A WISE Test of Links Between Megamaser Activity and Nuclear Obscuration

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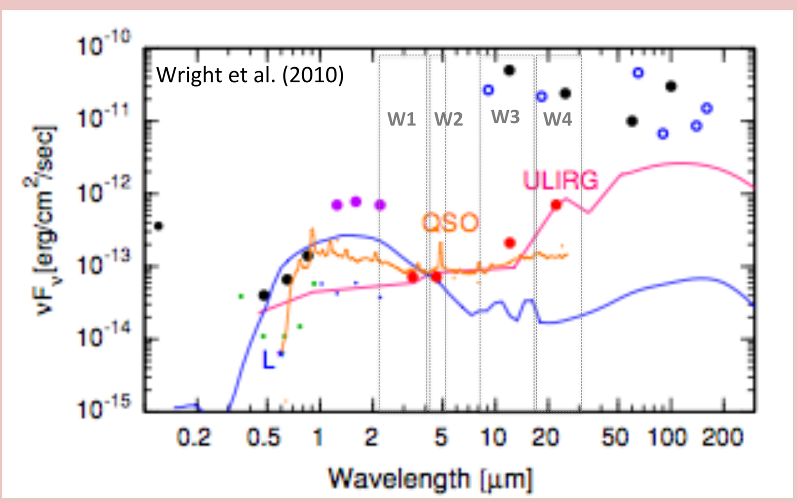
Water Megamasers and Mid-IR Emission

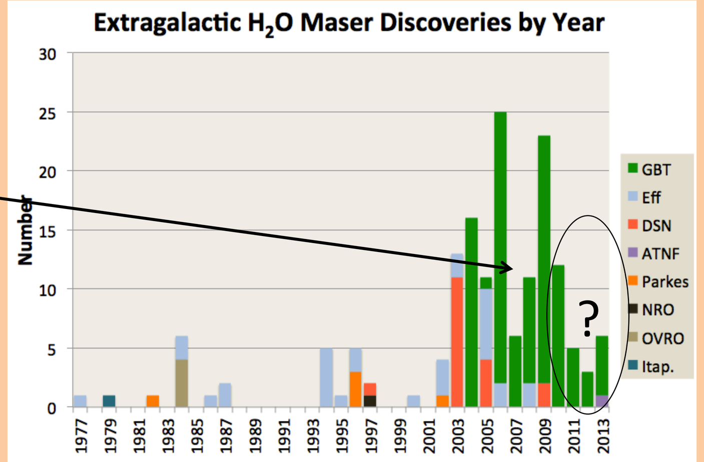
Water megamaser disks detected in 22 GHz emission in galactic nuclear regions provide direct geometrical distances to galaxies and the most precise and thus independent constraints of the Hubble Constant H_0 in the nearby universe, as well as the most accurate masses of supermassive black holes. Nevertheless, these systems are extremely rare. Improvements on their detection rates in future surveys rely on better understanding of their physical properties, in relation to those of their host galaxies. While there is some evidence that megamasers may be associated with the molecular disk or torus that surrounds and (partially) obscures an actively accreting massive black hole ($M_{BH} \sim 10^7 M_{sun}$) harbored by a galactic nucleus (i.e., an Active Galactic Nucleus, or AGN), the true nature of the nuclear galactic activity remains ambiguous for a large majority of nearby galaxies: a mix of processes including emission from star-forming regions, other ionization sources (shocks, turbulence, etc.), nuclear obscuration, as well as host galaxy starlight obfuscate their true classification. Exploiting information on the thermal infrared should be crucial for tackling questions like*: Are megamaser disks always related to black hole accretion? Does maser activity depend on the black hole mass, the accretion rate, the type of associated nebular emission, the small-scale environment, or the morphology of their host? Do they require dusty/molecular tori? Strong star-formation? All of the above? What is the true detection rate of disk megamaser emission? Can we eventually find enough of them to constrain H_0 to levels required to decipher the nature of dark energy?*

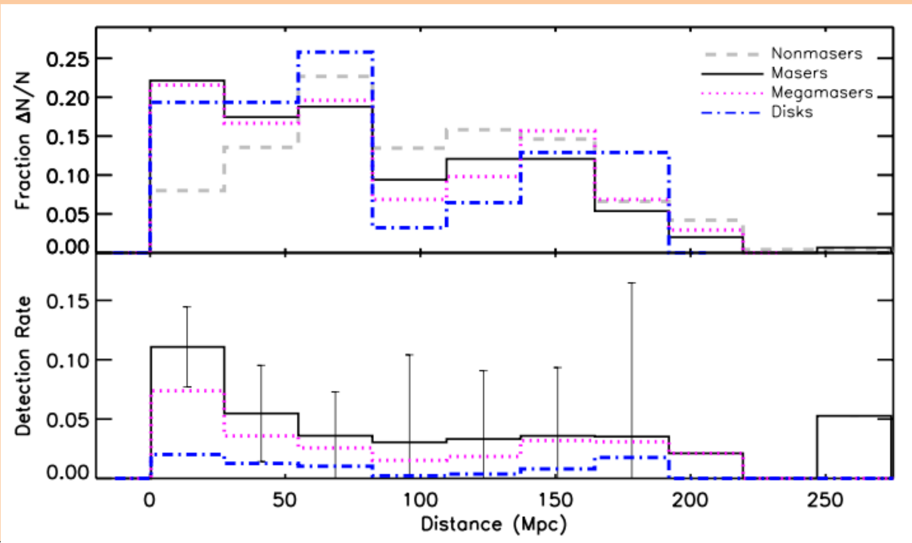
Because the circumnuclear dust in AGNs is hot (i.e., at temperatures reaching its sublimation limit, ~1500K; e.g., Simpson 2005), its emission is enhanced and much redder than the stellar light with a typical Rayleigh-Jeans tail in the 3–10 µm range, producing a distinctive mid-IR emission. Wide-Field Infrared Survey Explorer (WISE; Wright et al. 2010) data offer unprecedented insight in this regard: redder colors, [3.4] - [4.6] > 0.8, seem to reliably separate from star-forming systems the AGNs where accretion dominates the bolometric luminosity output, and when the AGN is highly obscured (e.g. Yan et al. 2013, Assef et al. 2013).



The Data: Detection of Masers, Megamasers, and Disks // WISE Counterparts

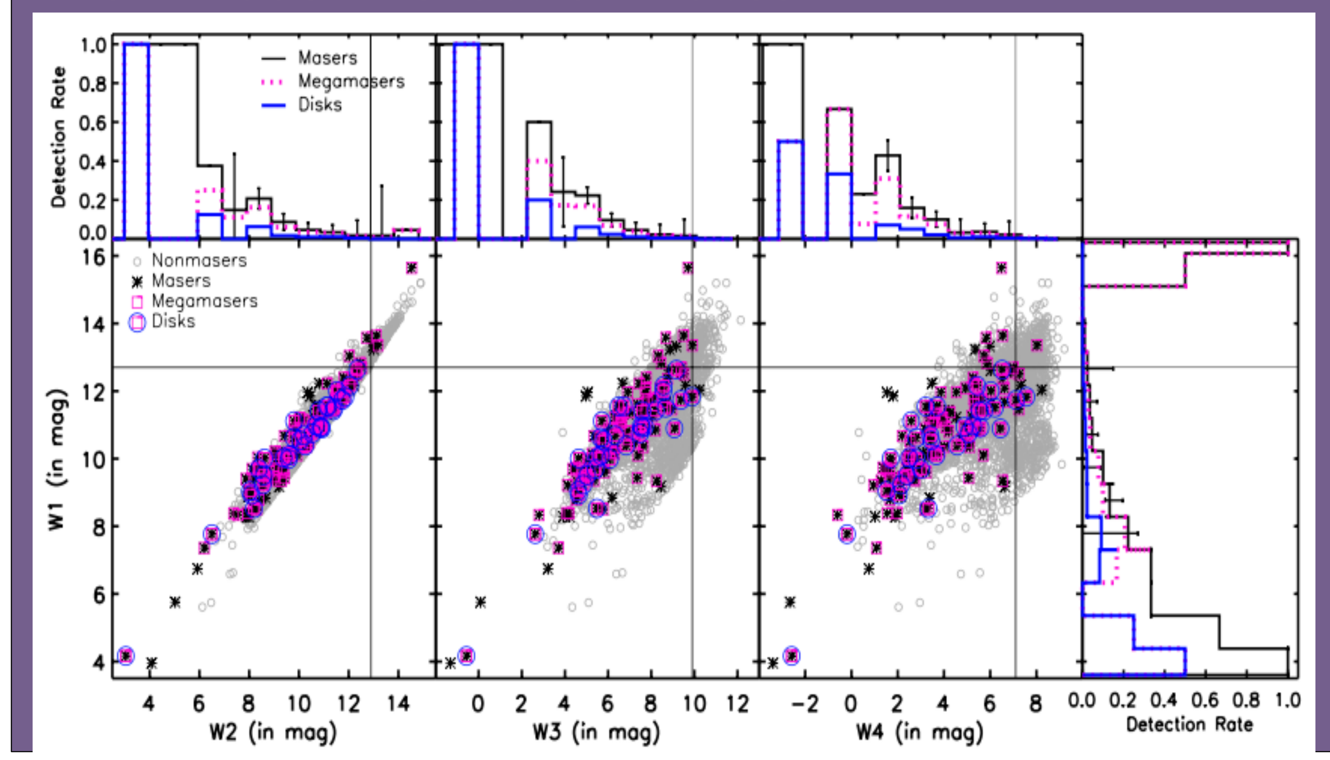
The Megamaser Cosmology Project (MCP; Reid et al. 2013; Kuo et al. 2013, 2015**)** makes publicly available the largest sample of galaxies surveyed in 22 GHz water maser emission. Of > 3500 galaxy nuclei surveyed so far, only ~ 3% are found to host masers, with ~40% of them possibly originating in disks. Previous selection of target maser galaxies was based on optical selection, which appears to have exhausted the current databases.





	Masers	Non-Masers
MCP Sources	151	3490
WISE 3" Detections	134	2767
Cross-match result	88.7%	79.3%

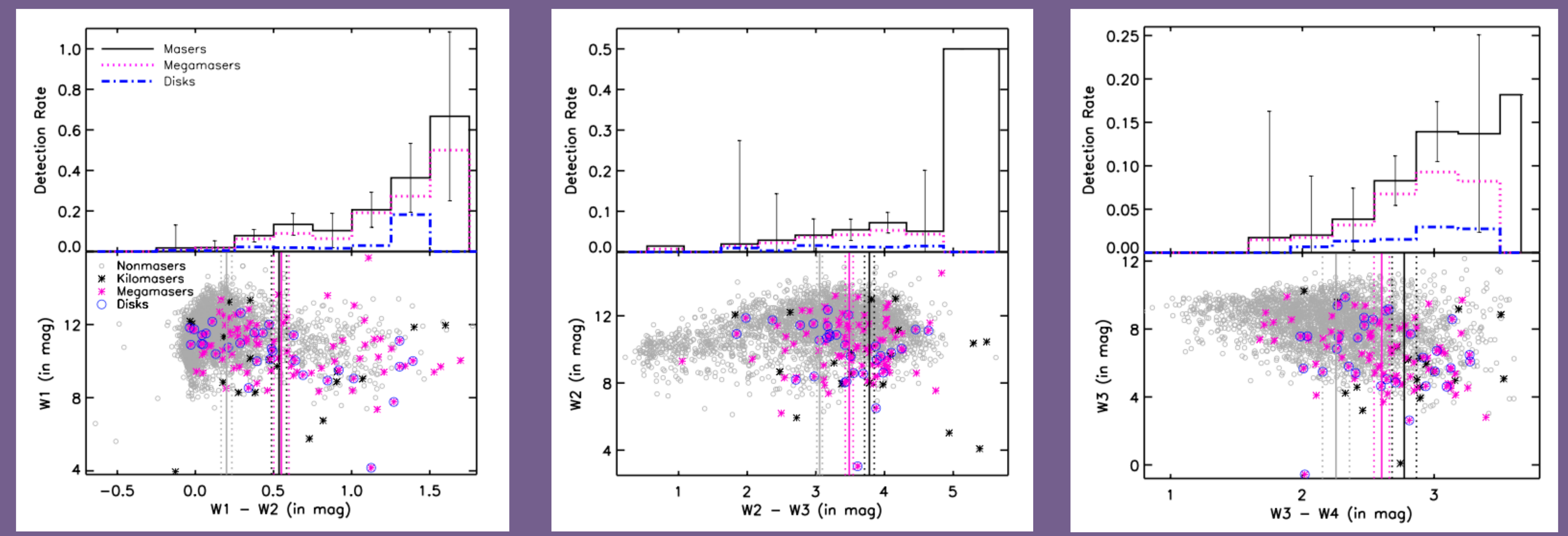
WISE Maser Detection Rates



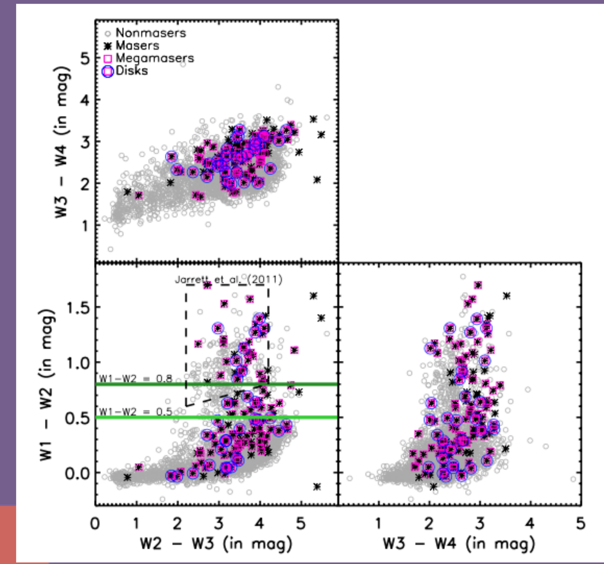
New brightness cuts in mid-IR:
W1 < 12.7
W2 < 12.9
W3 < 9.9
W4 < 7.1

could increase the overall maser detection rate to 5%, and possibly by a factor of ~5 (to ~20%) among galaxies with bright mid-IR emission, at current sensitivity in maser detection.

WISE Colors and Maser Detection



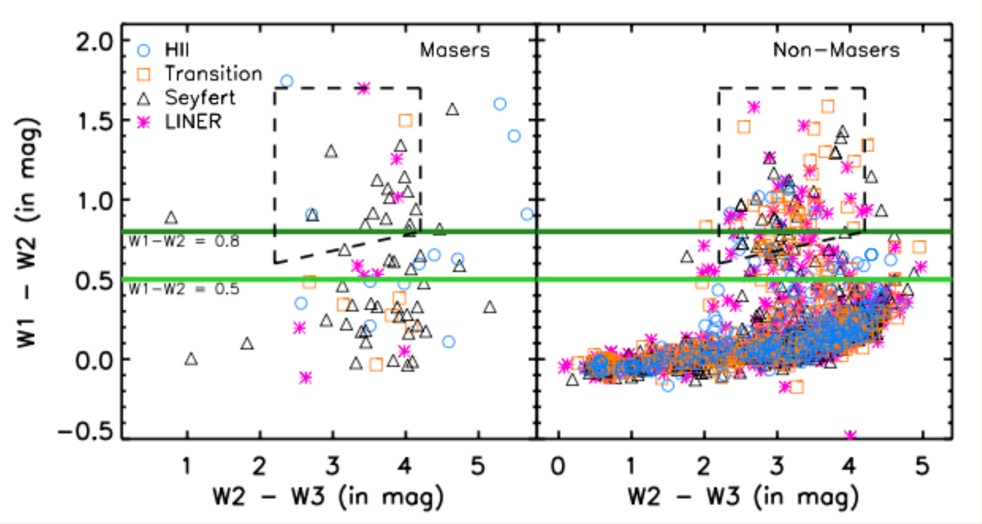
Maser galaxies exhibit trends towards redder mid-IR colors; both megamaser and disk detection rates appear to increase for redder WISE colors, however, they seem to be characterized by a "Goldilocks range" in the WISE properties. Interestingly, only 20% of all maser galaxies, that include only ~40% of maser disks, have red mid-infrared colors that are highly suggestive of heated dust by powerful accreting massive black holes, and therefore are associated with obscured AGN activity.



WISE AGN Criterion	Non-Masers	Masers	Mega-Masers	Disks
W1-W2 > 0.8	155	38 (20%)	29 (15%)	8 (4.2%)
Jarrett et al. (2011)	189	35 (16%)	28 (13%)	8 (3.6%)
W1-W2 > 0.5	320	60 (16%)	44 (12%)	11 (2.9%)

WISE Colors + Optical Spectral Signatures (available for 60% of the MCP sample)

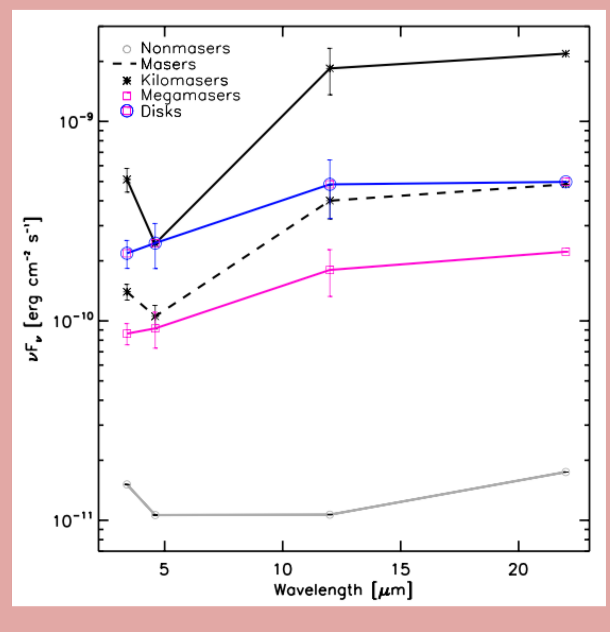
The fraction of galaxies with AGN-like red WISE colors is higher among masers than among non-masers, for all spectral types. The fraction is highest among Seyferts, however, this could be due to target selection biases (e.g., Constantin 2012). LINER and Seyfert megamasers show equally significant fractions of AGN-like WISE colors, but disks are only found in Seyferts. The fraction of disks in WISE blue Seyferts is however 55%.

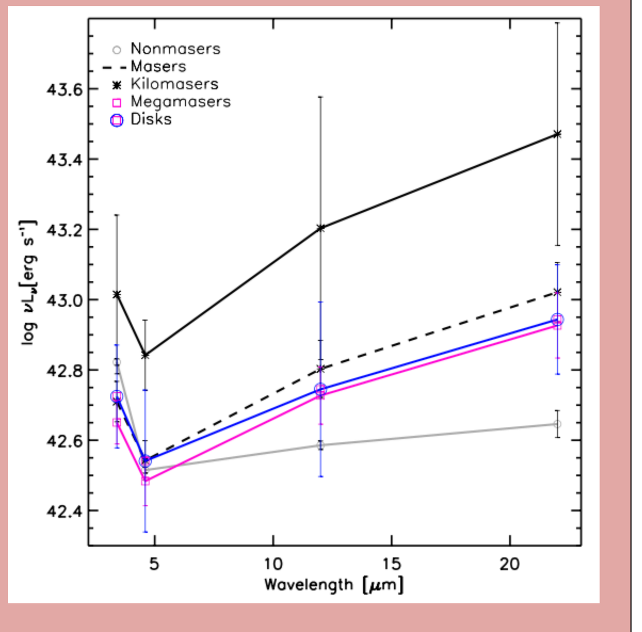


	Non-Masers (% with W1-W2 > 0.8)		Masers (% with W1-W2 > 0.8)		Mega-Masers (% with W1-W2 > 0.8)		Disks (% with W1-W2 > 0.8)	
H II	228	5 (2.2%)	13	3 (23%)	1	0 (0%)	0	0 (0%)
Transition	347	23 (6.6%)	8	1 (10%)	4	0 (0%)	0	0 (0%)
Seyfert	350	21 (6.0%)	49	17 (35%)	41	14 (34%)	11	5 (45%)
LINER	415	24 (5.8%)	10	3 (30%)	8	3 (38%)	1	0 (0%)

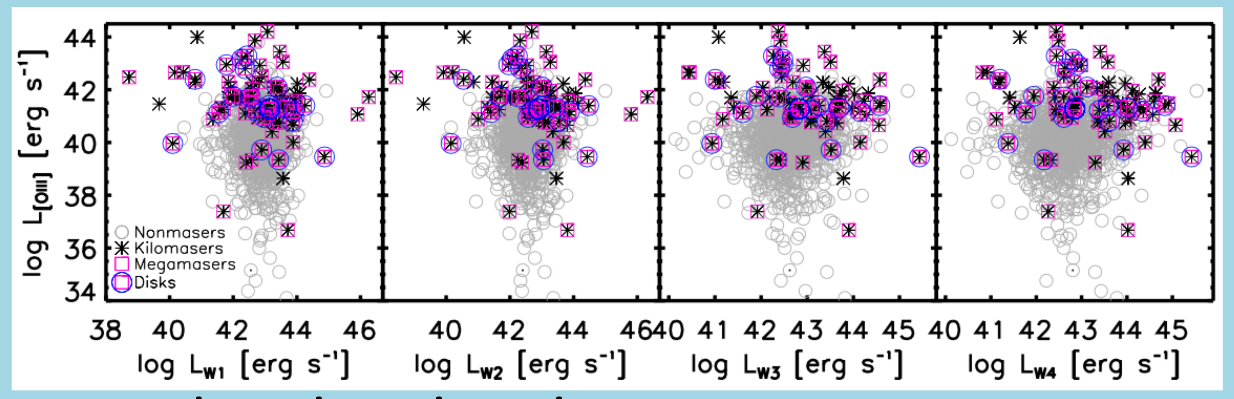
Mid-IR Spectral Energy Distributions (SEDs)

Average mid-IR spectral energy distributions for various types of maser galaxies and non-masers reveal, again, that maser disks display "goldilocks" characteristics: in this case, mid-IR spectral indices that are intermediate between those of kilomasers and the non-detections.

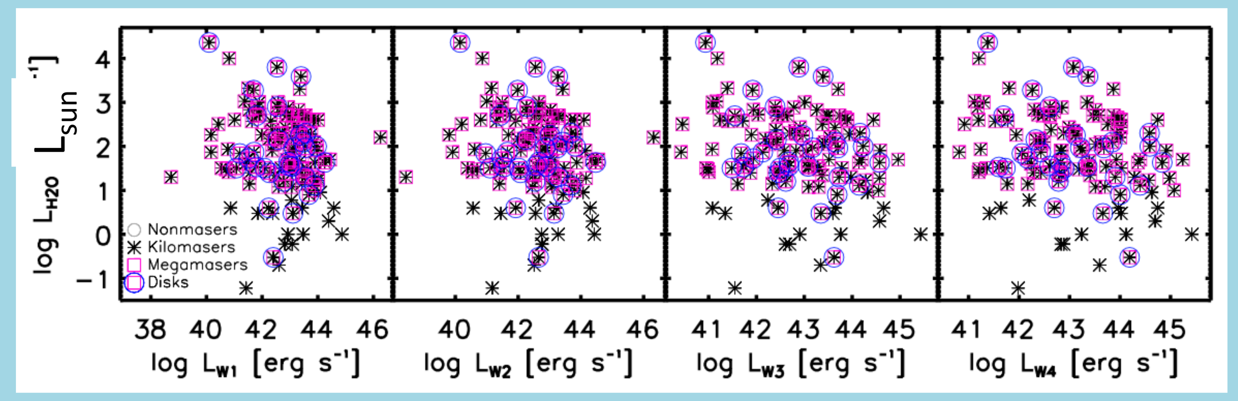




$L_{[O\ III]}$ vs. L_{W1}, L_{W2}, L_{W3}, L_{W4}



L_{H2O} vs. L_{W1}, L_{W2}, L_{W3}, L_{W4}



There is a clear (although weak) negative correlation between the strength of the H_2O emission and the mid-IR luminosity in all four WISE bands, which is also reflected in the apparent trends with the [O III] luminosity which was previously found to positively correlate with L_{H2O} : the most luminous megamaser disks are found among the weakest mid-IR emitters.

Conclusions

Using data from the Wide-Field Infrared Survey Explorer (WISE) we systematically studied the mid-IR properties of the galaxies with and without nuclear water maser emission to better constrain the connection between water masing activity and the circumnuclear dust absorption and radiation reprocessing galaxy centers. We found:

- a higher (5%) maser detection rate among the WISE detected galaxies, and especially high (18%) for [3.4] - [4.6] > 0.8 systems.
- mid-IR colors and luminosities are useful in separating masers from non-masers, however, there is little to say about distinguishing among different types or morphologies of the masing activity (i.e., maser vs. megamaser, vs. maser disk) based on their WISE properties.
- of all maser disks, ~60% are in fact in the blue ([3.4] - [4.6] < 0.8) mid-IR region, showing once again that the megamaser disks are not necessarily associated with obscured/reddened Seyfert-type activity, and that the SMBH accretion associated with the maser disk is heavily buried in hosts of other type(s) of dominant emission.

=> need new theoretical alternatives for the "seed" radiation for the powerful megamaser emission, and novel consideration of the geometry of this emission; the mid-IR emission does not seem to be very sensitive to the maser pumping mechanism.

=> maser disk detection could remain the only way to acknowledge these particular accreting SMBHs, and thus a novel way to compute an improved census of active BHs in galaxy centers.

References

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