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A new jet/outflow maser in the nucleus of the Compton-thick AGN IRAS 15480-0344

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Abstract. Investigations of H_2O maser galaxies at X-ray energies reveal that most harbor highly absorbed AGN. Possible correlations between the intrinsic X-ray luminosity and the properties of water maser emission have been suggested. With the aim of looking into these correlations on a more solid statistical basis, we have search for maser emission in a well-defined sample of Compton-thick AGN. Here we report the results of the survey, which yielded a surprisingly high maser detection rate, with a particular focus on the newly discovered luminous water maser in the lenticular (field) S0 galaxy IRAS 15480-0344. Recently, VLBI observations have been obtained to image the line and continuum emission in the nucleus of this galaxy. The radio continuum emission at VLBI scales is resolved into two compact components that are interpreted as jet knots. Based on the single-dish profile, the variability of the maser emission, and the position of the maser spots with respect to these continuum sources, we favor of a jet/outflow origin for the maser emission, consistent with similar cases found in other radio-quiet AGN. This scenario is consistent with the hypothesis of the presence of strong nuclear winds recently invoked to explain the main characteristics of field S0 galaxies.

Keywords. Masers, galaxies: active, galaxies: nuclei.

1. Introduction

Active galactic nuclei (AGN) associated with water masers are usually characterized by high levels of absorption both in the optical (i. e. they are spectroscopically classified as Sy2 or LINERS) and in the X-rays (e. g. Braatz *et al.* 1997; Madejski *et al.* 2006; Zhang *et al.* 2006). In the X-rays, in particular, the measured columns densities are usually above 10^{23} cm^{-2}, with a large fraction of sources in the Compton-thick (CT) regime ($N_{\rm H} > 10^{24}$ cm^{-2}), especially those hosting H_2O masers associated with a nuclear accretion disc (Greenhill *et al.* 2008; Castangia *et al.* 2013).

The maser phenomena in AGN are thought to be intimately connected to X-ray emission, since photons at these energies are the most promising candidates to provide the necessary excitation mechanism for the maser emission (Neufeld *et al.* 1994). In this picture, a relationship between X-ray luminosity and the intensity of the maser emission is expected. Hints of such a correlation have been claimed (Kondratko, Greenhill & Moran 2006), although the level of significance is low, possibly due to the small number of sources used in the analysis. Larger and well-defined samples of AGN, with good X-ray data, are required to better study the fundamental relationship between X-ray properties and maser emission in this class of sources.

Far-infrared (FIR; 20–100 μm) emission is also thought to play an important role in water maser emission. FIR emission has been proved to be an efficient indicator of the

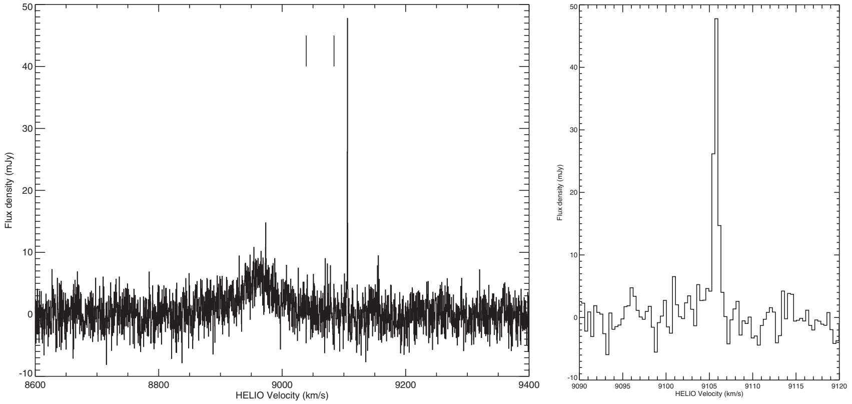

Figure 1. *Left panel:* GBT spectrum of the H_2O maser emission in IRAS15480. The vertical lines mark the recessional velocity of the galaxy and the CO centroid velocity, 9084 and 9039 km s^{-1}, respectively (Castangia *et al.* 2016). *Right panel:* Zoom of the narrow emission feature.

presence of extragalactic water masers, both those associated with star formation and those associated to AGN (Henkel *et al.* 2005; Castangia *et al.* 2008; Darling 2011). In particular, a sample of galaxies with IRAS point source flux density >50 Jy, yielded a maser detection rate of 23%, among the highest ever obtained in extragalactic maser searches (Henkel *et al.* 2005; Surcis *et al.* 2009). Hence, "ad hoc" samples of AGN, selected on the basis of their X-ray and FIR emission, have the potential, not only to shed light on the properties of the innermost region of AGN, but also constitute a promising group of targets to search for water maser emission.

With the purpose of studying the X-rays/maser connection, we searched for 22 GHz water maser emission in a well defined sample of 36 CT AGN, 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). All the galaxies in the sample were already observed at 22 GHz in previous surveys, and water maser emission was detected in 17/36 of them. We re-observed some of the non-detected sources in order to improve their upper limit on the maser luminosity. These new observations lead to the discovery of a new luminous water maser in the lenticular (S0) galaxy IRAS 15480-0344 (hereafter IRAS15480) confirming the exceptionality of this sample (Castangia *et al.* 2016). Indeed, with the detection of IRAS15480, the maser detection rate of the entire sample becomes 50%, making the CT AGN sample used here one of the most prolific samples for finding extragalactic water masers (Castangia *et al.* in prep.). Here we present the H_2O maser in IRAS15480 and discuss its origin in light of new VLBI images of the radio continuum emission in the nuclear region of the galaxy.

2. The maser in IRAS15480

IRAS15480 is an isolated lenticular galaxy that harbors a Seyfert 2 nucleus (Young *et al.* 1996). On April 7, 2012, we detected 22 GHz water maser emission in IRAS15480 using the Green Bank Telescope (GBT). The spectrum consists of two main features: a broad blueshifted component, with a full width at half maximum (FWHM) linewidth of ∼90 km s^{-1} and a narrow (FWHM<1 km s^{-1}) one close to the systemic velocity of the galaxy (Fig. 1; for details, see Castangia *et al.* 2016). The total isotropic luminosity is ∼200 $L_\odot$. Single-dish spectra at two subsequent epochs revealed the stability of the narrow component, whose properties (velocity, linewidth and peak flux density)

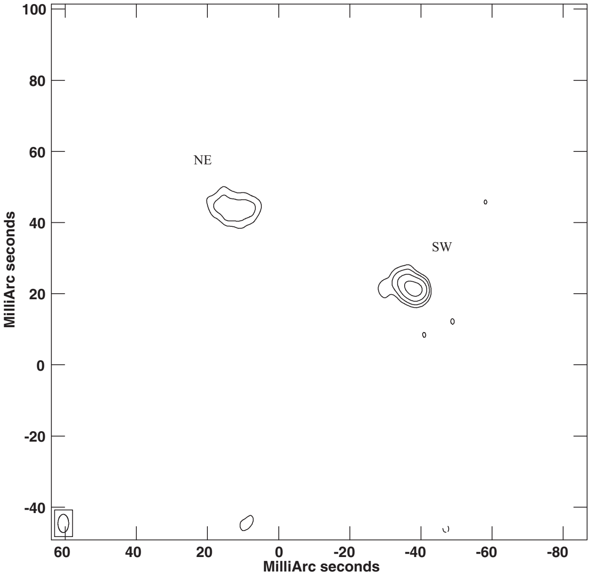

Figure 2. EVN map of the radio continuum emission in IRAS15480 at 5 GHz (Castangia *et al.* in prep.). Contour levels are (-1, 1, 2, 4, 8...)×0.2 mJy/beam (5σ).

remained constant within the errors in the three epochs. On the contrary, the peak and integrated flux density of the broad emission feature decreased to half of their initial values in approximately one month. Following the discovery, we performed interferometric observations with the Very Long Baseline Array (VLBA) and confidently detected the narrow component, which is located in the nuclear region of the galaxy. A weaker maser feature has also been detected in the velocity range of the broad component. The spatial separation between the maser spots is ~15 pc. The different single-dish profiles and variability, together with the spatial separation between the two features suggest a composite origin for the maser emission in IRAS15480. On the basis of its large linewidth and strong spectral variability, we believe that the broad component might originate from the interaction of a jet with the interstellar medium of the host galaxy. The small linewidth and the absence of high velocity features, instead, indicate a possible association with a nuclear outflow or wind for the narrow component. Although we favour a jet/outflow origin for the maser in IRAS15480, the possibility that all of the maser emission is produced in a slowly rotating ($V_{\rm rot} \sim 110\,{\rm km\,s^{-1}}$) accretion disc, with a rather large radius (15 pc), however, cannot be completely ruled out.

3. The radio continuum emission from the nucleus of IRAS15480

The Very Large Array (VLA) detected radio emission towards the nucleus of IRAS15480 at 1.7 and 8.4 GHz with measured flux densities of 42 mJy (NVSS; Condon *et al.* 1998) and 11 mJy (Schmitt *et al.* 2001), respectively. The 8.4 GHz VLA map is, to date, the highest resolution image of the nuclear region of IRAS15480 and shows an unresolved radio source with less than 60 pc diameter (Schmitt *et al.* 2001). In order to study the nuclear region of IRAS15480 with an angular resolution comparable with that of our VLBA spectral line maps, we observed the nucleus of IRAS15480 with the European VLBI network (EVN) at 1.7 and 5 GHz, in the period between February and March 2015. The EVN images display two bright sources (Fig. 2): a slightly resolved source located in the southwest (SW) and a second more extended one at distance of ∼30 pc along P.A.∼ 60° (NE). Interestingly, one of the two maser spots (the one corresponding to the broad blueshifted line) is coincident with source NE, while the narrow line emission at the systemic velocity seems to originate in a region between the two continuum components (Castangia *et al.* in prep.). The flat spectral index and high brightness temperature of the southwestern source suggest that its radio emission might be interpreted as synchrotron self-absorbed emission from the base of a jet. The presence of the northeastern source with a steeper spectral index reinforces this interpretation and points towards a "compact-jet" scenario to explain the radio emission from the nucleus of IRAS15480, as have been proposed for other Seyfert galaxies (e. g. Caccianiga *et al.* 2001; Giroletti & Panessa 2009; Bontempi *et al.* 2012). In this context, the association of the blueshifted maser spot with the northeastern source would be in agreement with our initial interpretation that part of the maser emission originates from a jet-cloud interaction (e. g. NGC1068, Gallimore *et al.* 2001; Mrk348, Peck *et al.* 2003), indicating that we may have added a new source to the few confirmed jet/outflow masers reported so far (Tarchi *et al.* 2012, and references therein).

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