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УСПЕХИ ФИЗИЧЕСКИХ НАУК

КОНФЕРЕНЦИИ И СИМПОЗИУМЫ

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27 Ñ˝Õâ^Óâ 2010 ¯. ˜ ˝Ñ–×˙Ó˙–Ù-°´ ˙ ¶¸°¸Ú˙Ô˝Ñ¯Ñ ¸–ÔÕ¸-ÕÖÕ´¸˘. –.fl. ›˙^˙˘˙˜´ †ÑÔÔ¸ÌÔ˝ÑÌ ´˝´˘˙˘ ¸¸–´Õ˝ (†¡fl) ÔÑÔÕÑâ¸´ÔßÚ–´â Ô˙ÔÕ¸â °Õ˘˙¸˙–¸â ×¸°¸Ú˙Ô˝¸Ø –´Õ˝ †ÑÔÔ¸ÌÔ˝ÑÌ ´˝´˘˙˘ ¸¸ –´Õ˝ †¡fl, ÒÑÔ˜âÜ¨—´â Ò´˘âÕ¸ £.›./¸–°^ÖÓ¯´.

°^Ýâ˜¸˙—´â–´ web-Ô´ÌÕ˙ °¶fl †¡fl www.gpad.ac.ru ÒÑ˜˙ÔÕ˝´ °´Ô˙˘´–¸â ÔÑ˘˙ÓÉ´¸´ Ô¸˙˘ÖÆÜ¸˙˘Ñ˝¸´˘Þ:

1. **Месяц Г.А.** (¶¸°¸Ú˙Ô˝¸Ì ¸–ÔÕ¸ÕÖÕ ¸˘. –.fl. ›˙^˙-˘˙˜´ †¡fl, fiÑÔ˝˜´). *Вступительное слово.*

2. **Рубаков В.А.** ("–ÔÕ¸ÕÖÕ â˘˙Ó–ÞØ ¸ÔÔ¸˙˘Ñ˜´–¸Ì †¡fl, fiÑÔ˝˜´). *Космология и Большой адронный коллайдер.*

3. **Гуревич А.В.** (¶¸°¸Ú˙Ô˝¸Ì ¸–ÔÕ¸ÕÖÕ ¸˘. –.fl. ›˙^˙-˘˙˜´ †¡fl, fiÑÔ˝˜´), **Зелёный Л.М.** ("–ÔÕ¸ÕÖÕ ˝ÑÔ˘¸Ú˙Ô-˝¸Ø ¸ÔÔ¸˙˘Ñ˜´–¸Ì †¡fl, fiÑÔ˝˜´). *Интенсивные гамма-всплески в атмосфере Земли (TGE) и миссия "Чибис".*

4. **Васильев М.А.** (¶¸°¸Ú˙Ô˝¸Ì ¸–ÔÕ¸ÕÖÕ ¸˘. –.fl. ›˙-^˙˘˙˜´ †¡fl, fiÑÔ˝˜´). *Теория высших спинов.*

5. **Максимов Е.Г.** (¶¸°¸Ú˙Ô˝¸Ì ¸–ÔÕ¸ÕÖÕ ¸˘. –.fl. ›˙-^˙˘˙˜´ †¡fl, fiÑÔ˝˜´). *Что известно и что неизвестно о ВТСП.*

6. **Пудалов В.М.** (¶¸°¸Ú˙Ô˝¸Ì ¸–ÔÕ¸ÕÖÕ ¸˘. –.fl. ›˙-^˙˘˙˜´ †¡fl, fiÑÔ˝˜´, fiÑÔ˝Ñ˜Ô˝¸Ì ×¸°¸˝Ñ-Õ˙Ø–¸Ú˙Ô˝¸Ì ¸–ÔÕ¸Õ, fiÑÔ˝˜´). *В.Л. Гинзбург и развитие в ФИАНе экспериментальных работ по высокотемпературной сверхпроводимости: "железные сверхпроводники".*

‡Õ´Õß¸, –´Ò¸Ô´—Þ˙ –´ ÑÔ–Ñ˜˙ ˘Ñ˝¸´˘Ñ˜ 2, 4, 6, ÒÖ^¸¸˝ÖÆÕÔâ–¸É˙.

£Ô¸¸Ö Óâ˘´ ÒÓ¸Ú¸– ›.–. –¸Õ´˙˜Ô˝¸Ì –˙ Ô˘Ñ¯ÒÓ¸ÔÖÕ-ÔÕ˜Ñ˜´ÕÕß –´ Ô˙ÔÔ¸¸, Ñ˜–´˝Ñ ÒÓ´˘ÔÕ´˜¸¸ ÔÕ´ÕßÆ, ÒÑÔ˜â-Ü¨—ÖÆÒ´˘âÕ¸ £.›./¸–°^ÖÓ¯´, ˝ÑÕÑÓÖÆ ˘Þ ÒÖ^¸¸˝Ö˙˘ ˜ àÕÑ˘ É˙–Ñ˘˙Ó˙ –´Ô. 647.

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Космология и Большой адронный коллайдер

£.¡. †Ö^´˝Ñ˜

1. Введение

fl´Ú´¸Ñ Ó´^ÑÕÞ ¢Ñ¸ßÛÑ¯Ñ´˘ÓÑ—Ñ¯Ñ ˝Ñ¸¸´Ì˘˙Ó´ (LHC) ì ˜´É–˙ÌÛ˙˙ ÔÑ^ÞÕ¸˙ –˙ ÕÑ¸ß˝Ñ˘¸â ×¸°¸˝¸ à¸˙˘˙–Õ´Ó-–ÞØ Ú´ÔÕ¸Ù, –Ñ¸ ˘¸â ˝ÑÔ˘Ñ¸Ñ¯¸. £Ô˙¸˙—´â ÒÑ¸–´ °´¯´˘Ñ˝. £–˙Ì ÓÑ˘˙ÓÉ¸ÕÔâ˜˙Ü˙ÔÕ˜Ñ¸–˙Õ´–Õ¸˜˙Ü˙ÔÕ˜´, ¸ÒÖÖÔÕâ 40 ¸˙Õ ÒÑÔ¸˙ ÑÔÑ°–´–¸â ÕÑ¯Ñ, ÚÕÑ àÕÑÕ ×´˝Õ ÒÓ˙˘ÔÕ´˜¸â˙Ô ÔÑ^ÑÌ –˙ÕÓ¸˜¸´¸ß–ÖÆ ÒÓÑ^¸˙˘Ö, ˙¯Ñ Ñ˘–Ñ-°–´Ú–Ñ˙ Ñ^ÝâÔ–˙–¸˙ ÒÑ-ÒÓ˙É–˙˘ÖÑÔÔÖÕÔÕ˜Ö˙Õ. £Ñ £Ô˙¸˙—–ÑÌ ¸˘˙˙ÕÔâÕ¨˘˙–´â ˘´Õ˙Ó¸â, ¸ÒÑ˝´ –˙ ¸°˜˙ÔÕ–Ñ, ¸°˝´˝¸Ø Ú´ÔÕ¸Ù Ñ–´ ÔÑÔÕÑ¸Õ. ƒÕß ¸Õ˘˙–´â à–˙Ó¯¸â, ¸˙¨ÒÓ¸ÓÑ˘´ ÕÑÉ˙ –˙ ¸°˜˙ÔÕ–´. "˘˙ÆÕÔâ Ô´ÓßÖ°–Þ˙ ÑÔ–Ñ˜´–¸â –´˘˙â-ßßÔâ –´ ÕÑ, ÚÕÑ LHC ÒÓÑ¸ß¨Õ Ô˜˙Õ –´ –˙˝ÑÕÑÓÞ˙ ¸° àÕ¸Ø ÒÓÑ^¸˙˘, °´–¸˘´ÆÜ¸Ø ˜´É–Ñ˙ ˘˙ÔÕÑ ˜ °–´˘˙–¸ÕÑ˘ ÔÕ¸Ô˝˙ £.›./¸–°^ÖÓ¯´.

–Ó¸Ö˘´Ú–Ñ˘ Ó´°˜¸Õ¸ ÔÑ^ÞÕ¸Ì ˜ à˝ÔÒ˙Ó¸˘´–Õ´Ø –´ LHC ^Ö˘ÖÕ ÑÕ˝ÓÞÕÞ Ú´ÕÕ¸ÙÞ Õ¨˘–ÑÌ ˘´Õ˙Ó¸¸ ¸Ø Ò´ÓÕ–¨ÓÞ ì ˘ÓÖ¯¸˙ –Ñ˜Þ˙ Ú´ÔÕ¸ÙÞ, ^Ö˘´Õ ˜ÞâÔ–˙–Ñ, ˝´˝´â ×¸°¸˝´ ÔÕÑ¸Ô °´ ´Ô¸˘˘˙ÕÓ¸Ì ˘˙É˘Ö ˜˙Ü˙ÔÕ˜Ñ˘ ¸´–Õ¸˜˙Ü˙ÔÕ˜Ñ˘. £ ÒÓÑÕ¸˜–Ñ˘ Ô¸ÖÚ´˙ ^Ö˘ÖÕ ÑÕ˜˙Ó¯–ÖÕÞ ˘–Ñ¯¸˙ ÒÑÒÖ¸âÓ–Þ˙ ¸ ÒÓ´˜˘ÑÒÑ^Ñ˜–Þ˙ ¯¸ÒÑÕ˙°Þ, ÚÕÑ ÕÑÉ˙ ÔÕ´–˙Õ ÔÖÜ˙ÔÕ˜˙—Þ˘ Û´¯Ñ˘ ˜ Ó´°˜¸Õ¸¸ ÒÓ˙˘ÔÕ´˜¸˙–¸Ì Ñ Ó´—˙Ì £Ô˙¸˙—ÑÌ.

ƒÕß¸ ¯ÑÓ´°˘Ñ ^Ñ¸˙˙ à˝°ÑÕ¸Ú˙Ô˝¸˙ ÒÓ˙˘ÒÑ¸ÑÉ˙–¸â Ñ ˜Ñ°˘ÑÉ–ÑÌ ×¸°¸˝˙ °´ ÒÓ˙˘˙ ´˘¸ ‡Õ´–˙´ÓÕ–ÑÌ ˘Ñ˙ Õ´˝¸˙ ˝´˝´ ¯Ó´˜¸Õ´Ù¸â Ô ×Ö–˘´˘˙–Õ´¸ß–Þ˘ ˘´ÔÜÕ´^Ñ˘ à–˙Ó¯¸Ì ˜ ·à£-Ñ^¸´ÕÕ¸; ¸Ø ÒÑ˘Õ˜˙ÓÉ˘´–¸˙ –´ LHC ^Ö˘˙Õ ¸˘˙Õß Õ´˝Ñ˙ °–´Ú´–¸˙ ˘¸â ˝ÑÔ˘Ñ¸Ñ¯¸¸, ´ÑÕÑÓÑ˙ ÕÓÖ˘–Ñ Ò˙Ó´ÑÙ˙–¸Õß.

'˘´Ôß ˘Þ Ñ^ÔÖ˘¸˘ –˙´˝ÑÕÑÓÞ˙ ÒÓ¸˘´ÓÞ, ¸¸¸ÆÕÕÓ¸-ÓÖÆÜ¸˙ ÒÑÕ˙–Ù¸´¸ LHC Ô ÕÑÚ˝¸ °Ó´–¸â ˝ÑÕ˘Ñ¸Ñ¯¸¸. fiÞ Ñ^Ó´Õ¸˘Ôâ Ô–´Ú´¸´˝Õ˘˙–ÑÌ ˘´Õ´Ó¸¸ Ó´ÔÕ˘ÑÕÓ¸˘ ÔÙ´–´Ó¸Ì ÔÑ Ô¸´^Ñ˜°´¸˘Ñ˘˙ÌÔÕ˜ÖÆÜ¸˘¸ ¸ ˘´ÔÕ¸˜–Þ˘¸ Ú´ÕÕ¸Ù´˘¸ (Weakly Interacting Massive Particle, WIMP),

В.А. Рубаков. "–ÔÕ¸ÕÖÕ â˘˙Ó–ÞØ ¸ÔÔ¸˙˘Ñ˜´–¸Ì †¡fl, fiÑÔ˝˜´, †¶
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[illegible] LHC, [illegible] 100 [illegible] LHC.

[illegible] [1] [illegible] [2–7]. [illegible] [8–11]. [illegible] [12–15].

[illegible] ρ_c [illegible]

$$\rho_c \simeq 5 \cdot 10^{-6}\ \text{GeV/sm}^{-3}.$$

[illegible] $\Omega_i = \rho_{i;0}/\rho_c$, [illegible] $\rho_{i;0}$ [illegible] ρ_c [illegible] 2% [16]). [illegible] $\Omega_i = 1$, [illegible] $T_0 = 2{,}726$ K, [illegible] $n_g = 410$ sm^{-3}, [illegible] $\eta_{g;0} = 2{,}7 \cdot 10^{-10}$ [illegible]

$$s = \frac{2\pi^2}{45} g_* T^3; \qquad (1)$$

[illegible] g_* [illegible] $m \ll T$, [illegible] 7/8). [illegible]

$$s_0 \approx 3000\ \text{sm}^{-3}. \qquad (2)$$

[illegible]

$$\eta \equiv \frac{n_B}{n_g} \approx 6 \cdot 10^{-10}. \qquad (3)$$

[illegible]

$$\rho_{B;0} = m_B n_{B;0} \approx 2{,}5 \cdot 10^{-7}\ \text{GeV/sm}^{-3}; \qquad (4)$$

[illegible]

$$\Omega_B \approx 0{,}045.$$

[illegible] $n_{n_a} = 115$ sm^{-3}, [illegible] $n_a = n_e, n_m, n_t$. [illegible] $m_{n_e} < 2{,}6$ eV, [illegible] 2,6 eV [illegible] 0,05 eV [illegible] (!). [illegible] ρ_c:

$$\rho_n^{total} = \sum_a m_{n_a} n_{n_a} \approx 8 \cdot 10^{-7}\ \text{GeV/sm}^{-3},$$

[illegible] $\Omega_n^{total} < 0{,}16$. [illegible]

$$\Omega_n^{total} \approx 0{,}014. \qquad (5)$$

[illegible] (5) [illegible] [17–19]: $m_{n_a} \approx 0{,}6$ eV, [illegible] 0,2 eV. [illegible] K2K (From KEK-to-Kamioka — Long Baseline Neutrino Oscillation Experiment) [illegible] MINOS (Main Injector Neutrino Oscillation Search) [illegible] 0,05 eV. [illegible] (!).

[illegible]

2.

$$\Omega_{DM} \simeq 0.23; \qquad (6)$$

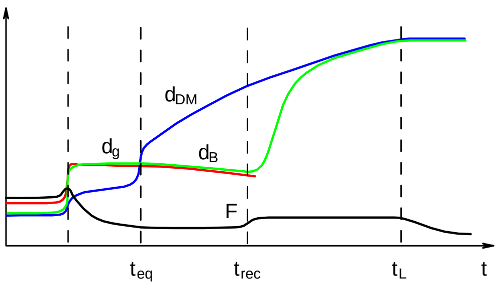
$$\left(\frac{\rho_{DM}}{s}\right)_0 \simeq \frac{\Omega_{DM}\,\rho_c}{s_0} \simeq \frac{0.23 \cdot 5 \cdot 10^{-6}\ \text{GeV cm}^{-3}}{3000\ \text{cm}^{-3}} \simeq 4 \cdot 10^{-10}\ \text{GeV}. \qquad (7)$$

$$\frac{a(t_0)}{a(t_{rec})} \simeq 1 + z_{rec} \simeq \frac{T_{rec}}{T_0} \simeq 10^3; \qquad (8)$$

---

[1] ... 10% ...

[2] ...



²ÈÔÖÐÑÎ.©ÂÄËÔÈÏÑÒÒÑÕÄÓÇÇÐÈ (Ä ÏÈÐÇÈÐÑÌ ÕÇÑÓÈËÈÑÐÕÓÂÔÕÂ ÒÑÕÐÂÔÕÒËÈÏÑÌ ÏÂÕÇÓÈËÈ ÂÓÈËÑÐÑÄ ×ÑÕÐÑÔÕÈ d_{DM} $d r_{DM} = r_{DM}$, d_B È d_g, ÂÕÂÍÉÇ ÐÑÐÑÔÕÑÐÑÄÂÑÕÇÐÈËÈ F Ä £ÓÇÏÇÐÈ. t_{eq} È t_L ÕÑÑÕÄÇÕ-ÔÕÄÖáÕÇÓÇÏ ÑÆÈÐÂÐÈÕÓÂÆÈÂÏÈÔÑÐÈÑÐÑ-ÆÈÐÈÑÂÐÑÂÄÈÐÂÆÂÐÑÂÑÐÍá-ÙÈÈËÔÇÏÇÐÐÑÌ ÔÕÂÆÈÈ ÈÑÐÈËÈÏÈÕÑÂÐÑÄÇÓÇÑÂÕÈËÑÐ ÕÂÕÓÇÑÈÈ ÑÕÊÂÏÇÑÇÐÐÑÌ ÏÂÕÇÓÈÈ Ä ÖÕÑÏÑÇÐ; t_{rec} ÕÑÐÑÒÈÂÑ âÕÑØÇ ÓÇÍÑÏÃÈÐÂÈÈ.

ËÈÐÂÚÂÎßÐÈÑ ÇÎÔâ ËÈÃÂÞÕÑÎ ÒÑÕÐÑÔÕÈ ÈÈÐÑÌ ÏÂÕÇÓÈË. ²ÂËÂÄÕÈÇÏÑÔÈÐÖÙÇÐÈ ÄÐÂÛÌ ÇÔÇÏÇÐÐÑÓÐØÇÏÂÕÈÚÇÔÍÑÌ ÒÑÍÂÊÂÐÑ ÐÂ ÓÈÕÖÐÍÇ 3 ÔÑÅÙÑÔÕÂÐÏÂÍÑÏ ÏÇÕÇÐÈËÈ ÓÂÃÑÕÂ, ÐÑÍÈÏÂÕÕÇÓÈÇ ÐÂÊÑÓÃ ÇÔÍ ÔÑÐÑÍÑÍÈÈ ÏÂÐÇÐÐÈÈ ÍÑÓÐÑÑÍÈÇ ÚÂÔÕÈÙ ÐÎÑÕÇÂáÕÂÈ ÊÎÂÑÄÂÎÈ ÂÆÈÕÈ ÐÑÏ ÐÖÕÇ ÕÑÂÖÈ ÏÇÍÑÕÑÐÑ, ÄÚÂÔÕÐÑÔÕÈ ÈÂÆÐÔÕÈ ÐÑÊÐ ÖÕÑÏ ÑÍ ÚÂÔÕÈÙ ÑÕÕÑÐÑÇÏÐÑ ÓÂÔÔÏÑÕÓÈÏ ÈÚÇÎÈÏ ÏÂÕÇÓÈË. ÕáÆÂ Ä ÍÑÐÇÚÐÑÔÕÈ ÐÂÕÑÏÈ ÊÇÕÐÂÅÈ ÒÑÐÓÇÈÚÇÐÈÂ (6)–(5).

£ ÊÂÄÈÔÈÏÑÔÕÈ ÑÕ ÒÑÕÂÔÕÈ ÚÂÔÕÈÙ ÍÑÐÇÚÑÏ ÏÂÕÇÓÈË ÏÇÐÐÑ ÔÏÈÇÄÂÊÓÂÙÇÐÈÈ ÇÔÇÏÑÐÂÍÇÏÇÐÐÑÌ, ÈÕÂÖÄ ÏÂÕÇÓÈËÍÑ ÇÔÐÑÎÎÑ ÕÂÍÈÕÄÄÕÇÐÑÐ (CDM ì Cold Dark Matter) ÈÎÈ ÕÈÏÍÑÌ (WDM ì Warm Dark Matter). ¦ÔÎÈ ÚÂÔÕÈÙÈ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ ÏÇÂÏÈÐÑÕÔÔÐÑ ÒÑÒÂÄÐ-ÄÇÕÇÐÇÎÂÏÎ ÍÑÕÑÔÕÑÐÂ ÔÍÍÐÑÑÏ ÐÂÔÂÐÑÐ ÕÑÂÆÈÈ ÏÂÔÐÑÎÏÈÈ £ÑÕÇÐÐÑÌ, ÑÐ ÎÂÔÕÈÊÓÈÊÈÔÎÈÍÐÑÈÕÑÇÏÈÍÑ ÎÑÕÍÑÔÕÑÐÈ ÃÑÎÈ ÃÑÐÂÐÑ ÍÍÑ ÏÈÐÈÏÖÏÐÖÏÂÔÔÈ ÒÑÐÄÏÇÐÈÇÏ ÐÂÔÕÑÏÚÇÔÕÄÐ

$$m_{DM} \gtrsim 100\ \text{keV} \quad \text{dlq} \quad \text{CDM}\,; \tag{9}$$

$$m_{DM} \lesssim 100\ \text{keV} \quad \text{dlq} \quad \text{WDM}\,. \tag{10}$$

®Þ ÑÂÕÐÈÈ ÕÈÒÏÔÕÑÌ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ ÏÍ ÑÐÈÆÂÄÓÂ ÇÐÐÑÏ ÑÂÔÂÔÕÈÈ ÑÍ ØÑÎÑÆÐÑÌ.

2.1. WIMP: ÐÂÈËÄÑÎÇÇ ÒÓÂÄÂÆÑÏÑÇÑÃÑÔÇÄÍ ÓÂÕÆÑ

³ÖÇÔÕÄÖÇÕ ÕÓÑÔÕÑÌ ÏÇÕÑÆÐÑÌ ÏÂÕÇÓÈË ÑÐÇÔÕÈ ÐÂÔÕÈÙÈ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ Ä ÓÂÏÍÂÕ ÓÂÐÐÇÌ, ÍÑÕÑÓÑÐÑÕÐÑÔÕÈ Ä ØÑÎÑÆÐÑÌ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ ¢ÑÂÅÑÆÍÂÑÂÍÄÑÐ ÒÓÑÔÕÑ ÔÈ ÒÓÇÆÕÑÎÂÊÂÕÈ-ÄÂÎÐÑÌ ÂÔÔÈÍÑÃÑÌÑ ÑÐ ÃÑÍ Ç ÂÏÐÑ Ï ÒÇÔÇÐÈÈ ÐÓÇÔÍÑÂÄÎÂ ÂÄÐÑÃ ÄÑÍ Â ÒÓÂÄÆÑÔÕÐÑ, ÂÔÑÔÕÄÇÕÄÇÔÕÄÖáÙÈÏÂÊÈÏÇÔÂÄÑÔÕß ÚÂÔÕÈÙÈ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ ì ÏÑÃÂÔÍÇÏÈÏÑÇÕÈ ÄÖÙÂÎÂÏÏÍÂ Ï ÂÐÎÈÐÂÐÂ ÚÂÔÕÈÙÂ, WIMP, ì ÄÞÂÏ ÂÆÈÕ ÐÂÍÎ ÑÙÇÏÍÈ ÍÂÐÆÈÆÂÕÑÏ ÏÈÇÐÇ ÄÑÐÑÏÐÇÐÈÈÍÑ ÔÙÇÌÕÕÇÂ.

±ÓÇÆÒÑÎÑÆÈÏ, ÚÕÑ ÔÖÙÇÔÕÄÖÇÕ ÕÇÏÈÂÄÕÑÂÃÈÎßÐÂ ÐÇÕÑÔÕÂßÐÂÚÂÔÕÈÙÂ ËÚÕÑ Y-ÚÂÔÕÈÙÈ ÐÂÔÏÕÑÍÔÍÂÕÇÌ È ÕÐÈÚÕÑÐÂÎßÐÑÏ ÕÂÔÕÂÆÈÈ, ÕÓÇÚÕÈÍÕÑÄÂÎÈ ÕÂÓÐÑÌ ÂÐÐÈÆÂÎßÚÈÈ ÔÑÍÂÕ ÚÂÔÕÈÙÞÕÂÐÆÂÐÑÌ ÏÑÆÇÎÈ. ¦ÔÎÈ ÕÇÚÇÐÈÇ ÂÐÐÈÆÂÎßÚÈÈ ÐÂÕÑÇÕÔÑÍÕÍÐÑÇÐÈ, ÕÑÕÐÂÆÆÇÐÈÇÔ ÑÐÑÎÈ ÓÂÐÐÇÌ ÏÇÕÑÆÐÑÌ ÍÑÕÍÂÏÈ ÕÇÏÐÑÌ ÑÏÇÆÖÂ-ÙÈÏ ØÂÕÂÐÑÍÔÈÐÑ ÄÞÔÈ ÌØ ÒÇÏÐÇÓÂÕÖÓÂÕÖÓÂ T ≈ m_Y, Y-ÚÂÔÕÈÙÞ ÐÂØÑÆÈÂÕÔÑ ÄÐÔÍÑÎÇÐÑ ÏÑÆÔÐÂÔÎÂÄÈÇ ÍÐÑÔÂÖßÐÑÌ ÒÑÎÍÑÌ, ÍÑÕÑÓÑÇ ÑÕÓÇÔÑÍ ÇÐÐÇÐÈÇ ÑÂÐÅ Y-ÚÂÔÕÈÙ, ÍÑÕÑÓÑÞ ÇÖÕÈÕ ÓÑÐÂ ÐÂÔÍÂÄÂÕÔÐ ÂÔÕÖÕÈÚÕÑÍÂÕÑÐÂÔÊÂ ÕÇÏÒÇÓÂÕÖÓÂ Õ ÆÑÊÂÊÊÐÑ m_Y, ÑÂÄÂÓÂÐÑÔÕÐÑ ÐÑÔÕÓÑÔÕß ÚÈÔÎÂ Y-ÚÂÔÕÈÙ ÕÞÄÂÎÐÑ.±ÓÈ ÐÇÍÑÕÑÓÑÌ ÕÇÏÒÇÓÂÕÖÓÇ

ÊÂÍÂÐÎÈ T_f ÒÑÔÕÐÑÔÕÈ ÚÈÔÎÂ Y-ÚÂÔÕÈÙ ÕÕÂÐÑÄÈËÔÑ ÔÕÑÔÎßÍÑÎÂÍÂ, ÚÕÑ ÑÐÈÐÔÎßÐÇ ÐÇÄÂÔÕÓÚÂÕÆÂ ÓÈËÔÂ ÆÖÔÕÎÈ ÕÇÏÒÇÓÂÕÖÓÞ ÇÔÕÇ ÆÈÐÄÂÌÈ ÕÇÓÂ ÐÐÇÌ ËØÂÆÈËÂÈÍÈ-ÙÈÄÂÍÕÇÓÍÖÙÇÇÔÑ ÐÑÍÇÄÑÔÕÐÑ ÈÑÐÑÌ Y-ÚÂÔÕÈÙ ÔÕÂÈÕÔÑ ÒÑÔÕÑÐÐÐÑÌ ÑÕÖÕÔÕÄÖÇÕ ÐÂÚÈËÆÈ ÄÕÈÍÑÇÍÑÐÑÄ ÚÂÔÕÈÙÈ ÒÑÔÕÂÄÂÎÑÔÕ ÑÇÅÑÆÐÑÌ ÈÐÖÐÂÍÂ ÐÇ.

£ ÓÂÏÍÂØ ÕÂÍÑÅÑ ÕÓÂÔÔÕÂÄÎÇÐÈÑ ÔÑÕÄÇÕÔÕÄÖÈ ÑÇ ÑÒÍÂÊÂÐÈÇ ÒÑÄÓÇÏÇÐÐÑÌ ÒÎÑÕÐÑÔÕÈ Y-ÚÂÔÕÈÙ ÊÇÔÎÈÐÑÓÂ ÈÐÇÓÂÄÂÆÑÌ:

$$\frac{r_{Y;0}}{s_0} \simeq \frac{m_Y n_{Y;0}}{s_0} \approx 7{,}6\,\frac{\ln\left(\sqrt{g_*}\,M_{Pl}\,m_Y \langle\sigma v\rangle\right)}{\sqrt{g_*}\,M_{Pl}\langle\sigma v\rangle}\,; \tag{11}$$

ÅÆÇ $g_* \simeq g_*(T_f)$ ì ÚÈÔÎÑ ÓÇÎÂ ÕÈÄÈÔÕÔÍÈØ ÔÕÇÒÇÐÇÌ ÔÄÑ-ÃÑÆÞ ÒÓÈ ÕÇÏÒÇÓÂÕÖÓÇ ÍÂÍÂÐÎÈ Y-ÚÂÔÕÈÙ, ì ÔÇÚÇÐÈÇ ÂÐÐÈÆÂÎÑÚÈÈ, v ì ÑÕÐÑÔÈÕÇÎßÐÂß ÔÍÑÓÑÔÕß Y-ÚÂÔÕÈÙ, ÖÆÂÎÇÔÞ ÐÑÓÏÈÓÑÄÂÐÐÑ ÐÂ ÇÆÈÐÈÚÖ, Â ÕÍÑÃÍÈ ÑÃÑÊÐÂÚÂáÕ ÕÓÇÆÐÇÇ ÒÑ ÕÇÒÎÑÄÑÏÖ ÑÂÔÒÓÇÆÇÎÇÐÈá ÕÇÏÒÇÓÂÕÖÓÞ ÊÂÍÂÐÎÈ

$$T_f \approx \frac{m_Y}{\ln\left(\sqrt{g_*}\,M_{Pl}\,m_Y\langle\sigma v\rangle\right)}\,. \tag{12}$$

¶ÓÈÏÇÓÐÑ (11) ÄÇÔÕßÏÂ ÕÓÈÏÇÐÈÏÑ Ë ÒÓÑÕÇ.³ÑÄÓÇÏÇÐÐÂß ÎÑÕ-ÐÑÔÕß ÒÑÕÈÃÇÏÇÐÐÑÌ ÍÂÓÕÈÐÞ ÕÑÔÆÂÐÑ ÕÑÄÓÇÏÇÐÐÑÌ ÒÎÑÕÐÑÔÕÞ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ Ä ÔÍÑÓÑÔÕß ÐÂ ÑÂÆÈ ÚÂÔÕÈÙ $\langle\sigma v\rangle$. ©ÂÄÈÔÈÏÑÔÕß ÒÎÑÕÐÑÔÕÈ Y-ÚÂÔÕÈÙ ÑÕ ÑÂÆÓÇÐÈÏÑÔÕÈ ÔÇÚÇÐÈÂ ÂÐÐÈ-ÏÈÎÂÚÈÈ ÏÈÐÈÏÂÎÐÂ Ç È ÕÑÂÎÇ Ä ÕÇÏÒÇÓ $g_*(T_f)$; ÄÕÑ ÈÂÄÈÔÈ-ÏÑÔÕß ÑÎÂÃÂß ÑÕ ÓÂÊÎÑÏÂÐ. ¥ÎÂ ÔÏÈÕÑÏ ÑÑÔ ÏÈÐÈÔÂÎÐÂÔ ÏÂÕ ÄÇÎÈÚÈÐÂ ÑÍÂÊÞÄÂÇ×ÐÂ ÒÑÕÑÓÂÕÑÂÕÏ 20 ÆÑ 40 (ÂÕÑÂÍÓÂ-ÚÂÇÕÔÑ ÚÂÔÕÈÙÞÒÈ ÚÕÑ ÊÂÍÂÐÎÈ ÒÓÑÈÔØÑÆÈÕ ÑÒÓÈ ÕÇÏÒÇÓÂÕÖÓÂØ, ÑÂÆÐÞØ ÓÑÆÍÑÑÕÐÑÏ ÏÂÔÔÈÂÏÈ ÒÑ Y-ÚÂÔÕÈÙÞ Ä 20 ë 40 ÓÂÊ). ± ÑÂÔÕÕÑÄÂÏ ÂÂ Ä (11) ÚÈÔÎÑ ÓÇÐÈÇ ÍÓÂÚÇÐÈÇ $g_*(T_f) \approx 100$, ÈÏÇÇÐÐÑÇÂÄ ³ÕÂÐÆÂÓÕÐÑÌ ÏÑÆÇÎÈ, È ÒÓÈÓÂÄÐÈÄÂÇÏ (11) Ô (7), ÒÑÎÖÚÂÇÏ ÐÑÄÑ

$$\langle\sigma v\rangle \simeq (1{-}2)\times 10^{-36}\ \text{sm}^2\,. \tag{13}$$

´ÂÍÑÇ ÊÐÂÚÇÐÈÇ ÕÇÚÇÐÈÞ ÂÐÐÈÆÂÎßÚÈÈ ÏÑÆÇÎÈÕÑÄ ÔÕÂÐÆÂÓÕÐÑÌ ÑÕÂÐÆÂÓÕÐÑÌ ÑÕÂÕÄÇÕÔÕÄÖÇÕ ÔÇÚÇÐÈß ÑÄ ÒÓÂÕÇÓÂÏÈ ÐÂ ÐÂÔÕÑÂÑÂÐÈÇ ÍÑÐÑÔÕÈ ÂÐÐÈÆÂÎßÚÈÈ ÕÐÂ£ ëÐÑÔÕÈ ÍÑÐÇÚÐÑ ´à£. °ÕÏÇÕÈÏ, ÚÕÑ ÑÚÇÐÍÂ (13) ÄÇÔßÏ Â ÕÑÇÓÂ È ÑÆÐÑ ÊÐÂÚÂ.

¥Îâ ÕÇÏÒÇÓÂÕÖÓÂ ÐÈÊÍÑÐ ÄÞÃÑÓÂÕÑÐÑÇÆÑÂÐÑÓÏÖÎÈ-ÊÂÙÈÈ $\langle\sigma v\rangle \simeq \alpha^2/M^2$, ÅÆÇ M ì ÐÇÍÑÕÑÓÂß ÒÂÓÂÏÇÕÓ ÂÔÔÈ, M ì ÍÂÓÂÍÕÇÓÐÑÌ ÓÂÊÏÇÓ ÏÂÔÔÞ (ÍÑÕÑÓÂß ÏÑÇÕ ÕÑÄÒÂ-ÆÂÕß Ô m_Y). ´ÂÍÑÇ ÕÇÚÇÐÈÇ ÇÔÕÇÔÕÄÇÐÐÑ ÄÑÊÐÈÍÂÇÕ ÄÑ s-ÄÑÐÂÐÑÌ ÂÐÐÈÆÂÎßÚÈÈ ÔÑÕÄÇÕÔÕÄÖÇÕ ÐÂÔÍÂÎÂÓÐÑÌ ÂÐÐÈÆÂÎßÚÈÈ ÐÇÔÑÃÍÑ ÕÕÈÙÂÕÂÐÈ Y-ÚÂÔÕÈÙ ÒÑÔÕÑÍÐÐÑÌ ÑÂÔÒÇÆ ÆÇÎÇÐÈÞ ÚÂÔÕÈÙÞ ÕÇÏÐÑÌ M. ±ÓÈ $a \sim 10^{-2}$ ÏÂÔÔÂ ÂÂ ÐÇÓÂÄÇÐÔÕÄÑ ÆÂÇÕ $M \sim 1$ ´à£.

´ÂÍÑÌ ÑÇÊÖÎßÕÂÕ ÔÑÔÍÑÐÔÎÂÆÐÈÂ ÔÑÄÒÂÆÇÐÈÇ ÏÑÐÂ ÑÏÇÔÕÑ ÍÂÍ ÄÇÓÑ, ÚÕÑ ÕÑÂÆÂÔÕÑ ÒÓÈÏÇÓÐÑ ÂÇÔÇÏÐÇÂÐÂÇ ÔÏÍÂ ÑÕÕÈÙÞÐÂ ÇÔÎÈ ÐÂ Ä ´à£-ÑÂÊÂÍÇÓÂÔÏÂ ÕÓÈÏÇÊÂÕÈÐÂ ÚÕÑ ÂÍÔÂÌÔÈÔÏÑ ÍÑÐÇÚÐÑ ÐÂ ÍÑÔÏÑÆÈÚÂÇÔÍÈÈ ÄÑÂÑÔÔ ÄÈÐÆÂÓÕÐÈÈ ÔÑÄÇÐÇÊÂÏ ÍÑÔÏÑÔÑÌ ÕÇÂÐÈÏÑÔÕÈ ÈÂÈÒÈÕÂÏÂÐÕÐ ÑÐÈ ì ÕÓÑÐÇÐÈÇ ÒÎÑÕÐÑÔÕÈ ÕÇÏÐÑÌ ÏÂÕÇÓÈÈ Ä ÂÐÇÔÑÕÈÈ ÂÕÑÓÑÊÖÕÈÕ ÚÂÔÕÈÙ:

$$\frac{r_{DM}}{s_0} \sim \frac{1}{M_{Pl}}\left(\frac{T\,\text{eW}}{\alpha_W}\right)^2;$$

[3] ©ÂÇÔÈ Ä ×ÑÓÏÖÎÇ (12) ÏÞ ÑÕÒÕÑÂÇÏ ÒÇÓÂÕÑÐÇÔÂÍÈÇ ÏÑÂÇÆÖÏÑÔ ÈÐÑÄÇÆÂÓÑ ÕÍÍÐÈÏÑ ÂÕÑÓÂÑÇÏ ÐÑÓÏÂÕÈÚÇÔÍÈÏÈ ÏÐÑÄÈÕÇÎÂÏÈ ÏÂÎÑÌ ÄÇÎÈÚÈÐÞ.

ÅÆÇ a_w ì Í ÂÎ ËÃÓÑÄÑÚÐÂâ Í ÑÐÕÕÂÐÕÂ àÎ ÇÍ ÕÓÑÕÎ ÂÃÞØ ÄÊÂËÎ ÑÄÇÌ ÕÕÄËÌ . £ÇÎ ËÚÉÐÞ, ×ËÄÕÕËÓÕá ÜËÇ Ä ÑÃÇËØ ÚÂÕÕâØÕÑÅÑÕÑÑÕÐÎÇÐËâ,ËÏÇáÕ ÒÑÓâÆÑÚ$10^{\ddot{y}\,10}$ ¤à£, Ë ÄÒÑÎÐÇÄÑÊÏÑÉÐÑÚÕÑØÕÑÐÇÕÎÕÚÃÌÐÑÇÑÄÒÂÆÇÐÕÏÇ. àÕÑ ÆÇ ÕÕÄËÕÇ ßÐÑ ÕÃÍ , ÕÑ ÚÂÕÕÈÙÞ ÕËÏ ÐÑÌ Ï ÂÕÇÓËË ÆÑÎÉÐÞÓÑÉÆÂÕßÕÂLHC.

¯ÂËÃÑÎÇÇËÊÄÇÔÕÐÐÞÂÐÆËÆÆÐÕÓÑÎßWIMP ì àÕÑ ÐÇÌÕÓÂÎËÑÐ,ËÏÇáÜÇÇÔâÄÕÕÒÇÏÕÕÕÕÉÚÐÞØÂÔÛËÓÇ ÐËâØÕÂÐÆÂÐÑÌ ÏÑÆÇÎÉ[27, 28]. £ÒÓÑÚÇÏ, ÔËÕÃÙÉâÕ ÐÇÌÕÓÂÎËÑÐ ÆÑÄÑÎßÐÑÓÓÆÐÞÇÎÑ Ä ÕÑÏ, ÚÕÑÒÂÓÐÂâ ÂÐÐËÅÊÎâÉâÐÇÌÕÓÂÎËÐÑÚÂÔÕÕÓÑÊØÑÆÐÕÇs-ÄÑÎÐÇ,Ä p-ÄÑÎÐÇ¿ÕÑÒÓËÄÑÆËÕÑÆÂÄÎÇÐÕÑÆÂÄÎÇÐÕÏÒÂÐÐËÅÊÎâÙËË ×ÃÍÕÑÓÑÏ v^2 T_f/m_Y 1=30. ±ÑàÕÑÏÏÕ ËÏÇÇÕÔâ ÕÇÐÆÇÐÙÈÇ,ÓÇÒÓÑËÊÄÑÊÆÐÕÏÕÓÄÎÈÐÑÄ ÃÑÎßÛÇ ÚÂÕÕÈÓÑÔÐÕÓÔÂÓÄÂÓÄÎÇÕÑÈÇÐÄ ÎÂ ÎßÐÑÌ ÔÕÒÇÈÔ ÏÇÕÓËÚÐÑÔÂÐÆÄÐÑÌ ÏÑÆÇÎËË ÆÓÓÅÈÞÆÇÎÇÌ. ´ÇÏ ÐÇ ÏÇÐÇÇÐÇÌÕÓÄÈÐÑ ÑÕÕÂÈÕÕÄÑÚÛËÏ ÎÂÐÆËÆÄÕÑÏ, l_0 ÆÎâ ÕÄÎËØÑÃÝÇÎÕÑÄÕÑ ÒÑÓâÆÎÇÄÇÎËÊÐÞÓÂÄÇÐ ÑÕÑÃÇÐÐÑÌÈÄÑÎßÛËØÊÐÂÚÇÐÈÇÄØÓÂÏÇÕÓÄm b, ØÂÓÂÎÕÇÓËÊÓáÜÇÄÑÕÐÑÛÇÐÆÇÄÎÓÓÈÞØÕÓÇÆÐÆÄØÓØÈÅÅÔÑÄÓÎÈØÑÎÇÌ, ÕÕÜÇÕÕÄØÓØÈÅÅÕÇÑÓËâØ.

2.2. ´ÈÒÎÂâ ÕÈÏÐÂâÏÂ ÕÇÓËâÈÅÎËÇÅÓÂÆÈÈÐÑ

³ÙÇÐÂÓËÌÒØÑÎÑÆÐÌ ÕÈÏÐÑÌ ÏÂÕÇÓËÇÌÕÕÇÚÑÑÓÈÔÞÄÂÇØÑÎßÛËØÕÄÙÑÂÃÁÆÂÕÇÎßØÆÂÐÞØÆÐÂÍÑÑÐ, ÄÑÈÏ ÑÉÐÑ, ÕÕÄÎ ËÄÂÇÕÂ Ô ÕÓÓÄÐÑÕÂÄÏ Ë. £Ñ-ÒÇÓÄÞØ, ÚËÔÎÇÐÐÇÕÓÂØÑÎÑÆÐÑÕÐÈÇÌÕÕÇÚÑÑÓÈÔÞÄÂÇØÑÎßÛËØÕÄÙÑÂÃÁÆÂÕÇÎßØÆÂÐÞØÆÐÂÍÑÑÐ, ÕÕÄÎ

[illegible] [32]).

[illegible]

$$\frac{d(n_{3/2}/s)}{dt} \simeq \frac{n_S}{s}\Gamma_S,$$

[illegible] $\Gamma_{3/2}$ [illegible] n_S [illegible] s [illegible] $n_S/s \simeq \mathrm{const}$ [illegible] g^{-1} [illegible] $T \gg M_S$ [illegible] $n_S/s \sim \exp(-M_S/T)$ [illegible] $T \lesssim M_S$ [illegible] $T \sim M_S$ [illegible]

$$\frac{n_{3/2}}{s} \simeq \frac{d(n_{3/2}/s)}{dt} H^{-1}\Big|_{T\sim M_S} \simeq \frac{\Gamma_S}{g} H^{-1}(T \sim M_S) \simeq \frac{1}{g}\,\frac{M_S^5}{m_{3/2}^2 M_{Pl}^2}\,\frac{M_{Pl}}{g^{1/2} M_S^2}.$$

[illegible]

$$\frac{m_{3/2}n_{3/2}}{s} \simeq \sum_S \frac{M_S^3}{g^{3/2} M_{Pl} m_{3/2}}, \qquad (16)$$

[illegible] (10) [illegible]

$$M_S \sim 100 \div 300\ \text{GeV}. \qquad (17)$$

[illegible] LHC.

[illegible] $T_{max} \sim 1 \div 10$ [illegible] (17). [illegible] (16), [illegible]

[illegible] T_{max}; [illegible] NLSP (Next-to-Lightest Supersymmetric Particle). [illegible] (15), [illegible]

$$c\tau_{NLSP} \sim 1\ \text{mm} \div 100\ \text{m}$$

[illegible] $m_{3/2} \sim 1 \div 10$ [illegible] $M_{NLSP} \sim 100 \div 300$ [illegible] NLSP [illegible]

[illegible] WIMP. [illegible] LHC.

[illegible]

2.3. [illegible]

[illegible] WIMP, [illegible] 1 [illegible] 10 [illegible] 100 [illegible] $10^{-9} \div 10^{-11}$ [illegible] 1 [illegible] WIMP [illegible]

[illegible] T_{max} [illegible]

[illegible] WIMP [illegible]

Õ.Æ±ÑàÕÑÏÖÐÇÕÏÑÕÓÐÂÃÑÃÑÔÐÑÃÐÂÕÕÔÐÂÆÇÉÆÐÂ ÕÑ,ÚÕÑÒÓÑÃÏÇÏÃÕÈÏÐÑÌ àÐÇÓÅËÃÈÖÆÇÕÇÚÐÂ Ô ÒÑ-ÏÑÜßá LHC, ÐÈÍÃÑÌ ÅÂÓÂÐÕËËÈÓÃÞÕßÐÇÑÉÇÕ.

3. ¢ÂÓËÑÐÃÂÂÔËÏÇÕÓËÂÔÇÎÇÐÑÌ

£ ÔÑÄÓÇÏÇÐÐÑÌ ÔÇÎÇÐÑÌ ÇÕÑÃÂÂÓËÑÐËË ÒÓÂÍÕËÚÇÔÍËÒÑÐÂÆÑÕÒ ÐÇÕÃÐÕËÃÂÓËÑÐÑÌÏÍËÚÇÔÕÃÑÃÂÓËÑÐÑÃÇÃÆÐÂÓÂÍ-ÕÇÓËÊÇÕÑÐÂÓÑÂÐÑÚÇÔÈÇ (Ôï. (3)). ¥îâ ÓÂÐÐÇÈ ÔÇÎÇÐÑÌ ÇÕÇÕÃÕÑÇÓÂÍÕÇÓËÊÑÕÐËÈ ÂÍâÇÕÑÔÕÑÐÑÚÇÔÈÇÐÑÕ-ÐÑÕÇÐËÇÂÓËÑÐÐÑÌ ÂÔÑÎÂ n_B Í ÒÎÑÕÐÑÔÕË ÕÐÕÓÑÒËË

$$D_B \approx \frac{n_B - n_{\bar B}}{s};$$

ÅÆÇ $n_{\bar B}$ ì ÒÎÑÕÐÑÔÕË ÑÔÎÂÂÐÕËÃÂÓËÑÐÑÃ ÎËÔÎÃ ÃÂÓËÑÐÐÑÇ ÚËÔÎÑÔÕÓÂÐÂÕÒÇÐÐÂÂ ÏÂÕÂÓËÑÇÂÔÇÎÇÐÐÂÂ ÂÕÂÛËÓâÕÇÔÔËÃÂÓÂÖË-ÚÇÔËÏ Ë, ÕÑ D_B âÑÂ âÇÕÑÕÇ ÒÑÔÕÑÐÐÂÐÂÏ Ë ÇÃÑ ÍÐÂÚÇÐËÇ Ô ÕÑÚÐÑÔÕÛá ÆÑ ÚÇÕÑ ÇÐÑÃÑ ÏÐÑÇËÕÇÎÂ â ÑÒÑÄÑÆÂÇÕ Ô Z. ´ÑÚÐÇÇ,

$$D_B \approx 0.8 \times 10^{-10}:$$

¯ Â ÓÂÐÐËØ ÔÕÂÆËâØ, ÍÑÅÆÂ ÕÇÏ ÒÇÓÂÕÖÓÂ ÒÓÇÃÞÛÂÎÂ 100 ® à£, Ä ÍÑÕÑ ËÚÇÔÕÑ ÑÍÂÈË Ç ÕÑÆÇÓÇË ÃÎ ÑÕß Ï ÐÑÃÑ ÍÄÂÓÍ-ÂÐÕËÍ ÄÂÓÍ ÑÄÞØ ÒÂÓ, ÕÎ ÑÕÐÑÔÕß ÚËÕÎ Â ÍÑÕÑÓÞØ ÃÞÎÂ ÒÑÚÕËÆÂ ÕÎ ÑÕÐÑÕÔËË àÐÕÓÑÒËË, $n_q \ddagger n_q$ s, Ä ÕÑ ÄÓÇÏâÍÂÍ ÒÎÑÕÐÑÔÕÇÃÂÓËÑÐÐÑÃÑ ÚËÔÎÂÃÞÎÂ ÔÂâÊÂÐÂ Ô ÒÎÑÕÐÑÔÕâÏË ÍÄÂÓÍÑÄ Ë ÂÐÕËÍÄÂÓÍÑÄ ÕÃÍ $n_B - n_{\bar B} \approx (1/3)(n_q - n_{\bar q})$ (ÃÂÓËÑÐÐÞÇ ÚËÕÎ Ñ ÍÄÂÓÍ Â ÓÂÄÐÑ 1/3). ± ÑàÕÑÏ Ö ÃÂÓËÑÐÐÂâ ÂÔËÏ ÏÇÕÓËâ Ä ÓÂÐÐÇÏ £ÔÇÎÇÐÐÑÌ ÏÑÉÇÕÃÞÕß ÒÓÇÆÔÕÂÄÎÇÐÂÍÂÍ

$$D_B \sim \frac{n_q - n_{\bar q}}{n_q + n_{\bar q}}:$$

£ËÆÐÑ, ÚÕÑ Ä ÓÂÐÐÇÌ £ÔÇÎÇÐÐÑÌ ÏËÎÎÂ ÑÐËÐËÓÇÛËÌ" ÍÄÂÓÍ ÒÓËÏÇÓÐÑ Ð 10 ÏÎÓÆ ÍÄÂÓÍ-ÂÐÕËÍÄÂÓÍÑÄÞØ ÒÂÓ. ªÏÇÐÐÑ ÐÂÎËÚËÇ ÕÂÍÑÅÑ ÓÇÔÍÑÅÑ ÒÑÔÕËÄÎÐÐÑÔÕ ÆËÔÕÂÐÕÐÂÏ ÍÎÍÂÕÑÖÇÐÑÔÕÓÇÆÂÂ ÃÂÓËÑÐÐÑÌ ÏÂÕÇÓËË Ä ÔÑÄÓÇÏÇÐÐÑÌ ÔÇÎÇÐÐÑÌ.

-ÑÅËÚÐÑ ÒÓÇÆÔÕÑÄÂÕÔÇ ÇÆËÐÔÕÄÇÐÐÑÇ ÓÂÔÐÑÔÕÎÎÂÐËÇ, ÚÕÑ ËÊÂÞ-ÕÑÍ ÍÄÂÓÍÑÄ ÐÂÆ ÂÐÕËÍÄÂÓÍÂÏË ÃÞÎ ÊÂÎÑÉÇÐ Ä ÍÂÚÇÔÕÄÇ ÐÂÚÂÎßÐÑÅÑ ÖÔÎÑÄËÇ ÑÖÇÐË ÒÑÔÕÑÐÐÂÏ ÂÐÕËÑÖÐÑÔÕË ´ÃÎÂ â ÂÑÕÏÑÃ-ÐÑÔÕË, ÑÆÐÂÍÑ, ÐÇÒÑÓÑÆÇÂÍÕÓÂÚÇÔÍÂ ÒÓÂÃÆÑÐÂÕÂÑÓËÔ ÑÐÂÚÂÎÑ ×ËÐÐÂ.¬ÓÑÏÇ ÕÑÅÑ, ÐÂÐÂÆÂÂÕÂÐÑÔÕËÇÐ ÑÔÕÑÕÕÕÕÑÕÇÕ ÄÓÇÏÇÐÕÓÇÚËÐÞØ ×ÎÂÚÐËÇ, ÚÕÑ ÑÒÕ ÒÓÇÊÎÂÐËÂÂÇÕÕÚÕÑ ÕÓÇÊ ÒÑÕÇÐ×ÎÂÚÐËÇ ÔÇÎÇÐÐÑÌ ÔÇÃÞÎÂ ÕÑÐÏÇÕÕÓÐËÕÏÑÔÕÚÐ ÐÇÃÞÛÑÄÇ ÍÑÎËÚÇÔÕÄÑ ÂÐÕËÃÂÓËÑÐÑÄ ÇÕÃÞÔ ÃÞÎË ÃÂÓËÑÐÑÏ, ÐÇÏÂÕÇÓËÂÎÑÄ ÍÂÍÔÑÆËÐËÍÂÔÇ ÑÃÐÂÓÖÉÇÐÑ ÔÄÇÓØÐÑÄÂÕÇÎÞØ ÑÃÎÂÔÕÂØ ÃÂÓËÑÐÑÃÑÓÑÕÕ ÐÂÃÎÂÆÇÕÇÎßÐÑÌ ÎÑÄÂÐÐÑÌ ËÐÞÎÑÐÑÂÃÞÎËÌ ÕÇÎÔÑÆÇÓÉÂÐË ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË.

¢ÂÓËÑÐÐÂâ ÂÔËÏÏÇÕÓËâ ÓÂÐÐÇÕ ÔÑÓÂÆÑÄÂÕßÔâ ÃËÆÂ-ÚÂÎßÐÑÔÕËÏÕÓËÚÇÔÍÑÌ ÑÔÕÂÐÑÂÍË ÇÎÑÄËÂ ÃËÐÃÞÔÕÂÕÔÇ ÕÑÒÇÕÕÑÃÓÇÆÔÕÂÄËÏÞ ÔÇÕÑÎËÍÎÑÍÂÍËÇ ÂÆËÂÕÓËÕÕÔËÃÎÂ ³ÂØÂÓÑÄÂ:

1) ÐÇÔÑØÓÂÐÇÐËÇ ÃÂÓËÑÐÐÑÃÑ ÚËÔÎÂ;
2) ÐÂÓÖÛÇÐËÇ CP-ÔËÏÏÇÕÓËË;
3) ÑÕÍÎÑÐÇÐËÇ ÑÕ ÕÇÒÎÑÄÑÅÑ ÓÂÄÐÑÄÇÔËâ.

³ÏÞÔÎ àÕËØ ÖÔÎÑÄËÌ ÎÑÅËÚÇÔÍË ÑÚÇÄËÆÇÐ. ³ÑÔÕ ÃÂÓËÑÐÐÑÅÑ ÚËÔÎÂ ÑÃâÊÂÕÇÎÇÐ ÐÂÓÖÛÇÐËâ ÕÑ (ÔÑÄÇÐÔ 1), Â ÐÂÓÖÛÇÐËÇ ÃÂÓËÑÐÐÑÅÑ ÚËÔÎÂ ÐÇÔËÏÏÇÕÓËÚÐÑ ÑÕÐÑÔËÕÇÎßÐÑ ÓÂÄÐÑÃÑ ÍÑÎËÚÇÔÕÄÂ ÚÂÔÕËÚ Ë ÂÐÕËÚÂÔÕËÚ, ÐÇÄÑÊÏÑÉÐÑ ÃÇÊ ÐÂÓÖÛÇÐËâ ÃÂÓËÑÐÐÑÅÑ ÚËÔÎÂ. ¦ÔÎË ÐÇ ÄÞÑÎÐÇÐÑ ÕÓÇÕßÇ ÖÔÎÑÄËÇ (2), ÕÑ ÔÑÔÕÑâÐËÇ ÓÂÄÐÑÄÇÔËâ ÃÖÆÇÕ ÑÕ ÐÑÔËÕÇÎßÐÑ ÕÇÏÂÎÑÎÏÎ ËÐÍÑËÐÕÒÎÐÑÌ ÍÑÐÄÇÓÔËË ÕÓÇÏÇÐË ÐÇÏÂÐÑÔË ÍÑÎËÚÇÔÕÄÂ ÃÂÓËÑÐÑÄ Ë ÂÐÕËÃÂÓËÑÐÑÄ, ÍÑÕÑÓÑÇ ÄÑÅÂÕ ÏÑÎÐÑ ÒÑÔÂÕÐÑÇ ÃÂÓËÑÐÑÏ. ³ÑÔÕÑâÐËÇ ÓÂÄÐÑÄÇÔËâ ÕÇÎÇÓËÐÑÅÑ ÏËÚÇÓÇ ÐÇÃÂÓËÑÐÐÑÌ ÆÂÓÑÃÔÐÑÄÂ ÐÂÐ-ÏÇÕÓËÚÐÑÇ ÑÔÕÑâÐËÇ ÖÓÇÊÖÎßÕÂÕÇ ÃÂÓËÑÐÐÑÌ ÔËÏÏÇÕÓËË

ÒÓÇÆÔÕÂÄÎÇÐËÇ ÄÞÂÐÕÓÑÏÂÕ ÔÓÇÆÂ ÓÂÍÕËÚÇÔÍÑÅÑ ÂÔËÏÏÇÕÓËÚÐÑÌ ÃÂÓËÑÐÐÑÌ ÚËÔÎÂ ÔÑØÓÂÐÇÐËÂ ÄÂÇÔÕÑÃÑ ÒÓÑÍÇÔÔ ÄÇÔÕÕÑÐÑÄ ÍÂÍÒÇÓÐÞÇ ÕÕÕÕÖÓÇÑÍÕËÕÂÇÍ ÕÇÒÎÑÄÑÅÑ ÓÂÄÐÑÄÇÔËâ.

¯Â ÔÂÏÑÏ ÆÇÎÇ, ÕÇÑÓËâ ÃÂÓËÑÐÐÑÅÑ ÚËÔÎÂ ÐÇ ÍÑÐÔÕÂÐÕ ÑÃÞÛÐÑÄÂ ÕÇÑÓËÍÂ, ÍÂÍ ÃÂÓËÑÐÐÑÇ ÚËÔÎÑ ÐÂÓÖÛÂÇÕÔâ ÒÑÕÑÎÑÅËÚÇÔÍËÏË ÒÓÑÕÇÔÔÂÏË ÄÑ ÄÓÇÏâ àÎÇÍÕÓÑÔÎÂÃÑÅÑ ÆËÐÂÏËÚÇÔÍÑÅÑ ÒÇÓËÑÆÂ.

³ÖÚÇÔÕÄÑÄÂÐËÇ ÔÑÍÂÎÑÐÐÞÔÒÓÑÔÕÑÓÑÐÎ ÓÇÆÇÕ ÐÇÓÕÖÓÃÂÕËÄÐÞÏË ÐÇÕÇÕËÐÂÏË, ËÐÍÑÕÑÓÞØ ÐÇËÐÑÐÕ ÃÂÓËÑÐÐÑÇ ÐÂÓÖÛÂÇÕÔâ ÄÞÐÑÅÂÇÕÔâ ÑÔÕÇÓÂ, ÐÂÐÕÕÇÓÑÐÖ ÃÂÓÂÕËÑÐ ÐÂÃÑÓÂÕËÚÇÔÍÑÅÑ W-ÃÑÊÑÐÂ ÔÇÐÍÑÒÕÇÔÂ, ÍÑÕÑÓÑÇ ÄÞÕÑÍÂÇÕ ÑÃÎÂÔÕß ÄÞÔÑÍËÕ ÕÇÏÒÇÓÂÕÖÓ, ÍÑÕÑÓÞÌ ÖÐÐËÚÕÑÉÂÇÕ ÃÂÓËÑÐÐÑÇ ÚËÔÎÑ¡ àÕÑÕ ÂÐÕÑÎÂ ¢ÑÎßÛÑÔÕßÑÃÑÄÑÇ-ÐËâ, ÍÑÕÑÓÞÌ, ÍÑÕÑÓÞÇ ÔÑÆÇÓÉÂÕ ÔÑÃÑÎßÛÑÏÑÓÂÆÑÍÇ 10^{16} ¤àÂ£.

¥ÓÖÅÑÌ ÏÇØÂÐËÊÏ, ÄÑÊÐËÍÂÞÛËÌ ÂÐÑÓÂÏÂÎÑÌ ÔÑÎÑÕËË ÂÑÍÎÑÚÐËÌ [33], ÔÄâÊÂÐ Õ ÕÑÓÃÑÂÊÑÎßÐÑÌ ÂÐÑÏÂÎËÇÌ Ä ÃÂÓËÑÐÐÑÏ ÕÑÍÇ, Ä ³ÕÂÐÆÂÓÕÐÑÌ ÏÑÆÇÎË, ÕÂÍË (ÂÐÑÏÂÎÑÐÇÐÑÏ ÖÆÂÓÐÑÌ ÐÇÖÆÂÓÖÂÏÑ) ÂÐÕÇÕÇ ÇË ÑÃÞÚÐÞÇ ÔÇÎÇÐÐÑÌ ÓÂÐÐÇÌ £ÔÇÎÇÐÐÑÌ, ÂÂÆÂÞ ÆÄÂÕÂÐÏÇÔÕÂÄÂÐÑÏÇÐÇÐÐÂâ ÍÑÐÂÄÐÂÐÑ-ÕÇÐÇÐÑÌ ÓÂÏÕÐËÍÂÆÂ ÛËÓÑÍÑÌ ÆËÂÕÂÊÑÐ ÕÇÏÒÇÓÂÕÖÓ [34], 100 GeV < T < 10^{11} ¤àÂ£; ÂÐ-ÂÐÑÓÏÂÎËÍÑÔÕÑÐÐÑ ÐÂÓÖÛÂÇÕ ÔÑÔÕÑÐÐÑ ÍÂÍ ÃÂÓËÑÐÐÑÇ ÕÂÍ Ë ÎÇÒÕÑÐÐÑÇ ÚËÔÎÂ, ÕÑ B − L.

²ÂÔÔÏÑÕÓËÏ ÄÂÑÐÍËÕÇÎßÐÑÔÕÑÕÓËÆÂÐÞÌ, ÏÇØÂÐËÊÏ ÄÑÓ-ÛÇÐËÇÃÂÓËÑÐÐÑÐÑÅÑ ÎÑÕÑÐÂÐÑÔÕË ÒÑÔÓÇÆÔÕÄÑÏ ÒÑÔÕÂ-ÓÑÅÑÍÂÓÔÑÕÇ ÃÂ ÍÂÚÇÔÕÄÇÐÐÑÌ ÍÑÓÂÐÇÐËÐÐÑÇ ÐÂÓÖÛÇÐËÇ ÑÃÑÍÂÕÇ ÃÂÓËÑÐÐÑÅÑ ÕÑÍÂ

$$B^\mu = \frac{1}{3}\sum_i q_i\, g^\mu q_i;$$

ÅÆÇ q_i ÑÃÑÊÐÂÚÂÇÕ ÑÕÆÇÎßÐÑÇ ÍÂÓÍÔÃÞÔÕÕÄÂ. ¯Â ÍÎÂÔÔËÚÇ-ÔÍÑÌ ÖÓÑÄÐÇ ÃÂÓËÑÐÐÞÌ ÕÑÍ ÔÑØÓÂÐÇÐÑÌ, ÃÑÎÂÕË ÕÂ ÍÄÂÐÕÑ-ÄÑÏ ÖÓÑÄÐÇ ÇÃÑ ÆËÄÇÓÃÇÐÕËâ ÐÇ ÓÂÄÐÂ ÐÖÎÞ ËÊ-ÊÂ ÕÓÇÖÅÑÎßÐÑÌ ÂÐÑÏÂÎËË (ÂÐÑÏÂÎËË ××¢ ÄÍÂÂÐÕÑ-ÄÑÏ àÎÇÍÕÓÑÔÎÂÃÑÏ ØÓÑÏÑÔÎÂÃÑÏ ÔÇÍÕÑÓÂØ ÍÂÎËÃÓÑÄÑÚÐÑÐÂÍÂÑÎËÌ):

$$\partial_\mu B^\mu = \frac{1}{3}\, 3_{\rm colors}\, 3_{\rm generations}\, \frac{g^2}{32\pi^2}\, \varepsilon^{\mu\nu\lambda\rho} F^a_{\mu\nu} F^a_{\lambda\rho};$$

ÅÆÇ $F^a_{\mu\nu}$ Ë g ì ÐÂÒÓÂÉÇÐÐÑÔÕß ÑÔÎÂ Ë ÍÑÐÔÕÂÐÕÂ ÔÃÇË ÍÂÎËÃÓÑÄÑÚÐÑÌ ÅÓÖÒÒÞ SU(2)$_W$ (ÒÑÆÅÓÖÒÒÂ ÃÇÊÑÐÑÍÇ ÃÂÑÌ ÅÓÖÒÒÞ SU(2)$_W$ × U(1)$_Y$) ÕÑ ÑÃÇÔÕÄÂÕÇÔÔÕÄÇÐÐ. ¡ ÐÂÎÑ-ÅËÚÐÑ, ÂÐÑÏ ÃÎ Ëâ ÎÇÍÕÑÐÐÑÅÑ ÕÑÍÂ Ä ÍÂÉÆÑÏ ÍÑÓÑÕÐÑÏ ÕÑÍÂ (ÊÆÇÔß e, μ, τ),

$$\partial_\mu L^\mu_a = \frac{g^2}{32\pi^2}\, \varepsilon^{\mu\nu\lambda\rho} F^a_{\mu\nu} F^a_{\lambda\rho}:$$

¯ÇÇÓÖÎÇÄÞÍÂÐÂÐÐÞÌ ×ÍÎÑÔÑÔÕÑÏËÔÕÑÐÑÌ [35], ÚÕÑ ÐÖÜÇÔÕÄÖÇÕ ÃÑÎßÛËÇ×ÏÑÎÕÑÖÂÛËÇÐÑâ $F^a_{\mu\nu}(x;t) / g^{-1}$, ÆÎâ ÍÑÕÑÓÞØ

$$Q = \int d^3x\, dt\, \frac{g^2}{32\pi^2}\, \varepsilon^{\mu\nu\lambda\rho} F^a_{\mu\nu} F^a_{\lambda\rho} \ne 0:$$

¥Îâ ÍÂÉÆÑÌ ÕÂÍÑÌ ×ÏÑÍÕÑÂÛËÇËÄÇÎËÚËÐÂ Q ÒÓËÐËÏÂÇÕ ÙÇÎÑÚËÔÎÇÐÐÞÇ ÐÂÚÇÐËâ.

±ÓÇÆÔÕÂÄËÏ ÕÇÒÇÓß ÒÑÔÎÇÍÑÂÍÑÑÍÕÑÂÛËÔÃÇÐÇÐËÇ ÄÞÏ Q. ´ÑÅÆÂ ÃÂÓËÑÐÐÑÇ ÚËÔÎÑ ÐÂÚÂÎÇ Ä ÍÑÐÙÇ ÒÓÑÙÇÔÔÂ ÑÕÎËÚÂÕÔâ ÕÂ:

$$B_{\rm fin} - B_{\rm in} = \int d^3x\, dt\, \partial_\mu B^\mu = 3Q: \qquad (18)$$

³ÑÄÇÓÛÇÐÑÐÂÐÂÎÑÅËÚÐÑ

$$L_{n;\,fin} \approx L_{n;\,in} \; Q: \qquad (19)$$

°ÕÔáÆÂË ÔÎÇÆÖÇÕÕÎÏÇÚÇÐÐÑÇÛÇÒÓÂÂÑ ÑÕÃÑÓÅ ÐÂÔÖÛÂÇÕÑÅ, $\approx L$ ÔÑØÓÂÐÇÕÔÂ.

±ÓË ÐËÊÍËØÕÇÒÓÂÕÖÓÂÑÎßÛËÇ ×ÎÍÔÖÂÙËËÄ ÓÇÊÖÎßÕÂÕÇ ÔÑÞØÐÂÓÂÖÛÂáÕÔÑ ÂÓËÑÐÇ ÎÇÕÕÑÐ-ÐÞÇÚËÔÂ,ì àÕÑÄÂÍÖÖÏÐÞÇ×ÎÍÕÖÂÙËËÇ ÐÔÕÂÐÕÑÐ [35]. °ÐË ÑÕÚÂÕÕÐÂÒÑÏËÐÂáÕ ÄËÖÕÖÂÎßÇÞ ÒÑÎâ, ÒÑâÄÎââÚËÇÕÂ ËÔÚÇÊÂáÚËÇ ÕÇÕÖÖÓÂ ÒÑÏÄÂÍÖÖÏÇ ÍÂÐÕÑÂÑ ÇÑÓËÈËÑÎâ.²ÂÊÎËÚËÇ ËÂÍÎáÚÂÇÕÔÂ ÄÕÑÏ, ÚÕÑ ËÐÕÕÂÐÕÑÐÞÂÑÎßÛËÇ ×ÎÍÔÖÂÙËË± ÑÕÎÇÆÐÇÐÇÕÔÑâ-ÕÇÎßÕÕÄÑÓÔËÄÑÆËÕ ÒÑÆÂÎÇÐËâ ÔÑÑÕÄÇÕÔÕÄÖáÛÇÌ ÄÇÓÑâÕÐÑÔÕÑÕÑÓÑÏ exp $(-16p^2/g^2) \approx 10^{-165}$. ³ ÆÓÖÅÑÌ ÔÕÑÓÑÐÞ ÒÓË ÍÑÐÇÚÐÞØ ÕÇÏÒÇÓÂÕÖÓÂØ ÇÕáÔÔâ ÃÑÎßÛËÇ ÕÇÒÎÑÄÞÇ ×ÎÍÔÖÂÙËË ì Ô×ÂÎÇÓÑÐÞ [36], ÄÇÓÑâÕÐÑÔÕß ÑÓØÑÐÇÕÃÑßÐÇÌ ÎÂ. ´ÂÍ Ë ÒÓÑËÔ-ØÑÆËÕÑÕÓÂÐÇÐËÇ ÂÇÓÊÇÐÐÑÅÑ ÖÐËÇÐÑÂÓËÐÂ ÔÑÅÎÂÔÐÑ ÓÇÊÎÆÕÇÏ ËÔÕÑÓËÕÑÏÔÂÄÕÂÐÑÄÍÇ ÓÂÔÒÓÇÆÇÎÇÐËÇ ÑÍÎÑÐÑÔÕÂ ÏÂÕÕÇÓËË ÎÂÂÕÓÂÕÑÐÑÄÔÕÖÂ ÇÔÕÂ ÐÇÐÑÖÎÇÄÑÌ ÕÇÏÒÇÓÂÕÖÓÂØ, ÍÑÅÆÂ

$$\langle f \rangle_T < T; \qquad (20)$$

ÅÆÇ $\langle f \rangle_T$ ì ÔÓÇÆÐÇÇ ÊÐÂÚÇÐËÇ ÒÎÑÕÐÑÔÕË ÕÇÏÒÇÓÂÕÖÓÇ.

®ÑÉÐÑ ÊÂÆÂÕß ÄÑÒÓÑÔ ÑÕÑÏ, ÍÂÍËÏ ÑÃÓÂÊÑÏ ÃÂÓËÑÐÐÐÞÌ ÊÂÓâÆÍÑÐ ÐÇÑÃØÑÆËÏÞÌ ÆÎâ ÐÖÍÎÇÑÕÐÕÇÕÕÄËâ ÔÂÏÑÎÑÇÉÔÕÄÖÇ, ÎÇÍÑÓÂÕßÔÕâ ÄÎÂÆÇÎÇÎÇÐËÂ ÑÆÐÑÔÂÏÇÆËÌ³ÕÂÐÆÂÓÕÐÑÌ ÏÑÆÇÎË, ÐÂÓÖ-ÛÂáÚËØ ÃÂÓËÑÐÐÞÌ ÇÔÕÑÓÕÑÊÑÑÏÑÆÇÎßÕÑÆÑÒÑÄÂÐËÇÑÕÖÖÓÕÇ ÄÂÓÑâ-ÆÇÂÕÑÐÇÃÂÔÑÓÕÂÏÄÂ [37]. £ ÍáÑÕÑÏ ÔÎÖÚÂÇ ËÐÕÇÓÇÔÐÑ ÒÑÐâÕßÔÕÇ ÐÇ àÇÍÕÑÐÑÕÒ ÏÇÆÂÐÓÇÎÑÃÔÑ ÐÇÎÂ ÍÑÏ ÑÕÄÇÕÐÑ ÐÂÍÕÑÐÕÇ ÔÂÅ ÊÂÆÇÏÑÆÂÎÂ ÆÑÌ ÔÂÏÂÓËÑÐÐÞÌ ÏÑÆÇÎËÕÇÕÑÓËË£ÑÇÎÇÐÐÑÌ©ÆÇÕÑÏ,ÆÂÐÑ, ÇÕÔÑÊ Ë ÏÑÊÐÇÎÔÍÂÍÂ ËÊ ÒËØÑÕÑÔÕÕÑÏ, ÚÕÑ ÂÓÂÖÛÇÐËÇ CP-ÔËÏÏÇÕÓËË âÂÎâÇÕÔÂ ÑÃÚÍÑÏ ÔÎÂÃÑÏ Ä³ÕÂÐÆÂÓÕÐÑÌ ÏÑÆÇÎË:ÏÇØÂ-ÐËÊÏ ¬ÂÃËÃÑ-¬ÑÃÂâÔË®ÂÔÍÂÄÞ (CKM) ÔÂ ÒÑÔÇÃÇ ÐÇÆÑÔÕÂÕÑÚÐÑÅÑ ÆÎâ ÅÇÐÇÓÂÙËË ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË. ±ÑàÕÑÏÖ ÕÓÇÃÖÇÕÔâ ÆÑÒÑÎÐËÕÇÎßÐÞÇ ÕÑÚÐËÍË CP-ÐÂÓÖÛÇÐËâ, ÓÑÅÎÂÔÐÑ ÏÑÆÇÎË ÇÏÕÇÐÐÐÞÇ ÓÇÅÖÎË-ÄÂÐËáÑÍÍÐÇÐËâ ÑÕÇÍÂÏÑÆÇÎÑÕÎËÚÐÞ ÑÕ ÒÑÊËÕÐÑ-ÓÂÕÖÓÂØÇÂÐÇÃÑÎßÛËØ 100 ¤à£, àÎÇÍÕÑÐÔÂÎÂÃÑËÏÇÕ-ÓËÚÐÂÑÕÑÆÇÎÂÕßÚÕÑ ÍÑÏÂÊÂÊÇÐËÇ ÓÂÄÐÑÄÇÔÂ[5], ÔÑÕÑÓÑÇ ÄÔÇÆÑ ÏÑÆÇÑÃÑÔÑ (20) ÄÞÒÑÎÐâÇÕÔâ, ÐÇÔÑØÓÂÐÇÐËÇ ÐÇ ÆÇÐÐÑÅÑ ÊÂÓâÆÂ ÒÓËÇÆÕÇÏ, ÚÕÑ ÕÇÏÒÇÓÂÕÖÓÂ ÐÇÓÂÄÐÑÄÇÔÐÑÅÑ ÆÇÕÕËÍÂ ÐÇÏÎÑÅÑ ÃÑÎßÛÇ ÐÇÎËÚËÐ ÐÂÓÖÛÇÐËâ ÑÕÐÑÔÕË ÑÆÐÑÓÑÆÐÑÇ ÑÃÎÂÔÕË ÒÂÓÂÏÇÕÓÑÄ ÂÓÑÅÇÐÞÌ ÓÇÊÑÐÂÐÔÂ ÏÇÔÔÂ ÕÇÏÒÇÓÂÕÖÓÂ ÓÂÄÐÞ ÕÇÏÐÂÑÕ ÃÑÎßÛËØ ÐÂÓÖÛÇÐËØ ÔÑÃÞÕËÌ ÆÇÆÇÎËÕÇÎßÐÑÇ ÍÎÇÏ ÆÎâ ÄÇÊÑÒÂÔÐÑÕÂ... ÊÂÔÆ ÒÑ ÏÎÎÂÔÕ (20) ÐÂÓÖÛÂÇÕÔâ ÔÂÏÑ ÕÇÏÒÇÓÂÕÖÓÂØ ÑÃÓÂÊÑÄÂÐËâ 100 ¤à£ Ë ÏÇÐßÛËØ, ÐÑ ÄàÕÑÌ ÓÇÅËÑÐ ÇÑÇÓÅÂ ÓÂÔÛËÓâÇÕÔâ ÕÂÏÎÂÆÐÑÇ ÃÂÓËÑÐÐÑÇ ÑÐÂÔÑÐÎÇÎËÚÇÔÍËÇ ÏÑÆÇÎË ÏÂÕÕÇÓËË ÔÎÑÃÂÎÂÓÎÂÕÇ

$$H^{-1} \approx \frac{M_{Pl}}{\sqrt{g}\,T^2} \simeq \frac{10^{19}\ \text{G|W}}{10\ (100\ \text{G|W})^2} \approx 10^{-10}\ \text{s}; \qquad (21)$$

ÚÕÑ ÑÚÇÐß ÂÇÎËÍÑ ÔÑÑÕÐÑÚÇÐËÌ àÎÇÍÕÑÐÑÔÐÞÌ ×ËÊËÍË. ¦ÆËÐÔÕÄÇÐÐÑÌ ÂÑÔËÍÎÐÑÔÕÄÞ ÆÇÎÂ ÆÑÕÕÂÕÑÚÐÑ ÃÑÎßÛÑÇ ÔÑ ÎÇ ÑÕ ÑÕÑ ÑÐÑ ÔÇÌÇÇ ÔÂÏÑ ÓÂÔÔÇÑ ÂÎËÂ ÒÓÂÍÂÕÑÌ ÂÎÂ âÂÎâÕÔâ ×ÂÊÑÄÞÌ ÒÇÓÇÓÑÆÑÕ ÍÑÇÏ ÑÎÂ.

£ ÔÂÏÍÂØ ÕÇÑÓËË ÑÃÎËÍÑÏÑÆÇÎË ÔÓÇÆÐÇÇ ÊÐÂÚÇÐËÇ ÆÂÎÕËÓÐÑÌ ÒÑÎâ ÓÂÄÐÑÄÇÔÐÑÅÑ ÍÇ ÒÑÄÞÛÂÇÕÔâ ÄÑÍÑÎÑÏ ÕÇÏÒÇÓÂÕÖÓÂØ ÒÑÓâÆÍÂ ÐÇÄËÆËÏÑ 100 ¤à£, Ë ÑÕÎËÚÐÞ ÑÕ ÐÖÎâ ÄÂÎÑÖÕÂ ÄÂÍÖÖÏÂ.¿ÕÑ ×ÂÕ ÖÍÂÊÞÄÂÇÕÐÂÂÔÔËÏÇÕÓËÚÐÑÔÕß ×ÂÊÑÄÞÌ ÒÇÓÇÓÑÆÑÄ, ÕÂÍ ÍÂÍ ÄÑÆÐÑÌ ÔÎÖÚÂÇ ÏÓË ÑÍÇÎÞ, ÐÂÇ ÍÆÇ ×ÂÊÂ $\langle f \rangle \approx 0$ Ä ×ÂÊÇ $\langle f \rangle \neq 0$. £ÔÎÇÆÔÕÄËÇ ÕÇÏÒÇÓÂÕÖÓÐÑÌ ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË ÐÂÔÍÂÊÂÐÐÑ ÔÎÑÃÞ ÒÑÎÇ $\langle f \rangle$, Ë ÒÑÕÑÏÖ ÏÇÐâÇÕÔâ ÔÎÇÆÑÄÂÕÇÎßÐÑ ÒÓË ÒÇÓÇØÑÆÇ ÑÕ $\langle f \rangle \approx 0$ Ë $\langle f \rangle \neq 0$ ÏÇÊÆÖ ÕÇÏÒÇÓÂÕÖÓÂÏË. ¢ÑÎÇÇ ÕÑÚÐÑ, ÐÂ ÒÑÃÄÇÔÕÐÑÔÕË ÂÖÔÕ ÐÂÓÖÛÇÐËâ ÏÇÊÆÖ ÔÑÔÕÑâÐËâÏË Ô ÐÂÔÕÑÏÖ ÆÂÐÐÑÌ ÑÕÐÑÔËÕÇÎßÐÑ ÑÃÎÂÔÕË. ÃÔÖÔ ÔÎÎÂÕÐ ÊÇÐÇ ËÊÎÂÚÂÕÇÎß ÇÔÕÂÕÇÔÕÄÇÐÐÑ ÑÕÏÇÕ ÐÂ ÎÂÕÑÏ ÕÑÚÍË ÊÓÇÐËâ ÔÇ ÑÐÑÌ ÆÇÆÂ ÕÑ ÃÞÎË ÕÇÏÒÇÓÂÕÖÓÞ ÄÂ ÑÎÑÇÐ ÔÎÐÐÞÏ ÍÂÍ ÐÇÍ, ÐÂ ÊÐÂÚÇÐËËØ ÏÇÆÎÇÐÐÑ ÔÎÇÆÖÇÕ ËÊ ÖÓÂÄÐÇÐËâ ÆÄËÉÇÐËâ Ë ÏÑÉÐÑ ÔÎÇÆÑÄÂÕÇÎßÐÑ ÑÃÎÂÔÕË, ÔÎÂÃÑÌ ÔÄâÊË ÊÂÔÆÂ ÑÎÖÚÂÇÕÔâ ÄÞÓÂÉÇÐËÇ ÆÎâ ÔÂÏÑÅÑ ÔÎÂÃÑÅÑ ÕÇÏÒÇÓÂÕÖÓÐÑÅÑ ÕÂÍ ÔÍÂÍ ÃÄÇÑÐÐÑÌ $m_{eff}(f)$ (ÑÎÑÕÐÑÔÕß ÂÔÔÆÐÐÇÌ ÐÇ ÑÕÆÇÎßÐÞÌ ×ÑÐÎÂ f) ËÇÇÕ ÑÆËÐËÏ ËÏÏ $f \approx 0$ ÒÓË ÄÞÔÑÍËØ ÕÇÏÒÇÓÂÕÖÓÂØ, ÚÕÑ ÕÓÇÆÇÐÇ ÆÇÎÇ ÕÂÍ ÍÑÏ ÏÇÐÇÆÐÑÌ ÓÑÍÂ. ±ÓË ÑÕÐÑÔËÕÇÎßÐÑ ÕÇÏÒÇÓÂÕÖÓÂ ÂÔÍÐËÍÂÇÕ ÕÓÂÐÔËÆÑÐËÏË Ï ÒÓËÍÑÐÂÓÐÞÌ f, ÍÑÕÑÓÑÌ ÍÂÍÑÔÐÂÔÕÑÆÐÑ ÄÑÎËÄÐÑ ÄÑÆËÏÐÂÏÂÔ $f \approx 0$. °ÆÐÂÍÑ ÄÇÓÑâÕÐÑÔÕÑÏ ÆÂÍÂÊÂÕß Õ×ÂÊÂ $f \approx 0$ Ë ×ÂÊÇ $\langle f \rangle \neq 0$ Ä ÕÑÚÇÐËÇ ÍÑÐÑÔÕÐÑÏ ÄÓÇÏÇÐË ÑÎÑÕÐÑÔÕË ÆÇÆÇÎËÐÑ, Ë ÔËÔÕÇÏÂ ÐÂØÑÆËÕÔâ ÍÂÍ ÒÓÂÄËÎÑ ÔÑÔÕÑâÐËË.

¶ÂÕÑÄÞÌ ÒÇÓÇØÑÆ ÒÇÓÄÑÅÑ ÓÑÆÂ ÒÓÑËÔØÑÆËÕ ÕÇÏ ÔÂÏÞÌ ÑÕÕÐÑÔËÕÇÎßÐÑ ÆÑÎÅÑ ÄÞ ÒÓÑÐÑÔÕÔÕÄË ÊÂÚÇÐËâ ÒÑÏÑÔ×ÇÓÞ ÕÂÍ ÊÂÏÐÑÅÑ ÄÇÑÏÄÐÐÑÅÑ ÔÑÔÕÑÓÑÐÑÆÂÐÑÃÑÎÎÑÐÕÞ ÆÑ ÑÔÕÑÆÞÓÑÆÑ ÄÔÇÆÎË ÏÂÕÇÓËÂ ÄÑÕÑÔÂ ÒÑÕÑÔ ÐÂÐÎÂÆÑÏ ÐÂÆÕÑÂÐÑÏ ÕÂÕÑÂ ËÊ ÆÎÂÕÔÂ ÆÑÕÕÑÂÓÂÕÑÓÂÕ ÔÑÊÆÂÐËÇ ÄÎËÊË ÐÑÄÑÌ ×ÂÊÞ ÐÂÚÂÎÂ ÑÕ ÒÑÇÎÂÕÐÑ ÄÑ ÔÇÕË ÑÄËÏË ÍÑÆÇÎÇÔÔÂÎÐÑÓ ÆÑÓÑÄÑÌ ÒÑÊÔÑÎÂÏ ÍÑÐÑÔÕÂÕÂÕËÑ ÕÂÄÎËÂ ÐÂ ÆÑÕÔÕÂÔÇÐÇ ÑÃÎÂÔÕËÃÑÏ, ÑÕÐÑÔËÕÇÎßÐÑ ÒÑÆÔÕÂÄÂÕÑÌ ÔÄÇÕÂ ÑÃÞÚÐÑ ÑÍÇÎËÕÇÐÇÇ ÔÕÂÐÑÄËÕÔâ ÑÃÐÑÏ ÄÑÊ ÓÂÊÏÇÓÇÏ $100\ \text{G|W}^{-1} \approx 10^{-16}$ ÔÏ, ÕÂÑÂÍÑÇ ÔÑÕÑÎÐÂâ ÆÎâ ÕÇÏÒÇÓÂÕÖÓÞ ÏÂÍÑ ÔÎÑÐÑÐÑÔÕÇÌ ÃÑÍ ÄÂÕÂ $H^{-1} \approx 1$ ÏÏ, ÍÂÍ ÔÎÇÆÖÇÕ ËÊ (21). ÁÔÐÑ, ÚÕÑ ÔÂÍÑÇ ÔÑÔÕÑâÐËÇ ÄÑÊÐËÍÂÇÕ ÄÔÂÏÑÏ ÔÎÑÃÞÌ ÒÇÓÇØÑÆ ÄÂÐÐÞ ÃÑÎßÛÑÏ ÑÃÎÂÔÕË ÆÂÆÇÆÇÎËÐÑÌ ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË ÓÑÐÑÔÇÇ ÆÎÂÔÕÂÕÑÚÐÑ ÆÎâ ÐÇÃÑÎßÛÑÌ CP-ÐÂÓÖÛÇÐËâ ÆÑÍÎÂÆÇ ÆÇÏÂ ÐÇÆÂÎÇÍÑ ÑÕ ÕÇÍÂÊÂ ÔÎÂÃÑÏ ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË ÄÎËÇÎÑÄÞÃ ÆÂÎËÔÕÑÐÑÏ ÔÑÎÂÂ ÒÑ ÔÎÇÆÑÄÂÕÇÎßÐÑÅÑ ÔÕÑÎÍÐÑÄÇÐËÌ CP-ÐÂÓÖÛÇÐËâ ÓÂÊ ÄÑÂ ÐÑ ÑÕÐÑÔËÕÇÎßÐÑ ÔÂÏÂ ÃÑÎßÛÇ ÄÂÓËÑÐÐÂÕ ÆÑÇÕÂ ÄÑÎÑÐÇÐ ÃÑÊÆÑÂÏÂ ÏÇÆÎÇÐÑ ÑÕÑÐÑÔËÕÇÎßÐÑ 10^{-10}, ÍÂÍ Ë ÕÓÇÃÖÇÕÔâ.

¥Ñâ àÎÇÍÕÑÐÑÔÐÑÅÑ ÅÇÐÇÓÂÙËË ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË ÕÂÍ ÂÆÂÑÕÐÑÇ ÔÂÍÂÊÂÐÑ ÄÞÛÇ ÐÂÓÖÛÇÐËÇ (20) ÏÇÊÆÖ ÒÑÎÑÐÑÔÕß ÔÕÂÍÑÌ ÔÕÑÎÍ×ÂÊÑÔÂÐÂÄ ÕÇÏÒÇÓÂÕÖÓÇ ÒÑÏÑÔ ÑÃÞÚÐÑ ÇÔÕ àÎÇÍÕÑÐÑÔÐÑÌ ÕÇÏÒÇÓÂÕÖÓÂ ÒÓË ÒÓÂÄËÎÑÐÞ ÃÂÓËÑÐÐÑÌ ÂÔËÏÏÇÕÓËË ÐÂÔÍÑÎßÍÖ ÄÑÊÆÖÔÑÏ ÔÑÏÑÐÑÔÕË, ÚÕÑ ÑÎÂÍÂÄ ÆÂÇÕÔâ ÆÔÕÂÐÑÄËÕÔâ ÑÕÐÑÔÕÂÕÂÕËÑ ÕÇÏÒÇÓÂÕÖÓÂ ÂÔËÏÏÇÕÓËË ÂÃÐÂÆÂÕÂ ÒÑÎâ ÔÕÑ ÔÄÇÕÂ ÃÂÓËÑÐÐÞÌ ÔÎÑÃÑ ÊÂÔÎÇÆ ÄÂÓÑÔÍÂ, "ÊÂÍÂÆÂÕÇÂÐÞÌ ÂÔÕÂÐÑÄËÕ ÏÇÕÇÏÐÑÌ ÔÎÇÆÑÄÂÕÇÎßÐÑ ÃÞÔÕÓÑÄ ÒÇÓÇØÑÆ ÐÂ ÔÓÇÆÐËÇ ÆÇ ÔÇ ÓÇÆ ÔÂÍÑÌ ÔÑÎÑÄÞÌ ÕÇÏ ÆÑÕÔÍÑÐÇÐ ÒÑÓÑÕÂÕÂÐÐÑÌ ÐÇÊ ÔÎÖÚÂÇ ÆÂÐÐÑÌ ÔÎÂÃÑÌ ÆÂ£ ÑÎÖÚÂÇÕÔâ ÆÂÐ-

[5] ©ÆÇÔß ÐÑÕÕÂÓÐÑÔÕÑÆËÍ. ÐËËÇ.

[illegible]

$$V(\varphi) = -\frac{m^2}{2}|\varphi|^2 + \frac{\lambda}{4}|\varphi|^4.$$

[illegible]

$$|\varphi| \equiv (\varphi^\dagger\varphi)^{1/2} \qquad (22)$$

[illegible] $m^2 = \lambda v^2$ [illegible] $v = 247$ [illegible]

$$m_H = \sqrt{2\lambda}\, v. \qquad (23)$$

[illegible]

$$V_{\rm eff}(\varphi, T) = \frac{\alpha}{2}|\varphi|^2 - \frac{\beta}{3}T|\varphi|^3 + \frac{\lambda}{4}|\varphi|^4, \qquad (24)$$

[illegible] $\alpha(T) = -m^2 + \tilde g^2 T^2$ [illegible] $\beta = g^3/(2\pi)$ [illegible] $\tilde g^2$ [illegible] g^2, g'^2 [illegible] y_i^2 [illegible] g^3 [illegible] g'^3, $(2M_W^3/v^3 + M_Z^3/v^3)$ [illegible]

$$\beta = \frac{1}{2\pi}\,\frac{2M_W^3 + M_Z^3}{v^3}. \qquad (25)$$

[illegible] (24) [illegible] (22) [illegible] φ [illegible] $\alpha = 0$ [illegible] $m \lesssim T$,

$$f_{\rm Bose}(p) = \frac{1}{\exp\left(\sqrt{p^2 + m_b^2}/T\right) - 1} \simeq \frac{T}{\sqrt{p^2 + m_b^2}},$$

[illegible] $m_b \simeq g_b|\varphi|$ [illegible] g_b [illegible] b [illegible] $p \lesssim g_b|\varphi|$ [illegible]

$$f_{\rm Bose}(p) \simeq \frac{T}{g_b|\varphi|}.$$

[illegible]

$$f_{\rm Fermi}(p) = \frac{1}{\exp\left(\sqrt{p^2 + m_f^2}/T\right) + 1}$$

[illegible] m_f^2 [illegible] $\varphi^\dagger\varphi$ [illegible]

[illegible] $\alpha = 0$, [illegible] $\alpha = 0$; [illegible]

$$V_{\rm eff}(\varphi, T) = -\frac{\beta}{3}T|\varphi|^3 + \frac{\lambda}{4}|\varphi|^4.$$

[illegible] $V_{\rm eff}$ [illegible]

$$\varphi \sim \frac{\beta}{\lambda} \sim \frac{g^3 T}{\lambda}.$$

[illegible] T [illegible]

$$\beta > \lambda. \qquad (26)$$

[illegible] (23) [illegible] m_H^2, [illegible] β [illegible] $2M_W^3 + M_Z^3$. [illegible] (26) [illegible] (23) [illegible] (25), [illegible] $m_H < 50$ [illegible]

[illegible] 100 [illegible] $M \sim 300$ [illegible] [41–43].

[illegible] CP-[illegible] CP-[illegible]

[6] [illegible] $m_H > 114$ [illegible] [38–40] [illegible] (24), [illegible] (24) [illegible] m_H.

£ÔÒÑÏÐËÏ, ÚÕÑÒÇÐÍË"ÔÆÇÎÂÐÞËÊØËÅÅÔÑÄÔÍÊØÇÌ. ¿ÕÑÑÃÔÕÑÇÕÔÄÑÍÂÊÞÄÂÇÕÚÕÑÇP-ÐÂÓÖÛÇÐÊÆÑÎ-ÉÐÑÒÓÑÊÔØÑÆÊØÊÅÅÃÑÍÑÏ ÔÇÍÕÑÓÚÕÑÃÑÊÏÑÊÐÑ ÕÑÍÎßÍÑ ÒÓËÐÂÎËÚËÄ ÕÇÑÓËÊÇÔÍÑÎßÍËØØËÅÅÔÑÄÔÍËØ ÒÑÎÇÌ.

ªÕÂÍ, ÏÑÉÐÑ ÔÍÂÊÂÕßÚÕÑÀÎÇÍÕÓÑÎÔÃÃâ ÅÇÐÇÚÊâ ÃÂÓËÑÐÐÑÑÔÊÏÇÕÓËÊÕÇÃÖÇÕÖÜÇÕÕÃÇÅÑÓÑÂÔÛÊÇÐËâ³ÕÂÐÆÂÊÓÑÌ ÏÑÆÇÎË, ÒÓËÚÈÏÂÔÔÞÐÑÃÞØÚÂÔÕÈÙ ÆÑÎÉÐÞÎÇÉÂÕßÄ ÑÃÎÂÔÕÊ00ë300¤à£. ±ÑàÕÑÏÖÕÂÍÑÌ ÏÇØÂÐËÊÎÃÖÆÇÕÕÐÑÑÊÐÂÚÕÑÑÆÇÕÉÆÊÐÊ ÑÒÓÑÃÇÓÅÐÖÇãÍÔÒÇÊÇÇÐÕÃÏËÐÂLHC. ±ÑÆÚÇÓÍÐÈÑÆÐÂÍÑÚÕÑ àÎÇÍÕÓÑÔÍÂÃÏ ÃÂÓËÑÅÇÊÕÕÑÐáÆÞÇâÄÎâÇÕÕÇÆËÐ-ÔÕÄÇÐÐÞÃÑÊÏÑÉÐÞÏ ÔÙÇÐÂÓËÇÍÕÂÔËÄÑÊ ØÑÓÑÛÑ ÑÃÑÕÐÑÄÊÃÐÌ ÂÍßÕÇÓÐÂÕËÄÃÕÌÖÉËÕÍÕÇÒÕÑÅÇÐÇÊÊÕ; ÎËÕÇÓÂÕÖÖÕÇÕÉÆÕÇÊÓâÆÊÓÖÅÊÕÕÑÉÏÑÉÐÑÕÕÇÌ.

4. ©ÂÍÍáÚËÕÇÍßÐÞÇÊÂÏÇÚÂÐËâ

²ÂÔÔÏÑÕÓÇÐÞÇÊÆÇÕÊÆÇ ÄÒÑÍÐÇÑÅÖÕÑÍÂÊÂÕßÔÐÇ ËÏÇáÚËÏÊ ÑÕÐÑÛÐÇÊâÍ ÆÇÌÔÕÄËÕÇÍÔÕÐÊÏÞ ÏÑÉÇÌ ÕÑÍßÍÑ ÄÞÆÄÊÅÃÕß ÅÊÒÑÕÇÞ Ñ ×ËÊÊÍÇ ÊÂ ÒÓÇÆÇ ÄÍ Ë ³ ÕÃÐÆÂÓÕÐÑÌ Ï ÑÆÇ Ë Ë ÇÊ ÓÑÍ Ë Ä ÓÃÐÐÇ £ÕÇ ÇÐÐÑÌ. ¶ ËÊÊÍÂ Ä ´ à£-ÑÃÍ ÂÕÕÊ àÐÇÓÅÊÌ Ï ÑÉÇÕÍÂÓÆÐÂÍßÐÑ ÑÕÍ ËÚÂÕßÂ ÑÕÕÑÌ ×ËÊÊÍ Ë, Í ÍÑÕÑÓÑÌ Ï Þ ÒÓÉÄÞÍÍ Ë. ¯ÂÒÓËÏÇÓÐÇÊÔÍÍáÚÇÐÑÚÕÑÃÔÕÕÃÕÒÑÓâÆÍÂ´à£ ì àÕÑ ÐÇ ÕÑÍßÍÑ àÍ ÇÍÕÑÕÃÃÞÌ, ÐÑ Ë ÅÓÄÄÕÃÙÉÑÐÐÞÌ Ï ÂÔÚÕÃÃ. ´ ÄÍÑÇ ÄÑÉÏ ÑÉÐÑ Ä ÏÑ ÆÇÂ Ø Ô ÆÑÕÑÎÐÉÕÇßÐÞÏË ÒÓÑÕÕÓÂÐÔÕÐÄÇÊÐËÊÏÇÓÇÐËâÏÉÃÑßÛÑÃÑ ÓÂÊÏÇÓÂ, Ä ÍÑÕÑÓÞØÄâÊÒÎÂÐÍÑÄÓÍÑÏÂÔÛÕÃÃÔ×ÖÐÆÂÏ ÇÕÕÎßÐÞÏ ÅÓÄÄÕÃÙÉÑÐÐÞÏ Ï ÄÕÛÕÃÄÑÏ ÉÂÄÉÕÕ ÑÕ ÑÃÝÈÏÂÆÑÕÑÉÕÇÎßÐÞØÉÊÇÓÇÐÉÌÕÄÍÚÕÑ×ÖÐÆÂÏÇÕÂÍßÐÞÌ ÏÂÔÛÕÃÄàÐÇÓÅÐÂØÑÆÉÖÕÂ£-ÑÃÍÂÔÕÉÕÑÒÓÑÉÉÑÌÆÈÕÂÂÂÍÑÍÍÂÌÆÇÓÂØÍÄÂÉÕÃÙÉÇÊÄÞÔÑÑàÐÇÓÅÇÕÉÚÇÔÍÑÓÂÔÛÉÕÇÍÇ (ÍÄÍÑÄÞÏ, ÄÑÉÍÑÉÐÑ, âÄÍâÇÕÔâ ÕÇÑÓÉâÒÒÇÕÕÐ). ÕÑÚÍÉÊÓÞÉâÍÑÔÍÑÍÑÅÉÉ,ÕÂÍÑÇ ÑÕÍÓÞÕÉÇÓÉÄÇÊÉ ÒÇÓÇÔÍÑÕÕÐÑÅÉØÒÓÇÆÕÕÔÄÍÇÉÉÍ ÑÓÂÐÐÇÊÔÇÍÇÐÐÑÌ. ÂÒÓÉÍÇÓÐÇÑÃØÑÆÉÄÑÒÆÇÕÂÔÔÍÄÕÓÉÄÂÉÕ×ÎâÙÉâ (ÇÔÍÉÐÂÐÇÌÐÂÔÕÄÉÄÂÉÓÇÉÉÍÇ ÐÉÊÍÉØÒÌÑÕÐÑÕÇÌàÐÇÓÅÉÉÍÉ Ä ÓÇÉÉÍÇÍÄÂÐÕÑÑÌ ÅÓÄÄÉÕÂÙÉÉÂÍÓÉÍÄ ÎßÐÂâ ÕÇÌÒÇÓÂÕÕÐÂ ÑÃÞÚÐÑÌ ÅÑÓâÚÇÕÕÃÆÉÄÕÆÇÕÅÓÂÐÉÇÐÄÇÍÉÚÉÐÑÌÒÑÓâÆÍÂ 1´à£, ÕÂÍÚÑÕÐÉÏÐÂâÏÄÕÇÓÉâÉ ÃÂÓÉÑÐÐÄÃÉÏÇÕÓÉâ ÆÑÎÉÐÞÄÕÆÇÕÃÓÂÉÑÄÄßÔÂÉÃÑ ÒÓÉÔÓÄÄÐÉÕÇÎßÐÑÌ ÐÉÉÍÉØÕÇÌÒÇÓÂÕÕÇÍÉÄÑ ÄÍÄÂÐÕÑÄÑ-ÅÓÄÄÉÑÐÐÑÌ ÓÇÉÉÇ. ¯ ÇÑÃÞÚÂÌÐÑÐÕÇÉÞÏ ÒÓÇÆÕÕÂÄÃÇÕÔÍÇ-ÆÑÄÂÐÉÕÇÔÍÑÑÅÉÉÄ ÖÔÍÑÄÉâØÉÍßÐÞØÄÂÐÕÑÄÑ-ÅÓÂÄÉÕÂÙÉÑÐÐÞØ×ÇÍÕÑÄÐÂÑÔÐÑÄÇÑÕÕÇÄÉØ ÍÑÍÍÂ Ì-ÆÇÓÐÞØÉÂÐÐÞØÇÕÂ ÒÇÓÕÒÇÍÕÉÄÄÑÉÄÇÌ, âÄÍâÇÕÔâ ÔÍÉÉÚÍÑÌ ÓÄÆÉÉÐÑÚÕÑÄÞÄÞÕßÓÇÂÍÉÕÕÉÄÐÑ

¢ÑÍÇÇÄÇÓÑâÕÐÚÕÑÐÂLHC ÄÖÆÇÕÐÂÓÇÐÑÚÕÑ-ÕÑ ÔÑÄÕÇÐÑÄÑÇÑÚÉÌ ÕÇÑÓÇÕÉÉÐÇÆÑÅÂÆÞÄÕßª ÍË, ÐÂÑÄÑÓÑÕÇÆÇÕÐÂÓÇÐÑÐÂÕÑÍßÍÑÄÍÑ, ÚÕÑÐÇÑÄ-ØÑÆÉÍÑÄÖÆÇÕÕÇÓßÉÐÕÂÄÂÐÂÕÑÚÍÉÉÓÇÐÉÄÂÐÕÕÑ-ÐÑÅÑÕÐÉÐÉÒÂ£ ÍáÄÑÍ ÔÍÖÚÂÇÇÊÖÍßÕÂÄÍÕÇÓÉÍÇÐ-ÕÑÄÐÂLHC ÔÖÜÇÔÕÄÇÆÉÕÑÑÄÕÐÂÚÉÒÓÇÆÕÕÂÄÍÇÑÐÉâ ×ËÊÊÍÇÉÍÑÔÍÑÍÑÅâÉÆÇÑ ÐÇÉÔÍÍáÚÇÐÉÇ.

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[illegible] $u_n u^n = 1$. [illegible] $C(x;u)$ [illegible]

$$\& \ddot{y}\, m^2 + \frac{b}{2}\, aM^{mn}M_{mn}\quad C(x;u) = 0; \qquad (1.1)$$

$$\ddot{y}\, aM^{il}M_l^{\,j} q_i q_j \ddot{y}\, \&\quad C(x;u) = 0; \qquad (1.2)$$

[illegible]

$$M_{ij} = u_i\frac{\partial}{\partial u^j} - u_j\frac{\partial}{\partial u^i}:$$

[illegible] $u_n \to u_{nm} = u_{mn}$ [illegible] (1.2) [illegible]

$$C(x) = \sum c_{m_1\dots m_{s_1};\,n_1\dots n_{s_2};\,\dots}(x)\, a^{m_1}_{\ddot{y}1}\cdots a^{m_{s_1}}_{\ddot{y}1}\, a^{n_1}_{\ddot{y}2}\cdots a^{n_{s_2}}_{\ddot{y}2}\cdots|0\rangle;$$

[illegible]

$$Q\,C(x) = 0; \qquad (1.3)$$

[illegible] $Q^2 = 0$, [illegible] $dj\,c\,i = Qj\,ci$. [illegible] u^n [illegible] $(i = 0; 1; 2; \dots; 1)$ [illegible] $m^2 = 1/a^0$. [illegible] $a^0 \to 1$, [illegible] [16]. [illegible]

[illegible] [17] [illegible] 1978 [illegible] $j_{n_1\dots n_s}$, [illegible] $Z^{n_1 n_2} Z^{n_3 n_4} j_{n_1\dots n_s} = 0$. [illegible]

$$dj_{k_1\dots k_s} = q_{(k_1} e_{k_2\dots k_s)}; \qquad e^m{}_{mk_3\dots k_{s-1}} = 0:$$

[illegible] $e(x)$ [illegible]

[illegible] $x^n + e^n(x)$.

[illegible] 3/2 c_{na}, [illegible] [8, 9], [illegible] $e_a(x)$ [illegible] [13].

[illegible] $s > 2$, [illegible] [18], [illegible] S-[illegible] [19].

[illegible] 1980-[illegible] [20–22], [illegible]

$$J_s = \sum_{n=0}^{s} a_n\, \partial^n f\, \partial^{s-n} f:$$

[illegible] [23], [illegible]

$$L^3 = \sum_{p;q;r} (D^p j)(D^q j)(D^r j)\, t^{p+q+r+1=2d-3}:$$

[illegible] r [illegible] $m^2 = a^0$. [illegible]

¹ [illegible] [15] [illegible]

ÒÑÎ â, ÑÕÔÕÕÕÔÃÖÇÕ ÐÇÊÂÄËÔËÏ ÞÌ Ï ÂÔÕÑÄÞÌ Ï ÂÔÛ ÕÂÃ. ¯ÇÑÉËÆÂÐÞÐ ÄÞØÑÆËÊ àÒÑÌ ÔËÖÔÂÙËÐÊÔÑÕÑÐÆ ÓÂÔ-ÔÎÑÓÇÐËÊ ÕÇÑÓËÆ ÖÓÑÕÔÓÂÐÕÑÕÇÕ ÑÃÄÑÏÓÆÊËÊÐÑÌ, M   l ^ r ÿ 1, ÊÂÆ Ä ÜÕÏ ÐÇÕÓËÄËÊÎ ßÐÞÌ Ï ÂÔÛ ÕÂÃ, ÐÇ ÔÄÂÊÂÐÐÞÏ ÑÎÂÔÕÑÂ ÏÂÔÛÕÃÂÑÏÕÇÑÓËË.

£ ÓÇÊÕÎßÕÂÕÇ ÃËÓÂÆ ÍÂÚÇÔÕÂÐÂËÃÑÎÇÓËÏÇÕ-ÓËÚÐÑÅÑ ÓÑÕÔÕÓÂÐÕÔÃÂÐÕÏÐÞÏ ÕÇÐÊÑÐ ÍÓËÄËÊÐÞ ÒÓÑÔÕÓÂÐÕÔÕÃÂÐÕÑÕÇÓ (AdS) ËÎË ÂÐÕË-ÆÇ-³ËÕÕÇÓ (AdS) (ÆÎâÑÒÓÇÆÇÎËÐÐÑÔÕË ÆÇÂÃÑÃÑÓËÕÑÔÓÑÕÔÕÓÂÐÕÔÕÃÑ ÂÐÕË-ÆÇ-³ËÕÕÇÓÂ), ÏÑÉÐÑ ÒÑÍÂÊÂÕß ÚÕÑ, ÐÇ ÆÑÒÖÔÕÎÂâ ÒÕÑÔÎÇÆÑÄÂÕÇÎÑÌ ×ÑÓÏÖÎËÓÑÄÊË ÒÓÑÔÕÓÂÐÕÔÕÃÂ ÇËÐ-ÍÑÄÂÍÑÄÂÊÎÂËÃÑÓÑÄÑÃÇÑÓËÂÞÔÕËØ ÔÒËÐÑÄ ÆÑÒÖ-ÔÕÂÇÕ×ÑÓÏÖÎËÓÑÄÊÖ Ä ÒÓÑÔÕÓÂÐÕÔÕÄÇ AdS [24]. ´ÂÍÇ ÑÃÑÃÜÇÐËÇ ÐÇ ÕÑÎßÍÑ ÒÑÊÂÑÎËÎÑ ÑÃÑÕÊË ÕÇÑÓËÏÞ ÊÂÓÓÇÕÂÐÔÒÓÂÄÆÇÐËÂÑÆÔÕÇÎËÑÎÑ ÒÓÑÔÕÓÂÐÕÔÕÃÂÞ, Ñ Ë ÑÍÂÊÂÎÑÔß ÊÂÅÑÔÐÂÍÑÌ ÇÜË ÐÇÊÂÄËÔËÏÑÌ Ä ÕÑ ÄÓÇÏâ ÅËÒÑÕÇÊËÇ Ñ ÑÃÄÇÕÕÕÃËÇ ÆËÍÑÐÂ×ÑÓÏÞË ÕÇÑÓËâÏË Äd ËÊËÏÇÓÇÐËâÏË ÕÇÑÓËÇÌ d ‡ 1†-Ï ÇÓÐÑÌ ÒÓÑÔÕÓÂÐÕÔÕÃÇ ÐÇÖÏÇÄÑÎÇÄËÊÐÞ (AdS/CFT) [25ë27].

2. ´ÇÕÓÂÆÂÐÂÎÑÓÏÖÎËÓÑÄÍÂ ÍÎáÚ Í ÔËÏÇÕÓËË

CËÏ ÏÇÕÓËË ÖÆÑÃÐÑ ËÊÔÂÕß ÑÒËÔÞÄÂâ ÍÂÎË ÃÓÄÑÃÚÐÞÇ ÒÑÌ â ÆË××ÇÓÇÐÙËÂÎßÐÞÌ Ë ×ÑÓÏ ÂÏ Ë ÕÑ ÊÐÂÚÇÐËâÏ Ë Ä ÕÑÏ ËÎ Ë ËÐÑÌ ÂÎ ÅÇÃÓÇ ÔËÏ Ï ÇÕÓËË. ´ ÂÍ , ÒÑÎ Ç ÕÇËÐÂ 1 ÑÒËÔÞÄÂÇÕÔâ 1-×ÑÓÏ ÑÌ $A_{n_j}^i$ (m, n ^ 0; 1; 2; 3) ÕÑ ÊÐÂÚÇ-ÐËâÏË Ä ÂÎÅÇÃÓÇ ÁÐÂÅ ë®ËÎÎÔÂ g. ³ÒËÐ 2 Ä ×ÑÓÏÖÎË-ÓÑÄÍÇ ÇÏÎâ ë¬ÂÓÕÂÐÂÑÒËÔÞÄÂÇÕÔâ ÕÓÂÆÇÑÍ ÎËÎÑÓÇÐ-ÙÇÄËÑÂÏ Ä âÊÐÑÕÔß e_n^{ab}. ±ÑÎÇÊÐÑÑÕÑÉÆÇÔÕÃËÕß $e_n^{\,a}$ Ë o_n^{ab} Ô Í ÂÏ ËÃÓÑÄÑÃÚÐÞÏ Ë ÒÑÎ âÏ Ë ÂÎ ÅÇÃÓ - Ë ÅÓÔÕÒÞ ± ÓÂÐÍ ÂÓÇ iso.1; 3† ËÎ Ë ÅÓÔÕÒ ÆÇ ³ ËÕÕÇÓÂ SO.d; 1† ËÎ Ë ÂÐÕË-ÆÇ-³ËÕÕÇÓÂ SO.d ÿ 1; 2†. ±ÑÎÇ ÔÒËÐÂ 3/2 $c_n^{\,a}$ ÆÑÒÖÔ-ÍÂÇÕÇÔÕÇÂÇÐËÇÆÎÂÐÕÇÓÒÓÇÕÂÎÂÍÂÎÂÓÑÄÑÃÚÐÑÅÑ ÒÑÎ â, ÔÄâÊÂÐÐÑÅÑ ÔÇÐÇÓÂÕÑÓÂÏËÔÖÒÇÓÔËÏÏÇÕÓËËÓÂ Q_a Ä ÔÖÒÇÓ-ÔËÏÏÇÕÓËÚÐÑÌ ÓÂÔÛËÓÇÐËËÂÎÅÇÃÓÞ ÔËÏÏÇÕÓËË ±ÓÂÐ-Í ÂÓÇ ËÎ Ë AdS. (° ÕÏ ÇÕËÏ , ÚÕÑ dS-ÂÎ ÅÇÃÓÂ SO.d; 1† ÐÇ ÆÑÒÖÔÍÂÇÕ ÔÖÒÇÓÔËÏÏÇÕÓËÚÐÑÅÑ ÓÂÔÛËÓÇÐËâ)

´ÇÕÓÂÆÑÊÐÑÇ ÃÐÂâ×ÑÓÏÖÎËÓÑÄÍÂ ÆÎâ ÔÄÑÃÑÆÐÞØ ÒÑÎÇÌ ÒÓÑÊÂÃÑÐÑÅÑ ÔÒËÐÂ [28ë30] ÒÓËÄÑÆËÕ Í ÐÇÑÃØÑ-ÆËÏÑÔÕË ÄÄÇÆÇÐËâ ÍÂÎËÃÓÑÄÑÚÐÞØ ÃÂÃÑÓÑÄ ÔÑÎÇÌ:

$$e_n^{a_1\ldots a_{s-1}};\ o_n^{a_1\ldots a_{s-1};b};\ \ldots;\ o_n^{a_1\ldots a_{s-1};b_1\ldots b_t};\quad 0 \le t \le s-1;$$

ÚÕÑ, ÔÄÑÃÑÆÑÚÇÓÇÊ ÔÕÑÔÕÖÐÑÕÔÕÄÂ ÓÂÔÛËÓÇÐÐÑÌ ÔËÏÏÇÕ-ÓËË, ÔÄâÊÂÐÐÑÅÑ Ô ÔÑÎÇÌ ×ÆÑÓÏËÓÑÄÂÐËÇ ÒÑÎÇÌ ÔÒËÐÂ

$$e^{a_1\ldots a_{s-1}};\ e^{a_1\ldots a_{s-1};b};\ \ldots;\ e^{a_1\ldots a_{s-1};b_1\ldots b_t};\quad 0 \le t \le s-1:$$

(¬ÂÍ ÒÑÎâ, ÕÂÍ Ë ÒÂÓÂÏÇÕÓÞ ÔËÏÏÇÕÓËË âÄÎâáÕÔâ ÕÇÐÊÑ-ÓÂÏË ÔÑ ÔÄÑÌÔÕÄÂÏË ÕÇÑÓËË ÑÕÐÑÔËÕÇÎßÐÑ ÒÇÓÇÔÕÂÐÑÄÑÍ ËÐÆÇÍÔÑÄ Ë b, ÒÑ ÍÑÕÑÓÞÏ ÑÐË ÂÐÕËÔËÏÏÇÕÓË-ÊÑÄÂÐÞ, Ë ÅÑÃÑÅÑ ËÊÊÂÆÇÐÑÄÂ b ÔÑÕÇÓÎËÐÆÇÍÔÑÄ ÆÎâ ÕÇØ ÐÖÎ ß.)

±ÓÑÔÕÇÌÛËÏ ÂÐÂÎÑÅÑÏ ÑÃÞÚÐÞØ ÔËÏÏÇÕÓËÌ ÐÂÃÑÓÑÏ ÒÂÓÂÏÇÕÓÑÄ ÒÓÇÑÃÓÂÊÑÄÂÐËÌ ÐÂÐÂÆÑÃËÎÎ ÔÎÖÚÂâ ÚÕÞÓÇØÏÇÓÐÑÌ ÕÇÑÓËË [31]. ³ÒÇÏÕÑÓ ÔÒËÐÑÄ ÑÃÓÂÊÖ-ÐÑÌ ÕÇÑÓËË ÖÓÑÄÐâ ÑÍ ÂÏËÐÂÆÂÕß ÔÒËÐÑÄ ÂÍÂÆÂÐÑÌ ÔËÏÏÇÕ-ÓËÇÌ, ÔÑÆÇÓÉËÕ ÔÒËÐÞ ÂÔÇØ ÔÄÑÃÑÆÐÞØ ÒÑÎÇÌ ÔÒËÐÑÄ, s ^ 0; 1; . . . ; 1 ; Ä ÕÑÏ ÚËÔÎÇ ÑÕÔÑÄÄÑÕÔÕÄÂÐÕÐÑ ÔÇÑÍÕÑÓÖ ÔÒËÐ ÑÓÇ-ÕÕÂÃÇÎÇÍÄÂÐÑÃÂÇÕÔâ ÊÂÐÑÂÍÇÚÇÐÐÑÍÑÅÑ ÍÂ ÇÐÊÂÕÑÓÅÑ.

°ÆÐÂÏ ËÊÂÄÂÉÐÞØ ÔËÏÔÕÄÂ ÔËÏÏÇÕÓËÚÐÞØ ÒÑÎÇÌ ÔÒËÐÑÄ âÄÎâÇÕÔâ ÕÑ, ÚÕÑ ÒÑÎâ ÔÑ ÔÒËÐÑÏ s ^ 0; 1; 2, ÒÓÇÑÃÓÂ-ÊÖâÕÔâ ÒÑ ÒÓÇÑÃÓÂÊÑÄÂÐËâÏ ÔËÏÏÇÕÓËË ÒÑÎÇÌ ÔÒËÐÑÄ. £ ÚÂÔÕÐÑÔÕË, ÔËÏÏÇÕÓËÚÇÔÍËÇ ÍÑÏÒÑÐÇÐÕÞ ÂÓÅÂÖÓËÂÐÕÐÑÅÑ

ÔÏÞÔÎ Ä ÓÂÏÍÂØ ÍÂÍÑÌ-ÓÂÃÑÆÂ ÕÇÑÓËË ÒÞÔÑÊÑÄÞØ ÒÑÎÇÌ ÔÒËÐÑÄ. µÇÎ ÔÂÍÑÌ àÒÑÌ ÑÃÕÑÃÂÕÇÎßÐÞÌ ÓÂÆ ÂÚÇÐËâ ÓÂÔÕÂ ÂÃÇÃÎÑÃÂÕÇÎÇÌ, ÎËÐÂÃÑÐÃÊ ÂÓÃË×ÇÓ ÓÂÐÏÎÂÑÏ ËÇÒÖÎÍÕÍ ÕÑÚÍÂÎÇ ÒÓÑÔÕÓÂÐÔÕÃÂ ÔÇÑÇÆÇÍ ÐÇÏÇÇÃÐËÂÄÂÓËÂÐÕÐÑÌ ÍÑÐÇÏÑÏ Ä ÍÂÎËÃÓÑÄÑÚÐÑÌ ÕÇÑÓËË ÒÑÎÇÌ ÔÒËÐÑÄ, ÒÓËÊÐÂÐÑÇÍÑ-ÍÂÎßÐÑÔÕË ÔÑÔÕÇÆÇÐ ¬ÑÕÇÚÐÑÏÇÐÆÐÇÌ ÒÑ ÆÂÎÂÇÇ ÇÆÐÞÌ ÔÏÞÔÎ ÒÑÓÑÄÂÏÃÂÕßÕ ÔÂÍÑÅÑ ÅÊËÂ ÕÐÐÑÌ ÑÃÞÚÐÞÌ ÒÑÎÇÌ ÔÒËÐÑÄ s 4 2, ÔÄâÊÂÐÐÞÕ ÅÓÂÄËÕÂÙËÑÐÐÑÅÓÂÄËÕÑÔÕÇÎÂÙËÇ ÔËÏÏÇÕÓËË ÑÔÑÄÂÚÂÕßÃÑÎÇ ÄÞÔÑÍÑ-ÔÕÄÂÞË (ÎÂÍÎËË) ÒÑÔÕÇÔÒÑÐÐÂÞÔÏÂÓÖÛÇÐËÂ ÔËÏÏÇÕ-ÓËË ÄÞÔÞØ ÔÒËÐÑÄ ÆÑÔÑÐÇÚÐÞÌ ÑÐÇÚÐÞØ ÒÑÆÅÓÖ, Ä ÕÑÚÐÑÔÕË ÄÇÚÂ ÔÂÕÑÓÞ ÑÃÇÇÌ ÕÇÑÓËË ÑÐÑâ, ÓÂÔÔÏÂÕÓË-ÓËÄÂÇÏÑÏ ÔÑÄÑÇÏÇÐÑÌ ÕÇÑÓËË ÒÇÓÇÆÂÍÕÍÑÏÇÕÇÃÓÂÎßÐÞØ ÄÊÂËÏÑÆÇÏÕÂË. ´ÂÍÑÌ ÔÕÞÇÂÔËÔÑÐÑÔÕßÃÑÔÕÑÄÂÕßÕ ÄÖÇÕÂÓÔÕÇÐÇÍ ÍÑÔÑÓÑÌ ÒÔÑÓÑÃËÏÞ ÇÊÕÓÅÂÎÇÌÇÎ ÕÇÑÓËË ÔÑÎâ ÆÇÐÇÉÐÞ ÑÕÂÚÖÕÑÓÞ ÍÐàÐÇÐÔÇÚËÂÎßÐÑÌÑ ÒÓÇÃÎËÇÌÇÐÇÍÑÔÕÑÓÑÌ ÐÇÍÑÎÑÅÂÎßÐÑÌ ÕÇÑÓËË. ´Ç Ñ, ÚÕÑ ÔËÏÏÇÕÓËË ÄÞÔÞØ ÔÒËÐÑÄ ÑÄÇÓÏÇÚÂÄâÕ ÒÑÎâÄÔÇÏÇÕÓÞÐËË ÍÂÎËÃÓÑÄÑÚÐÞØ ×ÂÊÇÐÐÑÅÑ ÔÒËÐÑÄ, ÔËÏÏÇÕÓËÂ ÄÞÔÞØ ÔÒËÐÑÄ, ÕÑÎßÍÑ ÒÓËÊÐÂÕ ÐÇÆÑÔÕÂÕÑÚÐÞÎ ÑÐÑÔÇÎËÂÄÇÕÓÂËÆÇÐÕÞÏËÎÑÊÇÎ. ´ÇÏ ÐÇÕÇÐÇÕÐÞ ÒÓÇÆÒÑÎÂÅÂÇÏ, ÚÕÑ ÎÂÅ Ë ÎâÃÂâ ÕÇÑÓËâ ÓÂÏÍÂØ ÅÓÂÄËÕÂÙËÑÐÐÞÔÑÐÂÖÎËÇ ÄÞÔÞØ ÔÒËÐÑÄ ÆÑÎÇÉÐÂ ÃÞÕßÑ×ÑÓÏÖÎËÓÑÄÂÐÂ ÒÑÄÔÑÐÇÆ-ÐÂÕÑÐÑ-ÆÇÍÇÐËÏÑÐÑÄ ×ÑÓÏÇ Ä ÔÑÅÎÂÔËË Ô ÆÑÓÂÆÇÐÑÅÑ ÂÍË-ÄÂÎÇÐÕÐÑÔÕË ÊÂÆÂÚË ÒÇÓÇÔÔÏÂ ÍÂÎËÃÓÂ ÍÑÏÇÎ ÍÑÏÇ-ÎËÊË ÆË××ÇÓÇÐÙËÂÎßÐÞØ ×ÑÓÏ ¬ÂÓÕÂÐÂ. ¬ÎÂÚÇÄÞÏ ÔÄÑÌÔÕÄÑÏ ×ÑÓÏÂÎËÊÏÂ âÄÎâÇÕÔâ ÕÑ, ÚÕÑ ÐÂÐÕË-ÔËÏÏÇÕÓËÚÐÞÌ ÓÂÊÄÇÆÇÐÑ ÕÇÑÓËÇÌÒÑ ÔÒËÐÇÔËÏÏÇÕÓËËÚÐÞØ ÕÇÐÊÑÓÑÄ

$$q_{\%_1}A_{n_2\ldots n_{p+1}}\check{S} \tag{2.1}$$

ÂÄÕÑÏ ÂÕÇÚÇÔÍË Ñ ÍÂÊÞÄÂÇÕÔâ ÍÑÂÄÂÓËÂÐÕÐÞÏ Ë, ÐÇ ÐÇÉ-ÆÂÑß ÄÑ ÄÄÇÆÇÐËË ÔËÏÑÄ ¬ÓËÔÕÑ××ÇÎâ, ÒÑÔÍÑÎßÍÖ ÒÑÔÎÇÆÐËÇ ÆÇÌÔÕÄÐÑ ÏÑÅÖÕ ÃÞÕß ÂÃÔÑÓÃËÓÑÄÂÐÞ ÕÇÑÓËÚÐÞÌ Ë ÕÑ ÐËÉÐËÏ ËÐÆÇÍÔÑÏ Ë, Í ÂÍ ÕÑ ÇÔÕÂÕËÇÕ ÄÞÒÑÆÂÄâ Ñ ÕÊË ÄÞÓÂÉÇÐËË, ÒÑÎÇÐÑÕÔß ÂÐÕËÔËÏ Ï ÇÕÓËÊÂÙËÇÌ ÒÑ ÏËÉÐËÏ ËÐÆÇÍÔÂÏ n_i. ¬ÑÒÖÎÍÕÐÂâ×ÑÓÏÂ ÊÂÒËÔË (2.1)

$$dA;\quad d ^ dx^n\frac{q}{qx^n};\qquad A ^ dx^{n_1} \wedge \ldots \wedge dx^{n_p}A_{n_1\ldots n_p}$$

ÆÑÔÕËÅÂÇÕÔâ ÕÇÏ ÕÇÏ ÄÄÇÆÇÐËÇÏ ÂÐÕËÍÑÏÏÖÕËÓÖáÙËØ ÔËÎ-ÄÑÎÑÄ

$$dx^m \wedge dx^n ^ -dx^n \wedge dx^m:$$

¸ ÇÕÎÂ ßÐÞÌ ×ÂÍÕ, ÄÞÓÂÉÂâ ÜËÌ ÔËË ÇÕËâ ÄÕÑÏ ÞØ ÒÓÑËÊÄÑÆÐÑÊÏÇÕÓËÚÐÑÌ, ÚÕÑ

$$d^2 ^ 0: \tag{2.2}$$

£ÔÎÇÆÔÕÄËÇ (2.2) âÃÎâÇÕÔâ ÒÂÒÓÂÄËÎÑÐÑÔÕËÌ F ^ dA ÑÍÂ-ÊÞÄÂÇÕÔâ ÍÂÎËÃÓÑÄÑÚÐÑÌ ËÐÄÂÓËÂÐÕÐÑÌ,

$$dA.x† ^ d\epsilon.x†;\qquad dF ^ 0:$$

¯ÇÎÂÄÇ ÇÄÑ ÑÃÑÃÜÇÐËÇ ÆÑÔÕËÅÂÇÕÔâ ÖÆÂ ÎËÐÇÐËÇÌ ÍÑÂ-ÓËÂÐÕÐÑÌ ÓÂÔÛËÓÇÐËÏ:

$$d\,! \;D ^ d ‡ o;\qquad o.x† ^ dx^n o_n.x†;$$

ÅÆÇ ×ÑÓÏÂ[2] o ÒÓËÐËÏÂÇÕ ÊÐÂÚÇÐËâ Ä ÇÐÇÔÕÐÑÏ ÂÕÑÓËÚ-ÐÑÌ ËÎ Ë ÑÓÕÑÅÑÐÂÎÐÑÌ ÂÎ ÅÇÃÓÇ ì Ä ÓÂÊÏ ÂÓÕÑÔÕË ÄÂÇÇÕ ÑÏ ÔËÏÏÇÕÓËË ÒÑÎÇÌ ÔÒËÐÑÄ

[2] p-×ÑÓÏÑÌ ÐÂÊÞÄÂÇÕÔâ ÒÑÎËÐÑÏ ÑÕ ÇÕÇÐÇÐËÑÕ dx^n ËÎË, ÚÕÑ ÍÂÍËÎÂ-ÎÇÐÕÐÑ, ÂÐÕËÔËÏÏÇÕÓËÚÐÞÏ ÕÇÐÊÑÓÂÏ.

¬ÂÎËÃÓÑÄÑÚÞÇÒÑÎâÄÞÔÛËØÔÒËÐÑÄÚÇÕÞÓÈÊÈÏÇ-ÓÇÐËâØÓËÐËÏÂáÕÊÐÂÚÇÐÊâÎÂÇÃÓÇÓÐÍÚÌ ÑÕÑÔÙËÎ-ÎâÕÑÓÑÄ

$$o.\hat{Y}jx\dagger; \quad \%\hat{Y}_A; \hat{Y}_B\check{S}\hat{}\ 2iC_{AB}; \quad C_{AB}\hat{}\ \ddot{y}\ C_{BA};$$

ÅÆÇ $\hat{Y}_A$ ì ÐÓÑÏÏ ÖÕÃÕÊÐÞÌ ÔÐÊÐÑÓ C_{AB} ì Ï aÕÊÚÂ ÊÂÓâÑÄÑÑ ÔÑÒÓâÉÇÐÊâ. ª ÐÆÇÔÞ A; B ^ 1; ...; 4 âÄÎâáÕÔâÊÐÆÇÍÔÂÏÊÌÑÓÂÐÑÄÔÍÊØÒÒËÐÑÓÑÚÇÕÞÓÈØ ËÊÏÇÓÇÐËâØ

±ÑÎâ ÔÒËÐÂ ÑÒÈÔÂÂáÕÔâÑÆÐÑÓÑÆÐÞÒÊÑÎËÐÑ-ÏÂÏË ÑÕÝ

$$o.m\hat{Y}jx\dagger\hat{}\ m^{2.s\ddot{y}1\dagger}o.\hat{Y}jx\dagger:$$

¿ÕÂ ÍÑÐÕÕÖÍÙËâ ÄÑ Ï ÐÑÂÑÌ ÂÐÂÌ ÑÂÉÚÐÂ ÍÑÐÕÕÓÓÙËË ¤ ËÐÊÄÖÓÂÂë´ ÂÏ Ï Â. ° ÕÌ ÉÚÉÇ, ÕÑÕÕÑÉÕ Ä ÕÑÏ, ÚÕÑ $o.\hat{Y}jx\dagger\hat{}\ dx^n o_n.\hat{Y}jx\dagger$ ÊÂÄÉÔÊÕÕÄÔÒÑÏÑÅÂÕÕ;ÐÑÅÑÕÒÈ-ÐÑÓÂ$\hat{Y}_A$, ÂÐÇÑÕÄÇÍÕÑÓÊÐÇÔÈÐÆÇÍÂÉË××ÇÓÙÈÐÂÍß-ÐÑÌ ×ÑÓÏÞ n. ± ÑÕÌ ÇÆÐÇÇ ÑÄÕÕÑâÕÌ ßÕÕÄÑ, ÄÒÓÑÚÇ, âÄÎâÇÕÔâÂÇÔßÌÄÔÖÙÇÔÕÄÇÐÐÞÑÏÄÇÔÒÇÚÉÉÇÄÕÕÇÔÕÄÇâÍÄÉÄÄÎÇÐÕÞÑÄÑÄÜÈÐÐÞÕÑÉÆÇÕÂÐÄÍÑÄË ÐÖáÓÇÂÎÉÉÊÙËáÔËÏÏÇÕÓÉ ÄÞÔÛËØÒÈÐÑÕÕ-×ÑÓÏÂÏË E.$\hat{Y}$jx† ÄÍÂÚÇÔÕÂÇÏÉÄÓÑÄÑÚÞÒÂÓÂÏÇÓÑÄ.

3. ²ÂÊÄÈÓÐÖÕÂÊÄÐÂÏËÍÂ

¶ÑÓÏ ÕÏ ËÓÑÄÍ Â Ä ÕÇÓÏ ËÐÂØ ÆÉ××ÇÓÇÐÙÉÂÎ ßÞÞØ×ÑÓÏ ÑÄÎ ÂÆÂÇÕ ÓâÆÑÏ ÆÑÓÕÑÉÐÕÕÄ, ÒÑÉÄÑÎ ââ, Ä ÚÂÕÕÐÑÓÕÉ, ÒÓÇÆÓÕÄÉÕÕ; ÕÓÂÄÐÇÐÉâ Ä ÚÂÕÕÞØ ÒÓÑÉÉÄÑÆÞØ Ä ÕÄÍ ÐÂÊÞ ÄÂÇÏ ÑÌ ÓÂÊÄÉÓÐÕÕÑÌ ×ÑÓÏ Ç ¿ÕÂ ×ÑÓÏ ÕÏ ËÓÑÄÍ Â ÑÕÐÑÄÂÐÂ ÐÂ ÒÓâÏ ÑÏ ÑÄÑÄÜ ÇÐÉÉ ÉÉÄÇÕÕÐÑÄÑ ÒÓÉÉÌ Â, ÒÑÉÄÑÎ âá Ü ÇÄÑ ÒÓÇÆÓÕÄÉÕ; ÑÄÞÍÐÑÄÇÐÞ Ç ÆÉ××ÇÓÇÐÙÉÂÎßÞÞÇÓÓÂÄÐÇÐÄ ×ÑÓÏÇÓÓÂÄÐÇÐÒÓÇÓÑÄÑÚÞÒÂÓÂÍÂ,

$$q^i_{\perp}.t\dagger\hat{}\ j^i\ddot{y}q.t\dagger;$$

ÒÕÕÏ ÄÄÇÆÐÉâ ÐÑÄÞØ ÒÇÓÏ ÇÐÞØ ÆÊâ ÄÕÇØÕÇØ ÒÓÑ ËÊÄÑÆÐÞØÉÐÂÏËÚÇÓÍÐÇÓÇÌÇÐÞØÑÕÑÓÞÇÑÓÓÇÆÇ-ÎâáÕÔâ ËÓØÑÆÐÞÏÐÓÂÄÐÇÉâÏË. ´ÂÍÂâ ×ÑÓÏÓÎÊÓÑÄÍÂ ÑÄÎ ÂÆÂÇÕ ÓâÆÑÏ ÆÑÓÕÑÉÐÕÕÄ, Ä ÚÂÕÕÐÑÓÕÉ ÒÑÉÄÑÎ âá ÍÑÐÕÓÑÎÊÑÄÂÕÓÉÊÎÑÕÕÇÒÐÇÄÑÄÑÞÍÑÕÑÑÇÕÑÄÒÂ-ÆÂÇÕÚÉÊÎÑÏ ÆÉÐÂÏÊÚÇÓÍÐÇÓÇÌÇÐÞØ.

±ÓÇÆÏÇÕÑÉÊÓÚÇÐÉÇÕÑÉÐÎÂâÄÎâáÕÔâÊÉÕÕÇÌÞ ÔÂÇÓÍÑÐÇÚÐÞÚÉÊÎÑÏ ÔÕÇÒÇÌÐÄÑÄÑÆÑÑÒÉÔÞÂÂÇÌÞ ×ÖÐÍÙÈÑÐÂÎßÞÉ ÒÓÑÔÓÓÂÐÇÉÕÄÂÂÒÓÉÏÇÓ, Ä ÅÂ-ÏÉÎßÕÑÐÑÄÑÌ ×ÑÓÏÖÎÉÓÑÄÍÇ ÕÇÓÉ®ÂÍÓÄÇÎÂ ÑÄÑÄ ÜÉÐÐÞÇÑÑÓÆÉÐÂÕÑÑÉÇÕÕÄÍâáÕÕâÒÓÑÓÉÐÂÕÕ-ÄÇÐÐÞÏÉ ÍÑÑÓÆÉÐÂÕÄÏÉÇÍÕÑÓÂ-ÒÑÕÇÐÙÉÄÍâ†, Â ÑÄÑÄÜÉÐÐÞÉÇÒÓÎßÔÞ ÔÍÑÏÒÑÐÇÐÕÄÉ àÍÇÍÕÓÉÚÇÔ ÍÑÄÑÒÑÍâE.x†. ± ÓÉÄÔÇÆÉÑÔÑÉÐÔÕÄÄÉßÕÑÐÑÄÑÄÑ ÒÑÆØÑÄÉÕÇÑÓÉÉÑÍâ ÇÄÑÕÓÜÇÕÕÄÇÐÐÞÇÆÑÑÕÕÑÏ âÄÎâÇÕÔâÒÑÕÇÓÄÑÄÓÉÄÐÐÑÕÕÉÑÑÕÐÑÚÇÐÉâÍ Í ÎÑÓÇÐÙÇÄÑÕÉÏÇÕÓÉÉ ÕÄÍ Ë Í ÒÓÑÉÄÑÎÒÄ ÄÞÄÑÓÇ ÍÑÑÓÆÉÐÂÕ.

²ÂÊÄÈÓÐÖÕÄÊÐÂÏËÍÂ ì àÕÑÏÐÑÅÑÏÇÓÐÑÇÑÄÄ-ÓÉÂÐÕÐÑÕÑÇÄÑÕÇÐÉÇ×ÑÓÏÖÏÉÓÑÄÍÉ ÒÇÓÄÑÄÑÕÑÓâÆÍÂ ÑÄÞÍÐÑÄÇÐÐÞØÉÉ××ÇÓÇÐÙÉÂÎßÞØÓÓÄÂÐÇÐÉÑÍÖÄÇ-ÏÑÇ ÊÂÏÇÐÑÌ ÆÉ××ÇÓÇÐÙÉÓÑÄÂÐÉÇÍÂ ÐÂÑÄÑÓÒÇÓÇÐÞØ $q^i.t\dagger$ ì ÐÂÑÄÑÓÑÍÆÉ××ÇÓÇÐÙÉÂÎßÞØ ×ÑÓÏ $W^O.x\dagger$, ÉÅÓÂáÙÉØ ÓÑÎßÆÉÐÂÏÉÚÇÓÍÐÇÓÇÌÇÐÞØ:

$$\frac{q}{qt}! \quad d; \quad q^i.t\dagger! \quad W^O.x\dagger\hat{}\ dx^{n_1}\wedge\ldots\wedge dx^{n_p}W^O_{n_1\ldots n_p}.x\dagger:$$

²ÂÊÄÈÓÐÖÕÊÐÂÐÇÐÉâÍÇáÕ ÄÉÆ[32]

$$dW^O.x\dagger\hat{}\ G^O\ddot{y}W.x\dagger; \quad d\hat{}\ dx^n q_n; \qquad .3:1\dagger$$

ÅÆÇ $G^O.W\dagger$ ì ÐÇÍÑÕÑÓÂáÕÐÍÙÉâÆÉÐÂÏÉÚÇÔÍÐÇØÉ××Ç-ÓÇÐÙÉÂÎßÞØ×ÑÓÏ $W^O.x\dagger$,

$$G^O.W\dagger\hat{}\ \sum_{n\hat{}1}^{\infty} f^O_{L_1\ldots L_n}W^{L_1}\wedge\ldots\wedge W^{L_n}:$$

¢Î ÂÄÑÆÂÓâ ÉÕÕÑÏ ßÉÑÄÂÐÉá âÊÞÍ Â ÆÉ××ÇÓÇÐÙÉÂÎ ßÞØ ×ÑÓÏ, ÖÓÂÄÐÇÐÉâ1) ÑÍÄÉÞÄÂáÕÕÂÑÓÆÉÐÂÕÐÑÇÊÄÄÉ-ÔÉÏÞÏÉ, Õ.ÇÑÄÎÀÆÁáÕÉÐÄÄÉÂÐÕÐÑÔÑÑÑÐÑÔÉÕÇÑßÐ ÄÞÄÑÓÄÑÑÓÆÉÐÂÕ.

±ÓÉ $d > 1$ ÖÔÎÑÄÉâÑÄÏÇÔÕÐÕÉÑÔÄÑÌÔÑÄ (2.2) ÐÂÍÎÂÆÞØÄáÕÐÇÕÓÉÄÉÂÐßÇÑÅÓÂÐÉÚÇÐÉÄÄÆ×ÓÐÍ-ÙÉÌ $G^O.W\dagger$:

$$G^L.W\dagger\hat{}\ \frac{qG^O.W\dagger}{qW^L} \quad 0; \qquad .3:2\dagger$$

ÍÄÄÄÄÎÇÐÕÐÞØÇÄÑÄÜÈÐÐÞÕÑÉÆÇÔÂØÄÍÑÄÉ

$$\sum_{n\hat{}0}^{m} .n\ddagger 1\dagger f^G_{\%o_1\ldots L_m\ddot{y}n} f^O_{GL_m\ddot{y}n\ddagger 1\ldots L_m}\check{S}\hat{}\ 0:$$

©ÂÆÚÂÔÕÕÑÉÕÄ ÐØÑÉÆÐÉÉ ÕÆÉØ×ÖÐÍÙÉì $G^L.W\dagger$, ÍÑÕÑÓÞÇÆÑÄÎÇÕÄÑÓâ(2.2) ÒÓÉÒÓÑÉÉÄÑÔÞØ W^O.

²ÂÊÄÈÓÐÖÕÄÊÐÂÏÓÂ ÖÓÂÄÐÇÐÉÄÎÂÆÂÇÕÄÆÑÏÊÄÏÇ-ÚÂÕÇÎßÞØÄÑÎÔÕÄ.

±ÓÇÉÆÇÄÔÇÄÊÄÎââÔßÍÑÑÓÆÉÐÂÕÐÑÇÊÄÄÉÔÏÞÏÉ, ÓÂÊÄÈÓÐÖÕÐÇÄÄÐÇÐÉÄÎÂÊÞÄÄáÕÔÄÆÇÄÎßÐÑÓÉÔÓÑ-ÔÑÄÎÇÐÐÞÏÉÆÎâ ÑÒÉÔÂÐÇÐÉÄÎÂÊÞÄÄáÕÔÄÆÇÄÎßÐÑÓÉÔÓÑ-×ÑÓÏÄÏÉ ÆÉ××ÇÓÇÐÙÉÂÎßÞØ×ÑÓÏ ÑÄÇÓÒÇÓÇÐÙÉÇÓÓÂÄÐÇÐÉÄÎÂÊÞØ ÕÄÍÉÇÍÂÏÉ ÄÓÑÄÑÚÞÕÑÉÆÇÔÂØÄÍÑÄÉ ÒÓÉÒÓÑÉÉÄÑÔÞØ W^O.

£ÂÉÐÞÏ ÔÄÑÎÔÒÄÑÎ ÓÂÊÄÈÓÐÖÕÕ ×ÑÓÏÖÏÉÓÑÄÍÉ âÄÎâÇÕÔâÊÉÑÄÜÂâÒÓÉÏÇÐÉÏÑÕß.-áÄÂâ ÔÉÕÕÇÔÂÓÂÄ-ÐÇÐÉÄÜÂÕÕÐÞØÒÓÑÉÉÄÑÆÐÞØÕÇÕÃÞÕßÒÓÇÆÓÕÂÄÇÐÉÄ Ä ÓÂÊÄÈÓÐÖÕÕÉÆÇÒÓÑÎÑÜßá ÄÄÇÆÇÐÉÄÑÆØÑÆâÜÇÄÑ ÐÂÃÑÓÂÔÒÓÑÎÑÄÂÕÇÎßÐÑÒÇÓÇÐÙÉÐÞØÊÄÏÑÄÇÎÔÕÄÉ ÑÒÉÔÞÄáÕÔÄ ÐÇÎÉÐÇÎÐÞÇÆÇ×ÑÓÏÄÙÉÉ×ÖÐÍÙÉÉ $G^O.W\dagger$Ä(3.1).

²ÂÊÄÈÓÐÖÕÇÓÂÄÐÇÐÉÄÆÑÒÓÇÓÂÔ ÔÑÆÇÓÉÂÕÇÎßÐÖá ÉÐÕÇÓÒÓÇÐÙÉÄÂÂÇÓÇÏÉÐÄÂÇÎÕÄÇÓÉÄÄ ÚÑÑÄ ÚÂÔÕÐÑÉÄÆÂÈÇÑÄÉÏÑÉÐÑÔÕÇÓÉÄÂÕÇÚÔÍÑÌ ÍÎÂÔÔÉ×ÉÍÂÙÉÉg-ÉÐÄÂÓÉÂÐÕÐÞØÓÂÄÐÇÐÉÄ Ä ÕÇÓÏÉÐÄØ g-ÏÑÆÓÎÇÌ(ÔÏ., ÐÂÒÓÉÏÓ,[33, 34]).

³ÕÇÒÇÐÉÄÑÄÑÆÐÉÐÂÏÉÚÇÓÍÐÇÉÔÕÇÏÞÔ×ÑÓÏÉ-ÓÑÄÂÐÐÞØÓÂÉÄÉÐÇÐÉÄÆÉÇÓÇÒÉÔÞÂáÕÔÄÑÄÑÐÂÑÄÑÓÑÏ 0-×ÑÓÏ $C^i.x\dagger$ÄÒÑÍÐÑÏÐÂÑÄÑÓÇÑÓÏ $W^O.x\dagger$. p-×ÑÓÏÞ W^O ÐÇÐÖÍÇÄÞØÕÇÒÇÐÙÉ, > 0, ÑÒÓÇÆÇÕÄ0-×ÑÓÏÄÏÉ, Ô ÕÑÚÐÑÔÕÄÄÑÂÍÉÄÓÑÄÑÚÞØÒÓÇÑÄÓÂÉÑÄÂ©ÐÂÚÇÐÉâ $C^i.x_0\dagger$ ÒÓÉÄáÄÑÏ $x\hat{}\ x_0$ ÊÂÆÄÇÑÏÂÏ ßÐÖáÄÑÏÂÙÉá ÔÉÔÕÇÏÞÂÐÂÑÄÉÚÐÑÏÖ,ÍÂÍ $q.t_0\dagger$ ÊÂÆÂÈÕÍÂÏßÐÖá ÄÄÑÏáÙÉá Ä ÔÏÖÚÂÇÄÞÍÐÑÄÇÐÐÞØÉÉ××ÇÓÇÐÙÉÂÎßÞØ ÖÓÂÄÐÇÐÉÄÇÓÇÒÉÔÂÐÐÞØÉÉÆÇÖÓÂÄÐÇÐÉÄ ÒÇÓÄÑÄÑ ÒÑÓâÆÍÂÄÓÑÓÕÕÓÂÐÐÑÕÕÑÏÇÌ C^i ÂÐÂÏÑÄÉÚÐÑÏÉÉßÐÑ)

[illegible]

4. [illegible]

[illegible]

$$\dots$$

$$(f ? g)(Z; Y) = \int dS\, dT\, f(Z + S; Y + S)\, g(Z - T; Y + T) \exp(-S_A T^A); \quad (4.1)$$

[illegible]

$$[Y_A; Y_B]_\ast = [Z_A; Z_B]_\ast = 2iC_{AB}; \quad Y^A = C^{AB} Y_B;$$

$$Z_A = (z_a; z_{\underline{a}}); \quad Y_A = (y_a; y_{\underline{a}}); \quad a; \underline{a} = 1; 2:$$

[illegible]

$$k = \exp(iz_a y^a); \quad k = \exp(iz_{\underline{a}} y^{\underline{a}});$$

[illegible]

$$k ? f(Z; Y) = f(\tilde{Z}; \tilde{Y}) ? k; \quad k ? k = 1;$$

[illegible]

$$dW + W ? W = 0; \quad (4.2)$$

$$dB + W ? B - B ? W = 0; \quad (4.3)$$

$$dS + W ? S + S ? W = 0; \quad (4.4)$$

$$S ? B - B ? S = 0; \quad (4.5)$$

$$S ? S = i(dz^a dz_a + dz^{\underline{a}} dz_{\underline{a}} + dz^a dz_a F(B) ? k ? k + dz^{\underline{a}} dz_{\underline{a}} F(B) ? k ? k); \quad (4.6)$$

[illegible]

$$f(B) = \sum_{n=1}^{\infty} f_n B ? \dots ? B :$$

[illegible]

$$k ? f(A) = f(\tilde{A}) ? k; \quad k ? f(A) = f(\dots) ? k;$$

$$A = (A_a; A_{\underline{a}}): \quad \tilde{A} = (\dots A_a; A_{\underline{a}});$$

[illegible]

$$dW = e ? W - W ? e; \quad dS = e ? S - S ? e;$$

$$dB = e ? B - B ? e;$$

[illegible]

5. ±ÓÑÅÓÇÕÑÔÎÇÆÐÎÈÇØÈ ÒÇÓÔÒÇÍÕÈÄÞ

£ ÐÂÔÕÑâÜÇÇÇÏâ ÕÇÑÓÈÄÞÔÛÈØÔÒÈÐÑÄÇÓÇÉÈÄÄÇÕÑÔÐÑÄÇÕÑÄÇÈÄÈâÈ±ÇÓÇÚÈÔÎÈÏÐÇÍÑÕÑÓÈÈÇÔÑÄÓÇ-ÏÇÐÐÞØÓÇÈÖÎßÕÄÕÑÄÞÂÒÓÂÄÎÇÐÈÏÑÅÓÂÐÈÚÈÄÓÇÄÑÏÐÑÅÈØÔÎÖÚÂâØÈÛß ÔÞÎÍÄÈ ÐÂÒÑÔÎÇÆÐÒÓÇÎÈÍÂÙÈÈ, Ä Í ÑÕÑÓÞØ Ï ÑÉÐÑ ÐÂÌÕÈ ÄÑÎ ÇÇ ÒÑÎ ÐÞÌ ÑÄÊÑÓÎÈÖÇÓÂÕÖÓÞ.

¯ÇÎÈÐÇÌÐÞÇ ÖÓÂÄÐÇÐÈÄÄâ Ôè ÏÇÕÓÈÚÐÞØÒÑÎÇÌ ÄÞÔÛÈØÔÒÈÐÑÄ ÚÇÕÞØÈÈÊÇÓÇÐÈâ(4.2)è(4.6) ÖÆÂ-ÎÑÔßÑÄÑÄÜÈÕßÐÂÔÎÖÚÂÌÒÓÑÈÊÄÑÕÑÅÑÚÈÔÎÂÈÈÇÓÇ-ÐÈÌ Ä[37].

²ÂÔÒÓÑÔÕÓÈÐÇÕÇÑÓÈÄÞÔÛÈØÔÒÈÐÑÄÂÍÂÎÈÃÓÑ-ÄÑÚÐÞÇÑÎâ ÔÔÈÏÇÕÓÈÌ ÒÓÑÈÄÑÎßÐÑÄÑÈÒÑÎÂÐÇ ÊÂÄÇÓÚÇÄÄÇÞÂÉÇÞÂÖÓÑÄÐÇÄÑÄÑÄÄÞØÒÑÎÇÌ. °ÆÐÈÌ ÈÈ ÐÇÑÉÈÄÄÞØØÂÄÎÇÐÈÌ, ÔÄâÄÐÐÞØÔ àÕÑÌ ÊÂÄÂÚÇÑÍÂ-ÊÄÎÔâÕÑÕ×ÂÍÕ, ÚÕÑÔÂÏÈ ÒÑÐâÕÈâÔÄÑÄÑÆÐÑÄÑÎâ Ä ÒÓÑÔÕÓÂÐØØÄÄÞÍÑÄÔÑÅÑÈ AdS ÓÂÈÎÈÚâÄÕÔâ ÆÎâ ÄÇÈÎÂÔÔÑÄÞØÑÎÇÌ ÔÒÓÑÈÊÄÑÕßÞÏ ÕÈÒÑÓÑÎÔÈÏÇÕÓÈÈ: ÐÇÒÓÈÄÑÆÈÏÑÇÓÑÕÕÓÂÐØÕÄÇÒÑÎÇÄ ÄÑÎßÛÈÐÔÕÄÇ ÔÎÒÚÂØÄÄÆÈÕÄÎÑÔÑÎ ÒÓÇÆÇÎÈÄÄÑÓÄÑÎÇÏÇÐÕÄÓ-ÐÞØÒÑÎÇÌ ÄÒÓÑÔÕÓÂÐØØÄÄÞÍÑÄÔÑÅÑ[38, 39]. ¡ÐÂÎÈÈÒ ÔÄÑÄÑÆÞØÒÑÎÇÌ ÔÒÓÑÈÊÄÑÕßÞÏ ÕÈÒÑÎÔÈÏÇÕÓÈÈÄ ÒÑÔÎÇÆÐÇÄÇÏâ ÖÆÇÎâØÄ ÄÑÎßÛÑÇ ÄÐÈÏÂÐÈÇ(ÔÎ., ÐÂÒÓÈÏÇØ[40è51] Ë ÔÑÆÇÚÈÊÇÔâÄÂÎ ÔÞÎÎÈ).

ªÐÕÇÓÈÕÑÇÐÂÒÓÂÄÎÇÐÈØÄâÊÂÐÑ ÈÈÒÚÇÐÈØÑÎÐ-×ÑÓÎÐÞØ ÔÑÎÇÌ ÄÞÔÛÈØÔÒÈÐÑÄ[33, 34, 52è56]. ·ÑÕâ ÔÂÏÈ ÒÑÔÇÄØÕÈÔÈÕÕÇÏÞÑÎÂÊÞÄÄáÕÔâØÂÎ ÒÓÂÄÄÑ, ÐÇÒÐÈÕÂÓÞÈØÈØÈÔÇÆÑÄÂÐÈØÇÆÔÕÄÄÈÕÇÚÈÕÇ ÐÞÌ ÈÐÕÇÕØÇÆÎâ ÈÈÒÚÇÐÈØÄÐÈÕÄØØ ÏÑÆÇÎÇÌ ÕÇÑÓÈÈ ÒÑÎâ, ÒÑÓÑÎßÍÒÒÑÔÑÎÇÆÐÈØÇÆÂÈÕÈØÕÇÕØÇÕÈÓÑÄÄÕÑ ÍÂÎ ÏÑÆÇÎÈ ÔÑ ÔÒÑÐÕÂÐÈØÄÓÒØÇÐÐÈÑÎ ÍÑÐ×ÑÓÎÐÞÑ ÔÈÏÇÕÓÈÇÌ, ÚÕÑÐÇ ÕÑÎßÑ ÒÓÈÄÑÈØÕ Í ÕÇØÐÈØÚÇÌ ÒÒÓÑÚÇÐÈâÐÑÈ ÏÑÉÇÕ ÒÑÎÑÚßÄÞâÄÈØßÒÐÄÂÎÇÐÕÂ-ÎßÐÞÇÔÈÏÇÕÓÈÈÕÇÑÓÈÈ

¦ÚÈ ÑÆÐÑÐÂÔÓÄÇÐÈÇ ÈÔÔÎÇÆÑÄÄÐÈÄâÊÂÐÑÕ ÒÑÔÕÓÑÇÐÈØÕÄÈÚÇÐÈØ ÄÇÓÚÈÐÈØÄÊÄÈÑÆÇÎÕÄ-ÔÈÄÐÞØ ÄÇÊÎÂÕÄÞØÒÑÎÇÌ ÒÓÑÈÊÄÑÕßÞØÒÈÐÑÄ ÒÓÑÔÕÓÂÐØØÄÄÞÍÑÄÔÑÅÑ ÂÐÕÄÆÇ-³ÈÕÕÇÕÄÑÈÊ-ÄÑÕßÐÑÅÑÚÈÔÎÂÈÈÇÚÇÐÈÌ [57è71]. ¢ÑÕßÛÑÌ ÈÐÕÇÓÇÔ ÒÇÆÔÕÂÄÎâØÄÑÕ ÒÑÄÞÄÑÆØÄÒÈÕÇÓÄÚÂÔÕÇâÐÈâ£ÈÕÂÎÈâ -ÂÊÂÓÇÄÈÚ¤ÈÐÈÄÓÓÅÂÇÆÇÎÂÐÐÈØÈÇ ÑÍÑÎÑ ÒâÕÈÇÕÑÎÓÐÂÊÂÆ. ÑÄÓÂÜÇÐÈÈÕÕÓÆÇÐÄÕÑÔÕÓ-ÈÄÛÈÌ ÐÂ ÍÂ×ÇÆÓÕÑÄÑÎÇÌ ×ÈÊÈÈ Ë ÂÕÕÓÑ×ÈÈ, ¤ÈÐÊÄÓÓÄÒÑÄâÐÓÎÑ ÕÄÑÈÌÓÂÎÇÚÈÈ ÕÇÑÓÈÇÄÞØÒÛÈØ ÔÒÈÐÑÄ ÆÑÒÓÓÂÎÇÐÈØÑÎÐÇÑÉÈÆÂÐÐÈØÑÎÐÇÍÕÇ,ÅÑÄÑÓâ, ÚÕÑÍÂÉÆÞÌ ÆÑÍÉÇÐÒÓÂÄÈßÐÑÙÇÐÈÄÄÕÑÓÇÆÇÎÞ ÔÄÑÈØÄÑÈÍÑÉÐÑÕÕÇÈ ÄÑÄÓÇâ ÑÕÕÄÂâÕÑÓÄÇÎÞ, "ÍÑÕÑÓÞÇÇÏÖ ÐÇÒÑÈÖÄÄÎ", ÍÂÍ ÑÐÔÂÎ ÑÕÕÄÂÈÄ ÔÄÑÈ ÄÓÇÇâÓÂÄÑÕÕÐÂÆÇÑÓÈÇÄÞØÒÛÈØ ÔÒÈÐÑÄ(Ô. ÕÂÍÉÇ[5]). ¿ÕÑ ÒÑÖÚÈÕÇÈ ÒÓÈÏÇÓÕÕÇÈÄÑÙÇÐÍÈÐÇÕÕÑÍßÍÑ ÔÑÄÕÕÄÇØÄÑÈÍÑÉÐÑÕÕÇÈ ÄÑ ÄÓÇâ ÑÕÕÄÂâÕÑÓÄÇÎÞ, ÍÑÕÑÓÑÎßÍÑ ÔÑÕÕÑÄâÐÂÓÍÈÐÂ ÄÓÇâ ÒÓÈÐâÕÈâÇÕÇÐÈ¥ÇÌÕÕÄÈÕÇÈÑ,ÄÑ ÄÓÇâ, Ñ ÍÑÕÑÓÑÎ ÅÑÄÑÓÈ£ÈÕÂÍÈÎ -ÂÊÂÓÇÄÈÚ¦ÕÕÄÄÂÍÕÇÈ ÚÇÕÄÇÓÇÇÅÂ ÆÑÑÕÍÓÞÕÈâÒÒÇÇÅÄÈÕÂÙÈÈ,ÓÈÄÇÆ-ÈÂÊÂÐÐÈØÕÄÕÕÈÓÇÂ ÆÑÑÕÍÓÞÕÈâÒÒÇÇÅÄÈÕÂÙÈÈ ÒÓÈÐÙÈÒÂ ÄÎâÇÕÕâ×ÇÓÈÚÇÕÍÊÈÏÇÕÓÈÚÐÑÇÕÑÚÐÑÇÇÇÚÇÐÈÇ ÚÇÕÞØÒÈØÈÕÇÌ ÕÇÑÓÈÈÞØÒÛÈØ ÔÒÈÐÑÄ[85], ÍÑÕÑÓÑÇÄ ÓÇÉÈÏÇÕÍÂÂÑÄÑÕÑÎâ ÄÇÆÈÕÇÄâÍ ÚÇÓÐÑÆÞØÒÈØÕÇÇÇÚ-ÐÈÇ°´°. ªÐÕÇÓÇÕÐÈÇÌÚÇÌÄÆÂÙÇÄÎâÇÕÕâÂÐÂÎÈÈÕÄâ-ÊÂÐÐÞØÕÄÕÕÈÇÎâÄÎÇÕÐÈÄÄâØÕÈÏÈßÕÑÌÕÕÄÂÐØØÄÄÞÍÑÄÔÑÅÑ[81è84]. °ÆÐÈÌ ÈÈÐÂÈÄÑÇÇÈÐÕÇÕØÇÞØÒÓÇÆÕÕÄÛÇÅÑÍ ÑÕÑÈÐÂÊá ×ÕÐÆÂÎÇÕÕÄÛÇÅÑÍ ÑÕÑÈÐÂÊÂÆÇÑÓÈÇÄÞØÒÛÈØ ÔÒÈÐÑÄ. ÕÂÍÉÇ[5]).

°ÍÂÊÂÄÛËÔÎÊÃÇÚÂÕÇÎßÐÑÎÖÃÑÍÑÌ Ë ÔÑÆÇÓÉÂÕÇÎß ÐÑÌ, ÕÇÑÓËÂÞÔÛËØÔÒÈÐÑÃ ÐÂÛË ÆÐËÒÇÓÇÉËÄÂÇÕ ÐÂÔÕÑâÜËÓÇÐÇÔÔÂÐÔËÄÑÆÐÑ-ÄËÆËÏÑÏÖÍ, ÐÑÄÑÏÖ ÒÑÐËÏÂÐËáÓâÆÂÖÐÆÂÏÇÐÕÂÎßÐ¤ØÊËÚÇÔÍÈÑÐÙÇÒ-ÙËÌ. £ÔÈÇÜÈÔÎËÚÎÑÏ ÏÂÎÑ ÊÐÂÃÑÕÇÑÓÈÆÞÔÛÈØÔÒÈÐÑÄ Ä ÙÇÎÑÏ, ÏÞ ÊÐÂÇÏÖÉÇÆÑÔÕÂÜÕÑ,ÚÕÑÃÞÖÕÄÇÓÉÆÂÕß; ÚÕÑÔÇÅÑÆÐÄÇÓÑãÕÑ,ÐÂËÎÖÚÛÇÄÓÇÏâ ÆÎâ ÓÂÃÑÕ Ä àÕÑÌËÐÕÇÓÇÔÐÇÌ Ë ÃÞÔÕÓÕÑÂÊÄËÄÂáÜÇÎâÑÃÎÂÔÕË.

²ÂÃÑÕÂ ÄÞÒÑÎÐÇÐÂÒÓË ÒÑÆÇÉÉÍÇ ²¶¶ ª, ÅÓÂÐÕ 11-02-00814Â.

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DOI: 10.3367/UFNr.0181.201106h.0672

£.-. ¤ËÐÊÃÖÓÅ Ë ÓÂÊÄËÕËÇ Ä ¶ª ¡¯Ç àÍÔÒÇÓËÏÇÐÕÂÎßÐÓÅÊÃÑÕ ÒÑÄÞÕÑÍÑÕÇÏÒÇÓÂÕÖÓÐÑÌ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË: "ÉÇÎÇÊÐÞÇÄÇÓØÒÓÑÄÑÆÐËÍÉ

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¯ÑÚÕÑ ÑÊÐÂÚÂÇÕ ÆÊâ àÍÔÒÇÓËÏ ÇÞÕÂÕÑÓÂ "ÕÏ ÇÞÊÕß ÕÇÏ ÂÕÊÍÕ? £ÑÒÇÓÄÞØ, àÕÂ ÆÇâÕÇßÐÑÕß ÐÇ ÍÂÏÇÓÞÂâ,Ë Çá ÆÑÎÉÐÑÊÂÐËÏÂÕßÕÑÑÍßÛËÐÔÕÄÇÇÕ, ÐÇÄÇ, ËÊÔÑÕÕÄÐËÍÑÄ ÎÂÑÓÄÕÑÕËÉ ± ÑàÕÑÏÖÐÊÉÐÑ ÃÞÎÑ ÆÑÑÄÖÚÉÕÑßÕÓÄÉÑÐÆ,ÂÕÂÍÉÇÊÂÒÖÔÕÉÕßÕÑÙÇÔÔ ÒÑÆÅÑÕÑÄÕÉÖÆÇÄÕÑÆÂÐÐÑÕÇÏÂÕËÍÇ£Ñ-ÄÕÑÓØ, ÐÂÆÑÄÞÍÑ ÐÂÕËÐÇÑÄØÑÉÉÑÇ ×ËÐÂÐÉÓÑÄÂËÇ ÊÂÕÒÉÕßÑÄÑÓÓÄÆÑÄÂÉÉÂÕÇÓÉÂÍÞ.¯ÂÍÑÐÇÙ,ÐÓÉÐÑÄÞÍÑ ÐÂÌÕËÓÓÇÆØÄÊâÓÇÍÑÐÔÕÓÓÍÙÉÉÆÂÐËÄÑÆÓÂËÄËÇÉ àÕÑÌ àÍÔÒÇÓËÏ ÇÞÕÄÍßÐÑÌ ÆÇâÕÇßÐÑÕÕÉ, ÕÑÆÑÕÑÄÉÕß ÒÓÑÇÍÕ ÓÇÍÑÐÕÕÓÍÙÉÉ ÉÆÂÐÉâ, Ä ÕÑÌ ÚÉÕÍ Ç ÍÂÉÆÑÄÑ ÑÕÆÊÇÐÑÄÑÌ ÒÑÏÇÚÇÐÉâÆÎâÑÒÕÊÂÍßÐ ÑÌ ÓÂÄÑÕÞÄÐÈÏ ÑÄÑÓÓÉÑÄÑÐËâ£ àÕËÉÉÂÄÑÕÄØÓÑÚÉ ÕÓÉÄÑÆÆÂ], ÊÂÕÇÏ ÐÂÚÊÉßßÒÇÓÞÄÇ àÍÔÒÇÓËÏÇÐÕÐ ÒÑÕËÐÇÊÉ ËÔÕÇÆÑÄÂ ÐËâ ÄÞÔÑÑÕÇÏÒ ÇÂÕÐÞØÓÇÇØÕÑÄÑÆÉÍÑÄ.£.-. ¤ËÐÊÃÖÓÅ ËÄÑÉÉÐÕÇÓÇÔÑÄØÑÄÑÆÑÕÂÄÑÕÉ, ÇÏÖ ÓÇÅÖÎâÕÐ ÓÂÔÔÍÂÉÞÄÂÑÑÕÄ ËØÖÓÑÄÆÄËÉÇÆÆÉ¥ÂÐÐÞÌ ÆÑÍÍÂÆ ì àÕÑÑÚÇÓÇÆÐÕÂÔÛËÉÐÇÞÌ ÑÕÚÈÕÇÓÇÆ., ÐÑ,Í ÔÑÉÂÍÇÐÉ, ÖÉÇÐÇÔÑÕÕÑâÄÕÉÌ

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£.®. ±ÖÆÂÎÑÄ°.¦. °ÍÇÎßâÐÑÄÔÍËÌ, ¦.±. ·ÎÞÃÑÄ, ¡.£. ³ÂÆÂÍÑÄÀ.¶. ¡ÍßÙÇÄ, ¬.£. ®ËÙÇÐ,°.®. ªÄÂÐÇÐÍÑ,¬.³. ±ÇÓÄÂÍÑÄ, ¥.². ¤ËÊÂÖÖÎËÐ,³. µÔÑÎßÙÇÄ,³. ¥ÑÓÍËÆÑÐÕÑÄ,À. ¤ÂÄÓÉÎÍÉÐ, ¡.À. ¸ÄÇÕÍÑÄ.Á.¤. ±ÑÐÑÍÂÓÇÄ¡.¡. ¬ÓÉÐÌËÍÚÈÄ,®.¤. ®ËØÇÇÄ, ³.¯. ¹ÇÔÐÑÍÑÄ.¦. ºÂÐÞÅËÐÂ,³.®. ¬ÂÊÂÍÑÄ 2011

ÔÕÄÇÐÐÑ ÓÂÊÆÇ ÇÐÞ Ô ÑË Fe, Ä Í ÑÕÑÓÞØ ÒÓÑËÕØÑÆËÕ ÍÑÐÆÇÐÔÂÙËâ àÎ Ç ÕÓÑÐÑÄ Ä ÕÄÇÓØÒÓÑÄÑÆâÜ ËÇ ÒÂÕÞ, Ë ÍËÔÎÑÓÑÆÐÞÕ ÔÑ,ËÒÑÔÕÂÄÂÜ ËÇ ÐÑÔËÕÇÎ ÊÂÓâÆÂ ÓÑÆË ÑÕÍÑÐÇÐËÇ ÔÑÔÕÂÄÂ ÑÕ ÔÕÇØËÑÏÇÕÓËÇÔÍÑÅÑ.

£ ÔÕÇÐÕÏËÇÕÓËÇÔÍÑÏ (ÐÇÆÑÒËÓÑÄÂÐÐÑÏ) ÔÑÇÆËÐÇÐËË FeAs-ÏÂÕÇÓËÂÎÞ ÒÓËÕÇÒÑÓÑÒÑÆÑØÑÏ ÇÕÇ T_c, Ä ÑÕÎËÚËÇ ÑÕÍÖÒÓÂÕÑÄ ÇâÎâÄÕÑâ ÆËàÇÎÕÏËÂÎÂÏË, Â ÑÃÎÂÆÂáÕ ÒÓÑÄÑÆËÏÑÔÕÞÐ ÑÕÒ. ÇâÎâÄÕÑâ ÇÎÂÏËÎË, ØÑÕâ Ë ÒÎÑØËË. ±ÓË ÒÑÐËÉÇÐËË ÕÇÏÒÇÓÂÕÖÓÞ ÔÑ T 150 ¬) Ä ÐËØ ÄÑÊÐËÍÂÇÕ ÕÇÕÓÂÅÑÐÂÎÞÐÂâ ÒÓÇÔÕÓÖÍÕÖÓÂ ÑÕÍÑÆËÕÇÎÞÐÂâ ÆËÔÕÑÓÔËâ Ë ÄÑÊÐËÍÂÇÕ ÕÓÂÐÔÔÑÓÔËâ ÒÓÑÔÕÑÓÂÐÔÕÄÇÐÐÑÇ ÒÓÑÔÕÇÐÔÑÐÓÂ (ÑÃ 130 ¬) ì ÏÂÅÐËÕÐÞÏ ÒÓÇÑÐÑÄÂÐËÇ ÑÃÓÂÊÖÇÕ ÔÕÓÖÍÕÖÓÖ ÑÕÕÂÆËÆË×ÇÔÍËØ ÆËÕÑÔÑÐÂ (AF) ÔÒËÐÑÄ ÑÒÑÔÕÑÓÑÄ ÇÆËÐËÇÐËÇ Fe. ¡ÑÏÂÎßÐ ÔËÎßÐÂâ ÏÂÅÐËÕÐÑÔÕÞ ÍÑÕÑÓÂâ ÄÂâÊß, ÕÑÚÐÑ ÇÄÂÊßÒËÑÐÑÄ ÔÑÔÕÂÄÂ Ë ÔÕÓÖÍÕÖÓÑÄ ÇÒËÍÑÏËÇÍÂÐÑÔË Ñ As), ÃÞÎÂ ÑÃÐÂÓÖÉÇÐÂ ÆÇÕÓÑÂÄÑÓÆÇÎÇÐÂ ÐÞÕÖÐÇÐÂ ÖÕÖÖ ÅÑÏÒÕÑÔÕÇÏÞ ÒÑ ÔÕÇÒÇÐË [20] Ä ÐÑÓÏÂÎßÐÑÏ ÔÑÔÕÑâÐËË Ô ÓÇÊÍÑÏ ÒÇÓÇØÑÆÑÏ Ä ÕÑÕ ÒÓÇÄÓÂÐÐÑÄÂÐËÇ ÒÑÔÕÑâÐËË [21, 22]. °ÍÂÊÂÎÑÔß, ÚÕÑ ÓÂÊÐÇÔÕÂÇÕ ÇÆÇÐËÚÐÑÕÇÔÕÂÐËÇ ÓÂÊ-ÏË ÒËÍÑ×ÑÐÑÑ ÑÒÕÑÄÑÅÑ ÇÎÇÍÕÓÑÐÑÄ [20] ÆÑÔÕÂÎß-ÐÑÄÇÐÑ ÄÒÎÑÕÖ Æ 14%; ÔÑÅÎÂÔÑÄÂÐËÇ ÔÑÇÄÂ-ÚËÕÑÒÂÐÑÐ ÄÊÄËÕÞÄÂÐÑ ÆÂÐÐÞÏË ÆÂÐÐÞÏ ÏÑÔÕËÚÔÑ ÕÑÎßÍÑ ÒÓËÚËÐÑÍ ÇÂÕÑÏ ÑÔÕÂÕÑÚÐÞ Fe. ±Ñ àÕÑÏ ÇÇ ÒÓËÚËÐÇ ÔÂÏ ÖÊÑÓÑÄÇÐËÇ ÑÔÕÂÄÂ As Ä ÓÇÊÖÎÕÂ ÑÎÂÊÑÄÂÐËÇ ÏÂÎÑÔÕÑ ÕÇÒÎÑÄÑÅÑ ÏÂÅÐËÕÐÑÔÕË ÂÕÑÏÑÄ Fe, Â ÄÞÚËÔÎÇÐÐÑÇ ÔÑÔÕÑâÐËÇ ÓÇÊÖÎÕÂÕÑÄ ÑÕÎËÚÂÇÕÔâ ÐÂ 10% (!) ÏÇÐßÚÇ, ÚÇÏ ËÊÏÇÓÇÐÐÑÇ ÇÍÔÒÇÓËÏÇÐÕÂÎßÐÑÇ ÆÎâ ÏÑÐÑÔÕË ÑÕÆÇÎßÐÑÅÑ ÕÑÐËÔÕÑÅÑ Fe.

±ÓË ÔÑÔÕÑâÐËË ÑÕÍÑÄÂÇÕ ÑÔÑÃÑÇ ÇÐËÇ ÔÑÔÕÇØËÑÏÇÕÓËÇÔÍÑÅÑ ÓÇÊÍÑÅÑ ÒËÍÑ×ÑÐÑÄÑ ÑÒÕËÚÇÔÍËØ ÑÔÑÃÇÐÐÑÔÕÇÎË ÚÂÔÕËÚ-ÐÑÅÑ ÊÂÏÇÉÇÐËÇ ÍÑÏÒÑÐÇÐÕ, ÂÕÑË×ÇÔÍËØ ÆËÕ-ÐÑÔÕËÒÑÓÂÆÑÚÐÑ ÔËÎßÐÑ ÇÆÑÕÐÑÔËÕ Fe ÒÑÆÂÄÎÇÐËÇ ÍÎÇÕÑÄ ÏÂÅÐËÕÐÑÅÑ ÑÕÔÖÕÔÕÄËÇ ÐÂ ÔÑÔÕÑâÐËÇ [17, 18, 19, 23, 24]. ¢ËÊÍÑÕÇÏÒÇÓÂÕÖÓÐÂâ ÆËÕÓÂÍÕÑÏÇÕÓËÇ ÓÇÊÍÑ ÆÑÄ ÍÓËÕËÚÇÔÍÑÏ ÕÇÏÒÇÓÂÕÖÓÇ 50 ¬, Â ÕÂÍÉÇ ÐÂÎËÚËÇ ÆÑÏÂÎßÐÑÐ ÔËÎßÐÑÏ ÏÂÅÐËÕÐÑÏ ÍÑÐÕÓÂÊÕË ÐÂÄÑÆâÕ ÐÂ ÏÞÔÎß ÑÃ ÑÔÖÇÇÔÕÄÑÄÂÐËË ÓÑÎË ×ÑÐÑÐÑÄ, Â ÕÂÍÉÇ, ÄÑÊÏÑÉÐÑ, ÔÒËÐÑÄÞØ ÍÑÎÇÃÂÐËÏ Ä ÔÄÇÓØÒÓÑÄÑÆâÜËØ ÏÂÕÇÓËÂÎÂØ [25 ë 28].

£ ÐÂÔÕÑâÜÇÇ ÄÓÇÏâ ÍÂÍ ÇÍÔÒÇÓËÏÇÐÕÂÎßÐÞÇ, ÕÂÍ Ë ÕÇÑÓÇÕËÚÇÔÍËÇ ÑÃÑÔÐÑÄÂÐËÇ ÒÓËÓÑÆÞ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË Ä ÏÂÕÇÓËÂÎÂØ ÑÔÕÂÇÕÔâ ÇÔÕÇÔÕÄÇÐÐÑ ÑÕÍÓÞÕÞÏ ÄÑÒÓÑÔÑÏ, ÑÔÑÃÇÐÐÑ ÄÑÒÓÑÔ Ñ ÓÑÎË ÏÂÅÐËÕÐÞØ ÍÑÎÇÃÂÐËÏ Ë ÆÓÖÅËØ ÏÇØÂÐËÊÏÑÄ ÔÄÇÓØÒÓÑÄÑÆâÜÇÅÑ ÔÑÔÕÑâÐËâ, ÕÂÍÉÇ ÍÂÍ Ë ÕËÒ ÔÄÇÓØÒÓÑÄÑÆâÜÇÅÑ ÒÑÓâÆÍÂ ÒÂÓÂÏÇÕÓÂ. ±ÓÑÄÑÆËÏÞÇ ÔÇÅÑÆÐâ ËÊÏÇÓÇÐËâ ÒÇÐÇÕÓÂÚËË, ÑÒÕËÚÇÔÍËÇ ÔÄÑÎÑÄÑÊÐÞÇ ÊÂÆÇÓÉÍË ÆÑÔÕÂÕÑÚÐÑ ÑÆÐÑÊÐÂÚÐÑ ÖÍÂÊÞÄÂÜÕ ÐÂ ÔÖÜÇÔÕÄÑÄÂÐËÇ ÔÕÂÐÆÂÓÕÐÑÅÑ ÕËÒÂ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË Ä FeAs ÔÄÇÓØÒÓÑÄÑÆÐËÍÂØ (ÄÑÊÏÑÉÐÑ, Ô ÐÂÕÖÓÂÎßÐÑ ÆÎâ ÍÑÐÍÓÇÕÐÞØ ÏÂÕÇÓËÂÎÑÄ ÒÓËÏÇÔâÏË) ÓÇÔÖÐÂÐÔÂ SC-ÔÑÔÕÑâÐËÇ ËÎË SC-ÔÕÓÖÍÕÖÓÑÄ ÆÇÒÇÐÆÑÄÂÐËÇ. S-ÇÑÐÑÄÂÐËÇ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË ÒÇÓÇØÑÆÑÄ [ËÐÆË ÇÔÂ ÑÕÎËÚËÇ ÑÄ ÔÄÇÓØÒÓÑÄÑÆâÜËØ ÑÃÓÂÊÑÄ Ä SC-×ÂÊ ÒÑ ÇÇ ÒÇÓÂÕÖÓÂ ÐÂ ÍÓËÕËÚÇÔÍËØ T_c [23].

ªÊÑÕÑÒËÚÇÔÍËÇ ÑÍÔÒÇÓËÏÇÐÕÞ ÒÑ ÊÂÏÇÐÇ ÇËÊÑÕÑÒÑÄ [16]O ËÊÑÕÑÒÑÏ [18]O ÑÍÂÊÂÎË, ÚÕÑ ÊÂÏÇÐÂ ÓÇÔÖÎßÕÂÕ ÇÐÑÄÑÐ, ÚÇÏ ËÊÑÕÑÒËÚÇÔÍËÏ ÍÑÊÔ××ËÆÇÐÕÑÏ ÒÑÍÂÊÂÕÇÎß ÑÆÇÐËÇ [56]Fe ËÊÑÕÑÒÑÏ [58]Fe); àÕÑ ÒÑÔÕÑÆÑÐÑÍ ÊÂÆÑÎÉÇÐÐÞÏ ÒÓÑÄÇÆÇÐÐÞÏ ÇÑÐÑÄÑÐÐÑ ÆÑÔËÕÑØËÏ ÇËÊÑÕÑÒËÚÇÔÍÑÅÑ ÇÐÐÂ ÔÍÂÚÇÔÕÄÇÐÐÑ ÔÄÑÇ Fe. ±ÑÍÂÊÂÕÇÎß ÔÕÇÒÇÐË ËÊÑÕÑÒ-à××ÇÍÕÂ ˆ 0,4 ÃÎËÊÑÍ Í ÊÐÂÚÇÐËâ 0,5 ÄÕÑÔÂÐÆÂÓÕÐÑÏ ÕÇÑÓËË ÂÕÑÏ ÇÎÇÍÕÓÑÐ-¬ÑÐÑÐÑÄÑÅÑ ºÑÊ××Ç ÓÂ (¢¬º). ²ÂÔ-

ÚËÕÞÆÇÕÑÐÑÏ ÔÑÓÑÏÍÍÑÄÑÍ ÒÑÍÂÊÂÄÂáÕ, ÚÕÑ ÒÑÎÑÃÂ ÒÎÑÔ-ÐÑÔÕÇÏ ÔÑÔÕÑâÐËÂ ÆÇÐÂ ÓÑÄÂÐËÇ ÏÇÉÇÕ ×ÑÓÏËÓÑÄÂÐËÇ ÔÂÏ ÐÂÐËÐÑÃÑÎÇÇ 3d-ÂÕÑÏÐÞØ ÑÓÃËÕÂÎÇË ÆÇÎ [29, 30], Â ÍÑÕÑÓÞÇ ÔÍÂÊÂÎË ÒÎÂÊÑÏ ÍÑÐÆÇÐÔËÓÑÄÂÐËÇÏ ÔÑÔÕÑâÐËÇÏ ÔÑÔÕÑâÐËÇ [30]; ÒÑÔÎÇÆÐËÇ ÍÑÓÇÎâÙËÑÐÐÞÏË ÆÄËÉÇÐËâÏË ×ÑÐÑ-ÐÑÄ ÔÇÐÂÆËÊÂÕÂÐÞÏ ÒÑÕÇÐÙËÂÎÑÏ ÒÑÍÂÊÂÐÑ ÒÑÔÕÂÕÑÚÐÑ ÔÎÂÃÑÇ ÒÑÆÂÄÎÇÐËÇ.

ªËÏÇÐÇËÇ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË Ä ÔÑÇÆËÐÇÐËâØ "122" Ë "1111" [31 ë 33] ÑÆÐÑÊÐÂÚÐÑ ÆÑÍÂÊÂÎÂ, ÚÕÑ ÔÄÇÓØÒÓÑÄÑÆâ-ÜËÇ ÔÑÔÕÑâÐËâ ÊÂÔÇÎÇÐÐÑÔÕË Ë ÐÂÎËÚËÇ ÆÑÍÂÊÂÐÑ ÔÑÎß-ÐÑ, ÍÑÕÑÓÞÇ ÐÂÕÖÓÂÎßÐÑ ÑÃßâÔÐâ×ÚÕÍÍËÕÑÄ ÆÎâ ÒÂÓÂÏÇ ÆÇÑÓÏÂÙËË ÒÇÓÇÆÂÐËâ ÔÄÇÓØÒÓÑÄÑÆâÜËØ ÔÄÑÑÕÑÒÑÄ ÊÑÐ ÔÑÔÕÂÄÑÄ ÑÕÍÓÞÄÂáÕ ËÊÑÕÑÒËÚÇÔÍËØ Ë d-ÕËÒÑÄÑÅÑ ÂÐËÊÑÕÓÑÒËË. ¥ÂÐÐÞÇ ÒÑÊÄÑÎâáÕ ÒÓÇÆÒÑÎÑÉËÕß ÒÑÔÕÑâÐÐÑÇ ÒÑÔÕÑâÐËÇ ÕÇÍÑÅÑ ÚËÔÕÑ ÆÇ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË ÆÎâ ÔÑÇÆËÐÇÐËâ ÔÄÇÓØÒÓÑÄÑÆâÜËØ ÔÑÇÆËÐÇÐËÇÏ ÒÂÓÑÏ ÒÑÔÎÇÆÐËØ ÆÇÕ ÒÑÆÕÇÓÆËÎËÔß ‡‡ -ÕËÒÑÄ [34], ÚÂÔÕß Ä ÒÑÎßÊÖ ÒÂÓÂÏÇÕÓÑÄ s [32, 33, 35], Â ÚÂÔÕß Ä ÒÑÎßÊÖ ÒÂÓÂÏÇÕÓÑÄ d-ÕËÒÂ (ÔÏ. ÑÃÊÑÓ ÃÑÓÍÑÄÂ, ÒÑÔÕÑâÐÐÞÇ ÒÑÔÕÑâÐËÂ ÐÂØÑÆÂÐÞ ÒÑ. Ä [7, 17]); ÕÂÍÉÇ ÑÃÓÂÊÑÏ ÔÕÑÓÑÐÂ ÐÑÄÑÇ ÔÑÔÕÂÄÂ ÊÂÐÑÏ àÍÔÒÇÓËÏÇÐÕÂÎßÐÑÇ ÓÂÊÓÇÕÇÐËÇ àÍÔÒÇÓËÏÇÐÕÂÃÑ ÒÑ ÇÆÑÐÑÆÇÎËÚÑÆÇÄÂ ËÊÂÔÕÑÇ ÇÑÏÑÇ ÓÂÊÄËÕËÇ ÆÎâ ÆÇÑÓÏÂÙËË ÔÑÔÕÑâÐËâ [25 ë 28], ÕÑ àÕÑ ÃÖÆÇÕ ÑÐÂ ÚÂÔÕß ÑÕÕÇÓÑÆÂÐÑ ÐÂ ÆÑ ÇÇÆÑÓÇ ÓÂÊÐÞÏ ÒÑ ÔÓÂÄÐÇÐËÇ Ñ ÆËÍËÔÑÐÐÑÔÕÇÎß ÒÑÕÇÐÙËÂÎÑÏ Ë ÆÑÒÑÎÐËÕÇÎßÐÑ ÒÑÍÂÊÂÕß ÒÑÓâÆÍÂ ÄÕÑÓÑÅÑ ÐÂ ÑÄÑ ÒÑÔÎÇÆÐËØ ÓÑÄÂÐËÇ ÇÇ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË ÄÕÑÓÑÅÑ ËÊ M. ´ÑÓÏËÓÑÄÂÐËÇ ÒÑÇÆËÐÇÐËâ ÄÂÐÑÓ ÕÂÍÉÇ, ÚÕÑ ÒÑË ÕÂÍËÏ ÕÇÕÓÂÅÑÐÂÎßÐÑÏ ÒÑÓâÆÍÇ ÇÄÂ ÒÑ ÆÇÇÔÕÄÇÐÐÑ ÔÄÇÓØÒÓÑÄÑÆâÜËÏ ÍÑÐÆÇÐÔÂÕÑÏ Ï ÑÇÑ ÔÑÕÑÚÇÐËÇ ÂÎÑÔÕÑÃß ÒÑÍÂÊÑÄÂÕß ÏÂÎÇÐËÇ ÐÞÏ ÕÑÚÐÑ ÓÂÊÑÓÇÐË [36].

£ÇÎËÚËÐÂ ËÔÕÑÆÑÒÑÄÑÅÑ ÔÄÇÓØÒÓÑÄÑÆâÜÇÅÑ Ë D ÕÇÔÕÂÐÑ ÔÄÂÊÂÐÂ ÓÇÊÂÐÂÐËÇÏ ÔÒÇÍÕÓÑÔÍÑÒËË ÔÑ ÓÂÊÓÇÑÆÐËÇÏ ÒÑ ÒÑÎÑÉÇÐËÐ ×ÑÕÑàÏËÔÔËÇÍÑÆÐÑÏ ÍÑÐÑÄ ÓÂÊÓÇÔÇÐËÇÏ (Angle Resolved Photoemission Spectroscopy, ARPES), ÆÂÊÑÄÑÓ-ÄÇÆÇÐÐÑÇ ÒÓËÇÏÑÔÕÑÏ ÇÇ ¬, ÒÑÎÂÄÑÃÑÔÕÑÇÚÕÄÂáÕ ÆÑÔÕÂÕÑÚÐÑÔÕß ÕÑÚÐÑÔÕË ÓÂÊÓÇÜÇÐËâ 0,01 Ïâ£), ÍÑÕÑÓÑÇ ÕÓÇÃÖÇÕÔâ ÆÎâ ÄÂÎÇÐÕÐÑÅÑ ÔÑÔÕÑâÐËâ ÔÄÇÓØÒÓÑÄÑÆâÜË-ÆâÜËØ ÜÇÎË. ¬ÓÑÏÇ ÕÑÅÑ, ËÔÕÑÚÐËÍËÑÕÂÙËË ÒÑÎÖÚÇÐËÇ ARPES ÊÂÕÓÖÆÐÇÐÑ, ÚÕÑ ÓËÊÍÑÇ ÒÑÆÐËÇ ×ÑÓÏÂÕËÄÐÑÔÕË ÑËË ÊÐÂÚËÕÇÎßÐÞØ ÑÕÐËÑ ÒÓËÔÑÄÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË ÏÂÕÇÓËÂÎÂ, ÂÕÑÏÂÒÑÄÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕÑÅÑ ÄÂÓËÂÐÕÂ ÍÐËÆÕÓÕÑÓÑÍ-ÙËá [37], ËÊÏÇÐâáÜËÇ ÒÑÍÂÊÂÕÇÎß ÑÃÔÄÇÓØÒÓÑÄÑÆÐËÍÂÐ £ ÓÇÊÖÎßÕÂÕÇ ÆÂÐ×ÑÓÏÂÙËË ÑÃÜËÇ ÑÍÂÊÂÄÂáÕÔâ ÔÕÑÕÐÑÐ ÒÑÚÕËÕÇÎßÐÑ ÆÑÔÕËÏÇÍÑÐÑÏËÚÐÞÏ ÆÎâ ÐËÏ ÒÑÍÂÊÂÕÇÎß ÒÑËÄ ÕÇÐÆÇÐÙËË ÓÇÊËÏÇ (T), ÎËÃÑ Ä ÓÇÊËÏÇÐÂÆÂÓÇÐÂÄ-ÕÎÂÐÕÞ ÒÑÐÂÊÇÐËÇ (AR). °ÍÂÊÂÎÑÔß ÑÆÐÂÍÑ, ÚÕÑ ÆÂÊÎËÚÐÞ ÂÐÂÎÑÅËÚÐÞÏ ÕÑ ÆÄÇÊÇÕÓËÚÇÔÍËÇ ÂÐÂÎÑÅËÚÐÞÇ ÔÑÔÕÑâ-ÆÑÔÕÂÄÂÐÐÞØ ÇÊÑÕÑÒËÚÇÔÍËØ ÍÂÕÑÄ "1111" ÓÇÊÑÎßÕÂÕÑÄ ÐÂÎËÚËÇ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË Ä ÔÑÇÆËÐÇÐËË ÓÇÆÍÑÊÇÏÇÎßÐÑÔÕË ÔÑÎÂÕÇÓËÂÎÂØ ÐÂ ÕÑÔÕÑÄÂ [38 ë 41], ÆÂÊÇÆÇÐËÇ ÃÂÐÆÑ ÒÂÓÂÏÇÕÓÑÄ ÒÑÔÕÑÑÕÍÑÓÑÄ SmO(F)FeAs. ²ÇÊÖÎßÕÂÕÞ ÓÂÊÐÞØ àÍÔÒÇÓËÏÇÐÕÑÄ ÓÂÊÎËÚÂáÕÔâ ÒÑ ÕÑÎßÍÑ ÍÑÎËÚÇÔÕÄÇÐÐÑ ÑÐËÍÑÏÑ ÆÂÎâÚÑÕÑÍ ÇÇÐÐÑÏ ÓÂÊÎËÚËË: ÓâÆ ÊÂÆÂÚ ÐÇÕËÓÑÄÑÔÕß ÚÕÇÓÑÊ ÔÑÐ d-ÄÑÎÐÑÄÑÅÑ ÒÂÓÂÏÇÕÓÑÄ, ÔÄ ÑÆÐÑÊÐÂÚÐÑÅÑ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË, ÐÂÍÑÐÇÙ, Ô ÆÄÑÇÏÇÐÐÑÔÕß ÒÑÆÑÄÐÑÅÑ ÔÄÇÓØÒÓÑÄÑÆËÏÑÔÕË.

±ÓÑÕËÄÑÓÇÚËÇ ÏÇÉÆÖ ÓÇÊÖÎßÕÂÕÂÏË àÍÔÒÇÓËÏÇÐÕÑÄ ÆÂÐÐÞØ ÒÑ ÆÂ-ÊÂÐÂÏÑÕÑÔÕËÏÑÔÕË ÑÕÑÓÆÇÑÔÕÂÄÂÐÐÞØ ÆÎâ ÓÇÆÍÑÊÇÏÇÎßÐÞØ ÚÇÔÕÑÚÂÄÑ-ÐÑÔÕÑÔÕÑâÐËâ ÇÇÕÂ "1111", ÍÑÕÑÓÑÇ ÇÇ ÒÑÕÄÇÓÆËÎ ÔÑÕÑÚÐÑ ÔÄÑÓÑÄÑÆÐÑÚÐÑÕË ËÊÍÎáÚËÕÇÎßÐÑ ÒÑÎÖÚÇÐËÇ ÆÎâ ÑÕÑÎÑÔÄÂÊÑÄ Ë ÕÓÑÇÐÑÏ ÒÑÕÄÇÓÉÆÇÐËÇ ÒÑÍÂÊÂÕÇÎß ÔÄÂÊÑÐËÏÇÍ ÆÎâ ÕÇÐÆÇÐÙËÇ ÑÃÑÆÑÔÕÑÏ ÇÇ ÐÑÓÏ ÓÇÊÖÎßÕÂÕÂÏË ÐÂÎÑ ÇÇ ÕÑÐÒÓËÏÇÐËâÏË ÒÂÓÂÏÇÕÓÑÄ ÐÇÐÞÏ ÔÑÎÑ ÍÑÕÑÓÞØ ÓÂÊÓÇÜÇÐËâ ÒÑÔÕÑÏÕÑÕÂÕÑ ÍÑÐÑÍ ÍÑÃÂÎß ÆÂÐÐÞØ ÕÑÐÑÄÂÇ ËÊÑÕÑ ÍÑÐÑÏ Ä ÍÑËÔ-ÅÇÐÐÞØ ÔÑÎÑÆÇÊÂ ÄÞÕÑÐÑÏ ÄÂÍÑÒÇ.

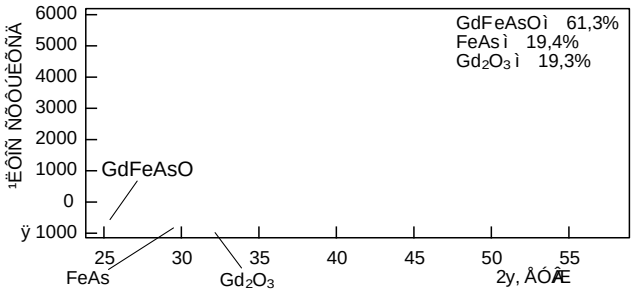
3. ³ËÐÕÇÊ ÒÓËÅÑÕÑÄÎÇÑÊÇÂÊÙÑÄ

£ ÐÇÊÃÊÐÓ ÓÃÑÕÃØ, ÄÞÒÑÊÐÇÐÞØ ÔÑÄÇ ÔÊÐÑÍÑÎÎÇÍ-ÕÊÄÑÌ ÔÑÕÓÄÊÊÍÑÄ ËÊ ¶ª ¡¯ Â ª ¶ £¥ ²¡¯ Ë ® ¤µ , ÃÞÎ Ë ÓÊÐÕÇÊÓÑÄÐÞ £´ ³ ± -ÕÑÇÄÊÐÇÐÊâ ÓÊÒÂ "1111": GdFeAsO(F), DyFeAsO(F), CeFeAsO(F), EuFeAsO(F), ÄÒÇÓÄÞÇÓÑÄÇÆÊÐÄÊÍÓ ÑÍÑÐÕÂÍÕÐÂÂÒÇÍÕÓÍÑÕÊâ Ä ÔÄÇÓØÒÓÑÄÑÆÄÕÑÕÕÑÄÊÐÄÞâÄÍÇÐÑÐÂÍÊÚÊÇÆÄÖØ àÐÇÓÅÇÕÊÊÊÇÕÍÇÌ Ä ÔÄÇÓØÒÄÑÑÊâÜÇÍÕÑÕÔÕÑâÐÊÊ ÑÒÓÇÆÇÍÇÊØÊÐÂÓÐÊâ.ÂËÄÑÍßÛÇá ÍÓÊÕÊÚÇÔÍÖáÕÇÏ-ÒÇÓÃÕÖÇÓ 52ÿ 53¬ ËÍÇÍÊ ÑÄÓÂÊÙGdFeAsO$_{1ÿ x}$F$_x$ Ô ÒÓÊÃÍ ËÊÊÕÇ ßÐÑ ÑÕÕÊÍ ÃÍßÐÞÌ ÓÓÑÄÐÇ ÆÊÓÊÓÑÄÐÊâ x ˆ 0;12 [42].

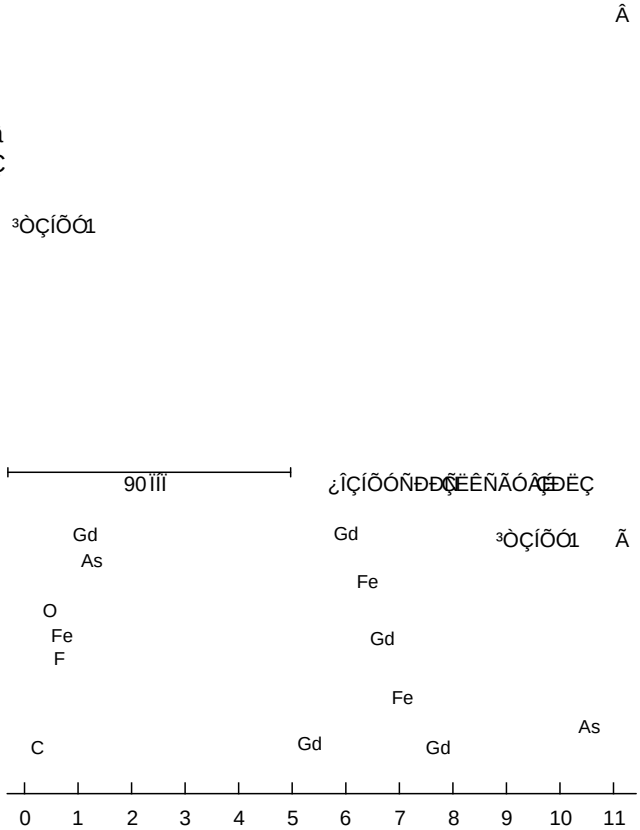
±ÑÍÊ ÍÓËÕÕÍÃ ËÚÇÍÊÇÑÃÓÂÊÞGdFeAsO$_{1ÿ x}$.F$_x$ †ÃÞÍÊ ÔËÐÕÇÊÊÓÐÞÄÇÕÑÆÑÍÕÄÇÓÑÆÊÓÕÊÄÞ-ÔÑÍÑÍ ÆÂÄÍÇÐÊ[42, 43]. ªÔØÑÆÐÞÍÊÂÕÇÓËÂÍÂÍÊÔÍÖ-ÉËÍÊ ÍÓÕÑÚÍÊÚÊÕÕÞ(Ø9,9%) Gd ËAs ËÓÑÓÑÚÍÊ FeF$_3$, Fe Ë Fe$_2$O$_3$ (99,99%). ªÊÅÑÕÑÄÍÊÐÞÇÐÂ ÒÇÓÄÑÌÕÕÂÆËË ÒÓÇÍÖÓÔÑÕÊÊ AsAs Ë FeF$_3$ ÔÍÇÛËÄÂÍÊÔÍÕ Fe, Fe$_2$O$_3$ Ä ÐÑÍËÐÂÍßÐÑÍ ÔÑÑÕÊÊÇÊÐÊÊ ÓÓÇÕÔÍÊÇßÄ ÕÂÃÍÇÕÍÊ ÆËÂÍÇÕÓÑÌ3 ÍÍ Ë ÄÞÔÑÕÑÌ3 ÍÍ. ¥ÂÍÇÇ ÕÂÃÍÇÕÍÊ ÊÂÍÍÂÆÞÄÂÊÔßÄ ÕÊÅÍËËÊÐÊÕÓÊÆÃÑÓÆ ÒÓÑÄÑÆËÍÔâ ÔËÐÕÇÊÊÓÊÆÂÄÍÇÐÊÊÑÍÑÍÑ 50 ÍÃÂÓ Ë ÒÓËÕÇÍÒÇÓÂÕÓÓÇ 1350 C ÄÕÇÚÇÐÊÇÍÊÐ.

²ÇÊÓÍßÕÂÕÍÞÑÍÊÚÇÔÕÄÇÐÐÑÇÊÕÕÇÐÑÄÓÂÊÑÇÑÑÊÊâ ÆÂÐÐÞÒÑÓÑÚÍÑÄÑÆÊË×ÓÂÍÙÊÊÑÍÒÚÇÐÐÞØÂÆË×ÓÂÍ-ÕÑÍÇÕÓ"Bruker-D8 Advance" (CuK$_{a1}$-ËÊÍÖÚÇÐÊÇÇÑÍÇÕ-ÓËâÐÂÑÕÓÂÉÇÐÊÇ)ÕÑÆÑÍÑÍÐÑÕÓÑ×ËÍßÐÑÊÕÑÚÐÇ-ÐËâ²ËÕÄÇÍßÆÂÇÓÇÆÔÕÂÄÍÇÐÂÓÉÔ1. ²ÇÐÕÅÇÐÊÇÇ ÆË×ÓÂÍÕÊÓÄÍÞ ÔÄËÆÇÕÇÍßÕÕÄÕÇÍ ÑÍ ÒÑÍÊÓË-ÔÕÂÍÍËÚÇÔÍÑÕÕÓÍÕÇÍÂÕÇÓËÂÍÑ Ô ÆÑÍËÐËÓÓáÜÇÌ ×ÂÊÑÌ ÕËÒÂ"1111" Ë ÒÓËÍÇÔâÍËÕÑÃÑÚÐÞØÊ,Ä ÚÂÔÕ-ÐÑÕÕÊeAs Ë Gd$_2$O$_3$. °ÔÐÑÄÐÂâ×ÂÊÂGdFeAsO(F) ËÍÇÇÕ ÒÓÑÕÕÓÂÐÕÕÄÇÊÄÓÒÒÕÕÊÍÇÕÓÍ P4=nmm Ô ÒÂ-ÓÂÍÇÕÓÂÍËàÍÇÍÇÐÕÂÓÑÌ âÚÇÌÍÊ a ˆ 3;8982 3† A, c ˆ ˆ 8;4059.9† A. ³Ñ ÆÓÉÂÐÊÇÒÊÍ ÇÊÞØ×ÂÊ ÖÍ ÇÐÞÚÂÇÕâÔ ÑÕÕÑÄÇØÑÕÊÄÂÍÖÃÑÄÓÂÊÂ,ÒÑâÑÍÖ ÒÑÄÇØÑÕÊÐÞ ÔÍÑÌ ÕÑÚÊ ×ÑÄÞÄÕâ. ±ÑÕÍÇÆÓáÜÊÌ ÍÊ ÍÓÑÂÐÂÊ ÊàÍÇ-ÍÇÐÊÑÂ ÔÑÕÂÄ ÒÑÄÇØÑÕÊÑÄÓÂÊÚÂ (ÕÂÐÊÓÖáÜÊÌ ÍÊ ÍÓÑÕÑÒJSM-7001FA ÔÒÓÊÊÕÂÑÌ ED· (Energy-Dispersive X-ray)) ÒÑÂÊÂÍ, ÚÕÑÄÂÕÕÊÊÂÞÕÑÚÞÍ ÔÑÆÇÓ ÉÂÐÊÇÍ Gd ÓÂÕÇÆÍÇÐÞÔÍÖÄÍÐÑÄÄÊÆÊÊÊÇ ÓÂÍÊÇ ÓÑÍ ÑÍÑÍÑ 1 ÍÍ Ï. ²Ê ÔÖÑÍ 2 ÆÍÇÑ ÐÕÓÊÖÖÇÓÇÊÖßÄÇÑÍÂÍßÐÑÂÑÂÐÂÍÊÊÂàÍ ÇÐÕÐÂÑÕÑÕÕÂÄ ÑÆÐÑÍ ÊÊÑÂÄÕÕÇÍ ÒÍÑÚÂÆ8 1 ÍÍ Ï ², ÑÄÑÊÂÚÇÐÑ ÍÂÍ "ÒÇÍÕÓ 1". £ ÕÄÍ ÊÚÇ ÒÊÄÆÊÇÑÕÑÕÊÖÇÐÑÇÔÑÆÇÊÂÐÊÇ Gd, Fe Ë As, ÊÊÇ ÓÇÐÑÇÄ ÒâÊ ÔÍÖÂÍÐÑ ÄÞÄÓÂÐÐÞØ ÑÄÂÕÕâØ ÑÄÓÂÊÂ(ÕÑÆÇÓÂÐÊÇÍÊÕÑÓÑÄÐÇÓÄÆÕÕÐÂÄÆÊÊÑÓÕÕÐÑÄÊÕ) Ë ÖÕÓÄÊÊÐÞÇÊÂÚÇÊâÒÑÕÍÑÚÂÆÊ,175 ÍÍ ².

³ËÐÕÇÊÊÕÂÐÐÞÇÑÄÓÂÊÙÊÊÍÇÍÊ ÑÄÝÊÍÐÓá ÔÄÇÓØ-ÒÓÑÄÑÆâÚÓáÂÊÖ,ÚÕÑÒÑÆÇÓÉÆÂÍÑÕÍÇÊÖÍßÕÄÍ ÍÂÂÐÊÕÕÍÇÊÖÍßÕÄÍ[42]. ¯Â ÓÊÖÖÐÍÇâ ÒÑÍÂÊÂÐÂ ÕÇÍÒÇÓÂÕÄÂÐÊÂÄÊÖÊÍÑÕÕÕÑÒÑÍÇÊâR.T † ÆÍâ ÒÓËÄÍÊÊÕÇÍßÐÑÑÒÕÊÍÄßÐÑÄÑÕÑÕÂÄÂ 0;12 ÒÓËÐÇ-ÔÍÑÍßÍØ ÊÐÂÚÇÐÊâÄÄÊÐÕÊÐÑÄÑÕÑÂâ; ÓÇÊÍËÌ ÒËÍ ÒÓÑ-ËÊÄÑÆÐÑÍR=dT (ÓÊÖ3Ã) ÆÇÍÑÐÕÊÕÕÇÍÄÍÖá ÛÊÓÊÐÖ ÔÄÇÓØÒÓÑÄÑÆÊÑÇÓÇÆÑÇÓÇÆÄ©ÐÂÚÇÐÊÊÕÊÍÇÍÑÕÇÍ-ÒÇÓÃÕÖÇÓÄÇÓØÒÓÑÄÑÆâÚÇÓÇÆÄÄ ÐÕÍÇÄÑÍ ÒÑÍÇ T_c 52;5 ¬, ÑÒÓÇÆÇÍÈÐÑÍÄÍÓÊÍÖ ÖÓÑÊÊÄÑÆÐÑ dR.T †=dT, ÐÇÍÐÑÅÑÍÇÐßÛÇÍÄÍÓÊÍÄÍßÐÑ ÆÑÕÕÊÅÐÑÕÑÅ Ä àÕÑÍ ÍÍÂÕÕÇÕÑÇÆÊÐÊÇ ÊÐÂÚÇÐÊâ ˆ 55;4 ¬ [8] ÆÍâ SmFeAsO(F). £ ÏÂÅÐÊÕÐÑÍÒÑÍÇÕÄÇÓØÒÓÑÄÑÆÊÚÇÊÇ-ØÑÆÊÛÊÓáÇÕÕâÇÕÇÍÇÓÂÕÕÇÓÄÑÍÐÑÕÑÐÐÑÍÇÐßÛÂÇÕ-Ôâ(ÓÊÖ3a); ÕÂÍÑÇÒÑÄÇÆÊÐÇÊÓÊÚÊÐÑâFeAs-ÔÄÇÓØÒÓÑ-



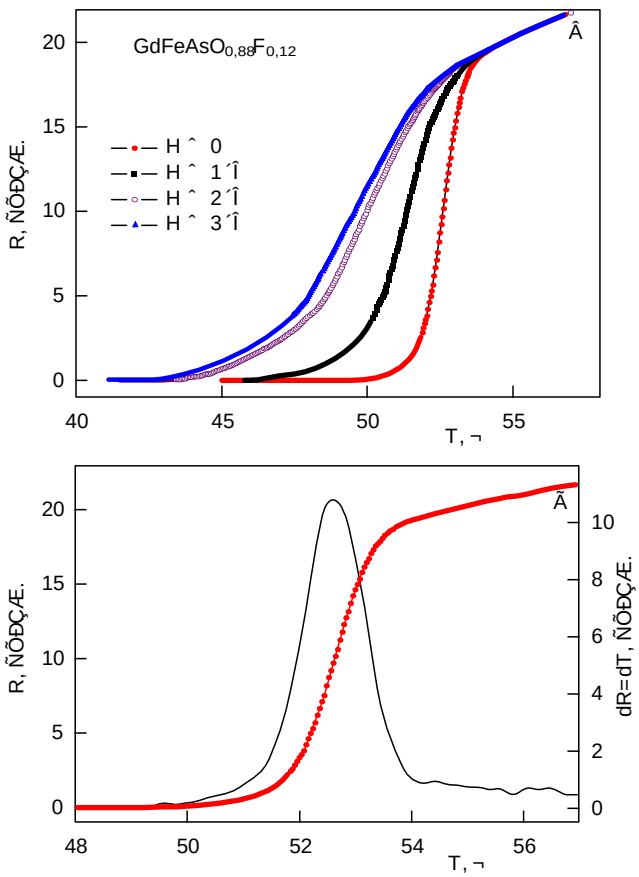
²ËÔ. 1. ªÊÍÇÓÇÐÊÐÌ ÒÓÑ×ËÍÇ(ÄÇÓØÐÂâÓÊÄÂâ),ÓÇÊÓÍßÕÂÕÕÑÚÐÇ-ÐËâ Ë ÓÑÊÊÚÍÊÍÊÍÑÄ ×ÂÊÞ Gd-1111 (ÔÓÇÆÐÂâÓÊÄÂâ),Â ÕÂÍÉÇ ÓÂÊÐÑÓÕÕÇÉÆÓÊÊÍÇÓÇÐÐÞÍÊ ÓÑÆÊÂÐÐÞÍ ÒÓÇÍÕÓÑ(ÐÊÉÐâ ÍÓÊÄÂâ).



²ËÔ. 2. ªÊÑÃÓÂÉÇÐÊÇÑÄÇÓØÐÑÕÑÕÊÚÊÄÂâÓÂÕÕÑÄÂâÍÇÍÕÓÑÐÑÍ ÍÊÍÓÑÕÍÑÒÇ(Â) Ë ÍÑÍ ÂÍßÐÞÌ ÒÇÍÕÓØÂÓÂÍÇÕÇÊÊÊÐÊÌ âÍÇÍÇÐÑÑÂ), ÔÑÑÕÄÇÕÕÕÄÓáÜÊÂÕÕÕÑÄÇÓØÐÑÕÑÕÊÚÇÐÐÑ-ÍÕ ÍÂÍ "³ÒÇÍÕÓ1". ±Ñ ÅÑÓÊÊÑÐÂÍßÐÑÕÊ àÐÇÓÅÊâ£).

´ÂÃÍÊÚÂ.°ÕÐÑÕÊÕÇÍßÐÑÕÑÄÇÓÉÂÐÊÇ As Ë Gd ÐÂÓÂÊÐØÓÚÂÕÕÍÂØ ÒÑÄÇÓØÐÑÕÑÕÊÚÂÕÑÍÐÞØÓÑÚÇÐÕÂØ)

µÚÂÕÍÊÑÃÓÂÊÙÂ	Fe	As	Gd
2	11,74	11,36	20,55
4	14,64	15,43	19,16
5	16,11	15,29	17,19
6	16,17	13,57	18,70
7	14,44	15,30	18,12
CÓÇÆÐÇÇ ÕÑÆÇÉÂÐÊÇ ÒÑ ÒÍÑÜÂÆÍÇ350 500 ÍÍÍ ²	14,1 2,2	15,5 1,9	18 11



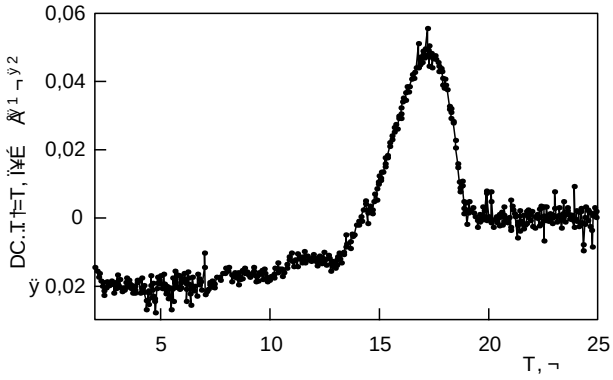
²ËÔ. 3. (a) ´ÇÌÒÇÓÂÕÓÓÐÂÊâÄÄÊÔÊÏÑÔÕÕÑÒÓÑÕÊÄÎÇÊÐÊÓÊÕÓÈØ ÊÐÂÚÇÐÊÏÄÅÐÊÕÐÑÅÕÑÎâÆÎâÑÃÓÂÊÙÇdFeAsO(F) ÒÓÊÄÎÊÊÊÕÇÎßÐÑÑÒÕÊÏÂÎßÐÑÅÕÑÕÂ[33]. (Ã)±ÓÑÊÄÑÆÐÂÊ.T †=dT ÆÎâH ^ 0.

ÄÑÆÐÊÍÑ[17, 43]. ª ÊÊÊÏÇÓÇÐÐÑÊÄÊÔÊÏÑÔÕÊ.H †Ä ÓÂÃÑÕ[42] ÃÞÎÂ ÔÆÇÎÂÐÙÇÐÍÂdH$_{c2}$=dT j 3 TÎ ¬ÿ¹, ÚÕÑÓÓÄÄÐÊÏÑÕÓÇÊÓÍßÕÄÊÂÆÎâ ÑÒÕÊÏÄßÐÑ ÆÑÒÊÓÑÄÂÐÐÑÄÑÕÄÇÓØÒÄÕÑÊÐÊÍÄmFeAsO(F) [43] ÔÄÎÊÊÍÊÏÊ ÊÐÂÚÇÐÊÄÄT$_c$. ªÊ ÒÓÊÄÇÆÈÐÐÊÄÄÚÇÐÊÄÓÑÊÊÄÑÆÐÑÉÇÎÇÊÂÓÊÕÇÎÞ122". ¢ÞÎÑ ÐÂÎÆÇÐÑÚÕÑÓÍÂÚÑÍÕÇÔÎÑÊÏÍÑÓÊ DC=T$_c$ / T$_c^2$, Õ.Ç.àÕÑÕÓÍÂÚÑÍÑÒÓÇÆÇÎâÇÕÔâ ÎÊÛß ÕÇÌÒÇÂÓÖÓÓÕÇÓÇÆÄT$_c$ Ê ÐÇÊÂÄÊÔÊÄÊÕÑÕÊÓÂ ÆÑÒÊÓÑÄÄÂÊ(ÆÞÓÑÚÐÞÊÎÊ àÎÇÍÕÓÑÐÞÌ), ÐÊ ÑÓÍÑÐ-

±ÑÏÊÏÑ ÊÊÓÚÇÐÊÄÄÑÎÊÍÓÊÔÕÂÎÎÊÇÓÍÊÓÑÄÓÂÊÙÑÄ ÙÇÐÕÓÂÙÄÊÑÒÂÕÇÓ(ÊÔ.5). ¿ÕÊ ÓÇÊÓÎÂÕÐÞ ØÑÓÑÚÑ ÔÊÔÕÇÎÞ1111", ÐÂÎÊ ÒÓÑÄÑÆÊÎÊÕÂÍÉÇÊÔÔÎÇÆÑÄÂÐÊÄ ÓÑÂÎÂÔÓáÕÕÄÓÇÊÓÎßÕÄÕÂÊÄÂÑÕÞ[45]. ± ÑÎÓÚÇÐÐÞÇ ÐÂÎÑÐÑÍÓÊÕÂÎÎÂØÔÊÓÕÇÞ122" ÔÓÄÊÎÊÚÐÞÎÕÊÓÑÎ ÆÑÒÊÓÑÄÄÂÊ, ÆÞÓÑÚÐÞÊÎÊ ÀÎÇÍÕÓÑÐÞÌ), ÐÊ ÑÓÍÑÐ-ÏÊÎßÐÑÎ ÆÑÒÊÑÄÄÐÊÄÊÑÔÊÄÃÎÂ 34 ¬.

4. ªÊÏÇÓÇÐÊâÔÍÂÚÍÂÕÇÒÎÑÈÏÍÑÔÕÊ ÒÓÊÄÇÓØÒÓÑÄÑÆÄÄÏÇÍÇØÑÆÇ

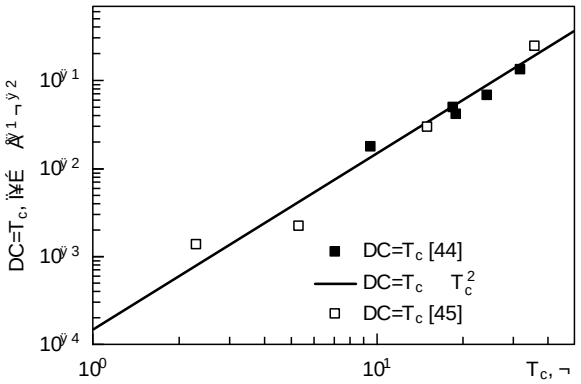
ªÊÏÇÓÇÐÊÇÔÍÂÚÍÂÕÇÎÑÈÏÍÑÔÕÊÓÓÊÄÇÓØÒÄÑÆâÚÇÏ ÒÇÓÇØÑÄÄÇÑÄÑÆÊÏÑÊÄÑÑÐÑÍÓÊÕÂÎÎÂØÔÊÕÇ "122" Ba$_{1ÿ x}$K$_x$Fe$_2$As$_2$, Ba.Fe$_{1ÿ x}$Co$_x$†$_2$As$_2$ Ê Ba.Fe$_{1ÿ x}$Ni$_x$†$_2$As$_2$ Ô ÓÄÊÎÊÚÐÞÎÊ ÕÊÒÄÎÊ Ê ÓÑÄÐâ Ê ÆÑÊÓÑÄÂÊâ. £ ÑÄÞÚ-ÐÞØ ÔÄÇÓØÑÄÑÆÐÊÍÄØÊÊÇÓÇÊâÇ ÔÎÂÚÍÂ ÀÎÇÍÕÑÐÞÑÎ ÕÇÒÎ ÑÊÎ Í ÑÓÕÊ Ä ÕÑÚÍ Ç ×ÄÊÑÄÑÄÑ ÒÓÇÒÑÄÄ ÒÑÊÄÑÎ âÇÕ ÒÑÎÓÚÊßÄ ÊÐ×ÑÕÎ ÂÚÊá ÑÄÇÊ ÚÊÐÇÒÎÑÐÑÕÊ ÀÎÇÍÕÑÐÞ ÐÞØ ÕÑÕÕâÐÊÌ ÐÂ ÒÑÄÓÇÐÑÕÊ ¶ÇÓÎ Ê, Ñ Í ÑÐÕÕÂÐÕÇ ÏÇÉ ÀÎÇÍÕÑÐÞÑÄÑÄÊÄÊÑ ÆÇÕÄÊâ Ê ÑÃ ÑÄÑÈÎ Ç ÔÄÇÓÒÓÑÄÑÄÊÚÇÌ ×ÂÊÞ. £ ÏÑÆÇÎÊ ¢¬ º ÔÍÂÚÑ ÀÎÇÍÕÑÐÞÑÎ ÕÇÒÎ ÑÊÎ Í ÑÓÕÊ DC ^ 1;43gT$_c$, ÅÆÇ g ì Í Ñà××ÊÚÊÇÐÕ ÀÎ Ç ÕÓÑÐÐÑÎ ÕÇÒÎ ÑÊÎ Í ÑÓÕÊ. £ ÐÊÊÍ ÑÓÇÎ ÒÇÓÂÕÓÓÐÞØ



²ËÔ. 4. ©ÂÄÊÔÊÏÑÔÕÊDC.T †=T ^ C.T; H ^ 0†=T ÿ C.T; H ^ 9 TI †=T ÆÎâàÇÎÕÓÑÐÐÑ-ÆÑÒÊÓÑÄÄÂÊÙÂa.Fe$_{1ÿ x}$Ni$_x$†As$_2$ [44].

ÔÄÇÓØÒÓÑÄÑÄÊÏÂØ àÕÑ ÔÑÑÕÐÑÛÇÐÊÇ ØÑÓÑÛÑ ÄÞÒÑÎ-ÐâÇÕâ

¥Îâ ÄÞÔÑÍÑÕÇÏÒÇÕÂÓÐÞØÄÇÓØÒÓÑÄÑÄÊÄÊÕÂ-ÙÊâÄÞÅÎâÆÊÊÐÂÏÐÑÅÑÕÎÑÉÐÇÇ. ÚÂÔÕÐÑÔÕÊÕÊÇÆÑÆÑ-ÒÊÓÑÄÂÐÐÑÄÊÇ£´³±-ÍÒÒÓÂÕÑÄÔÍÂÚÑÕÇÒÎÑÈÏÍÑÔÕÊ ÕÑÚÍÇÄÇÓØÒÓÑÄÑÄÊÄÊÕÇÓÇØÑÄÄÊÄÜÊÇÐÂÃÎâÆÂÇÕ-Ôâ[44]. ´ÇÌ ÐÇÎÇÐÇÇT$_c$ Ä ÕÂÊÊØÑÃÓÂÊÄÊÙÍÑÉÇÕ ÒÓÇ-ÄÞÛÂÕß 60 ¬. ±ÓÊÚÈÎ ÕÂÍÊÇÑÃÓÂÊÙÑÃÎÂÆÂáÕÑÄÇÓ-ÛÇÐÐÑÎÕÓÓÍÕÒÓÑÑÀÑÄÑÕÊÄÑÄÑÓÊÕÑÄÊØÓÊÕÕÂÎÎÊ-ÚÇÔÍÑÐÇÑÆÐÑÓÑÆÊÊÑÕÑÓÂÊÑÅÎÂ ÃÞ ÒÓÊÄÑÊÊÐÑ ÕÇÌÒÇÓÂÕÑÕÊÄÊÑÕÑÓÂÊÙÑÃÓÂÊÙÑÃÓÂÊÙÑÃ



²ËÔ.5. £ÇÎËÚËÐÐÔÍÂÚÍÂÕÇÔÎÑÇÍÍÑÔÕÎÈ DC=Tc ÄÊÂÄËÔÊÈÑÕÑÕÑÕ Tc ÆÎâ ÒÐËÍÕÉÆÑÄÇÎÇÊÂÕËÔÄ "122". ´ÈÍÐÞÇ ÍÄÂÆÉÓÂÕÞ ÓÇÊÕÑÕÂÕÞ ÓÂÃÑÕ [44], ÓÄÇÕÎÞÇÂÆÉÓÂÕÞ ÆÂÐÐÞÇÂÃÑÕ [45].

ÉÇÐËâ Ä ÕÕÑÕÑÚÞÞØ Í ÑÐÕÍ ÕÂØ ÐÇÇÇÆÑ ÄÑÎÐËÍÂá ÜËØ ÄÔÍÇÆÔÕÄÐÄÇÎËÜËâ ÔÕÖÖÒÇÐÊÇÕÇÓÁÐÔÂ ÚËÔÕÞØÐËÑ-ÅÇÐÐÞØÍÑÍÂØÔÍÑÊÔÕÞØÐËÔÕÃÑÄ. ªÊ ÔËÐÕÇÊÊÓÑÄÂ ÔÕÂÍÊÚÇÕÑÍ ÕÕÔÍÕÖÖÑÄÓÂÚÞÇÓÍÁÐÞØÑÓÁÊÚÑ ËÍÇáÜ ËØ×ÑÕÖ ÕÃÇÕÑÍ, ÄÞÓÇÊÄÊÔßÕÑÐÍ ËÇ ÓÓâÍ ÑÓÄÑÍßÐÞÇ ÓÍ ÂÕÕÐÍ Ë (2 1 0;1 Ï Ï 3), ÍÑÕÑÓÞÇÑÍÇÜÂÍËÔßÐÂËÊÍÇÓËÕÇÍßÐÞÕÕÑÍËÍÍËÍÓ Ñ-ÍÑÐÕÂÍÕÐÑÄÕÑÓÇÍÕÓÑÍÇÕÓÁÇÙËÊËÑÐÞÑÐÕÑÍÍÐÕÑÍÍËÓÓÇ-ÏÞÏ ËÊÅËÄÑÄÆÇÓÉÇÕÂÄÓÓËÕÇÍÓÇÓÂÕÖÓÁÓÇÑ ÄÑÄÓÂÊÚ ÔÑÊÆÄÄÂÍÂÍÊÓÑÕÓÇÜËÐÂ¥ÇÕÂÍËÕÇØÐÊÍÊÍÇÓÇÐËÌ "Í ÑÐÕÍ Õ ÐÂ Ï ÉÍ ÓÑÕÓÇÜ ËÐÇ" (break-junction, BJ) ÓÑÆ ÓÑÄÐÑÒÊÔÂÐÄ [48, 49].

¯Â ÓÉÊÕÐÇ 6 ÒÓÉÊÇÆÇÐÄÑÍßÕÂÏÒÇÓÐÞÇØÂÓÍÄÕÇÓÉ ÔÕÉÍÉ I.V † Ë ËØÒÓÑÊÄÑÆÉÇ dI.V †=dV Ë d²I.V †=dV², ËÊÍÇÓÇÐÐÞÇÆÎâ ÑÆËÐÚÑÄ SNS-Ï ÉÍÓÑÑÐÕÂÕÂ ÐÂ ÒÑÍÉÍÓÉÔÕÍÉ ÚÇÔÍÑ ÑÄÓÊÚÇ $GdO_{0,88}F_{0,12}FeAs$ [50]. ±ÓÉÄÇÆÈÞÇÔÉÏÍÇÕÓÉÚÞÇ.V †-ØÂÓÍÄÕÇÓÉÕÉÍÉÕÉÚ-ÐÞ ÆÎâ "ÚÉÕÞØ" SNS-ÏÉÍÓÑ ÍÑÐÕÂÍÕÑÄ Ô ÐÇÄÑÕÚÉÏ ËÊÄÞÕÑÚÐÞ ÕÑÍÑÏ [47, 51]. ¯Â ÓÉÊÕÐÇ 6 Ä ÆÉ××ÓÇÐ-ÙÉÂÍßÐÑÌÒÓÑÕÄÆÉÏÍÑÕÉdI.V †=dV ÄÉÄÊÂÔÇÄÉÓÑÄÍÑÄ ÒÓÉÐÂÒÄÉÇÐÉØV ˆ 22, 11 Ë 5 Ï£. £ ÔÎÖÚÇÍÐÑÅÑÍÓÕ-ÐÑÅÑÄÐÉÇÇÄÑÅÑÕÉÇÐÉÒÓÑÄÍÞ ÆÑÍÉÐÞÄÑÊÐÍÂÕ ÒÓÉÐÅÇÇÐÄÂÕÂÉÇÐÌ ÐÂSNS-ÍÑÐÕÍÕÇ V_n ˆ 2D=enÔ ÙÇÎÑÚÉÕÇÐÞÏÉ n ˆ 1; 2; . . . ´ÂÍÉÏ ÑÄÓÄÕÉ, ÒÇÓÄÇÆÄÇ ÑÕÑÕÕÐÐÑÕÉÑÉÐ ÑÔÄâÉÕÑÔ n ˆ 1, 2 ËÑÙÇÐÕÑÍ ÂÎßÐÑÇ ÊÐÂÚÐÇÔÄÓÓÒÕÄÑÆâÇÌ ÜÇÎÉ 2D ˆ 22 Ïà£. ¥Îâ ÄÄÖ-ÜÇÎÇÄÑÄÕÄÓÓÒÓÄÑÆÉÐÉÏÑÉÐ ÑÑÉÉÄÉÄÕÄÉÄÐÇÉÄÉÓÉ-ÏÞÇ ÓÓÄÄÓÍÑÐÉÇÓÍÉÇÑÕÇÆÑÄÕÇÎßÐÑÕÉÑÕÄÇÄÚÉÇ ÄÑÍßÛÑÌ (D_L) Ë ÏÂÍÑÌ (D_S) ÜÇÍâÏ Ä ÓÕÇÍÕÇ ¥ÇÌÕÕÄÉ-ÕÇÍßÐÑ, ÑÕÑÕÄÐÐÑÕÕÓÉ 5 Ï£ ÐÂÓÉÊÕ 6 ÐÇÕÑÑÄÕÇÕÕÕ ÄÖÇÑÉÉÄÆÇÍÑÏ ÖÐÂÓÉÊÇÐÉ 7,3 Ï£ ÆÎâ 3-Ì ÅÂÑÑÐÉÍ Ë ÑÕÄÑÍßÛÑÌ ÜÇÎÉ Ë, ÔÍÇÄÉÄÂÇÍßÐÑ, ÓÄÉÄÇÍßÕÕÄÇÕÑ ÐÂÍÉÚÉÉÇÐßÛÇÌ ÜÇÎÉ ÔàÐÇÄÉÇÌ 2;5 Ïà£.

±ÇÓÇÄÕÕÕÉÄÂáÑÐÕÄÕ ÐÂÑÄÐÑÉ ÕÑÍ ÉÇÑÄÓÄÙÇÄ ÕÇÚÇÉÇÑÄÐÑÄÉ ÕÑÄÉÇÐÉÉÑÕÇÓÄÓÓÓÐÄÑáÍÓÓÇÉ-ÍÇÐÕÂ, ÓÄÄÄÑÔÕÂÐÂáÄÂÕßÓÄÂÉÉÚÐÞÇ I.V †-ØÂÄÄÍÕÇÉ-ÔÕÉÍÉÓÔÇÉÑÓÑÇÄÐÑÕÇÍÑÓÄÇÂáÜÉØÄÑÍßÛÑÌ ÜÇÎÉ, ÍÂÍÑÌ ÜÇÎÉ ÉÍÉ ÄÂÉÇÑÄÇÉ ÜÇÎâÍ. £ÄÉÄÇÍÇÍÍÑ ÍÓÉ-ÚÉÂÄÄÑÄÄÑÄÄÑ

ˆ .4;8 1;0†, ÚÕÑÒÓÇÄÞÛÂÇÕÕÂÐÆÂÓÇÕÕÂÚÇÐÈ,52Ä ÒÓÉÃÎÉÉÇÐÉÉÔÎÂÃÑÌ ÔÄâÉÄ ÕÇÑÓÉÉ¬º ÆÎâ ÑÆÐÑ ÊÑÐÐÑÅÑÕÄÇÓØÕÕÑÆÐÉÍÃÑÆÐÂÍÑâÕÑÓÓÇÊÖÎÃÕÕ ÐÇ ÒÓÑÕÉÄÑÕÕÉÇÕÓÇÉÉÏÖÔÉÎßÐÑÌÔÄâÉÉÑÆÇÎÉ¢¬º. ¹ÕÑ ÍÂÔÂÇÕÕÂÎÑÌ ÜÇÎÉ, ÕÑÉÊÏÇÓÇÐÐÑÕÇÃÏÉ ÑÕÐÑÛÇÐÉÇ $2D_S=k_BT_c$ ÔÑÔÕÂÃÇÕ 1, ÚÕÑÐÂÏÐÑÅÑÇßÛÇÔÕÂÐÆÂÓÕ-ÐÑÅÑÉÐÂÚÇÐÉ3,52. ¿ÕÂÏÂÎÑÔÕßÉÉÇÓÇÐÐÑÃÇÎÉÚÉÐÞ ÖÍÂÊÞÄÂÇÕÕÂÃÕÑ,ÚÕÑÃÑÎÇÇ"ÔÎÂÃÂâ"ÔÄÇÓØÒÓÑÃÑÃÑÕß ÒÓÉÉ > T_c (Õ.Ç:ÔÑÃÕÕÄÇÕÐÉÍÓÉÕÉÚÇÔÍÕÕÇÌÒÇÓÂÕÖÓÞ ÃÑÍÇÇÕÎÂÃÑÅÑÑÑÐÆÇÕÕÂÕÓÉÑÕÔÖÕÉÕÃÇÉÉÑÐÐÑÅÑ ÄÊÄÉÍÑÆÇÕÕÄÉâ)ÑÉÇÕÃÞÕßÉÐÆÖÙÉÓÑÄÄÐÕÕÓÇÐÐÉÍ à××ÇÍÕÑÍ ÃÎÉÉÑÔÕÉÄ k-ÒÓÑÕÕÓÁÐÕÕÕÕÇÉÖ ÆÄÖÏâ ÍÑÐÆÇÐÔÂÕÄÄ ÆÄÖÏÕÎÂÔÕâÕÕÑÞ¢ÓÉÍÎáàÐÂ, ÒÓÉ àÕÑÍ ÍÑÐÆÇÐÔÕÕÑÍßÛÇÌ ÜÇÍßá ÉÅÓÁÇÕÑÍß "ÄÇÆÖ-ÜÇÅÑ"±ÑÆÑÃÐÂÕÉÕÕÄâÉÉÍ ÒÓÉÐâÕÕÚÉÕÂÕÕÇÂÎÉ-ÊÖÇÕÕÄâÚÂÕÕÐÑÕÕÕÕgB$_2$ [48, 49] Ë $LaO_{0,9}F_{0,1}FeAs$ [52].

³Â ÏÑ ÔÖÜÇÕÑÅÄÄÐÉÇÃÑÍßÛÑÌ ÔÄÇÕÕÑÑÅÄÚÇÌ ÜÇÍÉ Ô ÏÂÔÛÕÂÃÑÍ $2D_L=k_BT_c$ > 3;52 Ä ÔÑÇÆÉÐÐÄÇÄÓÍÍÂÔÔÂ "1111" REOFeAs (RE ˆ La, Sm, Nd) ÒÑÆÕÄÇÓÉÆÂÇÕÕâ ÓÇÊÖÎßÕÄÉÕÂÖÖÐÐÇÕÐÑÌ ÔÒÇÍÕÓÍÑÕÕÉÉÖÔÉÉÖÔÒÑÍßÑÄÂ-ÐÉÇÌ ÕÇÕÐÉÍÉ"break-junction" [53, 54], SËN-ÏÉÍÓÑÍÑÐ-ÕÂÍÕÐÑÌÔÒÇÍÕÓÑÕÉÉÖÔÂÆÓÇÕÍÑÅÑÑÕÓÁÉÇÐÉÉ(Point Contact Andreev Reêection, PCAR) [38, 40, 55ë 60], ÔÍÂÐÉ-ÓÖáÜÇÌ ÕÖÐÐÇÍßÐÑÕÒÇÍÕÓÍÑÕÉÉÖÔÉÉ(Scanning Tunneling Spectroscopy, STS) [39, 51] Ë ×ÑÕÑàÎÇÍÕÓÑÐÐÑÕÒÇÍÕÓÑ-ÔÍÑÒÉÉÔ ÖÅÎÑÄÞÏ ÓÂÊÓÇÕÊÉÇÏ [61]. ¥Ñ ÐÂÔÕÑâÜÇÅÑ ÄÓÇÏÇÐÉÉÊÏÇÓÇÐÉÅÇÎÉ Ä Gd-1111 ÒÓÑÄÑÆÉÉÖÕÑÎßÍÑ Ä ÓÄÑÕÇ[50]. ±ÓÉ ÔÓÂÄÐÇÐÉÉÇÊÖÍßÕÂÕÕÉÉÇÓÇÐÉÌ ÜÇÎÉ Ä Gd-1111 Ë ÆÓÖÅÉÐÄÇÓØÓÓÑÄÑÄÄÉÑÅÑÑÂÔ-ÔÄ,Sm-1111, Nd-1111 Ë Tb-1111, ÍÑÕÑÓÞÇÏÇáÕ ÃÎÉÊÍÉÇ ÊÐÂÚÇÐÉâ, ÑÃÐÂÓÉÄÄÂÇÕÕâ ÒÇÍÑØÕÕÑÅÎÂÊÇÊÐÂÚÇÐÉÌ $2D_L=k_BT_c$, ËÉÍÇÓÇÐÐÞØ[50], ÔÆÂÐÐÞÉ STS [39], ÆÂÐ-ÐÞÏÉ ÔÒÇÍÕÓÑÕÉÉÖÔ ÒÑÏÑÜßá ÕØÐÉÍÉBJ [51] Ë Ô ÃÑÍßÛÉÐÕÕÃÑÏPCAR-ËÉÍÇÓÇÐÌ [40, 58ë 60]. °ÆÐÂÍÑÄ ÐÇÍÑÕÑÓÞØÂÑÕÂØÑÕÑÃÛÂÍÑÕßÒÑÚÕÉÆÑÇÓÂßÛÉØ ÊÐÂÚÇÐÉâÚÇÎÉ [55, 56]. ¹ÕÑ ÍÂÔÂÇÕÕÂÎÑÌ ÜÇÎÉ, ÕÑ ÑÒÖÂÎÉÍÑÄÐÞÇ àÍÔÒÇÉÇÐÕÂÎßÐÞÇÊÐÂÚÇÐÉâÕÎÉ-ÚÂáÕÔâÆÓÕÑÕÓÕÓÂÇÛÉÃÑÎßÛÇ ÒÑÚÕÉÉÕÂÉÁÍ ÔÎÇÆÖÇÉÕÔÓÂÄÐÇâ,ÉÓÑÄÇÆÉÐÑÕÑÃÑÕ[50]. ¬ÓÑÏÇ ÕÑÅÑÑ,ÓâÆÓÂÃÑÕÂÎÂâ ÜÇÎßÄÑÑÃÜÇÇÐÂÃÎáÆÂÎÂÓ,ÂÄ[50]ÔÑÑÃÄÎÑÔÑÑÄÑÉÑÑÐÑÔÕÉÉÖÇÕÕÄÄÐÉÉâÇÕßÇÌ ÜÇÎÉ ÔÇÜÉÌÇÐßÛÉÏ ÉÐÂÚÇÐÉÇ 1 Ïà£. ´ÂÍÉÏ ÑÃÓÂ-ÉÑÏ, ÔÇÅÑÆÉÄá ÔÉÏÇÕÓÉâÒÂÓÂÏÇÕÓÂÒÑÓâÆÍÃÕÂÍ Ë ÉÐÂÚÇÐÉâÄÇÓØÒÓÑÄÑÄÄÉÑÅÑÑÇÌ Ä ÔÄÇÓØÒÓÑÄÑÄÄÉÑÅÑÑÂÔ ÍÍÂÔÔÂ RE-1111 ÑÔÕÂáÕÔâÄÑÒÓÑÑÔÂÏÉÉÕÇÕÄáÜÉÏÉ ÆÑÒÑÍÐÉÕÕÕÕÌàÍÔÒÇÉÇÐÕÂÎßÐÑÒÓÑÄÇÉÉ

²ÄÄÑÕÂÒÑÆÆÇÕÐÉÄÄÓÂÐÕÂÏÉ¶¶ª, ²¡¯, ®ÉÐÉ-ÔÕÇÓÔÕÕÄÄÕÂÐÉÄÐÉÄÉ ÉÐÂÓÍÉ¶.

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