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Supernova dynamics in the laboratory: Radiative shocks produced by ultra-high pressure implosion experiments on the National Ignition Facility[1]

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Thermonuclear fuel experiments on the National Ignition Facility implode 2-mm diameter capsules with a cryogenic deuterium-tritium ice layer to 1000x liquid density and pressures exceeding 100 Gbar (10^{11} atm). About 200 ps after peak compression, a spherical supernova-like radiative shock wave is observed that expands with shock velocities of $u_S =$ 300 km/s, temperatures of order 1 keV at densities of 1 g/cc resulting in a radiation strength parameter of $Q \sim u_S^5 = 10^4$. Radiation-hydrodynamic simulations indicate that the shock launched at stagnation first goes down a strong density gradient while propagating outward from the highly compressed DT fuel ($\sim$ 1000g/cc) to the ablation front ($\sim$ 1 g/cc). Similar to what happens inside a star, the shock pressure drops as it accelerates and heats. The radiative shock emission is first observed when it breaks out of the dense compressed fuel shell into the low-density inflowing plasma at the ablation front mimicking the supernova situation where the shock breaks out through the star surface into surrounding in-falling matter [1,2]; the shock is subsequently approaching the supercritical state with a strong pre-cursor followed by rapid cooling. These observations are consistent with the rapid vanishing of the radiation ring 400 ps after peak compression due to strong radiation losses and spherical expansion. The evolution and brightness of the radiative shock provides insight into the performance of these implosions that have the goal to produce burning fusion plasmas in the laboratory. By modifying the capsule ablator composition and thickness, the stagnation pressure, density gradients, shock velocity and radiative properties could be tailored to study various regimes related to supernovae radiative remnants.

[1] W. David Arnett, Supernovae as phenomena of high-energy astrophysics, Ann NY Aca. Science 302, 90 (1977).
[2] L. Ensman and A. Burrows, Shock breakout in SN1987A, ApJ 393, 742.

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