Astrophysical Masers:
Unlocking the Mysteries of the Universe
Proceedings IAU Symposium No. 336, 2017
A. Tarchi, M.J. Reid & P. Castangia, eds.

doi:10.1017/S1743921317010614

Water maser emission in hard X-ray selected AGN

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Abstract. Water megamaser emission is powerful in tracing the inner region of active nuclei, mapping accretion disks and providing important clues on their absorption properties. From the X-ray spectra of AGN it is possible to estimate the intrinsic power of the central engine and the obscuring column density. The synergy between X-ray and water maser studies allows us to tackle the AGN inner physics from different perspectives. For a complete sample of AGN selected in the 20-40 keV energy range, we have investigated the presence of water maser emission and its connection to the X-ray emission, absorption and accretion rate. The hard X-ray selection of the sample results in a water maser detection rate much higher than those obtained from optically-selected samples.

Keywords. galaxies: active, radio lines: galaxies, X-rays: galaxies

1. Introduction

Our knowledge of the geometry of the inner structure of Active Galactic Nuclei (AGN) is still very limited. We still need to identify the boundaries between the accretion disk, the Broad Line Region and the molecular torus. The clumpy nature of the obscuring torus has been established by means of X-ray and IR arguments, however recent interferometric infrared data have found evidence of a poloidal dusty structure, further complicating the already fuzzy picture of the obscuring material around super massive black holes (see Ramos Almeida & Ricci 2017 for a review).

The combination of hard X-ray and water maser studies of AGN offers a unique opportunity to improve our knowledge of the inner structure of AGN, in particular of the correct distribution of the column density, a key ingredient of the accretion history of the Universe. On one hand, hard X-rays (above 10 keV) are very effective in finding nearby AGN (both unabsorbed and absorbed) since they are transparent to obscured regions/objects, i.e. those that could be missed at other frequencies such as optical, UV, and even X-rays. On the other hand, water maser emission is able to trace the molecular gas content and dynamics in nearby AGN (Greenhill *et al.* 2003). However, so far only a small fraction of AGN have a detected 22 GHz water maser emission line, this fraction ranges between ~ 7 % from a galaxy survey (Braatz *et al.* 2007) up to ~ 26 % from an optically selected sample of nearby AGN (Panessa & Giroletti 2013).

Recently, a possible relation between the water maser and the X-ray emission have been reported. Indeed, statistical studies on a sample of 42 H2O maser galaxies have shown that 95% are heavily obscured with column density $N_H > 10^{23}$ cm^{-2} and 60% of them are

Compton thick ($N_H > 10^{24}$ cm^{-2}). The fraction of Compton thick sources increases when considering only masers in accretion disks (76% have been found to be Compton thick, Greenhill *et al.* 2008, see also Castangia *et al.* 2013). In addition, a tentative correlation has been found between maser isotropic luminosity and unabsorbed X-ray luminosity (Kondratko *et al.* 2006).

In this work, we present preliminary results on the fraction of water maser emission in a hard X-ray selected sample of AGN and on the correlation between water maser and unabsorbed hard X-ray luminosity.

2. The Sample

The soft gamma-ray sky has being surveyed by INTEGRAL/IBIS and by Swift/BAT in the last 15 years at energies greater than 10 keV. The various all sky catalogues released so far contain large fractions of active galaxies, i.e. $\sim$ 30% among INTEGRAL/IBIS and up to 70% among Swift/BAT sources (see for example Bird *et al.* 2010, Bird *et al.* 2016, Baumgartner *et al.* 2013 and references therein). Together these samples provide the most extensive list of soft gamma-ray selected active galaxies known to date.

In this work, we focus on the large sample of AGN extracted from INTEGRAL/IBIS, considering the sample of 272 AGN discussed by Malizia *et al.* (2012) added with 108 sources that have been discovered or identified with active galaxies afterwards (Malizia *et al.* 2016). This set of 380 soft gamma-ray selected AGN is fully characterized in terms of optical class/redshift and X-ray properties including information on the X and soft gamma-ray fluxes and high energy absorption. This sample is not complete nor uniform and so to overcome this limitation we have considered a subset of AGN (all included in the sample of 380 objects) which represents instead a complete sample. This sample is thoroughly discussed in Malizia *et al.* (2009) and is made of 87 galaxies detected in the 20-40 keV band.

In order to look for possible water maser counterparts, we have consulted the catalogues maintained on the Web site of the Megamaser Cosmology project (MPC, https://safe.nrao.edu/wiki/bin/view/Main/MegamaserCosmologyProject) which is the largest and most comprehensive catalog of all galaxies surveyed for water maser emission at 22 GHz (Reid *et al.* 2009 and Braatz *et al.* 2010). The literature has also been searched for report of water maser observations/detection, to integrate and complete our information. We have found water maser information for 40% (total sample) and 75% (complete sample) of the sources.

3. Results

We have found that the fraction of detected water maser emission in the total sample of 380 AGN is around 15$\pm$3 %, increasing up to 19$\pm$5 % in the complete sample. If we consider only optically selected type 2 sources, this fraction raises up to 22$\pm$5 % for the total sample and 31$\pm$10 % for the complete sample. These results suggest that the hard X-ray selection is very efficient in selecting water maser sources and that the low fractions observed so far are likely due to observational biases (Panessa *et al.* in preparation). In Figure 1, we show the water maser versus unabsorbed 20-100 keV luminosity correlation. This correlation is, however, only marginally significant (correlation coefficient R=0.43) and more data are needed to confirm it.

https://doi.org/10.1017/S1743921317010614 Published online by Cambridge University Press

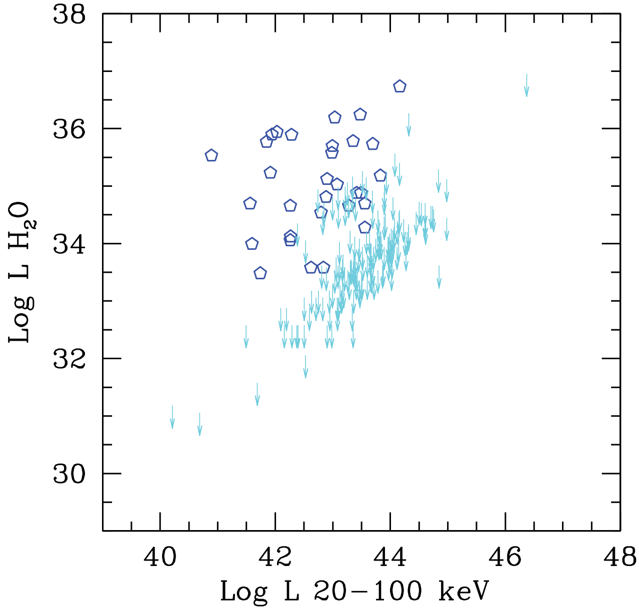

Figure 1. The water maser emission luminosity versus the unabsorbed 20-100 keV luminosity of the total sample. Blue polygons are the water maser detections and cyan arrows are upper limits (Panessa *et al.* in preparation).

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