Scientists on the hunt for planetary formation fossils reveal unexpected eccentricities in nearby debris disk

June 14 2022, by Amy C. Oliver

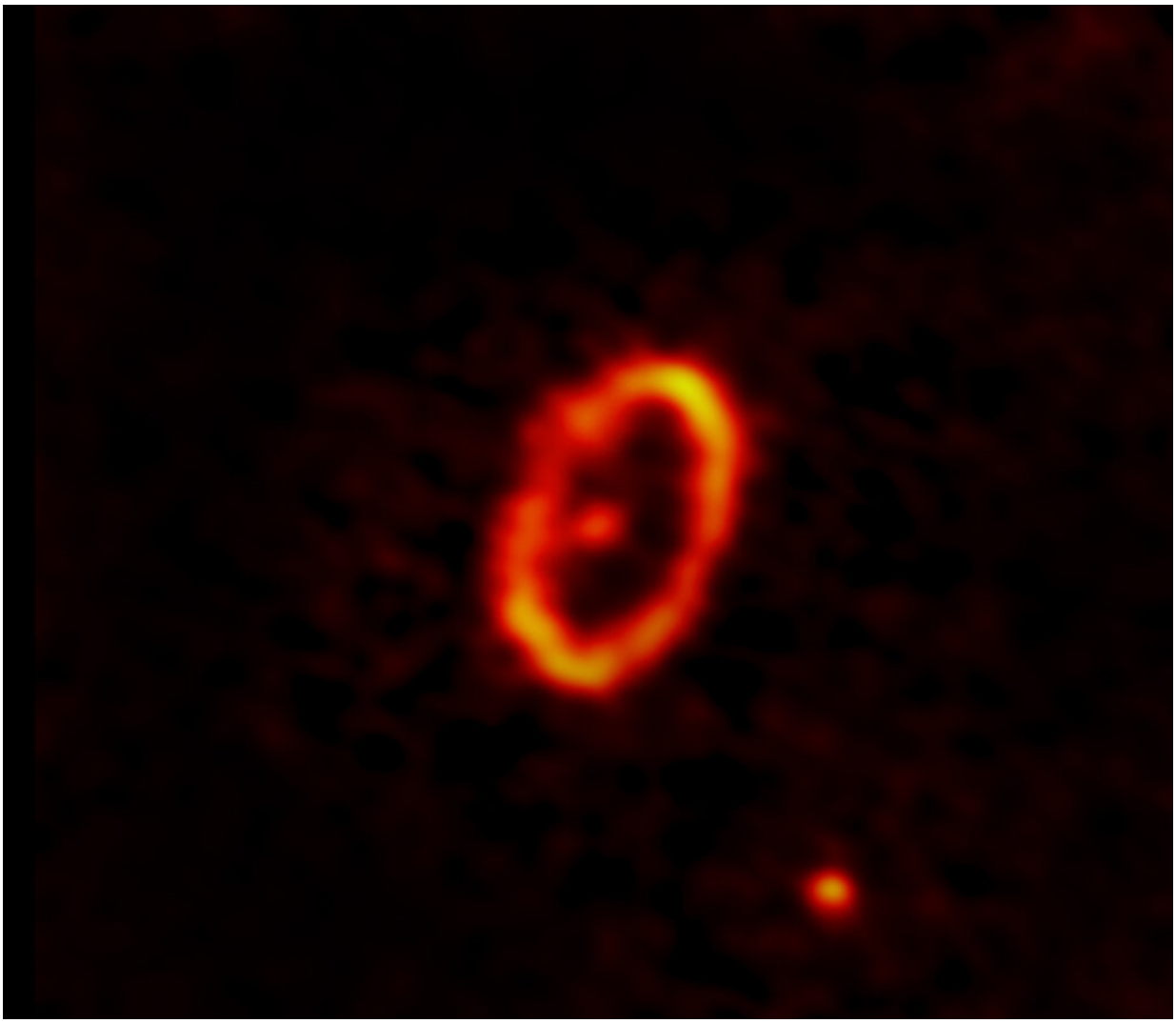
Artist's impression of the billion-year-old Sun-like star, HD 53143, and its highly eccentric debris disk. The star and a second inner disk are shown near the southern foci of the elliptical debris disk. A planet, which scientists assume is shaping the disk through gravitational force, is shown to the north. Debris disks are the fossils of planetary formation and since we can't directly study our own disk— also known as the Kuiper Belt— scientists glean information about the formation of our Solar System by studying those we can see from a distance. Credit: ALMA (ESO/NAOJ/NRAO); M. Weiss (NRAO/AUI/NSF)

Using the Atacama Large Millimeter/submillimeter Array (ALMA), astronomers have imaged the debris disk of the nearby star HD 53143 at millimeter wavelengths for the first time, and it looks nothing like they expected. Based on early coronagraphic data, scientists expected ALMA to confirm the debris disk as a face-on ring peppered with clumps of dust. Instead, the observations took a surprise turn, revealing the most complicated and eccentric debris disk observed to date. The observations were presented today in a press conference at the 240th meeting of the American Astronomical Society (AAS) in Pasadena, California, and will be published in an upcoming edition of *The Astrophysical Journal Letters* (*ApJL*).

HD 53143—a roughly billion-year-old sun-like star located 59.8 light-years from Earth in the Carina constellation—was first observed with the coronagraphic Advanced Camera for Surveys on the Hubble Space Telescope (HST) in 2006. It also is surrounded by a debris disk—a belt of comets orbiting a star that are constantly colliding and grinding down into smaller dust and debris—that scientists previously believed to be a face-on ring similar to the debris disk surrounding our sun, more commonly known as the Kuiper Belt.

The new observations were made of HD 53143 using the highly sensitive Band 6 receivers on ALMA, an observatory co-operated by the U.S.

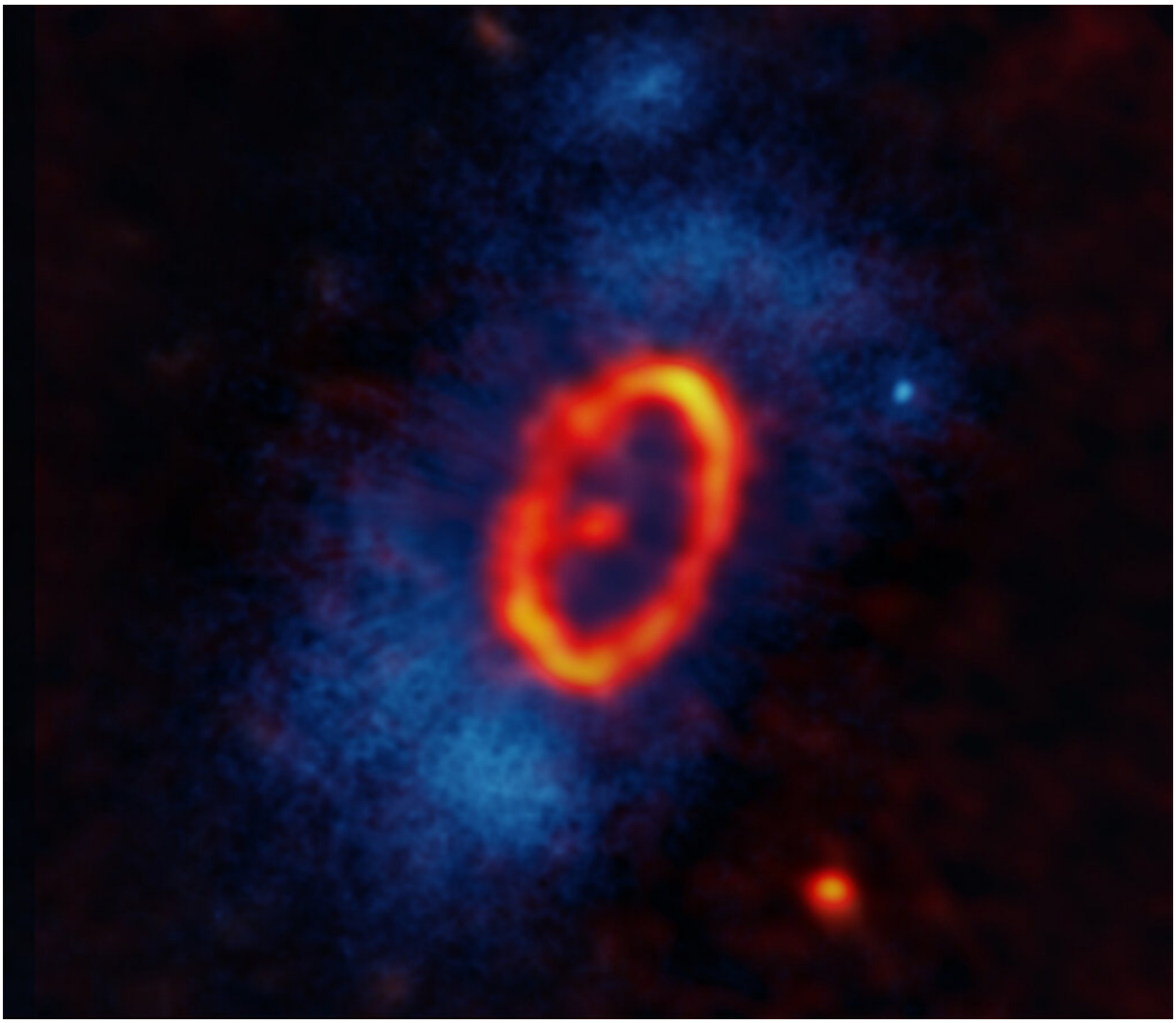
National Science Foundation's National Radio Astronomy Observatory (NRAO), and have revealed that the star system's debris disk is actually highly eccentric. In ring-shaped debris disks, the star is typically located at or near the center of the disk. But in elliptically shaped eccentric disks, the star resides at one focus of the ellipse, far away from the disk's center. Such is the case with HD 53143, which wasn't seen in previous coronagraphic studies because coronagraphs purposely block the light of a star in order to more clearly see nearby objects. The star system may also be harboring a second disk and at least one planet.



While studying HD 53143— a roughly billion-year-old Sun-like star— in millimeter-wavelengths for the first time, scientists discovered that the star's debris disk is highly eccentric. Unlike ring-shaped debris disks, in which the star sits in the center, HD 53143 is located at one foci of an elliptical-shaped disk, and is shown as the unresolved dot below and left of center. Scientists believe a second unresolved dot in the north of this image to be a planet that is perturbing and shaping the debris disk. Credit: ALMA (ESO/NAOJ/NRAO), M. MacGregor (U. Colorado Boulder), S. Dagnello (NRAO/AUI/NSF)

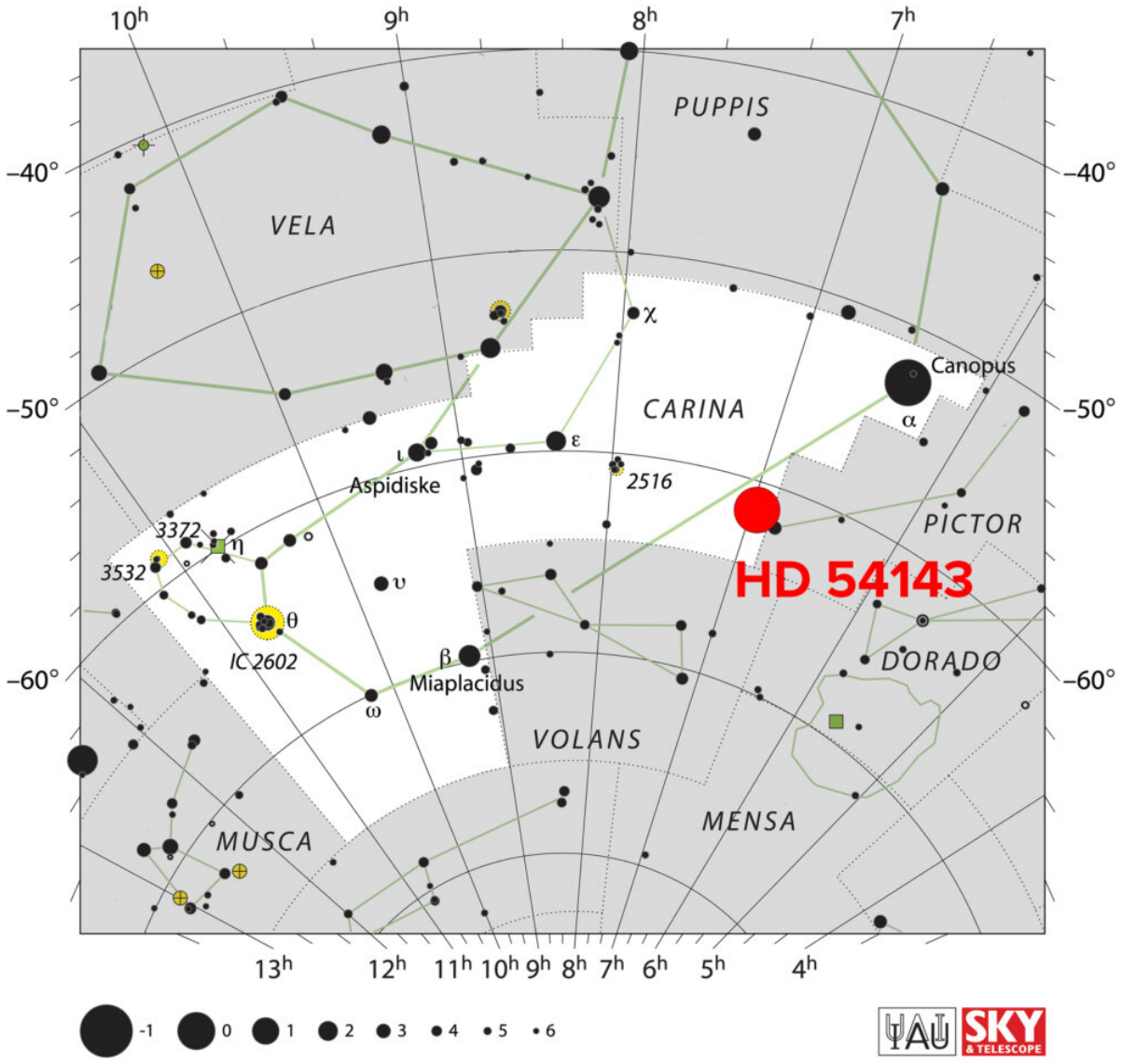
"Until now, scientists had never seen a debris disk with such a complicated structure. In addition to being an ellipse with a star at one focus, it also likely has a second inner disk that is misaligned or tilted relative to the outer disk," said Meredith MacGregor, an assistant professor at the Center for Astrophysics and Space Astronomy (CASA) and Department of Astrophysical and Planetary Sciences (APS) at CU Boulder, and the lead author on the study. "In order to produce this structure, there must be a planet or planets in the system that are gravitationally perturbing the material in the disk."

This level of eccentricity, MacGregor said, makes HD 53143 the most eccentric debris disk observed to date, being twice as eccentric as the Fomalhaut debris disk, which MacGregor fully imaged at millimeter wavelengths using ALMA in 2017. "So far, we have not found many disks with a significant eccentricity. In general, we don't expect disks to be very eccentric unless something, like a planet, is sculpting them and forcing them to be eccentric. Without that force, orbits tend to circularize, like what we see in our own solar system."



Composite image of the HD 53143 star system. Shown in orange/red, millimeter-wavelength data from Atacama Large Millimeter/submillimeter Array (ALMA), reveal a previously unobserved eccentric debris disk orbiting HD 53143 in the form of an ellipse. Am unresolved dot shows the star off-center near the southern foci of the disk, while a second unresolved dot to the north indicates the potential presence of a planet. Optical data from the Hubble Space Telescope's Advanced Camera for Surveys (ACS) is shown in blue and white; a coronagraphic mask blocks out the starlight, allowing researchers to see what's happening in the region surrounding HD 53143. Credit: ALMA (ESO/NAOJ/NRAO), M. MacGregor (U. Colorado Boulder), S. Dagnello (NRAO/AUI/NSF)

Importantly, MacGregor notes that debris disks aren't just collections of dust and rocks in space. They are a historical record of planetary formation and how planetary systems evolve over time. and provide a peek into their futures. "We can't study the formation of Earth and the solar system directly, but we can study other systems that appear similar to but younger than our own. It's a bit like looking back in time," she said. "Debris disks are the fossil record of planet formation, and this new result is confirmation that there is much more to be learned from these systems and that knowledge may provide a glimpse into the complicated dynamics of young star systems similar to our own solar system."



HD 53143 is located in the Carina constellation, roughly 59.8 light-years from Earth. Credit: IAU/Sky & Telescope

Dr. Joe Pesce, NSF program officer for ALMA, added, "We are finding planets everywhere we look, and these fabulous results by ALMA are showing us how planets form—both those around other stars and in our

own solar system. This research demonstrates how astronomy works and how progress is made, informing not only what we know about the field but also about ourselves."

More information: MacGregor et al, "ALMA Images the Eccentric HD 53143 Debris Disk," *The Astrophysical Journal Letters* (2022). ui.adsabs.harvard.edu/abs/2020 … .prop16202S/abstract

Provided by National Radio Astronomy Observatory