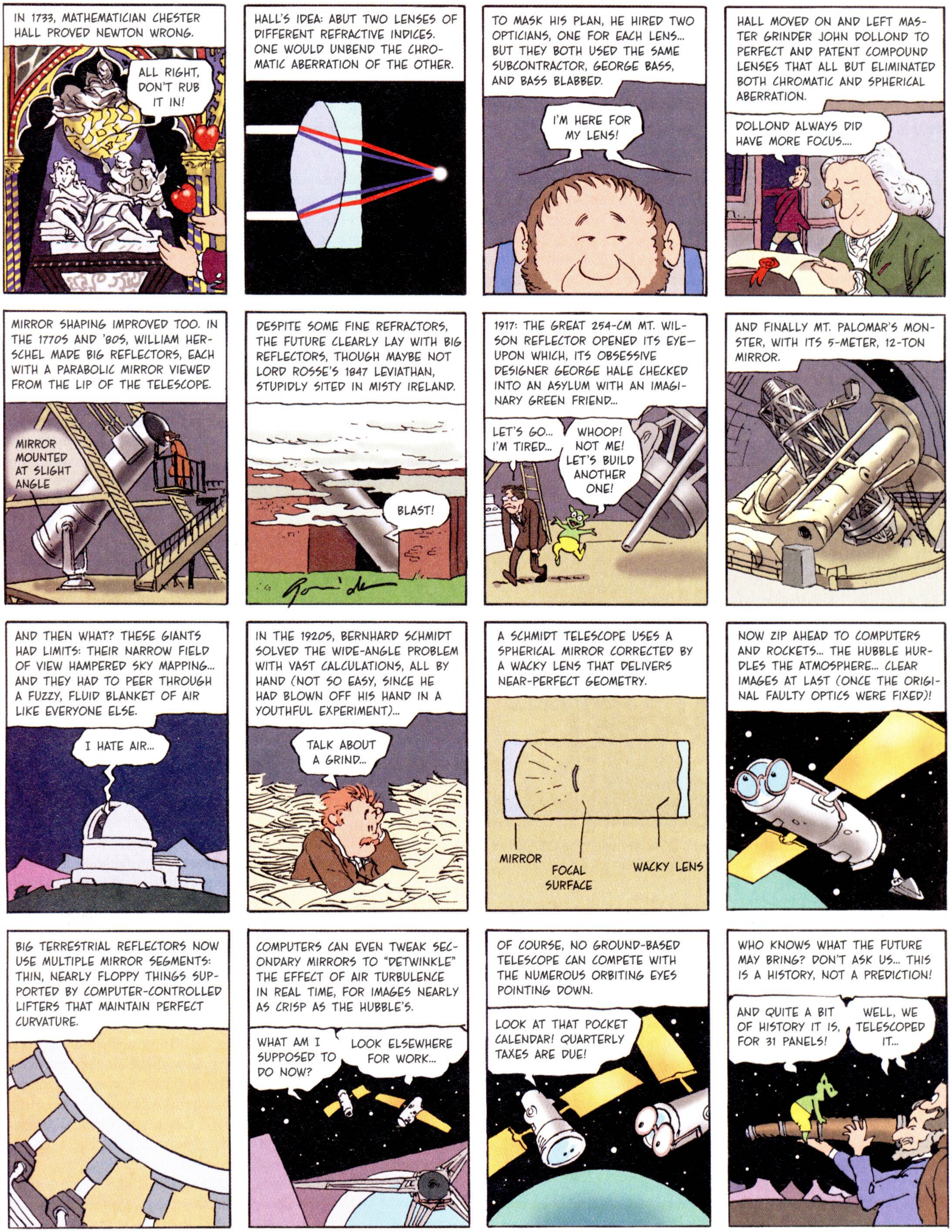


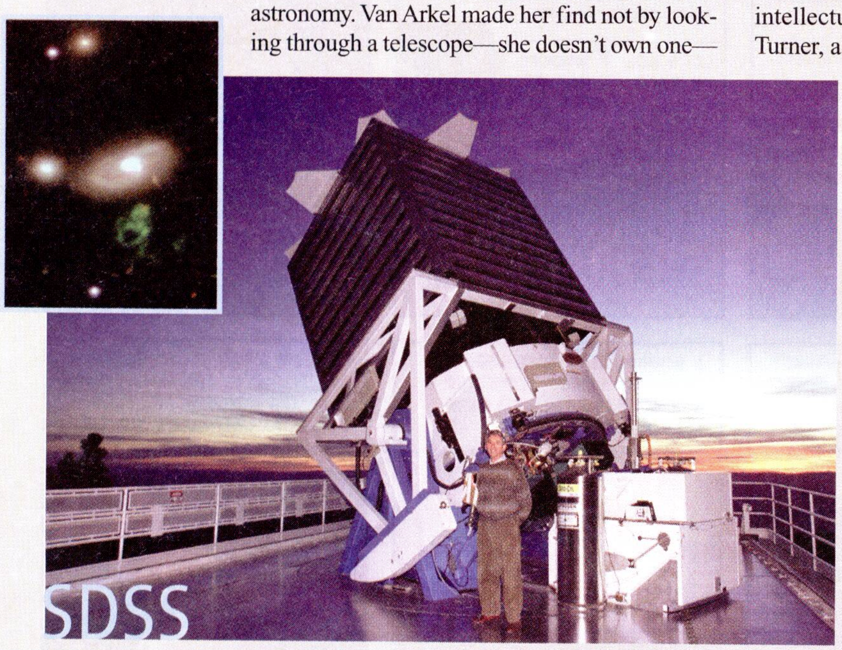
CREDIT: ASTRONOMER WILLIAM ALSCHULER TEACHES AT CAL ARTS; HE GROUND HIS FIRST TELESCOPE LENS IN 8TH GRADE

Astronomy Hits the Big Time

Four hundred years after the invention of the telescope, astronomy is flourishing. But even as the discoveries keep coming, the field is rapidly evolving toward huge telescopes, large collaborations, and—alas—bigger headaches

Because anyone can search the sky, astronomy remains the most democratic of sciences—perhaps the only one in which an amateur can still make a bona fide discovery. In August 2007, Hanny van Arkel did just that. The primary-school teacher from Heerlen, the Netherlands, spotted a strange blue blob in the sky. The intergalactic ghost turned out to be an enormous cloud of gas that is reflecting the light lingering from a now-dead quasar in a nearby galaxy to create a never-before-seen "light echo." The discovery of Hanny's Voorwerp (Dutch for Hanny's Object) earned Van Arkel, 25, a moment of fame. "My name was all over the world, and that's fun," she says.

At the same time, the discovery highlights dramatic changes within astronomy. Van Arkel made her find not by looking through a telescope—she doesn't own one—



Data factory. The Sloan Digital Sky Survey's 2.5-meter telescope catalogs all it can see. An amateur found the strange "light echo" known as Hanny's Voorwerp (*inset*, green) in the mounds of data.

but by viewing on her computer some of the millions of images of galaxies captured by the Sloan Digital Sky Survey, an 8-year-old project cataloging everything that can be seen in a vast swath of sky with a 2.5-meter telescope on Apache Point in New Mexico. Van Arkel is one of more than 160,000 volunteers helping to classify 1 million galaxies as part of an outreach program called Galaxy Zoo.

Four hundred years after the invention of the telescope, the heavens continue to yield mind-bending surprises: stellar explosions called gamma-ray bursts that momentarily outshine the rest of the entire universe in gamma-ray light, the bizarre dark energy that is stretching space and speeding the expansion of the universe, and strange planets orbiting other stars.

But even as the science flourishes, the practice and culture of astronomy are changing. Telescopes have grown steadily over the centuries, but the ones now in planning are truly immense—optical behemoths with mirrors measuring 30 meters or more across, and radio-telescope arrays spanning thousands of kilometers. Their costs will be measured in billions of dollars apiece. Meanwhile, some researchers are performing huge surveys that take a whole new approach to collecting data, spotting everything in sight and recording it all in vast computerized databases. Already considered "big science," astronomy is rapidly growing much bigger. And with that growth comes some of the headaches that plague other fields: increasing competition for limited resources and longer times to see projects completed.

"We shouldn't lose sight of the fact that it's good to have this problem," says Roger Blandford, a theoretical astrophysicist at Stanford University in Palo Alto, California. "It's a sign that astronomy is as intellectually and scientifically exciting as it's ever been." Michael Turner, a cosmologist at the University of Chicago in Illinois, agrees: "This is a very special time in astronomy, when you finally know enough about the universe to ask a variety of big questions, and you have the tools to go after the answers."

Still, as astronomers reap an ever-greater understanding, they may be losing the romance of their craft. As computerized data streams and remote-controlled observatories become the norm, the lone astronomer trekking to the mountaintop for a night of observing is quickly becoming a quaint anachronism.

A variety of riches

Strikingly, as astronomers have learned more, their field has continued to grow more diverse. Whereas scientists in fields such as particle physics have homed in on a few key conceptual questions—is there a Higgs boson?—astronomers find themselves blessed with an ever-longer list of mysteries ripe for exploration: What's speeding up the expansion of the universe? How did the first galaxies form? Where do cosmic rays come from? What is the nature of the black hole in the middle of our galaxy?

Much of this progress has been driven by technology. Astronomers have continued to improve their ability to detect the electromagnetic radiation of various wavelengths that emanates from stars and galaxies, from the advent of radio astronomy in the 1940s, to the birth of x-ray astronomy in the 1960s, to precision studies of the microwaves lingering from the big bang starting in the 1990s.

Most recently, the high-energy gamma-ray universe is coming into focus. These energetic photons are too rare to be picked up by the small telescopes of orbiting observatories and are blocked by the atmosphere. But when one strikes the atmosphere, it sets off an avalanche of electrons and other charged particles. As they zip through the air, these particles produce a pulse of light called Cerenkov radiation that special ground-based telescopes can detect. In 2004, the four telescopes of the High Energy Stereoscopic System (H.E.S.S.) in Göllschau, Namibia, became the first to spot a source of high-energy gamma rays shining in the sky (*Science*, 3 September 2004, p. 1393; 5 November 2004, p. 956).

Other Cerenkov telescopes, including VERITAS in the United States and MAGIC in the Canary Islands, have joined the search, and astronomers now have more than 100 sources to study. Such high-

CREDITS: DAN LONG, APACHE POINT OBSERVATORY; (INSET) GALAXY ZOO PROJECT, ING; (TOP BANNER) NASA