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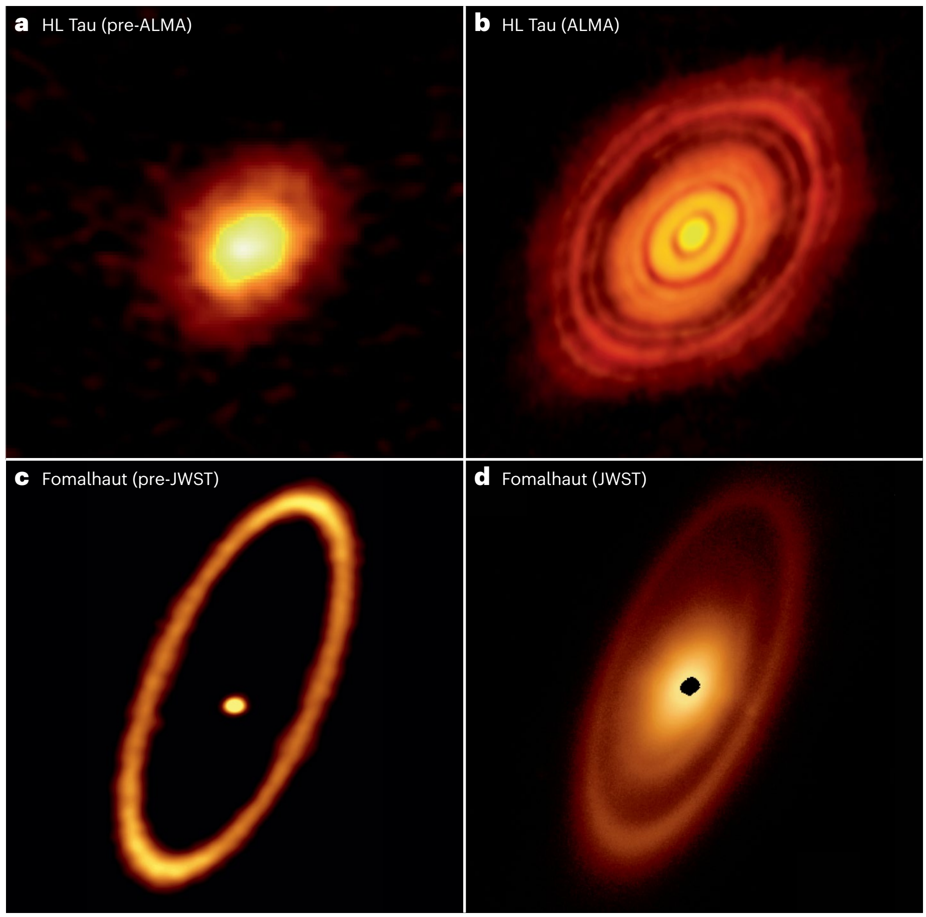
The JWST disk revolution is not being televised

Early JWST results on high-redshift galaxies have attracted a lot of press and much debate, but other areas of astronomy and astrophysics are also uncovering new understanding about the Universe with JWST, albeit with less of a fanfare.



CREDIT: AAS (PANEL A); ALMA (ESO/NAOJ/NRAO) (PANEL B); ALMA (ESO/NAOJ/NRAO), M. MACGREGOR (PANEL C); SPRINGER NATURE LTD (PANEL D)

Close to a decade ago, the Atacama Large Millimeter/submillimeter Array (ALMA) was being manoeuvred into a configuration that would allow it to achieve angular resolutions of less than a tenth of an arcsecond. In this configuration, ALMA returned images of the circumstellar disk surrounding the young solar analogue HL Tau in "an astonishing level of detail"[1]. Whereas previously HL Tau's disk had appeared as a centrally peaked 'blob' in 1.3 mm emission (see image panel **a**), the ALMA image (panel **b**) revealed regularly spaced concentric rings and gaps, bringing tangibility to dreams about other worlds orbiting other Suns. It was a step-change in our understanding of planet formation: now young planetary systems actually looked like the numerical simulations. But the observations opened up new questions too: were planets creating those apparent gaps? Or were the gaps something to do with the radial freeze-out points of different volatiles, like water and carbon dioxide? Why were the gaps more evident in dust rather than gas? Was something unusual happening hydrodynamically, involving pressure bumps?

Further ALMA observations, starting with individual disks – such as the nearby face-on disk around TW Hya[2] – and building up to the DSHARP survey of 20 disks[3], have shown us that substructures in disks are commonplace. And it is not just a matter of rings and gaps, but spiral arms, streamers, dust traps, misalignments and other features are now routinely seen in ALMA disk observations. And it is not just continuum features that ALMA has revealed in exquisite detail, molecular line observations have opened up the chemistry of these planet-forming disks like never before. It goes without saying that these observational developments have inspired a multitude of further multi-wavelength observational, theoretical and numerical studies.

Fast-forward to the present day: JWST is operational, and looking around the popular science press there are numerous headlines like "Huge young galaxies seen by JWST may upend our models of the Universe" and "The JWST is already delivering on its promise to transform cosmology". There is no doubt that JWST is delivering exciting new understanding about early galaxies and the young Universe. But the 'early Universe' is only one of JWST's science themes, and exciting results have been coming in under the 'Other worlds' banner too, which includes studies of forming planetary systems. As examples, this issue of *Nature Astronomy* features both a continuum study (Fomalhaut) and a molecular line study (2MASS-J16053215-1933159) of two potentially planet-forming disks.

The fame of Fomalhaut precedes it: one of the nearest and brightest stars in the sky, and the striations of its circumstellar debris disk look spectacular in Hubble Space Telescope optical imaging. In the infrared (SOFIA, Spitzer) the disk appears as an almost featureless region of concentrated emission, and at longer wavelengths (Herschel, ALMA; see image panel **c**) the images are dominated by a wide, dusty Kuiper-belt analogue and what appeared to be a compact asteroid-belt analogue close to the star. In an Article by András Gáspár and collaborators, the sensitivity of JWST to low-surface-brightness extended emission reveals what was missing: substructure (see image panel **d**). The MIRI images not only reveal an intermediate belt, misaligned with the outer belt, but also that the compact asteroid belt is much broader than first thought and it is separated from the intermediate belt by a gap. Some of these features within the disk could be related to planets.

The second Article featuring JWST data in this issue comes from the MINDS project, which aims to survey ~50 disks with JWST. In a study led by Benoît Tabone, the observations are of the low-mass disk around a low-mass M dwarf star (2MASS-J16053215-1933159), the most common type of star in the Galaxy, and a frequent host to exoplanetary systems. This work exhibits the spectroscopic capabilities of MIRI effectively: the 5–17 micron spectrum is surprisingly packed with carbon-rich molecules such as acetylene, diacetylene and even benzene! Typically disks around solar-metallicity stars are expected to be oxygen-rich, and while there are weak H_2O and CO_2 features in the spectrum, hydrocarbons dominate. This finding leads the authors to conclude that either hydrocarbon molecules form more efficiently in disks around very low-mass stars or there is carbon grain destruction in the inner disk.

So while JWST's early observations of extremely distant, cosmologically young objects are hitting the headlines, there are exciting developments in other fields of astronomy appearing with increasing pace. Whether JWST sparks a circumstellar disk revolution in the way that ALMA did in the late 2010s remains to be seen, but certainly the combination of JWST looking at warm, approximately micron-sized dust grains and ALMA looking at cold, (sub-)millimetre grains looks set to be a powerful combination for unlocking further secrets of the planet-formation process.

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