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URSA MAJOR NEWS

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A Renaissance in Gamma-Ray Burst Research

THE STUDY OF GAMMA-RAY BURSTS (GRBs), which are Nature's strongest explosions, is enjoying a rebirth owing to the launch (November 2004) of NASA's SWIFT satellite. Berkeley astronomers are taking a leading role in new developments with ground-based infrared telescope observations of GRBs following alerts from SWIFT via internet.

GRBs were discovered serendipitously in 1967 by military satellites, and their origin remained a complete mystery for 30 years. In fact, astronomers did not even know their distances — in the solar system, or at the edge of the Universe — until February 1997 when the BeppoSAX satellite discovered a fading X-ray "afterglow" that was associated with a GRB. Later detection of radio and optical afterglows accurately pinpointed GRB locations in distant galaxies. Since 1997 a great deal has been learned about the origin and physics of the majority of GRBs — the so-called "long-soft" GRBs *(see Fig. 1)*. The consensus opinion is now that massive stars are the progenitors of all long-soft GRBs. The dense centers of stars that are born with masses significantly more than our Sun (by more than about ten times) collapse after they expend their nuclear fuel. This implosion leads to an explosion of the outer layers that glow briefly and brilliantly and are known as supernovae. A small fraction of supernovae also produce detectable bursts of gamma-rays. Just what determines this bifurcation is not well understood, but may be related to the spin of the progenitor system or to the type of central object created during collapse phase (a neutron star, for most, a black hole for a few). Professor Eliot Quataert and former postdoc Todd Thompson are studying the details of some of the "central engine" models for long-duration GRBs.

While great strides continue to be made in understanding long-soft bursts, the "Afterglow Revolution" has not been kind to those trying to study short-hard bursts *(Fig. 1)*. Of the tens of short-hard GRBs discovered since 1997 only four were localized on the sky to an uncertainty smaller than the fields-of-view of moderate aperture ground-based optical or radio telescopes. And none of these positions were relayed from the discovering satellite to ground-based observers in real-time. The same questions, already answered for long-hard bursts, still applied: from what distances (galactic or cosmological) do short bursts occur? What is the physics of the emission mechanisms? What are the energetics of the explosions? Do short bursts even have afterglows? Are supernovae associated with short bursts?

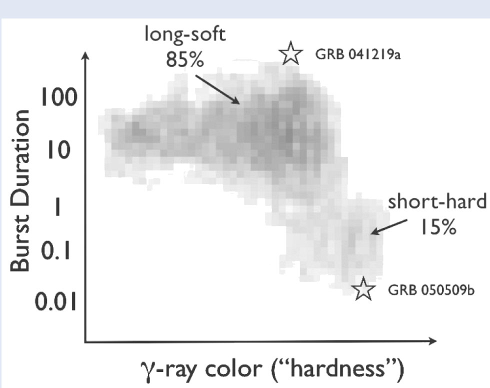


Fig. 1*. Illustration of the diversity in Gamma-Ray Burst properties. GRBs last from tens of milliseconds to several hundreds of seconds. Those that are more "red" in Gamma-Ray "color" and last longer than about 2 seconds comprise the "long-soft" class; soft means red. The shorter and "bluer" subclass are the "short-hard" GRBs; blue means hard. GRB 050509b is the first well-studied short-hard bursts, and has already yielded great insights to the nature of such bursts. We discovered the first contemporaneous infrared emission from a GRB by rapidly observing the position of the very long-duration GRB 041219a. The nomenclature of GRBs is their yymmdd date followed by letter indicating order during day.*

New Clues to the Origin of Short-Hard Bursts

On May 8, 2005, the SWIFT satellite discovered the short-hard GRB 050509b, and relayed an accurate position from its X-Ray detector to the ground in real-time. We quickly marshaled an imaging and spectroscopy campaign on the Keck telescopes in Hawaii, the WIYN 3.5m telescope in Arizona, the PAIRITEL 1.3m in Arizona, and the Gemini 8m in Hawaii. PAIRITEL is the 1.3 meter Peters Automated Infrared Imaging telescope on Mt. Hopkins in Arizona which I developed over the last three years and continue to operate as principal investigator; PAIRITEL narrowly survived the recent forest fire there. The Keck data were acquired through our UC Target of Opportunity Override program (with principal investigator Kevin Hurley, SSL; and co-I Jason X. Prochaska, UCSC). The *ad hoc* observing team included a bevy of UC observers including Berkeley's own Joseph Hennawi, Michael Cooper, Brian Gerke, Jeffery Newman, Alex Filippenko, Ryan Chornock, Dave Pooley, and Ryan Foley.

What we found was something markedly different than what is typically found near long-soft GRBs: an apparent elliptical galaxy "host" near the center of a cluster of galaxies at moderately low-redshift ($z = 0.2248$). Why is this important? Ellipticals are comprised almost entirely of old stars and stellar remnants, and by implication of the physical association, this short-hard burst was then a product of "activity" of old stars; this is in stark contrast to their long-soft cousins that are associated with young stars.

The fact that the GRB position was offset by about 40 kpc in projection from an elliptical was also an important clue in favor of merging remnant models. A neutron star binary is formed after both stars in a massive star binary die in supernova events. Most systems are disrupted in the explosions, but a

(continued on page 2)

Gamma-Ray Burst Research

(continued from page 1)

few survive to form gravitationally bound binary systems that are ejected from their birthplaces at speeds of several hundred km/s. Over time, the binary orbit decays as the system radiates gravitational energy. After hundreds to thousands of million years, these neutron star pairs coalesce. The combination of delayed merger time and fast motion allows, and basically requires, systems such as these to coalesce far from where they are born (see Fig. 2). No one knows exactly what happens when a double neutron star system coalesces, but the rest mass energy available and dynamical timescale are well in-line with the properties of short-hard gamma-ray bursts.

In these observations we have effectively solved the distance scale puzzle (and, by extension the energetics question) for short-hard bursts. From all of the data we and others have assembled thus far, the merging neutron star model now looks to be the "best bet" for short-hard GRBs. However, inferences from this one burst are by no means the smoking gun for the merging neutron star model. The position is also consistent with faint blue galaxies at higher redshift, and so there is a small chance (<1%) that GRB 050509b arose from greater distances and from perhaps young stars. New short burst localizations in the year ahead will strengthen our conclusions.

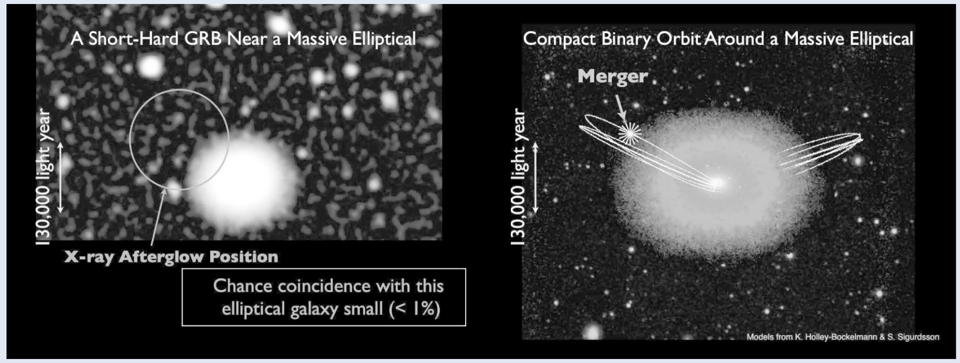


Figure 2: *Simulation (left) of a neutron star binary merger event in a massive elliptical galaxy. The binary system travels at high velocity from its birth site and traverses the galaxy for about 1 billion years, trapped in the deep potential of the galaxy. Eventually the compact objects merge with each other. At right, our observations from the Keck telescope showing the X-ray afterglow position of GRB 050509b. The offset from the apparent host galaxy is consistent with this merging neutron star progenitor model.*

Future looks bright for gray burst research

The Berkeley GRB group is now reaching a point where we can hope to address, in parallel, many of the critical open questions. I am very interested in using GRBs as probes of the distant universe and cosmology. A number of us are also interested in exploring the connection of GRBs to supernovae. Kevin Hurley and Steve Boggs at SSL continue to explore the high-energy emission of GRBs and related phenomena. For years, Alex Filippenko, Weidong Li, Saurabh Jha and the Katzman Automatic Imaging Telescope (KAIT) team have studied the early afterglow emission at optical wavelengths. The KAIT-PAIRITEL telescope pair will provide unprecedented coverage of early afterglows and will help us to identify the redshifts of distant GRBs in near-real time. ◆

Josh Bloom (mail to: jbloom@astro.berkeley.edu) recently joined the UC Berkeley astronomy faculty as an assistant professor. He arrived from Cambridge, MA where he was a Junior Fellow at the Harvard Society of Fellows. He did his graduate work at Caltech and Cambridge University. Josh is married to Ana Bellomo, originally from Barcelona, Spain, and the two are now settling down in their Berkeley Bungalow home.

Sackler Lecture

This year our Raymond and Beverly Sackler Distinguished Lecture in Astronomy was given on April 6, 2005. Steven Squyres, Professor at Cornell University and the Principal Investigator of the Mars Exploration Rover Mission, presented an inspiring talk on the findings of the twin robot geologists: Rovers Spirit and Oppor-tunity. After an animated movie showing one of the robots in action on Mars' surface, Steven gave an excellent review of the robots' search to date for evidence that once upon a time liquid water flowed on Mars. The search for water on Mars' surface is viewed as an important milestone in the search for life.

If you missed this exciting event, you can repeat the web cast at: http://webcast.berkeley. edu/events/details.html?event_ id=201 ◆

2005 Commencement Astronomy Award Winners

Maureen Elizabeth Teyssier was awarded the Department Citation for outstanding scholarly effort.

The Dorothea Klumke-Roberts Award is given annually to an outstanding undergraduate student in Astronomy. The 2005 Award was shared between **Mohan Ganeshaligam** and **Charles Conroy**.

The Mary Elizabeth Uhl Award for distinguished PhD research in Astronomy or Physics was given to **Mark Reuben Krumholtz** for his thesis "Computational and Theoretical Investigations of Star Formation" supervised by Chris McKee, and **Joshua Simon** for his thesis "Dark Matter in Dwarf Galaxies: Observational Tests of the Cold Dark Matter Paradigm on Small Scales" supervised by Leo Blitz.

Julie Comerford, **Joe Converse** and **Katie Peek** are this year's Outstanding Graduate Student Instructors.

Katie Peek was also presented an award for Teaching Effectiveness, one of just 15 awarded on the campus. ◆

New Graduate Students

Katey Alatalo is a graduate of the University of Michigan where she worked on the Robotic Optical Transient Search Experiment (ROTSE). She arrived in the summer to work with Josh Bloom. When not in the lab, Katey enjoys trying new and different foods, watching movies, playing tennis, long drives, and especially watching sporting events.

Kristen Gillmon is a Colorado native and completed her undergraduate degree at the University of Colorado. Her undergraduate research was on molecular hydrogen in the interstellar medium, but she has many interests and would like to try something new. She looks forward to moving to Berkeley and getting to live near the ocean.

Jeffrey Silverman is originally from Anaheim, Ca. in Orange County, just minutes from Disneyland. He majored in Astrophysics and Mathematics at Rice University. He did his senior research project on gamma-ray bursts and is inter-ested in pursuing observational high energy astrophysics in grad school. He enjoys playing the saxophone and softball and hopes to continue these activities at Berkeley.

Andrew Wetzel is a graduate of Harvey Mudd College where he received his B.S. in Physics. This summer Andrew is working at Los Alamos National Laboratory doing research in cosmology. He is an avid musician, playing percus-sion and violin, and mainly interested in orchestral music and jazz. Andrew organized a debut of his composition for string trio this past spring. ◆

2005 Commencement

Astrophysics A. B. Degree

Jonathan Michael Bretan
Nicholas Szandor Hakobian
In Tai Kim
Michael Curtis McFarlane
Brandon James Swift
Ashley Anne Chandler
Charles Francis Conroy
Jason Lee Curtis
Jeremy Michael Dalmas
Shannon Colleen Fitzgerald
John Frye Graham
Javiera Magdalena Guedes
Amanda Lea Heiderman
Elizabeth Anne Hulsey
Mohammed Omair Khan
Emily Rose Landes
Liliana Ivonne Lopez
Yolanda Marchante-Ortiz
Bonnie Kathleen Meinke
Matthew Ryan Moore
Pinal Prabhudas Patel
Emily Rauscher
Christopher Daniel Sheehy
Katsuki Shimasaki
Kurt Thomas Soto
Kathryn Joyce Stanonik
Rachel Rebecca Strickler
Maureen Elizabeth Teyssier
Richard Atsuki Urata
Cassandra Belle VanOutryve
Harus Jabran Zahid

Astrophysics M.A. Degree

Michael Caldwell Cooper
Louis-Benoit Desroches
Michael Patrick Fitzgerald
Ryan Joseph Foley
Conor Murray Laver
Karin Marie Sandstrom

Astrophysics Ph.D. Degree

Steven Arthur Dawson – "Lyman-Alpha-Emitting Galaxies At High Redshift: Direct Detection of Young Galaxies in a Young Universe" – Advisor: Hyron Spinrad

Nathan Todd McCrady – *"The Super Star Cluster Population of the M82 Nuclear Starburst"* – Advisor: James Graham

Joshua David Simon – *"Dark Matter in Dwarf Galaxies: Observational Tests of the Cold Dark Matter Paradigm on Small Scales"* – Advisor: Leo Blitz

Erik William Rosolowsky – *"Molecular Cloud Populations Across Galactic Environments"* – Advisor: Leo Blitz ◆

Ultra-Luminous Infrared Galaxies —

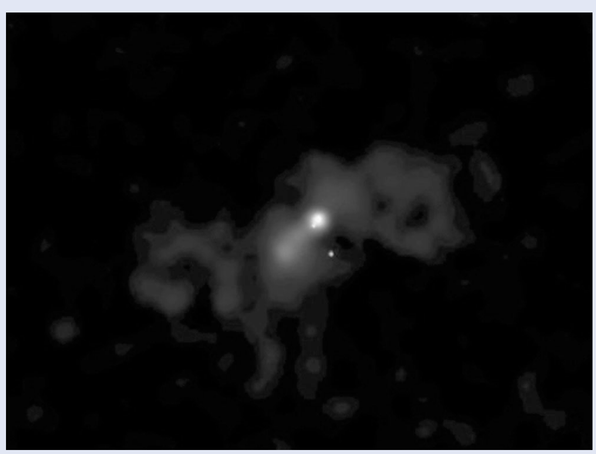
Todd A. Thompson & Eliot Quataert

Ultra-Luminous Infrared Galaxies (ULIRGs) are not like our own. Our Milky Way's 100 billion stars have formed at a relatively steady rate for a time comparable to the age of the universe. Not all galaxies produce their stars so quiescently. Some undergo huge bursts of star formation. ULIRGs are the most massive, gas-rich, luminous examples of such starbursts in the universe. Whereas the fuel for forming stars in our Milky Way, some billions of solar masses of gas, is distributed on a scale of four kiloparsecs, these starbursts contain roughly the same amount of gas, but on a scale ten to one hundred times smaller. Their central nuclei — hundreds of parsecs across — have average gas densities thousands of times larger than the Milky Way, and they form stars hundreds to thousands of times faster. As a result, they exhaust their fuel supply in just a thousandth of the age of the universe. ULIRGs are truly a flash in the pan!

ULIRGs are interesting as more than merely an extremum of star formation in our universe. They are thought to be triggered when two galaxies collide; the gravitational forces of the interaction drive each participant's reservoir of gas into its nucleus. The resulting starburst is thought to be a key element in the formation of spiral bulges (the spherical, rather than disk-like, component of stars in a galaxy) and elliptical galaxies which have very little gas content in their current form. The ULIRG population thus probably represents a short epoch in the life of any galaxy that experiences a gas-rich collision. The strong correlation between black hole mass and stellar mass in spiral bulges and ellipticals also suggests a deep connection between the starburst phenomenon and the growth of massive black holes at the centers of galaxies.

A number of researchers, faculty, and students at UC Berkeley have their hands in the starburst game. In particular, Reinhard Genzel has worked on characterizing both the low- and high-redshift ULIRG population and James Graham has worked on the quintessential local ULIRG, Arp 220. Leo Blitz and his group have also contributed significantly to the observational characterization of extra-galactic star formation.

On the theoretical front, Mark Krumholz and Chris McKee have recently worked out a theory of star formation applicable to a wide range of environments. In a separate effort, we have developed a theory for understanding the regulation of star formation in ULIRGs, together with visiting Miller professor Norm Murray. Although these massive starbursts form stars at a remarkable rate, they are not maximal in the sense that all of their gas is converted into stars on a single dynamical timescale. In fact, given their very large gas reservoir and their compact configuration, their star formation rates are more than an order of magnitude below this maximal value. What process supports the gas in ULIRGs, preventing complete collapse and fragmentation? We suggest that radiation produced by the stars themselves pushes back on the dusty gas in the dense interstellar medium of ULIRGs, contributing to its pressure support and halting its collapse. In this way, the current generation of stars determines the rate at which future stars are born. ◆



The image shows an X-ray image obtained by NASA's Chandra X-ray observatory. The image shows a bright central region at the waist of a glowing hour-glass-shaped cloud of multimillion degree gas that is rushing out of the galaxy at hundreds of thousands of miles per hour. This emission is produced by a "superwind" generated by hundreds of millions of newly-formed stars, triggered by the collision. Farther out, Chandra sees giant giant lobes of hot gas, possibly thrown out by the impact of the collision, and which possibly may escape the galaxies entirely. Chandra also detects two point sources of X-ray emission, possibly arising near massive black holes in the galactic nuclei.

Faculty • Don Backer – Chair • Jon Arons • Gibor Basri • Leo Blitz • Josh Bloom • Eugene Chiang • Marc Davis • Imke de Pater • Alex Filippenko • Al Glassgold • James Graham • Carl Heiles • Raymond Jeanloz • Richard Klein • Chung-Pei Ma • Geoff Marcy • Chris McKee • Eliot Quataert • Hy Spinrad - Emeritus • Harold Weaver - Emeritus • Jack Welch - Emeritus • Martin White

New Post Docs

Darren Croton is arriving from University of Munich where he worked on large scale structure as seen in the Millenium Super-computer simulation. He will work with Marc Davis on the DEEP2 observational project.

Marijke Haverkorn, our new Jansky Fellow, is arriving from CfA where she worked on Galactic magnetic fields using Faraday rotation mapping and tomography. She will work with Carl Heiles and other members of the radio group.

Ruediger Kneissl arrived this Spring from Cambridge University where he worked on next generation cosmic microwave background anisotropy experiments. He will work with the APEX-SZ team.

Matthew Browning is arriving from the University of Colorado where he worked on 3-D convective MHD magnetic dynamo models. He is coming with an NSF Postdoctoral Fellowship to work with Gibor Basri on stellar dynamos, particularly in fully convective stars.

Philip Chang, a new Miller Fellow, comes from the University of California, Santa Barbara, where he did his PhD on nuclear burning on the surfaces of neutron stars, working with Lars Bildsten. As with all Miller Fellows, he is free to pursue research problems of his own devising. He will work with Jon Arons and Eliot Quataert.

Josh Eisner is a Miller Fellow and will be arriving from California Institute of Technology. Josh's research interests include using adaptive optics and optical interferometry to study the circumstellar environment of young stars. He will be working with James Graham.

Andrew West is arriving from the University of Washington where he worked on exploring global star formation over a range of galaxy types by examining relations between cold HI gas and stars. He will join RAL and work with Leo Blitz.

Mate Adamkovics arrived in January from the University of Illinois at Urbana-Champaign where he has designed and constructed instrumentation for measuring the photochemical kinetics of aerosol formation, and used state of the art cavity ringdown spectroscopy technique to study small molecular ions relevant to interstellar space. He will work with Imke de Pater.

Nat Butler is the recipient of the Charles H. Townes Postdoctoral Fellow. He completed his PhD at MIT where he worked on the High Energy Transient Explorer mission to detect Gamma-ray Bursts, and conducted GRB follow-up observations in the optical and X-ray bands.

Bryan Johnson is arriving from the University of Illinois at Urbana-Champaign. He will work with Eliot Quataert and carry out independent research in theoretical astrophysics, cosmology and planetary science.

Saurabh Jha graduated from Harvard in 2002 and previously served as a Miller Fellow at Berkeley. He will work on a number of projects with Alex Filippenko including developing a next-generation supernova follow-up telescope system.

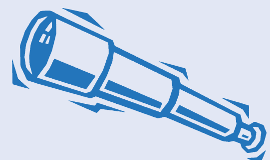
Bjoern Schmekel is a new postdoc who comes to us from Cornell University, where he did his PhD on coherent synchrotron radiation from particle beams, with application to pulsars and to laboratory accelerators. He worked with with Richard Lovelace and Ira Wasserman. He will be working with Jon Arons on coherent emission from relativistic winds and jets. ◆

Faculty News

Eliot Quataert and **Eugene Chiang** achieved the rank of Associate Professor joining the tenured ranks of the faculty.

Jack Welch retired June 30th, and will continue research as a Professor in the Graduate School.

Professor Geoff Marcy was recently awarded the Shaw Astronomy Prize. The Prize honors individuals who have achieved significant breakthroughs in academic and scientific research or application and whose work has resulted in a positive and profound impact on mankind. ◆



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Upcoming Events

Parents Weekend and Homecoming – Sept. 30-Oct. 2

Football: CAL vs. Arizona (Saturday, Oct. 1)

SPECIAL PRESENTATIONS

"New Worlds Discovered and Prospecting for Life in the Universe"
Speaker: Professor Geoff Marcy
Friday, September 30, 6-7 p.m., Barrows Hall, Lipman Room

"Dark Energy and the Runaway Universe"
Speaker: Professor Alex Filippenko
Saturday, October 1, Noon-1 p.m., Bechtel Engineering Center, Sibley Auditorium

CAL Day – April 22, 2006