Disruption of giant molecular clouds by massive star clusters

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(PhysOrg.com) -- New computer simulations show that the light from massive stars is, by itself, enough to blow apart the nebula where the stars are born. While this 'radiation pressure' was by and large overlooked in the past, these new results show how, even before a single star explodes as a supernova, massive stars carve out huge bubbles and limit the star formation rates in galaxies.

The findings are being presented by Dr. Elizabeth Harper-Clark and Prof. Norman Murray of the Canadian Institute for Theoretical Astrophysics (CITA) at the 2011 meeting of the Canadian Astronomical Society (CASCA) in London, ON, Canada.

Galaxies are the birthplace of stars. As the stellar population changes, so the galaxy evolves. Yet, the stately pace of this evolution remains unexplained. It is generally believed that the pace of star formation is regulated by the outflow of energy from other stars and possibly black holes.

The lifetime of a Giant Molecular Cloud (GMC, a large star-forming nebula) and the total mass of stars that form within it are crucial to the understanding of star formation rates across a galaxy. In particular, the stars within a GMC can disrupt their host and consequently quench further star formation. Indeed, observations show that our own galaxy, the Milky Way, contains GMCs with extensive expanding bubbles but without supernova remnants, indicating that the GMCs are being disrupted before any supernovae occur.

Radiation from stars interacts with the gas in the surrounding GMC in two main ways: ionization and radiation pressure. Ionization works by forcibly ejecting electrons from atoms at high speed; these electrons then heat up the gas, increasing the gas pressure. Radiation pressure is more subtle and often ignored -- the momentum from the light is transferred to the gas atoms when light is absorbed. These momentum transfers add up, always pushing away from the light source, and produce the most significant effect, according to these simulations.

The simulations performed by Harper-Clark represent the first calculations of the effects of radiation pressure on GMCs and show that this pressure is capable of disrupting such clouds, the main star-forming units in galaxies. "The results suggest that the slow rate of star formation seen in galaxies across the universe may be the result of radiative feedback from massive stars," says Professor Murray, Director of CITA.

Simulating entire GMCs is challenging, due to the large variety of physics that needs to be included and the computational power required to accurately simulate a GMC over tens of millions of years. Using the radiative-magneto-hydrodynamic code Enzo, Harper-Clark ran multiple simulations of GMCs under different conditions.

Harper-Clark robustly found that with only the light emitted by the stars (radiation) during their lifetimes the GMC could be completely blown apart, cutting off star formation after a percentage between 5% and 20% of the original cloud's mass had been converted into stars.

Interestingly, when supernovae were included in the simulations they were found to be unimportant. Both with and without the light from stars, supernovae were not significant on the disruption of the GMC, nor did they alter the subsequent star formation. With no radiation feedback, supernovae exploded in a dense region leading to rapid cooling. This robbed the supernovae of their most effective form of feedback, hot gas pressure. When radiative feedback is included, the supernovae explode into an already evacuated (and leaky) bubble, allowing the hot gas to expand rapidly and leak away without affecting the remaining dense GMC gas. "These simulations suggest that it is the light from stars that carves out nebulae, rather than the explosions at the end of their lives," says Dr. Harper-Clark.

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