

# STATE OF THE UNIVERSE 2007

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Martin Ratcliffe

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# STATE OF THE UNIVERSE 2007

NEW IMAGES, DISCOVERIES AND EVENTS

 Springer

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*Front cover illustration:* In January 2002, a dull star in an obscure constellation suddenly became 600,000 times more luminous than our Sun, temporarily making it the brightest star in our Galaxy. The mysterious star, known as V838 Monocerotis, has long since faded back to obscurity, but this Hubble Space Telescope image reveals dramatic changes in the illumination of surrounding dusty cloud structures. The effect, called a 'light echo', has been unveiling never-before-seen dust patterns since the star suddenly brightened. Image courtesy NASA, ESA, and The Hubble Heritage Team (STScI/AURA).

*Back cover illustration:* This infrared image of the spiral arms of the nearby galaxy Messier 81 was obtained by NASA's Spitzer Space Telescope. Winding outwards from the bluish-white central bulge of the galaxy, where old stars predominate and there is little dust, the grand spiral arms are dominated by infrared emission from dust. The infrared-bright knots within the spiral arms show where massive stars are being born in giant clouds of ionized gas and dust. Image courtesy NASA/JPL/Caltech/Harvard-Smithsonian Center for Astrophysics.

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■ Close inspection of the 2006 Hubble Space Telescope color mosaic of the Orion Nebula reveals numerous treasures that reside within this nearby, intense star-forming region. Southwest of the Trapezium stars located in the center of the nebula, this stunning Hubble Heritage portrait captures a variety of intricate objects. Deeply contrasting areas of light and dark blend with a palette of colors mixing to form rich swirls and fluid motions. Image courtesy NASA, ESA, and The Hubble Heritage Team (STScI/AURA), with thanks to ANSA, ESA, M. Robberto (Space Telescope Science Institute) and the Hubble Space Telescope Orion Treasury Project Team.

## Preface

# STATE OF THE UNIVERSE 2007

**I**MAGINE, IF you will, standing next to a spectacular river flowing down a mountain-side. High in the distance, at a higher altitude, there's a cascade of water heading in your direction. Right where you are standing, and taking your photograph, the river is broad, turbulent, and full of drama. Near the river bank, some water even turns back upstream in small eddies. These momentary diversions are quickly whisked downstream by the full flow of the river. There are many small ripples, some large waves, and here and there, the infrequent but spectacular explosion of spray.

You take your photograph. It's a snapshot, a still scene, the frenzied motion of the river frozen for a moment in time. The river is broad from your vantage point, yet apparently stationary in your image.

This book is like your photograph. It's a snapshot, one moment in time, of a veritable gush of astronomical information that is pouring down from high mountain top observatories, and space telescopes orbiting high above the Earth.

Within its pages is an attempt to capture some of the flavor of the dynamic, fast-paced, and sometimes turbulent, flood of astronomical information about our Universe. It is an attempt to provide an impression, like your photograph, of our state of knowledge of the Universe. Like each passing wave in the river, the information in this book is not static, it's moving, and by the time you read this, in places, it will have already moved on.

This is the first book in an annual series that brings you the some of the greatest discoveries in astronomy that have occurred during the previous year. It's a bridge between the public pronouncements of astronomy news and the professional researcher. With 30-second sound bites about a

recent Hubble discovery, many listeners may be left wanting, knowing there is more to the story than the popular media have time for.

New extrasolar planets, new views of our Milky Way, evidence of black holes colliding, and the most dramatic images from the world's best telescopes, are the most visible part of a deeper story. It's an astounding story that's being revealed, step by step, through careful, painstaking work by the world's astronomers. By reading this book, you will gain a deeper understanding of what the images mean and how they tie in to the broader picture of astronomical research.

Telescopes in orbit, such as Spitzer, Hubble, Swift, Chandra and XMM Newton, are reaching far beyond any telescope before them. Ground-based optical and radio telescopes are providing new and unprecedented views of the depths of space. The Very Large Telescope (VLT), Keck, Gemini, the Very Large Array (VLA) and the Green Bank Radio Telescope are just a few of the instruments that are revolutionizing our view of the cosmos.

Large scale deep surveys, notably the Sloan Digital Sky Survey, are producing astonishing new results, from the recognition of new streams of stars in our own Milky Way, out to some of the most distant quasars known. New telescopes soon to come on line, or in the early stages of planning, such as the new Large Binocular Telescope, or the futuristic Giant Magellan Telescope, indicate that the flood of information is set to increase dramatically. Strange-looking telescopes search for gravitational waves (LIGO), and the origin of cosmic rays (VERITAS). Each new telescope is historically associated with giant leaps forward in our understanding of the cosmos.

Keeping track of all the new results is hard. The exciting developments in the understanding

of our origins, of the early beginnings of the Universe, clues to the nature of dark matter and dark energy, of how planets are formed, and how stars live out their lives and die, occur every month. Each new result adds a tiny piece to the jigsaw puzzle, leading the way to a fuller and more complete understanding of the Universe around us. Rarely are such details offered in one place. This book attempts to fill the gap between research and everyday news. It's a unique insight into many of these developments, not only from the news releases from major observatories, but also from the researchers themselves.

The book is split into two main parts. The first part, 'A Year in News and Pictures', reviews month-by-month some of the major new findings in chronological order covering the period from April 2005 to March 2006 (defined by the publication schedule). While there is no way one can review every news story (such a book would run to over 500 pages), the aim is to provide a broad survey of the leading stories that reflect not only the picturesque and dramatic, but also the astronomically significant and astonishing.

Each news item has a number of web links to enable you to take your research further. The links take you to web sites designed for the general public reader, and I have provided, in many cases, additional links to the actual research paper or research web site. These hard-to-find web sites provide much deeper information for those who have a background in physics and astronomy and wish to read further. The research papers are often listed on a web site called 'astro-ph', short for astrophysics. This is both a goldmine for undergraduate students studying astronomy at major universities, while at the same time an opaque reservoir of inexplicable titles for those not well versed in physics and astronomy research. If that is the case, stick to the first web site listed as a link.

During the research for this book I've consulted the extensive volume of press releases available from all the major observatories around the world, and with that significant thanks go to all the press officers and education and public outreach specialists of all astronomical institutions. Their work is vital in conveying the complex language of research into the exciting and palatable words for public consumption.

The second part of this book consists of invited review articles from leading researchers

and science writers. I am enormously indebted to them for their major contributions to this volume. The topics highlight some of the most active areas of current research, reflecting the state of our knowledge now, and placing many of the news stories in the first section of the book into a broader context.

I am very grateful to James Kaler for writing a review of the year 2005-06 for this book. He is well known in the planetarium community for keeping many of its profession up to date each year through lectures at annual conferences, and he was a natural choice for writing about our current 'State of the Universe'. His article highlights the most significant discoveries of the year, and places them in context of our broader astronomical knowledge.

The remaining nine chapters in the features section focus on specific topics currently undergoing the most active research. Ray Villard, a science writer in his own right and Hubble's Press Officer since the launch of the Hubble Space Telescope, brings us the highlights of the year from that most magnificent of instruments orbiting a few hundred kilometers above our heads.

Richard McCray, world-renowned expert on the famous 1987 supernova in the Large Magellanic Cloud, gives us the most recent update regarding the search for the central compact object, and the dramatic flaring of the gaseous ring surrounding the supernova. The collision of the supernova debris with this slow-moving ring is of gargantuan proportions, and McCray's review is timely with the entire ring now illuminated.

Neil Gehrels, Principal Investigator for the SWIFT gamma-ray observatory, with co-author and colleague, Peter Leonard, outline some dramatic new discoveries and the progress made in the past year in our understanding of the origin of some of these bursts.

The Milky Way was a hot topic at the January 2006 Winter AAS meeting, with many new results from the Spitzer Infrared Space Telescope, and from the SDSS. Chris Wanjek, an experienced science writer, provides a dramatic overview of the most recent results, from the central bar to a warped disk.

The director of the newly completed Large Binocular Telescope (LBT), Richard Green, and colleague John Hill, provide insightful commentary on this revolutionary telescope.



■ Editor Martin Ratcliffe at Wichita State University's Lake Afton Public Observatory, writes about astronomy and teaches an introductory course in Cosmology at the WSU. He was Director of the first digital planetarium theater in Wichita, Kansas. The Lake Afton facility is like many around the world that offer opportunities for the general public and students to find out more about astronomy. Image courtesy Classic Impressions by Trey Allen, with acknowledgement to Lake Afton Public Observatory.

The pair of gravitational wave observatories called LIGO recently began a continuous run of observations. Laura Cadonati gives us the benefit of her considerable expertise to tell the story of this remarkable development. The potential for great discoveries probably lies in the next few years. Read her article to see what we might expect.

Michelle Thaller, an expert at conveying information to the public in an exciting way, as well as being an astronomer, reviews the outstanding science coming from the infrared Spitzer Space Telescope. The images are dramatic. The science is astounding. Check out what's cool with Spitzer this year.

One of the great surveys of the cosmos using the Hubble Space Telescope is the COSMOS galaxy survey. Anton Koekemoer, an astronomer at the Space Telescope Science Institute, leads the observations, and we are privileged to have his contribution. News from COSMOS graces the halls of every recent AAS meeting. Anton provides a complete background to the survey.

Finally, on a lighter, yet serious, note, Phil Plait provides humorous and incisive critique of the crazy claims that appear from time to time. Past stories like the wild face on Mars, or the Moon Hoax, rear their heads, and typically require some simple logic to discredit. Phil dedicates his web site badastronomy.com, to exposing these wild claims for what they are.

Finally, you'll find appendices filled with information about all the large telescopes, current and planned, with web links to keep you abreast of their current status and most recent breaking news, in addition to a list of extrasolar planets. These lists will be updated each year.

This book is designed to begin a new level of exploration into astronomy. The general reader interested in astronomy, students at community colleges and first year undergraduates, teachers and writers will all find valuable information here.

If you are a student of astronomy at a local community college and need some ideas and access to information for term papers, this book provides a very concise doorway to the most recent and exciting discoveries in astronomy, and leads you directly to the web sites that provide

images and technical information you can use for your paper. For more advanced students, direct links to the actual research papers written by the astronomers themselves open the door to second and third year astronomy and physics students with a strong mathematical background.

Amateur astronomy clubs will find this useful as a source for potential speakers via the topical news items.

More advanced students who may be figuring out what area of research interests them as they pursue a career will be able to gauge which universities are studying particular areas of astronomy from their news releases and research team web sites.

For the general reader wanting to keep pace with developments in the science of astronomy, this book is probably all you need, but passionate followers of astronomy will also subscribe to some of the fine monthly magazines that regularly review astronomy, such as *Sky and Telescope* and *Astronomy* magazines.

For the science writer, this book provides a handy reference for all those press releases you wonder what to do with. If you want to know what stories broke in June 2005, this book provides easy access to the main stories, and the web links to help you research further. This is especially valuable to writers who want to link various 'discoveries' into the context of a bigger picture story.

To help guide you along in further discovery, if you come across a word you don't understand, like "magnetar", try entering the word into a search on the internet to find its meaning. Look for links to bona-fide university web sites to delve deeper into the topic of interest.

Thanks certainly go to the team of science writers whose work provided the raw material for the news items. The people listed below were particularly useful, if not directly, then indirectly.

My thanks go to Lori Stiles of the University of Arizona News Services, Megan Watzke (Chandra PIO), Peter Michaud (Gemini PIO), Lars Lindberg Christensen (European Hubble Space Telescope PIO), Laura Kraft (Keck Observatory PIO), David Aguilar (Harvard University), Christine Pulliam (Harvard University), Whitney Clavin (JPL),

Dolores Beasley (NASA headquarters), Cheryl S. Gundy and Donna Weaver, (Space Telescope science writers), Susan Hendrix (Goddard Space Flight Center), Steve Koppes University of Chicago, Robert Tindol (Caltech), Tina McDowell (Carnegie Institution), and last but not least, Rebecca Johnson (McDonald Observatory PIO).

It is important to remember one thing regarding press releases. They do provide a popular level introduction to cutting edge research. However, there have been instances where a new discovery or claim has been proved incorrect with further research. Such is the natural process of science. This is the strength of science at work.

Typically, new research takes years to ferret out the true story. A press release highlights one particular nugget of information on the way to this fuller understanding. Therefore, each news item in this book should be read with this in mind. If you accept any news story as the correct view, you may find an opposing view held by other scientists. The debate between them is competitive and, at times, fierce. Experiencing this process is to become engaged in it.

Many of the dramatic steps forward in our understanding of the Universe never make the pages of local newspapers, and the general public and students miss a great opportunity to share in the excitement of this rapidly growing subject. After all, astronomy encompasses the entire Universe. Our lives are intimately linked to the formation of stars, since we are made of the chemical elements that are known to be formed inside massive stars. Earlier generations of massive stars have long since exploded, seeding the universe with elements heavier than hydrogen and helium. Iron, an element that courses through our veins in the hemoglobin molecule in blood, originally came from the centers of early stars. When you look at the sky, there's little surprise that most of us feel some sense of awe – it's more than awe, it's a direct connection we have to the Universe. It's in our blood. As I tell my students, if you don't feel that connection, you're probably not alive.

And my thanks would not be complete without mentioning my students who have passed through the astronomy introductory courses at Butler County Community College, Baker University, and the cosmology course at Wichita State University, all in Kansas. Passing

on the free access to the world of astronomy is a passion I enjoy sharing, and it is my hope that many students will carry the interest for life.

Unknown to my editor and publisher, this kind of book has been in the back of my mind ever since the first day I attended a meeting of the American Astronomical Society. That was in 1992 in Columbus, Ohio. As a planetarium director for the Buhl Planetarium at Pittsburgh's Carnegie Science Center, I was keen to ensure our shows reflected current research. On arrival at the meeting I met Steve Maran, Press Officer of the AAS, and he graciously allowed me access to the press room. Ever since then, missing only a few meetings, I have witnessed the veritable avalanche of exciting astronomical results being discussed and published. Each year I really expected that the next year could not bring any more startling results. And yet each year always does. My sincere thanks and appreciation goes to Steve Maran for opening that door to me 14 years ago.

Soon after my first AAS meeting, I began to think about instituting an annual 'State of the Universe' address in January around the time of the January AAS meeting. While this never came to fruition, I have kept every news release from those days in the hope that someday, items like that would be of some use. This book is the brainchild of John Mason and Clive Horwood, my patient and ever-supporting Editor and Publisher. Yet when they suggested the book to me, their ideas were falling on already fertile ground. I'd like to thank them profusely for their attentive nurturing, positive encouragement, and patience, for this first volume.

Finally my heartfelt thanks and dedication of my work go to my wife, Shawn, who shares my passion for love and life, and whose active encouragement of my writing enabled this project to be completed, and to the memory of Rev. Dr Gary Cox, who shared in the excitement of astronomical discoveries over the past few years.

**Martin Ratcliffe**

Wichita, Kansas

August 2006

**BUNNY**



**FELINE  
ASTRONOMER**



# PUBLISHER'S NOTE

**I**N MY youth I was an avid collector of 'annuals' which, in the UK, consisted of a large-format book containing strip cartoons, short stories and other items and puzzles designed to stimulate the imagination and therefore the learning process.

In developing the range of books in the Praxis imprint *Popular Astronomy* it occurred to me there was a real need for a book for enthusiasts of all ages on popular astronomy. I found a kindred spirit for this idea in Martin Ratcliffe who is also a lover of annuals.

This provided the ideal opportunity to fulfil a longstanding ambition of mine to produce a book - an annual - containing various reviews of new images, discoveries and events in the Universe. And let's illustrate the chapters with a series of one-page cartoons on the various topics, to lighten the learning curve and make the reader smile.

The cartoons show how the very latest telescopes, exciting discoveries and the astronomers behind those discoveries might be seen through the eyes of a cat! This allowed me to have some 'publishing fun' with our cover designer and illustrator, Jim Wilkie,

in developing this idea and thus immortalising my wife Jo's incredible 20-year old Russian Blue cat, Bunny, as AstroKat!

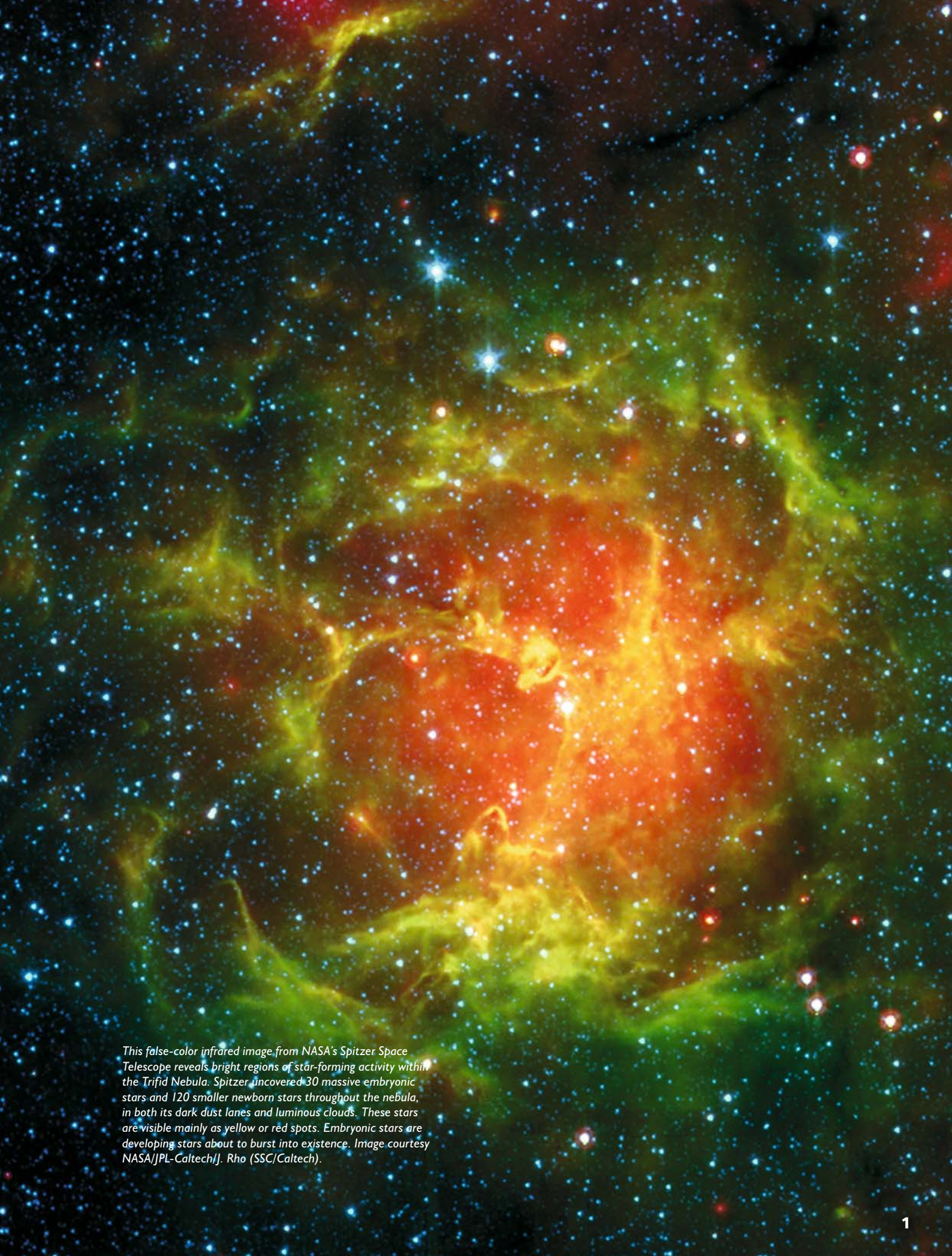
Sincere thanks go to Jim's wife, Rachael, for helping to shape and focus the cartoon ideas with Jim and to Arthur Foulser of BookEns, who surpassed the design challenge I set him for the layout of the text. To our intrepid *Popular Astronomy* Advisory Editor, John Mason, a big thank you for his work on the final selection of images and other essential detail.

I've always believed learning should be fun, so for the first time since I started the Praxis imprint over a decade ago, I decided to write a publisher's note to explain the thinking behind this book. To all readers, please enjoy this annual and other volumes in future years. This is the start of a classic series and the very first volume usually becomes a prime collector's item, so you should keep your copy as a treasure after reading it.

Finally, a big thank you to Harry Blom of Springer New York for his enthusiastic support for this project.

*Clive J Horwood*



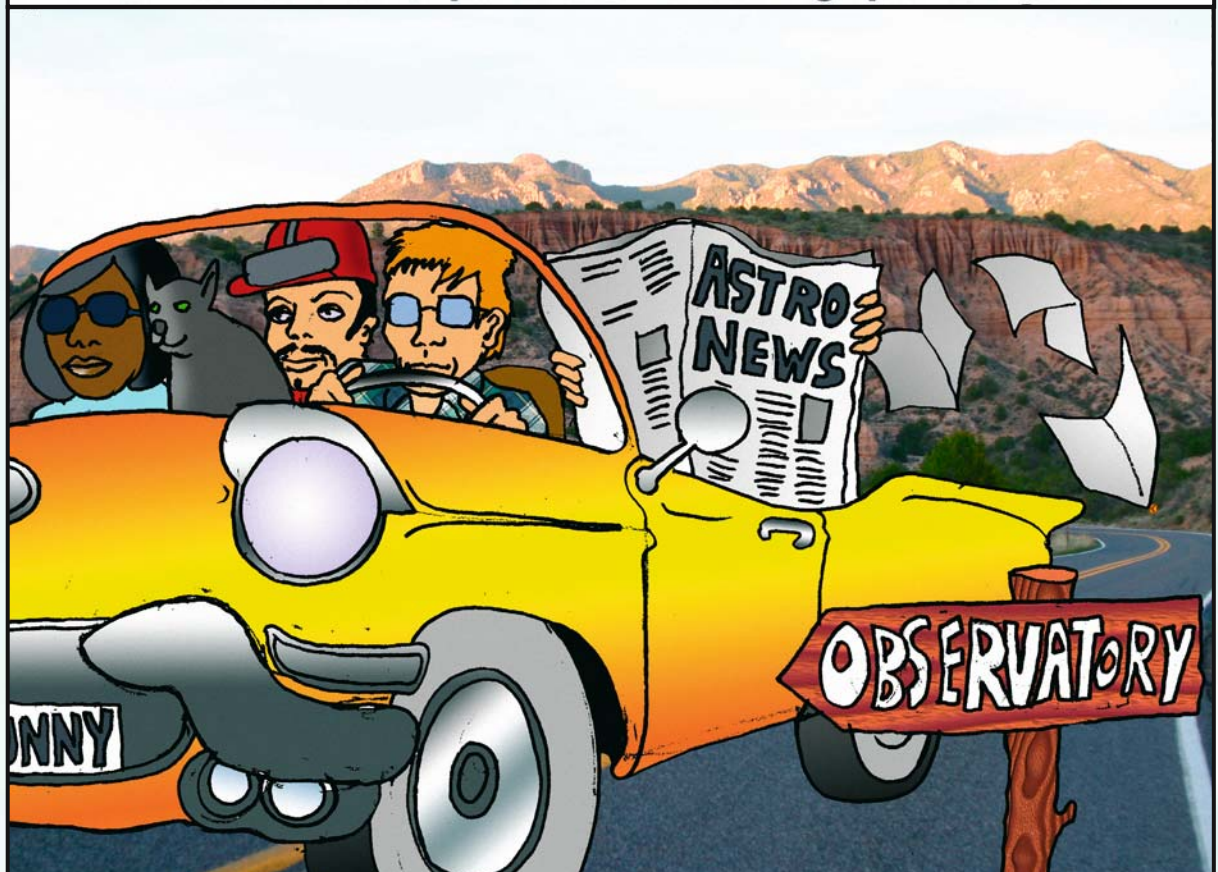


*This false-color infrared image from NASA's Spitzer Space Telescope reveals bright regions of star-forming activity within the Trifid Nebula. Spitzer uncovered 30 massive embryonic stars and 120 smaller newborn stars throughout the nebula, in both its dark dust lanes and luminous clouds. These stars are visible mainly as yellow or red spots. Embryonic stars are developing stars about to burst into existence. Image courtesy NASA/JPL-Caltech/J. Rho (SSC/Caltech).*

# 1

## A year in NEWS...

... Bunny always enjoyed the trip to work; the Human Astronomers sometimes tried to pass the time catching up on the news



Each month a flood of new results pours in from the world's observatories. Here *Martin Ratcliffe* reviews the major highlights, selected from the hundreds of news reports released between April 2005 to March 2006. You'll find a concise review of the selected discoveries and web links to images and research articles. Each news item reflects another step toward a more complete and fuller understanding of our Universe.

# ...and PICTURES

## APRIL 2005 - MARCH 2006

### APRIL 2005

2 April 2005

#### First Stars seen in Distant Galaxies

**THREE LEADING** instruments, two orbiting and one on the ground, have detected light coming from the most distant galaxies ever observed, indicating it comes from the first stars to form when the universe was at a much earlier age.

The Spitzer Space Telescope and the Hubble Space Telescope teamed up with the 10-meter Keck telescope on Hawaii. The Hubble Ultra Deep Field image was used to select the most distant galaxies, and Spitzer and Keck were used to determine their nature.

"We used the images from the Hubble Ultra Deep Field to identify objects likely to be galaxies 95 per cent of the way across the observable Universe," said Andrew Bunker of the University of Exeter, England. "These images are our most sensitive picture of the Universe so far, and they enabled us to discover the faintest objects yet."

The Keck Deep Extragalactic Imager and Multi-Object Spectrometer (DEIMOS) was used to take spectra of the galaxies and they showed a redshift of 6, indicating the light left the galaxy at a time when the universe was only about 700 million years old.

"We proved these galaxies are indeed among the most distant known by using the Keck telescopes to take a spectrum," said Elizabeth Stanway (University of Wisconsin, Madison).

Seeing star formation in the early universe, shortly after the Big Bang, was not expected, but is supported by other observations. Following the Big Bang, the universe was filled with hot expanding gas, and no stars. The end of this so-called Dark Age occurred when the first stars turned on. The picture now forming is that the

Dark Ages probably ended between 200 and 500 million years after the Big Bang.

<http://www.keckobservatory.org/news/science/spitzer/050402.html>

<http://arxiv.org/abs/astro-ph/0508271>

5 April 2005

#### First Distance Measurement of a Gamma-Ray Burst Detected by Swift

The first distance measurements to Gamma-Ray Bursts (GRBs) detected by the new orbiting Swift spacecraft have been determined. Swift detected two bursts on March 18 and 19, called GRB 050318 and GRB 050319. Shortly after the announcement of the bursts went out, ground based telescopes swung into action to detect any afterglow. The redshift of the afterglow can lead to a distance determination. For GRB 050318 the distance was about 9.2 billion light years, and for GRB 050319 it was 11.6 billion light years.

"Swift will detect more gamma-ray bursts than any satellite that has come before it, and now will be able to pin down distances to many of these bursts too," said Peter Roming, UVOT Lead Scientist at Penn State. "These two aren't distance record-breakers, but they're certainly from far out there."

Swift was launched in November 2004, and provides very rapid acquisition of the location of a GRB to within a few arcminutes, alerting telescopes on the ground to perform follow-up observations. The goal is to understand what causes GRBs, a long standing puzzle since they were first detected over 30 years ago.

[http://swift.gsfc.nasa.gov/docs/swift/news/2005/uvot\\_redshift\\_psu.html](http://swift.gsfc.nasa.gov/docs/swift/news/2005/uvot_redshift_psu.html)

<http://xxx.lanl.gov/abs/astro-ph/0509060>

<http://xxx.lanl.gov/abs/astro-ph/0511132>

6 April 2005

## Era of Galaxy and Black Hole Growth Spurt Discovered

Galactic mergers triggering massive bursts of star formation in the distant universe appear to be rich nurturing grounds for the largest black holes. One of the longest duration exposures with the Chandra X-ray Observatory combined with the submillimeter and optical observations reveal very young galaxies just 3 to 4 billion years after the Big Bang experienced tremendous growth of their central black holes. The results provide the first direct evidence that the mass of stars in a galaxy is linked to the size of its central black hole.

"The extreme distances of these galaxies allow us to look back in time, and take a snapshot of how today's largest galaxies looked when they were producing most of their stars and growing black holes," said David Alexander of the University of Cambridge, UK.

Star formation rates indicated by the submillimeter observations from the James Clerk Maxwell Telescope (JCMT) and optical observations from the 10-m Keck telescope, both located on Mauna Kea in Hawaii, are about 100 times the rate in the Milky Way, or about one

star per day. Hubble images show the galaxies observed by JCMT were young merging pairs.

"The Keck observations allowed us to determine that these galaxies were forming their stars at a colossal rate," said Dr. Alexander. "Our detection of X-ray emission with Chandra indicates that their black holes were also growing at the same time. These findings provide direct observational support for the simultaneous growth of large galaxies and their black holes."

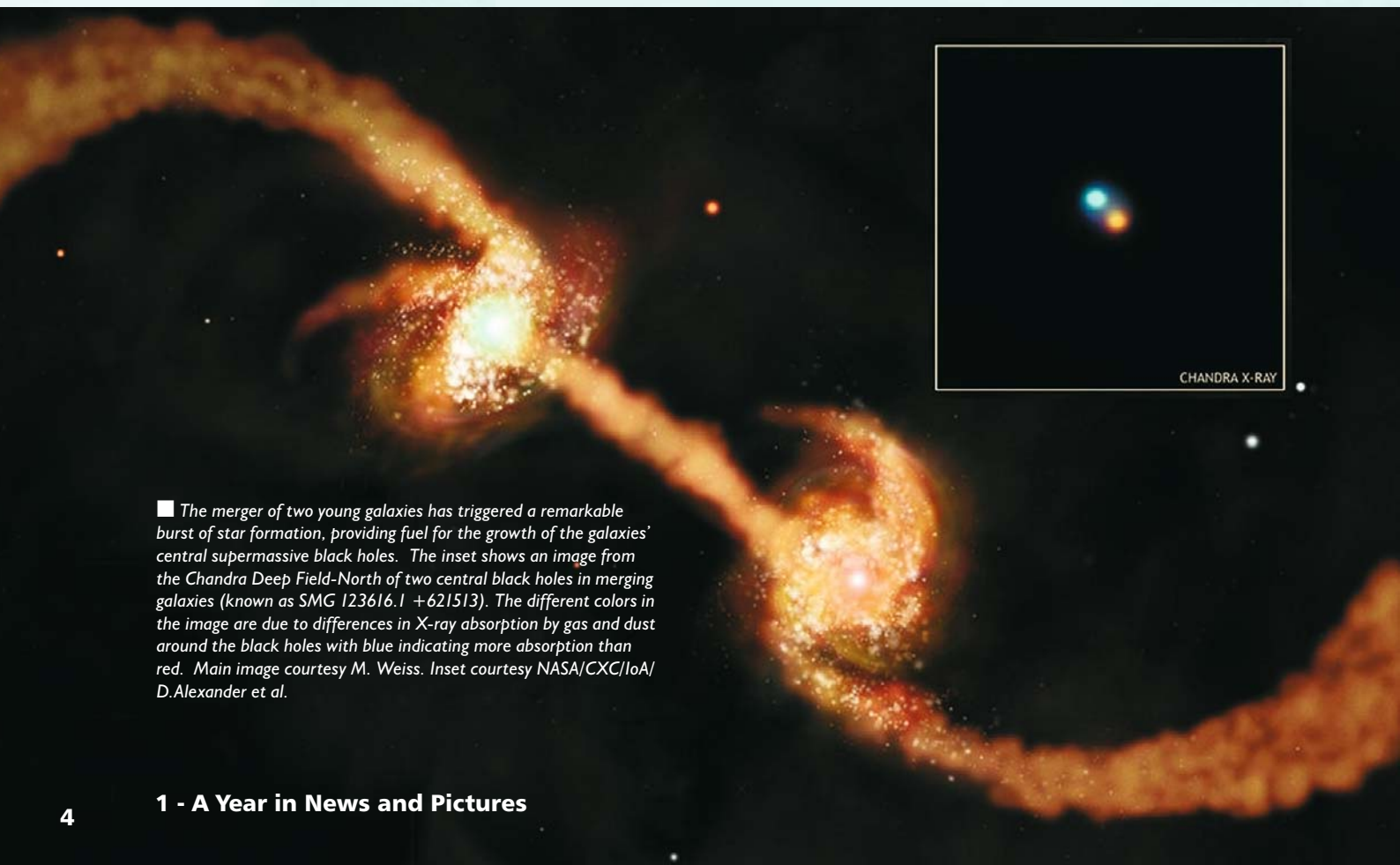
Supercomputer simulations by Tiziana Di Matteo of Carnegie Mellon University in Pittsburgh, Pennsylvania, show that the merging of two galaxies drives gas into the central regions of galaxies. The sudden inflow of material raises temperatures and pressures, triggers star formation, and provides ample fuel for feeding a central black hole.

"It is exciting that these recent observations are in good agreement with our simulation. We seem to be converging on a consistent picture of galaxy formation with both observations and theory," said Di Matteo.

[http://chandra.harvard.edu/press/05\\_releases/press\\_040605.html](http://chandra.harvard.edu/press/05_releases/press_040605.html)

<http://www.sr.bham.ac.uk/nam2005/pr9.html>

<http://xxx.lanl.gov/abs/astro-ph/0503453>



■ The merger of two young galaxies has triggered a remarkable burst of star formation, providing fuel for the growth of the galaxies' central supermassive black holes. The inset shows an image from the Chandra Deep Field-North of two central black holes in merging galaxies (known as SMG 123616.1 +621513). The different colors in the image are due to differences in X-ray absorption by gas and dust around the black holes with blue indicating more absorption than red. Main image courtesy M. Weiss. Inset courtesy NASA/CXC/IoA/D.Alexander et al.

7 April 2005

## Concentrated Dark Matter at the Cores of Fossil Galaxies

Ancient galaxy clusters typically harbor one very massive central galaxy, giving the impression that many of the original cluster members have merged into the single giant galaxy.

Recent X-ray observations of the hot gas surrounding such "fossil clusters" have shown a remarkable concentration of dark and normal matter in the cores of the clusters compared with more normal clusters.

"When we first discovered the large halos of hot gas in which some very compact groups of galaxies are embedded, we realized that just a few billion years of further evolution would leave a single, giant, merged galaxy sitting at the centre of a bright X-ray halo," said Trevor Ponman of the University of Birmingham, England.

Six fossil groups have been identified, most located up to two billion light years away. One of the largest is the giant elliptical galaxy, NGC 6482, located 100 million light years away in the constellation Hercules. This galaxy shines with the equivalent of 110 billion suns. The Chandra and XMM Newton X-ray observatories detected shocked gas in the cluster reaching 10 million degrees C. The heating is explained as coming from the gravitational collapse of the cluster.

Dark matter in the cluster is only detected by its gravitational influence, since it cannot be seen directly. The high temperature leads to a high density of material centered on NGC 6482. To build such structures takes a very long time.

"The explanation for such a centralized dark matter distribution could be that the system formed at very high redshift - when the Universe was very young and dense," said Habib Khosroshahi, also from the Birmingham team.

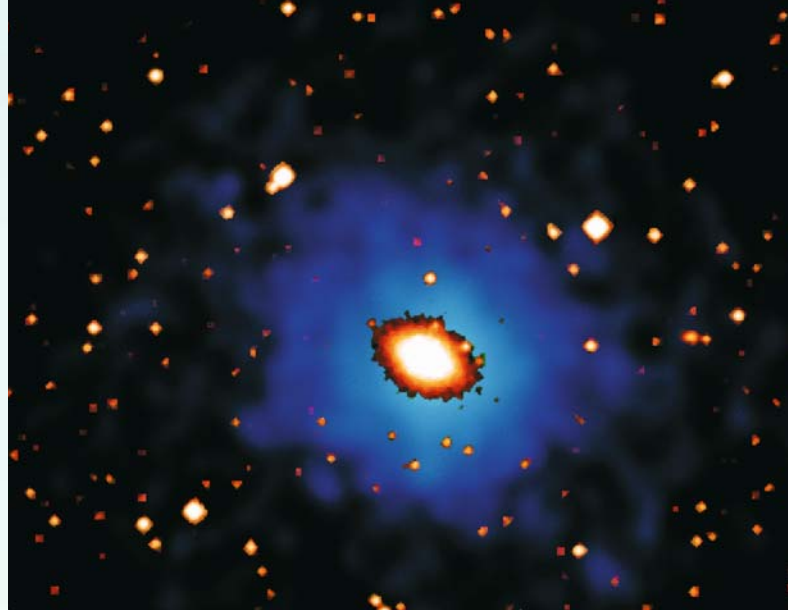
[http://chandra.harvard.edu/press/05\\_releases/press\\_040705.html](http://chandra.harvard.edu/press/05_releases/press_040705.html)

<http://xxx.lanl.gov/abs/astro-ph/0401023>

8 April 2005

## X-ray Vision of Violence in Interacting Galaxy Clusters

New results from the European Space Agency's orbiting XMM-Newton observatory are illuminating the massive cosmic "pile-ups" that occur between massive galaxies embedded in massive



clusters. The gas lying between galaxies is riddled with shock waves that raise its temperature to millions of degrees.

Astronomers used XMM Newton to map the gas distribution and temperature in three giant galaxy clusters and found collisions in clusters occur at up to about 2,000 kilometers per second.

Abell 1750 (A1750) contains two clusters 3 million light years apart just beginning to interact. They are located 1.1 billion light years from Earth. Slightly closer, at 800 million light years from Earth, is Abell 3266. A boomerang-shaped shock wave is caused by a smaller cluster starting to make headway into a more massive cluster. It's expected that the younger A1750 will look like this in a couple of billion years. A third and even older example is A3921, located 1.2 billion light years from Earth. The encounter of two clusters has already occurred, with the lighter cluster almost totally disrupted but leaving a region of shocked gas in its wake.

"This research shows the violent manner by which the largest structures in the Universe form, and that the formation has happened in the recent past," said Elena Belsole of the University of Bristol, England. "The process is still taking place today. In several billion years the group, of which our galaxy is a member, will be torn apart as it merges with the nearby Virgo cluster."

<http://xmm.vilspa.esa.es/>

<http://xxx.lanl.gov/abs/astro-ph/0501377>

■ **Above:** Chandra X-ray observations of the giant elliptical galaxy NGC 6482, at the centre of this image, show that it is surrounded by a vast cloud of hot gas (shown in blue), which has a temperature of about 10 million degrees Celsius. This giant galaxy is believed to have grown to its present size by cannibalizing its neighbors, leaving only the X-ray halo to tell the tale. Image courtesy Habib Khosroshahi and University of Birmingham, UK.

11 April 2005

## Scientists Track Collision of Powerful Stellar Winds

The powerful stellar winds of two stars in a binary system are colliding, generating radio waves. The Very Long Baseline Array (VLBA) radio telescope has provided unique details of these winds, providing new insight into the nature of the wind and of the stars themselves.

"The spectacular feature of this system is the region where the stars' winds collide, producing bright radio emission. We have been able to track this collision region as it moves with the orbits of the stars," said Sean Dougherty of the Herzberg Institute for Astrophysics in Canada.

One of the stars is a Wolf-Rayet type, weighing in at 20 times the mass of the Sun. The companion star is more than double this mass, at 50 solar masses. Wolf-Rayet stars are known for their violent stellar winds, and it impacts the lesser wind from the more massive companion. The binary system, called WR 140, has an orbital period of 7.9 years and the elliptical nature of the orbit changes the impact location of the winds and their relative effects on each other. The VLBA observations provide accurate observational data for more detailed modeling of the system.

"People have worked out theoretical models for these collision regions, but the models don't seem to fit what our observations have shown," said Mark Claussen, of the National Radio Astronomy Observatory in Socorro, New Mexico. "The new data on this system should provide the theorists with much better information for refining their models of how Wolf-Rayet stars evolve and how wind-collision regions work."

<http://www.nrao.edu/pr/2005/wr140/>

<http://xxx.lanl.gov/abs/astro-ph/0501391>

■ **Left:** Motion of the violent collision region where the powerful winds of two giant stars slam into each other. The region moves as the stars, part of a binary pair, orbit one another. This graphic superimposes VLBA images of wind collision region on diagram of orbit of Wolf-Rayet (WR) star and its giant (O-type) companion. Image courtesy Dougherty et al., NRAO/AUI/NSF.

19 April 2005

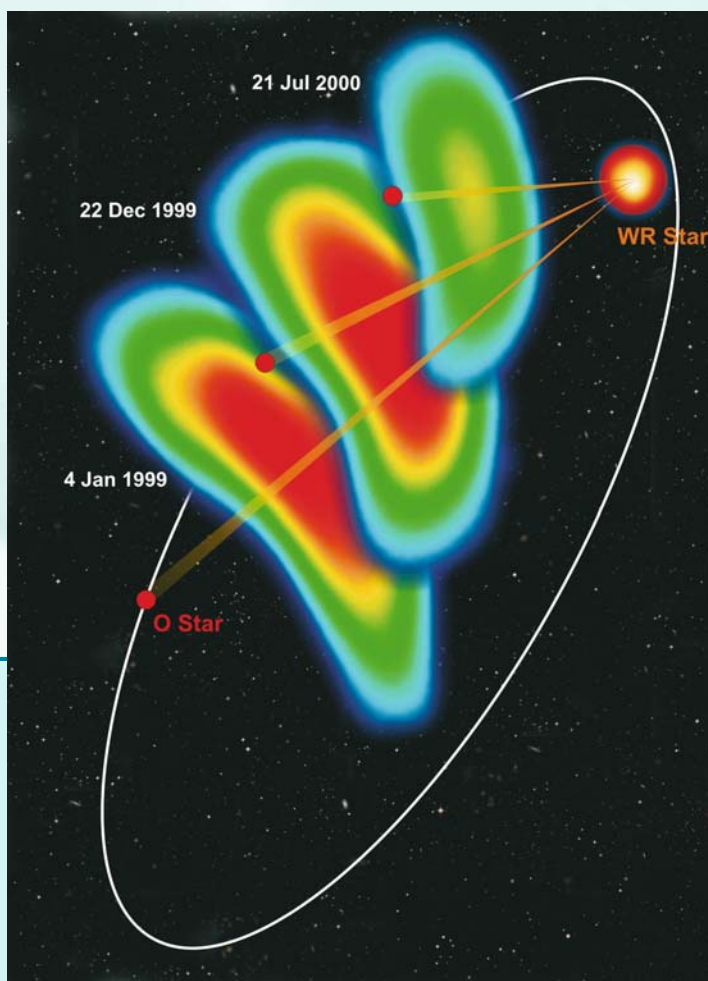
## Star Explosions on the Half Shell

The question of why some supernovae explosions appear to create a shell from the ashes around them, and yet others do not, has been one of those little troubling problems in astrophysics. The solution, it turns out, is to look long and hard at the supernovae that appear not to have shells.

Recently researchers at the University of Manitoba used the Chandra X-ray Observatory and spent 150 hours imaging one supernova remnant, and to their surprise, a very faint shell was visible that had previously been unseen.

The detection of the shell solves a decades-old mystery. Dr. Samar Safi-Harb and her graduate student, Heather Matheson, say that all star explosions likely create a shell; but some create a faint ('soft') shell, or only half of an easily detectable shell.

"Most star explosions make well-defined and colorful shells, the signature of a classic star explosion," says Safi-Harb. "But even some



famous explosions, such as the Crab Nebula, have no obvious shells. It could be that the Crab Nebula is like a soft-shell crab with a thin, barely visible shell."

The shells are formed when the heavier elements such as nitrogen, oxygen and iron, produced during the supernova explosion, strike the gas in the interstellar medium. They can exist for thousands of years after the initial explosion. X-rays are produced in these high energy collisions, and understanding such interactions is crucial to understanding how all the heavy elements become distributed throughout the universe. Supernovae are the delivery mechanism for all of the heavy elements that seed the interstellar medium with the raw materials that ultimately will go on to form dusty disks around a new generation of stars. These dusty disks can accrete to form planets. The carbon, nitrogen and oxygen vital for the development of life are, as observations show, scattered throughout interstellar gas clouds thanks to earlier supernovae explosions.

The remnant studied by Safi-Harb and Matheson, called G21.5-0.9, revealed only parts of a shell distributed around the supernova remnant. It's a relatively young remnant at a few thousand years old.

"This is sort of a supernova remnant served on the half-shell," says Matheson. "Why we don't see a full shell as we do around other supernova remnants is the next question we'd like to answer. Why there isn't one around the famous Crab Nebula is another mystery."

Variations in the density of the interstellar medium, and asymmetry in supernova explosions, are two of the likely explanations for the partial shells.

[http://chandra.harvard.edu/press/05\\_releases/press\\_041905.html](http://chandra.harvard.edu/press/05_releases/press_041905.html)

<http://xxx.lanl.gov/abs/astro-ph/0504369>



25 April 2005

## Hubble Celebrates 15th Anniversary with Spectacular New Images

The Hubble Space Telescope, a joint project between the European Space Agency and NASA, reached its 15-year anniversary in orbit, following its launch from the cargo bay of the Space Shuttle on 24 April 1990. To celebrate the event, and to highlight the more than three-quarters of a million images, in addition to the hundreds of thousands spectra, two very large images were released to the public. The two targeted objects are very well known: Eagle Nebula (M16) in Serpens, and Whirlpool Galaxy (M51) in Canes Venatici.

The Eagle Nebula image shows a massive column of dense gas and dust whose outer envelope is glowing by irradiation by ultraviolet light from a group of massive nearby stars.

■ **Above:** This image, made by combining 150 hours of archived Chandra data, shows the supernova remnant G21.5-0.9. The central bright cloud of high-energy electrons is surrounded by a distinctive shell of extremely hot gas. Although many supernovae leave behind bright shells, others do not. This supernova remnant was considered to be one that had no shell until it was revealed by Chandra. Image courtesy NASA/CXC/ Univ.Manitoba/H.Matheson and S.Safi-Harb.



■ This image acquired by the Advanced Camera for Surveys on NASA's Hubble Space Telescope shows a soaring pillar of cold gas and dust within a stellar nursery called the Eagle Nebula (M16). The pillar is a giant incubator for newborn stars. A torrent of ultraviolet radiation from a group of massive, hot, young stars [off the top of the image] is steadily eroding the pillar and sculpting fantasy-like landscapes in the gas. Image courtesy NASA, ESA and The Hubble Heritage Team (STScI/AURA).

Such pillars are the nurseries for thousands of new stars. Light from the embedded stars can be detected by infrared radiation, but in this Hubble image they are shrouded by their dusty cocoons hidden in the giant column.

The Whirlpool Galaxy image reveals hundreds of pink glows from HII star-forming regions that delineate the spiral arms, enhanced by spidery dust lanes and massive clusters of hot stars. The companion galaxy that passed through the plane of M51 and now lies behind it has dragged, by gravitational interaction, one of the spiral arms out of place.

The new images celebrate the major list of scientific achievements of the Hubble Space Telescope:

- **Helped astronomers calculate the precise age of the universe (13.7 billion years old);**
- **Helped confirm the existence of a strange form of energy called dark energy;**
- **Detected small proto-galaxies that emitted their light when the universe was less than a billion years old;**
- **Proved the existence of super-massive black holes;**
- **Provided sharp views of a comet hitting Jupiter;**
- **Showed that the process of forming planetary systems is common throughout the galaxy;**
- **Taken more than 700,000 snapshots of celestial objects such as galaxies, dying stars, and giant gas clouds where stars are born.**

<http://hubblesite.org/news/2005/12>

<http://heritage.stsci.edu/2005/12a>