A Comparative Study of the Wide-Field Infrared Survey Explorer Properties of Maser and Non-Maser Galaxies in the Mid-Infrared

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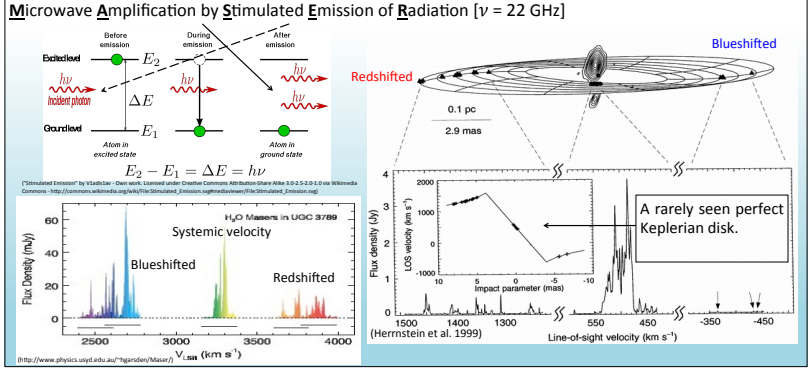
Abstract

There is increasing evidence that supermassive black holes (SMBHs) reside in the centers of galaxies, and that their properties are strongly correlated, which suggests the possibility of a co-evolution of SMBHs and their host galaxies. Signs for SMBH growth, or accretion of the surrounding material, are found in the so-called active galactic nuclei (AGNs). A small fraction (4%) of all galaxies also display the exotic 22GHz water maser emission in their centers, and for a majority of these sources the maser intensity is millions of times stronger than that observed in the Milky Way, thus called megamasers. About 20% of the megamasers are in a disk-like configuration, which makes them extremely valuable for: (1) obtaining the only direct distance measurements to extragalactic sources, offering thus an independent value for the Hubble constant and thus for the geometry of the universe as well as the nature of dark energy, and for (2) providing the most accurate measurements of the masses of SMBHs. While the exact mechanism of water maser emission production is not known, there is tentative evidence that disk masing conditions are associated with AGN activity, and in particular with the potentially obscured AGN. Dusty red AGN remain hidden in their optical signatures, but can be discovered by means of their mid-infrared properties because the AGN heated dust reemits at longer wavelengths. The Wide-Field Infrared Survey Explorer (WISE) provides the largest and best quality database of mid-infrared observations, and we use the WISE public catalogs to investigate the relationship between maser activity, the host galaxy's mid-infrared characteristics, and the associated optical spectral signatures of the degree to which SMBH accretion dominates the energetics. We present new and improved maser detection rates based on the 12 μm and 22 μm WISE bands, along with tentative conclusions on the properties of the obscuring material in relation to the maser activity.

The Physics of Masers, Megamasers, and Disk Configuration

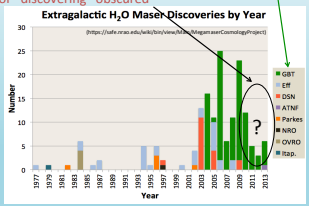
Microwave **A**mplification by **S**timulated **E**mission of **R**adiation [ν = 22 GHz]



Detection of Masers, Megamasers, and Disks

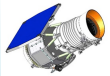
The Megamaser Cosmology Project (MCP) is an international collaboration that provides the most comprehensive search and therefore the largest sample of galaxies detected in water maser emission.

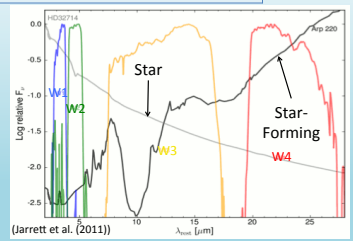
Previous selection of target maser galaxies was based on optical selection, which exhausted the SDSS data. Thus, we need new and improved selection techniques using WISE, which is a prime tool for discovering obscured AGN.



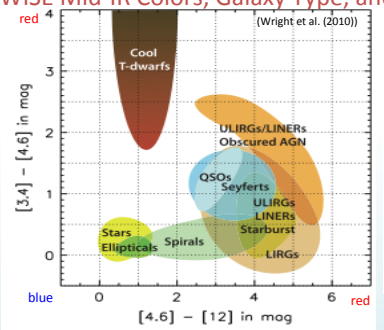
The Wide-Field Infrared Survey Explorer (WISE) is an all-sky survey in the mid-infrared with observing bands at W1 (3.4μm), W2 (4.6μm), W3 (12μm), and W4 (22 μm).

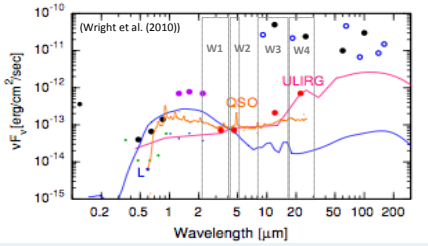
	Masers	Non-Masers
MCP Sources	162	3339
WISE Detections	161	3266
Cross-match result	98.8%	97.8%

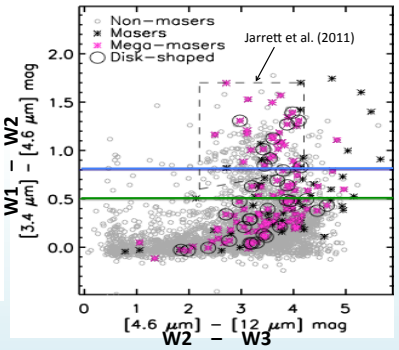




WISE Mid-IR Colors, Galaxy Type, and Maser Activity







Maser Detection Rates and WISE AGN Classification:

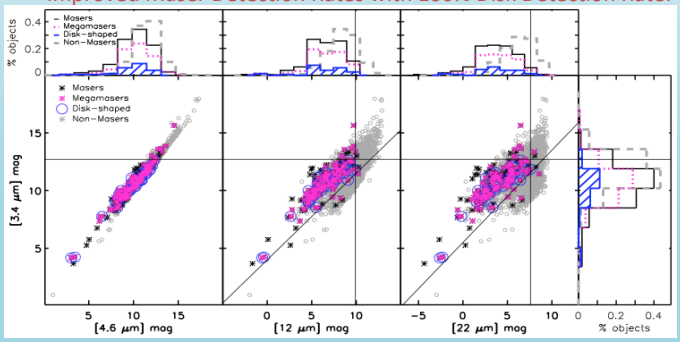
WISE AGN Criterion	Non-Masers	Masers	Mega-Masers	Disks
W1-W2 > 0.8	162	44 (21%)	31 (28%)	9 (26%)
Jarrett et al. (2011)	196	37 (16%)	30 (28%)	10 (29%)
W1-W2 > 0.5	336	72 (18%)	48 (44%)	13 (38%)

WISE color-color diagrams show that the proposed WISE AGN selection techniques:

1. W1-W2 > 0.8 (blue)
2. Jarrett et al. (2011) (dashed gray)
   - 2.2 < W2-W3 < 4.2
   - W1-W2 < 1.7
   - W1-W2 > 0.1*(W2-W3) + 0.38
3. W1-W2 > 0.5 (green)

improve the maser detection, but miss a high fraction of the disk systems.

Improved Maser Detection Rates with 100% Disk Detection Rate:



New Proposed Criteria with 100% disk detection rate:

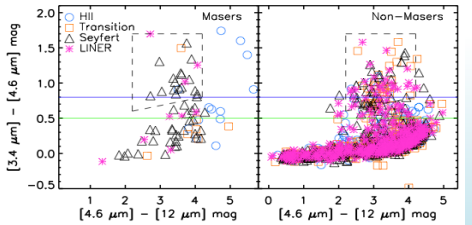
- W1 < 12.7
- W1 > 0.75*W3 + 4.0 and W3 < 9.9
- W1 > 0.8*W4 + 5.5 and W4 < 7.6

can increase the overall maser detection rate by a factor of 2.

	W2 Limits	W3 Limits	W4 Limits
Non-Masers	2628	2052	1913
Masers	151 (5.4%)	143 (6.5%)	143 (7.0%)
Mega-Masers	102 (96%)	98 (90%)	98 (90%)

WISE-AGN Classification & Optical Spectral Signatures

WISE color-color plots with the optical spectral classes (for only 80 maser galaxies) reveal that only < 4% of the Seyferts are recovered as AGN. There is a high fraction of optically selected AGN with megamaser disk emission that do not meet the WISE AGN cuts. Interestingly, non-maser Transition objects show a similarly high fraction of WISE AGN detection => a strong need for monitoring in 22GHz emission.



WISE AGN Cuts	W1 – W2 > 0.5, 241 objects				Jarrett et al. (2011), 141 objects				W1 – W2 > 0.8, 123 objects			
	Non-Masers	Masers	Mega-Masers	Disks	Non-Masers	Masers	Mega-Masers	Disks	Non-Masers	Masers	Mega-Masers	Disks
H II	24	8	1	0	9	1	0	0	6	5	0	0
Transition	41 (17%)	2	1	0	31 (22%)	2	1	0	24 (20%)	1	1	0
Seyfert	49 (20%)	25 (10%)	20 (8%)	6 (2%)	32 (23%)	17 (12%)	14 (12%)	5 (4%)	23 (19%)	17 (14%)	14 (11%)	5 (4%)
LINER	55	6	5	0	32	3	3	0	26	3	3	0

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