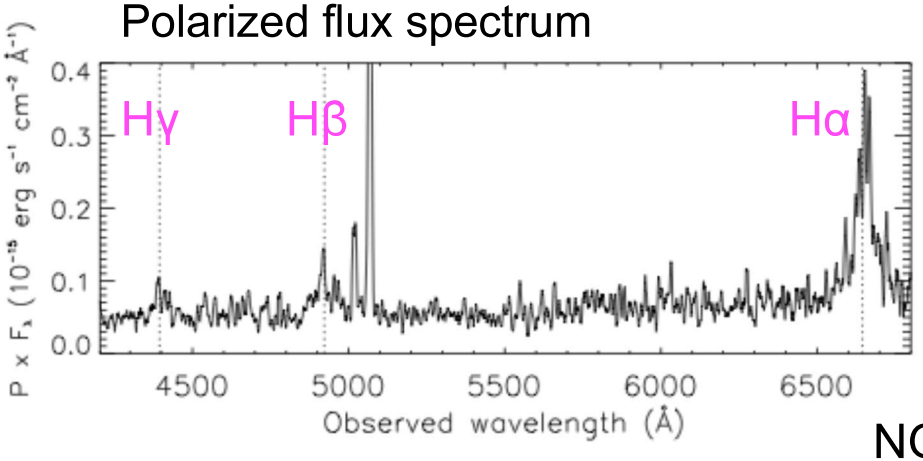
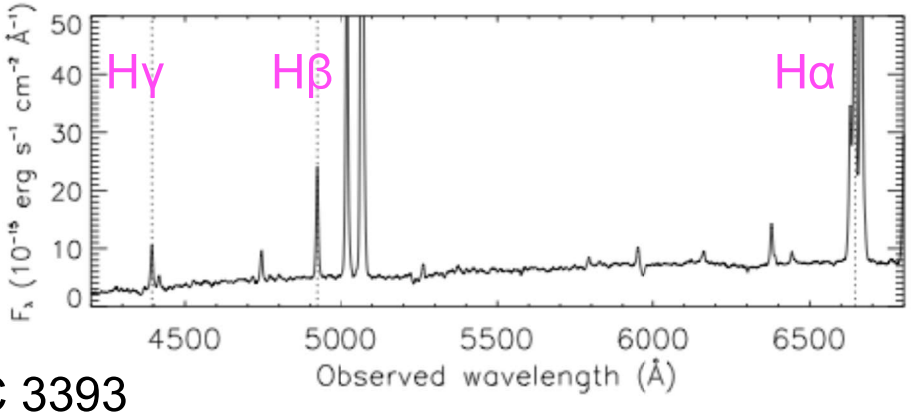
Upholding the unified model for AGN

VLT/FORS2 spectropolarimetry of Seyfert 2 galaxies

Polarized flux spectrum



Total flux spectrum



NGC 3393

Cristina Ramos Almeida – Ramón y Cajal fellow @ IAC

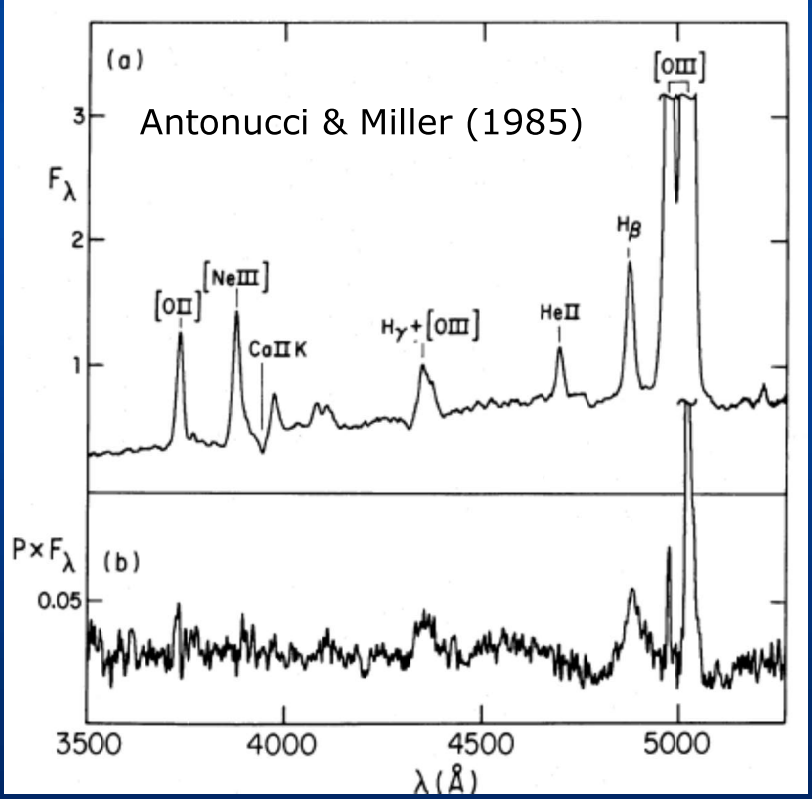
M. Martínez González, A. Asensio Ramos, J. Acosta Pulido,

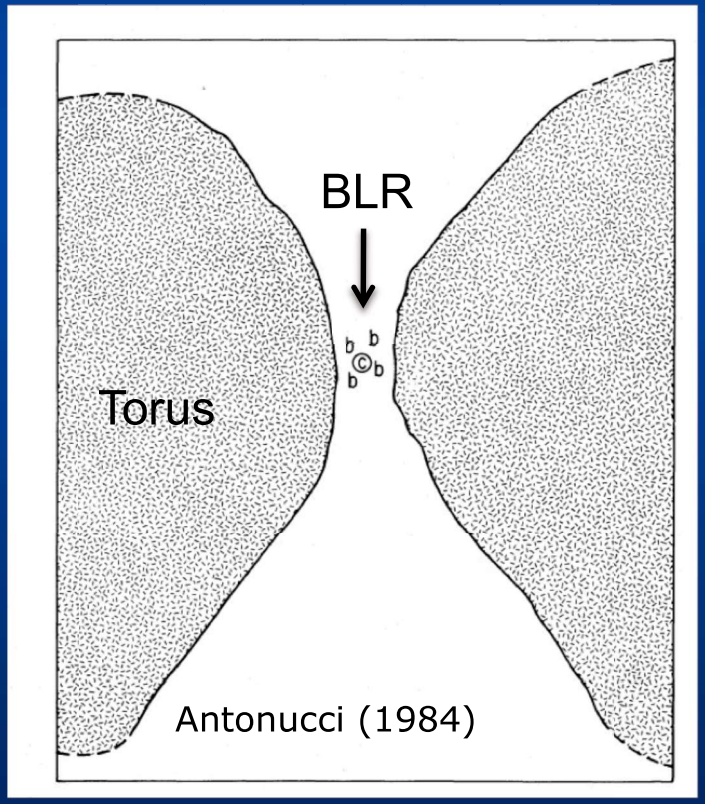
S. Hönig, A. Alonso-Herrero, C. Tadhunter & O. González-Martín

Introduction

Spectropolarimetry and torus properties

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





Introduction

Spectropolarimetry and torus properties

- Origin of AGN unification → 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.

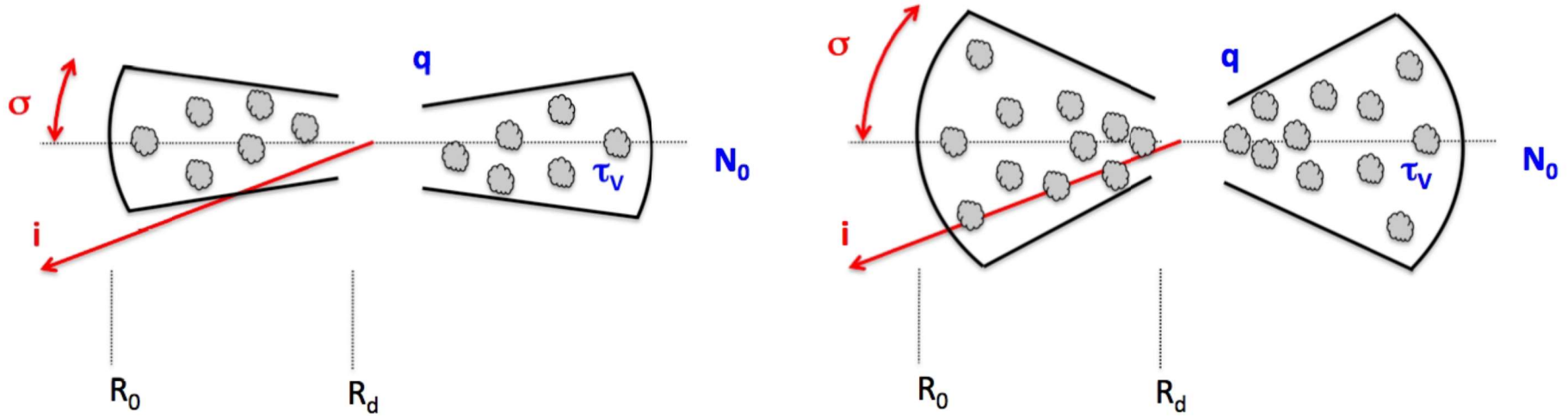
Results from our modelling could explain lack of polarized broad lines in 50-70% of nearby Seyfert 2 galaxies.

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); Mateos et al. (2016)

Spectropolarimetry

VLT/FORS2

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

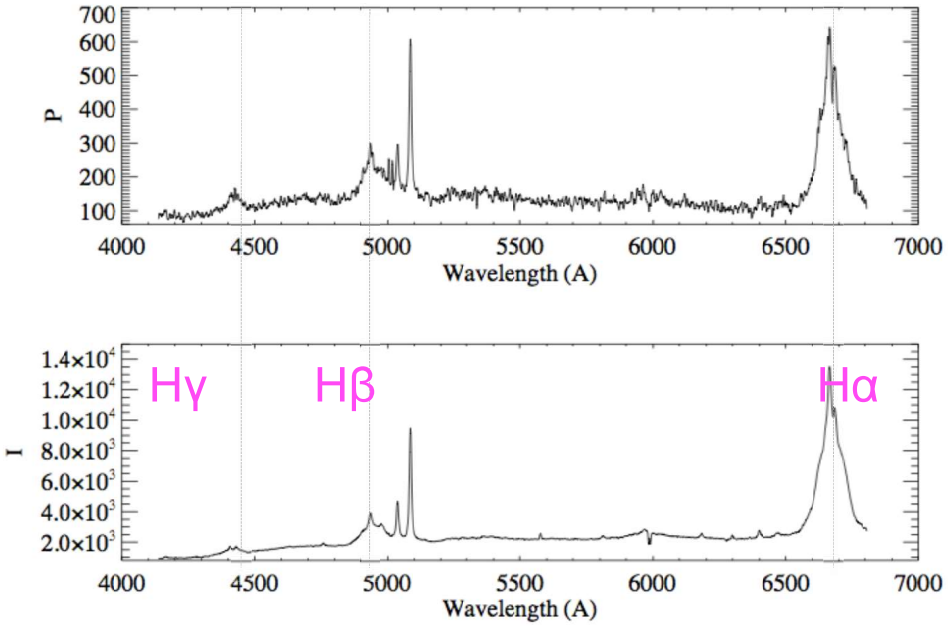
- FORS2/VLT observations → 19 objects
  (15 Seyfert 2 and 4 Seyfert 1 galaxies).

Spectropolarimetry

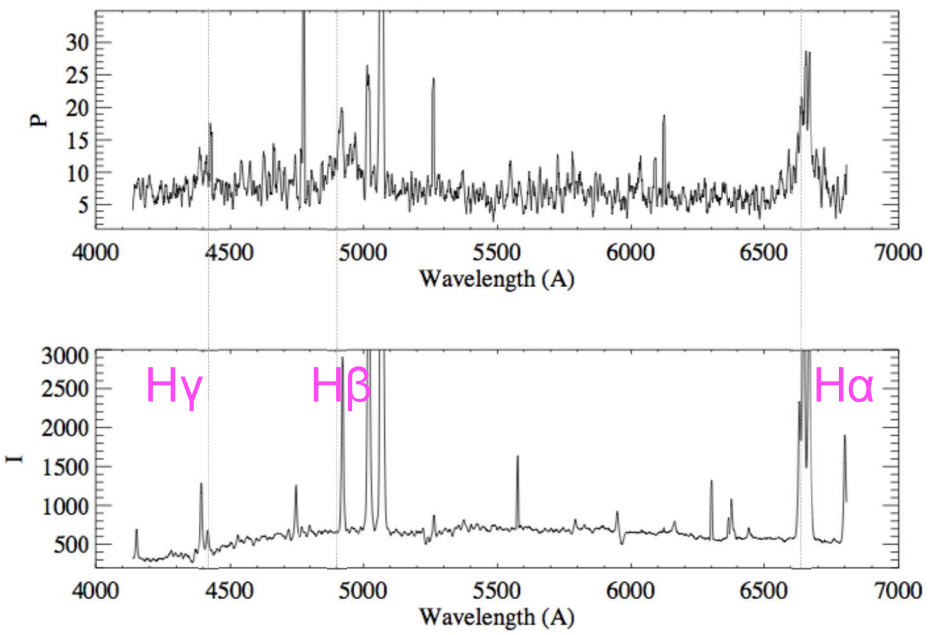
VLT/FORS2

- VLT/FORS2 spectropolarimetry 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. 2016, MNRAS, in press

Spectropolarimetry of Sy2

VLT/FORS2

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

Galaxy	Previous classification			Axis ratio	i_{torus}	Ref.	σ_{torus}	Ref.	log n_H	Compton	log L^{int}_{2-10}	log L_{bol}	Ref.
	Type	Data	Ref.	(b/a)	(deg)		(deg)		(cm^{-2})	thick	(erg s^{-1})	(erg s^{-1})	
Circinus	HBLR	√	a	0.44	90	m	60	s1	>24.5	√	42.6	43.8	1
IC 2560	...	×	...	0.63	90	n	...	...	>24.5	√	41.8	43.1	2
IC 5063	HBLR	√	b,c	0.68	80	o	60	s2	23.4	×	42.8	44.0	1
NGC 2110	HBLR	√	d,e	0.74	40*	p	45	s3	22.5	×	42.5	43.9	3
NGC 3081	HBLR	√	f	0.78	71	q	75	s4	23.9	×	42.5	43.6	1
NGC 3281	NHBLR	×	g	0.50	62	r	50	s5	23.9	×	42.6	43.8	1
NGC 3393	NHBLR	×	h†	0.91	90	n	67	s6	>24.5	√	41.6	42.9	2,4
NGC 4388	HBLR	√	i,j	0.23	90	n	45	s7	23.5	×	42.9	44.1	1
NGC 4941	NHBLR	×	g	0.54	76	s	50	s8	23.8	×	41.3	42.6	5
NGC 5135	NHBLR	√	k,l	0.71	12	s	60	s9	>24.5	√	43.1	44.4	1
NGC 5506	NHBLR‡	√	c	0.30	40	t	45	s10	22.5	×	43.0	44.3	1
NGC 5643	NHBLR	×	g	0.87	74	q	60	s11	>24.5	√	42.1	43.4	6,7
NGC 5728	NHBLR	√	i§	0.57	90	n	60	s12	>24.5	√	43.3	44.6	1
NGC 5793	...	×	...	0.34	90	n	...	...	>24.5	√	42.1	43.4	8
NGC 6300	NHBLR	√	c	0.66	77	u	...	...	23.3	×	41.8	43.1	9

Spectropolarimetry of Sy2

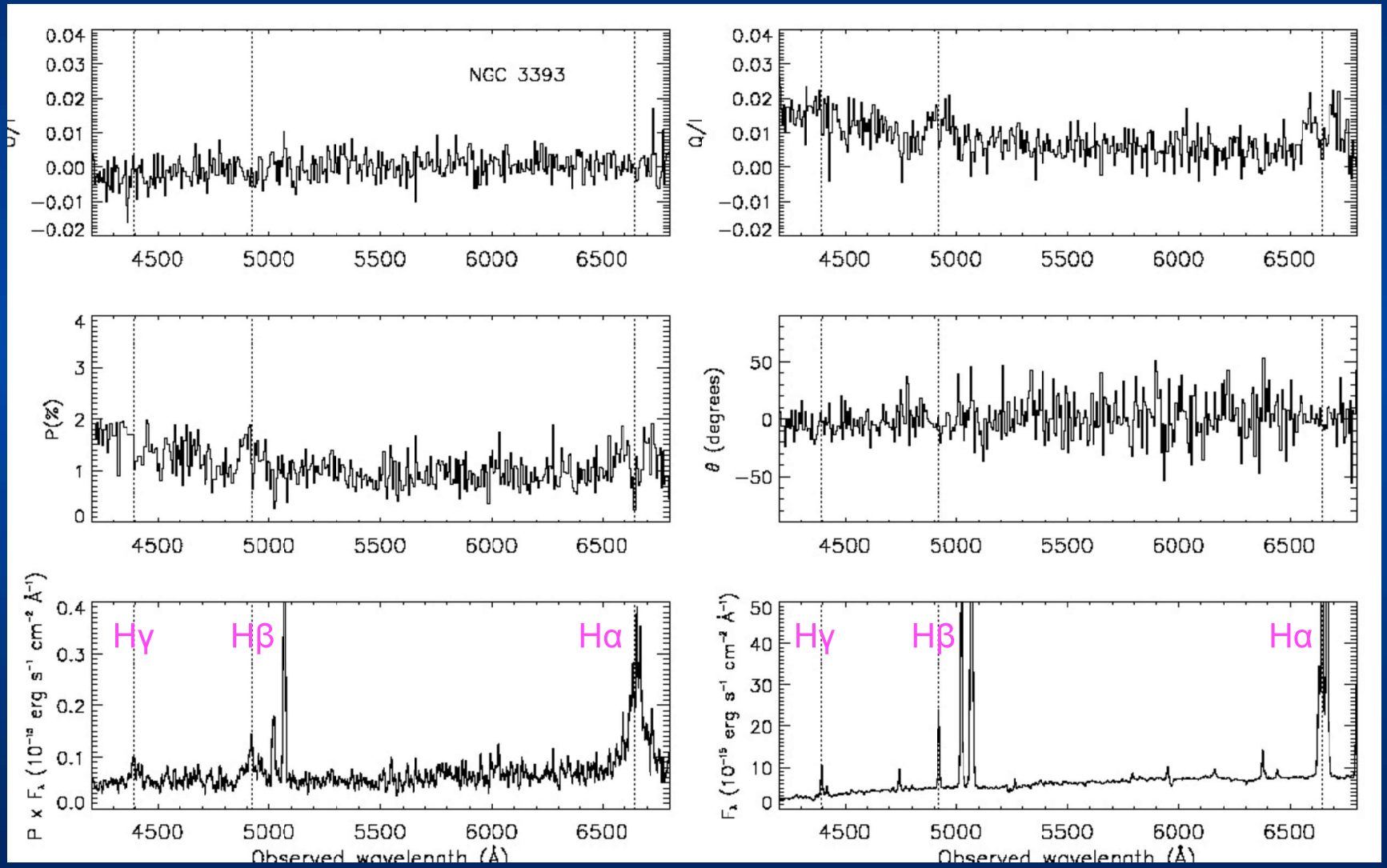
VLT/FORS2

- VLT/FORS2 spectropolarimetry 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 published data!).
  - 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



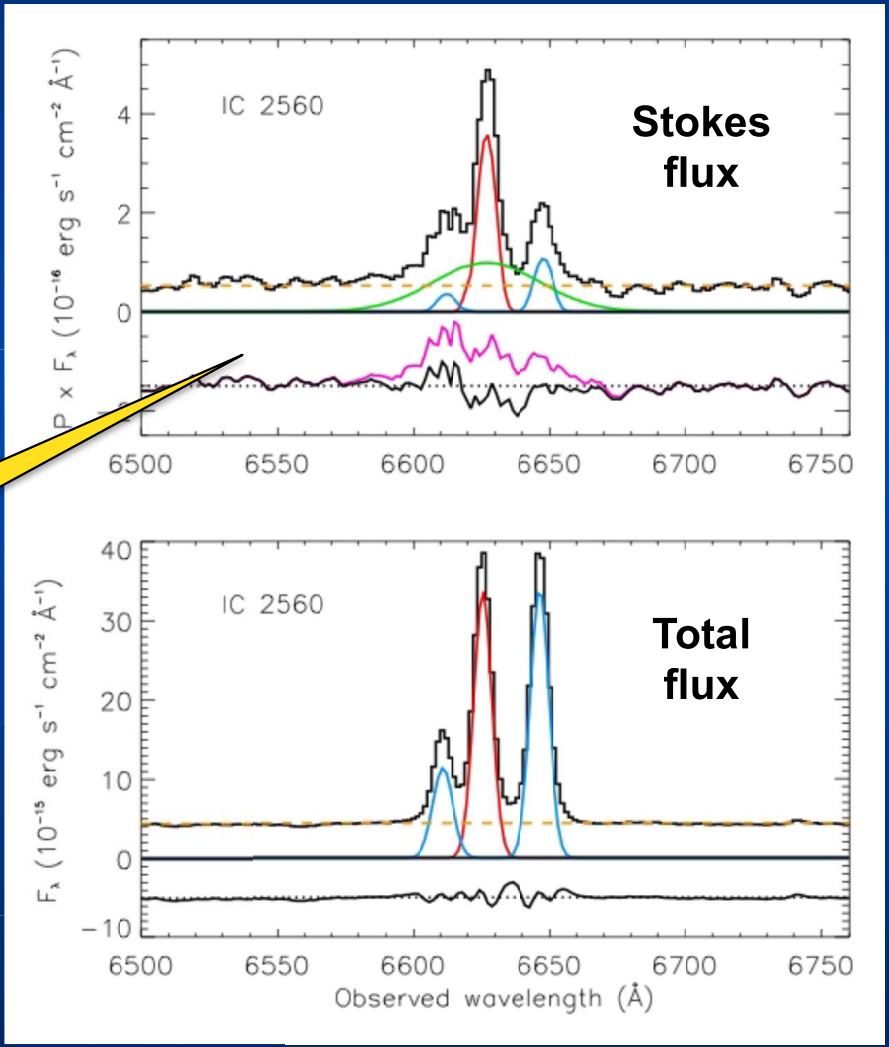
Spectropolarimetry of Sy2

VLT/FORS2

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

Narrow lines 300 km/s

Broad line 2100 km/s



Spectropolarimetry of Sy2

VLT/FORS2

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

- We detect scattered broad lines in 11/15 galaxies at ≥4σ (73%).

  – 11 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.

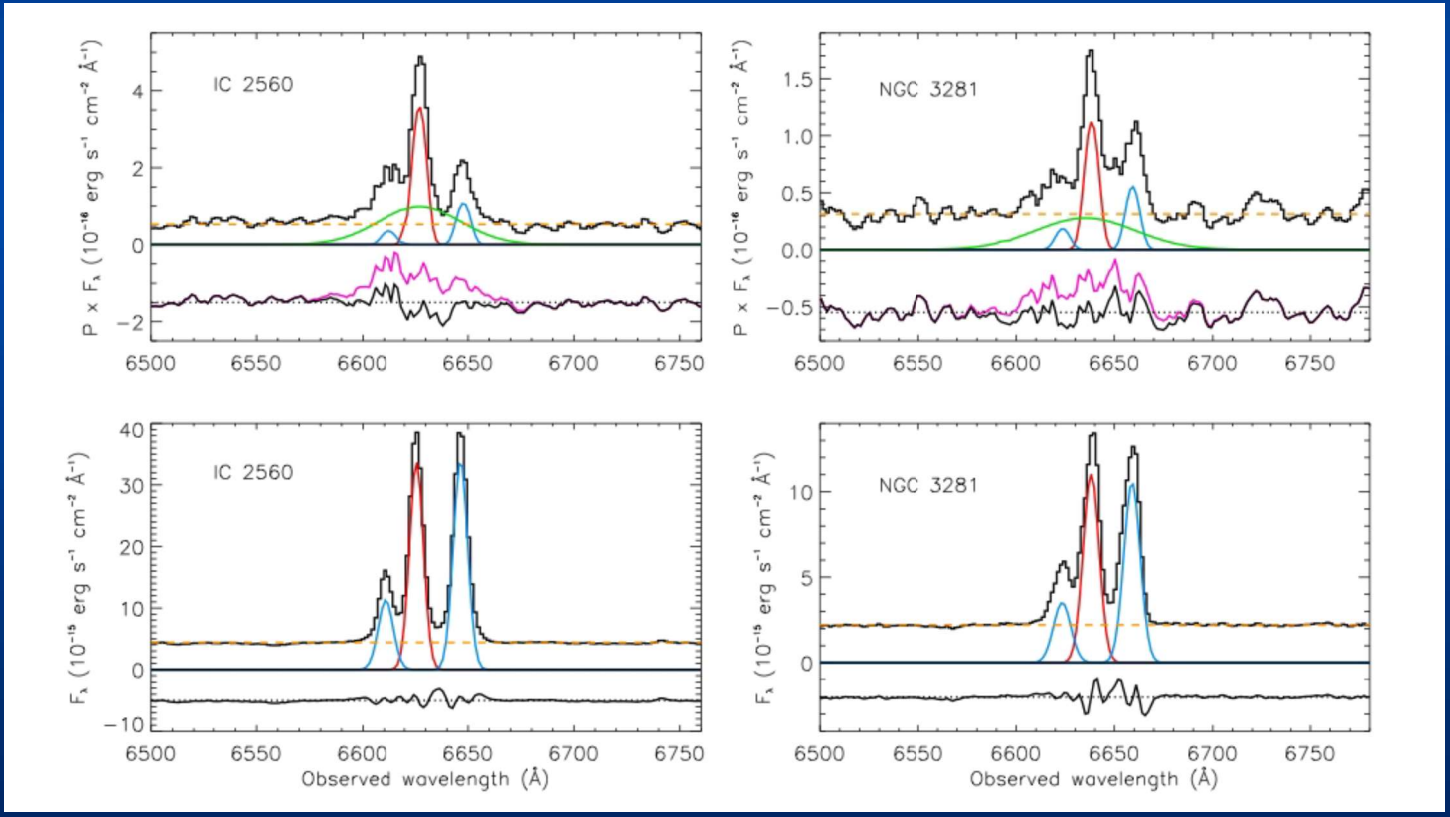
  – FWHMs range between 2000 and 10000 km/s.

Ramos Almeida et al. 2016, MNRAS, in press

Spectropolarimetry of Sy2

VLT/FORS2

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



Spectropolarimetry of Sy2

VLT/FORS2

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

- We detect scattered broad lines in 11/15 galaxies at ≥4σ (73%).

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

Spectropolarimetry of Sy2

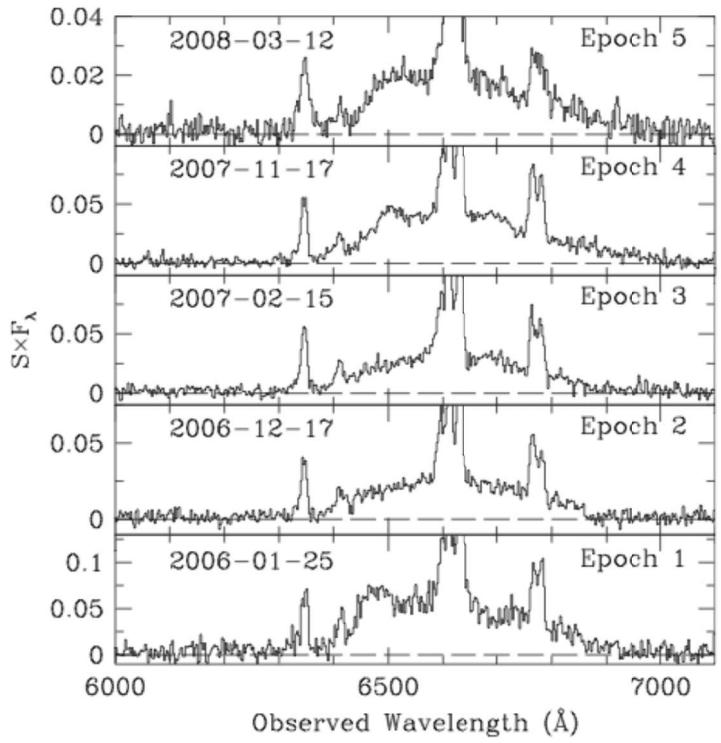
VLT/FORS2

Galaxy	Apt. (″)	Exp. (s)	Δ_U	Δ_Q	BIC Hα	$P_{H\alpha}$ (%)	$\theta_{H\alpha}$ (deg)	P_V (%)	θ_V (deg)	Hα FWHM (km s^{-1})	Hβ FWHM (km s^{-1})	HBLR
Circinus†	1.0	250	4.4	4.9	228	1.77±0.06	19±2	1.71±0.02	17±3	2300±500	2800±2700	√
IC 2560	1.3	300	-4.7	1.1	363	0.82±0.08	104±2	0.77±0.03	91±1	2100±300	1800±1000	√
IC 5063	1.6	200	4.0	0.3	3865	5.08±0.37	-1±3	3.54±0.23§	-6±4	2800±200	2600±600	√
NGC 2110†	0.8	300	15.5	-20.7	2214	2.54±0.07	75±2	0.67±0.03	87±4	9600±1400	9500±4800	√
NGC 3081	1.0	200	-2.4	-5.9	59	0.54±0.08	89±2	0.29±0.03	86±8	2700±700	3000±2100	√
NGC 3281	1.1	300	-4.0	3.5	98	1.09±0.20	89±1	0.96±0.03	94±3	2700±700	3500±2200	√
NGC 3393	1.0	300	-0.5	10.4	744	1.16±0.07	2±1	0.63±0.02	2±4	5000±600	5100±800	√
NGC 4388	0.9	200	-7.2	1.1	157	0.78±0.11	128±19	0.53±0.04	95±9	4500±1400	4300±1100	√
NGC 4941	0.8	300	4.5	-0.9	10	0.24±0.06	38±11	0.06±0.02	18±7	2900±700	2900	√
NGC 5135‡	0.8	300	-4.0	-0.9	75	0.67±0.08	105±7	0.66±0.03	104±3	3400±1200	3700±1900	√
NGC 5506‡	0.9	200	-3.3	5.6	...	6.62±0.62	77±3	11.5±0.2	75±2	...	...	?
NGC 5643	0.8	300	3.7	1.6	...	1.08±0.05	77±3	1.15±0.02	83±1	...	...	×
NGC 5728	0.9	300	3.4	-1.9	...	1.57±0.06	57±1	1.40±0.02	57±1	...	...	×
NGC 5793	1.1	300	-2.3	1.3	9	0.18±0.08	118±12	0.08±0.03	86±13	3500±1200	...	?
NGC 6300	0.8	300	-1.1	-6.4	15	0.82±0.09	69±4	0.80±0.03	50±5	4200±2800	...	√

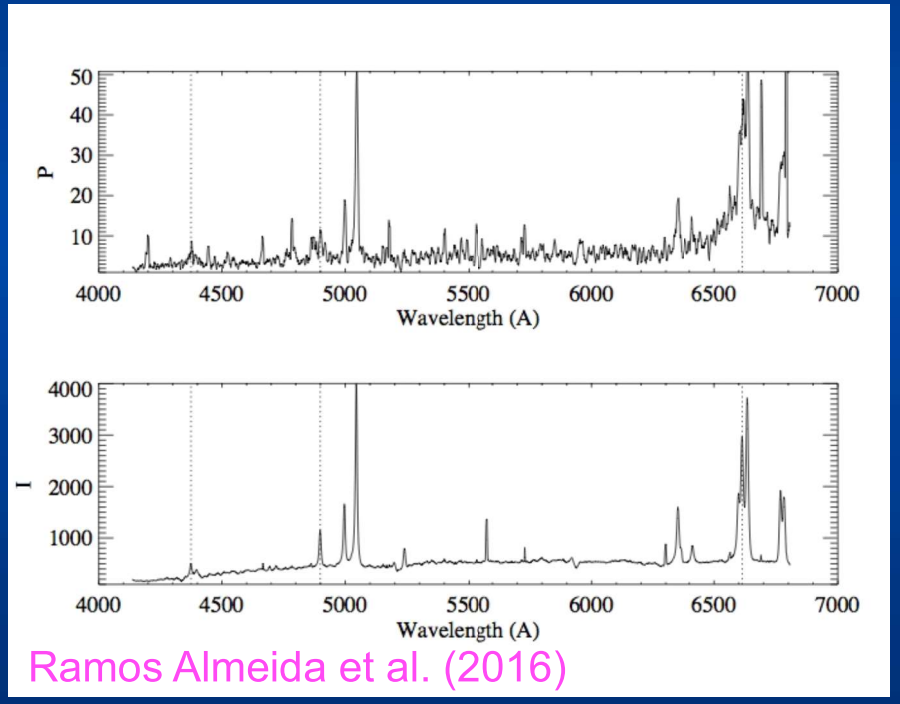
Spectropolarimetry of Sy2

VLT/FORS2

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



Tran (2010)



Ramos Almeida et al. (2016)

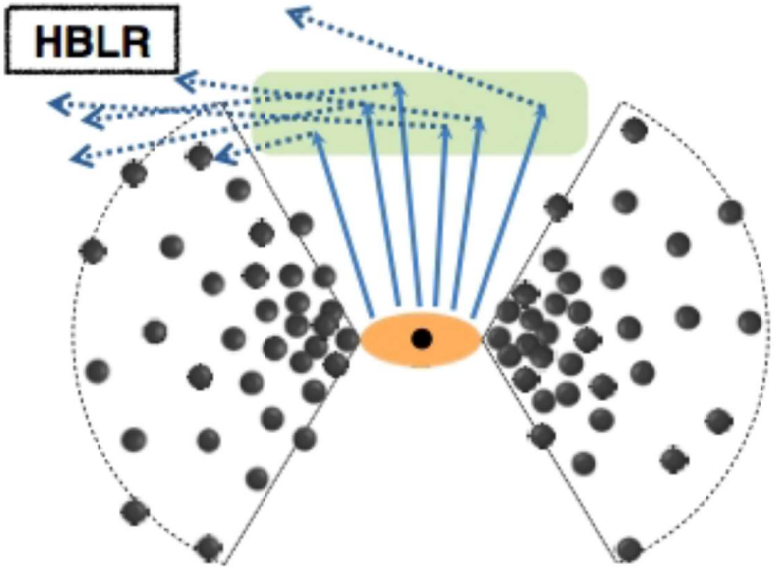
Broad lines display significant variability in strength and profile on timescales of 1 yr.

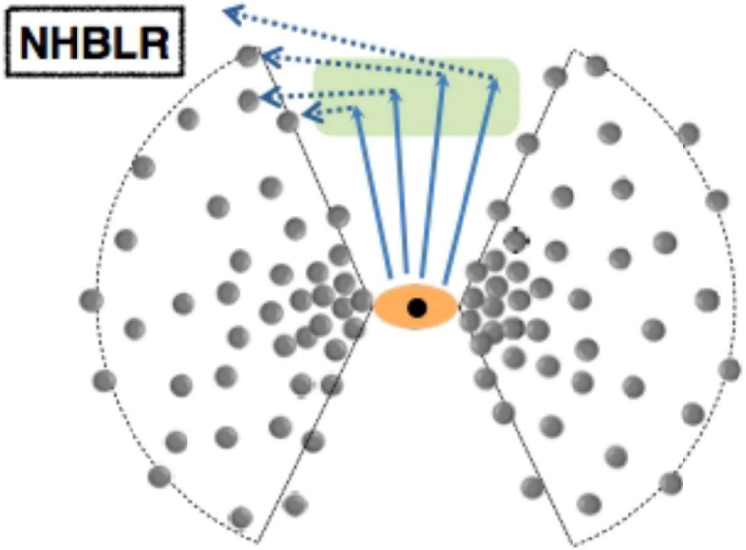
Spectropolarimetry of Sy2

VLT/FORS2

- No correlation between torus width/inclination and properties of polarized spectra (P, θ, FHWM broad lines).
  - Size of scattering region too small or close to the nucleus for the scattered light to be detected whatever the torus inclination?

Ichikawa et al. (2015)





Spectropolarimetry of Sy2

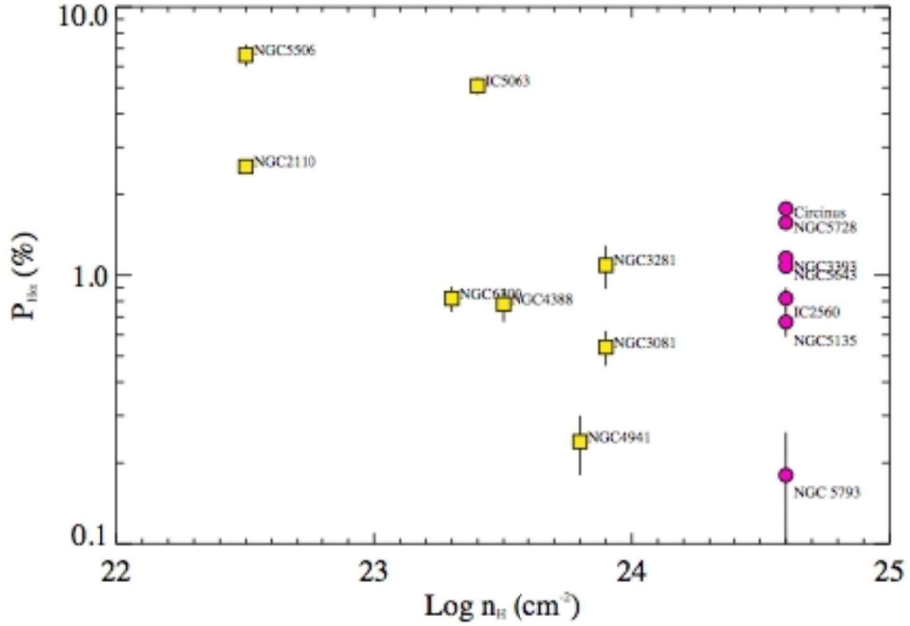
VLT/FORS2

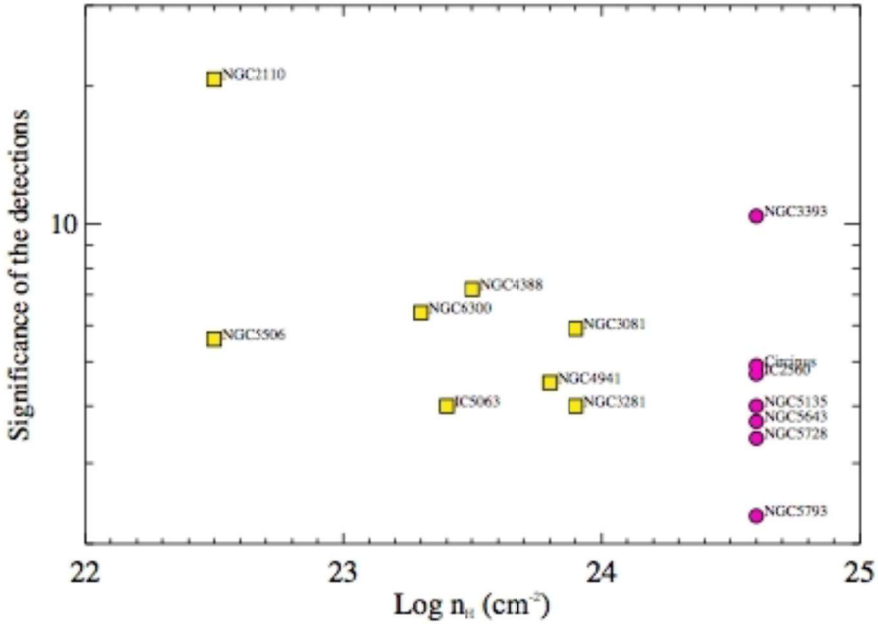
- No correlation between torus width/inclination and properties of polarized spectra (P, θ, FHWM broad lines).
  - Size of scattering region too small or close to the nucleus for the scattered light to be detected whatever the torus inclination?
  - The majority of our torus inclination constraints model-dependent & we are biased to edge-on orientations → larger and complete sample observations required.

Spectropolarimetry of Sy2

VLT/FORS2

- Broad components in both Compton-thin and Compton-thick souces – no correlation between n_H and the detectability of scattered broad lines.
- The largest polarization degrees are measured for the galaxies with lower n_H.

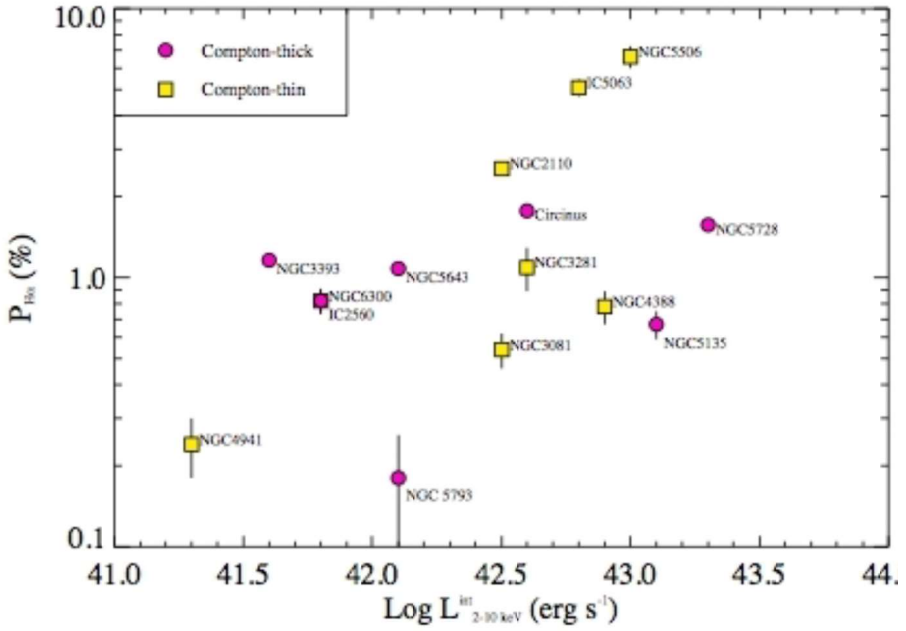


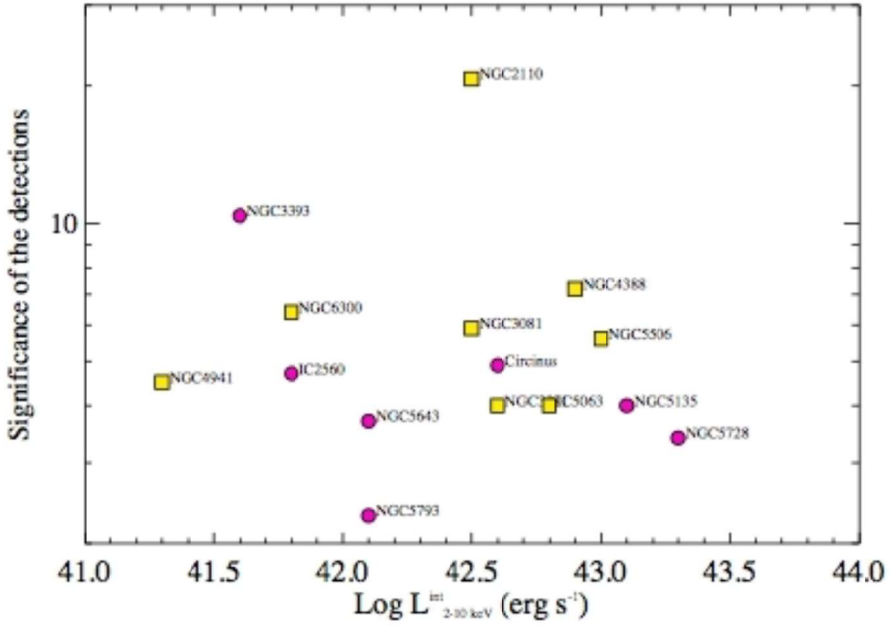


Spectropolarimetry of Sy2

VLT/FORS2

- In general, the more luminous the galaxies, the higher the polarization degrees.
- High luminosities and low column densities → higher polarization degrees, but that does not necessarily imply more HBLR detections.





Summary

Ramos Almeida et al. 2016, MNRAS, in press

- We detect polarized broad lines in 11/15 galaxies at the ≥4σ level (73%). 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 10 targets, and just broad Hα in NGC 6300 (also in NGC 5793 but at 2σ).
- The largest polarization degrees are measured for the galaxies with lower n_H, but there is no correlation between n_H and the detectability of scattered broad lines.

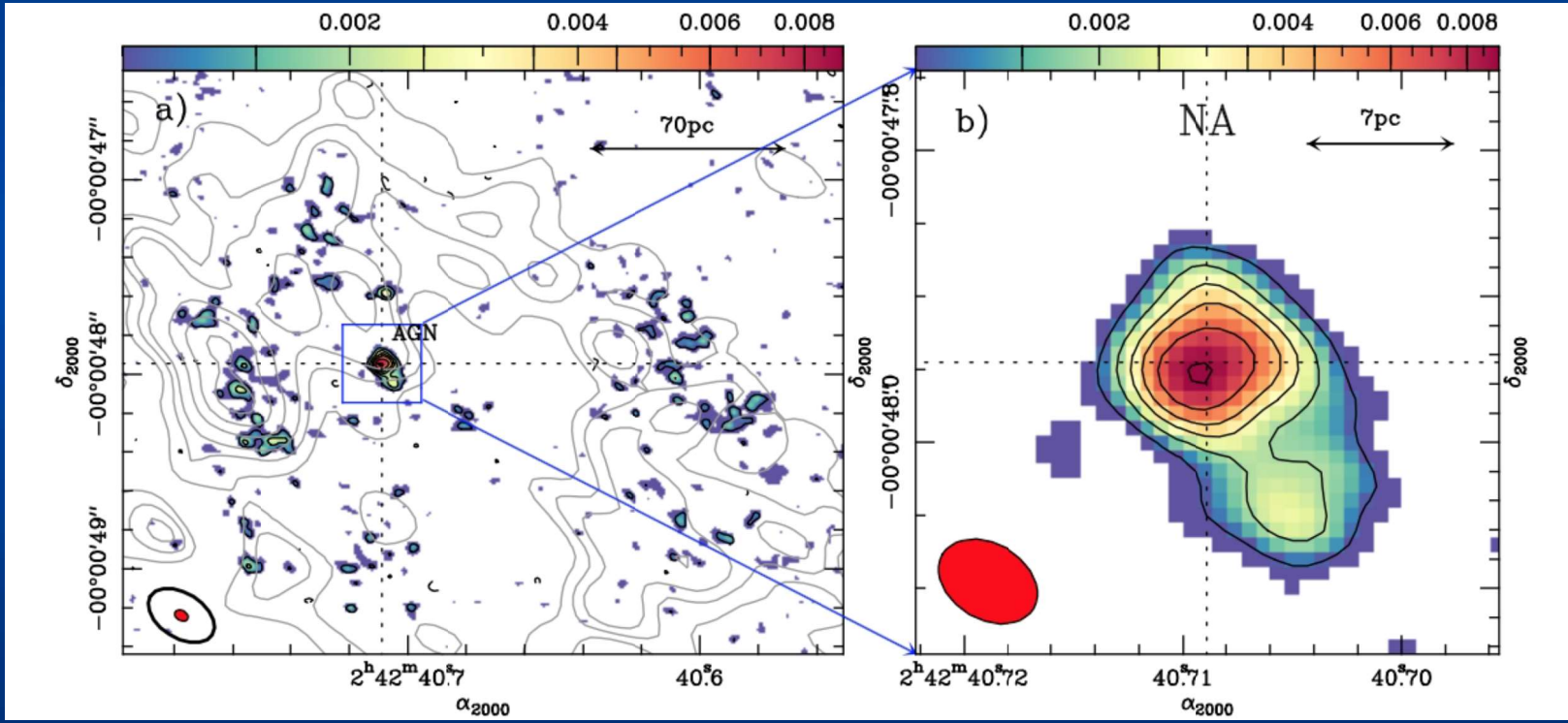
This research was supported by a Marie Curie Intra European Fellowship within the 7th European Community Framework Programme.

MARIE CURIE ACTIONS

ALMA Cycle 2 observations

First image of the AGN torus

Cycle 2 observations of the active galaxy NGC 1068 – angular resolution 4 pc!!!



García-Burillo, Combes, Ramos Almeida et al. (2016)