AMERICAN MUSEUM of NATURAL HISTORY

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EVIDENCE OF A PLANET IN FORMATION?

ASTROPHYSICISTS OBSERVE A CIRCUMSTELLAR DISK WITH TELL-TALE SIGNS OF PLANET FORMATION

Astrophysicists have a new window into the formation of planets. Ben R. Oppenheimer, Assistant Curator in the Department of Astrophysics at the American Museum of Natural History, and colleagues have imaged a structure within the disk of material coalescing from the gas and dust cloud surrounding a well-studied star, AB Aurigae. Within that structure, it appears that an object is forming, either a small body currently accreting dust or a brown dwarf (a body intermediate between stars and planets) between 5 and 37 times the mass of Jupiter. The observations, accepted for publication this June in the *Astrophysical Journal*, represent a significant step toward direct imaging and study of exoplanets (planets orbiting stars other than the Sun), and may bear on theories of planet and brown dwarf formation.

Young stars generally have material widely spread around them that organizes itself into a disk over time. Astronomers believe that this is where planets form. The new image, which is sensitive to the dust around the star but not starlight, shows a horseshoe-shaped structure orbiting AB Aurigae with two denser, brighter clumps of material in a ring around the star next to a darker area. This darker area, a structure relatively depleted of widespread material previously predicted in models of planet formation but never seen before, is thought to be the point at which material is coalescing into a planet or brown dwarf. Further imaging of this area shows a barely visible spot dead center, a spot too bright to be light reflected off a formed planet but consistent with an object in the process of development that is accreting new material. The two brighter clumps, equidistant from the hole and presumably trailing and leading it in its orbit around the star, seem similar to the Trojan objects that orbit the Sun along with Jupiter. Such a structure has been predicted to form in disks where a planet is present, because of the gravitational interaction between the planet and the star it orbits.

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"The deficit of material could be due to a planet forming and sucking material onto it, coalescing into a small point in the image and clearing material in the immediate surroundings. This would look like a hole in the disk," says Oppenheimer. "We are seeing something happening in the disk that seems to be indicative of the formation of a small body, either a planet or a brown dwarf."

Finding planets outside of our solar system is a new phenomenon. It is only in the last 15 years that nearly 300 extrasolar planets have been identified around distant stars. Most of these objects are more massive than Jupiter, orbit very close to their stars, and are identified by indirect methods such as the wobble created by the gravitational pull. None of the known exoplanets have yet been imaged or seen directly, because the light of a star overwhelms the faint glow of a nearby planet.

Oppenheimer and his colleagues circumvented this glare by attaching a coronagraph to a unique U.S. Air Force telescope on Maui, Hawaii. The telescope compensates for turbulence in the Earth's atmosphere, permitting extremely high image quality from the ground. The Lyot Project coronagraph, built on a floating table in a clean-room optics lab at the Rose Center for Earth and Space at the Museum and named for the French astronomer who invented solar coronagraphy (www.lyot.org), blocks light from the center of the image of a nearby star to reveal faint objects around it. Stellar coronagraphs have been routinely used for several decades, but the Lyot Project's is more precise and exceeds the resolution of the Hubble Space Telescope.

Oppenheimer's team used additional polarization filters to detect even fainter objects much closer to the star than previously possible. Polarization selects light scattered off the disk, distinguishing it from the light of the star, which is not generally polarized. The technology enabled the team to see the disk of material around AB Aurigae with unprecedented sensitivity. Objects up to 100,000 times fainter than and just half an arcsecond from the star (an angle about 100 times finer than the human eye can discern) could be imaged. This is thousands of times better than other instruments.

AB Aurigae is well-studied because it is young, between one and three million years old, and can therefore provide information on how stars and objects that orbit them form. One unresolved question about planet formation is how the initial thick, gas-rich debris disk evolves into a thin, dusty region with planets. The observation of stars slightly older than AB Aurigae shows that at some point the gas is removed, but no one knows how this happens. AB Aurigae could be in an intermediate stage, where the gas is being cleared out from the center, leaving mainly dust behind. "More detailed observations of this star can help solve questions about how

some planets form, and can possibly test competing theories," says Oppenheimer. "And if this object is a brown dwarf, our understanding of them must be revamped." Brown dwarfs have been found orbiting stars since a team (which included Oppenheimer) first discovered one in 1995, but they are not believed to form in circumstellar material.

The team contributing to this research included Douglas Brenner, Anand Sivaramakrishnan, and Remi Soummer of the Department of Astrophysics, AMNH; Sasha Hinkley and Neil Zimmerman of the Department of Astronomy, Columbia University; Jeffrey Kuhn and David Harrington of the Institute for Astronomy, University of Hawaii; James Graham and Marshall Perrin of the Department of Astronomy, University of California at Berkeley; James Lloyd of the Department of Astronomy, Cornell University; and Lewis Roberts of the Boeing Company, now at NASA's Jet Propulsion Laboratory.

The research was funded in part by the National Science Foundation, NASA's Terrestrial Planet Finder Program, and individual donors. The U.S. Air Force provided access to the AEOS telescope and significant financial support for the project.

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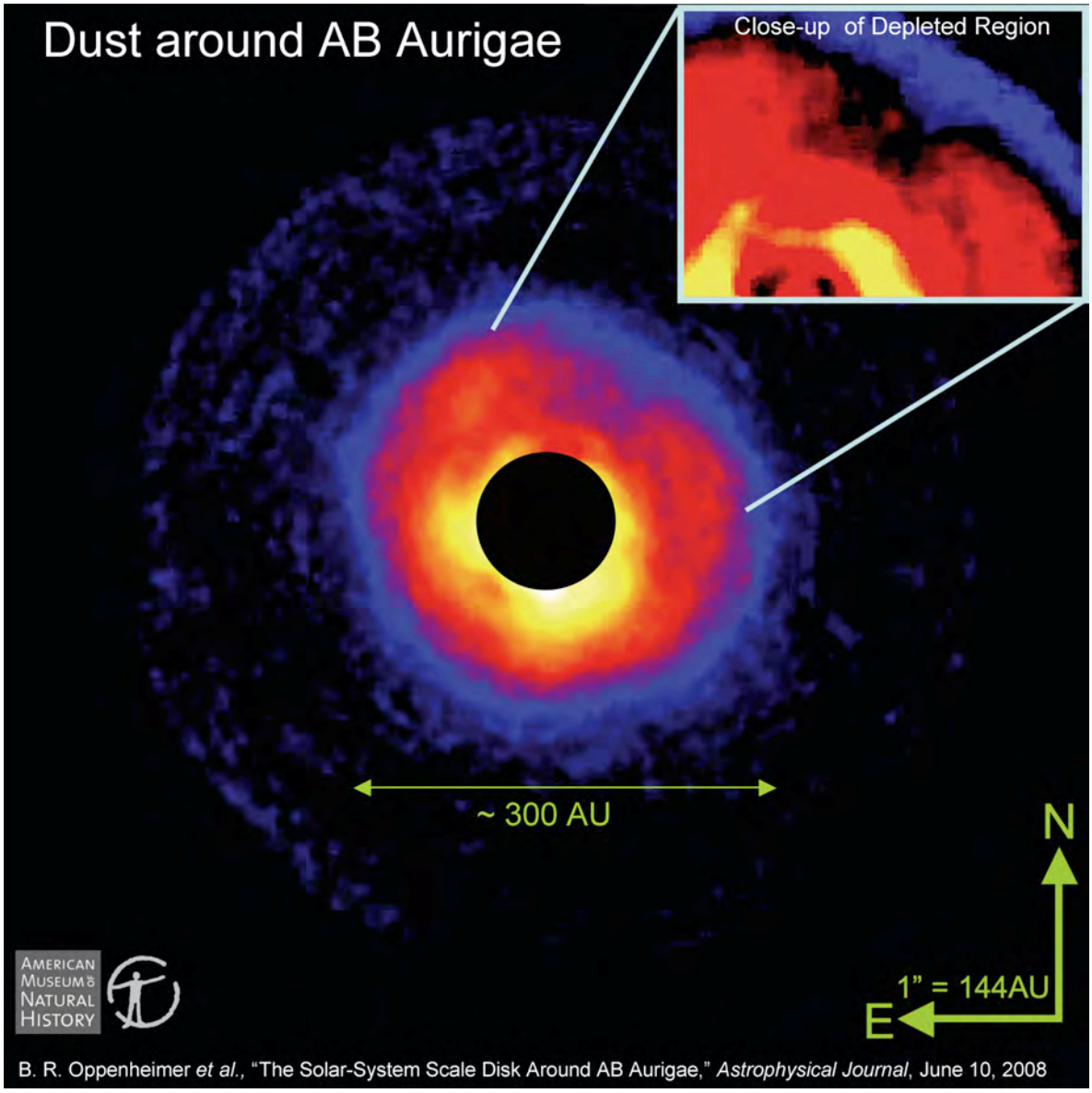

Figure credit: The Lyot Project. **Figure information**: Coronagraphic image of the polarized light around the star AB Aurigae, showing the distribution of dust in the inner part of a complex disk of material around this star. The shaded middle region is covered to block out light from the star. The inset at upper right is a blow-up of the depleted region of dust to the NNW of the star. This depleted region and the denser clumps near the ends of the white guide lines seem to indicate the formation of a small body within the depleted region. The scale of the image is indicated by the arrow, which corresponds to about 300 times the distance between the Earth and Sun. The orbit of a planet like Neptune, if it were orbiting this star, would be at the edge of the black circle on this scale.

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American Museum of Natural History

The American Museum of Natural History is one of the world's preeminent scientific, educational, and cultural institutions. Since its founding in 1869, the Museum has advanced its global mission to explore and interpret human cultures and the natural world through a wide-reaching program of scientific research, education, and exhibitions. The Museum accomplishes this ambitious goal through its extensive facilities and resources. The institution houses 46 permanent exhibition halls, state-of-the-art research laboratories, one of the largest natural history libraries in the Western Hemisphere, and a permanent collection of more than 30 million specimens and cultural artifacts. With a scientific staff of more than 200, the Museum supports research divisions in Anthropology, Paleontology, Invertebrate and Vertebrate Zoology, and the Physical Sciences. The Museum shares its treasures and discoveries with approximately four million on-site visitors from around the world each year. AMNH-produced exhibitions and Space Shows can currently be seen on five continents in engagements that reach audiences of millions. In addition, the Museum's Web site, www.amnh.org, extends its collections, exhibitions, and educational programs to millions more beyond the Museum's walls.

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