

VUV photo processing of large cationic PAHs in astrophysical conditions: coupling a VUV source to the PIRENEA setup

Anthony Bonnamy, Alexandre Marciniak, Gabi Wenzel, Sébastien Zamith, Sabela Quiroga, Diego Peña, Giacomo Mulas, Christine Joblin

▶ To cite this version:

Anthony Bonnamy, Alexandre Marciniak, Gabi Wenzel, Sébastien Zamith, Sabela Quiroga, et al.. VUV photo processing of large cationic PAHs in astrophysical conditions: coupling a VUV source to the PIRENEA setup. GdR EMIE, Oct 2020, Ile d'Oléron, France. hal-03017838

HAL Id: hal-03017838

https://hal.science/hal-03017838

Submitted on 21 Nov 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



VUV photo-processing of large cationic PAHs in astrophysical conditions: coupling a VUV source to the PIRENEA setup



A, Marciniak^{1,†}, A, Bonnamy¹, G, Wenzel¹, S, Zamith², S. Quiroga³, D. Peña³, G. Mulas⁴ and C. Joblin¹

¹ IRAP, Université de Toulouse (UPS), CNRS, CNES, Toulouse, France ² LCAR/IRSAMC, Université de Toulouse (UPS), CNRS, Toulouse, France

³ Centro de Investigación en Química Biolóxica e Materiais Moleculares (CiQUS) and Departamento de Química Orgánica, Universidade de Santiago de Compostela, E-15782 Santiago de Compostela, Spain ⁴ Istituto Nazionale di Astrofisica – Osservatorio Astronomico di Cagliari, Via della Scienza 5, I-09047 Selargius (CA), Italy

† Correspondence to : alexandre.marciniak@irap.omp.eu

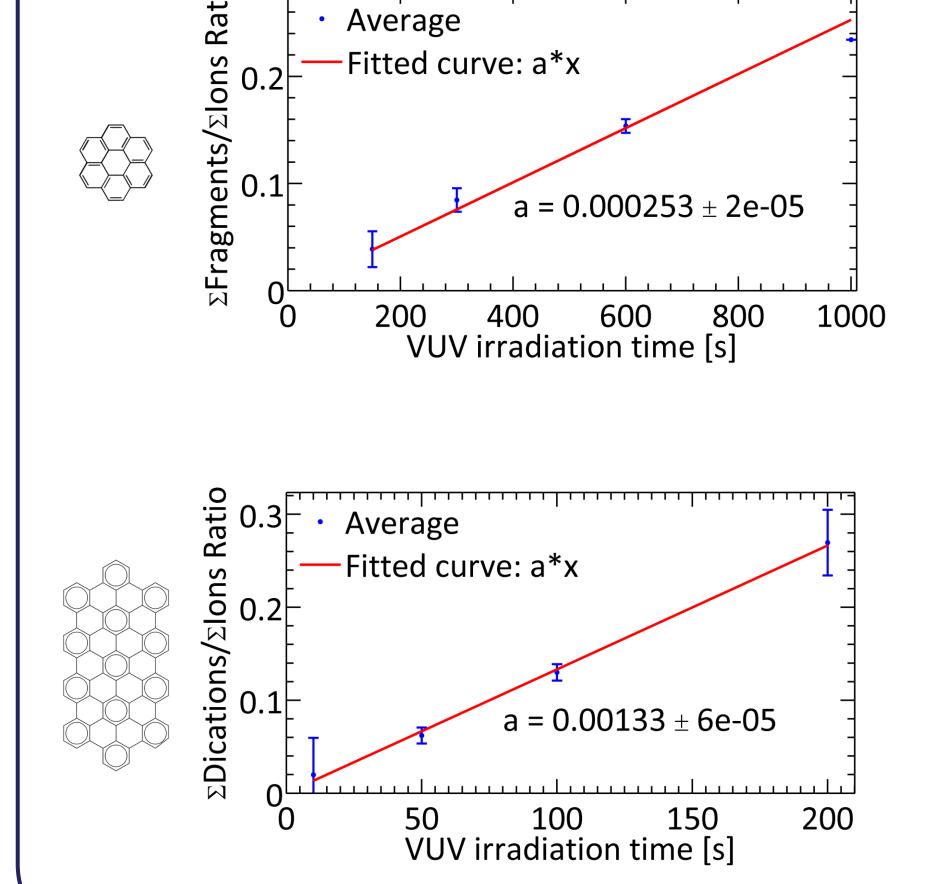
Abstract

Studying the interaction of polycyclic aromatic hydrocarbons (PAHs) with UV and VUV light is crucial for the understanding of the physical and chemical evolution of the interstellar medium. Photoprocessing by VUV irradiation leads to variation of the hydrogenation and ionization states of PAHs [1] and plays an important role in the heating of the gas [2]. Recent laboratory studies have shown that the VUV photoexcitation of large PAHs rather induces further ionization [3,4] and, more surprisingly, it can also induce non-statistical dissociation [5]. We have recently coupled a VUV source based on a Xe-Ar tripling cell to the PIRENEA (Piège à Ions pour la Recherche et l'Etude de Nouvelles Espèces Astrochimiques) setup which consists of a cryogenic (35 K) ion cyclotron resonance cell that is especially well suited to investigate ionization on long timescales [1,5]. The produced VUV photons (10.5 eV) are sufficiently energetic to trigger dissociation in small/medium-size PAHs [6] and ionization in large PAH cations [4]. We present first measurements of VUV processing of several PAHs in a cryogenic and collisionless environment which is appropriate for interstellar conditions.

Experimental Method: VUV photo-processing of isolated PAH molecules Xe only $P_{-}P_{UV} = 100 \text{ mW}$ ICR cell Superconducting $(\sim 10^{-11} - 10^{-10} \text{ mbar},$ Ablation laser Cryogenic magnet ~35 K, storage over (266 nm) shields **Differential** several minutes) Coronene-coated pumping end window Sample $(\sim 10^{-8} \text{ mbar})$ 300 400 UV beam-blocker target P_{tot} [Torr] Port aligner Valve Xenon:Argon tripling cell MgF₂ lens ~2 mm $(\sim 250 \text{ mbar})$ Parent UV pulse, (355 nm, $\vec{B}_0 = 5 \text{ T}$ ~10 mJ, 6 ns @ 10 Hz) VUV beam, 118 nm $(\sim 10^{11} \text{ photons.s}^{-1} @ 10.5 \text{ eV})$ **Cation production VUV** Generation Photo-physics in a collisionless environment **High-resolution mass spectrometry (FT-ICR-MS)** Cationic coronene (C₂₄H₁₂+) VUV irradiation (1000 sec) C₇₈H₂₆⁺ VUV irradiation (400 sec) C₇₈H⁺₂₆ -VUV on $C_{24}H_{12}^{+}$ ─VUV on VUV off -VUV off $C_{78}H_{26}^{2+}$ unit.) 0.6^{-} 0.6^{-} (arb. (arb) 0.4^{-} 0.4^{-} 0.2-0.2-476 478 480 482 484 299 300 ➤ Only fragments [Cor-H]⁺ and sequentially [Cor-2H]⁺ > Only dications with the same initial distribution of isotopes and fragments

Preliminary results

Study as a function of the VUV irradiation time



Implications in VUV photo-processing of PAHs

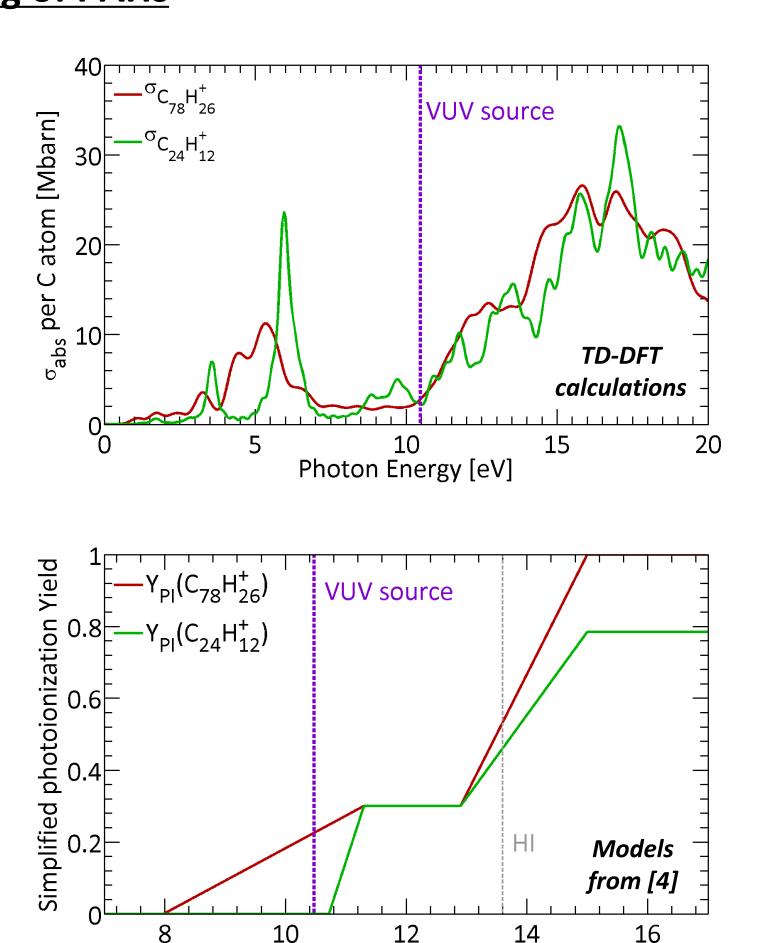
- The measured photo-products formation rate of C₇₈H₂₆⁺ is **5.25 times** larger than the one of $C_{24}H_{12}^+$.
- The absolute VUV photo-absorption cross-section of $C_{78}H_{26}^{+}$ is about **3.25 times** larger than the one of $C_{24}H_{12}$ + (ratio of C atom number).
- A simple model for the photo-ionization yield of large PAH has been derived from measurements in a previous study [4]: \sim **0.23** at 10.5 eV for C₇₈H₂₆⁺.

$$\text{Absorbed photons per second} = \begin{cases} \sigma_{abs}(C_{24}H_{12}^+) \times \varphi_{VUV} = \frac{a(C_{24}H_{12}^+)}{Y_{diss.}(C_{24}H_{12}^+)} \\ \sigma_{abs}(C_{78}H_{26}^+) \times \varphi_{VUV} = \frac{a(C_{78}H_{26}^+)}{Y_{ion.}(C_{78}H_{26}^+)} \end{cases}$$

if ϕ_{VUV} is constant

$$\Rightarrow Y_{\text{diss.}}(C_{24}H_{12}^+) \approx \frac{a(C_{24}H_{12}^+)}{a(C_{78}H_{26}^+)} \times \frac{\sigma_{\text{abs}}(C_{78}H_{26}^+)}{\sigma_{\text{abs}}(C_{24}H_{12}^+)} \times Y_{\text{ion.}}(C_{78}H_{26}^+) \approx 0.14$$

- > The retrieved dissociation yield at a VUV energy close to the threshold is consistent with the results found by Zhen and coworkers [6].
- > This shows that a large fraction of the 10.5 eV photons absorbed by C24H12+ are relaxed by radiative cooling.



Photon energy [eV]

Perspectives

- Calibration to determine robust values of the dissociation yield combining experiments on smaller PAHs.
- Molecular systems from strongly dissociative to intermediate case where dissociation and ionization are in competition.
- VUV photo-chemistry by molecular gas injection.

Bibliography

- [1] J. Montillaud, C. Joblin and D. Toublanc, A&A, 552, A15 (2013) [2] E. L. O. Bakes and A. G. G. M. Tielens, ApJ, 427, 822 (1994)
- [3] J. Zhen, P. Castellanos, D. M. Paardekooper et al., ApJL, 804:L7 (2015)
- [4] G. Wenzel, C. Joblin, A. Giuliani et al., A&A, 641, A98 (2020)
- [5] C. Joblin, G. Wenzel, S. Rodriguez Castillo et al., J. Phys. Conf. Ser., 1412, 062002 (2020)

