Emergence of a narrow H$_2$O maser feature in NGC 1052

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ABSTRACT

We report emergence of a narrow H$_2$O maser feature with an FWHM of 21 km s$^{-1}$ in the LINER NGC 1052, which has been known to show only broad (FWHM $>$ 100 km s$^{-1}$) maser line profile with relatively bright continuum radio emission. The new narrow maser feature with the peak flux density of 47 mJy at $V_{\text{LSR}} = 1787$ km s$^{-1}$ is redshifted by 328 km s$^{-1}$ with respect to the systemic velocity. Broad features with the peak velocities of 1510 and 1704 km s$^{-1}$, redward than ever before, are also detected. The profile of the new narrow feature possibly shows brightening by $16 \pm 9\%$ and narrowing by $30 \pm 12\%$ between 2003 May 30 and June 2. At the same time, the
continuum flux density has also increased by 21%. Synchronous variation of maser and continuum flux densities in the time scale of days resembles to that in Mrk 348, which is also a broad megamaser source with bright radio continuum. Continuum and maser brightening and narrowing indicate that increase of the background seed photon and increase of maser gain have occurred simultaneously. A jet component running behind a mixture of ionized regions and X-ray dissociation regions at a subrelativistic velocity can produce such short-time variation. Another explanation is an interaction between the jet and molecular clouds.

Subject headings: galaxies: active — galaxies: individual (NGC 1052, PKS B0238–084, J0241–0815) — galaxies: nuclei — masers — radio lines: galaxies — techniques: spectroscopic

1. Introduction

Water maser emission in active galactic nuclei (megamaser) is a remarkable tool to illustrate circumnuclear molecular gas in the parsec-scale vicinity of the central engine. Its high brightness allows us imaging at sub-milliarcsec resolution using very-long-baseline interferometry (VLBI). Spectral features of masers can be narrower than the thermal width, hence, precise gas dynamics of molecular gas can be traced. Brilliant megamaser observations have unveiled structure and rotation of parsec-scale molecular gas disks and derived enclosed masses which suggest existence of supermassive black holes.

More than 30 megamasers in active galactic nuclei are known to date. Most of them are classified as Seyfert 2 or LINER (e.g. Braatz, Wilson, & Henkel 1997) except one Seyfert 1 galaxy (Hagiwara et al. 2003). Radio continuum emission in megamasers is generally weak (Braatz, Wilson, & Henkel 1997). No maser emission was found in a survey for Fanaroff-Riley I radio galaxies (Henkel et al. 1998), and only four radio-loud objects are identified as megamasers: NGC 1052 (Braatz, Wilson, & Henkel 1994; Claussen et al. 1998), Mrk 348 (Falcke et al. 2000; Peck et al. 2003), TXS 2226–184 (Koekemoer et al. 1995), and 3C 403 (Tarchi, Henkel, Chiaiberge, & Menten 2003).

Spectral features of most megamaser sources spread in a wide velocity range up to \( \lesssim 2000 \) km s\(^{-1}\) (Nakai, Inoue, & Miyoshi 1993; Nakai et al. 1995), consisting of many narrow spike-like components with several km s\(^{-1}\). Narrowing of the line profile represents exponential amplification through population-inverted molecular gas, whose gain is preferentially large at the line center (Elitzur, Hollenbach, & McKee 1989; Dopita & Sutherland 2003). Some megamasers also cast a broad component of \( \gtrsim 100 \) km s\(^{-1}\) (Maloney 2002b). Three of four radio-loud megamasers (NGC 1052, Mrk 348, and TXS 2226–184) exhibit only a broad maser profile. All of them cast bright radio continuum emission from parsec-scale jets. The relation between radio continuum emission and maser is still unclear, especially in terms of lack of narrow maser features. Claussen et al. (1998) showed that maser spots in NGC 1052 lie along the continuum ridge of the western
jet. They suggested that the masers did not lie in a Keplerian disk as found for NGC 4258 but originated in molecular clumps in the jet or in a sheath around it, or arose from amplification of radio continuum radiation from the jet by molecular clouds in front of the jet. Falcke et al. (2000) detected a luminous megamaser during a radio flare in Mrk 348; increase of the maser and continuum fluxes by a factor of three, and speculated that the maser flare is related to the flare in the nuclear jet. Peck et al. (2003) imaged the maser flare event in Mrk 348, which following a continuum flare, and found that the maser arises from a region less than 0.25 pc in extent along the receding jet. They claimed that the maser amplification is the result of an interaction between a radio jet and an encroaching molecular cloud. If the maser flare is caused by the continuum flare, the maser emission must be unsaturated, unlike the case of most megamasers (Maloney 2002a). It is important to collect the radio continuum and maser flare events for understanding the maser mechanism in radio-loud sources.

The elliptical galaxy NGC 1052 with LINER is the nearest object in the radio-loud and broad megamaser sources. The redshift of \( z = 0.0049 \) (\( V_{\text{sys}} = 1459.1 \text{ km s}^{-1} \) with respect to the local standard of rest; Knapp, Faber, & Gallagher 1978) corresponds to the distance of 20.3 Mpc and the angular scale is 98 pc arcsec\(^{-1}\), if we adopt the Hubble constant of 72 km s\(^{-1}\) Mpc\(^{-1}\) (Spergel et al. 2003). Two-sided jets, which extend to a double lobe separated by \( \sim 2.8 \) kpc, are visible at radio (Jones, Wrobel, & Shaffer 1984), optical and X-ray (Kadler et al. 2004a) wavelengths.Parsec-scale jets were imaged with VLBI (Claussen et al. 1998; Kameno et al. 2001; Vermeulen et al. 2003; Kameno et al. 2003; Kadler et al. 2004b), whose position angle is \( \sim 65^\circ \) and different from \( \sim 95^\circ \) in kpc-scale. Vermeulen et al. (2003) monitored the two-sided jet motion which displays roughly equal outward motions of \( \sim 0.78 \pm 0.12 \) mas yr\(^{-1}\) (0.25 \pm 0.04 c for the Hubble constant of 72 km s\(^{-1}\) Mpc\(^{-1}\)), and claimed that the orientation of the jet must be fairly close to the plane of the sky with the lower limit of the inclination of 57\(^\circ\). The eastern jet is brighter than the western one by a factor of 2.4 \pm 0.1, suggesting Doppler beaming effect of approaching and receding sides, respectively, inclined by \( \sim 50^\circ \) (Kameno et al. 2001). The western receding side and a part of the jet is obscured by free–free absorption due to a geometrically thick torus composed by cold dense plasma (Kameno et al. 2001; Vermeulen et al. 2003; Kameno et al. 2003; Kadler et al. 2004b).

Monitoring observations of the \( \text{H}_2\text{O} \) maser from 1994 March to 2002 April by Braatz et al. (2003) show complex changes during the period including velocity drifts, bifurcation, and flux variations. At the last epoch on 2002 April, the maser had dimmed and broadened redward. No narrow line have been detected throughout their monitoring.

\( \text{H}_2\text{O} \) maser spots distribute along the western jet (Claussen et al. 1998). The spots consists of two clusters, both centered at 0.29 and 0.32 pc from the continuum emission gap where the central engine is supposed to be. A velocity gradient along the western jet was found; the higher velocity at closer location to the central engine, by 100 km s\(^{-1}\) mas\(^{-1}\). No maser spots have been detected to the east side. The alignment of masers along the jet and the velocity gradient indicate that the masers do not lie in a Keplerian disk, and suggest that the masers arise in dense molecular clouds excited by low-velocity shocks by jets or amplification of radio continuum from the jet by molecular
clouds foreground to the jet, as claimed by Claussen et al. (1998).

The position of maser spots coincides with the region where the free–free absorption shows heavy optical depth (Kameno et al. 2003). Absorption lines of HI (Vermeulen et al. 2003) and OH (Omar et al. 2002) have been also detected along the jets. These results indicate that molecular, neutral, and ionized gas coexist in the sub-parsec vicinity of the central engine, and reflect a unique circumstance of NGC 1052.

In this report we present results of H$_2$O maser observations for NGC 1052, searching for a narrow spike-like component such as that found in the majority of other megamasers.

2. Observations and Data Analyses

We conducted observations of H$_2$O $J_{K+,K-} = 6_{16} - 5_{23}$ maser emission toward NGC 1052 using the Nobeyama 45-m radio telescope\(^1\) for 4 days from May 30 through June 2, 2003.

A dual circular polarization HEMT (High Electron Mobility Transistor) receiver was tuned at the central frequency of 22 GHz, targeting $V_{\text{LSR}} = 1459.1$ km s$^{-1}$ in radio definition. Eight high-resolution acousto-optical spectrometers (AOS-H), with 2048 spectral channels in the 40-MHz bandwidth, were used. The effective spectral resolution is 37 kHz, corresponding to 0.5 km s$^{-1}$ at the observing frequency. We also used four wide-band spectrometers (AOS-W), which covers the 250-MHz bandwidth or $3.37 \times 10^3$ km s$^{-1}$. Telescope time was allocated for 7 hours a day during the source elevation is above 25°. Simple position switching scans, consisting of a 30-second integration for each on- and off-source, were continued between system noise calibration procedures at every 20 scans.

The system noise temperature was 189 and 164 K in mean on May 30 and June 2, respectively, while it became 400 – 2000 K on May 31 and June 1 due to fog and rain. Thus, the data on May 31 and June 1 were not used in the final results. Total on-source integration time was 9525 and 9357 sec. on May 30 and June 2, respectively.

Spectral analyses, including flagging, integration, passband calibration, intensity calibration with atmospheric attenuation correction, and baseline subtraction, were performed using the NEWSTAR software package developed in the Nobeyama Radio Observatory. The baseline was determined by a linear regression in the line-free velocity ranges of $1334.5$ km s$^{-1} < V_{\text{LSR}} < 1380.6$ km s$^{-1}$ and $1847.4$ km s$^{-1} < V_{\text{LSR}} < 1870.2$ km s$^{-1}$. The continuum level was measured by averaging line-free frequency ranges in AOS-W spectral data. To convert the antenna temperature, $T_A^*$, to the flux density, $S$, the antenna gain value of $S/T_A^* = 2.77$ Jy K$^{-1}$ was applied.

The r.m.s. noise in obtained maser spectra, which is derived from a statistics in line-free

\(^1\)The Nobeyama Radio Observatory (NRO) is a branch of the National Astronomical Observatory of Japan (NAOJ), which belongs to the National Institutes of Natural Sciences (NINS).
3. Results

3.1. Maser Emission

Figure 1 shows the overall spectrum of H$_2$O maser emission of NGC 1052, integrated dual polarization signals for all available observing time of 18882 sec. The continuum level, estimated from a linear regression within line-free velocity ranges, is subtracted, where the velocity range of the maser emission spans $1450 \leq V_{\text{LSR}} \leq 1850$ km s$^{-1}$. The velocity range of the maser is more redshifted than ever seen, compared with the monitoring program by Braatz et al. (2003). The peak flux density is 89 mJy at $V_{\text{LSR}} = 1786$ km s$^{-1}$. The isotropic luminosity for the overall spectrum is $187 \pm 14$ L$_{\odot}$.

We attempt parameterizing for the spectrum using a multiple Gaussian fit. The first trial to fit with two broad (FWHM > 160 km s$^{-1}$) Gaussian components results in an unacceptable residual of $\chi^2$/d.o.f. = 3922.4/2042. Then we add the third component with a narrow (FWHM = 21 km s$^{-1}$) component, which reduces the residual to a moderate value of $\chi^2$/d.o.f. = 2889.7/2039. The best-fit parameters are listed in table 1.

3.1.1. Broad Components

Two broad components centered at 1703.8 and 1564.8 km s$^{-1}$ shows the FWHM of 174 and 149 km s$^{-1}$, respectively. The velocity widths are similar to those in past observations (Braatz, Wilson, & Henkel (1996); Braatz et al. (2003)). The peak velocity of brighter component is $1703.8 \pm 1.2$ km s$^{-1}$, which is higher than ever observed.

3.1.2. Narrow Component

The spectral component with a sharp profile, which peaks 47 mJy at 1787 km s$^{-1}$ with the FWHM of 21 km s$^{-1}$, is detected for the first time. Its isotropic luminosity is $10.1 \pm 0.5$ L$_{\odot}$. It appears in each spectrum on May 30 and June 2, while no significant narrow profile was not seen before 2002 April (Braatz et al. 2003). Thus, the new component has emerged between 2002 April and 2003 May.
Fig. 1.— The H$_2$O maser spectrum of NGC 1052 observed using the Nobeyama 45-m radio telescope. Dual polarization signals are integrated for 18882 sec using high-resolution acousto-optical spectrometers (AOS-H). Dashed lines indicate best-fit Gaussian components whose parameters are listed in table 1. The solid line is a summation of these three Gaussian components.
Fig. 2.— Spectral profiles of the new narrow component on May 30 (bottom) and June 2 (top). Solid lines show the best-fit Gaussian profiles whose parameters are listed in table 2.
We examined difference in the narrow component between May 30 and June 2. A T-test for the velocity range of 1774.5 to 1800.8 km s\(^{-1}\) results in \(T = 1.078\) for d.o.f = 97, which corresponds to \(P(t > T) = 0.28\). Thus, the difference between May 30 and June 2 is not statistically significant. However, the peak flux density and the FWHM of the narrow feature derived from Gaussian fitting showed a possible difference. Table 2 lists the parameters of the narrow component as results of a single Gaussian fit for velocity range of 1774.5 to 1800.8 km s\(^{-1}\), after we subtracted continuum and wide maser components by linear baselines ranging 1734 - 1760 and 1814 - 1841 km s\(^{-1}\). The peak flux density varies from 44.3 ± 2.5 to 51.5 ± 2.6 mJy by 2.0σ. The FWHM also varies from 23.1 ± 2.3 to 16.2 ± 1.0 by 2.7σ, at the same time.

3.2. Continuum Emission

Continuum flux densities were measured by averaging line-free spectral channels. The flux densities were 642 ± 33 mJy and 775 ± 24 mJy on May 30 and June 2, respectively. The uncertainty was derived from the standard deviation of four independent spectrometers. Although accuracy of the absolute flux density will be ∼ 5% due to systematic errors, the increase by 21% exceeds the uncertainty and is real.

4. Discussion

4.1. The Location of the Narrow Component

Since our observations were made with a single-dish telescope, we have no information about the location of the newly emerged narrow feature. Nevertheless, we attempt to estimate the location based on the velocity and the flux density.

The position–velocity diagram presented by Claussen et al. (1998) provides a clue for the location. They reported that the velocity gradient is ∼ 100 km s\(^{-1}\) mas\(^{-1}\) along the western jet. If we assume that the velocity gradient is kept until our observations, the extremely red velocity of 1787 km s\(^{-1}\) corresponds to \(\lesssim 0.5\) mas (0.05 pc) from the central engine. Claussen et al. (1998) also showed that flux densities of maser spots closer to the central engine are tend to be larger. The newly emerged bright narrow component of ∼ 50 mJy is likely to locate at < 0.5 mas from the central engine, if the tendency is applicable to the feature, too.

4.2. Time Variability

The new narrow component must have emerged after 2002 April, and possibly changed brighter and narrower within three days from May 30 to June 2. The continuum flux density has also brightened at the same time.
The intensity of unsaturated maser is a product of a background input intensity (seed photons) and a gain through excited molecular gas which has inverted population. Variation of the input intensity or gain can result in variation of the output intensity, such as emergence of a new component. The output intensity $I(v)$ at the velocity $v$ is given by

$$I(v) = I_0(v) \exp(\tau(v)),$$

where $I_0$ is the input intensity and $\tau$ is the optical depth through the excited molecular gas. The exponential term describes the gain. We would like to ascertain the cause of the emergence of the narrow feature. When the velocity distribution of the excited molecular gas is approximated by a Gaussian function as

$$\tau(v) = \tau_0 \exp \left[ -\frac{(v - v_0)^2}{2\sigma_v^2} \right],$$

where $v_0$ is the mean velocity and $\sigma_v$ is the standard deviation of the velocities of the molecular gas. Since the gain is an exponential function of the optical depth for unsaturated masers, the velocity width of an amplified spectrum will be narrower than $\sigma_v$. Increase of the optical depth makes the output velocity width narrower, and makes the intensity larger at the same time (Dopita & Sutherland 2003).

Since the newly emerged feature is bright and narrow, the emergence is likely to be due to sporadic increase of the optical depth. The maser flux density, $S$, possibly increased by $\sim 20\%$, while the line width became narrower by $\sim 30\%$ within the time scale of $\Delta t \sim S/\dot{S} \sim 10^6$ sec. These time variabilities also indicate that column density of excited molecules along the line of sight has changed. Short-time variation can happen when the line of sight sweeps a heterogeneous molecular cloud.

The continuum flux density also increased by $\sim 20\%$ at the same time. These synchronous phenomena seem causal, hence, perhaps, brightening of the maser is not only due to variation of the optical depth but also to increase of seed photons. A relative motion of the continuum source behind the excited molecular cloud can be a simple explanation. A jet knot component running behind the cloud is a candidate of the seed photon source.

The flare time scale limits the maximum scale of the seed photon source and inhomogeneity of the molecular clouds. It is estimated as $v_j \Delta t$, where $v_j$ is the apparent transverse velocity of the jet. Applying $v_j = 0.25 \pm 0.04c$ (Vermeulen et al. 2003) and $\Delta t \sim 10^6$ sec, the size will be $\sim 0.003$ pc or $\sim 0.03$ mas.

The estimated knot size is so small that high brightness temperature is required. When the brightness temperature of a Gaussian blob with the apparent size of $\phi = 0.03$ mas increases by

$$\Delta T_b = 1.224 \times 10^{12} \Delta S \nu^{-2} \phi^{-2}(1 + z) = 3.3 \times 10^{11} K,$$

the observed flux density variation can be produced. This value exceeds the peak intensity of 229 mJy beam$^{-1}$ (or $T_b = 1.7 \times 10^9$ K) in the 22-GHz map by Claussen et al. (1998), implying fine
structure in the jet which is unresolved in the continuum VLBI map. The size of \( \simeq 0.003 \) pc also describes inhomogeneity scale in excited molecular gas.

4.3. Models and Physical Conditions

In following subsections, we aim to propose plausible models to explain the observed phenomena and examine their reality by derived physical conditions.

4.3.1. X-Ray Dissociation Region

Since occurrence of megamasers is related to X-ray luminosity and atomic column density, maser excitation is considered to be powered by X-ray irradiation of dense gas by the central engine (Maloney 2002b). Large mean free path of X-ray photons with \( E \gtrsim 1 \) keV can produce an X-ray dissociation region (XDR), where water molecules are heated above \( \sim 400 \) K to generate population inversion, in a molecular cloud. Such an XDR with excited water molecules is effectively produced under the condition of

\[
7 < \left( \frac{F_X}{10^5 \text{ erg s}^{-1}\text{cm}^{-2}} \right) \left( \frac{N_H}{10^{24} \text{ cm}^{-2}} \right)^{-0.9} \left( \frac{P}{10^{11} \text{ cm}^{-3} \text{ K}} \right)^{-1} < 12, \tag{4}
\]

where \( F_X \) is the X-ray flux, \( N_H \) is the atomic column density, and \( P \) is the gas pressure.

In the case of NGC 1052, the column density of \( N_H = 0.6 - 0.7 \times 10^{22} \text{ cm}^{-2} \) and the X-ray luminosity of \( L_X = 1.4 \times 10^{41} \) erg s\(^{-1} \) were measured (Kadler et al. 2004a). The flux density at 0.1 pc from the central engine yields \( F_X = 1.2 \times 10^5 \) erg s\(^{-1} \) cm\(^{-2} \) and then \( P \sim 10^{10} \) cm\(^{-3} \) K is derived. For \( T \sim 10^3 \) K in excitation condition of H\(_2\)O masers, the molecular density of \( n_H \sim 10^7 \) cm\(^{-3} \) is required, so that the path length through the XDR will be \( L_{\text{LOS}} \sim N_H/n_H = 2 \times 10^{-4} \) pc. This is an order of magnitude smaller than the transverse size of \( v_j \Delta t \simeq 0.003 \) pc, nonetheless, a moderate filling factor in the XDR can pad the gap.

4.3.2. The Torus Scanner Model

This model does not conflict with the XDR model but a kind of it extension. The sub-parsec-scale torus, which is composed of cold dense plasma, molecular gas, and the XDR between them, may control the continuum and maser flux densities. Cold dense plasma in the torus attenuates the continuum emission from the jet. Since free–free absorption (FFA) is substantial along the western jet within 10 mas from the central engine, time variability of the continuum flux density can be ascribed to changes of the attenuation through cold dense plasma. When a knot runs behind inhomogeneous mixture of plasma and molecular gas in the torus, the attenuation by FFA and the maser gain along the line of sight would change. Escape from the ionized region will increase the
Fig. 3.— A schematic diagram of the jets and torus in NGC 1052. Double-sided jets are inclined by $\gtrsim 57^\circ$ with respect to the line of sight. Cross section of a geometrically thick molecular torus perpendicular to the jet is drawn. The inner face of the torus is ionized by irradiation from the central engine and causes free–free absorption. The X-ray dissociation region (XDR) is formed in the interlayer, where excited molecular gas performs maser amplification.
continuum flux density, and entrance into the molecular cloud increases the maser flux density and decreases the maser velocity width at the same time (see figure 3). The optical depth in terms of FFA is a function of frequency $\nu$ in GHz as

$$\tau_\nu = \tau_0 \nu^{-2.1},$$  \hspace{1cm} (5)

and the FFA coefficient $\tau_0$ in NGC 1052 can be regressed as $\tau_0 = 245 \theta^{-1}$, where $\theta$ is the separation from the central engine in mas (Kameno et al. 2003). The gradient of the optical depth, $d\tau/d\theta$, at 22 GHz and at $\theta = 0.31$ mas can produce the decrease of attenuation by 20% and the apparent motion of 0.03 mas for 0.25$c$ in three days.

4.3.3. Interacting Maser Model

Interacting masers are another mechanism for extremely bright masers. When two maser clouds sized $\sim 10^{14}$ cm are aligned along the line of sight ("interaction") with the separation of $\sim 10^{16}$ cm, the maser emission is beamed and high brightness temperatures up to $10^{17}$ K can be produced (Deguchi & Watson 1989). Synchronicity of continuum and maser flares is not required in this model. A typical relative velocity of two clouds in NGC 1052 can be estimated as $\sim 200$ km s$^{-1}$ from the velocity width of broad maser. Motion in $\sim 10^6$ sec will be $\sim 10^{11}$ cm, much less than the typical size of a maser cloud. Thus, it is difficult to change the alignment of two maser clouds in such a short time scale.

4.3.4. The Jet Maser Model

As is explained for the flares of maser and continuum in Mrk 348 (Peck et al. 2003), an interaction between the radio jet and an encroaching molecular gas can produce population-inverted maser region. Since the jet orientation of NGC 1052 is close to the plane of the sky, expanding shock can yield a long path length along the line of sight.

In the case of NGC 1052, this model can be examined by kinetics and energetics of jets. The propagation speed of the shock front, $v_s$, is related to the jet velocity $v_j$ and the density ratio of the jet $\rho_j$ and molecular gas $\rho_0$ as

$$v_s = v_j \left( \frac{\rho_0}{\rho_j} \right)^{-1/2}. \hspace{1cm} (6)$$

The apparent jet velocity of 0.25$c$ can be applied here, because of the jet orientation close to the plane of the sky. The maximum expansion velocity is close to the most redshifted maser velocity of $\sim 400$ km s$^{-1}$ with respect to the systemic velocity. The density ratio is estimated to be $\sim 4 \times 10^4$ and $\rho_j$ will be $\sim 5 \times 10^{-18}$ kg m$^{-3}$ for a molecular cloud of $n_H = 10^8$ cm$^{-3}$ and $\rho_0 = 2 \times 10^{-13}$ kg
The estimated jet density yields a kinetic power of the jet $P_j$ as

$$P_j = \frac{\pi}{2} \rho_j v_j^3 r_j^2,$$

(7)

where $r_j$ is the transverse radius of the jet. High resolution radio continuum images at 22 and 43 GHz (Kadler et al. 2004b) show that the receding knot component B2b at 0.5 mas from the central engine has the size of FWHM= 0.21 ± 0.01 and 0.224 ± 0.002 mas, respectively, corresponding to $r \sim 0.01$ pc. Thus, we have $P_j = 6 \times 10^{35}$ W ($6 \times 10^{42}$ erg s$^{-1}$). The estimated jet power is an order of magnitude larger than observed X-ray luminosity. An X-ray statistical study of energetics in radio lobes and jets (Isobe 2002) indicates that the jet power is similar to or larger than the X-ray luminosity of the central engine, so that the case of NGC 1052 can be realized. Emergence of the bright narrow component can be understood by occasional alignment of the shock along the line of sight.

An unanswered question for the jet maser model is absence of blueshifted maser emission in those objects.

5. Summary

The H$_2$O megamaser of NGC 1052 was observed on May 30 through June 02, 2003. It’s broad spectral component shifted to a higher velocity range than ever seen. A new bright narrow component emerged for the first time, with the peak flux density of 47 mJy and the FWHM of 21 km s$^{-1}$ at $V_{\text{LSR}} = 1787$ km s$^{-1}$, redshifted by 328 km s$^{-1}$ with respect to the systemic velocity. A flux density of the narrow component probably increased within three days by 16 ± 9 %, while the velocity width decreased by 30 ± 12%. At the same time, the flux density of continuum emission also increased by 21%.

Extremely high velocity of the new narrow component indicate that its location is within 0.05 pc from the central engine. The brightening and the narrowing indicate that the emergence of the new narrow component is caused by increase of a maser gain through excited molecular gas. Synchronous variation of the maser and continuum flux densities suggests that the continuum component is the seed photon source to be amplified through a population-inverted molecular gas. An XDR with a moderate condition of $T \sim 10^3$ K, $n_H \sim 10^7$ cm$^{-3}$, and $L_{\text{LOS}} \sim 2 \times 10^{-4}$ pc can effectively produce excited water molecules. When a knot runs behind such the XDR, increase of the continuum flux density due to decrease of attenuation and increase of maser gain can be realized within the short time scale of $\sim 10^6$ sec. Another possible explanation is an interaction between the jet and the molecular gas, like the case of Mrk 348.

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REFERENCES


This preprint was prepared with the AAS \LaTeX macros v5.2.
Table 1: Gaussian parameters for the spectral profile

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<th>Component</th>
<th>Peak Flux Density [mJy]</th>
<th>Peak Velocity [km s(^{-1})]</th>
<th>FWHM [km s(^{-1})]</th>
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<td>163.0 ± 3.7</td>
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<td>(\chi^2 = 3922.4/d.o.f = 2042)</td>
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<td>Three-component Gaussian fit</td>
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Table 2: Gaussian parameters for the new narrow component

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<th>Peak Velocity [km s(^{-1})]</th>
<th>FWHM [km s(^{-1})]</th>
<th>(\chi^2 / d.o.f)</th>
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<td>May 30</td>
<td>44.3 ± 2.5</td>
<td>1786.2 ± 0.7</td>
<td>23.1 ± 2.3</td>
<td>94.0/95</td>
</tr>
<tr>
<td>June 2</td>
<td>51.5 ± 2.6</td>
<td>1787.5 ± 0.4</td>
<td>16.2 ± 1.0</td>
<td>78.0/95</td>
</tr>
</tbody>
</table>