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Integral Field Spectroscopy of Post-AGB Stars with UKIRT and SINFONI-VLT

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Abstract. We use H_2 as a marker to trace the interaction between the older and slower AGB wind and the newer fast wind. Integral field spectroscopy is a tool to probe the interactions of these winds. The measurement of the various line ratios makes it possible to differentiate between the excitation mechanisms. We have obtained *K*-band observations with UIST+IFU at UKIRT and SINFONI at VLT. The UKIRT observations enable us to locate the areas of emission over an area of $\sim 6 \times 3$ arcseconds, whilst SINFONI can provide high resolution sub-arcsecond observations. *IRAS* 19306+1407 is a B0/1 spectral type post-AGB/Young PN with a bipolar outflow and displays a mixture of shocks and fluorescence. It has emission lines that emanate from an elongated bipolar structure and bright arcs. The combination of H_2 and existing polarimetry enables us to analyse the gas and dust around this evolved star.

Keywords. Stars, individual: *IRAS* 19306+1407, stars: AGB and post-AGB, stars: circumstellar matter

1. Introduction

The post-main sequence evolution for the majority of stars in the Galaxy is dominated by the mass loss occurring on the Asymptotic Giant Branch (AGB). The mass loss in the AGB stage lasts 10^6–10^7 years and ends with an increase in mass-loss rate ('super-wind stage') up to 10^{-4} $M_\odot$ yr^{-1}. The Generalised Interacting Stellar Winds model, a modified form of the Interacting Stellar Winds model (Kwok, Purton & Fitzgerald 1978), and the Three Winds model (Schmidt-Voigt & Köppen 1987, Maret & Schönberner 1991, Frank 1994) try to explain the various PNe morphologies. These models are poorly constrained by observations. We are using our molecular hydrogen (H_2) imaging of the interaction of the slow and fast winds to provide much needed information on PN shaping.

Bipolar post-AGB stars show dramatic collimation of the mass-loss winds. This can indicate a fast wind in the direction of the long axis of the nebula. We can then directly compare predictions and observations and hence explain the formation and shaping of PNe.

2. Technique and Results

Integral field spectroscopy (IFS) is a recent development in astronomy. It is possible to obtain spectroscopic and imaging information simultaneously in one exposure. The measurement of the various line ratios, 1-0S(1), 2-1S(1) and 3-2S(3) transitions makes it possible to differentiate between the excitation mechanisms. The ratio of 1-0S(1)/2-1S(1) can be used to discriminate between shocks (high ratios) and fluorescence (low ratios). The 1-0S(1)/3-2S(3) ratio is used as a check for fluorescence.

IRAS 19306+1407 is a B0/1 spectral type post-AGB star with a bipolar outflow. We used the Integral Field Unit of UIST (IFU), at the United Kingdom InfraRed Telescope (UKIRT), to locate areas of emission. These observations were followed up, at greater

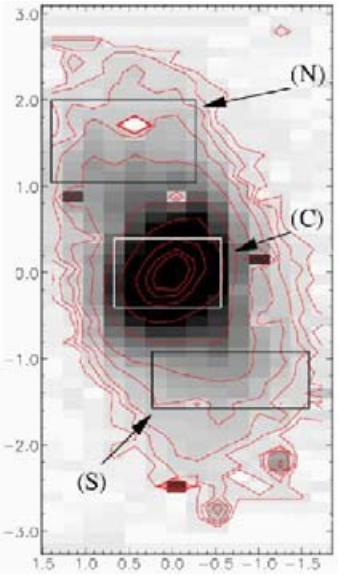

Figure 1. A continuum subtracted image of the main H2 line, 1-0S(1), taken with UKIRT. The solid boxes indicates the North (N), Central (C) and South (S) regions. The line ratios are displayed in Table 1.

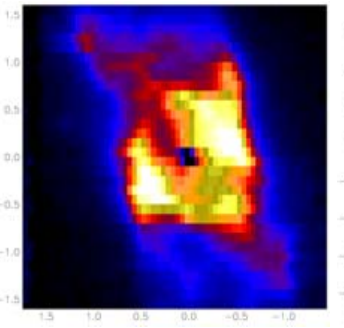

Figure 2. A continuum subtracted SINFONI image of the main H_2 line. The central region shows little or no H_2 emission, whilst highlighting two bright arcs and an outflow.

Table 1. A summary of the important line ratios for three regions (North, central and South)

Region	$\frac{1-0S(1)}{2-1S(1)}$	$\frac{1-0S(1)}{3-2S(3)}$
North	8.06	32.88
Central	8.31	4.36
South	6.85	35.14

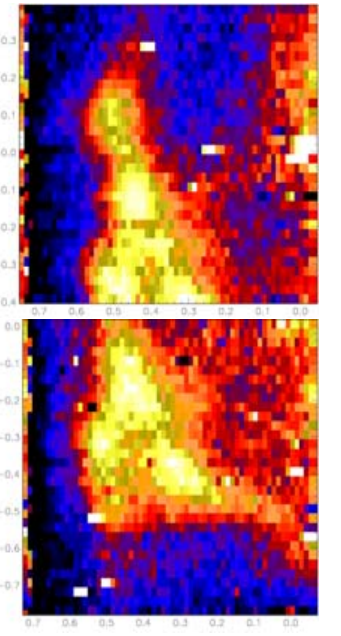

Figure 3. Sub-arcsecond IFS images of the SE arc, showing a clumpy structure.

Note: axes units are in arc seconds.

spatial and spectral resolution, using the Spectrograph for INtegral Field Observations in the Near Infrared (SINFONI) in conjunction with Adaptive Optics (AO) at the Very Large Telescope (VLT).

In Fig. 1 we have selected three regions (North, Central and South). Fluorescence is quite strong in the central region (line ratios given in Table 1), whilst a mixture of shocking and fluorescence takes place in the northern and southern regions. The H_2 shows a bipolar morphology, with emission at large offsets following the scattered light seen in the optical HST image.

Our initial results from SINFONI (Fig. 2 & 3) show that two bright arcs (SE-NW) are seen with an apparent outflow (NNE-SSW). The bright arcs mark an equatorial torus, which seems twisted w.r.t. the long axis and is also seen in polarimetric imaging of dust-scattered light (Lowe & Gledhill 2006, submitted). The sub-arcsecond imaging of the SE arc shows a clumpy structure, which may indicate that the torus is being eroded by a fast wind or material is being swept up into clumps.

In our future analysis of the SINFONI data, it will be possible to produce line ratio maps, extinction maps and excitation maps for this and other post-AGB stars.

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