Water Megamasers and Mid-IR Emission

Water megamaser disks detected in 22 GHz emission in galactic nuclear regions provide direct geometrical distances to galaxies and the most precise and thus independent constraints of the Hubble Constant $H_0$ in the nearby universe, as well as the most accurate masses of supermassive black holes. Nevertheless, these systems are extremely rare. Improvements on their detection rates in future surveys rely on understanding their physical properties, in relation to those of their host galaxies. While there is some evidence that megamasers may be associated with the molecular disk or torus that surrounds and (partially) obscures an actively accreting massive black hole (M$_{BH}$ ~ 10$^7$ M$_{sun}$) harbored by a galactic nucleus (i.e., an Active Galactic Nucleus, or AGN), the true nature of the nuclear galactic activity remains ambiguous for a large majority of nearby galaxies: a mix of processes including emission from star-forming regions, other ionization sources (shocks, turbulence, etc.), nuclear obscuration, as well as host galaxy starlight obfuscate their true classification. Exploiting information on the thermal infrared should be crucial for tackling questions like: Are megamaser disks always related to black hole accretion? Does maser activity depend on the black hole mass, the accretion rate, the type of associated nebular emission, the small-scale environment, evidence that understanding of their physical properites, in relation to those of their host galaxies.

While there is some distance to galaxies and the most precise and thus independent constraints of the Hubble Constant $H_0$ (100 km s$^{-1}$ Mpc$^{-1}$), our new water maser detections (see below) are the only way to constrain $H_0$ to levels required to decipher the nature of dark energy.

Because the circumnuclear dust in AGNs is hot (i.e., at temperatures reaching its sublimation limit, ~1500K; e.g., Simpson 2005), its emission is enhanced and much redder than the stellar light with a typical Rayleigh-Jeans tail in the 3–10 μm range, producing a distinctive mid-IR emission. Wide-Field Infrared Survey Explorer (WISE; Wright et al. 2010) data offer unprecedented insight in this regard: redder colors, ([3.4] – [4.6] > 0.8), seem to reliably separate from star-forming systems the AGNs where accretion dominates the bolometric luminosity output, and when the AGN is highly obscured (e.g. Yan et al. 2013, Assef et al. 2013).

The Data: Detection of Masers, Megamasers, and Disks // WISE Counterparts

The Megamaser Cosmology Project (MCP; Reid et al. 2013; Kuo et al. 2013, 2015) makes publicly available the largest sample of galaxies surveyed in 22 GHz water maser emission. Of > 3500 galaxy nuclei surveyed so far, only ~3% are found to host masers, with ~80% of them possibly originating in disks. Previous selection of target maser galaxies was based on optical selection, which appears to have exhausted the current databases.

WISE Colors and Optical Spectral Signatures

The fraction of galaxies with AGN-like red WISE colors is higher among masers than among non-masers, for all spectral types. The fraction is highest among Seyferts, however, this could be due to target selection biases (e.g., Constantini 2012). LINER and Seyfert megamasers show equally significant fractions of AGN-like WISE colors, but disks are only found in Seyferts. The same fraction of disks in WISE blue Seyferts is however 55%.

WISE Colors and Maser Detection

Maser galaxies exhibit trends towards redder mid-IR colors; both megamaser and disk detection rates appear to increase for redder WISE colors, however, they seem to be characterized by a “Goldilocks range” in the WISE properties. Interestingly, only 20% of all maser galaxies that include only ~40% of maser disks, have red mid-infrared colors that are highly suggestive of heated dust by powerful accreting massive black holes, and therefore are associated with obscured AGN activity.

Conclusions

The data from the Wide-Field Infrared Survey Explorer (WISE) we systematically studied the mid-IR properties of the galaxies with and without nuclear water maser emission to better constrain the connection between water masering activity and the circumnuclear dust absorption and radiation reprocessing galaxy centers. We find:

- a higher (5%) maser detection rate among the WISE detected galaxies, and especially high (18%) for ([3.4] - [4.6] > 0.8) systems.
- mid-IR colors and luminosities are useful in separating masers from non-masers, however, there is little to say about distinguishing among different types or morphologies of the masering activity (i.e., maser vs. megamaser, vs. maser disk) based on their WISE properties.
- of all maser disks, ~60% are in fact in the blue ([3.4] - [4.6] < 0.8) mid-IR region, showing once again that the maser disks are not necessarily associated with obscured/reddened Seyfert-type activity, and that the SMBH accretion associated with the maser disk is heavily buried in hosts of other type(s) of dominant emission.

Mid-IR Spectral Energy Distributions (SEDs)

Average mid-IR spectral energy distributions for various types of maser galaxies and non-masers reveal, again, that maser disks display “goldilocks” characteristics; in this case, mid-IR spectral indices that are intermediate between those of kilonovae and the non-detections.

References


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