▶ EARTH

By Kirsten Weir

CRASH TEST

Sarah Stewart smashes things to learn how our solar system evolved.

Sarah Stewart fires this 6-meter-long gun in her lab to simulate the effects of cosmic collisions.

Top: Courtesy Harvard University; Bottom: NASA (4)

From behind the safety of a steel door and a concrete block wall, Sarah Stewart presses a button that fires her big gun. In the next room, the 6-meter- (20-foot-) long blaster shoots a metal disk into a block of ice at 2.6 kilometers per second—more than 5,800 miles per hour. Stewart hears a thud and a clanging sound. The light fixtures overhead sway. Impact!

Stewart routinely smashes chunks of ice with speeding projectiles to find out how collisions in space have shaped our solar system. She is a professor of planetary science at Harvard University.

"The sad thing is, we spend weeks setting up an experiment," she says. "Then you hit it, and it's all blown to pieces, and we literally vacuum it up afterward." Sad, maybe, but the destruction has led to some major discoveries.

PLANET EVOLUTION

Stewart was born in Taiwan, the daughter of an American father and a Taiwanese mother. Her dad was in the Air Force, so she moved around the world as she grew up.

As a kid, Stewart loved getting lost in the pages of science-fiction novels. In college, she got hooked on astronomy and signed up to work in a lab, studying how planets form. That led to a graduate degree at the California Institute of Technology, where she began researching collisions in space. "Coming out of high school, I would never have predicted that I'd work on planets colliding with one another," she says.

Planets are created when smaller rocks crash into one another and fuse, Stewart explains. Even after a planet has formed, it keeps getting pummeled. Most of the moons and rocky planets in the solar system are pockmarked with craters from smashups with comets and asteroids. "Collisions have occurred the whole time the solar system has been in existence," Stewart says.

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The collisions leave lasting impressions. Nearly every rocky body in the solar system has an odd feature that can be explained by a crash, says Stewart. (See "Crash Victims.") Impacts happen elsewhere in the universe too. Many *exoplanets* (planets that exist outside our solar system) are surrounded by telltale dust clouds that could have been caused only by collisions, she notes.

"If you want to understand the solar system, you want to understand impact events and what they left behind," Stewart says. "It's like a detective story."

MASTER BLASTER

Stewart studies one particular material that's prevalent in space: "I have this special love of ice," she admits. Most of the rocky bodies in our solar system are at least partially covered in one form of ice or another.

Plain old water ice is composed of two atoms of hydrogen and one atom of oxygen—H_2O. Not all water ice is created equal, however. "You can arrange the hydrogens and oxygens in different ways," Stewart says. Scientists know of at least 15 different crystal structures of frozen H_2O, and more are being discovered all the time.

Water ice also mixes with other compounds, such as ammonia or methane. Those ices each have many different crystal structures too.

The impact of a collision in space can transform the crystal structure of ice. "When you take normal ice and hit it really fast with an asteroid or a comet, you can make forms of ice that last just a few seconds," says Stewart.

To understand those fleeting, frozen forms, Stewart gets out the big gun. She fires metal disks into blocks of ice to mimic what happens when a space rock hurtles into the icy shell of a moon or a rocky planet. For fractions of a second, the block of ice experiences the extremely high pressures and temperatures that occur during a cosmic collision.

During that split second, scientific instruments record temperature, pressure, and other variables. After the blast, Stewart collects the smashed sample to examine how it changed and pours over the data collected by the instruments. Then she plugs every detail into a computer model to help her understand how a similar impact might affect a real planet.

MYSTERY SOLVED

Last year, Stewart's big gun helped solve a mystery—the unusual craters within craters in the ice on three of Jupiter's moons (Europa, Callisto, and Ganymede). Her experiments revealed how the odd craters formed. At the moment of impact, Stewart discovered, ordinary ice on the surface was transformed into two different phases of ice not normally seen on Earth. Although the two forms lasted for only a moment, they left their mark in the shape of a crater within a crater.

For Stewart, solving such mysteries is the best part of being a scientist. "You have this tremendous feeling of excitement," she says, "when you realize something absolutely new that nobody else in the world knows." CS

Crash Victims

Cosmic collisions have molded some of our solar system's rocky bodies. Here's how:

• Mercury has an unexpectedly small *mantle*. The mantle is the layer of a rocky planet that exists between the crust and the core. "One theory is that a giant impact blew off most of the mantle," says scientist Sarah Stewart.

• Venus has a *retrograde* rotation. It spins in the opposite direction as most of the other planets rotate. (Earth turns counterclockwise; Venus turns clockwise.) A huge collision might have sent it spinning backward.

• Earth's moon formed, most scientists believe, after a Mars-sized object called Theia smashed into the young Earth. The impact ejected chucks of rock into space that gradually *accreted* (fused) to become the moon.

• Mars has a *crust* that is twice as thick at the south pole as it is at the north pole. The crust is the solid outermost layer of a rocky planet or moon. A collision may have ripped off part of the planet's northern crust.