Sub-pixel effects and pointing error

- 2 effects due to non-uniform sky signal at scales < pixel size, both described as extra "noise" terms = offset * gradient of signal, (same formalism as Gravitational Lensing + leakage T → P)

▶ **Sub-pixel effects and pixelized map:**

  - signal *usually* assumed uniform in pixel during map making (NGP),

  - but samples distributed all over pixel, far (~ 60") from pixel nominal center ,

  - for Planck-HFI frequency maps (averaged over many samples, several detectors):

    - ★ hits center of mass ~ 6" from pixel center,

    - ★ offset weakly correlated between pixels (~ white noise)
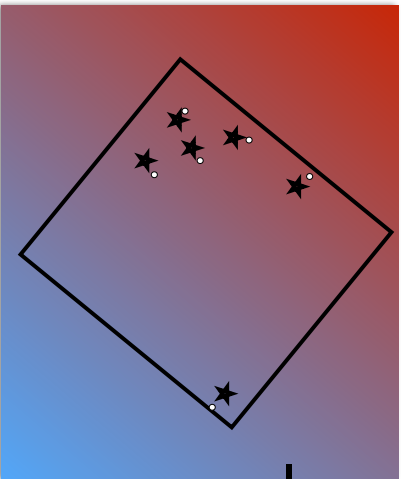
▶ **Pointing error:**

  - small (~ 3") offset between real and measured sample position,

  - how does it averages in each pixel over samples and detectors ?

Sub-pixel effects and pointing error
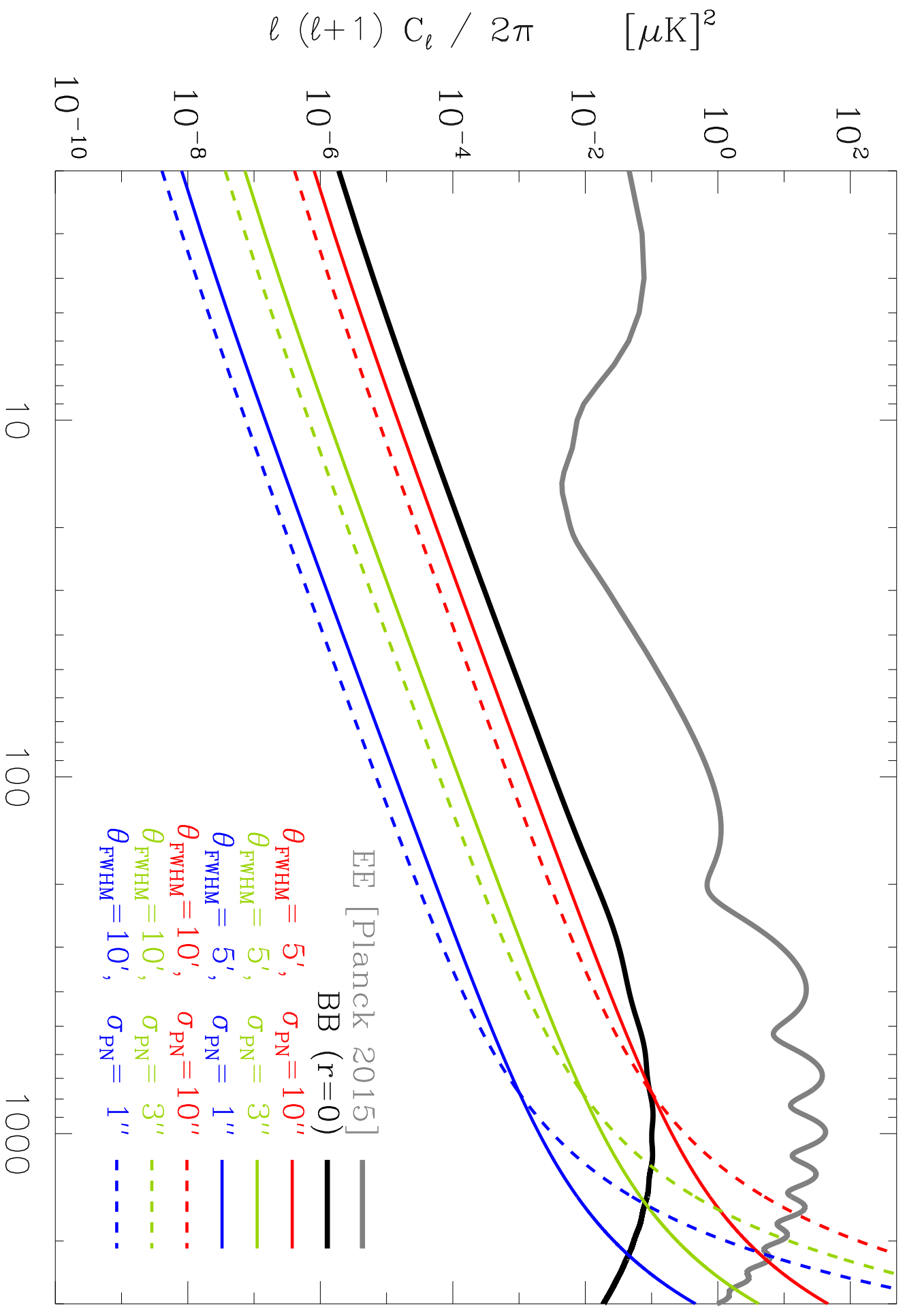
Measured power spectra (X,Y in {T,E,B}):

$$\tilde{C}_{\ell}^{XY} = W_{\ell}^{\text{pix}} \sum_{X'Y'} W_{\ell}^{XY,\, X'Y'} C_{\ell}^{X'Y'} + N_{\ell}^{XY}$$

pixel smearing

X'Y' (Non circular) beam

Sky spectra

sub-pixel "noise"

one finds

$$N_{\ell}^{TT} \sim N_{\ell}^{EE} \sim N_{\ell}^{BB} >> N_{\ell}^{TE} \sim N_{\ell}^{TB} \sim N_{\ell}^{EB}$$

If Pointing Noise is white with variance/pixel σ_{PN}^2 then

$$N_{\ell}^{EE} = N_{\ell}^{BB} \simeq \sigma_{\text{PN}}^2 \sum_{\ell'} \ell'(\ell'+1) \frac{2\ell'+1}{4\pi} C_{\ell'}^{TT} B_{\ell'}^2$$

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Axis labels:
- Vertical (left): $\ell \, (\ell+1) \, C_\ell \, / \, 2\pi \quad [\mu K]^2$
- Horizontal (bottom): Multipole ℓ

Y-axis tick labels: 10^{-10}, 10^{-8}, 10^{-6}, 10^{-4}, 10^{-2}, 10^{0}, 10^{2}

X-axis tick labels: 22, 10, 100, 1000

Legend:
- EE [Planck 2015]
- BB (r=0)
- $\theta_{\mathrm{FWHM}} = 5'$, $\sigma_{\mathrm{PN}} = 10''$
- $\theta_{\mathrm{FWHM}} = 5'$, $\sigma_{\mathrm{PN}} = 3''$
- $\theta_{\mathrm{FWHM}} = 5'$, $\sigma_{\mathrm{PN}} = 1''$
- $\theta_{\mathrm{FWHM}} = 10'$, $\sigma_{\mathrm{PN}} = 10''$
- $\theta_{\mathrm{FWHM}} = 10'$, $\sigma_{\mathrm{PN}} = 3''$
- $\theta_{\mathrm{FWHM}} = 10'$, $\sigma_{\mathrm{PN}} = 1''$

Conclusions

- Make identical circular small beams, and modulate polarisation by other means than scanning only ! (eg, front-end rotating Half Wave Plates)

- **Otherwise**:

  - ✦ **T→P leakage** and **P↔P cross-talk** due to beam mismatch (and polar efficiency and inter calibration inaccuracy) **can _not_ be ignored** (at least in Planck)

  - ✦ **Analytical tool to model them fully now available (QUICKPOL)**,

    - ▶ validated with simulations,

    - ▶ allowing extensive error propagation (no need for full focal plane simulations),

    - ▶ which seems to greatly improve TE inter-frequency consistency in Planck-HFI data (preliminary).

  - ✦ Applicable to other problems ?

    - ▶ HPW specific systematic problems

    - ▶ data mosaicking (heterogeneous data processing)