H_2O maser emission in starburst galaxies

P. Castangia, A. Tarchi, C. Henkel, K. M. Menten

Max-Planck-Institut für Radioastronomie

e-mail: pcastang@mpifr-bonn.mpg.de

OAC INAF Osservatorio Astronomico di Cagliari

Introduction and outline

The properties of H_2O masers, high brightness temperatures (about 10^{12} K), small size of individual spots (< 10^{14} cm), and narrow linewidth (few km/s), make them a powerful tool to study the structure and dynamics of the emitting gas, because can be mapped at sub-milliarcsec resolution using VLBI. The importance of the most luminous water masers, the "megamasers", is primary, since they can be used to determine the masses of nuclear engines in AGN and to map accretion disks (e.g. NGC 4258; Greehhill et al. 1995, Miyoshi et al. 1995). Recently, however, also the less luminous sources, the "kilomasers" are gaining more and more scientific relevance, because they can mark the location of regions of massive star formation that are highly obscured by dust at optical wavelengths and can be used to determine, through measurements of proper motion, distances and three dimensional velocity vectors of their host galaxies (e.g. M33, IC10; Brunthaler et al. 2005, 2006).

Here we report the results of the interferometric follow-ups of **two new kilomasers** and of the well-known kilomaser source in **NGC 253**, observed in our survey. All the interferometric observations have been performed with the Very Large Array (VLA).

The survey

Since FIR emision commonly arises from dust grains heated by newly formed stars, a sample of FIR bright galaxies is a suitable tool to detect H_2O masers associated with young massive stars. We have searched for 22 GHz water maser emission in two samples of galaxies with declination $\delta > -30°$ and IRAS Point Source flux densities at 100μm S > 50 Jy (Sample A, Henkel et al. 2005) and 30 < S < 50 Jy (Sample B, Castangia et al. 2007), with the Effelsberg 100-m telescope. The surveys yielded 4 new detections. In particular we have found **2 new kilomaser sources** with L_{H2O} ~1 L_{SUN} in the nearby spiral galaxy **NGC 3556** and in the merging system **NGC 520**. A relationship between FIR flux density and likelihood of detectable water maser emission was also established (see Fig. 1). The newly detected masers and the **well-known kilomaser source** in **NGC 253** have been followed-up using interferometric observations to derive positions and constraints on the size and brightness temperature of the emitting spots.

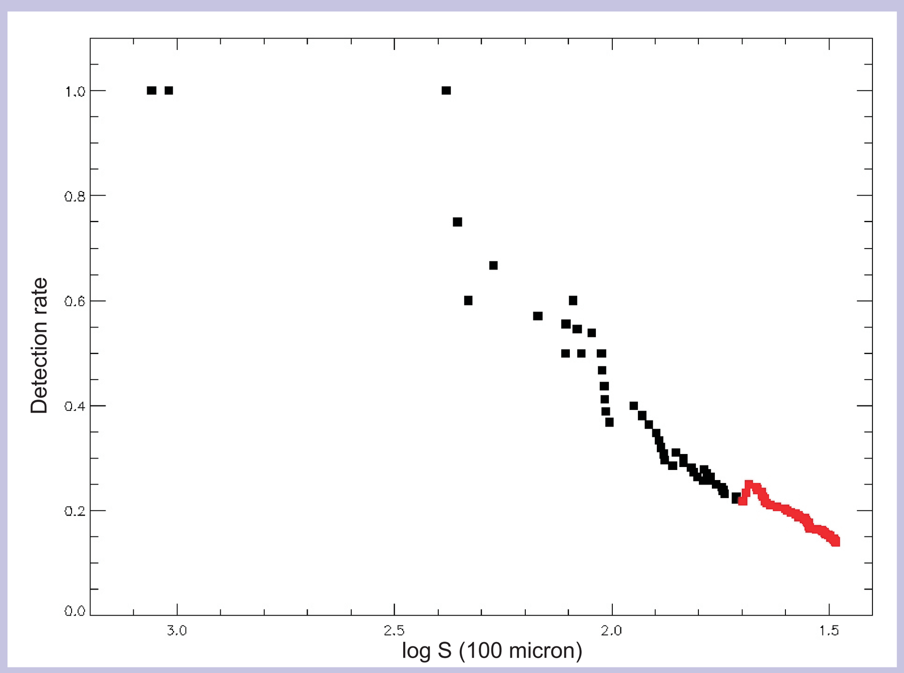
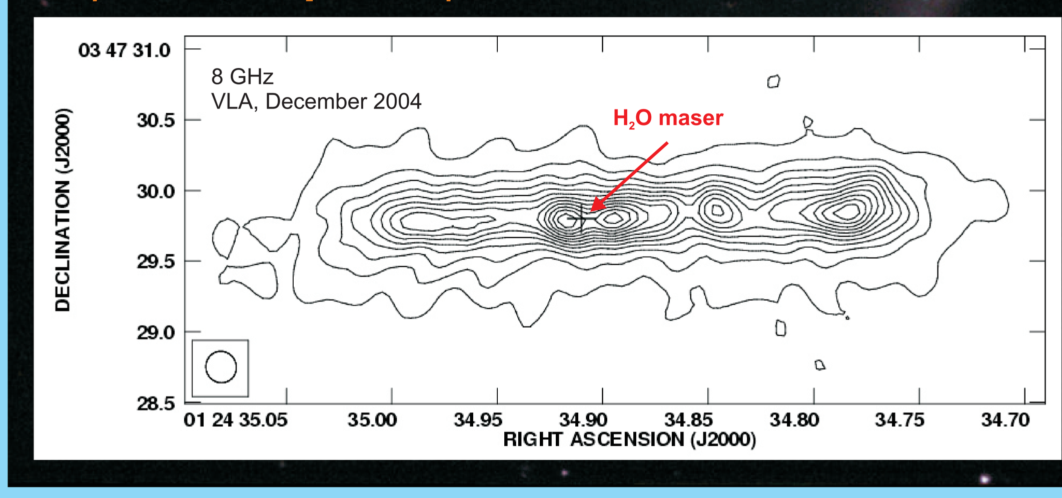


Fig.1: H_2O maser cumulative detection rate above a certain 100 μm IRAS Point Source Catalogue flux density for the parent galaxy. Black and red filled squares represent the values derived using Sample A (Henkel et al. 2005) and B (Castangia et al. 2007), respectively.

NGC 520

The H_2O emission in NGC 520, originating from a < 0.02 pc sized region with a brightness temperature, T_b, >10^{10} K, is close to one of the two radio continuum sources located in the inner parsec of the dominant nuclear region of the merger system. The maser is either associated with a young supernova remnant (SNR) or a low luminosity AGN (LLAGN). We favour the former scenario because the narrowness and variability of the maser feature resemble more those of two other kilomasers, observed in IC 10 (Henkel et al. 1986) and IC 342 (Tarchi et al. 2002), that are associated with star formation.

Fig. 2: VLA A-array radio continuum map of the nuclear region of NGC520 at 8 GHz. Contour levels are: -1, 1, 2, 3, 4, 5...16 × 0.1 mJy/beam. The cross marks the position of the H_2O maser spot.



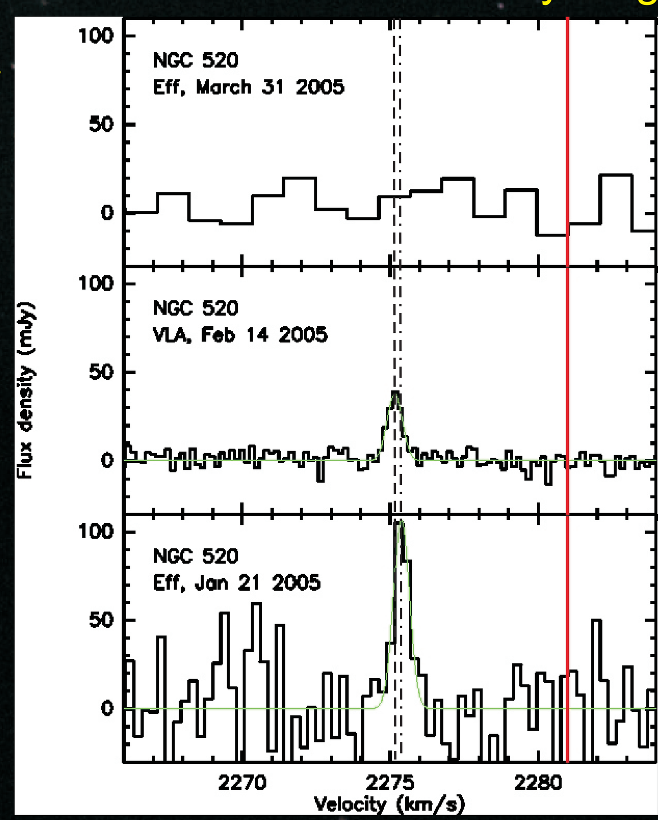


Fig. 3: H_2O kilomaser spectra toward NGC520. Channel spacings are 1.1 km/s (lower and upper panels) and 0.3 km/s. The vertical line indicates the systemic velocity of the galaxy, V_{sys}=2281 km/s (NED). The dash-dotted and dashed lines represent the peak velocities of the Effelsberg and VLA spectra, respectively.

NGC 3556

The kilomaser in NGC 3556 is somewhat resolved both in space and velocity, indicating that we are likely observing a collection of weak masers, the brightest of which has an isotropic luminosity of ~0.3 L_{SUN}. This maser is coincident (within the relative position errors of ~0.1") with a compact continuum source for which a multi-frequency study rules out an AGN nature.

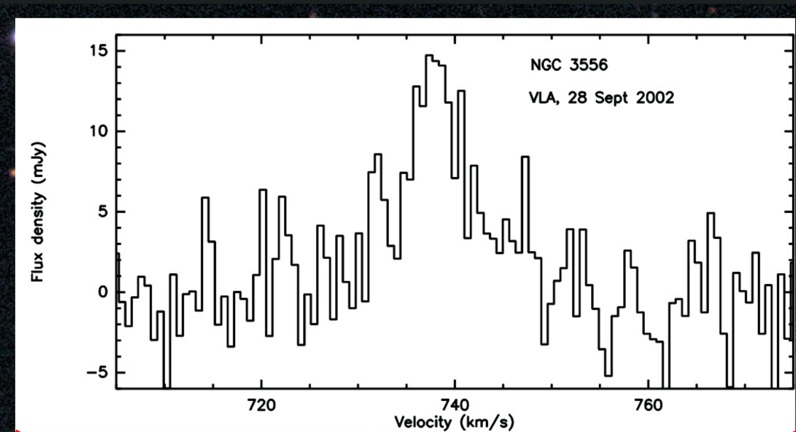
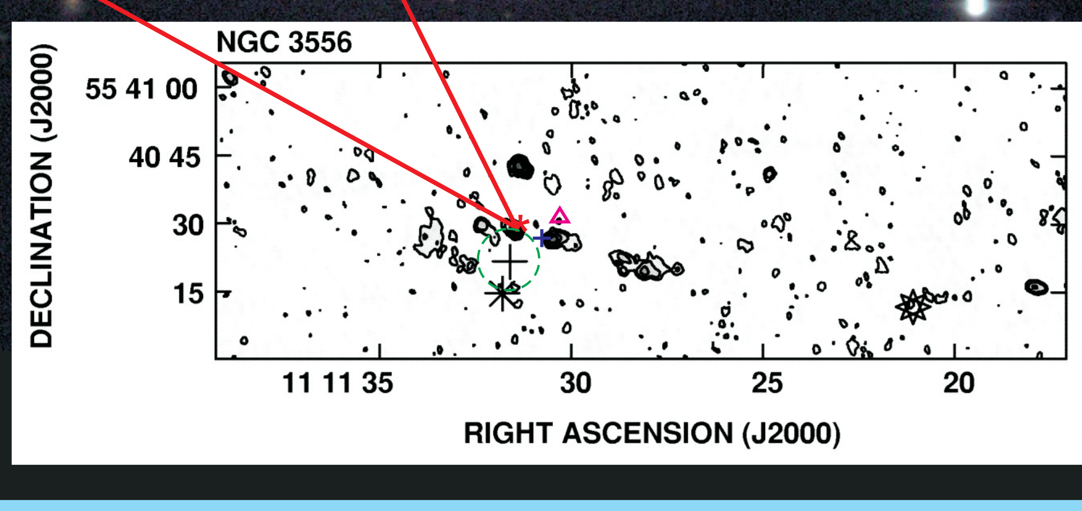


Fig. 6: The water maser feature observed in September 2002 with the VLA CnB-array, towards NGC3556. The channel spacing is ~0.7km/s.

Fig. 7: A VLA A-array map of the continuum emission of NGC3556 at 20cm (Irwin et al. 2000). The asterisk identifies the optical center. The black cross indicates the HI kinematic center given by King & Irwin (1997) with the relative error (dashed-line circle). The blue cross denotes the 2m peak. The pink triangle marks the position of Chandra source 35. The position of the water maser is indicated by the red star.



NGC 253

In NGC 253, the main H_2O maser component is associated with the source TH4, which is confidently identified as a SNR, confirming the conclusion of Hofner et al. (2006). The large discrepancy in velocity of the maser line w.r.t. to that of the neighbouring larger scale gas can be justified in terms of an association with a close-by molecular superbubble recently detected (Sakamoto et al. 2006). Alternative explanations involving a counter-rotating nuclear structure or expanding gas motions in a supernova shell are however viable.

Fig. 4: VLA A-array map of the continuum emission at 22GHz in the nuclear region of NGC253. Contour levels are -2, 2, 4, 8, 16, 32, 64 × 0.6 mJy/beam.

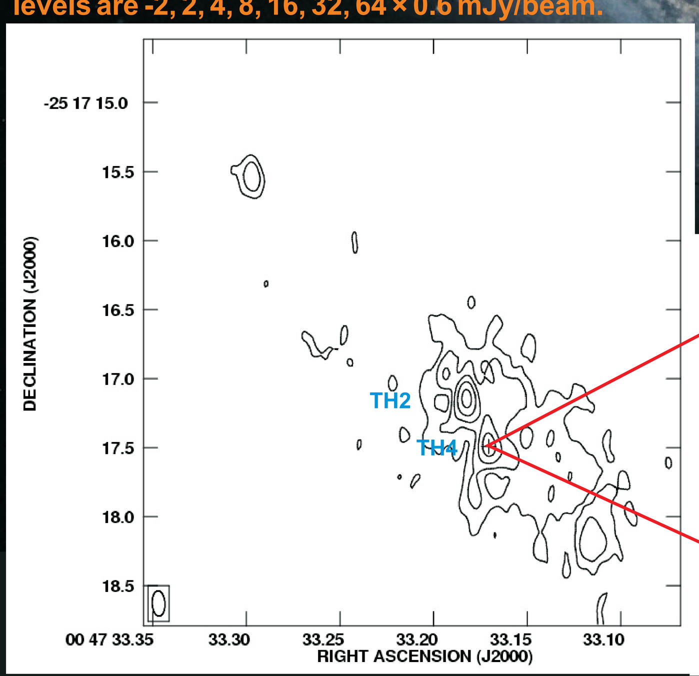
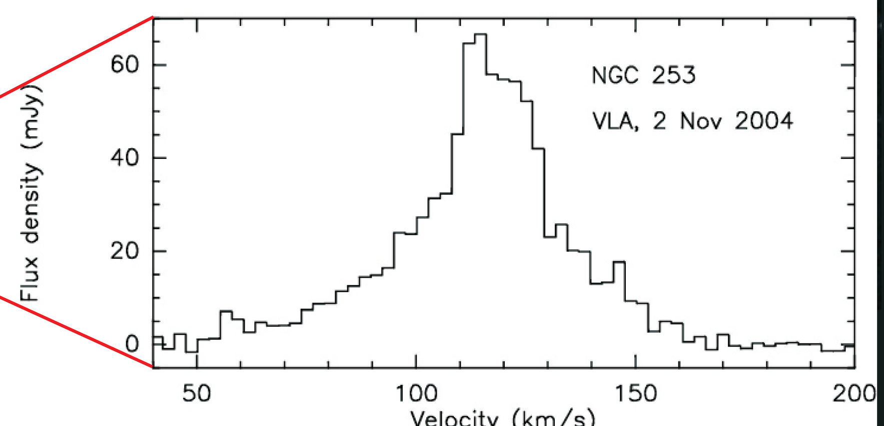


Fig.5: VLA spectrum of the water maser detected towards NGC253. The channel spacing is ~2.6 km/s.



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