

# Alain & Bernadette

## Alice & Bob challenge



**ETH** zürich



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# 1.A. How to create a cat state?

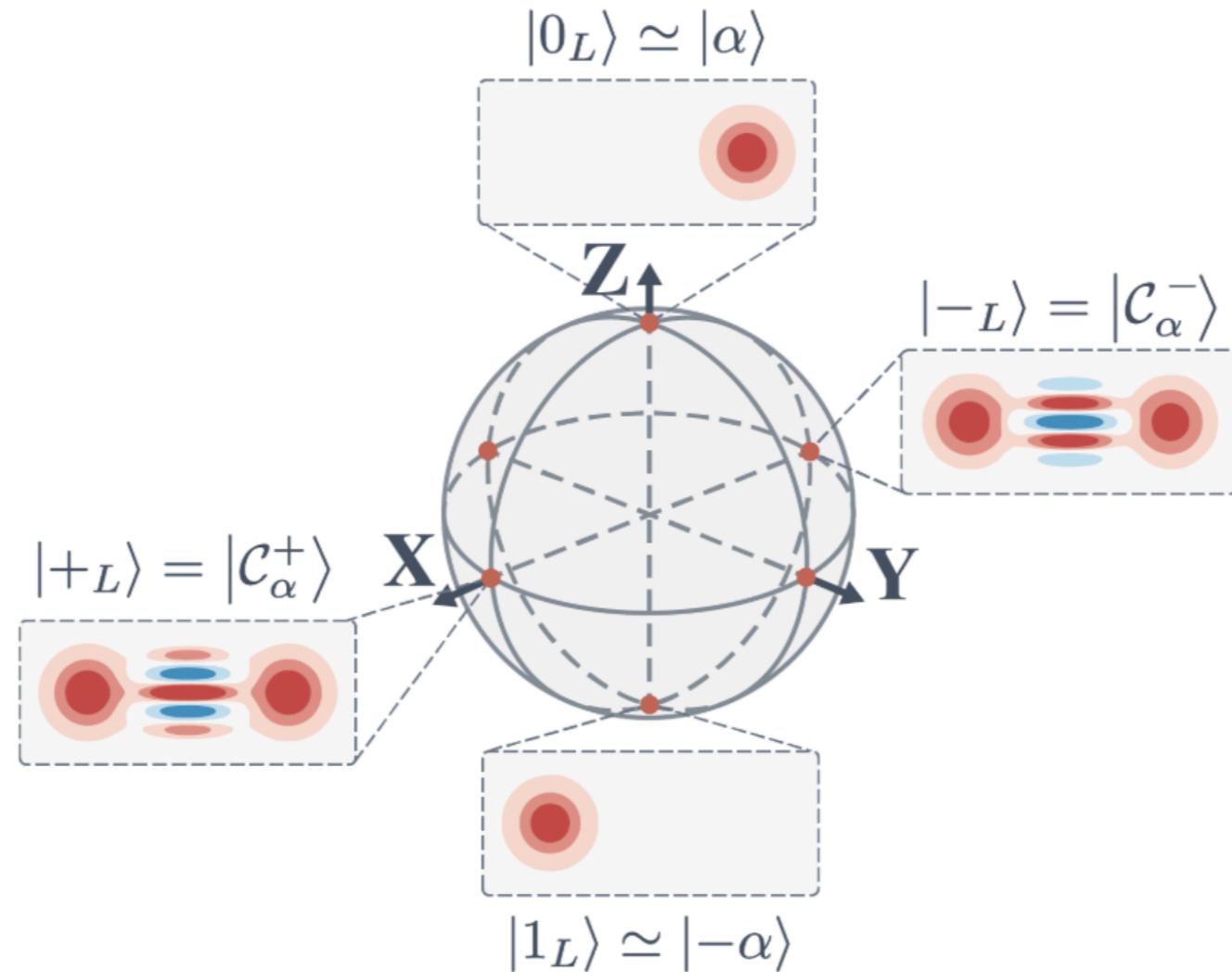
$$\frac{d\rho}{dt} = \mathcal{L}(\rho) = -i[H, \rho] + \kappa_b \mathcal{D}[\hat{b}](\rho)$$

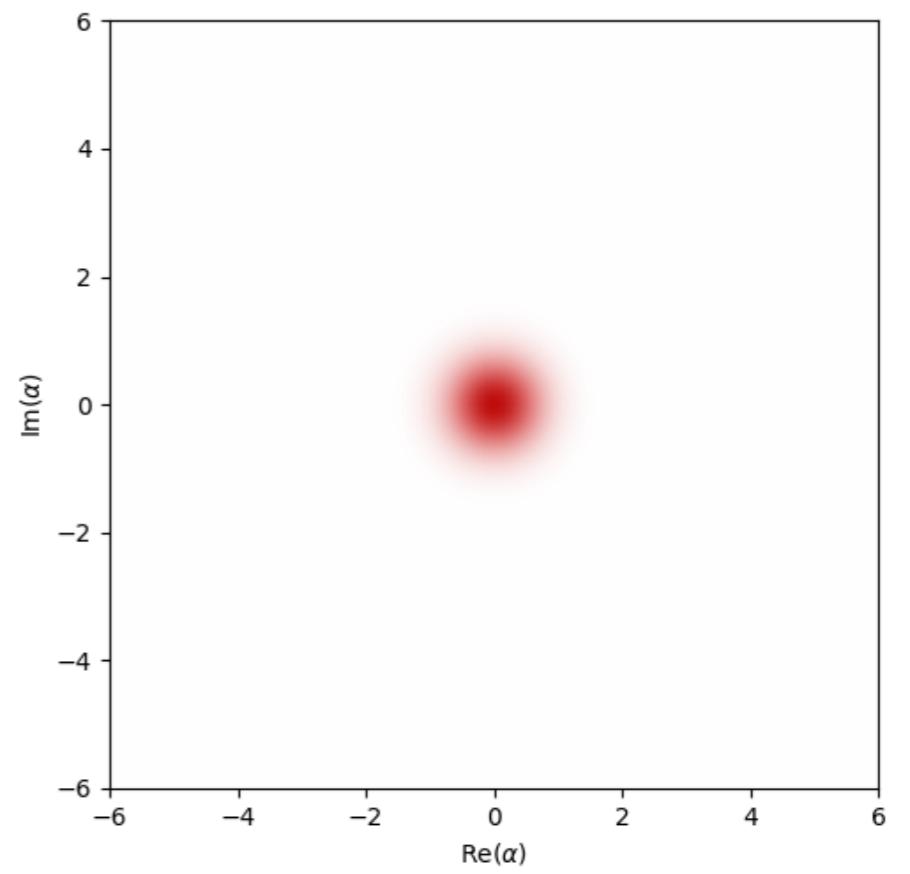
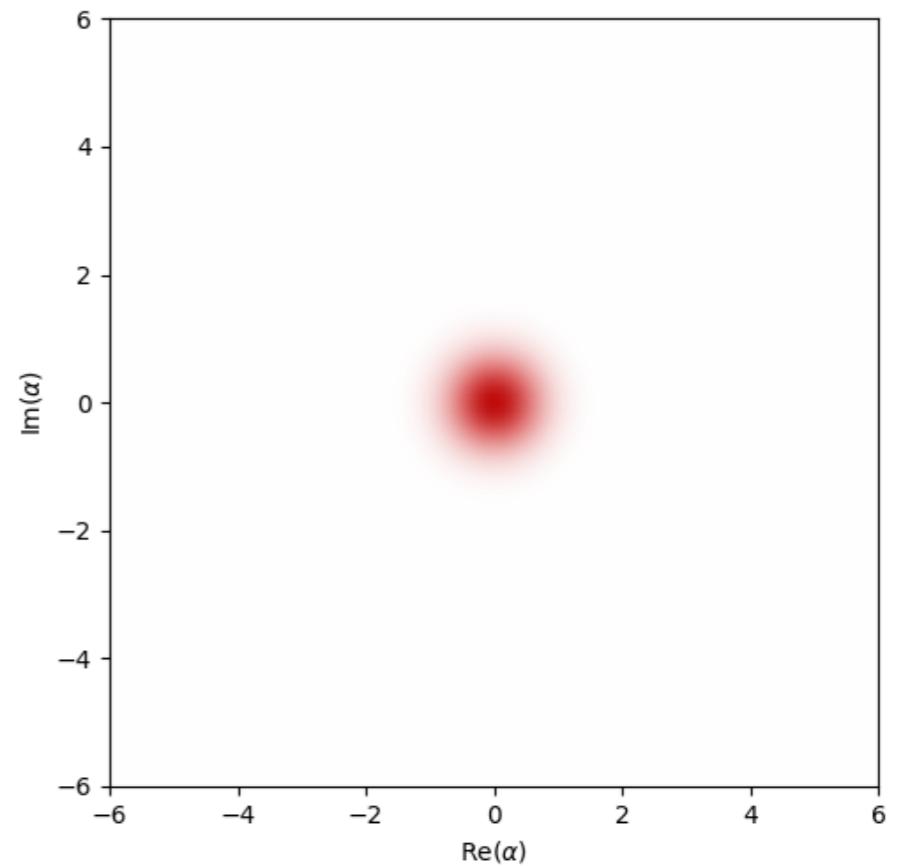
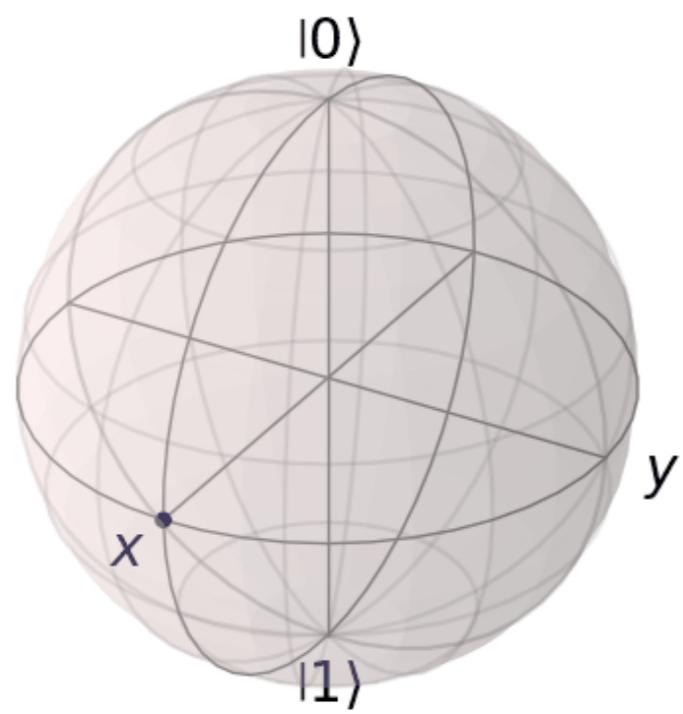
$$H = g_2^* a^{\dagger 2} b + g_2 a^2 b^\dagger + \epsilon_b^* b + \epsilon_b b^\dagger$$

$$\mathcal{D}[b](\rho) = b\rho b^\dagger - \frac{1}{2} (b^\dagger b\rho + \rho b^\dagger b)$$

# Bonus

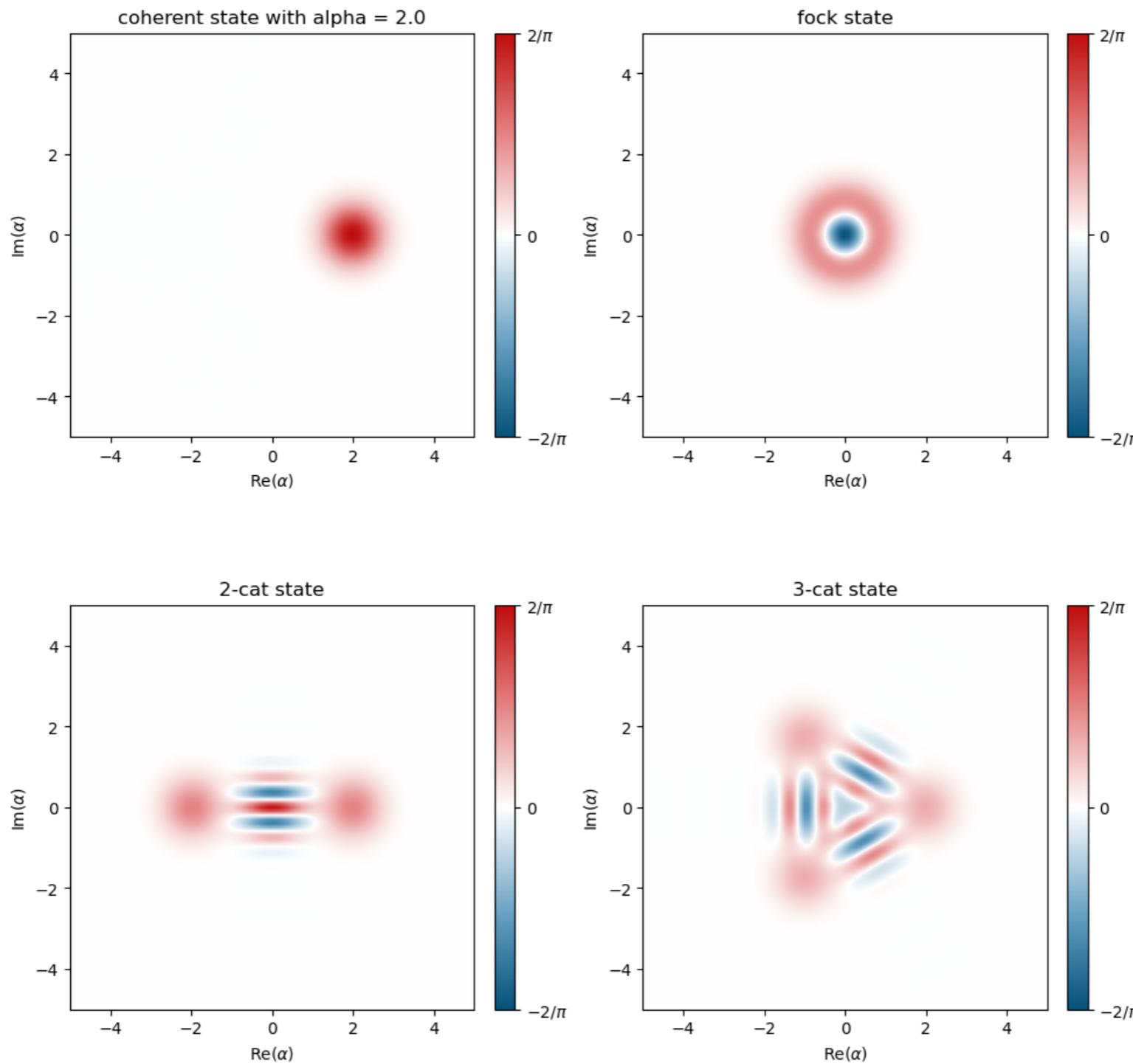
## Phase-space qubit equivalence





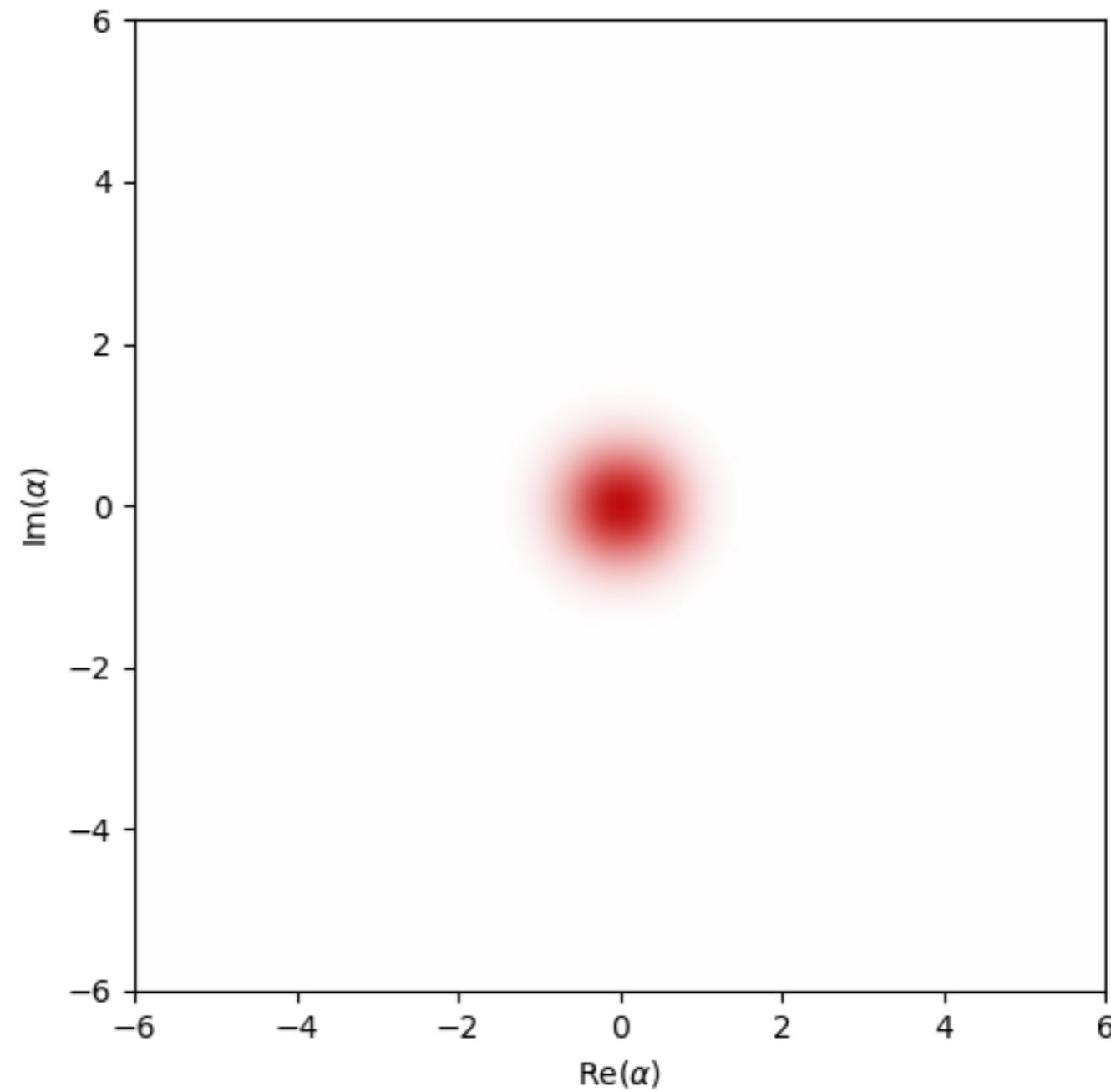
# 1.A. Generating Wigner Functions

## 1.A.1. Static Wigner function plots



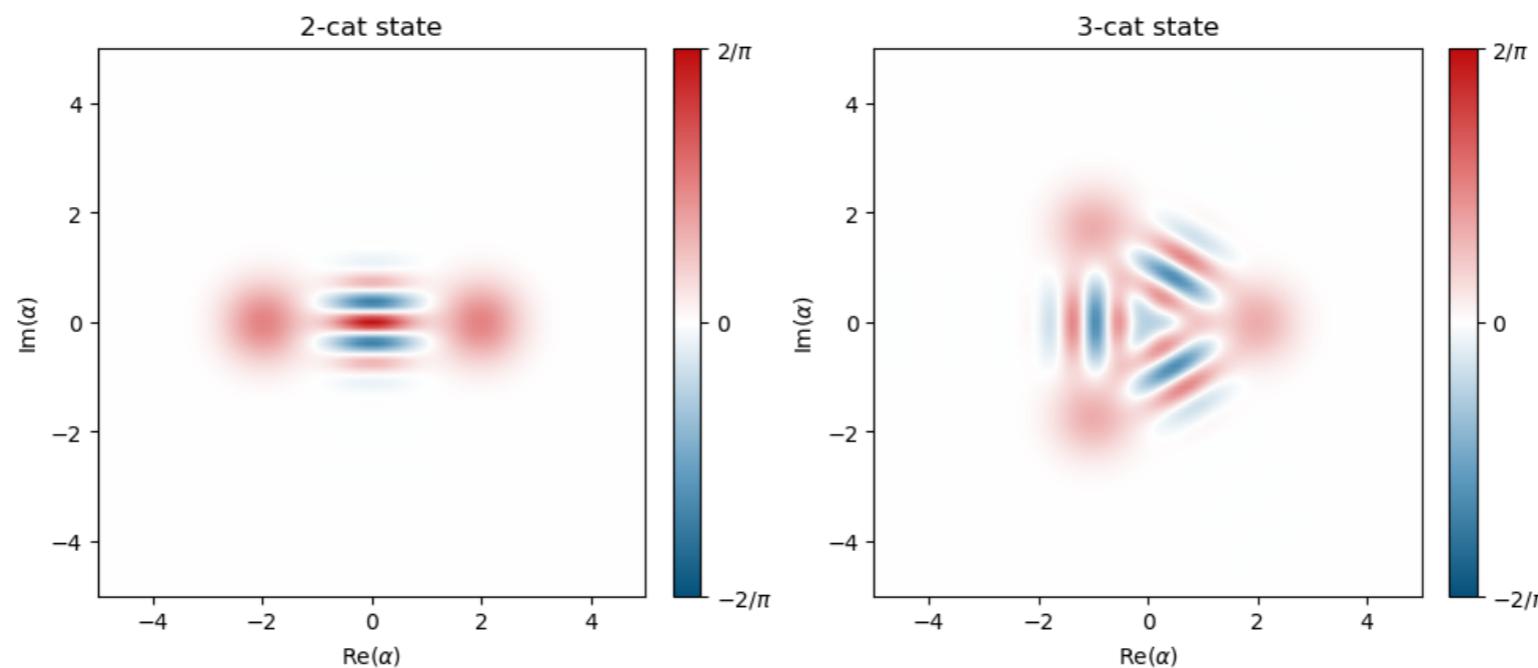
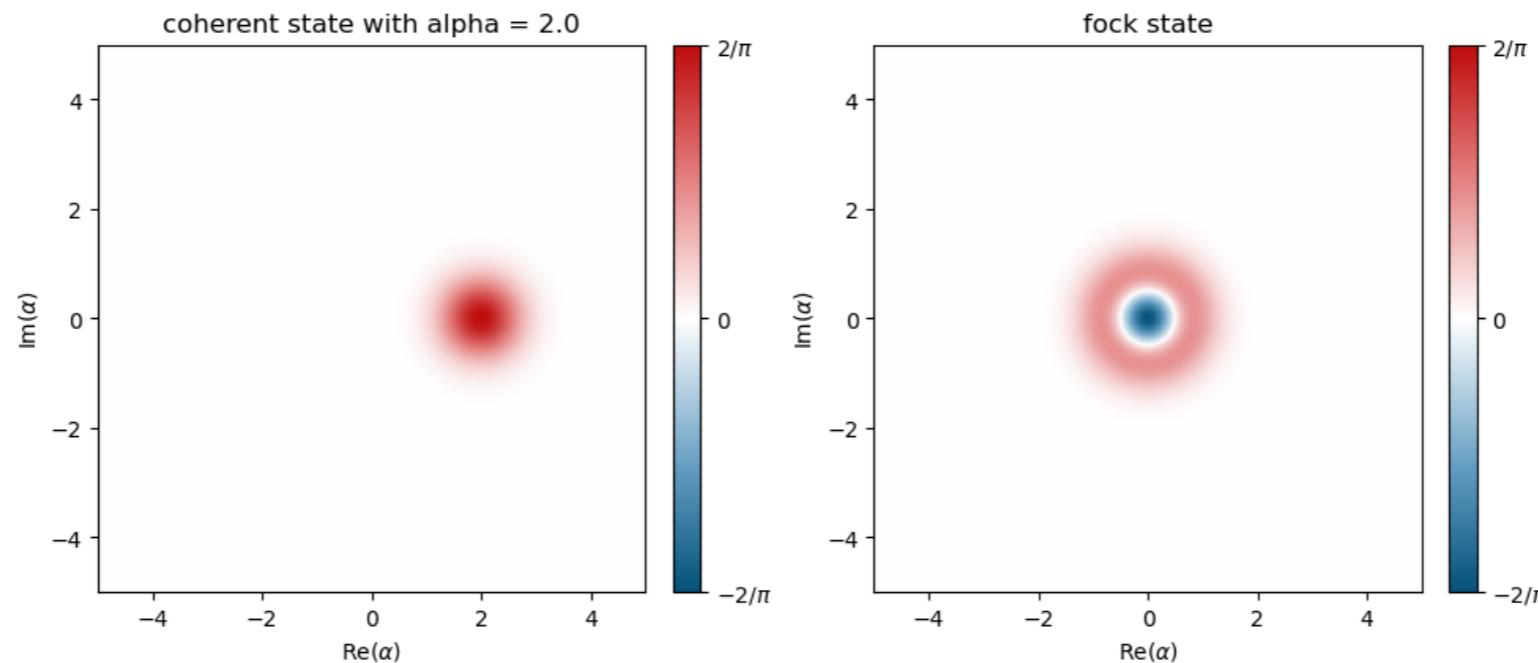
# 1.A. Generating Wigner Functions

## 1.A.2 Dissipative cat state's Wigner function



# 1.B. Density Matrix Reconstruction from Wigner Data

## 1.A.1. Static Wigner function plots



# 1.B. Density Matrix Reconstruction from Wigner Data

## 1.B.1. rho\_reconstruction method

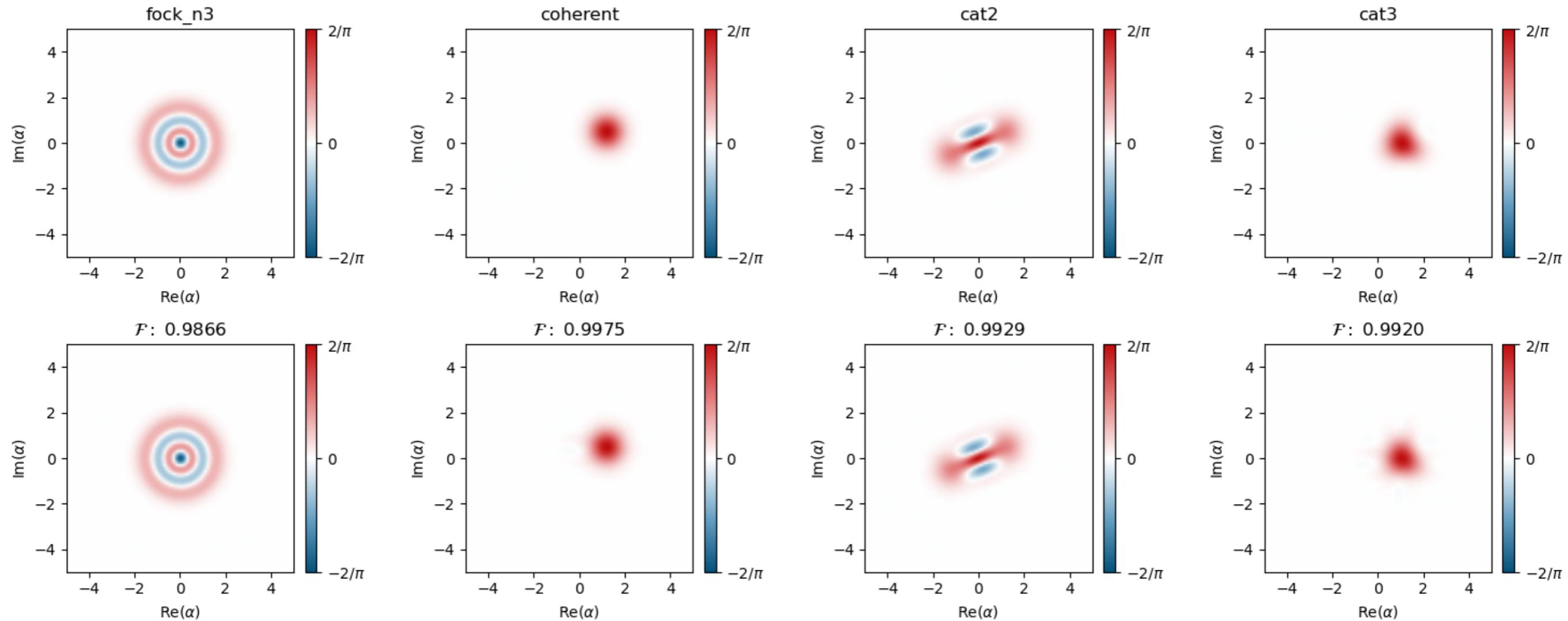
```
def rho_reconstruction(
    W_grid: np.ndarray,
    xvec: np.ndarray,
    pvec: np.ndarray,
    alpha_list: Sequence[complex],
    N_psi: int,
    rho_reference: dq.QArray,
    N_fit: Optional[int] = None,
    solver: str ='SCS',
    objective: str ='sum_squares',
    **kwargs
) -> Tuple[dq.QArray, List[float], List[dq.QArray], TomographyMetrics]:
```

- Validate shape of xvec, pvec and W\_grid.
- Make a wigner interpolation in the range of xvec and pvec.
- Calculate  $w_k$  from alpha\_list.
- Calculate  $E_\alpha$  from alpha\_list.
- Define  $\rho_{\text{obj}}$  with constrains (cvxpy).
- Calculate  $p = \text{Tr}(E_\alpha \rho_{\text{obj}})$
- Minimize using 'objective'  $dist(p - w_k)$ .
- Get metrics (fidelity, trace distance, etc.)

# 1.B. Density Matrix Reconstruction from Wigner Data

## 1.B.2-3. Synthetic data

$N = 30$     $N \text{ fit} = 100$     $\alpha$  points:  $200 \times 200$



0.013727

0.022967

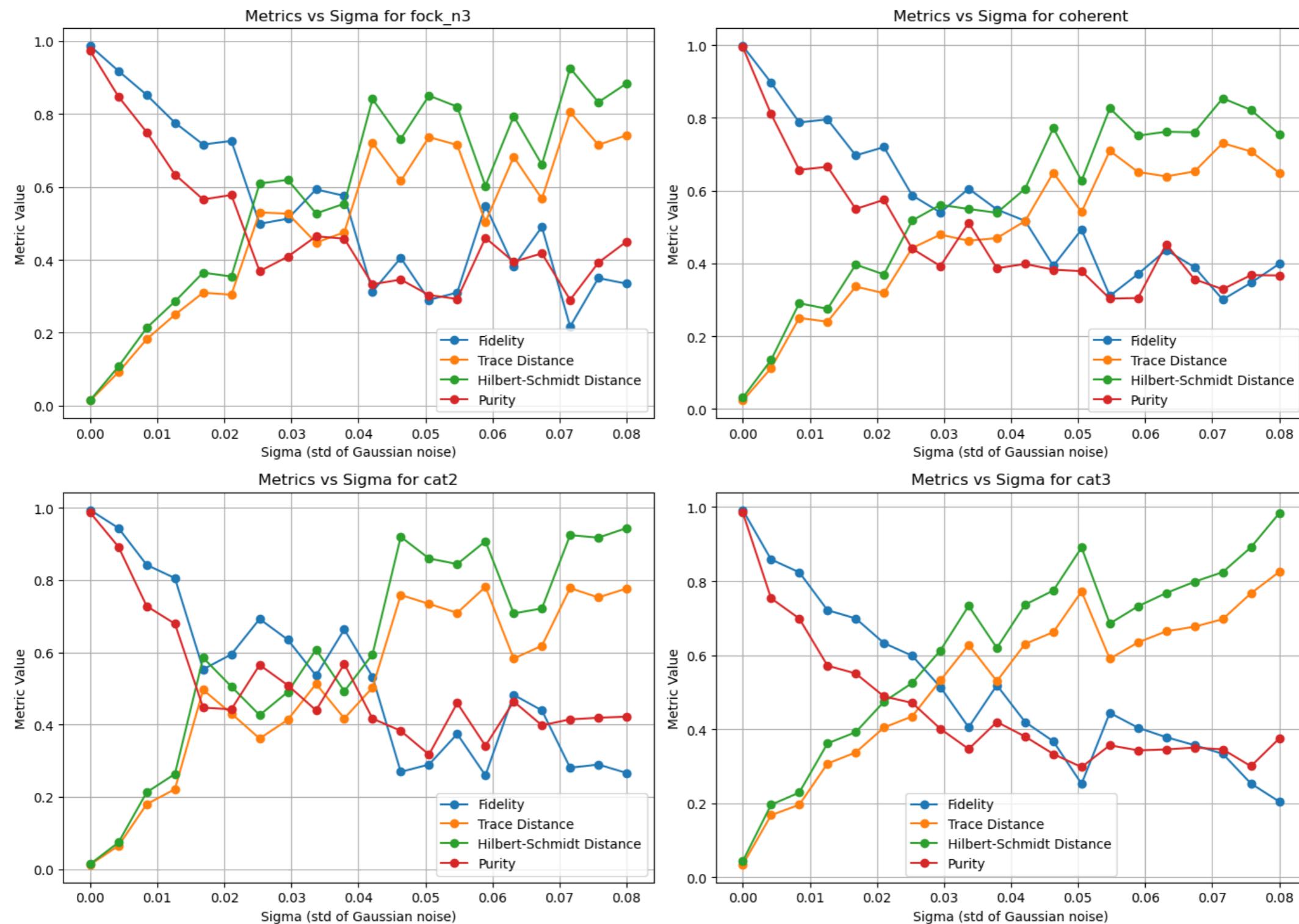
0.012412

0.033844

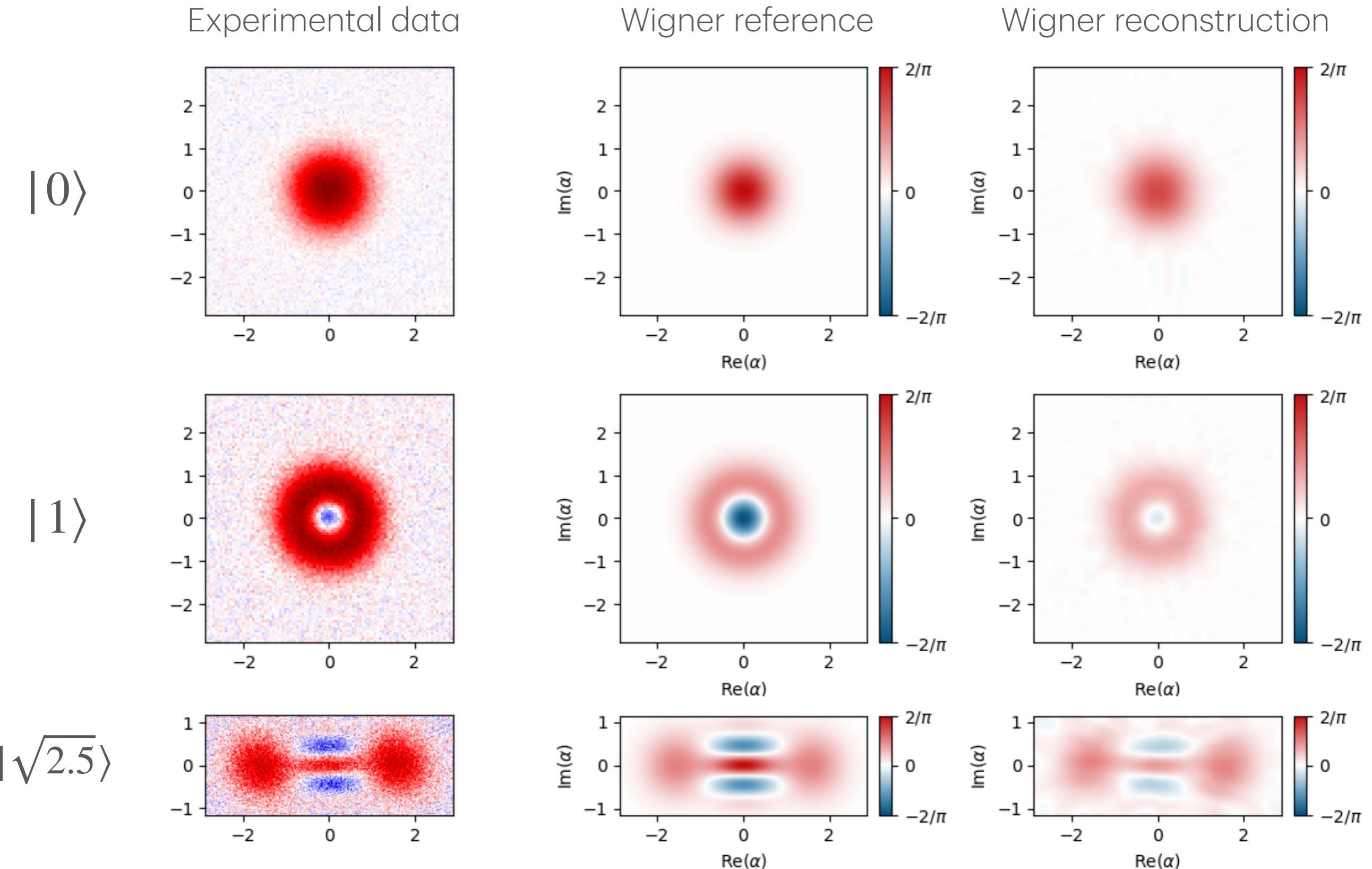
Trace distances

# 1.C. Robustness of the fit

## 1.C.1. Gaussian noise

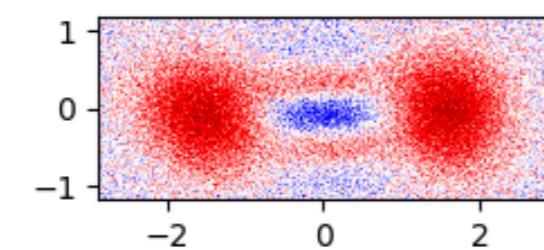


## 1.C. Robustness of the fit

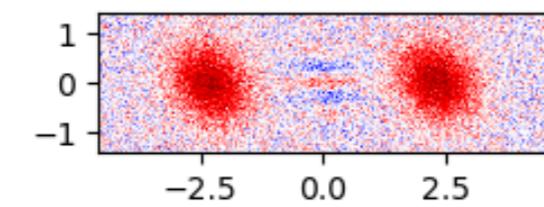


# 1.C. Robustness of the fit

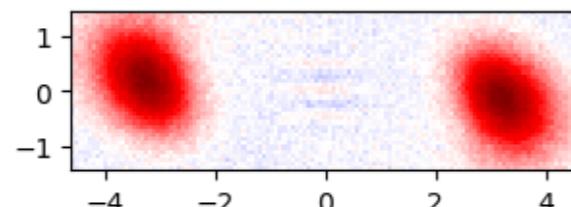
$|\sqrt{2.5}\rangle$



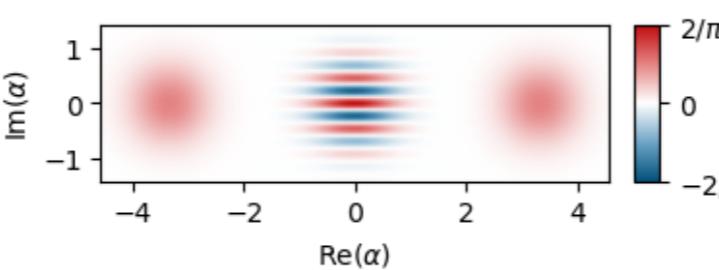
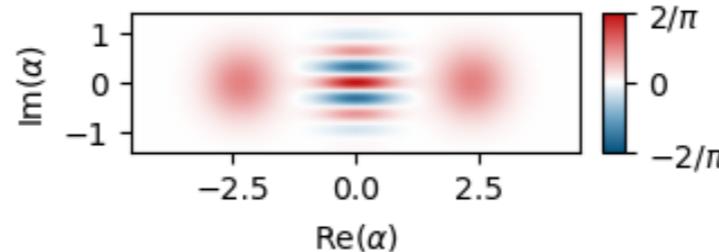
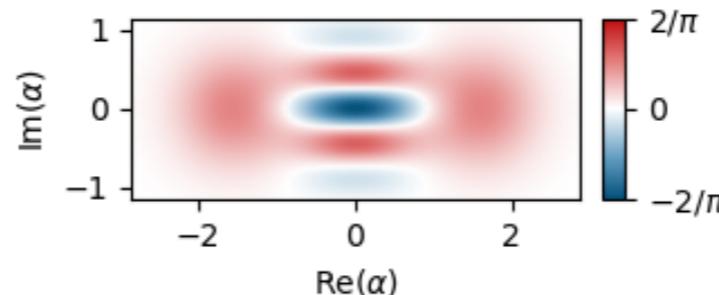
$|\sqrt{5.6}\rangle$



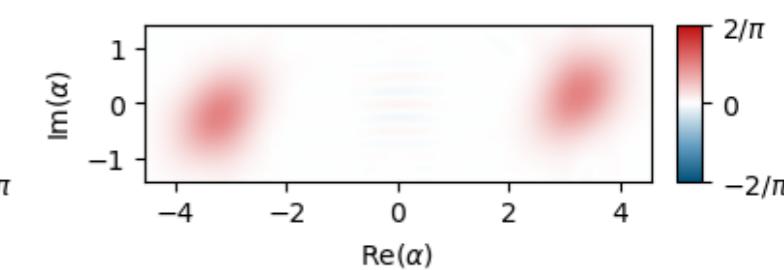
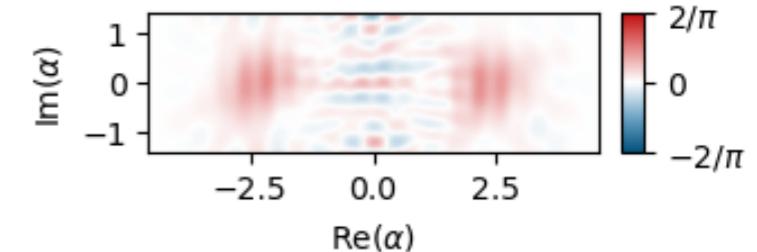
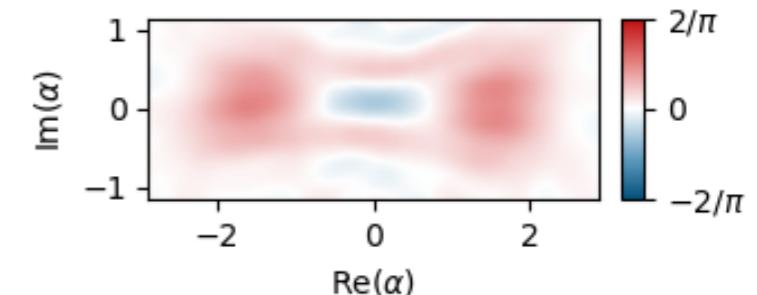
$|\sqrt{11.3}\rangle$



Wigner reference



Wigner reconstruction

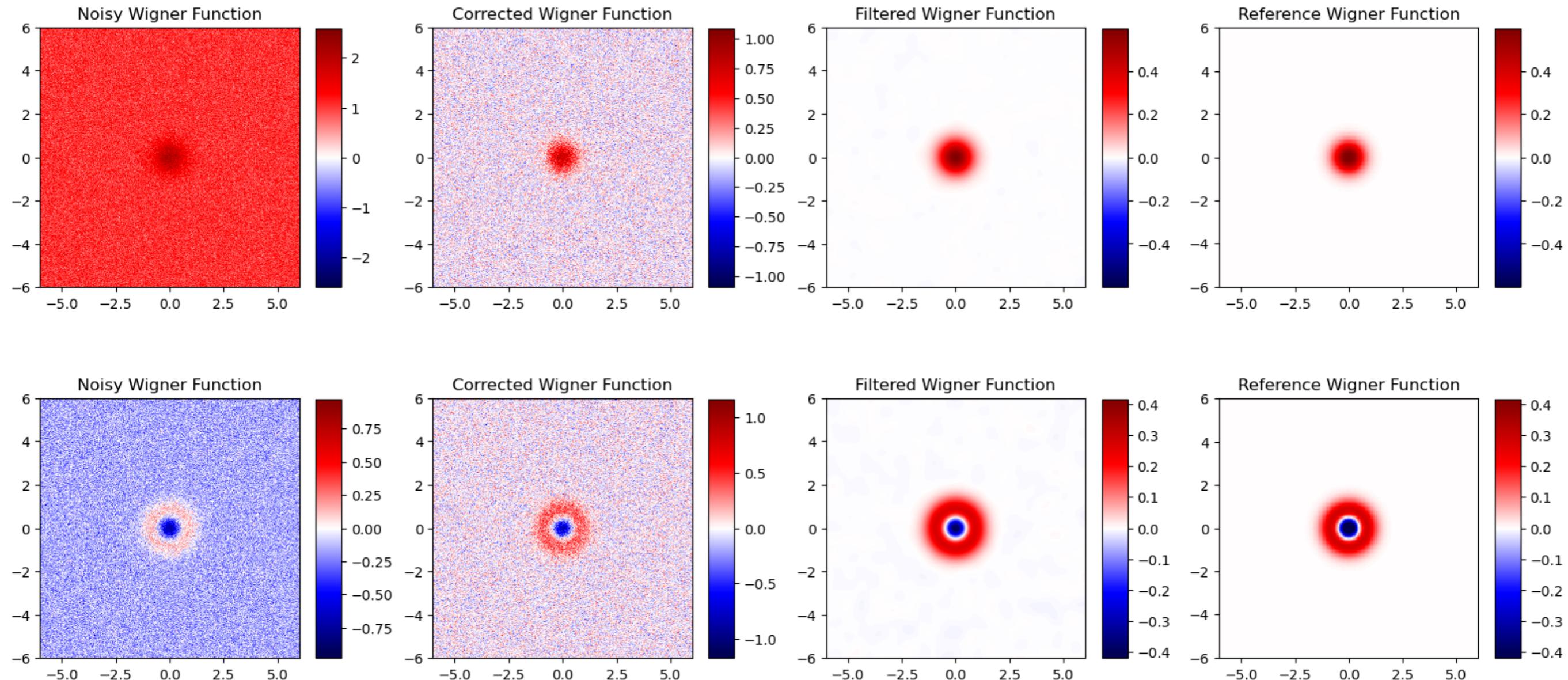


## 1.C. Robustness of the fit

	Fidelity	Trace distance	Purity
$ 0\rangle$	0.868	0.868	0.770
$ 1\rangle$	0.519	0.482	0.438
$ \sqrt{2.5}\rangle$	0.679	0.352	0.568
$ - \sqrt{2.5}\rangle$	0.609	0.422	0.532
$ \sqrt{5.6}\rangle$	0.525	0.556	0.533
$ \sqrt{11.3}\rangle$	0.487	0.540	0.500

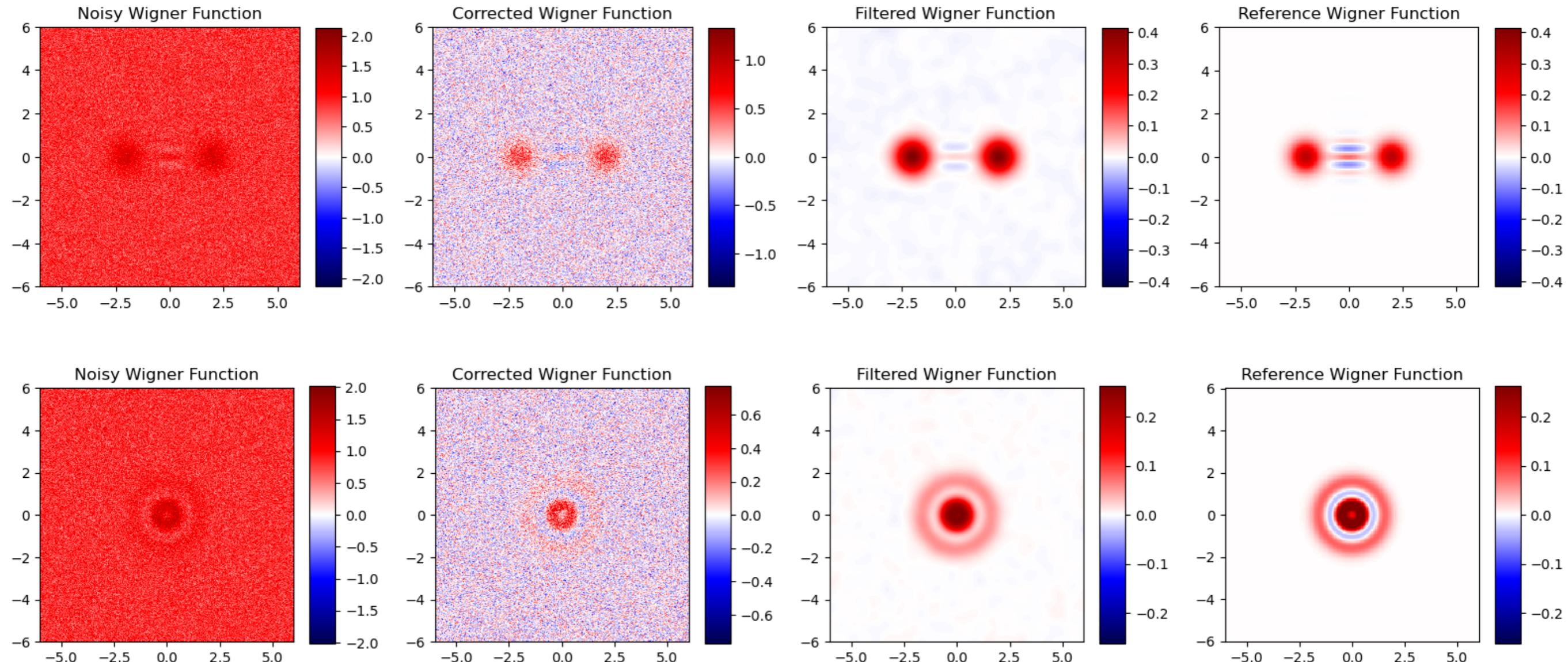
# 2. Denoising

## 2.A. Correcting Affine Distortions and Background Noise



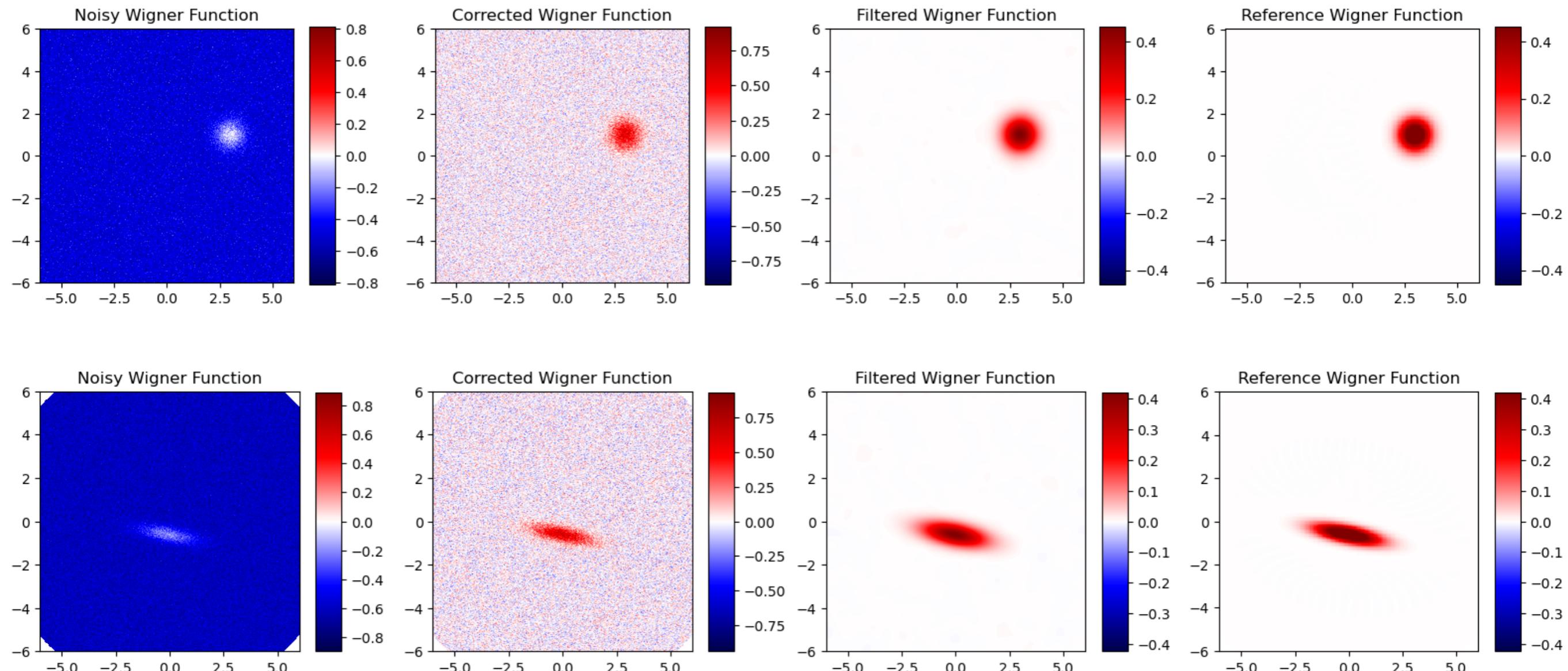
# 2. Denoising

## 2.A. Correcting Affine Distortions and Background Noise



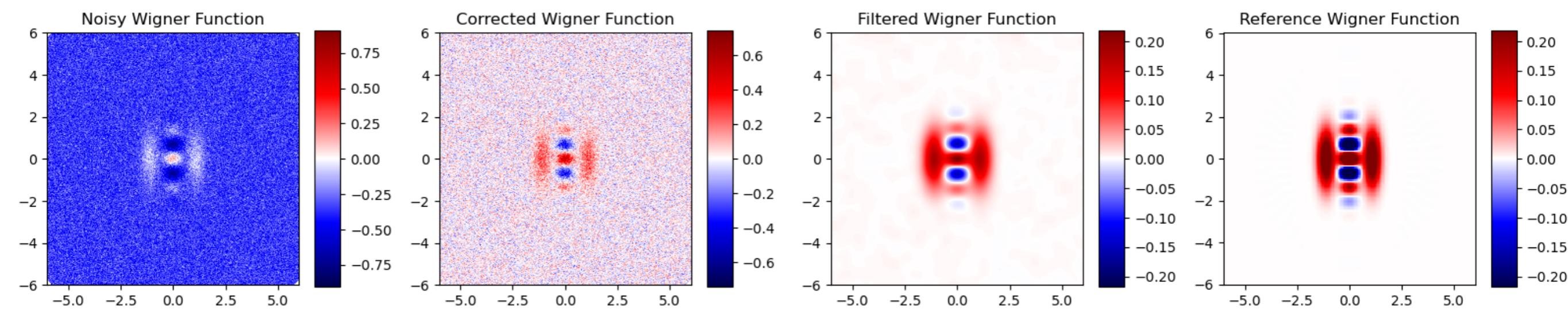
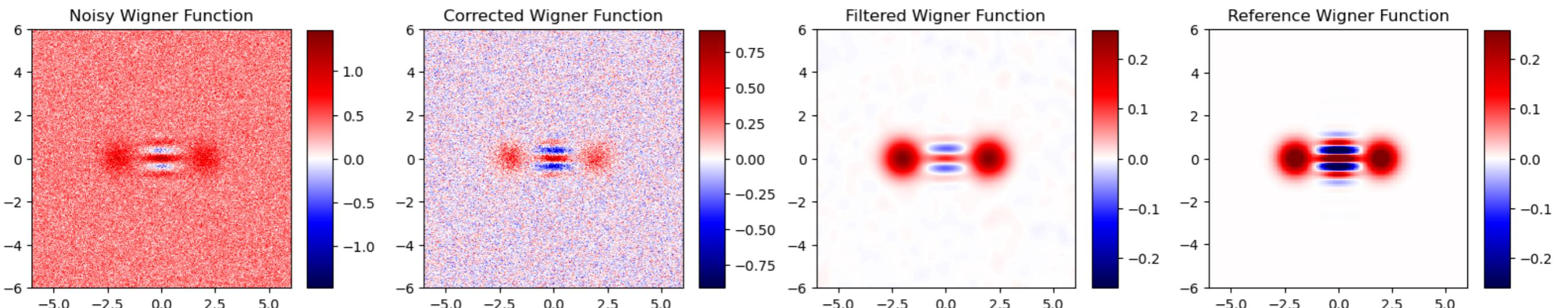
# 2. Denoising

## 2.A. Correcting Affine Distortions and Background Noise



# 2. Denoising

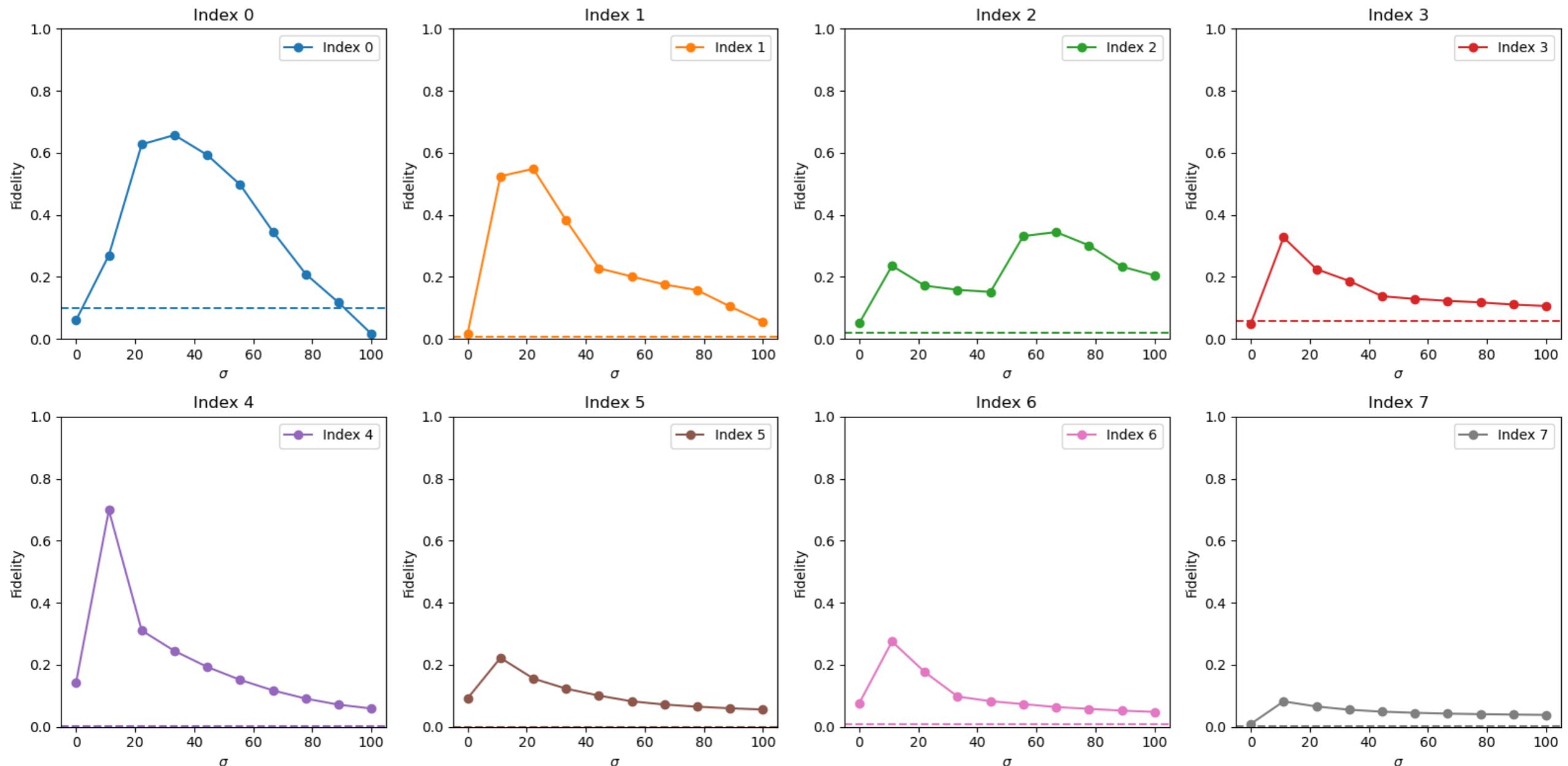
## 2.A. Correcting Affine Distortions and Background Noise



# 2. Denoising

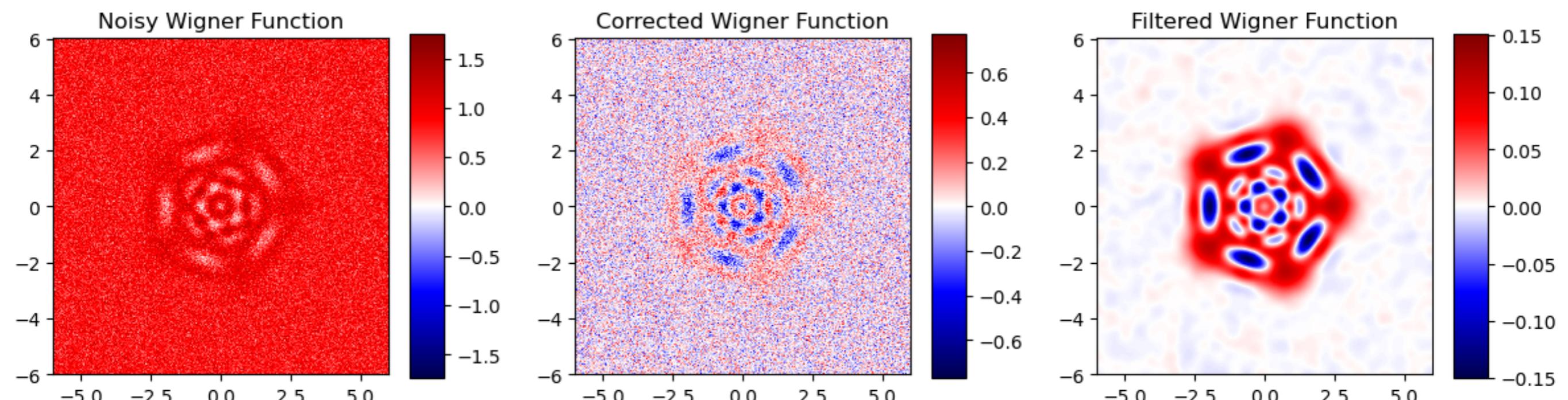
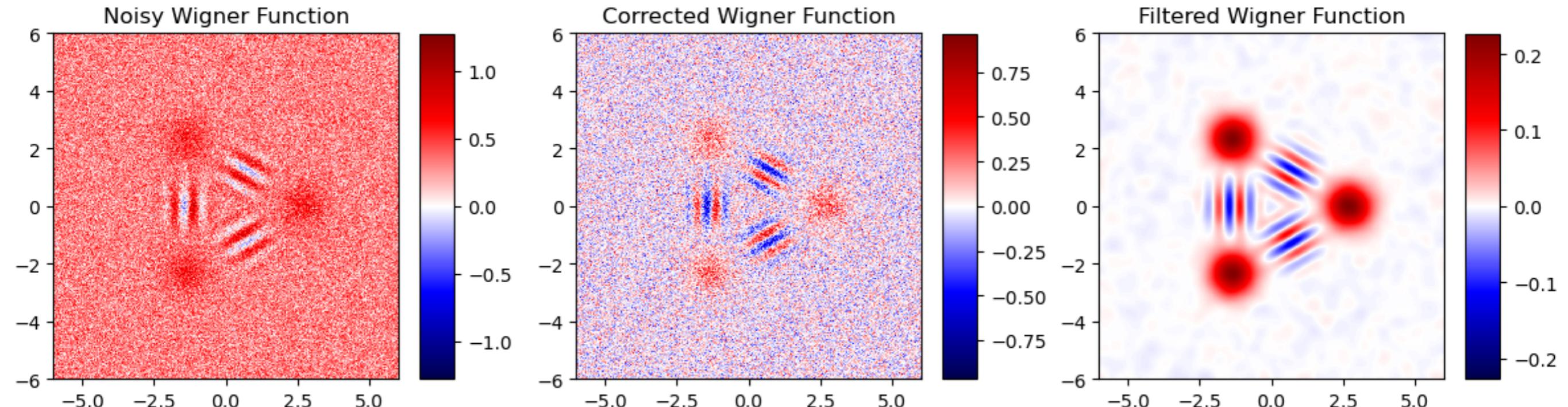
## 2.A. Correcting Affine Distortions and Background Noise

A filter with  $\sigma \approx 15$  tends to work better for all the measurements



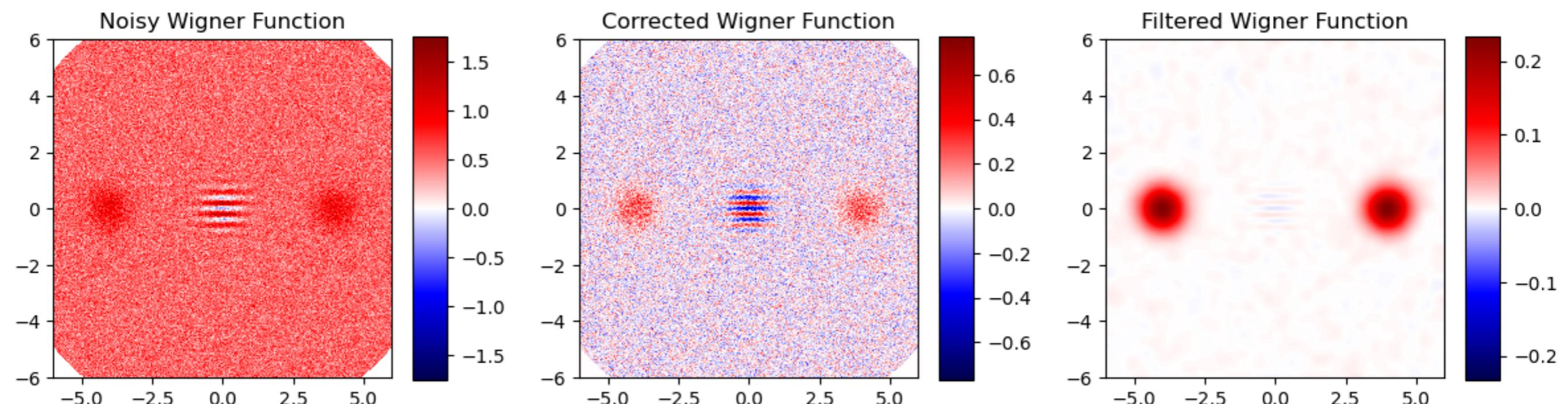
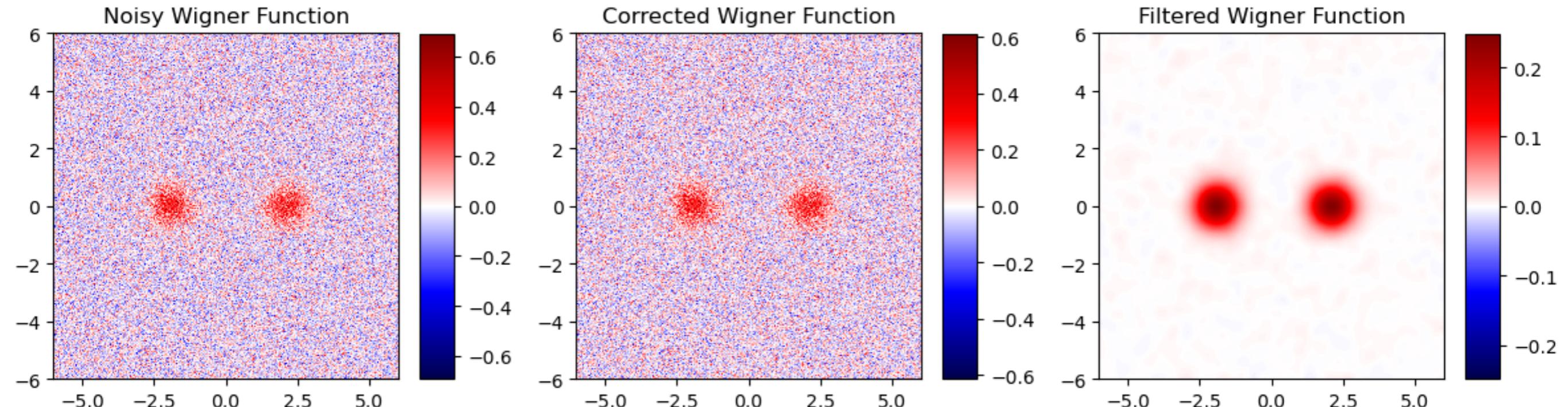
# 2. Denoising

2.A. Fixing  $\sigma = 15$  for the other values



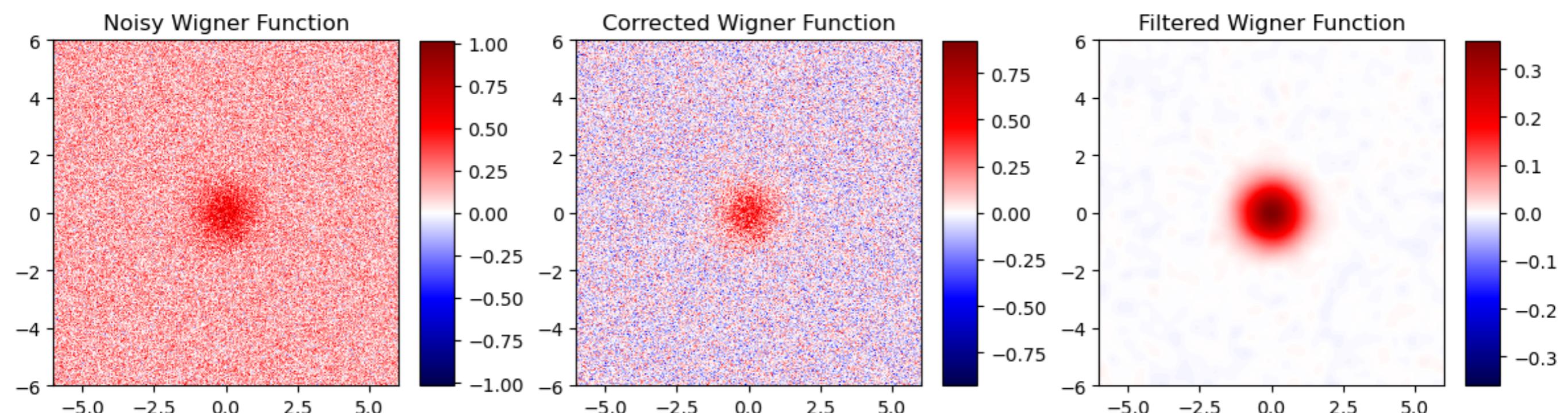
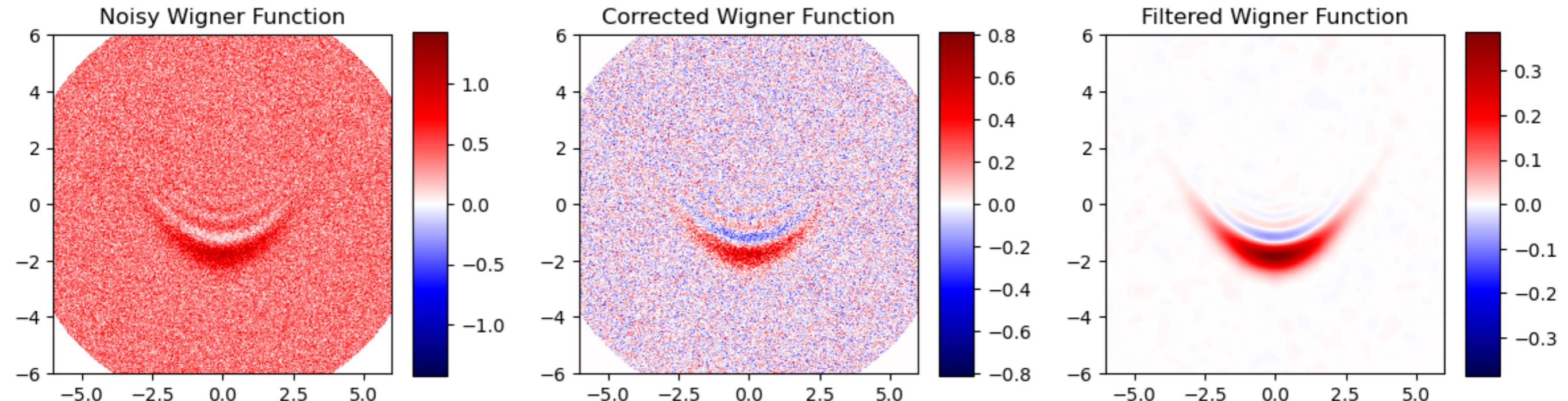
## 2. Denoising

2.A. Fixing  $\sigma = 15$  for the other values



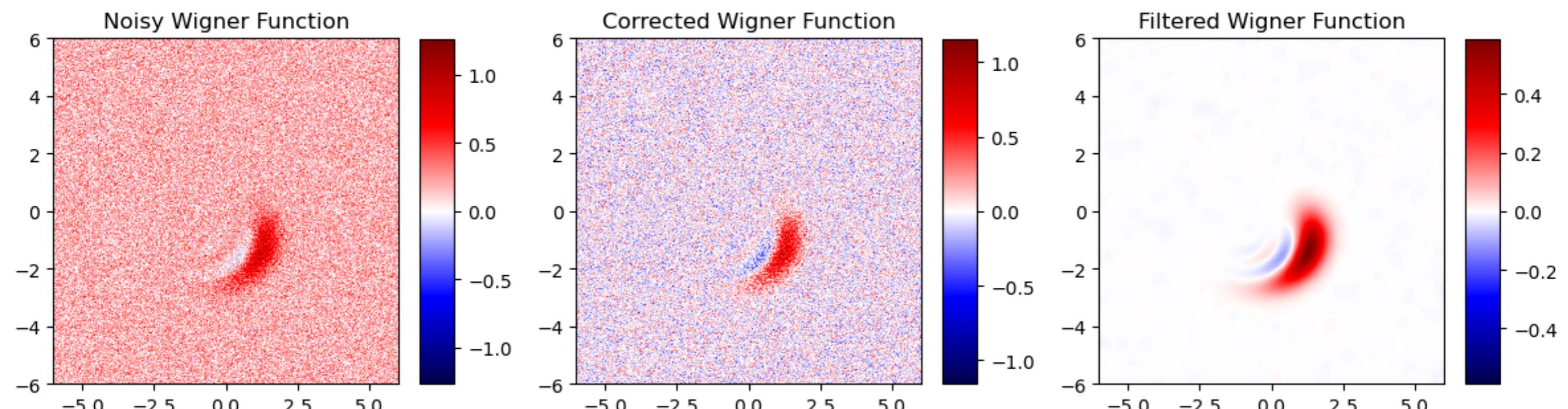
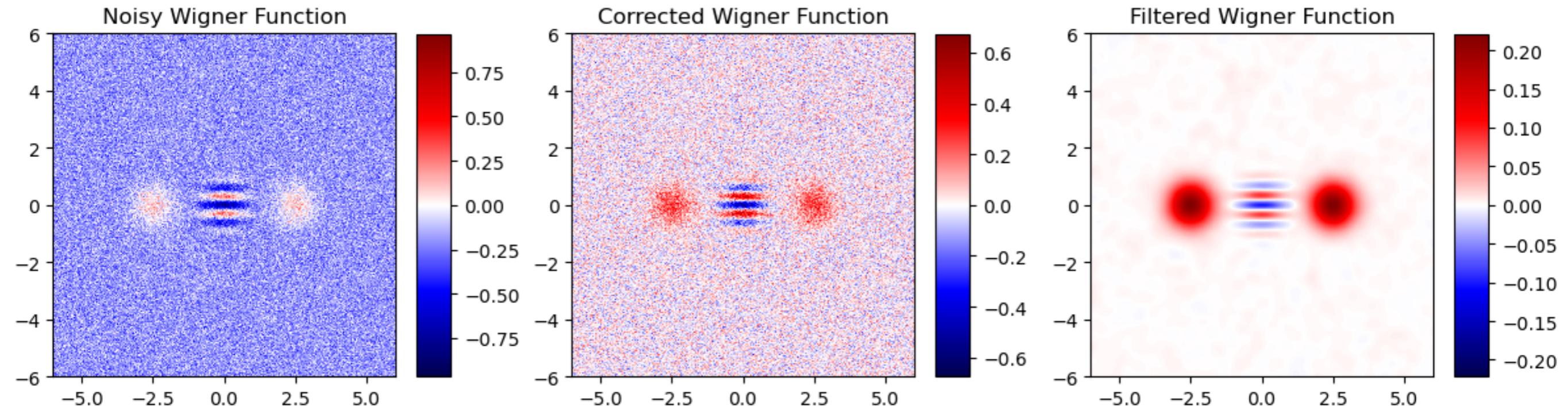
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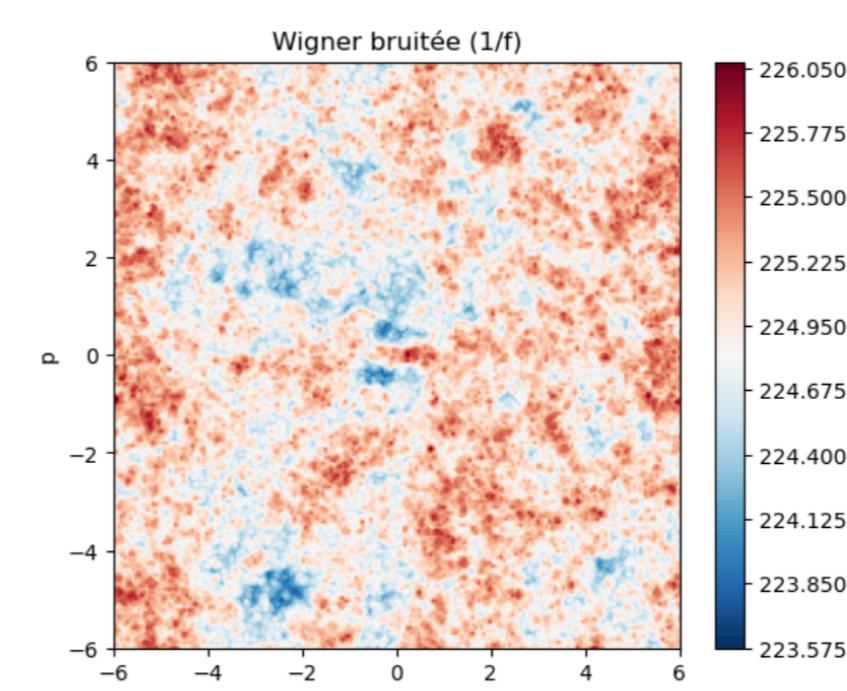
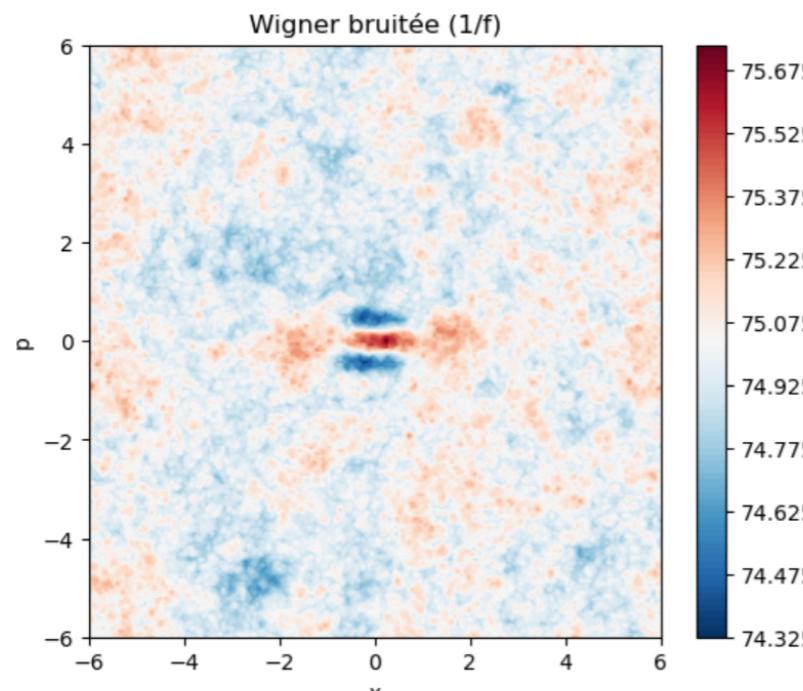
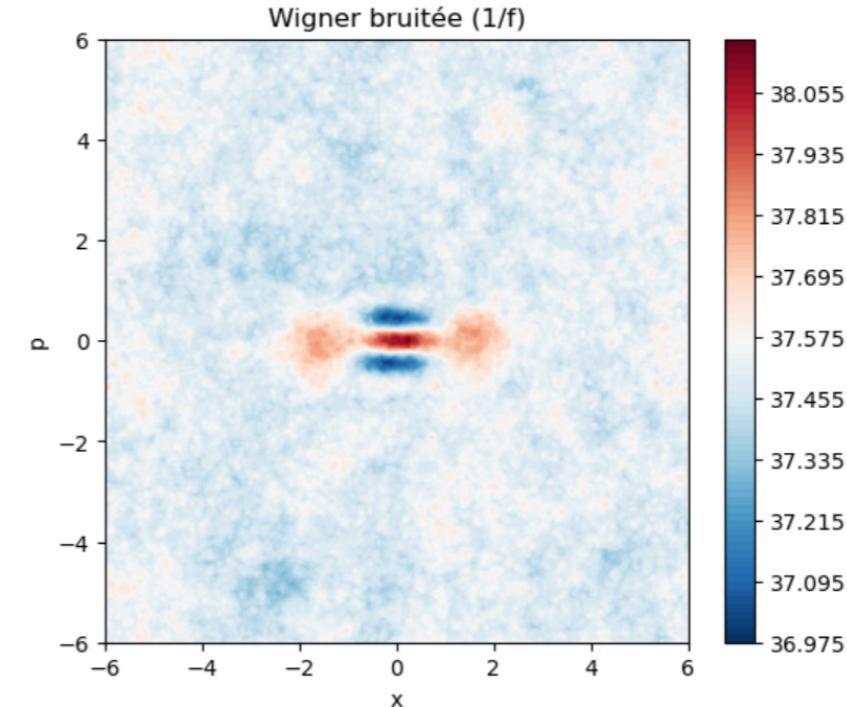
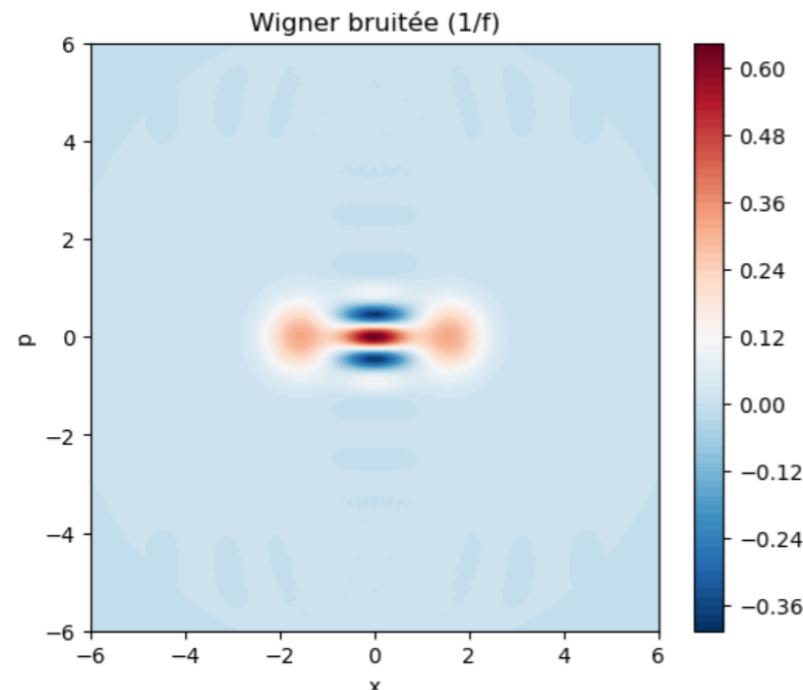
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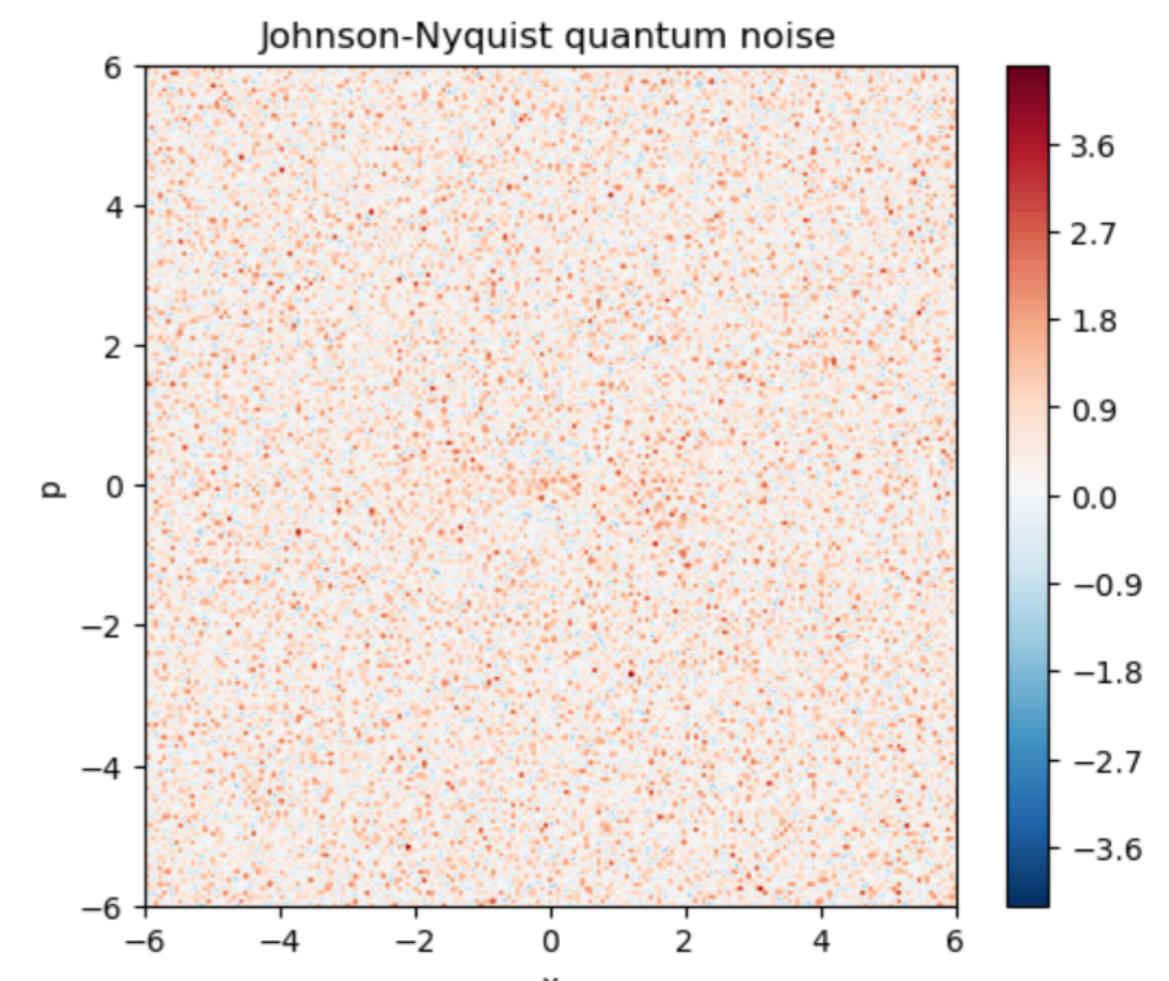
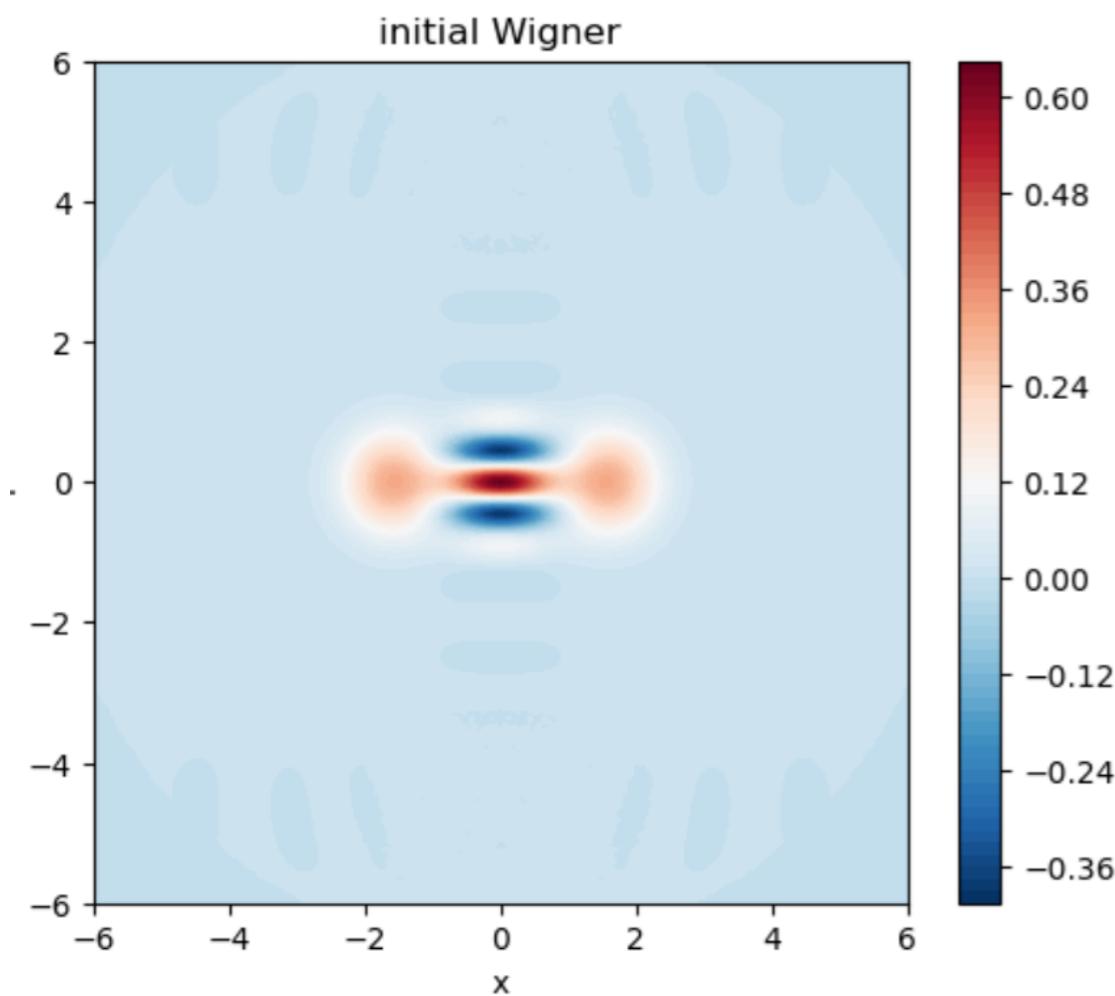
## 2. [OPTIONAL] Noise channels

Noise in superconducting qubits:

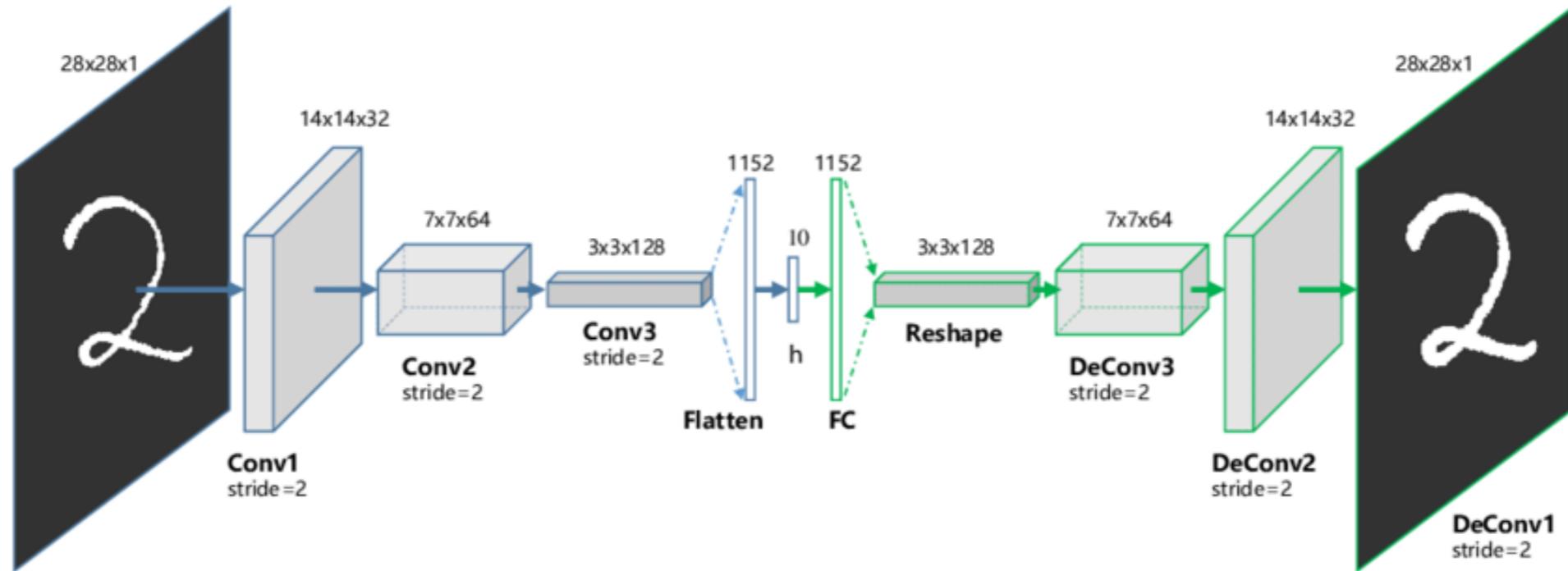
1/f noise, thermal noise



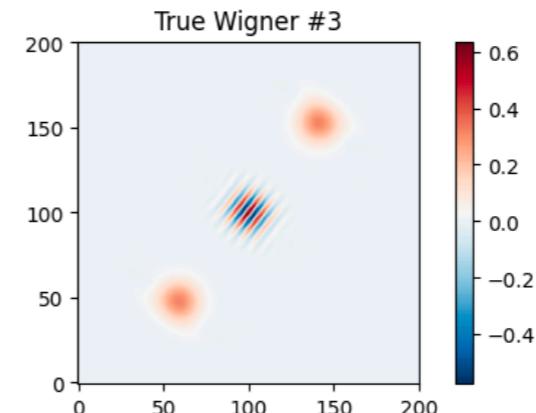
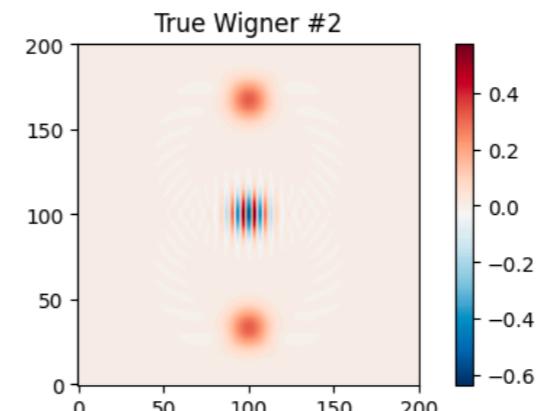
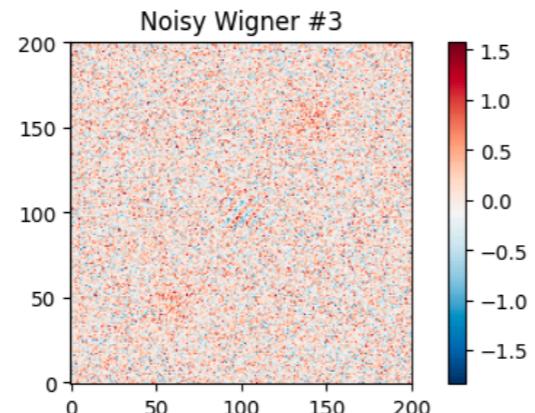
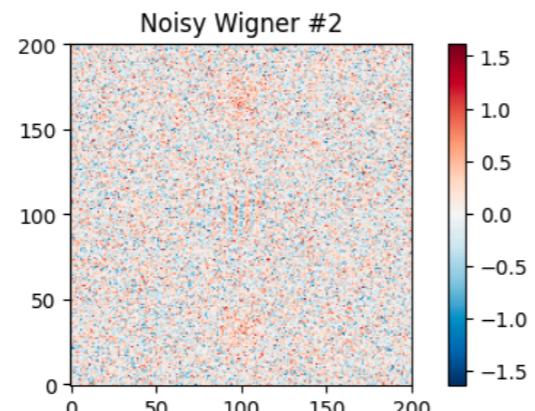
## 2. [OPTIONAL] Noise channels



## 2. [OPTIONAL] Denoising with CNNAutoencoders



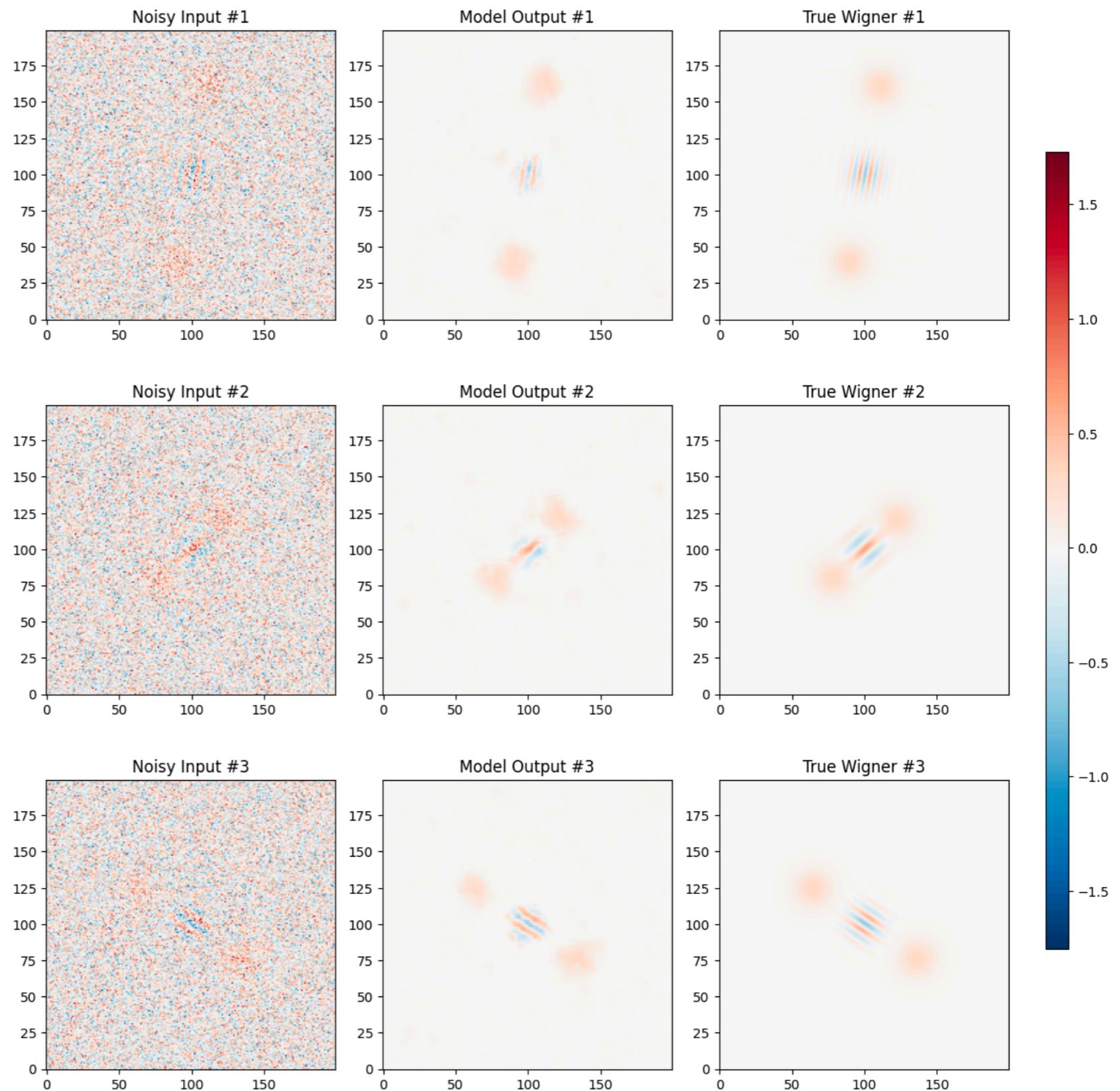
Input data



Target data

## 2. [OPTIONAL] Denoising with CNNAutoencoders

Results on validation set





fidelity and purity over time for the dissipative cat qubit

