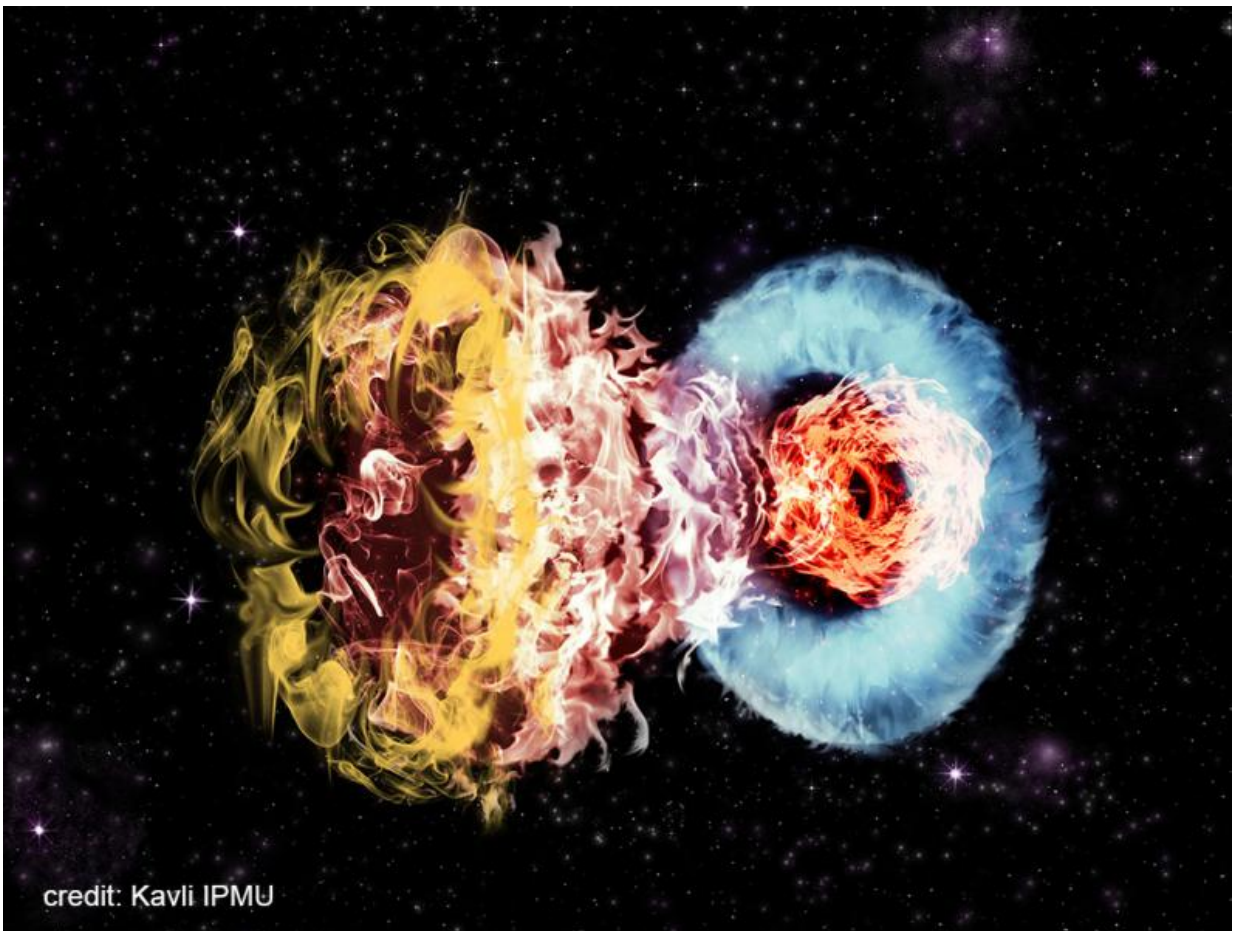


Violent collision of massive supernova with surrounding gas powers superluminous supernovae

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Artist's conception of a shock-interacting supernova. Successive eruptions of a massive star produce ejecta with different velocities: the blue ring corresponds to slowly moving layers which are punched by fast ejecta (red-to-yellow) which shoots out. Interaction of those gas masses is via radiating shock waves which

produce enormous amounts of light. This explains the phenomenon of Superluminous Supernovae with minimum requirements to the energy budget of explosions. Credit: Kavli IPMU

In a unique study, an international team of researchers including members from the Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) simulated the violent collisions between supernovae and its surrounding gas— which is ejected before a supernova explosion, thereby giving off an extreme brightness.

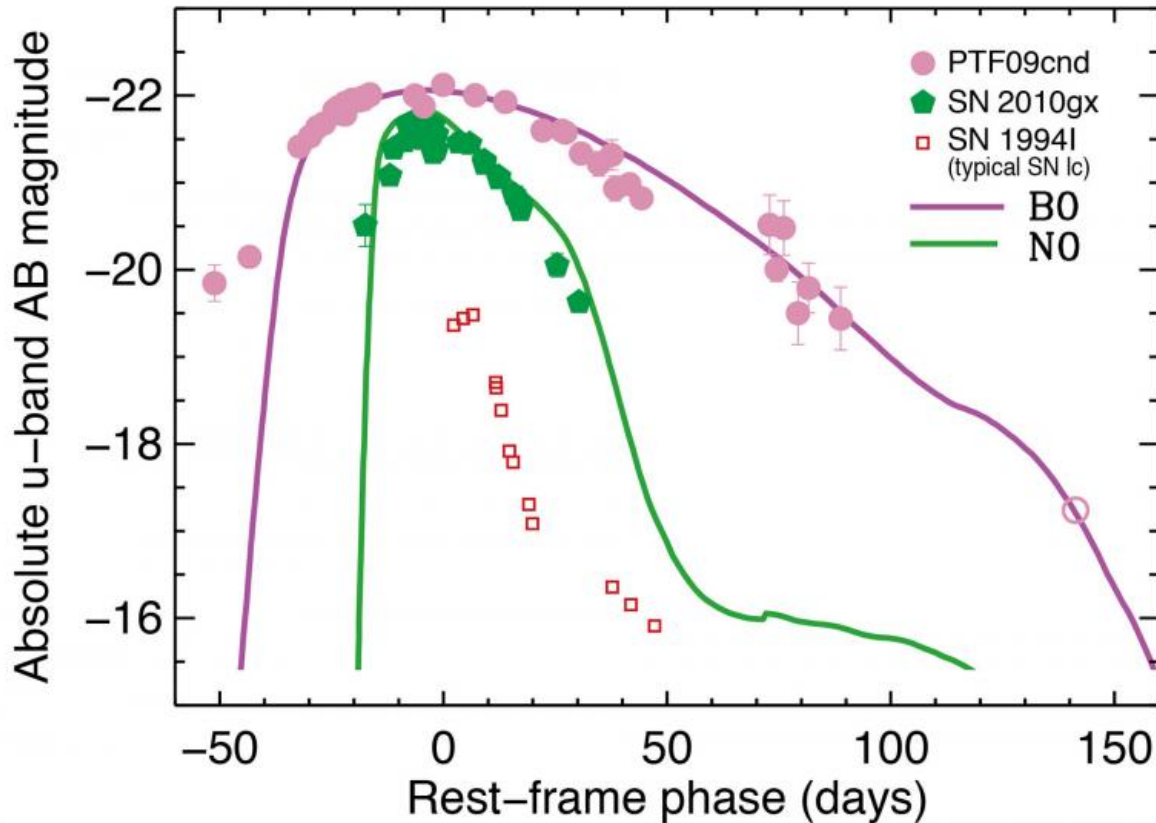
Many [supernovae](#) have been discovered in the last decade with peak luminosity one-to-two orders of magnitude higher than for normal supernovae of known types. These stellar explosions are called Superluminous Supernovae (SLSNe).

Some of them have hydrogen in their spectra, while some others demonstrate a lack of hydrogen. The latter are called Type I, or hydrogen-poor, SLSNe-I. SLSNe-I challenge the theory of stellar evolution, since even normal supernovae are not yet completely understood from first principles.

Led by Sternberg Astronomical Institute researcher Elena Sorokina, who was a guest investigator at Kavli IPMU, and Kavli IPMU Principal Investigator Ken'ichi Nomoto, Scientific Associate Sergei Blinnikov, as well as Project Researcher Alexey Tolstov, the team developed a model that can explain a wide range of observed light curves of SLSNe-I in a scenario which requires much less energy than other proposed models.

The models demonstrating the events with the minimum energy budget involve multiple ejections of mass in presupernova stars. Mass loss and buildup of envelopes around massive stars are generic features of stellar

evolution. Normally, those envelopes are rather diluted, and they do not change significantly the light produced in the majority of supernovae.



Absolute u-band light curves for a fast-fading SLSN-I SN 2010gx and for a slowly fading one PTF09cnd are shown together with two calculated light curves for models N0 and B0 (from the paper by Sorokina et al.), which demonstrates that the interacting scenario can explain both narrow and broad light curves. The light curve of the typical (with “normal” luminosity) SN Ic, SN 1994I, is plotted for comparison. Credit: Kavli IPMU

In some cases, large amount of mass are expelled just a few years before the final explosion. Then, the "clouds" around supernovae may be quite

dense. The shockwaves produced in collisions of supernova ejecta and those dense shells may provide the required power of light to make the supernova much brighter than a "naked" supernova without pre-ejected surrounding material.

This class of the models is referred to as "interacting" supernovae. The authors show that the interacting scenario is able to explain both fast and slowly fading SLSNe-I, so the large range of these intriguingly bright objects can in reality be almost ordinary supernovae placed into extraordinary surroundings.

Another extraordinarity is the chemical composition expected for the circumstellar "clouds." Normally, stellar wind consists of mostly hydrogen, because all thermonuclear reactions happen in the center of a star, while outer layers are hydrogenous.

In the case of SLSNe-I, the situation must be different. The progenitor star must lose its hydrogen and a large part of helium well before the explosion, so that a few months to a few years before the explosion, it ejects mostly carbon and oxygen, and then explode inside that dense CO cloud. Only this composition can explain the spectral and photometric features of observed hydrogen-poor SLSNe in the interacting scenario.

It is a challenge for the [stellar evolution](#) theory to explain the origin of such hydrogen- and helium-poor progenitors and the very intensive mass loss of CO material just before the final explosion of the star. These results have been published in a paper accepted by *The Astrophysical Journal*.

More information: Elena Sorokina et al. TYPE I SUPERLUMINOUS SUPERNOVAE AS EXPLOSIONS INSIDE NON-HYDROGEN CIRCUMSTELLAR ENVELOPES, *The Astrophysical Journal* (2016). [DOI: 10.3847/0004-637X/829/1/17](https://doi.org/10.3847/0004-637X/829/1/17)

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