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A New Parallel Algorithm for modeling the Elliptical Galaxies Surface Brightness in GPUs

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A tsunami of data is coming up, large telescopes are gathering images of millions of galaxies in the Universe [3]. Galaxy evolution is inferred and described by analyzing the galaxy structure and properties [1]. One approach commonly used for measuring the galaxy structure from an astronomical image is to consider a mathematical model for describing the galaxy surface brightness. Several models have been proposed for this purpose, for example, the de Vaucouleurs and Sérsic law. However, these models require a two-dimensional numerical integration to generate a synthetic digital image, because they cannot be analytically integrated [6]. Additionally, algorithmic approaches and software tools for estimating the model's parameters (especially those based on a Monte Carlo algorithm) requires the generation of hundred thousands of synthetic images to compare with the observed images. Usually, only one galaxy analysis can take form 60 to 200 minutes with 20 CPUs (Central Process Unit) [5]. Therefore, dealing with large galaxy samples will demand a huge computational cost which, for example, 1.000.000 galaxies would require at least 5.7 years (even if we use 20 nodes from our cluster).

In work several numerical integration algorithms and the Graphics Processing Units (GPUs) are used for speeding up the synthetic images generation. The GPUs have enormous computing power and since 2006, they have become programmable thanks to several programming languages developed, such as OpenCL, and CUDA (Compute Unified Device Architecture). On other hand, fast adaptive algorithm for multidimensional integration using GPUs have been implemented in GPUs with huge speedups (45 times faster than the CPU) [4]. This parallel implementation, called VEGAS, use an adaptive Monte Carlo algorithm and importance sampling to speedup its convergence [2].

To test these integration algorithms we developed a python new program, called PyMakeImage. This program prototype can generate synthetic images considering the following algorithms: (a) the numerical multidimensional integrator scipy.nquad (NQUAD); (b) the conventional Monte Carlo (MC); (c) VEGAS algorithm. These algorithms performance and accuracy have been evaluated using PyMakeImage and CPUs. Figure 1a shows the relative error integration errors as function of the distance to the central pixel. NQUAD has a good accuracy, but is the slowest algorithm, while MC has the worst relative error values. VEGAS present intermediate error values. Figure 1b present the Monte

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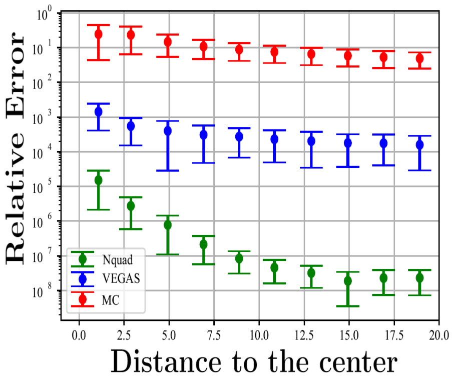
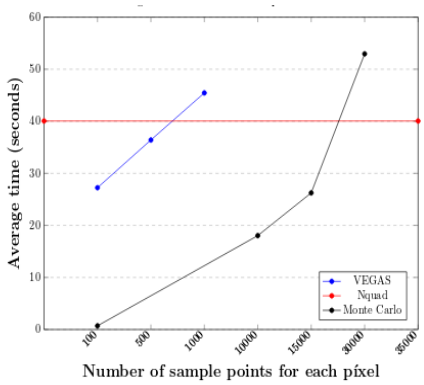
Carlo algorithms run-time as function of the random samples size considered to computed the pixel integration. VEGAS is at least 10 times slower than the conventional MC.



(a) Integration relative error for the considered integration algorithms. The comparison have been done with an image generator developed in [6]



(b) Performance evaluation in CPU, considering 10 runs mean run-time.

These results shows that the proposed method, VEGAS has a good accuracy, but the performance on CPUs is slower than standard MC. Therefore a CUDA version is still under develop to achieve a faster and better numerical integration. This will improve significantly the performance tools like GALPHAT (GALaxy PHotometric ATtributes) [6]

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