



## Photoionization of Polycyclic Aromatic Hydrocarbons: contribution to the heating of the Interstellar Medium

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### The Aromatic Infrared emission Bands (1984) : The AIBs

ISO spectrum of NGC7023 D.Cesarsky et al. 1996

- Stochastic heating of carriers: N<sub>C</sub>~50; T~1000 K Sellgren (1984), ApJ 277, 623
- Candidates : The PAH molecules - Léger & Puget 1984, A&A 137, L5 - Allamandola et al 1985, ApJ 290, L25
- > 10 to 20% of total carbon in PAHs  $X_{PAH} \sim 10^{-7} (N_C \sim 50)$



Detailed IR spectrocopy revealed the presence of PAHs Cations



Fig. 1. Photoionization cross-sections per C atom in  $M_b$  for coronene (solid line) and pyrene (dashed-line)



What are the implications of the presence of such PAHs cations in ISM?

- The VUV starlight from surrounding stars is at work on PAHs, in particular in the case of reflexion nebulae.
- The VUV light from «hot» stars (T~10 000 to 50 000 Kelvin), globally known as the ISRF (InterStellar Radiation Field), provides the adequate photons for ionizing the neutral PAHs.
- Consequently, phoelectrons (fast or not) are created, which can contribute to heat the surrounding medium by collisions: Very old question:

Watson 1972, Jura 1976, Draine 1972, Bakes & Tielenns 1994

• Their Kinetic Energy release distribution is important for astrophysicists in order to model the local conditions from observed interstellar objects.

# What is known about the kinetic energy (KE) of the photoelectrons ejected from PAHs?

- It is assumed by astronomers (since the 1990's) to be given by an empirical law, giving the partition function of the photoelectron kinetic energy g(Nc, IP) as a parabolic function centered on:
  g(Nc, IP) = ½[(hv –IP)/hv] [Nc being the number of C atoms]
- The distribution of KE values (expected between 0 and hv-IP) for a series of photoionization events is just estimated, but not measured nor calculated.

This situation motivated an extensive experimental program at SOLEIL Synchrotron facility, the results of which are the main goal of this presentation.





#### The Set-up at the SOLEIL Synchrotron



#### **DESIRS VUV Beamline, SAPHIRS**





**DELICIOUS III** 





Description of the set-up performances: G. Garcia et al., RSI, <u>80</u>, 023102 (2009)

## Adjustment of the skimmer position



## Our selection of « Astro-PAHs »











С14H10 C16H10 C20H12 C15H12 C15H12 C15H12 Phenanthrene Fluoranthene Perylene 3-methylphenanthren 4methylphen

#### All IP's are found between 7 and 7.8 eV



## Slow Photo-Electron Spectra (similar to TPES)

 $SPES(hv) = \int_{0}^{KE} A(energy + KE, KE) dKE,$ where A(energy, KE) is the 2D matrix

and  $KE_{max}$  is the selected upper kinetic energy, here 500 meV for most of the PAHs and 50 meV for 3 selected PAHs. In practice the steps in photon energy were also of 0.5 or 0.05 eV (more density of points but same resolution)









#### Slow PhotoElectron Spectrum







Slow PhotoElectron Spectrum

Full dehydrogenation of the CH3 substituant occurs by successive H-losses, which appear clearly from 5, 9 and 11 eV above IP







#### Slow PhotoElectron Spectrum



## Total Ion Yields (PEPICO)



### **Great similarity** between the various PAHs

Results in agreement with previous studies, like Jochims et al (1997), including Coronene C24H12. Peak values in between 17 and 18 eV



## Total Ion Yields (case of fine scans)







# The Kinetic Energy Release Distribution (KERD)

Analysis of the kinetic energy carried out by the ejected photoelectrons :

It is one of the direct outcomes of the SOLEIL photoelectron-photoion coincidence set-up

The distribution peaks very close to 5 eV, and vanishes near 15 eV.















# SUMMARY



- T-PEPICO measurements using the DELICIOUS3 spectrometer mounted on the SAPHIRS set-up installed on the DESIRS beamline at SOLEIL have been done (including participants from IAS).
- The slow photoelectron spectra (SPES) of the whole series of PAHs have revealed the rich vibronic structures of the relevant cations excited states, as well as the appearance energies for de-hydrogenation (H-loss) dissociative ionization channels. The vibronic structures of the corresponding product species, have also been properly characterized.
- Quantitative experimental study of the KE distribution for a series of PAHs of different sizes and shapes, including non planarity and aliphatic branching has been achieved.



# CONCLUSION



- We confirm that the total VUV ionization yield (TIY) reaches a maximum, in agreement with the VUV absorption peak, which remains close to 18-20 eV for the parent PAHs.
- A convergence of the different PAHs photoelectrons KERD's has been demonstrated.
- Considering any possibility of addition of the main findings in the current computer codes in use by the ISM astrophysical community is now possible.

