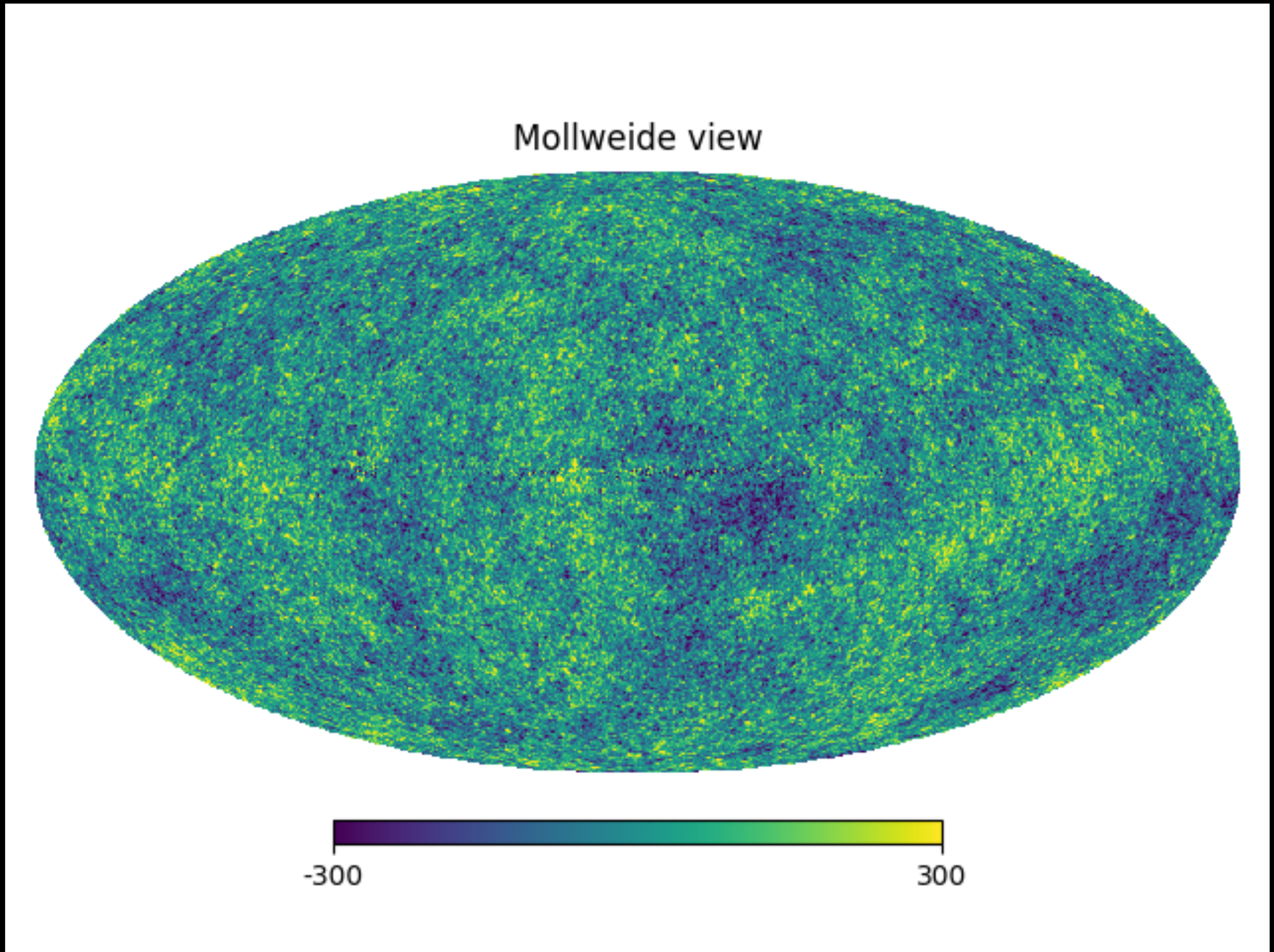
PS From All-sky Maps

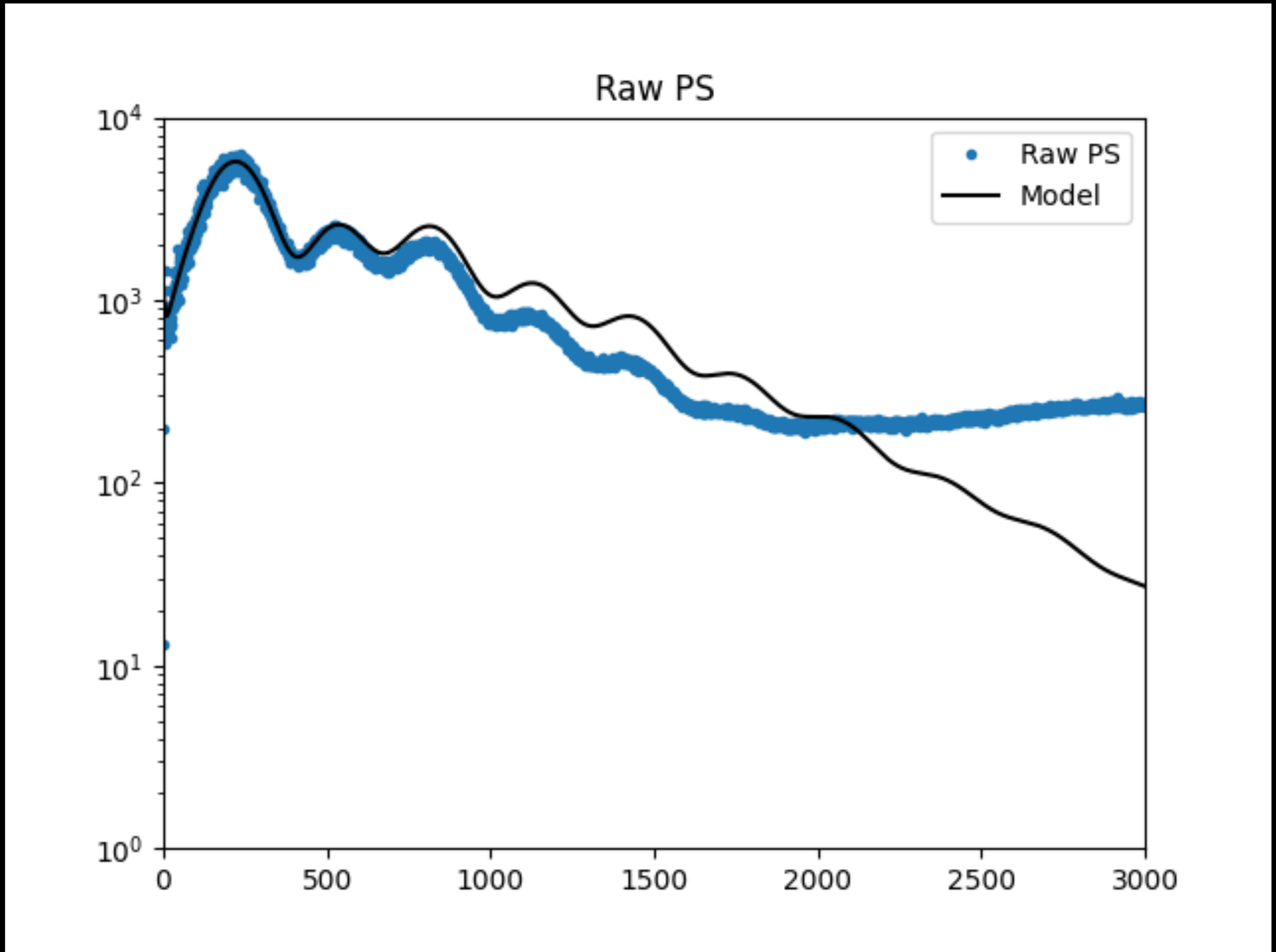
Planck Map (Foreground-cleaned)



Raw PS

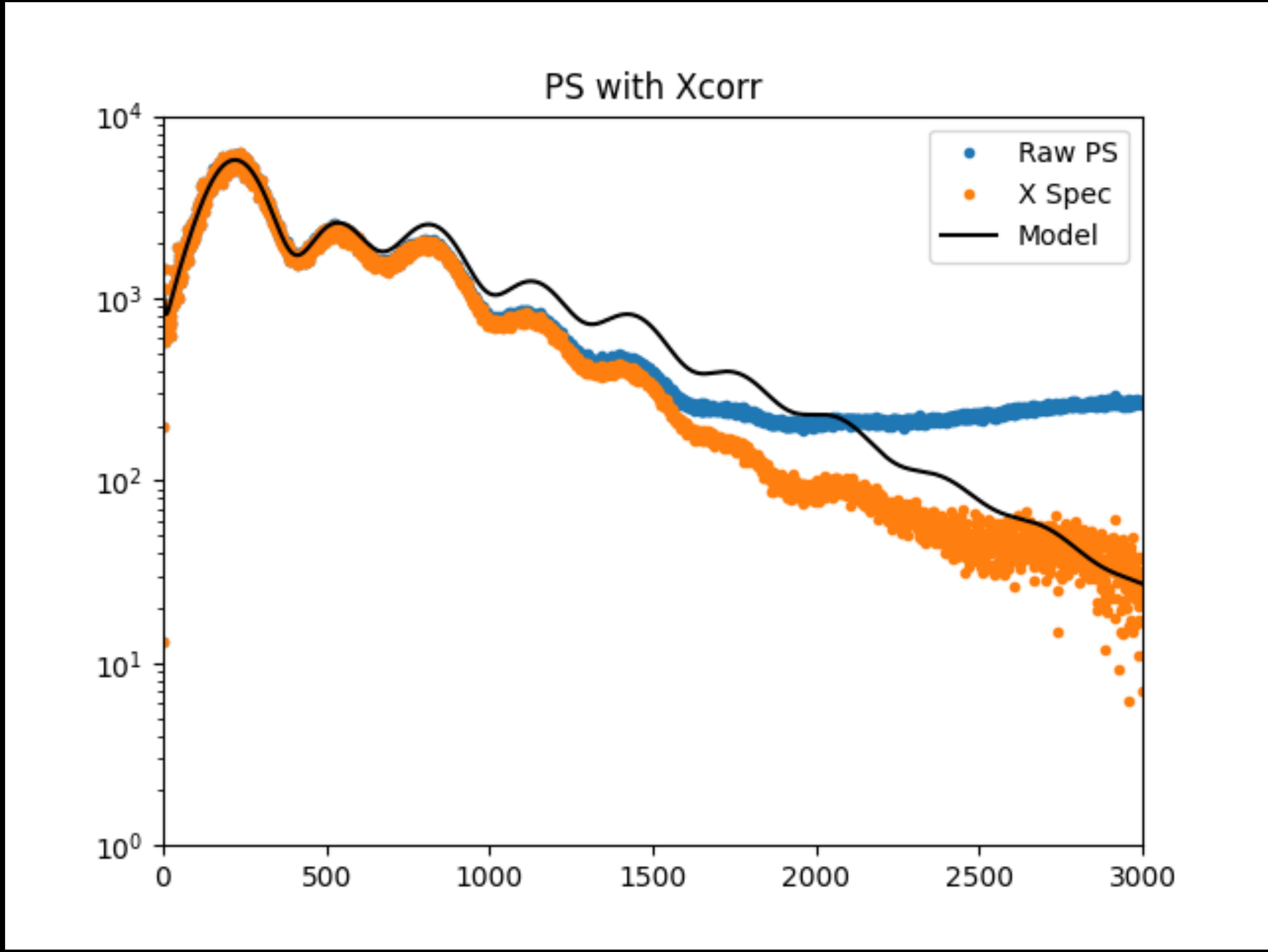
- Spectrum is clearly related, but some issues.

- Orange is best-fit from papers. Spectrum is below model at l=1500, above at l=2500.



X-Spec

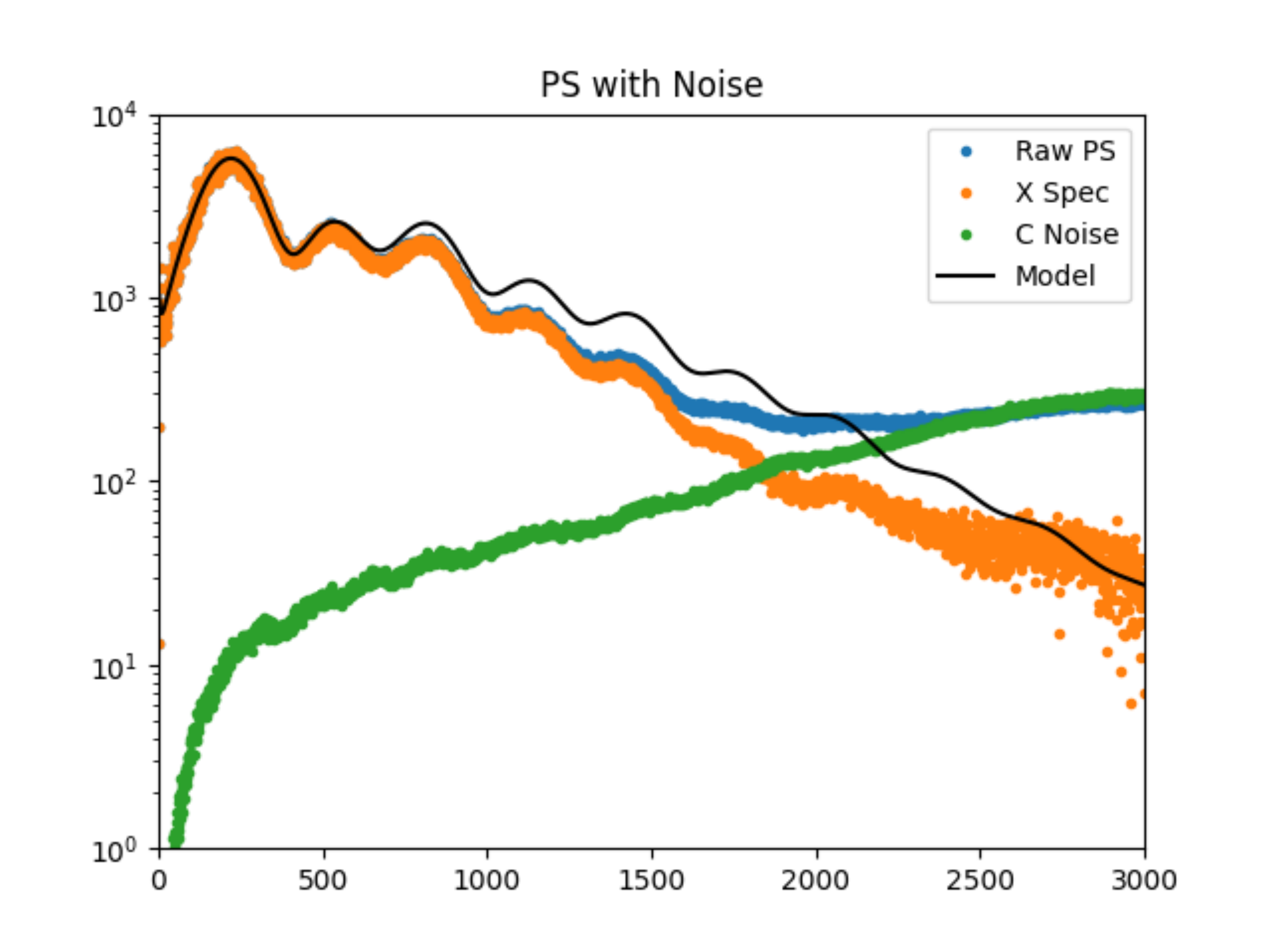
- Map=signal+noise
- $C_l = C_l(\text{signal}) + C_l(\text{noise})$
- Split data in half:
  a_{lm1}=SHT(map 1),
  a_{lm2}=SHT(map 2)
- $\langle a_{lm1}^{*} a_{lm2} \rangle = Cl(\text{signal}) + n_{lm1}^{*} n_{lm2} = Cl(\text{signal})$
- We've lost some SNR, but turns out with more splits we can buy back.



Noise Spec

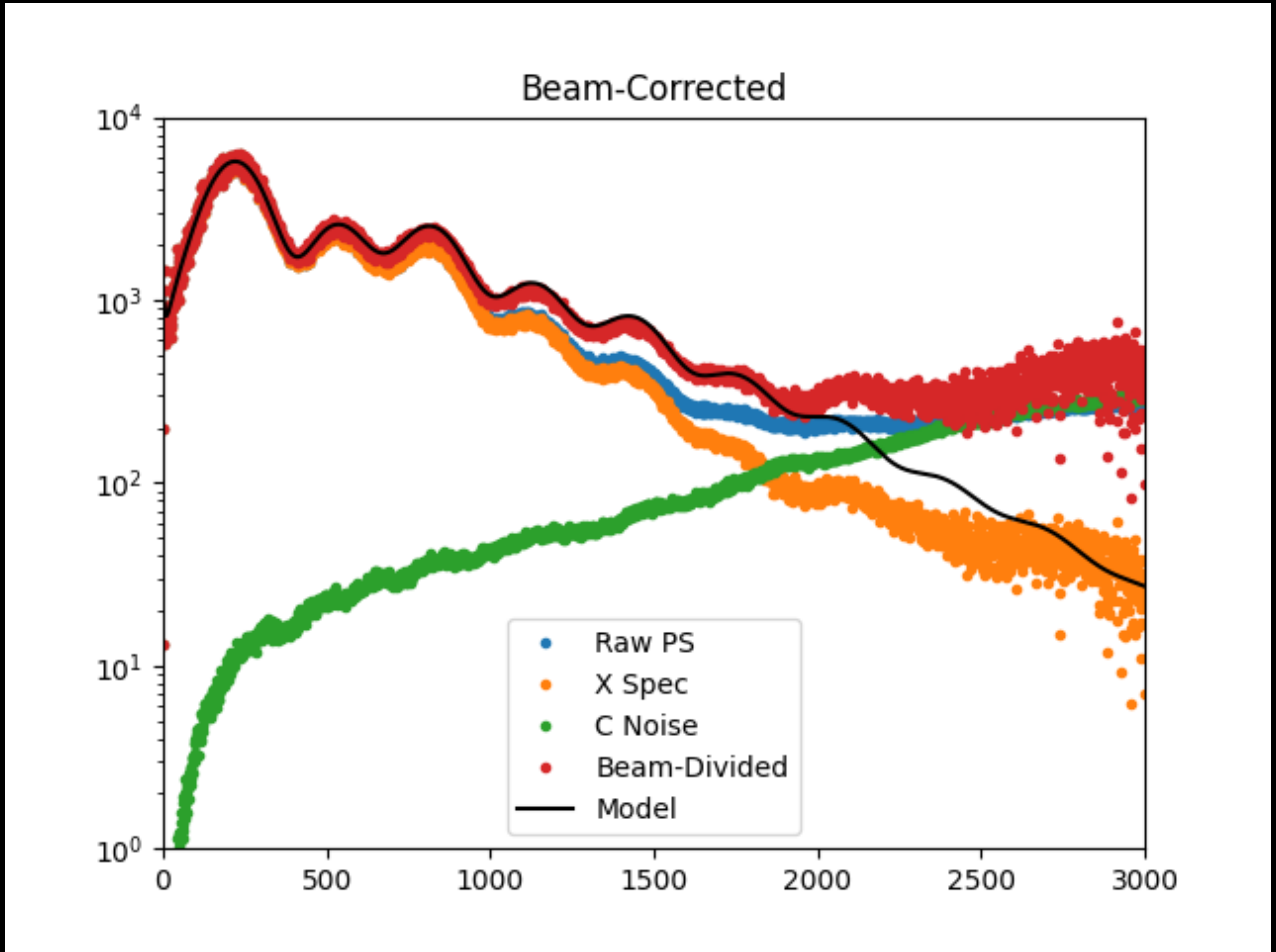
- We can also check PS of map difference. Gives us estimate of noise.

- NB - σ(m1-m2)=2σ((m1-m2)/2)



Beams

- In real space, we measure sky convolved with instrument beam.
- In FT, we then measure sky transform times beam transform
- SHT similar (for circular beam): $C_{l,obs}=C_{l,true}B_l$.
- B_l=Gaussian, σ~1300

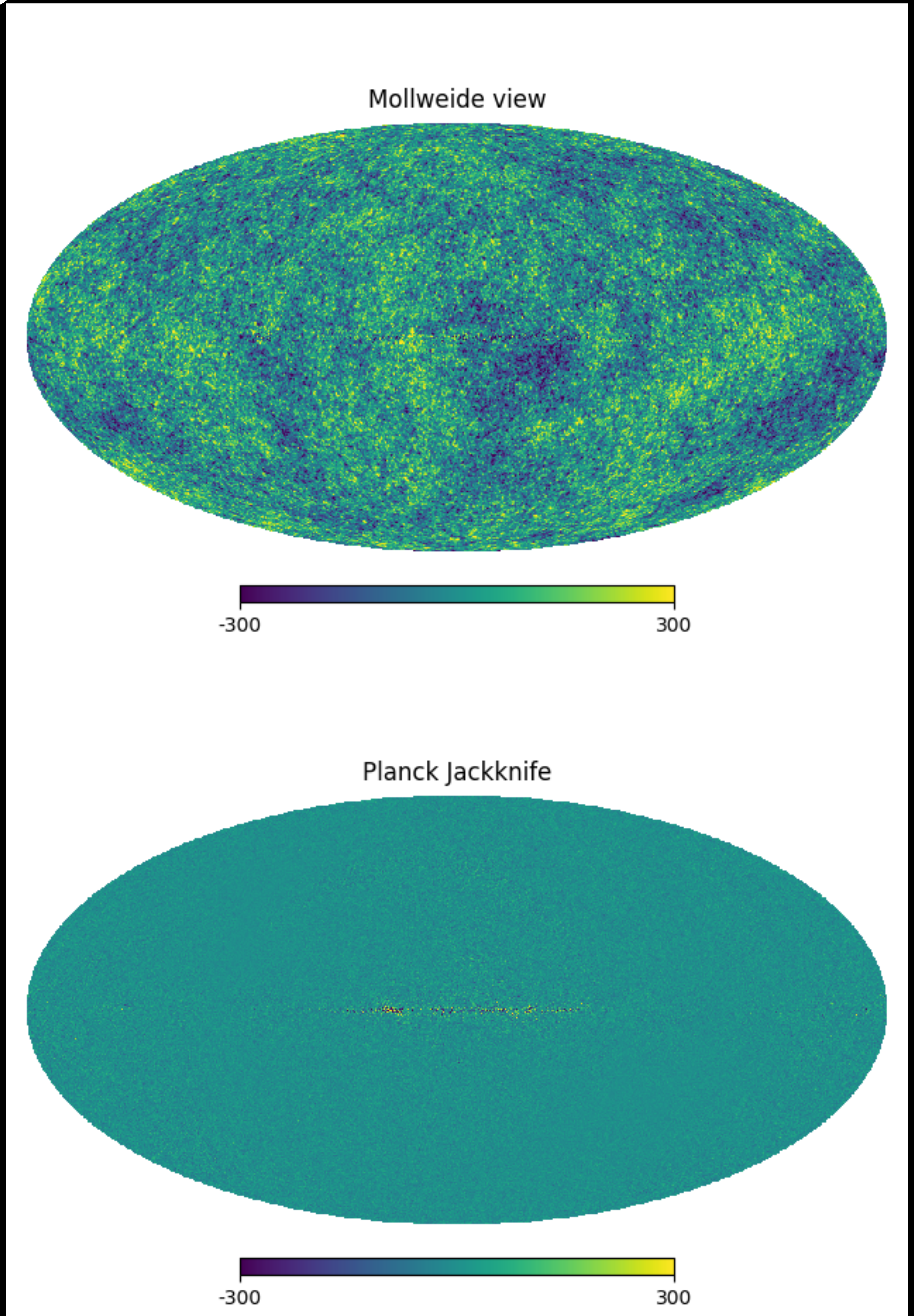


What Else could be Wrong?

- Our beam guess was sloppy. Should really use real beam
- Beam also frequency-dependendent. This map combination of others, so should use all beams for all frequencies
- Foregrounds - point sources dominate at high ell (small scales). Residual source contamination could be problem.

Masking

- Often we don't have full sky/need to remove map regions.
- We call this *masking*, and need to account in taking PS.
- One way (polspice) - estimate angular correlation function C(θ).
- C_l is P_l transform of C(cos(θ)).
- Estimate C(θ) only over unmasked pixels. Will introduce noise correlations, but will get unbiased estimate of PS.



Noise

- What is $Var(\sum a_{lm}^2)$? $Var(a_{lm}^2)=(2/4)C_l$ where C_l is total power spectrum.

- We get $C_{l,sky}+N_l$. for each mode, so $(2l+1)(C_{l,sky}+N_l)$ where $2l+1$ comes from real/complex at each m except for m=0.

- $Var(C_{l,estimated})=Var(\sum a_{lm}^2/(2l+1))=(C_{l,sky}+N_l)/\sqrt{(2l+1)}$

- Key points - at low l, even if N_l is tiny, $C_{l,sky}$ noise is large because $\sqrt{(2l+1)}$ is small. At high l, $C_{l,sky}/\sqrt{(2l+1)}$ is small, but N_l can get very large.

- The $C_{l,sky}$ noise term is called Cosmic (or sample) variance. We can't improve without more universes. The thermal noise term can get improved, with beating down measurement errors

- Often cosmic & thermal noises are reported separately. Make sure you're using the right one!

- Note - once N_l gets smaller than $C_{l,sky}$, you don't improve by integrating deeper. In a partial sky measurement, you want to observe until $N_l=C_{l,sky}$, i.e. SNR=1, then move on to new patch.

NB - all factors of 2 guaranteed correct to within a factor of 2 (or so).