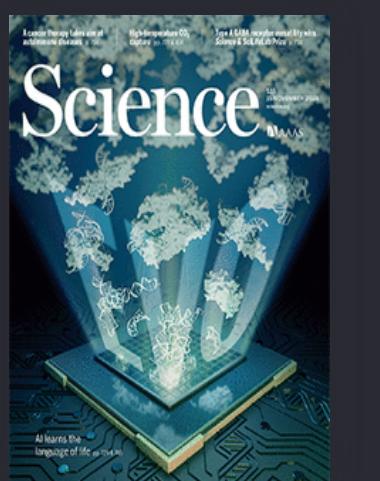


## Details



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## ARTICLE

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## Abstract



## MISTRY

# Formation of interstellar 1-cyanopyrene: A four-ring polycyclic aromatic hydrocarbon

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romatic hydrocarbons (PAHs) are organic molecules containing adjacent aromatic emission bands show that PAHs are abundant in space, but only a few specific PAHs detected in the interstellar medium. We detected 1-cyanopyrene, a cyano-substituted one related four-ring PAH pyrene, in radio observations of the dense cloud TMC-1, using the 100-m Telescope. The measured column density of 1-cyanopyrene is  $\sim 1.52 \times 10^{12} \text{ cm}^{-2}$ , from which we estimate that pyrene contains up to 0.1% of the carbon in TMC-1. This abundance indicates that interstellar PAH chemistry favors the production of pyrene. We suggest that some of the material that is delivered to young planetary systems is carried by PAHs that originate in the interstellar clouds.

PAHs are also present in meteorites classified as carbonaceous chondrites, which are material left over from the formation of the Solar System (7). They have also been found in samples collected from comets (8) and asteroids (9). Laboratory isotopic analysis of asteroid PAHs has shown that at least some of them formed in the cold ISM (10). Potential formation mechanisms include kinetically controlled mass growth processes, where the rate of formation determines the products that form (rather than the relative thermodynamic stabilities) (11). PAHs could alternatively form in high-temperature (~1000 K) regions, such as circumstellar envelopes around evolved stars (12), but it remains unclear whether PAHs are inherited from these regions into molecular clouds. Small PAHs (those with  $\leq 35$  carbon atoms) are expected to be destroyed by shock waves, cosmic rays, and UV photons faster than they can be injected from circumstellar envelopes into the ISM (13). Contrary to this prediction, small two-ring PAHs have been observed in the cold interstellar cloud TMC-1, which is

ene formed in cold interstellar (O). Some low-temperature mechanisms for naphthalene have been proposed, but chemical models have so far not been able to reproduce its inferred abundance. Identifying pyrene in cold molecular clouds may therefore constrain low-temperature mechanisms that impact the way in which carbon is carried to the final stages of stellar evolution.

## cyanopyrene in TMC-1

radio observations of TMC-1 with 1.4 GHz coverage from approximately 1990 to 2000. The data were collected with the 305 m Robert C. Byrd Green Bank Telescope (GBT) as part of the GBT Observations of TMC-1: PAHs and Organic Molecules (GOTHAM) project. PAHs are organic molecules that must have a permanent dipole moment in order to be detected with rotational transitions. Host PAHs have a small or zero permanent dipole moment, so they cannot be readily observed with radio astronomy, but their presence can be directly inferred by searching for their CN- and CH-functionalized analogs. Laboratory experiments have shown that CN-functionalized PAHs can be used as efficient proxies for their pure hydrocarbon analogs, which do not possess permanent dipoles (23, 24).

smallest PAH in which all rings are at least two others (termed tricondensed). Substituting a one of the H atoms of pyrene by a N atom (C<sub>17</sub>H<sub>9</sub>N), which has a large electric dipole moment and is polarizable with radio spectroscopy. Cyanopyrene isomers are possible, but no published laboratory rotatory was available for them. Theoretical quantum chemical (25) of the lowest-energy isomer, (25), finding predicted permanent of  $\mu_a = 4.8$  D and  $\mu_b = 2.5$  D, and  $b$  components of its

