Astrophysical Masers and their Environments
Proceedings IAU Symposium No. 242, 2007
J.M. Chapman & W.A. Baan, eds.

doi:10.1017/S1743921307013488

Positional coincidence between an H_2O maser and a plasma torus in NGC 1052

S. Sawada-Satoh[1]†, S. Kameno[2], K. Nakamura[2], D. Namikawa[2], K. M. Shibata[3] and M. Inoue[3]

[1]ASIAA, P.O. Box 23-141, Taipei 10617, TAIWAN
email: sss@yamaguchi-u.ac.jp

[2]Kagoshima University, Korimoto, Kagoshima, Kagoshima 890-0065 JAPAN

[3]NAOJ, Osawa, Mitaka, Tokyo 181-8588 JAPAN

Abstract. We present VLBA observation towards the nucleus of a nearby radio galaxy NGC 1052. In NGC 1052, two-sided jet structure and a dense plasma circumnuclear torus with a radius of 0.7 pc have been found around the central mass. It emits a H_2O megamaser, which is redshifted with respect to the systemic velocity of the galaxy (1491 km s^{-1}) with a large velocity width of 100 km s^{-1} (FWHM). The maser gas is found at the inner jet components of both the approaching and receding jets. The maser gas is positionally coincident with a plasma torus. The maser gas in NGC 1052 could be explained as a circumnuclear torus or disk, as found for the nucleus of NGC 4258.

Keywords. galaxies: active, galaxies: individual(NGC 1052), galaxies: H_2O maser

1. Free-free absorption opacity distribution

The continuum images at 15, 22 and 43 GHz show the two-sided jet structure which consists of several components. After restoring with a same beam size, we obtained spectral indices along the jets. The spectral indices indicate that most parts of the two-side jet structure have optically thin spectra at 15–43 GHz except its inner edge part; a steeply inverted spectrum ($\alpha = 3.2$; $S \propto \nu^{-\alpha}$) is revealed between B and C3. The spectrum index exceeds the theoretical limit for synchrotron self-absorption ($\alpha = 2.5$). The highly inverted spectrum of the inner edge of the jets implies that synchrotron emission is obscured through free-free absorption (FFA) by the foreground dense plasma, and it is consistent with past multi-frequency observations (Kameno *et al.* 2001, Vermeulen *et al.* 2003 and Kadler *et al.* 2004).

Fitting the continuum spectrum at 15–43 GHz to FFA model ($S_\nu \propto \nu^{-\alpha} \exp(-\tau\nu^{-2.1})$), we obtained FFA opacity (τ) distributions along the jet axis (figure 1), which reveals that a high opacity ($\tau > 1000$) is found in the inner edge. It implies that the dense cold plasma covers ∼2 mas in the inner edge of the jets, where the central engine is supposed to exist.

2. H_2O maser emission

In our observation, significant maser emission within the velocity range of 1550–1850 km s^{-1} was detected. The maser spots consists of two clusters; the east cluster and the west cluster are located at Component B and C3, respectively. The velocity range of the east cluster is 1550–1850 km s^{-1}, which is the same as the whole velocity width

† Present address: Yamaguchi University, Yoshida, Yamaguchi, Yamaguchi 753-8512 JAPAN

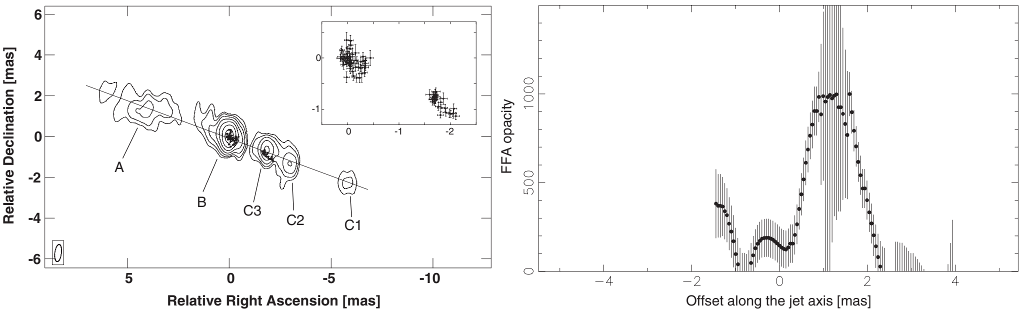

Figure 1. *Left*: Relative distributions of H_2O maser spots (full circle) with respect to the continuum image at 22 GHz (contour). Continuum jet features are labelled by A, B, C3, C2 and C1, along the jet axis (solid line). The inset box shows the detailed distributions of maser spots. *Right*: Free-free absorption opacity along the jet axis.

of the H_2O maser profile. The maser spots with a velocity of 1550–1700 $\mathrm{km\,s^{-1}}$ in the east cluster are distributed within 0.1 pc, although the masers with a velocity of 1700–1850 $\mathrm{km\,s^{-1}}$ are concentrated within 0.02 pc on the peak of Component B. On the other hand, the west cluster is detected with a velocity range of 1550–1750 $\mathrm{km\,s^{-1}}$ along the NE-SW direction or the jet axis. It shows a velocity gradient of $\sim 200\,\mathrm{km\,s^{-1}\,mas^{-1}}$ along this direction. We note that Claussen *et al.* (1998) showed a velocity gradient along the east-west direction ($\sim 100\,\mathrm{km\,s^{-1}\,mas^{-1}}$) in the maser cluster of the west jet component.

3. Discussions

The maser gas is located where FFA opacity is large, or where the plasma torus covers the foreground of the inner edge of the jets. The positional coincidence between the plasma and the H_2O masers supports the subparsec-scale torus model, which consists of dense plasma, molecular gas, and the X-ray dissociation region (XDR: Maloney 2002) described by Kameno *et al.* (2005). The other possible explanation is the jet model. The jet propagation hits the molecular gas in the AGN region. The molecular gas within or at the front shock of the jet emits the maser. The west maser cluster shows some velocity gradient along the jet axis. This trend is also seen in Mrk348 whose H_2O maser has been explained an interaction between a jet and a molecular cloud (Peck *et al.* 2003). The west cluster is seen at the receding jet, and the velocity of the west cluster is all redshifted.

Acknowledgements

The VLBA is operated by the NRAO, a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

References

Claussen, M. J.,Diamond, P. J., Braatz, J. A., Wilson, A. S., & Henkel, C. 1998, *ApJ* 500, L129
Kadler, M., Ros, E., Lobanov, A. P., Falcke, H., & Zensus, J. A. 2004, *A&A* 426, 481
Kameno, S., Sawada-Satoh, S., Inoue, M., Shen Z.-Q., & Wajima, K. 2001, *PASJ* 53, 169
Kameno, S., Nakai, N., Sawada-Satoh, S., Sato N., & Haba, A. 2005, *ApJ* 620, 145
Maloney, P. R. 2002, *PASA* 19, 401
Peck, A. B., Henkel, C., Ulvestad, J. S., Brunthaler, A., Falcke, H., Elitzur, M., Menten, K. M., Gallimore, J. F. 2002, *ApJ* 590, 149
Vermeulen, R. C., Ros, E., Kellermann, K. I., Cohen, M. H., Zensus, J. A., & van Langevelde, H. J. 2003, *A&A* 401, 113

https://doi.org/10.1017/S1743921307013488 Published online by Cambridge University Press