THE NATURE OF MAGNETIC CHEMICALLY PECULIAR STARS PHENOMENON AND THE ORIGIN OF LITHIUM

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ABSTRACT. According to the modern theory of the evolution of chemical elements their origin seems understandable for most of the elements, from the lightest up to the heavy ones. For element with atomic number Z=3 (lithium) the situation is following: the physical processes and the possible mechanisms of lithium production in stars of different types and ages remain completely unidentified up to now.

This paper is an attempt to explain the observed properties of lithium in the magnetic chemically peculiar (MCP) stars by the existence of a neutron star (NS) companion. It is supposed that MCP stars are binary systems with stable relativistic outflow of charged particles falling on the poles of MCP stars along the magnetic field lines (Gopka et al., 2010). The production of lithium is possible as a result of interaction of highly accelerated charged particle and the photosphere of MCP star. The location of lithium spots on the magnetic poles seems natural.

The problem of lithium formation is directly connected to the problem of origin of MCP stars. The assumption of origin of double systems with presupernova is based on the observations of binary population in OB association Sco2 (Brown, 2001) is discussed. The distribution of primordial binary population clearly answers the question about the origin of systems with NS companions. The phenomenon of MCP stars with lithium production can be the key to he understanding of the origin of Li in other stellar objects.

It is assumed that the formation of binaries with a primary star at the evolutionary stage of pre-supernova occurs in the areas of star formation due to the ambient matter accretion and the mass exchange between the stars of intermediate mass in binary systems. The explosion of a more massive companion as a type II supernova results in a qualitative change in binary system when a young star is accompanied by a neutron star. Such systems can be a lithium producers.

An important aspect of this assumption is a clear understanding of the evolutionary status of young objects at the stage before the main-sequence, the progenitors of MCP stars, such as the Herbig AeBe stars. The observational data for Herbig AeBe stars (and for T Tauri stars with Herbig AeBe properties continuing in the region of stars with masses less than 2 $M_\odot$) indicate the existence of young stars surrounded by accretion disks with typical outflow along the magnetic field lines of the disk. It was pointed by Grinin & Tambovtseva (2012) and now can be explained in the framework of our model of MCP stars (Gopka et al., 2010). On the other hand, the binary systems containing a NS companion and the detectable lithium, were really identified by Martin et al. (1994) and Rebolo et al. (1995).

Key words: stars, magnetic chemically peculiar stars, evolution, lithium, binary stars, neutron stars.

1. Introduction: lithium in the Universe

The origin of lithium in the atmospheres of some MCP stars is not understood up to now, and the main reason for this seems to be the lack of understanding of the nature of MCP stars. Recall that MCP stars are part of upper main sequence CP stars, these are the slowly rotating stars with anomalous chemical abundances, but unlike other CP (Hg-Mn, Am) stars MCP stars have global, mainly dipole magnetic field up to 30 kilogauss. The spectral types of these objects are B2-F0 and the range of the masses is 1.6-8 $M_\odot$ (Braithwaite et al., 2010).

MCP stars show the periodical variations of light and (or) spectral features, magnetism, radial velocity, radio, X-ray, and IK-emissions. The modern stellar evolution theory is unable to answer why we can observe the lithium in the atmospheres of some MCP stars, and why we not always can detect the lithium in the atmospheres of other representatives of this type stars.

Lithium is observed in the areas of magnetic poles in the atmospheres of stars, that was shown and modelled at the first in the works of Polosukhina et al. (1999, 2000), Shavrina et al. (2000, 2001). The lithium abundance in the polar spots can be significantly higher than he "cosmic" values and up to 6 dex exceeds the solar concentrations (Polosukhina et al. 1999, 2000, Shavrina et al. 2000, 2001, Kochukhov et al. 2004, Drake et al., 2005). Note, that the lithium abundance is equal to $logN$(Li)=1.03 in the atmosphere of the Sun and to $logN$(Li)=3.25 for meteorites (Spite & Spite, 2010).

The high abundance of lithium in MCP stars reflects the complex physical processes in these stars and requires challenging modeling beyond the standard stellar theory (as the main sequence stars with magnetic field). The phenomenon of MCP stars with lithium production can be the key to the understanding of the origin of Li in other stellar objects.

As a rule, the study of lithium is carried out using the doublet of neutral lithium at 6708 Å. It will be interesting to note that the doublet of Li consists of four lines: 6707.761 Å & 6707.912 Å for ^{7}Li isotope and 6707.921 Å & 6708.072 Å for ^{6}Li one (Meissner et al., 1948). According to Wallerstein & Conti (1968) the intensities of components are in the ratio of 2:1 for both isotopes. Therefore, as we can see, the weaker ^{7}Li component almost exactly overlaps the stronger ^{6}Li component.

In the analysis of high quality spectra one can use a weaker subordinate lithium line at 6103 Å. Note, that there are no significant differences between the LTE and non-LTE abundances extracted from the 6708 Å and 6103 Å lines as it was shown for metal poor dwarf stars by Lambert (2004) and Asplund (1999, 2000). The typical error of LTE abundances is near 0.2-0.5 dex from the difference between $logN$(Li) that was found for the 6708 Å and 6103 Å lines as it was shown by Ford et al. (2002), Shavrina et al. (2005b), and Ruchti et al. (2011) for metal poor and MCP stars.

The wavelengths of lines of singly ionized lithium fall in the soft X-ray region (Gurzadyan, 1985), the wavelength of resonance line of Li II is 199 Å (Faraggiana et al., 1986).

The infrared lithium line at the wavelength 8126 Å was used by Pavlenko et al. (1995) and Rebolo et al. (1994, 1995) in the analysis of Li-rich stars of late spectral classes.

Reeves (2009) shows that the abundances of the light chemical elements such as Li, Be, and B are dependent on the nuclear interactions of elementary particles.

Lithium can not survive under the high temperatures in internal layers of stars. According to Spite & Spite (2010) ^{7}Li is destroyed when the temperature reaches the value of $2.5{\cdot}10^6$ K and ^{6}Li is destroyed when the temperature is higher than $2{\cdot}10^6$ K.

The Big Bang nucleosynthesis was responsible for the origin of the isotope ^{7}Li and negligible amount of ^{6}Li one as it was discussed by Reeves (2009), Spite & Spite (2010), and Knouth et al. (2002). But only 10 percents of currently observed abundance of ^{7}Li isotope is the result of primordial nucleosynthesis (Knouth et al., 2002).

In the series of papers since 1970's Reeves and collaborators have found that the Galactic cosmic rays are responsible for production of ^{6}Li isotope, which is a product of spallation reactions between the Galactic cosmic rays and the interstellar C, N, and O nuclei, therefore Li is a fragmentation of C, N, and O nuclei.

In this scenario the part of ^{7}Li isotope is only 10 to 25 percents of total lithium production as it was shown by Reeves et al. (1970), Reeves (2009), and Knouth et al. (2002). The nature of cosmic rays sources is continued to be debated (Ramaty et al., 2000).

Modern investigations show that the stellar nucleosynthesis is responsible for major part of ^{7}Li isotope. The increase of ^{7}Li abundance for stars with [Fe/H]>-0.5 indicates the existence of stellar source of ^{7}Li isotope and also proves that lithium can be a result of some physical processes in the stellar interiors, for example the Cameron-Fowler mechanism in AGB stars (Reeves, 2009; Spite & Spite 2010; Knauth et al., 2003; Lambert, 2004).

Numerous observations of lithium in hundreds of stars at various evolutionary stages (pre-MS, MS, post-MS) provide the evidence of some processes which modify the surface lithium abundance. The definition of the evolutionary phase of Li-rich stars is absolutely critical for understanding the processes that create the lithium in stellar atmospheres (Ruthti et al., 2011). According to investigation of Prantzos (2012) intensive theoretical and observational works about production and evolution Li in the stellar source remains elusive at present.

2. The lithium abundances in the atmospheres of MCP stars and the cooler stars.

Gopka et al. (2007, 2008, 2010) proposed that MCP stars are binary systems with NS companion. Let's overview shortly the most important results of investigations of lithium in stellar atmospheres with special attention to MCP stars. The main efforts will be devoted to the observational results which directly or indirectly support our hypothesis.

It is known, that the progenitors of MCP stars can be Herbig AeBe objects (Braithwaite et al., 2010; Hubrig et al., 2012). These stellar objects are at the pre-main sequence evolutionary stage. Their masses are between 2 and 10 $M_{\odot}$.

Recall that Herbig (1947, 1950a, 1950b, 1957, 1960) identified the objects that are at the early stages of the star formation characterized by a significant amount of circumstellar matter around any of them and shaded by dense clouds of dust and gas.

The Herbig AeBe objects are located in star-forming areas, are essentially the protostars on the stage of compression, they exhibit the emission lines in the spectra (hydrogen, helium, S II, O II, and other elements) and the lines of lithium in absorption. The spectra of these objects are characterized by variations of line profiles including P Cyg type profiles which testify the movement of matter from the star with velocities up to hundreds kilometers per second. They are also characterized by variability of brightness and polarization, the energy distribution in the spectrum shows two peaks.

It seems interesting to discuss here T Tauri type stars which are not strongly distinct from Herbig AeBe objects. T Tau stars have masses less than two solar mass, its ages are accepted to be young objects which do not cross the MS zero-age line.

Both Herbig AeBe and T Tauri stars have the accretion disks, and the outflow of matter, which is inextricably linked to the magnetic field of the discs.

The origin of accretion and outflow along the magnetic lines, "frozen" in the disk, and the origin of the magnetic field configuration in the disk was pointed for example by Grinin & Tambovsheva (2012). It was found that the magnetospheres of Herbig AeBe stars occupies the area of about 2-3 radii of the star for the most rapidly rotating stars, whereas for T Tauri stars it extends up to 5-10 radii of the star.

The spectra of Herbig AeBe and T Tauri stars exhibit the lines of lithium in absorption. As it will be discussed here after we guess that MCP stars can be the next evolutionary phase of Herbig AeBe.

The enrichment of lithium occurs at an earlier stage of evolution, as it was shown by Grankin (2012).

The lithium abundance is known for a relatively small number of MCP stars, Kochukhov (2008) pointed a dozen stars. The number of MCP stars with identified lines of Li in their spectra could be higher, but the variations of Li line wavelength with rotational phase in some stars results in the decrease of the number of Li stars due to misidentification of shifted Li line as it was pointed by Polosukhina et al. (1973, 1999), Faraggiana et al. (1996), and Gerbaldi & Delmas (1996).

An important reason of the small number of MCP stars with known Li abundance is that the lithium is expected to be essentially ionized (Faraggiana et al., 1986). The calculation shows that for the temperature of T Tau stars (the object with lower temperatures than those of MCP stars) the dominate state of lithium is Li II, therefore, the main part of lithium atoms in the atmospheres of MCP stars are ionized atoms (Gurzadiyn, 1985) but the lines of ionized lithium are beyond the optical wavelength region, as it was mentioned here before.

The strong magnetic field is the reason of additional problem in the identification of the lithium line in the spectra of MCP stars. Kochukhov (2008) analysed the lithium line 6708 Å as a function of the strength of magnetic field for 17 magnetic Ap stars and obtained that the line profile changes noticeably in the strong magnetic field stronger than 5 kGs.

Faraggiana et al. (1986) calculated that the equivalent width of lithium line 6708 Å should be 1, 8, 35, and 69 mÅ for temperatures 9000, 8000, 7000, and 6500 K respectively if the abundance of lithium in the stellar atmosphere is equal to $logN$(Li)=3 (the upper limit of cosmic lithium abundance).

Very strong lithium lines at 6708 Å have been discovered in the spectra of only several stars of asymptotic red giants branch (AGB), namely in intermediate mass AGB stars WZ Cas and WX Cyg by McKellar (1941) and Feast (1954). Faraggiana et al. (1999) found that the variability of equivalent widths is strong, for example WZ Cas shows the equivalent widths in the range from 10.7 Å to 3.43 Å in direct relation with variations of T_{eff}, the heavy blending of Li 6708 Å line by molecular lines for these AGB stars was also noted.

It was supposed that Cameron-Fowler mechanism is responsible for high lithium content at the surface of the intermediate-mass AGB stars. As the result of the action of this mechanism, lithium could be transported to the surface of stars, since the convective envelope contacts with the H-burning shell where ^{3}He-enrichment takes place from proton-proton reaction chain (Ruchti et al., 2011).

Kipper & Wallerstein (1990) investigated the late type SC stars with temperatures as low as T_{eff}=2320-3750 K and found that these stars exhibit the equivalent widths of Li 6708 Å line near 500 mÅ. Kipper & Wallerstein (1990) obtained the abundances of Li in SC stars to be equal to $logN$(Li)=-1.6 (in the scale $logN$(H)=12).

Ruchti et al. (2011) found only eight Li-rich giants in the sample of over 700 metal-poor stars. The abundances of Li for these eight stars show the values $logN$(Li)=2.30-3.63. According to this work, only one per cent of all giants are Li-rich stars and the frequency of Li-stars occurrence is independent of the metallicity. The lithium lines in the spectra of lithium-rich giants are very strong, for example the equivalent width of Li line in the star J142546.2-154629 is 540 mÅ. The lithium line at 6103 Å is also enhanced in the spectra of lithium-rich giants. The Li-rich giants in the sample investigated by Ruchti et al. (2011) are consistent with old age and low-masses stars, with masses less than 1 $M_{\odot}$. Li-rich AGB and RGB stars, according to Ruchti et al. (2011), show the range of masses 0.8-5 $M_{\odot}$. The frequency of Li-reach objects among these type stars is very low.

The Li-rich stars pose the new questions. Koch et al. (2011) concluded that new results about high Li-content in dwarfs are not easily understood in the frame of simple evolutionary mechanisms. They found very high abundance of lithium, namely $logN$(Li)=4.21, in the atmosphere of super-Li turnoff dwarf in the metal-poor globular cluster with the age of 12 Gyr (Koch et al., 2012; Koch et al., 2011). Earlier a dwarf with $logN$(Li)=4.29 was discovered in the young open cluster NGC 6633 (the age is only 700 Myr) by Deliyannis et al. (2002).

The investigation of lithium abundances in magnetic stars began in the 60th of the former century and this problem is still not clear. It is possible to point papers by Wallerstein (1965), Wallerstein & Merchant (1965), Wallerstein & Conti (1968), Wallerstein (1968), Gerbaldi et al. (1995), Faraggiana et al. (1986), Polosukhina et al. (1999, 2000), Shavrina et al. (2000, 2001, 2003, 2004, 2005a, 2005b, 2009), Drake et al. (2005), Kochukhov et al. (2004), Kochukhov (2008), etc. The list can be continued.

For two MCP stars HR7575 and γ Equ Wallerstein (1965) and Wallerstein & Merchant (1965) found the ratio ^{6}Li/^{7}Li=0.5 and the Li abundance $logN$(Li)=3 (in the scale $logN$(H)=12). These authors concluded that some MCP stars show a higher lithium content, than that of some F and G stars. It was pointed that the highest content of ^{6}Li isotope is observed when the ratio of ^{6}Li/(^{7}Li+^{6}Li) is in the range from 0.19 to 0.47. These high values of the ^{6}Li/^{7}Li ratio for MCP stars can shed light on the possible physical mechanisms of production and preservation of both isotopes, probably indicating the spallation production.

An important remark of Wallerstein (1965) is that the abundance of ^{6}Li is significantly higher in MCP stars and it surely indicates on the local lithium production, but the author can not prove that the spallation has occurred on the stellar surface.

It is important to note that Wallerstein & Conti (1968) were unable to find lithium lines in other six investigated Ap stars. These authors supposed that lithium isotopes are synthesized on the stellar surfaces, but the relation to other spectroscopic peculiarities of Ap stars, especially to the stars without lithium, was not understood.

Later a possibility of nucleosynthesis by spallation reactions for Przybylski's star (HD101065, the prototype of roAp stars) was theoretically shown by Goriely (2007). Goriely was the first who studied the interaction of the stellar photosphere material with the flux of high energy particles. The result was the production of heavy elements in stellar atmospheres. The observed abundance pattern of Przybylski's star (including the possible actinides with short decay times) was obtained as a result of numerical fit of a net of spallation reactions in the atmosphere. Lithium isotopes also can be synthesized in these reactions.

Warner (1966) was the first who noted the presence of lithium in the Przybylski's star and estimated the isotopic ratio ^{6}Li/^{7}Li=0.3. Shavrina et al. (2003) made the detailed spectrum synthesis of this star at the wavelength of lithium doublet 6708 Å. It has been shown that lithium is present in a complex blend and the abundance of lithium is 3.1 dex (in the scale $logN$(H)=12). The isotopic ratio ^{6}Li/^{7}Li was found to be close to 0.3. Note that for freshly synthesized lithium in cosmic rays this ratio is higher and equal to 0.5-0.8 (Knauth et al., 2003).

Faraggiana et al. (1986) using high resolution spectrum of the Li 6708 Å region, concluded, that there is no correlation between the intensity of 6708 Å feature and the other properties of MCP stars. They resumed that the accurate theoretical model of lithium production is absent, so all situations are possible and the mechanisms of Li synthesis remain fully unidentified.

Shavrina et al. (2009) evaluated the lithium abundance in the atmosphere of HR465 as $logN$(Li)=5.4 in the phase of enhanced lanthanides (the spectrum was observed in 2004, Bs 1500 Gs), which is 2 orders of magnitude higher than the cosmic lithium abundance. In the phase of enhanced lines of chromium and even higher magnetic field value (Bs=4500 Gs) the lithium line is not detected. Remember that HR465 has period of spectral variability of 23 years, when the strong lines of chromium in the spectrum of this star are changed by strong lines of lanthanides.

The method of modelling of the Li line red asymmetry was proposed by Shavrina et al. (2005) for γ Equ (T$_{eff}$=7750 K, logg=4). Later Shavrina et al. (2006) studied the lithium abundance and the isotopic ratio ^{6}Li/^{7}Li in several roAp stars with narrow lines.

For the star HD137949 the errors in Li abundance value due to uncertainty of model atmosphere parameters were studied. So, for the models with effective temperatures and surface gravities equal to $T_{\rm eff}$=7750 & $\log$ g=4.5, $T_{\rm eff}$=7500 & $\log$ g=4.5, and $T_{\rm eff}$=7500 & $\log$ g=4.5, the values of lithium abundance were found as $logN$(Li)=4.1, 3.6 and 3.9 respectively.

One of the interesting results of this study was the red asymmetry of the lithium line Li 6708 Å for γ Equ in the spectra obtained with short exposures. It appears to be possible to fit the observed profile for 6708 Å line in two ways, the first is to increase the isotopic ratio ^{6}Li/^{7}Li, the second is to decide that the profile could be formed in the matter flow falling on the star, and to shift the profile in accordance with the observed radial velocity.

We constructed the synthetic profiles of Pr III 6706.7 Å and Li I 6708 Å lines for γ Equ in two ways. The first: the red asymmetry of lithium line profile was modelled by enhanced ^{6}Li abundance. The best fit to spectra observed at Nordic telescope with spectral resolution R=170000 was reached with $v \sin i$ =8 km s^{-1} and ^{6}Li/^{7}Li=0.5.

The second way is to explain the red asymmetry by fall of lithium formation layers on the star after sudden kicking upward due to shock wave (Shibahashi et al. 2004). Authors of this paper showed that the line profile variations show the monotonic blue-to-red motion only for the lines formed in the high atmosphere near the magnetic polar regions. The results are illustrated by Fig. 1.

In terms of our model of MCP stars as a binary system with NS such approach would be consistent with reality: in certain positions of binary system, we can observe both the incident flux of high-energy plasma and the magnetic pole region, as the main place of the lithium production. Fig. 2 shows the model of MCP star as a binary system with NS.

The proposed hypothesis of MCP stars origin is consistent with the fact that available observations of Li-rich MCP stars clearly detect the falling flux of matter on the pole regions of the stars. Is this mechanism responsible for the observed red asymmetry in γ Equ and other roAp stars is a problem for future studies and discussions, but the red asymmetry is one more detail which supports the picture of our model of the MCP star phenomenon (Gopka & Ulyanov, 2008; Gopka et al., 2010). In this case the problem of ^{6}Li origin will disappear.

3. The origin of binaries with MCP star and neutron star companions.

The question of the origin of lithium in the atmospheres of MCP stars is a part of a larger problem of the MCP stars origin. Where is the switch that distributes the stars on the MS as 80 percents without anomalies in their atmospheres and 20 percents with an abnormal chemical composition?

In other words, where to find such a large number of supernovae to each MCP star? Our point of view is that the better understanding of the star formation is necessary. Let's consider the observations in the areas of star formation.

Brown (2001) analyzed the double (and multiple) systems in the young association Sco 2 and found that the systems with B0-B3 primaries are more frequent than the systems with B4-B9, A, and F primaries.

What does it mean? What is the possible way to interpret it and how it relates to the origin of MCP stars? The answer is: directly.

Our model answers the question about the appearance of a large number of protostars with masses close to the presupernova masses on stage of formation of double systems because this process may occur in dense star-forming regions. Naturally, it can happens in the next way.

The evolution of more massive protostars in a binary system should be faster, so the size of the primary star should decrease, and the size of the secondary companion appeared to be larger than the primary one because of the slow contraction. The secondary companion should be closer to the filling of its Roche lobe.

As the birthplace of stars is characterized by increased the density of dust, the filling of the Roche lobe for the second component in the initial stage of star formation is almost guaranteed. Under the assumption of the Roche lobe filling for less massive protostar companion the exchange of mass through the Lagrange point from less massive star to more massive star should start.

As a result, the evolution of more massive primary protostar is accelerated even more, while the less massive star should lost loses its mass and the rate of compression. The primary star in such binaries works as a "vacuum cleaner".

The process of "vacuum cleaner" changes the evolution of the most massive binary systems and changes (increases) the population of binaries with more massive primaries as it is illustrated by Fig. 3.

That is why the relative number of binary systems with massive primary companions should increase in comparison with the fraction of binaries with less massive primaries.

The second consequence of the "vacuum cleaner" is that the double systems of intermediate mass at the stage before MS are formed as a result of mass exchange in the double systems with large mass differences.

Sirotkin (2004) published the results of numerical simulation of mass exchange in binary systems and found that in the case of less massive component is closer to fill its Roche lobe, the mass transfer can occur in a dynamic time scale. These calculations support our hypothesis and allow to point the duration of effective "vacuum cleaner" to be of the same order as a dynamic time scale. That is why the results of this process can be easily detected even for young binaries.

The third consequence of "vacuum" process is that the "greedy" stars in the binary systems with the masses of primaries of 8-10 $M_\odot$ in the progenitor state (it corresponds to spectral type near B2), quickly evolves through the type II supernova explosions to neutron star remnants.

A fourth consequence of the "vacuum cleaner" process is that the number of binary pairs with NS and low-massive stars (MCP stars) on the MS will be more numerous on the MS than the number of pairs with massive primaries. This is confirmed by observational data obtained by Kochukhov & Bagnulo (2006). These low-mass stars previously lost their masses to more massive companions. At the moment of explosion of more massive companion it lost almost 6 $M_\odot$, and enriched the atmosphere of low-massive star and the interstellar medium by r-process elements.

One of the results of supernova explosion is also the redistribution of angular momentum of the system.

The rotation of future MCP star should be braked, as it follows from the observations of rotational velocities of modern MCP stars.

Artemenko (2012) points the observational evidence of effective mechanism of braking the rotation of stars with observed lithium at the early evolutionary stages in the Taurus-Auriga region of star formation. T Tauri type stars in the mass range 0.3-3.0 $M_\odot$ show approximately constant angular velocity during the first 10 million years of evolution. It outlines the existence of effective braking mechanisms which prevents the increase of rotational velocity with the compression of the star.

4. Conclusion: the consequence of our supposition of lithium origin in binary stars.

The problem of lithium origin in stellar atmospheres of stars today is one of the unsolved problems of astrophysics. We propose to have a look at this problem from the point of view of the most promising physical mechanism of lithium production, namely the synthesis of this element in the binary systems of intermediate mass stars at the early evolutionary stages.

Ambartsumian (1958) was the first who showed that the stellar associations are non-stable systems, consist of many young O, B0, B1, B2 spectral type hot giants, named B associations. It was discussed by later investigations, as an example Tetzlaff et al. (2011) published a catalog of runaway stars which were lost by these associations.

The explanation of mechanism of stellar formation in OB associations, as well as in the case of T-associations needs improvements. Binns et al. (2007) made the review of main properties of OB associations and tried to explain the origin of galactic cosmic rays by supernova explosions in these stellar complexes.

The distribution of binaries similar to that found by Brown (2001) is one the main characteristics of B associations. Based on the observed distribution of binaries obtained by Brown (2001) we did acsent on the evidence of overpopulation of binaries with primordial stars in pre-supernova state.

We suggest the evolutionary scenario of binary system with initial massive OB component and less massive component. The massive component attracts the matter from less massive component and after increasing of its mass accelerates the evolution and goes to Supernova II type explosion and to the neutron star. The atmosphere of less massive component should be irradiated by the high-energy particles from neutron-star component. The spallation reactions in this relativistic flux can product lithium.

The similar systems were observed by Martin (1994), Martin et al. (1994) and Rebolo et al. (1994, 1995). These authors detected binary systems with compact objects such as neutron stars and Li-rich objects. For system Cen X-4 containing a neutron star and K-type star with T_{eff}=4250 K, the equivalent width of lithium line is 480 mÅ corresponds to lithium abundance $logN$(Li)=3.3 dex (Rebolo et al. 1994, 1995).

This system belongs to the subclass of low mass X-ray binaries. The characteristic feature of such subclass is that during the period of several years or some weeks one can observe strong outbursts reaching the peak of X-ray luminosities of about $5 \cdot 10^{38}$ $erg\ s^{-1}$. At this time we can observe both lithium absorption and H_α emission in the photosphere of secondary component.

Fujimoto et al. (2008) theoretically examined the production of Li and the high isotopic ratio ^{6}Li/^{7}Li on the surface of low-mass secondary through the spallation of C,N,O nuclei by hot neutrons (>10MeV) in the transient soft X-ray radiation of a neutron star.

The supposed scenario have very important consequences from the point of view of stellar evolution theory. Let us point few of them.

1. The formation of lithium in MCP star can be explained by spallation reactions in the matter flow moving toward the star (namely to the magnetic poles). It is naturally interpreted in the framework of MCP stars phenomenon model proposed by Gopka & Ulyanov (2008) and Gopka et al. (2010).

The main counter-argument is improbable large number of supernovae, which then should evolve to NS. In our explanation of the phenomenon of MCP stars, we interpret the observational data of binary systems in stellar formation regions, which could explain the increased frequency of systems with companions at the stage of presupernova formation. The birthplaces of these systems are the OB associations (Ambartsumian, 1958) with overpopulation of B-type stars.

2. An important result of our consideration is the understanding of the nature and the evolutionary status of Herbig-AeBe stars as binary systems and progenitors of MCP stars. This is clear from the upper scenario. Fig. 1 by Gopka et al. (2010) and Fig. 1 by Grinin & Tambovtseva (2011) are similar.

According to Martin (1994) in order to detect the binary companions the lithium 6708 Å resonance doublet could be used. Its equivalent width is the function of effective temperature of of the star (when it is assumed the mass of 1.5 $M_\odot$ for invisible star). The equivalent width increases from 4 to 147 and 192 mÅ if the temperature decreases from 18000, 12000, and 9000 K (spectral classes B2, B8, and A2) respectively. The spectral lines with above pointed strengths can be easily detected for stars with spectral types B8 and later.

3. The binary systems with NSs in which the mass of optical stars are less than 5 $M_\odot$ are most likely formed as the result of the decay of triple or more multiple systems. As it was shown by Dewey & Cordes (1987) and Hinkle et al. (2005) the binary

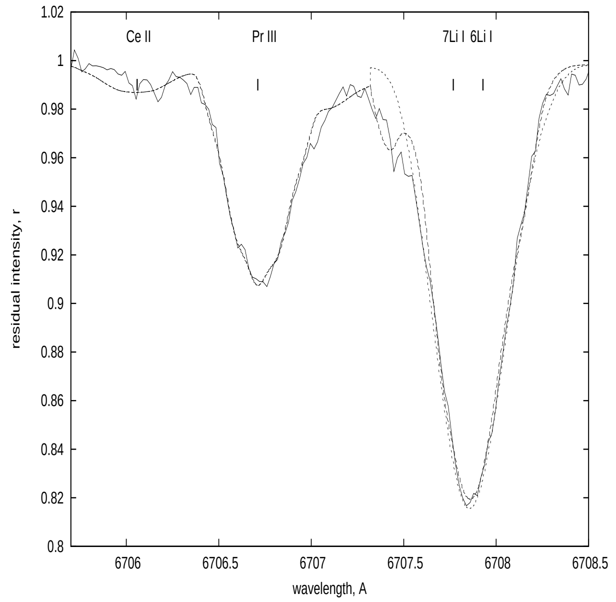

Figure 1: The spectrum of γ Equ in the vicinity of Li I 6708 Å line. Solid line - observations, NORDIT telescope. Dashed line - synthetic spectrum calculated with log N(Li) =-8.40, ^{6}Li/^{7}Li =0.5, vsini=8 km s^{-1}. Dotted line - synthetic spectrum calculated with ^{6}Li/^{7}Li =0.08 (solar value), vsini=3 km s^{-1}. and red shifted by $\Delta\lambda$=0.065 Å (2.9 km s^{-1}).

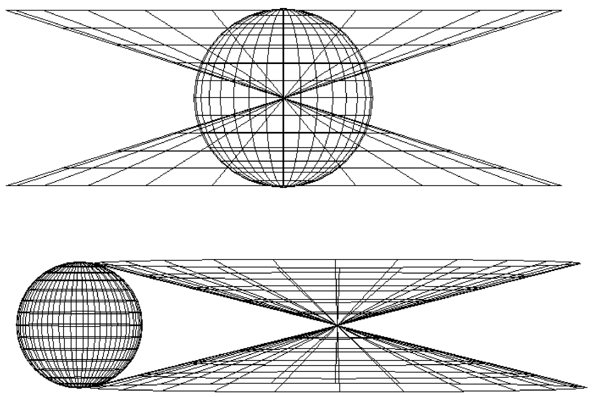

Figure 2: The supposed model of MCP stars as a stable magneto-dynamic configuration: star-neutron star at early stages of stellar formation (Gopka et al., 2007, 2008, 2010). This model confirms the observed kinematics of the circumstellar outflow for both progenitors of MCP stars on the stage before MS (Herbig AeBe objects), and for stars of T Tau type. The position of NS is the point of intersection of two cones. Two panels show the double system at different phases.

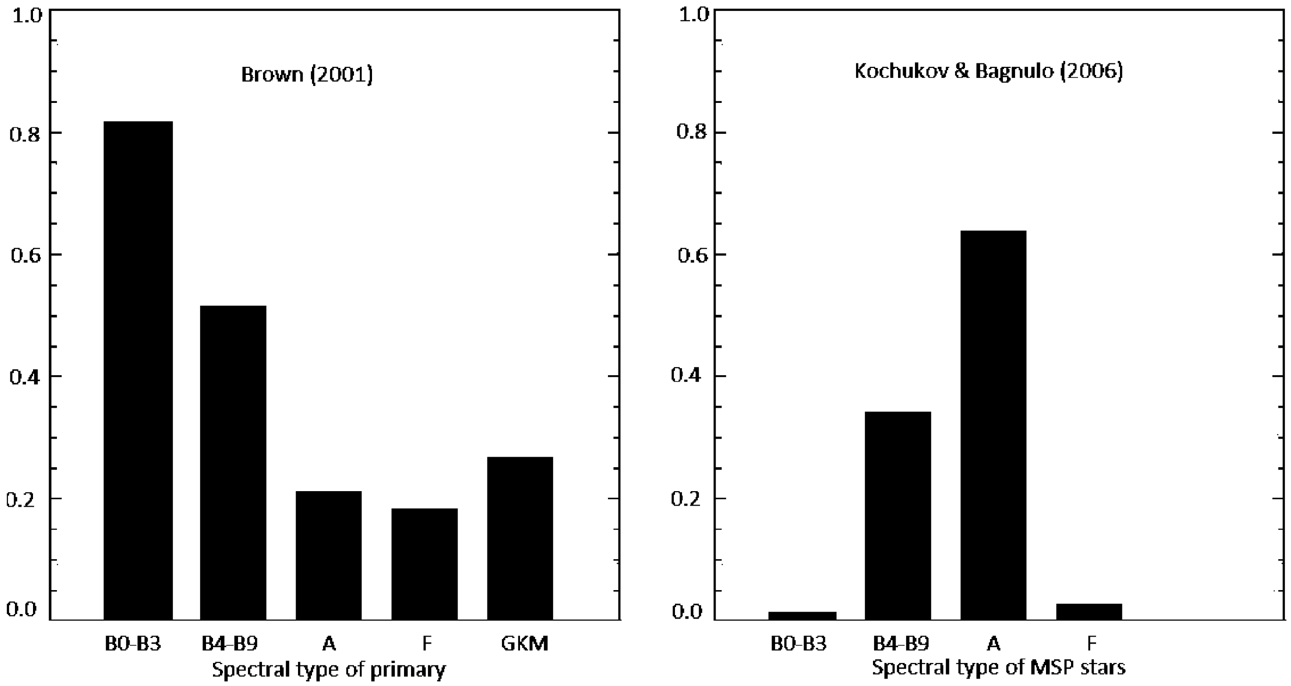

Figure 3: Upper panel: the distribution of observed fraction of stellar systems as ratio of the number of multiple systems to the total number of systems as a function of spectral type of the primary (Brown, 2001). Bottom panel: the distribution of MCP stars as a function of spectral type. The data are taken from Kochukhov & Bagnulo (2006).

system remains binary after the supernova explosion only if its mass is more than one half of the total mass of the binary system before the explosion. For example, the system T Tauri is a gravitationally bound multiple star with the total mass of about 6 $M_\odot$ (Kohler, 2008).

Li-rich RGB giants and AGB supergiants can be considered as probably dissipated triple or multiple systems with NS.

4. The lowest limit of the optical star mass in this scenario is not confined which has been confirmed by observational data.

The proposed mechanism of lithium formation needs additional observational confirmation.

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