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Spectropolarimetric observations of magnetic white dwarfs at the 6 m telescope BTA

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Abstract. We present results of spectropolarimetric observations of magnetic white dwarfs made at the Russian 6 m telescope BTA and results of NIR photometric observations with the Russian-Italian AZT-24 telescope located at Campo-Imperatore. The list of observed objects includes white dwarfs from SDSS: SDSS J2247+1456 and SDSS J0211+21115. We discuss the effects of vacuum polarization in a strong magnetic field and magnetic collision induced absorption in atmospheres and coronas of magnetic white dwarfs.

1 Introduction

The study of magnetic white dwarfs is very important since they present the cosmic laboratories for investigation of matter properties in an extremely strong magnetic field. Magnetic white dwarfs may also test the role of magnetism in phases of stellar evolution. One of the excellent reviews of the situation with magnetism of white dwarfs has been presented by Wickramasinghe and Ferrario (2000). The current data from the Sloan Digital Sky Survey (SDSS DR3) are providing a wealth of information on stellar population including magnetic white dwarfs (Vanlandingham et al. 2005). Magnetic white dwarfs also allow studying the effects of strong $B \geq 10$ MG magnetic fields on atomic and molecular structures and their emission process.

We used in our observations the universal reducer SCORPIO of the 6 m telescope. The description of this device was presented by Afanasiev and Moiseev (2005).

The list of our targets is presented in Table 1. The magnitudes of magnetic fields were obtained through features of hydrogen in fields up to 1000 MG and were present by Vanlandigham et al. 2005 (see Fig.1 of their paper). The IR data were obtained by the Pulkovo team as a result of observations at the Russian-Italian 1.1 m telescope located at Campo-Imperatore, Italy. In the current paper we report our polarimetric observations of a number of strongly magnetized white dwarfs made at the 6 m telescope with the help of SCORPIO. We discussed two mechanisms to explain our spectropolarimetric observations of magnetic white dwarfs: vacuum polarization and existence of Rydberg atomic states with large dipole moments arising because of atomic collisions in a strong magnetic field of a white dwarf. Both mechanisms can explain the observed rotations of the polarization ellipses and the observed depression of the IR spectral energy distribution (Gnedin et al. 2006).

2 Observational Data

Our spectropolarimetric observations were obtained in 2005 November with SCORPIO (Afanasiev et al. 2005), a multimode focal reducer mounted at the 6-m telescope (BTA) of the Special Astro-

Table 1: Our target list

The name	mag.	B(MG)
G 227-35	V=15.5	170-180
G 240-72	V=14.2	200
GrW+70.8247	V=13.2	320
GD 229	V=14.8	300-700
PG 1031+234	V=15.1	500-1000
SBS 1349+5434	V=17.5; J = 16.142; H = 16.670; K = 16.552	760
SDSS J0021+1502	R=17.9	550
SDSS J2247+1456	R=17.6	560
SDSS J2346+3853	R=19.3	1000
SDSS J0211+2115	R=17.2	210
SDSS J0211+0031	R=18.5	490
SDSS J1003+0538	R=18.5	900
PG 2357+125	V=16.4	?
PG 1015+014	J = 16.4; H = 16.295; K = 16.338	120
HE 1049-0502	V=17.5; J = 14.251; H = 13.662; K = 13.520	800

Table 2: Observational details

Object	Date	Total exposure (sec.)	Resolution (A)	Spectral range (A)	Seeng (arcsec.)
Grw +70.8247	28.11.2005	1200	10	3500-7200	3.0
SDSS J0021+1502	30.11.2005	6000	10	3500-7200	3.5
SDSS J0211+0031	30.11.2005	4000	10	3500-7200	3.5
SDSS J0211+2115	28.11.2005	6000	10	3500-7200	3.0
SDSS J1003+0538	01.12.2005	2880	10	3500-7200	2.0

physical Observatory of the Russian Academy of Sciences. See Table 2 for observation details. All spectropolarimetric data were processed with the help the IDL computer programs.

In Fig.1 the results of our spectropolarimetric observations of the well-known magnetic white dwarf GrW+70.8247 are presented. The data were obtained during 2005 November run of observations at the 6 m telescope. The total exposure was 1200 seconds. Fig.1 presents the wavelength dependences of circular and linear polarizations (degree and position angle). The most striking feature presented in Fig.1 is the jump of the positional angle in the spectral region near λ5000Å. This jump was first discovered by West (1989) when he analysed the polarimetric measurements in IR range together with the optical polarimetric data. Spectropolarimetric observations of GrW+70.8247 were also made at the 6 telescopem in 1999 July (Gnedin et al. 2006).

Another important feature is the narrow one at λ4150Å. This feature is displayed in all spectral distributions of Stokes parameters. In linear polarization it looks like an absorption feature, whereas in circular polarization it looks like an emission one (Gnedin et al. 2001). Possible interpretation of these features will be presented below.

In Fig.2 we present the result of spectropolarimetric observations of the white dwarf SDSS J0211+2115 obtained at the 6 m telescope in November, 2005. The magnetic field magnitude estimated via hydrogen features (Fig.1 from Vanlandingham et al. 2005) appears to be $B = 210$ MG.

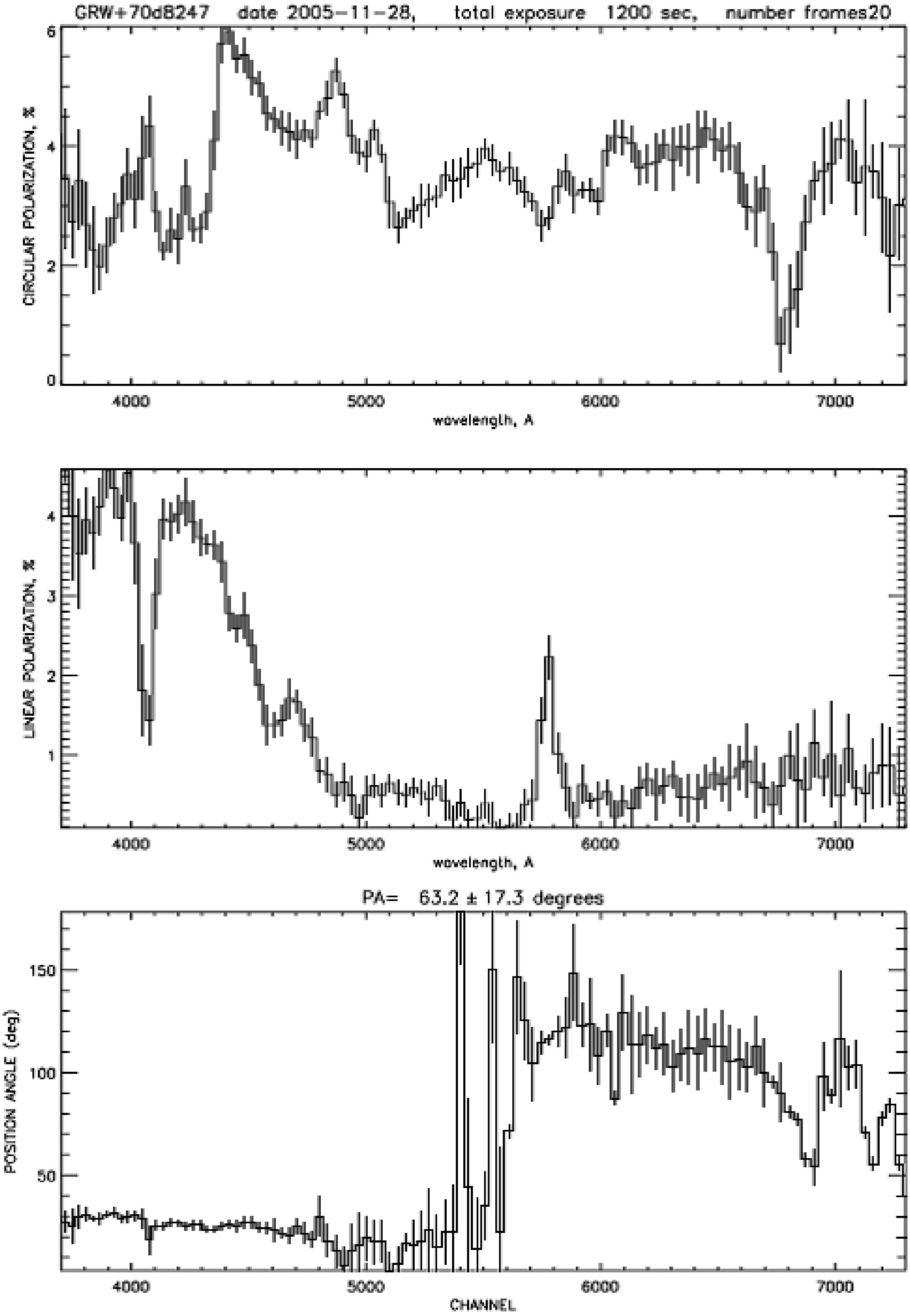

Figure 1: The results of our spectropolarimetric observations of the magnetic white dwarf GrW+70.8247.

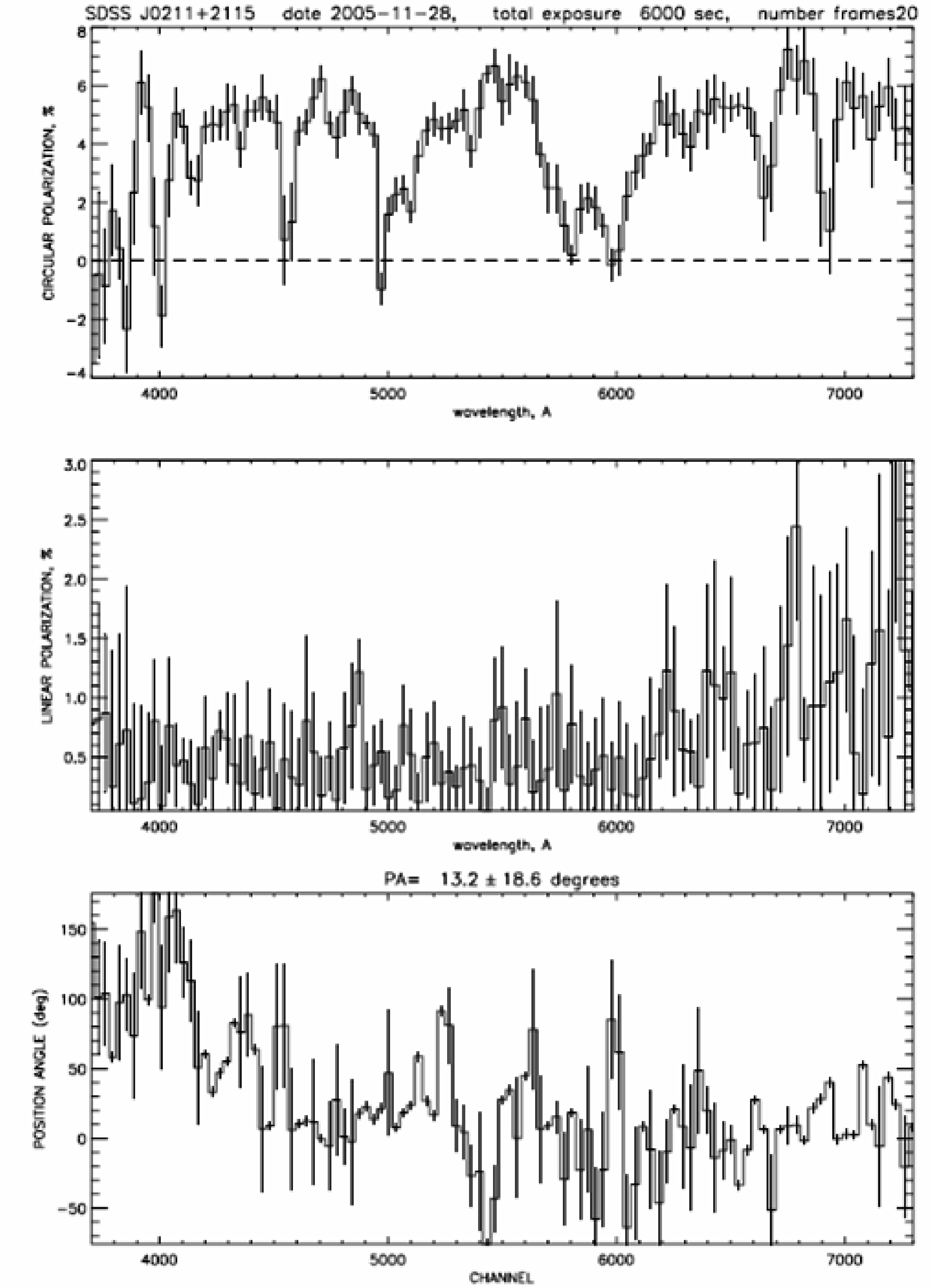

Figure 2: The result of spectropolarimetric observations of the white dwarf SDSS J0211+2115.

The observed polarization spectra are highly structured. This object was not included in the SDSS DR3 white dwarf catalog (Eisenstein et al. 2005).

Fig.3 presents spectropolarimetric data on the magnetic white dwarf SDSS J0021+1502. The polarization spectra are not highly structured as compared with the white dwarf SDSS J0211+2115. This fact means that the magnetic field strength exceeds a value of $\sim$ 500 MG. With such strong fields, polarization is derived from the continuum rather than from lines (e.g., Schmidt et al., 1996) and it is because of this the polarization spectra are not highly structured.

Fig.4 presents the polarization data of the magnetic white dwarf SDSS J0211+0031. Its magnetic field strength can be estimated as $B \geq 450$ MG. At last, Fig.5 displays the wavelength dependence of the Stokes parameters of linear polarization for SDSS J1003+0538. Here also the absence of strong structuring of polarization spectra confirms the existence of an extremely strong magnetic field at the surface of this white dwarf. Its magnetic field strength has been estimated as $B \approx 900$ MG by Vanladnigham et al. (2005).

GD 356 is unique in being the only magnetic white dwarf to show Zeeman lines of hydrogen in emission. It means for photospheric models that the temperature structure of the white dwarf atmosphere is inverted and that the line emission region covers less than 10% of the stellar surface (Ferrario et al. 1997).

Another explanation of this unique phenomenon can be provided by the model of “radiative discon” (Bespalov and Zheleznyakov 1990, Zheleznyakov and Serber 1994, Zheleznyakov 1997).

The most intriguing result has recently been obtained by Brinkworth et al. (2003). They reported the detection of low amplitude ($\sim \pm 0.2\%$) near sinusoidal photometric (V-band) variability in GD 356, with a period of 0,0803 days ($\sim$ 115 minutes). This effect has been interpreted as the rotation period of this star with a dark spot on its surface covering 10% of the stellar surface. The results of observations by Brinkworth et al.(2003) are presented in Fig.6. It seems likely that this spot is also the cause of the Zeeman emission providing temperature inversion. But it should be mentioned that there exists another way for producing a temperature inversion. Such inversion may be produced by a periodical flow on the magnetic white dwarf surface as a result of inhomogeneous temperature distribution (Gnedin et al. 2001). The inhomogeneous distribution of temperature on the stellar surface can produce a noticeable amount of broad-band and resonance polarization of radiation of a white dwarf with a strong magnetic field. The results of spectropolarimetric observations of GD 356 made at the 6 m telescope have been presented in the paper by Gnedin et al. (2001).

The most interesting new result has recently been obtained by Pulkovo astronomers A.A. Arkharov, V.M. Larionov, Yu.N. Gnedin (2006) in infrared observations of GD 356 with the 1.1 m telescope of Pulkovo Observatory equipped by IR CCD camera and located at Campo Imperatore in Italy. They confirmed the existence of photometric variability of this object with a 115 min period in IR bands. However, it turned out that the IR variability has a higher amplitude value by, at least, an order of magnitude.

The most exotic model explaining the IR variability of this unique object can be constructed if one suggests that GD 356 is a white dwarf with a strange matter core extended up to the surface of the white dwarf. The possible existence of strange matter stars has recently been speculated (see, for instance, Glendenning et al. 1995a,b, Mathews et al. 2006). Mathews et al. (2006) proposed a list of compact strange dwarfs. GD 356 can probably be included in this list.

3 Results and Discussion

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 the most important effects is so-called polarization of electron-positron plasma by a strong magnetic field. Just like in ordinary magnetoactive plasma the photon propagation in a magnetized vacuum is also

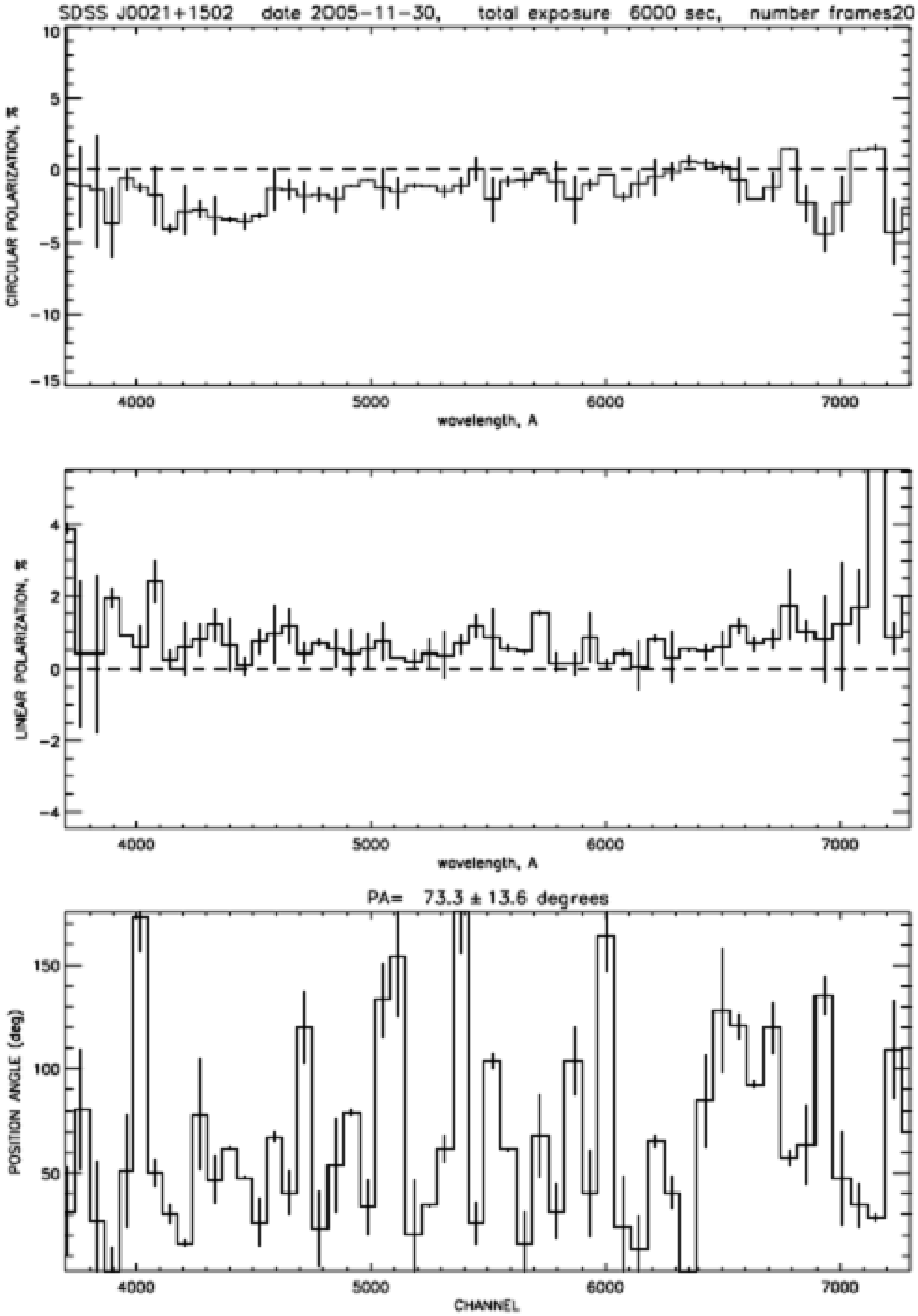

Figure 3: The spectropolarimetric data of the magnetic white dwarf SDSS J0021+1502.

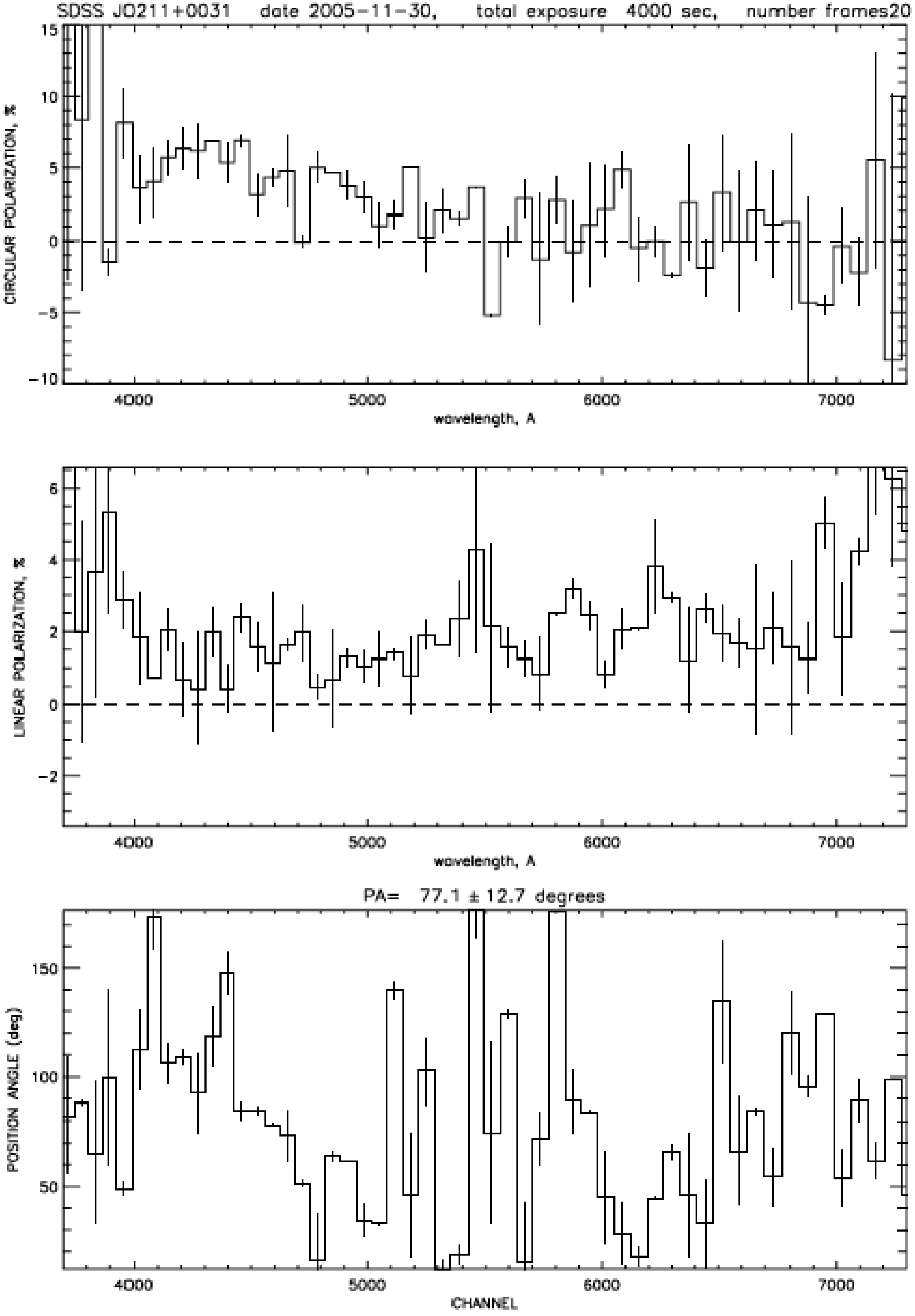

Figure 4: The polarization data of the magnetic white dwarf SDSS J0211+0031.

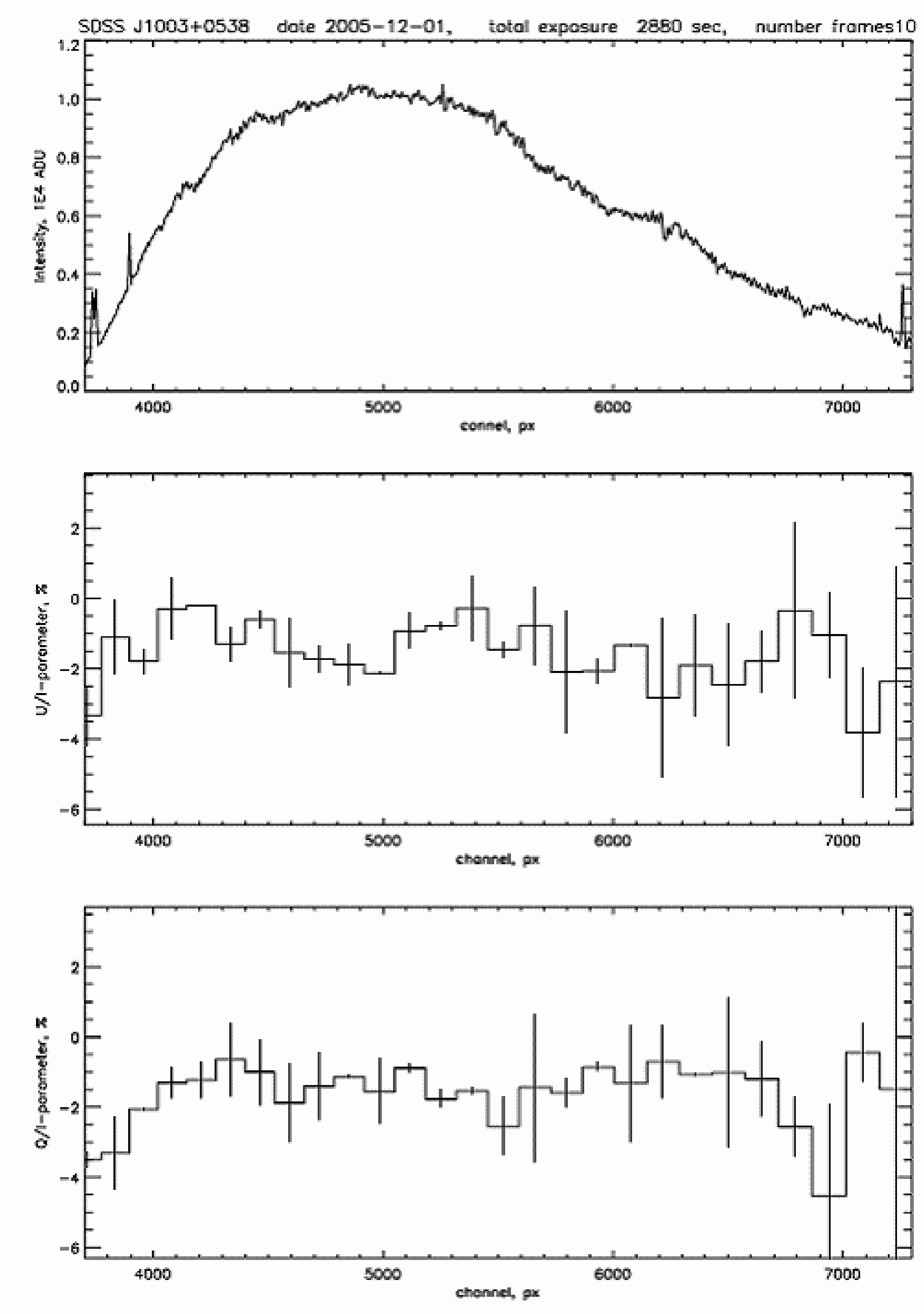

Figure 5: The wavelength dependence of the Stokes parameters of linear polarization for SDSS J1003+0538.

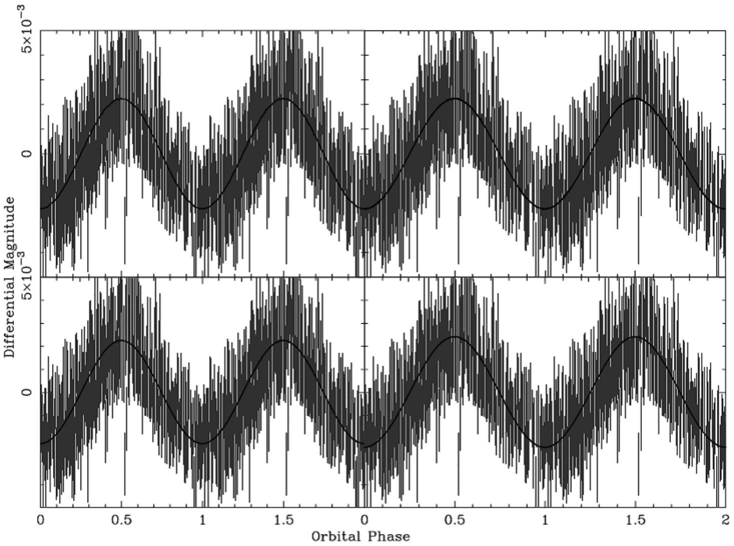

Figure 6: The results of observations by Brinkworth et al. (2003).

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

$$B \geq B_C = \frac{m_e^2 c^3}{e\hbar} = 4.414 \times 10^{13} G, \tag{1}$$

where B_C is the magnetic field value at which the electron cyclotron energy $\hbar\omega_B = \frac{\hbar e B}{m_e c}$ 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 $B \ll B_C$.

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

$$n_1 = 1 + \frac{7}{90\pi}\frac{e^2}{\hbar c}\left(\frac{B_\perp}{B_C}\right)^2 ; \; n_2 = 1 + \frac{2}{45\pi}\frac{e^2}{\hbar c}\left(\frac{B_\perp}{B_C}\right)^2 , \tag{2}$$

where $B_\perp = B \sin\theta$ and θ 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. The vacuum polarization effect modifies the dielectric property of the medium and the polarization of photon modes propagating in a magnetoactive plasma, thereby altering the radiative scattering and absorption opacities.

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

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

$$\varphi = \frac{\omega}{c}\int |n_1 - n_2| dl = \frac{l}{5 \times 10^{-7} cm} \frac{\hbar\omega}{m_e c^2} \left(\frac{B_\perp}{B_C}\right)^2 . \tag{3}$$

For neutron stars (NS) at $\hbar\omega = 1KeV$, $B_\perp = 4 \times 10^{12} G$ the magnitude $\varphi \sim 1$ after transversing a very small $l = 0.3mm \ll R_{NS}$ distance (R_{NS} is the 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 where the electric vector lies in the **KB** plane or at a right angle to it).

For WDs:

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

in the optical spectral range. The situation for WDs looks better because there is no complete depolarization in this situation. As a result it becomes possible to search the vacuum polarization effect in the optical spectral range via polarimetric observations.

Especially interesting effects arise when one analyzes the interaction of radiation with a "mixture" of vacuum and plasma in a strong magnetic field because of the different types of 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 to the linear polarization of normal modes cancel out each other. This case is called "vacuum resonance". One of these specified energies lies in the region of cyclotron energy $\hbar\omega_B$ and corresponds to the vacuum resonance number density

$$N_{V,1} = \frac{1}{60\pi^2} \left(\frac{m_e c}{\hbar}\right)^3 \left(\frac{\hbar\omega_B}{m_e c^2}\right)^4 \cong$$

$$\cong 3 \times 10^8 \left(\frac{B}{4 \times 10^8 G}\right)^4 cm^{-3} . \tag{5}$$

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

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

$$WD : N_{V,2} = 10^8 Y_e^{-1} \left(\frac{1\mu m}{\lambda}\right)^2 \left(\frac{B}{3 \times 10^8}\right)^2 cm^{-3} , \tag{6}$$

where Y_e is the 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:

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

$$WD: \ \lambda_V = 0.283 \left(\frac{10^8}{Y_e N_V}\right)^{1/2} \left(\frac{B}{3 \times 10^8}\right) \mu m \, . \tag{7}$$

Neutron stars and white dwarfs are characterized by different situation. For neutron stars the vacuum resonance lies in the deep layers atmosphere (photosphere) of a star. For magnetic WDs the number density value $\leq 10^8 cm^{-3}$ lies only in the uppermost layer of the atmosphere ($N_V \sim 10^8 cm^{-3}$ 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). It is Zheleznyakov and his colleagues who showed that the pressure of cyclotron radiation in the magnetic WD photosphere can be comparable and even 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. They claimed that the structure of plasma envelopes of magnetic WDs with the effective temperature $T_e \geq 10^4 K$ is drastically different from the structure of thin hot corona. If the plasma density of such an envelope is high enough, it can strongly distort the photosphere spectrum and give rise to the broad and deep depressions bands in the observed radiation spectrum.

One also needs to take into consideration that the strong large-scale magnetic fields have effects 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 a non-magnetic case. They found quantitatively that a mean surface poloidal field strength of 100 MG and a toroidal field strength of 10 MG may increase the scale height at least by a factor of 10.

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 $\leq 90^0$. 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 a result of resonant conversion of photon modes across the vacuum resonance.

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:

$$E_{con} \geq 1.5 eV \left(\frac{10^9 cm}{R_{WD}}\right) . \tag{8}$$

In this case the adiabatic probability of conversion is $P_{con} = 1 - \exp\left(-\frac{\pi}{2}\frac{E}{E_{con}}\right)$. The jump probability can be calculated from the Landau-Zener formula: $P_j = \exp\left(-\frac{\pi}{2}\frac{E}{E_{con}}\right)$. This process is not accompanied by the essential conversion of photon modes.

The second effect important for observations 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. 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. In the Zheleznyakov radiation-driven discon model of MWD the increase of cyclotron absorption can strongly distort the photospheric spectrum and give rise to the broad and deep depression bands in the observed radiation from such radiation-driven discon.

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

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

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

Therefore we introduce, purely formally, for magnetized non-ionized gas:

$$n_1 = 1 + 2\pi N_a \alpha_{||}; \quad n_2 = 1 + 2\pi N_a \alpha_{\perp}\,, \tag{9}$$

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

Let us consider the case where $\alpha_{||} > \alpha_{\perp}$. It is this case that realizes 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 when the cyclotron energy $\hbar\omega_B$ is comparable to the Rydberg energy. This condition implies a field strength:

$$B > B_0 = \frac{Z^2 m_e^2 e^3 c}{\hbar^3} = 2.35 Z^2 \times 10^9 G\,. \tag{10}$$

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 becomes greater than its longitudinal velocity.

Eq. (10) means that the Bohr radius of an hydrogen atom $r_0 = \frac{\hbar^2}{m_e e^2}$ becomes larger than the so-called magnetic length $a_m = (c\hbar/eB)^{1/2}$ that determine the transverse size of an atom. The atom acquires an ellipsoidal cigar shape instead of the typical spherically symmetric form.

The magnetic field strength (10) is rather high for a typical magnetic white dwarfs. Therefore the neutron stars are exactly 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, Ho et al. 2003).

However there can exist a situation in which atoms become anisotropic in the magnetic white dwarfs with the typical magnetic field strengths $B \sim 10^6 \div 10^8 G$. Such a situation actually exists if the atoms appear in strongly excited (Rydberg) states. For an atom in a highly, $n \gg 1$, excited 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:

$$\langle r_n^3 \rangle = \frac{n^2}{8Z^3}[21n^4 + 35n^2 + 4] \; \overrightarrow{n \longrightarrow \infty} \; \frac{21}{8Z^3} n^6\,, \tag{11}$$

or for a hydrogen atom: $\langle r_n^3 \rangle^{1/3} = (21/8)^{1/3} n^2\, r_0\,$.

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

$$B_0 \cong \frac{1.7}{n^2} \times 10^9 G\,. \tag{12}$$

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 a critical one if the hydrogen atom is found in the excited state with $n > 3$.

Now it is possible to get the full analogy of magnetic CIA to the vacuum polarization effect. Let us consider the case $\alpha_{||} > \alpha_{\perp}$ and suggest for the full analogy to the vacuum polarization: $\alpha_{||}/\alpha_{\perp} = 7/4$.

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

$$\left(\frac{B_{\perp}}{B_C}\right)^2 \equiv \frac{180\pi^2 \hbar c}{7e^2}\alpha_{||}N_a \,. \tag{13}$$

In mixed hydrogen and helium gases, colliding pairs of atoms and molecules such as $H_2 - H_2$, $H_2 - He$, $H - He$ can be sources of the 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, also via the collision process. The originated Rydberg states acquire a large dipole moment and therefore can produce strong absorption in the infrared range of the spectrum.

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. In the atmosphere of a white dwarf an atom is exposed to the electric fields of surrounding atoms, ions and free charges. 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 $\geq 10^8 V/m$. It is also of importance 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 ≥ 10 (Fendt and Dravins 2000).

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

$$N_V \cong 10^{18} Y_e^{-1} (E/3eV)^2 \left(\frac{180\pi^2 \hbar c}{7e^2}\alpha_{||}N_a\right) =$$

$$= 10^{18} Y_e^{-1} (E/3eV)(3.5 \times 10^4 \alpha_{||} N_a) \,. \tag{14}$$

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:

$$N_a \geq \frac{7}{180\pi^2}\frac{e^2}{\hbar c}\frac{1}{\alpha||} \approx 4 \times 10^{19} \left(\frac{\alpha_H}{\alpha_{||}}\right) \,. \tag{15}$$

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 radically increase 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. by ~six magnitudes lower than 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 the form:

$$E_V = 3\left(\frac{Y_e N_V}{10^{18}}\right)^{1/2} \left(\frac{180\pi^2 \hbar c}{7e^2}\alpha_{||}N_a\right)^{-1/2} =$$

$$= 3\left(\frac{Y_e N_V}{10^{18}}\right)^{1/2} \left(\frac{\alpha_{||}}{\alpha_H}\right)^{1/2} \left(\frac{N_a}{4 \times 10^{19}}\right)^{1/2} \,. \tag{16}$$

The adiabatic condition is to be:

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

where $H = kT_{WD}R_{WD}^2/GM_{WD}m_p$ is the height of the homogeneous atmosphere of a white dwarf. Its value for the magnetic dwarf GrW+70.8247 is $\sim 10^4 cm$ ($T_{WD} \approx 10^4 K$, $R_{WD} \approx 10^9 cm$, $M_{WD} \approx 0.5 M_{\odot}$).

The polarimetric jump in the orientation of the polarization ellipse by an angle $\leq 90^0$ and the suppression of SED in the near infrared region of spectra of white dwarfs with strong magnetic fields display two possible physical mechanisms responsible for both phenomena: vacuum polarization or magnetic CIA. The critical difference between the two mechanisms is the characteristic scale factor. For the vacuum polarization this scale factor is $l = R_S$, for the magnetic CIA it is $l = H = kTR_S^2/GM_{WD}m_H$, i.e. the homogeneous atmosphere height. It means that the vacuum polarization effect displays existence of 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. therein). It was shown that the structure of plasma envelopes of magnetic white dwarfs 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. As a result, an extended envelope in the white dwarf magnetosphere as well as the disk near the magnetic equator are formed. Zheleznyakov (1997) called this phenomenon “radiative-driven discon”. If the plasma density of such an envelope is high enough ($N_e \geq 10^8 cm^{-3}$), it can distort the photospheric spectrum and produce broad and deep depression bands in the observed radiation from a 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 the vacuum resonance mentioned above.

The same physical situation can originate as a result of the CIA process in the magnetized photosphere of a white dwarf with a strong magnetic field. Strong magnetic field produces the orientation of photospheric atoms. The CIA process of oriented atoms and molecules into magnetized photosphere displays simultaneously the change of orientation (rotation) 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 a regime is rather fast ionization of Rydberg atoms embedded in the photospheric plasma of a magnetized white dwarf.

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