MILLER INSTITUTE NEWSLETTER

Winter 2009

Miller Fellow Focus: Maryam Modjaz

The Explosive Deaths of Massive Stars

Massive stars die violently. Unlike our own sun, which will die gradually in around 5 billion years, most massive stars explode at the end of their short lifetimes. Here, massive stars, which are rarer in the universe than stars like our sun, are defined as being at least 10 times more massive than our sun. They find their demise either as a core-collapse Supernova (SN or Supernovae, SNe, for plural), which is a brilliant and fleeting fireworks display with up to a billion times the luminosity of our sun, or as a Gamma-Ray Burst (GRB), which is an explosion that creates relativistic jets and briefly (for between 2 to several hundred seconds) outshines the gamma-ray universe, or as a combination of these. Both SNe and GRBs are visible over large distances through the universe: a recent GRB holds the record for the most distant explosion observed, at 12 billion light-years. However, astronomers still do not fully understand the exact conditions that lead to each kind of stellar explosion. A clear understanding of the production of GRBs, SNe, and their stellar progenitors is critical for using them as indicators of star formation throughout the universe as well as for tracing the universe's chemical enrichment history since each explosion is believed to eject, and more importantly, synthesize different kinds of heavy elements.

Maryam Modjaz, currently a 2nd year Miller Fellow, studies these explosions and their environments with small and large telescopes on earth and in orbit and hopes to provide insight on their observable properties, stellar progenitors, and respective production mechanisms. She works in the Department of Astronomy with her Miller host Professor Alex Filippenko (a former Miller Fellow and Miller Professor), her collaborator Professor Josh Bloom, and their respective teams. Her main tools are optical and near-infrared spectroscopy plus photometry (the amount of light in different filters), obtained as a function of time.

Optical and near-infrared spectra are the SN's fingerprints, as they reveal the chemical composition of the SN ejecta via spectral lines, which are unique to each SN type. The time evolution of SN spectra also allows for scans since the photosphere (the spectral line-forming region) recedes into the SN ejecta as a function of time gradually revealing the chemical composition of the interior layers. After the initial explosion, stellar material with a mass a few times that of our sun are launched (constituting the SN ejecta) and expand at many thousands of kilometers per second and in some cases moving at 30,000 kilometers per second (a tenth of the speed of light!), which is reflected in the spectra by velocity shifts of spectral lines via the so-called Doppler effect.

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Studying SNe is a form of stellar forensics: from the light of the explosion, astronomers re-construct how the massive star looked like pre-explosion (Welcome to "CSI Universe"!). In particular, over the last 20 years, astronomers have realized that the various subtypes of core-collapse SN are most probably the result of massive stars exploding with different amounts of intact outer layers (see Fig. 1): Type II SN are from stars that have their outermost Hydrogen (H) layer intact, while progenitor stars of Type Ib SN have been stripped of that H layer while retaining the next-inner layer of Helium (He), and Type Ic SN progenitors have their H layer as well as most or all of their next-inner layer of He stripped off. And while a SN explosion is the moment of death for a star, it is also the moment of ejection and creation of elements that are vital for our own life on earth, such as iron, calcium and oxygen.

SNe are transient, rare, and unpredictable. Most SNe at their peak brightness last only a couple of weeks. Their frequency is approximately one per several hundred years for a galaxy like our Milky Way. No one can tell in advance exactly when a star will explode (although in our galaxy, we are aware of potential SN stars such as Betelgeuse). That is why SN hunters around the world try to spot these celestial fireworks in faraway galaxies. In particular, Professor Filippenko, along with Weidong Li, operates the world's most successful nearby SN search, using a small robotic telescope called the Katzman Automatic Imaging Telescope, at nearby Lick Observatory on Mt. Hamilton in San Jose, CA.

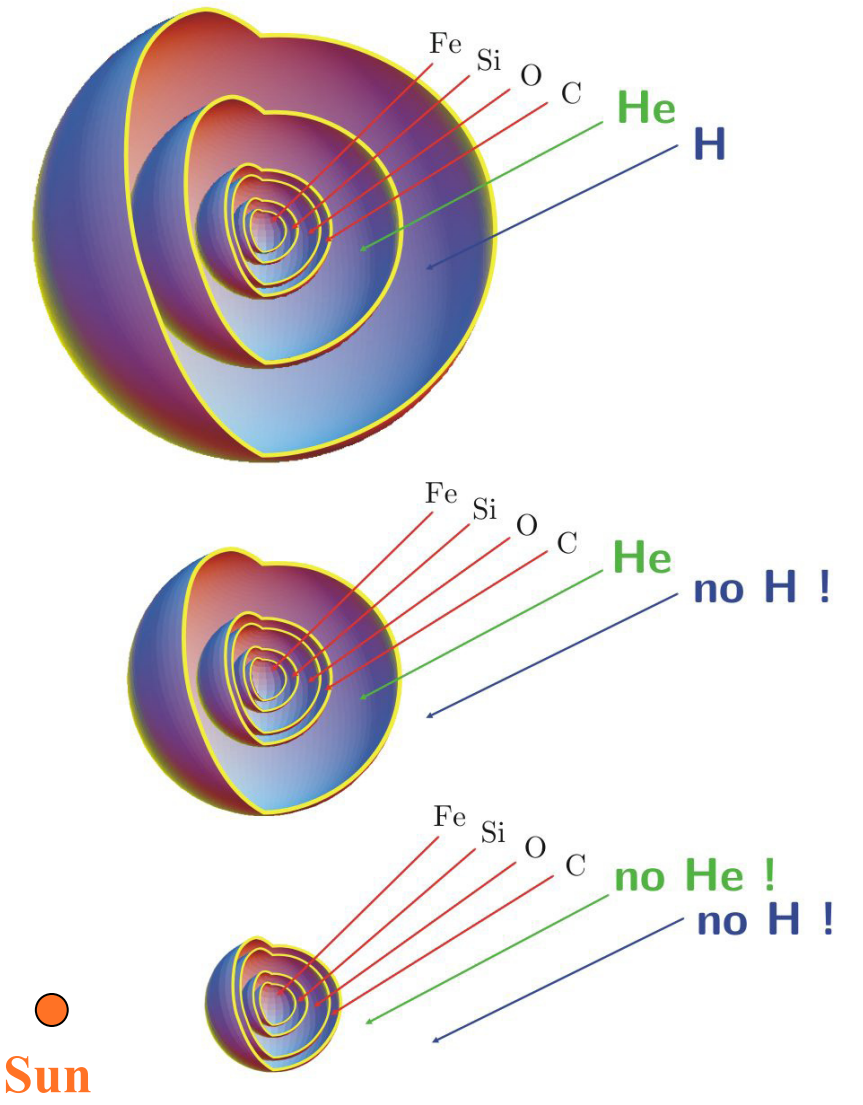

Figure 1: ***Schematic drawing of massive stars before explosion, with different intact outer layers. Massive stars at the end of their lives have a so-called "onion-structure" with layers of different elements that are the result of successive stages of nuclear fusion during the stars' lifetimes. Envelope sizes are not drawn to scale; in particular, the outermost Hydrogen envelope in the star at the top can be up to 100 times larger than shown. The size of the sun is shown for approximate comparison. The make-up of the progenitor is believed to give rise to different kind of supernovae. The star at the bottom is likely to produce Gamma-ray bursts.***

Credit*: Maryam Modjaz*

Moreover, SNe do not ask astronomers if it is a convenient time for them to explode (or more accurately, if it is a convenient time for their light to reach Earth). On January 9, 2008, during the first year of her Miller tenure, Maryam was alerted by a world-wide email message from Princeton astronomers to their serendipitous discovery of a mysterious X-ray Transient in a nearby galaxy. No astronomer knew exactly what the object was. Maryam and her collaborators began observ-

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Awards & Honors

December 18, 2008: **Steven Brenner** (Miller Professor 2007 - 2008) and **Bin Yu** (Miller Professor Spring 2004) have both been named 2008 Fellows of the American Association for the Advancement of Science (AAAS).

December 8, 2008: A new human evolution exhibit in the Valley Life Sciences Building on the UC Berkeley campus has been dedicated in honor of the late **F. Clark Howell** (Miller Professor 1974 - 1975), who inspired generations of students in the field of paleoanthropology.

November 21, 2008: **Randy Schekman** (Miller Senior Fellow) was awarded the 2008 Dickson Prize in Medicine.

November 21, 2008: **Yuan T. Lee** (Miller Professor 1981 - 1982) has been elected president of the International Council for Science (ICSU). His appointment will begin April 2010.

October 21, 2008: **Walter Alvarez** (Miller Professor 1986 - 1987, 2001 - 2002) has been awarded the Vetlesen Prize, the highest award in the Earth Sciences.

October 17, 2008: **Manuel Cardona** (Visiting Miller Professor Spring 2000) has been elected a Foreign Member of the Accademia Nazionale dei Lincei (Rome, Italy), which is the oldest scientific academy in the world and included Galileo Galilei as one of the charter members.

October 7, 2008: **Adam Riess** (Miller Fellow 1996 - 1998) has been named one of 25 MacArthur Fellows for 2008.

October 1, 2008: **Sergio Ferrara** (Visiting Miller Professor Fall 2008) has been awarded an Advanced Investigator Grant from the European Research Council (ERC) of 1.7 million euros to conduct "frontier research" in Italy.

September 26, 2008: **Andrew Streitwieser** (Miller Professor 1964 - 1965, 1979 - 1980) has been named the 2009 recipient of the Roger Adams Award of the American Chemical Society.

September 19, 2008: **Raymond Jeanloz** (Miller Professor Fall 1992, Executive Director 1998-2003) was awarded the 2008 Hans Bethe Award from the Federation of American Scientists.

Publications

The following Miller Institute members have recently published works resulting from research during their Miller Institute terms. For more information about these publications, please visit the Miller Institute's website at: http://millerinstitute.berkeley.edu/publications.htm.

Sergio Ferrara
Visiting Miller Professor Fall 2008

Julius Lucks
Miller Fellow 2007-2010

Yue Wu
Miller Fellow 2006-2009

Miller Professorship Awards

The Miller Institute is happy to announce the awards for Miller Research Professorship terms during Academic Year 2009-2010. Recipients are released from teaching and administrative duties, allowing them to pursue their research, following promising leads as they develop.

Rebecca Heald	Molecular & Cell Biology
Stephen Leone	Chemistry/Physics
Steven Lindow	Plant and Microbial Biology
Lior Pachter	Mathematics
Bruce Rannala (UC Davis)	Integrative Biology
Barbara Romanowicz	Earth and Planetary Science
Dan Stamper-Kurn	Physics
Kenneth Wachter	Statistics

Birth Announcements

Congratulations to John and **Erin Cunningham Dueber** (Miller Fellow 2004 - 2007) on the birth of their daughter, Natalie Lynn, born August, 1 2008.

Congratulations to Diana and **Steven Brenner** (Miller Professor 2007 - 2008) on the birth of their daughter, Sophia Michelle, born August 29, 2008.

Congratulations to Vannessa and **Raman Sanyal** (Miller Fellow 2008 - 2011) on the birth of their son, Konstantin Souren, born October 18, 2008.

Obituaries

Neil Bartlett (Visiting Miller Professor 1967 - 1968, Miller Professor 1986 - 1987), best known for his experiment that showed that compounds can be formed from Xenon, passed away on August 5th from an aortic aneurysm. He was 75.

David Freedman (Miller Professor Fall 1990), a UCB professor of statistics who was influential in steering the course of the U.S. Census, passed away on October 17th after a battle with bone cancer. He was 70.

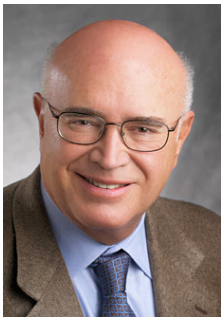
Visiting Miller Professorship Awards

The Miller Institute is pleased to announce the Visiting Miller Professorships granted during this year's competition. The purpose of the Visiting Professorship program is to bring promising or eminent scientists to the Berkeley campus for collaborative research interactions. The recipients will be on campus for terms during Academic Year 2009-2010.

François Baccelli *INRIA, Ecole Normale Supérieure, France*	Electrical Engineering & Computer Science Hosted by Venkat Anantharam
Lincoln Greenhill *Harvard University*	Astronomy Hosted by Donald C. Backer
David Gubbins *University of Leeds, UK*	Earth & Planetary Science Hosted by Bruce Buffet
John Hartwig *University of Illinois, Urbana-Champaign*	Chemistry Hosted by Robert Bergman
Mark Kirkpatrick *University of Texas, Austin*	Environmental Science, Policy, and Management Hosted by Rosemary Gillespie & George Roderick
L. Lacey Knowles *University of Michigan, Ann Arbor*	Integrative Biology Hosted by Craig Moritz
Antonio Neto *Boston University*	Physics Hosted by Alessandra Lanzara
Eve Ostriker *University of Maryland, College Park*	Astronomy Hosted by Christopher McKee
Graeme Segal *Oxford University*	Mathematics Hosted by Constantin Teleman
Omar Yaghi *UCLA*	Chemistry Hosted by Paul Alivisatos

2009-2014 Senior Fellowship Award

Miller Institute Announces the 2009 Miller Senior Fellow



The Miller Institute is pleased to announce that University Professor Gabor Somorjai has been named as Miller Senior Fellow, for a period of five years to run from July 1, 2009 through June 30, 2014.

Professor Somorjai will join Professor Randy Schekman in this Miller Senior Fellowship program, which takes its place alongside the Institute's other programs: the Miller Fellowships, the Miller Research Professorships and the Miller Visiting Professorships.

Within the Institute's general purpose of supporting excellence in science at UC Berkeley, the Miller Senior Fellows program advances that goal by providing distinguished faculty awardees with significant discretionary research funds. The program enhances the Institute's efforts through bringing a group of senior faculty into the Institute who, on a long term basis, can provide mentorship for the Miller Fellows, the creative young women and men who we attract to Berkeley, for the enhancement of the scientific life of the campus and as an occasional route to the recruitment of new members of the Berkeley faculty.

The appointment of Gabor Somorjai continues the tradition of the high standard that we seek for Miller Senior Fellows, set by the appointment of Professor Randy Schekman as the first Senior Fellow. Gabor is a scientific powerhouse with a strong reputation of outstanding citizenry on campus and around world. He helped to transform the science of materials surfaces into the modern, sophisticated molecular scale discipline that it is today. His pioneering contributions to molecular surface chemistry and catalysis have led us towards new and selective catalysts in energy conversion and chemical processes. The combination of instrumentation development for atomic and molecular studies of surfaces and interfaces, and the concepts that emerged from these pioneering studies, is the stamp of Professor Somorjai in the field of surface science. He has accumulated an impressive series of honors and prizes, and has mentored more than 120 PhD students and almost 200 postdoctoral fellows, about 100 of whom hold faculty positions, with many more filling leadership roles in industry. He nevertheless gives his time to many worthy service roles, here in Berkeley, nationally and internationally.

The Miller Institute looks forward to a fruitful and productive relationship with the 2009 Miller Senior Fellow, Professor Gabor Somorjai.

Fall Dinner 2008 Snapshot

The Miller Institute Annual Fall Dinner was held on Friday, December 5. This year's guest speaker was UC Berkeley Professor of Linguistics George Lakoff who delivered a talk entitled "The New Enlightenment: What the Cognitive and Brain Sciences Tell Us About Politics, Philosophy, and Science Itself."

Photo: ***(Left to right) Nancy Walls, Miller Senior Fellow Randy Schekman, Miller Professor Zack Powell, and Executive Director Mimi Koehl***

For more pictures from the Fall Dinner, visit:
http://millerinstitute.berkeley.edu/page.php?nav=128

Credit: ***J. Bloom, M. Modjaz & SN/GRB PAIRITEL Team***

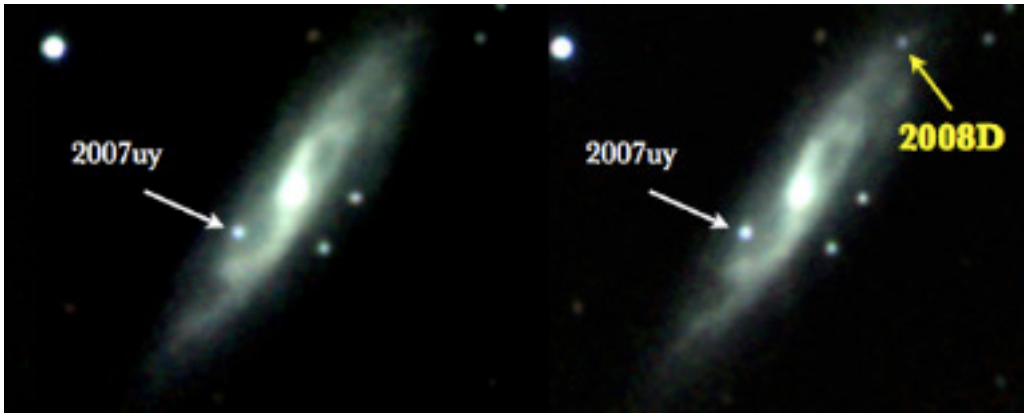


Figure 2: ***Images of Galaxy NGC 2770 90 million light-years from Earth before and after a massive star exploded as supernova 2008D. This galaxy also harbored another SN, SN 2007uy, which had exploded only weeks prior to SN 2008D. From the observed spectra (not shown), Maryam classified 2008D as a SN of type Ib since its spectrum exhibits He rather than H indicating that the progenitor star had its outermost H layer removed while retaining its next-inner layer of He (see*** **Figure 1** ***on*** **page 2***).***

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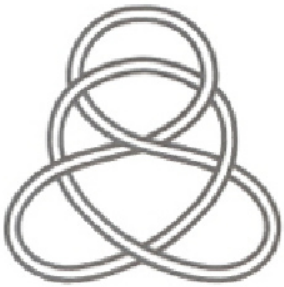
ing it immediately (Fig. 2) and obtained spectra over many weeks that ultimately identified this transient as a Type Ib SN, dubbed SN 2008D.

As it turned out, this SN had produced a burst of X-rays lasting less than 10 minutes, signaling the exact moment of death of the star. Core-collapse SNe are ignited after nuclear reactions in the star's core convert all its material to iron, at which point nuclear fusion stops. Unable to continue providing the pressure to hold itself up against the inward force of gravity, the iron core of the star collapses inward, generating a rebound shock wave that ultimately explodes the star. This shock wave had produced SN 2008D's X-rays -- something that had been predicted by SN theorists for the last 30 years, but had not been observed in a normal SN. While some astronomers argue that this SN also contained a stifled and therefore weak GRB that gave rise to the X-ray emission, work by Maryam and independently by her Princeton colleagues has shown that the observations are consistent with the properties of a normal Type Ib SN from a compact star. Moreover, Maryam concluded from more recent spectral line data which probe the SN core that the explosion was not round, but rather aspherical.

Maryam completed her Ph.D. at Harvard University in 2007 with Professor Robert Kirshner (a former Visiting Miller Professor). Part of her thesis work showed intriguing observational results confirming the hypothesis that low metallicity of the stellar progenitor might be a key factor for GRB production, since she found that the sites of SN without GRBs systematically had higher metallicities than the sites of SN with GRBs.

The recent SN 2008D fits this picture, since the metallicity at the site of SN 2008D is relatively high and consistent with the sites of those SN without GRBs. Maryam is now in the process of obtaining more spectra on the metallicities at the sites of different SN subtypes to probe if there are systematic trends for comparison with metallicities at GRB sites. Furthermore, she will gather new data and re-analyze existing data of SNe with and without GRBs to see if there are specific differences in their spectra that might give clues to the different composition of their progenitor stars.

Maryam's love for astronomy was kindled during her childhood in Germany by Was ist Was? children's books on astronomy. Her passion for astronomical research has led her to remote places where observatories are located, such as the top of the Chilean Andes, the summit of Mauna Kea in Hawaii, the radio-free zone in Greenbank, West Virginia, and the desert in New Mexico. If she is not on a mountain top or at the computer, she can be found ballroom dancing in Berkeley and San Francisco or cooking crêpes at home.



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Tom Hunt
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Help Make a Difference

The Miller Institute continues to interest deserving scientists from around the world. Increasing our endowment is becoming more and more necessary to maintain proportional growth in our programs. While the Institute's endowment will weather the current economic storm, we find a growing need for new financial support. Increasing our endowment through continued wise investment and new donations is becoming significantly more important.

Join friends and Miller alumni in contributing to this important endeavor by logging on to **millerinstitute.berkeley.edu**. Click on "Make a Gift" to help support the independent research of the Miller Institute members.

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