On the Velocity Field and the 3D Structure of the Galactic Soccer Ball Abell 43

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Planetary nebulae (PNe) and their central stars (CSs) are ideal tools to test evolutionary theory: photospheric properties of their exciting stars give stringent constraints for theoretical predictions of stellar evolution. The nebular abundances display the star's photosphere at the time of the nebula's ejection which allows to look back into the history of stellar evolution – but, more importantly, provide even a possibility to investigate on the chemical evolution of our Galaxy because most of the nuclear processed material goes back into the interstellar medium via PNe.
The recent developments in observation techniques and a new three-dimensional photoionization code MOCASSIN (Ercolano et al. 2003) enable us to analyze PNe properties precisely by the construction of consistent models of PNe and CSs. In addition to PNe imaging and spectroscopy, detailed information about the velocity field within the PNe is a pre-requisite to employ de-projection techniques in modeling the physical structure of the PNe.

Introduction

In July 1998, we performed imaging and spectroscopy of the PN A 43 and its exciting star. The Hα and [O III] λ 5007 Å images (Fig. 1) show prominent deviations from spherical symmetry which deserve further investigation.

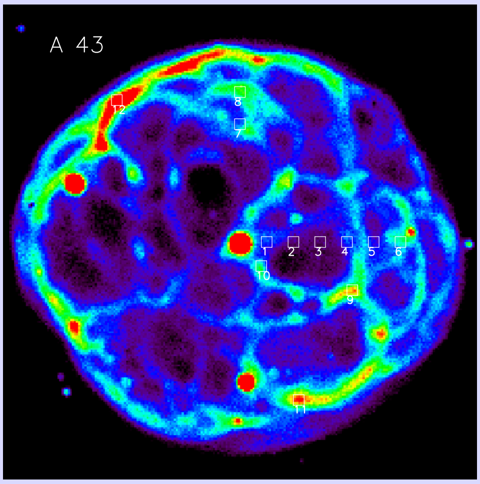

Fig. 1. [O III] λ 5007 Å image (FOV 90"×90") of the PN A 43 (exposure time 40 min) obtained with the Danish 1.54m telescope and DFOSC (La Silla, Chile). The white squares indicate the selected CES aperture (2"×2") positions.

Subjective image interpretations of different observers range from "radial filaments" over "soap bubbles" to "penta- and hexagons like a (soccer) football's seams". However, instabilities in the nebula's surface are prominent. The most likely explanation might be that the old, slow AGB wind matter is swept up to a thin shell by the fast central star wind. While the invisible inner, high-pressure bubble is expanding due to the released energy of the stellar wind, instabilities in the dense, moving shell may appear (Vishniac 1983), effective enough to produce filament-like surface structures of the shell matter. As these filaments form, the intrafilament region can expand out ahead of the filaments, giving rise to a somewhat "lumpy" outer edge on the shell. This is quite obvious on the image of A 43. Similar PNe are known, e.g. NGC 6894, NGC 7048, or NGC 7139 (Balick 1987) but the edges of their shells appear smooth and round in projection. Thus, A 43 is an excellent test case even for hydrodynamical models!

On the 3D Stucture of A 43

Although it appears likely that A 43 is an "almost" ideal PN, i.e. with a spherical shell — besides some density variation within the shell, we tried to employ a deprojection technique (Bremer 1995) in order to improve the interpretation of the nebula morphology and to determine the 3D density structure reliably. However, it became clear that another constraint, a "third dimension" in addition to the 2D narrow-band image is necessary.
In order to make progress, we performed high-resolution spectroscopy (centered on [O III] λ 5007 Å, resolution 2 km/sec) in July 1999 of the PN A 43 at ESO's 3.6m telescope (La Silla). We obtained 12 CES spectra at different positions (Fig. 1, 2) in the nebula.

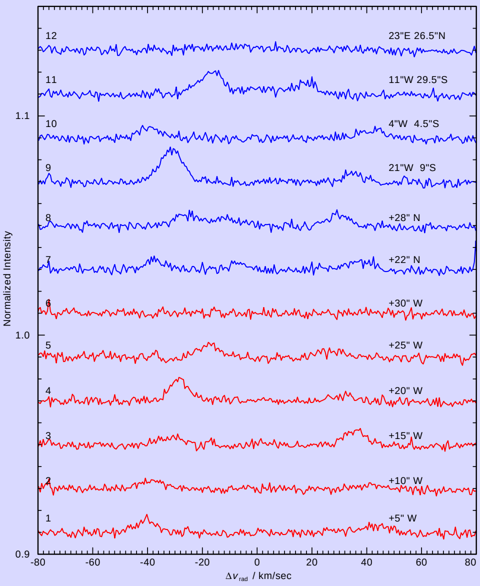

Fig. 2. Velocity measurements from [O III] λ 5007 Å. The system velocity of 79.4 km/sec ($\pm$ 5 km/sec) is subtracted. The aperture numbers on the left side correspond to the positions given in Fig. 1.

From the velocity curves, it is possible to distinguish between front and back of the PN, e.g. see aperture 9 which is located on a high-density part (Fig. 1). The main [O III] λ 5007 Å stems clearly from the front of the PN.

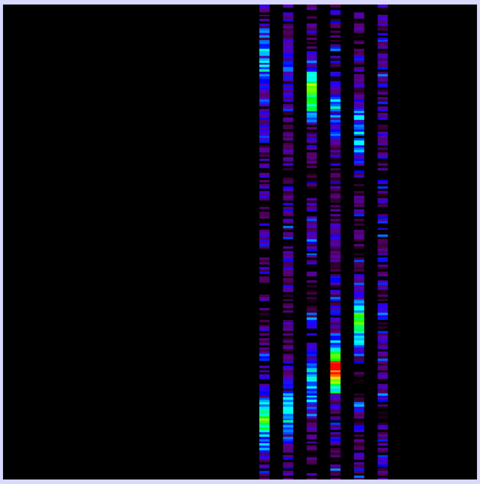

Fig. 3. Intensity of [O III] λ 5007 Å in apertures 1 - 6 (see Fig. 1.). The horizontal axis shows $-50'' < \Delta$ RA $< +50''$. The vertical axis is the differential radial velocity in km/sec ($-55 < \Delta v < +55$).

Results

The CES spectra of A 43 show an expansion velocity of the shell, measured in [O III] λ 5007 Å of up to 60 km/sec (Fig. 2). A 43 has an almost spherical shell with strong density variations (Fig. 1, 3).
The spectra allow to construct a "third dimension" (Fig. 3) to construct a 3D density distribution. However, it turned out that 12 positions in the nebula are not sufficient to provide a reliable database for the de-projection method. Since a reliable 3D density distribution is a crucial input for any 3D photoionisation code, a spatially more complete measurement (about ten times more positions) of the radial velocity is necessary.

References

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