Multiple Degradation and Reconstruction Network for Single Image Denoising via Knowledge Distillation

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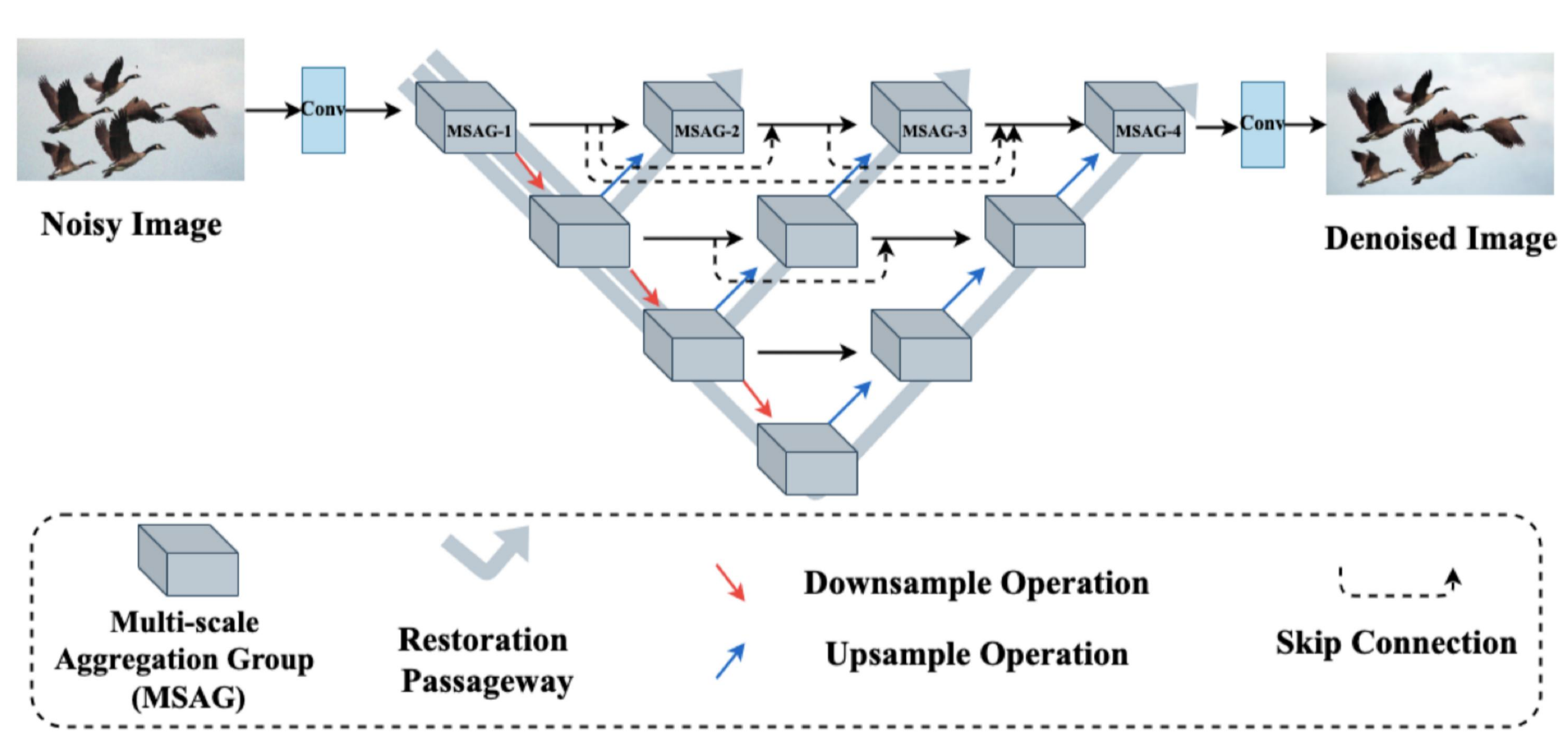
Motivation & Contributions

Different from previous works that blindly increase the depth of the network, we explore the degradation mechanism of the noisy image and aim to introduce the knowledge distillation strategy to the model.

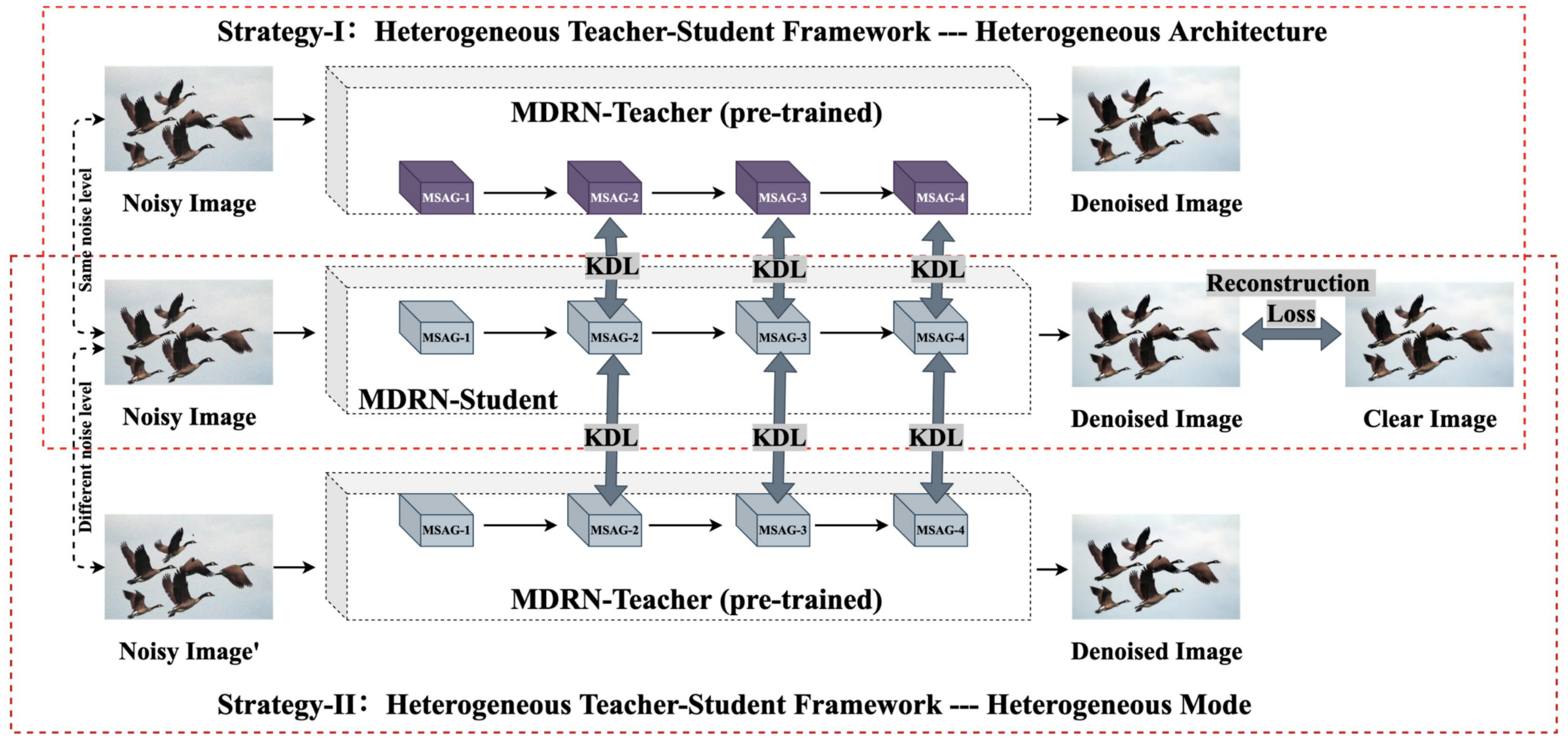
- We propose a lightweight and efficient **Multiple Degradation and Reconstruction Network (MDRN)** for image denoising, which can progressively remove image noise.
- We propose a **Multi-Scale Aggregation Group (MSAG)** for feature extraction. MSAB is the basic components of MDRN, which can extract rich multi-scale features with few parameters.
- We propose two **Heterogeneous Knowledge Distillation Strategies (HKDS)** for SID. With the help of HKDS, MDRN can learn richer and more accurate features from the teacher model.

Method

Multiple Degradation and Reconstruction Network (MDRN)



Heterogeneous Knowledge Distillation



- **Reconstruction Loss**

$$\mathcal{L}_{RL} = \|F_{SID}(I_{noisy}) - I_{clear}\|_1$$

- **Knowledge Distillation Loss**

$$\mathcal{L}_{KDL} = \sum_{i=2,3,4} \|S^i_G(I_{noisy}) - T^i_G(I'_{noisy})\|_1$$

Ablation Studies

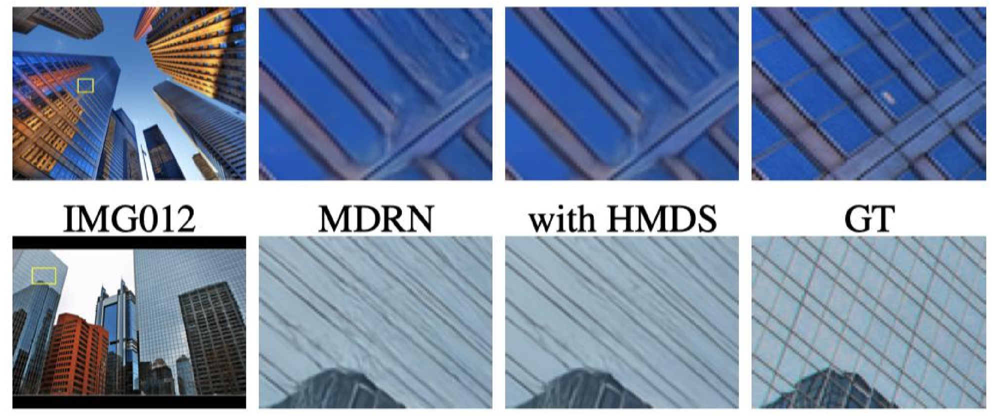
Method	Para.	Set12		BSD68		Urban100	
Noise Level	-	σ=15	σ=50	σ=15	σ=50	σ=15	σ=50
FFDNet	851K	32.75	27.32	31.63	26.29	32.42	26.52
MDRN (2B)	770K	32.87	27.35	31.72	26.31	32.82	26.74
MDRN (2B) + HADS	770K	**32.96**	**27.43**	**31.78**	**26.40**	**32.98**	**26.84**

Method	Para.	Kodak24		CBSD68		Urban100	
Noise Level	-	σ=30	σ=70	σ=30	σ=70	σ=30	σ=70
FFDNet	851K	31.39	27.68	30.31	26.53	30.53	26.39
MDRN (2B)	770K	31.40	27.69	30.38	26.59	30.66	26.57
MDRN (2B) + HADS	770K	**31.47**	**27.73**	**30.42**	**26.63**	**30.78**	**26.64**

Method	Parm.	Set12	BSD68	Urban100
Noise Level	-	σ=50	σ=50	σ=50
MLEFGN	6.86M	27.54	26.39	27.22
MDRN	2.38M	27.56	26.41	27.24
MDRN + HMDS (25)	2.38M	**27.63**	**26.46**	**27.38**

Method	Parm.	Kodak24	CBSD68	Urban100
Noise Level	-	σ=70	σ=70	σ=70
MLEFGN	6.86M	27.94	26.75	27.28
MDRN	2.38M	27.96	26.77	27.32
MDRN + HMDS (50)	2.38M	**28.00**	**26.81**	**27.45**


IMG039 MDRN-2B with HADS GT
IMG026 MDRN-2B with HADS GT

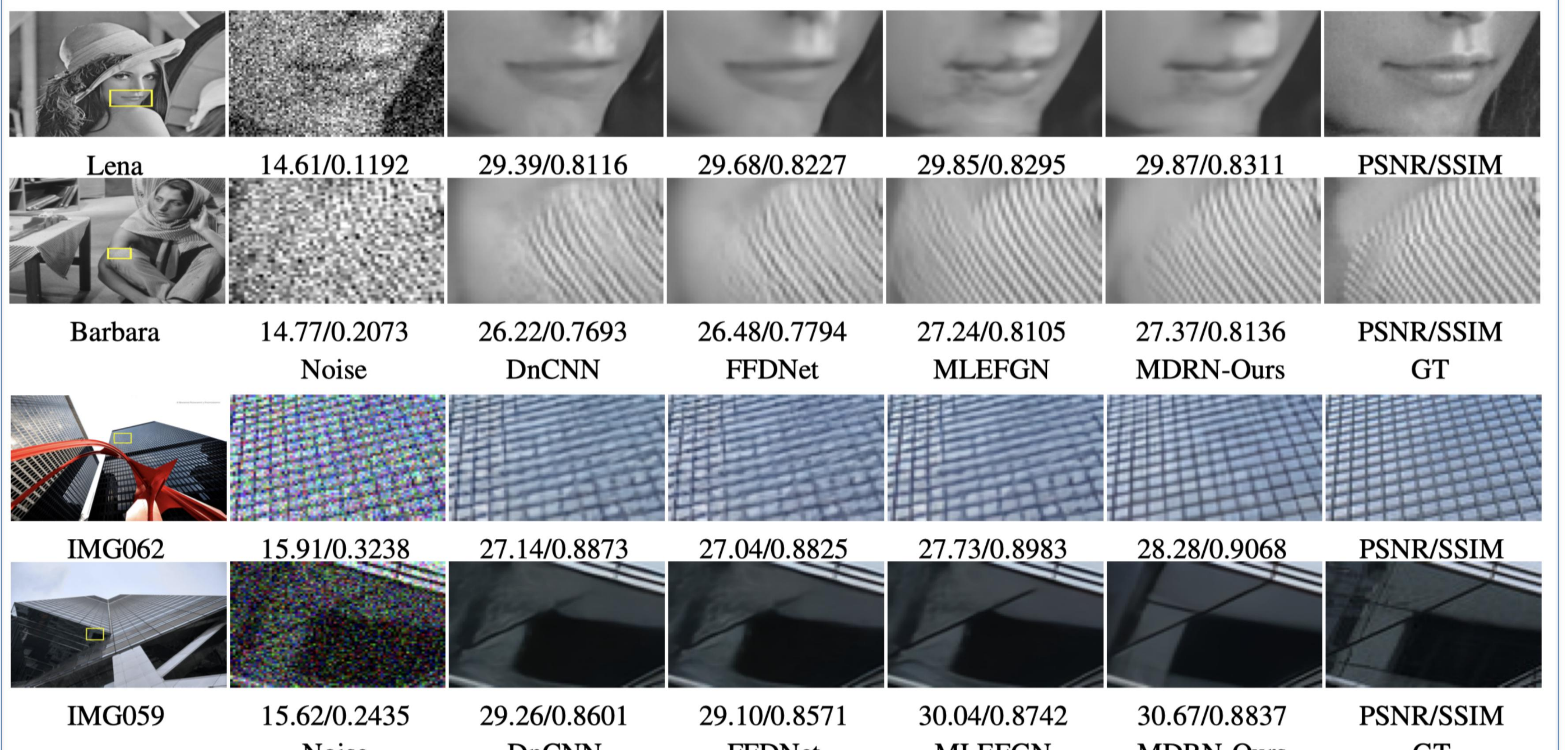

IMG012 MDRN with HMDS GT
IMG099 MDRN with HMDS GT

Results

Method	Set12			BSD68			Urban100		
Noise Level	σ=15	σ=25	σ=50	σ=15	σ=25	σ=50	σ=15	σ=25	σ=50
BM3D	32.37	29.97	26.72	31.08	28.57	25.62	32.34	29.70	25.94
RED30	32.83	30.48	27.34	31.72	29.26	26.35	32.75	30.21	26.64
TNRD	32.50	30.06	26.81	31.42	28.92	25.97	31.98	29.29	25.71
IRCNN	32.77	30.38	27.14	31.63	29.15	26.19	32.49	29.82	26.14
DnCNN	32.86	30.43	27.18	31.73	29.23	26.23	32.68	29.97	26.28
FFDNet	32.75	30.43	27.32	31.63	29.19	26.29	32.42	29.92	26.52
MLEFGN	33.04	30.66	27.54	31.81	29.34	26.39	33.21	30.64	27.22
MFENANN	32.95	30.63	27.55	31.73	29.29	26.38	-	-	
DRNet	33.01	30.64	27.46	31.81	29.35	26.39	-	-	
MDRN (Ours)	*33.06*	*30.67*	*27.56*	*31.83*	*29.36*	*26.41*	*33.22*	*30.67*	*27.24*
MDRN+ (Ours)	**33.10**	**30.71**	**27.60**	**31.86**	**29.39**	**26.44**	**33.31**	**30.78**	**27.31**

Method	Kodar24			CBSD68			Urban100		
Noise Level	σ=30	σ=50	σ=70	σ=30	σ=50	σ=70	σ=30	σ=50	σ=70
CBM3D	30.89	28.63	27.27	29.73	27.38	26.00	30.36	27.94	26.31
RED30	29.71	27.62	26.36	28.46	26.35	25.08	29.02	26.40	24.74
TNRD	28.83	27.17	24.94	27.64	25.96	23.83	27.40	25.52	22.63
IRCNN	31.24	28.93	N/A	30.22	27.86	N/A	30.28	27.69	N/A
DnCNN	31.39	29.16	27.64	30.40	28.01	26.56	30.28	28.16	26.17
MemNet	29.67	27.65	26.40	28.39	26.33	25.08	28.93	26.53	24.93
FFDNet	31.39	29.10	27.68	30.31	27.96	26.53	30.53	28.05	26.39
MLEFGN	31.67	29.38	27.94	30.56	28.21	26.75	31.32	28.92	27.28
MDRN (Ours)	*31.68*	*29.40*	*27.96*	*30.57*	*28.23*	*26.77*	*31.35*	*28.96*	*27.32*
MDRN+ (Ours)	**31.73**	**29.44**	**28.01**	**30.61**	**28.27**	**26.82**	**31.41**	**29.00**	**27.37**

Visual Comparison


Lena 14.61/0.1192 29.39/0.8116 29.68/0.8227 29.85/0.8295 29.87/0.8311 PSNR/SSIM
Barbara 14.77/0.2073 26.22/0.7693 26.48/0.7794 27.24/0.8105 27.37/0.8136 PSNR/SSIM
Noise DnCNN FFDNet MLEFGN MDRN-Ours GT
IMG062 15.91/0.3238 27.14/0.8873 27.04/0.8825 27.73/0.8983 28.28/0.9068 PSNR/SSIM
IMG059 15.62/0.2435 29.26/0.8601 29.10/0.8571 30.04/0.8742 30.67/0.8837 PSNR/SSIM
Noise DnCNN FFDNet MLEFGN MDRN-Ours GT