Cosmic Jekyll & Hyde
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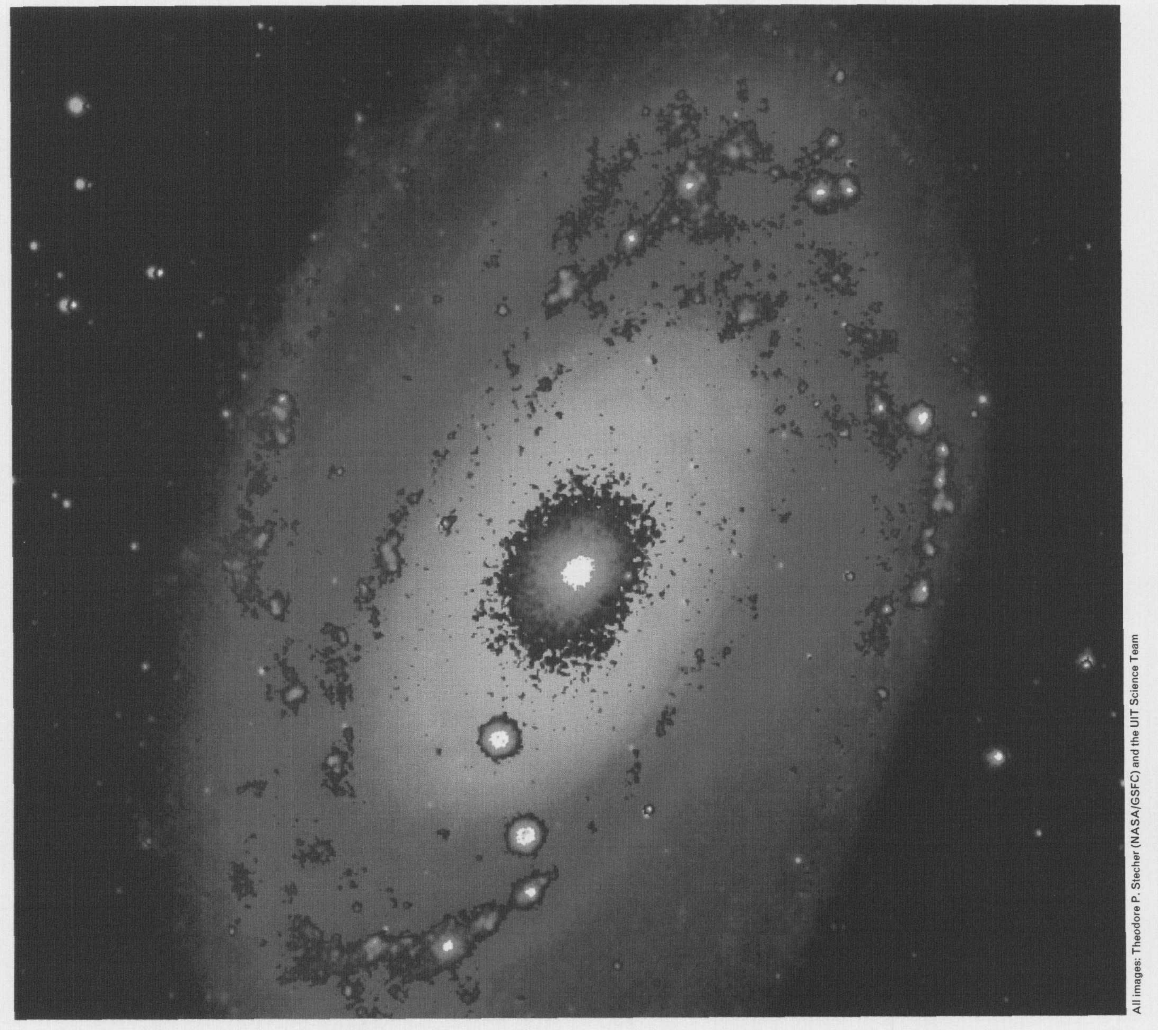
COSMIC
JEKYLL HYDE

A galaxy in ultraviolet light takes on a whole new look, a cosmic case of Dr. Jekyll turning into Mr. Hyde.

by Marcia Bartusiak

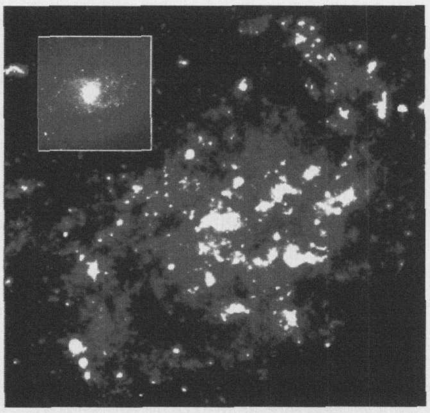


All images: Theodore P. Stecher (NASA/GSFC) and the UIT Science Team

OF THE MANY BRANCHES OF ASTRONOMY, there are two that rarely mingled in the past. The entire universe once stood between them.

In one of those branches reside the astronomers who largely study the nearby universe, specifically our cosmic neighborhood in ultraviolet light. Ultraviolet light consists of invisible waves given off by particularly hot objects. It occupies a special slice of the electromagnetic spectrum: more energetic than the blue and violet light visible to our eyes, but less powerful than x rays and gamma rays. Through this window, observers can spy hot interstellar gases, active galactic centers, and bright, blue-white, newborn stars.

Astronomers in the other branch patiently probe the distant universe,



The ultraviolet view of spiral galaxy M33 shows active star formation. A visible light image is shown (inset) for comparison.

attempting to collect the trickle of visible and infrared rays emanating from the farthest reaches of the cosmos. Once a thankless task, this enterprise has recently blossomed due to advanced detectors and new instruments, such as the Hubble Space Telescope and the giant Keck telescopes on Hawaii's Mauna Kea. As a result, astronomers can now view galaxies situated several billion light-years away (and, given the time it takes light to travel, billions of years into the past). They are at last unveiling the infant universe.

But how should astronomers interpret those far-off signals? Although observers of the distant universe are gathering visible light waves with their optical telescopes, those rays left the young galaxies as ultraviolet light. After journeying across the vast oceans of space over billions of years, these very short waves get stretched — highly "redshifted" — with the universe's expansion. By the time they reach Earth, ultraviolet waves are lengthened to visible and infrared wavelengths. Yet, distant-galaxy hunters are still observing an ultraviolet universe, only one far younger and more remote. To fully understand what they are seeing, they need to compare notes with the ultraviolet experts in the other branch.

In this montage of spiral galaxy M81, the orange and yellow correspond to visible light, while the blue and white knots mark intense ultraviolet emission — where the hot, newborn stars have formed.

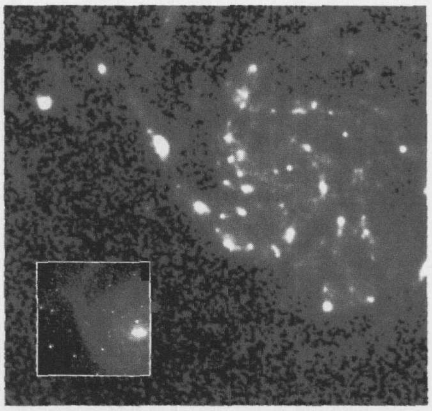
With that in mind, the two diverse groups finally met last spring for a three-day conference at the University of Maryland. "It was an idea whose time had come," said conference organizer William Waller, an ultraviolet astronomer at NASA's Goddard Space Flight Center, at the opening session. Conferees received violet-ink pens to mark the occasion (as well as their notebooks). Here was the opportunity for cross-talk on the "ultraviolet universe at low and high redshift," the title of the meeting.

THE ULTRAVIOLET UNIVERSE IS LESS KNOWN THAN THE RADIO, INFRARED, OR X-RAY sky. "It's wavelength chauvinism," declared Jay Gallagher of the University of Wisconsin. "But to understand the far universe, we have to understand the ultraviolet." Ultraviolet images are few, however, partially because most ultraviolet light is filtered out by atmospheric oxygen and ozone before it reaches the ground (which is fortunate because it causes sunburns and skin cancer), a fact which makes spaceborne detectors necessary.

Although the International Ultraviolet Explorer was one of the longest running space telescopes (launched in 1978 and expected to last three years, it operated until 1996), its data were spectroscopic. Astronomy's first successful ultraviolet image, taken by Apollo 16 astronauts in 1972, was a portrait of the Large Magellanic Cloud, the Milky Way's largest satellite galaxy. Since then, ultraviolet images have come from three chief sources: high-altitude balloons, the Hubble Space Telescope, and the Ultraviolet Imaging Telescope, part of the Astro Observatory flown aboard the space shuttle in 1990 and 1995.

These instruments reveal regions of active star formation — populations of stars less than a billion years old and thousands of degrees hotter than ordinary stars. Such hot sources can be 100 times fainter in visible light (where ordinary stars stand out), because they emit most of their light in the ultraviolet. Consequently, a galaxy in the ultraviolet takes on a whole new look, a cosmic case of Dr. Jekyll turning into Mr. Hyde.

Take the Large Magellanic Cloud, for example. Through optical telescopes, it looks like a broad swath of diffuse light. In the ultraviolet, however, "It's a mess: clumps of glowing sources," noted Robert O'Connell of the University of Virginia, as he displayed the image to conferees. His next picture depicted the Pinwheel



Spiral galaxy M101 looks familiar in visible light (inset), but it takes on a whole new appearance when viewed in ultraviolet light.

Galaxy (M33) in Triangulum, whose spiral arms look so smooth and symmetrical in visible light. With ultraviolet eyes, however, it appears fragmented and disorganized. M81, a beautiful spiral in Ursa Major, was another example. Its large central bulge, quite prominent in visible-light images, turns into a small droplet in the ultraviolet, surrounded by a ringlike necklace of spiral arms.

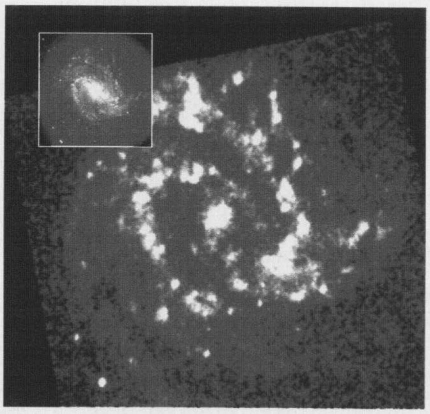
Older populations of more ordinary stars, too cool to emit much ultraviolet light, become invisible in the ultraviolet. Similarly, the bars in barred spiral galaxies can disappear altogether when viewed in ultraviolet light. O'Connell pointed out that the Hubble Deep Field, a recent probe by the Space Telescope of the distant universe out to some 12 billion light-years, uncovered few barred spirals. "Maybe that's a reflection of this effect," he remarked.

INDEED, NOTING SUCH TRANSFORMATIONS BETWEEN THE ULTRAVIOLET- AND VISIBLE-light universe is crucial for understanding the far universe. Astronomers must know what a local galaxy looks like in the ultraviolet in order to differentiate a true evolutionary effect in a distant galaxy — an event uniquely linked to the galaxy's birth — from normal, everyday ultraviolet occurrences.

"There is a systematic bias," cautioned Tony Tyson of Lucent Technologies on day two of the conference. "Things are dimming as we proceed outward. Normal things tend to look like points of light." A particularly bright knot of star formation awash in ultraviolet light, he warned, might be the only thing seen at a distance and thus be mistaken for an unusual galaxy.

Others are not so sure. Roberto Abraham of the Royal Greenwich Observatory in England has been comparing galaxies at both high and low redshift and claimed that distant galaxies are of another class altogether. Surveys of the distant universe are indeed revealing a rather strange cosmos. The Canada-France redshift survey, an extensive examination of galaxies halfway back to the Big Bang, reveals many blue irregular galaxies. The Hubble Deep Field displays numerous ragged galaxies and compact nuclei surrounded by fuzzy nebulosities. Are these merging galaxies? Are they fragments just now coalescing into full-blown galaxies? Or are they normal galaxies that only appear peculiar because they are being viewed in ultraviolet light redshifted into visible light?

To solve the puzzle, Abraham took a sample of typical local galaxies and modeled how these galaxies would appear if suddenly redshifted more than halfway across the universe. Generally, central bars disappear and spiral arms turn into rings, just as observed in images from the Ultraviolet Imaging Telescope. But after comparing these results with the Hubble Deep Field, he concluded that the early universe still has far more irregular, peculiar, and merging galaxies than our local galactic neighborhood. When looking at the Deep Field, he said, astronomers are seeing proto-galaxies that are "experiencing their first burst of star formation." Some spectral studies back him up; they indicate that the stars in these far galaxies look rather young, no more than two billion years old.



Although M83's spiral arms are prominent in visible light (inset), they stand out even more in ultraviolet light.

Chris Martin of Caltech reached a similar conclusion but with a different approach. Analyzing data from a balloon-borne detector, he examined some 95 galaxies at varying distances. He claims that there are more galaxies shining in ultraviolet light than in visible as the universe is probed farther and farther outward. This implies a dramatic evolution in star formation through time. The Milky Way currently makes one or two stars a year. But when the universe was several billion years younger, says Martin, galaxies were producing 50 to 100 solar masses worth of stars each year. The early universe was an epoch of starbursting, which means galaxies starbursting today might serve as a model of that former era.

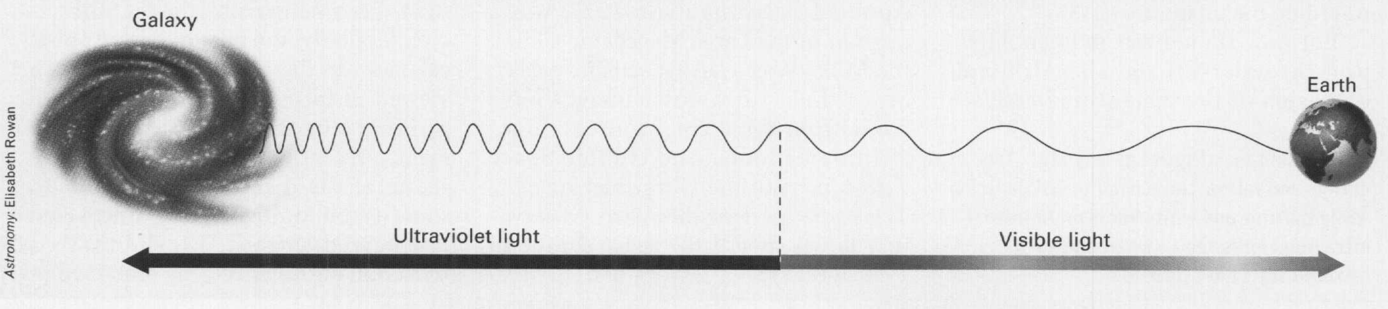
But Claus Leitherer of the Space Telescope Science Institute wondered if that's truly the case. After examining spectral information from several telescopes, he concluded that early galaxies weren't bursting so much as they were simmering — undergoing vigorous but not explosive star formation. "Nearby starbursters may not be the best template for interpreting high redshift spectra," Leitherer advised his fellow astronomers.

SUCH DIVISION OF OPINION WAS SEEN THROUGHOUT THE CONFERENCE, WHICH IS NOT unexpected when information is so new. Astronomers are only getting their first glimpse of the far universe and many obstacles stand in their way. Stars, for instance, form in regions of dust, which absorb and scatter ultraviolet light. Part of the signal from the far universe is thus lost, making interpretation more difficult.

The feistiest debate at the meeting concerned what the ultraviolet signals from the early universe are telling us about galaxy evolution. Some contended that the distant objects are "sub-galactic clumps" in the act of merging into the galaxies of today. Galaxies, they said, did not condense out of huge gas clouds fully formed from the start. Rather, they assembled from small disks of gas, each about 3,000 light-years wide, joining to form a spherical bulge. Later, some of these bulges might enwreathe themselves in gas and turn into spiral galaxies. Some of these spirals, in turn, could collide and merge to form giant elliptical galaxies.

But others cautioned that the ultraviolet information from the far universe could be misleading. Instead of small galactic building blocks, the distant objects might be pockets of intense star formation embedded

Short-wavelength ultraviolet waves coming from the distant universe are stretched into longer-wavelength visible light waves by the universe's expansion. So when astronomers look to the distant universe in visible light, they are actually studying light that originated in the ultraviolet.

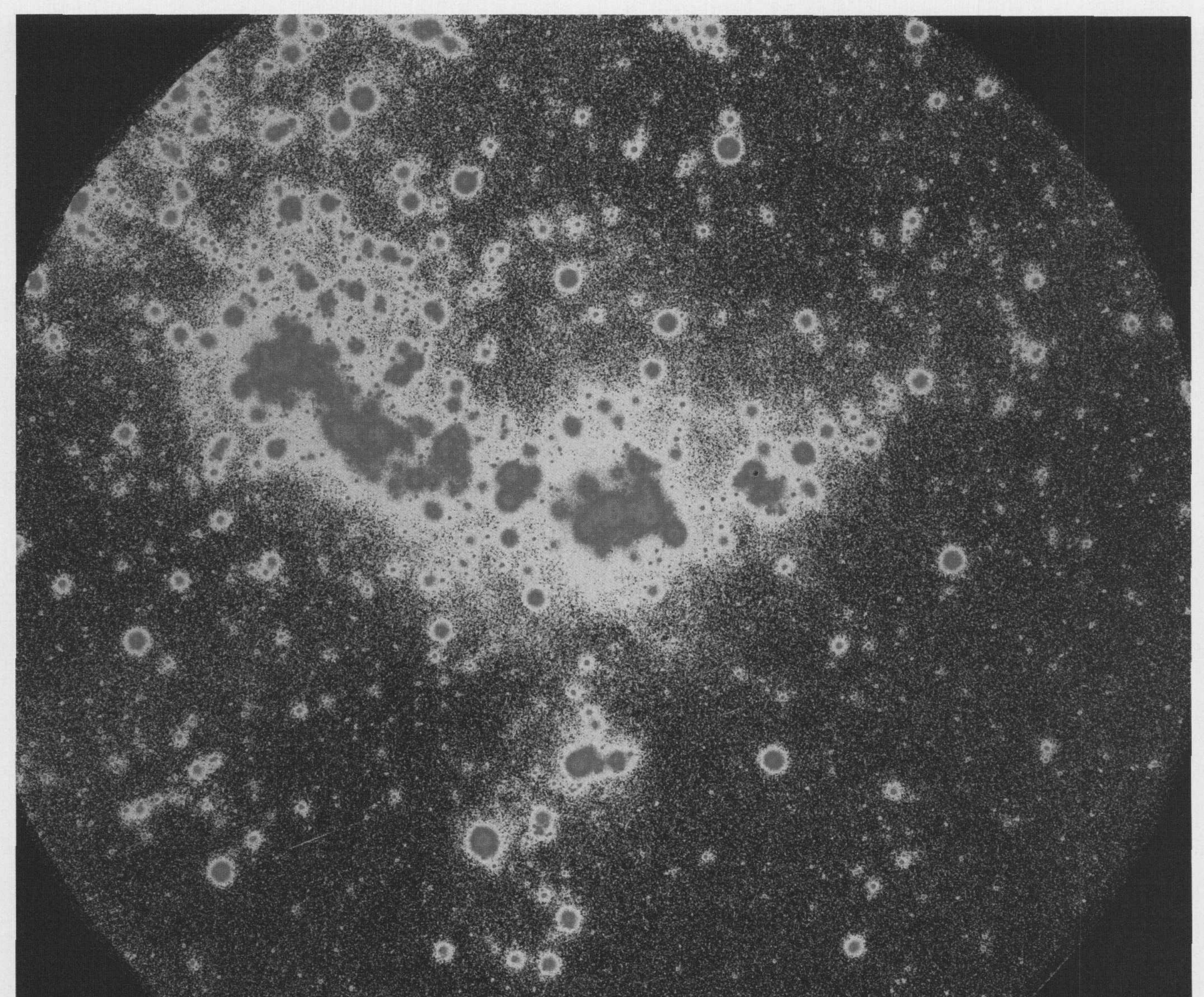


within larger galaxies. Indeed, some claim they are seeing full-size galaxies already in place and at a time when the universe was a mere babe, just 15 percent of its current age. This implies that the biggest galaxies formed fairly quickly and then coasted into the modern era largely intact while smaller galaxies coalesced later.

More ultraviolet data would help settle these conflicts, but the last ultraviolet all-sky survey was conducted more than two decades ago. Noah Brosch of Wise Observatory in Israel noted that the future "looks bleak" and blamed it on a lack of "sexy discoveries." With few instruments on hand, ultraviolet astronomy didn't find interesting objects such as pulsars, black holes, and quasars, the type of finds that propelled the fields of radio and x-ray astronomy. "We're a hundred years behind optical astronomy," lamented Brosch.

Ultraviolet astronomers will have the Far Ultraviolet Spectroscopic Explorer, scheduled to launch at the end of 1998. And there's talk of dedicating the Hubble Space Telescope to ultraviolet studies once the Next Generation Space Telescope goes up. "For the next 10 to 15 years, NASA's 'big ticket' missions are all in the infrared rather than the optical and ultraviolet," noted O'Connell. "But the optical-ultraviolet is the most information-rich part of the electromagnetic spectrum. Our concern is that, even though missions like the Next Generation Space Telescope will observe the ultraviolet light of very distant objects that has been redshifted into the visible, we won't have the wherewithal to understand them very well because we can't do our ultraviolet 'homework' on nearby systems." To catch up to their colleagues in the neighboring bands of the electromagnetic spectrum, ultraviolet astronomers may just have to be patient. ■

Award-winning science journalist Marcia Bartusiak is a member of Astronomy's *editorial advisory board.*



A small section of the Large Magellanic Cloud looks like a glowing mass of clumps in ultraviolet light. All of the ultraviolet images in this article were taken by the Ultraviolet Imaging Telescope, which flew aboard the space shuttle in 1990 and 1995.