from the fertilized egg that do not form the embryo, such as the yolk? A step towards answering this question would be to determine whether the outcome remains the same when embryos instead of ovaries are transplanted — although, admittedly, the sheer magnitude of such an undertaking seems prohibitive. Second, what about paternal mutations, which were not analysed in this study? Third, what is the role of other types of age-related genetic factor, such as mutations resulting in placental growth disturbances? A wide range of factors, including age-related decline in metabolic or placental functions, could conceivably contribute to such anomalies. But on the basis of both Schulkey and co-workers' model and another recent study[12], it seems clear that these factors must be under genetic control.

Future studies will need to be large, and to focus on multigenerational families, if they are to provide sufficient statistical evidence for genetic risk. Studies similar to Schulkey and colleagues' should be designed to better quantify epigenetic risk factors. Subsequently, the fraction of risk attributable to different factors needs to be defined, in particular those amenable to interventional strategies, such as the use of folate supplements. In light of the increasing average maternal age at childbirth, and the advent of egg freezing as an employee benefit in some countries, the authors' study provides a timely opportunity to improve risk stratification and management of the stages immediately before and after conception, to prevent birth defects. ■

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PLANETARY SCIENCE

Prebiotic chemistry on the rocks

Organic compounds called nitriles have been detected in material surrounding a young star. The finding hints at a vast reservoir of ice and volatile species that can seed the surfaces of young rocky planets or moons. **SEE LETTER P.198**

GEOFFREY A. BLAKE & EDWIN A. BERGIN

The recipe for creating a habitable planet such as Earth contains several essential ingredients. Once the key components — a silicate mantle and a metallic, iron-rich core — have been built, there must be sufficient liquid water and appropriate forms of carbon and nitrogen available near the surface, along with a sprinkling of sulfur and phosphorus. Water and the organic carriers of the necessary elements (C, N, S, P) are known as volatiles because temperatures must be very low (below about 150 kelvin) for them to be frozen into the pebbles that are the seeds of rocky worlds. On page 198 of this issue, Öberg *et al.*[1] report the discovery of spectral emission lines from gaseous molecules of C–N-containing organic species in potentially planet-forming environments using the Atacama Large Millimeter/submillimeter Array (ALMA). The observed lines trace the surface of a vast reservoir of icy bodies that can deliver volatile organics to the surfaces of young rocky planets or to moons circling gas-giant planets at distances from the central star at which liquid water is stable.

Stars are born in giant clouds of gas and dust, such as the famous Orion nebula, which is part of the 'sword' in the constellation of Orion. These clouds host a complex web of chemistry involving hundreds of molecular species[2], most of them organic. The particular environment under study here is a 'protoplanetary disk' of gas, dust and ice surrounding a young (that is, a few million years old) star called MWC 480 in the constellation of Taurus. Once a young star is nearly fully assembled, these disks rotate in Keplerian orbital motion, and are the birthplaces of planetary systems. The physical conditions in disks vary greatly, with hot and dense regions of gas and dust near to the star and much colder gas, dust and eventually ice at greater distances from it[3].

To build planets, material inherited from

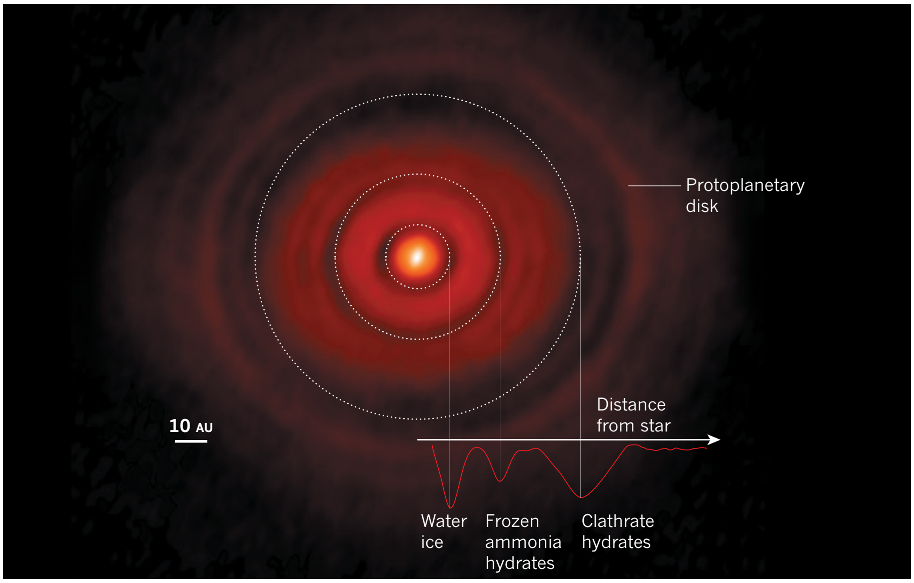

Figure 1 | HL Tau disk. The image shows a face-on millimetre-wave view of the protoplanetary disk around the young star HL Tau (located at the bright central blob but not detected in this image). The dotted circles represent the locations of emission dips (dark regions) where water ice, frozen ammonia hydrates and clathrate hydrates are expected to condense. Combining such images, which can directly probe the disk's dust and ice content, with spectral-line observations such as those presented by Öberg *et al.*[1] for the disk around the young star MWC 480, which selectively probe the gas and ice reservoirs of the disk, will provide insights into the evolution of water and organic chemistry during planet formation. 1 AU is the distance from Earth to the Sun. (Image created by K. Zhang in G. A. Blake's research group, from public-domain commissioning and science verification data from the ALMA observatory[8].)

the natal cloud travels radially and vertically through diverse conditions in the disk. Small grains of ice and dust grow larger and settle vertically, eventually forming objects such as asteroids and comets in the densest, mid-plane region of the disk — a zone that is extremely difficult to study directly because it is largely obscured by the overlying dust, ice and gas. Near the surface of the inner part of the disk, close to the central star, conditions are warm enough for spectral emission from simple volatiles to be detected at infrared wavelengths[4]. However, such data do not reveal whether more-complex species are present, nor what chemistry prevails in the outer regions of the disk, where icy, kilometre-sized or larger bodies known as planetesimals should form and eventually coalesce into even larger bodies. Enter ALMA and the pioneering observations of Öberg and colleagues.

In their study, Öberg *et al.* have detected spectral emission lines associated with the rotational states of three C–N-containing species — hydrogen cyanide (HCN), acetonitrile (CH_3CN) and cyanoacetylene (HC_3N) — in the disk surrounding MWC 480 at distances between 30 and 100 astronomical units from the central star (1 AU is the distance from Earth to the Sun). At these distant and cold radii, such nitrile compounds should be locked into icy dust grains or planetesimals.

MWC 480 has roughly twice the mass of the Sun and is brighter. The distances probed compare well with those over which comets were assembled in our own Solar System. The new ALMA data sample the atmosphere of the outer parts of the protoplanetary disk, where only highly volatile species can remain in the gas phase, and where icy grains, lofted high into the disk atmosphere from the cold midplane, can interact with ultraviolet photons from the young star, driving species trapped on the grain surfaces into the gas phase. The nitriles fall into the latter category, and are central to prebiotic chemistry, because they probably represent precursors of more-complex species, such as amino acids.

By modelling the observed emission, Öberg *et al.* concluded that the organic nitriles must be abundant in the disk ices, even more so than is currently observed in comets. It has been known for some time that primitive Solar System bodies inherit starting materials from the earlier stages of the star-formation process. But this work, along with other recent studies (see, for example, ref. 5), demonstrates that protoplanetary disks are active engines of chemical synthesis, and that such environments are vital for building chemical complexity long before a planetary surface is created. The potentially prebiotic chemistry traced by asteroids and comets in the Solar System is therefore replicated, at least in part, in other young planetary systems — suggesting that planets are supplied with these life-bearing elements as they are born.

We stand to learn a great deal about the early steps of planet formation and the chemistry of volatiles in the coming decade, particularly as ALMA ramps up to its full capabilities. A spectacular early hint of what is to come is provided by the ALMA millimetre-wave imaging data released earlier this year for HL Tau (Fig. 1), a young star with substantial surrounding cloud material. It would be surprising for planet formation to be at an advanced stage in HL Tau's disk. The high gas-accretion rate in such young stars can move the snowline radii, beyond which certain molecules condense, out to large distances from the star[6], making the snowlines potentially easier to study in such objects. One possible explanation for the emission dips observed by ALMA (Fig. 1) is that they correspond nicely to the expected locations for the condensation radii of water ice, frozen ammonia (and hydrogen sulfide) hydrates and clathrate hydrates (which contain carbon dioxide, methane, carbon monoxide or nitrogen gas) — locations at which rapid pebble growth has been predicted to occur[7]. As the pebbles' diameters grow to be substantially larger than the observing wavelength, the dust and ice emission would drop.

By combining infrared spectra with high-resolution, millimetre-wave imaging data, and with spectral-line observations such as those described by Öberg and co-workers to probe the upper layers of the disk, it will be possible to determine the speciation of the most abundant volatile species, examine their distributions, and assess the likelihood of their delivery to nascent planetary surfaces. ■

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MOLECULAR BIOLOGY

RNA interference hangs by a thread

The Paf1 protein complex in fission yeast has been found to protect protein-coding genes from inhibition by RNA-mediated silencing of transcription, by stimulating the release of nascent transcripts from DNA. SEE LETTER P.248

MIKEL ZARATIEGUI

RNA interference (RNAi) is a mechanism of gene regulation that uses small RNAs called short interfering RNAs (siRNAs)to silence the expression of specific targets that have complementary nucleotide sequences. This can occur through post-transcriptional silencing, which degrades the target transcript, or through modification of chromatin (the complex of proteins, RNA and DNA in which DNA is packaged in the cell), which prevents transcription from initiating. RNAi always causes transcript degradation, but its effect on chromatin is bewilderingly inconsistent; only some targets in some organisms exhibit RNAi-mediated chromatin modifications, despite the evolutionary conservation of this mechanism. In this issue, Kowalik *et al.*[1] (page 248) report that the target transcript must remain associated with the site of transcription for RNAi to act on chromatin, providing a possible explanation for this variability.

Researchers can exploit RNAi to inhibit any RNA sequence of choice, simply by introducing a source of siRNA, such as a double-stranded RNA molecule that can be processed to siRNA by the nuclease enzyme Dicer. During transcription, siRNA can hybridize with a complementary nascent transcript and induce the deposition of silencing chromatin marks, leading to the formation of an inheritable repressive type of chromatin called heterochromatin. The inheritance of silencing chromatin modifications down generations of cells is an example of epigenetic memory.

By forming complexes with Argonaute effector proteins, siRNA can locate and silence target sequences even if they are located at distant sites, a process called silencing *in trans*. This phenomenon is crucial for repressing the