Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
Proceedings IAU Symposium No. 343, 2019
F. Kerschbaum, M. Groenewegen & H. Olofsson, eds.

doi:10.1017/S1743921318007524

Chemical enrichment of galaxies as the result of organic synthesis in evolved stars

Sun Kwok[1,2], SeyedAbdolreza Sadjadi[2] and Yong Zhang[2,3]

[1]Dept. of Earth, Ocean and Atmospheric Sciences, University of British Columbia, Canada
emails: skwok@eoas.ubc.ca, sunkwok@hku.hk

[2]Laboratory for Space Research, The University of Hong Kong, Hong Kong, China

[3]School of Physics & Astronomy, Sun Yat Sen University, Zhuhai, China

Abstract. Infrared spectroscopic observations have shown that complex organics with mixed aromatic-aliphatic structures are synthesized in large quantities during the late stages of stellar evolution. These organics are ejected into the interstellar medium and spread across the Galaxy. Due to the sturdy structures of these organic particles, they can survive through long journeys across the Galaxy under strong UV background and shock conditions. The implications that stellar organics were embedded in the primordial solar nebula is discussed.

Keywords. stars: AGB and post-AGB, ISM: molecules, planetary nebulae: general

---

1. Introduction

It has been recognized since the 1950s that heavy elements synthesized in AGB stars contribute to the atomic chemical enrichment of the Galaxy. Advances in millimeter-wave and infrared spectroscopy have led to our current realization that AGB stars are major galactic sources of molecules and minerals. Over 80 gas-phase molecules and various inorganic solids such as silicates, silicon carbide, and refractory oxides have been detected in the circumstellar envelopes of AGB stars. These molecules and solids are formed in the stellar winds of AGB stars over very short ($\sim 10^3$ yr) time scales and are ejected into the interstellar medium via stellar winds (Kwok 2004).

2. Evolved stars as sources of complex organics

The unidentified infrared emission (UIE) bands, consisting of a family of emission bands and broad emission plateaus superimposed on an underlying continuum, was first detected in planetary nebulae, descendents of AGB stars. The UIE bands are now seen in reflection nebulae, diffuse interstellar medium, and external galaxies. In some active galaxies, the amount of energy emitted in the UIE bands can be as high as 20% of the total energy output of the galaxy. In the astronomical community, it is commonly believed that small (< 50 carbon atoms) polycyclic aromatic hydrocarbon (PAH) molecules are responsible for the UIE phenomenon. However, the PAH hypothesis has a number of problems (Kwok & Zhang 2013, Zhang & Kwok 2015). As an alternative, a mixed aromatic-aliphatic model (MAON) has been proposed (Kwok & Zhang 2011, Figure 1).

Mixed aromatic/aliphatic hydrocarbons with amorphous structures are natural products of combustion and are common products of energetic bomdbarments of simple hydrocarbon molecules in laboratory simulations. Experimental infrared spectra of such compounds show naturally broad emission features resembling the astronomical UIE bands (Dischler *et al.* 1983). We are currently undertaking quantum chemistry calculations to study the vibrational modes of MAON-like molecules with the goal of

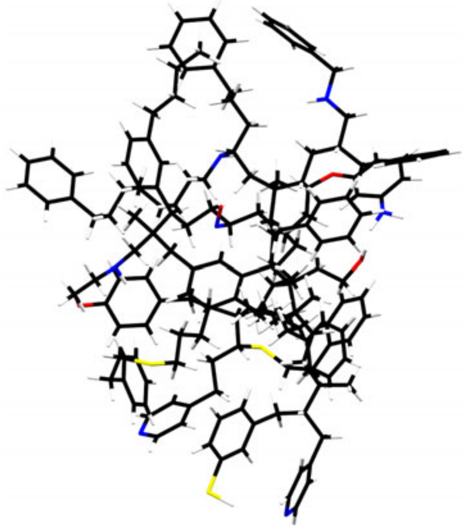

Figure 1. The MAON structure is characterized by a highly disorganized arrangement of small units of aromatic rings linked by aliphatic chains. This structure contains 169 C atoms (in black) and 225 H atoms (in white). Impurities such as O (in red), N (in blue), and S (in yellow) are also present. A typical MAON particle may consist of multiple structures similar to this one.

testing the hypothesis that MAONs are the chemical carriers of astronomical UIE bands (Sadjadi *et al.* 2015, 2017).

3. Implications

The large-scale production and distribution of complex organics by evolved stars suggests that the Galaxy has been heavily enriched by organic compounds. The detection of UIE bands in galaxies with redshift of as high as 2 suggests that organic synthesis already began as early as 10 billion years ago. Pre-planetary systems including the primordial solar nebula could have been enriched by stellar organics. The fact that macro-organics with MAON-like structures have been identified in meteorites, comets, interplanetary dust particles, and planetary satellites suggests that there may be a stellar-solar system connection (Kwok 2016). It is even possible that the early Earth may have inherited some of these stellar organics (Kwok 2017). The possible role of stellar organics on the origin of life on Earth represents a fascinating topic for future investigations (Kwok 2018).

Acknowledgment

This work was supported by a grant from the Natural Sciences and Engineering Research Council of Canada.

References

Dischler, B., Bubenzer, A., & Koidl, P. 1983 *Solid State Commun*, 48, 105
Kwok, S. 2004 *Nature*, 430, 985
Kwok, S. 2016 *A&AR*, 24, 8
Kwok, S. 2017 *Nature Astronomy*, 1, 642
Kwok, S., 2018 Chapter 4.2 in *Handbook of Astrobiology*, Vera Kolb (ed.), CRP Press
Kwok, S., & Zhang, Y. 2011, *Nature*, 479, 80
Kwok, S., & Zhang, Y. 2013, *ApJ*, 771, 5
Sadjadi, S., Zhang, Y., & Kwok, S. 2015 *ApJ*, 801, 34
Sadjadi, S., Zhang, Y., & Kwok , S. 2017 *ApJ*, 845, 123
Zhang, Y., & Kwok, S. 2015, *ApJ*, 798, 37