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A Seyfert Nucleus in BL Lacertae?

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Abstract. We have obtained spectroscopic observations of the broad Hα line in BL Lacertae over a period of 30 months. These data show that the line equivalent width is anti-correlated with the continuum flux implying that the broad line emission is not powered primarily by synchrotron emission from the relativistic jet. The most probable explanation is that the broad line region in BL Lacertae is photoionized by continuum emission from an accretion disk which at optical wavelengths is dominated by the Doppler beamed synchrotron continuum.

1. Introduction

The continuum properties of BL Lac objects and optically violent variables (OVVs) quasars are very similar. Conventionally the two classes of object are distinguished by the strength of their emission lines with OVVs having strong broad emission lines whereas the BL Lac Objects exhibit only weak narrow emission lines . Recently however, broad emission lines have been discovered in BL Lacertae (Vermeulen et al. (1995)) How is this Broad $H\alpha$ emission powered? The Only apparent source of ionising photons is the featureless continuum believed to be beamed synchrotron emission from the jet. The broad-line region (BLR) would then be illuminated by a highly anisotropic radiation field . Corbett et al. 1996 (C96 hereafter) showed that the observed Hα equivalent width is consistent with the jet Lorentz factors and viewing angles implied by the superluminal motion of the radio source (Mutel et al. 1990). However, thermal radiation from an accretion disk can provide an equally acceptable explanation without contravening current observational data. In principal, we can distinguish between these two continuum sources from the way in which the Hα equivalent width, $W_{H\alpha}$, varies with the optical continuum brightness. If an accretion disk is the primary source of photoionizing radiation for the BLR, the line emission will be independent of variations in the observed optical continuum, since this is dominated by synchrotron emission, and $W_{H\alpha}$ will therefore be inversely proportional to the continuum brightness. In contrast if the jet ionises the BLR the $H\alpha$ equivalent width should be independent of the optical continuum brightness for a radiation-bounded BLR. We have therefore studied

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the relationship between the line equivalent width of the broad Hα line and the optical continuum flux in BL Lacertae, over a period of 30 months.

2. Results & Discussion

While the continuum flux varied by more than a factor of 5 we detect no clear changes in the broad Hα flux. The variation of $W_{H\alpha}$ with the local continuum flux is shown in Fig. 1. It is clear that $W_{H\alpha}$ is anti-correlated with the continuum flux. A good fit to the data is obtained with $W_{H\alpha} = constant/F_{\lambda}$, indicating that the line flux stays constant as the optical continuum varies. This behaviour is clearly incosistent with radiation-bounded BLR illuminated by a jet. The obvious explanation is that the BLR is photoionized by a second, more isotropic source of ionizing photons which is weakly variable and sufficiently feeble at UV-optical wavelengths that it is overwhelmed by the beamed synchrotron emission. Thermal emission from the surface of a hot accretion disk would have these features. The only escape route from this conclusion would be if the BLR is partially matter-bounded. In this case, as the continuum flux increases the BLR becomes fully ionized along the axis of the beam and hence the line luminosity no longer increases linearly with the continuum. Calculations show that for this to work the BLR column density $N \leq 10^{23} cm^{-2}$ and the jet Lorentz factor and viewing angle must be close to the limit permitted by the radio data.

Would an accretion disk continuum sufficiently strong to explain the observed $W_{H\alpha}$ produce an observable signature, such as a flattening of the continuum spectrum in the near UV? We estimate (C96) that the characteristic disk temperature must be $T > 1.2 \times 10^5$K for the thermal component to remain undetected in the optical spectrum. Cooler disks producing the same ionizing luminosity will make larger contributions to the optical continuum.

3. Conclusions

Our results show that the broad Hα line in BL Lacertae does not respond to changes in the power of the Doppler-beamed synchrotron emission which dominates the optical continuum. The most likely explanation for the the observed inverse correlation between $W_{H\alpha}$ and continuum brightness is that the BLR is photoionized by emission from a second continuum source which is not directly observed in the optical band. An obvious candidate is a hot accretion disk. The lack of a detectable big blue bump requires the accretion disk temperature $T > 1.2 \times 10^5$K. Hence these observations provide the first, albeit indirect, evidence that like Seyfert galaxies BL Lacertae must possess both a BLR and an accretion disk. In order to confirm the presence of such a source, observations in the far-UV or soft X-rays are required.

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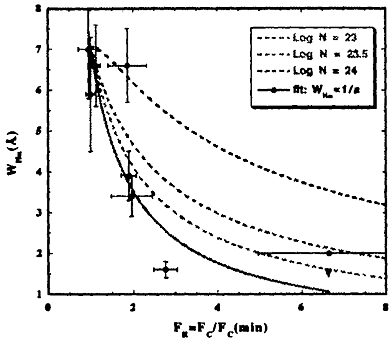

Figure 1. Plot showing the variation of $W_{H\alpha}$ with the continuum flux under the line for the data after correction for galactic redenning and the host galaxy contribution. The solid line is the best $\propto 1/x$ fit to the data and the dotted lines represent the expected behaviour of a partially matter-bounded BLR photoionized by synchrotron emission from the jet.

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