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HST/NICMOS Imaging of the Planetary Nebula Hubble 12

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Abstract. Images of Hubble 12 were obtained with the HST/NICMOS instrument in the F110W, F164N, and F166N filters of NIC1, and the F160W, F187N, F190N, F212N, F215N filters of NIC2. The images show the structure of the inner "torus" and lobes much clearer than previous ground-based images. In particular, the [Fe II] lobes are clearly resolved and shown to be distinct from the H_2 emission structures. Apparent changes in the inner ionized and neutral bipolar shell implies periodic mass loss or changes in stellar wind shape or direction. The H_2 in the "eye" is radiatively excited and shows a complex morphology that suggests that several mass ejection events are responsible for producing this structure. The position angle of the H_2 and [Fe II] lobes differ, indicating a possible precession of the ejection axis.

1. Observations and Reductions

Images of Hubble 12 (Hb 12) were obtained with the HST/NICMOS instrument on 13 Nov 1997. The images in the F110W, F164N, and F166N were taken with NIC1, and the F160W, F187N, F190N, F212N, F215N images were obtained with NIC2. The MULTIACCUM mode and spiral dither patterns were used.

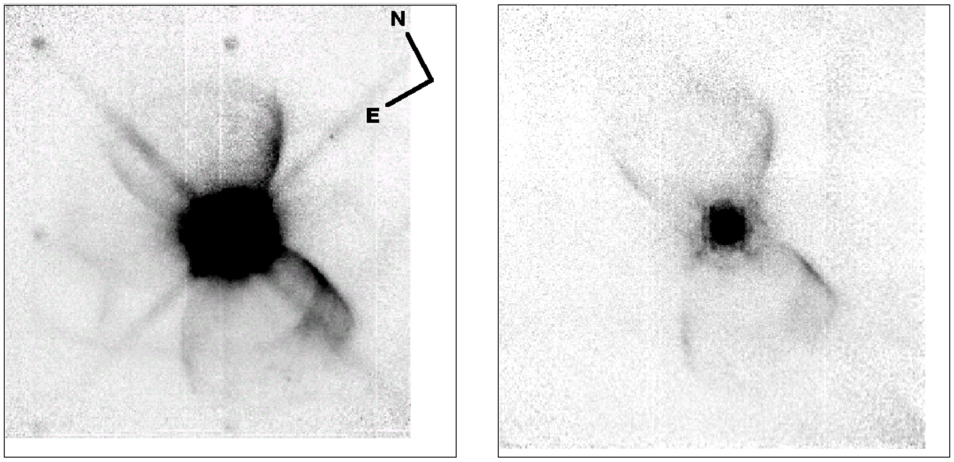

Figure 1. Hubble 12, in the F110W (left) and F164N filters (right). The field size for each is $\sim$ 13 arcsec square. The orientation of the images shown in the F110W image is the same for all images presented here. The F110W filter includes contributions from the bright Paschen β line and line emission from H_2, [Fe II], and He I lines within the bandpass. The F164N filter samples the [Fe II] line at 1.64 μm.

The NICMOS CALNICA and CALNICB pipelines were used to reduce the data. In general a few dither sets were obtained in each filter; these were aligned and averaged to produce the final images. The bright central star makes the region near the core difficult to see clearly, and adds a number of image artifacts. The lines that run approximately from corner to corner are part of the diffraction pattern of the instrument. The horizontal and vertical lines that run through the star are array artifacts caused when the central star saturates in the long integrations. In future reductions we will attempt to subtract the point source in the core to better study the region around it.

2. Results and Discussion

Hb 12 has been notable primarily because it represents one of the clearest cases known of UV excited near-IR fluorescent H_2 emission (Dinerstein et al. 1988; Ramsay et al. 1993, Hora & Latter 1996, Luhman & Rieke 1996). Dinerstein et al. had mapped the inner structure and found it to be elliptical surrounding the central star; the deep H_2 images in Hora & Latter (1996) showed the faint bipolar lobes extending N-S, and the torus or "eye"-shaped strucure at the base of the lobes around the central star. The H_2 line ratios observed in the torus were in excellent agreement with predictions by theoretical H_2 fluorescence calculations (see also Luhman & Rieke 1996). Hora & Latter also detected [Fe II] line emission at 1.64 μm in a position along the edge of the shell, but not at the H_2 line peak emission location to the E of the central star.

Previous HST-WPC2 imaging by Sahai & Trauger (1998) in Hα showed the inner structure to have an "hourglass" shape, and a small bipolar structure

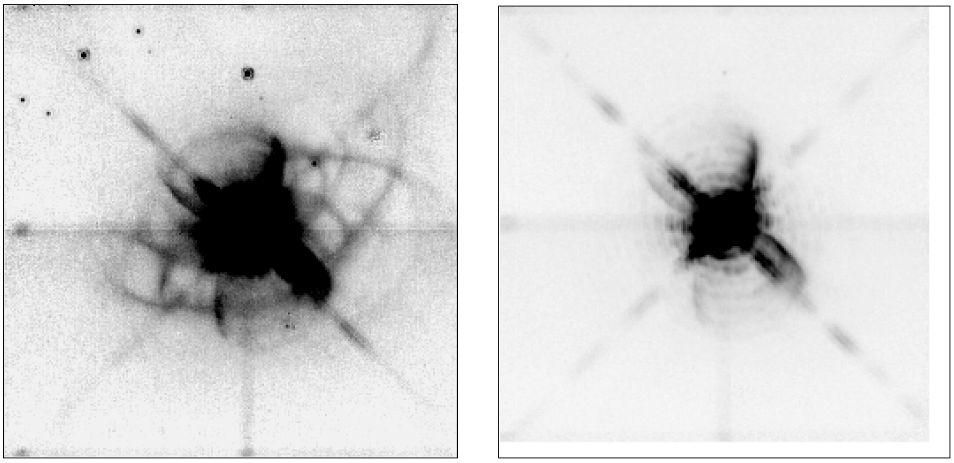

Figure 2. Hubble 12, in the F160W (left) and F187N filters (right). The field size shown in each image is $\sim$ 19 arcsec square. The bandpass of the F160W filter includes lines from the Brackett series of H I and line emission from H_2, [Fe II], and He I lines as well. The narrowband F187N filter samples the Paschen α (H I) line.

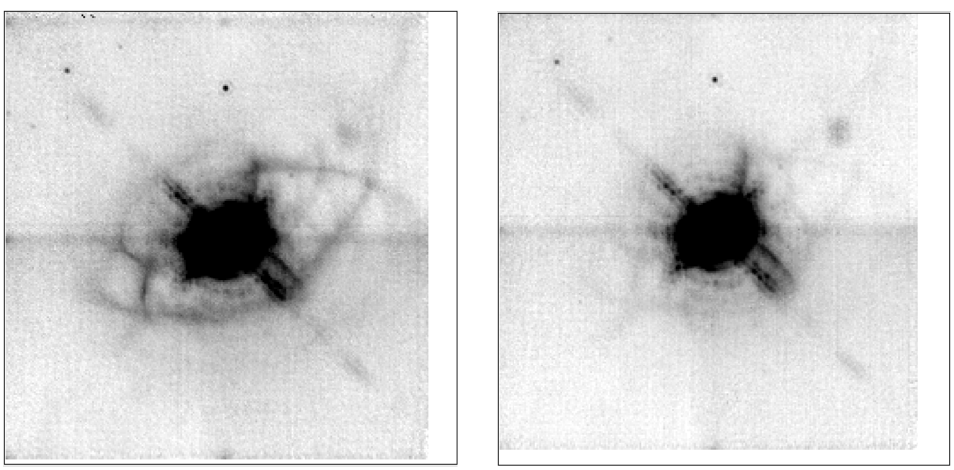

Figure 3. Hubble 12, in the F212W (left) and F215N filters (right). The field size shown in each image is approximately 19 arcsec square. The F212N filter samples the H_2 line at 2.12 μm, the F215N filter measures the nearby continuum (as well as a small contribution from the Brackett γ feature at 2.16 μm.

in the core region, with lobes roughly E-W within a few tenths of an arcsec from the star. Welch et al. (1999a,b) obtained ground-based images in the [Fe II] line and nearby continuum and found that the line emission was also distributed along the inner hourglass nebula. The HST images presented here show the symmetry axes of the hourglass and the H_2 eye and bipolar nebula differ in their alignment by $\sim 5°$. A comparison of these images with the inner bipolar structure found by Sahai & Trauger shows that its alignment differs by $\sim 20°$ from the hourglass and outer H_2 lobes. The different orientation of the structures suggests that the central source may be precessing between discrete outflow events. Also, the structures seen in the H_2 image indicate other possible outflow events and remnants of other bipolar hourglass nebulae. Hb 12 may therefore be another example of a PN with multiple nested bipolar bubbles.

The inner hourglass is bright in the Paschen α and [Fe II] lines, but the outline of the "eye" appears only in the H_2 and the wide bandpass filters (in continuum plus H_2 line emission). This implies that the regions where only H_2 is detected are somehow shielded from what has ionized the inner hourglass. There is no evidence for [Fe II] emission from other regions in the nebula, and the density of the inner hourglass does not seem sufficient to provide effective shielding of the other regions from radiation from the central star, which might suggest shock excitation in an interacting wind. This hypothesis must be confirmed with investigation of the velocity structure in the nebula. The strong influence of FUV photons elsewhere in this object argues that the [Fe II] emission is excited by FUV photons in the PDR. We will be investigating this possibility through detailed chemical modeling.

We obtained high-resolution IR spectra of Hb 12 in the H_2 and [Fe II] lines using CSHELL at the IRTF (Kelly, Hora, & Latter 1999) which indicates that the N lobe is inclined towards us. We also have additional medium-resolution spectra of the faint extended H_2 lobes to determine the excitation properties of the outer nebula. We are in the process of analyzing these data along with the optical and IR imagery to understand the structure of this interesting and complex nebula.

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