Hubble's grand new vistas

Early results from the space telescope's new camera and spectrograph prove there's a lot of life left in the aging observatory. **by Richard Talcott**

September 9 was a special day for number-lovers, as the calendar page turned to 09/09/09. For astronomers and everyone else who loves the night sky, the 9th proved even more auspicious. It was the day we got our first peek at how the recently refurbished Hubble Space Telescope now performs. No one was disappointed.

"We're giddy with the quality of data," says Heidi Hammel of the Space Science Institute in Boulder, Colorado. Hammel led the team that made the first science observations with Hubble following May's servicing mission. She convinced NASA to interrupt the orbiting observatory's recommissioning to view Jupiter after a comet or asteroid unexpectedly smashed into the giant planet in mid-July.

The servicing mission "left Hubble as a new, state-of-the-art observatory," claims Ed Weiler, an associate administrator at NASA Headquarters in Washington,

Stephan's Quintet reveals its true identity as a group of four plus one in this WFC3 image combining visible and infrared observations. The four yellowish galaxies include three spirals (top left and two at center) with distorted shapes and elongated spiral arms, signs of ongoing encounters, along with a normal elliptical (lower right). The bluish galaxy at lower left shows individual stars because it lies only 40 million light-years from Earth, some 7 times closer than the others. All images: NASA/ESA/The Hubble SM4 ERO Team

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The Bug Nebula looks more like a butterfly in this WFC3 image. This planetary nebula shows what happens when a star some 5 times more massive than the Sun nears the end of its life. The star's tenuous outer layers were blown off in several episodes during the past 2,200 years and created the butterfly's wings, which now span more than 2 light-years. The dying star lies hidden by a thick dust ring at the nebula's center.

D.C. The seven-member crew of the space shuttle *Atlantis* not only installed two new instruments — the Wide Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS) — but also repaired two others — the Advanced Camera for Surveys (ACS) and the Space Telescope Imaging Spectrograph (STIS).

The new camera debuts

The results of the astronauts' efforts were on display September 9. University of Virginia astronomer Bob O'Connell, who chairs WFC3's science oversight committee, says WFC3 "works better than we expected." And expectations were high to begin with.

The camera's initial targets included a compact group of galaxies known as Stephan's Quintet, the crowded central regions of the massive globular cluster Omega Centauri, a region of active star formation in the Carina Nebula, and the wispy tendrils of a dying Sun-like star in the Bug Nebula.

Besides choosing an array of different subjects, astronomers picked objects that showcase the new camera's capabilities. WFC3 has two channels: one that views the cosmos at visible and ultraviolet wavelengths and one that captures near-infrared radiation. So, the camera can record hot objects (bright in ultraviolet), cool objects (bright in infrared), and those in between (brightest at visible wavelengths) at the same time. WFC3 already has become Hubble's new workhorse. Half of the telescope's observations in the next year will use this camera.

While WFC3 records light to create pictures, COS breaks down light into its constituent colors. The resulting spectrum reveals an object's temperature, composition, density, and velocity. COS operates about 10 times more efficiently than its predecessors on Hubble, which means that in the same length of time, it can observe 10 times as many objects — or objects one-tenth as bright.

For the first spectral observations, scientists targeted supernova remnant N132D in the Large Magellanic Cloud, active galaxy Markarian 817, and quasar PKS 0405–123. The quasar observation spotlights one of COS's primary tasks.

Astronomers use quasars to probe the "cosmic web" — the long, narrow filaments of galaxies and diffuse gas that populate the intergalactic medium. Because each filament lies at a different distance from Earth, cosmic expansion shifts its spectral fingerprint by a different amount. In looking at PKS 0405–123, which lies 7 to 8 billion light-years from Earth, researchers detected nearly 5 times as many hydrogen-gas filaments along this line of sight.

New life for old equipment

Although astronomers felt undeniable excitement over the first results from the new instruments, they also were happy to see a return to life for some old friends. STIS stopped working in 2004 and ACS in 2007, the results of separate electronics failures.

NASA didn't design either instrument to be fixed in orbit. Scientists kept their fingers crossed that the spacewalking astronauts would manage to get one functioning again, but both are working great. These repaired instruments will complement observations made with the new camera and spectrograph.

A fifth instrument — the Near Infrared Camera and Multi-Object Spectrograph (NICMOS) — also appears to be returning to life. Mission controllers had to shut down the instrument's cooling system while making a computer upgrade in September 2008. But the system stubbornly refused to restart. In

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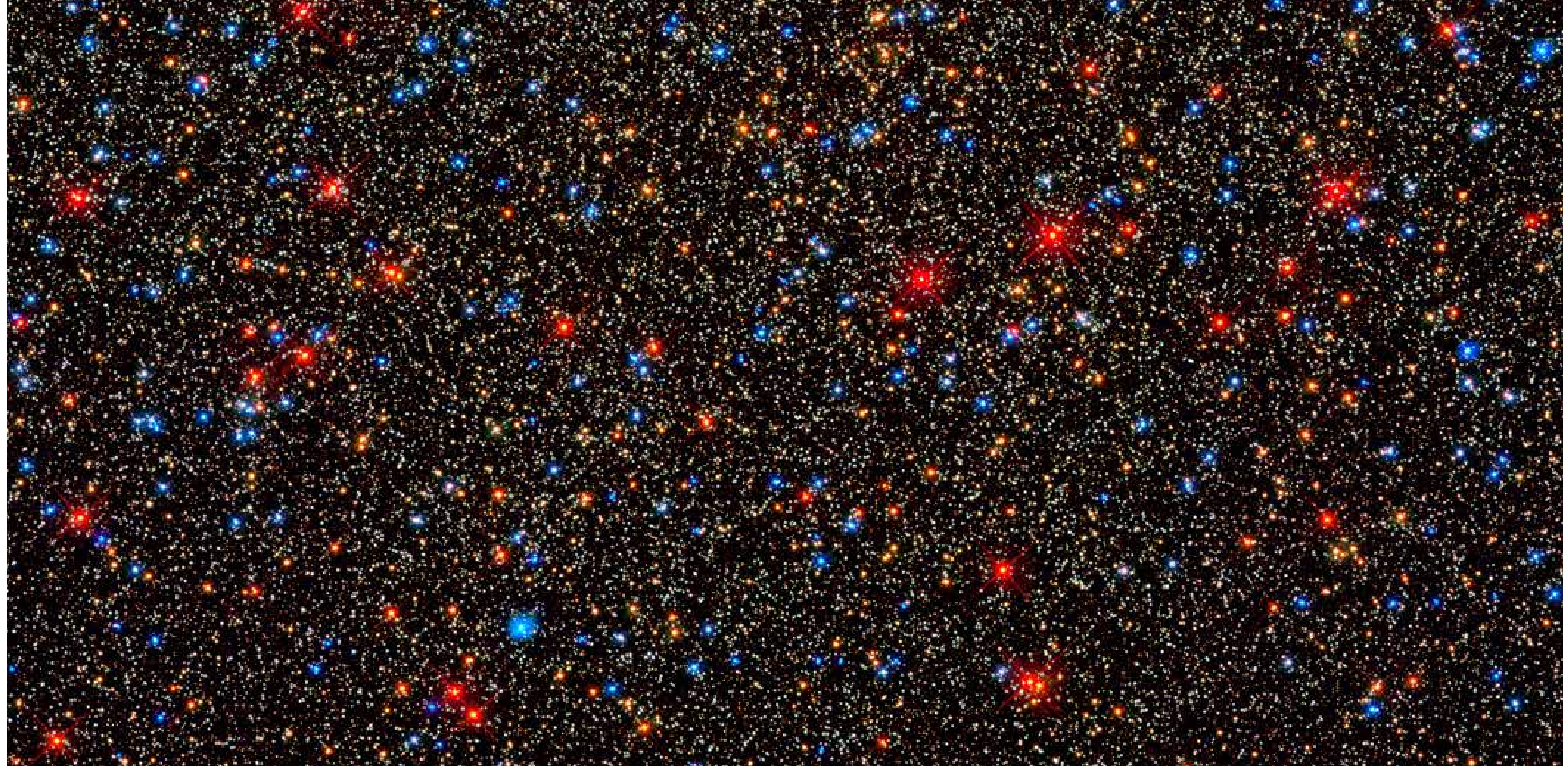
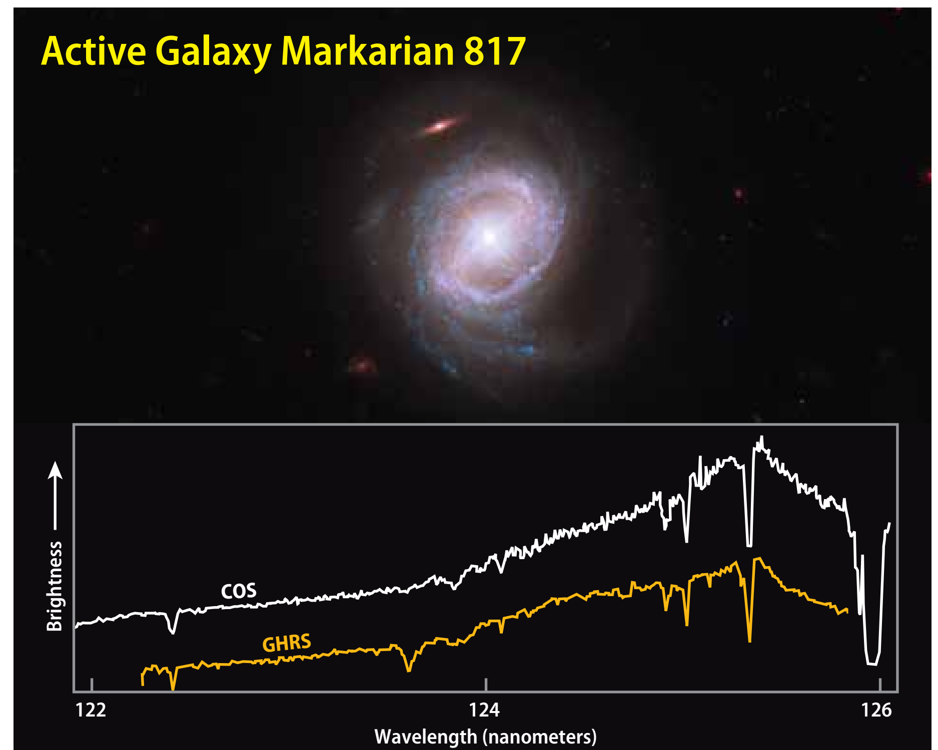
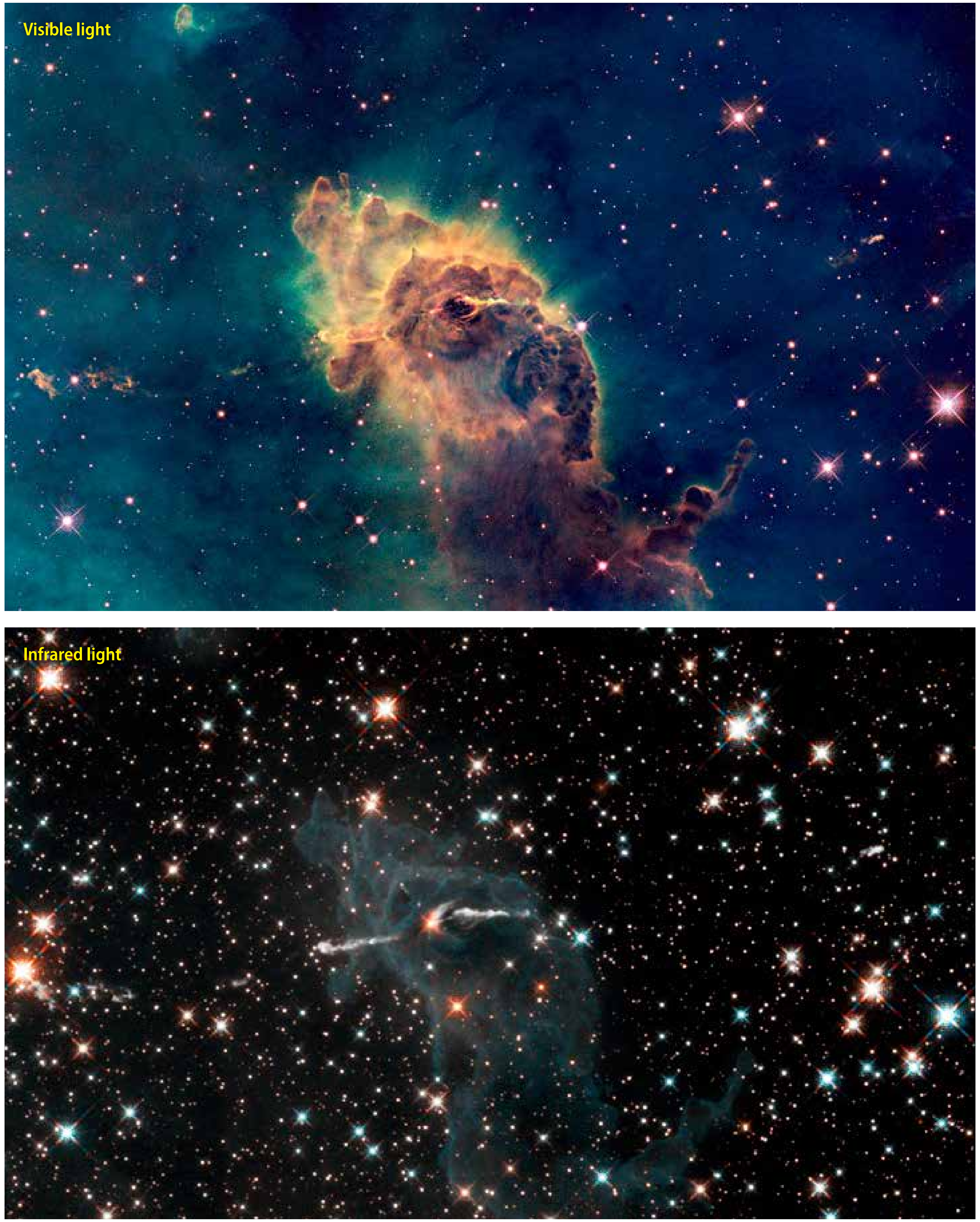


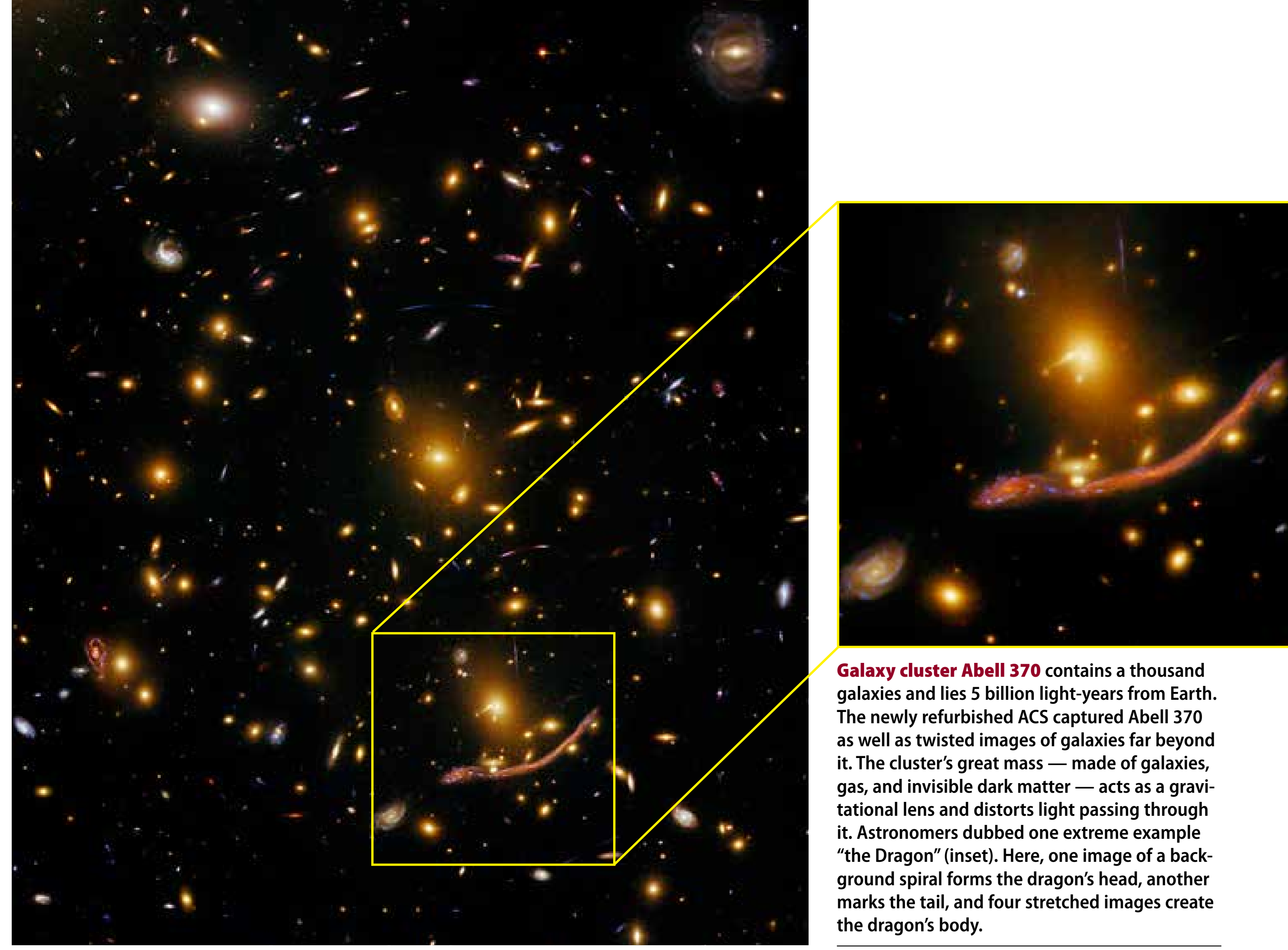
Globular cluster Omega Centauri contains nearly 10 million stars that formed more than 10 billion years ago. This WFC3 image shows the inner 12 light-years, home to some 100,000 stars. Still, Hubble resolves them all. The color contrast here is real. Most of the stars are yellow, like the Sun, and fuse hydrogen into helium. The red stars are more evolved giants that have expanded and cooled. And the blue stars have evolved even further, shedding their outer layers and glowing strongly in the ultraviolet.



Active galaxy Markarian 817 shows off the expanded capabilities of the new COS instrument. This view compares a COS spectrum with that from one of its predecessors, the Goddard High Resolution Spectrograph (GHRS). COS is 10 times more sensitive than GHRS, so it records more light and has a higher signal-to-noise ratio. This view also shows all the wavelengths captured by GHRS but only one-eighth of those COS records. WFC3 photographed the galaxy (top).



The Carina Nebula holds many wonders, including a 3-light-year-long pillar of gas and dust seen here in two different wavelength ranges. In visible light (top), WFC3 captures the pillar's tip. Massive stars (located off the top of this image) evaporate some of its gas, creating the greenish streamers. The big stars also compress the gas, triggering star formation. In infrared light (above), WFC3 penetrates the gas and dust, revealing some of these fledgling stars. High-speed jets spurt from one of those stars at speeds up to 850,000 mph (1.4 million km/h).



Galaxy cluster Abell 370 contains a thousand galaxies and lies 5 billion light-years from Earth. The newly refurbished ACS captured Abell 370 as well as twisted images of galaxies far beyond it. The cluster's great mass — made of galaxies, gas, and invisible dark matter — acts as a gravitational lens and distorts light passing through it. Astronomers dubbed one extreme example "the Dragon" (inset). Here, one image of a background spiral forms the dragon's head, another marks the tail, and four stretched images create the dragon's body.

August, however, engineers got it going, and the cooling system was bringing NICMOS down to its operating temperature of –321° Fahrenheit (–196° Celsius).

Worth the long wait

The shuttle astronauts released Hubble in May. That's when engineers and scientists on the ground got to work. They spent the summer making sure all of the telescope's instruments worked the way they were supposed to.

The Servicing Mission Observatory Verification (SMOV in NASA-speak) took months to complete because the ground team had so much to do. The first task: Make sure Hubble could point accurately. The *Atlantis* astronauts replaced all six of Hubble's gyroscopes. Engineers calibrated the gyroscopes by changing Hubble's orientation in a precise way and then looking at the data they generated.

Getting the new instruments up to speed took even longer. First, both WFC3 and COS had to "outgas" — release the extraneous atoms and molecules that arise naturally from being built on Earth. The instruments use high-voltage power, and stray gases conduct electricity, which could cause a short circuit and ruin the instrument. To prevent this, engineers raised the voltage slowly and checked the circuitry at each stage.

Stray gases also absorb light at certain wavelengths. So, any such gases left in the instrument would reduce the instruments' sensitivity and impart their own spectral fingerprints.

Next, engineers had to align and then focus both WFC3 and COS, which were weightless and in the vacuum of space for the first time. The ground team accomplished this by using tiny mirrors and other mechanisms built into the instruments. The process took a few weeks for each.

Finally, scientists and engineers calibrated the instruments. Each scientific observation includes data both from the sky and from the instrument. By viewing a familiar astronomical object, scientists can compare what should be visible with what they actually see. Then, they either adjust the instrument or, more often, set up computer processing on the ground to remove these "instrument signatures."

Digging deeper and farther

Now that Hubble is operating at a higher level than ever before, astronomers anticipate all its new discoveries. Among the first observations scheduled is another Hubble Ultra Deep Field. WFC3 will take this image in the infrared, and it promises to be the deepest view ever of the cosmos. Some researchers expect it to turn up galaxies within 500 million years of the Big Bang.

Hubble now has the capability to observe the atmospheres of some exoplanets. Such observations should reveal the compositions of these atmospheres, perhaps even those of earthlike planets that the Kepler mission will locate.

Hubble has built an outstanding legacy during its first 19 years in orbit. It appears destined to add more superlatives in the years ahead.