It is 3:00 A.M. Lights are on in a windowless room adorned with toy bats, galaxy mobiles, and a computer screen that refreshes itself every second with a new display. It monitors incoming data from the Arecibo telescope, 1,500 miles away. A "talk" window allows an electronic conversation with the telescope operator in the control room at the Arecibo Observatory; a phone sits prominently on the desk beside the screen, just in case the Internet goes on the blink. A member of the Cornell EGG (ExtraGalactic Group) is spending another night in Cornell’s "Camuy Cave"—in the Space Sciences Building—observing, remotely, with the Arecibo telescope, on a hunt for starless galaxies.

"Starless galaxies? Aren't galaxies supposed to be conglomerates of billions of stars?” one might ask.

“Well, not exactly,” an EGG astronomer would reply with a grin and explain the situation.

It turns out that the main constituent of galaxies is not matter of the kind of which we are made—stars and planets, rocks, carbon, hydrogen—what scientists call "baryonic matter," but rather, matter of a mysterious form, referred to as "dark." It is labeled "dark" because it is invisible; it cannot be seen by any telescope.

Although dark matter is nearly ten times more abundant than baryonic matter, it can only be detected through its gravitational interaction with the more familiar, baryonic form. In a normal galaxy, baryonic matter—stars and interstellar gas and dust—resides deep inside a huge, massive envelope of dark matter, known as a "halo." By studying the baryonic component, the Cornell EGG team hopes to learn about the invisible, dark halo.

In addition to the "EGGHeads," Professors Riccardo Giovanelli and Martha P. Haynes, Astronomy, the EGG team includes astronomy graduate students, Kristine Spekkens, Christopher M. Springob,
Karen L. Masters, Amelie Saintonge, Barbara Catinella, and Brian R. Kent; senior, Lisa Wei; and Visiting Professor Rebecca A. Koopmann, Union College. Over the summer, NSF Research Experience for Undergraduates summer students, Ann Martin (SUNY-Buffalo) and Anna VanDuzer (University of South Dakota), also contributed to the EGG team by compiling a database of related information from other telescopes.

Cosmologists cannot construct model universes in their laboratories, but they are able to simulate the conditions believed to describe the universe at different stages in its history through elaborate computer codes. Such "numerical simulations" provide the details of the story of the formation and evolution of galaxies and larger structures, such as the clusters and superclusters of galaxies, since the "Big Bang." They also predict that the lowest mass galaxies may consist almost entirely of dark matter, containing so little baryonic matter that they are unable to make any stars at all. These low mass objects could be starless galaxies. Do such objects truly exist? The Cornell EGGfolks aim to find out.

If there are no stars, how can the EGGfolks know that a galaxy exists? The answer is, even if the baryonic matter in the starless galaxy failed to make any stars, there still might be small amounts of hydrogen gas mixed with the dark matter. Hydrogen is, by far, the most abundant element in the universe, and fortunately, it emits radio waves at a wavelength that can be detected by the Arecibo telescope. Therefore, the Cornell EGG astronomers spend a lot of time sitting in front of computers in the Camuy Cave, sifting through huge amounts of radio noise, looking for the hydrogen signal of a starless galaxy. It is the cyber-space equivalent of looking for a needle in the cosmic haystack.

The EGG search has been made possible by improvements in Arecibo’s capabilities in the last few years. While the advances of technology make the hunt feasible, it still remains a daunting and complex task. The definition of the new search strategies, the effects of ever-increasing radio frequency interference produced by human activities, and the discrimination of signals produced by cosmic sources amid the radio noise are all challenges to the EGG team.

The Arecibo radio telescope is the largest on Earth, capable of collecting more photons of radiation at once than any other, thereby enabling the discovery of the faintest radio sources. Yet, the ongoing search for starless galaxies is only a pilot project, in anticipation of grander things to come, after Arecibo overcomes its "Cyclops complex." The Arecibo L-band feed array (ALFA), under construction, will turn Arecibo into a 7-pixel "camera." Then, the "ultimate" hunt for starless galaxies will begin.
of the sky. As for most single-dish radio telescopes, an image made with Arecibo today needs to be constructed by recording a single pixel at a time. A solution to this limitation was recognized many years ago, when Giovanelli, then the head of the Radio Astronomy group at the Arecibo Observatory, and others on the Arecibo staff investigated the feasibility of constructing a multipixel detection system for Arecibo.

The implementation of such a device was made possible by the recent upgrade of the telescope, which radically altered its optical design. Under construction, however, is the Arecibo L-band Feed Array (ALFA), and within the next year, it will turn Arecibo into a 7-pixel "camera," making it possible to sweep the sky much faster. Then, the "ultimate" hunt for starless galaxies, an All-sky, Fast ALFA survey, known to the EGGfolks as "ALFALFA," will begin.

The task of conceiving and implementing new observing techniques at Arecibo is not new for Giovanelli and Haynes. As graduate students, they were among the first to use Arecibo for extragalactic studies after the radio telescope was provided with a new antenna surface in 1974, enabling the first observations of hydrogen with the big dish. Over the years, their long affiliations with Arecibo and Cornell have involved them in several new expansions of the telescope's capabilities in observational cosmology. Their pioneering work on mapping the large-scale, filamentary nature of the distribution of galaxies, largely conducted at Arecibo, brought them the 1989 Henry Draper Medal of the National Academy of Sciences.

Like Giovanelli and Haynes, who began their careers as young researchers on the staff at Arecibo, the current EGG graduate students are gaining experience and expertise far beyond what they might learn in a classroom: the design of a major radio survey; the development of observing strategies; the consideration of trade-offs in strategy, science goals, and the many practicalities; the development of sophisticated software tools; and the handling of large volumes of data. Typical of an effort of this magnitude, results and answers do not come quickly, and all "grades" of EGGfolks are contributing to the hunt for starless galaxies.

Long, observation-intensive projects, like this one, benefit enormously from the ability to carry on observations remotely using graphical computer tools developed by the Arecibo Observatory staff. Located a short distance from the Arecibo Observatory in the karst region of Puerto Rico, the real Camuy Cave is part of an extensive subterranean cave system reported to be the largest in the western hemisphere. This one is a lot more scenic than its Cornell namesake!

Martha P. Haynes
Goldwin Smith Professor of Astronomy

Riccardo Giovanelli
Astronomy

For more information:
http://www.astro.cornell.edu/Galaxy/egg.html