Stars and star cluster heat up their environment even a million years after their birth, say scientists

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How does the presence of a star or a gravitationally bound group of stars (star cluster), influence their environment? A previously unclear phenomenon has now been answered, thanks to a recent collaborative work from scientists at the Raman Research Institute (RRI), the Indian Institute of Science (IISc) and P.N Lebedev Physical Institute, Moscow, Russia. They have successfully developed a theoretical model to simulate the interactions between a star cluster and its surroundings, enhancing our understanding about processes that lead to the formation of stars, clusters and galaxies.

The birth of a star begins with gases accumulating under gravity until it gets hot enough to initiate nuclear fusion -- a process where lighter atoms merge to form heavier atoms with an enormous outburst of energy. A strong shock wave then pushes the surrounding gas and debris into a bubble, similar to the Oort cloud surrounding our Sun. Following this, radiation from the newborn star bombards the surrounding gas to further push it away. But now, questions have been raised on the mechanism through which the stars, or clusters of stars, transfer their energy to the surrounding gas. Prevalent theories suggest that gaseous winds from the stars, and the explosions at the end of the life of stars, heat up the gas in their vicinity. This hot gas physically pushes the surrounding gas away, transferring mechanical energy in the process. But this idea did not quite explain some of the observations, thus requiring a deeper study.

The current research represents a paradigm shift. According to the new theoretical insight provided by the collaboration, pressure of the radiation dominates during the interaction between stars and the surrounding gases for the first million years of its life following which the interaction continues through the heating of the gases. Indeed, previous observations have recorded the heating of the surrounding gases. The researchers specifically predict that the heating is due to high energy photons emitted by the star cluster, which bombard the surrounding gas particles thus causing their temperature to increase.

“What we found, something which wasn’t really anticipated, is that radiation from clusters has a two pronged effect in a way. Initially, the cluster exerts radiation pressure where it interacts by pushing against the gas. After about a million years, the radiation pressure decreases as the gas particles move far away from the cluster, but the thermal pressure starts heating the gases, causing it to expand. This thermal pressure wasn’t understood very well”, explains Biman Nath, a Professor of Astronomy and Astrophysics at RRI.

The researchers then built a computer model to simulate the effects of radiation pressure and thermal pressure from a star cluster on its surrounding environment. When they compared their results to observations from the Tarantula Nebula, also known as 30 Doradus, it was found to match closely. “Earlier observations of the nebula showed that the X-ray luminosity from the star cluster, or the brightness of X-rays, was much lower than what was theoretically predicted. Now, after incorporating our new insights, the observations match the predictions very well", remarks Mr. Siddhartha Gupta, a postgraduate student at RRI and IISc.

The current study advances our knowledge of the formation and evolution of galaxies, but we are far from a complete understanding of the processes. "Galaxies are made of two major building blocks - gasses and stars. So it's very important to understand the interactions between these building blocks at a micro level, to really understand how galaxies form. People have looked at the macro-scale interactions, but there are severe gaps in our understanding of these micro-level interactions. This work can be thought of as a starting point towards our understanding of the evolution of galaxies", says Mr. Gupta about the importance of this work.