Beyond Dark Clouds
Carbon Chemistry in Protostars with the ngVLA

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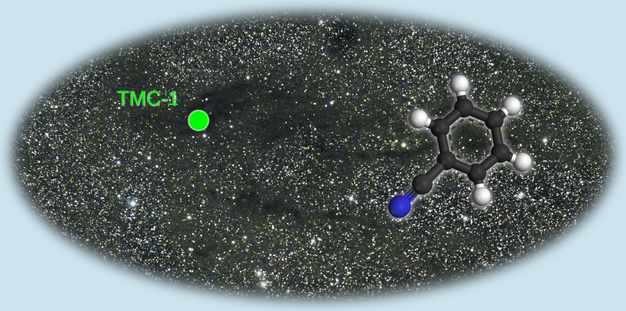
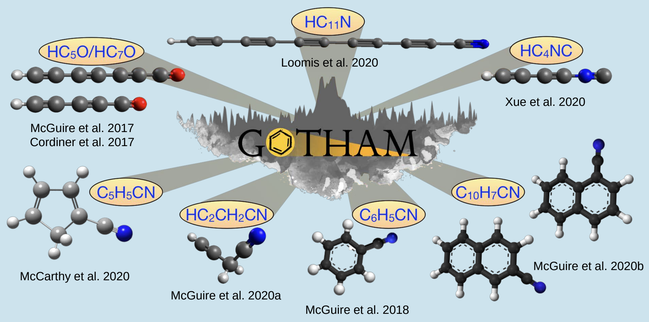
What's New?



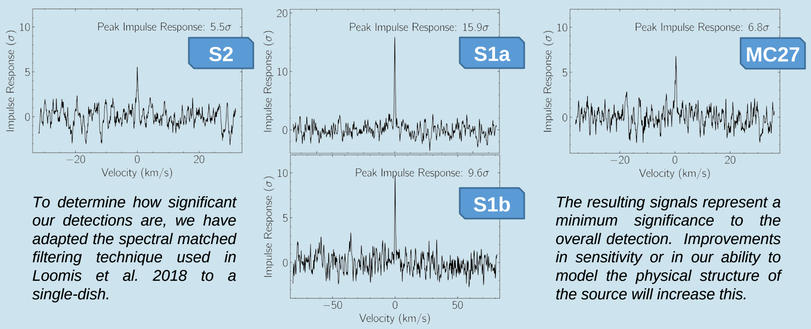
In 2018, McGuire et al. published the first detection of a molecule containing a benzene ring – benzonitrile (cyanobenzene; C_6H_5CN) using radio astronomy (GBT Observations). Aromatic molecules like C6H5CN and its larger cousins the polycyclic aromatic hydrocarbons (PAHs) were until very recently thought to form predominantly in the envelopes of post-AGB stars. C_6H_5CN, however, was found in TMC-1, a cold, dark, starless cloud. This detection hints that there may be a vast reservoir of undetected large carbon molecules (PAHs) present and influencing the star-formation process from its very beginning. **GOTHAM** (GBT Observations of TMC-1: Hunting Aromatic Molecules) and **ARKHAM** (A Rigorous K-band Hunt for Aromatic Molecules) are projects to investigate this possible new chemistry.

GOTHAM is a deep, broadband spectral line survey of TMC-1 that has already resulted in numerous new molecule and isotopologue detections. In fact, the GOTHAM collaboration will shortly publish the first detections of true, individual PAH molecules in the ISM – and they are present at this very earliest stage of the star-formation process!



<u>GOTHAM and ARKHAM Teams</u>

Brett McGuire (PI), Andrew Burkhardt, Steve Charnley, Ilsa Cooke, Martin Cordiner, Eric Herbst, Sergei Kalenskii, Kelvin Lee, Ryan Loomis, Mike McCarthy, Anthony Remijan, Christopher Shingledecker, Mark Siebert, Eric Willis, Ci Xue



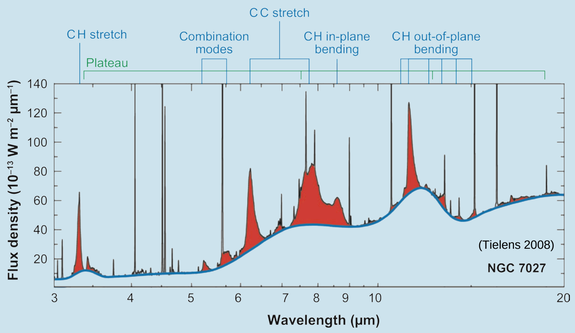
To determine how significant our detections are, we have adapted the spectral matched filtering technique used in Loomis et al. 2018 to a single-dish.

The resulting signals represent a minimum significance to the overall detection. Improvements in sensitivity or in our ability to model the physical structure of the source will increase this.

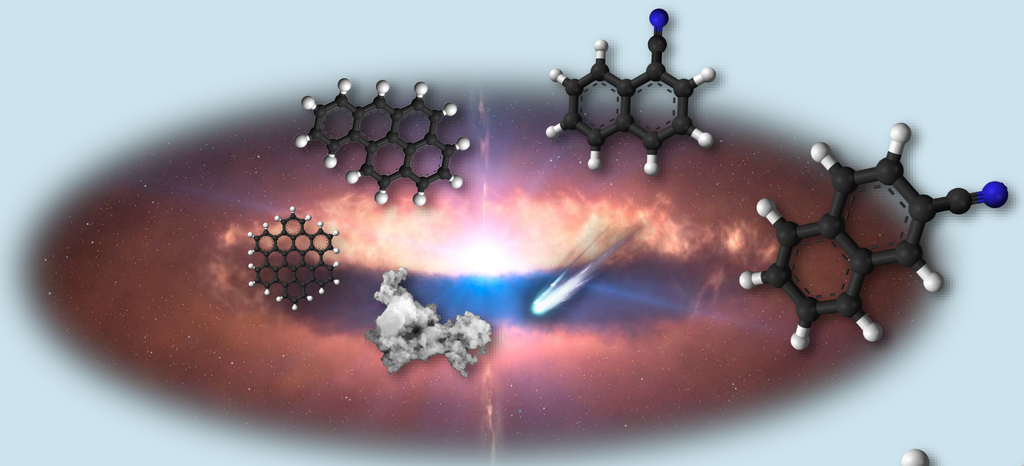
ARKHAM is a targeted search for C_6H_5CN in sources other than TMC-1. The goal is to discover whether aromatic chemistry is widespread, or just a chemical curiosity unique to TMC-1. So far, we have surveyed 4 sources for C_6H5_CN from Serpens 2 (S2), a cold cloud a little earlier in its evolution than TMC-1, through Serpens 1a and 1b, which are beginning to collapse, and up to MC27, which has evidence of an active embedded protostar. We have found C_6H_5CN in all of them. These detections lead us to believe that this chemistry is indeed ubiquitous at least through the initial stages of protostar formation. (Burkhardt et al. 2020)

What's Next?

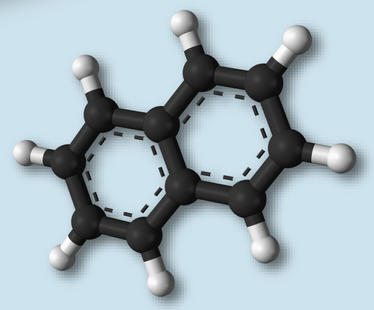
The biggest question is how this new reservoir of carbon impacts what we know about the process of star and planet formation and how it is linked with the existing detections of PAHs through the Unidentified Infrared Emission bands in bright regions of the galaxy like PDRs. We are already expanding ARKHAM to more sources, including more protostellar sources. Yet, the detection around MC27 is likely from the cloud – not the infalling material in the protostellar core. If we want to trace our new PAHs, which may influence every aspect of planet the planet forming process from dust aggregation to the C/O ratio in exoplanetary atmospheres, we will certainly need high angular resolution interferometric observations. The VLA lacks the sensitivity, while ALMA's frequency range is highly suboptimal for detecting the emission of PAHs, which peak in the cm-wave regime.

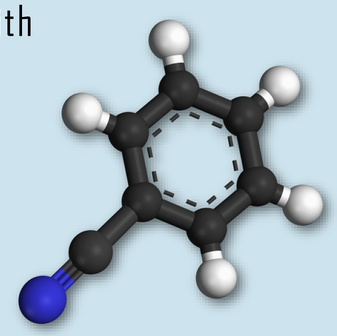


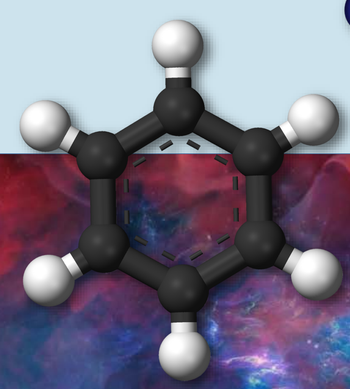
We Need The ngVLA to Observe Complex Chemistry Around Young Stars



As the emitting region of complex molecules from the natal cloud compacts around a forming protostar, even massive single-dish facilities like the GBT aren't sensitive enough to detect weak emission from large carbon molecules like PAHs due to beam dilution. Only the ngVLA will match the needed spatial resolution with the high surface brightness sensitivity required to study complex chemistry in the early star-formation process.







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