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A search for variability in Narrow Line Seyfert 1 Galaxies

II. New data from the Loiano monitoring programme

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Abstract. We present part of the results from a spectroscopic monitoring programme on a sample of AGNs, relative to Narrow Line Seyfert 1 Galaxies: following the idea that Balmer-line variability can help discriminate among the possible models for these objects, and on the basis of a first monitoring project with long time-scales, we now add to the previous database new variability results, both on short and long time-scales. The comparison with a similar data-set of normal Seyfert 1's suggests now a statistically different behaviour of NLS1s with regard to the 1-year variability properties, and a clearer trend of NLS1s towards weaker variability is suggested by the comparison between the 1-month variations of NLS1s and those of the typical Seyfert 1 NGC 5548. Although these results do not take into account the possible role of the relative contribution of narrow components to the line fluxes, and of the continuum variability amplitudes (both of which can in principle be different in the two classes of objects), they are consistent with the model of a BLR which is on average larger in NLS1s.

Key words: galaxies: active – galaxies: nuclei – galaxies: Seyfert

1. Introduction

The widespread property of variability of the continuum and broad lines emitted by Active Galactic Nuclei has been used in recent years to obtain constraints on the structure and kinematics of the Broad Line Region, through intensive spectral monitoring and the use of reverberation mapping techniques (Blandford & McKee 1982, Peterson 1993, Robinson 1994, Alloin et al. 1995): the inferred sizes of the BLR range from a few light days to about a light month, and therefore direct information on the region through imaging techniques is not available.

Narrow Line Seyfert 1 Galaxies (Osterbrock & Pogge 1985) are a sub-class of Seyfert 1's located at the lower end of the broad line width distribution: the FWHM of the permitted lines does not exceed 1000-1500 km s^{-1} in these objects. In most other properties NLS1s are similar to 'normal' Seyfert 1's: they have different widths of permitted and forbidden lines, intense FeII lines and high ionization transitions, normal line ratios and average luminosities. They present, on average, lower equivalent widths compared to Seyfert 1's (Osterbrock & Pogge 1985, Goodrich 1989), but again this is the extension to low FWHM of a trend observed throughout the whole Seyfert 1 population. NLS1s are efficiently found in soft X-ray selected Seyfert 1 samples, in which they represent $\sim$ 16-50% of all objects (Stephens 1989, Puchnarewicz et al. 1992), compared to the $\sim$ 10% found in optically-selected samples. Boller et al. (1996) found that NLS1s have generally much steeper soft X-ray (ROSAT) continuum slopes than normal Seyfert 1's, and present in a few cases rapid soft X-ray variability. The 2-10 keV spectra have also been found to be steeper in NLS1s than in other Seyfert 1's (Brandt et al. 1997).

The line-of-sight component of the velocity of the broad line emitting gas may be unusually small for several reasons, among which a lower mass of the central black hole, projection effects due to gas motions in a plane (e.g. that of a disk) observed almost pole-on, a larger BLR size, a lack or obscuration of the inner, high velocity regions of the BLR. The explanation of this behaviour can therefore provide insight on the more general problem posed by the great diversity among broad emission line profiles.

Permitted line variability, being directly related to the size, geometry and kinematics of the Broad Line Region, is potentially very useful to discriminate among some of the mentioned hypotheses: a lack of widespread variability in NLS1s would in fact suggest that the visible BLR is located at a higher distance from the central engine than in normal Seyfert 1's; similar variability properties in NLS1s and Seyfert 1's could instead imply a smaller central mass or an anisotropic kinematic structure for the BLR.

Since no NLS1 has ever been intensively monitored, and virtually no information was available on the presence of variability in this class of objects when the project started, we per-

Send offprint requests to: M.E. Giannuzzo formed a preliminary simple observational programme aimed at determining whether variability is a common characteristic of NLS1s as a class (Giannuzzo & Stirpe 1995, Giannuzzo & Stirpe 1996 – hereafter Paper I): we adopted a statistical approach, by evaluating the optical line flux percentage variations on a time-scale of 1 year for a sample of NLS1s, and comparing our results with those of an existing similar data-set of normal Seyfert 1's. We did not find evidence for a weaker or less common variability in Narrow Line Seyfert 1's, and discussing the competing models we concluded that a larger BLR or a smaller black hole mass could be the most probable explanations; we stressed that a short-term monitoring program could help discriminate between the two possibilities. This kind of observations could also address the problem of the generality of reverberation mapping results, since until now only AGNs with high variability and normal line profiles have been monitored, perhaps discriminating against different types of BLRs (Robinson 1995).

In this work the observations reported in Paper I are added to new data on NLS1s from a spectroscopic monitoring programme, conducted at the Bologna Observatory on a larger sample of AGNs, which lasted a few years: this following step of the project aims therefore at collecting information on the variability properties of a greater number of objects on different time-scales, though not in much detail. We have thus enlarged the previous data-set on 1-year percentage variations of the optical lines (this time both Hβ and Hα have been considered), allowing in this way a more accurate statistical comparison than before; furthermore, we evaluated the short-term variations of the line fluxes with the aim to compare them, in the case of Hα, with those of some monitored Seyfert 1's, while in the case of Hβ we used as a comparison object the best studied Seyfert 1, NGC 5548, the light curve of which has been well sampled for several years (Korista et al. 1995 and references therein).

Sect. 2 describes the observations and data reduction and analysis, Sect. 3 presents our results and the statistical comparisons between NLS1 and Seyfert 1 variability properties; finally, Sect. 4 includes a discussion on the results and our conclusions.

2. Observations, data reduction and analysis

The sample of AGNs chosen for the monitoring campaign includes 5 objects classified (sometimes 'marginally') as Narrow Line Seyfert 1's, 2 of which were included also in the sample observed at ESO (Paper I): more specifically, the NLS1 group includes the prototype of the class, I Zwicky 1 (e.g. Halpern & Oke 1987), Akn 564 (Osterbrock & Shuder 1982), NAB 0205+024, Mkn 335 and PG 1211+143 (classified by us on the basis of published spectra according to the Osterbrock & Pogge 1985 criteria). The last two objects are considered as 'marginal' because their permitted line FWHM is slightly larger than the $\sim$ 1000 km s^{-1} limit, being 1200 km s^{-1} in Mkn 335 (unpublished data collected by the authors) and 1600 km s^{-1} in PG 1211+143 (Stirpe 1990), but in both cases the narrow line had been subtracted, which increased the measured line FWHM; furthermore, they share other properties with typical NLS1s,

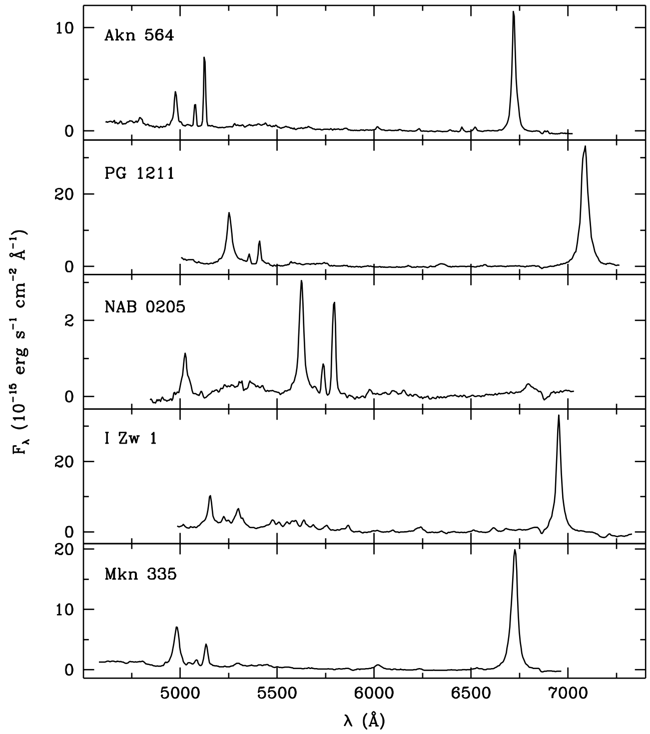

Fig. 1. Representative continuum-subtracted spectra of the monitored Narrow Line Seyfert 1 objects.

such as intense FeII emission and weak forbidden lines. A sample continuum-subtracted spectrum for each of the observed NLS1s is plotted in Fig. 1.

The observations were carried out at the Cassini 1.52 m telescope operated by the Bologna Observatory, using two different spectrographs. A log of the observations is given in Table 1. In the first part of the monitoring campaign (October 1991 – March 1994) the spectra were obtained with a Thomson 7882 CCD (576×384 pixels) mounted on a Boller & Chivens spectrograph. The 350 l/mm grating used at first order gives a coverage of 2500 Å with a resolution of 4.5 Å/pixel. The grating angle was adjusted for each object in order to cover, when possible, both the Hα and Hβ spectral regions. In the summer of 1994, a new all-transmitting spectrograph named BFOSC (Bologna Faint Object and Spectrograph Camera) replaced the Boller & Chivens. The new instrument, working at the Cassegrain focus of the telescope as a focal reducer, is based on a EFOSC concept (Enard & Delabre 1982). The observations after July 1994 were therefore carried out with a Thomson coated CCD (1024×1024) mounted on BFOSC, with a projected pixel size of 0.56 arcsec. The used grism gives a larger but fixed spectral range (4000–7850 Å) and a resolution of 4 Å/pixel.

The slit width was 2.5 arcsec, matching the typical seeing of the site, with the exception of the March 1995 observation of NGC 5548, for which a double width was chosen due to bad seeing conditions, and a few observations of Akn 564 and Mkn 335, for which the good seeing ensured that also with a slit 2.0 arcsecs wide all the flux entered the instrument.

Table 1. Log of Loiano and ESO (marked with '(E)') observations used throughout this work.

Galaxy	α (1950)	δ (1950)	m_V	z	Date of observation	Julian date (JD – 2400000)	Integration time (minutes)
Mkn 335	00 03 45.2	+19 55 29	13.85	0.025	1991 Oct 16	48546.4	30
					1992 Aug 1	48836.5	30
					1992 Sep 1	48867.4	30
					1993 Aug 11	49211.5	90
					1993 Aug 20	49220.5	60
					1994 Aug 8	49573.5	40
					1994 Aug 27	49592.6	40
					1994 Oct 13	49639.4	40
					1994 Nov 25	49682.4	30
					1994 Dec 13	49700.3	30
					1995 Jul 22	49921.6	30
					1995 Aug 20	49950.6	30
					1995 Aug 31	49961.5	30
					1996 Oct 1 (E)	50358.6	20x2
I Zwicky 1	00 50 57.8	+12 25 20	14.03	0.061	1991 Oct 16	48546.5	60
					1992 Aug 2	48837.6	30
					1992 Sep 1	48867.0	90
					1993 Aug 12	49212.6	80
					1993 Aug 19	49219.6	60
					1994 Aug 26	49591.6	60
					1994 Dec 13	49700.3	60
					1995 Jan 3	49721.3	30
NAB 0205+024	02 05 14.5	+02 28 42	15.40	0.155	1992 Aug 31	48866.6	60
					1992 Sep 1	48867.6	60
					1993 Aug 20	49220.6	90
					1993 Oct (E)	49267.2	60x2
					1994 Aug 29	49594.6	60
					1994 Sep (E)	49626.2	90x2
					1994 Oct 13	49639.5	60
					1994 Nov 25	49682.4	60
					1994 Dec 12	49699.4	60
					1995 Jan 2	49720.3	60
PG 1211+143	12 11 44.8	+14 19 53	14.63	0.085	1992 Jan 30	48652.6	30
					1993 Feb 11	49030.5	60
					1993 Mar 15	49062.5	40
					1994 Mar 4	49416.5	20
					1994 Dec 13	49700.7	40
					1995 Jan 2	49720.6	60
					1995 Feb 4	49753.6	40
					1995 Mar 18	49795.5	60
					1995 Apr 9	49817.4	40
					1996 Mar 10	50153.5	30
					1996 Mar 11	50154.5	30
NGC 5548	14 15 43.5	+25 22 01	13.73	0.017	1992 Feb 1	48654.6	30
					1992 May 26	48769.4	30
					1993 Feb 12	49031.5	60
					1993 Mar 14	49061.6	30
					1993 Jul 14	49183.4	30
					1994 Jan 24	49377.7	45
					1994 Mar 4	49416.6	45
					1995 Mar 18	49795.6	30
					1996 Mar 10	50153.6	30
Akn 564	22 40 18.3	+29 27 48	14.16	0.025	1992 Aug 1	48836.5	40
					1992 Sep 1	48867.4	30
					1993 Jul 15	49184.6	30
					1993 Aug 10	49210.5	60
					1993 Aug 20	49220.4	60
					1994 Aug 8	49573.5	60
					1994 Aug 26	49591.5	60
					1994 Sep (E)	49625.7	30x2+60x1
					1995 Jul 21	49920.6	60
					1995 Aug 29	49959.4	60
					1996 Oct 1 (E)	50358.6	20x2

The observations were performed with standard procedures, including the acquisition of bias and dome flat field frames, for subsequent background and pixel to pixel sensitivity correction, and of calibration lamp frames for wavelength calibration; standard stars were observed to perform flux calibration.

Together with the data on the NLS1s of our sample, we were interested in the NGC 5548 observations, to be added to literature data in the variability comparison as a typical Seyfert 1 galaxy.

The data reduction was performed with standard IRAF tasks. As is usual in variability studies, to obtain line fluxes which are accurate within a few percent we also intercalibrated our spectra to correct for slit losses, by using the fact that the strong forbidden lines emitted by the Narrow Line Region remain constant on very long time-scales, and can therefore be used as standard

Table 2. Measured Balmer line fluxes (some points considered less reliable are indicated in parenthesis).

Galaxy	JD - 2400000	Hα^1	Hβ^1	Galaxy	JD - 2400000	Hα^1	Hβ^1
Mkn 335	48546.4	773	292	PG 1211+143	48652.6	1662	512
	48836.5	707	268		49030.5	–	531
	48867.4	817	285		49062.5	1571	462
	49211.5	884	282		49416.5	1813	565
	49220.5	(471)	251		49700.7	1901	555
	49573.5	(1355)	250		49720.6	1393	529
	49592.6	789	270		49753.6	1464	570
	49639.4	904	325		49795.5	1608	600
	49682.4	935	273		49817.4	1587	584
	49700.3	864	270		50153.5	1492	579
	49921.6	876	327		50154.5	(2046)	575
	49950.6	1090	325	NGC 5548	48654.6	1785	418
	49961.5	822	313		48769.4	1098	163
	50358.6	971	269		49031.5	1998	447
I Zwicky 1	48546.5	1096	313		49061.6	1859	428
	48837.6	1290	316		49183.4	2234	536
	48867.0	1383	305		49377.7	1528	457
	49212.6	1295	339		49416.6	1848	397
	49219.6	1444	352		49795.6	1862	452
	49591.6	1257	353		50153.6	1858	401
	49700.3	1506	353	Akn 564	48836.5	403	103
	49721.3	1448	354		48867.4	415	96
NAB 0205+024	48866.6	–	123		49184.6	368	96
	48867.6	–	123		49210.5	361	83
	49220.6	–	119		49220.4	347	84
	49267.2	–	119		49573.5	389	100
	49594.6	–	99		49591.5	385	99
	49626.2	–	114		49625.7	452	99
	49639.5	–	111		49920.6	341	86
	49682.4	–	100		49959.4	410	81
	49699.4	–	113		50358.6	445	83
	49720.3	–	115				

[1] Units are 10^{-15} erg s^{-1} cm^{-2}.

candles. Since the [SII] λ6717.0, λ6731.3 Å lines are quite weak and not well resolved in all spectra, we used the strong [OIII] λ4958.9, λ5006.8 Å transitions for the calibration in the whole observed spectral region: as a result, the correction is much more accurate in the Hβ portion of the spectrum than in that of Hα, and in a way not easy to quantify. The correction parameters (wavelength shift and scale factor) to be applied to all the spectra of each object, with reference to one chosen spectrum, are automatically calculated by a code (van Groningen & Wanders 1992) which makes use of a χ^2 minimum research procedure on the difference spectrum in the wavelength range of the forbidden lines. We found that after the correction the integrated fluxes of the two [OIII] lines for each object differ by less than 10% from their average value.

A possible problem of this method, however, is the fact that different seeing conditions may cause different portions of the NLR and the BLR to enter the slit in observations at different epochs, therefore leading to errors in the calibration. In Paper I we performed several tests of the data against this source of error, concluding that, within the uncertainties intrinsic to the method, this kind of problem does not appreciably affect the reliability of the internal calibration.

To the spectra thus obtained from the Loiano programme, we added (after having performed on them the usual internal calibration) two spectra of Akn 564 and Mkn 335 obtained at the ESO 1.52 m telescope in October 1996 as part of another programme: the covered spectral range is in this case $\sim$ 2400 Å with a resolution of 4.6 Å/pixel, and the observations have been performed with a 2 arcsec slit. We also included some of the data from the ESO observations used in Paper I. Table 1 also includes information on these observations, thus giving a complete list of the data taken by the authors and used throughout this paper.

3. Variability results and comparison with Seyfert 1's

The fluxes of the strongest optical lines (Hα and Hβ) were measured from all our spectra, for each object and each observing

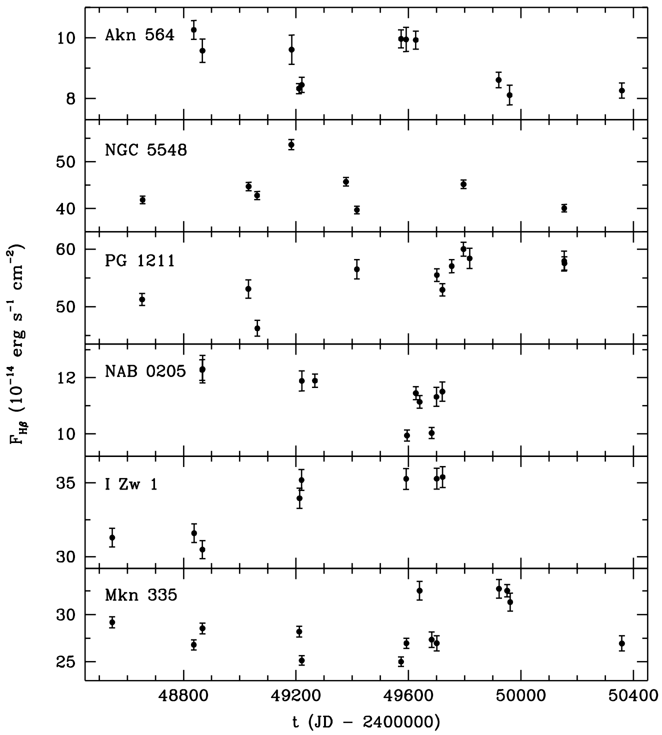

Fig. 2. Total Hβ light curves of the observed NLS1s and of the Loiano observations of NGC 5548.

date, by fitting a straight-line continuum under the lines and integrating the overlying fluxes.

The uncertainties on these fluxes, and consequently on the calculated percentage variations, were evaluated as described in Paper I, the major contribution being the uncertainty on the internal calibration mentioned above; this contribution was then estimated by slightly perturbing the scale factors of the spectra and measuring the ranges within which no appreciable changes could be seen. The obtained percentage uncertainties on the line fluxes fall in the range 3-5%, and the errors on the flux variations we used for the following analysis are therefore approximately twice this amount.

Fig. 2 shows the total Hβ light curves of the observed NLS1s: similarly to what we found for the 'ESO sample', most objects appreciably varied their line fluxes at least in some of the considered time intervals. The Hβ light curve of NGC 5548, as given by our Loiano observations only, is also plotted in the figure.

In Table 2 the measured Hα and Hβ fluxes for the Loiano and ESO spectra are reported. Not having enough literature data on the Seyfert 1 short-term variability of other emission lines (such as FeII or HeII), we did not measure their fluxes and relative variations. We did not evaluate the continuum flux either, because it is expected to be contaminated by the host galaxy starlight in different amounts for different observations, due to the different seeing conditions, slit apertures and source distances; therefore it is not possible to determine the global continuum variability properties in a reliable way.

Table 3. Global variability properties of the Hβ flux of each object within the Loiano + ESO monitoring campaigns (see text for details).

Galaxy	Classification	σ^1 ($F_{H\beta}$)	F_{var} ($F_{H\beta}$)
Mkn 335	NLS1	27	8.9%
I Zwicky 1	NLS1	21	5.4%
NAB 0205+024	NLS1	8	6.6%
PG 1211+143	NLS1	40	6.5%
NGC 5548	Sy 1	102	24.6%
Akn 564	NLS1	8	8.3%

[1] Units are 10^{-15} erg s^{-1} cm^{-2}.

The variability behaviour of individual Narrow Line Seyfert 1's in the Loiano (+ ESO) sample is quantified in Table 3, which reports, for each object, the rms (σ) of the Hβ flux throughout the whole campaign, and the fractional variation F_{var}, defined (Clavel et al. 1991) as the ratio of the rms fluctuation to the mean line flux, corrected for the mean measuring error. Note that this last quantity is very similar ($\sim$ 5-9%) for all the NLS1s, while it is much higher for NGC 5548, the only Seyfert 1 observed at the same telescope and approximately on the same time baseline, and the data of which are therefore also reported in the table for comparison. This is a first indication of a lesser degree of variability amplitude displayed by Narrow Line objects.

To perform a direct quantitative comparison, we first evaluated, for each NLS1 in the 'Loiano sample', all the relative flux variations [1] on time intervals ranging from $\sim$ 10 months to $\sim$ 14 months; to these data we added the similar ones obtained from the previous ESO campaign (provided that there are no overlapping intervals, to avoid to include twice the same relative variation) and from the 1996 ESO observations mentioned above. We thus obtained a data-set of 28 points (i.e. relative flux variations) for Hβ and 27 points for Hα.

As for the Seyfert 1's, also in this case we enriched the previous data-set: first we added to the de Ruiter & Lub Seyfert 1 sample (de Ruiter & Lub 1986, Lub & de Ruiter 1992; see also Paper I for details on the sample – line fluxes have been obtained in the same way as for ESO and Loiano spectra) the data of the typical Seyfert 1 NGC 5548 taken from Loiano observations for the period since 1992. We then took some points from the Hα and Hβ NGC 5548 literature data that we collected to perform the short time-scale comparison (Wamsteker et al. 1990, Korista et al. 1995 and references therein). The data-set includes in this case 135 points for Hβ and 88 for Hα.

To compare the short-term variability properties of the two classes of AGNs, we chose a short average time interval, such that the relative variations measured on this scale would be both representative of the characteristics of the objects and numerous enough to allow as accurate a statistical comparison as possible. Since the Loiano light curves are not evenly sampled, and the time gaps are sometimes of the order of several months, we took

[1] Here and in the following we always refer to relative variations taken from single measurements – only the 5 ESO points are the result of averaged spectra – and computed with respect to the flux mean value.

all the relative variations of the optical lines on time intervals ranging from ~ 10 days to ~ 45 days, the average interval being around 27 days. In this way we used all the data, maximizing the available information and obtaining finally 23 points for Hβ variations and 17 points for Hα ones, having added to the Hβ set also 2 variations calculated with ESO Paper I observations.

A similar kind of information can be obtained, in the case of Hβ, for the typical Seyfert 1 galaxy NGC 5548, which we take here as representative of the Seyfert 1 class as regards variability characteristics (although, as mentioned in Sect. 1, the generality of its properties is to be determined): since in fact this object has been optically monitored for several years with high temporal resolution, it is possible to check its monthly variations by properly sampling its Hβ light curve for the period $\sim$ 1989-1992 (Korista et al. 1995 and references therein). The sampling has been performed by simply taking the observation closest in time to the epoch which is separated from the previous point by a time interval equal to the average chosen one (in this way we also 'mimick' the uneven sampling of NLS1 data). To these observations, sampled so that the average time interval is of the order of 27 days, we also added the Loiano data of the same object which were not temporally overlapped to the literature light curve. We collected in this way a total of 56 points for Hβ variations. In the case of Hα, we tried to collect literature data on several LAG (Robinson 1994) and AGN Watch monitored objects, again sampling the literature light curves to obtain line flux relative variations on $\sim$ 1 month time-scale. However, this last data-set resulted to be very inhomogeneus; on the other hand, the [OIII] correction of the Loiano data does not give for the Hα region a calibration accurate enough to allow a reliable comparison, and therefore we did not use the Hα 1-month variations in the following analysis.

Similarly to what we did in Paper I, a first statistical comparison between Seyfert 1's and NLS1s can be performed with these data by constructing, for each class of object, time-scale of variations, and emission line, a histogram including all the measured relative variations (in absolute value). We then compared the resulting histograms relative to Seyfert 1's and NLS1s for each group of parameters, as plotted in Fig. 3a–c: the 1-year data obtained for Hα and Hβ variations seem now to show a trend of Narrow Line Seyfert 1's towards weaker variability, and a clearer trend in this sense is suggested by the 1-month Hβ results, where the NLS1 histograms display a steeper decline and go to zero at around 15-20% percentage variability.

A more quantitative way to evaluate the statistical behaviour of the two classes of objects is the application of the Kolmogorov-Smirnov (K-S) test, which gives the probability (P) that two continuous data samples are drawn from the same parent population, together with the maximum distance (D) between the 2 cumulative probabilities; since P depends on the number of data points in each sample, larger samples have higher statistical significance, while more conservative results are obtained for smaller samples. This is the case, for example, of the Hβ line flux data reported in Paper I, for which the K-S test gives $D \simeq 0.2$ and $P \simeq 58\%$: our conclusion that there was no

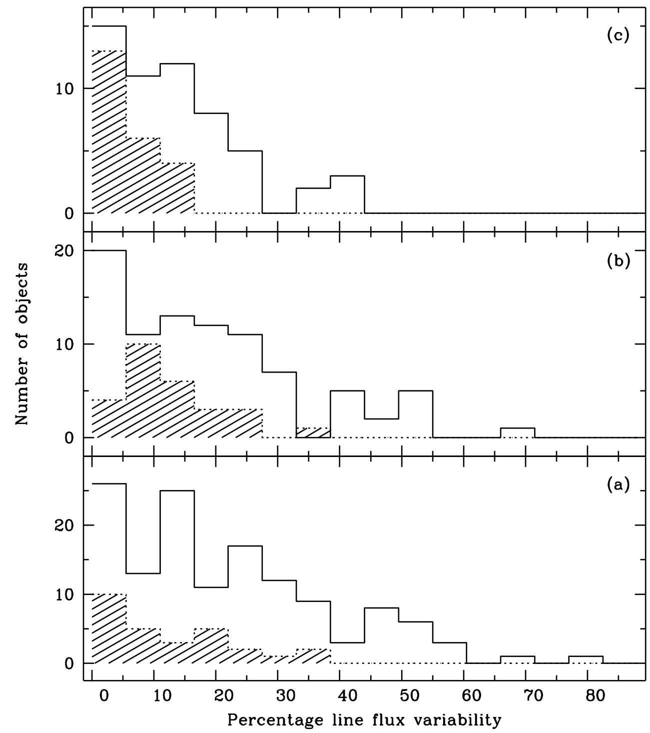

Fig. 3a–c. Statistical comparison between the variability properties of Seyfert 1 galaxies (open histograms) and NLS1s (shaded histograms): **a** Hβ flux variations over a time interval of $\sim$ 1yr; **b** same as **a** but for Hα variations; **c** Hβ variability on a monthly time-scale.

evidence for a different behaviour was therefore justified at that time.

The same test on the enlarged 1-year samples, however, gives now different results, i.e. $D \simeq 0.3$ and $P \simeq 5.4\%$ for Hβ and $D \simeq 0.3$ and $P \simeq 3.9\%$ for Hα; so it seems improbable that the 2 sets of data are taken from objects with similar variability properties. A lower probability that their parent population is the same is obtained by the K-S test applied to Hβ 1-month data: here, in fact, we got $D \simeq 0.4$ and $P \simeq 0.8\%$. Note that neither the histogram appearance nor the K-S test results for the short-term variations result substantially altered if we sample the NGC 5548 Hβ light curve in a slightly different way (e.g. starting from a different point), the probability P always ranging between 0.5 and 0.9% and the distance D between 0.41 and 0.43.

4. Discussion and conclusions

As already mentioned in Sect. 1, we discussed the various interpretative models for Narrow Line Seyfert 1 spectra in Paper I, concluding that the possibilities of a smaller black hole mass or a BLR size which is larger on average are the most probable ones. The other interpretations are in fact in some way inconsistent with observational results: for example, a projection effect explanation would imply too narrow a cone of visibility for NLS1s to justify their being more than 10% of the known Seyfert 1 population; a depletion of the innermost part of the

BLR would produce very low line equivalent widths, while the obscuration hypothesis is quite unlikely, since the results of X-ray observations all suggest that we have a direct view of the nucleus.

The knowledge of the variability behaviour of these objects, compared to other Seyferts, can therefore be crucial in the understanding of their nature, allowing us to estimate the BLR size. However, the analysis of variability data can be potentially influenced by some effects: first of all, if the relative contribution of the (constant) narrow component to the total line flux is more important in NLS1s than in normal Seyfert 1's, then a global weaker variability is observed in the former objects, even if their broad component fluctuations are on average of the same amplitude as those of Seyfert 1's. However, the evaluation of the ratio between narrow and broad component of Hα and Hβ in the Stirpe (1990) Seyfert sample shows that the relative contributions to the total line fluxes are not dramatically different in the two classes of objects, the narrow component being on average $\sim$ 4% of the broad one in normal Seyfert 1's and $\sim$ 6% in NLS1s; furthermore, it results to be 6% in NGC 5548, which assures that, at least in the short-term comparison with this object, our measured relative variations are smoothed by the same factor. Another possible bias in the interpretation of the results is the unknown continuum variability which drives the line fluctuations: again, an intrinsically lower continuum variability amplitude in NLS1s would result in a weaker line variability, even if the BLR has a 'standard' size in these objects. Given the lack of other information (e.g. correlations between optical/UV variability amplitude and broad line width), we assume that the ionizing continuum has the same variability properties in these objects as in other Seyferts. In both cases, since a more detailed analysis of the data (involving the subtraction of narrow line components and host galaxy continuum from the spectra, to evaluate the continuum fluctuations) is beyond the scope of this paper, we will assume that the potential 'smoothing' effects are small compared to the one of which we found evidence.

Based on the ensemble of data that we collected in this work, the weaker variability of NLS1s, implied by the histogram comparisons and the K-S test both for long- and short-term observations, seems to exclude that the broad line emitting gas is located as close to the centre as in normal Seyfert 1's, as assumed in the 'small black hole mass' model. It seems more probable, instead, that in these objects the gas extends further out: its distance should be not so high as to completely smear out the ionizing continuum variations in the line reprocessing, but large enough to 'smooth' their amplitude more than normal BLRs do, producing in this way the statistically weaker variability that we observe. This is of course assuming that the physical conditions (like the electron density or the column density) in the ionized gas emitting the broad lines are similar in NLS1s and in normal Seyfert 1's.

The fact that we actually observed short-term variations in these objects, though with small amplitude, implies that, in the 'extended BLR' picture, the emissivity radius of their BLR gas is probably closer to our estimate of $r_{min}(NLS1) \sim 3r_{min}(Sey1)$, made in the case of this model in Paper I, than to the upper limits that can be set on the basis of the average time-scale of the observations: the 1-month histograms we constructed include in fact percentage variations measured on several time intervals, the mean of which is of the order of 27 days, but which also include $\Delta t \sim$ 10-20 days; the sample is not large enough to allow a more detailed evaluation of the variability at the level of a few days, without losing in statistical significance. Only through an intense monitoring campaign on one or more NLS1s (one observation every few days) it would be possible to estimate the BLR size by measuring the lag between line and continuum light curves.

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