Cosmology is the large-scale search of the observable universe and beyond to answer the ultimatum: “How did the universe begin?” In 1941, Erik Holmberg discovered that two galaxies approaching at a certain distance would experience a gravitational pull toward each other, consequently forming one large galaxy. Holmberg simulated the gravitational pull of two galaxies by setting up two clusters of lightbulbs, each representing a single galaxy. He then simulated the gravitational force with light intensity, changing the position of the light bulb one by one, after each iteration of calculation to approximate the future behavior of these two lightbulb clusters. But what would happen if three, four, or maybe a hundred galaxies were nearby? Certainly, the number of calculations needed would exceed what we could feasibly manage by hand.

General Purpose Graphic Processing Units (GPGPUs) are utilized in cosmological calculations and simulations as they require an immense iteration of independent arithmetic. Capturing the behavior of two galaxies in proximity is one thing, but of hundreds of galaxies is another. With the vast computational power GPGPUs offer, we can now confirm or deny existing cosmological theories by building a simulated database and comparing that with our observations.

One example of how GPGPUs are leveraged is the N-body simulations. N-body simulations are used to simulate the force dynamics of particles, and Holmberg’s experiment can be considered an N-body simulation. The all-pairs N-body algorithm of a cosmological simulation calculates the updated acceleration of a particle due to every other particle within proximity of influence. Without the parallelism offered by GPGPUs, modeling billions of chain events would take an immense amount of time. A particular application of this N-body simulation is the dark energy survey (DES). The goal of DES is to understand more about dark energy by mapping our universe and analyzing patterns within the cosmic structures. Abacus is an example of an open-source, high-accuracy cosmological N-body simulation code. The code runs 70 million particle updates per second on their supercomputer.

Another example is the two-point angular correlation. The two-point angular correlation function calculates the probability of the existence of two galaxies within a fixed distance. By calculating this number over an extensive range of galaxies, we can model an approximate distribution of clusters of galaxies, allowing us to understand the structure of the cosmic web and dark matter. However, the calculations required for this mapping involve potentially billions of galaxy pairings, making the use of GPGPUs essential. Their ability to perform calculations in parallel allows us to process this enormous dataset efficiently, turning a task that could otherwise be prohibitively time-consuming into one that is both manageable and precise.