CHEMICAL COMPOSITIONS OF CRAB NEBULA FILAMENTS

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ABSTRACT. The chemical compositions in filaments of Crab Nebula are obtained using two methods: new Ionization Correction Factors taking into account density inhomogeneities of the nebular gas, and new 3-stages method based on the optimized photoionization modelling of the nebular gas.

Key words: Crab Nebula; nebular diagnostics; photoionization modelling.

The problem of the determination of physical characterstics and chemical compositions in filaments of Crab Nebula was considered by Woltijer (1958), Holovatyy & Pronik (1973), Contini et al. (1977, 1978). It was shown by Holovatyy & Pronik (1973), that the chemical abundances increase outwards nebula. For our research we used the observed spectra, obtained by Fesen & Kirshner (1982).

The electron temperatures T_e, electron densities n_e, ionic abundances and chemical compositions for individual filaments of Crab Nebula are obtained, using code FREE DIAGN (Holovatyy et al., 1999) with new Ionization Correction Factors, which take into account density inhomogeneities of nebular gas (Holovatyy & Havrylova, 2005).

Distances from the center of Crab nebula to the individual filaments are recalculated for the R=1800 pc. To the determination of distances to the observed parts of Crab Nebula the averaged over radius and weigthed over electron density ionic abundances O^+/H^+ and O^{++}/H^+. We derived the following dependece of distances to the corresponding observed filaments of Crab Nebula on oxygen ionic abundances:

$$r = 689,70 \times \left(\frac{O^{++} + O^{+}}{H^{+}} - 7,02 \times 10^{-4}\right). \quad (1)$$

The radial distribution of chemical compositions in Crab filaments are obtained. The increasing of the abundances outwards nebula were confirmed for He/H, O/H, Ne/H and were not confirmed for S/H and N/H (see Fig.1 and first two dependences in Fig.2).

Also the chemical compositions in filaments of Crab Nebula were obtained using new 3-stages method based on the optimized photoionization modelling (OPhM) of the nebular gas (Melekh B.Ya. et al.: 2012). This method uses the diagnostic ratios between the emission line intensities. The following diagnostic ratios (DRs) between emission line intensities are used to the reproducing of the observed data (Melekh, 2009): λ6731[SII] / λ6716[SII], λ7323[OII] / λ7332[OII], λ3727[OII] / λ6300[OI], λ4686(HeII) / λ4471(HeI), λ4686(HeII)/ λ5876(HeI), λ4471(HeI) / λ5412(HeII), λ5876(HeI) / λ5412(HeII), λ4959[OIII] / λ4363[OIII], λ5007[OIII] / λ4363[OIII], λ5007[OIII] / λ3727[OII], λ6731[SII] / λ6312[SIII].

At the first stage the ionization structure of nebula was determined, using mainly reproducing of the observed diagnostic ratios between line intensities. At the second stage the chemical elements abundances were corrected at the ionization structure obtained at previous stage. At the last third stage all free parameters were 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 following free parameters were used for OPhM of Crab Nebula: hydrogen density, covering factor, energy distribution in ionizing spectra and chemical abundances (He/H and O/H for Stage I, all available chemical elements for Stage II and Stage III). To initialization of the chemical composition of elements the corresponding data obtained previously by diagnostic methods were used. To comparison of modelling results with observed ones the model emission line spectra, the flux in H_β line, the nebular outer radius and the DRs were used.

The ionizing Lyc-spectrum was also varied during optimization process. It allows to reproduce the optimal energy distribution in the ionizing radiation spectrum in the modelling region and, therefore, the detailed consideration of the ionizing radiation transfer from pulsar to the modelling (observed) part of nebula is not required. Peter van Hoof's optimization algorithm Phymir (*http://dissertations.ub.rug.nl/faculties/science/1997/p.a.m.van.hoof*) was used to the minimization of χ^2-function. For OPhM of nebular gas in filaments we used Gary Ferland's code Cloudy 08.00 (*http://www.nublado.org*), upgraded by us to the including of the ionizing spectrum shape to the free parameters as well as to the comparison of the model

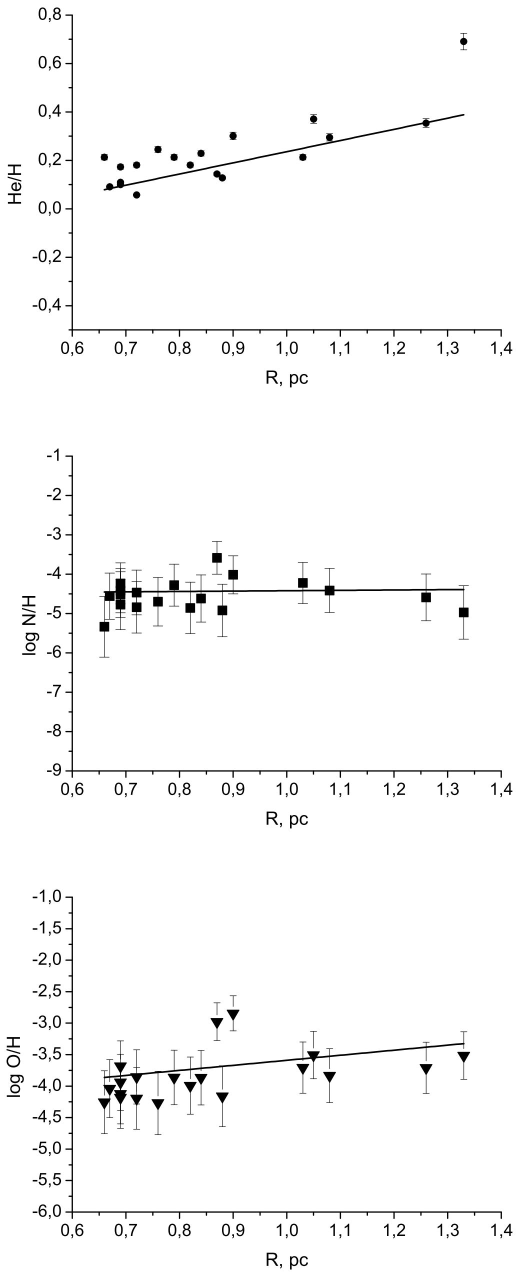

Figure 1: The radial distribution of He/H, N/H and O/H in Crab Nebula filaments.

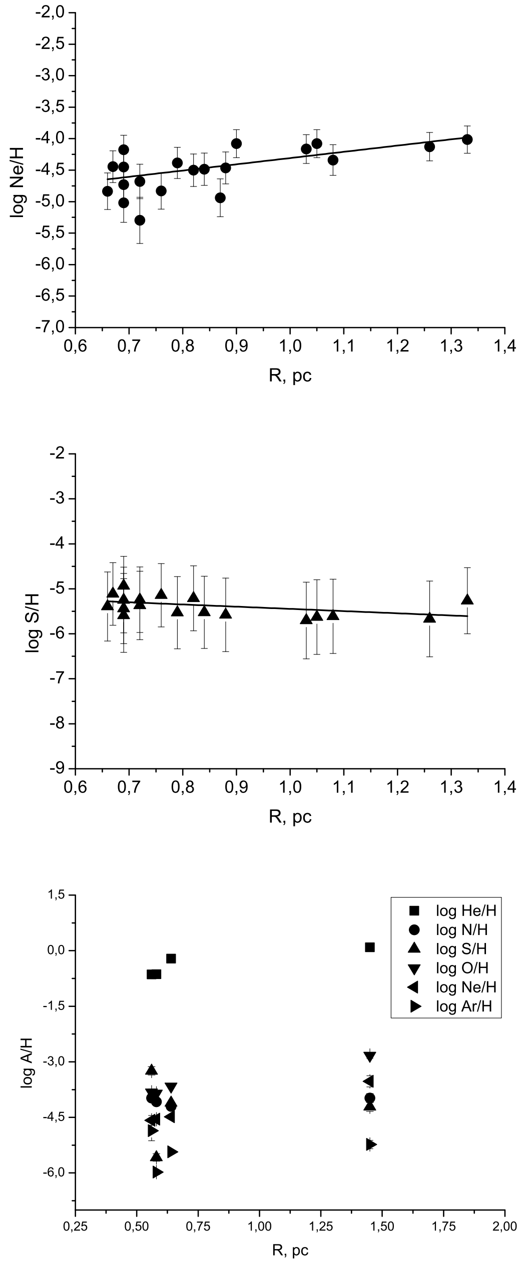

Figure 2: The radial distribution of Ne/H and S/H in Crab Nebula filaments. The bottom (last) figure shows the chemical compositions in Crab filaments obtained using OPhM.

DRs with observed ones. The sensitivity of the relative line intensities and the diagnostic ratios to the chemical abundances variations were analyzed and taken into account.

The radial distribution of the chemical compositions in Crab Nebula filaments were analyzed using OPhM results for 4 parts of Crab Nebula filaments. At present the OPhM results can not confidently confirm the increasing of the abundances outwards nebula (see last Fig.2). It is planed to calculate the OPhM of all regions of Crab Nebula observed by Fesen, Kirshner.

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