The Case for investment in GPUs at SLAC.

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The study of the structure of the universe requires that we make observations of as much of the universe as possible. Telescope surveys currently measure the properties of millions of galaxies, and future datasets such as DES and LSST will contain billions of galaxies. The cosmological quantities that we calculate of tern require the calculation of correlation function over pairs of galaxies, a calculation that scales a the square of the number of galaxies. Even with today's datasets of millions of galaxies, this is an enormous computational task. Approximation functions (such as KD trees, see Jarvis et al. [1] for details) have been developed to reduce this computational time, but these approximations necessarily reduce the accuracy of the measurement. In current datasets the statistical uncertainty in the measurement is enough that any errors introduced by this uncertainty are negligible, but as we obtain more data and lower our statistical uncertainty then these systematic errors will limit the ultimate accuracy of our measurement. We can, however, make the full calculation in a reasonable amount of time by taking advantage of the computational power of GPUs.

I have implemented the two-point angular correlation function, and the weak lensing aperture mass statistic, on the GPU and released the code publicly [2]. I've also presented this work at the GPU Technology Conference in 2012 and 2013 [3, 4].

Perhaps more importantly, this GPU implementation of the aperture mass statistic has allowed me to confront the issues surrounding this weak lensing measurement in a systematic way. My work [5] uses large numbers of cosmological simulations, which are then turned into 'mock' galaxy catalogues of what this theoretical Universe would look like if we could observe it with LSST. I then use these mock catalogues to determine the significance of various experimental issues (galaxy shape measurement error, masked areas etc) on measurement of the aperture mass statistic. There is no way to approximate the aperture mass statistic. Using optimised CPU code to calculate the aperture mass for one map of simulated cosmology takes 60 minutes; on the GPU it takes 45 seconds giving a compute-time reduction of 60x. Using the GPUs allows me to make a systematic optimisation of analysis parameters to minimize errors and biases from the choices of these parameters, in a way that would not be possible using the CPU batch system. The simulations I work with consist of 500 maps for each of 8 different model cosmologies, which would take days on the CPU batch system but can be completed in 36 hours on the four KIPAC GPUs.

My research plan for the next 2 years will further develop this analysis methodology, and relies critically on the use of GPUs. Obtaining more, and newer, GPUs would be a tremendous advantage in my work, as it would allow me to run through a complete set of simulated universes in a matter of hours, allowing even better exploration of parameter space. In addition, it would allow me to produce my papers faster, since the majority of time required to complete papers so far is still the compute time of the aperture mass maps, even using the GPUs.

Another issue with the limited number of GPUs in the KIPAC cluster is that I am not the only user of the GPU cluster! Risa Wechsler's group in KIPAC is also using the GPUs, with a modified version of my two-point correlation GPU code, to calculate the correlation function in their large-scale cosmological simulations. As we compete for compute resources, the work rate of both groups will suffer, and this is not likely to improve in the future.

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