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H_2O maser and hard X-ray emission in AGN

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Studies of water megamaser radio sources provide a unique way to map accretion disks and to estimate masses of the nuclear engines in Active Galactic Nuclei (AGN). Broadband X-ray spectroscopy (0.1–100 keV) of AGN allows us to estimate the amount of intrinsic absorption and to derive intrinsic AGN luminosities. Therefore, complementary radio and X-ray observations of AGN potentially constitute an essential tool to understand the physics of these objects. Here, we present preliminary results of a survey to search for water maser emission in a complete sample of AGN selected in the hard X-ray band, between 20 and 40 keV, from INTEGRAL/IBIS observations. To date, we have discovered a new water maser in the NLSy1 IGRJ16385-2057. With this new detection, the fraction of water maser hosts in our INTEGRAL AGN sample is of 17% (11/66), much higher than typical detection rates obtained in surveys of optically-selected samples of AGN.

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1. Introduction

H_2O maser emission in AGN can be associated with three distinct phenomena: (1) they may form in accretion disks, at distances of 0.1-1 pc from the supermassive black holes; (2) they may be the result of the interaction between the inner part of radio jets and molecular clouds of the host galaxies; and (3) may be associated with wide-angle nuclear outflows (for a review see e. g. [7, 4]). High angular resolution observations (with the Very Long Baseline Interferometry; VLBI) of water maser sources, accompanied by single-dish monitoring, provide a unique way to map accretion disks and to estimate masses of the nuclear engines [6], as well as to determine the shock speeds and densities of radio jets [12]. Therefore, studies of H_2O maser sources constitute an excellent tool to study the physics of AGN, especially of type 2 objects, which are often obscured, at optical/UV wavelenghts, by large column densities of gas and dust along the line of sight. X-ray observations, in particular those extending above 10 keV, are also fundamental to study obscured AGN. Indeed broadband X-ray spectroscopy (0.1–100 keV) of AGN allow us to estimate the amount of intrinsic absorption and to derive intrinsic AGN luminosities. Recently, correlations between H_2O maser and X-ray emission in AGN have been reported. Statistical studies on a sample of 42 H_2O maser galaxies have shown that 60% are Compton thick ($N_{\rm H} > 10^{24}$ cm^{-2}) and 95% are heavily obscured ($N_{\rm H} > 10^{23}$ cm^{-2}) AGN [3]. The percentage of Compton thick sources increases when considering only masers in accretion disks (16/21$\sim$76% have been found to be Compton thick). Furthermore, a rough correlation has been found between maser isotropic luminosity and unabsorbed X-ray luminosity [5].

Here, we present preliminary results of an ongoing survey to search for water maser emission in a complete sample of 88 AGN selected in the hard X-ray band, between 20 and 40 keV, from INTEGRAL/IBIS observations. The sample has been extracted from the list of 140 extragalactic objects in the third IBIS survey [1] following the method described in [8]. The X-ray and hard X-ray properties of the sample as a whole and, separately, of the different Seyfert classes which made up the sample, have been studied in detail for a proper determination of the column density and the unabsorbed flux (i.e. type1: [10]; type 2: [2]; NLSy1: [11]). It has been shown, from the column density distribution of the sample, that the fraction of absorbed ($N_{\rm H} > 10^{22}$ cm^{-2}) objects is nearly 40%. In particular, limiting this analysis to the local universe, $\sim$80% of the sources are absorbed and 24% are Compton thick [8]. Given the aforementioned trend of maser galaxies to be highly absorbed or even Compton thick (see Sect. 1), the objects in the sample are suitable targets to search for new megamaser sources. Moreover, all of them are very luminous X-ray emitters ($L_{2-10{\rm keV}} > 10^{42}$ ergs/sec) further increasing the probability to detect luminous masers.

2. Observations

Observations of the 6_{16}–5_{23} transition of ortho-H_2O (rest frequency 22.23508 GHz) have been carried out with the largest radiotelescopes in the world. We have been awarded 16 hours of observing time with the 100$\times$110-m Green Bank Telescope (GBT) and 40 hours with the Effelsberg 100-m telescope in the northern hemisphere. The 70-m Tidbinbilla antenna of the NASA Deep Space Network has been used to observe the southern sources of the sample (56 hours). 8 AGN

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belonging to the complete catalog were already observed between March and April 2010, as part of a survey of 27 newly discovered INTEGRAL AGN, whose coordinates, redshifts, and optical classifications were reported in [9] for the first time. A new survey, targeting the remaining 80 sources in the complete sample of INTEGRAL AGN, started in October 2010 and is still ongoing. To date, 66 galaxies ($\sim$75% of the sample) have been searched for H_2O maser emission, 35 galaxies have been observed at 22 GHz for the first time by us, while the remaining ones belong to past surveys.

3. Preliminary results and follow-ups

On March 28, 2010 we detected a narrow maser line in the NLSy1 galaxy IGR J16385-2057 at $v_{\rm LSR} = 8047\,{\rm km\,s^{-1}}$, with an isotropic luminosity of $7\,{\rm L_\odot}$ (Fig. 1, bottom panel). The spectrum, observed one month later, shows instead a line with $L_{\rm H2O}$=14 $\rm L_\odot$ redshifted by $20\,{\rm km\,s^{-1}}$ (Fig. 1, middle panel), indicating that we are observing a group of flaring narrow lines close to the systemic velocity of the galaxy. At first sight, the line profile suggests that the maser emission may originate in an accretion disk (although we did not detect any high velocity emission feature in the 6649–9492 $\rm km\,s^{-1}$ range) or a nuclear outflow, rather than being associated with the radio-jet. Indeed, water masers produced by jet-cloud interactions typically show large line widths of the order of $\sim$100 $\rm km\,s^{-1}$. However, we cannot rule out a star formation origin of the maser in IGR J16385-2057, since the isotropic luminosity is intermediate between that of H_2O masers associated with AGN and that of the weaker masers related to star forming regions (e. g. NGC 2146; [13]). Interferometric observations are thus necessary to unveil the origin of the maser emission in IGR J16385-2057.

The detection of water maser emission in a NLSy1 galaxy was quite unexpected since, out of the 150 water maser sources known to date, maser emission has been discovered in only very few type 1 Seyfert galaxies [14]. Interestingly, this is also one of the rare masers found in an elliptical galaxy whose radio continuum morphology resembles that of radio galaxy [15].

With 10 known maser galaxies and the new detection obtained in IGR J16385-2057, a preliminary water maser detection rate of 11/66 $\sim$17% has been obtained for the INTEGRAL complete sample. Such a detection rate is much higher than any water maser detection rate typically obtained in surveys of optically-selected samples of AGN. Observations aimed at the completion of the present survey have been either already allocated or proposed for. Presently, we are leading a first statistical analysis of the main characteristics of the (masing and non-masing) galaxies in the sample. A detailed investigation of the radio characteristics of IGR J16385-2057 has been also entertained by us.

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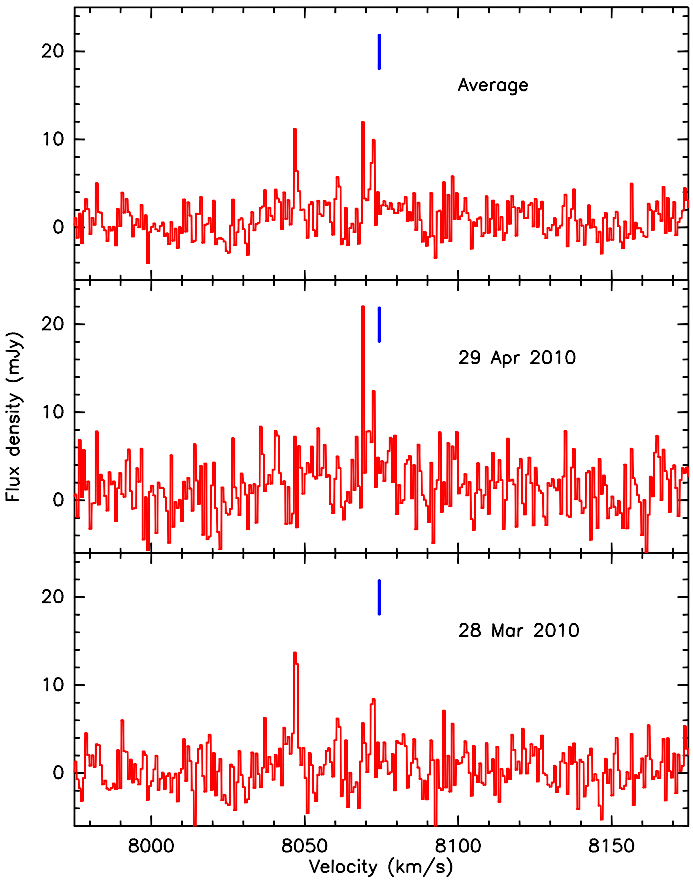

Figure 1: *Bottom and middle panels:* H_2O maser spectra toward IGR J16385-2057, observed with the GBT in two epochs, March 28 and April 29, 2010. *Top panel:* Average spectrum of the two epochs. Channel spacings are 0.7 km s^{-1}. The blue vertical lines indicate the systemic LSR velocity of the galaxy.

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