Active Galactic Nuclei and Related Phenomena
IAU Symposium, Vol. 194, 1999
Yervant Terzian, Daniel Weedman, Edward Khachikian, eds.

Estimating the Number of Broad-Line Region Clouds

M. Dietrich

Landessternwarte Heidelberg, Königstuhl, D-69117 Heidelberg, Germany

The observed emission-line spectrum of active galactic nuclei is consistent with cold dense gas photoionized by a central continuum source (cf. Ferland & Persson 1989). The estimate of the filling factor of the line-emitting region yields $f \sim 10^{-6}$ only (cf. Osterbrock 1993) and motivated the picture of numerous clouds moving around a central black hole. Early estimates of the number of BLR clouds indicated a lower limit of 10^4 to 10^5 individual clouds (Capriotti et al. 1981; Atwood et al. 1982). Recently, Arav et al. (1998) estimated the number to be at least of the order of 10^7 discrete emitters. But the number and the nature of these clouds are still unknown.

A finite number of clouds will introduce a characteristic microstructure in the line profile which can be separated from the random observational noise. Hence, we observed 3C 273 with high spectral resolution ($\Delta v \sim 9$ km s^{-1}) with the NTT at La Silla, ESO. Proper parts of the outer wings were selected taking into account instrumental effects, presence of narrow emission lines, and contamination by atmospheric features. The line profiles were prepared following the method suggested by Tonry & Davis (1979). The resulting residuals of the Hα and Hβ emission lines were analysed using the interpolating cross-correlation method (cf. Gaskell & Peterson 1987). The significance of a cross-correlation peak was compared with the 3-σ threshold.

We studied simplified models in order to analyse the observed line profiles. We computed models with cloud widths of FWHM = 15 km s^{-1} to 100 km s^{-1}. The cloud ensembles ranged from 10^4 to 10^8 discrete identical emitters. The distribution of the ensemble was given by clouds moving on randomly orientated Keplerian orbits around a massive black hole ($M_{bh} = 10^8 M_\odot$). The distance of the clouds to the central energy source was restricted to $r_{in} = 0.1$ light days and $r_{out} = 100$ light days. Photon noise was added to the residuals to simulate S/N ratios comparable to the observations. The simulated profiles were treated in the same way as the real observations.

The blue wing of the Hα line profile of 3C 273 is shown together with simulations of cloud ensembles with $N_{cl} = 10^8$ (Fig. 1). The cumulative profile of clouds with FWHM = 15 km s^{-1} still shows too much structure. The profiles become smoother for significantly larger width (FWHM = 100 km s^{-1}) of the clouds.

The ICCF of the real observation is displayed together with the corresponding ICCFs of the model residuals. No significant peak is visible in the ICCF calculated with the observed Hα and Hβ line profiles of 3C 273 (Fig. 1). Even for large cloud numbers ($N_{cl} = 10^8$) a significant ICCF peak can be expected for clouds with FWHM $\simeq$ 15 km s^{-1}. The situation changes if the line width of an

https://doi.org/10.1017/S0074180900162187 Published online by Cambridge University Press

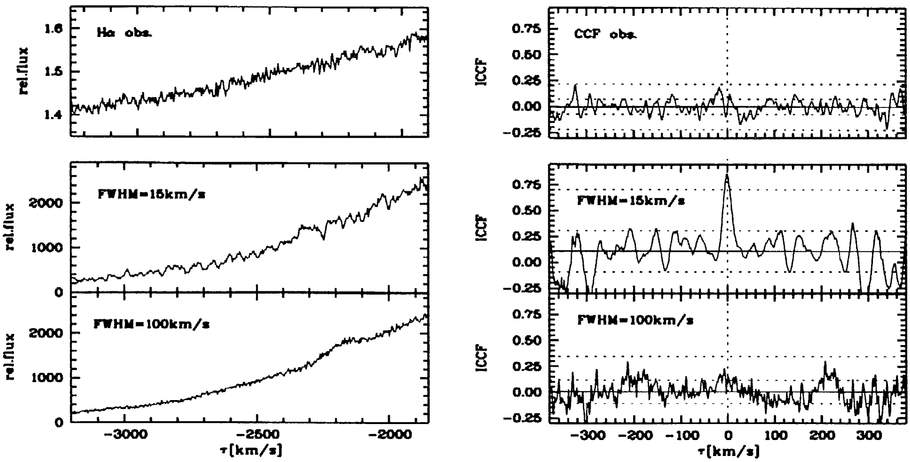

Figure 1. The observed Hα line profile of 3C 273 (top left side) and for cloud ensembles ($N_{cl}=10^8$) with FWHM = 15 km s^{-1} (middle) and FWHM = 100 km s^{-1} (bottom). The corresponding ICCFs are displayed in the three panels at the right side. The dashed lines represent the 1-σ and 3-σ thresholds.

individual cloud is significantly larger than 15 km s^{-1}. In the case of 10^8 clouds with FWHM = 100 km s^{-1} no significant ICCF peak is detectable.

This result indicates that the number of BLR clouds is larger than $N_{cl} = 10^8$ assuming a FWHM of 15 km s^{-1} for an individual cloud, i.e. the profile width is caused entirely by thermal broadening ($T_e \simeq 2\,10^4$ K). But the number of clouds might be of the order of 10^8 if the width of a discrete emitter is of the order of 100 km s^{-1} due to optical depth effects (Davidson & Netzer 1979) or electron scattering (e.g. Bottorff et al. 1997). However, the large number of clouds provides evidence that bloated star models can be ruled out if only red giant stars are taken as sources for the BLR clouds.

Acknowledgments. This work has been supported by DFG grant SFB 328.

References

Arav, N., et al. 1998, MNRAS, 297, 990

Atwood, B., Baldwin, J.A., & Carswell, R.F. 1982, ApJ, 257, 559

Bottorff, M., et al. 1997, ApJ, 479, 200

Capriotti, E., Foltz, C., & Byard, P. 1981, ApJ, 245, 386

Davidson, K. & Netzer, H. 1979, in Rev. Mod. Phys., 51, 737

Ferland, G.J. & Persson, S.E. 1989, ApJ, 347, 656

Gaskell, C.M. & Peterson , B.M. 1987, ApJS, 65, 1

Osterbrock, D.E. 1993, ApJ, 404, 551

Tonry, J. & Davis, M. 1979 AJ, 84, 1511

https://doi.org/10.1017/S0074180900162187 Published online by Cambridge University Press