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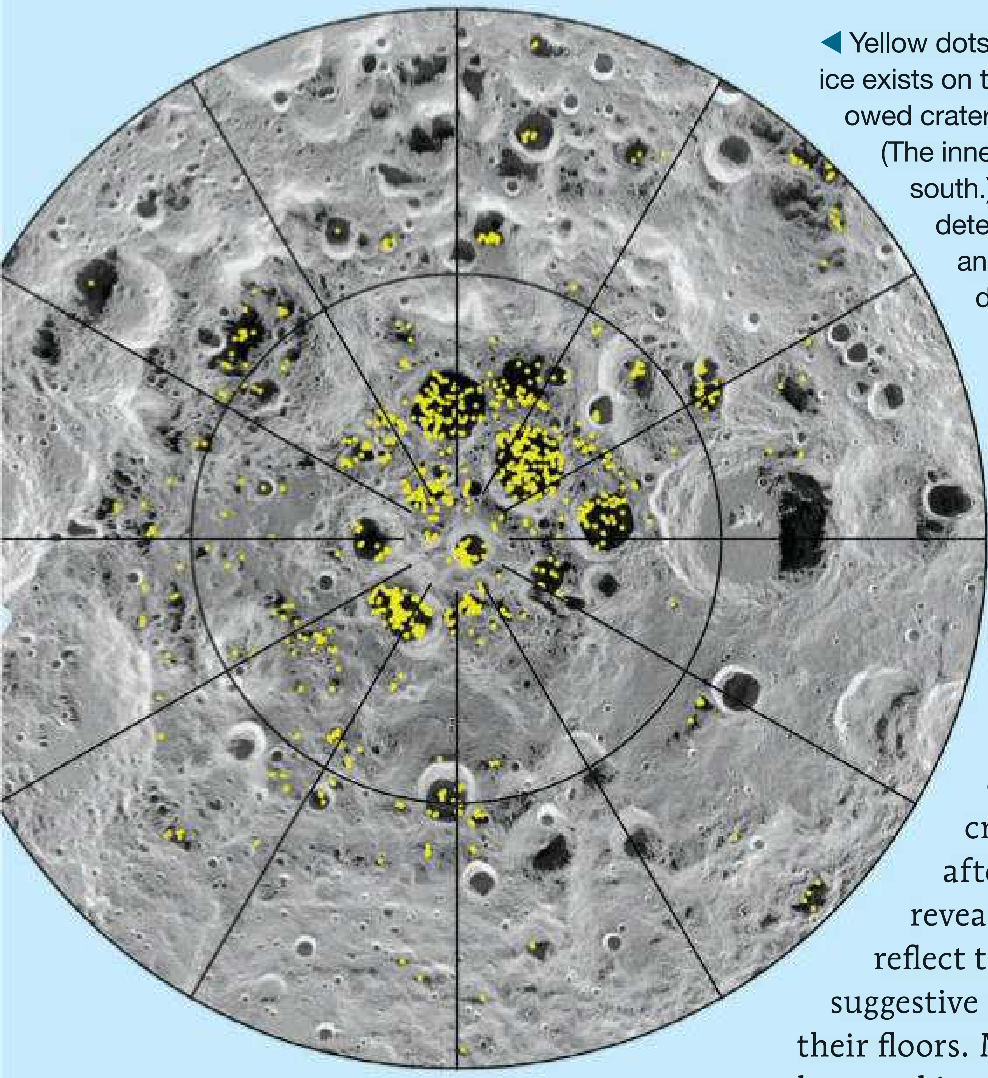

◀ Yellow dots on this map show where water ice exists on the floors of permanently shadowed craters near the Moon's south pole. (The inner black circle marks latitude 85° south.) The dots represent positive detections from multiple instruments: an infrared spectrometer on Chandrayaan 1 together with a laser altimeter, far-ultraviolet mapper, and infrared radiometer on the Lunar Reconnaissance Orbiter.

SOLAR SYSTEM

Solid Evidence of Water Ice on Moon

AFTER MORE THAN A DECADE of tantalizing but inconclusive hints, new research shows convincingly that patches of water ice lie exposed on the floors of many permanently shadowed lunar craters. Shuai Li (University of Hawai'i) and colleagues make use of near-infrared spectra from India's Chandrayaan 1 orbiter, which operated between 2008 and 2009, and report the findings in the September 4th *Proceedings of the National Academy of Sciences*.

Water ice can remain inside these craters because their floors are never exposed to direct sunlight, the consequence of a lunar spin axis that's nearly (within 1½°) perpendicular to the ecliptic plane. Temperatures at these always-dark crater floors are extremely low, plunging as low as 40K (–390°F). Any local traces of water vapor — delivered, say, by a small comet's impact — will freeze out in these "cold traps" and remain there.

Earlier observations had supported water ice deposits inside these craters, but the evidence had been indirect. For example, as early as 1994, radar pulses fired from the orbiting Clementine spacecraft and recorded on Earth after bouncing off the Moon revealed that some polar craters reflect the radio energy strongly, suggestive of water ice sequestered on their floors. More recently, images from **lunar orbiters** have shown that the polar craters' shadowed floors are relatively bright at ultraviolet and near-infrared wavelengths. But "bright" doesn't automatically translate to "ice" — other explanations are possible.

Another strong piece of evidence came from a spectrometer on NASA's Lunar Reconnaissance Orbiter that counted neutrons emitted from the lunar poles within a specific energy range, which signifies interaction with hydrogen atoms and thus, most likely, water. But this instrument can't distinguish water molecules (H_2O) from their chemical relative hydroxyl (OH), which readily binds to rocky minerals. Also, the neutrons could have come from the surface or from depths of up to a few tens of centimeters (up to a foot).

The work of Li and colleagues sidesteps all of these ambiguities by looking for three specific near-infrared absorptions — near 1.3, 1.5, and 2.0 microns — created by vibrations in water ice molecules lying directly on the lunar surface. They carefully examined spectral maps made by Chandrayaan 1's Moon Mineralogy Mapper, or M^3, and found that regions featuring absorption at all three wavelengths correspond to permanently shadowed crater floors at both lunar poles.

Modeling suggests that this three-band technique is sensitive enough to identify surface deposits heavily mixed with the dust and rocks that make up lunar "dirt," containing as little as 5% water ice by weight. The M^3 spectra only signal the presence of water in craters poleward of latitude 70°, and 90% of the positive detections occur within 10° of each pole.

Understanding the processes that delivered water ice to the Moon helps us understand the origin of water on Earth and throughout the solar system, Li explains. Of course, knowing that water ice lies exposed at the lunar poles is also a big plus in the minds of those designing future lunar colonies.

■ J. KELLY BEATTY

EXOPLANETS

Astronomers "Weigh" Beta Pictoris b

ASTRONOMERS HAVE OBTAINED a precise new mass measurement for Beta Pictoris b, a gas-giant planet 63 light-years from Earth. Ignas Snellen and Anthony Brown (both at Leiden University, The Netherlands) reported the measurement August 20th in *Nature Astronomy*.

The exoplanet came to light in 2008, when the European Southern Observatory's Very Large Telescope in Chile captured the infrared glow of the planet still in the throes of formation. But in the decade since, astronomers have been struggling to nail down the planet's detailed properties, especially its mass. They suspected the planet has a mass several times that of Jupiter, due to its influence on the star's large debris disk. Later mass estimates based on direct imaging ranged from 4 to 17 times Jupiter's mass.

Now, Snellen and Brown have used exquisite positional data from the Hip-