



Science & Discovery

Vatican Astronomers Aid the Search for Solar System Origins

Jesuit brothers are working with NASA to help analyze an ancient asteroid sample.

By Gwendolyn Rak

NASA/Erika Blumenfeld & Joseph Aebbersold

IN the beginning, Earth was without form. The solar system was but a disk of dust and gas swirling around a young Sun, until the rocky bits began to coalesce into planets, moons, and asteroids about 4.5 billion years ago. Over the eons, the rubble grew and evolved to become the planets and their moons we know today. Earth was born. The asteroids, meanwhile, remained largely as they were in the beginning, a time capsule of the early solar system.

To get a glimpse of that early planetary history, NASA seven years ago launched OSIRIS-REx — short for Origins, Spectral Interpretation, Resource Identification, and Security-Regolith Explorer — to bring an asteroid sample to Earth. On September 24, 2023, the spacecraft successfully returned a capsule packed full of 4.29 ounces (121.6 grams) of material retrieved from the surface of asteroid [Bennu](#) (which also goes by the scientific name of 1999 RQ36). Initial findings [already indicate](#) high amounts of carbon-bearing molecules and [water](#), supporting theories that collisions with asteroids like Bennu could have delivered essential elements for life on Earth.

And the research is just getting started.

In fact, most of the OSIRIS-REx sample was stuck inside the spacecraft's capsule [until early January 2024](#). Now that it has been freed, NASA plans to distribute the remaining pieces of the Bennu sample around the world. But before they leave the pristine conditions of NASA's clean room, scientists must measure the basic physical properties of the space rocks, including density — a deceptively tricky task, given the material's porous nature. To do so, the U.S. agency is using an instrument provided by a scientist who is employed by a different government: the Vatican.

"I am fascinated by the fact that asteroids preserve the early history of the solar system in a way that planets don't," says Brother [Robert J. Macke](#), the astronomer at the Vatican Observatory who built the device, called a pycnometer, based on his work with meteorites.

Macke is one of about a dozen Jesuit brothers employed by the Vatican, and he has teamed up with scientists at NASA to study the asteroid sample. Through his research and engineering, he will contribute to our understanding of the solar system's origins, not through theology, but using traditional scientific methods



The OSIRIS-REx container holding a sample of asteroid Bennu sits inside a specially prepared "glove box" at NASA's Johnson Space Center.

[Dante Lauretta]



On September 24, 2023, a container delivered 4.29 ounces (121.6 grams) of rocks and dust from asteroid Bennu. The container landed in the Utah desert.

[NASA/Keegan Barber]

The Vatican's observatory

Formally founded in 1891, the Vatican Observatory is based in Castel Gandolfo, a small town 15 miles southeast of Rome. The town is the home of the Pope's summer residence, but nestled in the palace's private gardens, Jesuit astronomers research the heavens.

The Observatory's laboratories and offices are housed in a former convent built in the 17th century. Except for a framed photo of Pope Francis visiting the same room, Macke's laboratory resembles a typical modern lab: wooden cabinets, black benches, shiny scientific instruments, plenty of electrical outlets to power them. And, behind a glass wall across the room, two wooden cabinets hold a thousand meteorites.

The [meteorite collection](#) consists of roughly 1,200 samples, which are the subject of scientific research. Much of that research was spearheaded in the 1990s by the current director of the Observatory, [Guy Consolmagno](#). Surprised by a glaring lack of data about the basic physical properties of meteorites, Consolmagno decided to catalog the space rocks' densities and porosities.

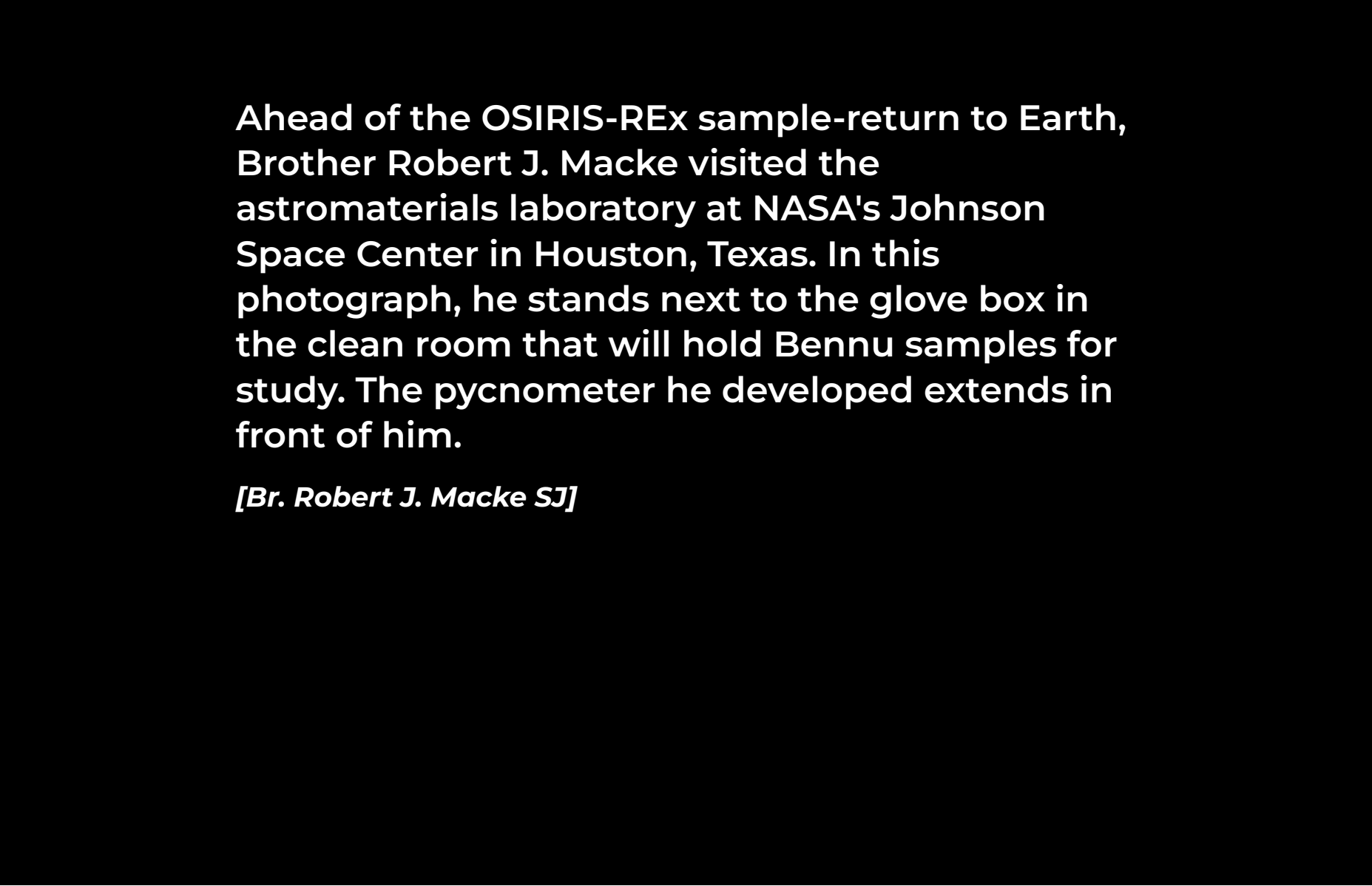
"Our mission at the Observatory is to be a sign to the world of the compatibility of faith and science. Doing good science is one of the best ways we can do that," says Macke, who also [runs a YouTube channel](#) in support of this mission.

Macke is now the curator of the meteorite collection, processing requests from other scientists and seeking new samples. He also safeguards the collection: "I keep an eye on the meteorites to make sure they don't walk off," he says.



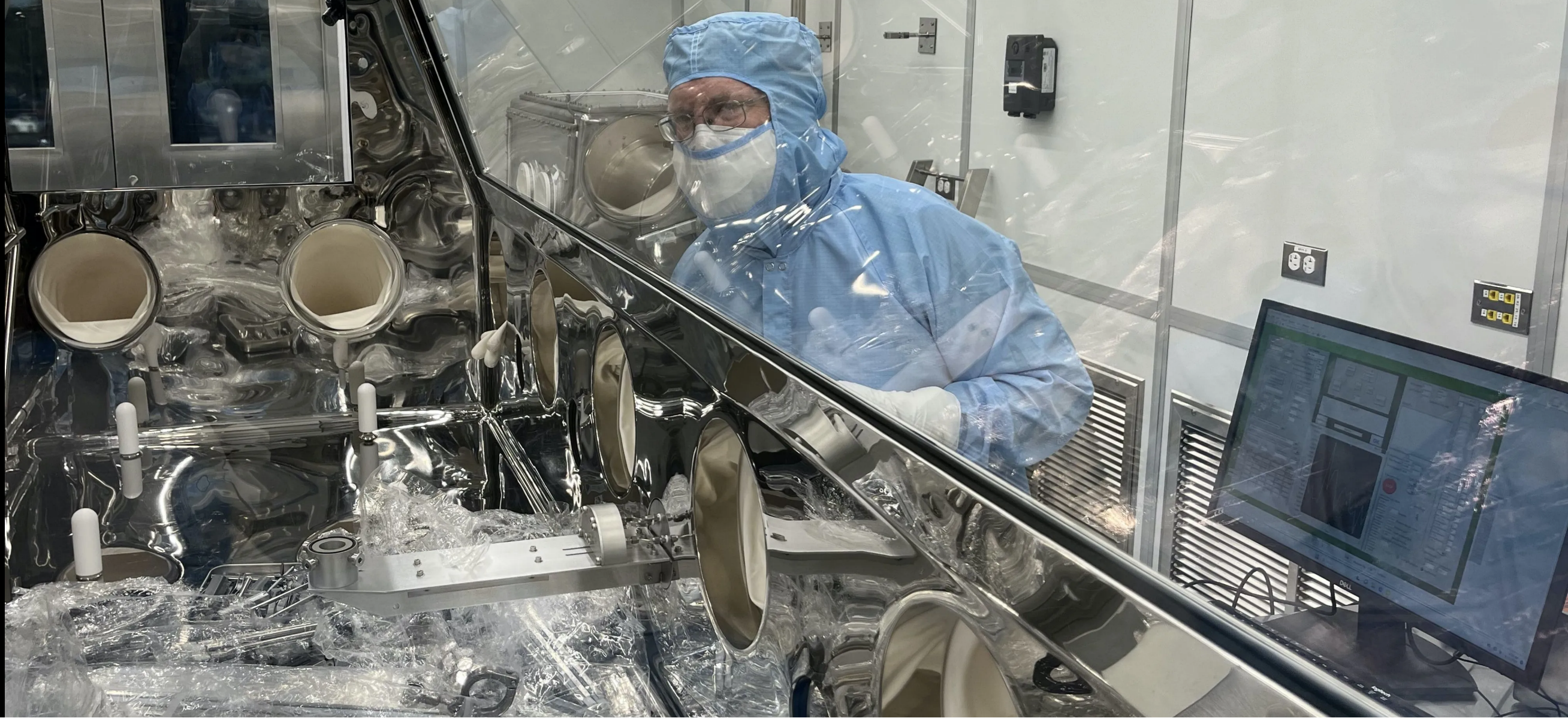
The Vatican's meteorite collection houses some 1,200 samples.

[Vatican Observatory]



Ahead of the OSIRIS-REx sample-return to Earth, Brother Robert J. Macke visited the astromaterials laboratory at NASA's Johnson Space Center in Houston, Texas. In this photograph, he stands next to the glove box in the clean room that will hold Bennu samples for study. The pycnometer he developed extends in front of him.

[Br. Robert J. Macke SJ]



Providing a pycnometer

Macke and Consolmagno continue to publish on the physical properties of meteorites as some of the leading experts in the field. In fact, their research gained the attention of [Andrew Ryan](#), the head of the OSIRIS-REx sample physical and thermal analysis working group.

Ryan used data from [one of Macke's papers](#) in particular to help link Bennu to a primitive class of meteorites that are rich in carbon and contain chondrules, droplets of minerals thought to be some of the earliest solids formed in the solar system. When later tasked with preparing a physical analysis plan for NASA's mission, he reached out to the brother-astronomers.

"I specialize in these rather basic physical properties: density, porosity, magnetic susceptibility," Macke explains. He joined the NASA team and custom built a pycnometer to measure the rocks' volumes without damaging or contaminating them. And, because of the Jesuit vow of poverty, Macke would complete the work without a salary — a boon to the OSIRIS-REx team, whose resources were already stretched thin.

"He kind of saved our butt, quite honestly," says [Dante Lauretta](#), chief scientist of the OSIRIS-REx mission. "We are really grateful for Brother Bob's [Macke's] participation in our program."

The instrument is simple in concept and relies on a fundamental property of ideal gases: that pressure and volume are inversely proportional. It consists of two chambers, and in one, researchers place the sample. They pump in gas and note the pressure. They then open a pathway connecting the chambers so the gas can disperse — the pressure decreases, and they measure that value. The change is related to the volume of the rock itself, excluding the empty pockets enclosed in the porous material. A scanner uses patterns of optical light to calculate the bulk volume including its empty pockets, and the two measurements provide porosity.

Macke's challenge was designing the pycnometer to avoid contamination.

"When a carbon-rich asteroid lands on Earth and becomes a meteorite, it's immediately colonized by bacteria," Lauretta says. Exposure to atmospheric humidity can also change the rock's chemical composition within hours to days, and the scientists have to be cautious of introducing foreign particles.

That's why the Bennu sample was immediately brought to a clean room in Houston, (NASA's Johnson Space Center, located in Houston, is currently home to the space agency's collection of pristine space rocks.) To maintain the conditions, Macke had to design the pycnometer to fit inside a special contaminate-free chamber, the size of a dining table. The instrument is bolted to the side of the "glove box" technicians use to access the sample, and its chambers are flushed with inert nitrogen gas to keep it pristine.

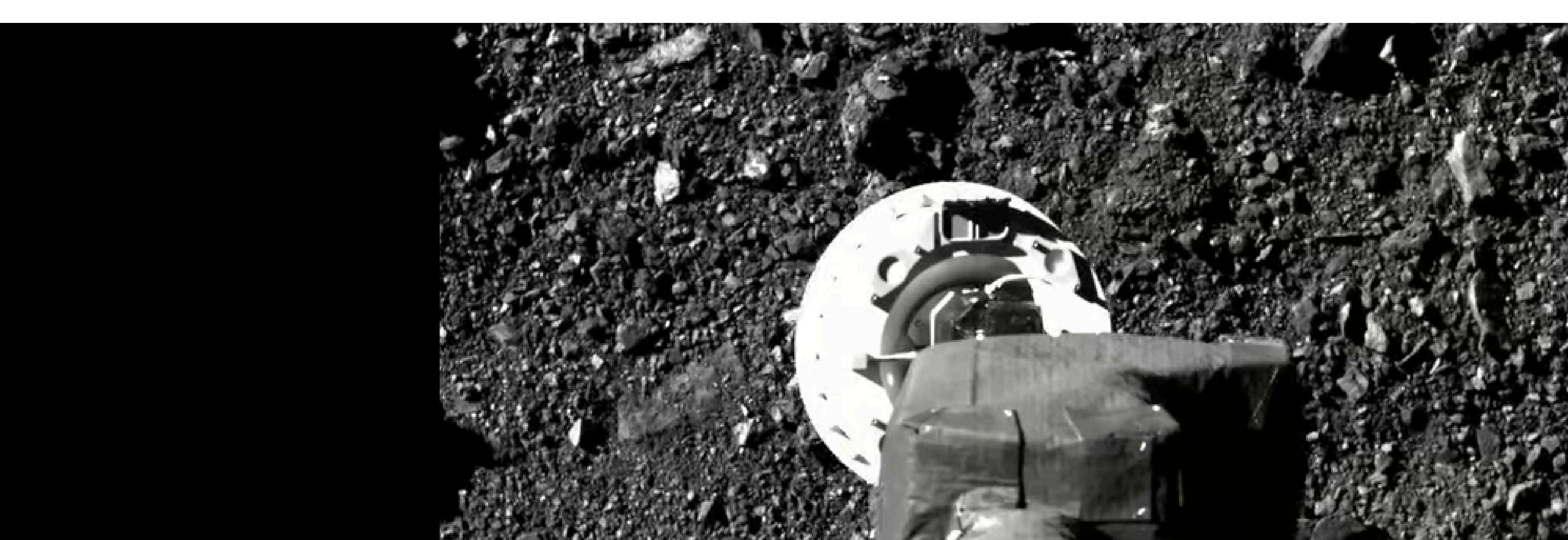
Macke's efforts to stave off contamination have paid off: Because he can study the sample without altering it, he is given access to a significant portion of the material before pieces are shipped off to various research teams. Otherwise, he would only be able to study the physical and thermal science working group's allotted share of the sample — just a gram-and-a-half.

"That would have been four or five measurable stones in the pycnometer, if that," Ryan says. The larger sample size will help scientists to develop a better sense of Bennu's total density, as well as differences in the individual stones that make up the larger asteroid sample.



Brother Robert J. Macke stands in front of a reproduction from a manuscript in the Vatican Library depicting the fall of the meteorite Ensisheim (France, 1492).

[Vatican Observatory]



On October 20, 2020, the OSIRIS-REx spacecraft reached out and touched asteroid Bennu. The action disrupted the surface material, and the craft collected a sample to later bring to Earth.

[NASA/Goddard/University of Arizona]

Measuring Bennu's materials

Scientists believe Bennu is primarily made of two types of boulders, both are dark and carbon-rich, so density and porosity could help differentiate the rocks, allowing for even distribution among scientists receiving pieces of the sample.

The measurements have inherent importance, too. Typically, the only physical properties we know about asteroids are derived from remote temperature data. Knowing exactly where the OSIRIS-REx sample came from allows scientists to link density and porosity to thermal data from remote observations, which may improve predictions of what other asteroids' surface material is like.

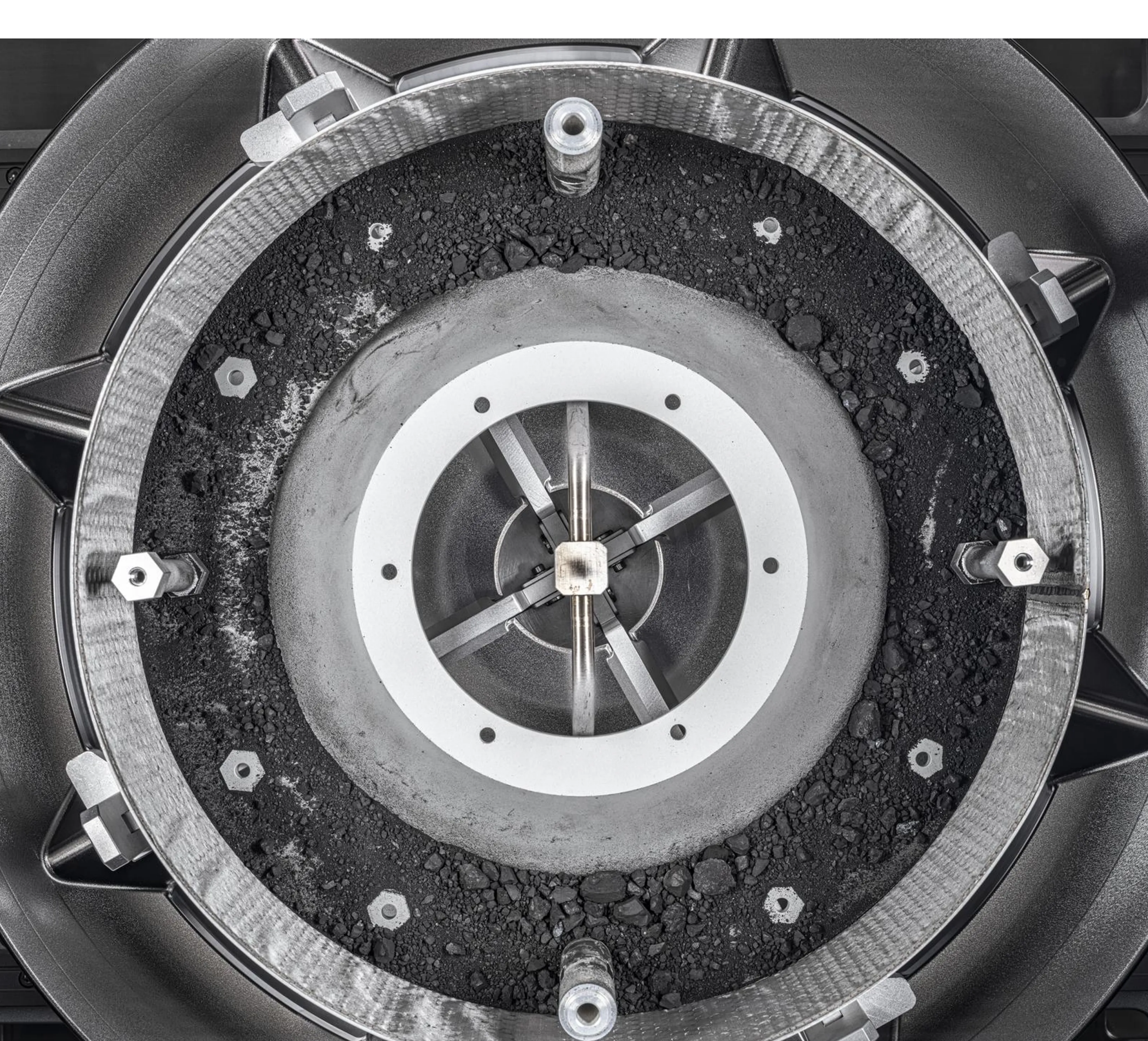
These properties could also hint at the evolution of materials in Bennu and the larger asteroid it broke off of. For example, Ryan says, "there are models that say the parent body might have been kind of a mud ball," consisting of highly aqueous, clay-like minerals. Early analysis shows that there was very likely liquid water on Bennu's parent body, and different densities may reflect different concentrations of water-based activity.

"These basically are fossils," Macke says. "They are the fossils that we need to study in order to understand the early history of the solar system."



A curation specialist at the astromaterials laboratory at NASA's Johnson Space Center in Houston, Texas, prepares to remove the lid to the pycnometer, which is attached to the inside of the glove box.

[Br. Robert J. Macke SJ]



Once NASA curation specialists removed the tight bolts from the OSIRIS-REx sample container, they could count the full amount of collection material. This photograph shows a top-down view of the Touch-and-Go-Sample-Acquisition-Mechanism (TAGSAM) head, with the lid removed.

[NASA/Erika Blumenfeld & Joseph Aebbersold]

Solar system origins

The OSIRIS-REx mission has already begun illuminating the mysteries of our early stellar neighborhood, true to the first letter in the acronym: Origins.

"That was the very first word I wrote down when I was coming up with the mission name," Lauretta says. So far, the research appears to support the idea that an asteroid may have delivered the building blocks of life on Earth.

For Macke, there is no conflict between science and his religious beliefs. "The way I see it, the universe and everything in it, including the laws of physics, is God's creation," Macke says. "By studying the creation, in all of its fascinating details, it's a way of showing appreciation."

Those details include the first epoch of the solar system. At that time, 4.5 billion years ago, rocky debris floated around briefly before being swept up by the first clumpy asteroids. And not much has happened to them since, says Lauretta, until OSIRIS-REx collected some debris and brought it back to Earth. Now, he and Macke, along with dozens of others, are revealing the sample's secrets.

"These rocks have stories to tell," Lauretta says. ✨

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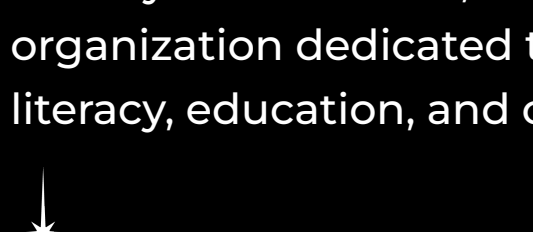
Brother Robert Macke stands in his laboratory at the Vatican Observatory and places a meteorite sample into a previous pycnometer he built.

[Vatican Observatory]

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