66 Eyes on the Sky: ALMA’s New Perspective

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What did our solar system look like when it was in its infancy? What would an outsider’s view show us? Thanks to ALMA, or Atacama Large Millimeter Array, a new radio telescope in the Atacama Desert in Chile, we may now have a unique new way to see exactly what goes on in the early life of a planetary system.

The theory of the origin of our solar system is nothing new. In the 18th century, Immanuel Kant, Pierre-Simon Laplace, and Emanuel Swedenborg proposed a model that we still use in its refined but largely unchanged form today. Their idea was that at some point around 4.6 billion years ago, a pocket of swirling gas and dust collapsed in on itself, gathering mass from the surrounding cloud until it was able to begin fusing hydrogen, beginning the life cycle of a new star: our sun. In the remaining spinning disk of gas and dust, grains began to stick together forming small clumps. These tiny clumps stuck to other clumps in larger and larger sizes, colliding, shattering, and re-forming in a chaotic and violent process until eventually the solar system as we know it was formed.

While this theory is widely accepted today, since the 18th century it has fallen into and out of favor several times, being challenged and disputed over and over again. Part of the reason for the uncertainty is that we have never been able to get a bird’s eye view of this process first hand, at least, not until ALMA.

The ALMA radio telescope, located in the Atacama Desert in northern Chile, is the latest international collaborative effort in modern radio astronomy. It began in 1997 when the National Radio Astronomy Observatory (NRAO) in the United States agreed to combine their efforts with the European Southern Observatory (ESO) to create a radio telescope with unrivaled

ALMA’s powerful dishes poised under a beautiful night sky.
Credit: Christoph Malin, ESO, 2012, http://www.almaobservatory.org/en/visuals/images/?g2_itemId=4637
sensitivity and resolution. The United States contributed the Millimeter Array (MMA), which offers exceptional frequency coverage, and the Europeans brought to the project their Large Southern Array (LSA), which offered unparalleled sensitivity. Later, in 2004, the National Astronomical Observatory of Japan (NAOJ) would become a partner in the project, adding their Atacama Compact Array and three new receiver bands to the array.

The array’s power as an observatory comes from the number and versatility of the antennas. Sixty-six separate antennas will be linked together to form what is called an interferometer, which gives the telescope the effect of having a much greater diameter than it actually does, enhancing its ability to resolve distant objects. ALMA’s antennas can be moved around the project site, giving it the ability to have separations ranging from about 150 meters to around 14 kilometers, which gives astronomers an instrument versatile enough to observe celestial objects from the very large to the very small with better resolution than that from Hubble and the Very Large Array seen in the movie Contact.

This resolution allowed astronomers to image the early stages of formation of a new planetary system like never before. Using ALMA, astronomers observed a T Tauri star named HL Tau. T Tauri stars are the youngest observable stars in the universe, still in the process of collapsing prior to fusion igniting in their cores and moving them onto the main sequence. Since their core temperatures are too low for fusion, they are instead powered by the release of gravitational energy as they contract. About half of the known T Tauri stars have disks of gas and dust surrounding them, called protoplanetary disks because they are thought to be the progenitors of planetary systems.

The ALMA astronomers found just such a disk of gas and dust surrounding HL Tau. The disk surrounding this particular young star is warm enough to emit light in the X ray bandwidth, making it appear to ALMA as a glowing aura surrounding the star. The accretion disk features prominent dark rings throughout, which are thought to be regions of the young system where small fledgling planets, or planetoids, are “vacuuming up” all the dust and gas in their orbits, expanding the rings as they grow more and more massive. This finding appears to be direct visual evidence of planets forming right before our eyes, giving confirmation to the theories of the formation of our own solar system.
However, the data are not exactly what astronomers expected. HL Tau is estimated to be around 100,000 years old, yet it already has planets forming in its circumstellar disk. This process was previously thought to take much longer than the time period seen in HL Tau. According to Catherine Vlahakis of ALMA, "When we first saw this image we were astounded at the spectacular level of detail. HL Tauri is no more than a million years old, yet already its disk appears to be full of forming planets. This one image alone will revolutionize theories of planet formation."

ALMA is currently approaching completion, and since this is its first precision image in the almost-complete configuration it was designed for, we can expect many more exciting discoveries in the future. ALMA is a gargantuan undertaking by all the organizations involved, but it is already clear that the payoff will be tremendous. According to Tim de Zeeuw, Director General of the European Southern Observatory, “This high resolution image of HL Tauri demonstrates what ALMA can achieve when it operates in its largest configuration and starts a new era in our exploration of the formation of stars and planets.” Unique and wonderful discoveries are clearly just beyond the horizon.

For more information about ALMA, please visit:

- [https://public.nrao.edu/telescopes/alma](https://public.nrao.edu/telescopes/alma)

**Sources Cited**

