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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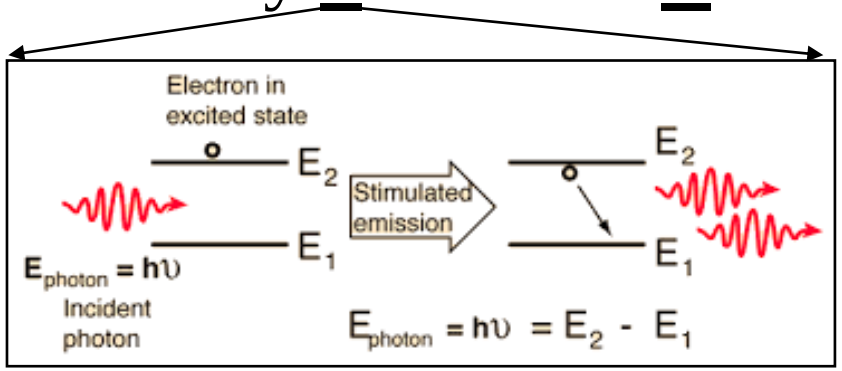
Astrophysical Megamasers

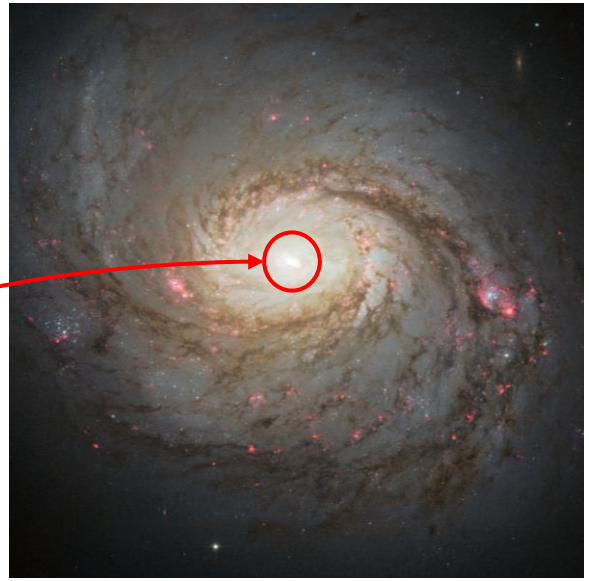
Microwave **A**mplification by **S**timulated **E**mission of **R**adiation



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

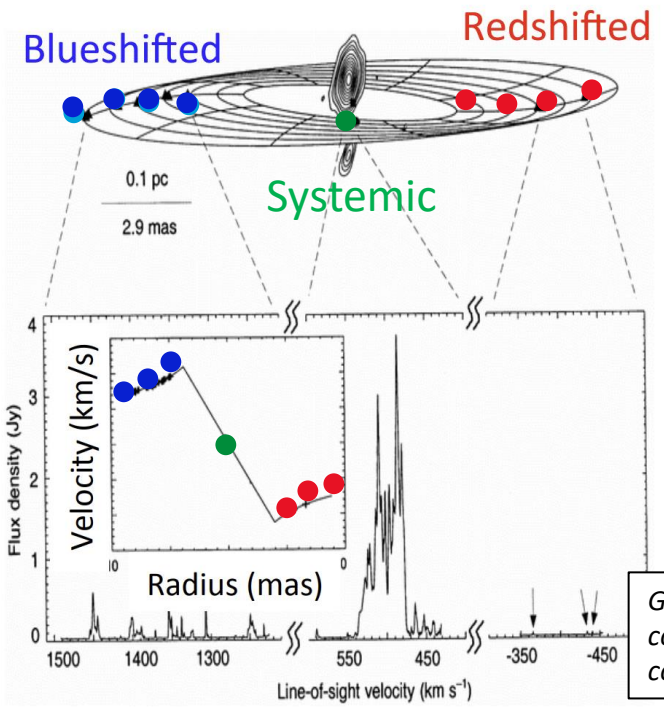
Megamasers

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

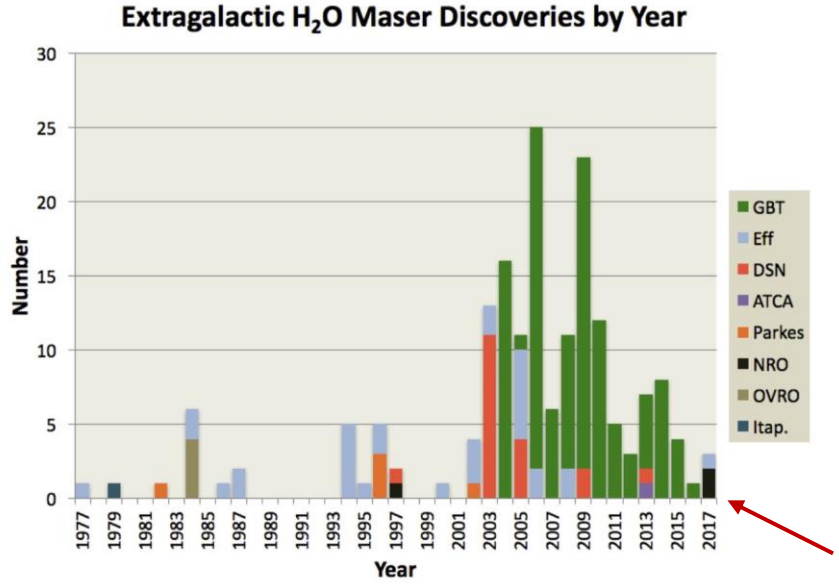


Megamasers in Galactic Centers

- Perfect disk-like configuration
  - Direct measurement of distances to galaxies
    - Constrains Hubble constant, H_0
    - 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

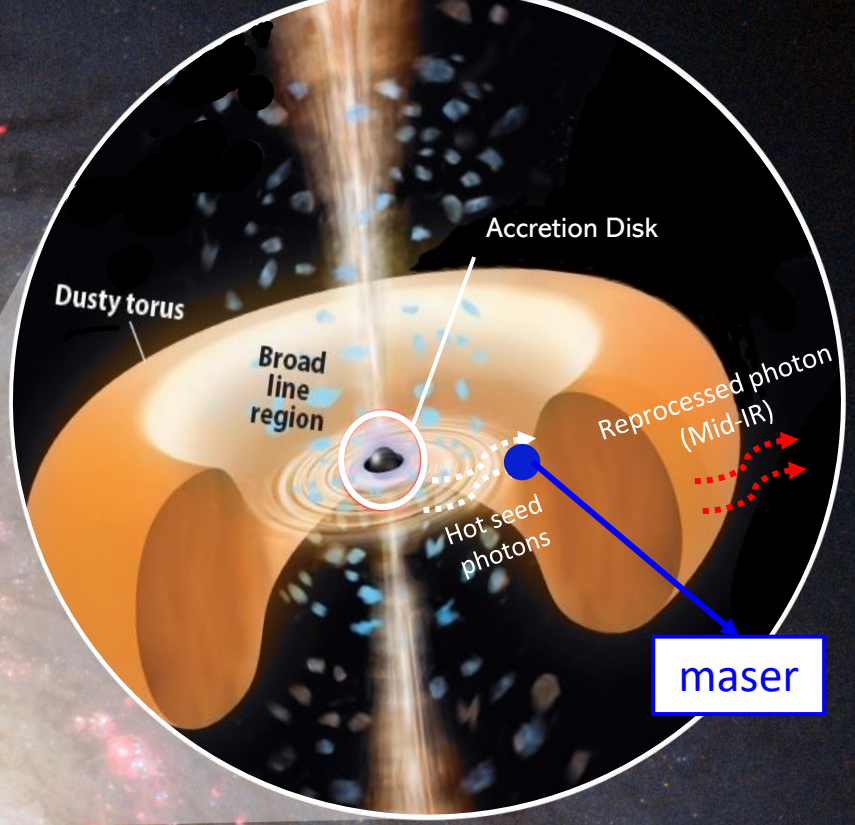


GBT spectrum at 22 GHz reveals three components suggesting disk-like configuration (Herrnstein et al. 1999)



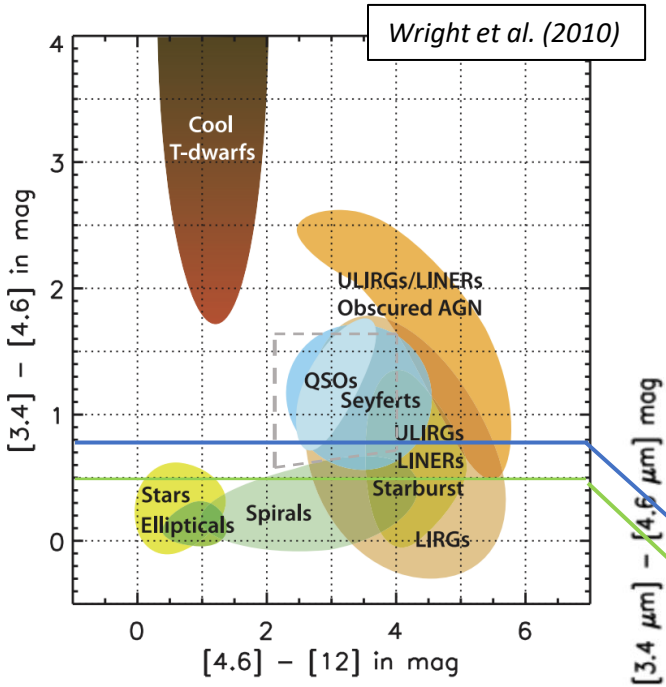
Active Galactic Nucleus (AGN)

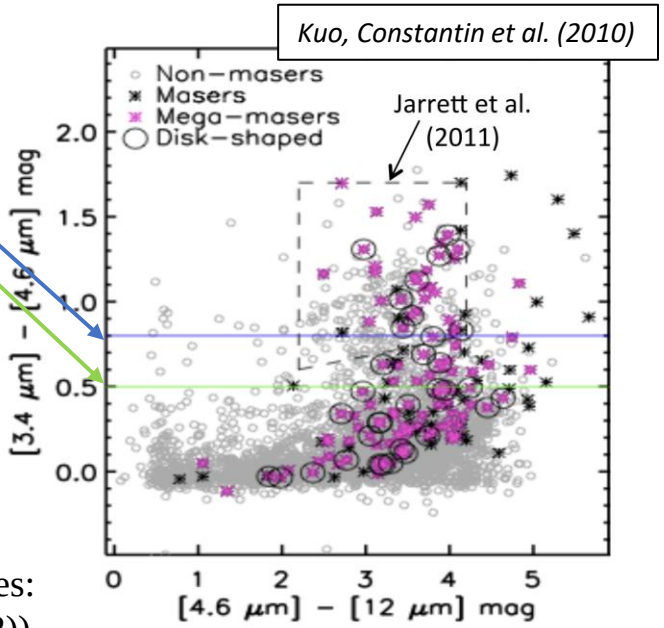
- Maser activity may be associated with accretion disk emission
- Accretion disk supplies seed photons for maser emission
- Dust in inner edge of torus provides masing conditions (e.g. temperature, number density)
- Dust reprocesses radiation from accretion disk and re-emits in mid-IR



Mid-IR Emission

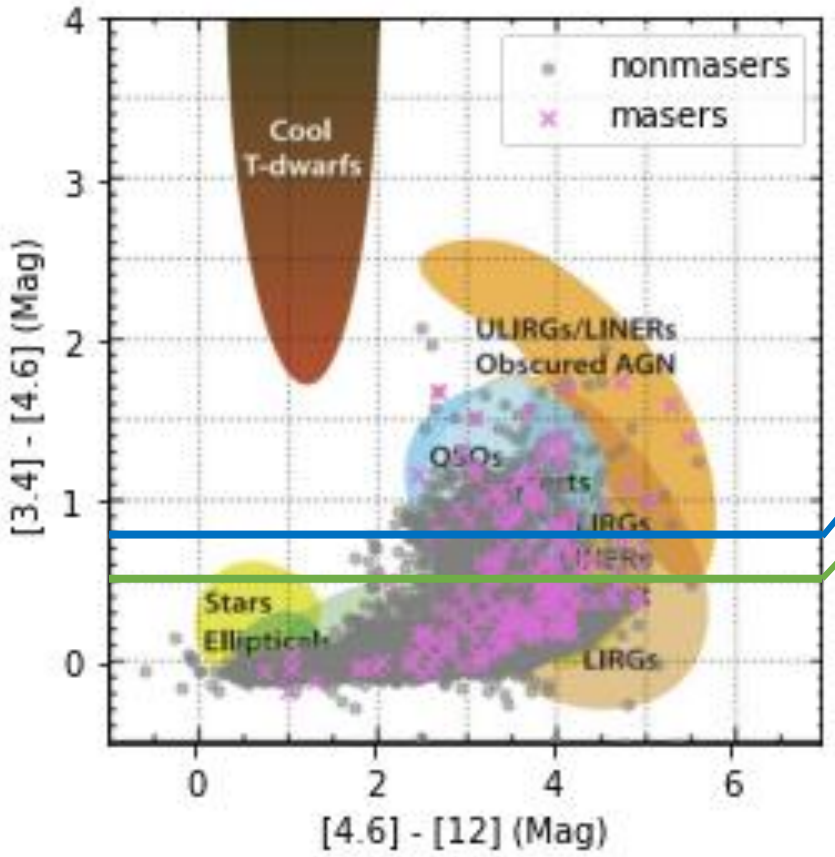
- 3 main ionization processes could account for masing activity
  - AGN
  - Hot, young star formation
  - Shocks
- Only AGN capable of short time span variability
- Identifying variability could further connection between masers and AGN

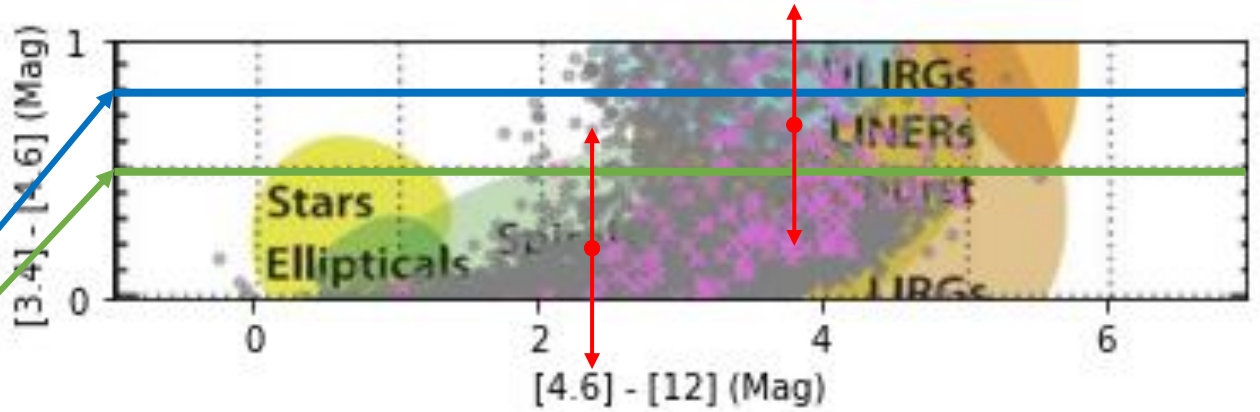




Proposed WISE AGN selection techniques:
1. W1-W2 > 0.8 (blue) (Stern et al. (2012))
2. W1-W2 > 0.5 (green) – more relaxed AGN criterion (Ashby et al. (2009))
3. Jarret et al. (2011) (dashed gray) – least contamination

Variability

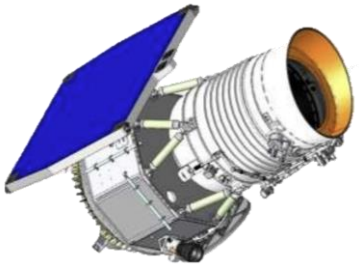




Begs the questions:

- 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?

Data Selection



Galaxies Surveyed

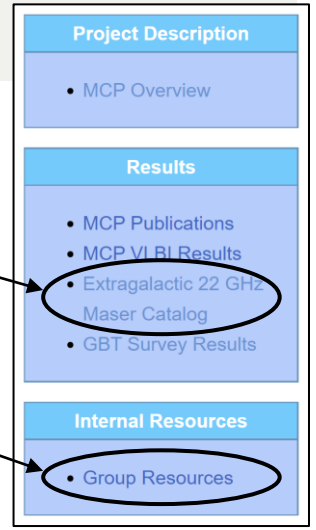
- Megamaser Cosmology Project (MCP)
  - International collaboration surveying for 22GHz emission in galaxy centers using GBT, VLA, VLBA, and Effelsberg telescopes (radio)
  - Maser & Non-maser samples

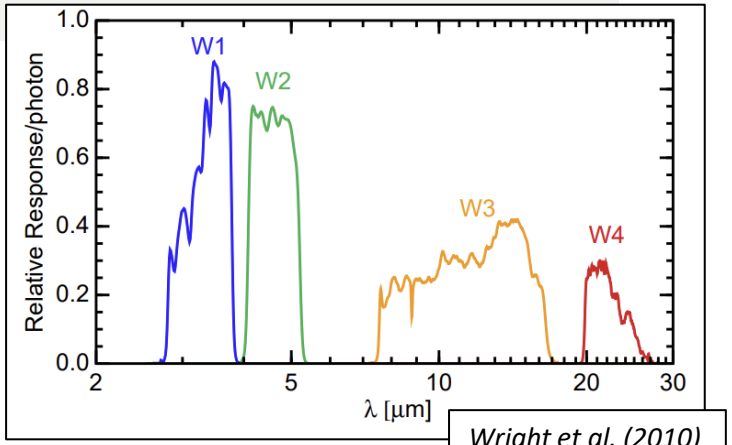
Mid-Infrared Counterparts

- **W**ide-field **I**nfrared **S**urvey **E**xplorer (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”

Masers

NonMasers

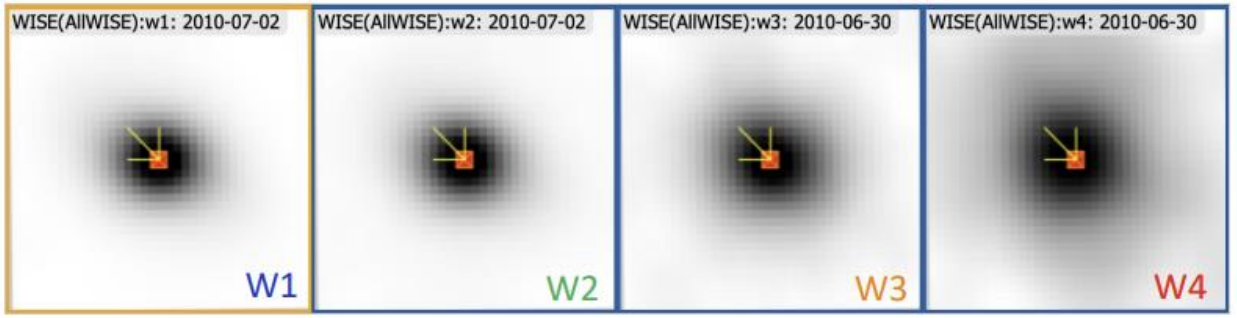




Wright et al. (2010)

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



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)
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  - Learn SQL
  - Removing duplicates
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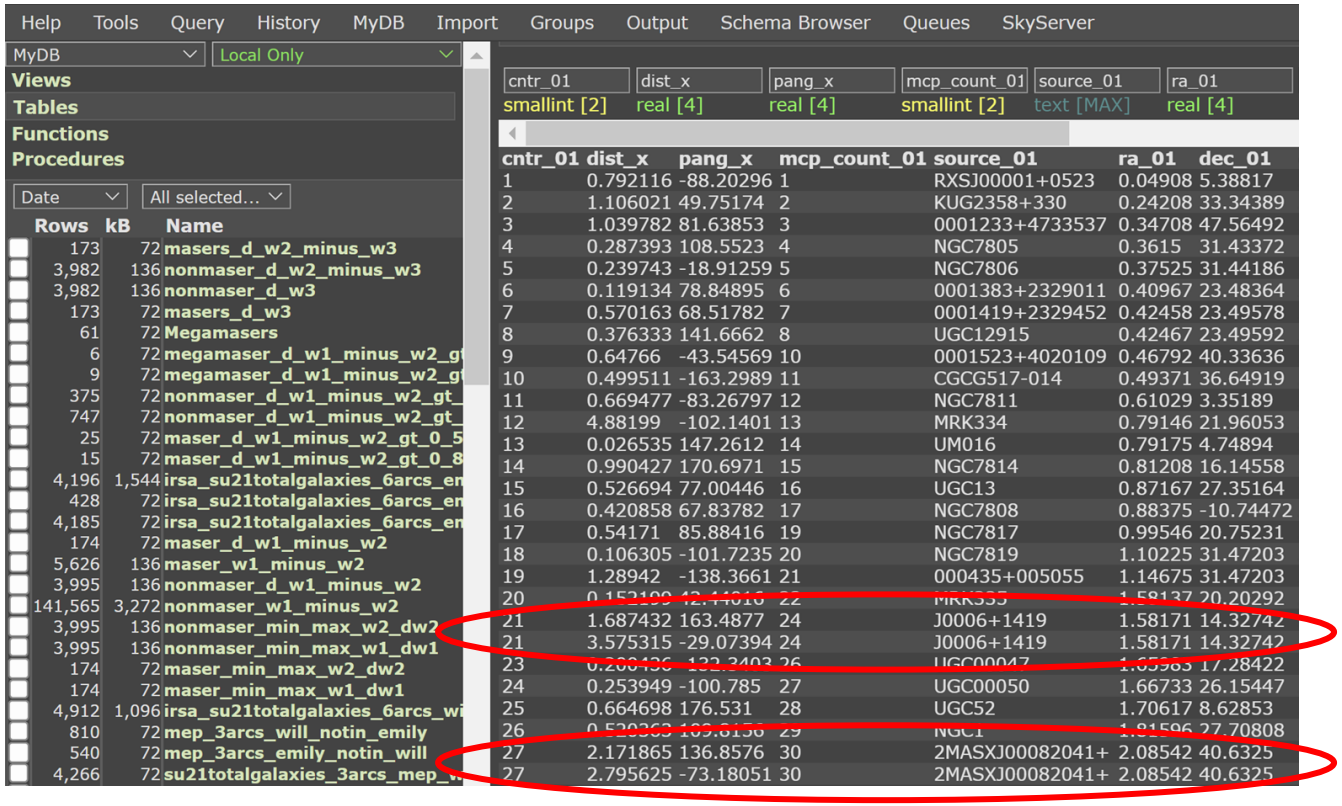

Example of duplicates in a table in the CasJobs database

Cross-matching & Data Selection

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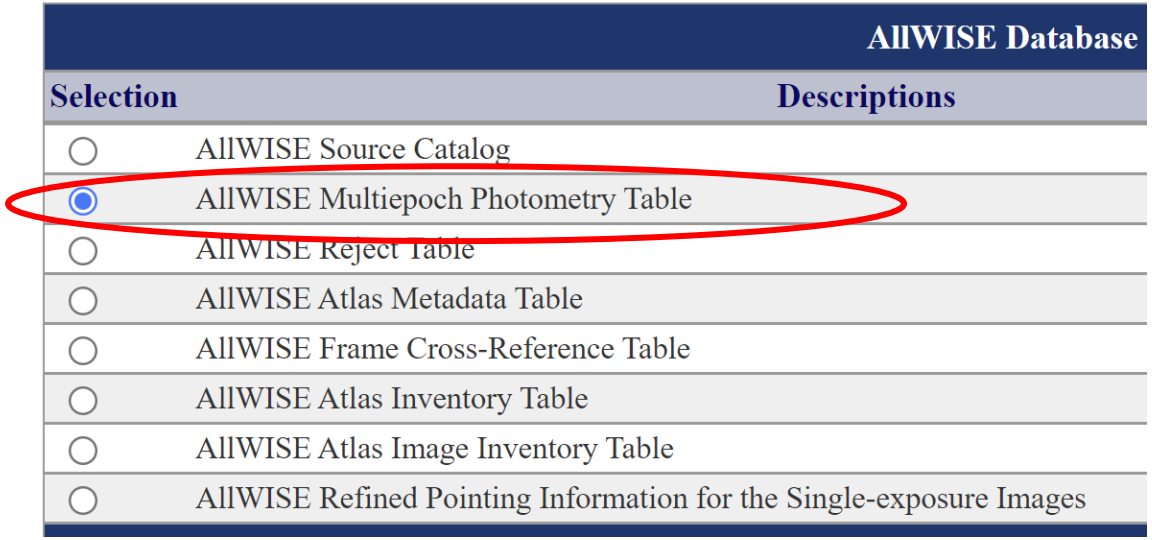
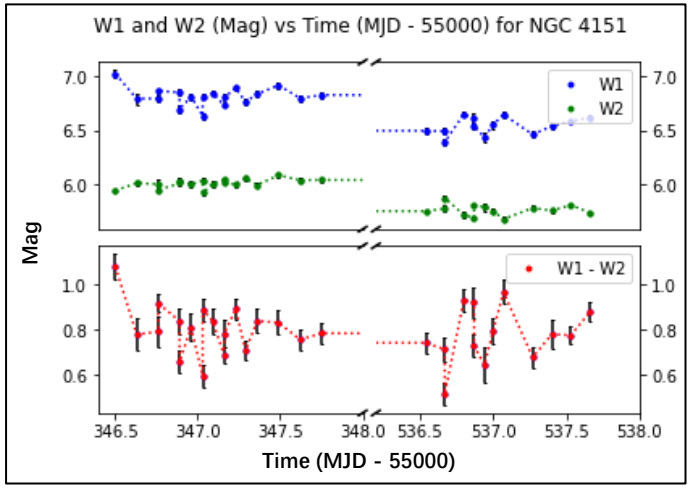


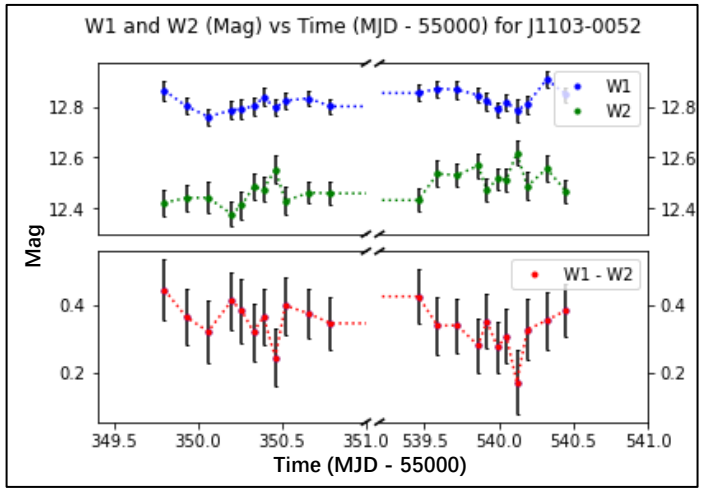
AllWISE Database	
Selection	**Descriptions**
○	AllWISE Source Catalog
◉	AllWISE Multiepoch Photometry Table
○	AllWISE Reject Table
○	AllWISE Atlas Metadata Table
○	AllWISE Frame Cross-Reference Table
○	AllWISE Atlas Inventory Table
○	AllWISE Atlas Image Inventory Table
○	AllWISE Refined Pointing Information for the Single-exposure Images

Preliminary Results

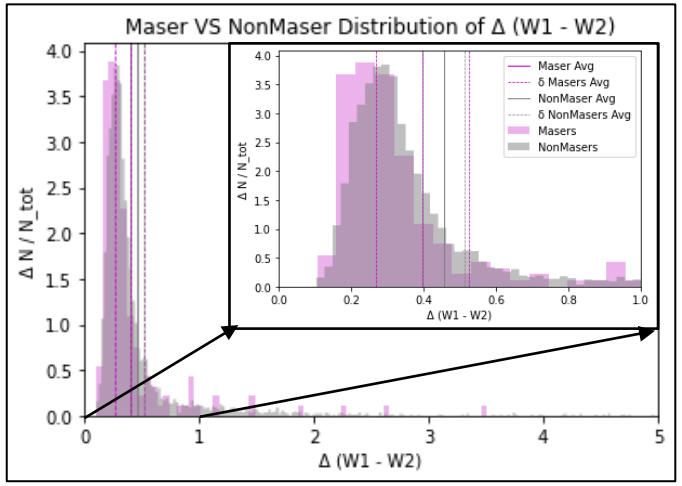
Is there Mid-IR variability? **Yes!**

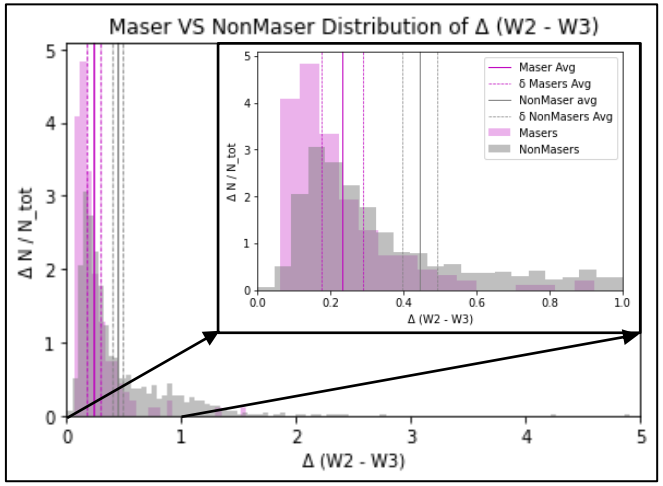
- Examples of variability in individual bands (W1, W2) and the W1 – W2 color





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





Acknowledgements

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