A NIR view of the Narrow Line Region of AGNs

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Motivations of this work

- From the spectroscopic point of view, AGNs have been poorly studied in the NIR region, particularly in the interval between 1- 2.4μm.
- Systematically absent from most surveys. It does not fall within the spectral coverage of optical CCD detectors or infrared satellites (i.e., ISO, Spitzer).
- Just up to a few years ago, most NIR spectra covered only individual lines or consist of single aperture of one band.
- Individual dataset tend to be obtained with different instruments using a variety of observing modes.

Motivations of this work

- The availability of LS & XD spectrographs allow to obtain spectra in the interval 0.8-2.4 μm in a single integration free of seeing and aperture effects. - Winge et al. (2000), Kotilainen et al. (2002, 2003); Ramos-Almeida 2005 – Mrk 78; Glikman et al. (2006) constructed a NIR template of quasars using XD.

- Things are evolving rapidly. 3D datacubes now allow to obtain $>10^3$ spectra of the centre individual objects at unprecedent spatial and spectral resolution. - Riffel et al. 2006 – ESO428-G14; Zuther et al. – Mrk 609; Muller et al. (this symposium, NGC1068).

- But still we need to observe a representative sample of nearby AGNs to study in detail line emission & continuum properties covering the whole JHK bands. Reference for classifying high-z sources, put constrains on models.

Main goals

- Assembling a homogenous atlas of moderate resolution (R ~ 800) spectra of AGN in the NIR to allow secure intercomparison of their properties.

- Study the excitation mechanisms of the most prominent emission lines, in particular, those not seen in the optical (i.e., H_2 and [FeII] and coronal lines (see talk of Portilla).

- Investigate the continuum emission in a transition zone where the central engine no longer dominates whilst dust emission and young circumnuclear stellar emission start becoming important.

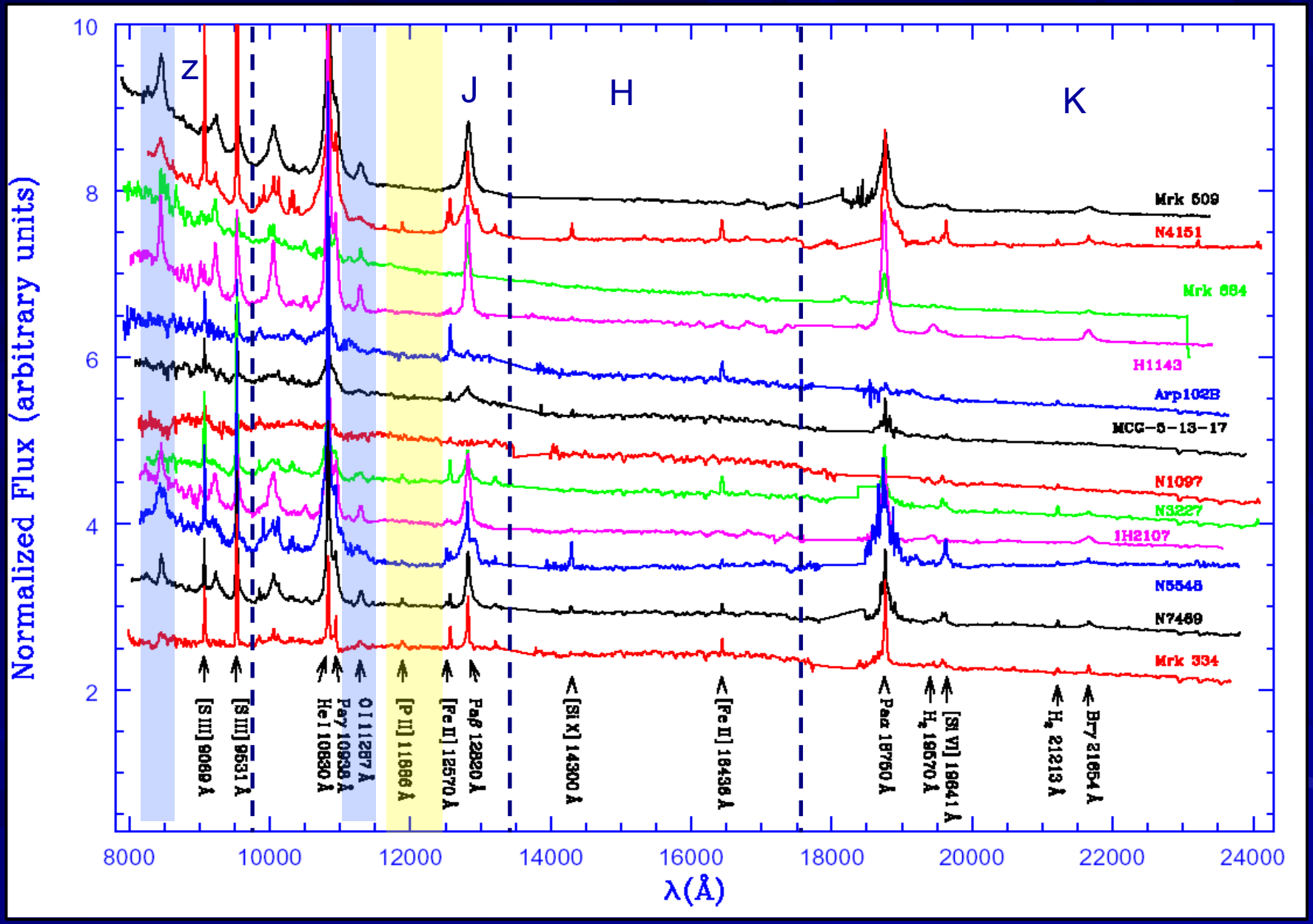
- Get clues about the ionization structure of the NLR using NIR emission lines.

The sample

- 49 AGNs: 32 Type 1 (12 classical, 13 NLS1, 7 quasars), 17 Seyfert 2, 4 starbursts.
- Most Seyfert galaxies were selected from CfA survey. QSOs are from PG catalogue, NLS1 from Boller et al.
- Spectra obtained at the 3.1 m. NASA IRTF - Mauna Kea.
- The integrated nuclear spectrum covers, for most cases, the inner 200 pc.
- For most sources, our spectra are the first ones taken in this wavelength interval.
- Spatial information covering distances of up to 500 pc for a sub-sample of objects was possible.

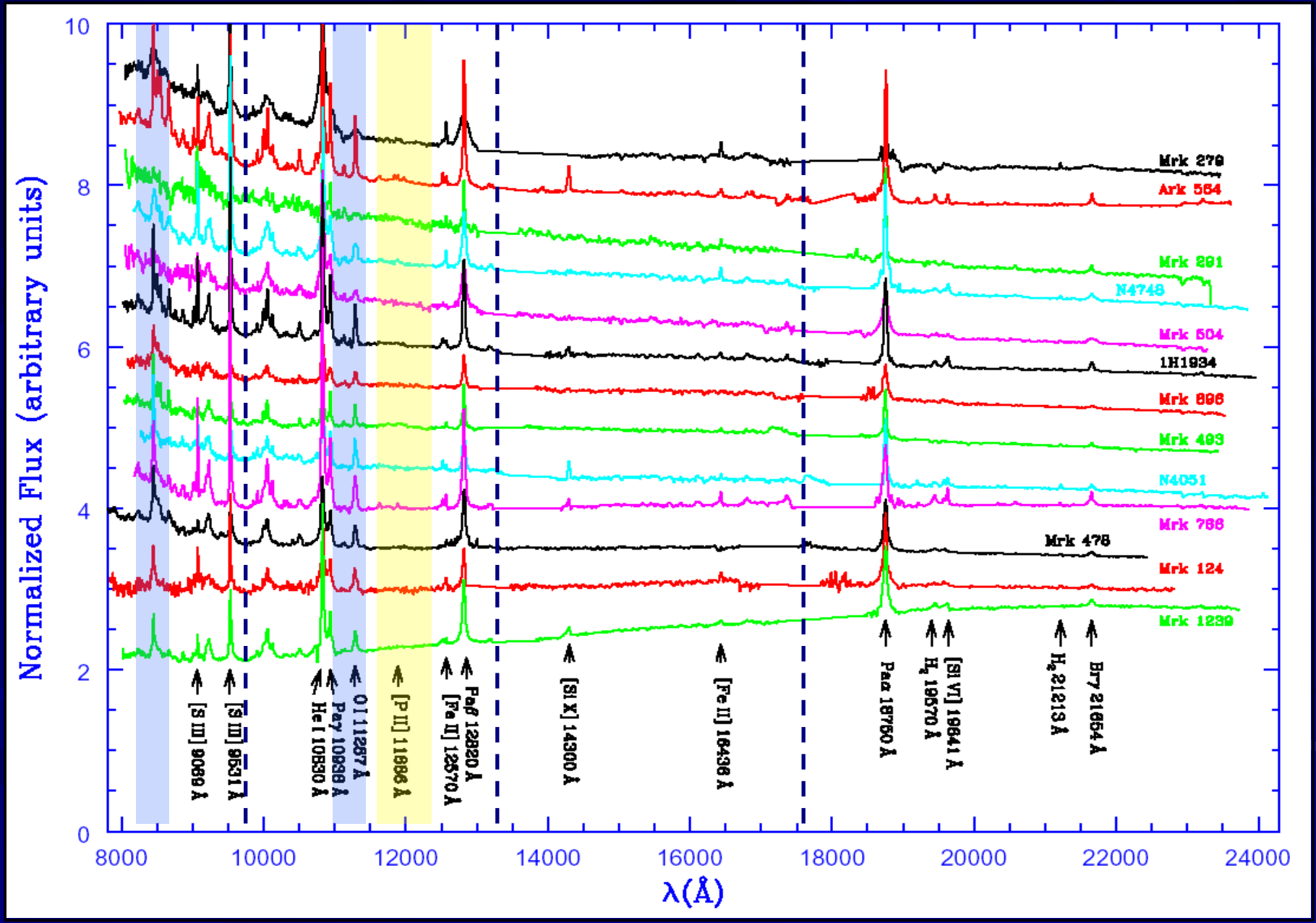
Type 1 sources

Classical Seyfert 1 Galaxies



Riffel, Rodríguez-Ardila, Pastoriza 2006

The Sample – Narrow Line Seyfert 1 Galaxies



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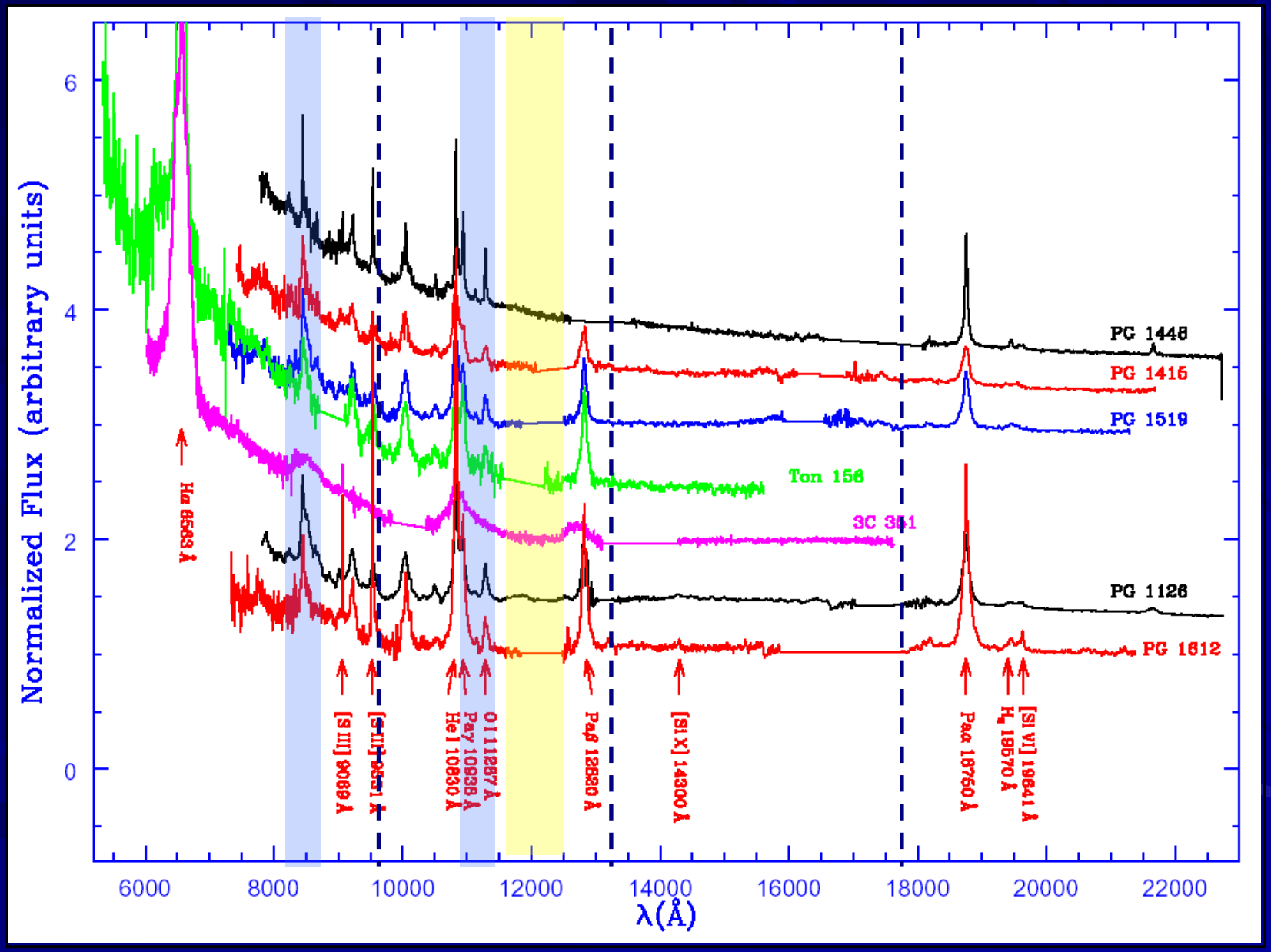
Quasars



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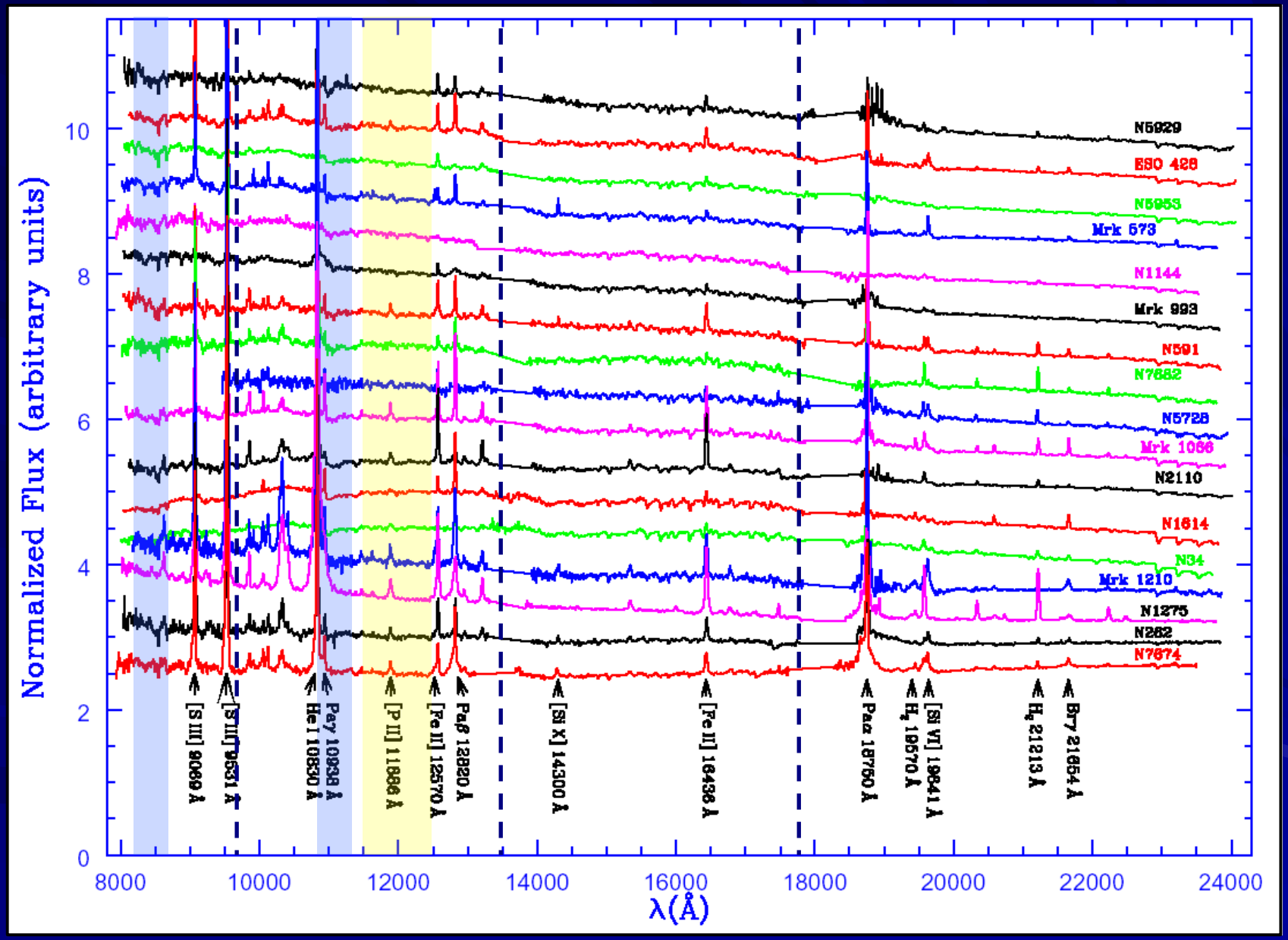
Type 2 Galaxies

Seyfert 2 Galaxies



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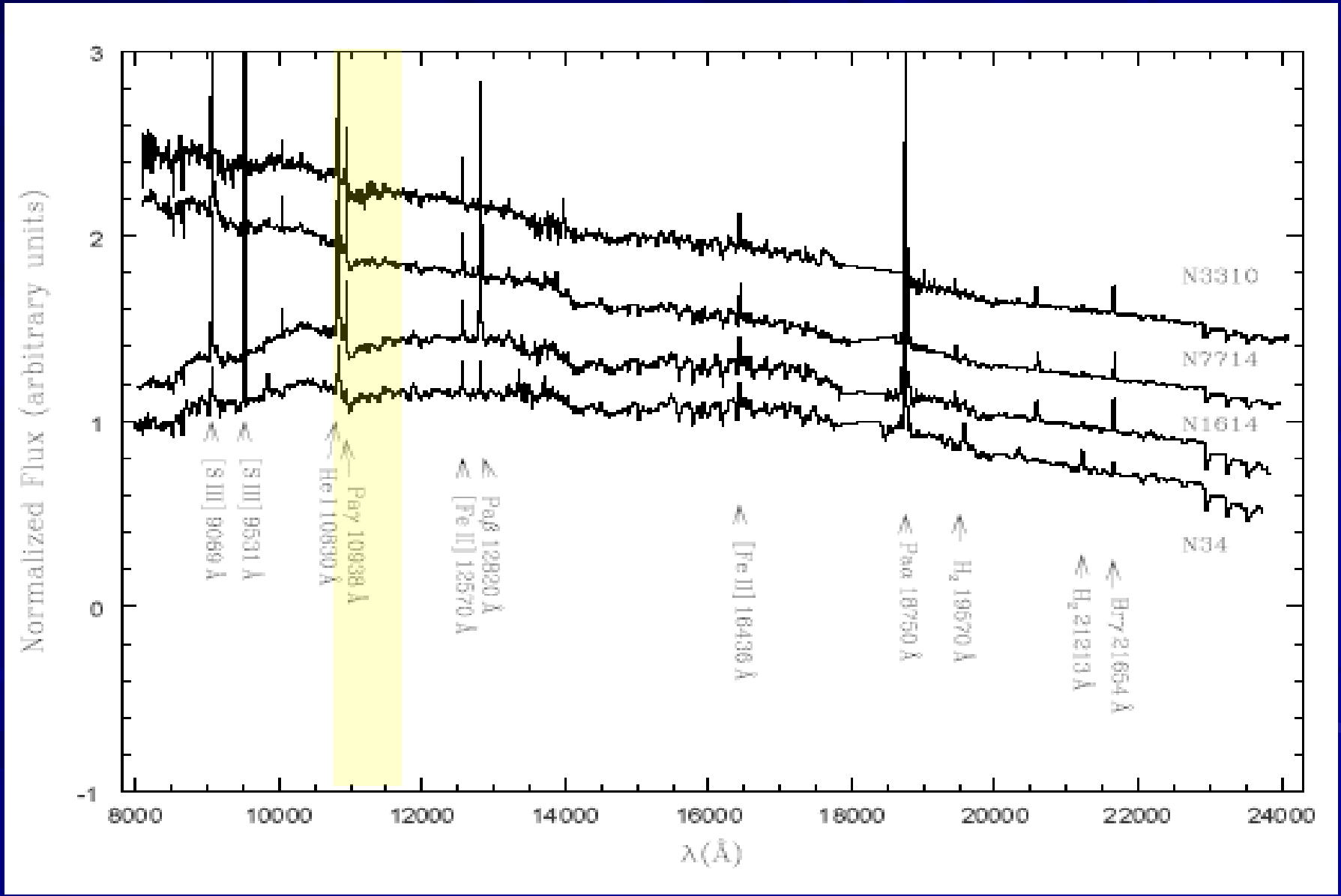
Starbursts


Normalized Flux (arbitrary units)
λ(Å)
N3310
N7714
N1614
N34
[S III] 9069 Å
[S III] 9531 Å
He I 10830 Å
Paγ 10938 Å
Paβ 12820 Å
[Fe II] 12570 Å
[Fe II] 16436 Å
Paα 18750 Å
H2 19570 Å
H2 21213 Å
Brγ 21654 Å

Considerations about the continuum emission

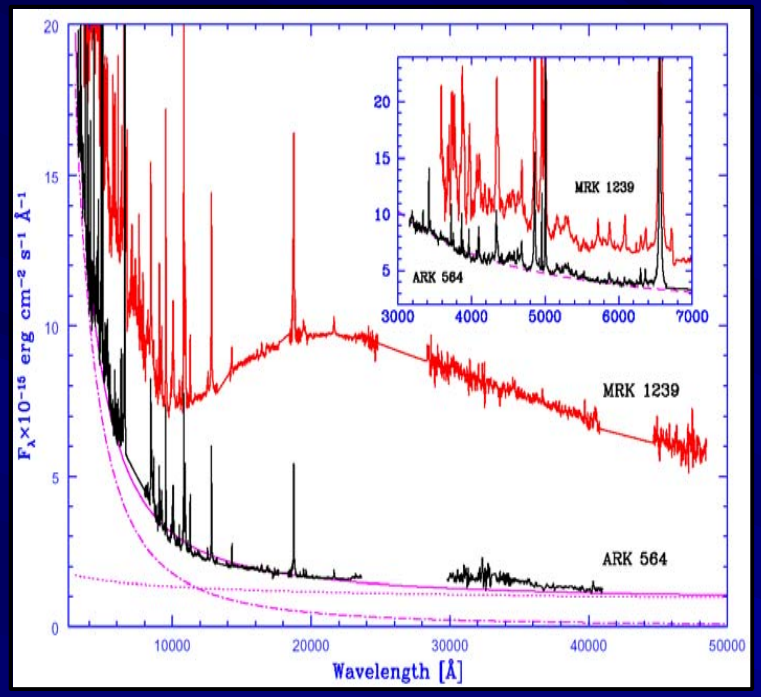
- Quasars, NLS1s and Sy 1's are rather similar both in line and continuum emission, with a clear "turning point" at □1.1μm. We interpret it as the red end of the power-law optical continuum and the start of the warm dust continuum emission (with peak at 60 μm). Agreement with the findings of Glikman et al. (2006). Mrk1239, Mrk 478 and Mrk766 are the exception.

- Type 1 sources display a nearly featureless continuum in the NIR, with only a few sources showing absorption features (2.3 μm CO). The lack of stellar features can be interpreted in terms of the continuum emitted by the unresolved nucleus.

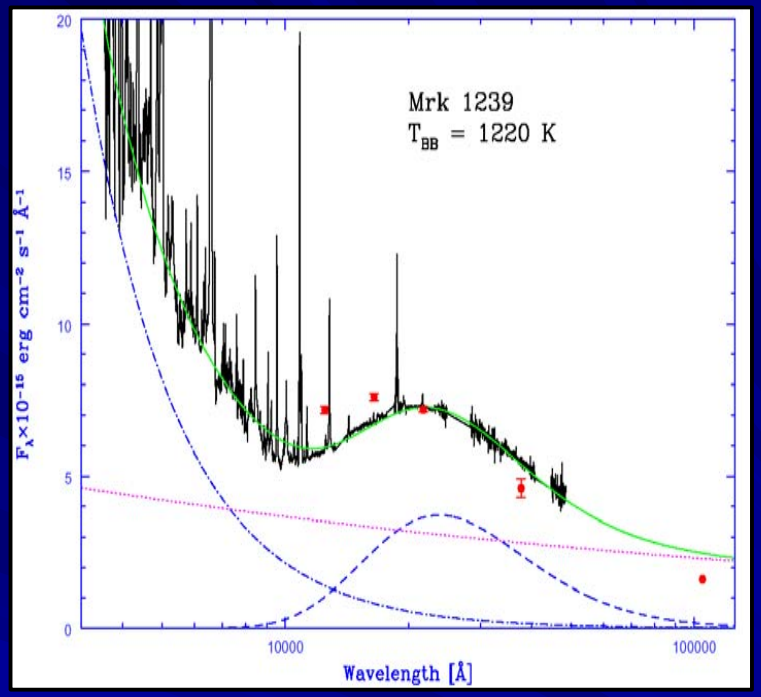
- None of the Seyfert 2s display the blue rise of the continuum shortward of 1.1 μm. Moreover, all objects show prominent absorption lines and bands in *H* and *K*. Stellar dominated.

- Indeed, the 2.3 μm CO bandheads are present in all sources but NGC 1275 and NGC 262. In *J*, most Seyfert 2s display an absorption band at 1.1 μm, not reported before in AGNs. Two groups based on its shape (more later)

The case of Mrk 1239: an extreme bump in the NIR



Rodríguez-Ardila & Mazzalay, 2006



Mrk 1239 displays a strong excess of emission in the NIR region, not observed in any other object of its class. In the optical, we measured an E(B-V) of 0.54 for the continuum. Izw1 (Rudy et al), Mrk478, NGC 7674, ,Mrk 766, shows an excess too.

The excess of emission follows a simple blackbody curve at T=1220K, close to the evaporation temperature of graphite dust grains. This, along with the large extinction derived for the continuum suggest that we are observing a spectral signature of dust located in the obscuring torus.

The hot dust hypothesis

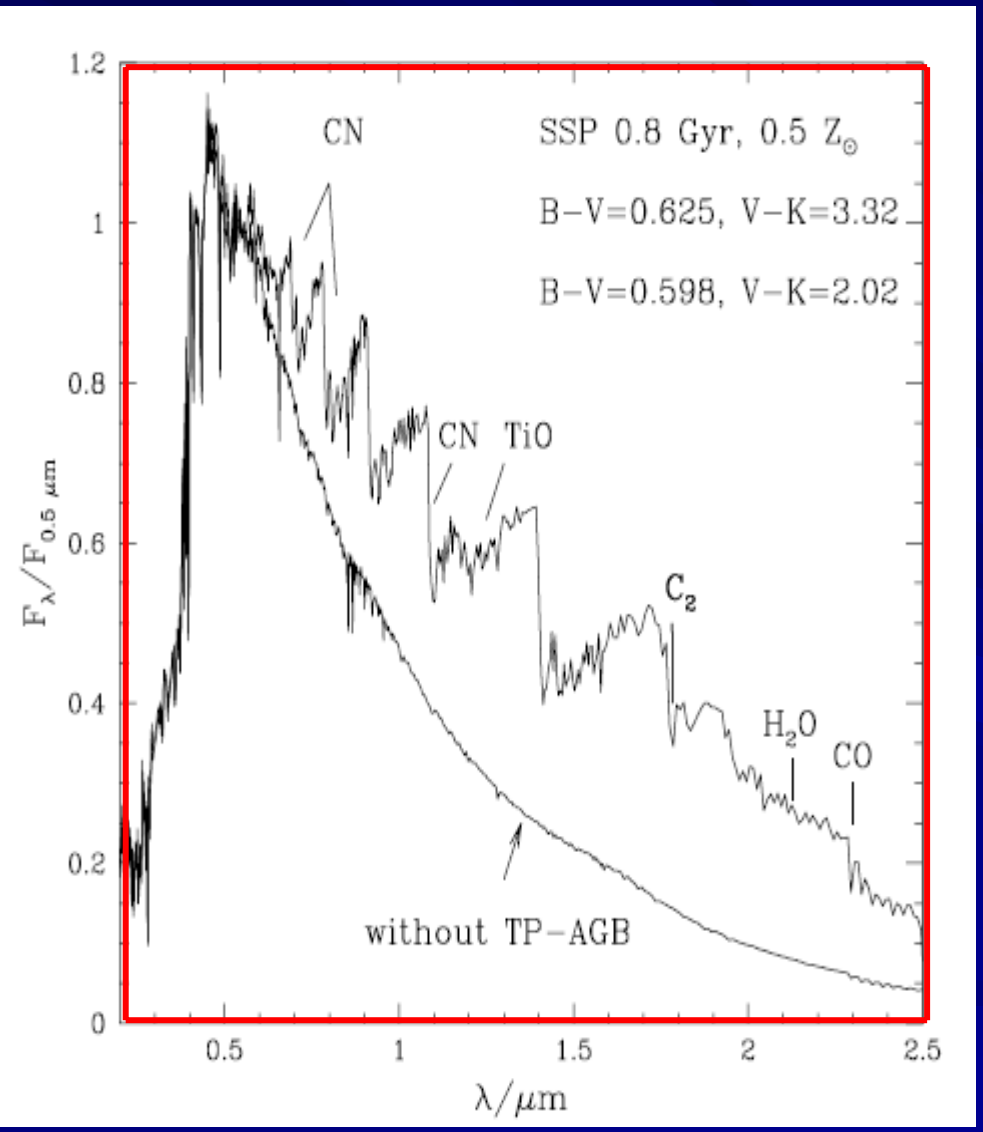
Galaxy	Mass [$M_\odot$]	Reference
Mrk 1239	2.7×10^{-2}	This work
NGC 7469	5.2×10^{-2}	Marco & Alloin 1998
Fairall 9	2.0×10^{-2}	Clavel et al. 1989
NGC 3783	2.5×10^{-3}	Glass 1992
Mrk 766	2.1×10^{-3}	Rodríguez-Ardila et al. 2005
NGC 1566	7.0×10^{-4}	Baribaud et al. 1992

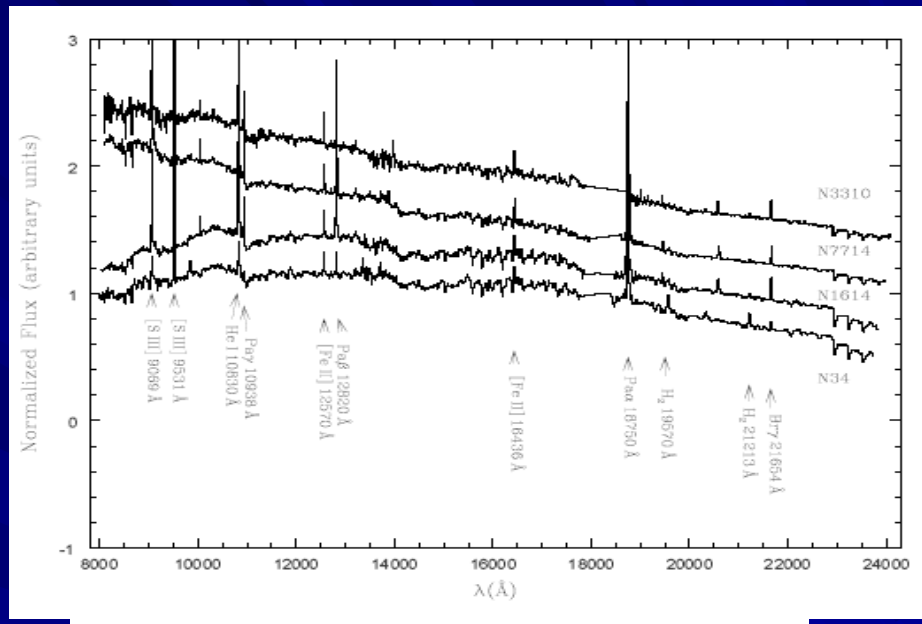
Mrk1239 has the second largest mass of hot dust reported for an AGN up today. The lack of star formation, the strong polarization and low extinction derived for the emission lines support the scenario where the hot dust is located between the narrow line region and the broad line region.

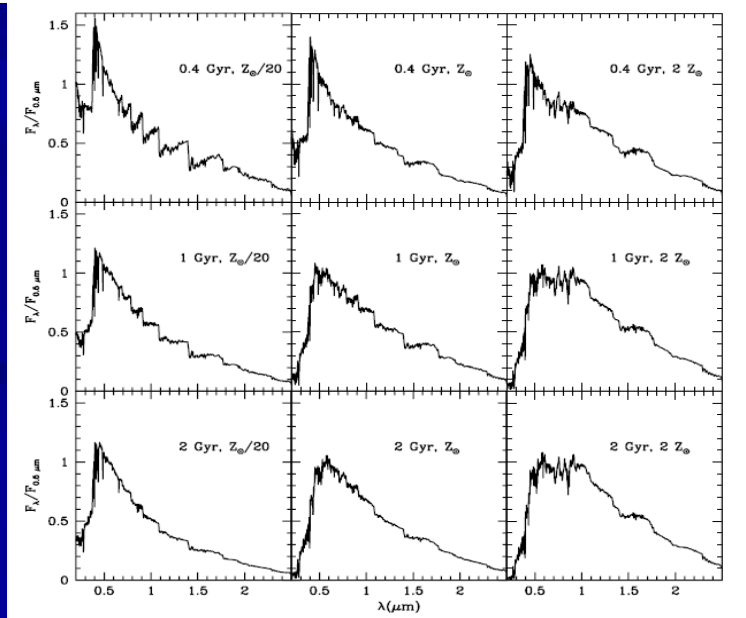
The stellar continuum component

- Circumnuclear star formation is commonly detected in Active Galactic Nuclei (Sturm 1999, Storchi-Bergmann et al. 2005).
- It is currently thought that the AGN & Starburst are related to gas inflow (perturbations, mergers or tidal interactions, Shlosman et al. 1989; Fathi et al. 2006).
- But … tracing starburst in AGN reliably is difficult.
- Models of Maraston (2005) predict the presence of CH, CN and C_2 from young/intermediate stellar populations, particularly enhanced in the NIR.
- The CN arise from stars with $0.3 < t < 2$ Gyr in the TP-AGB phase.
- Its detection is an unambiguous signature of the presence of young/intermediate SP in a well-constrained age, signaling the occurrence of SB activity.

CN 1 μm band as a tracer of young-intermediate stellar population







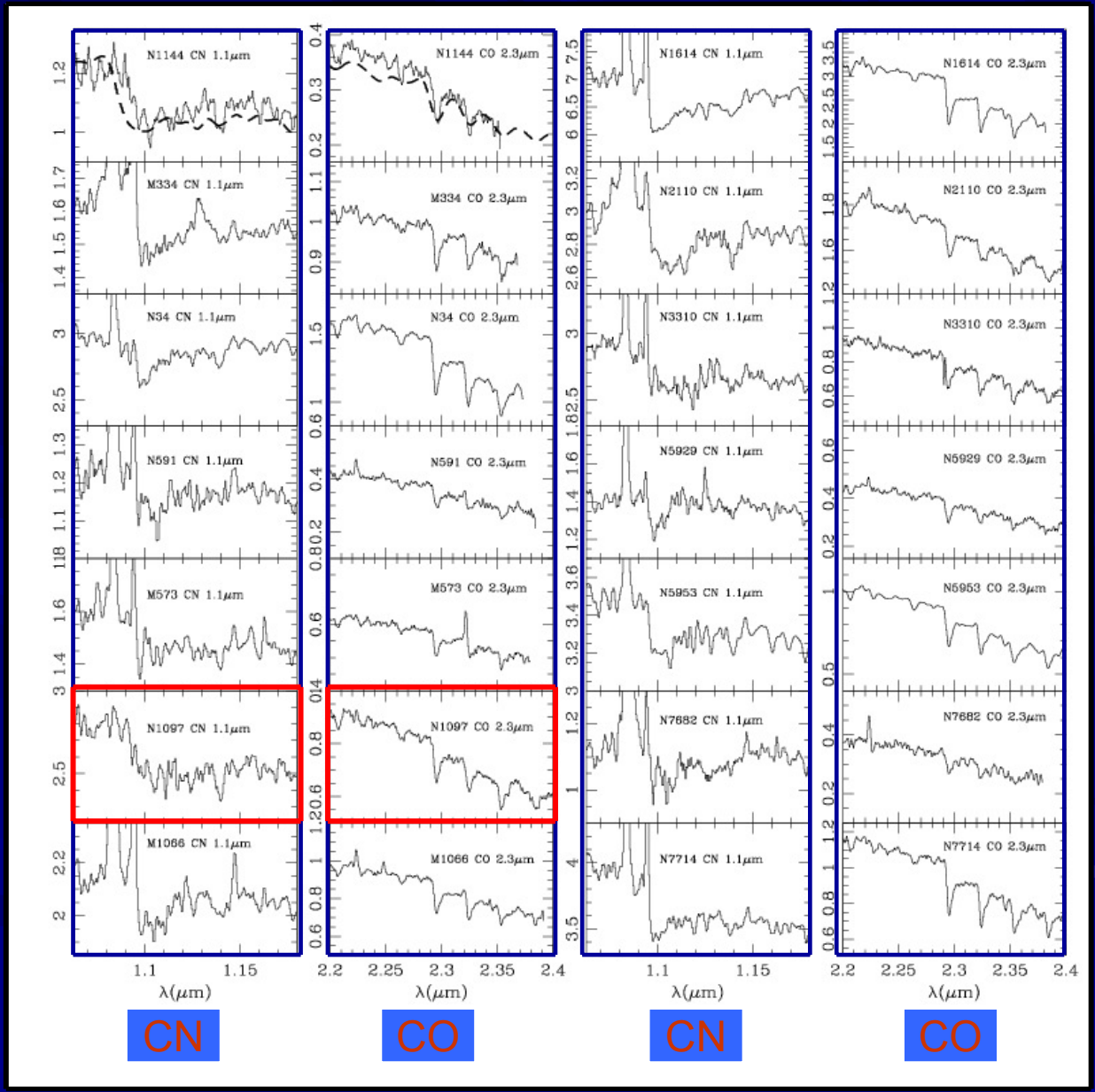
Maraston 2005

→ Young/intermediate stellar population in AGNs can be traced by the 1.1 μm CN band.

→ 9 out of 16 Sy2 show the CN band. In NGC1097 it is also detected.

Optical SP synthesis in 4 of our objects (Raimann et al. 2003) revealed that old population (~10 Gyr) dominates the inner 10^2 pc.

Useful to detect SB in distant Type II quasars!!



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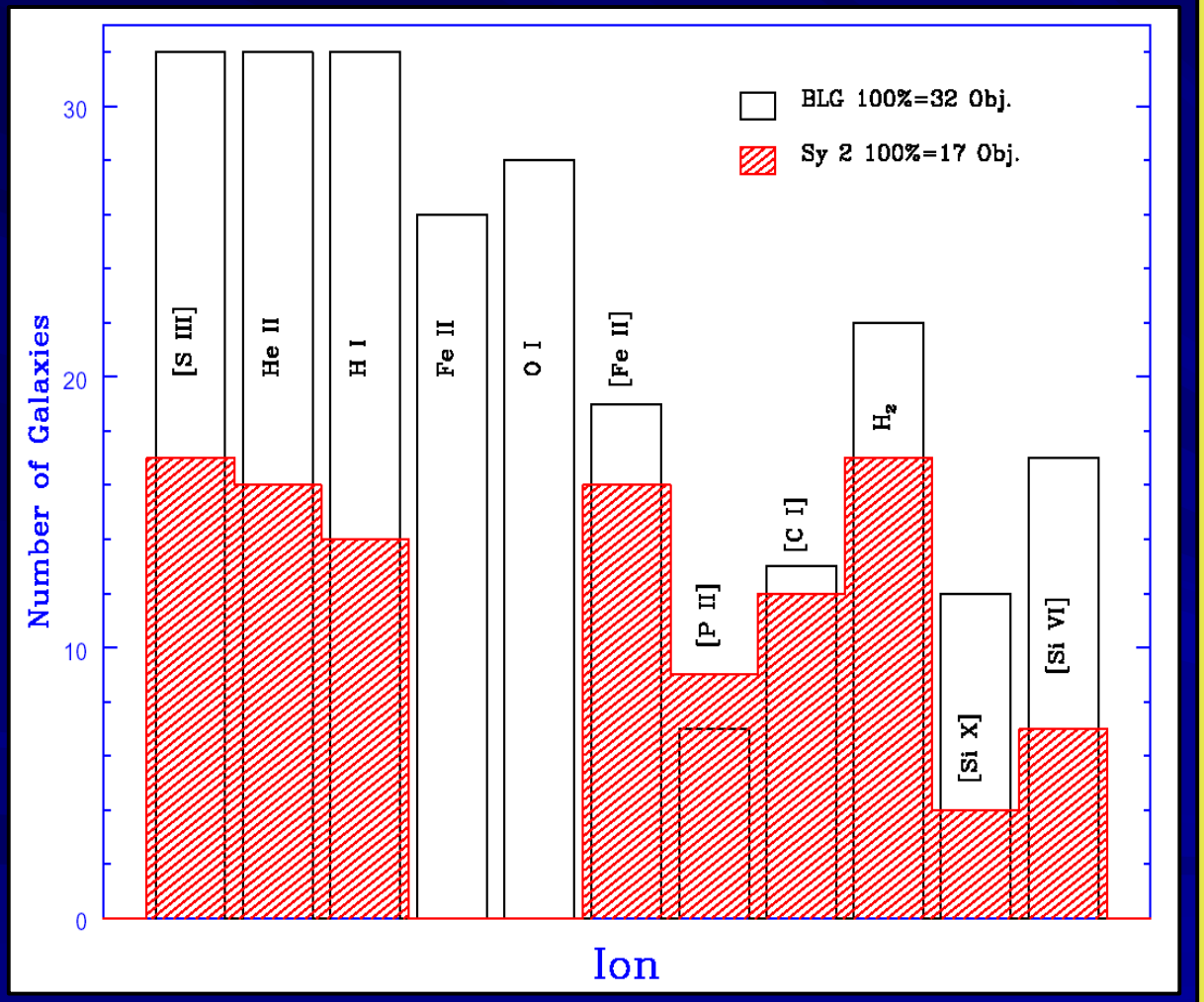
Emission line demography for the sample



- FeII and OI are spectral features exclusive of Sy1 galaxies. Even obscured Sy2 show no evidence of these lines.
- NLR features are more prominent in Sy2 objects.
- [PII], expected to be very weak or not present at all because of its low abundance (10^{-5} H), is observed in 30% of the objects. Dust grains destroyed by shocks??
- Coronal lines (Portilla's Talk).

The origin of the H_2 & [FeII]

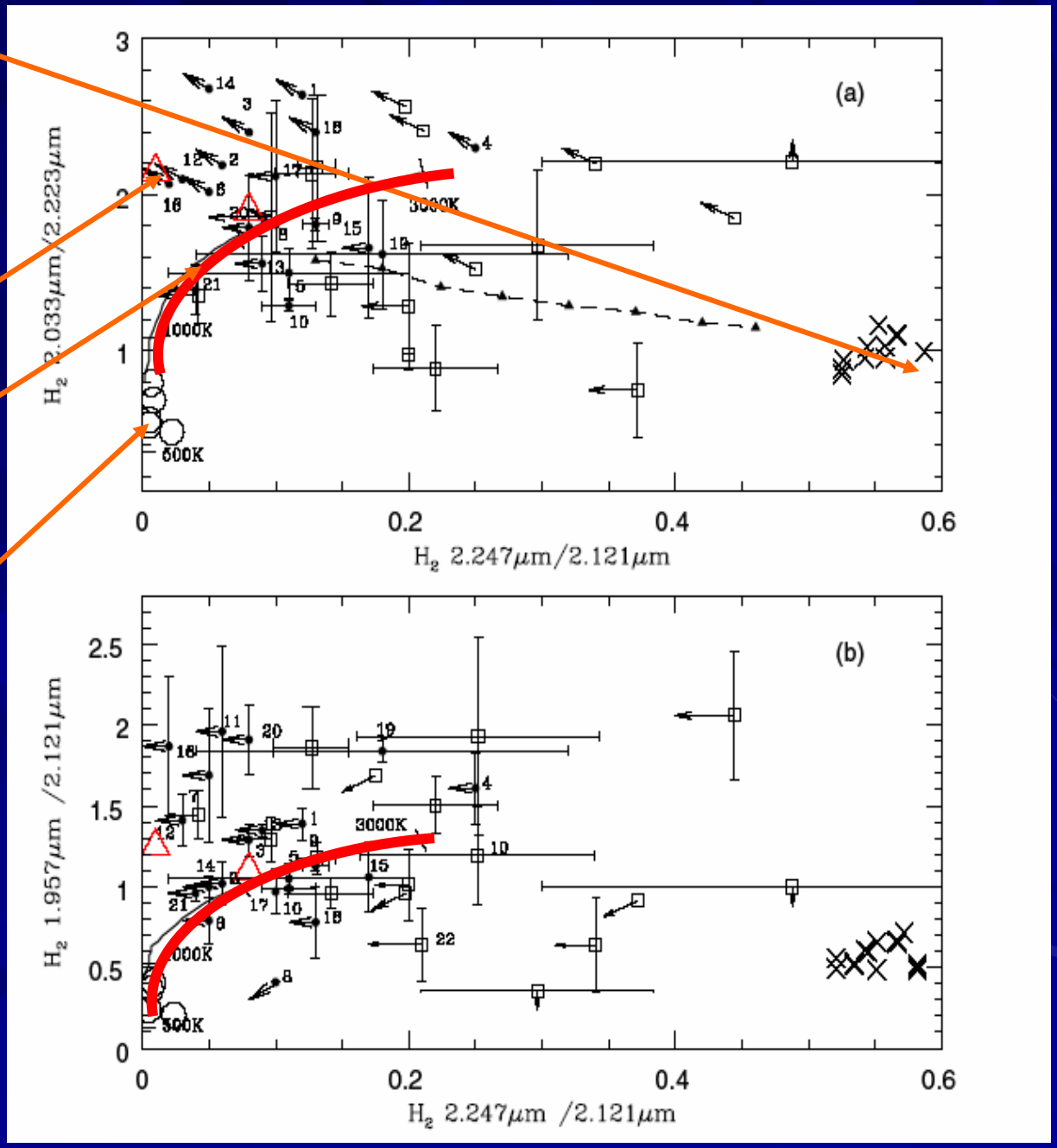
- Problem: determine the dominant excitation mechanism of the NLR emitting gas.
- Particularly evident for H_2 and [FeII]
- Detected both in AGN and starburst.
- H_2 & [FeII] has both been proposed as a tracer of star formation.
- [FeII] is a realiable reddening indicator for the NLR.
- No study involving a reasonably number of AGNs have been done.

Excitation UV models of (Sterberg & Dalgrano 1986).

X-rays thermal excitation models of Leep & McCray (1983).

Thermal shocks models of Mouri (1994).

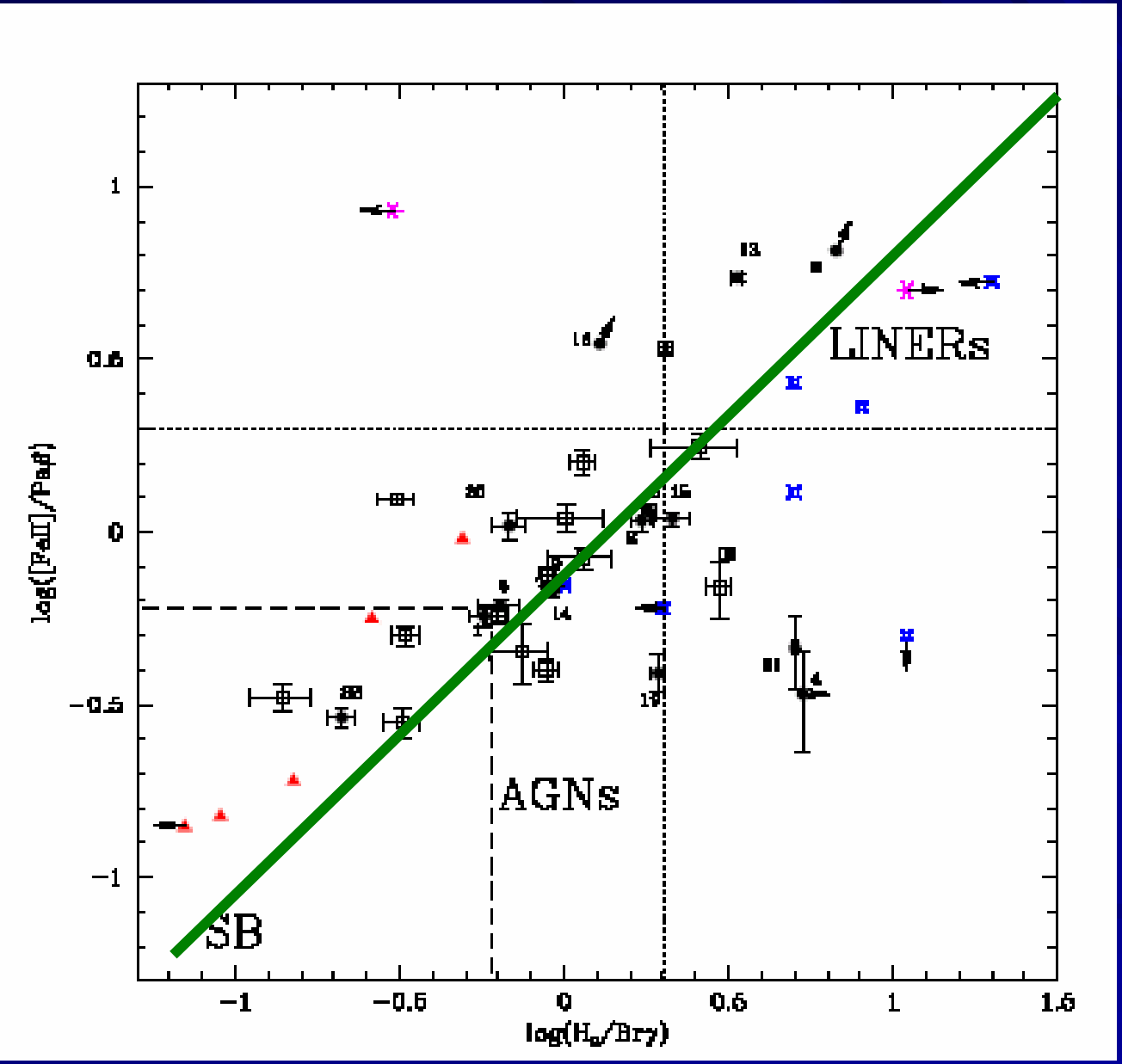
UV excitation models of Sterberg & Dalgrano (1986).



The dominant excitation mechanism of H_2 is thermal (shocks and X-ray illumination).

(Rodríguez-Ardila, Riffel & Pastoriza, 2005)

A diagnostic diagram for the NIR region



Is there a real correlation between the [Fe II] and H_2 for the different emission line objects or does the diagnostic diagram shows an evolutionary sequence between the objects?

(Rodríguez-Ardila, Riffel & Pastoriza 2005)

Final Remarks

- A representative NIR spectral atlas of AGNs is presented and analyzed in terms of the most common spectral features and continuum characteristics.

- The continuum in Type 1 sources are rather similar and can be represented by two PL. There is break at 1.2 μm, where the optical PL no longer dominates and the one from warm dust start becoming important.

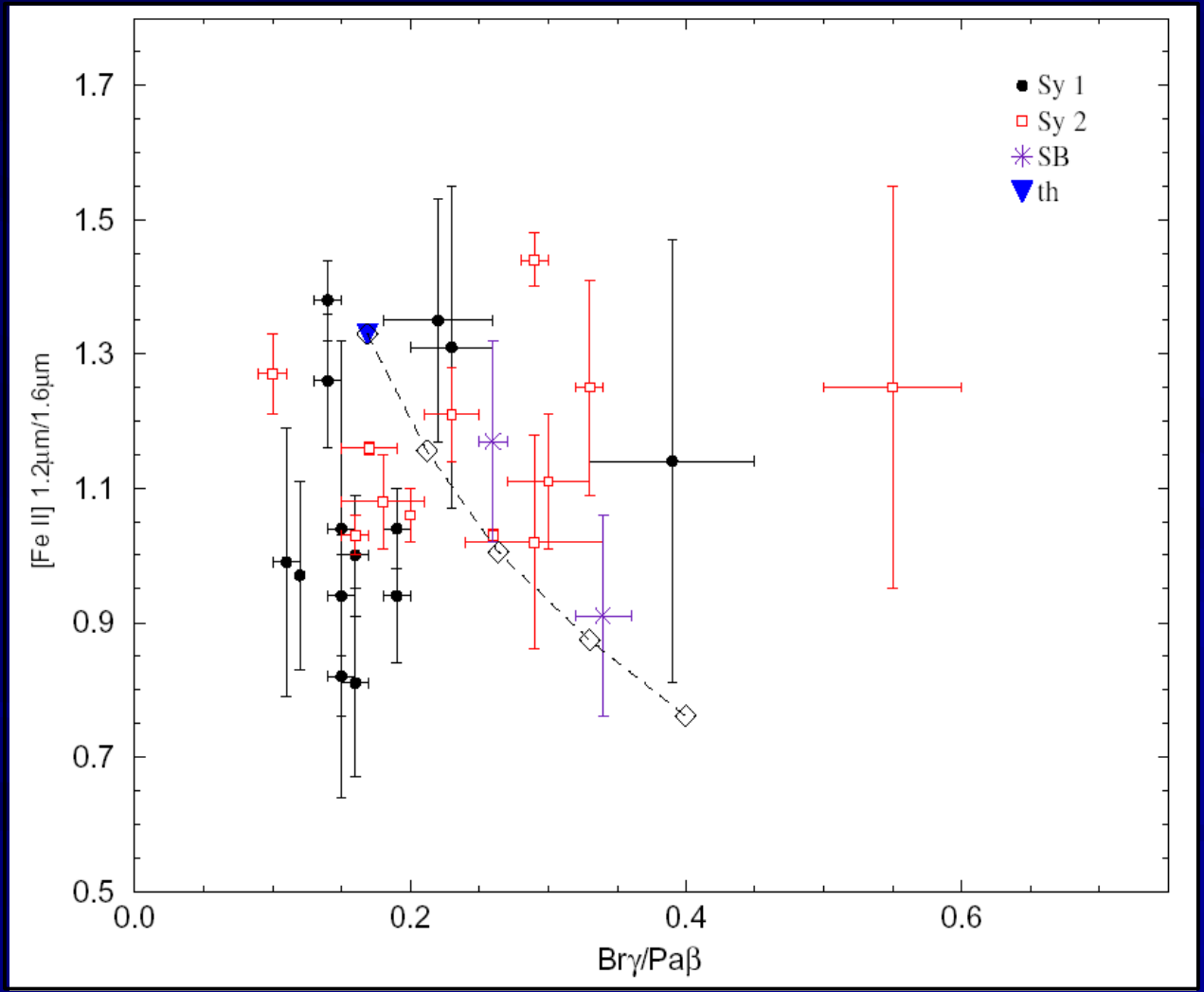
- Even in the NIR, where the extinction is less severe than in the optical, most Sy2 galaxies are dominated by a red stellar continuum. Some Sy2 appear to be dominated by Sy1-like continuum emission, suggesting that they have an obscured BLR. However, none of these latter objects show evidence of spectral features that are exclusive of Sy1 galaxies (OI and FeII lines).

- CN bands are observed, for the first time in AGNs. It implies the presence of SP of $0.3 < t < 2$ Gyr.

- Mrk1239, one of the objects studied, displays a strong NIR excess of emission, with a strength not observed in any other object either of our sample or reported in the literature. We show that a blackbody at T=1220 K adequately reproduces the NIR bump. It mat be related to dust confined in the inner few pc of the nuclear region.

- H_2 is common to all types of Seyferts. The relative strength of the lines suggest that they have a thermal origin. [FeII]/Paβ and H_2/Brγ discriminates between the different degrees of activity.

Extinction towards the NRL and BLR

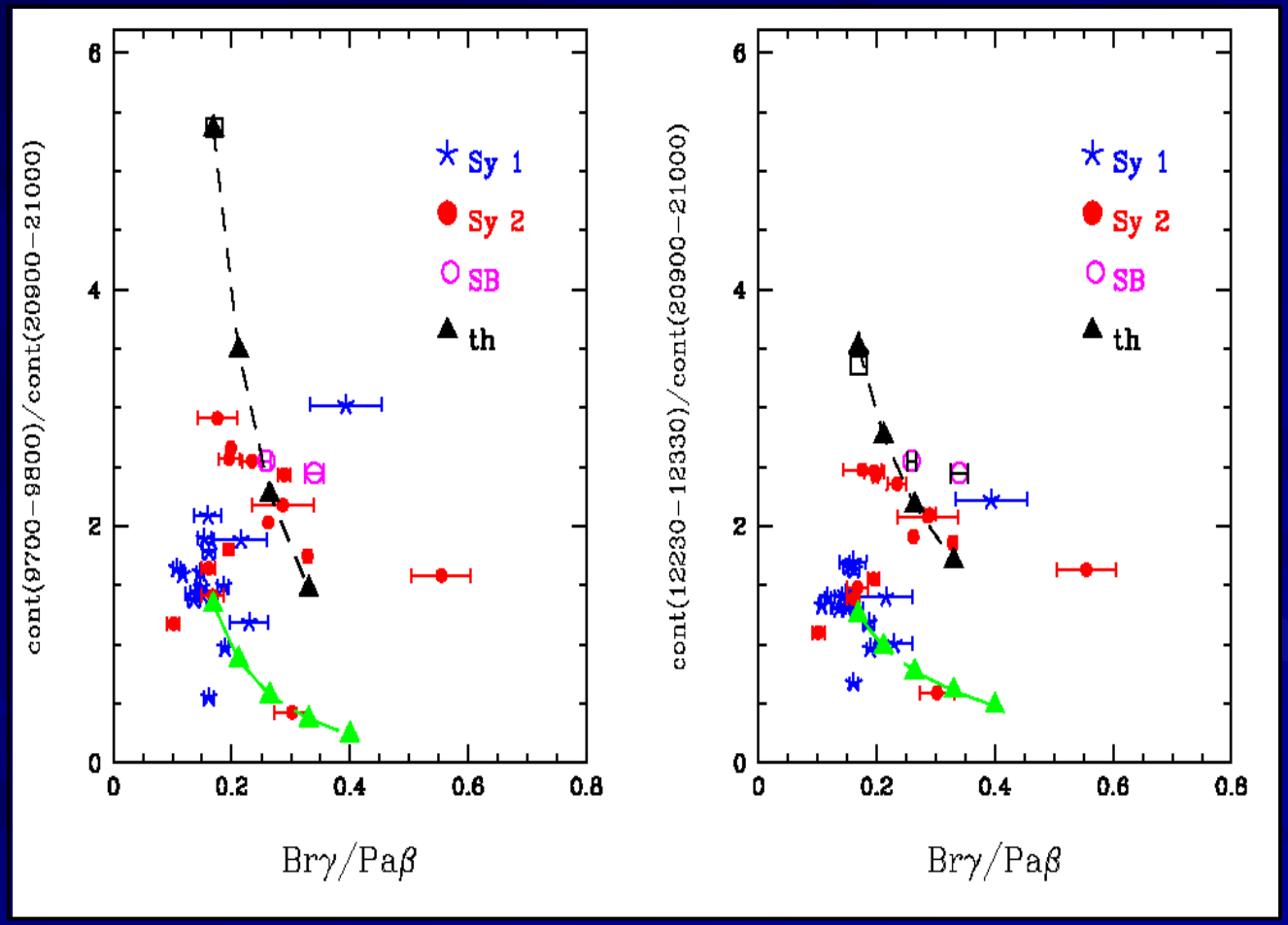


- The blue triangle shows the intrinsic line ratios according to case B (Brγ/Paβ) and Bautista & Pradhan collisional rates ([FeII], R=1.31).

- The dashed line is a sequence of reddening, in steps of E(B-V)=0.5, assuming the CCM law.

- Few objects follows the reddening curve. Sy1s tend to display higher extinction in the [FeII] region. The HI decrement shows little dust in these same objects.

Continuum vs line extinction



- The black dashed line is an extinction sequence adopting a stellar continuum. (N3310). The green curve is for a power-law Continuum (Mrk 493).

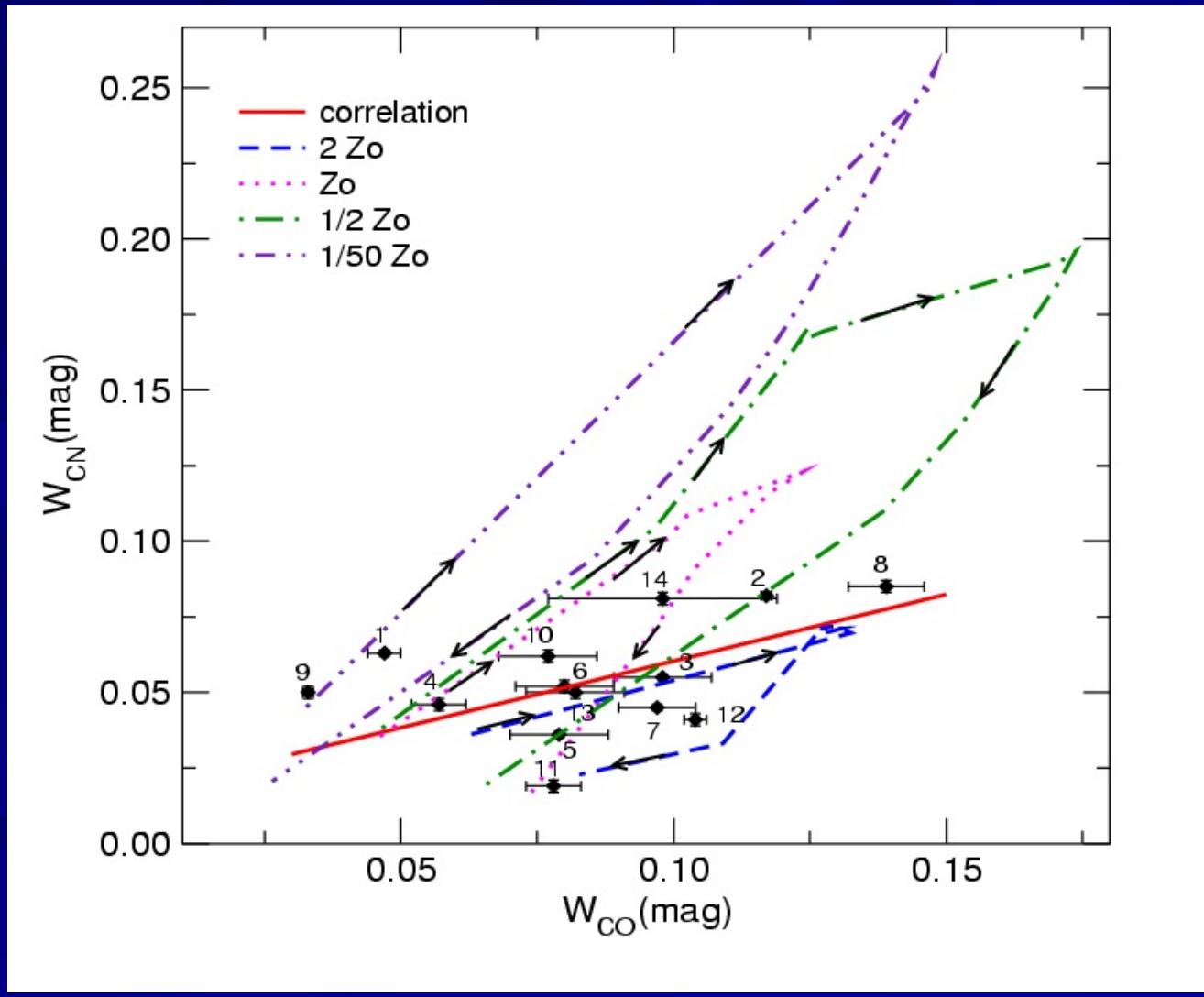
- The continuum for most Sy1 shows little or no evidence of reddening. Those Sy2 dominated by stellar light have a redder continuum. Some Sy2s behaves more like Sy1s in the NIR.

Relationship between CN and CO

- The arrows indicate the age sequence of the models.

- NGC34, Mrk573, NGC 1144, NGC 3310, NGC7682, NGC 7714 dominated by stars with solar/half solar metallicity.

- NGC 591, NGC1097, Mrk1066, NGC5929, NGC 5953 have SP with high metallicity.



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