Bull. Astr. Soc. India (1999) **27**, 221-225

Interstellar biomolecules and infrared astronomy

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Abstract. The ubiquitous presence of organic molecules in the interstellar clouds, comets and asteroids, and the evidence of extraterrestrial amino acids in carbonaceous meteorites strongly support a cosmic perspective on the origin of life. Hoyle and Wickramasinghe in a series of publications have argued that dust grains in interstellar clouds contain bacteria and that the disruption of bio-grains in the presence of a UV flux is responsible for the large scale presence of Polycyclic Aromatic Hydrocarbons and other organic polymers. In the present communication it is proposed that proteins and polypeptides will also result in the disruptions of bacteria in the interstellar clouds. These polypeptides have characteristic vibrational modes of the amide group in the polymer chain. The observational regions in the infrared for the amide modes of α helical polypeptides is suggested. Since amino acids appearing on disruptions of biotic matter may be predominantly in polymeric form and rotational transitions would not occur, their vibrational transitions are of significant importance. Thus infrared spectroscopy of circumstellar shells and dense clouds in the star forming regions for the amide bands in the 2.5 to 18 μm IR range would play a decisive role in the theories of interstellar biomolecules.

Key words : organic interstellar molecules, infrared spectroscopy

1. Introduction

It is well established that C, N, O and other elements of our bodies were created billions of years ago in the interiors of stars while H came from the big-bang itself! What is much less clear is that our molecules are the product of cosmic chemistry or biology. A vast variety of interstellar molecules have been identified to date. Organic molecules are found to be ubiquitously present in the interstellar clouds, comets and asteroids. Meteorites, especially carbonaceous chondrites, have been found to contain significant quantities of extraterrestrial Amino Acids (Kvenvolden et al., 1970). All these evidences strongly support a cosmic perspective on the origin of life and theories of 'PANSPERMIA' - (Cosmic delivery of pre-existing organisms seeded earth with life).

Hoyle and Wickramasinghe (H & M) in a series of publications (Hoyle & Wickramasinghe 1977, 1984; Wickramasinghe et al., 1989a, b; Wickramasinghe 1995) have argued that dust grains in interstellar clouds contain bacteria, such as E-coli which survive in comets on cloud condensation to stars and planets. Their arguments are based mainly on the excellent fittings of the UV extinction curves with the laboratory opacity curves for terrestrial spore forming bacteria (Wickramasinghe 1989b). They have also obtained good agreement of the observed infrared fluxes with the predicted curves for bacteria and bacterium-silica mixture (Wickramasinghe 1989b; Wickramasinghe 1995). These comparisons have been controversial mostly because the bacterial grain spectra are taken in solid state, which generally do not have any sharply localized spectral features like the well defined rotation or rotation - vibration lines found in the gas phase molecular spectra (Moore and Donn 1982).

H & W further argue that the formation of large organic molecules and especially Polycyclic Aromatic Hydrocarbons (PAH) on such vast scales, as the observations suggest, cannot be explained via inorganic processes. Therefore, the production of organic matter must be due to biological processes wherein bacteria accept inorganic matter as nutrient and grow exponentially (analogous to colony formation by terrestrial bacteria). Their contention is that PAH and other organics are the degradation product of these bacteria in the presence of a UV flux (Wickramasinghe 1989a, b; Wickramasinghe 1995).

In the present communication it is proposed that considering the presence of bacteria and their disruptions in interstellar clouds will also lead to the presence of proteins and polypeptides - important functional substances in living organism. Which may be observed in the infrared through the vibrational signatures of the peptide linkage - The amide group modes.

2. Amide modes

The proteins and polypeptides are biopolymers made up of different amino acids linked together by the peptide bonds (NH—CO). This amide group linkage has characteristic vibrational modes with frequencies falling in the infrared region. The polypeptides go into helical conformations stabilized by the interchain or intrachain hydrogen bonding (-N-H...O=C-). Most of the biologically important polypeptides go into α helical conformation; having 18 residues in five turns.

The peptide linkage gives rise to in-plane and out-of-plane vibrational modes (Amide A, B and Amide I to VII) the frequencies of which depend greatly on the type of helix and hydrogen bonding. Vibrational study of several poly α-amino acids (polymer of a particular amino acid), which are model compounds to study proteins, suggest that the frequencies of Amide A, Amide I, II, III and VI are independent of the side chain or the particular amino acid (Gupta V. D. et al., 1995, 1996(a-d), 1997) and are therefore characteristic of α helical polymer. Figure 1 shows the normal coordinates of the amide bands along with the vibrational frequency for the α helical polypeptides.

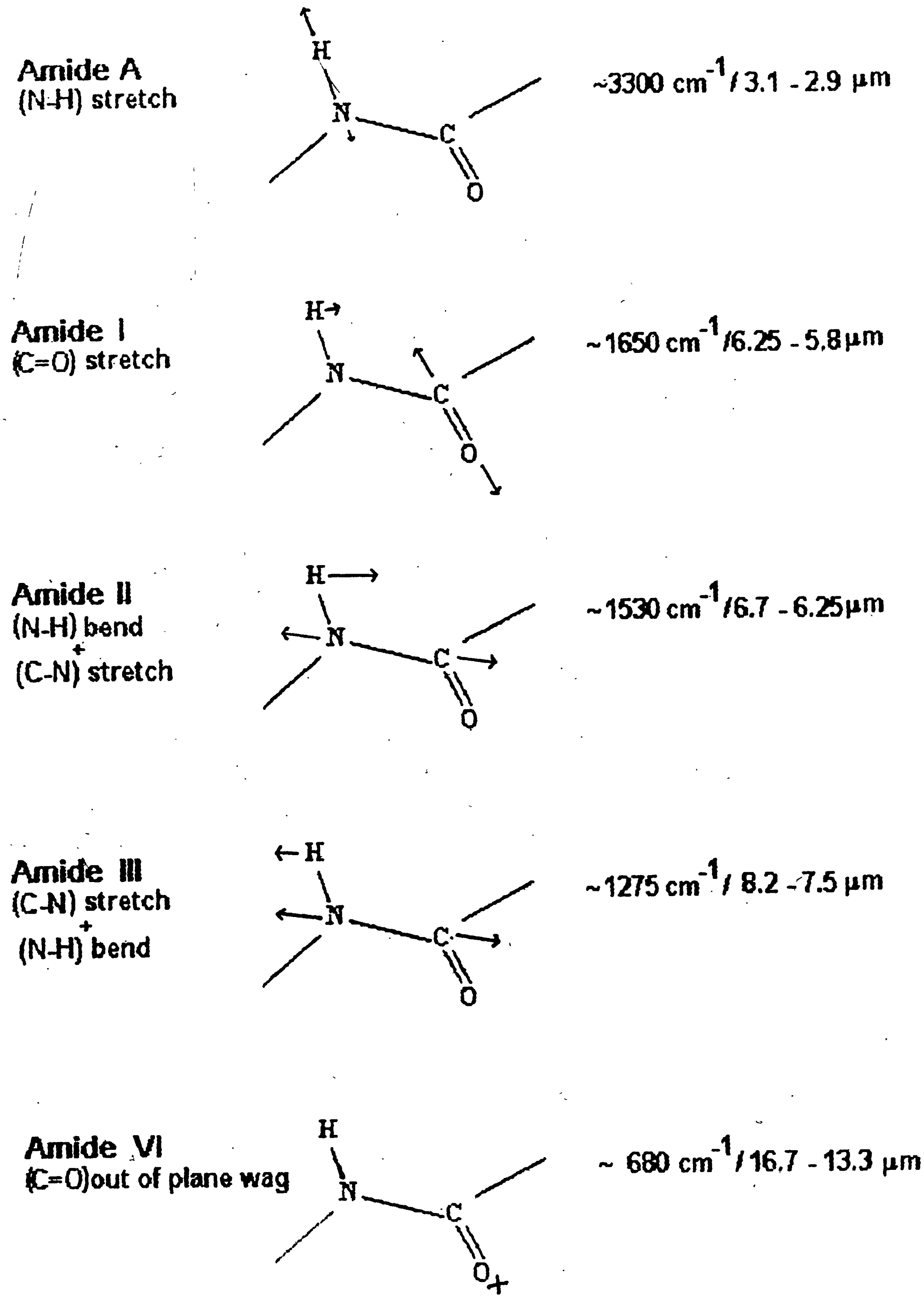

Figure 1. Normal coordinates and vibrational frequencies of amides.

3. Infrared astronomy

Molecular species have characteristic vibrational and rotational transition energies and can be identified by their vibrational and rotational spectra. The ongoing search for the simplest biologically important amino acid, glycine (NH_2-CH_2-COOH), in the millimeter wavelength region looks for rotational transitions (Synder 1997). But amino acids appearing on disruptions of biotic matter may be predominantly in polymeric form and rotational transitions would not occur. Also a large fraction of organic matter is incorporated in interstellar grains and ice mantles as solid phase and thus are not free to rotate. Therefore, the vibrational transitions gain significant importance and provide observational means for detecting the organic composition of interstellar dust.

The fundamental inter atomic vibrations of most molecular species fall in the infrared energy range, 5000 - 330 cm^{-1} (2-30 μm). Although ground based IR observations in this range are handicapped by the presence of atmospheric molecules and only the very intense bands can be resolved. But the advances in infrared detector sensitivities, mainly with the advent of array detectors, and development of efficient spectrometers with optical surfaces having high reflectance (McLean and Ian 1995), have tremendously expanded the potential of IR in the studies of organic features. This along with space missions (ISO with its Short Wavelength Spectrometer) have given a great impetus to the study of IR spectra of molecules in the ISM (Whittet 1996).

The observational results already point towards the presence of complex organic molecules in stellar outflows and in diffuse interstellar medium. Near infrared observations of diffuse interstellar medium have shown absorption features near 2950 cm^{-1} (3.4 μm), attributed to (C-H) stretching of aliphatic hydrocarbon grains, to be present in several regions of our galaxy and even in dust-embedded Seyfert galaxies (Pendleton 1997). The unidentified IR bands have now unequivocally been attributed to PAH and are ubiquitous in proto planetary nebulae, planetary nebulae, reflection nebulae, H_2 regions and extragalactic sources (Puget and Leger 1989; Allamandola 1985; Joblin 1996). The PAH features are in absorption as well as in emission with the UV photons from the central star of the AGB pumping the molecules to fluoresce in IR.

Under intense UV or particle irradication the biological grains can be fragmented hence individual strands of polypeptides can become free. Absorption of a UV photon by such strands will excite the molecule and in a collision free (low density) environment the relaxation will occur via emission of IR photons corresponding to its fundamental vibrational frequencies. All the characteristic amide bands for such possible strands occur in the 2.5 to 18 μm range. Therefore infrared spectroscopy of circumstellar shells and dense clouds in the star forming regions, which are sites for UV photoprocessing and organic refractory, is important. The simultaneous presence of all these bands will be a direct evidence for the presence of such polypeptides and the bacterial grain hypothesis.