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Understanding jets in post-AGB close binaries

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Abstract. We have discovered jets in post-AGB binaries. The orbital motion allows us to carry out tomography of the jet as light from the primary star shines through the jet cone. Jets play a major role in many astrophysical environments, from young stellar objects to galaxies. They are also used to study the energetics of accretion phenomena in systems such as red transients and stellar mergers. We use high-resolution, optical, time-series spectra to constrain theories of jet launching, and the impact of jets on the evolution of these post-AGB binaries.

Keywords. Spectroscopy, post-AGB, jets and outflows, accretion, binaries

1. Introduction

Astrophysical jets are observed in many astronomical objects, ranging from young stellar objects to the extremely energetic jets from active galactic nuclei. Jets are key components in the shaping of non-spherical, collimated planetary nebulae and pre-planetary nebulae (Sahai & Trauger 1998). Although jets are a ubiquitous phenomenon in the Universe, the physical processes governing these energetic events remain poorly understood. Recently, we found that jets are commonly observed in post-AGB binary systems (Gorlova *et al.* 2012, Gorlova *et al.* 2015, Bollen *et al.* 2017).

Binaries with the primary on the asymptotic giant branch (AGB) can suffer mass transfer. Some enter a common envelope interaction, which shrinks the orbit and ejects the envelope, leaving a central compact binary and a collimated planetary nebula (De Marco 2009). Others seem to suffer less in-spiral for some unknown reasons and result in cooler post-AGB stars with companions in 100–1000-day orbits, dusty, circumbinary disks and, we now know, pervasive jets (Van Winckel 2003, Van Winckel *et al.* 2009). The jet originates from an accretion disk around the secondary, main sequence star component. In our previous work, we have analysed the observational data of post-AGB, jetting binary BD+46°442 (Bollen *et al.* 2017). We showed that these jets have wide opening angles (half-opening angles $< 40°$), with a fast, thin outflow along the jet axis and a slower, dense outflow at the jet walls. The source of the accretion might be from the circumbinary disk, not the primary, opening interpretation avenues for these systems. This study has revealed the potential of our spectroscopic data in deriving the jet structure, which gets to the heart of the launch mechanism.

Here, we aim at determining the spatio-kinematic structure of jets observed in post-AGB binary systems to get a more complete understanding of the accretion and jet launching processes.

2. Methodology and results

The high-resolution optical spectra (from the dedicated Mercator Telescope on La Palma; Raskin *et al.* 2011) show phase-dependent variations in the Balmer lines, which can be explained by the presence of a jet that emerges from an accretion disk around the companion. Due to the orbital motion of the binary system, the jet blocks the light coming from the primary component during each orbital period when it transits in front of the primary. The scattering of the continuum photons from the primary component by the hydrogen atoms in the jet gives us unique insight in the density and velocity structure in different parts of the jet. This tomography of the jet is a novel technique to determine its spatio-kinematic structure.

In this study, we focus on IRAS19135+3937, which is well-sampled throughout its orbital phase. We have written a code that creates a geometrical model of the jet configuration and computes a synthetic spectra from the model over the whole binary orbit, based on several parameters such as jet density, inner and outer velocity, jet opening angle, radius of the primary component, and inclination of the system. We implement two jet configurations in our model: an X-wind configuration (based on the X-wind model for protostellar outflows by Shu *et al.* 1994) and a disk wind configuration (based on the wind model by Blandford & Payne 1982). We fit these synthetic spectra to our observational data using an MCMC-fitting routine, in order to determine accurate parameters fully constraining the spatio-kinematic structure of the jets.

Both X-wind model and disk wind converge to the simplest jet configuration with a jet comprising a slow (10 km/s) dense cone with a fast (750–1050 km/s) low density core.

3. Conclusions

Theories of accretion and jet formation in general and their impact on post-AGB binary systems, planetary nebulae, and pre-planetary nebulae, in particular, are currently incomplete. Data of jets is hardly ever sufficient to fully constrain their parameters. Our data comprising more than 20 post-AGB objects with jets, thanks to the use of a dedicated telescope, has exquisite spectroscopic and temporal resolution. Eventually, we aim to determine the jet mass, mass-loss rate and disk accretion rates which will be key in a model of jet launching.

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