DeepTrack - Example 2 - Tracking single particle

January 24, 2019

1 Example 2: Tracking of a single optically trapped particle with DeepTrack 1.0

Example code to use DeepTrack to track a single optically trapped particle. See also Figure 2.

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

1.1 1. INITIALIZATION

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

1.2 2. PLAY VIDEO TO BE TRACKED

The video to be tracked is played.

Change the video file in the code to view different videos:

1. DeepTrack - Example 2 - Optically Trapped Particle Good.mp4
2. DeepTrack - Example 2 - Optically Trapped Particle Bad.mp4

Note that the video file must be in the same folder as this notebook.

```
In [4]: %%HTML

        <video width="400" height="400" controls>
        <source src="DeepTrack - Example 2 - Optically Trapped Particle Good.mp4" type="video/
        </video>
```

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

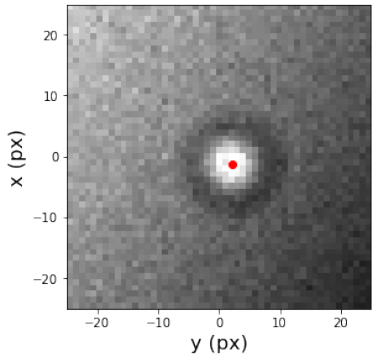
1.3 2. CHECK IMAGE GENERATION ROUTINE

Here, we simulate images of single particles similar to those we want to track. The particle position is chosen randomly from a normal distribution with mean of 0 and standard deviation of 2 pixels. The particle has a radius between 2 and 3 pixels, and a point-spread function obtained from the combination of a Bessel functions of first and second order of positive and negative intensity respectively, resulting in a particle with a dark ring around a bright center. The image

background, SNR and gradient intensity are randomly selected from a wide range of values. This results in particle images corresponding to a dark ring around a brigth center 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 2 - Pretrained network.h5".

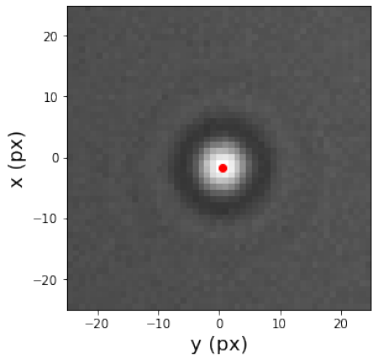
Comments: 1. The image_parameters_function is a lambda function that determines the kind of particle images for which the deep learning network will be trained. Tuning its parameters is the simplest way to improve the tracking performance. 2. The image_generator is a lambda function that works as image 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 [5]:
```
### 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 ,2, 1), ],
    particle_center_y_list=lambda : [normal(0 ,2, 1), ],
    particle_radius_list=lambda : uniform(2, 3, 1),
    particle_bessel_orders_list=lambda : [[1, 2], ],
    particle_intensities_list=lambda : [[uniform(.7, .9, 1), -uniform(.2, .3, 1)], ],
    image_half_size=lambda : 25,
    image_background_level=lambda : uniform(.2, .5),
    signal_to_noise_ratio=lambda : uniform(5, 100),
    gradient_intensity=lambda : uniform(0, .8),
    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)
```



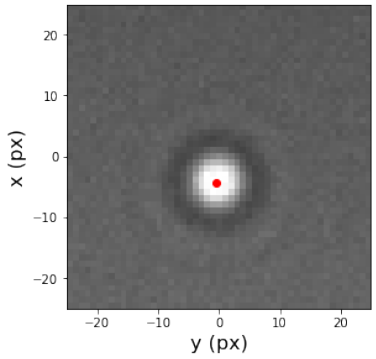
particle center x = -1.35 px
particle center y = 2.08 px
particle radius = 2.26 px
Bessel order = 1.00
particle intensity = 0.70

image half size = 25.00 px
image background level = 0.46
signal to noise ratio = 17.23
gradient intensity = 0.67
gradient direction = 2.59



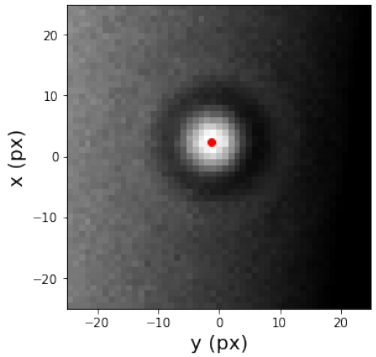
particle center x = -1.60 px
particle center y = 0.55 px
particle radius = 2.19 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.32
signal to noise ratio = 58.83
gradient intensity = 0.04
gradient direction = 0.32



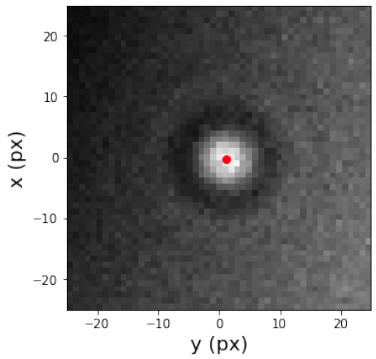
particle center x = -4.25 px
particle center y = -0.37 px
particle radius = 2.19 px
Bessel order = 1.00
particle intensity = 0.85

image half size = 25.00 px
image background level = 0.37
signal to noise ratio = 46.71
gradient intensity = 0.07
gradient direction = -1.69



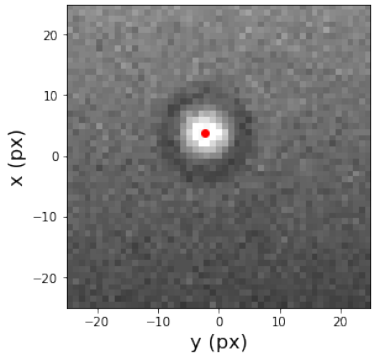
particle center x = 2.46 px
particle center y = -1.23 px
particle radius = 2.52 px
Bessel order = 1.00
particle intensity = 0.81

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 32.51
gradient intensity = 0.78
gradient direction = 3.03



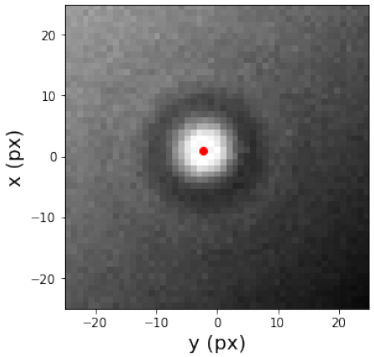
particle center x = -0.34 px
particle center y = 1.15 px
particle radius = 2.42 px
Bessel order = 1.00
particle intensity = 0.71

image half size = 25.00 px
image background level = 0.26
signal to noise ratio = 18.99
gradient intensity = 0.48
gradient direction = -0.36



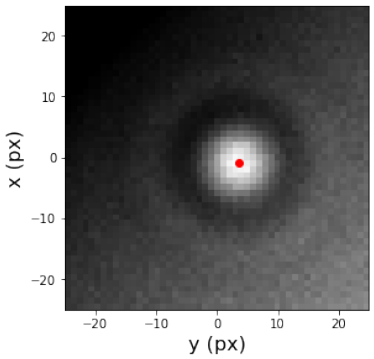
particle center x = 3.77 px
particle center y = -2.29 px
particle radius = 2.16 px
Bessel order = 1.00
particle intensity = 0.77

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 19.29
gradient intensity = 0.36
gradient direction = 1.64



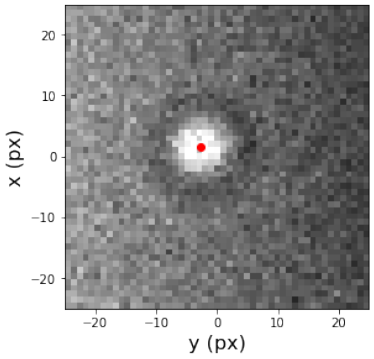
particle center x = 1.01 px
particle center y = -2.24 px
particle radius = 2.59 px
Bessel order = 1.00
particle intensity = 0.88

image half size = 25.00 px
image background level = 0.34
signal to noise ratio = 29.81
gradient intensity = 0.60
gradient direction = 2.35



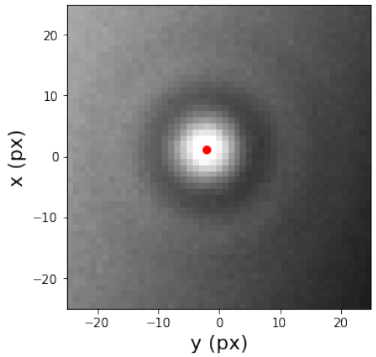
particle center x = -0.94 px
particle center y = 3.50 px
particle radius = 2.99 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 30.24
gradient intensity = 0.64
gradient direction = -0.81



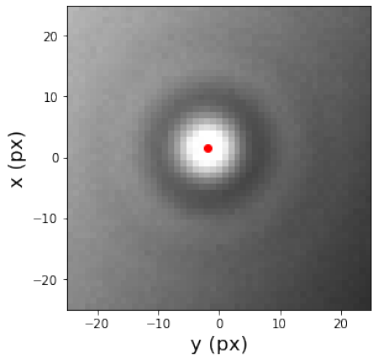
particle center x = 1.53 px
particle center y = -2.70 px
particle radius = 2.46 px
Bessel order = 1.00
particle intensity = 0.81

image half size = 25.00 px
image background level = 0.44
signal to noise ratio = 10.02
gradient intensity = 0.47
gradient direction = -3.09



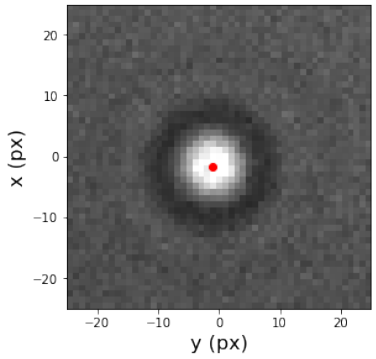
particle center x = 1.18 px
particle center y = -2.16 px
particle radius = 2.87 px
Bessel order = 1.00
particle intensity = 0.72

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 63.21
gradient intensity = 0.61
gradient direction = 2.76



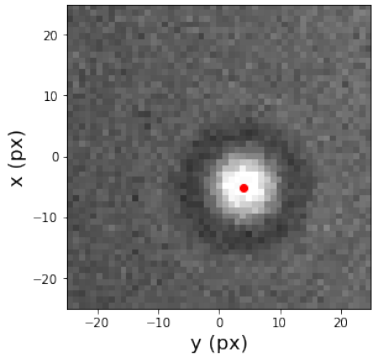
particle center x = 1.56 px
particle center y = -1.95 px
particle radius = 2.79 px
Bessel order = 1.00
particle intensity = 0.76

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 94.60
gradient intensity = 0.56
gradient direction = 2.66



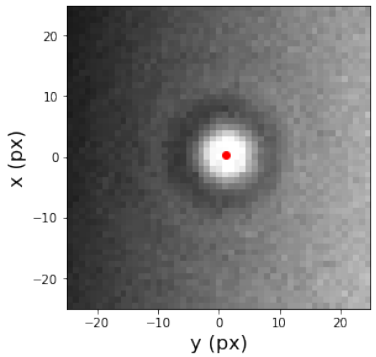
particle center x = -1.60 px
particle center y = -1.08 px
particle radius = 2.81 px
Bessel order = 1.00
particle intensity = 0.90

image half size = 25.00 px
image background level = 0.33
signal to noise ratio = 20.80
gradient intensity = 0.05
gradient direction = 1.08



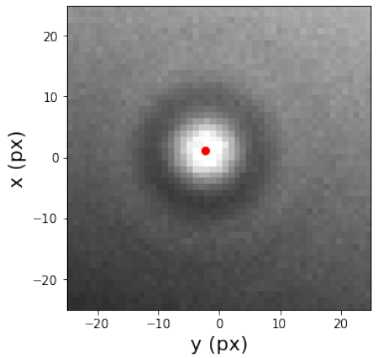
particle center x = -5.04 px
particle center y = 4.09 px
particle radius = 2.90 px
Bessel order = 1.00
particle intensity = 0.81

image half size = 25.00 px
image background level = 0.37
signal to noise ratio = 17.72
gradient intensity = 0.12
gradient direction = 0.19



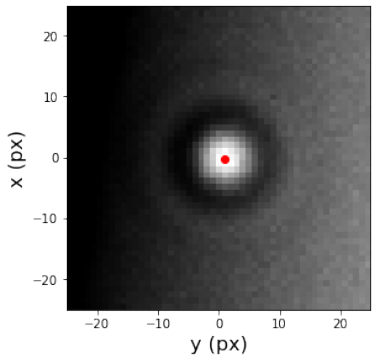
particle center x = 0.37 px
particle center y = 1.23 px
particle radius = 2.50 px
Bessel order = 1.00
particle intensity = 0.87

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 30.48
gradient intensity = 0.78
gradient direction = -0.14



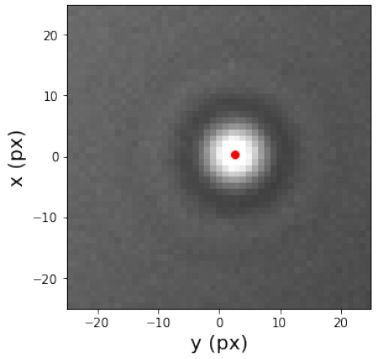
particle center x = 1.12 px
particle center y = -2.24 px
particle radius = 2.97 px
Bessel order = 1.00
particle intensity = 0.70

image half size = 25.00 px
image background level = 0.44
signal to noise ratio = 44.32
gradient intensity = 0.58
gradient direction = 1.26



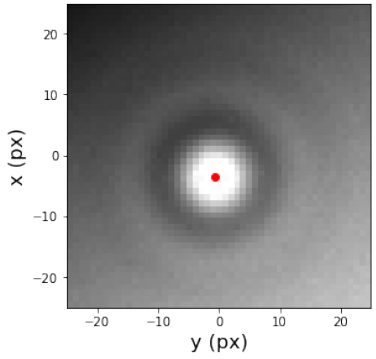
particle center x = -0.18 px
particle center y = 1.05 px
particle radius = 2.43 px
Bessel order = 1.00
particle intensity = 0.83

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 36.97
gradient intensity = 0.80
gradient direction = -0.16



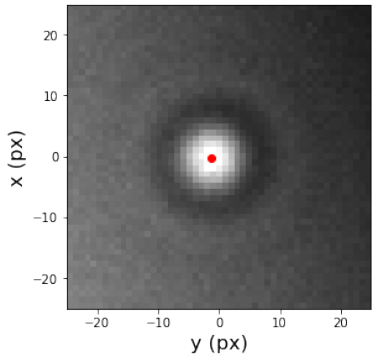
particle center x = 0.38 px
particle center y = 2.65 px
particle radius = 2.61 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 65.02
gradient intensity = 0.13
gradient direction = 2.64



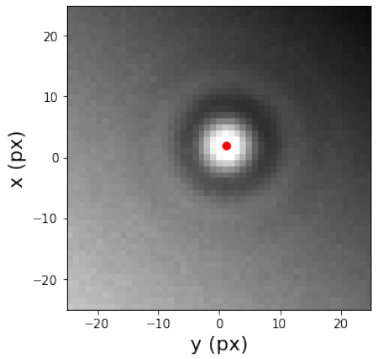
particle center x = -3.55 px
particle center y = -0.72 px
particle radius = 2.90 px
Bessel order = 1.00
particle intensity = 0.88

image half size = 25.00 px
image background level = 0.43
signal to noise ratio = 95.25
gradient intensity = 0.72
gradient direction = -1.00



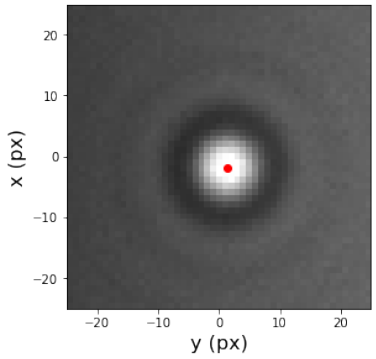
particle center x = -0.34 px
particle center y = -1.29 px
particle radius = 2.71 px
Bessel order = 1.00
particle intensity = 0.76

image half size = 25.00 px
image background level = 0.31
signal to noise ratio = 43.14
gradient intensity = 0.44
gradient direction = -2.77



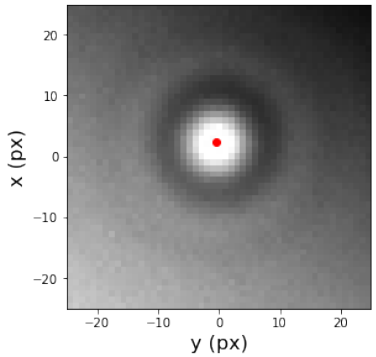
particle center x = 1.97 px
particle center y = 1.25 px
particle radius = 2.26 px
Bessel order = 1.00
particle intensity = 0.85

image half size = 25.00 px
image background level = 0.40
signal to noise ratio = 72.98
gradient intensity = 0.74
gradient direction = -2.31



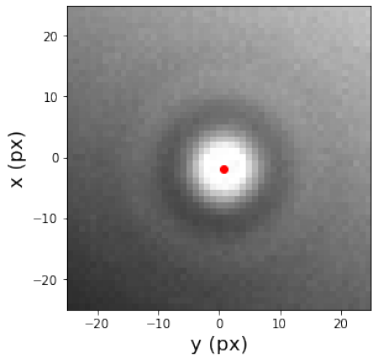
particle center x = -1.86 px
particle center y = 1.38 px
particle radius = 2.68 px
Bessel order = 1.00
particle intensity = 0.83

image half size = 25.00 px
image background level = 0.32
signal to noise ratio = 75.48
gradient intensity = 0.20
gradient direction = -0.05



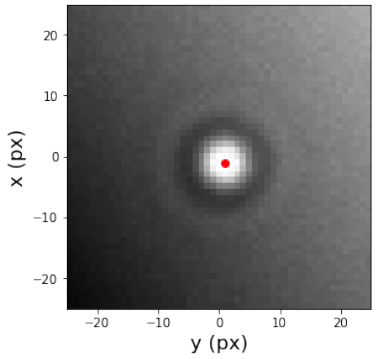
particle center x = 2.29 px
particle center y = -0.45 px
particle radius = 2.84 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.42
signal to noise ratio = 70.51
gradient intensity = 0.77
gradient direction = -2.19



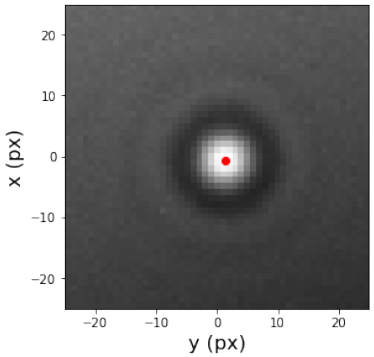
particle center x = -1.86 px
particle center y = 0.78 px
particle radius = 2.92 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 64.02
gradient intensity = 0.62
gradient direction = 1.04



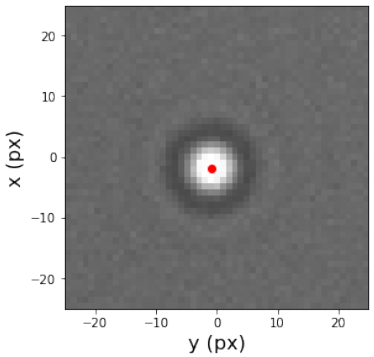
particle center x = -1.13 px
particle center y = 0.94 px
particle radius = 2.07 px
Bessel order = 1.00
particle intensity = 0.88

image half size = 25.00 px
image background level = 0.35
signal to noise ratio = 57.90
gradient intensity = 0.66
gradient direction = 0.59



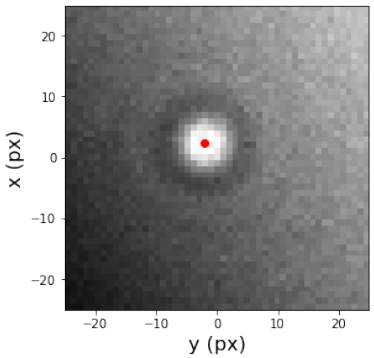
particle center x = -0.68 px
particle center y = 1.32 px
particle radius = 2.38 px
Bessel order = 1.00
particle intensity = 0.77

image half size = 25.00 px
image background level = 0.29
signal to noise ratio = 67.74
gradient intensity = 0.24
gradient direction = 1.91



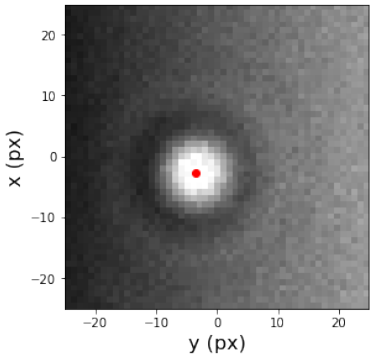
particle center x = -1.88 px
particle center y = -0.94 px
particle radius = 2.01 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 53.49
gradient intensity = 0.01
gradient direction = 0.97



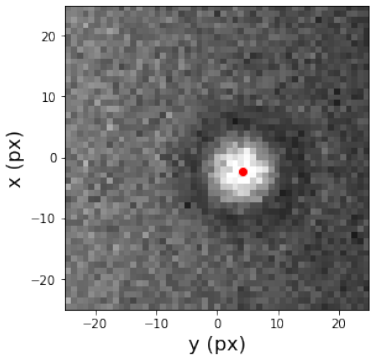
particle center x = 2.30 px
particle center y = -2.13 px
particle radius = 2.24 px
Bessel order = 1.00
particle intensity = 0.81

image half size = 25.00 px
image background level = 0.42
signal to noise ratio = 24.75
gradient intensity = 0.74
gradient direction = 0.60



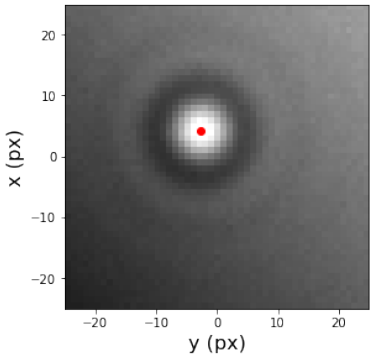
particle center x = -2.76 px
particle center y = -3.45 px
particle radius = 2.85 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 28.15
gradient intensity = 0.69
gradient direction = -0.04



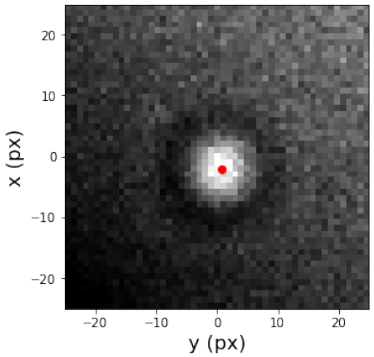
particle center x = -2.28 px
particle center y = 4.13 px
particle radius = 2.83 px
Bessel order = 1.00
particle intensity = 0.78

image half size = 25.00 px
image background level = 0.37
signal to noise ratio = 10.28
gradient intensity = 0.32
gradient direction = 3.12



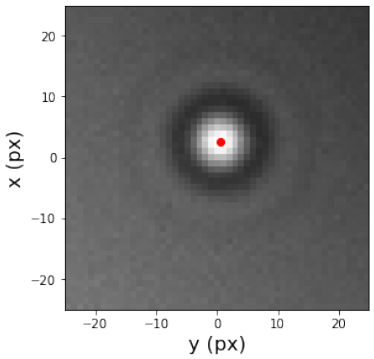
particle center x = 4.22 px
particle center y = -2.67 px
particle radius = 2.53 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.37
signal to noise ratio = 82.28
gradient intensity = 0.51
gradient direction = 0.81



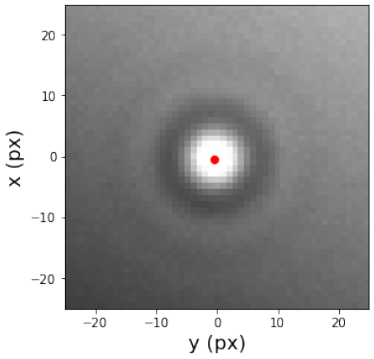
particle center x = -2.10 px
particle center y = 0.74 px
particle radius = 2.82 px
Bessel order = 1.00
particle intensity = 0.83

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 9.75
gradient intensity = 0.53
gradient direction = 0.82



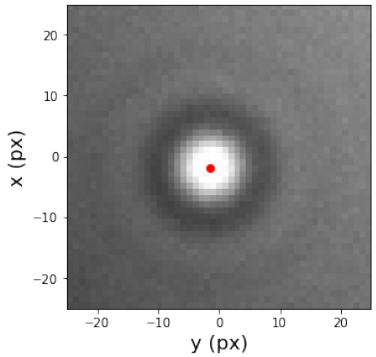
particle center x = 2.64 px
particle center y = 0.47 px
particle radius = 2.30 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.34
signal to noise ratio = 64.72
gradient intensity = 0.25
gradient direction = -2.37



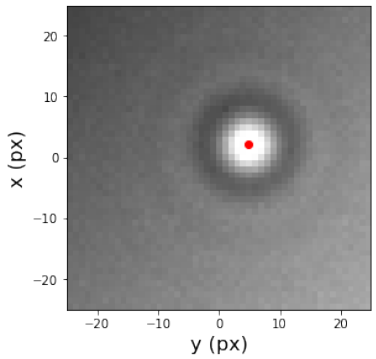
particle center x = -0.38 px
particle center y = -0.44 px
particle radius = 2.51 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 90.12
gradient intensity = 0.48
gradient direction = 1.06



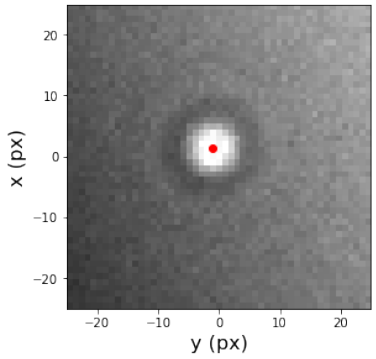
particle center x = -1.88 px
particle center y = -1.55 px
particle radius = 2.91 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.43
signal to noise ratio = 59.71
gradient intensity = 0.25
gradient direction = 0.61



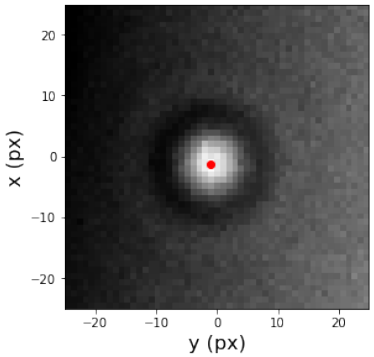
particle center x = 2.14 px
particle center y = 4.85 px
particle radius = 2.41 px
Bessel order = 1.00
particle intensity = 0.74

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 69.64
gradient intensity = 0.40
gradient direction = -0.76



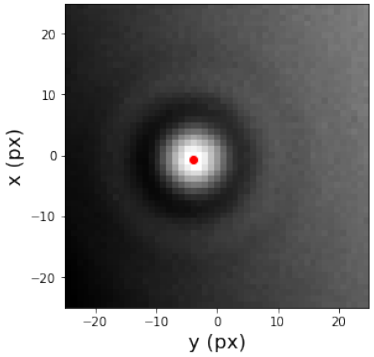
particle center x = 1.38 px
particle center y = -1.08 px
particle radius = 2.12 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.44
signal to noise ratio = 29.25
gradient intensity = 0.50
gradient direction = 0.46



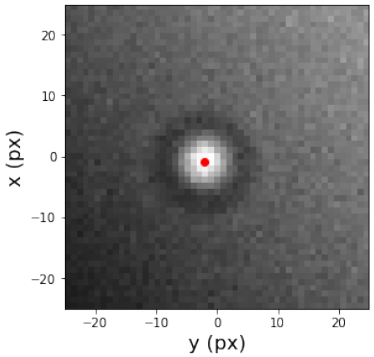
particle center x = -1.20 px
particle center y = -1.00 px
particle radius = 2.74 px
Bessel order = 1.00
particle intensity = 0.76

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 24.75
gradient intensity = 0.58
gradient direction = -0.19



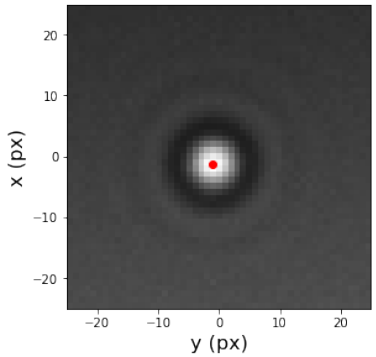
particle center x = -0.68 px
particle center y = -3.90 px
particle radius = 2.69 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.25
signal to noise ratio = 62.26
gradient intensity = 0.58
gradient direction = 0.34



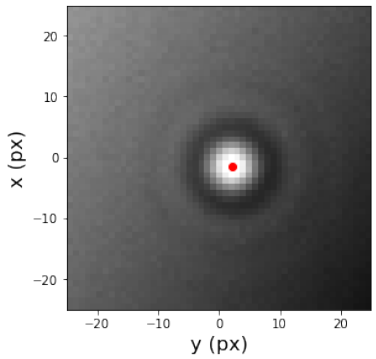
particle center x = -0.95 px
particle center y = -2.17 px
particle radius = 2.22 px
Bessel order = 1.00
particle intensity = 0.71

image half size = 25.00 px
image background level = 0.35
signal to noise ratio = 23.83
gradient intensity = 0.49
gradient direction = 0.67



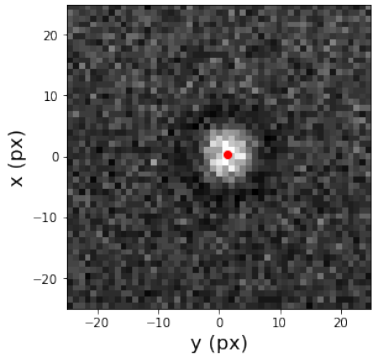
particle center x = -1.26 px
particle center y = -0.98 px
particle radius = 2.05 px
Bessel order = 1.00
particle intensity = 0.79

image half size = 25.00 px
image background level = 0.25
signal to noise ratio = 88.43
gradient intensity = 0.16
gradient direction = -1.49



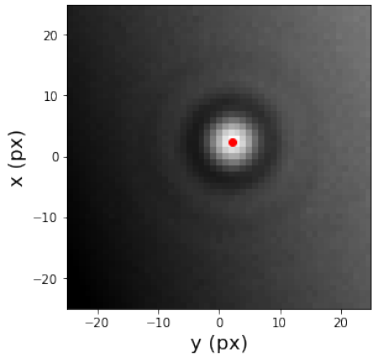
particle center x = -1.52 px
particle center y = 2.21 px
particle radius = 2.12 px
Bessel order = 1.00
particle intensity = 0.85

image half size = 25.00 px
image background level = 0.33
signal to noise ratio = 78.92
gradient intensity = 0.53
gradient direction = 2.56



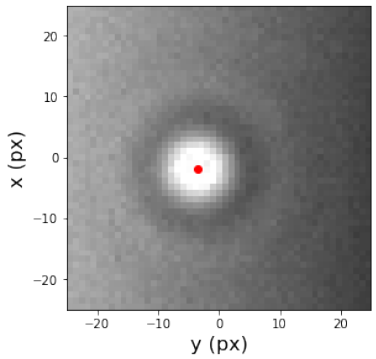
particle center x = 0.35 px
particle center y = 1.39 px
particle radius = 2.44 px
Bessel order = 1.00
particle intensity = 0.78

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 5.79
gradient intensity = 0.09
gradient direction = 1.49



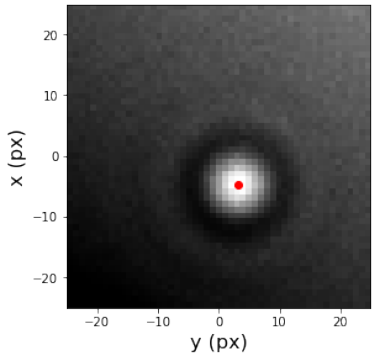
particle center x = 2.42 px
particle center y = 2.22 px
particle radius = 2.10 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 84.03
gradient intensity = 0.55
gradient direction = 0.37



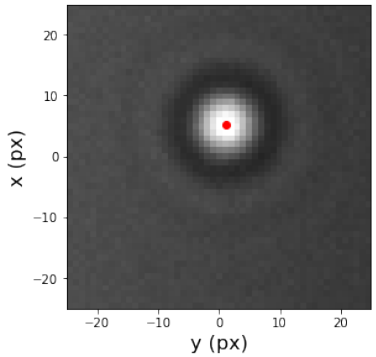
particle center x = -1.97 px
particle center y = -3.60 px
particle radius = 2.90 px
Bessel order = 1.00
particle intensity = 0.78

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 47.26
gradient intensity = 0.60
gradient direction = 3.08



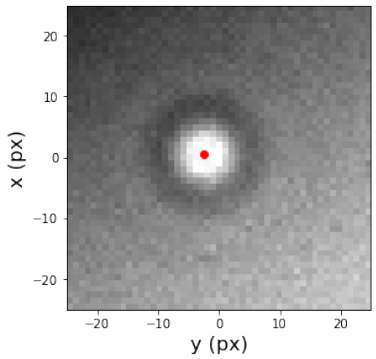
particle center x = -4.81 px
particle center y = 3.23 px
particle radius = 2.53 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 34.52
gradient intensity = 0.51
gradient direction = 1.00



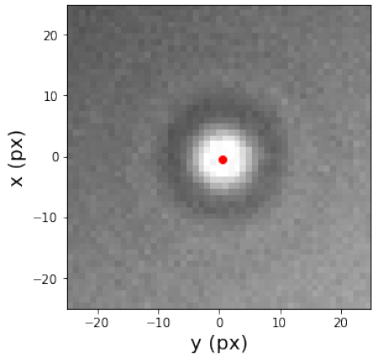
particle center x = 5.25 px
particle center y = 1.09 px
particle radius = 2.54 px
Bessel order = 1.00
particle intensity = 0.82

image half size = 25.00 px
image background level = 0.27
signal to noise ratio = 62.94
gradient intensity = 0.12
gradient direction = 3.05



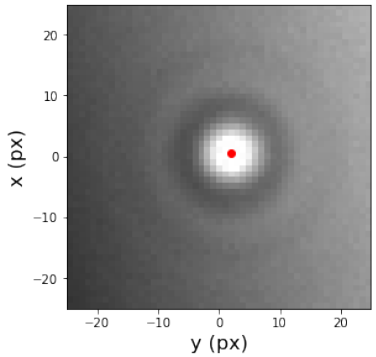
particle center x = 0.53 px
particle center y = -2.40 px
particle radius = 2.61 px
Bessel order = 1.00
particle intensity = 0.77

image half size = 25.00 px
image background level = 0.49
signal to noise ratio = 27.56
gradient intensity = 0.67
gradient direction = -1.03



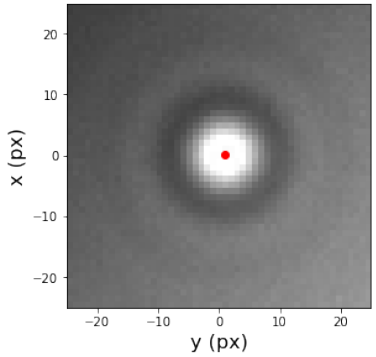
particle center x = -0.41 px
particle center y = 0.61 px
particle radius = 2.73 px
Bessel order = 1.00
particle intensity = 0.77

image half size = 25.00 px
image background level = 0.49
signal to noise ratio = 38.41
gradient intensity = 0.30
gradient direction = -0.92



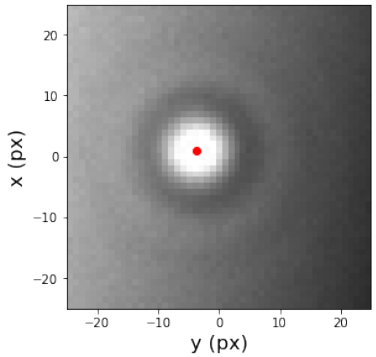
particle center x = 0.52 px
particle center y = 2.02 px
particle radius = 2.52 px
Bessel order = 1.00
particle intensity = 0.79

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 86.12
gradient intensity = 0.56
gradient direction = 0.28



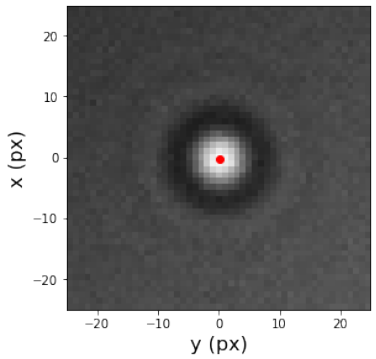
particle center x = 0.17 px
particle center y = 0.95 px
particle radius = 2.93 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.42
signal to noise ratio = 83.84
gradient intensity = 0.36
gradient direction = -0.73



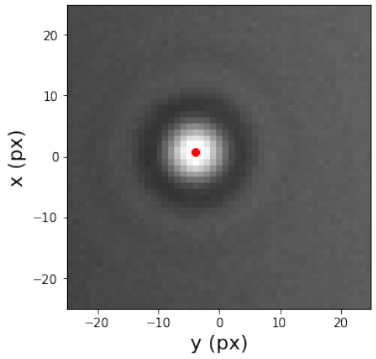
particle center x = 0.97 px
particle center y = -3.68 px
particle radius = 2.75 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 79.82
gradient intensity = 0.68
gradient direction = 2.96



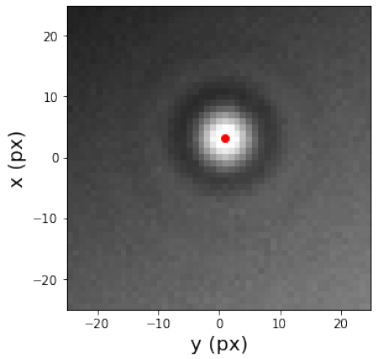
particle center x = -0.36 px
particle center y = 0.17 px
particle radius = 2.36 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.28
signal to noise ratio = 39.00
gradient intensity = 0.14
gradient direction = -0.85



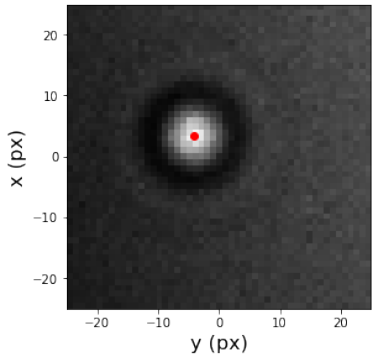
particle center x = 0.74 px
particle center y = -3.99 px
particle radius = 2.49 px
Bessel order = 1.00
particle intensity = 0.80

image half size = 25.00 px
image background level = 0.33
signal to noise ratio = 78.52
gradient intensity = 0.14
gradient direction = 0.19



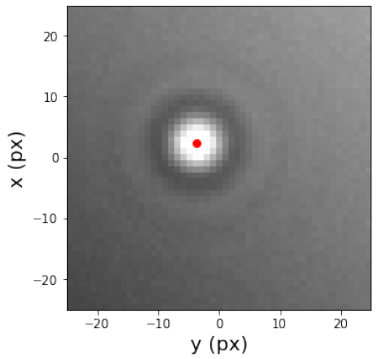
particle center x = 3.22 px
particle center y = 1.01 px
particle radius = 2.37 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.31
signal to noise ratio = 58.47
gradient intensity = 0.39
gradient direction = -1.00



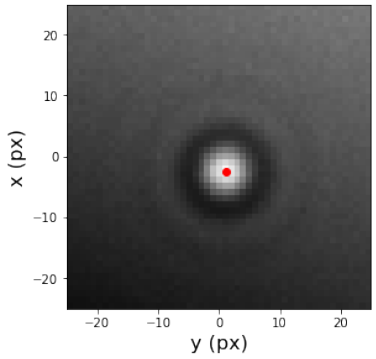
particle center x = 3.40 px
particle center y = -4.21 px
particle radius = 2.42 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.20
signal to noise ratio = 25.28
gradient intensity = 0.26
gradient direction = 0.22



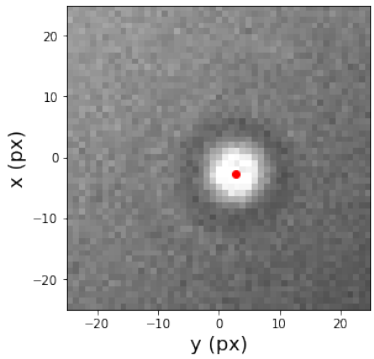
particle center x = 2.36 px
particle center y = -3.74 px
particle radius = 2.16 px
Bessel order = 1.00
particle intensity = 0.87

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 87.57
gradient intensity = 0.36
gradient direction = 0.81



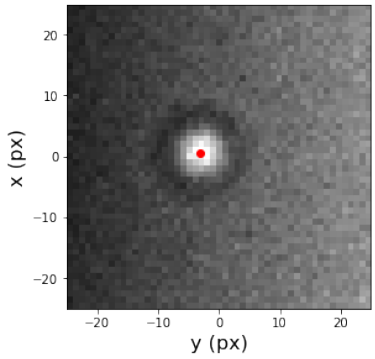
particle center x = -2.53 px
particle center y = 1.09 px
particle radius = 2.11 px
Bessel order = 1.00
particle intensity = 0.72

image half size = 25.00 px
image background level = 0.27
signal to noise ratio = 65.56
gradient intensity = 0.46
gradient direction = 1.22



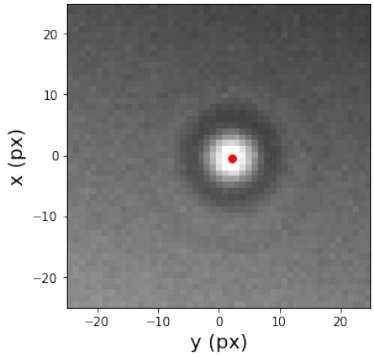
particle center x = -2.71 px
particle center y = 2.85 px
particle radius = 2.52 px
Bessel order = 1.00
particle intensity = 0.83

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 22.20
gradient intensity = 0.29
gradient direction = 2.33



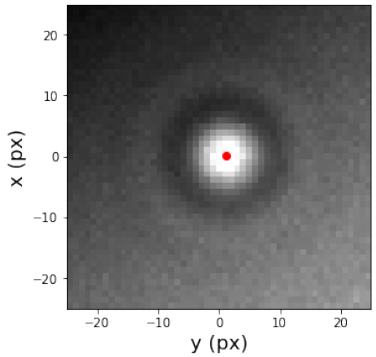
particle center x = 0.64 px
particle center y = -3.03 px
particle radius = 2.09 px
Bessel order = 1.00
particle intensity = 0.72

image half size = 25.00 px
image background level = 0.35
signal to noise ratio = 17.38
gradient intensity = 0.58
gradient direction = -0.06



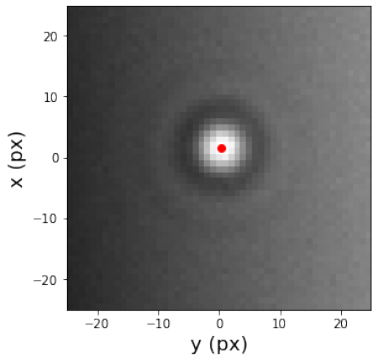
particle center x = -0.44 px
particle center y = 2.15 px
particle radius = 2.19 px
Bessel order = 1.00
particle intensity = 0.76

image half size = 25.00 px
image background level = 0.41
signal to noise ratio = 51.30
gradient intensity = 0.36
gradient direction = -1.86



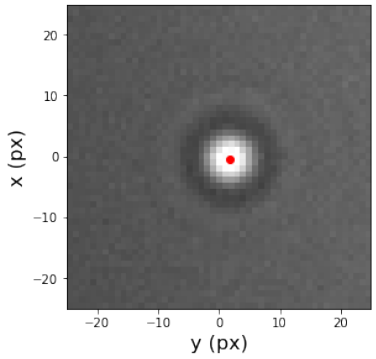
particle center x = 0.10 px
particle center y = 1.16 px
particle radius = 2.74 px
Bessel order = 1.00
particle intensity = 0.82

image half size = 25.00 px
image background level = 0.33
signal to noise ratio = 38.82
gradient intensity = 0.59
gradient direction = -1.01



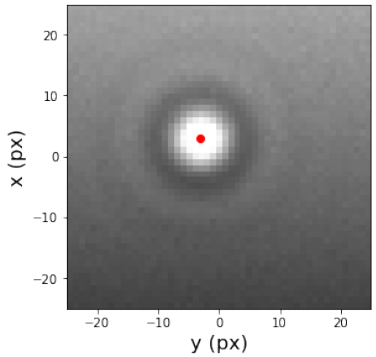
particle center x = 1.60 px
particle center y = 0.43 px
particle radius = 2.05 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.35
signal to noise ratio = 77.23
gradient intensity = 0.52
gradient direction = 0.07



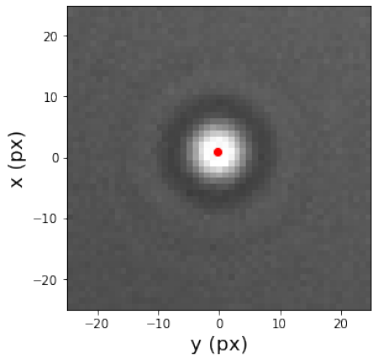
particle center x = -0.45 px
particle center y = 1.80 px
particle radius = 2.06 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 51.22
gradient intensity = 0.11
gradient direction = 0.23



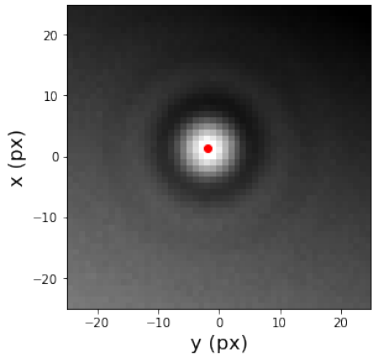
particle center x = 2.90 px
particle center y = -3.04 px
particle radius = 2.43 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 83.85
gradient intensity = 0.54
gradient direction = 1.56



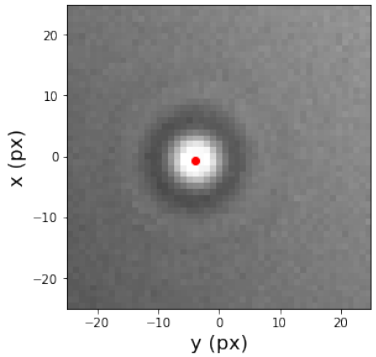
particle center x = 0.87 px
particle center y = -0.24 px
particle radius = 2.38 px
Bessel order = 1.00
particle intensity = 0.85

image half size = 25.00 px
image background level = 0.34
signal to noise ratio = 60.55
gradient intensity = 0.07
gradient direction = 1.01



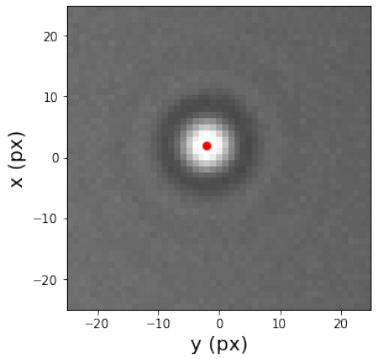
particle center x = 1.35 px
particle center y = -1.85 px
particle radius = 2.42 px
Bessel order = 1.00
particle intensity = 0.87

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 88.92
gradient intensity = 0.54
gradient direction = -1.98



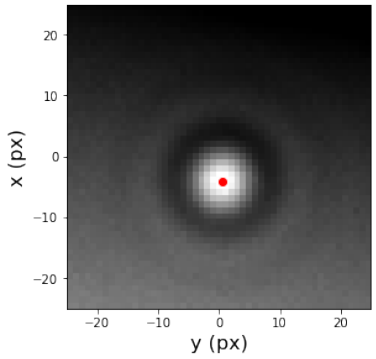
particle center x = -0.70 px
particle center y = -3.91 px
particle radius = 2.25 px
Bessel order = 1.00
particle intensity = 0.79

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 55.93
gradient intensity = 0.24
gradient direction = 0.58



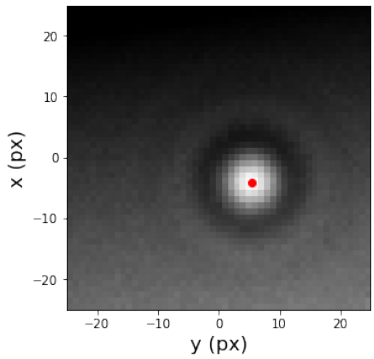
particle center x = 2.02 px
particle center y = -2.05 px
particle radius = 2.20 px
Bessel order = 1.00
particle intensity = 0.80

image half size = 25.00 px
image background level = 0.40
signal to noise ratio = 74.19
gradient intensity = 0.07
gradient direction = -2.94



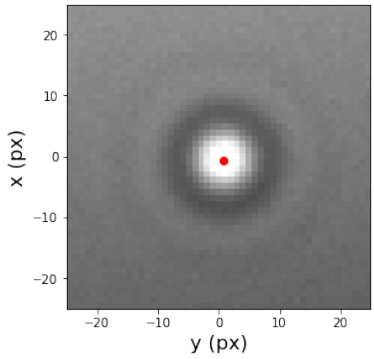
particle center x = -4.04 px
particle center y = 0.51 px
particle radius = 2.59 px
Bessel order = 1.00
particle intensity = 0.82

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 73.96
gradient intensity = 0.67
gradient direction = -1.76



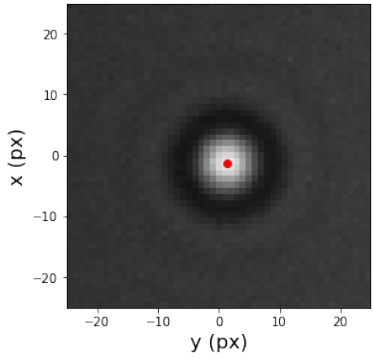
particle center x = -4.11 px
particle center y = 5.32 px
particle radius = 2.44 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 54.83
gradient intensity = 0.66
gradient direction = -1.43



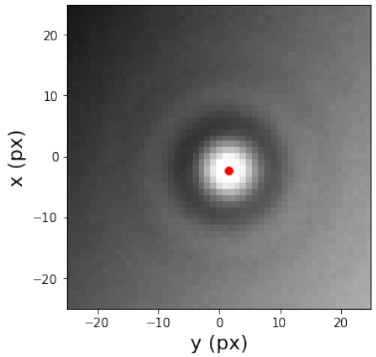
particle center x = -0.57 px
particle center y = 0.83 px
particle radius = 2.61 px
Bessel order = 1.00
particle intensity = 0.74

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 86.46
gradient intensity = 0.24
gradient direction = 1.71



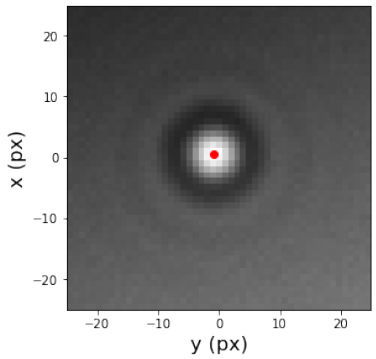
particle center x = -1.36 px
particle center y = 1.36 px
particle radius = 2.50 px
Bessel order = 1.00
particle intensity = 0.71

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 60.86
gradient intensity = 0.05
gradient direction = -0.11



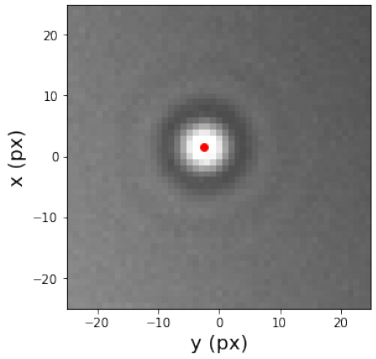
particle center x = -2.28 px
particle center y = 1.55 px
particle radius = 2.51 px
Bessel order = 1.00
particle intensity = 0.81

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 97.58
gradient intensity = 0.61
gradient direction = -0.57



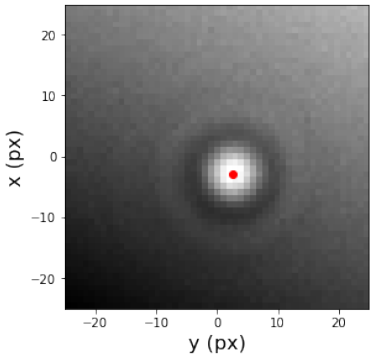
particle center x = 0.51 px
particle center y = -0.88 px
particle radius = 2.19 px
Bessel order = 1.00
particle intensity = 0.72

image half size = 25.00 px
image background level = 0.32
signal to noise ratio = 84.93
gradient intensity = 0.33
gradient direction = -1.23



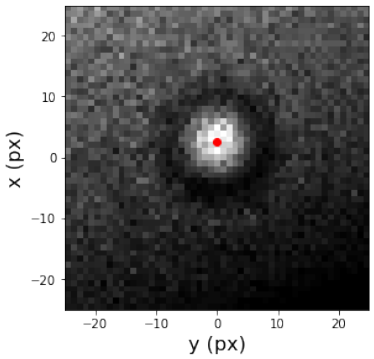
particle center x = 1.56 px
particle center y = -2.50 px
particle radius = 2.04 px
Bessel order = 1.00
particle intensity = 0.89

image half size = 25.00 px
image background level = 0.43
signal to noise ratio = 79.13
gradient intensity = 0.24
gradient direction = -2.70



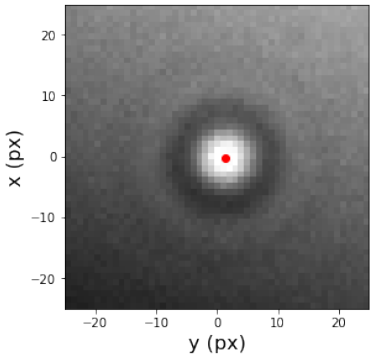
particle center x = -2.90 px
particle center y = 2.64 px
particle radius = 2.21 px
Bessel order = 1.00
particle intensity = 0.78

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 61.51
gradient intensity = 0.77
gradient direction = 1.11



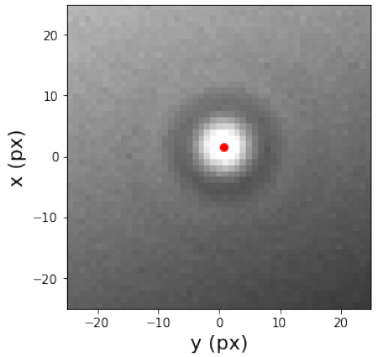
particle center x = 2.48 px
particle center y = -0.03 px
particle radius = 2.74 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 8.22
gradient intensity = 0.58
gradient direction = 1.91



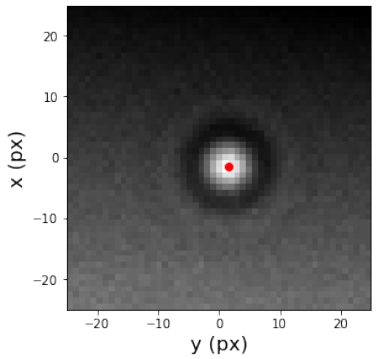
particle center x = -0.32 px
particle center y = 1.32 px
particle radius = 2.54 px
Bessel order = 1.00
particle intensity = 0.76

image half size = 25.00 px
image background level = 0.39
signal to noise ratio = 42.21
gradient intensity = 0.60
gradient direction = 1.25



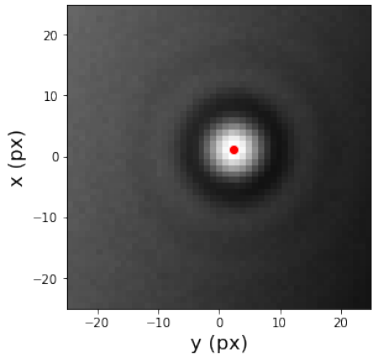
particle center x = 1.66 px
particle center y = 0.77 px
particle radius = 2.35 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 66.34
gradient intensity = 0.53
gradient direction = 1.98



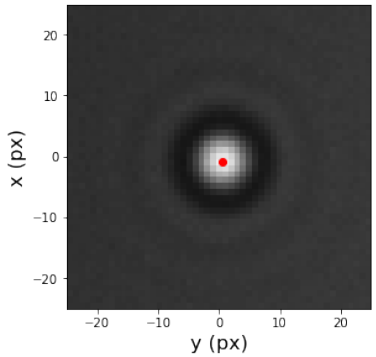
particle center x = -1.53 px
particle center y = 1.52 px
particle radius = 2.06 px
Bessel order = 1.00
particle intensity = 0.77

image half size = 25.00 px
image background level = 0.23
signal to noise ratio = 32.89
gradient intensity = 0.61
gradient direction = -1.68



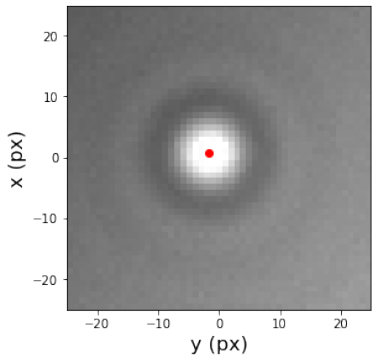
particle center x = 1.21 px
particle center y = 2.48 px
particle radius = 2.41 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.24
signal to noise ratio = 83.99
gradient intensity = 0.36
gradient direction = 2.81



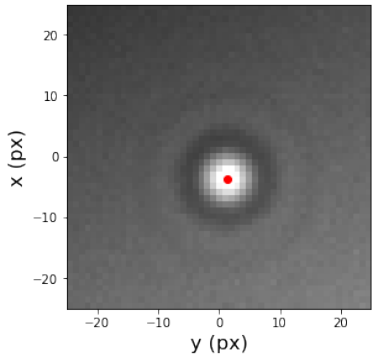
particle center x = -0.79 px
particle center y = 0.60 px
particle radius = 2.26 px
Bessel order = 1.00
particle intensity = 0.74

image half size = 25.00 px
image background level = 0.20
signal to noise ratio = 93.74
gradient intensity = 0.05
gradient direction = -0.25



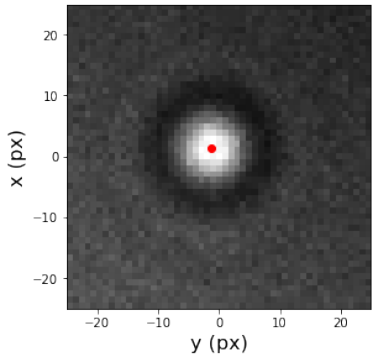
particle center x = 0.69 px
particle center y = -1.60 px
particle radius = 2.83 px
Bessel order = 1.00
particle intensity = 0.73

image half size = 25.00 px
image background level = 0.49
signal to noise ratio = 99.72
gradient intensity = 0.26
gradient direction = -0.66



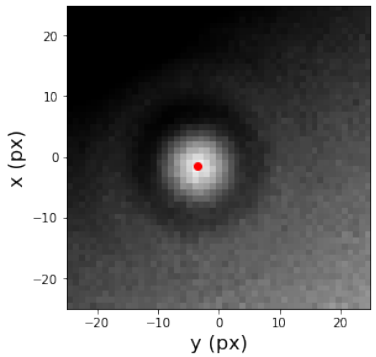
particle center x = -3.69 px
particle center y = 1.36 px
particle radius = 2.12 px
Bessel order = 1.00
particle intensity = 0.77

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 71.94
gradient intensity = 0.31
gradient direction = -1.13



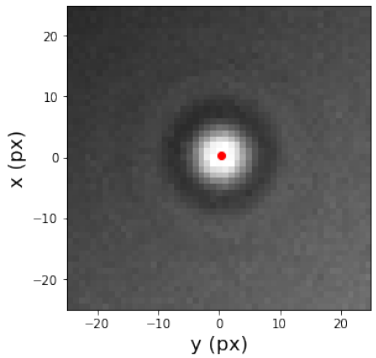
particle center x = 1.36 px
particle center y = -1.35 px
particle radius = 2.96 px
Bessel order = 1.00
particle intensity = 0.82

image half size = 25.00 px
image background level = 0.24
signal to noise ratio = 18.79
gradient intensity = 0.20
gradient direction = -2.22



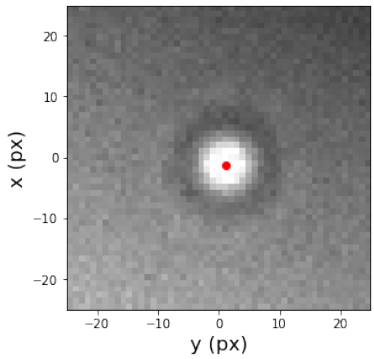
particle center x = -1.53 px
particle center y = -3.54 px
particle radius = 2.92 px
Bessel order = 1.00
particle intensity = 0.71

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 29.59
gradient intensity = 0.74
gradient direction = -1.03



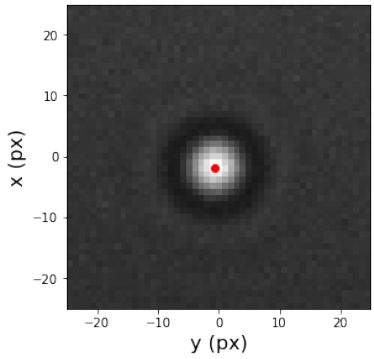
particle center x = 0.25 px
particle center y = 0.33 px
particle radius = 2.40 px
Bessel order = 1.00
particle intensity = 0.88

image half size = 25.00 px
image background level = 0.30
signal to noise ratio = 49.58
gradient intensity = 0.27
gradient direction = -0.83



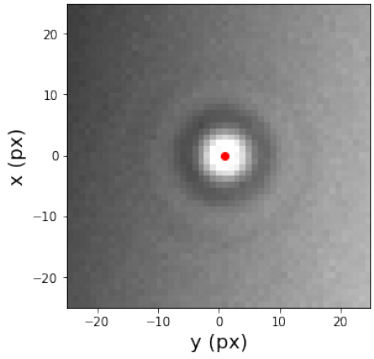
particle center x = -1.25 px
particle center y = 1.22 px
particle radius = 2.40 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 28.51
gradient intensity = 0.46
gradient direction = -2.01



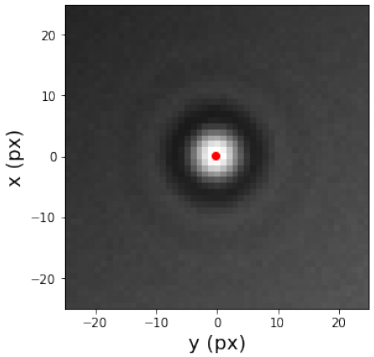
particle center x = -1.79 px
particle center y = -0.64 px
particle radius = 2.28 px
Bessel order = 1.00
particle intensity = 0.80

image half size = 25.00 px
image background level = 0.21
signal to noise ratio = 38.00
gradient intensity = 0.05
gradient direction = 1.41



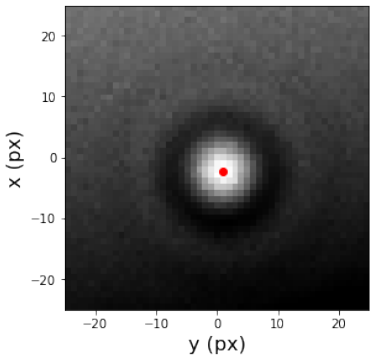
particle center x = -0.07 px
particle center y = 1.03 px
particle radius = 2.15 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.48
signal to noise ratio = 63.96
gradient intensity = 0.58
gradient direction = -0.23



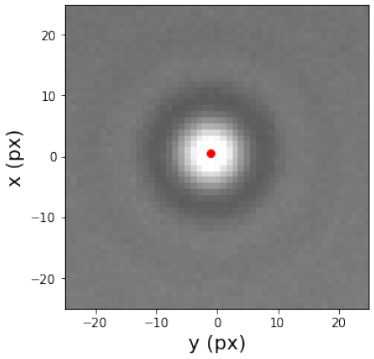
particle center x = 0.22 px
particle center y = -0.27 px
particle radius = 2.17 px
Bessel order = 1.00
particle intensity = 0.85

image half size = 25.00 px
image background level = 0.24
signal to noise ratio = 80.63
gradient intensity = 0.19
gradient direction = -0.82



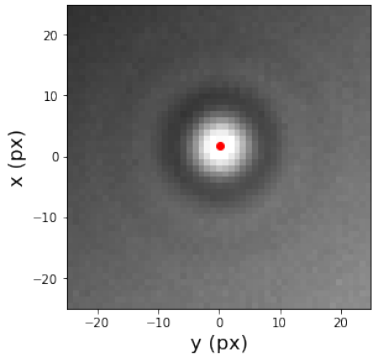
particle center x = -2.31 px
particle center y = 0.90 px
particle radius = 2.78 px
Bessel order = 1.00
particle intensity = 0.84

image half size = 25.00 px
image background level = 0.22
signal to noise ratio = 33.46
gradient intensity = 0.59
gradient direction = 1.77



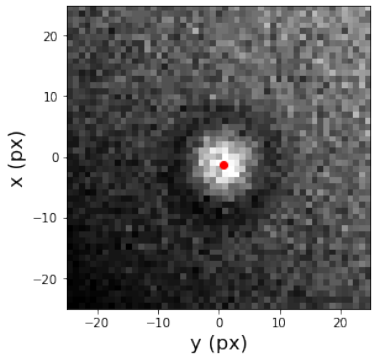
particle center x = 0.48 px
particle center y = -1.14 px
particle radius = 2.91 px
Bessel order = 1.00
particle intensity = 0.71

image half size = 25.00 px
image background level = 0.47
signal to noise ratio = 99.42
gradient intensity = 0.05
gradient direction = -1.40



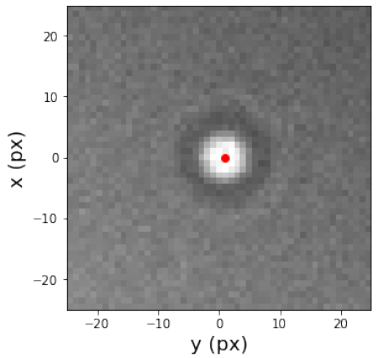
particle center x = 1.70 px
particle center y = 0.22 px
particle radius = 2.58 px
Bessel order = 1.00
particle intensity = 0.80

image half size = 25.00 px
image background level = 0.38
signal to noise ratio = 75.30
gradient intensity = 0.37
gradient direction = -0.86



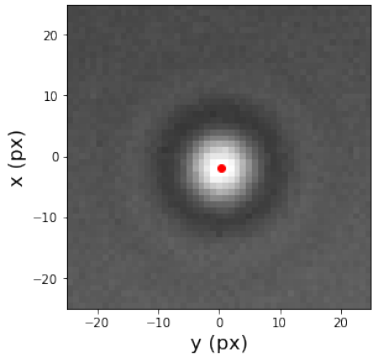
particle center x = -1.29 px
particle center y = 0.83 px
particle radius = 2.80 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.28
signal to noise ratio = 6.86
gradient intensity = 0.58
gradient direction = 0.81



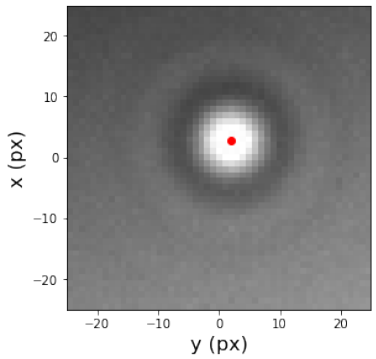
particle center x = 0.01 px
particle center y = 0.87 px
particle radius = 2.01 px
Bessel order = 1.00
particle intensity = 0.79

image half size = 25.00 px
image background level = 0.45
signal to noise ratio = 29.18
gradient intensity = 0.17
gradient direction = -2.25



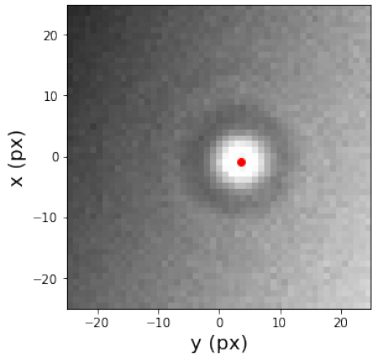
particle center x = -1.97 px
particle center y = 0.27 px
particle radius = 2.93 px
Bessel order = 1.00
particle intensity = 0.72

image half size = 25.00 px
image background level = 0.33
signal to noise ratio = 57.21
gradient intensity = 0.11
gradient direction = -1.34



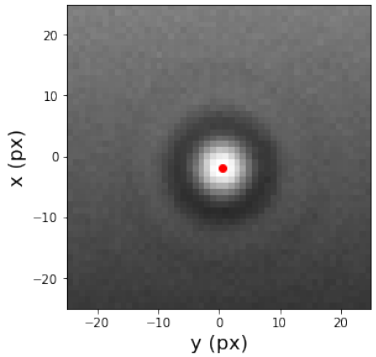
particle center x = 2.76 px
particle center y = 1.93 px
particle radius = 2.81 px
Bessel order = 1.00
particle intensity = 0.86

image half size = 25.00 px
image background level = 0.43
signal to noise ratio = 78.65
gradient intensity = 0.35
gradient direction = -1.27



particle center x = -0.86 px
particle center y = 3.54 px
particle radius = 2.37 px
Bessel order = 1.00
particle intensity = 0.75

image half size = 25.00 px
image background level = 0.50
signal to noise ratio = 39.28
gradient intensity = 0.72
gradient direction = -0.41



particle center x = -1.98 px
particle center y = 0.48 px
particle radius = 2.45 px
Bessel order = 1.00
particle intensity = 0.74

image half size = 25.00 px
image background level = 0.36
signal to noise ratio = 58.86
gradient intensity = 0.39
gradient direction = 1.63

1.4 3. USE A PRETRAINED DEEP LEARNING NETWORK

The pretraiend network saved in the file "DeepTrack - Example 2 - Pretrained network.h5" is loaded and its performance tested on a selected video.

Change the video file to select the various videos:

1. DeepTrack - Example 2 - Optically Trapped Particle Good.mp4
2. DeepTrack - Example 2 - Optically Trapped Particle Bad.mp4

Note that the file "DeepTrack - Example 2 - Pretrained network.h5" and the video file must be in the same folder as this notebook.

Comments: 1. number_frames_to_be_tracked can be changed to track different number of frames. If number_frames is equal to 0 then the whole video is tracked.

In [6]:
```
### Define the video file to be tracked
video_file_name = 'DeepTrack - Example 2 - Optically Trapped Particle Good.mp4'

### Define the number of frames to be tracked
number_frames_to_be_tracked = 2

### Load the pretrained network
saved_network_file_name = 'DeepTrack - Example 2 - Pretrained network.h5'
network = deeptrack.load(saved_network_file_name)

### Track the video
(frames, predicted_positions) = deeptrack.track_video_single_particle(
    video_file_name,
    network,
    number_frames_to_be_tracked)
```

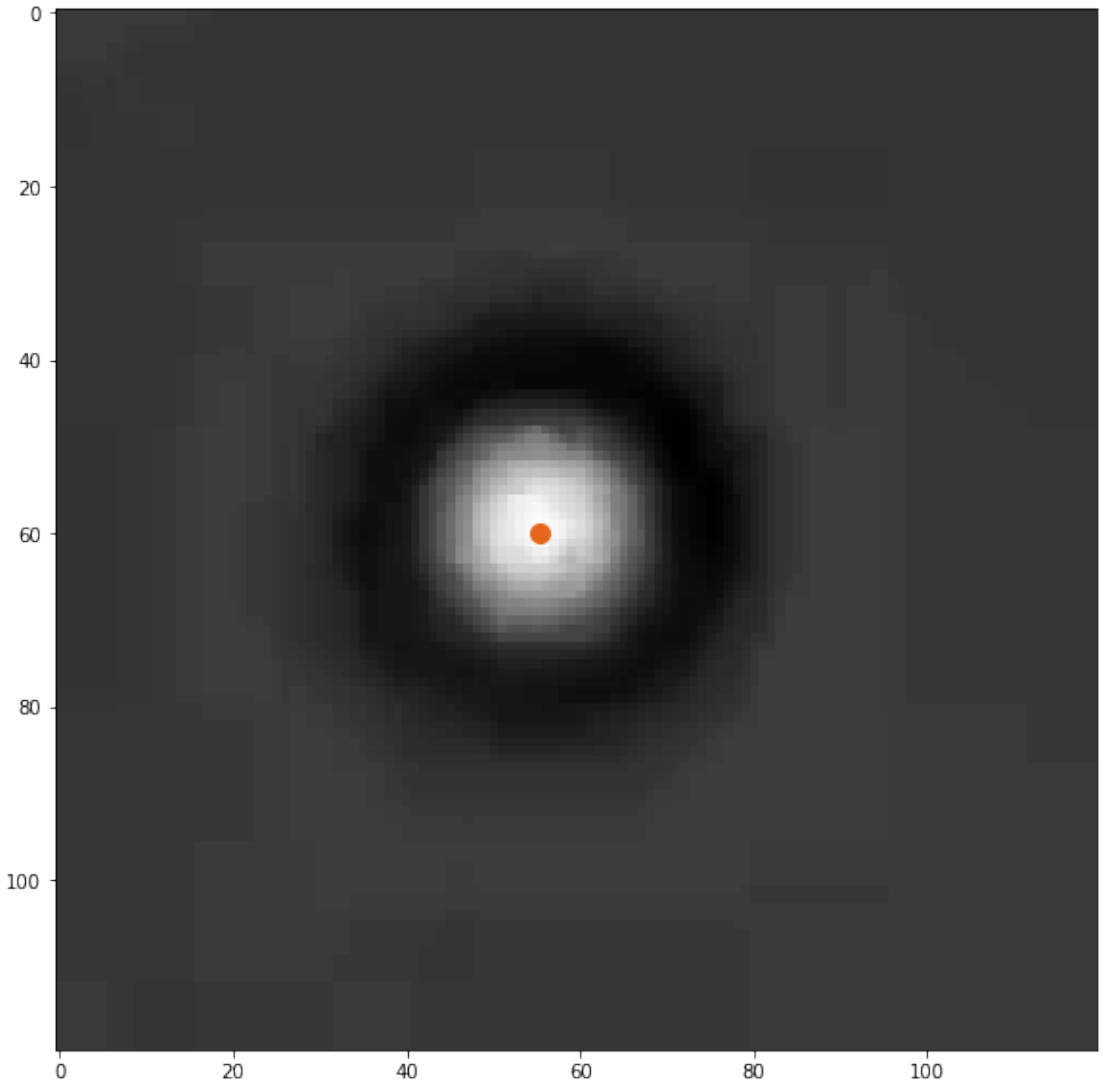
```
/anaconda3/lib/python3.6/site-packages/h5py/__init__.py:36: FutureWarning: Conversion of the se
  from ._conv import register_converters as _register_converters
Using TensorFlow backend.
```

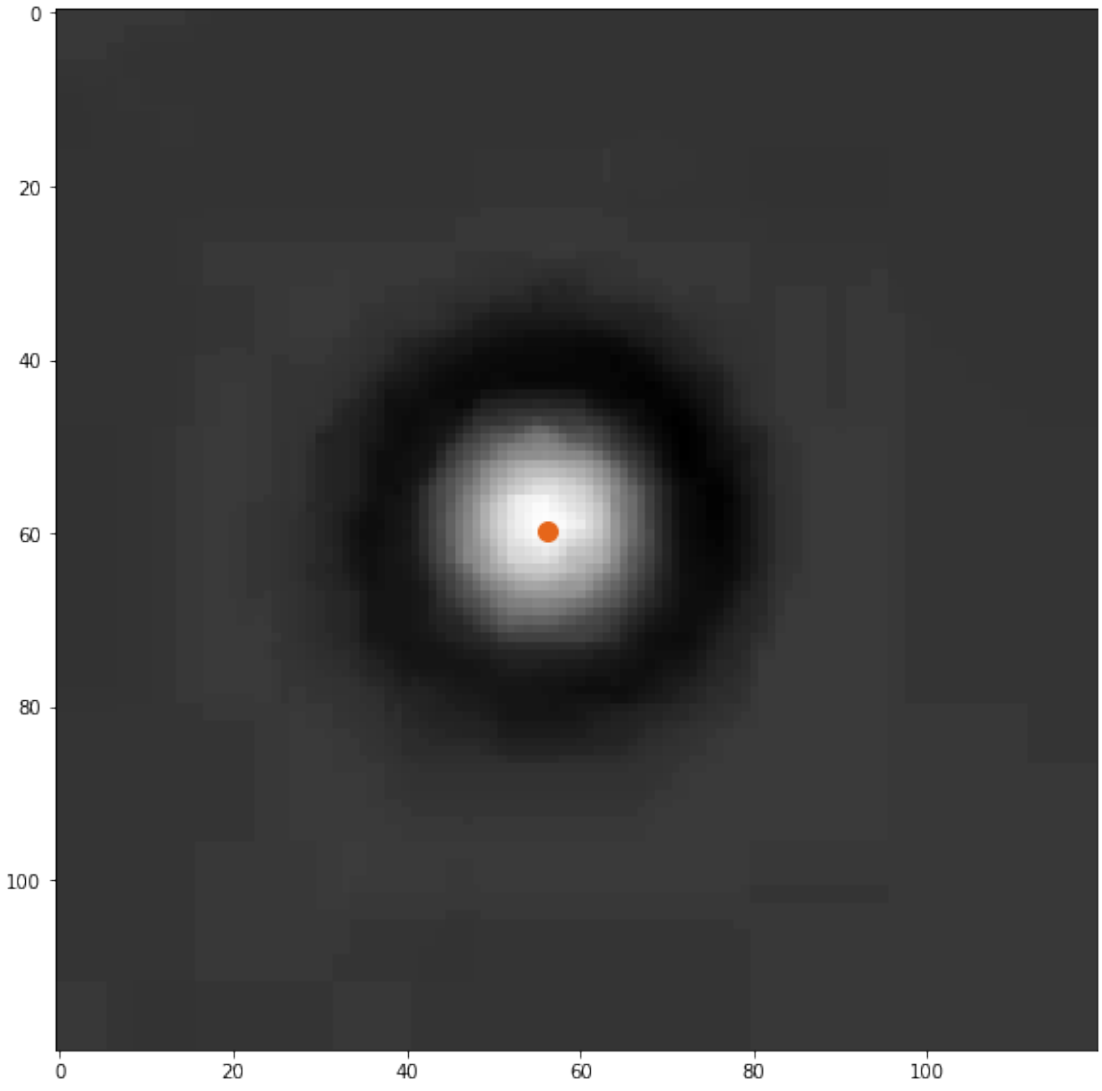
1.5 4. SHOW EXAMPLES OF TRACKED FRAMES

The tracked frames are shown.

Comments: 1. The orange symbol is the deep learning network prediction for the position (x, y).

```
In [7]: ### Visualize tracked frames (maximum 10 frames at a time)
        deeptrack.show_tracked_frames_single_particle(
            min(number_frames_to_be_tracked, 10),
            frames,
            predicted_positions)
```




0
20
40
60
80
100
0
20
40
60
80
100