A Virtual Universe for the ESA Euclid Satellite: The Euclid Flagship Simulation

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Upcoming large scale structure surveys such as EUCLID, DES, LSST, WFIRST will measure the result of billions of years of evolution from the small amplitude linear matter fluctuations observed in the Cosmic Microwave Backgroud (CMB). On the very largest scales these fluctuations are still evolving linearly, but most of the leverage on cosmological parameters from these surveys comes from smaller, highly non-linear scales. Only numerical N-body simulations capture this non-linear evolution with the required precision. These are, however, very expensive when they must meet the upcoming survey requirements. We have performed the World's largest simulation of this type, called the Euclid Flagship Simulation (v2.0), with 4 *trillion* particles evolving under their own self-gravity. This simulation is only possible on a few of the largest machines in the World; it was run on the Piz Daint supercomputer at CSCS in Lugano, Switzerland using just under a million node hours. The code used is called PKDGRAV3, which is a Fast Multipole Method (FMM) tree-code that has been optimized for GPUs and uses the memory resources of the computing system in a very efficient way. I will present the recent significant advances in our ability to use these modern hybrid supercomputers to greatly accelerate such simulations. Of principal importance are algorithmic advances as well as leveraging *all* system resources at once. These simulations are used to generate a virtual universe of galaxies that is designed to match as closely as possible the expected signal of Euclid, allowing us to quantify all systematics and to assess the performance of the mission in determining the nature of dark matter, dark energy and possible extensions to General Relativity. These are some of the most fundamental open questions in Physics today.