Astrobiology News January 2022: Why Doesn't Our Solar System Have a 'Super-Earth'?

Over the years, I've written a number of *Astrobiology News* columns that report on the incredible diversity of exoplanets that we've discovered during the past few decades. Eight years ago, in January 2014, I wrote a column on hypothesized 'superhabitable' worlds,[1] which might belong to a category of exoplanets that are known as 'super-Earths.' Super-Earths are worlds that are larger than Earth, but smaller than Neptune.[2] They are between two and ten times the mass of Earth, and they may have diverse compositions, including rock, ices, water, and gas. Roughly 30% of the exoplanets discovered to date have been classified as super-Earths, yet our own Solar System lacks such a world – why? A recent paper that appeared in *Nature Astronomy* traces the reason for this back to the early architecture of the Solar System, to a time when gas and dust rings surrounded the young Sun, and only the building blocks of what would become the planets existed.[3]

Large flattened structures of gas and dust around young stars are known as protoplanetary disks. The Atacama Large Millimeter/submillimeter Array (ALMA) in Chile has produced striking images of rings (and other features) in protoplanetary disks, and provided evidence that planets form within these structures.[4] The authors of the recent paper in *Nature Astronomy* used a supercomputer to run hundreds of simulations of the early Solar System to explore the connection between rings and features seen today in our Solar System. Rice University astrophysicist André Izidoro and his colleagues attribute the architecture of our Solar System to 'pressure bumps' that resulted in the accumulation of dust and the release of large amounts of vaporized gas at three places in the early Solar System.

In the Rice simulations, pressure bumps at the sublimation lines (where solids change directly to vapor) of silicate, water and carbon monoxide produced three distinct rings. At the silicate line, the basic ingredient of sand and glass, silicon dioxide, became vapor. This produced the sun's nearest ring, where Mercury, Venus, Earth and Mars would later form. The middle ring appeared at the 'snow line', where ice sublimates to water vapor, and the farthest ring at the carbon monoxide line.

It turns out timing is very important – in the simulations where the middle pressure bump formed later on, there was enough material in the inner Solar System to form super-Earths. Izidoro and his colleagues have been able to reproduce a number of features of our Solar System that are missing in many previous models, including the asteroid belt between Mars and Jupiter; the location, stable orbits, and masses of Mercury, Venus, Earth, and Mars; the dichotomy between the chemical make-up of objects in the inner and outer Solar System; and a Kuiper Belt of small icy and rocky bodies beyond the orbit of Neptune.[5]

Finding evidence of protoplanetary disks around young stars is the goal of the *Zooniverse* project *Disk Detective*.[6] *Disk Detective* uses huge amounts of data from surveys of the entire sky, and relies

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[1] http://www.theclergyletterproject.org/pdf/abnews12014.pdf
[2] https://exoplanets.nasa.gov/what-is-an-exoplanet/planet-types/super-earth/
[3] https://www.nature.com/articles/s41550-021-01557-z
[4] https://almascience.eso.org/alma-science/planet-forming-disks
[5] https://news.rice.edu/news/2022/earth-isnt-super-because-sun-had-rings-planets
[6] https://www.zooniverse.org/projects/ssilverberg/disk-detective

on volunteers from all walks of life to help identify stars that are likely to be surrounded with dusty disks. Identifying such stellar candidates is the first step in finding good targets for high-resolution observations with instruments like ALMA that can help us learn about the different environments that produce diverse planetary systems. Learning more about the conditions that produce other planetary systems helps us better understand the birth environment of our own.

Until next month,

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