# A Universe of Color

## *Photographing the many hues of the night sky*

By RON COWEN

Woody Allen approached the astronomy community with an unusual request last year. For an upcoming movie, he needed a flashy image of the heavens – something "fresh and sexy," the message said. For David Malin, working with the Anglo-Australian Telescope (AAT) in Coonabarabran, Australia, the request couldn't have come at a better time.

Since 1976, Malin has built up a collection of photographs that record the colors of the universe. Snatching bits of precious observing time from odd corners of the night, he and his colleagues used the 3.9-meter AAT to capture the striking reds, blues, and greens of myriad heavenly bodies – wispy molecular clouds, clusters of stars, and galaxies in the throes of starbirth.

But that work came to a virtual halt five years ago, when supernova 1987A erupted, lighting the Milky Way's nearest companion galaxy – the Large Magellanic Cloud in the southern sky – with the brilliance of 100 billion suns. Suddenly, all large telescopes that could gaze at the southern celestial hemisphere – including the AAT – were devoted to tracking the evolution of this burned-out star. There was little time left over for Malin to continue his photographic survey.

By 1991, supernova 1987A had faded, and Allen's request – combined with Malin's unwavering interest in astronomical photography – earned the astronomer and his team three whole nights on the telescope. Although Allen opted not to use his photos, Malin recorded several new and illuminating pictures of the heavens.

Last April, Malin dazzled audiences at a meeting of the Royal Astronomical Society in Durham, England, with his team's photographs.

While captivating, many of the images highlight features that astronomers are already familiar with, says Malin. But the photographs do have several advantages over other types of celestial observations, he notes. Color adds depth to a flat image of the sky, indicating the relative proximity of objects. For example, if part of a dusty Milky Way cloud lies closer to Orion, that portion will appear yellower, since it basks in the yellow light of this familiar nebula.

The true-to-life color images also provide a valuable teaching tool, sparking curiosity in schoolchildren and helping older students understand the heavens. "When you have to explain to students all the interactions going on in galaxies, it's difficult to describe – even with a black-and-white photograph," Malin says. "But all of a sudden you show this color picture and everything falls into place straight away. One's understanding – and appreciation – of the subtle changes in color across a galaxy suddenly comes to the fore."

And each hue, he says, tells a separate story.

Consider the spiral galaxy NGC 300 (photo A). Astronomers already knew that this galaxy contains a large population of young, hot, blue stars concentrated along its spiral arms. But in the


*Photo A: Blue light from hot, young stars dominates this image of the spiral galaxy NGC 300. Photo B: Another spiral, NGC 3628, sports a brown dust stripe running through its middle and patches of blue and pink star-forming regions at the edges of its arms. Photo C: Dust and old, cool stars lend a pale yellow tint to the core of the spiral galaxy NGC 1365, while vigorous starbirth colors the arms blue and pink. Photo D: The remnant of a sun-like star, the planetary nebula Ack 277-03 has a bluish interior caused by ultraviolet starlight bombarding oxygen gas. Hydrogen and nitrogen contribute to the red glow of the nebula's exterior.*

photograph recently taken by Malin's team, the intense blue overwhelms every other color, suggesting that the galaxy must have undergone a burst of star formation no more than a few million years ago. Says Malin: "Astronomers might say the spiral arms of this galaxy have a color index of near zero, meaning they are blue. That's not very exciting. But when you see the image, the color pops out in a beautiful way, often revealing other subtleties that mere numbers can't express.... Instead of memorizing a number, you see the picture and say, 'What a blue galaxy; how interesting.'"

Malin has also photographed the spiral galaxy NGC 3628 (photo B), a member of a trio of galaxies in the constellation Leo. A brown stripe running through the middle of the galaxy signifies a feature common in spirals: a lane of dust. The dust absorbs blue light as well as some green, resulting in the brown appearance. The brown stripe and the blue and pink star-forming regions at the edges of the spiral appear slightly distorted. This appearance dovetails with previous measurements, made at other wavelengths, indicating that nearby galaxies are tugging on the object, gravitationally stealing matter and puffing out the slender ends of the spiral arms.

Malin's image of NGC 1365 (photo C), another spiral galaxy, reveals a variety of stellar populations. The galaxy's center has a yellowish cast, due mostly to the presence of old, cool stars. Dust located at the core absorbs blue light and exaggerates the yellow color. The pale pink areas along the kinks of the galaxy's spiral arms denote regions of vigorous starbirth. In these regions, the hottest and most massive of the new stars shine ultraviolet light on surrounding gas and dust, causing it to glow with the ruddy hue of fluorescent hydrogen. Elsewhere, the hot, young stars have blown away the dust, tinting the arms sky blue.

In photographing a pair of lung-shaped galaxies called the Antennae galaxies (see cover), Malin captured the colors of two gigantic bodies in the process of devouring each other.

Each "lung," he notes, represents a spiral galaxy that bumped into its neighbor about a million years ago. The galaxy on the right had much more gas – the raw material for stars – than its partner. Thus, the collision triggered a more intense wave of star formation in the right galaxy, accounting for its richer colors, says Malin. The telltale red of starbirth lurks even behind the brown, dusty regions of this gas-rich spiral, he adds.

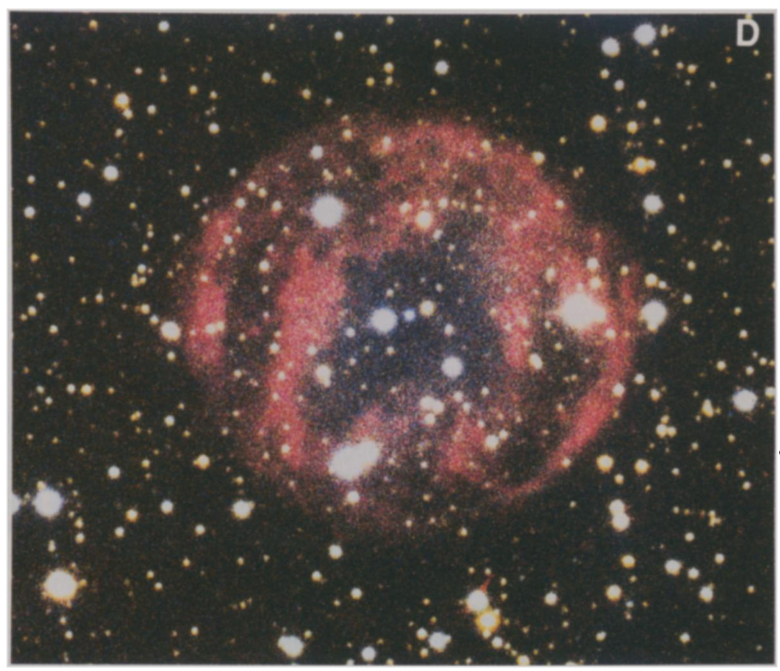
"This image is an excellent example of where the use of color brings out information that has been known but puts it all in an absolutely solid perspective," he says. "We've known that star formation goes on in these galaxies, but here it is all laid out before us in a kind of global view."

To photograph the colors of the night sky, Malin relies on a technique that dates back more than a century. Scottish physicist James Clerk Maxwell used the method in 1861, when he displayed the first color photograph at a meeting of the Royal Society of London. Attempting to capture the bright colors of a Scottish tartan ribbon, he took three images of the object, each with a black-and-white negative sensitive to a different primary color – red, green, or blue. He then illuminated positive slides made from each negative, using colored filters matching the red, green, or blue hues to which each plate had been sensitized. When Maxwell superimposed the three images on a white wall, a vibrant image of the tartan appeared, resplendent in its highland colors.

(Years later, scientists discovered that Maxwell's "red-sensitive" plate actually recorded ultraviolet light. That error didn't pose a problem for Maxwell's experiment, however, because the red parts of the tartan happened to emit as much ultraviolet light as red.)

Today, Malin and a few other astronomers still construct color photos from black-and-white plates, in part because of the uneven responsiveness of standard color film. Ordinary color film has high sensitivity to red, green, and blue but is remarkably insensitive to other colors. This feature makes little difference in photographing objects illuminated by the sun, which emits roughly equal intensities of light at all wavelengths. But consider a scene lit by fluorescent light, which emits a much higher proportion of green than other colors. Color film will misleadingly suffuse the entire scene with a greenish cast. Color film also skews


C


D


B

Photos: Malin, © Anglo-Australian Telescope Board

Malin, © Anglo-Australian Telescope Board

*The dark blobs in this image are Bok globules, dense clouds of dust blocking the light from a Milky Way star-forming region called IC 2944. The blobs have unusually sharp edges, suggesting that starlight has eroded parts of the clouds.*

the spectra of astronomical objects such as gas clouds, which emit or reflect light strongly at just a few wavelengths.

By combining black-and-white images à la Maxwell, astronomers can avoid the pitfalls of color imbalance. The plates also make it easier to manipulate the quality of the final image. Thus, researchers can amplify images of faint stars and galaxies as well as highlight the fine detail of very bright objects that would otherwise appear overexposed. In both cases, astronomers work to bring the hidden colors – and shapes – of celestial bodies to light.

To reveal the details of regions so bright that they appear washed out on a standard photograph, Malin uses a technique called unsharp masking. First, he makes a fuzzy positive by passing diffuse light through the original glass negative and onto photographic film. He then sandwiches together the blurry positive print and the negative to make a new print. The blurry positive subtracts large-scale variations in brightness from the negative, so the final print highlights only the fine detail otherwise hidden in ultrabright regions.

In order to image dim objects, which are difficult to pick out against the faint background of light from the night sky, Malin takes advantage of the nature of the photographic emulsion. Light striking the emulsion causes crystals of silver halide to develop into grains of silver; since dim light penetrates only the uppermost layers of the negative, the dark grains that form the dimmest images lie near the top. To amplify these faint images, astronomers pass a diffuse source of light through the fully developed negative onto high-contrast film. Such film effectively enlarges the size of all grains, but the diffuse light highlights the negative's topmost grains. As a result, dim spots become more prominent in the final image.

Five years ago, Malin used this technique to identify one of the faintest galaxies known in the universe, a massive but nearly invisible object now known as Malin 1 (SN: 5/16/87, p.308).

Astronomers have been able to take color pictures of the night sky ever since about 1909, when red-sensitive emulsions were invented. But for nearly 50 years, most researchers simply weren't interested. They realized early on that most celestial objects were strongly colored, but they spent most of their time recording spectra rather than taking pictures.

Spectral analysis – determining the intensity of individual wavelengths of light emitted and absorbed – reveals much about the chemical composition and physical condition of stars and galaxies. And the amount by which these wavelengths are shifted toward the redder or bluer end of the electromagnetic spectrum indicates whether a body is moving away from Earth or toward it.

However, the colors astronomers assign to stars, based on their spectra, are sometimes misleading, notes Malin. For example, the elderly, puffed-up stars called red supergiants have a temperature similar to that of a tungsten-halogen floodlamp and actually look yellow, not red. "Red supergiant is a terrific name that trips off the tongue, but it's not correct," Malin says. Other errors abound. For example, a false-color image taken with the Hubble Space Telescope portrays the globular cluster 47 Tucanae as bright red, but this aged, star-packed region of the Milky Way is really yellow-white, as a recent image taken by Malin's team shows.

These color misnomers stem from the way researchers have traditionally classified stars, Malin says. At the turn of the century, scientists designated a group of blue, hot stars as "A" stars, the reference standard for measuring the color of astronomical objects. Stars cooler than A stars are labeled red, while hotter stars are labeled blue – regardless of their appearance to the eye.

In the 1940s, some researchers suggested that stars could be classified by recording their true colors. But it wasn't until the late 1950s that someone began to document what those colors were. Bill Miller, a research photographer at the Mt. Wilson-Palomar Observatories near Escondido, Calif., pioneered the effort, using color film to take images of the heavens with the famed 200-inch Hale Telescope atop Mt. Palomar.

It was a slow, tedious process. Color films of that era responded slowly to light, requiring Miller to make unusually long exposures. Long exposures increase the likelihood of color imbalance, and the photographer spent long hours in the darkroom, carefully correcting for erroneous shifts in color. By the early 1960s, several magazines, including NATIONAL GEOGRAPHIC, had published Miller's collection of about a dozen photos. "The pictures blew people's minds away; they'd never seen anything like it," Malin recalls.

In 1976, one year after beginning work with the AAT, Malin traveled to California to spend a week with Miller, learning the trials and tribulations – and the joys – of color photography from the pro. Miller, who was about to retire, told the younger researcher that he had intended to switch from color film to a system of three black-and-white plates. Upon returning to Australia, Malin says, he more or less "took over the color work from Miller," instituting his own three-plate, black-and-white method.

According to Malin, visible-light color photographs have a significant advantage over images taken at other wavelengths.

"The color pictures I'm producing are colors the eye would see if you could turn its sensitivity up a million-fold. You don't have to make any translation from [another wavelength] to something that you can understand and know. . . . People can't digest X-ray or ultraviolet images as readily."

More and more people are digesting Malin's colorful universe. Textbook publishers have printed the images for more than a decade now. And the Australian government has found Malin's pictures flashy enough to immortalize three of them on postage stamps issued earlier this year. □