The Photon:

Spotlight

Physics Alumni | UM Physics Research

On Alumnus Dr. Zoa Conner

If you were to ask a physicist who inspired them to pursue physics, many might mention a high school teacher. Alumna **Dr. Zoa Conner** is no exception, but few would describe their physics teachers as "a very tall, red-haired woman who modeled during the summer."

It's a bit unusual, but that's the point. Zoa notes that her teacher was "a very real person and not the old guy with the wacked-out hair and pocket protector, like the stereotype."

After working closely with her physics teacher and learning more about the field, Zoa realized how much she enjoyed and excelled in physics. "Up till that point, I thought math was the coolest thing in the world. But with physics, I learned how things work and got to use the math."

So it's not surprising that Zoa continued her studies in physics, first at Carnegie Mellon University where she earned her B.S., and then at the University of Maryland where she earned her master's and doctoral degrees. At Maryland, Zoa was involved with the Particle Astrophysics Group for five years working with the Super-Kamiokande detector, doing work such as writing hardware components of the Super-Kamiokande calibration system and writing analysis software to study solar neutrino physics.

After her graduate work at Maryland, Zoa was awarded the Robert R. McCormick Postdoctoral Fellowship with the Enrico Fermi Institute at the University of Chicago, where she performed her research in gamma-ray astronomy for about two years.

Amidst it all, Zoa recognized the importance of being in an environment where she flourished. She noticed that this was the case particularly for woman scientists and worked to create environments where women scientists were encouraged to excel.

Among the many other outreach and community service activities that she participated in throughout her career, Zoa worked as an instructor and organizer in the UM Physics Department's annual Physics Summer Girls Outreach Program for two consecutive years, organized networking meetings

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On Space Plasmas

Exploring Space Plasmas in the Solar System

by Douglas C. Hamilton
Professor, UM Physics

A plasma is a gas of charged and neutral particles that is sufficiently ionized so as to affect its dynamical behavior. A plasma is a good electrical conductor and is strongly affected by magnetic fields. Plasmas are the most common form of matter, comprising more than 99% of the visible universe (see Figure 1). When conducting detailed studies on space plasmas, instruments must be carried on spacecraft directly to the various plasma sites. A variety of experimental techniques are used to detect ions and electrons (and therefore, plasmas) with energies from 1 eV to many GeV.

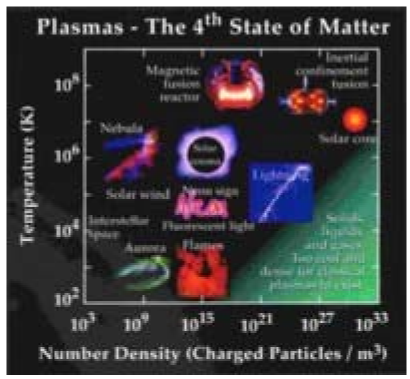

Fig. 1: *Plasmas - The 4th State of Matter. The figure illustrates where many plasma systems occur in terms of typical density and temperature conditions.*

The basic equations for studies of electromagnetic systems (of which plasmas are a prime example) are Maxwell's equations for electromagnetism and the plasma Boltzmann equation. But, we have learned that the velocity distributions of space plasmas are almost never simple Maxwellians. Nature finds a way to transfer a significant amount of energy to a small fraction of the particles, so that there is almost always an energetic, non-Maxwellian tail to the distributions.

The study of plasma acceleration processes is an important focus of space physics. Collisionless shock waves, which are found on a huge range of scales from planetary bowshocks to the heliospheric termination shock, are very efficient particle accelerators. Another acceleration process involves magnetic reconnection, which converts magnetic energy into particle energy.

Beginning with Prof. Gloeckler's first space plasma measurement instruments, the determination of the elemental composition and ionization state of space plasmas has been a specialty of the Maryland group. These capabilities have been important in determining the origin of various plasma populations. Space plasma measurements also contribute to the determination of universal abundances, a critical check on theories of nucleosynthesis.

The Maryland Program

The experimental space physics program at the University of Maryland had its origins in cosmic ray studies more than four decades ago, initially with balloon-borne experiments. Over the years, techniques to detect individual ions and determine their energy, mass, and in some cases, charge state, at much lower energies have been developed and miniaturized for use on spacecraft. Currently, data are being returned from 17 active experiments carried on 11 different spacecraft. The oldest, IMP 8, was launched in 1973, and the youngest, IMAGE, was launched on March 25, 2000. These 11 spacecraft are deployed throughout the solar system. Five are in Earth orbit, two are at the L1 Lagrangian point between the Earth and Sun, one is in a polar orbit around the Earth, two are well beyond the orbit of Pluto and are headed out of the solar system, and one is destined to go into orbit around Saturn in 2004. Maryland group members involved in analyzing the returned data and in developing new instrumentation are **Profs. George Gloeckler, Glenn Mason, and Douglas Hamilton**, research staff **Dr. Fred Ipavich, Dr. Joseph Dwyer, Dr. John Paquette, and Dr. Mihir Desai**, graduate student **Matthew Hill**, and six physics undergraduates.

WHERE ARE THE PLASMA SYSTEMS?

The Solar Wind

Fig. 2: *The Sun in soft X-rays.*

In the earliest days of the space age, it was discovered that supersonic plasma streams more or less continuously from the Sun, carrying the solar magnetic field with it. The speed and density are extremely variable but average about 400 km/s in the ecliptic plane with a density of about 5 ions/cc at 1 AU (the orbit of the Earth). About a decade ago, Ulysses became the first spacecraft leave the ecliptic plane and enter a solar polar orbit. Ulysses measurements indicate the solar wind at high solar latitudes travels almost twice as fast and is quite steady.

Solar wind composition reflects that of the Sun, the largest reservoir of mass in the solar system. The group's solar wind composition measurements have become more capable with time. We now have three spectrometers on three different spacecraft that have the resolution to separate even relatively rare isotopes. (Fig 2)

Magnetospheric Plasmas

All the planets in the solar system except Venus and Mars (with no information on the currently unexplored Pluto) have intrinsic magnetic fields that carve out cavities in the solar wind (magnetospheres). Plasmas of various origins are trapped in these regions. At Earth there are two sources of magnetospheric plasma with comparable strengths: the solar wind and the ionosphere. They can be distinguished by their composition. Singly ionized helium and oxygen are indicative of the cool ionosphere, while doubly charged helium and highly charged oxygen point to the solar wind's origin in the hot solar corona. Both sources contribute protons. Although most of the solar wind is deflected by the Earth's magnetic field, about one particle in a thousand enters the magnetosphere. Solar wind variability drives so-called space weather. The biggest space weather events are geomagnetic storms during which the radiation belt surrounding the Earth intensifies, large space currents flow, and large magnetic fluctuations are observed at ground level, sometimes causing damaging surges in the power grid.

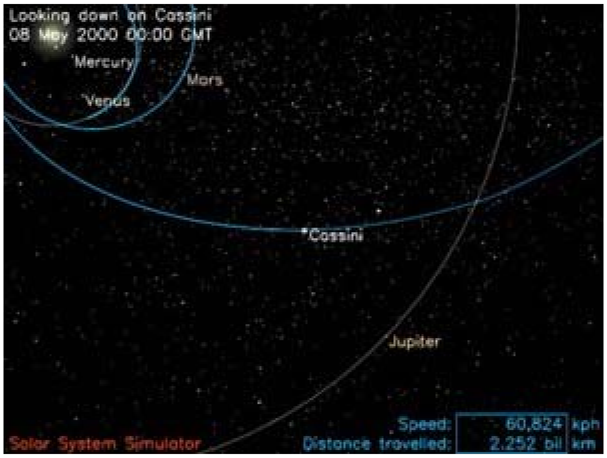

***Fig. 3:** Cassini's trajectory and status as of May 8, 2000.*

For the outer planets, there are additional sources of magnetospheric plasmas because they have moons embedded within their magnetospheres. For example, earlier flybys of Saturn indicated the presence of a heavy ion plasma component, but resolution was insufficient to identify which element or elements were present. Our instrument on Cassini will distinguish between nitrogen ions, probably from the atmosphere of Saturn's moon Titan, and water products that would originate from Saturn's icy moons. (Fig 3)

Solar Energetic Particles

Spacecraft in interplanetary space occasionally observe large energetic particle events at energies up to 100 MeV and more, lasting for days. Until the last decade, it was thought these particles were accelerated at the Sun in solar flares, localized explosive releases of energy that appear as a sudden, short-lived brightening of an area of the chromosphere, accompanied by X-ray and radio emission. We have since learned that the observed flare-association does not imply cause and effect. Rather the large particle events are all associated with coronal mass ejections (CMEs) -- powerful eruptions in which as much as ten billion tons of the Sun's atmosphere can be blown into interplanetary space. CMEs travel outward from the Sun at speeds up to 2000 km/s. The solar energetic particles are produced at CME-driven shocks, the particles with the highest energies being accelerated close to the Sun where the shock is strongest but with acceleration up to an MeV occurring all the way out to 1 AU. CMEs can trigger magnetic storms as they pass the Earth.

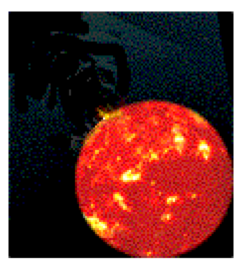

***Fig. 4:** An animation illustrating a coronal mass ejection (CME).*

(Fig. 4)

THE FUTURE

Future scientific space missions are planned for first-time exploration and for attacking space physics problems with new approaches. Some of these missions involve multiple spacecraft and are designed to simultaneously probe the multiple physical scales of the Earth's magnetosphere. Another will fly as close as 4 solar radii from the center of the Sun to explore the source of the solar wind from inside the solar corona.

Fig. 5: *Configuration of the Cassini spacecraft before the Titan probe is released. (Click image to enlarge.)*

Fig. 6: *Cassini spacecraft sitting atop a Titan IV rocket at Cape Canaveral. (Click image to enlarge.)*

Maryland experiments will be carried on the two spacecraft comprising the STEREO mission, one spacecraft deployed in solar orbit at 1 AU some 45° ahead of the Earth and the second up to 60° behind the Earth. STEREO's goal is to image the birth and liftoff of CMEs in 3-D, particularly those directed towards the Earth, and then to investigate the particles and fields associated with them as the ejecta passes the spacecraft. Another Maryland experiment will be aboard Messenger, the first spacecraft to orbit the planet Mercury. The future is exciting.

Tel: 301.405.3401
1117 Physics Bldg.
University of Maryland
College Park, MD 20742

Contact the editor.
Contact the webmaster.

for women scientists and served as a member of a Carnegie Mellon advisory committee that worked to improve campus life for women scientists. She also participated in the Second Annual Science, Gender and Community Curriculum Reform Institutes for Faculty, sponsored by the National Science Foundation.

As her postdoc work began to wind down, Zoa was looking for a change. She wanted to do something that would allow her to devote quality time to her career as well as her son. Enter George Washington University's new "Women in Science and Technology" program.

In 1999, Zoa was offered a position as the first program director of GW's new "Women in Science and Technology" program, one of four interdisciplinary, residential living and learning programs (the Women and Power Leadership Programs) for first-year women housed on the Mount Vernon campus. There she would both develop and direct the fledgling program and serve on faculty at GW, teaching astronomy classes. "I like [research], and I'm good at it. But there are things related to it that I can't do. I have a little one, and I want to spend time with him. That was one of the contributing factors to me taking this job. I'm still trying to figure out how to combine the two. That's one of the primary obstacles for women - the balancing act between family and work."

The GW position fit many of Zoa's different interests - mentorship of women, teaching and the field of science.

As a professor, Zoa incorporates her love for science with her ability to create an environment that allows people to flourish. Recognizing that the sciences can be daunting due to the inaccessibility of scientific vocabulary Zoa says that she "talk[s] in little words, but [uses] big concepts."

Not surprisingly, she enjoys the challenge of introducing students to the field. "I'm different - prefer to teach non-scientists that have to take a science to graduate."

Whether as a professor, program director, student, researcher or mentor, it is clear that Zoa is doing her part to make a difference for future generations of women scientists, and as a result, for science as a whole. "I think that science benefits in diversity. Women are going to ask questions that no one else will and figure out how to answer them."

• See Zoa's profile

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College Park, MD 20742

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