Learning denoising without clean images

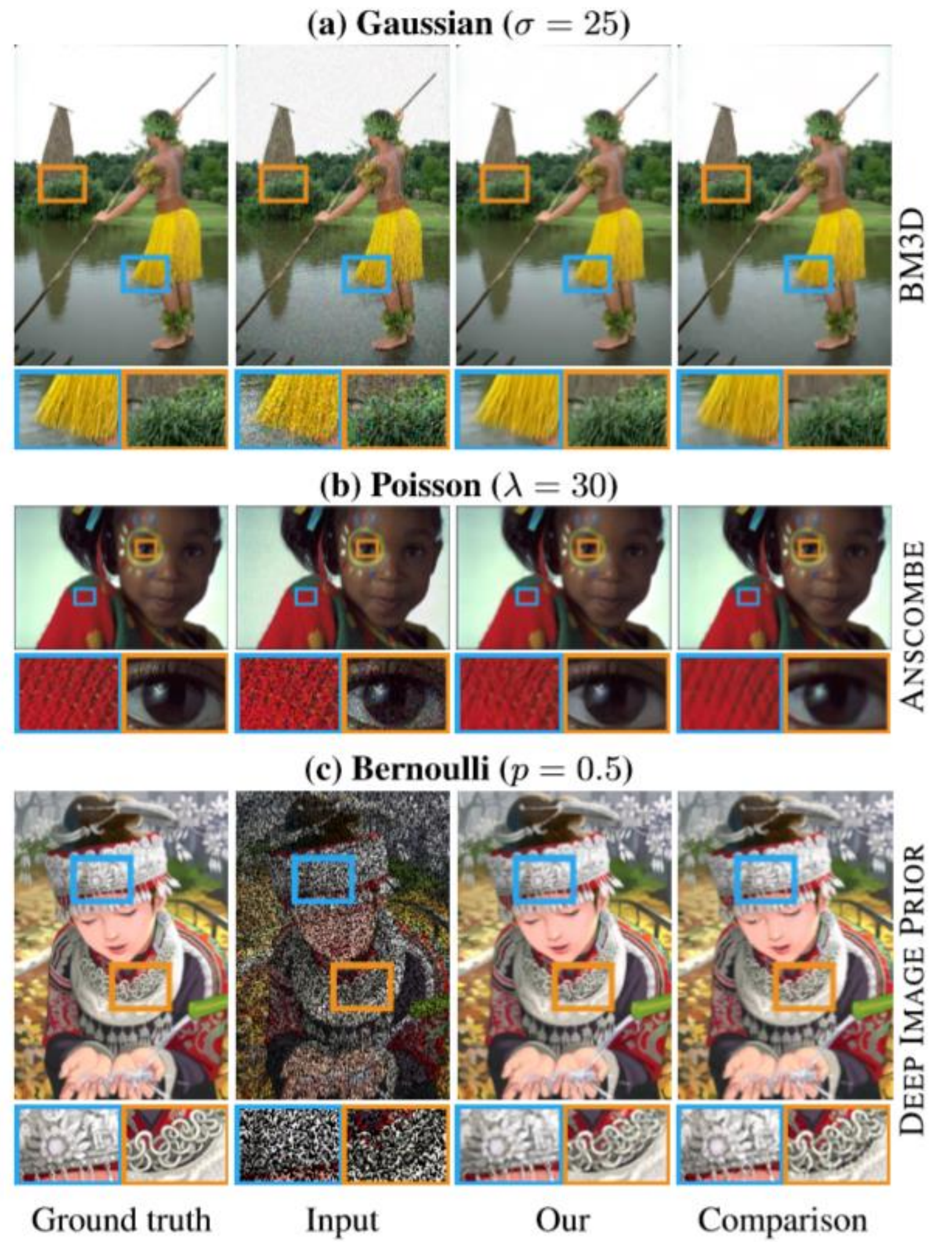
- - **Noise2Noise: Learning Image Restoration without Clean Data**
Jaakko Lehtinen, Jacob Munkberg, Jon Hasselgren, Samuli Laine, Tero Karras, Miika Aittala and Timo Aila (2018)
- - **Noise2Void: Learning Denoising from Single Noisy Images**
Alexander Krull, Tim-Oliver Buchholz and Florian Jug (2019)
- - **DenoiSeg: Joint Denoising and Segmentation**
Tim-Oliver Buchholz, Mangal Prakash, Alexander Krull and Florian Jug (2020)

Traditional method

- training networks for denoising requires pairs of noisy and clean images
- obtaining clean training targets is often difficult or tedious: a noise-free photograph requires a long exposure, This can be a difficult procedure since the biological sample must not move between exposures

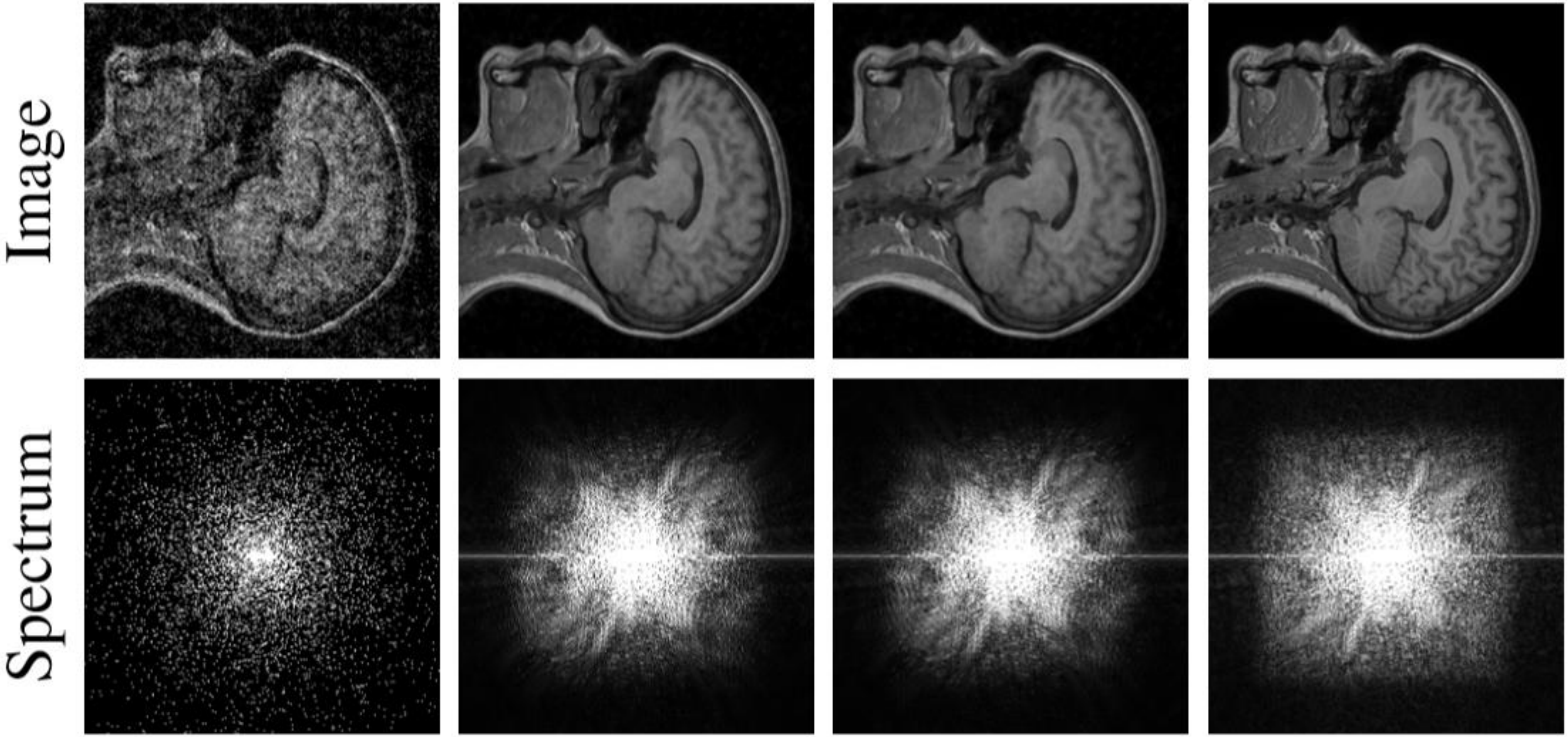
Noise2Noise - Learning Image Restoration without Clean Data

- This method maps between a noisy input pixel and its noisy target and apply basic statistical reasoning to signal reconstruction by machine learning
- It requires that two images capturing the same content (s) with independent noises (n, n') can be acquired
- It attempts to learn a mapping between pairs of independently degraded versions of the same training image, i.e. (s + n, s + n'), that incorporate the same signal s, but independently drawn noise n and n'
- Works for different types of noises
- Works for reconstruction of undersampled MRI scans


(a) Gaussian ($\sigma = 25$)
BM3D
(b) Poisson ($\lambda = 30$)
ANSCOMBE
(c) Bernoulli ($p = 0.5$)
DEEP IMAGE PRIOR
Ground truth
Input
Our
Comparison

Input ($p \approx 0.25$)	L_2	L_1	Clean targets	Ground truth
17.12 dB	26.89 dB	35.75 dB	35.82 dB	PSNR

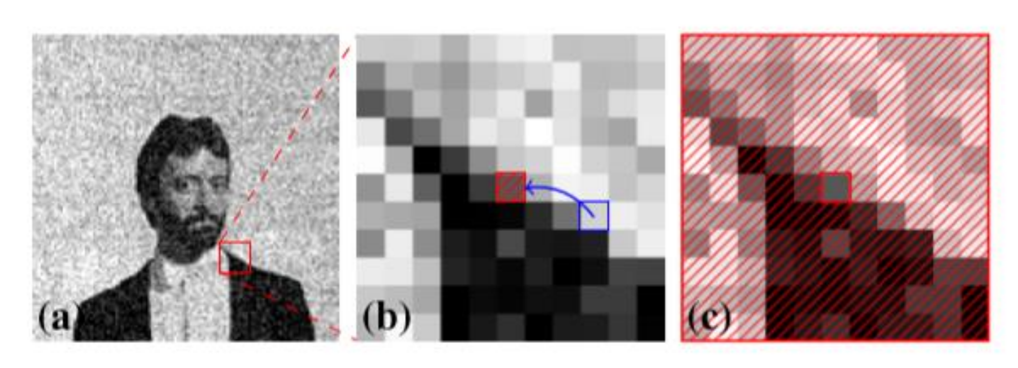
Input ($p = 0.70$)	L_2 / L_1	L_0	Clean targets	Ground truth
8.89 dB	13.02 dB / 16.36 dB	28.43 dB	28.86 dB	PSNR

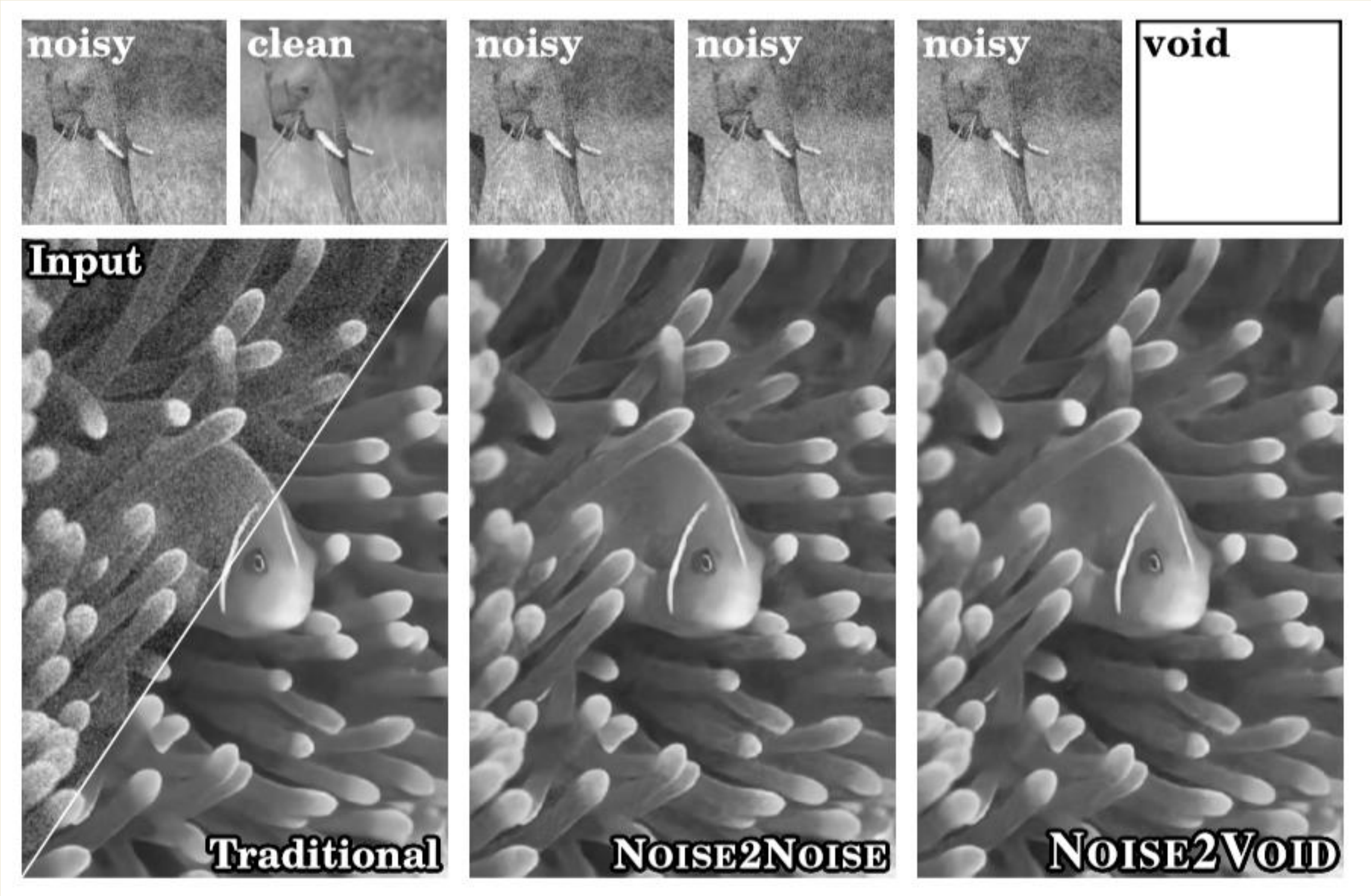


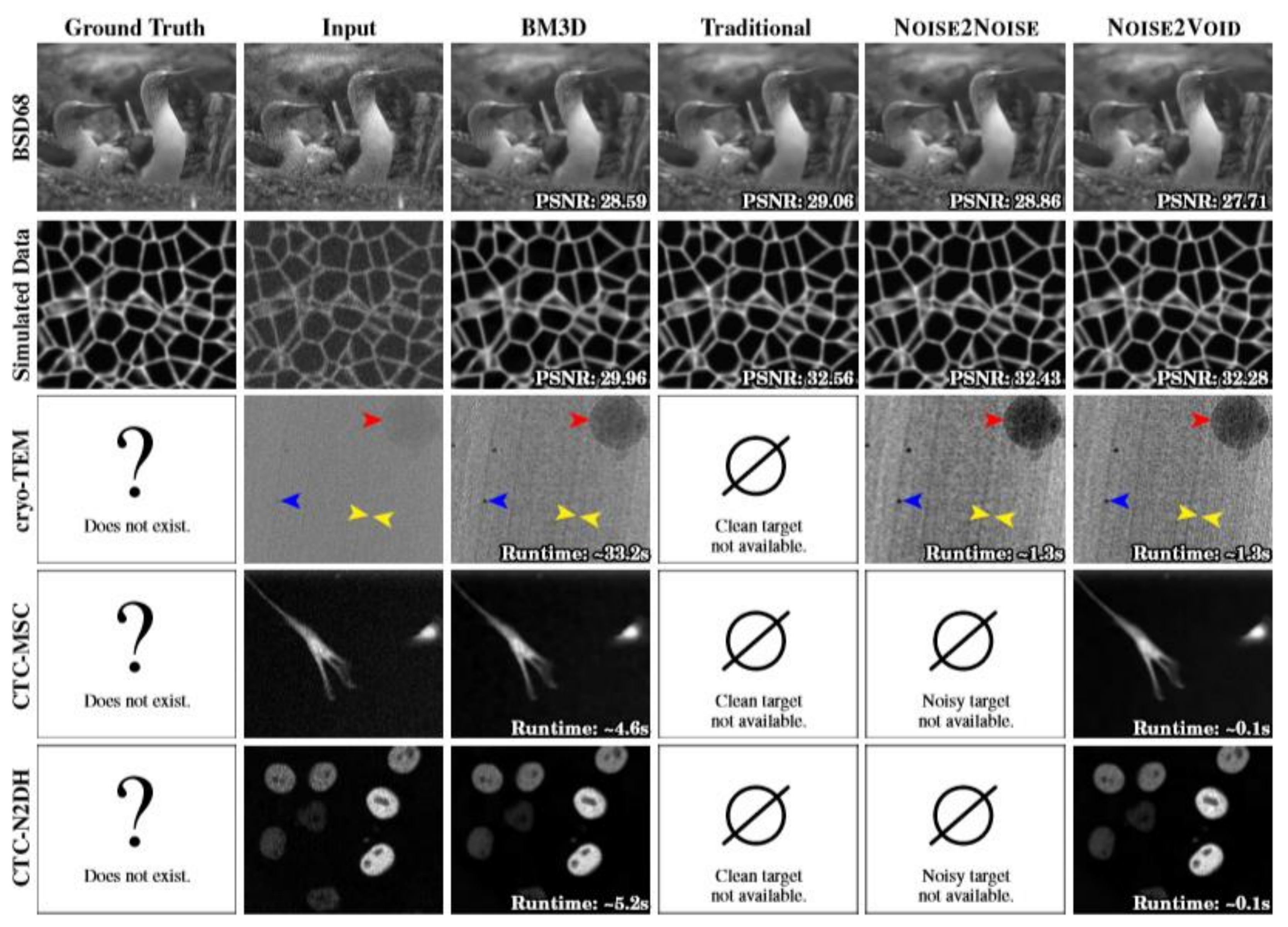
(a) Input 18.93 dB | (b) Noisy trg. 29.77 dB | (c) Clean trg. 29.81 dB | (d) Reference

Noise2Void - Learning Denoising from Single Noisy Images

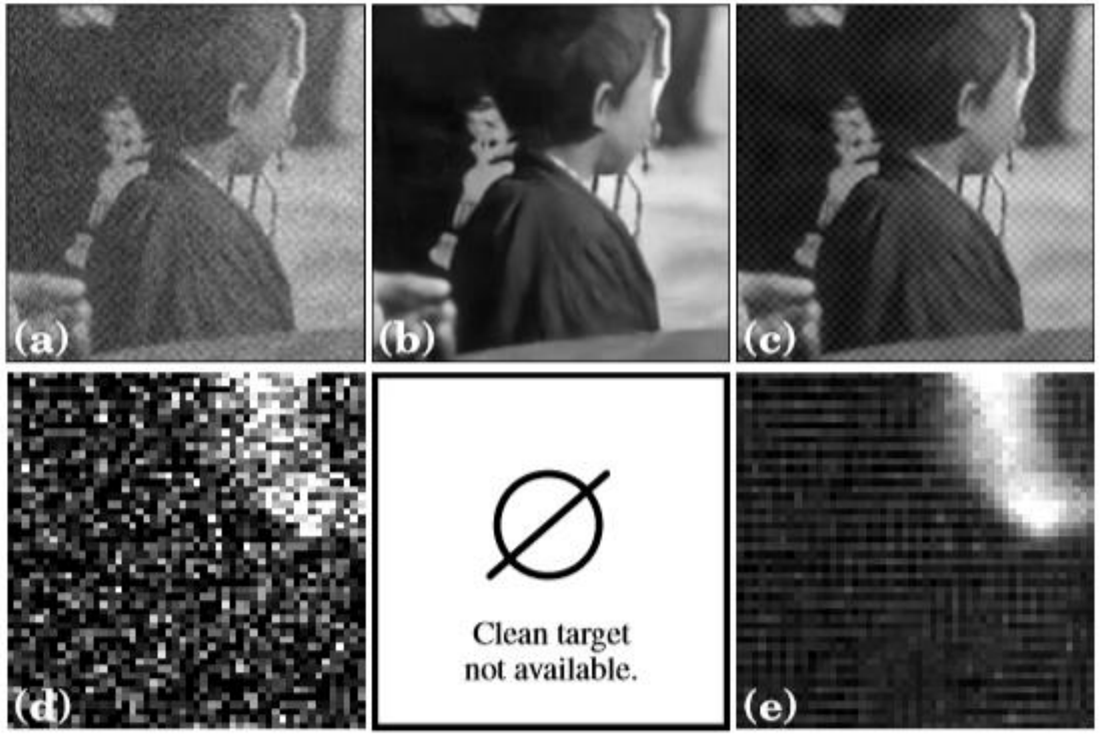
- This method can be applied to data for which neither noisy image pairs nor clean target images are available
- It predicts pixel values based on their noisy surroundings
- It shows that blind-spot networks can learn to remove pixel wise independent noise when they are trained on the same noisy images as input and target.

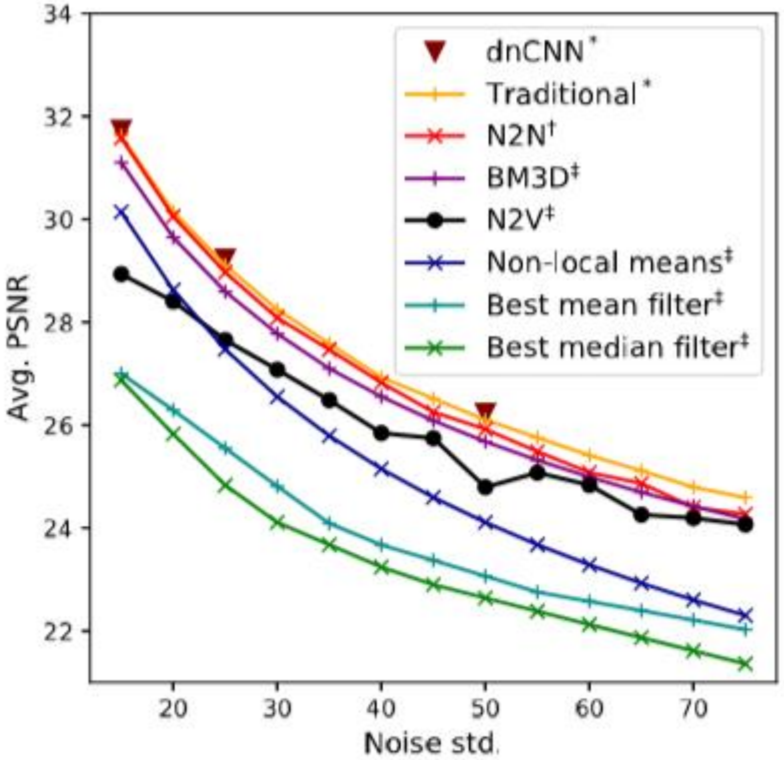



noisy
clean
noisy
noisy
noisy
void
Input
Traditional
NOISE2NOISE
NOISE2VOID



Ground Truth
Input
BM3D
Traditional
NOISE2NOISE
NOISE2VOID
BSD68
PSNR: 28.59
PSNR: 29.06
PSNR: 28.86
PSNR: 27.71
Simulated Data
PSNR: 29.96
PSNR: 32.56
PSNR: 32.43
PSNR: 32.28
cryo-TEM
Does not exist.
Runtime: ~33.2s
Clean target
not available.
Runtime: ~1.3s
Runtime: ~1.3s
CTC-MSC
Does not exist.
Runtime: ~4.6s
Clean target
not available.
Noisy target
not available.
Runtime: ~0.1s
CTC-N2DH
Does not exist.
Runtime: ~5.2s
Clean target
not available.
Noisy target
not available.
Runtime: ~0.1s

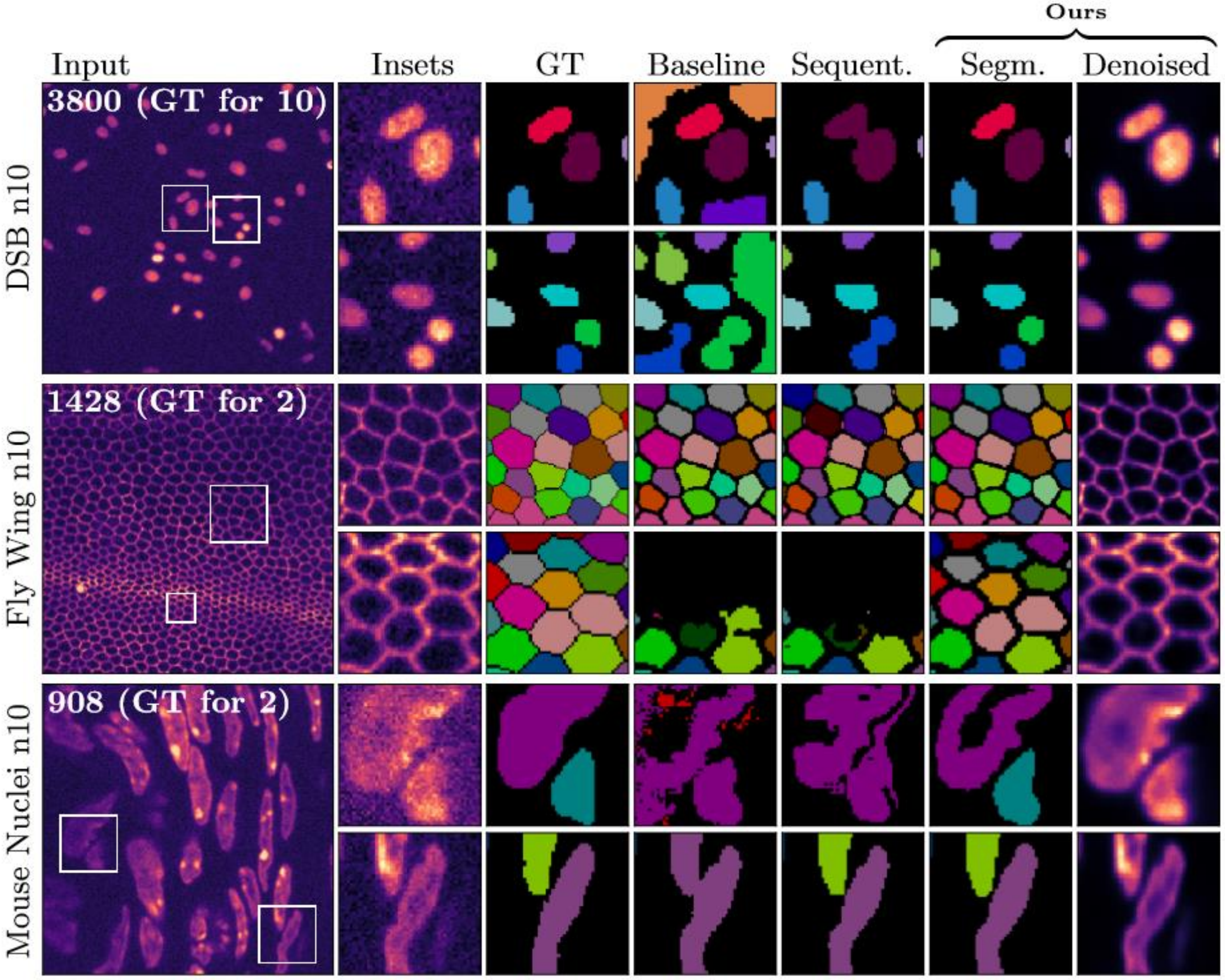

(a)
(b)
(c)
(d)
Clean target not available.
(e)

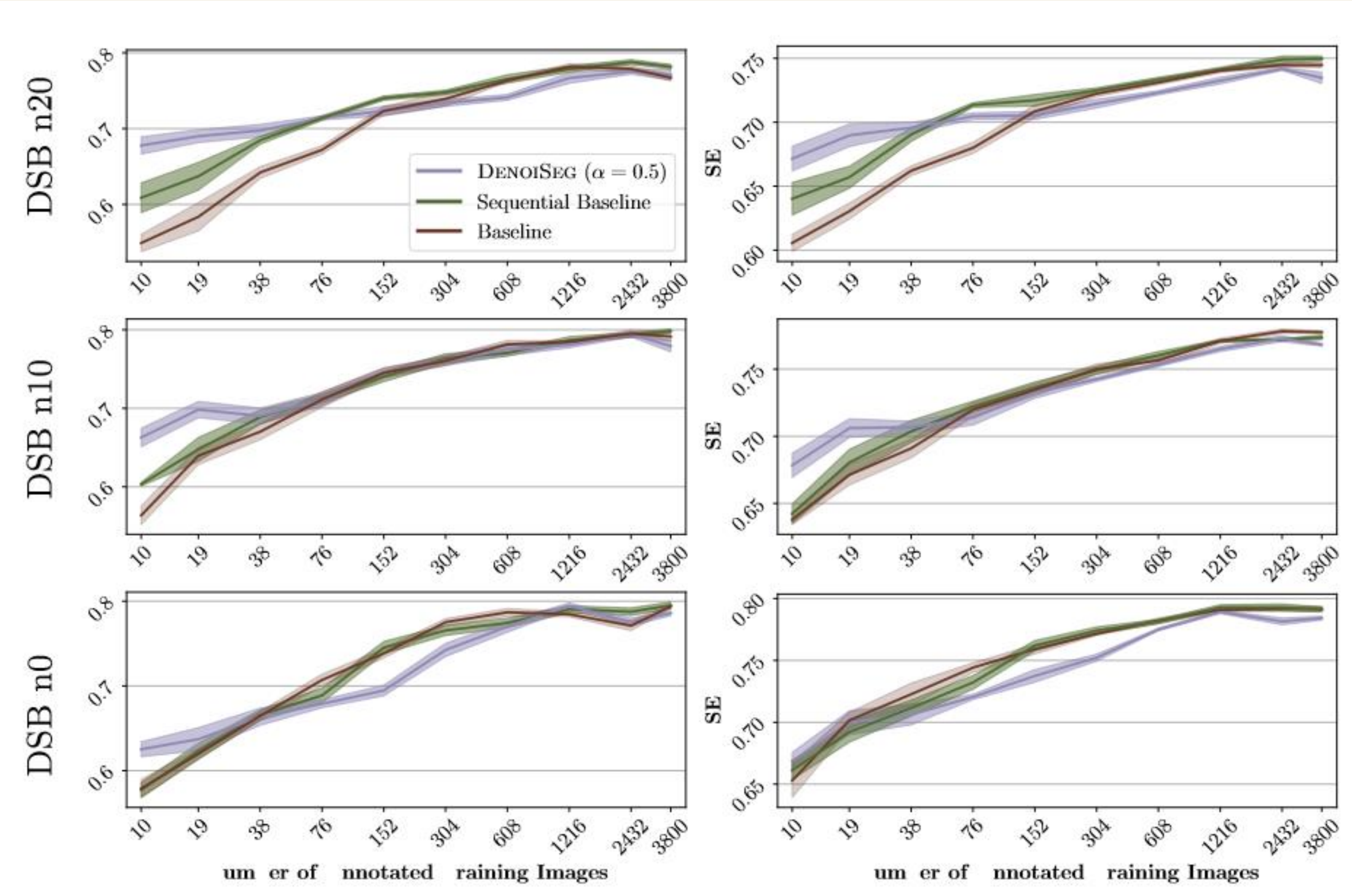

Avg. PSNR
Noise std.
22
24
26
28
30
32
34
20
30
40
50
60
70
dnCNN*
Traditional*
N2N†
BM3D‡
N2V‡
Non-local means‡
Best mean filter‡
Best median filter‡


Mean filter (5x5)
Median filter (5x5)
N2V

DenoiSeg - Joint Denoising and Segmentation

- This method is a single network that jointly predict the denoised image and the desired object segmentation
- It can be trained end-to-end on only a few annotated ground truth segmentations. They achieve this by extending Noise2Void
- A U-Net is trained with a joint self-supervised denoising loss (Ld) and a classical segmentation loss (Ls). Both losses are weighted with respect to each other by a hyperparameter α.
- The proposed network produces four output channels corresponding to denoised images, foreground, background and border segmentation


Ours
Input
Insets
GT
Baseline
Sequent.
Segm.
Denoised
3800 (GT for 10)
DSB n10
1428 (GT for 2)
Fly Wing n10
908 (GT for 2)
Mouse Nuclei n10



DSB n20
DSB n10
DSB n0
DenoiSeg ($\alpha = 0.5$)
Sequential Baseline
Baseline
SE
0.8
0.7
0.6
0.75
0.70
0.65
0.60
0.80
10
19
38
76
152
304
608
1216
2432
3800
um er of nnotated raining Images

QUESTIONS?