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.)

Keck High-Resolution Spectroscopy of Mrk 335: Constraints on the Number of Emitting Clouds in the BLR

Nahum Arav, Tom A. Barlow, and Roger D. Blandford

Theoretical Astrophysics, Caltech 130-33, Pasadena, CA 91125, USA

Ari Laor

Physics Department, Technion, Haifa 3200, Israel

Abstract. By applying cross-correlation (CC) techniques to high-resolution ($\sim 6\,\mathrm{km\,s^{-1}}$), high S/N (~ 400 at Hα line center) spectra of Mrk 335, we are able to put a lower limit of $\sim 3 \times 10^6$ on the number of emitting clouds in this objects. This limit is applicable for clouds with $T = 2 \times 10^4\,\mathrm{K}$ and an optical depth of a few hundred in their Hα line. Current BEL models based on stellar atmospheres of bloated stars can be ruled out based on this lower limit.

1. Introduction

The nature and origin of the broad emission lines (BELs) observed in many types of active galactic nuclei (AGNs) remains unknown. The standard model assumes that the BELs are the product of emission from a large number of clouds. Since it is difficult to create and maintain small free clouds in the BEL region, a class of models was developed which create the BELs out of stellar atmospheres or bloated stars (Scoville & Norman 1988; Kazanas 1989; Alexander & Netzer 1994). In these models the individual sources are slow ($\sim 10\,\mathrm{km\,s^{-1}}$) outflows emanating from supergiant stars. The total number of contributing stars is less than 10^5.

One way to test this model (or any other model of discrete emitters) is to search for a direct signature of the individual clouds. The idea is to use cross-correlation (CC) techniques on a high-resolution, high S/N spectrum of a bright AGN. The line profiles are fitted with a smooth function and the residuals are then cross-correlated. If any of the microstructure in the line profiles is due to contributions from individual emitting clouds, we should obtain a statistically significant CC signal at zero velocity shift. Existence of a CC signal can give a model-dependent estimate for the number of clouds that produce the line. A null result can be translated to a lower limit (again model-dependent) for the number of contributing clouds using Monte Carlo simulations. A simple version of this approach was used by Atwood, Baldwin, & Carswell (1982) on a moderate resolution spectrum of Mrk 509, and the lack of CC signal in their data was interpreted as a lower limit of 5×10^4 for the number of emitting clouds.

https://doi.org/10.1017/S0252921100040069 Published online by Cambridge University Press

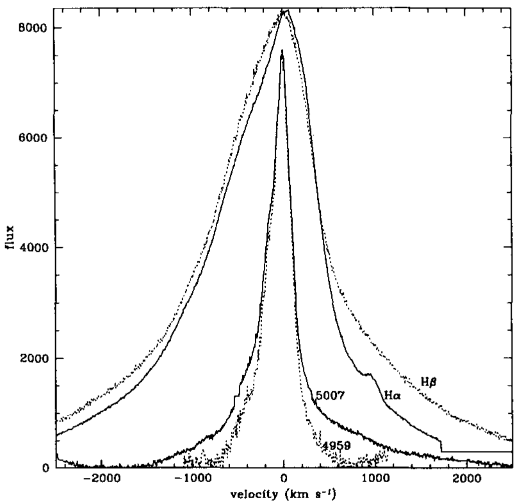

Figure 1. Mrk 335 line profiles (continuum subtracted) in arbitrary scaling that matches the peaks of Hα and Hβ, and separately the peaks of the [O III] $\lambda\lambda$4959, 5007 for the sake of comparison.

2. Constraints on Bloated-Star Models for the BEL Region

When we applied the CC analysis described above to the Hα and Hβ BELs from a high-resolution, high S/N spectrum of Mrk 335 (see Fig. 1), we found a null result. In the bloated-star models, due to the low invoked wind velocity, the emission profile from an individual bloated star can be approximated as a Gaussian with a width of 30–40 km s^{-1}. Our Monte Carlo simulations showed that under these conditions at least $\sim 3 \times 10^6$ individual emitters are needed to suppress a CC signal. This limit is higher by at least a factor of 30 than the largest allowed number of such stars. This is enough to exclude the current version of these models. We note that in Mrk 335 the number of contributing stars must be much smaller than 10^5 since the size of its BLR is about an order of magnitude smaller than that of a typical bright quasar, which is the benchmark for the above models. The detailed results of this study will appear shortly.

Acknowledgments. We thank Tom Bida for acquiring these observations and S. Vogt for leading the construction of the HIRES spectrograph.

References

Alexander, T., & Netzer, H. 1994, MNRAS, 270, 803.
Atwood, B., Baldwin, J. A., & Carswell, R. F. 1982, ApJ, 257, 559.
Kazanas, D. 1989, ApJ, 347, 74.
Scoville, N., & Norman, C. 1989, ApJ, 332, 162.

https://doi.org/10.1017/S0252921100040069 Published online by Cambridge University Press