



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

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# Table of Contents

I. Background

II. Question

III. Methods

IV. Results

# Table of Contents

## I. Background

I. What is a maser?

II. Why are megamasers important?

III. Mid-Infrared

I. What part of the masing process involves Mid-IR?

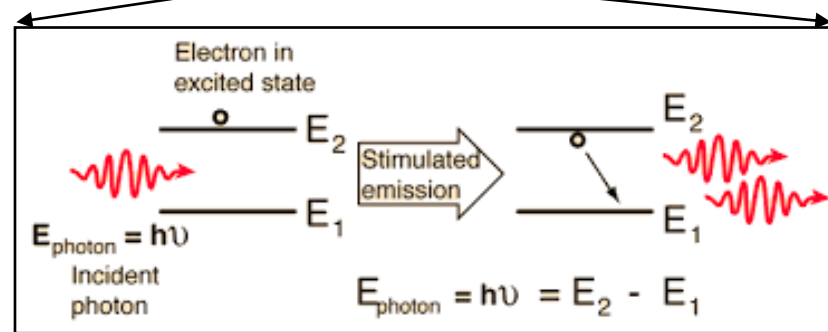
## II. Question

## III. Methods

## IV. Results

# Astrophysical Megamasers

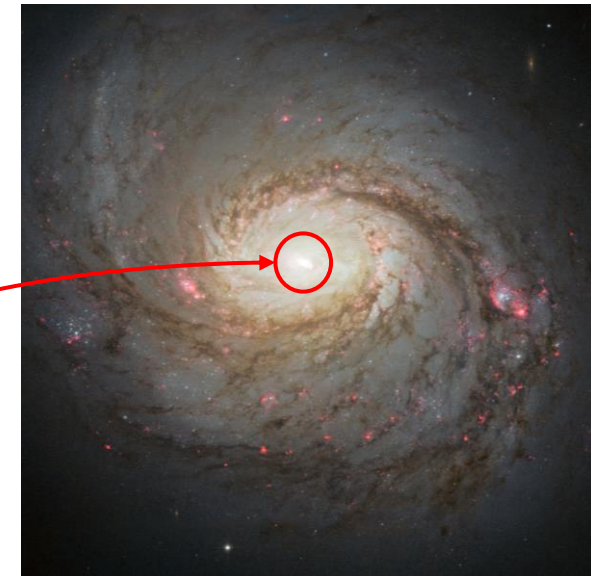
## Microwave Amplification by Stimulated Emission of Radiation



- Water masers detected at  $\nu = 22$  GHz

## Megamasers

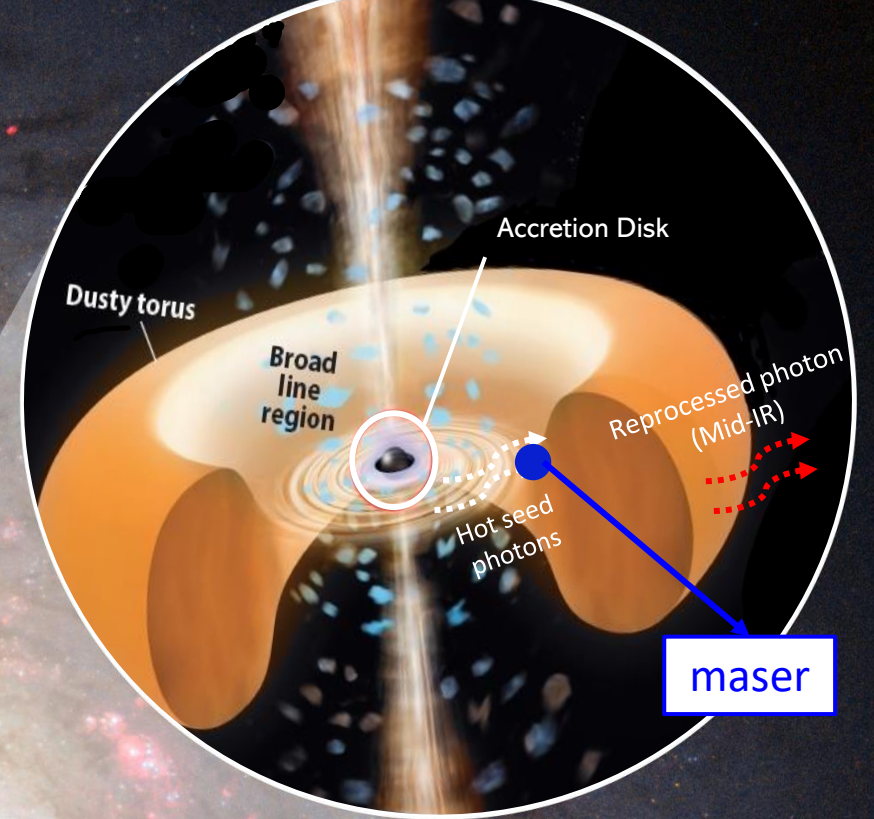
- $10^6$  more powerful than masers associated with spiral arms of our galaxy
- Detected in galaxy centers





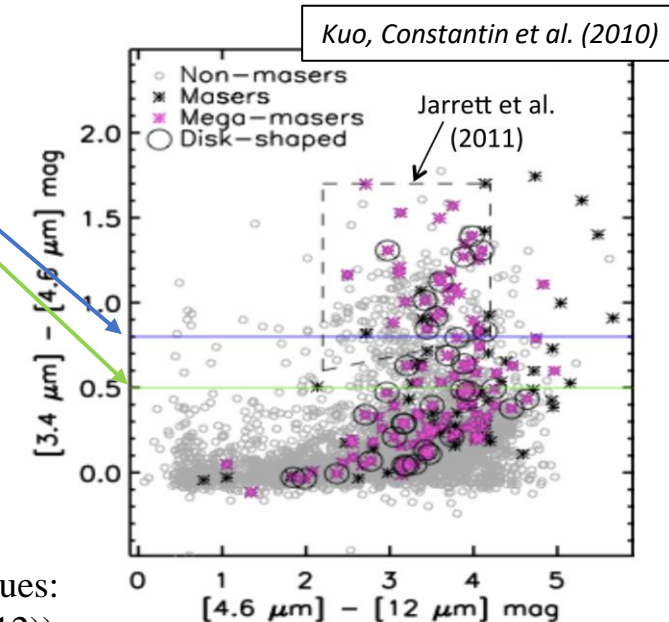
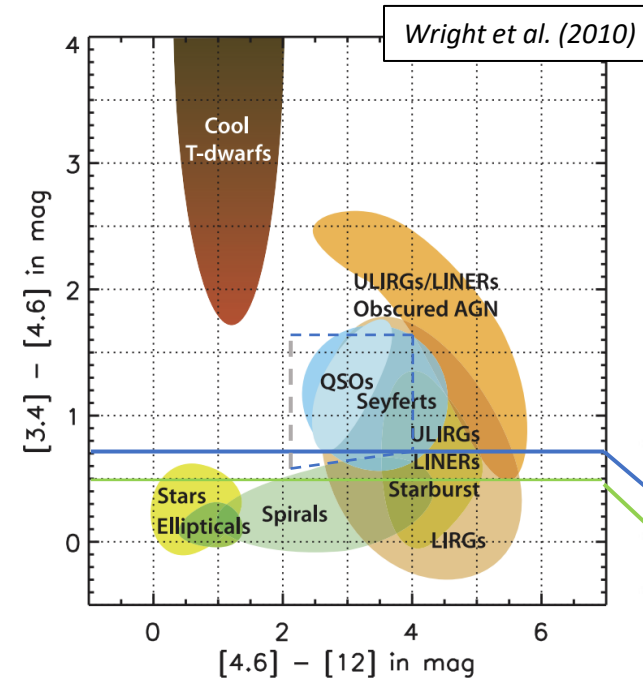
# Active Galactic Nucleus (AGN)

- 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

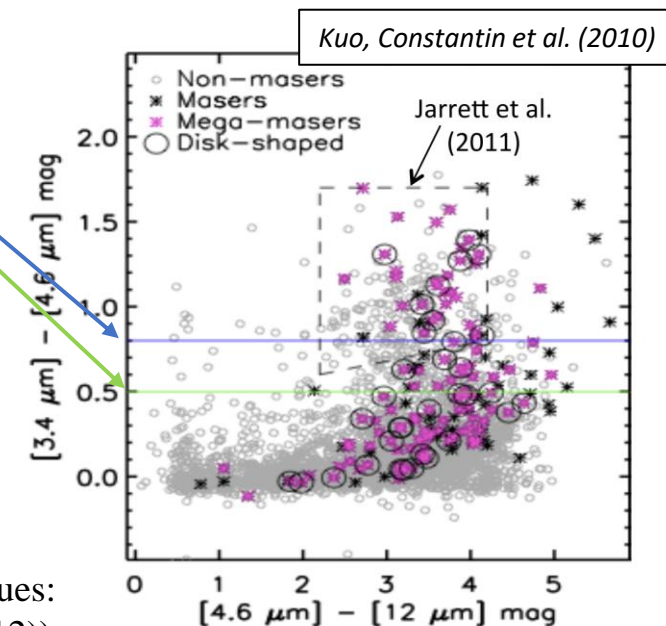
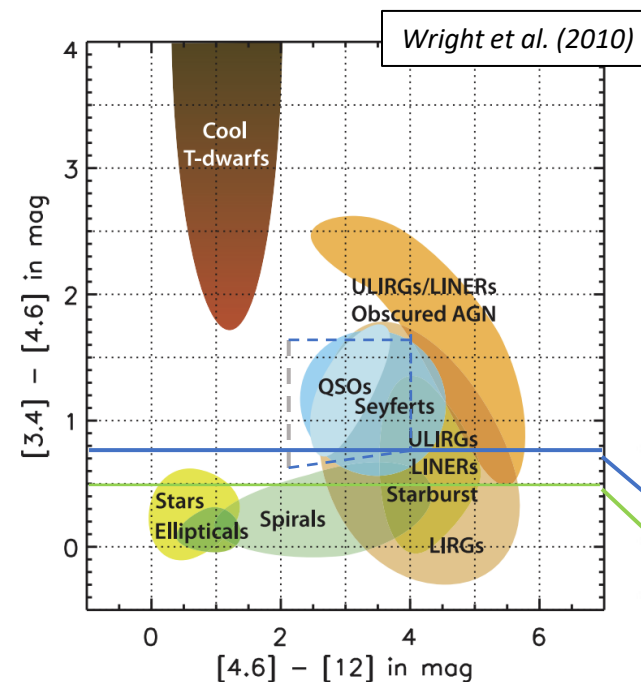


Proposed WISE AGN selection techniques:

1.  $W1-W2 > 0.8$  (blue) (Stern et al. (2012))
2.  $W1-W2 > 0.5$  (green) – more relaxed AGN criterion (Ashby et al. (2009))
3. Jarrett et al. (2011) (dashed gray) – least contamination

# Mid-IR Emission

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I. Background

II. Question

I. Is there Mid-IR variability?

II. Is maser detection dependent on variability?

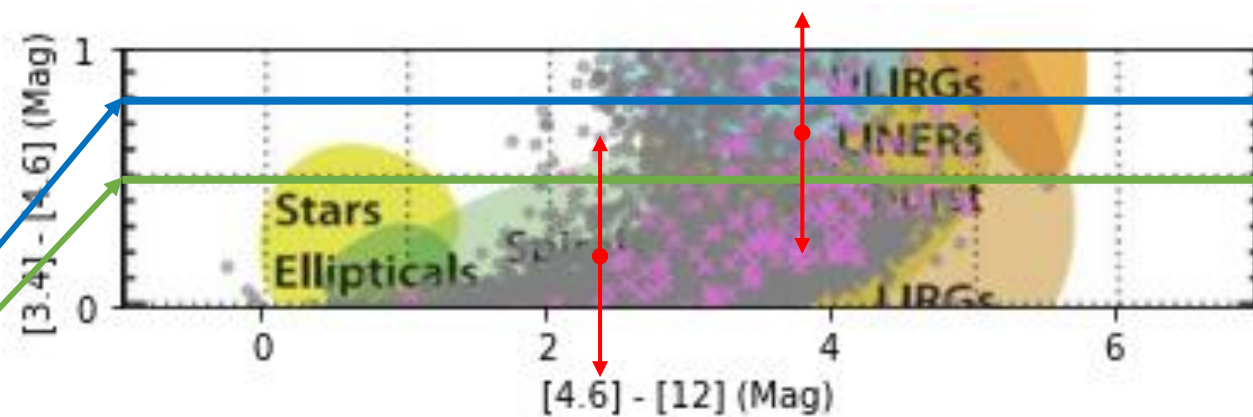
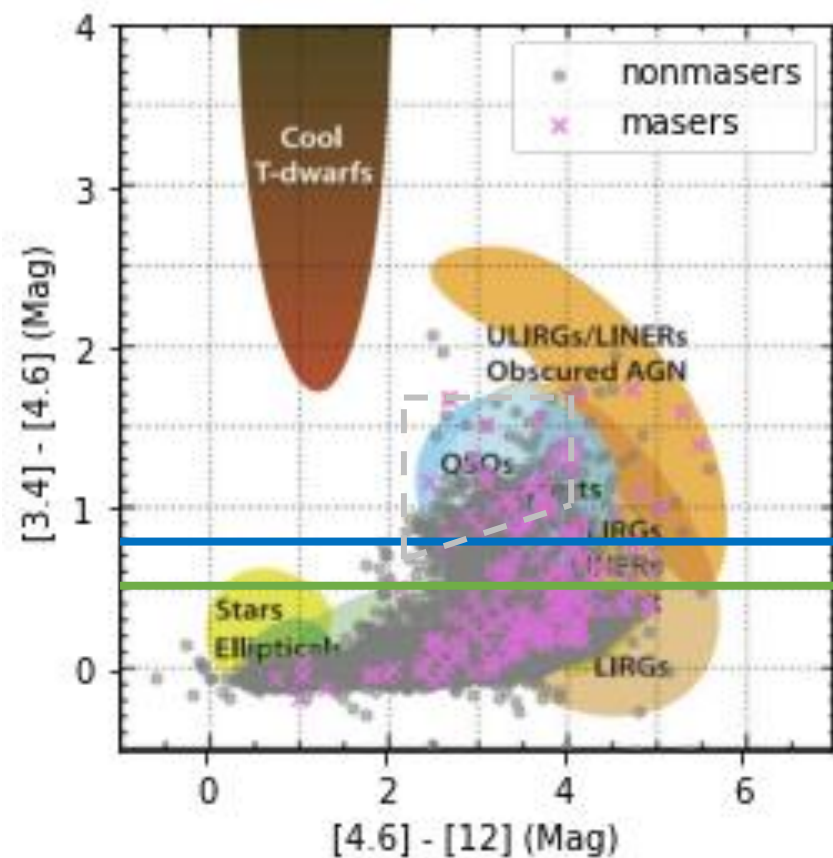
III. Do maser properties correlate with variability?

I. How different is this phenomenon for maser hosts vs. galaxies without masers?

III. Methods

IV. Results

# Variability



Begs the questions:

- Is there Mid-IR variability?
- Is maser detection dependent on variability?
- Do maser properties correlate with variability?
  - How different is this phenomenon for maser hosts vs. galaxies without masers?

# Table of Contents

I. Background

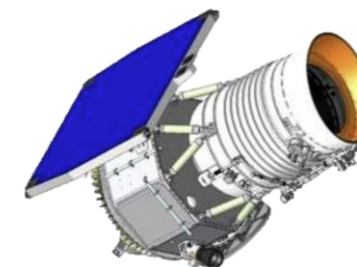
II. Question

III. Methods

I. Where did we get our data from?

IV. Results

# 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

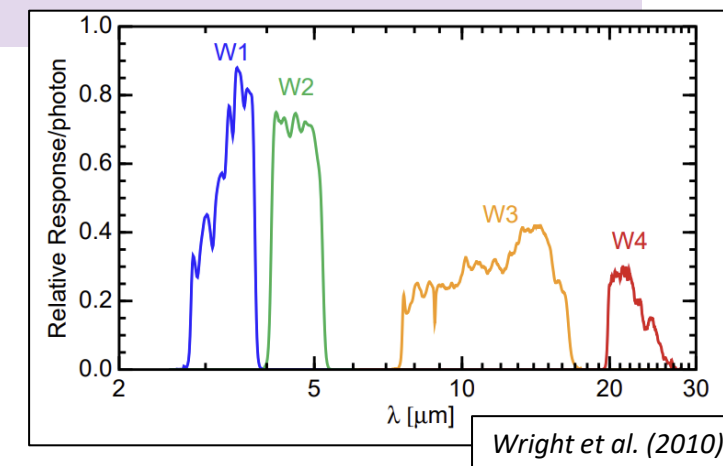
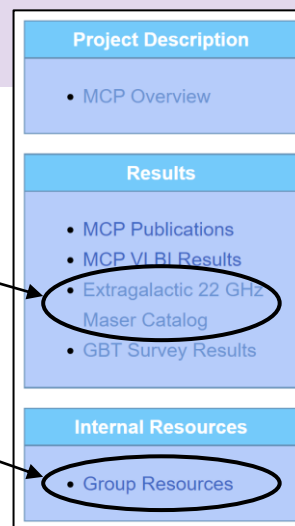
## Mid-Infrared Counterparts

- 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  $\mu\text{m}$ 
  - WISE “bands”



Masers

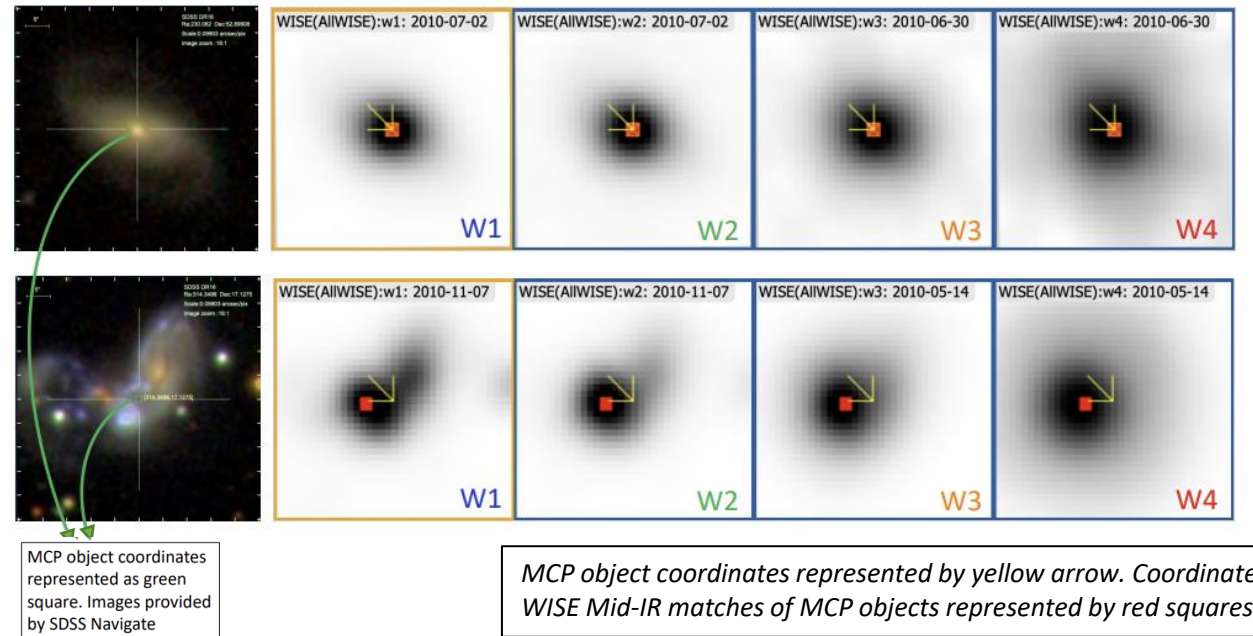
NonMasers



Wright et al. (2010)

# Cross-matching & Data Selection

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



# 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 Multi-epoch Photometry catalog
  - Multiple observations over time scales of hours to years

cntr_01	dist_x	pang_x	mcp_count_01	source_01	ra_01	dec_01
1	0.792116	-88.20296	1	RXSJ00001+0523	0.04908	5.38817
2	1.106021	49.75174	2	KUG2358+330	0.24208	33.34389
3	1.039782	81.63853	3	0001233+4733537	0.34708	47.56492
4	0.287393	108.5523	4	NGC7805	0.3615	31.43372
5	0.239743	-18.91259	5	NGC7806	0.37525	31.44186
6	0.119134	78.84895	6	0001383+2329011	0.40967	23.48364
7	0.570163	68.51782	7	0001419+2329452	0.42458	23.49578
8	0.376333	141.6662	8	UGC12915	0.42467	23.49592
9	0.64766	-43.54569	10	0001523+4020109	0.46792	40.33636
10	0.499511	-163.2989	11	CGCG517-014	0.49371	36.64919
11	0.669477	-83.26797	12	NGC7811	0.61029	3.35189
12	4.88199	-102.1401	13	MRK334	0.79146	21.96053
13	0.026535	147.2612	14	UM016	0.79175	4.74894
14	0.990427	170.6971	15	NGC7814	0.81208	16.14558
15	0.526694	77.00446	16	UGC13	0.87167	27.35164
16	0.420858	67.83782	17	NGC7808	0.88375	-10.74472
17	0.54171	85.88416	19	NGC7817	0.99546	20.75231
18	0.106305	-101.7235	20	NGC7819	1.10225	31.47203
19	1.28942	-138.3661	21	000435+005055	1.14675	31.47203
20	0.152100	12.14010	22	MRK335	1.58137	20.20292
21	1.687432	163.4877	24	J0006+1419	1.58171	14.32742
21	3.575315	-29.07394	24	J0006+1419	1.58171	14.32742
23	0.200130	132.2403	26	UGC00047	1.05983	17.28422
24	0.253949	-100.785	27	UGC00050	1.66733	26.15447
25	0.664698	176.531	28	UGC52	1.70617	8.62853
26	0.520203	109.8158	29	NGC1	1.81596	27.70808
27	2.171865	136.8576	30	2MASXJ00082041+	2.08542	40.6325
27	2.795625	-73.18051	30	2MASXJ00082041+	2.08542	40.6325

Example of duplicates in a table in the CasJobs database

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  - Multiple observations over time scales of hours to years

AllWISE Database	
Selection	Descriptions
<input type="radio"/>	AllWISE Source Catalog
<input checked="" type="radio"/>	AllWISE Multiepoch Photometry Table
<input type="radio"/>	AllWISE Reject Table
<input type="radio"/>	AllWISE Atlas Metadata Table
<input type="radio"/>	AllWISE Frame Cross-Reference Table
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# Table of Contents

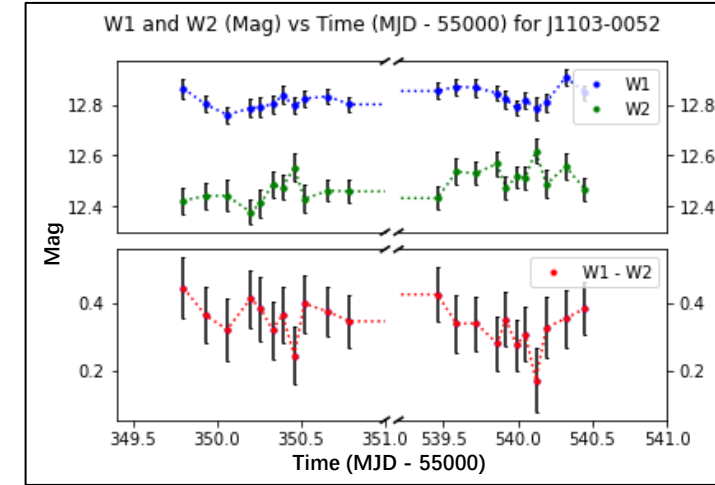
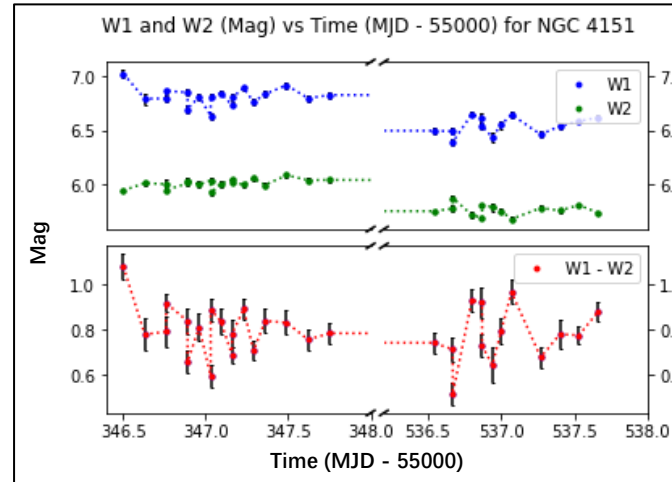
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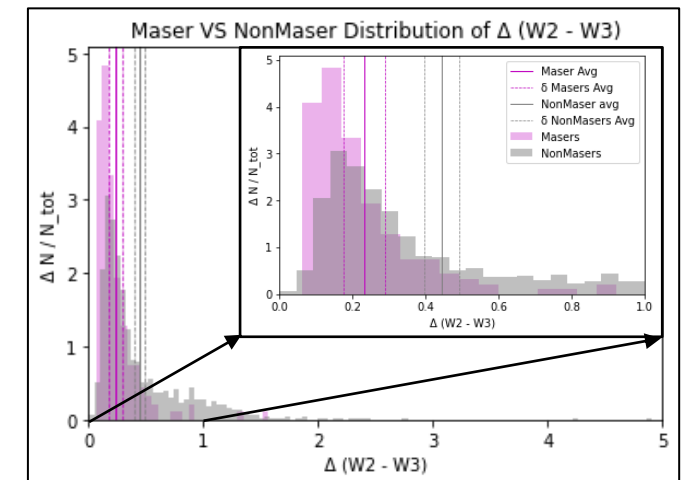
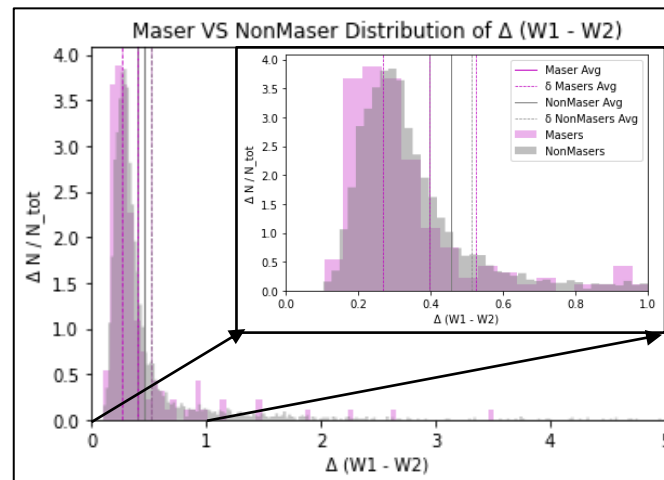
# Preliminary Results

Is there Mid-IR variability? **Yes!**

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



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



# Acknowledgements

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