Chemical Constraints on the Formation and Evolution of Habitable Worlds

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Scientific Goals:

- Summarize the carbon budget in the ISM.
- Follow the carbon through the formation of stars and evolution of planetary systems.
- Investigate the delivery of volatiles to terrestrial planets.

*Explain the carbon deficit in the inner solar system in the context of a theory of terrestrial planet formation that makes predictions concerning the frequency and nature of habitable worlds around stars in the Milky Way.*
Tearing Away the Cosmic Veil: Infrared Imaging and Spectroscopy

Seeing Through the Pre-Collapse Black Cloud B68
(VLT ANTU + FORS 1 - NTT + SOFI)

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Measuring Gas Phase ISM Abundances:

First detection of H3+ and H2 in same source (Phoenix at KPNO)
Courtesy Craig Kulesa (U. Arizona)
2.4 – 45 µm spectrum of interstellar ices

Follow the carbon...
Gas content as a function of radius and age.

Velocity resolved CO emission at 4.7 microns from Blake and Boogert (2004)
Terrestrial planets have been discovered!

Earth-mass planets discovered around pulsars
Wolszczan, A. (1994)

Debris disks also found around evolved stars.

Spitzer observations of warm debris around normal stars suggests terrestrial planets may be common

Meyer et al. (2008)
Su et al. (2006)
Spitzer Provides Evidence of Planet Formation: Could Terrestrial Planets Outnumber Gas Giants?

Meyer et al. (2008); Kenyon & Bromley (2004; 2006)
From Stellar Spectra to Planetesimal Composition:

M. Jura (2006)
Key Investigations:

- Millimeter wave observations of the ISM and molecular clouds.
- Laboratory studies of meteorites and sample returns.
- Infrared spectroscopy of young stellar objects with ground- and space-based telescopes.
- Theoretical models of evolving disk chemistry.
- Observational study of the evolution of young stars: variability, x-ray/UV activity, and abundances.
Strategic Impact on NASA:

- **Key to Vision for Space Exploration.**
  - Inform searches for Earth-like planets and habitable environments of other stars.
  - Understanding history of solar system.
- **Guide planning/use of Spitzer, SOFIA, Herschel, Kepler, WISE, JWST, and other NASA-supported astronomical facilities.**
- **Guide exploitation/development of Stardust, Deep Impact, OSIRIS, and lunar exploration.**
- **Drive development/selection of TOPS, Astrobiology Explorer, TPF architectures.**
Participating Institutions:

- The University of Arizona / LAPLACE.
- University of California-Los Angeles:
  » Young, Jura, others.
- Goddard:
  » Mandell, Mumma, Charnely, others.
- CIW:
  » Boss, Nitler, Ciesla, others.
- NASA-Ames: Davis.
- University of Hawaii: Meech.
- External Participant: E. Bergin (U. Michigan)