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Post-AGB binaries as tracers of stellar evolution.

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Abstract. In this contribution the focus is on post-AGB binaries. It is now well established that these are often surrounded by stable long-lived circumbinary discs of gas and dust. Here we introduce our monitoring programme with our high-resolution spectrograph HERMES mounted on the 1.2m Mercator telescope. We illustrate the use of time-series high-resolution spectra and show that jets observed in many systems are launched at the location of the companion. The jet is likely originating from a circum-companion accretion disc. The link of these systems to some PNe relies on the detection of similar orbits and hence wide spectroscopic orbits among central stars of PNe. The conclusion is that Keplerian discs as well as circum-companion discs are fundamental to understanding the properties and evolution of these interacting evolved binaries.

Keywords. stars: AGB and post-AGB,(stars:) binaries: spectroscopic, techniques: radial velocities

1. Introduction

In the Galaxy some 80 optically bright post-Asymptotic Giant Branch (post-AGB) objects are identified with circumstellar dust near the sublimation temperature, while the central star is not in a dust-losing phase (e.g. Gezer *et al.* 2015 and references therein). In the Magellanic clouds, many more have been identified (Kamath *et al.* 2014; Kamath *et al.* 2015) It is now also well established that the circumstellar dust in these systems is trapped in a very compact stable disc (e.g. Hillen *et al.* 2016b and references therein) of gas and dust. The inner radius of the disc has been resolved with interferometric imaging by Hillen *et al.* 2016 and in some objects the kinematics were spatially resolved in CO and Keplerian rotation of the inner parts have been resolved (e.g. Bujarrabal *et al.* 2016a and references therein). The inferred luminosity of these objects is significant, pointing to a large scaleheight of the disc.

In the past decade it became clear that these object represent a peculiar phase in binary stellar evolution (Van Winckel 2003). The binaries are now not contact systems, but the orbits are now too short to accommodate an AGB star: these stars must have been subject to severe interaction in the past when the primary was at AGB dimensions. It is assumed that during the interaction, the disc, which seems now in hydrostatic equilibrium, was formed. Contrary to many central stars of PNe (see review of D. Jones these proceedings), the binaries did not suffer severe spiral-in and escaped the interaction phase on orbits between a few hundred and a few thousands of days (e.g. Van Winckel *et al.* 2009, Manick *et al.* 2016 and references therein).

We monitor northern bright (m(v) $<$ 12.0) objects with our high-resolution spectrograph HERMES (Raskin *et al.* 2011) mounted on our 1.2m Flemish Mercator telescope. We tuned our operational model such that regular monitoring can be obtained throughout the year. Our programme has been running since 2009 (e.g., Van Winckel *et al.*

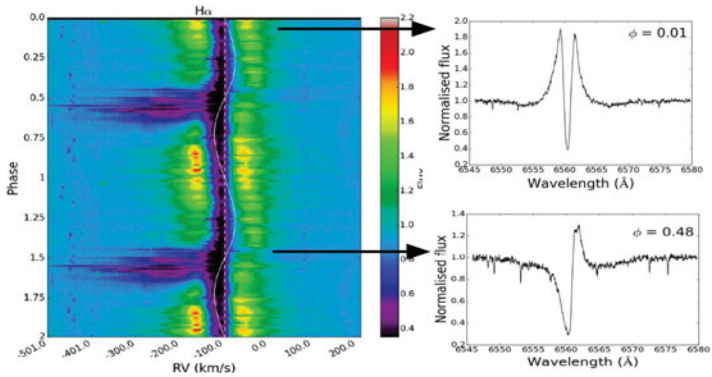

Figure 1. On the left panel we show the dynamic spectra around the H_α-line which we fold on the orbital period. On the right we show representative spectral line-profiles.

2010, Gorlova *et al.* 2014). Here we report on some newly discovered features in these time-series of high-resolution spectra.

2. Jet creation

The orbital elements are only the first observables deduced from our time-series (e.g. Van Winckel *et al.* 2009; Manick *et al.* 2016 and references therein). Also phased resolved line-profiles can be studied and here we focus on the H_α profile.

In Fig. 1 we show a two dimensional representation of the H_α profile of BD+46°442 (Gorlova *et al.* 2012, Bollen *et al.* 2017). The most apparent feature is the strong blue shifted absorption component which appears in the spectra during the phase when the companion is in lower conjunction. The interpretation of these P-Cygni profiles is that during this orbital phase, continuum photons of the evolved luminous primary are scattered out of the line-of-sight by line scattering on high-velocity hydrogen atoms. This high-velocity outflow originates around the companion, and is likely launched from a circumcompanion accretion disc (Bollen *et al.* 2017).

The modelling of these spectra (Fig. 2) is made complicated as the inclination is not very well constrained but the opening angle of the jet must be quite large. Doppler tomography, using the spectra obtained outside conjunction, allows us to reconstruct in velocity space the accretion disc of the companion which is the origin of the H_α shell profiles (Fig. 1, phase 0.1).

While not all objects have been studied in great detail, the phase resolved spectra shows that jet creation is very common with the launching side around the companion.

3. PNe connection

Ingredients which are deemed to be important also in the PNe phenomena are present in the post-AGB binaries with circumbinary discs. Binary interaction processes as well as jet creation processes are now resolvable in space and time. The evolutionary link between these post-AGB binaries and PNe is, however, not clear. The post-AGB systems may evolve too slow to ever become a PNe.

Moreover, while spiralled-in systems in PNe are common, wider spectroscopic orbits are largely unknown, with the noticeable exception of BD+33°2642 and LoTr5 (Van Winckel *et al.* 2014). For the latter we have obtained now data covering one full orbit of around 2800 days (Fig. 3).

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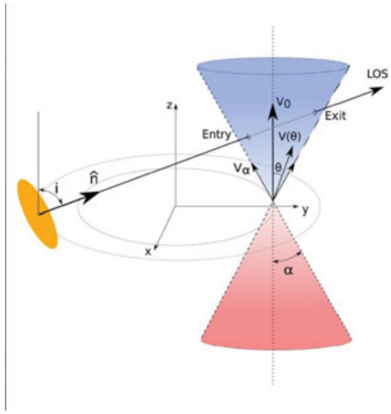

Figure 2. The geometric model. Fitting this model to the phase-resolved spectra indicate that the opening cone is wide (> 60 degrees) with a velocity law indicative of angle dependent outflow velocity which is higher on the symmetry axes and decreases towards the edge of the cone (Bollen *et al.* 2017).

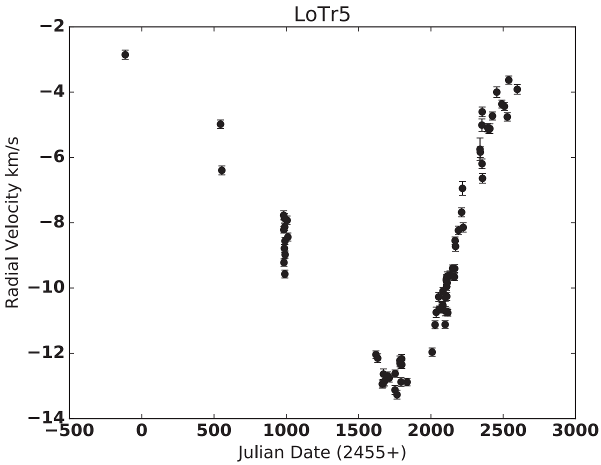

Figure 3. The radial velocity curve of LoTr5, one of the few central stars of PNe with wide spectroscopic orbits.

4. Conclusions

Binary post-AGB systems are characterised by rather large orbits (several hundreds of days) and show a common SED characteristic pointing to the presence of a stable circumbinary disc of gas and dust with a significant scale-height.

The systems are complex and we report here on the detection of high-velocity outflows at the location of the companion. The jets show wide opening angles and are likely launched in a circum-companion gas accretion disc.

The evolutionary connection to PNe is as yet unclear but more evolved counterparts of binary post-AGB stars are now possibly identified (Van Winckel *et al.* 2014). While spiralled-in systems are commonly observed among central stars of PNe (see review of D. Jones), this is not the case for post-AGB stars as these binaries have escaped a phase of strong interaction on rather wide and often eccentric systems (Van Winckel *et al.* 2009).

Disclosing the different binary evolutionary channels leading to the large variety of evolved systems is a challenge for the coming years.

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Discussion

Chen: Does the infrared excess vary with the orbital motion?

van Winckel: For the moment there is no evidence for this. The stars are now not losing mass with dust: They are too old. The inner rim of the disc is Keplerian in rotation and located by the star. So any pulsation will be reflected into the rim. Whether the near-IR light curve changes on the timescale of the orbit is unknown as yet.

Sloan: To address the marvelous question about infrared variability, it is good to recall that the deactivated WISE mission covers the entire sky every six months and in each visibility region, you get photometry every scan.

van Winckel: Thanks for the suggestion! We will certainly do so!

Q: Can you estimate the amount of accretion? Is the orbital plane of the binary alligned with the plane of the circumbinary plane? Do you have precession from the jet?

Q: Can you reconcile the large opening angle of the jet with the much narrower opening at the base of most bipolar lobes?

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