Emission Lines in Active Galaxies: New Methods and Techniques
ASP Conference Series, Vol. 113, 1997
B.M. Peterson, F.-Z. Cheng, and A.S. Wilson (eds.)

A Critical Test for Photoionization of Seyfert NLRs

S.K. Metz,[1] C.N. Tadhunter,[1] A. Robinson,[2] and D.J. Axon[3]

[1] *Dept. of Physics, University of Sheffield, S3 7RH, UK*

[2] *Department of Physical Sciences, University of Hertfordshire, Hatfield, Hertfordshire AL10 9AB, UK*

[3] *S[Space Telescope Science Institute, Baltimore, MD 21218, USA*

Abstract. We present measurements of the central ionizing photon flux q across three spatially resolved Seyfert NLRs, with implications for the ionization mechanisms.

1. A critical test with a surprising result

A common assumption of models of Seyfert NLRs is that the line-emitting gas is photoionized by photons emitted by a central source. There is evidence to support this assumption for the ENLR, but detailed observations of the NLR (high [O III] temperatures; disturbed kinematics; close association with radio structures) are driving the evolution of more complex models involving shocks (see Morse et al. 1996) or a two-component ionizing continuum (Binette et al. 1996).

A critical test of the central source model uses the ionization parameter, defined as the ratio of the density of ionizing photons to gas density, which can be written as

$$U = \frac{q}{n_e r^2 c} > \frac{q}{n_e \left(r/\cos\theta\right)^2 c}$$

where q is the number of ionizing photons emitted per unit time per steradian, n_e is the electron density, r is the distance of the emission-line cloud from the source, and θ is the angle between a line from the source to the cloud and the plane of the sky. Using [O III] λ5007/[O II] λ3727 to determine U, [S II] λ6717/λ6731 for the density, and estimating r, allows a straightforward determination of q. If the central source assumption is correct, wherever we measure q, we should get the same value.

Using data obtained with long-slit spectroscopy at the WHT on La Palma, we measured q across the NLR of three nearby Seyferts — NGC 4151, NGC 2110, and NGC 2992 — with the slit aligned along the radio structure. As Fig. 1 shows, far from being constant as expected, q rises dramatically with increasing distance from the nucleus.

To explain this result in terms of a projection effect requires the projection factor to increase, i.e., θ to increase, towards the nucleus in all three objects. This rules out the sharp-edged geometry of a filled bi-cone. This would also mean the value of q derived at the boundary of the NLR is closest to the true

https://doi.org/10.1017/S0252921100040549 Published online by Cambridge University Press

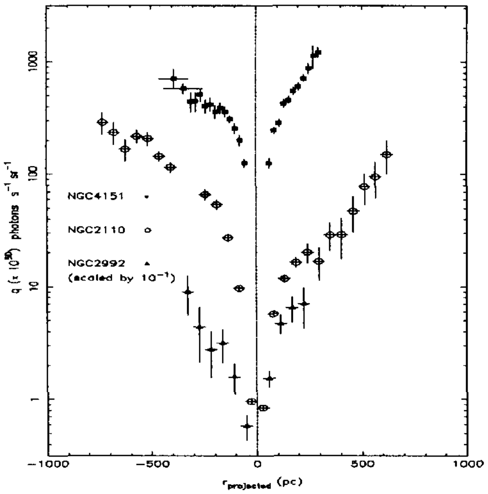

Figure 1. Variation of q, the ionizing photon flux, with radius in NGC 4151, NGC 2110, and NGC 2992. If all the photons come from the central source, then q should be constant ($H_0 = 75\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$).

value. Fixing q at this value allows an estimate of the de-projected r, e.g., for NGC 2110, setting $q = 100 \times 10^{50}$ photons $\mathrm{s^{-1}\,sr^{-1}}$ implies a minimum distance of the clouds from the nucleus of 240 pc, placing a strong constraint on the NLR geometry.

A two-component ionizing continuum due to a mixture of ionization-bounded and matter-bounded clouds cannot account for an increase in q by factors of 10^2–10^3.

The extended radio sources coincident with the NLR, suggest that high-velocity shocks due to interaction of the radio jet with the gas clouds could be a source of ionizing photons. Alternatively, shock ionization, producing significantly lower [O III] λ5007/[O II] λ3727, could become more important with decreasing r, and would in fact have to dominate close to the nucleus.

2. Conclusion

The dramatic increase in q with increasing projected r in the NLRs of these objects places unfeasible constraints on the geometry of one component central source photoionization models, and poses serious problems for the distribution and make-up of of the clouds in the ionization-bounded/matter-bounded cloud mix model. This supports the inclusion of jet-induced shocks, although a consistent model remains elusive.

References

Binette, L., Wilson, A. S., & Storchi-Bergmann, T. 1996, A&A, 312, 365.
Morse, J. A., Raymond, J. C., & Wilson, A. S. 1996, PASP, 108, 426.

https://doi.org/10.1017/S0252921100040549 Published online by Cambridge University Press