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BLAST off: Balloon-borne instrument to probe far-off galaxies

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There's no starship to take scientists to the mind-boggling edges of the universe to watch and study cosmic childbirth firsthand. But a balloon-borne telescope should help cosmologists squint into the submillimeter wavelength so they can finally get a better picture of star formation in distant galaxies as well as those in our own backyard.

The project is called BLAST, which stands for Balloon-borne Large-Aperture Sub-millimeter Telescope. A multi-university team launched its instrument payload from the Long Duration Balloon facility on the Ross Ice Shelf on Dec. 21 at 2:50 p.m. The polar vortex, a sort of atmospheric cyclone, will carry the BLAST payload around the continent, eventually depositing it about two weeks later near its original launch location.

Its mission: to image the formation of galaxies at the early frontier of the universe where starburst (star formation) is occurring more rapidly. These submillimeter "pictures" will help scientists fill gaps in their knowledge about the universe's structure and its evolution.

"We've built the most sensitive instrument that we can build to look at distant galaxies and look at star formation there," said Mark Devlin, BLAST principal investigator from the University of Pennsylvania.

Scientists use the submillimeter waveband for these types of observations for a couple of reasons. First, the gas clouds required for star formation obscure regular optical observations like those performed by the Hubble Space Telescope. Also, there is a lot of energy in the submillimeter band emanating from these cataclysmic events.

In a better light

BLAST sails into its orbit through the stratosphere with the help of a special balloon constructed out of ultra-thin polyethylene film, the same sort of material used for plastic bags at the grocery store but a little more resilient.

The mirror for the two-meter-diameter telescope is made out of aluminum, which offers near-optical glass quality but at a fraction of the cost, according to Devlin. Photons enter through the front of the telescope and reflect off the primary mirror to a secondary mirror, which directs the light into the receiver.

Liquid nitrogen first chills the instruments to 77 degrees Kelvin. (Absolute zero, 0 degrees K, is the lowest possible temperature where nothing could be colder and no heat energy remains in a substance.) Liquid helium then drops the temperature even further, to 4 degrees K. Eventually, the temperature cools to just three-tenths of a degree above absolute zero as additional liquid helium is pumped into the system.

"There's a whole refrigeration system self-contained in there which we've developed over the
past couple of years that works really well now," Devlin said.

The receiver divides the photons into three "colors" or wavelengths as they pass through filters onto a detector array made of bolometers, heat sensors that can pick up even the weakest signals. The photons are only perhaps 30 degrees K or a little warmer, hence the need for extreme cold to detect the low-energy light. It's sort of like sweeping your hand across a day-old campfire and trying to find a warm ember.

In the end, the reconstructed picture will be an image not unlike what one would see in the optical wavelength, though at a lower resolution than what something like the Hubble telescope takes, according to Barth Netterfield, the project's co-principal investigator.

To capture those fleeting embers from the distant bonfires of starbursts, the BLAST gondola will need to point away from sun and through clear patches in our own galaxy. The sun is both friend and foe to the scientists. A direct hit on the mirror will fry the instruments. Sun shields protect the sensitive equipment, for despite the frigid temperatures of the stratosphere, inside the payload it's about room temperature, Devlin said.

The Antarctic summer sun is also benevolent. The 24-hour-a-day sunlight provides power to the gondola through the solar panels on the back, which open like wings. The sun's constant position doesn't cause fluctuations in the balloon's altitude because it doesn't cool off or heat up the helium between night and day.

To keep BLAST fixed on a single spot in the sky requires more technological innovation than assistance from Mother Nature. To maintain a lock on a distance speck for very long, the instrument must know where it is. In this case, BLAST identifies its position relative to a nearby known star. It can immediately learn this by using one of two star cameras that can take optical pictures. Software can recognize the star pattern and basically tell the gyroscope where to adjust if needed.

The big picture

The BLAST scientists hope that where they point the telescope will reveal a violent sea of
starbursts.

The universe started off with matter distributed very smoothly.

We know this from observations of the Cosmic Microwave Background, which formed about 400,000 years after the Big Bang, Devlin explained. BLAST will look at galaxies in their mid-to-late formation stages when the universe was between 3 and 7 billion years old.

"If we see hundreds of thousands of these starburst galaxies, we're going to be able to say a lot about star formation history of the universe," said Netterfield, from the University of Toronto.

He said cosmologists also hope to spy colliding galaxies, which can give birth to massive stars. These events will help answer questions like: how many stars are forming, and how hot are they?

"It's thought that a large fraction of stars are made from these collisions," Netterfield noted.

BLAST launched out of Sweden last year for a spin around the Arctic, but a busted mirror shortly after the launch stymied most of its extra-galactic objectives. The researchers still collected data on luminous objects closer to home. This time around, the team hopes to discover if the system it has painstakingly developed will do everything the models and equations say it will. "It's a huge challenge," Netterfield said.

The data from the experiment are obviously an important investment in time and money but also represent the future careers of the graduate students who will write their theses on various aspects of the project. Devlin and Netterfield both say that programs like BLAST are important proving grounds for young scientists, who must not only understand the cosmogenic complexities of their fields but how to manage projects from the ground up.

"Everybody has a specialty, but they know about all the instruments," Devlin said. "These people go off and do phenomenal things."

Enzo Pascale, an Italian graduate student at the University of Toronto, got a dose of project management last year in the absence of Netterfield.

"I basically try to keep an eye on everything," he said while replacing a faulty component of hardware in preparation of BLAST's upcoming launch. The team works in the bay of one of the two main Long Duration Balloon (LDB) buildings constructed in 2005. The gondola dominates the floor area.

Devlin noted that the National Science Foundation is particularly responsible for the success of scientists in the sub-orbital work supported by NASA that he and colleagues do from LDB.

"We really appreciate that we're here," he said.

There is still much scientists don't know about the 14 billion-year-old universe. For Netterfield, the universe is too fun a place not to poke around, not to ask the next big question.

"It's fun. That's it. It's art. It's interesting," he said of the urge to explore for exploration's sake. "We should spend some fraction of our resources just on things that are interesting - not just because it has any immediate, intrinsic value."

"It may have someday."

*NSF-funded research in this story: Mark Devlin, University of Pennsylvania;
Barth Netterfield, University of Toronto; http://chile1.physics.upenn.edu/blastpublic/.*