One Earth,

It may seem that astronomers work independently to observe the night skies. But astronomy is little-known for its significant history of international collaboration—it is a global science.

Internationalization in astronomy has intensified in recent decades and this year—the International Year of Astronomy—is no exception.

By Nicole Branan

THE NORTHERN SUN STILL HOVERS HIGH IN THE SKY above Ulaanbaatar as some 50 students stream out of the National University of Mongolia's lecture halls on a mild summer evening. Over the past eight hours the Mongolian natives received a crash course in astronomy, covering everything from Japan's flagship telescope in Hawaii, to the origin of the universe, to how stars can switch from bright to dim. But at the end of this full day of lectures, the group's appetite for all things celestial is still not satisfied. Some 35 of them, led by a group of enthusiastic amateur astronomers, head off to a "star party," a stargazing session in the outskirts of Mongolia's capital where the night is dark and the view of the universe spectacular.

"The next day they told me they were observing until 3 a.m.," said Katrien Kolenberg, one of the lecturers.

One Sky

Just a few days earlier most of the group had not heard much about astronomy; the subject is rarely taught in Mongolia. That's what Kolenberg, an astronomer and postdoc at the University of Vienna, and a team of several other passionate astronomers from all over the world came here to change. Kolenberg and her colleagues are members of the International Astronomical Union (IAU), a global organization whose goal is the promotion of astronomy through international cooperation. Part of its missions is to improve astronomical education throughout the world, and it does that through various programs, said Edward Guinan, IAU member and professor of astronomy and astrophysics at Villanova University. IAU's involvement usually starts with a program called Worldwide Development of Astronomy, he explained. "There, we have an astronomer go to a country for up to a week, give four or five talks in different places and introduce astronomy," Guinan said. During a follow-up program called Teaching Astronomy for Development (TAD), one or more lecturers conduct a one-week school, such as the one in Mongolia. Eventually the IAU tries to hold an International School for Young Astronomers (ISYA), which not only includes international lecturers but also students from around the world.

IAU has conducted such outreach programs for decades and in a large number of countries, ranging from Turkey to Vietnam. IAU first became involved in Mongolia in 2004; as a result, the country joined the union in 2006. Kolenberg traveled there a year later to give a lecture series herself and returned the following summer for this first international astronomical summer school in the country.

Although astronomy is generally not part of Mongolian curricula, the interest and enthusiasm for the subject among natives are enormous. The country has a lively amateur astronomer community, consisting of more than 60 people who meet regularly and even build their own telescopes, Kolenberg said. So, it's not surprising that the IAU's international school attracted a large number of students and amateurs. Even secondary school teachers came, often from far away parts of the vast country, Kolenberg said. "Some of them traveled for days just to attend the school."

Mongolia's clear night skies offer spectacular opportunities for astronomers but currently astronomy is not part of the country's school curricula. IAU programs are trying to change that. Inset: After IAU's international astronomical summer school Kolenberg and others traveled to the western part of the country to view a solar eclipse.

PHOTOS COURTESY OF KATRIEN KOLENBERG. BACKGROUND PHOTO BY KOSMAS GAZEAS

EDITOR'S NOTE:
The study of science is often underrepresented in discussions on education abroad and international exchange as traditionally these areas were established in humanities and social science disciplines. This article is the seventh and final installment in an occasional feature series on science in international higher education. Previous articles have been on marine biology (March/April 2007), archaeology (July/August 2007), engineering (November/December 2007), global climate change (May/June 2008), architecture (September/October 2008), and agriculture (March/April 2009).

And when asked at the end of the week who wanted to become a professional astronomer "many students raised their hands," she said.

But Mongolia currently offers no opportunities to pursue degrees in astronomy, and students would have to leave the country and study abroad, Kolenberg said. Meeting and interacting with an international team of instructors may have been a start for developing the international mindset that is required for education abroad. "We were four lecturers with very different backgrounds," Kolenberg said. For example, one of the instructors was Ray Jayawardhana, a Sri Lankan native who is now at the University of Toronto; another was Kazuhiro Sekiguchi of the National Astronomical Observatory of Japan. George Miley, who came as IAU's vice president, works at Leiden University in the Netherlands, and Kolenberg, a Belgian native, now lives in Austria. "The students were very curious about our lives and our backgrounds," Kolenberg said. Opening students' minds to the option of education abroad is part of the intention of the IAU's programs because after getting an education in a different part of the world, students can bring their knowledge back to their home country and improve things there, said John Percy, IAU member and professor of astronomy and astrophysics at the University of Toronto.

Mongolia is not the only country where education opportunities and resources in the field of astronomy are scarce. For example, many students in the developing world "have nobody in their country who is adept at using frontline facilities, whether it's the Hubble Space Telescope or a ground-based telescope or state-of-the art computers," Percy said. "The very best way to deal with this is for them to go abroad and spend some time at an institute where they can get this kind of training and experience and interact with lots of people around them," he added. "This not only trains them but it also makes them feel that they are part of an international community, and it gives them somebody they can then interact with by e-mail when they get back to their own country."

The IAU has conducted international education and outreach

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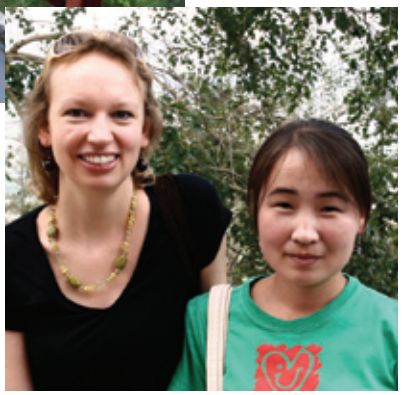
Mongolia is the least densely populated country in the world. To attend the IAU's international astronomical summer school in Ulaanbaatar, some teachers traveled for days across the vast country. Inset: After the IAU's international astronomical summer school Kolenberg and others traveled west to view a solar eclipse. One their way they encountered this shaman and his helpers as they were preparing for the (shamanistic) eclipse ceremony in western Mongolia (in the Gobi Altai region).



Kolenberg and Mongolian student Batsaikhan Bayartungalag who attended IAU's international astronomical summer school 2008 and who also helped organize the school.

Kolenberg and a Mongolian geophysics Ph.D. student who attended IAU's international astronomical summer school, 2008.

programs for several decades, but it has expanded these efforts over the last 10 years or so, Guinan said. The programs offer a great way to foster cultural exchange. "The students get to know another culture and they form networks." The networking aspect is really important and is one of the major outcomes of such programs as ISYA, he added. "Some of the students who met during these programs are now professional astronomers and collaborate." And often the various countries that the students come from are not necessarily friends. "Some of them have no relations, yet the students get along extremely well."

The programs are beneficial for the lecturers as well. "It's a two-way street," Guinan said. "The students get to meet astronomers, but it is also good for the people doing it in that they are really helping people out and the students are really appreciative. In some cases you are making a difference in people's lives." Often students and teachers become life-long friends, he added. "I get e-mails that go back years and years from these programs, and I have seen students get out of their country and get their Ph.D.'s and be successful; it's really nice to see that happen." Kolenberg agreed, "I really like this part of the work," she said. "Being an astronomer might be useful but it's even more useful to teach it to people who might otherwise not get it."

Mongolia wasn't always without astronomy education. Before the political transition in the early 1990s, the field was taught at many schools. But after the socialist system crumbled, being an astronomer wasn't regarded or compensated very highly any longer, Kolenberg said. "Teachers had to take up additional jobs just to get by," she said. That's a problem in many developing countries. "People are always fascinated by the sky but getting paid to study the sky is really unlikely." Part of the reason is that astronomy is a science that is unlikely to bring immediate benefits for the economy, she added.

The Astronomical Observatory of Mongolia, founded in 1957, is a reminder that astronomy was once thriving in the country but "most of the domes are empty now," Kolenberg said. However, that may be about to change. IAU's involvement in recent years has led to an astronomy course being reinstated at the National University of Mongolia, and secondary school teachers who attended the international school now have the background and resources to teach astronomy in their classrooms. In addition, several IAU member countries are thinking about installing a telescope in Mongolia for international use, which would help "get astronomy going again in the country," Kolenberg said. This would also help other nations.

One of the hurdles of any astronomical observation is the day-and-night cycle, which limits observations with single telescopes to 10 hours or so. That's why it's nice to have observ-

ing sites at different longitudes, so that once dawn breaks in one part of the world, astronomers further west can take over, Guinan said. "There are networks of telescopes set up around the globe at different longitudes so you can monitor something for 30 or 40 hours straight." But Mongolia's longitude currently doesn't have many observing sites, so a telescope there would fill this gap, Kolenberg said. Having telescopes distributed around the globe is advantageous for other reasons as well. Take cosmic phenomena, such a supernovae, for example. With telescopes located in different countries but in the same hemisphere, astronomers can pick and choose the best one, Guinan said. For example, if there is bad weather above a U.S. telescope, "you can observe from one in a different country where it isn't cloudy." This instills a lot of international cooperation across the globe, Guinan said. Villanova University, for example, has a robotic telescope in Arizona and is networked in with people from the Middle East and the Canary Islands. "Often I'll get a call from someone saying 'Can you observe this star for me?'" Just the other day Guinan received an e-mail from a student in Turkey whom he had met during last year's ISYA program, with such a request.

Mongolian students attending IAU's international astronomical summer school, 2008.

Sharing Across Borders

International collaboration in astronomy centers is not only around connecting different telescopes but also sharing individual ones. In fact, the global astronomical community has a long tradition of jointly using facilities. Many telescopes, including those in space, are set up such that anybody can apply to work on them. "You just write a proposal from wherever you want to and if it's accepted, you get time on the telescope," Guinan said. "This sharing goes back decades." And it happens between many countries in the world. Iran, for example, is in the process of building a three-meter telescope and "they want to have international cooperation." During a TAD program this fall in Iran, IAU members will meet with astronomers there and share their expertise, Guinan said.

The ability to use different facilities in different places around the globe is often a necessity because to observe the entire sky, astronomers need telescopes in the northern and the southern hemisphere, said Stephen Pompea, scientist and manager of science education at the National Optical Astronomy Observatory (NOAO) in Tucson, Arizona. This has resulted in a "natural collaboration among astronomers" and makes astronomy "very much an international science." For example, NOAO, which provides facilities to astronomers, operates not only Kitt Peak National Observatory near Tucson but also Cerro Tololo Inter-American Observatory in Chile. NOAO is also the U.S. representative for the Gemini Observatory, which consists of two eight-meter telescopes, one in Hawaii and one in Chile. NOAO staff is involved in all of these places, "so, there is very much a sense of people going back and forth across countries in astronomy."

Another reason for international collaboration stems from the fact that not every place in the world is equally well suited for peering deep into the night skies. The best locations have little turbulence in the atmosphere and a large number of clear nights per year. That's why Chile has emerged as an astronomical mecca and now hosts several of the world's top observatories, which attract researchers from all over globe. But being at the mercy of meteorological conditions has also led some countries to become leaders in specialized applications. For example, "the U.K. and the Netherlands are countries that have absolutely lousy conditions for observing the sky using ordinary light but they are perfectly good locations for radio telescopes," Percy said. And after World War II, when large numbers of engineers with expertise in radar technology were looking for new and interesting things to do, these countries put all the more effort into developing radio astronomy. As a result "the U.K. and the Netherlands immediately took the lead," Percy said. Today radio astronomers often end up spending time there or work together with researchers in these countries.

Another reason for extensive international collaboration is the fact that the field of astronomy is relatively small. "If I count my dozen main collaborators, they come from a dozen different countries. That's just the way astronomy works because it's a small science. If you look for the people who have expertise and interests that are similar to your own, you are not likely to find them next door," Percy said.

Internationalization of Astronomy Swells in Recent Decades

This internationalization has even intensified in recent decades, said David Spergel, professor and chair at Princeton University's

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Mongolian students attending IAU's international astronomical summer school, 2008.

Department of Astrophysical Sciences. Flipping through peer-reviewed science journals reveals that collaborations have grown tremendously. "If you looked at the *Astrophysical Journal* 30 years ago, a significant fraction of the papers had one or two authors. Today many of the papers in the *Astrophysical Journal* have a dozen authors, and sometimes these are big collaborations that will have 50 authors and when you look at where those people are, they are spread around the world." And scientific contributions from countries other than the United States have picked up in recent decades. "What has happened—and I think this is true across all sciences—is that, although lots of good science is still being done in the U.S., if you look at important papers an increasing fraction are now coming from Europe and Asia," he said. And as the field of astronomy and astrophysics becomes more international, it gets more important for students to have the opportunity to work in international collaborations while still in school, he added. That's why Princeton's Department of Astrophysical Sciences offers a number of international education projects for its undergraduate and graduate students as well as for its postdocs. Last year, for example, seven graduate students traveled to South Africa to take part in a one-week summer school at the University of KwaZulu-Natal. Astronomers from the United States, Japan, Chile, and South Africa gave lectures for South African, Chilean, and U.S. students. "The advantage of having the school in South Africa was that it gave our students a chance to meet people from around the world, and it gave South African students a chance to meet us," Spergel said. The school opened up opportunities to build networks, he added. That's important because "the way you build scientific projects is by getting to know people."

For the last few years, Princeton has also participated in Partnerships for International Research and Education, a National Science Foundation program that supports international research collaborations. Under this program, two Princeton postdocs currently divide their time between the United States and Spain, and the United States and South Africa, respectively. This arrangement allows them to work with different researchers from different countries and different cultural backgrounds, Spergel said. Having postdocs travel back and forth between the United States and another country also provides a gateway for junior researchers to go abroad. "One of our postdocs will be supervising one of our undergraduates in South Africa this summer, for example," Spergel said. "Another undergrad will be spending the summer in Chile, doing some observational work with another one of our students there." This kind of collaboration not only provides opportunities for cultural exchange, but it also maximizes the scientific output by combining the various strengths of the institutions involved. "For example, if you spend time in Chile, you are part of a major observational community, and if you spend time at Princeton, you are part of a major theoretical community."

Astronomy Students Don't Just Observe the Sky, They Go Abroad, Too

While some universities, such as Princeton, set up international astronomy and astrophysics programs, many students go abroad on their own. One example is María de los Ángeles Peña Guerrero, a Mexican native, who completed her entire undergraduate education at the University of Arizona in Tucson. Guerrero had wanted to study at the National Autonomous University of Mexico (UNAM), but

Attendees received a certificate at the end of IAU's international astronomical summer school, 2008. Left: Greek astronomer Kosmas Gazeas, who arrived on the last day of the school to join Kolenberg and others for a trip to view a solar eclipse. Fourth from left: Lecturer Katrien Kolenberg, sixth from left: Lecturer George Miley. The person on the right is a Mongolian university professor who attended.

when she finished high school UNAM was coming out of a more than one-year-long strike and she had to look for other options. After participating in an astronomy camp at the University of Arizona, she decided to move and pursue her degree there. The experience of living and studying abroad was valuable, both personally and professionally, however, being immersed in a *completely* different culture was extremely difficult, she said. For example, "'friendship' means a completely different thing in the U.S. than it does in Mexico," she said. "I tried to make friends the way I do here [in Mexico] and it works well here but it is really, really different in the U.S. and that was very painful," said Guerrero, who completed a master's degree in astronomy at UNAM this year and is now pursuing a Ph.D. She thought of quitting school and going back to Mexico many times during her four years in Arizona, "but at the same time I knew that if I quit, I would never be happy with myself," she said. These experiences helped her to get to know herself. "During my time in the U.S., I learned much professionally, but I think I learned much more personally." For example, after several conversations with teachers and supervisors, including Pompea, at the beginning of her senior year "there was a moment where I realized I had to finish and I had to finish well to be okay with myself, and I just turned on a switch and started working. At that point I realized that it doesn't matter where I go, I'll be fine because I can turn on that switch." This experience will benefit her in her professional career, she said. "It's always good when the people who are going to hire you know that you are capable of going somewhere else and do what you have to do." Pompea agreed that the ability to work with a large variety of people from different cultures and with different personalities is tremendously important for astronomers. "The modern astronomer works in collaborative groups and those collaborative groups are often composed of people with different backgrounds who come from different countries," he said. "The ability to succeed in astronomy today very much depends on the ability of the researcher to work in these collaborative groups successfully, to bring a particular skill to the group, and to get along with the group. So, I think international education is very valuable for developing that collaborative mindset and opening it to new ideas and new techniques in astronomy. The people who are successful in this field bring a very wide perspective to the table."

Global Cooperation for the International Year of Astronomy—2009

The collaborative nature of the field is exemplified by the numerous global projects that are currently underway as part of the International Year of Astronomy (IYA), a global effort initiated by the IAU and the United Nations Educational, Scientific, and Cultural Organization UNESCO. The year is a celebration of the 400th anniversary of Galileo Galilei's first use of the telescope, and it aims to kindle worldwide interest in astronomy and science. Thousands of people in more than 140 countries are participating, and with IYA's many global education and outreach projects that are currently underway all over the globe "there is a tremendous amount of collaboration and exchange," said Pompea. Building long-term collaborations is one objective of the IYA. "There is certainly a desire to build new partnerships and establish long-term projects that will go on for quite some time," Pompea said. For example, astronomers hope the IYA programs will help build long-term education programs that will boost science and astronomy literacy in children and the general public worldwide. One step toward that goal is the IYA Galileoscope, a high-quality, low-cost educational telescope kit developed by a team of volunteers, ranging from astronomy educators to optical designers, for use in classrooms, after-school programs, and even universities. Students can assemble the Galileoscope themselves and view such objects as the moon and the planets in Earth's solar system. Astronomers at NOAO as well as graduate and undergraduate students from the University of Arizona took part in developing educational materials that are supplied along with the telescope. Students also took the Galileoscope out to the field for testing, Pompea said. It isn't clear yet how many Galileoscopes will eventually go out into the world, but "the goal is to have this as a tool for kids for a long time to come because the need for a very high quality, inexpensive telescope and for the educational activities that we are developing with it will be there for a long time."

International Teacher Training in Astronomy

Educating the educators about teaching astronomy is just as important as teaching and providing students with resources. A step toward that goal is the IYA Galileo Teacher Training Program (GTTP), aimed at training and empowering teachers ranging from elementary to high-school level worldwide. The program's goal is to establish a global network of "Galileo Ambassadors," astronomy educators who can train teachers how to most effectively use various astronomy edu-

"One of the things people sometimes say about the International Year of Astronomy is 'One earth, one sky.' We all share the same sky and when you are in space you don't see political borders."

cation tools and resources in their classrooms. These become "Galileo Master Teachers" who can then pass their knowledge on to their colleagues, said Mary Kay Hemenway, an astronomer at the University of Texas at Austin and a member of the international GTTP task force. Hemenway will hold several training workshops that will turn U.S. and Australian educators into Galileo Master Teachers this summer at McDonald Observatory in the West Texas Davis Mountains. One focus of the sessions will be a relatively new pedagogical approach for structuring science lessons, which focuses on engaging rather than lecturing students, Hemenway said. For decades, the predominant way of teaching science labs looked something like this, she said: "Someone tells the students 'this is what you are going to do, this is what you are going to find out, here is a list of equipment, here are the steps you need to do, here are the graphs you have to make, and here are the questions you have to answer.'" In her classes, Hemenway has replaced this conventional model with a new one, which turns labs from instructor-centered to student-centered. That way students will have a better conceptual grasp of the topic, said Hemenway, who has used this approach successfully at different levels ranging from kindergarten to college. However, many teachers around the world are not familiar with such new ideas and still use conventional science lesson structures. "If they have been out of school for more than about 10 years, most of their formal education was probably the kind of physics course that you and I had," Hemenway said. The GTTP sessions this summer will introduce teachers to new approaches, and for the many instructors around the globe that won't be able to attend the workshops, GTTP will make a Web site available with science education resources in different languages. "The goal is to go out there and make it possible for a lot of people to pull materials and activities that are recommended for producing a good science experience for children from the Web," Hemenway said.

Astronomy for Everyone, Everywhere

Some IYA projects aim to engage anyone, from small kids to adults everywhere in the world. One example is the GLOBE at Night program, an international citizen-science campaign aimed at raising awareness of the impacts of light pollution. The program, now in its fourth year, connects people from all over the world by letting them take measurements of local levels of night sky brightness, which are then assembled into a world map. The latest campaign took place in March, when thousands of families, kids, and students from countries all over the world went outside at night to look at the constellation of Orion. They recorded the number of stars they were able to see by comparing their view of Orion with a set of template images and then reported their results online. "In a very light-polluted city you would just see a few of the major stars of Orion and in a very dark rural environment you would see a tremendous number of stars," Pompea said. A world map on the GLOBE Web site let everyone see the results as they came in, giving stargazers across the globe a sense of connection, Hemenway said. By participating in the program "you become aware of what the dark skies mean not just in your own community, whether that's a rural community in West Texas or a big city like Washington, D.C., but also what they are like for someone in Egypt or Mexico or South Africa." Sharing this global perspective is valuable for students because they "feel they are part of a world," she added. And after all, that's what astronomy is all about. "One of the things people sometimes say about the International Year of Astronomy is 'One earth, one sky.' We all share the same sky and when you are in space you don't see political borders." **IE**

NICOLE BRANAN is a freelance journalist based in Colorado Springs, Colorado. Her latest article for *IE* was "Planting Seeds of Change" in the March/April 2009 issue, which was also part of the "internationalization of science disciplines" feature series.