GoogleMatrix

October 1, 2021

```python
[126]: import time
       from matplotlib import pyplot as plt
       import numpy as np
       from einops import repeat
```

```python
[106]: def A_matrix(size = 5000, ratio = 0.5):
           A = np.random.rand(size, size)
           return (A < ratio).astype(int)

       def a_vector(A):
           a = np.sum(A, axis = 0)
           return (a == 0).astype(int)

       def H_matrix(A):
           H = A / repeat(np.sum(A, axis = 0) + a_vector(A), 'n -> m n', m = np.
        ↪shape(A)[0])
           return H

       def S_matrix(H, a):
           a = repeat(a, 'n -> m n', m = np.shape(a)[0])
           S = H + a / np.shape(a)[0]
           return S

       def G_matrix(S, alpha = 0.85):
           G = alpha * S + (1 - alpha) * np.ones(np.shape(S)) / np.shape(S)[0]
           return G
```

```python
[125]: time_start = time.time ()

       A = A_matrix(size = 5000, ratio = 0.2)
       a = a_vector(A)
       H = H_matrix(A)
       S = S_matrix(H, a)
       G = G_matrix(S)
       w, v = np.linalg.eig(G)

       time_end = time.time ()
```
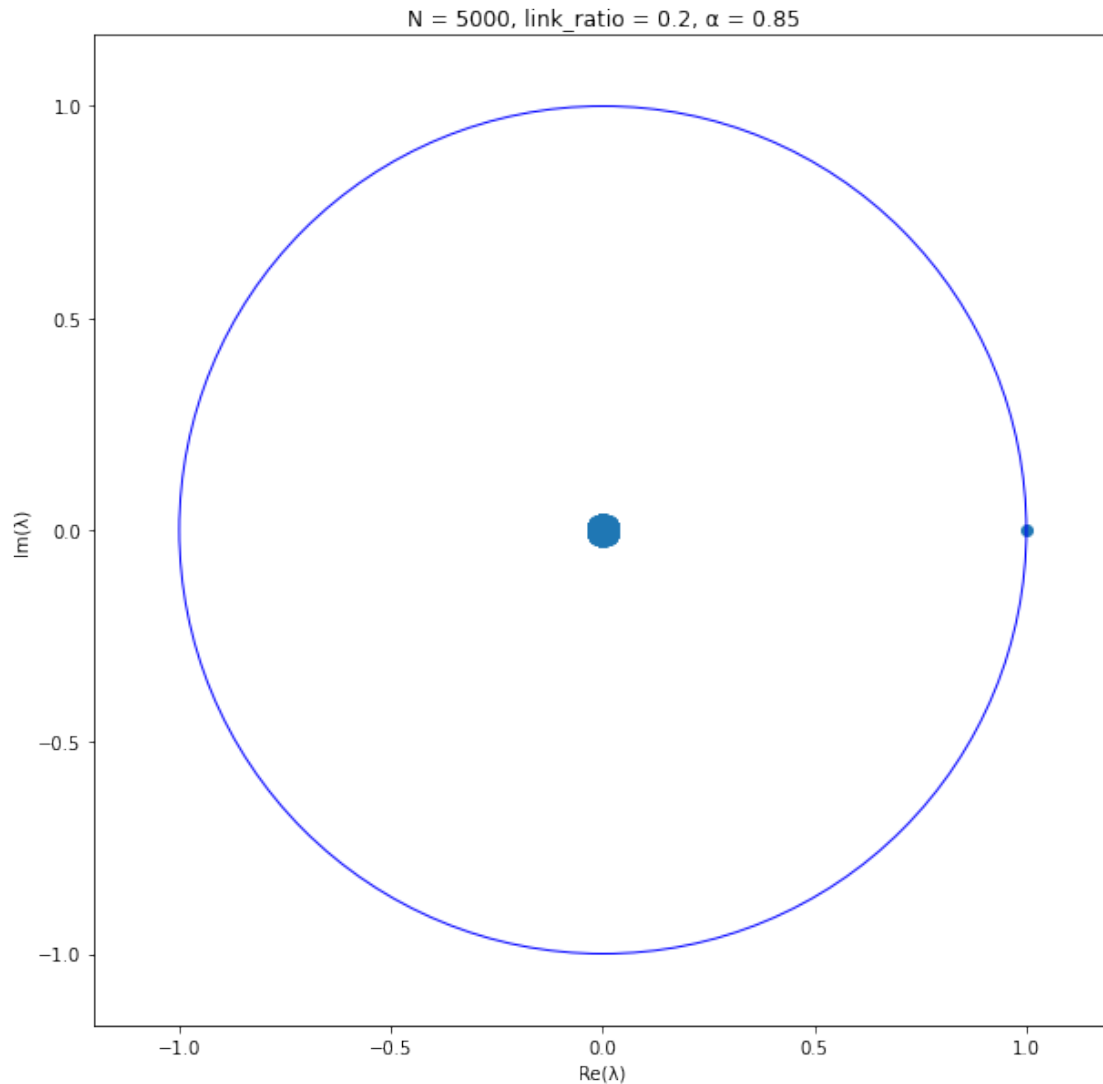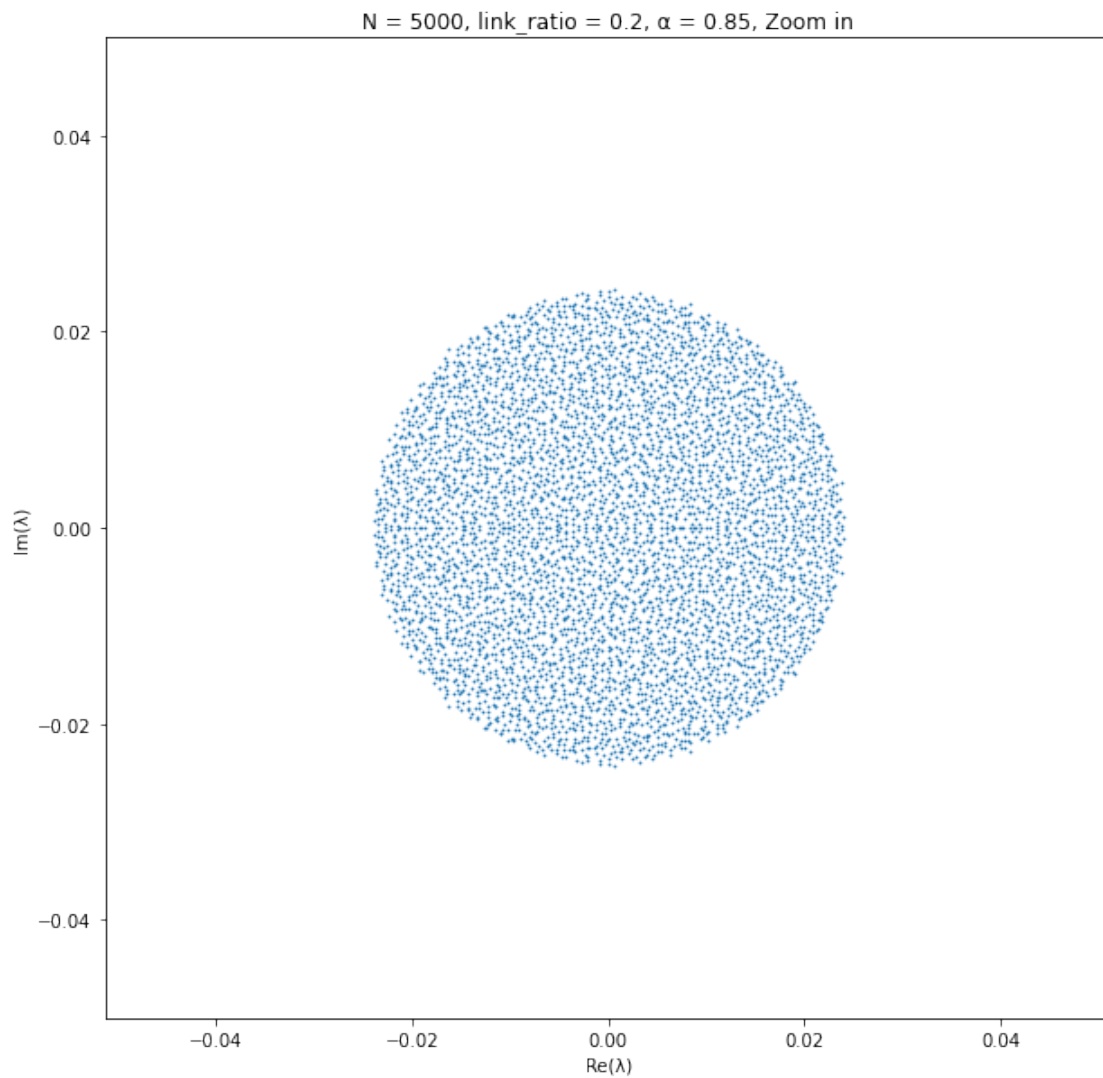
```
print('time elapsed: %.2f s'%(time_end-time_start))
```

time elapsed: 83.29 s

[166]:
```
plt.figure(figsize = (10, 10))
C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
ax = plt.gca()
ax.add_artist(C)
plt.axis('equal')
plt.xlim(-1.2, 1.2)
plt.ylim(-1.2, 1.2)
plt.scatter(np.real(w), np.imag(w))
plt.xlabel('Re( )')
plt.ylabel('Im( )')
plt.title('N = 5000, link_ratio = 0.2,   = 0.85')
plt.show()
```


N = 5000, link_ratio = 0.2, α = 0.85

```
[167]: plt.figure(figsize = (10, 10))
       C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
       ax = plt.gca()
       ax.add_artist(C)
       plt.axis('equal')
       plt.xlim(-0.05, 0.05)
       plt.ylim(-0.05, 0.05)
       plt.scatter(np.real(w), np.imag(w), s = 2, marker = '.')
       plt.xlabel('Re( )')
       plt.ylabel('Im( )')
       plt.title('N = 5000, link_ratio = 0.2,   = 0.85, Zoom in')
       plt.show()
```

N = 5000, link_ratio = 0.2, α = 0.85, Zoom in
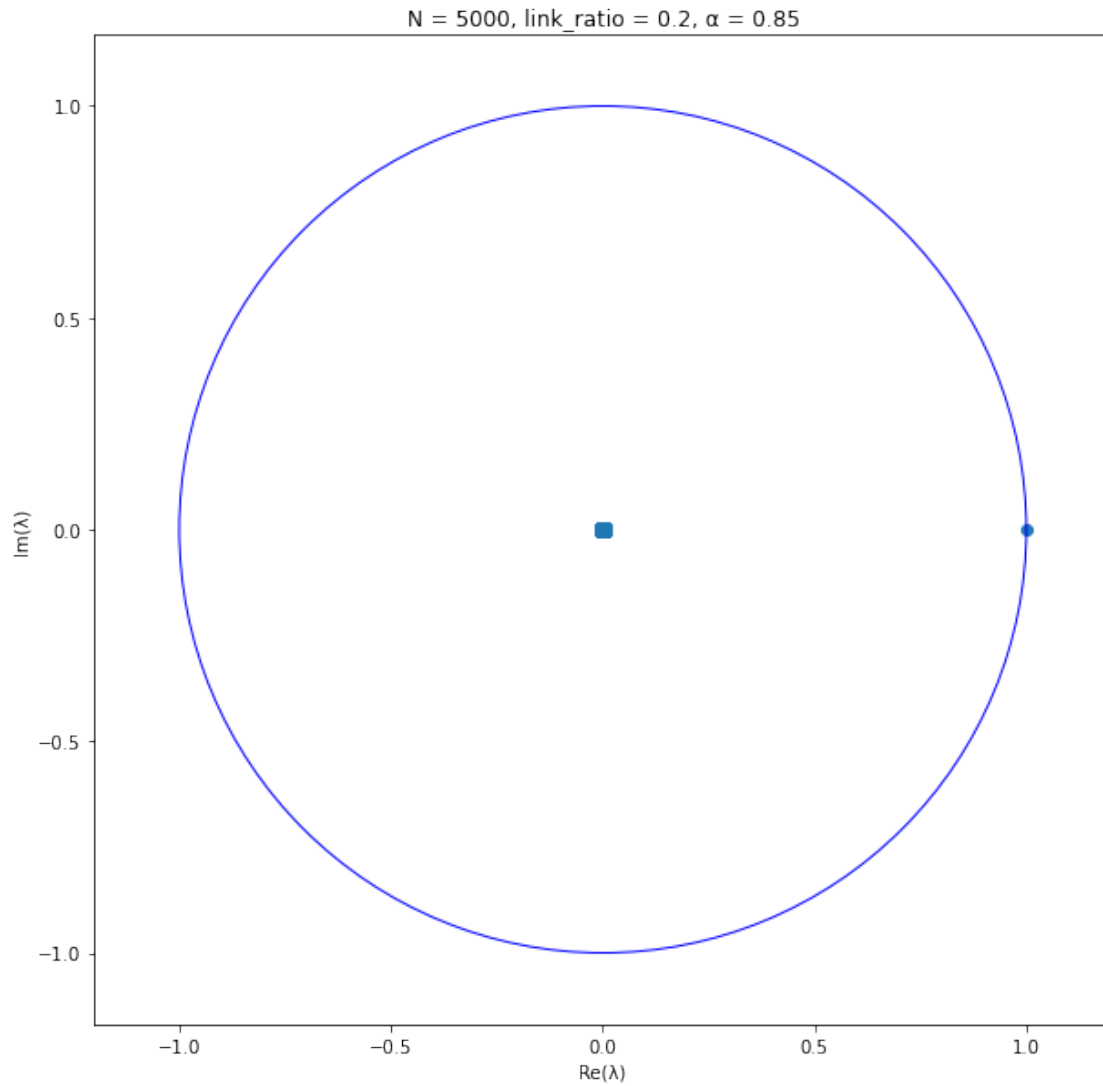
```
[168]: time_start = time.time ()

       A = A_matrix(size = 5000, ratio = 0.8)
       a = a_vector(A)
       H = H_matrix(A)
       S = S_matrix(H, a)
       G = G_matrix(S)
       w, v = np.linalg.eig(G)

       time_end = time.time ()
       print('time elapsed: %.2f s'%(time_end-time_start))
```
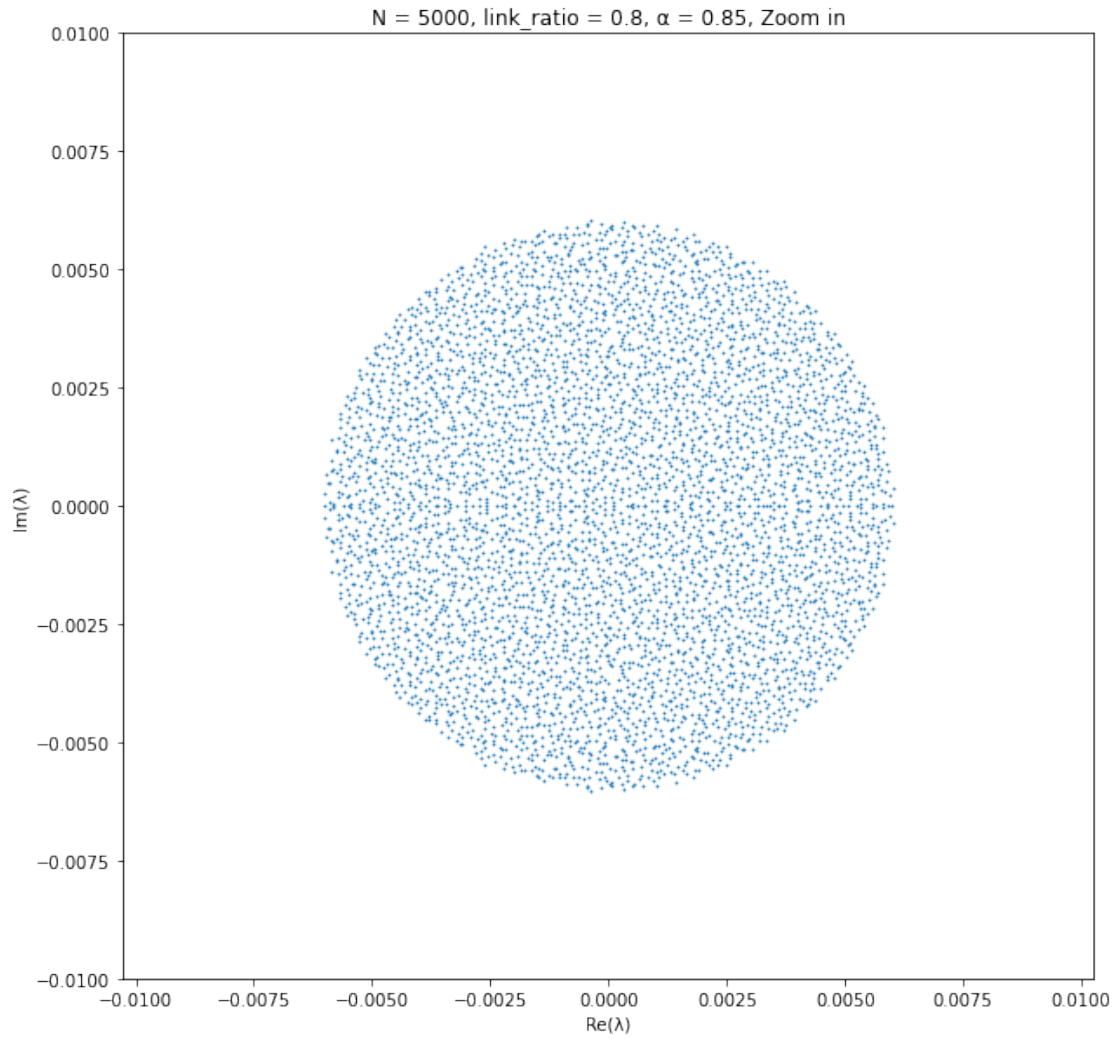
time elapsed: 73.42 s

```
[169]: plt.figure(figsize = (10, 10))
       C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
       ax = plt.gca()
       ax.add_artist(C)
       plt.axis('equal')
       plt.xlim(-1.2, 1.2)
       plt.ylim(-1.2, 1.2)
       plt.scatter(np.real(w), np.imag(w))
       plt.xlabel('Re( )')
       plt.ylabel('Im( )')
       plt.title('N = 5000, link_ratio = 0.8,   = 0.85')
       plt.show()
```

N = 5000, link_ratio = 0.2, α = 0.85

```
[175]: plt.figure(figsize = (10, 10))
       C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
       ax = plt.gca()
       ax.add_artist(C)
       plt.axis('equal')
       plt.xlim(-0.01, 0.01)
       plt.ylim(-0.01, 0.01)
       plt.scatter(np.real(w), np.imag(w), s = 2, marker = '.')
       plt.xlabel('Re( )')
       plt.ylabel('Im( )')
       plt.title('N = 5000, link_ratio = 0.8,   = 0.85, Zoom in')
       plt.show()
```
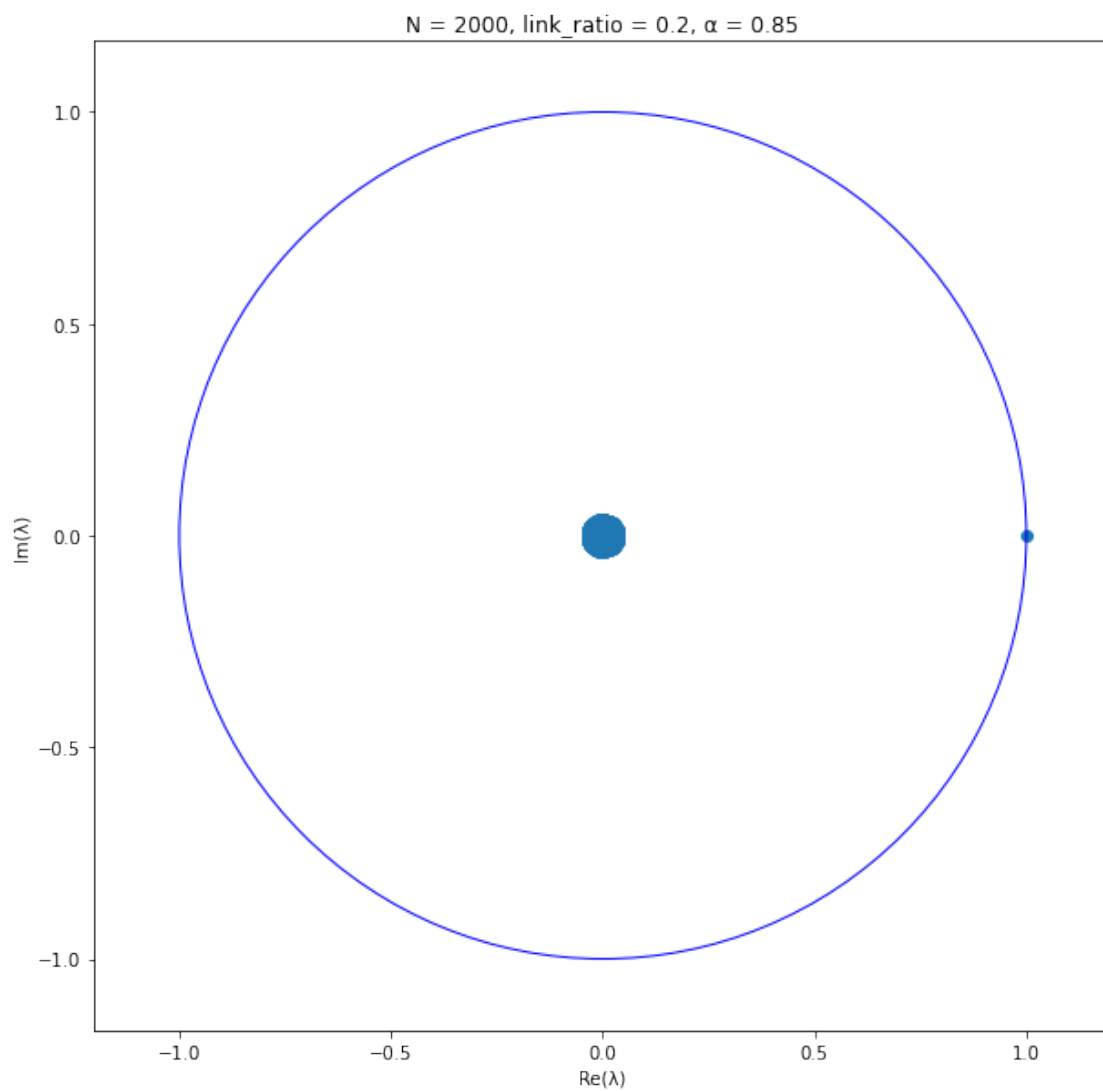
N = 5000, link_ratio = 0.8, α = 0.85, Zoom in

[176]:
```
time_start = time.time ()

A = A_matrix(size = 2000, ratio = 0.2)
a = a_vector(A)
H = H_matrix(A)
S = S_matrix(H, a)
G = G_matrix(S)
w, v = np.linalg.eig(G)

time_end = time.time ()
print('time elapsed: %.2f s'%(time_end-time_start))
```
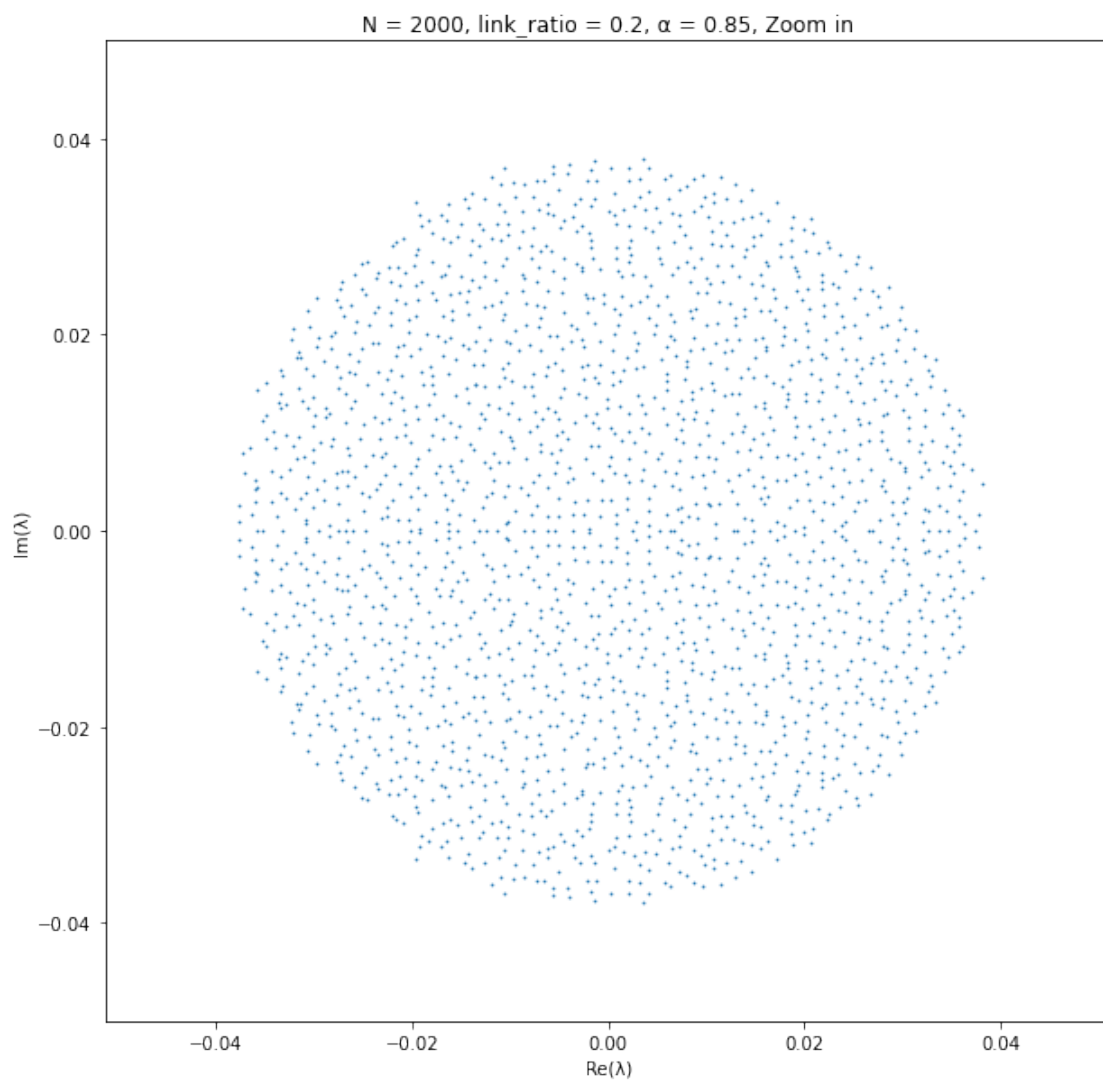
time elapsed: 9.10 s

```
[177]: plt.figure(figsize = (10, 10))
       C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
       ax = plt.gca()
       ax.add_artist(C)
       plt.axis('equal')
       plt.xlim(-1.2, 1.2)
       plt.ylim(-1.2, 1.2)
       plt.scatter(np.real(w), np.imag(w))
       plt.xlabel('Re( )')
       plt.ylabel('Im( )')
       plt.title('N = 2000, link_ratio = 0.2,   = 0.85')
       plt.show()
```


N = 2000, link_ratio = 0.2, α = 0.85

```
[179]: plt.figure(figsize = (10, 10))
       C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
       ax = plt.gca()
       ax.add_artist(C)
       plt.axis('equal')
       plt.xlim(-0.05, 0.05)
       plt.ylim(-0.05, 0.05)
       plt.scatter(np.real(w), np.imag(w), s = 2, marker = '.')
       plt.xlabel('Re( )')
       plt.ylabel('Im( )')
       plt.title('N = 2000, link_ratio = 0.2,   = 0.85, Zoom in')
       plt.show()
```


N = 2000, link_ratio = 0.2, α = 0.85, Zoom in

```
[180]: time_start = time.time ()

       A = A_matrix(size = 5000, ratio = 0.2)
       a = a_vector(A)
       H = H_matrix(A)
       S = S_matrix(H, a)
       G = G_matrix(S, alpha = 0.2)
       w, v = np.linalg.eig(G)

       time_end = time.time ()
       print('time elapsed: %.2f s'%(time_end-time_start))
```
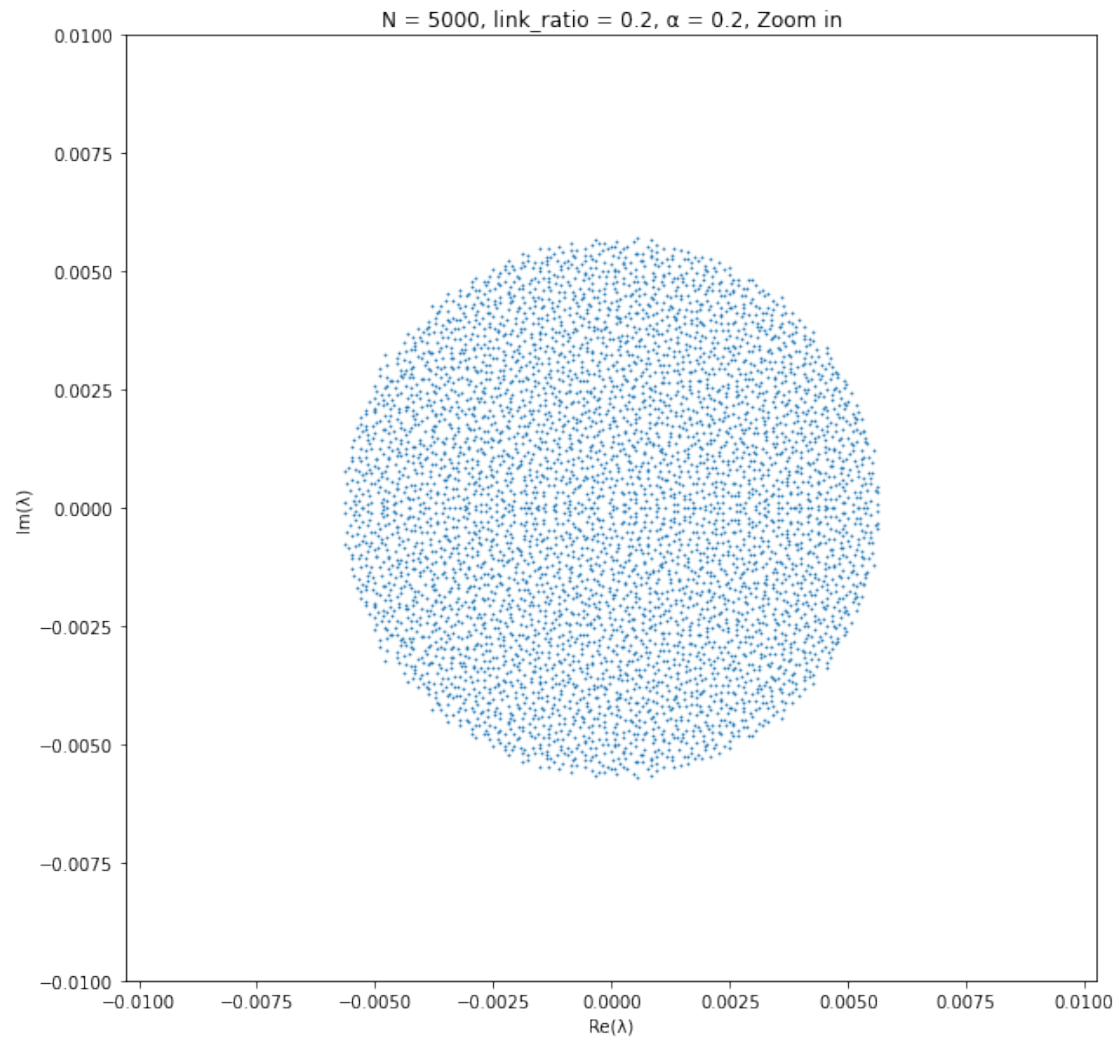
time elapsed: 82.14 s

```
[185]: plt.figure(figsize = (10, 10))
       C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
       ax = plt.gca()
       ax.add_artist(C)
       plt.axis('equal')
       plt.xlim(-1.2, 1.2)
       plt.ylim(-1.2, 1.2)
       plt.scatter(np.real(w), np.imag(w))
       plt.xlabel('Re( )')
       plt.ylabel('Im( )')
       plt.title('N = 5000, link_ratio = 0.2,   = 0.2')
       plt.show()
```
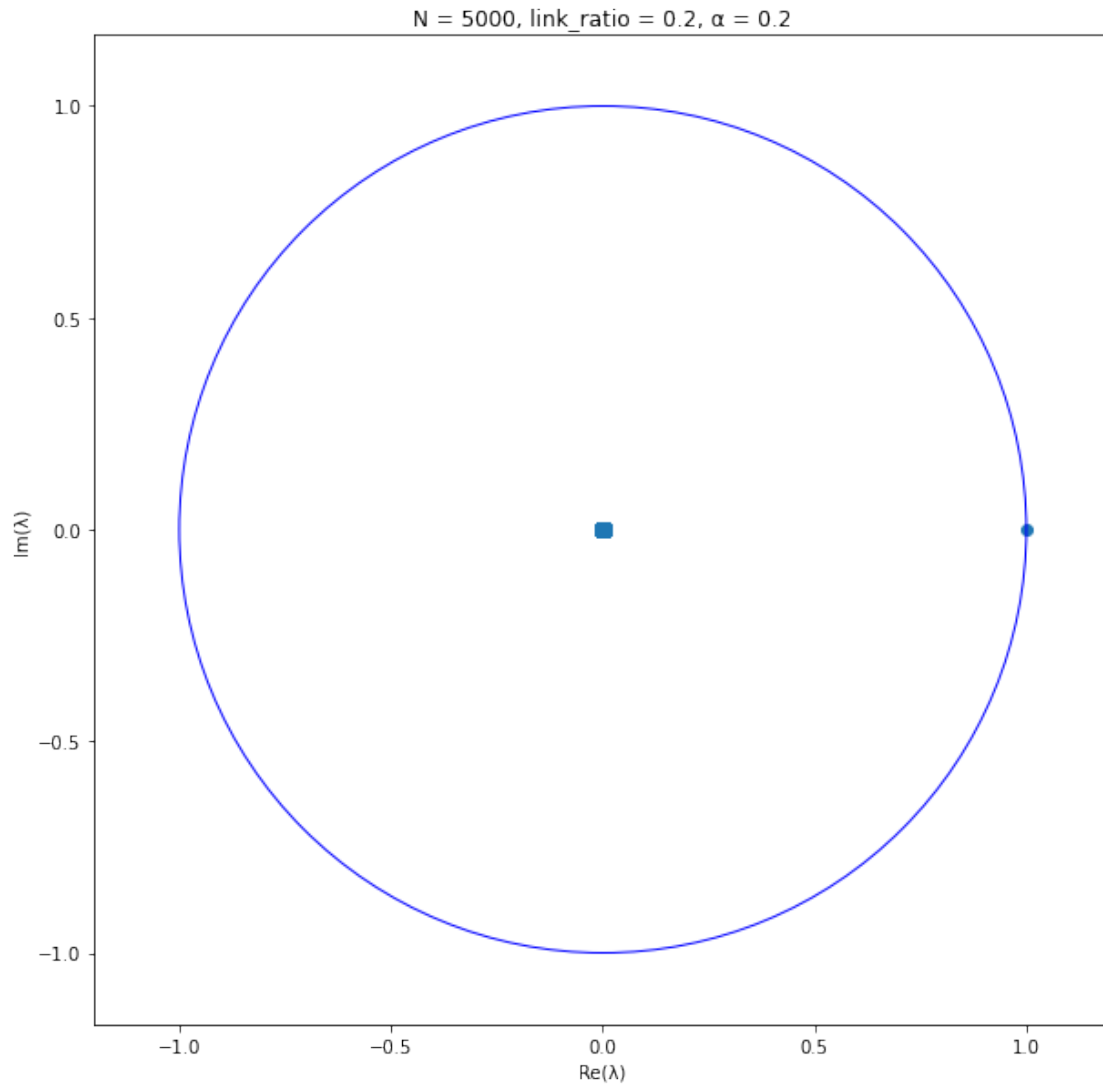
N = 5000, link_ratio = 0.2, α = 0.2

```
plt.figure(figsize = (10, 10))
C = plt.Circle((0,0), 1, edgecolor = 'b',facecolor  = 'None' )
ax = plt.gca()
ax.add_artist(C)
plt.axis('equal')
plt.xlim(-0.01, 0.01)
plt.ylim(-0.01, 0.01)
plt.scatter(np.real(w), np.imag(w), s = 2, marker = '.')
plt.xlabel('Re( )')
plt.ylabel('Im( )')
plt.title('N = 5000, link_ratio = 0.2,   = 0.2, Zoom in')
plt.show()
```

N = 5000, link_ratio = 0.2, α = 0.2, Zoom in

[ ]: