Posudek práce

předložené na Matematicko-fyzikální fakultě
Univerzity Karlovy

☐ posudek vedoucího ☑ posudek oponenta
☑ bakalářské práce ☐ diplomové práce

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Název práce:	Weyl and conformal symmetries
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Odborná úroveň práce:
☑ vynikající ☐ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Věcné chyby:
☑ téměř žádné ☐ vzhledem k rozsahu přiměřený počet ☐ méně podstatné četné ☐ závažné

Výsledky:
☐ originální ☑ původní i převzaté ☐ netriviální kompilace ☐ citované z literatury ☐ opsané

Rozsah práce:
☐ veliký ☑ standardní ☐ dostatečný ☐ nedostatečný

Grafická, jazyková a formální úroveň:
☐ vynikající ☑ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Tiskové chyby:
☐ téměř žádné ☐ vzhledem k rozsahu a tématu přiměřený počet ☑ četné

Celková úroveň práce:
☑ vynikající ☐ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Slovní vyjádření, komentáře a připomínky oponenta:

Conformally invariant fields play a distinguished role in physic, for example they describe massless particles. It is well-known that quantum effects can break conformal invariance of classical field, leading to a non-vanishing expectation value of the trace of the energy-momentum tensor – the so-called Weyl anomaly. On classical level, such anomalies can be typically cured by the "improvements" of the energy-momentum tensor. Similarly, gravitational anomalies describe situations when promoting a flat-space theory to diffeomorphism invariant theory yields a non-conserved energy-momentum tensor. In the thesis it is shown that in the case of two-dimensional Liouville theory anomalies arise already on a classical level and, interestingly, it is impossible to combine both diffeomorphism invariance and Weyl symmetry (i.e. invariance under local conformal rescalings of the metric) at the same time.

The first chapter of the thesis is a brief review of the formalism of (conformal) Killing vectors, conformal Lie algebra, Witt algebra and covariant differentiation of spinors. Then, different ways of introducing the energy-momentum tensor are discussed: canonical one using the Noether theorem, Belinfante-Rosenfeld procedure and variational approach á la Hilbert. Next, it is demonstrated that Poincaré-invariant action for $n = 2$ Liouville theory can be promoted to fully conformally invariant action by introducing appropriate transformation law for the field. Resulting action suffers from the anomaly already on the classical level and corresponding improved traceless energy-momentum tensor is found. It is shown that corresponding generators satisfy the Virasoro algebra.

In the second chapter, the question of Weyl gauging is addressed, i.e. the question of promoting scale invariant fields to fields invariant under local Weyl transformations. This is done by introducing the potential W_μ. Expressions involving specific combinations of W_μ are then rewritten in terms of the Ricci tensor, making the coupling of the fields to curvature explicit (Ricci gauging). Specific case $n = 2$ is investigated separately.

Third chapter, the core of the thesis, is devoted to the anomalies in the Liouville theory. Explicit expression for W_μ is found and the improvement of the energy-momentum tensor is analyzed in detail. It is shown that W_μ does not transform covariantly under diffeomorphisms and hence diffeomorphism invariance of the theory is incompatible with the local Weyl symmetry. Results are summarized in the Conclusions part and in the appendices many auxiliary calculations are collected.

The thesis is full of lengthy calculations. Some of them are not original but it is obvious that the author became very familiar with the topic and mastered the formalism very well. In the part with original results the author shown a great creativity and ability to perform complicated and lengthy calculations and proofs. My only objection is a frequent appearance of typos, missing commas or periods in equations etc. This, however does not diminish the scientific value of the thesis.

I would like to ask few questions.

1. I understand that calculation of $\nabla_\mu T^{\mu\nu}$ is length and complicated and was not finished. Is there, however, any fundamental problem in the calculation that must be solved? Or one just needs the patience to finalize the calculation?

2. Are there any other theories in which we could expect classical anomalies? Would the result hold if one replaces the scalar field in Liouville action by, say, spinor field?

Conclusion. I think this is a high-level and remarkable thesis with very nicely written introduction and interesting new results and it would qualify as a diploma thesis. I **recommend** to accept it as a bachelor thesis.

Práci:

☑ doporučuji

☐ nedoporučuji
uznat jako bakalářskou.

Navrhuji hodnocení stupněm:
☑ výborně ☐ velmi dobře ☐ dobře ☐ neprospěl

Místo, datum a podpis oponenta:

Martin Scholtz, Praha, 10. června 2019