broad consensus in the community on the importance of the project. We have been fortunate in benefitting from the interest, encouragement, and support of the staff of various observatories at which these observations have been made. In addition to the tangible scientific return from these programmes, we believe that the large-scale international collaborations in the AGN field have greatly enhanced the mutual interactions of the astronomers involved in the project, have led to a *much more efficient use of telescope* time, and have resulted in a better coordination of programmes, thus leading to faster and unquestionable progress in our understanding of the AGN phenomenon.

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On the Variability of Narrow-Line Seyfert 1 Galaxies

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1. Introduction

Narrow-line Seyfert 1 (NLS1) galaxies are characterised by the relatively low projected velocities of their line-emitting nuclear gas. We describe a spectroscopic programme based on a search for variability, which attempts to constrain the causes of their difference with respect to other Seyfert 1 galaxies.

Active galaxies which are classified as Seyferts (characterised by a luminous nucleus of stellar appearance, with a non-stellar blue continuum and strong emission lines) are divided into two categories according to the widths of their lines: in Seyfert 2 galaxies, forbidden and permitted lines all have the same width (~ 1000 km s^{-1}), while in Seyfert 1 galaxies the permitted lines have an additional component of much greater width (~ 10^4 km s^{-1}). The difference is attributed to the presence of both a broad line region (BLR) and a narrow line region (NLR) in the nuclei of Seyfert 1's, while only the latter is present, or visible, in Seyfert 2's. The BLR is characterised by higher densities, higher velocities of the gas which forms it, and by a smaller size than the NLR: in fact, BLRs are so compact (≪ 1 pc) that even in the closest active galactic nuclei (AGN) they cannot be resolved spatially. The large velocities present in the BLR are generally attributed to the gravitational effects of a massive (>10^7 $M_\odot$) accreting black hole, which is the prime cause of the nuclear activity.

The distinction between type 1 and type 2 Seyferts is by no means clearcut. Spectropolarimetry (e.g. Antonucci & Miller, 1985) has revealed that several (though not necessarily all) Seyfert 2's contain BLRs which are hidden to conventional spectroscopy by obscuring material (possibly a dust torus). This has sparked a debate on the possibility that all Seyferts may be described within a unified model, in which the orientation of the nuclear axis determines the aspect of a source's spectrum, and therefore its classification. Within this framework, Seyfert 2 nuclei are viewed at large inclination angles, and Seyfert 1's at medium and small ones.

1.1 *What is a narrow-line Seyfert 1 galaxy?*

The broad components of Seyfert 1's display a great variety of profiles and widths (e.g. Osterbrock & Shuder, 1982, Stirpe, 1990), and it is tempting to explain it on the basis of projection effects. In particular, the so-called 'narrow-line Seyfert 1 galaxies' (Osterbrock & Pogge, 1985) are at the lower end of the broad line width distribution in the Seyfert 1 class. While they are clearly distinct from Seyfert 2's because of the different widths of permitted and forbidden lines, and because of the presence of Fe II lines (which are not emitted by the NLR and are therefore absent in Seyfert 2 spectra), the width of their broad components is barely larger than that of the forbidden lines[1] (FWHM ≤ 1000 km s^{-1}). Studies of NLS1s have shown that the broad components of the lines have ratios similar to those of 'normal' Seyfert 1's and, on average, lower equivalent widths (Osterbrock & Pogge, 1985, Goodrich, 1989); this last property, however, is the extension to low FWHM of a trend observed throughout the Seyfert 1 population. Some NLS1 galaxies present in their spectra high ionisation iron lines like [FeVII] λ5721, λ6087 and [Fe X] λ6375 (Osterbrock, 1985, Osterbrock & Pogge, 1985), in some cases with high intensity: these are properties common in Seyfert 1 galaxies, but quite rare in Seyfert 2's. NLS1s comprise approximately 10% of optically selected Seyfert 1's, but a significantly higher percentage ~ 16–50%) of soft X-ray selected Seyfert 1 samples (Stephens, 1989, Puchnarewicz et al., 1992). Boller et al. (1995) report the observation with ROSAT of a sample of NLS1s, finding that the objects in this class have generally steeper soft X-ray continuum slopes than normal Seyfert 1's, and rapid soft X-ray variability.

[1]It is important to realise that we are referring to objects whose maximum observed velocities from the BLR are low, not to objects in which the broad component of the emission lines is very weak compared to the narrow component, but also very broad: the FWHM of the permitted line (broad + narrow component) can be similar in objects of these two types, and sometimes a low signal-to-noise ratio in a spectrum can mask a weak but very broad component, and cause an object to be misclassified.

The question which we wish to address is what causes NLS1s to have such narrow lines: this can provide insight into the more general problem posed by the great diversity present among the broad emission lines of AGN. Some of the possible answers are:

1. NLS1s are not intrinsically different from other Seyfert 1's, and the low velocities in their lines are caused merely by projection effects. If, for example, the BLR has a flattened configuration in which the gas moves preferentially in the plane perpendicular to the axis of symmetry (as in an accretion disk), our line of sight towards NLS1s should form a small angle with the axis itself.

2. The main difference between NLS1s and normal Seyfert 1's is the mass of the central black hole, which is smaller in the former type of object, and therefore causes the BLR gas to move at lower velocities.

3. The broad line gas in NLS1s moves at lower velocities because it is on average at larger distances from the black hole than in normal Seyfert 1's. In this scenario, the BLRs of NLS1s have a larger emissivity-weighted radius than those of normal Seyfert 1's.

4. The inner region of the BLR, in which the gas moves at the highest velocity, is hidden from our sight by orientation effects: it is possible, within the Seyfert unified model, that NLS1s are objects seen at relatively large inclination angles, and that only the outer part of the BLR is observed.

1.2 Variability

A common characteristic of Seyfert 1 nuclei is their strong variability: the UV/optical continuum and emission lines vary on time scales of a few days if not less. Normally the emission line variations lag those of the continuum by a few days or weeks, indicating that the size of the BLR is less than a few tenths of a parsec. A great effort has been invested during recent years in the monitoring of Seyfert 1's (see Robinson, 1994 and Alloin et al., 1995, and references quoted in both reviews), in an attempt to unravel the structure of the BLR through the technique of reverberation mapping (Blandford and McKee, 1982). Because of the large amounts of telescope time required for adequate monitoring campaigns (which typically consist of one observation every few days for several months), care has always been taken to select targets which were well known to be highly variable, e.g. NGC 4151, NGC 5548, NGC 3783, Fairall 9. All the targets chosen for monitoring have broad components of normal widths, so the results obtained so far do not necessarily generalise to the Seyfert 1 population as a whole, and in particular to NLS1s. In fact, it is not even known whether NLS1s are optically variable, except for one case (NGC 4051, Peterson et al., 1985). Yet this information could be very useful to constrain the hypotheses listed in the previous section on the nature of NLS1s, as pointed out by Robinson (1995). A lack of widespread variability, in fact, would suggest the absence of broad line-emitting gas very close to the central black hole, and would therefore indicate that the BLR is located at higher distance from the centre than in normal Seyfert 1's, or that the inner and most responsive region of the BLR is obscured. If instead variability is as common in NLS1s as in Seyfert 1's, this could imply a smaller central mass or an anisotropic kinematic structure for the BLR.

Therefore, we have performed a simple observational programme to determine whether variability is a common characteristic of NLS1s.

2. Observations and Preliminary Results

The programme consists in the observation of a sample of NLS1 galaxies at two epochs separated by about one year. For each object we obtained spectra covering the main optical lines, and compared the integrated line fluxes measured for the two epochs. The results of this search for variability for our sample were then compared with those of a larger existing data-base on 'normal' Seyfert 1's, obtained with the same (relatively long) time scale. The sample we have chosen consists of 12 objects, and is formed by all the NLS1s known in the literature with $m_V \leq 16.0$ and intrinsic luminosity comparable to that of known variable Seyferts, and which were suited to our observing conditions. The observations were performed at the 1.52-m ESO telescope located at La Silla, Chile, during two observing runs in early October 1993 and late September 1994. In both cases we used the same instrumental configuration, covering the 3700–7500 Å range at a resolution of ~ 1.9 Å/pxl. The S/N ratio of ~ 50 allows us to detect or exclude flux variations down to a level of ~ 10%.

The spectra were taken with standard procedures, and reduced making use of the standard IRAF reduction tasks. Before being able to compare the spectra obtained at different epochs, however, we performed a sort of 'internal' calibration to correct for differential slit losses in each couple of spectra, making use of the strong forbidden lines present in the Seyfert spectra: as mentioned previously, the forbidden lines are emitted by the NLR, which is much larger than the BLR, and therefore remain constant on time scales of decades. Imposing that the integrated flux of the forbidden lines chosen for the calibration is the same for the two spectra of each object, we could therefore find a scale factor to correct for in one of the two spectra, so making it comparable to the other one. The calculation of the correction parameters is performed by a Fortran code (see van Groningen & Wanders, 1992) which makes use of a chi-square minimum research procedure on the difference spectrum in the wavelength range including the forbidden lines; together with a scale factor and a shift in pixels, it also gives in output the FWHM (in pixels) of the Gaussian with which one of the two spectra may be convolved to best match the other. We found that this method gives better results, i.e. smaller residual fluxes in the difference spectra in the region of the chosen forbidden lines, than the method of direct evaluation of the forbidden line fluxes through a (e.g. Gaussian) fitting of the line profiles, not only since allowance is made for a slight shift in wavelength, but also because there is no need to make hypotheses on the shape of the lines, which is often far from being Gaussian. A problem with this method may exist, however, when the NLR is spatially resolved and its extension is comparable with the projected slit width: in this case, in fact, a different seeing effect in observations separated in time may cause different portions of the narrow line fluxes to enter the instrument, and therefore lead to errors in the calibration. We are currently testing our data against this source of error, by a quantitative evaluation of the spatial extension of the nuclei; however, the appearance of the bidimensional images seems to exclude the presence of light losses caused by the seeing, since our galactic nuclei are compact and the observing conditions were quite good. An exception is represented by NGC 1365: its extended and composite nuclear structure requires special attention in the analysis of the narrow lines.

To achieve an accurate calibration in the covered spectral range, we applied the internal calibration method separately to the Hα part of the spectra, making use of the [S II] λ6717.0, λ6731.3 Å lines, and to the Hβ region, through the [O III] λ4958.9, λ5006.8 Å lines. To actually calculate the integrated flux for the strongest optical lines (mainly Hα and Hβ), we first fitted and subtracted the continuum under the lines, and then evaluated the flux through an interactive IRAF task.

The major sources of uncertainty on the estimated line fluxes are due to the process of internal calibration mentioned above and to the evaluation (by hand) of the fluxes themselves. Notice that, the [O III] lines being very intense compared to the [S II] features, the calibration of the

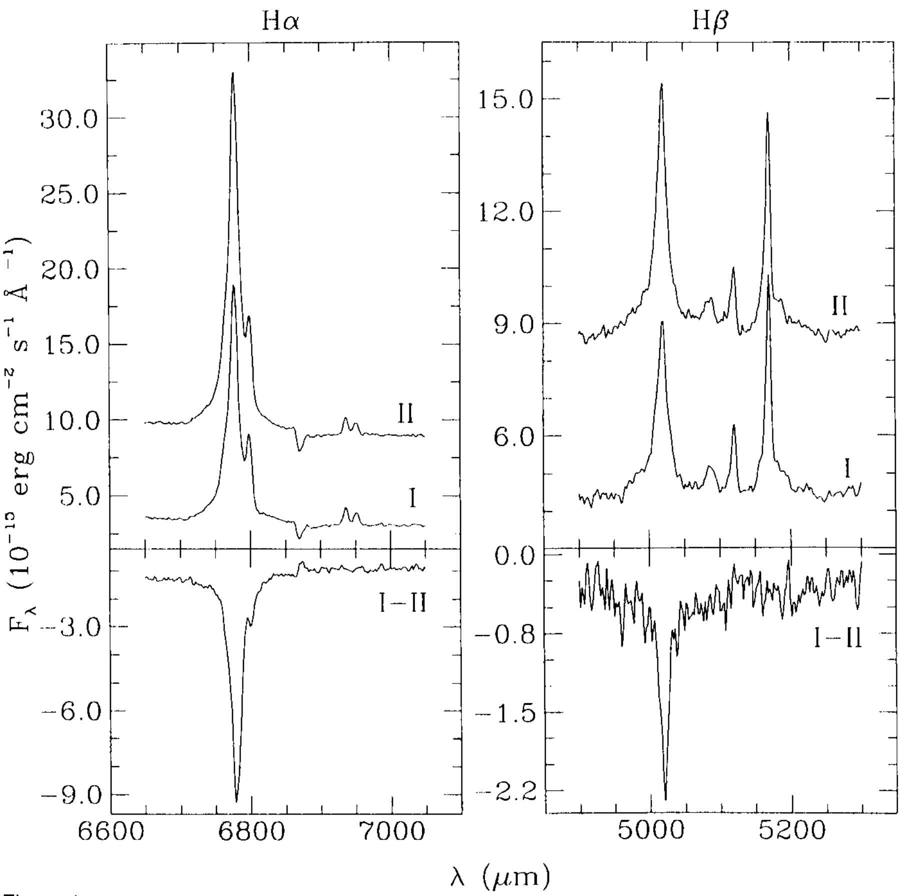

Figure 1.

Hβ region is usually more accurate than that of the Hα region.

We considered reliable only the measured flux variations above 3σ, where σ is the estimated uncertainty on the variation, finding that out of 12 objects, 9 show appreciable variations between the two epochs. In particular, two objects (IRAS 0345+0055 and NAB 0205+024) show no variation and another one (Akn 564) displays a very weak decrease below our threshold; four objects (ESO 012–G21, Mkn 359, Mkn 915[2] and NGC 1365) underwent strong increases in luminosity (in the range 20–40%). We detected a marginal variability in H 0707–495 and Mkn 1044 (in the range 10–20%), while for three objects (IRAS 0444–052, Mkn 1126 and Mkn 896) we observed a clear variation only in one of the two main emission lines (Hα and Hβ).

In Figure 1 we plot the two spectra (1993 and 1994) of ESO 012-G21 and the difference spectra showing clearly the line flux increase both in Hα and Hβ.

3. Comparison with the Seyfert 1 Sample and Discussion

The de Ruiter and Lub dataset with which we compared our results consists of a sample of about 20 Seyfert 1 galaxies, selected with no previous knowledge of variability characteristics: they were all Southern Seyfert 1's which were known when the programme was started (1979). The objects have been spectroscopically monitored at the 1.52-m ESO telescope on long time scales, more precisely from one year to the next for about 15 years.

To use this optical spectra data-set as a comparison sample, we first evaluated, approximately with the same criteria used for our sample, the Hβ flux for each object and each observation epoch (sometimes calculating the mean value of more observations taken a few days apart) constructing an Hβ light curve for each Seyfert 1 galaxy. We then calculated the relative variation of the line flux for each 1-year interval. Since this time range is much greater than the typical time scale of line and continuum variations, which ranges from days to months (see § 1.2), we can assume that the annual relative variations are independent, being probably associated to different 'events' (bursts or declines of luminosity). We therefore constructed a global histogram, including all the annual relative variations (in absolute value) for all the objects, which in this way forms a statistically meaningful sample on variability data.

The data on the Hβ line flux show that virtually all the monitored galaxies display significant variability, at least in some of the time intervals covered. To determine how the NLS1 galaxies behave as a class, compared to the 'normal' Seyfert 1

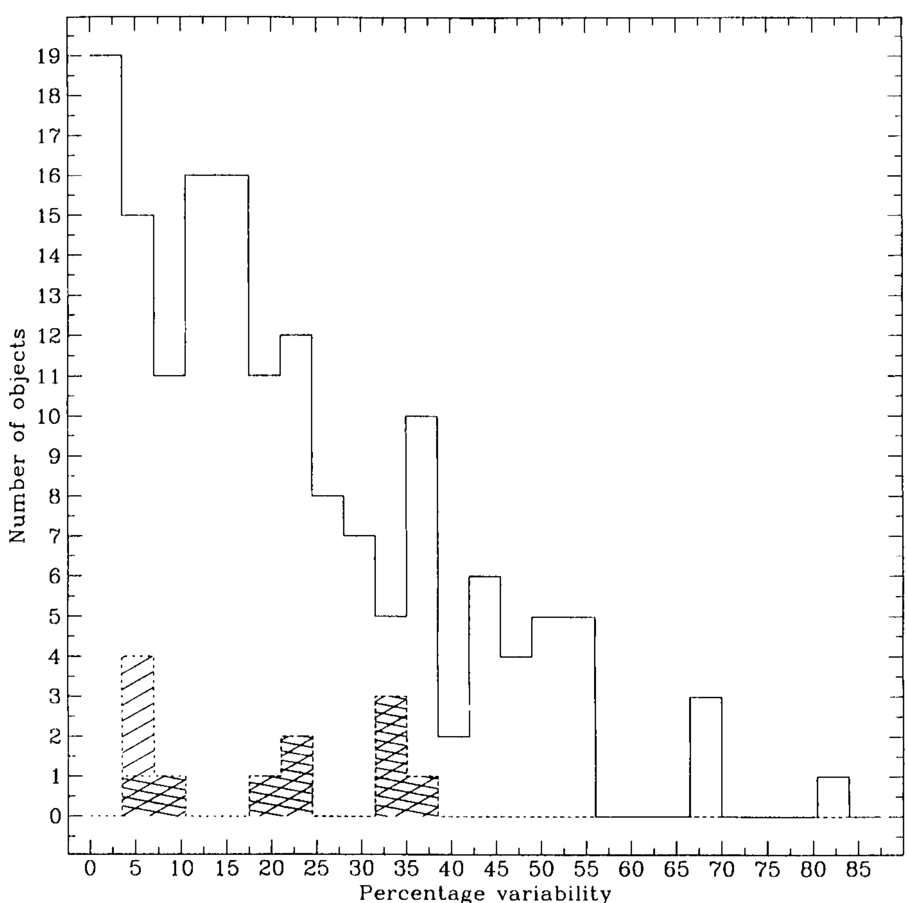

Figure 2.

[2]Notice, however, that this object may have a very broad but weak component in its emission lines (which in our spectra appears only in the Hα line), and therefore may have been misclassified as a NLS1 (see note 1).

population, we drew a histogram as described above for our results too: the number of objects in the sample is too small to easily analyse the observed variability from a statistical point of view; nonetheless, there is no apparent trend of the NLS1s towards weak or absent variability characteristics; on the contrary, the objects for which we clearly detected a flux variation appear to distribute in the histogram in a similar way with respect to the comparison sample, e.g. they can reach relative variations around 30–40%. In Figure 2 we plot the two histograms described above, which show no evidence for a weak variability in the NLS1 sample, especially when only the flux variations above 3σ are considered.

While the absence of variability, or a significantly lower variability with respect to 'normal' Seyfert 1's, would have had strong implications on the interpretation of the NLS1s' spectrum, excluding that a smaller central mass or projection effects could be responsible for the narrower lines, the presence of variability on a time scale of one year does not entirely exclude the possibility (among the four listed in § 1.1) that we are actually observing broad line emitting gas located at relatively high distance from the centre (which represents the whole or only the outer part of the BLR); this gas could in fact be insensitive to variations on short-time scales, but responsive to long-term trends similar to the ones easily recognisable in the Hβ light curves of the de Ruiter and Lub data-set. To discriminate between the competing models it would be necessary to monitor a variable NLS1 (e.g. NGC 4051) with quite short time scales (days or weeks), such that the presence of variability would surely imply that the line-emitting gas is located very close to the centre (as in 'normal' BLRs), and therefore that a small black-hole mass or projection effects are to be responsible for the low FWHM observed. In a relatively long monitoring, moreover, it would be possible to measure the lag between the line and continuum light curves to have a better estimate of the BLR size, and compare it to that of other Seyferts.

At this stage we can set, for the size of the observed BLR in NLS1s, an approximate upper limit of the order of the light-year, since we would not observe any significant variations if the line-emitting gas would be located tens or hundreds of parsecs from the centre (as happens in the NLR). The observed BLR could represent therefore the outer part of a 'normal-sized' but partially obscured BLR, or the entire BLR in a type of object in which for some reason there is no line-emitting gas in the inner parsec region.

We can notice, however, that the annual relative variations measured in our comparison sample appear to belong to a long-term trend approximately in 30% of the cases (estimated by taking the events in which at least 4 points in the light curve show the same variation sign); therefore, a common variability in NLS1 galaxies, as that displayed by our data (~ 75% of objects varied in luminosity between the two epochs), is more probably consistent with models in which a BLR with 'canonical' size produces smaller observed velocities of the line-emitting gas, either for projection effects or for intrinsic reasons. We therefore tend to favour these types of explanation, that should be theoretically modelled to be able to compare in detail our predictions with the observed line profiles.

The fact that variability is detected in so many NLS1s is in any case a strong indication that these objects are not radically different, in size and nature, from normal Seyfert 1 galaxies.

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The DUO Programme:

First Results of a Microlensing Investigation of the Galactic Disk and Bulge Conducted with the ESO Schmidt Telescope

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Summary

We present the first results of a search for microlensing amplifications towards the Galactic centre region, aimed at investigating the populations of the disk and bulge in a wide field.

For this purpose, we used a first set of Schmidt plates taken on La Silla from April to September, 1994, digitised with the MAMA microdensitometer, and analysed with a software specially developed for highly crowded fields.

Some ten microlensing candidates, including what appears to be an amplification by a double lens, could be present in the data produced by the reduction of half of the field. Thousands of variable stars are also evidenced by this survey.