

Cooling dynamics of nitrogen-containing PAH cations (PANHs)

S. Indrajith¹, J. E. Navarro Navarrete¹, P. Martini¹, M. C. Ji¹, M.H. Stockett¹, M. Gatchell¹,
H. Cederquist¹, H. T. Schmidt¹, and H. Zettergren¹

¹Department of Physics, Stockholm University, 114 21, Stockholm, Sweden
suvasthika.indrajith@fysik.su.se

Polycyclic aromatic hydrocarbons (PAHs) are a class of organic molecules based on two or more fused aromatic rings, with hexagonal rings as typical dominant constituents. They are found and formed in a wide variety of environments. In the case of extraterrestrial environments, PAHs are believed to be an important component in interstellar dust and gas and as such are responsible for infrared emission features that dominate the spectra of many galactic and extragalactic sources [1]. Numerous experimental and theoretical studies on PAHs have been carried out in the past decades, but how they may survive in space is still not fully understood [2].

PAHs that contain one or more nitrogen atoms are so-called polycyclic aromatic nitrogen heterocycles (PANHs). The existence of PANHs in space has been inferred by their detection in meteorites [3], and they may be present in the haze surrounding Saturn's largest moon Titan [4]. Their presence in astrophysical environments is further supported by the recent discoveries of two interstellar nitrile group functionalized PAH molecules (1- and 2- cyanonaphthalene) [5] and one of the simplest nitrogen-bearing aromatic molecules (benzotrile: $c\text{-C}_6\text{H}_5\text{CN}$) [6] in the TMC-1 molecular cloud. One key issue is the cooling dynamics of such molecules, which affects their abundances in the ISM [7].

The ultra-high vacuum and low-temperature environment provided by the DESIREE ion-beam storage ring facility [8] is ideal for following ultraslow molecular relaxation processes of astrophysical interest on timescales exceeding seconds, where fragmentation, recurrent fluorescence, and IR emission compete. In this talk, I will present such studies of PAH molecules with a focus on the spontaneous and laser-induced decays of acridine ($\text{C}_{13}\text{H}_9\text{N}$) and phenazine ($\text{C}_{12}\text{H}_8\text{N}_2$) cations. Both molecules are members of the PANH family and consist of three planar aromatic rings but differ in that a C–H groups in the central anthracene ring have been replaced by one N to form acridine or two N to form phenazine. Fig.1 shows examples of the spontaneous decays of hot acridine and phenazine cations as monitored through the yields of neutrals due to unimolecular dissociation products as functions of ion beam storage time. These curves provide information on the characteristic radiative cooling times for which the decays are quenched, which together with results using laser probing techniques allow following the cooling dynamics in unprecedented detail.

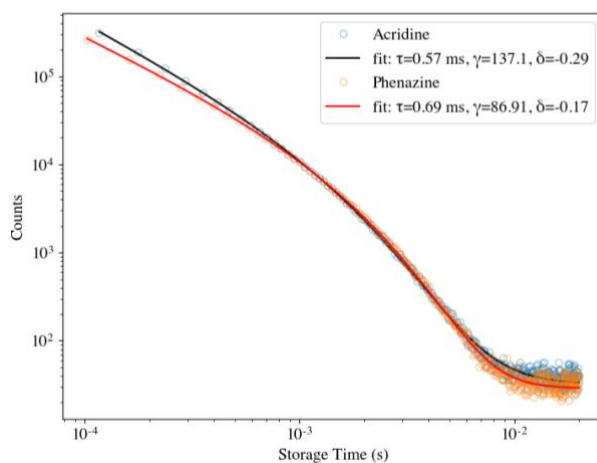


Figure 1: Spontaneous decay of acridine and phenazine cations as a function of storage time.

References:

- [1] A. G. G. M. Tielens, *Ann. Rev. Astron. Astrophys.* 46, 289 (2008) [2] C. Joblin and A. G. G. M. Tielens, *EAS, EDP Sciences* (2011) [3] P. G. Stoks and A. W. Schwartz, *Geochim. Cosmochim. Acta* 45, 563 (1981) [4] H. Imanaka, *Icarus* 168, 344 (2004) [5] McGuire et al., *Science* 371, 1265–1269 (2021) [6] McGuire et al., *Science* 359, 202–205 (2018) [7] J. Montillaud, C. Joblin, and D. Toubanc, *A&A* 552, A15 (2013) [8] [1] R. D. Thomas *et al.*, *Rev. Sci. Instrum.*, 82(6):065112, 2011.