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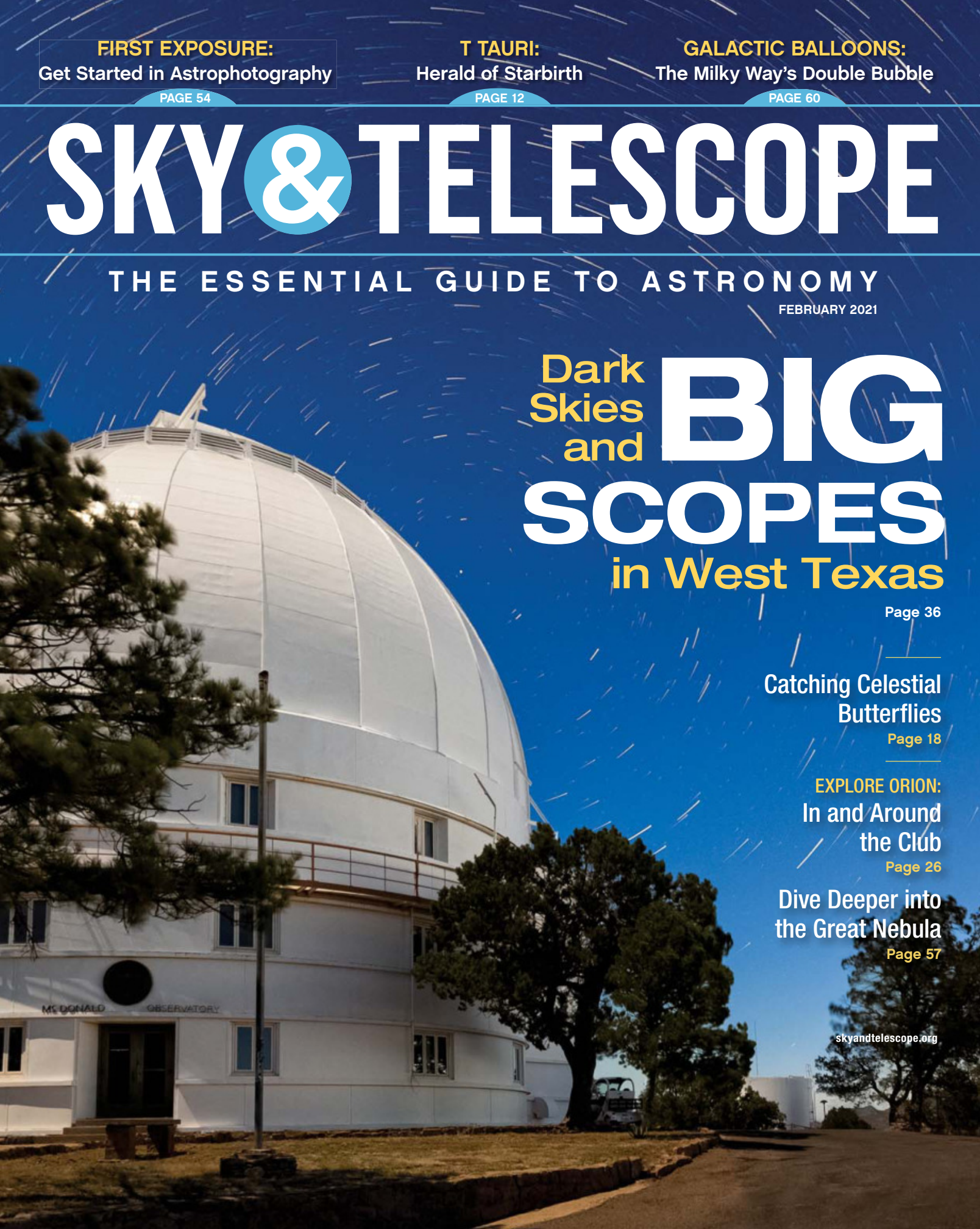

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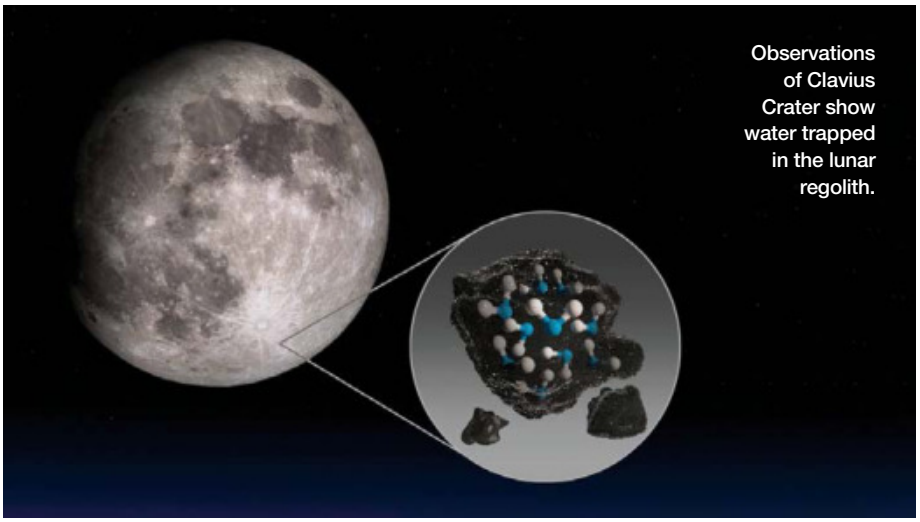

Observations of Clavius Crater show water trapped in the lunar regolith.

NASA / DANIEL RUTTER

THE MOON

Water on the Moon Not Just in Polar Craters

PERMANENTLY DARK CRATER FLOORS at the Moon's poles appear to hold plentiful water ice — but they're not the only places to look. The Stratospheric Observatory for Infrared Astronomy (SOFIA) has found evidence of water molecules sheltering in the Moon's sunlit Southern Highlands. And an analysis of lunar topography has revealed enough *micro cold traps* — small areas where ice collects — to affect the Moon's potential water content. However, more work is needed to understand what the discoveries' effects will be on lunar exploration.

The first result, reported by Casey Honniball (now at NASA Goddard) and colleagues on October 26th in *Nature Astronomy*, follows on previous studies that had found spectral fingerprints of hydrogen on the sunlit part of the Moon. However, while those features could come from water, they could also indicate hydroxyl-containing minerals. While the Sun's harsh ultraviolet radiation ought to break up water molecules, it would not split hydroxyl groups.

Honniball's team used the airborne SOFIA telescope to investigate two regions for a particular spectral feature at 6 microns that's unique to water: one around 60°S near Clavius Crater, where high hydrogen levels had previously been measured, and a reference site at lower northern latitudes in Mare Serenitatis, where hydrogen levels were low. The researchers not only found water molecules, they also report that the Clavius site hosts concentrations 100 to 400 parts per million higher than the reference site.

But how have the water molecules survived? Comparing spectra of the Clavius site with those of meteorites and Earth-based basalts showing signs of water interaction, Honniball's team suggested that water could be trapped in impact glasses formed after micrometeorites smash onto the lunar surface.

Separately, but in the same issue of *Nature Astronomy*, Paul Hayne (University of Colorado, Boulder) and colleagues analyzed the topography in 5,250 images taken by NASA's Lunar Reconnaissance Orbiter. Using photos taken when sunlight struck the surface at steep angles, they identified the distribution of shadows and modeled the surrounding landscape. They report large numbers of permanently shadowed cold traps as small as one centimeter across, increasing the total cold-trap area by 20%, to about 40,000 square kilometers (15,000 square miles), or 0.15% of the lunar surface.

Both discoveries open several additional questions, and more observations are coming soon on both fronts: from SOFIA and from in situ investigations aboard NASA's polar lander, due to launch in 2022.

■ JEFF HECHT

FROM THE DPS

(Very) Small Chance of Apophis Impact in 2068

Sunlight's subtle effect may turn near-Earth asteroid 99942 Apophis toward Earth by April 2068, but chances for impact remain small. At the virtual meeting of the Division for Planetary Sciences (DPS), David Tholen (University of Hawai'i) announced that the asteroid's orbit is slowly tightening. Discovered in 2004, the roughly 350-meter-wide rock was originally thought to be on a collision course with Earth in 2029 or 2036, but more precise observations reduced the chance of impact in those cases to zero. However, the *Yarkovsky effect*, the subtle net force of sunlight on a small rotating body, tweaks Apophis's orbit over longer periods of time. Tholen and colleagues gauged this effect by precisely measuring the asteroid's position using the 8.3-meter Subaru telescope on Mauna Kea, Hawai'i. Their results indicate that the semi-major axis of the asteroid's orbit is decreasing by 170 meters per year, so its Earth encounter in 2068 may be closer than thought. The chance of impact remains small, though, currently about 1 in 150,000. Much depends on how close Apophis comes to Earth when it passes by in 2029.

■ GOVERT SCHILLING

The Nature of Psyche

Researchers say 16 Psyche, target of NASA's eponymous Psyche mission, shows iron on its surface. High radar reflectivity had already suggested metals on the main-belt asteroid, and at the virtual meeting of the Division of Planetary Sciences, Tracy Becker (Southwest Research Institute) presented ultraviolet Hubble Space Telescope observations that confirm surface iron. At least 10% of Psyche's surface would need to be iron to explain the UV signal, Becker and colleagues report in the December *Planetary Science Journal*. But at the same meeting, Lauri Siltala (University of Helsinki) presented a new mass measurement for the asteroid, resulting in a density of just 3.4 grams per cubic centimeter – much lower than expected for a supposedly iron-nickel body. Siltala measured Psyche's mass by its effect on a number of small main-belt asteroids. However, even if Psyche's composition is more of a mix, it's still more iron-rich than most asteroids and could have experienced *ferrovolcanism* — Becker might even have detected its metallic lava flows.

■ GOVERT SCHILLING