Faculty Profile

- Faculty Directory
- Curriculum Vitae
- List of Publications
- Research Group Homepage

Lucy Ziurys

Professor

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Honors

- Fellow of the American Physical Society, 2008
- National Science Foundation Creativity Award, 2001
- Elizabeth and Keith Hege Galileo Circle Fellow, 1999
- National Science Foundation Visiting Professorship for Women, 1994-1996
- National Science Foundation Presidential Faculty Fellow, 1992-1995
- National Science Foundation Presidential Young Investigator, 1990-1992

Education and Appointments

- B.S. 1978, Rice University
- Ph.D. 1984, UC Berkeley

Research Interests

- Physical
- Astrobiology and Astrochemistry
- Chemical Physics
- Instrument Development
- Spectroscopy/molecular Structure

Research Summary

Chemical Physics/Spectroscopy/Astrochemistry

At present, more than 130 different chemical species have been detected in interstellar space, primarily in giant gas clouds located throughout our Galaxy, and in gas envelopes surrounding old stars. Despite the extreme conditions of interstellar space, which is typically quite cold (T ~ 10-50 K) and very diffuse (n ~ 10^3 - 10^6 particles/cc), chemistry flourishes, producing a wide range of common, but often exotic, compounds, including many reactive radicals and molecular ions. It is now recognized that we live in a *molecular* universe.

Figure 1: An image of VY Canis Majoris, an evolved supergiant star, and its associated, molecule-rich, envelope which contains unusual phosphorus-containing species (HST image).

One of the primary objectives of our research is to study the chemistry occurring in the vast regions of space via an interdisciplinary approach that involves high resolution molecular spectroscopy in the laboratory, radio astronomical observations, and chemical modeling. We are interested in discovering which chemical compounds exist and in which types of interstellar sources, how they are formed, and how this impacts the origins of solar systems and planets, and ultimately life. Of interest are small molecules containing metals such as iron, magnesium, and chromium; these species are also significant for organometallic chemistry. Small organic molecules related to sugars and nucleic acids are another area of investigation, and how they relate to the organic material found in meteorites. Phosphorus-bearing species are also of interest, primarily because of their biochemical importance.

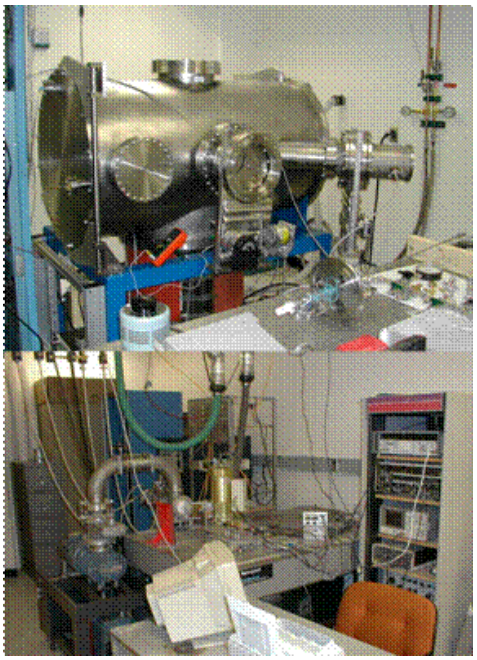

Figure 2: Two of the Ziurys group spectrometers: the pulsed, Fourier transform microwave system (top) and the low-temperature, direct absorption instrument (bottom).

Laboratory studies focus on the measurement of gas-phase rotational spectrum of species of astrophysical interest in the microwave, millimeter and sub-millimeter regions of the electromagnetic spectrum (~3-660 GHz). This goal requires design and construction of our own spectrometer systems, as shown in Figure 2. Currently, there are four working instruments in the Ziurys group: two mm/sub-mm direct absorption systems, a velocity-modulation spectrometer specifically designed to study molecular ions, and a pulse, Fourier transform microwave (FTMW) machine. Part of the laboratory work also concerns developing exotic synthetic techniques for creating these transient species in detectable concentrations. We have succeeded in recording the spectra of a wide range of metal-bearing species, in particular radicals and, more recently, ions, such as AlNC, CrCN, $FeCO^+$, FeO^+, MnH, and $HZnCH_3$. Many of these species have unpaired electrons, and thus their spectra exhibit complex fine and hyperfine splittings (see Figure 3). Analysis of such data requires a detailed knowledge of quantum mechanics. Other investigations include possible pre-biotic species such as $EtNH_2$ and hydroxyacetone. The fingerprints? measured in the laboratory enable such species to be identified in space.

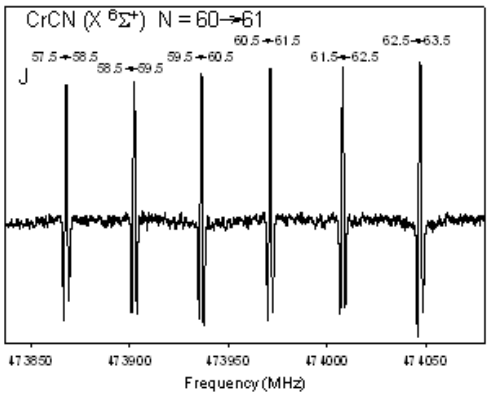

Figure 3: Laboratory spectrum of CrCN, showing the sextet pattern apparent in each rotational transition which results from the presence of 5 unpaired electrons in this radical.

Interstellar molecules are primarily studied using the telescopes of the Arizona Radio Observatory (ARO), part of Arizona's Steward Observatory. ARO operates the Submillimeter Telescope (SMT) on Mount Graham, AZ, and the 12 m at Kitt Peak (see Figure 4).

Figure 4: The Submillimeter Telescope (SMT) of the Arizona Radio Observatory, located at Mt. Graham, AZ.

Observational studies in the Ziurys group include the identification of new interstellar species, such as AlNC, CH_2OHCHO, and PO, which is usually conducted in conjunction with laboratory work. Other projects involve elucidating the chemistry associated with evolved stars, such as VY Canis Majoris, and the survival of molecules in planetary nebulae such as the Helix. Observations are also currently being conducted to trace the history of carbon and organic chemistry, from the origin of the element in nucleosynthesis, to the formation of the first organic compounds around evolved stars and their subsequent injection into the interstellar medium, to organic synthesis in dense clouds and in the pre-solar nebula, and the transport organic material to planet surfaces via comets and meteorites.

Selected Publications

- "A Millimeter-Wave Observations of CN and HCN and their ^{15}N Isotopologues: A New Evaluation of the $^{14}N/^{15}N$ Ratio Across the Galaxy," G.R. Adande and L.M. Ziurys, *Ap.J.,* 744, 194 (2012).
- "Gas-Phase Synthesis and Structure of Monomeric ZnOH: A Model Species for Metalloenzymes and Catalytic Surfaces," L.N. Zack, M. Sun, M.P. Bucchino, D.J. Clouthier, and L.M. Ziurys, *J. Phys. Chem.,* 1542, 50 (2012).
- "Fourier-Transform Microwave Spectroscopy of FeCN ($X^4\Sigma i$): Confirmation of the Quartet Electronic Ground State," L.N. Zack, J. Min, B.J. Harris, M.A. Flory, and L.M. Ziurys, *Chem. Phys. Letters,* 514, 202 (2011)
- "Observations of the [HNCS]/[HSCN] Ratio in the SgrB2 and TMC-1: Evidence for Low Temperature Gas-Phase Chemistry," G.R. Adande, D.T. Halfen, L.M. Ziurys, D. Quan, and E. Herbst, *Ap.J.,* 725, 651 (2010).
- "The Rotational Spectrum of CuCCH ($X^1\Sigma^+$): A Fourier Transform Microwave *DALAS* and Millimeter/Submillmeter Study," M. Sun, D.T. Halfen, J. Min, B. Harris, D.J. Clouthier, and L.M.

Ziurys, *J. Chem. Phys.,* 133, 174301 (2010).

- "Activation of CH_4 by Zinc: Gas-Phase Synthesis, Structure, and Bonding in HZnCH3," M.A. Flory, A.J. Apponi, L.N. Zack, and L.M. Ziurys, *J. Am. Chem. Soc.,* 132, 17186 (2010).
- "The Arizona Radio Observatory 1mm Spectral Survey of IRC+10216 and VY Canis Majoris," E.D. Tenenbaum, J.L. Dodd, S.N. Milam, N.J. Woolf, and L.M. Ziurys., *Ap.J. Suppl.,* 190, 348 (2010).
- "Millimeter/Submillimeter Velocity Modulation Spectroscopy of FeO^+ ($X^6\Sigma^+$): Characterizing Metal Oxide Cations," D.T. Halfen and L.M. Ziurys, *Chem. Phys. Letter,* 496, 8 (2010).
- "Exotic Metal Molecules in Oxygen-Rich Envelopes: Detection of AlOH ($X^1\Sigma^+$) in VY Canis Majoris," E.D. Tenenbaum and L.M. Ziurys, *Ap.J. (Letter),* 712, L93 (2010).
- "Millimeter-Wave Rotational Spectroscopy of FeCN ($X^4\Delta_i$) and FeNC ($X^6\Delta_i$): Determining the Lowest Energy Isomer," M.A. Flory and L.M. Ziurys, *J. Chem. Phys.,* 135, 184303 (2011).
- "Formation of Peptide Bonds in Space: A Comprehansive Study of Formamide and Acetamide in SgrB2(N)," D.T. Halfen, V. Ilyushin, and L.M. Ziurys, *Ap.J.,* 743, 60 (2011).
- "Iron-Containing Molecules in Circumstellar Envelopes: Detection of FeCN ($X^4\Delta_i$) in IRC+10216," R.L. Pulliam, J.L. Edwards and L.M. Ziurys, *Ap.J. (Letters),* 733, L36 (2011).
- "Circumstellar Ion-Molecule Chemistry: Observations of HCO^+ in the Envelopes of O-Rich Stars and IRC+10216," R.L. Pulliam, J.L. Edwards, and L.M. Ziurys, Ap.J. *(Letters)* to appear in October 20 p2 sent on (2011)
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