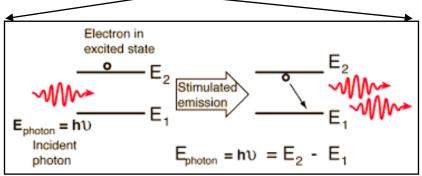
Image credit: NASA, ESA & A. van der Hoeven; Hubble optical light imaging of NGC 1068

Mid-Infrared Variability of Galaxies Surveyed for Water Megamaser Emissions Emily McPike, Dr. Anca Constantin Department of Physics & Astronomy James Madison University



Astrophysical Megamasers

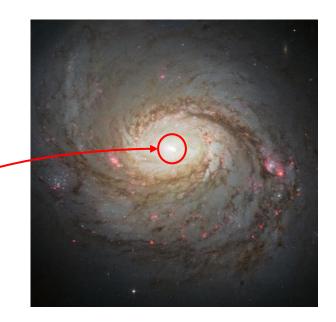
<u>M</u>icrowave <u>A</u>mplification by <u>S</u>timulated <u>E</u>mission of <u>R</u>adiation



• Water masers detected at v = 22 GHz

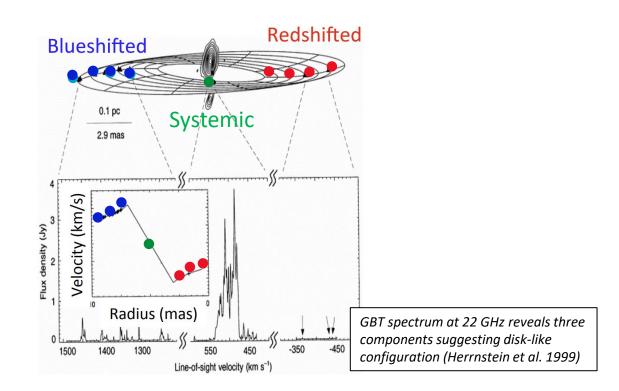
Megamasers

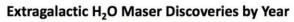
- 10⁶ more powerful than masers associated with spiral arms of our galaxy
- Detected in galaxy centers

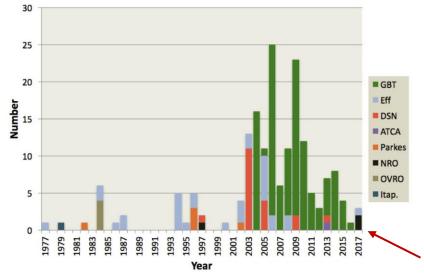


Megamasers in Galactic Centers

- Perfect disk-like configuration
 - Direct measurement of distances to galaxies
 - Constrains Hubble constant, H₀
 - H_0 = rate at which the universe expands
 - Accurate measurement of SMBH masses
- The need for H_2O maser disks
 - ~3% surveyed galaxies hold masers
 - ~20% maser hosting galaxies in disk-like configuration







2022?

Active Galactic Nucleus (AGN)

Accretion Disk

maser

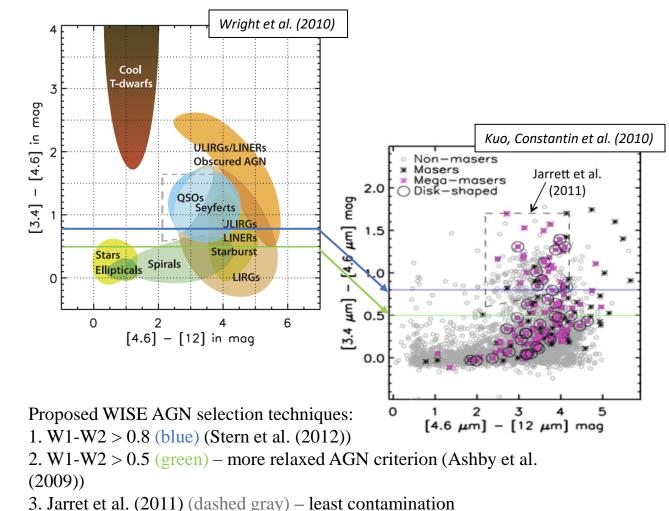
Dusty torus

Broad line region

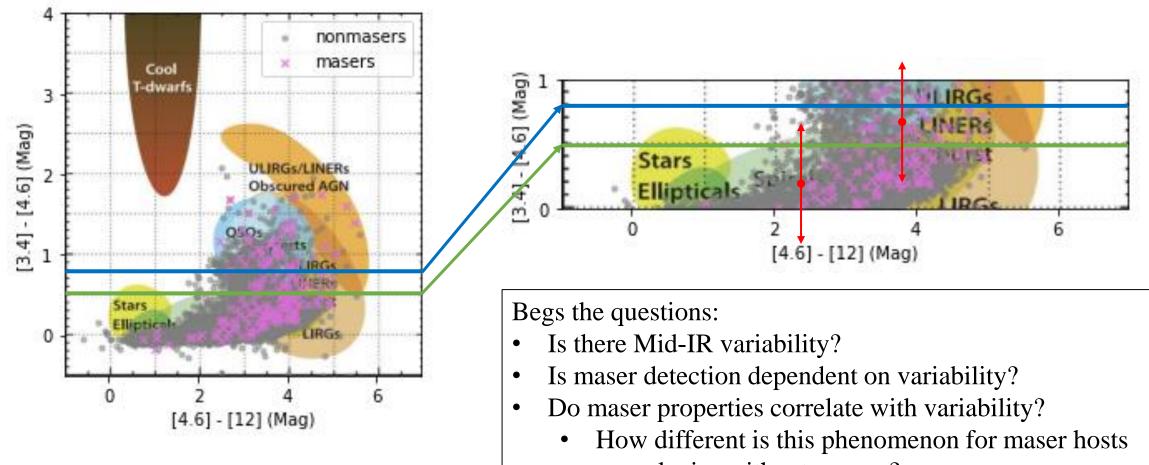
- Maser activity may be associated with accretion disk emission
- Accretion disk supplies seed photons for maser emission
- Dust in inner edge of torus provides masing conditions (e.g. temperature, number density)
- Dust reprocesses radiation from accretion disk and re-emits in mid-IR

Mid-IR Emission

- 3 main ionization processes could account for masing activity
 - AGN
 - Hot, young star formation
 - Shocks
- Only AGN capable of short time span variability
- Identifying variability could further connection between masers and AGN

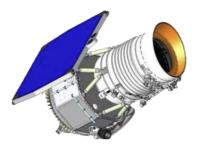


Variability



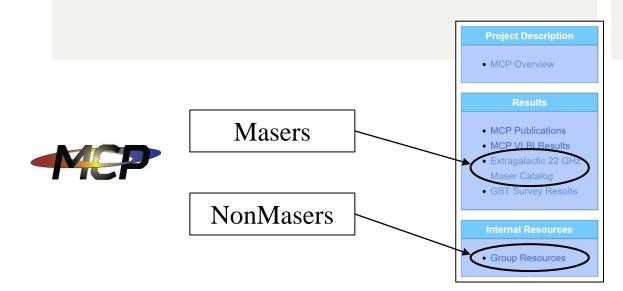
vs. galaxies without masers?

Data Selection



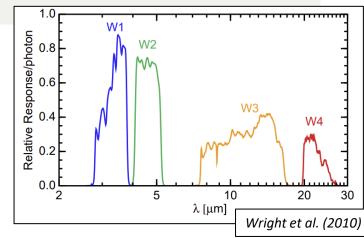
Galaxies Surveyed

- Megamaser Cosmology Project (MCP)
 - International collaboration surveying for 22GHz emission in galaxy centers using GBT, VLA, VLBA, and Effelsberg telescopes (radio)
 - Maser & Non-maser samples



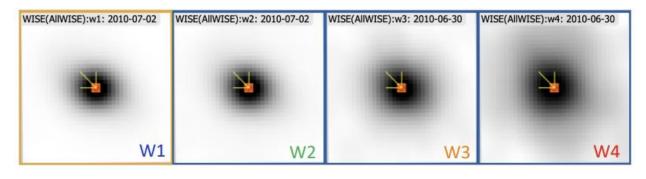
Mid-Infrared Counterparts

- Wide-field Infrared Survey Explorer (WISE)
- Surveyed the sky with best sensitivities in Mid-IR
- Measured brightness (magnitudes W1, W2, W3, W4) of objects at 3.4, 4.6, 12 & 22 μm
 - WISE "bands"



Cross-matching & Data Selection

- Find counterparts of MCP data in WISE catalogs (NASA/IPAC)
- Data sifting
 - Learn SQL
 - Removing duplicates
- Re-cross-match with Multiepoch Photometry catalog
 - Multiple observations over time scales of hours to years



MCP object coordinates represented by yellow arrow. Coordinates of WISE Mid-IR matches of MCP objects represented by red squares.

Cross-matching & Data Selection

- Find counterparts of MCP data in WISE catalogs (NASA/IPAC)
- Data sifting (took a summer!!)
 - Learn SQL
 - Removing duplicates
- Re-cross-match with Multiepoch Photometry catalog
 - Multiple observations over time scales of hours to years

Help Tools Query History MyDB Impo	rt Group	os Outpu	t Schei	ma Browser	Queues	SkyServer		
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Views	cntr_01	dist_:	x	pang_x	mcp_coun	t_01 source_0)1 ra_	_01
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173 72 masers d w2 minus w3	4	0.287393	108.5523	4	NGC78	805	0.3615	31.4337
3,982 136 nonmaser_d_w2_minus_w3	5	0.239743 -	-18.91259	€ 5	NGC78	806	0.37525	31.4418
3,982 136 nonmaser_d_w3	6	0.119134	78.84895	6	00013	83+2329011	0.40967	23.4836
173 72 masers_d_w3	7	0.570163 6	58.51782	7	00014	19+2329452	0.42458	23.4957
61 72 Megamasers	8	0.376333 :	141.6662	8	UGC12	2915	0.42467	23.4959
6 72 megamaser_d_w1_minus_w2_gt	9	0.64766 -	-43.54569	ə 10	00015	23+4020109	0.46792	40.3363
9 72 megamaser_d_w1_minus_w2_gt	10	0.499511 -	-163.2989	Ə 11	CGCG	517-014	0.49371	36.6491
375 72 nonmaser_d_w1_minus_w2_gt_	11	0.669477 -	-83.26797	7 12	NGC78	811	0.61029	3.35189
747 72 nonmaser_d_w1_minus_w2_gt_	12	4.88199 -	-102.1401	l 13	MRK3	34	0.79146	21.9605
25 72 maser_d_w1_minus_w2_gt_0_5	13	0.026535 :	147.2612	14	UM010	5	0.79175	4.74894
15 72 maser_d_w1_minus_w2_gt_0_8	14	0.990427	170.6971	15	NGC78	814	0.81208	16.1455
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428 72 irsa_su21totalgalaxies_6arcs_en 4,185 72 irsa su21totalgalaxies 6arcs en	16	0.420858 6	57.83782	17	NGC78	808	0.88375	-10.744
174 72 maser_d_w1_minus_w2	17	0.54171 8	85.88416	19	NGC78	817	0.99546	20.7523
5,626 136 maser w1 minus w2	18	0.106305 -	-101.7235	5 20	NGC78	819	1.10225	31.4720
3,995 136 nonmaser_d_w1_minus_w2	19	1.28942 -	-138.3661	l 21	00043	5+005055	1.14675	31.4720
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3,995 136 nonmaser_min_max_w2_dw2	21	1.687432	163.4877	24	J0006	+1419	1.58171	14.3274
3,995 136 nonmaser min max w1 dw1	21	3.575315 -				+1419	1.58171	14.3274
174 72 maser_min_max_w2_dw2	23	0.200430	122 3403	2.26	LIGCO			17.2842
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4,912 1,096 irsa_su21totalgalaxies_6arcs_wi	25	0.664698	176.531	28	UGC52	2		8.62853
810 72 mep_3arcs_will_notin_emily	26		109.0150		NGCI		1.91596	
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4,266 72 su21totalgalaxies_3arcs_mep_	27	2.795625 -	-73.18051	1 30	2MAS	XJ00082041+	2.08542	40.6325

Cross-matching & Data Selection

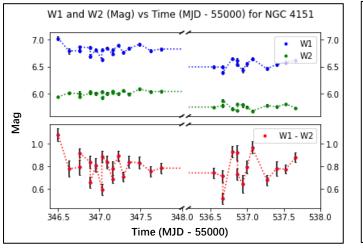
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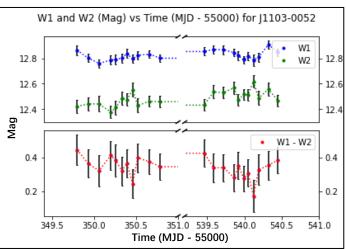
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\bigcirc	AllWISE Atlas Metadata Table	
\bigcirc	AllWISE Frame Cross-Reference Table	
\bigcirc	AllWISE Atlas Inventory Table	
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Preliminary Results

Is there Mid-IR variability? Yes!

Examples of variability in individual bands (W1, W2) and the W1 - W2color





Maser Avg

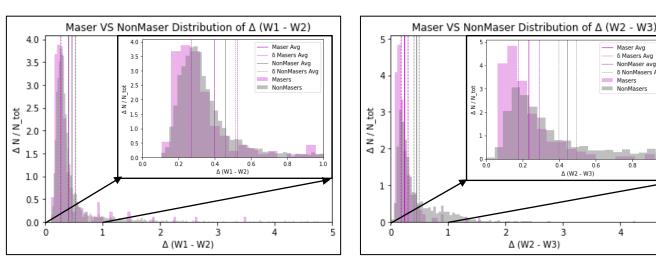
δ Masers Avg

NonMaser avg

0.8

δ NonMasers Avo

- Statistical comparison in the • distribution of the change in the color of maser and nonmaser galaxies
- Δ (W2-W3) greater for nonmasers
- Δ (W1-W2) shows similar trend, although less statistically significant



Acknowledgements

This work has been supported by JMU's Physics and Astronomy Department and the National Science Foundation award NSF:AST #1814594. This research has made use of the NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

