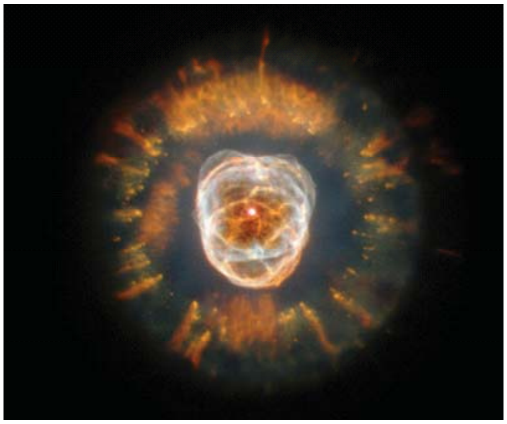
VISITING DISTINGUISHED RESEARCHER PROFILE
NETA BAHCALL

PI Distinguished Research Chair Dr. Neta Bahcall recently visited PI from Princeton University, where she is the Eugene Higgins Professor of Astrophysics. Dr. Bahcall is an observational cosmologist who has pioneered quantitative approaches to the understanding of astronomical data which have yielded key insights into such fundamental questions as the large-scale structure, mass, and fate of the universe, galaxy formation, the nature of quasars, and dark matter.

Dr. Bahcall, you've been appointed as one of PI's first Distinguished Research Chairs and you're one of the first to pay a research visit to PI. What are your impressions?
PI is a very unique place, very different from the usual university or institute. The scientific directions at PI are all very fundamental, cutting edge research. Which scientific direction is more important? Well, we don't know, and that's why it is important to try different directions and different methods. This is what you do here at PI.

By being here for two weeks, I have had the chance to talk to many people, get to know them and what they are working on. I had the opportunity to feel the atmosphere of the place, which is wonderful: warm, friendly, informal, and scientifically very dynamic and interactive. I feel very much at home here. I talked with people in cosmology, particle physics, string theory, quantum gravity, and more. We discussed specific projects, recent advances in the field, possible work for the future, and debated many exciting scientific possibilities. I gave a talk at the Cosmology Summer School, and talked with many students. It was interesting for me to see the high level of the students; their knowledge of theoretical physics was excellent, and I discussed with them observational aspects of cosmology, which they were less familiar with and eager to learn. I wanted to take the opportunity to explain to the students how observational cosmologists measure the properties of the universe—like dark matter, dark energy, the structure of the universe, and more. How do we know, for example, that there is dark matter in the universe even though we cannot see it—after all it's dark! How do we measure it? So I showed them the data, how we can "see" the dark matter in indirect ways, through its gravitational effects, and how we use the data to determine the mass-density of the universe. This was new and interesting to many of them.

You are an observational astrophysicist, and Perimeter is a "theoretical" physics institute. What are your thoughts on the interface between observational data and theoretical physics? Are they coming closer together?
The connection between observational cosmology and theoretical physics is very strong, especially in the last decade, with the discovery of dark energy. The two fields are joined: observational data discover the existence of these amazing new components of the universe—dark matter and dark energy; these have not been expected and they reveal fundamental new ideas about basic physics and the laws of nature. These discoveries reflect the need for new and yet unexplored direction in theoretical physics. To understand what dark matter is, what is or are the particles that make up the dark matter, is still an important open question. The nature of the mysterious dark energy, a phenomenon that was neither expected nor yet understood, is probably the most fundamental new puzzle in theoretical physics. Is it really dark energy that makes the universal expansion accelerate? Is it the cosmological constant that was originally suggested by Einstein, and if so, why does it have this highly unexpected value? Or is it something totally different like the need to modify general relativity on a large scale, or add extra dimensions, or something else? These are examples of the tight connection between theoretical physics and observational cosmology. We live in such an exciting scientific time!



Eskimo Nebula, image courtesy of NASA

I feel that we are on the verge of something big, we just don't know what it is. These new discoveries promise to yield something fundamentally new. It is important for observational cosmologists and theoretical physicists to interact and communicate with each other so that they can work together to solve these mysteries. It is also important that whatever new theory emerges, it has predictive power so it can be tested. Otherwise how would we know which model or which theory is correct?

What is the focus of your work?
I work on various topics in observational cosmology. What is the large scale structure of the universe and how did it form? How and when did galaxies, clusters, and superclusters form and how do they evolve from early times to now? How much dark matter exists in the universe? What else is out there in the universe, and how does it impact the formation and evolution of the universe?

Hubble Space Telescope. Image courtesy of NASA

Your late husband, John Bahcall, was also an astrophysicist. I'm guessing you had some good answers to your three children's questions about the night sky.
Well, it was embedded in their atmosphere. Many of our discussions around the dinner table were about astrophysics and other scientific developments; John and I would frequently discuss our respective work. The kids would sometimes ask questions and sometimes just say, "Oh, astronomy again!" It was fun!

Both you and your husband were involved in the development of the Hubble Space Telescope program, right?
Yes. John was involved with the telescope since the very beginning, in the early seventies. He and Lyman Spitzer are considered the "fathers" of the Hubble Space Telescope. John saved the Hubble from death three times. Because of budget cuts, the Hubble program was cancelled early on, in the 70's. John and Lyman went to Congress—I think they were the first scientists to lobby Congress for science, and they reversed the cancellation of the Hubble. John did it again a few years later when the Hubble was cut again. And again, more recently, John helped reverse the decision a few years ago to cancel the final repair mission to the Hubble – the one that finally flew so successfully just a few months ago.

Did you go to the launch?
John and I went to see the Hubble launch in 1990, but the countdown was stopped for technical difficulties at minus four minutes.

When did they discover that there was a problem with the images coming back from space?
The first images came and everybody was cheering, saying, "It works!" But of course it wasn't working well – the focus was bad. One of the outstanding optical astronomers said right away, "Something doesn't look quite right to me." But the engineers said they still needed to focus the telescope. It was not clear for two or three weeks what was going on. It turned out to be a spherical aberration in the mirror. The horrible thing was that the mirror, while polished extremely well, was polished to the wrong shape! The only slightly good thing was that because the mirror was polished so well, they could model it exactly and then correct for it with software and algorithms. And of course later there were big brainstorming sessions of top engineers and scientists about how can we possibly repair the telescope in space...

"Pillars of Creation," image courtesy of NASA.

How was it fixed?
They fixed it like you fix your eyes when you have poor vision. Your optician fits you with eyeglasses to counteract whatever your eye lens problem is. That's what they did; they put eyeglasses on the Hubble to correct for its bad vision. Designing the corrective lenses was actually not so difficult, because they knew the imperfection; but how do you put those glasses on in space? They designed an incredibly innovative instrument: it was an entire replacement unit designed so that once it was placed in the Hubble, a fan opened up and placed the corrective lenses in front of each of the cameras. And it has worked perfectly well ever since!

Several years ago, after the Hubble had been in operation for many years, a scheduled mission to repair the telescope and place new science instruments on it was cancelled. Without the repair, the Hubble Telescope would have slowly died, becoming space junk. John worked hard again to change this decision [in 2004/05], and once again succeeded in doing so, and thus saving the Hubble one more time. The mission finally took place a few months ago--I have a nice story about it. The kids and I were invited to the launch and we all went; it was spectacular!. It's very special to experience a live launch: the earth shakes, the long fiery plume is bright red, the noise is roaring, and the shock waves hit your entire body. Your heart races.

And here is the story I wanted to tell you: while I was visiting the Space Telescope Science Institute last year, I met with the astronauts of this final planned mission. One of them told me that John was a hero to him, for saving Hubble, and he said, "When I go to the Hubble I would like to take something personal of John's with me." I was so moved; I started crying. I said, "That would be wonderful." Of course, you have to send something small into space... I thought about it and talked it over with our kids. And finally, I sent John and my wedding rings, tied together, to the Hubble.

—Interview by Natasha Waxman

Ed. Note: The mission to repair the Hubble Telescope was successfully completed in May, 2009. It is expected to be operational until at least 2014. It will probe the ultraviolet, infrared and visible spectrums in search of the earliest star systems, and study the large-scale structure of the universe, including the star-driven chemical evolution that produces carbon and the other elements necessary for life.

To view Dr. Bahcall's recent talk, "Weighing the Universe," go to www.pirsa.org/09060066