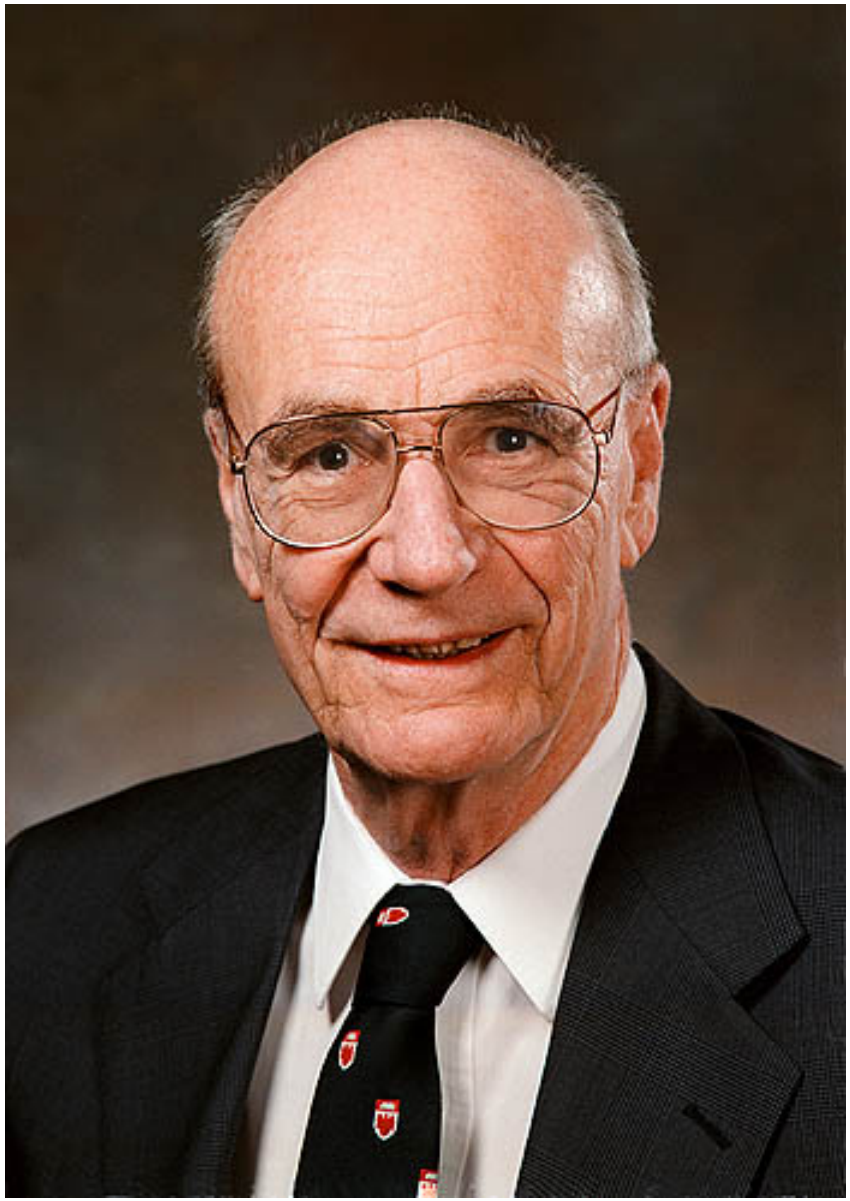
A Quarter Century of Narrow-Line Seyfert 1s

Richard Pogge
Department of Astronomy
The Ohio State University

Narrow-Line Seyfert 1s and Their Place in the Universe
Milano – 4-6 April 2011



Donald Edward Osterbrock
1924 – 2007

Don Osterbrock's Three Questions:

1) What are they? Describe them.

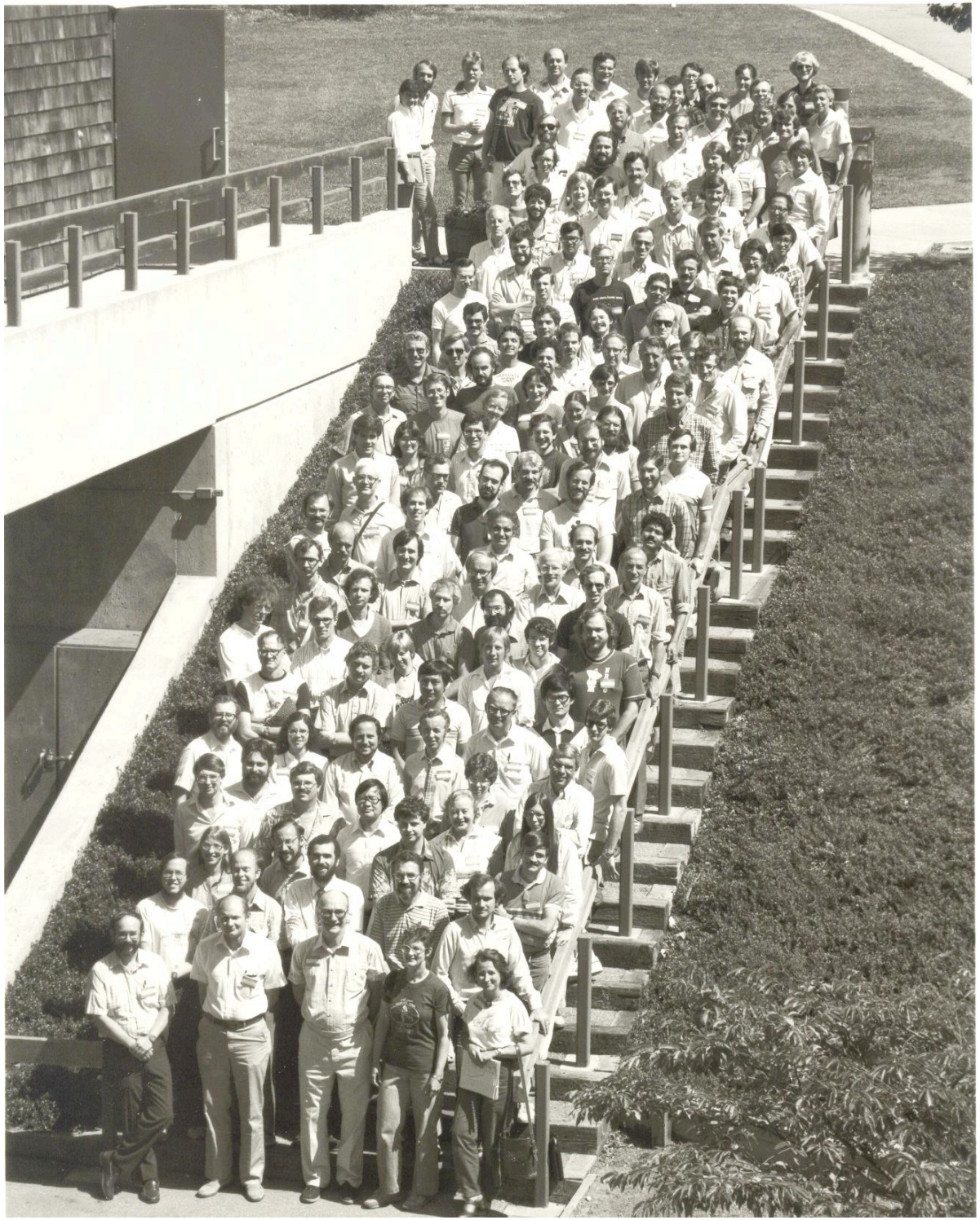
2) How do they work? What is the physics?

3) How do they evolve?

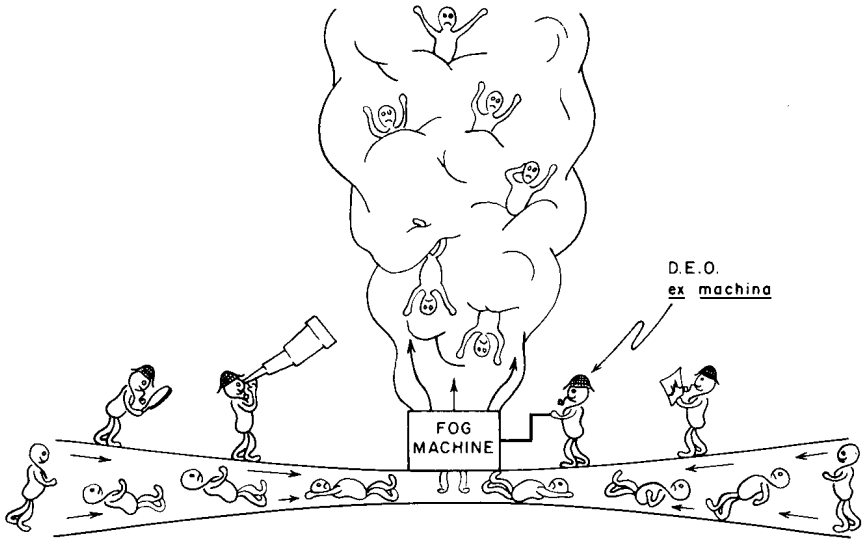
7th Santa Cruz
Astrophysics Workshop
16-27 July 1984

aka “Quasar Camp”

Held in honor of
Don Osterbrock’s
60th Birthday



State of AGN Knowledge in 1984:



Fate of Theorists trying to understand
the Central Engine according
to Mitch Begelman (1984 Workshop)

Host galaxies of QSOs were still "Quasar Fuzz" and little understood beyond Boroson & Oke's result.

No unification model for AGN (spectropolarimetry was in its infancy and the data were still puzzling).

Size of the BLR was unknown to orders of magnitude, and estimates from variability were controversial.

Only 10s of AGN with good X-ray spectra from HEAO-1 and HEAO-2

The masses of AGN central black holes were as conjectural as whether there were black holes at all...

State of Astronomical Practice in 1984:

The first 800x800 CCDs were just being deployed at telescopes.

Computers and their disk drives filled special climate-controlled rooms.

Computer-to-computer data transfer was a graduate student carrying a magnetic tape.

Scientific papers were composed on typewriters, then submitted and refereed using the national post.

Nearly all groups employed professional draftsmen to compose graphs.

"This unusual object merits further observations..."

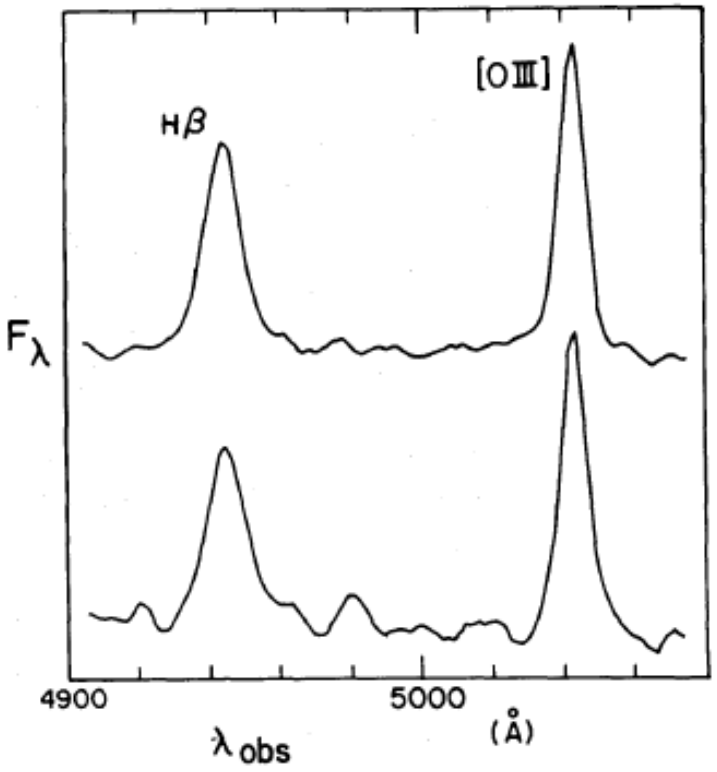
Davidson & Kinman 1978, *ApJ*, **225**, 776.

On the possible importance of Markarian 359

Hβ only 520 km/s, slightly wider than [O III]λ5007, but much narrower than Seyfert 1s

Forbidden-line ratios like Seyfert 1s, especially the high-excitation lines.

[O III]/Hβ and [N II]/Hα intermediate between Seyfert 1s and 2s



THE SPECTRA OF NARROW-LINE SEYFERT 1 GALAXIES[1]

DONALD E. OSTERBROCK AND RICHARD W. POGGE
Lick Observatory, Board of Studies in Astronomy and Astrophysics, University of California, Santa Cruz
Received 1985 January 2; accepted 1985 April 9

ABSTRACT

Measurements are presented of a group of active galactic nuclei with all the properties of Seyfert 1 or 1.5 galaxies, but with unusually narrow H I lines. They include Mrk 42, 359, and 1239 (previously studied by other authors) as well as Mrk 493, 766, 783, and 1126. One other somewhat similar object, Mrk 1388, is also included in the discussion; measurements of its spectrum have been published elsewhere. For these objects, narrow-line widths, relative intensities of the emission lines, etc., are all similar to those in other Seyfert 1 galaxies. Some, in particular Mrk 493 and Mrk 42, have relatively strong Fe II emission; in others, especially Mrk 359, 783, and 1126, it is quite weak.

As a group, these narrow-line Seyfert 1 galaxies have approximately normal luminosities. Their Hβ emission-line equivalent widths are, on the average, somewhat smaller than in typical Seyfert 1's. Overall, these narrow-line Seyfert 1 galaxies show a wide variety of deviations from the properties of typical Seyfert 1 objects. They clearly demonstrate that the Seyfert phenomenon is not a simple one-parameter effect.

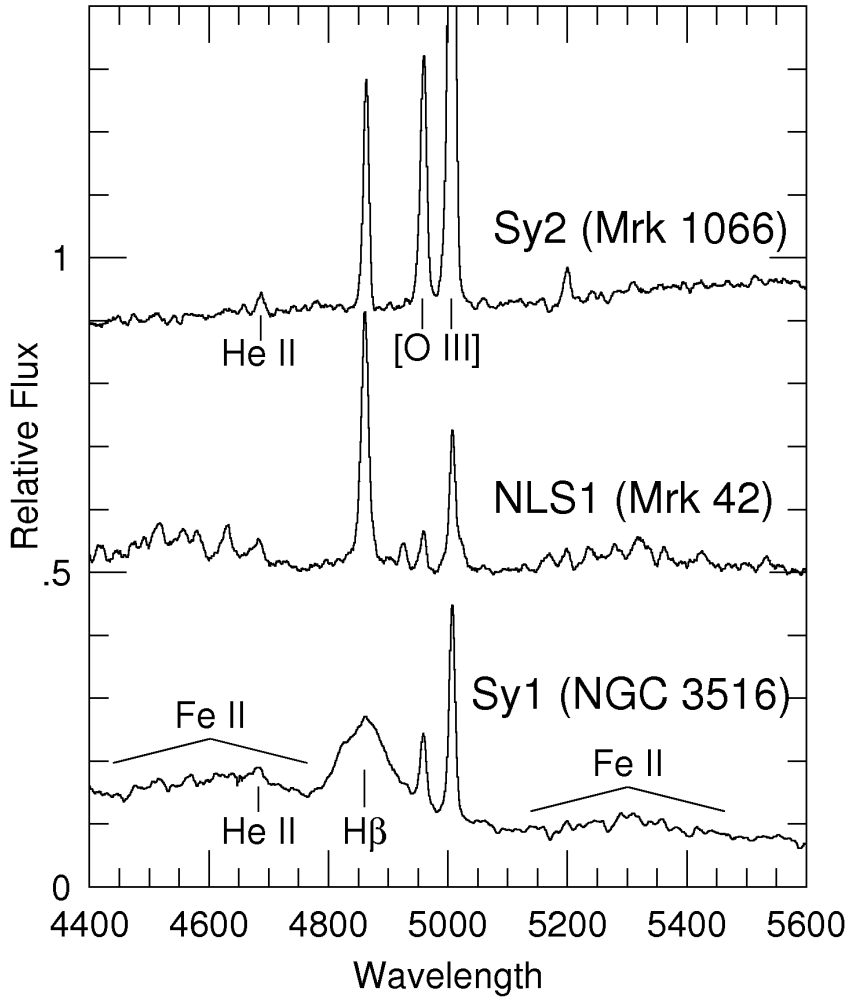
Subject headings: galaxies: nuclei — galaxies: Seyfert

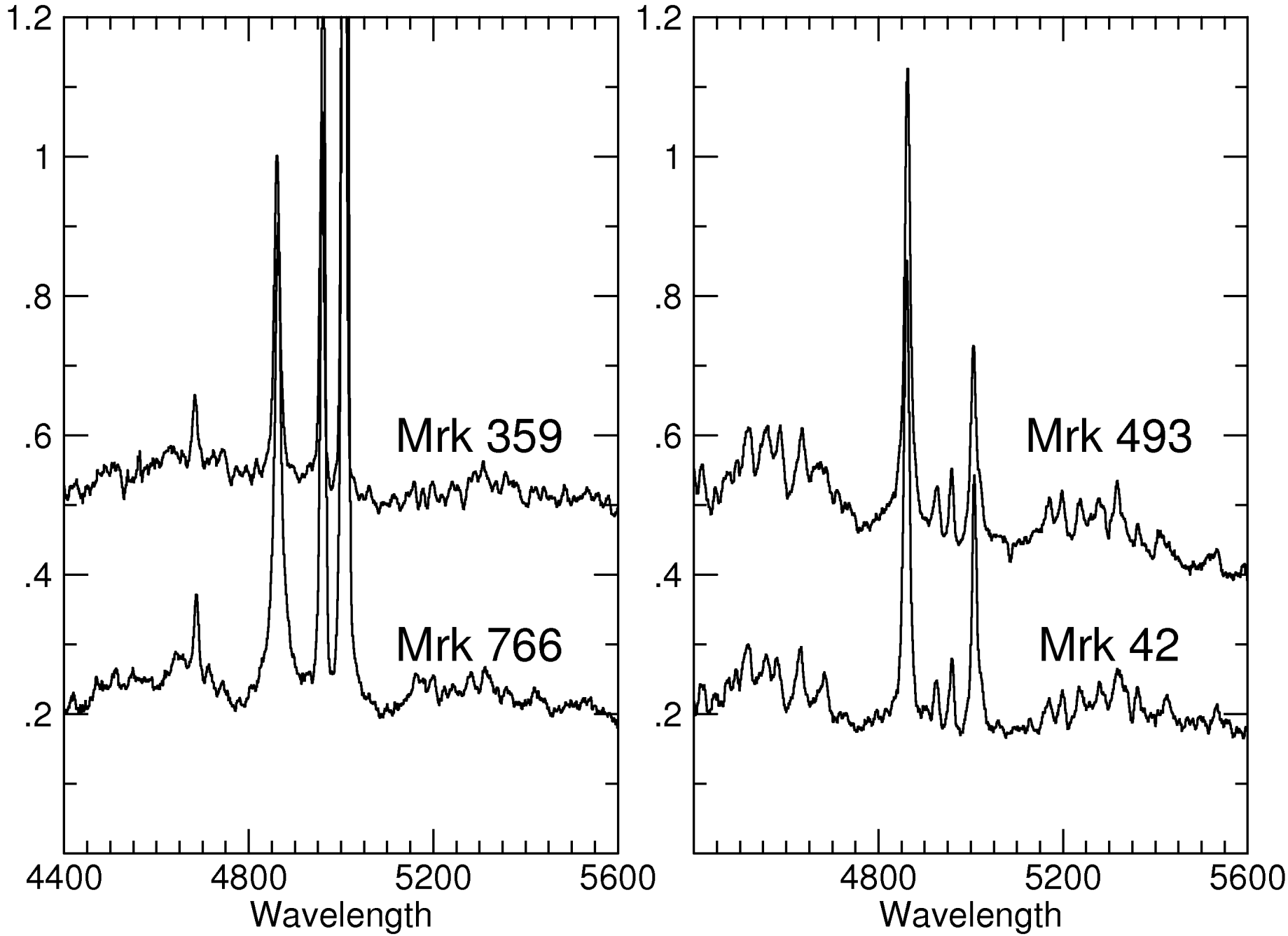
"Overall, these narrow-line Seyfert 1 galaxies show a wide variety of deviations from the properties of typical Seyfert 1 objects."
Osterbrock & Pogge (1985)

Narrow permitted lines only slightly broader than the forbidden lines.

[O III]/Hβ < 3, but exceptions if strong [Fe VII] & [Fe X] lines, unlike Seyfert 2s.

Goodrich 1989 added the explicit FWHM(Hβ) < 2000 km/s criterion




1.2
1
.8
.6
.4
.2
Mrk 359
Mrk 766
4400
4800
5200
5600
Wavelength
1.2
1
.8
.6
.4
.2
Mrk 493
Mrk 42
4800
5200
5600
Wavelength

The Strange Case of I Zwicky 1

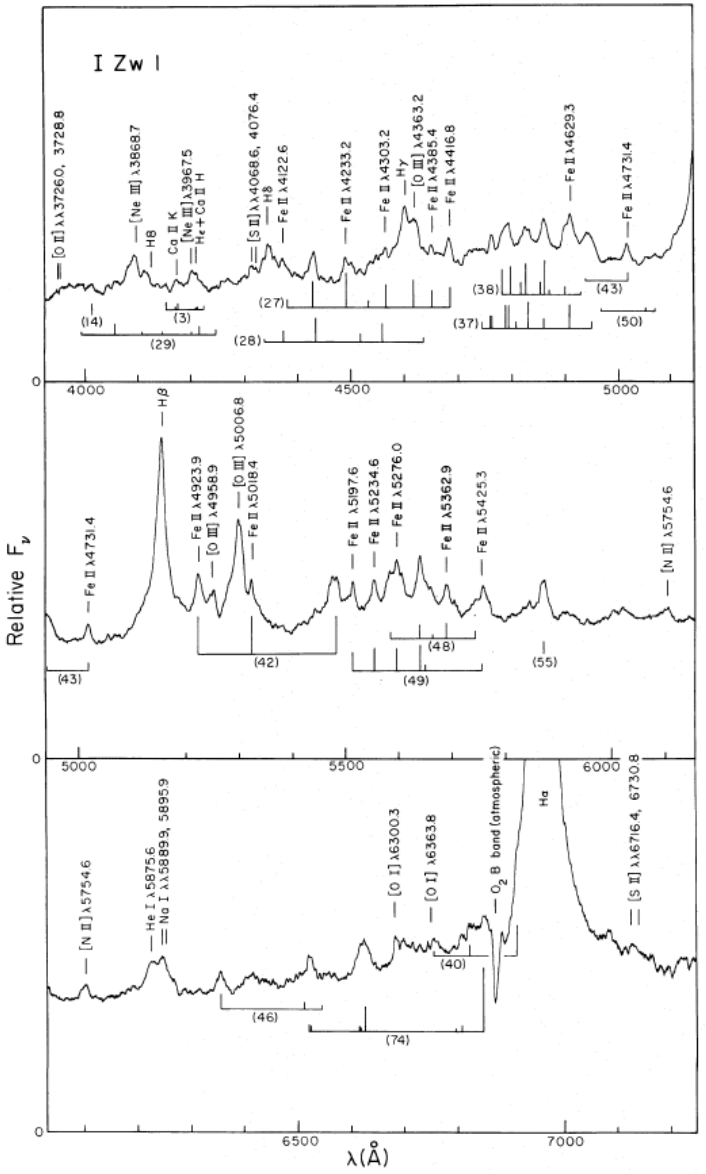
I Zw 1 lies at the boundary between Seyfert 1s and QSOs.

Sargent 1968: Noted strong Fe II.

Phillips 1976 & 1977: Strong FeII

Lauer & Oke 1979:

"The galaxy I Zw 1 is not a typical type 1 Seyfert since the permitted & forbidden lines are of comparable breadth."



The Strange Case of I Zwicky 1

Halpern & Oke 1987, ApJ, 312, 91:

- Drawn to Mrk 507 & 5C3.100 by their large X-ray luminosities compared to other Sy2s.
- Their spectra are like I Zw 1, and are at the high-luminosity end of Seyfert 1s.
- Noted at the end of their paper that *"X-ray selection is apparently an efficient means of finding I Zw 1 objects."*

The first explicit hint about the possible importance of X-rays for NLS1s.

"X-ray selection may be an efficient way to find narrow-line Seyfert 1 galaxies."
Stephens 1989, AJ, 97, 10

Stephens (1989):

- 10 NLS1s out of 65 X-ray selected AGNs

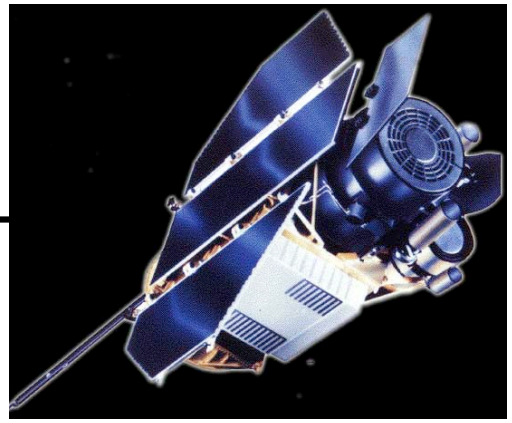
Puchnarewicz et al. (1992 & 1995):

- 50% of Soft X-ray selected AGNs are NLS1s

In hindsight, NLS1s in other X-ray samples:

- Remillard et al. 1986, ApJ, 301, 742 (HEAO-1)
- Gioia et al. 1984, ApJ, 283, 495 (Einstein MSS)

The ROSAT Renaissance



Grupe et al. 1993:

Geneva IAU Symposium Poster

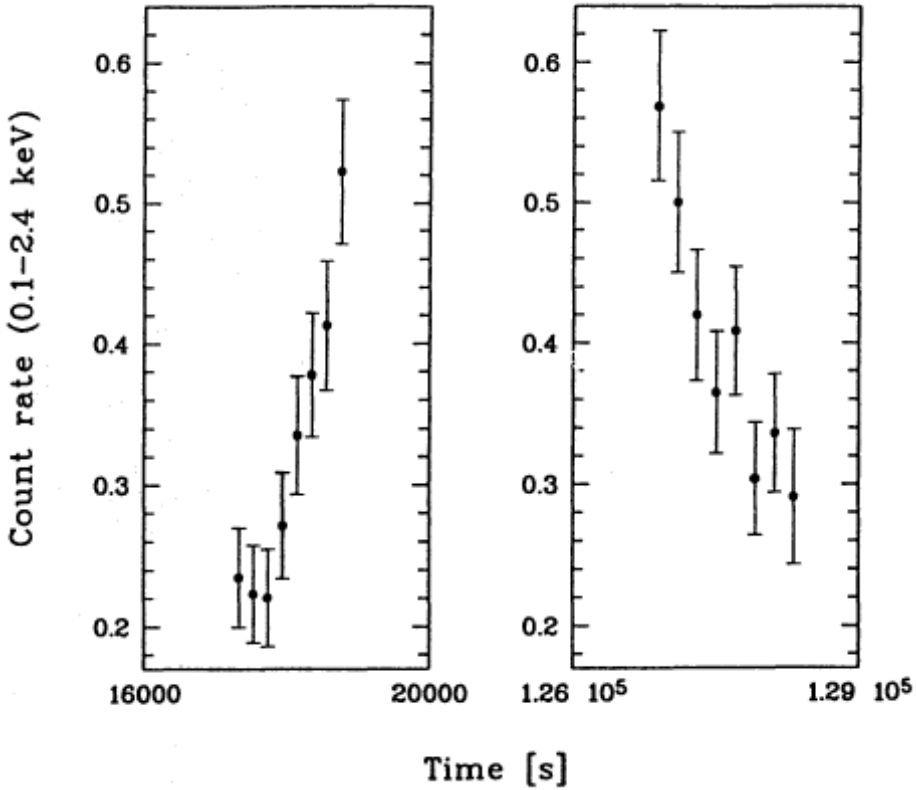
40 new Seyferts in the ROSAT All-Sky Survey

~50% were NLS1s

Boller et al. 1993:

Rapid X-ray variability of NLS1 IRAS13224–3809

0.1-2.4 keV brightness increased a factor of 4 with a doubling time of 800 seconds!



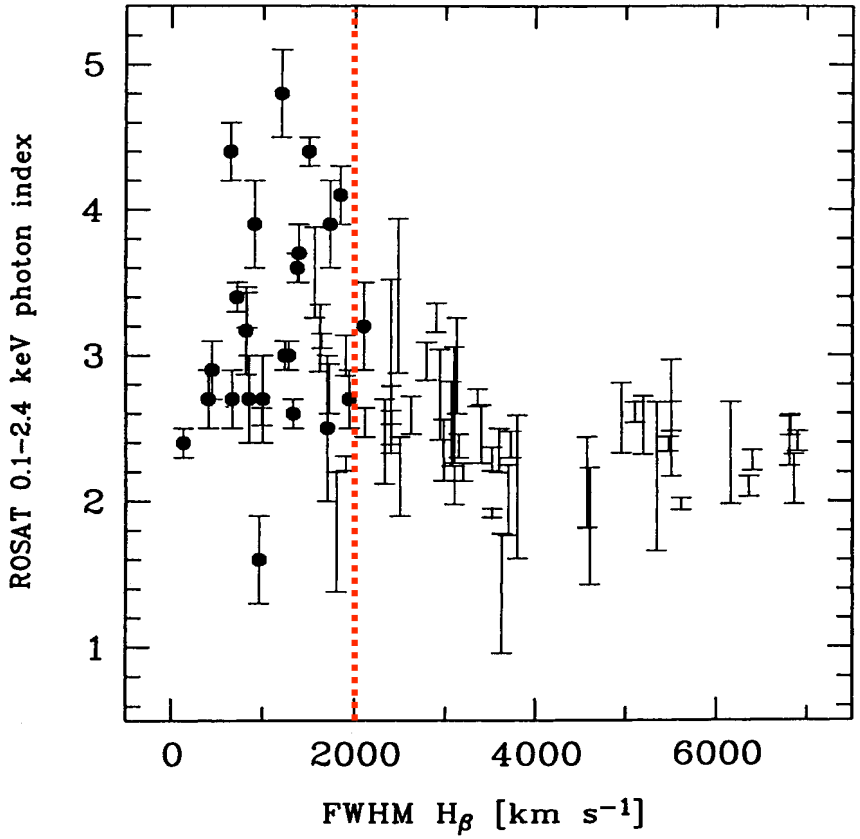
Extreme Soft X-ray AGNs

Boller, Brandt, & Fink 1996, A&A, 305, 53

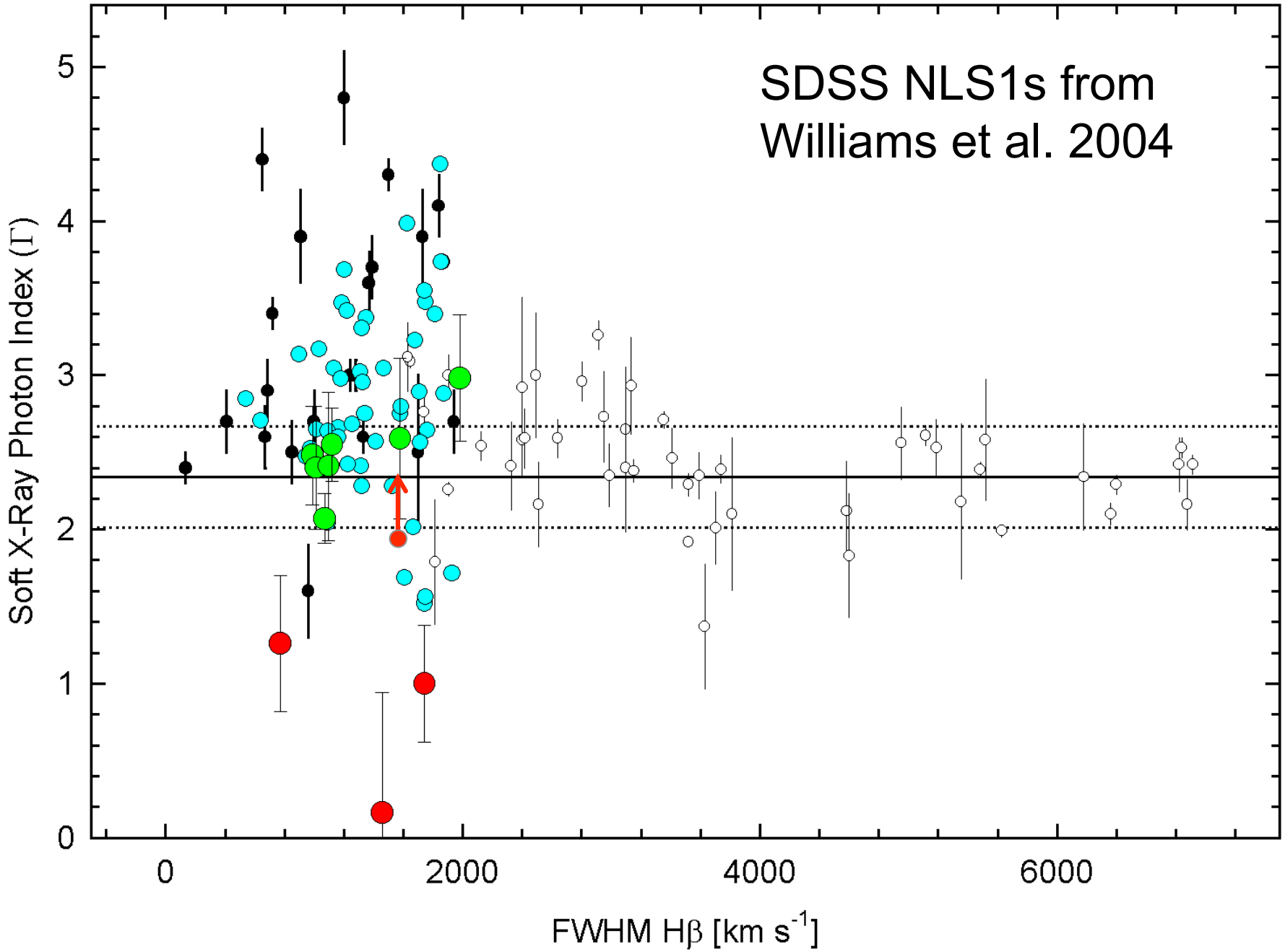
NLS1s are strong soft X-ray excess sources

Show extreme & rapid X-ray variability

Have steep 2-10 keV power-law continua



NLS1s are extreme yet relatively common objects.


SDSS NLS1s from
Williams et al. 2004
Soft X-Ray Photon Index (Γ)
FWHM Hβ [km s^{-1}]
0
1
2
3
4
5
0
2000
4000
6000

"They clearly demonstrate that the Seyfert phenomenon is not a simple one-parameter effect."
Osterbrock & Pogge (1985)

So what *are* the parameters?

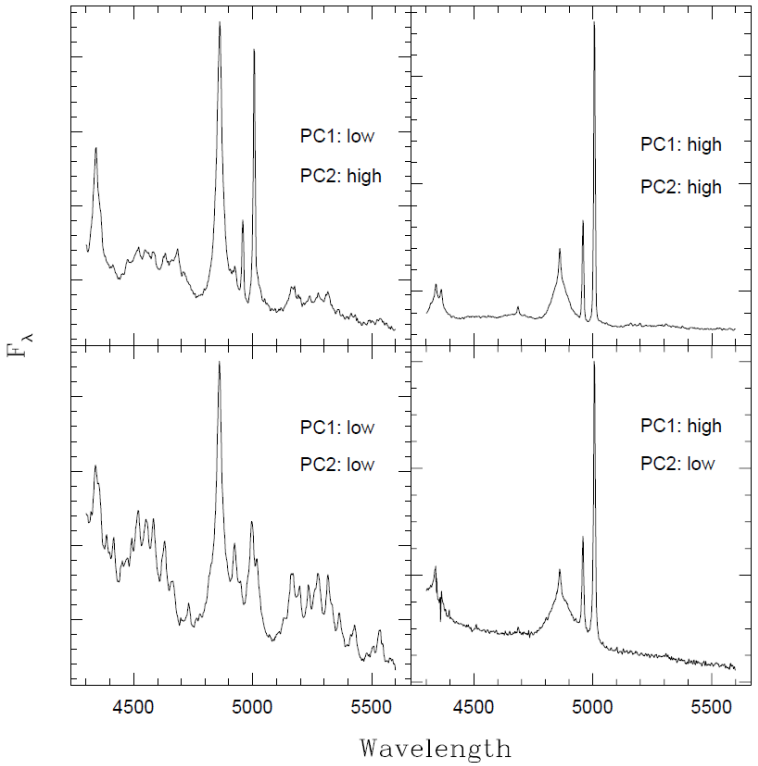
- Black hole mass?
- Accretion Efficiency?
- Mass Accretion Rate?
- Orientation or obscuration?
- Fundamental differences of structure?
- Something else we haven't thought of yet?

Lies, Damned Lies & Principal Components Analysis

Boroson & Green (1992): Eigenvector 1

The primary variance is due to an anticorrelation between FeII and [O III]λ5007

Additional variance from the correlation between FWHM(Hβ) and the peak flux of [O III]



NLSy1s lie at one extreme end of this relation.

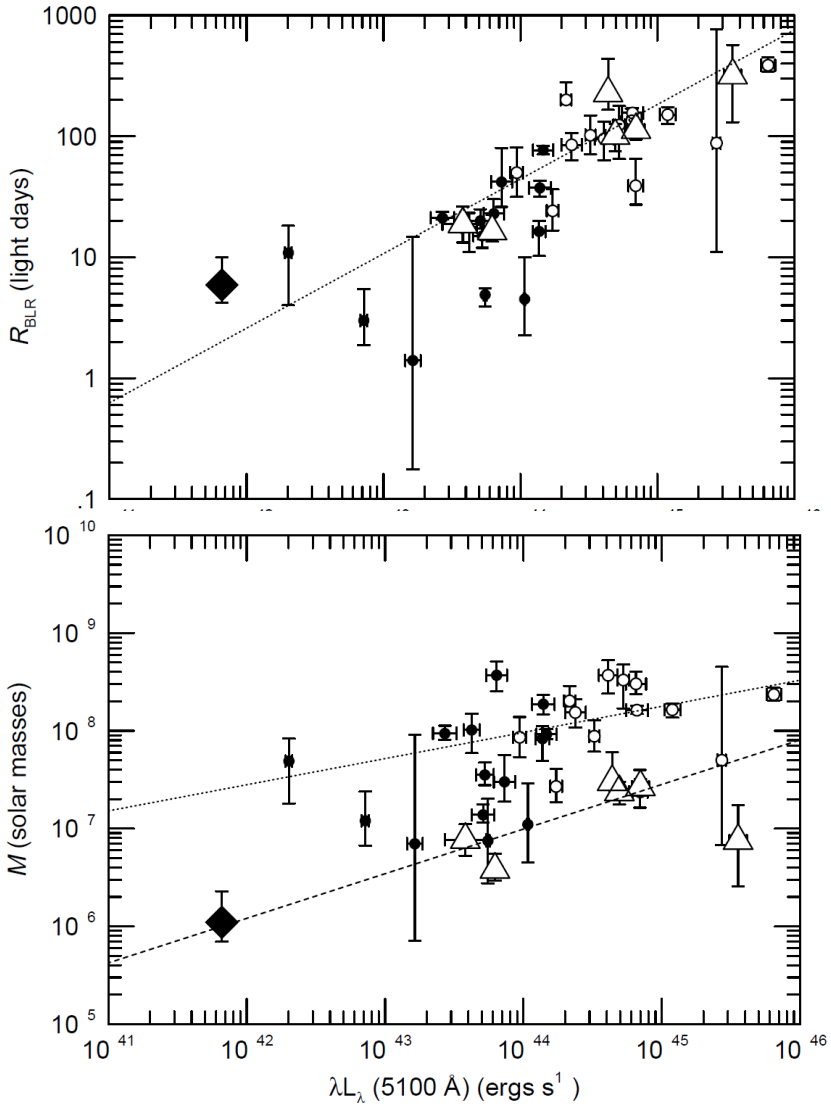
"it might be that NLS1s are best described as low-mass, high-accretion rate systems"
Peterson et al. 2000

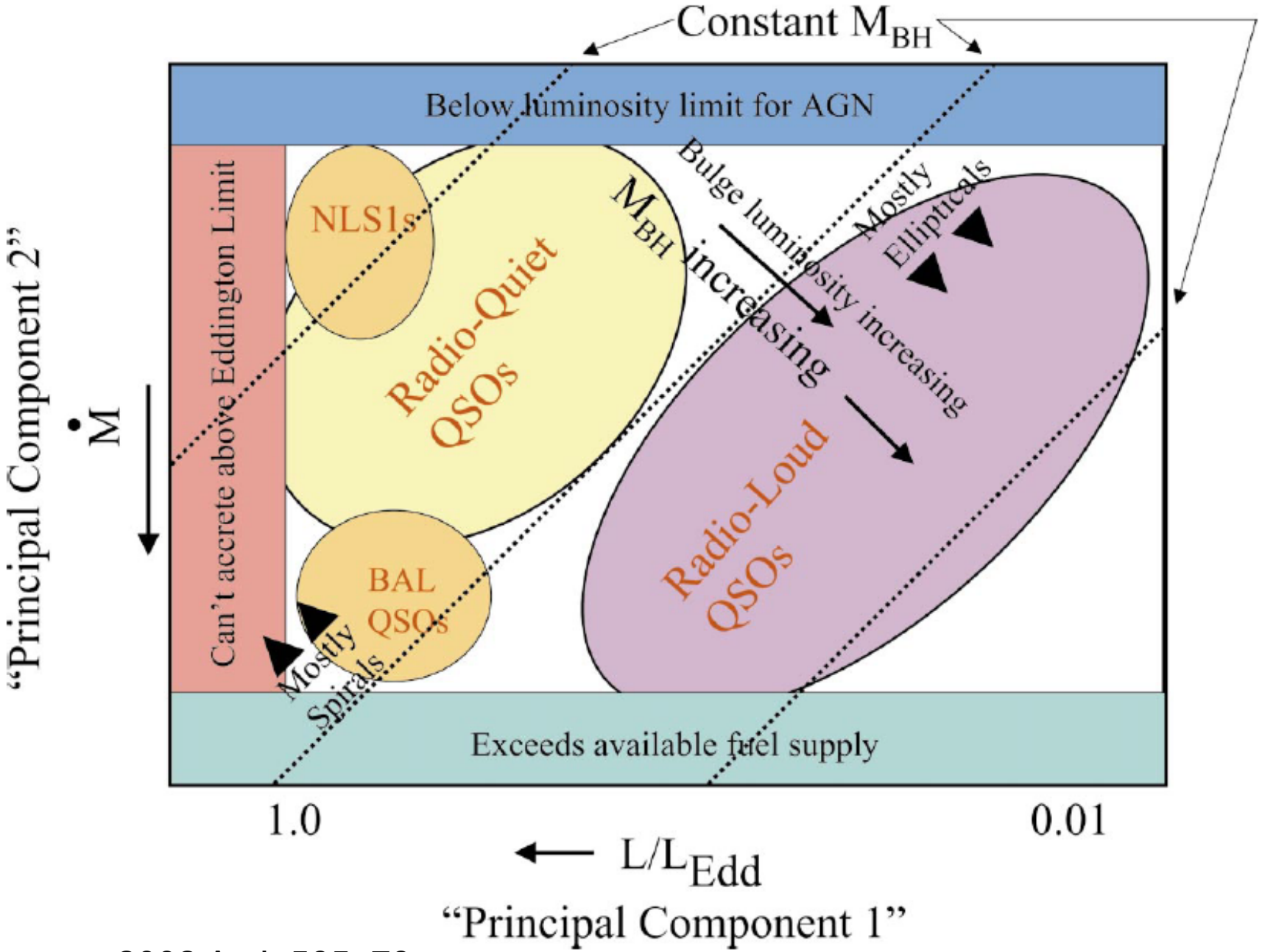
32 reverberation mapped AGN with good M_{BH} estimates.

7 NLS1s including NGC4051
All obey the same R-L relation as Broad-Line AGN.

All lie ~1 dex below the M/L relation for broad-line AGN.

Low Mass for given L, implies greater accretion rate (L/L_{edd})





Boroson, 2002 ApJ, 565, 78

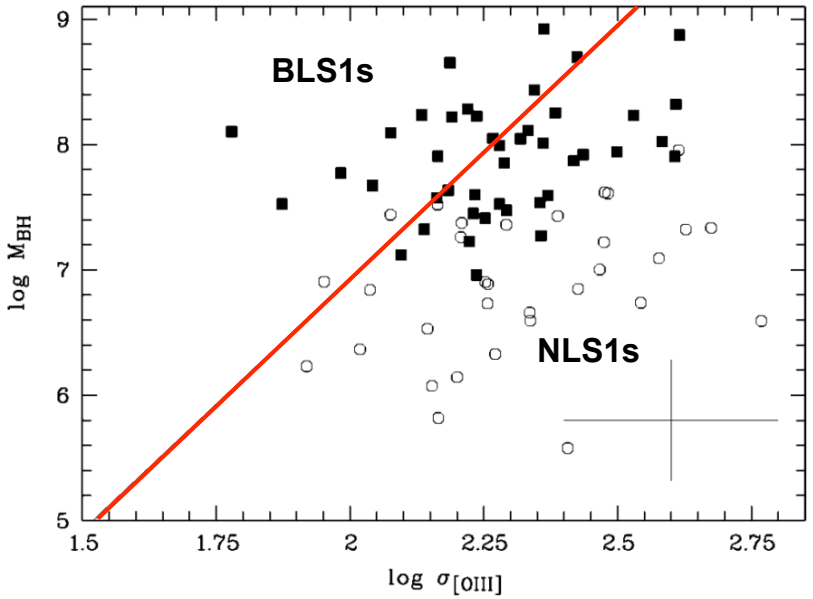
NLS1s and AGN/Black Hole Evolution

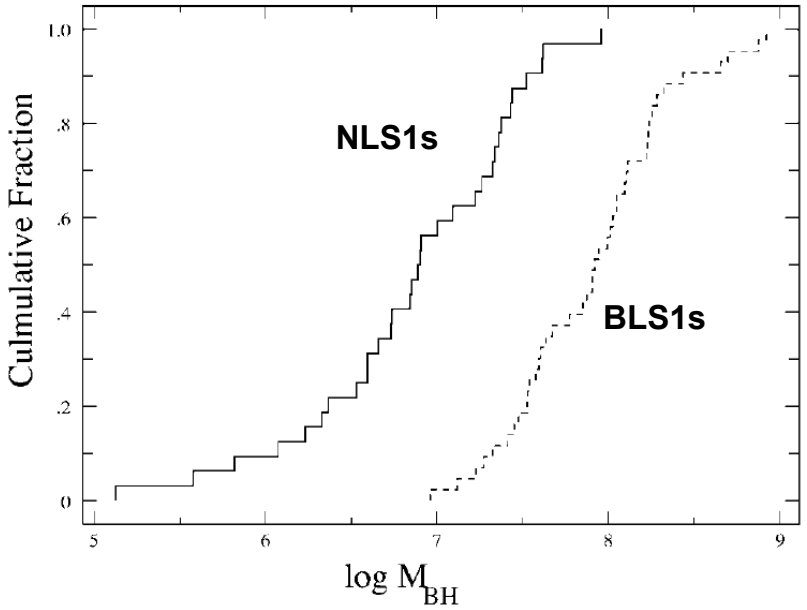
Mathur et al. (2001) noted that NLS1s with good M_{BH} estimates lie off the M_{BH}-σ Relation.

Confirmed by Wandel (2002) and Grupe & Mathur (2004) with larger samples.

Steps Toward AGN Evolution:

- Young(er) black holes?
- Different modes of growth?





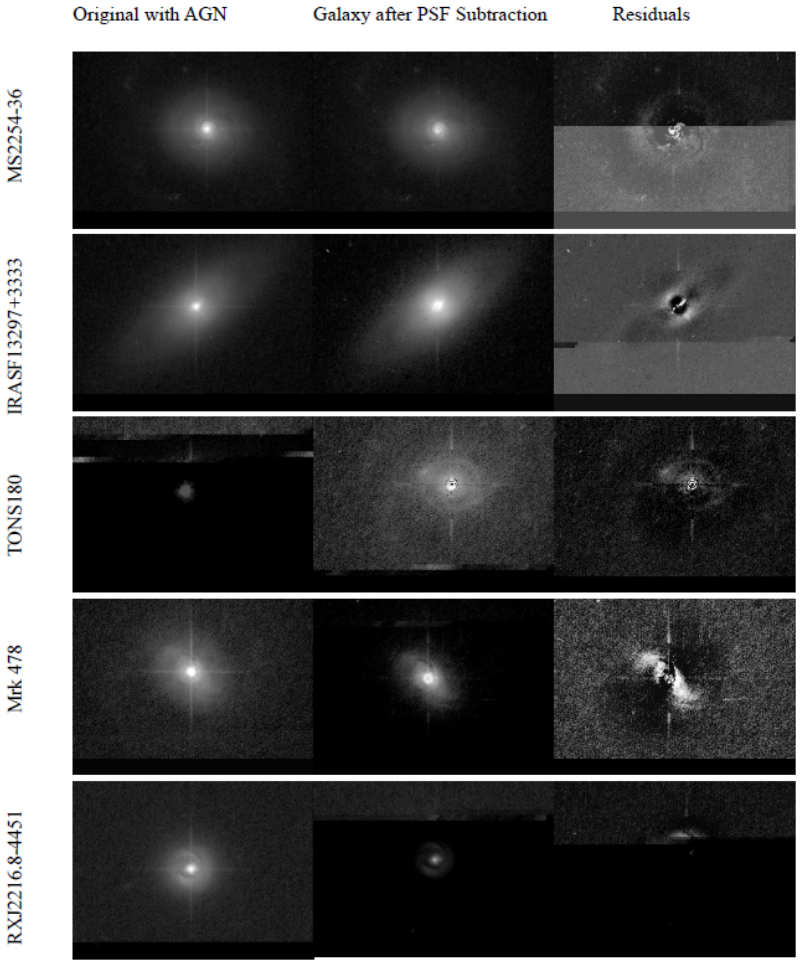
"Little can be said about the morphological characteristics of these galaxies, since even the nearest have redshifts z ≥ 0.01."

Osterbrock & Pogge 1985

Mathur, Fields, Peterson, & Grupe 2011 (astro-ph 1102.0537)

HST/ACS observations of 10 NLS1 with high estimated Eddington ratios.

All appear to be in galaxies with pseudobulges lying below the Kormendy & Maggorian relations.



The View from Milano (2011)

Far from being a curious subclass of AGN, NLS1s have played an important role in our growing understanding of the AGN phenomenon.

Providing rich insights into AGN physics.

Offering increasing hints as to the nature of AGN/Galaxy co-evolution.