

microwave radiation up to 280 GHz.

Looking for the SZ effect is important for two reasons. Of course it will help cosmologists to distinguish between intrinsic properties of the CMB and secondary foreground effects. But it also promises to be a particularly sensitive way of studying

the clustering of galaxies at a very early stage of cosmic evolution.

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References

1. CBI Collaboration, <http://arXiv.org/abs/astro-ph/0205384> through 0205388.
2. See <http://map.gsfc.nasa.gov>.

Choreographing Wave Propagation in Excitable Media

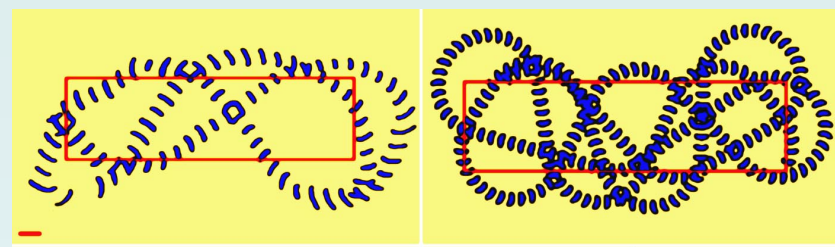
Excitable media can be coaxed into complex spatiotemporal patterns, including spiral waves and oscillating tiger stripes (see *PHYSICS TODAY*, July 2001, page 18). Like the antics of the Three Stooges, this captivating behavior often emerges in a state of near or actual chaos. But the excitable medium on display here has been so thoroughly tamed that its handlers, a team from West Virginia University in Morgantown, not only keep the onset of chaos at bay, they also direct the patterning at will and bestow on individual waves the kinetic behavior of a particle under the influence of a potential.

To develop their control techniques, the WVU team, led by Ken Showalter, worked on a Belouzhov-Zhabotinsky (BZ) system. In BZ systems, two or more reactions, mediated by a catalyst, consume and supply each other's intermediary species. The upshot of this chemical symbiosis is a zone of reacting species that travels through the medium like a tsunami in the open ocean.

In the WVU experiments, the chemical action takes place in a matchbox-sized tray. Covering the bottom of the tray is a thin layer of gel that contains a light-activated catalyst. Postdocs Tatsunari Sakurai and Eugene Mihailuk switch on the BZ reaction at a particular location in the tray by spotlighting the reactants and the catalyst beneath with visible light. The size of the spot controls medium's excitability and, with it, the size of the wave. Further, by increasing or decreasing the intensity of illumination at the edges of the wavefront, the WVU researchers can establish excitability gradients across the wavefront to control its direction of propagation.

The control method is reminiscent of the old-fashioned toy in which the player directs one or more tiny balls in a small box by carefully tipping the box this way and that. The player has to react quickly to the ball's changing path, but the WVU researchers could prescribe the path of their wavefronts in advance.

Here's how. After setting a wave in motion, the researchers take an image of the tray with a video camera. The wave is brighter than its unexcited surroundings, and its size and location are easily measured. These measurements go into the feedback step: determining the pointing direction and brightness of the reaction-controlling spotlight. By comparing the current image with an image taken two seconds earlier,



the researchers can tell whether the wave needs a bigger or smaller dose of light to maintain its stability. By also applying a predetermined control algorithm, they know how much of a light gradient to apply across the wavefront to change its direction.

Conceivably, any algorithm can be used. The lefthand panel shows a sequence of snapshots tracking the course of a single wave. Under the algorithm's control, the wave is made to execute figure eights and, at certain times, to bounce off the notional boundary (red rectangle) as if undergoing a reflection. The righthand panel shows a similar course, but one simulated on a computer by Sakurai and Showalter's graduate student Florin Chirila.

What is the use of such a control mechanism? Showalter points out that wave behavior is ubiquitous in living systems and the excitable media in them are always adapting to various perturbations—even to the wave behavior itself. His team's method could provide a way to study those mechanisms.

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Reference

1. T. Sakurai, E. Mihailuk, F. Chirila, K. Showalter, *Science* **296**, 2009 (2002). ■