Cosmology Dependent Covariances with Cosmic Emulators

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Computing the Shear Power Spectrum

We are interested in the shear power spectrum for tomographic weak lensing:

$$C^{ij}(l) = \frac{9H_0^4\omega^2}{4c^4}\int_0^{\chi_h} d\chi \frac{g^i(\chi)g^j(\chi)}{a^2(\chi)} P_\delta\left(\frac{l}{f_K(\chi)}, \chi\right)$$

where

- $g^j(\chi)$ is the lensing efficiency (contains source galaxy information).
- $f_K(\chi)$ is the comoving angular diameter distance.
- $a(\chi)$ is the scale factor
- P_δ is the matter power spectrum

And its covariance matrix.

Computing the Covariance Matrix

- The covariance matrix is calculated using CosmoLike: http://www.sas.upenn.edu/∼ekrause/CosmoLike/
- $\mathrm{Cov}(C^{ij}(l_1), C^{ij}(l_2)) =$ Gaussian term + trispectrum + halo sample variance.
- Trispectrum term: $T_{1h} + (T_{2h,(2,2)} + T_{2h,(1,3)}) + T_{3h} + T_{4h} + T^{HSV}$ from halo model (Cooray and Hu, 2001).
- Halo sample variance term as in Sato et al, 2009.
- For details see: Krause et al., (in prep) Eifler et al. 2013 [arXiv:1302.2401] and Huff et al. 2013 [arXiv:1311.1489]

Unfortunately, the covariance matrix:

- Depends on cosmology (see Eifler, 2009, Dodelson and Schneider, 2013).
- Needs to be recalculated at each step of MCMC analysis
- Calculations are too expensive for this to be practical.

Answer: Create an emulator!

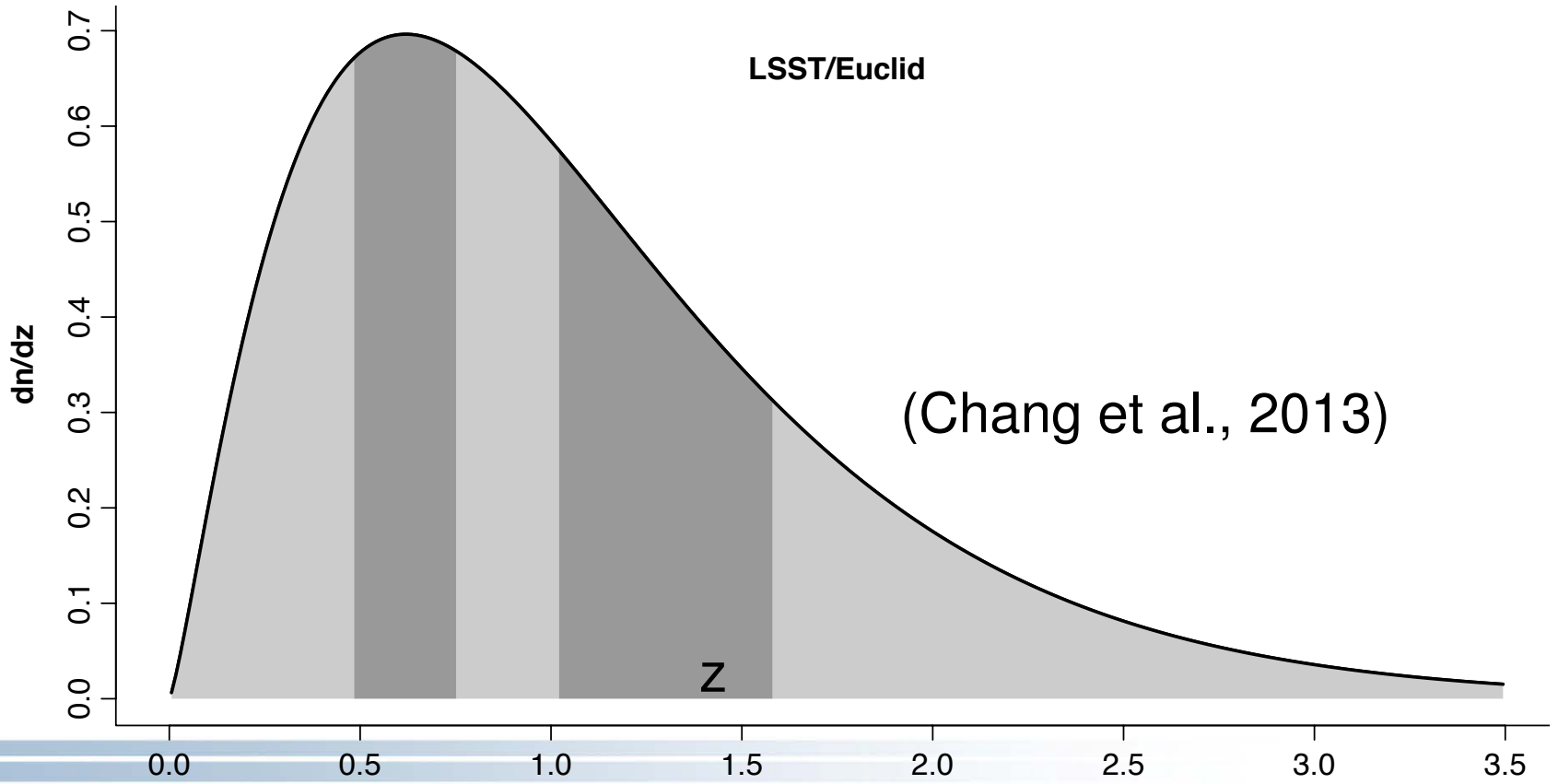
How the emulator works:

- Set of high precision measurements (in this case, from PT and halo model) made according to a design.
- A Gaussian Process maps the parameter space.
- The hyperparameters are conditioned according to the measurements from N-body simulations.
- Predictions are made by locating the new parameters in the design matrix and recalculating the covariance function using the known hyperparameters.
- The emulator is only conditioned once to set the hyperparameters, so each prediction is actually quite fast.

Covariance Emulator

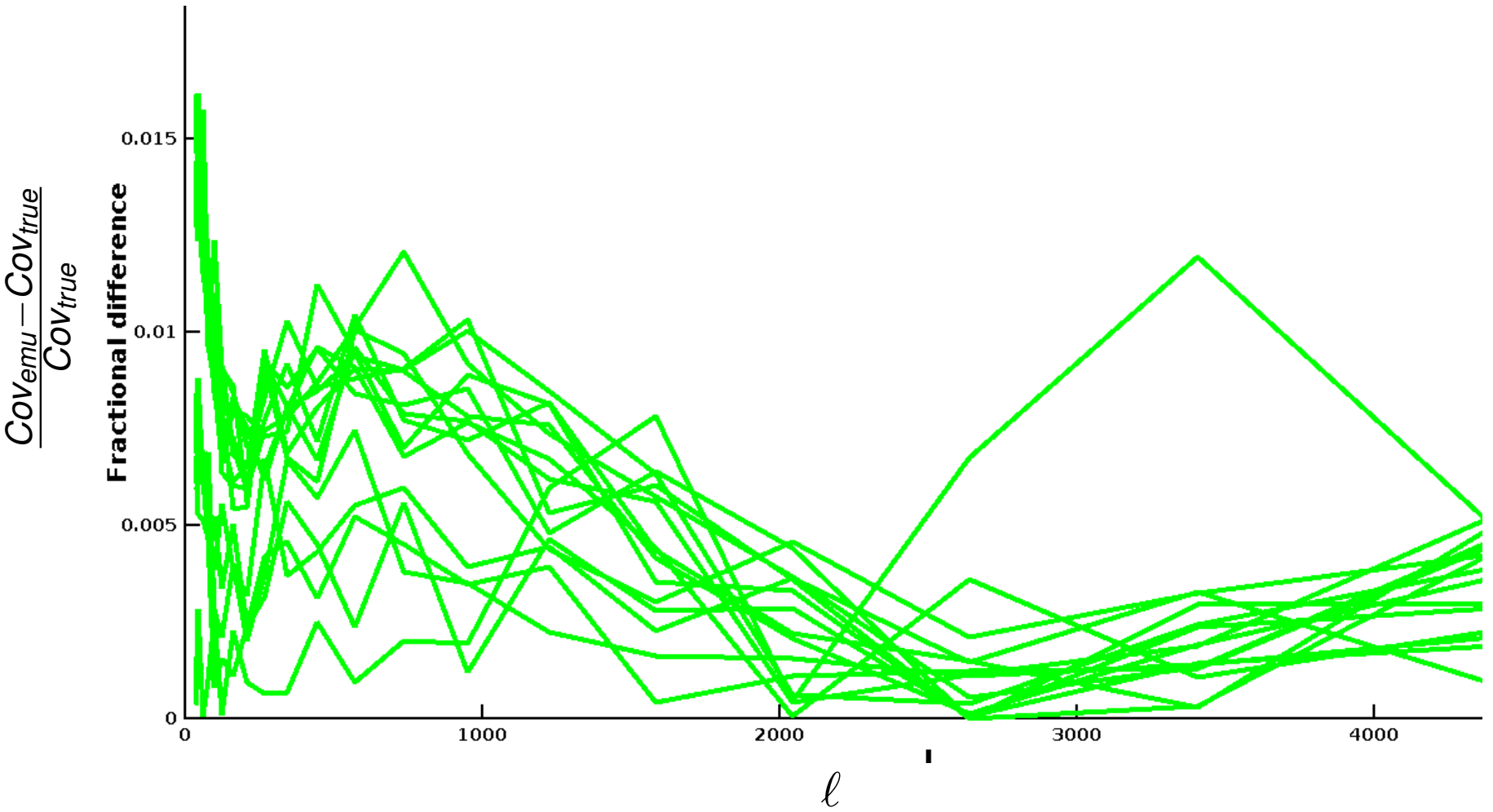
- 6 cosmology parameters: $\omega_m, \omega_b, n_s, \sigma_8, h, w$, 100 model design.
- 5 redshift bins between $0 \leq z \leq 4$
- 20 bins between $30 \leq \ell \leq 5000$.
- Redshift distribution for LSST modelled as $n(z) = N(z)^{\alpha} \exp\left[-(z/z_0)^{\beta}\right]$, $\alpha = 1.27, \beta = 1.02, z_0 = 0.5$

dn/dz



(Chang et al., 2013)

Preliminary Results



Ongoing Issues:

- Non-Gaussian terms are difficult to emulate.
- Speed is a problem: each prediction is $\sim$ 20 mins.
- Size of matrix inversion is computationally expensive.

Possible solutions:

- Coarser binning?
- Approximate the matrix inversion?
- GPUs?

Nonetheless, the performance of the initial emulator is promising.