Construction and classification of novel BPS Wilson loops in quiver Chern–Simons-matter theories

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Abstract

In this paper we construct and classify novel Drukker–Trancanelli (DT) type BPS Wilson loops along infinite straight lines and circles in $\mathcal{N} = 2, 3$ quiver superconformal Chern–Simons-matter theories, Aharony–Bergman–Jafferis–Maldacena (ABJM) theory, and $\mathcal{N} = 4$ orbifold ABJM theory. Generally we have four classes of Wilson loops, and all of them preserve the same supersymmetries as the BPS Gaiotto–Yin (GY) type Wilson loops. There are several free complex parameters in the DT type BPS Wilson loops, and for two classes of Wilson loops in ABJM theory and $\mathcal{N} = 4$ orbifold ABJM theory there are supersymmetry enhancements at special values of the parameters. We check that the differences of the DT type and GY type Wilson loops are Q-exact with Q being some supercharges preserved by both the DT type and GY type Wilson loops. The results would be useful to calculate vacuum expectation values of the DT type Wilson loops in matrix models if they are still BPS quantum mechanically.

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1. Introduction

BPS (Bogomol'nyi–Prasad–Sommerfield) Wilson loops are important nonlocal objects in supersymmetric gauge theories, and in AdS/CFT correspondence [1–3] they are dual to probe F-strings/membranes in string/M theory [4–7], when they are in fundamental representation of the gauge group. BPS Wilson loops in three-dimensional quiver superconformal Chern–Simons-matter (CSM) theories are more complex than those in four-dimensional super Yang–Mills theories. One can use only bosonic fields and construct Gaiotto–Yin (GY) type Wilson loops [8], and also one can use both bosonic and fermionic fields and construct Drukker–Trancanelli (DT) type Wilson loops [9].

In $\mathcal{N} = 2$ CSM theories there are 1/2 BPS GY type Wilson loops along infinite straight lines and circles, and in $\mathcal{N} = 3$ CSM theories there are 1/3 BPS GY type Wilson loops [8]. The Aharony–Bergman–Jafferis–Maldacena (ABJM) theory is an $\mathcal{N} = 6$ CSM theory with gauge group $U(N) \times U(N)$ and levels $(k, -k)$, and it is dual to M-theory in $AdS_4 \times S^7/Z_k$ spacetime or type IIA string theory in $AdS_4 \times CP^3$ spacetime [10]. In ABJM theory, there are 1/6 BPS GY type Wilson loops [11–13] and 1/2 BPS DT type Wilson loops [9] along infinite straight lines and circles. The construction of the latter ones resolved the puzzle about the existence of the half BPS Wilson loop dual to half BPS F-string solution found in [11,13]. In ABJM theory there are more general BPS DT type Wilson loops along general curves that preserve fewer supersymmetries [14–18]. The $\mathcal{N} = 4$ CSM theories were constructed in [19–21], and a special case is the $\mathcal{N} = 4$ orbifold ABJM theory that has gauge group $U(N)^{2r}$ and alternating levels $(k, -k, \cdots, k, -k)$ and is dual to M-theory in $AdS_4 \times S^7/(Z_r \times Z_{rk})$ spacetime [21–24]. Recently, 1/4 BPS GY type Wilson loops and 1/2 BPS DT type BPS Wilson loops in $\mathcal{N} = 4$ orbifold ABJM theory were constructed in [25,26]. BPS Wilson loops in more general $\mathcal{N} = 4$ CSM theories were also constructed in [26].

As announced in [27], we found novel DT type BPS Wilson loops in quiver superconformal CSM theories. In $\mathcal{N} = 2$ quiver superconformal CSM theories, though the supersymmetries are relatively fewer, we found that there still exist DT type 1/2 BPS Wilson loops. This construction, when applied to theories with more supersymmetries, leads to DT type Wilson loops preserving two Poincaré supercharges (and also two superconformal charges), when the Wilson loops are along straight lines and the parameters in the Wilson loops are not under further constraints. In ABJM theory and $\mathcal{N} = 4$ CSM theory, supersymmetry (SUSY) enhancements for Wilson loops can appear for special values of these parameters. We find no SUSY enhancement for Wilson loops in $\mathcal{N} = 3$ CSM theories. This is consistent with the results in the dual M-theory side [28].

This paper is an extension of [27], with calculation details and more examples. We also pay more attention to classification of DT type Wilson loops. We construct novel DT type BPS Wilson loops along straight lines and circles in several quiver superconformal CSM theories. We investigate the case of a generic $\mathcal{N} = 2$ quiver CSM theory with multiple bifundamental and anti-bifundamental matter in section 2, the case of an $\mathcal{N} = 3$ quiver CSM theory in section 3, the case of ABJM theory in section 4, and the case of $\mathcal{N} = 4$ orbifold ABJM theory in section 5. We conclude with discussion in section 6.

2. Generic $\mathcal{N} = 2$ quiver CSM theory

We consider a generic $\mathcal{N} = 2$ quiver superconformal CSM theory with bifundamental matter. We pick two adjacent nodes in the quiver diagram and the corresponding gauge groups are $U(N)$ and $U(M)$. The vector multiplet for gauge group $U(N)$ includes gauge field A_μ, and auxiliary