Mem. S.A.It. Vol. 74, 492
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Memorie della

High ionization winds in the narrow line region of active galactic nuclei

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Abstract. We study the distribution of the radial velocity difference between the [O III]λ5007 line and Hβ emission line in a sample of 187 Seyfert 1 and low-redshift quasars. We identify objects with large blue-shifts (which we call 'outliers'), with shifts to the blue up to 1000 km s^{-1}. While the occurrence of such large shifts between narrow lines poses a potential challenge to the accuracy of redshift determinations, we also show that outliers are relatively infrequent, and not randomly distributed across the range of optical spectral properties. Large blue shifts occur only in a particular section of the Eigenvector-1 diagram. We suggest that this phenomenon could be associated to a high ionization outflow originating in the active nucleus.

Key words. galaxies: active – galaxies: quasars: general

It is generally believed that the radial velocity of the [O III]$\lambda\lambda$4959,5007 lines is close to the systemic velocity of every active galactic nucleus (AGN). However recent observations indicate that for I Zw 1, the prototype of the NLSy1 class, the [O III] lines are blue shifted relative to the reference frame, determined from H I measurements, by ≈500 km s^{-1} (about 8 Å, undoubtedly larger than measurement/calibration errors; see Marziani et al. 1996). The narrow line region (NLR), where most of [O III]$\lambda\lambda$4959,5007 is emitted, has now been partly resolved in the nearest AGN (e.g., Falcke et al. 1998). The geometry of the line emitting region has been found not to be spherically symmetric, suggesting that integrated [O III]$\lambda\lambda$4959,5007 emission may be dependent on how the source is oriented with respect to the line of sight. We measured the difference between the radial velocity of the [O III]λ5007 line and Hβ starting from spectra of 187 type-1 AGN (i.e. Seyfert 1 and low-redshift quasars). The dataset encompasses CCD spectra that were obtained over the past 10 years for studies of H$\beta_{\rm BC}$

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at $z \lesssim 0.8$. The sample has an absolute B magnitude of $\overline{M_B} \approx 23.7 \pm 2.0$ ($H_0 = 50$ km s^{-1} Mpc^{-1}, $q_0 = 0$). We de-redshifted the spectra using Hβ measurement, whenever Hβ narrow component or the top of the line could be clearly identified. After that, optical Fe II_{opt} emission blends were subtracted. We considered the difference in the radial velocities $\Delta v_{r[OIII]}$=v_r([O III]λ5007)$-v_r$(Hβ) as measured on the Fe II_{opt} subtracted spectrum, employing a Gaussian fit to the top of the lines. Therefore, $\Delta v_{r[OIII]}$ should be regarded as peak shift measurements (not influenced by the strong blueward asymmetry often observed at the [O III]$\lambda\lambda$4959,5007 line base). The values of $\Delta v_{r[OIII]}$ are in the range from -950 to $+280$ km s^{-1}, with an average $< \Delta v_r > \approx -30$ km s^{-1}. The sample standard deviation is $\sigma \approx 135$ km s^{-1}.

In the following, we will refer to objects with $\Delta v_{r[OIII]} \lesssim$-300 km s^{-1} as 'blue outliers', i.e. objects whose [O III] lines are significantly blue shifted relatively to Hβ emission. We identify 7 blue outliers in our sample: I Zw 1, PKS 0736, PG 0804+761, Ton 28, PG 1402+26, PG 1415+45, PG 1543+489. All they are exclusive of Population A (i.e. objects with FWHM(Hβ_{BC}) $\lesssim$ 4000 km s^{-1} following Sulentic et al. 2000), with the largest negative $\Delta v_{r[OIII]}$ occurring at minimum FWHM(Hβ_{BC}). Here we would like to mark the possible existence of candidates for 'red outliers', with [O III] lines red displaced relatively to Hβ with $\Delta v_{r[OIII]}$>150 km s^{-1}. However, these objects need higher resolution and 2D spectra to be studied. Five out of 7 blue outliers have C IVλ1549 observations with FOS/STIS in the HST archive. Analysis of HST observations points to that large [O III]$\lambda\lambda$4959,5007 shifts tends to be associated to very large C IV$\lambda1549_{BC}$ shifts [the condition seems necessary but not sufficient to define outliers: not all objects with large C IV$\lambda1549_{BC}$ blueshift in Marziani et al. (1996) are [O III]$\lambda\lambda$4959,5007 outliers!].

Further insight can be gained if we consider the distribution of the outliers in the so-called 'optical Eigenvector 1' diagram, which shows FWHM(Hβ_{BC}) versus the equivalent width ratio of the Fe II_{opt} blend peaked at λ4570 and of Hβ_{BC}(R_{FeII}= W(Fe IIλ4570)/W(Hβ_{BC})). The distribution of blue outliers in this parameter plane is obviously different. The blue outliers with the largest blueshifts tend to occupy the lower right part of the diagram. The two-dimensional Kolmogorov-Smirnov tests (Fasano & Franceschini, 1987) shows that the distribution of outliers is significantly different (to a confidence level of 0.99) from the distribution of the typical AGN. We constructed a purely kinematical model in which [O III]$\lambda\lambda$4959,5007 and C IVλ1549 are both assumed to arise in a radial flow constrained in a cone of half opening angle about 85^0 (e.g. a high-ionization, optically thin wind), where the receding part of the flow is obscured by an optically thick accretion disk, i.e. we are able to see the approaching part of the flow and the near side of the disk assumed to emit Hβ. This simple model reproduces the shift and FWHM values of C IVλ1549 and [O III]λ5007 measured on the Ton 28 spectrum. To conclude, we suggest the blue outliers are not peculiar objects, but rather AGN emitting at extreme L/M with a compact NLR, and whose [O III]λ5007 emission is due to a high ionization wind propagating outward from the BLR. A predominance of blueshifts in the sample indicates that [O III]λ5007 peak velocity is affected by outflow motions occurring in the inner most narrow line region.

Acknowledgements. We acknowledge support from the Italian MURST through grant Cofin 00−02−004.

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