Ghostly and beautiful—"planetary nebulae" get more meaningful physical presence

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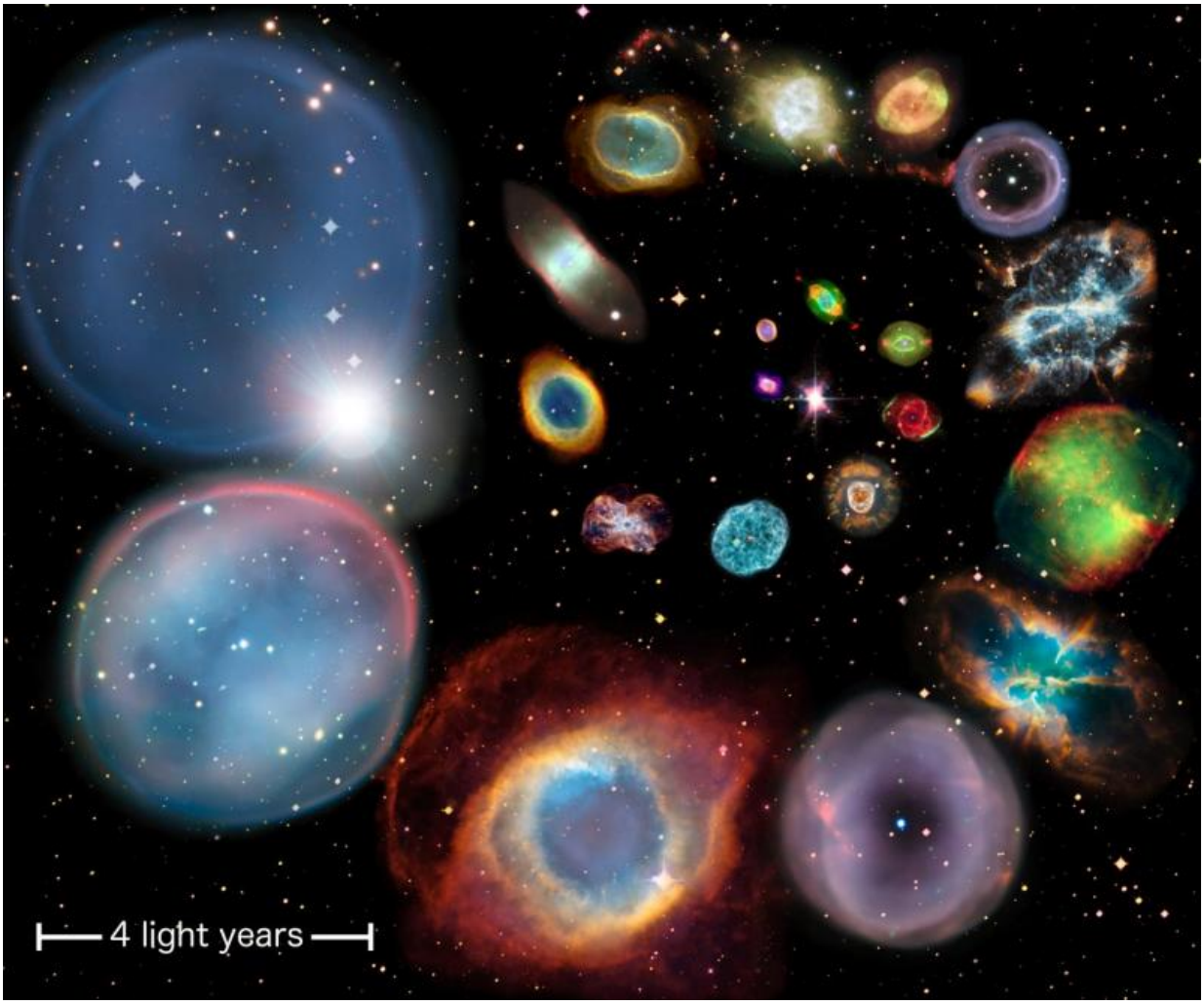


A collage showing 22 individual planetary nebulae artistically arranged in approximate order of physical size. The scale bar represents 4 light years. Each nebula's size is calculated from the authors' new distance scale, which is applicable to all nebulae across all shapes, sizes and brightnesses. The very

largest planetary nebula currently known is nearly 20 light years in diameter, and would cover the entire image at this scale. Credit: ESA/Hubble & NASA, ESO, Ivan Bojicic, David Frew, Quentin Parker

A way of estimating more accurate distances to the thousands of so-called planetary nebulae dispersed across our Galaxy has been announced by a team of three astronomers based at the University of Hong Kong: Dr David Frew, Prof Quentin Parker and Dr Ivan Bojicic. The scientists publish their results in *Monthly Notices of the Royal Astronomical Society*.

Despite their name, planetary nebulae have nothing to do with planets. They were described as such by early astronomers whose telescopes showed them as glowing disc-like objects.

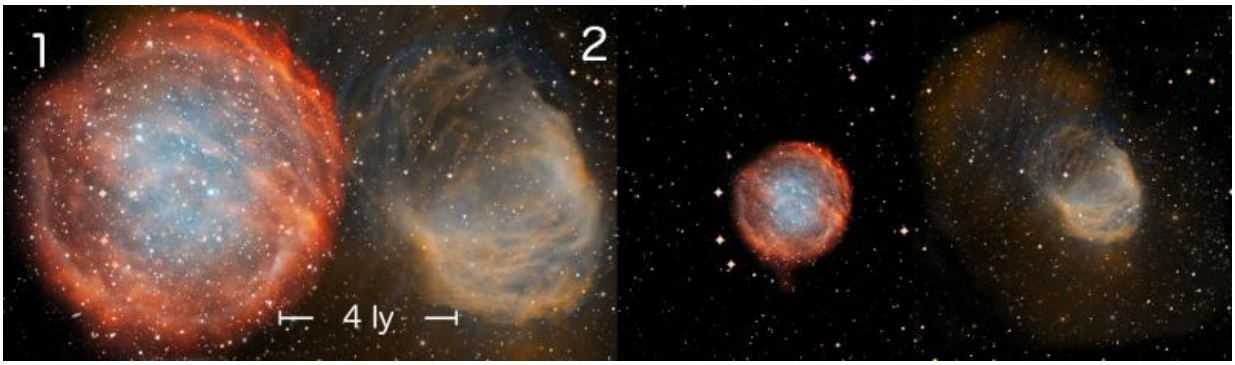
We now know that planetary nebulae are actually the final stage of activity of stars like our Sun. When they reach the end of their lives, these stars eject most of their atmosphere into space, leaving behind a hot dense core. Light from this core causes the expanding cloud of gas to glow in different colours as it slowly grows, fading away over tens of thousands of years.

There are thousands of planetary nebulae in our Galaxy alone, and they provide targets for professional and amateur astronomers alike, with the latter often taking spectacular images of these beautiful objects. But despite intense study, scientists have struggled to measure one of their key properties – their distance.

Dr Frew, lead author on the paper, said: "For many decades, measuring distances to Galactic planetary nebulae has been a serious, almost intractable problem because of the extremely diverse nature of the

nebulae themselves and their central stars. But finding those distances is crucial if we want to understand their true nature and physical properties."

The solution presented by the astronomers is both simple and elegant. Their method requires only an estimate of the dimming toward the object (caused by intervening interstellar gas and dust), the projected size of the object on the sky (taken from the latest high resolution surveys) and a measurement of how bright the object is (as obtained from the best modern imaging).



A comparison of the distance scales of two highly evolved nebulae, numbered (1) PuWe 1, (2) Abell 21. Previous distance scales were often inaccurate for the largest, most evolved planetary nebulae, which are the most common type in the Galaxy. The left panel shows the physical sizes of two nearby nebulae, presented at a common scale and using the authors' new calculations. The scale bar represents 4 light years. The right panel shows the physical sizes calculated from a commonly used older distance scale, which considerably underestimates the distances and hence sizes of these objects. Credit: NOAO/AURA/NSF, Ivan Bojicic, David Frew, Quentin Parker (HKU)

The resulting so-called 'surface-brightness relation' has been robustly

calibrated using more than 300 planetary nebulae whose accurate distances have been determined via independent and reliable means. Prof Parker explained that, "the basic technique is not new but what marks out this work from what has gone before is the use of the most up-to-date and reliable measurements of all three of those crucial properties".

This is combined with the use of the authors' own robust techniques to effectively remove "doppelgangers" and mimics that have seriously contaminated previous planetary nebulae catalogues and added considerable errors to other distance measurements.

The new approach works over a factor of several hundred thousand in surface brightness, and allows astronomers to measure the distances to planetary nebulae up to 5 times more accurately than previous methods. "Our new scale is the first to accurately determine distances for the very faintest planetaries" said Dr Frew. "Since the largest nebulae are the most common, getting their distances right is a crucial step".

Planetary nebulae are a fascinating if brief stage in the life of a low- to middle-weight star. Being able to better measure distances and hence the sizes of these objects will give scientists a far better insight into how these objects form and develop, and how stars as a whole evolve and die.

More information: D. J. Frew et al. The H surface brightness-radius relation: a robust statistical distance indicator for planetary nebulae, *Monthly Notices of the Royal Astronomical Society* (2015). DOI: 10.1093/mnras/stv1516

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