New insights into optically *elusive* AGN

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Outline

* Introduction
* Narrow emission-line galaxy sample
  * Selection
  * Classification
* X-ray & optical properties
* Why X-ray Sy2 are optically misclassified as SF

Introduction

XMM-Newton and SDSS

* 3XMM catalogue:
  * ~ 370,000 unique X-ray sources
  * Sky coverage: 2%
  * Flux limit: 10^{-15} erg.cm^{-2}.s^{-1}

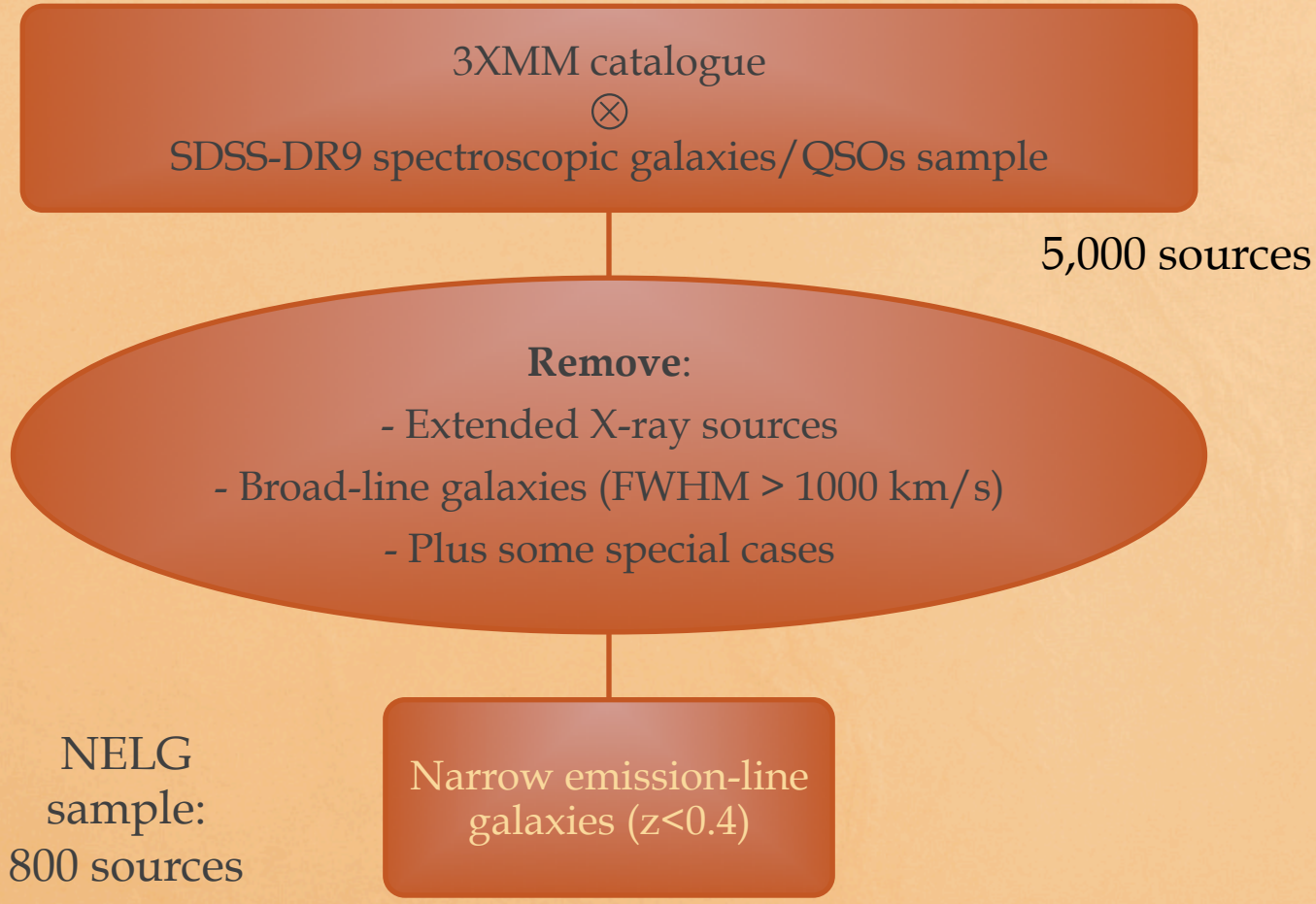
* SDSS-DR9 spectroscopic sample:
  * 1,457,002 galaxies: $14.5 \lesssim r \lesssim 17.7$
  * 228,468 quasars
  * GALSPEC products from the MPA-JHU group

GALSPEC (Kauffmann et al. 2003): improved spectral products
- line fluxes corrected for Galactic reddening
- stellar absorption lines subtracted
- additional galaxy parameters derived

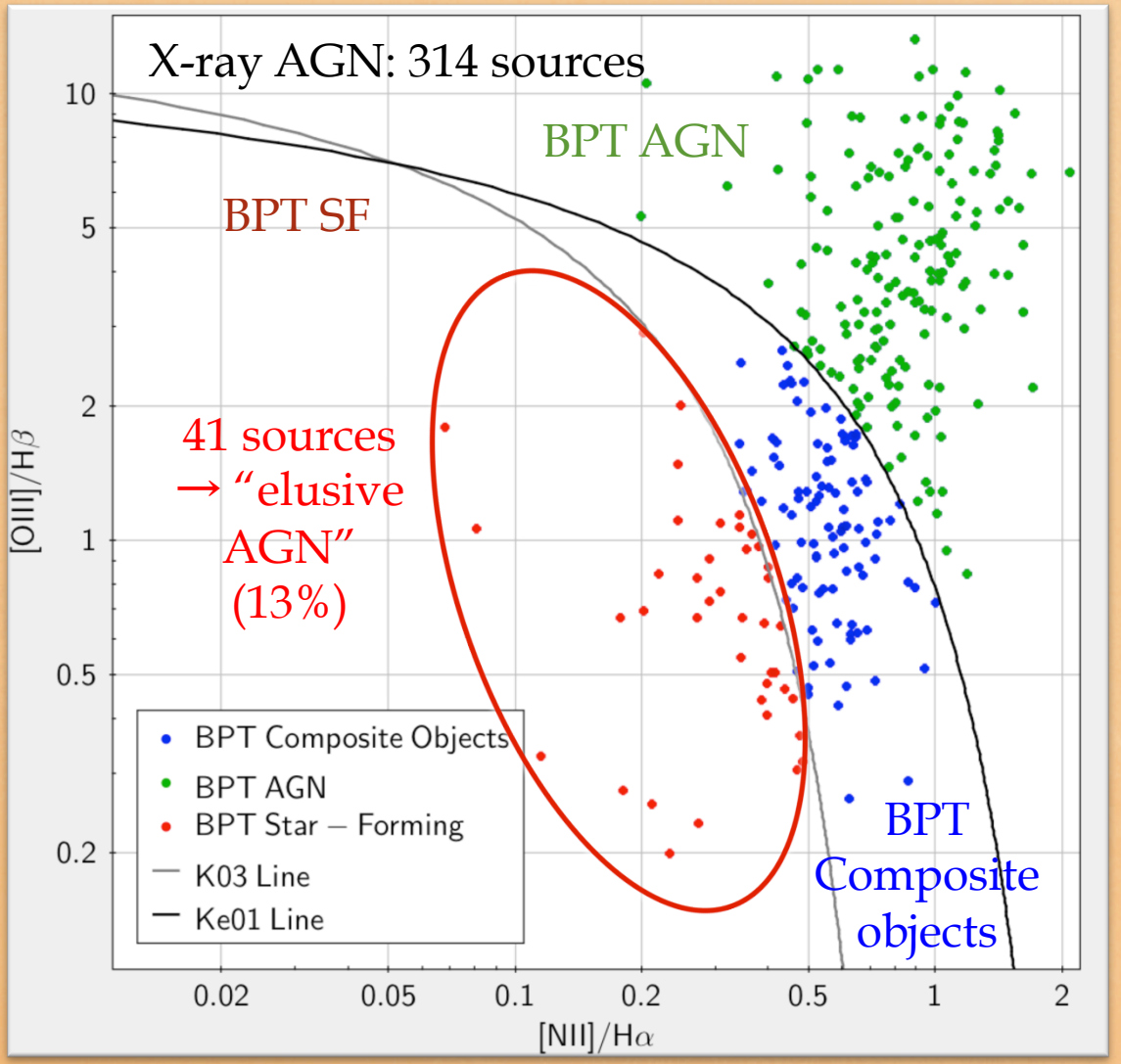
* 45% 3XMM sources lie in SDSS survey region

NELG sample

Source selection

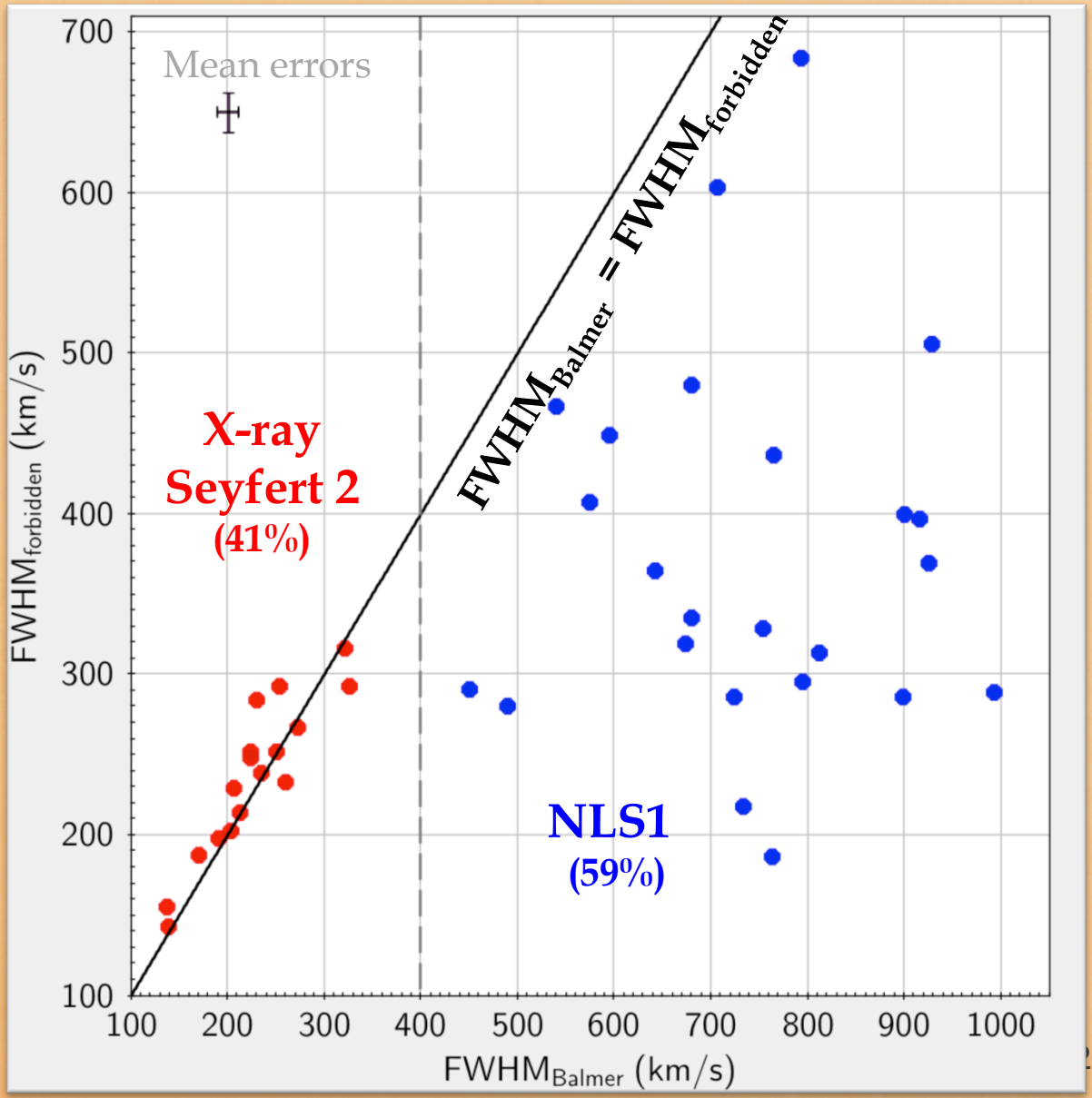


NELG: X-ray vs. optical classification



* Optical: BPT diagnostic diagram (Baldwin, Philips & Terlevich 1981)
  * Based on *narrow* emission line ratios
  * Separates SF galaxies and type 2 AGN by their excitation mechanism
* X-ray: $L_{HX} > 10^{42}$ erg.s^{-1}
  * Remove sources with X-ray powered by SF

X-ray & optical properties



Emission-line width

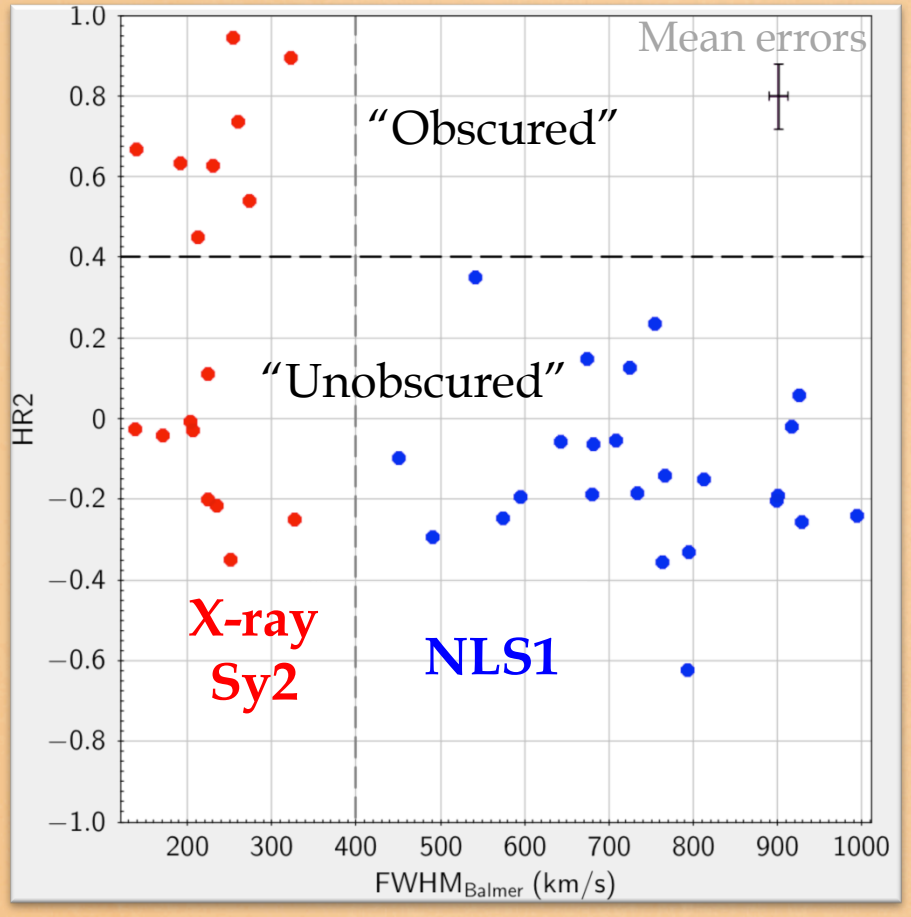
- NLS1
  - "Broad" lines can extend down up to ~ 500 km/s
  - BPT-SF region (Castello-Mor et al. 2012)
  - Permitted lines larger than forbidden lines ($v^2 = M \cdot G/R$)

Obscuration

* Hardness Ratio (HR): X-ray spectral shape & absorption indicator
  * Low HR (HR2 < 0.4) → unabsorbed X-ray spectra

→ **NLS1**: all have a low HR

→ **X-ray Sy2**: obscured and unobscured HR

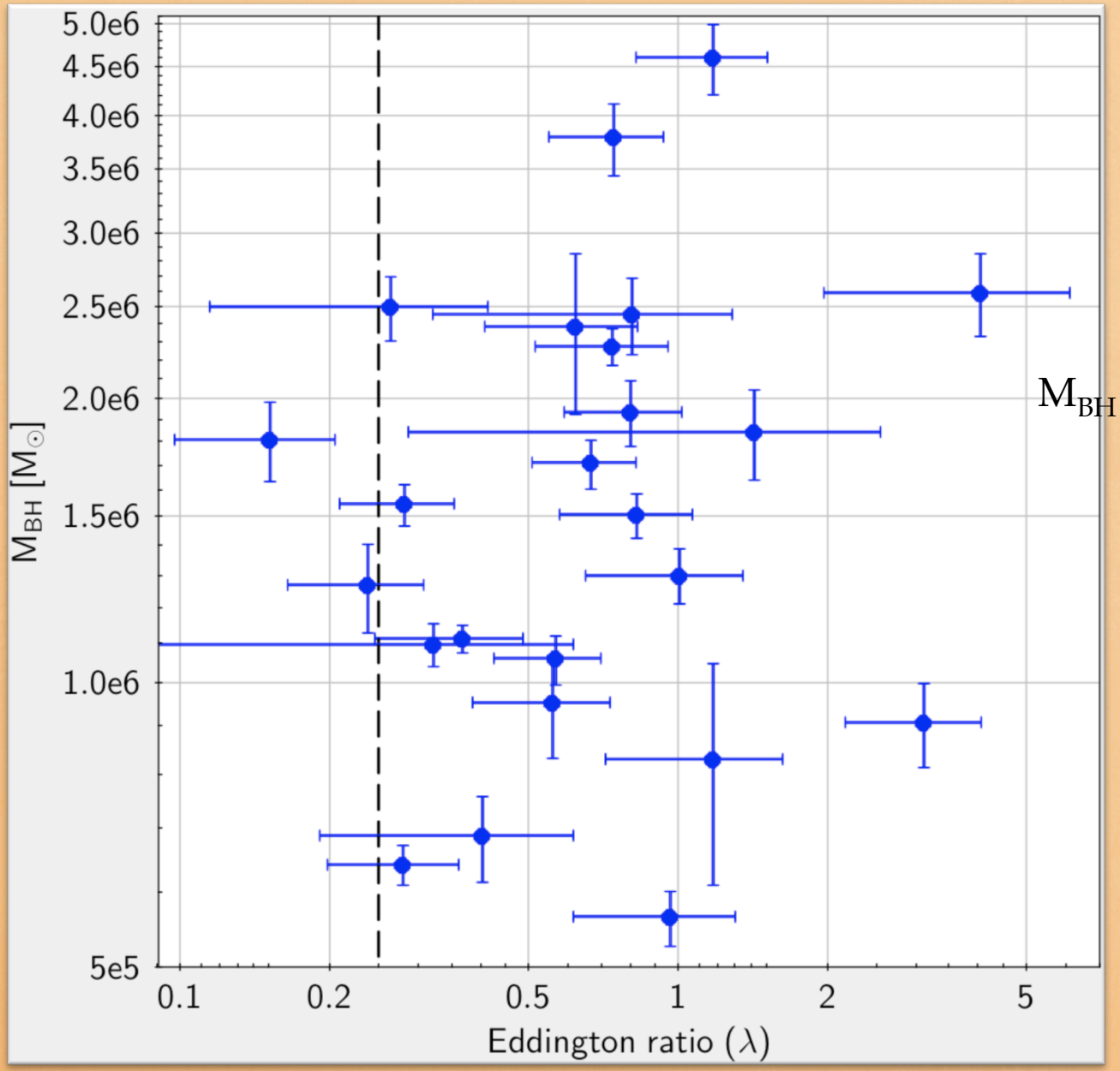


* X-ray spectral analysis
  * Fitting: absorbed PL + additional components (soft excess, Fe K line)
  * Low number of counts → large errors

→ **NLS1**: unobscured + steeper photon index

→ **X-ray Sy2**: high HR2 → signs of absorption

NLS1: BH mass & Eddington ratio



* **<u>BH mass</u>**: virial equilibrium

→ scaling relation (Xiao et al. 2011)

$M_{BH} \propto (L_{5100Å})^{0.5}.FWHM_{H\alpha}{}^{2.06}$

→ NLS1: expected low mass BH

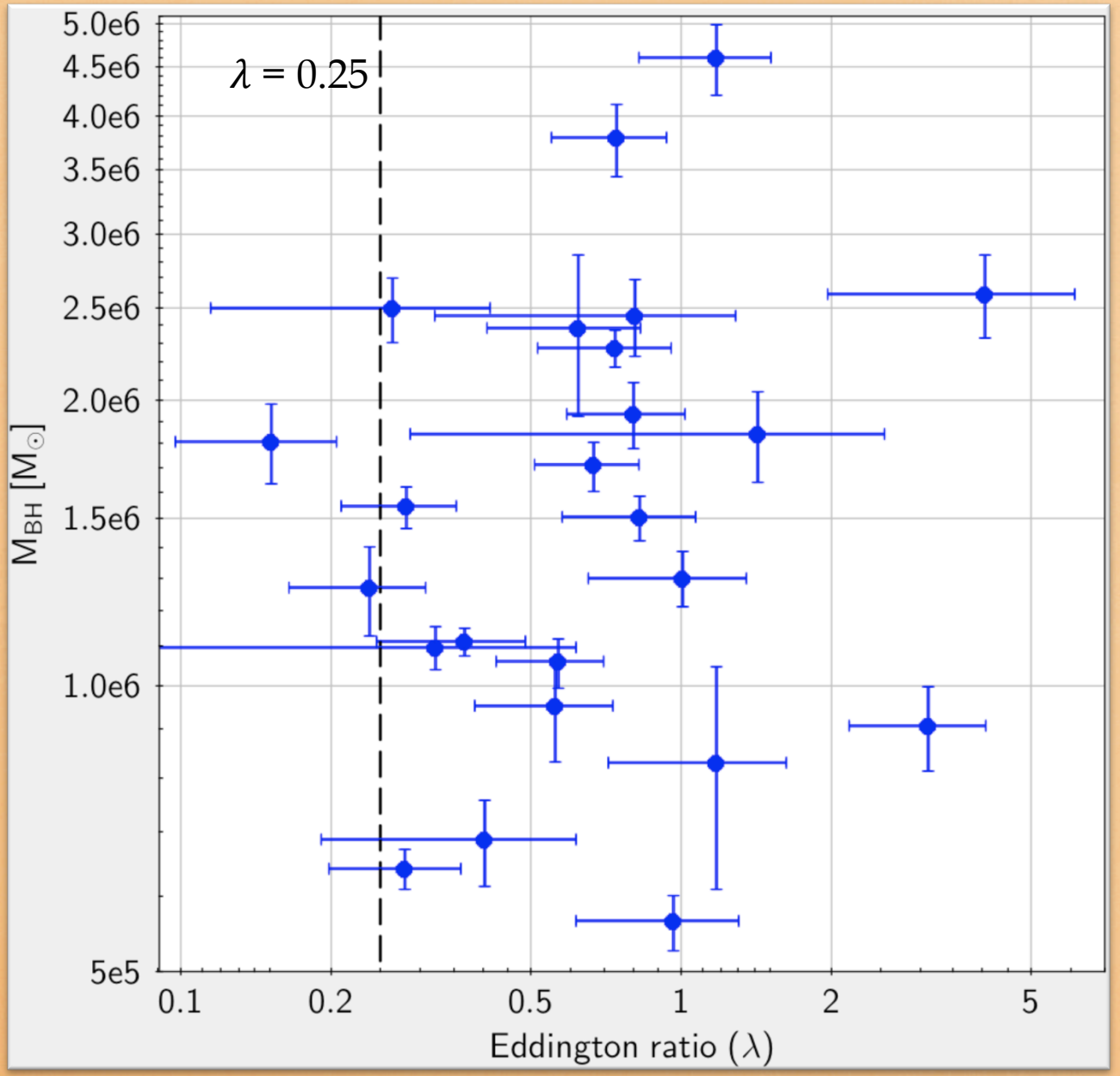
Typical AGN:

$M_{BH} \sim 10^7 - 10^8\ M_\odot$

→ Observed:

$M_{BH} < 5{\cdot}10^6\ M_\odot$

NLS1: BH mass & Eddington ratio



* **Eddington ratio** λ**:**

$\lambda = L_{bol} / L_{Edd}$

$\rightarrow \lambda \propto L_{HX} / M_{BH}$

* NLS1: expected high λ

→ Netzer et al. 2007: $\lambda > 0.25$

→ Observed:

$\lambda \gtrsim 0.25$

Why X-ray Sy2 are optically classified as SF?

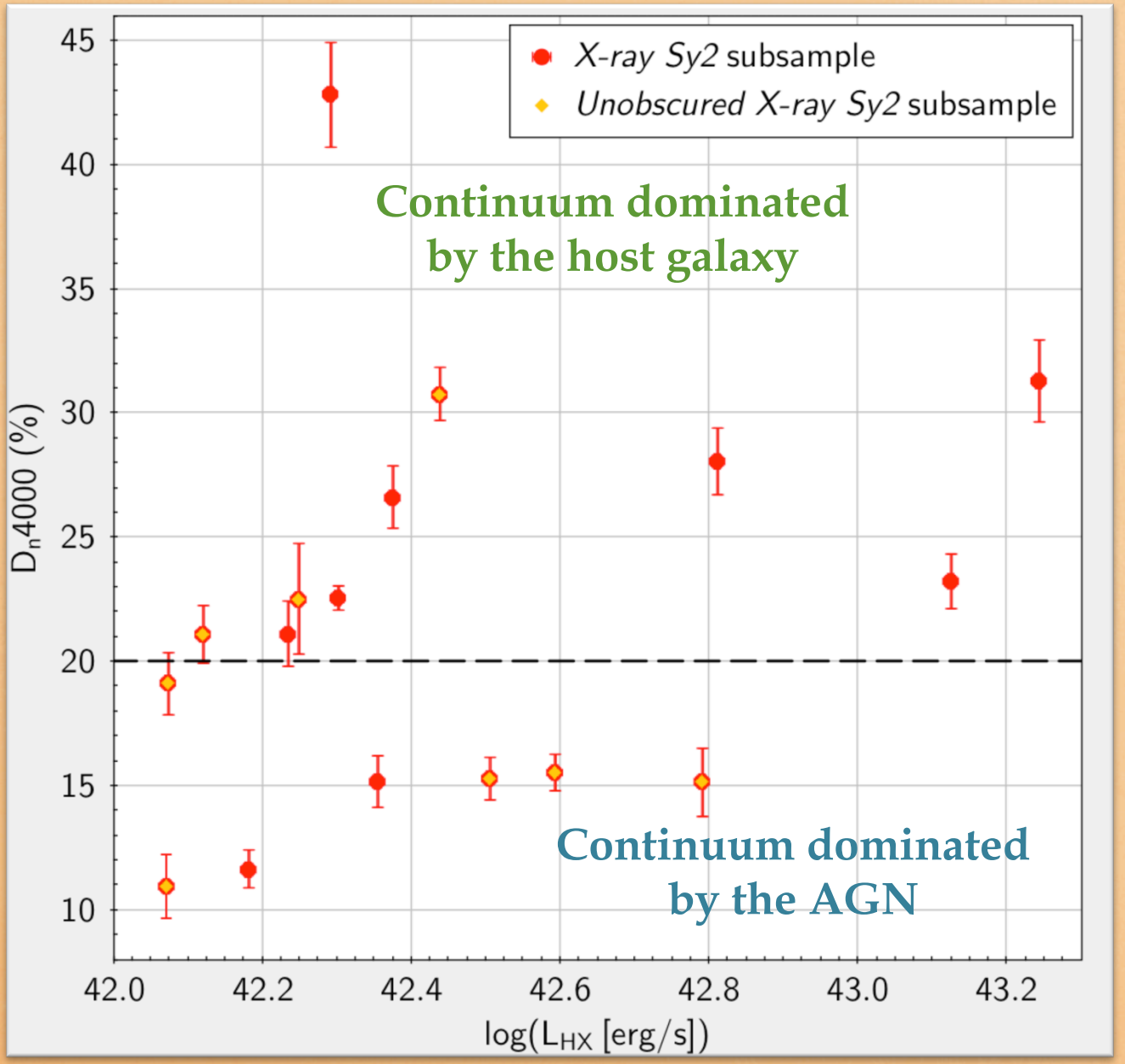
1. Obscuration hypothesis

* Compton-thick (CT) absorbers
  * Spherical gas clouds surrounding the nuclei (Comastri et al. 2002, Civano et al. 2007) → ionizing photons could not create the NLR
  * Host galaxy gas and dust along the line of sight hiding the NLR (Rigby et al. 2006)

➡ Mid-IR luminosity (Goulding et al. 2011) → no CT obscuration

+ Unobscured X-ray Sy2: truly unabsorbed

2. Optical dilution hypothesis

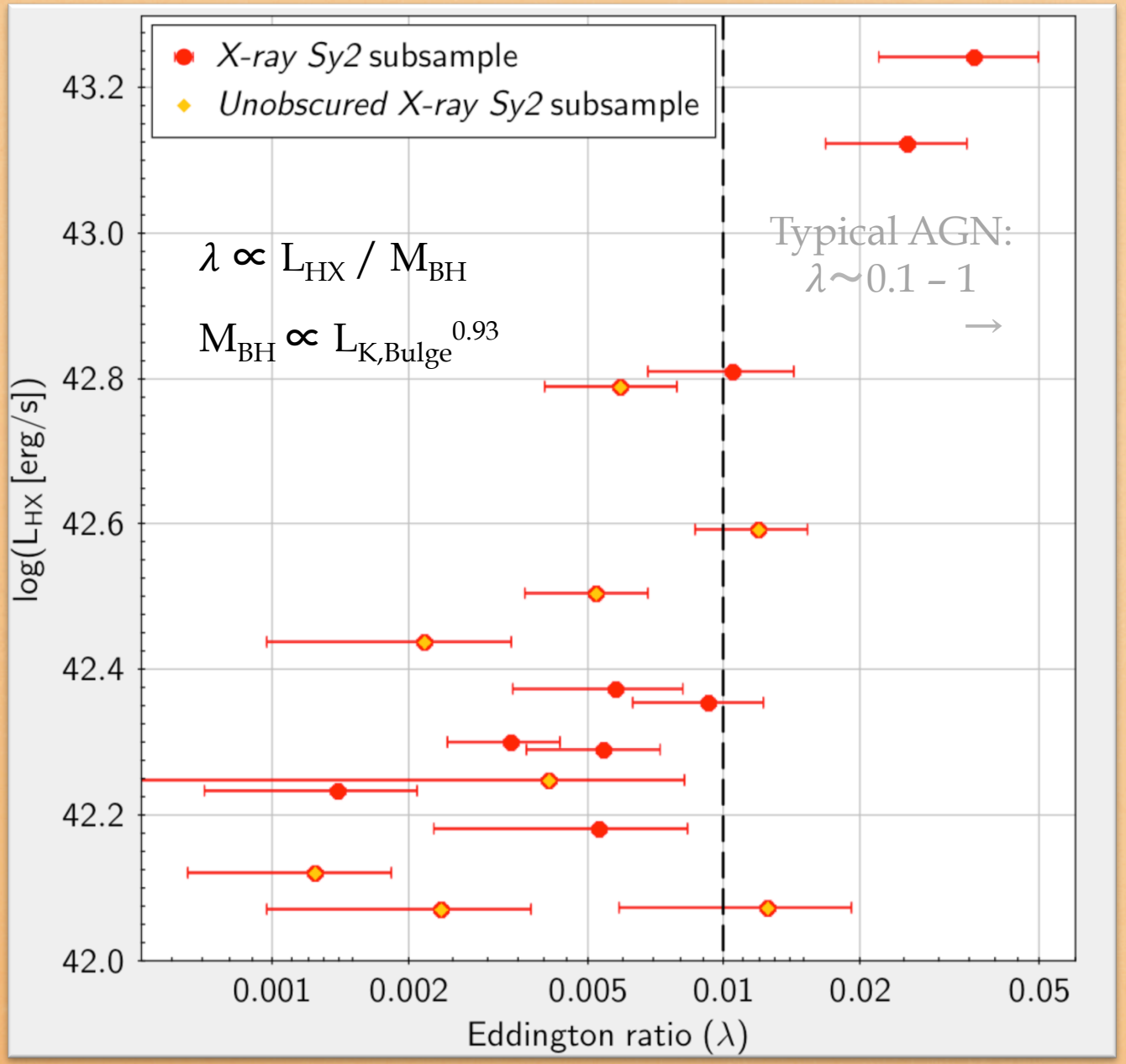


* AGN intrinsic weakness in respect to the host galaxy
  * 4000Å break: D_n4000

➡ 60% are dominated by galaxy starlight

+ possible SF contribution

3. Low accretion rates hypothesis



* Intrinsically weak optical emission compared to other AGN
  * Low λ

➡ X-ray Sy2: $\lambda < 0.05$

* Unobscured X-ray Sy2: $\lambda \lesssim 0.01$

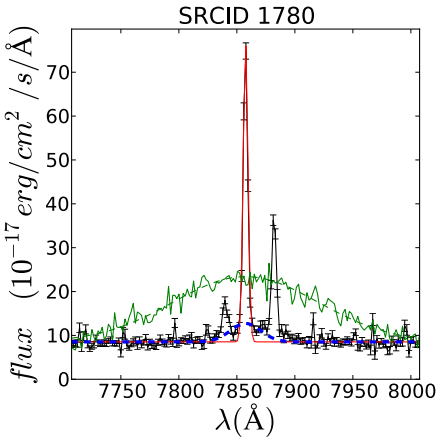
➡ True Sy2

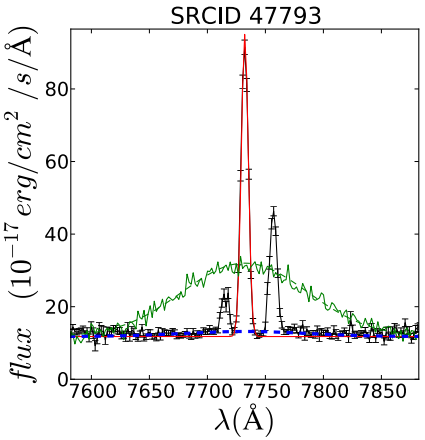
True Sy2

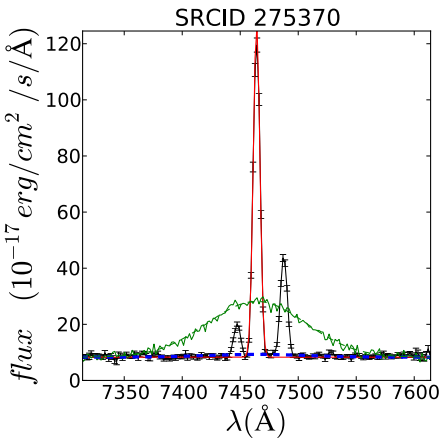
$$M_{BH} \propto L_{5100Å}^{0.52} \cdot FWHM_{B.H\,\alpha}^{2.06}$$
$$L_{B.H\,\alpha} \propto L_{5100Å}^{1.16}$$

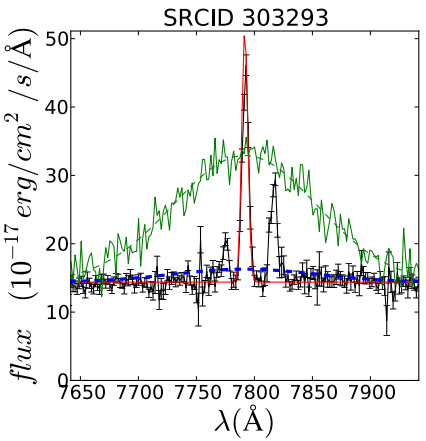
* True Sy2: No optical BL + no intrinsic absorption
  * No BLR: Trump et al. 2011 → BLR disappear for $\lambda < 10^{-2}$

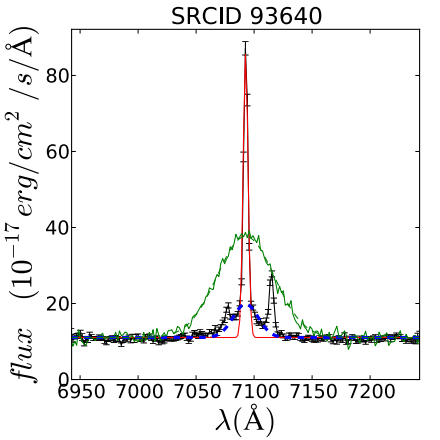
NL fitted BL predicted BL measured/upper limit

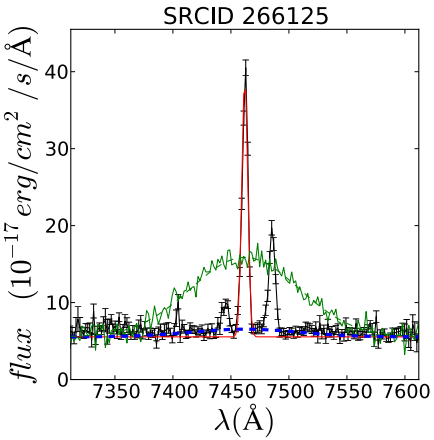


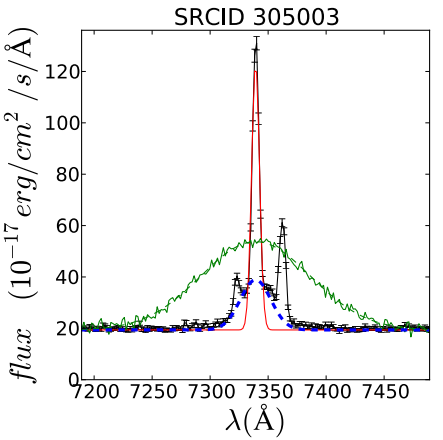


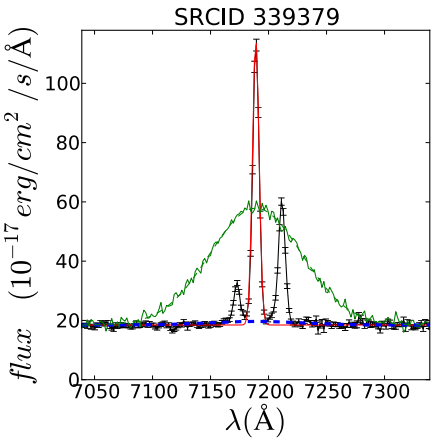


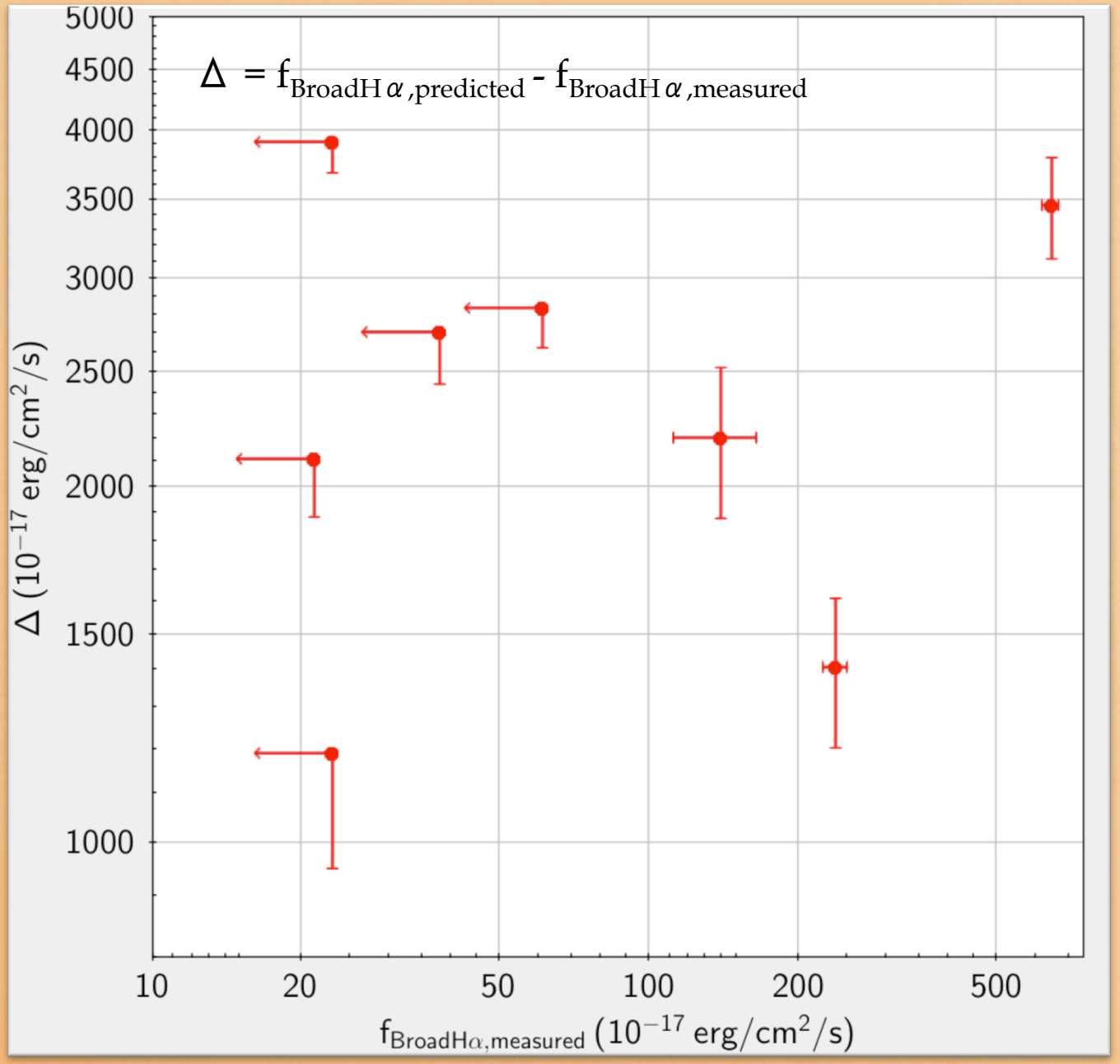












* Observations consistent with predictions → Δ ~ 0

* Δ ~ 2500

➡ Large differences between the predicted and observed fluxes

➡ No BL

Conclusions

* X-ray NELGs: BPT diagram and X–ray AGN selection → 13% of the sources misclassified as BPT-SF
* Nature of these "elusive AGN":
  * 59%: NLS1s → contribution to the Balmer line flux from both the BLR and NLR
  * 41%: X-ray Sy2
    * Misclassification: optical dilution by the host galaxy stralight + low accretion rates (optically underluminous)
    * Unabsorbed Sy2: very low λ + lack BL → **True Sy2**