Stellar and AGN accretion disc alignments from SDSS data

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We study the intrinsic shapes and orientations of type I and II AGN galaxies in the Sloan Digital Sky Survey Data Release 7 (SDSS DR7), by studying the distribution of projected axis ratios of AGN hosts separated into spiral and elliptical galaxies. We define control samples of non-AGN galaxies that mimic the colour, luminosity and concentration distributions of the AGN population, taking into account the effects of dust extinction and reddening. Assuming that AGN populations have the same underlying shapes as their corresponding control samples we find that the type I AGN population is strongly biased toward face-on galaxies, while the spiral type II AGN toward edge-on galaxies. Ellipticals type II show a much weaker tendency, consistent with random orientations. Those tendencies could be explained with a central obscuring torus of ≈ 40 degrees of azimuthal height located preferentially in the galactic plane. This points towards a geometrical alignment between optical light and accretion discs, putting important constraints on gas inflow and accretion processes.

Motivation

The aim of this work is to study the possible alignment between galaxy/accretion disc/radio jets with a novel technique based on the model by Padilla & Strauss (2008, PS08) using a large AGN sample. Lagos, Cora & Padilla (2009) show that if such alignments were to occur, massive galaxies should host BHs with high spin values, regardless of the detailed physics of the BH. Since the BH spin regulates the mass-to-energy conversion (Marconi et al. 2004) and possibly the existence of radio jets (Sikora et al. 2007), **this study has a strong impact in our understanding of galaxy formation**.

The intrinsic shapes of AGN host galaxies in the SDSS

Catalogue: $27,450$ SDSS DR7 galaxies classified as AGN and separated in Seyfert type I (broad-lines), type II (narrow-lines) and type III (star forming galaxies) following Hao et al. (2005).
Method: **We assume that AGN hosts have the same shapes than non-AGN galaxies (control samples) but possibly with different inclinations with respect to the line of sight**. Control samples were selected using the spectroscopic SDSS DR7 galaxy sample, as follows:

- **We do not consider type III AGNs** since their hosts may show high amounts of gas and dust, and uncommon blue colors.
- **We classified galaxies by morphology**, where elliptical galaxies are those with $f_{\rm dev} > 0.9$.
- We select control samples so that they match the $V_{\rm MAX}$**-weighted (i)** $g-r$, **(ii)** M_r **(both corrected), and (iii) concentration** (r_{90}/r_{50}) properties of the AGN hosts.

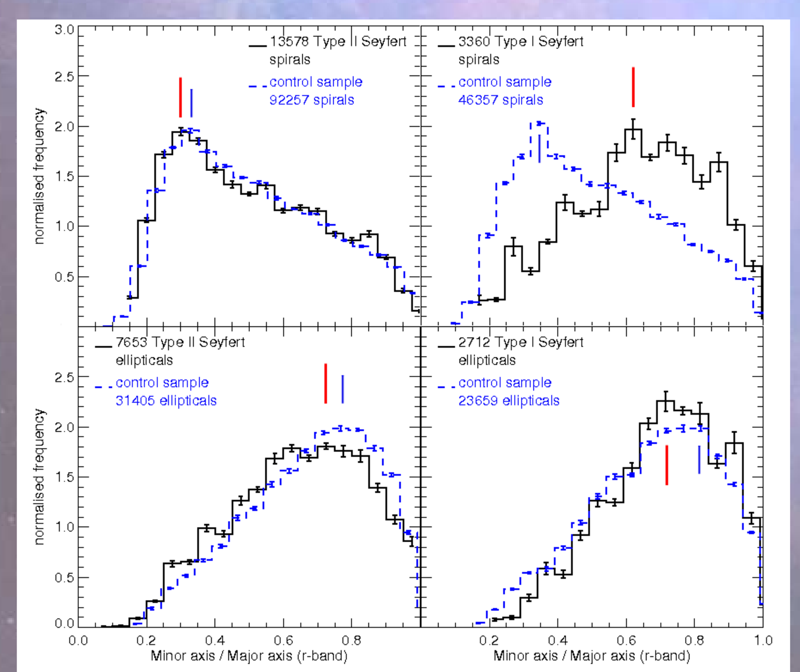

Figure 1: Projected axis ratio, b/a, distributions for each AGN (black) and their corresponding control samples (blue). Vertical red and blue lines indicate distribution peaks. Errors were calculated using the jackknife technique.

The projected b/a distribution peaks (Fig. 1) indicate that:
→ **type I AGN tend to be preferentially face-on, while type II preferentially edge-on.** This tendency is clearer for spiral galaxies.
→ the morphological type is the most important parameter, there is little effect coming from the Seyfert type.

→ Characterising shapes with the model by PS08

PS08 models galaxies as triaxial ellipsoids parametrised by two axis ratios, middle to major (B/A) and minor to middle (C/B), with lognormal and gaussian distributions characterised by 8ean and dispersion μ and σ, and $1-\gamma$, σ_γ, respectively.

- **The model calculates the ratio of the number of galaxies seen at inclination angle** θ **to the expected number without extinction (which depends on** ϵ, σ, γ, σ_γ **and extinction** E_0**).**
- We use this model to construct the distribution $N_{\rm model}(b/a)$ and compare it with the observed one through a χ^2 test, thus selecting the best parameter set (Table 1).

Sample	E_0	μ	σ	γ	σ_γ	$P_{\rm MAX}$
TI Ell	0.0	-0.89 $\pm$ 0.3	2.3 $\pm$ 0.1	0.45 $\pm$ 0.03	0.21 $\pm$ 0.05	0.86
TII Ell	0.0	-1.35 $\pm$ 0.2	1.7 $\pm$ 0.3	0.45 $\pm$ 0.03	0.23 $\pm$ 0.01	0.87
TI Spi	0.3 $\pm$ 0.1	-0.85 $\pm$ 0.2	1.7 $\pm$ 0.1	0.75 $\pm$ 0.01	0.07 $\pm$ 0.01	0.47
TII Spi	0.6 $\pm$ 0.1	-0.35 $\pm$ 0.4	2.4 $\pm$ 0.3	0.78 $\pm$ 0.03	0.1 $\pm$ 0.03	0.33

Table 1: Best-fitting model for each control sample. The last column shows the likelihood associated to the parameter set.

The model reproduces nicely the observed b/a distributions (Fig. 2).

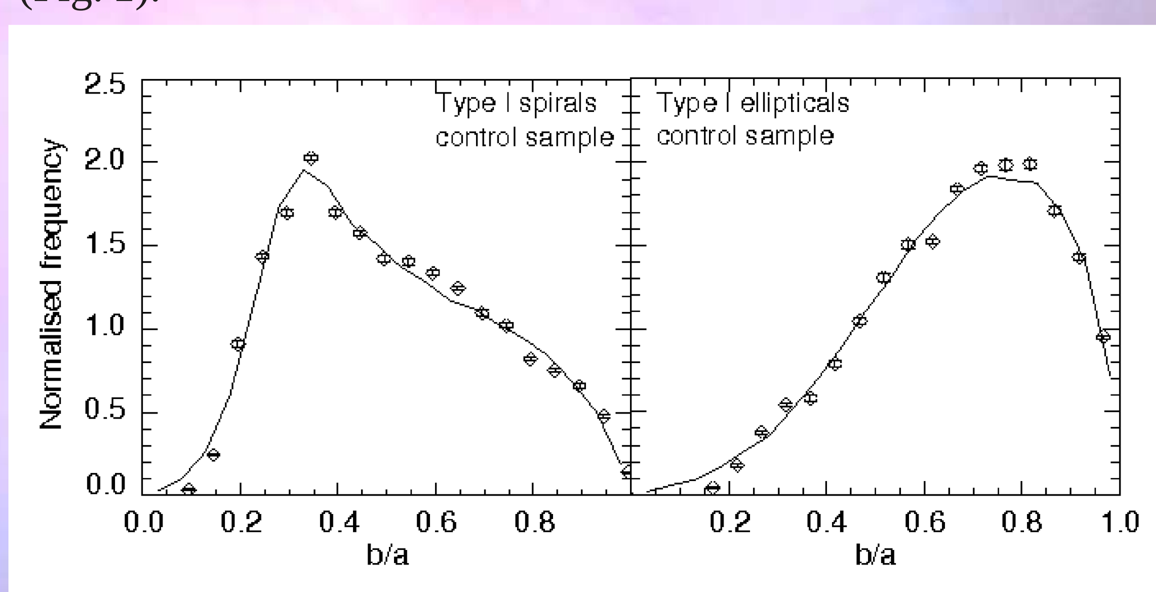

Figure 2: $V_{\rm MAX}$-weighted axis ratio distributions for type I control samples (type II are very similar). Symbols correspond to SDSS galaxy samples and lines are the best-fitting models for the parameters shown in Table 1.

AGN orientations alignments

We study possible face- or edge-on preferences in the AGN population by calculating the predicted θ distribution for a set of projected b/a (Fig. 3) through the parameters of Table 1.

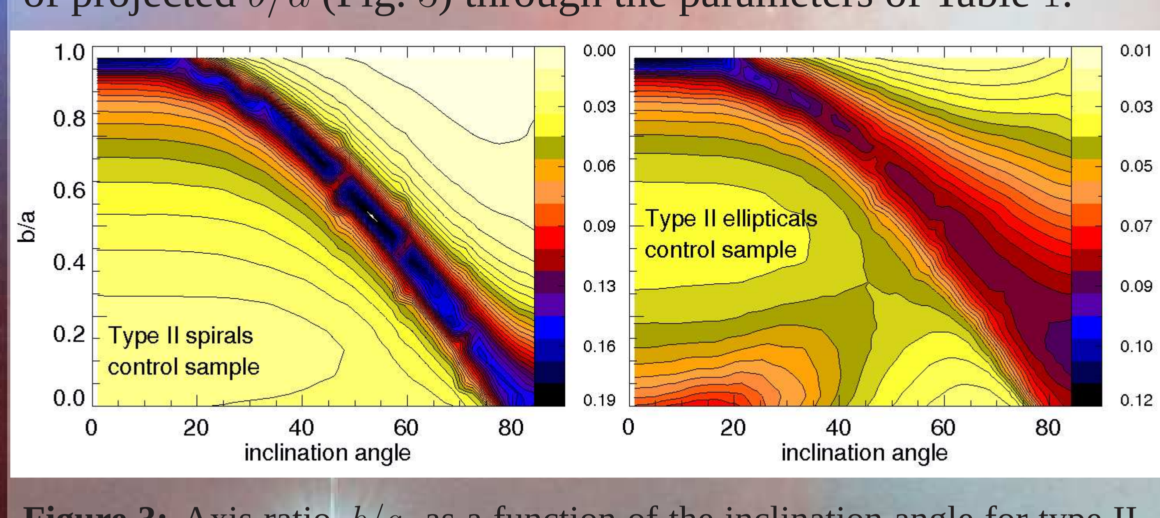

Figure 3: Axis ratio, b/a, as a function of the inclination angle for type II control sample (type I are very similar). Darker colors represent higher probabilities.

We use the **frequencies of Fig.** 3 **(properly weighted)** to construct the $cos(\theta)$ distribution of each AGN and control sample (top panels Fig. 1). **For control samples, we find almost flat** $cos(\theta)$ **distributions,** consistent with random orientations.

Main results:

- **Fig.** 4 **shows that type II AGN spirals have a strong tendency to be edge-on, while type I show the opposite tendency. Although weaker, this result is also found for AGN hosted by elliptical galaxies.**

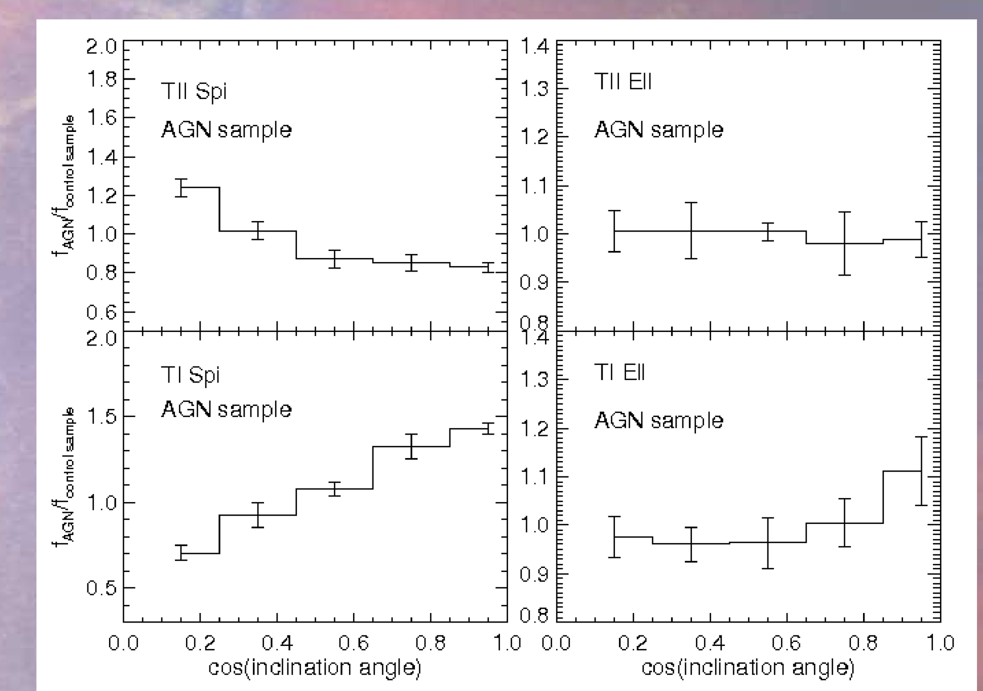

Figure 4: Distribution of the ratio between normalised frequencies of $cos(\theta)$ of the AGN population and the corresponding control samples (i.e. to account for details in the $cos(\theta)$ distributions of control samples which are not perfectly flat). Errors were calculated using the jackknife technique.

- This result, in addition to the resulting ratio of type I to type II AGNs (≈ 0.25), indicate that **the absorption of** H **lines is produced by a broad torus preferentially aligned with the galaxy light.**

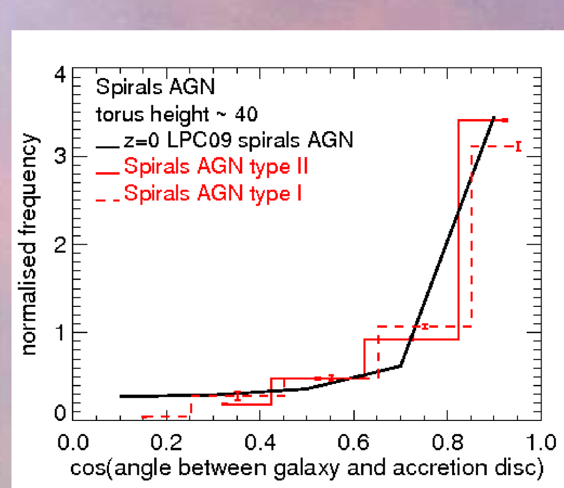

Figure 5: Distribution of $cos(\phi^{\rm Galaxy}_{\rm torus})$ under the assumption of random torus orientations between $0-80$ degrees. The theoretical prediction by LPC09 is in solid black line.

- **We quantify that the torus width is typically about** ≈ 40 **degrees of azimuthal height**, by considering that the fraction of the sphere covered by the torus corresponds to the $V_{\rm MAX}$-weighted fraction of type II to the total AGN number. **This indicates an important degree of alignment between galaxy discs and torus (Fig.** 5**).**

Conclusions

- Structural parameters of AGN control samples (Table 1) are **consistent with the full SDSS DR6 spiral/elliptical population (PS08).**
- Samples of the **same morphology and different Sy type have very similar structural properties**, supporting the AGN unified model.
- **The orientation distributions of the AGN samples reveal that type I AGN have a strong tendency of being face-on, while type II show the opposite, but weaker, tendency.**
- **Random distributions in** $cos(\theta)$ **for AGN are ruled-out with a confidence of** $\delta\chi^2 \gtrsim 10$ **for spirals and** $\delta\chi^2 \gtrsim 1$ **for ellipticals.**

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