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On the 3D structures of the planetary nebula Abell 43

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Abstract

The planetary nebula Abell 43 (PN G036.0+17.6) is called "Galactic Soccerball" because images remind of the seams of a leather ball. Geometrically, this is a so-called "truncated icosahedron". We present an attempt to construct its 3D density structure based on narrow-band imaging and high-resolution spectroscopy. Its central star is a so-called born-again star that experienced a late He-shell flash and is, thus, hydrogen-deficient.

Introduction

Narrow-band images of PNe are 2D projections. The construction of reliable 3D structures that represent the real PNe is difficult in most cases. Since state-of-the-art 3D photoionization models (e.g. MOCASSIN, Ercolano et al. 2003) of PNe need precise information about the PN structure, we combine narrow-band imaging and high-resolution spectroscopy in order to construct the structure of A 43.

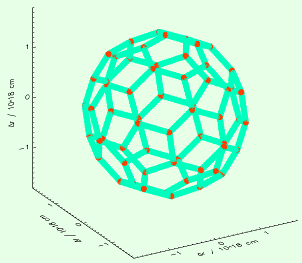

Fig. 2. Synthetic density distribution. The density in the region of the vertices is higher (red) than the density in the region of the edges (green).

Construction of the 3D PN model

Procedure to construct the 3D density structure:

- Construction of a truncated icosahedron (arbitrary circumradius and orientation).
- Creation of a 3D model-grid cube and insertion of the truncated icosahedron inside.
- Assumption of a density distribution around the edges of the truncated icosahedron, in order to construct the seams.
- Vertices are loaded three times, edges are loaded twice.
- Minimal constant density inside the shell between the edges.
- Inside the bubble we compute the density based on the mass-loss rate of the central star, the velocity of the stellar wind and the elemental abundances of the central star.

Procedure to model the velocity distribution:

- Inside the bubble every grid point has the velocity of the fast wind of the central star.
- Inside the shell every grid point has the expansion velocity of the nebula.
- Outside the bubble every grid point has the velocity of the former slow AGB wind.

The data is computed by a FORTRAN program and visualized via IDL (Interactive Data Language).

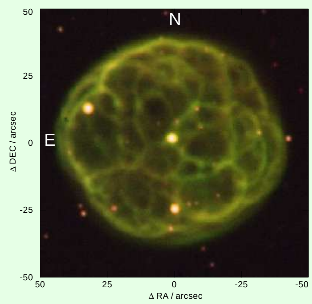

Fig. 1. Image of A43, H α, ESO / DFOSC, exposure time: 1882 sec (red), [O III], ESO / DFOSC, exposure time: 1882 sec (green), [N II], ESO / EMMI, exposure time: 1200 sec (blue), FOV = 100" $\times$ 100"

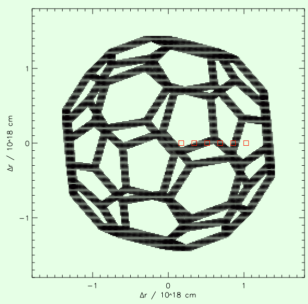

Fig. 3. Projection of the 3D model. The red squares show locations of the apertures (2" $\times$ 2") of our CES observations.

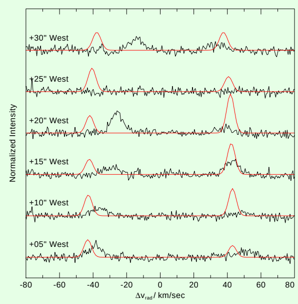

Fig. 5. Synthetic spectra (red) and CES observations (black, cf. Fig. 3)

Images

We have narrow-band images of [O III] λ 5007 Å (Fig. 1) and H α, obtained with the Danish 1.54 m telescope and DFOSC as well as narrow-band images of He II λ 4686 Å, [N II] λ 4994 Å, [S II] λ 6717 Å and [S III] λ 9532 Å, obtained with the 3.6 m NTT and EMMI. Since we know the spectroscopic distance of A43 (2800 pc, Napiwotzki 2001), the angular size of the nebula is equal to a linear diameter of 1 pc.

Spectra

We have high-resolution spectra, centered on [O III] λ 5007 Å, obtained at ESO's 3.6 m telescope with CES (resolving power R = 220 000 – 235 000, Fig. 5). Additionally, we have high resolution spectra of H α, H β, He II λ 4686 Å, [N II] λ 4994 Å and [O III] λ 5007 Å, obtained with the 3.6 m NTT and EMMI (R = 35 000 – 88 600, Fig. 4)

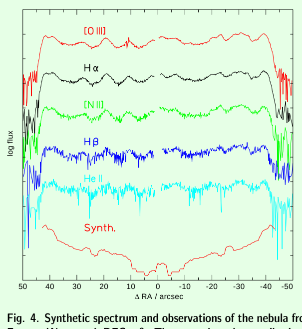

Fig. 4. Synthetic spectrum and observations of the nebula from East to West at Δ DEC = 0. The central star's contribution is omitted.

Test

We test the synthetic spectrum of the nebula (Fig. 4) from East to West at Δ DEC = 0 (Fig. 1). In addition, we test the synthetic spectra of a Doppler-broadened line (Fig. 5) by comparing with the observations. Size and positions of the aperture (Fig. 3) are like those of the CES spectra. A few synthetic lines look similar in relation to height, width and position. Nevertheless, the synthetic spectrum is computed without any photoionization model.
An animation of the 3D model will be shown at
http://astro.uni-tuebingen.de/~friederich/A43.html

References

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Napiwotzki, R. 2001, A & A, 367, 973

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