SOME STATISTICAL PICTURE OF MAGNETIC CP STARS EVOLUTION

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ABSTRACT. We discuss some statistical results on the evolution of magnetic CP stars in the framework of the supposition about their binary nature.

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

1. Introduction

It is well known that CP stars of upper main sequence can be divided on magnetic chemically peculiar stars (MCP stars or Bp-Ap stars) and non-magnetic (Hg-Mn stars and Am-Fm stars). Hg-Mn stars have temperatures more than 10 000 K, Am-Fm stars are cooler than 10 000 K. Some authors concluded that there exists a relationship between Hg-Mn stars and Am-Fm star (Adelman, Adelman & Pintado, 2003).

MCP stars are overlapped with Hg-Mn stars in the region of the hot temperatures of HR diagram and with Am-Fm stars in the region of the cooler temperatures. Evolutionary state of chemically peculiar (CP) stars of upper main sequence is the subject of some working hypotheses and numerous debates. The new observational facts on these stars cause more and more questions. Some reviews of specialists include the list of unsolved problems concerning this topic. Thus, it should be stated that origin of CP stars is not completely understood at present.

The MCP stars show more complicated phenomena among CP stars (Rudiger & Scholz, 1988). Now we do not have a hypothesis that could be able to explain an origin of anomalies of their chemical abundances and their kinematics, as well as an origin of their magnetic field. Some characteristics of MCP stars show that they do not support old ideas about chemical evolution. Some existing inexplicable facts (Gopka et al., 2004, Gopka et al., 2006) force us to suppose that MCP stars are the binary systems consisting of the two intermediate-mass stars experienced mass transfer between the originally less massive star and its more massive companion in the state of the pre-supernova explosion with mass near to $8M_{\odot}$. As a result, the present day MCP star was permanently influenced by the supernova remnant (neutron star, NS) and some its properties were formed under this influence (Gopka, Ulyanov & Andrievsky, 2008a,b). Such a model is supported by the results of the numerous investigations of MCP stars from IR to X-rays observations. The evolutionary change of the MCP star properties with mass reflects the change of the system's mass ratio (both for visible and invisible neutron star companion, Gopka, Ulyanov, Yushchenko et al., 2010).

2. On the increasing of rotational period of the low-mass MCP stars in the framework of model MCP star binarity

For some MCP stars an intensive mass-loss from magnetic poles is known. As an example, for the helium-strong stars σ Ori E and HD 37017 Drake et al. (1994) estimated mass-loss rate is near 10^{-9} $M_{\odot}$ per year with observed significant outflow velocity of about 600 $km\ s^{-1}$. Such a phenomenon can be easily understood in our phenomenological model of MCP stars (see Fig. 1). Important consequence of this conclusion is supported by statistical results of an increasing of the rotational period for low-mass MCP stars.

Fedorova (1997) investigated the qualitative changes of the low-mass X-ray binary evolution. When the matter is accreted by the low-mass star, the hard radiation occurs.

Fedorova obtained the theoretical dependence of the semimajor axis size upon the companion masses supposing that all accreted matter is lost by the X-ray binary. Fig. 1 schematically shows how this process works in binary system where one companion is NS.

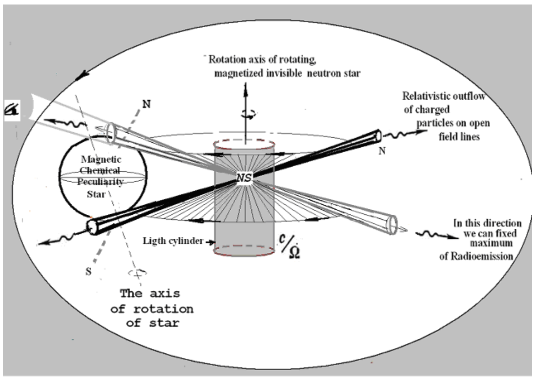

Figure 1: Schematic model of MCP star as a binary system with neutron star companion.

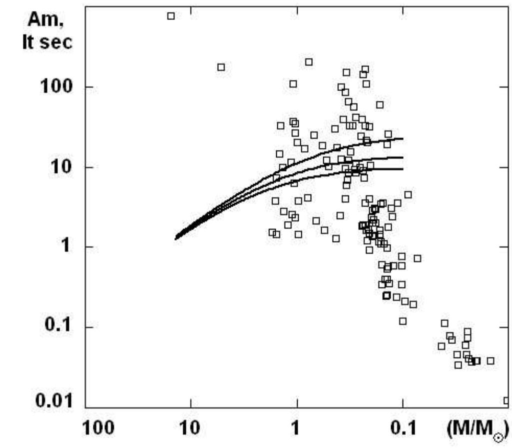

Figure 2: Distribution of the semimajor axis of the binary system (A_m) depending on the median mass of the star-companion. Solid lines illustrate qualitative behavior under the Jeans mode conditions corresponding to $0.8M_\odot, 1.4M_\odot, 2.0M_\odot$ of NS mass (from the top to bottom respectively).

Some part of the matter of MCP star falls onto NS, while some part is removed away from the system due to magnetic stellar wind. This scenario is in the base of our assumption that MCP star is a donor and NS is an acceptor.

When so-called Jeans mode conditions are realized in the binary system, the change of the system semimajor axis (A_m) due to the mass-loss is given by the follow equation:

$$(\frac{dA_m}{dt})_{los} = \frac{-A_m}{(M_{star} + M_{ns})} \cdot (\frac{dM_{star}}{dt})_{los}, \qquad (1)$$

where A_m is the semimajor axis, M_{star} is the mass of the MCP star, M_{ns} is the NS mass.

Integration of this equation produces so-called Jeans invariant:

$$A_m \cdot (M_{star} + M_{ns}) = const. \qquad (2)$$

We simulated the dependence of the semimajor axis size upon the mass of MCP star in an interval from $8M_\odot$ to $1.6M_\odot$. We found that semimajor axis of the binary system increases if MCP component has the mass in the range $1.6M_\odot$ - $8M_\odot$ and NS component has the mass near to $1.35M_\odot$. The semimajor axis of the close binary system increases more rapidly for the MCP stars in combination with lower mass NS (Fig. 2). This qualitatively confirms the statistical dependence obtained by Kochukhov & Bagnulo (2006). According to these authors rotation braking (an increase of the rotational period) takes place within the range of small masses of the star which is companion of NS.

We also used observation data from ATNF pulsar catalogue (atnf.csiro.au). Among 1879 pulsars that are present in the ATNF pulsar catalogue only 141 PSRs are the binary system components. As a rule their non-relativistic star-companions are the low mass objects. Only 18 system show the star-companion masses in the range $8M_\odot$ to $1.6M_\odot$ (that is appropriate for MCP star masses).

For the low-mass star-companion, when $M_{star} << M_{NS}$, the semimajor axis of the system does not increase even in the case of a strong stellar wind from the donor (Fig. 2).

We give the orbital period distribution as a function of the mass of the non-relativistic star-companion in Fig.3.

One can assume that for the binary systems in the range of star masses from $0.3M_\odot$ to $2M_\odot$ an increase of the orbital period can occur (Fig. 3.). Unfortunately, in the ATNF catalogue there is some deficiency of the pulsar companions in the mass range from $2M_\odot$ up to $8M_\odot$ (it is MCP mass range), and this prevents complete statistical analysis.

Fig. 3 shows that the behavior with the Jeans mode condition corresponds to another range of masses of the star-companion: $M_{star} \in [0.3M_\odot, 2.0M_\odot]$.

3. Conclusion

We have adopted the model of MCP stars as a close binary system with undetected NS as one of the components. This model explains many properties of MCP stars, in particular: secular decrease of the semimajor axis of the binary systems, statistical distribution of the MCP star orbital periods as a function on their masses, and some other properties.

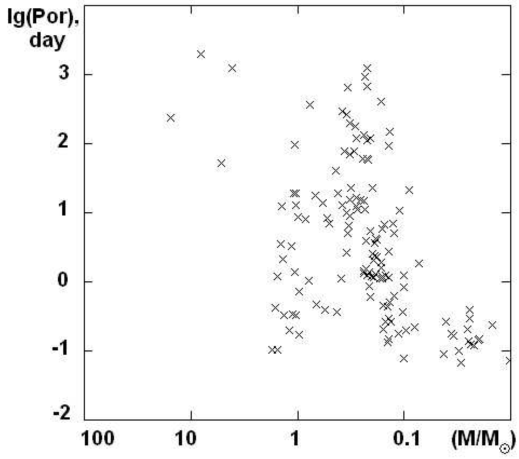

Figure 3: Distribution of the orbital periods (P_{or}) as a function of the star-companion median mass ($M/M_{\odot}$).

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