GPS/CSS Workshop

CSIRO PUBLISHING

*Publications of the Astronomical Society of Australia*, 2003, **20**, 28–30 www.publish.csiro.au/journals/pasa

# HST/STIS Spectroscopy of CSS sources: Kinematics and Ionisation of the Aligned Nebulae

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*Received 2002 June 30, accepted 2002 September 30*

**Abstract:** We have obtained long slit spectra of 3C 67 and 3C 277.1 with the HST/STIS spectrograph. We present our preliminary results on the diagnostic emission line ratios along the radio source axes in 3C 67 and 3C 277.1.

**Keywords:** galaxies: active — galaxies: individual (3C 277.1, 3C 67) — quasars: emission lines

## 1 Introduction

Recent work has identified the GPS and CSS sources as the most likely candidates for the progenitors of the large scale powerful 3CR FR II sources. Current models for the evolution of powerful radio galaxies suggest that these sources propagate from ∼10 pc to megaparsec scales at roughly constant velocity through an ambient medium. WFPC2 Linear Ramp Filter images have revealed the presence of bright emission line gas aligned, and in projection co-spatial, with the radio source, which provides a potential diagnostic probe. Groundbased observations of broad and highly structured [O III] 5007 lines strongly suggest that the radio source is dominating the emission line kinematics.

We have observed two CSS sources (3C 67, $z = 0.3102$, 3C 277.1, $z = 0.3210$) with STIS long-slit spectroscopy in order to determine the kinematics and physical properties of the emission line gas interacting with the radio source and the jets. Images and integrated kinematics can be found in de Vries et al. (1997, 1999; see also Gelderman & Whittle 1994). These two CSS sources were selected because of their bright extended emission lines aligned with powerful linear radio sources and will provide a first look at the range of conditions in the nebula and the dynamics of the radio source. Results on the kinematics are presented by O'Dea et al. (2002). Here we present preliminary results on the emission line diagnostics in 3C 67 and 3C 277.1.

## 2 Diagnostic Ratios

We have used *Specfit* (Kriss 1994) to fit Gaussians to the brightest emission lines in our sources. We measured the integrated line flux, central wavelength (i.e. velocity offset relative to the nucleus), and line width (FWHM). We have used the Galactic dereddening curve in Cardelli, Clayton, & Mathis (1989) and the measured Galactic values of Schlegel, Finkbeiner, & Davis (1998). In Tables 1 and 2 we present the values and variation, respectively, of the (dereddened) line intensity ratios along the radio source axes.

## 3 Results

We detect diagnostic emission lines in the lobes out to distances of ∼0.5 arcsec (∼3 Kpc, $H_0 = 72\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $q_0 = -0.55$, Freedman et al. 2001) from the nucleus. We examine the behaviour of the diagnostic line ratios as a function of distance from the nucleus and the kinematics

 10.1071/AS02027 1323-3580/03/01028

**Table 1. Summary of the average values of the line flux (dereddened) ratios for the emission lines in 3C 67 and 3C 277.1**

| Ratio | 3C 67 Nucleus | 3C 67 Lobes | 3C 277.1 Nucleus | 3C 277.1 Lobes |
|---|---|---|---|---|
| [O III] 5007/H$\beta$ | $11.5 \pm 1$ | $8 \pm 4$ | $1.75 \pm 0.75$ | $1.3 \pm 0.5$ |
| [O III] 4363/[O III] 5007 | $0.48 \pm 0.02$ | $0.4 \pm 0.2$ | $0.85 \pm 0.3$ | $0.9 \pm 0.1$ |
| | | $0.7 \pm 0.3$ | | $0.5 \pm 0.1$ |
| [O II] 3727/[O III] 5007 | $0.10 \pm 0.03$ | $0.25 \pm 0.1$ | $0.05 \pm 0.05$ | $0.3 \pm 0.2$ |

**Table 2. Summary of the general behaviour of the diagnostic line ratios for 3C 67 and 3C 277.1 along the radio source axes**

| Ratio | Versus | 3C 67* | 3C 277.1* |
|---|---|---|---|
| [O III] 5007/H$\beta$ | Distance | Independent | Independent |
| | Velocity offset | Independent | Independent |
| | FWHM | Independent | Independent |
| [O III] 4363/[O III] 5007 | Distance | Asymmetric? | Asymmetric |
| | Velocity offset | Asymmetric? | Independent |
| | FWHM | Independent | Independent |
| [O II] 3727/[O III] 5007 | Distance | Symmetric | Symmetric |
| | Velocity offset | Asymmetric? | Independent |
| | FWHM | Independent | Independent |

* Symmetric: Similar values in both lobes. Asymmetric: Significantly different values (error bars do not overlap) in the two lobes. A question mark denotes an observed trend where the values lie within the errors. Independent: The ratio seems to vary randomly along the source.

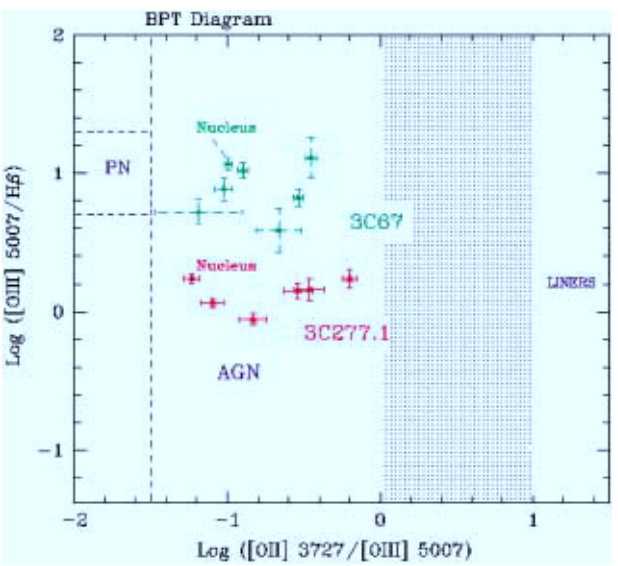


**Figure 1** BPT diagram for 3C 67 (dashed) and 3C 277.1 (solid). We have also labelled the *approximate* loci for planetary nebula (PN), AGN, and LINERs, based on the data from Moy & Rocca-Volmerange (2002), Heckman (1980), Baldwin et al. (1981), and Ferland & Netzer (1983). The shaded area corresponds to the region where AGN and LINERs overlap.

(velocity offset and FWHM). We find the following preliminary results:

- [O III] 5007/H$\beta$ is independent of both the kinematics and the distance from the source. The ratio is systematically higher in 3C 67 than 3C 277.1 though the loci of points in the BPT (Baldwin, Philips, & Terlevich 1981) diagram (Figure 1) are generally consistent with the known range of AGN.
- [O II] 3727/[O III] 5007 is higher in the lobes than in the nucleus in 3C 67. For 3C 277.1 the values of the ratio are similar in the lobes and nucleus. Both 3C 67 and 3C 277.1 show relatively high ionisation, especially the nucleus of 3C 67.
- [O III] 4363/[O III] 5007 appears to differ (though the errors are large) between the two lobes of 3C 277.1. The ratio seems to be higher in the nucleus of 3C 277.1 than in the nucleus of 3C 67.

The data seem to be consistent with the hypothesis that the gas has been shocked by the radio source, although the analysis of these results in terms of the ionisation properties of the gas and its relation to the kinematics is in progress.

## Acknowledgments

Support for this work was provided by NASA through grant number GO-08104.01-97A from the Space Telescope Science Institute, which is operated by the Association of Universities for Research in Astronomy, Inc., under NASA contract NAS5-26555. These observations are associated with program 8104. WDV's work was performed under the auspices of the US Department of Energy, National Nuclear Security Administration by the University of California, Lawrence Livermore National Laboratory, under contract No. W-7405-Eng-48.

https://doi.org/10.1071/AS02027 Published online by Cambridge University Press

## References

Baldwin, J. A., Philips, M. M., & Terlevich, T. PASP, 1981, 93, 5
Cardelli, J. A., Clayton, C., & Mathis, J. S. ApJ, 1989, 345, 245
de Vries, W. H., O'Dea, C. P., Baum, S. A., & Barthel, P. D. 1999, ApJ, 526, 27
de Vries, W. H., et al. 1997, ApJS, 110, 191
Ferland, G. J., & Netzer, H. ApJ, 1983, 264, 105
Freedman, W. L., et al. 2001, ApJ, 553, 47
Gelderman, R., & Whittle, M. 1994, ApJS, 91, 491
Heckman, T. M. 1980, A&A, 87, 152
Kriss, G. 1994, PASP, 61, 437
Moy, E., & Rocca-Volmerange, B. 2002, A&A, 383, 46
O'Dea, C. P., et al. 2002, AJ, 123, 2333
Schlegel, J. D., Finkbeiner, D. P., & Davis, M. ApJ, 1998, 500, 525

https://doi.org/10.1071/AS02027 Published online by Cambridge University Press