Could massive gravitons be viable dark matter candidates?
23 March 2022, by Ingrid Fadelli

Today, many research teams worldwide are trying to detect dark matter, an invisible substance that is believed to account for most of the matter in the universe. As does not reflect or emit light, its presence has been indirectly revealed via its gravitational interactions with visible matter.

So far, the most promising dark matter candidates are axions, neutrinos, and weakly interacting massive particles. Recently, however, some physicists also started investigating the possibility that another type of hypothetical particles, massive gravitons, could be viable dark matter candidates.

Theory suggests that massive gravitons were produced during collisions between ordinary particles in the hot and dense environment of the early Universe, in the few instants following the Big Bang. While theories predict their existence, these particles have so far never been directly detected.

Researchers at Korea University and University of Lyon have recently carried out a theoretical study exploring the possibility that massive gravitons could be good dark matter candidates. The results of their theoretical calculations were published in a paper in Physical Review Letters.

"Our study started by looking at extra dimensions, particularly warped extra dimensions, which have been studied a lot in the past 20 years," Giacomo Cacciapaglia, one of the researchers who carried out the study, told Phys.org. "When gravity propagates in this invisible space, it materializes massive gravitons. Their coupling to ordinary matter is very weak, being of gravitational origin."

Relic density of the massive graviton in the parameter space of the warped model. The points along the red line reproduce the observed Dark Matter in the Universe, while the shaded regions are excluded. Credit: Cai, Cacciapaglia & Lee.
The process through which massive gravitons would theoretically be produced is extremely rare. For this reason, the rate at which these particles are produced would be significantly lower than the rate of production of "ordinary" particles. Cacciapaglia and his colleagues Haiying Cai and Seung Lee wondered whether enough massive gravitons were produced in the early universe for them to be considered a good dark matter candidate.

"By computing the production rate of these particles, we discovered that some processes are enhanced below the scale where the Higgs boson generates masses for the ordinary particles, 1 picosecond after the Big Bang," Cacciapaglia said. "We showed that this enhancement is enough to create the right amount of dark matter in the form of massive gravitons with masses below the MeV."

The calculations performed by Cai, Lee and Cacciapaglia show that instead of being associated with unknown physics occurring shortly after the Big Bang, the production of massive gravitons is most effective below the energy scale in which Higgs bosons reside. Higgs bosons are elementary particles that carry the Higgs field, the field that gives mass to fundamental particles such as electrons and quarks.

"This draws a direct connection between the physics studied at the Large Hadron Collider in Geneva and the early Universe physics of gravity and Dark Matter," Cacciapaglia said. "Our results imply that gravitational dark matter is produced 1 picosecond after the Big Bang, at a time when particle physics is well described by the current theories."

In the future, the results gathered by this team of researchers could inspire new studies and calculations exploring the production of massive gravitons in the universe. Meanwhile, Cacciapaglia and his colleagues plan to build on the theoretical model introduced in their paper, while also evaluating other dark matter candidates.

"We now plan to investigate other features of a concrete model in warped extra dimension that we sketch in the article," Cacciapaglia added. "We are particularly interested in the role played by a scalar particle called radion and on the potential testability at current and future particle colliders."


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