Arms Control

## A Simple Way To Reduce Nuclear Weapons

Modern nuclear weapons depend on a heavy form of hydrogen known as tritium. Without this material, nuclear weapons would be far less compact and less powerful. But tritium is radioactive and decays rapidly, half of it disappearing in 12.3 years. Thus if the U.S. and the U.S.S.R. were to cease tritium production, the tritium charges in nuclear weapons could not be replaced regularly, as is now the case—forcing a yearly reduction in nuclear arms of about 5.5 percent. If begun now, a tritium ban would automatically lead to a 50 percent cut in warheads by the year 2001.

That is the essence of a new proposal by a group of scientists, military men, and arms controllers with impressive credentials. They argue that direct arms control negotiations are easily delayed. The deadlines set by a tritium ban would put pressure on governments and negotiators from both sides to make steady progress, while preserving each country's options as to what types of weapons to retire.

A ban on tritium production would also allow both countries to shut down the old and potentially dangerous reactors used to make tritium—reactors of a type similar to that involved in the Chernobyl accident—and save the cost of building new ones. Safety concerns in fact have led the U.S. to shut down one of its tritium reactors and to operate two others at half power; the cost of building two replacement reactors is estimated at a minimum of $6.8 billion.

Whether such a ban would affect both sides equally and whether both sides would agree to such a far-reaching proposal are open questions. But the simplicity of the proposal—compared with the complexity of the proposals to reduce nuclear weapons themselves—and the gradual time scale of its effect are appealing. Furthermore, such an agreement would be relatively easy to verify. The operation of tritium production reactors is detectable from space.

Smaller amounts of tritium are produced by some types of commercial power reactors, such as those in Canada, and by the nuclear weapons programs of France, Britain, and China—and these might have to be brought under some form of monitoring too. But these and other complications might be well worth a careful look—in return for such an ingenious and automatic "time clock" for nuclear arms reductions.

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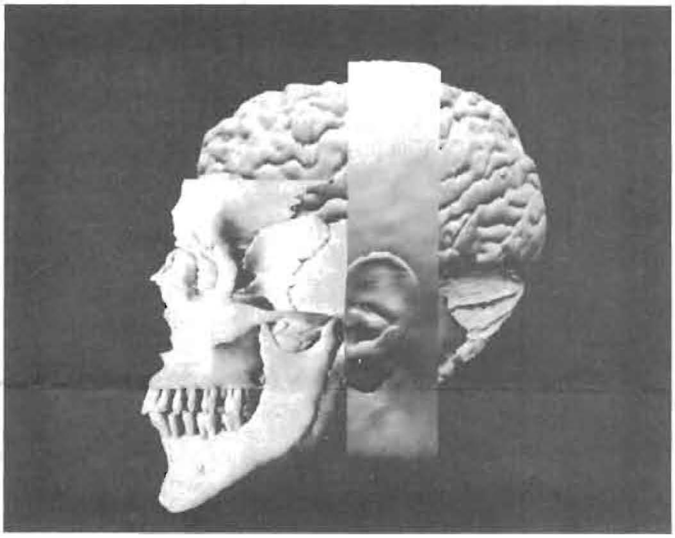
Electronic Medicine

## Bringing the Anatomy Book To the Screen



In several years, if all goes well, medical students at the University of Washington Medical School in Seattle and elsewhere will be able to put a video disk in a machine and call up any part of the human body for study. They will be able to rotate the images to view them from any angle, have the computer peel back the skin or make it transluscent, look in detail at particular tissues or bones—in short see the human body in three-dimensions from inside and out.

Although other electronic anatomy books are in preparation, the distinction of the University of Washington effort is that it combines images from several sources. In the image above, for example, the skull is from a CT or X-ray scan, the strip of skin is from Magnetic Resonance Imaging, and the brain image itself is derived from dozens of images of actual brain tissue taken from cadavers.

The process required to create the data base is laborious. A particular organ from a cadaver is slowly frozen, cut into thin sections, and photographed slice by slice using a technique developed at the University of Uppsala in Sweden. The image is then converted to a digital form—essentially a string of numbers that a computer can interpret as a graphic image. In the computer, software allows the user to mix images, rotate them, disassemble them, and shade or color them at will. So far, the investigators have completed work on the brain, the eye, and the wrist, but expect to complete the whole body within a decade.

In addition to its use for medical education, says project administrator Marel Norwood, the data base may prove useful to surgeons planning delicate operations—laser treatments or cutting out tumors near critical nerves, for example—and to doctors who want a better means to explain a procedure or an illness to their patients. Ultimately, says project head Cornelius Rosse, "the system should be as clever as an anatomy professor," so that students can solve problems with it, thus enhancing their learning far beyond what a textbook can offer.

Astronomy

## Cosmic Origins: Galaxies Far, Far Away

Through a combination of tenacity, dramatic advances in electronic detectors, and sheer good fortune, astronomers are pushing back the boundaries of the visible universe at a pace that has caught them by surprise. "It's definitely a breakthrough," remarks Joseph Silk of the University of California at Berkeley, "We theorists are so excited by the new data that we're finding it hard to catch up."

Just a decade or two ago, observers were lucky to photograph a galaxy any farther out than 5 billion light-years. Not anymore. A number of research groups are beginning to sight galaxies at more than twice that distance—a leap toward the edge of the visible universe, as well as a sudden jump into its past.

Since light travels at a finite speed, about 186,000 miles per second, the farther away a celestial object is, the longer its light takes to reach earthbound telescopes. Thus, assuming a moderate age for the cosmos of 15 billion years (current estimates vary from 10 to 20 billion years), the new record-breaking finds are allowing astronomers to glimpse the cosmos when it was roughly a fifth its present age, just a few billion years after that explosive moment of creation known as the "Big Bang."

Starved for data from the far reaches of the cosmos, theorists are hoping that the new discoveries will shed light on one of astronomy's most stubborn mysteries: Exactly when and how galaxies—those separate island of stars, nebulae, and planets—came to emerge from the sea of particles generated during the Big Bang.

Hyron Spinrad, a veteran galaxy hunter at the University of California at Berkeley, once compared these endeavors to those of a pole vaulter. "Every year," he said, "we raise the bar a little higher."

Indeed, Spinrad and his colleagues moved the limits of the visible universe out to nearly 10 billion light-years, but only after some two decades of work. Today, the far-galaxy record is racing outward as if a celestial gold rush were in progress; each advance involves hundreds of millions of light-years.

- In the mid-1980's, Stanislav Djorgovski, a Spinrad protégé who was trying out a new filter technique, uncovered what may be a galaxy that resides some 11.5 billion light-years from Earth. (Quasars, believed to be the abnormally brilliant cores of distant galaxies, are seen farther, but the full bodies of these galaxies cannot be discerned.) This sighting is still being debated.
- By focusing optical telescopes onto the positions of powerful, yet invisible, radio sources, astronomers spotted additional candidates. This past spring Kenneth Chambers, a graduate student at Johns Hopkins University, announced the discovery of a galaxy nearly as far out as Djorgovski's find, about 10.5 billion light-years; Simon Lilly of the University of Hawaii quickly surpassed that bench mark by unmasking a galaxy a billion light-years more distant.
- Before the astronomical community could fully absurd Lilly's discovery, Chambers and his colleagues went on to uncover a galaxy almost 12 billion light-years away, a realm that extragalactic astronomers hardly hoped to reach. This current record-holder resides in the northern constellation Ursa Major, just south of the Big Dipper. Moreover, Chambers' on-going survey, a part of his thesis work, now includes seven galaxies beyond 10 billion light-years.

How these discoveries confirm or challenge current theories of galaxy formation is still uncertain. One of the most popular scenarios holds that luminous galaxies grew within clumps of dark, unknown matter—possibly yet-to-be-discovered elementary particles—which may comprise 90 percent or more of the universe's contents.

According to this "dark-matter" theory, small clouds began to coalesce and merge when the universe was about one billion years old; mature galaxies, like our own Milky Way, became abundant only after another three or four billion years had passed.

The far-off galaxies found by Lilly and Chambers, however, seemed to have emerged much earlier than the dark-matter timetable calls for. They are strikingly young. According to University of Arizona astronomer Simon White, who models the dark-matter scenario on computers, this is not a problem as yet. "Most of these distant galaxies are very strong radio sources, which are rare objects in the universe," he explains. A few can easily pop up early on. In fact, many have proposed that quasars and other unusually active galaxies were the first to turn on their central "engines," with more ordinary galaxies, vastly more numerous, forming at a later time.

Chambers agrees with White: "We're not looking at normal galaxies, but it's still exciting to find stellar systems that far out."

### Early Galaxies An Enigma?

"But if these types of galaxies are found to be quite common at early times," notes White, "then our current models would certainly not accommodate them."

Experts agree that final answers will have to await the results of galaxy surveys that trace entire populations of galaxies through time—in other words, studying the celestial forest as a whole, rather than the individual trees.

One such survey, being conducted by a team of American and Canadian astronomers, is already offering some intriguing clues on the universe's history. Over the last several years, using a telescope in the remote Chilean Andes, J. Anthony Tyson of Bell Laboratories and several colleagues have been repeatedly imaging 12 tiny, and what appear to be blank, patches of the nighttime sky. After six to seven hours of total exposure time, a freckle-like array of faint bluish objects emerged in the picture.

Tyson's team believes these dim specks are galaxies in the first bloom of youth, when hosts of newborn stars gave off tremendous surges of ultraviolet light. On their way through deep space, these UV rays would have stretched with the expansion of the universe until they now appear blue. Each object is hundreds of millions of times fainter than the stars seen with the naked eye.

These findings, as well as the searches for the most distant galaxies, would have been impossible without the use of charge-coupled devices, or CCD's, which act as extremely sensitive electronic photographic plates.

Critics have cautioned that these "blue fuzzies," some 25,000 of which have been found to date, could be merely dwarf galaxies that are relatively nearby. But Tyson contends that new observations, recently conducted at a telescope atop Mauna Kea in Hawaii, clinch the far-galaxy interpretation. The brightest of the objects were directly determined to be at least 6 billion light-years away. And both the shapes and brightness levels of the dimmer objects, says Tyson, are consistent with distances ranging out to 11 billion light-years.

### A Slow Down for Galaxies

This extended distribution through time suggests that galaxies evolved gradually over a span of several billion light-years, a pattern that agrees nicely with the dark-matter theory. "The universe is definitely not a horse race, where stars started burning all at once," says Tyson. The era of galaxy formation might then be compared to a slow dawn breaking over the universe, rather than a sudden burst of fireworks going off in the cosmos' early days.

To venture even farther back, other groups are taking advantage of new electronic infrared detectors. By gathering ancient light waves that have been stretched to the infrared, beyond the optical region of the electromagnetic spectrum, astronomers have the opportunity to gaze at even earlier times in the universe's history. Lennox Cowie and Lilly in Hawaii may already be glimpsing primeval galaxies undergoing their first stage of star formation.

Meanwhile, observers like Chambers continue their searches for the oldest galactic specimens they can find. "I expect that our record is only going to hold for a very short time, since other groups are also pursuing these techniques." He believes they have the potential to look as far back as 13 billion light-years or more.

No one yet knows what might be found in such a far domain—perhaps protogalaxies, or possibly the age of primordial darkness before galaxies even blossomed. Whatever the case, these far-galaxy hunters are bringing us ever closer to our cosmic origins.