X-Ray Characteristics of Water Megamaser Galaxies

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Abstract

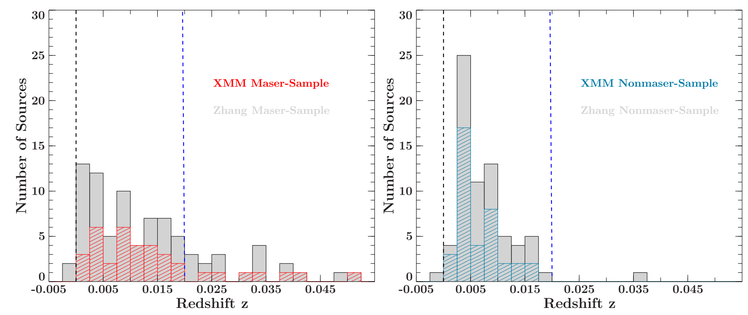
Water maser galaxies are a rare subclass of Active Galactic Nuclei (AGN). They play a key role in modern cosmology, providing a unique way to measure geometrical distances to galaxies within the Hubble flow. Modern megamaser observational programs have the goal to measure the Hubble parameter with an accuracy of 3% and to provide a constraint on the equation of state of dark energy. An increasing number of independent measurements of suitable water masers is providing the statistics necessary to decrease the uncertainties of such measurements. Studies at X-ray energies have the potential to yield important constraints on target-selection criteria for future maser surveys, promising increased detection rates of new megamaser galaxies.

We have compiled the X-ray characteristic properties for a unique and homogeneous sample of Type 2 AGN with water megamaser activity observed by XMM-Newton and for a control sample of non-maser galaxies, both analyzed in a uniform way. A comparison of the luminosity distributions confirm previous results (from smaller and/or less systematic studies) that water maser galaxies appear more luminous than non-maser sources. In addition, the maser phenomenon goes along with more complex X-ray spectra, higher column densities and higher equivalent widths of the Fe Kα line. Both a sufficiently luminous X-ray source and a high absorbing column density in the line of sight towards that source are necessary prerequisites to favor the appearance of the water megamaser phenomenon in AGN.

Sample Selection

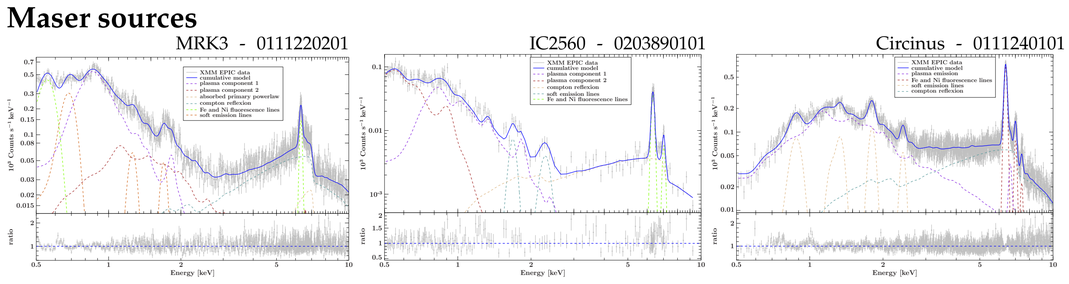
Based on the sample of Zhang et al. (2012, A&A, 538, A152) we compiled a sample of maser (30 Type 2 AGN) and non-maser (38 Type 2 AGN) galaxies which have been observed with *XMM-Newton*. The sources were uniformly extracted and analyzed. The plots on the right hand side show a comparison of the redshifts of our *XMM*-selected sub-samples and the whole sample of Zhang et al. (2012). To avoid biases potentially introduced by having significantly different redshift distributions between the two samples, we cut the maser sample at z=0.02.

Below, we present three X-ray spectra from each of the maser and non-maser samples, representing the typical distribution of the used spectral components (absorbed primary power law, ionized plasma emission, soft power law, Fe and Ni fluorescence lines, soft emission lines, Compton reflection) in each sample. To extract the intrinsic nuclear X-ray emission we just consider the primary power-law component uneffected by absorption and scattering effects.

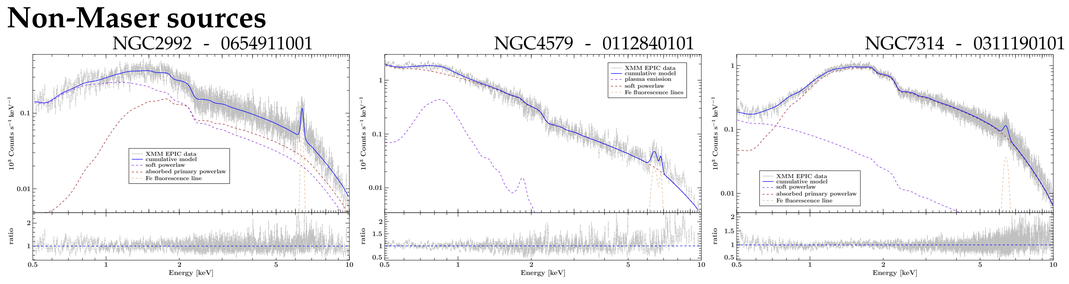


Comparison of Maser and Non-Maser Spectra (3 representatives out of each sample)

- **Maser sources**



- **Non-Maser sources**

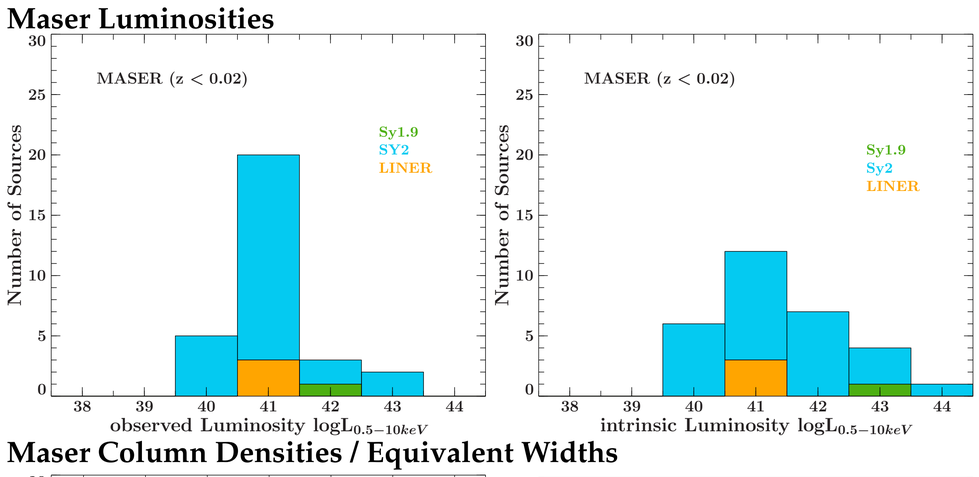


- Typical models of maser X-ray spectra include a highly absorbed power law, multiple ionized plasma emission components, strong Fe lines and X-ray reflection.
- Non-maser spectra can typically be described by a dominating weakly or partially absorbed power law, ionized plasma emission and emission from neutral iron.
- Soft X-ray emission of maser galaxies is generally more complex than in non-maser sources.
- Maser galaxies exhibit a higher fraction of X-ray reflection than non-maser galaxies. Purely reflection-dominated spectra are only observed among masers.

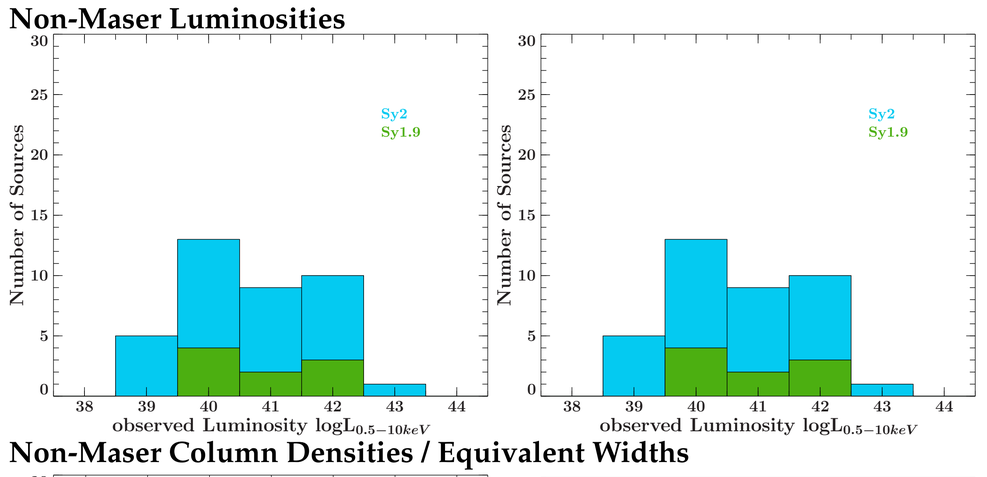
→ **In general, the physical processes in maser sources are more complex than in non-maser sources!**

Comparison of Maser and Non-Maser source properties (luminosities and column densities)

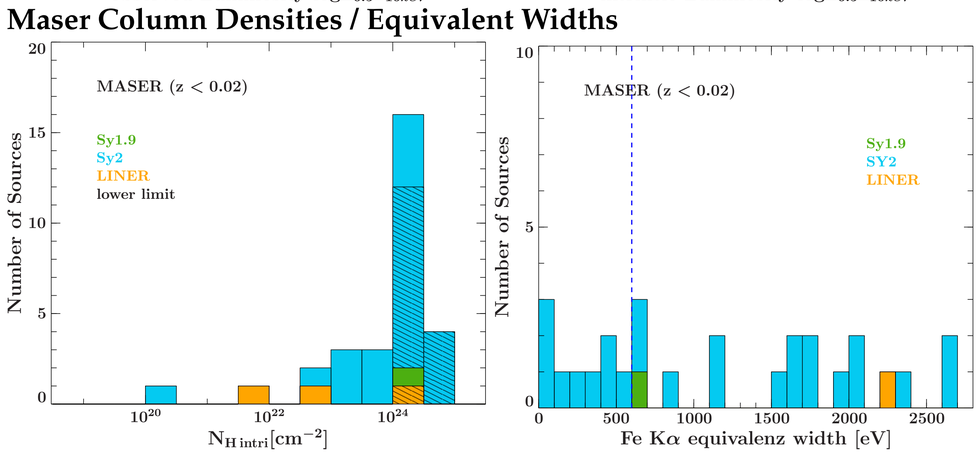
- **Maser Luminosities**



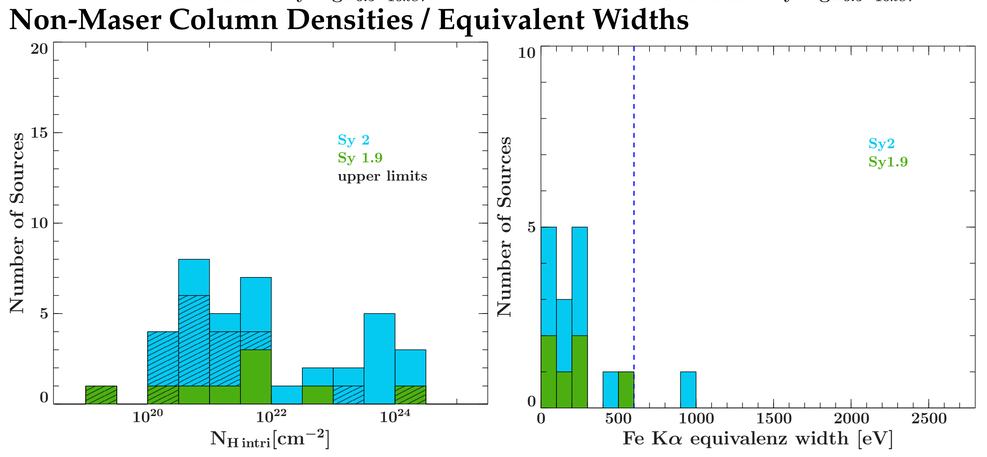
- **Non-Maser Luminosities**



- **Maser Column Densities / Equivalent Widths**



- **Non-Maser Column Densities / Equivalent Widths**



Upper panel: Distributions of observed and intrinsic luminosities in the maser sample (left) and non-maser sample (right). Different colors indicate various types of Type 2 AGN. **Lower panel:** Column density (left)/equivalent width (right) distribution of the maser and non-maser sample. Color coding as above, shaded regions indicate lower and upper limits of the N_H value, respectively.

Results

- Previous findings of higher absorbing column densities in maser galaxies (e.g. Castangia et al. 2013, Greenhill et al. 2008) are generally confirmed
- Water maser galaxies tend to be more luminous than non-maser sources (Maser fraction increases towards high intrinsic luminosities, see Table1)
  → **High column densities and high intrinsic luminosities foster maser-phenomenon**
  → **High equivalent width of Fe Kα line (> 600 eV) is a strong indicator of the maser phenomenon**

Table 1: Maser fraction for intrinsic luminosity

luminosity bin [log(L)]	39	40	41	42	43	44
maser/non-maser [%]	0	0.4	1.7	0.9	1.3	1

Acknowledgments

This research makes use of data obtained by *XMM-Newton*, an ESA science mission funded by ESA Member States and the USA (NASA). Futhermore this work was partially funded by the Graduiertenkolleg GRK 1147 from the DFG.

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