noise power spectrum

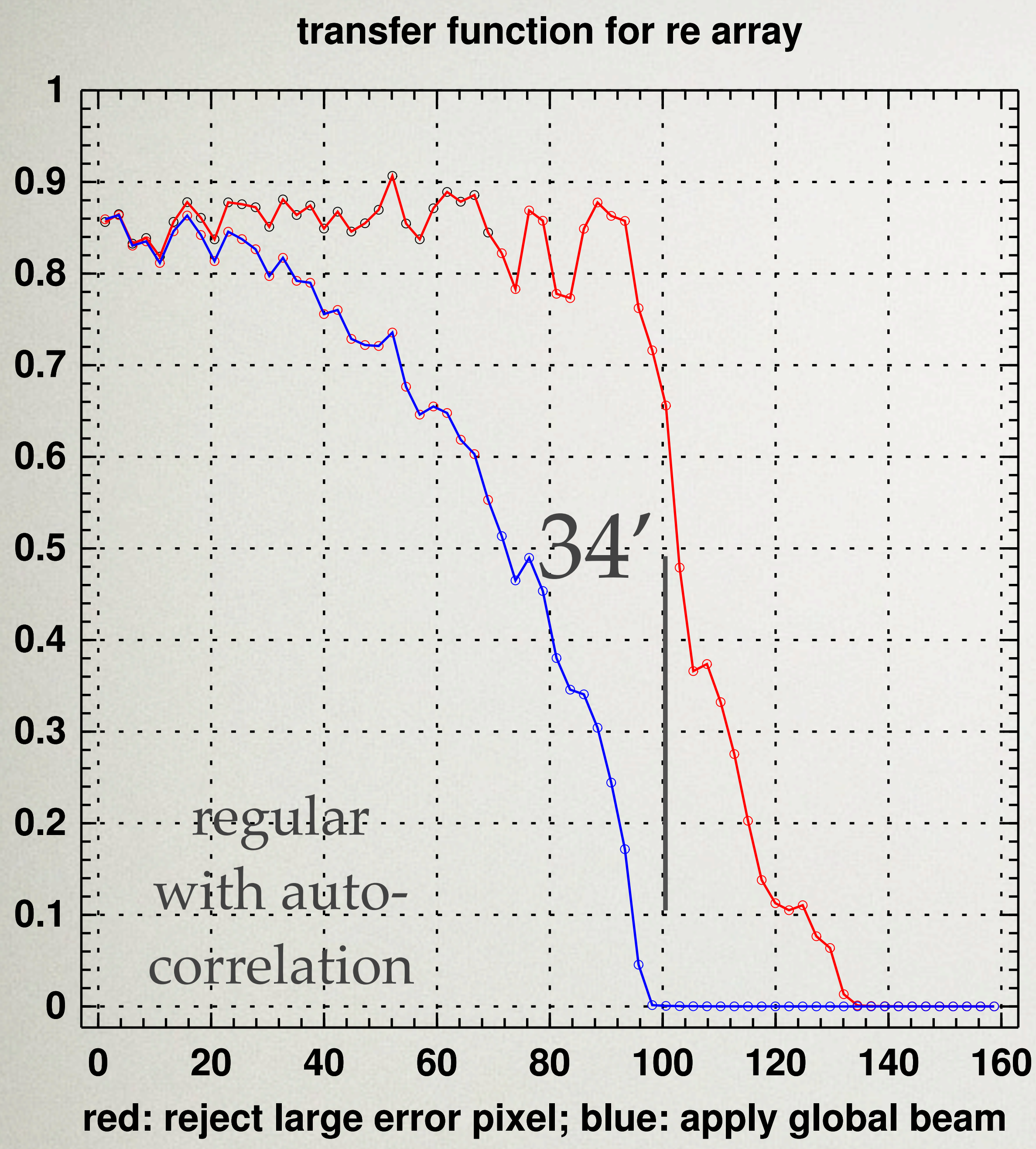
- $T(t_\perp)$: Compute the reconstructed map for a white noise input map, compute the power spectrum of the reconstructed map
- Noise power spectrum: reconstruct the map with the visibility noise only (F(u,v)=0) and compute the power spectrum
- take the average over several input noise map/ visibility noise realizations (single/few realizations right now)

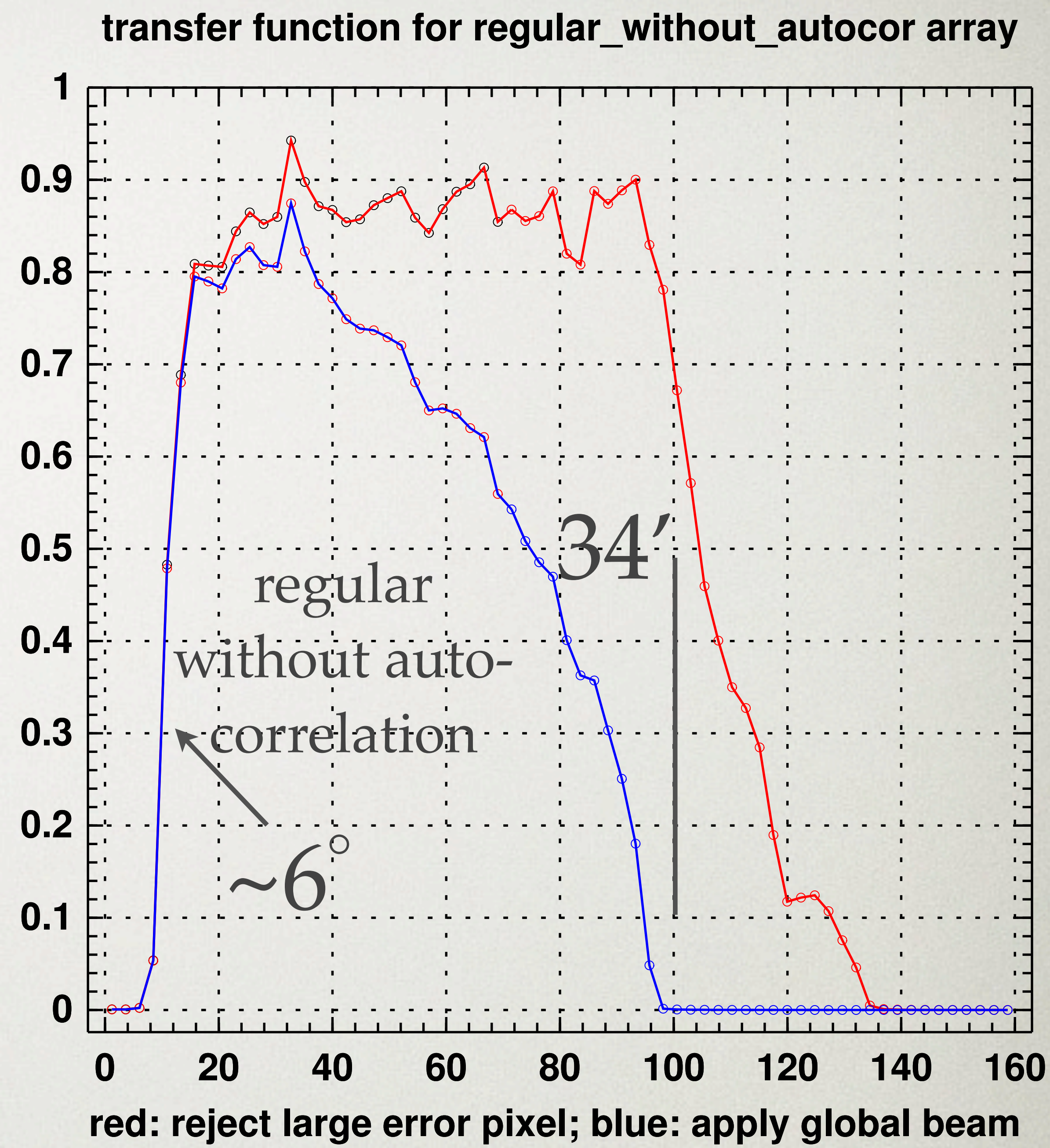
$$
\begin{aligned}
t_\perp &= \sqrt{u^2+v^2} \\
T(t_\perp) &= \frac{P_{rec}(t_\perp)}{P_{in}(t_\perp)} \\
P_{noise}(t_\perp) &= P_{noise-V}(t_\perp)
\end{aligned}
$$





Transfer function for configurations (c)-irregular and (b)-circular rejecting high noise-variance modes (red), and with global beam weighting (blue)

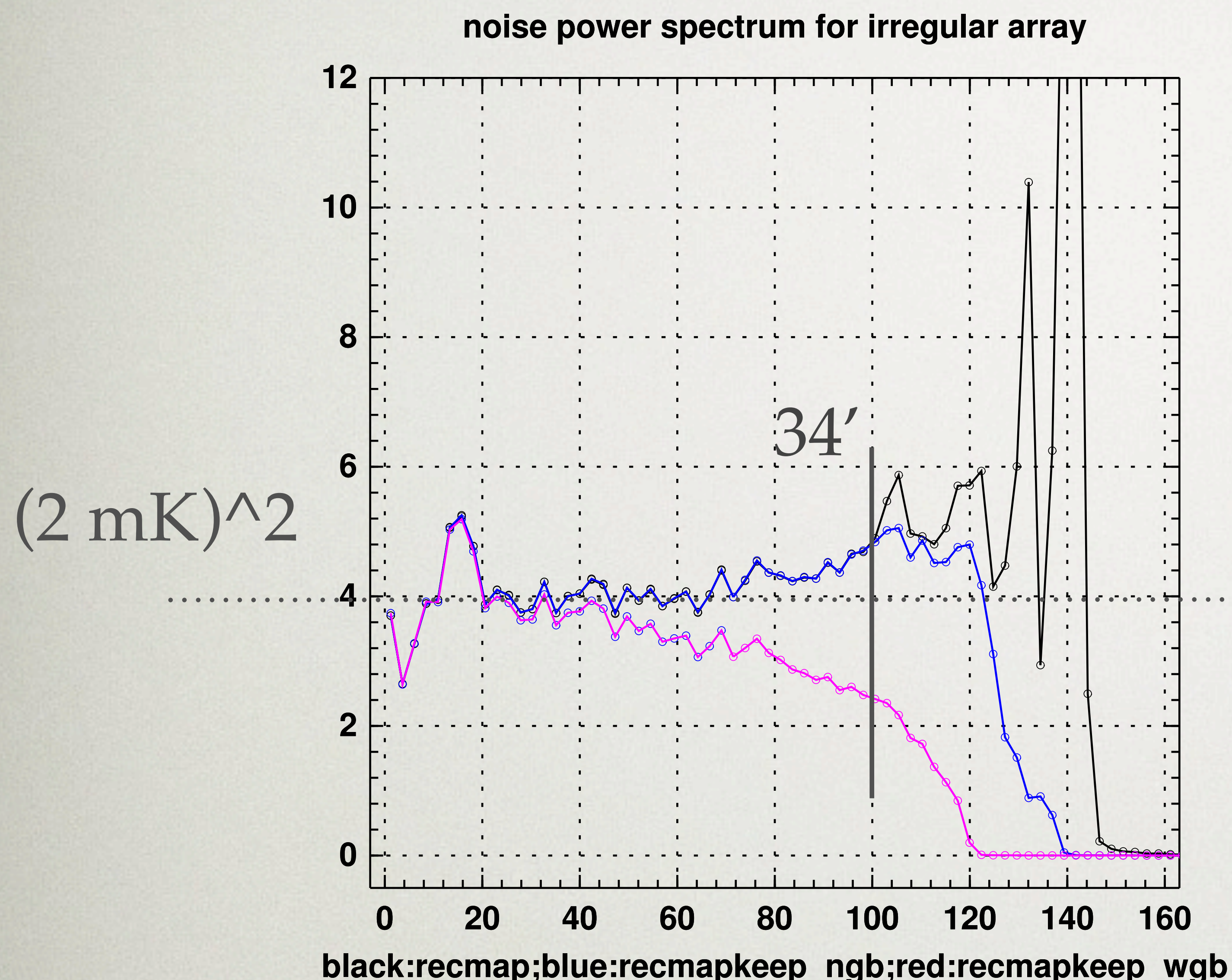


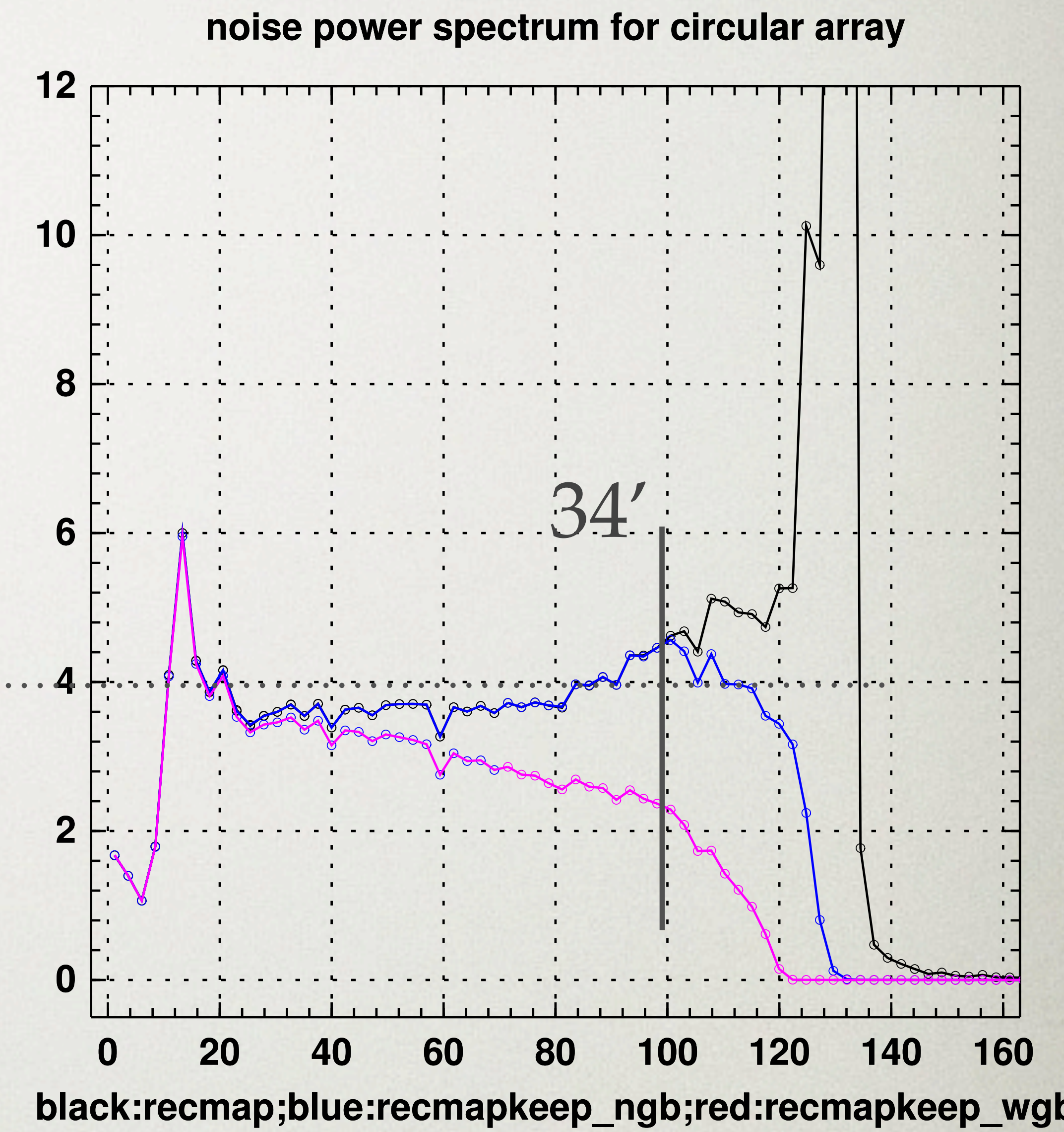


Transfer function for configurations the regular array - with/without autocorrelations rejecting high noise-variance modes (red), and global beam weighting (blue)

Irregular array (c)

Circular array (b)

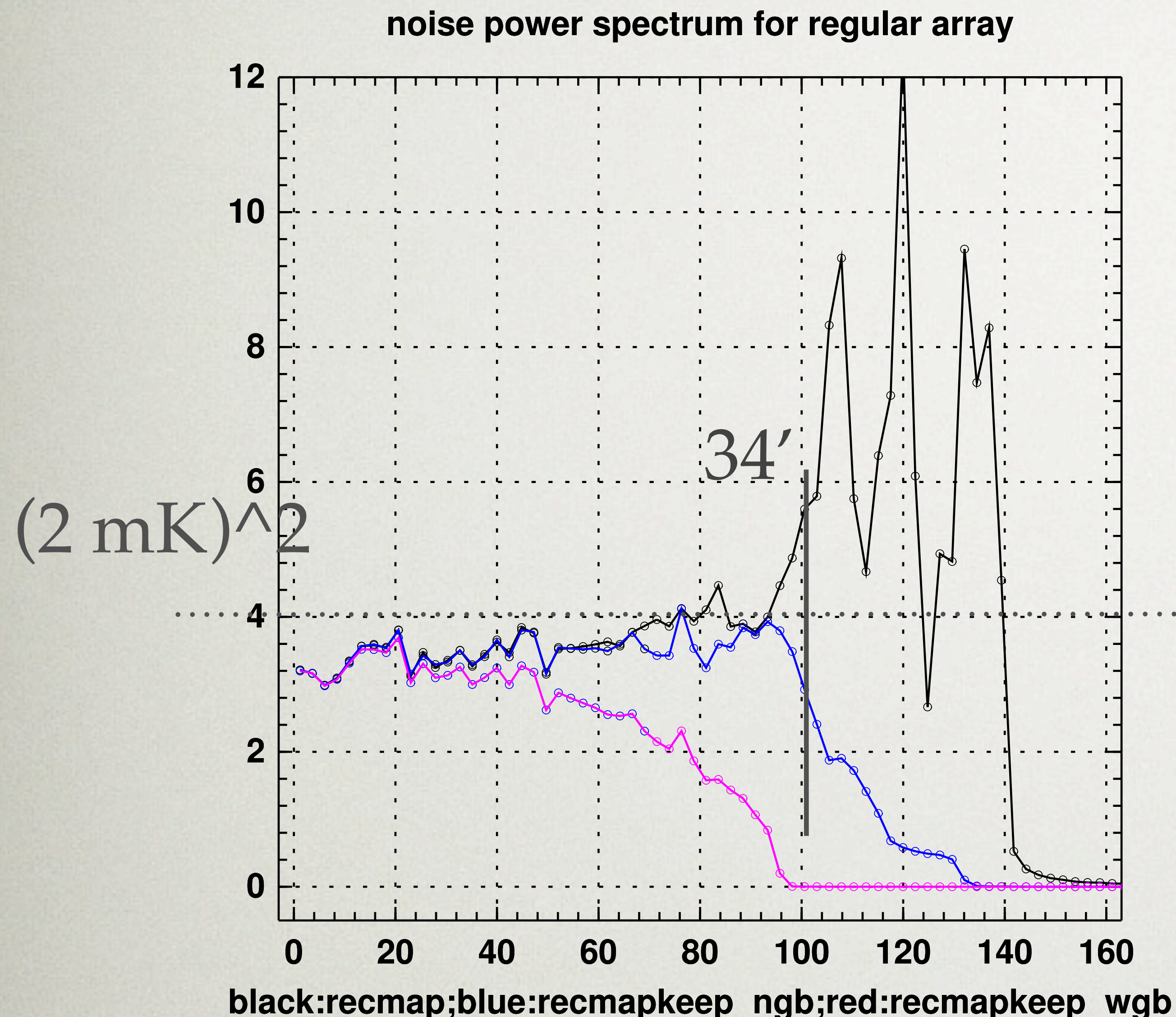




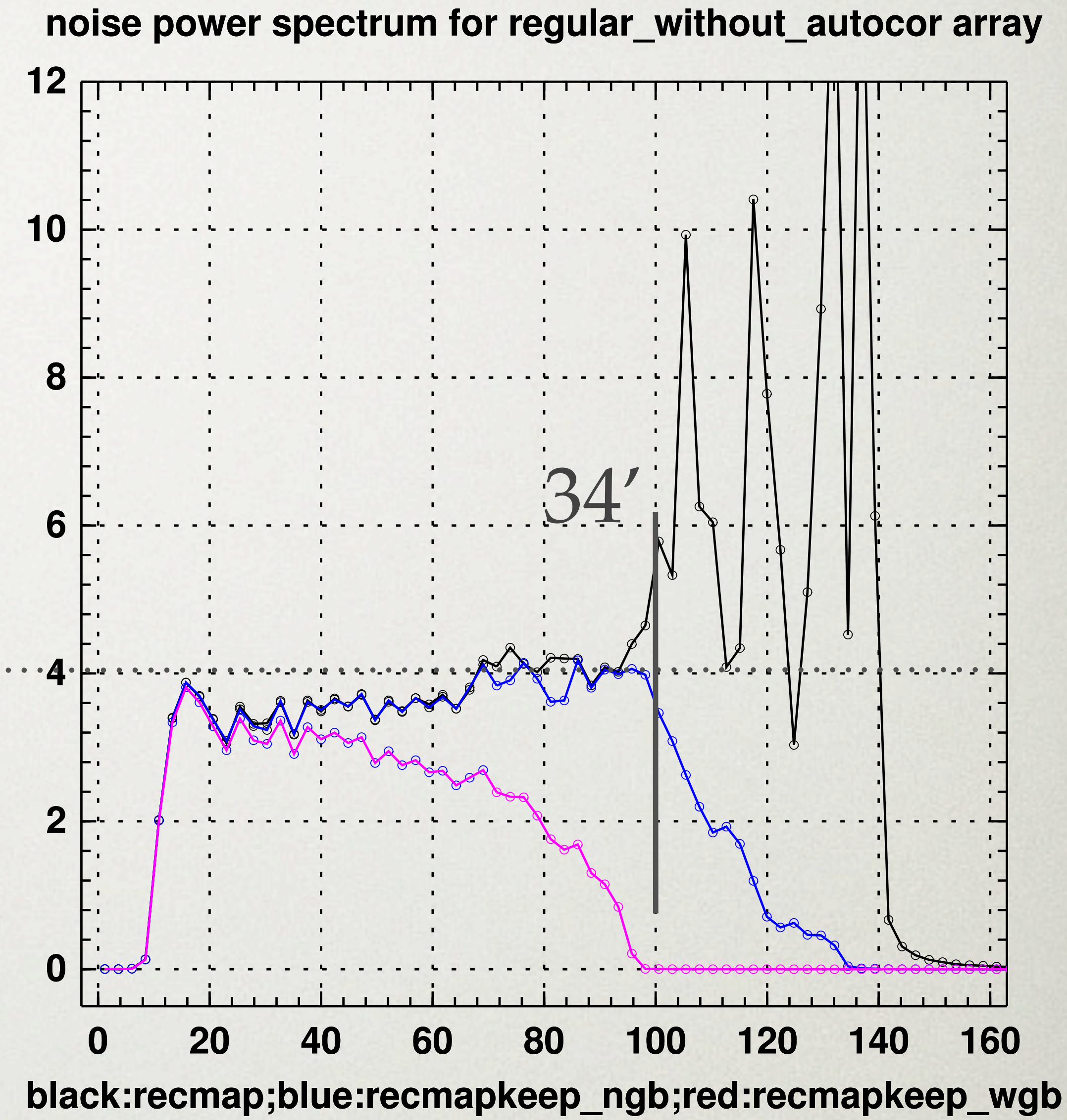
Noise power spectrum

Tsys = 100 K, 6 month total observation time (9 scans), Δν=1 MHz, ~ 250 (α) x 15 (δ) ~ 3700 deg^2 covered (latitude ~ 45 deg)

Regular array (a) with autocorrelation



Regular array (a) without autocorrelation



Noise power spectrum regular array, with and without autocorrelation

- better sky reconstruction with more independent baselines → more uniform (u,v) plane coverage, better isotropy of the synthetized beam

- Possibility to optimize the beam, decreasing frequency dependency using weights on the reconstructed (u,v) plane

- Better reconstruction when increasing the number of δ scans (over the same sky area), without noise penalty

- Choice between (b)-circular or (c)-irregular configuration ?