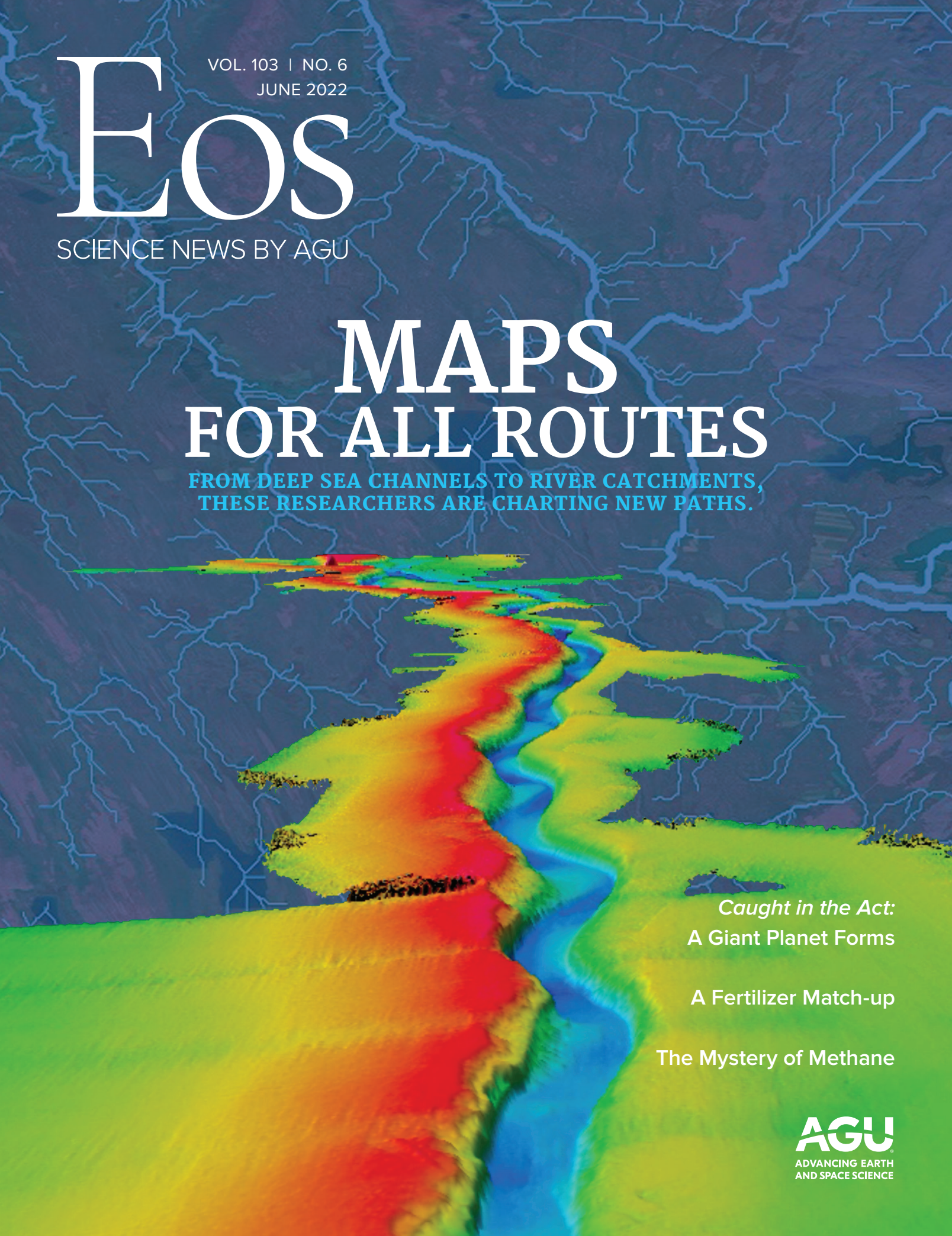
VOL. 103 | NO. 6
JUNE 2022

Eos

SCIENCE NEWS BY AGU

MAPS FOR ALL ROUTES

FROM DEEP SEA CHANNELS TO RIVER CATCHMENTS, THESE RESEARCHERS ARE CHARTING NEW PATHS.



Caught in the Act: A Giant Planet Forms

A Fertilizer Match-up

The Mystery of Methane

AGU
ADVANCING EARTH AND SPACE SCIENCE

Giant Planet's Formation Caught in Action

Planetary scientists strive to understand the ins and outs of planet formation. Discoveries of unusual planetary systems don't make this formidable task any easier. In particular, Jupiter-class gas giants on far-flung orbits have challenged what is known as the standard formation scenario.

Scientists converged on the scenario that our solar system's giant planets formed via accretion within the gaseous protoplanetary disk. Rocky planetary cores fed on pebbles or planetesimals, and once the cores reached a certain mass, they began gobbling up the surrounding gas, rapidly becoming giant planets. But that process works only when planets form relatively close to their host stars—the gas giants found on wide orbits would not have had time to grow a sufficiently massive core before the gaseous disk dissipated.

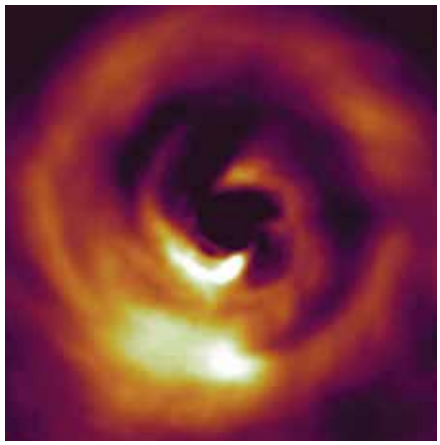
The unstable disk model is one of several alternative models suggesting that a massive and gravitationally unstable protoplanetary disk could fragment into dense clumps, directly giving birth to wide-orbiting planets. However, the model still lacks convincing evidence.

"This is probably the youngest directly imaged planet in a disk."

Now, a team of scientists has made a discovery that might be just the evidence the community has been waiting for. The team imaged a massive protoplanet orbiting the star AB Aurigae at about 93 times the distance between Earth and the Sun. Scientists caught the planet in an early stage of formation, still embedded in a protoplanetary disk. The properties of both the planet and the disk match well the predictions of the unstable disk model. The study was published in *Nature Astronomy* (bit.ly/AB-Aurigae).

AB Aurigae System Takes Shape

The young system AB Aurigae has been on astronomers' radar for a long time. The central star is more than twice as massive as the Sun and lies about 520 light-years away. Its massive protoplanetary disk, mapped over a wide wavelength range from optical to radio,



This image of the AB Aurigae system shows protoplanet AB Aur b (the lower bright "blob") orbiting a long distance from its host star. Credit: Thayne Currie/Subaru Telescope

is incredibly complex. Two gaseous spiral arms wind and twist away from the star within a region encircled by a pebble-sized dust ring. Something had to clear the dust inside the ring, and the spirals indicate an unstable disk; both features are smoking gun evidence of baby planets hidden in the disk.

These considerations were in the back of Thayne Currie's mind when he pointed the Subaru Telescope in Hawai'i toward the system for the first time. "For some reason, we couldn't observe our primary target, so I had to make a flash decision, and I said, 'AB Aurigae!'" recounted Currie, an astrophysicist at NASA Ames Research Center and lead author of the study.

Currie and his colleagues observed planet-forming disks in near-infrared light with a stellar coronagraph. This specialized instrument is designed to block a host star's light and thus enable the observation of the much fainter disk.

The first images of the AB Aurigae system contained a bright blob south of the star. Subsequent observations with other instruments and a reanalysis of archival Hubble Space Telescope data confirmed that the blob was genuine. After performing several checks—such as observing the object's position changing in time, consistent with counterclockwise orbital motion—the team realized they were looking at a protoplanet (named AB Aur b) of about 9 Jupiter masses embedded in the disk.

"The conclusion of the source being a planet seems robust," said Ilse Cleeves, an assistant professor at the University of Virginia who was not involved with this study. "This is probably the youngest directly imaged planet in a disk." Infant planets like this one are hard to find, although not for lack of trying. So far, the search has come up with two other protoplanets, both orbiting the same star. But in contrast to AB Aur b, they have already cleared most of their disk's material.

"In the field of planet formation, we're not starved for ideas, but we're starved for actual constraints on the ideas."

The Fate of the Protoplanet Unknown

"In the field of planet formation, we're not starved for ideas, but we're starved for actual constraints on the ideas," said Sean Raymond, an astronomer at the Laboratoire d'Astrophysique de Bordeaux in France who was not involved with the research. "Having real, concrete observations of what's happening is key." In that sense, AB Aur b is quite a catch. It provides direct evidence that Jupiter-like planets can form at large distances from a star. Moreover, together with the spiral features, the discovery supports the unstable disk model.

Other plausible models for the formation of wide-orbiting gas giants invoke planet migration. According to Raymond, a planet can indeed form closer in and then have its orbit expand, but the models have yet to convince astronomers that such a scenario is robust.

The fate of AB Aur b is not clear-cut. "We don't know necessarily if it will survive in the long term," said Cleeves. Depending on the properties of the disk, the protoplanet might migrate inward, which could tear it apart. But given that the protoplanet has already begun tidying up the inner region, "its fate might actually be OK," said Cleeves.

By **Jure Japelj** (@JureJapelj), Science Writer