PLANETARY NEBULAE: THEIR EVOLUTION AND ROLE IN THE UNIVERSE
IAU Symposium, Vol. 209, 2003
S. Kwok, M. Dopita, and R. Sutherland, eds.

Analysis on Internal Motions of the Halo Planetray Nebula, H4-1

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Up to now, ten planetary nebulae are regarded as halo planetary nebulae (halo PNe). We obtained low- and moderate-dispersion spectra of the spatially resolved halo planetary nebula H4-1 in the wavelength region of $\lambda\lambda$3700-6800 Å with the Cassegrain Spectrograph of 74-inch telescope at Okayama Astronomical Observatory. In the moderate dispersion observation, we were able to obtain [O III] $\lambda\lambda$4959,5007 and Hα of H4-1 at several position angles (P.A.). The image was spatially resolved and its apparent angluar size should be less than 10.″0.

We can analyze the emission line profiles in two dimensions, namely in the direction of dispersion and along the length of slit depending on the position angle. Since the slit width in our observation was 1.″8, two dimensional analysis can give us information on the velocity field around the circumstellar space of the nebula. We show only two samples of the contour plots of the [O III]λ5007 in figure 1. The contour level are divided into 100 parts between 3σ levels of rms and 1/10 of the normalized top of each line profile. We define the expansion velocities of wing components at FWZI (Full Width at Zero Intensity), V_{FWZI} and estimate it at [O III]λ5007 of such wings as 487kms^{-1} at P.A.135° and 610kms^{-1} at P.A.180°. Among these values the wing components at P.A.180° are clearly blue shifted as a whole. This strongly suggest

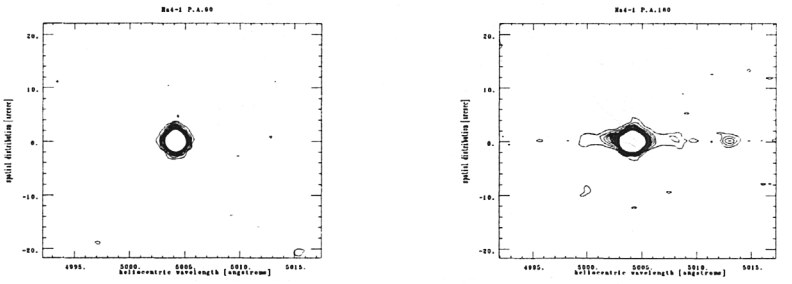

Figure 1. The contour of [O III]λ5007 at P.A.90°(left) and P.A.180°(right). The panel at P.A.180° clearly shows broad weak components.

the existence of rather high velocity gaseous flow other than the main stream. Morever, this flow can not be explained by the stellar wind which was reported

https://doi.org/10.1017/S0074180900209674 Published online by Cambridge University Press

by Feibelman (1994, PASP,106,75). As to P.A.45°, 90°, 165°,195°, there are no such broadened wing component. Concerning Hα, we also detect a broad wing component at P.A.180°, while there is not at P.A.90°. The width of the wing component of Hα at P.A.180° is estimated as $V_{FWZI} \sim 442 \mathrm{kms}^{-1}$. The tendency for V_{FWZI} at P.A.180° to be broader than P.A.90° is also confirmed in both Hα and [O III]λ5007. Therefore, we can confirm an intermediate high velocity flow between the main stream and the stellar wind.

To summarize the measurements on the width of the broadened wing components in connecting with the position angles, we show the resultant values in figure 2(a). We plot them with respect to the centre of system, namely the centre of the main component. In figure 2(b), we also show the relation between the expected FWZIs and the position angles at [O III]λ5007. These values can be estimated from observed FWHMs when we assume that they are equivalent to the result of the FWHMs in the single Gaussian fitting. Figure 2(a) reveals a clearly anisotropic feature like a bipolar flow in companion with the figure 2(b). Given the seeing size (1.″5) and the slit width (1.″8) we must keep in the mind that figures 2(a) and 2(b) should be interpreted as the spatial resolution is nearly 2.″0. At the time of observation at P.A.165° the seeing condition was worse than other positions. Therefore, we suspect an adopted integration time was not enough to reach the level by which we can detect the broad wing.

Further detailed analyses and interpretation are described in a full paper (Otsuka, M., Tamura, S., Yadoumaru, Y., and Tajitsu, A. 2002, to be submitted to PASP.).

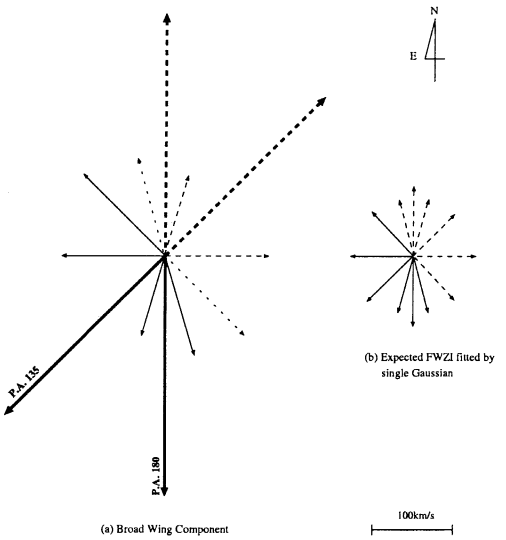

Figure 2. The relation between observed V_{FWZI} and P.A. at [O III]λ5007 ((a), left). The relation between the expected V_{FWZI} from observed V_{FWHM} and P.A. at [O III]λ5007 ((b), right). The solid arrows indicate gas flow toward us, the broken arrows leaving us. Left(a) implies H4-1 has bipolar flow between P.A. 135° and 180°. On the other hand, right(b) implies the main part of H4-1 is isotropically expanding.

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