The Time-Travel Project

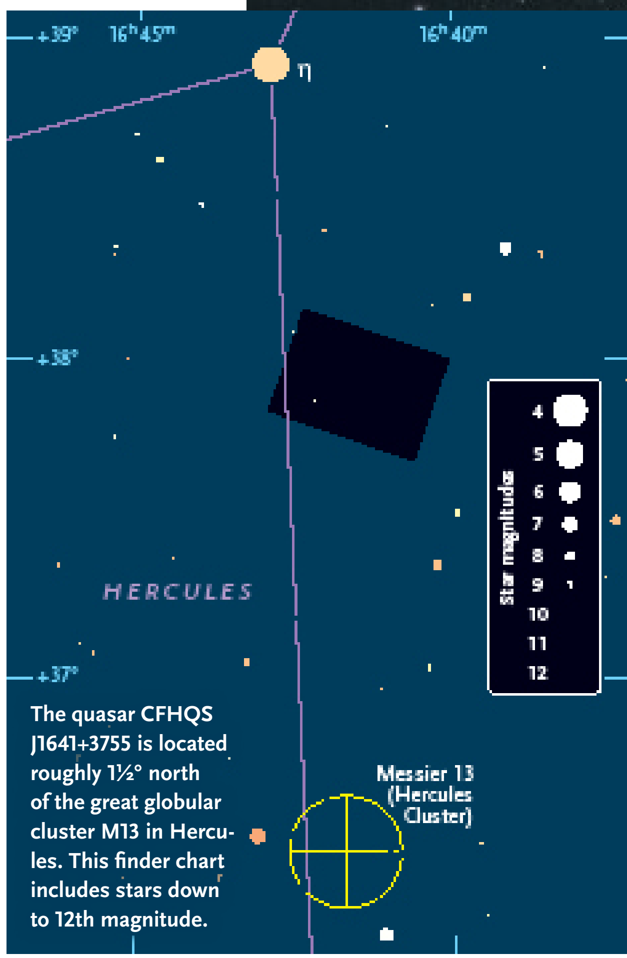
Two amateurs reach back in time — way back — to photograph the young universe.

JOHANNES SCHEDLER

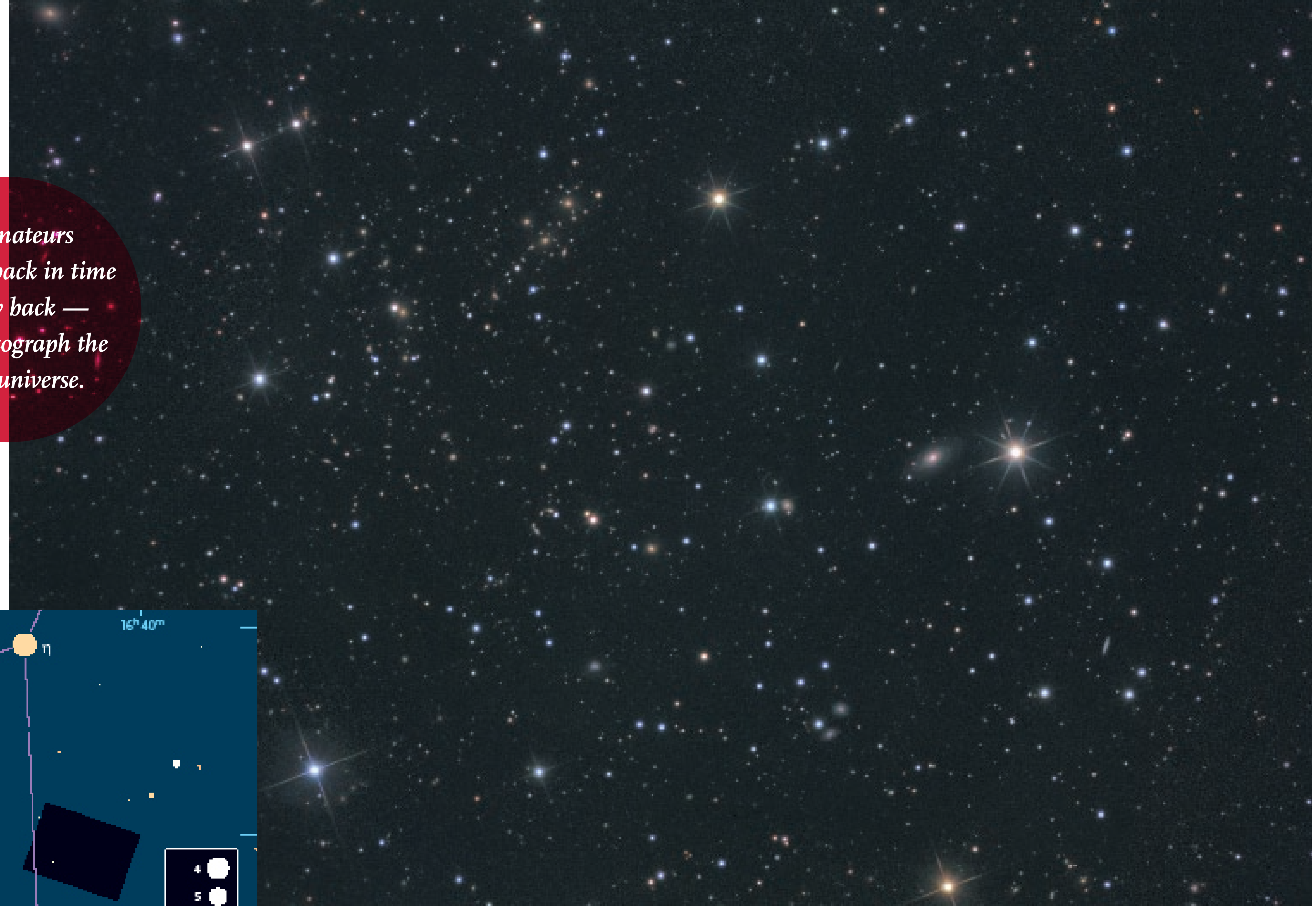
THE EQUIPMENT available to amateur astronomers today is astounding. Professional-grade telescopes, mounts, and CCD cameras are now within our reach, and many of us use them to produce beautiful photographs of our universe. But amateur astrophotography isn't only about taking pretty pictures: we also have the tools to do serious research on par with that done at many universities and other professional facilities. Furthermore, we amateurs don't have to compete for precious telescope time and can expose as long as conditions permit. The sky is now the limit, *literally*.

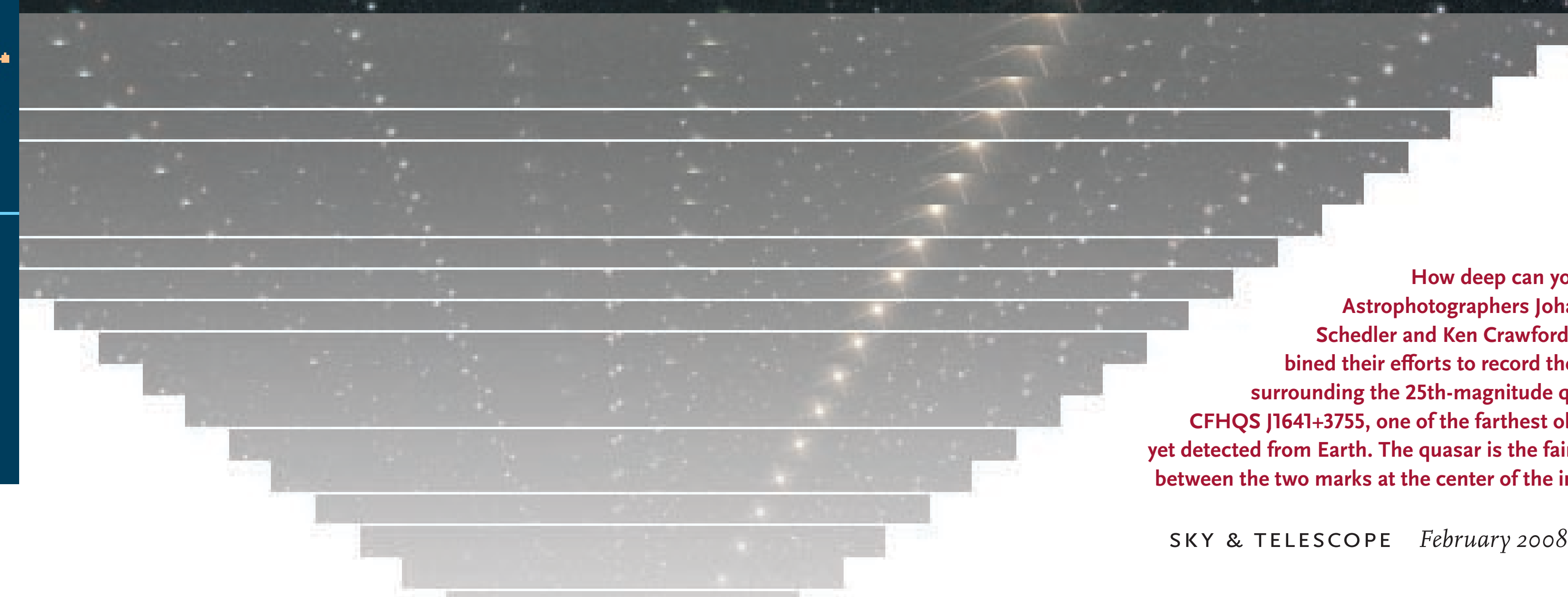
While my astronomical pursuits have centered around recording beautiful images of nebulae, star clusters, and galaxies, in June 2007 I stumbled upon a publication that launched me in a new direction. It described the discovery of four very distant quasi-stellar objects (QSOs), more commonly known as quasars. These things look like stars in most telescopes (hence their name), but they're actually the extremely energetic nuclei of active galaxies. Their light comes from ultrahot gas spiraling around supermassive black holes. Quasars emit the combined energy of hundreds of normal galaxies, making them among the most luminous objects in the universe.

The four newfound quasars captured my imagination because of their very high *redshifts* — that is, because their emissions from hydrogen and other familiar gases appear at much longer wavelengths than normal. In the prevailing Big Bang cosmology, the universe is expanding, such that on large scales everything is rushing away from everything else. Just as a train whistle is Doppler shifted



The quasar CFHQS J1641+3755 is located roughly 1½° north of the great globular cluster M13 in Hercules. This finder chart includes stars down to 12th magnitude.





JOHANNES SCHEDLER / KEN CRAWFORD

How deep can you go? Astrophotographers Johannes Schedler and Ken Crawford combined their efforts to record the area surrounding the 25th-magnitude quasar CFHQS J1641+3755, one of the farthest objects yet detected from Earth. The quasar is the faint dot between the two marks at the center of the image.

to a lower tone as it passes by, a celestial object's light is redshifted to longer wavelengths as it recedes.

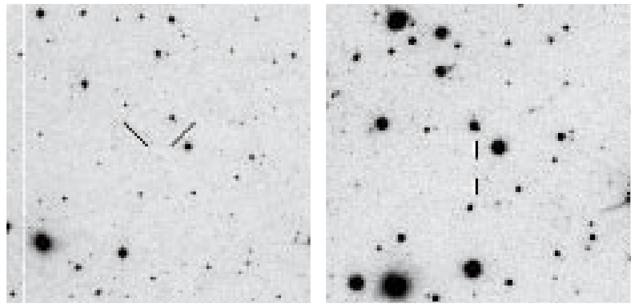
To understand why more distant objects — like quasars — have higher redshifts, think of a loaf of raisin bread. As the yeast makes it rise (expand), the raisins move apart, and from each one's perspective, *more distant raisins recede faster.* Ditto for galaxies and quasars in an expanding universe. For this reason, most astronomers consider redshift to be a good indicator of distance in the cosmos.

An observed redshift (abbreviated z) of 1 means that each wavelength emitted by the object has been shifted longward by 100%. One of the four quasars I learned about last June set a new record at the time: an astounding z of 6.43. The feeble light from this object has been traveling since the early childhood of our universe, when it was only about 7% of its current age.

Although we can be fairly certain about the redshifts of such far-flung objects, their actual distances in light-years remain debatable and depend upon the values chosen for the various cosmological parameters that define the expansion of the universe (*S&T*: March 2006, page 69). Still, there's little doubt that high-redshift quasars are billions of light-years away and represent the universe in its infancy.

Hunting Ancient Prey

It occurred to me that such an elusive object just might be within reach of my own 16-inch Cassegrain telescope and sensitive CCD camera. I selected the newly discovered quasar with the best location for viewing from my own northern site: the object designated CFHQS J1641+3755, located in the constellation Hercules at right ascension $16^h 41^m 21.64^s$, declination +37° 55′ 20.5″, about 1½° north of the great globular cluster M13. I then began a series of



Left: **This negative discovery image from the Canada-France High-*z* Quasar Survey shows the object targeted by the author. North is up. *Right:* Schedler and Crawford's combined 8-hour exposure reveals the faint quasar at the exact same location; note that the frame is rotated counterclockwise slightly.**

30-minute exposures to see what I could record.

On the first night, after exposing for a total of 4 hours, I could see objects in the field down to magnitude 23.5, but the quasar didn't show up at all at the expected position. I should have read that paper more carefully — it stated that the recessional velocities of these QSOs is so great that the objects' strongest emissions appear longward of 850 nm in the near infrared. For the target I'd chosen, with a z of 6.04, the Lyman-α emission of hydrogen, normally at 121.6 nm in the ultraviolet, is redshifted beyond visibility to 855.5 nm in the near infrared!

As if that wasn't bad enough, I soon realized I had another problem: my SBIG STL-11000M CCD camera is barely sensitive to near-infrared light; its quantum efficiency is about 5% at 855.5 nm and quickly drops to zero longward of that. Perhaps the moderate light pollution of my location in Wildon, Austria, was also enough to

The Deepest Amateur Image?

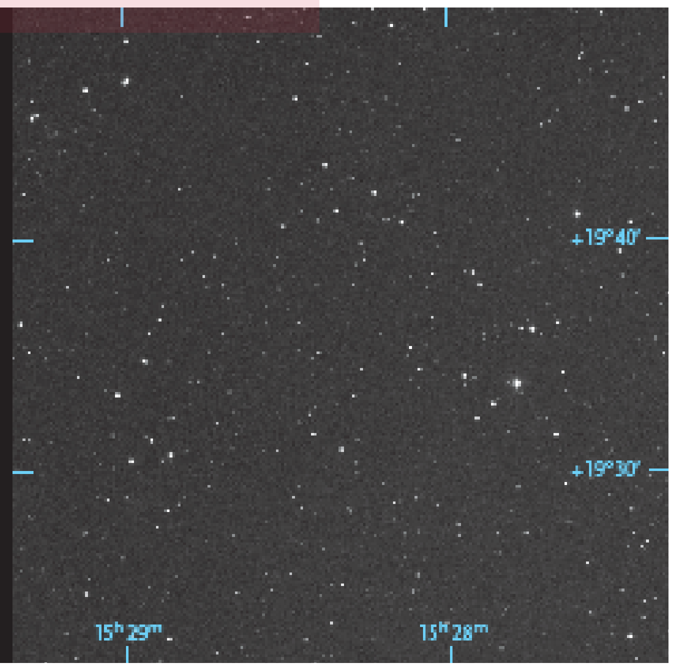
What's the faintest object ever recorded by amateurs? In 1998 professional astronomer Bradley E. Shaefer issued a challenge to see how deep amateur equipment could go (*S&T*: May 1998, page 119). Within a year, Canadian amateur Paul Boltwood recorded a 24.1-magnitude object with his 16-inch Newtonian telescope and homemade CCD camera (*S&T*: May 1999, page 126).

How does Schedler and Crawford's image compare? The short answer is, "They're apples and oranges." Boltwood worked mainly at visual wavelengths, whereas Schedler and Crawford went after a near-infrared target. Also, the region of Schaefer's Deep-Field Challenge had been well studied beforehand, with precise measurements made of each object in the field, whereas the quasar field is less familiar.

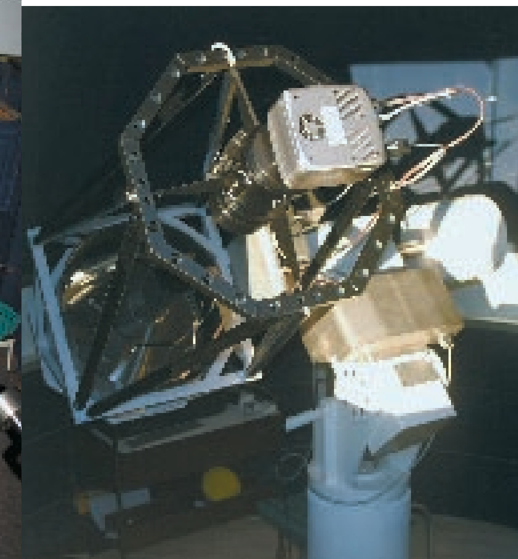
What *can* be said of Schedler and Crawford's image is that it captures the most distant object ever recorded by amateurs, as James McGaha encouraged readers to do in his article "The Outer Limits: Observing Quasars at High Redshifts" (*S&T*: March 2006, page 69). That's a Herculean feat in itself. Perhaps it's time for amateurs with modern equipment to revisit the Deep-Field Challenge field, shown at right.

Schaefer's target area is centered in this ½°-wide field based on a red-light photograph made with the 48-inch Oschin Schmidt telescope on California's Palomar Mountain. Although stars are recorded to about 20th magnitude, there is no sign of the possible host galaxy responsible for a gamma-ray burst that occurred in January 1996 and drew astronomers' attention here in the first place.

— *Sean Walker*



DIGITIZED SKY SURVEY



Left: **Ken Crawford with his 20-inch Ritchey-Chrétien telescope and Yankee Robotics Trifid-2 6303E CCD camera. *Right:* Johannes Schedler. Both imagers use state-of-the-art equipment. *Middle:* Schedler's 16-inch Cassegrain telescope and SBIG STL-11000M CCD camera are shown in f/3 prime-focus mode.**

LEFT TO RIGHT: LISA CRAWFORD, ROSWITHA SCHEDLER (2)

overpower the weak signal of the quasar. So I resolved to seek out another amateur with a higher-sensitivity camera to help with this project.

My friend Ken Crawford in Camino, California, also spends his nights recording the beauty of the night sky. His particular interest lies in revealing extremely faint tidal interactions between galaxies that have only been hinted at in professional images. When I offered him the opportunity to collaborate on this challenge, he was excited and agreed to spend a few nights recording data with his 20-inch RC Optical Systems Ritchey-Chrétien telescope.

Ken's dark location close to the Sierra Nevada mountains, combined with his infrared-sensitive Yankee Robotics Trifid-2 6303E CCD camera, meant that he could record infrared sources much fainter than I could achieve with my own equipment. The Kodak KAF-6303E detector in his camera has a quantum efficiency of roughly 30% at 850 nm, so he should have a better chance of capturing CFHQS J1641+3755.

He attempted to collect the exposures on the first available night. But due to the faintness of the guide star he chose, his automated tracking software was unable to reacquire the star after performing an unattended "meridian flip" with his German equatorial mount (necessary for these mounts when the target crosses the north-south meridian).

The next night he again set up to capture images, but this time he programmed the equipment to use longer guiding exposures to ensure he would be able to record data for as long as possible. In the end, he was able to record a total of 4.4 hours of exposures. As we had hoped, his final, stacked image had twice the signal-to-noise ratio as that of my own luminance image. When I combined his unfiltered raw image with my own, the quasar appeared *exactly* at the predicted position. We'd done it!

It was thrilling enough to have snared the quasar (its "visual" magnitude calculated from known stellar magnitudes is 24.8), but a nice bonus in our image (seen on page 89) was a dense galaxy field east of the quasar as well as some closer galaxies. The largest galaxy in the image is 16th-magnitude MAC 1640+3754, to the right of center. Of course, for aesthetic reasons I also recorded color data. The yellowish hue of the faint galaxies is caused by absorption of shorter wavelengths by intergalactic dust.

Amateurs have the tools and the know-how today to do serious science; many of us are searching for near-Earth asteroids, discovering supernovae, and watching distant planets crossing in front of their host stars (see page 22). Now we can also contribute to professional research by providing follow-up observations to confirm the existence of some of the most distant objects observable today. It would be interesting to find out just how deep we really can go from our own backyards.

REDSHIFT

The redshift (z) of an object defines how much its light has been displaced toward longer wavelengths. A redshift of 1 means a 100% shift, or doubling of wavelengths, and corresponds to a distance of roughly 7.7 billion light-years. To explore the relationship between other redshifts and distances, visit Ned Wright's Cosmological Calculator at www.astro.ucla.edu/~wright/CosmoCalc.html.

Johannes Schedler, *who lives in southeastern Austria, is one of today's premier amateur astrophotographers. You can see more of his images at www.panther-observatory.com.*