TACC's Scientific Computing Curriculum Enables Young Researcher to Excel in Astronomy

Astronomy is a field driven by profound questions, powerful telescopes, digital detectors, and high-performance computing (HPC).

But for Austin Gatlin, a first-year student at The University of Texas at Austin with a desire to understand the nature of stars, black holes and galaxies, the connection between today's astronomy research and HPC was as murky as dark matter.

The Hobby-Eberly Telescope at McDonald Observatory, a research facility of The University of Texas at Austin, is currently the world's 4th largest optical telescope. Austin Gatlin led public tours of the observatory, including visits to telescopes and explanations of HPC's role in astronomy.

Gatlin's undergraduate advisor explained that astronomers use HPC to understand the physical nature of what they observe via telescopes. She recommended a new computing course, Introduction to Scientific Programming in Fortran95/2003 & C, developed by the Texas Advanced Computing Center (TACC), so that Gatlin could begin to learn the programming languages commonly used by faculty and researchers in the wider astronomy and astrophysics community.

"Before the class, I didn't know anything about high-performance computing," Gatlin said. "But HPC is a prerequisite for any science research position. If you don't know how to write code, you don't get research jobs, so I knew I had to take the course."

On the first class day, TACC Director Jay Boisseau, one of the course instructors, clearly laid out the relationship between science and HPC, and explained the challenges of computational science. He even assigned homework.

If Gatlin's confidence was shaken, this would have been the time to drop the course. But he persevered, and his hard work increased his self-confidence and desire to succeed.

In the Introduction to Scientific Programming class, Gatlin learned how to use the Linux operating system, how to write code in Fortran and C (the dominant programming languages of HPC), and how to operate a supercomputer — all crucial steps towards becoming a bonafide astronomer.

The course impacted Gatlin in fundamental ways. "My perspective of astronomy and astrophysics has changed since I completed the scientific computing course," he said. "I've learned so much about the relationship between HPC and scientific research, and the inseparability of the two."

Gatlin's experience with scientific programming also gave him a distinct advantage when looking for a research internship in the field. "The biggest benefit the

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course provided was the opportunity to successfully apply for a job in astronomy or astrophysics," Galvin said. "The key word being successfully."

Gatlin secured a highly competitive summer internship at the McDonald Observatory in West Texas, which attracts about 100,000 visitors each year. Most of these visitors, he found, knew that astronomers need telescopes to observe and take breathtaking images of stars, nebulae and galaxies. But few understood how astronomers interpret their images or use the knowledge gained from their images to fine-tune our understanding of the universe. And they certainly didn't know that much of the preparatory and post-processing work of astronomy is actually done on high-performance computers.

Leading public tours of the observatory, Gatlin explained what astronomers do with telescopes, such as the Hobby-Eberly Telescope at the McDonald Observatory, and also how they use HPC to study the universe. "I never went a day without talking about the role of computing in astronomy," Gatlin said. "You literally cannot explain what an astronomer does without talking about computers and scientific computing. Astronomy is built around computers."

Gatlin impressed upon visitors that unexpected results in virtual models of the universe created on supercomputers often become the inspiration for innovative cameras and detectors used to find the new objects that astronomers' HPC experiments predicted. Moreover, HPC, he explained, is essential to make sense of the massive streams of data that emerge from the new telescopes and detectors they construct.

Ultimately, the cycle of observation, improved simulations, and new insights into the universe enables scientists and engineers to inspire discovery across not just astronomy, but throughout many science fields, directly affecting our standard of living, security, and competitiveness in the global economy.

The knowledge Gatlin gained in the programming course allowed him to tell a complete story about how astronomers utilize massive parallel computers to better understand the universe. "Visitors really enjoyed it," he said.

Now, with essential HPC knowledge in hand, Gatlin will advance to the four upper-level scientific computing courses that The University of Texas at Austin offers to undergraduate and graduate students under the Division of Statistics and Scientific Computation. Through these courses, which are taught by TACC staff, he can continue to build his understanding of computational science — a critical component in attaining his undergraduate degree in astronomy and advancing his future career as a researcher.

The University created the new Division of Statistics and Scientific Computation within the College of Natural Sciences in part because HPC has become such an integral aspect of science and engineering. These courses open the field of advanced computing to a broad range of students, regardless of their major.

Guided by professors and senior scientists, students like Austin Gatlin will enter the job market armed with the knowledge and skills needed to accelerate science in the 21st century.

"In no other courses can students get HPC concepts in a better environment," said Kent Milfeld, research associate at TACC and an instructor of the Parallel Computing for Scientists & Engineers course. "From small scale to extreme scale, students are introduced to basics and nurtured in all aspects and practices of

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high-performance computing. Students leave these classes prepared to incorporate the latest HPC technologies and practices in their research."

In a competitive world moving quickly towards new frontiers of knowledge, generating a large and diverse pool of qualified young scientists will make the difference between future success and falling behind. TACC's Scientific Computing Courses are critical for increasing the number of students who are skilled in computational science and HPC and who have the ability to apply this knowledge to science and engineering problems.

"I am unbelievably fortunate to have taken this class," Gatlin said. "I feel like I have an edge over the competition now…all thanks to scientific computing."

TACC's Scientific Computing Curriculum

Computational science and HPC are quickly evolving beyond elective courses reserved for computer science students. Although the power and breadth of national cyberinfrastructure resources continues to grow and industry demand for this skill set increases, few undergraduate and graduate students understand the central role of HPC in research and engineering, much less how to apply it.

A talented team at TACC has assembled an interrelated set of courses that puts undergraduate and graduate students on the fast track to HPC knowledge and careers in computational research and industry. In all these classes, students use TeraGrid supercomputers to complete assignments and projects. In the process, they learn how to access and devote scientific computing to enhance science and engineering.
In the fall of 2008, the scientific computing curriculum was offered for the first time to undergraduate students through the newly formed Division of Statistics and Scientific Computing at UT Austin's College of Natural Sciences. The initial four offered classes have subsequently grown to five courses, the newest of which will be taught starting Spring 2009.

In the Parallel Computing for Scientists & Engineers</i> course, graduate and undergraduate students learn from Dr. Kent Milfeld, TACC Research Associate.

The Scientific Computing Curriculum includes:

- Introduction to Scientific Programming: Instructors teach students both the Fortran and C programming languages, with an emphasis on advanced applications in science and engineering, culminating in students writing their own programs to run on TACC's systems.
- Scientific/Technical Computing: Students learn to apply the basic methods of scientific computing to science and engineering disciplines.
- Parallel Computing for Scientists & Engineers: The most powerful supercomputers harness thousands of processors to work on a multitude of complex computing tasks all at once, or in parallel. Instructors lay a comprehensive foundation for students to use parallel computing hardware and software, focusing on application development, performance, and scalability.

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- Distributed & Grid Computing for Scientists & Engineers: The rapidly growing power of grid computing has opened many new, user-friendly technologies to HPC resources. Students evaluate several grid-computing technologies, including the TeraGrid, and use them to complete their course work.
- Visualization & Data Analysis for Scientists & Engineers: Supercomputers accept input, run programs and return enormous volumes of raw data. Making sense of these records requires data and information analysis expertise, coupled with visualization resources, converting the output to visually appealing images that compellingly display the researchers' results. Students learn and use the basic techniques for information analysis and visualization programming to produce accurate, evocative, and interactive displays of data.

Together, these courses are a direct way for students to learn how HPC enhances science and engineering. Without such a curriculum, students must forge crooked, branching pathways – like hiking without a map – to acquire a coherent skill set for applying HPC in their specific fields.

TACC has made the development and implementation of its Scientific Computing Curriculum a high priority as part of its mission to enhance society through the application of advanced computing technologies, and educational development of the people that use them.

TACC's Education Programs in a Nutshell

In addition to the Science Computing curriculum, TACC helps high school and higher education students, teachers, faculty, and researchers advance their capability to experiment, discover, and change the world with HPC. Diverse educational activities enable students from high school to graduate level to reach for the most pressing challenges facing the world. Teachers and faculty can incorporate HPC into their instruction, and endeavor to produce their own courses for their students. TACC and Girlstart, a local non-profit organization, have collaborated to produce "IT Girl" for high school girls to engage their passion for technology by solving current problems.

High school students and their teachers visit TACC for a special behind the scenes tour

U-Compute

TACC developed the U-Compute program in response to the growing number of reports that high school graduates lacked the essential problem-solving skills of Science, Technology, Engineering and Math

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(STEM) career fields. U-Compute's mission is to raise high school students and teachers' confidence to solve real world problems with computational science and TACC's HPC resources. Based on our successful summer 2008 pilot program, TACC will broaden U-Compute to serve high-achieving, low-income students and their teachers. With help from TACC experts and University of Texas at Austin scientists, students and teachers will explore topics like global climate change and utilize advanced levels of computing: visualizing data, running simulations, and tapping into the TeraGrid, a nation-wide network of HPC resources. Students will select and solve specific problems, while teachers will write lesson plans and labs. Over the following year, TACC will mentor students and encourage them to compete in-state or national student competitions, including those hosted by TeraGrid and the SC Education Program.

Project "IT" Girl '09

Girlstart is a non-profit organization created to empower girls to excel in math, science, and technology. Founded in 1997 in Austin, Girlstart has established itself as a best-case practice leader in empowering, educating, and motivating girls to enjoy and become more proficient in these fields. TACC is collaborating with Girlstart on a three-year journey with 60 girls to accomplish the following goals:

- Increase girls' interest and competency in science, technology, engineering, and math (STEM).
- Increase girls' interest in pursuing STEM education and career paths.
- Prepare girls and their families for college.

Through this program, IT Girls are asking big questions and defining their own projects to answer them. They are developing important problem solving and project management skills while applying technology throughout the process. The program empowers the IT Girls to pursue career-related interests in a variety of fields, such as industry, the arts, science, and engineering.

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The Ranger supercomputer is funded through the National Science Foundation (NSF) Office of Cyberinfrastructure "Path to Petascale" program. The system is a collaboration among the Texas Advanced Computing Center, The University of Texas at Austin's Institute for Computational Engineering and Science, Sun Microsystems, Advanced Micro Devices, Arizona State University, and Cornell University.

Ranger is a key resource of the NSF TeraGrid (www teragrid.org), a nationwide network of people, resources and services, also sponsored by the NSF Office of Cyberinfrastructure, which enables discovery in U.S. science and engineering. The TeraGrid provides scientists and researchers expertise in and access to large-scale computing power, networking, data-analysis, and visualization systems.

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