graduate students, John Grey.

The first nucleic acids to have evolved are thought to be RNAs that have both the information and the catalytic abilities to replicate themselves. Grey pointed out a chemical similarity between that reaction and the transesterification reaction postulated to occur during editing. "The idea in both cases is that you have RNA-directed RNA replication," Cech says. Viewed in this way, he adds, editing may not be a variant of splicing that was invented by the trypanosomes, but something much older. "I'm not saying that the mechanism today is exactly like what was there in the prebiotic world. I'm sure it, too, evolved," Cech explains. "But editing has the right feel to be a direct descendant from RNA replication."

Whatever the origins of RNA editing, Stuart has new evidence suggesting what it's modern function might be. His lab has shown that edited messages are present in the trypanosomes that cause African sleeping sickness only when the proteins they synthesize are needed. Editing may therefore be a way of regulating which proteins are synthesized when. If so, and if editing is found just in the parasite and not in the host, then the editing machinery may be a possible target for drugs that control trypanosome infections in humans.

Such drugs are not likely to come any time soon, however. "Right now the best [therapeutic] targets are still the surface antigens," Sollner-Webb says. "Guides are not only not on the surface, but are hidden away in mitochondria, and not enough is known about the whole editing process for them to be a good target."

The next goal, the researchers all say, is to develop good test tube systems for studying editing so that they can work out the exact functions of all the components of the machinery. When that's been done, they may or may not have their therapeutic target, but they will for sure have removed the last veil of mystery from another of Mother Nature's surprises. ■ MICHELLE HOFFMAN

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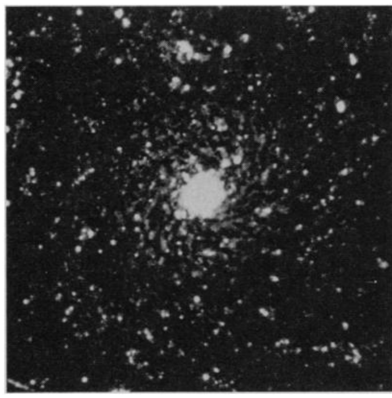
A Long, Hard Look at the Virgo Cluster

New images reveal the stars in a distant galaxy—and heat up a long-simmering debate about the universe's age and size

MIT ASTRONOMER JOHN TONRY THOUGHT he might see something new last February, when he aimed the powerful Canada-Hawaii-France telescope at the distant collection of galaxies called the Virgo Cluster. A visiting astronomer at the Dominion Astrophysical Observatory's facility on Mauna Kea, Tonry had just finished his own observing run and planned to use his remaining minutes to photograph the Virgo Cluster as a favor to Dominion colleagues Robert McClure and Michael Pierce. Working in Tonry's favor were crystal-clear weather, the thin air on the 14,000-foot peak, and a prototype adaptive-optics system, which eliminates atmospheric turbulence by monitoring the twinkling of a star and adjusting the telescope's optics to compensate (see *Science*, 28 June, p. 1786).



Dominion Astrophysical Observatory

Seeing stars. *NGC 4571, one of the galaxies in the Virgo Cluster.*

Yet the quality—and the unsettling cosmological implications—of the resulting images startled Tonry. In every earlier photograph of the Virgo Cluster, which lies at a distance of tens of millions of light-years, entire galaxies had been smudges, their individual stars indistinguishable. Astronomers hadn't expected to make out individual stars in such distant galaxies until the Hubble Space Telescope is cured of its blurry vision. But now, when McClure and Pierce analyzed Tonry's images, they could pick out individual stars within one of those galaxies—the most distant stars ever seen. The achievement is testimony to the rapid progress being made in ground-based astronomy. "Every day observations from the ground get better," says Tonry.

At the same time, the images have sent a ripple of uncertainty through the cosmological community. The reason? Analysis of Tonry's sharp images suggests that the universe is smaller and younger than most cosmologists have assumed.

The grand cosmological implications of these images flow from the fact that McClure and Pierce were able to use them as cosmic distance measurements. The individual stars seen in the galaxy images gave McClure and Pierce the astronomical equivalent of scale bars. By assuming that the brightest of those stars are giving off as much light as the brightest stars in our own galaxy, the astronomers were able to estimate how far away the Virgo Cluster has to be to explain the stars' apparent brightness. The result—50 million light-years—is tens of millions of light-years closer than had been assumed.

"This is extremely important for estimating the distance scale of the universe," says McClure. That's because the Virgo Cluster's distance gives astronomers a new yardstick for measuring the distances to other galaxies, even ones whose individual stars still can't be seen. Ordinarily, the distance to another galaxy has to be estimated based on its red shift —the degree to which the galaxy's light is dragged toward the red end of the spectrum by its velocity away from our own galaxy.

Because of the expansion of the universe, the red shift increases with distance. But astronomers can't translate a specific red shift into an exact distance. The translation involves a number called the Hubble constant, which describes how the recession rate increases with distance. The trouble is that the Hubble constant is far from certain—something Simon Lilly, an astronomer at the University of Toronto, calls "pretty much a disgrace." "All astronomers should be working on that problem," he says. Among those who are, the favored value is 50—the units are kilometers per second per megaparsec—but a few cosmologists have held out for a value approaching 100.

Calibrating the Hubble constant more precisely has required two things: the red shift of a sample galaxy and an independent measure of its distance. But the sample galaxy should be a distant one, with a high red shift that is unlikely to reflect local motions such as rotations around clusters. For such a remote galaxy, getting a precise distance was always the stumbling block. Now the high-resolution images of the Virgo Cluster galaxy have given astronomers that second ingredient. For the first time, they have a fix on an object sufficiently distant that its red shift should be a good indicator of the universe's expansion rate. To many cosmologists, though, the value for the Hubble constant that falls out of the calculations is unsettling.

The value implied, about 85, is unfashionably high. It means that the universe is expanding faster than expected, and that any given redshift actually marks a smaller distance than had been thought. In short, the universe as a whole is smaller—hence younger—than people had pictured. A Hubble constant of 85 points to an age of only 10 billion years instead of the 15 to 20 billion years that is commonly assumed.

And there's the rub. As cosmologist Edward Berchinger of MIT points out, independent calculations based on the rate at which primordial hydrogen and helium have been forged into heavier elements support an older universe. Those heavy elements can be measured in the spectra of stars, and in the oldest stars of globular clusters they are abundant enough to indicate that the clusters are more than 10 billion years old. How can the universe be younger than the objects in it?

That paradox makes some cosmologists reluctant to accept the new value for the Hubble constant. "My suspicion is still that the Hubble constant has a lower value," meaning an older universe, says cosmologist David Schramm of the University of Chicago. He warns against staking too much on this one new measurement, recalling that in 20 years he has heard countless new estimates of the Hubble constant. Cosmologists, he says, often joke that the statement, "I've found the Hubble constant" ranks right up there with, "The check's in the mail." But other researchers say the Virgo observation confirms other, less direct evidence of a small universe. "A lot of different lines of evidence are pointing to this," says Tonry.

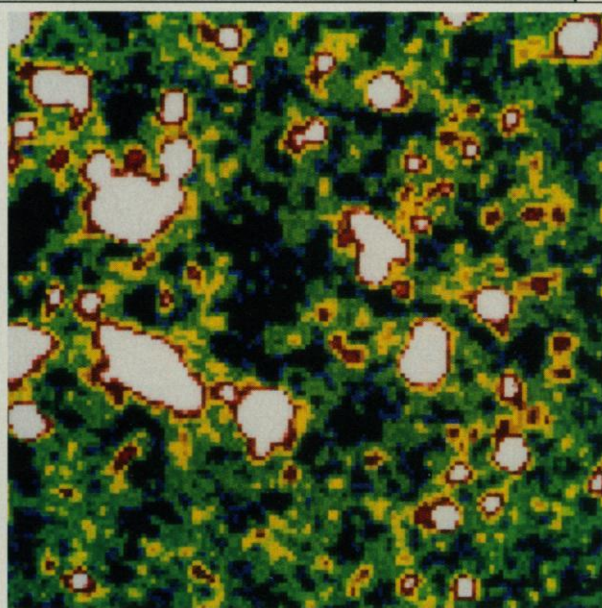
He and McClure believe that high values for the Hubble constant are here to stay—and that squaring them with what is known about the age of the universe will take some revolutionary new ideas. Or not so new: One possibility the workers raise is a cosmological constant—a factor in the equations describing the expansion of the universe that would allow the vacuum of space to contain some energy and generate otherwise unaccountable forces. A universe influenced by a cosmological constant could have expanded more slowly in the past and then sped up; it could thus be as small as the Virgo observations imply and yet be older than 10 billion years, consistent with the oldest globular clusters. Most cosmologists, though, think it would be rash to embrace such a radical scheme without waiting for further confirmation of the Virgo Cluster observations.

One thing unites Tonry and McClure with cosmologists in other camps: They're all rooting for the Hubble Space Telescope. Once it is repaired, the Space Telescope should be able to confirm whether or not cosmologists really do have a problem on their hands by picking out a particular type of star, called a Cepheid variable, in many different galaxies. Cepheid variables shine with a well-known luminosity, making them an ideal standard of cosmic distance. "It [would be] like having 100 watt light bulbs up there," says Berchinger. With that set of beacons, it might be possible to pin down the size and age of the universe to everyone's satisfaction. ■ FAYE FLAM

Looking Toward the Edge

In recent weeks, ground-based telescopes have not only resolved the most distant stars ever seen (see main text); they've also glimpsed what may be the most distant galaxies, at the outer fringes of the universe. Working at the European Southern Observatory in Chile, Joseph Silk of the University of California, Berkeley, and his international team of colleagues say they've captured images of galaxies more than 2.5 times fainter than any object seen before.

The team recorded the images with the help of the vast light-collecting power of the 4-meter New Technology Telescope (NTT). They aimed the NTT at one patch of seemingly empty space for more than 6 hours, until the telescope's detectors began to register a sparkle of faint galaxies in the blackness. Judging from the faintness of the galaxies, Silk estimates that they lie between 10 billion and 18 billion light-years away. The deep-space image carries the observers far back in time, to when the universe was perhaps one third its present age.


European Southern Observatory

Outskirts of the universe. *The deepest-ever image of space, crowded with infant galaxies.*

It also offers a glimpse of the early evolution of galaxies. Astronomers realized in the 1980s that galaxies must have had checkered histories, during which their size, shape, and brightness changed. Indeed, the distant galaxies are bluer than closer, more modern galaxies, probably because of the intense ultraviolet light generated by star formation.

Before Silk and his colleagues conclude anything about galactic evolution, though, they will try to dispose of a troubling possibility: that they are looking at very dim, nearby objects rather than bright ones at enormous distance. The objects are too dim to allow direct measurement of their red shift—a rough distance indicator. The astronomers will instead employ a battery of tricks to estimate red shift, such as comparing the relative intensities of light of different colors. But if the images are what they seem to be, other astronomers say, they are gems in the rough. "Any way you look at it, [the results] will be important and exciting," says University of California, Santa Cruz, astronomer David Coo.

Silk offers an example: If the team succeeds in sorting out the relative distances of their faint galaxies, they may even have a chance of finding the very edge of the visible universe. They will know they have reached it when the number of galaxies present at increasing distances drops off sharply, he says. ■ F.F.