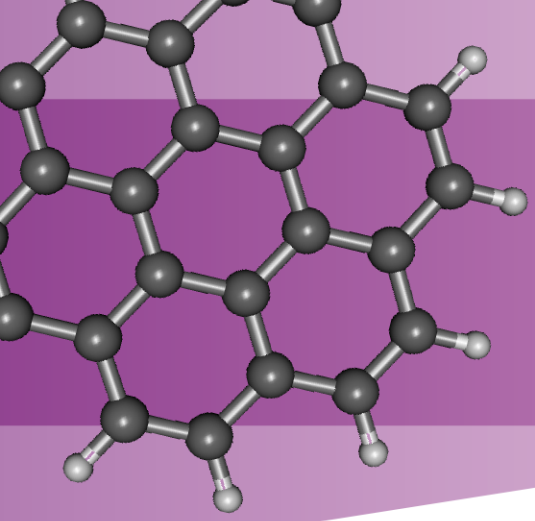
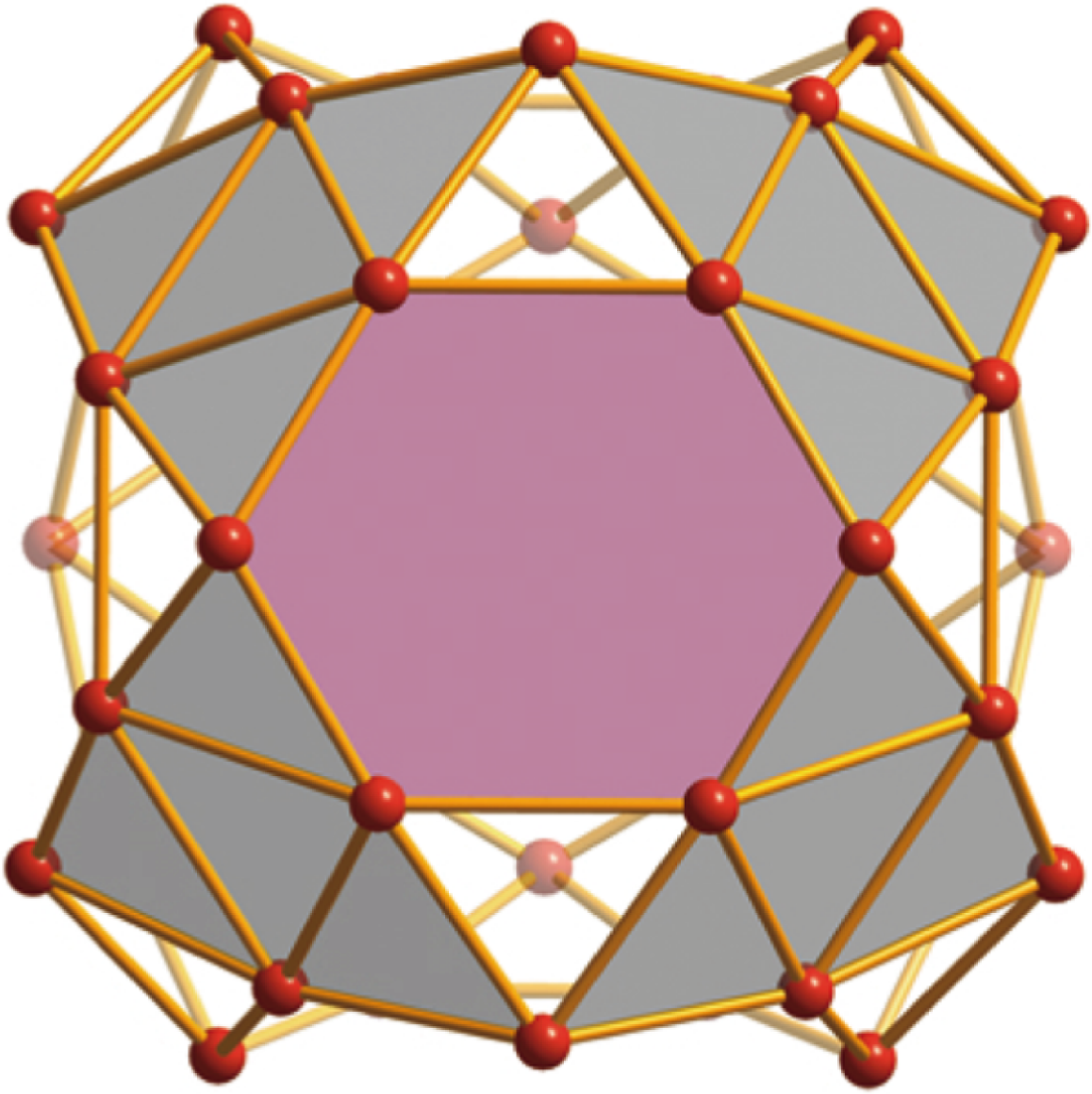


AstroPAH

A Newsletter on Astronomical PAHs

Issue 13 | November 2014



Borospherene (B_{40})

Editorial

Dear Colleagues,

We are happy to start another year of AstroPAH, welcoming you to our 13th release.

In this issue, we have In Focus the exciting discovery of borospherenes, the boron equivalent of fullerenes. The structure of borospherene is also featured on the cover as our Picture of the Month.

You will find a diversity of paper abstracts covering astronomical, model and laboratory studies: from monomers to clusters, with or without functional groups, to aromatic molecule production in a flame. Also included are abstracts for the original papers on borophene and borospherene.

We would like to draw your attention to a final call and a first announcement of important events in our meetings section.

We thank you all for your contributions and please keep them coming. You can send us your contributions anytime! The deadline for publication in the next issue is in the box below.

Best regards

The Editorial Team

Next issue: 16 December 2014.
Submission deadline: 5 December 2014.

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Contents

PAH Picture of the Month 1
Editorial 2
In Focus: From planar boron clusters to borophene and borospherene 4
Recent Papers 10
Meetings 17

PAH Picture of the Month

The structure of the B_{40} all-boron fullerene or borospherene.

Credits: S. D. Li, J. Li, and L. S. Wang

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Design by Isabel Aleman

From Planar Boron Clusters to Borophene and Borospherene

L. S. Wang, H. J. Zhai, S. D. Li, J. Li , & A. I. Boldyrev

All-boron analogues of hydrocarbons

Carbon is not only the element of the organic world, it has, in recent years, become the most important element in nanoscience and nanotechnology, giving rise to the fullerenes, carbon nanotubes, and graphene. Boron is next to carbon in the periodic table. However, owing to its electron deficiency (four valence atomic orbitals with only three valence electrons), boron has quite different chemical bonding properties from carbon. The electron deficiency suggests that boron atoms have to share electrons, which has led to peculiar structures and unusual chemical bonding in elemental boron and boron compounds.

Among the main group elements, boron has the second highest melting temperature after carbon, implying strong boron-boron bonds. However, there was little information about the structures and properties of elemental boron clusters, in comparison to carbon. To understand the structure and chemical bonding of elemental boron clusters and to discover potentially novel boron-based nanostructures, we have initiated a systematic experimental and theoretical research program on elemental boron clusters since the early 2000s. Our strategy is to combine photoelectron spectroscopy of size-selected cluster anions with computational chemistry.

It was surprising to find that, though boron usually forms cage-like three-dimensional (3D) structures in the solid state and in boranes as a result of optimal electron sharing, small and medium-sized clusters of boron are planar or quasi-planar (2D).[1−4] It has been found that the planarity of boron clusters comes from two main factors: the presence of localized two-center two-electron (2c-2e) σ bonds at the periphery of the cluster and the ability of the inner boron atoms to bond with each other and with the peripheral atoms through the formation of delocalized σ and π bonds. If the number of delocalized σ and π electrons satisfies the $4n$+2 rule for aromaticity, the resulting clusters will adopt high-symmetry structures like in the case of planar B_9^- cluster (**Figure 1**).[1] The B_9^- cluster has eight peripheral 2c-2e σ bonds, three 9c-2e delocalized σ bonds, and three 9c-2e delocalized π bonds, as established by electron localization analyses using a method called AdNDP. The six completely delocalized bonds (three σ and three π) make this cluster doubly aromatic (σ and π), which is why this cluster has such high symmetry (D_{8h}). The π bonding pattern in B_9^- is similar to that in the prototypical aromatic

molecule benzene. It has been found that many planar boron clusters exhibit π bonding patterns akin to that found in polycyclic aromatic hydrocarbons (PAHs), giving rise to the concept of boron clusters as hydrocarbon analogues.[2,5–7]

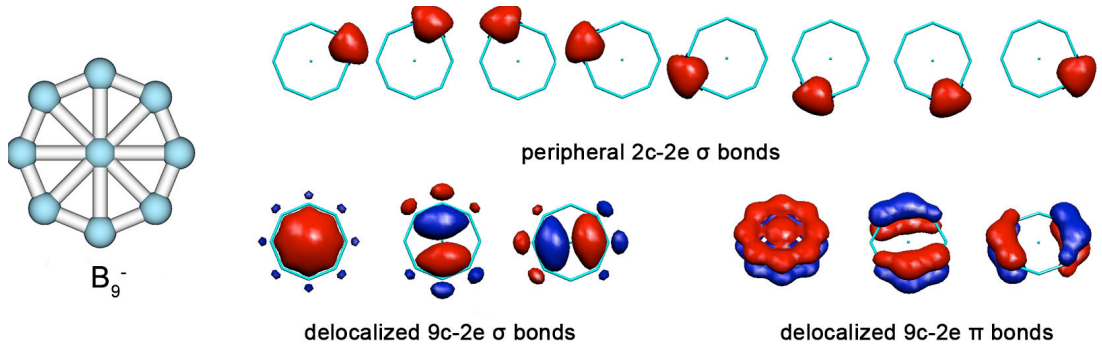

Figure 1 - The structure and bonding pattern of the planar B_9^- cluster.

The π bonding molecular orbitals of the B_{16}^{2-} dianionic cluster are compared to those of naphthalene in **Figure 2a** and one can see that there is a perfect analogy between the two systems.[5] A similar comparison is made for the π-bonding orbitals of the B_{23}^- cluster in **Figure 2b** and phenanthrene, and again one can see a one-to-one correspondence.[7] It is worthy to note that understanding the chemical bonding in pure boron clusters has helped us design novel aromatic transition-metal-doped boron molecular wheels (M©Bn).[8] The Ta©B10- and Nb©B10- clusters were found to have a record high coordination number of 10 in a planar environment.[9]

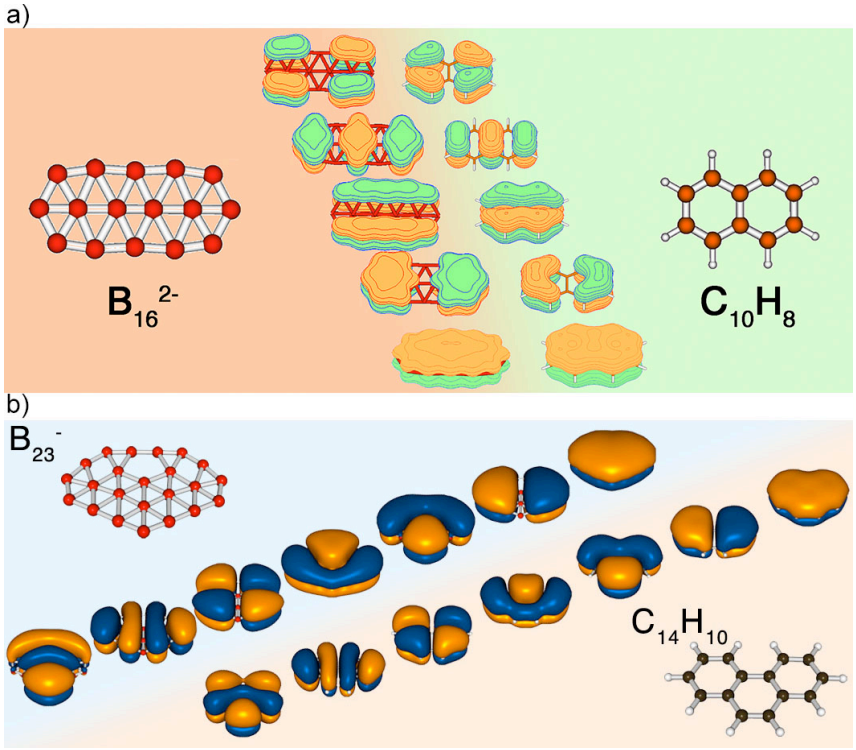

Figure 2 - Comparison of the π bonding orbitals in a) the B_{16}^{2-} cluster and naphtalene ($C_{10}H_8$); b) the B_{23}^- cluster and phenanthrene ($C_{14}H_{10}$).

The B_{36} cluster: All-boron analogue of coronene

The systematic experimental and computational investigations over the past decade have firmly established not only the planar structures of small B_n^- and B_n (n = 3-25) clusters, but also the aromatic bonding nature in these clusters. For larger boron clusters, the global minimum structural searches become extremely challenging. One open question is the 2D to 3D structural transition in boron clusters. For cationic B_n^+ clusters, an ion mobility study suggests that this transition may happen at n = 16.[10] However, there is no direct experimental evidence for the 2D-to-3D transition for neutral boron clusters, even though computationally B_{20} was suggested to be a 3D-tubular type structure.[11] Beyond n = 25, only four B_n^- clusters have been recently characterized experimentally, including the quasi-planar chiral B_{30}^- cluster,[12] the hexagonal B_{35}^- with a hexagonal double vacancy,[13] the hexagonal B_{36}^- cluster,[14] and the all-boron fullerene B_{40}^- cluster.[15]

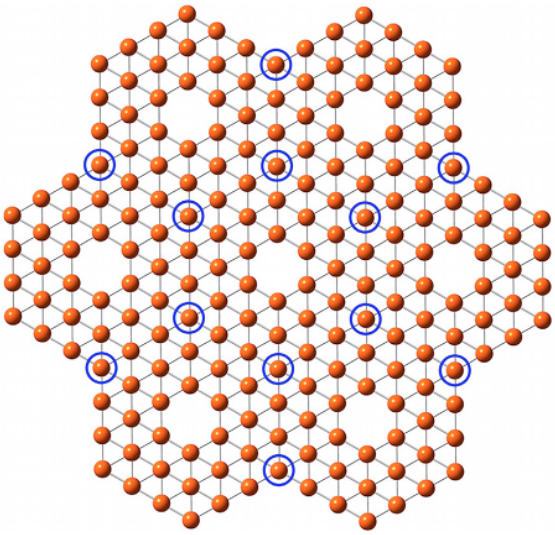

Figure 3 - Schematic view of borophene constructed from planarized B_{36} clusters.

Both B_{36}^- and its neutral B_{36} are found to be quasi-planar with a central hexagonal vacancy, using combined photoelectron spectroscopy and theoretical calculations.[14] This observation suggests that the hexagonal B_{36} may be viewed as a building block for infinitely large atom-thin boron layers (**Figure 3**), dubbed **borophene**,[14] analogous to graphene, which is built out of hexagonal C_6 units. A subsequent AdNDP analysis of the hexagonal B_{36} cluster showed that its π bonding pattern is analogous to coronene (**Figure 4**).[16]

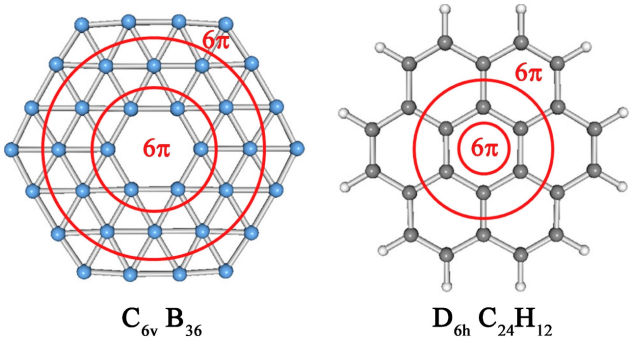

Figure 4 - Comparison between the π bonding patterns of B_{36} and coronene ($C_{24}H_{12}$). The circles indicate the delocalized π systems.

The quasi-planar B_{36} structure consists of close-packed boron atoms with a perfect hexagonal hole at the center. The stability of the beautiful B_{36} hexagonal structure may be understood from its chemical bonding: the concentric dual π aromaticity, as revealed from the AdNDP analysis. Of the 54 pairs of valence electrons in B_{36}, there are 18 peripheral 2c-2e σ bonds for the outer ring and 24 multi-center σ bonds. The remaining 12 pairs of electrons in B_{36} are responsible for the π framework, forming two separate concentric π systems and each conforming to the (4n+2) Hückel rule for aromaticity. This π bonding pattern is analogous to that of the PAH coronene ($C_{24}H_{12}$) (**Figure 4**).[16]

The hydrogenation of the six apex B atoms on the periphery of B_{36} leads to the hexagonal B_{36} H_6 model cluster, which is found to be a true minimum.[16] Hydrogenation appears to enhance the planarity of the B_{36} cluster, due to the slightly expanded size of the outer B_{18} ring. The π bonding patterns in $B_{36}H_6$ are found to be similar to that in the parent B_{36} cluster.

The photoelectron spectrum of B_{35}^- was found to exhibit some similarity to that of B_{36}^-. Recently, it is found that the structures of B_{35}^- and B_{35} are very similar to those of B_{36}^- and B_{36}

with an additional hexagonal vacancy (**Figure 5**), resulting in a double hexagonal vacancy.[13] Interestingly, the π chemical bonding in B_{35}^- is found to be analogous to that in the PAH, benzo(g,h,i)perylene ($C_{22}H_{12}$). The B_{35}^- cluster is also found to be a flexible building block for borophene with variable hexagonal hole densities.

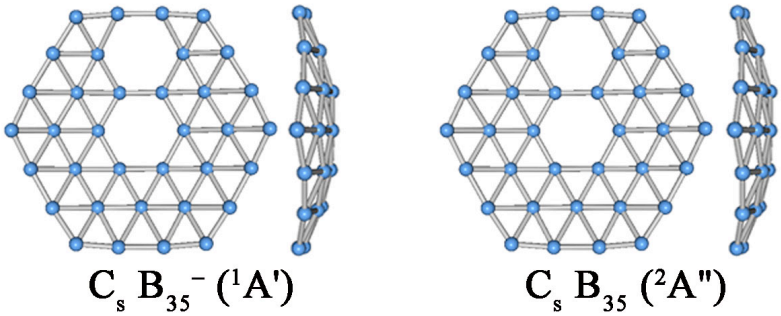

Figure 5 - The optimized structure of B_{35}^- and B_{35}.

All-boron fullerenes: B_{40}^- and B_{40}

After the discovery of fullerene C_{60},[17] free standing cage structures of elemental clusters have been observed only in Au_{16}^-, small tin (stannaspherene), and lead (plumbaspherene) clusters.[18–20] Until the recent discovery of the first all-boron fullerenes,[15] dubbed borospherene, B_{40} and B_{40}^-, there has been no experimental evidence for a free-standing boron cage cluster.

The B_{40}^- cluster was produced in a laser-vaporization clusters source, similar to the original observation of the C_{60} fullerene,[17] and characterized using photoelectron spectroscopy. The photoelectron spectrum of B_{40}^- distinguishes itself from those of other boron clusters: it possesses an extremely low electron detachment energy of 2.62 eV. The overall spectral pattern suggests a remarkably stable neutral B_{40} cluster with a large energy gap.

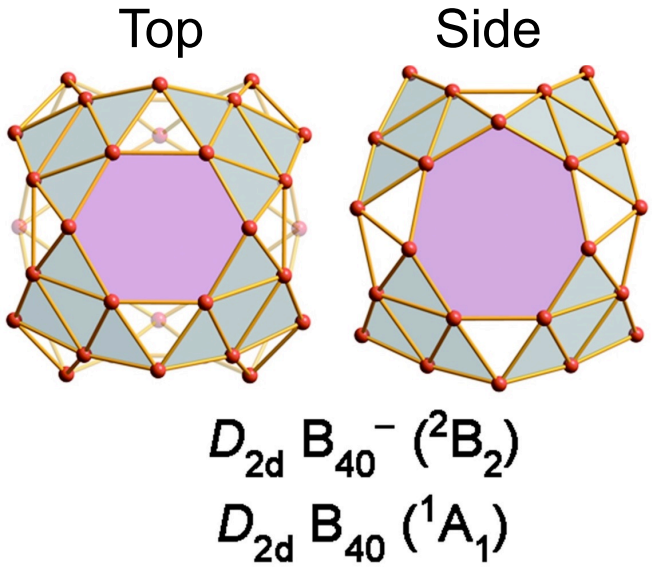

Figure 6 - Top and side views of the optimized cage structures of B_{40}^- and B_{40}.

Extensive global minimum searches were conducted for B_{40}^- and B_{40} using different theoretical methods. All levels of theory predict a quasi-planar global-minimum structure for B_{40}^- along with a low-lying cage-like fullerene structure (**Figure 6**). However, for neutral B_{40} the fullerene-like cage is calculated to be overwhelmingly the most stable structure. It turned out that both the B_{40}^- cage and the planar B_{40}^- isomer were produced experimentally in the anion cluster beam and contributed to the observed experimental spectra based on the comparison of simulated spectra with the experimental data.

The cage structures of B_{40}^- and neutral B_{40} are very similar, both with D_{2d} symmetry, consisting of 16 tetracoordinated and 24 pentacoordinated B atoms (**Figure 6**). The cage surface of the B_{40} borospherene is less smooth in comparison with the C60 fullerene, containing two

hexagonal holes on the top and bottom and four heptagonal holes on the waist, akin to a perforated Chinese red lantern. The cage is elongated slightly along the two-fold main molecular axis going through the hexagons. The B_{40} cage can be built from eight equivalent, planar B_6 triangles (grey shaded), which share four corners within the top half of the cage and four within the bottom half. Alternatively, the all-boron fullerenes can be viewed as consisting of interwoven double-chain boron ribbons: eight horizontal B_9 ribbons and four vertical B_{10} ribbons. Molecular dynamics simulations for the B_{40} borospherene show that it is stable even at high temperatures (700 and 1000 K). The B_{40} cage is also found to be an exceptionally stable electronic system, as evidenced by a large energy gap between its highest occupied and lowest unoccupied molecular orbitals. This gap was calculated to be 3.13 eV for B_{40}, compared to that of C_{60} (3.02 eV) calculated at the same level of theory.

The chemical bonding of borospherene was analyzed using AdNDP and was found to be highly unusual: all electrons are delocalized or shared without a single 2c-2e localized bond (**Figure 7**). Of the 60 pairs of valence electrons in B_{40}, a total of 48 are basically 3c-2e bonds, one on each B_3 triangle on the borospherene surface. The remaining 12 bonds are essentially characterized as delocalized π bonds: four 5c-2e π bonds, four 6c-2e π bonds, and four 7c-2e π bonds evenly distributed along the interwoven double boron chains over the cage surface. Thus, all the valence electrons in B_{40} are delocalized as either σ or π bonds and there is no localized 2c-2e bond

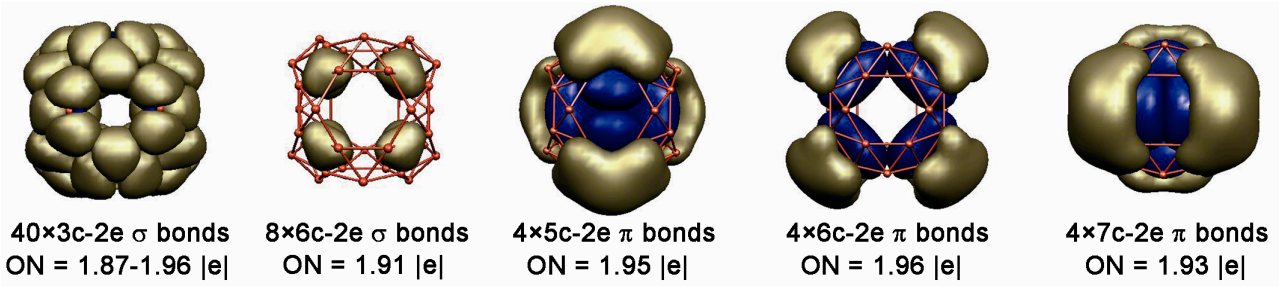

Figure 7 - Results of chemical bonding analyses for the B_{40} borospherene.

Preliminary calculations indicate that doping B_{40} with a metal atom M (Ca, Y, La) results in endohedral boron fullerenes M@B_{40} with M slightly off-center along the two-fold molecular axis, analogous to Ca@C_{60}. The B_{40} borospherene also offers valuable model systems for hydrogen storage. Notably, every B atom is on the edge of a hexagonal or heptagonal hole, which facilitates H and/or H_2 adsorption and release.

Even though boron and carbon have very different chemistries, the finding of similarity between elemental clusters of boron and PAHs is surprising and intriguing. Among all the molecules that have been detected in the interstellar space, carbon-containing molecules dominate that list, including a number of PAHs and the fullerenes C_{60} and C_{70}. However, there are no boron-containing molecules detected in the interstellar space. Boron is a rare element on earth and in space. It remains to be seen if boron-containing molecules or even elemental boron clusters may exist in the interstellar space.

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Abstracts

The Immediate Environments of Two Herbig Be Stars: MWC 1080 and HD 259431

Dan Li[1], Naibí Mariñas[1] and Charles M. Telesco[1]

[1] Department of Astronomy, University of Florida

Deep mid-infrared (10-20 μm) images with sub-arcsec resolution were obtained for two Herbig Be stars, MWC 1080 and HD 259431, to probe their immediate environments. Our goal is to understand the origin of the diffuse nebulosities observed around these two very young objects. By analyzing our new mid-IR images and comparing them to published data at other wavelengths, we demonstrate that the well extended emission around MWC 1080 traces neither a disk nor an envelope, but rather the surfaces of a cavity created by the outflow from MWC 1080A, the primary star of the MWC 1080 system. In the N-band images, the filamentary nebulosities trace the hourglass-shaped gas cavity wall out to $\sim$0.15 pc. This scenario reconciles the properties of the MWC 1080 system revealed by a wide range of observations. Our finding confirms that the environment around MWC 1080, where a small cluster is forming, is strongly affected by the outflow from the central Herbig Be star. Similarities observed between the two subjects of this study suggest that the filamentary emission around HD 259431 may arise from a similar outflow cavity structure, too.

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The Astrophysical Journal, 796, 74 (2014)

http://stacks.iop.org/0004-637X/796/74

Properties of Polycyclic Aromatic Hydrocarbons in the Northwest Photon Dominated Region of NGC 7023. II. Tradiational PAH Analysis Using k-Means as a Visualisation Tool

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Polycyclic aromatic hydrocarbon (PAH) emission in the Spitzer-IRS spectral map of the northwest photon dominated region (PDR) in NGC 7023 is analyzed using the ”traditional” approach in which the PAH bands and plateaus between 5.2 - 19.5 μm are isolated by subtracting the

underlying continuum and removing H_2 emission lines. The spectra are organized into seven spectroscopic bins by using k-means clustering. Each cluster corresponds to, and reveals, a morphological zone within NGC 7023. The zones self-organize parallel to the well-defined PDR front that coincides with an increase in intensity of the H_2 emission lines. PAH band profiles and integrated strengths are measured, classified, and mapped. The morphological zones revealed by the k-means clustering provides deeper insight into the conditions that drive variations in band strength ratios and evolution of the PAH population that otherwise would be lost. For example, certain band-band relations are bifurcated, revealing two limiting cases; one associated with the PDR, the other with the diffuse medium. Traditionally, PAH band strength ratios are used to gain insight into the properties of the emitting PAH population, i.e., charge, size, structure, and composition. Insights inferred from this work are compared and contrasted to those from Boersma et al. (first paper in this series), where the PAH emission in NGC 7023 is decomposed exclusively using the PAH spectra and tools made available through the NASA Ames PAH IR Spectroscopic Database.

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Visible Photodissociation Spectra of the 1- and 2- Methylnaphthalene Cations: Laser Spectroscopy and Theoretical Simulations

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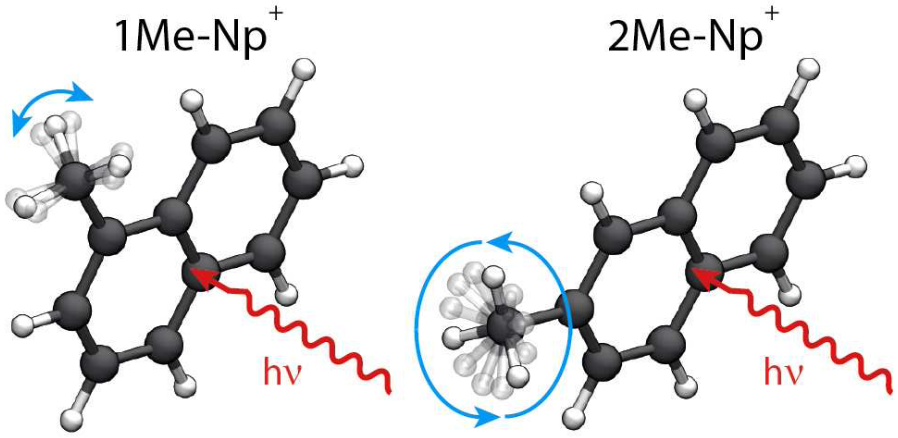
The electronic absorption spectra of the two methyl derivatives of the naphthalene cation were measured using an argon tagging technique. In both cases, a band system was observed in the visible range and assigned to the $D_2 \leftarrow D_0$ electronic transition. The 1-methylnaphthalene$^+$ absorption bands revealed a red shift of 808 cm^{-1}, relative to those of the naphthalene cation (14 906 cm^{-1}), whereas for 2-methylnaphthalene$^+$ a blue shift of 226 cm^{-1} appeared. A short vibrational progression, similar to the naphthalene cation, was also observed for both isomers and found to involve similar aromatic ring skeleton vibrations. Moreover, insights into the internal rotation motion of the methyl group were inferred, although the spectral resolution was not sufficient to fully resolve the substructure. These measurements were supported by detailed quantum chemical calculations. They allowed exploration of the potential energy curves along this internal coordinate, along with a complete simulation of the harmonic Franck-Condon factors using the cumulant Gaussian fluctuations formalism extended to include the internal rotation.



Sketch of the main result of this paper. Once the photon is absorbed, 1-methylnaphthalene$^+$ and 2-methylnaphthalene$^+$ show different internal rotation motions of the methyl group.

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Photoionization of cold gas phase coronene and its clusters: Autoionization resonances in monomer, dimer, and trimer and electronic structure of monomer cation

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Polycyclic aromatic hydrocarbons (PAHs) are key species encountered in a large variety of environments such as the Interstellar Medium (ISM) and in combustion media. Their UV spectroscopy and photodynamics in neutral and cationic forms are important to investigate in order to learn about their structure, formation mechanisms, and reactivity. Here, we report an experimental photoelectron-photoion coincidence study of a prototypical PAH molecule, coronene, and its small clusters, in a molecular beam using the vacuum ultraviolet (VUV) photons provided by the SOLEIL synchrotron facility. Mass-selected high resolution threshold photoelectron (TPES) and total ion yield spectra were obtained and analyzed in detail. Intense series of autoionizing resonances have been characterized as originating from the monomer, dimer, and trimer neutral species, which may be used as spectral fingerprints for their detection in the

ISM by VUV absorption spectroscopy. Finally, a full description of the electronic structure of the monomer cation was made and discussed in detail in relation to previous spectroscopic optical absorption data. Tentative vibrational assignments in the near-threshold TPES spectrum of the monomer have been made with the support of a theoretical approach based on density functional theory.

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R2PI Spectroscopy of Aromatic Molecules Produced in an Ethylene-Rich Flame

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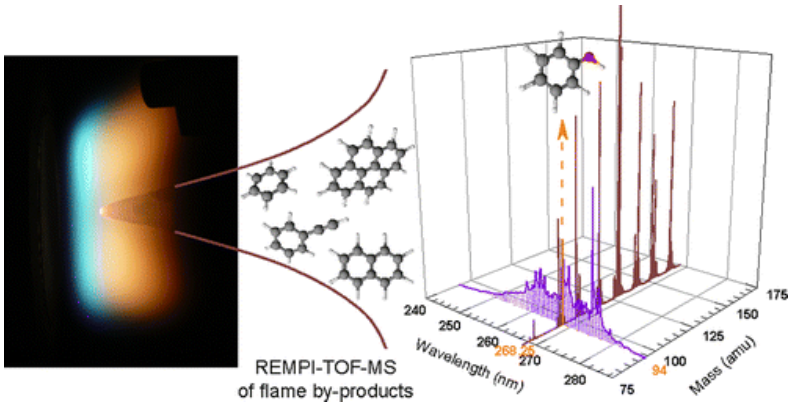

Mass spectrum of PAH molecules produced in an ethylene-rich flat flame.

Laser spectroscopy, combined with mass spectrometry, was applied to study the spectra of aromatic molecules produced in a premixed ethylene-rich flat flame. These studies produce new gas-phase electronic spectra of polyaromatic compounds, which ultimately will guide the understanding of the chemical processes that lead to polycyclic aromatic hydrocarbon (PAH) growth or PAH formation locking. Resonant two-photon ionization (R2PI) spectra of all species detectable in a specific fuel-rich flame were recorded simultaneously during a single scan of the laser wavelength, within the 220-330 nm range. Comparison with spectra available in the

literature allowed us to identify 16 aromatic species. In the PAH forming region of this flame, we found that the main PAHs are accompanied by a great diversity of other species, including in particular various side-chains on aromatic networks. We also show that this technique allows, at least in some cases, to distinguish between different isomers associated with the same mass peak, although the extracted PAHs are only cooled down to room temperature.

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Planar hexagonal B_{36} as a potential basis for extended single-atom layer boron sheets

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Boron is carbons neighbour in the periodic table and has similar valence orbitals. However, boron cannot form graphene-like structures with a honeycomb hexagonal framework because of its electron deficiency. Computational studies suggest that extended boron sheets with partially filled hexagonal holes are stable; however, there has been no experimental evidence for such atom-thin boron nanostructures. Here, we show experimentally and theoretically that B_{36} is a highly stable quasiplanar boron cluster with a central hexagonal hole, providing the first experimental evidence that single-atom layer boron sheets with hexagonal vacancies are potentially viable. Photoelectron spectroscopy of B_{36}^- reveals a relatively simple spectrum, suggesting a symmetric cluster. Global minimum searches for B_{36}^- lead to a quasiplanar structure with a central hexagonal hole. Neutral B_{36} is the smallest boron cluster to have sixfold symmetry and a perfect hexagonal vacancy, and it can be viewed as a potential basis for extended two-dimensional boron sheets.

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http://www.nature.com/ncomms/2014/140120/ncomms4113/full/ncomms4113.html

Quasi-planar aromatic B_{36} and B_{36}^- clusters: all-boron analogues of coronene

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Flat boron has recently emerged as a fascinating concept in cluster science. Here we present computational evidence for the quasi-planar all-boron aromatic B_{36} (C_{6v}, $^1A_1$) and B_{36}^- (C_{2v}, $^2A_1$) clusters, established as the global-minimum structures on the basis of Stochastic Surface Walking (SSW) searches. The energetics for low-lying isomeric structures are evaluated using the validated density-functional method at the PBE0/6-311+G* level. Our global-minimum structures are in line with a recent report (Z. A. Piazza et al., Nat. Commun., 2014, 5, 3113). These structures consist of two-dimensional close-packing boron with a perfect hexagonal hole at the center, which may serve as molecular models for the monolayer boron α sheet. Chemical bonding analysis indicates that B_{36} and B_{36}^- are all-boron analogues of coronene ($C_{24}H_{12}$), featuring concentric dual π aromaticity with an inner π sextet and an outer π sextet. The hydrogenated $B_{36}H_6$ (C_{6v}, $^1A_1$) model cluster shows similar bonding properties, which possesses concentric triple aromaticity with inner π, outer π, and outer σ sextets.

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http://pubs.rsc.org/en/Content/ArticleLanding/2014/CP/C4CP02032D#!divAbstract

Observation of an all-boron fullerene

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After the discovery of fullerene-C_{60}, it took almost two decades for the possibility of boron-based fullerene structures to be considered. So far, there has been no experimental evidence for these nanostructures, in spite of the progress made in theoretical investigations of their structure and bonding. Here we report the observation, by photoelectron spectroscopy, of an all-boron fullerene-like cage cluster at B_{40}^- with an extremely low electron-binding energy. Theoretical calculations show that this arises from a cage structure with a large energy gap, but that

a quasi-planar isomer of B_{40}^- with two adjacent hexagonal holes is slightly more stable than the fullerene structure. In contrast, for neutral B_{40} the fullerene-like cage is calculated to be the most stable structure. The surface of the all-boron fullerene, bonded uniformly via delocalized σ and μ bonds, is not perfectly smooth and exhibits unusual heptagonal faces, in contrast to C_{60} fullerene.

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http://www.nature.com/nchem/journal/v6/n8/full/nchem.1999.html#affil-auth

FINAL CALL FOR CONTRIBUTED TALKS
Second Workshop on Experimental Laboratory Astrophysics

Kauai, Hawaii – February 23-26, 2015

Contributed talks and poster presentations are invited for the 'Second Workshop on Experimental Laboratory Astrophysics' in Poipu, Kauai, Hawaii, February 23-26, 2015. During the last decade, significant new experimental techniques have been developed to investigate the interaction of ionizing radiation (UV, VUV, gamma rays, charged particles) and of neutrals (atoms, radicals, molecules, grains) with surfaces of solids (ices, minerals, carbonaceous compounds) in the Solar System and in the Interstellar Medium (ISM). These processes provide new fundamental insights – sometimes on the molecular level – into the processes that are critical to the chemistry in the ISM, star and planet forming regions, and on/in icy objects in the Solar System from the formation of the simplest molecule (molecular hydrogen) to astrobiologically important species such as amino acids and sugars.

Accommodation: The workshop will take place in the Sheraton Kauai Resort in Poipu, Kauai, Hawaii, starting with a reception and registration on February 22, 2015, at 6 pm (Sunday). The hotel will allocate a block of rooms for workshop participants. Reservations must be made by December 1, 2014. Group rates are available three days pre and post group arrival and departure dates.

Transportation: Sheraton Kauai Resort is a short drive (20 minutes) from the airport (LIH). LIH can be reached from LAX, SFO, or HNL.

Registration: The registration and abstract deadlines are December 1, 2014. The registration fee of USD 350 includes the reception, snacks, and a book-of-abstracts; the late registration fee after December 1, 2014, is USD 600. No refunds will be given after December 1, 2014.

Further information with links to registration, confirmed invited speakers, and room reservations can be found at:

http://www.chem.hawaii.edu/Bil301/Ice2015.html

The Organizers:

Brant Jones, University of Hawaii
Murthy Gudipati, JPL
Mark Loeffler, NASA Goddard
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FIRST ANNOUNCEMENT
Bridging Laboratory Astrophysics and Astronomy
A Focus Meeting within the IAU XXIX General Assembly

3 to 5 August 2015

Honolulu Convention Center, Honolulu, Hawaii, USA

Laboratory astrophysics is the Rosetta stone that enables astronomers to understand and interpret the cosmos. This Focus Meeting will discuss the strong interplay between astronomy and astrophysics with theoretical and experimental studies into the underlying processes that drive our Universe. These processes involve atoms, molecules, dust and ices, plasmas, planetary science, and nuclear and particle physics.

The IAU Commission 14 (Atomic and Molecular Data) and the Laboratory Astrophysics Division of the American Astronomical Society (AAS LAD) have coordinated their efforts for a joint meeting at the next GA in the form of a Focus Meeting to help bridge Laboratory Astrophysics and Astrochemistry with Astronomy by bringing together expert data providers and data users of laboratory and astronomical data. This is a truly multidisciplinary meeting that will bring together astronomers with theoretical and experimental chemists and physicists to discuss the state-of-the-art research in their respective disciplines and how their combined expertise can address important open questions in astronomy and astrophysics.

The program will consist of invited review talks by leading astronomers and laboratory astrophysicists at the forefront of the field, invited and contributed topical talks and posters that will provide opportunities for the presentation of new scientific developments, and discussion. For more information, see the website:

http://astronomy2015.org/focus_meeting_12

Interested scientists can register, submit abstracts, arrange lodging and logistics through the IAU General Assembly website:

http://astronomy2015.org .

Early registration is open until 1 Dec 2015.

We look forward to a productive cross-disciplinary exchange of ideas and hope to see many of you there. Farid Salama, Lyudmila Mashonkina and Steve Federman on behalf of the SOC

SOC:

Martin Asplund, Australian National University, Australia
Beatriz Barbuy, University of Sao Paulo, Brazil
Paul Drake, University of Michigan, USA
Steven Federman, University of Toledo, USA
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Harold Linnartz, Leiden Observatory, The Netherlands
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Next issue: 16 December 2014
Submission deadline: 5 December 2014