Gleria02

January 3, 2023

[72]:
```python
from IPython.display import display, HTML
display(HTML("<style>.container { width:100% !important; }</style>"))
```

```
<IPython.core.display.HTML object>
```

[73]:
```python
from sortedcontainers import SortedList
from random import random
import matplotlib.pyplot as plt
from matplotlib import colors
from math import pow, log
import time
import sys
from IPython.display import display, clear_output
```

A recreation of the mode in:

Galera, E., Guilherme Roncaratti Galanti, and Osame Kinouchi. "Invasion percolation solves Fermi Paradox but challenges SETI projects." International Journal of Astrobiology 18.4 (2019): 316-322.

"The simulations are done in a square lattice with edge L = 100 that will represent a portion of the Galaxy (the relation with true astro- nomical size is discussed later). Our model is two-dimensional because to consider the thickness of the Galaxy will not change the main conclusions. Each site (i, j), i = 1, …, L; j = 1, …, L has a habitability barrier Eij [0, 1], which is an uniform random number generated and fixed from the start of the simulation (quenched disorder). This number intends to represent how hard it is to find a habitable planet in the unitary square with coordinates (i, j): the lower Eij, the easier to colonize that region. We discuss other choices for P(Eij) later. Each site represents an area of D $\times$ D ly2 and can have two states: Sij = 0 (unoccupied) and Sij = 1 (colonized). We start with a single occupied site (the seed) at the centre of the lattice that represents a single mother civilization. Then, at the next time step, this civilization tries to colonize all its four nearest neighbours with indexes k = i $\pm$ 1, l = j $\pm$ 1 with probability P(Skl = 1) = p(E) = exp(− Ekl)."

[74]:
```python
def grow(t,x,y,event_stack,beta):
    def add_event(x1,y1):
        event_stack.add([t+pow(space[x1][y1],beta),x1,y1])

    # stop when edge reached
    if colonies[x][y]<0:
        return False
```

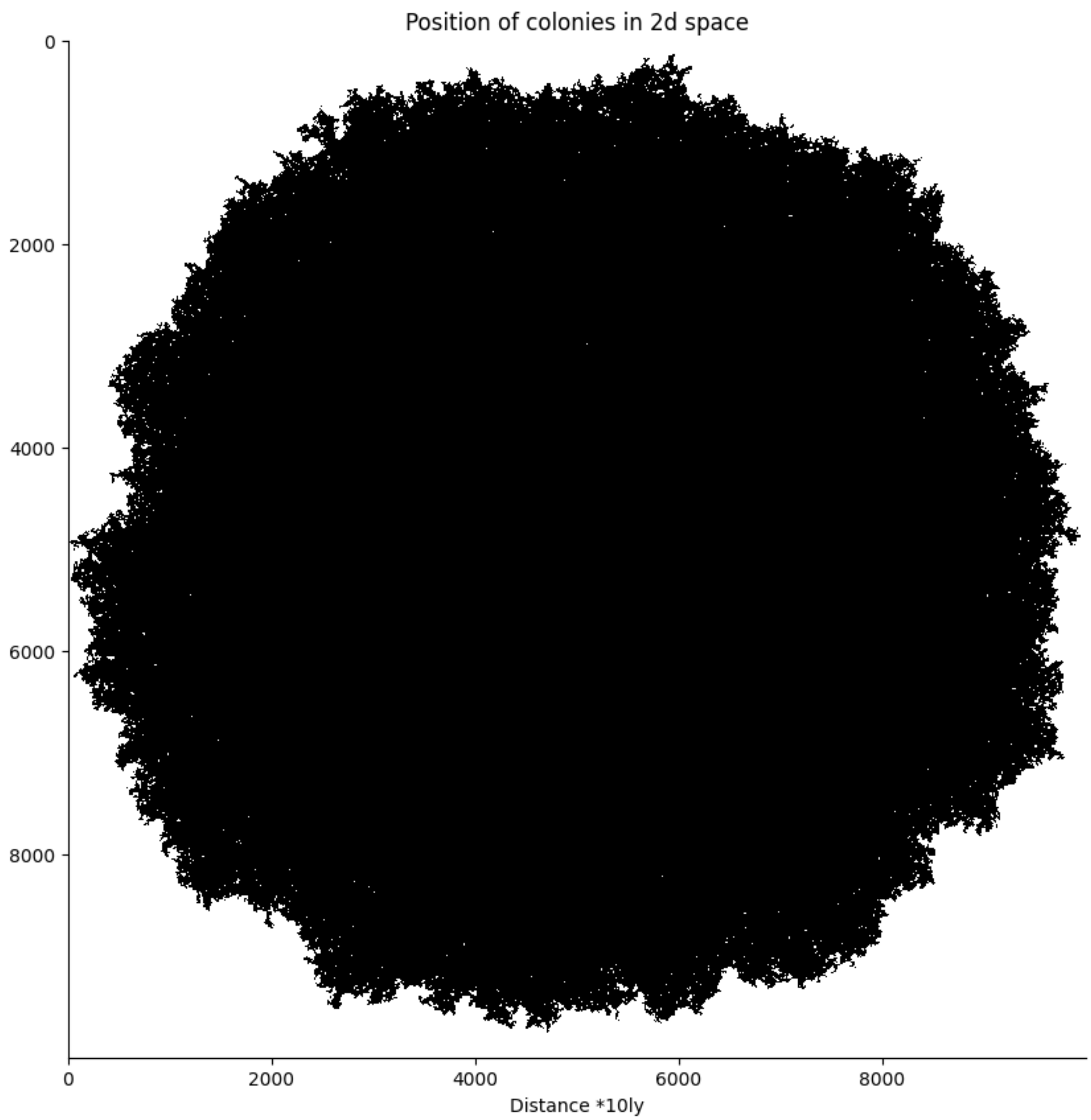
```python
    if colonies[x][y]==0:
        # if empty set to colinised
        colonies[x][y]=1
        # and add growth into the cordinates of the neighbours at a random time␣
 ↪into the event loop
        add_event(x+1,y)
        add_event(x-1,y)
        add_event(x,y+1)
        add_event(x,y-1)

    return True
```

[75]:
```python
size=10000
beta=25

event_stack=SortedList([])
#set all as edge -1

colonies=[[-1]*size for i in range(size)]
space=[[0]*size for i in range(size)]
# set all but edge as empty 0
for x in range(1,size-1):
    for y in range(1,size-1):
        colonies[x][y]=0
        space[x][y]=random()
# seed colony at mid point
_=grow(0,size//2,size//2,event_stack,beta)
```

[76]:
```python
start = time.time()
iterations=0
flag = True
while(flag):
    # get earliest event from stack ( stack is self sorting by event time)
    e = event_stack.pop(0)
    flag = grow(e[0],e[1],e[2],event_stack,beta)

    iterations+=1
t=e[0]
end = time.time()
delta = end - start
ccs=(sum([i.count(1) for i in colonies]))
print(f'{ccs} colonies when the edge of space reached in: {t:.3E} simulated␣
 ↪time and {iterations} iterations and {delta:.3F} real seconds')
```

```
47054865 colonies when the edge of space reached in: 3.440E-04 simulated time
and 130681651 iterations and 1345.622 real seconds
```

[77]:
```python
cmap=colors.ListedColormap(['#ffffff','#ffffff','#000000'])
fig, ax = plt.subplots()
ax.imshow(colonies,cmap=cmap)
ax.set_title('Position of colonies in 2d space')
ax.set_xlabel("Distance *10ly")
fig.set_figwidth(10)
fig.set_figheight(10)
for spine in ['top', 'right']:
    ax.spines[spine].set_visible(False)

plt.show()
```



[ ]:

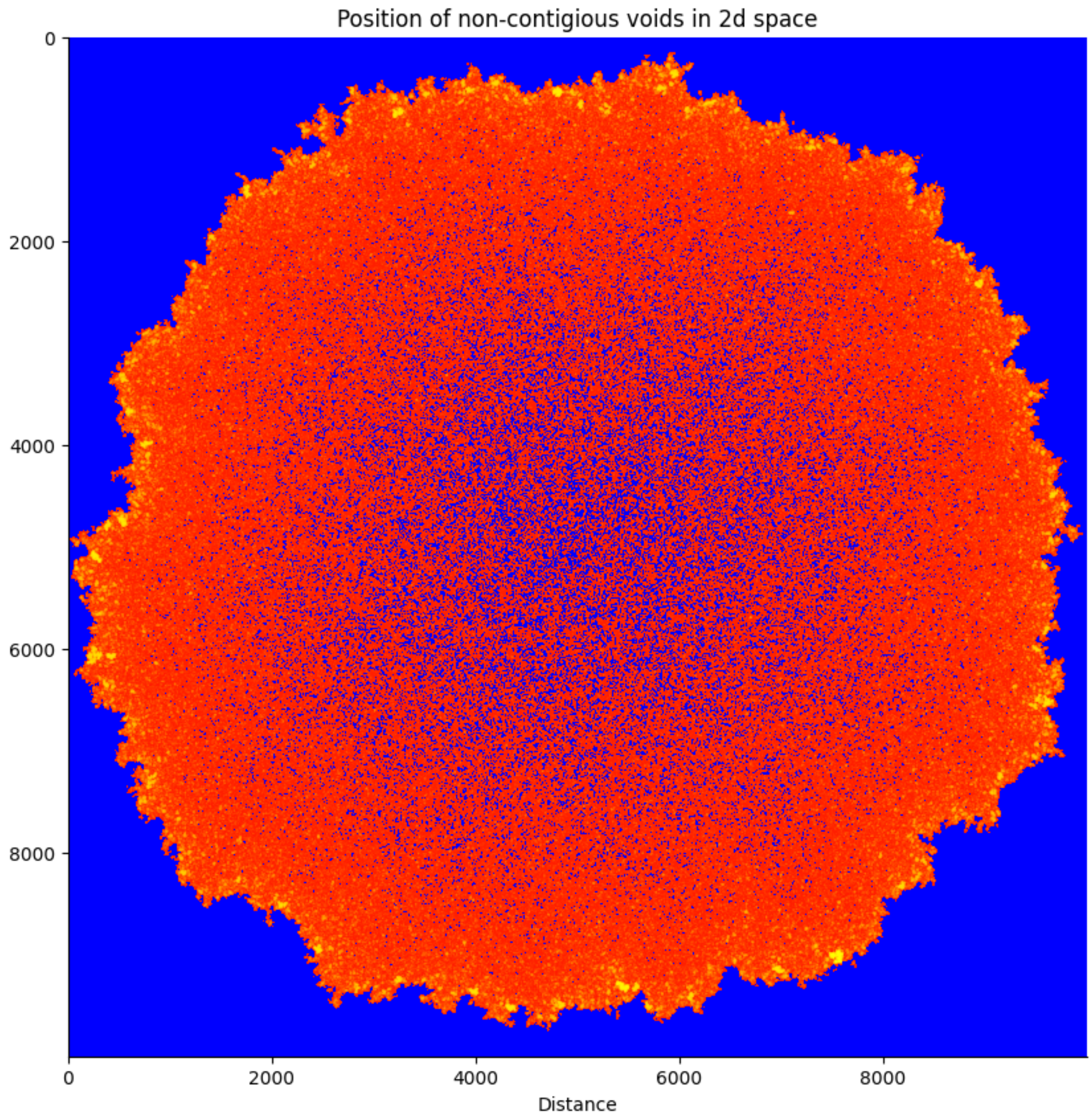
0.1 Analysis

[78]:
```
def queCount(area,size,x,y,n):

    def check_validity(x,y):
        if[x,y] in q or x < 1 or x >= size or y < 1 or y >= size or area[x][y] !
 ↪= 0:
            return False
        return True

    q=[[x,y]]
    count =0
    while (len(q)>0):
        x1,y1 = q.pop(0)
        area[x1][y1]=n
        count+=1
        if check_validity(x1+1,y1):
            q.append([x1+1,y1])
        if check_validity(x1-1,y1):
            q.append([x1-1,y1])
        if check_validity(x1,y1+1):
            q.append([x1,y1+1])
        if check_validity(x1,y1-1):
            q.append([x1,y1-1])
    return count
```

[79]:
```
gaps={}
cols={}
mark=2
for x in range(1,size-1):
    for y in range(1,size-1):
        if colonies[x][y]==0:
            sz =queCount(colonies,size-1,x,y,mark)
            if sz not in gaps:
                gaps[sz]=0
            cols[mark]=sz
            gaps[sz]+=1
            mark+=1
```

[80]:
```
spaces=[[0]*size for i in range(size)]
max_size=0
for x in range(1,size-1):
    for y in range(1,size-1):
        if colonies[x][y]>2:
```

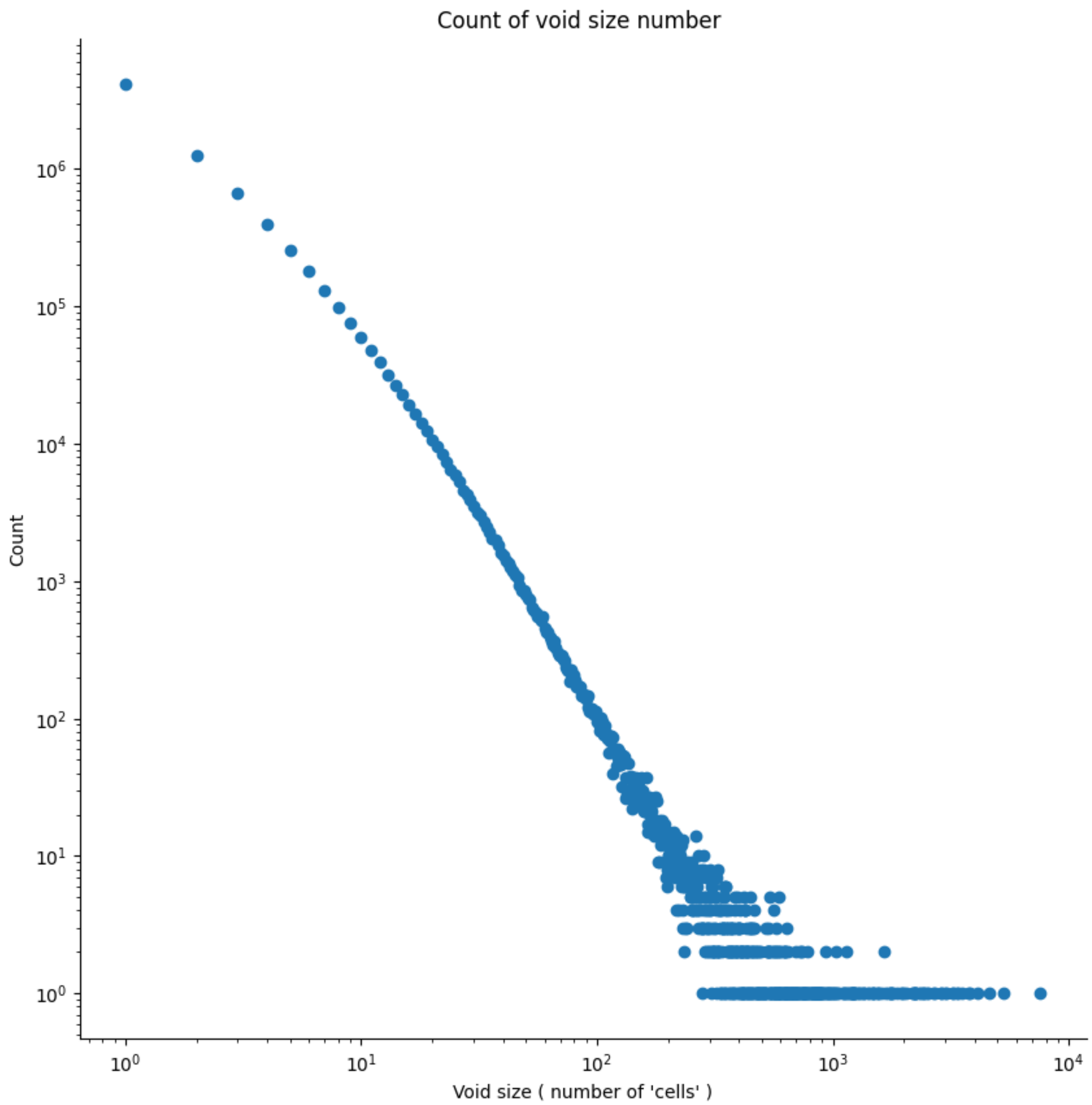
```python
            spaces[x][y]=cols[colonies[x][y]]
            if(cols[colonies[x][y]]>max_size):
                max_size=cols[colonies[x][y]]
        else:
            spaces[x][y]=colonies[x][y]

c=[(0,0,1),(0,0,1)]
for i in range(3,max_size):
    c.append((1,log(i)/log(max_size),0))


cmap=colors.ListedColormap(c)
fig, ax = plt.subplots()
fig.set_figwidth(10)
fig.set_figheight(10)
ax.set_title('Position of non-contigious voids in 2d space')
ax.set_xlabel("Distance")
ax.imshow(spaces,cmap=cmap)
for spine in ['top', 'right']:
    ax.spines[spine].set_visible(False)

plt.show()
```



Colours show the size of the voids. The more yellow the colour the larger the void. Note that while the size distribution is fractal (see graph below) their spatial distribution is towards the periphery of the colony cluster

[81]:
```
x=list(gaps.keys())
y=list(gaps.values())
fig, ax = plt.subplots()
ax.scatter(x[1:],y[1:])
ax.set_title('Count of void size number ')
ax.set_xlabel("Void size ( number of 'cells' )")
ax.set_ylabel('Count')
fig.set_figwidth(10)
```

```python
fig.set_figheight(10)
for spine in ['top', 'right']:
    ax.spines[spine].set_visible(False)
ax.set_xscale('log')
ax.set_yscale('log')
plt.show()
```




```
[ ]:
```