Exploding waves from colliding dissipative pulses

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The interaction of traveling waves in dissipative systems, physical systems driven by energy dissipation, can yield unexpected and sometimes chaotic results. These waves, known as dissipative pulses (DSs), are driving experimental studies in a variety of areas that involve matter and energy flows.

In the journal *Chaos*, researchers studied collisions between three types of DSs to determine what happens when these traveling waves interact. "We intended to find out whether one could get spatially localized chaotic behavior by colliding pulses that are regular in space and time," said Orazio Descalzi, an author on the paper.

Descalzi and colleague Helmut Brand used two coupled cubic-quintic complex Ginzburg-Landian equations (CQCGLEs) to model collisions of stationary and oscillating DSs at different speeds. CQCGLEs are mathematical equations that other researchers have used for nearly three decades to study DSs, and they can be derived from reaction diffusion or hydrodynamic equations. "It is the simplest possible model for such phenomena," Descalzi said.

DSs have been observed in binary fluid convection in cars, optical systems like high-powered lasers and biological phenomena like cell movement. "Recently, the importance of localized dissipative structures for corrosion surfaces in electrochemistry has been demonstrated," Descalzi said.

Colliding pulses can interact in several ways, depending on factors like the pulse propagation speed. At lower speeds, pulses either interpenetrate or form bound states, Descalzi explained. At higher velocities, colliding DSs undergo partial annihilation or, under certain conditions, explode. "Explosions are irregular periods of rapid growth that are followed by sudden collapse to the initial profile," Descalzi said.

In their study, the researchers observed 10 different types of DS interactions including interpenetration, stationary bound states, oscillating bound states, and exploding DSs. The researchers were surprised to observe exploding DSs because the types of pulses colliding were not the type that typically explode. "We observed that regular pulses were transformed into explosive pulses," Descalzi said. Another unexpected result was the creation of an oscillating bound state with two frequencies from two DSs with one frequency colliding.

These results address the transition from regular DSs to localized chaotic behavior during collision, and report on previously undescribed complex behavior. The study's findings also point to possible future research avenues. Outside of nonlinear optics, where exploding DSs have been observed, studies have been limited to stationary DSs. The authors note that systems from nonlinear optics studies could be modified to experimentally study collisions of various DSs to test the predictions in their study.

More information: "Collisions of non-explosive dissipative solitons can induce explosions," *Chaos* (2018).
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