Broad emission line variability in the Seyfert 1 galaxies NGC 5548 and NGC 3783

G.M. Stirpe1, A.G. de Bruyn2, and E. van Groningen3

1 Sterrewacht Leiden, Postbus 9513, 2300 RA Leiden, The Netherlands
2 Radiosterrwacht Dwingeloo, Postbus 2, 7990 AA Dwingeloo, The Netherlands
3 Astrophysics Division, ESTEC, Postbus 299, 2200 AG Noordwijk, The Netherlands

Received July 3, 1987; accepted January 11, 1988

Summary. High quality spectra are presented for the Seyfert 1 galaxies NGC 5548 and NGC 3783. Hz and Hβ were observed at different epochs, with time intervals between 4 and 13 months. The spectra have been scaled to each other by normalizing the flux of the narrow lines: we believe that this internal calibration gives an accuracy of 5% or less, better in most cases than absolute spectrophotometry.

The difference spectra show that the broad emission lines have varied not only in flux, but also in shape. In particular, the broad line profiles of Hz and Hβ in NGC 5548 have changed differently, suggesting that two components with different physical characteristics are present in the broad line region (BLR). We compare our data with those recently published by Peterson (1987) and Peterson et al. (1987) and conclude that the supermas- sive binary scenario proposed by the latter is not unique. The ob- served variations can be interpreted in an accretion disk scenario.

The whole data-set also provides evidence against models based on outflowing motion, since the blue side of Hβ in NGC 5548 increased at a time when the continuum was decreasing.

In both objects the HeⅡ λ4686 line is more strongly variable than the Balmer lines, and in NGC 3783 its width in the difference spectrum is larger than that of Hβ, indicating that the HeⅡ line is emitted predominantly closer to the central energy source than the Balmer lines; it is not necessary, however, to assert that the HeⅡ difference is emitted by a different, smaller region than the BLR. Furthermore, we show that NⅢ λ4640 Bowen emission is present in this source, and is partly responsible for the greater width of HeⅡ λ4686.

A limit to our results is given by the long time intervals separ- ating our observations, which do not allow us to set as strong constraints on the BLR as high quality, frequent monitoring of Seyfert 1 spectra would.

Key words: galaxies – Seyfert – line profiles – spectrophotometry

1. Introduction

It is now generally believed that the continuum and emission lines of active galactic nuclei (AGNs) are produced by a massive black hole interacting with the gas surrounding it, and that the lines are Doppler-broadened because of large scale motions of the gas itself. However, it is not yet clear which model is the most suitable to describe the dynamics and kinematics of AGNs, and of the broad line region (BLR) in particular. For the latter, many models, involving inflow, outflow, rotation, and various combinations of all these, have been proposed in the last decade, and most of them can be adjusted to give satisfactory fits to the observed line profiles (though not necessarily satisfactory physical scenarios), leaving us in an ambiguous situation as to our knowledge of BLRs. Variability studies provide constraints on the available models, and also allow us to overcome problems introduced by the narrow emission lines. These are not always easy to separate from the broad lines, but by subtracting two spectra of the same object the narrow lines should cancel completely, since they do not vary on short time-scales. Any residuals left would represent a pure broad-line contribution. Variability of the emission lines in a Seyfert 1 galaxy was first reported by Andrellat and Souffrin (1968) in NGC 3516, and has since been observed in many other sources, particularly NGC 4151 (Penston and Pérez, 1984; Ulrich et al., 1984).

In the context of a program on broad emission line profiles in AGNs, we have repeatedly observed the Hz and Hβ regions of two bright Seyfert 1 galaxies, NGC 5548 and NGC 3783. NGC 5548 is one of the best studied sources of its kind, thanks to its variability and its brightness. By examining the published spectra (de Bruyn, 1980; Peterson et al., 1982; Wilson and Ulve- stad, 1982; Malkan and Filippenko, 1983; Osterbrock, 1984; De Robertis, 1985; Crenshaw and Peterson, 1986; Peterson, 1987; see also references in Weedman, 1977) it is clear that the broad emission line intensities and profiles, as well as the continuum luminosity, have undergone considerable changes. The line profiles of NGC 3783 have been analysed by Pelat et al. (1981) and by Menzies and Feast (1983): the latter, in particular, notice a variation in the line profile of Hz.

These two sources, therefore, can provide very useful information on the structure of BLRs. However, our whole analysis will be considerably limited by the time-interval (from 4 months to more than a year) separating our observations. Seyfert 1 galax- ies have been observed to vary on time scales as short as a few weeks or less, which means that our difference spectra may not

Send offprint requests to: G.M. Stirpe

* Based on observations collected at the Observatorio del Roque de los Muchachos, La Palma, Spain, and at the European Southern Observatory, La Silla, Chile.
reflect single events, but the combination of a series of events occurring on shorter time scales. In this paper we present our recent, high quality spectra, and study the variations undergone by the broad lines during the periods separating our observing runs. We will show that the combination of high resolution and high signal-to-noise reveals profile differences even if only moderate (30\%) variations have occurred.

2. Observations and reduction

2.1. NGC 5548

We have observed NGC 5548 three times with the Intermediate Dispersion Spectrograph at the 2.5 m Isaac Newton Telescope (INT) at the Observatorio del Roque de Los Muchachos on the island of La Palma (Spain), in February and June 1985, and in July 1986; we will henceforth refer to these runs with numbers 1, 2 and 3 respectively. During all runs we used the 235 camera, the same grating (giving a dispersion of 66 Å/mm), and the same slitwidth (1.1 arcsec). We used the IPCS detector during run 1 to observe the blue part of the spectrum at a resolution of 1.9 Å while during runs 2 and 3 we have observed both the Hz and Hβ spectral regions with the GEC CCD chip, which gave us a resolution of 2.2 Å. In velocity this corresponds to 100 km s\(^{-1}\) (Hz) and 136 km s\(^{-1}\) (Hβ). Along the slit one resolution element equalled 2 arcsec (IPCS) and 1 arcsec (CCD). We stress that all spectra on the last two occasions were taken with exactly the same configuration, therefore minimizing the differences due to instrumental effects. Also the seeing was similar during all runs (between 1 and 1.5 arcsec), which is also important for this object, since the narrow line region may be resolved and thus give different contributions in very different seeing conditions: for reasons explained above, we want to avoid this as much as possible. Moreover, the intensity of the narrow lines is often the only reliable means we have to scale the spectra to each other (in the absence of absolute spectrophotometry).

Table 1 gives the observing log for this source. The reduction of all CCD spectra was performed on the VAX 11/785 at Leiden, using the FIGARO package, following the usual procedure of bias and preflash subtraction and flat-field division. For the latter we used a white lamp exposure. The spectra have been extracted using a modified version of the optimal extraction method described by Horne (1986): because charge-transfer inefficiency on the GEC CCD introduces substantial distortion in the spatial profile columns, we have fitted the latter with a spline-curve instead of the simple polynomial suggested by Horne. Since the underlying galaxy is resolved, using the Horne method means that more stellar continuum emission is gathered than by the simple extraction of the central columns. However, because our main goal is to study the broad emission lines (which come from a spatially unresolved region) and their difference, we have opted for this method because it optimizes the signal-to-noise ratio and allows to overcome eventual distortion due to CCD misalignment, which was noticeable during run 3. The difference spectrum should not be affected by the method used since the stellar continuum does not vary on these short time scales. The IPCS spectrum was reduced at ESA/ESTEC, with the MIDAS package, also with the Horne method. For all spectra, the wavelength calibration was obtained by using comparison spectra from Cu/Ar and Cu/Ne lamps. The single scans have been corrected for extinction, using the coefficients for La Palma available from the Royal Greenwich Observatory, added to give a total of 5 spectra, and calibrated with Feige 56 (run 1), HD 140283 (run 2), BD +17°4708 and BD +26°2606 (run 3), using the fluxes published by Oke and Gunn (1983) and Stone (1977). The absolute calibration is significantly affected by light-loss due to seeing and guiding errors, and we estimate it to be accurate within 50\%. However, as will be shown in Sect. 3, the spectra can be scaled relative to each other with much higher accuracy.

Because we have used a GEC CCD during the last two runs, and because Hz is a very intense emission line, we had to make sure that charge transfer did not affect our scans in different measure, thereby introducing spurious structure in the difference spectrum. By examining the shape of the single spatial profile columns, and measuring their deviation from a smooth curve in correspondence of Hz, we could see that charge transfer ineffi-

<table>
<thead>
<tr>
<th>Date obs.</th>
<th>Line</th>
<th>Int. time (sec)</th>
<th>Approx. seeing (arcsec)</th>
<th>Airmass</th>
<th>Wavel. cov. (Å)</th>
<th>Resol. (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High resolution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85 Feb. 9</td>
<td>Hβ</td>
<td>1500</td>
<td>1.5</td>
<td>1.01</td>
<td>3720–6260</td>
<td>1.9*</td>
</tr>
<tr>
<td>85 Jun. 2</td>
<td>Hz</td>
<td>750</td>
<td>1.0</td>
<td>1.40</td>
<td>6150–6980</td>
<td>2.2</td>
</tr>
<tr>
<td>85 Jun. 2</td>
<td>Hz</td>
<td>750</td>
<td>1.5</td>
<td>1.48</td>
<td>6150–6980</td>
<td>2.2</td>
</tr>
<tr>
<td>85 Jun. 2</td>
<td>Hβ</td>
<td>1000</td>
<td>1.0</td>
<td>1.18</td>
<td>4550–5380</td>
<td>2.2</td>
</tr>
<tr>
<td>85 Jun. 2</td>
<td>Hβ</td>
<td>1300</td>
<td>1.0</td>
<td>1.23</td>
<td>4550–5380</td>
<td>2.2</td>
</tr>
<tr>
<td>86 Jul. 18</td>
<td>Hβ</td>
<td>1500</td>
<td>1.5</td>
<td>1.67</td>
<td>4570–5400</td>
<td>2.2</td>
</tr>
<tr>
<td>86 Jul. 18</td>
<td>Hβ</td>
<td>1500</td>
<td>1.5</td>
<td>1.90</td>
<td>4570–5400</td>
<td>2.2</td>
</tr>
<tr>
<td>86 Jul. 19</td>
<td>Hz</td>
<td>1000</td>
<td>1.3</td>
<td>1.09</td>
<td>6190–7020</td>
<td>2.2</td>
</tr>
<tr>
<td>86 Jul. 19</td>
<td>Hβ</td>
<td>1500</td>
<td>1.3</td>
<td>1.14</td>
<td>4570–5400</td>
<td>2.2</td>
</tr>
<tr>
<td>Low resolution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>86 Jul. 17</td>
<td>Hz, Hβ</td>
<td>1000</td>
<td>2.0</td>
<td>1.63</td>
<td>4200–7580</td>
<td>9.0</td>
</tr>
</tbody>
</table>

* The detector used for the February 1985 Hβ spectrum was the IPCS. All other spectra in this table were taken with the GEC CCD.
Table 2. Observing log for NGC 3783 Hβ (ESO/MPI 2.2 m tel., La Silla)

<table>
<thead>
<tr>
<th>Date obs.</th>
<th>Int. time (sec)</th>
<th>Approx. seeing (arcsec)</th>
<th>Airmass</th>
<th>Wavel. cov. (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>86 May 21</td>
<td>1800</td>
<td>2.0</td>
<td>1.06</td>
<td>4500–5380</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>2.0</td>
<td>1.03</td>
<td>4500–5380</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>2.0</td>
<td>1.02</td>
<td>4500–5380</td>
</tr>
<tr>
<td>87 Jan. 12</td>
<td>1800</td>
<td>1.5</td>
<td>1.04</td>
<td>4530–5410</td>
</tr>
<tr>
<td></td>
<td>1200</td>
<td>1.5</td>
<td>1.02</td>
<td>4530–5410</td>
</tr>
</tbody>
</table>

... (rest of the text continues)
Fig. 1. a Spectra of Hβ in NGC 5548 taken at the 2.5 m INT on La Palma at the dates given. All have been rebinned to 1 Å pixels. The wavelength scale is in the rest frame of the galaxy, which has an assumed redshift of 0.0169. The redshift has been determined by using the peaks of the narrow lines. The flux scale is normalized so that the peak of Hz in 1985 (e) has flux $F_\lambda = 10$. b Difference spectra for Hβ. The vertical scale is blown up by a factor 2 with respect to a. The high residual of [O iii] λ5007 in the February–June 1985 difference is due to saturation of the IPCS in the February spectrum. c Hz spectra of NGC 5548, plotted and normalized as for Hβ. d Difference between the two Hz spectra shown in c. The vertical scale is blown up by a factor 4.

The results of Peterson. We find that the line has increased by 30% on the blue side, developing a strong shoulder, while the red side has decreased by 20%. Unfortunately, we do not have a spectrum of Hz from February 1985. If the velocity field of the BLR were independent from position, the line should vary in intensity and not in profile on light-crossing time scales, as also noted by Peterson (1987). No profile variation is immediately evident from Peterson’s 1985 series of Hβ spectra although from
our spectra it is clear that one has occurred between February and June of that year. However, Peterson’s difference spectra indicate a variation in the blue side of Hβ between February and March (Peterson, personal communication). The variation in the profile, therefore, seems to have occurred for the major part on a very short time scale (about a month). Our results thus rule out a position-independent velocity field.

Between June 1985 and July 1986 the variation in the flux of the broad Hz and Hβ was 20% and 30%, respectively (see Fig. 1). But in addition, the profiles of the two lines appear to have varied differently: the marked bump at the centre of the difference spectrum of Hz has no counterpart in Hβ. However, the blue dip at $-2400$ km s$^{-1}$ does correspond to the blue dip in Hz. Although it has been known for a long time that the Balmer decrement changes when the continuum and line intensities change (de Bruyn, 1980), such drastic differences in the line profiles have not been observed before. The most likely explanation for this difference is that at least two physical components contribute to the broad line profiles. In order to explain the dissimilar difference spectra of Hz and Hβ the components must have different Balmer decrements. To derive some quantitative information on these ratios we have divided Hβ by Hz for the two epochs. These ratios are shown in Fig. 3. They show that at the epoch of minimum brightness (July 1986) the Hβ/Hz ratio is much smoother than observed in June 1985. A possible interpretation is that a component which was visible in June 1985 had disappeared or become much weaker by July 1986. Notice also that the Balmer decrement becomes flatter at high velocities, as already observed in other sources, which suggests that very high densities are present in the BLR (van Groningen, 1984).

We have also divided the two broad Hz profiles, cleansed from the narrow lines as well as possible, by each other (Fig. 4), to establish the relative variation of the profile, which reaches 30% on the blue side and 20% on the red side. The considerable structure shown by the ratio could be due to two factors, and maybe a combination of both: a) the continuum is varying continuously and at random, and what we observe is the response of the surrounding gas, propagating across the BLR’s velocity structure; b) different parts of the BLR respond differently to changes in the continuum. The two hypotheses do not in any way exclude each other, and are in fact both likely: the past history of variability in NGC 5548 supports the first, and our current knowledge of the BLR structure (it is now generally agreed that it has a multi-component nature) supports the second.

The double structure we observe in the Hz difference spectrum is similar (though of opposite sign) to the Hβ difference spectrum in Peterson (1987). The peak velocities of the red features are in agreement, but in our difference spectrum the blue feature peaks at a more negative velocity ($-2400$ km s$^{-1}$ against $-2100$ km s$^{-1}$). Also, the intensity of the variation is

<table>
<thead>
<tr>
<th>Table 3. Equivalent widths of main lines (Å)</th>
<th>NGC 5548</th>
<th>NGC 3783</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line</td>
<td>Feb. 85</td>
<td>June 85</td>
</tr>
<tr>
<td>Hα (broad)</td>
<td>–</td>
<td>628</td>
</tr>
<tr>
<td>Hβ (broad)</td>
<td>113</td>
<td>146</td>
</tr>
<tr>
<td>[O III] λ 5007</td>
<td>48$^a$</td>
<td>66</td>
</tr>
</tbody>
</table>

$^a$ The [O III] λ 5007 line in this spectrum is saturated: the EW in the table is obtained by multiplying that of [O III] λ 4959 by a factor 3
Fig. 3. a The broad line profiles of Hα and Hβ in June 1985, in 100 km s⁻¹ bins and normalized to their values at 0 km s⁻¹. To obtain them, a power-law continuum has been fitted to the spectra and subtracted, and the blending lines ([N II] λ 6548, 6584 from Hα, Fe II λ 4924, He II λ 4686, and [O III] λ 4959 from Hβ) and the narrow Balmer components have been subtracted in order to obtain a smooth profile. A scaled Hα profile was used as a template for the subtraction of the broad lines. The same, centred at 5000 Å, was used to eliminate the broad wing under [O III] λ 5007. The separation of this feature from Hβ is highly uncertain, but for the purpose of this work the procedure followed is sufficiently accurate. The uncertainty on the position of the continuum does not affect the obtained profiles between -3000 km s⁻¹ and +3000 km s⁻¹. b The Hβ/Hα ratio as function of velocity for NGC 5548 in June 1985 and July 1986

stronger on both sides. However, our Hβ difference spectra show very different profiles, and in the February–June 1985 period the two sides of the line have actually varied in opposite senses. This could support the supermassive binary scenario proposed by Peterson et al. (1987). However, we consider this scenario to be unlikely, mainly because of the absence of any correlation between the variation of the blue side and that of the continuum between February and June 1985: both sides of the line, of comparable intensity, underwent comparable but opposite variations, while the continuum decreased by about 40%. This would imply that, in the binary scenario, the continuum corresponding to the blue BLR varied less than that corresponding to the red BLR, and yet produced a comparable effect on its emission lines. We believe a scenario with one multicomponent BLR, where time-delay effects are present, to be more satisfactory. The double component Hz difference spectrum and Peterson's Hβ difference spectrum have the sort of profile one expects from an accretion disk (van Groningen, 1983). The other difference spectra, however, do not have such a profile. It is possible to invoke delay effects and multiple components to explain these profiles. As shown by van Groningen (1984), the accretion disk model is compatible with the line profiles of other Seyfert 1 galaxies, but at least another component must be present, and furthermore there must be a mechanism through which the continuum source illuminates the disk. A scattering medium, possibly non-uniform, would solve this last problem, and could also account for additional time-delays in the spreading of the variation across the BLR.

As already mentioned in the introduction, the difference spectra are probably produced by the superposition of a series of short time scale variations, which can be both positive and negative, thus working against each other in the difference spectrum structure. This is confirmed by examining the data published by Peterson et al. (1987). It appears that during their 1985 campaign the continuum of NGC 5548 decreased by about 40%, while the total Hβ flux was about the same in May and February, having undergone slight variations in between. This is consistent with our 1985 spectra. But, although the Hβ flux remained constant, we did observe significant profile variability. At the beginning of the 1986 campaign by Peterson et al. the source was again in a high state, which is certainly not the case in July 1986: our spectra taken at that epoch show the source to be in an even lower state than in June 1985. Evidently, a lot has happened between our second and third run, with the source undergoing at least one outburst and subsequently weakening, contrary to the February–June 1985 interval, when at least the continuum seems to have decreased monotonically. This means that the Hβ difference spectrum from runs 1 and 2 should reflect a more straightforward sequence of events, while our difference spectra from runs 2 and 3 are separated by positive and negative variations. It is therefore impossible to say, without seeing intermediate spectra, whether, for instance, the central bump in the Hz difference spectrum for runs 2 and 3 is not actually due to a component which has increased sometime during the rising phase of the continuum.

A feature which is detected only in the second run is broad He II λ 4686. Only the narrow line is visible in the other spectra, although the broad component might be drowned in structure.
caused by the various Fe II multiplets. The peak appearing in the difference spectra at about 4650 Å has the same velocity with respect to the He II line as the blue feature of Hβ, suggesting a common origin. Due to the low signal-to-noise ratio in this part of the spectrum, it is difficult to say how the He II width compares to that of Hβ, but the line has certainly varied more than Hβ in percentage (at least 50% versus 30%), as noticed for other epochs by Peterson and Ferland (1986). We will see in the next section that NGC 5548 is not unique in this.

3.2. NGC 3783

Because of the slight difference in resolution between the 1986 and 1987 spectra, the former had to be smoothed before the subtraction. The best smoothing was chosen on the basis of the residuals of the [O III] lines. The two spectra and the difference spectrum are shown in Fig. 5. An examination of the spatial profiles of Hβ and the [O III] lines revealed no difference, as in NGC 5548. Here too, thus, the relative scaling must be accurate to within 10% or less.

Hβ has decreased in flux by about 15%, but there is no evidence for profile variation, contrary to what was observed in Hα by Menzies and Feast (1983) between 1976–77 and 1982. However, the most interesting feature in the difference spectrum is the He II λ 4686 line, which proportionally shows a much more dramatic decrease (about 50%), although it too does not show any profile variation. As observed by Peterson and Ferland (1986) in NGC 5548, the He II difference line appears to be much broader than in Hβ. We believe that this is partly due to a variation in the N III Bowen emission lines, whose presence in NGC 3783 was first noticed by Cooke et al. (1976). These lines are strongly associated with the He II lines (Seaton, 1960), and one would expect them to be coupled to the He II line flux. These lines could at least partly justify the width of the feature in the difference spectrum. As shown in Fig. 6, subtracting from our 1986 spectrum a scaled Hα profile, centred at 4686 Å, and broadened by 40%, leaves a broad residual centred at 4640 Å. The fact that no residual is left on the red side of the He II line (the two narrow features are [Ar IV] λλ 4711,4740 at a ratio of 1.0:1.2) is convincing evidence that the broad residual is indeed the N III λ 4640 Bowen fluorescence lines. Their approximate ratio to the broad He II λ 4686 is 25%, consistent with model calculations (Netzer et al., 1985; Eastman and MacAlpine, 1985). The uncertainty in the flux is too high to set further constraints. A similar result is obtained also for the 1987 spectrum, where the flux of the whole He II–N III complex is about 50% lower. The ratio of the N III lines to He II λ 4686 remains constant within the uncertainties. N III emission is also present in the Seyfert 1 galaxies 3C 120 and Markarian 509 (Baldwin et al., 1980; van Groningen, 1984) and Arakelian 564 (unpublished spectrum), and is fairly conspicuous in all three objects. Up to now, however, its presence has scarcely been underlined.

Why the emission lines on this occasion should vary in flux only and not in profile, after showing profile variation in the past, is uncertain. One possibility is that the variation occurred on a short time scale, with the continuum remaining constant for a long period before and after it. The emission line would then reassert the same shape, though with different intensity, once the variation had completely crossed the BLR.

While the broad lines have decreased in flux, the continuum level has increased in the eight months separating the observations. This could be an effect of seeing and guiding errors, which
might have caused more stellar continuum to enter the slit during the second run, or it could be a genuine increase of the non-stellar continuum. If the latter is true, our spectrum would have been taken in the delay period between a variation of the continuum and the response of the lines. We would then expect the line of to have increased in the weeks following our observations.

4. Conclusions

Although our results do not give a clear picture of the BLR, we can at least set some constraints on the dynamics of this region.

We do not support the super-massive binary scenario for NGC 5548 (Peterson et al., 1987), given our difference spectra. It is clear from our spectra that the broad emission lines do not consist of a slightly redshifted main body flanked by a weaker component at high negative velocity. Instead, as is visible also in previously published spectra of Hβ (Osterbrock, 1984; Malkan and Filippenko, 1983), there are two high velocity shoulders at about −2400 km s⁻¹ and +1600 km s⁻¹, both of which vary. They could well be produced by an accretion disk illuminated indirectly by a non-uniform scattering medium (van Groningen, 1984).

Furthermore, the observations argue against models dominated by outflow, since the blue shoulder of NGC 5548 increased between February and June 1985, with most of the variation taking place in the first months, while the continuum was steadily decreasing (Peterson, 1987). If the bulk motion in the BLR was radially outwards, we would expect the blue side of the line to follow the variations of the continuum with very little delay, contrary to what is observed.

The greater width of the He II λ4686 line in the difference spectra of NGC 5548 (Peterson and Ferland, 1986) and NGC 3783 is not necessarily due to a separate region. We have shown that the line can be artificially broadened by the presence of N II Bowen emission, at least in NGC 3783 (we cannot be sure of this in NGC 5548); furthermore, the wings of the Balmer lines in the individual spectra are just as broad as those of He II.

It is clear that more positive and constraining results can only come from monitoring Seyfert 1 spectra at high resolution (2–3 Å), high signal-to-noise (> 50:1) and short time scales (about a week). For moderate variations (≤ 30%) in line flux a resolution of only 1/10 of the line width appears to be insufficient to separate moderate profile variations from calibrations errors. It also makes it impossible to apply internal calibration, which we believe to be a more accurate means than absolute spectrophotometry to scale the spectra from different epochs to each other. Only with high quality observations, if at all, we will be able to notice time delay effects, and eventually separate different components of the BLR. We have conducted a small campaign of this kind at the INT in May–July 1987, the results of which are now being analysed.

Acknowledgements. The authors are grateful to Dr. B.M. Peterson and to an anonymous referee for their useful comments on this paper.

The Isaac Newton Telescope is operated on the island of La Palma by the Royal Greenwich Observatory at the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofisica de Canarias.

GMS acknowledges support by the Netherlands Foundation for Astronomical Research (ASTRON), with financial aid by the Netherlands Organization for the Advancement of Pure Research (ZWO).

References