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

Extinction Maps and Dust Distribution of Planetary Nebulae

Ting-Hui Lee, Sun Kwok

Department of Physics and Astronomy, University of Calgary, Calgary, Canada T2N 1N4

Jeremy Lim

Institute of Astronomy and Astrophysics, Academia Sinica, P.O. Box 23-141, Taipei, Taiwan 106

Abstract. We present an indirect method to probe the dust distribution in PNe. Using the free-free continuum flux density and Hβ recombination line flux relationship and the Case B Hα/Hβ line ratio, we determined the expected Hα flux from the radio continuum maps. The dust optical depth distribution of each planetary nebula was then derived from the expected to observed Hα flux ratio. With *HST WFPC2* and *VLA* A-array observations, dust optical depth maps with resolution as high as $\sim 0.1''$ can be obtained.

1. Introduction

Although the dust component in PNe has been extensively studied by infrared spectroscopy, very little is known about the dust distribution due to the limited imaging capabilities in the mid-infrared. Here we use an alternate method to derive the dust distribution by comparing the hydrogen recombination line map of PNe with its corresponding radio free-free continuum map. The recombination line (e.g. Hα) and free-free continuum emissions are independent tracers of the distribution of the ionized gas because both of their fluxes are proportional to $n_e^2 V$ under optically thin conditions. Since only the Hα emission is affected by the dust, extinction maps can be derived from the ratio of the Hα and radio maps. Such extinction maps can be interpreted as maps of the dust distribution if the dust is associated with the ionized region. With high-resolution Hα images observed by *HST WFPC2* and radio continuum images observed by radio interferometers such as the *VLA*, we are able to obtain point-to-point spatial extinction distribution in PNe with high angular resolution.

2. Data Acquistion and Optical Depth Calculation

The *HST WFPC2* Hα images were obtained under the GO program 8307 (see Kwok, Su, and Sahai, these proceedings) and the radio continuum maps were obtained with *VLA* at λ2cm in A-configuration in 1998. The Hα images were aligned by eye with the radio continuum maps. Each Hα image was convolved

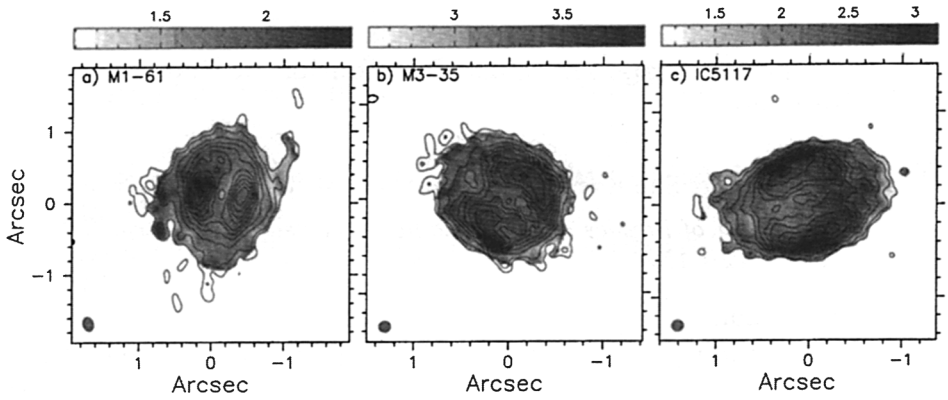

Figure 1. Dust optical depth maps at 656.3nm (Hα) for 3 PNe. The contours are 2cm radio continuum emission with first level at 3σ.

with an extended gaussian to generate an image matched in beam size with its corresponding radio image. The radio continuum image was then divided by the resultant Hα image to determine the optical depth for each pixel.

Using the free-free continuum flux density and Hβ recombination line flux relationship (Pottasch 1984) and the Case B line ratio of Hα/Hβ=2.85, we have:

$$F_{exp}(H\alpha) = 6.85 \times 10^{-10}(\nu/GHz)^{0.1}(S_\nu/Jy) \ \text{ erg cm}^{-2}\text{s}^{-1}$$

assuming $T_e = 10^4 K$, an He to H number ratio of 0.11 and the fraction of He in singly ionized form of 0.5. The dust optical depth at each pixel was then calculated by taking the natural logarithm of the ratio of the expected and observed Hα flux.

3. Results and Discussion

Figure 1 shows our result images for 3 PNe. In general, the optical depth is higher when the radio emission (and Hα emission) is stronger, suggesting that the ionized gas and dust distributions are similar in the ionized region. The individual objects also show slightly different dust distributions. For instance, M1-61 only shows one strong extinction peak in the region of the eastern radio peak whereas IC5117 has two extinction peaks falling slightly outside of the radio peaks. With infrared-optimized telescopes such as Gemini, sub-arcsecond mid-infrared imaging is now possible (see Volk & Kwok, these proceedings). We hope to compare our extinction maps with results of direct imaging to test the validity of this method.

References

Pottasch, S. R. 1984 in Planetary Nebulae: A Study of Late Stages of Stellar Evolution (Dordrecht: D. Reidel Publishing Company)

https://doi.org/10.1017/S0074180900208917 Published online by Cambridge University Press