Interim report - NAI Director’s Discretionary Award 2008

Title: Evolution of Organic Matter in Space: UV-Vis Spectroscopy Investigation on Nanosatellites (EO-Mission)

Ehrenfreund, Salama, Ricco, Bryson, et al.

EXPOSE-R was launched to the International Space Station ISS (Russian module) in November 2008. On 23 December 2008, the first space walk to attach EXPOSE-R to the external URM-D unit of the ISS failed due to technical problems. Another EVA on March 10, 2009 was successful and activated EXPOSE-R and sample exposure. Space exposure is planned for a period of at least 12-18 months.

1) Ground-based monitoring of EXPOSE-R samples in simulated space environment:

January 2009: A newly purchased Ocean Optics HR4000 spectrometer was installed in the laboratory of Dr. Farid Salama with a fiber optic interface that uses Ocean Optics Spectrasuite software for data collection. This spectrometer shares many of the optical design features, as well as much of the software, with the O/OREOS (organism/organic exposure to orbital stressors) flight spectrometer presently under development for a nanosatellite launch in February 2010 (see additional details in section 3 below).

February 2009: Postdoctoral associate Kathryn Bryson was hired to work on this DDF project at NASA/ARC.

March 2009: Transmission/absorption spectra were recorded by Dr. Bryson at approximately 11 months after original sample deposition for 9 of the 16 sample cells in the closed-bottom ground witness sample carrier of the EXPOSE-R Organics experiment. The cells contained thin films of C_{60}, C_{70} (both buckminsterfullerenes), dibenzo[jk,a'b']octacene, tetracene, ovalene, 2 samples of coronene, diphenanthro[9,10-b;9'10'-d]thiophene, and chrysene.

May 2009: The above 9 samples were remeasured by Dr. Bryson, and all the other cells in the closed-bottom ground witness sample carrier were also measured, in May at approximately 13 months after original sample deposition. The entire sample set included 2 samples of coronene, chrysene, triphenylene, tetracene, perylene, diphenanthro[9,10-b;9'10'-d]thiophene, ovalene, tetrabenzo[de,no,st,c'd']heptacene, dicoronylene, C_{60}, C_{70}, C_{60}/C_{70}/C_{84} mixture, circobiphenyl, dibenzo[jk,a'b']octacene, and dinaphtho[8,1,2-abc:2'1',8'-klm]coronene (as an example, the spectrum of ovalene is shown in Figure 1). The measurements confirm that no alterations have occurred in the spectra of the ground sample. These preliminary measurements and studies were reported at the AAS 214th Conference (see Figure 3).
Access to all the samples in the EXPOSE-R carrier was made possible in May by the implementation of a high-precision x-y-z slide assembly (Velmex) that allows for positioning the sample carrier relative to the spectrometer input over hundredths of millimeters (see Figure 2). This allows multiple measurements of precisely the same location to be made on each cell window at any time desired. This is a crucial improvement since the thin films are not in general absolutely homogeneous.

**Figure 1.** Comparison of the spectrum of ovalene in the EXPOSE-R ground control carrier between March and May 2009.
Figure 2. The spectrometer with the x-y-z slide assembly examining the closed-bottom ground witness sample carrier.

2) Development of a laboratory prototype UV-Visible spectrometer for in-situ measurements of organic materials on future free-flyers and lunar surface exposure facilities

In addition to the measurements on the EXPOSE-R samples, Dr. Bryson also collected preliminary spectra of samples of materials under consideration for the O/OREOS Nanosatellite mission mentioned above. These samples included thin films of anthra-rufin, phenylalanine, porphyrin (tetr phenylprphyrin), and ovalene.

Additional measurements in the coming months by Dr. Bryson will provide information than can help with the final downselect of materials for the O/OREOS mission, in addition to providing spectroscopic information that will help in optimizing the film thickness for this mission. In addition, degradation of these and similar films by UV irradiation may also be measured in Dr. Salama’s laboratory using the spectrometer described above, providing further data relevant to the measurements to be made during the O/OREOS mission.

3) Detailed characterization of the prototype’s performance via in-situ spectral measurements of control EXPOSE-R samples versus time in a simulated space environment, in direct comparison with a reference laboratory spectrometer.
A key goal of this DDF is to explore the potential scientific return using small-satellite-compatible spectrometer technology to study space environment-related effects on materials of astrobiological relevance. There is a close synergy between measurements made to date, as well as those planned for the next several months, using the laboratory UV-visible spectrometer purchased for this project, and measurements to be made on the same organic thin-film materials using an engineering test unit (ETU) spaceflight UV-vis spectrometer under development for the O/OREOS mission. In particular, the electronics and software are essentially identical between the DDF laboratory and the O/OREOS flight spectrometer and, based on specifications, the laboratory spectrometer’s optical bench should provide marginally better performance (spectroscopic parameters, dark levels), while the spaceflight prototype should provide significantly better measurement temperature stability (a requirement of the O/OREOS mission scenario) and better performance at spaceflight levels of shock and vibration. By comparing spectral changes in a number of astrobiologically relevant organic materials for these two spectrometers, we will understand whether the constraints on size and power placed on the flight unit result in any probable decrease in its ability to provide scientifically informative return for such materials. Such information will guide the development of the next-generation small-satellite-compatible UV-visible spectrometer, which in all probability will be based on the O/OREOS flight instrument with modifications according to the results of this DDF-funded study of performance vis a vis key science measurements. Because of this close coupling and relevance of the O/OREOS flight project, together with its tight budgetary constraints, we decided to support $25 k of the total cost of the O/OREOS engineering test unit development and fabrication using funds from this project. We believe that expenditure will provide a relatively high payoff in terms of the impact on future space missions that take advantage of the spectrometer technology developed in O/OREOS and refined using science measurement results from this DDF project.
UV And Space Exposure Of Aromatic Compounds On The EXPOSE-R Facility Onboard ISS

Kathryn Bryson¹, F. Salama², P. Ehrenfreund³, A. J. Ricco², Z. Peeters⁴, B. H. Foing⁵, E. Monaghan⁶, D. Wills⁶, M. Breitfellner⁶, E. Jessberger⁷, F. Robert⁸, M. Mumma⁹

¹Ray Area Environmental Research Institute, ²NASA Ames Research Center, ³Leiden Institute of Chemistry, Netherlands, ⁴NASA Goddard Space Flight Center, ⁵ESA-SCI-S, ESTEC, Netherlands, ⁶ESAC, Spain, ⁷Univ. Muenster, Germany, ⁸LEME, France

Introduction
- Polycyclic aromatic hydrocarbons (PAHs) and fullerenes
- Possible carriers for numerous astronomical absorption and emission features [1-4]
- Identified in molecules [5,6]
- Aromatic networks likely most abundant organic material in space [7,8]

Organics Experiment
- On the multi-user facility EXPOSE-R
- Mounted on the external platform of the ISS
- Activated in March 2009 after a successful spacewalk
- Thin films of selected PAHs and fullerenes are being subjected to low Earth orbit environment
- 12-18 months (effective exposure 1300-2000 h)
- Will monitor chemical evolution, survival, destruction and chemical modification in space environment
- Radiation dose collected by the samples during flight exceeds the limits of simulations in the laboratory
- Dark samples are being shielded from UV photons (Fig. 1A)
- Experiment hosts pressurized and vented sample cells

Experimental
- UV/ VIS spectra of the ground closed top sample center was collected in the Astrophysics and Astrochemistry Lab at NASA Ames in March ’09
- Ocean Optics HR4000 UV/ VIS Spectrometer
- 16 µm slit aperture
- 200-1050 nm range
- UV/ VIS spectra were repeated of the ground sample in May ’09 with the high-precision x-y-z slide assembly (Fig. 2)
- x-y-z slide assembly allows for high-precision repetition of sample spot measurements on each thin film
- Ground sample spectra will be compared to the sample exposed to low earth orbit

Results
Examples of the UV/ VIS spectra for the closed bottom ground samples for the three different dates

Conclusions
Some changes in absorption intensity are monitored between the March and May spectra, likely due to different locations of the thin films being analyzed.
With the new high-precision x-y-z slide assembly we will remedy this problem.
Otherwise no noted differences in the ground samples over 2 months storage in a dry container.

References

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Figure 1 – A. Diagram of the sample trays. The lower sample carrier is the dark control. B. Diagram of the open vented sample cells and the closed/pressurized sample cells.

Figure 2 – Ocean Optics HR4000 UV/ VIS Spectrometer with x-y-z slide assembly in the Astrophysics and Astrochemistry Laboratory at NASA Ames.

Figure 3. Poster contribution at the AAS 214th conference, Pasadena, CA, June 8-11, 2009