Astronomers discover an unusual, slowly evolving superluminous supernova

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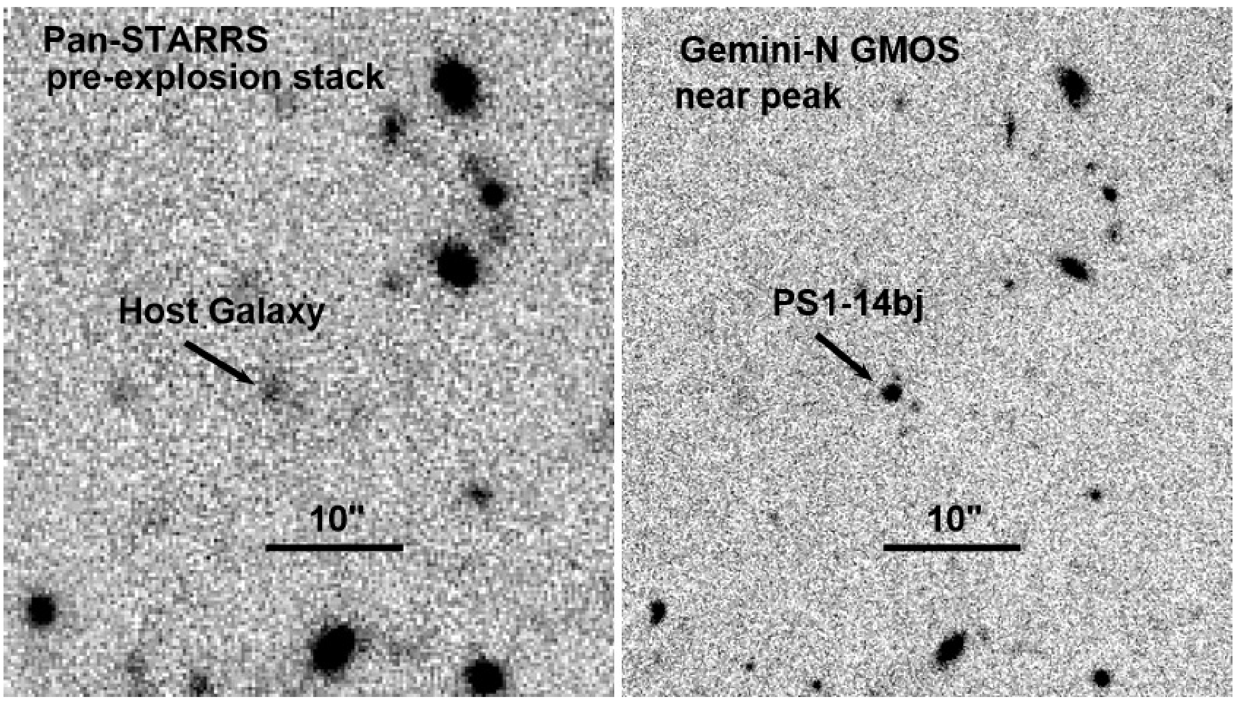

Stacked iP1 PS1/MDS pre-explosion image of the field around PS1-14bj (left), compared to an i-band image from GMOS taken near peak (right). A faint host galaxy is clearly seen at the supernova position. In the GMOS image, which has significantly better seeing (0.4″ FWHM, compared to 1.3″ in the template), it appears that the host galaxy may have some structure or multiple components. Credit: Lunnan et al., 2016.

(Phys.org)—A team of astronomers has found a hydrogen-poor superluminous supernova with exceptional properties. According to a research paper published online on May 17, on the arXiv pre-print server, the cosmic explosion, designated PS1-14bj, shows an exceptionally slow rise to maximum light and a very leisurely fade-out. It the longest rise time measured in a superluminous supernova to date.

PS1-14bj was first detected in November 2013 by an international team of researchers led by Ragnhild Lunnan of the California Institute of Technology. The astronomers used the Pan-STARRS telescope (PS1) on Mount Haleakala in Hawaii to find this supernova and employed a set of other telescopes worldwide to conduct follow-up observations of the object.

PS1 is excellent at finding supernovae and other objects that change or move in the sky. PS1-14bj was found as part of a project carried out by PS1, called the Medium Deep Survey, that imaged the same fields of the sky every night to search for transient objects like supernovae.

What drew the attention of the astronomers was that the newly discovered supernova was rising in brightness to maximum light much more slowly than usual.

"PS1-14bj stood out in the PS1 data by rising in brightness much slower than a common supernova does, which is what initially prompted us to follow it up further," Lunnan told Phys.org.

Follow-up observations allowed the team to obtain spectra and additional optical images of PS1-14bj. It turned out that this supernova evolves very slowly as its rise time to maximum takes more than 120 days, and it also fades away very slowly (about 250 days). To put that in perspective, ordinary supernovae usually take a few weeks to rise to maximum light, while a typical superluminous supernova rise time might be 30 to 50 days.

According to Lunnan, this slow evolution is similar to what is expected for a special kind of explosion mechanism called a pair-instability supernova, and PS1-14bj fits some of the theoretical expectations of what such an explosion would look like.

However, it also has some properties that are very hard to explain in a pair-instability model. What puzzles the scientists is its unusual color evolution, with the color temperature rising prior to peak, and staying constant within uncertainties around 8,000-10,000 K through the peak and decline. The team speculates about how the color stays blue, indicating high temperatures, as the supernova fades away, rather than cooling.

"This means that there is some energy source heating the supernova ejecta at very late times, and it's unclear what that energy source is. One possibility is that there is material around the star, a shell of gas that got ejected from the star before it exploded, and as the supernova explosion runs into this the gas is heated by the collision," Lunnan said.

Other possible explanation offered by the scientists is that the supernova could be powered by a magnetar. It is a rapidly spinning neutron star with a strong magnetic field that was formed from the core of the star as the star went supernova, which could then also be heating the supernova ejecta to very late times.

"Every time we discover something we haven't seen before, it adds to our understanding. For example, PS1-14bj shows us that there exist superluminous supernovae that have the kind of broad, slow light curves that are predicted by pair-instability supernova models. Of course, discovering new things also tends to add to the list of things we don't yet understand, but that is part of the fun of doing science," Lunnan concluded.

Since PS1-14bj has faded away, the team will now focus on the study of the host galaxy to determine what kind of star exploded. They hope to find out whether the star came from a very low metallicity galaxy or not.

More information: PS1-14bj: A Hydrogen-Poor Superluminous Supernova With a Long Rise and Slow Decay, arxiv.org/abs/1605.05235

Abstract

We present photometry and spectroscopy of PS1-14bj, a hydrogen-poor superluminous supernova (SLSN) at redshift z=0.5215 discovered in the last months of the Pan-STARRS1 Medium Deep Survey. PS1-14bj stands out by its extremely slow evolution, with an observed rise to maximum light ≳125 days in the rest frame, and exponential decline out to ~250 days past peak at a measured rate of 9.75×10−3 mag day−1, consistent with fully-trapped 56Co decay. This is the longest rise time measured in a SLSN to date, and the first SLSN to show a rise time consistent with pair-instability supernova (PISN) models. Compared to other slowly-evolving SLSNe, it is spectroscopically similar to the prototype SN 2007bi at maximum light, though somewhat lower in luminosity (Lpeak≃4.4×1043 erg s−1) and with a flatter peak than previous events. In addition to its slow evolution, PS1-14bj shows a number of peculiar properties, including a near-constant color temperature for >200 days past peak, and strong emission lines from [O III] λ5007 and [O III] λ4363 with a velocity width of ~3400 km s−1, in its late-time spectra. These both suggest there is a sustained source of heating over very long timescales, and are incompatible with a simple 56Ni-powered/PISN interpretation, or any model that predicts a monotonically decreasing temperature (such as the simple magnetar spin-down model). A modified magnetar model including emission leakage at late times can reproduce the light curve, in which case the blue continuum and [O III] features would be interpreted as material heated and ionized by the inner pulsar wind nebula becoming visible at late

times. Alternatively, the late-time heating could be due to interaction with a shell of H-poor circumstellar material.