From left: Michael Porter, Alyssa Carter, Jenny Ji, Alex Viloria Winnett, and Reid Akana, who all work in the lab of chemical engineer Rustem F. Ismagilov.

Here's how it worked: contact tracers from local public health departments, clinics, and testing sites, including Caltech's Student Wellness Services, shared study details with people recently infected with SARS-CoV-2 and their uninfected housemates. The 410 participants who enrolled self-collected their samples once or twice a day for about two weeks and sent the samples to the lab to be analyzed with a high-sensitivity research assay. The Ismagilov lab team then calculated viral load in each sample type (saliva, nasal swabs, and throat swabs) to see where the virus accumulated first and figure out how sensitive a diagnostic test would need to be to detect the virus in that sample.

Although they are still analyzing data, Ismagilov's team has released three preprints online and a publication in the *Journal of Clinical Microbiology* that outline several important findings thus far: the virus generally appears first in oral samples, which suggests that many early infections are not being detected by nasal-swab tests; viral load is highly variable among sample types, suggesting that there is no single best COVID-19 test type and better testing strategies are needed; and taking COVID-19 tests first thing in the morning helps improve test sensitivity significantly, suggesting a simple change that can make tests more reliable.

Ismagilov says performing a large study like this amid the pandemic added challenges to every aspect, from getting the study organized, designed, and launched, to running the study and securing the necessary and often scarce lab reagents.

"It would have been easier to do nothing, but the team felt very strongly they had to make this contribution," Ismagilov says.

The Ismagilov lab's COVID-19 study is already having a ripple effect on the group's future work. To make the COVID-19 study a reality, the group built a new infrastructure for conducting longitudinal community-based studies, says Natasha Shelby, scientific research manager for the Ismagilov lab and study administrator for the COVID-19 study.

"That infrastructure will open so many doors to study health conditions that have been challenging to understand," she says, adding that the group has plans to publish their study-design templates to help other labs launch similar studies and get critical data right when a new pathogen emerges.

"We answered the questions we set out to answer," Ismagilov says. "I witnessed incredible dedication and self-sacrifice, not only from our lab but from many other members of the Caltech community, including volunteers who made the study possible."

Yaser Abu-Mostafa is a professor of electrical engineering and computer science. The student research that led to the creation of the CS156 model was supported by Caltech trustee and alumnus Charles Trimble (BS '63, MS '64); the Summer Undergraduate Research Fellowship program; and the Clinard Innovation Fund, established by entrepreneur and Caltech alumnus Gary Clinard (BS '65, MS '66).

Pamela Björkman is the David Baltimore Professor of Biology and Bioengineering and a Merkin Institute Professor. Her work on a universal vaccine is funded by the Merkin Institute for Translational Research, Wellcome Leap Inc., the National Institutes of Health, and the Bill & Melinda Gates Foundation, among other supporters.

Richard Flagan is the Irma and Ross McCollum-William H. Corcoran Professor of Chemical Engineering and Environmental Science and Engineering. His face-mask studies were funded by Caltech's Jacobs Institute for Molecular Engineering for Medicine.

Rustem F. Ismagilov is the Ethel Wilson Bowles and Robert Bowles Professor of Chemistry and Chemical Engineering, a Merkin Institute Professor, and director of the Jacobs Institute for Molecular Engineering for Medicine. His COVID-19 study has been funded in part by the Bill & Melinda Gates Foundation, the Ronald and Maxine Linde Center for New Initiatives at Caltech, and the Jacobs Institute for Molecular Engineering for Medicine.

Read the online version of this story to learn about more of Caltech's COVID-19 research, including a biosensor developed by medical engineer Wei Gao:

The POWER *of* Observation

After a decade in space, the small but powerful NuSTAR space telescope still has more to see.

NASA's Nuclear Spectroscopic Telescope Array (NuSTAR), led by Caltech and managed by JPL, turned 10 years old in June. This space telescope detects high-energy X-ray light and studies some of the most energetic objects and processes in the universe. The mission's principal investigator is Fiona Harrison, the Harold A. Rosen Professor of Physics and the Kent and Joyce Kresa Leadership Chair of the Division of Physics, Mathematics and Astronomy at Caltech. Here are some of the ways NuSTAR has opened our eyes over the last decade:

Seeing X-Rays Close to Home

Different colors of visible light have different wavelengths and different energies; similarly, there is a range of X-ray light, or light waves with higher energies than those human eyes can detect. NuSTAR detects X-rays at the higher end of the range. There are not many objects in our solar system that emit the X-rays NuSTAR can detect, but both the sun and Jupiter do. NuSTAR's studies could help scientists explain why the sun's outer region, the corona, is many times hotter than its surface. NuSTAR's observations of Jupiter, made contemporaneously with JPL's Juno mission, found that high energy X-rays are produced as particles slam into the planet's atmosphere.

Illuminating Black Holes

Black holes do not emit light, but some of the biggest ones we know of are surrounded by disks of hot gas that glow in many different wavelengths of light. NuSTAR can show scientists what is happening to the material closest to the black hole and reveal how black holes produce bright flares and jets of hot gas that stretch for thousands of light-years into space. The mission has measured temperature variations in black hole winds that influence star formation in the rest of the galaxy. Recently, NuSTAR supported the Event Horizon Telescope (EHT) in its effort to capture the first-ever direct images of the shadows of black holes. (For more on EHT, see page 20.)

Finding Hidden Black Holes

NuSTAR has identified dozens of black holes hidden behind thick clouds of gas and dust. Visible light typically cannot penetrate those clouds, but the high-energy X-ray light observed by NuSTAR can. In recent years, scientists have used NuSTAR data to find out how black holes become surrounded by such thick clouds, how that process influences their development, and how obscuration relates to a black hole's impact on the surrounding galaxy.

Fiona Harrison, NuSTAR principal investigator

Bright green sources of high-energy X-ray light captured by NuSTAR overlaid on an optical-light image of the Whirlpool galaxy and its companion galaxy, M51b (the bright greenish-white spot above).

Revealing the Power of 'Undead' Stars

NuSTAR is a kind of zombie hunter: It finds the undead corpses of stars. Known as neutron stars, these are dense nuggets of material left over after a massive star runs out of fuel and collapses. Though neutron stars are typically the size of a large city, they are so dense that a teaspoon of one would weigh about a billion tons on Earth. Their density, combined with their powerful magnetic fields, makes these objects extremely energetic: one neutron star located in the galaxy M82 beams with the energy of 10 million suns.

Solving Supernova Mysteries

Stars are mostly spherical, but NuSTAR observations have shown that when they explode as supernovae, they become an asymmetrical mess. The space telescope solved a major mystery in the study of supernovae by mapping the radioactive material left over by two stellar explosions. It traced the shape of the debris and in both cases revealed significant deviations from a spherical shape. Because of NuSTAR's X-ray vision, astronomers now have clues about what happens in an environment that would be almost impossible to probe directly. The NuSTAR observations suggest that the inner regions of a star are extremely turbulent at the time of detonation.