The Optical-Infrared Study of Geometric Model of Young Planetary Nebula IRAS 21282+5050

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ABSTRACT

We present high angular resolution **Hubble Space Telescope** (HST) optical and near-infrared imaging of the compact planetary nebula (PN) IRAS 21282+5050 (hereafter IRAS 21282). Optical images of this object reveal several complex morphological structures including three pairs of bipolar lobes and an elliptical shell lying close to the plane of the sky. From near-infrared observations, we found a dust torus oriented nearly perpendicular to the major axis of elliptical shell. The results suggest that IRAS 21282 is a multipolar PN, and these structures developed early during the post-AGB evolution. From a three-dimensional (3D) model, we derived the physical dimensions of these apparent structures. Assuming these lobes are shaped by wind interactions, these geometric structures could be the result of multiple phases of fast winds with temporal and directional variations. When the 3D model is viewed from different orientations, IRAS 21282 shows similar apparent structures as other multipolar PNs. We suggest that PNs with very different apparent structures may in fact have similar intrinsic structures.

INTRODUCTION

- Multipolar nebulae are defined as objects that possess at least two pairs of axial symmetric structures. Examples of multipolar PN discovered by deep and high-dynamic-range optical imaging include He 2-47, M 1-37 (Sahai, R. 2000, ApJ, 537, 43), and NGC 6644 (Hsia et al., 2010, ApJ, 725, 173). Under earlier classification schemes (round, elliptical, bipolar, and irregular), these objects were classified as “Elliptical” or “Bipolar”.
- Recent classification schemes find 12% of 150 post asymptotic giant branch stars (Post AGBs; Manchado et al., 2011, ASPC, 445, 161) and 20% of 119 young PNs (Sahai et al., 2011, AJ, 141, 134) to be multipolar. A study of multipolar or quadrupolar PNs (Hsia et al., 2014, APJ, 787, 25) suggests that these multipolar structures could be the result of interactions between previously ejected AGB winds and later-developed multiple-phase fast winds separated by time or directional variations. What is the nature and formation of multipolar lobes? The origin and physical mechanisms of these structures are still a mystery.

OBSERVATION

- We have analyzed the high-resolution optical images on IRAS 21282 retrieved from the Space Telescope Science Archive. The optical and near-infrared images were obtained under programs 9463, 8345 (PI: R. Sahai), and 7365 (PI: W. B. Latter) using the Advanced Camera for Surveys (**ACS**), Wide Field Planetary Camera 2 (**WFPC 2**) and Near-Infrared Camera Multiobject Spectrometer (**NICMOS**) with four filters (F606W, F656N (Hα), F160W, and F205W) on **HST**. The actual observations were made with different exposures to allow for the imaging of both bright central region and faint outer parts. The processed F606W ,F656N (Hα), F160W, and F205W images are shown in Figures 1 and 2.
- Optical mid-resolution spectra of the nebula were performed by the ***2.16 m telescope*** of NAOC. The measurements were observed using by a Optomechanics Research Inc. (**OMR**) spectrograph with spectral dispersions of 1 A pixel $^{-1}$. A slit width of 3.0” was set through bright core of the source to allow greater throughput for weak emissions of faint nebulosity observed in the run. The reduced spectrum of this PN is shown in Figure 3.

DATA REDUCTION

- **HST images:** The data were processed through the standard HST pipeline calibration. **Bias subtraction** and **flat-field correction** were performed. Data were taken in two-step dithered positions to enhance **spatial sampling** and **cosmic rays removal** using the **IRAF/STSDAS** package.
- **Optical Spectrum**: The spectral data were processed with standard package , which includes **bias and flat-field correction**, **cosmic-ray removal**, **wavelength calibration** and **flux density calibration** based on three spectral standard stars.

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RESULTS

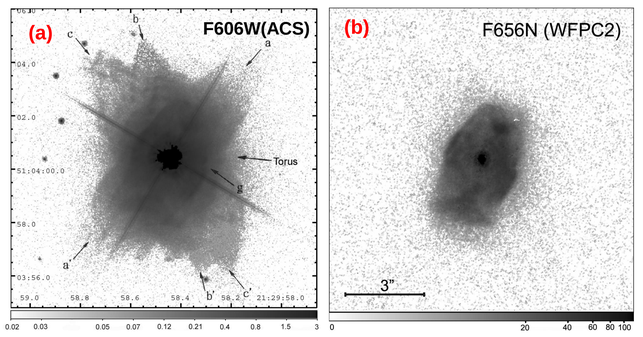

Fig 1. HST F606W and Hα images of IRAS 21282. (a). Three pairs of lobes are marked as a−a’, b−b’, and c−c’ and central cylinder shell is labeled as “g”, which may be another pair of bipolar lobes orientated almost along the sky plane. (b). The appearance of this nebula seen at Hα corresponds to the cylinder structure (marked as g) shown in F606W image.

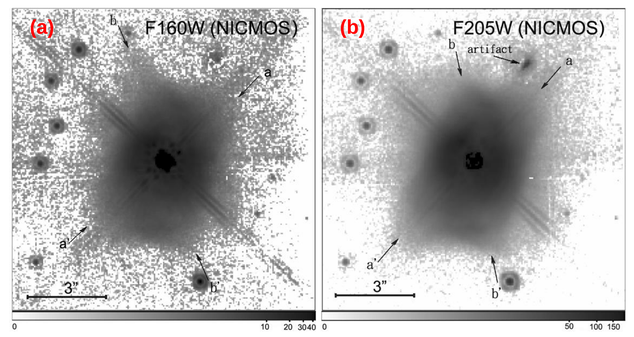

Fig 2. HST NICMOS images of IRAS 21282 reveal an elliptical nebula in the F160W (a) and F205W (b) images. Two pairs of bipolar lobes a−a’ and b−b’ can be seen in both images, but the lobe c−c’ is not found in any of these images.

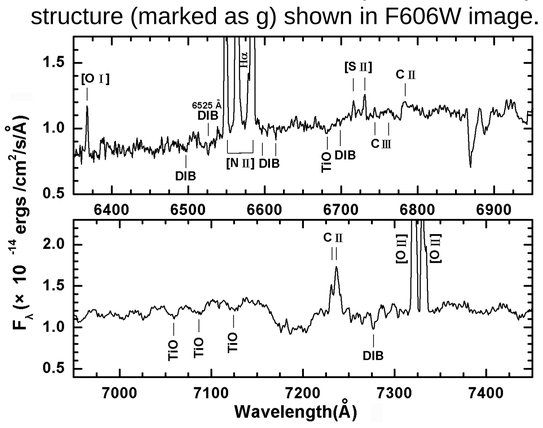

Fig 3. NAOC OMR spectrum of IRAS 21282 (not corrected for extinction) in the wavelength range 6300 A° to 7500 A°. The emission lines, diffuse interstellar bands (DIBs), and absorption lines are marked.

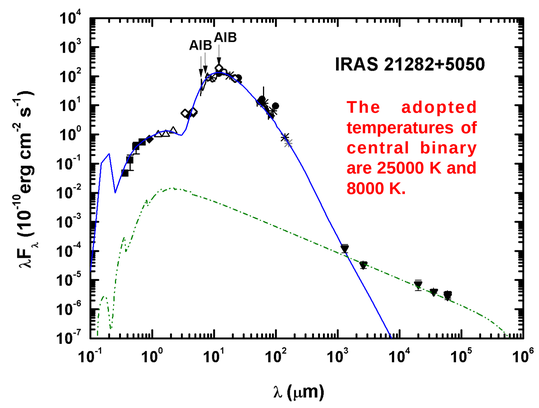

Fig 4. Spectral energy distribution (SED) of IRAS 21282. The green curve represents the nebular gas b-f and f-f emissions. The blue curve is a dust continuum radiation transfer model fit of the emergent flux. The excess in the ultraviolet part of the model curve is the reddened photosphere of the hot central star. The aromatic infrared bands (AIBs) are marked.

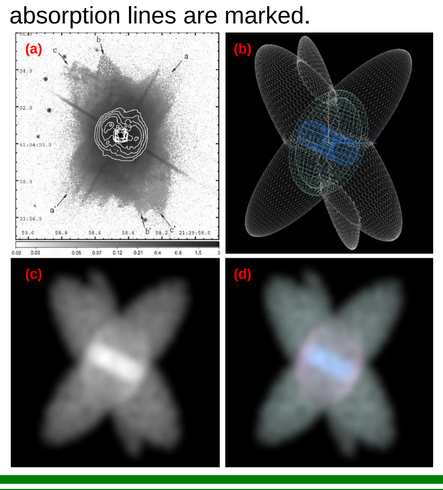

Fig 5. Comparison of optical-infrared observations and corresponding 3D model images of IRAS 21282. (a). The gray frame shows the HST F606W image with the NICMOS F205W image overlaid as logarithmic contours (white line). The central complex contours indicate the location of central star. (b). SHAPE 3D mesh model. The bipolar lobes a−a’, b−b’, and c−c’ are displayed in white and the fourth pair of lobes observed in the HST Hα image (marked as g in Fig. 1a) is shown in light blue. The infrared torus observed in HST NICMOS image is shown in dark blue. (c). The rendered image in gray scale. (d). Rendered image with the outer three lobes (a−a’, b−b’, and c−c’), inner bipolar lobe, and the equatorial torus shown in white, red, and blue, respectively.

CONCUSSION

- From the optical images, we can find at least three pairs of distinct lobes, a dust torus, and a central cylindrical shell lying almost close to the plane of the sky. The orientation of the infrared dust torus is approximately perpendicular to the elliptical shell. Therefore, we suggest that this cylinder-shaped structure could be the fourth pair of bipolar lobe and its symmetry axis is perpendicular to the dust torus.
- From the optical spectrum of the central star, we find both DIB and TiO absorption bands, the latter suggests the presence of a cool companion. In addition, the results gained from our SED fitting also suggest that there may be a binary nucleus in IRAS 21282+5050.