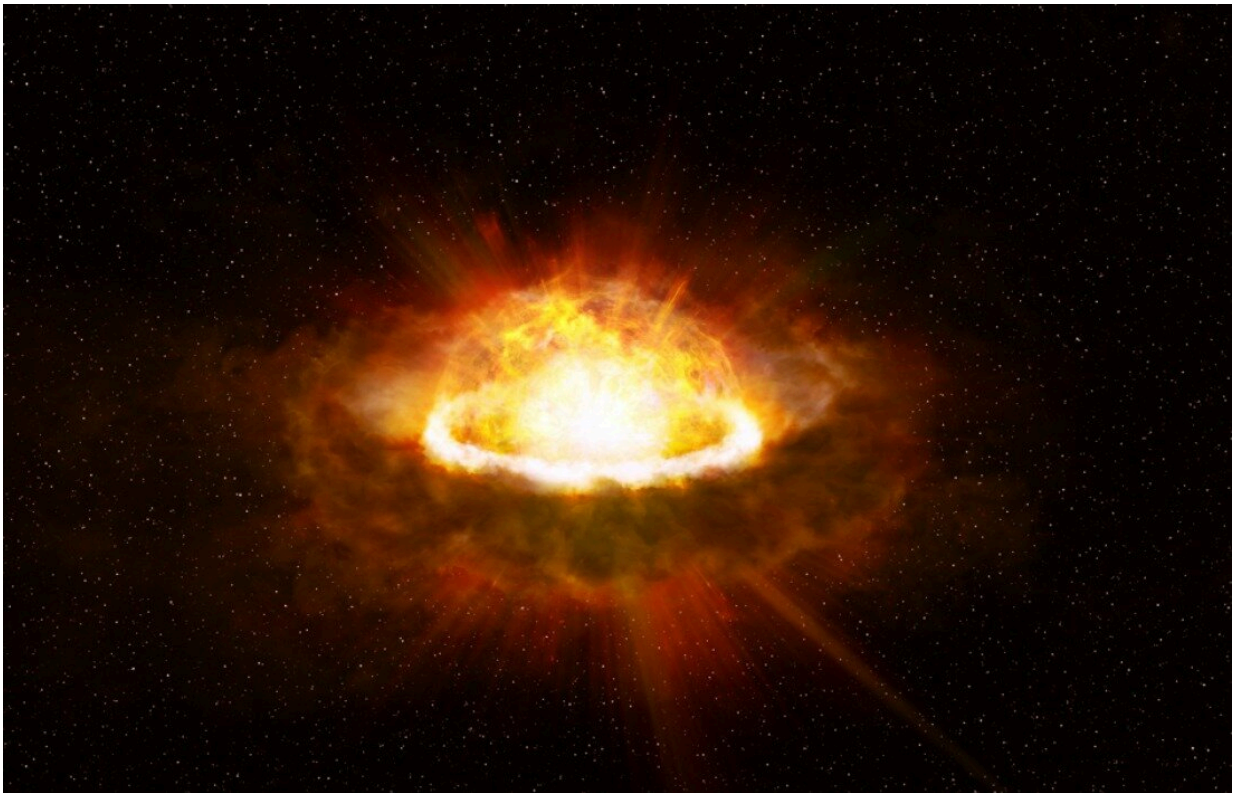


Researchers capture the fastest optical flash emitted from a newborn supernova

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Artist's concept of the high energy released from an interaction between a confined CSM (torus-like) and supernova ejecta soon after the white dwarf explosion. Credit: Kiso Observatory, The University of Tokyo

A team of astronomers has discovered the fastest optical flash of a Type Ia supernova, and reports a study in *Astrophysical Journal Letters*

published on December 8.

Many stars end their lives through a spectacular explosion. Most [massive stars](#) will explode as a supernova. Though a white dwarf star is the remnant of an intermediate mass star like our sun, it can explode if the star is part of a close binary star system, where two stars orbit around each other. This type of [supernovae](#) is classified as Type Ia supernovae.

Because of the uniform and extremely high brightness of the Type Ia supernova, which is about 5 billion times brighter than our sun, they are widely used by researchers as a standard candle for distance measurements in astronomy. As the most successful example Type Ia supernovae helped researchers discover the accelerating expansion of our universe. But despite the great success of the Type Ia supernova cosmology, researchers are still puzzled by [basic questions](#) such as what the progenitor systems of Type Ia supernovae are, and how Type Ia supernova explosions are ignited.

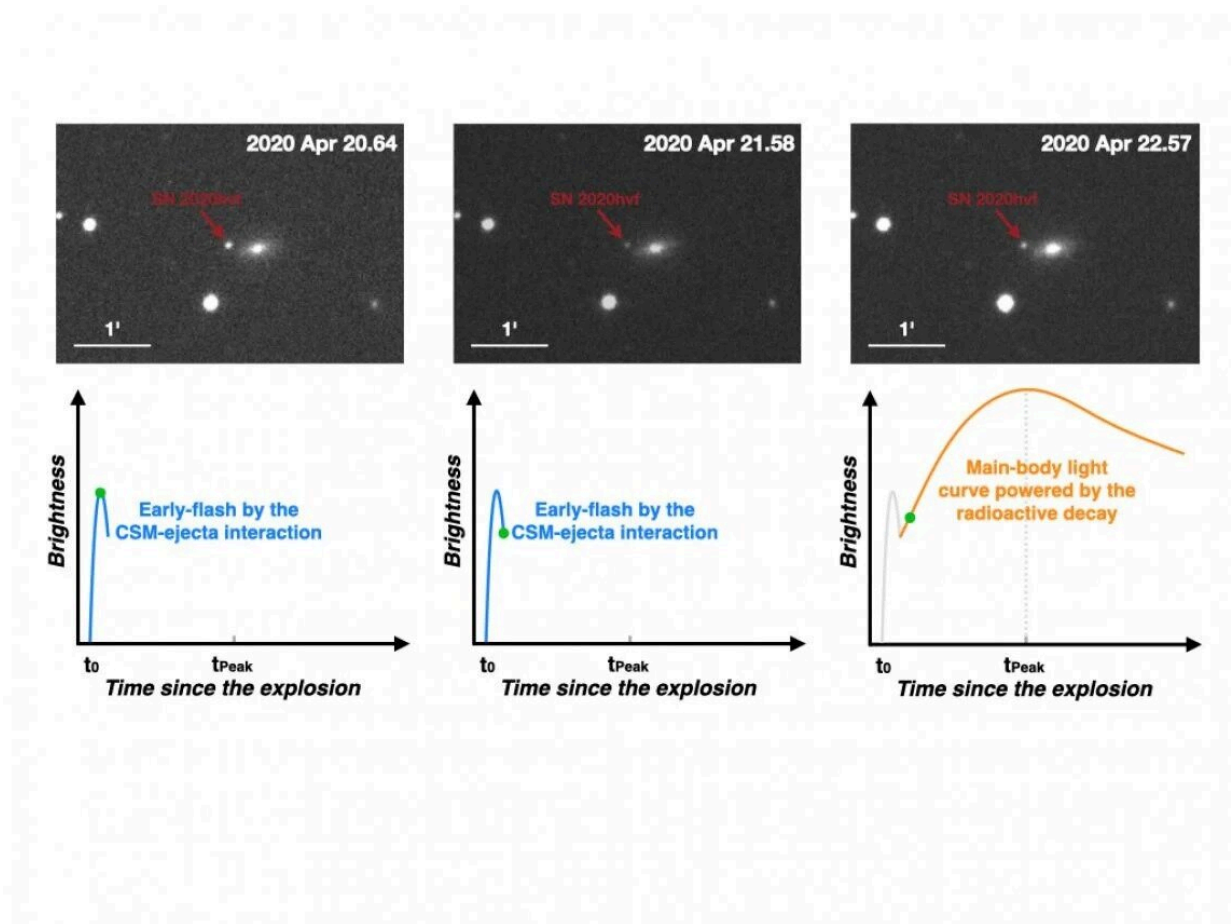
To figure out these long-standing issues, a team of astronomers, led by Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) Project Researcher Ji-an Jiang, attempted to catch Type Ia supernovae within one day of their explosions, called early-phase Type Ia supernovae, using new-generation wide-field survey facilities, including the Tomo-e Gozen camera, the first wide-field mosaic CMOS sensor imager in the world.

By regularly checking early-phase supernova candidates discovered by the Tomo-e transient survey, one transient, Tomo-e202004aaelb, caught Jiang's attention.

"Tomo-e202004aaelb was discovered with high brightness on April 21 in 2020. Surprisingly, its brightness showed significant variation in the next two days and then behaved like a normal early-phase Type Ia supernova.

We have discovered several early-phase Type Ia supernovae that show interesting excess emission in the first few days of their explosions but have never seen such a fast and prominent early emission in optical wavelengths. Thanks to the high-cadence survey mode and the excellent performance of Tomo-e Gozen, we can perfectly catch this amazing feature for the first time. Such a prompt early flash should originate from a different origin compared to previously discovered early-excess Type Ia supernovae," said Jiang.

Computational simulations by Kyoto University Associate Professor Keiichi Maeda showed that the origin of the mysterious fast optical flash can be explained by the energy released from an interaction between supernova ejecta and a dense and confined circumstellar material (CSM) soon after the supernova explosion.



Upper panels: The first three-nights observations of a peculiar Type Ia supernova, Tomo-e202004aaelb (SN 2020hvf), with the Tomo-e Gozen Camera. Low panels: Schematic light curves of Tomo-e202004aaelb (green circles denote the stages that the supernova was staying during the corresponding upper panel observations). Credit: Kavli IPMU, The University of Tokyo

"We have not seen such a short and bright flash from Type Ia supernovae before, even with a recently increasing number of very early discoveries soon after the supernova explosion in the last few years, including those discovered by our team. The nature of the CSM must reflect the nature of the progenitor star, and thus this is a key to understanding what kind of a star explodes and how they do so. A

question is what makes this supernova so special," said Maeda.

Through spectroscopic observations by the Seimei telescope of Kyoto University, the team found that the SN is a variant of brightest Type Ia supernovae.

"At the first look of the spectrum taken just after the initial flash, it stood out as something different from normal supernovae. We noticed that a brightest class of Type Ia supernovae might look like this one if they would be observed in such an early phase. Our classification was subsequently confirmed as the spectra evolve to look more and more similar to the previously found bright Type Ia supernovae," said Kyoto University Project Researcher Miho Kawabata.

The team's result shows at least a fraction of Type Ia supernovae originate from a dense CSM environment, which provides a stringent constraint on the progenitor system of these spectacular phenomena in our universe. Given that Tomo-e202004aaelb (SN 2020hvf) is much brighter than typical Type Ia supernovae used as the distance indicator, the discovery will enable Jiang and his collaborators to test various theories which have been proposed for these peculiar overluminous Type Ia supernovae.

"Previously, we have constructed [theoretical models](#) of super-Chandrasekhar-mass rotating white dwarfs and their explosions. Such massive models can be consistent with the peak brightness of SN 2020hvf, but more theoretical work is necessary to explain the detailed observational properties. SN 2020hvf has provided a wonderful opportunity of collaboration between the theory and observations." said Kavli IPMU Senior Scientist Ken'ichi Nomoto.

Jiang's team will continue looking for the answer of the long-standing origin issue of Type Ia supernovae by carrying out transient surveys with

telescopes all over the world.

"We have used Type Ia supernovae to measure the expansion of the universe, although their origins are not well understood. The early-phase photometry of Type Ia supernovae provides unique information to understand their origins, and hence, should contribute to more accurate measurements of the expansion of the universe in near future," said Kavli IPMU Senior Scientist and University of Tokyo Professor Mamoru Doi.

More information: Ji-an Jiang et al, Discovery of the Fastest Early Optical Emission from Overluminous SN Ia 2020hvf: A Thermonuclear Explosion within a Dense Circumstellar Environment, *The Astrophysical Journal Letters* (2021). [DOI: 10.3847/2041-8213/ac375f](https://doi.org/10.3847/2041-8213/ac375f)

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