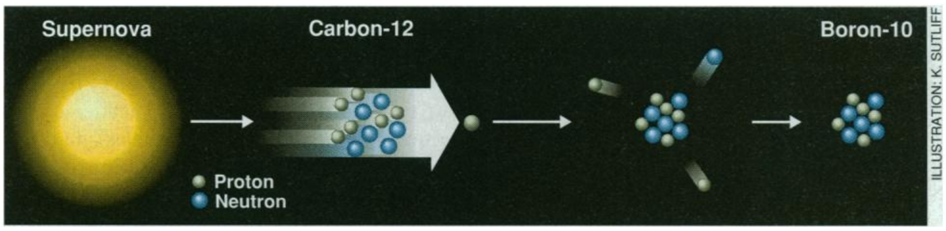
MEETING BRIEFS

Hubble Spectrograph Takes a Hard Look in the Ultraviolet

GREENBELT, MARYLAND—On 11 and 12 September, astronomers gathered at the NASA Goddard Space Flight Center to review the accomplishments of one of the Hubble Space Telescope's less heralded instruments, the Goddard High-Resolution Spectrograph (GHRS), which has recorded the most detailed spectra ever of ultraviolet light from stars and planets. Next February, astronauts will remove the GHRS to make room for a new instrument, but the GHRS is ending its career on some high notes, delivering insights into the history of the chemical elements and hints of familiar features on distant worlds.



Heavy hitter. Flung from a supernova, a carbon nucleus collides with a proton in the interstellar gas to form boron. Nitrogen and oxygen nuclei may undergo similar reactions.

Birth of B and Be

For astrophysicists, the elements boron and beryllium have long been a pesky pair. Since the 1960s, researchers have believed that helium and hydrogen, the lightest elements in the universe, originated in the primordial big bang, and that elements heavier than boron were made in the hot interiors of stars. But these two "light" elements are probably too large to have formed in the big bang yet too small and fragile to withstand the intense heat of a star. Researchers therefore believe that these atoms must have been made in collisions between other nuclei in interstellar space. Now the GHRS has turned the most popular picture of this process on its head.

The new observations leave the main actors in the element-forming scenario unchanged, but reverses their roles. Physicists had pictured hydrogen and helium nuclei flying through space as high-energy cosmic rays that slam into heavier atoms of carbon, oxygen, or nitrogen, stripping them down to form the light elements. The new observations, though, imply that it's the heavy nuclei that are the projectiles. "We need to reverse which is the target and which is the thing hitting it," says Douglas Duncan, an astrophysicist at the University of Chicago.

Duncan, who presented the findings at the meeting's poster session, says that the new results finally pin down the origin of these two elements. "For 40 years we have been filling in the puzzle," he says. "This helps us fit the last few pieces in place." Grant Mathews, an astrophysicist at the University of Notre Dame in Indiana who has studied the nucleosynthesis of the light elements, agrees but sees the new results as mainly a refinement. "This just puts more emphasis than we thought on the heavies hitting the lights," he says.

Both element-forming scenarios rely on exploding stars, called supernovae, to drive the process. In the earlier theory, the supernovae would have contributed in two ways. Past generations of supernovae would have prepared the ground by strewing heavy nuclei through interstellar space, while each new supernova would supply cosmic ray projectiles by accelerating hydrogen or helium nuclei in its shock wave. That picture implies a slow start for light-element formation: In the early days of the galaxy, when it had experienced relatively few supernovae, carbon, oxygen, and nitrogen would have been scarce in the interstellar gas, and the cosmic rays would have had few targets.

Duncan and his colleagues set out to test this idea by measuring the intensity of boron's signature in the spectrum of ultraviolet light from 11 stars of varying ages. Because the composition of a star's surface is a sample of the mix of elements from which it formed, the result was a chronicle of the galaxy's boron abundance. To Duncan's surprise, there were significant amounts of the element in even the oldest stars, and its abundance did not increase as quickly as he and his colleagues expected in progressively younger stars.

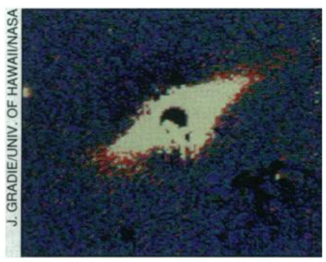
The simplest way to explain the early abundance of boron, Duncan says, is that the original cosmic ray theory was backwards. Instead of flinging the helium and hydrogen into a background of heavier atoms, the supernova shock waves must be spitting out cosmic rays of oxygen, carbon, and nitrogen. These heavy elements then collide with a preexisting background of hydrogen and helium. Because those nuclei were made at the beginning of time, in the big bang, there has never been any shortage of target nuclei.

There may even be direct evidence of the process, from a star-forming region in the Orion nebula, an area with many large young stars that periodically explode as supernovae. The nebula gives off unusually high levels of gamma rays. And their energy, says Duncan's collaborator, Lewis Hobbs, an astrophysicist at the University of Chicago's Yerkes Observatory, is just what a high-energy carbon or oxygen would be expected to radiate after colliding with a lower energy hydrogen or helium. Indeed, the gamma ray observations together with some of Duncan's early data had already led several researchers and theorists to propose a similar theory for the formation of light elements. But the new GHRS observations are much more conclusive, Duncan says.

Mathews thinks that both processes are probably creating light elements today. The puzzle piece was in the right place, he says—just upside-down. Now that it has been righted, he says, "we see the picture clearly."

Hints of Distant Comets?

Over the past 2 years, astronomers have detected planet after planet around other stars, evidence that ours is not the only solar system. But at the Goddard meeting, other researchers reminded their colleagues that a case has also been building for smaller solar-system bodies around at least one other star, Beta Pictoris. By studying the disk of gas and dust that swirls around this relatively near neighbor, GHRS investigators led by Anne-Marie Lagrange of the Laboratory of Astrophysics in Grenoble, France, have amassed two lines of evidence that the disk is home to swarms of comets.



Comets' lair? The Beta Pictoris disk.

Carol Grady of Eureka Scientific in Oakland, California, says that the comet idea surprised many astronomers when Lagrange and her colleagues first proposed it 10 years ago to explain some odd features of the disk's spectrum, seen with ground-based telescopes. But in light of the GHRS and other observations, the notion "now makes a lot of sense," she says.

With the GHRS, Lagrange and her colleagues have identified shifts in certain lines in the ultraviolet spectrum—presumably caused by the Doppler effect—that seem to come from blobs of gas falling toward the star at several hundred kilometers per second. The simplest explanation, says Sara Heap of Goddard, who has studied the Beta Pictoris system, is that the observed spectral lines come from gas that evaporates from solid bodies plunging toward the star in near free fall, most likely comets.

Infalling comets can also explain another feature of the GHRS data: the ultraviolet signature of carbon monoxide and neutral carbon in the star's dust cloud. Radiation from the star should quickly destroy these relatively fragile species, Lagrange says. But comets could be replenishing the supply by ferrying gas and dust inward from the far reaches of the disk, she says. Together, the evidence suggests that as many as a few hundred comets a year plunge toward this young star, says Lagrange, probably about the same number as in the early days of our own solar system.

Aurora on Ganymede

Just last summer, planetary scientists learned that the Jovian moon Ganymede has two planetlike features: a magnetic field and perhaps a trace of an atmosphere (*Science*, 19 July, pp. 311 and 341). Now, with the help of the GHRS, they may have found a third, the offspring of the first two. Astrophysicist Doyle Hall of Johns Hopkins University in Baltimore and his colleagues have detected hints of an aurora at Ganymede's poles.

The aurora—ultraviolet emissions from high-energy oxygen molecules—is a ghost of the powerful auroras on Earth and Jupiter, but it is the first to be seen on a moon, Hall says. And it is presumably generated by the same basic mechanism as planetary auroras: Magnetic field lines funnel high-energy electrons and other charged particles from space into Ganymede's polar regions, where they collide with gas molecules and excite them into giving off radiation.

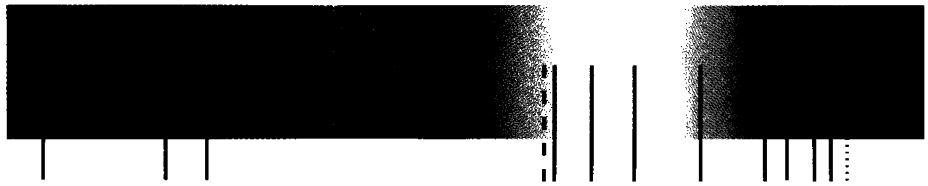
The emissions from Ganymede's aurora are so faint that they eluded Galileo, the spacecraft that swooped by Ganymede last summer and detected its magnetic field. "We had the luxury of parking the [Hubble telescope] on Ganymede for five full orbits," says Hall, giving the scientists time to pick up very faint signals. "Galileo just doesn't have that kind of time as it swings by."

Hall cautions that definitive proof of the aurora will require an actual image of the moon rather than just spectrographic data. But John Clarke of the University of Michigan, who studies Jupiter's aurora, calls the find "potentially exciting." He says that comparisons with Ganymede might give scientists a sharper picture of the interactions that give rise to Earth's aurora. "It will be interesting if we have a case that is different from Earth, but not entirely different," he says.

–Gretchen Vogel

MATERIALS SCIENCE

Plastics May Add New Colors To Lasers' Light Show



Across the rainbow. Work done by three teams (shown in solid, dashed, and dotted lines) shows that plastic polymers can emit laserlike light in colors all along the visible spectrum.

A. HEEGER, R. FRIEND, V. VARDENY

Lasers are one of this century's shining technological success stories, having metamorphosed from the ungainly machines of the 1960s to the ubiquitous crystals that today help electronic devices play music, read computer discs, and scan grocery labels. But although the semiconductor alloys in the laser diodes of CD-ROM drives and compact-disc players can turn out red and infrared beams with ease, researchers have had a tougher time coercing these inorganic materials to emit rays of yellow, green, or blue light—colors that could boost the amount of data stored on a compact disc, for example.

In recent weeks, however, a trio of research groups has produced laserlike beams from a new and potentially more versatile source—a variety of plastic films. Their results are sparking new excitement in the laser community. The new reports are "very nice work," says Francis Garnier, a semiconducting polymer expert at France's Centre National de la Recherche Scientifique in Thiais. If this basic research does lead to practical polymer lasers, the new materials would have an advantage over their inorganic counterparts, says Garnier, because "you can play with polymers much more easily than with inorganic semiconductors to create the colors you want." Indeed, on page 1833 of this issue, one team, led by researchers at the University of California, Santa Barbara (UCSB), already reports coaxing light in colors across much of the visible spectrum from these skinny bits of plastic.

But Garnier and others quickly point out that polymers have a long way to go to fulfill such brilliant dreams. At this point, the beams coming from these experimental plastic films don't show all the hallmarks of true laser light. And in all three experiments, the plastics emitted laserlike light only after being blasted by light from another laser. To become commercially useful, the devices will need to perform when powered by electric current, a difficult task because the polymers burn out quickly and are inefficient at turning electrical charges into light, says Richard Friend, a physicist at Cambridge University in the United Kingdom and leader of the second research team. Nevertheless, many researchers remain cautiously optimistic. "I'm full of promise and upbeat" that such problems will be solved, says Valy Z. Vardeny, a physicist at the University of Utah, Salt Lake City, who led the third team. After all, he says, "this is only the beginning of the story."

At the heart of the plastic light-emitters is a class of materials known as semiconducting polymers, which, unlike most plastics, are able to conduct electricity. In 1990, Friend and his Cambridge colleagues showed that these materials could also emit a yellow-green glow when pumped with electricity, creating devices known as light-emitting diodes (LEDs). Not long after, researchers created other polymer LEDs that gave off a range of different colors. The obvious next step was to try to turn these versatile light-emitters into lasers. That's a tough job, however, because it requires coaxing the plastics to first emit and then to amplify light of a single wavelength, with the waves all exactly in step; these traits give lasers their precision and intensity.

Lasers achieve this singular behavior because each photon emitted by the material stimulates the release of another photon, at the same wavelength as the first and exactly in phase with it. In a true laser, a chain reaction ensues, and this cascade of stimulated emission generates an intense pulse of light at a single wavelength.

But although early experiments with semiconducting polymer films did reveal some stimulated emission, the materials didn't actually lase, because the chain reaction that prompts the light to emerge at one wavelength never got started, explains Alan Heeger, who led the UCSB group. Preliminary work suggested that the films tended to lose energy to heat rather than emitting it as light, a fault known as poor "luminescence efficiency." And other work indicated that