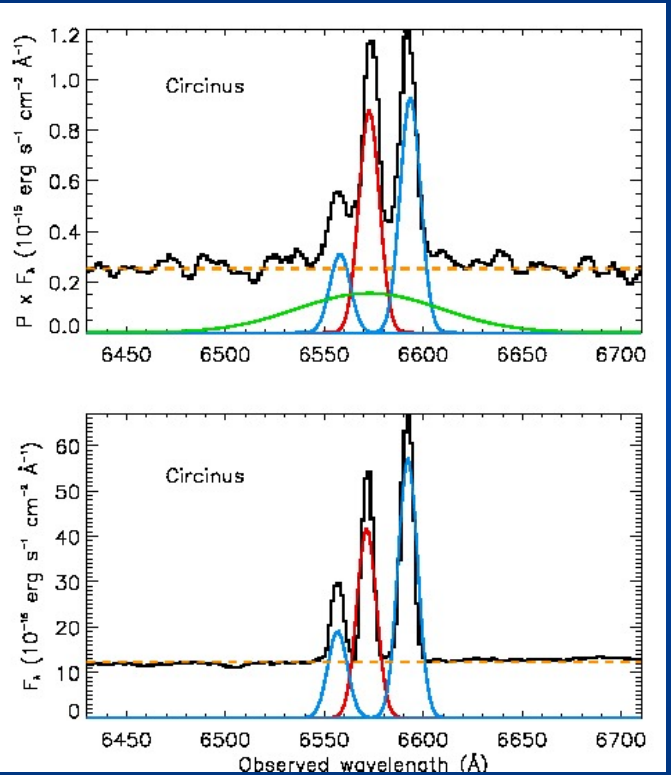
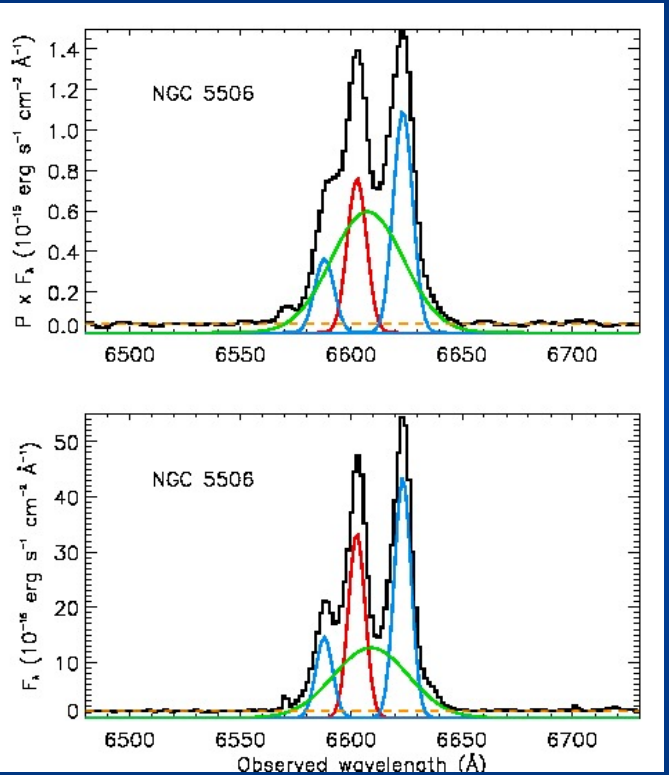
Upholding the unified model for AGN

VLT/FORS2 spectropolarimetry of Seyfert galaxies





Cristina Ramos Almeida – Marie Curie Fellow @ IAC

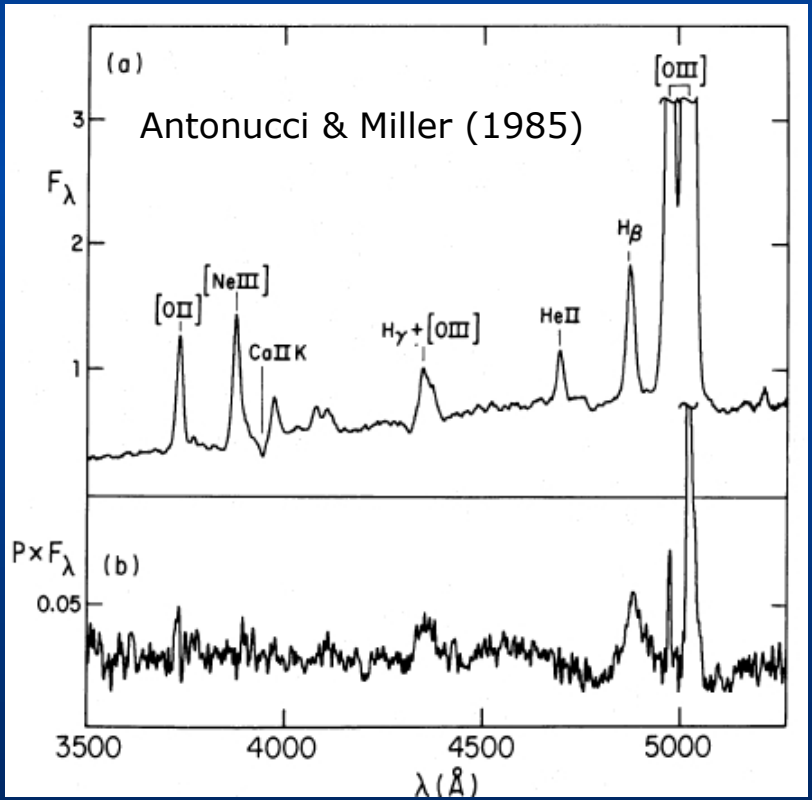
M. Martínez González, A. Asensio Ramos, J. Acosta Pulido,

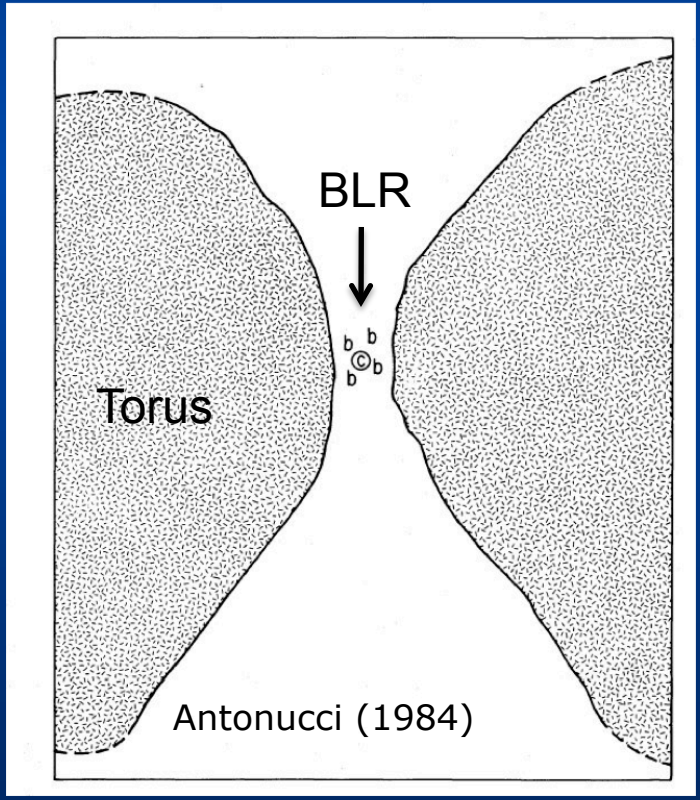
S. Hönig, A. Alonso-Herrero, C. Tadhunter

Introduction

Spectropolarimetry and torus properties

- Origin of unification scheme → detection of polarized broad lines in 3C234 (Antonucci 1984) and NGC 1068 (Antonucci & Miller 1985).





Introduction

Spectropolarimetry and torus properties

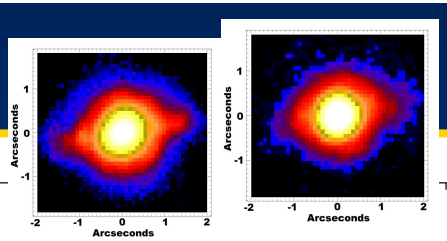
- Origin of unification scheme → detection of polarized broad lines in 3C234 (Antonucci 1984) and NGC 1068 (Antonucci & Miller 1985).

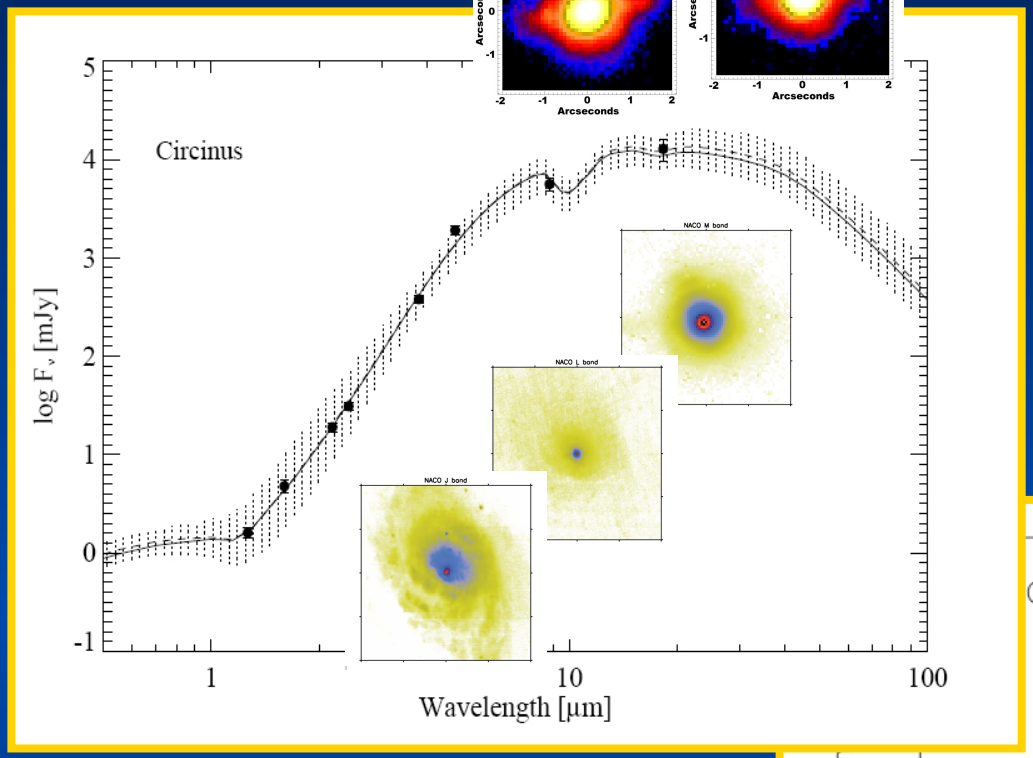
- Only 30-50% of nearby Sy2s show Sy1-type polarized spectrum (Moran et al. 2001; Tran 2001, 2003). Implications?

  - 1) not all Seyferts harbour a hidden BLR (Tran 2001, 2003; Gu & Huang 2002)
  - 2) distribution of dust within the torus and inclination not as simple as predicted by the unified model.

Results from our modelling could explain lack of polarized broad lines in 50-70% of nearby Seyfert 2 galaxies.

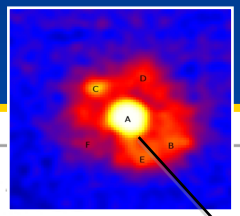
Circinus

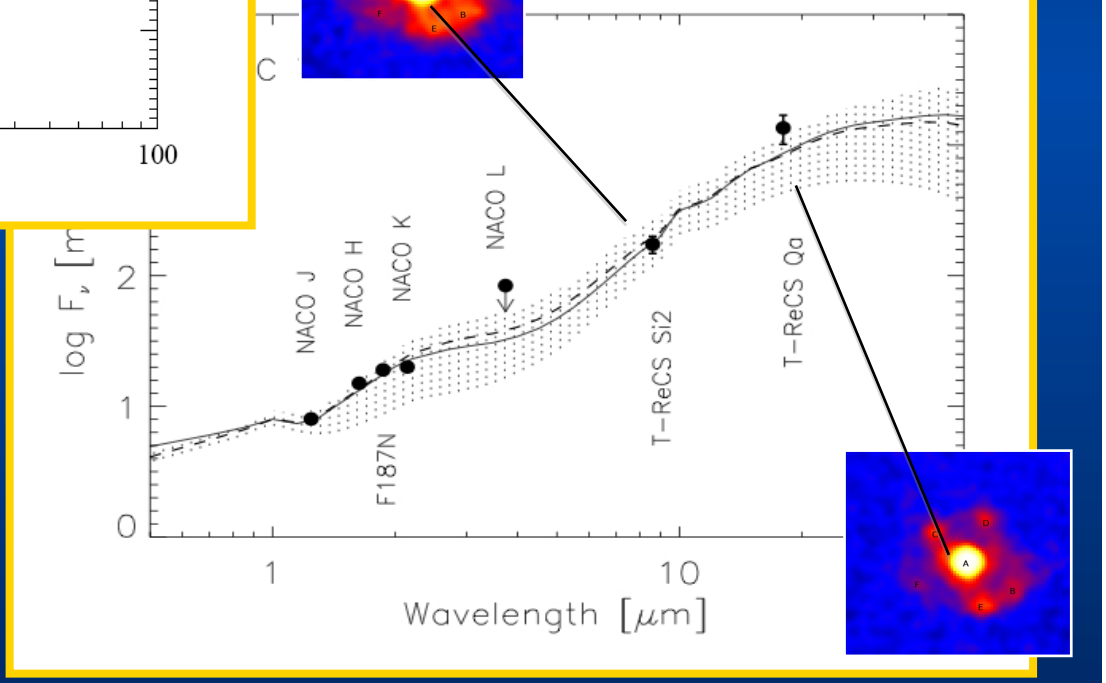




NIR data from NACO / VLT
(Prieto et al. 2010)

NGC 7469





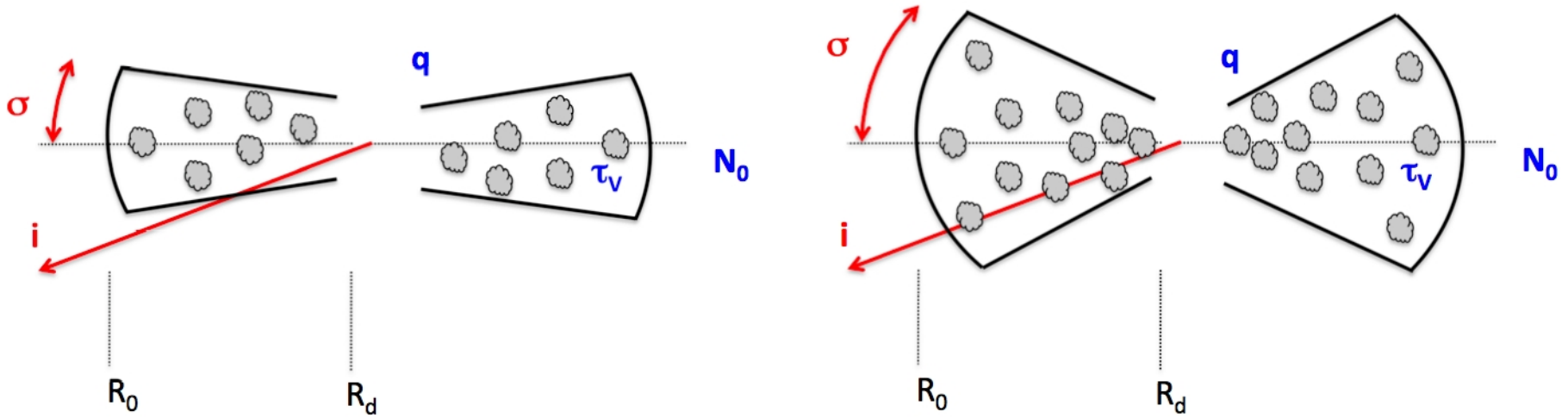
MIR data from T-ReCS /Gemini-South
(Packham et al. 2005; RA et al. 2011)

Motivation

Are the obscuring tori of Type 1 and 2 Seyferts different?

If all Seyfert nuclei are identical, as simple unification predicts, only the viewing angle determines the classification.

Our results suggest that the classification as Type-1 or Type-2 may also depend on the intrinsic properties of the torus, which vary from source to source as well.



Ramos Almeida et al. (2009, 2011, 2014)

Spectropolarimetry

VLT/FORS2

- Homogeneous dataset of polarized optical spectra of a representative sample of Seyfert galaxies with constraints on their torus properties.

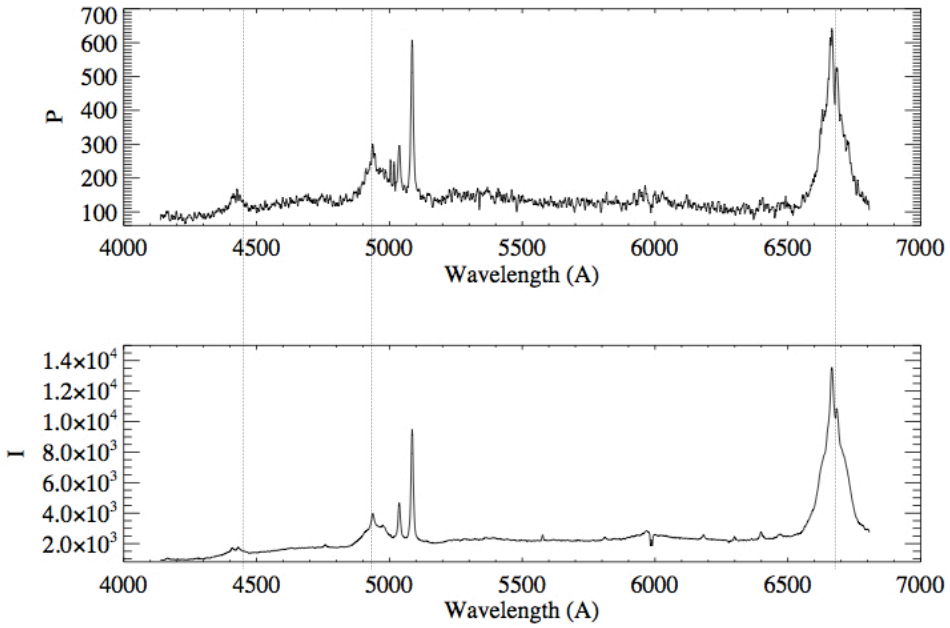
- FORS2/VLT observations → 19 objects
  (15 Seyfert 2 and 4 Seyfert 1 galaxies).

Spectropolarimetry

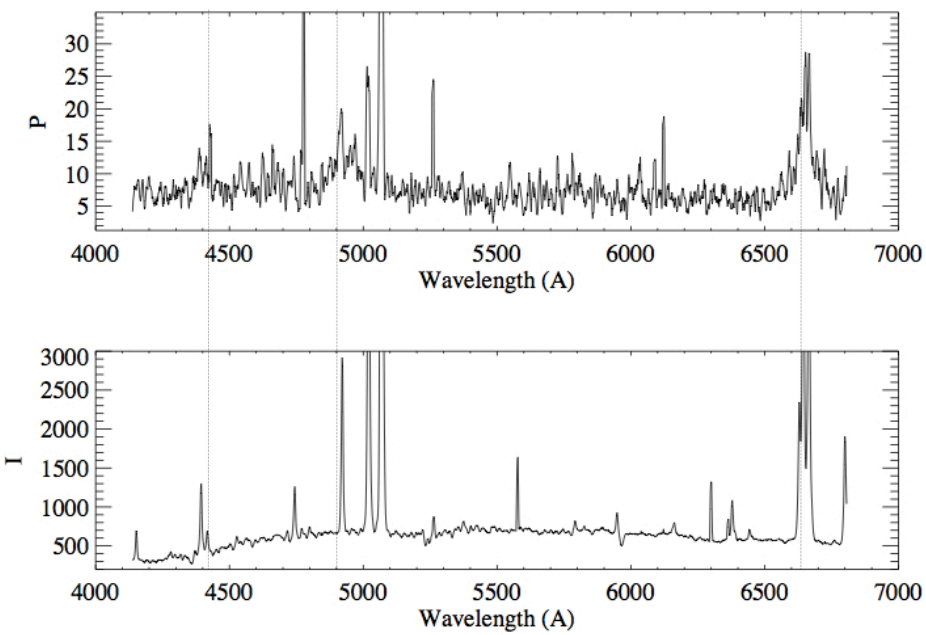
VLT/FORS2

- VLT/FORS2 spectropolarimetric observations of 15 Seyfert 2 and 4 Seyfert 1 galaxies in the range 4000-7000 Å – Hα, Hβ and Hγ.

Seyfert 1



Seyfert 2



Ramos Almeida et al. 2015, MNRAS, submitted

Spectropolarimetry of Sy2

VLT/FORS2

- VLT/FORS2 spectropolarimetric observations of 15 Seyfert 2 (Sy2) galaxies in the range 4000-7000 Å – Hα, Hβ and Hγ.

PROPERTIES OF THE SAMPLE AND DETAIL OF THE OBSERVATIONS.

Galaxy	Literature classif.	Published spectropol.	Ref.	i_{torus} (deg)	Ref.	Log n_H (cm^{-2})	Compton thick	Ref.	Aperture ($''$)	Exptime (s)
Circinus	HBLR	√	a	90	m	>24	√	1,2	1.0	250
IC 2560	...	×	...	90	n	>24	√	3	1.3	300
IC 5063	HBLR	√	b,c	80	o	23.3	×	1,2	1.6	200
NGC 2110	HBLR	√	d,e	40*	p	22.5	×	4	0.8	300
NGC 3081	HBLR	√	f	71	q	23.9	×	1	1.0	200
NGC 3281	NHBLR	×	g	62	r	23.9	×	5	1.1	300
NGC 3393	NHBLR	×	h†	90	n	>24	√	6	1.0	300
NGC 4388	HBLR	√	i,j	90	n	23.4	×	2	0.9	200
NGC 4941	NHBLR	×	g	76	s	23.6	×	2	0.8	300
NGC 5135	NHBLR	√	k,l	12	s	>24	√	1,2	0.8	300
NGC 5506	NHBLR‡	√	c	40	t	22.5	×	1,2	0.9	200
NGC 5643	NHBLR	×	g	74	q	23.8	×	1,2	0.8	300
NGC 5728	NHBLR	√	i§	90	n	>24	√	5	0.9	300
NGC 5793	...	×	...	90	n	...	...	...	1.1	300
NGC 6300	NHBLR	√	c	77	u	23.3	×	2	0.8	300

Spectropolarimetry of Sy2

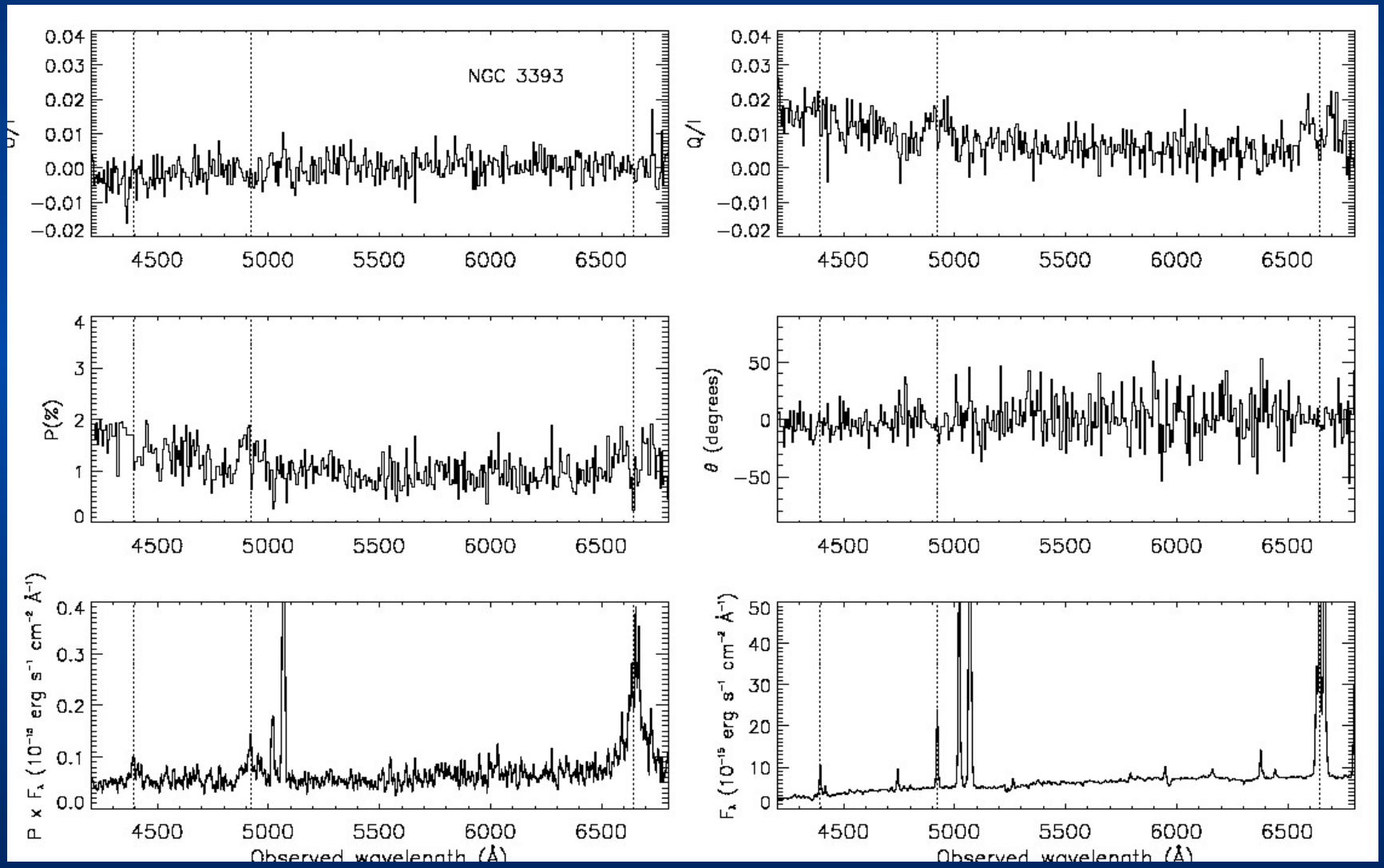
VLT/FORS2

- VLT/FORS2 spectropolarimetric observations of 15 Seyfert 2 (Sy2) galaxies in the range 4000-7000 Å – Hα, Hβ and Hγ.

- The sample includes galaxies previously classified as HBLR and non-HBLR (some of them without known spectropolarimetry).
  - Five Sy2 classified as HBLR based on previous data.
  - Four Sy2 classified as NHBLR based on previous data.
  - Six Sy2 without spectropolarimetry data.

Spectropolarimetry of Sy2

VLT/FORS2



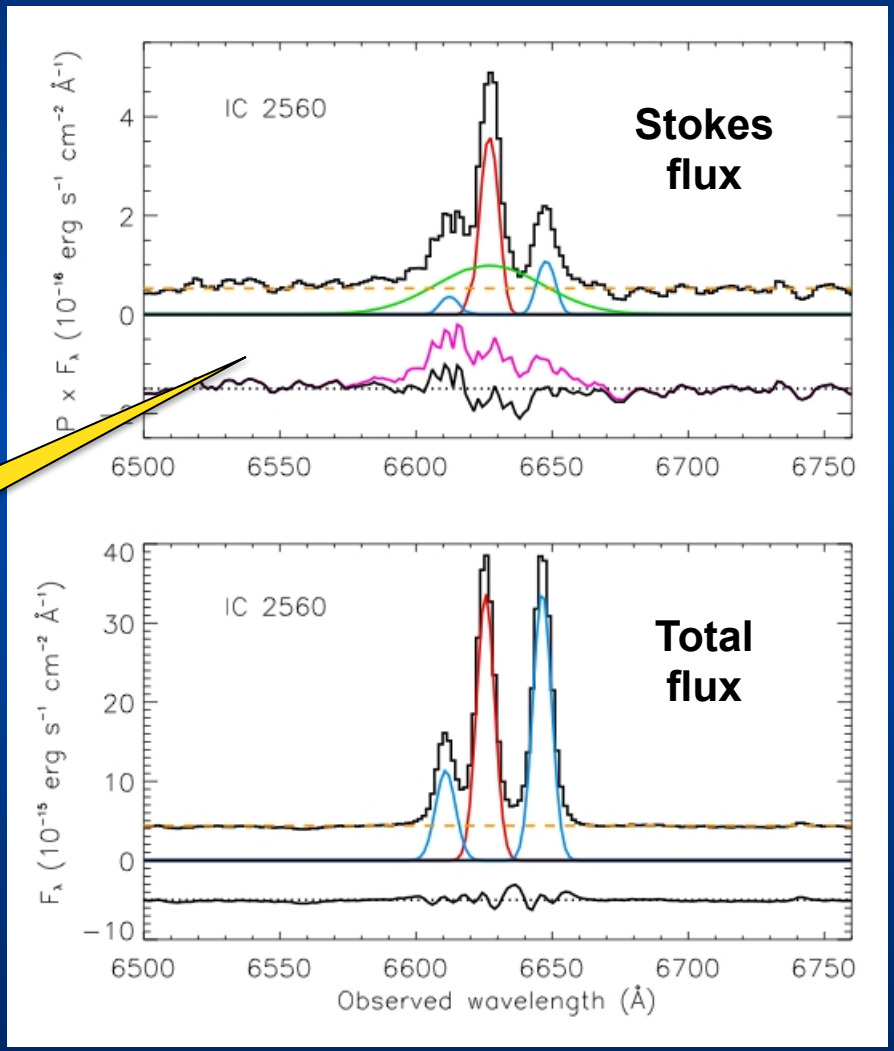
Spectropolarimetry of Sy2

VLT/FORS2

- We fit Gaussian components to the emission line profiles in total and Stokes flux spectra using DIPSO.

Narrow lines 300 km/s

Broad line 2100 km/s



Spectropolarimetry of Sy2

VLT/FORS2

- VLT/FORS2 spectropolarimetric observations of 15 Seyfert 2 (Sy2) galaxies in the range 4000-7000 Å – Hα, Hβ and Hγ.

- We detect scattered broad lines in 14/15 galaxies at the 3σ level.

  – 14 galaxies with detections include sources classified in the literature as HBLR and non-HBLR.

  – For the Seyfert 2 galaxy NGC 5793 we detect broad Hα at the 2σ level.

  – FWHMs range between 1300 and 9600 km/s.

Ramos Almeida et al. submitted to MNRAS

Spectropolarimetry of Sy2

VLT/FORS2

- VLT/FORS2 spectropolarimetric observations of 15 Seyfert 2 (Sy2) galaxies in the range 4000-7000 Å – Hα, Hβ and Hγ.

- We detect scattered broad lines in 14/15 galaxies at the 3σ level.

Some NHBLR misclassified → publications reporting differences between HBLR/NHBLR objects questioned.

Spectropolarimetry of Sy2

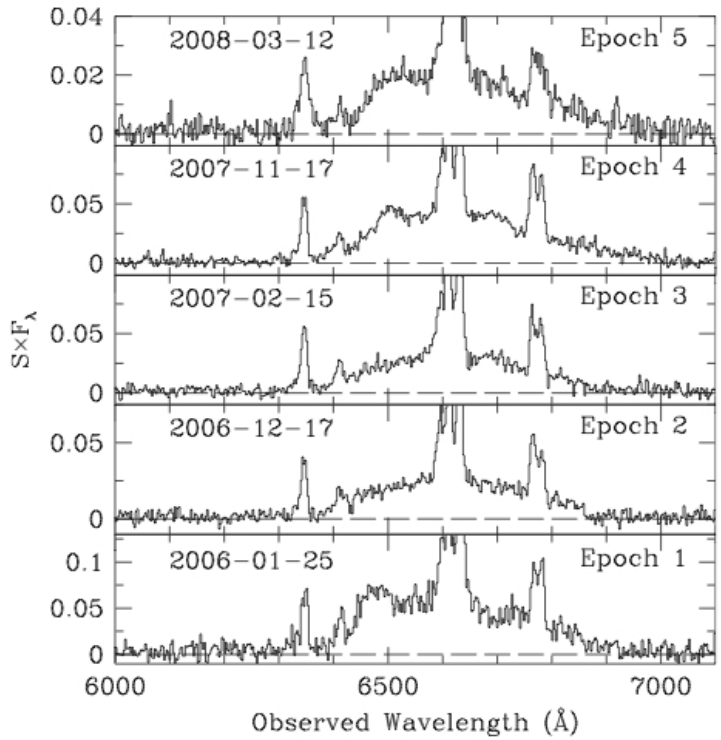
VLT/FORS2

Galaxy	Δ_U	Δ_Q	$P_{H\alpha}$ (%)	$\theta_{H\alpha}$ (deg)	P_V (%)	θ_V (deg)	Hα FWHM (km s^{-1})	Hβ FWHM (km s^{-1})
Circinus[†]	4.2	5.1	2.30±0.06	43±1	2.20±0.02	43±3	2300±500	2800±2700
IC 2560	-4.7	1.1	0.82±0.08	104±2	0.77±0.03	91±1	2100±300	1800±1000
IC 5063	4.0	0.3	5.08±0.37	-1±3	3.54±0.23[§]	-6±4	2800±200	2600±600
NGC 2110[‡]	15.5	-20.7	2.62±0.07	71±2	0.66±0.03	73±2	9600±1400	9500±4800
NGC 3081	-2.4	-5.9	0.54±0.08	89±2	0.29±0.03	86±8	2700±700	3000±2100
NGC 3281	-4.0	3.5	1.09±0.20	89±1	0.96±0.03	94±3	2700±700	3500±2200
NGC 3393	-0.5	10.4	1.16±0.07	2±1	0.63±0.02	2±4	5000±600	5100±800
NGC 4388	-7.2	1.1	0.78±0.11	128±19	0.53±0.04	95±9	5700±1900	5000±2300
NGC 4941	4.5	-0.9	0.24±0.06	38±11	0.06±0.02	18±7	3100±600	3100
NGC 5135	-4.0	-0.9	0.43±0.05	106±6	0.43±0.02	104±3	3600±1000	3700±1900
NGC 5506	3.1	-5.7	3.29±0.15	77±1	2.73±0.05	75±1	1750±50	1700±300
NGC 5643	6.3	1.7	1.08±0.05	77±3	1.15±0.02	83±1	1300±400	1300±700
NGC 5728	3.4	-1.9	1.57±0.06	57±1	1.40±0.02	57±1	1900±100	1900
NGC 5793	-2.3	1.3	0.18±0.08	118±12	0.08±0.03	86±13	3500±1200	...
NGC 6300	-1.1	-6.4	0.82±0.09	69±4	0.80±0.03	50±5	4200±2800	...

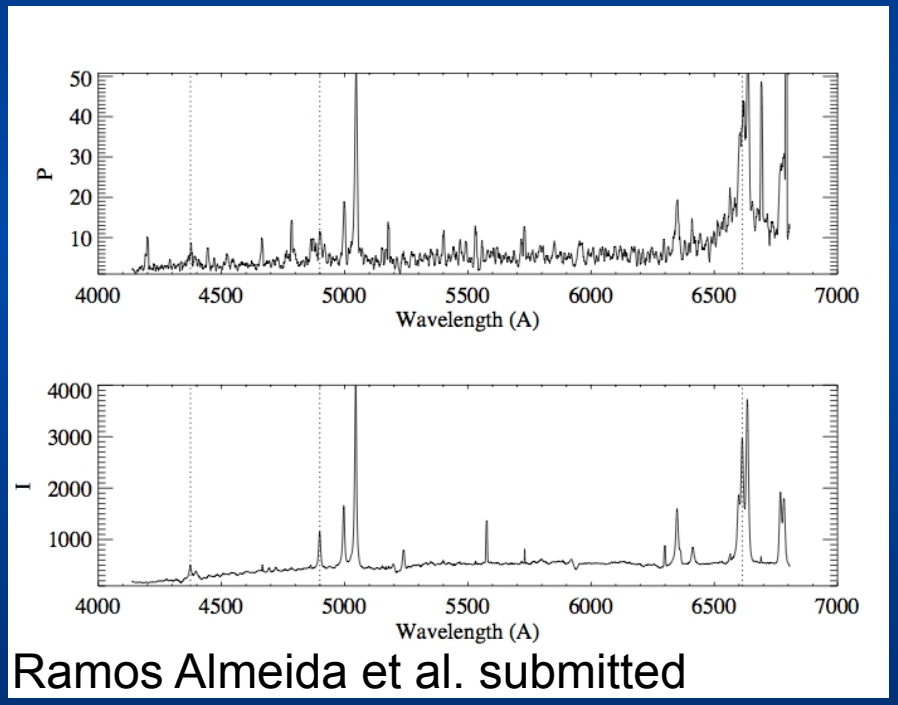
Spectropolarimetry of Sy2

VLT/FORS2

- The broadest lines observed: NGC 2110 (FWHM ~ 10.000 km/s)



Tran (2010)



Ramos Almeida et al. submitted

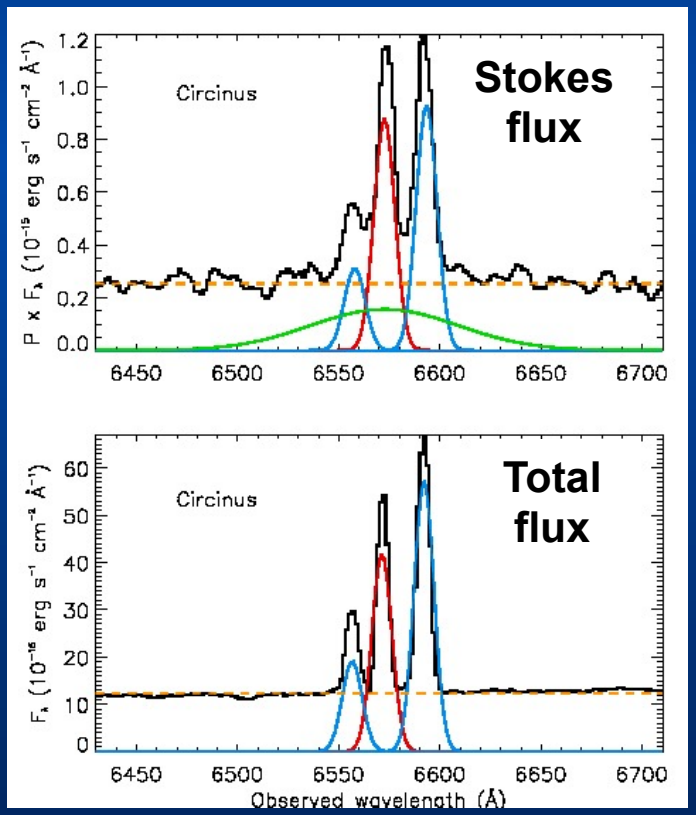
Broad lines display significant variability in strength and profile on timescales of 1 yr.

Spectropolarimetry of Sy2

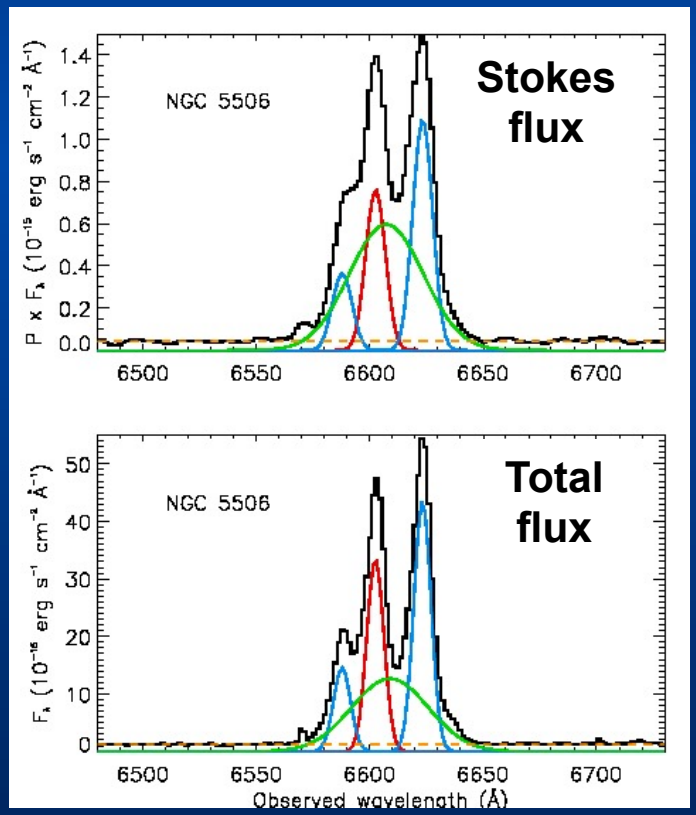
VLT/FORS2

- We can divide the Seyfert 2 galaxies in two groups attending to the FWHM of the polarized broad components.

FWHM > 2000 km/s



FWHM < 2000 km/s



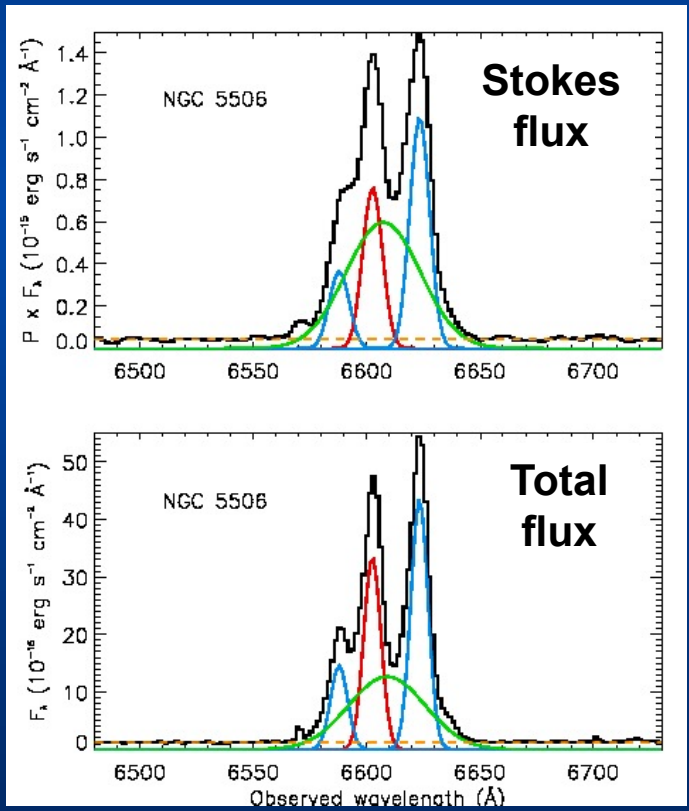
Spectropolarimetry of Sy2

VLT/FORS2

- Three Sy2 show polarized broad components of FWHM < 2000 km/s: NGC 5506, NGC 5643, and NGC 5728.

- Are these “broad” components the intermediate ones often detected in near-infrared observations?

  – NGC 5506 (Nagar et al. 2002)
  – Mrk 573 (Ramos Almeida et al. 2008)



Spectropolarimetry of Sy2

VLT/FORS2

- Broad components in both Compton-thin and Compton-thick souces – no correlation between N_H and detectability of scattered broad lines.

- No correlation between torus inclination and properties of polarized spectra (P, θ, FHWM broad lines, peak intensity ratios), but see Marin (2014) for a sample of 53 AGN.

  – Scale height of scattering region too large for the scattered light to be detected whatever the torus inclination? (see Ichikawa et al. 2015).

  – The majority of our torus inclination constraints model-dependent & we are biased to edge-on orientations → larger and complete sample observations required.

Summary

Ramos Almeida et al. submitted to MNRAS

- We detect polarized broad lines in 14/15 galaxies at the 3σ level. For the Sy2 NGC 5793 we detect broad Hα at the 2σ level.
- Some galaxies previously treated as NHBLR misclassified → publications reporting differences between HBLR/NHBLR objects brought into question.
- We detect scattered broad Hα and Hβ components in 13 targets, and just broad Hα in the other two.
- We can divide the sample in two groups attending to the FWHM of the scattered broad lines (FWHM < 2000 km/s or FWHM > 2000 km/s).

This research was supported by a Marie Curie Intra European Fellowship within the 7th European Community Framework Programme.

MARIE CURIE ACTIONS