DeepTrack - Example 1b - Training

January 24, 2019

1 Example 1b: Training of DeepTrack 1.0

Example code to train DeepTrack.

DeepTrack 1.0 Digital Video Microscopy enhanced with Deep Learning version 1.0 - 30 November 2018 Í Saga Helgadottir, Aykut Argun & Giovanni Volpe Soft Matter Lab

1.1 1. INITIALIZATION

```
In [1]: import deeptrack
```

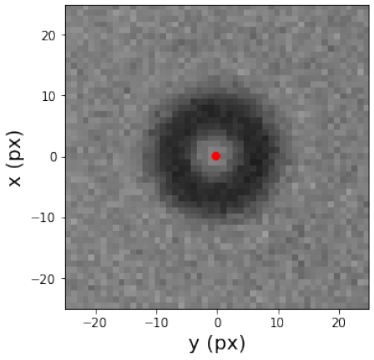
1.2 2. DEFINE AND CHECK IMAGE GENERATION ROUTINE

Here, we simulate images of a variety of single particles. The particle position is chosen randomly from a normal distribution with mean of 0 and standard deviation of 1 pixel. The particle has a radius between 1.5 and 3 pixels, and a point-spread function obtained from Bessel function of the first kind of first or second order with positive or negative intensity. The image background, SNR and gradient intensity are randomly selected from a wide range of values. This results in particle images corresponding to dark or bright spots or rings of different intensities on a brigth or dark background with varying SNR and gradient intensity. This image generator was used to train the pretraiend network saved in the file "DeepTrack - Example 1a - Pretrained network.h5".

Comments: 1. The image_parameters_function is a lambda function that determines the kind of particle images for which the deep learning network will be trained. Tuning its parameters is the simplest way to improve the tracking performance. 2. The image_generator is a lambda function that works as image genrator. It does not need to be changed in most cases. 3. The parameter number_of_images_to_show determines the number of sample images that are shown. 4. The red symbol superimposed to the images represents the ground truth particle position.

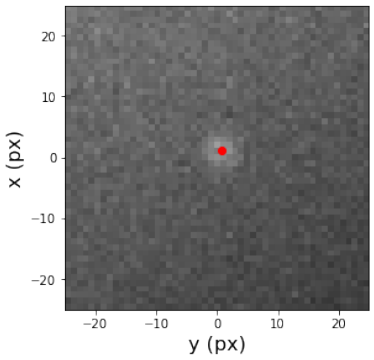
```
In [2]: ### Define image properties
        %matplotlib inline
        from numpy.random import randint, uniform, normal, choice
        from math import pi

        image_parameters_function = lambda : deeptrack.get_image_parameters(
           particle_center_x_list=lambda : normal(0, 1, 1),
           particle_center_y_list=lambda : normal(0, 1, 1),
           particle_radius_list=lambda : uniform(1.5, 3, 1),
           particle_bessel_orders_list=lambda : [[randint(1, 3),], ],
```

```
    particle_intensities_list=lambda : [[choice([-1, 1]) * uniform(.2, .6, 1), ], ],
    image_half_size=lambda : 25,
    image_background_level=lambda : uniform(.2, .8),
    signal_to_noise_ratio=lambda : uniform(10, 100),
    gradient_intensity=lambda : uniform(0, 1),
    gradient_direction=lambda : uniform(-pi, pi))

### Define image generator
image_generator = lambda : deeptrack.get_image_generator(image_parameters_function)

### Show some examples of generated images
number_of_images_to_show = 100

for image_number, image, image_parameters in image_generator():
    if image_number>=number_of_images_to_show:
        break

    deeptrack.plot_sample_image(image, image_parameters)
```



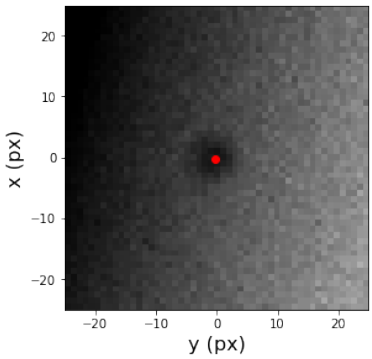
particle center x = 0.21 px
particle center y = -0.36 px
particle radius = 2.99 px
Bessel order = 2.00
particle intensity = -0.46

image half size = 25.00 px
image background level = 0.50
signal to noise ratio = 20.17
gradient intensity = 0.03
gradient direction = -2.96



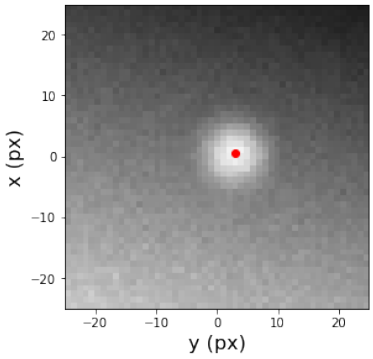
particle center x = 1.21 px
particle center y = 0.68 px
particle radius = 1.62 px
Bessel order = 1.00
particle intensity = 0.21

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 20.46
gradient intensity = 0.23
gradient direction = 2.11



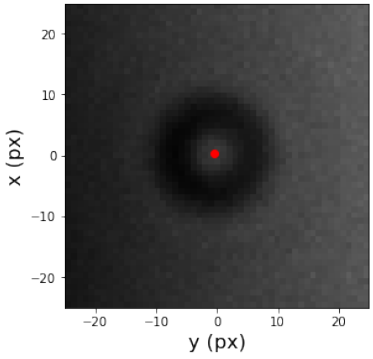
particle center x = -0.36 px
particle center y = -0.36 px
particle radius = 1.86 px
Bessel order = 1.00
particle intensity = -0.20

image half size = 25.00 px
image background level = 0.28
signal to noise ratio = 21.18
gradient intensity = 0.80
gradient direction = -0.28



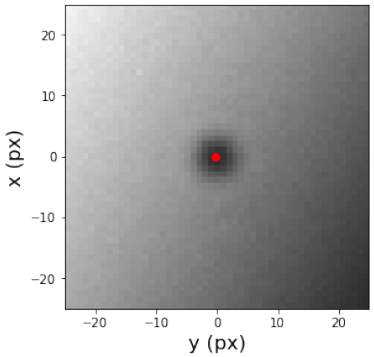
particle center x = 0.62 px
particle center y = 2.93 px
particle radius = 2.56 px
Bessel order = 1.00
particle intensity = 0.53

image half size = 25.00 px
image background level = 0.44
signal to noise ratio = 41.00
gradient intensity = 0.78
gradient direction = -1.84



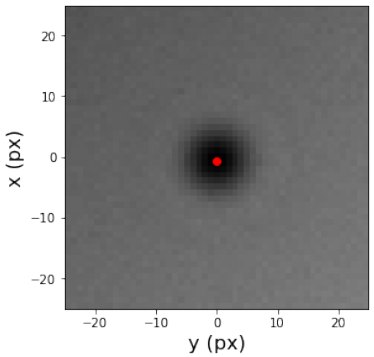
particle center x = 0.30 px
particle center y = -0.51 px
particle radius = 2.78 px
Bessel order = 2.00
particle intensity = -0.23

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 45.92
gradient intensity = 0.37
gradient direction = 0.15



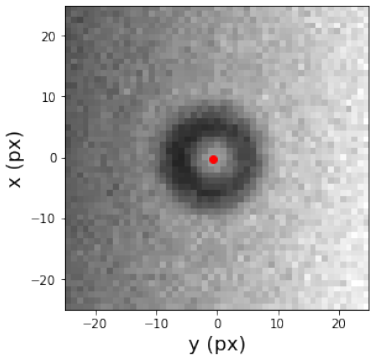
particle center x = -0.15 px
particle center y = -0.22 px
particle radius = 1.86 px
Bessel order = 1.00
particle intensity = -0.39

image half size = 25.00 px
image background level = 0.56
signal to noise ratio = 94.53
gradient intensity = 0.81
gradient direction = 2.60



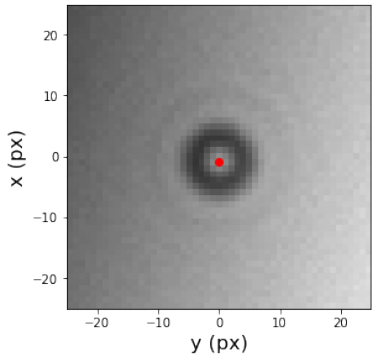
particle center x = -0.61 px
particle center y = 0.00 px
particle radius = 2.67 px
Bessel order = 1.00
particle intensity = -0.41

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 90.82
gradient intensity = 0.15
gradient direction = -0.83



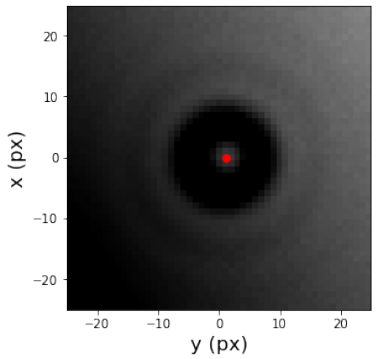
particle center x = -0.29 px
particle center y = -0.65 px
particle radius = 2.42 px
Bessel order = 2.00
particle intensity = -0.57

image half size = 25.00 px
image background level = 0.64
signal to noise ratio = 21.00
gradient intensity = 0.78
gradient direction = -0.10



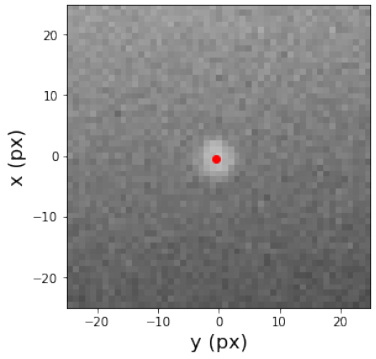
particle center x = -0.80 px
particle center y = 0.02 px
particle radius = 1.69 px
Bessel order = 2.00
particle intensity = -0.48

image half size = 25.00 px
image background level = 0.59
signal to noise ratio = 85.85
gradient intensity = 0.63
gradient direction = -0.30



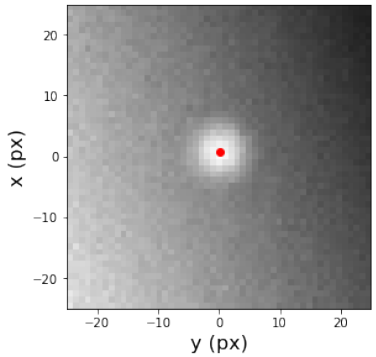
particle center x = 0.03 px
particle center y = 1.21 px
particle radius = 2.32 px
Bessel order = 2.00
particle intensity = -0.55

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 81.18
gradient intensity = 0.62
gradient direction = 0.59



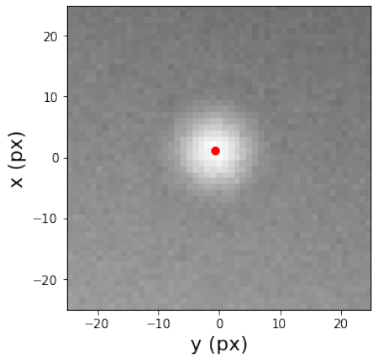
particle center x = -0.49 px
particle center y = -0.48 px
particle radius = 1.57 px
Bessel order = 1.00
particle intensity = 0.31

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 25.72
gradient intensity = 0.36
gradient direction = 1.71



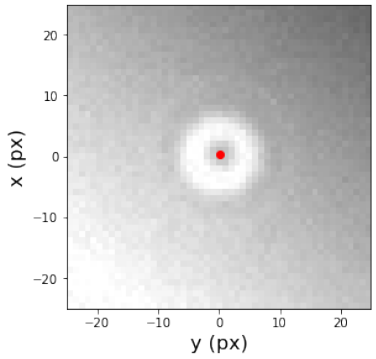
particle center x = 0.85 px
particle center y = 0.23 px
particle radius = 2.22 px
Bessel order = 1.00
particle intensity = 0.49

image half size = 25.00 px
image background level = 0.49
signal to noise ratio = 43.65
gradient intensity = 0.83
gradient direction = -2.75



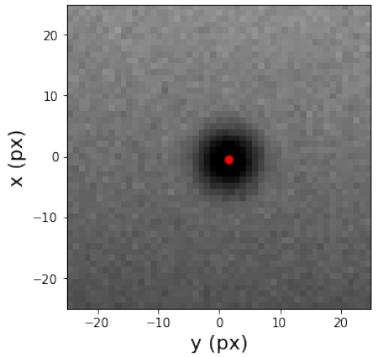
particle center x = 1.14 px
particle center y = -0.75 px
particle radius = 2.98 px
Bessel order = 1.00
particle intensity = 0.46

image half size = 25.00 px
image background level = 0.52
signal to noise ratio = 54.56
gradient intensity = 0.20
gradient direction = -1.87



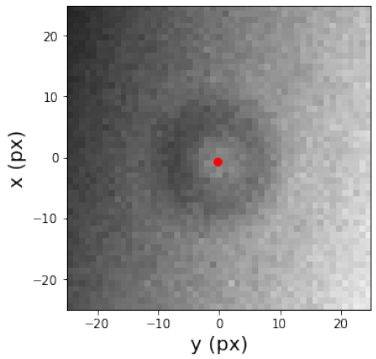
particle center x = 0.28 px
particle center y = 0.20 px
particle radius = 1.83 px
Bessel order = 2.00
particle intensity = 0.39

image half size = 25.00 px
image background level = 0.73
signal to noise ratio = 66.16
gradient intensity = 0.68
gradient direction = -2.29



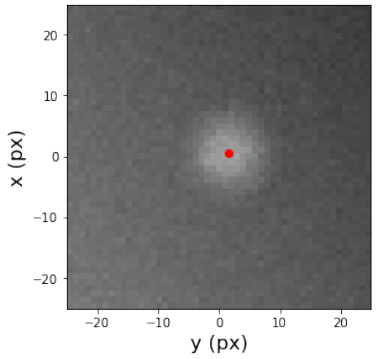
particle center x = -0.51 px
particle center y = 1.51 px
particle radius = 2.71 px
Bessel order = 1.00
particle intensity = -0.55

image half size = 25.00 px
image background level = 0.44
signal to noise ratio = 31.87
gradient intensity = 0.33
gradient direction = 1.53



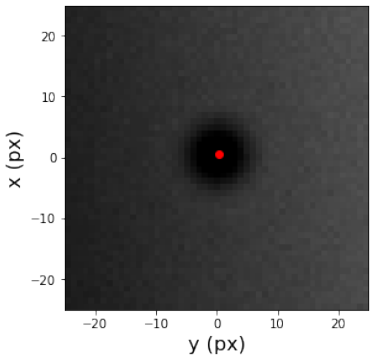
particle center x = -0.74 px
particle center y = -0.28 px
particle radius = 2.98 px
Bessel order = 2.00
particle intensity = -0.21

image half size = 25.00 px
image background level = 0.53
signal to noise ratio = 28.31
gradient intensity = 0.86
gradient direction = -0.27



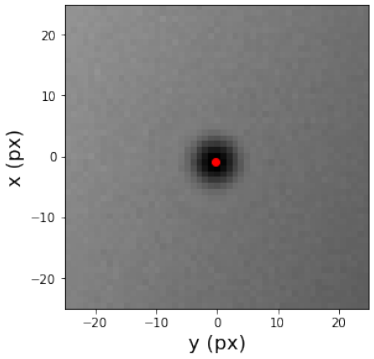
particle center x = 0.64 px
particle center y = 1.64 px
particle radius = 2.92 px
Bessel order = 1.00
particle intensity = 0.28

image half size = 25.00 px
image background level = 0.35
signal to noise ratio = 45.50
gradient intensity = 0.24
gradient direction = -2.54



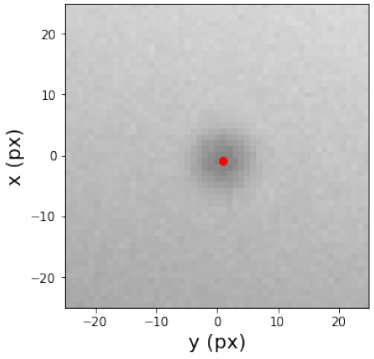
particle center x = 0.48 px
particle center y = 0.33 px
particle radius = 2.61 px
Bessel order = 1.00
particle intensity = -0.34

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 52.71
gradient intensity = 0.26
gradient direction = 0.15



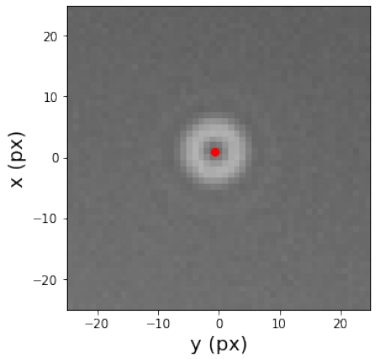
particle center x = -0.95 px
particle center y = -0.36 px
particle radius = 1.89 px
Bessel order = 1.00
particle intensity = -0.51

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 90.66
gradient intensity = 0.23
gradient direction = 2.67



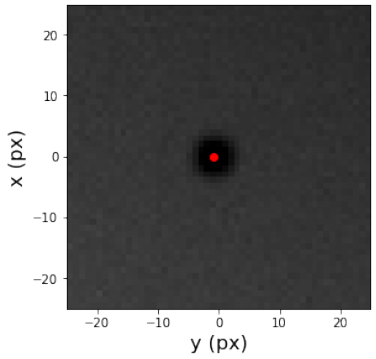
particle center x = -0.83 px
particle center y = 0.87 px
particle radius = 2.58 px
Bessel order = 1.00
particle intensity = -0.23

image half size = 25.00 px
image background level = 0.76
signal to noise ratio = 91.83
gradient intensity = 0.22
gradient direction = 1.31



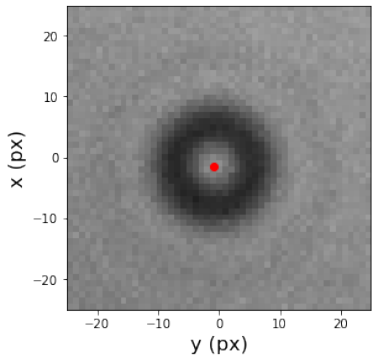
particle center x = 1.00 px
particle center y = -0.66 px
particle radius = 1.50 px
Bessel order = 2.00
particle intensity = 0.38

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 92.34
gradient intensity = 0.08
gradient direction = -1.87



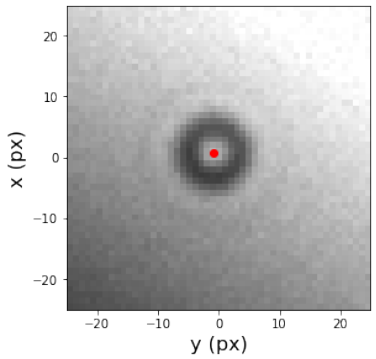
particle center x = -0.15 px
particle center y = -0.82 px
particle radius = 1.65 px
Bessel order = 1.00
particle intensity = -0.33

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 51.98
gradient intensity = 0.08
gradient direction = -2.17



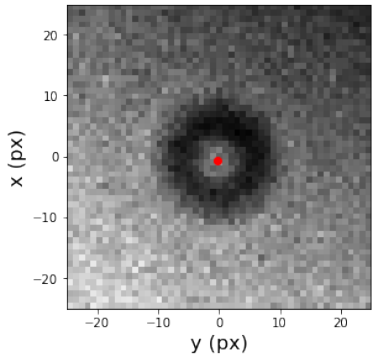
particle center x = -1.39 px
particle center y = -0.81 px
particle radius = 2.84 px
Bessel order = 2.00
particle intensity = -0.52

image half size = 25.00 px
image background level = 0.55
signal to noise ratio = 35.78
gradient intensity = 0.10
gradient direction = 0.98



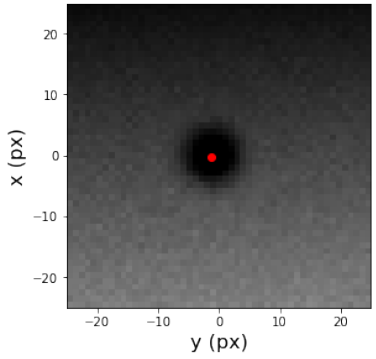
particle center x = 0.78 px
particle center y = -0.82 px
particle radius = 1.80 px
Bessel order = 2.00
particle intensity = -0.59

image half size = 25.00 px
image background level = 0.71
signal to noise ratio = 49.94
gradient intensity = 0.89
gradient direction = 1.03



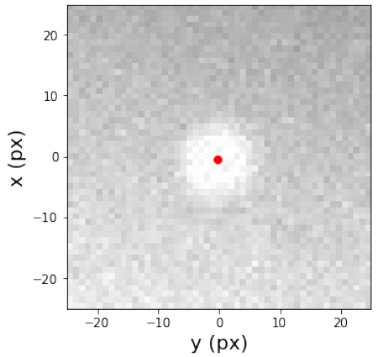
particle center x = -0.71 px
particle center y = -0.22 px
particle radius = 2.65 px
Bessel order = 2.00
particle intensity = -0.56

image half size = 25.00 px
image background level = 0.50
signal to noise ratio = 11.62
gradient intensity = 0.73
gradient direction = -2.07



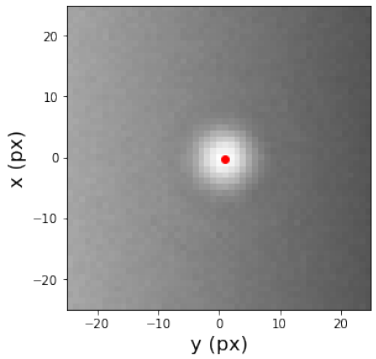
particle center x = -0.27 px
particle center y = -1.19 px
particle radius = 2.40 px
Bessel order = 1.00
particle intensity = -0.43

image half size = 25.00 px
image background level = 0.27
signal to noise ratio = 36.42
gradient intensity = 0.64
gradient direction = -1.54



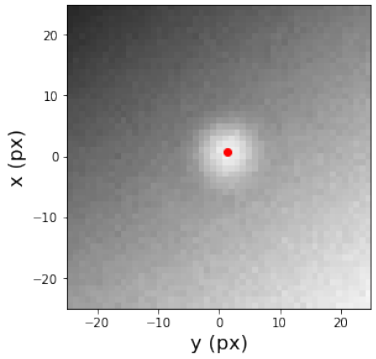
particle center x = -0.50 px
particle center y = -0.31 px
particle radius = 2.80 px
Bessel order = 1.00
particle intensity = 0.35

image half size = 25.00 px
image background level = 0.79
signal to noise ratio = 30.68
gradient intensity = 0.30
gradient direction = -1.82



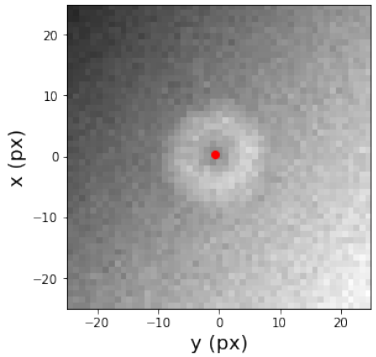
particle center x = -0.20 px
particle center y = 0.89 px
particle radius = 2.32 px
Bessel order = 1.00
particle intensity = 0.51

image half size = 25.00 px
image background level = 0.49
signal to noise ratio = 98.85
gradient intensity = 0.45
gradient direction = -3.12



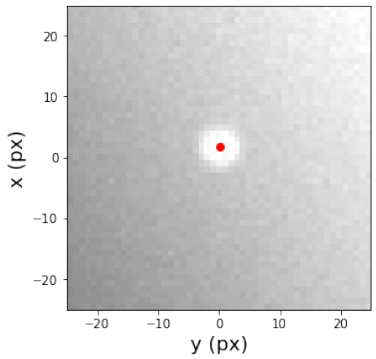
particle center x = 0.78 px
particle center y = 1.36 px
particle radius = 2.40 px
Bessel order = 1.00
particle intensity = 0.38

image half size = 25.00 px
image background level = 0.56
signal to noise ratio = 65.76
gradient intensity = 0.82
gradient direction = -0.92



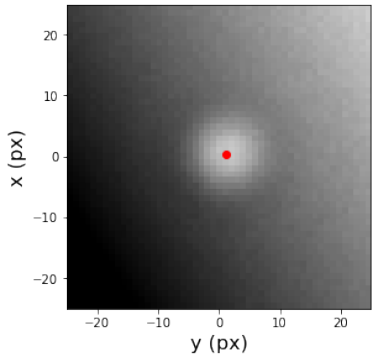
particle center x = 0.28 px
particle center y = -0.58 px
particle radius = 2.17 px
Bessel order = 2.00
particle intensity = 0.27

image half size = 25.00 px
image background level = 0.57
signal to noise ratio = 32.64
gradient intensity = 0.82
gradient direction = -0.66



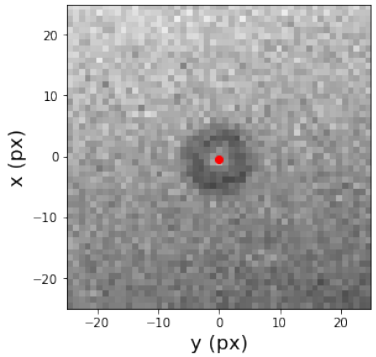
particle center x = 1.68 px
particle center y = 0.12 px
particle radius = 1.53 px
Bessel order = 1.00
particle intensity = 0.42

image half size = 25.00 px
image background level = 0.77
signal to noise ratio = 67.99
gradient intensity = 0.47
gradient direction = 0.59



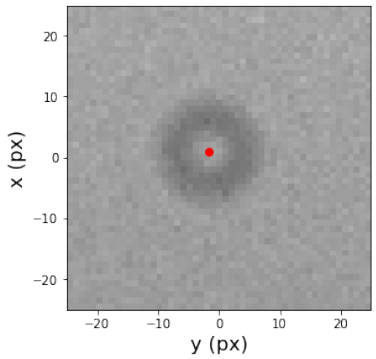
particle center x = 0.44 px
particle center y = 1.24 px
particle radius = 2.88 px
Bessel order = 1.00
particle intensity = 0.43

image half size = 25.00 px
image background level = 0.34
signal to noise ratio = 82.97
gradient intensity = 0.97
gradient direction = 0.57



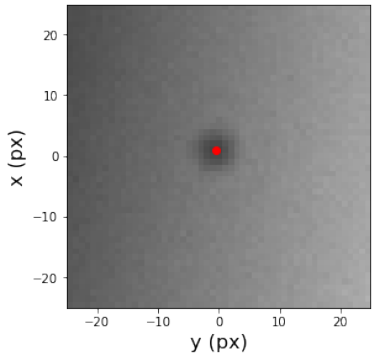
particle center x = -0.56 px
particle center y = -0.11 px
particle radius = 1.68 px
Bessel order = 2.00
particle intensity = -0.35

image half size = 25.00 px
image background level = 0.62
signal to noise ratio = 14.57
gradient intensity = 0.50
gradient direction = 1.79



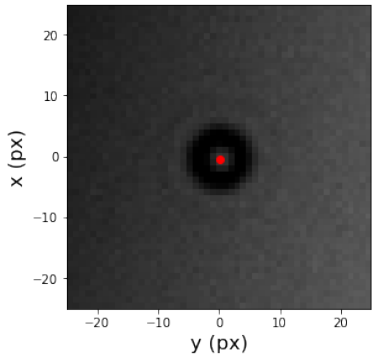
particle center x = 1.03 px
particle center y = -1.58 px
particle radius = 2.34 px
Bessel order = 2.00
particle intensity = -0.22

image half size = 25.00 px
image background level = 0.63
signal to noise ratio = 41.77
gradient intensity = 0.05
gradient direction = 1.62



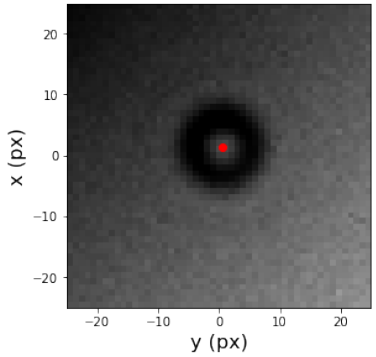
particle center x = 1.00 px
particle center y = -0.51 px
particle radius = 1.67 px
Bessel order = 1.00
particle intensity = -0.22

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 91.21
gradient intensity = 0.46
gradient direction = -0.18



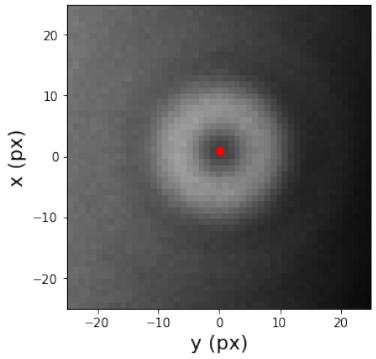
particle center x = -0.43 px
particle center y = 0.24 px
particle radius = 1.51 px
Bessel order = 2.00
particle intensity = -0.37

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 46.95
gradient intensity = 0.29
gradient direction = -0.28



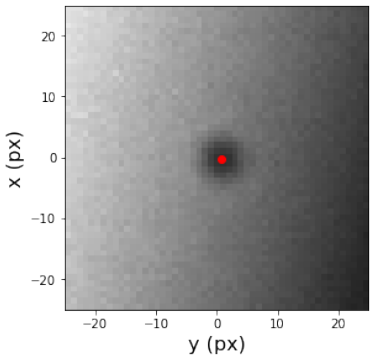
particle center x = 1.30 px
particle center y = 0.61 px
particle radius = 2.07 px
Bessel order = 2.00
particle intensity = -0.41

image half size = 25.00 px
image background level = 0.29
signal to noise ratio = 34.08
gradient intensity = 0.55
gradient direction = -0.83



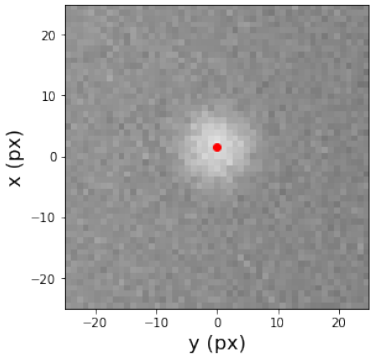
particle center x = 0.93 px
particle center y = 0.05 px
particle radius = 2.96 px
Bessel order = 2.00
particle intensity = 0.42

image half size = 25.00 px
image background level = 0.25
signal to noise ratio = 71.23
gradient intensity = 0.53
gradient direction = 2.98



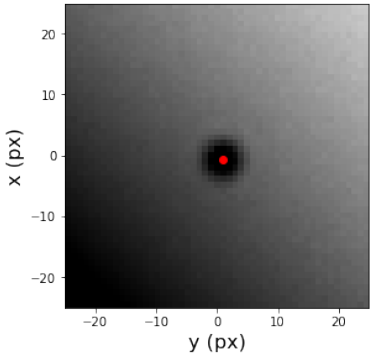
particle center x = -0.26 px
particle center y = 0.74 px
particle radius = 1.92 px
Bessel order = 1.00
particle intensity = -0.32

image half size = 25.00 px
image background level = 0.51
signal to noise ratio = 53.78
gradient intensity = 0.90
gradient direction = 2.89



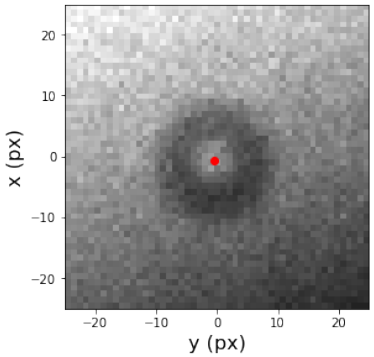
particle center x = 1.54 px
particle center y = -0.13 px
particle radius = 2.96 px
Bessel order = 1.00
particle intensity = 0.32

image half size = 25.00 px
image background level = 0.55
signal to noise ratio = 29.16
gradient intensity = 0.08
gradient direction = 2.97



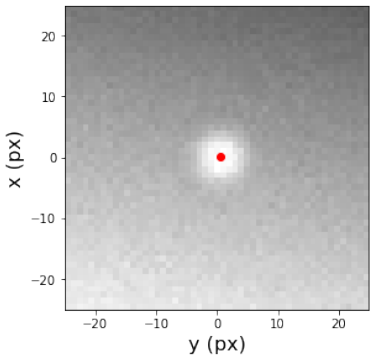
particle center x = -0.73 px
particle center y = 1.01 px
particle radius = 1.62 px
Bessel order = 1.00
particle intensity = -0.53

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 93.95
gradient intensity = 0.90
gradient direction = 0.80



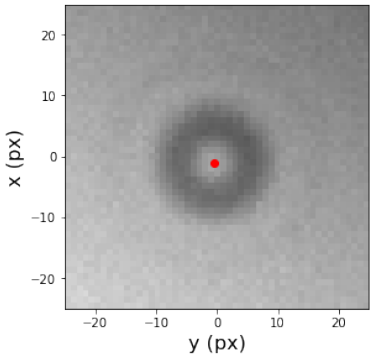
particle center x = -0.73 px
particle center y = -0.52 px
particle radius = 2.77 px
Bessel order = 2.00
particle intensity = -0.36

image half size = 25.00 px
image background level = 0.57
signal to noise ratio = 17.75
gradient intensity = 0.90
gradient direction = 1.95



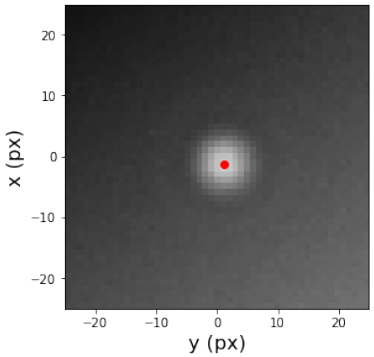
particle center x = 0.07 px
particle center y = 0.60 px
particle radius = 2.07 px
Bessel order = 1.00
particle intensity = 0.39

image half size = 25.00 px
image background level = 0.66
signal to noise ratio = 54.41
gradient intensity = 0.68
gradient direction = -1.79



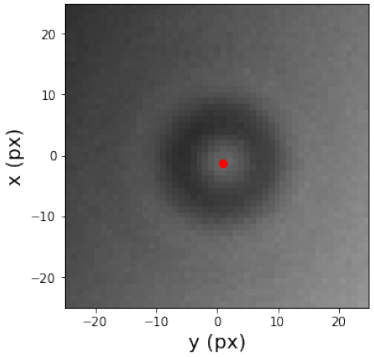
particle center x = -1.10 px
particle center y = -0.56 px
particle radius = 2.59 px
Bessel order = 2.00
particle intensity = -0.34

image half size = 25.00 px
image background level = 0.64
signal to noise ratio = 62.40
gradient intensity = 0.39
gradient direction = -2.14



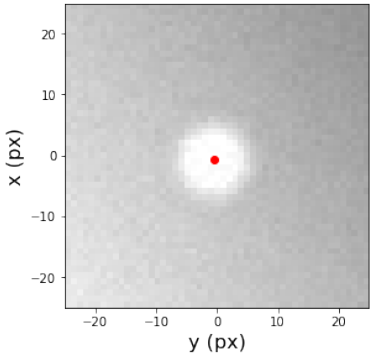
particle center x = -1.21 px
particle center y = 1.18 px
particle radius = 2.12 px
Bessel order = 1.00
particle intensity = 0.54

image half size = 25.00 px
image background level = 0.26
signal to noise ratio = 85.68
gradient intensity = 0.38
gradient direction = -0.95



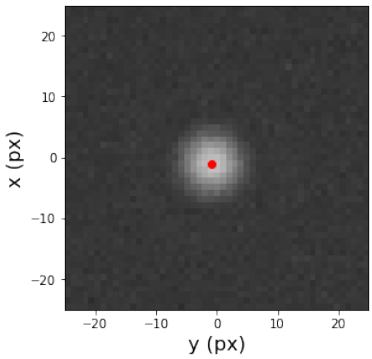
particle center x = -1.18 px
particle center y = 1.02 px
particle radius = 2.90 px
Bessel order = 2.00
particle intensity = -0.24

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 90.64
gradient intensity = 0.42
gradient direction = -0.46



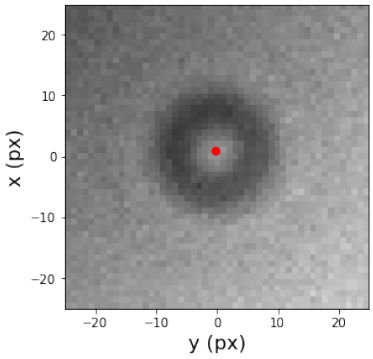
particle center x = -0.73 px
particle center y = -0.53 px
particle radius = 2.58 px
Bessel order = 1.00
particle intensity = 0.51

image half size = 25.00 px
image background level = 0.75
signal to noise ratio = 69.28
gradient intensity = 0.36
gradient direction = -2.57



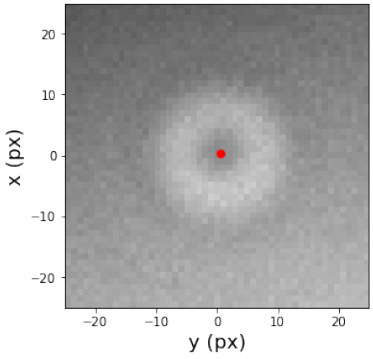
particle center x = -1.11 px
particle center y = -0.84 px
particle radius = 2.43 px
Bessel order = 1.00
particle intensity = 0.55

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 40.43
gradient intensity = 0.01
gradient direction = -1.06



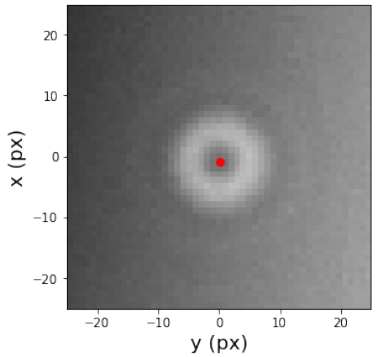
particle center x = 0.86 px
particle center y = -0.27 px
particle radius = 2.88 px
Bessel order = 2.00
particle intensity = -0.37

image half size = 25.00 px
image background level = 0.57
signal to noise ratio = 29.40
gradient intensity = 0.44
gradient direction = -0.77



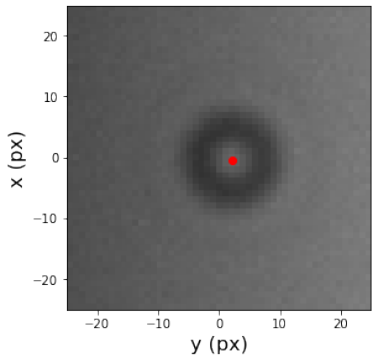
particle center x = 0.37 px
particle center y = 0.63 px
particle radius = 2.93 px
Bessel order = 2.00
particle intensity = 0.26

image half size = 25.00 px
image background level = 0.55
signal to noise ratio = 46.81
gradient intensity = 0.45
gradient direction = -1.31



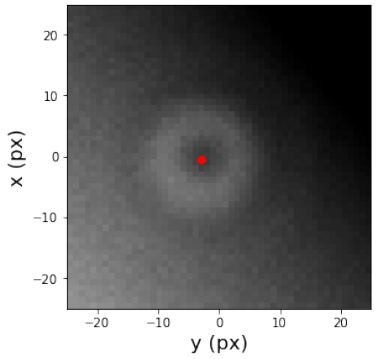
particle center x = -0.88 px
particle center y = 0.09 px
particle radius = 2.12 px
Bessel order = 2.00
particle intensity = 0.38

image half size = 25.00 px
image background level = 0.42
signal to noise ratio = 76.38
gradient intensity = 0.51
gradient direction = -0.23



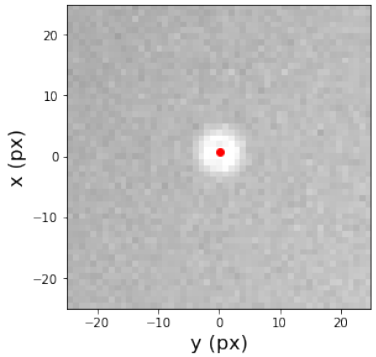
particle center x = -0.40 px
particle center y = 2.14 px
particle radius = 2.29 px
Bessel order = 2.00
particle intensity = -0.25

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 89.13
gradient intensity = 0.25
gradient direction = -0.06



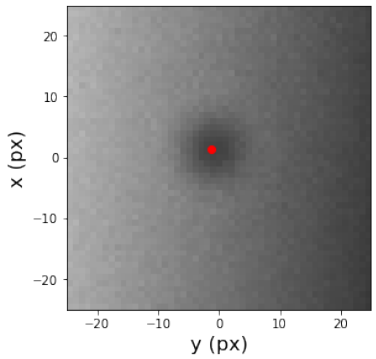
particle center x = -0.40 px
particle center y = -2.86 px
particle radius = 2.58 px
Bessel order = 2.00
particle intensity = 0.21

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 50.35
gradient intensity = 0.74
gradient direction = -2.45



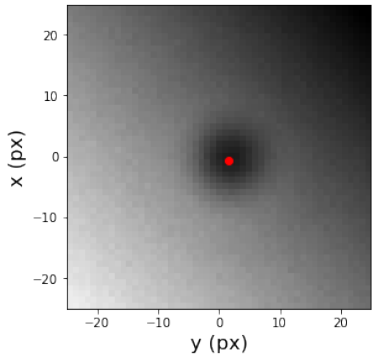
particle center x = 0.79 px
particle center y = 0.22 px
particle radius = 1.79 px
Bessel order = 1.00
particle intensity = 0.45

image half size = 25.00 px
image background level = 0.73
signal to noise ratio = 43.05
gradient intensity = 0.11
gradient direction = -0.49



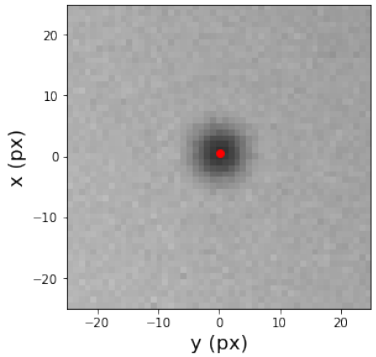
particle center x = 1.39 px
particle center y = -1.30 px
particle radius = 2.81 px
Bessel order = 1.00
particle intensity = -0.22

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 67.67
gradient intensity = 0.63
gradient direction = 3.05



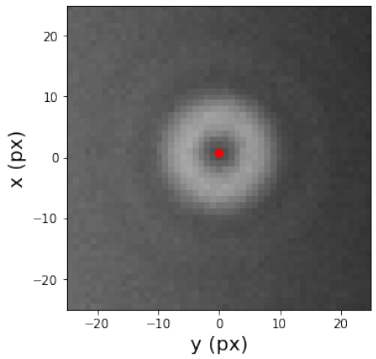
particle center x = -0.69 px
particle center y = 1.53 px
particle radius = 2.98 px
Bessel order = 1.00
particle intensity = -0.33

image half size = 25.00 px
image background level = 0.46
signal to noise ratio = 98.23
gradient intensity = 0.97
gradient direction = -2.41



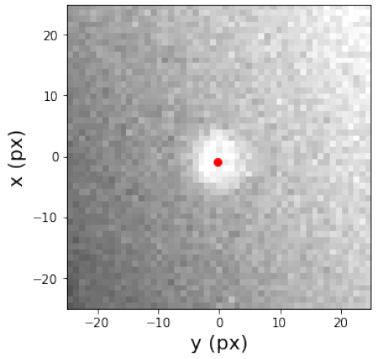
particle center x = 0.55 px
particle center y = 0.05 px
particle radius = 2.33 px
Bessel order = 1.00
particle intensity = -0.47

image half size = 25.00 px
image background level = 0.66
signal to noise ratio = 52.22
gradient intensity = 0.11
gradient direction = -2.70



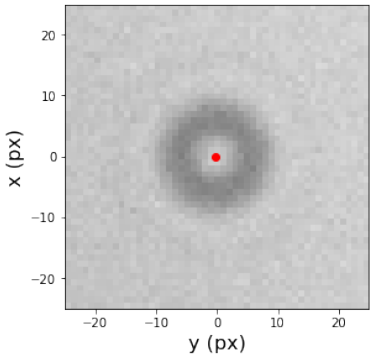
particle center x = 0.74 px
particle center y = -0.02 px
particle radius = 2.49 px
Bessel order = 2.00
particle intensity = 0.44

image half size = 25.00 px
image background level = 0.30
signal to noise ratio = 62.00
gradient intensity = 0.28
gradient direction = -3.02



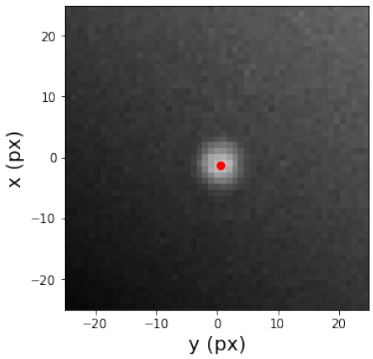
particle center x = -0.82 px
particle center y = -0.22 px
particle radius = 2.33 px
Bessel order = 1.00
particle intensity = 0.45

image half size = 25.00 px
image background level = 0.69
signal to noise ratio = 21.06
gradient intensity = 0.65
gradient direction = 0.46



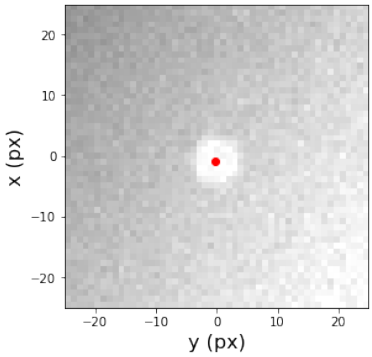
particle center x = 0.01 px
particle center y = -0.25 px
particle radius = 2.54 px
Bessel order = 2.00
particle intensity = -0.36

image half size = 25.00 px
image background level = 0.79
signal to noise ratio = 52.94
gradient intensity = 0.06
gradient direction = 0.44



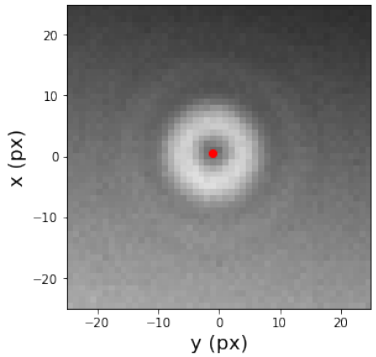
particle center x = -1.23 px
particle center y = 0.55 px
particle radius = 1.67 px
Bessel order = 1.00
particle intensity = 0.56

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 38.88
gradient intensity = 0.38
gradient direction = 0.89



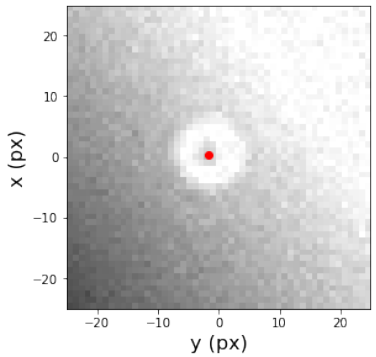
particle center x = -0.95 px
particle center y = -0.25 px
particle radius = 1.64 px
Bessel order = 1.00
particle intensity = 0.52

image half size = 25.00 px
image background level = 0.80
signal to noise ratio = 34.99
gradient intensity = 0.44
gradient direction = -0.61



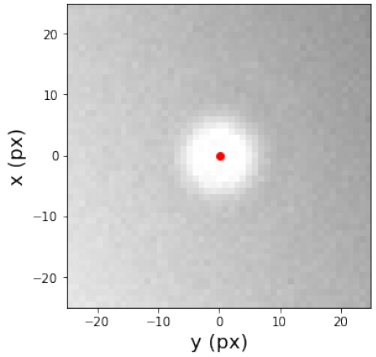
particle center x = 0.60 px
particle center y = -1.06 px
particle radius = 2.13 px
Bessel order = 2.00
particle intensity = 0.55

image half size = 25.00 px
image background level = 0.42
signal to noise ratio = 63.62
gradient intensity = 0.61
gradient direction = -1.74



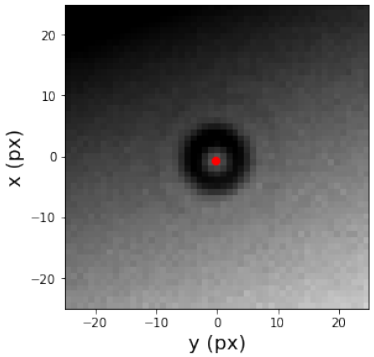
particle center x = 0.41 px
particle center y = -1.73 px
particle radius = 1.59 px
Bessel order = 2.00
particle intensity = 0.41

image half size = 25.00 px
image background level = 0.78
signal to noise ratio = 30.98
gradient intensity = 0.97
gradient direction = 0.70



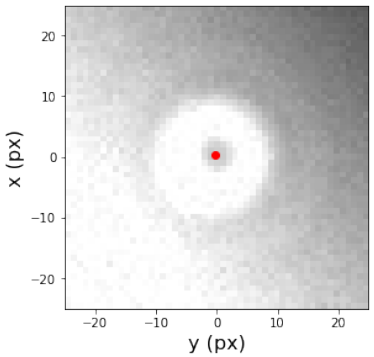
particle center x = -0.08 px
particle center y = 0.18 px
particle radius = 2.79 px
Bessel order = 1.00
particle intensity = 0.50

image half size = 25.00 px
image background level = 0.74
signal to noise ratio = 79.76
gradient intensity = 0.34
gradient direction = -2.69



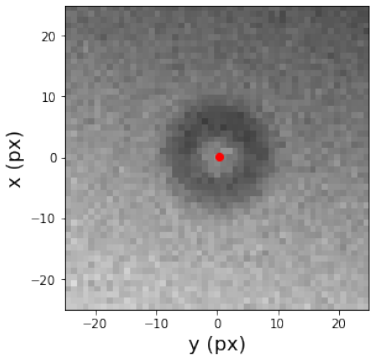
particle center x = -0.68 px
particle center y = -0.23 px
particle radius = 1.60 px
Bessel order = 2.00
particle intensity = -0.49

image half size = 25.00 px
image background level = 0.35
signal to noise ratio = 50.42
gradient intensity = 0.99
gradient direction = -1.21



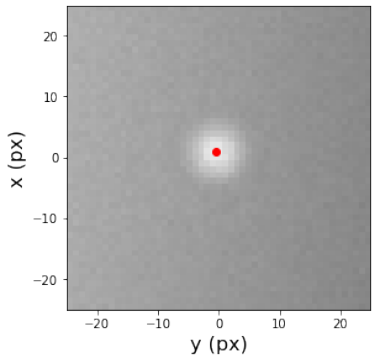
particle center x = 0.27 px
particle center y = -0.27 px
particle radius = 2.54 px
Bessel order = 2.00
particle intensity = 0.48

image half size = 25.00 px
image background level = 0.78
signal to noise ratio = 46.14
gradient intensity = 0.88
gradient direction = -2.42



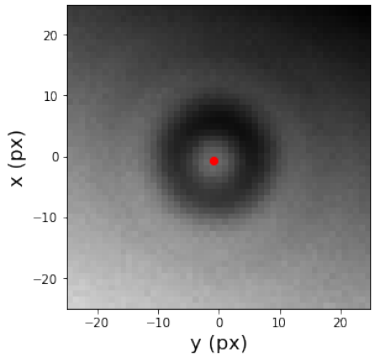
particle center x = 0.18 px
particle center y = 0.30 px
particle radius = 2.52 px
Bessel order = 2.00
particle intensity = -0.31

image half size = 25.00 px
image background level = 0.55
signal to noise ratio = 24.46
gradient intensity = 0.54
gradient direction = -1.84



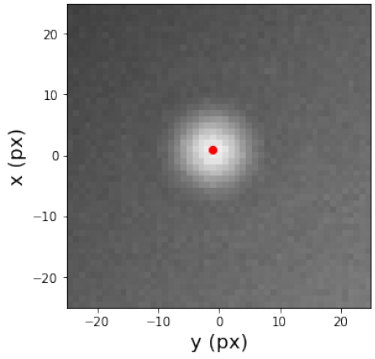
particle center x = 0.87 px
particle center y = -0.37 px
particle radius = 2.10 px
Bessel order = 1.00
particle intensity = 0.30

image half size = 25.00 px
image background level = 0.61
signal to noise ratio = 99.45
gradient intensity = 0.20
gradient direction = 3.01



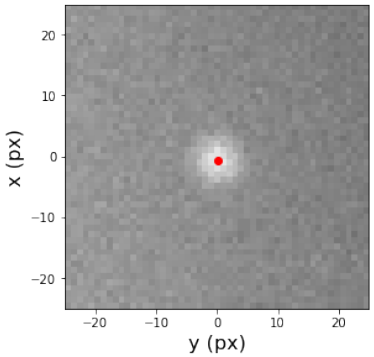
particle center x = -0.70 px
particle center y = -0.82 px
particle radius = 2.78 px
Bessel order = 2.00
particle intensity = -0.39

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 74.32
gradient intensity = 0.91
gradient direction = -1.95



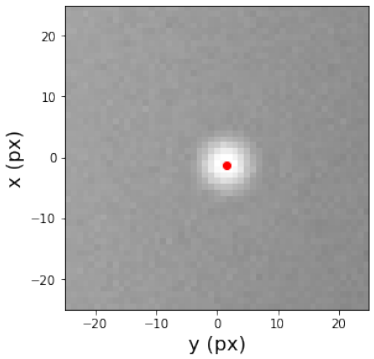
particle center x = 0.86 px
particle center y = -1.13 px
particle radius = 2.84 px
Bessel order = 1.00
particle intensity = 0.57

image half size = 25.00 px
image background level = 0.37
signal to noise ratio = 58.23
gradient intensity = 0.23
gradient direction = -0.72



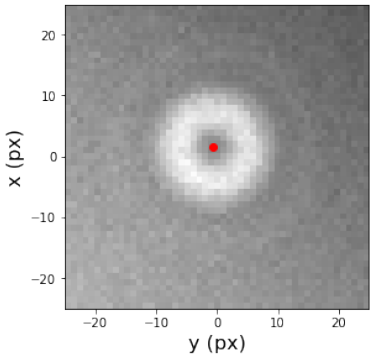
particle center x = -0.75 px
particle center y = 0.16 px
particle radius = 1.99 px
Bessel order = 1.00
particle intensity = 0.35

image half size = 25.00 px
image background level = 0.55
signal to noise ratio = 32.00
gradient intensity = 0.16
gradient direction = -2.88



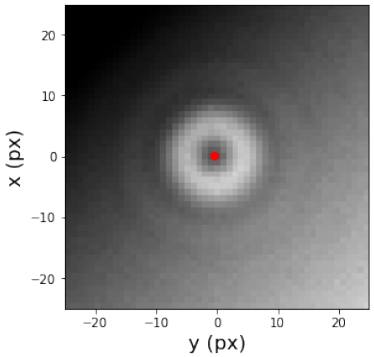
particle center x = -1.25 px
particle center y = 1.54 px
particle radius = 1.98 px
Bessel order = 1.00
particle intensity = 0.47

image half size = 25.00 px
image background level = 0.59
signal to noise ratio = 75.44
gradient intensity = 0.13
gradient direction = 2.95



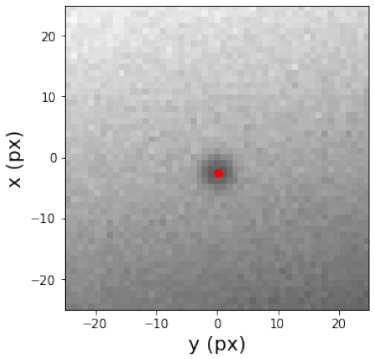
particle center x = 1.53 px
particle center y = -0.63 px
particle radius = 2.49 px
Bessel order = 2.00
particle intensity = 0.52

image half size = 25.00 px
image background level = 0.53
signal to noise ratio = 37.24
gradient intensity = 0.36
gradient direction = -2.38



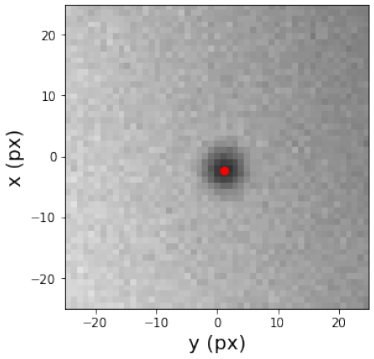
particle center x = 0.15 px
particle center y = -0.50 px
particle radius = 2.09 px
Bessel order = 2.00
particle intensity = 0.57

image half size = 25.00 px
image background level = 0.33
signal to noise ratio = 85.19
gradient intensity = 0.94
gradient direction = -0.81



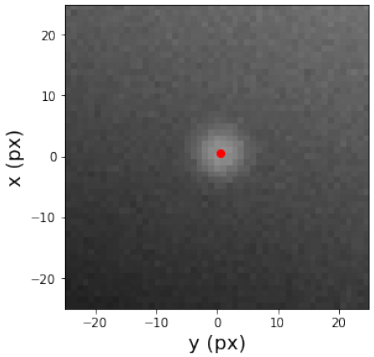
particle center x = -2.43 px
particle center y = 0.11 px
particle radius = 1.52 px
Bessel order = 1.00
particle intensity = -0.32

image half size = 25.00 px
image background level = 0.67
signal to noise ratio = 37.63
gradient intensity = 0.64
gradient direction = 1.81



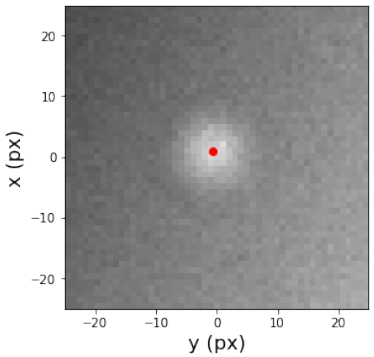
particle center x = -2.22 px
particle center y = 1.19 px
particle radius = 1.82 px
Bessel order = 1.00
particle intensity = -0.49

image half size = 25.00 px
image background level = 0.67
signal to noise ratio = 33.15
gradient intensity = 0.39
gradient direction = -2.86



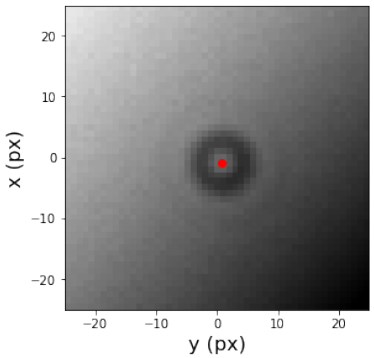
particle center x = 0.55 px
particle center y = 0.62 px
particle radius = 2.19 px
Bessel order = 1.00
particle intensity = 0.28

image half size = 25.00 px
image background level = 0.29
signal to noise ratio = 43.35
gradient intensity = 0.35
gradient direction = 1.19



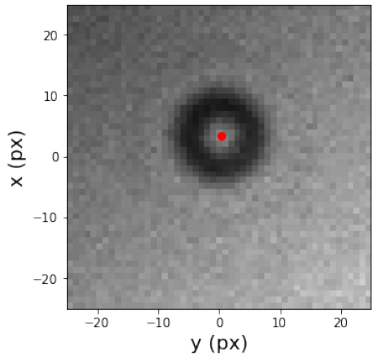
particle center x = 0.89 px
particle center y = -0.74 px
particle radius = 2.77 px
Bessel order = 1.00
particle intensity = 0.34

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 40.75
gradient intensity = 0.38
gradient direction = -0.51



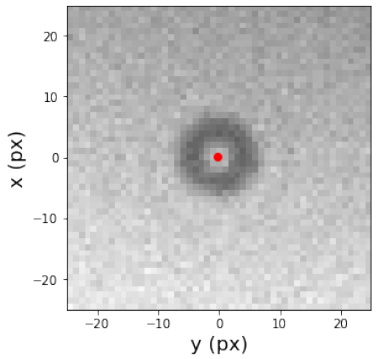
particle center x = -0.92 px
particle center y = 0.81 px
particle radius = 1.52 px
Bessel order = 2.00
particle intensity = -0.30

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 96.29
gradient intensity = 0.96
gradient direction = 2.40



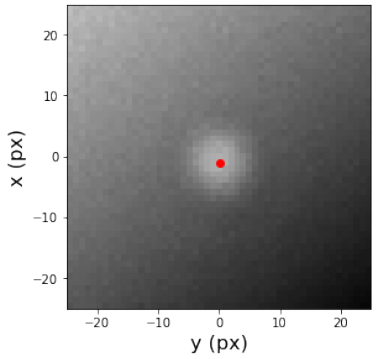
particle center x = 3.32 px
particle center y = 0.29 px
particle radius = 2.20 px
Bessel order = 2.00
particle intensity = -0.52

image half size = 25.00 px
image background level = 0.52
signal to noise ratio = 27.12
gradient intensity = 0.46
gradient direction = -0.89



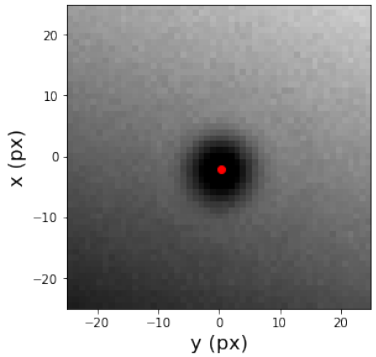
particle center x = 0.12 px
particle center y = -0.26 px
particle radius = 1.88 px
Bessel order = 2.00
particle intensity = -0.47

image half size = 25.00 px
image background level = 0.75
signal to noise ratio = 26.77
gradient intensity = 0.37
gradient direction = -1.77



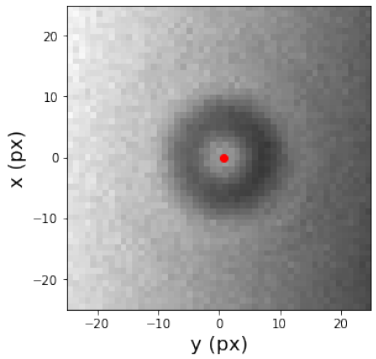
particle center x = -1.05 px
particle center y = 0.10 px
particle radius = 2.52 px
Bessel order = 1.00
particle intensity = 0.32

image half size = 25.00 px
image background level = 0.38
signal to noise ratio = 69.85
gradient intensity = 0.72
gradient direction = 2.24



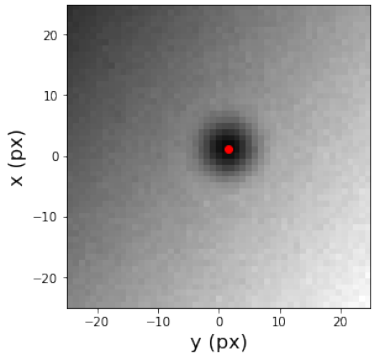
particle center x = -2.15 px
particle center y = 0.30 px
particle radius = 2.78 px
Bessel order = 1.00
particle intensity = -0.60

image half size = 25.00 px
image background level = 0.46
signal to noise ratio = 54.92
gradient intensity = 0.76
gradient direction = 1.19



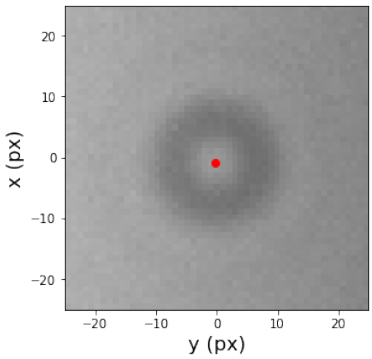
particle center x = -0.04 px
particle center y = 0.85 px
particle radius = 2.72 px
Bessel order = 2.00
particle intensity = -0.41

image half size = 25.00 px
image background level = 0.62
signal to noise ratio = 40.02
gradient intensity = 0.83
gradient direction = 2.98



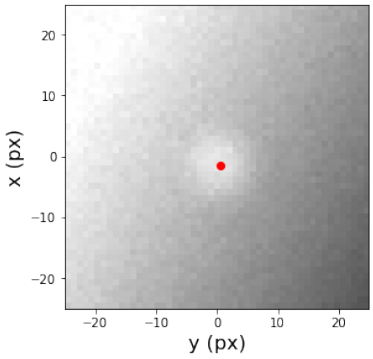
particle center x = 1.21 px
particle center y = 1.64 px
particle radius = 2.34 px
Bessel order = 1.00
particle intensity = -0.57

image half size = 25.00 px
image background level = 0.58
signal to noise ratio = 67.37
gradient intensity = 0.81
gradient direction = -0.65



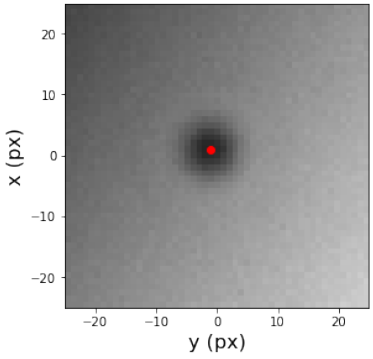
particle center x = -0.94 px
particle center y = -0.23 px
particle radius = 2.97 px
Bessel order = 2.00
particle intensity = -0.21

image half size = 25.00 px
image background level = 0.61
signal to noise ratio = 88.69
gradient intensity = 0.22
gradient direction = -3.13



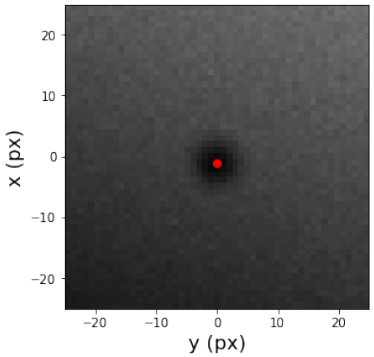
particle center x = -1.48 px
particle center y = 0.51 px
particle radius = 2.66 px
Bessel order = 1.00
particle intensity = 0.20

image half size = 25.00 px
image background level = 0.72
signal to noise ratio = 65.50
gradient intensity = 0.81
gradient direction = 2.62



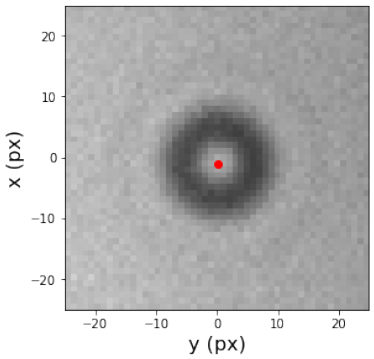
particle center x = 0.88 px
particle center y = -1.11 px
particle radius = 2.42 px
Bessel order = 1.00
particle intensity = -0.39

image half size = 25.00 px
image background level = 0.54
signal to noise ratio = 85.57
gradient intensity = 0.55
gradient direction = -0.61



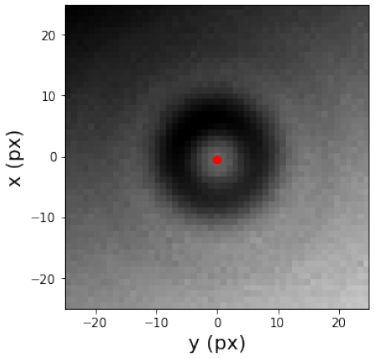
particle center x = -1.11 px
particle center y = -0.06 px
particle radius = 1.94 px
Bessel order = 1.00
particle intensity = -0.24

image half size = 25.00 px
image background level = 0.26
signal to noise ratio = 43.54
gradient intensity = 0.36
gradient direction = 1.21



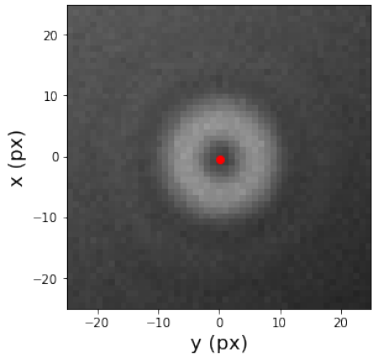
particle center x = -0.98 px
particle center y = 0.22 px
particle radius = 2.56 px
Bessel order = 2.00
particle intensity = -0.54

image half size = 25.00 px
image background level = 0.67
signal to noise ratio = 39.67
gradient intensity = 0.20
gradient direction = -2.89



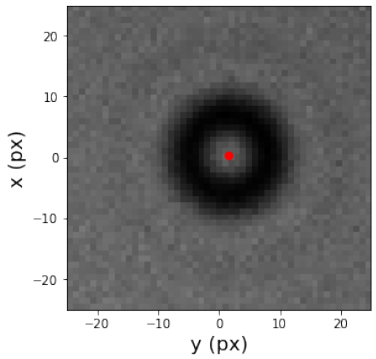
particle center x = -0.54 px
particle center y = -0.00 px
particle radius = 2.91 px
Bessel order = 2.00
particle intensity = -0.45

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 54.62
gradient intensity = 0.84
gradient direction = -1.10



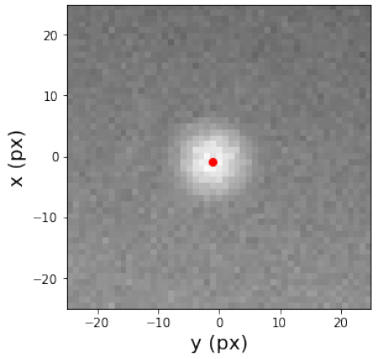
particle center x = -0.48 px
particle center y = 0.22 px
particle radius = 2.60 px
Bessel order = 2.00
particle intensity = 0.43

image half size = 25.00 px
image background level = 0.25
signal to noise ratio = 47.47
gradient intensity = 0.21
gradient direction = 2.20



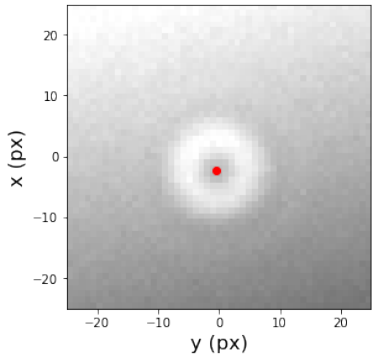
particle center x = 0.43 px
particle center y = 1.57 px
particle radius = 2.85 px
Bessel order = 2.00
particle intensity = -0.51

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 28.97
gradient intensity = 0.06
gradient direction = -2.21



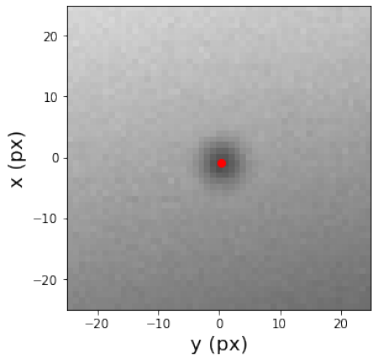
particle center x = -0.77 px
particle center y = -1.09 px
particle radius = 2.77 px
Bessel order = 1.00
particle intensity = 0.46

image half size = 25.00 px
image background level = 0.50
signal to noise ratio = 34.08
gradient intensity = 0.18
gradient direction = -1.70



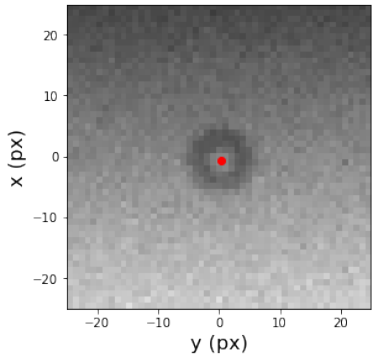
particle center x = -2.24 px
particle center y = -0.46 px
particle radius = 2.18 px
Bessel order = 2.00
particle intensity = 0.32

image half size = 25.00 px
image background level = 0.75
signal to noise ratio = 84.59
gradient intensity = 0.69
gradient direction = 1.82



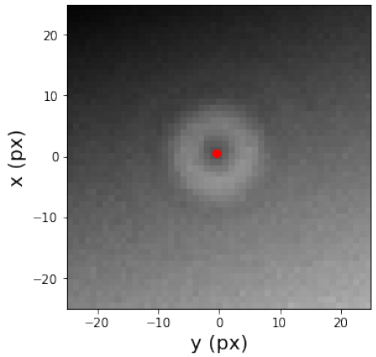
particle center x = -0.87 px
particle center y = 0.43 px
particle radius = 1.93 px
Bessel order = 1.00
particle intensity = -0.32

image half size = 25.00 px
image background level = 0.64
signal to noise ratio = 78.82
gradient intensity = 0.49
gradient direction = 1.82



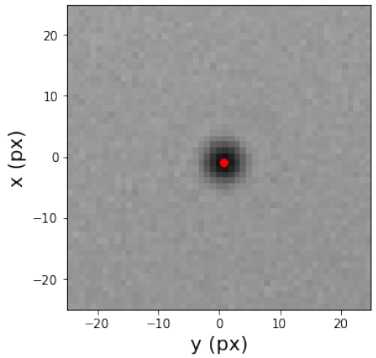
particle center x = -0.62 px
particle center y = 0.32 px
particle radius = 1.55 px
Bessel order = 2.00
particle intensity = -0.26

image half size = 25.00 px
image background level = 0.54
signal to noise ratio = 29.89
gradient intensity = 0.73
gradient direction = -1.55



particle center x = 0.58 px
particle center y = -0.41 px
particle radius = 2.10 px
Bessel order = 2.00
particle intensity = 0.26

image half size = 25.00 px
image background level = 0.34
signal to noise ratio = 63.96
gradient intensity = 0.75
gradient direction = -1.24



particle center x = -0.93 px
particle center y = 0.82 px
particle radius = 1.73 px
Bessel order = 1.00
particle intensity = -0.55

image half size = 25.00 px
image background level = 0.59
signal to noise ratio = 55.72
gradient intensity = 0.04
gradient direction = 1.86

1.3 3. CREATE AND COMPILE DEEP LEARNING NETWORK

The parameters of the deep learning network are defined and the network created. The summary of the network is printed where the output shape and number of parameters for each layer can be visualized.

Comments: 1. The parameter input_shape determines the shape of the input image (x-pixels by y-pixels by color channels). 2. The parmameter conv_layers_dimensions determines the number and size of convolutional layers. 3. The parameter dense_layers_dimensions determines the number and size of dense layers.

```
In [3]: ### Define parameters of the deep learning network
        input_shape = (51, 51, 1) # Change to determine the shape of the input image [x-pixels
        conv_layers_dimensions = (16, 32, 64) # Change to determine the number and size of con
        dense_layers_dimensions = (32, 32) # Change to determine the numebr and size of dense

        ### Create deep learning network
        network = deeptrack.create_deep_learning_network(input_shape, conv_layers_dimensions, c

        ### Print deep learning network summary
        network.summary()
```

```
/anaconda3/lib/python3.6/site-packages/h5py/__init__.py:36: FutureWarning: Conversion of the se
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv_1 (Conv2D)              (None, 49, 49, 16)        160
_________________________________________________________________
pooling_1 (MaxPooling2D)     (None, 24, 24, 16)        0
_________________________________________________________________
conv_2 (Conv2D)              (None, 22, 22, 32)        4640
_________________________________________________________________
pooling_2 (MaxPooling2D)     (None, 11, 11, 32)        0
_________________________________________________________________
conv_3 (Conv2D)              (None, 9, 9, 64)          18496
_________________________________________________________________
pooling_3 (MaxPooling2D)     (None, 4, 4, 64)          0
_________________________________________________________________
flatten (Flatten)            (None, 1024)              0
_________________________________________________________________
dense_1 (Dense)              (None, 32)                32800
_________________________________________________________________
dense_2 (Dense)              (None, 32)                1056
_________________________________________________________________
output (Dense)               (None, 3)                 99
=================================================================
Total params: 57,251
Trainable params: 57,251
Non-trainable params: 0
_________________________________________________________________
```

1.4 4. TRAIN DEEP LEARNING NETWORK

The parameters for the training of the deep learning network are defined and the network is trained. The sample size, iteration number, MSE, MAE and the time of each iteration is printed.

Comments: 1. The parameter sample_sizes determines the sizes of the batches of images used in the training. 2. The parameter iteration_numbers determines the numbers of batches used in the training. 3. The parameter verbose determines the frequency of the update messages. It can be either a boolean value (True/False) or a number between 0 and 1.

In [4]:
```
### Define parameters of the training
sample_sizes = (8, 32, 128, 512, 1024)
iteration_numbers = (4001, 3001, 2001, 1001, 101)
verbose = .01
```

```
        ### Training
        training_history = deeptrack.train_deep_learning_network(network, image_generator, samp
```

```
Sample size      8   iteration number      1   MSE       2.79 px^2   MAE       1.20 px   Time
Sample size      8   iteration number    101   MSE       0.89 px^2   MAE       0.73 px   Time
Sample size      8   iteration number    201   MSE       0.55 px^2   MAE       0.58 px   Time
Sample size      8   iteration number    301   MSE       0.17 px^2   MAE       0.34 px   Time
Sample size      8   iteration number    401   MSE       0.17 px^2   MAE       0.34 px   Time
Sample size      8   iteration number    501   MSE       0.10 px^2   MAE       0.26 px   Time
Sample size      8   iteration number    601   MSE       0.09 px^2   MAE       0.25 px   Time
Sample size      8   iteration number    701   MSE       0.07 px^2   MAE       0.21 px   Time
Sample size      8   iteration number    801   MSE       0.06 px^2   MAE       0.20 px   Time
Sample size      8   iteration number    901   MSE       0.05 px^2   MAE       0.19 px   Time
Sample size      8   iteration number   1001   MSE       0.05 px^2   MAE       0.19 px   Time
Sample size      8   iteration number   1101   MSE       0.08 px^2   MAE       0.23 px   Time
Sample size      8   iteration number   1201   MSE       0.15 px^2   MAE       0.23 px   Time
Sample size      8   iteration number   1301   MSE       0.08 px^2   MAE       0.21 px   Time
Sample size      8   iteration number   1401   MSE       0.13 px^2   MAE       0.29 px   Time
Sample size      8   iteration number   1501   MSE       0.05 px^2   MAE       0.19 px   Time
Sample size      8   iteration number   1601   MSE       0.04 px^2   MAE       0.17 px   Time
Sample size      8   iteration number   1701   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size      8   iteration number   1801   MSE       0.03 px^2   MAE       0.14 px   Time
Sample size      8   iteration number   1901   MSE       0.10 px^2   MAE       0.25 px   Time
Sample size      8   iteration number   2001   MSE       0.06 px^2   MAE       0.19 px   Time
Sample size      8   iteration number   2101   MSE       0.14 px^2   MAE       0.31 px   Time
Sample size      8   iteration number   2201   MSE       0.09 px^2   MAE       0.24 px   Time
Sample size      8   iteration number   2301   MSE       0.04 px^2   MAE       0.18 px   Time
Sample size      8   iteration number   2401   MSE       0.13 px^2   MAE       0.30 px   Time
Sample size      8   iteration number   2501   MSE       0.03 px^2   MAE       0.15 px   Time
Sample size      8   iteration number   2601   MSE       0.09 px^2   MAE       0.25 px   Time
Sample size      8   iteration number   2701   MSE       0.04 px^2   MAE       0.17 px   Time
Sample size      8   iteration number   2801   MSE       0.03 px^2   MAE       0.13 px   Time
Sample size      8   iteration number   2901   MSE       0.03 px^2   MAE       0.13 px   Time
Sample size      8   iteration number   3001   MSE       0.05 px^2   MAE       0.16 px   Time
Sample size      8   iteration number   3101   MSE       0.04 px^2   MAE       0.15 px   Time
Sample size      8   iteration number   3201   MSE       0.07 px^2   MAE       0.22 px   Time
Sample size      8   iteration number   3301   MSE       0.04 px^2   MAE       0.15 px   Time
Sample size      8   iteration number   3401   MSE       0.08 px^2   MAE       0.24 px   Time
Sample size      8   iteration number   3501   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size      8   iteration number   3601   MSE       0.03 px^2   MAE       0.13 px   Time
Sample size      8   iteration number   3701   MSE       0.04 px^2   MAE       0.16 px   Time
Sample size      8   iteration number   3801   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size      8   iteration number   3901   MSE       0.03 px^2   MAE       0.14 px   Time
Sample size      8   iteration number   4001   MSE       0.04 px^2   MAE       0.16 px   Time
Sample size     32   iteration number      1   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size     32   iteration number    101   MSE       0.07 px^2   MAE       0.19 px   Time
Sample size     32   iteration number    201   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size     32   iteration number    301   MSE       0.04 px^2   MAE       0.17 px   Time
```

```
Sample size     32   iteration number    401   MSE       0.03 px^2   MAE       0.14 px   Time
Sample size     32   iteration number    501   MSE       0.07 px^2   MAE       0.14 px   Time
Sample size     32   iteration number    601   MSE       0.04 px^2   MAE       0.16 px   Time
Sample size     32   iteration number    701   MSE       0.04 px^2   MAE       0.15 px   Time
Sample size     32   iteration number    801   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size     32   iteration number    901   MSE       0.04 px^2   MAE       0.16 px   Time
Sample size     32   iteration number   1001   MSE       0.03 px^2   MAE       0.13 px   Time
Sample size     32   iteration number   1101   MSE       0.05 px^2   MAE       0.17 px   Time
Sample size     32   iteration number   1201   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size     32   iteration number   1301   MSE       0.02 px^2   MAE       0.13 px   Time
Sample size     32   iteration number   1401   MSE       0.04 px^2   MAE       0.16 px   Time
Sample size     32   iteration number   1501   MSE       0.03 px^2   MAE       0.12 px   Time
Sample size     32   iteration number   1601   MSE       0.06 px^2   MAE       0.18 px   Time
Sample size     32   iteration number   1701   MSE       0.03 px^2   MAE       0.15 px   Time
Sample size     32   iteration number   1801   MSE       0.03 px^2   MAE       0.12 px   Time
Sample size     32   iteration number   1901   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size     32   iteration number   2001   MSE       0.05 px^2   MAE       0.17 px   Time
Sample size     32   iteration number   2101   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size     32   iteration number   2201   MSE       0.03 px^2   MAE       0.14 px   Time
Sample size     32   iteration number   2301   MSE       0.03 px^2   MAE       0.15 px   Time
Sample size     32   iteration number   2401   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size     32   iteration number   2501   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size     32   iteration number   2601   MSE       0.04 px^2   MAE       0.15 px   Time
Sample size     32   iteration number   2701   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size     32   iteration number   2801   MSE       0.03 px^2   MAE       0.14 px   Time
Sample size     32   iteration number   2901   MSE       0.03 px^2   MAE       0.15 px   Time
Sample size     32   iteration number   3001   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size    128   iteration number      1   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    128   iteration number    101   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size    128   iteration number    201   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    128   iteration number    301   MSE       0.03 px^2   MAE       0.12 px   Time
Sample size    128   iteration number    401   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    128   iteration number    501   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    128   iteration number    601   MSE       0.04 px^2   MAE       0.15 px   Time
Sample size    128   iteration number    701   MSE       0.04 px^2   MAE       0.16 px   Time
Sample size    128   iteration number    801   MSE       0.02 px^2   MAE       0.09 px   Time
Sample size    128   iteration number    901   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    128   iteration number   1001   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size    128   iteration number   1101   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size    128   iteration number   1201   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    128   iteration number   1301   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    128   iteration number   1401   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size    128   iteration number   1501   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size    128   iteration number   1601   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    128   iteration number   1701   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    128   iteration number   1801   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size    128   iteration number   1901   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    128   iteration number   2001   MSE       0.02 px^2   MAE       0.11 px   Time
```

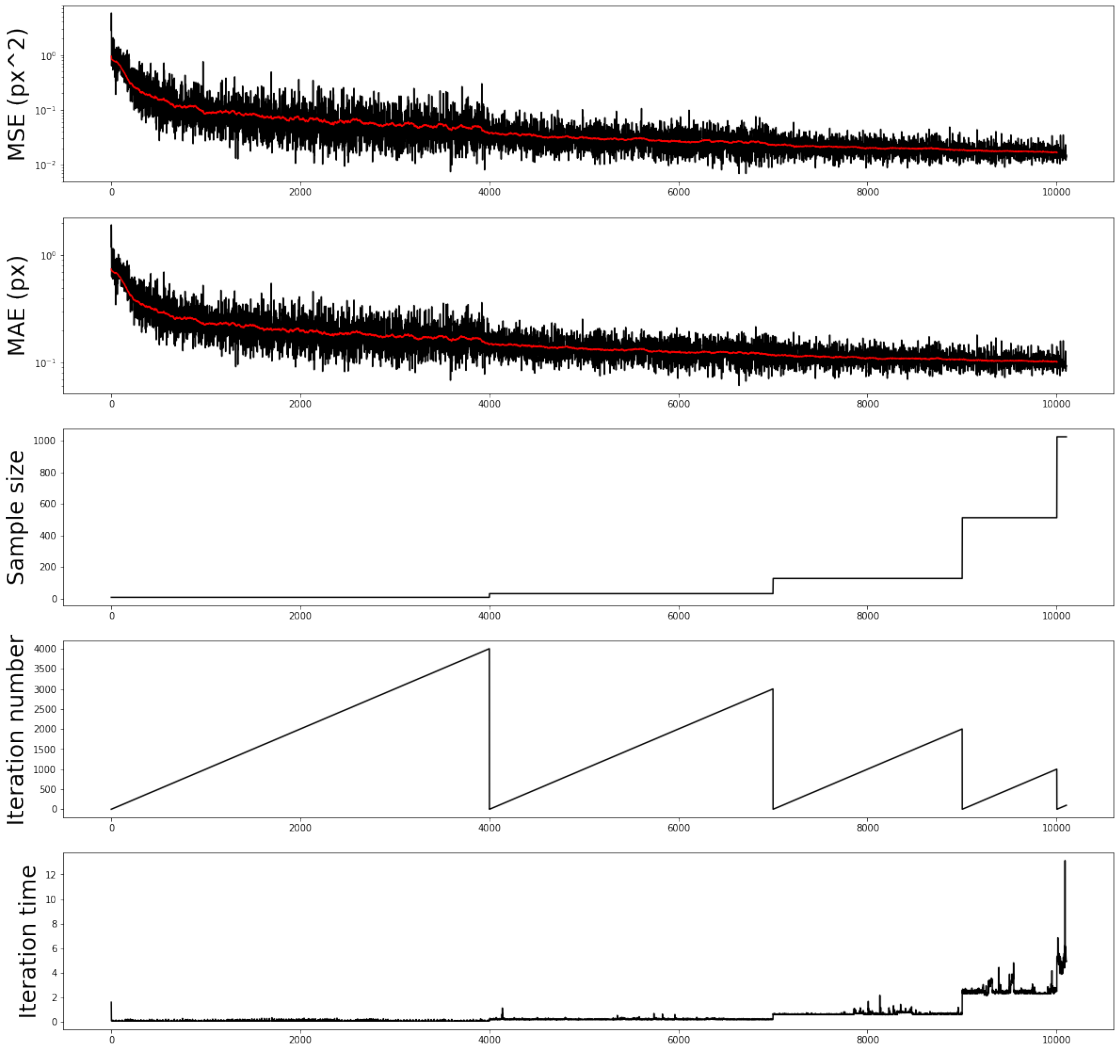
```
Sample size    512   iteration number      1   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size    512   iteration number    101   MSE       0.02 px^2   MAE       0.10 px   Time
Sample size    512   iteration number    201   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    512   iteration number    301   MSE       0.01 px^2   MAE       0.08 px   Time
Sample size    512   iteration number    401   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    512   iteration number    501   MSE       0.01 px^2   MAE       0.08 px   Time
Sample size    512   iteration number    601   MSE       0.02 px^2   MAE       0.11 px   Time
Sample size    512   iteration number    701   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size    512   iteration number    801   MSE       0.01 px^2   MAE       0.10 px   Time
Sample size    512   iteration number    901   MSE       0.01 px^2   MAE       0.09 px   Time
Sample size    512   iteration number   1001   MSE       0.03 px^2   MAE       0.14 px   Time
Sample size   1024   iteration number      1   MSE       0.02 px^2   MAE       0.12 px   Time
Sample size   1024   iteration number    101   MSE       0.01 px^2   MAE       0.09 px   Time
```

1.5 5. PLOT LEARNING PERFORMANCE

The learning performance is plotted. The MSE, MAE, sample size, iteration number and iteration time are plotted against the number of timesteps.

Comment: 1. The parameter number_of_timesteps_for_average determines the length of the average. It must be a positive integer number.

```
In [5]: ### Plot learning performance
        number_of_timesteps_for_average = 100
        deeptrack.plot_learning_performance(training_history, number_of_timesteps_for_average)
```



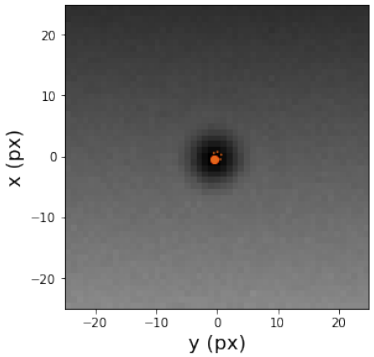
1.6 6. TEST DEEP LEARNING NETWORK ON NEW SIMULATED DATA

The deep learning network is tested on new simulated data (parameters are defined in Section **??**).

Comments: 1. The parameter number_of_predictions_to_show determines the number of predictions that are shown. 3. The red symbol superimposed to the images represents the ground truth particle position. 4. The orange symbol is the deep learning network prediction for the position (x, y), and the circle is the prediction for the radial distance r.

```
In [6]: ### Test the predictions of the deep learning network on some generated images
        number_of_predictions_to_show = 10

        for image_number, image, image_parameters in image_generator():
            if image_number>=number_of_predictions_to_show:
                break
```

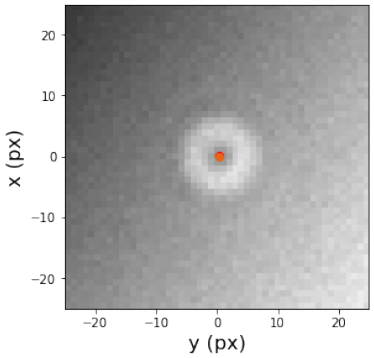
```
predicted_position = deeptrack.predict(network, image)

deeptrack.plot_prediction(image, image_parameters, predicted_position)
```



particle center x = -0.57 px
particle center y = -0.48 px
particle radius = 2.06 px
Bessel order = 1.00
particle intensity = -0.37

predicted x = -0.56 px
predicted y = -0.55 px
predicted r = 0.74 px

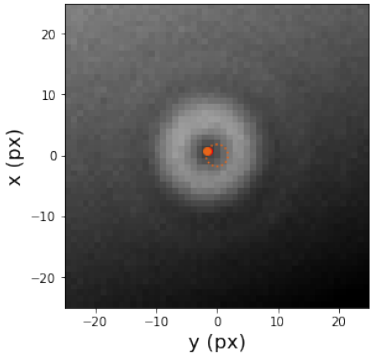
image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 98.06
gradient intensity = 0.50
gradient direction = -1.59 rad



particle center x = 0.05 px
particle center y = 0.42 px
particle radius = 1.75 px
Bessel order = 2.00
particle intensity = 0.35

predicted x = 0.04 px
predicted y = 0.32 px
predicted r = 0.35 px

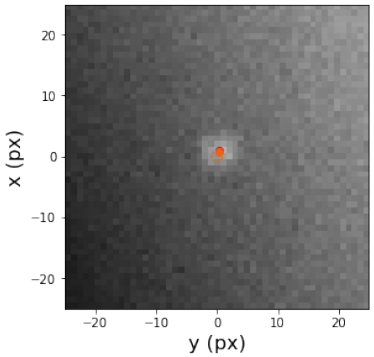
image half size = 25.00 px
image background level = 0.57
signal to noise ratio = 49.32
gradient intensity = 0.72
gradient direction = -0.64 rad



particle center x = 0.81 px
particle center y = -1.56 px
particle radius = 2.28 px
Bessel order = 2.00
particle intensity = 0.43

predicted x = 0.69 px
predicted y = -1.74 px
predicted r = 1.81 px

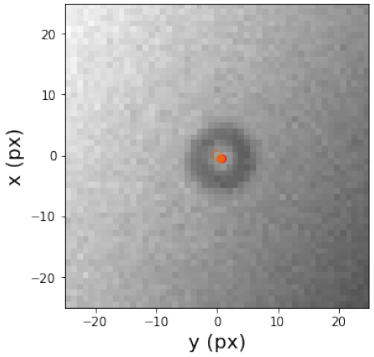
image half size = 25.00 px
image background level = 0.24
signal to noise ratio = 50.80
gradient intensity = 0.58
gradient direction = 1.94 rad



particle center x = 0.92 px
particle center y = 0.37 px
particle radius = 1.55 px
Bessel order = 1.00
particle intensity = 0.28

predicted x = 0.81 px
predicted y = 0.36 px
predicted r = 0.88 px

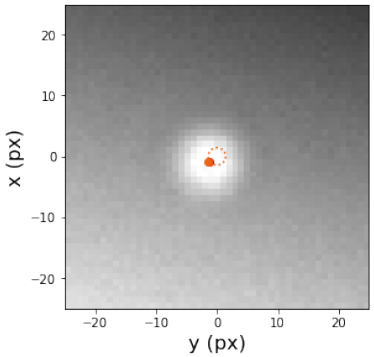
image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 26.42
gradient intensity = 0.55
gradient direction = 0.43 rad



particle center x = -0.47 px
particle center y = 0.79 px
particle radius = 1.61 px
Bessel order = 2.00
particle intensity = -0.31

predicted x = -0.46 px
predicted y = 0.64 px
predicted r = 0.81 px

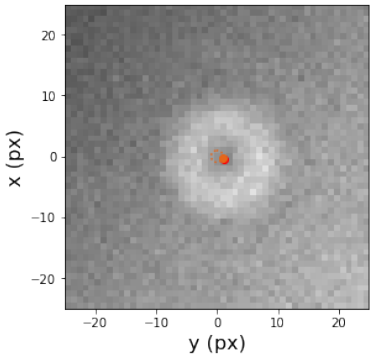
image half size = 25.00 px
image background level = 0.65
signal to noise ratio = 37.52
gradient intensity = 0.66
gradient direction = 2.61 rad



particle center x = -0.78 px
particle center y = -1.33 px
particle radius = 2.57 px
Bessel order = 1.00
particle intensity = 0.53

predicted x = -0.79 px
predicted y = -1.39 px
predicted r = 1.42 px

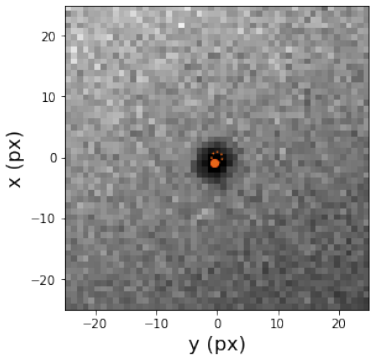
image half size = 25.00 px
image background level = 0.56
signal to noise ratio = 80.67
gradient intensity = 0.74
gradient direction = -1.87 rad



particle center x = -0.43 px
particle center y = 1.13 px
particle radius = 2.59 px
Bessel order = 2.00
particle intensity = 0.32

predicted x = -0.25 px
predicted y = 0.94 px
predicted r = 0.96 px

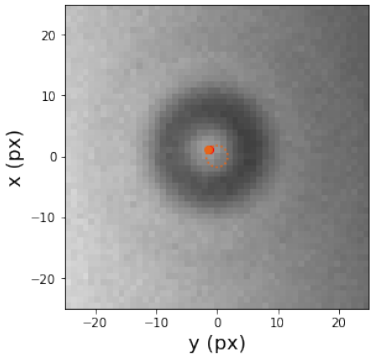
image half size = 25.00 px
image background level = 0.54
signal to noise ratio = 26.24
gradient intensity = 0.40
gradient direction = -0.72 rad



particle center x = -0.81 px
particle center y = -0.40 px
particle radius = 1.69 px
Bessel order = 1.00
particle intensity = -0.59

predicted x = -0.88 px
predicted y = -0.46 px
predicted r = 0.89 px

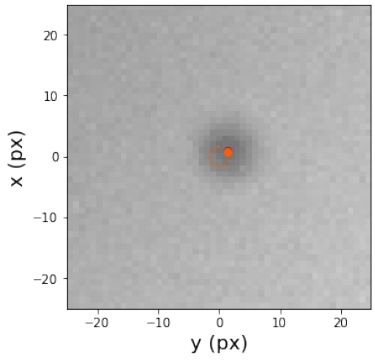
image half size = 25.00 px
image background level = 0.52
signal to noise ratio = 12.02
gradient intensity = 0.46
gradient direction = 2.05 rad



particle center x = 1.18 px
particle center y = -1.35 px
particle radius = 2.85 px
Bessel order = 2.00
particle intensity = -0.40

predicted x = 1.13 px
predicted y = -1.40 px
predicted r = 1.77 px

image half size = 25.00 px
image background level = 0.60
signal to noise ratio = 59.92
gradient intensity = 0.57
gradient direction = -2.96 rad



particle center x = 0.88 px
particle center y = 1.44 px
particle radius = 2.48 px
Bessel order = 1.00
particle intensity = -0.25

predicted x = 0.80 px
predicted y = 1.34 px
predicted r = 1.58 px

image half size = 25.00 px
image background level = 0.70
signal to noise ratio = 70.73
gradient intensity = 0.15
gradient direction = -0.57 rad

1.7 7. SAVE DEEP LEARNING NETWORK

Comments: 1. The parameter save_file_name is the name of the file where the deep learnign network is saved. 2. By default, the network is saved in the same folder where DeepTrack 1.0 is running.

In [7]:
```
### Prepare file name
from datetime import datetime as time

save_file_name = 'Network ' + time.now().strftime('%Y-%m-%d-%H%M%S')

save_file_name += ' C'
for conv_layer_dimension in conv_layers_dimensions:
    save_file_name += '-' + str(conv_layer_dimension)

save_file_name += ' D'
for dense_layer_dimension in dense_layers_dimensions:
    save_file_name += '-' + str(dense_layer_dimension)

save_file_name += ' training'
for sample_size, iteration_number in zip(sample_sizes, iteration_numbers):
    save_file_name += '-' + str(sample_size) + 'x' + str(iteration_number)

save_file_name += '.h5'

### Save deep learning model
import os

if not os.path.exists(save_file_name):
    network.save(save_file_name)
    print('Saved deep learning network as:')
    print(save_file_name)
```

```
Saved deep learning network as:
Network 2018-12-07-144959 C-16-32-64 D-32-32 training-8x4001-32x3001-128x2001-512x1001-1024x10
```