Highlights of Astronomy, Volume 15
XXVIIth IAU General Assembly, August 2009
Ian F. Corbett, ed.

doi:10.1017/S1743921310010677

SpS1-Infrared spectroscopy of post-AGB objects

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Post-AGB (pAGB) objects are low to intermediate initial mass ($\leqslant$8 $M_\odot$) objects that have terminated normal nuclear burning and as a result are undergoing rapid evolution toward the white dwarf sequence. In classical pAGB objects evolution is to hotter effective temperatures at roughly constant luminosity. However, there are also several classes of pAGB objects that have revived nuclear burning after approaching or being on the white dwarf sequence. These include objects with delayed final helium shell flashes (e.g. Sakurai's star) and white dwarf mergers (e.g. R CrB stars). Binary evolution plays a critical role in many of these systems. A group of pAGB supergiants with large infrared excesses are suspected to be binaries that have undergone common envelope evolution. Further details on many of these objects can be found in reviews, see for instance Van Winckel (2003) and Herwig (2005).

The use of infrared (IR) tools has greatly increased our understanding of pAGB evolution. The strong infrared excess of these objects makes them very bright in the infrared and easily detectable in the mid-infrared. Many objects become embedded in their AGB mass loss and are optically obscured. The reduction of the obscuration and the brightness of pAGB objects in the IR makes them ideal targets for detailed analysis using IR spectroscopy. We report on three specific groups of pAGB objects.

Post-common envelope binaries: Van Winckel *et al.* (1995) identified a class of pAGB single-lined, long-period, spectroscopic binaries. The primary star of these binaries is an early-type supergiant with very peculiar abundances. These objects typically have strong IR excesses, carbon-rich circumstellar dust, and a photospheric abundance pattern characterized by a severe deficiency of refractory elements and a near-solar abundance for volatile elements. The orbits of these objects suggest previous common envelope evolution when the primary was at the tip of the AGB. A circumbinary Keplerian rotating disk appears a common feature of these pAGB binaries (De Ruyter *et al.* 2006).

Hinkle *et al.* (2007) report on high-resolution infrared spectroscopy in the 2.3-4.6 μm region. In the prototype HR 4049 the 4.6 μm spectrum shows a rich forest of CO and H_2O emission lines. All the spectral lines observed in the 2.3-4.6 μm spectrum are circumbinary in origin and originate in oxygen rich gas in contrast to the extended circumstellar carbon-rich gas. The emission and absorption line profiles show that the circumbinary gas is located in a thin, rotating layer near the dust disk. The velocities of the disk and the spectroscopic orbit yield masses for the individual stars, for HR 4049 $M_{A\ I}$ ~0.58 $M_\odot$ and $M_{M\ V}$ ~0.34 $M_\odot$. Chemical processing in the disk is the likely method for producing the chemical peculiarities seen on the stellar photosphere.

Final flash objects: Final helium shell flash evolution occurs in stars that have terminated their AGB stage and are either on the constant luminosity pAGB track or just entering the early white dwarf sequence. A final helium burning thermal pulse returns the star briefly to the AGB (Herwig 2005). The final flash episode is an astronomically very brief but probably fairly common event in stellar evolution. The mass loss associated with the final flash planetary nebula stage has been proposed to explain the shape and composition of exotic multi-shell planetary nebulae.

Hinkle *et al.* (2008) undertook a detailed investigation of the 80^+ year old final flash object V605 Aql. The cloud of ejecta was imaged at high spatial resolution in both optical emission lines and infrared continuum. The He I 10830 Å spectrum was also observed. The obscuring circumstellar shell was shown to be a disk with extended structure including knots. The obscuration of V605 Aql by dust marked the emergence of the hot white dwarf remnant from an optically thick pseudo-photosphere. This white dwarf drives a 2500 km s^{-1} wind principally in one plane resulting in a circumstellar disk. Where the wind encounters the circumstellar disk He I 10830 Å emission is created and hot, ∼1500 K, grains are generated. Grains exit the disk at 350 K and the accompanying gas is then expanding at ∼140 km s^{-1}. The strong concentration of the mass loss to the disk suggests the white dwarf is now rotating rapidly. There is convincing evidence in the literature that this process is also seen in V4334 Sgr and is still going on in the old final flash objects A30 and A78.

Double degenerate mergers: The category of hydrogen-deficient luminous stars includes, in order of increasing effective temperature, the hydrogen-deficient carbon (HdC) stars, the R Coronae Borealis (RCB) stars, and the extreme helium (EHe) stars. The origins of the HdC, RCB and EHe stars have remained a puzzle for decades. Two different scenarios have been presented. In one, the double-degenerate (DD) scenario the H-deficient supergiant is formed from the merger of a He white dwarf (WD) with a carbon-oxygen WD. In the other, these H-deficient stars result from a final, pAGB helium shell flash. The remaining H-rich envelope is ingested by the He-shell and the ensuing nucleosynthesis includes large-scale conversion of H to He.

Clayton *et al.* (2005, 2007) made the remarkable discovery from medium-resolution infrared spectra that the oxygen in HdCs was primarily the isotope ^{18}O and not the usual dominant isotope ^{16}O. This work supports the origin of HdC and RCB stars via the DD scenario. Exploratory calculations by Clayton *et al.* (2007) suggested that the merger is very rapid and induces nucleosynthesis that converts ^{14}N by α-capture to ^{18}O resulting in a high abundance of ^{18}O relative to ^{16}O. García-Hernández *et al.* (2009) have followed up with a high spectral resolution of C, N, O abundances in the HdC and RCB stars and support the results of Clayton *et al.*(2005, 2007).

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