POISSON-LIE T-DUALITY IN N=2 SUPERCONFORMAL FIELD THEORIES.

S. E. Parkhomenko
Landau Institute for Theoretical Physics
142432 Chernogolovka, Russia

Abstract

The supersymmetric generalization of Poisson-Lie T-duality in superconformal WZNW models is considered. It is shown that the classical N=2 superconformal WZNW models posses a natural Poisson-Lie symmetry which allows to construct dual σ-models.

Introduction.

Target space duality in string theory has attracted a considerable attention in recent years because it sheds some light on the geometry and symmetries of string theory. The well known example of T-duality is mirror symmetry in the Calaby-Yao compactifications of the superstring. Duality symmetry was first described in the context of toroidal compactifications. For the simplest case of single compactified dimension of radius $R$, the entire physics of interacting theory is left unchanged under the replacement $R \rightarrow \alpha/R$ provided one also transforms the dilaton field $\phi \rightarrow \phi - \ln (R/\sqrt{\alpha})$. This simple case can be generalized to arbitrary toroidal compactifications. The T-duality symmetry was later extended to the case of nonflat conformal backgrounds possessing some abelian isometry (abelian T-duality) in.

Of more recent history is the notion of non-abelian duality. The basic idea of non-abelian duality is to consider a conformal field theory with non-abelian symmetry group. The non-abelian duality did miss a lot of features characteristic to the abelian duality. For example the non-abelian T-duality transformation of the isometric σ-model on a group manifold $G$ gives non-isometric σ-model on its Lie algebra. As a result, it was not known how to perform the inverse duality transformation to get back to the original model. Indeed, while the original model on $G$ was isometric, which was believed to be an essential condition for performing a duality transformation, the dual one did not possess the $G$-isometry.

A solution of this problem was proposed recently where it was argued that the two theories are dual to each other from the point of view of the so called Poisson-
Lie T-duality. In [10] a large class of new dual pairs of \( \sigma \)-models associated with each
Drinfeld double [11] was constructed. The main idea of the approach is to replace the
requirement of isometry by a weaker condition which is the Poisson-Lie symmetry of the
theory. This generalized duality is associated with two groups forming a Drinfeld double
and the duality transformation exchanges their roles.

The discussion in [10] was quite general. In order to apply Poisson-Lie T-duality
in superstring theory one would like to know if there are dual pairs of conformal and
superconformal \( \sigma \)-models. In particular, it would be interesting to construct mutually dual
pairs of N=2 superconformal field theories.

The simple example of dual pair of conformal field theories associated with the
\( O(2,2) \) Drinfeld double was presented in work [12]. The supersymmetric generalization of Poisson-
Lie T-duality was considered in [13]. The present note is devoted to the construction of
dual pairs of N=2 superconformal WZNW models. In particular, after brief review of the
Manin triple construction of N=2 superconformal WZNW models in the section 1, we will
show in the section 2, that the classical N=2 superconformal WZNW models posses very
natural Poisson-Lie symmetry which we will use to construct Poisson-Lie T-dual \( \sigma \)-models.

Section 3 we will apply the results of section 2 to N=2 superconformal WZNW model
associated with the Manin triple \((sl(2,R) \oplus R, b_+, b_-)\), where \( b_\pm \) are the Borel subalgebras
of \( sl(2,R) \) and construct its Poisson-Lie dual \( \sigma \)-model.

1. The classical N=1 superconformal WZNW model.

In this section we briefly review a supersymmetric WZNW (SWZNW) models using
superfield formalism [14] and formulate conditions that a Lie group should satisfy in order
for its SWZNW model to possess extended supersymmetry.

We parametrize superworld sheet introducing the light cone coordinates \( x_\pm \), and grass-
man coordinates \( \Theta_\pm \). The generators of supersymmetry and covariant derivatives are

\[
Q_\pm = \frac{\partial}{\partial \Theta_\pm} + i \Theta_\pm \partial_\pm, \quad D_\pm = \frac{\partial}{\partial \Theta_\pm} - i \Theta_\pm \partial_\mp.
\]

They satisfy the relations

\[
\{D_\pm, D_\pm\} = -\{Q_\pm, Q_\pm\} = -2\Theta_\pm, \quad \{D_\pm, D_\mp\} = \{Q_\pm, Q_\mp\} = \{Q, D\} = 0,
\]

where the brackets \( \{,\} \) denote the anticommutator. The superfield of N=1 supersymmetric
WZNW model

\[
G = g + i \Theta_- \psi_+ + i \Theta_+ \psi_- + i \Theta_- \Theta_+ F
\]

takes values in a Lie group \( G \). We will assume that its Lie algebra \( g \) is endowed with
ad-invariant nondegenerate inner product \( <,> \).

The inverse group element \( G^{-1} \) is defined from

\[
G^{-1} G = 1
\]

and has the decomposition

\[
G^{-1} = g^{-1} - i \Theta_- g^{-1} \psi_+ g^{-1} - i \Theta_+ g^{-1} \psi_- g^{-1} - i \Theta_- \Theta_+ g^{-1} (F + \psi_- g^{-1} \psi_+ - \psi_+ g^{-1} \psi_-) g^{-1}
\]
For physical reasons one has to demand the group $G$ is a real manifold. Therefore it is convenient to consider $G$ as a subgroup in the group of real or unitary matrices i.e. one has to impose the following conditions on the matrix elements of the superfield $G$:

\[
g^{mn} = g^{mn}, \quad \bar{\psi}_\pm^{mn} = \psi_\pm^{mn}, \quad \bar{F}^{mn} = F^{mn}
\]

or

\[
g^{mn} = (g^{-1})^{mn}, \quad \bar{\psi}_\pm^{mn} = (\psi^{-1})_\pm^{mn}, \quad \bar{F}^{mn} = (F^{-1})^{mn},
\]

where we have used the following notations

\[
\psi^{-1}_\pm = -g^{-1}_\pm \psi^{-1}g^{-1}, \quad F^{-1} = -g^{-1}(F + \psi^{-1}_- \psi_+ - \psi_+ g^{-1} \psi_+)g^{-1}.
\]

In the following we will assume that the superfield $G$ satisfy (6) i.e. the Lie group $G$ is a subgroup of the group of nondegenerate real matrices.

The action of N=1 SWZNW model is given by

\[
S_{SWZ} = \int d^2x d^2\Theta(<R_+^-, R_-^+>) - \int d^2x d^2\Theta dt <G^{-1} \frac{\partial G}{\partial t}, \{R_-, R_+^+\}>,
\]

where

\[
R_\pm = G^{-1} D_\pm G.
\]

The classical equations of motion can be obtained by making a variation of (9):

\[
\delta S_{SWZ} = \int d^2x d^2\Theta <G^{-1} \delta G, D_- R_+ - D_+ R_- - \{R_-, R_+^+\} >.
\]

Taking into account kinematic relation

\[
D_+ R_- + D_- R_+ = -\{R_+, R_-\}
\]

we obtain

\[
D_- R_+ = 0.
\]

The action (8) is invariant under the super-Kac-Moody and N=1 superconformal transformations [14].

In the following we will use supersymmetric version of Polyakov-Wiegman formula [15]

\[
S_{SWZ}[GH] = S_{SWZ}[G] + S_{SWZ}[H] + \int d^2x d^2\Theta <G^{-1} D_+ G, D_- H H^{-1} >.
\]

It can be proved as in the non supersymmetric case.

In works [16, 17, 18] supersymmetric WZNW models which admit extended supersymmetry were studied and correspondence between extended supersymmetric WZNW models and finite-dimensional Manin triples was established in [17, 18]. By the definition [11], a Manin triple $(g, g_+, g_-)$ consists of a Lie algebra $g$, with nondegenerate invariant inner product $<,>$ and isotropic Lie subalgebras $g_\pm$ such that $g = g_+ \oplus g_-$ as a vector space. The corresponding Sugawara construction of N=2 Virasoro superalgebra generators was given in [17, 18, 19].
To make a connection between Manin triple construction of \[17, 18\] and approach of \[16\] based on complex structures on Lie algebras the following comment is relevant.

Let \(g\) be a real Lie algebra and \(J\) be a complex structure on the vector space \(g\). \(J\) is referred to as a complex structure on a Lie algebra \(g\) if \(J\) satisfies the equation
\[
[Jx, Jy] - J[Jx, y] - J[x, Jy] = [x, y]
\]
for any elements \(x, y\) from \(g\). Suppose the existence of a nondegenerate invariant inner product \(<,>\) on \(g\) so that the complex structure \(J\) is skew-symmetric with respect to \(<,>\). In this case it is not difficult to establish the correspondence between complex Manin triples and complex structures on Lie algebras. Namely, for each complex Manin triple \((g, g_+, g_-)\) exists a canonical complex structure on the Lie algebra \(g\) such that subalgebras \(g_\pm\) are its \(\pm i\) eigenspaces. On the other hand, for each real Lie algebra \(g\) with nondegenerate invariant inner product and skew-symmetric complex structure \(J\) on this algebra one can consider the complexification \(g^C\) of \(g\). Let \(g_\pm\) be \(\pm i\) eigenspaces of \(J\) in algebra \(g^C\) then \((g, g_+, g_-)\) is a complex Manin triple. Moreover it can be proved \[17\] that there exists one-to-one correspondence between complex Manin triple endowed with a hermitian conjugation (involutive antiautomorphism) \(\tau : g_\pm \to g_\pm\) and the real Lie algebra endowed with \(ad\)-invariant nondegenerate inner product \(<,>\) and the complex structure \(J\) which is skew-symmetric with respect to \(<,>\). Therefore we can use this conjugation to extract a compact form from a complex Manin triple.

If a complex structure on a Lie algebra is fixed then it defines the second supersymmetry transformation \[16\].

In this paper we concentrate on \(N=2\) SWZNW models based on real Manin triples. The case of \(N=2\) SWZNW models on compact groups will be considered in near future.

2. Poisson-Lie T-duality in \(N=2\) superconformal WZNW model.

In this section we will describe the construction of Poisson-Lie T-dual \(\sigma\)-models to \(N=2\) SWZNW models.

For the description of the Poisson-Lie T-duality in \(N=2\) SWZNW we need a Lie group version of Manin triple \[21, 22\]. Let’s fix some Manin triple \((g, g_+, g_-)\) and consider double Lie group \((G, G_+, G_-)\) \[21\], where the exponential groups \(G, G_\pm\) correspond to Lie algebras \(g, g_\pm\). Each element \(g \in G\) admits a decomposition
\[
g = g_+ g_-^{-1}
\]
For SWZNW model on the group \(G\) we obtain from \[16\] the decomposition for the superfield \[4\]
\[
G(z_+, z_-) = G_+(z_+, z_-) G_-^{-1}(z_+, z_-)
\]
Due to \[17\], \[14\] and the definition of Manin triple we can rewrite the action \[3\] for this model in the following form
\[
S_{swz} = -\int d^2 \! x d^2 \! \Theta <\rho^+_+, \rho^-_>,
\]
where the superfields
\[
\rho^\pm = G^\mp DG_
\]
\[19\]
correspond to the right invariant 1-forms on the groups $G_\pm$.

To generalize (16) we have to consider the set $W$ of classes $G_+ \backslash G/G_-$ and pick up a representative $w$ for each class $[w] \in W$:

$$G = \bigcup_{[w] \in W} G_+ w G_- = \bigcup_{[w] \in W} G_w$$

(20)

This formula means that there is the natural action of complex group $G_+ \times G_-$ on $G$, and the set $W$ parametrizes $G_+ \times G_-$-orbits $G_w$.

The corresponding generalization for the action (18) is given by

$$S_{swz} = - \int d^2 x d^2 \Theta < \rho_+^+ w \rho_-^{-1} >$$

(21)

Following [10] we consider a variation of the action (21) for SWZNW model on the group $G$ under the right action $G_+ \times G_-$. Let us concentrate at first on the class of identity from (20).

$$\delta S_{swz} = - \int d^2 x d^2 \Theta (< D_+ X^+, \rho_-^{-} > - < D_- X^-, \rho_+^{+} >) +$$

$$\int d^2 x d^2 \Theta (< X^+, \{ \rho_+^{+}, \rho_-^{-} \} > - < X^-, \{ \rho_-^{-}, \rho_+^{+} \} >),$$

(22)

where $X^\pm = G_\pm^{-1} \delta G_\pm$. From (22) we obtain the Noetherian currents $\rho_\pm^\pm$ which satisfy on extremals

$$D_+ \rho_-^{-} + \{ \rho_-^{-}, \rho_+^{+} \}^- = 0,$$
$$D_- \rho_+^{+} + \{ \rho_+^{+}, \rho_-^{-} \}^+ = 0,$$

(23)

where the brackets $\{,\}$ correspond to Lie brakets on $g$. These equations can be joint into zero curvature equation for $F_{+-}$- component of super stress tensor $F_{MN}$

$$F_{+-} = \{ D_+ + \rho_+^{+}, D_- + \rho_-^{-} \} = 0$$

(24)

Using standard arguments of super Lax construction [23] one can show that from (24) it follows that the connection is flat

$$F_{MN} = 0, \ M, N = (+, -, +, -).$$

(25)

The equations (24) are the supersymmetric generalization of Poisson-Lie symmetry conditions [11]. Indeed, Noetherian currents $\rho_\pm^\pm$ are generators of $G_+ \times G_-$ action on $G$, while the structure constants in (24) correspond to Lie algebra $g$ which is Drinfeld’s dual to $g_+ \oplus g_-$. Due to (23) we may associate to each extremal surface $(G_+(x_+, x_-, \Theta_+, \Theta_-), G_-(x_+, x_-, \Theta_+^{-}, \Theta_-))$ a mapping $G(x_+, x_-, \Theta_+, \Theta_-)$ from the super world sheet into the group $G$ such that

$$L^+_+ + \rho_+^{+} = L_-^- + \rho_-^{-} = 0,$$

(26)

$$L_+^+ = L_-^- = 0,$$

(27)

where $L^\pm$ are $g_\pm$-components of the current $L = DGG^{-1}$ and $G \in G$. 

5
One can rewrite (26), (27) as the equations in Drinfeld’s double of $G$. Let
\[ D = G \times G \] (28)

For each pair of superfields $\Lambda = (G_1, G_2) \in D$ there is the decomposition
\[ \Lambda = (G_+, G_-)(G, G) = H \tilde{H}, \] (29)
where $H = (G_+, G_-)$, $\tilde{H} = (G, G)$. The equations (26), (27) can be rewritten in the form
\[ \ll D_\pm \Lambda \Lambda^{-1}, E_\pm \gg = 0, \] (30)
where $\ll, \gg$ is the natural inner product on Lie algebra of $D$ and the subspaces $E_\pm$ are given by
\[ E_+ = (0, g), \ E_- = (g, 0) \] (31)

The equations (30) with appropriate choice of mutually orthogonal subspaces $E_\pm$ are the supersymmetric generalization of corresponding equations from [10]. In the case when the subspaces are chosen in general position (which corresponds to nondegeneracy of the bilinear form determining the Lagrangian of $\sigma$-model) one can use the construction [10] to obtain the action for Poisson-Lie T-dual $\sigma$-model. But in our case the subspaces (31) are not in general position and the bilinear form determining the Lagrangian of N=2 SWZNW model is singular as it is easy to see from (18). It makes impossible to apply straightforward construction [10]. Instead we will use the method developed in [12].

Let us suppose that instead of (29) we use the decomposition
\[ \Lambda = \tilde{F} F, \] (32)
where $F = (U_+, U_-)$, $\tilde{F} = (U, U)$. Taking into account (31) we rewrite (30) in the following form
\[ R_+^+ + \lambda_+^+ = R_-^- + \lambda_-^- = 0, \] (33)
\[ R_+^+ = R_-^- = 0, \] (34)
where $R^\pm$ are $g_\pm$-components of the current $R = U^{-1} DU$, $U \in G$, $\lambda_\pm^\pm = D_\pm U_\pm U_-^{-1}$, $U_\pm \in G_\pm$. In dual picture we should have an action for dual $\sigma$-model on the group $G$ and the action of $G$ on itself such that the Noetherian currents satisfy zero curvature equation for $F_{\pm}$-component of super stress tensor taking values in Lie algebra $g_+ \oplus g_-$ which is Drinfeld’s dual Lie algebra to $g$. But in view of the constraint (34) the action of dual $\sigma$-model has to be contained corresponding Lagrange multipliers. Using the arguments of [12] we can write the action of dual $\sigma$-model in the following form
\[ \tilde{S}_{swz} = - \int d^2x d^2\Theta(\langle \lambda_+^+, \lambda_-^- \rangle + \langle R_+, \lambda_-^- \rangle + \langle \lambda_+^+, R_-^- \rangle) \] (35)

It is easy to see from (33) that the currents $\lambda_+^\pm$, $\lambda_-^\pm$ play the role of the Lagrange multipliers (with values in $g_+ \oplus g_-$). The corresponding equations of motion include apart from (33), (34) zero curvature equation
\[ \tilde{F}_{\pm} = \{ D_+ - \lambda_+^+, \lambda_-^- + \lambda_+^+ \} = 0, \] (36)
where the brackets \{ , \} correspond to Lie brackets on \( g_+ \oplus g_- \). Excluding from (35) all \( \lambda \)'s except the Lagrange multipliers we obtain
\[
\tilde{S}_{swz} = -\int d^2x d^2\Theta(<R_+^+, R_-^- > + < R_+^-, \lambda_-^- > + < \lambda_+^-, R_+^+ >) \tag{37}
\]

Now we turn to the remainder adjacent classes from (20). The generalization of (24), (26), (27) is straightforward. In each class \([w]\) the Noetherian currents \( \rho_+^w \) and \( \rho_-^w \) take values in the subspaces \( g_+^w \equiv w^{-1}g_+ \cup g_+ \) and \( g_-^w \equiv wg_-\, w^{-1} \cup g_- \) correspondingly, while the constraints \( L_{w+}^\pm \) and \( L_{w-}^\pm \) take values in the complements \( g \setminus g_+^w \) and \( g \setminus g_-^w \):
\[
F_{w,-} = \{ D_+ + \rho_+^w, D_- + \rho_-^w \} = 0 \tag{38}
\]
\[
L_{w+}^\pm + \rho_+^w = 0, \tag{39}
\]
\[
L_{w-}^\pm = 0, \tag{40}
\]

The arguments we have used to obtain (37) can be applied (with relevant modifications) to each class \([w]\). Taking into account (38), (39), (40) we obtain the generalization of (37)
\[
\tilde{S}_{swz} = -\int d^2x d^2\Theta(<R_{w+}^+, R_{w-}^- > + < R_{w-}^-, \lambda_{w+}^+ > + < \lambda_{w-}^-, R_{w+}^+ >), \tag{41}
\]

where \( R_{w+}^\pm \) and \( R_{w-}^- \) take values in the same subspaces like the currents \( \rho_+^w \) and \( \rho_-^w \), \( R_{w+}^- \) and \( R_{w-}^+ \) take values in the complements \( g \setminus g_+^w \) and \( g \setminus g_-^w \) correspondingly.

3. Poisson-Lie T-dual \( \sigma \)-model to \( \mathbb{N}=2 \) SWZ NW model on \( \text{SL}(2, \mathbb{R}) \times \mathbb{R} \).

The Lie algebra of the group \( G = \text{SL}(2, \mathbb{R}) \times \mathbb{R} \) has the basis
\[
e_0 = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix}, \quad e_1 = \begin{pmatrix} 0 & 1 \\ 0 & 0 \end{pmatrix} \tag{42}
\]
\[
e^0 = \begin{pmatrix} 0 & 0 \\ 0 & -1 \end{pmatrix}, \quad e_1 = \begin{pmatrix} 0 & 0 \\ 1 & 0 \end{pmatrix} \tag{43}
\]

Note that both sets of generators (42), (43) span the Borelian subalgebras \( b_-, b_+ \) correspondingly and they are maximally isotropic with respect to the non-degenerate invariant inner product defined by the brackets
\[
< e_i, e_j > = \delta_i^j. \tag{44}
\]

Hence we have Manin triple \((g, b_+, b_-)\). Let \( B_\pm = \exp(b_\pm) \). The decomposition (20) is given by Bruhat decomposition
\[
G = G_1 \bigcup G_w, \tag{45}
\]

where
\[
G_1 = B_+ B_-, \quad G_w = B_+ \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} B_- \tag{46}
\]
In the class of identity we parametrize the element \( g \in G_1 \) by the matrix
\[
g = \begin{pmatrix} 1 & 0 \\ u & 1 \end{pmatrix} \begin{pmatrix} 1 & v^{-1} \\ 0 & 1 \end{pmatrix} \begin{pmatrix} \exp(a_+) & 0 \\ 0 & \exp(a_-) \end{pmatrix}.
\]

The classical constraint \( R_+ = 0 \) takes the form
\[
D_+ a_+ - v^{-1} D_+ u = 0,
\]
\[
D_+ (u + v) = 0,
\]
the classical constraint \( R_- = 0 \) takes the form
\[
D_- u = 0,
\]
\[
D_- a_- + v^{-1} D_- u = 0
\]
Under these constraints, the remaining components of the currents are
\[
R_+ = -2D_+ \omega e^0 - \exp(2\phi)D_+ ve^1,
\]
\[
R_- = 2D_- \omega e_0 - \exp(-2\phi)v^{-2}D_- ve_1,
\]
where we have introduced new variables
\[
\phi = (a_+ - a_-)/2, \quad \omega = (a_+ + a_-)/2
\]
so that the action in (47) becomes
\[
\tilde{S}_1 = \int d^2x d^2\Theta(4D_+ \omega D_- \omega + D_+ \ln v D_- \ln v)
\]
and thus describes two free scalar superfields \( \omega \) and \( \ln v \).

In the class \([w]\) we have an appert from constraints (48), (49) additional constraints
\[
\exp(a_+ - a_-) D_+ u = 0,
\]
\[
\exp(a_- - a_+) v^{-2} D_- (u + v) = 0.
\]
Under the constraints (48), (49), (53) the action in (47) becomes
\[
\tilde{S}_w = -\int d^2x d^2\Theta 4D_+ \omega D_- \omega
\]
and thus describes free scalar superfield \( \omega \).

ACKNOWLEDGEMENTS

I'm very grateful to A. Yu. Alekseev, B. L. Feigin, A. Kadeishvili, I. Polubin and Y. Pugai for discussions. This work was supported in part by grant RFFI-96-02-16507, INTAS-95-IN-RU-690.
References

[1] L. Brink, M. B. Green and J. H. Schwartz, *Nucl.Phys* **B198** (1982) 474; K. Kikkawa, M. Yamasaki, *Phys. Lett.* **B149** (1984) 357;

[2] E. Alvarez and M. A. R. Osorio, *Phys. Rev.* **D40** (1989) 1150;

[3] K. Narain, H. Sarmadi and E. Witten, *Nucl.Phys* **B279** (1987) 369;

[4] T. H. Busher, *Phys. Lett.* **B194** (1987) 51; *Phys. Lett.* **B201** (1988) 466;

[5] X. de la Ossa and F. Quevedo, *Nucl. Phys.* **B403** (1993) 377;

[6] A. Giveon and M. Rocek, *Nucl. Phys.* **B421** (1994) 173; E. Alvarez, L. Alvarez-Gaume and Y. Lozano, *Phys. Lett.* **B336** (1994) 183; A. Giveon, E. Rabinovichi and G. Veneziano, *Nucl. Phys.* **B322** (1989) 167;

[7] B. E. Fridling and A. Jevicki, *Phys. Lett.* **B134** (1984) 70;

[8] E. S. Fradkin and A. A. Tseytlin, *Ann. Phys.* **162** (1985) 31;

[9] T. Curtright and C. Zachos, *Phys. Rev.* **D49** (1994) 5408; T. Curtright and C. Zachos, *Phys. Rev.* **D52** (1995) R573;

[10] C. Klimcik and P. Severa, *Phys. Lett.* **B351** (1995) 455; C. Klimcik and P. Severa, Poisson-Lie T-duality and Loop groups of Drinfeld Doubles, *CERN-TH/95-330 hep-th/9512040*;

[11] V. G. Drinfeld, Quantum groups, *Proc. Int. Cong. Math., Berkley, Calif.* (1986) 798.

[12] A. Yu. Alekseev, C. Klimcik and A. A. Tseytlin, Quantum Poisson-Lie T-duality and WZNW model, *CERN-TH/95251 hep-th/9509123*

[13] K. Sfetsos, Poisson-Lie T-duality and supersymmetry, *THU-96/38 hep-th/9611199*

[14] P. DI Vecchia, V. G. Knizhnik, J. L. Petersen and P. Rossi, *Nucl.Phys* **B253** (1985) 701;

[15] A. Polyakov and P. Wiegmann, *Phys. Lett.* **B131** (1983) 121;

[16] Ph. Spindel, A. Sevrin, W. Troost and A. van Proeyen, *Nucl. Phys.* **B308** (1988) 662; *Nucl. Phys.* **B311** (1988/89) 465;

[17] S. E. Parkhomenko, Zh. Eksp. Teor. Fiz. **102** (July 1992) 3-7.

[18] S. E. Parkhomenko, *Mod. Phys. Lett.* **A11** (1996) 445;

[19] E. Getzler, Manin Pairs and topological Field Theory, *MIT-preprint* (1994).

[20] M. A. Semenov-Tian-Shansky, Dressing Transformations and Poisson-Group Actions, *RIMS, Kyoto Univ.* **21** (1985) 1237.

[21] J.-H. Lu and A. Weinstein, *J. Diff. Geom.* **V31** (1990) 501.
[22] A. Yu. Alekseev and A. Z. Malkhin, Commun. Math. Phys. V162 (1994) 147.

[23] J. Evans and T. Hollowood, Nucl. Phys. B352 (1991) 723;

[24] V. G. Drinfeld, DAN SSSR V262 (1983) 285.