

Near-Infrared Spectroscopy of Seyfert Galaxies. Nuclear Activity and Stellar Population.

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Abstract

- Near-IR spectroscopy of Sy2 galaxies with jet-gas interaction : Mrk348, Mrk573, Mrk1066, NGC7212 & NGC7465.
- Long slit observations with LIRIS / WHT in the range 0.8 – 2.4 μm.
- Study of the excitation and ionization mechanisms in the NLR, affected by the jet.
- Characterization of nuclear stellar population through absorption features in H and K bands.
- Continuum of Sy2 : stellar templates + BB component.
- Reclassification of Mrk573 (obscured NLSy1) and NGC7465 (Type-1 LINER) based on detection of broad components in the recombination lines + O I and Fe II lines.

Introduction: Seyfert Galaxies

- Seyfert galaxies : Seyfert 1 & Seyfert 2 => Unification Models ?

Seyfert 1 :

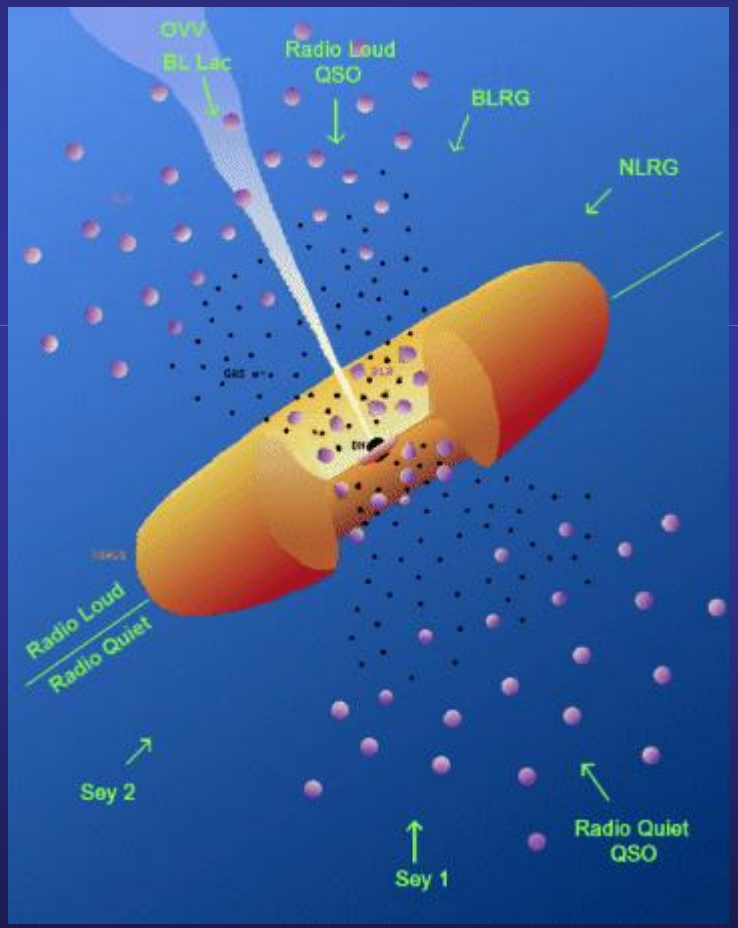
Permitted lines widths ~ 10^4 km/s (BLR)

Permitted & forbidden lines widths ~ 500 km/s (NLR)

Seyfert 2 :

Permitted & forbidden lines widths ~ 500 km/s (NLR)

BLR not observable or not existing…polarized spectrum !



Introduction : Infrared

- Advantages of the infrared range in the study of Seyfert galaxies:
  - Wide variety of diagnostic tools to characterize the NLR, partially ionized regions or molecular clouds.
  - Possibility of unveiling higher density regions than the NLR through a less extincted LOS.
  - Study of stellar content of the nuclear region due to lower contribution of the active nucleus to the continuum.

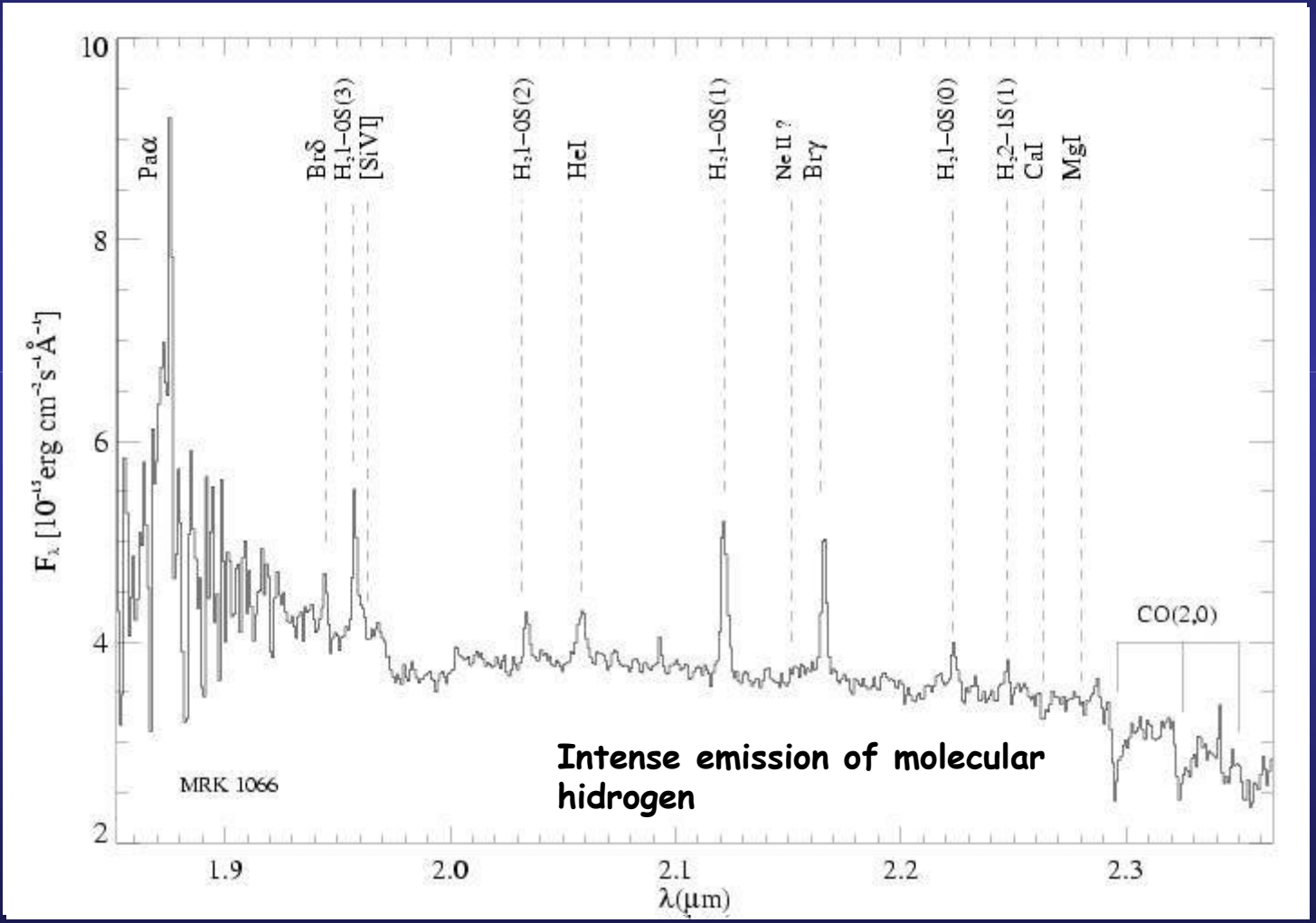
Observations

- Near-infrared long-slit spectra of five Seyfert 2 in the range 0.8 – 2.4 μm taken with LIRIS / WHT from 2005 July to 2008 August.
- Homogeneus data set, taken with the same instrument covering the same spectral range.
- Slit width 0.75” (spectral resolutions ~450 and 500 km/s in ZJ and HK, respectively).

Galaxy	morphology	z_{spec}	distance (Mpc)	scale (pc arcsec^{-1})	E(B-V) (mag)	N_H (cm^{-2})
Mrk 348	SA(s)0/a	0.015 [a]	60	291	0.067	$1.3\text{x}10^{23}$
Mrk 573	(R)SAB(rs)0+	0.017 [b]	69	333	0.023	$>1.6\text{x}10^{24}$
Mrk 1066	(R)SB(s)0+	0.012 [c]	48	233	0.132	$9\text{x}10^{23}$
NGC 7212	Sab	0.027 [d]	106	516	0.072	$>1.6\text{x}10^{24}$
NGC 7465	(R')SB(s)0	0.007 [e]	26	127	0.078	$4.6\text{x}10^{23}$

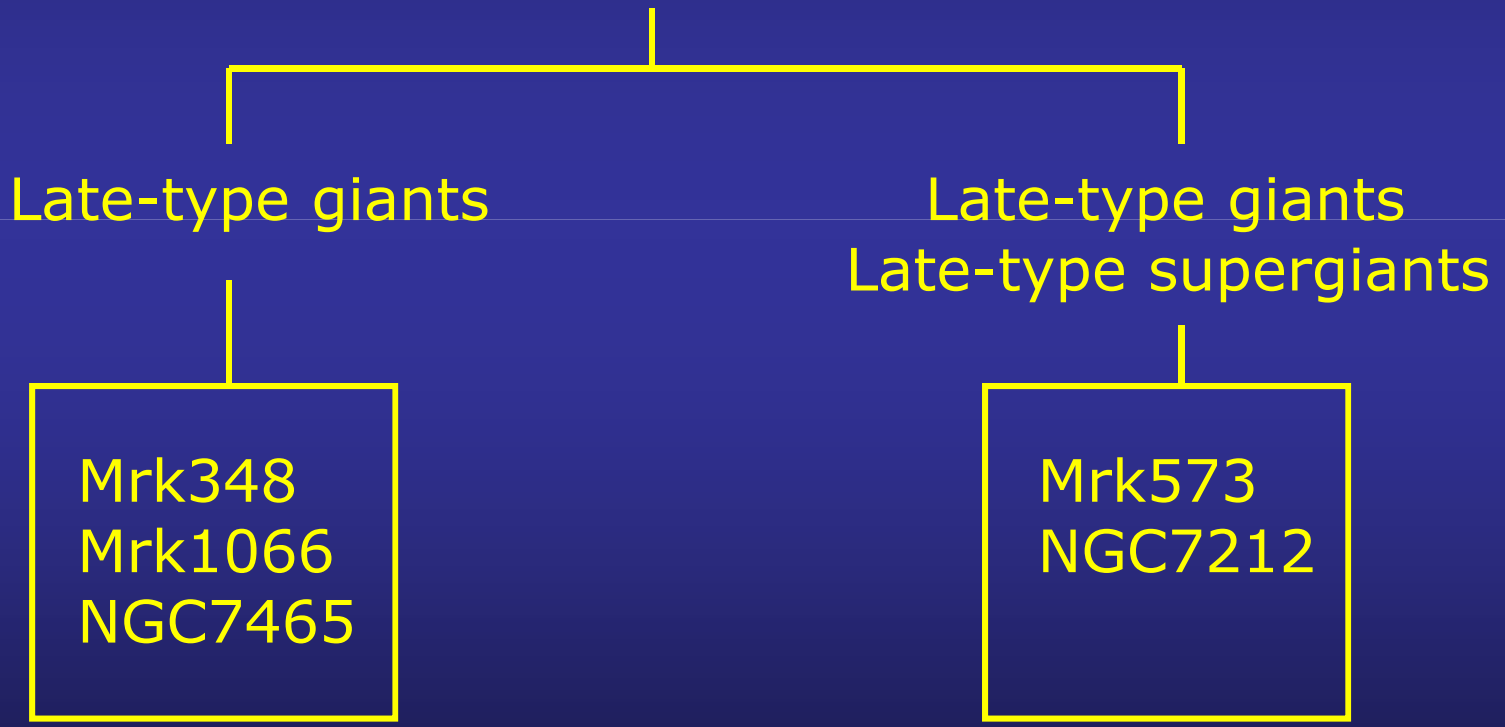
Nuclear Spectra

Nuclear spectra extracted covering 1.5'' in the ZJ and HK ranges.

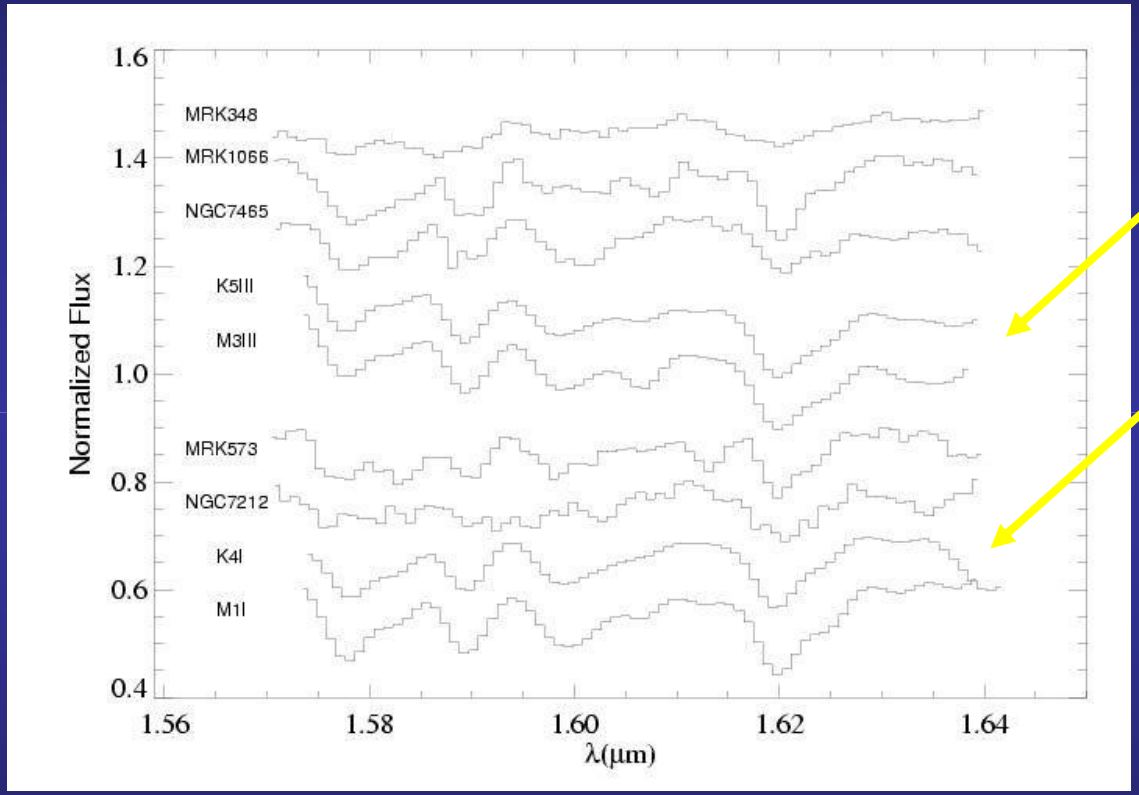


The Underlying Stellar Population

- EW(CO 1.62)/EW(Si I 1.59) = good T indicator for late-type stars (Origlia et al. 1993).



The Underlying Stellar Population



Comparison with digitally available spectra from Dallier et al. (1996).

Lower limit of ~100 Myr for the age of the nuclear stellar population of the galaxies <= intermediate-to-low mass giants dominate the near-infrared spectra (Renzini & Buzzoni 1986).

The Underlying Stellar Population

- EW(CO 1.62)/EW(Si I 1.59) not a reliable diagnostic to discriminate between old stellar population (red giants) and recent starburst (red supergiants).
- Prominent CN 1.1 μm band => existence of thermal-pulsing AGB stars with ages ~ 0.3 - 1 Gyr (Maraston 2005).



- Stellar population in the nuclear region of the galaxies dominated by late-type giants and supergiants (low fraction).
- Average age between 100 Myr and 1 Gyr according to observed stellar features.

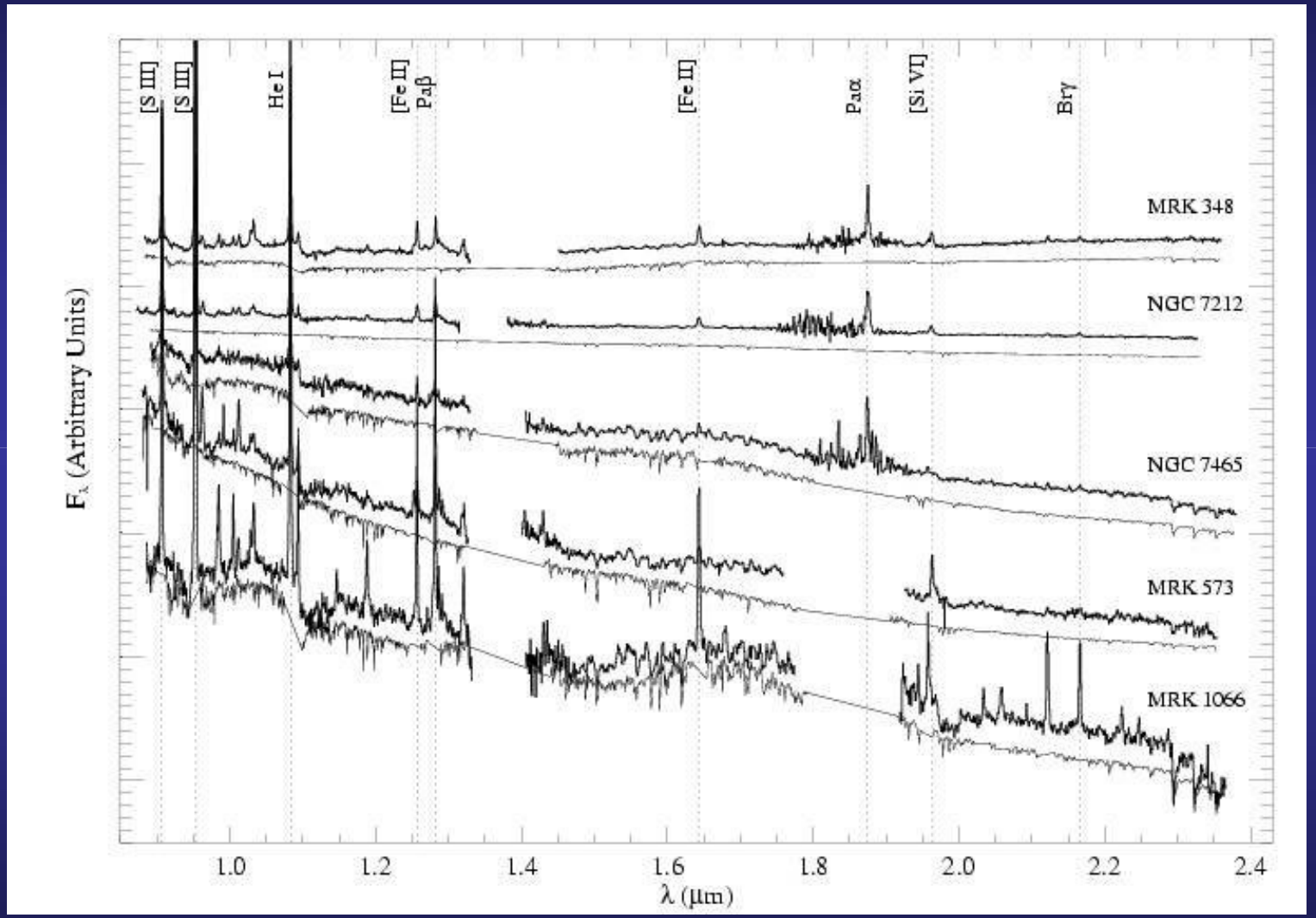
The Continuum Spectra

- The emission from the active nucleus does not longer dominate the J band in Seyfert 2 (Kishimoto et al. 2005; Riffel et al. 2006).
- Reprocessed nuclear emission from hot dust emerges in K band as important source of continuum (Rodríguez-Ardila and Mazzalay 2006; Glickman et al. 2006).

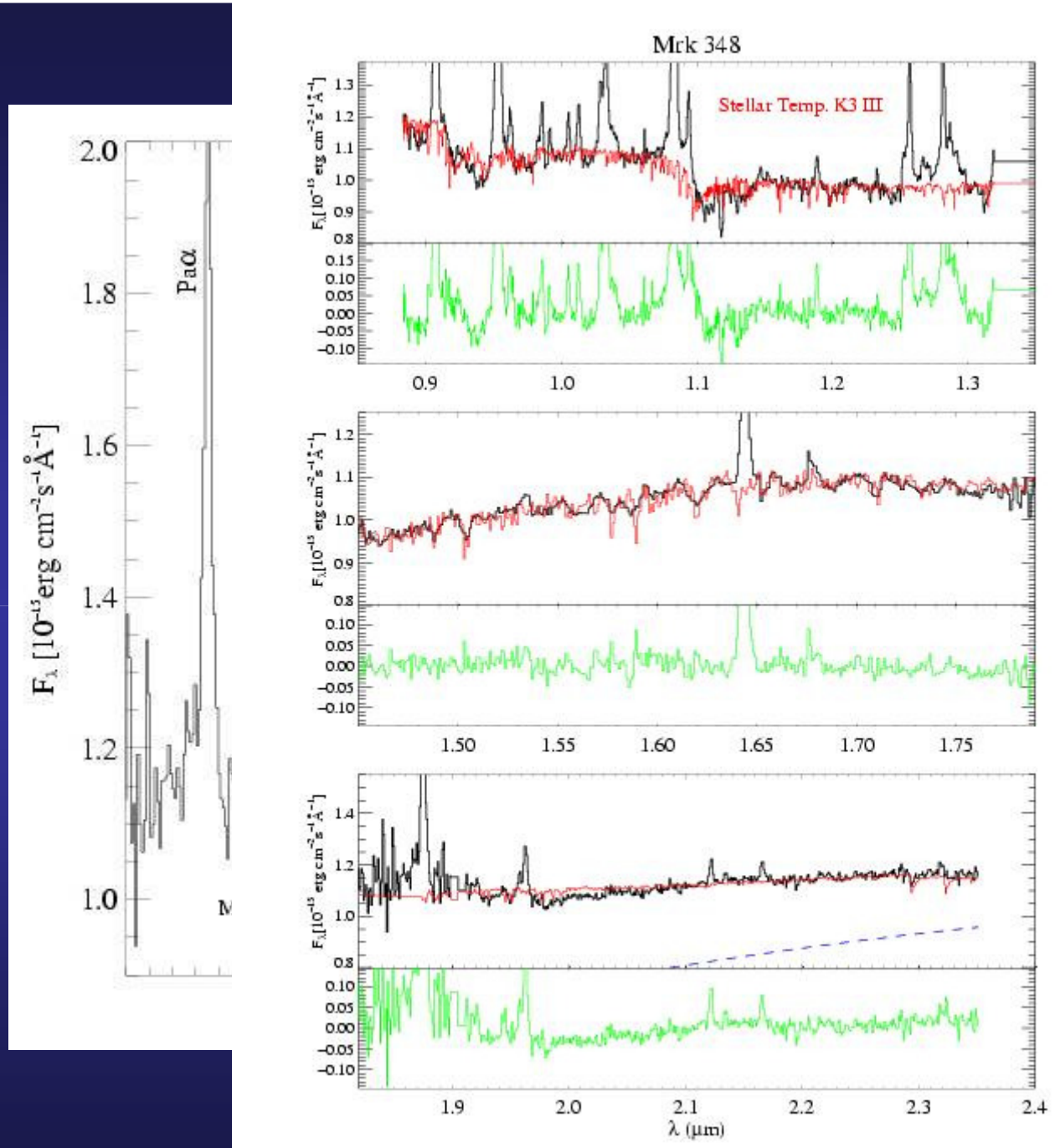


- Best of modelling Sy2 continua = composition of stellar templates + rising contribution at K band (BB).
- A power-law component (associated to the active nucleus) not relevant in the near-infrared for Sy2.

The Continuum Spectra



- Stellar templates from the IRTF stellar library (Cushing et al. 2005; Rayner et al. 2009).



Re a Ramos Almeida

Extinction towards the nucleus

- Obscuration of nuclear regions:
  - **[Fe II]λ1.257 / [Fe II]λ1.644**
  - Paγ / Paβ => dependent of N_e and T_e.

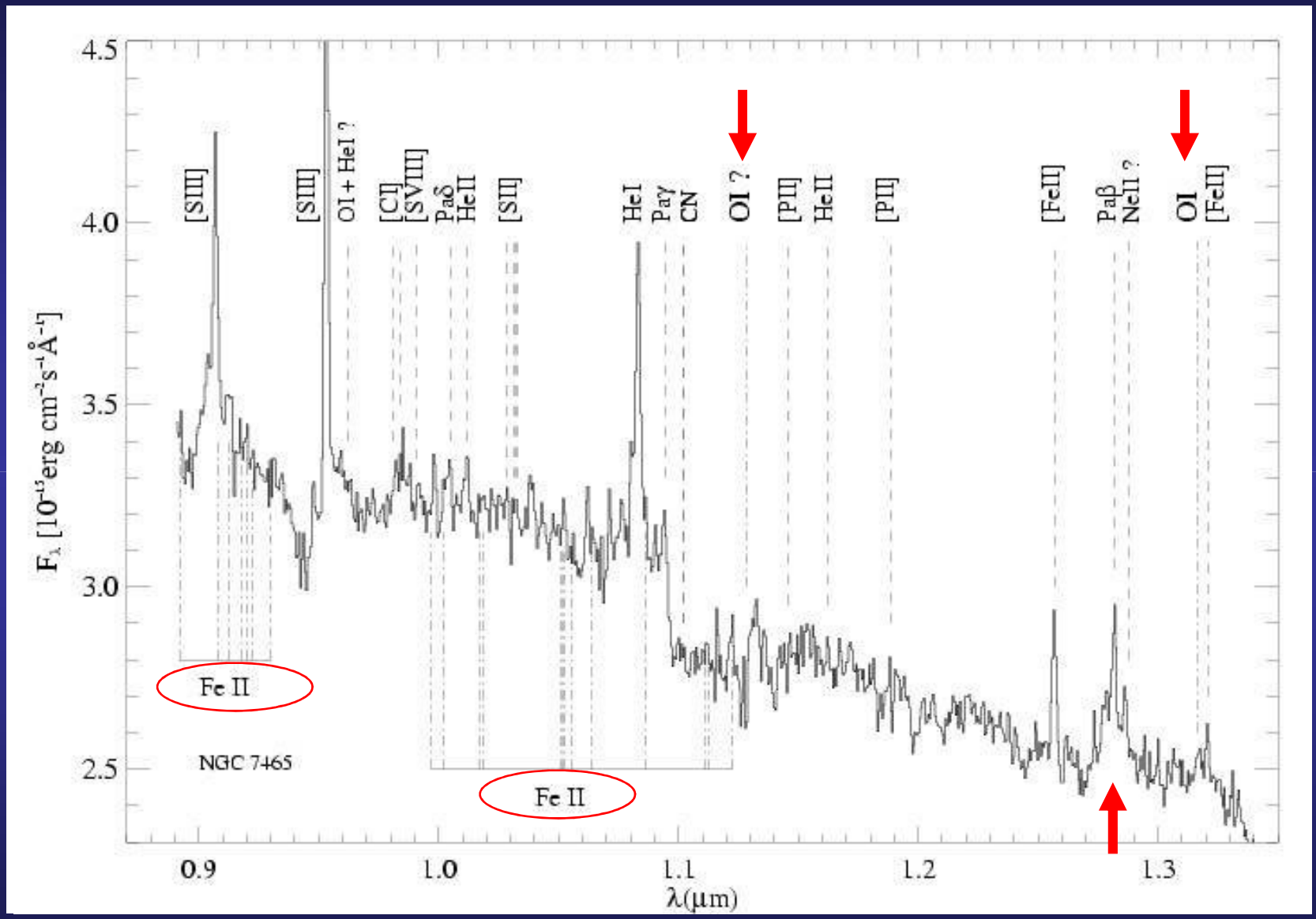
- Av α $\lambda^{-1.75}$ (Draine 1989).
  - Mrk348 => Av ~ 6 mag
  - Mrk1066 => Av ~ 4 mag
  - NGC7212 => Av ~ 2 mag
  - NGC7465 => Av ~ 1 mag
  - Mrk573 => Av < 1 mag

High extinct NLR



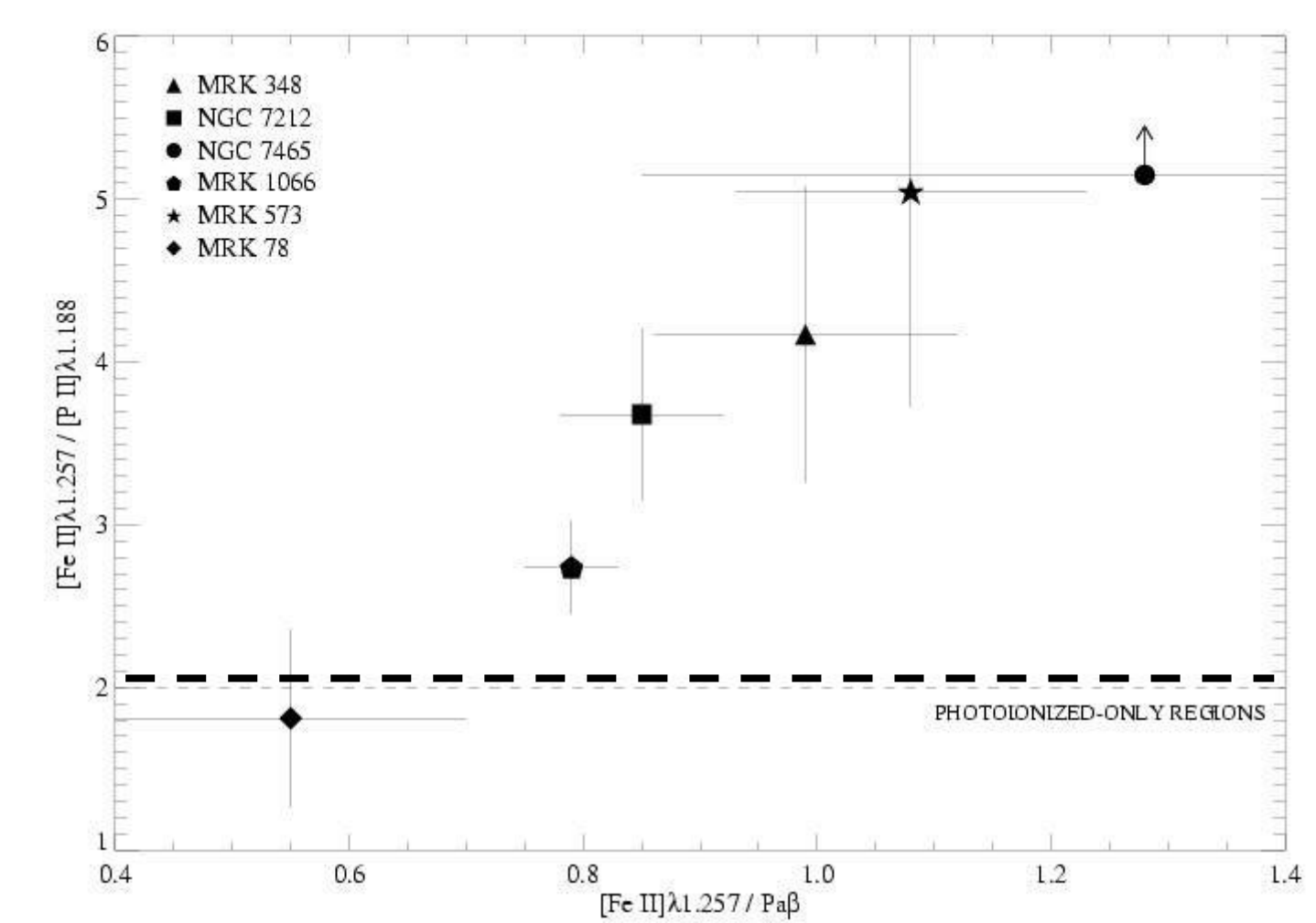
Less extinct NLR

- The two nuclei with broad emission lines detected (Mrk573 and NGC7465) have the less extinct NLRs.


4.5
4.0
3.5
3.0
2.5
F_λ [10^{-15}erg cm^{-2}s^{-1}Å^{-1}]
[SIII]
[SIII]
OI + HeI ?
[CI]
[SVIII]
Paδ
HeII
[SII]
HeI
Paγ
CN
OI ?
[PII]
HeII
[PII]
[FeII]
Paβ
NeII ?
OI
[FeII]
Fe II
NGC 7465
Fe II
0.9
1.0
1.1
1.2
1.3
λ(μm)

Photoionization vs Shock excitation

- [F … of
  [F
  R…
- [F
  re…



Conclusions

- Continua of the 5 galaxies modelled with combination of stellar templates + BB component associated with hot dust emission.
- UV/optical power-law contribution to near-infrared nuclear continuum negligible in Seyfert 2 galaxies.
- Stellar population of galaxies dominated by late-type giants, with average age between 100 Myr and 1 Gyr.
- Diferent values of the Av for the NLR of galaxies. These with detection of broad lines have the less extinguished NLRs.
- Coronal lines with IP > 100 eV detected in Mrk348, Mrk573 & NGC7212. Extremely faint or undetectable in NGC7465 & Mrk1066 => low-luminosity AGN nature.

Conclusions

- Not only photoionization, but also excitation due to radio-jet interaction is taken place in NLR of galaxies, based on diagnostic diagrams involving Fe and P.
- Several molecular lines in the K band, likely thermally excited, although UV fluorescence cannot be discarded.
- Detection of broad wings in Paα and Paβ profiles, together with O I and Fe II in Mrk573 => confirmation of its classification as obscured NLSy1 (Ramos Almeida et al. 2008).
- Reclassification for first time of NGC7465 as Type-1 LINER. Lack of high-ionization lines, strong H_2 emission, broad wings in Paβ and Brγ (FWHM > 2000 km/s) and O I and Fe II.

Work during the thesis.

- Near-infrared spectroscopy of Seyfert galaxies.
  - Nuclear and extended emission.
  - Interaction with radio emission.
  - Stellar populations in the nuclear regions.

- Mid-infrared photometry of Seyfert galaxies (ISOCAM data).
- High-resolution infrared SED analysis of Seyfert galaxies.
- Multiwavelength SED analysis of AGN at high-redshift.

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- "The Narrow-Line Region of the Sy2 Galaxy Mrk 78: An Infrared View."
  - Ramos Almeida et al. 2006, ApJ, 645, 148
- "Unveiling the Narrow-line Seyfert 1 Nature of Mrk 573 using Near-infrared Spectroscopy."
  - Ramos Almeida et al. 2008, ApJ, 680, L17
- "Near-infrared Spectroscopy of Seyfert Galaxies. Nuclear Activity and Stellar Population."
  - Ramos Almeida et al. 2009b, ApJ, in press

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- "The mid-infrared emission of Seyfert galaxies. A new analysis of ISOCAM data."
  - Ramos Almeida et al. 2007, AJ, 134, 2006
- "High Spatial Resolution SEDs of Seyfert Galaxies: A test for the Clumpy Torus Models."
  - Ramos Almeida et al. 2009c, in preparation
- "Characterization of AGN and their Hosts in the Extended Groth Strip: a Multiwavelength Analysis."
  - Ramos Almeida et al. 2009a, AJ, 137, 179

Thanks!