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Investigating the relation between FIR flux density and maser phenomena

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Abstract. During the last years, we have searched for water emission toward a sample comprised of all galaxies visible by the 100-m Effelsberg telescope (Dec. > −30°), with known recessional velocities, and with 100 μm IRAS point source fluxes > 50 Jy. We have obtained a maser detection rate of 22%, far above the corresponding rates reached in previous works on other selected samples. Furthermore, we have been able to show a relationship between FIR flux density and maser phenomena.
Here we discuss the outlined results of our past survey and describe an on-going project aimed to broaden the observational campaign toward galaxies with 100 μm IRAS point source fluxes in the range 30–50 Jy, in order to confirm the correlation found and, hopefully, to discover additional maser sources for relevant follow-up interferometric studies.

Key words. Masers – Galaxies: active – Galaxies: jets – Galaxies: starburst – Radio lines: galaxies

1. Introduction

So far, evidence has been collected for three distinct classes of extragalactic H_2O masers:
(1) masers with high luminosities (> 10 $L_\odot$; defined "megamasers"), tracing accretion disks in active galaxies. They allow us to map nuclear accretion disks, to determine nuclear masses, and accurate distances to their parent galaxies, thus having an impact on the cosmic distance scale. NGC 4258 is the best studied target of this class (e. g. Greenhill et al. 1995; Miyoshi et al. 1995; Herrnstein et al. 1999).
(2) masers (also belonging to the "megamasers" category) in which at least a part of the H_2O emission is believed to be the result of an interaction between the nuclear radio jet and an encroaching molecular cloud. Monitoring line and continuum fluxes can provide estimates, through reverberation mapping, of the speed of the material in the jet (see e. g., for Mrk 348: Peck et al. 2003).
(3) masers, typically with lower maser luminosities (< 10 $L_\odot$; the "kilomasers"), often associated with prominent star forming regions in large scale galactic disks. This kind

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of masers can be used to pinpoint locations of high mass star formation and to determine distances through complementary measurements of proper motions and radial velocities (e. g. Greenhill et al. 1993). So far, these have been found in galaxies containing bright IRAS point sources (e. g. IC 10 Argon et al. 1994; NGC 2146 Tarchi et al. 2002b).

2. Recent observations

In the last years we performed several observations with the Effelsberg 100-m telescope, in a search for 22 GHz water emission in different types of galaxies (see also next section). Among those, we have undertaken a deep search on a sample comprised of all galaxies with Dec. > −30°, known recessional velocities, and IRAS point source flux densities of $S_{100\mu m}$> 50 Jy (e. g. IRAS 1989). The sample provided 4 new detections. Follow-up interferometric studies of these detections have been published (IC 342 Tarchi et al. 2002a; NGC 2146 Tarchi et al. 2002b) or are on-going (NGC 3556 and Arp 299) and they represent important steps for a better understanding of the debated nuclear or off-nuclear origin of kilomasers (Ho et al. 1987).

When adding the maser sources identified in previous surveys (and hence not re-observed by us) to our new detections, the detection rate for this sample is 22%, a value far above the corresponding rates deduced from any other carefully selected samples (see e. g. Henkel et al. 1984; Braatz et al. 1996; Henkel et al. 1998; Greenhill et al. 2002).

Such a positive result allowed us to carry out a statistical study on maser detection probabilities, which indicates that only a tiny fraction of the detectable luminous maser sources has been discovered so far. Moreover, it has constituted a considerable help in deriving a preliminary H_2O maser luminosity function (Peck et al. 2003, 2004).

3. Discussion and future developments

Although H_2O extragalactic masers are much sought after objects, detection rates in large surveys have been disappointingly low (e. g. in BL Lac objects or in FR I sources, see Henkel et al. 1998). In the most successful surveys, detection rates are a few percent (e. g. Braatz et al. 1996). The 22% detection rate obtained in our FIR-based sample described above is thus a significant result.

FIR emission commonly arises from dust grains heated by newly formed stars. In the Milky Way, 22 GHz H_2O masers are associated with sites of (mostly) massive star formation. Therefore a sample based on FIR bright galaxies is a particularly suitable choice to detect extragalactic H_2O masers associated with young massive stars, i. e. the class (3) described in Sect. 1 (some very luminous "megamasers" have also been detected in galaxies of the sample). Such masers have the potential, through follow-up interferometric observations using instruments like the VLA or VLBA/VLBI, to pinpoint the location of prominent star forming regions and to estimate their distance through complementary measurements of proper motion and radial velocity (e. g. Greenhill et al. 1993). Monitoring such masers and determining their three dimensional velocity vectors allow us to derive the gravitational potential of galaxies or groups of galaxies and to improve our understanding of their evolution with time (e. g. Brunthaler et al. 2002).

The high rate of maser detections in our sample of FIR luminous galaxies strongly suggests that a relationship between FIR flux density and maser phenomena exists, consistent with the assessment of Henkel et al. 1986. Figure 1 shows the cumulative detection rate above a given 100 μm IRAS Point Source Catalog flux for the parent galaxy. The cumulative detection rate declines with decreasing FIR flux, passing from 100% to about 25% for fluxes of ∼ 1000 and 50–100 Jy, respectively. In order to confirm such trend and, possibly to detect new maser sources we are extending the FIR-sample towards galaxies that have 100 μm flux densities in the range 30–50 Jy.

We intend to first observe these sources with the 100-m Effelberg telescope. If detected, more accurate positions will be determined with the VLA. If the newly found masers are strong and interesting enough, i.e. if additional

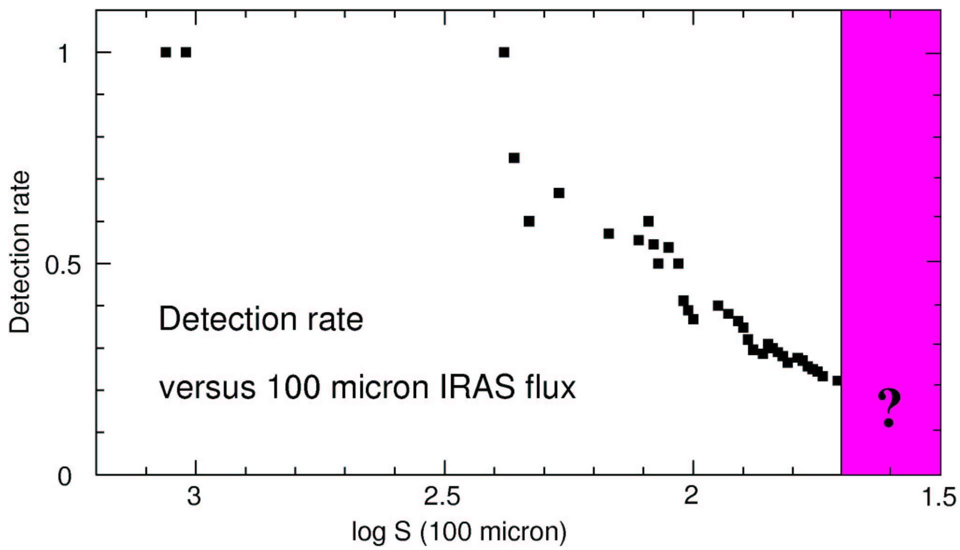

Fig. 1. Detection rate of the H_2O FIR-maser sample including all galaxies above a given 100μm IRAS Point Source Catalog flux density (Peck et al. 2004).

observing time is justified, we will then monitor the sources with the VLBA (for proper motion studies) and at Effelsberg (to determine velocity drifts or indications of interactions between jets and molecular clouds).

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