The Comet-Disk Connection: Understanding Volatile Distributions in Young Protoplanetary Systems via Synergy Between Comets and Disks. E. L. Gibb[1,2], B. P. Bonev[2,3], K. Willacy[4], M. Mumma[3,5], M. A. DiSanti[3,5], G. L. Villanueva[2,3], L. Paganini[2,3], [1]University of Missouri – St. Louis, 1 University Blvd, St. Louis, MO 63121, gibbe@umsl.edu, [2]Goddard Center for Astrobiology, NASA GSFC, Mail Stop 690, Greenbelt, MD 20771, [3]Catholic University of America, Washington, DC 20061, [4]Caltech/JPL, Mail Stop 169-506, Pasadena, CA 91109, [5]Solar System Exploration Division, NASA Goddard Space Flight Center, Mail Stop 690, Greenbelt, MD 20771.

Introduction: The emergence of the terrestrial biosphere may be linked to delivery of exogenous water and prebiotic organic matter from bodies like asteroids and comets during the early solar system. Comets are icy bodies that are remnants from the formation of planets in the outer solar system (beyond ~5 AU, where 1 AU, or Astronomical Unit, is the distance between the Earth and the Sun). They were gravitationally scattered by the forming gas giant planets into their current reservoir of either the Oort Cloud or Kuiper Belt. The Oort Cloud is a spherical distribution of comets located ~10,000-50,000 AU from the Sun and the Kuiper Belt is a flattened distribution just beyond the orbit of Neptune. Since their formation nearly 4.5 billion years ago, comets have been frozen in their respective reservoirs, preserving a record of the chemical composition and processing of the early solar system.

When a comet is gravitationally perturbed from its reservoir into an orbit that brings it to the inner solar system, heat from the Sun causes icy volatiles to sublimate, forming a gas coma. Remote observing techniques at near-infrared and radio wavelengths can be used to determine “mixing ratios” for various molecules. These ratios relate the abundances of, for example, CH_4, C_2H_2, C_2H_6, H_2CO, and CH_3OH to H_2O, the most abundant volatile. For relatively bright comets, isotopologues (HDO/H_2O, CH_3D/CH_4, etc.) can also be observed or stringently contrained. Observations have found strong evidence that mixing ratios vary substantially among comets [1,2,3,4]. However, we still face serious uncertainties in decoding the cosmogonic significance of the measured abundances.

The Disk Connection: One issue in interpreting current molecular abundances in comet comae is that the observed composition may be an end product of a variety of processes, including chemical evolution in the protoplanetary disk, dynamical evolution in the young solar system, and (perhaps) thermal evolution during successive perihelion passages. Improved understanding of their relative importance requires both a larger sample size of observed comets and a comprehensive synergy with astrochemical models.

Chemical models find that protoplanetary disks can be divided into three distinct regions: (1) a cold midplane, where ices freeze to dust grains beyond ~3-5 AU (and where comets and the giant planets formed); (2) a warm molecular layer, where ices sublimate and are processed via gas-phase reactions; and (3) a hot disk atmosphere containing predominantly atoms and atomic ions (see Fig 1). Material from the different layers can be mixed by transport processes, which are only recently being incorporated into disk models [5]. Hence, we may now begin to address the issue of how disk processes can affect comet compositions.

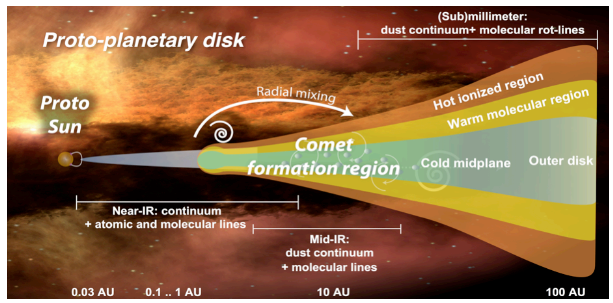

Figure 1: Illustration of the chemical regions and mixing processes in a protoplanetary Disk (Courtesy Goddard Visualization Center, A. Mandell, G. Villanueva).

Disk/Comet Synergy: By comparing comet compositions with ice phase compositions in the midplanes of protoplanetary disk models, we will address the following questions: What chemical reaction pathways dominated the synthesis of cometary compounds? What processes in the protoplanetary disk have left strong signatures in cometary ices? Can models provide testable predictions for the chemical diversity observed among comets?

We will present initial comparisons between relative abundances for several cometary volatiles and those predicted for different positions in the midplane of the protoplanetary disk where comets formed. We will also discuss how models link observations of volatiles in comets with studies of protoplanetary disks around solar type stars and the early solar system.

References:

[1] Mumma M. J. and Charnley S. B. (2011) *ARA&A, 49,* 471. [2] Gibb E. L. et al. (2012) *ApJ, 750,* 102. [3] Villanueva G. L. (2011) Icarus*, 216*, 227. [4] Dello Russo et al. (2009) *ApJ*, *703*, 187. [5] Heinzeller, D. et al. (2011), *ApJ*, *731*, 114.

Acknowledgments: This work is supported by NSF (AST 1211362) and NASA (Exobiology NNX11AG44G, Astrobiology, PATM, PAST).