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

doi:10.1017/S1743921307013518

Water-vapor maser disk at the nucleus of the Seyfert 2 IC 2560

Aya Yamauchi[1], Naomasa Nakai[1], Yuko Ishihara[2], Philip Diamond[3] and Naoko Sato[4]

[1]University of Tsukuba, 1-1-1 Ten-nodai, Tsukuba, Ibaraki 305-8571, Japan
email: yamauchi@physics.px.tsukuba.ac.jp

[2]Koriyama City Fureai Science Center, 2-11-1 Ekimae, Koriyama, Fukushima 963-8002, Japan

[3]Jodrell Bank Observatory, University of Manchester, Macclesfield, Cheshire, SK11 9DL, UK

[4]Wakayama University, 930 Sakaedani, Wakayama, Wakayama 640-8510, Japan

Abstract. We observed the H_2O maser at the nucleus of the Seyfert 2, IC 2560, using the VLBA and the phased VLA. The systemic, red-shifted and blue-shifted maser features and a continuum component have been detected. We propose a maser disk in the nuclear region. The systemic and red-shifted features are emitted from a nearly edge-on disk with the position angle of $PA = -47°$. The thickness is $2H < 0.025$ pc. The binding mass is $3.5 \times 10^6 M_\odot$. Assuming the Keplerian rotation, the radii at the disk are $r = 0.087 - 0.335$ pc and the rotation velocities are 213–418 km s^{-1}. The mean density within the inner radius is $1.3 \times 10^9 M_\odot$ pc^{-3}, suggesting a massive black hole at the center. A continuum component is considered as a jet ejected from the nucleus, with an angle of 70° from the disk. The blue-shifted maser feature is located on the continuum component, being interpreted to be a 'jet maser'.

Keywords. galaxies:active, galaxies:individual (IC 2560), galaxies:nuclei, galaxies: Seyfert

---

IC 2560 is a Seyfert 2 glaxy at a distance of 26 Mpc (Aaronson *et al.* 1989) and its systemic velocity is $V_{\rm LSR,rad} = 2876$ km s^{-1} (Strauss *et al.* 1992). We observed the systemic maser features and continuum emission of IC 2560 on 1998 January 2 and the systemic and high-velocity features on 2000 April 10, using the VLBA and the phased VLA. The synthesized beams were 2.2×1.8 mas (1998) and 1.00×0.36 mas (2000).

Fig.1(a) shows the distribution of H_2O masers in a coordinate system relative to the position of the strongest maser feature at $V_{\rm LSR} = 2876$ km s^{-1}. The systemic features (2867–2890 km s^{-1}) are located around $(\Delta RA, \Delta Decl) \approx (0, 0)$ mas. The peak intensity is 0.145 Jy beam^{-1}. A red-shifted feature (3201 km s^{-1}) is detected at $(\Delta RA, \Delta Decl) = (-0.84, 0.77)$ mas. Its angular separation from the strongest systemic feature is 1.14 ± 0.03 mas (0.144 ± 0.004 pc), and its peak intensity is 0.062 Jy beam^{-1}. A blue-shifted feature (2656 km s^{-1}) is detected at $(\Delta RA, \Delta Decl) = (-1.57, 0.13)$ mas. Its angular separation from the strongest feature is 1.58 ± 0.47 mas (0.199 ± 0.006 pc), and its peak intensity is 0.030 Jy beam^{-1}. 22-GHz continuum emission is detected with a peak flux density of 1.8 ± 0.3 mJy beam^{-1}. Assuming that the peak position of the 2876 km s^{-1} maser feature observed in 1998 is the same as the position observed in 2000, the continuum map is overlaid on the maser map, as seen in Fig.1(a). The peak position of the continuum component is at $(\Delta RA, \Delta Decl) = (-1.40, -0.72)$ mas $= (-0.176, -0.090)$ pc.

The spatial distribution of the systemic and red-shifted features and the continuum component strongly suggest that we are seeing an edge-on maser disk rotating around $(\Delta RA, \Delta Decl) \approx (0, 0)$ mas, and a jet ejected from the centre, perpendicular to the maser disk, as is observed in NGC 4258 (Miyoshi *et al.* 1995, M95). The blue-shifted feature near the continuum component clearly does not belong to the disk but is probably a

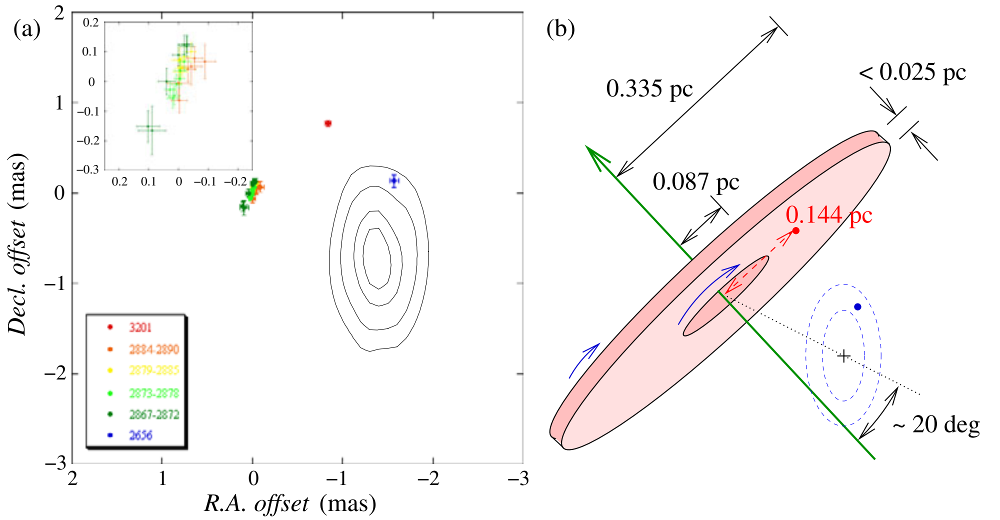

Figure 1. (a) Distributions of maser emission and continuum component in the nuclear region. The contour levels are 3, 4, 5, and 5.5σ ($1\sigma = 0.31$ mJy beam^{-1}). (b) Model for the maser disk.

'jet maser' which may be pumped by collisions between a molecular gas and the jet and stimulated by continuum radiation of the jet as seen in NGC 1068 (Gallimore *et al.* 2001). A least-squares fit to the systemic and red-shifted features gives the position angle of the disk, $PA = -47°$. The distribution of the systemic features measured perpendicularly to the PA indicates that the thickness of the disk is $2H < 0.20$ mas (0.025 pc). The red-shifted feature we detected lies at a radius of $r = 1.14 \pm 0.17$ mas (0.144 ± 0.021 pc) and rotates with a velocity of $V_{\rm rot} = 325$ km s^{-1}, which means that the mass inside the radius is $(3.5 \pm 0.5) \times 10^6 M_\odot$, assuming a spherical distribution of the central matter.

In single-dish observations, more blue- and red-shifted maser features are detected. Assuming that the blue-shifted features at $V_{\rm LSR} = 2458$–2556 km s^{-1} and the red-shifted features at $V_{\rm LSR} = 3089$–3222 km s^{-1} are located in the disk, the rotation velocities are $V_{\rm rot} = 213$–418 km s^{-1}. If the rotation is Keplerian ($V_{\rm rot} \propto r^{-1/2}$) as in NGC 4258 (M95), the disk radii can be estimated to be $r = 0.087$–0.335 pc. The mean volume density inside the inner radius is $\rho = (1.3 \pm 0.6) \times 10^9 M_\odot$ pc^{-3} which is comparable with that of NGC 4258 ($3.4 \times 10^9 M_\odot$ pc^{-3}, M95) and thus suggests the existence (Ishihara *et al.* 2001) of a massive black hole of $M_{\rm BH} \approx 3.5 \times 10^6 M_\odot$ at the nucleus of IC 2560.

Acknowledgements

A. Y. thanks the IAU Grant and the Hayakawa Fund in Astronomical Society of Japan.

References

Aaronson, M., Bothun, G. D., Cornell, M. E., Dawe, J. A., Dickens, R. J., Hall, P. J., Sheng, H. M., Huchra, J. P., Lucey, J. R., Mould, J. R., Murray, J. D., Schmmer, R. A., & Wrighy, A. E. 1989, *ApJ* 338, 654

Gallimore, J. F., Henkel, C., Baum, S. A., Glass, I. S., Claussen, M. J., Prieto, M. A., & Von Kap-Herr, A. 2001, *ApJ* 556, 694

Ishihara, Y., Nakai, N., Iyomoto, N., Makishima, K., Diamond, P., & Hall, P. 2001, *PASJ* 53, 215

Miyoshi, M., Moran, J., Herrnstein, J., Greenhill, L., Nakai, N., Diamond, P., & Inoue, M. 1995, *Nature* 373, 127

Strauss, M. A., Huchra, J. P., Davis, M., Yahil, A., Fisher, K. B., & Tonry, J. 1992 *ApJS*, 83, 29

https://doi.org/10.1017/S1743921307013518 Published online by Cambridge University Press