Cosmologists probe beyond the Big Bang

September 5 2014, by Linda B. Glaser

A long tradition of cosmology research in Cornell's College of Arts and Sciences has given birth to a vigorous effort by a new generation of cosmologists to understand the Cosmic Microwave Background (CMB), the thermal radiation left over from the Big Bang.

"A large portion of all knowledge about the history of the universe as a whole is revealed when you fully understand the CMB," says Michael Niemack, assistant professor of physics, whose work centers on CMB measurements.

Cosmology, the study of the nature and evolution of the universe, has progressed enormously during the past 30 years, says Jeevak Parpia, professor and chair of physics. "We are in an era of 'precision' cosmology."

"This is a time of very rapid advances in the field," agrees Liam McAllister, associate professor of physics and a specialist in string theory. "You don't know on any given day what new discovery you're going to see posted that night on arXiv."

Henry Tye, the Horace White Professor of Physics Emeritus, was one of the pioneers in understanding inflation in string theory, and he left a legacy of unusual cooperation at Cornell among cosmologists of all sorts. McAllister says it's quite rare to find a university like Cornell where there are meaningful collaborations linking string theorists, experimentalists and astronomers, such as his and Niemack's research with associate professor of astronomy Rachel Bean.

"Cosmology at Cornell is a wonderful example of the culture of collaboration within arts and sciences disciplines, between highly skilled instrumentalists and researchers pondering the theoretical implications of physical laws," says Gretchen Ritter, the Harold Tanner Dean of the College of Arts and Sciences.

"CMB research is a rich, ever-evolving field with a science mix that excites both the astronomy and physics communities," adds Terry Herter, chair of astronomy. "Striving to understand the origin and evolution of the universe and fundamental physics at the same time – it doesn't get much better than that."

McAllister, recipient of a National Science Foundation Early Career Award for his work on theoretical models of the early universe, seeks to understand how the theories of the inflation that occurred in the universe's earliest moments can be founded on a secure theoretical footing and emerge from a mathematically consistent structure.

"We'd like to understand the physics behind inflation," he says. "One of our responsibilities as theorists is to try to predict the results of future experiments and interpret the results of existing experiments."

According to McAllister, what's needed is a theory in which the laws of gravity are fundamentally quantum mechanical, but that behave according to classical physics in systems that are big enough and slow moving. So far, he says, string theory is the only approach that offers a consistent theory of quantum gravity.

On the experimental side, the higher resolution CMB measurements that Niemack is pursuing relate directly to the tests of general relativity that Bean is interested in.

The completion of the Cornell Caltech Atacama Telescope (CCAT) project, which will be the largest submillimeter telescope in the world, will be a boon for cosmologists, says Niemack. He and Bean plan to use CCAT to probe galaxy cluster velocities with much higher precision than is now possible.

Experiments probing the CMB have the potential to reveal laws of nature at a much more fundamental level than has been proven in any other way. "For example, results from CMB polarization observations could have a transformative effect on the kinds of problems related to the early universe that we theorists pursue," says McAllister.

"That's what makes it so compelling," adds Niemack. "Any one of these observations or experiments could fundamentally change how we see the universe."

Experimental cosmology

Cornell's experimental cosmology research group – which includes assistant professor of physics Michael Niemack, postdoctoral researchers Francesco De Bernardis and Shawn Henderson, and graduate students Brian Koopman and Patricio Gallardo – recently announced the first results from a Cosmic Microwave Background study using a polarization-sensitive camera (ACTPol) that Niemack led the design of for the 6-meter Atacama Cosmology Telescope.

"ACTPol has a unique niche in science that we can pursue better than anyone else because of the capabilities that we've built into our instrument," says Niemack. "We're looking for tiny, tiny signals, roughly a part in 10^7 above the background over a range of scales that have not been probed before."

An upgrade to be completed this year will add three times as many detectors and an additional frequency channel to ACTPol, enabling the group to probe physics at grand unification energy scales, a trillion times higher energy than is probed at the Large Hadron Collider.

Provided by Cornell University