Calculations show close Ia supernova should be neutrino detectable offering possibility of identifying explosion type

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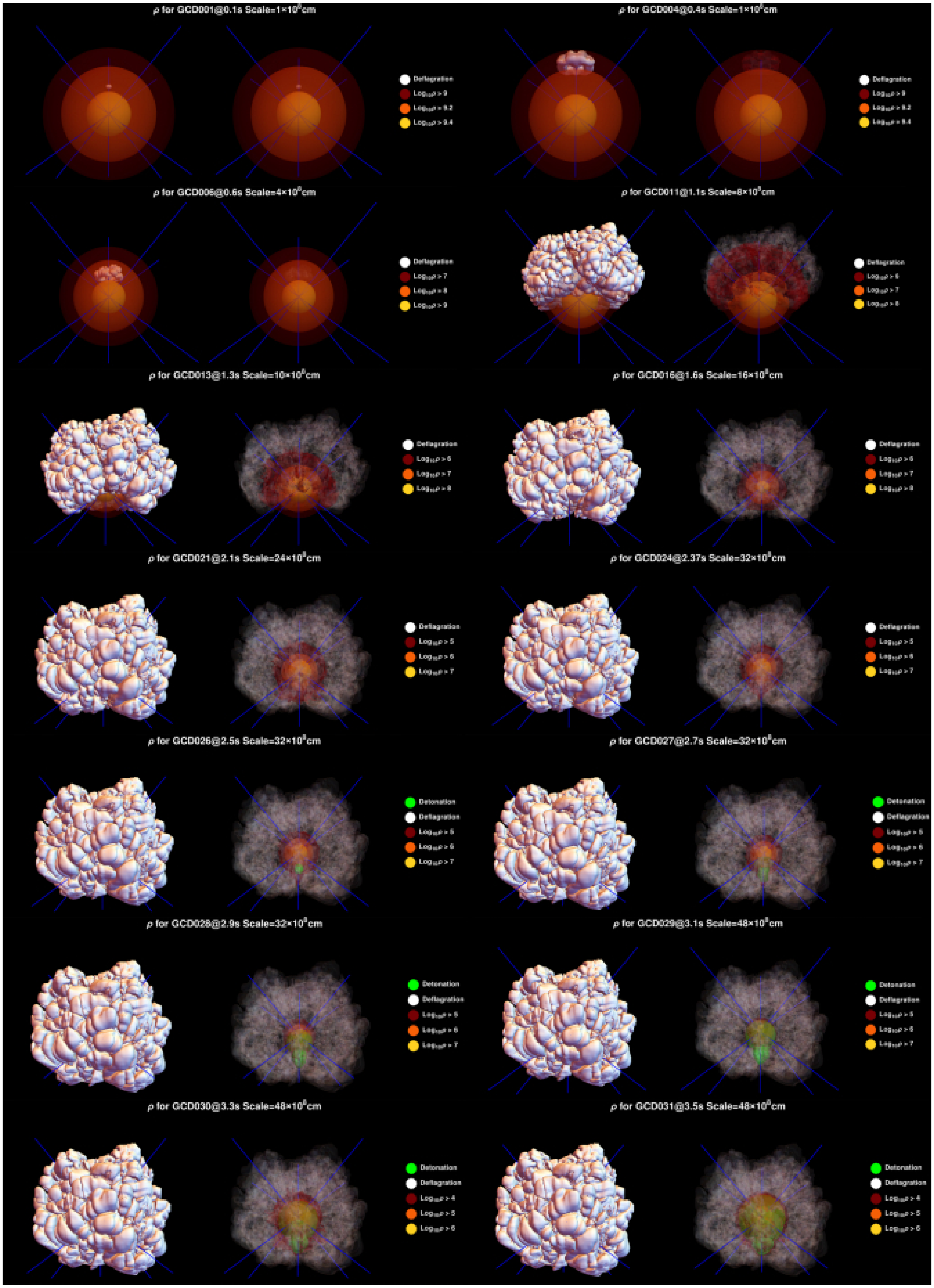

ρ for GCD001@0.1s Scale=1×10^8cm
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ρ for GCD013@1.3s Scale=10×10^8cm
ρ for GCD016@1.6s Scale=16×10^8cm
ρ for GCD021@2.1s Scale=24×10^8cm
ρ for GCD024@2.37s Scale=32×10^8cm
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ρ for GCD028@2.9s Scale=32×10^8cm
ρ for GCD029@3.1s Scale=48×10^8cm
ρ for GCD030@3.3s Scale=48×10^8cm
ρ for GCD031@3.5s Scale=48×10^8cm

Density contour plots including deflagration (white) and detonation (green) surfaces. Credit: arXiv:1609.07403 [astro-ph.HE]

(Phys.org)—A team of researchers at North Carolina State University has found that current and future neutrino detectors placed around the world should be capable of detecting neutrinos emitted from a relatively close supernova. They also suggest that measuring such neutrinos would allow them to explain what goes on inside of a star during such an explosion—if the measurements match one of two models that the team has built to describe the inner workings of a supernova.

Supernovae have been classified into different types depending on what causes them to occur—one type, called a la supernova, occurs when a white dwarf pulls in enough material from a companion, eventually triggering carbon fusion, which leads to a massive explosion. Researchers here on Earth can see evidence of a supernova by the light that is emitted. But astrophysicists would really like to know more about the companion and the actual process that occurs inside the white dwarf leading up to the explosion—and they believe that might be possible by studying the neutrinos that are emitted.

In this new effort, a team led by Warren Wright calculated that neutrinos from a relatively nearby supernova should be detectable by current sensors already installed and working around the planet and by those that are in the works. Wright also headed two teams that have each written a paper describing one of two types of models that the team has built to describe the process that occurs in the white dwarf leading up to the explosion—both teams have published their work in the journal *Physical Review Letters*.

The first model is called the deflagration-to-detonation transition; the second, the gravitationally confined detonation. Both are based on theory regarding interactions inside of the star and differ mostly in how spherically symmetric they are. The two types would also emit different kinds and amounts of neutrinos, which is why the team is hoping that the detectors capable of measuring them will begin to do so. That would allow the teams to compare their models against real measurable data, and in so doing, perhaps finally offer some real evidence of what occurs when stars explode.

More information: 1. Warren P. Wright et al. Neutrinos from type Ia supernovae: The gravitationally confined detonation scenario, *Physical Review D* (2017). DOI: 10.1103/PhysRevD.95.043006 , *Arxiv*: arxiv.org/abs/1609.07403

Abstract
Despite their use as cosmological distance indicators and their importance in the chemical evolution of Galaxies, the unequivocal identification of the progenitor systems and explosion mechanism of normal Type Ia supernova (SN Ia) remains elusive. The leading hypothesis is that such a supernova is a thermonuclear explosion of a carbon-oxygen white dwarf but the exact explosion mechanism is still a matter of debate. Observation of a Galactic SN Ia would be of immense value in answering the many open questions related to these events. One potentially useful source of information about the explosion mechanism and progenitor is the neutrino signal.
In this paper we compute the expected neutrino signal from a Gravitationally Confined Detonation (GCD) explosion scenario for a SN~Ia and show how the flux at Earth contains features in time and energy unique to this scenario. We then calculate the expected event rates in the Super-K, Hyper-K, JUNO, DUNE, and IceCube detectors and find both Hyper-K and IceCube would see a few events for a GCD supernova at 1 kpc or closer, while Super-K, JUNO, and DUNE would

see a events if the supernova were closer than ~0.3 kpc. The distance and detector criteria needed to resolve the time and spectral features arising from the explosion mechanism, neutrino production, and neutrino oscillation processes are also discussed. The neutrino signal from the GCD is then compared with the signal from a Deflagration-to-Detonation Transition (DDT) explosion model computed previously. We find the overall event rate is the most discriminating feature between the two scenarios followed by the event rate time structure. Using the event rate in the Hyper-K detector alone, the DDT can be distinguished from the GCD at 2σ if the distance to the supernova is less than 2.3kpc for a normal mass ordering and 3.6kpc for an inverted ordering.

2. Warren P. Wright et al. Neutrinos from type Ia supernovae: The deflagration-to-detonation transition scenario, *Physical Review D* (2016). DOI: 10.1103/PhysRevD.94.025026 , *Arxiv*: arxiv.org/abs/1605.01408

Abstract
It has long been recognized that the neutrinos detected from the next core-collapse supernova in the Galaxy have the potential to reveal important information about the dynamics of the explosion and the nucleosynthesis conditions as well as allowing us to probe the properties of the neutrino itself. The neutrinos emitted from thermonuclear - type Ia - supernovae also possess the same potential, although these supernovae are dimmer neutrino sources. For the first time, we calculate the time, energy, line of sight, and neutrino-flavor-dependent features of the neutrino signal expected from a three-dimensional delayed-detonation explosion simulation, where a deflagration-to-detonation transition triggers the complete disruption of a near-Chandrasekhar mass carbon-oxygen white dwarf. We also calculate the neutrino flavor evolution along eight lines of sight through the simulation as a function of time and energy using an exact three-flavor transformation code. We identify a characteristic spectral peak at ~10 MeV as a signature of electron captures on copper. This peak is a potentially distinguishing

feature of explosion models since it reflects the nucleosynthesis conditions early in the explosion. We simulate the event rates in the Super-K, Hyper-K, JUNO, and DUNE neutrino detectors with the SNOwGLoBES event rate calculation software and also compute the IceCube signal. Hyper-K will be able to detect neutrinos from our model out to a distance of ∼10 kpc. At 1 kpc, JUNO, Super-K, and DUNE would register a few events while IceCube and Hyper-K would register several tens of events.

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