THE CBS SPECTRA INVESTIGATION AS METHOD OF THE PN CHEMICAL COMPOSITION ANALYSIS

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ABSTRACT. We report the results of the investigations of chemical composition of close binaries which had gone through the stage of common envelope and which are the remnants of planetary nebular cores. High resolution spectra for different phases of orbital period of V471 Tau were taken by RTT-150 telescope and were investigated by the modified SYNTH-K program. It was found that the spectra show noticeable variability with appearance of emission components depended on the orbital period phase. For chemical composition determination the "solar" oscillator strengths for 700 lines were taken. It was found that the chemical content of V471 Tau is composite one and characterized by excess of ?-process elements in the contrast to small underabundance of iron-peak elements. The estimation of different elements excesses allows to determine their contents in planetary nebular phase.

Key words: Stars: binary: cataclysmic; stars: individual: Sun, V471 Tau

1. Introduction

Modern theory of chemical evolution of our Galaxy considers several sources of changing of the matter composition:

1) supernovae SNI and SNII explosions,
2) formation of planetary nebulae (PN),
3) Novae explosions,
4) WR-stars,
5) natural radioactivity,
6) the interaction with cosmic particles.

To check the correctness and the accuracy of this theory two types of observational criteria may be used.

1) Global - the determination of chemical composition of the gas and stars of different ages and comparison with theoretical predictions. These criteria allow to check the theory as whole, but do net give a possibility to improve the models of different objects.

2) Particular - the determination of the nuclear synthesis efficiency for some objects using direct observations.

Unfortunately the complication of the theory for the SN and PN radiation formation put a limit on the accuracy 0.5-1.0 dex for chemical determinations. The chemical content of stellar remnants (white dwarfs and blue subdwarfs) is influenced by stratification effects. As a result we have no reliable direct observational data of nuclear synthesis at the final stages of stellar evolution.

In this work we investigate the possibility to get such data by alternative method of the probe. It is assumed that this probe should be in deep layers of evolving star. Then the chemical composition of a matter enriched by the probe may be investigated by traditional stellar atmospheres modeling. The natural realization of such a probe is close binary systems. These systems are forming from broad stellar pairs with the main component which after evolution on the main sequence stage is expanding up to the supergaint size. The orbital velocity of both components is 10 times larger then the rotational velocity of the envelope. As a result the system begins to loose the angular momentum, to decrease the large semiaxis and to mix a matter. Finally after the supergaint envelope loss secondary component (enriched by nuclear synthesis products) may be observed.

The accuracy of abundance determination of this component depends on the conditions of observations. In cataclysmic variables with bright accretion disc the radiation input of the secondary component is small, so the possibilities of investigation are limited. In massive X-ray binaries the disc luminosity is small, so there are good conditions to investigate the abundance of the matter produced by SNII. Precataclysmic variables gives an optimum possibility for the analysis of the nuclear synthesis efficiency during PN formation because there are no accretion effects. In our work we pot our attention on the old PN - V471 Tau.

V471Tau was discovered by Nelson and Yuong (1970) as eclipsing binary system with the orbital period $P = 0.^d52118$. The brightness of this object ($m_b = 10.24^m$, $m_V = 9.48^m$) permits to get high resolution spectra which show that red dwarf dominates in optical radiation. This objects has a variability with

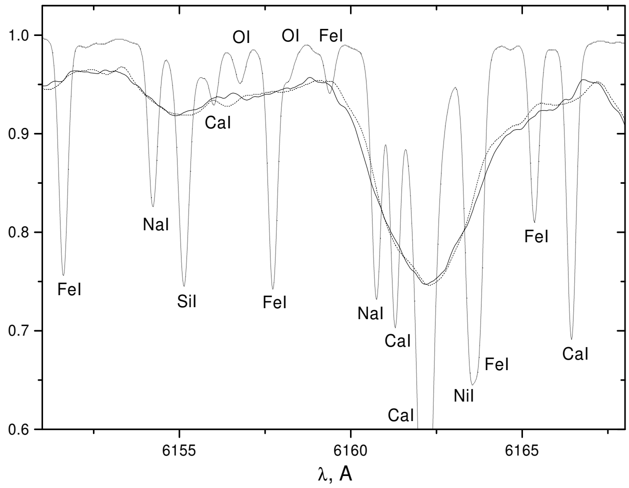

Figure 1: Theoretical (not broadened) profiles for l
forming blends and theoretical and observed blend

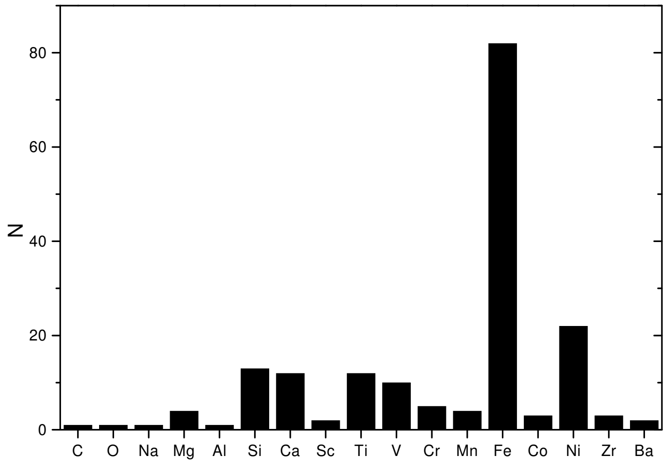

Figure 2: The distribution of numbers of abundance determinations for different elements.

unstable amplitude coursed by interaction of magn fields of both components. The full list of fundame stellar parameters was taken from the paper by O'B at al. (2001). Chemical abundance of the secondary component was analyzed by using moderate resolution spectra (Martin et al., 2001) and X-ray fluxes (Still et. al, 2003). The accuracy of abundance determinations for 4-5 elements is about 0.4 dex and shows considerable differences. So we decided to perform the abundance determination of this object with higher accuracy.

2. Observations and spectra modeling for V471Tau

Eleven spectra of high resolution ($\frac{\lambda}{\Delta\lambda} = 40000$, $S/N = 70-90$, $\Delta\lambda = 3900-8800\mathring{A}$) were observed by the RTT telescope during the nights 12/13, 13/14, December, 2004. Coude–eshelle spectrometer CES and CDC detector with nitrogen cooling was used. The data reduction was performed by DECH computer complex. The comparison of spectra in different phases showed the emission components in the Balmer lines which caused by reflection effects. Line profiles for heavy elements are not changing and may by used for abundance determination by stellar atmospheres models.

Spectra modeling was performed by using the SYNTH program and model atmospheres by Kurucz (1994). We include in calculations instrumental profile, macroturbulence ($V_{macro} = 1.8km/sec$) and microturbulence ($\xi_{turb} = 1.0km/sec$) broadening and stellar rotation. The velocity of the red dwarf rotation (Vsini=83 km/sec) was estimated from the analysis of the spectra. For stellar abundance analysis we redetermined line parameters by comparison of calculated solar spectrum with the flux Atlas for the Sun (Kurucz et al., 1984). In result we determined more than 600 solar oscillator strengths and van der Waals damping constants. The comparison of solar oscillator strengths $\log gf$ with Kurucz data (Kurucz,1994) showed that the last data in general are overestimated by the factor 0.14 dex independently on the ionization stage, excitation energy and wave lengths. Empirical van der Waals damping constants overestimate classical Unsold values by the factor 6. Moreover, there are two groups of lines with completely different (in 2.5 times) scaled factors for damping.

3. The analysis of results

The abundance determinations for V471Tau was performed by their variations to achieve the best agreement of observed and calculated blends as shown on fig.1. In result we have investigated 113 line blends, 104 blends gave us abundances for 16 Chemical elements. The iron abundance was based on 83 blends with the accuracy 0.02 dex. For 5 elements (Si, Ca, Ti, V, Ni) we had about 10 estimations with average accuracy 0.08 dex. For Mg, Cr, Mn, Co and Zr there were 3-5 estimations only. Abundances of other elements we found using 1-2 estimations and should be improved.

Chemical abundances relative to the solar ones are shown in fig 3. The analysis of these data allows to make the next conclusions.

1) The metalicity of V471Tau ([Fe/H])=- 0.2 dex) indicates that this star belongs to the thin galactic disc. At the same time it is less (0.3 dex) than the average stellar metalicity in the Hyada cluster. It is in a good agreement with suggestion of O'Brien et al. (2001) that V472Tau does not belong to the cluster.

2) The abundances of odd and iron group elements (Na, Al, Ca, Ti, Cr, Mn, Co, Ba) corresponds to the value of the metalicity. According to theoretical predictions these elements are not producing in stars with

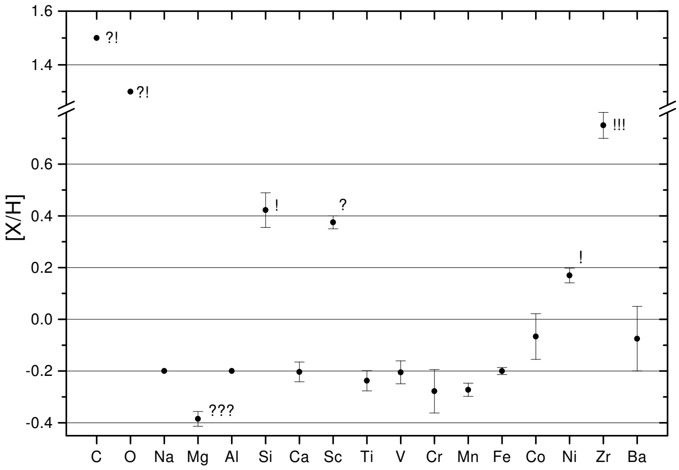

Figure 3: V471 Tau abundance [X/H] elements relative to the solar ones.

masses 5-7 $M_{\odot}$.

3) Large excesses for carbon ([C/H]=1.8 dex) and oxygen ([O/H]=1.3) are producing by α- process acting in the final stage of supergaint life. For white dwarfs with the mass 0.83 $M_{\odot}$ α- process must be ended by the synthesis of neon and magnesium. So we assume that these elements must be overabundant.

4) The circonium excess ([Zr/H]=0.73 dex) is explained by s-process acting simultaneously with α-process. The same excesses were found by Thevenin et al. (1997) for others elements of s-process ([Y/H]=0.40, [Sr/H]=0.80 dex) in the nuclei of PN Abell 35.

5) The deficiency of Mg ([Mg/H]=-0.38 dex) and the excess for Si ([Si/H]=0.42 dex) contradict to theoretical predictions mentioned above. We suppose that at the supergaint stage there were important transformation of Mg to Si in a process similar to α-process. The reasonsof such process should be investigated in details.

6) The excess of Sc ([Sc/H]=0.38 is probably coursed by measurement errors and needs additional analysis.

7) The excess for Ni ([Ni/H]=0.17) is in a serious contradictions with modern ideas about nuclear synthesis. This element is producing together with iron in SNI only. Therefore this result should be checked by observations and the theory.

Finally we conclude that abundance investigations of close binaries provide important information about the efficiency of nuclear synthesis on last stages of stellar evolution.

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References

Nelson B. and Young A.: 1970, *PASP*, **82**, 699.

O'Brien M.S., Bond H.E., Sion E.H.: 2001, *A. J.*, **563**, 971.

Martin L., Pavlenko J., Rebolo R.: 1997, *A. J.*, **326**, 731.

Still M. and Hussain G.: 2003, *A. J.*, **597**, 1059.

Kurucz R.L.: 1994, *SAO CD-ROMs. Cambridge, MA02138, USA.*

Kurucz R.L., Furenlid I., Brault J., Testerman L.: 1984, *Solar Flux Atlas from 296 to 1300nm.* Nat. Solar Obs., Sunspot, New Mexico.

Thevenin F. and Jasniewicz G.: 1997, *A&A.*, **320**, 913.