Fig 9

```
r = 1;
a = 0.09;
Omega = 50;
alpha = 2;
delta = 0.04;
f = 0.02;
K0 = 1;


B0 = 0.1;
I0 = 0.1;
P0 = 10;


tspan_total = [0 5000];
t_burn = 3000;


A_vec = 0:0.002:1;

bif_data = [];

% ODE
options = odeset('NonNegative', [1,2,3], 'RelTol', 1e-12, 'MaxStep', 0.1);


y0 = [B0; I0; P0];


for i = 1:length(A_vec)
    A = A_vec(i);
    fprintf('Running simulation for A = %.3f (%d/%d)\n', A, i, length(A_vec));


    [t, y] = ode15s(@(t,y) fluctuate_1B_nothre(t, y, A, f, r, K0, a, Omega, alpha, delta), tspa

    idx_steady = t > t_burn;
    t_steady = t(idx_steady);
    B_steady = y(idx_steady, 1) * 1e8;
    I_steady = y(idx_steady, 2) * 1e8;
    P_steady = y(idx_steady, 3) * 1e8;

    %Calculate the average value during the steady-state phase to use as the initial condition
    if ~isempty(B_steady)
        B0_next = mean(y(idx_steady, 1));
        I0_next = mean(y(idx_steady, 2));
        P0_next = mean(y(idx_steady, 3));
        y0 = [B0_next; I0_next; P0_next];
```

```
    else
        fprintf('Warning: No steady state data for A = %.3f\n', A);
    end


    if length(B_steady) < 3
        continue;
    end

    [troughs, ~] = findpeaks(-B_steady);
    troughs = -troughs;

    if ~isempty(troughs)
        for j = 1:length(troughs)
            bif_data(end+1, :) = [A, troughs(j)];
        end
    else
        bif_data(end+1, :) = [A, NaN];
    end
end
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Running simulation for A = 0.988 (495/501)
Running simulation for A = 0.990 (496/501)
Running simulation for A = 0.992 (497/501)
Running simulation for A = 0.994 (498/501)
Running simulation for A = 0.996 (499/501)
Running simulation for A = 0.998 (500/501)
Running simulation for A = 1.000 (501/501)
```
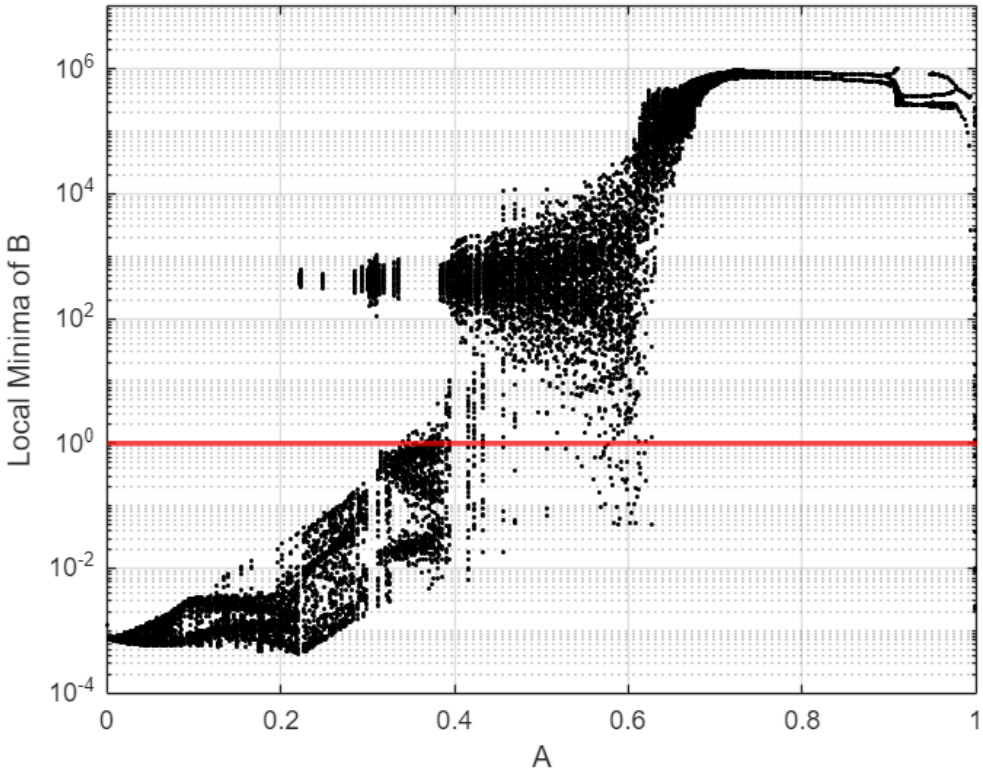

```
%Visualization
figure;
hold on;
plot(bif_data(:,1), bif_data(:,2), 'k.', 'MarkerSize', 5);
set(gca,'Yscale','log');
xlabel('A');
ylabel('Local Minima of B');
xlim([min(A_vec), 1]);
ylim([10^-4,10^7]);
yline(1, 'r-', 'LineWidth', 2, 'Color', 'red');
grid on;
box on;
hold off;
```



```
clear;
r = 1;
a = 0.09;
Omega = 50;
alpha = 2;
delta = 0.04;
A = 0.2;
K0 = 1;


B0 = 0.1;
I0 = 0.1;
P0 = 10;

y0 = [B0; I0; P0];

tspan_total = [0 5000];
t_burn = 3000;




bif_data = [];

% ODE
options = odeset('NonNegative', [1,2,3], 'RelTol', 1e-12, 'MaxStep', 0.1);
[t, y] = ode15s(@(t,y) fluctuate_1B_nothre(t, y, 0, 0, r, K0, a, Omega, alpha, delta), tspan_to
f0=PSD_max(y, t,tspan_total(2));

f_vec = logspace(log10(f0/1.5),log10(f0*5),500);



for i = 1:length(f_vec)
    f = f_vec(i);
    fprintf('Running simulation for f = %.5f (%d/%d)\n', f, i, length(f_vec));


    [t, y] = ode15s(@(t,y) fluctuate_1B_nothre(t, y, A, f, r, K0, a, Omega, alpha, delta), tspa


    idx_steady = t > t_burn;
    t_steady = t(idx_steady);
    B_steady = y(idx_steady, 1) * 1e8;


    if length(B_steady) < 3
        continue;
```

```
    end


    [troughs, ~] = findpeaks(-B_steady);
    troughs = -troughs;


    if ~isempty(troughs)
        for j = 1:length(troughs)
            bif_data(end+1, :) = [f, troughs(j)];
        end
    else
        bif_data(end+1, :) = [f, NaN];
    end
end
```

```
Running simulation for f = 0.00886 (1/500)
Running simulation for f = 0.00889 (2/500)
Running simulation for f = 0.00893 (3/500)
Running simulation for f = 0.00896 (4/500)
Running simulation for f = 0.00900 (5/500)
Running simulation for f = 0.00904 (6/500)
Running simulation for f = 0.00907 (7/500)
Running simulation for f = 0.00911 (8/500)
Running simulation for f = 0.00915 (9/500)
Running simulation for f = 0.00918 (10/500)
Running simulation for f = 0.00922 (11/500)
Running simulation for f = 0.00926 (12/500)
Running simulation for f = 0.00930 (13/500)
Running simulation for f = 0.00933 (14/500)
Running simulation for f = 0.00937 (15/500)
Running simulation for f = 0.00941 (16/500)
Running simulation for f = 0.00945 (17/500)
Running simulation for f = 0.00949 (18/500)
Running simulation for f = 0.00952 (19/500)
Running simulation for f = 0.00956 (20/500)
Running simulation for f = 0.00960 (21/500)
Running simulation for f = 0.00964 (22/500)
Running simulation for f = 0.00968 (23/500)
Running simulation for f = 0.00972 (24/500)
Running simulation for f = 0.00976 (25/500)
Running simulation for f = 0.00980 (26/500)
Running simulation for f = 0.00984 (27/500)
Running simulation for f = 0.00988 (28/500)
Running simulation for f = 0.00992 (29/500)
Running simulation for f = 0.00996 (30/500)
Running simulation for f = 0.01000 (31/500)
Running simulation for f = 0.01004 (32/500)
Running simulation for f = 0.01008 (33/500)
Running simulation for f = 0.01012 (34/500)
Running simulation for f = 0.01016 (35/500)
Running simulation for f = 0.01020 (36/500)
Running simulation for f = 0.01024 (37/500)
Running simulation for f = 0.01028 (38/500)
Running simulation for f = 0.01033 (39/500)
Running simulation for f = 0.01037 (40/500)
Running simulation for f = 0.01041 (41/500)
Running simulation for f = 0.01045 (42/500)
Running simulation for f = 0.01049 (43/500)
Running simulation for f = 0.01054 (44/500)
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Running simulation for f = 0.01058 (45/500)
Running simulation for f = 0.01062 (46/500)
Running simulation for f = 0.01066 (47/500)
Running simulation for f = 0.01071 (48/500)
Running simulation for f = 0.01075 (49/500)
Running simulation for f = 0.01079 (50/500)
Running simulation for f = 0.01084 (51/500)
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Running simulation for f = 0.01097 (54/500)
Running simulation for f = 0.01101 (55/500)
Running simulation for f = 0.01106 (56/500)
Running simulation for f = 0.01110 (57/500)
Running simulation for f = 0.01115 (58/500)
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Running simulation for f = 0.01129 (61/500)
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Running simulation for f = 0.01170 (70/500)
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Running simulation for f = 0.01370 (109/500)
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Running simulation for f = 0.02974 (301/500)
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Running simulation for f = 0.03851 (365/500)
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Running simulation for f = 0.04508 (404/500)
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Running simulation for f = 0.04987 (429/500)
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Running simulation for f = 0.05341 (446/500)
Running simulation for f = 0.05363 (447/500)
Running simulation for f = 0.05385 (448/500)
Running simulation for f = 0.05406 (449/500)
Running simulation for f = 0.05428 (450/500)
Running simulation for f = 0.05450 (451/500)
Running simulation for f = 0.05472 (452/500)
Running simulation for f = 0.05494 (453/500)
Running simulation for f = 0.05517 (454/500)
Running simulation for f = 0.05539 (455/500)
Running simulation for f = 0.05561 (456/500)
Running simulation for f = 0.05584 (457/500)
Running simulation for f = 0.05607 (458/500)
Running simulation for f = 0.05629 (459/500)
Running simulation for f = 0.05652 (460/500)
Running simulation for f = 0.05675 (461/500)
Running simulation for f = 0.05698 (462/500)
Running simulation for f = 0.05721 (463/500)
Running simulation for f = 0.05744 (464/500)
Running simulation for f = 0.05767 (465/500)
Running simulation for f = 0.05791 (466/500)
Running simulation for f = 0.05814 (467/500)
Running simulation for f = 0.05838 (468/500)
Running simulation for f = 0.05861 (469/500)
Running simulation for f = 0.05885 (470/500)
Running simulation for f = 0.05909 (471/500)
Running simulation for f = 0.05933 (472/500)
Running simulation for f = 0.05957 (473/500)
Running simulation for f = 0.05981 (474/500)
Running simulation for f = 0.06005 (475/500)
Running simulation for f = 0.06029 (476/500)
Running simulation for f = 0.06054 (477/500)
Running simulation for f = 0.06078 (478/500)
Running simulation for f = 0.06103 (479/500)
Running simulation for f = 0.06127 (480/500)
Running simulation for f = 0.06152 (481/500)
Running simulation for f = 0.06177 (482/500)
Running simulation for f = 0.06202 (483/500)
Running simulation for f = 0.06227 (484/500)
Running simulation for f = 0.06252 (485/500)
Running simulation for f = 0.06278 (486/500)
Running simulation for f = 0.06303 (487/500)
Running simulation for f = 0.06329 (488/500)
Running simulation for f = 0.06354 (489/500)
Running simulation for f = 0.06380 (490/500)
Running simulation for f = 0.06406 (491/500)
Running simulation for f = 0.06432 (492/500)
```

```
Running simulation for f = 0.06458 (493/500)
Running simulation for f = 0.06484 (494/500)
Running simulation for f = 0.06510 (495/500)
Running simulation for f = 0.06536 (496/500)
Running simulation for f = 0.06563 (497/500)
Running simulation for f = 0.06589 (498/500)
Running simulation for f = 0.06616 (499/500)
Running simulation for f = 0.06643 (500/500)
```

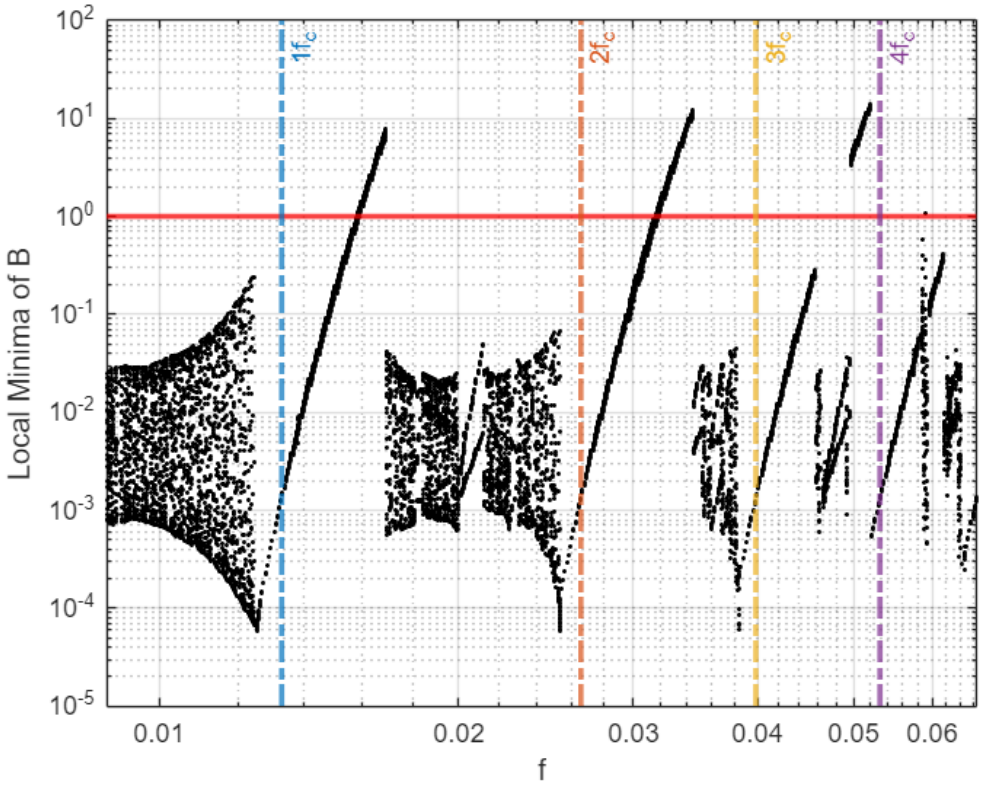
```
%Visualization
figure;
hold on;


plot(bif_data(:,1), bif_data(:,2), 'k.', 'MarkerSize', 5);


set(gca, 'YScale', 'log', 'XScale', 'log');
xlabel('f');
ylabel('Local Minima of B');
xlim([min(f_vec), max(f_vec)]);
grid on;

n_list = [1, 2, 3, 4];
colors = lines(5);

yline(1, 'r-', 'LineWidth', 2, 'Color', 'red');
for n = n_list
    x2 = n * f0;
    if x2 >= min(f_vec) && x2 <= max(f_vec)
        xline(x2, '-.', sprintf('%df_c', n), 'Color', colors(n,:), 'LineWidth', 2);
    end
end
box on;
hold off;
```




```
clear;
r = 1;
a = 0.09;
Omega = 50;
alpha = 2;
delta = 0.04;
K0 = 1;


B0 = 0.1;
I0 = 0.1;
P0 = 10;
y0 = [B0; I0; P0];


tspan_total = [0 5000];
t_burn = 3000;

% ODE

options = odeset('NonNegative', [1,2,3], 'RelTol', 1e-12, 'MaxStep', 0.1);
[t, y] = ode15s(@(t,y) fluctuate_1B_nothre(t, y, 0, 0, r, K0, a, Omega, alpha, delta), tspan_to
f0=PSD_max(y, t,tspan_total(2));
```

```
A_vec = 0:0.01:1;
f_vec = logspace(log10(f0/1.5), log10(f0*5), 100);


minB_matrix = zeros(length(A_vec), length(f_vec));


for i = 1:length(A_vec)
    A = A_vec(i);
    fprintf('Running simulations for A = %.4f (%d/%d)\n', A, i, length(A_vec));

    parfor j = 1:length(f_vec)
        f = f_vec(j);


        [t, y] = ode15s(@(t,y) fluctuate_1B_nothre(t, y, A, f, r, K0, a, Omega, alpha, delta),
                        tspan_total, y0, options);


        idx_steady = t > t_burn;
        B_steady = y(idx_steady, 1)*10^8;


        if ~isempty(B_steady) && all(isfinite(B_steady))
            minB_matrix(i, j) = min(B_steady);
        else
            minB_matrix(i, j) = NaN;
        end
    end
end
```

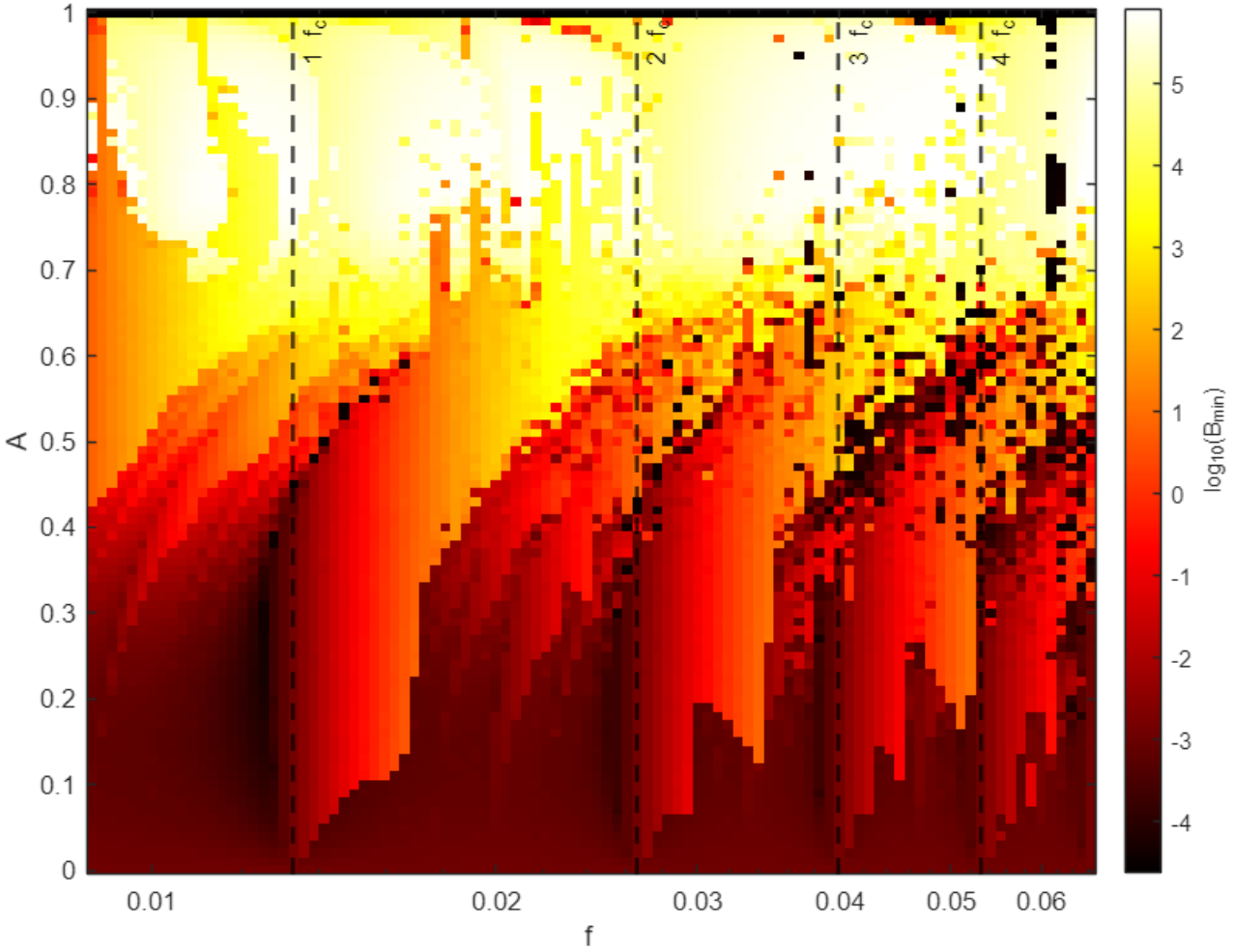
```
Running simulations for A = 0.0000 (1/101)
Starting parallel pool (parpool) using the 'local' profile ...
Connected to the parallel pool (number of workers: 8).
Running simulations for A = 0.0100 (2/101)
Running simulations for A = 0.0200 (3/101)
Running simulations for A = 0.0300 (4/101)
Running simulations for A = 0.0400 (5/101)
Running simulations for A = 0.0500 (6/101)
Running simulations for A = 0.0600 (7/101)
Running simulations for A = 0.0700 (8/101)
Running simulations for A = 0.0800 (9/101)
Running simulations for A = 0.0900 (10/101)
Running simulations for A = 0.1000 (11/101)
Running simulations for A = 0.1100 (12/101)
Running simulations for A = 0.1200 (13/101)
Running simulations for A = 0.1300 (14/101)
Running simulations for A = 0.1400 (15/101)
Running simulations for A = 0.1500 (16/101)
Running simulations for A = 0.1600 (17/101)
Running simulations for A = 0.1700 (18/101)
Running simulations for A = 0.1800 (19/101)
Running simulations for A = 0.1900 (20/101)
Running simulations for A = 0.2000 (21/101)
Running simulations for A = 0.2100 (22/101)
Running simulations for A = 0.2200 (23/101)
```

```
Running simulations for A = 0.2300 (24/101)
Running simulations for A = 0.2400 (25/101)
Running simulations for A = 0.2500 (26/101)
Running simulations for A = 0.2600 (27/101)
Running simulations for A = 0.2700 (28/101)
Running simulations for A = 0.2800 (29/101)
Running simulations for A = 0.2900 (30/101)
Running simulations for A = 0.3000 (31/101)
Running simulations for A = 0.3100 (32/101)
Running simulations for A = 0.3200 (33/101)
Running simulations for A = 0.3300 (34/101)
Running simulations for A = 0.3400 (35/101)
Running simulations for A = 0.3500 (36/101)
Running simulations for A = 0.3600 (37/101)
Running simulations for A = 0.3700 (38/101)
Running simulations for A = 0.3800 (39/101)
Running simulations for A = 0.3900 (40/101)
Running simulations for A = 0.4000 (41/101)
Running simulations for A = 0.4100 (42/101)
Running simulations for A = 0.4200 (43/101)
Running simulations for A = 0.4300 (44/101)
Running simulations for A = 0.4400 (45/101)
Running simulations for A = 0.4500 (46/101)
Running simulations for A = 0.4600 (47/101)
Running simulations for A = 0.4700 (48/101)
Running simulations for A = 0.4800 (49/101)
Running simulations for A = 0.4900 (50/101)
Running simulations for A = 0.5000 (51/101)
Running simulations for A = 0.5100 (52/101)
Running simulations for A = 0.5200 (53/101)
Running simulations for A = 0.5300 (54/101)
Running simulations for A = 0.5400 (55/101)
Running simulations for A = 0.5500 (56/101)
Running simulations for A = 0.5600 (57/101)
Running simulations for A = 0.5700 (58/101)
Running simulations for A = 0.5800 (59/101)
Running simulations for A = 0.5900 (60/101)
Running simulations for A = 0.6000 (61/101)
Running simulations for A = 0.6100 (62/101)
Running simulations for A = 0.6200 (63/101)
Running simulations for A = 0.6300 (64/101)
Running simulations for A = 0.6400 (65/101)
Running simulations for A = 0.6500 (66/101)
Running simulations for A = 0.6600 (67/101)
Running simulations for A = 0.6700 (68/101)
Running simulations for A = 0.6800 (69/101)
Running simulations for A = 0.6900 (70/101)
Running simulations for A = 0.7000 (71/101)
Running simulations for A = 0.7100 (72/101)
Running simulations for A = 0.7200 (73/101)
Running simulations for A = 0.7300 (74/101)
Running simulations for A = 0.7400 (75/101)
Running simulations for A = 0.7500 (76/101)
Running simulations for A = 0.7600 (77/101)
Running simulations for A = 0.7700 (78/101)
Running simulations for A = 0.7800 (79/101)
Running simulations for A = 0.7900 (80/101)
Running simulations for A = 0.8000 (81/101)
Running simulations for A = 0.8100 (82/101)
Running simulations for A = 0.8200 (83/101)
Running simulations for A = 0.8300 (84/101)
Running simulations for A = 0.8400 (85/101)
Running simulations for A = 0.8500 (86/101)
Running simulations for A = 0.8600 (87/101)
```

```
Running simulations for A = 0.8700 (88/101)
Running simulations for A = 0.8800 (89/101)
Running simulations for A = 0.8900 (90/101)
Running simulations for A = 0.9000 (91/101)
Running simulations for A = 0.9100 (92/101)
Running simulations for A = 0.9200 (93/101)
Running simulations for A = 0.9300 (94/101)
Running simulations for A = 0.9400 (95/101)
Running simulations for A = 0.9500 (96/101)
Running simulations for A = 0.9600 (97/101)
Running simulations for A = 0.9700 (98/101)
Running simulations for A = 0.9800 (99/101)
Running simulations for A = 0.9900 (100/101)
Running simulations for A = 1.0000 (101/101)
```

```
% Visualization
figure;
set(gcf, 'Position', [100, 100, 800, 600]);
imagesc(f_vec, A_vec, log10(minB_matrix));
colormap hot;
axis xy;
colorbar;
hcb = colorbar;
hcb.Label.String = 'log_{10}(B_{min})';
xlabel('f');
ylabel('A');
set(gca, 'XScale', 'log');
ylabel('A');
xlabel('f ');

hold on;
n_list = [1, 2, 3, 4];
colors = lines(4);
for n = n_list
    f_n = n * f0;
    if f_n >= min(f_vec) && f_n <= max(f_vec)
        xline(f_n, 'k--', sprintf('%d f_c', n), 'LineWidth', 1.5);
    end
end
box on;
axis tight;
hold off;
```


1 fc
2 fc
3 fc
4 fc
A
f
log10(Bmin)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.01
0.02
0.03
0.04
0.05
0.06
5
4
3
2
1
0
-1
-2
-3
-4