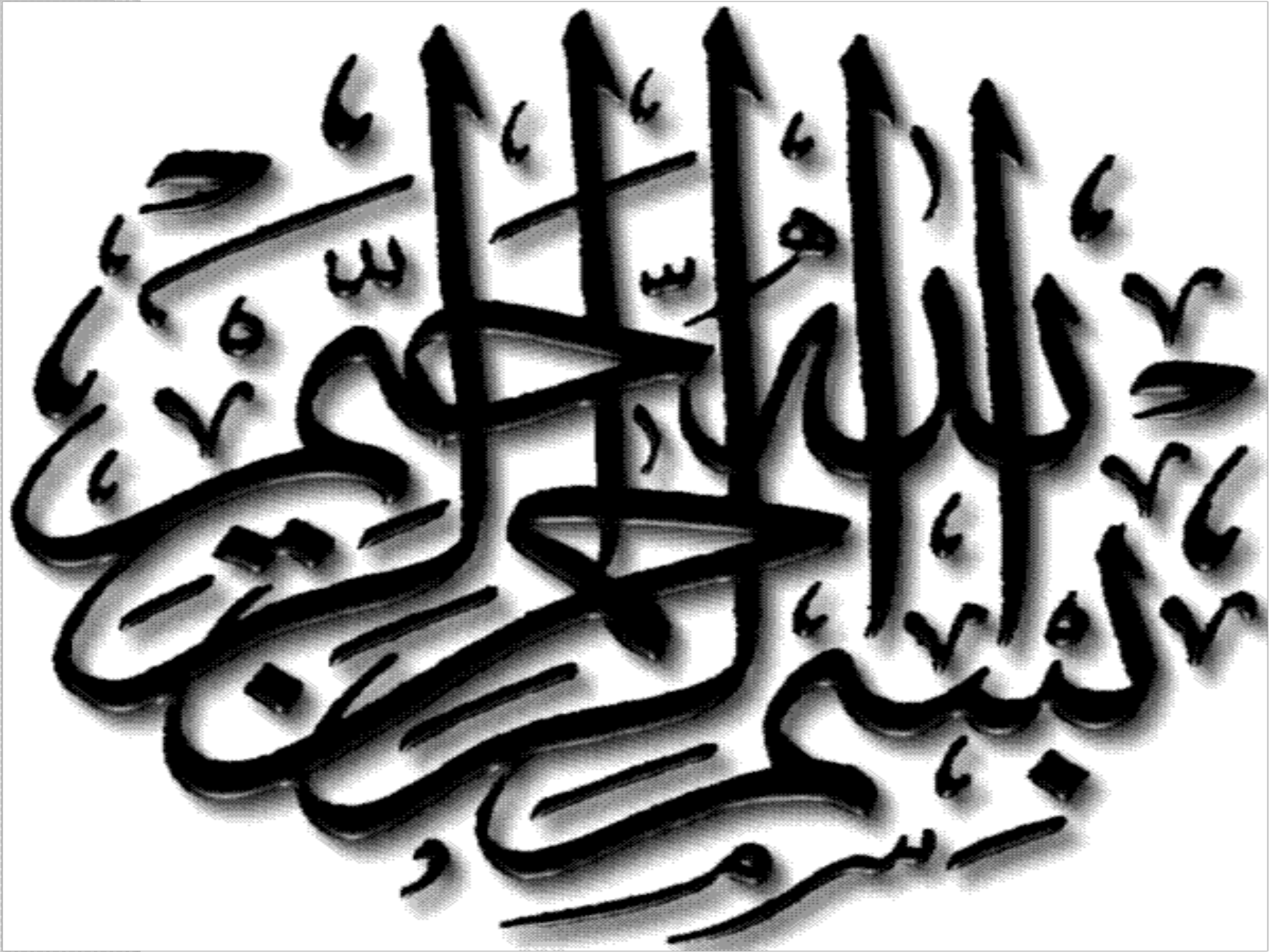
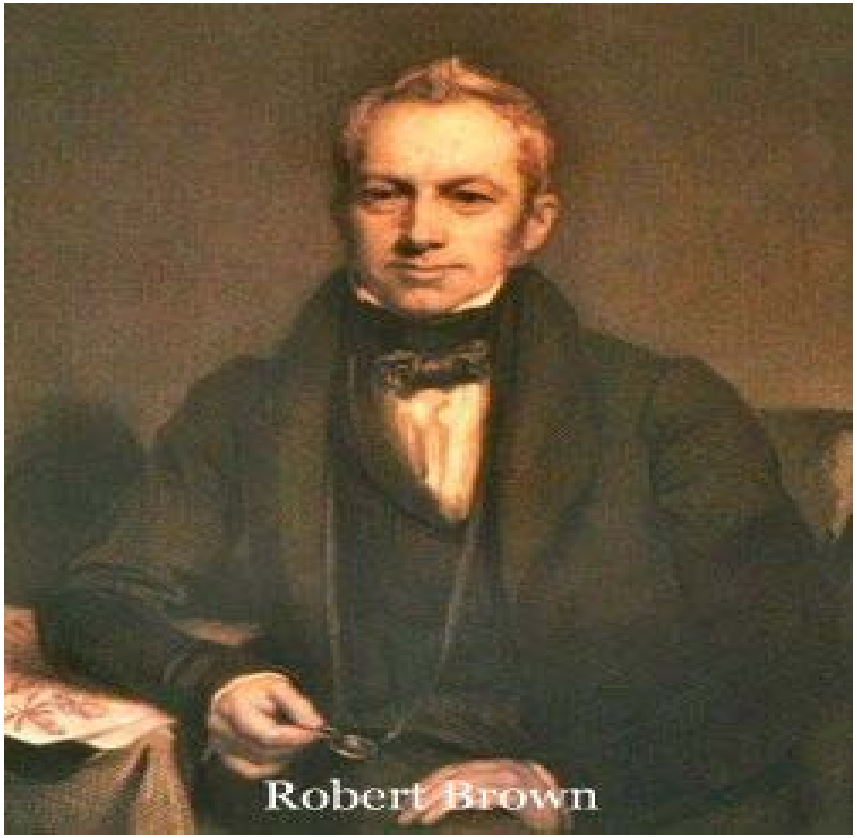
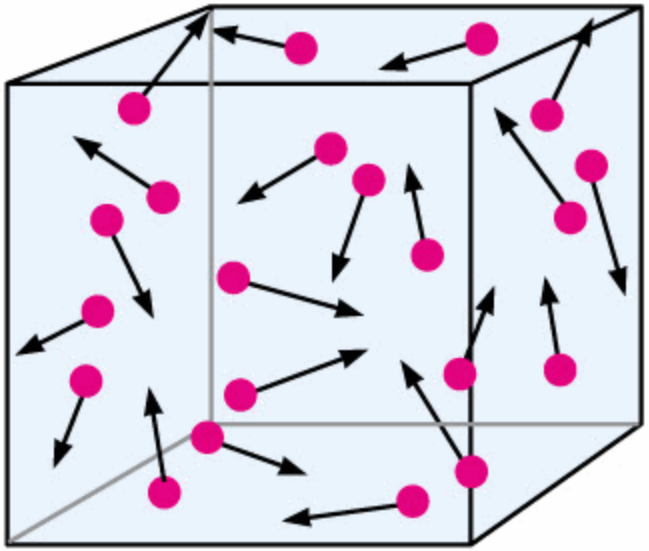

بسم الله الرحمن الرحيم

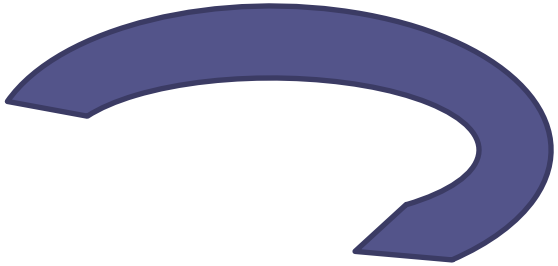
Tracking Brownian Motion through Video microscopy

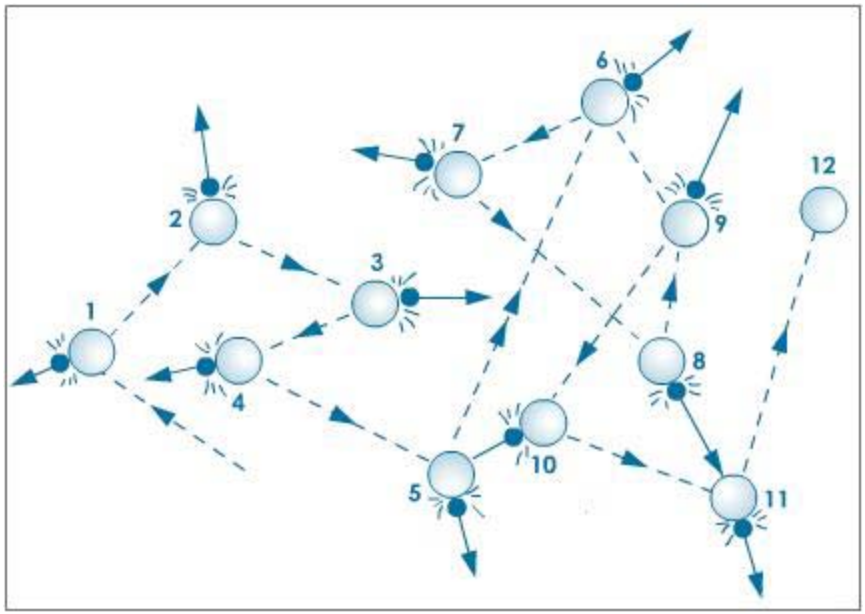
BROWNIAN MOTION

- Discovery of Robert Brown
- Random, jittery motion of suspended particles.








1
2
3
4
5
6
7
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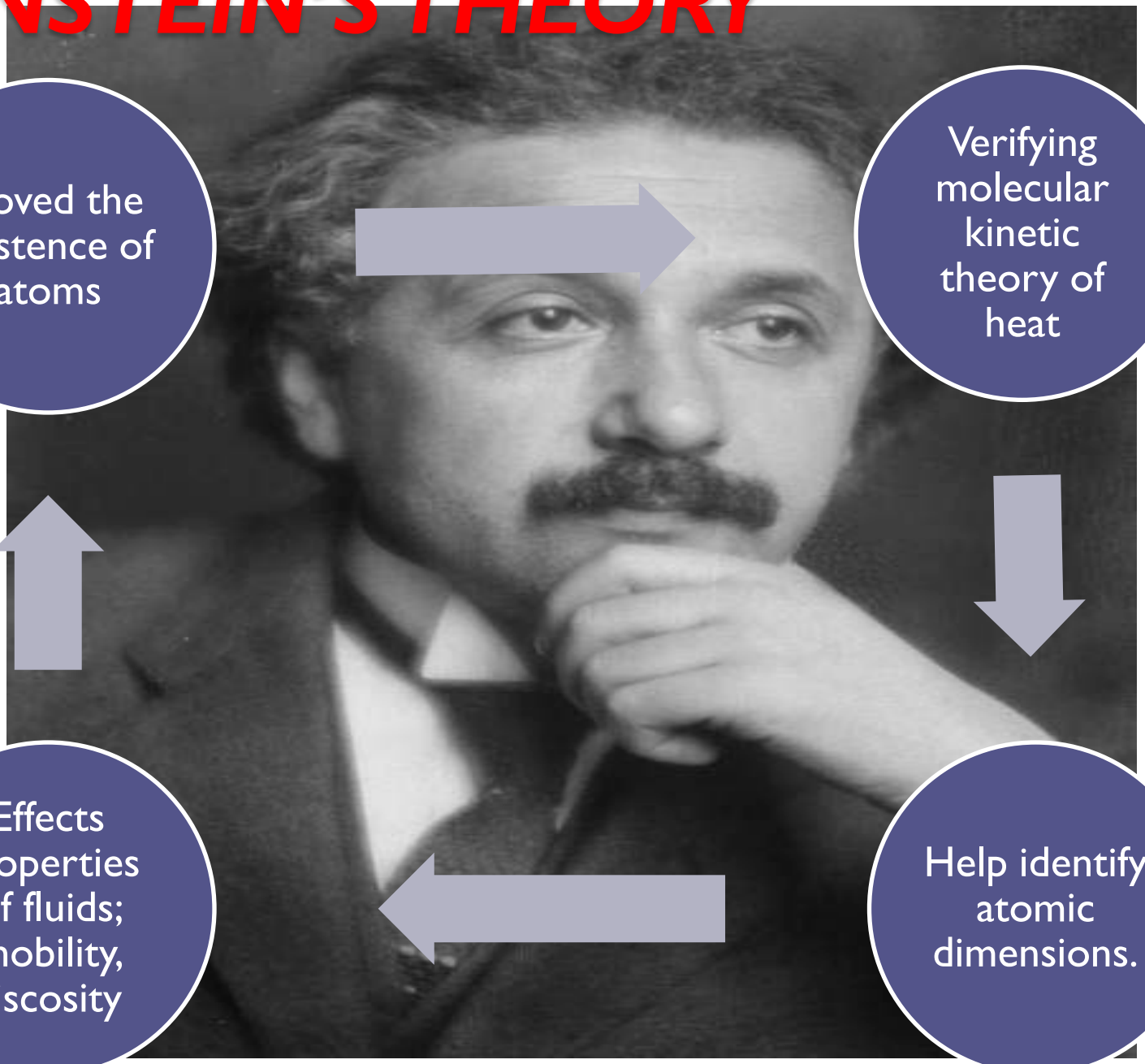
9
10
11
12

EINSTEIN'S THEORY



Proved the existence of atoms

Verifying molecular kinetic theory of heat

Effects properties of fluids; mobility, viscosity

Help identify atomic dimensions.

Mathematical Modeling

$$\frac{1}{2}mv^2 = \frac{3}{2}k_B T.$$

$$m\frac{d\mathbf{v}}{dt} = -\alpha\mathbf{v} + \mathbf{F}(t).$$

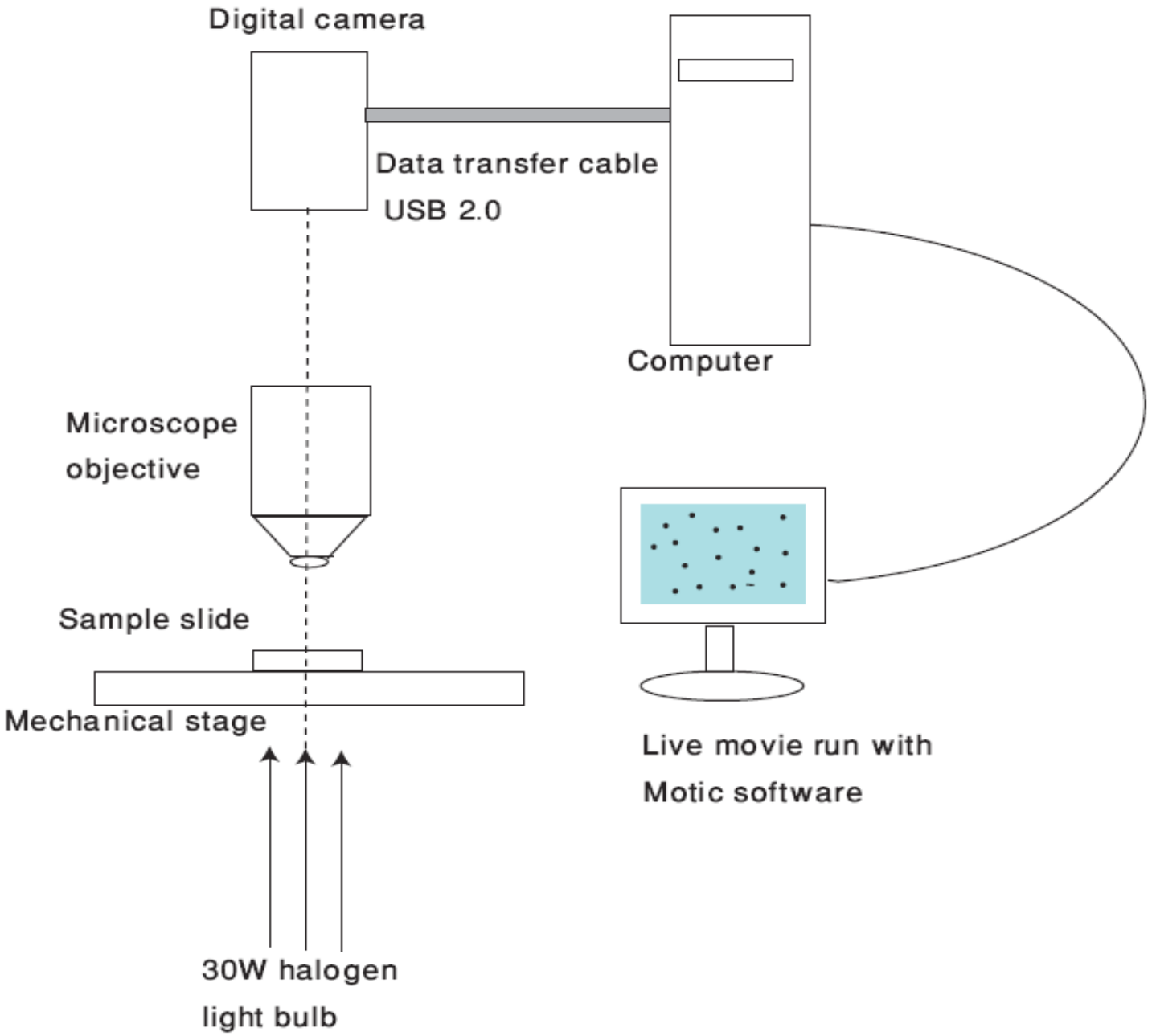
$$m\frac{d^2x}{dt^2} + \alpha\frac{dx}{dt} - F(t) = 0.$$

$$\langle r^2 \rangle = \frac{4k_B T}{6\pi\eta a}\tau.$$

$$D = \frac{K_B T}{\alpha}$$

$$N_A = \frac{2RT}{< r^2 > 3\Pi\eta a}\tau$$

EXPERIMENTAL PROCEDURE


Digital camera
Data transfer cable
USB 2.0
Computer
Microscope
objective
Sample slide
Mechanical stage
Live movie run with
Motic software
30W halogen
light bulb

- Custom observation slide preparation
- Focusing of the microscope
- Slide Analysis in Motic Image Plus 2.0
- Video making
- Image processing in MATLAB

MOTIC MICROSCOPE

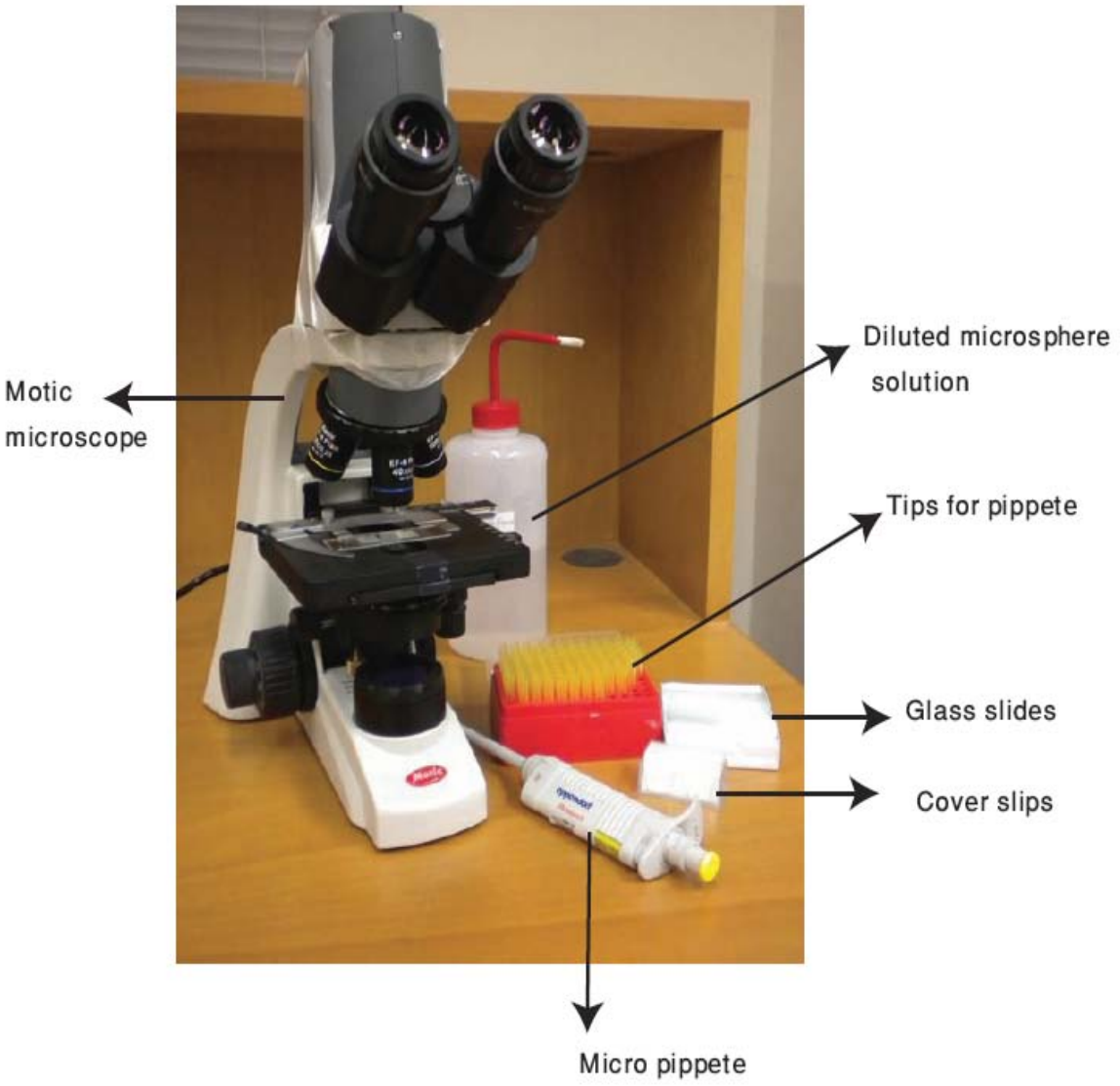
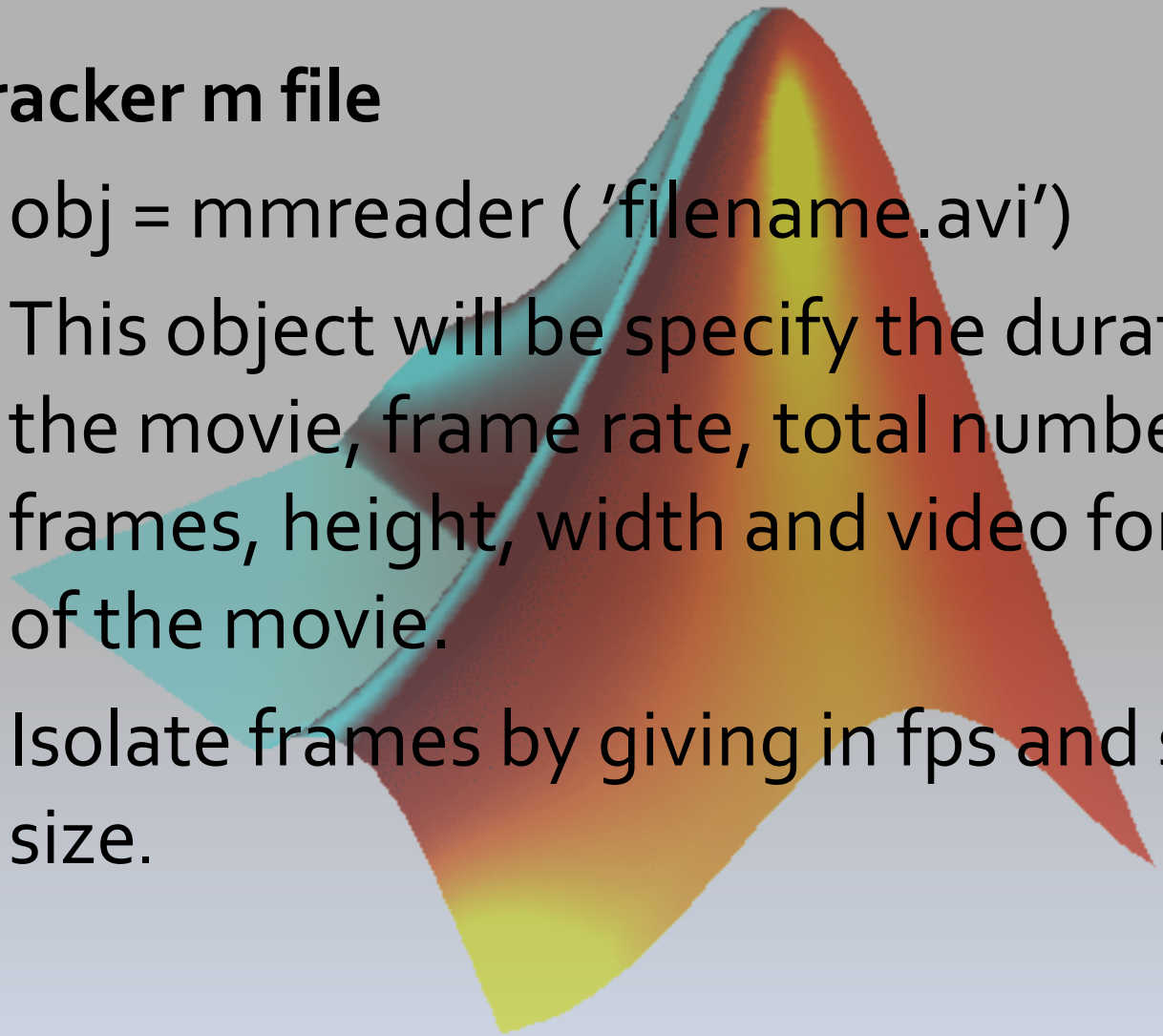


IMAGE PROCESSING IN MATLAB



- **Tracker m file**
  - obj = mmreader ('filename.avi')
  - This object will be specify the duration of the movie, frame rate, total number of frames, height, width and video format of the movie.
  - Isolate frames by giving in fps and step size.

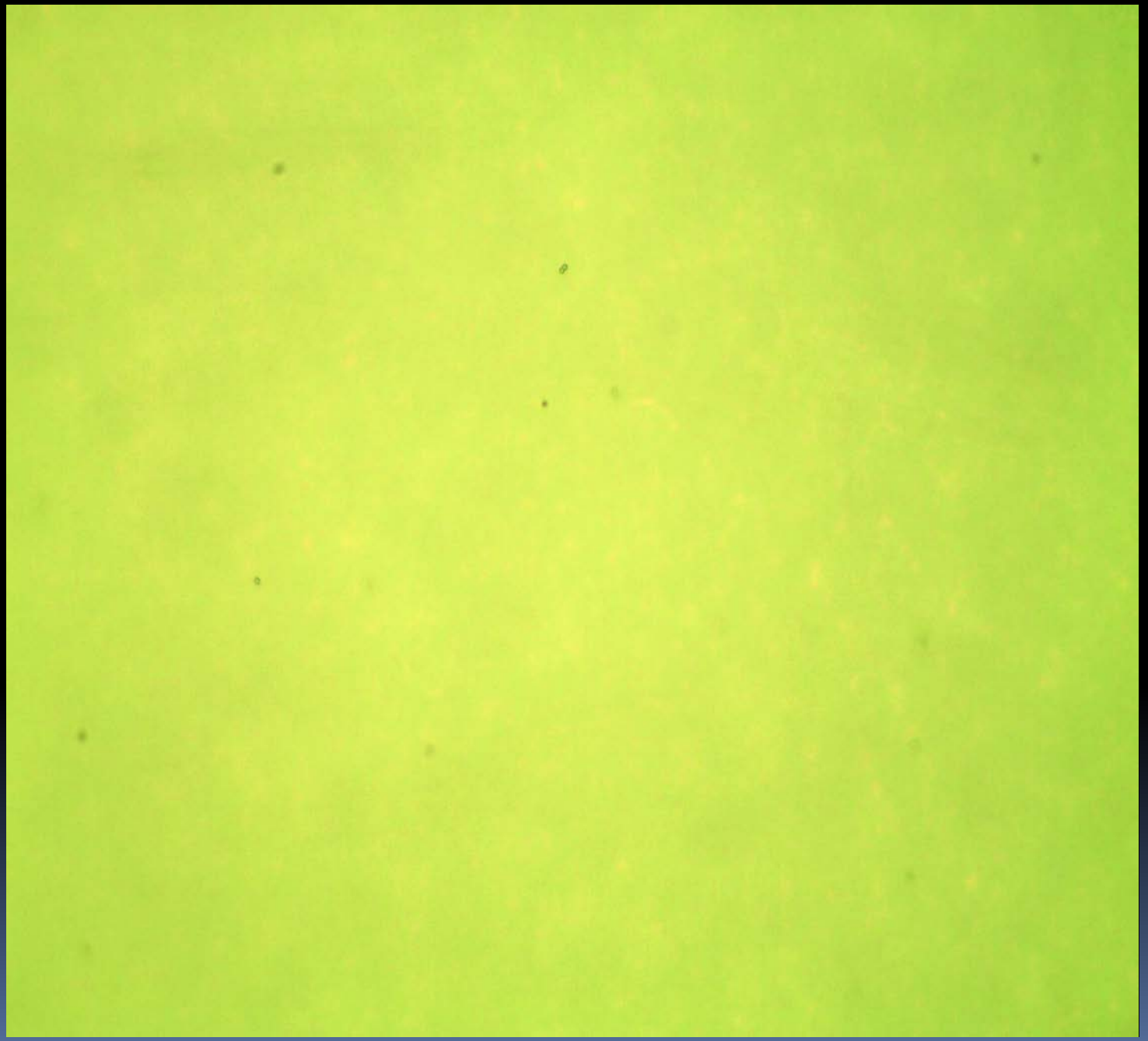


IMAGE PROCESSING IN MATLAB

- Imcrop ()
- Rgb2gray ()
- Incomplement ()

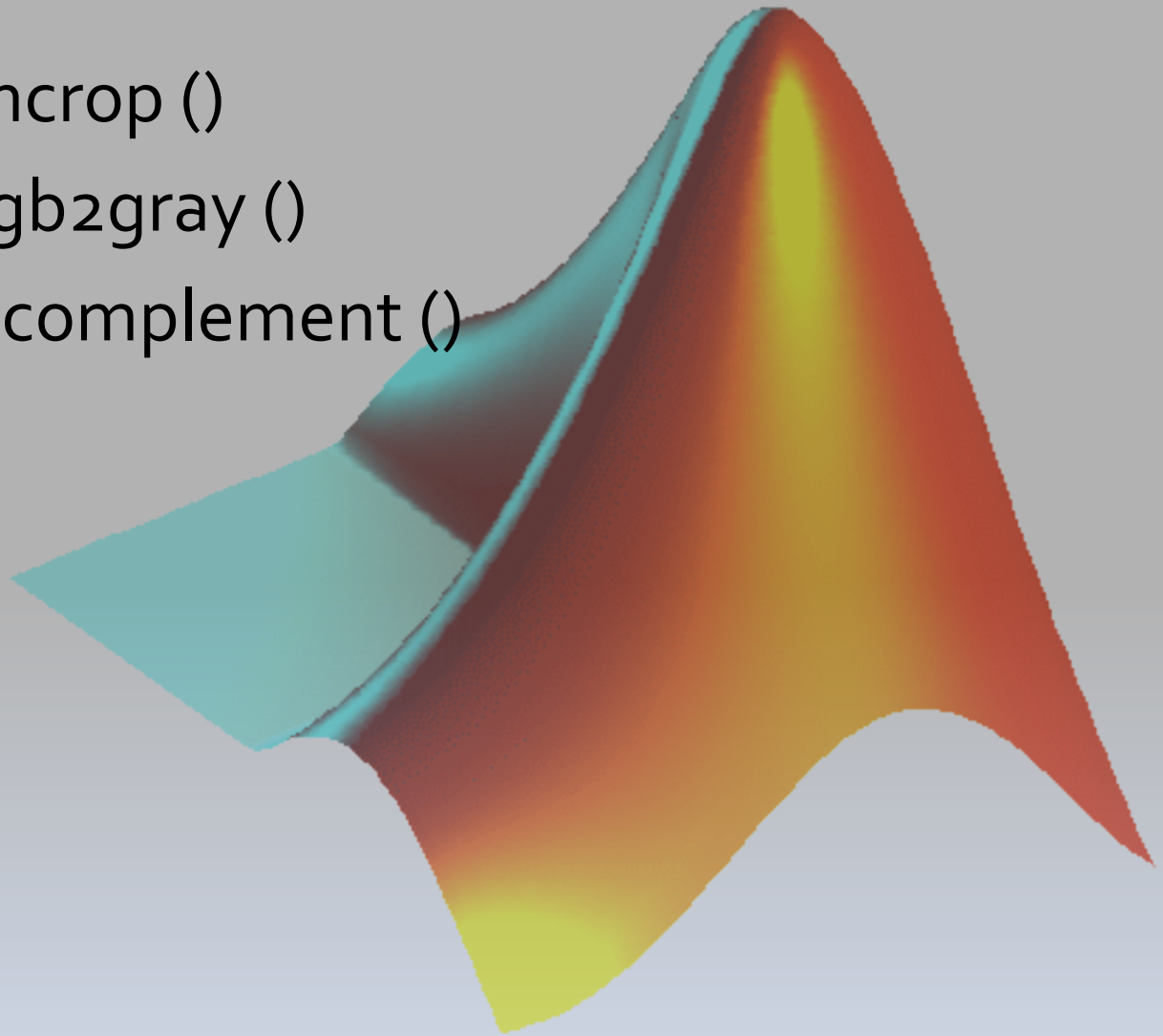
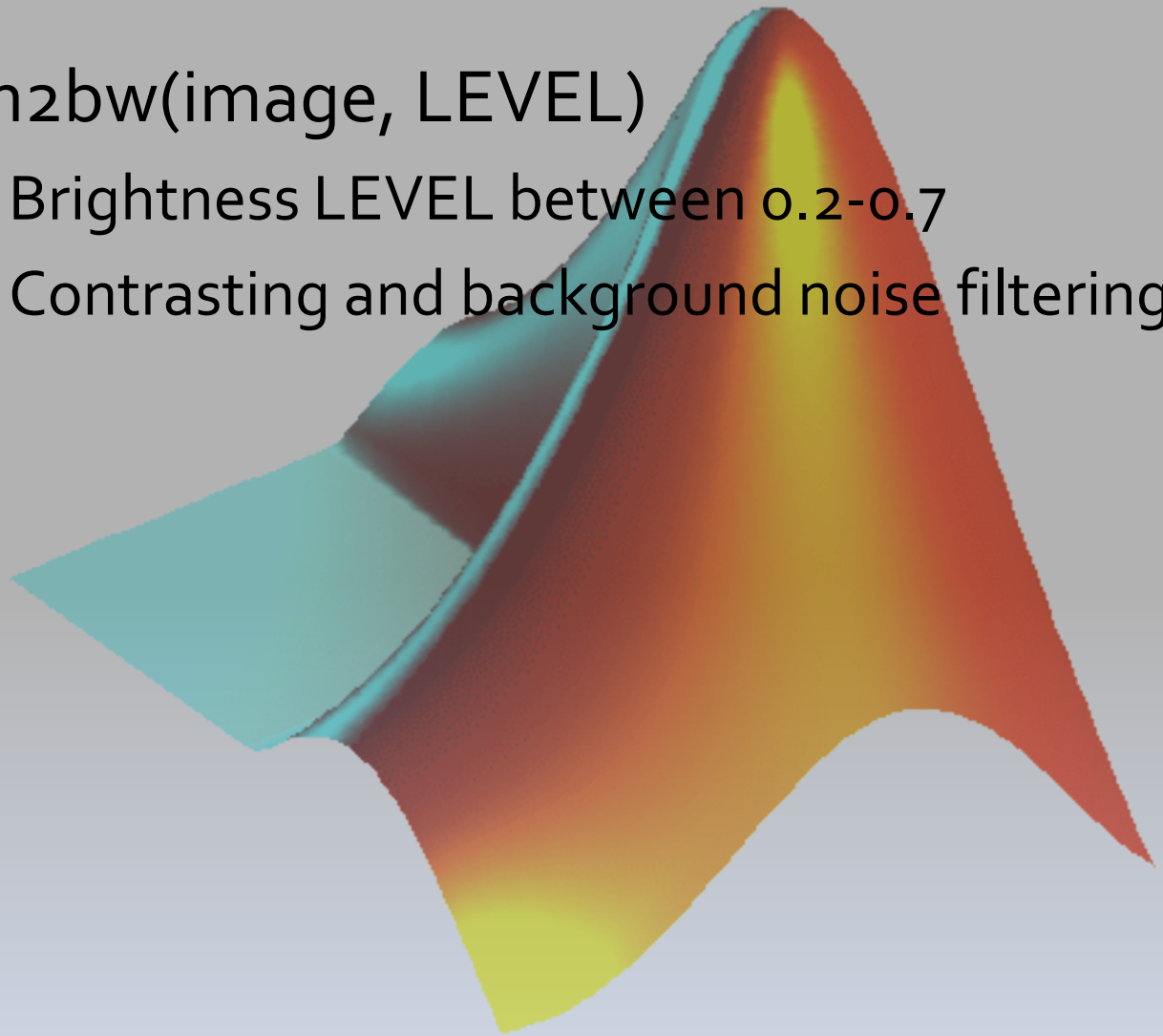
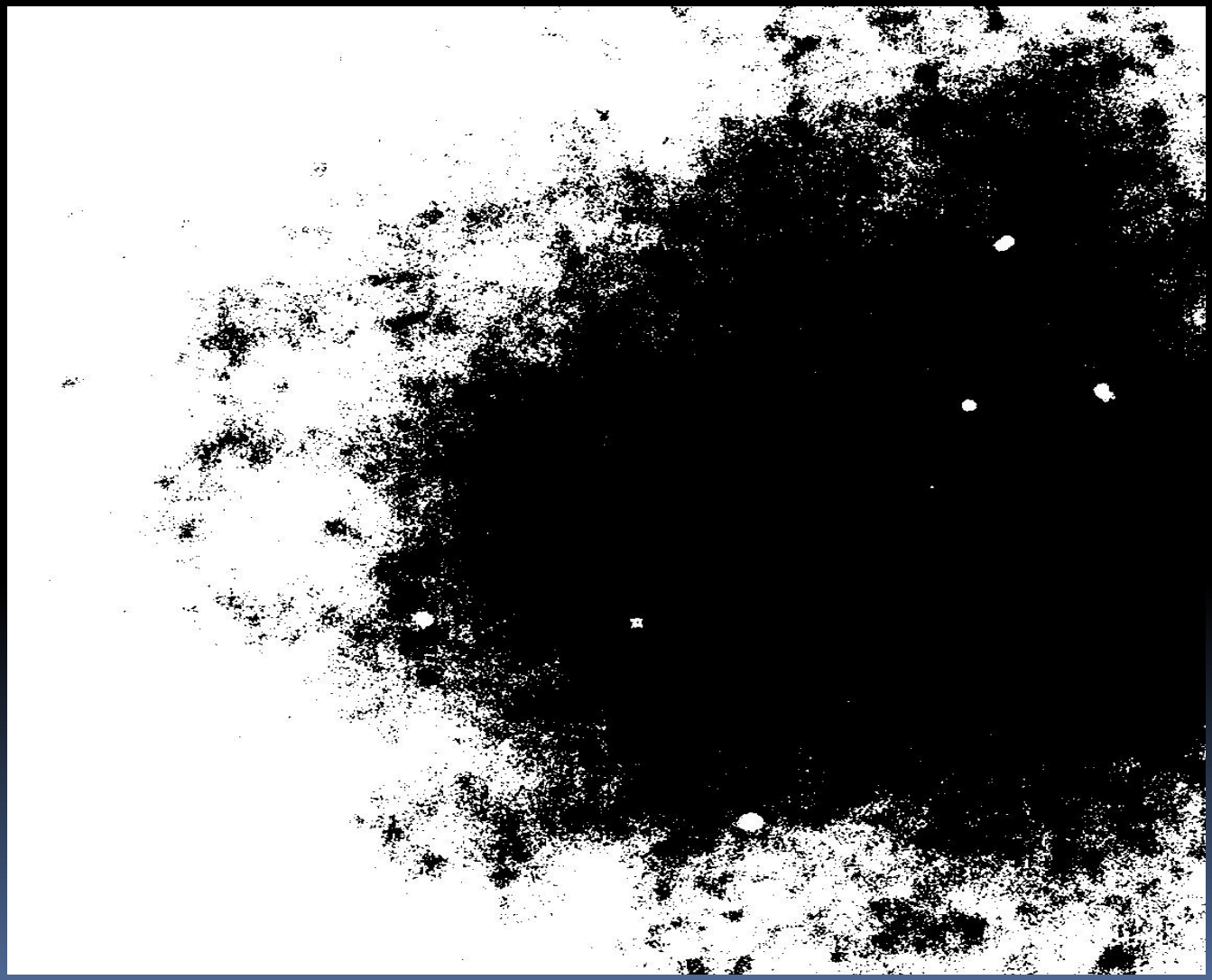


IMAGE PROCESSING IN MATLAB

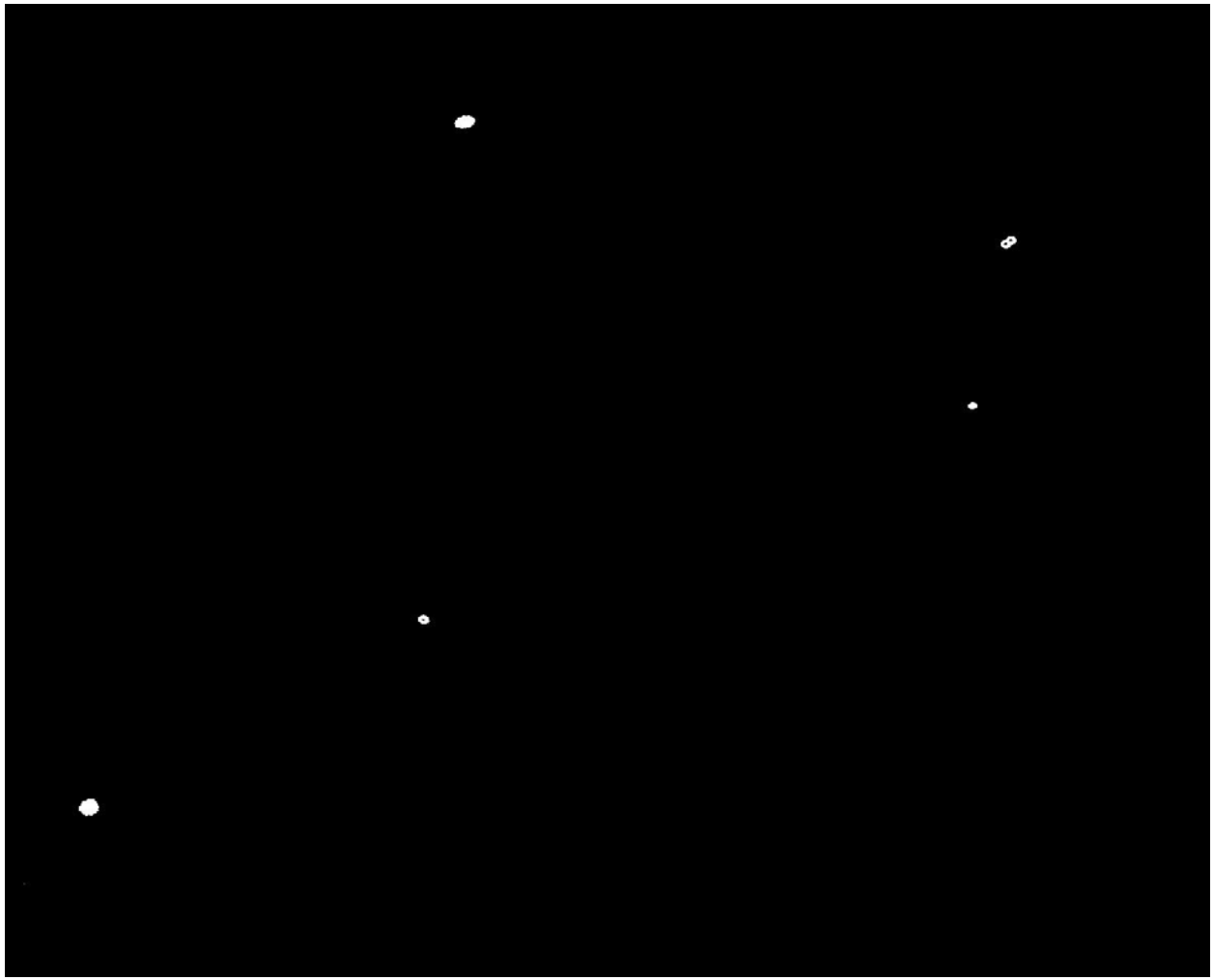
- Im2bw(image, LEVEL)
  - Brightness LEVEL between 0.2-0.7
  - Contrasting and background noise filtering



For level= 0.2



For level= 0.3



For level= 0.31

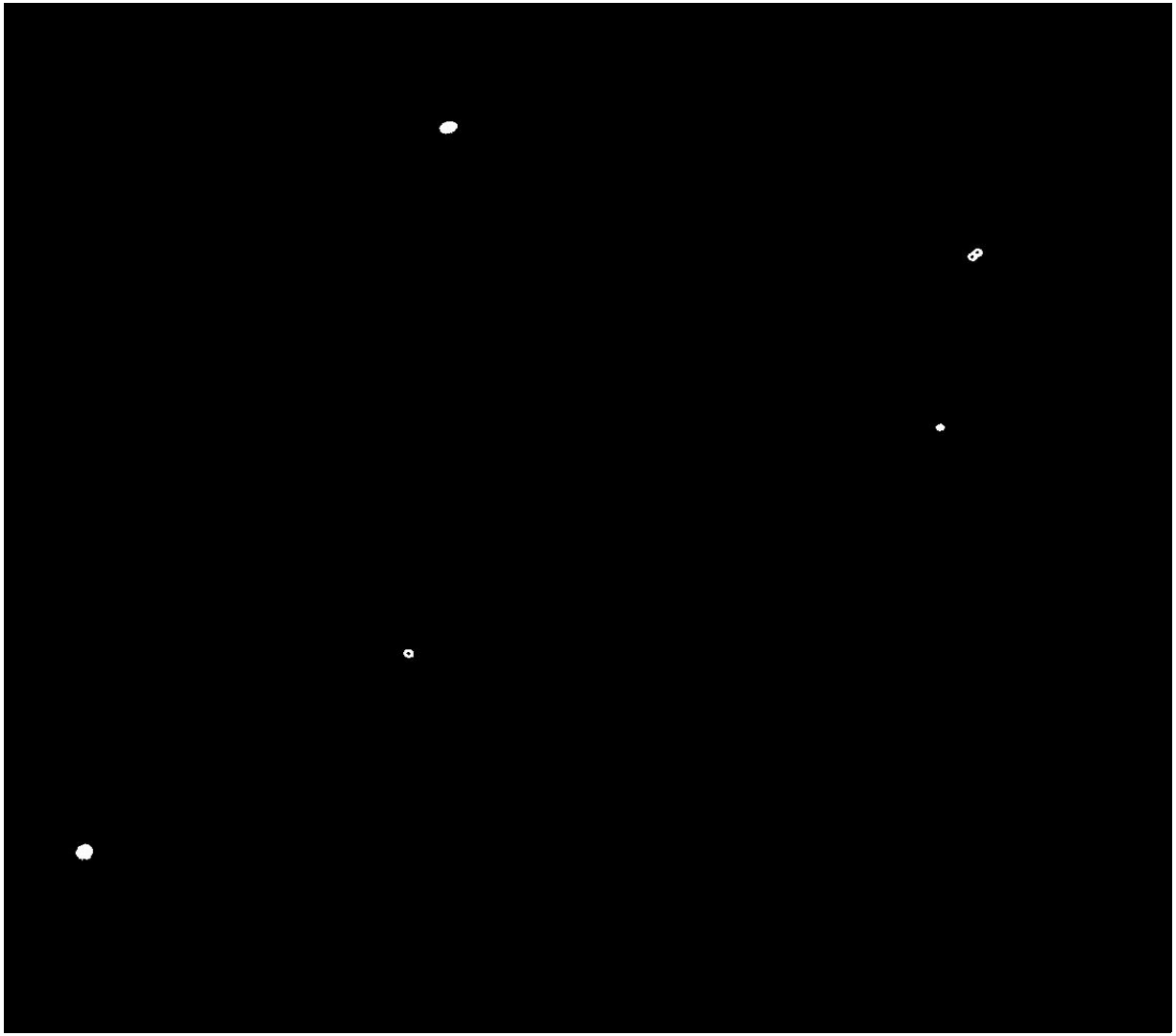
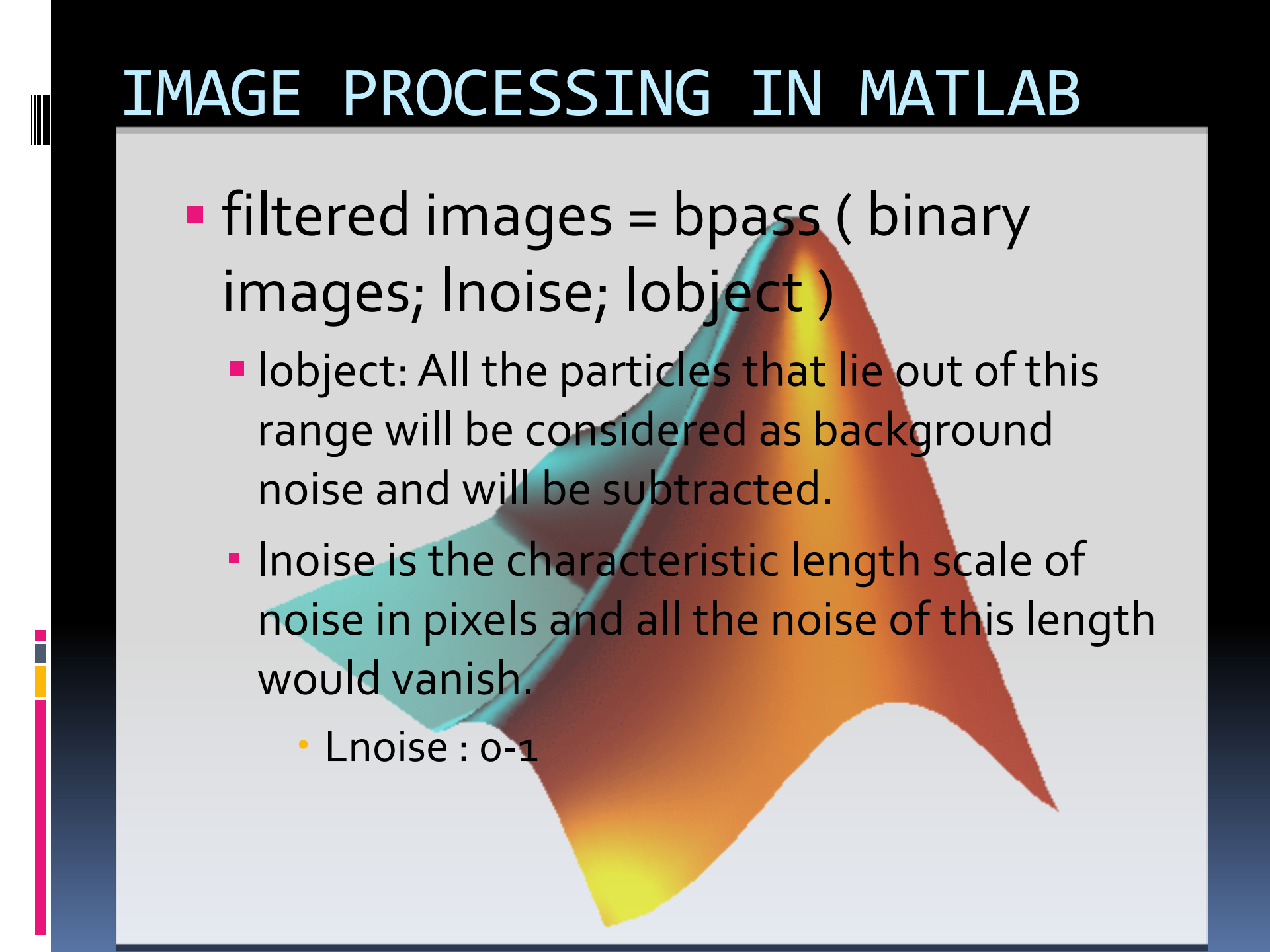
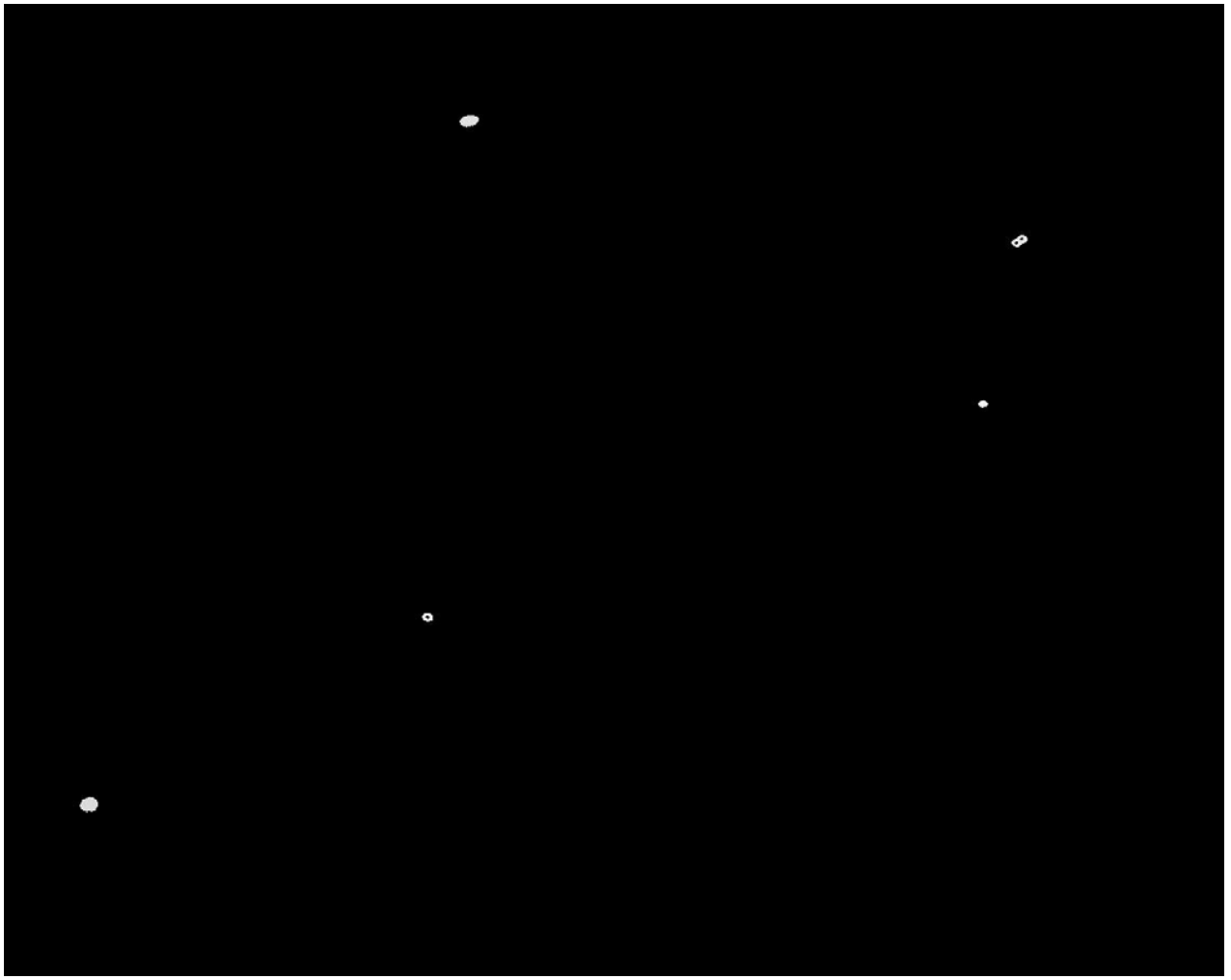


IMAGE PROCESSING IN MATLAB

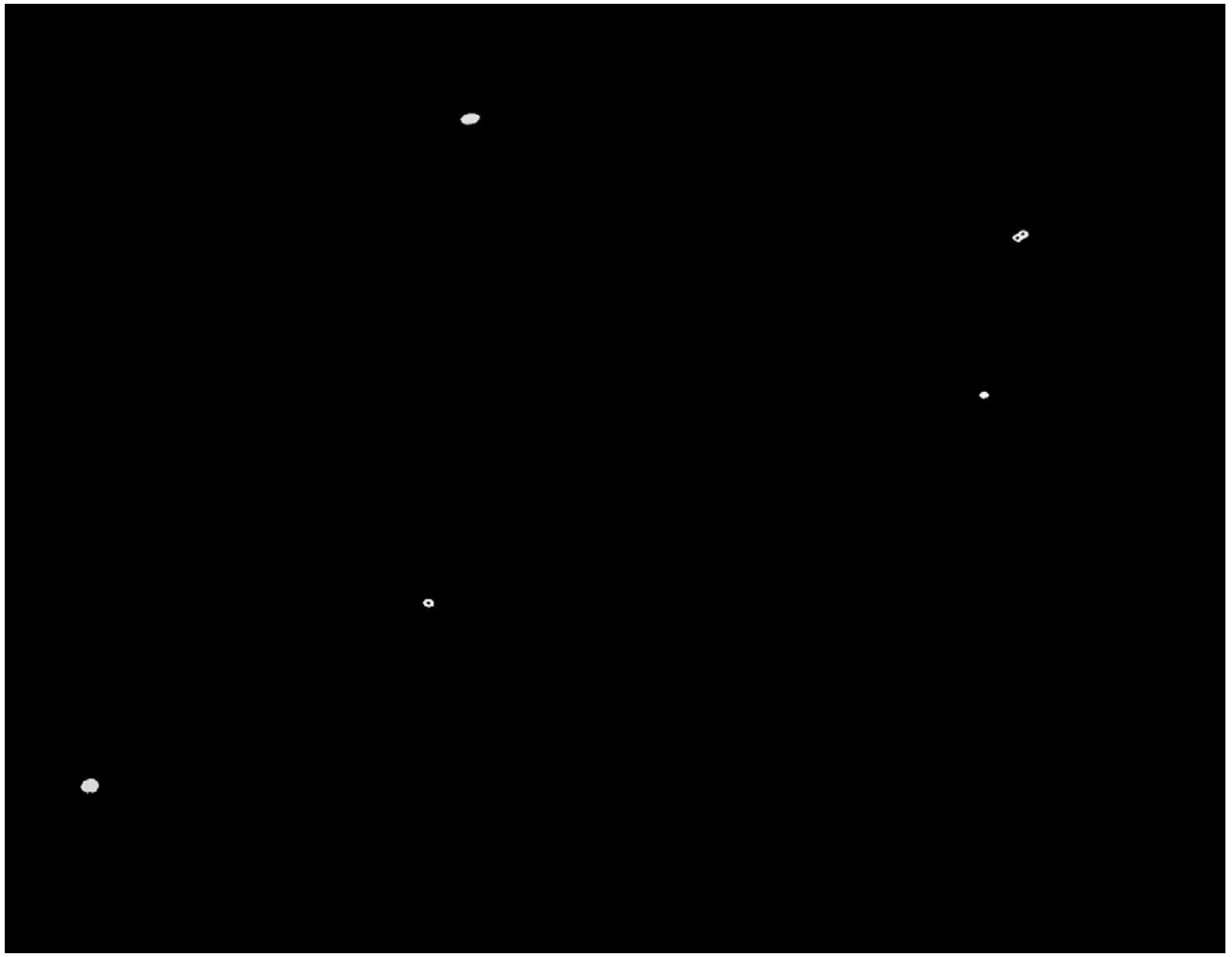
- filtered images = bpass (binary images; lnoise; lobject)
  - lobject: All the particles that lie out of this range will be considered as background noise and will be subtracted.
  - lnoise is the characteristic length scale of noise in pixels and all the noise of this length would vanish.
    - Lnoise : 0-1



For Iobject=20 and Inoise=0



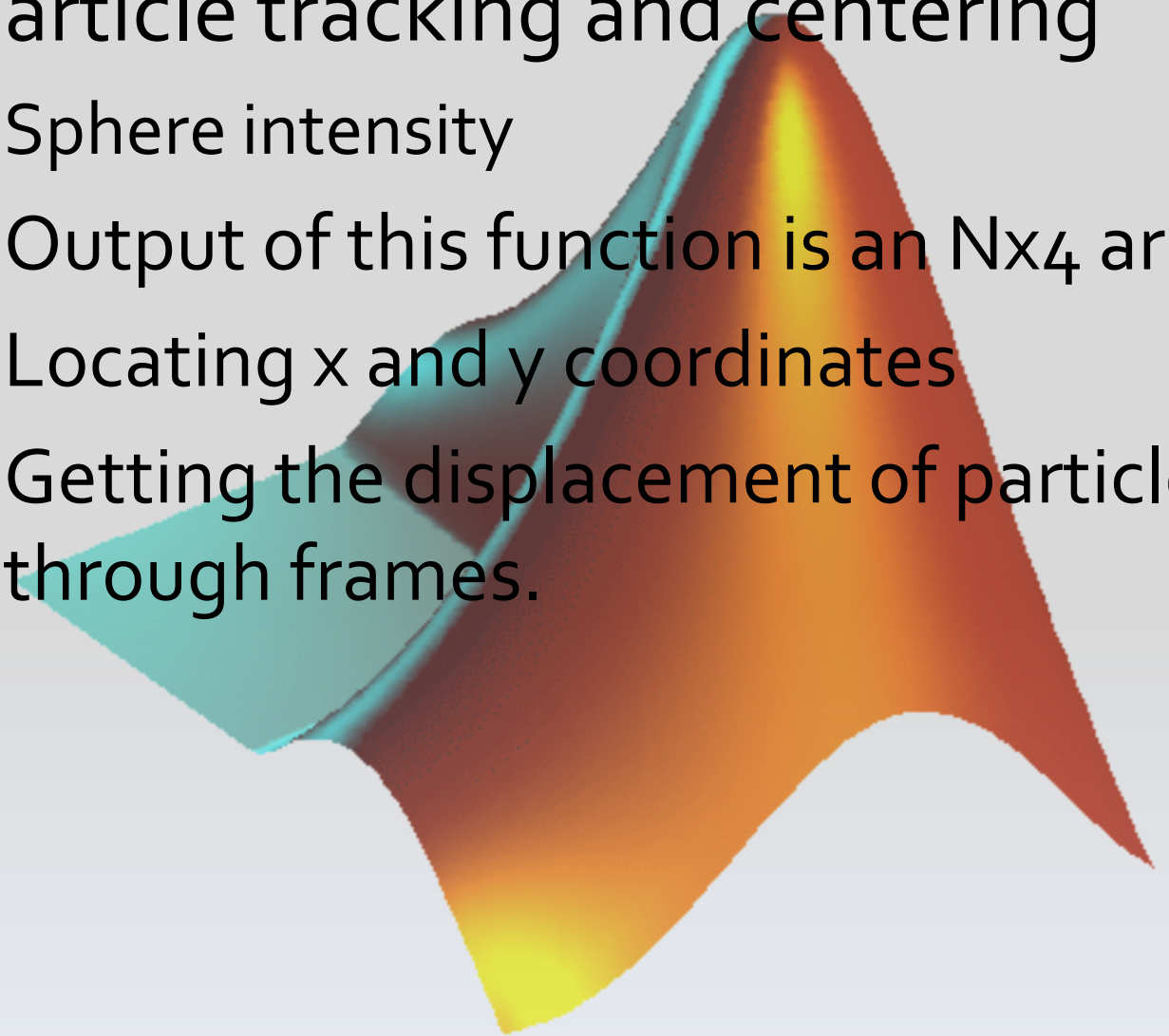
For Iobject=20 and Inoise=0.3



For Iobject=20 and Inoise=1

IMAGE PROCESSING IN MATLAB

- Particle tracking and centering
  - Sphere intensity
  - Output of this function is an Nx4 array
  - Locating x and y coordinates
  - Getting the displacement of particles through frames.



RESULTS

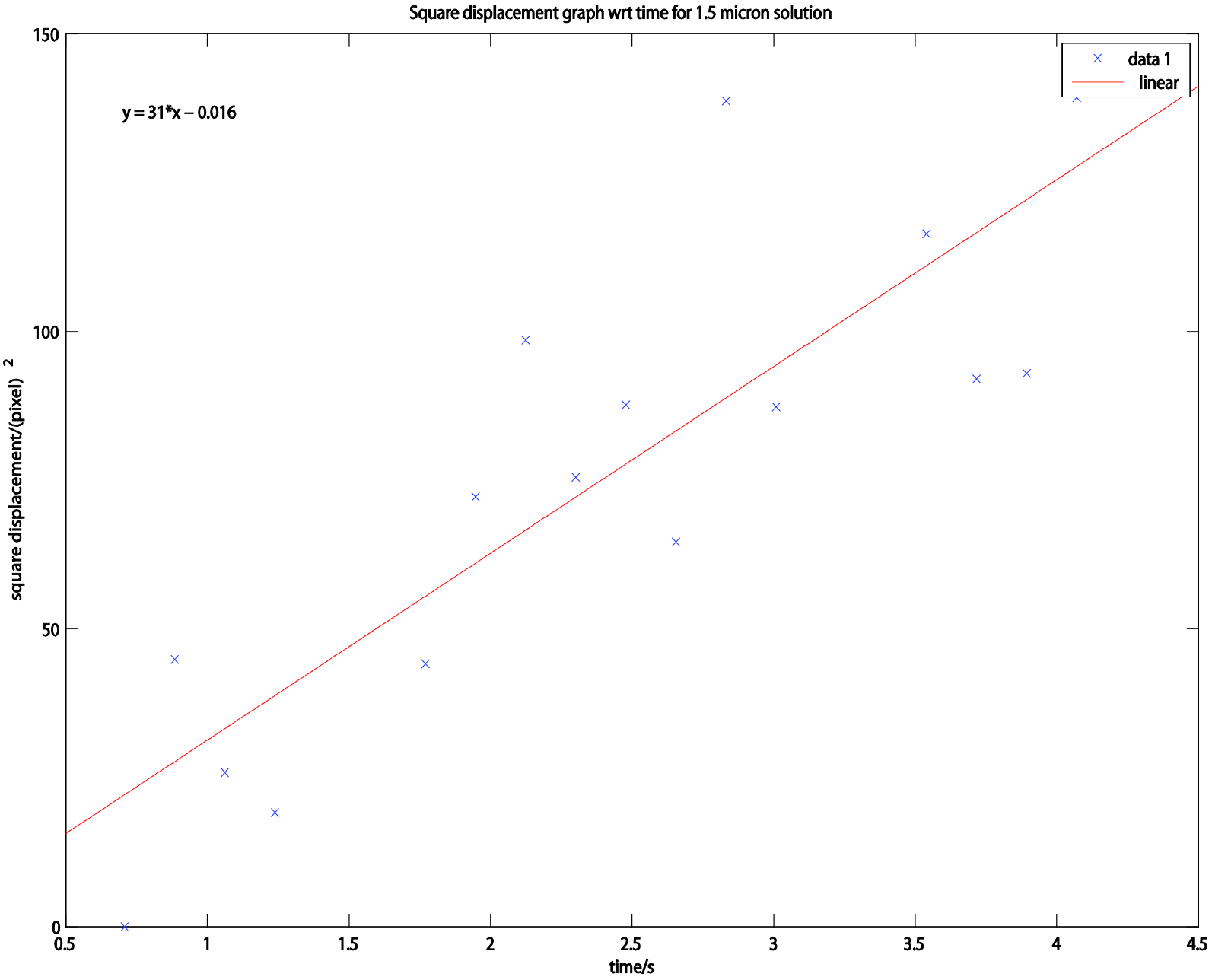
$$r_p^2 = (x_{np} - x_{0p})^2 + (y_{np} - y_{0p})^2,$$

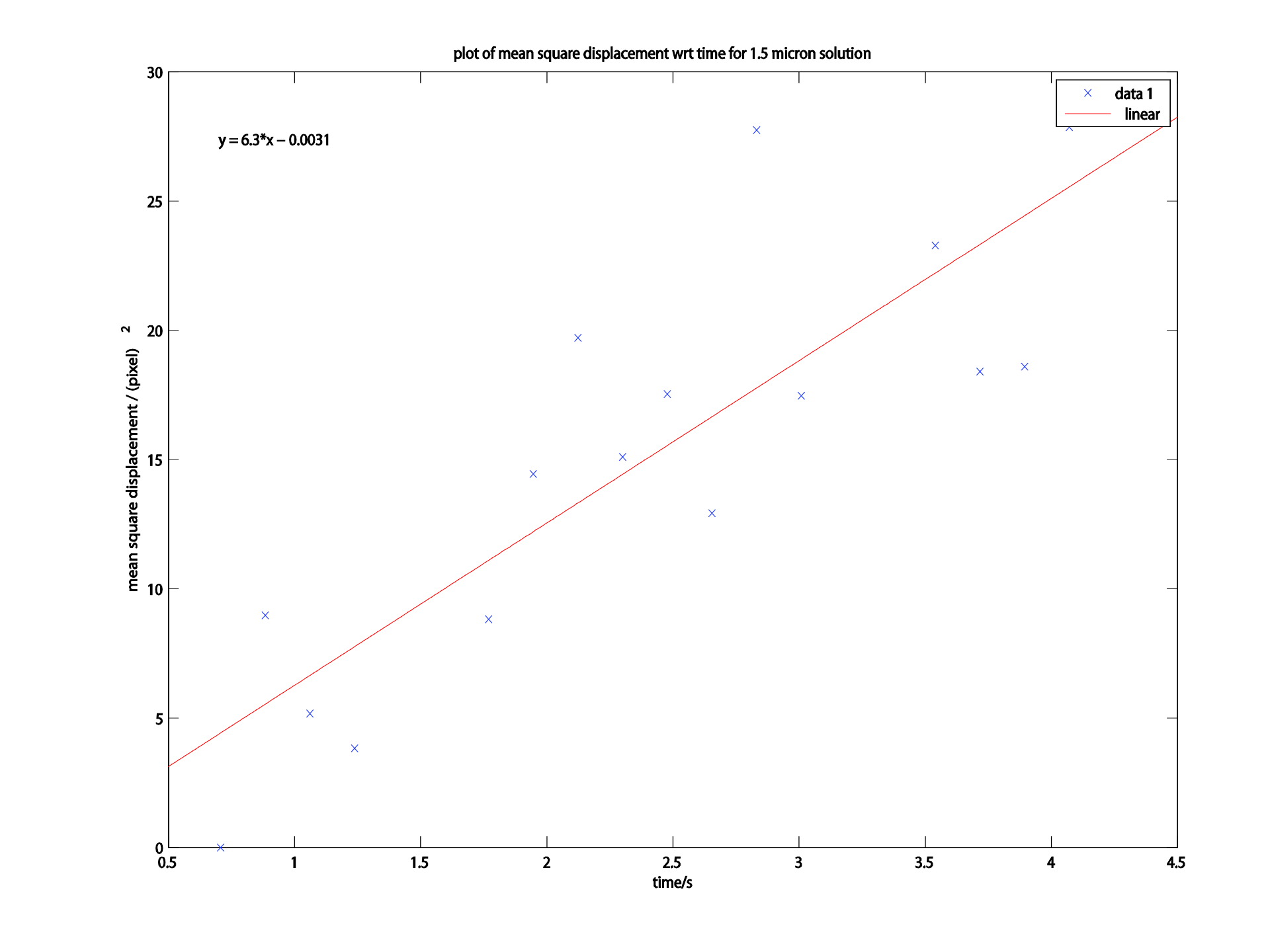
- Recall the relation below:

$$\langle r^2 \rangle = \frac{4k_B T}{6\pi\eta a}\tau.$$

- Hence, the plot of the mean square displacement and time is a straight line.

$$\langle r_n^2 \rangle = \frac{\sum_{p=1}^{N} r_p^2}{N}.$$


Square displacement graph wrt time for 1.5 micron solution
y = 31*x – 0.016
data 1
linear
square displacement/(pixel) 2
time/s
150
100
50
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5


plot of mean square displacement wrt time for 1.5 micron solution
y = 6.3*x – 0.0031
data 1
linear
mean square displacement / (pixel) 2
time/s
0
5
10
15
20
25
30
0.5
1
1.5
2
2.5
3
3.5
4
4.5

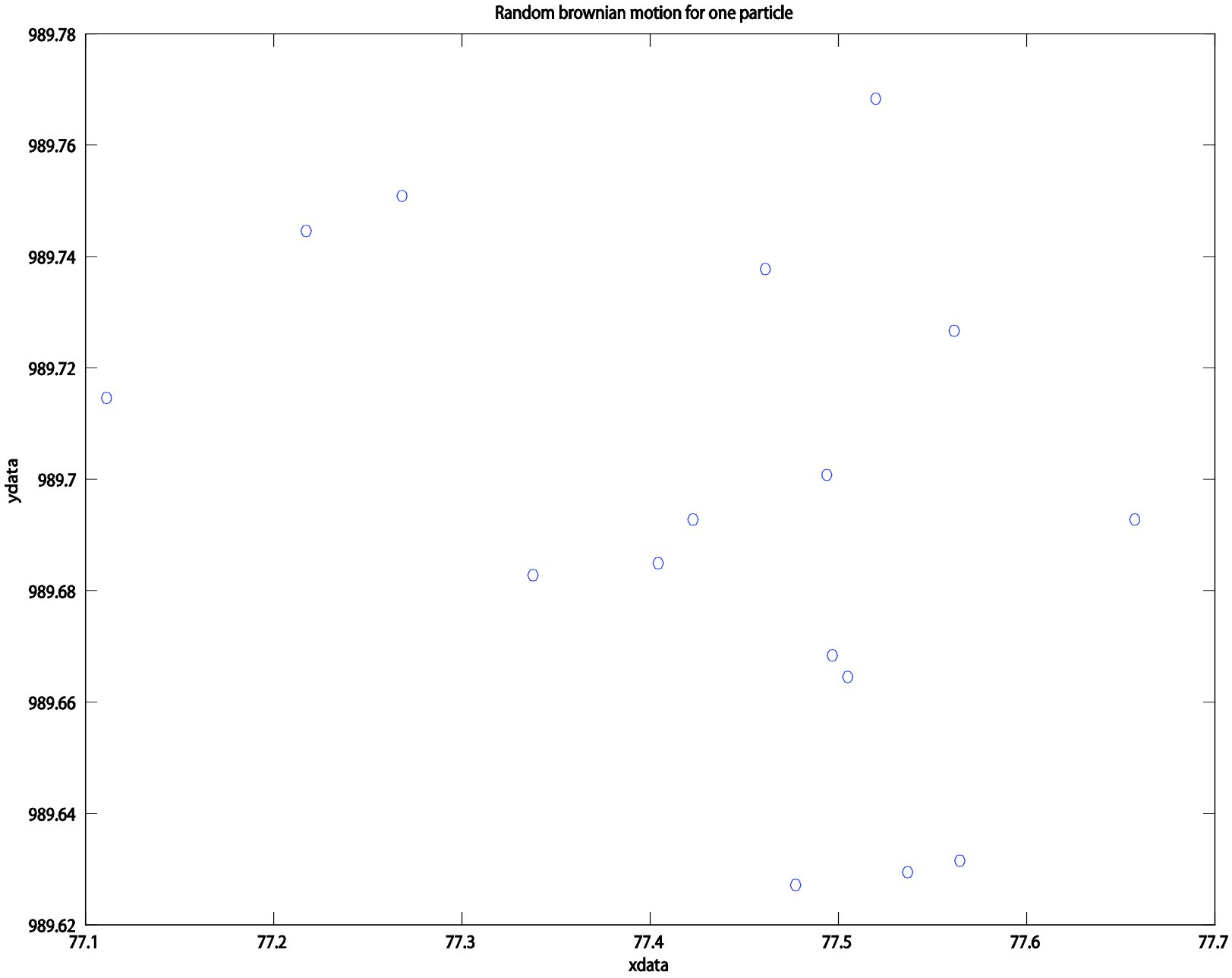
- The gradient of the graph is:

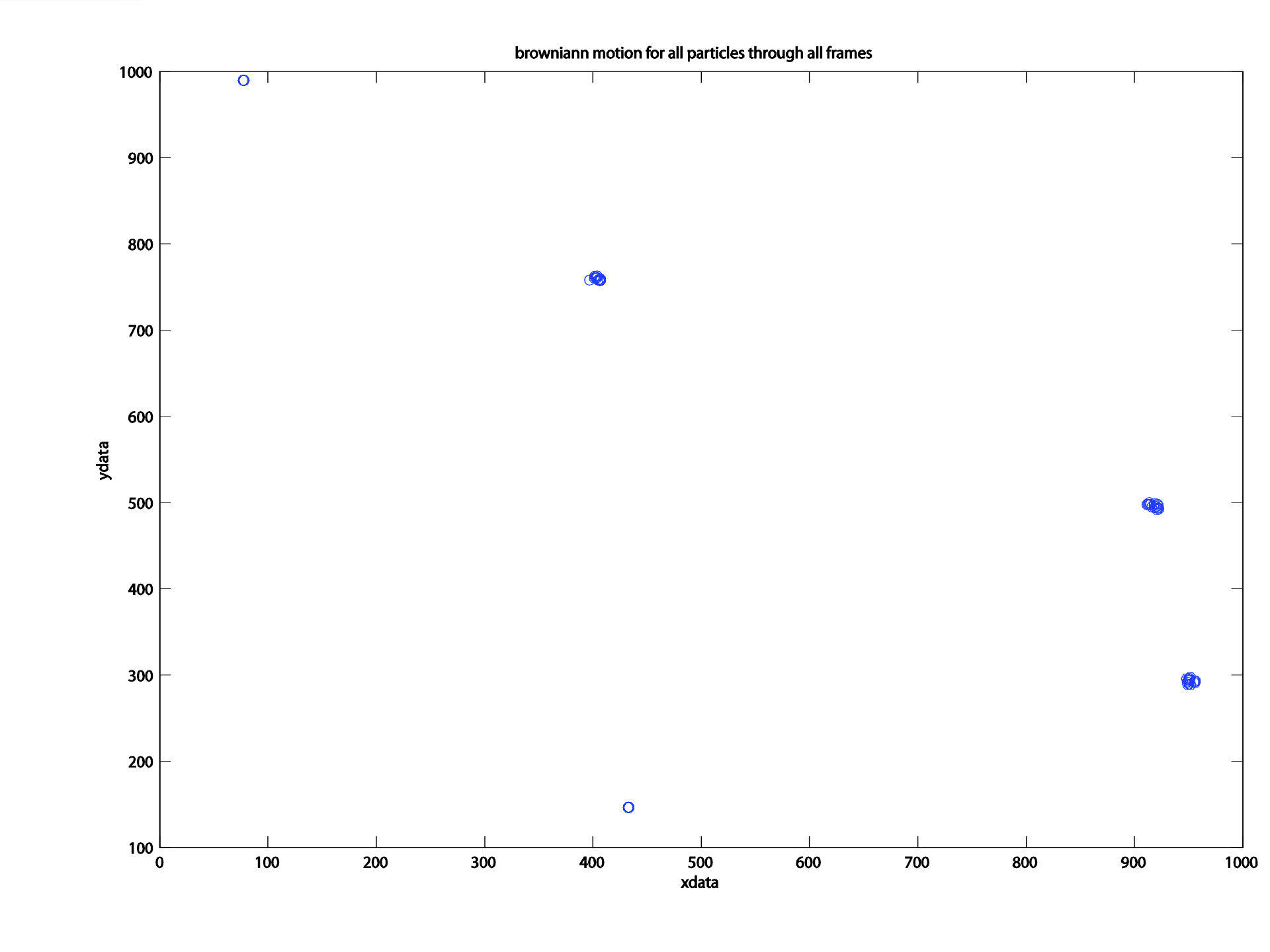
$$m = \frac{4K_BT}{6\Pi\eta a}$$

- We can hence calculate Boltzmann constant, the diffusion constant and Avogadro's constant.

$$D = \frac{K_BT}{\alpha}$$

$$N_A = \frac{2RT}{< r^2 > 3\Pi\eta a}\tau$$


Random brownian motion for one particle
989.78
989.76
989.74
989.72
989.7
989.68
989.66
989.64
989.62
ydata
77.1
77.2
77.3
77.4
77.5
77.6
77.7
xdata


browniann motion for all particles through all frames
ydata
xdata
1000
900
800
700
600
500
400
300
200
100
0
100
200
300
400
500
600
700
800
900
1000