Tentative detection of vibrationally excited Polycyclic Aromatic Hydrocarbons in Comets

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Abstract:

A search for the detection of vibrationally excited Polycyclic Aromatic Hydrocarbons on a sample of comets observed by Infrared Spectrometer (IRS) onboard Spitzer Space Telescope was initiated. A continuum was subtracted from the observed spectra to clearly delineate the presence of PAH emission bands in the wavelength 5.4 to 14 um. Our analysis showed the presence of Polycyclic Aromatic Hydrocarbons (PAHs) in the mid-infrared spectra of four comets.

The evolution of organic molecules on their journey from molecular clouds to the early solar system is not well understood. Comets are considered to be primitive bodies formed during the formation of solar system that contain agglomerate of frozen gases, ices and rocky debris. It is believed that comets are made of unaltered interstellar materials and preserve the early stages of solar nebula [1]. Polycyclic Aromatic Hydrocarbons (PAH) molecules consisting of fused benzene rings with a wide spread presence in the ISM of our own and external galaxies are believed to be frozen in comets. The infrared emission bands at 3.3, 6.2, 7.7, 8.6 and 11.2 um are attributed to the C-H stretching and bending vibrations and C=C stretching modes of PAH molecules [2]. Traditionally, Ultraviolet fluorescent spectra of PAH at 347, 356 and 364 nm was used for its identification [3].

The public archival spectroscopic data on a sample of comets observed by Infrared Spectrometer (IRS) onboard Spitzer Space Telescope covering the mid-IR region between 5.3 and 38 um [4] was used for the present analysis. The IRS stare observations using the Short-Low module was mostly used for the present study. The mid-infrared spectra was extracted from the Basic Calibrated Spectra (BCDs) using Spectroscopic Modeling Analysis and Reduction Tool (SMART) [5].

The extracted mid-infrared spectra in the wavelength range 5.3 and 14 um was subjected to continuum subtraction for clearly delineating the PAH bands. The continuum was defined by the pivotal on the spectra that are fitted by a third order polynomial for the entire region (see top panel of Fig 1). The bottom panel in Figure 1 shows the continuum subtracted spectra.

The mid-infrared spectra of four comets in our sample showed faint emission from PAH bands. The comets Schwassmann-Wachmann-3, Neat (C/2001 Q4), 46P/Wirtanen and McNaught (C/2006 P1) showed vibrationally excited PAH bands at 6.2, 7.7, 8.6 and 11.2 um.

The heliocentric distance ($r_{hi}$) of Schwassmann-Wachmann-3 was 1.47 AU and the distance between
the comet and Spitzer (Δs) was 0.78 AU during the observation. For Neat (C/2001 Q4) rₚ was 4.59 AU and Δs was 4.36 AU. For 46P/Wirtanen rₚ was 2.08 AU and Δs was 1.8 AU. The rₛ for McNaught (C2006 P1) is 3.6 AU and Δs was 2.2 AU. The position of these comets that approached Sun during its observation well suited for the detection of PAH at mid-infrared wavelengths. In addition, all sources showed silicate emissions at 9.8 μm. Thus a mixed chemistry minerology was observed. The mid-infrared spectra of Schwassmann-Wachmann-3 also showed a peak at 9.2 μm due to the aliphatic hydrocarbons. Lisse et al [6] found PAH emission bands in the deep impact ejecta of comet Tempel 1 using Spitzer. Takafumi Ootsubo et al [7] detected PAH and crystalline silicates in comet 21P/G-Z using the Cooled Mid-infrared Camera and Spectrometer (COMICS) on the 8.2 m Subaru Telescope. They propose that comets with crystalline silicate and PAH features may be formed in the circumplanetary disk around a gas giant planet like Jupiter or Saturn, owing to the favourable temperature conditions for the existence of the dust grain. Our results with spectral signatures of both PAH and silicate features observed in the comets and the possible pathways for incorporating them from the ISM will be discussed.

References:

Fig 1: Extracted raw spectra of comet Schwassmann-Wachmann 3 with pivotal points shown in orange filled circles for defining the continuum are shown in the top panel. The Continuum subtracted spectra is shown in the bottom panel.
