The AstroBiology Explorer (ABE) MIDEX Mission: Using Infrared Spectroscopy to Identify Organic Molecules in Space

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ABSTRACT

The AstroBiology Explorer (ABE) mission is one of four selected for Phase A Concept Study in NASA's current call for MIDEX class missions. ABE is a cooled space telescope equipped with spectrographs covering the 2.5-20 micron spectral range. The ABE mission is devoted to the detection and identification of organics and related molecular species in space. ABE is currently under study at NASA's Ames Research Center in collaboration with Ball Aerospace.

1. Introduction

One of the principal means by which organic compounds are detected and identified in space is by infrared spectroscopy. Past IR studies (telescopic and laboratory) have demonstrated that much of the carbon in the interstellar medium (ISM) is in complex organic species of a variety of types, but the distribution, abundance, and evolutionary relationships of these materials are not well understood. The Astrobiology Explorer (ABE) is a MIDEX mission concept designed to conduct IR spectroscopic observations to detect and identify these materials to address outstanding important problems in astrobiology, astrochemistry, and astrophysics. Systematic studies include the observation of planetary nebulae and stellar outflows, protostellar objects, Solar System Objects, and galaxies, and multiple lines of sight through dense molecular clouds and the diffuse ISM. ABE will also search for evidence of D enrichment in complex molecules in all these environments.

ABE is a cryogenically-cooled 60 cm diameter space telescope equipped with 3 cryogenic cross- dispersed spectrographs sharing a common slit. The spectrometers measure single spectral octaves (2.5-5, 5-10, 10-20 microns) and cover the entire range simultaneously. The spectrometers use state- of-the-art 1024x1024 pixel detectors, with a single InSb array for the 2.5-5 micron region and two Si:As arrays for 5-10 and 10-20 microns. The spectral resolution is >2000 across the entire spectral range. ABE would operate in a heliocentric, Earth drift-away orbit and will take maximum advantage of this environment for cooling, thermal stability, and mission lifetime. ABE's core science mission lasts ~1.5 years.

2. The Scientific Mission of the AstroBiology Explorer

In the course of its mission lifetime ABE will execute a focused series of observations designed to detect, identify, and determine the distribution of organics and related molecular species as they evolve through the cycle from stellar ejection, interstellar residence, and incorporation into forming stellar/planetary systems. The scientific tasks of the mission are described in the paragraphs that follow.

The Environments Surrounding Forming Stars - Independent of the formation site and interstellar evolution of cosmic organics, they must pass through dense clouds to end up on the surface of a planet. Thus, understanding the environment surrounding forming stellar systems is critical to addressing the role interstellar organics may play in the origin of life. Dense clouds are especially interesting because studies indicate that complex organic species are created in these environments (Dworkin et al. 2001) (Bernstein et al. 2002). ABE will greatly improve our understanding of the molecules in these environments by obtaining absorption spectra of embedded solar-mass protostars and background field stars probing lines of sight through nearby dense clouds in which star formation is occurring. ABE will be able to measure high signal-to-noise spectra from solar mass protostars, not just the high mass protostars previously observed (Gibb et al. 2000).

The Evolution of Complex Organic Molecules in the Interstellar Medium (ISM) - Polycyclic aromatic hydrocarbons (PAHs) represent one of the main forms of molecular carbon in space. These molecules are thought to be produced in the outflows of late type carbons stars forming protoplanetary and planetary nebulae (PPN/PN). PAHs are detectable via their characteristic IR emission features (Allamandola et al. 1989). The PAH population evolves as it is subjected to the increasingly intense radiation field of their central star. ABE will study this evolution by examining the spectra of PPN and PN at different stages of evolution. In addition, the PAH population will be further modified in the ISM by the interstellar radiation field, supernovae shock waves, condensation and irradiation in ices in dense clouds, etc. Thus, ABE will also study PAH evolution by examining PAH emission spectra from HII regions and their boundaries with dense molecular clouds.

The Distribution of Organic Compounds in the Diffuse Interstellar Medium - On the basis of limited observations along a few lines of sight within our galaxy, it is known that about 10% of the cosmic abundance of carbon in the diffuse ISM is in the form of aliphatic hydrocarbons (Sandford et al. 1991) (Pendleton and Allamandola 2002). These materials appear to be associated with comparable or greater amounts of aromatic hydrocarbons. ABE will use field stars to probe for organic absorption bands along multiple sight lines through our galaxy to determine the composition, abundance, and distribution of this material.

Organics in the Solar System (comets, asteroids, planetary moons)- Comets, asteroids, and the dust and meteoroids they produce are the principal bodies responsible for delivering interstellar materials to planetary surfaces (Chyba and Sagan 1992). Thus, understanding their organic contents is of direct interest to determining the role interstellar materials may have played in the origin of life. ABE will obtain spectra from a number of these objects, as well as from the surfaces of icy bodies in the outer solar system (KBOs, satellites of the gas giants, Pluto and Charon), objects that may either be repositories of interstellar organics or sites on which organics may be formed *in situ*.

The Cosmic History of Molecular Carbon- ABE will measure the spectra of galaxies to examine the relationships between the molecular component of galaxies as a function of type, composition, and cosmic distance. Spectral features such as the PAH emission bands and aliphatic absorption bands have both been seen in galaxies (Bridger et al. 1994) (Tran et al. 2001). Targets include ultraluminous IRAS galaxies, Starburst galaxies, Seyfert galaxies, distant ULGs, and dwarf, S0, spiral, elliptical, and colliding galaxies. ABE will also do more detailed spectral mapping of a few nearby galaxies.

Tracing Deuterium Enrichments - In favorable cases, ABE will obtain spectra with sufficiently high S/N to detect, or derive meaningful upperlimits to, the D/H ratios of IS organics. A number of astrochemical processes enrich organics in D in the ISM (Sandford et al. 2001) and the presence of D- enrichments in the organics in meteoritic materials provides the main proof that interstellar organics can survive incorporation into forming stellar systems and subsequent arrival on the surface of planets (Zinner 1997).

Guest Observations - ABE is prepared to carry out Phase F activities that would make approximately 20% of the missions total observing time available for a Guest Observer (GO) program. Time would be allocated to the general astronomical community on a competitive basis and would *not* be restricted to studies of direct interest to astrobiology. Thus, the capabilities of ABE could be used to address a wide variety of astrophysical issues that extend well beyond the central scientific goals of the ABE mission.

3. Additional Information

The Concept Study Reports for the current round of four MIDEX missions are due on October 16, 2002. Final selection of the two missions to be flown is expected in March 2003. The selected missions will fly in 2007 and 2008. ABE data would be archived at IPAC and made public under a "rolling release" in which all the data would be available by mid 2010.

Information about the ABE mission can be found at http://www.astrochem.org/abe.html and in several SPIE publications (Ennico et al. 2002) (Sandford et al. 2000) (Sandford et al. 2002). The most recent publications can be downloaded from the ABE website.

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