The role of bars in triggering active galactic nuclei galaxies

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Context.
Aims. Bars are considered an efficient mechanism for transporting gas toward the central regions of galaxies, potentially enhancing nuclear activity. However, the extent to which bars influence active galactic nuclei (AGNs) and whether their efficiency varies with environment remain open questions.
Methods. In this study, we aim to quantify the role of bars in triggering AGNs by comparing the AGN fraction in barred and non-barred galaxies across different environments.
Results. We constructed a sample of barred and non-barred galaxies from the Galaxy Zoo DECaLS catalog, ensuring a control selection where both samples share similar distributions in stellar mass, redshift, magnitude, concentration index and the local density parameter. AGNs were identified using spectroscopic data from Sloan Digital Sky Survey in order to obtain a final sample of barred AGNs galaxies (1330) and a control sample of unbarred AGNs (1651). We employ the [OIII]λ5007 luminosity ($Lum[OIII]$) and the accretion rate parameter $\mathcal{R}$ parameter as indicators of nuclear activity, based on these parameters, we applied specific criteria to distinguish between powerful and weak AGNs, allowing for a more precise assessment of the potential impact of bars on the supermassive black hole.
Conclusions. Our analysis reveals that barred galaxies tend to host a higher fraction of powerful AGNs compared to unbarred galaxies. From the analysis of Lum[OIII] we find that galaxies with higher nuclear activity tend to be massive, blue and with young stellar populations. In addition, we observed a slight tendency for barred galaxies to host less massive black holes, which were found to accrete matter more efficiently. The classification analysis of strong and weak bars indicates that galaxies with a more prominent bars exhibit higher nuclear activity. Furthermore, we study the environmental dependence of this trend. Although no significant differences between strong and weak bars were found in intermediate density environments, we observe a distinction in both low and high density environments, where galaxies with strong bars exhibit higher AGN activity.

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The relationship between Bar structures and AGN activity

- **Bar structures** are thought to efficiently transport gas into the nuclear region, thereby **fueling AGN**. → Any relations between barred galaxies and AGNs ?
- There are many observational reports supporting that bars can enhance nuclear activity, but some discrepancies remain, possibly due to factors such as data quality and sample selection criteria.
- This study uses deep and high-resolution images from Dark Energy Camera Legacy Survey (DECaLS), which enable the bar identification and classification.
  - Barred (incld. strength) or not: Galaxy Zoo (GZ) DECaLS classification
    - Morphological criteria: disk-like, spiral, barred, and face-on
  - AGN or not: SDSS DR7 + BPT (Coldwell+17)
    - $L_{[OIII]}$, M_s, $D_n(4000)$, M_u, M_r, and C
  - Control sample (i.e., unbarred AGN spirals): those with similar z (<0.1), M_s ($10^{9.5-12}$ M_{sun}), M_r (< -20.5 mag) and environment (Σ_5).

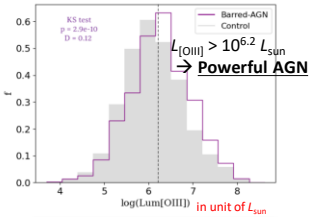


Fig. 3. Normalized distributions of log(Lum[OIII]) (top panel) and the accretion rate $\mathcal{R}$ (bottom panel). The solid line represent the $\mathcal{R}$ distribution using the same α and β parameter for both barred and unbarred galaxies. The dashed line represent the $\mathcal{R}$ distribution taking into account different values of alpha and beta for barred galaxies. The vertical line in both graphs represents the median of the barred sample.

Sample statistics:

	Powerful AGNs		Not powerful
Barred AGN spirals (N=1330)	Strong bars	Strong bars	
	Weak bars	Weak bars	
Control AGN spirals (N=1651)			

← Fig3: Comparison of nuclear activities b/w the samples.

Top: $L_{[OIII]}$ as a reliable indicator of nuclear activity
Bottom: accretion rate R
(M_{BH} estimated from M_{BH}-σ_* relation)

$R = \frac{\log(L_{[OIII]})}{M_{BH}}$ ~~$\log \frac{L_{[OIII]}}{M_{BH}}$~~ ?

- The barred sample shows higher nuclear activity compared to Ctrl.
  - Supporting that bars enhance nuclear activity by transporting gas.
- Categorize the sample above the peaks of the distributions as **powerful AGNs**.

$log M_{BH} = \alpha + \beta log(\frac{\sigma_*}{200})$

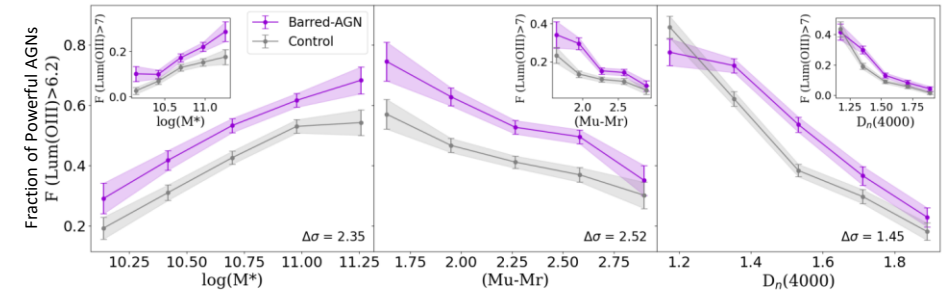


Fig. 4. Fraction of Lum[OIII] > $10^{6.2} L_\odot$ as a function of stellar mass, color (Mu-Mr), and the $D_n(4000)$ parameter (left, center, and right graphs, respectively). The values of the difference σ between the samples in each of the panels are presented. The inner graphs show the fraction of Lum[OIII] > $10^7 L_\odot$ as a function of the same properties, this value is used by Kauffmann et al. (2003) as a measure of extremely excess Lum[OIII].

↑ Fig4: Fraction of powerful AGNs as a function of galaxy properties.

- More massive, bluer, and younger galaxies show a higher fraction in both samples.
- The barred sample tends to have a higher fraction compared to Ctrl.
- Blue and young = intense star formation in central regions?
  → bars induce gas inflow and contribute to fueling AGNs?
- (Fig 8/9): Strong bars follow the same trend while weak bars does not (likely due to poor statistics).
  → Strong bars have a more significant role in AGN fueling.

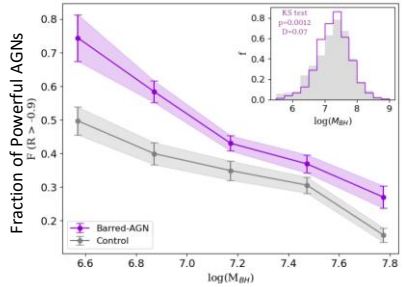
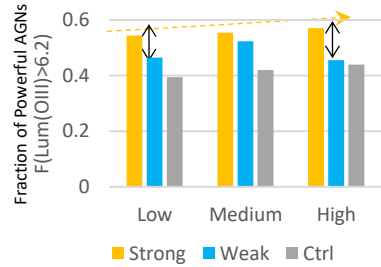


Fig. 6. Fraction of $\mathcal{R}$ > −0.9 as a function of black hole mass. Inner box show the distribution of black hole mass and values of KS-test are presented.

← Fig6: Fraction of powerful AGNs as a function of M_{BH}.

- Smaller BHs show a higher fraction of powerful AGNs.
- The authors interpret it as follows:
- Barred galaxies typically have pseudo-bulges which grow slowly through secular processes.
  - Classical bulges are formed more rapidly through mergers or violent relaxation.
  - → Barred galaxies tend to host smaller (low-mass) BHs, compared to Ctrl.
- Also, smaller BHs are expected to accrete gas more efficiently in their early growth stages (Alexander & Hickox 2012).
- → Smaller BHs in barred galaxies can be powerful.



← Table5: Fraction of powerful AGNs in various environments

- The barred sample, especially with strong bars, shows a higher fraction in denser environment.
- There is no significant difference b/w strong and weak bars in intermediate region. But in lower and denser regions, strong bars show a higher fraction.
- This can be explained as follows: in denser regions, gas infall from ICM enhances nuclear activity, while in field regions, early-formed bars (if exist) can transport gas over long timescales through secular evolution, thereby fueling AGNs.

- (Strong) Bars play a significant role in transporting gas and fueling AGNs.
- A larger statistical sample is needed for a more reliable study of weak bars.