

High resolution spectroscopy of NGC 7009

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The typical expansion velocity of a planetary nebula is about 20 km s^{-1} . Thus the frequently-used low-resolution spectroscopy does not resolve the dynamics of the nebula and the obtained information is scrambled along the line of sight. In this poster we present UVES spectra obtained along the major axis of NGC 7009. The object is resolved both on the sky and along the line of sight. We present analysis of the physical condition of the gas inside the nebula and its relation to the abundance discrepancy factor.

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High resolution spectroscopy of NGC7009

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One of the open problems in PN research is the abundance discrepancy factor, ADF, that is obtained from O II lines and [O III] lines. There are two main ideas that have been put forward to explain this difference: (a) variations of temperature in a chemically homogenous medium (e.g. Peimbert & Peimbert 2006, and references therein) or (b) variations of temperature due to a chemically inhomogeneous medium where there are high density hydrogen poor condensations of low temperature responsible for most of the recombination line intensities (e.g. Lu 2006, and references therein).

One possible way to search for clues to the solution of the problem is the high resolution spectroscopy. It resolves the cinematic of the object and gives additional information on the spatial distribution of the emission of the studied lines. In this poster we present the special and velocity distributions of O II and [O III] lines in planetary nebula NGC7009 and relate them to the density and temperature distribution.

Roughly speaking, NGC7009 is an expanding cylinder. The spectrum obtained with the slit along the major axis resolves the approaching and the receding walls of the nebula and their structures. We have compared position-velocity diagrams of [O III] 4959 to the sum of uncontaminated OII recombination lines (4639 + 4642 + 4649). In addition we determined the density using [Ar IV] 4711/4740 ratio (Fig. 3) and the temperature in the same region using [OIII] 4363/ [OIII] 4950 ratio (Fig. 4).

The data were obtained from the ESO VLT Data Base. They are UVES high dispersion spectra of NGC 7009 at two different positions taken on 08/2002 (Figure 1a and b). The blue spectrum covers from 3250 - 4500, while the red spectra cover 4600 - 6650 Å in two different detectors. The blue slit is 6.5" long and the red slit is 11" long.

Figure 1a. Location of the slits.

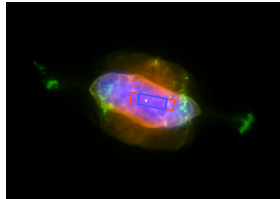


Figure 1b. Location of the slits.

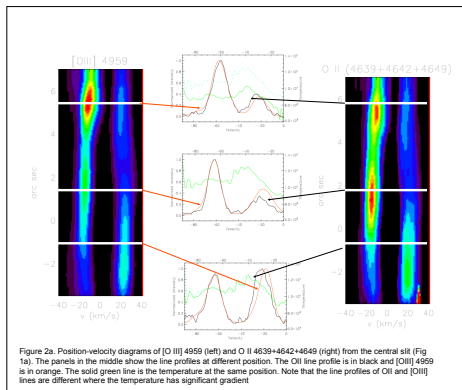
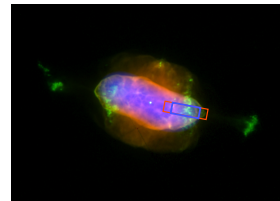


Figure 2a. Position-velocity diagrams of [O III] 4959 (left) and O II 4639+4642+4649 (right) from the central slit (Fig 1a). The panels in the middle show the line profiles at different position. The O II line profile is in black and [OIII] 4959 is in orange. The solid green line is the temperature at the same position. Note that the line profiles of OII and [OIII] lines are different where the temperature has significant gradient

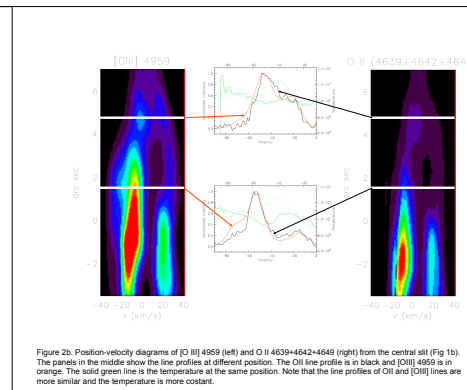


Figure 2b. Position-velocity diagrams of [O III] 4959 (left) and O II 4639+4642+4649 (right) from the central slit (Fig 1b). The panels in the middle show the line profiles at different position. The O II line profile is in black and [OIII] 4959 is in orange. The solid green line is the temperature at the same position. Note that the line profiles of OII and [OIII] lines are more similar and the temperature is more constant.

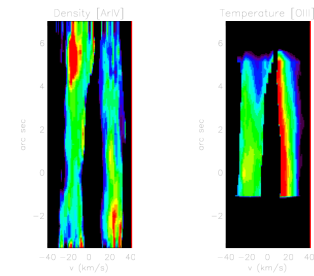


Figure 3a. [Ar IV] density from 4711/4740 in the position-velocity diagram. Values range from 3,000 to 6,000 cm⁻³ (from blue to red).

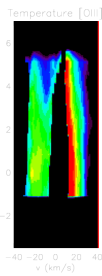


Figure 4a. [O III] temperature derived from 4959 & 4363 in the position-velocity diagram. Values range from 9,000 to 12,000 K (from blue to red).

Our results:

- † The approaching and receding walls of the nebula are different. The approaching section is practically isothermal, while the receding one shows a significant temperature gradient, being hotter in the inner region and colder outside.
- † Both regions of the nebula have practically the same density.
- † The [O III] forbidden and the O II permitted line profiles are similar in the approaching gas although they are significantly different in the receding gas.

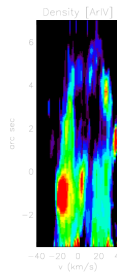


Figure 3b. [Ar IV] density from 4711/4740 in the position-velocity diagram. Values range from 3,000 to 6,000 cm⁻³ (from blue to red).

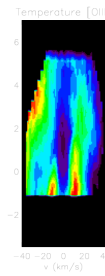


Figure 4b. [O III] temperature derived from 4959 & 4363 in the position-velocity diagram. Values range from 9,000 to 12,000 K (from blue to red).

References:
 Liu, X.-W. 2006, IAU Symp 234, 219
 Peimbert, M. & Peimbert, A. 2006, IAU Symp 234, 227

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