nbody.py: (original version)

```
-0.16908926275527172
-0.16905240492391141
-0.16901474404530115
-0.16902307738080738
-0.1690798593916716
-0.1690837851340391
-0.1690461237029509
-0.1690141632287673
-0.1690277860596755
-0.16908371256964286
-0.16908078067628346
-0.16904474158017624
-0.16901196403207439
-0.16903317301080864
-0.16908783999484456
-0.16908019793585344
-0.16904027123722912
-0.16900666759845165
-0.1690385994000913
-0.1690927820263521
-0.16907709741618646
-0.1690318157474469
-0.16900365578743826
-0.16904872400310705
-0.16909656666618936
-0.16907120739400114
-0.16902491372614678
-0.1690054028562737
-0.1690615084418881
-0.16909732952330989
-0.16906445026914277
-0.16901977601924423
-0.1690087837330612
-0.16906942996092264
-0.1690936981250834
-0.16905776550855287
-0.16901607122935539
-0.16901202092861942
-0.1690769590988439
-0.16909176966916228
-0.16905402040535616
-0.16901235909925366
-0.16901736033369455
-0.1690847459685499
-0.16909035534676262
-0.16904838452880422
-0.16900663034076266
-0.16902335367423574
-0.16909124149510837
-0.16908618459859356
-0.16904015517545168
-0.16900291923555205
-0.16903287494400335
```

```
-0.16909558331070956
-0.1690805511712076 5
-0.16903390308620184
-0.16900274590721814
-0.16904459300211724
-0.16909854774651836
-0.16907499697399825
-0.16902883385621698
-0.16900287426063337
-0.16905344993896332
-0.16909778695827116
-0.1690688542355601
-0.16902288517135491
-0.1690034111639226
-0.16906323202819348
-0.16909793327535813
-0.16906372791458069
-0.16901758963658736
-0.16900762655227408
-0.16907413362652127
-0.1690966701276139
-0.16905715253841647
-0.16901176533650106
-0.16901316541886924
-0.16908223578125162
-0.1690918842838697
-0.1690491567289713
-0.1690084483625472
-0.16902057135969534
-0.16908716660200046
-0.16908658831414558
-0.16904412116934314
-0.16900740673825185
-0.16902932050670785
-0.16909180276278374
-0.16908292959405574
-0.16903991544261052
-0.16900522540601676
-0.16903656773659115
-0.16909410318888132
-0.169078466211733
-0.16903274720873912
-0.16900284987920383
-0.1690462807510843
-0.1690971767866576
-0.16907293588692712
-0.16902628585294033
```

<mark>326007706 function calls in 139.087 seconds</mark>

   Ordered by: cumulative time

   ncalls tottime percall cumtime percall filename:lineno(function)
        1   0.000   0.000 139.087 139.087 {built-in method builtins.exec}
        1   0.000   0.000 139.087 139.087 nbody_0.py:1(<module>)
        1   0.688   0.688 139.087 139.087 nbody_0.py:127(nbody)

```
  2000000    28.762     0.000   138.390     0.000 nbody_0.py:69(advance)
 20000000    34.995     0.000    98.645     0.000 nbody_0.py:56(update_vs)
120000000    33.228     0.000    63.650     0.000 nbody_0.py:49(compute_b)
120000000    30.422     0.000    30.422     0.000 nbody_0.py:53(compute_mag)
 10000000     3.985     0.000     3.985     0.000 nbody_0.py:64(update_rs)
 20002000     3.362     0.000     3.362     0.000 nbody_0.py:46(compute_deltas)
 20002000     2.107     0.000     2.107     0.000 {method 'append' of 'list' objects}
 14001401     1.528     0.000     1.528     0.000 {method 'keys' of 'dict' objects}
      200     0.004     0.000     0.006     0.000 nbody_0.py:90(report_energy)
      100     0.003     0.000     0.003     0.000 {built-in method builtins.print}
     2000     0.001     0.000     0.001     0.000 nbody_0.py:87(compute_energy)
        1     0.000     0.000     0.000     0.000 nbody_0.py:110(offset_momentum)
        1     0.000     0.000     0.000     0.000 {method 'disable' of
'_lsprof.Profiler' objects}
```

nbody_1.py:

```
-0.16908926275527247
-0.16905240492390924
-0.16901474404529523
-0.1690230773808051
-0.16907985939166825
-0.1690837851340347
-0.1690461237029501
-0.16901416322876447
-0.1690277860596743
-0.16908371256964122
-0.1690807806762811
-0.1690447415801755
-0.16901196403207294
-0.1690331730108022
-0.16908783999484095
-0.16908019793585227
-0.169040271237232
-0.169006667598453
-0.1690385994009403
-0.1690927820263547
-0.16907709741618882
-0.169031815747448
-0.16900365578743654
-0.16904872400309928
-0.16909656666618625
-0.16907120739400391
-0.16902491372615247
-0.16900540285627882
-0.16906150844188397
-0.16909732952330978
-0.16906445026915173
-0.16901977601925314
-0.16900878373306116
-0.16906942996091393
-0.16909369812508884
-0.16905776550856255
-0.1690160712293723
```

```
-0.16901202092862222
-0.16907695909884222
-0.169091769669173358
-0.16905402040537185
-0.1690123590992729
-0.16901736033369652
-0.16908474596854227
-0.16909035534677078
-0.1690483845288214
-0.16900663034076482
-0.16902335367422314
-0.16909124149510274
-0.16908618459861163
-0.16904015517547252
-0.16900291923556668
-0.1690328749439878
-0.16909558331069982
-0.1690805511712164
-0.169033903086221
-0.16900274590722628
-0.16904459300209396
-0.16909854774650468
-0.16907499697399922
-0.16902883385621426
-0.1690028742606153
-0.1690534499389253
-0.16909778695826222
-0.1690688542355666
-0.16902288517135797
-0.16900341116392273
-0.16906323202817114
-0.16909793327536177
-0.16906372791459134
-0.16901758963659527
-0.16900762655226215
-0.1690741336264965
-0.16909667012760904
-0.1690571525384226
-0.1690117653365007
-0.16901316541884268
-0.16908223578122547
-0.16909188428385355
-0.16904915672896156
-0.1690084483625337
-0.1690205713596649
-0.16908716660197087
-0.16908658831413295
-0.16904412116933104
-0.16900740673822784
-0.16902932050667469
-0.16909180276275207
-0.1690829295940311
-0.1690399154425835
-0.1690052254059815
-0.16903656773655534
-0.16909410318885254
```

-0.16907846621170516
-0.16903274720871028
-0.16900284987918082
-0.16904628075107253
-0.16909717678663805
-0.1690729358868992
-0.16902628585291105

   Ordered by: cumulative time

   ncalls tottime percall cumtime percall filename:lineno(function)
        1   0.000   0.000   42.889   42.889 {built-in method builtins.exec}
        1   0.000   0.000   42.889   42.889 nbody_1.py:1(<module>)
        1   0.000   0.000   42.889   42.889 nbody_1.py:118(nbody)
      100   22.288   0.223   42.885   0.429 nbody_1.py:60(advance)
 20000000   17.566   0.000   17.566   0.000 nbody_1.py:51(update_vs)
 20001000   1.753   0.000   1.753   0.000 {method 'append' of 'list' objects}
 14000701   1.279   0.000   1.279   0.000 {method 'keys' of 'dict' objects}
      100   0.002   0.000   0.002   0.000 {built-in method builtins.print}
      100   0.001   0.000   0.001   0.000 nbody_1.py:81(report_energy)
        1   0.000   0.000   0.000   0.000 nbody_1.py:101(offset_momentum)
        1   0.000   0.000   0.000   0.000 {method 'disable' of
'_lsprof.Profiler' objects}

nbody_2.py:

-0.16908926275527172
-0.1690524049239141
-0.16901474404530115
-0.16902307738080738
-0.1690798593916716
-0.1690837851340391
-0.1690461237029509
-0.1690141632287673
-0.1690277860596755
-0.16908371256964286
-0.16908078067628346
-0.16904474158017624
-0.1690119640320743
-0.1690331730108064
-0.16908783999484456
-0.16908019793585344
-0.1690402712372912
-0.16900666759845165
-0.1690385994000913
-0.1690927820263521
-0.16907709741618646
-0.1690318157474469
-0.16900365578743826
-0.16904872400310705

-0.16909656666618936
-0.16907120739400114
-0.16902491372614678
-0.1690054028562737
-0.16906150844188811
-0.16909732952330989
-0.16906445026914277
-0.16901977601924423
-0.1690087837330612
-0.16906942996092264
-0.1690936981250834
-0.16905776550855287
-0.16901607122935539
-0.16901202092861942
-0.1690769590988439
-0.16909176966916228
-0.16905402040535616
-0.16901235909925366
-0.16901736033369455
-0.1690847459685499
-0.16909035534676262
-0.16904838452880422
-0.16900663034076266
-0.16902335367423574
-0.16909124149510837
-0.16908618459859356
-0.16904015517545168
-0.16900291923555205
-0.16903287494400335
-0.16909558331070956
-0.16908055117120765
-0.16903390308620184
-0.16900274590721814
-0.16904459300211724
-0.16909854774651836
-0.16907499697399825
-0.16902883385621698
-0.16900287426063337
-0.16905344993896332
-0.16909778695827116
-0.1690688542355601
-0.16902288517135491
-0.1690034111639226
-0.16906323202819348
-0.16909793327535813
-0.16906372791458069
-0.16901758963658736
-0.16900762655227408
-0.16907413362652127
-0.1690966701276139
-0.16905715253841647
-0.16901176533650106
-0.16901316541886924
-0.16908223578125162
-0.16909188428386907
-0.16904491567289713

-0.1690084483625472
-0.16902057135969534
-0.16908716660200046
-0.16908658831414558
-0.16904412116934314
-0.16900740673825185
-0.16902932050670785
-0.16909180276278374
-0.16908292959405574
-0.16903991544261052
-0.16900522540601676
-0.16903656773659115
-0.1690941031888132
-0.169078466211733
-0.16903274720873912
-0.16900284987920383
-0.1690462807510843
-0.1690971767866576
-0.16907293588692712
-0.1690262858529403

<mark>326007706 function calls in 125.639 seconds</mark>

Ordered by: cumulative time

ncalls	tottime	percall	cumtime	percall	filename:lineno(function)
1	0.000	0.000	125.639	125.639	{built-in method builtins.exec}
1	0.000	0.000	125.639	125.639	nbody_2.py:1(<module>)
1	0.574	0.574	125.639	125.639	nbody_2.py:132(nbody)
2000000	23.652	0.000	125.057	0.000	nbody_2.py:74(advance)
20000000	32.069	0.000	91.381	0.000	nbody_2.py:61(update_vs)
120000000	30.934	0.000	59.312	0.000	nbody_2.py:54(compute_b)
120000000	28.379	0.000	28.379	0.000	nbody_2.py:58(compute_mag)
10000000	3.661	0.000	3.661	0.000	nbody_2.py:69(update_rs)
20002000	3.048	0.000	3.048	0.000	nbody_2.py:51(compute_deltas)
20002000	1.904	0.000	1.904	0.000	{method 'add' of 'set' objects}
14001401	1.412	0.000	1.412	0.000	{method 'keys' of 'dict' objects}
200	0.004	0.000	0.006	0.000	nbody_2.py:95(report_energy)
100	0.002	0.000	0.002	0.000	{built-in method builtins.print}
2000	0.001	0.000	0.001	0.000	nbody_2.py:92(compute_energy)
1	0.000	0.000	0.000	0.000	{method 'disable' of '_lsprof.Profiler' objects}
1	0.000	0.000	0.000	0.000	nbody_2.py:115(offset_momentum)

nbody_3.py:

-0.16908926275527172
-0.1690524049239141
-0.16901474404530115
-0.16902307738080738
-0.1690798593916716
-0.1690837851340391
-0.1690461237029509
-0.1690141632287673

-0.1690277860596755
-0.16908371256964286
-0.16908078067628346
-0.16904474158017624
-0.16901196403207439
-0.16903317301080864
-0.16908783999484456
-0.16908019793585344
-0.16904027123722912
-0.16900666759845165
-0.1690385994000913
-0.1690927820263521
-0.16907709741618646
-0.1690318157474469
-0.16900365578743826
-0.16904872400310705
-0.16909656666618936
-0.16907120739400114
-0.16902491372614678
-0.1690054028562737
-0.1690615084418881
-0.16909732952330989
-0.16906445026914277
-0.16901977601924423
-0.1690087837330612
-0.16906942996092264
-0.1690936981250834
-0.16905776550855287
-0.16901607122935539
-0.16901202092861942
-0.1690769590988439
-0.16909176966916228
-0.16905402040535616
-0.16901235909925366
-0.16901736033369455
-0.1690847459685499
-0.16909035534676262
-0.16904838452880422
-0.16900663034076266
-0.16902335367423574
-0.16909124149510837
-0.16908618459859356
-0.16904015517545168
-0.16900291923555205
-0.16903287494400335
-0.16909558331070956
-0.16908055117120765
-0.16903390308620184
-0.16900274590721814
-0.16904459300211724
-0.16909854774651836
-0.16907499697399825
-0.16902883385621698
-0.16900287426063337
-0.16905344993896332
-0.16909778695827116

```
-0.1690688542355601
-0.16902288517135491
-0.1690034111639226
-0.16906323202819348
-0.16909793327535813
-0.16906372791458069
-0.16901758963658736
-0.16900762655227408
-0.16907413362652127
-0.1690966701276139
-0.16905715253841647
-0.16901176533650106
-0.16901316541886924
-0.16908223578125162
-0.1690918842838697
-0.1690491567289713
-0.1690084483625472
-0.16902057135969534
-0.16908716660200046
-0.16908658831414558
-0.16904412116934314
-0.16900740673825185
-0.169029320506 70785
-0.16909180276278374
-0.16908292959405574
-0.16903991544261052
-0.16900522540601676
-0.16903656773659115
-0.1690941031 8888132
-0.169078466211733
-0.16903274720873912
-0.16900284987920383
-0.1690462807510843
-0.1690971767866576
-0.16907293588692712
-0.16902628585294033
```

<mark>326007706 function calls in 132.748 seconds</mark>

Ordered by: cumulative time

```
 ncalls  tottime  percall  cumtime  percall filename:lineno(function)
       1    0.000    0.000  132.748  132.748 {built-in method builtins.exec}
       1    0.000    0.000  132.748  132.748 nbody_3.py:1(<module>)
       1    0.654    0.654  132.748  132.748 nbody_3.py:134(nbody)
 2000000   27.120    0.000  132.086    0.000 nbody_3.py:73(advance)
20000000   33.676    0.000   94.435    0.000 nbody_3.py:60(update_vs)
120000000   31.438    0.000   60.759    0.000 nbody_3.py:53(compute_b)
120000000   29.321    0.000   29.321    0.000 nbody_3.py:57(compute_mag)
10000000    3.807    0.000    3.807    0.000 nbody_3.py:68(update_rs)
20002000    3.229    0.000    3.229    0.000 nbody_3.py:50(compute_deltas)
20002000    2.028    0.000    2.028    0.000 {method 'append' of 'list' objects}
14001401    1.468    0.000    1.468    0.000 {method 'keys' of 'dict' objects}
     200    0.004    0.000    0.006    0.000 nbody_3.py:95(report_energy)
     100    0.003    0.000    0.003    0.000 {built-in method builtins.print}
    2000    0.001    0.000    0.001    0.000 nbody_3.py:92(compute_energy)
```

```
        1    0.000    0.000    0.000    0.000 nbody_3.py:116(offset_momentum)
        1    0.000    0.000    0.000    0.000 {method 'disable' of
'_lsprof.Profiler' objects}
```

nbody_4.py:

```
-0.16908926275527172
-0.1690524049239141
-0.16901474404530115
-0.16902307738080738
-0.1690798593916716
-0.1690837851340391
-0.1690461237029509
-0.1690141632287673
-0.1690277860596755
-0.16908371256964286
-0.16908078067628346
-0.16904474158017624
-0.16901196403207439
-0.1690331730108086
-0.16908783999484456
-0.16908019793585344
-0.1690402712372291
-0.16900666759845165
-0.1690385994000913
-0.1690927820263521
-0.16907709741618646
-0.1690318157474469
-0.16900365578743826
-0.16904872400310705
-0.16909656666618936
-0.1690712073940011
-0.16902491372614678
-0.1690054028562737
-0.1690615084418881
-0.16909732952330989
-0.16906445026914277
-0.16901977601924423
-0.1690087837330612
-0.16906942996092264
-0.1690936981250834
-0.16905776550855287
-0.16901607122935539
-0.16901202092861942
-0.1690769590988439
-0.16909176966916228
-0.16905402040535616
-0.1690123590992536
-0.16901736033369455
-0.1690847459685499
-0.16909035534676262
-0.1690483845288042
-0.16900663034076266
-0.16902335367423574
```

-0.16909124149510837
-0.16908618459859356
-0.16904015517545168
-0.16900291923555205
-0.16903287494400335
-0.16909558331070956
-0.16908055117120765
-0.16903390308620184
-0.16900274590721814
-0.16904459300211724
-0.16909854774651836
-0.16907499697399825
-0.16902883385621698
-0.16900287426063337
-0.16905344993896332
-0.16909778695827116
-0.1690688542355601
-0.16902288517135491
-0.1690034111639226
-0.16906323202819348
-0.16909793327535813
-0.16906372791458069
-0.16901758963658736
-0.16900762655227408
-0.16907413362652127
-0.1690966701276139
-0.16905715253841647
-0.16901176533650106
-0.16901316541886924
-0.16908223578125162
-0.1690918842838697
-0.1690491567289713
-0.1690084483625472
-0.16902057135969534
-0.16908716660200046
-0.16908658831414558
-0.16904412116934314
-0.16900740673825185
-0.16902932050670785
-0.16909180276278374
-0.16908292959405574
-0.16903991544261052
-0.16900522540601676
-0.16903656773659115
-0.16909410318888132
-0.169078466211733
-0.16903274720873912
-0.16900284987920383
-0.1690462807510843
-0.1690971767866576
-0.16907293588692712
-0.16902628585294033

```
   Ordered by: cumulative time

   ncalls   tottime  percall  cumtime   percall filename:lineno(function)
        1     0.000    0.000  116.403   116.403 {built-in method builtins.exec}
        1     0.000    0.000  116.403   116.403 nbody_4.py:1(<module>)
        1     0.547    0.547  116.402   116.402 nbody_4.py:129(nbody)
  2000000    15.296    0.000  115.849     0.000 nbody_4.py:77(advance)
 20000000    32.532    0.000   93.533     0.000 nbody_4.py:61(update_vs)
120000000    32.415    0.000   61.000     0.000 nbody_4.py:54(compute_b)
120000000    28.586    0.000   28.586     0.000 nbody_4.py:58(compute_mag)
 10000000     3.831    0.000    3.831     0.000 nbody_4.py:69(update_rs)
 20002000     2.994    0.000    2.994     0.000 nbody_4.py:51(compute_deltas)
  2000202     0.195    0.000    0.195     0.000 {method 'keys' of 'dict' objects}
      200     0.003    0.000    0.004     0.000 nbody_4.py:94(report_energy)
      100     0.002    0.000    0.002     0.000 {built-in method builtins.print}
     2000     0.001    0.000    0.001     0.000 nbody_4.py:91(compute_energy)
        1     0.000    0.000    0.000     0.000 nbody_4.py:112(offset_momentum)
        1     0.000    0.000    0.000     0.000 {method 'disable' of
'_lsprof.Profiler' objects}
```

nbody_opt.py:

```
-0.16908926275527247
-0.16905240492390924
-0.16901474404529523
-0.1690230773808051
-0.16907985939166825
-0.1690837851340347
-0.1690461237029501
-0.16901416322876447
-0.1690277860596743
-0.16908371256964122
-0.1690807806762811
-0.1690447415801755
-0.16901196403207294
-0.1690331730108022
-0.16908783999484095
-0.16908019793585227
-0.169040271237232
-0.169006667598453
-0.1690385994009403
-0.1690927820263547
-0.16907709741618882
-0.169031815747448
-0.16900365578743654
-0.16904872400309928
-0.16909656666618625
-0.1690712073940391
-0.16902491372615247
-0.1690054028562782
-0.16906150844188397
-0.16909732952330978
```

```
-0.16906445026915173
-0.16901977601925314
-0.16900878373306116
-0.16906942996091393
-0.16909369812508884
-0.16905776550856255
-0.1690160712293723
-0.1690120209286222
-0.1690769590988422
-0.16909176966917358
-0.16905402040537185
-0.1690123590992729
-0.16901736033369652
-0.1690847459685427
-0.16909035534677078
-0.1690483845288214
-0.16900663034076482
-0.16902335367422314
-0.16909124149510274
-0.16908618459861163
-0.16904015517547252
-0.16900291923556668
-0.1690328749439878
-0.16909558331069982
-0.1690805511712164
-0.169033903086221
-0.16900274590722628
-0.16904459300209396
-0.16909854774650468
-0.16907499697399922
-0.16902883385621426
-0.1690028742606153
-0.1690534499389253
-0.16909778695826222
-0.1690688542355666
-0.16902288517135797
-0.16900341116392273
-0.16906323202817114
-0.16909793327536177
-0.16906372791459134
-0.16901758963659527
-0.16900762655226215
-0.1690741336264965
-0.16909667012760904
-0.1690571525384226
-0.1690117653365007
-0.16901316541884268
-0.16908223578122547
-0.16909188428385355
-0.16904915672896156
-0.1690084483625337
-0.1690205713596649
-0.16908716660197087
-0.16908658831413295
-0.16904412116933104
-0.16900740673822784
```

```
-0.16902932050667469
-0.16909180276275207
-0.1690829295940311
-0.1690399154425835
-0.1690052254059815
-0.16903656773655534
-0.1690941031885254
-0.16907846621170516
-0.16903274720871028
-0.1690028498791808
-0.16904628075107253
-0.16909717678663805
-0.1690729358868992
-0.16902628585291105
```

<mark>22000606 function calls in 29.027 seconds</mark>

   Ordered by: cumulative time

```
   ncalls  tottime  percall  cumtime  percall filename:lineno(function)
        1    0.000    0.000   29.027   29.027 {built-in method builtins.exec}
        1    0.000    0.000   29.027   29.027 nbody_opt.py:1(<module>)
        1    0.000    0.000   29.027   29.027 nbody_opt.py:118(nbody)
      100   11.348    0.113   29.023    0.290 nbody_opt.py:62(advance)
 20000000   17.505    0.000   17.505    0.000 nbody_opt.py:51(update_vs)
  2000301    0.170    0.000    0.170    0.000 {method 'keys' of 'dict' objects}
      100    0.002    0.000    0.002    0.000 {built-in method builtins.print}
      100    0.001    0.000    0.001    0.000 nbody_opt.py:82(report_energy)
        1    0.000    0.000    0.000    0.000 nbody_opt.py:100(offset_momentum)
        1    0.000    0.000    0.000    0.000 {method 'disable' of
'_lsprof.Profiler' objects}
```

How much speedup:

	nbody runtime	optimized runtime	Speedup by
nbody_1	139.087	42.889	3.243
nbody_2	139.087	125.639	1.107
nbody_3	139.087	132.748	1.048
nbody_4	139.087	116.403	1.195
nbody_opt	139.087	29.027	4.792

speedup by = nbody runtime / optimized runtime