DOI: http://dx.doi.org/10.18524/1810-4215.2016.29.85238

HIP 13962 – THE POSSIBLE FORMER MEMBER OF BINARY SYSTEM WITH SUPERNOVA

Yushchenko V.[1], Yushchenko A.[2], Gopka V.[1], Shavrina A.[3], Kovtyukh V.[3], Hong K.S.[4], Mkrtichian D.[5], A-Thano N.[5]

[1]Astronomical observatory, Odessa National University, Odessa, 65014, Ukraine
vladimiryushchenko@gmail.com
[2]Department of Astronomy & Space Sciences, Sejong University, Seoul, 05-006, Korea,
[3]Main Astronomical observatory, National Academy of Sciences of Ukraine, Kiev, 03680, Ukraine
[4]Korea Astronomy and Space Science Institute, Daejeon, 305-348, Korea
[5]National Astronomical Research Institute of Thailand, Chiangmai, 50200, Thailand

ABSTRACT. The runaway supergiant star HIP 13962 (spectral type G0Ia) was recently pointed as a possible former binary companion of young pulsar PSR J0826+2637. The spectra of HIP 13962 were obtained in Haute-Provence observatory (France), in Bohuynsan observatory (Korea), and also in NARIT (Thailand) with 1.9, 1.8, and 2.4 meter telescopes respectively. The spectra were obtained in 1995, 2003, 2005, 2014, and 2015. Significant variations of the spectrum are detected. The cores of strong lines show complicated structure, the brightness of the star is variable. The cycles of photometric variations have been changed. We analyzed the spectral observations and present the preliminary chemical composition for elements from iron to lead. The abundance pattern can not be fitted by solar system $r-$ & $s-$process abundance distribution.

Key words: stars: individual: HIP 13962 – stars: abundances.

1. Introduction

In recent paper, published by Tetzlaff et al. (2014) it was shown that HIP 13962, G0 type runaway supergiant star of seventh magnitude, can be a former secondary member of binary system, with main component exploded as a Supernova near 3 millions years ago. The possible former main component of this system - young pulsar PSR J0826+2637 was also escaped from a small cluster Stock 7.

That is why it seems interesting to investigate the signs of contamination of the atmosphere of supergiant star HIP 13962 by nuclear processed matter. It can be a result of Supernova outburst in binary system. Note that this type contamination was predicted in many papers, for example by Proffitt & Michaud (1989), but was never directly confirmed.

Hopefully HIP 13962 can demonstrate the results the nearby Supernova explosion in its abundance pattern because of relatively short time passed after this event.

We used the archived and new spectral and photometrical observation of the star and found the different photometric behavior at different epochs, the anomalous variable profiles of strong spectral lines, the variability of the spectrum, and the anomalous chemical composition. Here after we present the short overview of preliminary results (Yushchenko et al., 2016).

2. Spectral observations

The archive of observations of 1.9 telescope of Haute-Provence observatory equipped by ELODIE spectrograph with spectral resolving power R=42000 was used. HIP 13962 was observed three times in 1995, 2003, and 2005 years.

Three additional spectra were observed at Bohuynsan Optical Astronomical Observatory (BOAO) 1.8 m telescope with spectral resolution near R=45000, in 2014 and 2015.

In 2014 four spectra were observed with 2.4 m telescope of National Astronomical Research Institute of Thailand (NARIT) with spectral resolution R=20000.

Signal to noice ratio of all used spectral observations exceeds 100 in the centers of echelle orders. The observed spectral regions are 4000–6800 ÅÅ, 3780–8877 ÅÅ, and 3722–8804 ÅÅ for Haute-Provence, BOAO, and NARIT observations respectively.

The initial reduction of BOAO and NARIT spectra was made using standard IRAF package, the final spectra processing, including continuum placement, coadding of the spectra, identification of spectral lines, and equivalent widths measurements was made using URAN program (Yushchenko, 1998).

The synthetic spectrum of HIP 13962 was calculated for the whole observed wavelength region. It was taken into account in continuum placement and identification of spectral lines.

3. Photometry

Turner et al. (2009) performed the photometrical observations of HIP 13962 and found that the brightness of the star is variable with amplitude less than 0.1 magnitude and periods 177 and 123 days.

We investigated HIPPARSOS photometry (Perryman, 1997) of the star. Fig. 1 shows, that variability with amplitude near 0.05 magnitude was observed at the time scale of few years.

Note that Turner et al. (2009) and HIPPARSOS observations were made at different epochs (time difference is near 15 years) and it is not surprising that the values of photometrical cycles are different. Both types of brightness variations are usual for supergiant stars, but it can be also the additional argument to confirm the reality of spectrum variations, discussed here after.

4. Atmospheric parameters

Parameters were derived by Kovtyukh (2007) and Kovtyukh et al. (2012) as follows: the effective temperature $T_{\rm eff}$=5871±130 K, the surface gravity log g= 1.2, the microturbulent velocity 11.5 km/sec. The projected rotational velocity was found to be equal vsin i = 29 km/sec - significantly higher than the typical rotational velocities of this type stars.

To estimate parameters of HIP 13962 in this investigation we used the first of BOAO spectra, observed in 2014. Castelli and Kurucz (2003) grid of atmosphere models and the clean iron lines in the observed spectrum allowed us to accept the values 5930 K, 1.0, and 6 km/sec for effective temperature, surface gravity and microturbulent velocity respectively.

The pointed values are close to previously determined by Kovtyukh (2007) and Kovtyukh et al. (2012). Here after we present the abundances calculated with these parameters.

5. Chemical composition

The identification of spectral lines in observed spectrum of HIP 13962 was based on the comparison with synthetic spectrum calculated for the whole wavelength region of observed spectra. The parameters for calculations of synthetic spectrum were taken from previous section, the abundances of heavy neutron captured elements were encreased by 0.5 dex.

Equivalent widths of spectral lines were measured in the the first of BOAO spectra, observed in 2014. The abundances for individual lines were calculated using Kurucz's program WIDTH9. Table 1 contains the mean values of abundances of iron and neutron captured chemical elements with respect to solar or solar system values (Grevesse et al., 2010), the errors, and the number of used lines.

More detailed description of used methodic can be found in Yushchenko et al. (2015) and in our earlier publications.

6. Discussion

Fig. 2 shows the chemical composition of HIP 13962 in comparison with solar system r- and s-processes abundance patterns. The abundances of elements with atomic numbers Z≤63 and lead can be easily explained by these patterns, the descrepancies are of the order of 0.2 dex.

The most interesting feature of derived chemical composition is the relatively low abundances of lanthanides with Z≥64. The deviations of these elements from solar s-process abundance distribution are clearly visible.

It is worth to mention that faint lines of many heavy elements, which are not listed in Table 1, can be identified in the spectrum of HIP 13962. The high level blending of these lines requires spectrum systnesis to obtain reliable abundances for these elements.

Table 1: Chemical composition of HIP 13962

Z	Ion	ΔlogN	σ	n
26	Fe I	-0.07	0.17	80
	Fe II	-0.05	0.18	18
29	Cu I	-0.52	0.12	3
39	Y II	0.39	0.22	10
40	Zr II	0.28		1
46	Pd I	0.44		1
57	La II	0.61	0.17	16
58	Ce II	0.34	0.19	19
59	Pr II	0.28	0.23	10
60	Nd II	0.39	0.23	50
62	Sm II	0.08	0.19	15
63	Eu II	0.30		1
64	Gd II	-0.10	0.24	4
65	Tb II	-0.36	0.04	3
66	Dy II	0.15	0.09	3
68	Er II	0.01	0.21	4
82	Pb II	0.23		1

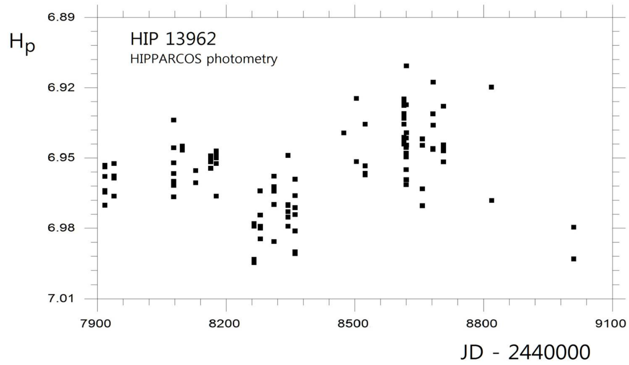

Figure 1: HIPPARCOS photometry of HIP 13962. The axes are time in Julian days and HIPPARCOS photometric system magnitude H_P.

As it was pointed here before our abundances are based on the first BOAO spectrum of HIP 13962, obtained in 2014. We found no strong differences for faint and medium strength lines between this spectrum and the other two BOAO spectra. The first Houte-Provence observatory spectrum, observed in 1995 repeats BOAO spectra for not strong lines. Tetzlaff et al. (2014) abundances were found from this spectrum.

2003 and 2005 year spectra, observed in Houte-Provence, have very different line profiles, both for strong and faint lines, as it is shown in Figures 3 and 4. The strongest lines in the spectrum are variable, it is confirmed also by NARIT spectra. The variations of hydrogen Hα line profiles are shown in Fig. 3.

The line profiles in 2003 and 2005 Haute-Provence spectra can be explained by strong additional light. Maybe it was an error in the reduction procedure of spectral observations. Why it happens twice? Was it a secondary light in spectrograph or in HIP 13962? It is necessary to have in mind the possiblility of real variations of observed object.

Of course the probability of error in reduction procedure seems higher. It can be confirmed by Fig. 4 where cosmic ray particle produce an emission at the wavelength of promethium line in 2003 year spectrum.

If the reason of spectral anomalies is not the instrumental effect, it is possible to expect the anomalous photometrical behaviour of HIP 13962 in 2003-2005. Turner et al. (2009) collected all published photometry, unfortunately there are no data in these years.

7. Conclusion

HIP 13962 was investigated to find the possible signs of nuclear processed matter as a result of Supernova explosion of its former binary companion, at present time - young pulsar PSR J0826+2637. We found both

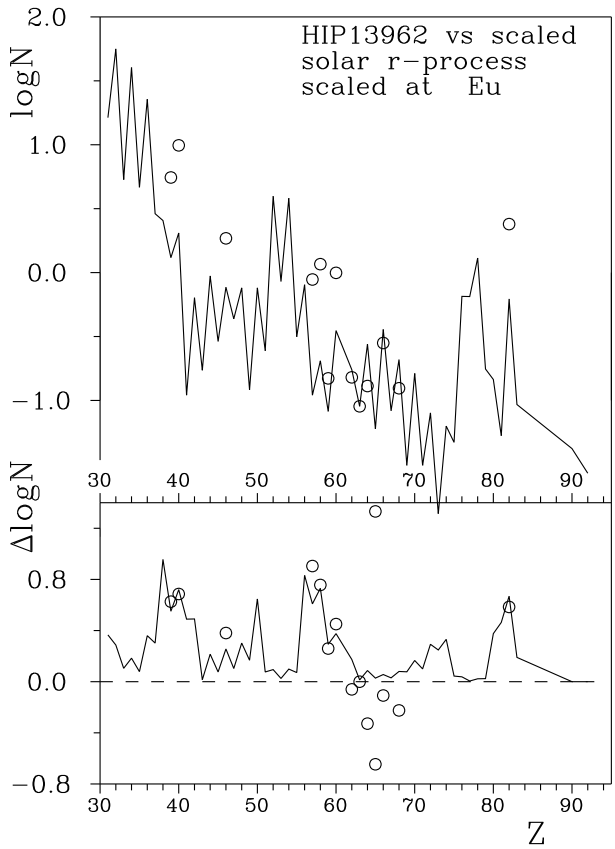

Figure 2: The top panel: comparison of surface abundances in HIP 13962 (circles) with solar system $r-$process abundance distribution (line) taken from Simmerer et al. (2004). and scaled to the observed abundance of europium. The bottom panel: deviations of observed abundances in HIP 13962 from scaled solar system $r-$process abundance distribution (circles). For comparison the solar system $s-$process distribution is shown by line.

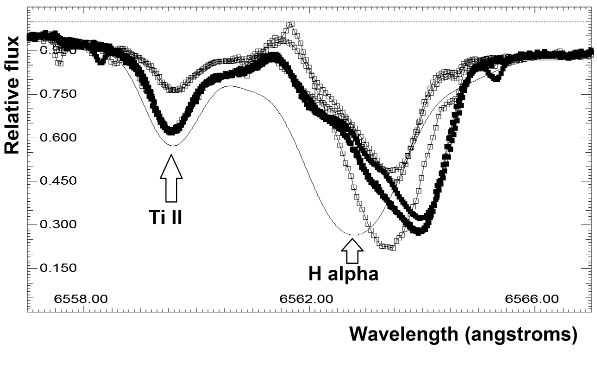

Figure 3: The spectrum of HIP 13962 in the vicinity of hydrogen Hα line. The axes are wavelength in angstroms and relative fluxes. Synthetic spectrum is shown by thin line. The wavelengts of Hα line and the strong line of ionized titanium are marked. Open squares designate Houte-Provence observatory spectra, solid squares are spectral observations obtained in Bohuynsan observatory.

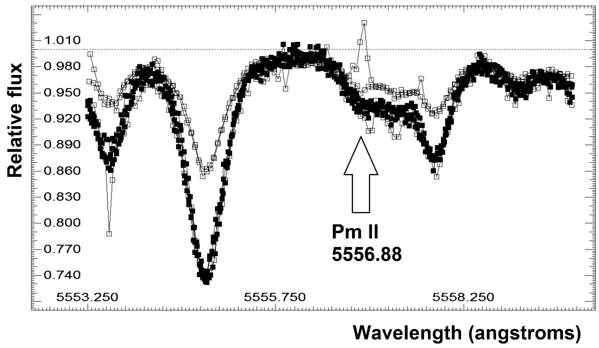

Figure 4: The spectrum of HIP 13962 in the vicinity of promethium line λ 5556.88 Å. The axes are wavelength in angstroms and relative fluxes. The observed spectra taken from Houte-Provence and Bohuynsan observatory telescopes are pointed by open and solid squares respectively.

over and underabundances of heavy elements.

The abundances of heavy elements with atomic numbers Z≤63 elements and lead can be aproximated by solar system $r-$ and $s-$processes abundance pattern. The abundances of Gd, Tb, Dy, and Er are lower than it can be expected from this solar fit.

Note that this results were made by model atmosphere method, it will be used to refine the parameters and abundances by spectrum synthesis method.

The variability of brightness and the strong variations of spectrum confirm the necessity of new spectroscopic and photometrical observations of this outstanding star.

Acknowledgements. This work was supported in part by the Korea Astronomy and Space Science Institute under the R&D program (Project No. 2015-1-320-18) supervised by the Ministry of Science, ICT and Future Planning. One of the authors (VY) was granted by the Swiss National Science Foundation (SCOPES project No. IZ73Z0 -128180/1) for this investigation and also for presentation of obtaibed result at the conference in Germany (Yushchenko et al., 2016).

References

Castelli F. & Kurucz R.: 2003, *IAU Symp. 210*, Poster contributions, A20, http://wwwuser.oat.ts.astro.it/castelli/grids.html.

Grevesse N., Asplund M., Sauval A.J., Scott P.: 2010, *As&SpSci*, **328**, 179.

Kovtyukh V.V.: 2007, *MNRAS*, **378**, 617.

Kovtyukh V.V., Gorlova N.I., Belik S.I.: 2012, *MNRAS*, **423**, 3268.

Perryman V.A.C. et al.: 1997, *The Hipparcos and Tycho Catalogues*, European Space Agency, CD-ROMs 1-8.

Proffitt C.R., Michaud J.: 1989, *ApJ*, **345**, 998.

Simmerer J., Sneden C., Cowan J.J., Collier J., Woolf V.M., Lawler J.E.: 2004, *ApJ*, **617**, 1091.

Tetzlaff N., Dincel B., Neuhaeuser R., Kovtyukh V.V.: 2014, *MNRAS*, **438**, 3587.

Turner D.G., Kovtyukh V.V., Majaess D.J., Lane D.J., Moncrieff K.E.: 2009, *Astronomische Nachrichten*, **330**, 807.

Yushchenko A.V.: 1998, in *Proceedings of the 20th Stellar Conference of the Czech and Slovak Astronomical Institutes, Ed. by J.Dusek (ISBN 80-85882-08-6, Brno)*, p. 201.

Yushchenko A.V., Gopka V.F., Kang Y.-W., Kim C., Lee B.-C., Yushchenko V.A., Dorokhova T.N., Doikov D.N., Pikhitsa P.V., Hong K., Kim S., Lee J.-W, Rittipruk P.: 2015, *AJ*, **149**, A59.

Yushchenko V., Yushchenko A., Gopka V., Shavrina A., Kovtyukh V., Hong K.S., Mkrtichian D., A-Thano N., presentation at the conf. *Stars on the run - a meeting on run away and hyper-volosity stars* Germany,Bamberg, August 16-19, 2016, *http://www.black-hole.eu/media/hvs2016/PDFs/Yushchenko.pdf*