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BASIC AND COMPUTATIONAL SCIENCE

Back to the Beginning: a universe filled with dark energy

In the spring of 2001, a supercomputer at the National Energy Research Scientific Computing Center (NERSC) gave proof that a supernova first glimpsed over three years earlier by the Hubble Space Telescope was 11.3 billion years old–so ancient and so far away that it exploded before the universe began to accelerate.

Good evidence that we live in an accelerating universe mostly filled with dark energy," is how astrophysicist Peter Nugent of NERSC's Scientific Computing Group characterizes the remarkable supernova dubbed SN 1997ff. Working with Adam Riess of the Space Telescope Science Institute (STScI), Nugent confirmed that 1997ff was a Type Ia supernova, the kind of bright, uniform event cosmologists use as "standard candles."

By comparing brightness and redshifts of Type Ia's, two international groups of astronomers and physicists –the Supernova Cosmology Project based at Berkeley Lab, of which Nugent is a member, and the High-Z Supernova Search Team, to which Riess belongs – discovered the universe's accelerating expansion, which they announced in 1998.

In collaboration with other researchers, physicist Peter Nugent uses Deep Field galaxy observations from the Hubble Space Telescope, along with his own calculations and the raw computing power of NERSC, to study dark

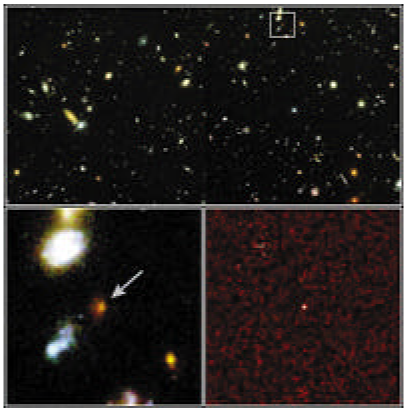
energy in the universe.

If expansion were slowing down or coasting, the highest-redshift Type Ia's they recorded should have been brighter; the researchers concluded that expansion must be accelerating instead. They were soon challenged by skeptics who tried to explain why distant supernovae looked dimmer than they really were.

One idea was that "gray dust" fills space and, like a neutral density filter, cuts the light from far-off objects. Another suggestion held that, since the early universe was poor in heavy elements, ancient exploding stars were dimmer because of their chemistry.

"But SN 1997ff is so far away, and thus so old, that it brings us information from an era when stars and galaxies were closer together and expansion was still slowing due to gravity," Nugent explains. "Cosmology turns things around a bit when we look that far back: things don't get as faint as quickly as they do at lower redshift. This was the case for 1997ff-effectively arguing against the notion that observations of distant Type Ia supernovae are systematically distorted by intervening gray dust or the chemical evolution of the universe, which would always make things fainter and fainter."

SN 1997ff was first found by Ron Gilliland of STScI and Mark Phillips of the Carnegie Institution of Washington during the last week of December, 1997, while searching for high-redshift supernovae in the Hubble Deep Field patch of galaxies. Sifting the data, they found two good candidates and asked Nugent to help them determine what this implied about the number of high-redshift supernovae in the universe as a whole.



Supernova 1997ff was discovered in a tiny corner of the Hubble Deep Field of galaxies.

Unfortunately SN 1997ff had been observed in only one range of frequencies. Spectra of high redshift objects are shifted well into the infrared, and without additional infrared observations not even its type could be confirmed. It seemed unlikely that anyone had made such observations.

Enter serendipity. Only 25 days after Gilliland and Phillips made their search, Rodger Thompson of the University of Arizona imaged part of the Hubble Deep Field in the near infrared. Thompson wasn't looking for supernovae, but many of his images accidentally included SN 1997ff and its host galaxy.

"Twenty-five days may seem like a long time, but highly redshifted objects are moving away from us so fast that time dilation is large," Nugent remarks. "At a redshift of 1.7, three and a half weeks in our frame of reference is only about nine days of elapsed time for the supernova itself."

In mid-1998 Mark Dickinson of STScI again caught infrared images of the greatly faded supernova and its host galaxy. Once more luck had provided a missing piece of the puzzle: Nugent proposed to Dickinson that by digitally subtracting the new images of the host galaxy from those made when the supernova was bright, remaining uncertainties could be eliminated.

Meanwhile Adam Riess had become intrigued by the accumulating data, and in July of 2000 he queried Nugent about doing cosmology on an unnamed supernova at a redshift "around 1.65." There was only one such supernova. "I guess I wasn't especially cagey," Riess later admitted.

Soon Riess and Nugent were collaborating. Among the numerous calculations Nugent performed at NERSC in communication with Riess, one of the most telling was a set of plots establishing that SN 1997ff was almost certainly a Type Ia supernova at a redshift of 1.7, first seen eight days after it exploded.

"Now we could do the cosmology," Nugent says: it pointed to a universe consisting of about one third matter and about two thirds dark energy, acting to offset gravity. Nugent says, "The results from SN 1997ff are one of the best arguments for the SNAP satellite"–the proposed SuperNova/ Acceleration Probe– "because a supernova at redshift 1.7 is too far away to be visible from the surface of the Earth. Only a space-based telescope could have found it."

By discovering many more such supernovae, SNAP could resolve the most basic cosmological questions, including the nature of the dark energy itself.

-- Paul Preuss