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Editors

Овај Зборник садржи радове које је научни одбор укључио у дневни ред X Националне конференције југословенских астронома - Београд, 22-24 септембар 1993, под покровитељством Савезног Министарства за науку, технологију и развој и Министарства за науку и технологију Србије који су делимично помогли одржавање конференције.

Организатори се захваљују спонзору конференције - Београдској индустрији пива и Привредној комори Србије која је за одржавање конференције ставила на располагање своју салу.

Љубазношћу Астрономске опсерваторије у Београду , Зборник излази у серији њених Публикација.

Уредници

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Publ. Obs. Astron. Belgrade No. 44 (1993), 7–10 *Introductory lecture*

OSCILLATIONS AND WAVES IN THE SUN AND STARS

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Abstract: A short review is given about some characteristics of acoustic, gravity, Alfvén and MHD-simple waves. Their possibilities for probing the stellar interior, heating the atmosphere and changing spectral line profiles are discussed.

INTRODUCTION

The idea that non-thermal flux from subphotospheric layers must carry energy to the stellar atmosphere, appear as early as it was obvious that solar corona has 10^3 times higher temperature than the photosphere (Biermann, 1946; Schwarzschild, 1948; Schatzman, 1949). The discovery of the photospheric 5-minute oscillations was made by Leighton *et al.* (1962). But it was not before 1975 (Ando and Osaki, 1975; Deubner, 1975) that oscillations and waves become one of the most exciting area of astrophysics. Very few astrophysical problems of great importance have been solved with such agreement between theory and observations. It can serve as an example of what scientific research should be like. By understending physics of the 5-minute oscillations solar astrophysics open a window for looking into the stellar interior. P-mode oscillations have also been detected from the other stars (Fossat *et al*, 1984; Noyes *et al*, 1984; Kurtz, 1990).

Since 1975 a torrent of scientific papers about oscillations has appeard in the leading astrophysical periodicals. Moreover, several international conferences (from 1984 to 1991) were devoted only to oscillations and waves in the Sun and stars (see Ref. 1–8). It is therefore a great challenge to give a short review of such important, complex and vast topic.

Without going into detailes, I shall concentrate on the origin and the main characteristics of oscillations and waves. Their essential contributions are: *probing of stellar interior*, *heating of stellar atmosphere* and *changing of spectral line profiles.*

ORIGIN, CHARACTERISTICS AND POSSIBILITIES

There are different forces in the stellar matter (pressure, gravity, magnetic) which act immediately after a small perturbation to return fluid to initial conditions. Oscillations or waves are the response of the medium to any perturbation. Turbulence in the convection zone (CZ) is one of possible mechanisms for their excitation. Two reflection boundaries (a resonant cavity) can produce a large number of resonant modes. There are about 10^7 resonant modes of solar interior. Such a rich spectrum of detected oscillations arises from modes whose periodes vary from a few minutes to several hours, and their horizontal wavelengths vary from less than thousand kilometers to global scales (Gough and Toomre, 1991).

The basic theory of the waves is founded on the well-known set of Lundquist partial differential equations. This consists of continuity, momentum and energy equations, plus equation of state in case of *non-magnetic* waves, but in case of *MHD* waves Alfvén theorem is needed (for detailes see Vukićević-Karabin, 1993; Brown *et al*, 1986; Leibacher & Stain, 1981).

Acoustic waves are produced by pressure as a restoring force. They can be progressive or standing (resonant p-mode). Acoustic waves exist only at frequencies:

$$\omega \geq \omega_{\mathrm{ac}} = \frac{u}{2H}, \tag{1}$$

where u is the sound speed, H is the pressure scale height. Wavenumbers are preferentially vertical:

$$k_z^2 = u^{-2}(\omega^2 - \omega_{\mathrm{ac}}^2). \tag{2}$$

Energy is transported to $\vec{k}$ direction:

$$\vec{v}_g \parallel \vec{k}, \quad v_g = v_{\mathrm{ph}} = u \neq f(k_x, \omega), \quad M = \frac{v}{u}, \tag{3}$$

where M is the Mach number, v is the fluid speed.

Acoustic waves are produced in CZ. Travelling upwards with increasing speed amplitude, due to $\rho v^2 u =$ const, they become shock waves. By dissipating energy, they can heat lower chromosphere sufficiently (Athay and White, 1978).

Resonant p-modes have characteristics which are determined by structure of the resonant cavity. This refers to the best-studied 5-min oscillations.

Long period oscillations (small l) are used to diagnose the solar interior. The base of the solar CZ, determined recently (Guzik & Cox, 1993) is at $0.712 \pm 0.001 R_\odot$, and there is no change in the rotation rate $\Omega(r)$ of the outer 50% $R_\odot$ (Gough and Toomre, 1991). Global oscillations have temporal and spatial coherence (Hill 1988, 1990).

Internal gravity waves (IGW) are produced by gravity (buoyancy) as a restoring force. They are restricted to low frequencies:

$$\omega \leq \omega_{\mathrm{BV}} = \left[\frac{g}{T}\left(\left|\frac{dT}{dr}\right|_{\mathrm{atm}} - \left|\frac{dT}{dr}\right|_{\mathrm{ad}}\right)\right]^{\frac{1}{2}}, \tag{4}$$

where ω_{BV} is Brunt-Vaïsälä frequency ($\omega_{\mathrm{BV}} < \omega_{\mathrm{ac}}$).

If $\omega_{\mathrm{BV}} > 0$, medium will support IGW, but if $\omega_{\mathrm{BV}} < 0$ the convection will start. That is why Schwarzschild criterium can be used for IGW. Internal gravity waves have horizontal wavenumbers ($k_x \neq 0$). Their horizontal speeds are greater than vertical ones.

The dispersion relation for incompressible medium is:

$$k_z^2 = k_x^2\left(\frac{\omega_{\mathrm{BV}}^2}{\omega^2} - 1\right), \tag{5}$$

and for compressible medium is:

$$k_z^2 = k_x^2\left(\frac{\omega_{\mathrm{BV}}^2}{\omega^2} - 1\right) - \frac{1}{4H^2}. \tag{5^a}$$

IGW are produced below and above CZ (between the photosphere and the chromosphere, November *et al*, 1979). Their characteristics differ from those of acoustic waves. IGW are highly dispersive with large horizontal wavenumber:

$$v_g \approx \omega_{\rm BV} H, \quad v_g = f(k_x, \omega), \quad k_x > k_z, \quad \vec{v}_g \perp \vec{v}_{\rm ph} \parallel \vec{k}. \tag{6}$$

IGW do not form shock waves, and play no role in the atmospheric heating. Their main contribution is in the spectral lines broadening. This is particularly evident at the photospheric limb lines due to k_x (Christensen- Dalsgaard & Gough, 1982; Brown *et al*, 1986; Severny *et al*, 1988). If $\vec{v}_g = 0$, energy is not transported from the place of disturbance (g-mode).

Alfvén and MHD-waves are produced by magnetic tension as a restoring force. They are generated in CZ similarly to acoustic waves.

Alfvén wave characteristics are:

$$k = \frac{\omega}{v_{\rm A}}, \quad v_{\rm A} = \frac{B_0}{\sqrt{4\pi\rho}}, \quad \vec{v}_{\rm A} \parallel \vec{B}_0, \quad \vec{v}' \perp \vec{B}_0, \quad \vec{v}_{\rm A} \neq f(\vec{v}'), \tag{7}$$

where B_0 is the local magnetic field, $v_{\rm A}$ is the Alfvén speed, $\vec{v}'$ is the speed of disturbance. Alfvén waves can propagate in any direction $\theta(\vec{k}, \vec{B}_0)$, but preferentially along $\vec{B}_0$. The dispersion relation for MHD-simple waves is:

$$\left(\frac{\omega^2}{k^2} - v_{\rm A}^2 \cos^2\theta\right)\left[\left(\frac{\omega^2}{k^2} - u^2\right)\left(\frac{\omega^2}{k^2} - v_{\rm A}^2\right) - u^2 v_{\rm A}^2 \sin^2\theta\right] = 0, \tag{8}$$

which gives:

$$\frac{\omega}{k} = u = \sqrt{\gamma\frac{p}{\rho}}, \quad \text{for acoustic waves;}$$

$$\frac{\omega}{k} = v_{\rm A} = \frac{B_0}{\sqrt{4\pi\rho}}, \quad \text{for Alfvén waves;}$$

$$\frac{\omega}{k} = \sqrt{u^2 + v_{\rm A}^2}, \quad \text{for MHD-simple waves.}$$

If $\omega/k > u$ and $\omega/k > v_{\rm A}$, there are MHD-fast waves, and if $\omega/k < u$ and $\omega/k < v_{\rm A}$ there are MHD-slow waves. Both fast and slow MHD are *magnetoacoustic waves.* If $u > v_{\rm A}$, the waves are longitudinal, but if $v_{\rm A} > u$, they are transversal. In the high atmosphere Alfvén waves are dominant because ρ decreases faster than $\overline{B}$. Their speed in the corona is $v_{\rm A} = 500 - 2000$ km/s, and they can reach from $6R_\odot$ to $200R_\odot$. Alfvén or magnetoacoustic waves can form shock waves. It is believed that these waves give significant contribution to heating the corona and acceleration of the solar wind (Velli, 1993; Holweg, 1991).

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THE APPROXIMATE VALUES OF ECCENTRIC ANOMALIES OF PROXIMITY

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Summary. The new expressions for finding the approximate values of eccentric anomalies of proximity, i.e. the minimal mutual distance between two elliptical orbits, has been derived, by using vectorial orbital elements. The application of these expresions is presented on the two pairs of orbits of minor planets, quasicomplanar and nonquasicomplanar.

1. INTRODUCTION

We started to consider the proximity problems almost thirty years ago, Lazović (1964). The starting point was determination of the minimal mutual distance between two elliptical orbits of the celestial bodies. For that distance we derived expressions with true anomalies in paper Lazović (1967), and in Lazović (1981) with eccentric anomalies as variables. There we obtained two trigonometric equations

$$\left.\begin{aligned} X_2 \sin E_1 + Y_2 \cos E_1 - S_1 \sin E_1 \cos E_1 = 0, \\ X_1 \sin E_2 + Y_1 \cos E_2 - S_2 \sin E_2 \cos E_2 = 0 \end{aligned}\right\} \tag{1}$$

for determination eccentric anomalies E_1 and E_2 of the proximity positions of two elliptical orbits. In their form, these equations are equal to those in Lazović (1964). They are valid generally in calculus of proximities of these orbits, no matter how large is the angle I between their orbital planes.

If unit vectors $\mathbf{R}_1$ and $\mathbf{R}_2$ are orthogonal on those planes, then we can calculate angle I by the expression

$$\cos I = (\mathbf{R}_1\mathbf{R}_2) = \cos i_1 \cos i_2 + \sin i_1 \sin i_2 \cos(\Omega_2 - \Omega_1), \tag{2}$$

besides the expression given in Lazović and Kuzmanoski (1974).

2. APPROXIMATE ECCENTRIC ANOMALIES OF THE PROXIMITY

The equations (1) are being solved by successive approximations with expressions given in Lazović (1981), if initial, i.e. approximate values of eccentric anomalies of the proximity positions of two elliptical orbits are known. Since proximities could be expected near to the crossing of these orbits, we will take eccentric anomalies corrensponding to the relative nodes of two considered orbits for requested approximate values. The intersection points of the orbits with a straight line defined as the intersection of two orbital planes are relative nodes. This line is representing the line of relative nodes; for every orbit from considered pair we have two relative nodes, and therefore two values of correnspoding eccentric anomalies. Let us denote heliocentric position vectors of minor planets 1 and 2 in the direction of the same relative nodes (both ascending or descending) of their orbits with $\mathbf{r}_1$ and $\mathbf{r}_2$; they are colinear $(\mathbf{r}_1\mathbf{r}_2) = r_1 r_2 > 0$. Expressed throught eccentric anomalie E_i they are

$$\mathbf{r}_i = a_i(\cos E_i - e_i)\mathbf{P}_i + b_i \sin E_i \mathbf{Q}_i, \qquad i = 1, 2 \tag{3}$$

where $\mathbf{P}_i$ and $\mathbf{Q}_i$ are known unit vectors in the orbital plane, mutualy orthogonal ($\mathbf{P}_i$ is in the direction of the perihelion of the orbit of the i-th minor planet), and whose coordinates represent the so called vectorial orbital elements.

For the considered relative node of the two orbits we can write following equations

$$(\mathbf{r}_1\mathbf{R}_2) = 0, \qquad (\mathbf{r}_2\mathbf{R}_1) = 0, \tag{4}$$

from where, after inserting (3) and introducing notations

$$\left.\begin{aligned} A_1 = b_1(\mathbf{Q}_1\mathbf{R}_2), \quad B_1 = a_1(\mathbf{P}_1\mathbf{R}_2), \quad C_1 = -a_1 e_1(\mathbf{P}_1\mathbf{R}_2), \\ A_2 = b_2(\mathbf{Q}_2\mathbf{R}_1), \quad B_2 = a_2(\mathbf{P}_2\mathbf{R}_1), \quad C_2 = -a_2 e_2(\mathbf{P}_2\mathbf{R}_1), \end{aligned}\right\} \tag{5}$$

we get two starting equations for requested eccentric anomalies E_1 and E_2 of the relative node

$$\left.\begin{aligned} A_1 \sin E_1 + B_1 \cos E_1 + C_1 = 0, \\ A_2 \sin E_2 + B_2 \cos E_2 + C_2 = 0. \end{aligned}\right\} \tag{6}$$

By dividing the first equation (6) with $\cos E_1$, and the second one with $\cos E_2$, we would get two square equations by $\tan E_1$ and $\tan E_2$, whose solutions are

$$\left.\begin{aligned} (\tan E_1)_{1,2} = \frac{-A_1 B_1 \pm C_1\sqrt{A_1^2 + B_1^2 - C_1^2}}{A_1^2 - C_1^2}, \\ (\tan E_2)_{1,2} = \frac{-A_2 B_2 \pm C_2\sqrt{A_2^2 + B_2^2 - C_2^2}}{A_2^2 - C_2^2}. \end{aligned}\right\} \tag{7}$$

With expressions (7) and (5) we can determine approximate values of eccentric anomalies of proximity. What we get are two solutions for $\tan E_i$ and from them four solutions for E_i, $(i = 1, 2)$. Among them only two, for chosen orbit, realy corrensposnd to two existing relative nodes. The first criterion for the selection of two corrensponding, among the four caculated values of E_i, is to take those which satisfy correnspoding equation (6). The second criterion for the selection of the corrensponding pair of values of eccentric anomalies E_1 and E_2 for the same relative node is that they correnspond to colinear vectors $(\mathbf{r}_1\mathbf{r}_2) = r_1 r_2 > 0$.

3. EXAMPLES

We will apply expressions, derived here, on minor planet pairs already used with their orbital elements as they were in order to compare methods Lazović (1980, 1981).

(215) **Oenone** = 1 and (1851) **Lacroute** = 2, $I = 0.^\circ 007$

$$(\tan E_1)_1 = 6.0111322, \quad (E_1)_1 = 80.^\circ 55488, \quad (E_1)_2 = 260.^\circ 55488;$$
$$(\tan E_1)_2 = 10.0895108, \quad (E_1)_3 = 84.^\circ 33974, \quad (E_1)_4 = 264.^\circ 33974.$$

The first criterion, that the first equation (6) is satisfied, is contented by $(E_1)_1$ and $(E_1)_4$ only, and therefore they corrенspond to two existing relative nodes.

$$(\tan E_2)_1 = 3.0561204, \quad (E_2)_1 = 71.^\circ 88127, \quad (E_2)_2 = 251.^\circ 88127;$$
$$(\tan E_2)_2 = 1.3055699, \quad (E_2)_3 = 52.^\circ 54973, \quad (E_2)_4 = 232.^\circ 54973.$$

The first criterion, that the second equation (6) is satisfied, is contented by $(E_2)_2$ and $(E_2)_3$ only, and therefore they corrенspond to existing relative nodes. Now, with values E_1 and E_2 selected in this manner we determine vectors $\mathbf{r}_1$ and $\mathbf{r}_2$, and take their scalar product; for $(\mathbf{r}_1\mathbf{r}_2) > 0$, as second criterion, we determine the pairs of eccentric anomalies for two corrensponding relative nodes. By this procedure we obtain that values are $(E_1)_1$, $(E_2)_3$ and $(E_1)_4$, $(E_2)_2$. With those values, taken as approximate values of the proximity positions, we would start calculation for finding the exact proximity positions by expressions given in Lazović (1981). Calculus showed that exact values are $E_1 = E_{215} = 81.^\circ 20275$ and $E_2 = E_{1851} = 53.^\circ 13885$. So, relative node of orbits of minor planets (215, 1851) with eccentric anomalies $E_{1,0} = (E_1)_1$ and $E_{2,0} = (E_2)_3$ is closer to the positions of proximity of these orbits; angular distances from which are $\Delta E_{215} = E_{215} - E_{1,0} = 0.^\circ 64787$ and $\Delta E_{1851} = E_{1851} - E_{2,0} = 0.^\circ 58912$, which are small values. Proximity distance of this pair of quasicomplanar orbits had the value $\varrho_{min} = 0.000004$AU.

(1) **Ceres** = 1 and (2) **Pallas** = 2, $I = 36.^\circ 653$

By similar treatment, as in previous example, for this pair we would find: $(E_1)_1 = 30.^\circ 96368$, $(E_1)_2 = 210.^\circ 96368$, $(E_1)_3 = 35.^\circ 83718$, $(E_1)_4 = 215.^\circ 83718$; $(E_2)_1 = 80.^\circ 99766$, $(E_2)_2 = 260.^\circ 99766$, $(E_2)_3 = 56.^\circ 03291$, $(E_2)_4 = 236.^\circ 03291$. The first criterion for the selection of the eccentric anomalies, i.e. that equations (6) are satisfied, determines values $(E_1)_1$, $(E_1)_4$, $(E_2)_2$ and $(E_2)_3$. The second criterion, $(\mathbf{r}_1\mathbf{r}_2) > 0$, determines correnspondig pairs of these anomalies for the two relative nodes. Those are $(E_1)_4$, $(E_2)_2$ and $(E_1)_1$, $(E_2)_3$. With them, after two successive approximations, we would find eccentric anomalies of the proximity positions of this pair of nonquasicomplanar orbits as $E_1 = 215.^\circ 34175$, $E_2 = 260.^\circ 30903$, which gives minimum distance $\varrho_{min} = 0.062696$AU. Here approximate values of eccentric anomalies of proximity are those for $E_{1,0} = (E_1)_4$ and $E_{2,0} = (E_2)_2$, so that that relative node is at the angular distances from the proximity positions of $\Delta E_1 = E_1 - E_{1,0} = -0.^\circ 49543$ and $\Delta E_2 = E_2 - E_{2,0} = -0.^\circ 68863$, which are again small values.

4. CONCLUSION

Our equations with eccentric anomalies as arguments for the calculus of proximity from Lazović (1981) are simpler than those with true anomalies in Lazović (1967), because they are shorter. The new expressions derived here represent complement to earlier expressions Lazović (1981), so that now we obtained complete general method for calculus of proximity of the two elliptical orbits of celestial bodies with eccentric anomalies and vectorial orbital elements.

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ON THE ONE TYPE OF THE RESTRICTED THREE BODY PROBLEM

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Summary: One type of the restrected three-body problem is formulated. The first integrals and the exact solutions are considered as they stand to the corrensponding ones in the general three-body problem. Equations of motion in Jacobi coordinates are expanded over Legendre polinomials, which gives suitable form for studing of the so called stelar configurations of the three-body problem.

1. INTRODUCTION

In general three-body problem (GTBP) of classical celestial mechanics subject is the motion of three material points which simultaniously attract each other by Newtonian gravity. It has been proved (Sundman, 1913) that solution of the problem can be expressed in the form of convergent series, but convergence is so slow that solution is practically unusable (Duboshin, 1964). Celestial mechanicists have formulated a few simplier problems (based on GTBP) which have some practical importance and are known as restricted three-body problems (RTBP) (for review see Szebehely 1962).

If mass of one of the three bodies, let's say m_0, is significantly greater than the sum of the other two masses ($m_0 \gg m_1 + m_2$, and m_1 and m_2 are of the same order of quantity) than it is reasonable to expect that gravitational influence of bodies m_1 and m_2 on body m_0 will be negligable. In general, gravitational attraction between bodies m_1 and m_2 could be negligable also, and as it was stated by Hénon and Petit (Hénon and Petit, 1986.) than problem reduces on two, practically independent, two - body problems for pairs $(m_0 - m_1)$ and $(m_0 - m_2)$. However, these authors have also noticed that if relative distance between bodies m_1 and m_2 is "sufficiently small, their mutual attraction becomes of the same order as the differential attraction from m_0", then their mutual attracion can not be neglected, and they classified such types of problems as Hill's type problems.

2. FORMULATION OF THE PROBLEM

In order to simplify GTBP, no matter how distant are bodies m_1 and m_2 from each other, one can entirely neglect the influence of bodies m_1 and m_2 on body m_0 (or fix body m_0 with inertial reference frame). *More generally, no matter how masses m_0, m_1, m_2 are related, one can fix body m_0 in order to obtain a type of RTBP. In that case problem would be to find the motion* *of bodies m_1 and m_2 if they are attracted by fixed body and by each other, and if initial conditions are known.* Comparing with problem of two fixed centers (e.g. Duboshin, 1964), this problem is in some way opposite and could be called problem of one fixed center. On the other side comparing this problem with various versions of RTBP one can see that, it is more complicated since motion of two bodies is not known. Here, we will just make note that type of problems in which one has mass configuration $m_0 \gg m_1 + m_2$ are very often classified as stelar types three body problems (e.g. Roy, 1982).

3. THE EQUATIONS OF MOTION AND THEIR EXACT SOLUTIONS

The equations of motion (notations are taken form fig. 1) in case explained in the previous chapter are:

$$\frac{d^2\mathbf{r}_1}{dt^2} = -Gm_0\frac{\mathbf{r}_1}{{r_1}^3} + Gm_2\frac{\mathbf{r}}{r^3}, \tag{1}$$

$$\frac{d^2\mathbf{r}_2}{dt^2} = -Gm_0\frac{\mathbf{r}_2}{{r_2}^3} - Gm_1\frac{\mathbf{r}}{r^3}, \tag{2}$$

where gravitational accelerations which bodies m_1 and m_2 are giving to the body m_0 are entirely neglected (or say the third equation from GTBP is neglected) because we put $\ddot{\mathbf{r}}_0 = \dot{\mathbf{r}}_0 = \mathbf{r}_0 = 0$. The equations of motion (1) and (2) of bodies (m_1, m_2) posses two first integrals (integral of angular momentum and integral of energy) which could be easily checked by direct calculation.

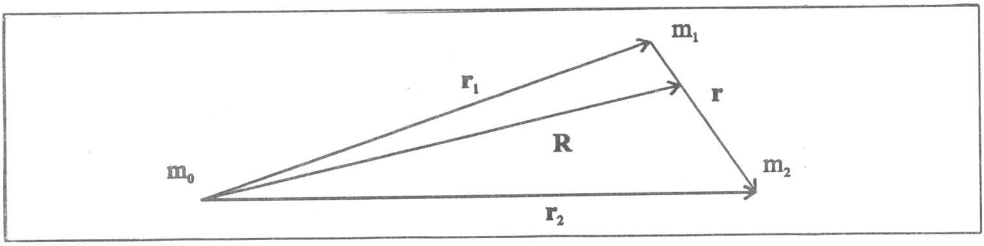

Figure 1.

The conservation laws are valid in this problem as in GTBP, but the integrals of motion of barycenter dissapeared because m_0 is fixed. On the other hand situation with exact solutions is different. While in GTBP two types of the exact solutions exist (colinear and triangle type), in this case one has colinear type only.

It is well known that if center of mass of the bodies m_1 and m_2 coincides with the position of the body m_0, and if initial velocities of bodies m_1 and m_2 are in directions making a fixed and the same angle with their radius vectors respect to the barycenter, than the equations (1) and (2) can be integrated in the finite form. Actually these equations are becoming one and the same equation:

$$\frac{d^2\mathbf{r}_i}{dt^2} = -G\frac{m' + 8m_0}{r_i{}^3}\mathbf{r}_i \quad (i = 1, 2), \tag{3}$$

where $m' = m_1 = m_2$ (that is the consequence of the condition, about coincidence of the body m_0 with the center of mass of the system m_1-m_2, mentioned above). In the equation (3) one can easily recognizes the equation of two body problem. Finally one can conclude that simplified colinear exact solution exists in this type of RTBP. It is simplified because m_0 has to be exactly on the half of the distance between m_1 and m_2 (which is also cosequence of the condition about coincidence of the body m_0 with the center of mass of the system m_1-m_2).

4. THE EQUATIONS OF MOTION IN JACOBI COORDINATES. COMPARISON WITH GTBP

Let us skip now to Hill's configuration of this problem. Relative distance among small bodies (denoted by $\mathbf{r}$) is very small (by magnitude) comparing with distance from their center of mass to the large mass (denoted by $\mathbf{R}$), (see fig. 1). Than we have desirable mass configuration and also $r \ll R$. In such kind of problems when hierarchy in configuration is discrenable, Jacobi coordinates $\mathbf{R}$, $\mathbf{r}$, are very convinient. If we put $m = m_1 + m_2$ and $\mu = m_1 m_2/(m_1 + m_2)$ then equations of motion (1) and (2) in Jacobi coordinates will take the following form:

$$\frac{d^2\mathbf{R}}{dt^2} = -G\frac{m_0}{m}\left[\left(\frac{m_2}{r_2{}^3} + \frac{m_1}{r_1{}^3}\right)\mathbf{R} + \mu\left(\frac{1}{r_2{}^3} - \frac{1}{r_1{}^3}\right)\mathbf{r}\right], \tag{4}$$

$$\frac{d^2\mathbf{r}}{dt^2} + G\frac{m}{r^3}\mathbf{r} = -Gm_0\left[\left(\frac{1}{r_2{}^3} - \frac{1}{r_1{}^3}\right)\mathbf{R} + \frac{1}{m}\left(\frac{m_1}{r_2{}^3} + \frac{m_2}{r_1{}^3}\right)\mathbf{r}\right], \tag{5}$$

If one compares these equations with corrensponding equations of GTBP, in Jacobi coordinates (see Roy, 1982, p.413) only small difference in equation (4) will be noticed (instead of m_0 on the right hand side one has $m_0 + m$, while equation (5) keeps the same form as in GTBP. Another, essential difference, is that noninertial motion of m_0 is neglected, while in GTBP m_0 has noninertial component of motion respect to the barycenter.

Functions in small brackets appearing in equations (4) and (5) can be expanded in series over derivatives of the Legendre's polinomials. If $P_k{}^{(1)}(x)$ is being derivative of Legendres polinomial $P_k(x)$ over x ($x = \cos\varphi$ where φ is angle between vectors $\mathbf{r}$ and $\mathbf{R}$), equations (4) and (5) could be written in the following form:

$$\frac{d^2\mathbf{R}}{dt^2} + G\frac{m_0}{R^3}\mathbf{R} = -G\frac{m_0}{R^3}\frac{\mu}{m}\sum_{k=2}^{\infty}(B_k\mathbf{R} + A_k\mathbf{r})\Delta^{k-1}P_k{}^{(1)}(\cos\varphi), \tag{6}$$

$$\frac{d^2\mathbf{r}}{dt^2} + G\frac{m}{r^3}\mathbf{r} = -G\frac{m_0}{R^3}\mathbf{r} - G\frac{m_0}{R^3}\sum_{k=2}^{\infty}(A_k\mathbf{R} + C_k\mathbf{r})\Delta^{k-1}P_k{}^{(1)}(\cos\varphi), \tag{7}$$

where

$$A_k = \frac{(-1)^{k-1} {m_1}^{k-1} - {m_2}^{k-1}}{m^{k-1}}, \quad B_k = \frac{(-1)^{k-1} {m_1}^{k-2} + {m_2}^{k-2}}{m^{k-2}},$$

$$C_k = \frac{(-1)^{k-1} {m_1}^{k} + {m_2}^{k}}{m^{k}}, \quad (k = 2, 3, ...); \qquad \Delta = \frac{r}{R}.$$

Coeffitients A_k, B_k and C_k are all in the interval $[-1, 1]$ for $k \geq 2$. Condition $\Delta \ll 1$ should provide that bodies m_1 and m_2 will be in binary system which will itself move around m_0.

Difference between equation (6) and corresponding equation in GTBP is, as one would expect, very small again. In all the places where m_0 appears in the (6), one should put $m_0 + m$ in order to obtain corresponding equation in GTBP. Equation for $\mathbf{r}$ (7) has again the same form as in GTBP. Right hand sides of equations (6) and (7) in this case could be treated as "perturbations" of two two-body problems (for $\mathbf{r}$ and $\mathbf{R}$). Perurbations are then separated into two components in directions of vectors $\mathbf{R}$ and $\mathbf{r}$ and expressed in form of the series which should converge for sufficiently small Δ.

5. CONCLUSION

Differences and similarities of RTBP and GTBP are clearly showing that, by complexisity, RTBP stands somewhere between GTBP and restrected three body problems (previously formulated). On the other side Jacobi form of the equations of motion (equations (6) and (7)) give suitable form for step by step study of Hill's configuration of RTBP as well as GTBP (since they are very similar), by including higher order approximations. At the end we will note that planar version of this problem looks even more promising for further analysis.

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"GENERIC TERM" TECHNIQUE IN COMPUTATION OF ASTEROID PERTURBATIONS

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For already quite some time people are trying to automatize the cumbersome algebraic manipulations associated with handling of complicated analytic expressions typical of theories of motion of celestial bodies. This is, however, not a straightforward task, and even nowadays there are but a few successfull solutions applicable to particular problems of celestial mechanics.

Perhaps the most important application of the kind is an automated development of the disturbing function (c.f. Kaula, 1962; Murray, 1993), which, in addition, has to be represented in some suitable computer readable form. Various approaches have been used for the purpose, the simplest and the most oftenly employed one being "the scheme with coded keys" (Henrard, 1989). This scheme, in turn, in computation of perturbations leads to the use of the so called "generic terms", which are constructed in such a way to include all the variables appearing in the development and to enable representation of all the different combinations (allowed by D'Alembert rules, for example) of these variables.

Milani and Knežević (1990) have implemented the generic term technique in their computation of asteroid proper elements. In the beginning, this was done only for the purpose of computation of the short-periodic perturbations, the long-periodic ones being computed in the same way somewhat later (Milani and Knežević, 1993). The perturbation computation was based on the LeVerrier's (1855) classical development of perturbing function up to degree four in eccentricity and inclination, adjusted by Yuasa (1973) for the use with an arbitrary number of perturbing planets. The purpose of this paper is to review the employed procedures and to discuss briefly the advantages and drawbacks of the specific solutions applied in these cases.

The method of elimination of the short-periodic terms by means of the canonical transformations, the corresponding Hamiltonian (including the indirect part) and the generating function of the transformation are described in detail by Knežević (1992). It has been adopted there for simplicity reasons to represent direct and indirect part of the initial Hamiltonian by means of two separate generic terms, which have been constructed following the same general idea, but accounting for the distinct features of the two developments:

$$H_d = \sum G_0 m_j \frac{b_1}{b_2}(b_3)^{(i)}(-1)^{b_4} i^{b_5} e^{b_6} e_j^{b_7} \sin^{b_8} I \sin^{b_9} I_j \times$$
$$\times \cos[(i+b_{10})\lambda_j - (i+b_{11})\lambda + b_{12}\tilde{\omega}_j + b_{13}\tilde{\omega} + b_{14}\Omega_j + b_{15}\Omega] \qquad (1)$$

$$H_i = \sum G_0 m_j \frac{a}{a_j^2}\frac{c_1}{c_2}(-1)^{c_3} e^{c_4} e_j^{c_5} \sin^{c_6} I \sin^{c_7} I_j \times$$
$$\times \cos[c_8\lambda_j - c_9\lambda + c_{10}\tilde{\omega}_j + c_{11}\tilde{\omega} + c_{12}\Omega_j + c_{13}\Omega] \qquad (2)$$

Here the subscript j refers to the perturbing planet, and i denotes the summation index; b_k $(k = 1, \ldots, 15)$ and c_l $(l = 1, \ldots, 13)$ are integers, b_3 in particular standing for the corresponding coefficient of Leverrier, function of the semimajor axes ratio (a/a_j). Note that the above generic terms are somewhat simpler from those in Knežević (1992); this is due to the fact that $\sin(I/2)$ and $\sin(I_j/2)$ are replaced in the present case by $(1/2)\sin I$ and $(1/2)\sin I_j$ and added to the corresponding already existing variables; this causes only differences of degree higher than fourth, and can be neglected when dealing with developments up to that degree (like in the case of the theory used by Milani and Knežević).

Having the above generic terms at one's disposal it is easy to represent the Hamiltonian by a list of b_k and c_l integers only, so that a typical term in the direct part:

$$-G_0 m_j \frac{1}{8}(40)^{(i)} e e_j \sin I \sin I_j \cos[(i-1)\lambda_j - (i-1)\lambda + \tilde{\omega}_j + \tilde{\omega} - \Omega_j - \Omega]$$

looks like:

[1 8 40 1 0 1 1 1 1 −1 −1 1 1 −1 −1],

and similarly for the indirect part. Once the Hamiltonian in the computer readable form of a list of integers is available, the procedure of separating the long- and the short-periodic parts, finding the partial derivatives of the generating function, and computing the auxiliary quantities becomes a matter of developping few simple routines in some standard programming language.

As for the long-periodic perturbations, instead of representing the Hamiltonian itself in a computer readable form, again for the sake of simplicity, the generating function of canonical transformation has been represented by means of a generic term:

$$S = \sum Y(n_1) n_2 \xi_{55}^{n_3} \xi_{56}^{n_4} \eta_{57}^{n_5} \eta_{56}^{n_6} \nu_{55}^{n_7} \nu_{56}^{n_8} \mu_{57}^{n_9} \mu_{56}^{n_{10}} \rho_1^{n_{11}} \rho_2^{n_{12}} \sigma_1^{n_{13}} \sigma_2^{n_{14}} \times$$
$$\times F(n_{15})[n_{16}\lambda_5 + n_{17}\lambda_6 + n_{18}\delta_5 + n_{19}\delta_6]/D(n_{20}). \qquad (3)$$

The detailed explanation for the quantities appearing in above expression, as well as for the procedures of separation of the integrable Hamiltonian and long-periodic generating function and computation of long-periodic perturbations can be found in Knežević (1993). It is enough to mention here that each perturbative term is again represented as a list of integers $n_m, (m = 1, \ldots, 20)$, like:

[1 4 1 0 0 0 0 0 0 0 2 1 0 0 2 1 0 0 0 1].

In the case of the analytical theory of asteroid motion by Milani and Knežević (1990; 1993), the integer files used in computations contain 252 records for the short-periodic perturbations, and 1000 records for the long-periodic perturbations. In this latter case, for example, the information stored in 300 literal terms is now given in a form that enabled replacement of a 1200 statements computer routine, which has even been too long and complex to be properly compiled by some optimizing compilers, with 50 statement routine based on a single do loop.

One can state, in conclusion, that the generic term technique provides a number of advantages with respect to classical algorithms with literal expressions: (i) the simpler procedures enable the programmes to be written in a few easily-testable lines; (ii) the error-free manipulation of the perturbing Hamiltonians of an arbitrary order/degree; (iii) a straightforward possibility for separation of resonant terms; (iv) representation of the long series developments in an easily-transportable, compressed, computer readable form. The most important drawback of the generic term technique is some performance penalty; since usually one accesses the integer files sequentially, the performance of the algorithm is slightly decreased; note, on the other hand, that this can be at least partly compensated by some specific code optimisations.

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THE ORIENTATION OF THE FK5 COORDINATE SYSTEM FROM THE MERIDIAN OBSERVATIONS OF THE SUN AND PLANETS

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Abstract: In this paper the elements of orientation of the fundamental system and the procedure for their calculation are presented. On the basis of the observation of the Sun, Mercury and Venus computed are the corrections ΔA and $\Delta\delta_o$.

1. Introduction

The determination of star coordinates and the compilation of the corresponding catalogues is not only important, but a central problem in astrometry today.

There is a constant interest in obtaining a knowledge of the structure of the Universe in space and time as good as possible. This requires the question of establishing of a fundamental coordinate system, necessary to determination of the star positions and proper motions of high accuracy, to be considered. Consequently the instruments, the measuring techniques and the calculation methods have been improved.

For the sake of compilations of new catalogues and improvements of the fundamental systems obtained earlier large observational programmes have been initiated, the instruments have been improved and automatised (photoelectric registration), new principles of formation of space coordinate systems have been extended and examined, the revolution and rotation of the Solar-System bodies have been studied, the composition of the terrestrial atmosphere has been examined, etc.

In this complex programme an important place is occupied by the tasks of studying the systematic catalogue errors, i.e. of determining the zero point for the star coordinates and the periodical errors of the catalogue system.

Whenever a new fundamental catalogue is compiled, appears the problem of determining an origin of the coordinate system as good and as accurate as possible.

Over the last 150 years the improvement of the coordinate system's origin has been done five times and hence some new ideas concerning the relationship with alternative, new, possibilities for determining the orientation of the fundamental coordinate system have appeared.

A more general approach to the question of the orientation of the coordinate axes in the star catalogues has been specially extended and also methods for solving these problems have been proposed. In order to improve the accuracy in the determining the position of the right-ascension zero point the list of observed objects has been enlarged, an increased number of modern measurements has been collected, etc.

All of this enables the task of the zero-point determination to be solved with a high accuracy.

The present examinations were undertaken after the recommendation at the XV IAU General Assembly and in 1984 it was decided to derive a new fundamental system comprising 3500 FK5 bright and faint stars and being based on the improvement of the FK4 fundamental system.

2. The Orientation of the Coordinate Axes

The determination of the coordinate-origin position (so-called zero point) and of the orientation angles for the coordinate axes in star catalogues consists of the calculation of the constant declination correction $\Delta\delta_o$ and of the orientation elements ΔA.

The equator of a catalogue KK is a small circle on the celestial sphere, parallel the great circle K_1K_1 and it is at the distance $\Delta\delta_o$ from the latter one (Fig.1). This distance is positive if KK is north of K_1K_1 and vice versa. The great circle TT is the dynamical or true equator. The true point of equinox N is defined as the intersection of the dynamical equator TT with the ecliptic EE. We shall denote as $x_ky_kz_k$, $x_1y_1z_1$ and xyz the coordinate systems corresponding to the circles on the sphere mentioned above. The axis of abscissae in the system xyz is directed from the centre of the sphere towards the point N_k, whereas the the ordinate perpendicular to it goes through the circle KK. In the rectangular coordinate system $x_1y_1z_1$ the abscissae axis is directed towards the point N_k' corresponding to the position of the catalogue equinox on the great circle K_1K_1 after the displacement of the catalogue equator KK by the distance $\Delta\delta_o$ (Fedorov, 1974).

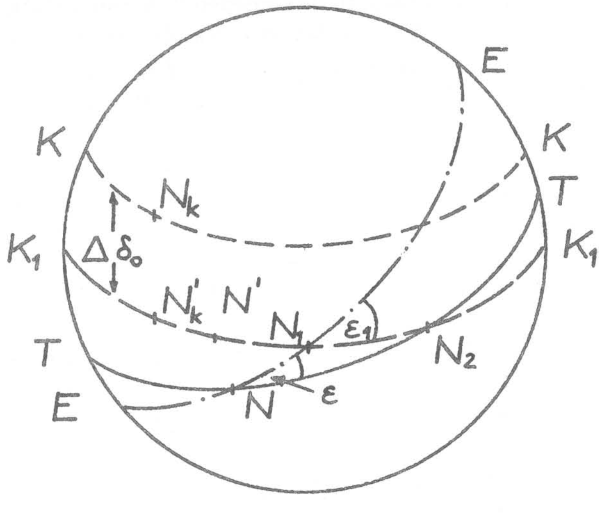

Fig. 1. Position of the equator of a catalogue with relation to the dynamical equator and the ecliptic

The ordinate axis of the coordinate system $x_1y_1z_1$ is in the plane of the great circle K_1K_1 . The axes z_k and z_1 are directed towards the pole of the catalogue equator. In the rectangular coordinate system xyz the axis x is directed towards the true-equinox point N, while the plane xy coincides with the equator one.

The question of axes orientation is reduced to the determination of the rotation angles for the rectangular coordinate system whose x_1y_1 plane coincides with the plane of the corrected equator K_1K_1 with respect to the axes of the rectangular coordinate system attached to the true equator TT.

The rotation angles are easily obtained by transforming the catalogue positions α_k, δ_k into the coordinates α, δ determining the planet positions in the true coordinate system. This transition is done in two phases: the catalogue equator KK is translated parallelly to itself to the distance $\Delta\delta_o$ so that it obtains the position K_1K_1 and the point N_k falls to the position N'_k . Then the system $x_1y_1z_1$ should be rotated to coincide with xyz .

This transformation may be also done in the opposite sense. The first rotation is done for the system xyz around the axis z by an angle $u = NN_2$, then by $\Delta\varepsilon$ equal to the angle N'_kN_2N around the new position of the axis x_1 going through the point N_2. The last rotation concerns the system by an angle $\omega = N'_2N'_k$ around the new position of the axis z.

When the circle TT is rotated by the angle $\Delta\varepsilon$, the point N occupies the position N' and $\omega - \alpha = N'_kN_2 - NN_2 = N'_kN_2 - N'N_2 = \Delta\alpha_o$, where $\Delta\alpha_o$ is the difference in the positions of the catalogue equinox and the true one on the equator K_1K_1 . Let the quantity $\Delta A = -\Delta\alpha_o$ be a constant correction of the catalogue right ascension for the conversion to the equinox N. Its practical role is the improvement of the star position in a catalogue. The name used in the literature for ΔA is "the equinox correction".

In order to determine the corrections of the coordinate-system origin (so- called zero point) and the orientation angles of the coordinate axes in star catalogues one should calculate the declination-correction constants $\Delta\delta_o$ and the orientation elements ΔA, $\lambda_1 - \lambda = \Delta\lambda$, $\varepsilon_1 - \varepsilon = \Delta\varepsilon$ throught which the rotation angles of the axes u, $\Delta\varepsilon$, ω are given.

The differences between the catalogue coordinates and the true ones in right ascension and declination are determined by means of the following formulae

$$\alpha_k - \alpha = -\Delta A \quad , \quad \delta_k - \delta = -\Delta\delta_o \tag{1}$$

where the displacement of the catalogue equator with respect to the dynamical one is not present.

For the purpose of determining the coordinate-system origin one utilises the differences $\alpha_k - \alpha_e$, $\delta_k - \delta_e$ where α_k and δ_k denote the corresponding right ascensions and declinations of the planets obtained from observations by applying the differential method in the reference-catalogues system, whereas α_e and δ_e are their ephemeris right ascensions and declinations

$$\alpha_k - \alpha_e = (\alpha_k - \alpha) + (\alpha - \alpha_e) \qquad \delta_k - \delta_e = (\delta_k - \delta) + (\delta - \delta_e). \tag{2}$$

The differences $\alpha_k - \alpha$ and $\delta_k - \delta$ are the changes of the coordinates due to the rotation of the dynamical equator with respect to the catalogue one, whereas the ones $\alpha - \alpha_e$ and $\delta - \delta_e$ are due to the errors in the determination of the orbits (Earth and other planets) used in the ephemeris calculation.

The differences between the catalogue right ascensions, i.e. declinations, and the true ones calculated by use of the formulae

$$[\alpha_k - \alpha, \delta_k - \delta] = [\Delta A, \Delta\delta_o, (\lambda_1 - \lambda)\sin\varepsilon, \varepsilon_1 - \varepsilon]M_1 \tag{3}$$

where is M_1 is the transformation matrix and (2) yield

$$[\alpha_k - \alpha_e, \delta_k - \delta_e] = [\Delta M_o + \Delta r, \Delta p, \Delta q, e\Delta r, 100\Delta a/a, \Delta e,$$
$$\Delta M_o' + \Delta\psi_3', \Delta\psi_1', \Delta\psi_2', 10e'\Delta\psi_3', 100\Delta e']M_2 M_3 +$$
$$+[\Delta\delta_o, \Delta\lambda \sin\varepsilon, \Delta\varepsilon_1]M_4 \quad . \qquad (4)$$

ΔM_o, Δe, $\Delta M_o'$, $\Delta e'$ denote the corrections of the mean anomaly and eccentricity of the planet orbits (a dash for Earth, without it for other planets), whereas Δa denotes the correction of the semimajor axis. The components of the vector of planet-orbit rotation in the rotating rectangular coordinate system Δp, Δq, Δr are related to the corrections of the orbital-node longitude $\Delta\Omega$, inclination Δi and angular distance node-perihelion $\Delta\omega$ by means of

$$\Delta i = \Delta p \cos\omega - \Delta q \sin\omega \ , \quad \Delta\Omega \sin i = \Delta p \sin\omega + \Delta q \cos\omega \ , \quad \Delta\omega + \Delta\Omega \cos i = \Delta r \ . \qquad (5)$$

The components of the Earth-orbit-rotation vector in the equatorial rectangular coordinate system $\Delta\psi_1'$, $\Delta\psi_2'$, $\Delta\psi_3'$ appear through the corrections of the inclination $\Delta\varepsilon'$ at the angular distance between the perihelion and the node of the Earth's orbit $\Delta\omega'$ and the difference between the catalogue equinox and the dynamical one ΔA in the mutual relationship (Duma and Minyajlo, 1976) :

$$\Delta\psi_1' = \Delta\varepsilon' \ , \quad \Delta\psi_2' = -\Delta A \sin\varepsilon \ , \quad \Delta\psi_3' = -\Delta A \cos\varepsilon + \Delta\omega' \ . \qquad (6)$$

Equations (4) contain 14 unknown quantities: the six corrections of the orbital elements (ΔM_o, Δi, $\Delta\Omega$, $\Delta\omega$, Δa, Δe), the four corrections of the Earth's orbital elements ($\Delta M_o'$, $\Delta\varepsilon'$, $\Delta\omega'$, $\Delta e'$), the three orientation elements (ΔA, $\Delta\lambda$, $\Delta\varepsilon_1$) and $\Delta\delta_o$ – the element of the sharp angle of the catalogue coordinate system.

Namely, equation (3) in the treatment of the planet observations is used for the purpose of correcting the zero point position in the coordinate system of the fundamental catalogue FK5.

In favour of this statement are also the values of the right ascension and declination corrections for the FK5 stars obtained on the basis of the Belgrade observational material for the period 1975 - 1991:

$$\Delta A = 0^s\!.014 \pm 0^s\!.006$$
$$\Delta\delta_o = 0''\!.05 \pm 0''\!.05 \quad .$$

3. Conclusions

On the basis of all said above one can say that the Belgrade observations of the Sun and planets with regard to both systematic and random errors are not inferior to the observations carried out at Washington, Greenwich, Cape, Nikolaev, Pulkovo, etc, but they even appear very good in quality when compared to them. Finally, we think that the number of observations should be made as large as possible, the behaviour of the instrument should be rigorously controlled and during the reduction procedure all possible influences should be taken into account in order to make them less significant.

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INFLUENCE OF UNACCOUNTED EFFECTS OF FLEXURE AND REFRACTION ON THE VALUES $O-C$ FOR OUTHER PLANETS DETERMINED WITH THE BELGRADE VERTICAL CIRCLE

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ABSTRACT.In this paper we show that the values $O-C$ for outher planets determined with the Belgrade Vertical Circle have to be corrected for remaining effects of flexure and refraction.The method for determination of corrections is given.

For reduction of observed declination of the planets determined with the Belgrade Vertical Circle (BVC) mean latitude $\overline{\varphi}$ was used which obtained from observations of selected southern stars with coordinates close to coordinates of the planets.

If there are unaccounted remaining of flexure and refraction, then for the latitude φ_i of a star the folowing formula have been used:

$$\varphi_i = \varphi_0 + b \sin z_i + \Delta\rho \tan z_i \tag{1}$$

where

φ_0 - latitude of BVC for the observational night;

b - coefficient of the horizontal flexure (for derivation z, measurements of the flexure are not included in calculation);

$\Delta\rho$ - correction for the refraction.

The mean value $\overline{\varphi}$ according to equation (1) is:

$$\overline{\varphi} = \varphi_0 + b\overline{\sin z_i} + \Delta\rho\overline{\tan z_i},$$

and the latitudes for calculation of declinations of the planets are:

$$\varphi_p = \varphi_0 + b \sin z_p + \Delta\rho \tan z_p.$$

The difference beetwen the latitudes φ_p and $\overline{\varphi}$ is:

$$\varphi_p - \overline{\varphi} = b(\sin z_p - \overline{\sin z_i}) + \Delta\rho(\tan z_p - \overline{\tan z_i}) \tag{2}$$

The difference $\Delta(O-C) = (O-C)_{\varphi p} - (O-C)_{\overline{\varphi}}$, where $O-C$ is calculated by φ_p and $\overline{\varphi}$ is:

$$\Delta(O-C) = \varphi_p - \overline{\varphi}$$

The unaccounted effects produce a systematic difference $\varphi_p - \overline{\varphi}$, in order to compute this difference it is necessary to derive from equation (1) the unknowns φ_0, b and $\Delta\rho$.These unknowns cannot be determined by the method of least squares because the coefficients of unknowns φ_0 and b are approximately equal, but the total effect $b \sin z + \Delta\rho \tan z$ on the quantity $\Delta(O - C)$ is anyway practically the same for different values of φ_0.

In Table 1 using for φ_0 the value of the mean latitude of BVC, $\varphi_0 = +44°48'07''.60$, the values $\Delta(O - C)$ for observations made in July 1984 are given.

Table 1. The values $\Delta(O - C)$ of planets

Data	*Mars*	*Jupiter*	*Saturn*	*Uranus*	*Neptune*
02.07.1984	-	-	$-0''.21$	$+0''.02$	-
10.07.1984	$-0''.24$	$+0''.05$	-	−0.04	$-0''.02$
11.07.1984	+0.16	−0.05	-	+0.02	-
12.07.1984	−0.26	+0.05	-	−0.05	−0.03
13.07.1984	−0.09	-	-	+0.00	+0.00
14.07.1984	−0.04	+0.02	-	+0.00	+0.01
15.07.1984	−0.29	-	-	−0.10	−0.08
19.07.1984	−0.28	+0.13	-	−0.03	+0.00
20.07.1984	−0.06	+0.03	-	-	+0.00
21.07.1984	-	+0.18	-	−0.12	−0.06
22.07.1984	−0.28	+0.16	-	−0.02	+0.02
M. value	$-0''.15$	$+0''.07$	$-0''.21$	$-0''.04$	$-0''.02$

According to equation (2) the values of coefficients of unknown b and $\Delta\rho$ are dependent of differences of zenith distance of planets, and some approximately mean zenith distance obtained from observations of stars.It means that the values $\Delta(O-C)$ are dependent of differences of declinations of planets and of some mean declination.During July 1984 declinations of Mars were higher than those of observational stars, and declinations of Uranus and Neptune where close to the mean one.

As seen from Table 1 the values $\Delta(O - C)$ for Mars are considerable and those for Uranus and Neptune negligible.

Our investigation shoved that using of the mean latitude $\overline{\varphi}$ obtained from observations of selected southern stars does not entirely eliminate the effects of flexure and refraction.

In order to get the true values of $O-C$ from exsisting observations with BVC it is necessary to find the corrections $\Delta(O-C)$ by method which we applied for reduction of observations from July 1984.

In future, it should be, beside southern stars, to observe zenith ones as well as stars in lower culmination, in order to determine more realistically the unknowns φ_0, b and $\Delta\rho$.

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INFLUENCE OF TEMPERATURE GRADIENT CHANGES ON SOLAR SPECTRAL LINE PROFILE PARAMETERS

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SUMMARY: In this paper we examine, theoretically, the influence of temperature gradient changes on 27 spectral line profiles.

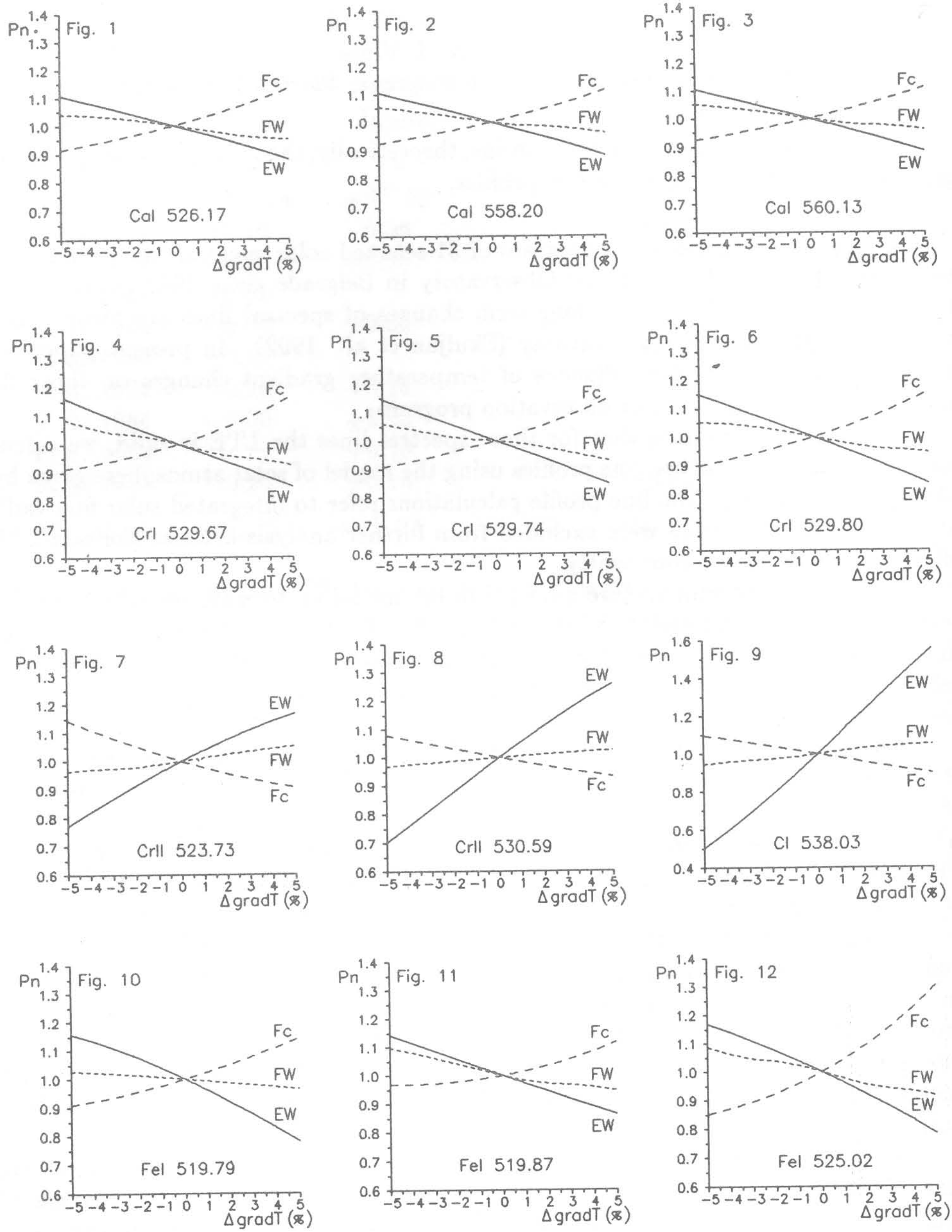
A long-term observational program of 31 selected solar spectral line profiles has been carried out at Astronomical Observatory in Belgrade since 1987 (Vince et al. 1988). It has been shown that long-term changes of spectral lines are present and related probably to the solar activity (Skuljan et al. 1992). In present paper we examine, theoretically, the influence of temperature gradient changes on those 31 spectral line profiles from our observation program.

Under the assumption that for those spectral lines the LTE is valid, we calculated the synthetic spectral line profiles using the model of solar atmosphere given by Maltby et al. (1986). The line profile calculations refer to integrated solar flux radiation. Four spectral lines were excluded from further analysis because the non-LTE effects influence them prominently.

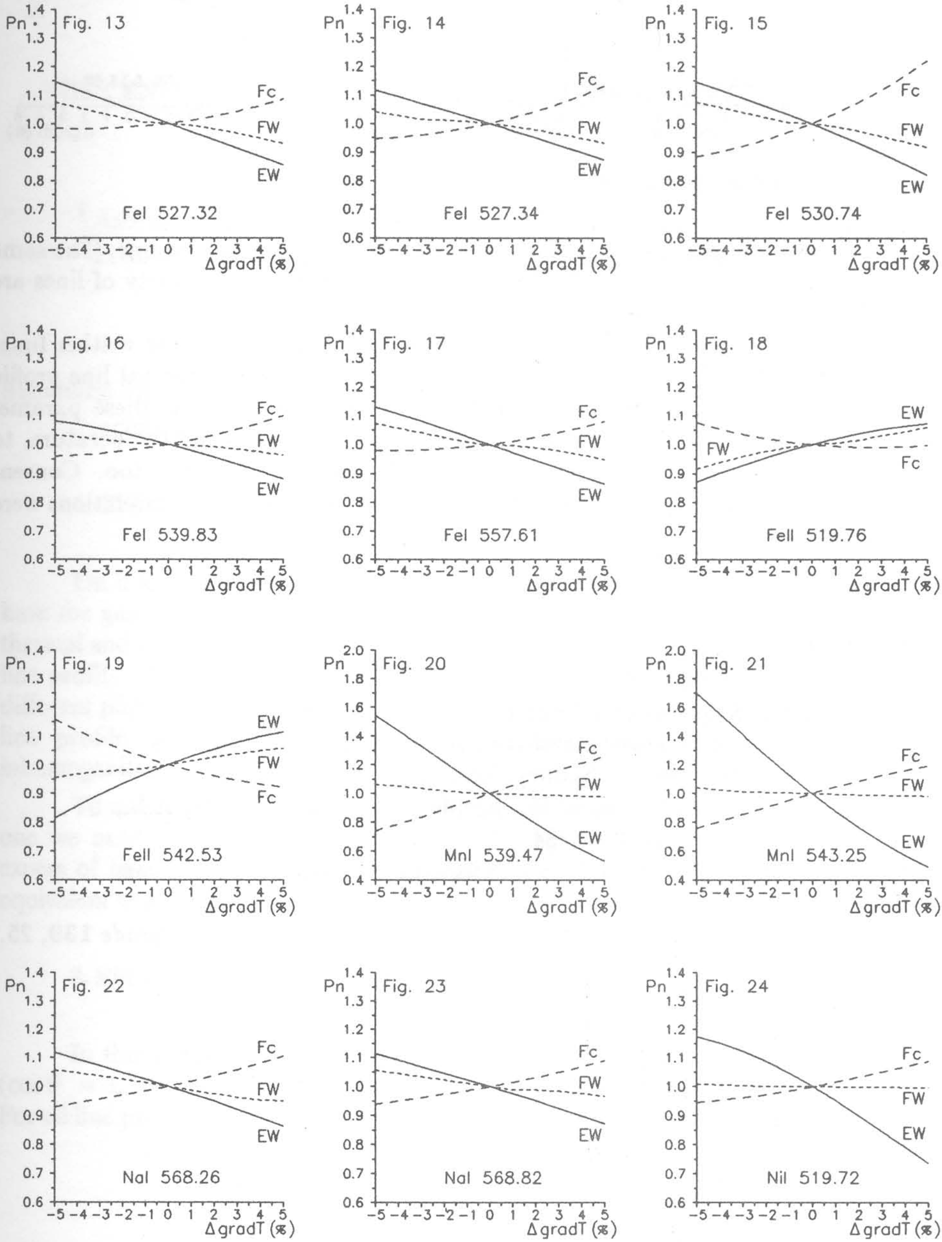
By variation of temperature gradient in the model up to ±5% we calculated the relative changes of equivalenth width (EW), full half-width (FW) and relative central flux (F_c) for 27 spectral lines. The calculation results are given in Figures 1-27., where relative variations of these parameters normalized to their unchanged model values are ploted against temperature gradient changes.

According to the general behaviour of the line parameter changes, we can devide the spectral lines into two groups. The spectral lines of the first group show increase of EW and FW, and decrease of F_c with positive changes of temperature gradient. All single-ionized atom lines and the CI 538.03 neutral atom line belong to this group. This behaviour of equivalent width variation, for instance, we can explain on the basis of simplified line formation theory (Gray, 1976), according to which the steepness of temperature gradient influence on EW-changes depends on ionization energy. The ionization energy is always positive, consequently the EW-change is positive too. The spectral lines of the second group show line parameters variations opposite of the first group. To this group belong all spectral lines of neutral atoms except CI 538.03 line. For these lines the steepness depends on the difference of excitation and ionization energy (E_{ex}-E_i), which is always negative ($E_{ex} < E_i$), consequently the EW-change is negative too.

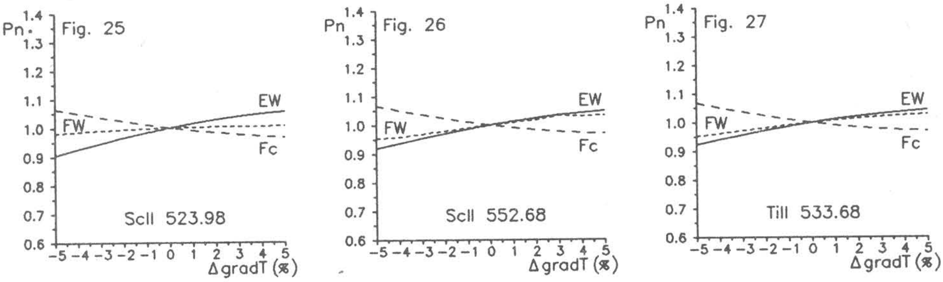
Detailed examination of graphs in Figures 1-27. shows that certain lines are very sensitive to the temperature change. Especially significant are the changes of equivalent widths of CI 538.03, MnI 543.25 and MnI 539.47. The temperature sensitiveness of CI 538.03 line is due to the fact that this line is formed very deep in solar photosphere (almost coincident with the continuum) where temeperature gradient is relatively high. Among all lines the MnI 539.47 line shows the greatest change in equivalent width. This great gradient is due to the large difference of the excitation



Figs. 1-12. Relative changes of normalized parameters (P_n: EW – equivalent width, FW – full half-width, F_c – central flux) with temperature gradient in percents



Figs. 13-24. Same as in Figures 1-12.



Figs. 25-27. Same as in Figures 1-12.

(E_{ex}=0 eV) and ionization energy (E_i=7.437 eV) of this ground-state line. The same explanation is valid for MnI 543.25 line. The profiles of a vast majority of lines are not so sensitive to the temperature changes.

On the basis of our analysis we can also say that it could not exist neither functional nor correlational connection between the changes of solar spectral line profile parameters and excitation energy of the lower energy level, because these parameters are not only sensitive to the excitation energy, but also to the temperature, to the ionization potential and, in some cases, to the electron pressure, too. Consenquently, some investigators' attempts (e.g. Babij, 1991) to find such correlations were unsuccessful.

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THE CENTER-TO-LIMB VARIATIONS OF SOME SOLAR SPECTRAL LINE PARAMETERS

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Summary: The statistical analyse of center-to-limb changes in equivalent widths and coefficients of asymmetry and excess of 83 Fraunhofer lines was done.

1. INTRODUCTION

On a low accuracy level solar photospheric spectral lines can be considered to have the gaussian profile because the most important source of line broadening is the thermal and microturbulent velocities, but high-resolution spectra reveal a non-gaussian line profile. This slight deviation from the gaussian profile may be produced by many different physical conditions in solar photosphere. For instance the asymmetries of the line profile can be traced back to photospheric temperature and velocity field inhomogenities.

To consider quantitatively the deviation of the spectral line profile from gaussian one we used a statistical analysis by introducing the coefficients of asymmetry and excess of intensity distribution function of the line profile. Beside we calculated the equivalent widths too.

2. SPECTRAL DATA AND REDUCTIONS

In this paper we analyzed 84 spectral lines of neutral elements for 5 positions ($\cos\theta$ = 1, 0.8, 0.6, 0.436, 0.28) at the solar disk published by Gurtovenko at all. (1975). For all line profiles at each position we calculated equivalent width:

$$W = \sum_{i=1}^{n} x_i y_i \qquad (1),$$

where x_i is the difference between central and measured wavelength, and y_i is the corresponding intensity.
Coefficients of asymmetry we calculated from:

$$As = \frac{\sum_{i=1}^{n} x_i^{3}\, y_i}{\sigma^3}\ , \qquad (2)$$

σ is dispersion, and coefficient of line excess from

$$Ex = \frac{\sum_{i=1}^{n} x_i^{4}\, y_i}{\sigma^4} - 3\ . \qquad (3)$$

We classified the line profiles according to excitation potential of lower energy level (χ_e) and to equivalent widths into different groups. Number of lines in each group are shown in Table 1.

Table 1 :Number of lines in each group used for the present analysis

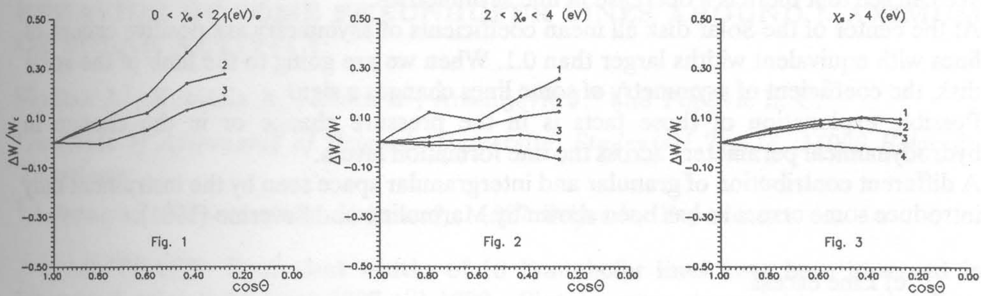
N	χ_e (eV)		
W (mA)	0 - 2	2 - 4	> 4
0 - 10	15	3	11
10 - 25	5	1	13
25 - 50	3	8	3
50 - 100	1	11	5
>100	0	4	0

As one can see, there are two groups with only one line. Those groups are linked with groups with lower equivalent widths.
For all groups we calculated mean relative changes of equivalent widths and mean changes of coefficient of asymmetry and coefficient of excess. The results are presented in Figures 1-9.

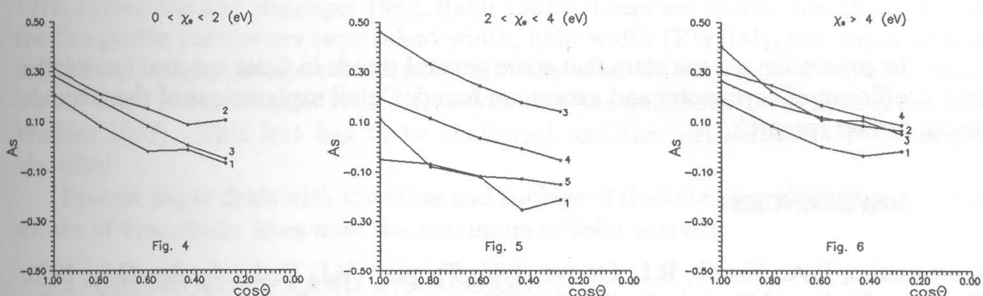
3. DISCUSSION

a) Equivalent width

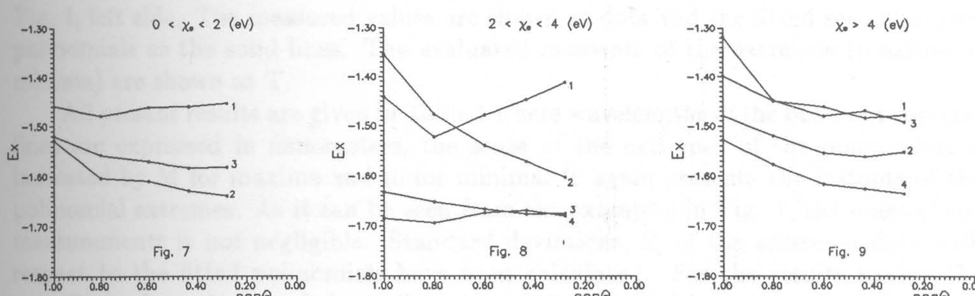
From Figures 1-3 one can see center-to-limb relative changes of equivalent widths of selected spectral lines.
Relative changes in equivalent widths are large for lines with lower χ_e , and lower equivalent width. Those results we can interpret with fact that effective temperature of photosphere decrease from center to limb of solar disk, and this lines are formed in thinner layers.
Changes of spectral lines with high χ_e are near zero and in some cases are negative. Possible reason for this is that those lines are less sensitive on temperature changes because they are formed almost in whole photosphere.
It is interesting that lines with the highest χ_e and the largest equivalent widths have small but negative changes.



Figs. 1-3: Center-to-limb relative changes of equivalent widths for different χ_e (In Fig.1: 1 - 0 < W < 10, 2 - 10 < W< 25, 3 - 25 < W < 50; Fig.2: 1 - 0 < W < 25, 2 - 25 < W < 50 3 - 50 < W < 100, 4 - W > 100; Fig.3: same as Fig.1 and 4 - W > 50)



Figs. 4-6: Center-to-limb changes of coefficient of asymmetry for different χ_e (Labels are same as in Figs.1-3 respectivelly.)



Figs. 7-9: Center-to-limb changes of coefficient of excess for different χ_e (Labels are same as in Figs.1-3 respectivelly.)

b) Line asymmetry

Figures 4-6 show center-to-limb variations of the coefficient of asymmetry.
We can see that there is a decrease in line asymmetries.
At the center of the Solar disk all mean coefficients of asymmetry are positive except of lines with equivalent widths larger than 0.1. When we are going to the limb of the solar disk, the coefficient of asymmetry of some lines changes a sign.
Possible explanation of those facts is in the pressure change or in the change in hydrodynamical parameters across the line formation layers.
A different contribution of granular and intergranular space seen by the instrument may introduce some errors as has been shown by Marmolino and Severino (1981).

c) Line excess

Center-to-limb variations of the line mean coefficients of excess are shown in Figures 7-9. All mean coefficients are between -1.3 and -1.7. Interpretation of that fact needs more analyses, but we think that possible solutions are in influence of different pressure broadening and large scale motions in solar photosphere.

4. CONCLUSION

In conclusion we can state that some general trends in Solar spectral line widths and coefficient of asymmetry and excess are found. Detail explanations of those trends needs further research.

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BEHAVIOR OF SOME FRAUNHOFER LINES AROUND MAXIMUM OF SOLAR ACTIVITY

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ABSTRACT: Equivalent widths of 18 Fraunhofer lines have been observed in integrated solar light from 1987 till 1992. Sixteen more dependable spectral lines out of 18 measured ones exhibit an extreme value (maximum or minimum) near the maximum of solar activity cycle.

1. INTRODUCTION

It is known that profiles of Fraunhofer spectral lines change with time (e.g. Babij 1976, Livingston and Holweger 1982, Babij 1991). There are indications that some of the line profile parameters (equivalent width, half- width (FWHM), line depth or line asymmetry) might change periodically–with the solar activity (e.g. Kharadze 1935, Derviz *et al.* 1961, Mitchell 1969, Stepanyan and Shcherbakova 1978, Livingston and Wallace 1987). This fact has to be confirmed and the mechanism of the changes identified.

Present paper deals with the sense and timings of the extreme values of equivalent widths of Fraunhofer lines near the maximum of solar activity.

2. OBSERVATIONS AND DISCUSSION

According to the concept given by Vince *et al.* (1988) a number of Fraunhofer lines have been observed at Belgrade Astronomical Observatory during the period 1987 - 1992. The instrument was described by Kubičela (1975) and Arsenijević *et al.* (1988), and the reduction procedure by Skuljan *et al.* (1992).

Equivalent widths of 18 Fraunhofer lines were observed in the light integated over the whole solar disk. As an example, results for four spectral lines are given in Fig. I, left side. The measured values are shown as dots and the fitted second degree polinomials as the solid lines. The evaluated moments of the extremes (maxima or minima) are shown as T.

All present results are given in Table 1 where wavelengths of the observed spectral lines are expressed in nanometers, the sense of the extremes of the polinomials is indicated by M for maxima and m for minima. T again presents the instants of the polinomial extremes. As it can be seen from the examples in Fig. 1, the noise of the measurements is not negligible. Standard deviations, S, of the scattered dots with respect to the fitted polinomials have been calculated. For the results having the overall absolute change of the polinomial smaller than the quantity $3Sn^{-2}$ (where $n = 25$ is number of observations of each line in six years) the extreme marks (M or m) in Table I have been put into brackets. The other ones we consider as statistcally more significant.

Table I *Measured Fraunhofer lines, sense (Ext.) and times (T) of the extreme values of the equivalent widths.*

Line	Ext.	T	Line	Ext.	T	Line	Ext.	T
FeII 519.76	(M)	1989.27	TiII 533.68	M	1989.66	ScII 552.68	M	1990.53
CrII 523.73	m	1990.40	MnI 539.47	M	1989.57	FeI 557.61	(m)	1990.56
ScII 523.98	m	1990.73	FeI 539.83	M	1990.86	CaI 558.20	M	1991.43
CaI 526.17	M	1990.05	FeII 542.53	m	1988.76	CaI 560.13	M	1990.75
CrI 529.67	M	1990.45	MnI 543.25	M	1990.52	NaI 568.26	m	1990.45
FeI 530.74	M	1990.68	FeI 550.68	m	1990.44	NaI 568.82	M	1991.45

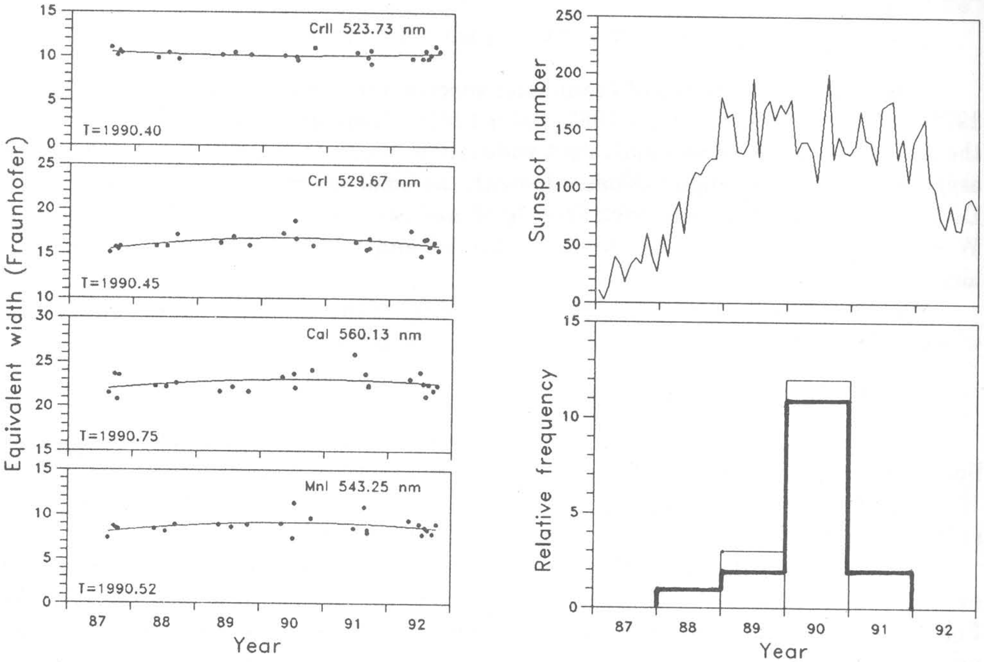

Fig. 1 *Left: equivalent widths (in fraunhofers) for some of the measured spectral lines (dots) and second degree polinomial fits (solid lines) during the years 1987 – 1992. The instants of the extreme values of the polinomials are given as T. Upper right: solar activity represented by relative sunspot number in the same interval. Lower right: distribution in time of the maxima and minima of the equivalent widths.*

The time–distribution of all measured equivalent width maxima and minima is shown in Fig. 1, lower right. Here the heavy line indicates the mentioned statistically more significant results. Comparing this distribution with variation of monthly mean values of the sunspot number, upper right, one can imediately notice a definite time–coincidence of both maxima: of the sunspot number and of the equivalent width extremes distribution.

The median of the last distribution indicates the maximum at the year 1990.4. At the same time the mean T from Table I, taking into account only the more dependable cases, amounts to 1990.4. However, there are two maxima (or an extended one) in the sunspot data. It is well seen in Figure 1. According to the international sunspot data the maximum of the 22nd activity cycle happened at 1989.54 with smoothed sunspot number (SSN) amounting to 158 (Coffey 1993). During 1991, from January till August, there was a secondary maximum with the mean SSN=147. Taking the corresponding SSN values as weights, one can calculate the weighted mean instant of the "extended" sunspot maximum amounting to 1990.4.

One can not avoid conclusion that both phenomena, sunspots and the equivalent width extremes, define perhaps equally well the instant of the solar activity maximum. Indeed, the difference between the corresponding times is really very small. In this sense the variations of the solar global Fraunhofer line equivalent widths might be considered as an additional index of solar activity.

The question why some of the observed Fraunhofer line equivalent widths correlate and some of them anticorrelate with solar activity, for the time being, remains open.

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THE USE OF ITERATION FACTORS IN THE LINE FORMATION PROBLEM WITH SPATIAL VARIATIONS IN PROFILE FUNCTION

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Abstract – In a previously published paper a simple and fast–convergent method using iteration factors is developed to solve two–level line transfer problem in a constant property medium. In this paper a spatial variation of the profile function is taken into account and a new iteration factors family is considered.

1. Introduction

In a previously published paper (Simonneau and Atanacković-Vukmanović, 1991), henceforth reffered to as Paper I, a simple and fast–convergent iterative method is developed to solve the two–level line transfer problem. The method represents an efficient way to accelerate Λ iteration scheme by the use of the quasi-invariant depth -dependent functions, so– called iteration factors.

In the two–level atomic case where the explicit form of the line source function enables a straightforward derivation of the angular and frequency integrated moments of the radiative transfer (RT) equation, the factors are defined as the ratios of the relevant radiation field intensity moments. Computed at the beginning of each iteration step from the formal solution of the RT equation with the given (old) source function, the factors are then used to close RT moment equations and, hence, to give new radiation field, i.e. new source function.

In order to check the convergence properties of the method in Paper I we considered the case of the constant property medium whose exact solutions are well known. The assumption made throughout the paper about depth independence of the profile function φ_x enabled frequency integration of the differential RT equation over profile function and definition of the corresponding closure relations.

Here we consider the case when φ_x is some specified function of depth. The iterative procedure described in Paper I can be directly applied. The only difference is that in getting RT equation moments the operator $\int[..]dx$ and not $\int[..]\varphi_x dx$ must be used.

2. The line formation with spatial variations in Doppler width

For the sake of simplicity in presentation we shall consider the time independent RT equation for a one– dimensional, planar and static medium with no background opacity. Using the standard notation, RT equation has the form:

$$\mu\frac{d}{d\tau}I(\mu,x,\tau)=\varphi(x,\tau)[I(\mu,x,\tau)-S(\tau)] \ , \tag{1}$$

where the line source function $S(\tau)$ under the assumption of complete redistribution is given by:

$$S(\tau)=\varepsilon B(\tau)+(1-\varepsilon)\int_{-\infty}^{\infty}\varphi(x,\tau)J(x,\tau)dx \ . \tag{2}$$

For pure Doppler broadening, $\varphi(x,\tau)$ is given by the Gauss normalized profile function:

$$\varphi(x,\tau) = \frac{1}{\sqrt{\pi}\delta(\tau)} e^{-x^2/\delta(\tau)^2} \quad , \tag{3}$$

where $x = (\nu - \nu_0)/\Delta\nu_D^*$ is frequency displacement from line center in some standard frequency interval $\Delta\nu_D^*$ (Doppler width at some reference depth point), and the parameter $\delta(\tau)$ is given by:

$$\delta(\tau) = \frac{\Delta\nu_D(\tau)}{\Delta\nu_D^*} \quad . \tag{4}$$

In order to solve eqs. (1) and (2) with $\varphi(x,\tau)$ given by (3) we proceed like we did in Paper I. After getting the angular moments of eq. (1) by applying the operators $\int ...d\mu$ and $\int ...\mu d\mu$, we perform their integration over line frequencies $\int_{-\infty}^{\infty} dx$ to get:

$$\frac{dH}{d\tau} = J_\varphi - S = \varepsilon(J_\varphi - B) \tag{5a}$$

$$\frac{dK}{d\tau} = H_\varphi \quad . \tag{5b}$$

In the above expressions we used eq.(2) and the following notation for the frequency moments:

$$H = \int H_x dx \ , \quad K = \int K_x dx \ , \quad J_\varphi = \int J_x \varphi_x dx \ , \quad H_\varphi = \int H_x \varphi_x dx \quad .$$

The system of two differential equations (5) with four unknown intensity moments needs two additional relationships to be solved.

Here we consider the most straightforward way to close the above system, i.e. the following iteration factors family:

$$F = \frac{K}{J_\varphi} \quad , \quad f_H = \frac{H}{H_\varphi} \quad . \tag{6}$$

The two factors take into account the anisotropy of the radiation field as well as the repartition of the energy over frequencies within the line profile. The factors are to be computed according to their definitions using the formal solution of eq. (1). Given the factors, the system (5) that can be rewritten using (6) as:

$$\frac{dH}{d\tau} = \frac{\varepsilon}{F} K - \varepsilon B \tag{7a}$$

$$\frac{dK}{d\tau} = \frac{1}{f_H} H \quad , \tag{7b}$$

is easily solved for the unknown moments H and K. New source function

$$S(\tau) = \varepsilon B + (1 - \varepsilon)\frac{K(\tau)}{F(\tau)}$$

is then used to start the next iteration step.

3. Results and discussion

For the case of pure Doppler broadening, depth dependence of the profile function $\varphi(x,\tau)$ means a depth variation in Doppler width $\Delta\nu_D(\tau)$. We shall make some tests of the above described procedure and the proposed family of the iteration factors specifying the spatial variations in Doppler width $\Delta\nu_D(\tau)$ in the form similar to the one given in Rybicki and Hummer (1967) and in Athay (1972). Namely, we consider two cases: (a) "cool" and (b) "hot" surface layer defined, respectively, by:

$$\Delta\nu_D(\tau) = 2 - e^{-A\tau} \tag{8a}$$

$$\Delta\nu_D(\tau) = 1 + e^{-A\tau} \tag{8b}$$

For $\Delta\nu_D^*$ we take Doppler width at great optical depths. The behaviour of parameter $\delta(\tau)$ for both cases and for three different values of $A = 10^{-1}, 10^{-2}$ and 10^{-3} is shown in Fig.1.

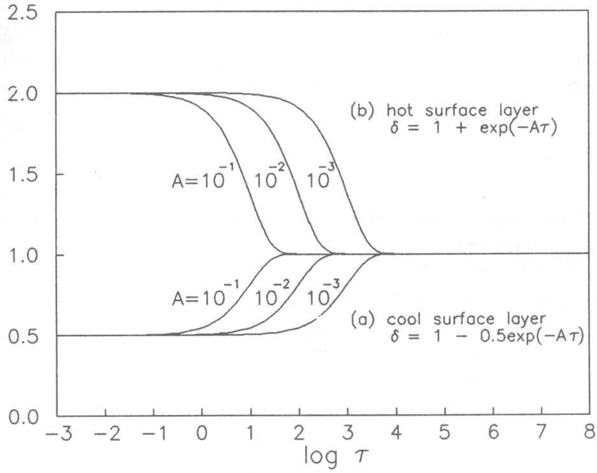

Fig.1. Parameter $\delta(\tau)$ characterizing spatial variation of the profile function

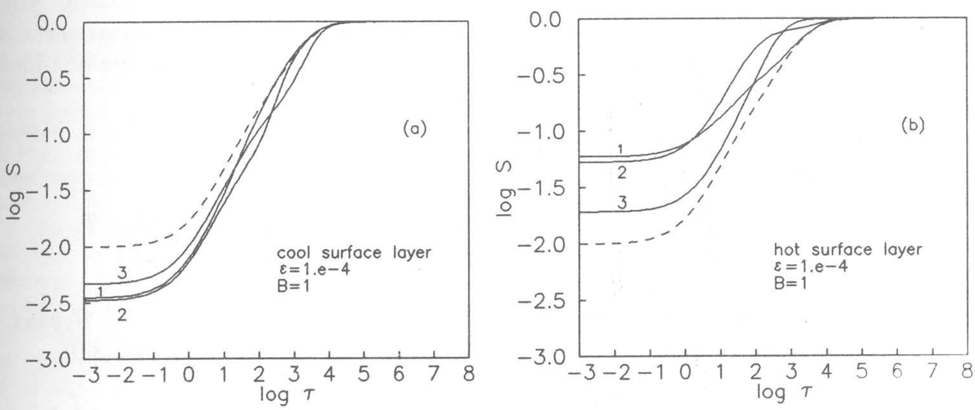

Fig.2. Source function vs. $log\tau$ in variable property media

The source functions obtained for the two cases (a) and (b) (Fig.1.) and for the semi-infinite medium with $\varepsilon = 10^{-4}$ and $B = 1$ are shown in Fig.2. The case of depth independent profile function ($\delta = 1$) is presented by the dashed curve. Curves labeled by $n = 1, 2, 3$ correspond to three different values of coefficient $A = 10^{-n}$ in depth varying Doppler width (eq.(8)).

The effects of depth–variations in profile upon the line source function are widely studied by Rybicki and Hummer (1967), Athay (1972). The behaviour of $S(\tau)$ obtained by our method and shown in Fig.2. is in a good agreement with the solutions considered therein. For a "cool" surface layer in all three cases $S(\tau)$ lies below the value $S(\delta = 1)$ due to a greater escape probability in the line wings (the profile φ_x is much narrower than in the $\delta = 1$ case). Besides, the thermalization length increases when $\Delta\nu_D$ grows deeper in the medium. The rate of convergence grows also with the thermalization length (see Table 1). With relation to 39 iterations needed for the convergence in $\delta = 1$ case, cases in which the increase of $\Delta\nu_D$ happens deeper require more iterations. In a "hot" surface layer, values of $S(\tau)$ are much larger than in the case $\delta = 1$ due to wider wings in the absorption profile that intercept the emergent photons. The so–called reflector efect on the radiation flowing up implies a decrease in thermalization length. The corresponding rate of convergence is very high (only 8 iterations are needed for the case $A = 10^{-3}$).

Table 1. Number of iterations necessary to achieve the convergence ($\varepsilon = 10^{-4}, B = 1$, (a) "cool" surface layer, (b) "hot" surface layer)

A	(a)	(b)
10^{-1}	42	28
10^{-2}	59	13
10^{-3}	73	8

The above results are obtained by the use of the most straightforward family of iteration factors. According to the results given in papers by Atanacković- Vukmanović and Simonneau (1991, 1993), we expect that the significant improvement in the rate of convergence would be achieved by an explicit treatment of the non-local (active) part of the radiation field.

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STARK SHIFTS OF C IV LINES IN THE SPECTRUM OF PG 1159-035

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Abstract. Using the semiclassical results for electron- and proton-impact shifts as well as a NLTE model atmosphere, we have calculated total Stark shifts (due to collisions with electrons and He^{2+}, C^{4+}, O^{6+}, H^{+} ions, estimating the ionic contribution within the adiabatic approximation) of the cores of *C IV* lines from 62 multiplets in the spectrum of the carbon rich, very hot, pulsating pre White Dwarf PG 1159-035 (log g=7; T_{eff}=140,000 K; C/He=0.7, H/He=0.21 by number), prototype of its class. Obtained shifts vary for six orders of magnitude, reaching $80 km/s$ for *6f–7g* multiplet.

1. Pressure and Stellar Spectral Line Shapes

Besides the important contribution to the widths of spectral lines in atmospheres of main sequence and high-gravity stars, collisions with neutral and charged particles are also cause of the shift (and asymmetry, due to the fact that each profile is formed in a thick atmospheric layer, with pressure and temperature variable with depth) of spectral lines. We have investigated in detail the contribution of the pressure broadening to the over-all asymmetries and shifts in the spectra of the Sun (e.g. Vince *et al.*, 1985; Kršljanin *et al.*, 1991) and of the hot stars (Kršljanin, 1989; Kršljanin & Dimitijević, 1992, Kršljanin & Marković-Kršljanin, 1992). Pressure contribution to the observed shifts is usually dominated and masked by thermal and different types of non-thermal motions in the stellar atmosphere, but in the case of "quiet" stellar atmospheres, accurate diagnostics of atmospheric motions would not be possible without knowledge of the reliable pressure broadening parameters.

Normal chemical composition of the stars rarely offer the possibility for the investigation of metallic lines with large principal quantum number, especially in high-gravity conditions (atmospheres of White Dwarfs are usually "purified" due to gravitational diffusion). The PG 1159 stars, with the combined strong chemical peculiarity, high gravity and very high temperatures, seem to be ideal objects for detailed investigation of Stark broadening contribution to the stellar spectral line shapes.

2. The Star: Atmospheric Properties and the Model

The PG 1159-035 was discovered in 1979 by McGraw *et al.* Its spectrum is characterized by a broad absorption trough due to *He II* 4686 and many neighbouring *C IV* lines, accompanied by central emission reversals (the emission does not exist in all stars of this type). Although the absence of *H* and *He I* absorption lines implied a hot, hydrogen deficient atmosphere, its chemical composition have been revealed only recently. Until now, 18 stars (Werner, 1992) of this type have been discovered (among them: 7 pulsators, 8 do not pulsate, 8 are the Central Stars of the Planetary Nebulae). PG 1159s are among the hottest stars known; with its atmospheres dominated by carbon and helium and with considerable amount of oxigen, they are defined as direct progenitors of DO White Dwarfs. Spectra of these stars show existence of very complex blends and no mass loss. Due to very high temperatures, precise chemical analysis of these stars requires highly sophysticated model atmospheres (line blanketed, NLTE, with real metal oppacities).

Here, for the prototype star, PG 1159-035 we have used a Kiel model atmosphere (Werner *et al.*, 1991; Rauch, 1991) constructed using the Axelerated Lambda Iteration tehnique, and with *H, He, C, N, O* atoms treated in detail (Fig. 1.). Adopted atmospheric parameters (due to best fit to the line spectra) are T_{eff} =140,000K, log g=7, with major abundances (by number): C/He=0.7, O/He=0.13, H/He=0.21 and with the traces of nitrogen. On the basis of this model, Rauch (1991) calculated formation depths of the cores of 96 *C IV* lines observed in PG 1159-035 spectrum, finding that they lay in the interval ($-2.9 < \log m < -1.4$) – Fig.1.

As for the observed shifts, Wesemael *et al.* (1985) found that the centers of major absorption troughs (*He II* 4686, *C IV* 4658) are redshifted in comparison with narrow emission *reversals. C IV 4441 is similarly shifted too. Amount of gass motions and gravity in these shifts is still uncertain.*

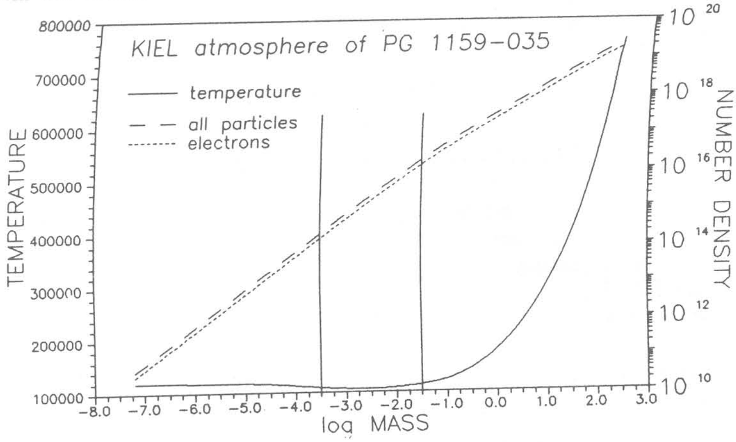

Fig.1. *NLTE model atmosphere of PG 1159-035. Region where cores of all examined C IV lines are formed is between two vertical lines (Rauch, 1991).*

3. Electron- vs. Ion-Impact Shifts

In a series of papers (see Dimitrijević & Sahal-Bréchot, 1993 and references therein) sets of Stark broadening parameters (electron-, proton-, and He^+-impact widths and shifts) of spectral lines of several multicharged ions of astrophysical interest are given. All these results were obtained by using the semiclassical-perturbation formalism (Sahal-Bréchot, 1969a,b). The most complete set of Stark widths and shifts is given for the *C IV* case (Dimitrijević *et al.*, 1991a,b; Dimitrijević & Sahal-Bréchot, 1992). It covers 62 of 96 lines observed and analyzed by Rauch (1991) in PG 1159-035. Although lot of lines with high principal quantum number are included, for ones with $n > 7$ (and $n > 9$ for l=s) it was not possible to obtain Stark broadening parameters of the same reliability.

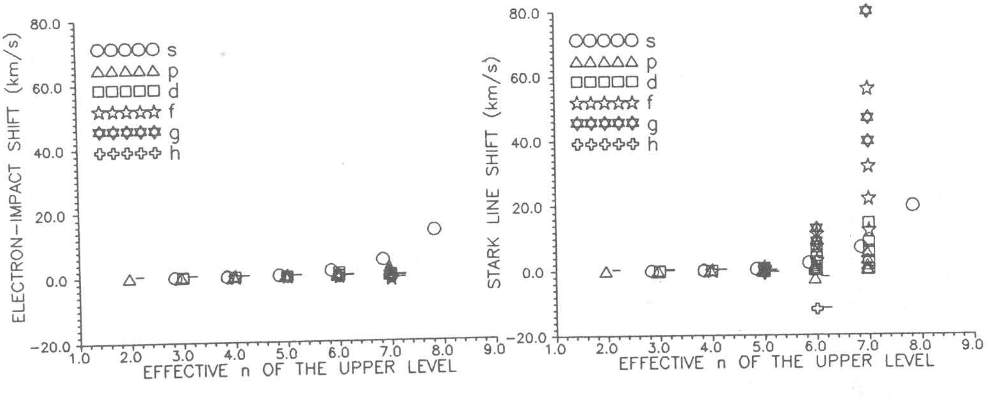

Fig.2. *Electron-impact (left) and total Stark shifts (right) of C IV line cores, in the PG 1159-035 spectrum (in velocity units), as functions of effective principal (abscissa) and orbital (explained in the legend) quantum numbers of the upper levels in transitions.*

In usual laboratory and stellar conditions ion-impact widths and shifts are only corrections to the electron-impact parameters. But in the case of PG 1159 stars, due to their chemical composition and temperatures, the contribution of ion-impact widths and shifts should be substantial, if not dominant. Ionization balance shows that impact contribution of C^{4+}, He^{2+}, O^{6+}, H^{+} and possibly O^{5+} ions should be taken into account. Starting from the consideration that when the impact approximation for the ionic perturbers is valid, the adiabatic approximation is also valid, one can expect that by using the adiabatic approximation, a certain scaling law may be found, that would allow us to estimate Stark shifts for all these ions as perturbers, starting from available semiclassical data on proton-impact shifts only. According to adiabatic theory of Lindholm and Foley (e.g. Kršljanin, 1989) Stark shifts (and widths) at a given temperature are proportional to $m^{-1/6}Z^{2/3}N$, where m is mass Z - charge, and N number density of the perturbers. Application of this scaling law in our case becomes trivial, since in the region where line cores are formed (Fig.1.) number densities of all most important ionic perturbers have the constant ratios one to each other and to electrons number density. Following this idea, one can obtain the estimate that the over-all ionic shift equals 13.63 times the proton-impact shift (contributions of the ionic species: He^{2+} - *44%*, C^{4+} - *41%*, H^{+} - *7%*, O^{6+} - *7%* and O^{5+} - *1%*).

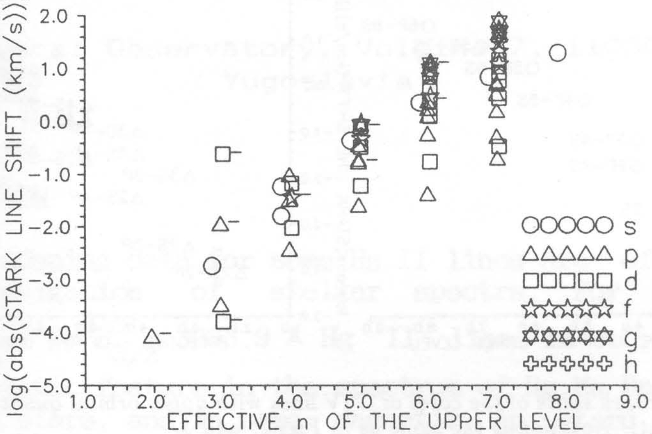

Fig.3.*Same as in Fig.2. but with shifts in a logarithmic scale. Negative (blue) shifts are denoted by minus signs.*

4. Shifted Stellar Line Cores: Results and Discussion

Calculated Stark shifts for 62 *C IV* lines in the atmosphere of PG 1159-035 are shown in Figs.2-5. as functions of their atomic parameters (effective principal and orbital quantum numbers of the upper levels in the transitions) and formation depths. A look into the numerical results shows the dominant role of the ion-impact broadening in most of the cases.

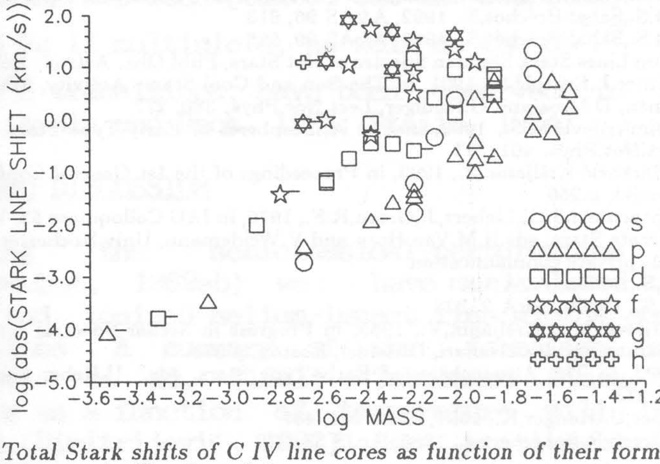

Fig.4.*Total Stark shifts of C IV line cores as function of their formation depths. Notation is the same as in Figs.2. and 3.*

For the transitions to s and p levels electronic and ionic contributions are of the same order of magnitude (for s transitions electrons slightly dominate; about 70% of the total Stark shifts are due to electron-impacts). For most of the d transitions electron-impact contribution is less than 10% and for f ones even less than 5% with opposite signs of electron and ion contributions as a rule. For transitions to g and h levels it seems that electron-impact contribution is negligible (we calculated shifts for 7 transitions to s levels, 21 to p, 17 to d, 10 to f, 6 to g and 1 to h level). Nine multiplets have blue total shifts and in 12 cases electron and ion contributions have the opposite signs. Least calculated shift is $9cm/s$ ($2s$–$2p$ resonant multiplet) and the largest one is 80 km/s ($6f$-$7g$). Distribution of the total shift values is the following: shifts $<10m/s$ have 6 lines, 10–$100m/s$ 9 lines, 100–$1000m/s$ 16 lines, 1–$10km/s$ 19 lines and $>10km/s$ 12 lines.

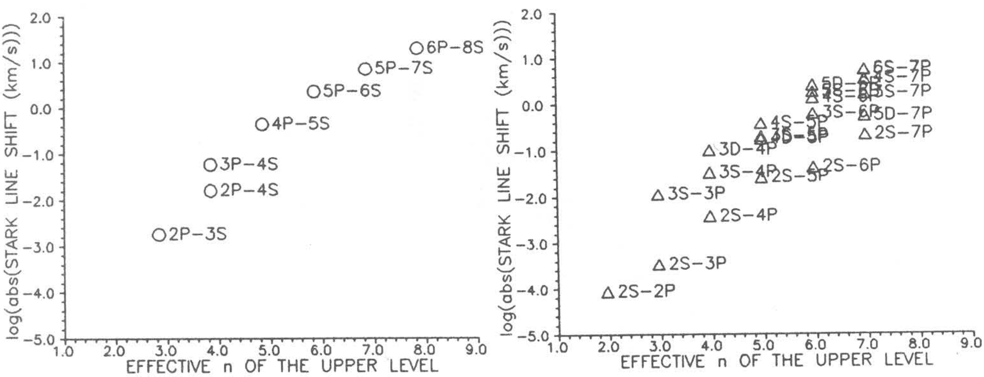

Fig.5. *Total Stark shifts of the cores of C IV lines with upper orbital quantum numbers s (left) and p (right). Notation is the same as in Figs.2. and 3.*

The figures show again the pronounced dependance of the stellar Stark shifts on the (effective) principal quantum number, especially regular within the spectral series. Substantial values of Stark shifts in PG 1159-035 predicted here suggest the need for more accurate calculation of widths and shifts due to collisions with He^{2+}, C^{4+} and O^{6+} ions, as well as the need for careful paralel analysis of theoretical and observed shifts.

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STARK BROADENING OF Hg II LINES IN STELLAR ATMOSPHERES

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INTRODUCTION

Stark broadening data for some Hg II lines are of importance for investigation of stellar spectra. For example the $6s^2\ ^2D_{5/2} - 6p^2P^o_{3/2}$ 3983.9 Å Hg II line is a strong and characteristic feature in the spectrum of Hg Mn Bp stars, most of the Mn stars, and in some magnetic Ap stars (Dworetsky, 1980; Cowley and Aikman, 1975; White et al., 1976; Wolf, 1983). This line is used, e.g., for the Hg abundance determination in the atmosphere of ϕ Her (Ryabchikova and Piskunov, 1988). The significance of the resonance $6s^2S$ - $6p^2P^o$ 1942 Å Hg II line for the Hg stellar abundance determination has been pointed out in Dworetsky (1980). The mentioned Hg II multiplets, as well as the $6p^2P^o$ - $6d^2D$ and $6p^2P^o$- $7s^2S$ transitions, have been observed in the α And spectrum (Aydin and Hack, 1978; Stalio, 1974).

RESULTS AND DISCUSSION

By using the semiclassical-perturbation formalism (Sahal-Bréchot, 1969ab) we have calculated electron-, proton-, and ionized-helium-impact line widths and shifts for 7 Hg II lines . A summary of the formalism is given in Dimitrijević et al. (1991). Tabulated Stark broadening parameters as a function of temperature will be published elsewhere (Dimitrijević, 1992). Here, we present and discuss the comparison with the experimental data (Murakava, 1966;

Djeniže et al., 1990).

For the most critical transitions, the values for log gf(3984 Å) = -1.85, log gf (1649.9 Å) = -0.06 and log gf (1942.3 Å) = -0.31, derived in Dworetsky (1980) on the basis of published laboratory and theoretical, data have been used. If we use the Coulomb approximation, we obtain log gf (3984 Å) = -0.25 and log gf (1649.9 Å) = +0.12. For our case, these differences are very important since, if we use Coulomb-approximation log gf values, the differences in line-width results may be as great as 50%.

TABLE I Comparison of the experimentally determined Stark full half widths of Hg II lines (W_M) with the present results (W_{SC}) and with calculations performed in Djeniže et al. (1990) by using the simple semiempirical method (Griem, 1968) (W_{SE}). The experimental data: a - Murakawa (1966); b -Djeniže et al (1990) and c - Djeniže et. al (1992).

λ(Å)	T(K)	$N/10^{16}$ (cm^{-3})	W_M (Å)	W_{SC} (Å)	W_{SE} (Å)	d_M (Å)	d_{SC} (Å)	Ref.
3983.9	6500	1	0.0238	0.0201	0.036	0.002	0.006	a
	37000	4.2	0.066	0.037	0.064			b
	48000	13.7	0.192	0.109		0.00	0.03	c
2847.7	37000	4.2	0.061	0.054	0.080			b
2224.7	42000	13.3	0.190	0.164	0.133*	-0.06	0.03	c

*Value at 40000 K.

In Table I we compare our results with experimental data (Murakava, 1966; Djeniže et al, 1990, 1992) and with calculations performed in Djeniže (1990, 1992) by using the simple semiempirical method (Griem, 1968). We must take into account the fact that for a heavy emitter with a complex spectrum, the accuracy of the semiclassical method is lower than it is for lighter atoms. However, the agreement with experimental data is satisfactory in the case of the 2847.3 Å as well as the 2224.7Å line width. In the case of the astrophysically important 3983.9 Å line, our results underestimate the real Stark width since, for broadening of the lower levels, only the most important transition $6s^2\ ^2D_{5/2}$ - $6p^2P^o_{3/2}$ has been taken into account. For this particular line, the accuracy may be improved by multiplying the semiclassical line widths by an averaged ratio of measured to calculated values. In this manner, we have a semiclassical temperature dependence, and the influence of neglected perturbing transitions is partly compensated for.

In the case of the shift a large disagreement exists, and in the case of 2224.7 line even the sign is different. However, one must take into account that shifts are considerably smaller than widths. Moreover, the theoretical shift accuracy is generally smaller than the width accuracy (see e. g. Dimitrijević, 1990).

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STARK SHIFTS OF ArI SPECTRAL LINES

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Introduction

Stark shift measurements of spectral lines are very interesting, because they can be successfully applied to diagnostic purposes. In order to estimate Stark shifts of ArI spectral lines in this experiment, we have used a special source of plasma, allowing combined measurements of glow and pulsed discharge (Djeniže and Labat, 1983). In such case we can believe that the spectral lines in glow discharge are almost unshifted.

Apparatus and procedure

The glow and pulsed discharge occurred in a Pyrex tube. The tube had two quartz windows at both its ends (fig. 1). Details of the experimental apparatus are given in Djeniže *et al* (1993). The effective plasma length was 70 mm, while the iner diameter of linear part of discharge tube was 5 mm. As a working gas we used the argon-helium mixture (72% + 28%) at the pressure of 266 Pa. Spectroscopic observations of isolated spectral lines were made along the axis of the discharge tube. By using this source it was possible to get a reproducable and homogenous plasma.

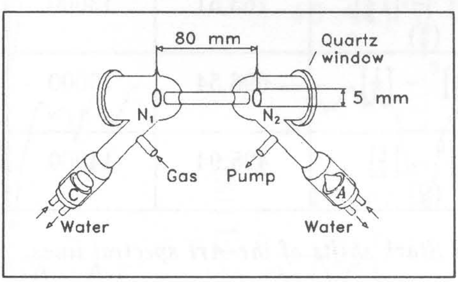

Fig. 1. The discharge tube.

The glow discharge was driven between water-cooled copper electrodes (C and A). The current was 50 mA. Auxiliary ring-shape nickel electrodes (N_1 and N_2) were positioned at the optical axis, 80 mm from each other. They were used to drive the pulse discharge, by repetitive discharge of 0.3 μF condenser initially charged to 10 kV.

The electron density in the positive column of the glow discharge was about $2 \times 10^{18}\mathrm{m}^{-3}$, hence it does not contribute to the Stark shift of spectral lines.

Parameters of the pulse plasma were determined by standard diagnostic methods. Electron temperature was found from the ratio of relative intensities of ArII 500.93 nm and ArI 696.54 nm spectral lines. The maximal value of the electron temperature was 13000 K with ±15% error. Atomic parameters required were taken from Wiese *et al* (1969). It was found that the electron temperature decayed slowly during the first 40 μs after the beginning of the discharge.

The electron density was measured by a single wavelength laser interferometry, using the 632.8 nm He-Ne laser line. The maximal value of the electron density was $3.8 \times 10^{22} m^{-3}$ corresponding to 10 μs after the beginning of the discharge. The errors of these measurements are estimated to be within $\pm 10\%$. All Stark shifts of spectral lines have been measured in this domain.

Recording of spectral lines profiles was done as described in details in Djeniže *et al* (1993). The line shift was found by the new method described in the same paper. The Stark shifts were measured relative to almost unshifted spectral lines emitted by the glow discharge at considerably lower electron densities. This measuring method could be very successful for Stark shift measurements of neutral lines.

Results

Experimentally determined Stark shifts (d_m) of the ArI lines are given in Table 1 together with the plasma parameters, i.e. electron density and temperature (N_e, T_e). The uncertainties in our experimentally measured Stark shift data are within $\pm 15\%$.

Transition	Multiplet	λ (nm)	T_e (K)	N_e ($10^{22} m^{-3}$)	d_m (nm)
4s – 4p	$[1\frac{1}{2}]^0 - [1\frac{1}{2}]$ (1)	763,51	13000	3,3	0,021
4s – 4p′	$[1\frac{1}{2}]^0 - [\frac{1}{2}]$	696,54	13000	3,3	0,010
4s′ – 5p′	$[\frac{1}{2}]^0 - [\frac{1}{2}]$ (9)	425,94	14000	2,6	0,023

Table 1. Measured Stark shifts of the ArI spectral lines.

Only experimental results exist for the ArI 763.51 nm and ArI 696.54 nm lines while there are some theoretical calculations also for the ArI 425.94 nm line. For this line our experimental result is about 39% less than the theoretical value based on the semiclassical Griem's theory (Konjević and Roberts, 1976). Similar results were obtained by other authors.

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SPECTRUM OF CP STARS: STARK WIDTH OF HEAVY ION LINES

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We present here the results of our investigation of Stark broadening for a number of astrophysically important heavy ion lines in order to provide the corresponding Stark broadening data needed for astrophysical purposes.

A number of heavy ion (Zn II, Sb II, Bi II, Pb II etc.) spectral lines has been observed in spectra of CP (O, B and A type) stars atmospheres (see e.g. Jacobs & Dworetsky 1982, Sadakane *et al.* 1988, Fuhrmann 1989, Danezis *et al.* 1991, etc.), where Stark broadening is the main pressure broadening mechanism. As an example two Zn II spectral lines for four Hg – Mn stars are shown in Fig. 1. Stark broadening data for heavy ion lines are of interest for analysis of hot CP star spectra as e.g. for abundance determination, for nucleosynthesis research, for investigation of pure diffusion in CP stars etc.

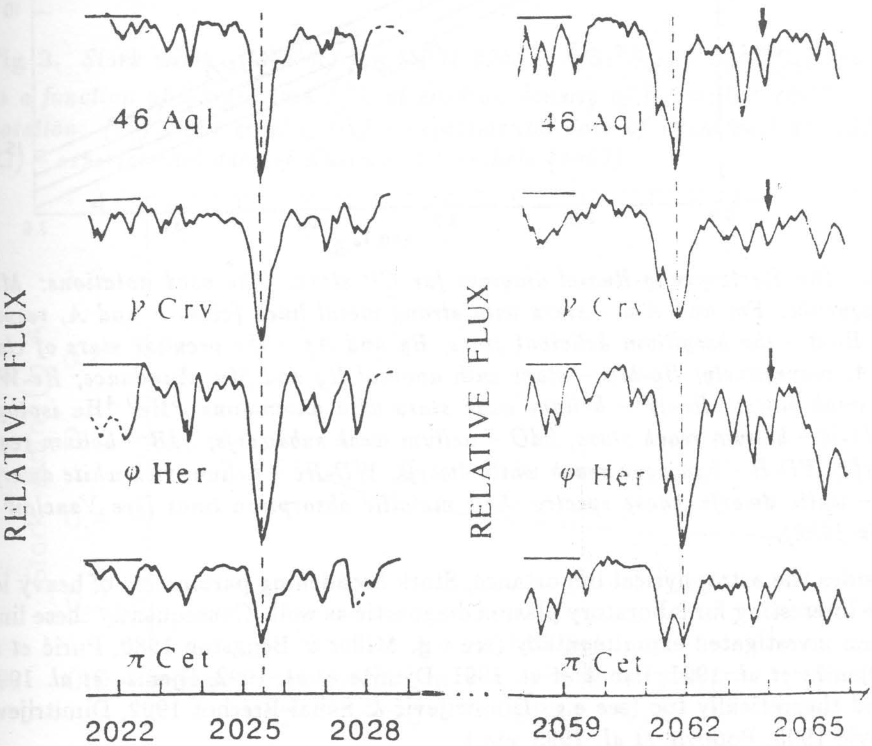

Fig. 1. *IUE specta around the Zn II 2025.5 Å and 2061.9 Å resonance lines in spectra of four Hg–Mn stars. The Zn II at 2064.2 Å subordinate line is indicated by an arrow (see Sadakane et al. 1988).*

Stark broadening is dominant pressure broadening mechanism for CP stars with $T_{eff} \gtrsim 10000$ K (see Fig.2). Howover Stark broadening of lines originating from energy levels with principal quantum numbers may be important even for cooler stars (Vince *et al.* 1985).

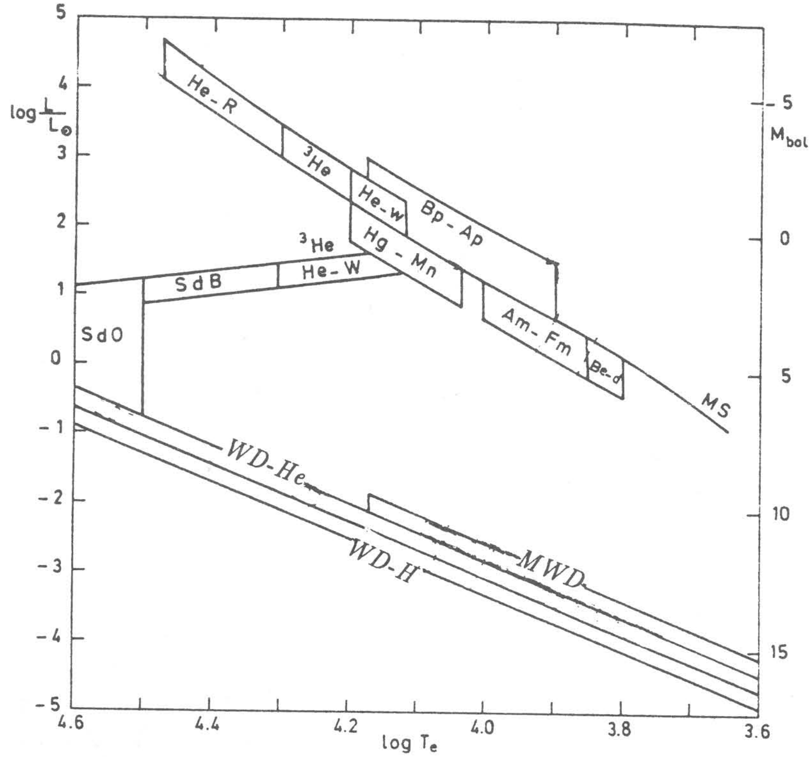

Fig. 2. *The Hertzsprung-Russel diagram for CP stars. The used notations: MS-main sequence; Fm and Am – stars with strong metal lines (class F and A, respectively); Be-d – the beryllium deficient stars; Bp and Ap – the peculiar stars of class B and A, respectively; Hg-Mn – stars with anomal Hg and Mn abundance; He-W – helium weak stars;* ^{3}*He-W – helium weak stars with anomalous* ^{3}He/ ^{4}He *isotopic ratio; He-R – helium reach stars; SdO – helium weak subdwarfs; SdB – helium reach subdwarfs; WD-H – hydrogen reach white dwarfs, WD-He – helium rich white dwarfs; MWD – white dwarfs whose spectra show metallic absorption lines (see Vauclair & Vauclair 1982).*

Besides the astrophysical importance, Stark broadening parameters of heavy ion lines are interesting for laboratory plasma diagnostic as well. Consequently these lines have been investigated experimentally (see e.g. Miller & Bengston 1980, Purić *et al.* 1985, Djeniže *et al.* 1991, Labat *et al.* 1991, Djeniže *et al.* 1992, Djeniže *et al.* 1993, etc.) and theoretically too (see e.g. Dimitrijević & Sahal-Bréchot 1992, Dimitrijević & Popović 1993, Popović *et al.* 1993, etc.).

We have investigated Stark width (HWHM) for several astrophysically important lines for seven of singly charged heavy ions (Zn II, Br II, Sb II, As II, Cd II, I II and Bi II). Stark broadening data are calculated within the modified semiempirical approach

(Dimitrijević & Konjević 1980) for electron density of $N_e = 10^{17}$ cm^{-3} and electron temperature range from 5000 to 50 000 K.

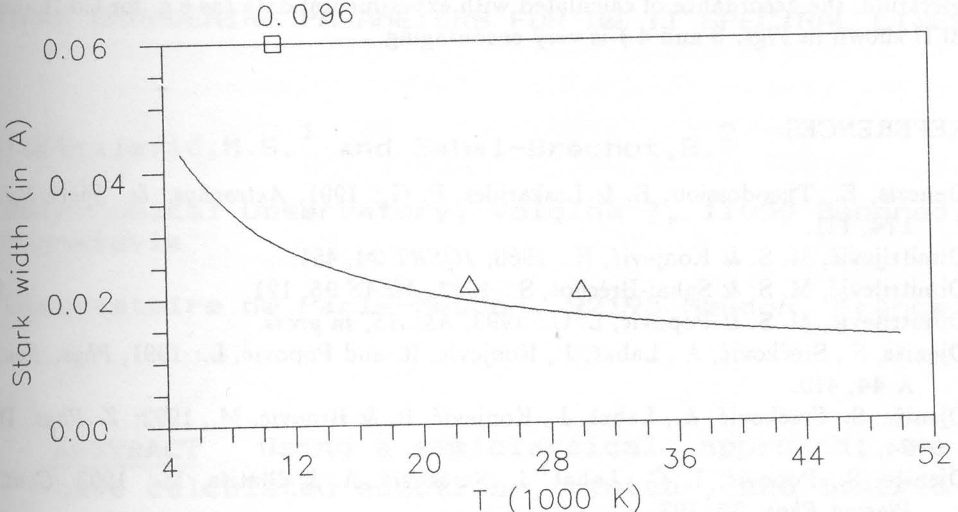

Fig 3. *Stark width (HWHM) for Cd II 2265.0 Å($5s^2S_{1/2} - 5p^2P^0_{1/2}$) spectral line as a function of temperature (T), at electron density of $N_e = 10^{17}$ cm^{-3}. The used notation: (—) - our results, (Δ) - experimental data of Djeniže et al. (1991) and (□) - experimental data of Kusch & Oberschelp (1967).*

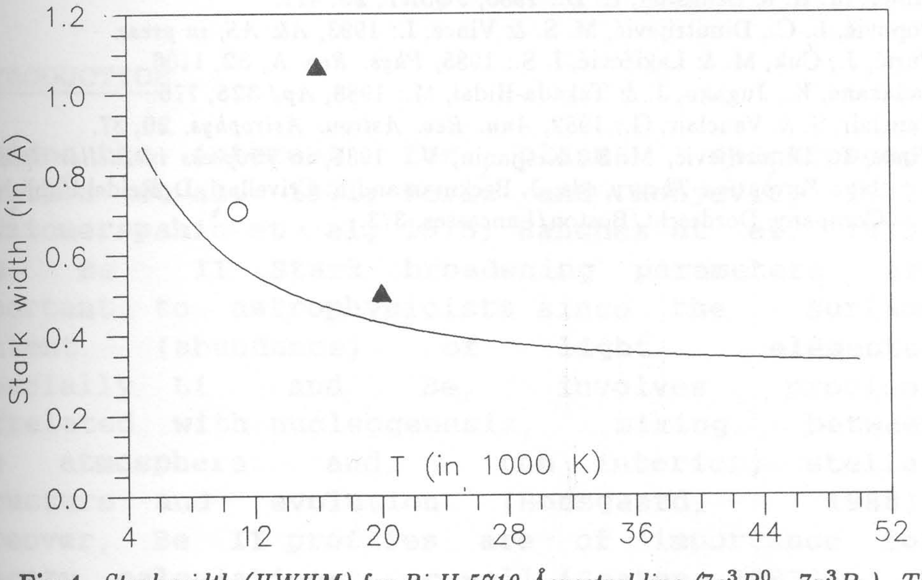

Fig 4. *Stark width (HWHM) for Bi II 5719 Åspectral line ($7s^3P^0_1 - 7p^3P_0$). The used notation: (—) - our results, ▲ - experimental data by Purić et al. (1985), ○ - experimental data by Miller & Bengston (1980).*

Our theoretical results have been compared with available experimental data (Kusch & Oberschelp 1967, Miller & Bengston 1980, Purić *et al.* 1985, Labat *et al.* 1991, Djeniže *et al.* 1991, etc.). Taking into account the complexity of heavy ion spectrum, the accordance of calculated with experimental data (as e.g. for Cd II and Bi II shown in Figs. 3 and 4.) is very encouraging.

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STARK BROADENING PARAMETERS FOR Be II SPECTRAL LINES

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ABSTRACT Using a semiclassical approach, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 30 Be II multiplets. The resulting data have been compared with existing experimental and theoretical values.

INTRODUCTION

Besides the interest for plasma spectroscopy (Platiša et al, 1971; Purić and Konjević, 1972; Hadžiomerspahić et al, 1973; Sanchez et al, 1973) the Be II Stark broadening parameters are important to astrophysicists since the surface content (abundance) of light elements, especially Li and Be, involves problems correlated with nucleogenesis, mixing between the atmosphera and the interior, stellar structure and evolution (Boesgaard, 1988). Moreover, Be II profiles are of importance for opacity calculations as well (Seaton, 1983).

The present paper concerns singly ionized beryllium: In order to provide reliable data for

Be II lines broadened by collisions with charged perturbers in stellar and laboratory plasmas, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 30 Be II multiplets, using the semiclassical-perturbation formalism (Sahal-Bréchot, 1969ab). The obtained results for perturber density of 10^{15} cm^{-3}, together with discussion, analysis and comparison with existing experimental and theoretical data will be published in Dimitrijević, and Sahal-Bréchot, 1992a). Since data are not linear with perturber density (N), due to the Debye screening effect, which is often important at high densities of interest for subphotospheric layers, Be II Stark broadening data tables for $N = 10^{16} - 10^{19}$ cm^{-3} together with the data for $N = 10^{13}$ cm^{-3} of special interest for stellar atmospheres, will be published in Dimitrijević and Sahal-Bréchot, 1992b. All details of the calculation procedure has been described in Dimitrijević, Sahal-Bréchot, Bommier (1991).

RESULTS AND DISCUSSION

In Tables I and II, the present results are compared with experimental data, (a-Sanchez et al, 1973; b-Hadžiomerspahić et al, 1973; c-Platiša et al, 1971;) with other semiclassical (Jones et al, 1971, also in Griem, 1974), with quantum-mechanical strong-coupling (Sanchez et al, 1973; Seaton, 1983) and with semiempirical calculations (Dimitrijević and Konjević, 1981) . We see that the widths fall within the error bars of both methods. However, for the shifts disagreement is larger. It should be noted that the shifts values are of lesser accuracy for semiclassical calculations than the widths (Griem and Shen, 1962; Roberts, 1968; Dimitrijević et al, 1981)

TABLE I Comparison between the experimental Stark full widths at half maximum of Be II lines (W_m) (a-Sanchez et al, 1973; b-Hadžiomerspahić et al, 1973; c-Platiša et al, 1971;) within $2s\,^2S - 2p\,^2P^o$ multiplet, with different calculations. Semiclassical calculations: W_{DSB}-present results; W_{JBG} - Jones, Benett and Griem (1971); quantum-mechanical calculations: W_S - Seaton (1988); W_{SBJ} Sanchez, Blaha and Jones (1973); semiempirical calculations: W_{DK} - Dimitrijević and Konjević (1981). The electron density N is equal to 10^{17} cm^{-3}.

λ(A)	T(K)	Wm(A)	Wm/WDSB	Wm/WJBG	Wm/WS	Wm/WSBJ	Wm/ WMSE	Wm/WDK	Ref.
3130.4	19000	0.070	0.80	0.82	2.43	1.69	1.43	1.51	4
	34800	0.04	0.60	0.57	1.49	1.09	1.10	1.01	3
3131.1	19000	0.070	0.80	0.82	2.43	1.69	1.43	1.51	4
	34800	0.06	0.91	0.86	2.23	1.64	1.66	1.51	3

TABLE II As in Table 1 but for the shift (d).

λ(A)	T(K)	dm(A)	dm/dDSB	dm/dJBG	dm/dS	Ref.
3130.4	16800	-0.03	6.1	0.80	2.32	1
	34800	-0.04	10.0	1.41	4.09	3
3131.1	16800	-0.03	6.1	0.80	2.32	1
	34800	-0.03	7.5	1.03	3.07	3

Be II lines broadened by collisions with charged perturbers in stellar and laboratory plasmas, we have calculated electron-, proton-, and ionized helium-impact line widths and shifts for 30 Be II multiplets, using the semiclassical-perturbation formalism (Sahal-Bréchot, 1969ab). The obtained results for perturber density of 10^{15} cm^{-3}, together with discussion, analysis and comparison with existing experimental and theoretical data will be published in Dimitrijević, and Sahal-Bréchot, 1992a). Since data are not linear with perturber density (N), due to the Debye screening effect, which is often important at high densities of interest for subphotospheric layers, Be II Stark broadening data tables for $N = 10^{16} - 10^{19}$ cm^{-3} together with the data for $N = 10^{13}$ cm^{-3} of special interest for stellar atmospheres, will be published in Dimitrijević and Sahal-Bréchot, 1992b. All details of the calculation procedure has been described in Dimitrijević, Sahal-Bréchot, Bommier (1991).

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3131.1	16800	-0.03	6.1	0.80	2.32	1
	34800	-0.03	7.5	1.03	3.07	3

Since the Be II 2s - 2p multiplet has the largest astrophysical importance within the Be II spectrum, the corresponding numerical data are provided in Table III.

TABLE III This table shows electron-, proton-, and ionized helium impact full half widths and shifts for Be II 2s-2p multiplet.

PERTURBER DENSITY = 0.1D+16(cm-3)							
PERTURBERS ARE		ELECTRONS		PROTONS		IONIZED HELIUM	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
Be II 2S-2P	2500.	0.126E-02	-0.109E-03	0.374E-05	-0.348E-05	0.637E-05	-0.348E-05
3131.5 A	5000.	0.802E-03	-0.106E-03	0.998E-05	-0.713E-05	0.154E-04	-0.705E-05
C= 0.31E+19	10000.	0.576E-03	-0.472E-04	0.219E-04	-0.134E-04	0.293E-04	-0.127E-04
	20000.	0.444E-03	-0.499E-04	0.366E-04	-0.216E-04	0.433E-04	-0.191E-04
	30000.	0.405E-03	-0.402E-04	0.460E-04	-0.261E-04	0.508E-04	-0.232E-04
	50000.	0.384E-03	-0.477E-04	0.552E-04	-0.326E-04	0.571E-04	-0.275E-04

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STARK WIDTHS OF FOUR- AND FIVE-TIMES CHARGED ION LINES FOR ASTROPHYSICISTS

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Important astrophysical applications of Stark broadening of multiply charged ion spectral lines are in the physics of stellar interiors (Seaton 1987). In subphotospheric layers, the modelling of energy transport requires radiative opacities and thus, certain atomic processes must be known with accuracy. At these high temperatures (10^5 K or more) and densities (10^{17} -10^{22}cm^{-3}) Stark broadening of strong multicharged ionic lines plays a non-negligible role in the calculation of the opacities, especially in the UV. Moreover, with the development of spectroscopy investigations from space, UV and extreme UV spectral line research has been further stimulated. The aim of this paper is to provide Stark broadening data of astrophysical interest for four- and five-times charged ion lines. In such a way, our intention is to complete such data, together with the published studies for N V and O VI lines (Dimitrijević and Sahal-Bréchot 1992ab) and with studies of C V, O V, P V and S VI lines, which are in preparation. Consequently, in the case of C V and O V, data calulations have been performed only for such cases for which atomic data set is not sufficient for semiclassical perturbation calculations. Since theoretical errors for shifts are considerably larger than for line widths, and since the astrophysical importance of multiply charged ion Stark widths is greater, only width calculations have been performed.

Stark line widths(FWHM) for 3 C V, 50 O V, 12 F V, 9 Ne V, 3 Al V, 6 Si V, 11 N VI, 28 F VI, 8 Ne VI, 7 Na VI, 15 Si VI, 6 P VI, and 1 Cl VI multiplet calculated using the modified semi-empirical approach (Dimitrijević and Konjević 1980) - (WMSE) will be published in Dimitrijević 1993a. A sample of results is presented in Table 1. Data are presented for an electron density of 10^{17}cm^{-3} and temperatures from 50,000 to 800,000 K. Data are linear with electron density, but at very high densities Debye screening should be considered (see e.g. Griem 1974). Moreover, for lines with very near perturbing levels broadening by inelastic proton collisions may be also important. Comparison of the present values with values calculated by using Eq. (526) in Griem (1974) have been performed, and the obtained agreement is satisfactory. As an example, the comparison for C V $3s^1S$ - $3p^1P^0$, N VI $2s^1S$ - $2p^1P^0$ and O V $4p^1P^0$ - $4d^1D$ cases is presented in Table 2. In comparison with the experiment of Purić et al (1988) for two O V lines, both approaches give about two times smaller values.

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Table 1. Stark width (FWHM) in Åunits calculated by using the modified semiempirical approach (Dimitrijević and Konjević 1980), at an electron density of 10^{17} cm^{-3}.

Transition	Lambda(A)	T(K)=50000	100000	200000	400000	800000
C V 1s21S - 3p1P	35.0	0.100E-04	0.881E-05	0.846E-05	0.700E-05	0.660E-05
C V 2s1S - 3p1P	247.3	0.431E-03	0.372E-03	0.362E-03	0.298E-03	0.266E-03
N VI 1s21S - 2p1P	28.8	0.418E-06	0.307E-06	0.248E-06	0.208E-06	0.176E-06
N VI 2s3S - 3p3P	161.2	0.951E-04	0.792E-04	0.676E-04	0.588E-04	0.575E-04
N VI 2p3P - 3d3D	173.9	0.553E-04	0.447E-04	0.367E-04	0.311E-04	0.312E-04
N VI 2p3P - 4d3D	130.3	0.368E-03	0.295E-03	0.239E-03	0.199E-03	0.159E-03
N VI 2p3P - 5d3D	116.8	0.846E-03	0.697E-03	0.577E-03	0.467E-03	0.374E-03
N VI 3p3P - 4d3D	500.9	0.616E-02	0.499E-02	0.408E-02	0.342E-02	0.283E-02
N VI 3p3P - 5d3D	346.7	0.780E-02	0.644E-02	0.534E-02	0.434E-02	0.352E-02
O V 2s21S - 3p1P	172.2	0.148E-03	0.115E-03	0.978E-04	0.838E-04	0.723E-04
O V 2s21S - 4p1P	135.5	0.424E-03	0.370E-03	0.320E-03	0.284E-03	0.271E-03
O V 2p1P -5d1D	154.0	0.153E-02	0.131E-02	0.110E-02	0.921E-03	0.766E-03
O V 3s1S - 4p1P	566.2	0.627E-02	0.543E-02	0.475E-02	0.419E-02	0.398E-02
O V 3p1P -4s1S	662.9	0.606E-02	0.510E-02	0.437E-02	0.394E-02	0.370E-02
O V 3p1P -4d1D	604.4	0.641E-02	0.546E-02	0.474E-02	0.433E-02	0.395E-02
O V 3p1P -5d1D	439.5	0.130E-01	0.111E-01	0.931E-02	0.782E-02	0.652E-02
O V 3d1D - 4p1P	798.3	0.887E-02	0.756E-02	0.649E-02	0.579E-02	0.559E-02
O V 2p21S -3s'1P	265.6	0.324E-03	0.282E-03	0.246E-03	0.210E-03	0.237E-03
O V 2p21S -3d'1P	231.8	0.940E-04	0.757E-04	0.617E-04	0.502E-04	0.495E-04
O V 2p21D -3s'1P	231.1	0.246E-03	0.214E-03	0.187E-03	0.159E-03	0.179E-03
O V 2p21D -3d'1P	205.1	0.841E-04	0.685E-04	0.564E-04	0.463E-04	0.455E-04
O V 2p21D -3d'1D	216.0	0.107E-03	0.861E-04	0.808E-04	0.691E-04	0.574E-04
O V 2p21D -3d'1F	207.8	0.796E-04	0.633E-04	0.516E-04	0.427E-04	0.390E-04
O V 3s3S -4p3P	529.2	0.508E-02	0.432E-02	0.373E-02	0.333E-02	0.310E-02
O V 3s3S -5p3P	390.8	0.790E-02	0.686E-02	0.594E-02	0.529E-02	0.454E-02
O V 3p3P -5s3S	469.1	0.940E-02	0.820E-02	0.722E-02	0.626E-02	0.566E-02
O V 3p3P -5d3D	447.3	0.110E-01	0.944E-02	0.826E-02	0.724E-02	0.609E-02
O V 2p23P -3d'3D	203.9	0.110E-03	0.894E-04	0.744E-04	0.624E-04	0.569E-04
O V 2p23P -3d'3P	202.3	0.107E-03	0.853E-04	0.716E-04	0.603E-04	0.532E-04
O V 2p23P -3s'3P	227.5	0.177E-03	0.141E-03	0.122E-03	0.106E-03	0.910E-04
F V 2p3s2P-2p3p2S	154.2	0.734E-04	0.543E-04	0.447E-04	0.384E-04	0.342E-04
F V 2p3s2P-2p3p2P	162.0	0.710E-04	0.590E-04	0.509E-04	0.439E-04	0.376E-04
F VI 2s21S -2p1P	535.2	0.295E-03	0.209E-03	0.148E-03	0.105E-03	0.830E-04
F VI 2s21S -3p1P	126.9	0.606E-04	0.462E-04	0.381E-04	0.324E-04	0.276E-04
F VI 2s21S -4p1P	99.2	0.173E-03	0.150E-03	0.132E-03	0.119E-03	0.104E-03
F VI 2p1P -3s1S	173.1	0.841E-04	0.667E-04	0.570E-04	0.491E-04	0.417E-04
F VI 2p1P -4s1S	123.3	0.169E-03	0.149E-03	0.130E-03	0.111E-03	0.106E-03
F VI 2p1P -3d1D	121.2	0.232E-04	0.173E-04	0.148E-04	0.121E-04	0.102E-04
F VI 2p1P -4d1D	121.1	0.140E-03	0.121E-03	0.102E-03	0.931E-04	0.857E-04
F VI 3s1S -4p1P	410.7	0.266E-02	0.228E-02	0.201E-02	0.184E-02	0.158E-02
F VI 3p1P -4s1S	476.5	0.297E-02	0.257E-02	0.224E-02	0.191E-02	0.180E-02
F VI 2p21S -3s'1P	183.9	0.111E-03	0.961E-04	0.831E-04	0.699E-04	0.694E-04
F VI 2p21S -4s'1P	129.5	0.263E-03	0.228E-03	0.198E-03	0.195E-03	0.159E-03
F VI 3s'1P -3p'1S	117.6	0.374E-04	0.288E-04	0.242E-04	0.208E-04	0.178E-04
F VI 3s'1P -3p'1P	123.3	0.364E-04	0.300E-04	0.256E-04	0.217E-04	0.202E-04
F VI 3s'1P -3p'1D	118.9	0.471E-04	0.384E-04	0.330E-04	0.330E-04	0.270E-04
F VI 3s'1P -4p'1D	413.5	0.627E-02	0.496E-02	0.392E-02	0.309E-02	0.250E-02
F VI 3s'1P -4p'1P	431.6	0.275E-02	0.241E-02	0.210E-02	0.188E-02	0.172E-02
F VI 2p3P -3s3S	153.8	0.566E-04	0.408E-04	0.326E-04	0.285E-04	0.248E-04
F VI 2p2'3P-3s'3P	161.3	0.685E-04	0.502E-04	0.409E-04	0.354E-04	0.307E-04
Ne V 2p21S -3s1P	184.7	0.895E-04	0.684E-04	0.575E-04	0.494E-04	0.428E-04
Ne V 2p21D -3s1P	173.9	0.790E-04	0.605E-04	0.509E-04	0.437E-04	0.379E-04
Ne V 2p23P -3s3P	167.7	0.686E-04	0.494E-04	0.393E-04	0.342E-04	0.298E-04
Ne VI 2p34S-2p23s4P	142.5	0.471E-04	0.344E-04	0.278E-04	0.241E-04	0.209E-04
Ne VI 2p2P -3s2S	138.6	0.404E-04	0.288E-04	0.229E-04	0.196E-04	0.169E-04
Na VI 2p21S -3s1P	134.5	0.356E-04	0.252E-04	0.186E-04	0.153E-04	0.131E-04
Na VI 2p21D -3s1P	127.8	0.321E-04	0.227E-04	0.168E-04	0.138E-04	0.118E-04
Na VI 2p23P -3s3P	123.9	0.301E-04	0.213E-04	0.168E-04	0.141E-04	0.121E-04
Al V 2p52P -3s2P	130.9	0.325E-04	0.229E-04	0.170E-04	0.139E-04	0.119E-04

Table 2. Comparison of Stark widths calculated here by using the modified semiempirical approach (Dimitrijević and Konjević 1980) (WMSE), with values obtained by using the Eq. (526) in Griem (1974) (WG). The electron density is 10^{17} cm^{-3}.

ELEMENT/TRANSITION LAMBDA(A)		T(K)	WMSE(A)	WG(A)
C V	3s1S - 3p1P	50000.	1.79	1.63
		100000.	1.57	1.36
	12202.6	200000.	1.46	1.18
	X=56.5	400000.	1.22	1.05
		800000.	1.21	0.949
N VI	2s1S - 2p1P	50000.	0.700E-02	0.812E-02
		100000.	0.516E-02	0.607E-02
	2833.7	200000.	0.420E-02	0.475E-02
	X=2.95	400000.	0.357E-02	0.395E-02
		800000.	0.305E-02	0.349E-02
O V	4p1P -4d1D	50000.	4.35	4.16
		100000.	3.79	3.43
	11913.1	200000.	3.30	2.96
	X=29.2	400000.	2.98	2.64
		800000.	2.81	2.41

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STARK BROADENING OF S VI LINES

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1. INTRODUCTION

The aim of this paper is to investigate Stark broadening of S VI line and to provide the corresponding Stark broadening data needed in astrophysics. By using the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), we have calculated electron-, proton-, and He III -impact line widths and shifts for 21 S VI multiplets . A summary of the formalism is given in Dimitrijević et al (1991). The complete results will be published elsewhere (Dimitrijević and Sahal-Bréchot 1993). Here, we present a sample of obtained results and discuss the results for S VI multiplets of interest for stellar plasma research. Moore (1950) e.g., gives a list of first five S VI multiplets in far UV to be of interest for astrophysics, and Seaton (1987) discuss the interest of Stark broadening data of spectral lines of multicharged ions for stellar opacities research.

2. RESULTS AND DISCUSSION

Energy levels for S VI lines have been taken from Joelsson, Zetterberg and Magnusson (1979). Oscillator strengths have been calculated by using the method of Bates and Damgaard (1949) and the tables of Oertel and Shomo (1968). For higher levels, the method described by Van Regemorter et al. (1979) has been used.

In addition to electron-impact full halfwidths and shifts, Stark-broadening parameters due to proton-, and He III- impacts have been calculated. A sample of our results for Stark broadening parameters of S VI multiplets are shown in Table 1, for perturber densities 10^{17} cm^{-3} and temperatures T = 100,000 - 800,000 K. We also specify a parameter c (Dimitrijević and Sahal-Bréchot 1984), which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding electron-impact full width at half maximum. For each value given in Table 1, the collision volume (V) multiplied by the perturber density (N) is much less than one and the impact approximation is valid (Sahal-Bréchot, 1969ab). The accuracy of the results obtained decreases when broadening by ion interact ions becomes important.

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Table 1. Stark broadening widths (FWHM) and shifts for S VI. The parameter c devided with the corresponding electron-impact width(FWHM), gives an estimate for the highest density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 0.1E+18 cm-3

PERTURBERS ARE:		ELECTRONS		PROTONS	
TRANSITION	T(K)	WIDTH(A)	SHIFT(A)	WIDTH(A)	SHIFT(A)
S VI 3S-3P	100000.	0.276E-02	-0.431E-04	0.434E-04	-0.212E-04
937.1 A	200000.	0.199E-02	-0.316E-04	0.868E-04	-0.391E-04
C=0.94E+20	400000.	0.149E-02	-0.462E-04	0.134E-03	-0.615E-04
	800000.	0.115E-02	-0.411E-04	0.176E-03	-0.845E-04
S VI 3S-4P	100000.	0.506E-03	0.747E-05	0.299E-04	0.451E-05
249.1 A	200000.	0.379E-03	0.727E-05	0.428E-04	0.758E-05
C=0.24E+19	400000.	0.295E-03	0.761E-05	0.511E-04	0.107E-04
	800000.	0.239E-03	0.716E-05	0.578E-04	0.135E-04
S VI 3S-5P	100000.	0.662E-03	0.178E-04	0.704E-04	0.155E-04
191.5 A	200000.	0.523E-03	0.236E-04	0.844E-04	0.215E-04
C=0.66E+18	400000.	0.427E-03	0.208E-04	0.956E-04	0.268E-04
	800000.	0.358E-03	0.200E-04	0.104E-03	0.324E-04
S VI 4S-4P	100000.	0.707E-01	-0.152E-02	0.341E-02	-0.164E-02
2598.4 A	200000.	0.539E-01	-0.218E-02	0.494E-02	-0.240E-02
C=0.26E+21	400000.	0.427E-01	-0.196E-02	0.606E-02	-0.315E-02
	800000.	0.349E-01	-0.188E-02	0.702E-02	-0.380E-02
S VI 4S-5P	100000.	0.800E-02	0.526E-04	0.752E-03	0.636E-04
628.2 A	200000.	0.634E-02	0.794E-04	0.898E-03	0.967E-04
C=0.71E+19	400000.	0.520E-02	0.598E-04	0.101E-02	0.133E-03
	800000.	0.437E-02	0.596E-04	0.111E-02	0.159E-03
S VI 5S-5P	100000.	0.812	-0.355E-01	0.631E-01	-0.331E-01
5536.1 A	200000.	0.649	-0.334E-01	0.780E-01	-0.429E-01
C=0.55E+21	400000.	0.535	-0.328E-01	0.908E-01	-0.516E-01
	800000.	0.451	-0.304E-01	0.103	-0.620E-01
S VI 3P-4S	100000.	0.856E-03	0.613E-04	0.243E-04	0.483E-04
390.2 A	200000.	0.644E-03	0.731E-04	0.499E-04	0.688E-04
C=0.59E+19	400000.	0.503E-03	0.712E-04	0.823E-04	0.872E-04
	800000.	0.404E-03	0.672E-04	0.108E-03	0.106E-03
S VI 3P-5S	100000.	0.789E-03	0.111E-03	0.572E-04	0.854E-04
251.6 A	200000.	0.614E-03	0.114E-03	0.962E-04	0.107E-03
C=0.11E+19	400000.	0.492E-03	0.108E-03	0.128E-03	0.130E-03
	800000.	0.403E-03	0.101E-03	0.161E-03	0.153E-03

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ION-ATOM RADIATIVE COLLISIONS AND THE OPACITY OF THE SOLAR ATMOSPHERE

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1. INTRODUCTION

The continuum opacity of the solar atmosphere in the visible range is dominated by radiation exchanges in formation and dissociation of the H^- ion: $H + e <-> h\nu + H^-$ (see Mihalas 1978). However other processes involving atoms and positive ions may also play a role in the opacity. The purpose of the present paper is to evaluate the contribution of these processes to the opacity. We will limit ourselves to the optical part of the electromagnetic spectrum (350 to 1250 nm) where the theory of the various processes involved can be considered as correct.

2. ATOMIC AND MOLECULAR RADIATIVE PROCESSES IN THE SOLAR ATMOSPHERE

The following processes can play a role in determining the opacity of the solar atmosphere.

i) positive ion - atom interactions:

$$A^+ + A <-> \varepsilon_\lambda + \begin{cases} A + A^+ & \text{(radiative charge exchange)}, \\ A_2^+ & \text{(ion-atom photoassociation)}, \end{cases} \qquad (1)$$

where is $\varepsilon_\lambda = h\nu = 2\pi\hbar c/\lambda$ is the energy of the interacting photon;

ii) free-free and free-bound process involving a positive ion:

$$A^+ + e <-> \varepsilon_\lambda + \begin{cases} A^+ + e, \\ A^*, \end{cases} \qquad (2)$$

where A^* is an atom in an excited state;

iii) free-free processes in the field of an atom:

$$A + e \leftrightarrow \varepsilon_\lambda + A + e; \qquad (3)$$

iv) formation and dissociation of H^-:

$$A + e \leftrightarrow \varepsilon_\lambda + H^-. \qquad (4)$$

In order to compare different processes, we will define the ratios (F) of emissivities (ε):

$$F_{ei}(\lambda) = \varepsilon_{ia}(\lambda)/ \varepsilon_{ei}(\lambda), \qquad (5a)$$
$$F^{ff}_{ea}(\lambda) = \varepsilon_{ia}(\lambda)/ \varepsilon^{ff}_{ea}(\lambda), \qquad (5b)$$
$$F^{fb}_{ea}(\lambda) = \varepsilon_{ia}(\lambda)/ \varepsilon^{fb}_{ea}(\lambda), \qquad (5c)$$

characterizing relative contribution of the process (1) in comparison with processes (2), (3) and (4) respectively. The meaning of indexes is: ei - electron-ion; ia - ion-atom; ea - electron-atom; ff - free-free; fb - free-bound. In the case of local thermal equilibrium, these ratios are also the ratios of the corresponding absorption coefficients.

All details of the calculations will be published in Mihajlov et al 1993. Here we present and discuss only the results for the solar atmosphere.

3. RESULT FOR THE SOLAR ATMOSPHERE AND DISCUSSION

Our calculation have been performed by using LTE solar photospheric model of Maltby et al. (1986) (their Table 11, photosheric reference model) for altitudes (h) lower than 600 km and chromospheric model of Vernazza et al.(1981) (their model C) for higher altitudes.

The comparison of (1) and (2) processes contribution is presented in Fig. 1 where the behavior of $F_{ia}(\lambda)$ as a function of height (h) is demonstrated (with f is denoted the correction factor close to unity defined in Mihajlov et al 1993). We can see two maxima, one in the photosphere and the other one in the chromosphere. This means that in these areas ion-atom radiation processes (1), not taken into account up to now, have the dominant role in the comparison with processes (2) for continuous emission (absorption) EM spectrum formation.

The comparison of (1) and (3) processes contribution is presented in Fig. 2 where the behavior of $F^{ff}_{ea}(\lambda)$ is demonstrated. One can see the photospheric and the chromospheric maximum of $F^{ff}_{ea}(\lambda)$ located in the same height range as for $F_{ei}(\lambda)$ in Fig. 1. These maxima however are of smaller intensity.

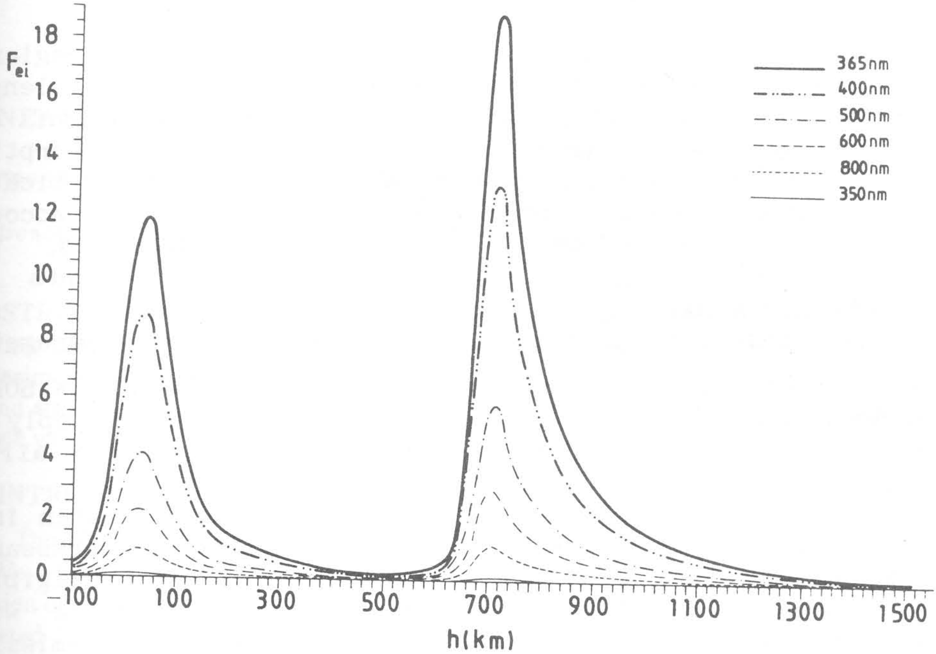

Fig. 1. The parameter $F_{ei}(\lambda)$, for $f_{ei}=1$, in the $350\ nm \leq \lambda \leq 800\ nm$ range ($350\ nm < \lambda_2 < 365\ nm$), as a function of *h*

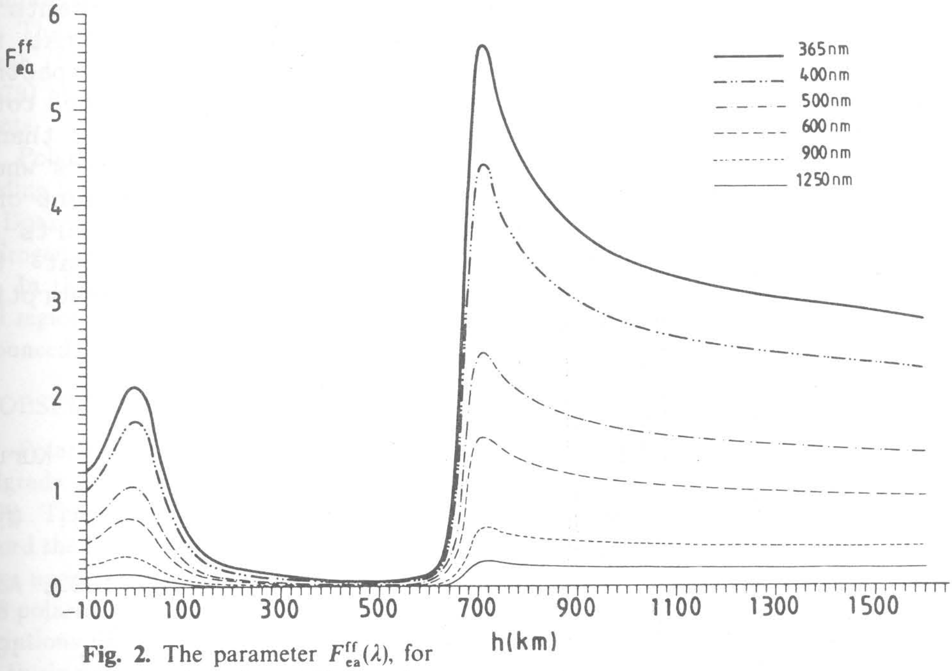

Fig. 2. The parameter $F_{ea}^{ff}(\lambda)$, for $f_{ea}^{ff}=1$, in the $350\ nm \leq \lambda \leq 1250\ nm$ range, as a function of *h*

In considered photosperic and chromospheric regions, electron-atom processes are always dominant for wavelengts larger than 1250 nm, including the infrared part of the spectrum at 1650 nm, where the minimum in H minus absorption occurs. Our calculation however, show that for sophysticated investigations ion-atom processes must be taken into account around 1650 nm since in the layers considered, the contribution of these processes is 5-15 percents of electron-atom ones.

Our calculations show that values of $F_{ea}^{fb}(\lambda)$ parameter change from ≈ 0.15 up to ≈ 0.05 in the -100 km ≤ h ≤ 50km, decrease slowly up to around 700 km and increases steply up to ≈ 0.1. After 700 km increases very slowly for all λ considered.

Our results show that the processes (1), not taken into account up to now for photosphera and chromosphera research from the spectroscopical point of view, are not negligibile and in particular layers become in fact even comparable with processes (4), the most important for continuous emission (absorption) spectrum formation for height range considered.

Present calculations for layer between h = 0 km and h = 605 km show that with the inclusion of processes (1), the continuum emergent intensity from this photospheric layer decreases from 0.28 percents at 500nm up to 0.14 percents at 800nm. We can conclude that in spite of the fact that the contribution of processes (1) to the total absorption spectrum is around 10% in particular atmospheric layers, the total contribution for the photosphera as the whole is less than 1 percent. This is the consequence of the fact that layers where the investigated processes (1) are of interest, represent only a small part of the photosphera, and in large parts of photosphera the proton density is so small that the contribution of processes (1) to the total absorption coefficient may be neglected.

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LINEAR OPTICAL POLARIZATION OF THE STAR BU Tau

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ABSTRACT. The intrinsic linear optical polarization percentage and position angle during the period 1986–1992 are presented. These data are the result of Belgrade polarimetric study of Be stars. Polarization percentage have a general decreasing trend starting with the value 0.57% and finishing with the value 0.32%. The position angle varied in a range between 58° and 71° without any general trend.

1. INTRODUCTION

During the long history of the survey of Be stars, BU Tau (Pleone, HD23862, B8Ve, $v \sin i = 350 km/s$) exhibited two times the phases of the formation and dissipation of the shell. First episode started 1938 and lasted till 1954. Second shell phase, started 1972 according to Goraya *et al.* (1990) and Doroshenko (1989), but one year earlier according to Kogure (1990). The most intensive absorption line spectra was observed during the period 1977–1985. During 1986, as all authors agree, started the dissipation of the envelope accompanied by the weakening of the emission. Goraya *et al.* (1990) concluded that the shell phase of Pleione wich started 1972 would be terminated during 1989.

The polarimetric measurements of Pleione were done sporadically by Van den Bergh (1956), Serkowski (1970), Coyne (1976), Markkanen (1977), Poeckert *et al.* (1979) and Breger (1984, 1986). The last shell phase is badly covered by measurements.

Polarization observations of Pleione started in Belgrade during 1986, when according to Doazan (1988) the shell spectrum began to weaken. That was initiated by V. Doazan after she started IUE observation of this star. During the same year the hydrogen emission, according to Doroshenko (1989) was still strong.

In this paper we present the Belgrade polarizaton data for Pelione in V spectral region during the period 1986–1992, when the weakening of the emmission was anounced.

2. OBSERVATION

Polarimetric observations were carried out with the 65 cm Zeiss refractor and Belgrade one chanell stellar polarimeter in V spectral region during the period 1986–1992. The polarimeter (Kubičela *et al.* 1976) was modified in 1979 to digitize and record the data. The angular velocity of the analyser was one turn per minute. In most cases under "one measurement" one point in Figures 1 and 2, one can understand up to 8 polarimetric 1 minute sine – wave signals phase – averaged. The typical standard deviations for one 8 minute measurement are 0.07% for Stoques parameters U and Q. During the whole interval of observation the instrumental system was carefuly checked by measuring polarized and nonpolarized standard stars.

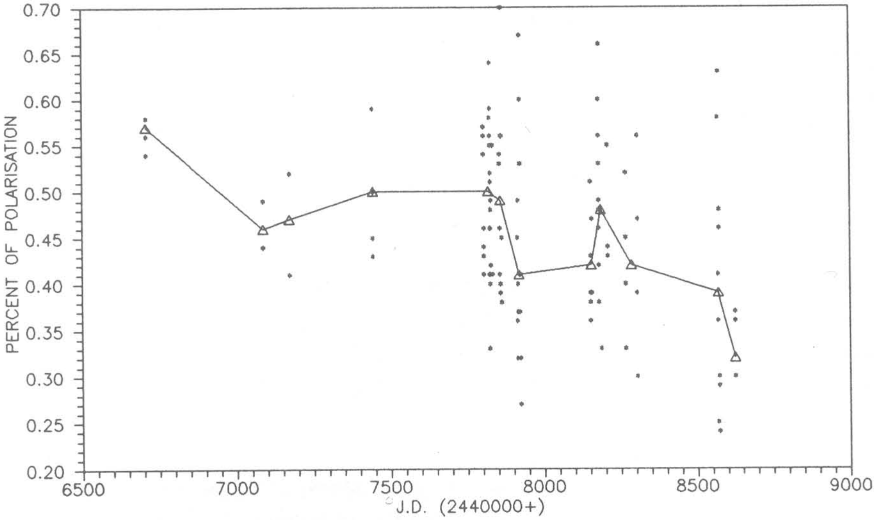

Fig. 1. *Intrinsic polarization percentage of the star BU Tau in V spectral region during the period 1986 – 1992 (dots). Triangles connected by full line denotes the monthly mean values.*

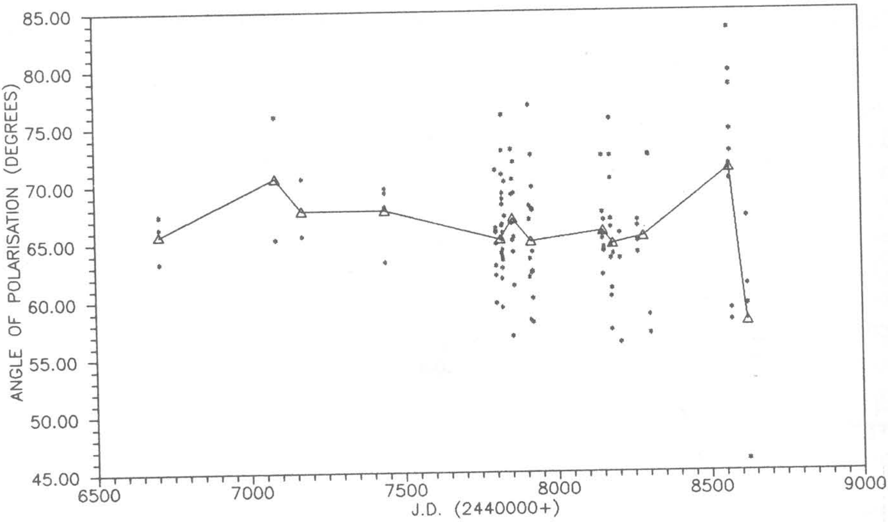

Fig. 2 *Position angles of the intrinsic polarization of the star BU Tau in V spectral region during the period 1986–1992 (dots). Triangles connected by full line denotes the monthly mean values.*

The detalied study of interstellar component in the direction of Pleione has been done and will be discussed elswhere. For the moment we can say that beyond our expectations, in the eastern region of the cluster where BU Tau is situated the interstellar material, both inside and in front of cluster, is very uniform. In this situation the problem of interstellar polarizaton component estimation is not so difficult. We considered the values of interstellar polarization parameters estimated by Poeckert *et al.* (1979), Mc Lean and Brown (1978) and Breger (1986), interstellar reddening, absorption and some other circumstances (Markkanen 1977) in the region of Pleione. It was found that Breger's (1986) values of interstellar polarization component in the direction of Pleione, with certainty, shoud be: percentage P=0.27% and position angle θ=113 degrees.

After extracting the interstellar polarization from the observed data the intrinsic polarization parameters were determined. Individual values of the intrinsic polarization percentage P and the position angle θ are shown in Figures 1 and 2. Monthly mean values are denoted by triangle marks and conected by the full line in both Figures. The respective r.m.s. errors are within the intervals from $\pm$0.02% to $\pm$ 0.13% and from $\pm 2^\circ$ to $\pm 8^\circ$.

3. CONCLUSION

During the period 1986 – 1992 the intrinsic polarization percentage of Pleione weakened from the value around 0.57% to the value around 0.32%. Through the whole period polarization percentage decreased not more than 0.25%. General decreasing trend of polarization percentage was followed by the weakening of the hydrogen emission. Namely, during 1986 the weakening of the emission has started, and we predict further weakening according to the fact that correlation of the polarization percentage and the emission was observed in all stars of our programe. The same correlation for Pleione exists during the period 1974–1988 with increasing emission, according to the published data. The observed polarization percentage confirms the dissipation phase of Pleione during the period 1986–1992.

For the position angle it is difficult to say what of the observed changes is real. In the case of small percentage this is always the case. Further analysis which will include existing data of other authors will be probably fruitful.

As the dissipation of the envelope is usualy accompanied by a V magnitude increase we expect the anticorrelation between polarization percentage and the magnitude of Pleone in the period 1986–1992 to be confirmed soon. This will be very interesting because, in the period 1974–1982, during an intensive shell phase, the behaviour was just the oposite. To our knowledge that was the exception in Be stars.

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ON THE MASS – LUMINOSITY RELATION

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Summary. The empirical mass–luminosity relation is analysed for the main sequence (MS) within the interval $-2.98 \le L/L_\odot \le 5.17$. The agreement with theoretical models is very satisfactory.

INTRODUCTION

For the components of various binary-system types for which the masses and the absolute bolometric magnitudes are known, one can construct an empirical M–L diagram. The first modern survey of the measured M and L (Harris *et al.*, 1963) comprises the visual binaries with $M \sim M_\odot$. The higher masses appear in the lists of Stothers (1972, 1973) concerning the components of eclipsing binaries and of Hutchings (1976) dealing with the case of spectroscopic ones. The survey of McClusky, Kondo (1972) for the visual and spectroscopic binaries also contains about one hundred systems in the case of which only the total mass is available. Finally, Popper's (1980) list contains the modern (accurate) determinations of the thermal characteristics, M, L and R, preferably for the stars of luminosity class V.

THEORY AND OBSERVATIONS

The dimension analysis for the homologous stars in the hydrostatical and thermal equilibrium yields the relation

$$L = CM^q, \tag{1}$$

with parameters C and q. Approximatively, for the laws of energy (ϵ) and opacity (κ) in the forms

$$\epsilon = \epsilon_o \rho^\lambda T^\nu, \quad \kappa = \kappa_o \rho^n T^{-s} \tag{2}$$

(ϵ_o and κ_o are known functions depending on the chemical composition only) the parameters C and q depend on the given X, Y, Z, λ, n and s, so that (1) is valid for radiative envelopes (in any case for the stars in radiative equilibrium). For the stars of the same (and homogeneous) chemical composition, with the same laws (2) and with the equation of state $P \sim \rho T$, C and q are constants — hence in that case (1) becomes

$$lg \frac{L}{L_\odot} = const + q \; lg \frac{M}{M_\odot} \tag{3}$$

with

$$q = \frac{3(3\lambda + n + \nu) + 2n\nu + s(2\lambda - 1)}{3(n + \lambda) + \nu - s}. \tag{4}$$

Fig. 1 gives an empirical lg$M$–lg$L$ diagram for the MS stars: 23 case of visual binaries, 108 case of eclipsing ones and 8 that of spectroscopic ones. It is seen that the theory yields a very good fit to the observations.

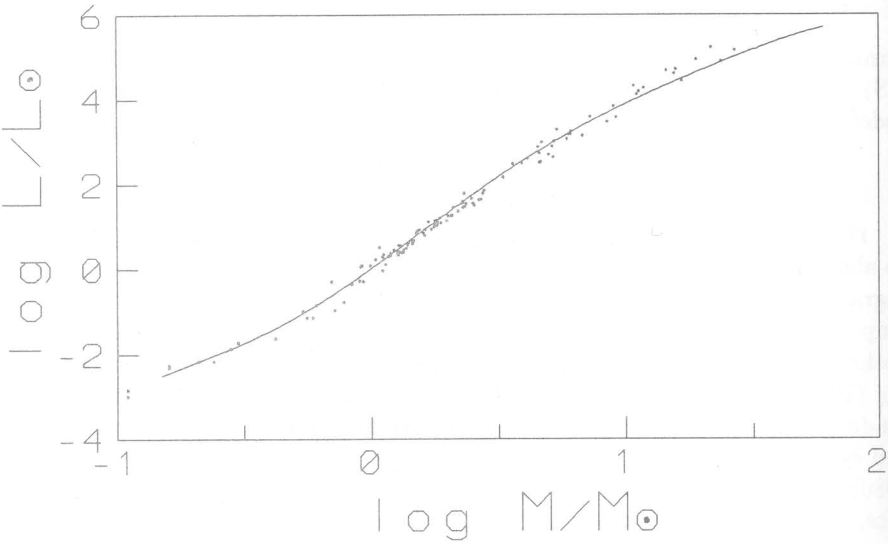

Fig. 1 Mass–luminosity diagram for the main sequence
... 139 stars from Popper's (1980) list,
— models with approximately solar chemical abundance
(from Tinsley, 1980).

Empirical relation (3) is given as a unique one for all stars in the chosen interval of L *i.e.* M along the main sequence: $q = 2.76$ for $-2.5 \leq \lg l \leq -1.1$ ($l = L/L_{\odot}$) and $q = 4$ for $-1.1 \leq \lg l \leq 1.9$ (Harris *et al.*, 1963); $q = 3.87$ for $-2.3 \leq \lg l \leq 5.1$ (McClusky, Kondo, 1972); $q = 3.01$ for $4.7 < \lg l < 6.7$ and $q = 2.7$ for the most massive stars only (de Jager, 1980). In Fig. 2a the rate of the luminosity change based on (3) is given for various L intervals, whereas in Fig. 2b one presents the same thing but for the cubic polynomial lg$L$(lg$M$) in the entire main sequence domain of Fig. 1.

As seen (Fig. 2a), for each of the main sequence intervals, the theoretical luminosity variations from the local approximation (3) exceed the observed ones. On the other hand, the general fit does not produce any systematic excess and it yields a very good agreement between the models and the observations in an extended surrounding of $M_{\odot}$ (Fig. 2b). In both cases (observations and models) the maximum values for q and $d\lg L/d\lg M$ correspond to the domain $M \sim M_{\odot}$. Formula (4) for Kramers opacity ($n = 1, s = 3.5$) and the pp reaction chain with $\nu = 2.5 - 4.5 (\lambda = 1)$ yields $q = 5.4 - 5.6$, and for the CN cycle with $\nu = 13 - 22$ one obtains $q = 5.1 - 5.2$. At the same time, approximation (3) about the maximum (Fig. 2a) yields $q = 3.7$ for the observations and $q = 4.3$ for the models (in Fig. 2b the maximum also occurs at 4.3). For Thomson scattering by free electrons ($n = 0, s = 0$) formula (4) yields

$q = 3$ independently of the values for λ and ν, though it is clear that the CN reactions appear (for hot – massive stars).

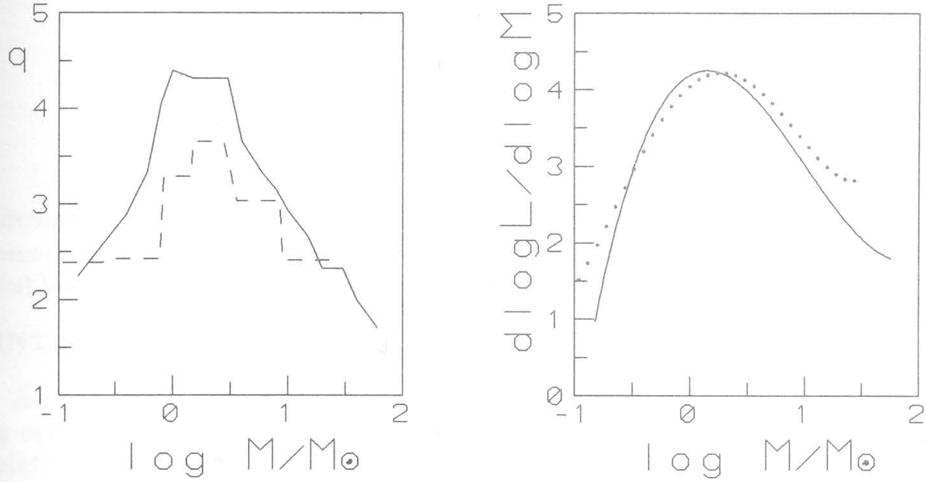

Fig. 2 Luminosity-change rate
left(a): from (3); right(b): from cubic $\lg L(\lg M)$;
- - - (...) observations; — models.

In the domain $M<M_\odot$ approximation (2) for κ is not valid in view of the dominant convection in the case of low-mass stars.

CONCLUSION

The theoretical stellar models for the main sequence phase yield very good fit to the observations on the mass–luminosity diagram. Here, on the basis of (local) linear relation (3), the models yield a systematically more rapid luminosity change with mass. In the case of the nonlinear approximation $\lg L(\lg M)$ the differences are significantly smaller (negligible for $M{\sim}M_\odot$) and not systematic. In both cases, q_{max} and $(dlgL/dlgM)_{max}$ are in the domain $M{\approx}2M_\odot$ where (according to theory) occurs the change in the transfer mechanism in the envelopes of the MS stars.

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ON THE CHOICE OF THE INITIAL CONDITIONS IN AN N-BODY EXPERIMENT

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Summary: The authors discuss the choice of the initial conditions in their numerical experiment concerning a simulation of a hypothetical open cluster containing 100 stars (mass points) based on the N-body approach.

1. INTRODUCTION

As well known, the dynamics of open star clusters is of a collisional type. The encounters, much more frequent than in the surrounding field, result in a relatively short relaxation time. Therefore, an approach where the interaction of the stars is direct following Newton's universal-gravitation law is fully justified.

It is clear that any experiment of such kind will be dependent of the initial conditions and of the applied mathematical method. Therefore, the intention of the authors is to discuss the choice of the initial conditions and the mathematical formalism applied by them.

2. THE INITIAL CONDITIONS

Our test stellar system contains 100 stars corresponding to the open clusters among the real stellar systems. For simplicity we neglect the presence of interstellar matter in it. Each star is characterised with seven parameters: the coordinates, the velocity components (or phase coordinates taken together) and the masses. The latter ones are treated as invariable throughout the experiment so that the only way of distinction among the stars is their masses.

The choice of the initial phase coordinates is done in a way enabling, at the initial moment, avoiding of any preferable concentration of massive stars near the centre of the system and vice versa. Also, at the initial moment, we have no binaries in the system since we expect both effects (concentrating of massive stars towards the centre and formation of binaries) to arise sponatneously in the course of our experiment.

Though, the test cluster is considered as isolated, or self-consistent, nevertheless its spatial limits are chosen to be within the tidally allowed sphere (Lagrangian neutral sphere, e. g. King, 1962). The distribution of stars in the distance to the centre is presented in Fig. 1.

The initial values for the velocity components follow from the condition that the cluster is gravitationally bound, i. e. its total kinetic energy is less than the modulus of the potential energy. The distrbution of the star impulses is presented in Fig.2. Both distributions (Figs. 1 – 2) are intended to comprise a completely random situation where the circumstance of gravitational binding should produce the future evolution.

The mass-distribution law (Fig. 3) is chosen according to the modern concepts (e. g. Marochnik and Suchkov, 1984 - p. 202); the interval is $[0.1, \mathcal{M}_\odot, -50\mathcal{M}_\odot]$, the mean mass is equal to $2.3\mathcal{M}_\odot$ and the dispersion to $7.05\mathcal{M}_\odot$. The choice of the interval is based on the usual mass values along the main sequence. The amount of the mean mass should be noted; it follows from the circumstance that the presence of early-spectral-type stars in the real open clusters should be expected.

3. THE MATHEMATICAL FORMALISM

For the numerical integration of the equations of motion we used symplectic integrator of the fourth order. This technique for the numerical integration of the ordinary differential equations conserves integrals of the equations exactly (Yoshida, 1992), i.e. truncation errors are constant throughout the integration process. However, we should mention here that it does not reduce round off erors.

We check validity of integrations by values of the first integrals (in this case one has ten integrals) on every step of integration.

4. FIGURES

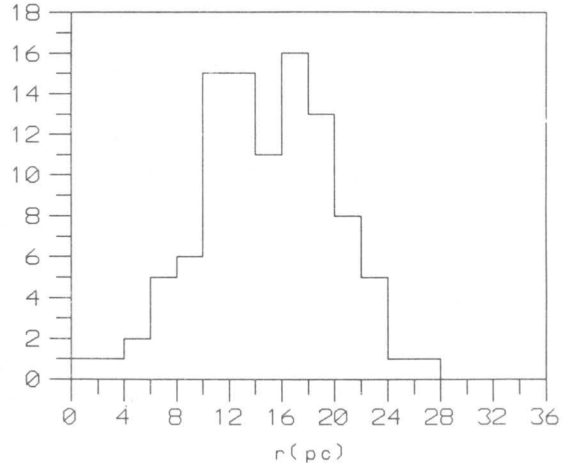

Figure 1. Histogram: number of stars versus distance to the barycentre

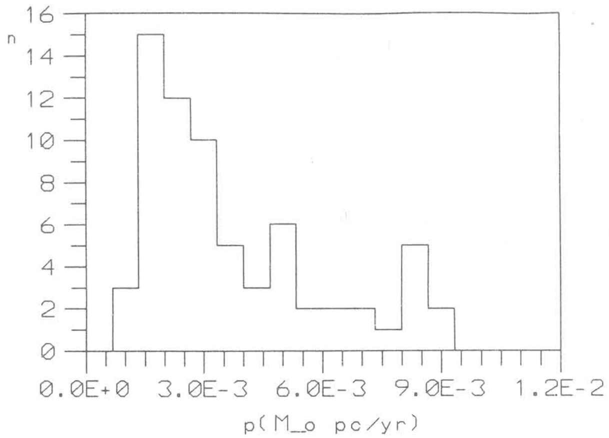

Figure 2. Histogram: number of stars versus impuls

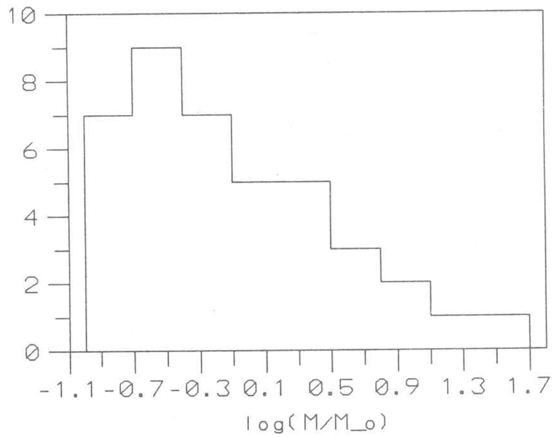

Figure 3. Histogram: number of stars versus mass

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ASTRONOMY EDUCATION IN FR YUGOSLAVIA

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General Information. Astronomy education in Yugoslavia follows the pattern of education in general: it is a subject upon which each republic decides independently. Generaly, astronomy education has longer and larger tradition in Serbia.

Historical Development. Astronomy education was following progres in general teaching. In Serbia, elements of astronomy were taught in elementary schools, within mathematical geography, since 1844, although in a very limited amount. More was taught in secondary schools: in Gimnazija in Sremski Karlovci since 1791, in Gimnazija in Novi Sad since 1816 and in Liceum in Beograd since 1839. Astronomy was often called cosmography then.There was a lot of changes in teaching plans later but, nevertheless, serbian pupils were never left without elementary astronomical contents.

Recently, educational reformation of 1969 introduced astronomy as a separate subject in the fourth year of secondary schools oriented to mathematics and natural sciences, with one lesson weekly. Reformation in 1978 allocated 2 lessons weekly to astronomy in the same type of schools. Reformation in 1987 did not change substantialy teaching of astronomy; it was mainly concerning classification of schools.

The real and unfortunate change came in 1990 when astronomy was joined to physics with only one lesson weekly. It lost its independence, the program got to be shrinked and the position of astronomy teachers worsened considererably. Astronomers and physicists tried to stop such a law, but in vain.

The textbooks of astronomy for secondary schools in this period have been written mainly by serbian writers; only one was translated.

It is very likely that some astronomical subjects were taught at the High School from its foundation in 1863. Several higher level textbooks ("Cosmometry" and "Cosmography" by Jovan Andonovich) and papers of serbian writers witness it. The first professor of astronomy and meteorology on the High School was appointed in 1884. It was Milan Nedeljkovich who got an uptodate astronomy education spending several years at the Paris observatory. He founded the Astronomical observatory in Belgrade in 1887. Soon after the foundation of the University of Beograd in 1905, astronomy education was improved by Milutin Milankovich who was appointed as the professor of applied mathematics and the director of the Department of rational mechanics, theoretical physics and celestial mechanics in 1909. Astronomy was separated for the first time as a study group in 1925-1927 due to the initiative of profesor Vojislav Mishkovich. Foundation of the Faculty of sciences in 1947 brought new changes in organization of teaching of astronomy. In 1951 the Department of mechanics and astronomy was founded and in 1962 the Department of astronomy became independent. Astrophysics started as a teaching subject at the Department of physics in 1954 and in 1958 was shifted to the Department of mechanics and astronomy. First doctoral thesises in astronomy at the University of Beograd were defended in 1956. The postgraduate studies in astronomy and astrophysics were introduced in 1966. The Department of astronomy transformed into the Institute of astronomy in 1971.

The major changes in the education plans happened in 1961 when two study groups: astronomy and astrophysics group were introduced bringing many new astronomical subjects and in 1990 when astronomy group oriented their study plans towards mathematics ang computer science. About half of the astronomical subjects have been covered with textbooks written by University professors. Some of them still wait publishing.

The amateur Astronomical Society "Ruđer Boskovich" founded in 1934 from the very begining has worked on public education. It was publishing the popular astronomical journal "Saturn" from 1935 to 1941 and "Vasiona" (Universe) from 1953 till today. It has been also organizing courses, lectures and observations.

Elementary Schools. Elementary school now is a compulsory eight years school. Selected astronomical topics are taught in elementary schools within the course named "Knowledge of Nature" (IV year), within geography (V) and within physics (later than VI). Details can vary from one republic to the other.

Secondary Schools. Secondary school is not a compulsory one. There is a large variety of types of secondary schools. Some of them are very specialized, preparing pupils for the work. Majority of better pupils is likely to choose "gimnazija". In Serbia, "gimnazija" type schools are 27 percents of the total number of secondary schools. It lasts four years.

Astronomy is not a separate course, due to the law passed in 1990; it is incorporated in physics and partly in geography. Astronomy within "gimnazija" is placed into the last year of physics. Number of lessons depends on a model. There are 2 models:

I model. (General type)

II model.

a. Natural sciences and mathematics oriented type,

b. Social sciences ang languages oriented type.

In the type *I* and *IIb* astronomy is included in physics, in the last year, with 5 lessons (or about 10 lessons if all subjects related to astronomy are counted). In the type *IIa* astronomy is also included in the last year physics but with 32 lessons, out of which 21 are used for teaching of new subjects and 11 are used for repetition and exercises. Schools are allowed to organize astronomy course as a volontary course, in the last year, with 70 lessons. The course is volontary in the sense that it represents an extra course which, once chosen, has to be followed by a pupil till the end. Astronomy will be taught according to this law from the automn 1993.

The textbook for such a program has been prepared by M. S. Dimitrijevich and A. Tomich. It is expected to be printed in spring 1994.

Some elements of astronomy are taught in majority of other types of schools within the II year physics. The suggested subjects are neutron stars, black holes, ideas of the general theory of relativity, the origin and evolution of celestial bodies. In medical schools 3 hours are given to astronomical subjects within physics.

In order to help secondary schools professors to keep in touch with new achievements in astronomy and with ways of teaching astronomy special lectures are presented at regular yearly meetings of professors.

University Education. There are 6 universities in Yugoslavia (in Beograd, Novi Sad, Kragujevac, Nish, Prishtina and Podgorica).

The University of Beograd is the only one which has astronomy as a study group. It has two divisions:

1. Astrophysical department which has a study program containing many courses in physics, two courses in mathematics, some general courses: such as foreign languages, pedagogy etc. and the following astronomical courses: general astronomy (I), general astrophysics (II year), practical astrophysics (III), reduction of astronomical observations (III), theoretical astrophysics (IV), structure and evolution of stars (IV), radio astronomy (IV), stellar astronomy (IV), methods of teaching astronomy and history of astronomy (IV). At the end of the third year students have a summer practice at the Astronomical observatory in Belgrade and during the forth year teaching practice in the Belgrade Planetarium, University, Youth Research Station in Petnica, popular astronomical journal and secondary schools.

Graduated astrophysicists have a right to teach astronomy and physics in secondary schools.

2. Astronomical department has a study program which contains a lot of mathematical courses particularly those related to programing, some general courses (as in the astrophysical department), course in theoretical mechanics (III) and the following astronomical courses: general astronomy (I), general astrophysics (II), positional astronomy (II), practical astronomy (III), reduction of astronomical observations (III), ephemeridal astronomy (IV), theoretical astronomy (IV), celestial mechanics and the motion of artificial satellites (IV) and stellar systems (IV).

Graduated astronomers obtained in 1990 the right to teach mathematics in secondary schools. They have also a right to teach astronomy but not physics what makes their position very awquard.

The undergraduate studies last four years. The average number of graduations is 3-5 per year.

There are 4 divisions on postgraduate studies (M.Sc. courses) at the University of Beograd:

1. Positional astronomy,
2. Astronomy and celestial mechanics,
3. Stellar astronomy,
4. Astrophysics.

The postgraduate studies last two years. A candidate has to pass exams and to do a M. Sc. thesis. The average number of graduations is about one per year.

There is also geodetic astronomy (IV) at the Faculty of Civil Engineering and one semester course of basics of astrophysics (III) for students of the teaching branch on the Faculty of Physics, in Beograd.

Some elements of astronomy are taught within mathematical geography.

Public Education. Public astronomy education in Yugoslavia is done by lectures at popular universities, on Radio and TV programs, in popular journals and books, in Planetariums, in popular observatories and amateur astronomical societies.

A long tradition in organization of lectures on recent discoveries in astronomy has Kolarchev Popular University in Beograd. It organizes every year, since 1964, at least one cycle of astronomy lectures. Particularly active institutions in public education are the Astronomical Society "Rudjer Boshkovich" in Beograd and the

Astronomical Society Novi Sad (ADNOS). Both are amateur societies whose members are professional astronomers as well, helping in popularization of astronomy.

There are two planetariums in Yugoslavia. One in Beograd was officially open in 1970 and had about 225 000 visitors untill now. One in Novi Sad is in the phase of instalation. The Planetarium in Beograd works mainly with schools. Both planetariums are small Carl Zeiss (Jena) instruments.

An interesting form of astronomical education are courses and summer schools for pupils interested in astronomy. The Youth Research Station in Petnica (founded in 1982) has been organizing 5 courses every year already several years. The first course is an introductory one, the second course is introduction into practical work, the third course is used for work on small research projects, the fourth is devoted to some higher forms of work and on the fifth one the projects are finalized. The best projects are stimulated to be published. The series starts with 50 candidates, number decreasing later to few best participants. The courses last several days (up to 10). The participants come to Petnica after the selection of best pupils interested in astronomy. The Astronomical Society "Rudjer Boshkovich" and ADNOS organize autumn and spring courses (in Belgrade and Novi Sad, respectively) for all who wish to come. Those who wish to become collaborators of the Astronomical Society "Rudjer Boshkovich" have to pass a final examination. There have been 325 of them. The Astronomical Society "Rudjer Boshkovich" organizes also yearly the Belgrade Astronomical Weekend, with lectures, visits to observatories and observations. All the courses are run by the stuff of these institutions although professional astronomers often give lectures as well.

There are also some other forms for teaching of astronomy in Yugoslavia. One of them is the regular yearly competition of pupils in tests and astronomical projects within the organization "Nauku mladima" (Science to the Youth). The projects are chosen by pupils while the examining committee consists of teachers and at the higher level of professional astronomers. It started in 1964. More than a hunderd thousands of pupils were participating in competition by tests, about 3400 pupils continued doing astronomical projects out of which about 50 were good quality ones. 38 projects have been published in parts or as a whole. There have been other competions of pupils in astronomy but with much less participants. One organized by Clubs of Young Technicians started in 1986, with a program similar to "Nauku mladima", having 7 –30 competitors yearly. The Union of organization for scientific and technical education of the youth of Serbia published in 1988 a handbook for participants of this last competition.

The Astronomical observatory in Belgrade, the popular observatories of the Astronomical Society "Rudjer Boshkovich" in Beograd and the Astronomical Society Novi Sad, the Belerofont observatory of the Faculty of sciences in Kragujevac and the small observatory of the Youth Research Station in Petnica receive visitors.

The Astronomical Society "Rudjer Boshkovich" publishes a non profit journal for popularization of astronomy "Vasiona". 166 numbers were published in which 23 articles were written by students as a part of teaching practice.

The Youth Research Station in Petnica publishes "Petnichke sveske" (Petnica Notes). There have been 31 numbers printed out of which 15 have been at least partly devoted to astronomical subjects.

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IN VELOCITY SPACES THE (UNPERTURBED) PLANETS MOVE IN CIRCLES ONLY

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It is well known that hodographs of motions in 1/r fields are circles, the equation of which is:

$$(v_x - A)^2 + (v_y - B)^2 = C^2$$

where v_x, v_y are the Cartesian components of velocity and A, B, C are the constants of motion determined by initial conditions (Sommerfeld A. 1964). Starting from the conservation laws we here show that the similar and quite useful relation exists between the polar components of velocity, $v_r = dr/dt$ and $v_\varphi = r\,d\varphi/dt$. The laws of conservation of total energy E and angular momentum L for a mass m moving in the field of mass M, $(M >> m)$, read:

$$E = \frac{1}{2}mv_r^2 + \frac{1}{2}mv_\varphi^2 - \gamma\frac{mM}{r} = const \qquad (1)$$

and

$$L = m\,v_\varphi r = const. \qquad (2)$$

If v_φ is expressed from (2) and substituted in (1) one obtains:

$$E = \frac{1}{2}mv_r^2 + \frac{1}{2}mv_\varphi^2 - mwv_\varphi \qquad (3)$$

where we have introduced the new quantity

$$w = \gamma\frac{mM}{L} \qquad (4)$$

which has dimensions of velocity and the meaning of which will become clear later. It is straightforward now to rewrite equation (3) as:

$$v_r^2 + \left(v_\varphi - w\right)^2 = u^2 \qquad (5)$$

where

$$u^2 = \frac{2E}{m} + w^2 = const. \qquad (6)$$

Equation (5) is the equation of a circle of radius u in the v_r, v_φ plane, the center of which is at the point w on v_φ axis (Figure 1.). This is the useful result referred to in the title of this paper.

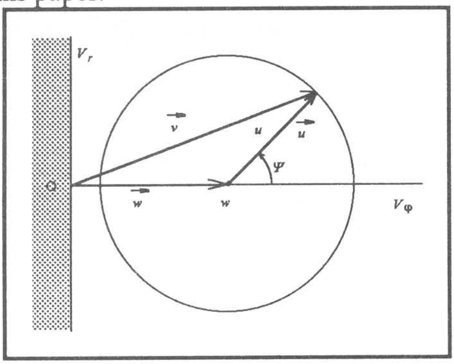

Figure 1. Trajectory in the v_r, v_φ plane. Due to the conservation of angular momentum velocity space reduces to a plane. Angular velocity v_φ can not be negative (no real retrograde motion is possible) and the shaded region is a kinematically forbidden one.

If E and L are once defined by initial conditions, w and u are given by (4) and (6) and the velocity circle is completely specified.

In a point on the circle defined by angle ψ (see Fig.1) the components of the velocity are:

$$\begin{aligned} v_r &= u \sin \psi \\ v_\varphi &= u \cos \psi + w \end{aligned} \qquad (7)$$

Also, if we introduce the vectors $\vec{w}$ and $\vec{u}$ as denoted in Fig .1, it is obvious that

$$\vec{v} = \vec{w} + \vec{u} \quad .$$

The distance r from the center of force at which angular component of velocity equals v_φ is now easily obtained from equations (2) and (7) :

$$r = \frac{L}{mv_\varphi} = \frac{L}{mw(1 + \frac{u}{w}\cos\psi)} \tag{8}$$

Since u is a fraction of w we may write

$$u = ew \tag{9}$$

where, with help of (6),

$$e^2 = \frac{2E}{mw^2} + 1 \tag{10}$$

and equation (8) now becomes:

$$r(\psi) = \frac{p}{1 + e\cos\psi} \tag{11}$$

This is immediately recognized as the general equation of a conic section in polar coordinates which is usually written as (the polar axis pointing from the pole, at the center of motion, towards the pericenter)

$$r = \frac{p}{1 + e\cos\varphi} \quad . \tag{12}$$

Direct comparison with equation (8) yields the values of the parameters of the trajectory : the focal parameter $p = L/mw$, the eccentricity $e = u/w$, or as given by equation (10), and, most useful, angle ψ in the velocity diagram is equal to the polar angle φ in the configuration space (or to the so called true anomaly of celestial mechanics). All other elements of the keplerian orbits may now be found from the expressions already deduced, equations (5) to (12).

To demonstrate the ease with which this is done we shall analyze only the basic characteristics of possible motions.

The simplest case corresponds obviously to $u = 0$. Then also $e = 0$, $v_r = 0$ and $v_\varphi = v = w$. Velocity diagram reduces to a point and trajectory is a circle with the radius $r_c = p$ and w is seen to be the velocity on the circular orbit with given L. From equation (1) total energy is seen to be $E = -mw^2/2$ what is its minimum possible value since u can not be negative.

If $1 > e > 0$ the trajectory is an ellipse (equation (12)) and u is smaller then w; the velocity circle does not touch the v_r axis. The characteristic points - the pericenter P, the apocenter A, and the points where the focal parameter touches the trajectory, FP, are marked in Figure 2. All the parameters of the trajectory are easily found and this is left as an exercise to the reader (for instance, velocity at pericenter is instantly seen to be $u + w$, radial velocity is seen to be maximum at FP and to equal u, etc.) Total energy is still negative, as follows from equation (10).

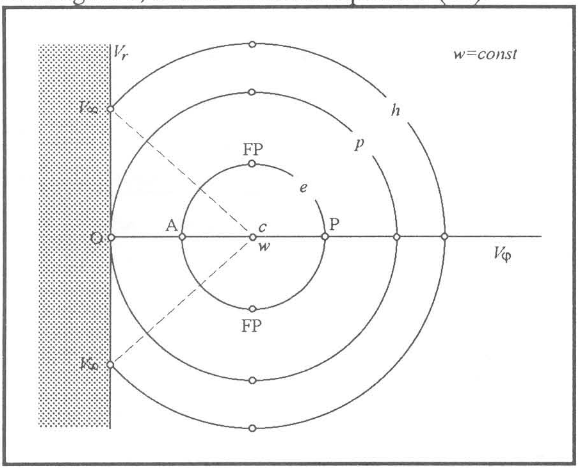

Figure 2. View of different conic section trajectories in velocity plane. Representative circles corresponding to circular (c), elliptic (e), parabolic (p) and hyperbolic (h) trajectories with given angular momentum (same w) are shown. Characteristic points are marked as described in the text.

The discussions of infinite motions equally easy yield the parameters of parabolic and hyperbolic trajectories.

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THE MEASUREMENTS OF TIME VARIATIONS OF COSMIC RAYS IN YUGOSLAVIA

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The time variations of cosmic-ray intensities have been systematically studied for at least some 50 years now, the first comprehensive review being by Elliot H. (1952). An enormous amount of data has been collected by a multitude of measuring stations scattered all over the world (Allkofer C.O. et al. 1984) and from that vast material much has been learned about the cosmic rays themselves as well as about the many astrophysical phenomena which influence their intensity. The intensity of primary and secondary cosmic rays vary on different time scales; long term variations have periods of one or more years while the short term ones are of periods from one day to a year. There are also shorter and aperiodic changes of intensity lasting for hours and maybe even less. All those variations are ascribed to terrestrial, solar and galactic causes, ranging from trivial meteorological conditions through solar flares to elusive galactic magnetic fields, and many models have been developed to account for all the effects observed. (Due to the blockade of scientific information we have no knowledge of the recent developments in the field.)

In Yugoslavia, however, the intensity of cosmic rays has never been systematically measured and no local data on variations of this intensity exist. We thus here give a short information about the potentials of our nuclear physics community in this respect which it may propose to the astrophysical community by using modest and mostly already available means.

For the purposes of cosmic-ray intensity monitoring a wide range of specific detectors exists. Main requirements are the discrimination of cosmic-ray events from those induced by other environmental radiations and large active areas in order to have good statistical sensitivity. They may be either telescopes or single detectors of adequate construction. Needless to say that neither of such detectors we possess at the moment.

We have, however, for the very different needs of a thallium solar neutrino experiment (Aničin I. et al. 1988), developed a simple single detector method for cosmic-ray intensity measurements which exploits the common detectors used in standard gamma-ray spectroscopy work (Aničin I. et al . 1991). The method is based on the fact that the cosmic rays, which at the bottom of the atmosphere consist mostly of high-energy secondary muons, passing through the detector medium loose some energy (typically 2 MeV/gcm^{-2}) and produce part of the continuos background spectrum. The low-energy part of this background spectrum below some 3 MeV is intermingled with the part produced by other environmental radiations but the higher-energy part is practically completely due to the cosmic rays. In the usual gamma-ray spectroscopy work those events usually end up as saturated pulses and the counting of those pulses offers the possibility to monitor the cosmic-ray intensity. We have also developed (D. Jovanović of "Digital Design", Belgrade) a low-cost multiscaler card operated by a standard AT computer which is well suited for the job. This is thus the only addition to a standard gamma-ray spectroscopy system needed to measure the variation of the intensity of secondary cosmic rays on Earth with time. An example of such measurement is shown in Fig. 1.

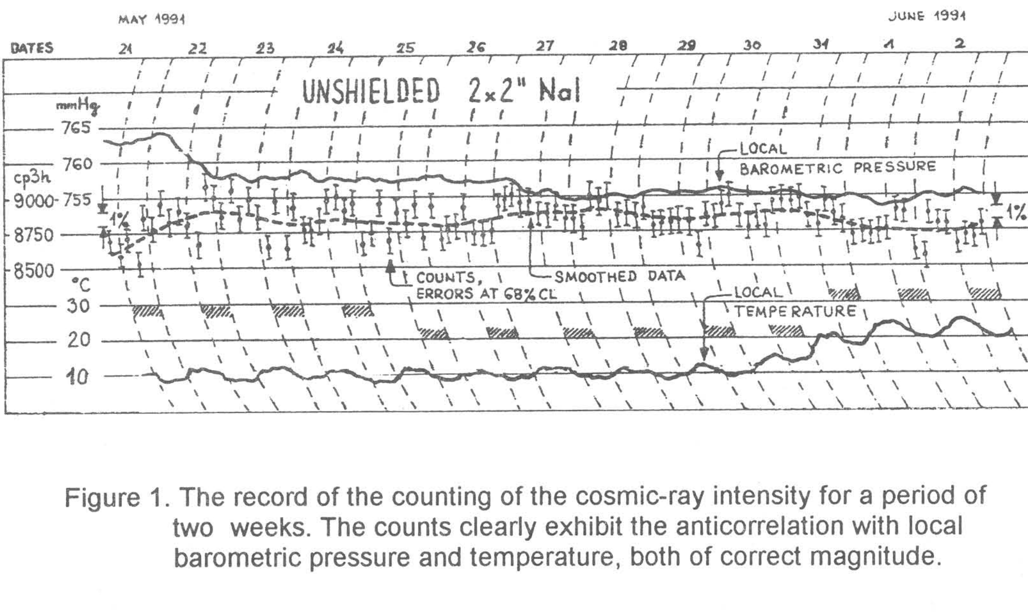

Figure 1. The record of the counting of the cosmic-ray intensity for a period of two weeks. The counts clearly exhibit the anticorrelation with local barometric pressure and temperature, both of correct magnitude.

The extent of the observable variation of intensity of the shortest duration is determined by the counting statistics, i.e. by the detector size. As a rule-of-thumb one may think of the detector with the cross section A (cm^2) of 100 cm^2 to yield about 3 counts per second and we may define a counting constant $k \approx 0.03$ cpspcm^2. The relative counting error of the count c is $r = \Delta c / c = 1/\sqrt{c}$ and if the measurement time is T seconds all the relevant quantities are connected as $T \cong 1/kAr^2$. With a detector of $A = 100$ cm^2 a change in the intensity of 1% (at the level of 10000 counts) may thus be observed in a counting time of 1 hour but a 10% change is observable on the scale of some 30 seconds (all on the 68% CL). Our standard detectors are typically of the cross-sections of about 25 cm^2 and the change of the order of 1% would be observed only if it lasted for at least 3 to 4 hours. If better sensitivity is needed bigger low-cost liquid scintillation detectors could be tailored for the purpose.

If such measurements are continuously performed at a number of more or less distant places, after correcting for local meteorological conditions, cross-correlations between the counts and correlations with geomagnetic data reveal whether the variations are local or occur at a larger scale. This also provides a means to checking the results. Fig. 2 is a map of potential measurement stations where measurements could be organized at low cost and with little additional effort.

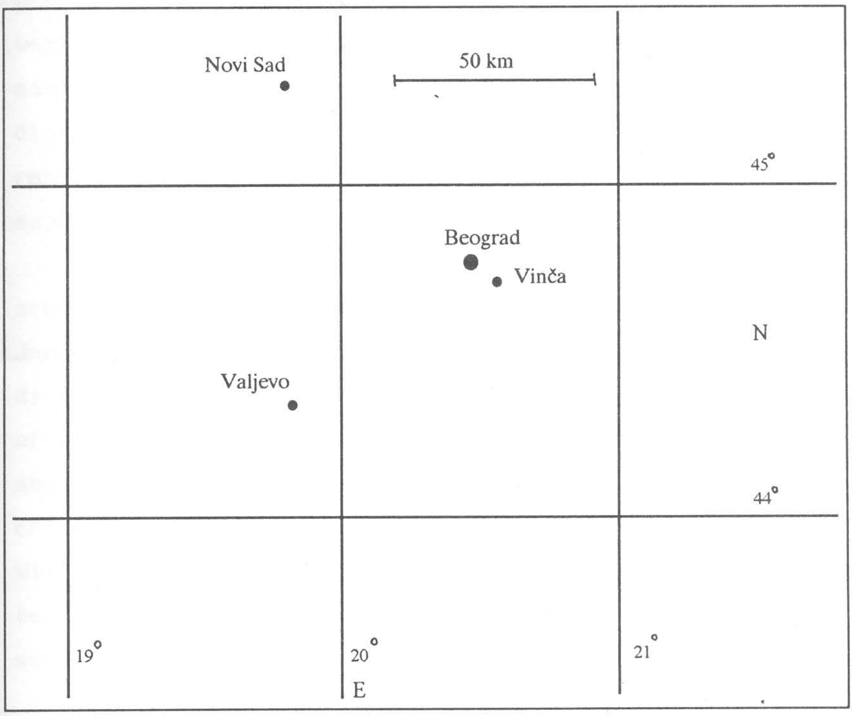

Figure 2. Map of the potential measuring stations at mutual distances ranging from 10 to 100 km

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SOME POSSIBLE ASTROPHYSICAL APPLICATIONS OF DIAMOND ANVIL CELLS

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The pioneering experiments of Bridgman,in the early and middle parts of our century,have marked the beginning of the modern period of experimental high-pressure work (for a review of his work see Bridgman,1964).Bridgman used large volume presses which could contain large samples and in which the P - T gradients were diminished,but which had the disadvantages of a limited P - T range,no direct observation of the sample was possible,and were expensive to install and maintain in operating conditions.

A breaktrough in high pressure experimental techniques occured near the middle of this century (Lawson and Tang,1950; Jamieson et al,1959;Weir et al,1959) with the invention of the diamond anvil cell (DAC).The first DACs were built with the aim of performing high-pressure x-ray diffraction studies and infrared absorption measurements under high pressure.Later evolution.described in detail in the literature (such as Jayaraman,1983,1986; Williams and Jeanloz,1991;Angel et al,1992;Itie,1992), has converted the DAC into a versatile quantitative tool for physical research.

The basic principle of the DAC is extremely simple.A sample is placed between the flat paralel surfaces of two opposed diamond anvils,and it is subjected to pressure when the diamonds are pushed together by an external force.Variations in DAC types arise from different ways of generating the external force ,transmitting it to the diamonds and alining them.In order to achieve hydrostatic experimental conditions,a gasket is inserted between the diamonds.

The gasket is a thin small metal foil, with a hole containing the pressure transmitting medium and the sample in its center. Pressure is measured in the "ruby scale": the R lines of ruby (Al_2O_3 doped with Cr^{3+}) have a well known pressure shift. Accordingly, a small chip of ruby is placed in the hole in the gasket, and its fluorescence is excited by a laser or any other source of strong light. This scale is linear up to at least 30 GPa (Jayaraman, 1983); in its non-linear form, the ruby scale can be applied for pressure measurements up to 250 GPa (Ruoff, 1992a); at higher pressure only X-ray diffraction measurements can be performed. Experiments in DACs are complicated by the miniaturized scale: for example, the hole containing the sample and a chip of ruby has a diameter of only 200 μm, while the typical size of the samples is of the order of 40-50 μm. Experiments can be performed in the interval of temperatures between 4K and around 7000 K (Williams and Jeanloz, 1991).

What applications can DAC experiments have in astrophysics? It is a "fact of life" that no direct observation of planetary or satellite interior is possible. Some of the observable planetary parameters critically depend on the conditions prevealing in their interiors, and the only experimental method for investigating them is the use of DACs.

For example, the giant planets of the Solar System contain a large percentage of hydrogen, and the obvious question is how does it behave under extremely high pressure (of the order of hundreds of gigapascals, as in the center of Jupiter). Theory predicts that hydrogen becomes metallic at a pressure of 200-300 GPa (for example, Wigner and Huntington, 1935; Barbee et al, 1989; Ashcroft, 1989 and many other papers). Claims were recently made that metallization of hydrogen was detected in a DAC at a pressure of $P \cong 200$ GPa (Mao and Hemley, 1989), but they were later shown to be incorrect (Ruoff, Greene, Ghandehari and Xia, 1992). Accordingly, the existence of metallic hydrogen in deep interiors of the giant planets, and its possible consequences on the observable planetary parameters is still an unsettled question.

A closely related problem is the behaviour of ice under high pressure. A new high pressure, low temperature phase, called ice XII, has recently been discovered (Bizhigitov and Sirota, 1986). It is stable for temperatures between 90 and 250 K, and in the pressure interval 1200 - 2150 MPa. The preceeding phase, ice XI, becomes metallic at P = 1.76 TPa (Hama et.al, 1990). Such data are relevant for modellization (and interpretation of observations) of the giant planets and their satellites: to the author's knowledge, they have not been widely used.

What about the interior of the Earth? Its composition is one of the most important planetological problems (Knittle and Jeanloz, 1991b), but it is generally assumed that it consists of a metallic core surrounded by a rocky crust (Jeanloz, 1990). Experiments in DACs have given valuable indications about the conditions in its deep interior, such as the central temperature (Williams, Jeanloz, Bass et al, 1987), the temperature at the core-mantle boundary (Knittle and Jeanloz, 1991b), or the possibility of chemical reactions between the silicates and liquid iron (Knittle and Jeanloz, 1991a). An analysis of melting of iron under high pressure (Čelebonović, 1993a) has given indications about the changes of the Gruneisen parameter of iron under pressure, which is an example of a planetologically motivated result in solid-state physics. Numerous other examples of DAC experiments giving planetologically interesting information can be found in the literature (such as Jeanloz, 1989, 1990; Williams and Jeanloz, 1991).

Instead of a conclusion, a preliminary information: some work concerning the high pressure behaviour of planetologically interesting materials is going on in the Institute of Physics. Those interested are invited to contact the author.

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MASS TRANSFER IN INTERACTING BINARY W SER-TYPE SYSTEMS

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By the method, proposed by Nazarenko V.V.(1993) and using the observational data, obtained by different authors, the physical conditions in the stream in the neighbourhood of the point L1 were calculated for three interacting binary systems of W Ser-type: β Lyr, V367 Cyg, RY Sct. Nazarenko V.V.(1993) showed, that the properties and dynamic of the stream in the neighbourhood of the point L1 can be calculated only on the basis of the parameters of the system and of the conditions in the atmosphere of the Roche lobe filling component, without using any additional assumptions.

Our calculation showed, that in the investigated systems saturation in the vicinity of the point L1 takes place. That means, that a further increase of the radius of the mass losing companion does not lead to a considerable increase of concentration of matter in the point L1. The process of reaching the saturated state of the mass losing component is good illustrated by Fig.1.

By changing the value Xo (Xo is the position of the deepest layer in the model atmosphere by Kuruch R.L. (1979) on the X-axis) we calculated several versions of the stream parameters near the point L1 for several observational data obtained by different authors. The results of our calculations are collected in Table 1. XL is the position of the point L1 on the X-axis, NL is the concentration of matter in the point L1, TL is the temperature in the point L1, VL is the X-component of the stream velosity and VL(s) is the sound velosity in the point L1. Rs is the stream radius, R is the Roche lobe of the mass losing star, $\dot{M}$ is the rate of mass transfer through the point L1. All dimensions are given in units of the distance between the components of the binary system, velosity are given in km/s.

The analysis of the obtained results shows that in the result of the evolutional expansion of the mass losing component the deep layers of its atmosphere reach the neighbourhood of the first Lagrangian point L1 and a stream of axial symmetric shape is formed. Its radius is comparable to the dimension of mass losing component (They are only two times less than the radii of the mass losing stars). The stream velocity along the X-axis in the neighbourhood of the point L1 amounts 20-30 km/s and is equal to the sound velocity in this point. This result confirms the supposition by Lubow S.H. & Shu F.H.(1975) about the stream velocity in the point L1. In perpendicular direction the stream is in hydrostatical equilibrium (its velocity does not exceed a few hundred m/s). It also agree well with the earlier assumption of Prendergast K.H. & Taam R.E.(1974). The calculated rate of mass transfer reaches 10^{-5} $M_\odot$/yr and also agree well with observed values of the rate of mass transfer.

For V367 Cyg the stream radii calculated on the basis of the system parameters obtained by the different authors, differ considerably. The maximum value of the

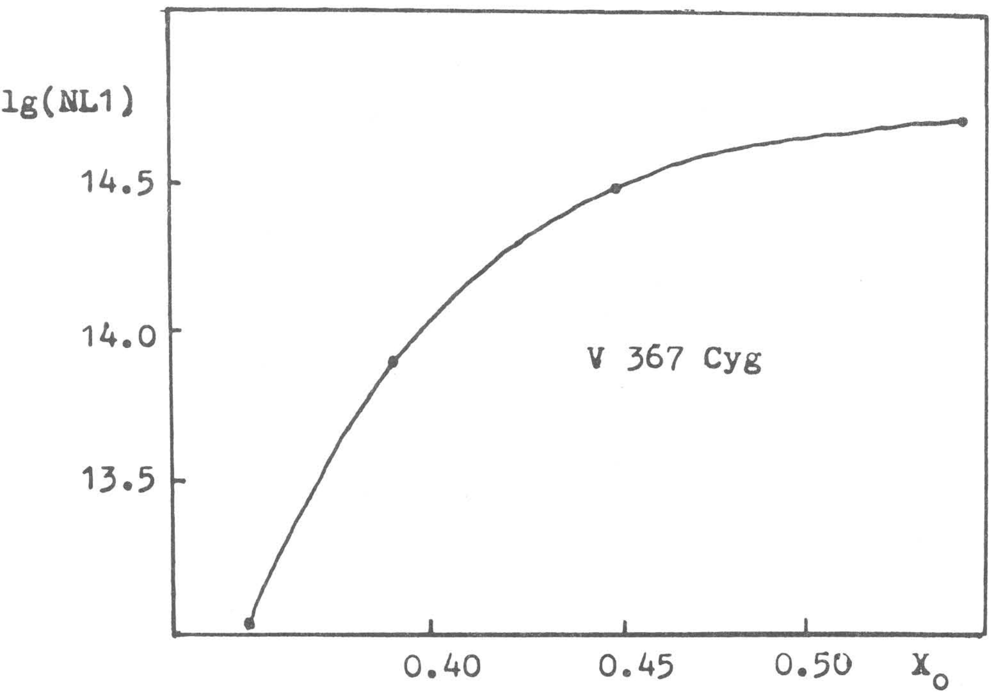

Fig.1

Table 1.Stream parameters in the neighbourhood of the point L1

Xo	XL	NL(cm^{-3})	TL(K)	VL	VL(s)	Rs	R	$\dot{M}(M_\odot/yr)$	Ref.
					β Lyr				
0.38	0.32	$6.4 \cdot 10^{14}$	46000	29.5	27.2	0.15	0.22	$6.4 \cdot 10^{-6}$	Ziolkowski
0.32	0.32	$3.0 \cdot 10^{14}$	32100	23.2	21.5	0.13	0.22	$1.9 \cdot 10^{-6}$	Ziolkowski
0.37	0.37	$3.0 \cdot 10^{14}$	32200	23.7	21.9	0.10	0.25	$1.3 \cdot 10^{-6}$	Skul'ski
					V367 Cyg				
0.54	0.45	$5.2 \cdot 10^{14}$	51780	28.5	26.7	0.19	0.34	$1.8 \cdot 10^{-5}$	Menchenkova
0.45	0.45	$2.8 \cdot 10^{14}$	37000	25.0	23.5	0.17	0.34	$6.1 \cdot 10^{-6}$	Menchenkova
0.39	0.45	$8.0 \cdot 10^{13}$	23200	19.7	18.5	0.14	0.34	$9.1 \cdot 10^{-7}$	Menchenkova
0.44	0.44	$3.8 \cdot 10^{14}$	23043	19.3	17.9	0.14	0.33	$4.0 \cdot 10^{-6}$	Pavlowski et al.
0.54	0.55	$2.7 \cdot 10^{14}$	36300	25.0	23.5	0.10	0.42	$1.0 \cdot 10^{-6}$	Li et al.
					RY Sct				
0.40	0.39	$1.4 \cdot 10^{15}$	69100	32.3	30.8	0.15	0.27	$1.0 \cdot 10^{-5}$	Antokhina et al.
0.33	0.39	$2.0 \cdot 10^{13}$	19344	19.1	16.3	0.08	0.27	$2.2 \cdot 10^{-8}$	Antokhina et al.

stream radius and the rate of mass transfer were calculated by using the parameters of the system obtained by Menchenkova E.V.(1990). The stream radius and the rate of mass transfer calculatedd on the basis of the parameters from Pavlowski K. et al.(1992) and Li Y.-F. et al.(1987) are smaller. That fact contradicts to the observational data about the existence of circumstellar matter with develope structure in the system V367 Cyg. That is why, we draw the conclusion that for V367 Cyg the parameters obtained by Menchenkova E.V.(1990) are more realistic: $M1= 2.3\ M_{\odot}$, $M2= 3.6\ M_{\odot}$, $T1= 12000$ K, $A= 53\ R_{\odot}$.

For β Lyr the maximum values of the stream radius and the rate of mass transfer obtained for the system parameters calculated by Ziolkowski J.(1976): $M1= 2.0\ M_{\odot}$, $M2= 11.7\ M_{\odot}$, $T1= 11000$ K, $A= 55\ R_{\odot}$.

For RY Sct the stream radius calculated on the basis of the different variants of the system parameters are equal.

More detailed report will be published in Astronomicheskij Zurnal (Moscow)

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SPECTRAL VARIATIONS OF PLEIONE

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Pleione (BU Tau, 28 Tau, HD23862) is one of the best investigated Be stars. It shows significant long term variations in its spectrum. Observations of Pleione over more than 100 years show that the active phases appear periodically: 1887-1904 (Be phase), 1904-1938 (B phase), 1938-1955 (Shell phase), 1955-1972 (Be phase), 1972-1989 (Shell phase), 1989- (Be phase). There are many investigations of the envelope of Pleione. At the same time, the nature of the underlying star have been investigated only very poorly, because of the complicate analysis of the shallow and broad lines observed in the spectrum of the rapid rotating star. Most of time in the spectrum of Pleione a great number of shell lines formed in the envelope of the star have been observed. It makes analysis of the spectrum of Pleione some more complicate problem. In the end of 1980s the shell spectrum of Pleione became considerable weak and the conditions for investigation of the underlying stellar spectrum, determination of the parameters of the stellar atmosphere and search for lines of an assumed companion became much better.

We obtained spectral observations of Pleione with the 6-m telescope of the SAO (Zelenchykskay) on April 5, 1990 and the 2.6-m telescope of the Crimean Astronomical Observatory (Nauchny) on December 10, 1990.

Our observations show, that during 1990

1. The lines of the shell spectrum of Pleione disappeared completely.
2. The spectral type of Pleione was equal to B8.
3. There are variations of the equivalent widths (more than two times) and the profiles of the hydrogen lines. (Fig.1) Observed variations cannot be a result of variations of the stellar luminosity, because the photometric variability of Pleione is less than 0.6 mag. This effect may be an evidence that the envelope was more develope in april and the profiles of the hydrogen lines were more distored.
4. The electron density, obtained for layers with different optical depths in december 1990 was equal to the value typical for main sequence stars with spectral type B8. In april 1990 the electron density in the Pleione atmosphere for layers with $\tau \approx 0.3$ was considerably smaller and corresponds to the value typical for supergigant of spectral type B8. This result can witness both about the change of the physical conditions in the Pleione atmosphere and the variation of the strenght of the envelope that leads to a change of the influence of the envelope to the profiles of the hydrogen lines.
5. No lines of the secondary component were discovered.

Detailed analyses of all published radial velocities measurements was carried out separately for hydrogen and for lines of metals. The observational data from the time interval 1938...1990 enable us to search for long term periodical variations of radial velocities. The radial velocities of the H lines show a larger scatter than metal lines. A number of lines show very negative values during the epochs 33000...34000 and 46000...47000. These intervals represent the shell phase of Pleione. Sich a scatter also occurs for several metal lines, esp. CaII and FeI. These data were not used for period search. Two methods for period determination were used:

1. Method of Lafler and Kinman
2. Fourier transformation.

The seach was carried out for period intervals 5000...15000 days (13.7...41 years). The best results were obtained for the metal lines because of the smaller scatter in the data. Both methods yielded almost the same results:

Lafler/Kinman	Fourier analysis
metal lines	
6411^d (17.6 yr)	6580^d (18 yr)
12450^d (34 yr)	12856^d (35yr)
H lines	
6500^d	4670^d
12400^d	11468^d

The calculated value of the orbital period of Pleione ($\approx$ 35yr) agree well with the variations of the spectral properties of the star (shell - non-shell phase). Our results agree well also with the conclusions published by Gies et al.(1990,AJ 100, 1601). In this work time resolved H_α spectroscopy was carried out during an occultation of Pleione by the moon. The observations concluded to an asymmetric envelope which is explained by a companion with $M = 2\ M_\odot$. During the periastron passage of the companion mass exchange by the primary star increases and a new shell phase begins. The semimajor axis was determined to a = 19.1 au, the excentricity by e = 0.46 and the inclination by $0^o < i < 43^o$.

For an exact determination of the orbital parameters more radial velocity measurements are necessary.

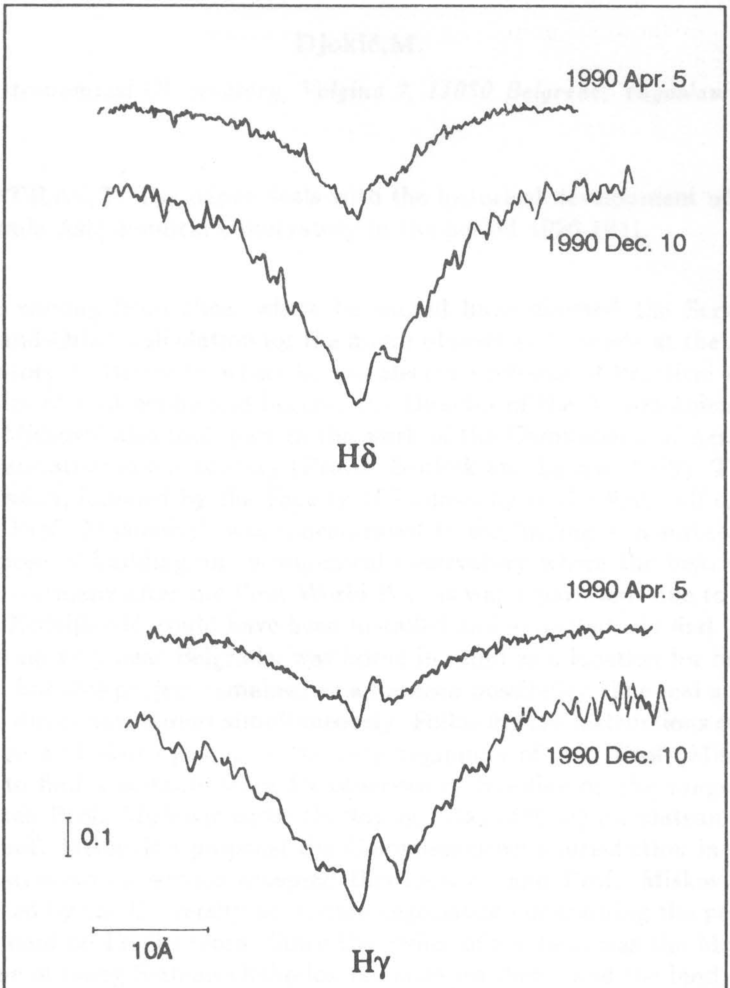

Fig 1: Variations of the profiles of the hydrogen lines $H\gamma$ and $H\delta$ in the spectrum of Pleione in 1990.

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THE ASTRONOMICAL OBSERVATORY OF THE BELGRADE UNIVERSITY BETWEEN 1926 AND 1941

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ABSTRACT: The paper deals with the historical development of the Belgrade Astronomical Observatory in the period 1926-1941.

After coming from Nice, where he should have directed the Service of the Ephemeris-and-Orbit Calculation for the minor planets and comets at the Astronomical Observatory, to Belgrade, where he was elected Professor of Practical Astronomy at the Faculty of Philosophy and became the Director of the Astronomical Observatory, Prof. Mišković also took part in the work of the Commission of Astronomical-Service Organisation in our country (Protić- Benišek and Djokić, 1989). The work of this Commission, founded by the Faculty of Philosophy in the first half of 1925 and directed by Prof. Milanković, was concentrated to the finding of a suitable location for the purpose of building an astronomical observatory where the instruments obtained from Germany after the First World War as war reparations due to the efforts of Prof. M. Nedeljković would have been installed and activated. At first Avala (511 m), a mountain very near Belgrade, was borne in mind as a location for building the observatory, but this project remained as a foreseen possibility. The real actions were going in two directions, almost simultaneously. Following the instructions of the Commission mentioned above passed in the very beginning of 1927 Prof. Mišković took some steps to find a suitable place for observatory building on the range of Fruška Gora. As such Prof. Mišković chose the top of Lišaj (490 m) on plateau Zmajevac. Following Prof. Mišković's proposal the Commission with jurisdiction in the organisation of astronomical service accepted this location and Prof. Mišković, himself, was authorised by the University to initiate negotiations concerning the possibility of leasing this land on Fruška Gora. Since the owner of the land was the Monastery of Rakovac (one of many Serbian Orthodox monasteries there) and the land, itself, had been already leased by the Mountaineer Society "Fruška Gora" from Novi Sad, it was necessary to get the assent of this Society for concessing the lease (Pakvor, 1989). A corresponding contract concerning this transaction, dated on July 17, 1927, was made between the Belgrade University and the Monastery of Rakovac but it remained unsigned by the contracting parties. The advantage of this location compared to that at which the Astronomical Observatory of Belgrade University would be finally built, according to the climatological data, is that it has about 25 clear days more a year and that the amplitude of annual variations in the air temperature is lower (Simić, 1954; Milosavljević et al., 1973).

According to the necessities in the teaching and in the general development of the Astronomical Observatory as an institution Prof. Mišković initiated an action for building a pavilion on the land which belonged to the Astronomical Observatory after the splitting of the old Observatory into the Astronomical and Meteorological ones in 1924. The work concerning the building of this pavilion with a dome of 6 m, in which the mounting of a Zeiss 200 mm refractor was foreseen, was given through a public auction, according to the Belgrade- Astronomical-Observatory archiv data, to engineer Siniša Švabić with a preliminary price of 97 000 dinars and it was finished in the following year (1928). On the same location two additional wooden pavilions were built: for the transit instrument of 100 mm and astrolab (Ševarlić and Arsenijević, 1989). With regard that the contract concerning the land lease on Fruška Gora for the purpose of building an astronomical obseravtory was not realised and that the space on the old location of the Astronomical Observatory was obviously insufficient to its progress, and especially that this insufficient space was menaced by the General Plan of City Development, a new contract was made on June 8, 1929 between the Borough of Belgrade and the University which foresaw that a land of 40 000 m2 on the Laudanov šanac (East Vračar) would be given to the University by the Borough, but followed by a condition that the land on West Vračar, used by that time by the Observatory, would be given back to the Borough on free disposition. In this connection one should consider the ruining of the 200 mm refractor pavilion in 1936 (Janković, 1984).

For the purpose of building the Astronomical Observatory on the new location was approved a State Bank credit of 9 557 000 dinars in total amount, to be payed during 25 years. Based on Prof. Mišković's drafts architect Jan Dubovi closely cooperating with him (the cooperation lasted 17 months) did the detailed plans according to which the Observatory was built. Following Prof. Mišković's proposal the authorised bodies established Dubovi's fee (comprising his part of the work) to 120 000 dinars.

After finishing the building the old observatory was left and the new one was moved in on July 1, 1932.

It is emphasized in the modern considerations concerning the building of the astronomical observatory that the effort of performing this task as qualitative as possible was evident. "The natural values of the terrain and the functional specifity were the initial advantage. The large location enabled to pay attention to each object and to include it into a urbanistic entirety." In these considerations one also finds for the main observatory building that "it, certainly, does the nucleus of this complex and all other objects are strongly directed to it." In the connection to this statement one should emphasize that the main building was the initial element from which the total complex should have been developed already in Prof. Miskovic's original draft. Its strict symmetry was especially expressed in the case of the main, southern, entrance to the building and "there is no element of the architectural tradition except the wide stairs and four simple columns but nevertheless your impression is as if you were entering a temple." The sentence on the frieze of the main building "Omnia in numero et mensura" has been said to, probably, in a way as brief as possible expess the value of the total Observatory Complex (Djurdjević, 1989). In this object, such as it is, the whole future activity of the Astronomical Observatory, as institution, would be developed. This activity within the time interval here borne in mind would occur uniformly but always followed by problems of financies and staff which as the initial problems, already from the time of the foundation of the Great-School Observatory, would remain to be present forever. The activity of the Astronomical Observatory in the period here considered involved many calculational, observational and editorial efforts and it was reduced by the events of war in early 1941 to see its restitution already in the early postwar period.

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Publ. Obs. Astron. Belgrade No. 44 (1993), 119–126

NIKOLA TESLA: THE MOON'S ROTATION

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ABSTRACT: The review of three articles by N. Tesla, published in the year 1919 in the journal *"Electrical experimenter"* is given, with special reference to the astronomical contents and to circumstances in which they appeared. We conclude that the famous experimenter Nikola Tesla was a serious theoretician, and popularizer, as well.

1. INTRODUCTION

Nikola Tesla, this great engineer – physicist died 5o years ago. Since his life's work has a lot of practically important inventions his three papers on the rotation of the Earth's Moon published in 1919, have fallen into oblivion. Because of their actuality up to our days we shall give extended excerpts of them. Yet, Tesla has had a more general, phylosophical approuch to the universe.

2. THE CONVICTION OF THE COSMICAL LINKAGE

N. Tesla published in *"New York Herald"* on October,12, 1919 the article **"Signals to Mars based on Hope of Life on Planet"**. There it is said: "The idea that other planet are inhabited by intelligent beings might be traced to the very beginnings of civilization. This, in itself, would have litlle significance, for many of the ancient beliefs had their origin in ignorance, fear or other motives - good or evil, and were nothing more than products of untrained or tortured imagination. But when a conviction lives through ages in the minds, growing stronger and stronger with increasing knowledge and intellectual development, it may be safely concluded that there is a solid truth, underlying the instinctive perception."

Indirectly, there are contained founds of Tesla's interest in astronomy manifested in the early ninetieths of the past century. Within the frames of wireless telegraphy investigations, Tesla had the idea of interplanetary communication. In the great polemics in the American press, after publication of P. Lowell's photos of Mars and Martian canals and of his papers on the possibility of life on Mars, Tesla advocated Lowell's opinion. Concretely, Tesla was on the side of those in the polemic, who belived, in principle, in the chance of the existence of the extraterrestrial inteligent life, and accordingly of the Martian life.

Prehistory of this position of Tesla can be found in his two scientific - phylosophical viewpoints:

(1) All living beings are automats, kept in motion by external impulses, and
(2) The matter contains no energy but the one got from outside.

In this, vertical line, lie the psyhophysical phenomena inadequately clean and somewhat shaded, living in depth of brain, as hallucinations, mental pictures and another, on which Tesla spoke. Looking for explanation of it, Tesla concluded that its origin lies in the surrounding objects and events, and their influence. Connecting this with Descarte's thesis on beings as automats, and developing it, arised viewpoint (1) quoted above.

This viewpoint, formed probably in his European days, has been the starting point for the explanation of phenomena and occurrences, arround and within himself.

A succesfull application of it up to events concerning Lowell, suggested him an extrapolation that some causes might not originate on the Earth. I.e.- they can be due to an extraterrestrial, cosmic, origin.

In 1899 in Colorado Springs Tesla experimented on 12 million volt emitting/recepting station, at that time only one on the Earth,s globe. Detecting a regular serie of pulses, in form 1, 2, 3... Tesla was inclined to the cosmical origine, to explain it.

The crossing of psyhological (out of time) verticale, with sociological (chronological) horizontale, gives just a point with events about P. Lowell. In this point the conception born in depth of soul appears at surface, changed the flow of affairs, not only forthcoming than preliminary, as well. How it heppend?

Old phenomena were seen in a new light. This is the millieu of Tesla's courageous claims. In there frames it is needed to see the articles about Moon's rotation, published in the journal *"The Electrical Experimenter"* in 1919. They are a story in cyclus of autobiographical essays (**"Famous Scientific Illusions"**, part I, February, 1919, p. 692-4) and two appendices challenged by the readers reactions in form of letters flow titled to Tesla and Hugo Gernsback, editor of journal, published separately but under the same title (**"The Moon's Rotation"**, issue of April, 1919, p. 866 and 892, and of June 1919, pp. 132, 133, 156, 157 and 160.). Note that H. Gernsback, engineer, and editor of **"The Electrical Experimenter"**, is the same H. Gernsback, the father of modern science-fiction literature. Engineer and fantast, spiritus movens of the movement for connection of fantasy and scientific facts. Would have they a better combination to express fully theirs sense and intentions ? We give a negative answer. The American public was very disturbced, the journal multiplied its tirage and readablity. On one side, this S.F. was born and another side Tesla gave detailed explanations of this opinion and knowledge about the Moon's rotation. These are his only papers talking on astronomy, precisely and directly.

3. THE MOON'S ROTATION

It is well known that the Moon shows always the same side to the Earth. The research work on the Moon's rotation was found the three laws, published by D. Cassini in 1693. We quote the first and second laws, which are concerned by Tesla's comments.

(1) The Moon revolve around the Earth, from west to east, about polar axis, with constant angular speed and period of rotation equal to the period of revolution about the Earth.

(2) The inclination of lunar equator to the ecliptic is constant.

How obtained these laws, it is unknown. But it can be proved that from all of possibles dynamical solutions, just this describes the motion with minimal losses of energy in the internal heating by friction. (Colombo, 1967) The dynamical interpretation of Cassini's laws is given by Lagrange in 1764 (Lagrange, 1780). He derived the theory of compulsory oscilations in the lunar rotation. If the primary period of rotation was different for the revolution period, after some time both give same values, because of terrestrial tidal action to the Moon.

The Moon's Rotation

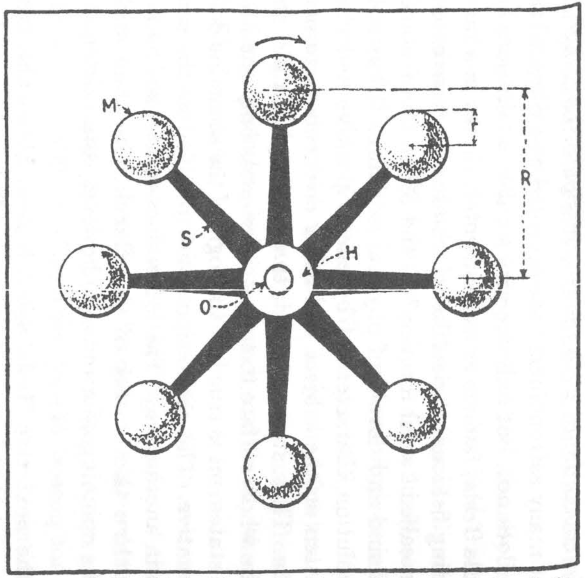
By NIKOLA TESLA

SINCE the appearance of my article entitled the "Famous Scientific Illusions" in your February issue, I have received a number of letters criticizing the views I exprest regarding the moon's "axial rotation." These have been partly answered by my statement to the *New York Tribune* of February 23, which allow me to quote:

In your issue of February 2, Mr. Charles E. Manierre, commenting upon my article in the *Electrical Experimenter* for February which appeared in the *Tribune* of January 26, suggests that I give a definition of axial rotation.

I intended to be explicit on this point as may be judged from the following quotation: "The unfailing test of the spinning of a mass is, however, the existence of *energy of motion*. The moon is not posest of such *vis viva*." By this I meant that "axial rotation" is not simply "rotation upon an axis nonchalantly defined in dictionaries, but is a circular motion in the true physical sense—that is, one in which half the product of the mass with the square of velocity is a definite and positive quantity. The moon is a nearly spherical body, of a radius of about 1,087.5 miles, from which I calculate its volume to be approximately 5,300,216,300 cubic miles. Since its mean density is 3.27, one cubic foot of material composing it weighs close on 205 lbs. Accord-

conclusions I have drawn. It is well known, of course, that the two bodies revolve around a common center of gravity, which is at a distance of a little over 2,899 miles from the earth's center.



If You Still Think That the Moon Rotates on Its Axis, Look at This Diagram and Follow Closely the Successive Positions Taken by One of the Balls M While It Is Rotated by a Spoke of the Wheel. Substitute Gravity for the Spoke and the Analogy Solves the Moon Rotation Riddle.

sling. In this case a *much more rapid* rotation is imparted to it in the *opposite sense*. There is no true analogy to these in the motion of the moon. *If the gravitational string, as it were, would snap, the satellite would go off in a tangent without the slightest swerving or rotation, for there is no moment about the axis and, consequently, no tendency whatever to spinning motion.*

Mr. Manierre is mistaken in his surmise as to what would happen if the earth were suddenly eliminated. Let us suppose that this would occur at the instant when the moon is in *opposition*. Then it would continue on its eliptical path around the sun, presenting to it steadily the face which was always exposed to the earth. If, on the other hand, the latter would disappear at the moment of *conjunction*, the moon would gradually swing around thru 180° and, after a number of oscillations, revolve, again with the same face to the sun. In either case there would be no periodic changes but eternal day and night, respectively, on the sides turned towards, and away from, the luminary.

Some of the arguments advanced by the correspondents are ingenious and not a few comical. None, however, are valid.

One of the writers imagines the earth in the center of a circular orbital plate, having fixedly attached

The lunar rotation at first glance appears as an elementary, but problem of classical mechanics, which was intensively examined in the past, it has not been fully solved. A simple form of the equations of motion can easily result in a confusion. (Moutsoulas, 1971) Other specialists for lunar motion have not come out from these frames. (Jakovkin, 1960).

What about the Moon's rotation where the subject of Nikola Tesla, a non - astronomer, in 1919 ?

In his first article (p. 692) Tesla said: "The greatest triumphs of man were those in which his mind had to free itself from the influence of delusive appearances." In the under - title: "1. The Illusion of the Axial Rotation of the Moon" (p. 693) Tesla is more concrete: "The spinning motion of a heavenly body must necesserily undergo modifications in the course of time, being either retarded by resistances internal or external, or accelerated owing to shrinkage and other causes. An unalterable rotational velocity thru all phases of planetary evolution is manifestly impossible. " This is fully in concordance with the conclussion of Lagrange, but not the next one:

"But many astronomers have accepted as a physical fact that such rotation takes place. It does not, but only appears so; it is an illusion, a most surprising one, too."

Nikola Tesla, famous as experimenter, thinks in a manner of physicist - theoretician, finding fishionably detailes which escaped from attention of others: "The truth is, the so called "axial rotation" of the Moon is a fenomenon deceptive alike to the eye and mind and devoid of physical meaning. It has nothing in common with real mass revolution characterized by effects positive and unmistakable. Volumes have been written on the subject and many erroneous arguments advanced in support of the notion. Thus, it is reasoned, that if the planet did not turn on its axis it would expose the whole surface to terrestrial view;as only one half is visible, it *must* revolve. The first statement is true but the logic of the second is defective, for it admits of only one alternative. The conclusion is not justified as the same appearance can also be produces in another way. The Moon does rotate, not on its own, **but about an axis passing thru the center of the Earth, the true and only one**. The unfailing test of the spinning of a mass is, however, the existence of energy of motion. The Moon is not possest of such *vis viva*."

At the next step Tesla asked himself about the intention of his discovery, in connection with the Moon's origin.: "Three theories have been advanced for the origin of the Moon. According to oldest, suggested by the... **Kant**, and developed by **Laplace..**, the planets have been thrown off from larger central masses by centrifugal force... Prof. **George H. Darwin** in an masterful essay on tidal friction furnished mathematical proofs, deemed unrefutable, that the Moon had separated from the Earth. Recently, his established theory has been attacked by Prof. **T. J. J. See** in a remarkable work on the *"Evolution of the Stellar Systems"*, in which he propounds the view that centrifugal force was altogether inadequate to bring about the separation and that all planets, including the Moon, have come from the depths of space and have been captured. Still a third hypothesis of unknown origin exists which has been examined and commented upon by Prof. **W. H. Pickering** in *"Popular astronomy of 1907"*, and according to which the Moon was torn from the Earth when the later was partially solidified, this accounting for the continents which might not have been formed otherwise. Undoubtedly planets and satellites have originated in both ways and, in my opinion, it is not difficult to ascertain the character of their birth. The following conclusions can be safely drawn:

1. A heavenly body thrown off from a larger one cannot rotate on its axis. The mass, rendered fluid by the combined action of heat and pressure, upon the reduction of the latter immediately stiffens, being at the same time deformed by gravitational pull. The shape becomes permanent upun cooling and solidification and the smaller mass continues to move about the larger one as the it were rigidly connected to it except for pendular swings or librations due to varying orbital velocity. Such motion precludes the possibility of axial rotation in the strictly physical sense. The Moon has never spun around as is well demonstrated by the fact that the most precise measurements have failed to show any measurable flattening in form.

2. If a planetary body in its orbital movement turns the same side towards the central mass this is a positive proof that it has been separated from the latter and is a true satelite.

3. A planet revolving on its axis in its passage around another cannot have been thrown off from the same but must have been captured."

As **arguments to Tesla's point of view** we quote further. Usually in further approximation the Moon has been assumed to be sphere. In the cited tractate, Lagrange demonstrated that the form of the Moon must be rotational ellipsoide with the largest axis orientated to the Earth. But, how been shown from analyses of determinations of the axis - amounts, triaxial ellipsoid as approximation gives noly better repressentation than the sphere model. (Podobed, Nesterov, 1978, p. 309). The "Lunar Orbitter" data give semi - axis which differs not more than 0.5 km.

How it can be occured, Tesla's article was provocation for many readers. As reaction and his answer to letters, Tesla has written second, and finally third article, with in detaile explanation of his opinions.

Here Tesla gave one correction, too. (April issue, p. 866): "I have stated in my article that the Moon rotates about an axis passing thru the center of the Earth, which is not strictly true, but it does not vitiate the conclusion I have drawn. It is well known, of course, that the two bodies revolve around a common center of gravity, which is at a distance of a litlle over 2899 miles from the Earth's center."

In details he explained the rotation (p. 866, April issue): "" Axial rotation" is not simply "rotation upon an axis nonchalantly defined in dictionaries, but is a circular motion in the true physical sense - that is, one in which half the product of the mass with the square of velocity is a definite and positive quantity."

At page 892. Tesla said:

"Even the well - known experiment with the Foucault pendulum, altho exhibiting similar phenomena as on our globe, would merely demonstrate a motion on the satelite about *some* axis. The view I have advanced is NOT BASED ON A THEORY but on facts *demonstrable by experiment.* It is not a matter of *definition* as some would have it. A MASS REVOLVING ON ITS AXIS MUST BE POSEST OF MOMENTUM. If it has none, there is no axial rotation, all appearances to the contrary notwithstanding."

His conception Tesla demonstrated in the mechanical models, writing:

"Consider first the case of two equal weights w and w_1, in Fig. 1. (Fig. 1) whirled about the center O on a string s as shown. Assuming the later to break at a both weights will fly off on tangents to their circles of gyration, and, being animated with different velocities, they will rotate around their common center of gravity *o*."... "The weights continue to rotate at the original rate and in the same direction. I know this to be a fact from actual experiments." Tesla showed it precisely mathematically in the third article. "The kinetic energy would then be equal to the sum of the energies of the translatory and axial motions, not merely in the abstract mathematical meaning, but as a physical fact."... "I shall first understake to demonstrate that there is no torque or rotary effort about center *C* and that the kinetic energy of the supposed axial rotation of the ball is mathematically equal to zero. This makes it necessary to consider the two halves separated by the tangential plane *pp* wholly independent from one another."... "These are the distance from center *O*, at which the masses of the half spheres may be concentrated and then the algebraic sum of their ewnergies - which are wholly translatory those of axial rotation being nil- will be exactly equal to the total kinetic energy of the ball as a unit." (The proof is correct derived, and we quote it not.)

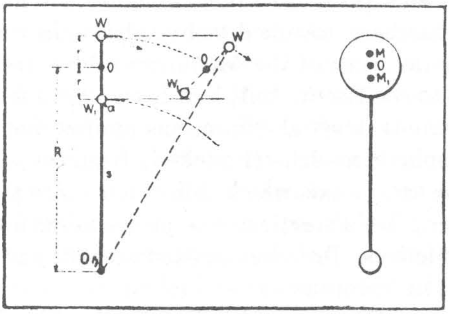


Diagram Illustrating the Rotation of Weights Thrown Off By Centrifugal Force.

The consideration was finished by the words: "It will be readily seen that if both strings are cut in the same instant the masses will fly off in tangents to their circular orbits, the angular movement becoming rectilinear without any transformation of energy occurring. Let us now inquire what will happen if the two masses are rigidly joined , the connection being assumed imponderable. *Here we come to the real bug in the question under discussion.* Evidently , so long as the whirling motion continues, and both the masses have precisely the same angular velocity, this connecting link will be of no effect whatever, not the slightest turning effort about the common center of gravity of the masses or tendency of equalization of energy between them will exist. The moment the strings are broken and they are thrown off they will begin to rotate but, as pointed out before, this motion neither adds to or detract from the energy stored. **The rotation is, however, not due to an exclusive virtue of angular motion, but to the fact that the tangential velocities of the masses or parts of the thrown off are different.**" (p. 156)

But, it is not the end of the story. Tesla showed the problem more generally. "Virtually all satellites rotate in like manner and the probability, that the acceleration or retardation of their axial motions - if they ever existed - should come to a stop precisely at a definite angular velocity, is infinitesimal while it is almost absolutely certain that all movement of this kind would ultimately cease. The most plausible view is that no true Moon has ever rotated on its axis, for at the time of its birth there must have been some deformation and displacement of its center of gravity thru the attractive force of the mother planet so as to make its peculiar position in space, relative to the latter, in which it persists irrespective of distance, more or less stable." (p. 157)

Here we can cite Savić's hypothesis about the origin of rotation of celestial bodies, developed in SK - theory (Savić, Kašanin, 1965, p. 70) giving the same results for the lunar rotation: "By studying the ionisation of various elements we reached the conclusion that the ionisation due to pressure can be brought about at the earliest moment during transition from phase 2 to phase 3... If, thus, a certain celestial body has not the phase 3 in its interior, because of its small mass, then it certainly does not have a magnetic moment... This is the case, for instance, with our Moon, since its mass is small for such a process... This is why the Moon has neither a magnetic moment nor a rotation of its own."

Tesla opposed the wide spreaded opinion **about the cause of optical libration in longitude**. "Referring to the librations of longitude I do not see that they have any bearing on this question. In astronomical treatises the axial rotation of the Moon is accepted as a material fact and it is thought that its angular velocity is constant while that of the orbital movement is not, this resulting in an apparent oscillation revealing more of its surface to our view. To a degree this may be true, but I hold that the mere change of orbital velocity, as will be ewident from what has been stated before could not produce these phenomena, for no matter how fast or slow the gyration, the position of the body relative to the center of attraction remains the same. The real cause of these axial displacements is the changing distance of the Moon from the Earth owing to which the tangential components of velocity of its parts are varied."... "The Moon actualy swings on the axis passing thru its center of gravity on which it is supported like a ball on a string. The forces involved in these pendular movements are incomparably smaller than those required to effect changes in orbital velocity." (p. 160)

This opinion we find in modern textbooks on general astronomy: "The libration on longitude can be geometrically interpreted as the consequence of uniform rotation about ITS axis and about variable velocity of revolution along the ellipse." (Podobed, Nesterov, 1975, p. 295). From the next cited text (on page 892, April issue): "From the character of motion of the satellite it may be concluded with certitude *that it is devoid of momentum about it's axis.* If it be bisected by a plane tangential to the orbit, the masses of the two halves are inversely as the distances of their centers of gravity from the Earth's center." (p. 892), we see that Tesla was very near to the conclusion that even nearly half of the Moon must be with higher mass than farther half. "Even after the calculation of the libration effects, it is not correct to assume that the mean position of the Moon's center is in fact the same as the centre of mass". (Podobed, Nesterov, p. 312) The existence of masscons under surface of lunar maria of the visible half is an argument in favour of the said before.

Our attention is devoted to the astronomical contents in Tesla's articles. But, these texts are very interesting from the view point of models used in explanation, with applied well-known physical laws. It is a theme for separate analysis, pedagogical and methodological.

From all, it follows that famous experimenter, Nikola Tesla was a serious theoretician, methodicist too, which well marked the peculiarities, where are invisible to other explorers. For the end of the story we quote the words of H. Gernsback, editor of "Electrical Experimenter": **"Dr Tesla explains... in a masterly way, so that everyone can understand them"**. (p. 692.)

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MORPHOLOGY OF THE GALACTIC DISC

Jelena Milogradov-Turin
Institute of Astronomy, Mathematical Faculty, University of Beograd
Studentski Trg 16, 11000 Beograd, p.f. 550

A review of recent results in radio astronomy, UV astronomy and optical astronomy, including the author's radio spectral indices work, related to the morhology of the Galaxy, is presented. It is shown that the galactic disc, apart from spiral structure, is dominated by bubbles, superbubbles and other remnants of violent events. Many important features of the local surrounding can be relatively simply explained by the hypothesis about near violent explosions.

Introductory lecture

CALCULATION OF STARK BROADENING PARAMETERS FOR STELLAR PLASMA INVESTIGATION

Dimitrijević, M. S.
Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia

Here is presented a review of semiclassical calculations of Stark broadening parameters and comparison of different semiclassical procedures is discussed, as well as the agreement with critically selected experimental data and more sophysticated, close coupling calculations. Approximate methods for the calculation of Stark broadening parameters, usefull especially in such astrophysical problems where large scale calculations and analyses must be performed and where a good average accuracy is expected, have also been discussed.

REGULATION OF HUMIDITY IN THE ATOMIC CLOCK ROOM OF THE BELGRADE OBSERVATORY

Grujić,R. , Damljanović,G.
Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia

On the basis of the collected data on the water elimination from the atomic clock room (the third cellar) of the administrative building of the Belgrade Astronomical Observatory with the instrument (Hygromatik), the examination of the changes of the eliminated water, temperature and humidity is performed during 1990.1-1993.0 . The interdependence of the amount of the eliminated water, temperature and humidity is derived. These examinations show that the instrument made possible the regulation of humidity keeping the constant level of temperature.

TOTAL SUNSPOT AREA AND THE SAVA RIVER FLOW, I

Jovanović, B. D.

Faculty of Agriculture, University of Novi Sad, Novi Sad, Yugoslavia

Spectral decomposition theorem has been applied in searching the solar activity influence on the Sava river flow at a station. The seven year lag has been found for maximum river flow.

ON THE SWIMMING OUT OF THE SOLAR MAGNETIC TUBES

Tomić[1] A. and Vince[2] I.

[1] *People's Observatory, Kalemegdan, 11000 Belgrade*
[2] *Astronomical Observatory, Volgina 7, 11000 Belgrade*

The classical analogy of Coulumb-interaction of the magnetic dipoles is applied to the solar global magnetic field and its magnetic tubes, in the context of Savić and Kašanin theoretical model of solar interior. Thence it follows that this mechanizm of interaction can originate the swimming out of the magnetic tubes in qualitative satisfactory manner according to observational data.

AN ANALYSIS OF CLOSE BINARIES (CB) BASED ON PHOTOMETRIC MEASUREMENTS

An Interpretation of CB Light Curve RX Cas by using the Inverse-Problem Method

G. Djuraševič

Astronomical Observatory, Volgina 7, 11050 Belgrade, Yugoslavia

The author considers the current problematics in the determination of the orbital and physical parameters for active close binaries (CB) of W Ser type based on the interpretation of photometric observations. One solves the problem in two stages: by obtaining a synthetic light curve in the case when the parameters of the corresponding CB model are given a priori (direct problem) and by determining the parameters of the given model for which the best fit between the synthetic light curve and the observations is achieved (inverse problem). In the particular case one analyses the light curves of CB RX Cas in the framework of the accretion-disc model. The change of the light curves with the system's physical-activity phase is analysed and the orbital and physical parameters of the system are determined for the maximum, minimum and the transition regime of the physical activity by applying the inverse-problem method.

AUTHOR INDEX

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ПРОГРАМ X НАЦИОНАЛНЕ КОНФЕРЕНЦИЈЕ ЈУГОСЛОВЕНСКИХ АСТРОНОМА

PROGRAMME OF THE X NATIONAL CONFERENCE OF YUGOSLAV ASTRONOMERS

Belgrade, September 22 – 24, 1993

***

среда, 22. 9. 1993.

9^{00} Свечано отварање

– Поздравни говор савезног министра за науку, технологију и развој *Др Милана Димитријевића*

– Поздравни говор представника главног спонзора, директора за велепродају БИП-а, *Шејић Милана*

9^{30} Пауза уз послужење

УВОДНА ПРЕДАВАЊА

INTRODUCTORY LECTURES

10^{00} М. Карабин:
ОСЦИЛАЦИЈЕ И ТАЛАСИ НА СУНЦУ И ЗВЕЗДАМА
OSCILLATIONS AND WAVES IN THE SUN AND STARS

11^{00} З. Кнежевић:
СОПСТВЕНИ ЕЛЕМЕНТИ МАЛИХ ПЛАНЕТА: ТЕОРИЈА И ПРАКСА
MINOR PLANETS' PROPER ELEMENTS: THEORY AND PRACTICE

12^{00} – 12^{30} *Пауза*

САОПШТЕЊА

CONTRIBUTED PAPERS

12^{30} Ј. Лазовић:
ПРИБЛИЖНЕ ВРЕДНОСТИ ЕКСЦЕНТРИЧНИХ АНОМАЛИЈА ПРОКСИМИТЕТА
THE APPROXIMATE VALUES OF ECCENTRIC ANOMALIES OF PROXIMITY

12^{45} З. Ћатовић:
О ЈЕДНОМ ТИПУ ОГРАНИЧЕНОГ ПРОБЛЕМА ТРИ ТЕЛА
ON THE ONE TYPE OF THE RESTRICTED THREE BODY PROBLEM

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