SPECTROPOLARIMETRY AND INFRARED PHOTOGRAPHY OF MAGNETIC WHITE DWARFS: VACUUM POLARIZATION EFFECT OR MAGNETIC CIA?

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Abstract

We present brief review of two probable physical mechanisms that can explain the results of photometric and spectropolarimetric observations of magnetic white dwarfs: vacuum polarization effect into a strong magnetic field and, so-called, magnetic collision induced absorption (magnetic CIA). Both mechanisms provide observed rotation of polarization ellipse and suppression of spectral energy distributions. The results of spectropolarimetric observations of magnetic white dwarfs made at Russian BTA-6m and the results of the near infrared photometric observations with Russian-Italian AZT-24 telescope located at Campo Imperatore are also presented.

1 Introduction

We present the results of spectropolarimetric and infrared photometric observations of a number of isolated magnetic white dwarfs. The spectropolarimetric observations were made at russian 6-m telescope (BTA-6m). The IR photometry of magnetic white dwarfs were made at AZT-24 telescope of Central Astronomical Observatory at Pulkovo, that is now installed at Campo Imperatore, Italy. The IR observations were made in frame reference of a program of Pulkovo, Rome and Teramo Observatories. We found deficiency of IR fluxes of some magnetic white dwarfs: GrW+70.8247, G99-47, WD1658+441, G240-72, GD229.

Spectropolarimetric observations of GrW+70.8247 and GD229 by BTA-6m showed the rotation of polarization ellipse, the polarization ellipse of GrW+70.8247 being rotated by 90°. We analyzed the optical and NIR continuum polarization of five magnetic white dwarf stars observed by West, 1989. We consider both effects of the polarization ellipse rotation and suppression of infrared fluxes for highly magnetized dwarfs as an indirect evidence of vacuum polarization effect though the collision induced absorption (CIA) into magnetized atmosphere can also explain effect of infrared fluxes suppression.

2 Short review of vacuum polarization effect by a magnetic field and its astrophysical manifestations

The high magnitudes of magnetic fields of neutron stars and white dwarfs give rise to new effects in the traditional physical processes involving interaction of radiation with matter. One of most important effects is so-called polarization of electron-positron plasma by a strong magnetic field. Just as in an ordinary magnetized plasma the photon propagation in a magnetized vacuum is also described in terms of two normal modes (waves) with different polarization states and refractive indices $n_{1,2}$. The polarization of the vacuum itself is due to virtual $e^+e^-$ pairs and becomes significant when the magnetic field strength
\[ B \geq B_C = \frac{m_e^2 c^3}{e \hbar} = 4.414 \times 10^{13} G \]  

(1)

where \( B_C \) is the magnetic field value at which the electron cyclotron energy \( \hbar \omega_B = \frac{\hbar c B}{m_e} \) is equal to electron rest mass energy \( m_e c^2 \). Nevertheless it appeared that the vacuum polarization must be taken into account in the analysis of many radiation processes even if the magnetic strength \( B \ll B_C \).

2.1

In his excellent review Adler, 1971, presented the expressions for refractive indices of normal modes in the magnetized vacuum at \( B < B_C \) and \( \hbar \omega < m_e c^2 \):

\[ n_1 = 1 + \frac{7}{90 \pi \hbar c} \left( \frac{B_\perp}{B_C} \right)^2; \quad n_2 = 1 + \frac{2}{45 \pi \hbar c} \left( \frac{B_\perp}{B_C} \right)^2 \]

(2)

where \( B_\perp = B \sin \theta \) and \( \theta \) is the angle between the photon wave vector and the magnetic field directions.

The normal modes in this case are linearly polarized, the electric vector of mode 1 oscillating in the magnetic field and wave vector plane and that of mode 2 oscillating in the perpendicular plane. Vacuum polarization effect modifies the dielectric property of the medium and the polarization of photon modes propagated in a magnetoeactive plasma, thereby altering the radiative scattering and absorption opacities (see Pavlov and Gnedin, 1984, and Meszaros, 1992, for reviews).

The existence of quite strong magnetic fields of neutron stars and white dwarfs provides possibilities to search the vacuum polarization effects in astrophysical observations of compact objects. Novick et al., 1977, were the first who have considered the possibility to measure of the phase shift between the vacuum polarization modes in radiation of neutron stars. Pavlov and Gnedin, 1984, were the first who mentioned the importance of the vacuum polarization effect and for magnetic white dwarfs. The following step was to analyze the interaction of radiation with a "mixture" of vacuum and plasma in a strong magnetic field (Gnedin et al., 1978, Pavlov and Gnedin, 1984). The modern detailed analysis of this situation was made in the series of papers by Lai and Ho, 2002, 2003, Ho and Lai, 2001, 2003, 2004, Ho et al., 2003.

2.2

The first important step for estimation of the vacuum polarization effect is to calculate the magnitude of the phase shift \( \varphi \) between the two normal waves due to the difference in their phase velocities:

\[ \varphi = \frac{\omega}{c} \int |n_1 - n_2| dl = \frac{l}{5 \times 10^{-7} cm m_e c^2} \left( \frac{\hbar \omega}{m_e c^2} \right) \left( \frac{B_\perp}{B_C} \right)^2 \]

(3)

For neutron stars (NS) at \( \hbar \omega = 1 K eV, \ B_\perp = 4 \times 10^{12} G \) the magnitude \( \varphi \sim 1 \) after transversing a very small \( l = 0.3 mm \ll R_{NS} \) distance (\( R_{NS} \) is a radius of NS). It means that the radiation of NS will be partially depolarized via the so-called Cotton-Mouton effect, which is the analog to the familiar Faraday effect for a medium in which the normal modes are polarized linearly. In this case the polarization ellipse "oscillates" around the direction of polarizations of the normal waves, changing the ratio of the axes and the direction of rotation of the electric vector in an oscillatory manner. It may lead to a perfect depolarization of circularly polarized radiation from a NS and to partially depolarized the linearly polarized radiation (except the cases when the electric vector lies in the \( KB \) plane or at right angle to it).

For WDs:

\[ \varphi = 1.2 \left( \frac{\hbar \omega}{3 eV} \right) \left( \frac{B_\perp}{4 \times 10^8 G} \right)^2 \left( \frac{R_{WD}}{10^9 cm} \right) \]

(4)

in the optical spectral range. The situation for WDs looks better because of there is no complete depolarization in this situation. In a result the possibility arises to search the vacuum polarization effect in the optical spectral range via the polarimetric observations.
Especially interesting effects arise if one analyzes the interaction of radiation with a "mixture" of vacuum and plasma in a strong magnetic field due to the different types of the anisotropy in plasma and vacuum. These effects arise in the region where the contribution from the vacuum to polarization of normal waves is of the same order of magnitude as that from the plasma. Specifically there are two values of photon energy at which the contributions of the vacuum and plasma on the linear polarization of normal modes cancel out each other. This case is called by "vacuum resonance". One of these specified energies lies in the region of cyclotron energy $\bar{\omega}B$ and corresponds to the vacuum resonance number density

$$N_{V,1} = \frac{1}{60\pi^2} \left( \frac{m_e c}{\hbar} \right)^3 \left( \frac{\hbar \omega_B}{m_e c^2} \right)^4 \approx 3 \times 10^8 \left( \frac{B}{4 \times 10^8 G} \right)^4 \text{cm}^{-3}$$

(5)

Another "vacuum resonance" phenomenon can be existed in the region outside the cyclotron energy if only the vacuum resonance number density is to be:

$$N_{V,2} = 6 \times 10^{19} Y_e^{-1} \left( \frac{E}{1 \text{KeV}} \right)^2 \left( \frac{B}{10^{12}} \right)^2 \text{cm}^{-3} \text{ for NS}$$

$$N_{V,2} = 10^8 Y_e^{-1} \left( \frac{1 \mu m}{\lambda} \right)^2 \left( \frac{B}{3 \times 10^8} \right)^2 \text{cm}^{-3} \text{ for WD}$$

(6)

where $Y_e$ is an electron fraction. In the completely ionized plasma $Y_e = \frac{Z}{A}$.

The location of the vacuum resonance photon (wavelength) at a given number density is:

$$NS : E_V = 0.24 \left( \frac{Y_e N_V}{6 \times 10^{19}} \right)^{1/2} \left( \frac{10^{12}}{B} \right) \text{KeV}$$

$$WD : \lambda_V = 0.283 \left( \frac{10^8}{Y_e N_V} \right)^{1/2} \left( \frac{B}{3 \times 10^8} \right) \mu m$$

(7)

Neutron stars and white dwarfs are characterized by different situation. For neutron stars the vacuum resonance lies into the deep layers atmosphere (photosphere) of a star (Lai and Ho, 2002, 2003, Ho and Lai, 2002, Ho et al., 2003, Potekhin and Chabrier, 2003, 2004). For magnetic WDs the number density value $\leq 10^8 \text{cm}^{-3}$ lies only in the most upper layer of the atmosphere ($N_V \sim 10^8 \text{cm}^{-3}$ corresponds to the distance $l \sim 20H$, where $H$ is the density scale height if only the electron fraction is not extremely low) or into the plasma environment (coronas or plasma envelopes produced by the pressure of cyclotron radiation, see Zheleznyakov, 1997, Bespalov and Zheleznyakov, 1990, Zheleznyakov and Serber, 1991). Namely Zheleznyakov and his colleagues showed that the pressure of cyclotron radiation in the magnetic WD photosphere can be compared and even can surpass the gravity force. Then hydrostatic equilibrium of plasma on magnetic white dwarfs can be disrupted by large radiation pressure and the radiation-driven ejection from the white dwarf photosphere can be possible. Zheleznyakov and his colleagues called this situation "radiation discon" object (see fig.8,9 from Zheleznyakov, 1997, book). They claimed that the structure of plasma envelopes of magnetic WDs with the effective temperature $T_e \geq 10^4 \text{K}$ is drastically different from the structure of thin hot corona. If the plasma density of such an envelope is large enough, it can strongly distort the photosphere spectrum and give rise to the broad and deep depressions bands in the observed radiation spectrum.

Also one needs to take into consideration that the influence of strong large scale magnetic fields on the structure and temperature distribution in WD atmospheres. For example, Fendt and Dravins, 2000, displayed that magnetic fields may provide an additional component of pressure support, thus inflating the atmosphere compared to non-magnetic case. They found quantitatively that a mean surface poloidal field strength 100 MG and a toroidal field strength of 10 MG may increase the scale height at least by factor 10.

2.4

Let us now consider the basic effects arising if photons are propagating across the vacuum resonance. The first main effect is changing the orientation of the polarization ellipse. It can rotate by the definite angle $\leq 90^\circ$. The magnitude of the rotation angle is dependent on the peculiarities of the plasma region.
at the vacuum resonance because the orthogonality of normal modes in the resonance region may be violated. The rotation of the polarization ellipse is result of resonant conversion of photon modes across the vacuum resonance (Gnedin and Pavlov, 1984, Lai and Ho, 2002, 2003).

Lai and Ho, 2002, investigated this process in detail and showed that the physics of this mode conversion is analogous to the Mikheyev-Smirnov-Wolfenstein mechanism for neutrino oscillations. They have demonstrated that the conversion process is more effective if the adiabatic condition is fulfilled at resonance. The last one requires for MWD:

\[ E_{\text{con}} \geq 1.5eV \left( \frac{10^9 \text{cm}}{R_{WD}} \right) \] (8)

In this case the adiabatic probability of conversion is \( P_{\text{con}} = 1 - \exp \left( -\frac{\pi}{2} \frac{E}{E_{\text{con}}} \right) \). The jump probability can be calculated with the Landau-Zener formula: \( P_j = \exp \left( -\frac{\pi}{2} \frac{E}{E_{\text{con}}} \right) \) (Lai and Ho, 2002, 2003). This process is accompanied without the essential conversion of photon modes.

The second important for observations effect is the suppression of Rayleigh-Jeans region of the black body spectrum and, partially, the proton cyclotron lines for neutron stars and other spectral lines (Ho and Lai, 2003). For magnetic WDs (MWDs) the essential modification of the electron cyclotron lines is realized because in the “vacuum+plasma” mixture the ordinary wave acquires also cyclotron resonance and increases the cyclotron absorption (Pavlov and Gnedin, 1984, Zheleznyakov, 1997). In the Zheleznyakov radiation-driven disc model of MWD the increase of cyclotron absorption may strongly distort the photospheric spectrum and give rise to the broad and deep depression bands in the observed radiation from such radiation-driven disc (Zheleznyakov, 1997).

In conclusion of this section one can say that the vacuum polarization may produce the observable effects in the radiation from radiation-driven disc of a magnetic white dwarf.

3 Magnetic collision induced absorption by Rydberg states into magnetic white dwarf

Here we suggest the complete analogy to the vacuum polarization effect that may act in partially ionized atmospheres of MWDs. Our main idea consists of the fact that in partially ionized plasma also it may exist the resonance region where contribution to the dielectric constant from non- and ionized components may cancel out each other. Even in the non-magnetized plasma such situation may arise because the refractive index of this plasma is equal: \( n = 1 + 2\pi N_H \alpha_H - \frac{\omega_p^2}{\omega^2} \) where \( N_H \) is the density of a neutral component, \( \alpha_H \) is the polarizability of a single atom (molecule), \( \omega_p \) is electron plasma frequency.

For hydrogen non-magnetized plasma the resonance energy is \( E_R \approx 10eV \sqrt{\frac{N}{N_H}} \). In the strong magnetic fields of WDs and NSs the atoms, especially in their high excited states acquires non-spherical shape and may be oriented by a strong magnetic field.

Therefore we introduce, pure formally, for magnetized non-ionized plasma:

\[ n_1 = 1 + 2\pi N_a \alpha_{||}; \quad n_2 = 1 + 2\pi N_a \alpha_{\perp} \] (9)

where the polarizability \( \alpha_{||} \) corresponds to the case when the electric vector of the electromagnetic wave lies in the (KB) plane, \( \alpha_{\perp} \) corresponds the electric vector orientation perpendicularly to the (KB) plane.

Let us consider the case when \( \alpha_{||} > \alpha_{\perp} \). This case is namely realized in a strong magnetic field. Atomic structure is affected by strong magnetic fields. It is well-known (see, for example, the book by Dolginov et al., 1995), that the critical value of the field at which the essential reform of an atom becomes important is reached if the cyclotron energy \( h\omega_B \) is compared to the Rydberg energy. This condition implies a field strength:

\[ B > B_0 = \frac{Z^2 m_e^2 e^3 c}{h^3} = 2.35Z^2 \times 10^9 G \] (10)

If \( B \gg B_0 \), the magnetic forces acting on an electron of an atom dominate over the Coulomb forces, the transverse size of the atom becoming less than the Bohr radius and the transverse velocity of the electron becoming greater than its longitudinal velocity.
The Eq.(10) means that the Bohr radius of an hydrogen atom \( r_0 = \frac{a_0^2}{mc^2} \) becomes larger that the so-called the magnetic length \( a_m = (\frac{\hbar c}{eB})^{1/2} \) that is namely determined the transverse size of an atom. The atom acquires the ellipsoidal cigar shape instead of the typical spherically symmetric form.

The magnetic field strength (10) is rather high for the typical magnetic white dwarfs. Therefore the neutron stars are namely suitable targets for the investigation of the behavior of atoms and molecules in a strong magnetic fields (Dolginov et al., 1995, Potekhin and Pavlov, 1997, Potekhin and Chabrier, 2003, 2004, Ho et al., 2003).

However there can exist the situation when atoms become anisotropic and in the magnetic white dwarfs with the typical magnetic field strengths \( B \sim 10^6 \div 10^8 G \). Such situation is really existed if the atoms appear in strongly excited (Rydberg) states. For an atom in highly \( n \gg 1 \) exciting state its characteristic size is \( r_n \approx r_0 n^2 \).

For example, Bethe and Salpeter, 1957, give for the average radius of highly excited state:

\[
\langle r_n^3 \rangle = \frac{n^{2}}{8Z^4} [21n^4 + 35n^2 + 4] \rightarrow \frac{21}{8Z^3} n^6
\]

or for a hydrogen atom: \( \langle r_n^3 \rangle^{1/3} = (21/8)^{1/3} n^2 \)

Thus for an strongly excited atom the critical magnetic field strength (10) is

\[
B_0 \equiv \frac{1.7}{n^2} \times 10^9 G
\]

For the magnetic white dwarf GrW+70.8247 the pole magnetic field strength \( B_p = 3.2 \times 10^8 G \) and this value is the critical one if the hydrogen atom is found in the excited state with \( n > 3 \).

Now it is possible to get the total analogy of magnetic CIA to the vacuum polarization effect. Let us consider the case \( \alpha_\parallel > \alpha_\perp \) and suggest for the total analogy to the vacuum polarization: \( \alpha_\parallel/\alpha_\perp = 7/4 \).

Following to the analogy between birefringences of magnetized vacuum and magnetized highly excited atomic states, one can obtain from Eqs.(2) and (9) the relation:

\[
\left( \frac{B_\perp}{B_C} \right)^2 = \frac{180 \pi^2 \hbar c}{7e^2} \alpha_\parallel N_a
\]

In mixed hydrogen and helium gases, colliding pairs of atoms and molecules such as \( H_2 - H_2, H_2 - He, H_2 - Ne \) can be sources of, so-called, Collision Induced Absorption (CIA) opacity. Another source of CIA opacity is the origin of highly excited (Rydberg) states of atoms in the photosphere of a magnetized white dwarf, via also the collision process. The originated Rydberg states acquire a large dipole moment and therefore can produce strong absorption in infrared range of spectrum.

Collision induced infrared absorption was discovered by Welsh and associates in 1949 in an attempt to observe an infrared absorption band of oxygen dimers. In pure and mixed gases a great variety of collision induced absorption spectra is now known. Several review of experimental work have been published (see, for instance, Welsh, 1972, van Kranendonk, 1980, Borysow and Frommhold, 1985, and also the 1981 October issue of the Canadian Journal Physics which contained a special section devoted to collision induced phenomena).

The process of CIA have been intensively applicable to stellar atmospheres, especially to white dwarf atmospheres (Bergeron et al., 1995, Borysow et al., 1997, Rohrmann et al., 2002). Recent detail calculations of \( H_2 - He \) absorption coefficients are available from Jorgensen et al., 2000. Most up-to-date CIA opacities due to \( H_2 - H_2 \) have been calculated by Borysow et al., 2001, for 1000 < \( T < 7000K \) and frequencies between 20 – 20000cm\(^{-1}\). \( H - He \) CIA data are now available for temperatures 1500 – 10000K and frequencies 50 – 11000cm\(^{-1}\).

Chemi-ionization and chemi-recombination processes in low temperature layers of white dwarf atmospheres are very important for producing helium atom Rydberg states population in weakly ionized layers of helium-rich DB white dwarfs (see Mihajlov et al., 2003). But all these processes (CIA, chemi-ionization and chemi-recombination) have been considered only for non-magnetized white dwarf atmospheres.

We present here only the phenomenology of the process producing atoms Rydberg states population taking into account the anisotropy of highly excited atomic states into strong magnetic fields of magnetized white dwarfs (see Eqs.(9)-(13)). The presence of a magnetic field can increase highly excited Rydberg atoms. Remarkably the magnetic field induces a permanent electric dipole moment of the atom (Lesanovsky et al., 2003, Raithel et al., 1993). Raithel et al., 1993, found in the experiments the evidence for large permanent electric dipole moments of Rydberg atoms in crossed electric and magnetic fields.
They found that the dipole moments have a large value if the scaled electric field strength have the value $EB^{-4/3} = 0.75$ (with electric and magnetic field strengths in atomic units). In the atmosphere of a white dwarf an atom is exposed to the electric fields of surrounding atoms, ions and free changes. The motional Stark effect gives an electric field perpendicular to the magnetic one. The mean values of the electric field felt by each atom in the atmosphere of a magnetic white dwarf can be $\geq 10^8 V/m$, i.e. these values correspond to the scaling relation of Raithel et al., 1993. It is also very important that a mean surface poloidal field strength of $\sim 100MG$ and a toroidal field strength of $2-10MG$ can increase a scale height by a factor of $\geq 10$ (Fendt and Dravins, 2000).

Let us estimate the resonance number density for magnetic CIA (MCIA) in the atmosphere of a magnetic white dwarf:

$$N_V \approx 10^{18} Y_e^{-1}(E/3eV) \left( \frac{180\pi^2hc}{7e^2} \alpha||N_a \right) = 10^{18} Y_e^{-1}(E/3eV)(3.5 \times 10^4 a||N_a)$$  \hspace{1cm} (14)

Let us estimate the number density $N_a$ of Rydberg state atoms required for the resonance number density $N_V \geq 10^{18} cm^{-3}$ at the level of white dwarf atmosphere:

$$N_a \geq \frac{7}{180\pi^2hc} \frac{e^2}{\alpha||} \approx 4 \times 10^{19} \left( \frac{\alpha_H}{\alpha||} \right)$$  \hspace{1cm} (15)

Here $\alpha_H = 0.67 \times 10^{-24} cm^{-3}$ is the classical polarizability of a free hydrogen atom without a magnetic field. The polarizabilities of highly excited atoms and quasimolecules are radically increased with the main quantum number: $\alpha|| \approx \alpha_H n^6$. For $n = 10$ the required number density $N_a \geq 4 \times 10^{13} cm^{-3}$, i.e. at ~six magnitude lesser the typical number density in a white dwarf atmosphere. For $n = 3 N_a \geq 10^{16} cm^{-3}$.

Correspondingly, the expression for the location of resonance photon energy takes a form:

$$E_V = 3\left( \frac{Y_e N_V}{10^{18}} \right) \left( \frac{180\pi^2hc}{7e^2} \alpha||N_a \right)^{-1} = 3\left( \frac{Y_e N_V}{10^{18}} \right) \left( \frac{\alpha||}{\alpha_H} \right) \left( \frac{N_a}{4 \times 10^{19}} \right)$$  \hspace{1cm} (16)

The adiabatic condition is to be:

$$E_{ad} > 7.6 \left( \frac{1 cm}{H} \right)^{1/3} eV \approx 0.35eV$$  \hspace{1cm} (17)

where $H = kT_WD R^2_{WD}/GM_WDM_p$ is the height of homogeneous atmosphere of a white dwarf. Its value for the magnetic dwarf GrW+70.8247 is $\sim 10^4 cm$ ($T_WD \approx 10^4 K$, $R_WD \approx 10^5 cm$, $M_WD \approx 0.5M_\odot$).

4 The results of spectropolarimetric and infrared photometric observations of magnetic white dwarfs

The basic observational phenomena of both physical effects considered above and connected with the fact vacuum polarization or existence of highly excited Rydberg states of atoms into a strong magnetic field modify the dielectric properties of a medium and the polarization modes, altering the radiative scattering and absorption opacities.

The basic effects across resonance are

(a) Change the orientation of the polarization ellipse by $\leq 90^0$ without the helicity changing.

(b) Suppression of Rayleigh-Jeans region of black body spectrum and cyclotron spectral lines. Both effects have been observable, including our spectropolarimetric observations by BTA-6m and infrared photometric observations by AZT-24 telescope in Campo Imperatore, Italy.

Still at 1989 West demonstrated measurements of the near infrared polarization of GrW+70.8247 combined with the optical spectropolarimetry of Landstreet and Angel, 1975. The near infrared polarimetry over the region 1.1 – 1.6$\mu m$ was obtained with IRPOL (West et al., 1988) attached to the MMT between 1985 July and 1986 November. West results demonstrated the real rotation of the orientation of the polarization ellipse exactly by $90^0$ near the wavelength $\lambda = 0.6\mu m$.

Fig.1 presents the results of our spectropolarimetric observations of GrW+70.8247 at 1999 July. The spectropolarimetric observations display the gradual rotation of the polarization ellipse at the wavelength range $\lambda\Delta 4800 - 5000 \AA$. This transition can be considered as a result of adiabatic conversion from the low-opacity X-mode to the high-opacity O-mode (and via versa) as it crosses the region where contributions
of polarizabilities from usual magnetoactive plasma and vacuum (or Rydberg atomic states) compensate each other. One ought to take into consideration the existence of the absorbing feature at the region near $\lambda = 4150$ Å. This feature exists in all Stokes parameters but if the linear polarization $P_l$ looks as depression, the circular polarization $V$ displays the excess at the level $P_V \sim -5\%$. One of the possible explanation of this feature is the "vacuum resonance" lying in the region of cyclotron energy (see Eq.(5)).

At 2002 we repeated the spectropolarimetric observations of GrW+70.8247. These results will be presented at next publications.

Fig.2 displays the wavelength dependence of Stokes parameters for the magnetic white dwarf GD229 obtained in the result of our observations at BTA-6m. This figure demonstrates also the jump of rotation angle of the polarization ellipse in the spectral region $\lambda \lambda$ 4200-4600 Å.

This behavior of the position angle reveals probably the phenomenon of magnetoelectric Jones birefrigence and dichroism (Jones effect) (Graham and Raab, 1983). This phenomenon reveals that certain uniaxial media may exhibit birefrigence and dichroism along axes which are at $\pm 45^\circ$ relative to the axis of anisotropy (the magnetic field direction in our case). In this case the additional contribution appears to the position angle when the direction of light propagation is perpendicular to the magnetic field:

$$\Delta \phi_J = \frac{2\pi}{\lambda} \int [n_{+45}(\lambda) - n_{-45}(\lambda)] dl$$

(18)

Recently Budker and Stalnaker, 2003, suggested that the interference between atomic magnetic dipole and electric field induced dipole transition amplitudes provides magnetoelectric Jones effect.

These spectropolarimetric observations (Fig.2) have been made at BTA-6m SAO RAN in 2002 July with the long slit spectrograph UAGS and the analyzer of the linear and circular polarization (Naidenov et al., 2002) located at the main focus of the telescope. The detector was CCD-camera with 1024x1024 pixels. The size of a pixel is 24x24 μm. The resulting dispersion was a 2.4 Å/pixel, in the spectral range $\lambda \lambda 3500 – 8000$ Å. The seeing was 1”.2. It allows to get the resulting spectral resolution $\sim 5$ Å. For reprocessing data the system MIDAS has been used. HD204827 has been used as spectropolarimetric standard (Turnshek et al., 1990).

Near IR observations of magnetic white dwarfs were obtained at the AZT-24 1.1m telescope in Campo Imperatore (Italy) with SWIRCAM during a period spanning July-August 2003. SWIRCAM is the infrared camera that incorporates 256x256 HgCdTe NIGMOS 3-class (PICNIC) detector at the focus of AZT-24. It yields a scale of 1”/0.4/pixel resulting in a field of view 4x4 sq. arcmin. The observations were performed through standard JHK broadband filters. The list of our targets includes GrW+70.8247, GD229, G240-72, GD356, G227-35, WD1031-234, WD1312+098.

The spectral energy distribution (SED) for GrW+70.8247 is presented at Fig.3. Here the Black Body SED is also presented. We see the real fact of SED suppression in JHK spectral ranges. Another example of such suppression of G99-37 SED is presented at Fig.4 (We used here only known observed data, see Bergeron et al., 2001).

5 Conclusions: distinctions between vacuum polarization and magnetic CIA effects

The polarimetric jump of the orientation of the polarization ellipse by the angle $\leq 90^\circ$ and the suppression of SED in near infrared region of spectra of white dwarfs with a strong magnetic field display two possible physical mechanisms responsible for both phenomena: vacuum polarization or magnetic CIA. The critical difference between these both mechanisms is the characteristic scale factor. For the vacuum polarization this scale factor is $l = R_S$, for the magnetic CIA it is $l = H = kT R_S^2 / G M_{WD} m_H$, i.e. the homogeneous atmosphere height. It means that vacuum polarization effect displays existence an extended region like an extended corona around a white dwarf. The most suitable physical situation is the discon model of Zheleznyakov and his co-authors (e.g. Zheleznyakov, 1997, and refs. in). It was shown that the structure of plasma envelopes of magnetic white dwarf is drastically different. The pressure force by photospheric radiation at cyclotron frequencies can exceed the gravitational force acting on a proton and can display ejection of plasma from the photosphere. In a result the formation of an extended envelope in the white dwarf magnetosphere as well as the disk near the magnetic equator are produced. Zheleznyakov, 1997, called this phenomenon "radiative-driven discon". If the plasma density of such an envelope is quite high ($N_e \geq 10^8$ cm$^{-3}$), it may distort the photospheric spectrum and produce the broad and deep depression bands in the observed radiation from magnetic white dwarf. The discon-like structure can also display
the rotation of the orientation of the polarization vector if one takes into account the effect of vacuum resonance mentioned above.

The same physical situation can be originated in the result of CIA process in the magnetized photosphere of a white dwarf with a strong magnetic field. Strong magnetic field produces the orientation of photospheric atoms. CIA process of oriented atoms and molecules into magnetized photosphere displays simultaneously the rotation of orientation of polarization vector and suppression of the spectral energy distribution of a magnetic white dwarf. This physical situation does not require the existence of extended magnetosphere of a white dwarf. The basic difficulty for such regime is quite fast ionization of Rydberg atoms embedded in a photospheric plasma of a magnetized white dwarf (e.g. Vanhaecke et al., 2004).

We suggest more detail analysis of both physical regimes in the next paper.

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Figure 1: The result of polarimetric observations of the magnetic white dwarf GrW+70.8247. The wavelength dependence of the Stokes parameters (from the top): $V$, $Q$, $U$, the degree of the linear polarization $P$ and the positional angle $\psi$. 
Figure 2: The results of polarimetric observations of the magnetic white dwarf G229. The wavelength dependence of the linear polarization degree $P$, the position angle $\theta$ and of the circular polarization $V$. 
Figure 3: The spectral energy distribution (SED) of the magnetic white dwarf GrW+70.8247 (black circles). The black body distribution is shown by open circles.
Figure 4: The same distributions as at Fig.3 for the magnetic white dwarf G99-37.