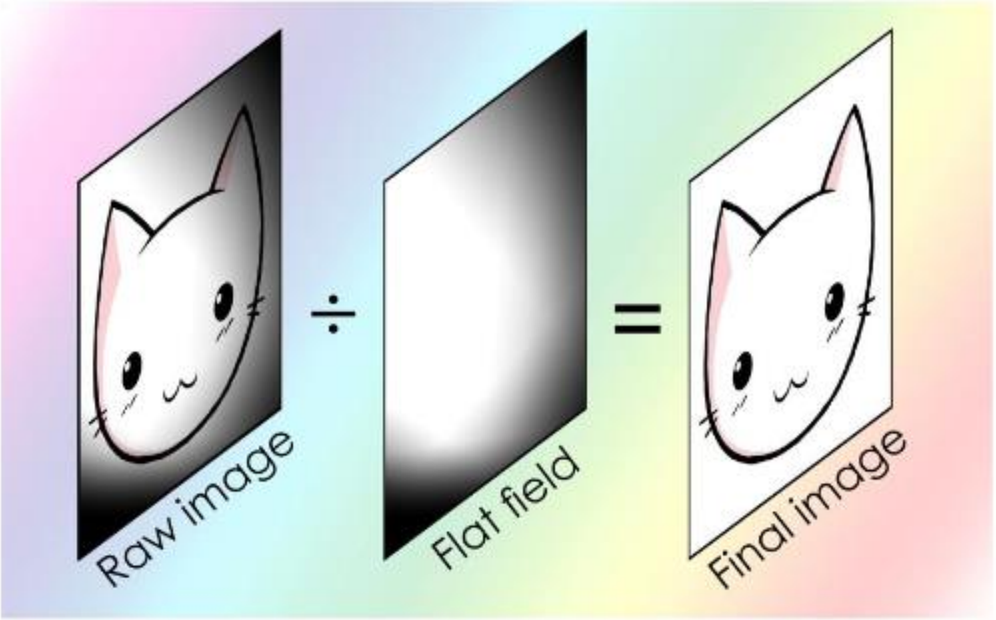
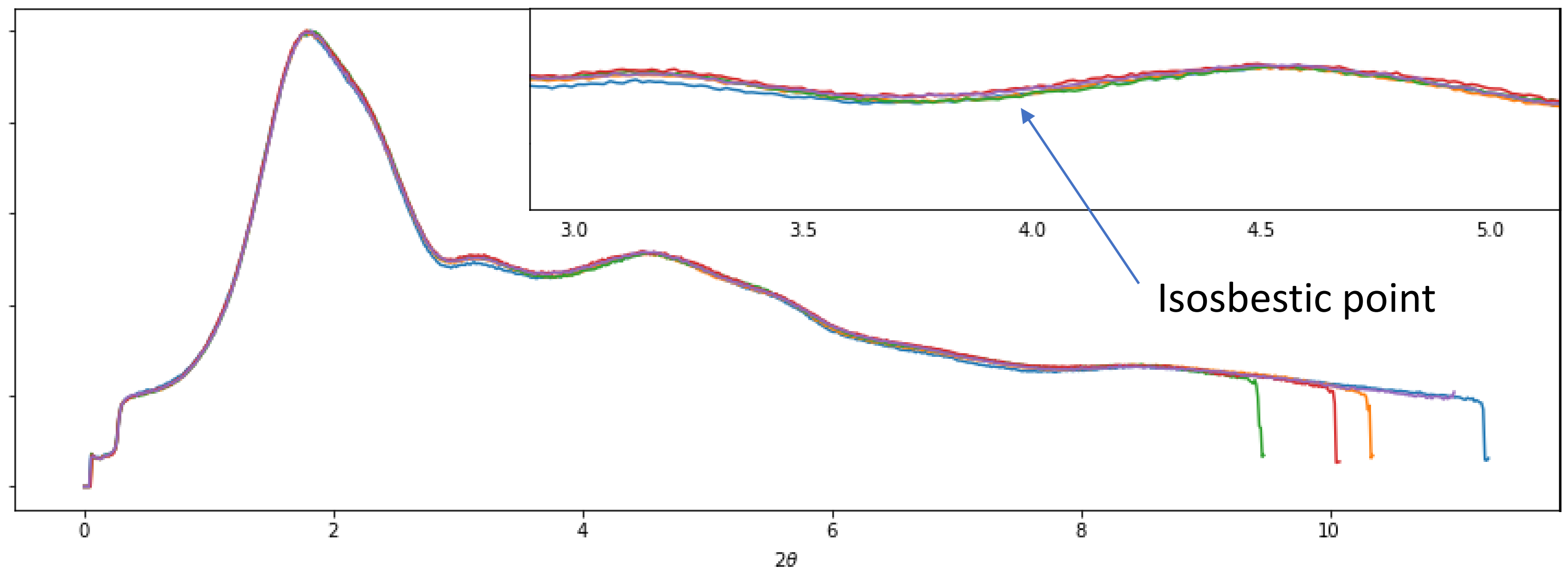
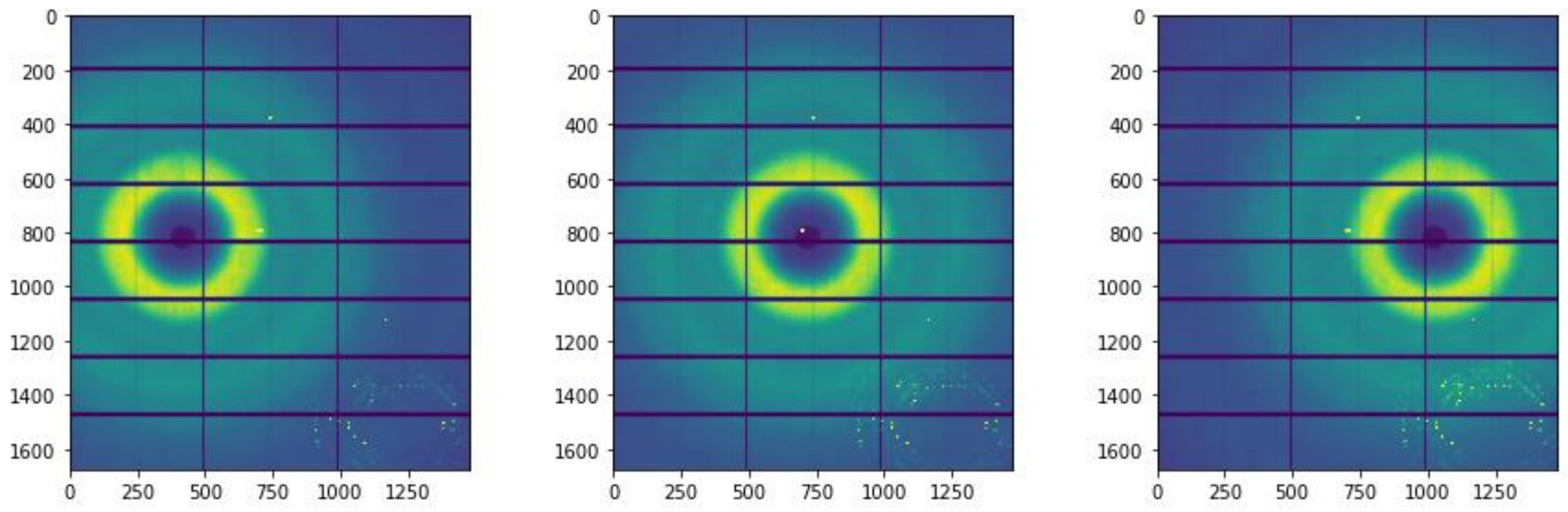
X-ray detector gain correction without flat fields

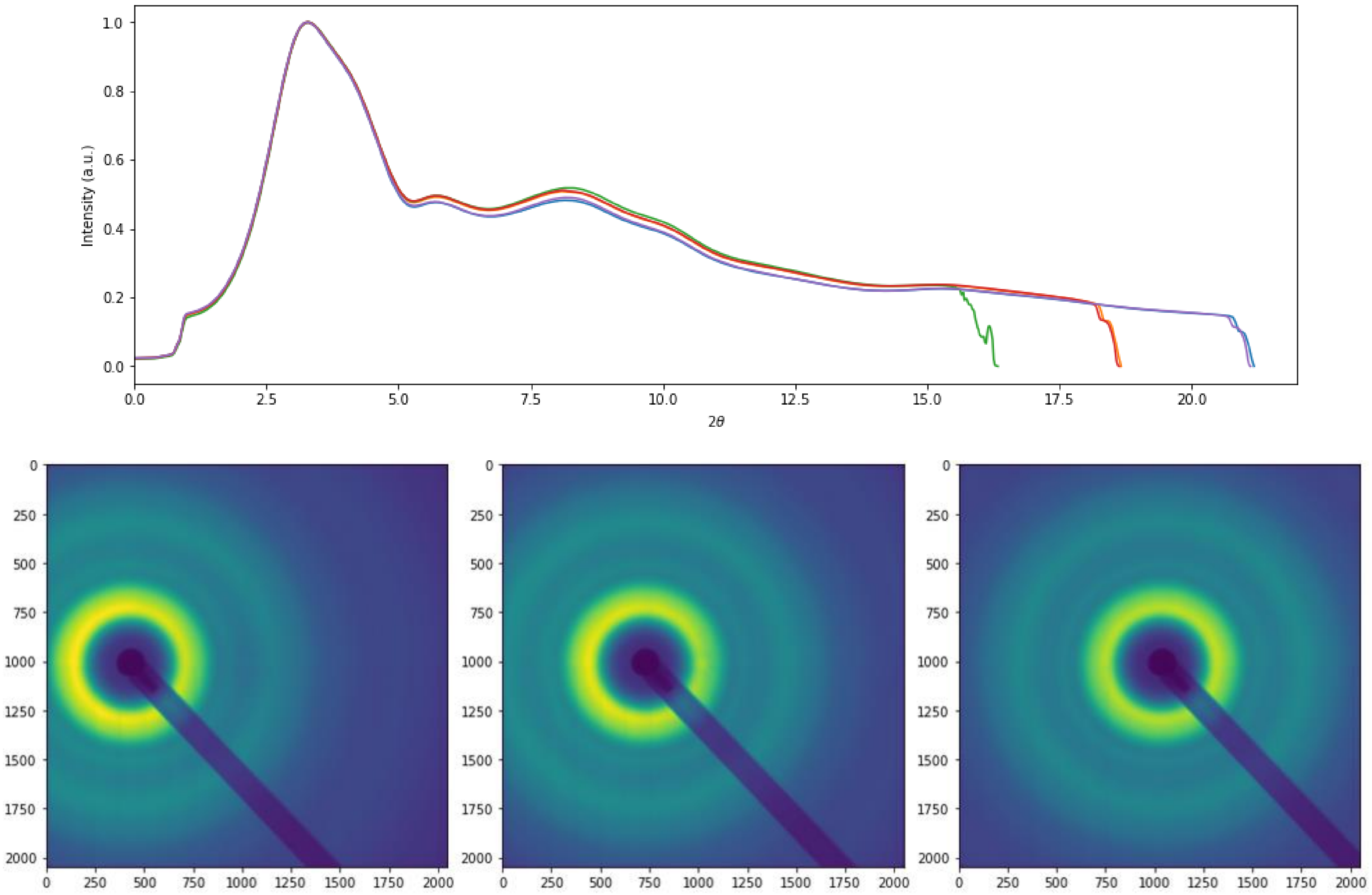
James Weng



Bunn, Catharine, "Constructing a Flat Field for Scientific Astronomical Imaging" (2014). Physics Capstone Project. Paper 10.
https://digitalcommons.usu.edu/phys_capstoneproject/10


3.0
3.5
4.0
4.5
5.0
Isosbestic point
0
2
4
6
8
10
2θ


0
200
400
600
800
1000
1200
1400
1600
0
250
500
750
1000
1250



Intensity (a.u.)
2θ

Measurements

$$y = A\,x$$

$y \rightarrow measurement$
$A \rightarrow measurement\ or\ sensing\ matrix$
$x \rightarrow measured\ signal$

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \longrightarrow \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} 0.9 & 0 & 0 \\ 0 & 1.3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Measured Signal

1.1	1.3	3.1	1.8	1.2
0.9	1.5	0.8	1.3	1.2
1	1.3	1.3	1.2	1.3
0.8	1.3	1	1.5	1.5
0.6	1.2	1.6	1.3	1.2

=

Gain map

1	1.2	3	1.7	1.1
0.8	1.4	0.7	1.2	1.1
0.9	1.2	1.2	1.1	1.3
0.7	1.2	0.9	1.4	1.4
0.5	1.1	1.5	1.2	1.1

×

Signal being measured

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

Flat field

+

Dark Frame/error

0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1
0.1	0.1	0.1	0.1	0.1

$$I_m(x, y) = G(x, y) \cdot S(x, y) + \varepsilon$$

Measured Signal

I_{00}	I_{10}	I_{20}	I_{30}	I_{40}
I_{01}	I_{11}	I_{21}	I_{31}	I_{41}
I_{02}	I_{12}	I_{22}	I_{32}	I_{42}
I_{03}	I_{13}	I_{23}	I_{33}	I_{43}
I_{04}	I_{14}	I_{24}	I_{34}	I_{44}

=

Gain map

G_{00}	G_{10}	G_{20}	G_{30}	G_{40}
G_{01}	G_{11}	G_{21}	G_{31}	G_{41}
G_{02}	G_{12}	G_{22}	G_{32}	G_{42}
G_{03}	G_{13}	G_{23}	G_{33}	G_{43}
G_{04}	G_{14}	G_{24}	G_{34}	G_{44}

×

Signal being measured

0	0.8	1	0.8	0
0.8	1.4	1	1.4	0.8
1	1	0	1	1
0.8	1.4	1	1.4	0.8
0	0.8	1	0.8	0

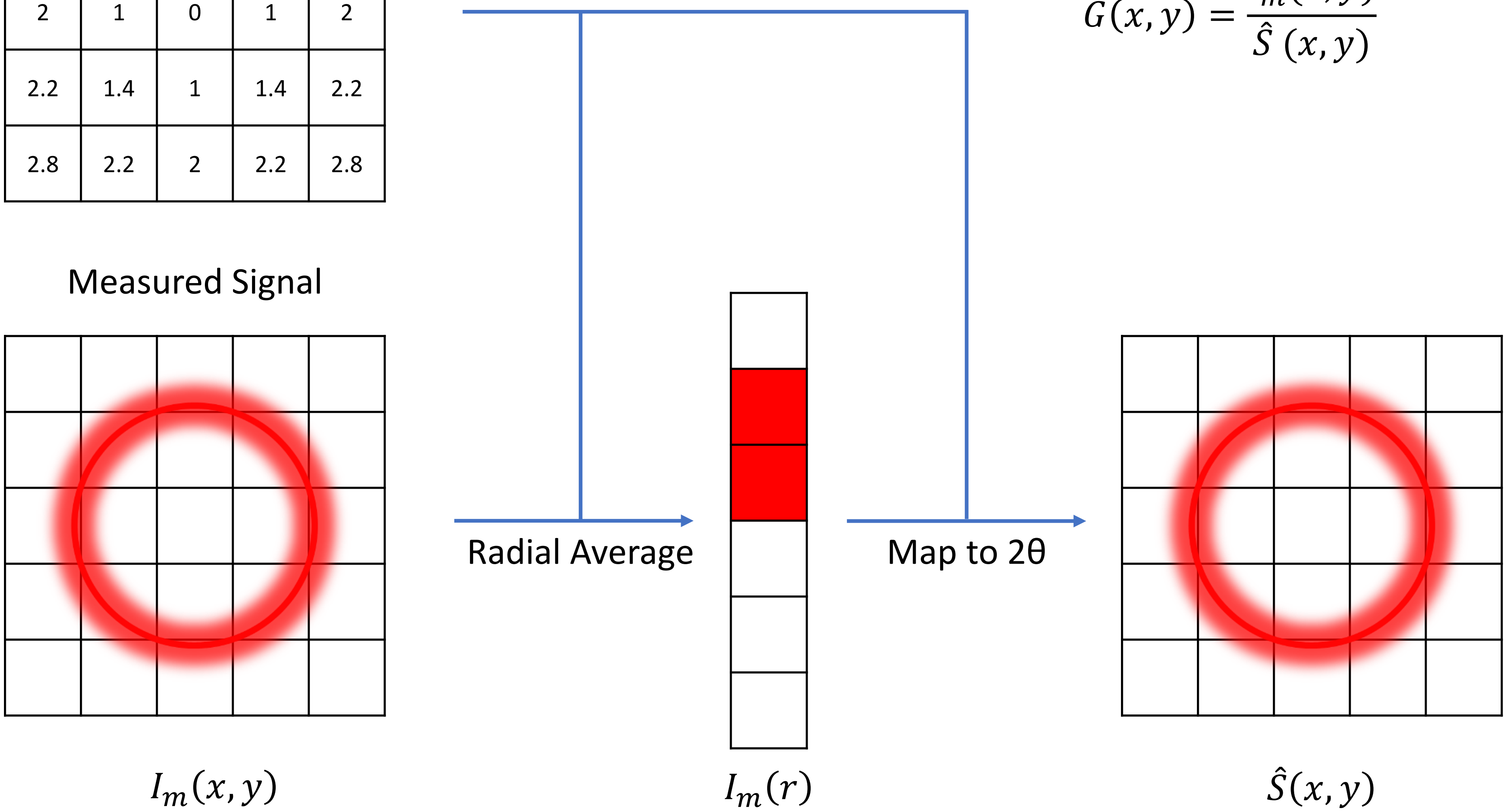
$$I_m(x,y) = G(x,y) \cdot S(x,y) + \varepsilon$$

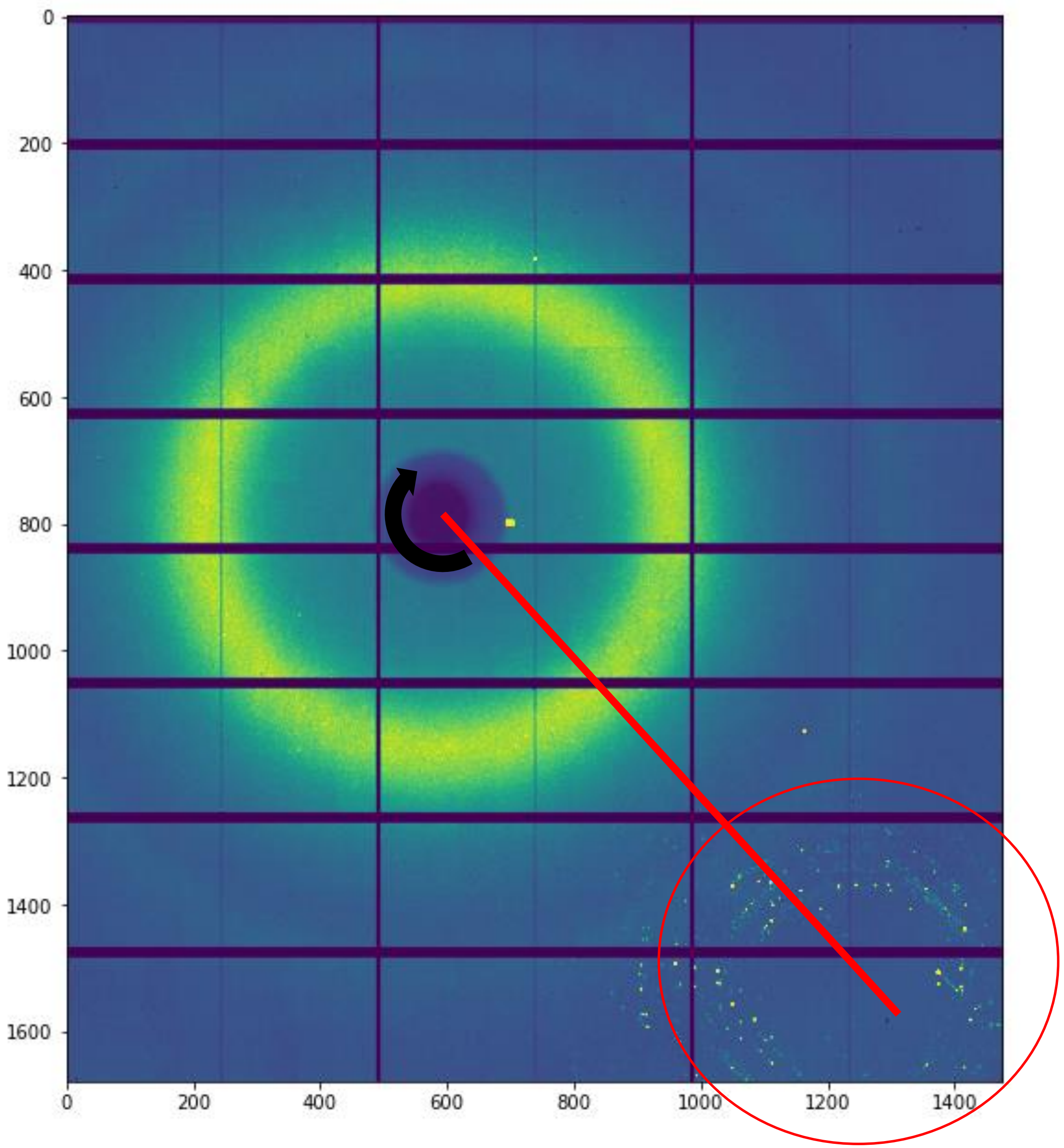
2θ positions

2.8	2.2	2	2.2	2.8
2.2	1.4	1	1.4	2.2
2	1	0	1	2
2.2	1.4	1	1.4	2.2
2.8	2.2	2	2.2	2.8

$$I_m(x,y) = G(x,y) \cdot S(x,y) + \varepsilon$$

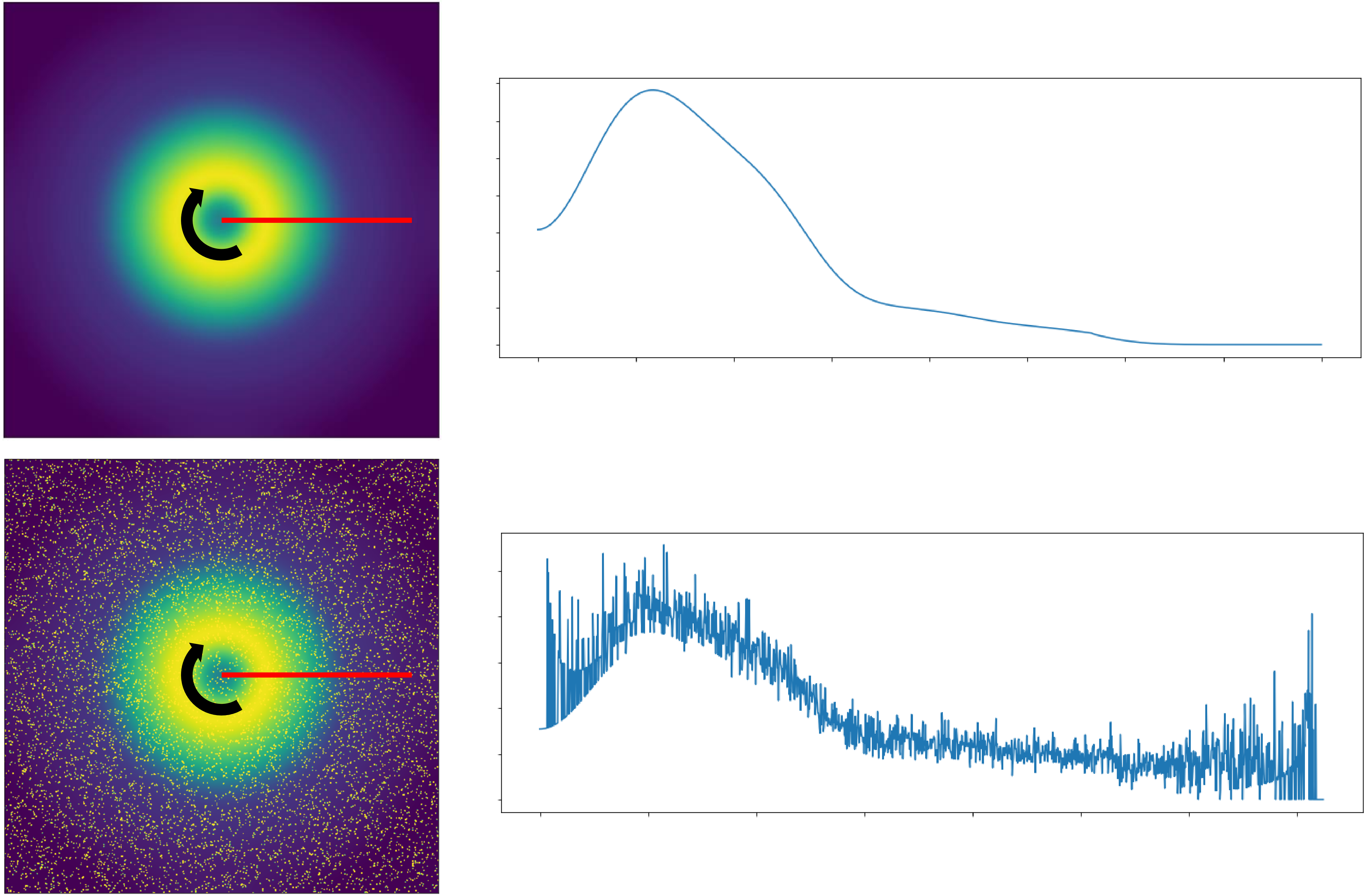
$$\hat{G}(x,y) = \frac{I_m(x,y)}{\hat{S}\,(x,y)}$$

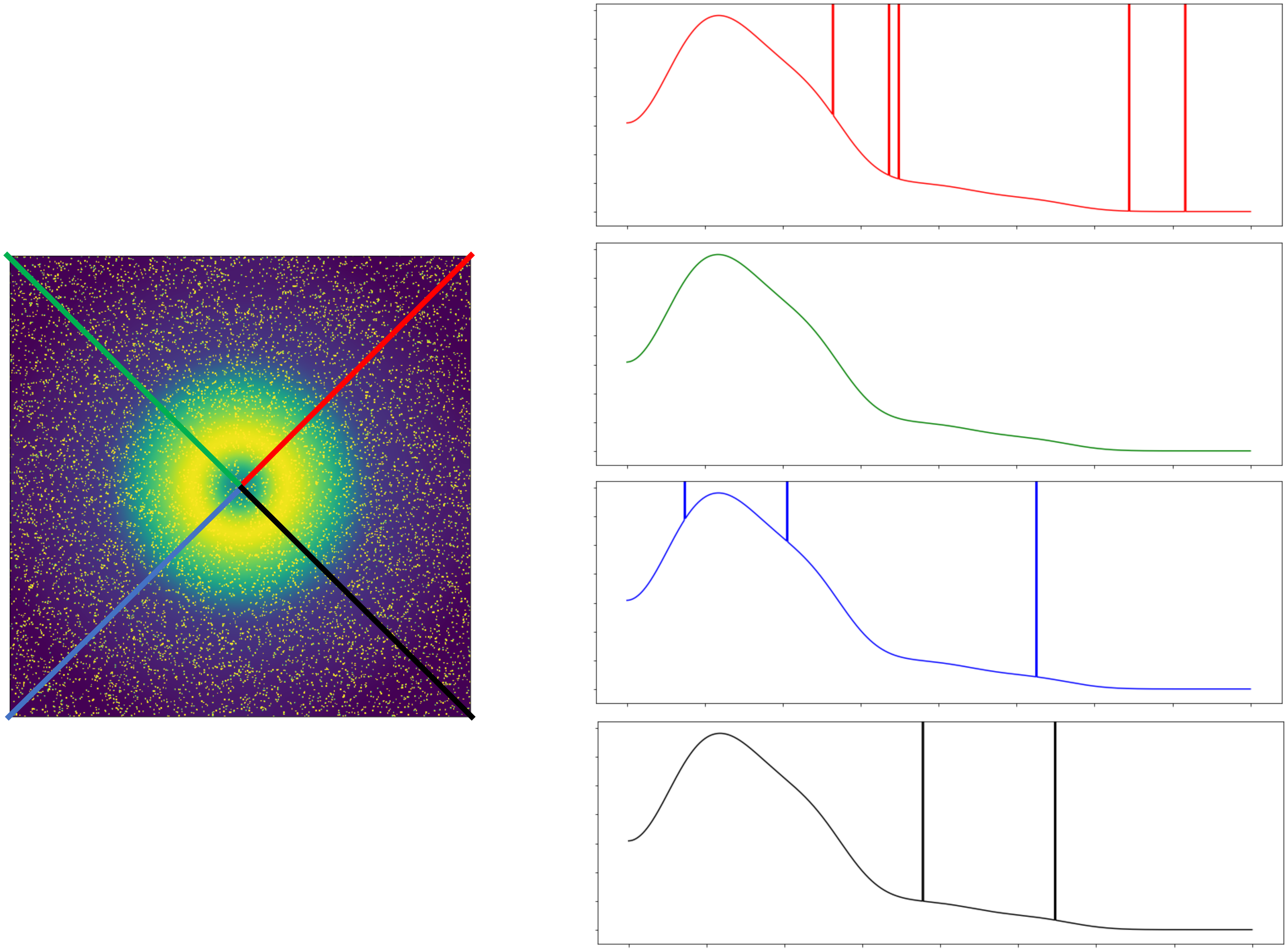


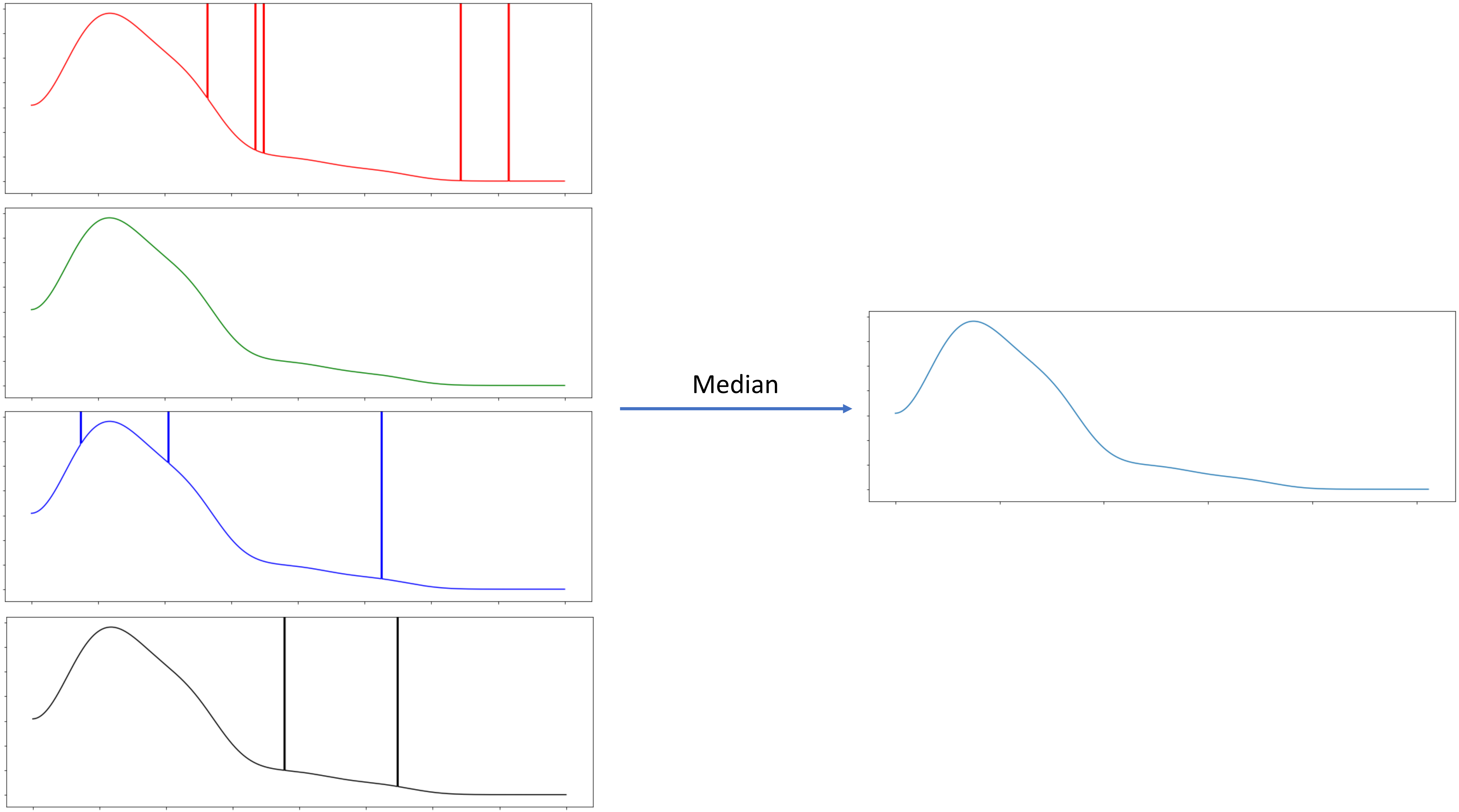


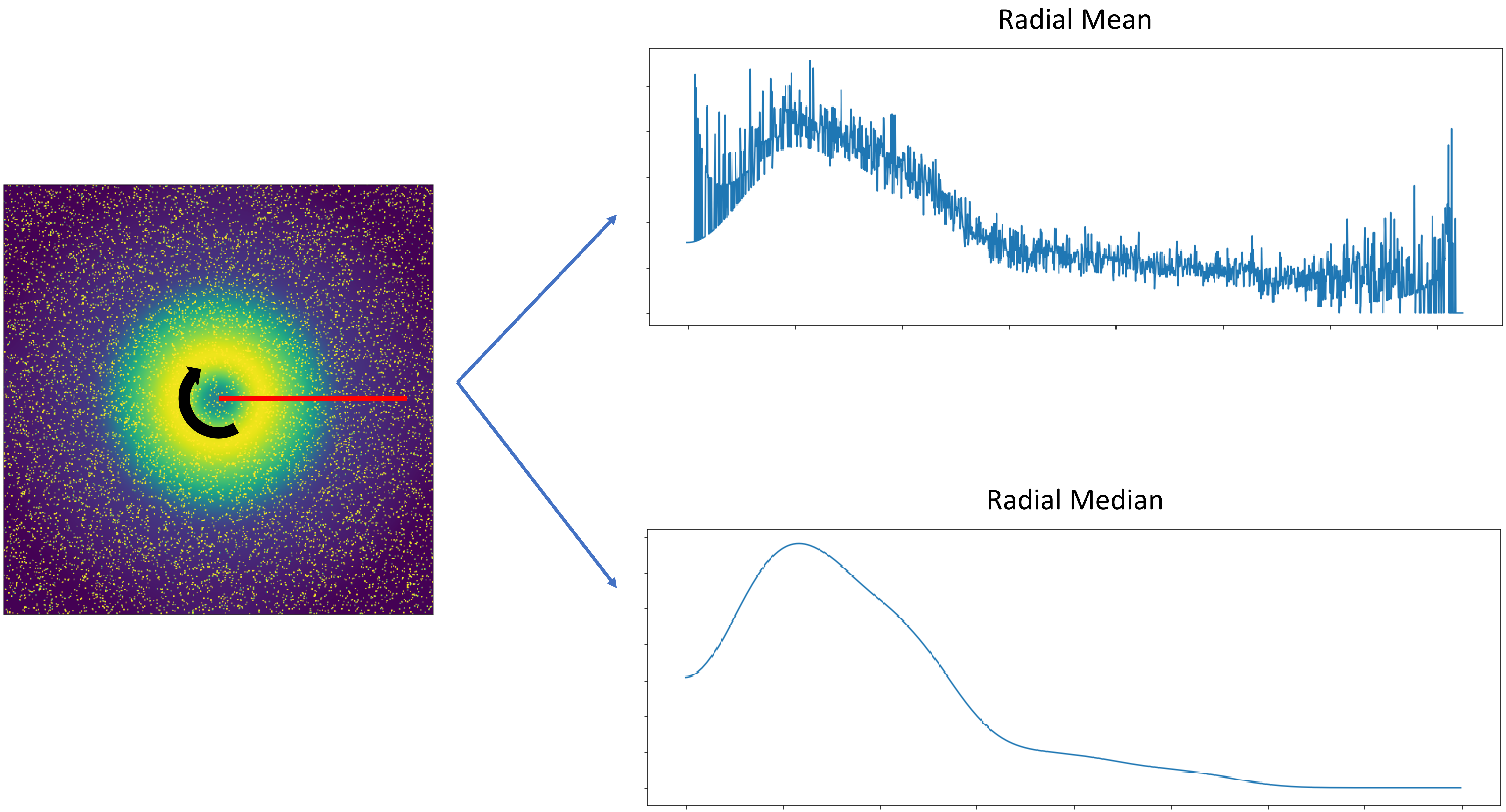
0
200
400
600
800
1000
1200
1400
1600
0
200
400
600
800
1000
1200
1400

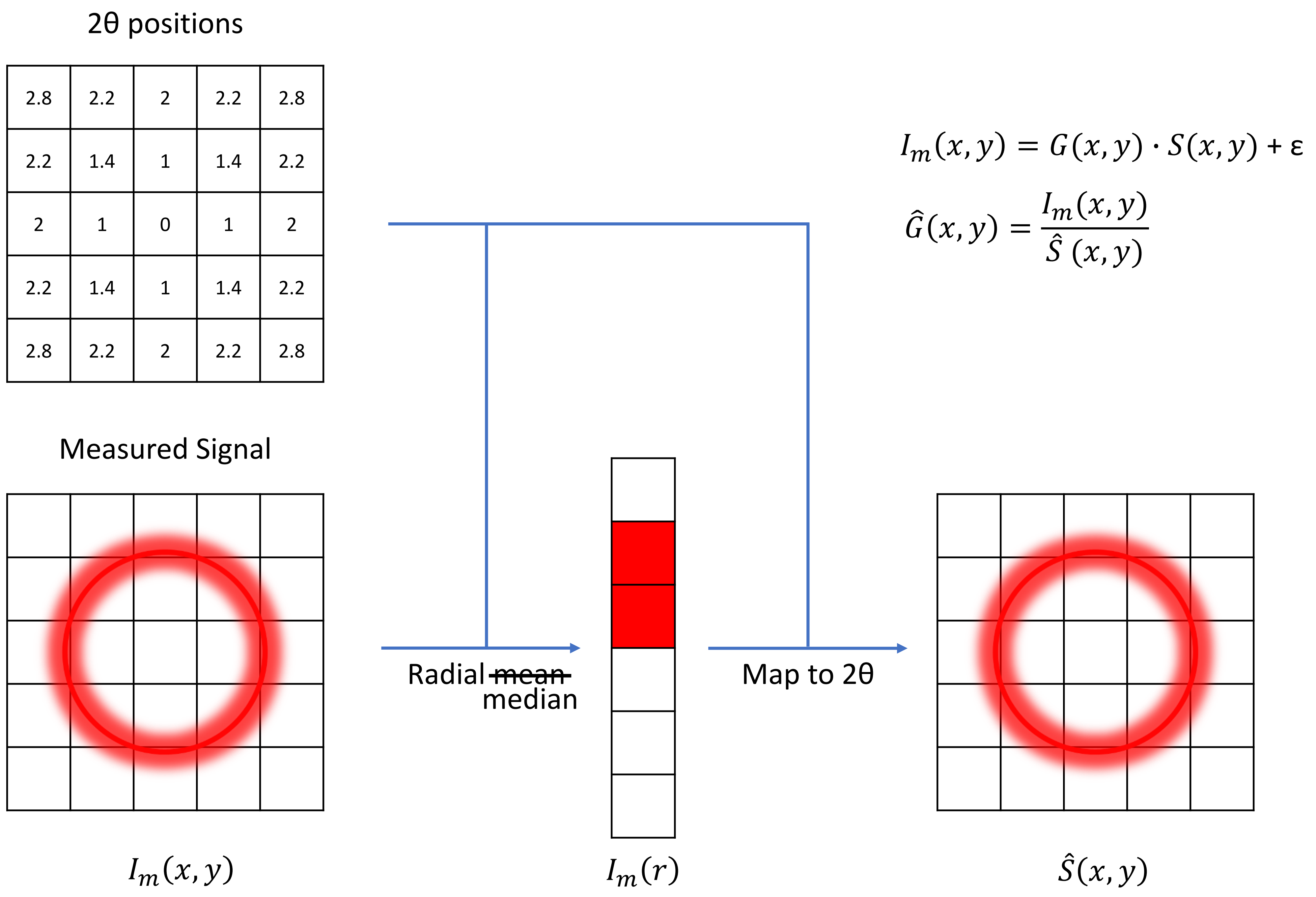
Outliers!



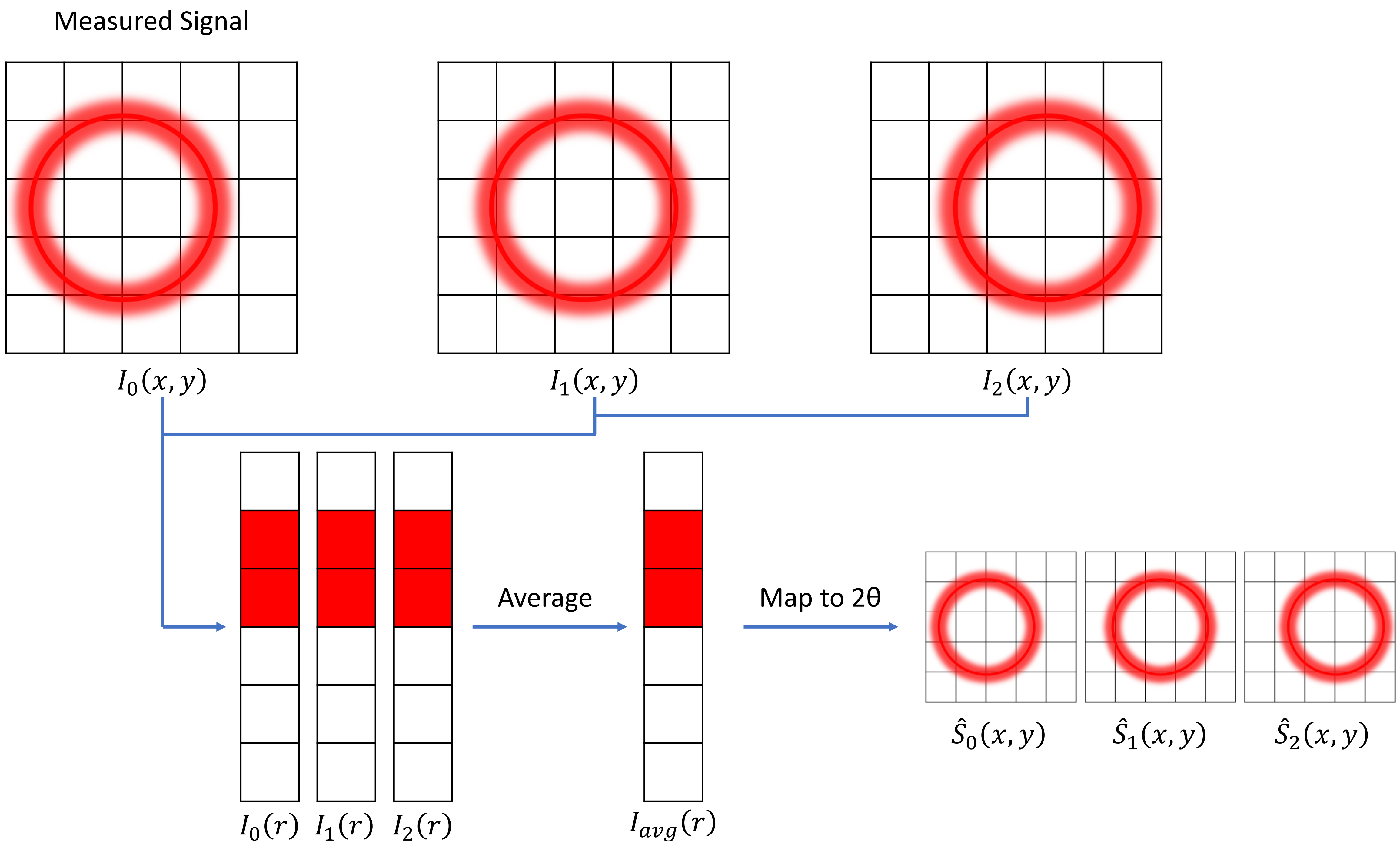



Median


Radial Mean
Radial Median

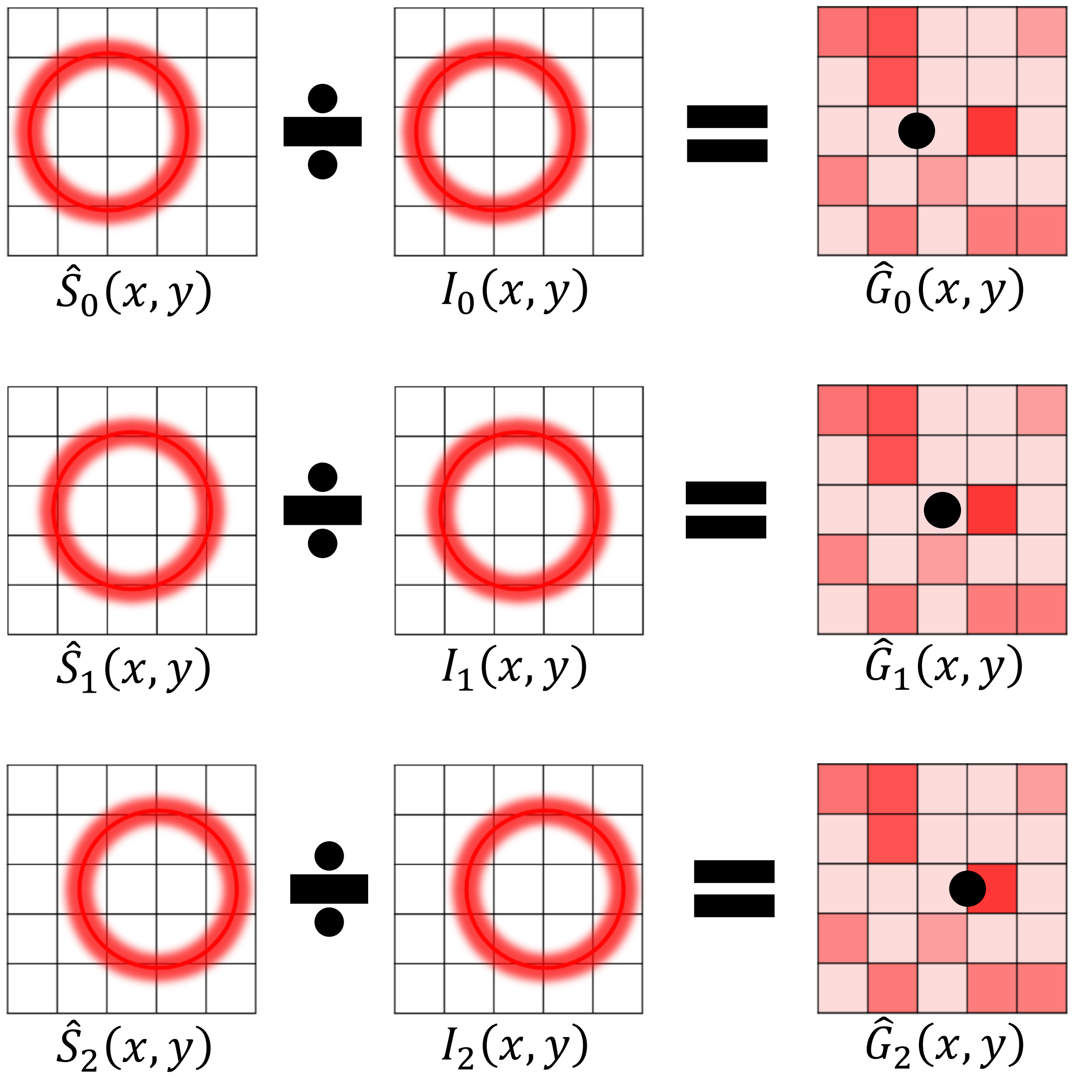


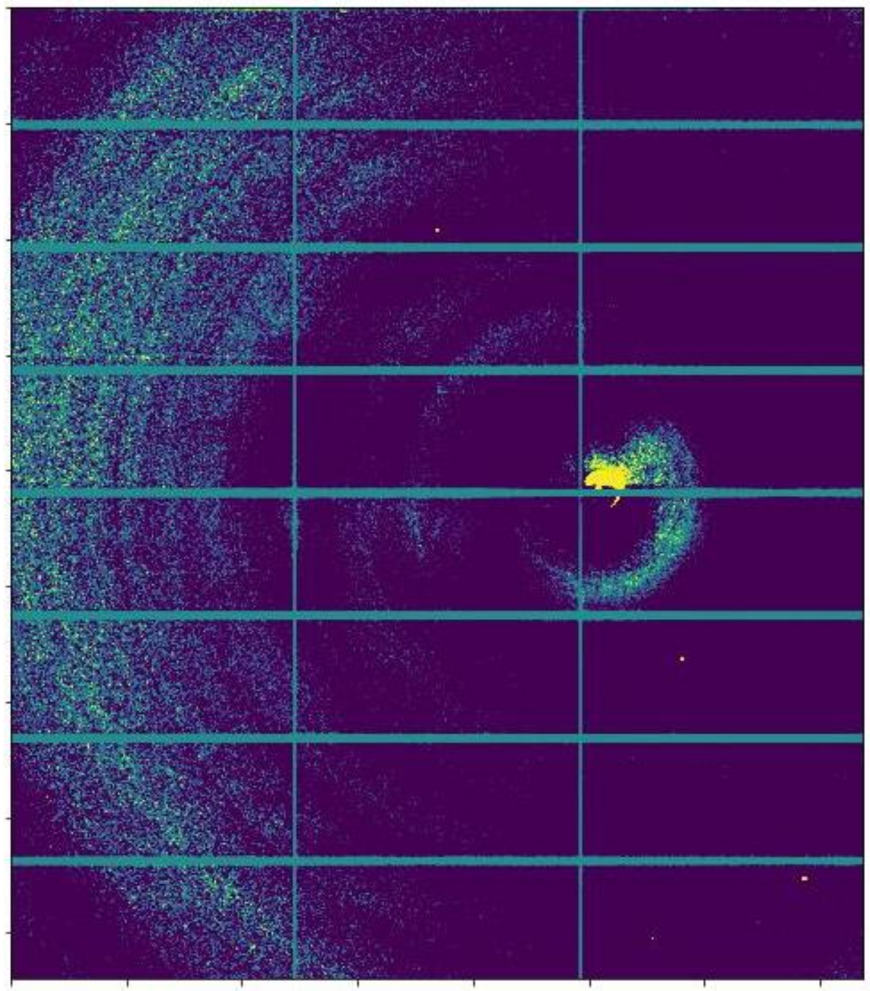
2θ positions
2.8 2.2 2 2.2 2.8
2.2 1.4 1 1.4 2.2
2 1 0 1 2
2.2 1.4 1 1.4 2.2
2.8 2.2 2 2.2 2.8
$I_m(x,y) = G(x,y) \cdot S(x,y) + \varepsilon$
$\hat{G}(x,y) = \frac{I_m(x,y)}{\hat{S}(x,y)}$
Measured Signal
Radial ~~mean~~ median
Map to 2θ
$I_m(x,y)$
$I_m(r)$
$\hat{S}(x,y)$

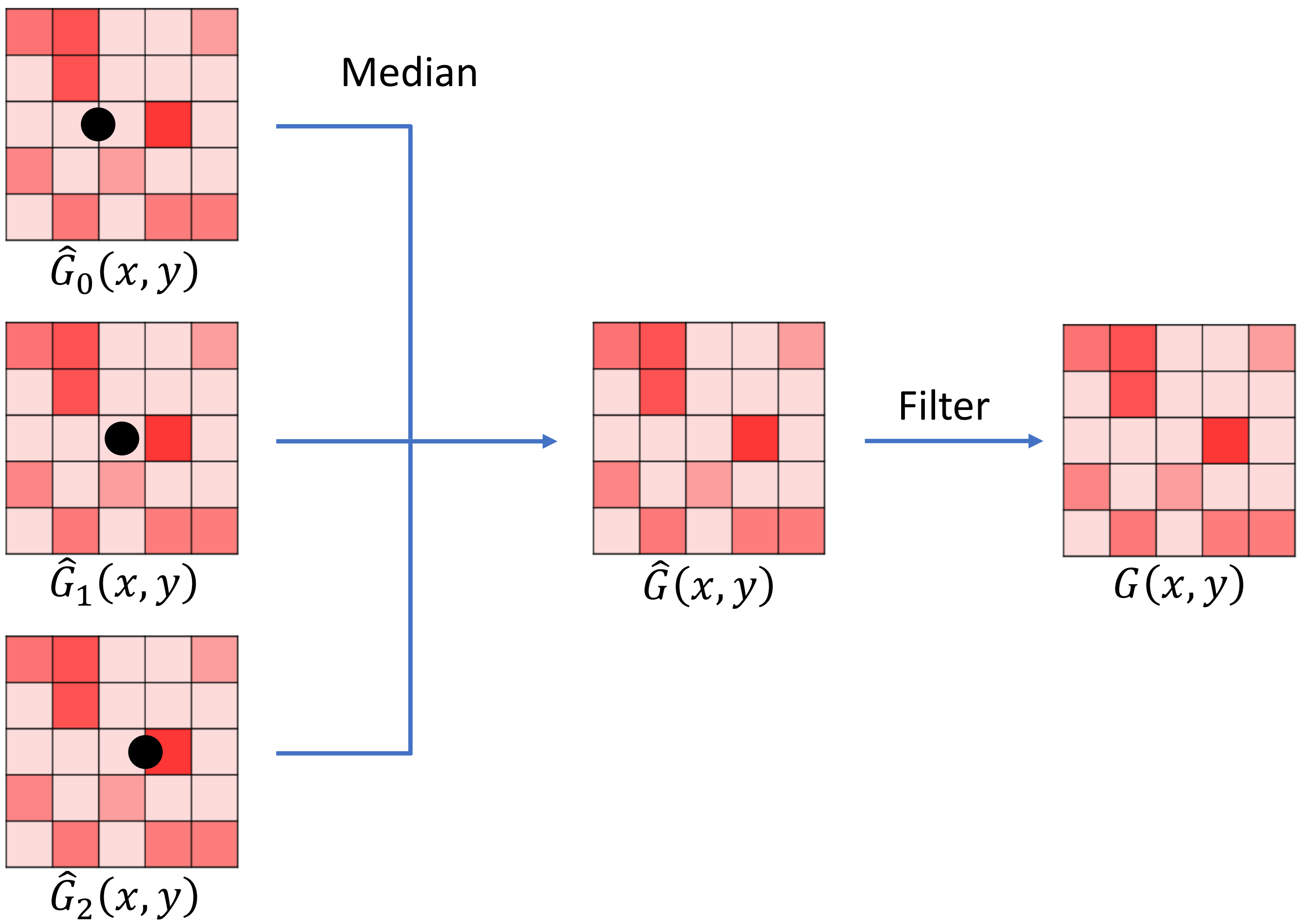


Measured Signal
$I_0(x,y)$
$I_1(x,y)$
$I_2(x,y)$
Average
Map to 2θ
$I_0(r)$
$I_1(r)$
$I_2(r)$
$I_{avg}(r)$
$\hat{S}_0(x,y)$
$\hat{S}_1(x,y)$
$\hat{S}_2(x,y)$

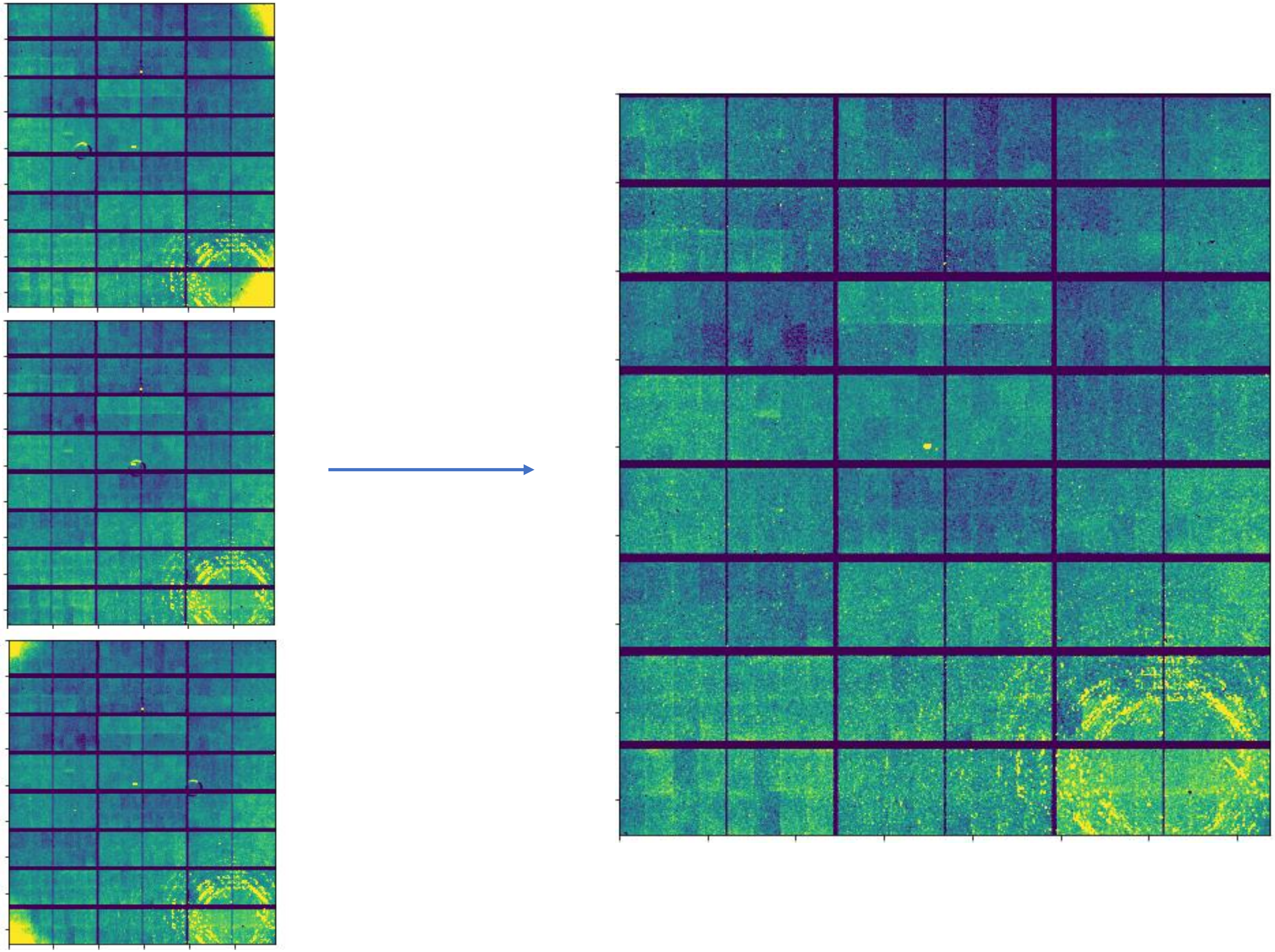
$$\hat{G}(x,y) = \frac{I_m(x,y)}{\hat{S}\,(x,y)}$$







Median
$\hat{G}_0(x,y)$
$\hat{G}_1(x,y)$
$\hat{G}_2(x,y)$
$\hat{G}(x,y)$
Filter
$G(x,y)$



Median filter

Input

3	1	1	11	1
1	1	1	1	1
1	1	87	1	1
12	1	1	1	1
1	1	1	39	1

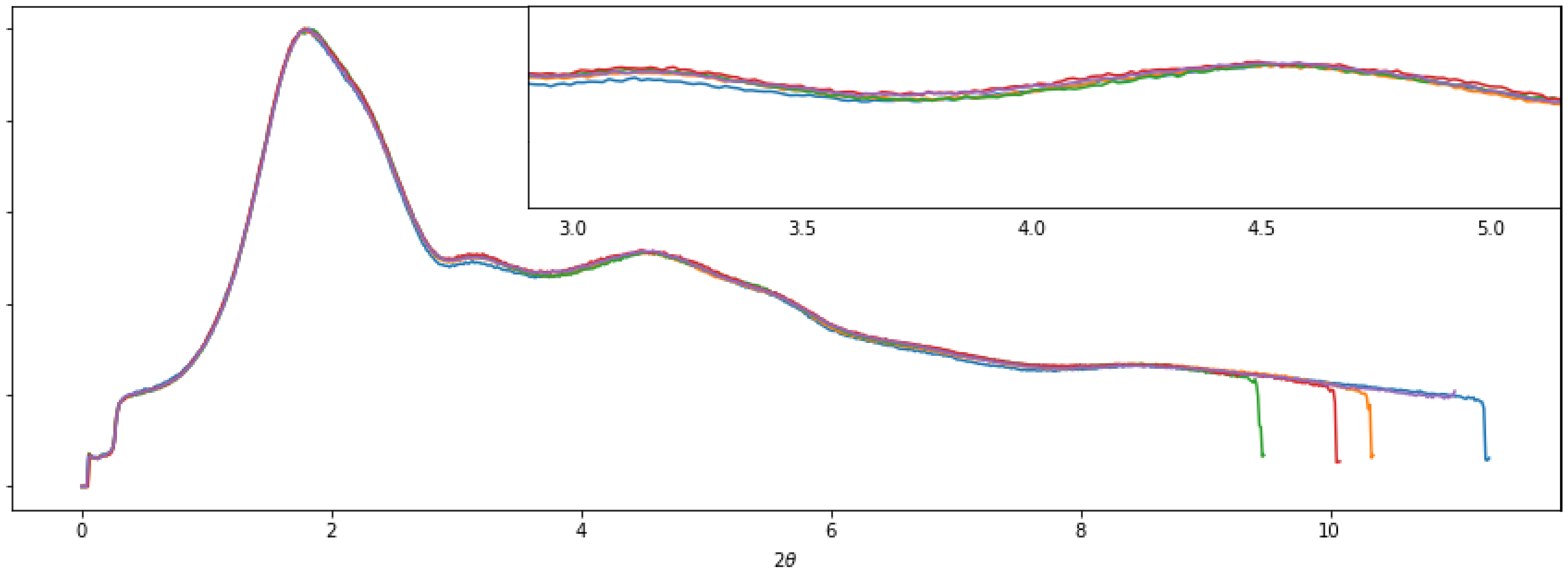
→

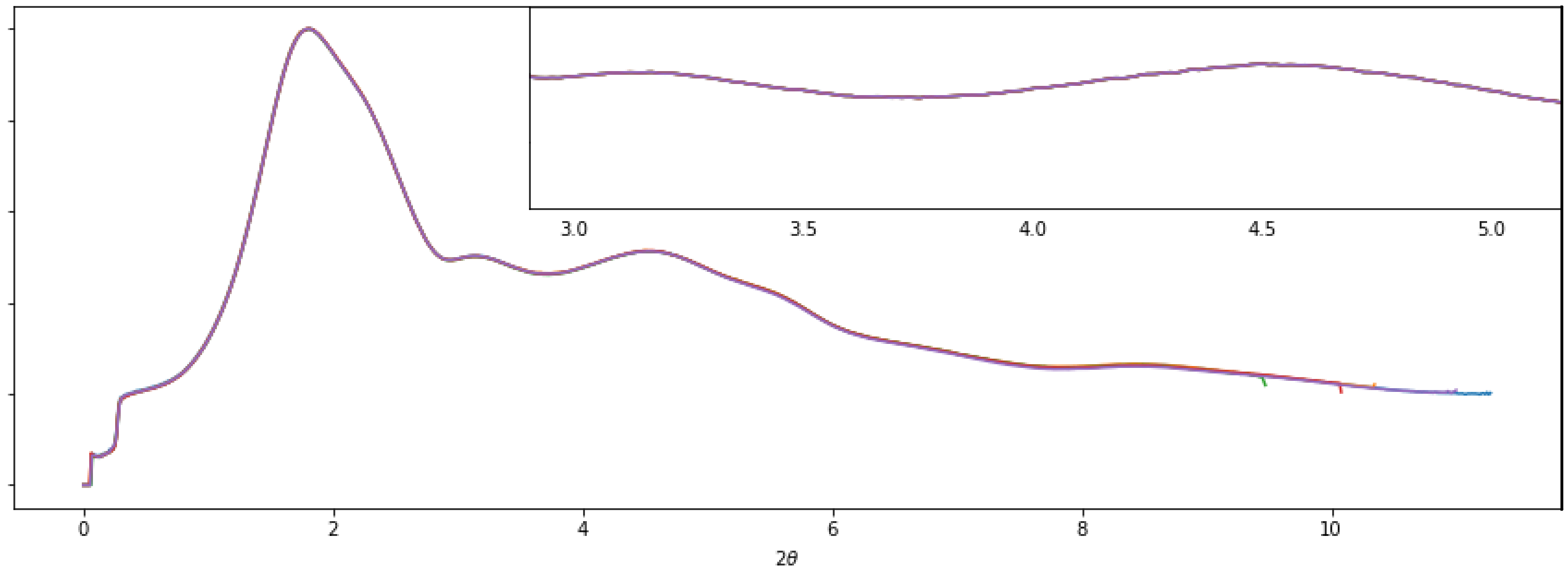
Output

1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1
1	1	1	1	1

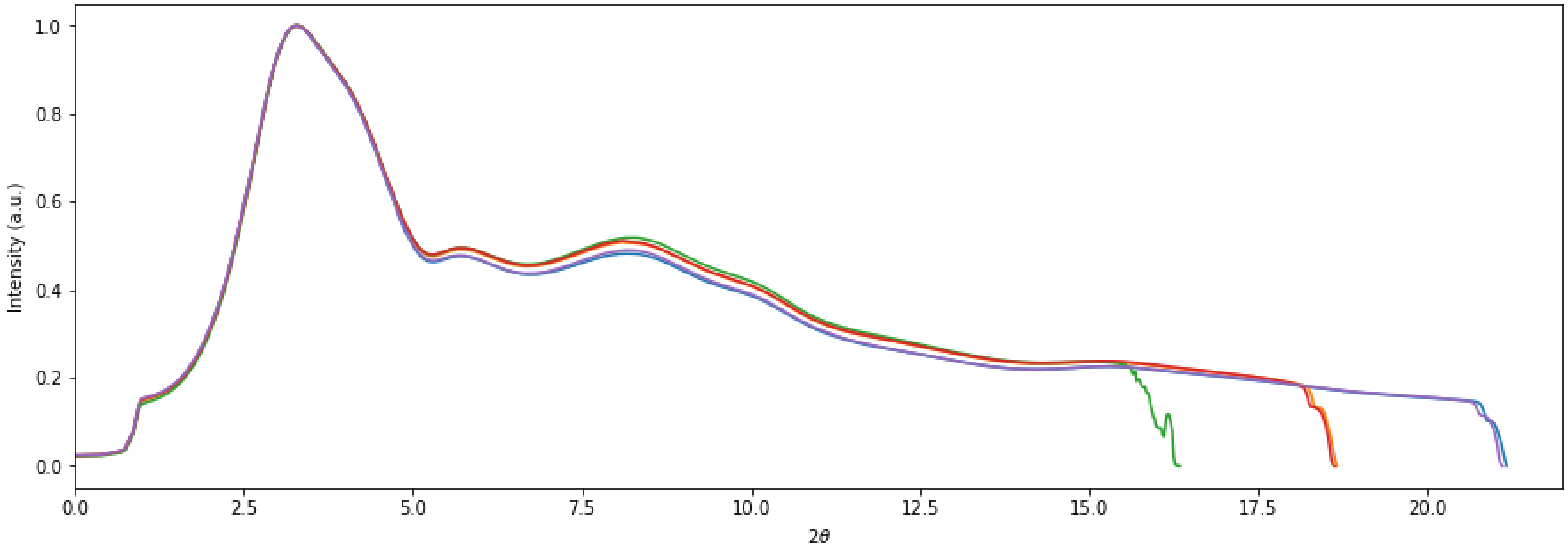
Detector point spread

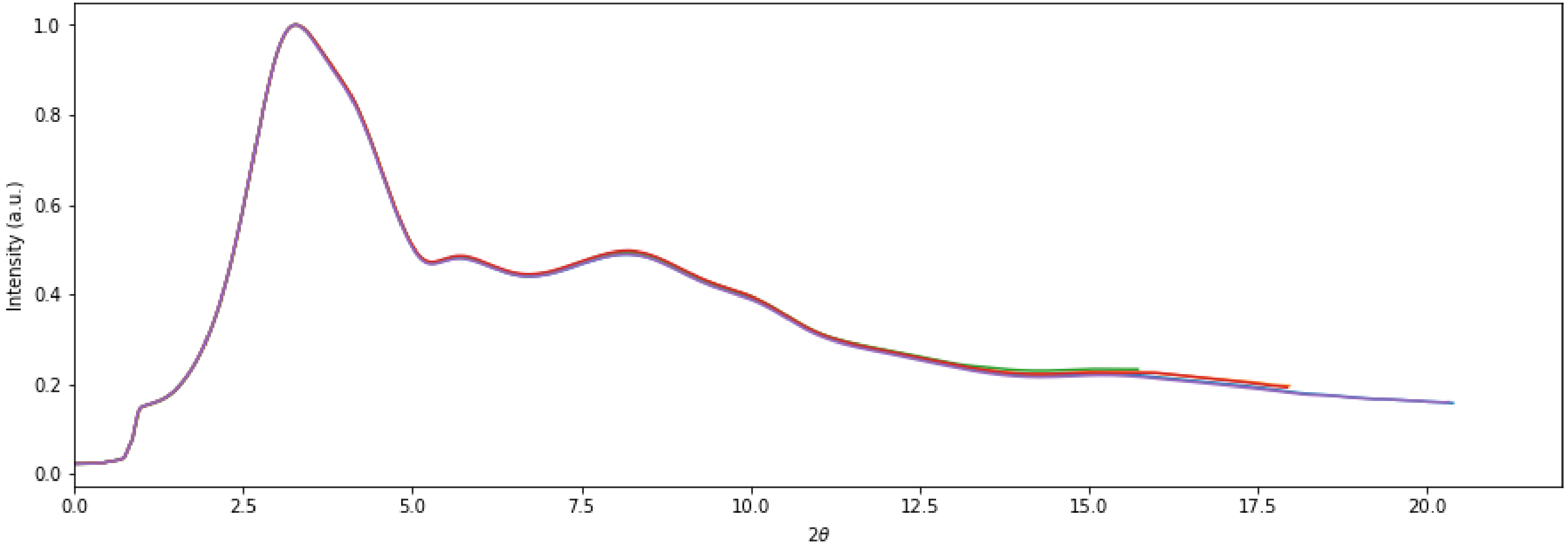
Pilatus

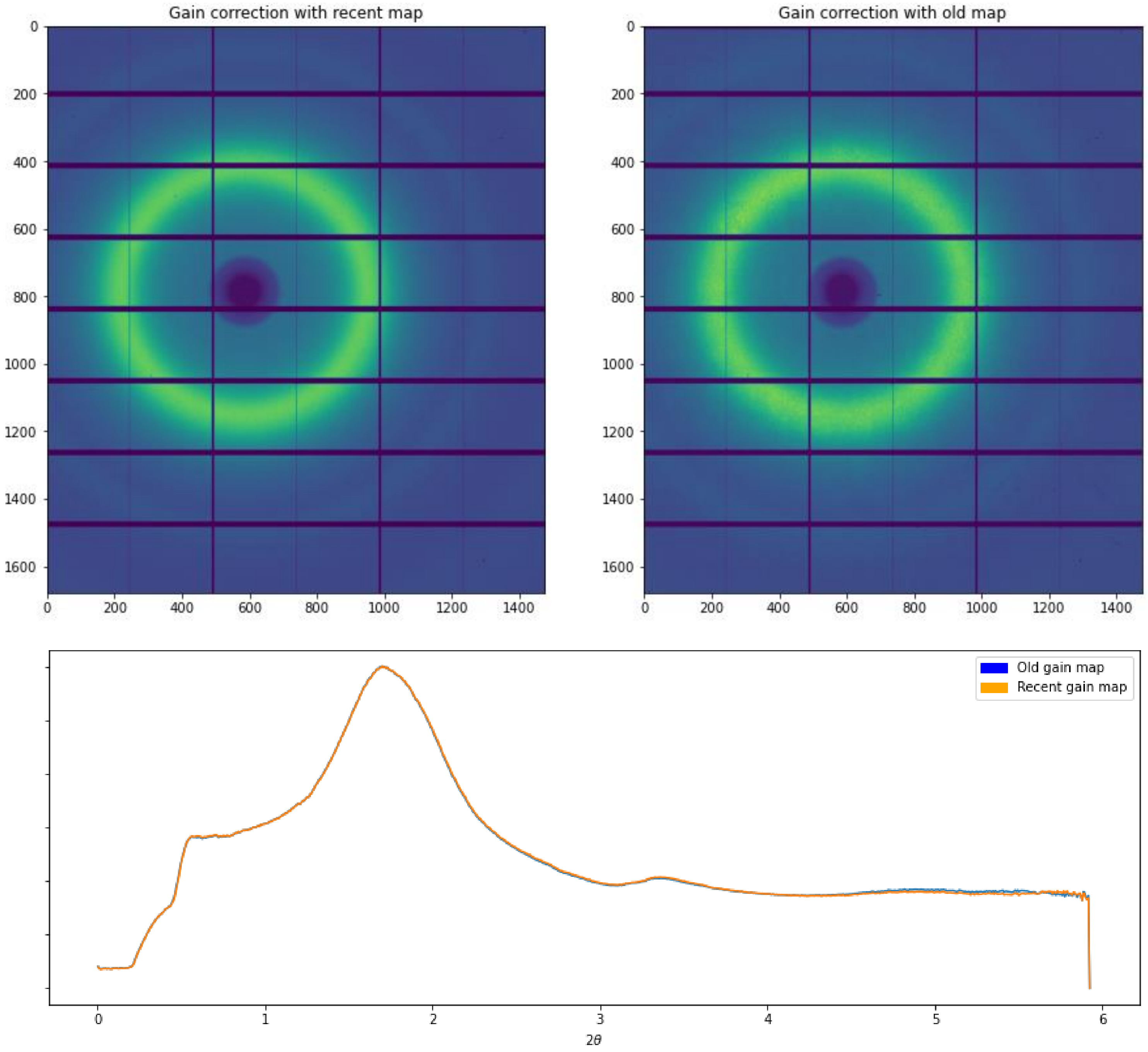


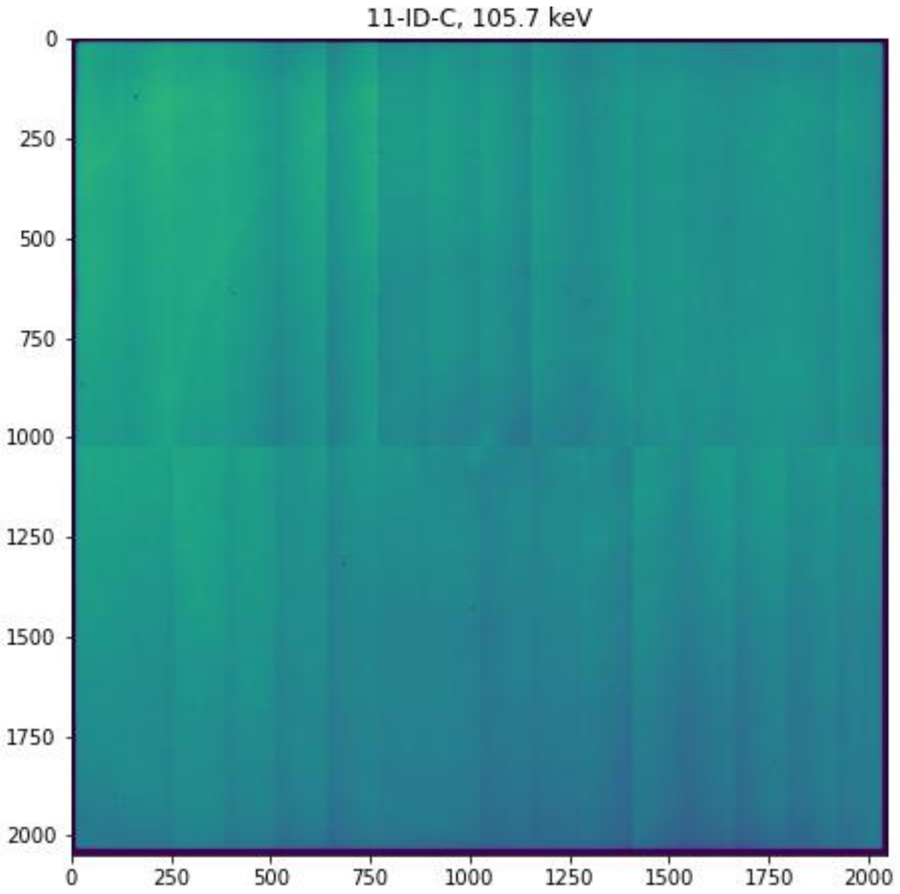


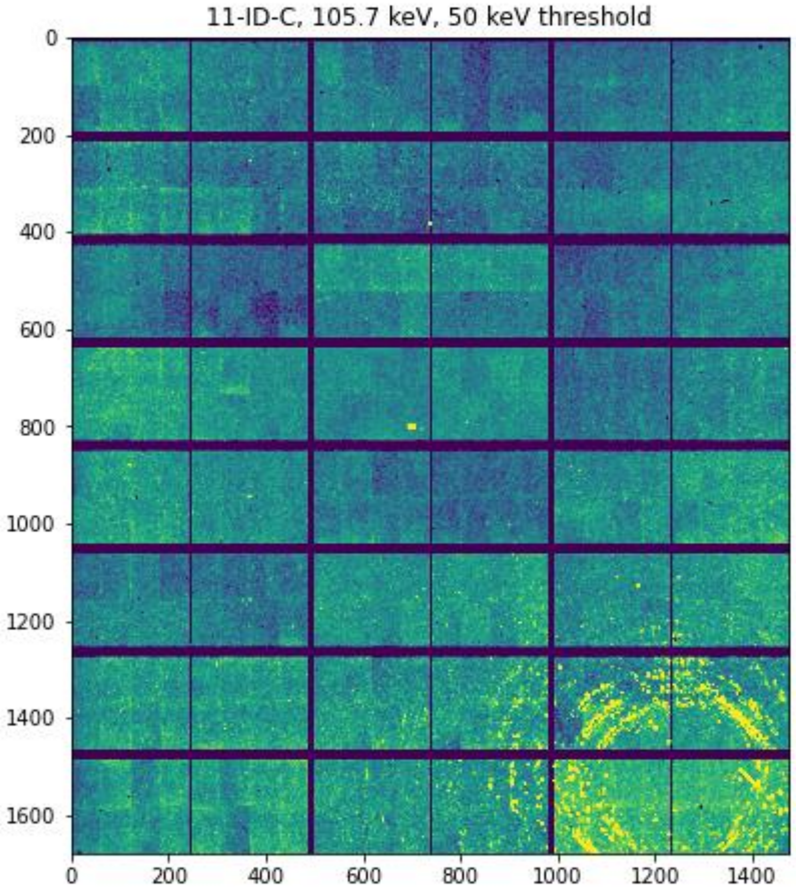
Perkin Elmer

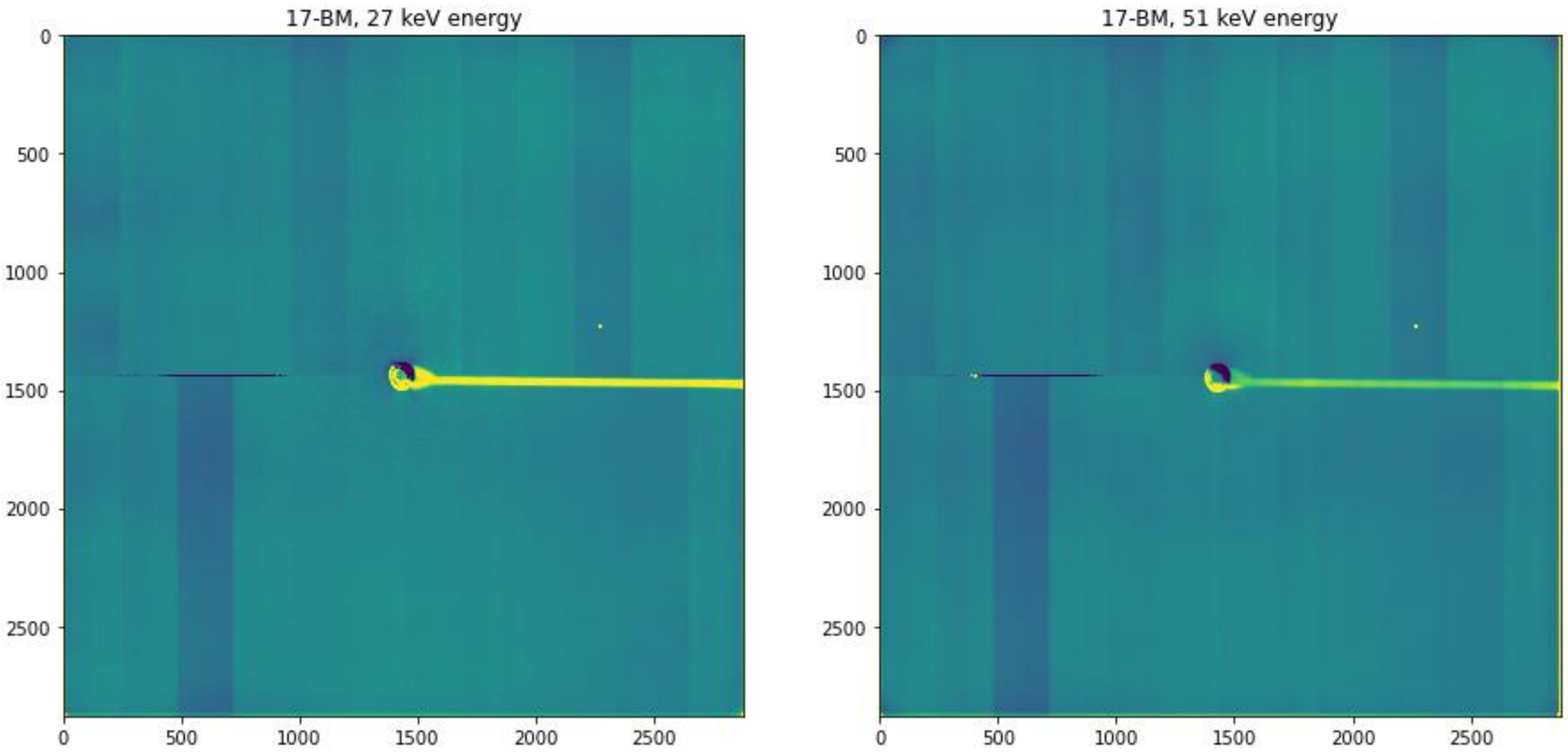


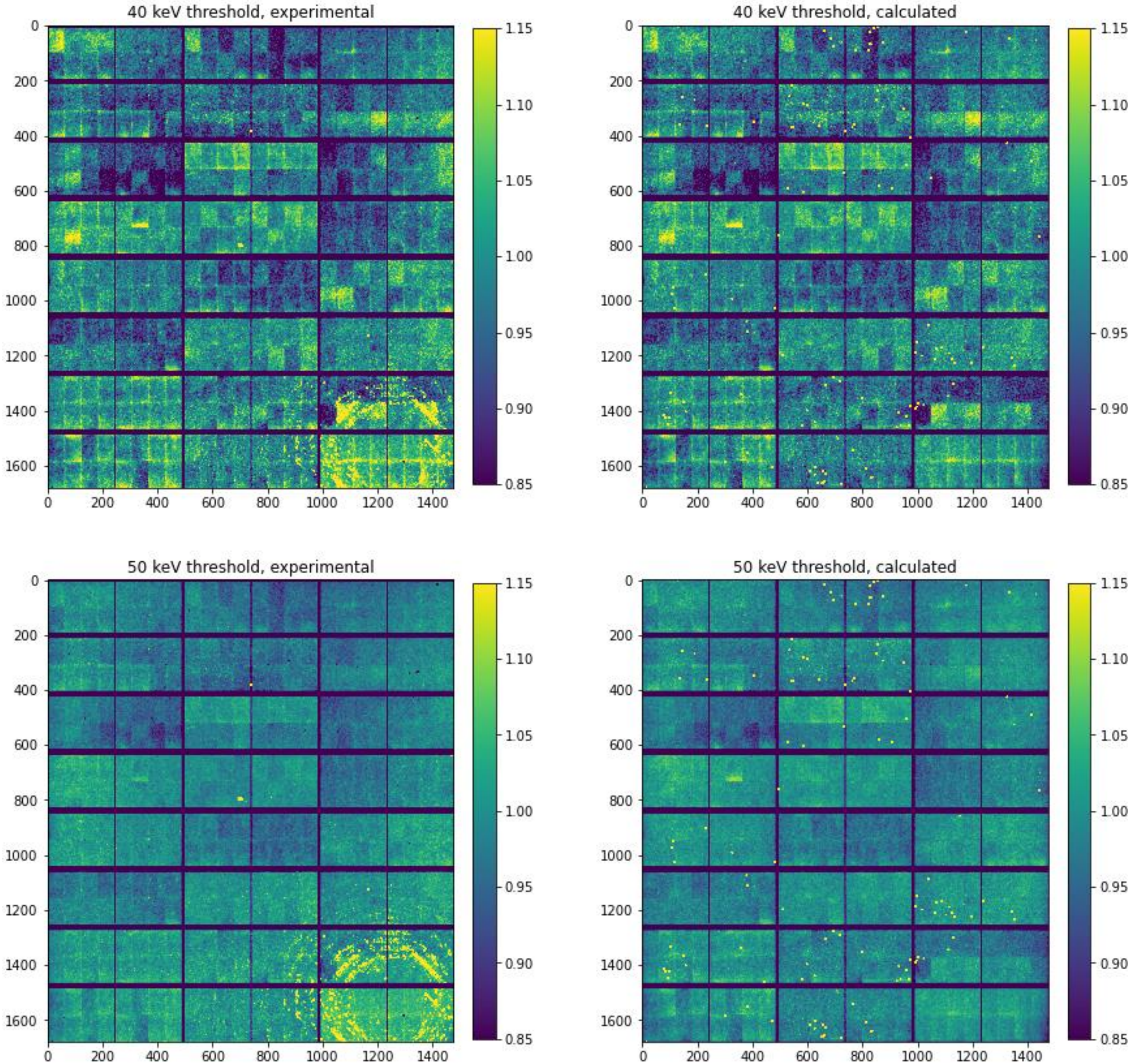


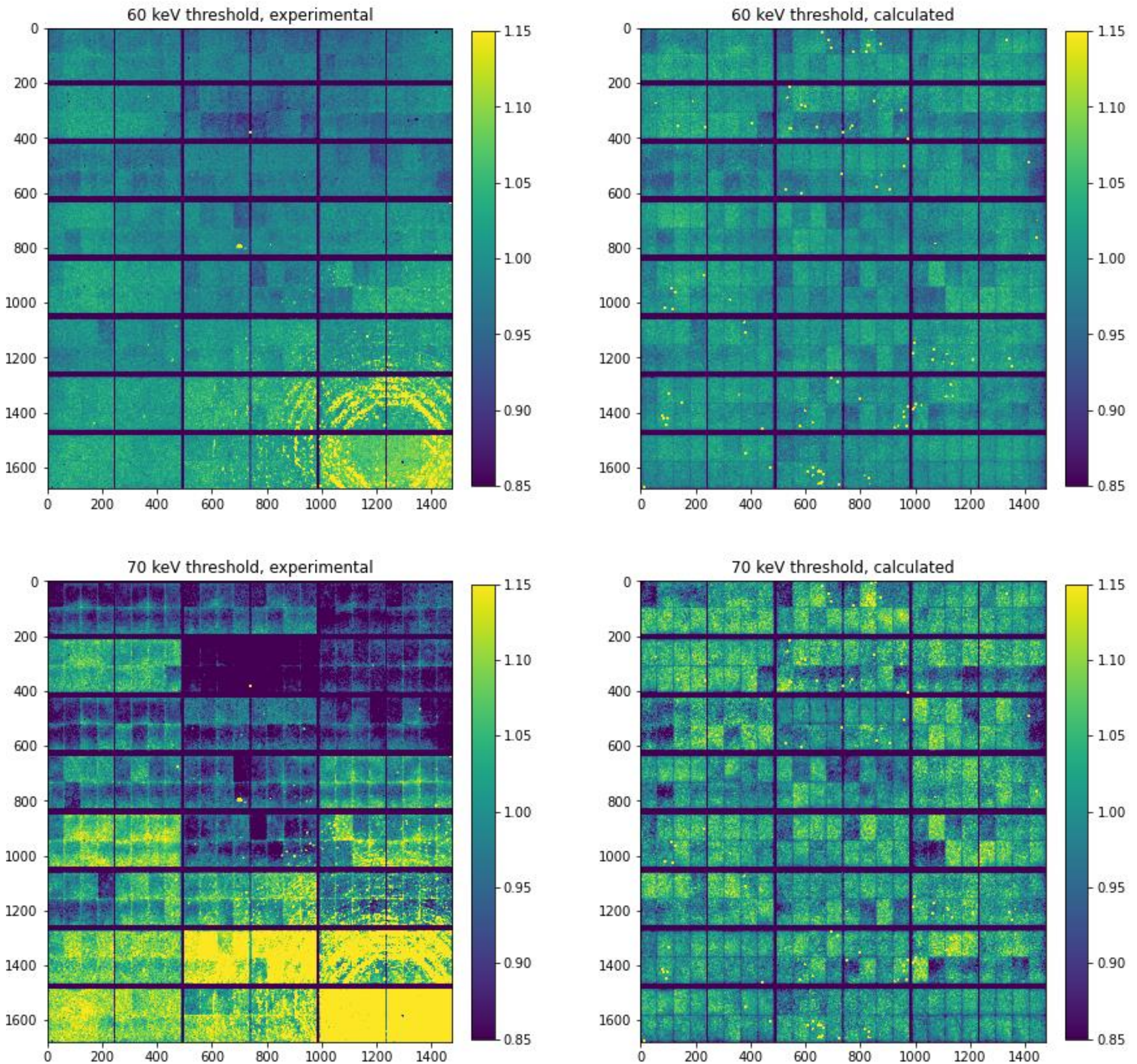

Gain correction with recent map
Gain correction with old map
Old gain map
Recent gain map
2θ

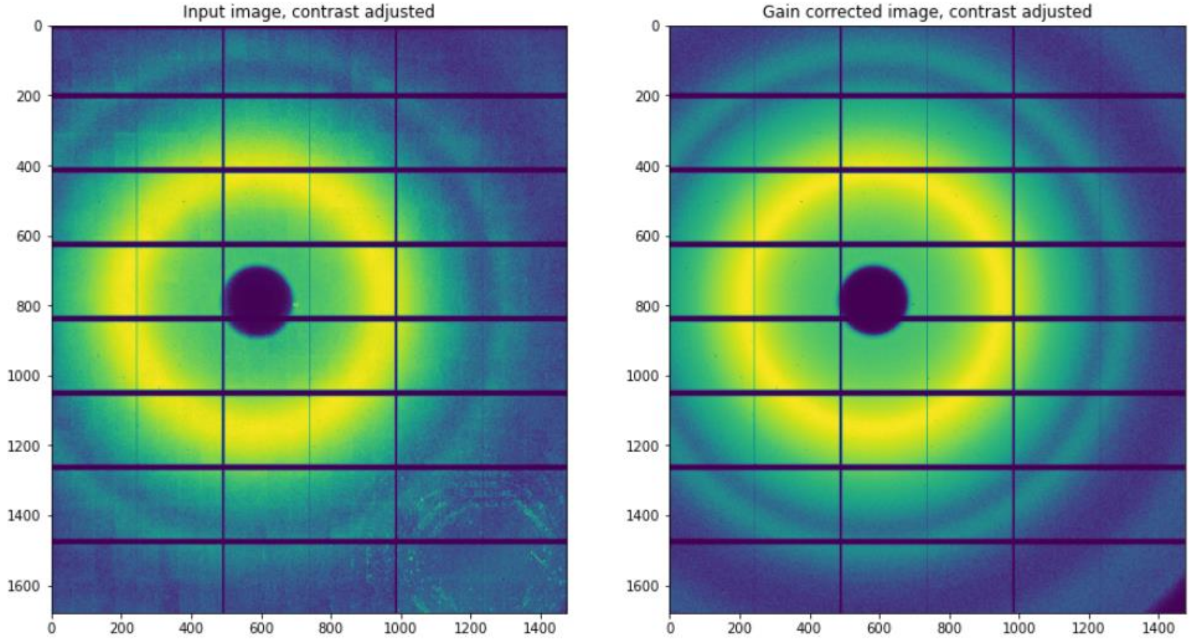

11-ID-C, 105.7 keV
0
250
500
750
1000
1250
1500
1750
2000
0
250
500
750
1000
1250
1500
1750
2000

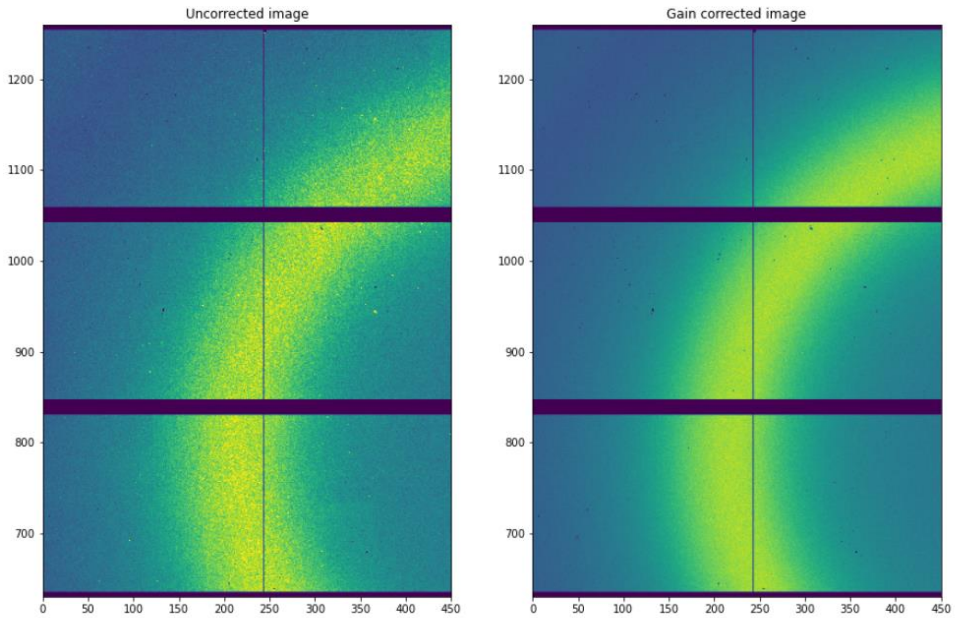

11-ID-C, 105.7 keV, 50 keV threshold
0
200
400
600
800
1000
1200
1400
1600
0
200
400
600
800
1000
1200
1400

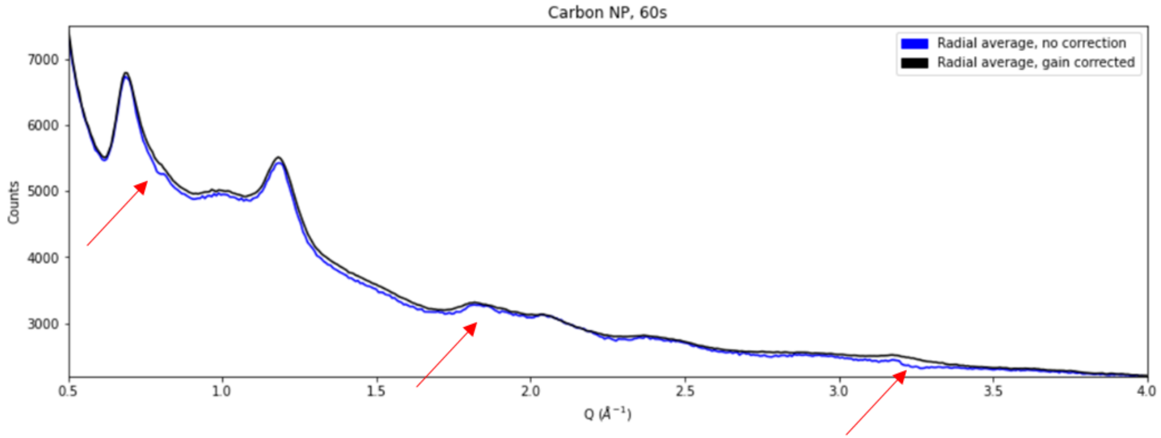

17-BM, 27 keV energy
17-BM, 51 keV energy
0
500
1000
1500
2000
2500

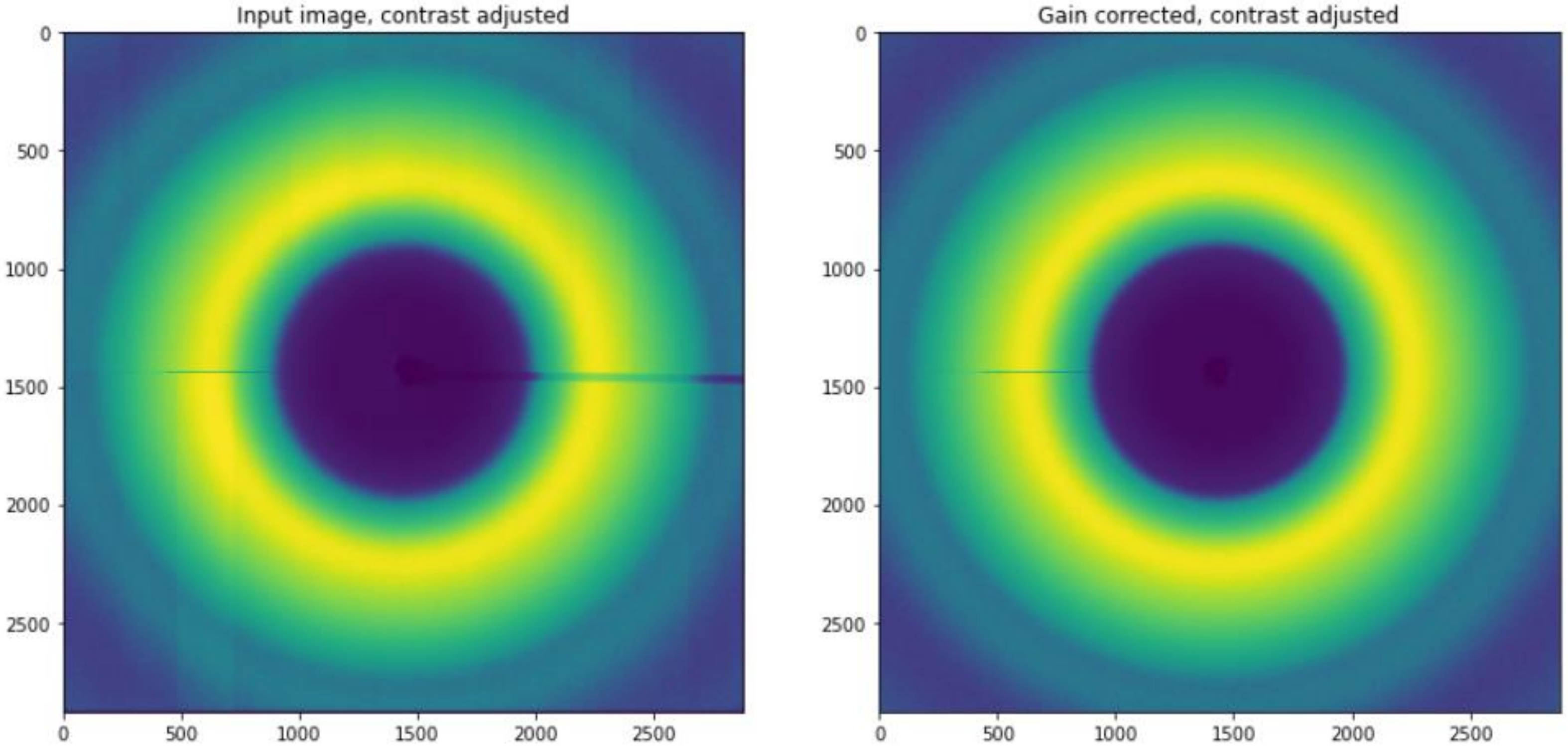

40 keV threshold, experimental
40 keV threshold, calculated
50 keV threshold, experimental
50 keV threshold, calculated
0
200
400
600
800
1000
1200
1400
1600
1.15
1.10
1.05
1.00
0.95
0.90
0.85

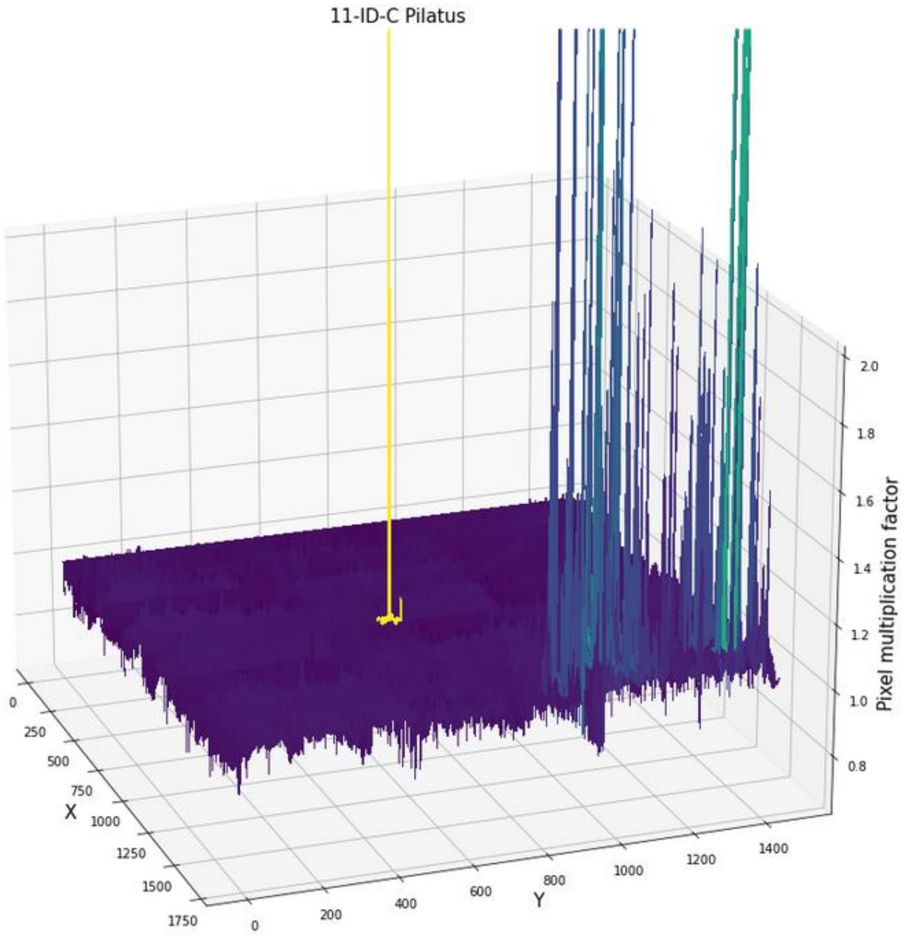

60 keV threshold, experimental
60 keV threshold, calculated
70 keV threshold, experimental
70 keV threshold, calculated
0
200
400
600
800
1000
1200
1400
1600
1.15
1.10
1.05
1.00
0.95
0.90
0.85


Input image, contrast adjusted
Gain corrected image, contrast adjusted

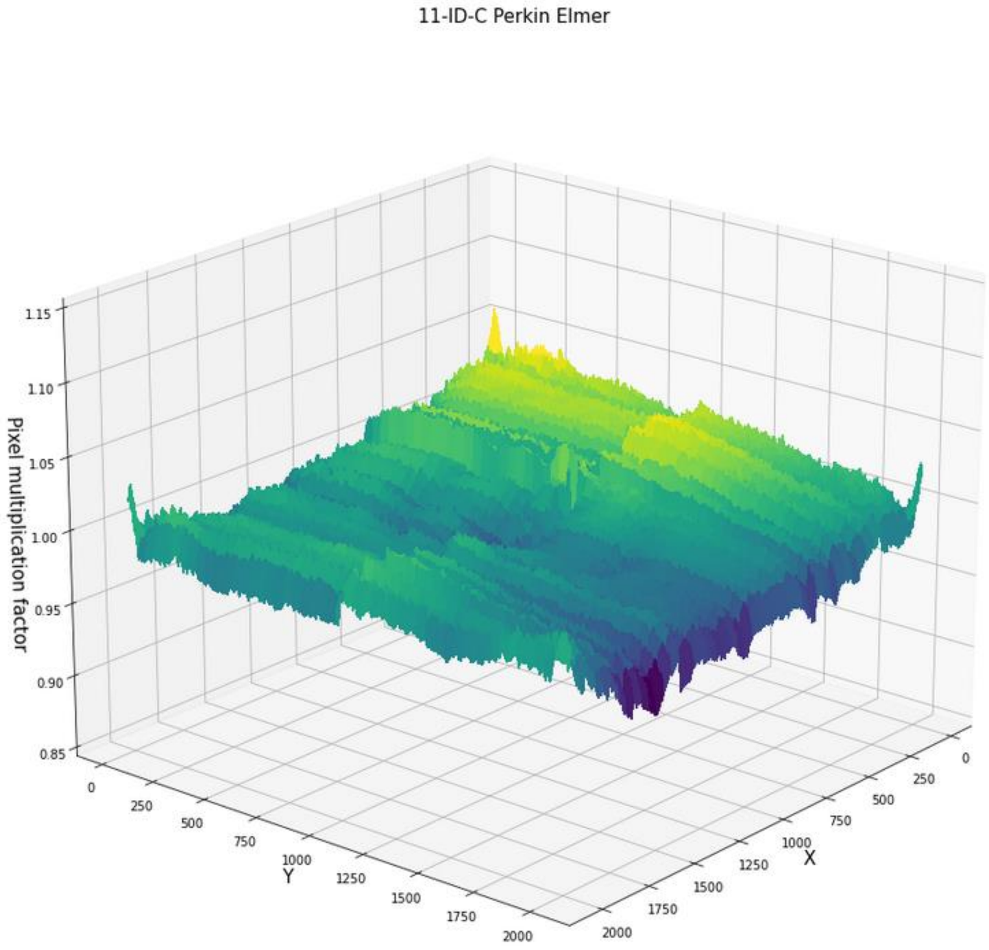

Uncorrected image
Gain corrected image


Carbon NP, 60s
Radial average, no correction
Radial average, gain corrected
Counts
Q (Å^{-1})

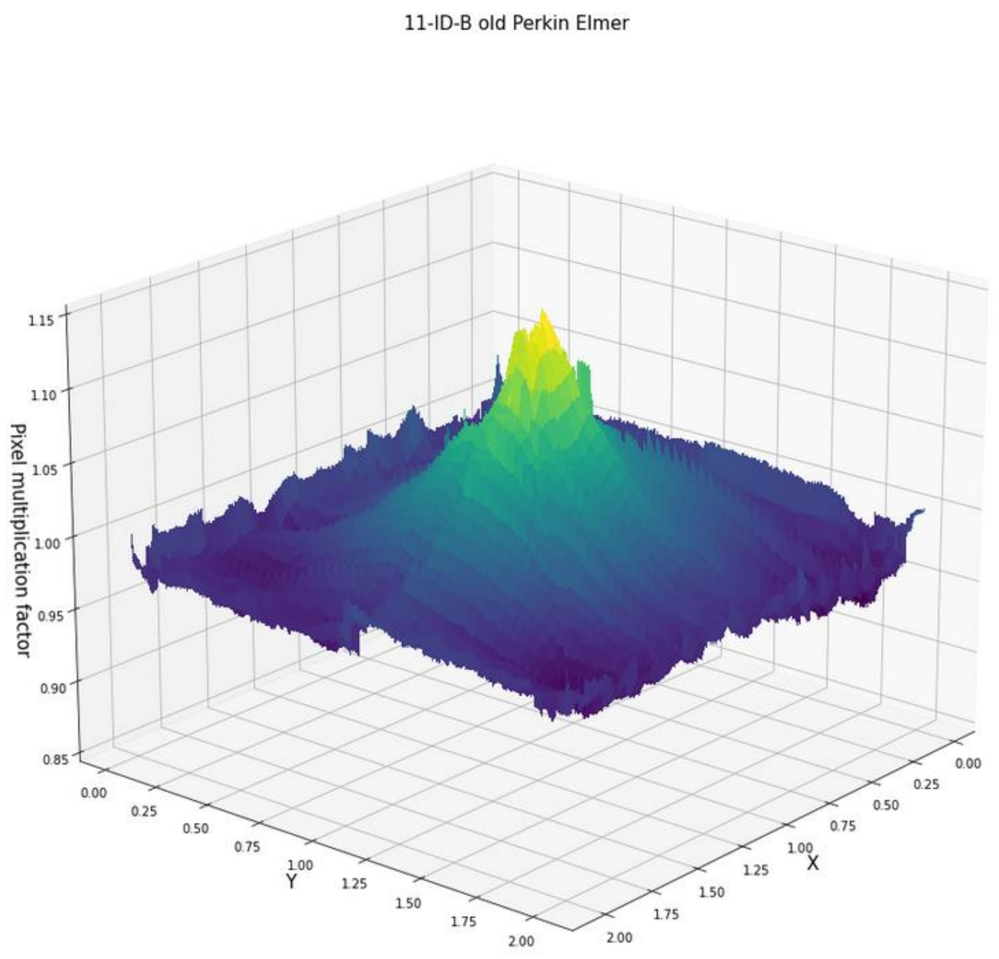

Input image, contrast adjusted
Gain corrected, contrast adjusted
0
500
1000
1500
2000
2500

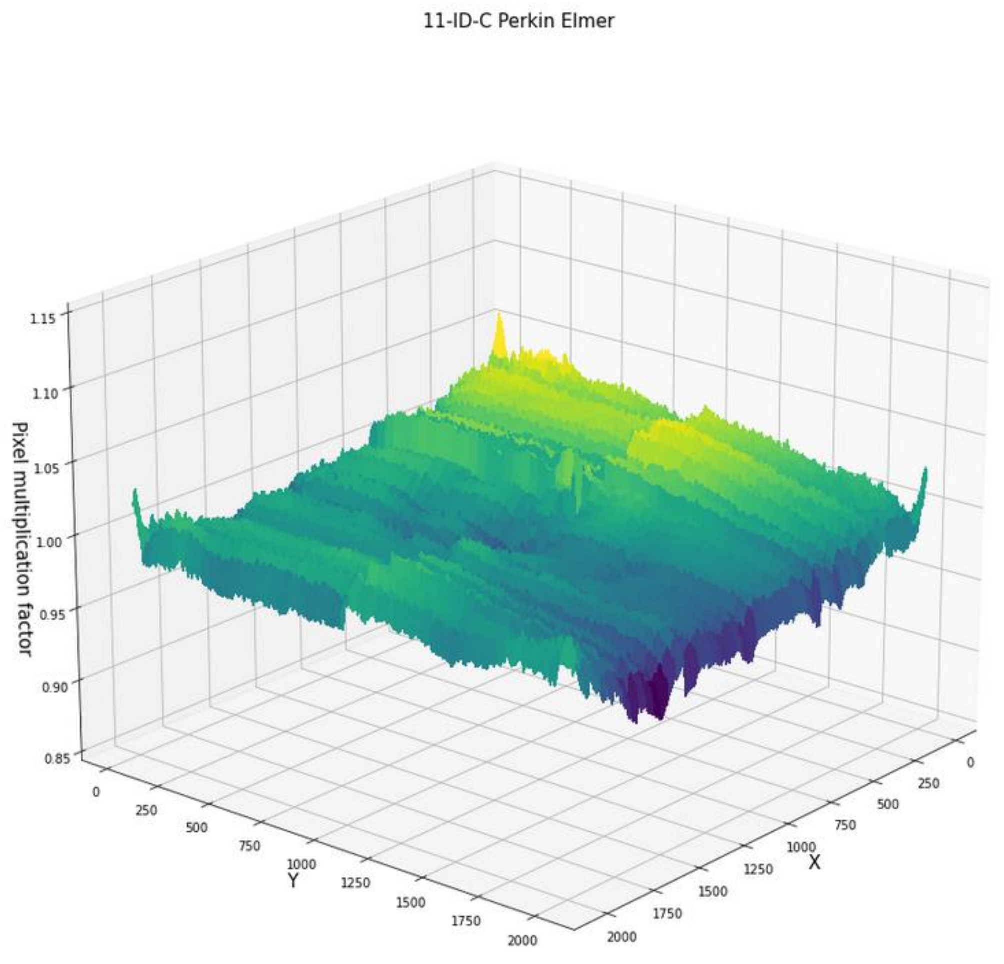


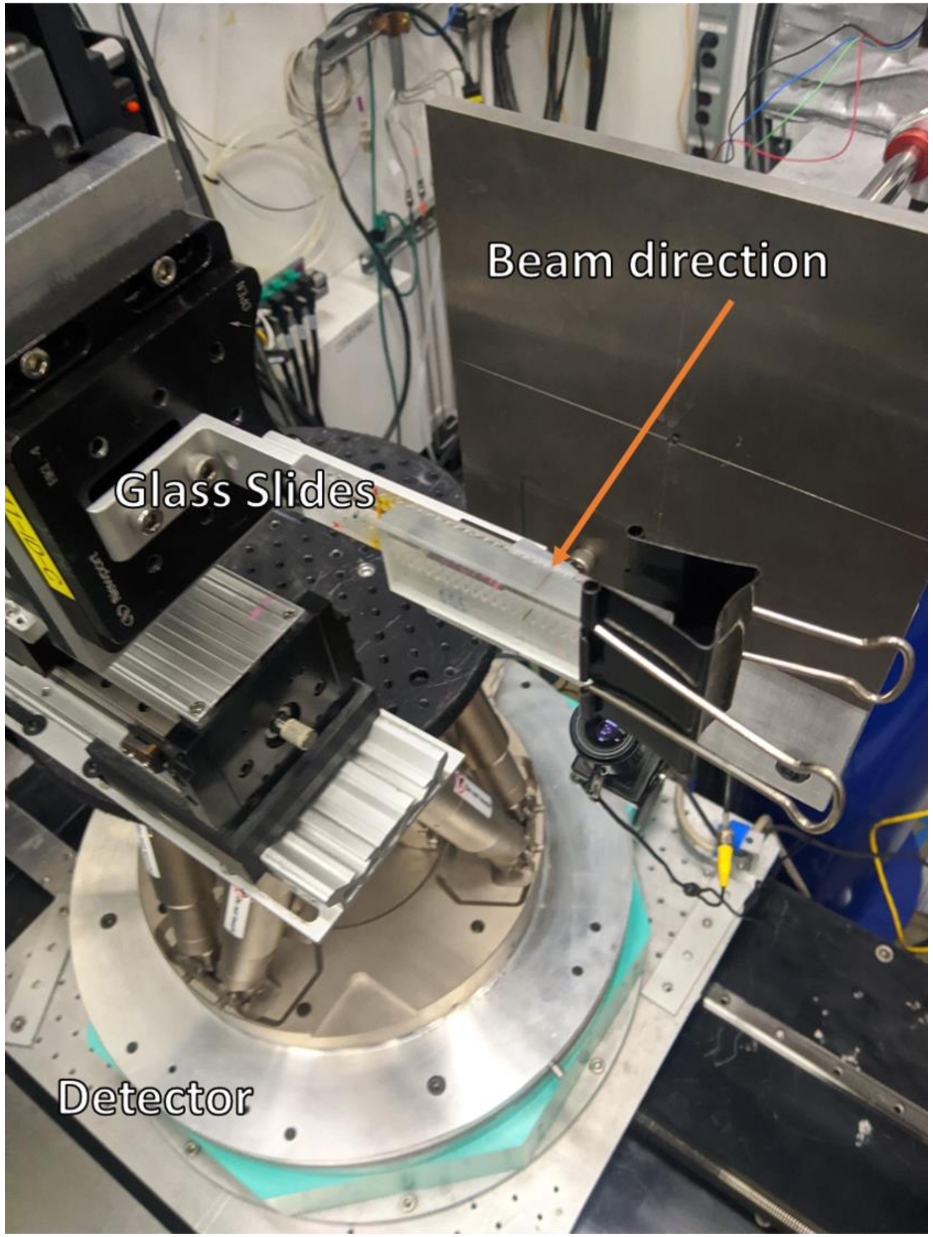
11-ID-C Pilatus
Pixel multiplication factor
X
Y
0
250
500
750
1000
1250
1500
1750
0
200
400
600
800
1000
1200
1400
0.8
1.0
1.2
1.4
1.6
1.8
2.0

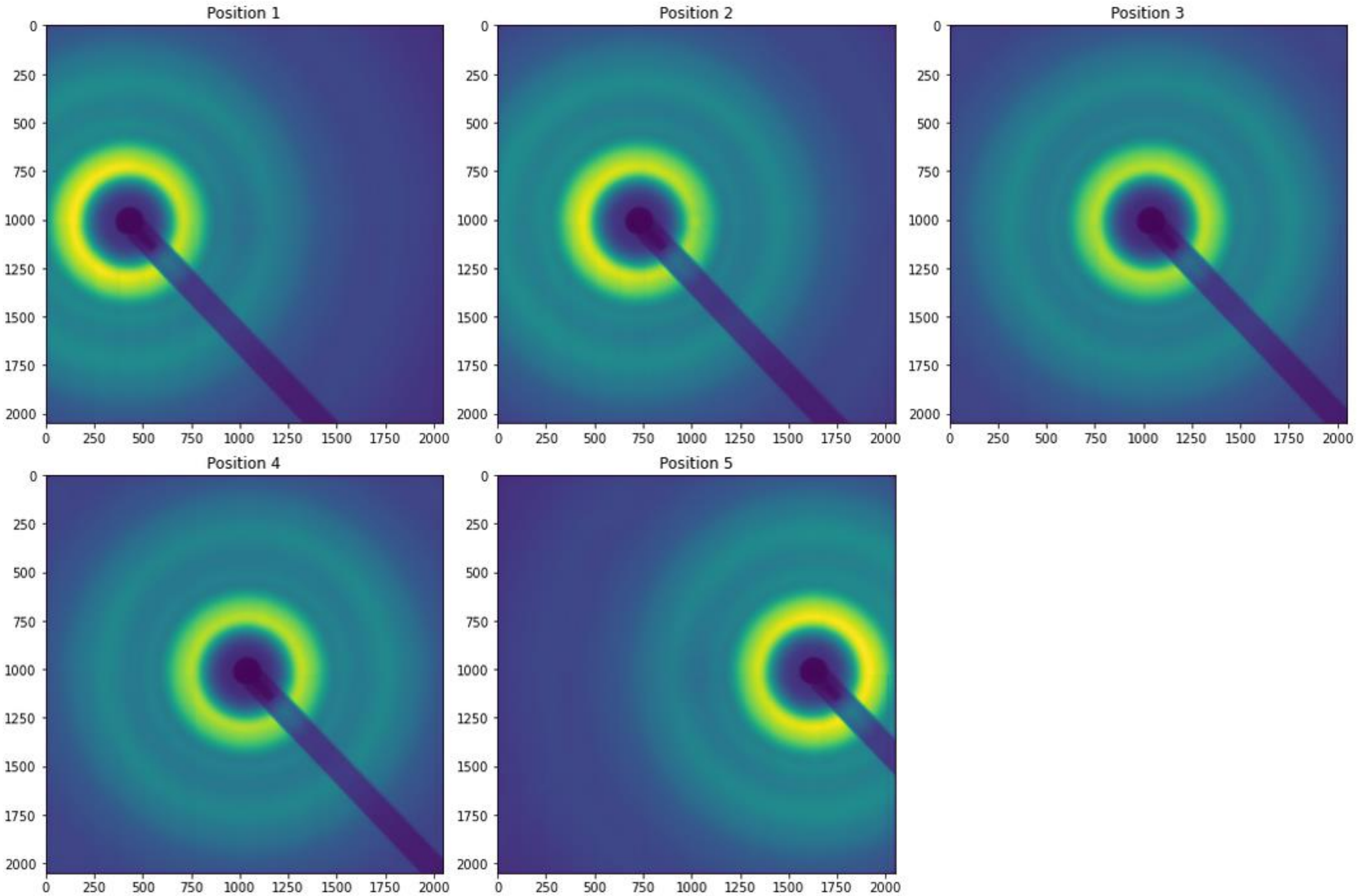


11-ID-C Perkin Elmer
Pixel multiplication factor
X
Y
0.85
0.90
0.95
1.00
1.05
1.10
1.15
0
250
500
750
1000
1250
1500
1750
2000
0
250
500
750
1000
1250
1500
1750
2000


11-ID-B old Perkin Elmer
Pixel multiplication factor
1.15
1.10
1.05
1.00
0.95
0.90
0.85
Y
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
X
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00


11-ID-C Perkin Elmer
Pixel multiplication factor
1.15
1.10
1.05
1.00
0.95
0.90
0.85
Y
0
250
500
750
1000
1250
1500
1750
2000
X
0
250
500
750
1000
1250
1500
1750
2000


Beam direction
Glass Slides
Detector



Position 1
Position 2
Position 3
Position 4
Position 5
0
250
500
750
1000
1250
1500
1750
2000

https://github.com/jmsweng/X-ray-detector-gain-map