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The Universe in Glorious X-rays

A NEW TELESCOPE IS POISED TO CREATE A MAP OF BLACK HOLES AND HUNDREDS OF THOUSANDS OF STARS

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New Space Telescope Will Map the Universe in High-Energy X-rays

A German-Russian mission called SRG will detect millions of supermassive black holes, many new to science, and hundreds of thousands of stars

By Davide Castelvecchi

Davide Castelvecchi is a senior reporter at *Nature* in London covering physics, astronomy, mathematics and computer science.

"HAVE YOU SEEN YOUR BODY IN X-RAYS? IT LOOKS COMpletely different," says Rashid Sunyaev. "We will do the same with the universe." Sunyaev, an eminent Soviet-born cosmologist at the Max Planck Institute for Astrophysics in Garching, Germany, could be about to get his long-held wish.

On July 13, a joint German–Russian mission called Spectrum-Roentgen-Gamma (SRG) launched into space to chart an unprecedented map. It won't be the first space telescope sensitive to high-energy "hard" x-rays, which offer astrophysicists a window into otherwise faint objects in the universe. But it will be the first able to create a full map of the sky in this part of the spectrum—one that will give researchers a new way to track the universe's expansion and acceleration over the eons. "Within a half year, we will cover the whole sky," says Peter Predehl, an x-ray astronomer at the Max Planck Institute for Extraterrestrial Physics, also in Garching, and a principal investigator for the mission.

SRG's main scientific goal is cosmological: to create a 3-D map of the cosmos that will reveal how the universe accelerates under the mysterious repulsive force called dark energy. Cosmologists can probe this force through galactic clusters, whose distribution encodes the structure and history of the universe. SRG will map a cosmic web of about 100,000 galactic clusters by detecting the x-ray glow from their intergalactic plasma and from the plasma filaments that join them. The mission will also detect up to three million supermassive black holes—many of which will be new to science—and x-rays from as many as 700,000 stars in the Milky Way.

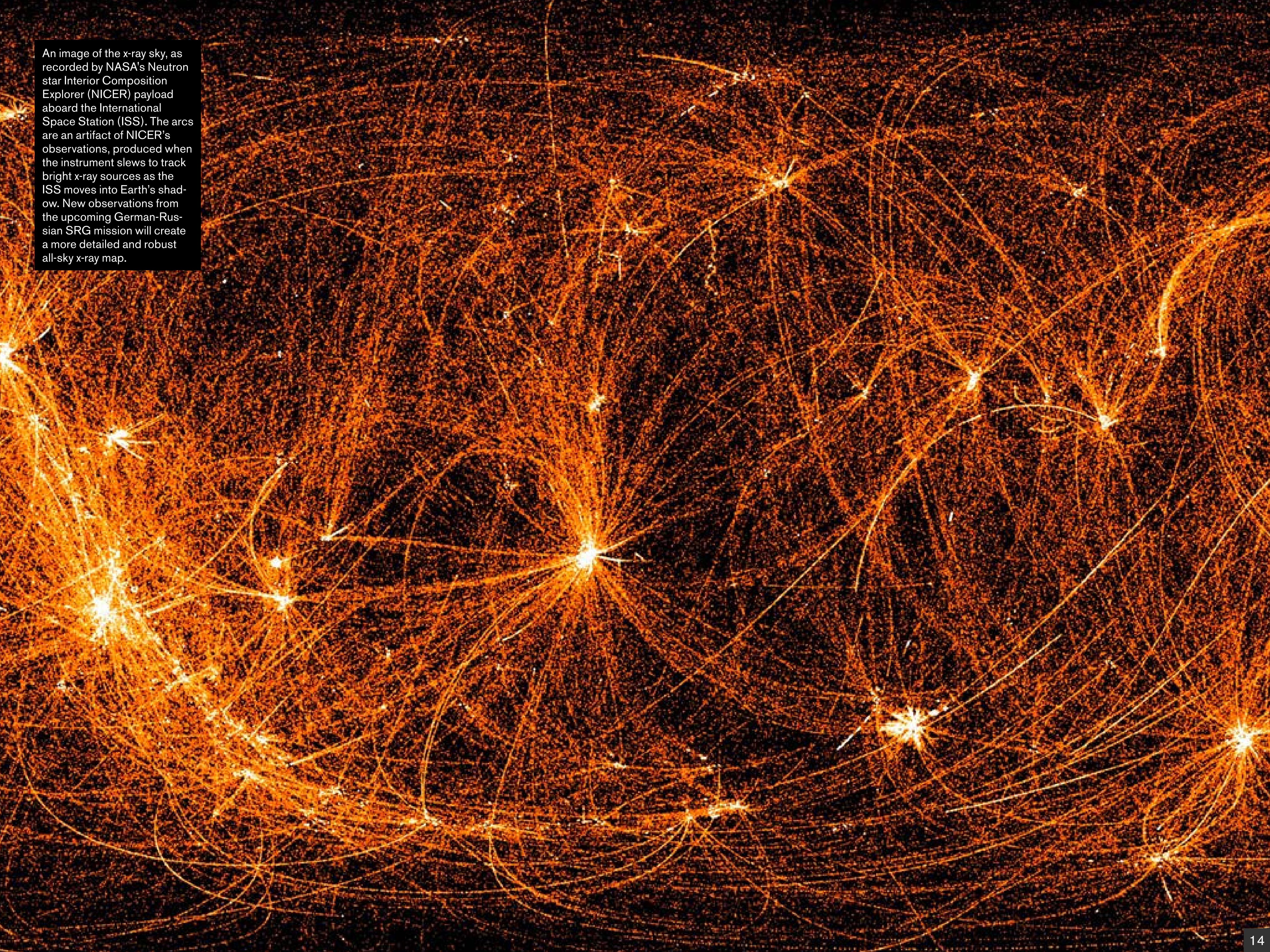
"It's going to be a great survey," says x-ray astronomer Giuseppina Fabbiano of the Harvard–Smithsonian Center for Astrophysics in Cambridge, Mass. Its data will have a unique role in the field for a long time, she adds.

RUSSIAN RESURRECTION

For Russia, SRG represents one of the most significant space science missions for decades, and it aims to bolster the country's astrophysics community, which has suffered decades of cuts and brain drain. The mission carries two independent x-ray telescopes: a German-built one called eROSITA (Extended Roentgen Survey with an Imaging Telescope Array) and a Russian-built one called ART-XC (Astronomical Roentgen Telescope—X-ray Concentrator), which is the first instrument of its kind in the history of Russian and Soviet space research, says Mikhail Pavlinsky, a high-energy astrophysicist at the Russian Academy of Sciences Space Research Institute in Moscow and principal investigator on ART-XC. "Now we have a new chance to return to world-class science," he says.

The spacecraft lifted off on a Russian-built Proton-M rocket from the Baikonur Cosmodrome in Kazakhstan. X-ray sky surveys have been conducted by previous missions, including one from Germany in the 1990s, called ROSAT. But that mission was sensitive only to "soft" x-rays, with energies of about two kiloelectronvolts (keV). Existing missions, such as NASA's Chandra X-ray Observatory and NuSTAR, can see higher-energy radiation and resolve tiny details of cosmic structures, but they see only small parts of the sky.

SRG's two instruments each cover x-ray bands that stretch to much higher energies: 0.2 to 10 keV for eROSITA, and five to 30 keV for ART-XC. (Despite its name—which was kept for historical reasons—SRG will not detect gamma radiation.) Each instrument is a bundle of seven x-ray telescopes that will frame the same swath of sky simultaneously; their combined power means that they will collect more photons than a single telescope. X-ray photons from the sky are few and far between, so



An image of the x-ray sky, as recorded by NASA's Neutron star Interior Composition Explorer (NICER) payload aboard the International Space Station (ISS). The arcs are an artifact of NICER's observations, produced when the instrument slews to track bright x-ray sources as the ISS moves into Earth's shadow. New observations from the upcoming German-Russian SRG mission will create a more detailed and robust all-sky x-ray map.

> **"So far, the dark matter explanation is still on the table" as a potential cause of the x-ray signal.**
> ***—Esra Bulbul***

the telescopes' semiconductor-based sensors—higher-energy versions of the sensors in ordinary digital cameras—will also be able to estimate the amount of energy contained in individual photons.

During its planned four-year mission, SRG will map the entire sky eight times, and researchers will compare the maps and look for changes. For instance, some of the supermassive black holes at galactic centers become extremely bright when they devour matter at a high rate and then go back to relative quiescence. Although most soft x-rays from these black holes are likely to be absorbed by surrounding dust, harder x-rays should get through, says Pavlinsky. ART-XC might see the objects appearing and then disappearing again from one year to the next, providing information about how black holes consume matter. "We wish to observe several thousand of these events during these four years," Sunyaev says.

SRG will also investigate the universe's distrubtion of ordinary matter and dark matter—the main engine of galaxy formation—and look for direct hints as to the nature of dark matter particles. It will do this by trying to confirm previous signals that showed peaks in x-ray emissions from some galactic centers, which some researchers have suggested come from the decay of an unknown, heavier relative of the known subatomic particles called neutrinos. These neutrinos could be a major component of dark matter, they suggest—although this interpretation is controversial. "So far, the dark matter explanation is still on the table" as a potential cause of the x-ray signal, says Esra Bulbul, an astrophysicist at the Max Planck Institute for Extraterrestrial Physics and a lead scientist on the mission.

A LONG TIME COMING

A hard x-ray space mission has long been on the cards for Russian and German astrophysicists: SRG's roots stretch back to the Soviet Union. In 1987, leading astrophysicists, including Sunyaev—with his mentors Yakov Zeldovich and Andrei Sacharov—proposed a major mission using hard x-rays, but plans were canceled after the Soviet Union fell in 1991.

The European and Russian space agencies revived the idea in 2004, but a proposal to send an x-ray telescope to the International Space Station was scrapped when NASA whittled down its space shuttle program, ultimately ending it in 2011. The German space agency and Roscosmos later approved a joint mission, and more ambitious design, in 2009.

"There have been many, many ups and down until the whole thing really came out of the woods," says Predehl.

Unusually, the mission has a special data arrangement that aims to support Russia's small astrophysics community. Instead of putting the data in one repository, as is typical for such missions, German researchers will store and analyze data on one half of the sky (the part west of the galactic center) and Russian scientists will do the same with the other half, giving them dedicated time to work on the data, says Sunyaev. The mission will later open the data to other researchers.

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