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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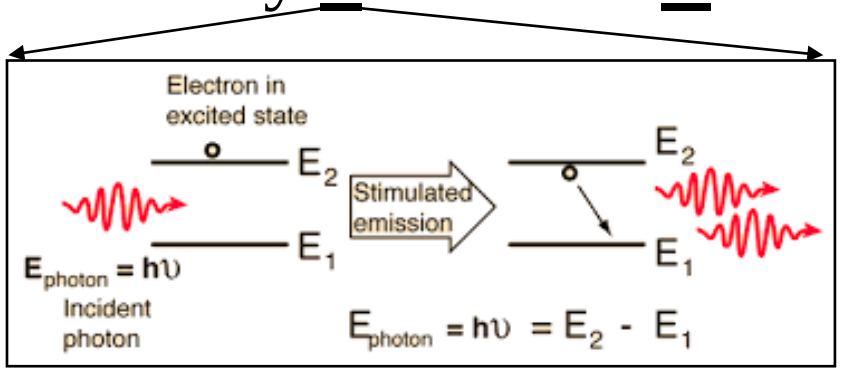
Astrophysical Megamasers

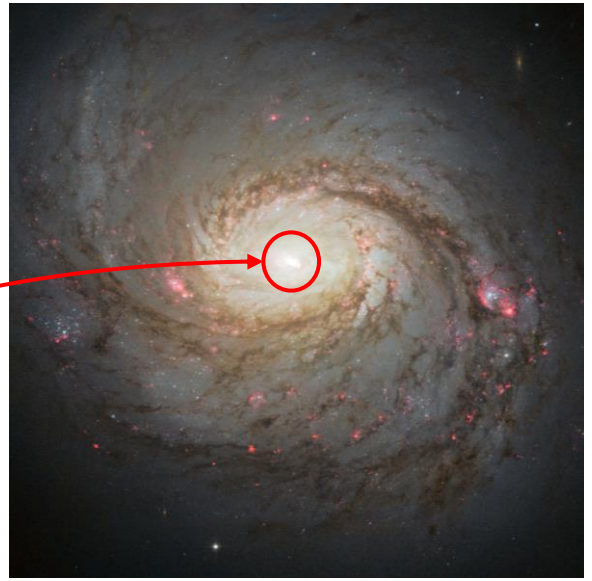
Microwave **A**mplification by **S**timulated **E**mission of **R**adiation



- Water masers detected at ν = 22 GHz

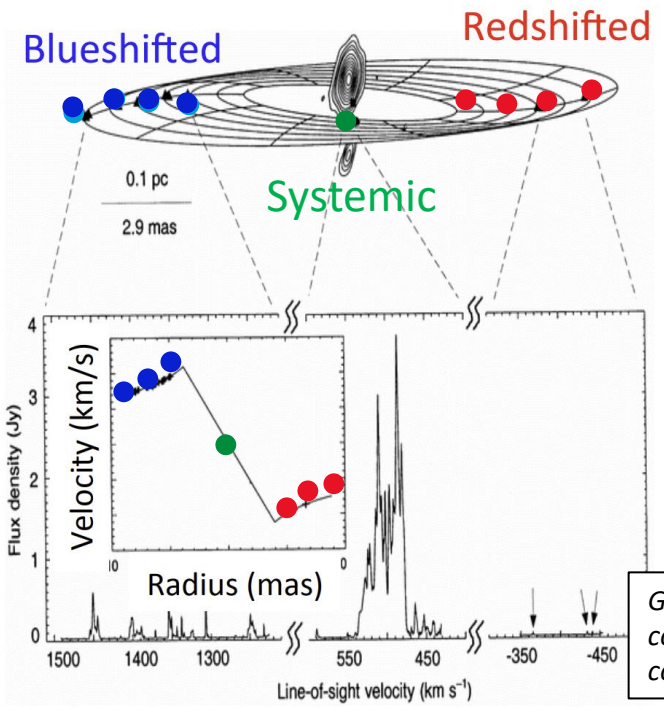
Megamasers

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

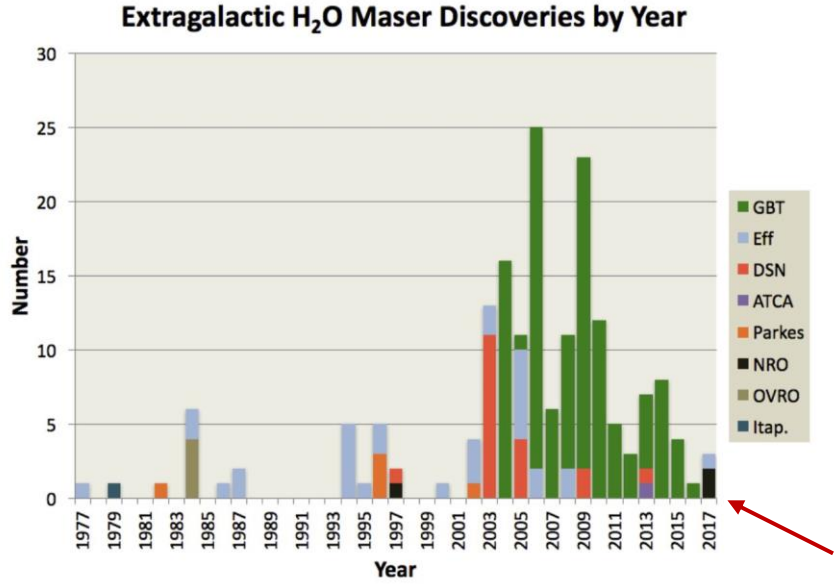


Megamasers in Galactic Centers

- 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

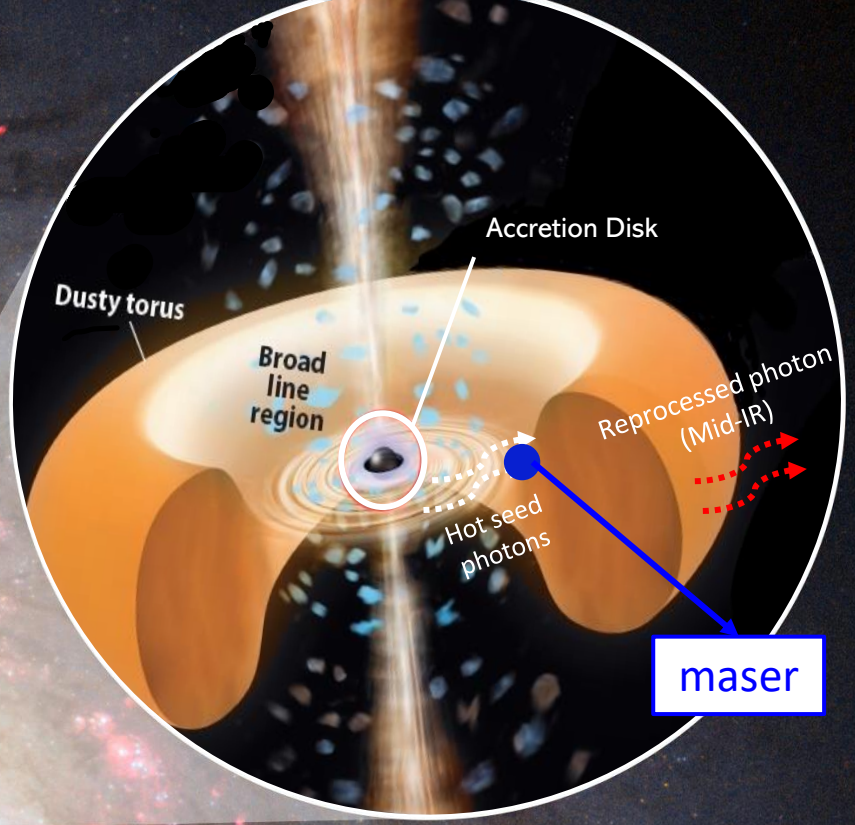


GBT spectrum at 22 GHz reveals three components suggesting disk-like configuration (Herrnstein et al. 1999)



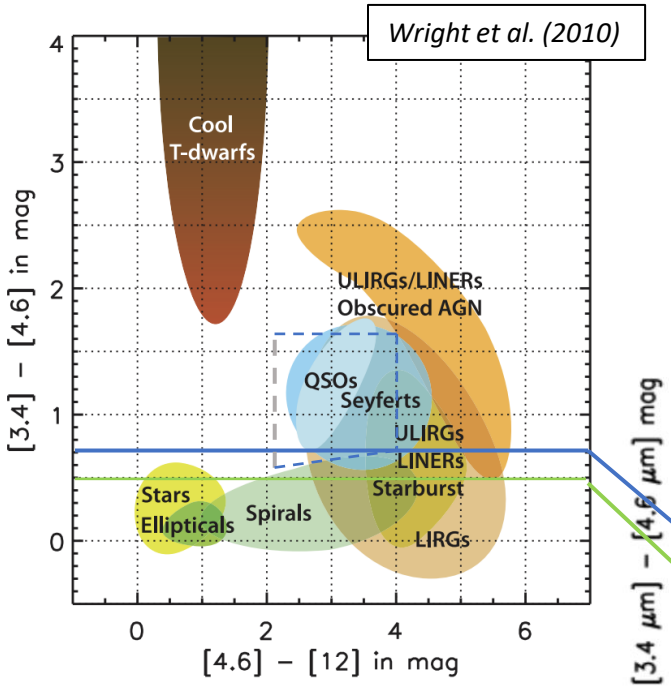
Active Galactic Nucleus (AGN)

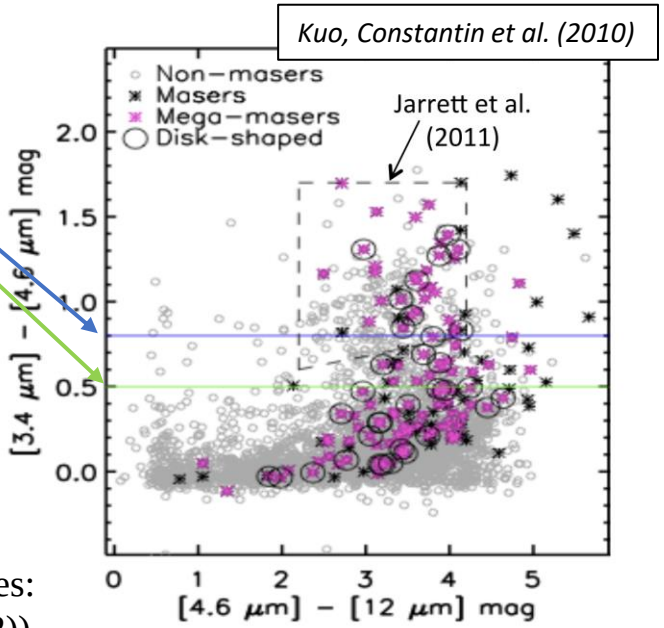
- Maser activity may be associated with accretion disk emission
- Accretion disk supplies seed photons for maser emission
- Dust in inner edge of torus provides masing conditions (e.g. temperature, number density)
- Dust reprocesses radiation from accretion disk and re-emits in mid-IR



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

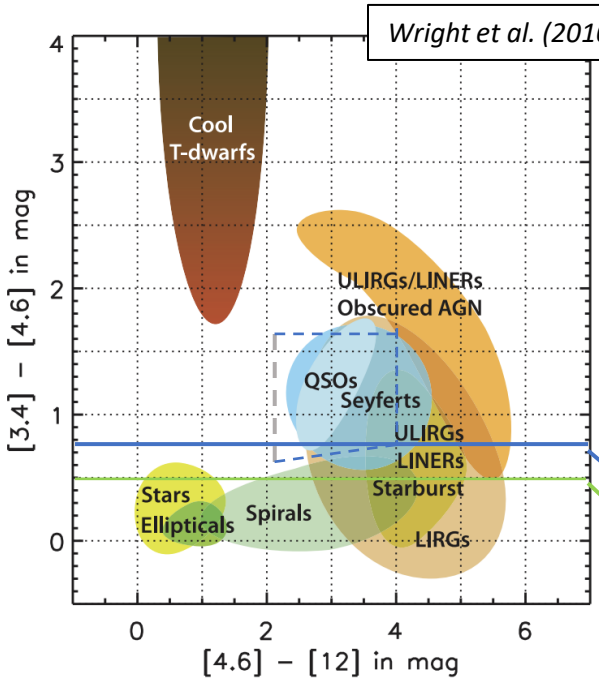


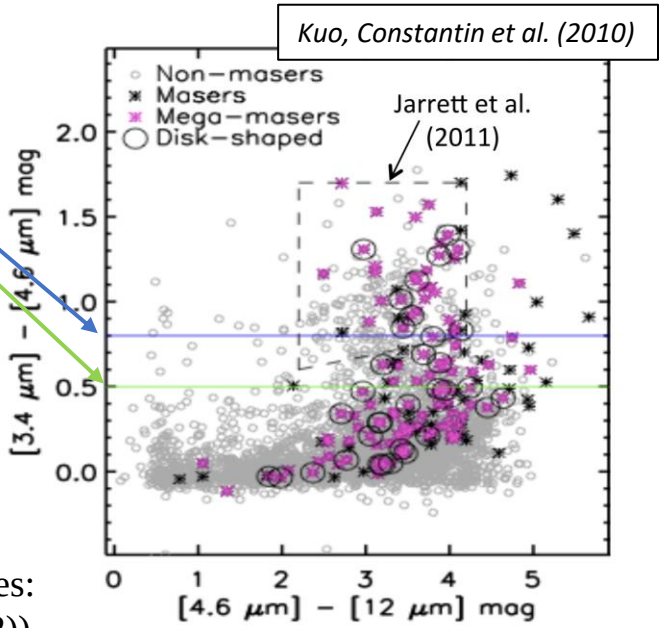


Proposed WISE AGN selection techniques:
1. W1-W2 > 0.8 (blue) (Stern et al. (2012))
2. W1-W2 > 0.5 (green) – more relaxed AGN criterion (Ashby et al. (2009))
3. Jarret et al. (2011) (dashed gray) – least contamination

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**





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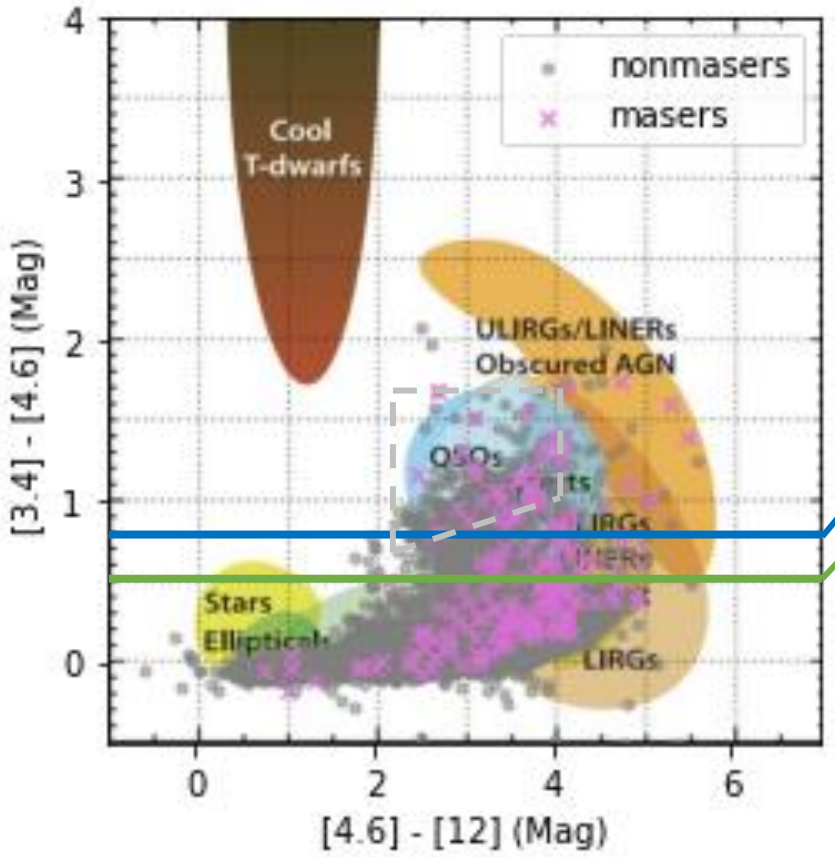
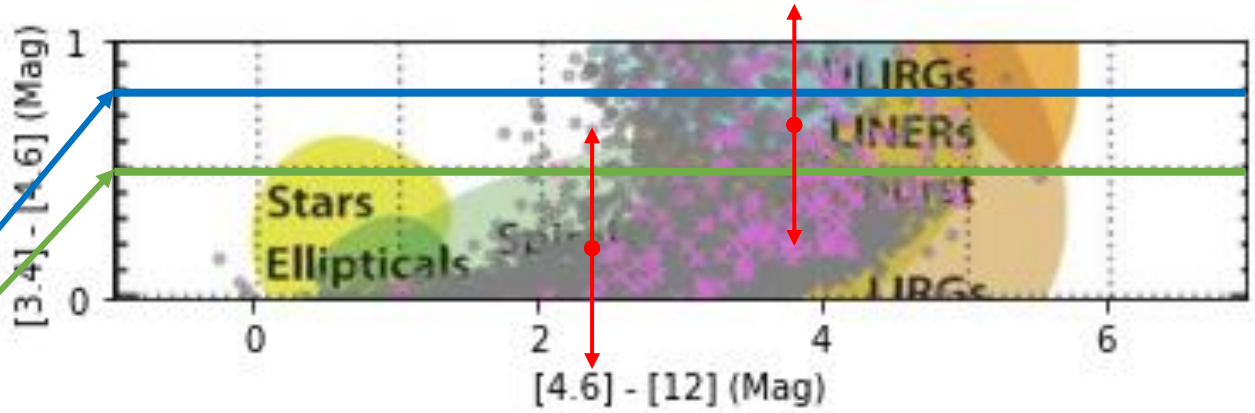
Variability





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?

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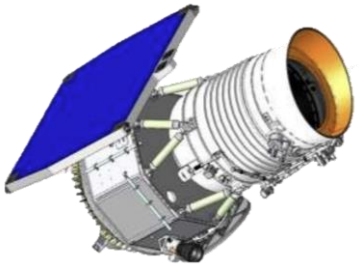
Data Selection



Galaxies Surveyed

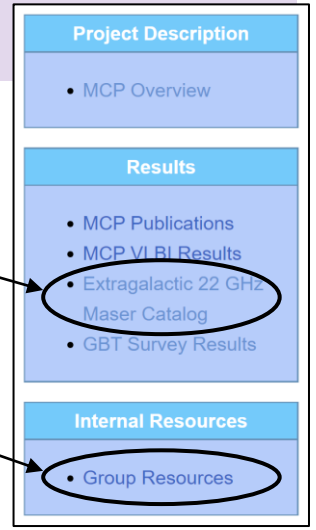
- Megamaser Cosmology Project (MCP)
  - International collaboration surveying for 22GHz emission in galaxy centers using GBT, VLA, VLBA, and Effelsberg telescopes (radio)
  - Maser & Non-maser samples

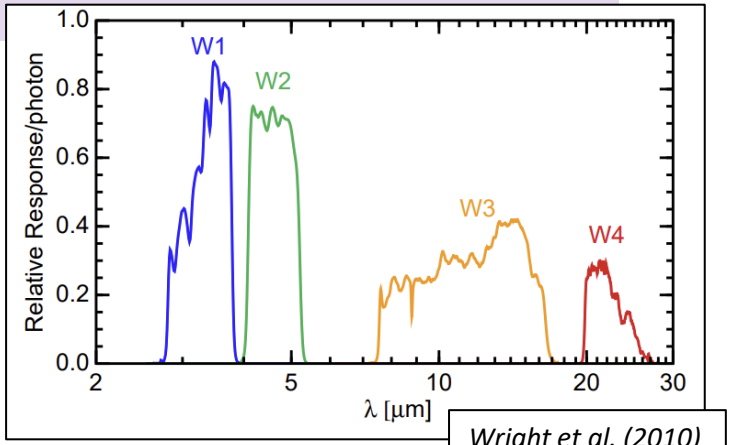
Mid-Infrared Counterparts

- **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

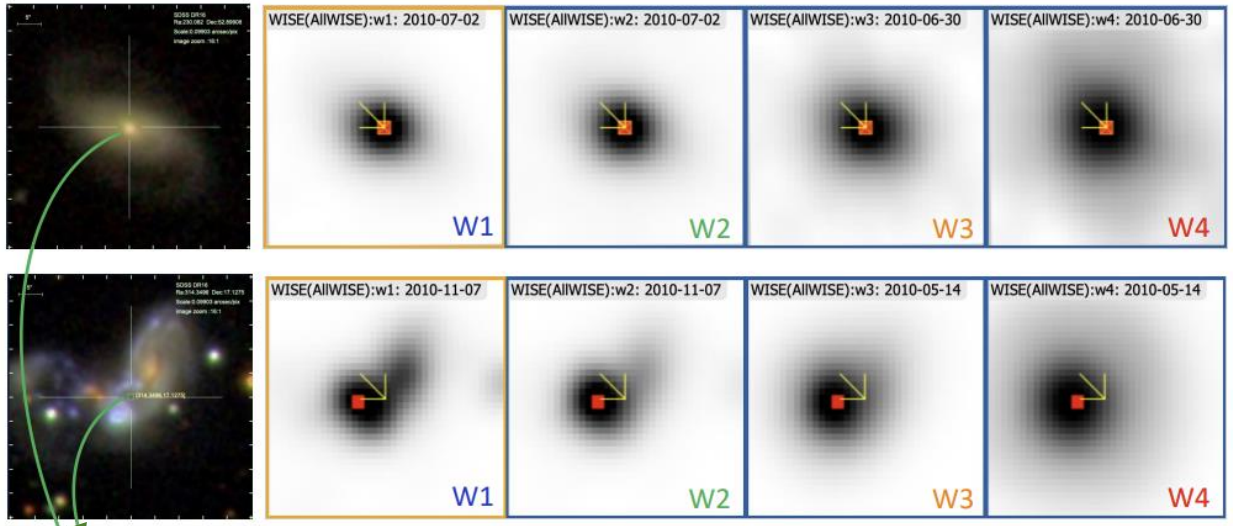




Wright et al. (2010)

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 as green square. Images provided by SDSS Navigate

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
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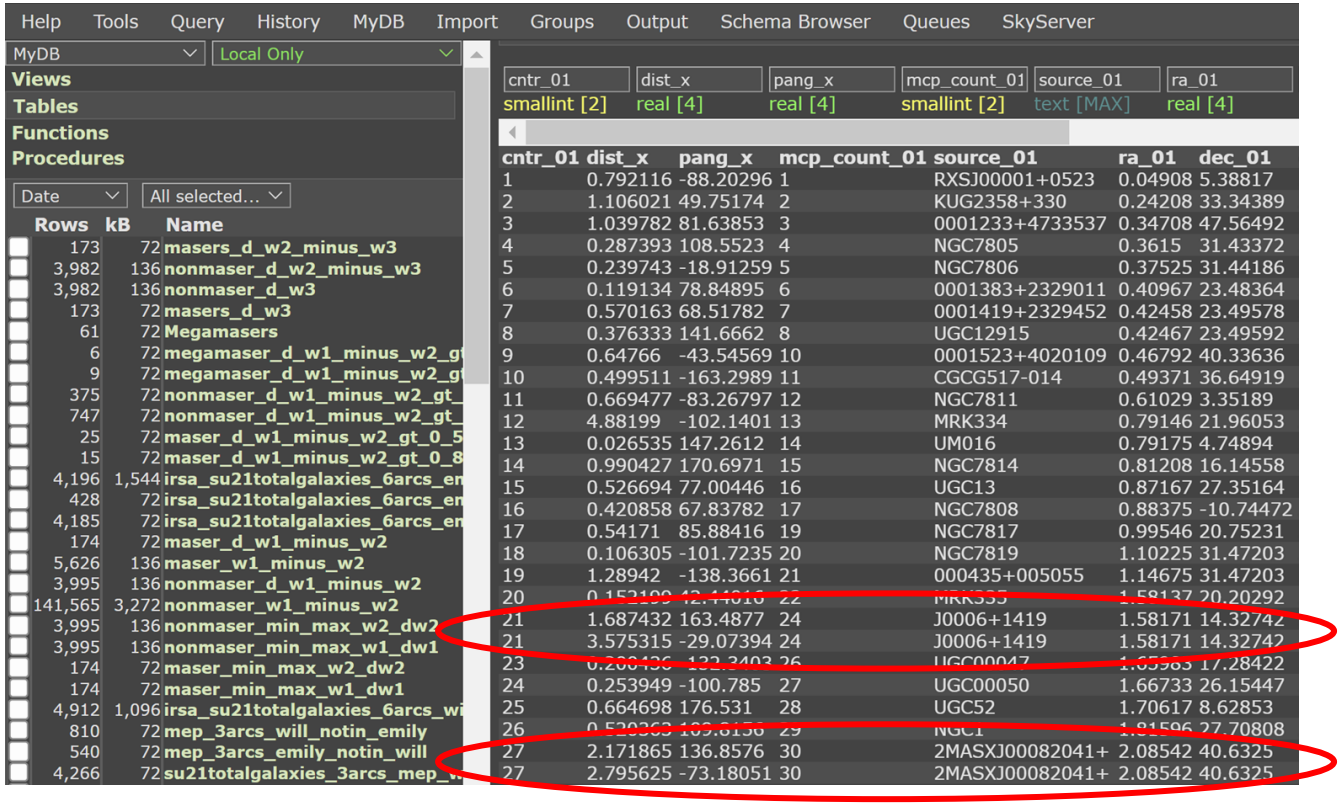

Example of duplicates in a table in the CasJobs database

Cross-matching & Data Selection

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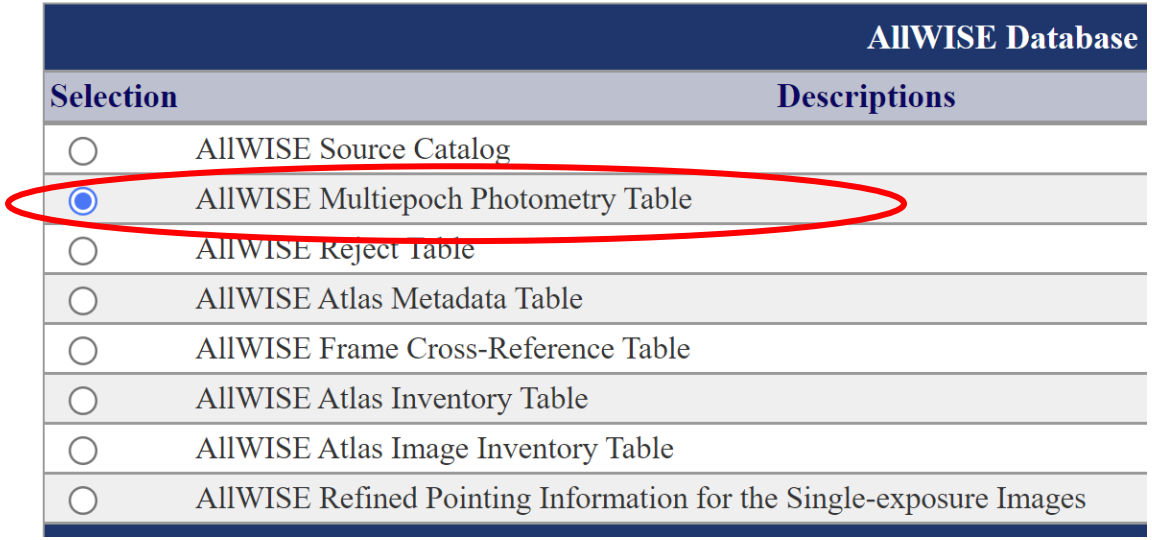

AllWISE Database	
Selection	**Descriptions**
○	AllWISE Source Catalog
◉	AllWISE Multiepoch Photometry Table
○	AllWISE Reject Table
○	AllWISE Atlas Metadata Table
○	AllWISE Frame Cross-Reference Table
○	AllWISE Atlas Inventory Table
○	AllWISE Atlas Image Inventory Table
○	AllWISE Refined Pointing Information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

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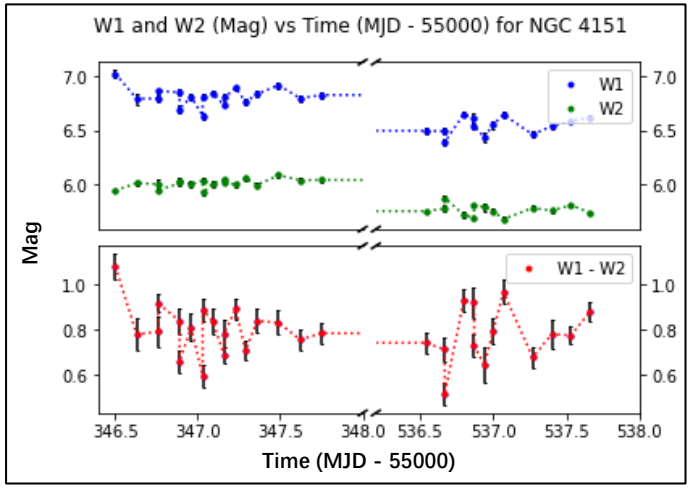
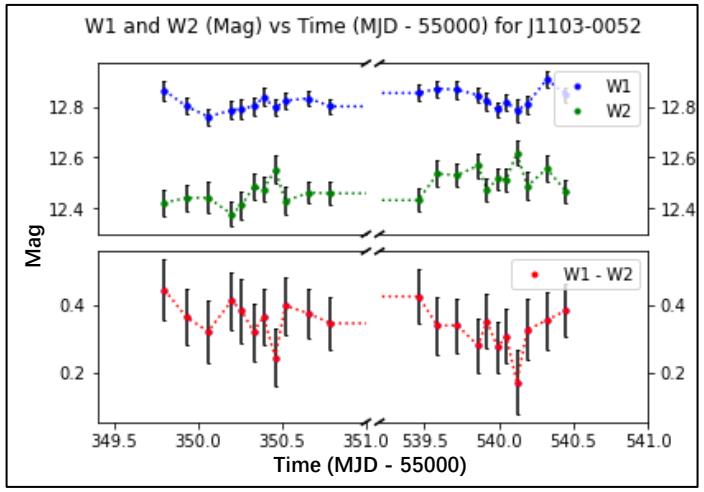
Preliminary Results

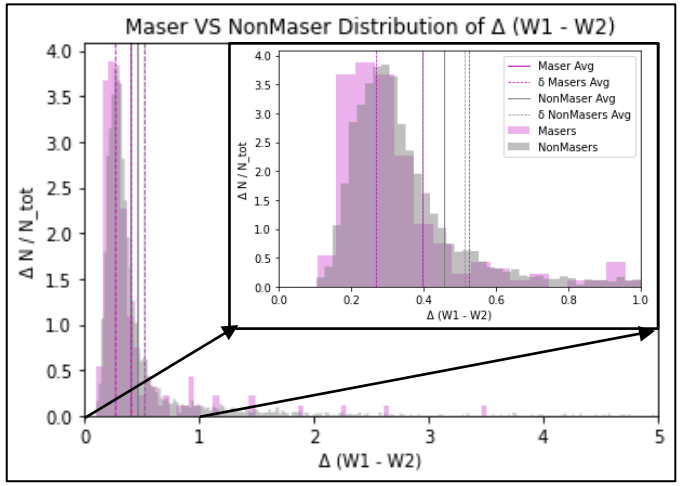
Is there Mid-IR variability? **Yes!**

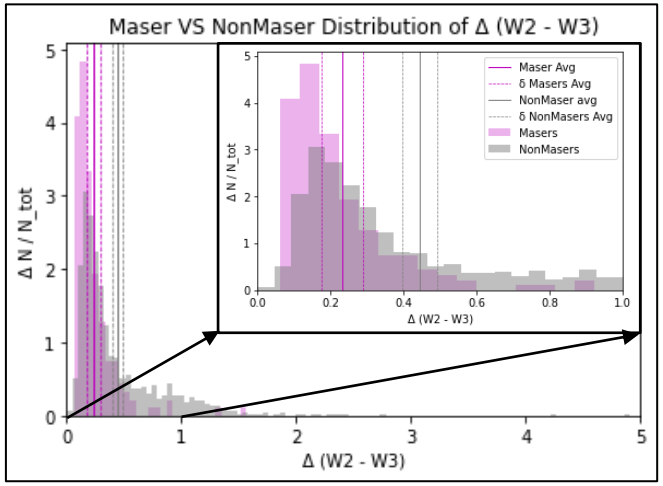
- Examples of variability in individual bands (W1, W2) and the W1 – W2 color





- Statistical comparison in the distribution of the change in the color of maser and nonmaser galaxies
- 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.