

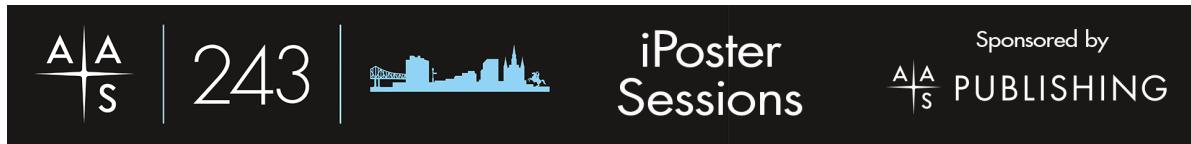
Exploring the Relationship Between Nuclear Dust Lanes and Active Galactic Nuclei

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MOTIVATION



Observational evidence suggests that most major galaxies host supermassive black holes (SMBH, $10^{6-9.5} M_{\odot}$) at their centers, some of which are in a phase of active material accretion. Supermassive black holes of this type, known as active galactic nuclei (AGN), are highly energetic objects that radiate in numerous spectral ranges as material inflow causes the object to increase in size. However, the origin of

the inflowing material and the scope of influence it has on the growth rate of AGN is not currently well understood. Early studies and observations suggest that a source of this inflowing material could be optically obscuring dust, or dust lanes, which are commonly found in and around galactic nuclei.

To better understand the relationships between dust lanes and their host galaxies, we present a sample of 336 nearby AGN ($z < 0.1$) used for comparative analysis across several galactic characteristics including Seyfert type, X-ray obscuration (column density, N_H), Bolometric luminosity (L_B), and Eddington ratio (λ).

DATA AND METHODS

Table 1. Sample AGN Demographics

Object	Morphology	Redshift (z)	Seyfert Type	N_H ($10^x cm^{-2}$)	Bol. Lum. ($\frac{erg}{s}$)	Edd. Ratio (λ)
Mrk 78	Elliptical	0.0373091	Sy2	23.01	6.59E+43	0.00538156
3C403	Elliptical	0.05839908	Sy2	20	1.21E+44	0.02557645
NGC 5194	Spiral/Merger	0.001	Sy2	N/A	1.08E+40	0.000316742
NGC 3998	Lenticular	0.00357417	Sy1.9	20.81	1.71E+41	2.36E-05
NGC 3079	Uncertain	0.00350451	Sy2	26	3.36E+41	0.11127085
NGC 4395	Spiral	0.00110586	Sy1	21.08	3.20E+40	0.011256885

Characteristics of our sample of 336 AGN used for comparative analysis. Morphological classifications of each sample object were obtained from GalaxyZoo (<https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/>) and all other demographics were reported in the 70-month Swift-Burst Alert Telescope (BAT) all sky survey (Ricci et al. 2017).

Our sample comes from a parent sample of AGN that were detected in the 70-month Swift-Burst Alert Telescope (BAT) all sky survey (Ricci et al. 2017). The first selection criterion for our sample was based on electromagnetic emission, such that objects selected emitted in the hard X-ray which allows for the detection of highly obscured AGN (Koss et al. 2022). Of the parent sample, 858 AGN were identified as emitting in the hard X-ray. From here, objects were classified as beamed and unbeamed, and our sample downsized to ~ 700 unbeamed objects. Finally, we applied a redshift cut in order to ensure we could probe the central parsecs of each object for optimal identification of dust lanes. After all cuts were made, our final sample contains 342 nearby AGN.

Table 2. Sample Dust Classifications

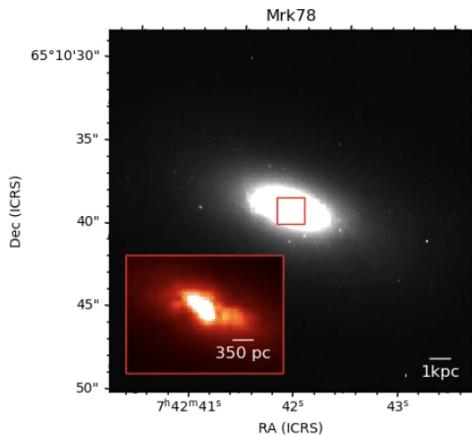
Object Name	Dust Features	Orientation	Location	Uncertainties	Notes
Mrk 78	Yes	No	Nuclear	No	None
3C403	Yes	No	Galaxy-wide	No	None
NGC 5194	Yes	No	Both	No	None
NGC 3998	No	No	Neither	No	Point-like Nucleus
NGC 3079	Yes	Yes	Galaxy-wide	Yes	Orientation
NGC 4395	No	No	Neither	Yes	Point-like Image

Dust classifications were assigned manually to every sample object during the visible inspection of each HST image through SAOImageDS9. The classifications outlined above were refined through several rounds of inspection of each image to support consistent classification.

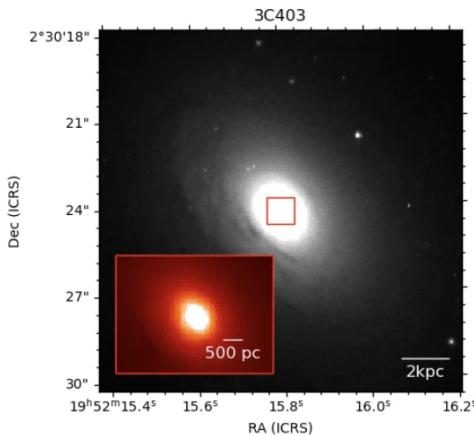
Object images were visually inspected and classified by dust features using SAOImageDS9, which allowed for the manual adjustment of pixel values, zoom and stretch scales, all of which were necessary for the visual identification of nuclear and galaxy-wide dust lanes.

Then we compared a variety of galaxy properties, i.e. Seyfert type, column density, bolometric luminosity and Eddington ratio with their determined dust classifications.

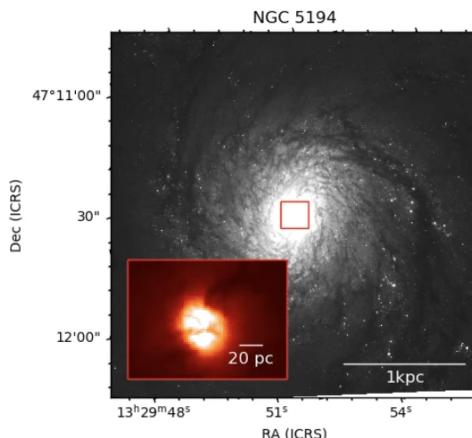
OUR SAMPLE



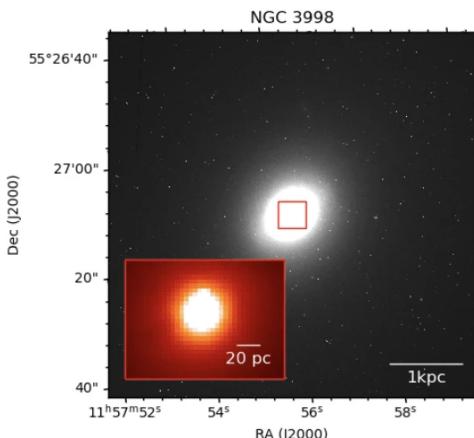
(a) Nuclear Dust Only



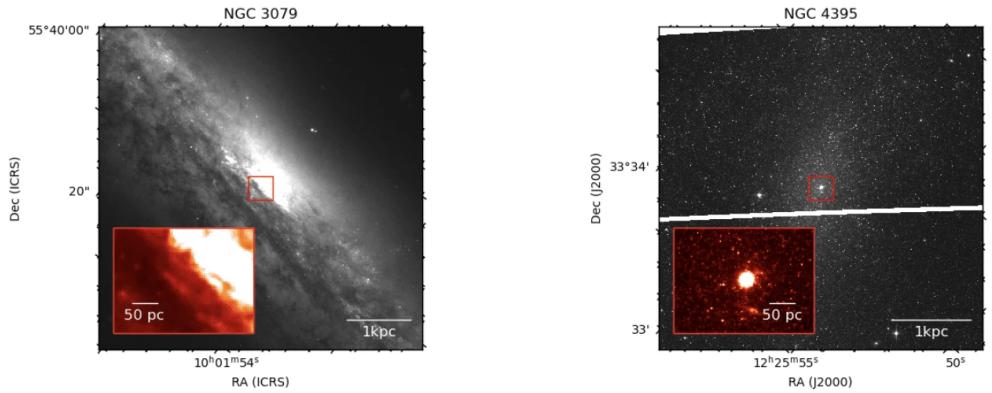
(b) Galaxy-wide Dust Only



(c) Both Dust Scales



(d) Neither Dust Scale



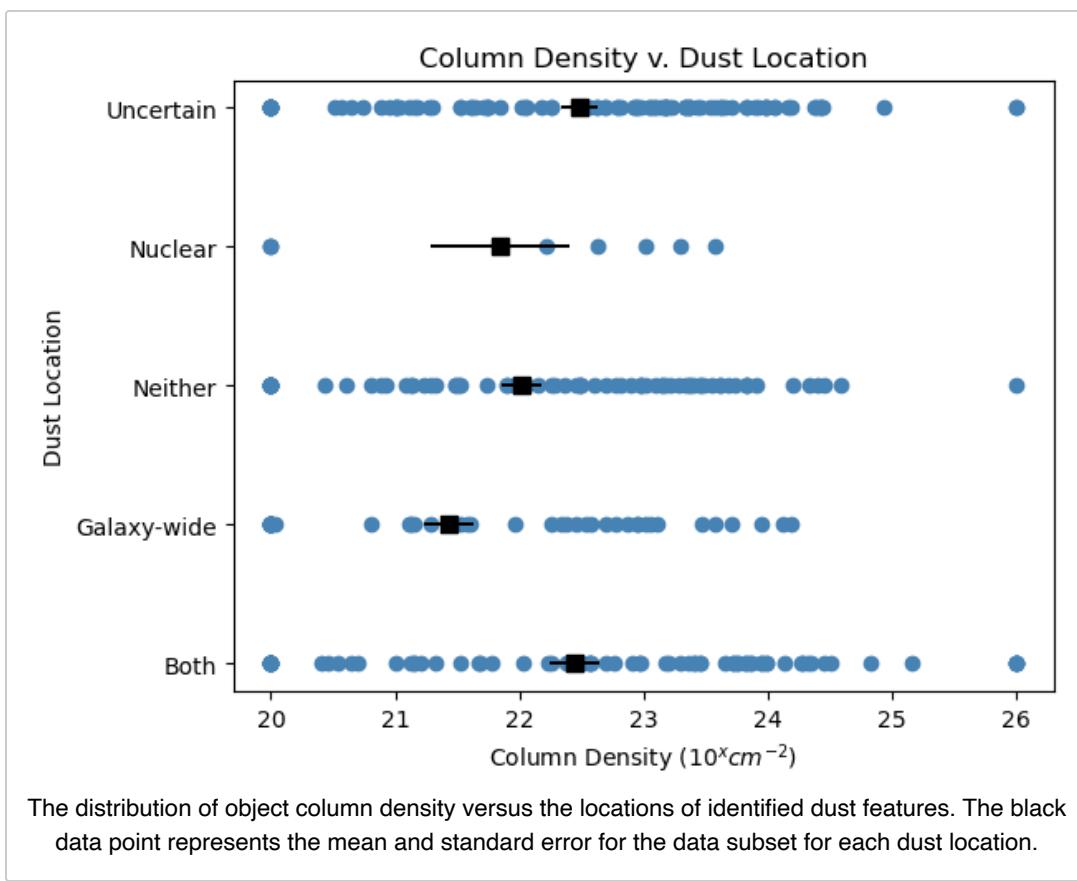
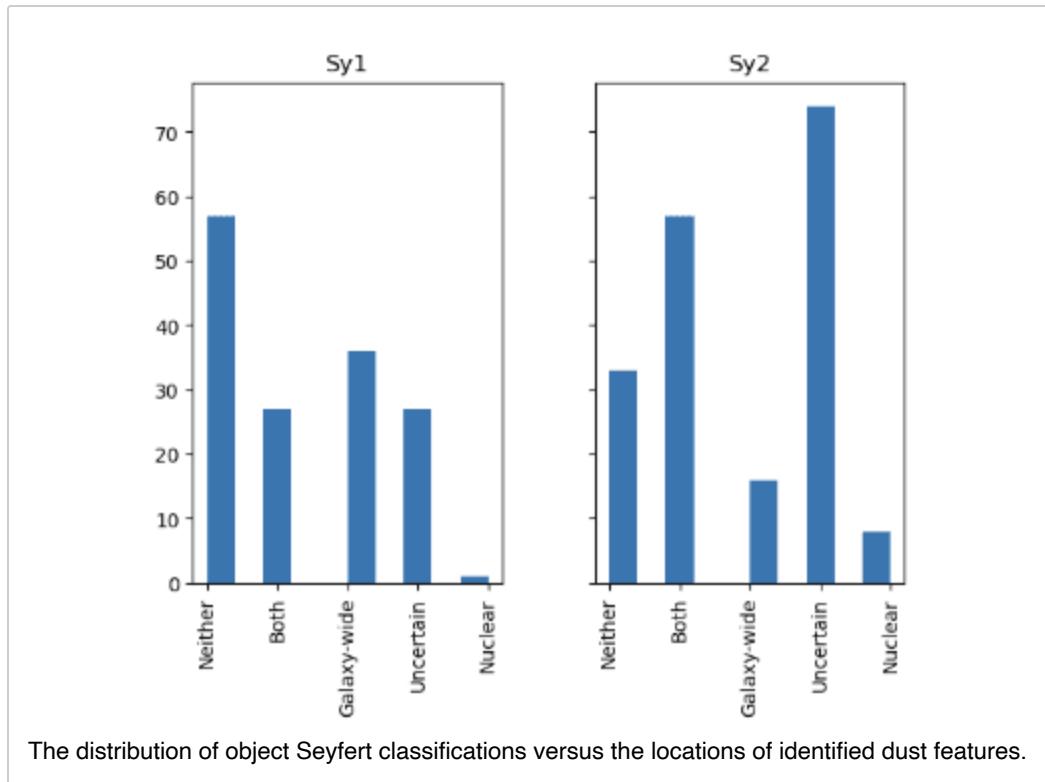
Examples of dust lane scale classifications. Red inserts are cutouts of the galactic center to better see dust around the central parsecs of each AGN. From top to bottom, left to right: (a) Mrk78: Nuclear dust lanes only, (b) 3C403: Galaxy-wide dust lanes only, (c) NGC 5194: Dust lanes across both nuclear and galaxy-wide scales, (d) NGC 3998: no dust lanes, (e) NGC 3079: uncertain dust lane scales due to orientation, (f) NGC 4395: point-like source (no dust lanes)

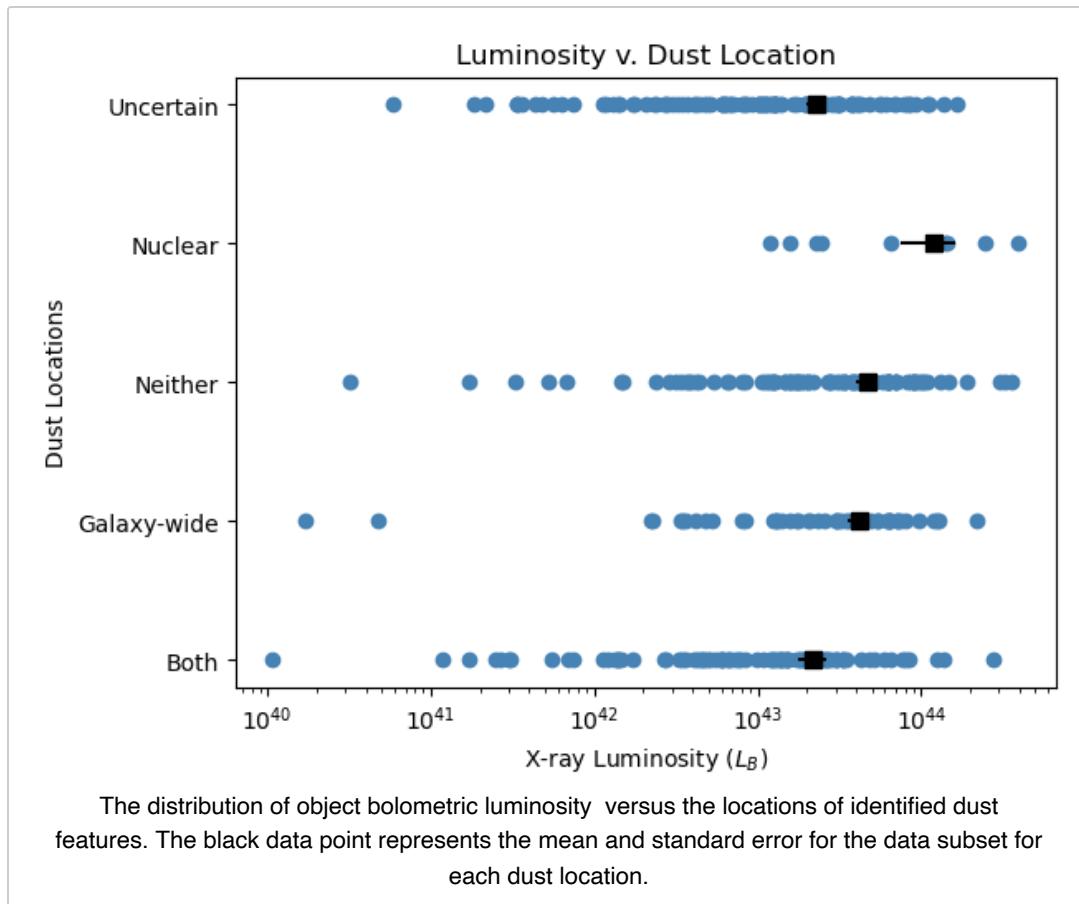
Out of our sample of 336 AGN, 246 objects were classified as exhibiting dust features on some scale including nuclear, galaxy-wide or both. The other 90 objects exhibit no distinct dust. An important fourth categorization of our sample are those that exhibit dust lanes on some scale, but due to their orientation we are unable to conclusively say whether or not the observed dust lanes are around the galactic nucleus. There are 101 objects within our sample that fall into this latter category.

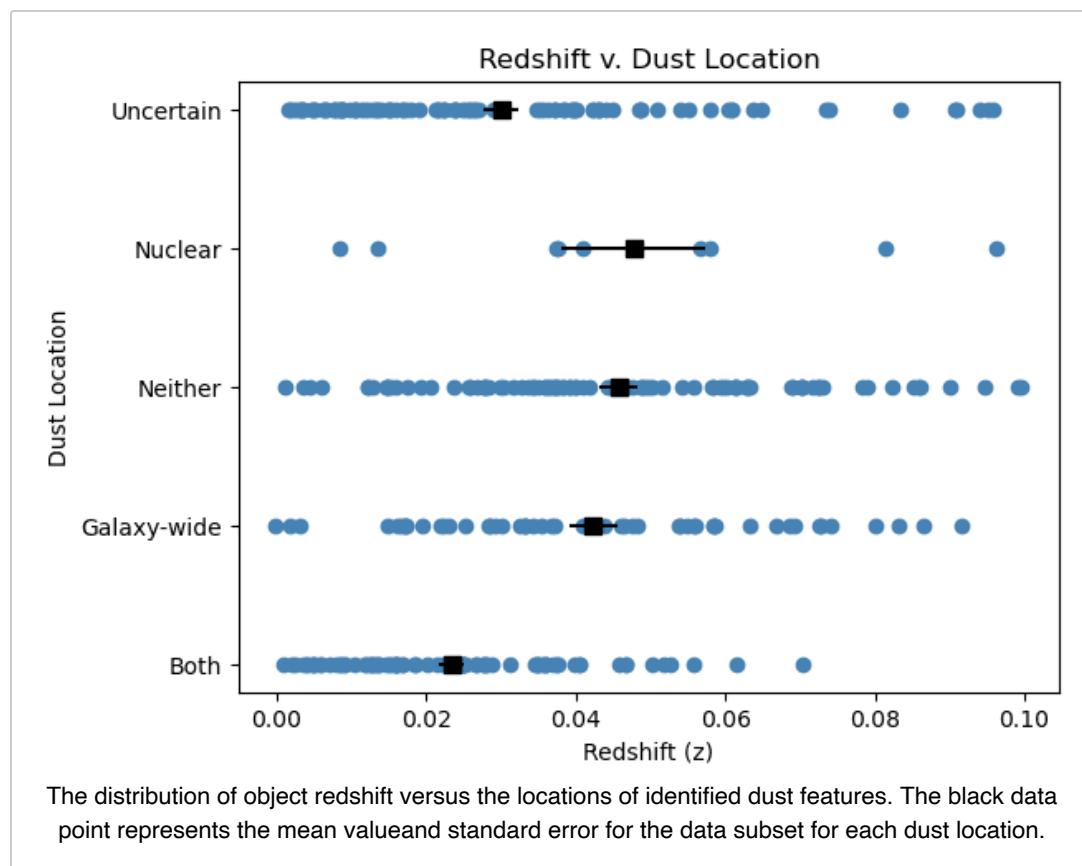
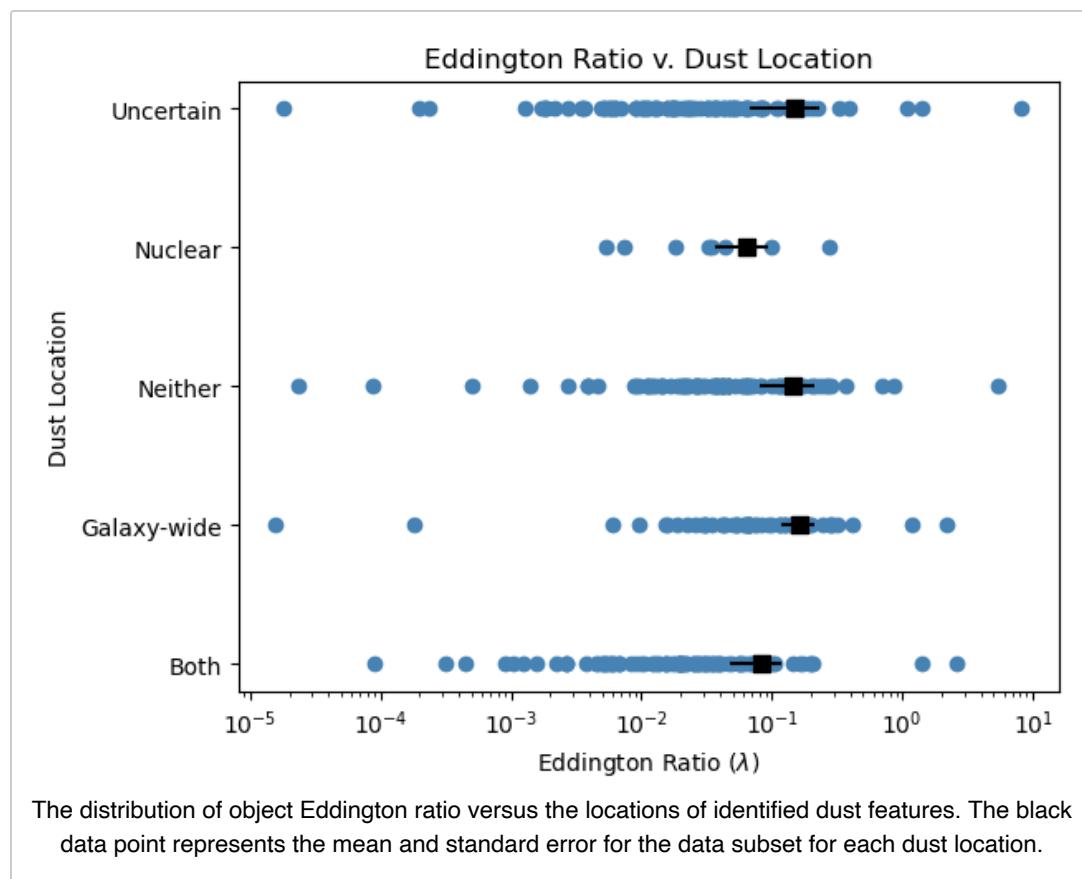
More explicit classifications show that 9 of the 246 objects that exhibit dust on some scale exhibit only nuclear dust lanes, 52 objects exhibit only galaxy-wide dust lanes and 84 objects exhibit dust lanes across both scales. AGN that fall into the category of exhibiting dust features on both scales are not ones that are observed at an obstructing orientation, meaning that the visual identification of dust in these cases is certain.

The majority of the 90 objects that were identified as having no dust features were done so confidently. A few objects in this category were noted as imaging similarly to a point-like object, inhibiting the identification of dust within the galaxy or around the nucleus. In this case, the AGN were classified as having no nuclear dust features so long as no other dust features on other scales were visually identifiable.

PROPERTIES AS FUNCTIONS OF DUST







CONCLUSIONS



Based on the comparative analysis conducted, we find that optically obscuring dust lanes are not significantly influential in the case of Seyfert type classification, column density, bolometric luminosity or Eddington ratio. This holds true even for properties like the Eddington ratio, that one would expect to be correlated with the existence of nuclear dust lanes. In order to better understand the role of dust on galactic scales, we require a larger sample of higher resolution images for further comparative analysis to be conducted.

ACKNOWLEDGMENTS

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References

- Bianchi S., Maiolino R., Risaliti G., 2012, Advances in Astronomy, 2012, 1
González-Martín, O. et al., 2013, A&A, 553, A35
Griffith R. L., Stern D., 2010, AJ, 140, 533
Guainazzi M., Fiore F., Matt G., Perola G., 2001, Monthly Notices of the Royal Astronomical Society, 327, 323
Guainazzi M., Matt G., Perola G. C., 2005, A&A, 444, 119
Koss M. J., et al., 2022, The Astrophysical Journal Supplement Series, 261, 2
Macchetto F. D., 1999, Supermassive Black Holes and Galaxy Morphology (arXiv:astro-ph/9910089)
Maiolino R., Risaliti G., Salvati M., 1999, A&A, 341, L35
Malizia, A. Bassani, L. Stephen, J. B. Bazzano, A. Ubertini, P. 2020, A&A, 639, A5
Malkan M. A., Gorjian V., Tam R., 1998, ApJS, 117, 25
Prieto M. A., Nadolny J., Fernández-Ontiveros J. A., Mezcua M., 2021, MNRAS, 506, 562
Ramos Almeida C., Ricci C., 2017, Nature Astronomy, 1, 679
Ricci C., et al., 2017, ApJS, 233, 17
Suh H., Hasinger G., Steinhardt C., Silverman J. D., Schramm M., 2015, The Astrophysical Journal, 815, 129
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TRANSCRIPT

ABSTRACT

We investigate the influence of optically obscuring nuclear dust lanes on numerous characteristics of nearby ($z < 0.01$) active galactic nuclei (AGN) including Seyfert type classification, column density, bolometric luminosity, and Eddington ratio. Using a sample of 336 AGN from the 70-month *Swift*/BAT survey, we visually catalog each sample AGN according to the existence, or lack, of identifiable dust lane features across nuclear and galactic scales. Previously, many of these dust lane features were invisible due to the low spatial resolution restrictions of ground-based imaging. Using optical images from the Hubble Space Telescope with high spatial resolution ($\sim 50\text{pc}$) allows for more sensitive detection of dust lanes across sample objects. Using comparative analysis, we assess the role of dust features in AGN and find that their existence does not significantly influence AGN growth rate, such that sample object classification by dust existence does not heavily correlate with higher X-ray obscuration levels or Eddington ratios. However, to fully understand the scope of the relationship between dust lanes and AGN, we require analysis of larger samples to include a broader range of AGN redshift, as well as detection and imaging instruments with higher sensitivity to samples that lie closer to the extremes of AGN characteristic limits. This project was supported in part by the NSF REU grant AST-2149985 and by the Nantucket Maria Mitchell Association.

