On Graphene in Space

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ABSTRACT

The 217.5nm interstellar extinction bump, the most prominent spectroscopic absorption feature in the interstellar extinction curve, remains unidentified since its first detection in 1965 (Stecher 1965, ApJ, 142, 1681). It was originally attributed to graphite (Stecher & Donn, ApJ, 1965, 142, 1683). But graphite fails to simultaneously account for both the stability of the central wavelength of the bump and the variation of the bump width. More recently, polycyclic aromatic hydrocarbon (PAH) molecules have been suggested as a candidate (Joblin et al. 1992, ApJ, 393, L89; Li & Draine 2001, ApJ, 554, 778; Steglich et al. 2011, ApJ, 712, L16). Although PAHs do have a strong absorption band around 200nm due to the pi-pi* electronic transition, individual PAHs also show other sharp absorption features which are not observed in the interstellar medium (ISM).

Recently, the detection of C_{24} (a planar graphene) was reported in planetary nebulae (García-Hernández et al. 2011, ApJ, 737, L30). This discovery inspires us to explore whether and how much graphene would exist in the ISM and how it reveals its presence through its ultraviolet (UV) extinction and infrared (IR) emission. We examine graphene as a potential candidate for the mysterious 217.5nm extinction bump. Graphene could arise from PAHs through a complete loss of their H atoms (Berné & Tielens, 2012, PNAS, 109, 401) or from graphite through fragmentation (grain-grain shattering). Both quantum-chemical computations and laboratory experiments have shown that the pi-pi* electronic transitions cause a strong absorption band near 217.5nm (Trevisanutto et al. 2010, Phys. Rev. B, 81, 121405; Nelson, et al. 2010, Appl. Phys. Lett., 97, 253110). We calculate the UV absorption of graphene and place an upper limit of ~7 ppm of C/H on the interstellar graphene abundance. We also model the vibrational excitation of graphene in the ISM. Graphene is stochastically heated by single photons and undergoes temperature fluctuation in the ISM. We calculate its IR emission spectra following its vibrational excitation and radiative relaxation. We also derive the abundance of graphene in the ISM by comparing the model emission spectra with that observed in the ISM.