# EMISSION-LINE VARIABILITY AND THE NATURE OF THE BROAD-LINE REGION

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Variability of the emission-line spectra of broad-line AGNs is now a well-established phenomenon (see Peterson 1988 for a review). The rapid variability of the emission lines and the strong correlation between continuum and line fluxes suggests broad-line region (BLR) dimensions too small to be consistent with theoretical estimates based on photoionization equilibrium considerations.

Numerous attempts have been made to estimate the time scale for the BLR response to continuum variations, which can be interpreted as the light-travel time across the BLR. A simple means of estimating the time scale for response is by cross-correlating the continuum and emission-line light curves (Gaskell and Sparke 1986; Gaskell and Peterson 1987; Maoz and Netzer 1988). Since this method requires evenly sampled data, it is necessary to interpolate at least one of the light curves between the actual observations to achieve a workable grid. Application of this method to real data thus depends on how reliably one can interpolate between observations. In the case of Akn 120, Gaskell and Peterson (1987) find that the BLR radius has a 50% probability of being larger than 14 light days and only a 10% probability of being larger than a light month. The large uncertainty is principally due to the low amplitude of variation relative to the measurement uncertainties during most of the time Akn 120 has been monitored (see also Edelson and Krolik 1988).

In light of these results, we have reanalyzed much of the existing data on Akn 120 (1) to verify the integrity of the data base and (2) to see whether or not the power spectrum of the continuum light curve might have sufficient amplitude to render interpolation between observations meaningless. We find that photometric and spectrophotometric data points obtained at intervals as long as two weeks match extremely well. We find no significant evidence for variations in the line or the continuum on time scales shorter than ~15 days; the differences between closely spaced observations are consistent with mean uncertainties of ~8% in both the lines and continuum, as we have quoted before. However, at longer intervals (15 - 40 days) several significant variations (> 3.5$\sigma$) are detected in both the lines and continuum. We conclude (1) that the integrity of the data base is high (i.e., the errors are approximately



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as previously quoted and the data are internally and externally consistent), and (2) that at the present level of accuracy there is little or no evidence for strong continuum variability in Akn 120 on short time scales, so that interpolating over ~20 days is not likely to be horribly misleading.

Peterson and Gaskell (1988) have found by comparison of the optical data with UV data presented by Alloin et al. (1988) that the optical continuum is very strongly correlated with the UV continuum and that the Hβ flux is strongly correlated with the C IV λ1549 flux. By making use of these correlations, the optical data can be used to fill in gaps in the UV coverage. This allows us to temporally resolve the continuum and line outburst studied by Alloin et al., and thus provides what we believe is an accurate estimate of the BLR response time in Akn 120, $c\tau_{LT} = 39 \pm 14$ light days.

The structure of the emission-line region also can be studied through emission-line variability. For example, in NGC 5548 (Stirpe et al. 1988) and Akn 120 (Alloin et al. 1988) subtracting a low-state line profile from a high-state profile reveals that the most variable component is double peaked, suggestive of a rotating disk signature. On the basis of analysis of extensive optical (Korista, Peterson, and Wagner 1988) and UV data (Reichert and Peterson 1988) for these objects, we find that on many occasions, the difference spectra do indeed seem to show double-peaked line profiles. However, we find a significant number of observations which suggest that the real situation is far more complicated. On some occasions, only one component is detected in the difference spectrum, and in others the components vary in an opposite sense to one another, which does not appear to be consistent with a photoionized rotating disk (Gaskell 1988). Moreover, there is some less certain evidence that on at least some occasions, there are *more* than two distinct components detected in difference spectra. Obviously the situation needs more study before it can be concluded that difference spectra prove the existence of a rotating disk structure.

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*References:*

Alloin, D., Boisson, C., and Pelat, D. 1988, *Astron. Ap.*, in press.
Edelson. R.A., and Krolik, J.H. 1988, *Astrophys. J.*, in press.
Gaskell, C.M. 1988, in *Active Galactic Nuclei: Proceedings of the Georgia State University Conference*, ed. P. Wiita and H.R. Miller, in press.
Gaskell, C.M., and Peterson, B.M. 1987, *Astrophys. J. Suppl.*, 65, 1.
Gaskell, C.M., and Sparke, L.S. 1986, *Astrophys. J.*, 305, 175.
Korista, K.T., Peterson, B.M., and Wagner, R.M. 1988, in preparation.
Maoz, D., and Netzer, H. 1988, *M.N.R.A.S.*, in press.
Peterson, B.M. 1988, *Publ. Astron. Soc. Pacific*, 100, 18.
Peterson, B.M., and Gaskell, C.M. 1988, in preparation.
Reichert, G.A., and Peterson, B.M. 1988, in preparation.
Stirpe, G.M., deBruyn, A.G., and van Groningen, E. 1988, *Astron. Ap.*, in press.

## DISCUSSION

GOODRICH From the work of Stirpe *et al.* and some of your earlier NGC 5548 work, and data on two objects in my paper, when there appear to be two components variable, the midpoint of their velocities appears blueshifted relative to the systemic velocity. I don't think that the people who want to ascribe these double peaks to accretion disks can explain this in their models.

PETERSON The difference profiles are not easily explainable. Many difference spectra show two components, but at least in the case of NGC 5548, all of the symmetry properties I have examined (velocity, width, intensity) seem to change with time.

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