Simulation of GMRT Observing Fields

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1 Introduction

A full exploitation of a powerful and verstile instrument like GMRT is not possible without a good image processing software package. AIPS meets many of our requirements. But some mapping problems and procedures are unique to GMRT and we need to develop a set of special tasks to meet these requirements. It is time now to start thinking seriously about these special problems and algorithms and to develop suitable mapping tasks that are specific to GMRT and to test them. We need to generate simulated data bases to test these programs. In this report we will deal with just one aspect of this, i.e. generation of test fields.

2 The Generation of Test fields

Our aim is to generate fields (at a given frequency) with the following characteristics.

- It has a specified area.
- Within the field the sources are randomly and uniformly distributed.
- The flux densities of sources within the field follow LogN-LogS relation.

We start with the source counts at 408MHz, given by the model of Kapahi and Subrahmanya(1983). This model is supposed to give a very good fit to the observed ones at 408MHz. Let $N_1(S_1)$ denote the number of sources per sterdian with flux density $\geq S_1$ at frequency ν_1(=408MHz). The values of $N_1(S_1)$ are given at $S_{1,i}$ for i=1,2,...,j. Now suppose we want to generate test fields at frequency ν_2 (=150MHz). For simplicity we assume that all the sources have the same spectral index $\alpha_0 = 0.85$. We have $S_{2,i} = S_{1,i}(\nu_1/\nu_2)^{\alpha_0}$. Let $N_2(S_2)$ be the number of sources per sterdian with flux density $\geq S_2$ at frequency ν_2. The counts at ν_2 are then given by

$$N_2\left(S_{1,i}(\frac{\nu_1}{\nu_2})^{\alpha_0}\right) = N_1\left(S_{1,i}\right)$$

for $i = 1, 2, \cdots, j$.

Now we need to know the area of the field. Let us consider a field of size $(x_r - x_l)(y_t - y_b)$ where (x_l, y_b) and (x_r, y_t) represent BLC and TRC of the field respectively. The area of field is given by $A = (x_r - x_l)(y_t - y_b)(\pi/180)^2$ sterdians. The source counts for this area are then given by

$$n_2\left(S_{1,i}(\frac{\nu_1}{\nu_2})^{\alpha_0}\right) = N_2\left(S_{1,i}(\frac{\nu_1}{\nu_2})^{\alpha_0}\right) A$$

for $i = 1, 2, \cdots, j$.

Suppose we want to generate sources brighter than S_2^{lim} and let $\overline{m} = n_2\left(> S_2^{lim}\right)$ where $\overline{m}$ is the mean number of sources in the field. Not all fields will have $\overline{m}$ sources. The number of sources in different fields are Poisson distributed with mean $\overline{m}$. Let k be the number of fields we want to generate. We generate (see Note 1) k Poisson deviates with mean $\overline{m}$. Let the deviates be denoted by m_i, $i = 1, 2, \cdots, k$. Note that each element m_i gives the number of sources in i^{th} field. Hence the following procedure needs to be repeated for each m_i. To be specific consider m_1. We generate (see Note 2) random deviates $sd_i, i = 1, 2, \cdots, m_1$ which follow the distribution given by $n_2(S_2)$. For each source we generate (see Note 3) two uniform deviates x_i, y_i which lie between x_l and x_r and y_b and y_t respectively. For each source we have sd_i, x_i and y_i.

3 The Program

We have developed two programs called "sim" and "altsim". Functionally both are same but the codes are completely independent. This was done because the generation of truly pseudo random numbers is a very tricky business and one can never be sure that the numbers generated do not have some correlation. The subroutine "altsim" uses subroutines from standard mathematical library. The other subroutine "sim" uses a set of carefully coded subroutines from various sources. You are urged to use both in your studies and make sure you get equivalent results (This, however does not necessarily mean that your simulations are correct!).

4 Future Work

The program was written with a particular application i.e. simulation of GMRT observing fields in mind. This explains why we have not considered the generation of observing fields at high ($> 1000MHz$) frequencies. To make the program more general we need to incorporate source counts at different frequencies. Also a thorough testing of the various routines to generate random deviates has not yet been done. Removal of these limitations and addition of new features can be given as a project to a graduate student.

Note 1. This requires a subroutine to generate Poisson deviates for a given mean.

Note 2. This requires a routine to generate random deviates that follow a given distribution in a tabular form.

Note 3. This requires a subroutine to generate uniform random deviates.

References

[1] Subrahmanya C. R. and Kapahi V. K. in *Early Evolution of the Universe and it's Present Structure* ,p47 Abell G.O. and Chincarin (eds), D. Reidel 1983.

[2] Bratley Paul, Fox B.L. and Schrage L.E. *A Guide to Simulation.* Springer-Verlag.

[3] Dagpunar John. *Principles of Random Variate Generation* Clarendon Press:Oxford 1988.

Host:GMRT
File:/home/softgrp/gmrtobssim/gmrtobssim.hlp
....
GMRTOBSSIM.HLP

"gmrtobssim.f" is a file that contains the "sim" subroutine which is used to simulate GMRT obseving fields. An equivalent subroutine (but independent) "altsim" is contained in the file "altgmsim.f". The calling sequence is same for both of them (except the name of course !) Examples of calling sequence and test outputs for "SIM" and "ALTSIM" are given in files
/home/softgrp/gmrtobssim/simtst.out
and
/home/softgrp/gmrtobssim/altsimtst.out
respectively.
....

SIMULATION OF GMRT OBSERVING FIELDS

This is a program to simulate GMRT observing fields. It can can generate sources at a given frequency that are randomly and uniformly distributed over primary beam. The flux densities of generated sources are in accordance with the counts of radio sources. This code is in a testing phase and users are requested to contact V.K. Kulkarni for any bugs/problems they might find. Suggestions for improvement are welcome. The file containing source code is given. Just compile it (f77) and link it with your program.

Calling sequence:

```
call sim (freq, slim, x1, x2, y1, y2, nf, nd, sd,
   xpos, ypos, nsou, iercode)

Integer nf, nd, nsou, iercode

REAL    x1, x2, y1, y2, freq, slim, sd, xpos, ypos

dimension       sd(nd), xpos(nd), ypos(nd)
```

Parameters:
INPUT:

freq ----- simulation frequency (38 MHz to 610 MHz)

slim ------ lower limit for flux density. Only sources with s > =slim are generated

x1, x2, y1, y2 ------ coordinates of external rectangular field so that (x2-x1)*(y2 -y1) gives area of field in square degrees.

nf .... The field number

nd .... Dimension of sd, xpos, ypos
If you expect n sources nd >n
Recommend nd = expected number + 2*sqrt(n)

OUTPUT:

sd .... Array of deviates (flux density in Jy)

xpos, ypos.... Arrays of co-ordinates of sources

nsou ...... Number of sources generated. Please note that nsou can be zero (see below)

iercode = 0 normal return
= 1 number of sources generated is 0. This is only a warning.
= 2 slim in either too small/too big. At 408 MHz the valid range for slim is the open interval(0.001,1000.0)in JYs.
=3 dimension of sd, xpos, ypos i.e. nd <nsou.
= anything else ......Internal error

contact vasant@gmrt

Host:GMRT
File:/home/softgrp/gmrtobssim/simtst.out

....

Below we give an example of calling sequence for "SIM" and some test output.

....

TEST PROGRAM:

```
        program tst
        parameter(nsiz=500)
c       For the following values of parameters
c       we expect <500 sources.
        dimension sd(nsiz),xpos(nsiz),ypos(nsiz)
10      continue
        freq=408.0
        slim=0.01
        x1=-1.5
        x2= 1.5
        y1=-1.5
        y2= 1.5
        nf=17
        nd=nsiz
        call sim(freq,slim,x1,x2,y1,y2,nf,nd,
     1  sd,xpos,ypos,kount,iercode)
        if(iercode.ne.0)write(*,*)iercode
        write(*,1020) freq,slim,x1,x2,y1,y2,nf,kount
1020    format(1x,'freq=',f5.1,2x,'slim=',f5.3,3x,
     1  'x1,x2,y1,y2 =',4(f4.1,1x), /,x,'field no.='
     2  ,i3,3x,'No. of sources=',i5)
        write(*,*)'     no.      Flux                x          y '
        do 10 i=1,kount
        write(*,1040) i,sd(i),xpos(i),ypos(i)
1040    format(2x,i4,2x,f9.4,5x,f7.4,2x,f7.4)
10      continue
        end
```

....

TEST OUTPUT:

freq=408.0 slim=0.010   x1,x2,y1,y2 =-1.5 1.5 -1.5 1.5
field no.= 17   No. of sources= 312

no.	Flux	x	y
1	0.0100	-1.2220	-1.2867
2	0.0100	-0.9865	-0.6076
3	0.0102	-0.8028	1.4293
4	0.0102	1.0369	0.7691
5	0.0103	-0.9206	-1.1153
6	0.0103	0.4074	0.7669
7	0.0103	-0.9757	-0.7051
8	0.0103	0.5211	-0.8724
9	0.0105	-0.1560	0.2895
10	0.0106	1.3228	-1.2345
11	0.0107	-1.0934	-0.6363
12	0.0108	-0.4809	-0.5379
13	0.0108	0.1202	-0.3419
14	0.0109	0.3750	0.1111
15	0.0109	-1.1038	0.8642
16	0.0109	-0.0344	-1.1564
17	0.0110	-0.9173	-0.6173
18	0.0111	-0.7712	-0.4706
19	0.0111	-0.5371	0.7335
20	0.0111	-0.7406	0.9373
21	0.0112	-1.0516	1.0418
22	0.0112	0.6778	1.2375
23	0.0113	0.6644	-0.1929
[illegible]	0.0114	1.0504	-1.1154
25	0.0114	-1.4285	0.7525
26	0.0114	0.2784	0.2499
27	0.0116	1.0851	-0.2997
28	0.0116	0.1587	0.5272
29	0.0117	0.6024	-0.8529
30	0.0117	0.9939	-1.4598
31	0.0117	0.1001	0.8205
32	0.0118	-0.2128	0.5524
33	0.0118	-0.7910	-1.2953
34	0.0119	-1.4660	0.4619
35	0.0119	1.0369	-1.4158
36	0.0120	-0.9277	1.0702
37	0.0120	0.8795	-1.2517
38	0.0120	1.1145	0.8418
39	0.0121	0.7590	0.8782
40	0.0121	-0.9015	0.0678
41	0.0121	-0.5257	-0.4175
42	0.0122	0.3277	0.3054
43	0.0122	-0.3674	-0.8301
44	0.0122	0.9777	-0.9107
45	0.0122	-0.5218	1.3290
46	0.0123	1.0292	-0.0437
47	0.0123	-0.0593	0.8377
48	0.0123	0.4748	0.3635
49	0.0124	0.7745	-1.4347
50	0.0124	-0.8549	-1.3781
51	0.0124	0.0796	0.3646
52	0.0125	0.4797	0.0764
53	0.0125	0.0800	0.3798
54	0.0126	0.3143	1.2682
55	0.0126	-1.0328	0.3167
56	0.0127	-0.7174	0.3540
57	0.0127	0.6575	-1.2619
58	0.0127	-0.4518	-0.4692
59	0.0127	-0.6951	-1.1722
60	0.0128	-0.5992	0.0746
61	0.0128	1.0574	-0.3445
62	0.0129	-1.1988	-0.4687
63	0.0130	1.1801	-0.7349
64	0.0131	0.3851	-1.4259
65	0.0132	0.2840	0.3074
66	0.0132	-1.3282	-0.2695
67	0.0133	-0.1072	-0.6742
68	0.0133	0.1939	0.7713
69	0.0133	-1.2449	0.9442
70	0.0137	1.4781	1.1244
71	0.0137	-0.3542	-1.3205
72	0.0138	-1.0560	0.8989
73	0.0139	0.8102	-0.6325
74	0.0139	-1.2741	1.1944
75	0.0139	-1.3331	0.2867
76	0.0140	-0.4690	-0.5906
77	0.0141	-1.1130	0.7670
78	0.0142	-0.2949	-0.6367
79	0.0142	0.4999	0.9124
80	0.0146	-0.5652	-0.8700
81	0.0146	-0.2047	-0.0612
82	0.0147	-0.5478	-1.3431
83	0.0149	-0.2010	0.9749
84	0.0151	0.8199	-1.0806
85	0.0151	0.9618	0.6661
86	0.0152	-0.2612	0.2006
87	0.0152	0.1280	0.5909
88	0.0155	-0.3321	0.4862
89	0.0155	1.0883	0.1949
90	0.0156	1.2442	0.0494
91	0.0156	-0.1955	-1.2868
92	0.0157	-0.8488	-0.6845
93	0.0157	-0.0214	0.6346
94	0.0158	-0.2012	-0.1977
95	0.0159	1.4685	-0.8985
96	0.0160	0.2770	-1.4415
97	0.0161	0.7421	1.0466
98	0.0165	0.8889	-0.8686
99	0.0166	1.0238	-0.0360
100	0.0166	-0.0631	-1.0987
101	0.0168	-0.8082	-0.6688
102	0.0168	-0.5843	-0.0242
103	0.0168	-0.6165	-0.8721
104	0.0172	0.9902	0.4499
105	0.0172	-0.4600	0.6846
106	0.0172	-0.3866	-1.0379
107	0.0176	-0.8864	0.2846
108	0.0176	-0.5511	-1.1383
109	0.0180	-0.1539	1.3538
110	0.0180	-1.3092	0.9798
111	0.0181	0.4958	0.2878
112	0.0181	-0.1068	-0.2128
113	0.0181	1.3266	-0.7306
114	0.0184	-1.0093	-0.3171
115	0.0184	0.5062	0.4870
116	0.0184	-0.9161	-0.1044
117	0.0185	-0.0151	-1.4853
118	0.0187	1.4103	-1.4808
119	0.0187	1.3651	-0.8395
120	0.0189	-1.2086	-0.1302
121	0.0189	1.0237	1.0859
122	0.0193	-0.3980	1.0612
123	0.0195	-0.9564	0.0817
124	0.0199	1.3690	-0.1815
125	0.0200	0.5397	1.0153
126	0.0201	-0.1243	-0.1472
127	0.0204	-0.1193	0.3742
128	0.0204	-0.9373	1.2018
129	0.0206	0.6720	0.1666
130	0.0207	1.1040	-0.6998
131	0.0209	-0.0109	-0.1300
132	0.0211	-0.2178	-1.4992
133	0.0211	0.1227	-1.4762
134	0.0213	0.4872	0.8041
135	0.0214	0.4312	0.2060
136	0.0216	0.6671	-1.2391
137	0.0216	-1.0482	0.1635
138	0.0217	1.2521	0.0971
139	0.0220	-1.4318	0.4348
140	0.0221	0.4728	0.6651
141	0.0223	-1.0926	0.4269
142	0.0226	1.3301	-1.3758
143	0.0227	0.1175	-0.1290
144	0.0227	-0.5050	0.4216
145	0.0228	-0.4100	-0.3437
146	0.0229	-0.5168	-0.6835
147	0.0230	-1.3965	-0.7250
148	0.0230	-0.5560	1.0237
149	0.0232	-0.2485	0.0755
150	0.0234	-0.7078	1.3950
151	0.0234	1.4781	-0.3877
152	0.0235	0.4106	-0.8135
153	0.0238	-0.6209	-0.1669
154	0.0242	0.1338	0.5312
155	0.0244	-0.0428	0.4204
156	0.0245	-0.9934	0.2436
157	0.0246	-0.2054	0.4651
158	0.0247	-1.3055	0.6938
159	0.0248	-0.0717	-1.1709
160	0.0250	0.6615	-1.4010
161	0.0251	-0.2556	-0.9288

[illegible]	0.0253	-1.0070	-1.1699
163	0.0256	-0.3413	-0.6920
164	0.0258	-1.1869	-1.1539
165	0.0260	-1.3853	-1.2941
166	0.0265	1.0957	1.1888
167	0.0268	-1.4762	-0.6417
168	0.0269	-0.4633	0.3479
169	0.0276	-0.4390	-1.2598
170	0.0282	-1.3988	-0.2867
171	0.0287	0.1079	0.0920
172	0.0290	-1.0691	-0.0563
173	0.0290	0.2333	0.9760
174	0.0291	-0.5483	1.3714
175	0.0296	-1.1796	0.2345
176	0.0296	-1.3051	-1.2337
177	0.0296	-0.9735	-0.8406
178	0.0297	1.2931	1.0624
179	0.0301	0.4718	-1.0251
180	0.0303	0.1949	1.2687
181	0.0318	0.8809	0.1298
182	0.0322	0.7382	-0.6374
183	0.0322	-1.4228	0.7826
184	0.0325	1.3165	0.5372
185	0.0326	0.3530	-0.2327
186	0.0334	-0.9366	-0.9681
187	0.0335	0.9492	-1.0884
188	0.0343	-0.6310	-0.3384
189	0.0345	-0.8644	1.1993
190	0.0347	0.8544	-0.6259
191	0.0349	-0.9254	0.1839
192	0.0350	-1.3056	0.9419
193	0.0364	0.0116	1.4955
194	0.0366	1.1692	0.3235
195	0.0382	-0.5867	0.6295
[illegible]	0.0385	1.4767	0.6291
[illegible]	0.0386	0.1361	-1.1110
198	0.0400	1.1052	1.2818
199	0.0409	-0.9822	0.5800
200	0.0411	1.3052	-1.0319
201	0.0412	-0.5923	-0.8899
202	0.0428	0.4005	0.7177
203	0.0430	0.5778	0.5967
204	0.0435	0.4793	1.4047
205	0.0445	-1.3914	-0.3758
206	0.0450	-0.2732	0.4292
207	0.0452	1.0491	-0.0501
208	0.0459	-1.1347	0.8564
209	0.0463	-0.8143	0.3741
210	0.0464	-0.4556	0.2882
211	0.0468	-0.0171	-0.1176
212	0.0469	0.0816	-0.8374
213	0.0469	0.7129	-0.4092
214	0.0483	-0.9244	0.3477
215	0.0492	0.3378	0.7761
216	0.0502	-0.8324	-0.0330
217	0.0515	-0.9453	-1.2374
218	0.0520	0.8814	0.0289
219	0.0545	1.3420	0.3176
220	0.0545	-1.1220	1.3271
221	0.0547	-0.3707	1.2353
222	0.0549	-0.4938	-1.2008
223	0.0552	-1.0090	-0.9523
224	0.0564	-0.7514	0.7379
[illegible]	0.0571	0.6130	0.8776
[illegible]	0.0573	-1.1025	-0.8158
227	0.0573	1.2109	1.0177
228	0.0578	1.0974	0.0066
229	0.0583	0.5377	1.1818
230	0.0583	1.3497	0.9097
231	0.0588	-0.3378	0.6916
232	0.0606	1.4728	-0.1255
233	0.0615	0.1727	-0.3362
234	0.0645	0.2678	-1.1248
235	0.0646	-0.8712	-0.7738
236	0.0648	0.9105	-1.2451
237	0.0650	0.4254	-0.9284
238	0.0655	0.9871	0.8393
239	0.0657	0.9236	-0.6257
240	0.0674	0.1262	0.3606
241	0.0689	0.2788	-1.1386
242	0.0698	1.2705	-0.5086
243	0.0706	-0.7671	0.9371
244	0.0733	0.8206	1.4644
245	0.0741	-0.5433	-0.2456
246	0.0750	1.0651	1.4658
247	0.0769	-0.9571	-0.4964
248	0.0779	-0.9748	-0.1648
249	0.0803	1.0377	-1.2527
250	0.0807	1.2379	-0.5058
251	0.0808	1.2737	1.1815
252	0.0814	0.5447	-0.6937
253	0.0818	0.0626	0.6440
254	0.0849	-0.5974	-0.2812
255	0.0850	-0.2734	0.9162
256	0.0854	-0.8358	1.2958
257	0.0874	0.1584	-0.2783
258	0.0906	0.6105	0.2219
259	0.0907	0.7151	-0.9992
260	0.0913	0.7140	0.5571
261	0.0923	1.0760	-0.2922
262	0.0945	0.3721	-1.2137
263	0.0947	0.6281	1.4857
264	0.0952	-0.5878	1.3645
265	0.0954	0.4507	-1.1598
266	0.0957	-1.0854	0.2456
267	0.0970	-0.7267	-0.9509
268	0.0971	0.3140	0.3215
269	0.1061	0.2022	0.0622
270	0.1071	0.2868	1.0549
271	0.1080	0.8304	1.1601
272	0.1109	0.5265	-0.4030
273	0.1156	-0.8501	-0.1707
274	0.1186	-0.7422	1.3345
275	0.1193	-1.0362	-0.1928
276	0.1236	0.2723	0.4775
277	0.1279	-0.2231	0.3971
278	0.1293	0.7823	-1.0894
279	0.1301	0.8422	-0.3130
280	0.1313	0.7651	1.1150
281	0.1314	0.4259	-0.5840
282	0.1325	-0.3807	-0.6617
283	0.1341	-0.5661	-0.8791
284	0.1513	-0.6571	0.9734
285	0.1560	-0.1717	0.4008
286	0.1582	-0.2972	1.2346
287	0.1633	-0.8989	0.5465
288	0.1634	0.1875	0.3324
289	0.1712	0.5191	0.3323
290	0.1780	-0.7544	1.1766
291	0.1801	-0.8805	0.3970
292	0.1818	-1.3605	1.3169
293	0.1894	-0.6148	-1.3342
294	0.1899	-0.6704	-1.2424
295	0.1999	-1.0192	0.1477
296	0.2065	0.6812	1.0271
297	0.2226	0.1127	1.4449
298	0.2476	1.4598	1.2084
299	0.2486	1.1622	1.3882
300	0.2624	-0.2979	-0.7015
301	0.2672	0.5961	0.0792
302	0.2678	0.5025	1.2211
303	0.3031	-0.5785	-0.2842
304	0.3063	-0.2317	1.2471
305	0.3264	-0.7568	1.4970
306	0.4489	0.9037	-0.7652
307	0.5451	-1.1268	-0.8004
308	0.5653	-1.4595	-1.1835
309	0.5913	1.4504	1.4783
310	0.6615	-0.9963	1.4548
311	0.8310	0.2661	0.2012
312	2.1403	-1.1636	-0.2678

Host:GMRT
File:/home/softgrp/gmrtobssim/altsimtst.out
Below we give an example of calling seq. for "ALTSIM"
and some test output.

....

TEST PROGRAM:

```
      program alttst
      parameter(nsiz=500)
c     For the following values of parameters
c     we expect <500 sources.
      dimension sd(nsiz),xpos(nsiz),ypos(nsiz)
50    continue
      freq=408.0
      slim=0.01
      x1=-1.5
      x2= 1.5
      y1=-1.5
      y2= 1.5
      nf=17
      nd=nsiz
      call altsim(freq,slim,x1,x2,y1,y2,nf,nd,
     1 sd,xpos,ypos,kount,iercode)
      if(iercode.ne.0)write(*,*)iercode
      write(*,1020) freq,slim,x1,x2,y1,y2,nf,kount
1020  format(1x,'freq=',f5.1,2x,'slim=',f5.3,3x,
     1 'x1,x2,y1,y2 =',4(f4.1,1x), /,x,'field no.='
     2 ,i3,3x,'No. of sources=',i5)
      write(*,*)'    no.      Flux             x           y '
      do 10 i=1,kount
      write(*,1040) i,sd(i),xpos(i),ypos(i)
1040  format(2x,i4,2x,f9.4,5x,f7.4,2x,f7.4)
10    continue
      end
```

....

TEST OUTPUT:

```
 freq=408.0  slim=0.010   x1,x2,y1,y2 =-1.5  1.5 -1.5  1.5
 field no.= 17   No. of sources=  301
```

no.	Flux	x	y
1	0.0100	-0.3730	-1.1932
2	0.0101	-1.4634	0.8883
3	0.0102	1.0100	0.6307
4	0.0103	-1.1960	-0.3516
5	0.0105	-0.1035	-0.2780
6	0.0106	-1.0767	-0.4847
7	0.0106	1.3393	0.0603
8	0.0106	-0.4554	1.4739
9	0.0106	0.9023	-0.3161
10	0.0107	0.5268	0.2839
11	0.0107	1.0928	1.3598
12	0.0107	0.2218	-0.6753
13	0.0108	-0.9654	1.2247
14	0.0109	0.9053	0.2046
15	0.0110	0.9192	-0.8375
16	0.0110	-0.0588	-0.6287
17	0.0112	-0.5561	-0.7074
18	0.0113	-0.6523	-0.6696
19	0.0113	-1.3443	-0.8088
20	0.0113	-1.3219	1.2902
21	0.0115	0.8657	-0.6633
22	0.0116	0.2178	-0.1446
23	0.0116	0.2227	-0.6271
24	0.0117	-0.3679	-0.0860
25	0.0118	1.0330	0.7380
26	0.0118	-1.1157	-1.3312
27	0.0119	-0.1358	1.3286
28	0.0121	0.5565	-0.2529
29	0.0121	0.3713	0.2593
30	0.0121	-1.4731	1.0845
31	0.0122	0.0219	1.4800
32	0.0122	0.6302	-1.3866
33	0.0122	-1.2016	0.1877
34	0.0123	1.3231	-0.8973
35	0.0123	0.7067	0.7644
36	0.0124	-1.3906	1.1514
37	0.0125	1.1083	-0.4079
38	0.0125	0.0916	0.8086
39	0.0125	0.4593	0.8652
40	0.0126	0.2397	-0.9363
41	0.0128	1.1676	0.2173
42	0.0128	-1.1522	0.5234
43	0.0129	0.2127	-0.8990
44	0.0129	-0.8133	-1.3001
45	0.0130	0.7884	-0.0425
46	0.0131	0.2150	-1.2650
47	0.0132	0.0879	-1.0329
48	0.0133	0.5026	-0.9088
49	0.0133	-0.3799	-1.0213
50	0.0133	1.3356	1.1968
51	0.0133	-0.3757	1.2270
52	0.0134	0.7691	-0.8131
53	0.0135	-1.4857	1.3032
54	0.0135	-0.3462	-1.3629
55	0.0138	0.9646	0.6872
56	0.0141	-0.6008	0.9702
57	0.0142	-1.2040	-1.0758
58	0.0143	0.8598	-0.4594
59	0.0145	-1.3409	-0.1064
60	0.0145	-0.7552	1.0774
61	0.0145	0.1900	0.8128
62	0.0146	-0.8951	0.3898
63	0.0146	-0.7366	1.1791
64	0.0146	-0.9561	1.0845
65	0.0146	-1.0313	1.4921
66	0.0148	0.8668	0.7343
67	0.0148	-0.4266	-0.3984
68	0.0149	0.9055	-0.2913
69	0.0149	0.2238	-1.3810
70	0.0149	-0.1972	1.4455
71	0.0151	0.7494	0.4998
72	0.0152	0.1871	0.2912
73	0.0154	1.2559	-0.0181
74	0.0156	1.0629	-1.3615
75	0.0157	1.4199	-1.2924
76	0.0158	-1.0272	1.1278
77	0.0159	0.3036	-0.4891
78	0.0159	-0.7929	-0.9435
79	0.0159	0.0830	-0.6512
80	0.0159	-1.3766	-0.1576
81	0.0160	-0.1118	-0.9528
82	0.0162	-0.1480	0.2373
83	0.0163	-1.4909	-1.1291
84	0.0164	1.3629	1.4946
85	0.0164	0.5778	0.2954
86	0.0167	0.1402	-0.8810
87	0.0167	0.8718	0.5454
88	0.0168	-1.3771	-0.3236
89	0.0168	0.5661	1.2956
90	0.0169	1.3289	0.4285
91	0.0170	1.3926	-0.0900
92	0.0171	-0.5544	0.9987
93	0.0173	0.9070	1.4683
94	0.0174	0.3843	-0.5796
95	0.0175	-0.7394	1.2031
96	0.0175	-0.1744	0.6792
97	0.0175	-0.2725	-1.3116
98	0.0176	0.1067	-1.1153
99	0.0176	-1.0843	-1.3310
100	0.0182	-1.2813	-0.2014
101	0.0182	-1.1078	1.4990
102	0.0182	0.0367	-1.0504
103	0.0182	1.0792	0.2179
104	0.0182	-0.0793	-0.8187
105	0.0183	0.9978	0.0841
106	0.0183	0.9975	0.3690
107	0.0190	0.1854	1.3605
108	0.0190	-0.7802	-0.2508
109	0.0191	-0.6312	-1.3466
110	0.0194	-0.1964	-1.1505
111	0.0197	-1.0102	1.3749
112	0.0203	-0.2188	0.0858
113	0.0204	-1.3297	-1.0059
114	0.0205	-1.2474	-0.4879
115	0.0207	-0.8094	-0.8498
116	0.0208	0.9809	1.1048
117	0.0209	-1.3584	-1.1437
118	0.0210	1.0435	-0.2847
119	0.0210	-0.0617	0.8136
120	0.0212	0.8857	-0.6367
121	0.0213	-0.0400	0.1284
122	0.0217	-1.3475	0.1421
123	0.0219	-0.0713	-0.9737
124	0.0219	-0.4737	-0.1247
125	0.0220	0.5509	-1.2203
126	0.0221	0.8133	-1.1314
127	0.0222	-0.6204	0.7243
128	0.0224	-0.9521	-0.4573
129	0.0225	-0.4547	1.4479
130	0.0227	-0.4118	-0.6417
131	0.0227	-0.6588	1.3792
132	0.0230	-0.8915	-1.2121
133	0.0232	0.7629	0.3331
134	0.0235	-0.2877	1.4467
135	0.0241	-0.3026	-1.2235
136	0.0243	-1.1000	1.3791
137	0.0244	0.5787	0.7541
138	0.0245	-0.6314	-0.7150
139	0.0249	1.3643	0.5893
140	0.0251	-0.8785	0.4846
141	0.0256	0.2280	-1.3678
142	0.0258	0.3452	-0.9671
143	0.0259	0.7272	0.6474
144	0.0260	0.4858	-1.2589
145	0.0260	-0.0929	-1.2413
146	0.0262	-1.1121	1.3142
147	0.0263	-0.5508	0.0047
148	0.0266	1.4077	-1.1220
149	0.0266	0.4745	-1.3925
150	0.0268	-0.0103	1.4887
151	0.0269	0.5736	1.0947
152	0.0271	-0.4120	-0.0351
153	0.0271	1.0333	0.2268
154	0.0275	-0.7710	1.3045
155	0.0275	1.2921	-1.2869
156	0.0279	0.4510	-0.8286
157	0.0280	0.1323	-0.2268
158	0.0285	1.2181	0.5285
159	0.0285	0.1508	-1.2416
160	0.0292	0.8119	1.4342
161	0.0299	-0.8026	1.0160
162	0.0300	0.2305	0.9338

163	0.0309	0.6384	-1.1370
164	0.0310	0.4216	-0.5715
165	0.0319	0.6916	-0.9519
166	0.0319	0.8358	0.8097
167	0.0322	1.2138	0.3661
168	0.0327	0.6297	0.0892
169	0.0340	1.4212	-0.7242
170	0.0340	-1.2445	-0.0572
171	0.0341	-0.9033	0.4467
172	0.0345	-0.4985	1.0212
173	0.0346	-0.1644	0.7629
174	0.0350	-0.6532	-0.6274
175	0.0353	0.1088	-0.7230
176	0.0361	0.7114	1.4150
177	0.0363	1.1929	0.4780
178	0.0366	0.2554	-0.1526
179	0.0367	0.4212	-0.3316
180	0.0371	0.9842	-1.3793
181	0.0373	-1.3229	-1.3527
182	0.0382	-1.2440	-0.7187
183	0.0383	-0.9400	-1.1968
184	0.0384	0.4048	-0.1172
185	0.0387	0.6163	-0.2565
186	0.0387	0.5765	-1.4613
187	0.0393	-1.3656	-1.1871
188	0.0393	1.0938	-1.0214
189	0.0395	-1.4705	-0.6248
190	0.0395	1.3809	0.8914
191	0.0398	0.3383	0.1223
192	0.0401	0.0435	-1.2101
193	0.0401	1.3619	-1.0232
194	0.0403	1.3628	-0.8977
195	0.0404	-0.5779	1.4166
196	0.0423	0.5544	0.1575
197	0.0425	-1.3827	-0.5824
198	0.0430	0.0449	1.1440
199	0.0454	0.9886	1.2156
200	0.0459	0.3265	0.2511
201	0.0467	-0.2644	-0.7080
202	0.0470	-1.0124	-0.2335
203	0.0474	-0.1975	0.8064
204	0.0481	-1.2825	0.4826
205	0.0482	1.4456	-1.2874
206	0.0486	-0.6977	0.8457
207	0.0487	0.4081	0.7803
208	0.0488	0.6975	1.3613
209	0.0491	0.9867	-0.0992
210	0.0492	0.6439	-1.2080
211	0.0499	1.4143	0.3494
212	0.0505	0.6808	0.3186
213	0.0505	-0.9140	0.8203
214	0.0522	-1.1508	-0.1949
215	0.0525	0.8518	0.4794
216	0.0529	-0.2806	-0.3138
217	0.0534	0.2915	0.5762
218	0.0535	-0.2082	1.4936
219	0.0553	-0.5056	1.1947
220	0.0554	-0.4650	-0.6616
221	0.0568	1.2159	-0.1513
222	0.0568	-1.4748	-0.6827
223	0.0601	1.0732	1.3537
224	0.0608	-0.9454	-0.7986
225	0.0617	-0.3226	-0.8143
226	0.0618	0.1818	1.2104
227	0.0622	0.7883	0.4647
228	0.0623	-1.2805	0.6170
229	0.0623	-0.9415	0.6760
230	0.0626	0.1553	-0.2306
231	0.0637	0.3825	0.2426
232	0.0642	0.4972	-1.2004
233	0.0666	-0.2426	-0.0383
234	0.0667	-0.8975	-1.0389
235	0.0681	-0.8834	-0.5006
236	0.0735	-1.3186	-0.2321
237	0.0743	-1.1570	0.9770
238	0.0765	1.3623	0.2528
239	0.0793	0.6767	0.7695
240	0.0796	-0.8059	-0.4726
241	0.0802	0.9687	-0.3096
242	0.0814	-1.0750	-0.9413
243	0.0823	-0.7942	1.1225
244	0.0823	1.0402	-1.2595
245	0.0826	-0.6047	-1.4291
246	0.0832	-0.5293	-0.2063
247	0.0832	0.8527	0.3955
248	0.0838	-0.1725	-0.9979
249	0.0857	0.9463	1.4658
250	0.0870	0.5069	-1.1603
251	0.0875	-0.4979	-1.0507
252	0.0883	-0.9032	-0.1057
253	0.0889	-0.0283	1.2516
254	0.0911	-0.2153	-1.2752
255	0.0925	0.5480	-0.1294
256	0.1003	0.8661	0.0384
257	0.1003	0.8942	-1.0628
258	0.1008	-0.1280	0.4255
259	0.1013	0.1644	-0.1718
260	0.1023	-0.7888	-0.4290
261	0.1025	-0.5236	-0.8858
262	0.1027	-1.4158	1.1235
263	0.1035	0.6202	-1.1083
264	0.1098	0.1171	0.8057
265	0.1135	-0.5239	-0.4771
266	0.1164	-0.0370	-0.6976
267	0.1176	-0.5830	-0.2763
268	0.1277	-0.3616	0.0499
269	0.1490	0.9085	-1.4533
270	0.1540	0.8602	0.5977
271	0.1563	1.4142	-0.0318
272	0.1571	-0.4726	-1.1718
273	0.1616	-0.0928	0.9903
274	0.1661	0.0989	0.6382
275	0.1808	-1.2176	1.3859
276	0.1899	0.3060	0.3680
277	0.1930	-0.3246	0.9019
278	0.1933	-0.9391	-1.1949
279	0.1973	-0.9644	-0.1227
280	0.2044	-0.3821	1.2294
281	0.2058	0.8653	1.4468
282	0.2068	1.3206	0.9769
283	0.2155	-1.0450	-0.6662
284	0.2213	-1.4307	-0.6727
285	0.2422	0.5161	1.1850
286	0.2583	-0.2025	0.7653
287	0.2620	-0.7807	1.4790
288	0.2645	0.1028	-1.0429
289	0.2989	0.3952	-0.0876
290	0.3274	1.4518	1.2667
291	0.4457	0.6586	-1.0452
292	0.5373	1.3332	-0.2072
293	0.5490	-0.1785	0.7041
294	0.5649	-0.8454	-0.9129
295	0.6375	1.1100	-1.0214
296	0.7823	-0.4268	-1.0608
297	0.9872	0.3506	0.8865
298	1.0159	-1.1506	-0.6702
299	1.5438	0.4431	0.3999
300	1.6507	0.5376	-0.7256
301	2.8012	0.3648	-0.7245