ASTRONOMY

Scrambling to Read the Meaning Of the Sky's Most Ancient Flare

This spring, a seemingly routine gamma ray burst triggered a worldwide race to catch a glimpse of the early universe

On 23 April, astrophysicist Nial Tanvir had just dropped his daughter off at school when an automated text message appeared on his cell phone. NASA's Swift satellite had just detected a gamma ray burst (GRB)—a brief flash of high-energy radiation emitted by a star collapsing to form a black hole. "Oh boy, here we go again," Tanvir, a researcher at the University of Leicester in the United Kingdom, recalls thinking.

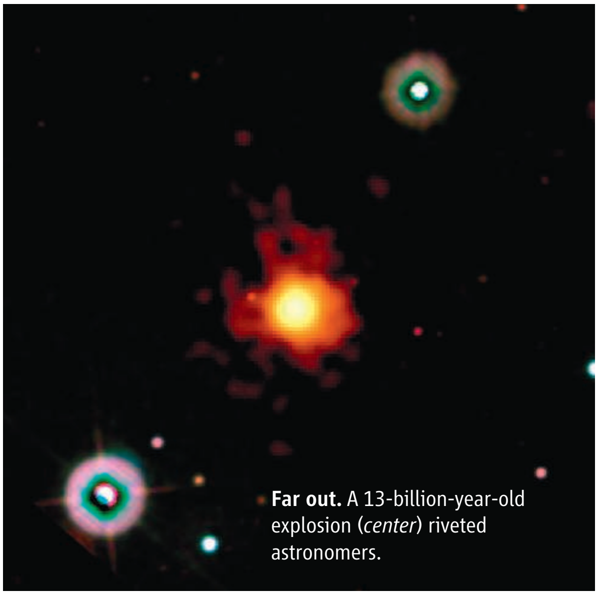
Tanvir's mix of excitement and ennui is familiar to GRB astronomers, who receive two or three burst alerts a week. They must respond quickly by pointing ground-based telescopes at the burst to observe its afterglow, which fades away in a matter of hours or days. Most GRBs turn out to be from the nearby universe and do not yield new insights. A coveted few, however, went off billions of years ago and provide a window on the enigmatic early universe. When Tanvir read the alert, he knew his team was in for a frenzy of observation and analysis that was more likely to produce a humdrum result than an interesting one.

As it turned out, GRB 090423 was the most distant burst astronomers had ever seen. In two papers on the arXiv preprint server (arxiv.org), Tanvir's group and a competing team led by Italian astronomer Ruben Salvaterra report that the burst's redshift of 8.2 means that it went off a mere 625 million years after the big bang, when the universe was less than 5% of its current age. The photons it spewed into space traveled for more than 13 billion years before reaching Earth.

Not only did the burst shatter the previous record for the farthest object seen—a galaxy at redshift 6.96, discovered in 2006—but it also proved that the universe came alive with stars within a few hundred million years of the big bang. "It brings us close to that magical point of first light," says Volker Bromm, an astrophysicist at the University of Texas, Austin. "We don't have to get much farther to catch the earliest stars." The discovery of GRB 090423 and the ensuing race to publish observations also offer a glimpse into 21st-century astronomy—a high-stakes pursuit in which communications networks make possible worldwide, round-the-clock collaborations, and pressures for cooperation and competition often come into simultaneous play. "This is extreme astronomy," says Don Lamb, a theoretical astrophysicist at the University of Chicago in Illinois.

All-night dash

Shortly after Tanvir received the alert, he was conversing via e-mail with his colleagues at the Joint Astronomy Centre (JAC) in Hilo, Hawaii, who had already started planning observations using the United Kingdom Infra-Red Telescope (UKIRT) near the summit of Mauna Kea. The good news was that night had only just begun in Hawaii—it was 10 p.m.—and the burst had gone off over the Pacific Ocean, which meant observations were possible. The bad news was that it was a windy night with gusts of up to 80 kilometers an hour blowing across the mountain. Opening the telescope's dome would subject the instrument to wobbling that would make it difficult to get any useful images.



Far out. A 13-billion-year-old explosion (*center*) riveted astronomers.

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"We were in fact closed for the night when we got the alert," says Tom Kerr, one of the observers at JAC. But he and his colleagues decided to take a chance. "Against our better judgment, we will try it," Kerr e-mailed Tanvir, starting the observation some 21 minutes after the burst. "We observed the target for 20 minutes, and then the wind got too much for us," he says.

Thousands of kilometers away, sitting in an auditorium listening to talks about the future of U.K. astronomy, Tanvir kept glancing at his laptop in anticipation of the first images. He was also in touch with scientists operating Gemini Observatory's 8-meter North telescope, also on Mauna Kea, which had begun taking observations in the optical band within minutes of the burst.

The burst appeared as a fuzzy spot in near-infrared images taken by UKIRT but didn't show up in optical images taken by Gemini. To Tanvir and others, this was a clue that it had occurred at a high redshift: Visible light from the burst had shifted to the near-infrared, and ultraviolet light—which should have shifted to visible wavelengths—had been absorbed by intergalactic hydrogen, causing the burst to vanish in the optical band.

By noon, Tanvir says, "we knew we were looking at something very interesting." He and Andrew Levan, an astronomer at the University of Warwick in the United Kingdom, grabbed lunch from the buffet table and found a quiet spot outside the auditorium to discuss the data. "We weren't going back to listen to any more talks," Tanvir says.

First they announced the UKIRT observations on the Ground Control Network (GCN), a NASA e-mail list that had circulated the automated burst alert. The GCN system serves as a bulletin board for the GRB community, enabling astronomers to coordinate follow-up observations. It also functions as a logbook and timeline of discovery. In flagging the burst for other astronomers, Tanvir and his colleagues had planted their own flag, too.

Across the Atlantic, Harvard University's Edo Berger and Pennsylvania State University's Derek Fox and Antonino Cucchiara were crunching new data taken by an infrared imager mounted on Gemini's North telescope starting 75 minutes after the burst. The objective was to confirm that the lack of an optical signal was indeed due to high redshift rather than to dust blocking visible light emanating from the burst. About 4 hours after Tanvir's circular on GCN, Berger and his colleagues posted the first estimate of how distant the burst was: a redshift of 9. Later that evening, they would revise the estimate to somewhere between 7 and 9.

More-detailed information and a definitive measurement of redshift could come only from spectroscopy. For Tanvir and his

collaborators, that meant a second night of observations, this time using the European Southern Observatory's 8.2-meter Very Large Telescope (VLT) in Chile.

Time was of the essence not only for getting the data but also for analyzing it to solidify the claim to discovery. And so, after debating whether to sleep at all, Tanvir went to bed, setting the alarm for 1:30 a.m. when the night would be starting in Chile. When he woke up, he tiptoed over to his spare bedroom and logged on to his computer.

There was troubling news: A technical problem at VLT had caused a delay. "For some time, it felt like that might scupper the situation," Tanvir says. Then, 17.5 hours after the burst, the telescope began taking spectra using the Infrared Spectrometer And Array Camera (ISAAC). Meanwhile, researchers at the Max Planck Institute (MPI) for Astrophysics in Garching, Germany, had posted a more definitive value of redshift—about 8.0—based on images taken 15 hours after the burst by a 2.2-meter telescope owned by MPI and ESO at the La Silla Paranal Observatory in Chile. The Italian group—led by Ruben Salvaterra, Guido Chincarini, and others at the Italian Institute of Astrophysics in Merate—was racing Tanvir's group to finish the spectral analysis. Using the 3.6-meter Telescopio Nazionale Galileo on La Palma in the Canary Islands, the researchers had begun taking near-infrared spectra of the burst's afterglow 3 hours before VLT.

When Tanvir started analyzing the VLT data, dawn was breaking over Cambridge. He saw a GCN circular from the Italian group, posted shortly after 4 a.m. It was the first spectroscopic result about the burst, reporting a redshift of 7.6. At 8:20 a.m., a bleary-eyed Tanvir posted the results of his group's spectral analysis showing a redshift of about 8.2, which turned out to be more accurate.

Splitting the difference

Even though every group that collects data on a burst could choose to publish independently, astronomers know they can increase their chances of publishing in a high-profile journal by combining observations. Strategic alliances start to form even while the observations are being made, says John Nousek, an astrophysicist at Pennsylvania State University, University Park, and one of 45 co-authors on the Salvaterra paper. Because GRBs are such a community event for astronomers, he says, there's a very public race to publish. "Of course, ego plays a role," he says.

For Tanvir and Salvaterra, the race to publish began as soon as the race to analyze observations had ended. Tanvir quickly began writing a draft, forming an alliance with the different groups he had been communicating with, including the researchers from Garching. Three days after the burst, he got an e-mail from Chincarini suggesting that the two groups work together.

Friendly rivals. Salvaterra (*left*) and Tanvir agreed to publish their papers together.

According to Tanvir, Chincarini spelled out one condition: An Italian astronomer would have to be made first author of the paper. Chincarini's implicit argument, Tanvir says, was that "their spectrum was obtained a few hours before us." But "we could argue that we got the correct measurements first," he says. Tanvir declined the offer.

Neil Gehrels, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and principal investigator for Swift, attempted to resolve the differences and have one paper. "We had e-mails and phone calls to discuss who was first, how far along the papers were, how unique the data sets were," says Gehrels, who eventually joined the Tanvir paper while assigning some of his colleagues to Salvaterra's team. After weeks of discussion, the two sides agreed to keep their papers separate but attempt to publish them simultaneously. On 9 June, the two papers appeared together on astro-ph, the astrophysical section of the arXiv preprint server, with a note indicating that each had been submitted to *Nature*.

Burst watchers. Left to right: The Very Large Telescope, United Kingdom Infra-Red Telescope, Telescopio Nazionale Galileo, and Gemini Observatory.

The astro-ph papers reach similar conclusions about the burst's redshift and significance. The Salvaterra paper makes the additional inference that the star that collapsed to produce the burst contained elements heavier than hydrogen and helium. That suggests it formed well after the first stars in the universe—made entirely of hydrogen and helium—had had time to synthesize heavier elements and spew them into the galactic medium.

Although Tanvir agrees that the star could not have been a first-generation object, he says the spectroscopic data are too sketchy to support any conclusions about its composition. Sandra Savaglio, a researcher at the MPI for Extraterrestrial Physics in Garching, Germany, is skeptical as well. "You can't say anything about the metallicity [composition] based on these spectra," she says.

The next time Swift detects a high-redshift burst, astronomers hope, telescopes on the ground will respond even faster, capturing data that will help paint a more vivid picture of the early universe. "There were no successful attempts to take spectra on the first night, which is a real pity," says Lamb. But he's optimistic that nature has more opportunities in store; and that not too far in the future, light from an even more ancient collapsing star will quicken the pulse of observers and gladden the hearts of theorists.

–YUDHIJIT BHATTACHARJEE

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