Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
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Water megamaser emission in hard X-ray selected, highly obscured AGNs

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Abstract. We took profit of the availability of large catalogs of active galact nuclei (AGNs) selected in the hard X-ray from satellite missions (e. g., INTEGRAL, Swift/BAT) to investigate the relation between the occurrence of water maser emission and the X-ray properties of the nuclei on a statistically meaningful basis. Our studies demonstrate that the hard X-ray selection may significantly enhance the maser detection rate over comparably large optical or infrared surveys. Here, we report on a recent survey to search for water maser emission with the Sardinia Radio Telescope (SRT) in a sample of heavily absorbed AGN taken from the 70 months Swift/BAT catalog.

Keywords. masers, galaxy: active, galaxy: nuclei

1. A search for H_2O megamasers with the SRT

Despite the important information that can be derived for AGNs and cosmology, water megamasers are rare, with detection rates of a few percent in optically-selected samples of AGNs. Statistical studies on the X-ray properties of H_2O maser galaxies reveal that objects with the higher X-ray luminosity and/or the higher column density more likely host masers. Studying a sample of 36 heavily absorbed AGNs ($N_H > 10^{23}$ cm^{-2}) including Compton-thick (CT) sources, we obtained a remarkable maser fraction of (50±12)%, one of the highest ever found in extragalactic maser surveys (Castangia *et al.* 2019). The sample was selected in the local Universe through a combination of mid-IR (IRAS) and X-ray (XMM-Newton) data (for details see Severgnini *et al.* 2012). In order to confirm the indications provided by previous studies on a firm statistical basis, we also selected a large sample of 380 hard X-ray AGNs detected above 20 keV with INTEGRAL/IBIS and searched for water megamaser emission among them in the literature and through new dedicated observations (Panessa *et al.* 2020). We also considered a sub-sample of 87 sources, limited in volume and statistically complete. We found detection fractions of (15±3)% and (19±5)% for the large and the complete samples, respectively. The fraction of detected masers increases in type 2 Seyfert galaxies (22±5)% and in CT AGNs, (56±18)% of which host water maser discs, in agreement with the results of

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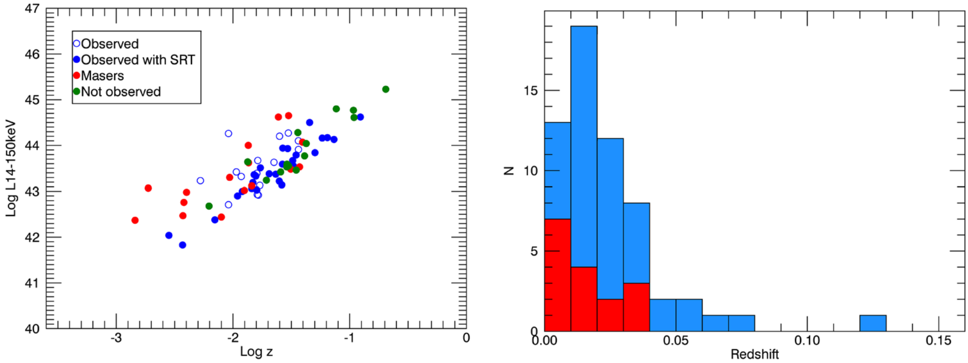

Figure 1. *Left*: Hard X-ray luminosity vs. redshift for the Ricci *et al.* (2017) sample. *Right*: Redshift distribution of the observed galaxies (blue) and of the known water masers (red) in the same sample.

Castangia *et al.* (2019). Overall, we conclude that hard X-ray samples of AGNs provide the opportunity of significantly increasing the maser detection efficiency over comparably large optical or infrared surveys (Panessa *et al.* 2020).

With the aim of detecting new luminous maser sources and comparing the results obtained with those of Castangia *et al.* (2019), we have observed a sample of 28 heavily obscured, hard X-ray selected AGNs, with the SRT (Prandoni *et al.* 2017). The targets were selected from the 75 Swift/BAT AGNs with $N_{\rm H} > 10^{23}\,{\rm cm}^{-2}$ reported in Ricci *et al.* (2017) (see the left panel of Fig. 1), 46 of which have already been observed in previous surveys (e. g. Megamaser Cosmology Project, Kondratko *et al.* 2006). Water maser emission were detected in 16 of them. From the 75 AGNs, we have selected the objects which can be observed with the SRT (Dec. $> -40°$) and whose maximum elevation at the SRT site is $\geq 30°$. Observations have been performed between December 2018 and May 2019. We employed two of the seven beams of the multi-feed K-band receiver in nodding mode and the SARDARA backend (Melis *et al.* 2018), with a bandwidth of 420 MHz and 16384 channels. This setup yielded a velocity coverage (at 22 GHz) of $3000\,{\rm km\,s}^{-1}$ and a channel spacing of 26 kHz ($\sim$0.35 km s^{-1}). We reached root mean square (rms) noise levels between 10 and 30 mJy per channel, slightly higher than those reported for the other samples (Castangia *et al.* 2019; Panessa *et al.* 2020). The survey yielded no confident detection, however, we obtained a number of tentative (signal-to-noise ratio $<$5 and/or presence of radio fequency interferences, RFI, in the spectra) water maser lines. The most promising of these features were observed again in April 2021, but not confirmed. This indicates that they are most likely produced by RFI, which affect about 50% of the spectra, or backend artifacts. Nevertheless, we cannot completely exclude the possibility that they are extremely variable water maser lines.

A preliminary statistical analysis of the Ricci *et al.* (2017) sample reveals an overall maser detection rate of (27±7)% (16/59), which is slightly higher than that obtained for the INTEGRAL complete sample, but significantly lower than the maser fraction extrapolated from the Severgnini *et al.* (2012) sample. While the higher fraction with respect to the INTEGRAL complete sample was expected due to the higher level of X-ray obscuration, the lower maser detection rate compared to the results of Castangia *et al.* (2019) is somewhat surprising. Indeed, the two samples have comparable redshift distributions (see the right panel of Fig. 1) and similar amounts of X-ray absorption. These results suggest that a key role in increasing maser detection efficiency might be played by a selection criterion that involves the mid-IR emission and deserves further investigations.

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