A glimpse at the formation of our Solar System

The remarkable story of how the Sun, the planets and other celestial objects that make up the solar system came to be

ASTROPHYSICAL SERIES

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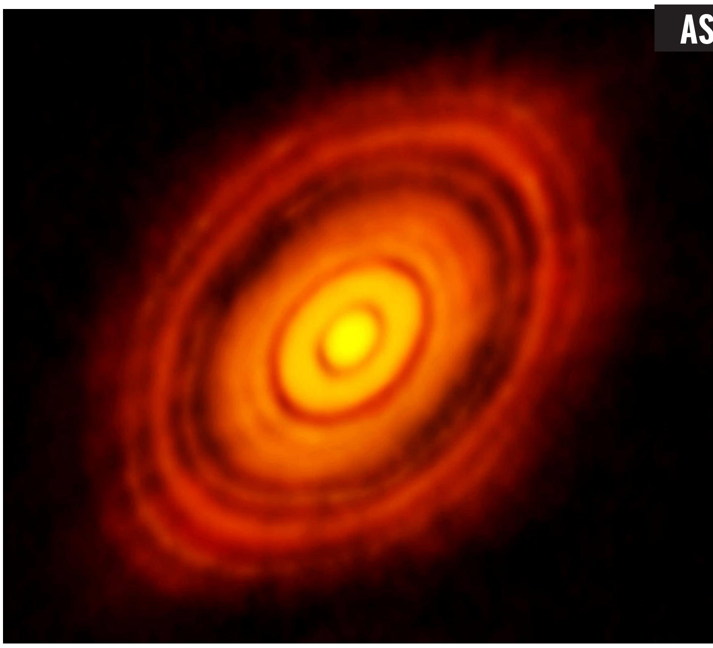
The history of our Solar System probably started 4.57 billion years ago when a fragment of a huge cloud of gas and dust started to contract because of its own gravity, somewhere in **interstellar** space. While contracting, it became denser and denser, until its core became a star – our Sun. But not all the matter went straight to the Sun...

A rotating disk

Rotation plays an important role in the formation of a planetary system like our Solar System. In all likelihood, our parent cloud fragment had some rotation, and this rotation accelerated upon contraction. Have you ever tried spinning on a rotating chair? If you do so (but be careful!), you could notice that you would spin faster when you pull your arms in close to your chest than when you stretch them out wide. It would work even better if you held something heavy in your hands, but in all cases, the more you would curl up, the faster you would spin. In the same way, when our parent cloud fragment curled up, it started to spin faster. As a result, the increased rotation flattened it into a disk, centered on the Sun. Such a disk made of gas and dust is known as a protoplanetary disk, as this is where planets can form. All planets and most other celestial bodies in the Solar System indeed orbit approximately in the same plane, which corresponds to the plane of the former protoplanetary disk.



IT ALL STARTED HERE *Solar system in formation: the HL Tauri protoplanetary disk as seen by the ALMA telescope.*
PHOTO: ALMA (ESO/NAOJ/NRAO)

From dust grains to planets

Our protoplanetary disk probably lasted "only" a few million years before being absorbed or blown away by the Sun, but most of the planet formation could be completed during that time. Our parent cloud was mostly made of gaseous hydrogen and helium, which are the main constituents of the Universe, but also included small dust grains. These grains are made of elements originating from stars and are ten to hundred times smaller than the dust particles you can find in your home. As these solids collided with each other, they grew until millimeter sizes and settled at the midplane of the disk. There, they could **coagulate** further to form asteroids (a kilometre to hundreds of kilometres in size), which in turn could merge in planet-sized objects, helped by their own gravitational attraction.

Temperatures varied across the disk, being higher closer to the Sun than further out. While water was gaseous in the inner regions, it was solid ice beyond a certain radius called the "snow line". Beyond this radius, the presence of ice with the stony material enhanced the growth of planets: planets formed below the snow line never exceeded the mass of the Earth, whereas outer planets reached ten times more, at which stage they even started to retain the **ambient** gas. This led to the formation of giant gas planets, among which Jupiter is the largest.

Although we still observe a clean separation between stone-dominated planets close to the Sun (Mercury, Venus, Earth, Mars) and giant planets further out (Jupiter, Saturn, Uranus, Neptune), some astrophysicists have hypothesized that the orbits of the giant planets changed significantly at different **epochs** in the history of the Solar System.

This would have had dramatic consequences, notably on the **flux** of asteroids near the inner planets. But nowadays, the planets are fortunately on rather stable orbits!

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ALL ABOUT ALMA

- HL Tauri is 450 light-years from Earth and the star is less than a million years old, which makes it pretty young by astronomical standards. The dark rings on the ALMA image may indicate the positions of planets under formation.
- ALMA is an array of telescopes located in the Atacama desert of Chile at 5000 metres altitude which observes the radio waves emitted by astrophysical objects such as stars and gas clouds. Each of its telescopes looks like a big satellite dish.
- The bigger a telescope is, the sharper its images are. ALMA dishes can be moved over distances up to 16 kilometres, making it one of the sharpest telescopes ever built.