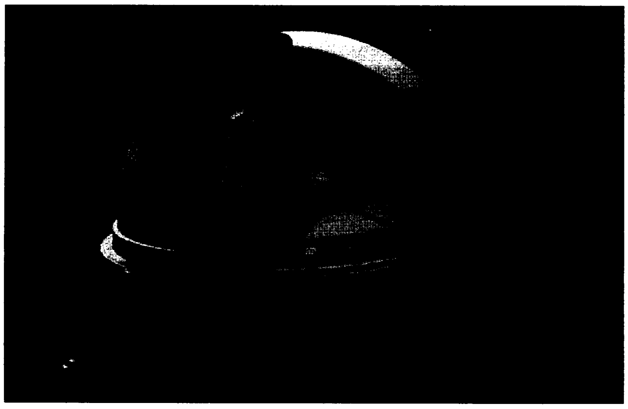
ASTRONOMY

Proposed Scope Takes Mirror Size to the Max

Last week, astronomers peered into their crystal ball and saw a lot of glass: a telescope with a 30- to 50-meter mirror, on which the largest telescopes being built today would fit like so many crackers on a plate. These 8- to 10-meter eyes on the sky will lose much of their sparkle next decade if the proposed Next Generation Space Telescope (NGST) is launched. Combining the distortion-free seeing of space with a powerful 4- to 8-meter mirror, the half-billion-dollar NGST would peer into the universe with unparalleled detail. But the astronomers who met last week* to consider a "maximum-aperture telescope" (MAXAT) aren't ready to cede the future to space.

They hope to persuade their colleagues, especially those who will prepare the next set of spending priorities for U.S. astronomy, that a mammoth ground-based telescope costing up to $1 billion is both feasible and scientifically justified. "It's not quite time to pull up our stakes on the ground," says workshop chair Jay Gallagher of the University of Wisconsin, Madison. "The scientific case for a large aperture is strong, and we see the combination of NGST and MAXAT as particularly powerful."



Wide eye. One design for a future ground-based telescope calls for a segmented mirror at least 30 meters across, tilted at a fixed angle.

Depending on its size, MAXAT could surpass the light-gathering power of NGST by 15- to 150-fold. That would open new vistas, especially in the near-infrared part of the spectrum, where astronomers can best correct for atmospheric blurring. MAXAT could take high-resolution spectra of distant galaxies and "decompose them into their building blocks," says Frank Bash of the University of Texas, Austin. The giant scope might also spot the first supernovae, study the life histories of stars, and peer into the hearts of nascent planetary systems to spy infant and mature Jupiter-sized planets.

If NGST flies, MAXAT could follow up its discoveries just as the twin 10-meter Keck Telescopes in Hawaii work with the Hubble Space Telescope: NGST would capture sharp images, and the huge ground-based instrument would scoop up light to make spectra that reveal what distant objects are made of and how they behave. "Once NGST is flying, this is the next obvious facility," says Matt Mountain, director of the multinational Gemini 8-Meter Telescopes.

The biggest technological challenge would not be MAXAT's gargantuan mirror, which would consist of a mosaic of hundreds of segments, says Roger Angel of the University of Arizona, Tucson. Rather, it's likely to be the adaptive optics controls that would adjust the telescope's optics to compensate for Earth's rippling blanket of air. "We would probably spend the better part of a decade figuring out how to make that affordable," says Angel, who wants to build a 15-meter prototype by putting thin glass into a dish resembling that of a radio telescope.

Gallagher's colleagues plan further meetings before writing a report in time for astronomy's decadal review committee, which will convene next year to set the field's priorities for 2000–10. Alan Dressler of the Carnegie Observatories in Pasadena, California, who hopes to take part in the review, is keeping an open mind until he sees the report. "We're just learning what to do with the 8- to 10-meter telescopes," Dressler says. But because big telescope projects take many years, he notes, "this is an ideal time to consider the next step."

How astronomers would pay for that step is another matter. MAXAT cost estimates range from $250 million to $1 billion depending on the technology adopted. For instance, a dish of segmented mirrors resting on a fixed mount similar to the Arecibo radio telescope in Puerto Rico could cut the costs dramatically and still bring 70% of the sky within view, says Bash. Even so, NASA and the National Science Foundation are unlikely to foot such bills alone—especially with NGST in the pipeline. "Our feeling was that this would have to be a world telescope," Mountain says.

Astronomers in Europe already are thinking along the same lines. Torben Andersen and Arne Ardeberg of Lund Observatory in Lund, Sweden, will hold an international meeting next June to discuss telescopes as large as 50 meters. And Roberto Gilmozzi of the European Southern Observatory (ESO) in Garching, Germany, is pushing his vision of a 100-meter behemoth dubbed OWL, for "overwhelmingly large."

Europe is a rival as well as a potential partner. ESO is pouring $800 million into its Very Large Telescope array of four 8.2-meter mirrors in Chile (*Science*, 1 May, p. 670), and most observers expect ESO to continue pushing the ground-based envelope. "Europe is seizing the leadership in ground-based astronomy, and not even in a subtle way," says Bruce Margon of the University of Washington, Seattle, who did not attend the workshop. "If we are going to concede leadership to them on the ground, we should at least do so by having thought about it."

—ROBERT IRION

Robert Irion is a science writer in Santa Cruz, CA.

* Maximum-Aperture Telescope workshop, 28–29 August, organized by the Association of Universities for Research in Astronomy, in Madison, Wisconsin.

ASTRONOMY

Galaxy's Oldest Stars Shed Light on Big Bang

FRANK RAY/MCDONALD OBSERVATORY

The early universe, fresh out of the big bang, would have delighted those who hated chemistry at school. The only things around were hydrogen, helium, a bit of lithium, and a few other elements no heavier than boron. All the other elements that fill the periodic table arrived later, forged in the nuclear furnaces of stars and dispersed when the stars exploded as supernovae. Cosmologists studying the element-forming processes in the big bang have been trying to look back through the clutter of more recently formed elements to learn the exact composition of that primordial star stuff. Now they have a rare sample of it: a collection of the very oldest stars in our own galaxy, some of which are more than 13 billion years old, formed just 1 or 2 billion years after the galaxy itself was born.

At an astronomy meeting* in Australia last month, Sean Ryan of the Royal Greenwich Observatory in Cambridge, U.K., Timothy Beers of Michigan State University in East Lansing, and John Norris of Australia's Mount Stromlo and Siding Spring Observatories announced the culmination of a 20-year survey: the identification of a tribe of 1000 stellar Methuselahs. "The ancient stars we are studying formed so early in the life of the galaxy that they contain very little [heavy elements]. That is why they are special," says Ryan. François Spite of Paris Observatory at Meudon notes that these stars

* The Third Stromlo Symposium. The Galactic Halo: Bright Stars and Dark Matter, Canberra, Australia, 17–21 August.

"are valuable to cosmology because they provide additional tests of the age of the universe and its initial composition."

Previously, the only way to study the universe's original makeup was to look at very distant galaxies. Because it takes so long for their light to reach us, we see them as they were soon after they formed, before many generations of stars had forged large amounts of heavy elements. But even the most distant galaxies appear to have been enriched in heavy elements by earlier stars. Also, because these galaxies are so faint, it is hard to discern much detail about the universe's primordial composition in their spectra.

To get a better sample of the early universe, Beers and his colleagues searched our own galaxy's halo, a spherical region of gas, dust, stars, and invisible "dark matter" surrounding the galactic disk, looking for stars whose spectra revealed very small amounts of elements heavier than boron. The astronomers made images of patches of the sky through an instrument called an "objective prism," which smears each star's point of light into a spectrum. "The survey was initiated in 1978, so we are 20 years into it," says Beers, who joined George Preston and Stephen Shectman of the Carnegie Institution's observatories in Pasadena, California, in the first phase of the search.

At first, the astronomers picked likely candidates by eye. Now they scan the plates digitally. "This allows us to find more candidates," says Beers. "Once we have a list of candidates, then we have to go to another telescope and take medium-resolution spectroscopy." By doing so, Beers, Ryan, and Norris identified about 1000 stars that have an iron content 100 times lower than that of the sun—a star that has been preceded by several tens of generations of stars. These stars survived so long because they are small, so they burned their nuclear fuel very slowly, says Ryan.

The old stars aren't completely pristine, however. At least one generation of short-lived stars must have preceded them, because even these oldest stars contain traces of heavy elements—including thorium, which enabled the team to "carbon-date" the stars. Thorium is a radioactive element with a half-life of 14.1 billion years; by measuring its abundance, "we get a direct estimate of the age at which the thorium was formed in presumably a supernova" prior to the star's formation, Beers says. The amount of thorium that has been decayed is determined by comparing it to the amount of europium, a stable element formed during the same nuclear process in the star. According to Beers, John Cowan at the University of Oklahoma, Norman, and Chris Sneden at the University of Texas, Austin, have determined the age of one star to be 13 billion years—close to the age that cosmologists have estimated for the universe as a whole from other data, such as the rate of cosmic expansion.

These stars are already living up to their potential as time capsules. Analyzing the stars' spectra to determine how much lithium their surface layers contain, says Ryan, "allows us to measure how much lithium was produced in the big bang." Beers says the early measurements match predictions based on theorists' picture of the element-forming processes in the primordial fireball.

–ALEXANDER HELLEMANS

Alexander Hellemans is a writer in Naples, Italy.

BIOLOGICAL CLOCKS

New Timepiece Has a Familiar Ring

Pendulums, quartz crystals, oscillating atoms—human beings have invented many different ways to keep track of time. Mother Nature, however, seems early on to have hit on one good design for the molecular clocks that govern circadian rhythms and used it repeatedly. The latest evidence for this comes from Masahiro Ishiura and Takao Kondo at Nagoya University in Japan and their colleagues, who on page 1519 describe the workings of the biological clock of the single-celled organisms known as cyanobacteria, or blue-green algae.

ELIZABETH GENTT/VISUALS UNLIMITED

Timeless design. Cyanobacteria such as this one use clocks that work much like ours.

The cyanobacteria clock, which paces 24-hour cycles of activities such as nitrogen fixation and amino acid uptake, is based on the same working principle as are those of fruit flies, mammals, and the bread mold *Neurospora*. At its core is a genetic oscillator, in which a gene produces a protein that accumulates for a while and then feeds back and turns off the gene, causing the protein's concentration to oscillate over a roughly 24-hour cycle. But despite that common scheme, the proteins that make up the cyanobacteria clock are completely different from those of other organisms.

The findings help settle a debate over whether all biological clocks are descended from the same evolutionary ancestor, or whether clocks have arisen more than once during the course of evolution. The cyanobacteria discovery is "the best evidence yet for [clocks'] independent evolution," says Northwestern University clock researcher Joe Takahashi. Keeping track of day-night cycles is apparently so essential, perhaps because it helps organisms prepare for the special physiological needs they will have at various times during the daily cycle, that clocks seem to have arisen multiple times, recreating the same design each time.

To identify the cyanobacterial clock proteins, Kondo and Ishiura began by isolating more than 100 strains with mutations that either abolished or altered the organism's daily activity cycles. The researchers identified the mutated genes by chopping up the cyanobacterial genome and searching for pieces that would restore the normal rhythms when introduced into the mutant bacteria. They found one DNA segment, containing three genes the team called *kaiA*, *-B*, and *-C*—"kai" is Japanese for "cycle"—that could restore all the mutants tested.

All three genes proved essential for the cyanobacterial clock; the Kondo-Ishiura team found that inactivating any one disrupts the organism's rhythms. Other work suggested that the proteins made by the genes are themselves part of the clock mechanism. For one, the researchers found that, as expected for clock components, the activity of the genes oscillates with a 24-hour cycle.

When the team took a closer look at the clock gene activity patterns, their findings suggested a familiar scenario: Early in the day the *kai* genes begin to produce RNA that is translated into protein. Next, KaiA protein apparently turns up the activity of the *kaiB* and *-C* genes. Then after a delay, KaiC seems to step in and turn the genes off. That causes protein levels to fall. As a result, KaiC stops repressing the genes and they come on again. If that model, which fits all the current data, proves true, says Ishiura, that means "regulation of the clock genes is analogous" to the three other known clock systems, in fruit flies, mammals, and *Neurospora*. In fruit flies, for example, the proteins Period and Timeless feed back to turn off their genes.

Many questions remain to be answered about the cyanobacterial clock. Ishiura and his colleagues don't yet know, for example, what causes the delay before KaiC feeds back to turn down its own gene. The ques-