# MULTI-STAGES OPTIMIZED PHOTOIONIZATION MODELLING OF PLANETARY NEBULA LMC SMP-21

B.Ya. Melekh, V.V. Holovatyy, N.V. Havrylova, M.M. Sokil, N.L. Tyshko, A.V. Demchyna

Department of Astrophysics of Ivan Franko National University,
Lviv, Ukraine, *bmelekh@gmail.com*

ABSTRACT. The new approximation expression for the representation of gas density distribution in planetary nebulae envelopes was proposed. The new multi-stages method for the caclulation of the chemical composition and physical parameters of planetary nebulae envelopes based on the optimized photoionization modelling was described. This method was used to the determination of physical characteristics and chemical composition in PN LMC SMP-21.

**Key words**: planetary nebulae; photoionization modelling.

The previous investigations on the gas distribution in the planetary nebulae (PNe) envelopes were based on analysis of the isophote maps for the sample of PNe with shape very close to the sphere at different evolution stages.

On the base of diagnostic methods results we obtained the relationships between electron density and the maximal value of hydrogen density as well as between above hydrogen density and radius of maximal density. In result, the method for the determination of the first approximation of the density distribution along sightline in PNe was developed. We propose accurate expression for the aproximation of the radial density distribution in real PNe envelopes: $\log n_H = (a0 + a1 * r)/(1 + b1 * r + b2 * r^2)$. Here $r$ is the distance from the nebula center (in parsecs); the values of $a0$, $a1$, $b1$, $b2$ are obtained from the aproximation of the density distribution in galactic PNe.

The three stages method to the determination of the optimal photoionization model (OPhM) of PNe envelopes was proposed. At the first stage the ionization structure of PNe envelope is under determination, using mainly reproducing of the observed diagnostic ratios between line intensities. At the second stage the chemical elements abundances are under correction at the ionization structure obtained at previous stage. At the last third stage all free parameters are employed in optimization process to avoid the consequences due to the assumptions used for division of the optimization process into the two first stages.

The division into stages was made on the base of the modelling estimation results of the sensitivity of diagnostic ratios to the variation of heavy elements. It was concluded that chemical abundances He/H, O/H, and S/H must be included as free parameters at the first calculation stage. Also, the N/H abundance should be included too if it has high values.

The OPhM-method was used to the determination of physical characteristics and chemical abundances in PN SMP-21 in Large Magellanic Cloud (see Table 1). G. Ferland's code *Cloudy* (*http://www.nublado.org*) upgraded by us was used to the calculation of OPhM.

Table 1: The optimal values of free parameters obtained from stage III for PN LMC SMP-21.

| Free parameters | Final optimal values of free parameters |
|---|---|
| $T^*_{eff}(Rauch^*)$, K | 190546 |
| $\log L_*$[erg/s] | 36.75 |
| $\log R_{in}$[cm] | 15.54 |
| log He/H | -0.99 |
| log N/H | -3.65 |
| log O/H | -3.70 |
| log Ne/H | -4.40 |
| log S/H | -5.18 |
| log Ar/H | -5.69 |
| Grain factor | 0.0011 |
| a0 | 3.57 |
| a1 | -33.73 |
| b1 | -24.22 |
| b2 | 368.83 |
| Filling factor | 0.28 |

* - Rauch stellar atmospheres were used to the desription of energy distribution in ioizing spectrum of PN nucleous.

## References

Melekh B.Ya.: 2009, *JPhS* **13, 3**, 3901.
Rauch T.: 2003, *A&A*, **403**, 709.
Holovatyy V.V., Mal'kov Yu.F.: 1992, *AZh* **69, 6**, 1166.