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Editorial: Planetary nebulae as tools for astrophysics

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Editorial on the Research Topic
Planetary nebulae as tools for astrophysics

Planetary nebulae (PNe) represent the ejected outer layers of an evolved low-to-intermediate mass star, and consist of ionized, neutral, and molecular components, along with dust. In total, the nebular material contains the stellar envelope that was ejected during the asymptotic-giant branch (AGB) phase or through binary interactions with a companion. The PN central star is formed by the former core of the AGB or red-giant branch progenitor of the PN, which is now contracting towards the white dwarf phase. The PN central star is a post-AGB object which has evolved crossing the Hertzsprung-Russell diagram, and has an effective temperature of 28,000 K up to more than 250,000 K. It emits a large fraction of its light as UV photons that ionize the envelope. PNe are mainly studied through imaging, photometry and low- and high-resolution spectroscopy techniques which allow determination of the physical conditions and chemical abundances in the nebula. Through this kind of analysis it is possible to study the physical processes in ionized plasmas, the evolution and characteristics of the central star, along with the mechanisms of ejection of the nebula and the evolution of the interstellar medium – in external galaxies as well as in the Milky Way – which will be enriched with elements produced in the stellar nucleosynthesis and brought to the stellar surface *via* several dredge-up episodes. Further, an accurate census of PNe provides an important constraint on a galaxy's star formation history. PNe are also useful in studying the kinematics of galaxies and their distances through the [O III] λ5007 Planetary Nebula Luminosity Function which is currently a secondary standard candle out to 20 Mpc.

The aim of this Research Topic is to present up-to-date articles from leading researchers on several of the above-mentioned areas of PNe studies; these are summarized below.

In his Review, Parker reviews basic PN properties and enumerates the challenges of compiling an accurate catalogue. He discusses the important contribution of multiwavelength searches in the infrared, radio, and x-ray, to finding previously undetected PNe, and then goes on to describe the HASH catalogue, an on-line SQL database and research platform containing more than 3,800 Milky Way Galaxy PNe and over 800 PNe in the Magellanic Clouds.

In their Mini-Review, Sabin et al. concentrate on the promise of the infrared spectral region for PN discovery, and its potential to reduce the discrepancy between expected and observed numbers of PNe. They describe the *IPHAS* survey as particularly fruitful, finding 781 compact PNe candidates, and 157 true, likely, and possible, extended PNe.

In his Review, López describes how studies of the internal kinematics of PNe offer important clues about mechanisms driving the observed collimated outflows and complex morphologies of PNe. The discovery of PN close-binary central stars that have undergone common-envelope ejection has provided a framework to investigate the fast bipolar outflows and equator-to-pole density contrasts that are often seen. López has also studied the mean expansion of PNe; results demonstrate a close correlation between the evolution of the ionized shell and the mass of the central star.

Kwok emphasizes the contributions of PNe to the next generations of stars and planets, with material containing atoms, molecules and both organic and inorganic solid particles. Molecules are formed prolifically by precursor AGB stars, and complex organics are then synthesized in their expanding circumstellar envelopes. The same kind of complex organic molecules are observed in carbonaceous chondrites in the solar system, signaling the possibility that these products of AGB/PN molecular synthesis might have found their way into the pre-solar nebula, and perhaps other proto-solar systems across the Galaxy, with implications for the prevalence of life.

In her Perspective, Dinerstein describes the importance of s-process trans-iron nuclides, the products of slow neutron addition, in demonstrating *in situ* enrichment by AGB stars. She recounts her successful identification of the 2.199 μm infrared PN emission line with a ground-term, fine-structure transition in twice-ionized krypton. Lines from many other s-process elements (e.g., selenium, germanium, rubidium, xenon) have become detectable with new generations of sensitive spectrometers on large telescopes, and continued progress is anticipated.

Stasińska et al.'s Original Research contribution describes how PNe (and post-PN central stars) have only relatively recently been recognized as sources of ionization in the diffuse interstellar medium of galaxies. They describe the concept of "retired" galaxies: those without current star formation, and whose observed ionization is provided by remnants of old stellar populations. The authors then present results incorporating new stellar evolutionary tracks into stellar population calculations, demonstrating how the ionizing flux evolves with the number and masses of PNe, which are themselves dependent on the age of the population.

In his Review, Ciardullo examines the history of the Planetary Nebula Luminosity Function as a standard candle. For several decades beginning in the 1980s, the PNLF was a forefront tool for determining extragalactic distances (despite the lack of a comprehensive underlying theory). But around a decade ago, use of the PNLF waned, due to method-related technical issues, among others. The technique, currently applicable to distances out to ~20 Mpc, is now on the rise again, thanks in part to the availability of integral-field instruments on large telescopes; distances out to ~40 Mpc are now achievable.

The reader of this compilation will come away with an appreciation of how planetary nebulae contribute to multiple research areas in astronomy, including stellar evolution, galactic chemical evolution, and cosmology.

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Author contributions

MP and KK drafted the text. MMB, CM, and MR commented on and edited the text.

Conflict of interest

Publisher's note