The 478th Convocation

Address: "Nature's Puzzling Answers"

By Angela V. Olinto

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Let me first congratulate the graduating class for all the efforts and accomplishments that brought you here today. This is a moment of celebration and a moment of reflection. You have had the great privilege of attending one of the top schools in the country, and with this privilege came a great deal of hard work. Think of all those books, papers, labs, midterms, and finals; and those debates, discoveries, disappointments, victories, and parties (well, maybe not so many parties). And for some of you, that dear thesis! You experienced "the best overall academic experience" of all schools in this country, according to the *Princeton Review*. I hope you agree.

I had the honor of teaching some of you, and I know how excellent you are. If you hadn't been so busy graduating, I would have hired you to help me with this address. Those I did not have the pleasure to meet, I'm sure you are also brilliant—even if you did not choose my class as one of your electives. I believe my fellow faculty will join me in thanking you for asking so many questions and for making us keep learning as we teach.

Now I ask you to join me in congratulating yourselves and in thanking your friends and family, who supported you through these trying years. Let's give those who are here in spirit or sitting just behind you a great round of applause!

You already have your degree in your mind and spirit, under these funny hats. But before you get called up here to receive a symbol of your accomplishments, let me share a few more thoughts with you.

What an interesting time to be graduating! You are graduating during the world Olympics and the Iraq War: two opposite pictures of international relationships. We all wish the world had more interactions like the Olympic Games than wars. In my field of science, we have a great tradition of international cooperation and respectful competition, much like the Olympics.

However, in the recent past our nation's leadership has alienated many outside of our borders, and it has become harder for my foreign colleagues to appreciate the greatness of this nation.

I just returned from a series of scientific meetings in different countries in Europe and Asia, and my colleagues abroad are acutely aware of the consequences that this country's decisions have for the world. Since they are seriously impacted by our choices, they would like to have a voice in the debate. The path that this super-powerful country takes moves the whole world. And engaging the world in a constructive manner is in our own self-interest. In my field, for example, the policy of unilateralism and the closing of our borders have started to erode our own scientific leadership.

I believe we have lost an opportunity to use our unique power to export to the world—in an intelligent, planned, non-violent way—the great values of this nation: our tradition of democratic institutions, of civil liberties, of respect for the rule of law and for a diversity of cultures, and most of all the value of accumulated knowledge and experience that is passed from one generation to the next, as exemplified by today's celebration of the 478th convocation!

Instead of dwelling on a lost chance, I am inspired to see the new leadership emerging in your generation. You seem to be following the advice of the last convocation speaker and engaging in the nation's debate over the consequences of our foreign policy decisions. You are part of the intellectual elite of this country and the planet needs you more than ever. It may be a lot to ask of you, but if you were averse to challenges you wouldn't be here today.

Although appalling acts by fellow humans fill newspapers everywhere, our complex civilization is also capable of creating art, music, architecture, science, and masterpieces in almost any human activity (maybe with the exception of spam!). I hope you had a chance to learn about many of humanity's brilliant works during your tenure here, and that this knowledge brings you hope and helps you transcend any difficulties you may encounter.

One of my favorites among human activities is our dialogue with Nature and Nature's surprising answers. Nature does not speak English. But, fortunately for us, she seems to speak very good mathematics (actually better than we do!). And while we learn the necessary mathematics to describe natural phenomena on Earth and in the Universe, we keep asking questions that guide us to the next ones. With this long tradition of creating good questions through theory and getting the answers through great experiments, we have built an impressive view of the Universe. However, a number of intriguing answers lead us to questions that remain open. Let me mention a couple of examples.

At this moment, this beautiful chapel is filled with joy as we gather to celebrate your achievements. This chapel is also filled with many particles, some of them coming from exploding stars very far away. If you open your hands, a couple of cosmic particles will cross your palm every second. These particles move very close to the speed of light and are called cosmic rays. Cosmic rays can reach incredibly high energies, ten million times higher than any particle we can accelerate on Earth, and their origin is an almost century-old puzzle.

There is reason to believe that the more common cosmic rays come from shocks produced by the explosive death of stars, while the highest-energy rays originate in supermassive black holes at the center of faraway galaxies. Others believe that relics of the early Universe, created just after the Big Bang, produced these particles. It has been hard to verify these ideas directly, because these charged particles do not point back to where they were created. Disturbed by cosmic magnetic fields, they follow contorted paths on their way here.

Fortunately, at ultrahigh energies, cosmic particles should point back to their birthplace. So, if we can observe them well, we will finally resolve the mystery of their origin. However, the highest-energy particles are rare and notoriously hard to detect. They hit our campus only once a century. But when they do, a tiny particle can light up an area from here to the Loop with a shower of low-energy particles.

Scientists from all over the world have joined a project started here at the University of Chicago by Professor James Cronin, a Nobel laureate. The goal of the project is to decipher the riddle of these ultra-energetic messengers that may come from outside our galaxy. In the Argentinean pampas, we are now building a 1,000-square-mile detector (the size of Cook County), named the

Auger Observatory. As part of this international effort, I am particularly pleased to have just visited our collaborators in Vietnam. During my lifetime the Vietnamese have suffered a devastating war, and now they are looking forward—engaging in a curiosity that unifies our planet: the quest for understanding how Nature works. Previous theories predicted that these ultrahigh-energy cosmic messengers wouldn't be there at all. Nature surprised us! Such surprises are the joys of working in science.

Another set of Nature's puzzling answers comes from studies of the evolution of the Universe. Asking questions about the beginning of the Universe is equivalent to understanding Nature at the highest energies. The late University of Chicago Professor David Schramm, who lived centuries in his very short lifetime, was a pioneer in exploring the interconnections between cosmology, astrophysics, and high-energy particles. Under his leadership, Chicago built a top team of faculty members who are now studying the Universe by using a variety of techniques. Starting with a sound theoretical base, we use telescopes on mountaintops, at the South Pole, and in balloons, as well as in satellites, large arrays in the Argentinean pampas, and even a new detector in a basement a few blocks north of here (on 56th Street).

With observations in all different frequencies, a symphony of data can be translated into a detailed account of the evolution of the Universe from its very early stages to the present. One of the techniques involves detecting very low-frequency waves or microwave radiation left over from when the Universe was only about 400,000 years old. A fistful of space has about one quarter of a million of these low-energy photons zipping through. They have traveled for about thirteen billion years and bring a message from an early phase of the Universe when radiation particles were dominant. The spatial, spectral, and polarization structure of this radiation (some of it discovered by our faculty) tells us about a blueprint of what later became galaxies and clusters of galaxies.

To complete the orchestration, higher-frequency waves (i.e., optical photons) are used to study the position and motion of a large number of galaxies and clusters of galaxies—such as in the Sloan Digital Sky Survey, a large project to map the Universe originated by our faculty. Together they tell us that the Universe began 13.8 billion years ago in a very hot, high-energy state. (Even hotter than it is today here in this chapel!)

During an early stage of exponential growth, called inflation, the blueprint for galaxies and larger structures was generated by quantum fluctuations. Today, we only observe quantum fluctuations in the smallest systems, such as in the realm of particle interactions. In my opinion, the possibility that the largest structures we see today came from effects only present in the smallest systems is one of those masterpieces worth remembering!

Inflation also flattened the geometry of the Universe, which is lucky for us because all the geometry and trigonometry we learned in high school still applies. After inflation, the Universe expanded more leisurely, going through well-understood phases in which nuclei and then atoms formed, then radiation decoupled from matter, and finally galaxies began to form.

There are some unanswered questions in this picture. We still don't know what most of the matter in the Universe is made of. The dynamics of galaxies and of the Universe as a whole point to the existence of large quantities of dark matter, matter different from you and me and from all the things we see. Ordinary matter is made of atoms, which are made of quarks and electrons. Dark matter is not made of the same particles, and special detectors (like the new one in the basement on 56th Street) are being built to try to detect it.

There is an even more puzzling question about the overall constituents of the Universe. In 1998, we learned that not only is the Universe expanding but it is also accelerating. This acceleration is likely caused by some energy that we cannot see, that we cannot observe directly—a dark energy. The dark energy may be associated with the energy of the vacuum, of emptiness, of nothingness.

Nature has again sent us puzzling answers: a Universe with only 4 percent ordinary matter, 23 percent dark matter, and 73 percent dark energy. The mysteries behind the dark matter and the dark energy lead us to new questions and to new experiments that may answer them.

I hope you will keep your curiosity alive and that you will follow the next round of answers that may solve many of our present puzzles (and probably bring new ones to challenge us further). Of the puzzles I mentioned, I believe that the origin of the highest-energy particles and the nature of the dark matter can be resolved in the next decade. The first are particles that we observe when we expected not to, and the second are particles we do not observe but should be there. Some of you may want to join me in looking for the answers, and others may prefer to stay tuned!

When I graduated from college, my mother asked me what I would do next. I answered: graduate school. She asked again after my Ph.D. I answered: postdoctoral studies. Finally she asked in somewhat of a desperate tone: But when will you ever finish your studies? Well, she is still waiting, but now she understands that, if I can, I will study until I am no more.

With all your talents and expertise, I hope you feel ready to create your own masterpiece in the world outside these walls. I wish you the good fortune of a long, healthy life full of challenges that drive you further and enrich your existence and that of those around you. I’m sure that each one of you has a lot to teach us and that this University’s tradition as the “teacher of teachers” will continue.

Let me close by paraphrasing one of our distinguished alumni, Professor Carl Sagan: In the vastness of space and the immensity of time, it has been a great joy to share a planet and a few minutes with you.

Thank you, Mr. President, honored colleagues, and guests, and most of all, congratulations to the newest alumnae and alumni of this great University.

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