CASPEN exit report

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Host: Keir Rogers, Oskar Klein Centre for Cosmoparticle Physics
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In the era of precision cosmology, it is becoming increasingly important to study the universe at several different cosmological epochs and at different length scales in order to break degeneracies. The Lyman-α forest, a series of absorption lines in the spectra of intermediate($2<z<5$) redshift quasars, is emerging as a promising probe of the growth of structure at small scales and at an otherwise poorly studied period of the universe's history. This information is particularly valuable for certain constraints such as the neutrino mass scale, Σm_ν, and the spectral index n_s. The clustering of these absorption lines is related to the underlying matter density field through a non-linear transformation and is also dependent on the properties of the Intergalactic Medium (IGM) that are difficult to model analytically. In order to obtain cosmological constraints, theory must be compared to data, and currently for the Lyman-α forest this involves running large and computationally expensive (10^4 CPU hour) hydrodynamical simulations in order to generate the observable flux statistics for a given cosmological model. Given the large number (10^5) models required to sample using current techniques, it is not feasible to run a simulation for every model, so it is necessary to run a suite of simulations distributed throughout parameter space, and interpolate the observable flux statistics between them.

Our group have recently been awarded a computing allocation on the DiRAC cluster in order to run such a suite of simulations and build an interpolator. This will use a Gaussian Process (GP) emulator to interpolate the flux statistics between the simulations, which represents a significant improvement over previous approaches. Keir Rogers has experience in building such an emulator and applying the Bayesian Optimisation refinement technique to them, so the purpose of this visit was to use his experience in this area in the construction of our own emulator.

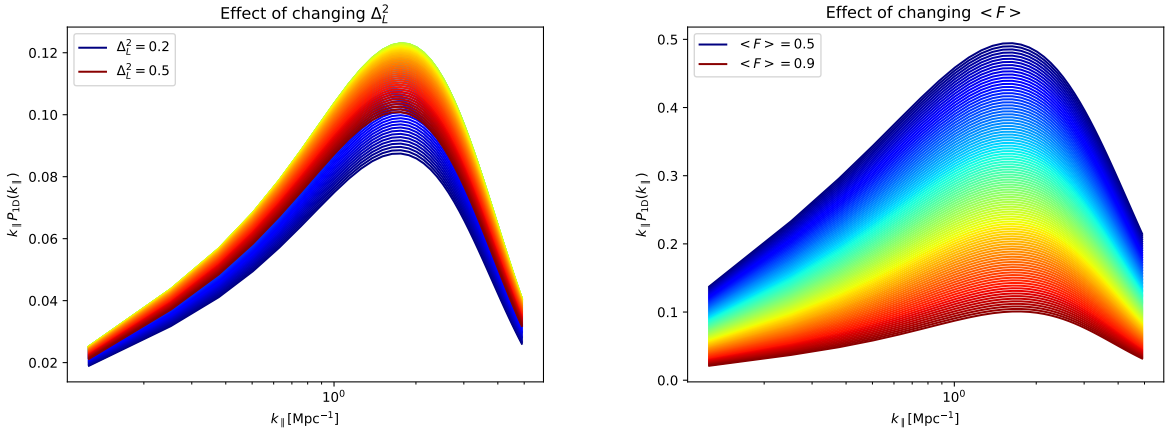

Figure 1: Predicted 1D flux power spectra for a range of models from a trained GP emulator, in this case using a 4th degree polynomial to fit the 1D flux power spectrum, in which the emulator learns the coefficients as a function of cosmology and IGM parameters. *Left:* Effect of changing the amplitude of the linear power, Δ_L^2, on the 1D power spectrum of the Lyman-α forest. *Right* The effect of changing the mean flux, $< F >$.

The trip was very beneficial for the purposes of the technical development of the project. We successfully trained our GP emulator on a test suite of simulations and are now able to return a predicted flux power spectrum for an arbitrary cosmological model. We experimented with training emulators on different parameter sets, and have working emulators that we can now test on an end-to-end analysis. Important discussions took place concerning issues such as scaling limitations of the GP algorithm, the

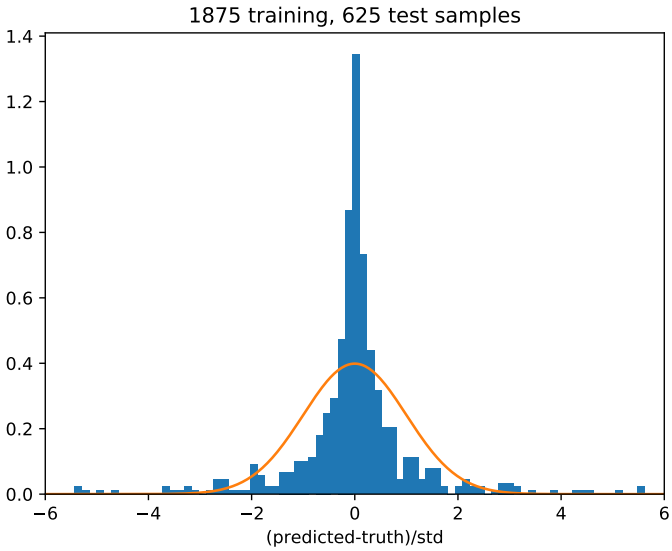

Figure 2: Cross-validation of a GP emulator trained on the 1D flux power for each k bin independently.

best approach to implement Bayesian Optimisation, and potential sources of systematics in the simulations. These are important steps towards completion of a first emulator which will lead to at least one publication.

More generally the visit was also beneficial through the discussion with other members of the OKC, who have a wide range of complementary interests. I gave the Cosmology and Gravitation seminar which resulted in some interesting and useful discussion on the effect of massive neutrinos on the Lyman-α forest clustering, and structure formation more generally. Discussions were also held about future potential collaborations and projects applying similar techniques to other cosmological probes.

I would like to thank Keir Rogers for his hospitality during the stay. This work was supported by collaborative visits funded by the Cosmology and Astroparticle Student and Postdoc Exchange Network (CASPEN).