

# Mid-infrared Variability of Active Galactic Nuclei in Cosmic Voids

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## Background & Introduction

### Goals:

- Quantify Active Galactic Nuclei (AGN) in cosmic voids vs. walls using variability in the mid-infrared
- Constrain the role of interactions in galaxy evolution

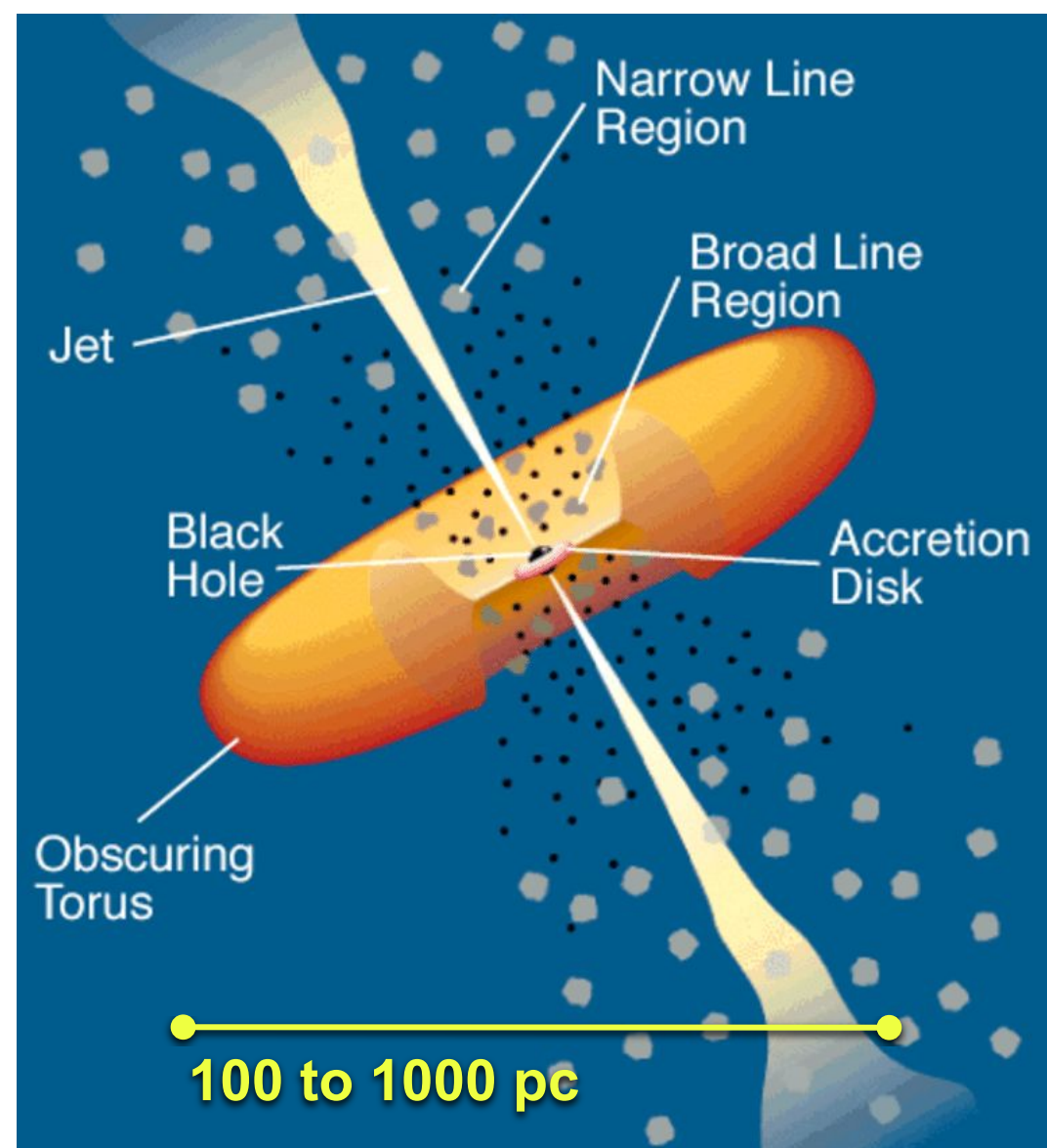
### What are Active Galactic Nuclei?

- Actively accreting supermassive black hole
- Emission lines reveal fast moving gas
- Jets (show in radio)
- Very red colors in mid-IR
- Variable emission

### What are cosmic voids?

- Most underdense environments
- ~80% of universe volume
- Less frequent interactions
- Distinguish between "nature" and "nurture"

From: C.M. Urry & P. Padovani



### Why mid-infrared variability?

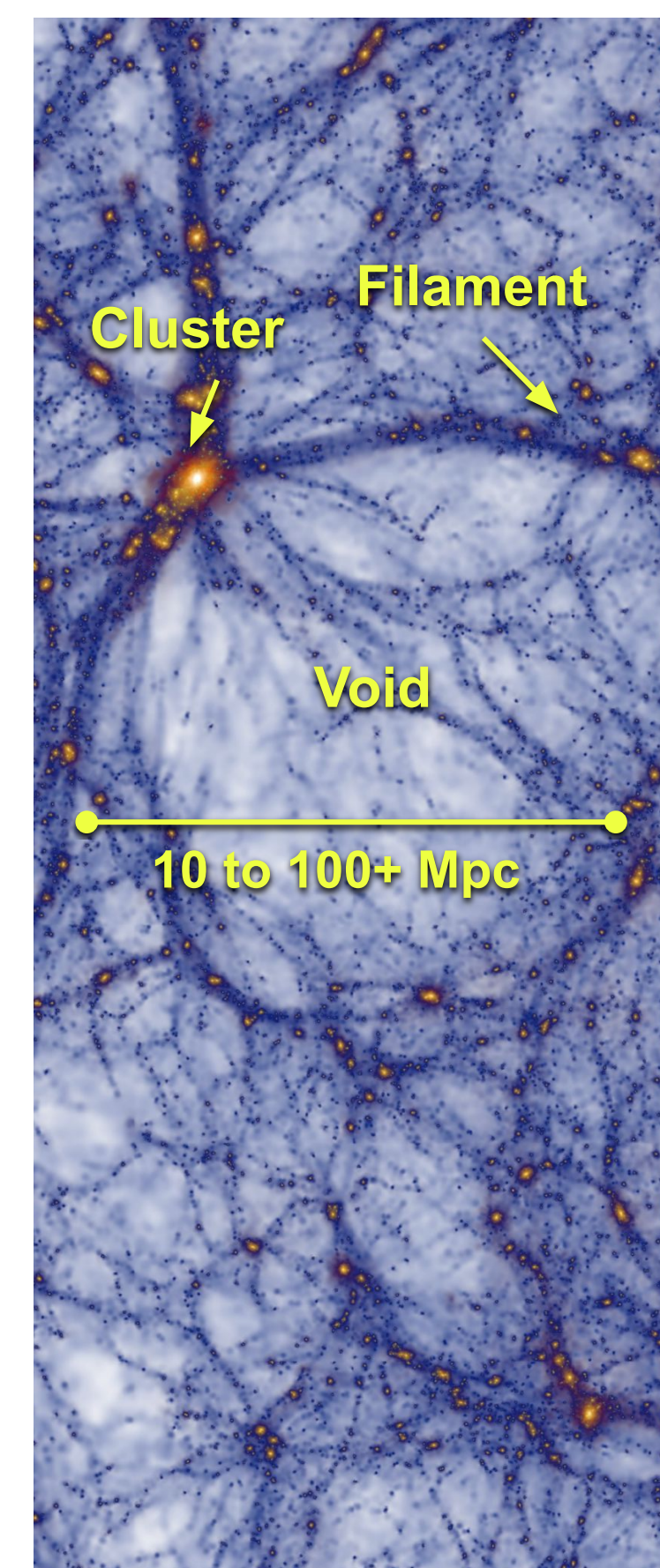
- Elusive AGN
- Absorption by circumnuclear dust (torus)
- Dilution from star-formation

From: Robert Gendler



From: NASA WISE

From: Max-Planck Institute for Astrophysics



Variability is essential for identifying active accretion onto supermassive black holes.

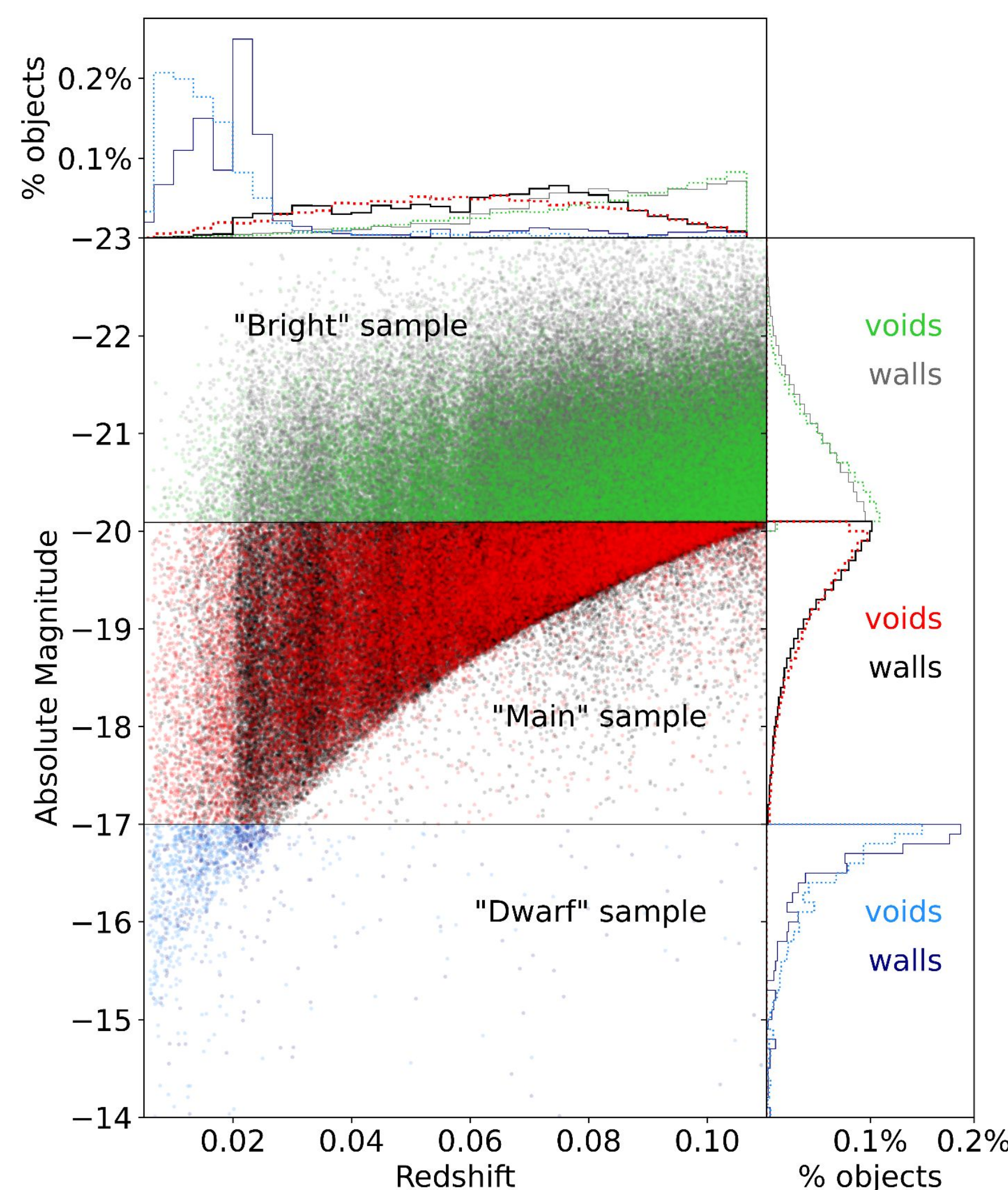
Dwarf galaxies are more variable in underdense cosmic regions.



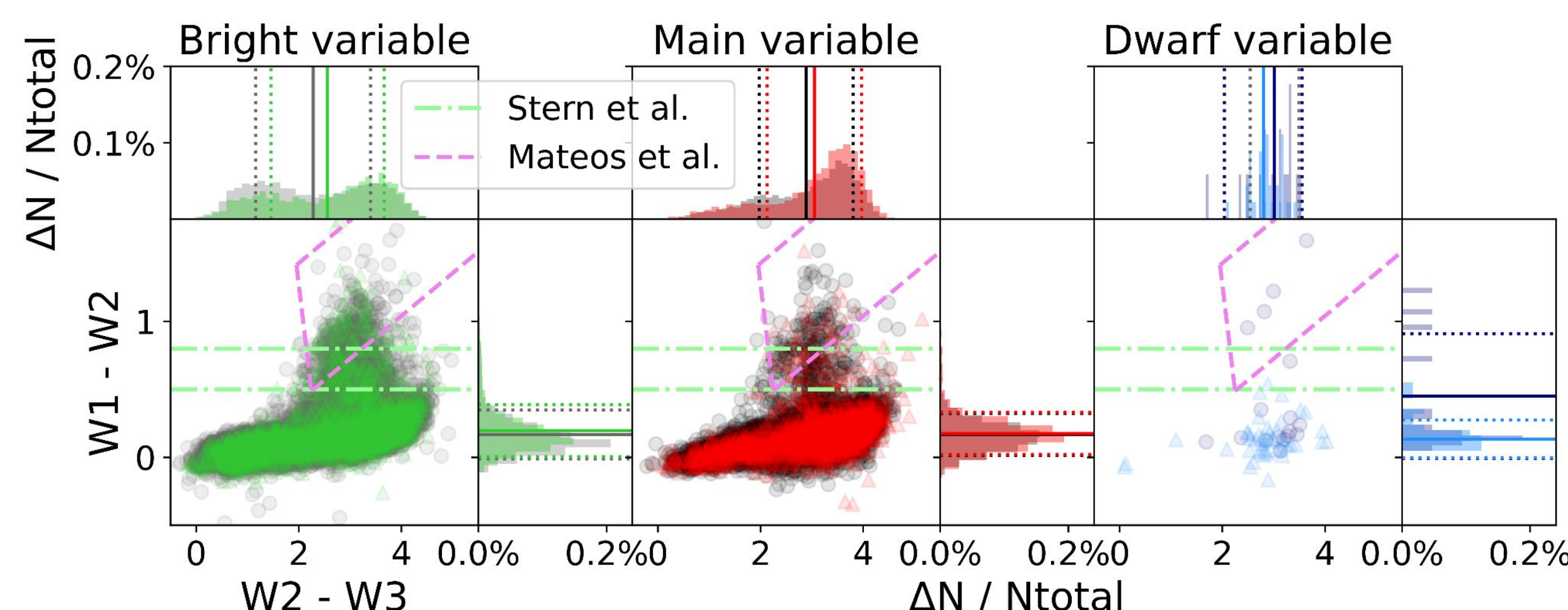
## Methods & Materials

- Void/wall galaxy catalogs from the Sloan Digital Sky Survey (Douglass et al., 2022)
- Mid-IR measurements from AllWISE/NEOWISE (8.4 years)
- Calculated variability using Pearson r (Secret & Satyapal, 2020)

From: NASA & JPL-Caltech



Step	Void Galaxies count (%)	Wall Galaxies count (%)
Crossmatch with mid-IR multi-epoch data	86,867 (100%)	245,721 (100%)
high S/N	79,499 (91.52%)	234,272 (95.34%)
# bins > 3	74,062 (85.26%)	223,753 (91.06%)
Remove M outliers	71,478 (82.28%)	220,051 (89.55%)
Crossmatch with colors (W1 - W2)	71,211 (81.98%)	219,324 (89.26%)

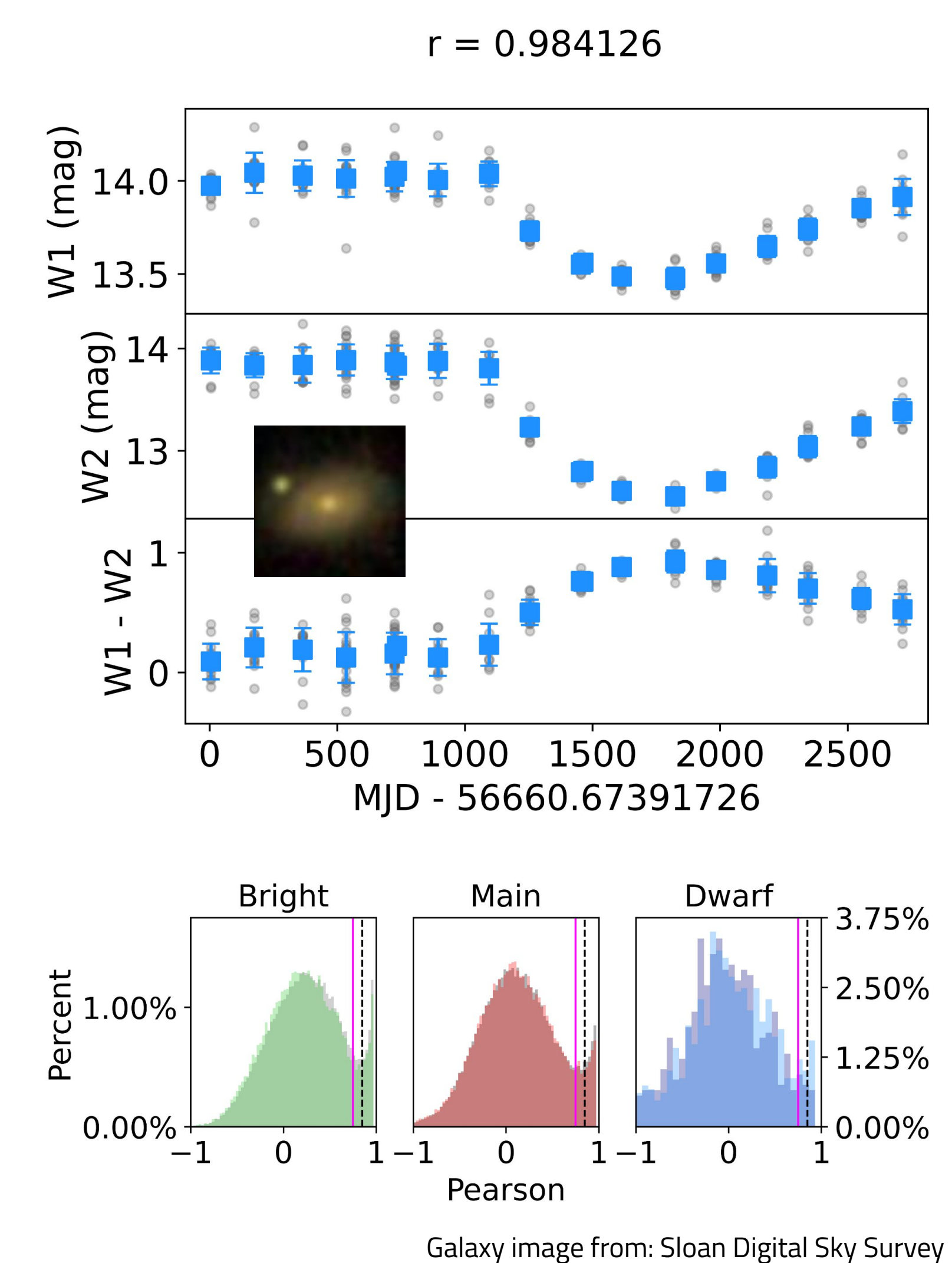


## Results & Conclusions

- Overall, galaxies are more variable in walls than in voids
- Interactions encourage accretion, but only among more luminous galaxies (Constantin et al., 2008)
- 25,000+ AGN are only identified with variability

Galaxy group	Total count	Percent of parent	Count (Percentage)	
			W1 - W2 < 0.5	W1 - W2 >= 0.8
(Parent) full voids	71211	100.0	70205 (98.59 ± 0.52)	320 (0.45 ± 0.03)
(Parent) full walls	219324	100.0	216698 (98.8 ± 0.3)	798 (0.36 ± 0.01)
Variable full voids (r > 0.75)	9258	13.0 ± 0.14	8806 (95.12 ± 1.42)	149 (1.61 ± 0.13)
Variable full walls (r > 0.75)	32365	14.76 ± 0.09	31003 (95.79 ± 0.76)	462 (1.43 ± 0.07)
Variable full voids (r > 0.85)	6753	9.48 ± 0.12	6409 (94.91 ± 1.66)	116 (1.72 ± 0.16)
Variable full walls (r > 0.85)	24074	10.98 ± 0.07	22975 (95.43 ± 0.88)	381 (1.58 ± 0.08)
(Parent) dwarf voids	726	100.0	697 (96.01 ± 5.09)	20 (2.75 ± 0.62)
(Parent) dwarf walls	528	100.0	497 (94.13 ± 5.88)	16 (3.03 ± 0.77)
Variable dwarf voids (r > 0.75)	69	9.5 ± 1.2	67 (97.1 ± 16.65)	1 (1.45 ± 1.46)
Variable dwarf walls (r > 0.75)	32	6.06 ± 1.1	23 (71.88 ± 19.65)	5 (15.62 ± 7.51)
Variable dwarf voids (r > 0.85)	45	6.2 ± 0.95	44 (97.78 ± 20.73)	0 (0.0)
Variable dwarf walls (r > 0.85)	17	3.22 ± 0.79	12 (70.59 ± 26.61)	4 (23.53 ± 13.08)

"Variable" = r > 0.75, r > 0.85



Galaxy image from: Sloan Digital Sky Survey