The first image of a new gaseous component in a planetary nebula

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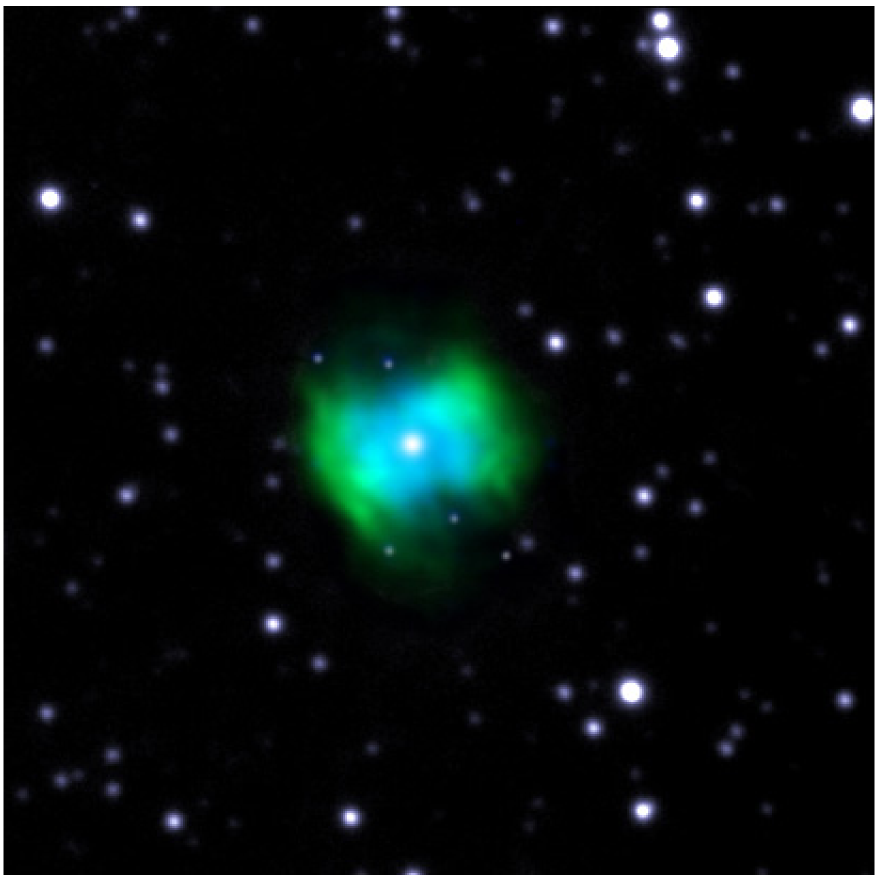

This is a false color image of the planetary nebula NGC 6778. In blue, the emission associated with weak lines of ion O++ recombination, taken with the OSIRIS tunable filter blue instrument in the GTC. In green, emission of the same ion in the excited lines by collisions, taken with the narrow filter [O III] of the Nordic Optical Telescope (NOT). The different spatial distribution of both emissions indicating the existence of two different gas components is clearly seen. Credit: Gran Telescopio CANARIAS (GTC).

After shining for many millions of years, stars end their lives, mainly, in two ways: very high mass stars die very violently as supernovae, while low mass stars end as planetary nebulae. In both cases they throw out into the interstellar medium the chemical elements synthesized in the interiors of the stars. For that reason, knowing the composition of this gas gives us information which is vital for understanding the chemical evolution of our Galaxy, and by extension, of the universe. Contributions to this have been made in images obtained by the Instituto de Astrofísica de Canarias and taken thanks to the tunable blue filter of the OSIRIS instrument on the Gran Telescopio CANARIAS (GTC) at the Roque de los Muchachos Observatory (Garafía, La Palma).

"The gas which forms the major part of the insterstellar medium", explains Jorge García Rojas, a researcher at the IAC who is the first author on the paper "can be observed because its atoms are ionized by the photons emitted by the hot stars embedded inside it (which can either very massive stars, or white dwarfs, which are also very hot). This makes the gas emit light over a range of wavelengths, including the visible, and depending on the atoms which make it up, we see different colours in the nebula.

Historically, the fractions (which we call the abundances) of the different atoms in the interstellar gas have been measured using the distinct spectral "footprint" of each ion in the spectrum, which is a characteristic set of spectral lines. There are basically two types of lines, those produced by collisions between the atoms or ions and the electrons in the surrounding gas, which are called collision lines, and which are very bright for elements such as oxygen, nitrogen and neon, and lines which are produced when ions capture free electrons, which are called recombination lines, and which are bright only for those gases with the highest abundances in the interstellar medium: hydrogen and helium.

"For more than 70 years", explains García Rojas "we have known that the weak recombination lines of the ions of elements, such as oxygen and carbon, give us values for their abundances which are much bigger than those obtained using collision lines, even though the collision lines are 1,000 to 100,000 times brighter than the recombination lines. This discrepancy has cast constant doubt about one of the methods which has been most used to measure chemical abundances in the universe".

The cause of this discrepancy is by no means clear, and since the 60's of the last century several different hypotheses have been proposed in attempts to resolve the problem but none has been able to explain the observational data in a satisfactory way. "One of the proposed scenarios", comments Romano Corradi, director of the GTC and another of the authors "is the presence of a component in the gas which is different from that which we normally find, poor in hydrogen and rich in heavier elements such as oxygen and carbon. This idea has been used to explain the observations of various objects, but the origin of this component of the gas is still a mystery".

"During the past few years our group", says David Jones, an astrophysicist at the IAC and another of the authors on the paper, "has discovered that the planetary nebulae with the biggest discrepancies in their abundances are usually associated with binary central stars which have been through a phase with a common envelope, that is to say the process of expansion of the more massive of the two stars has meant that the other star is orbiting within its outer atmosphere, and the viscosity has brought the stars very close to one another. Our study suggests that, at least for this type of stars, the evolution of the binary central object has caused the expulsion of a component of gas which is different from the main component".

To try to corroborate this theory, an image of the emission of a planetary nebula in the recombination lines of oxygen has been obtained with the GTC. These emissions are very weak, and to isolate them needs specialized instruments on large telescopes. The combination of a large telescope such as the GTC and an instrument with a tunable filter, such as OSIRIS has proved to be an ideal combination. "To do this", explains Antonio Cabrera Lavers, head of astronomy at the GTC and one of the authors of the paper, "we have used for the first time the blue tunable filter of OSIRIS to take a deep image centred on the emission from the recombination lines of one of the oxygen ions in the planetary nebula 6778".

"NGC6778", adds another of the authors, Hektor Monteiro, of the University fo Itajubá, Brazil, "is one of the planetary nebulae with the brightest recombination lines. We have found that the spatial distribution of this emission does not coincide with the spatial distribution of the bright collision lines. This result is very important because it is the first time that two different components of gas emitting lines due to the same ion have distinguished by direct imaging. The different dependence on temperature and density of the recombination lines and the collision lines allows us to infer that the metal rich component is a much colder and denser gas than the major fraction of the gas in the nebula.

"This result", concludes Pablo Rodriguez Gil of the IAC and the University of La Laguna, who is another author of the article "is further evidence of the importance of the evolution and the interaction of binary stars for the understanding of many aspects of astrophysics, including subjects which are apparently unrelated such as the chemical evolution of the universe".

More information: Jorge García-Rojas et al, IMAGING THE ELUSIVE H-POOR GAS IN THE HIGH adf PLANETARY NEBULA NGC 6778, *The Astrophysical Journal* (2016). DOI: 10.3847/2041-8205/824/2/L27 , arxiv.org/pdf/1606.02830v1.pdf

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