ITEP-42-94

Fermilab Library
0 1160 0072851 3

INSTITUTE OF THEORETICAL
AND EXPERIMENTAL PHYSICS

FERMILAB 42-94

MAR 9 199

LIBRARY

K.N.Zyablyuk

# ON THE LAGRANGIAN OF N=1, D=10 DUAL SUPERGRAVITY

MOSCOW 1994

UDK 530.145. N-16

ON THE LAGRANGIAN OF N=1, D=10 DUAL SUPERGRAVITY: Preprint ITEP 42-94/

K.N.Zyablyuk - M., 1994 - 12p.

We construct the lagrangian of dual supergravity by means the equations of motion derived from the superspace approach.

Ref. - 9.

© Институт теоретической и экспериментальной физики, 1994

The superspace formulation of supergravity is convenient to obtain the equations of motion for its fields. But there is no simple way to construct the lagrangian by these equations. In this paper the minimal lagrangian (i.e. one which contains not more than 2-nd power of derivatives) of D=10, N=1 dual supergrvity is obtained.

The dual version of supergravity has been introduced in [1]. Its multiplet contains: $e_m{}^a$– graviton, $\psi_m{}^\alpha$– gravitino, $\phi$ – dilaton, $\chi_\alpha$– dilatino and $M_{m_1 \ldots m_6}$– antisymmetrical potential (we do not consider the contribution of the gauge matter here). The equations of motion for these fields depend on the constraints imposed on the components of the correspondent superfields. We use the constraints introdused in [2] which are supposed to be the simplest ones. Equations of motion in this system of constraints (after some fields redefinition) have been obtaned in [3] and are listed in Appendix A of this paper. These equations have important property: they are linear in fields $\phi$ and $\chi$. Hence the lagrangian must be linear in dilaton and dilatino:

$$L = (\phi S_1 + \chi_\alpha S_2^\alpha)| \tag{1}$$

(the vertical line denotes 0-component of superfield).

In order to find $S_1$ and $S_2^\alpha$ it is necessary to use the torsion Bianchi identities. In this set of constraints they do not fix the components of the curvature $\mathcal{R}_{abcd}$ and the torsion $T_{abc}$ and $T_{ab}{}^\alpha$. General expressions for $S_1$ and $S_2^\alpha$ through these components, which contain not more than 2-nd power of derivative, are:

$$S_1 = \mathcal{R} + a\,T^2, \quad S_2 = b\,\Gamma^{ab} T_{ab}, \tag{2}$$

where $\mathcal{R} = \mathcal{R}_{ab}{}^{ab}$ , $T^2 = T_{abc}T^{abc}$ , $T_{ab}$ denotes $T_{ab}{}^\alpha$; the general factor before the lagrangian is not important here. The quantities $S_1$ and $S_2$ must vanish on

shell. But the torsion Bianchi identities guarantee, that the following relations are valid on shell (see [3])

$$\mathcal{R} - \frac{1}{3}T^2 = 0 \tag{3}$$

$$\Gamma^{ab}T_{ab} = 0 \tag{4}$$

(in the set of constraints presented in Appendix A; however the analogous relations take place in some other systems of constraints, for instanse in [4] – [5]). Hence $a = -1/3$.

In order to find factor $b$ it is necessary to consider some equation for $e_m{}^a$, $\psi_m$ or $M_{m_1 \ldots m_s}$. For this purpose we must write down the 0-components (see Appendix B) of the relations (A.3)–(A.7) and transform it to the form in which they may be derived from the lagrangian immediately.

We shall show, how one can do it for the potential $M_{m_1 \ldots m_s}$. To write down the 0-component of the relation (A.5) let us express the derivative with the flat index $D_a$ through the derivative with the world index $D_m$:

$$D_a| = e_a{}^m D_m| - \frac{1}{2}\psi_a{}^\alpha D_\alpha| \tag{5}$$

We take the spinor derivative $D_\alpha T_{abc}$ from the solution of the torsion Bianchi identities (see [3]):

$$DT_{abc} = -\frac{1}{2}\Gamma_{abc}{}^{fh}T_{fh} + \alpha\,\Gamma_{abc}\Gamma^{fh}T_{fh} \tag{6}$$

(the Bianchi identities give us only on shell fields values, i.e. while $\Gamma^{fh}T_{fh} = 0$; so one can choose arbitrary $\alpha$ in (6)). Then let us substitute the expressions (B.3) and (B.4) for the connection $\phi_{ma}{}^b|$ in the derivative $D_m$ according to (B.2) and after that substitute the components of the torsion $T_{ab}{}^\alpha|$ and $T_{abc}|$ from (B.5) and (B.6).

The terms

$$\beta\,\psi_{[a}\Gamma_{bc}(\,\phi\,\Gamma^f T_{d]f} - D_{d]}\,\chi - \frac{1}{36}\Gamma_{d]}\hat{T}\,\chi - \frac{1}{24}\hat{T}\Gamma_{d]}\,\chi\,)| = 0 \tag{7}$$

$$\gamma\,\psi_{[a}\Gamma_{bcd]}(\,\hat{D}\,\chi + \frac{1}{9}\hat{T}\,\chi\,)| = 0 \tag{8}$$

are equal zero on shell and thus can be added to resulting expression with arbitrary factors $\beta$ and $\gamma$. However the lagrangian must be invariant relative

to the transformation

$$M_{m_1\ldots m_6} \to M_{m_1\ldots m_6} + \delta_{[m_1} f_{m_2\ldots m_6]} \ , \tag{9}$$

which does not involve other fields. Consequently it must contain $M_{m_1\ldots m_6}$ only throught the strenght $\partial_{[m_1} M_{m_2\ldots m_7]}$. So the variation of action with respect to the potential must be the full derivative. This claim fixes all unknown factors unambiguously: $\alpha = 1/2$, $\beta = 3/2$, $\gamma = 0$.

As a result we derive the equation of motion for $M_{m_1\ldots m_6}$:

$$(\,\phi\, M_{[abc} - \frac{1}{8}\,\phi\,\psi_f \Gamma^{[f}\Gamma_{[abc}\Gamma^{h]}\psi_{|h|} + \frac{3}{2}\,\psi_{[a}\Gamma_{bc}\,\chi\,)_{;d]} = 0 \tag{10}$$

where

$$M_{abc} \equiv \frac{1}{6!}\,\epsilon_{abc}{}^{d_1\ldots d_7} M_{d_1\ldots d_6;\,d_7} \ ,$$

the semicolon denotes the ordinary covariant derivative which depends on the ordinary vielbein.

Taking into account (see (B.5), (B.6), (B.8)) that 0-components are

$$\mathcal{R}| = \frac{1}{4}\,M_{abc}^2 + \ldots;\ T_{abc}| = M_{abc} + \ldots;\ \Gamma^{ab}T_{ab}| = -\frac{1}{8}\,M_{abc}\Gamma^{ab}\psi^c + \ldots;$$

where the dots denote the terms of the lower order in the M-field, it is easy to see that the equation (10) can be derived from the lagrangian (1),(2) with $b = 2$.

So the lagrangian must be 0-component of the following stuff:

$$\mathcal{L} = \phi\,(\,\mathcal{R} - \frac{1}{3}\,T^2\,) + 2\,\chi\,\Gamma^{ab}T_{ab} \tag{11}$$

But there is an ambiguity in the field representation of the quantity $\mathcal{R}|$. Indeed, it is necessary to know the curvature components with the spinor indices in order to calculate $\mathcal{R}|$ from the formula $\mathcal{R}| = E_b{}^N E_a{}^M \mathcal{R}_{MN}{}^{ab}|$. We can take it from the solution of the torsion Bianchi identities in [3]. But as mentioned before the Bianchi identities give us only on shell fields values. Consequently $\mathcal{R}|$ may be presented in different forms which are equivalent up to the term

$$\psi_a\Gamma^a\Gamma^{bc}T_{bc}| \ , \tag{12}$$

vanishing on shell. One of the possible variants (B.8) is presented in Appendix B. It contains the terms with $M_{abc}$ which lead to

$$(\,\mathcal{R} - \frac{1}{3}\,T^2\,)| = -\frac{1}{12}\,M_{abc}^2 + \frac{1}{48}\,\psi_a\Gamma^{[a}\hat{M}\Gamma^{b]}\psi_b + \ldots$$

where $\hat{M} = M^{abc}\Gamma_{abc}$.

Substituting this expression into (11) one can derive the lagrangian which leads to the true equation for $M_{m_1\ldots m_6}$ (10). But if we added the term (12) to (B.8) we would get a wrong equation, different from (10). So the only expression for $\mathcal{R}|$ suitable for us is (B.8).

We see that equations (3), (4), (10) fix all the terms in the lagrangian without the equations of motion for $e_m{}^a$ and $\psi_m{}^\alpha$. But the straightforward calculation show us that variations of $L$ with respect to $e_m{}^a$, $\psi_m{}^\alpha$– fields vanish if one takes into account the equations of motion (A.3) – (A 7), derived from the solution of Bianchi identities. So all the assumptions about the lagrangian structure are confirmed.

Finally:

$$
\begin{aligned}
L = \phi R - \frac{1}{2}\phi\,\psi_a\Gamma^{abc}\psi_{c;b} - \frac{1}{2}\phi_{;a}\psi^a\Gamma_b\psi^b + 2\,\psi_a\Gamma^{ab}\chi_{;b} + \\
-\frac{1}{12}\phi\,M^2_{abc} + \frac{1}{48}\phi\,\psi_a\Gamma^{[a}\hat{M}\Gamma^{b]}\psi_b - \frac{1}{4}\chi\,\Gamma^{ab}\psi^c M_{abc} - \\
-\frac{1}{3\cdot 256}\phi\,(\psi^d\Gamma_{dabcf}\psi^f)^2 + \frac{1}{64}\phi\,(\psi_a\Gamma_b\psi_c)^2 + \frac{1}{32}\phi\,(\psi^a\Gamma^b\psi^c)(\psi_a\Gamma_c\psi_b) - \\
-\frac{1}{16}\phi\,(\psi_a\Gamma^b\psi_b)^2 + \frac{1}{8}(\chi\Gamma_{ab}\psi_c)(\psi^a\Gamma^c\psi^b) - \frac{1}{4}(\chi\Gamma_a\Gamma_b\psi^b)(\psi^a\Gamma_c\psi^c)
\end{aligned}
\tag{13}
$$

We shall write below the supersymmetry transformations for the fields of the multiplet. They are the variations of the correspondent superfields under the shift $\delta z^M = \varepsilon^M$, $\varepsilon^M| = (0, \varepsilon^\alpha)$ and may be easily obtained for $e_m{}^a, \psi_m, \phi$ and $\chi$. To derive the supersymmetry transformation for $M_{m_1\ldots m_6}$ it needs to write 0-component of variation $\delta T_{abc} = \varepsilon^\alpha D_\alpha T_{abc}$, taking $D_\alpha T_{abc}$ from (6) and $T_{abc}|$ from (B.6). Choosing $\alpha = 0$ in (6) one can transform this variation to the form:

$$
\epsilon_{n_1n_2n_3}{}^{m_1\ldots m_7}(\,\delta M_{m_1\ldots m_6} + 3\,\psi_{m_1}\Gamma_{m_2\ldots m_6}\varepsilon\,)_{;m_7} = 0 \tag{14}
$$

The relation (14) defines $\delta M_{m_1\ldots m_6}$ unambiguously up to the transformation of the form (9).

So the supersymmetry transformations in the system of constraints (A.1) and (A.2) are:

$$
\delta e_m{}^a = \frac{1}{2}\psi_m\Gamma^a\varepsilon
$$

$$
\delta\psi_m = 2\,\varepsilon_{;m} - \frac{1}{72}(\,3\hat{T}\Gamma_m + \Gamma_m\hat{T}\,)|\,\varepsilon - \frac{1}{2}C_{mpq}\Gamma^{pq}\varepsilon
$$

$$\delta\phi = -\chi\,\varepsilon.$$

$$\delta\chi = -\frac{1}{2}\,\phi_{;m}\Gamma^m\varepsilon + \frac{1}{4}\,(\psi_m\,\chi)\Gamma^m\varepsilon + \frac{1}{36}\,\phi\hat{T}|\,\varepsilon$$

$$\delta M_{m_1\ldots m_6} = -3\,\psi_{[m_1}\Gamma_{m_2\ldots m_6]}\,\varepsilon \tag{15}$$

where

$$C_{klm} = \frac{1}{8}\,(\,2\,\psi_k\Gamma_{[l}\psi_{m]} + \psi_l\Gamma_k\psi_m\,)\ .$$

A lot of work need to be done to check the invariance of lagrangian (13) relative to transformations (15). The following speculations allow to reduce it.

Let us divide the supersymmetry transformations on two parts:

$$\delta\int eL = \int e\,(A+B)\,\varepsilon \tag{16}$$

where $e = \det e_m{}^a$. Part $A$ contains all terms which can be written symbolicaly in powers of fields and derivatives:

$$A = (\chi + \phi\psi)\times(R + \partial^2 + M\partial + \psi^2\partial)$$

Terms in $B$ do not contain derivatives:

$$B = (\chi + \phi\psi)\times(M^2 + \psi^2 M + \psi^4)$$

(except of the derivative inside $M$: here $M$ denotes the strenth $M_{abc}$ but not potential).

Straightforward calculations show that $A = 0$. But hence it appears that $B = 0$ too.

To prove it let us suppose that fields obey the equations of motion. Then one can express the terms of kind $A$ through the terms of kind $B$ and substitute it in the right hand side of (16). Because the left hand side of (16) vanishes on shell then $B = -A = 0$. But part $B$ does not contain derivatives, therefore it is not changed after this substitution. So $B = 0$ in any case, not only on shell.

Let us suppose now that some terms with derivatives remain in $A$ because they cannot be expressed through the terms without derivatives by means the equations of motion. In this case we have a new differential equation $A = 0$. But all the equations the fields can obey are the equations of motion or its consequences. As a result we came to contradiction.

So in order to check the invariance of action relative to supersymmetry transformations it is necessary to show only that $A = 0$. It was made by author of this paper.

The lagrangian (13) does not contain the kinetic terms of dilaton and dilatino.[1] Therefore these fields cannot be interpreted in the traditional manner. Moreover one cannot formulate the perturbation theory with them. However, it is possible to transform the Einstein's term of action $\phi R$ to canonical form by means the vielbein conformal transformation and the dilaton kinetic term appears as a result. The dilatino kinetic term could arise if one diagonalize the terms with the derivatives of $\psi_m$ and $\chi$ in (13). Indeed, the field change $\{\Phi_i\} \to \{\Phi_i'\}$

$$
\begin{aligned}
e_m{}^a &= e^{\phi'/6}\, e_m{}^{a'} \\
\psi_m &= 2\, e^{\phi'/12} \left( \psi_m{}' - \frac{1}{6\sqrt{2}} \Gamma_m{}' \chi' \right) \\
\phi &= e^{-4\phi'/3} \\
\chi &= -\frac{2\sqrt{2}}{3}\, e^{-17\phi'/12}\, \chi' \\
M_{m_1 \ldots m_6} &= 2\, M_{m_1 \ldots m_6}{}'
\end{aligned}
\tag{17}
$$

leads to the lagrangian $L'$

$$\int e\, L = 4 \int e'\, L'$$

with the canonical kinetic terms:

$$
\begin{aligned}
L' = \frac{1}{4} R' + \frac{1}{2} \phi^{;a'} \phi_{;a}{}' - \frac{1}{12} e^{-2\phi'} M^2_{abc}{}' - \frac{1}{2} \psi_a{}' \Gamma^{abc} \psi_{c;b}{}' + \frac{1}{2} \chi' \Gamma^a \chi_{;a}{}' - \\
- \frac{1}{\sqrt{2}} \phi_{;b}{}' \psi_a{}' \Gamma^b \Gamma^a \chi' + \frac{1}{24} e^{-\phi'} \left( \psi_a{}' \Gamma^{[a} \hat{M}' \Gamma^{b]} \psi_b{}' + \sqrt{2}\, \chi' \Gamma^a \hat{M}' \psi_a{}' \right) + \ldots ,
\end{aligned}
\tag{18}
$$

where the dots denote the terms of 4-th order in fermionic fields. It is easy to see that lagrangian (18) is the well known lagrangian of dual supergravity [7] rewritten in the notations used here.

Note in conclusion the lagrangian (13) in fields parameterization [3] is simpler than lagrangian [7] in fields parametrization [8]. It allow us to hope that nonminimal terms which must be added for cancellation of anomalies presented in theory are more simple in this parametrization too.

[1] Absence of the dilaton kinetic term was noted in [6] for lagrangian obtained there.

Author thanks M.V.Terentjev for the formulation of the problem and help in decision of it. The research described in this publication was made possible in part by grant no. MOY000 from the International Science Foundation.

## Appendix A: constraints and equations of motion

Constraints, solution of Bianchi identities and equations of motions are taken from [3]. $\mathcal{R}_{abcd}$ , $N_{abc}$ here correspond to $-R_{abcd}$ , $-2\,N_{abc}$ in [3]; all other notations are the same. All necessary properties of $\Gamma$-matrices one can find in [8].

We use the following constraints for the torsion components:

$$T_{\alpha\beta}{}^{c} = \Gamma_{\alpha\beta}{}^{c}, \quad T_{\alpha\beta}{}^{\gamma} = T_{ab}{}^{c} = 0$$

$$T_{a\beta}{}^{\gamma} = \frac{1}{72}\,(\hat{T}\Gamma_a)_\beta{}^{\gamma}, \quad \text{where} \quad \hat{T} = T^{abc}\Gamma_{abc}\,. \tag{A.1}$$

Bianchi identities for the 7-form $N = dM$ relate the torsion components $T_{abc}$ with the components of $N$-field which are the strenght of potential $M_{m_1\ldots m_6}$:

$$N_{\alpha\beta a_1\ldots a_5} = -(\Gamma_{a_1\ldots a_5})_{\alpha\beta}\,, \; N_{abc} = T_{abc} \tag{A.2}$$

where

$$N_{abc} \equiv \frac{1}{7!}\,\epsilon_{abc}{}^{b_1\ldots b_7} N_{b_1\ldots b_7}\,,$$

all other components of $N$ are equal zero.

Equation of motion for the graviton $e_m{}^a$:

$$\phi\,\mathcal{R}_{ab} + D_{(a}D_{b)}\,\phi - \frac{1}{36}\,\phi\,\eta_{ab}T^2 + T_{c(a}\Gamma^c\Gamma_{b)}\,\chi = 0 \tag{A.3}$$

Equation of motion for the gravitino $\psi_m{}^\alpha$:

$$\phi\,\Gamma^b T_{ab} - D_a\chi - \frac{1}{36}\Gamma_a\hat{T}\,\chi - \frac{1}{24}\,\hat{T}\Gamma_a\,\chi = 0 \tag{A.4}$$

Equation of motion for the $M_{m_1\ldots m_6}$:

$$D_{[a}(\,\phi\,T_{bcd]}) + \frac{3}{2}\,T_{[ab}\Gamma_{cd]}\,\chi + \frac{3}{2}\,\phi\,T^2_{[abcd]} = 0 \tag{A.5}$$

Together with the equations (3), (4)

$$\mathcal{R} - \frac{1}{3}\,T^2 = 0 \tag{A.6}$$

$$\Gamma^{ab}T_{ab} = 0 \qquad (A.7)$$

they form the complete system of equations of motion definig the fields dynamics.

Although the $\phi$ and $\chi$ enter in the lagrangian in the noncanonical manner, they also obey the wave equations which can be easy derived from (A.3) + (A.6) and (A.4) + (A.7):

$$D^a D_a \phi + \frac{1}{18}\phi T^2 = 0 \qquad (A.8)$$

$$\hat{D}\chi + \frac{1}{9}\hat{T}\chi = 0 \qquad (A.9)$$

## Appendix B: 0-components of superfields

The method of transition from superfields to 0-components is standard and has been described in [9]. We list here only the expressions for it. The vertical line denotes 0-component of superfield.

Superspatial vielbein:

$$E_m{}^a| = e_m{}^a, \quad E_m{}^\alpha| = \frac{1}{2}\psi_m{}^\alpha$$
$$E_\mu{}^a| = 0, \quad E_\mu{}^\alpha| = \delta^\alpha_\mu \qquad (B.1)$$

Connection $\phi_{Ma}{}^b$, corresponding to $D_M$, is defined by means

$$D_M V^a = \partial_M V^a + V^b \phi_{Mb}{}^a, \qquad (B.2)$$

where $M = (m, \mu)$, $V^a$ – a vector. We suppose:

$$\phi_{ma}{}^b| = \omega_{ma}{}^b, \quad \phi_{\mu a}{}^b| = 0 \qquad (B.3)$$

In the system of constraints (A.1) the connection $\omega_{abc} = e_a{}^m \omega_{mbc}$ takes the form:

$$\omega_{abc} = \omega^{(0)}_{abc} + \frac{1}{2}T_{abc}| + C_{abc} \qquad (B.4)$$

where

$$C_{abc} = \frac{1}{8}\left(2\,\psi_a \Gamma_{[b}\psi_{c]} + \psi_b \Gamma_a \psi_c\right),$$

$\omega^{(0)}_{abc}$– ordinary connection depending on only ordinary vielbein $e_m{}^a$.

Torsion $T_{ab}{}^{\alpha}$ in the system of constraints (A.1) is:

$$T_{ab}| = \psi_{[b;a]} - \frac{1}{144}\,(\,\Gamma_{[a}\hat{T} + 3\hat{T}\Gamma_{[a})|\psi_{b]} + \frac{1}{4}\,\Gamma^{cd}\psi_{[a}C_{b]cd} \qquad (B.5)$$

the semicolon denotes the ordinary covariant derivative with the connection $\omega^{(0)}_{abc}$.

Relation of the $N$-field components with world and flat indices (see (A.2)) give us:

$$T_{abc}| = N_{abc}| = M_{abc} - \frac{1}{8}\,\psi^{d}\Gamma_{dabcf}\psi^{f} \qquad (B.6)$$

where

$$M_{abc} \equiv \frac{1}{6!}\,\epsilon_{abc}{}^{d_1\ldots d_7}M_{d_1\ldots d_6;d_7}\,,\quad M_{a_1\ldots a_6} \equiv e_{a_1}{}^{m_1}\ldots e_{a_6}{}^{m_6}M_{m_1\ldots m_6}\,.$$

The supercurvature $\mathcal{R}_{mna}{}^{b}$, corresponding to the connection $\phi_{ma}{}^{b}$, is:

$$\mathcal{R}_{mna}{}^{b} = 2\,\partial_{[m}\,\phi_{n]a}{}^{b} - 2\,\phi_{[m|a|}{}^{c}\,\phi_{n]c}{}^{b} \qquad (B.7)$$

The explicit expression for 0-component of $\mathcal{R}_{abcd}|$ through ordinary curvature $R_{abcd}$, corresponding to the connection $\omega^{(0)}_{abc}$, is very cumbersome. So we present here only the expression for $\mathcal{R}| = \mathcal{R}_{ab}{}^{ab}|$:

$$\mathcal{R}| = R - \frac{1}{2}\,\psi_a\Gamma^{abc}\psi_{c;b} + \frac{1}{2}\,(\psi^a\Gamma_b\psi^b)_{;a} + \frac{1}{4}\,T^2_{abc}| + \frac{1}{8}\,\psi_a\Gamma_b\psi_c M^{abc} +$$
$$+\frac{1}{64}\,(\psi_a\Gamma_b\psi_c)^2 + \frac{1}{32}\,(\psi_a\Gamma_b\psi_c)(\psi^a\Gamma^c\psi^b) - \frac{1}{16}\,(\psi_a\Gamma_b\psi^b)^2 \qquad (B8)$$

## References


[1] S.Gates Jr., H.Nishino, Phys.Lett. **B 173** (1986) 46.

[2] H.Nishino, Phys.Lett. **B 258** (1991) 104.

[3] M.V.Terentjev, Phys.Lett. **B 313** (1993) 351.

[4] L.Bonora, M.Bregola, K.Lechner, P.Pasti, M.Tonin, Nucl.Phys. **B 296** (1988) 877.

[5] J.Atick, A.Dhar, B.Ratra, Phys.Rev. **D 33** (1986) 2824.

[6] R.D'Auria, P.Fre, M.Raciti, F.Riva, Intern.J.Mod.Phys. **A 3** (1988) 953.

[7] S.Gates Jr., H.Nishino, Phys.Lett. **B 157** (1985) 157.

[8] M.V.Terentjev, Intern.J.Mod.Phys. **A 9** (1994) 239.

[9] J.Wess, J.Bagger, Supersymmetry and supergravity, Princeton, NJ, 1983.



Зяблик К.Н.

О лагранжиане дуальной N=I,D-I0 супергравитации.

Подписано к печати 30.05.94 Формат 60x90 I/I6 Офсетн.печ.
Усл.-печ.л.0,75 Уч.-изд.л.0,5 Тираж I23 экз. Заказ 42.
Индекс 3649

Отпечатано в ИТЭФ, II7259, Москва, Б.Черемушкинская,25