IoA Journal Club

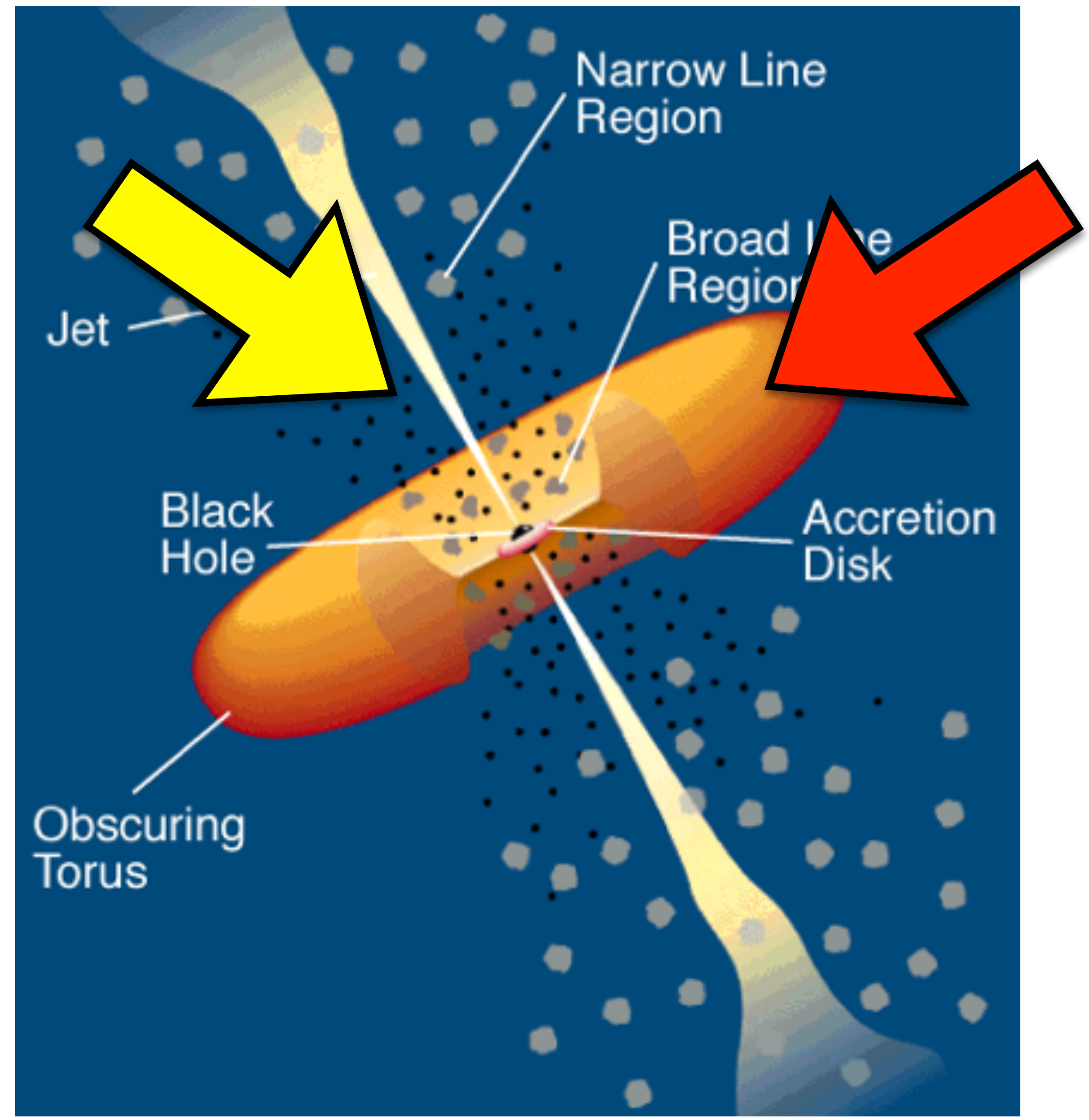
Debate on the toroidal structures around hidden- vs non hidden-BLR of AGNs

2016/07/08

Reported by T. Izumi

Unification scheme of AGNs

- All AGNs are fundamentally the same (Antonucci 1993)
- Toroidal obscuring region (torus) = optically and geometrically thick@optical
- Type-1 (w/ BLR) and Type-2 (w/o BLR), depending on the viewing angle

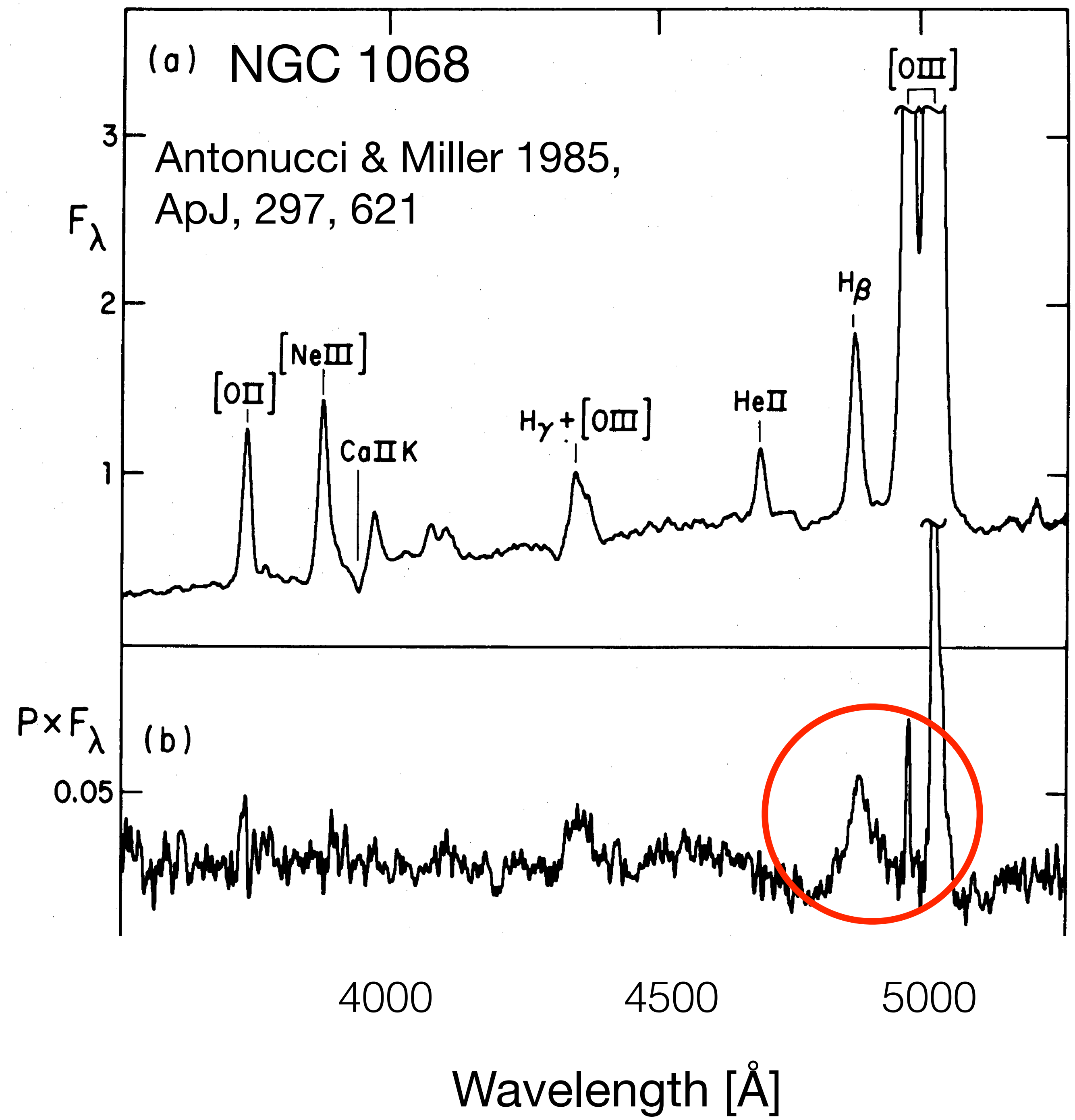


The basis of the classical torus

- Detection of the polarised BLR (PBL) in type-2 AGNs (e.g., NGC 1068: Antonucci & Miller 1985)

- Detection of the BLR through IR spectroscopy (e.g., Nagar+2002; Reunanen+2003)

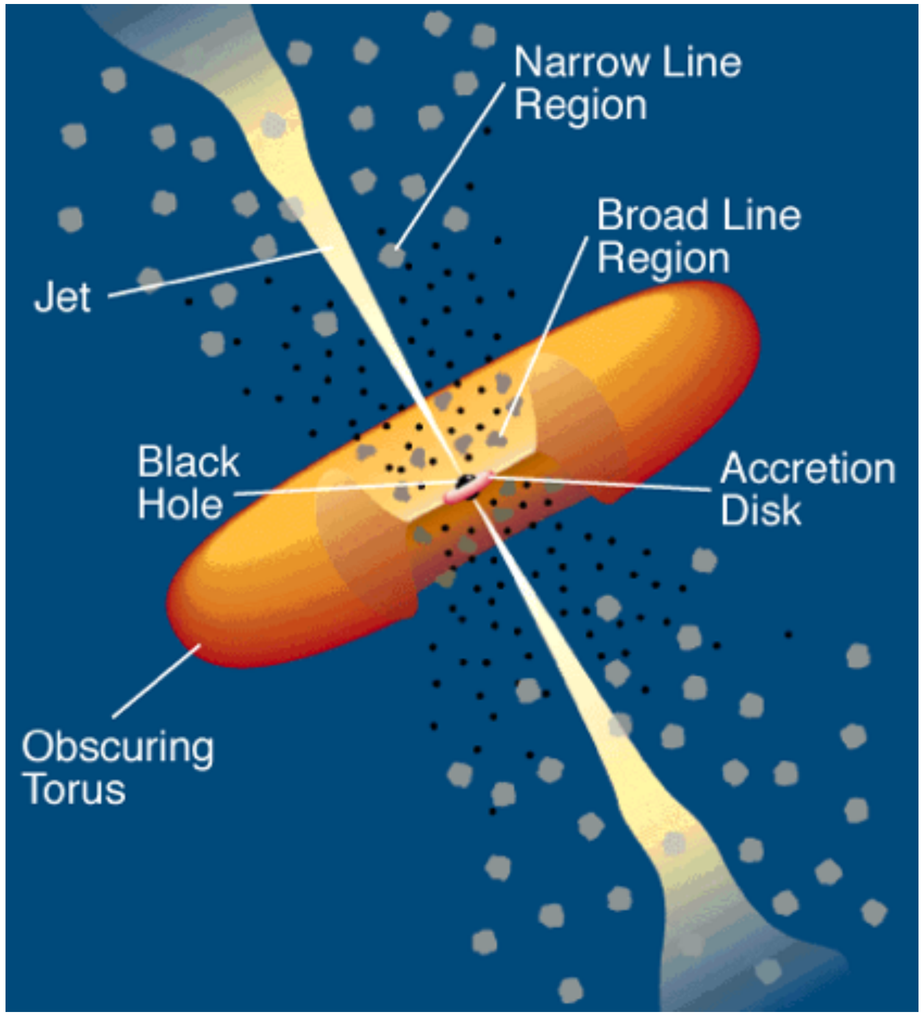
→ hidden broad line region
= **HBLR**



Type-2 → HBLR vs NHBLR

- But, only 30-50% of type-2 show PBLs (e.g., Tran+01, 03) → discuss later!

(1) Genuine lack of BLR
(e.g., Tran+11; Elitzur+09)
→ non-hidden broad line region
= **NHBLR / true Type-2**
(2) Complex effects of obscuration
(e.g., Gu+01, Lumsden+04, Shu +07)



Now try to reveal the torus-geometry of both HBLR and NHBLR!

1. Difference in the torus geometry?
K. Ichikawa et al. 2015, ApJ, 803, 57

THE DIFFERENCES IN THE TORUS GEOMETRY BETWEEN HIDDEN AND NON-HIDDEN BROAD LINE ACTIVE GALACTIC NUCLEI

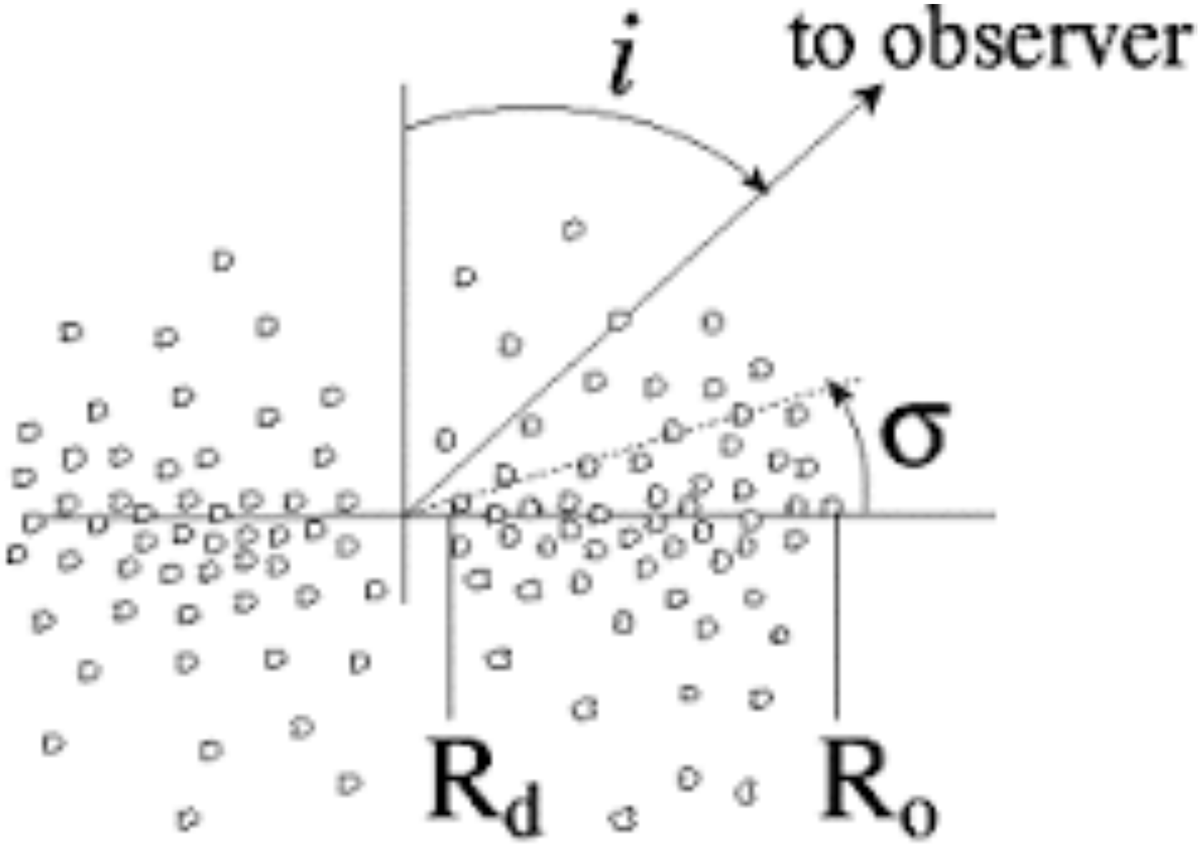
We present results from the fitting of infrared (IR) spectral energy distributions of 21 active galactic nuclei (AGNs) with clumpy torus models. We compiled high spatial resolution (~0.3–0.7 arcsec) mid-IR (MIR) *N*-band spectroscopy, *Q*-band imaging, and nuclear near- and MIR photometry from the literature. Combining these nuclear near- and MIR observations, far-IR photometry, and clumpy torus models enables us to put constraints on the torus properties and geometry. We divide the sample into three types according to the broad line region (BLR) properties: type-1s, type-2s with scattered or hidden broad line region (HBLR) previously observed, and type-2s without any published HBLR signature (NHBLR). Comparing the torus model parameters gives us the first quantitative torus geometrical view for each subgroup. We find that NHBLR AGNs have smaller torus opening angles and larger covering factors than HBLR AGNs. This suggests that the chance to observe scattered (polarized) flux from the BLR in NHBLR could be reduced by the dual effects of (a) less scattering medium due to the reduced scattering volume given the small torus opening angle and (b) the increased torus obscuration between the observer and the scattering region. These effects give a reasonable explanation for the lack of observed HBLR in some type-2 AGNs.

Sample

Name	z	d	Slit/Size	Type	Group	N_H	$\log L_{bol}^{(lit)}$	b/a	A_V	i	Ref
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
NGC 1365	0.0055	18	0.35/31	Sy1.8	Type-1	23.6	42.9	0.5	<5	···	(A1,B1,B1,···)
NGC 4151	0.0033	13	0.36/23	Sy1.5	Type-1	22.8	43.7	0.71	···	···	(A9,A9,···,···)
IC 4329 A	0.016	65	0.75/240	Sy1.2	Type-1	21.8	43.6	0.28	···	···	(A10,A9,···,···)
NGC 7469	0.016	66	0.75/240	Sy1	Type-1	20.7	45.1	0.72	···	···	(A9,A9,···,···)
NGC 1068	0.0038	15	0.36/26	Sy2	HBLR	>25	45.0	0.85	···	60–90	(A2,A9,···,A9)
NGC 2110	0.0078	31	0.36/54	Sy2	HBLR	22.5	43.9	0.74	5	40	(A9,A9,A9,A9)
MCG 5–23-16	0.0085	34	0.75/120	Sy2	HBLR	22.2	44.4	0.46	>6	53	(A9,A9,A9,A9)
NGC 3081	0.008	32	0.65/100	Sy2	HBLR	23.9	43.8	0.8	···	···	(A3,B2,···,···)
NGC 3227	0.0039	17	0.75/62	Sy2	HBLR	22.2	43.4	0.68	···	···	(A11,A9,···,···)
Circinus	0.0014	4	0.60/12	Sy2	HBLR	24.6	43.6	0.44	9	60–90	(A8,A9,A9,A9)
NGC 5506	0.0062	25	0.36/44	Sy2	HBLR	22.4	44.2	0.30	⩾11	40	(A9,A9,A9,A9)
IC 5063	0.011	46	0.67/150	Sy2	HBLR	23.3	44.5	0.68	7	···	(A2,A9,A9,···)
NGC 7582	0.0053	21	0.75/76	Sy2	HBLR	22.7	43.3	0.42	8,13	···	(A9,A9,A9,···)
NGC 7674	0.029	118	0.75/430	Sy2	HBLR	>25	45.0	0.91	~3–5	···	(A9,A9,A9,···)
NGC 1386	0.0029	11	0.31/17	Sy2	NHBLR	>25.0	42.9	0.4	···	65,85	(A2,B2,···,C1)
NGC 3281	0.011	43	0.35/73	Sy2	NHBLR	24.3	44.6	0.4	···	···	(A4,B1,···,···)
Cen A	0.0018	3	0.65/11	Sy2	NHBLR	23.7	44.0	0.4	14.0	···	(A5,B2,A9,···)
NGC 5135	0.014	59	0.70/200	Sy2	NHBLR	>25.0	44.4	0.7	···	···	(A2,B2,···,···)
NGC 5643	0.004	16	0.35/29	Sy2	NHBLR	23.8	42.7	0.9	···	···	(A6,B5,···,···)
NGC 5728	0.0094	40	0.35/69	Sy2	NHBLR	23.6	44.5	0.6	···	···	(A7,B6,···,···)
NGC 7172	0.0087	35	0.36/61	Sy2	NHBLR	22.9	43.8	0.46	···	···	(A2,A9,···,···)

- AGNs with high resolution IR measurements (to avoid the contamination from the hosts)
- HBLR or NHBLR → *Totally depends on the quality of spectropolarimetry*

Method: CLUMPY torus model



Free Parameters of the BayesClumpy

Parameters	Parameter Range
Torus radial thickness (Y)	[5, 30]
Torus angular width (σ)	[15°, 70°]
Number of clouds along an equatorial ray (N_0)	[1, 15]
Index of the radial density profile (q)	[0, 3]
Viewing angle (i)	[0°, 90°]
Optical depth of each cloud (τ_V)	[5, 150]

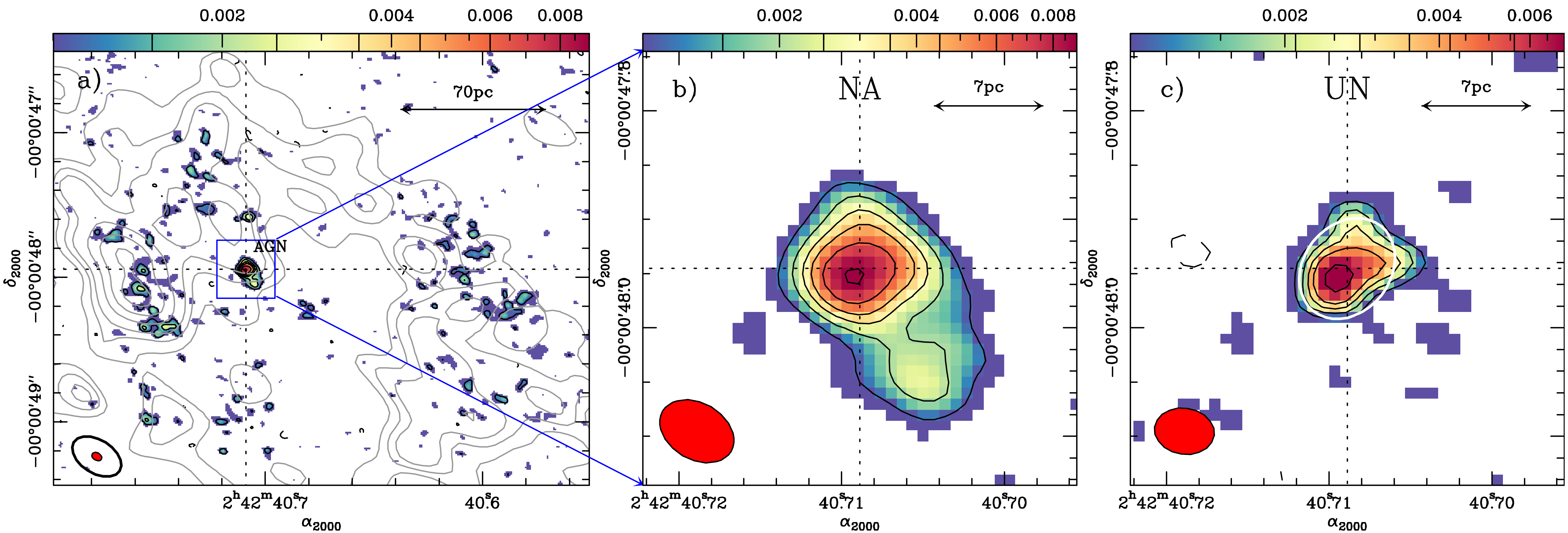
Note. Torus radial thickness Y is defined as $Y = r_{\rm out}/r_{\rm in}$, where $r_{\rm out}$ is the outer radius and $r_{\rm in}$ is the inner radius. The cloud distribution between $r_{\rm out}$ and $r_{\rm in}$ is parameterized as r^{-q}.

- To fit torus model to photometric/spectroscopic data
  - e.g., IR color, silicate absorption

- 5M models are now recorded in the CLUMPY database (https://www.clumpy.org)

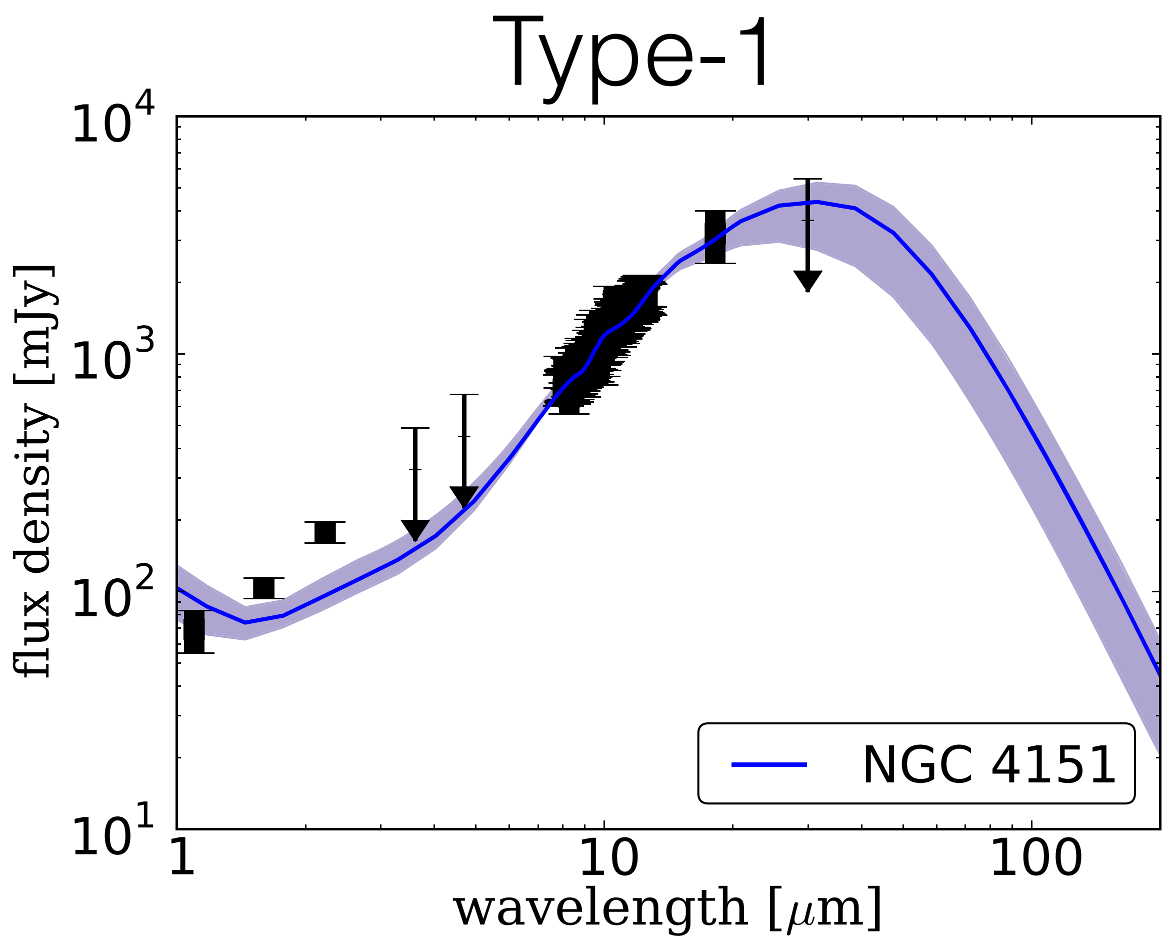
- Bayesian approach is adopted (uniform prior)

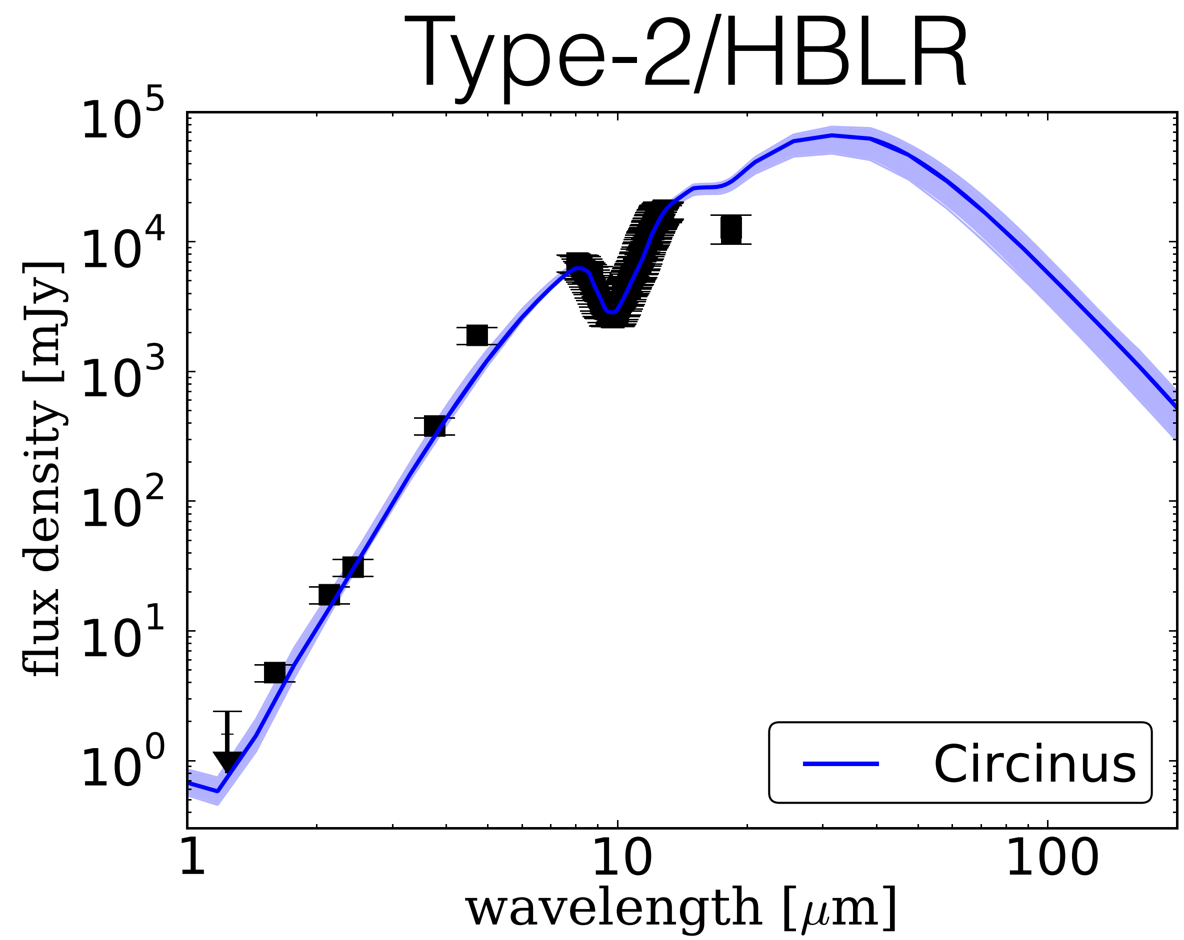
(Comments: to solve the degeneracy)



- We need to constrain some parameters!
- ALMA can now constrain the <u>outer radius</u> of the torus
  - Garcia-Burillo+16

Examples



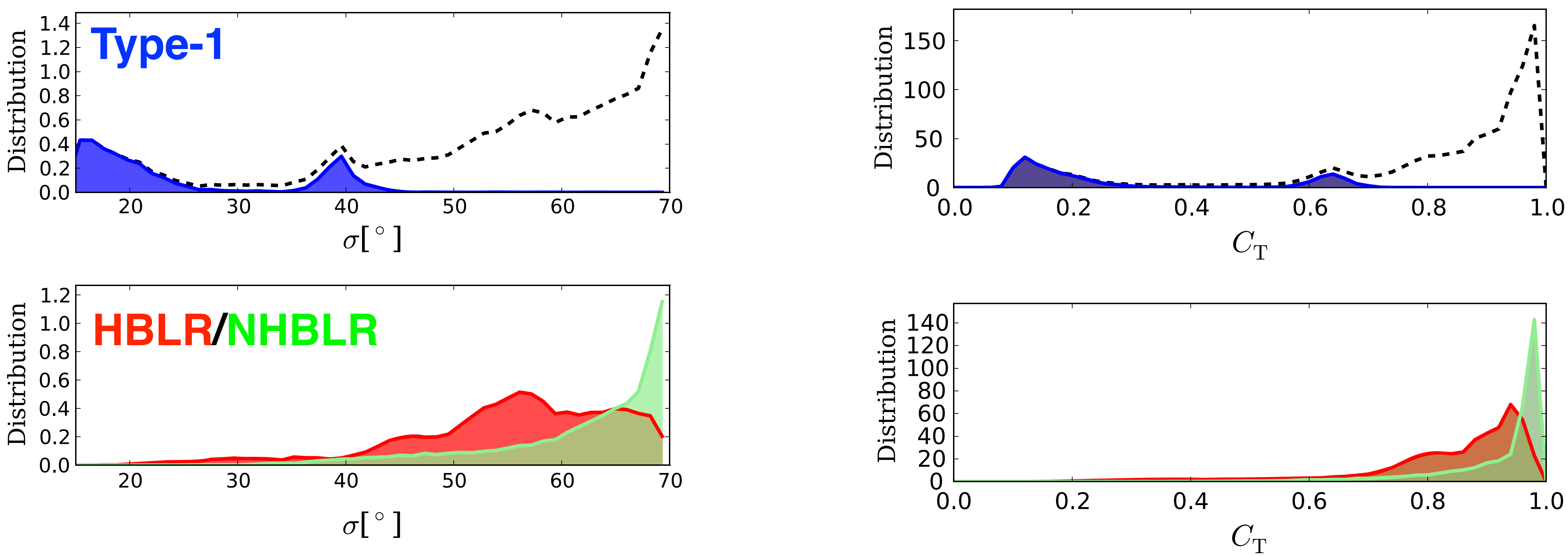


- Typically, type-2 AGN can be characterised by the deep silicate absorption and cooler IR color.

Results

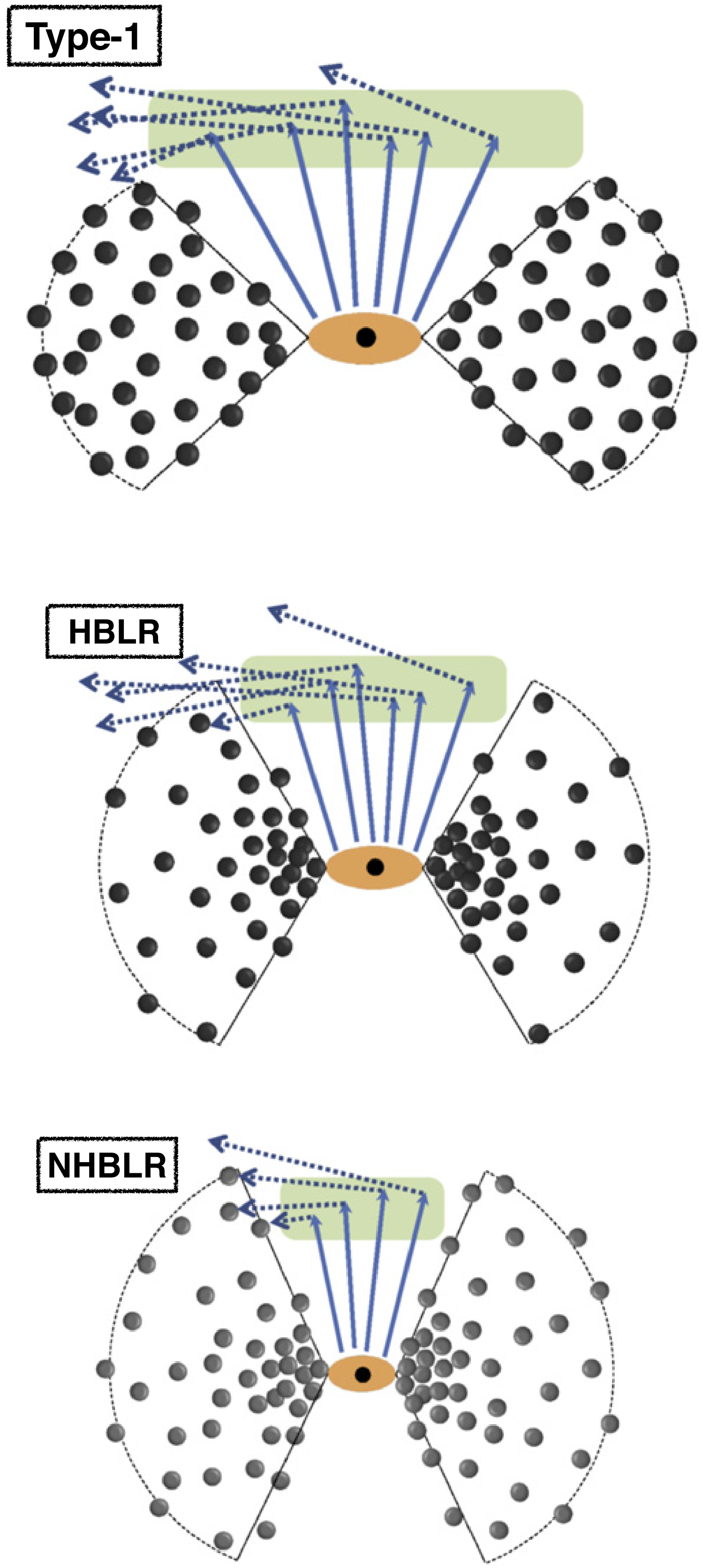
Torus Model Parameters from the Global Posterior Distributions

AGN Type	$\sigma_{\rm torus}$ [deg]	Y	N_0	q	τ_V	i [deg]	C_T	$\log L_{\rm bol}^{\rm (mod)}$ [erg/s]	$r_{\rm in}$ [pc]	$r_{\rm out}$ [pc]	H [pc]
All	56^{+6}_{-19}	18^{+2}_{-6}	12^{+1}_{-4}	$0.6^{+0.5}_{-0.5}$	81^{+23}_{-43}	48^{+12}_{-37}	$0.88^{+0.06}_{-0.38}$	$43.4^{+0.4}_{-0.5}$	$0.066^{+0.048}_{-0.024}$	$1.2^{+0.4}_{-0.8}$	$1.0^{+0.3}_{-0.6}$
Type-1	19^{+3}_{-3}	20^{+2}_{-11}	12^{+0}_{-2}	$0.7^{+0.5}_{-0.5}$	113^{+20}_{-31}	50^{+10}_{-46}	$0.18^{+0.06}_{-0.06}$	$43.9^{+0.3}_{-0.8}$	$0.126^{+0.066}_{-0.072}$	$1.6^{+0.4}_{-0.4}$	$1.0^{+0.0}_{-0.6}$
HBLR	56^{+4}_{-8}	18^{+1}_{-10}	10^{+1}_{-3}	$0.8^{+1.1}_{-0.8}$	98^{+34}_{-57}	46^{+14}_{-36}	$0.88^{+0.04}_{-0.14}$	$43.7^{+0.2}_{-0.7}$	$0.072^{+0.048}_{-0.030}$	$1.2^{+0.8}_{-0.4}$	$1.0^{+0.6}_{-0.3}$
NHBLR	64^{+2}_{-11}	18^{+2}_{-3}	13^{+0}_{-3}	$0.4^{+0.2}_{-0.4}$	43^{+17}_{-11}	48^{+17}_{-28}	$0.96^{+0.02}_{-0.10}$	$43.2^{+0.1}_{-0.8}$	$0.060^{+0.006}_{-0.042}$	$0.8^{+0.8}_{-0.4}$	$1.0^{+0.3}_{-0.6}$



- Now, the authors are focusing on the difference in σ and C_T (covering factor) between HBLR and NHBLR
  → statistically confirmed (right??)

Discussion①: geometry of the torus



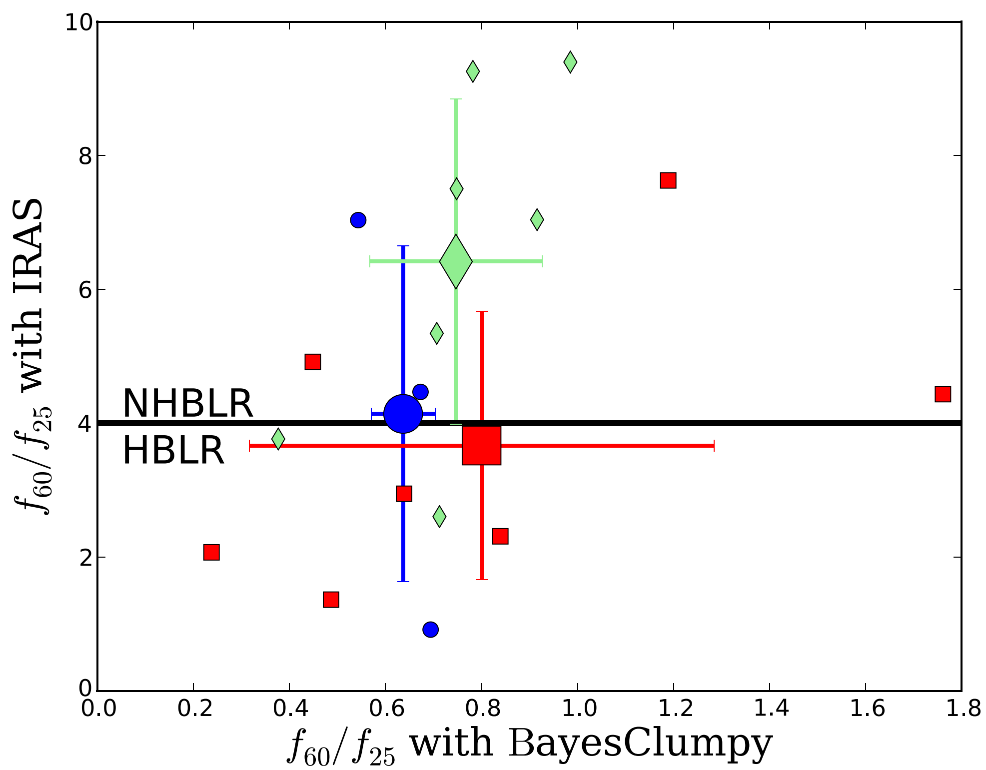
The authors claim:

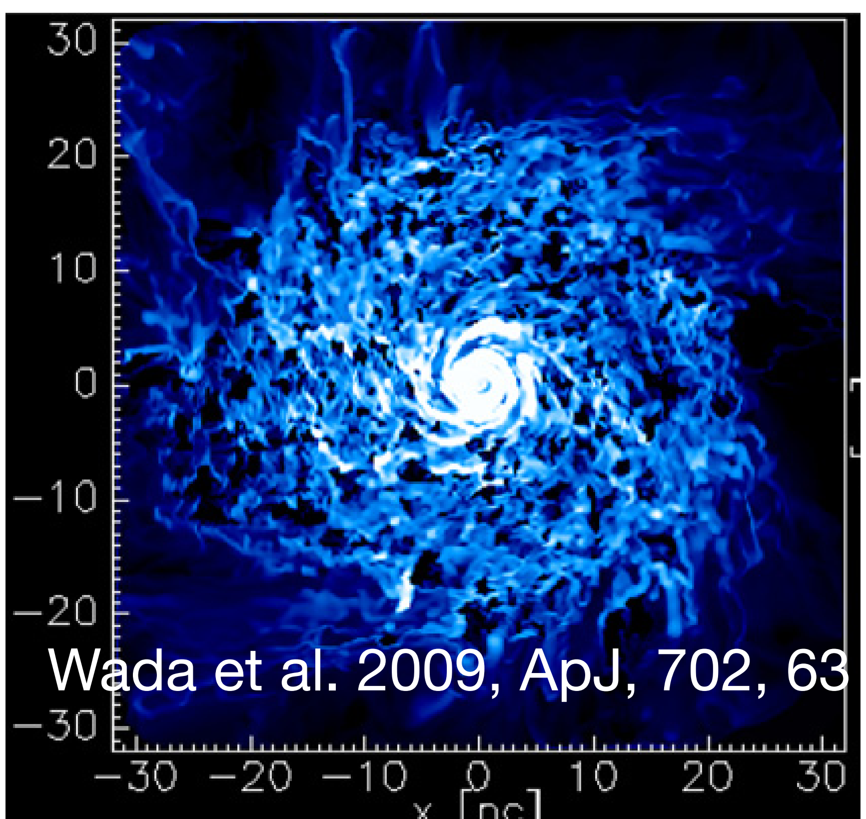
- AGN photons are electron-scattered
- Higher σ (geometrically thick) and higher C_T (smaller escape fraction) in NHBLR
  → Block the scattered light!

TI comments:

Do these results suggest no evolutionary sequence between HBLR and NHBLR???

Discussion②: obscuration by the hosts





- NHBLRs are known to have cooler IRAS colors
- But, this time the authors did not find any systematic difference in IR color at (sub)arcsec scale
  → Difference in color stems from the host
- Higher obscuration due to starburst in the hosts would contribute to obscure the nucleus as well!
  - e.g., Wada & Norman 2002

Summary

- Constrained the torus properties of Type-1/HBLR/NHBLR with high resolution IR measurements
- The torus of NHBLR is thicker than that of HBLR
  → non-detection of BLR would be due to stronger obscuration
- Probably, host galaxies are also contributing to the obscuration of the central AGNs

おまけ：However,,,

Upholding the Unified Model for Active Galactic Nuclei: VLT/FORS2 Spectropolarimetry of Seyfert 2 galaxies

ABSTRACT

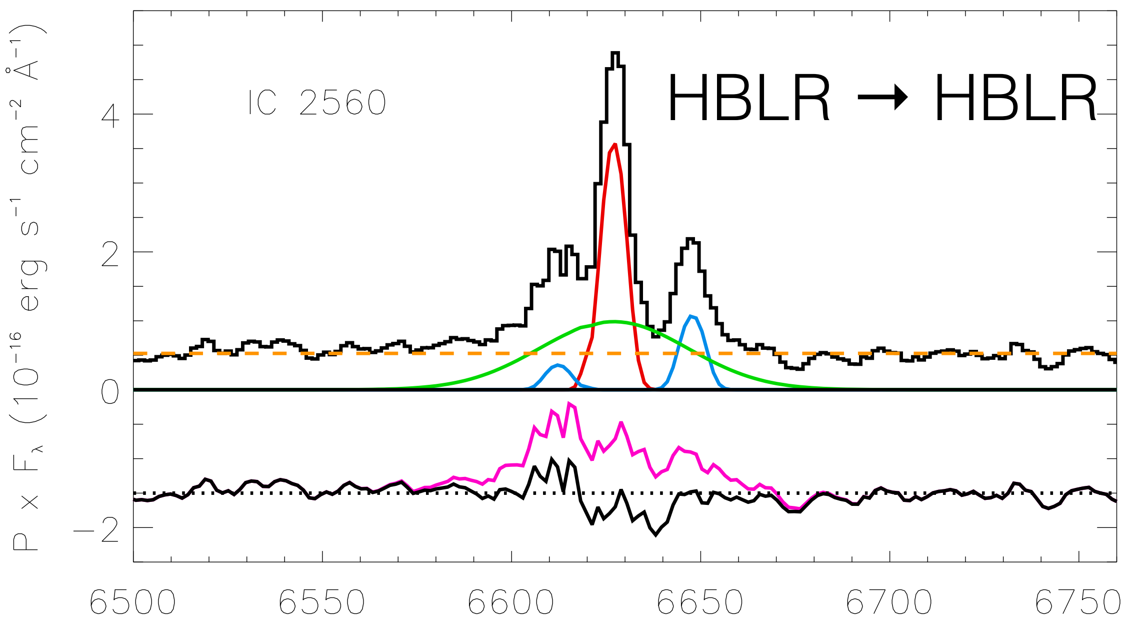
The origin of the unification model for Active Galactic Nuclei (AGN) was the detection of broad hydrogen recombination lines in the optical polarized spectrum of the Seyfert 2 galaxy (Sy2) NGC 1068. Since then, a search for the hidden broad-line region (HBLR) of nearby Sy2s started, but polarized broad lines have only been detected in ∼30–40% of the nearby Sy2s observed to date. Here we present new VLT/FORS2 optical spectropolarimetry of a sample of 15 Sy2s, including Compton-thin and Compton-thick sources. The sample includes six galaxies without previously published spectropolarimetry, some of them normally treated as non-hidden BLR (NHBLR) objects in the literature, four classified as NHBLR, and five as HBLR based on previous data. We report $\geqslant 4\sigma$ detections of a HBLR in 11 of these galaxies (73% of the sample) and a tentative detection in NGC 5793, which is Compton-thick according to the analysis of X-ray data performed here. Our results confirm that at least some NHBLRs are misclassified, bringing previous publications reporting differences between HBLR and NHBLR objects into question. We detect broad Hα and Hβ components in polarized light for 10 targets, and just broad Hα for NGC 5793 and NGC 6300, with line widths ranging between 2100 and 9600 km s^{-1}. High bolometric luminosities and low column densities are associated with higher polarization degrees, but not necessarily with the detection of the scattered broad components.

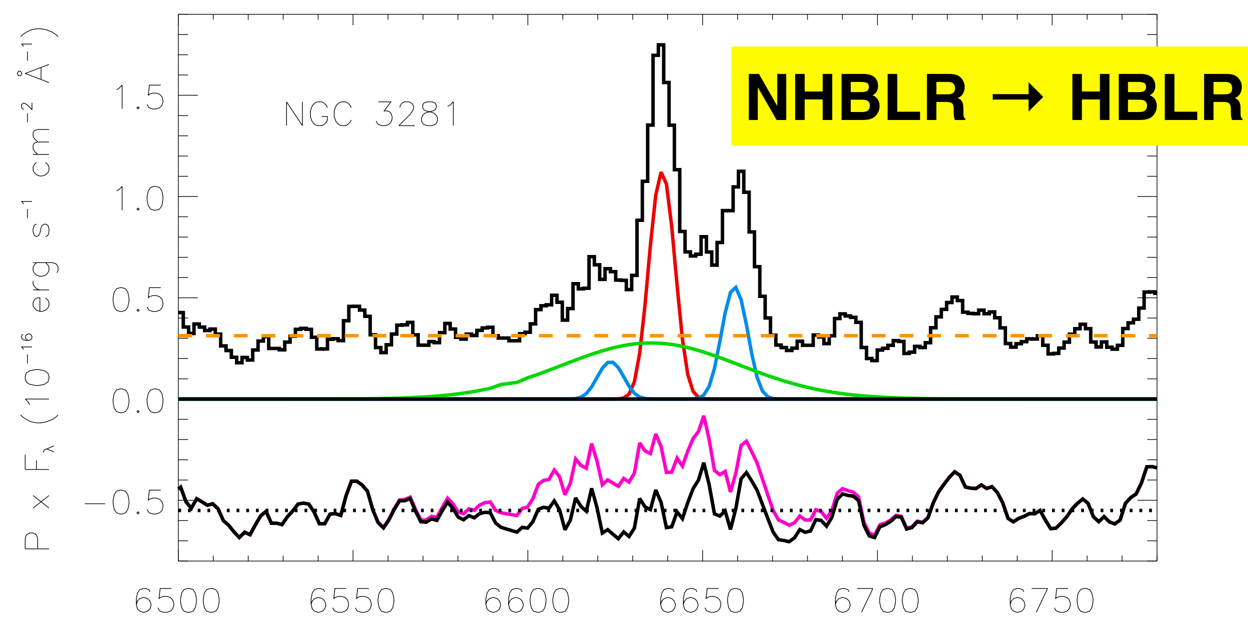
Sample

Galaxy	Previous classification Type	Data	Ref.	Axis ratio (b/a)	i_{torus} (deg)	Ref.	σ_{torus} (deg)	Ref.	log n_H (cm^{-2})	Compton thick	log L^{int}_{2-10} (erg s^{-1})	log L_{bol} (erg s^{-1})	Ref.
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

- Try to detect hidden BLR by spectropolarimetry
- Large telescopes are used to achieve high S/N
  → VLT/FORS2
- Host components are subtracted from the polarised spectrum

Results & Discussion

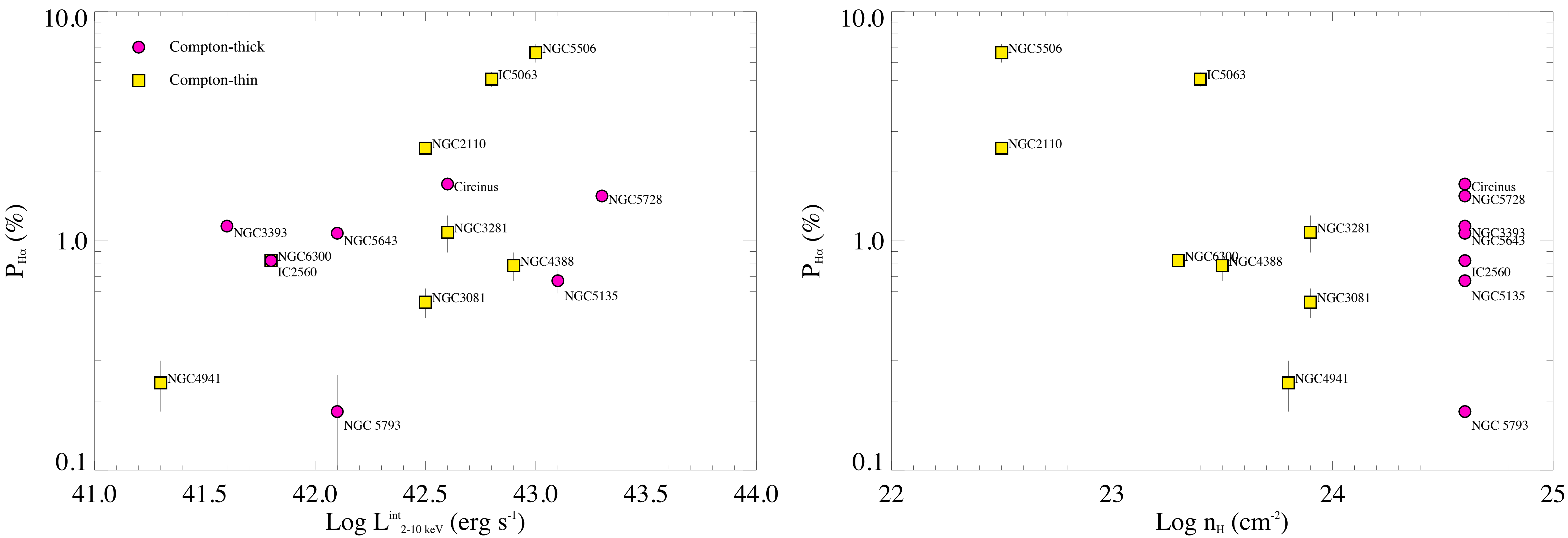




- HBLR was detected in 11/15 Type-2 Seyfert galaxies!!!
  → significantly higher fraction than the previous reports

- Clearly suggest the importance of high S/N measurement to accurately classify AGNs into sub-categories.

Results & Discussion



- These trends are consistent with previously found ones.
- These results suggest that the scatter has electron-scattered nature…???