Peering inside the 'deflagration-to-detonation transition' of explosions

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Explosions of reactive gases and the associated rapid, uncontrolled release of large amounts of energy pose threats of immense destructive power to mining operations, fuel storage facilities, chemical processing plants, and many other industrial applications.

To gain a better understanding of what's going on during these explosions, US Naval Research Laboratory research physicist Alexei Poludnenko, and Elaine Oran, senior scientist for reactive flow physics, teamed up with Sandia National Laboratories' Thomas Gardiner, principal member of technical staff, to study the deflagration-to-detonation (DDT) transition, which can occur in environments ranging from experimental and industrial systems on Earth to astrophysical thermonuclear supernovae explosions.

The team will present their findings at the upcoming American Physical Society's 64th Annual DFD Meeting, on Nov. 20-22, 2011, in Baltimore, Maryland.

"Explosions are most often driven by flames propagating at relatively slow subsonic velocities," explains Poludnenko. "Under certain conditions, however, this 'slow' mode of burning can transition to a completely different regime – detonation, a.k.a. the 'deflagration-to-detonation transition.' In this case, burning is driven by very fast, strong shock waves that can travel at more than 5 times the speed of sound. The power and destructive potential of such detonation-driven explosions is vastly greater than flame-driven ones. Understanding the conditions and physical mechanisms that can cause the transition between these two explosive modes is critical for developing proper preventive and protective measures in industrial settings."

Significant research efforts have been devoted to studying the deflagration-to-detonation transition, and progress has been made in understanding its role in confined systems. Importantly, it was discovered that walls and obstacles are instrumental in detonation formation. For example, burning in a closed space naturally leads to an increase in pressure and the formation of shocks that can be further amplified through reflections with walls and obstacles – ultimately producing a detonation.

Walls and obstacles were clearly important in these earlier studies. But scientists also wondered if unconfined flames could be inherently susceptible to the development of detonations.

"We've used detailed computer simulations of flames in hydrogen-air and methane-air mixtures in a fully unconfined environment under atmospheric conditions to study whether detonations can indeed form in such systems," Poludnenko says.

Among their findings: A subsonic flame evolving in the presence of sufficiently intense turbulence can spontaneously form a detonation both in reactive gases on Earth as well as in the interior of the white dwarf stars – providing a missing link for the current theoretical models of Type la supernovae (which are formed by the violent explosion of a white dwarf star).

This work is supported by the Naval Research Laboratory and the Air Force Office of Scientific Research. The talk, "Deflagration-to-detonation Transition in Unconfined Media," is at 5:19 p.m. on Sunday, Nov. 20, in Room 326.

More information: Abstract: http://absimage.aps.org/image/MWS_DFD11-2011-001628.pdf

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