Modeling Supernovae Core Collapse

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"What we've done," explains University of Arizona professor Adam Burrows, "is unlocked the core of supernovae. We have a computational tool that allows us to go into the core, and we see that there's gravitational radiation—much more than we thought."

Burrows is part of an international team of astrophysicists that includes Christian D. Ott from the Max Planck Gravitational Physics Institute in Potsdam, Germany, Eli Livne from Hebrew University in Jerusalem, and Luc Dessart, a peer at the University of Arizona. This team published an article on May 26th in *Physical Review Letters*, titled "A New Mechanism for Gravitational-Wave Emission in Core-Collapse Supernovae."

In their paper, the scientists set forth the results from three different computational models. These models are a new look at what actually might happen in the core during the collapse of a supernova. "It was assumed that such a core would be hard," explains Burrows to *PhysOrg.com*. "However, in this inner core, the g-modes wobble and generate gravitational waves. We've introduced a new concept into the mix, and it yields wave fluxes much larger than appreciated in the past."

When a supernova collapses to the point where it is too dense to avoid bouncing back out in an explosion, it can stall. Burrows says that neutrinos from deep inside the core can reignite the explosion, forcing the supernova outward. "The first instability of shock starts to wobble," he explains, "making the interior turbulent. This sets up the inner core to start oscillating, and we get gravitational waves that respond to the mass motion in the interior."

These waves are on such a large scale that a LIGO (Laser Interferometer Gravitational Wave Observatory) device could easily detect them. Using a LIGO detector, it would be possible to look for specific signatures that would indicate the formation of a black hole or neutron star. “If you find a black hole,” explains Burrows, “that might mean the shock was not revived. The smoking gun would be a great deal of gravitational radiation that stops within a millisecond. Strong gravitational noise followed by silence might be the signature of a black hole.”

Additionally, another signature, semi-pure tones, could also be detected by LIGO. “We’ve found that instead of having a broad frequency, there might be only a few frequencies. That’s another thing people can look for using LIGO,” says Burrows.

But Burrows admits that so far the models are just that—computer models of what could happen inside the core of a supernova. “It’s provisional,” he says. “We don’t know if it’s true. This is the first time that it’s been seen; it’s completely new. We have to put together new computational technologies to verify it.” He pauses a moment. “Or refute it.”

One of the biggest problems faced by Burrows and his like-minded peers is that what they have accomplished so far is at the edge of available technology. “We are doing these in two dimensions because doing it in three dimensions would be so much more expensive,” he says. And impractical. The kinds of astrophysical calculations that Burrows and his colleagues are working on right now can take months, even when using supercomputers.

Burrows, however, remains mostly undaunted. “We can learn the astrophysics of core collapse, see it as it happens. We can look back and peer inside. We are going to pursue this and see where it leads.”