

Optical variability of Seyfert nuclei. I. *VBLUW* photometry (*)

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Summary. — We report the first results on a monitoring programme of Seyfert galaxies. Combined spectroscopic and photometric observations of a sample of 15 Seyfert galaxies have been carried out at the European Southern Observatory since December 1979. In this paper we present the data on *VBLUW* photometry obtained between December 1979 and December 1982 and discuss their quality. The variability of Seyfert nuclei on timescales of ~ 1 day to ~ 1 year is investigated. Including 8 Seyfert galaxies that were observed only in one period of about two weeks we find in none of the Seyfert galaxies variations on timescales of ~ 1 day. Seyfert nuclei of type 2 do not show significant long term (~ 1 year) variability in the period between 1979 and 1982, whereas 10 out of 11 type 1 Seyfert nuclei that were observed during these three years have varied significantly in *V*, with amplitudes ranging from 0.1 to 0.6 magnitude. The number of objects with variable colour indices decreases monotonically going from (*V-B*) to the far ultraviolet colour index (*U-W*); in fact, only one object, Mkn 609, has possibly varied in (*U-W*). We present various two-colour diagrams and show that Type 1 Seyfert nuclei have a well-defined locus in these diagrams with a remarkably small scatter (~ 0.06 to 0.10 mag).

Key words : Seyfert galaxies — photometry — optical variability.

1. Introduction.

The nuclei of Type 1 Seyfert galaxies are well known to exhibit intensity variations in the optical region of the spectrum, both of the continuum and of the broad emission lines (see e.g. Lyutiy, 1973, 1979; Penston *et al.*, 1974; Peterson *et al.*, 1982).

Correlations between the continuum and emission line variations were discussed by de Bruyn (1980).

Although the occurrence of variability has been known for some time, very few long term systematic observing programmes have yet been carried out. As a result frequency and amplitude of the variations of Seyfert nuclei is still a matter of discussion. Clearly a better knowledge of the behaviour of various sources of emission (the continuum source, the broad line emission region) will lead to a more profound insight in the physical processes occurring in active galactic nuclei. Such a goal might be reached by detailed multifrequency studies of a few selected objects or by statistical investigations of samples of Seyfert galaxies, and it is the latter method which we have chosen here.

In order to be able to distinguish small intensity variations independently in the continuum and in the emission lines it is necessary to have spectra which are accurately

flux-calibrated. Although indispensable such highly accurate calibrations are notoriously difficult to achieve. For this reason we decided to take a slightly different road : a number of Seyfert galaxies was selected for regular study; each was observed photometrically on a number of nights during a period of one to two weeks, and in that same period the objects were also observed spectroscopically. Ideally a photometric observation should always have been done at the same moment a spectrum was taken, but for practical reasons this was not feasible. We thus have photometric and spectroscopic measurements usually separated by about a day. Fortunately no large intensity variations on timescales of days or weeks occurred, as we will show in the present article, so that we may hope to obtain spectra with the flux scale known to a few percent accuracy. We postpone discussion of the spectra, however, and concentrate first on the photometric data that are available now.

The passbands of the Walraven *VBLUW* photometric system happen to be located in a particularly interesting wavelength region of the spectrum (see Table I). Three of the filters (*L*, *U* and *W*) select radiation with wavelengths between 3000 and 4000 Å, where we may be able to follow the variability of the non-thermal continuum and investigate the presence of the 3000 Å « bump »; the importance of the « bump » is obvious, as it may represent black-body radiation from an accretion disk around the central nuclear object in active galactic nuclei (Malkan and Sargent, 1982; Malkan, 1983).

(*) Based on observations obtained at the Dutch telescope at ESO La Silla.

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In the present Paper, the first in a series dealing with variability of continuum and emission lines in Seyfert nuclei, we present *VBLUW* photometry for 23 Seyfert galaxies of both type 1 and 2; a subset of 15 has been observed regularly between 1979 and 1982, the remaining 8 were observed only in August 1980. The project is actually continuing and data obtained after December 1982 will be reported at a later stage.

In the next section we give a brief description of the properties of the Walraven photometric system, after which we discuss the observations and their accuracy. Various two-colour diagrams are given and finally, in the last section we investigate the variability detected from the *VBLUW* observations.

2. The *VBLUW* photometric system.

The Walraven photometer has up till now been used almost exclusively for the study of stars; therefore the *VBLUW* system is perhaps not well known in the field of extragalactic astronomy and we think it necessary to give here a brief description of its properties.

The photometer was designed and built by Walraven with the purpose to study, in particular, early type stars. It was attached to the Dutch 90 cm « light collector », then located in South Africa. An extensive report on the performance of the photometer, the reduction of data and definition of the ring of standard stars can be found in Lub and Pel (1977).

In 1978 the telescope and photometer were transferred to the ESO site at La Silla, Chile. New measurements revealed some minor alterations of the passbands after 1980, so we give in table I the present effective wavelengths and bandwidths of the *VBLUW* passbands (Pel and Lub, 1985), and the constant to convert to absolute fluxes.

The Walraven photometer measures all five colours simultaneously; it therefore combines economy of observing time with the possibility to determine accurate colour indices, since variations in the different channels are usually correlated — apart from the effects of photon statistics, of course.

It is customary to define the four colour indices (*V-B*), (*B-L*), (*B-U*) and (*U-W*), since they have a direct interpretation in the physics of stellar atmospheres. However, in the case of Seyfert galaxies it makes less sense to use partially overlapping colour indices. Therefore in the following we use *V*, (*V-B*), (*B-L*), (*L-U*) and (*U-W*). Note also that *V*, (*V-B*), etc. are given in $\log_{10}$ (intensity). When magnitudes are used (cf. Table V) this is stated explicitly. Finally, in order to distinguish *U*, *B* and *V* from the *UBV* magnitudes of the Johnson system we denote the latter by the subscript J.

3. Selection of objects.

The sample of Seyfert galaxies was selected from the lists of Weedman (1977, 1978) and therefore represents the objects known around 1978. To be included in our observing list they had to satisfy several criteria.

First, the nuclei obviously had to be visible through the eyepiece of the Dutch 90 cm telescope (in practice blind

offsets are too complicated). This condition eliminated some objects that were originally included: IC 4870 was very difficult to center in the 11.6 arcsec diaphragm and the data indeed turned out to have so much scatter as to make them useless. NGC 1365 was deleted for a slightly different reason: its nucleus not only is weak, but also multiple (Sersic and Pastoriza, 1965), rendering observation of always the same part of the nucleus virtually impossible. In general, the condition of good visibility of the object's nucleus corresponds to a magnitude limit of about $V_J = 15$. In fact, in our final list of objects presented in this paper only one (3C 120) has a nuclear magnitude fainter than 15 (in the 11.6 arcsec aperture).

A second selection criterion was the declination of an object. In order to avoid as much as possible observations through large air masses we limited ourselves to objects with $\delta < +15^\circ$.

Finally, since we observed regularly in December a right ascension range of roughly 22 to 13 hrs was imposed for the study of variability. Seyfert galaxies outside this right ascension range but satisfying the other two conditions were observed in August 1980 only.

None of the criteria was applied rigidly and we do not claim completeness of the sample. On the other hand there should be no particular biases in the selection procedure and hence the final sample used by us should be representative of the total collection of Seyfert galaxies known up till about 1978. Of course, we do not know anything about possible biases in the discovery procedures of Seyfert galaxies and in the construction of the original catalogues.

Thus 15 Seyfert galaxies (both type 1 and type 2) were observed regularly (i.e. at least once a year) between 1979 and 1982; they form our basic sample for the study of variability.

An additional 8 Seyferts were observed only in August 1980 and are used here to construct the two-colour diagrams in the *VBLUW* system.

4. The observations.

In principle every object should have been observed photometrically in every period on about 10 consecutive nights; in the following we will call such an observing sequence a run. In practice this means that in the best cases (e.g. Fairall 9) the number of *VBLUW* measurements is between 8 and 10 for the runs of December 1979 and August 1980 (each data point obtained at a different night) and 5 or less for December 1980, 1981 and 1982. These numbers refer to observations with an 11.6 arcsec diaphragm, which was chosen to minimize the contamination by starlight from the underlying galaxy.

As for photometry on such faint objects as are Seyfert nuclei nights of very good quality had to be used — and were used. It was decided to tie each measurement directly into the system of standard stars, avoiding the use of local reference stars. In this way systematic shifts in the colours were avoided and a good check on the quality of the observations was achieved.

The observations with the 11.6 arcsec aperture are listed in table II; we repeat that all entries are given in units of

$\log_{10}$ (intensity). As the *W* channel could not be used due to a malfunction on December 24 and 25, 1979, no (*U-W*) values are given for those dates.

An observation was usually done following a sequence of 2×2^6 seconds of sky, 4×2^6 seconds of object, 4×2^6 seconds of sky, 4×2^6 seconds of object and finally 2×2^6 seconds of sky. All passbands are measured simultaneously. The sky was measured 1.5 to 2 arcmin away from the nucleus, usually both above and below the object. In this way any contamination e.g. by faint stars could easily be detected. Thus each observation in table II consists of 2 independent measurements of the same object and represents roughly 8 minutes of integration on the object and 8 on the sky. An internal check on the quality of data was made by comparing the two independent measurements in one observation. If they differed by more than 2.5 times the RMS error (calculated from all measurements in an observing run), the observation was considered of low quality and the corresponding data in table II are distinguished by a colon. Such data were not used in the variability analysis.

Sometimes, a 16 arcsec, and in one case a 23 arcsec, diaphragm was used; these data are collected in table III. In the following we will always discuss the data obtained with the 11.6 arcsec diaphragm, unless stated otherwise.

The mean and RMS error per observing run were calculated from table II, using only the good quality data points, and are listed in table IV. Also given is V_J , the corresponding visual magnitude of the Johnson *UBV* system, calculated according to the formula $V_J = 6^m884 - 2.5(V + 0.039(V-B))$ (Pel and Lub, 1985).

5. Errors.

There are several sources of error; we will discuss their importance in the following.

The first and most bothersome that we were able to identify comes from the problem of a very faint nucleus — barely visible against its fuzzy envelope or the sky background — in the small aperture that we used. Bad centering leads to an enhanced sensitivity to seeing fluctuations and tracking errors. At large airmasses the effect of atmospheric dispersion becomes appreciable: the ultra-violet image is no longer centered on the visible image of the object. Indeed we found that objects which were hard to center had observed errors quite a bit larger than expected from photon statistics alone, e.g. (NGC 3783, IC 4329A).

Thanks to the excellent quality of the drive of the Dutch Telescope tracking errors were of minor importance. In case of doubt the object was checked every two minutes and, if necessary, recentered. A few measurements taken very low in the sky had to be rejected when preparing tables II and III.

Another problem, inherent to the type of observations reported here is the possible presence of concentration of emission other than the nucleus itself. In NGC 1566 Comte and Duquenois (1982) noted a small HII region about $10''$ from the nucleus, and this could introduce a small error ($< 1\%$) in the measurement. In general, however, the effect should be of minor importance and we have ignored such errors, except in the case of NGC 1365

where reliable photometry of the nucleus was not possible due to its multiplicity. The final limitation to the accuracy is due to photon noise, which is rather more complicated than usual, because we use integrating rather than photon counting electronics. Pel (1976) has given consideration to this problem for a typical measurement sequence, including reference star and sky measurements, for faint Cepheids. However, the photometer has been improved in several respects during and after its removal to Chile and thus we need to discuss this point anew: quite extensive (unpublished) tests done by J. Lub in 1979 have shown that typically for a 64 second integration the 1% accuracy level is reached at the following Walraven intensities (corresponding to a visual magnitude $V_J = 13^m8$):

<i>V</i>	<i>B</i>	<i>L</i>	<i>U</i>	<i>W</i>
– 2.76	– 2.76	– 2.30	– 2.46	– 2.22

The dark sky through the 11.6 arcsec aperture we normally used corresponds to a visual magnitude $V_J = 15.8$; its Walraven intensities are typically:

<i>V</i>	<i>B</i>	<i>L</i>	<i>U</i>	<i>W</i>
– 3.60	– 3.95	– 4.02	– 3.90	– 3.82

It is clear that for most objects the sky contribution is not yet too large. For a typical measuring sequence of 4 times 64 (or even 8 times 64) seconds the level of 1% shifts about a factor of 2 down, i.e., comes at a visual magnitude of $V_J = 14^m5$.

In figure 1 we have plotted the RMS errors in *V*, (*V-B*), (*B-L*), (*L-U*) and (*U-W*) against *V*, *B*, *L*, *U* and *W* respectively. The errors were calculated for each observing run, when the number of observations per object was at least 3, and using only data of high quality (see Table II). Also shown is the expected error due to the combined effect of photon statistics and dark-sky background. The errors in *V* and (*V-B*) do not show a dependence on intensity, but in *L*, *U* and in particular in *W* the effect of photon statistics becomes appreciable for the fainter objects.

The faintest object in our sample (ESO 185-IG13, with $V = -3.357$) has an error $\sigma(V) = 0.0333$, much higher than expected. We have here an example of the difficulty of centering such a faint object. Leaving out ESO 185-IG13 we find a mean error $\langle \sigma(V) \rangle = 0^m007$, to be compared with the expected error from photon statistics (about 0^m005). The difference is most probably due to the centering errors: as can be seen in figure 1, for a few objects the observed error in *V* is more than twice the expected one. We have kept this in mind when doing the variability analysis.

The colour indices should suffer less, as the measurements of all colours are done simultaneously; indeed, we find that the expected and observed errors in (*V-B*) are both about 0^m005 .

In (*B-L*), (*L-U*) and (*U-W*) the uncertainty of the measurement clearly increases as the intensity gets smaller. We tried best fits of the type $\sigma(B-L) = aI^b$, etc. (where *I* is the intensity of the faintest channel) in order to be used later in the variability analysis. These fits agree very well with the curves based on photon statistics and sky background, and therefore we conclude that the observed errors are close to what we expected *a priori*.

Two clearly deviating points are present in the (U - W) diagram; they represent the observing run of December 1979 of NGC 1566 ($\langle W \rangle = -3.26 \pm 0.04$) and Tol 0109-383 ($\langle W \rangle = -3.94 \pm 0.06$). Why the (U - W) measurements of 1979 are so noisy is due to several reasons: in the case Tol 0109-383, its value of W is well below the sky background ($W = -3.82$) and a large uncertainty is therefore to be expected, moreover the last few days of the December 79 run the dark current in the W channel was higher than normal and rising.

6. Two-colour diagrams.

Using the data of table IV for the 23 Seyfert galaxies in our sample we constructed two-colour diagrams; they are shown in figure 2. The colour indices were obtained by averaging over the whole three year period, weighting the values per run with the corresponding RMS errors. Thus for variable objects the mean colours are given.

The colours of type 1 Seyfert nuclei are strongly correlated; regression lines are shown in figure 2. The observed two-colour relations have surprisingly little scatter around these lines: about 0.05 to 0.06 magnitudes in all two-colour diagrams except (V - B)-(B - L) which has a scatter of about 0.10 mag. Note that both V and B are « contaminated » by strong emission lines ($H\gamma$, $H\beta$, $[O III] \lambda\lambda 4959, 5007$), also the contribution of starlight is most important in these two passbands.

In order to provide more clarity as to the meaning of a certain colour index, we calculated the two-colour relations for a power-law type spectrum, assuming a single spectral index over the whole wavelength range in a given diagram. The resulting relations are shown in figure 2 as dashed lines and corresponding values of the spectral index $\alpha (F_\nu \sim \nu^{-\alpha})$ are indicated. A deviation from this line obviously indicates that the spectral index does not stay constant over the whole range in wavelength.

A discussion of the presence of a real power law component, rather than the formal comparison with a power law just given, with spectra of Seyfert galaxies requires a thorough analysis. We have, at this stage, not tried to determine the contribution of starlight and emission lines to the observed colours. A discussion of the corrections necessary to obtain the nuclear continuum colours will be given in a future paper (de Ruiter and Lub, in preparation).

7. Variability.

In figure 3 we compare the « lightcurves » for the pair Tol 0109-383 and Fairall 9. These objects were always measured right after one another under the same observing conditions. The left hand panel shows the type 2 Seyfert Tol 0109-383 and illustrates the typical errors in measurement of a rather faint and red object which is evidently constant both in the colours and in V . Virtually all type 1 Seyfert behave differently: the right hand panel shows the type 1 Seyfert Fairall 9, which has varied by over 0.5 mag in V over the period of observation. The RMS error for each different observing period is of the order of only 0.01 mag.

The colour indices, if variable, mimic the behaviour of the V light curve quite well, and this is true for all the type 1 nuclei. However, the amplitude of the variations in general decreases steadily going from V via (V - B), (B - L) and (L - U) to (U - W). In fact, most objects have not shown any significant variation at all in (L - U) and (U - W). It should be said that variations in the ultraviolet colours are more difficult to detect: the uncertainty in the measurements generally increases towards the ultraviolet, thus making small changes impossible to detect. Moreover, the L , U and W passbands are relatively close in wavelength and consequently the spectral index of the continuum should change appreciably in order to produce a significant change in the ultraviolet colours.

The analysis of variability was done in two steps. First we performed a χ^2 -test on all lightcurves, assigning an error to each individual good quality data point in table II. This was done according to the mean observed relations in figure 1 for (B - L), (L - U) and (U - W). We adopted an error of 0.007 in V and of 0.005 in (V - B).

Values of χ^2 corresponding to probabilities $P < 0.01$ were considered as tentative evidence for variability in the period December 1979 till December 1982.

As a second step we also considered the observed error in an individual observing run; although the errors used in the χ^2 -test are the mean observed errors, this does not mean that, for example, centering problems for a particular object were properly accounted for. Therefore a formal probability smaller than 0.01 as obtained from the χ^2 -test, might indicate that the observations were difficult rather than that the object had varied. For this reason we calculated the observed error in the mean, i.e. the RMS error divided by $\sqrt{N}$, for each observing run with three or more measurements; if only one or two measurements were available in a run, it was assigned the highest error found in the other observations of the same object. The mean values of the different observing periods were then compared taking into account their actually observed errors.

In most cases the χ^2 -test was in good agreement with the comparison of the mean values, but for a few exceptions: NGC 4507 had significantly varied according to the χ^2 -test, but inspecting the errors for each individual observing period we note that they are much higher than expected. Taking this into account and comparing the mean values per run the evidence for variability disappears; apparently centering errors were more serious for NGC 4507 than for other objects (high airmass).

The results of the variability analysis are given in table V; a colon after an entry indicates that both tests gave a probability between about 0.01 and 0.001. When $P > 0.01$ 3 σ upper limits to the variability are given.

We also investigated variability on timescales of days. Such short term variability would show up if the error in the mean of an observing period was significantly higher than expected. Apart from a few isolated cases that could be explained by observational problems, such as NGC 4507, no trace of short term variability is seen. We conclude that intensity changes greater than 0^m05 on timescales of days are very rare.

On the other hand variability on timescales of a year with an amplitude in V greater than 0.1 mag is very common

indeed in Seyfert 1 nuclei. Leaving out the four type 2 Seyferts, then of the 11 type 1 Seyferts in our sample 10 have definitely varied.

We now discuss the objects in turn.

Tol 0109-383. This type 2 Seyfert is very faint and red; for this reason the $(U-W)$ index was not tested for variability.

Fairall 9. According to Danks *et al.* (1979), Martin *et al.* (1978) Fairall 9 had slightly varied in the visual; in the period 1979-1982 we find it to be the object that has shown the greatest variation in V and $(V-B)$. Although it has changed strongly its V intensity, the spectral shape has varied less drastically, or, in $(L-U)$ and $(U-W)$, not all (in both these colour indices the 3σ upper limit to any variation is 0.04 mag). Note that all colour indices, including $(U-W)$ are known with an accuracy of about 0.01 mag, as Fairall 9 is very strong in the ultraviolet.

Mkn 573. The intensities of this type 2 Seyfert are very similar to those of Tol 0109-383; $(U-W)$ was not tested for variability, as W is too weak.

Mkn 590. We observe a change of about 0.2 mag in V as well as in $(V-B)$ and $(B-L)$. Apparently both intensity and spectral shape have changed; for variations in $(L-U)$ and $(U-W)$ we can only set upper limits of 0.1 mag.

NGC 1068. Several groups have searched for variability of the nucleus of this type 2 Seyfert (e.g. Penston *et al.*, 1974; Lyutyi and Pronik, 1975; Kingham and O'Connell, 1979). According to Lyutyi and Pronik (1975) NGC 1068 had not varied in B_J and V_J , but U_J had changed by 0.2-0.3 mag. Kingham and O'Connell (1979) observed NGC 1068 in a period of 9 months and did not find variations: they give an upper limit of 0.015 mag, which is consistent with our findings for the period August 1980-December 1981. In the colour indices as well as in V any variation should have been smaller than 0.03-0.04 mag.

Mkn 609. The changes in V , $(V-B)$, $(B-L)$, $(L-U)$ and $(U-W)$ are all of the same order (about 0.1-0.15 mag), although the uncertainty in $(U-W)$ is so large that the significance of variation in this colour is marginal. Thus Mkn 609 is a good example of a Seyfert type 1 nucleus that varies both in intensity and in spectral shape.

NGC 1566. *VBLUW* photometry of this object was done by Van Genderen and Meurs (1981), in the period 1977-1978. They found no evidence for variability, in contrast with earlier reports (see references in Van Genderen and Meurs, 1981). Penfold (1979) has noted that NGC 1566 indeed had varied and, moreover, that the amplitude of the variation increases at shorter wavelengths. This behaviour is confirmed by the present observations: a modest variation in V — 0.16 mag — is accompanied by similar or even stronger changes in $(V-B)$, $(B-L)$ and $(L-U)$, up to 0.3 mag. Unfortunately the $(U-W)$ index was badly determined in December 1979 as well as in August 1980. Therefore we can only set a 3σ upper limit of 0.08 mag for the variation between December 1981 and December 1982.

3C 120. This type 1 Seyfert galaxy is one of the most studied objects for variability. It is known to vary on short timescales (months to a year): Cannon *et al.* (1971) found a change of 0.8 mag in only 2 months. Long term variability (> 10 years) seems to be of the order of 1.5 to

2 magnitudes (Cannon *et al.*, 1971; Lyutyi, 1979). Major changes in emission line strengths, on timescales of one year, have been detected by French and Miller (1981) and Oke *et al.* (1981), but not by Peterson *et al.* (1982).

Although 3C 120 is much redder than Fairall 9, in particular in $(V-B)$, both objects show a similar behaviour in their time variations: the intensity changes are much more pronounced than the changes in spectral index. Note that $(U-W)$ was badly determined in December 1979, so that for this colour we could only make a comparison between 1981 and 1982.

Mkn 618. According to Peterson *et al.* (1982) the continuum decreased in intensity, which is confirmed by our data. As for Fairall 9 and 3C 120 the changes are more important in intensity than in spectral shape.

Akn 120. Recently many studies concerning this object have been carried out. They all reveal that Akn 120 is highly variable, in emission line strengths and profiles (Kollatschny *et al.*, 1981; Schulz and Rafanelli, 1981; Foltz *et al.*, 1981), and in the continuum (Peterson *et al.*, 1982). On short timescales $\Delta B_J \approx 0.65$ mag over the period October 1977-September 1978 (Miller, 1979a), on long timescales $\Delta B_J \gtrsim 2$ mag (Lyutyi, 1979; Miller, 1979b). This strong variability is only partly confirmed by our data. Akn 120 has varied 0.16 mag in V , but this change refers to one period only (December 1980), V being at essentially the same level in the other observing periods. Moreover, any change in the colour indices should have been smaller than 0.04 mag. Therefore Akn 120 has behaved as Fairall 9, albeit on a more moderate scale.

NGC 3783. Optical variability was reported by Menzies and Feast (1983) and by Penfold (1979). The latter author remarked also that the variability was greatest at shorter wavelengths, as for NGC 1566. Indeed, for NGC 3783 the differences in V and $(V-B)$ are both of the order of 0.1 mag, and this may also be true for $(B-L)$ and $(L-U)$.

NGC 4507. This object was particularly hard to center since the nucleus is very faint compared to the underlying galaxy. Small changes would be interesting: NGC 4507 was classified as a type 2 Seyfert, but Véron *et al.* (1981) noted that a weak broad component is present in permitted emission lines. Unfortunately due to the observational difficulty we can only set upper limits of 0.06 to 0.1 mag in V , $(V-B)$ and $(B-L)$, while no analysis was done for $(L-U)$ and $(U-W)$ as reliable data are lacking for these colours.

NGC 7469. Weak variations were found by Cannon *et al.* (1971), Penston *et al.* (1974) and Peterson *et al.* (1982). Also in the period 1979-1982 we found only modest changes: 0.18 mag in V , 0.07 mag in $(V-B)$ and $(B-L)$ and < 0.07 in $(L-U)$ and $(U-W)$.

MGC 2-58-22. The variation in $(B-L)$ is very uncertain; it could be about 0.15 mag, but this conclusion is based on only one observation in December 1980. All other periods have essentially the same $(B-L)$.

NGC 7603. Tohline and Osterbrock (1976) found that H β is highly variable, in fact that in one period it disappeared, to reappear a few months later. Of all type 1 Seyferts in our sample NGC 7603 is the only one that stayed constant in V and all colours, at least in the periods covered by our observations. The upper limit to any variation in V is about 0.06 mag.

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TABLE I. — *Data on VBLW photometric system.*

	V	B	L	U	W
λ (Å)	5441	4298	3837	3623	3235
λ_{eff}					
BANDWIDTH (Å)	708	423	221	232	157
CAL CONSTANT (erg/s/cm ² /Å)	-11.172	-10.910	-10.818	-10.793	-10.673

TABLE V. — *Variation (36 limits) in objects with > 2 periods (magnitudes).*

NAME(TYPE)	V	V-B	B-L	L-U	U-W
TOL 0109-383(2)	<0.07	<0.04	<0.10	<0.18	--
ESO 113-IG45(1)	0.62	0.21	0.11	<0.04	<0.04
MKN 573(2)	<0.07	<0.05	<0.10	<0.14	--
MKN 590(1)	0.18	0.19	0.17	<0.08	<0.08
NGC 1068(2)	<0.04	<0.03	<0.03	<0.03	<0.04
MKN 609(1)	0.13	0.07	0.16	0.14	0.10:
NGC 1566(1)	0.16	0.16	0.28	0.15	<0.08
3C 120(1)	0.55	0.26	0.09:	<0.08	<0.15
MKN 618(1)	0.22	0.13	<0.08	<0.08	<0.12
AKN 120(1)	0.16	<0.04	<0.04	<0.04	<0.05
NGC 3783(1)	0.14	0.10	0.07:	0.06:	<0.11
NGC 4507(2)	<0.06	<0.08	<0.11	--	--
NGC 7469(1)	0.18	0.08	0.07	<0.07	<0.08
MCG 2-58-22(1)	0.26	0.23	0.15:	<0.05	<0.08
NGC 7603(1)	<0.06	<0.04	<0.08	<0.11	<0.15

TABLE III. — *VBLW photometry through a 16 arcsec aperture.*

DATE	V	V-B	B-L	L-U	U-W
TOL 0109-383					
10-12-80	-2.861	0.430	0.247	0.104:	0.222:
11-12-80	-2.859	0.428	0.236	0.090	0.224:
12-12-80	-2.871	0.423	0.261	0.034:	0.229:
13-12-80	-2.854	0.425	0.253	0.075:	0.217:
ESO 113-IG45					
10-12-80	-2.702	0.179	-0.052	-0.049	0.044
11-12-80	-2.703	0.180:	-0.048	-0.054	0.052
12-12-80	-2.704	0.177	-0.047	-0.054	0.051:
13-12-80	-2.705	0.181	-0.054	-0.054	0.039
7-12-82	-2.836	0.232	-0.023	-0.044	0.061
** 23 ARCSEC APERTURE					
7-12-82	-2.802	0.249	-0.003	-0.067	0.067
MKN 573					
12-12-80	-2.889	0.487:	0.157	0.162:	0.151:
13-12-80	-2.829	0.461	0.172	0.157	0.188
MKN 590					
12-12-80	-2.798	0.349	0.091	0.000	0.075
13-12-80	-2.793	0.349	0.121:	-0.037	0.103
NGC 1068					
12-12-80	-1.602	0.338	0.202	0.102	0.179
13-12-80	-1.604	0.388	0.195	0.100	0.166
MKN 609					
11-12-80	-2.909	0.280	0.198:	0.063:	0.086
12-12-80	-2.912	0.282	0.174	0.058	0.100
13-12-80	-2.914	0.283	0.186	0.066	0.117
11-12-82	-2.915	0.283	0.182	0.067	0.091
NGC 1566					
13-12-80	-2.280	0.424	0.313	0.070	0.250
11-12-82	-2.229	0.379	0.208	0.038	0.145
20-12-80	-2.224	0.373	0.214	0.017	0.140
3C 120					
11-12-80	-3.133	0.336	-0.014	0.022	0.079
13-12-80	-3.133	0.338	-0.011	-0.007	0.108
MKN 618					
11-12-80	-3.081	0.250	0.092	0.003	0.052
13-12-80	-3.077	0.257	0.093	-0.020	0.108
AKN 120					
11-12-80	-2.686	0.190	-0.004	-0.045	0.030
13-12-80	-2.692	0.196	0.003	-0.055	0.042
19-12-82	-2.674	0.187	-0.015	-0.047	0.021
20-12-82	-2.667	0.191	-0.013	-0.050	0.032
NGC 3783					
13-12-80	-2.604	0.347	0.084	-0.023	0.103
NGC 4507					
13-12-80	-2.659	0.469	0.249	0.145	0.246
NGC 7469					
10-12-80	-2.552	0.286	0.084	0.001	0.038
11-12-80	-2.554	0.289	0.076	0.002	0.058
8-12-82	-2.480	0.241	0.046	-0.011	0.052
MCG 2-58-22					
10-12-80	-2.489	0.285	0.258	0.055	0.235
NGC 7603					
10-12-80	-2.881	0.333	0.229	0.050	0.108:
11-12-80	-2.886	0.340	0.221:	0.017:	0.169:

TABLE II. — *VBLUW photometry through an 11.6 arcsec aperture.*

DATE	V	V-B	B-L	L-U	U-W	DATE	V	V-B	B-L	L-U	U-W	DATE	V	V-B	B-L	L-U	U-W		
TOL 0109-383						TYPE 2						IC 4329A						TYPE 1	
11-12-79	-3.035	0.424	0.233	0.070	0.246	20-11-81	-2.947	0.262	0.127	0.025	0.098	6-08-80	-2.791	0.519	0.245	0.115	--		
12-12-79	-3.035:	0.428:	0.201:	0.095:	0.255:	1-12-81	-2.939	0.263	0.134	0.017	0.096	8-08-80	-2.783	0.519	0.264	0.115	--		
15-12-79	-3.032	0.419	0.244	0.057	0.353:	2-12-81	-2.951	0.258	0.126	0.026	0.091	10-08-80	-2.782	0.521	0.281	0.069:	--		
20-12-79	-3.024	0.427	0.270:	0.033	0.157	3-12-81	-2.936	0.254	0.133	0.019	0.078	MKN 841						TYPE 1	
21-12-79	-3.034	0.429	0.228	0.107	0.123	10-12-82	-2.994	0.290:	0.158	0.102:	0.145:	TYPE 1							
22-12-79	-3.022	0.428	0.199	0.108	0.274:	11-12-82	-2.987	0.278	0.168:	0.057	0.115	8-08-80	-2.910	0.133	-0.052	-0.040	0.044		
24-12-79	-3.042	0.431	0.206	0.089	--	19-12-82	-3.033:	0.295	0.172	0.100	0.076:	10-08-80	-2.907:	0.134	-0.037	-0.044:	0.029:		
25-12-79	-3.060:	0.424:	0.192	0.107	--	20-12-82	-3.003	0.280	0.178	0.066	0.141	17-08-80	-2.878	0.118	-0.049	-0.042	0.045:		
6-08-80						NGC 1566						MKN 871						TYPE 1	
7-08-80	-3.038	0.432	0.217	0.095	0.238	TYPE 1						TYPE 1							
9-08-80	-3.032:	0.433	0.220	0.059	0.194	11-12-79	-2.414	0.403	0.247	0.062	0.184:	8-08-80	-3.244	0.305	0.128	0.025	0.092		
10-08-80	-3.033	0.423	0.231	0.077	0.238	12-12-79	-2.418	0.394	0.257	0.047	0.158	10-08-80	-3.227	0.324	0.101	0.026	0.111		
11-08-80	-3.011:	0.430:	0.230:	0.055:	0.158:	16-12-79	-2.422	0.395	0.259	0.060	0.185	ESO 140-G43						TYPE 1	
12-08-80	-3.029	0.429	0.235	0.066	0.229	20-12-79	-2.424	0.399	0.246	0.052	0.197:	TYPE 1							
13-08-80	-3.032:	0.424	0.233	0.063	0.285	22-12-79	-2.440	0.395	0.257	0.051	0.098:	8-08-80	-3.102	0.373	0.139	0.040	0.181		
17-08-80	-3.029	0.423	0.231	0.071	0.213	24-12-79	-2.410	0.397	0.247	0.044	--	10-08-80	-3.081	0.361	0.171	0.019	0.250		
9-12-80						25-12-79	-2.405	0.390	0.236	0.056	--	11-08-80	-3.087	0.353	0.175	0.028	0.167		
14-12-80	-3.019	0.423	0.205	0.105	0.172	6-08-80	-2.437	0.415	0.286	0.072	0.229:	13-08-80	-3.087	0.361	0.167	0.045	0.140		
20-11-81	-3.017	0.439	0.229	0.071	0.197	11-08-80	-2.432	0.416	0.285	0.089	0.222:	17-08-80	-3.104	0.376	0.131	0.033	0.230		
21-11-81	-3.029	0.437	0.209	0.098	0.272	12-08-80	-2.435	0.413	0.289	0.071	0.194:	ESO 141-G55						TYPE 1	
1-12-81	-3.014	0.436	0.231	0.064	0.281	21-11-81	-2.369	0.360	0.190	0.024	0.140	TYPE 1							
2-12-81	-3.026	0.426	0.216	0.101	0.259	25-11-81	-2.394	0.367	0.203	0.021	0.156	8-08-80	-2.743:	0.123	-0.053	-0.038	0.032		
3-12-81	-3.019	0.434	0.218	0.070	0.211	26-11-81	-2.384	0.366	0.199	0.030	0.158	10-08-80	-2.719	0.124	-0.055	-0.040	0.034		
FAIRALL 9 (ESO 113-IG45)						30-11-81	-2.383	0.361	0.176	0.027	0.137	11-08-80	-2.727	0.119	-0.055	-0.041	0.042		
TYPE 1						1-12-81	-2.375	0.357	0.184	0.028	0.131	13-08-80	-2.730	0.124	-0.052	-0.041	0.038		
11-12-79	-2.647	0.131	-0.060	-0.048	0.030	2-12-81	-2.377	0.358	0.182	0.026	0.143	17-08-80	-2.723	0.126	-0.050	-0.047	0.038		
12-12-79	-2.632	0.140	-0.060	-0.051	0.028	3-12-81	-2.368	0.357	0.183	0.027	0.137	NGC 6814						TYPE 1	
15-12-79	-2.648	0.130	-0.054	-0.064	0.023	10-12-82	-2.373	0.356	0.188	0.022	0.142	TYPE 1							
16-12-79	-2.635	0.133	-0.067	-0.052	0.027	11-12-82	-2.372	0.352	0.172	0.026	0.131	6-08-80	-2.842	0.436	0.169	-0.004	0.141		
20-12-79	-2.634	0.131	-0.063	-0.049	0.042	19-12-82	-2.372	0.347	0.175	0.012	0.117	7-08-80	-2.836	0.431	0.189	0.002	0.126		
21-12-79	-2.631	0.132	-0.068	-0.051	0.020	20-12-82	-2.373	0.348	0.170	0.016	0.122	10-08-80	-2.844	0.438	0.227	0.019	0.132		
22-12-79	-2.628	0.134	-0.057	-0.061	0.037	21-12-82	-2.367	0.350	0.170	0.010	0.136	11-08-80	-2.838	0.434	0.205	0.013	0.133		
24-12-79	-2.646	0.130	-0.069	-0.053	--	3C 120						13-08-80	-2.833	0.439	0.208	0.006	0.126		
25-12-79	-2.631	0.138	-0.065	-0.051	--	TYPE 1						17-08-80	-2.832	0.425	0.190	-0.006	0.116		
6-08-80						20-12-79	-3.308	0.373	0.021	-0.013	0.041	ESO 185-IG13						TYPE 2	
7-08-80	-2.651	0.139	-0.070	-0.046	0.031	21-12-79	-3.305:	0.362:	-0.007	-0.016	--	TYPE 1							
9-08-80	-2.655	0.141	-0.076	-0.055	0.045	22-12-79	-3.307	0.367	-0.018	-0.004	--	6-08-80	-3.374	0.152	0.082	0.120	0.134		
11-08-80	-2.662	0.139	-0.070	-0.055	0.040	9-12-80	-3.194	0.310	-0.007	-0.023	0.108	8-08-80	-3.363	0.152	0.044	0.115	0.100		
12-08-80	-2.659	0.137	-0.067	-0.059	0.046	14-12-80	-3.183	0.304	0.005	-0.059	0.102	10-08-80	-3.394	0.162	0.045	0.149	0.046		
13-08-80	-2.658	0.143	-0.078	-0.050	0.039	26-11-81	-3.090	0.266	-0.020	-0.030	0.107	11-08-80	-3.323	0.148	0.038	0.119	0.085		
17-08-80	-2.654	0.139	-0.074	-0.053	0.037	27-11-81	-3.089	0.261	-0.014	-0.020	0.078	13-08-80	-3.379	0.169	0.057	0.125	0.121		
14-12-80	-2.733	0.171	-0.062	-0.053	0.046	2-12-81	-3.086	0.270	-0.017	-0.030	0.100	17-08-80	-3.310	0.142	0.058	0.126	0.066		
20-11-81	-2.743	0.152	-0.058	-0.057	0.043	3-12-81	-3.086	0.268	-0.025	-0.020	0.100	II Zw 136						TYPE 1	
21-11-81	-2.733	0.162	-0.061	-0.050	0.049	20-12-82	-3.121	0.294	-0.038	-0.020	--	TYPE 1							
1-12-81	-2.745	0.168	-0.057	-0.063	0.055	MKN 618						TYPE 1							
2-12-81	-2.751	0.161	-0.054	-0.053	0.043	11-12-79	-3.128	0.196	0.019	-0.031:	0.052:	6-08-80	-3.169	0.150	-0.025	-0.066	0.071		
3-12-81	-2.752	0.160	-0.052	-0.054	0.048	12-12-79	-3.112	0.206	0.033	-0.050	0.041	7-08-80	-3.162	0.149	-0.027	-0.053	0.053		
7-12-82	-2.879	0.227	-0.038	-0.063	0.046	15-12-79	-3.112	0.215	0.026	-0.035	0.041:	10-08-80	-3.175	0.164:	-0.016:	-0.050:	0.127:		
19-12-82	-2.886	0.217	-0.029	-0.059	0.042	20-12-79	-3.110	0.191	0.022	-0.028	0.069	11-08-80	-3.164	0.150:	-0.035:	-0.043:	0.010:		
20-12-82	-2.882	0.212	-0.018	-0.064	0.042	MKN 7469						12-08-80	-3.173	0.160	-0.059	-0.054	0.076		
21-12-82	-2.890	0.211	-0.025	-0.058	0.038	21-12-79	-3.111	0.190	0.004	-0.024	0.075:	13-08-80	-3.166	0.145:	-0.017	-0.065	0.068		
MKN 573						22-12-79	-3.113	0.192	0.015	-0.056	0.069	17-08-80	-3.164	0.169	-0.033	-0.066	0.077		
TYPE 2						24-12-79	-3.112	0.189	0.015	-0.043	--	TYPE 1							
7-08-80	-2.941	0.472	0.152	0.150	0.227	14-12-80	-3.183	0.245	0.037	-0.016	0.074	13-12-79	-2.592	0.243	0.038	0.009:	0.116:		
9-08-80	-2.926	0.485	0.152	0.112	0.247	16-12-80	-3.178	0.236	0.057	-0.020	0.038:	15-12-79	-2.569	0.231	0.036	-0.019	0.035		
10-08-80	-2.934	0.470	0.132	0.126	0.253	1-12-81	-3.183	0.245	0.037	-0.016	0.074	21-12-79	-2.579	0.228	0.052	-0.018:	0.048		
13-08-80	-2.918	0.488	0.127	0.138	0.288	2-12-81	-3.169	0.235	0.046	-0.049	0.069	11-08-80	-2.604	0.244	0.033	-0.009	0.053		
9-12-80	-2.926	0.483	0.128	0.202:	0.206	3-12-81	-3.170	0.242	0.036	-0.035	0.087	12-08-80	-2.598	0.251	0.044	-0.022	0.054		
14-12-80	-2.921	0.477	0.166	0.176	0.182	20-12-82	-3.200	0.250	0.050	0.008	0.060	13-08-80	-2.599	0.254	0.042	-0.023	0.062		
1-12-81	-2.922	0.485	0.148	0.143	0.215	AKN 120						17-08-80	-2.608	0.253	0.049	-0.004	0.044		
2-12-81	-2.917	0.482	0.146	0.144	0.254	11-12-79	-2.718	0.173	-0.028	-0.045	0.020	9-12-80	-2.617	0.262	0.056	0.002	0.044		
3-12-81	-2.911	0.487	0.139	0.153	0.253	12-12-79	-2.710	0.169	-0.015	-0.056	0.017	2-12-81	-2.606	0.249	0.044	-0.011:	0.066		
MKN 590						20-12-82	-2.709	0.180	-0.027	-0.050	0.034	3-12-81	-2.594	0.252	0.046	-0.017	0.034		
TYPE 1						NGC 3783						TYPE 1							
15-12-79	-2.873	0.331	0.068	-0.054	0.024	12-12-79	-2.712	0.174	-0.026	-0.043	0.030	8-12-82	-2.548	0.228	0.029	-0.018	0.042		
20-12-79	-2.876	0.323	0.068	-0.042	0.068	16-12-80	-2.710	0.185	-0.021	-0.049	0.047	20-12-82	-2.542	0.233	0.025	-0.013	0.038		
22-12-79	-2.867	0.318	0.076	-0.051	0.072:	1-12-81	-2.657	0.169	-0.028	-0.044	0.036	MGC 2-58-22						TYPE 1	
6-08-80	-2.858:	0.266	0.016																

TABLE IV. — *Average colours and rms errors ; 11.6 arcsec diaphragm.*

DATE	V	V-B	B-L	L-U	U-W	V _j	DATE	V	V-B	B-L	L-U	U-W	V _j
TOL 0109-383							DEC 81	-3.170 .002	0.240 .004	0.036 .010	-0.038 .010	0.070 .017	14.79
ALL	-3.028 .009	0.429 .005	0.222 .013	0.082 .024	0.21 .05	14.42	AKN 120						
ESO 113-IG45							DEC 79	-2.722 .007	0.180 .007	-0.020 .005	-0.058 .008	0.022 .007	13.68
DEC 79	-2.637 .008	0.133 .004	-0.062 .005	-0.053 .005	0.030 .008	13.47	DEC 81	-2.656 .003	0.168 .001	-0.029 .003	-0.046 .005	0.038 .003	13.51
AUG 80	-2.659 .007	0.137 .002	-0.072 .004	-0.053 .004	0.030 .005	13.52	DEC 82	-2.714 .006	0.179 .005	-0.028 .002	-0.044 .006	0.032 .002	13.66
DEC 81	-2.745 .008	0.161 .006	-0.056 .004	-0.055 .005	0.048 .005	13.74	NGC 3783						
DEC 82	-2.884 .005	0.217 .007	-0.028 .008	-0.061 .003	0.042 .003	14.08	DEC 79	-2.680 .018	0.275 .010	0.023 .007	-0.057 .004	0.072 .015	13.57
MKN 573							NGC 4507						
ALL	-2.924 .009	0.481 .007	0.143 .013	0.143 .019	0.236 .032	14.16	ALL (N=5)	-2.774 .013	0.483 .010	0.214 .017	0.096 .032	0.241 .055	13.87
MKN 590							IC 4329A						
DEC 79	-2.872 .005	0.324 .007	0.071 .005	-0.049 .006	--	14.04	AUG 80	-2.785 .005	0.520 .001	0.263 .018	--	--	13.89
AUG 80	-2.835 .006	0.269 .004	0.025 .010	-0.047 .014	0.043 .010	13.96	MKN 841						
DEC 81	-2.810 .009	0.272 .006	0.011 .006	-0.046 .008	0.044 .007	13.89	AUG 80	--	0.128 .009	-0.046 .008	--	--	14.12
DEC 82	-2.844 .003	0.280 .005	0.041 .013	-0.040 .005	0.037 .020	13.97	ESO 140-G43						
NGC 1068							AUG 80	-3.092 .010	0.365 .009	0.157 .020	0.033 .010	0.194 .045	14.58
ALL	-1.750 .005	0.399 .004	0.170 .004	0.104 .004	0.168 .005	11.23	ESO 141-G55						
MKN 609							AUG 80	-2.725 .005	0.123 .003	-0.053 .002	-0.041 .003	0.037 .004	13.70
DEC 79	-2.971 .011	0.268 .009	0.158 .008	0.048 .017	--	14.29	NGC 6814						
DEC 81	-2.943 .007	0.259 .004	0.130 .004	0.022 .004	0.091 .009	14.22	AUG 80	-2.838 .005	0.434 .005	0.203 .014	0.005 .010	0.129 .008	13.94
DEC 82	-2.994 .007	0.286 .008	0.174 .013	0.078 .020	0.132 .014	14.36	ESO 185-IG13						
NGC 1566							AUG 80	-3.357 .033	0.154 .010	0.054 .016	0.126 .012	0.092 .033	15.27
DEC 79	-2.419 .011	0.396 .004	0.250 .008	0.053 .007	0.147 .045	12.90	II ZW 136						
AUG 80	-2.435 .003	0.415 .002	0.287 .002	0.077 .010	--	12.94	AUG 80	-3.168 .005	0.157 .009	-0.032 .016	-0.061 .007	0.069 .010	14.79
DEC 81	-2.379 .009	0.361 .004	0.188 .010	0.026 .003	0.143 .010	12.80	NGC 7469						
DEC 82	-2.371 .003	0.351 .004	0.175 .008	0.017 .007	0.130 .010	12.78	DEC 79	-2.580 .012	0.234 .008	0.042 .009	--	--	13.32
3C 120							AUG 80	-2.602 .005	0.251 .005	0.042 .007	-0.015 .009	0.053 .007	13.36
DEC 79	-3.308 .002	0.370 .006	-0.001 .020	-0.011 .006	--	15.12	MCG 2-58-22						
DEC 81	-3.088 .002	0.266 .004	-0.019 .005	-0.025 .006	0.096 .013	14.58	DEC 79	-2.948 .014	0.194 .002	-0.063 .006	-0.025 .007	--	14.24
MKN 618							AUG 80	-2.920 .005	0.184 .004	-0.058 .006	-0.024 .005	0.070 .009	14.18
DEC 79	-3.114 .006	0.197 .010	0.019 .009	-0.033 .012	0.058 .016	14.65	NGC 7603						
							AUG 80	-2.996 .009	0.318 .006	0.200 .010	0.029 .016	0.103 .015	14.35

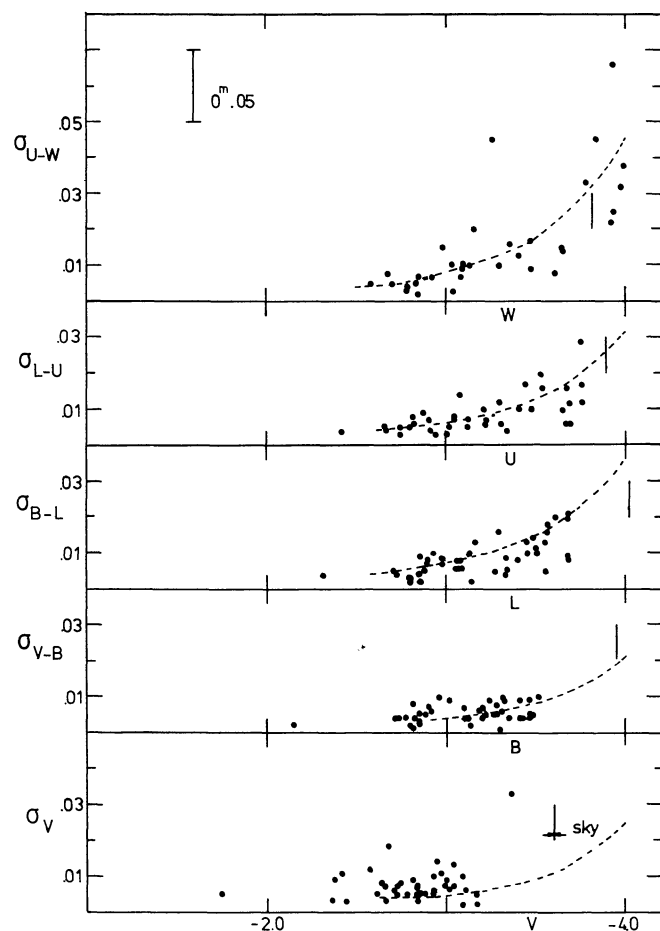


FIGURE 1. — Errors in log (intensity) for observing runs with more than two measurements, against Walraven intensities. For comparison an error of 0.05 in magnitude units is indicated. Dashed lines give expected dependence of errors on Walraven intensities for a typical measurement sequence. The intensity of the dark-sky background is indicated by the vertical bar.

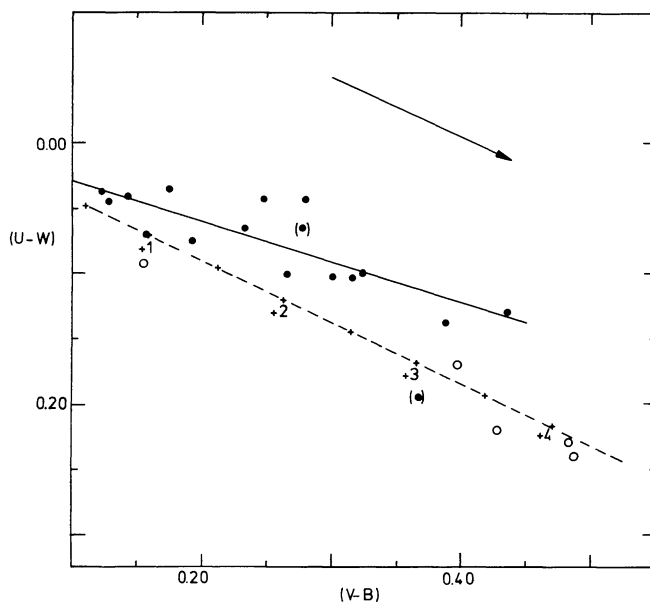
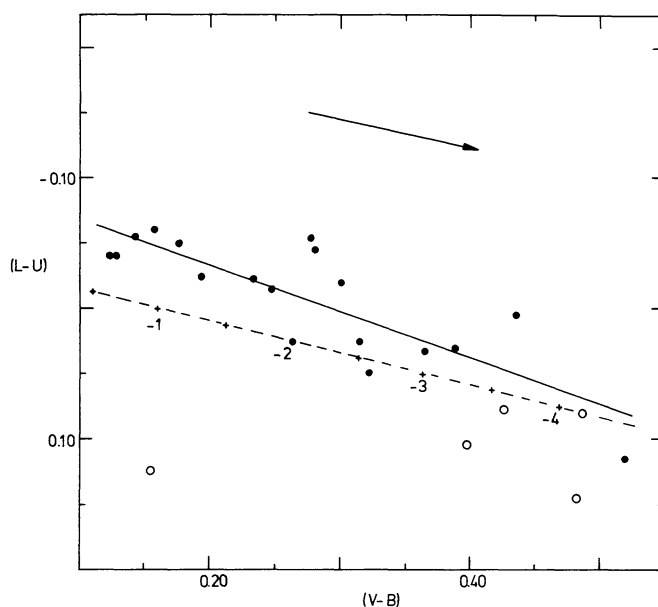
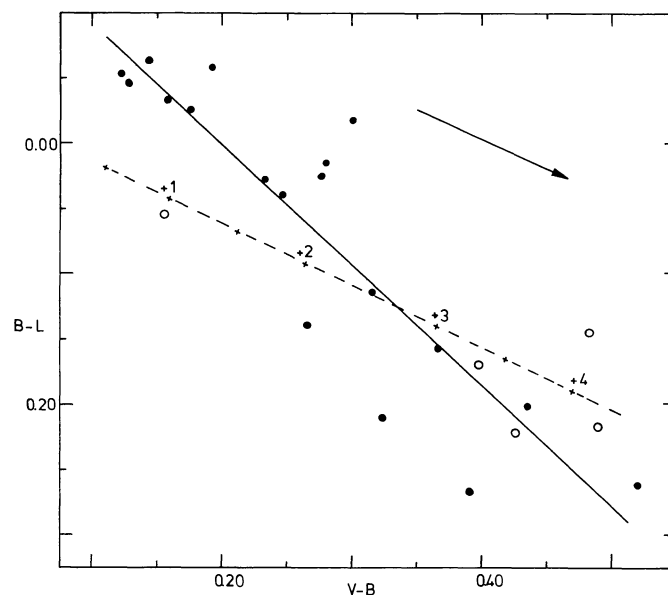


FIGURE 2. — Two-colour diagrams. Reddening line is indicated by an arrow. Black dots : type 1 Seyferts, open circles : type 2 Seyferts. The dashed lines give expected colours for a power law spectrum $F_v \sim v^{-\alpha}$. Different values of α are shown. The solid lines are linear fits (type 1 Seyferts only).

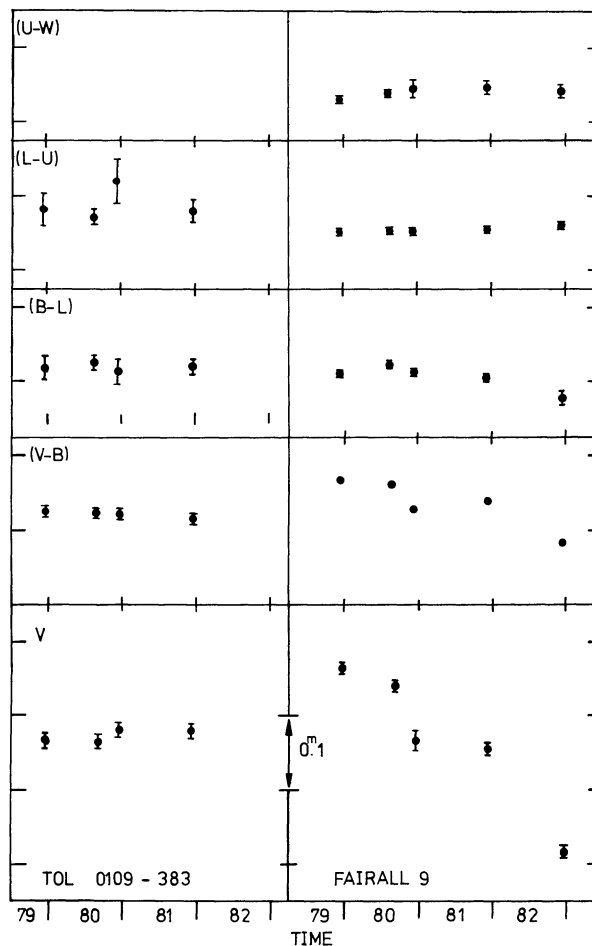
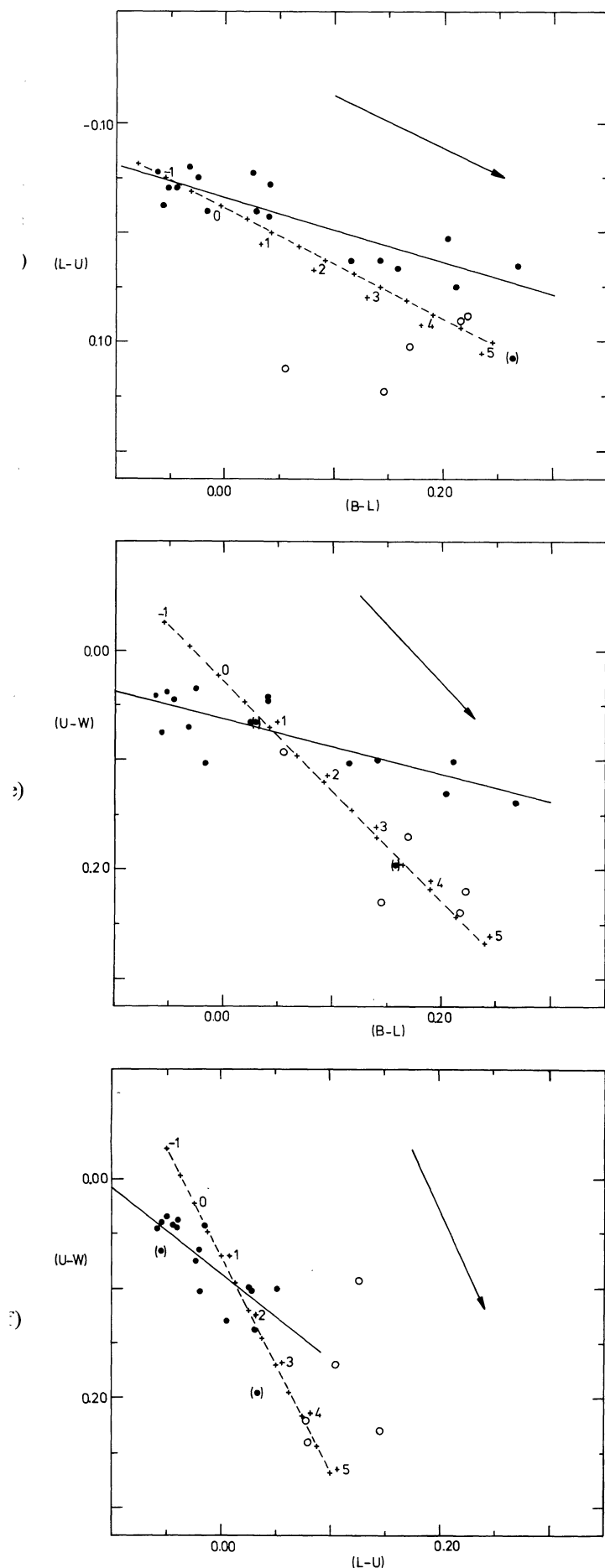


FIGURE 3. — Light curves in V , $(V-B)$, $(B-L)$, $(L-U)$ and $(U-W)$ for Tol 0109-383 (left hand panel) and Fairall 9 (right hand panel).

◀ FIGURE 2 (continued).