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## Universal amplitude ratios for self-avoiding walks on the kagome lattice

Keh Ying Lin<sup>†</sup> and Jing Xian Huang

Department of Physics, National Tsing Hua University, Hsinchu, Taiwan 300, Republic of China

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Abstract. We have calculated exactly the number, the mean-square end-to-end distance, the mean-square radius of gyration, and the mean-square distance of a monomer from the origin, for *n*-step self-avoiding walks on the kagome lattice up to 30 steps. We have estimated the connective constant and the critical amplitudes. Our numerical results are consistent with the theoretical prediction by Cardy and Saleur on the universality for certain amplitude ratios.

A self-avoiding walk (SAW) is a model of a polymer (de Gennes 1979). Recently, several combinations of critical amplitudes for two-dimensional SAWs were predicted to be lattice-independent (Cardy and Saleur 1989, Caracciolo *et al* 1990, Cardy and Guttmann 1993). These predictions have been confirmed for SAWs on the square, triangular and honeycomb lattices. The motivation of the present paper is to study numerically SAWs on the kagome lattice, and our results are indeed consistent with universality. Recent progress on SAWs have been reviewed by Lin and Hsaio (1993).

We are mainly interested in the following functions: (i) the chain generating function for SAWS  $C(x) = \sum c_n x^n$  where  $c_n$  is the total number of *n*-step SAWs; (ii) the mean-square end-to-end distance of *n*-step SAWs  $\langle R_e^2 \rangle_n$ ; (iii) the mean-square radius of gyration of *n*-step SAWS  $\langle R_g^2 \rangle_n$ ; and (iv) the mean-square distance of a monomer from the origin  $\langle R_m^2 \rangle_n$  of *n*-step SAWs.

The asymptotic forms at large *n* are believed to be (Cardy and Guttmann 1993)

$$c_n \approx A\mu^n n^{\gamma-1} \\ \langle R_e^2 \rangle_n \approx Bn^{2\nu} \qquad \langle R_g^2 \rangle_n \approx Cn^{2\nu} \qquad \langle R_m^2 \rangle_n \approx Dn^{2\nu}$$

where  $\mu$  is the connective constant. The exponents  $\gamma$  and  $\nu$  depend only on the space dimensionality d and not on the particular lattice chosen. The amplitudes A, B, C, D and the connective constant  $\mu$  vary from lattice to lattice. Exact values for the exponents have been derived for d = 2 and the results are (Nienhuis 1982)

$$\gamma = 43/32 = 1.34375$$
  $\nu = 3/4 = 0.75.$  (1)

For d = 3 the exact results are not available and we have

$$\gamma \approx 7/6 \qquad \nu \approx 3/5.$$
 (2)

Although the amplitudes are lattice-dependent, Cardy and Saleur (1989) used the c-theorem in conformal theory to prove that the amplitude ratios C/B and D/B are universal. However, their theoretical predictions are not consistent with numerical results (Guttmann and Yang 1990, Lam 1990). A minor mistake in the work of Cardy and Saleur (1989) was

† E-mail: lin@phys.nthu.edu.tw

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19 $46$ $815$ $736$ $3$ $445$ $704$ $922$ $194$ $090$ $889$ $621$ $20$ $121$ $881$ $736$ $9668$ $955$ $109$ $599$ $77$ $747$ $158$ $21$ $317$ $067$ $290$ $270$ $9668$ $955$ $109$ $599$ $777$ $151$ $21$ $317$ $067$ $290$ $270$ $15$ $653$ $573$ $184$ $927$ $22$ $2141$ $102$ $780$ $737$ $755$ $581$ $558$ $57184$ $927$ $23$ $2141$ $102$ $780$ $2703$ $293$ $689$ $633$ $165$ $860$ $1243$ $24$ $5558$ $956$ $2766$ $276$ $2376$ $2378$ $833$ $803$ $623$ $1634$ $25$ $144$ $102$ $780$ $276$ $2376$ $2376$ $2378$ $833$ $962$ $2443$ $25$ $374$ $438$ $836$ $907$ $762$ $116$ $3108$ $822$ $26$ $37444$ $334468$ $11948$ $322465$ $737$ $1365656$ $545$ $962$ $9162$ $27$ $96$ $94722$ $94$ $8322465$ $757$ $131636$ $653$ $762$ $715$ $27$ $96$ $94722$ $732$ $792$ $732$ $792$ $732$ $792$ $732$ $28$ $9762$ $9727$ $9767$ $732$ $926733376$ $732$ $732$ $732$ <td>17 969 517</td> <td>1 222 017 563</td> <td>62 186 629 663</td> <td>10 111 620 182</td>	17 969 517	1 222 017 563	62 186 629 663	10 111 620 182
20       121       881       736       9668       955       109       599       774       158         21       317       067       290       27       013       693       275       1       838       398       101       862         22       824       208       773       755       581       5       588       057       184       927         23       2       141       102       780       270       13       695       55       5       58       057       184       927         23       2       2       141       102       780       208       438       089       633       16       860       012       443         23       2       141       102       780       208       438       089       633       16       860       012       443         24       5       558       556       268       268       053       155       55       55       55       56       244       56       545       56       244       56       56       244       56       545       56       391       624       445       86       70	46 815 736	3 445 704 922	194 090 889 621	30 024 000 396
21       317 067 290       27 013 693 275       1 838 398 101 862         22       317 067 290       75 173 755 581       5 588 057 184 927         23       2 141 102 780       75 173 755 581       5 588 057 184 927         23       2 141 102 780       208 438 089 633       16 861 686 012 443         24       5 558 956 276       576 033 125 833       50 539 116 310 822         25       14 425 260 268       1 587 038 080 403       150 545 962 391 624         26       37 414 334 468       4 360 222 627 183       445 886 809 762 145         27       96 994 722 794       11 948 322 465 757       1 313 632 063 383 791         28       056 057       070 833 276       075 885 607 762 145         29       050 94 722 794       11 948 322 465 757       1 313 632 063 383 791	121 881 736	9 668 955 109	599 972 747 158	88 497 495 657
22       824 208 073       75 173 755 581       5 588 057 184 927         23       2 141 102 780       208 438 089 633       16 861 686 012 443         24       5 558 956 276       576 033 125 833       50 539 116 310 822         25       14 425 260 268       1 587 058 080 403       150 545 962 391 624         26       37 414 334 468       4 360 292 627 183       445 866 809 762 145         27       96 994 722 794       11 948 322 465 757       1 313 632 063 383 791         27       96 994 722 794       11 948 322 465 757       1 313 632 063 383 791         28       96 594 722 794       11 948 322 465 757       1 313 632 063 383 791	317 067 290	27 013 693 275	1 838 398 101 862	259 118 611 346
23       2       141       102       780       208       438       089       633       16       861       686       012       443         24       5       558       956       276       576       033       125       833       50       539       116       310       822         25       14       425       266       1       576       033       125       833       50       539       116       310       822         25       14       425       260       288       157       053       120       804       403       62       391       624         26       37       414       334       468       4       360       292       627       183       445       886       809       762       145         27       96       94       722       794       11       948       322       465       763       763       761       732       764       772       79       772       79       772       79       772       70       833       770       833       770       833       770       833       770       833       770       833	824 208 073	75 173 755 581	5 588 057 184 927	754 100 047 365
24     5 558 956 276     576 033 125 833     50 539 116 310 822       25     14 425 260 268     1 587 058 080 403     150 545 962 391 624       26     37 414 334 468     4 360 292 627 183     445 886 809 762 145       27     96 994 722 794     11 948 322 465 757     1 313 632 063 383 791       27     96 994 722 794     11 948 322 465 757     1 313 632 063 383 791	2 141 102 780	208 438 089 633	16 861 686 012 443	2 182 498 482 624
25     14 425 260 268     1 587 058 080 403     150 545 962 391 624       26     37 414 334 468     4 360 292 627 183     445 886 809 762 145       27     96 994 722 794     11 948 322 465 757     1 313 632 063 383 791       27     96 994 722 794     11 948 322 465 757     1 313 632 063 383 791	5 558 956 276	576 033 125 833	50 539 116 310 822	6 284 590 732 291
26         37         414         334         468         4         360         292         627         183         445         886         809         762         145           27         96         994         722         794         11         948         322         465         757         1         313         632         063         383         791           27         96         994         722         794         11         948         322         465         363         363         791         933         376         732         96         934         732         793         737         732         732         732         736         732         736	14 425 260 268	1 587 058 080 403	150 545 962 391 624	18 012 489 393 834
27         96 994 722 794         11 948 322 465 757         1 313 632 063 383 791           28         27         27         3 852 100 833 376 732	37 414 334 468	4 360 292 627 183	445 886 809 762 145	51 404 096 550 537
26 312 32 412 05 542 373 376 732 32 671 305 585 607 3 852 100 833 376 732	96 994 722 794	11 948 322 465 757	1 313 632 063 383 791	146 112 141 517 962
	251 416 952 773	32 671 205 585 607	3 852 100 833 376 732	413 882 091 090 767
29 651 055 515 786 89 086 229 814 062 11 237 995 271 643 907	651 055 515 786	89 086 229 814 062	11 237 995 271 643 907	1 167 724 197 217 793
30         1         685         795         303         428         242         471         516         931         336         32         653         731         490         314         182	1 685 795 303 428	242 471 516 931 336	32 653 731 490 314 182	3 284 859 612 821 943

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Table 1. Exact enumeration results for the number, mean-square end-to-end distance, mean-square radius of gyration and mean-square distance of a monomer from the origin, for

corrected by Caracciolo *et al* (1990). From exact enumeration results for the mean-square distance of the monomers to the origin, and the centre of mass to the origin on the square lattice up to 21 steps and the triangular lattice up to 15 steps, Guttmann and Yang (1990) obtained for both lattices

$$C/B = 0.1396 \pm 0.001$$
  $D/B = 0.4375 \pm 0.002.$  (3)

From a Monte Carlo study of SAWs on the square lattice, Caracciolo et al found that

$$C/B = 0.14026 \pm 0.00011$$
  $D/B = 0.43962 \pm 0.00033.$  (4)

We have calculated the number, mean-square end-to-end distance, mean-square radius of gyration, and mean-square distance of a monomer from the origin, of SAWs on the kagome lattice up to 30 steps and give the results in table 1. We used the first-order differential approximants (Guttmann 1989) based on the series of  $c_n$  to estimate the connective constant  $\mu$  and the critical amplitude A:

$$\mu = 2.5606 \pm 0.0002 \qquad A = 1.162 \pm 0.001. \tag{5}$$

The amplitude ratios C/B and D/B are calculated by extrapolation techniques (Guttmann 1989). We find

$$B = 0.848 \pm 0.001 \qquad C = 0.119 \pm 0.001 \qquad D = 0.373 \pm 0.001$$
  

$$C/B = 0.140 \pm 0.001 \qquad D/B = 0.440 \pm 0.001. \tag{6}$$

Our numerical results are in agreement with the prediction of Cardy and Saleur (1989) on the universality of certain amplitude ratios.

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