

**Farsighted
Astronomers**

They're on top of the world, looking back on creation.

by Marcia Bartusiak



For Stanislav Djorgovski's quest, clear skies aren't enough; he also needs a roomful of electronic gadgetry.

“**W**e can get a bit grouchy if bad weather sets in,” confesses Stanislav Djorgovski, peering anxiously out a window of the dining hall atop Kitt Peak, a massive and furrowed wad of earth that sits on a desert plain in southern Arizona. From the mile-high mountaintop, the surrounding countryside, brown and nearly barren, appears as desolate as a lunar landscape.

Djorgovski, known as George to his co-workers at the Harvard-Smithsonian Center for Astrophys-

ics in Cambridge, Massachusetts, has traveled more than 2,000 miles to observe the heavens from this famous perch, the world's largest complex for extragalactic, stellar, solar, and planetary research and an astronomical mecca for observers from around the globe. Using the giant Mayall telescope—one of the world's largest with its four-meter-wide mirror—Djorgovski and Patrick McCarthy, a colleague from the University of California at Berkeley, are about to spend three nights on the moun-

Photographs by Jim Richardson

tain photographing young galaxies situated in remote regions of the universe. Since light travels at a finite speed, about 186,000 miles per second, the farther away an object is, the longer its light takes to reach earthbound telescopes. Thus, when astronomers look out to the most distant reaches of the cosmos, they are in effect traveling into the past. The most farsighted of cosmic explorers, they are searching for that ancient epoch when galaxies first coalesced out of the primeval soup.

When Halley's comet streaked by Earth in late 1985, Kitt Peak was plagued by snowstorms. A year later, during Djorgovski's observing run, only a smattering of snow lurks in the mountain's crevices. Djorgovski's gamble has paid off. Applying for telescope time months in advance, as is required by observatory administrators, he could only hope that nature would be benevolent; observatories do not hand out rain checks. But as the setting sun paints the nearly cloudless western sky a vivid orange, spirits soar. "It's sure to be a good night," declares Djorgovski as he and McCarthy head up to "the Big Four" in one of the observatory's battered white pickup trucks.

They will put in their hours tonight not glued to the telescope's eyepiece but seated in a narrow room off to one side of the telescope. This area, with its glimmering array of clocks, gauges, and electronic paraphernalia, looks much like the control center for a spacecraft mission.

Above the telescope operator's L-shaped console, a pair of windows overlooks the giant reflector. Its broad mirror is mounted in a colossal blue prong. But now the window shades are pulled tight: the objects Djorgovski and McCarthy seek are so faint that any stray light could ruin the observation.

Ensnared in comfortable lounge chairs, the two astronomers spend most of the night in front of a computer monitor, either entering or checking the innumerable bits of data required for each observation, such as the desired filter or the position of the focus. "We've gotten spoiled by the new technologies," says Djorgovski. One of these is the charge-coupled device, or CCD. Astronomers have begun replacing cumbersome and inefficient photographic plates with

these ultrathin, stamp-sized silicon wafers. Photons of light entering the telescope strike the chip's surface and are converted into electrons, which get stored in electronic wells at the point of impact. Hundreds of thousands of these wells form a grid-like pattern, much like the dots, or pixels, that make up a satellite-transmitted photograph, over the CCD. The charges in all the wells are measured periodically by a computer, which swiftly converts this information to an image that can be studied and stored.

Djorgovski and McCarthy choose to examine their images as if the pictures were negatives: the stars and galaxies appear on a graphics terminal as dark specks against a light background.

Collecting data from the edge of the visible universe requires the use of the world's largest and most sophisticated telescopes, which are few in number; observatories receive many more requests for instrument time than they can accommodate. Only a small coterie of astronomers can hope to devote their life's work to the study of the universe's outermost boundaries.

The searches conducted by Djorgovski and McCarthy are part of a celebrated program initiated by Hyron Spinrad at Berkeley about 15 years ago. "Hy is just as much an artist as he is a scientist," says Djorgovski, a Yugoslav who first came to this country eight years ago and studied under Spinrad. "Hy's been known to spend as much as 30 hours of telescope time to figure out the distance to one far-off galaxy. I would have given up, but not Hy."

Spinrad likes to compare his endeavors to those of a pole vaulter. "Every year," he says, "we raise the bar a little higher."

The challenge escalates too. The deeper astronomers peer into space, the more they must strain their telescopic eyes. Galaxies appear dimmer, smaller, and fuzzier. Twenty years ago, astronomers were lucky if they could examine galaxies one billion light-years away. Today, thanks largely to CCD technology, observers are regularly detecting galaxies out to eight billion light-years and beyond, more than halfway back to creation.

Spinrad's ultimate goal? "The very beginning," he responds. "Of course,

the word 'beginning' means different things to different people. What I mean is the beginning of the universe's major constituents—the galaxies."

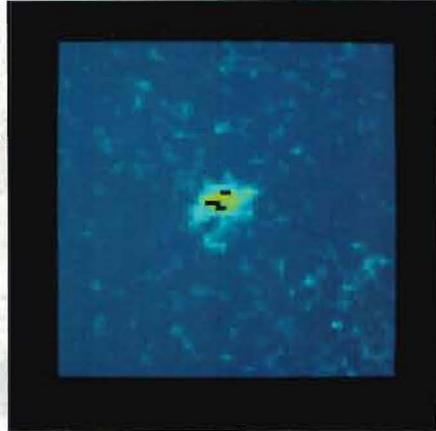
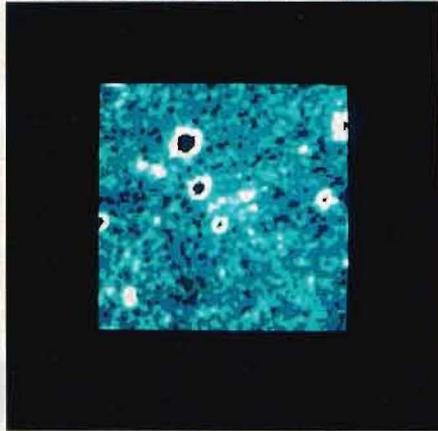
Each galaxy is a celestial island composed of tens of billions of stars. Astronomers believe that these galactic lumps congealed from the ocean of particles spawned in the primordial explosion, playfully dubbed the Big Bang, which occurred some 15 billion years ago. The



Kitt Peak's four-meter Mayall telescope allows astronomers to peer halfway back to the Big Bang.



Patrick J. McCarthy/Leuschner Observatory, UC Berkeley (2)



Patrick McCarthy won astronomical kudos for his study of the gas cloud surrounding radio source 3C 326.1. The far left photograph shows all visible light around the radio source. The near left photograph was taken through a special filter that admits only photons from ionized hydrogen that have the same redshift as 3C 326.1. The concentrated hydrogen may herald the birth of a galaxy.

Distant objects move away from us more quickly than nearby ones, so they appear redder.



The observing duo won't know until weeks of analysis are complete whether they've hit celestial paydirt tonight.



entire universe continues to expand, and galaxies go along for the ride.

To gauge a galaxy's distance, astronomers measure how much its light has reddened, or "redshifted," as the galaxy is carried away. The more distant a galaxy, the more quickly it moves away from us, and therefore the more the lightwaves traveling from it to us are "stretched"—made redder.

Spinrad's group finds many of its distant specimens with the help of radio-astronomy surveys. The far galaxies they seek emit intense radio waves from their centers. "The radio signal tells us where to point the telescope, or else we'd never find them," explains Spinrad. "About a third of our sources turn out to be washouts. Sometimes they're close by; sometimes we never find out what they are. But then we try again, sinking our teeth into these things like bulldogs."

The hunt continues at Kitt Peak. "We're going to try to image a few more distant galaxies tonight," says Djorgovski.

"But we could put many hours in," warns McCarthy, "and get nothing."

As the strains of a classical symphony emanate from a portable radio, telescope operator Dave Chamberlin types a series of commands into his terminal, which directs the telescope to the coordinates of an unseen, radio-emitting object labeled 3C 194 in the Third Cambridge catalog of strong radio sources.

Three pictures are taken: one with a blue filter, one each in red and yellow. Each exposure takes 10 minutes. What later appears on the graphics screen, amid a sprinkling of foreground stars and nearby galaxies, is a dim, elongated

fuzz. "We're finding that a lot of these very distant galaxies are hot dog-shaped," explains McCarthy. The Milky Way and most contemporary galaxies are either spiral or elliptical, configurations that astronomers consider more stable than the oblongs McCarthy studies. "They haven't settled down to the more quiescent stage we see around us today. It's possible that they're colliding or somehow interacting with some gas-rich neighbors," McCarthy suggests. Or perhaps, as Spinrad has proposed, these young galaxies are actually forming out of smaller, stellar units.

Only a couple of decades ago, such theories would have been considered preposterous. "When I was a kid," recalls Spinrad, "galaxies were separate, like the continents. But now we know that the continents haven't always been separate. The same may be true of galaxies." Astronomers are realizing that galaxies can be intimately involved with their neighbors—merging, swapping mass, and triggering stupendous bursts of star formation in one another. Perhaps such activity was even more prevalent eons ago.

At nine o'clock, the telescope is aimed in the direction of the constellation Cetus, the Whale. A low-pitched rumble fills the air as the massive dome moves into position overhead.

A few years ago, while trying out "the type of procedure that telescope committees aren't anxious to give time for," he says, Djorgovski uncovered the farthest "normal" galaxy on record; it resides some 11 billion light-years from Earth. (Quasars, the abnormally brilliant cores of distant galaxies, can be seen farther, but the full bodies of these

galaxies cannot be discerned.) He did this by pointing the telescope toward a bright, far-off quasar—an object whose redshift is known—and combing its vicinity for hidden neighbors. He figured that the quasar's companions, if any, might come into view when a filter was installed that would admit light that shared the quasar's redshift. "To use a musical analogy, the filter enables us to listen to one tone amidst a cacophony of noise," explains Djorgovski.

Djorgovski employs this strategy tonight, looking at a quasar in Cetus. After a 21-minute exposure, the CCD picture displays a distinct smudge to the east of the quasar. "A solid maybe," says Djorgovski. "Sometimes we can get blasé over the fact this blob on the screen may be three times older than our solar system." Surety will come as soon as a spectrum, a breakdown of the smudge's composite wavelengths of light, reveals the object's redshift.

At ten o'clock, Djorgovski and McCarthy, bundled up against a winter breeze, take a brief stroll on the catwalk that wraps around the middle of the 19-story-high dome. It's an opportunity to remind themselves that the glowing dots displayed on their TV monitors have a reality outside the control room. The Milky Way, the vast array of stars that mark the spiraling disk of our own galaxy, appears as a misty cloud stretching from horizon to horizon.

Returning to work, the two colleagues unmask what may be another distant galaxy. A quasar labeled S4063+68 has a suspicious companion, too. "Be still my foolish heart," quips Djorgovski with a mischievous grin, as he looks at a filament connecting the

point-like quasar with a softer blob. "Curiouser and curiouser," he says, leaning into the screen. "We've earned our salary tonight."

By three o'clock in the morning, though, their luck has run out. High cirrus clouds have drifted in, disrupting the view. McCarthy, working on his doctoral thesis, was hoping to photograph intriguing fountains of gas being ejected from some of the far-off galaxies. But the Berkeley student has already learned that patience is *de rigueur* in this specialty, along with confidence, dogged persistence, and, at times, a bit of arrogance.

"It's an exciting time for us," notes McCarthy, "because the advanced instrumentation is enabling us to do more than just locate these far, primitive galaxies. We can begin to study their environments as well."

In 1986 McCarthy and several colleagues traced an enormous cloud of energized gas—three times the size of our Milky Way—around a radio source known as 3C 326.1, situated some 10 billion light-years from Earth. It's McCarthy's most notable achievement to date: the cloud, which has the mass of 100 billion suns, is emitting a relatively small amount of starlight, compared with the brightness of the gas, which suggests that it might be a galaxy in the throes of birth, a late-blooming protogalaxy undergoing its first, turbulent bursts of star formation—"what astronomers have been seeking for decades," says McCarthy.

Spinrad concedes that there is a potential pitfall in these efforts. The remote, radio wave-emitting galaxies that his team surveys might not be truly representative of what's going on at the far frontier. Other farsighted astronomers, including Alan Dressler of the Mount Wilson and Las Campanas Observa-

tories, administered from Pasadena, California, and James Gunn of Princeton, search for more ordinary specimens, each a sort of galactic man-in-the-street.

"What did galaxies, like the sedate Milky Way, look like five billion years ago? Ten billion years ago?" asks Dressler. "To find out, we must scoop out a section of space, as if we had a steam shovel, catalog all the galaxies in that region, then scoop out another section farther out and compare." In this way, Dressler and his cohorts hope to discern how galaxies evolved.

Since 1980, Dressler and Gunn have spent more than 50 nights on Palomar mountain in Southern California using the famous five-meter Hale telescope to examine distant clusters of galaxies. They have perceived exciting new facets of the universe's personality. "There's much more activity than we supposed ten years ago," says Dressler.

"Young galaxies do look more 'wild' than their older colleagues," says Gunn. "Today, we may be settling down to a senile old age."

Less than an hour before dawn, Djorgovski and McCarthy, fueled by a never-ending supply of coffee, manage to squeeze in one more observation. It's their 15th target of the night. With no time to spare, they take a blind exposure, not sure if their candidate—one of McCarthy's gas-spewing galaxies—is in the telescope's field of view. The first image displayed on the CCD monitor shows nothing of interest, and McCarthy looks disappointed. But when the picture is scrolled to reveal what was previously offscreen, McCarthy hits the jackpot: he sees a long spray of material shooting out from his target galaxy.

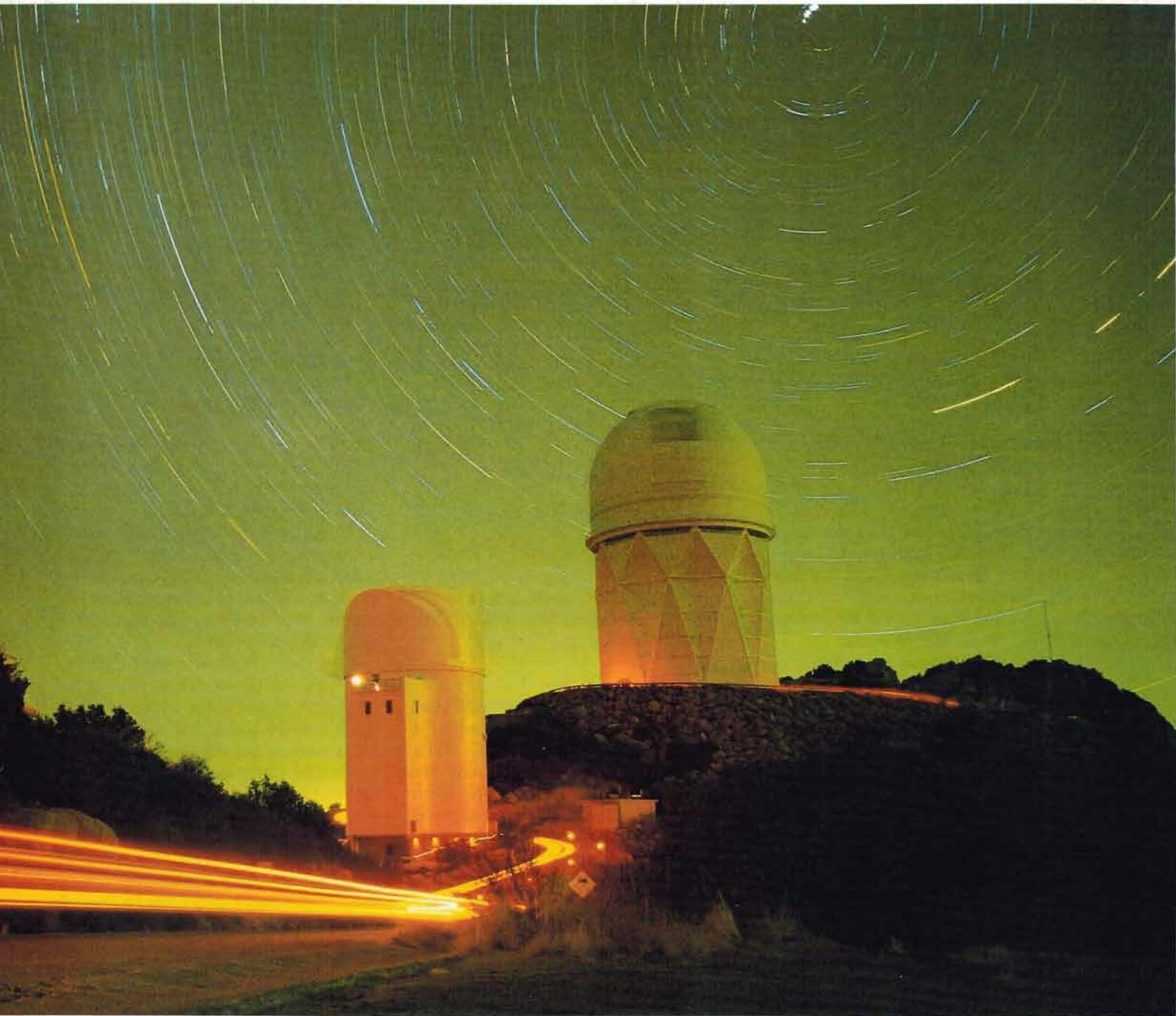
As the first rays of sunlight strike the stark white dome of the Mayall telescope, 12 hours of observing come to an



end. "On a scale of 1 to 10, I'd give this night an 8.5," concludes Djorgovski.

"Most nights," says McCarthy, "we usually average less than 5."

But their work has only started. After two more nights on the mountain—one extremely productive, the other spoiled by bad weather—the two astronomers travel back to their respective institutions, computer tapes in hand, to analyze their haul. "A lot of processing has



to be done before we even get to the science,” says McCarthy.

Still, ever so slowly, each and every pixel will add to an overall tapestry that astronomers have been weaving for centuries, a cosmic portrait that depicts a magnificent and ever-evolving story of creation.

Says Djorgovski: “It’s a challenge. It’s fun. It’s disorderly. It’s the best job in the world.” ←

The Kitt Peak facilities stand near the figurative center of the universe for farsighted astronomers.