

STATE OF THE UNIVERSE 2008

Martin Ratcliffe

STATE OF THE UNIVERSE 2008

NEW IMAGES, DISCOVERIES, AND EVENTS



Published in association with
Praxis Publishing
Chichester, UK



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Wichita
Kansas
USA

Front cover illustration: This infrared image from NASA's Spitzer Space Telescope shows the Helix nebula, the remains of a star that once looked like our Sun. When sun-like stars die, they puff out their outer gaseous layers. These layers are heated by the hot core of the dead star, called a white dwarf, and shine with infrared and visible colors. In Spitzer's view of the Helix nebula, infrared light from the outer gaseous layers is represented in blues and greens. The white dwarf is visible as a tiny white dot in the center of the picture. The red color in the middle of the eye denotes the final layers of gas blown out when the star died. Image courtesy NASA/JPL-Caltech/K. Su (Univ. of Arizona).

Back cover illustration: **(Top)** This image taken with the Advanced Camera for Surveys on NASA's Hubble Space Telescope depicts bright, blue, newly formed stars that are blowing a cavity in the center of a star-forming region in the Small Magellanic Cloud. Image courtesy NASA, ESA, and the Hubble Heritage Team (STScI/AURA) - ESA/Hubble Collaboration. **(Middle)** This composite image shows the Crab Nebula, the remains of a colossal stellar explosion called a supernova. The Chandra X-ray image is shown in light blue, the Hubble Space Telescope optical images are in green and dark blue, and the Spitzer Space Telescope's infrared image is in red. Image courtesy NASA, ESA, CXC, JPL-Caltech, J. Hester and A. Loll (Arizona State Univ.), R. Gehrz (Univ. Minn.), and STScI. **(Bottom)** This image by the Chandra X-ray Observatory shows Cassiopeia A, the youngest supernova remnant in the Milky Way. The red and green regions show material from the destroyed star that has been heated to millions of degrees by the explosion. Image courtesy NASA/CXC/MIT/UMass Amherst/M.D.Stage et al.

SPRINGER-PRAXIS BOOKS IN POPULAR ASTRONOMY
SUBJECT ADVISORY EDITOR: John Mason B.Sc., M.Sc., Ph.D.

ISBN: 978-0-387-71674-9 Springer Berlin Heidelberg New York

Springer is a part of Springer Science + Business Media (*springeronline.com*)

Library of Congress Control Number: 2007936093

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Cover design and cartoons: Jim Wilkie
Typesetting and design: BookEns Ltd, Royston, Herts., UK

Printed in Germany on acid-free paper

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■ **Pink Pleiades.** The Seven Sisters, also known as the Pleiades star cluster, seem to float on a bed of feathers in this infrared image from NASA's Spitzer Space Telescope. Clouds of dust sweep around the stars, swaddling them in a cushiony veil. The 19th-century poet Alfred Lord Tennyson described them as, "glittering like a swarm of fireflies tangled in a silver braid." The spider-web-like network of filaments, colored red in this view, is made up of dust associated with the cloud through which the cluster is traveling. One of the parent stars, Electra, can be seen extreme right, with the other three brightest members of the cluster above right and below left of center. Additional stars in the cluster are sprinkled throughout the picture in blue. Image courtesy NASA/JPL-Caltech/J. Stauffer (SSC/Caltech).

Preface

STATE OF THE UNIVERSE 2008

WELCOME TO the second volume of a popular level annual review of astronomical discoveries, State of the Universe 2008. In these pages you'll find easy-to-read, bite-sized sections of news from beyond our solar system, covering gamma-ray bursts and black holes to the newest extrasolar planet research and more, over a full 12-month period (April 2006 to March 2007).

In addition to the selected review of the top stories, I've invited ten authors and astronomers to contribute broader overviews of specific topics that are at the forefront of current research, placing the chronological news stories into a broader context.

I am particularly thankful to the research astronomers who gave of their valuable time to write these reviews, in between writing grant proposals, presenting papers at conferences, and actually observing with the world's best telescopes. Without their passion for communicating what they do to a broader audience, this book would be far less interesting.

I am pleased to welcome back for a second year, Jim Kaler, whose review of top news from the 12-months provides a versatile and insightful

segue from the news bites to the rest of the invited articles.

Seasoned science writer, Carolyn Collins Petersen, joins us for the first time. She reviews the latest news in low frequency arrays, and the prospects for major discoveries from studying long radio waves.

Planet formation and star formation are intimately linked, and I've invited four experts to review the current state of our knowledge in this rapidly developing field of research. Stephen Strom and Luisa Rebull review star formation, with the latest that the Spitzer Space Telescope is telling us. James Graham and Paul Kalas focus on their newest discoveries inside planetary debris disks.


The latest discoveries from the Chandra X-ray Observatory, one of NASA's Great Observatories, are reviewed by Chandra expert, Wallace Tucker. Observing at the other end of the electromagnetic spectrum is one of America's national treasures, the National Radio Astronomy Observatories. NRAO's Public Information Officer, David Finley, reviews recent discoveries made from its outstanding facilities.

The Sloan Digital Sky Survey (SDSS) has already revolutionized astronomy. One of the SDSS astronomers, Timothy Beers, contributes a feature reviewing another exciting year of discovery.

Hubble Servicing mission Project Scientist, Chris Blades, from the Space Telescope Science Institute, writes a timely and authoritative review of the exciting mission to update the Hubble Space Telescope, expected to occur in late 2008.

■ *The Great Cometary Show. Comet McNaught, the Great Comet of 2007, put on an impressive show for observers in the Southern Hemisphere. Astronomers in Chile, in particular at the Paranal Observatory, were able to capture amazing images, including this view on the evening of 16 January 2007. Two of the four VLT Auxiliary Telescopes are seen in the foreground. Image courtesy European Southern observatory (ESO).*





■ *The starburst galaxy NGC 1313. The very active state of this galaxy is evident from this composite image, showing many star formation regions. A great number of supershell nebulae – cocoons of gas inflated and etched by successive bursts of star formation – are visible. Images obtained with the FORSI instrument on one of the 8.2-m Unit Telescopes of the ESO Very Large Telescope. The data were extracted from the ESO Science Archive and fully processed by Henri Boffin (ESO).*

Jerry Nelson, whose bright revolutionary idea led directly to the construction of the twin 10-meter Keck telescopes, writes about the 400th anniversary of the telescope. He offers a unique insight into the exciting future of giant telescope construction and adaptive optics.

Alexei Filippenko, an award-winning teacher at UC Berkeley and a leading researcher of one of the teams that discovered the accelerating universe, introduces us to that greatest of mysteries, Dark Energy, in a highly readable article.

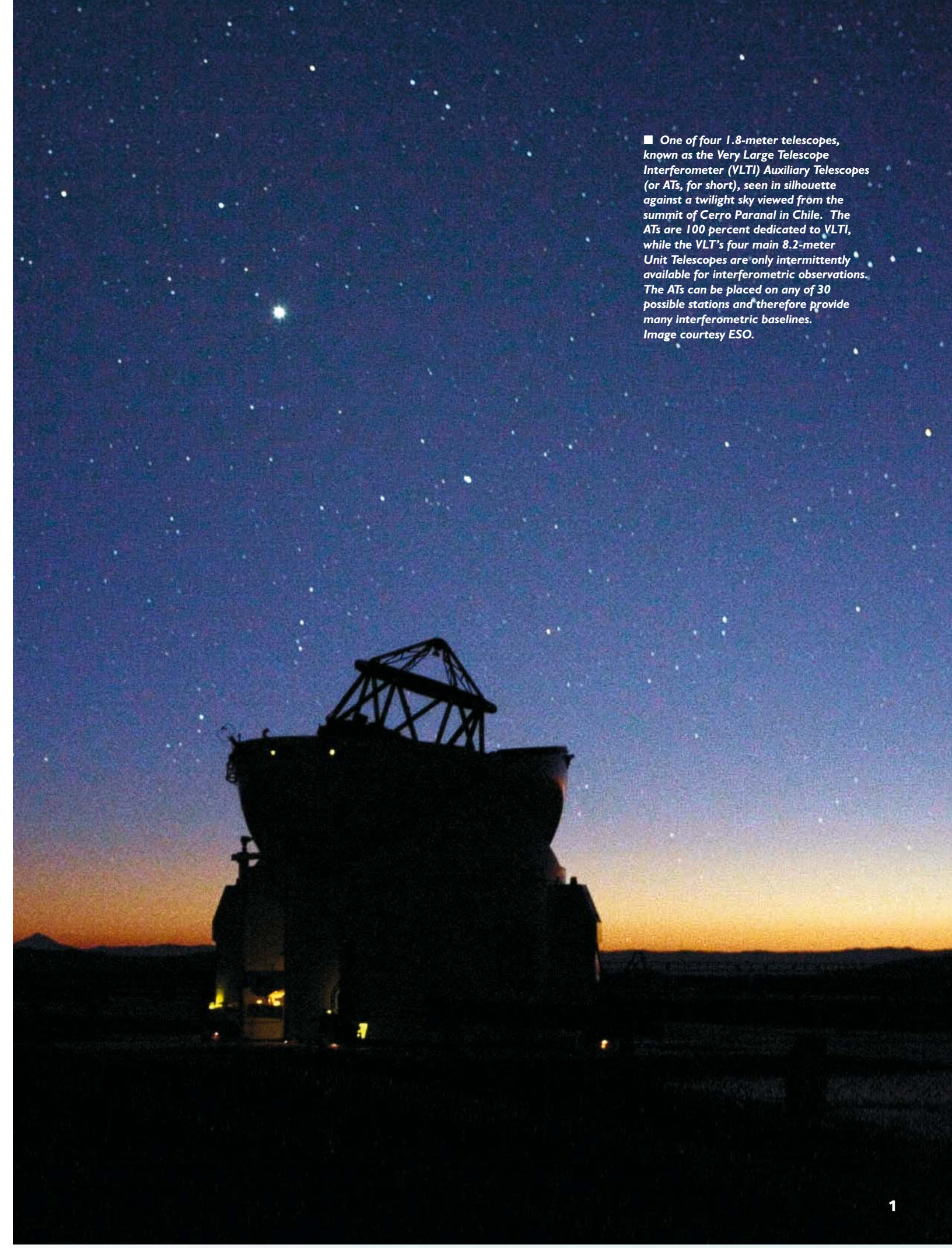
The book begins with my annual review of selected top news stories, complete with web links for further reading. I encourage you to take the internet journey; it will enrich your reading, and even link you to the original research papers. This book is a gateway to enormous resources, and is enough to keep you busy for an entire year, that is, until the third volume.

No book is possible without family support, and this one is no exception. For many weekends over six months, “the book” has been a constant presence at home, and for that I am eternally grateful to my wife, Shawn, for her love and active “you need to write” encouragement.

Martin Ratcliffe
Wichita, Kansas
August 2007



Martin Ratcliffe is Director of Professional Development for Sky-Skan, Inc., a digital planetarium manufacturer. For 12 years he has written the monthly night sky column for Astronomy magazine, and is a former President of the International Planetarium Society. Following an astronomy degree from University College London, he has spent 20 years running various planetariums and teaching astronomy.



■ One of four 1.8-meter telescopes, known as the Very Large Telescope Interferometer (VLT) Auxiliary Telescopes (or ATs, for short), seen in silhouette against a twilight sky viewed from the summit of Cerro Paranal in Chile. The ATs are 100 percent dedicated to VLT, while the VLT's four main 8.2-meter Unit Telescopes are only intermittently available for interferometric observations. The ATs can be placed on any of 30 possible stations and therefore provide many interferometric baselines. Image courtesy ESO.

1

A year in

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 2006 and March 2007. Each story profiles the main news and provides weblinks, allowing exploration of further details, images and the actual research articles, bridging the gap between short news bites and the original science.

...and PICTURES

APRIL 2006 - MARCH 2007

APRIL 2006

4 April 2006

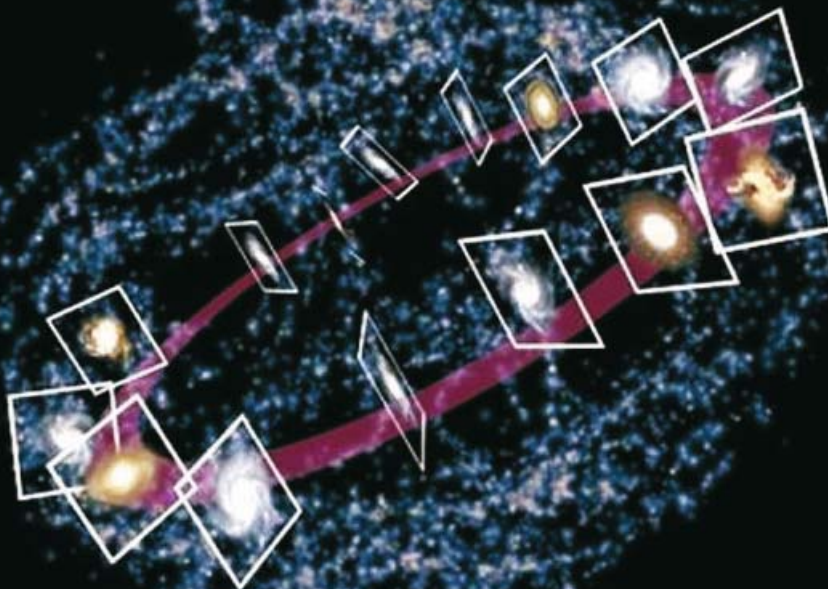
Galaxies Align Forming String of Beads

Astronomers have found that spiral galaxies are not randomly oriented in space. They appear to be preferentially aligned. The dramatic results come from a careful study of two huge galaxy surveys, the Sloan Digital Sky Survey and the Two-Degree Field Galaxy Redshift Survey, combined with precise locations of known voids, large spaces lacking in bright galaxies.

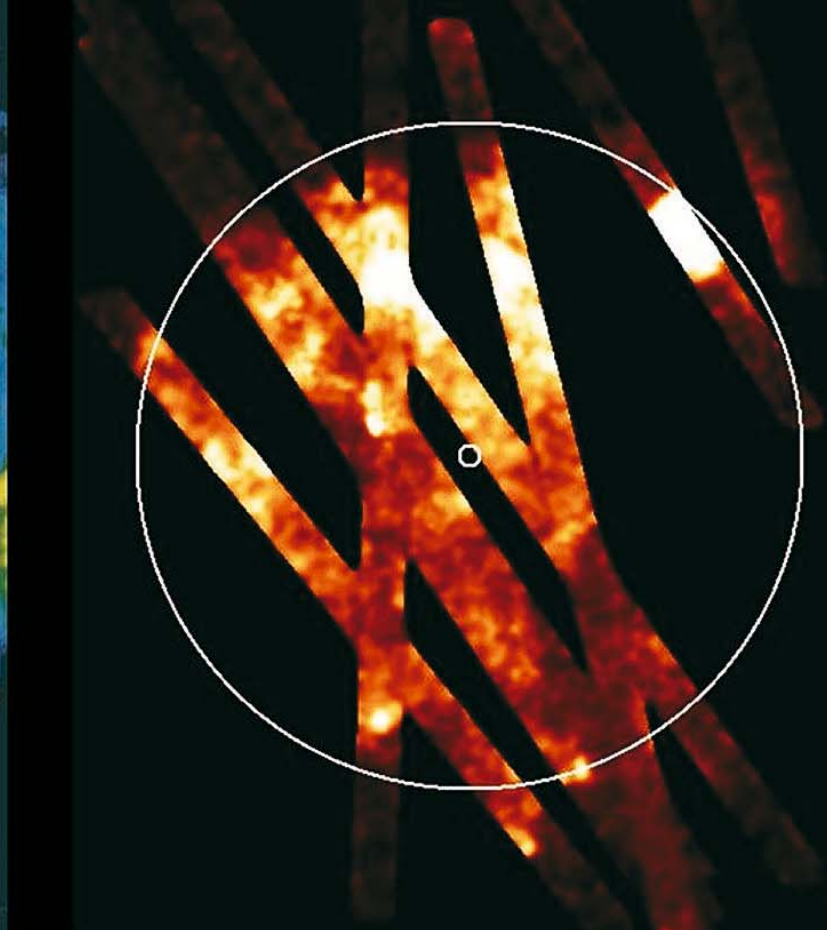
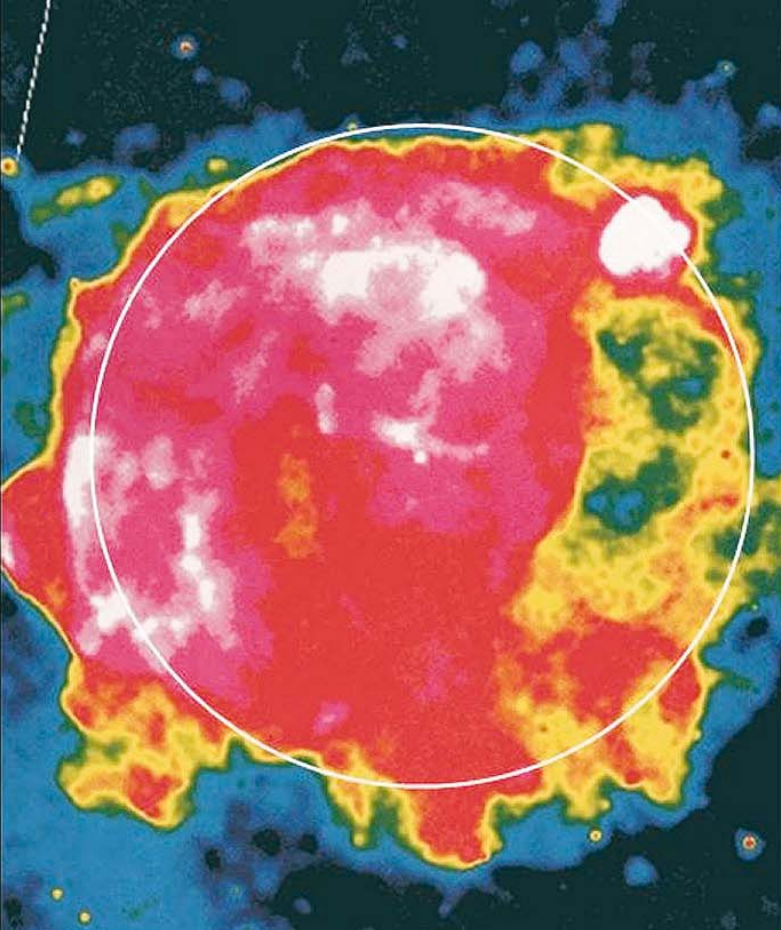
Throughout the universe, galaxies are known to be distributed along filaments surrounding large, bubble-like voids, creating a web-like large scale structure. Predictions made by supercomputer modeling of the universe show that following the Big Bang, this labyrinth-like structure forms as a natural consequence of the gravitational interaction of dark matter. Galaxies are the visible “tip-of-the-iceberg” to this primordial dark matter distribution.

Fred Hoyle, in 1951, and Jim Peebles, in 1969, studied the theoretical implications of the primordial matter distribution and its effects on the spin of galaxies or, more accurately, their angular momentum.

In the prevailing tidal torque theory (TTT), galaxies acquire angular momentum from tidal shear induced by the distribution of primordial matter. Such modeling predicts galaxies should be oriented perpendicular to the direction of the linear filaments of the large scale structure. Several



■ **Left:** 4 April 2006. The spin axes of spiral galaxies appear to be aligned with the large scale filaments that surround giant voids. Theory predicted such alignments due to the way infalling primordial gas pooled to form the first galaxies, but observational proof was absent until now. Image courtesy Gabriel Pérez Díaz, MultiMedia Service (IAC).



groups had searched for the alignments in the 1980s and 1990s. The difficulties lay in the accurate determination of galaxy orientation to the filamentary large scale structure.

The new results represent confirmation of the predictions. A team led by Dr. Ignacio Trujillo of the University of Nottingham, including astronomers from the Instituto de Astrofísica de Canarias (Spain), developed a successful analysis.

"We found that there is an excess of disk galaxies that are highly inclined relative to the plane defined by the large-scale structure surrounding them," said Dr. Trujillo. "Their rotation axes are mainly oriented in the direction of the filaments." The discovery opens the way to a deeper understanding of the formation of galaxies from the large scale structure of the universe.

<http://www.iac.es/gabinete/noticias/2006/m03d31e.htm>

<http://www.sdss.org/>

<http://xxx.lanl.gov/abs/astro-ph/0511680>

4 April 2006

XMM Newton Slew Survey Reveals Secrets of X-ray Sky

Space-based telescopes are under great demand to observe as many objects in the sky as possible. However, there is limited time for observing each target, and a significant amount of time is spent slewing the telescope from one target to another. This maneuvering results in lost time for observing. Now, astronomers using the European Space Agency's XMM-Newton X-ray observatory have a new approach to analyze X-rays collected during these slewing periods.

The new technique has resulted in the detection of over 4,000 X-ray bright objects, ranging from close binary stars where matter from one star collides and explodes on the surface of its neighbor, to active galaxies, and outwards to distant quasars 10 billion light-years from Earth.

The XMM-Newton Slew Survey is the deepest hard-band all-sky survey ever performed, probing ten times deeper than all previous surveys. The energy range spans the 0.2 – 2 keV band, matching the ROSAT survey from the 1990s, but also extending to harder X-rays in the 2 – 12 keV band.

■ **Above:** 4 April 2006. A comparison of the Vela supernova remnant from ROSAT (left) and XMM Slew Survey (right), reveals some similar features and some that have apparently changed and are presumably variable. A 3.5-degree radius circle on both images acts as a useful guide to compare features. The small circle on the XMM-Newton Slew image indicates the position of the Vela pulsar. Image courtesy Andy Read (University of Leicester, UK), ESA, the Max-Planck-Institut für Extraterrestrische Physik and the ROSAT Mission.

Indicative of the kinds of new results being obtained is a slew across the Vela supernova remnant, recording in just a few seconds similar features previously requiring dedicated pointing by ROSAT. Many variable sources are evident between the two images. Another result is a dramatically brighter distant elliptical galaxy, NGC 3599. Located 40 million light-years away, this normally quiet galaxy shows up 200 times brighter in X-rays than in previous observations made by ROSAT. An active supermassive black hole at the galaxy's core may be the culprit.

As UK astronomer Dr. Andrew Read, of Leicester University in England, explains, "Over a quarter of the entire sky has already been covered in the 400 or so slews so far performed ... giving us large scale views of the biggest X-ray objects in the sky". Dr. Read expects the entire sky will be covered during the lifetime of the XMM-Newton mission.

<http://www.star.le.ac.uk/~amr30/Slew/>

<http://sci.esa.int/xmm/>

<http://arxiv.org/abs/astro-ph/0610070>

<http://arxiv.org/abs/astro-ph/0512157>

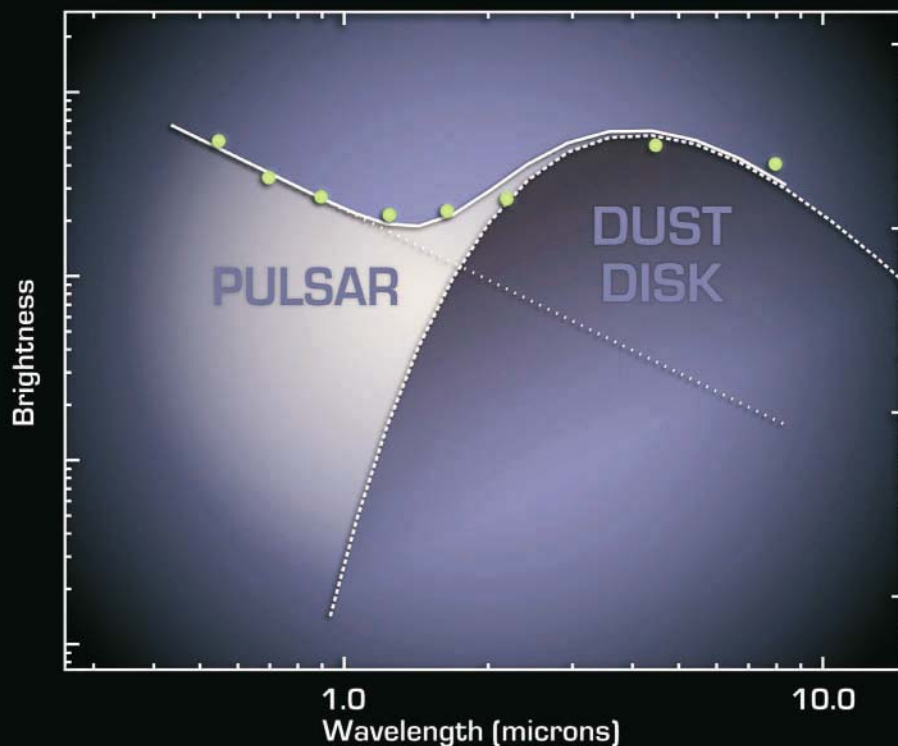
5 April 2006

Gemini/HST Survey Reveals Building-block Process in Evolution of Massive Galaxy Clusters

In March 2005 the first results from a survey of near and far galaxies, using the Hubble Space Telescope and the twin 8-meter Gemini telescopes, suggested that current theories of how galaxies evolved from their early beginnings to seniority may require some revision. The problem lies in the fact that if the stars in early galaxies simply got older, they would not look like the galaxies we see in large clusters today. Those first results suggested such "passive evolution" is the incorrect model for the history of star formation within galaxies. New results from galaxy cluster Abell 1689, studied by astronomers with the Gemini/HST Galaxy Cluster Project, support the requirement for new thinking.

The passive evolution model showed that galaxies in the center of large clusters produced stars early in their lifetimes and then aged without further changes. The new results reveal that stars in young distant galaxy clusters are very different from those in older, nearby clusters.

When we see galaxies at different distances we are looking back in time. By comparing the chemical makeup of stars in both distant and nearby galaxy clusters, the chemical evolution of galaxies can be determined. The Gemini



■ **Left:** 5 April 2006. This chart shows the spectrum of the pulsar 4U 0142+61 taken by the Spitzer Space Telescope (SST). It reveals the tell-tale infrared hump that identifies a dusty disk around the dead core of a star, the first ever detection of fallback material following a supernova explosion. The two green dots on the right represent data from SST, and are combined with other data from ground based telescopes. The predicted contributions of light from the pulsar and the dust disk are shown by dotted lines. Image courtesy NASA/JPL-Caltech.

Multi-Object Spectrograph enables the required analysis of starlight.

"We found the earliest galaxy clusters have a huge variation in the abundances of elements such as oxygen and magnesium, whereas the chemistry of galaxies in the sample of closer clusters appears to be much more homogeneous," explained Dr. Jordi Barr of Oxford University, England.

The observations suggest that the young clusters acquired more elements from mergers with other galaxies. The results also show that lower mass galaxies sustain star formation for about four times longer than their more massive cousins. If a lower mass galaxy which had greater chemical mixing caused by prolonged star formation later merged with a massive galaxy, triggering a new burst of star formation, the chemical makeup would become more homogeneous in the resulting merged galaxy.

Barr adds, "This difference in chemistry proves that the clusters must actively change over time. If the galaxies in the old clusters have acquired a complete "set" of elements, it's most likely that they have formed from the mergers of several young galaxies".

http://hubblesite.org/gallery/album/entire_collection/pr2003001a/

<http://arxiv.org/abs/astro-ph/0608150>

<http://arxiv.org/abs/astro-ph/0601403>

5 April 2006

Spitzer Space Telescope Finds Hints of Planet Birth Around Dead Star

In another first for the Spitzer Space Telescope, infrared observations have uncovered a planet-forming debris disk around a pulsar, the compact remains of a supernova explosion. The idea that material can remain around a pulsar following the explosive death of a star is not new. Astronomers call the debris that has insufficient velocity to escape "fallback". Theoretical models suggest that fallback can trigger the collapse of a neutron star to form a black hole, but until now, observational evidence of fallback material has never existed. If the fallback has sufficient angular momentum it may form a rotating disk of material around the pulsar.

Spitzer found evidence of the disk, resembling those found around young stars, from its infrared glow, and weighs in at an estimated ten Earth masses. The estimated lifetime of the

disk exceeds the pulsar spin-down period of at least a million years, suggesting the possibility of some of the material sticking together to form planets. The pulsar, called 4U 0142+61, lies in Cassiopeia 13,000 light-years away.

Due to the extreme environment, with harsh X-rays illuminating the disk, any future planets would be unlikely to produce any life. Yet thanks to "fallback", the debris disk does form. "We're amazed that the planet-formation process seems to be so universal," said Dr. Depto Chakrabarty of the Massachusetts Institute of Technology in Cambridge. "Pulsars emit a tremendous amount of high energy radiation, yet within this harsh environment we have a disk that looks a lot like those around young stars where planets are formed."

These observations provide a missing link between the 1992 discovery of three planets orbiting the pulsar PSR B1257+12 by Aleksander Wolszczan. They were the first planets found outside our solar system.

The team, including Chakrabarty and MIT colleagues, Zhongxiang Wang and David Kaplan, also surveyed four other pulsars and didn't find any disks. However, calculations show that deeper infrared observations with Spitzer could detect one around Puppis A.

<http://www.spitzer.caltech.edu/Media/releases/ssc2006-10/index.shtml>

<http://xxx.lanl.gov/abs/astro-ph/0604076>

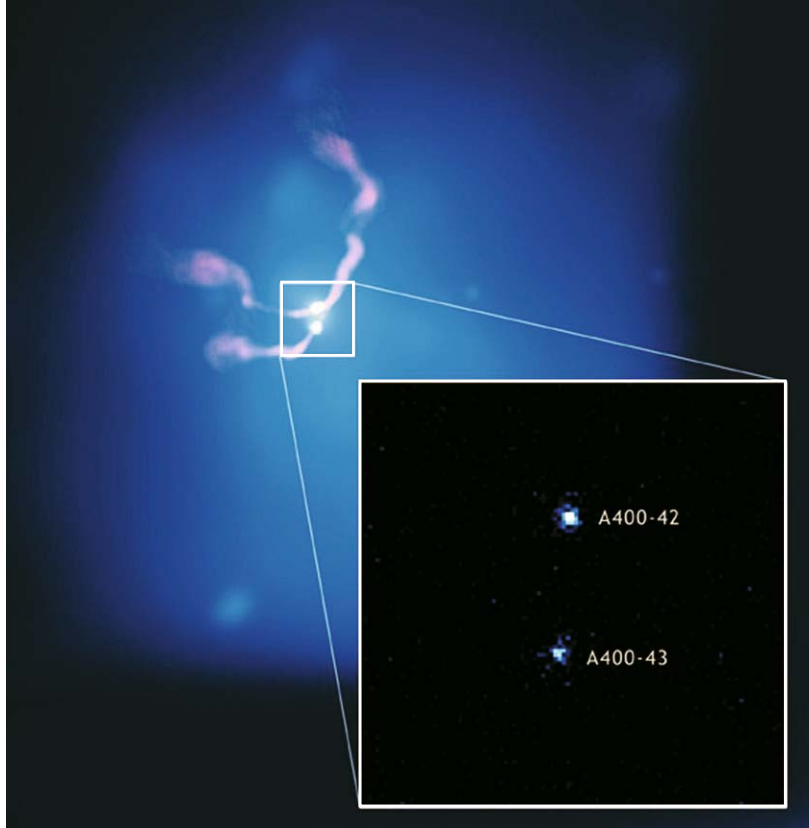
<http://xxx.lanl.gov/abs/astro-ph/0606686>

5 April 2006

Swift Observes an Unusual Bang in the Far Universe

Gamma-ray bursts continue to be a hot topic as more and more GRBs are detected by the highly successful orbiting Swift observatory. While many bursts fit a growing pattern, either a massive star collapsing to form a black hole, or a merger of a neutron star and a black hole, once in a while a burst occurs that doesn't fit any of the current models.

Newly announced studies of a gamma-ray burst that occurred on 1 August 2005 provided the first evidence of a different type of burst, perhaps the result of the formation of a rare kind of neutron star. The new burst occurred 9 billion light-years from Earth.



6 April 2006

Study Finds Two Supermassive Black Holes Spiraling Toward Collision

Astronomers using the Chandra X-ray Observatory have detected a pair of supermassive black holes at the center of the galaxy cluster, Abell 400. Eventually, if the two supermassive black holes are orbiting each other, they will spiral in toward a merger.

The two black holes lie at the center of two active galactic nuclei (AGN) that currently lie about 25,000 light-years apart. The AGNs are observed as the double radio source in 3C 75, discovered in the mid-1980s by the Very Large Array in Socorro, New Mexico. Data taken from the VLA show two pairs of intertwined jets of plasma emanating from each AGN. The oppositely-directed jets are distorted by the passage of the pair of galaxies through the intragalactic hot X-ray gas in which they are embedded. Supermassive black holes are presumed to be the source of jets in AGNs. Careful analysis of the way the two pairs of jets are intertwined, by astronomers from the University of Virginia, Bonn University, and the U.S. Naval Research Laboratory, show that the pair of black holes are gravitationally bound.

Craig Sarazin from the University of Virginia explains, "The jets are similar to the contrails produced by planes as they fly through the air on Earth. From the contrails, we can determine where the planes have been, and in which direction they are going. What we see is that the jets are bent together and intertwined, which indicates that the pair of supermassive black holes is bound and moving together."

In the distant future when the two black holes do collide, gravitational waves will be emitted. Understanding the frequency of such mergers will aid the development of future gravitational wave detectors. In 2002, the Chandra Observatory observed a similar pair of supermassive black holes, but at a much later stage of evolution, in the core of the galaxy NGC 6240. (See also 18 April and 1 May stories.)

<http://chandra.harvard.edu/photo/2006/a400/>
<http://xxx.lanl.gov/abs/astro-ph/0603272>

Typically, a burst is followed by a slowly fading afterglow in X-rays and optical wavelengths. Most long bursts are thought to be caused by a black hole swallowing a large star.

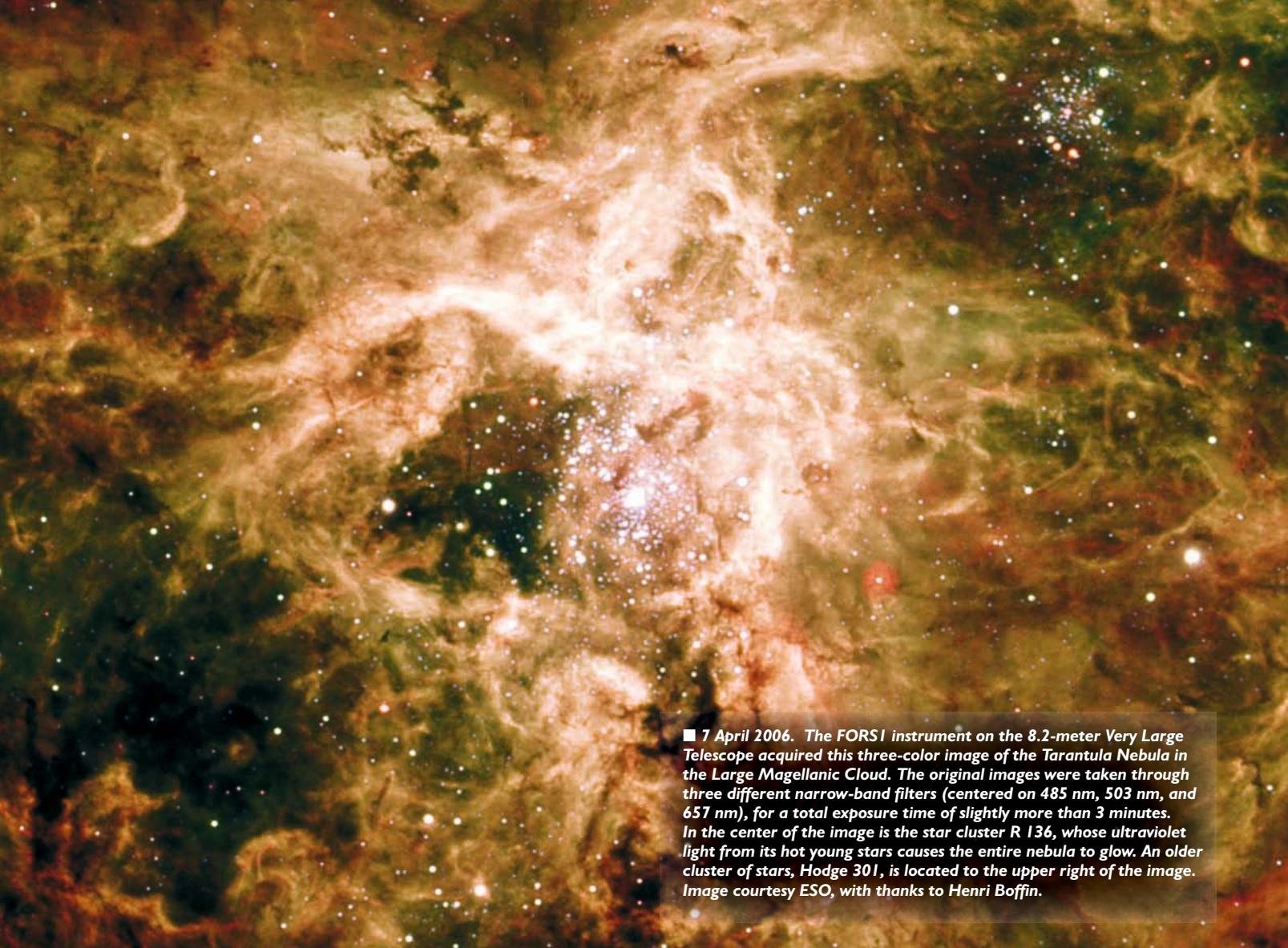
The 1 August event (called GRB 050801) did show the usual afterglow but the initial bright flare was missing. A steady emission for over 4 minutes in X-rays and optical eventually led to a normal type of fading. The level of bright emission has not been seen before, and provides hints to the nature of the central engine powering the burst.

"This feature might be explained if we assume that, rather than a black hole, the core of the star has shrunk its mass and its magnetic field into an object known as a magnetar," said Massimiliano De Pasquale of the Mullard Space Science Laboratory (MSSL), University College, London. Magnetars are unusually rare neutron stars with a magnetic field thousands of times stronger than typical pulsars.

The observations were aided by the earliest detection from the ground of the optical afterglow following the burst detection by the orbiting Swift observatory. The automated ROTSE-IIIC telescope at the H.E.S.S. site in Namibia, was imaging the location 21.8 seconds after Swift's initial detection. ROTSE III is a worldwide network of four robotic telescopes built for fast automated response to triggers from orbiting gamma-ray observatories such as Swift.

<http://swift.gsfc.nasa.gov/>
<http://xxx.lanl.gov/abs/astro-ph/0601350>

■ **Above left:** 6 April 2006. This image is a composite of X-ray (blue) and radio (pink) images of 3C 75 located in the galaxy cluster Abell 400. It shows the twin pair of radio jets immersed in a vast cloud of multi-million degree X-ray emitting gas that fills the cluster. The jets emanate from the vicinity of two supermassive black holes (also shown inset). These black holes are in the dumbbell galaxy NGC 1128 at the center of the giant radio source 3C 75. Images courtesy NASA/CXC/Alfa/D. Hudson & T. Reiprich et al. – X-ray; NRAO/VLA/NRL – Radio.



■ 7 April 2006. The FORS1 instrument on the 8.2-meter Very Large Telescope acquired this three-color image of the Tarantula Nebula in the Large Magellanic Cloud. The original images were taken through three different narrow-band filters (centered on 485 nm, 503 nm, and 657 nm), for a total exposure time of slightly more than 3 minutes. In the center of the image is the star cluster R 136, whose ultraviolet light from its hot young stars causes the entire nebula to glow. An older cluster of stars, Hodge 301, is located to the upper right of the image. Image courtesy ESO, with thanks to Henri Boffin.

7 April 2006

VLT FORS Image of the Inner Parts of the Tarantula Nebula

The Tarantula nebula, located at the northern end of the Large Magellanic Cloud, is a spectacular star forming region located 170,000 light-years away. It's one of the largest such clouds visible in detail from Earth, and consequently the target of many telescopes. In a newly-released image by the European Southern Observatory's Very Large Telescope (VLT), one of the largest and most advanced telescopes on Earth, the fine detail of the glowing tendrils of this magnificent nebula are revealed.

The VLT is a set of four 8.2-meter telescopes atop Cerro Paranal in Chile. This image was acquired in 2002 and 2003 using one of the four giant telescopes, and photographed through three selected color filters. The three filters allowed light centered on three wavelengths to be recorded, at 485 nanometers, 503 nm, and 657 nm. With a total exposure of about 3 minutes,

the three individual images were later combined to produce a color picture.

A giant young cluster of hot blue stars called R 136 causes the nebula to glow. Their ultraviolet radiation penetrates clouds of hydrogen gas causing it to re-emit light with a distinctive pink color at a wavelength of 656.3 nanometers. R 136 contains many massive stars, some over 50 times the mass of our Sun. The cluster is estimated to be two to three million years old.

To the upper right of the image is another cluster, called Hodge 301. This is about ten times older than R 136, as indicated by the number of stars that have progressed to the red giant stage.

The images were taken with the FORS1 instrument (focal reducer and low resolution spectrograph), which contains a 2048 x 2046 pixel camera capable of producing a resolution of 0.2 arcseconds on an 8.2 meter telescope.

<http://www.eso.org/outreach/press-rel/pr-2006/pr-13-06.html>

<http://xxx.lanl.gov/abs/astro-ph/0501568>

<http://xxx.lanl.gov/abs/astro-ph/9910426>

18 April 2006

Breakthrough in Black Hole Simulation

Colliding black holes provide scientists with the most extreme environments in which to test Einstein's General Theory of Relativity. Predictions of the appearance of gravitational waves from such encounters have proved extremely hard to calculate, until now. Scientists at NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Maryland, successfully ran the largest 3D astrophysical simulation ever performed on NASA's supercomputer, called Columbia. Previous attempts had caused computer crashes, so the recent success was particularly welcoming to the group who devised new ways of translating Einstein's equations into a code the computer could handle.

The simulations recreate the conditions around a pair of orbiting equal-mass, non-spinning black holes. Each black hole distorts the very fabric of spacetime, and the orbiting pair spiral inwards while generating gravitational waves for many years before the actual merger takes place. Given the number of black hole pairs being discovered (e.g. see 6 April story), being

able to simulate them allows greater insight into being able to detect the waves. The Laser Interferometer Gravitational-Wave Observatory (LIGO) is now operational and is at the forefront of the observational challenge of detecting gravitational waves (see article 'The Search for Gravitational Waves ... Listening to Space with LIGO' by Laura Cadonati in State of the Universe 2007). Characterizing gravitational waves in the final phase of merging is crucial to extracting a real signal from observational data.

"These mergers are by far the most powerful events occurring in the universe, with each one generating more energy than all of the stars in the universe combined. Now we have realistic simulations to guide gravitational wave detectors coming online," said Joan Centrella, head of the Gravitational Astrophysics Laboratory at GSFC.

In a major step, the repeated simulations show "profound agreement" to within 1 percent. Such repeatability gives Dr. John Baker, the lead author of the research paper, and colleagues, significant confidence in the results. A number of other research groups are following similar approaches using different techniques. It's only a matter of time before the historic first detection of gravitational waves from a black hole merger occurs.

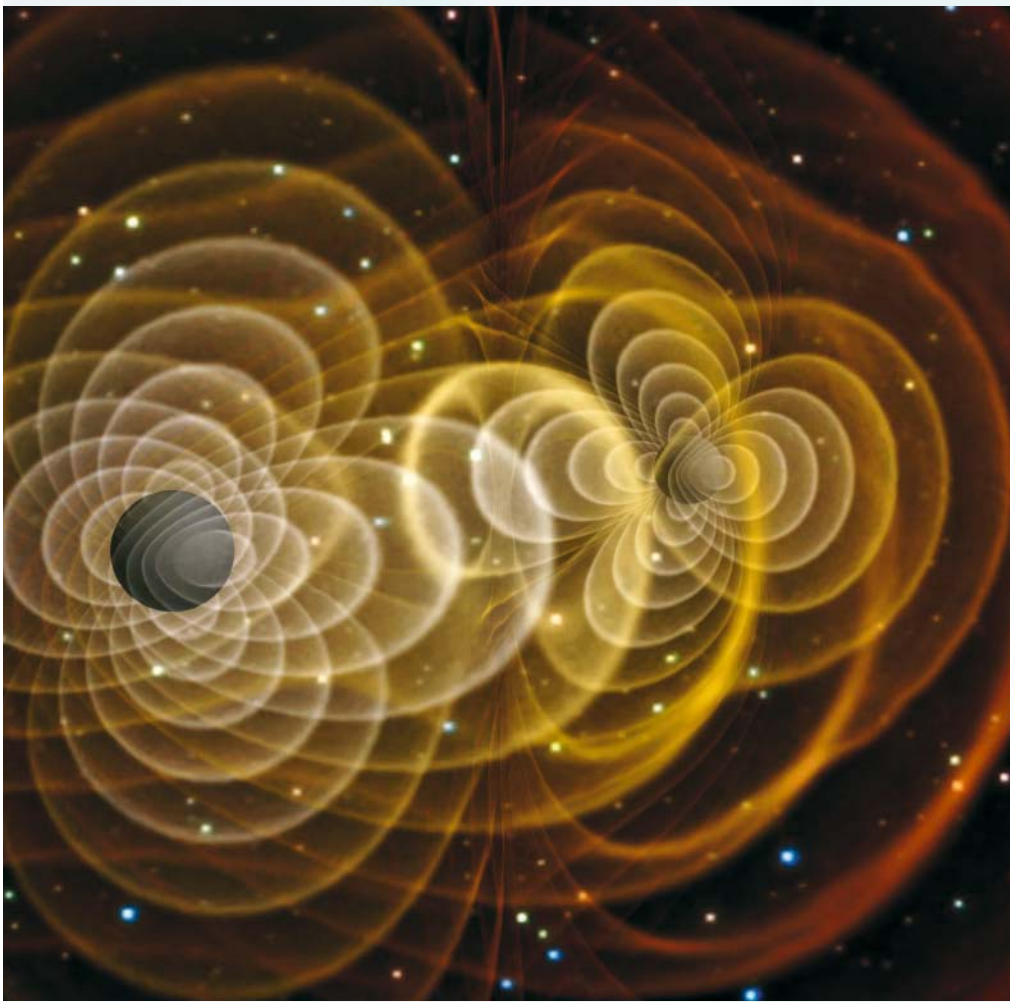
(Note: A second paper by the same authors has been published in early 2007 and the link is provided below. In it they predict current detectors may soon be successful given recent theoretical modeling advances. (See also 6 April and 1 May stories.)

<http://www.nasa.gov/vision/universe/starsgalaxies/gwave.html>

<http://arxiv.org/abs/gr-qc/0602026>

<http://arxiv.org/abs/gr-qc/0701016>

■ **Left:** 18 April 2006. This visualization shows the product of the largest three-dimensional simulations of merging supermassive black holes ever performed using the Columbia supercomputer at the NASA Ames Research Center. Using Einstein's theory of general relativity to predict the nature of gravitational waves from such mergers, the simulation provides a new foundation for the detection of gravitational waves. Image courtesy Henze, NASA.



20 April 2006

ESA's ISO Provides the First Clues of Monstrous Stars Being Born

Observations from the now defunct Infrared Space Observatory (ISO) appear to have achieved the first look at a birthplace of massive stars. Two very dense molecular cloud cores each have enough material to produce at least one O-type star along with a cluster of smaller stars.

The regions were found during the serendipity survey performed by ISO during slews between targets, and therefore took advantage of otherwise unused observing time on the orbiting observatory.

One of the cores contains the mass equivalent of 75 suns, and shows signs of infalling gas. The core currently has a chilly temperature of about 16 Kelvin (-256.5 deg Celsius). The second cloud has a slightly lower temperature, a mass of 280 suns, and little turbulent motion, indicating the cloud is near the initial conditions just prior to collapsing to form stars.

The regions where high-mass stars are formed are hidden from view because they lie in

dense cores such as these, and require infrared observations to penetrate them. Astronomers have long held that stars are formed within such dark clouds. One particular struggle has been to explain how high-mass stars form? These results suggest what some astronomers suspected: that high-mass stars form in regions of very low temperature and low turbulence.

"This opens up a new era for the observations of the early details of high-mass star formation," says Oliver Krause, Max-Planck Institute for Astronomy, Heidelberg, Germany and Steward Observatory, Arizona. He adds that another major question is "why do some clouds produce high- and low-mass stars, whilst others form only low-mass stars?"

The answers may come with larger and better telescopes. This region and others like it will be high on a target list for Herschel, a 3.5-meter infrared space telescope due for launch in 2008, and for SOFIA, the Stratospheric Observatory for Infrared Astronomy, housed inside a high-flying jumbo jet.

http://www.esa.int/esaSC/SEM8MZNFGLI_index_0.html

<http://xxx.lanl.gov/abs/astro-ph/0509710>

■ 24 April 2006. The Hubble Space Telescope took this image of the well-known galaxy, M82. Dozens of bright clumps represent starburst regions where intensive star formation is taking place. The violet stellar winds blast filaments of hydrogen gas high above the plane of the galaxy. Image courtesy NASA, ESA and the Hubble Heritage Team STScI/AURA, with thanks to J. Gallagher (University of Wisconsin), M. Mountain (STScI) and P. Puxley (NSF).

■ 24 April 2006. A combination of X-ray, infrared and radio observations make up this image of the galaxy NGC 4696. A vast cloud of hot gas (red) surrounds high-energy bubbles 10,000 light-years across (blue) on either side of the bright white area around the central supermassive black hole. Data from this image led scientists to conclude that the conversion of energy by matter falling into the black hole is super-efficient. (The green dots in the image show infrared radiation from star clusters on the outer edges of the galaxy). Images courtesy NASA/CXC/KIPAC/S. Allen et al. – X-ray; NRAO/VLA/G. Taylor – Radio; NASA/ESA/McMaster Univ./W. Harris – Infrared.



24 April 2006

Messier 82 helps Hubble celebrate 16 years in orbit

The European Space Agency and NASA celebrated the sixteenth birthday of the telescope by releasing a spectacular image of the starburst galaxy, Messier 82. M82 is a favorite of amateur astronomers, and its cigar-shaped smudge of light is visible in small telescopes. It is located 12 million light-years away in the constellation of Ursa Major.

M82 is a remarkable galaxy for a number of reasons. The star formation rate is ten times that found in our own galaxy, the Milky Way. Driven by huge stellar winds, plumes of hydrogen gas leap above and below the disk of the galaxy.

The image was taken in March 2006 by the Advanced Camera for Surveys. Like all color images from any professional telescope, images are composites of black and white images taken through specific color filters used to isolate the emission of different gases. The image showing ionized hydrogen gas, for example, is colored red, since the emission occurs in the red part of the spectrum. This image is a composite of six individual images extending from visible wavelengths to infrared. Infrared light is invisible to our eyes, so representative color used to illustrate those wavelengths.

<http://www.spacetelescope.org/images/html/heic0604a.html>

<http://xxx.lanl.gov/abs/astro-ph/0612547>

24 April 2006

Chandra Finds Black Holes Are “Green”

Black holes conserve energy very well. This is the conclusion of astronomers studying nine supermassive black holes with the Chandra X-ray Observatory. The black holes, found near the center of giant elliptical galaxies, each produce high energy jets traveling at near the speed of light in opposite directions from the black hole. Infalling matter provides the fuel for these jets, and astronomers wanted to find out just how energy efficient, or “green”, the black holes were. The results show that the jets carry away most of the energy released as matter falls towards the black hole.

“If a car was as fuel-efficient as these black holes, it could theoretically travel over a billion miles on a gallon of gas,” said team member Dr. Christopher Reynolds of the University of Maryland, College Park.

The black holes found in elliptical galaxies are far more quiescent than energetic quasars, yet more energy is being emitted by high energy particles than in visible light or by X-rays. The jets punch through the hot, X-ray emitting, intergalactic gas, creating large cavities or bubbles. The energy required to inflate these bubbles provides a perfect way to measure the power of the jets.

With such high energy being deposited into the galaxy, the hot gas is less likely to cool, becoming less inclined to collapse to form new sites of star formation. Consequently the black hole central engines generating these jets place an upper limit on the growth of the largest galaxies.

<http://chandra.harvard.edu/photo/2006/bhcn/>

<http://xxx.lanl.gov/abs/astro-ph/0602549>



■ 26 April 2006. The Spitzer Space Telescope captured this dramatic view of the colliding pair of galaxies, NGC 2207 and IC 2163. Giant beads showing large regions of active star formation are thought to have been caused by waves generated during the collision, creating the even pattern along the spiral arms. This picture, taken by Spitzer's infrared array camera, is a four-channel composite. It shows light with wavelengths of 3.6 microns (blue); 4.5 microns (green); and 5.8 and 8.0 microns (red). Starlight has been intentionally subtracted from the image to enhance the dusty features. Image courtesy NASA/JPL-Caltech/D. Elmegreen (Vassar).

26 April 2006

Galaxies Don Mask of Stars in New Spitzer Image

In an eye-catching image, the infrared Spitzer Space Telescope reveals a brilliant chain of star forming regions that appear to have been produced when two galaxies collided.

The brilliant central bulges of the two galaxies, NGC 2207 and IC 2163, are colored blue, resembling a couple of eyes peering through a delicate red mask of dust. The colors in the image are representative of different features, with gas showing as red and stars indicated by blue. The galaxies lie 140 million light-years from Earth in the constellation of Canis Major.

One spiral arm in particular appears to be studded with a regular pattern of bright concentrations. Similar concentrations dot the entire pair of galaxies. These are dusty clusters of newborn stars, made brightly visible by viewing them in infrared light.

"This is the most elaborate case of beading we've seen in galaxies," said Dr. Debra Elmegreen of Vassar College in Poughkeepsie, N.Y. "They are evenly spaced and sized along the arms of both galaxies."

The beads were presumably formed when the two galaxies first met. The gravitational perturbations set up waves of star formation along the spiral arms. A bright ring of star formation along oval arcs, with the appearance of an eyelid, is indicative of formations predicted

to occur in grazing encounters of two galaxies. There are over 200 clumps along the spiral arms or the oval arcs.

The brightest clump is so large that it accounts for five percent of the total infrared light coming from both galaxies. Such a huge cluster could be so dense, astronomers suggest, that the central stars of the cluster may have merged to form a black hole.

<http://www.spitzer.caltech.edu/Media/releases/ssc2006-11/release.shtm1>

<http://xxx.lanl.gov/abs/astro-ph/0605524>

<http://xxx.lanl.gov/abs/astro-ph/0508660>

MAY 2006

1 May 2006

VLBA Reveals Closest Pair of Supermassive Black Holes

The closest pair of supermassive black holes ever discovered has been found by astronomers using the Very Long Baseline Array (VLBA). The pair weighs in at more than 150 million times the mass of our Sun and lies at the center of the elliptical galaxy, 0402+379.

"These two giant black holes are only about 24 light-years apart, and that's more than 100 times closer than any pair found before," said Cristina Rodriguez of the University of New Mexico (UNM) and Simon Bolivar University in Venezuela.