# A Multi-wavelength-based Method to de-project Gas and Dust Distributions of several Planetary Nebulae

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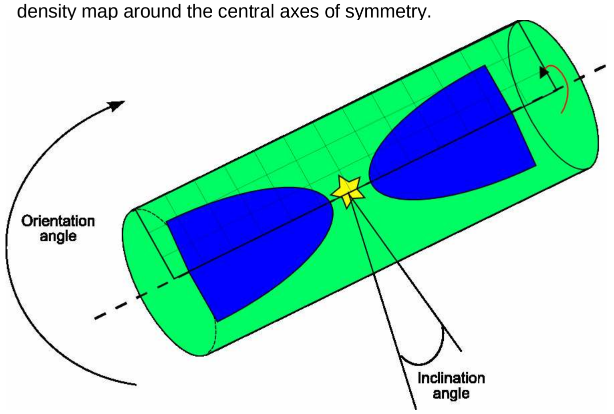
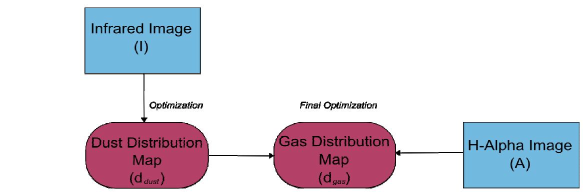
## Abstract

This work addresses the problem of reconstructing the 3D structure of planetary nebulae from 2D observations. Assuming axial symmetry, our method jointly reconstructs the distribution of dust and ionized gas in the nebulae from two observations, one at visible and one at specific radio or infrared wavelengths. In an iterative inverse rendering framework we optimize for the emission and absorption densities which are correlated to the gas and dust distribution. Our model accounts for the absorption and scattering due to the dust present in the nebula. At every step, we obtain a 3D volume of the nebula by rotating a 2D density map around the central axes of symmetry.

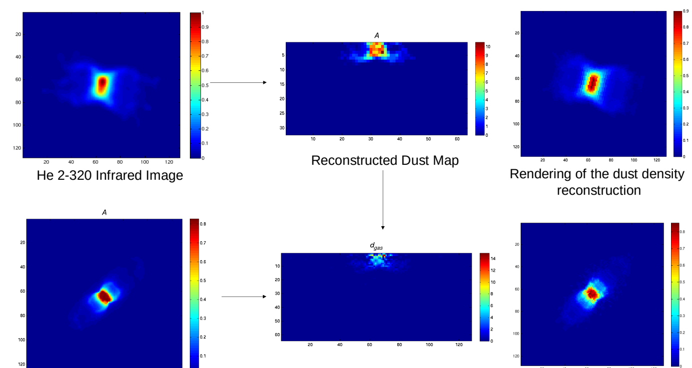



The axis symmetric model of a planetary nebula. The orientation angle determines the rotation of the nebulas axis of symmetry in the plane perpendicular to the viewing direction. The inclination angle measures the tilt of the axis in relation to the viewing direction.

## Results for Planetary Nebula He 2-320




Flowchart of the reconstruction process when using an infrared / H-Alpha image pair as input. Starting from the infrared image, the nebula's dust distribution is recovered in a first step. In a second step, we recover the gas distribution, while constantly comparing the current rendering with the H-Alpha input image.



He 2-320 Infrared Image

Reconstructed Dust Map

Rendering of the dust density reconstruction

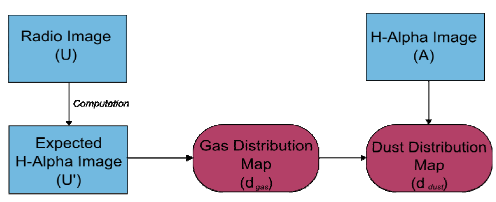
He 2-320 H-Alpha Image

Reconstructed Gas Map

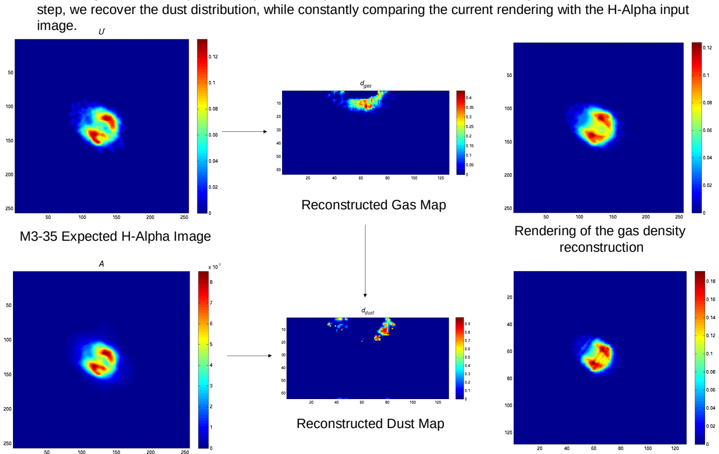
Rendering of the gas and dust density reconstruction

Note: Infrared datasets kindly provided by Kevin Volk, Gemini Observatory

## Results for Planetary Nebula M3-35




Flowchart of the reconstruction process when using an radio / H-Alpha image pair as input. Starting from the radio image, we first compute the expected H-Alpha flux and recover the nebula's gas distribution. In a second step, we recover the dust distribution, while constantly comparing the current rendering with the H-Alpha input image.



M3-35 Expected H-Alpha Image

Reconstructed Gas Map

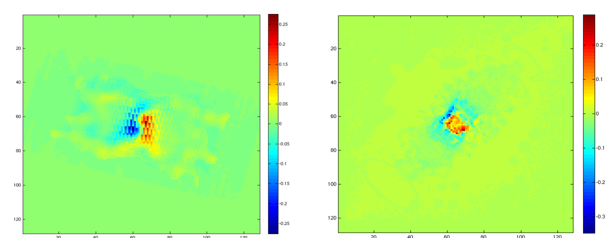
Rendering of the gas density reconstruction

M3-35 H-Alpha Image

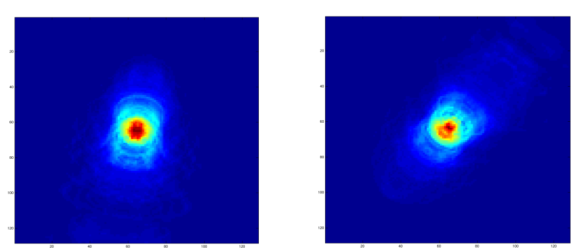
Reconstructed Dust Map

Rendering of the gas and dust density reconstruction

## Analysis of the results for Planetary Nebula He 2-320



Difference between the input and the reconstructed images for Nebula He 2-320. Left: for the dust density reconstruction. Right: for the gas density reconstruction.



Renderings of the nebula with different inclination and orientation angles. Here we take absorption and scattering due to dust into account.

## References

LEE T.-H., KWOK S.: *Dust Extinction in Compact Planetary Nebulae*. The Astrophysical Journal 632 (Oct. 2005), 340–354.
MAGNOR M., KINDLMANN G., HANSEN C., DURIC N.: *Constrained inverse volume rendering for planetary nebulae*. In Proc. IEEE Visualization 2004, Austin, USA (Oct. 2004), pp. 83–90.

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