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A Quarter Century of Narrow-Line Seyfert 1s

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The class of active galaxies known as narrow-line Seyfert 1s were first systematically described a little over 25 years ago by Osterbrock & Pogge (1985). At the time of that paper, these were considered to be a relatively rare and peculiar subclass of Seyfert galaxies. Their subsequent discovery in large numbers in soft X-ray surveys and the recognition that they lie at one extreme of the principal eigenvector of optical spectroscopic properties for AGN as a whole, however, has made them objects of considerable interest for the past quarter century. This paper reviews the historical roots of the class, and describes some of the unique properties that have given them such a crucial role helping to piece together the puzzle of active galaxies.

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[*] Speaker.

[†] This talk was originally scheduled as the social dinner talk, but the chosen restaurant venue was artfully configured in a way amenable to a pleasant meal but not for an after-dinner speech, so the talk became the workshop opener. If this review is less exhaustive and has more highly selective literature citations than typical that is the reason. This is, in the end, a personal overview of the field by one of its accidental founders.

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1. Prehistory

The discovery of any new class of astronomical objects is almost never as clean as a single, “definitive” paper. Instead, the defining paper is often the first systematic investigation into what others had previously reported as objects that might be interesting for further study, usually because they possess unusual or at least extreme properties that make them stand out from other similar objects. So it is with the recognition of the existence of the class of objects we know as Narrow-Line Seyfert 1s (NLS1s).

The watershed year in the prehistory of NLS1s is 1978, in an often overlooked but very important paper by Davidson & Kinman [6]. The title of their paper was prescient: “On the possible importance of Markarian 359”. In it, they described the unusual and potentially important spectral properties of Markarian 359. Mrk 359 has a Seyfert 1-like spectrum with unusually narrow permitted lines; the FWHM of Hβ was $520\pm100\,\mathrm{km\,s^{-1}}$, comparable to what is seen in classic Seyfert 2s. Their speculation was that perhaps a broader component of Hβ had vanished (the broad Balmer lines were know to be variable, while the narrow lines were not seen to vary), but otherwise the object was puzzling, and they closed by saying that “[t]his unusual object merits further observations”.

The second curiosity of 1978 that marked the road to NLS1s was a pair of papers by Koski [20] and Phillips [32] on the galaxy Markarian 42. Both noted that Mrk 42 has many of the spectral properties of Seyfert 1s, but that the Fe II and H I lines were very narrow like, those seen in Seyfert 2s.

An object of much interest in the prehistory of NLS1s is still a fundamental object of study to this day: I Zwicky 1. I Zw 1 lies at the ragged (and frankly arbitrary) luminosity boundary that is used to delineate Seyfert 1s from QSOs, and remains unique as having the narrowest of the narrow lines of any NLS1 (I believe this is still true, but perhasp narrower NLS1s are still to be uncovered in the SDSS). Sergent [36] noted the unusually strong Fe II emission lines in early photographic spectra. Phillips, in two papers in 1976 and 1977 [30, 32] also noted the strong and *narrow* Fe II emission as a characteristic feature of this object, going further to use the narrowness of the lines to help identify the particular multiplets responsible for the lines. These were important papers in the study of Fe II emission in AGN, as in other objects the lines were so broad that the Fe II lines were hopelessly blended together. Phillips’ work on I Zw 1 was among the first to identify particular lines for later study. Finally, Oke & Lauer [27] noted “...I Zw 1 is not a typical type 1 Seyfert since the permitted and forbidden lines are of comparable breadth”. Here is one of the defining characteristics of what became NLS1s, again as an “isn’t that odd...” throw away line in a paper on a single object.

Finally, Osterbrock & Dahari [26] undertook a systematic classification of a sample of Seyferts and candidate Seyferts, and noted in their tables that four showed unusual properties, namely “narrow H I and Fe II [with] Fe II strong” (Mrk 493), and “Very narrow H I ... but noticeably wider than [O III]” (Mrk 783). It was this work that led Don Osterbrock to undertake a systematic search for and study of those objects which, along the lines first noted by Davidson & Kinman, had all the basic spectral characteristics of Seyfert 1s, but unusually narrow permitted lines. Don, always the good teacher on the look-out for good student projects, decided to pose this problem to a first-year graduate student who came knocking on his door looking for a research project for the upcoming summer term. That graduate student, of course, was myself in the spring of 1984.

2. Quasar Camp

In 1984, during the spring of my first year as a graduate student at UC Santa Cruz, I had enough of just taking classes, and having gotten a taste of research with Gerry Neugebauer's IR group while an undergraduate at Caltech, I was itching to get back into it. UCSC had no formal way at that time for pairing students with prospective advisers, so I took matters into my own hands and went walking down the hall knocking on doors. Don Osterbrock was not my first choice of research advisers, but in retrospect he was the best possible choice for me. The brief afternoon discussion that led to my getting involved in the hunt for other narrow-lined odd-ball Seyfert 1s was fateful. Don became my teacher, PhD advisor, colleague, and friend. He was one of the towering figures of 20th century astronomy, and his passing in 2007 at the age of 82 was a great loss to us all.

I began working with Don in May of 1984. That summer the 7th Santa Cruz Astrophysics Workshop was "Astrophysics of Active Galaxies and Quasi-Stellar Objects" and was to mark Don's 60th birthday. For two weeks, leaders in AGN research from around the world gathered among the redwood forest on the beautiful campus of UC Santa Cruz overlooking Monterey Bay to review the state of knowledge of AGN at the time. It became affectionately known to the participants as "Quasar Camp". I attended the workshop both as a junior participant and as a student helper, carting AV equipment, copying papers, scaring up transparency stock for talks, and helping lost astronomers (and future colleagues) find their way through the park-like campus.

What was our state of knowledge of AGN in 1984? In summary, these are the five major questions that were discussed at length at the workshop:

1. The host galaxies of QSOs were still called "Quasar Fuzz" and still little understood beyond the fundamental results of Boroson and Oke that their spectra — extremely difficult to observe — were suggestive of being normal, perhaps early-type galaxies.

2. There was as yet no "unification" model for Type 1 and Type 2 AGN. Spectropolarimetry was still in its infancy technically, and the data were puzzling. The first hints that NGC 1068, soon to be the unification poster child, was unusual and important came out in posters at this meeting.

3. The size of the broad-line region (BLR) in AGN was unknown to orders of magnitude, and estimates of the BLR size derived from early broad-line variability data presented at this meeting were very controversial. My first encounter with my future postdoctoral mentor and colleague Brad Peterson was watching him get savaged by the theorists when he dared suggest that the Hβ variability lag relative to the continuum in some nearby Seyfert 1s suggested that the BLR was about 10x smaller than photoionization theory said it should be [Brad was right...]

4. Only a few 10s of AGN had been detected well enough at X-rays with HEAO-1 and HEAO-2 to derive crude X-ray spectra, and there was much discussion as to what the soft X-ray spectrum was or wasn't. X-ray astronomy, which plays such a crucial role in NLS1s, was still very much in its promising infancy

5. The masses of AGN central black holes were still conjectural at best. Indeed, whether AGN were powered by supermassive black holes at all was also considered to be an open question, and much discussed (the “Black Hole Paradigm” so central to current research was still in its fitful early stages of acceptance with significant components of denial evident at the workshop).

These questions, and the lively discussions inside and outside the formal sessions, set the intellectual backdrop of the project Don and I were engaged in to find and study systematically Seyfert 1s with unusually narrow lines. It was the apparent vitality of the field and wide-open questions that led me to want to continue on in this area, and I’ve never looked back. It was a great summer in more ways than one.

It was not just the state of AGN knowledge at the time that set the stage for our work, but also the state of the astronomical practice in 1984. Again, the distinction then and now is instructive:

1. The first generation of CCD detectors were just starting to be deployed at telescopes. The largest was an 800x800 pixel device built by Texas Instruments for the then in-construction Hubble Space Telescope. The flight spares from the original WFPC1 instrument batch were distributed to the community by a joint NSF and NASA program to get these literally priceless devices into the hands of U.S. astronomers and onto telescopes. One of the objects in our original NLS1 study was observed using the first Lick TI CCD on the 3-meter Shane telescope. So much of my early career was catalyzed by learning how to best use these first astronomical CCDs.

2. Computers and their disk drives were huge machines that filled entire climate-controlled rooms. UCSC had a large VAX 11/780 computer from the now defunct Digital Equipment Corporation. We were so excited when the dean gave us a special grant to increase the core memory of the VAX from 4 megabytes to 16 megabytes. The fastest supercomputer in the world in 1984 was the Cray-2 with 4 processors and 512 megawords of memory. The Cray 2 benchmarked at 1.6 gigaflops, but that performance required it be liquid cooled with Fluorinert and cost about US$15 million.[1]

3. Computer-to-computer data transfers were carried out by a graduate student carrying a magnetic tape down the hall (“sneakernet”) — slow and mostly reliable, but with a somewhat large packet size (even larger if you dropped the tape and it unspooled down the hallway...). We told ourselves that at least we weren’t using punch cards and paper tape.

4. Scientific papers were composed on mechanical typewritters and then submitted and refereed using the national post. It took 6 months to a year to iterate twice from submission to publication.[2]

5. Nearly all research groups employed full-time professional draftsmen to hand-compose graphics for papers and presentations using black-ink and a Leroy Lettering Set for text. If you

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[1] To put this in perspective, I gave my talk at this meeting using an Apple iPad2, whose 2 processors deliver the same 1.6 gigaflop performance as the Cray 2 with the same memory capacity, but it weighs 600g, runs for 10 hours on battery power, and costs US$500.

[2] In this age of e-mail, astro-ph, and e-publishing, it still takes as long, so the bottleneck isn’t technology.

look carefully at the figures in Osterbrock & Pogge [28], the first few figures are hand-composed, but the last was created using an early version of Mongo on the VAX computer (Lick's draftsman retired soon thereafter).

Such was the scientific and technical backdrop against which our own investigations into what became NLS1s played out. The late 1980s were an extremely exciting time to be a graduate student in astronomy. Observationally, the rise of CCDs was to work a real revolution in how we acquired data, requiring us to develop whole new bodies of technique along the way. My own dissertation (on a different subject), was carried out with a CCD on a 1-meter telescope and would have been nearly unthinkable on the largest telescopes of the day when I began graduate school. Similarly the coming revolution in computers and the internet was to completely change how we do astronomy. Lick Observatory and UC Santa Cruz were at the center of all this, and it was an amazing place to be. I was very fortunate.

3. The Defining Moment(s)

In Osterbrock & Pogge [28], we defined NLS1s to be those galaxies whose nuclear spectra are generally like those of Seyfert 1s (strong Fe II, [O III] relatively weak compared to the Balmer lines), but with line widths much narrower than typical Seyfert 1s. The formal spectral classification criteria for NLS1 galaxies that has emerged since are:

- Narrow permitted lines only slightly broader than the forbidden lines.
- [O III]/H$\beta < 3$, but exceptions are allowed if there is also strong [Fe VII] and [Fe X] present, unlike what is seen in Seyfert 2s.
- FWHM(Hβ)$<2000\,\mathrm{km\,s^{-1}}$.

The first two criteria are from our original classification [28], while the maximum line-width criterion that has become such an important part of the current classification, was introduced by Goodrich [12] in his spectropolarimetric study of these and related objects.

The essence of the classification is shown graphically in Figure 1, which contrasts the spectrum of the NLS1 Mrk 42 with representative Seyfert 1s and 2s. While the Hβ line of the Mrk 42 is not much wider than that in the Seyfert 2 Mrk 1066, the other spectral lines, especially [O III] and Fe II, appear in about the same proportions, if with narrower Fe II widths, as they do in Seyfert 1s like NGC 3516.

I've chosen Mrk 42 for this example figure because it has strong and distinctive Fe II emission lines, which is often how one first spots them (the narrow lines look superficially like a Seyfert 2, but the Fe II is the give-away). While many (perhaps most) NLS1s show strong Fe II, not all do. This is why strong Fe II is not part of the formal classification we used in 1985. This is illustrated in Figure 2, which shows more modern spectra of four of the original NLS1s from the 1985 study. Note in particular that the ur-NLS1, Mrk 359, has relatively weak and unremarkable (but still present) Fe II emission lines.

This "some do, some don't" nature of the Fe II lines is recapitulated in the soft X-ray properties of NLS1s as we'll see later. Herein lies a caution: while NLS1s are a fairly well-defined and distinctive subclass of AGN, they are also a *diverse* subclass.

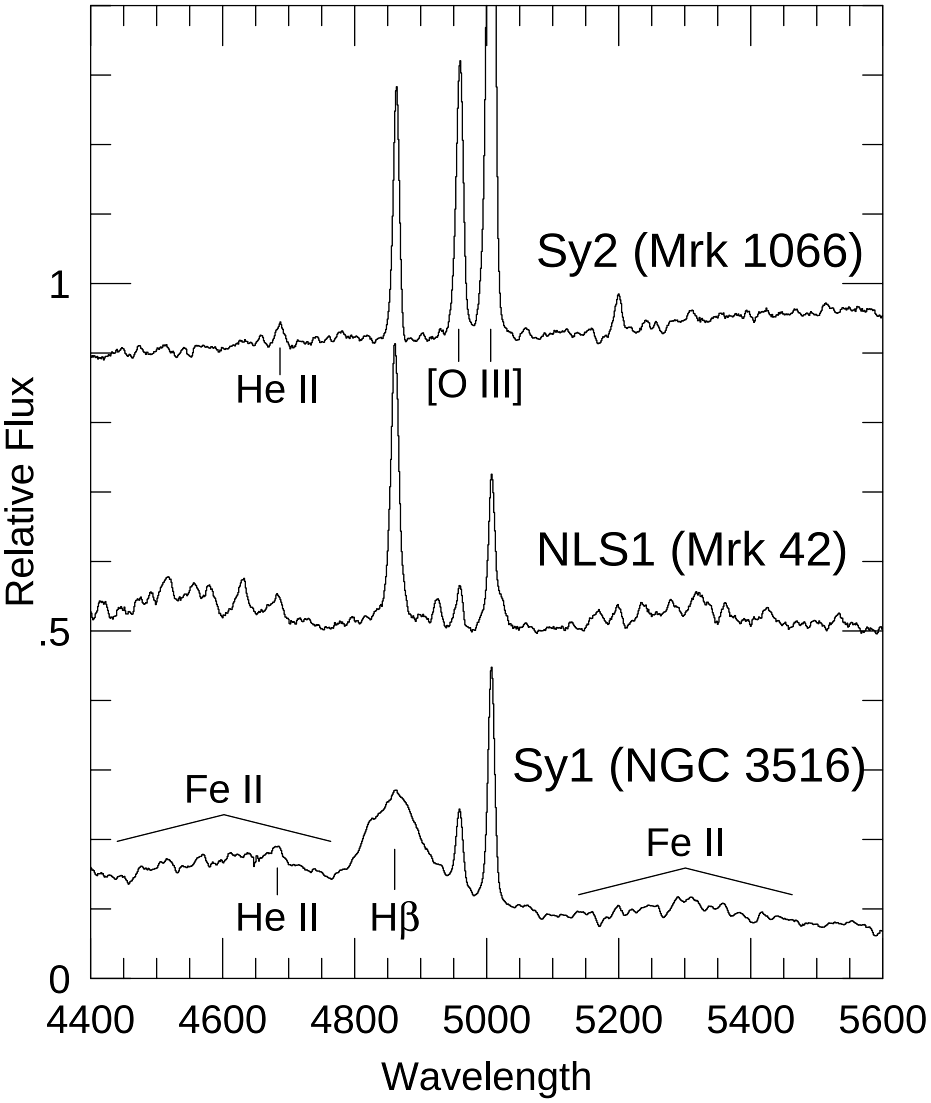

Figure 1: Spectra in the region around Hβ of the NLS1 Mrk 42 (center), the Sy1 NGC 3516 (below), and the Sy2 Mrk 1066 (above). All were taken with the Lick 3m Image-Tube Spectrograph at comparable resolution and signal-to-noise ratio.

4. The Case of I Zw 1

The first connection between NLS1s and objects like I Zw 1 was made by Halpern & Oke [17] in their 1987 study of Mrk 507 and 5C3.100. These two objects were notable for being unusually X-ray luminous compared to other Seyfert 2s. Halpern & Oke's spectra showed that they were *not* in fact Seyfert 2s as classified by earlier papers, but instead they had spectra reminiscent of I Zw 1 with strong Fe II and narrow permitted and forbidden lines. Their luminosities make them NLS1s near the high-luminosity end of Seyfert 1s. Another notable aspect of this paper is it is one of the first times that NLS1s were noted to be interesting X-ray sources.

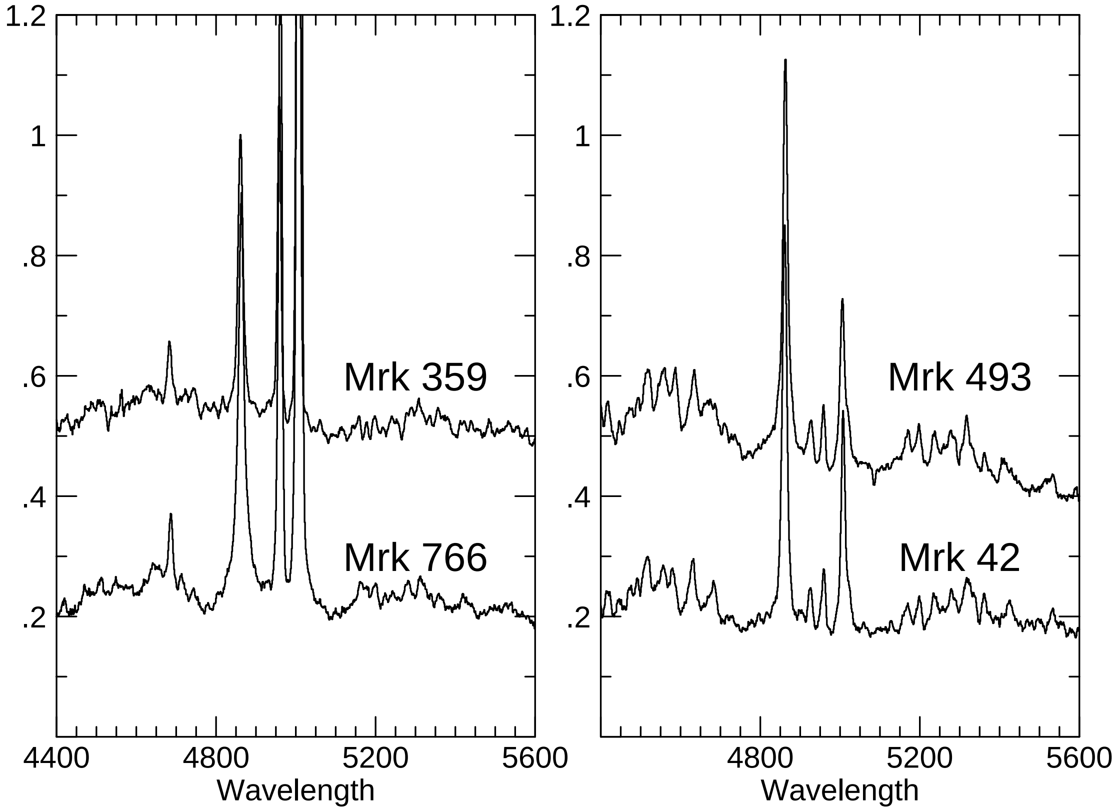

Figure 2: Spectra in the region of Hβ, [O III], and Fe II for four NLS1s from Osterbrock & Pogge [28] (replotted for this figure).

The tale of the initial classification of Mrk 507 and 5C3.100 as Seyfert 2s is instructive. The earlier published spectra are characterized by narrow Hβ and [O III] lines, but the Fe II lines are lost in the noise. With these data, the objects meet the basic criteria for being Seyfert 2s. Halpern & Oke's higher signal-to-noise ratio spectra revealed clear Fe II emission lines, declassifying them as Seyfert 2s. Similarly, Schmidt & Green [38] rejected Mrk 684 from their 1983 Palomar catalog of bright QSOs because of its narrow emission lines (they likened it to a Seyfert 2 rather than a QSO), largely because the criterion that Type 1 equals broad lines was still the norm. Don and I re-observed this object as part of our study [28] and found it was an NLS1 (interestingly, as a side note, this was the first time Don and I used the then brand-new CCD detectors with the Lick 3m spectrograph).

The initial mis-classification of objects as Seyfert 2s because of poor signal-to-noise ratio masking either weak Fe II or weak broad lines (or both) has been a persistent problem in the AGN classification game. The long and (until recently with SDSS) mostly fruitless search for high-luminosity "Quasar 2s" — objects with QSO luminosities but Seyfert 2-like spectra (i.e., no broad lines) — was mostly a tale of poor signal-to-noise ratio leading to mistaken identification of luminous I Zw 1-like NLS1s as Type 2 QSOs. This game has, of course, changed dramatically of late as the X-ray community has hijacked the original "Type 2 equals narrow lines" definition of "Type 2 AGN", and made it instead mean "obscured AGN". This redefinition by fiat has, if you will, obscured and confused the search for QSO-luminosity analogs of Seyfert 2s. That, however, is another story for another day.

5. The ROSAT Renaissance

Sally Stephens' PhD dissertation at UCSC was a spectroscopic study of 65 X-ray selected AGN. Of these, 10 were NLS1s, or $\sim$15%, leading her to remark that "X-ray selection may be an efficient way to find narrow-line Seyfert 1 galaxies" [39]. Subsequent work by Puchnarewicz and collaborators [33, 34] found that about 50% of their ultra-soft X-ray selected AGN were NLS1s. In hindsight, an examination of the spectra of AGN found in the HEAO-1 survey of Remillard et al. [35] and the Einstein MSS of Gioia et al. [11] found roughly similar proportions of NLS1s among them, if they were unrecognized as such at the time. These were the X-ray AGN that made such an impression at the 1984 Quasar Camp.

The prescience of Sally's remarks were brought home to me at the 1993 IAU Symposium 159 in Geneva, which I was attending as a new assistant professor at Ohio State. There I met Dirk Grupe, then a graduate student, who impressed me first by pronouncing my surname correctly[3], and second by his his poster paper [13], wherein he and his collaborators described their ground-based spectroscopic follow-up of 40 new, ultra-soft X-ray selected Seyferts discovered by the ROSAT All-Sky Survey. Fully $\sim$50% of the RASS soft X-ray selected AGN were NLS1s! In that same year, Boller et al. [1] inaugurated what I call the "ROSAT Renaissance" in the study of NLS1s with their paper describing the simply astoundingly violent X-ray variability of IRAS 13224$-$3809. IRAS13224 increased in 0.1$-$2.4 keV brightness by a factor of 4 with a doubling time of 800 seconds. This was not what was seen in regular Seyferts by a long ways. Thus, not only were NLS1s showing up in unusually large proportions in soft X-ray selected samples of AGN, they were also standouts in being among the most variable AGN known outside of more traditionally extreme beamed sources like blazars.

In the late 1990s, the X-ray astronomers (primarily the ROSAT team) essentially took ownership of the NLS1 class. In their landmark paper of 1996, Boller, Brandt, & Fink [3] published the results of a study of 46 NLS1s, half of which were X-ray *discovered*. This paper demonstrated the remarkable soft X-ray properties of NLS1s:

- Soft (0.1$-$2.4 keV) photon indices of $\Gamma \approx 1-5$, compared to ~ 2 for typical Seyfert 1s.
- Rapid, high-amplitude X-ray variability (doubling times of minutes to hours).

While some NLS1s have the steepest soft X-ray excesses yet observed, it is clear from Figure 8 of Boller, Brandt & Fink [3] that not all NLS1s are ultra-soft excess sources. This is more apparent in the work of Williams et al. [42] using SDSS-selected NLS1s with measurments from the RASS or subsequent Chandra follow-up. When plotted as shown in Figure 3 from [42] it becomes clear that it is the *dispersion* in Γ that increases dramatically for FWHM(Hβ)$<$2000 km s^{-1} where the NLS1s reside, not just the steepness of the spectrum. A number of spectroscopically classified NLS1s have photon indices more typical of the general run of Seyfert 1s.

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[3] Pogge means "Frog" in the Low or Plattdeutsch dialect of German spoken by my emigrant ancestors.

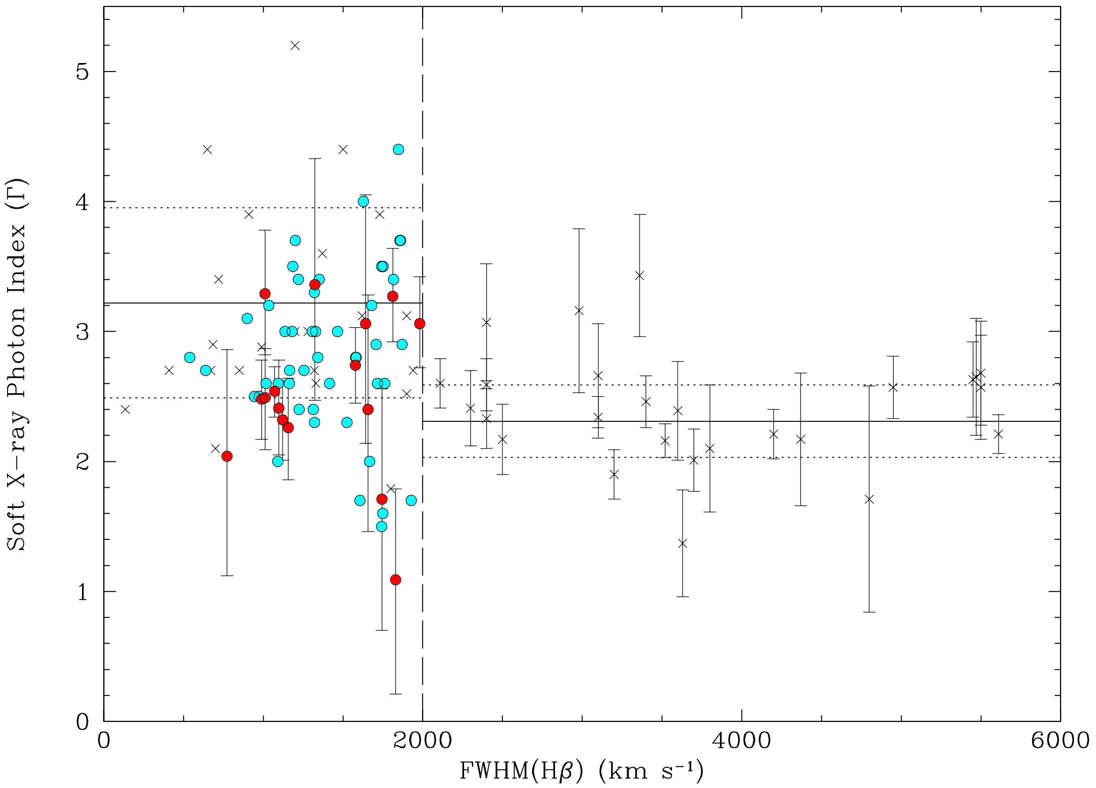

Figure 3: The soft X-ray photon index (Γ) plotted against FWHM(Hβ) for the original NLS1s of Boller, Brandt, & Fink (crosses), and the SDSS NLS1s of Williams et al. [42] (red and blue circles).

This is why soft-X-ray excess is a common but not defining characteristic of NLS1s. While searching for ultra-soft X-ray sources has proven to be an excellent way to find new NLS1s, it is biased against NLS1s with harder 0.1−2.4 keV X-ray spectra, and such samples could well exclude most of the NLS1s in the survey area.

6. Lies, Damned Lies, and Principal Components Analysis

In our 1985 paper, we remarked that "[NLS1s] clearly demonstrate that the Seyfert phenomenon is not a simple one-parameter effect" [28]. But what could the other parameter (or parameters) be that lead to the distinct NLS1 class? Among the possibilities are the black hole mass, the mass accretion rate, the accretion process radiative efficiency, orientation or obscuration effects, or perhaps fundamental differences of the structure of the central engine.

One fruitful approach, now more common given our access to very rich surveys, is to attack the problem through population statistics. In this regard NLS1s display their remarkable ability to seek out the extreme. The landmark study was Boroson & Green's 1992 paper examining the emission-line properties of low-redshift QSOs [4]. Their principal components analysis (PCA) revealed two convincing eigenvectors among a variety of emission-line and continuum measurements for 87 QSOs in the BQS catalog with $z < 0.5$. The second eigenvector is essentially a relatively weak Hβ Baldwin Effect. The principal eigenvector, the so-called Boroson & Green Eigenvector 1, is stronger but its underlying physical basis was elusive at the time (and some argue, still is, but that is now a minority opinion). The principal driver behind Eigenvector 1 is a strong anticorrelation between the strengths of the Fe II and [O III] λ5007 emission lines. Additional contributions come from a correlation between the FWHM of Hβ and the peak of [O III]. At one extreme end of AGN along Eigenvector 1 are those objects with the strongest Fe II, the weakest [O III], and the narrowest Hβ lines; all of which are the defining spectral characteristics of NLS1s.

While it may seem quaint to some in the age of SDSS to draw statistical conclusions from a few 10s of objects, I wonder if perhaps we are fooling ourselves into thinking that more is always better. The central limit theorem can only take you so far in the face of systematic effects, and in the days of 100 or so objects constituting a "large" sample of AGN, the investigators actually could look at and know their data. This is perhaps why key insights were gained by thoughtful investigators with only (by modern standards) sparse data.

PCA, while a powerful tool, is still something of a blunt instrument; it measures only the largest sources of variance among a large number of possibly unrelated parameters. Our observables (e.g., line and continuum properties) are not always the physical properties we most want, like black hole masses, accretion rates, etc. The hope of PCA is to try to tease out which parameters might be relevant. Brad Peterson's work using reverberation mapping to estimate the masses of the black holes has worked something of a revolution on the question. We now have a way to estimate the central black hole mass from the variability data independent of assumptions about the mass accretion rate (before, nearly all mass estimates for AGN were made by assuming some specific accretion rate, usually $L/L_{Edd} = 1$ to set at least a lower limit on the black hole mass). In their 2000 paper [29], Peterson and collaborators presented 32 AGN with good M_{BH} estimates from reverberation. Of these 7 were NLS1s. All AGN, broad- and narrow-line, obey the same radius-luminosity relation, which stems from basic photoionization physics, and NLS1s and broad-lined AGN span a similar range in luminosity. However, when you compare estimates of L/L_{Edd} by making a mass-luminosity plot, the NLS1s in Peterson's study all lie about 1 dex below the M/L relation for broad-line AGN. The implication is that NLS1s have lower black hole masses for their luminosity, and so to have that luminosity must be accretting at a higher rate.

Boroson's subsequent work in 2002 to expand upon the 1992 paper has produced an iconic plot, still much discussed, that plots the first two eigenvectors on 2D plane. Eigenvector 1 is now identified as the variation in the specific accretion rate (L/L_{Edd} or the "Eddington Rate") and Eigenvector 2 is identified as the total mass accretion rate ("M-dot"). NLS1s in this schematic lie at the high-Eddington/low-accretion mass corner of the plane, where the results of Peterson and subsequent other authors put them. By sitting at one extreme of the AGN eigenvector, NLS1s are giving us an important handle on how to make the jump from phenomenology to physics.

7. NLS1s and AGN/Black Hole Evolution

In our 1985 paper, we briefly considered the morphological characteristics of the NLS1s we found, but the observational source material we had at hand was sorely limited. Basically, we had the Palomar Observatory Sky Survey plates (literally on 14×14-inch glass plates stored in large cabinets in a climate-controlled room) and little else. The first CCD imagers in use at Lick were crude at best, and later that summer I made my first, abortive, attempts to take CCD images of

NLS1 hosts with the Lick 1-meter. This was the age when 2-arcsec seeing was considered pretty good instead of a pretext for going to bed early. As a consequence, we wrote that "[l]ittle can be said about the morphological characteristics of these galaxies, since even the nearest have redshifts $z \geq 0.01$". In the intervening years, we have learned that AGN and their host galaxies co-evolve, and we have discovered tight correlations between black hole masses and host galaxy properties, the most important of which are the $M_{BH} - \sigma$ relation [8, 10] and the $M_{BH} - L_{bulge}$ or "Maggorian" relation [22]. Galaxies and AGN, unlike stars, are complex *systems*, and so we don't expect the story of AGN evolution to be as clean as that we can tell for stars. NLS1s, however, are beginning to give us some insights into what AGN evolution might look like.

At the last major NLS1 meeting in 2000 in Bad-Honnef Germany, Smita Mathur [23] made the bold conjecture that NLS1s were AGN in the early stages of their evolution. In a follow-up paper in 2001, Mathur and collaborators [24] noted by way of support for this idea that NLS1s with good M_{BH} estimates tended to lie *below* the normal $M_{BH} - \sigma$ and $M_{BH} - L_{bulge}$ relations for normal galaxies and broad-line AGN. Subsequent work with larger samples and arguably better data by Wandel [40] and Grupe & Mathur [14] further fleshed out this picture: NLS1s tend to lie about 1 dex on average below the $M_{BH} - \sigma$ for broad-line AGN. Two interpretations were suggested: either NLS1s are younger AGN still at an early stage of their evolution, and therefore have not yet reached the limiting mass suggested by various feedback models for explaining the tight $M_{BH} - \sigma$ relation, or they were in galaxies where there is a different mode of growth than experienced by the broad-line AGN.

Recently, Mathur et al. [25] have presented HST Advanced Camera observations of 10 NLS1s selected as having high L/L_{Edd} ratios. All of these NLS1s lie well below the $M_{BH} - L_{bulge}$ relation, and at least five galaxies lie below the Kormendy relation [19] for galaxy bulges, indicating that they have "pseudobulges" rather than normal bulges [9]. From this Mathur et al. conclude that the black holes in these NLS1s are in their main growth phase, and that the growth is governed by secular processes thought responsible for pseudobulge formation, rather than merger-driven growth as seen in the earlier-type galaxies that make up most of the data in the traditional $M_{BH} - \sigma$ and $M_{BH} - L_{bulge}$ relations, and which, indeed, are the hosts of broad-line AGN. If confirmed (and there was much discussion of this topic at this meeting, see especially the contributions of Mathur and Davies), it suggests the the exciting possibility is that the extreme properties of NLS1s are once again giving us crucial leverage on AGN physics, now pointing to a way to start addressing the very difficult problem of AGN evolution.

8. The View from Milano

Since their recognition as a class of AGN more than a quarter century ago, NLS1s have played an increasingly important role in advancing our understanding of the AGN phenomenon. As seen in recent years, and in the papers presented at this workshop, they have provided rich insights into AGN physics, and are beginning to give us our first real clear window on the modes of AGN evolution.

That a subclass of AGN should excite such interest among astronomers working in a variety of areas and across the electromagnetic spectrum speaks volumes to their importance. They really are more than just Seyfert 1s with narrow lines.

My thanks to the Workshop organizers, particularly the SOC and Luigi Foschini who invited me to give this talk, and to all the participants for a very lively and stimulating three days in Milan. My most sincere gratitude, however, must be to the late Donald Osterbrock, who 25 years ago gave me a first-year project that has led me into this wonderful profession. I have been most fortunate as a student first at Caltech then at UC Santa Cruz of having learned science from many of the leaders in our field, but it was Don who more than anyone else taught me how to be a scientist. For that I am forever grateful.

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