



## 13424 - The Necklace Nebula as a probe of close binary evolution

Cycle: 21, Proposal Category: GO

(Availability Mode: SUPPORTED)

### INVESTIGATORS

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### VISITS

<i>Visit</i>	<i>Targets used in Visit</i>	<i>Configurations used in Visit</i>	<i>Orbits Used</i>	<i>Last Orbit Planner Run</i>	<i>OP Current with Visit?</i>
01	(1) NECKLACE-OFFSET	COS/FUV	1	24-Jun-2013 22:42:17.0	yes

1 Total Orbits Used

### ABSTRACT

Mass loss from evolved stars is a fundamental but poorly understood process. In particular, the production of collimated outflows is observed in a large variety of sources, and evolution in interacting binaries has been traditionally invoked to explain it. The Necklace Nebula was only discovered in 2011 but is proving to be a key target to investigate this issue: it is one of the few planetary nebulae for which the association between close-binary evolution and the formation of jets was established, and the only one for which the jet ejection process can be directly associated with accretion on the secondary star. In particular, accretion would have occurred right before the onset of a fast evolutionary phase in which the two stars share a common envelope (CE) and then eject it. Pre-CE accretion is supported by the gas kinematical ages, and most important by our finding that the secondary star is carbon-rich, a fact that can naturally be explained by accretion from the wind of the primary when the latter was a carbon-rich AGB star. The decisive test to confirm this hypothesis, tying all loose ends about the evolution of the system, is to prove that the nebular gas is also carbon-

rich. For this reason, we aim to determine the C/O abundance ratio of the nebula using COS. The HST is needed because the dominant C and O ions can only be detected at FUV wavelengths. Confirmation of our hypothesis will provide for the first time a fully consistent description of the mass loss, mass transfer and mass accretion processes occurring during CE, a phase that is crucial to understand classes of objects such as cataclysmic variables, novae, low-mass X-ray binaries, and SNIa.

## **OBSERVING DESCRIPTION**

Our main goal is to demonstrate that  $C/O > 1$  in the Necklace nebula. The UV range, only accessible with the HST, contains emission lines covering all the expected dominant ionization stages for C and O, and in particular O III] 1661-6 and C III] 1907-9 for O<sup>++</sup> and C<sup>++</sup>, respectively, and CIV 1548-50 and O IV] 1397-1407 for O<sup>+++</sup> and C<sup>+++</sup>. The C<sup>+</sup> abundance, while it could be derived from the line at C II 1335/36, is estimated to provide a negligible contribution in this high excitation nebula, as is O<sup>+</sup> (Corradi et al. 2011).

We have estimated the expected surface brightness (SB) of the UV lines in the inner nebula from the analysis of the optical data in Corradi et al. (2011), assuming the gas physico-chemical conditions and reddening determined there, and  $C/O=1$ . They are indicated in the following:

Emission line SB (10<sup>-16</sup> erg cm<sup>-2</sup> s<sup>-1</sup> arcsec<sup>-2</sup>)

O IV] 1397-1407 SB=5

O III] 1661-6 SB=1

C IV 1548-50 SB=50

He II 1640 SB=40

C III] 1907-9 SB=15

These line SBs, and in particular those of O III] and O IV], are too faint to be measured using STIS. We therefore plan to take advantage of the superior sensitivity of COS, at the expense of being limited to its single 2".5 circular aperture. We propose to use the G140L grating in the FUV channel ( $\lambda$  1105) to have all relevant lines in a single shot. The aperture will be positioned in the inner nebula in a way that intersects the slit position of the optical spectra in Corradi et al. (2011).

As the source is extended and uniformly fills the COS aperture, spectral resolution will be degraded to  $R=165$  according to the COS manual (p. 67). This corresponds to 10 angstrom at 1650 ang, still good enough to resolve nearby lines such as He II 1640 from O III] 1661-6. For the abundance determination, there is no need to resolve line multiplets from the same element such as C IV1458 from C IV1450, or the several O IV] lines around 1400 ang.

Our exposure time estimate is based on the SB of the faintest among the crucial lines, namely O IV] 1397-1407. No precise measurement is needed of the fainter O III] 1661-6 line, as the corresponding O<sup>++</sup> abundance was safely derived from the bright [O III] 4959+5007 optical lines.

## Proposal 13424 (STScI Edit Number: 0, Created: Monday, June 24, 2013 9:42:24 PM EST) - Overview

Adopting the O IV] SB= $5 \times 10^{-16}$  erg cm<sup>-2</sup> s<sup>-1</sup>, the COS ETC (simulation COS.sp.516269) for a spectral distribution with "no continuum" and an emission line centered at 1402 and 10 ang wide (O IV] is a blend of nearby lines), we obtain SNR=1.67 per resel with a 630 sec exposure. As all emission lines in the output spectrum will be broadened to ~8 ang, while the resel in the ETC is ~6 pixel=0.5 ang, the actual SNR over the whole line will be about four times higher. This implies a final SNR~13 for the integrated O IV] line for a total integration of 630s $\times$ 4=2520 sec over the orbit allocated (see below). For the C III] 1907-9 line, the lower efficiency of the G140L gratings is compensated by a larger line flux, and a similar SNR is expected. C IV and He II will have a SNR $\geq$ 30 (simulation COS.sp.516270). This is adequate for our purposes.

As coordinates are precisely known, and the nebula is sufficiently uniform within 1 arcsec from the indicated target position, the pointing accuracy of the HST is sufficient and no target acquisition is required. The visibility of the target is 54 min per orbit. Taking into account overheads for guide-star acquisition, and setup of first science exposure, this leaves enough time to accommodate a total integration on source of about 42 min in the allocated single orbit.

The match of the UV spectrum with the optical one will be done with the bright He II 1640 UV line, whose intrinsic flux ratio with respect to the He II optical lines is fixed by the known gas physical conditions (this will also minimize errors in the reddening estimates). In practice, we will perform a complete chemical analysis taking advantage of the combination of HST/UV and the existing ground-based optical spectra.

Proposal 13424 - NECKLACE-OFFSET-COS-SPEC (01) - The Necklace Nebula as a probe of close binary evolution

Tue Jun 25 02:42:25 GMT 2013

<b>Visit</b>	<b>Proposal 13424, NECKLACE-OFFSET-COS-SPEC (01)</b> <b>Diagnostic Status: Warning</b> Scientific Instruments: COS/FUV Special Requirements: (none)
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<b>Diagnostics</b>	(NECKLACE-OFFSET-COS-SPEC (01)) Warning (Form): A target acquisition should probably be performed before doing spectroscopy or coronagraphy with STIS or COS.
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<b>Fixed Targets</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Name</th> <th>Target Coordinates</th> <th>Targ. Coord. Corrections</th> <th>Fluxes</th> <th>Miscellaneous</th> </tr> </thead> <tbody> <tr> <td>(1)</td> <td>NECKLACE-OFFSET Alt Name1: IPHASXJ194359.5+1709 01</td> <td>RA: 19 43 59.2730 (295.9969708d) Dec: +17 09 2.73 (17.15076d) Equinox: J2000</td> <td>Epoch of Position: 2000</td> <td>V=17+/-1  O IV] 1397-1407 SB=5e-16 erg cm-2 s-1; C IV 1549 SB=5e-15 erg cm-2 s-1; He II 1640 SB=4e-15 erg cm-2 s-1; C III] 1908 S B=2e-15 erg cm-2 s-1</td> <td>Reference Frame: ICRS</td> </tr> </tbody> </table>	#	Name	Target Coordinates	Targ. Coord. Corrections	Fluxes	Miscellaneous	(1)	NECKLACE-OFFSET Alt Name1: IPHASXJ194359.5+1709 01	RA: 19 43 59.2730 (295.9969708d) Dec: +17 09 2.73 (17.15076d) Equinox: J2000	Epoch of Position: 2000	V=17+/-1  O IV] 1397-1407 SB=5e-16 erg cm-2 s-1; C IV 1549 SB=5e-15 erg cm-2 s-1; He II 1640 SB=4e-15 erg cm-2 s-1; C III] 1908 S B=2e-15 erg cm-2 s-1	Reference Frame: ICRS
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<i>Comments: Magnitude refers to the central binary star (not to be included in the PSA), surface brightness to the selected nebular region where the PSA will be positioned</i>													

<b>Exposures</b>	<table border="1"> <thead> <tr> <th>#</th> <th>Label (ETC Run)</th> <th>Target</th> <th>Config,Mode,Aperture</th> <th>Spectral Els.</th> <th>Opt. Params.</th> <th>Special Reqs.</th> <th>Groups</th> <th>Exp. Time (Total)/[Actual Dur.]</th> <th>Orbit</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>NECKLAC E-OFFSET-COS-SPEC (510664)</td> <td>(1) NECKLACE-OF FSET</td> <td>COS/FUV, TIME-TAG, PSA</td> <td>G140L 1105 A</td> <td>FP-POS=ALL; FLASH=YES; BUFFER-TIME=8000; EXTENDED=YES; SEGMENT=A</td> <td></td> <td></td> <td>632 Secs (2528 Secs) [==&gt;(Split 1)] [==&gt;(Split 2)] [==&gt;(Split 3)] [==&gt;(Split 4)]</td> <td>[1]</td> </tr> </tbody> </table>	#	Label (ETC Run)	Target	Config,Mode,Aperture	Spectral Els.	Opt. Params.	Special Reqs.	Groups	Exp. Time (Total)/[Actual Dur.]	Orbit	1	NECKLAC E-OFFSET-COS-SPEC (510664)	(1) NECKLACE-OF FSET	COS/FUV, TIME-TAG, PSA	G140L 1105 A	FP-POS=ALL; FLASH=YES; BUFFER-TIME=8000; EXTENDED=YES; SEGMENT=A			632 Secs (2528 Secs) [==>(Split 1)] [==>(Split 2)] [==>(Split 3)] [==>(Split 4)]	[1]
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