JWST reveals dust and molecules in the planetary nebula, NGC 6302

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Objectives

- What form of dust grains from evolved stars are produced and processed before they are integrated into the ISM?
- How to form both oxygen-rich dust (crystalline silicates) and carbonaceous dust (PAHs) in a single object?

Target: Planetary Nebula, NGC 6302

- NGC 6302 is a bipolar nebula, with a dusty torus at the waist of the bipolar structure (Fig. 1).
- One of the most luminous PNe: total luminosity of ~14,000 solar luminosities (Wright et al. 2011).
- The central star is one of the hottest white dwarfs known: effective temperature of ~220,000 K (Wright et al. 2011)
- The distance is estimated to be 1.03+-0.27 kpc (Gomez-Gordillo et al. 2020).

JWST Observations

MIRI spectral mapping of 5 × 5 tiles was used to cover the heart of NGC 6302 (Fig. 1).

The mapped area: ~18.5 arcsec x 15.5 arcsec @5 μm to 22.9 arcsec x 19.3 arcsec @20 μm

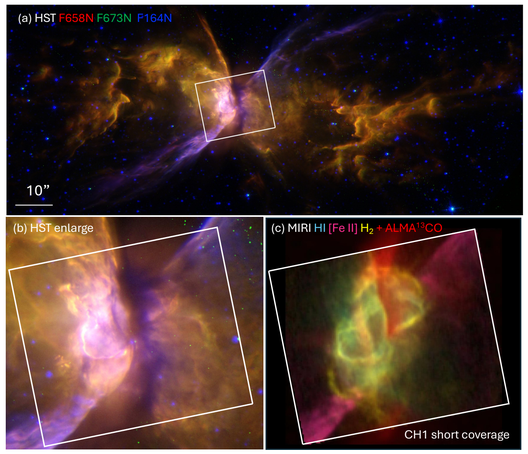
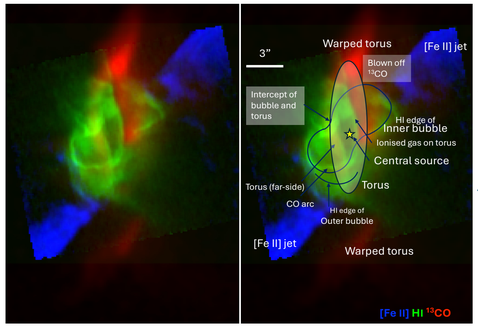


Fig. 1: The JWST/MIRI mapped area (white box)

Results are published in:

- Matsuura et al. (2025) MNRAS 542, 1287
- Bhatt et al. (2025) 2025arXiv250914556B



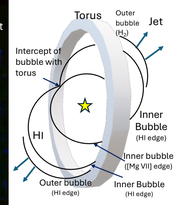


Fig. 2: Morphology of NGC 6302’s heart

Results 1: Large dust grains in the torus

The torus (Fig. 2) of NGC 6302 exhibits self-absorption by dust, even at 20 μm.

The extinction curve toward the torus suggests the presence of large dust grains. Fig. 3 compares the extinction in the torus with the ISM extinction curve from Weingartner & Draine (WD; 2001) and with the extinction curve corresponding to a grain radius of 2 μm. The overall extinction curve is well fitted by the model with 2 μm grains.

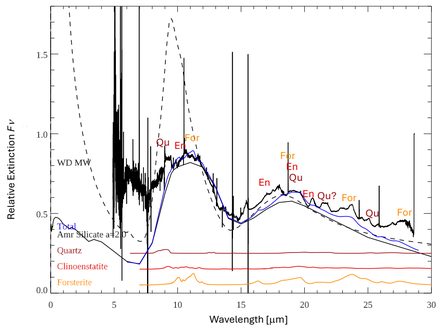


Fig. 3: The derived relative extinction values as a function of wavelength at the torus

Results 2: Crystalline silicates in the torus and outflow

Spatially resolved JWST spectral mapping shows crystalline silicates are present in both the torus and the outflow.

Fig. 3 shows the extinction curve towards the torus, identifying quartz (Qu), Forsterite (For), Enstatite (En).

The extinction map (Fig. 4) shows that regions of high extinction, therefore high dust mass, are located in the torus.

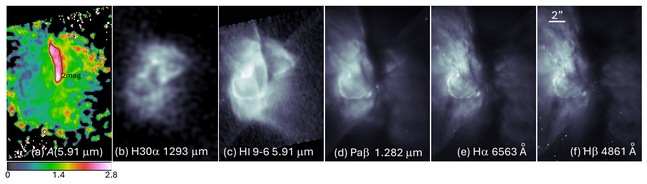


Fig. 4: Extinction map and H^+ map

Results 3: PAHs at bubbles and edge of the torus & stratification of H^+, H_2 and PAHs

In contrast to crystalline silicates, PAH emission is detected at the bubbles, which are at the base of the bipolar outflow, and along the edge of the torus.

The stratification of this PN proceeds outward as H^+, H_2, and then PAHs at the inner bubble (Fig. 5). This sequence differs from that typically observed in PDRs, where the order is H^+, PAHs, and H_2. The cause of this unusual stratification in NGC 6302 may be related to a delayed formation of PAHs following H_2 formation, or to a higher electron density that enhances PAH excitation.

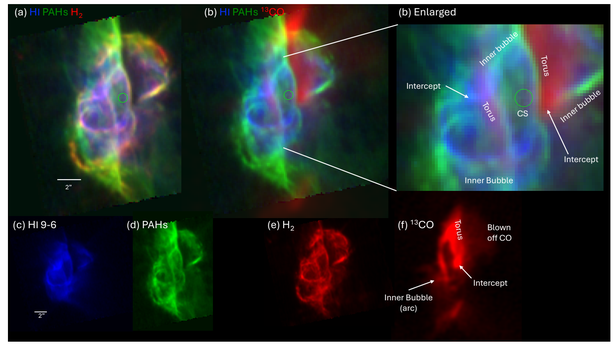


Fig 5. Stratification of H^+, PAHs and H_2, with ^{13}CO indicating the torus.

Results 4: First detection of CH_3^+ in a PN or an evolved star

CH_3^+ is considered a key molecule in the formation pathway of PAHs, and its first detection was reported in the Orion Bar.

We now report the detection of CH_3^+ in NGC 6302: the first such detection in a PN.

The molecule is found inside the PAHs emitting region, specifically in the bubble, the torus, and at the interface between the bubble and the torus.

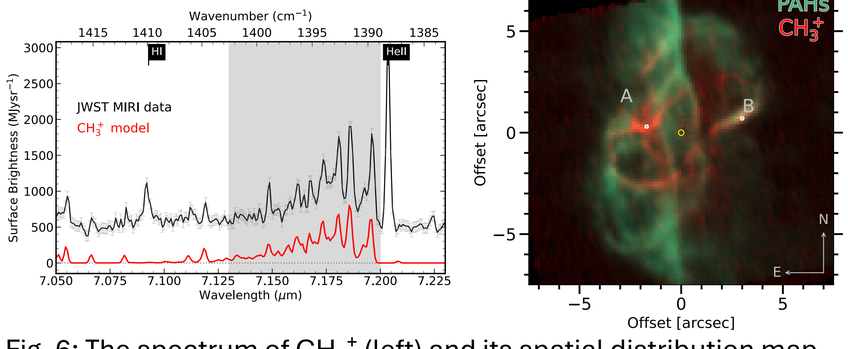


Fig. 6: The spectrum of CH_3^+ (left) and its spatial distribution map (right) in NGC 6302. CH_3^+ is found in the bubble region, slightly inward of the PAH emission.