Photometric redshift with Deep Learning technique
Application to HSC Deep Survey

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Cosmic Web And Galaxy Evolution With Deep Learning

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We will discuss :

1 - Photometric Redshift and Deep Learning

2 - Multimodality

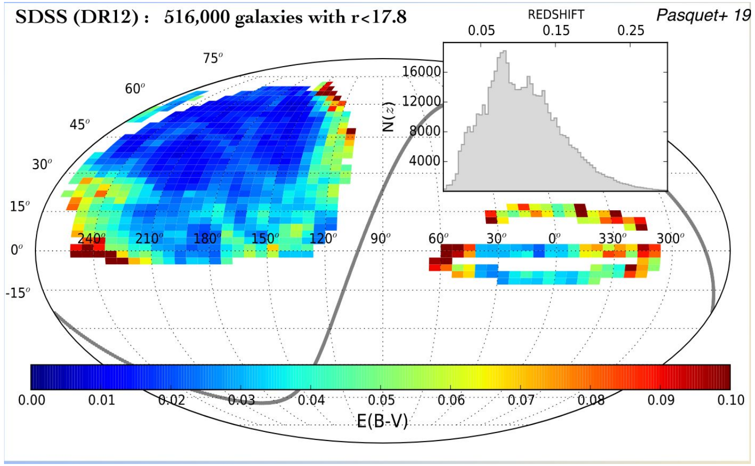
3 - Application To High Redshifts

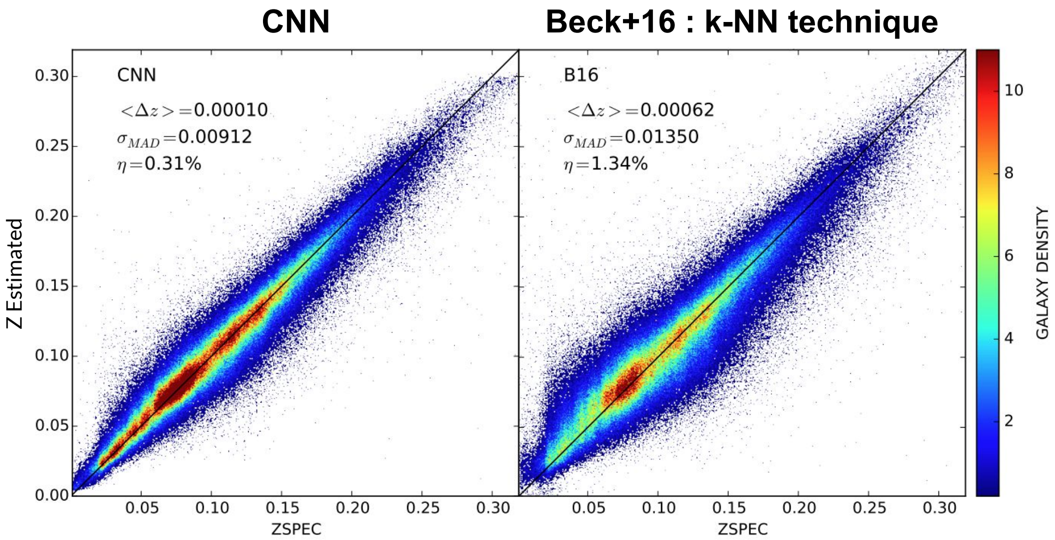
4 - Mismatch problem

Photometric Redshift Estimation

- SED Fitting : Fitting photometric data to galaxies templates with known properties.
- Machine Learning: Training machine learning models on extracted useful features from photometric data (magnitudes, colors ...etc) while using spectroscopic redshifts as ground truth.
- Deep Learning: Training deep neural networks directly on photometric images while using spectroscopic redshifts as ground truth.

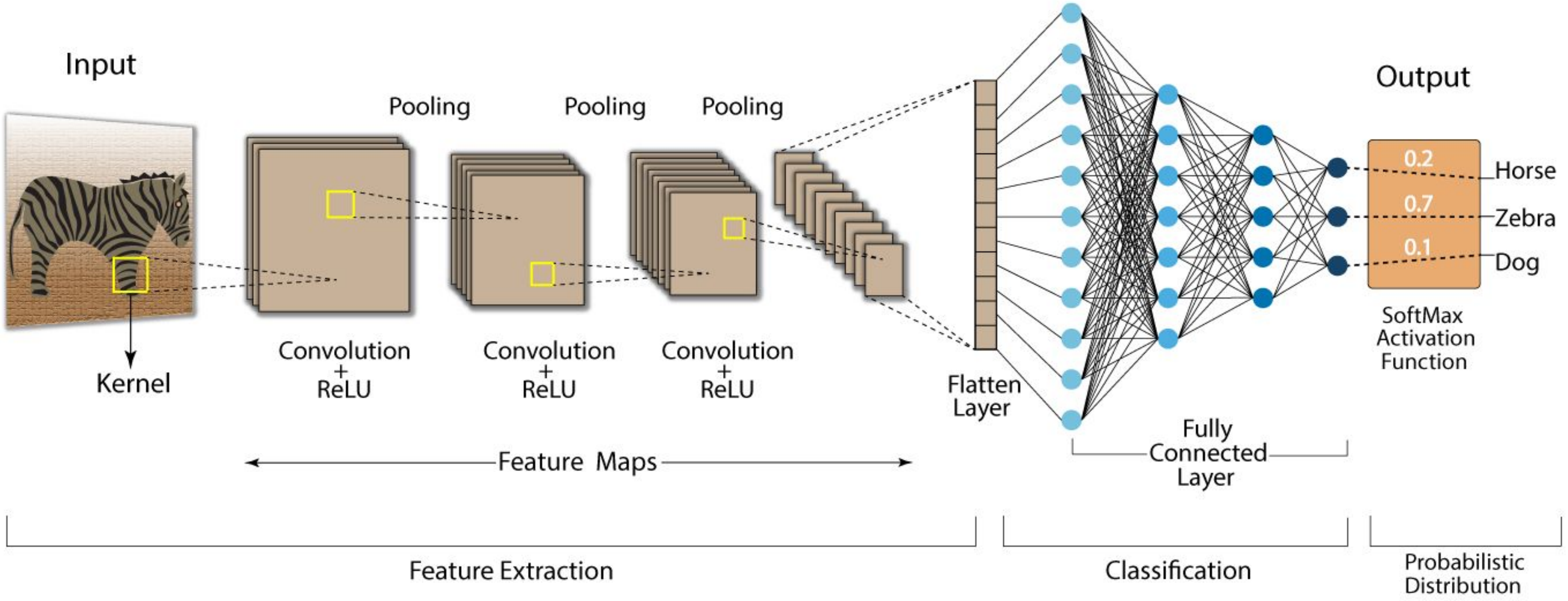
Deep network performance compared to released SDSS photo-zs



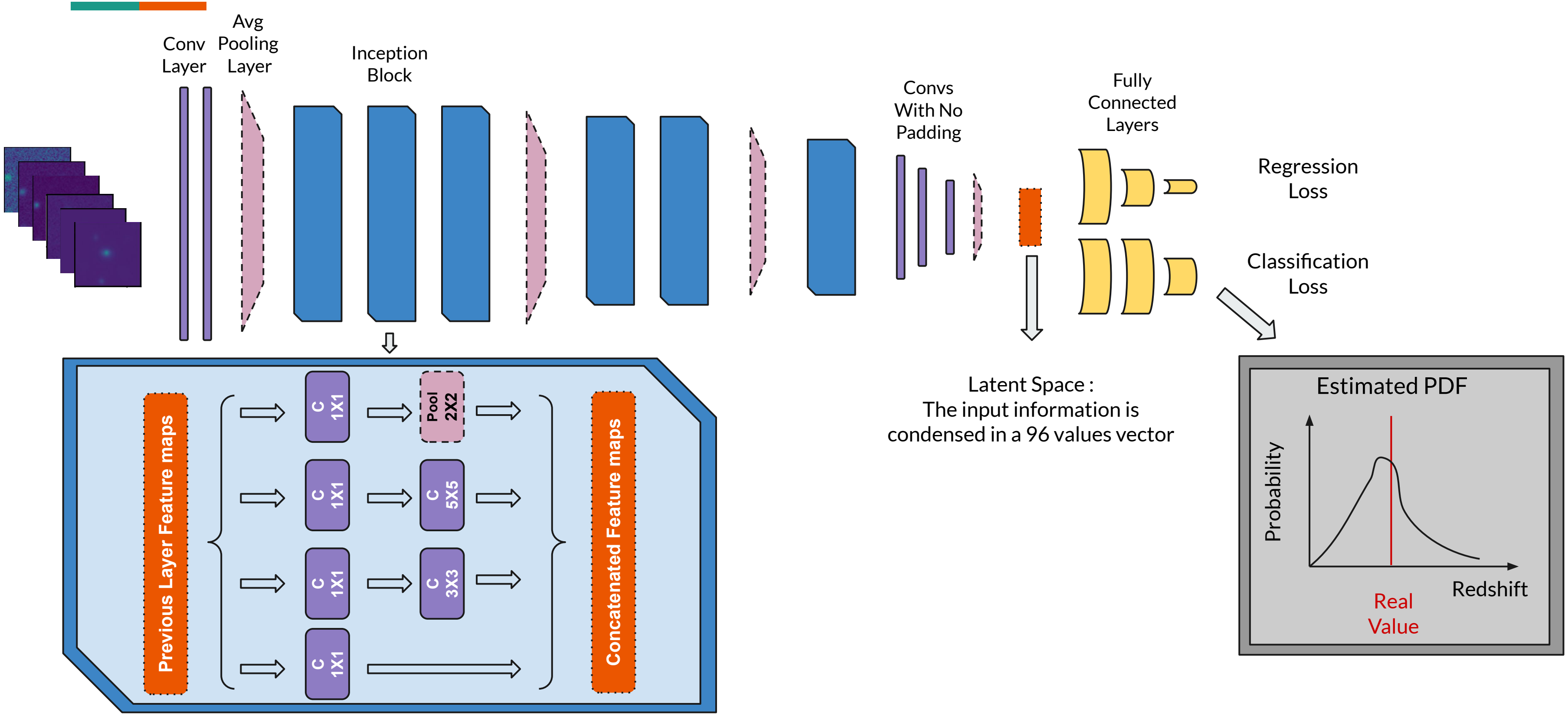


JP et al 19

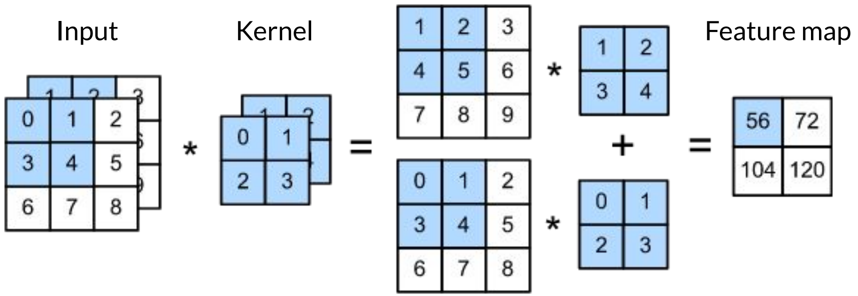
Convolutional neural networks (CNN)

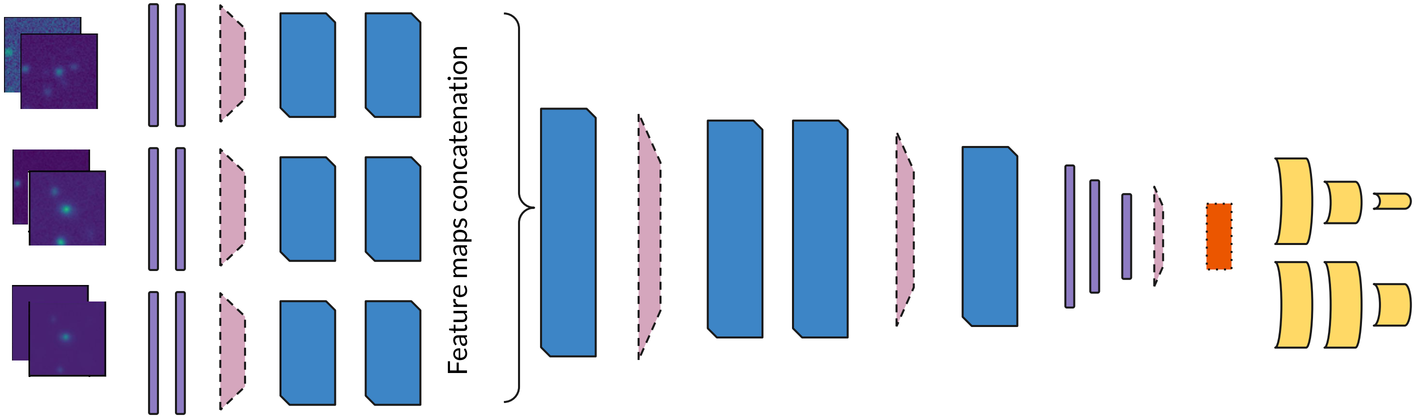


Model Architecture : Inception



Multi Modal Approach



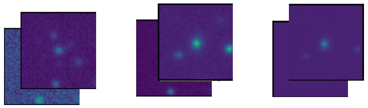


Comparative results on the SDSS r < 17.8

Normalized Residuals : $\Delta z = (z_{\text{phot}} - z_{\text{spec}})/(1 + z_{\text{spec}})$		
Normalized Mad (Median absolute deviation)	Outliers Fraction (ratio of catastrophic failures)	Bias
1.48 * Median(|Δz –Median(Δz)|)	$\|\Delta z\| \geq 0.05$	Mean(Δz)

Experiences	σ 10^{-3}	η %	$<\Delta z>$ 10^{-3}
SDSS r < 17.8			
Pasquet et al (19)	09.12	0.31	0.1
Dey et al (22)	08.98	0.19	0.07
Hayat et al (21)	08.25	0.21	0.1
Treyer et al (22)	08.02	0.18	-0.29
Multi-Modal Network	07.82	0.16	-0.36

Multimodality configuration

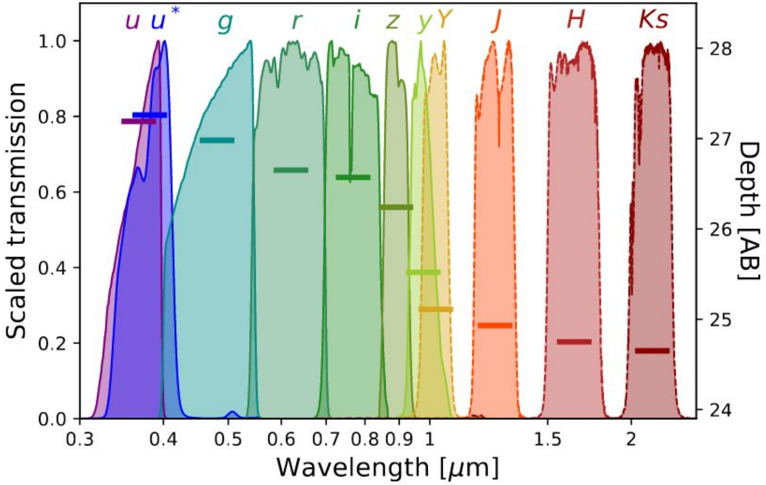


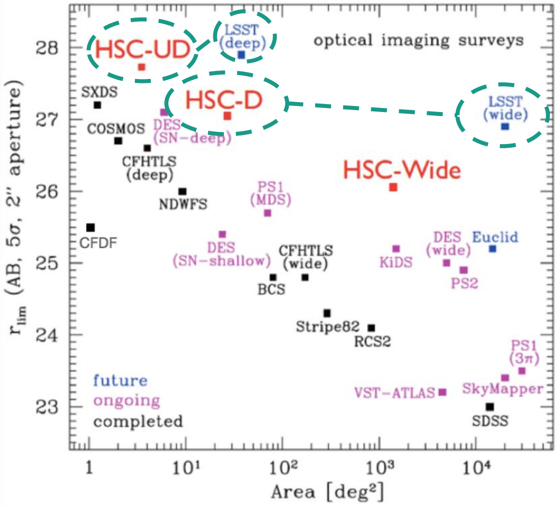
[u,g],[u,r],[g,r],[g,i],[r,i],[r,z],[i,z]

Application To High Redshifts

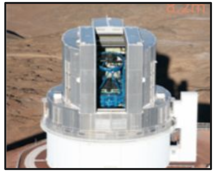
CLAUDS+HSC : a unique dataset until LSST

CLAUDS + HSC + VIRCAM : u + grizy + jhk

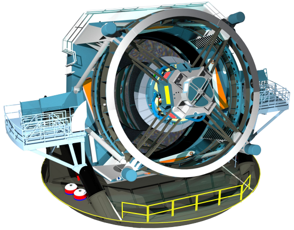




CLAUDS

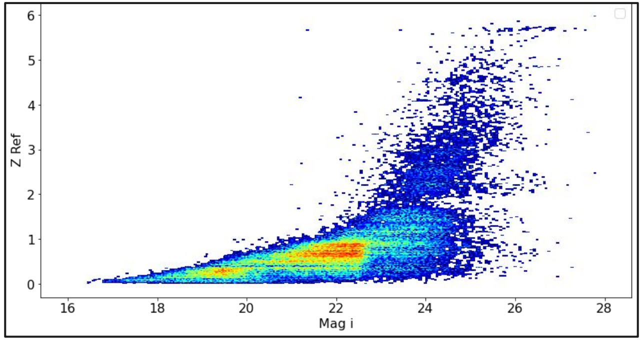


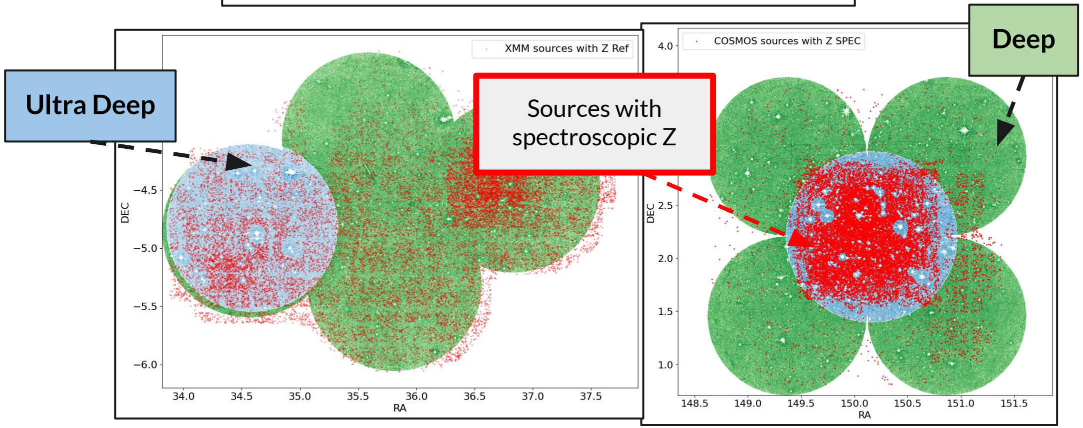
HSC



Sources Distribution

Sources with spectroscopic Redshift



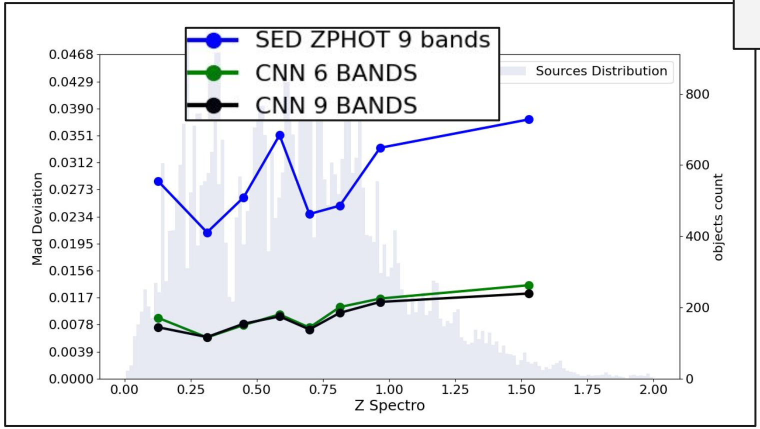


CNN ZPHOT Compared to SED ZPHOT (G. Desprez et al - 22)

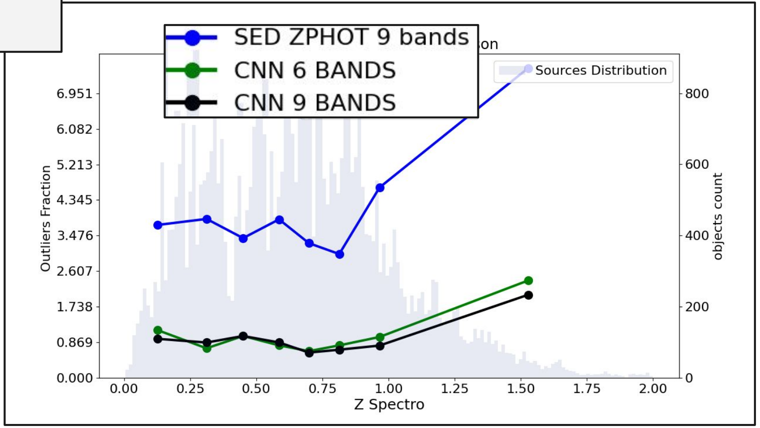
Bright sources (Mag i <= 24)

45 K

MAD



Outliers fraction %

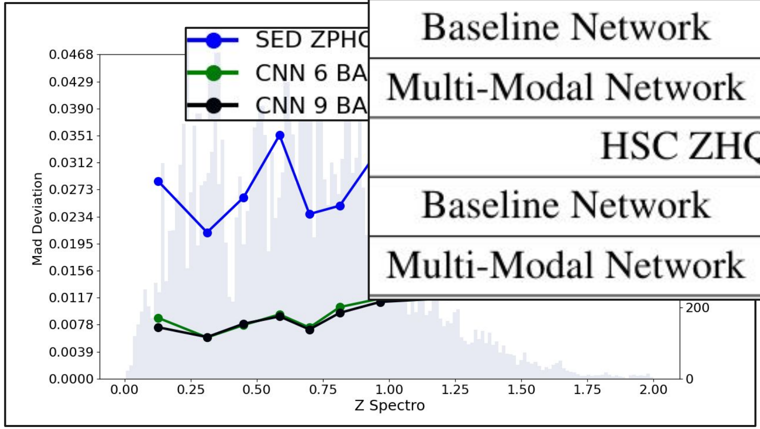


CNN ZPHOT Compared to SED ZPHOT (G. Desprez et al - 22)

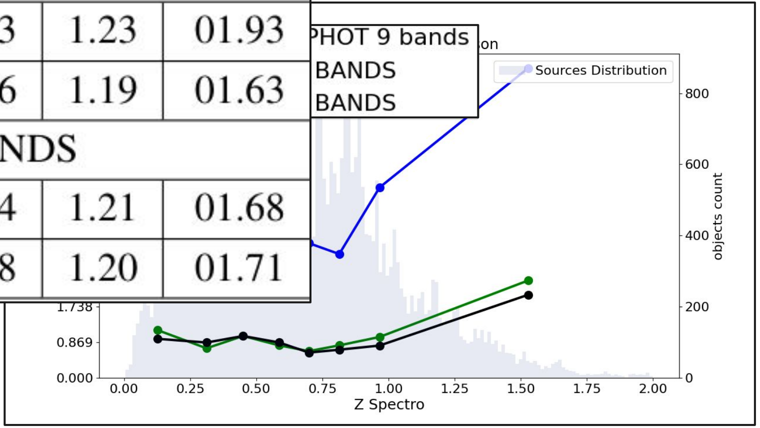
Bright sources (Mag i <= 24)

Experiences	σ 10^{-3}	η %	$<\Delta z>$ 10^{-3}
HSC ZHQ 6 BANDS			
Baseline Network	09.33	1.23	01.93
Multi-Modal Network	08.76	1.19	01.63
HSC ZHQ 9 BANDS			
Baseline Network	08.54	1.21	01.68
Multi-Modal Network	07.48	1.20	01.71

MAD

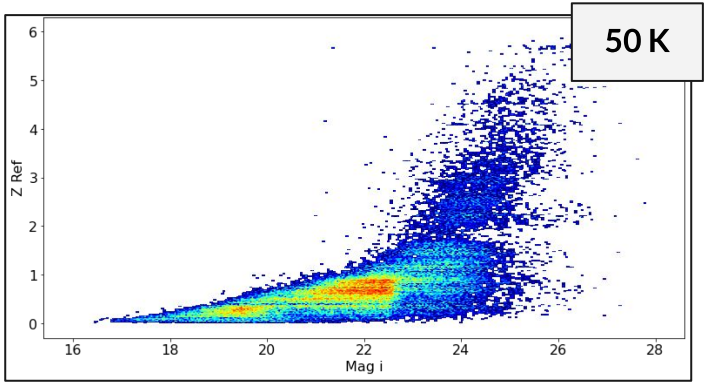


Ou

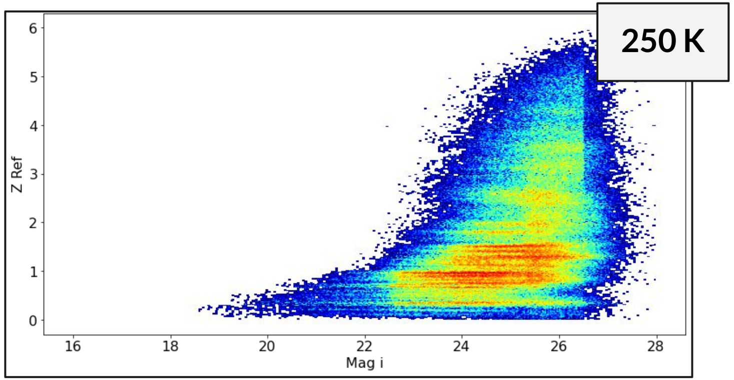


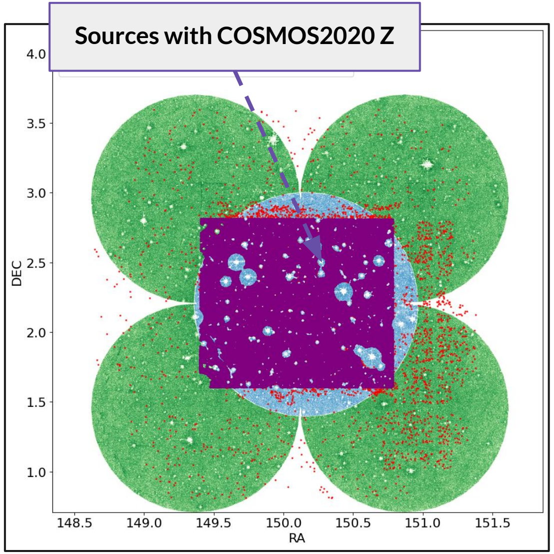
COSMOS2020 for faint sources

Sources with spectroscopic Redshift



COSMOS2020 Z : Sources with 30-bands based SED Redshift

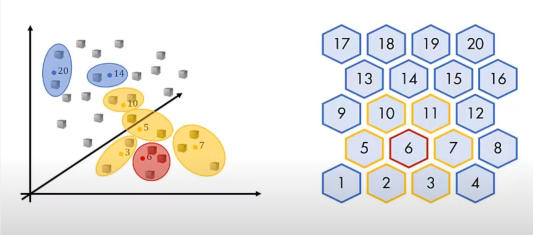




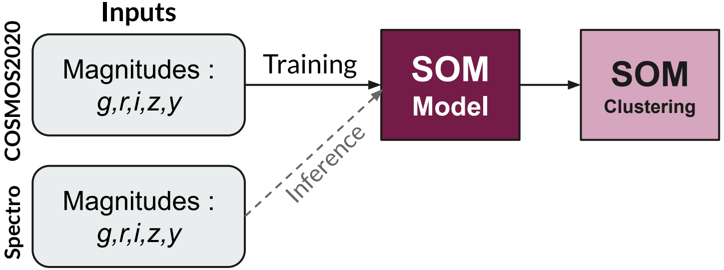
Combining COSMOS2020 and spectroscopic Z sources

Self Organizing Maps

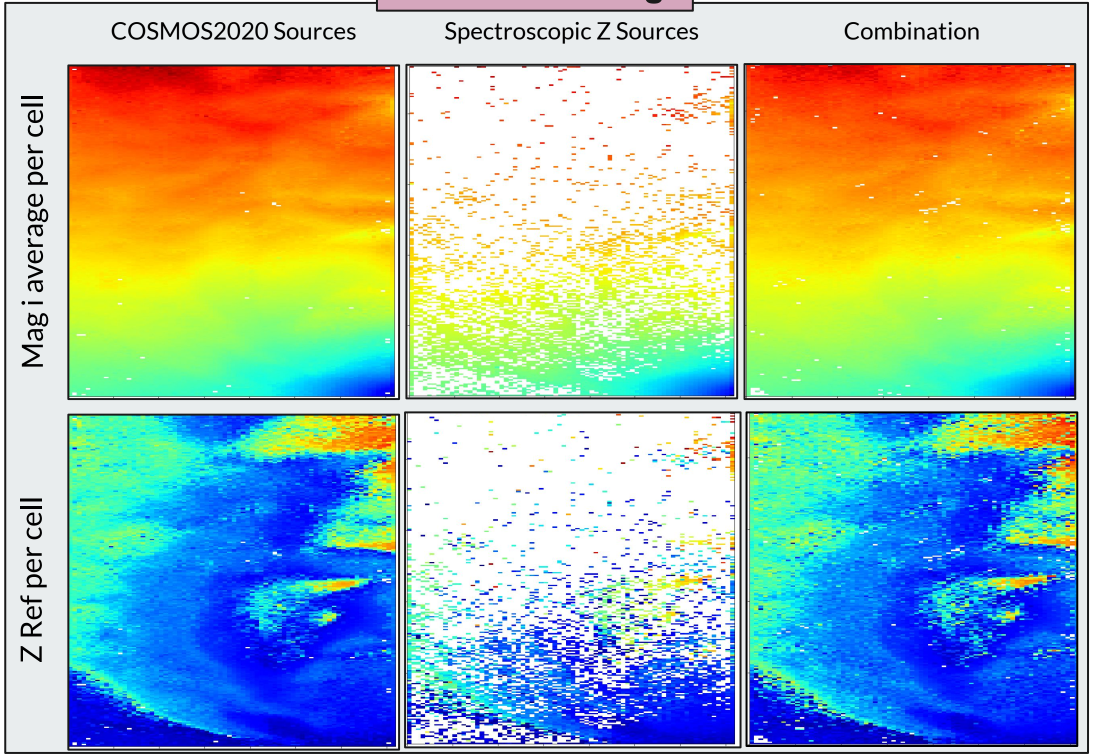
- Dimension reduction and clustering technique
- Preserves the topological structure



Reducing *g,r,i,z,y* magnitudes input space to a two dimensional space



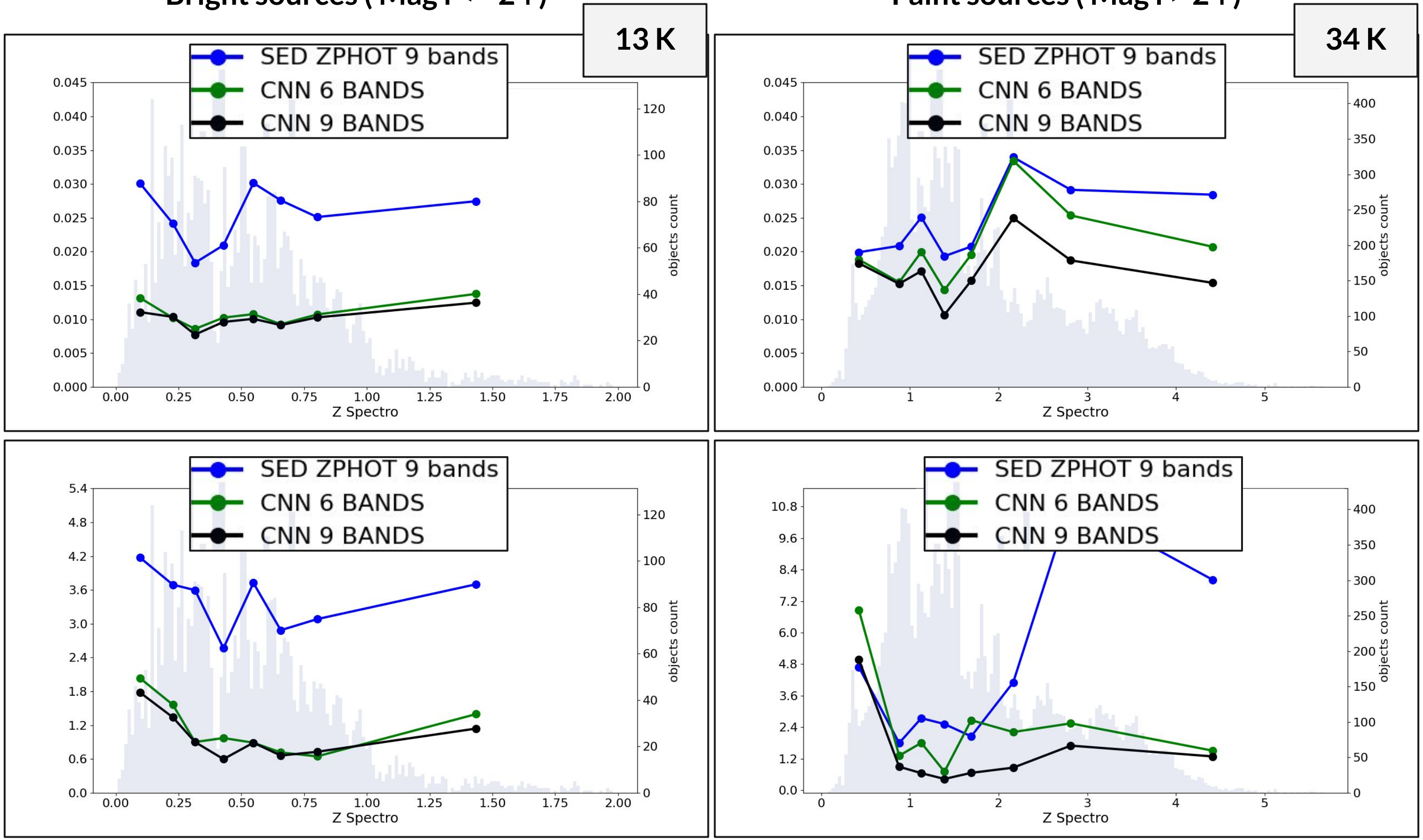
SOM Clustering



CNN ZPHOT Compared to SED ZPHOT on Spectro - COSMOS2020

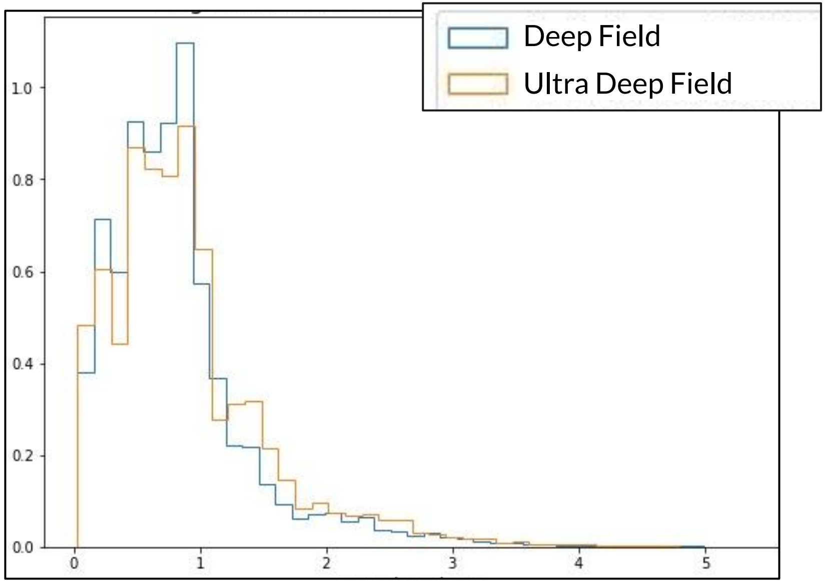
Bright sources (Mag i <= 24) — Faint sources (Mag i > 24)

MAD / Outliers fraction %



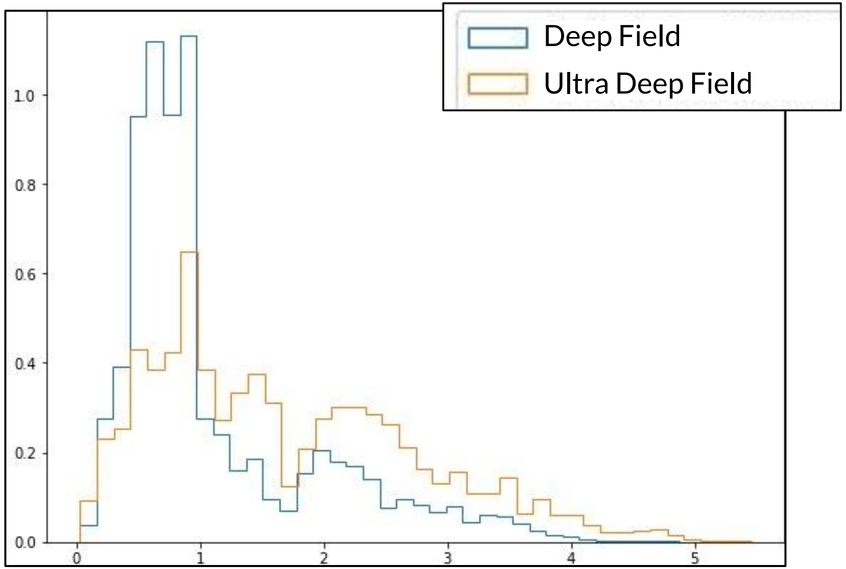
CNN redshift estimation is sensitive to the photometric image acquisition conditions

Bright Sources 18 <= i <= 24



Estimated Z

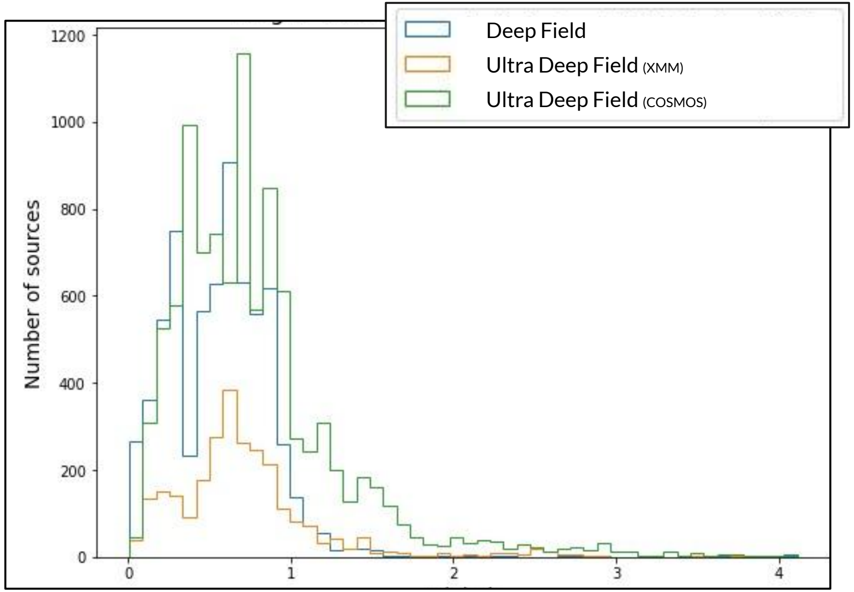
Faint Sources 24 <= i <= 26.5



Estimated Z

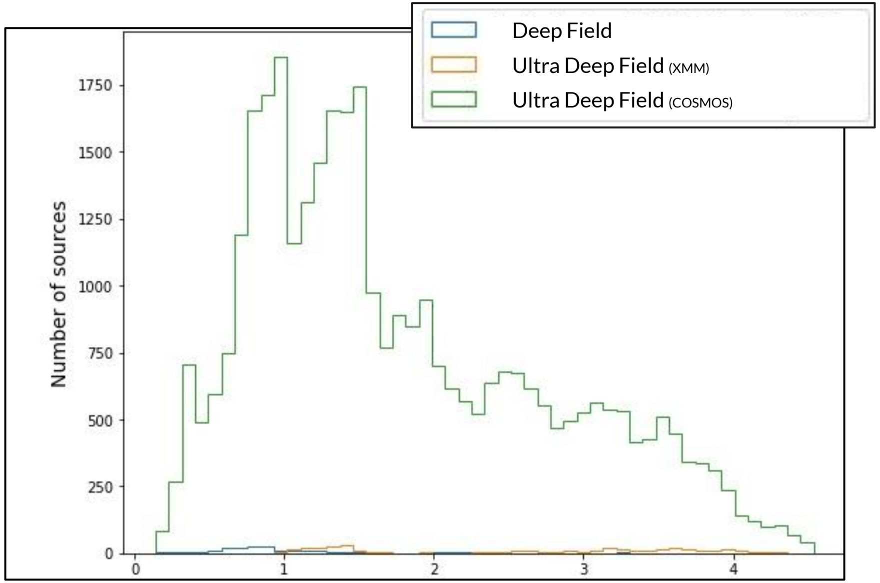
CNN redshift estimation is sensitive to the photometric image acquisition conditions

Bright Sources Training Set



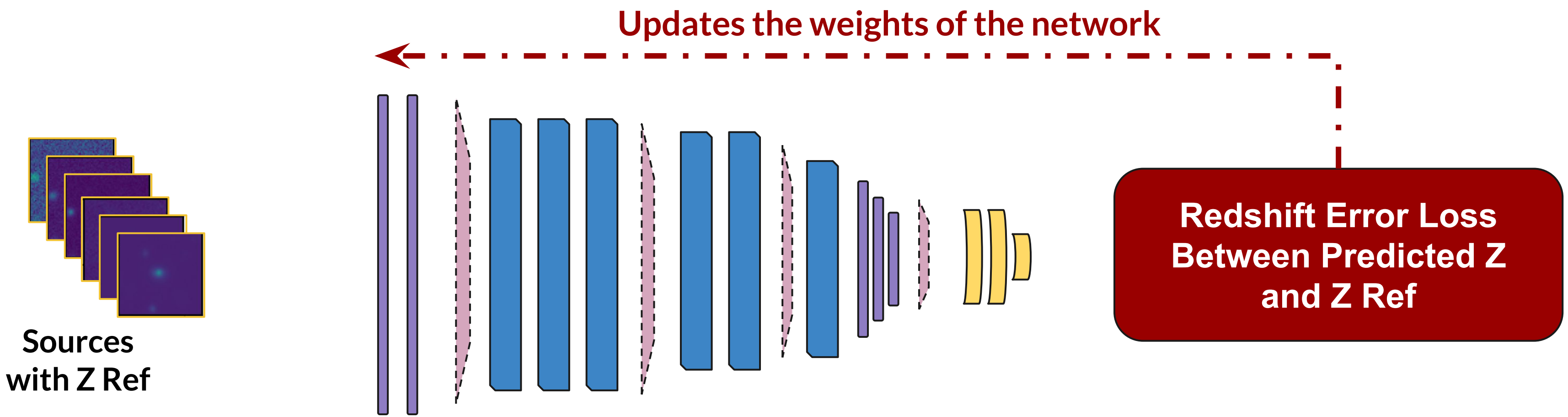
Redshift training labels

Faint Sources Training Set

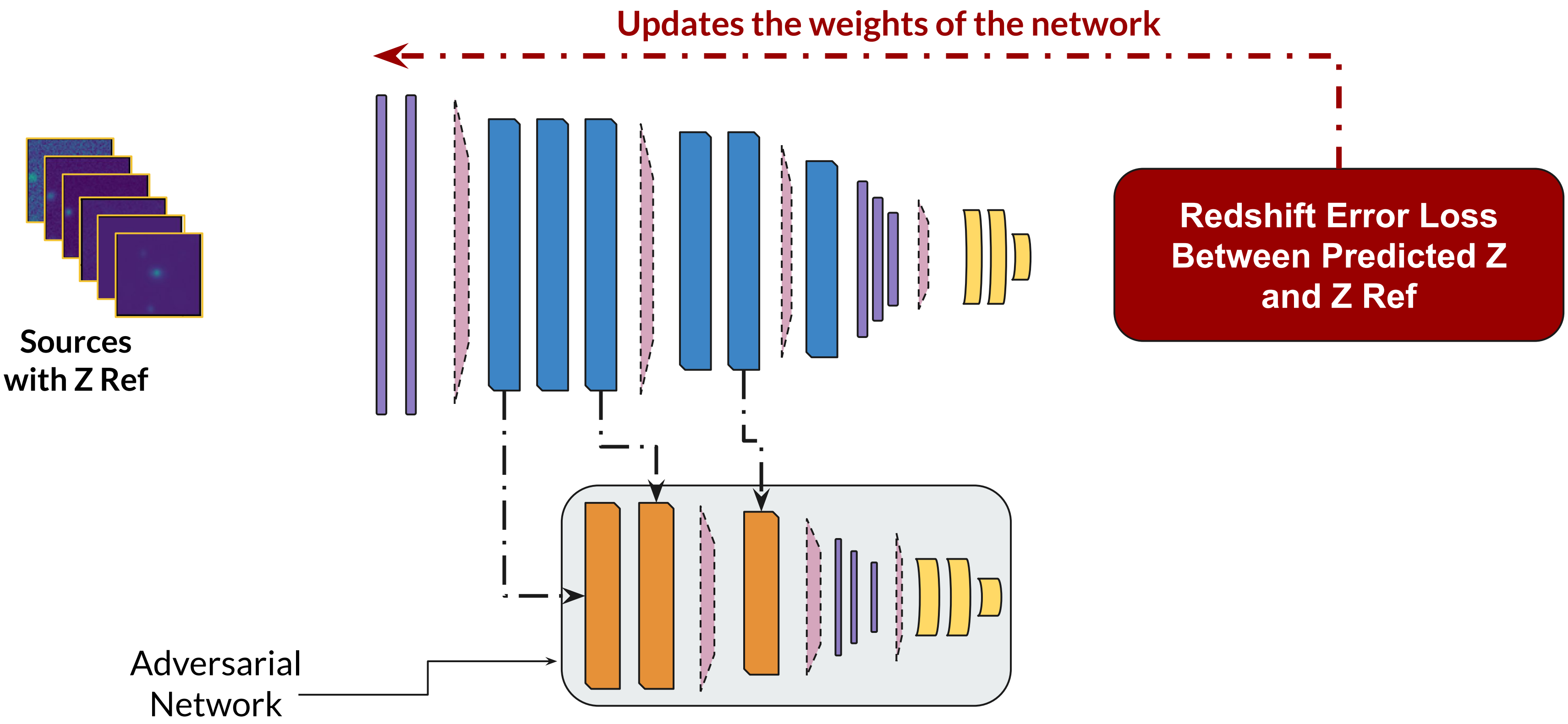


Redshift training labels

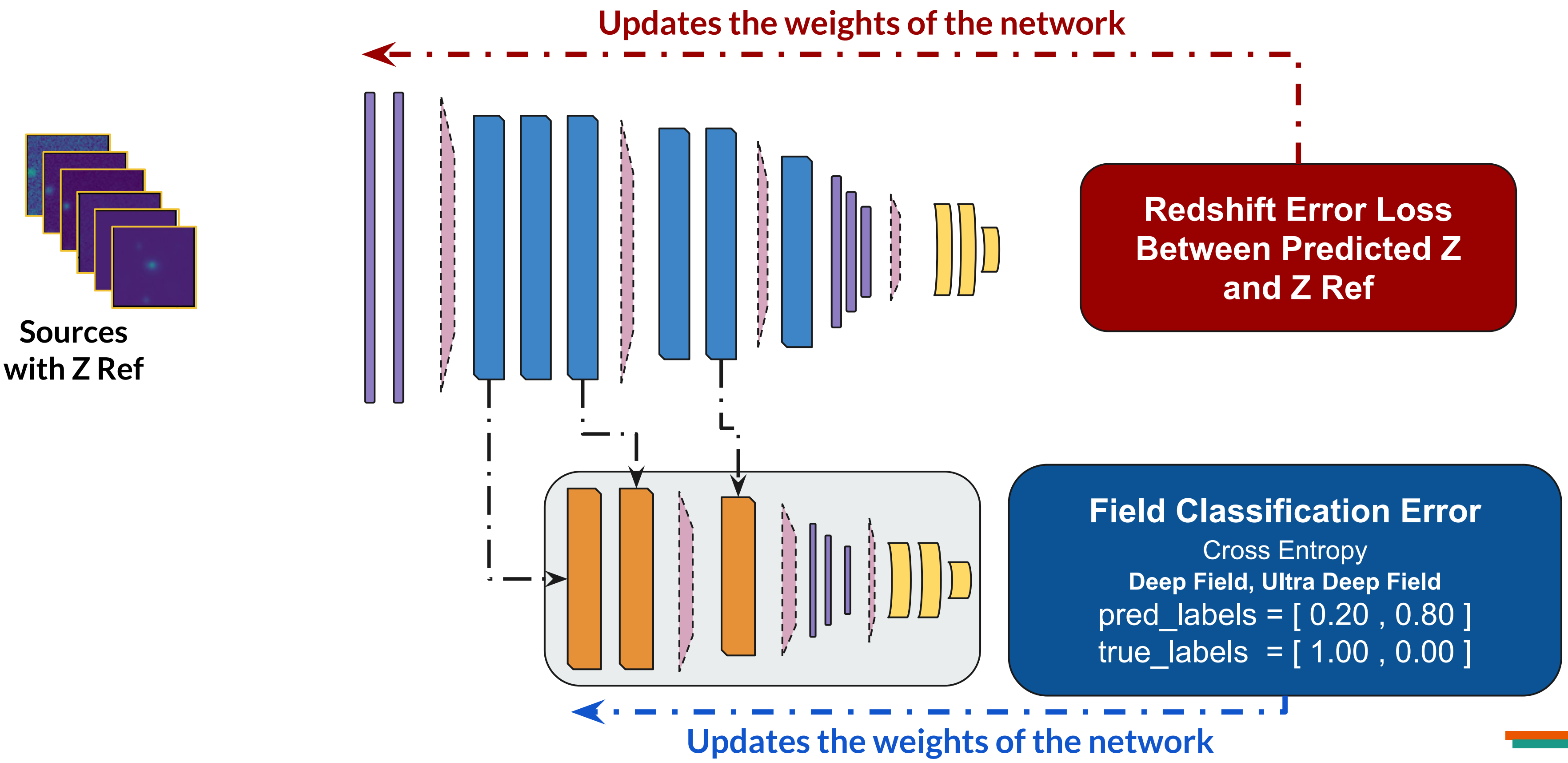
Domain matching with adversarial training



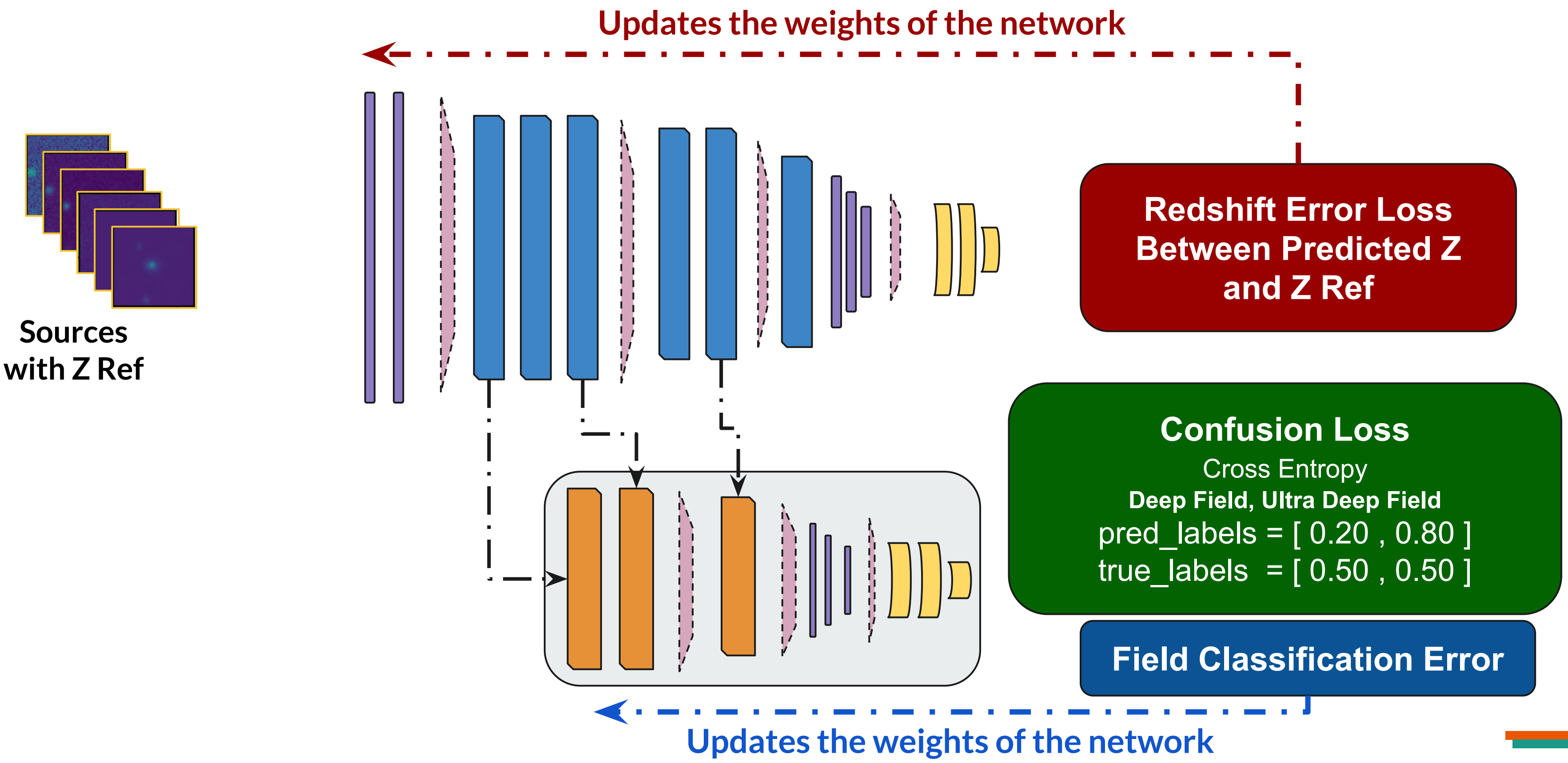
Domain matching with adversarial training



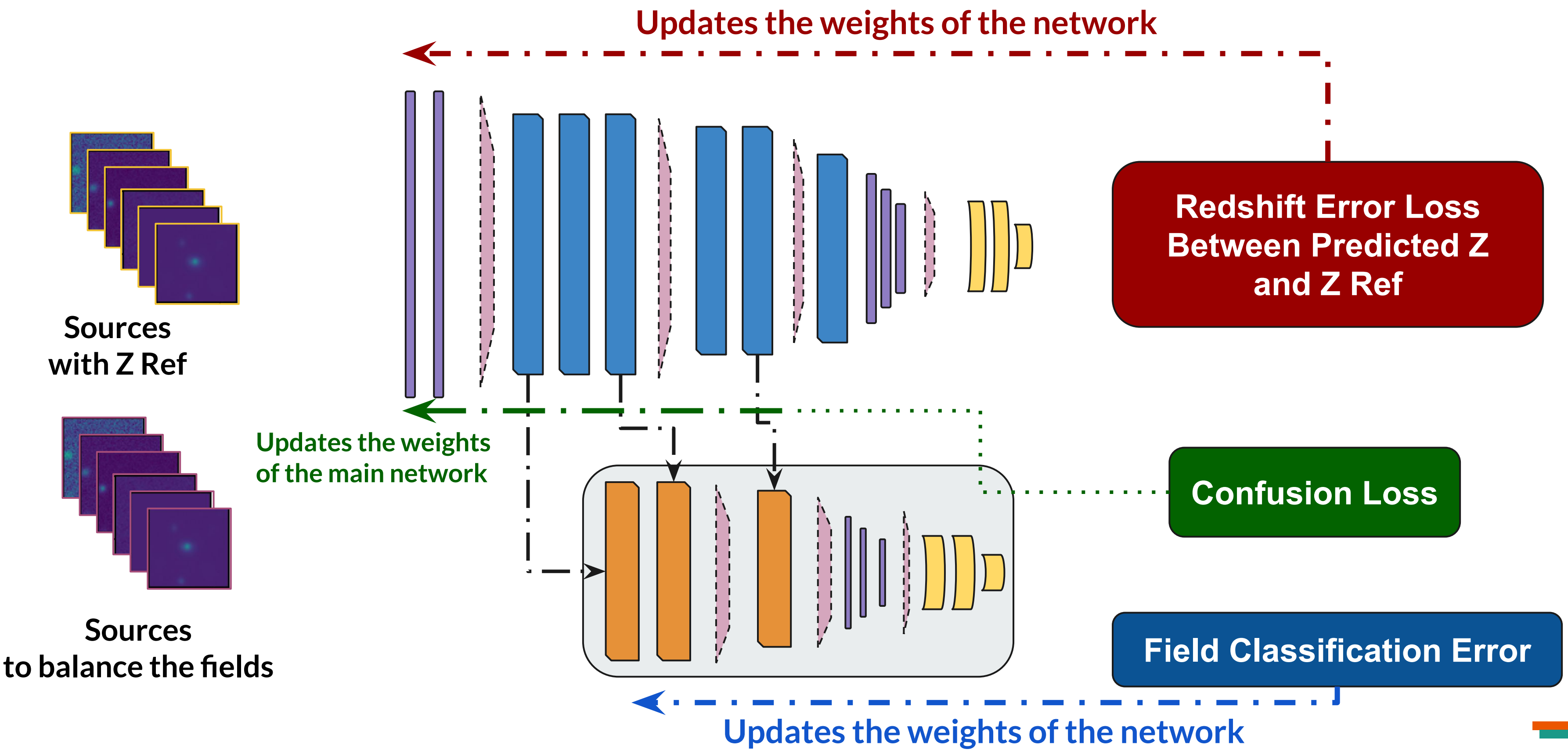
Domain matching with adversarial training



Domain matching with adversarial training

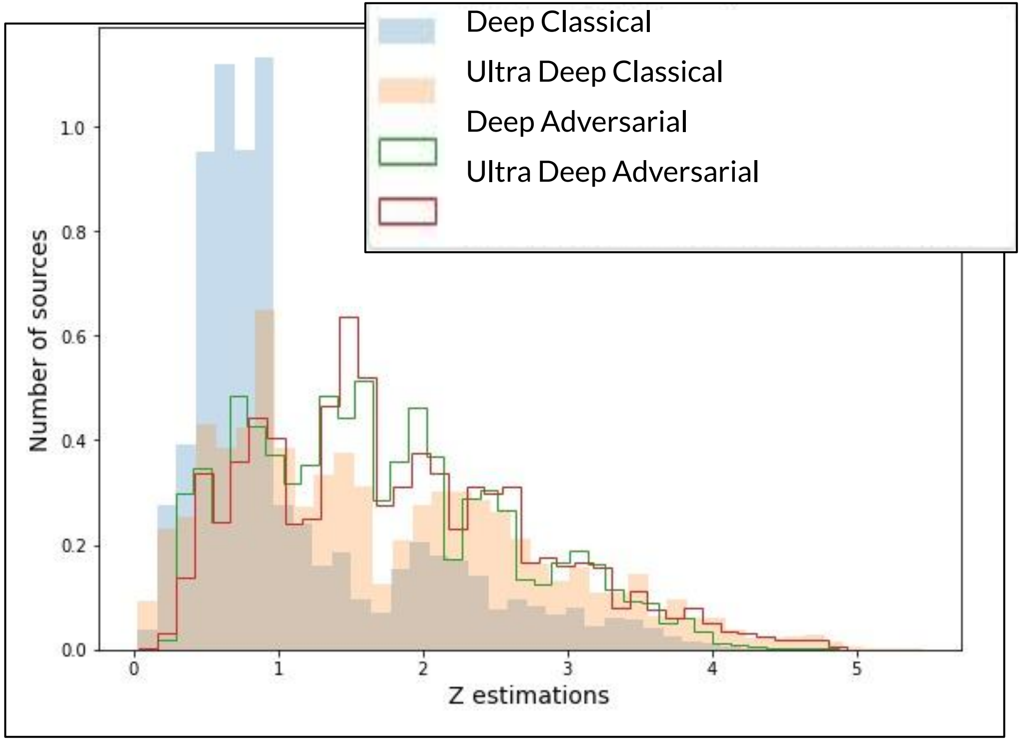


Domain matching with adversarial training



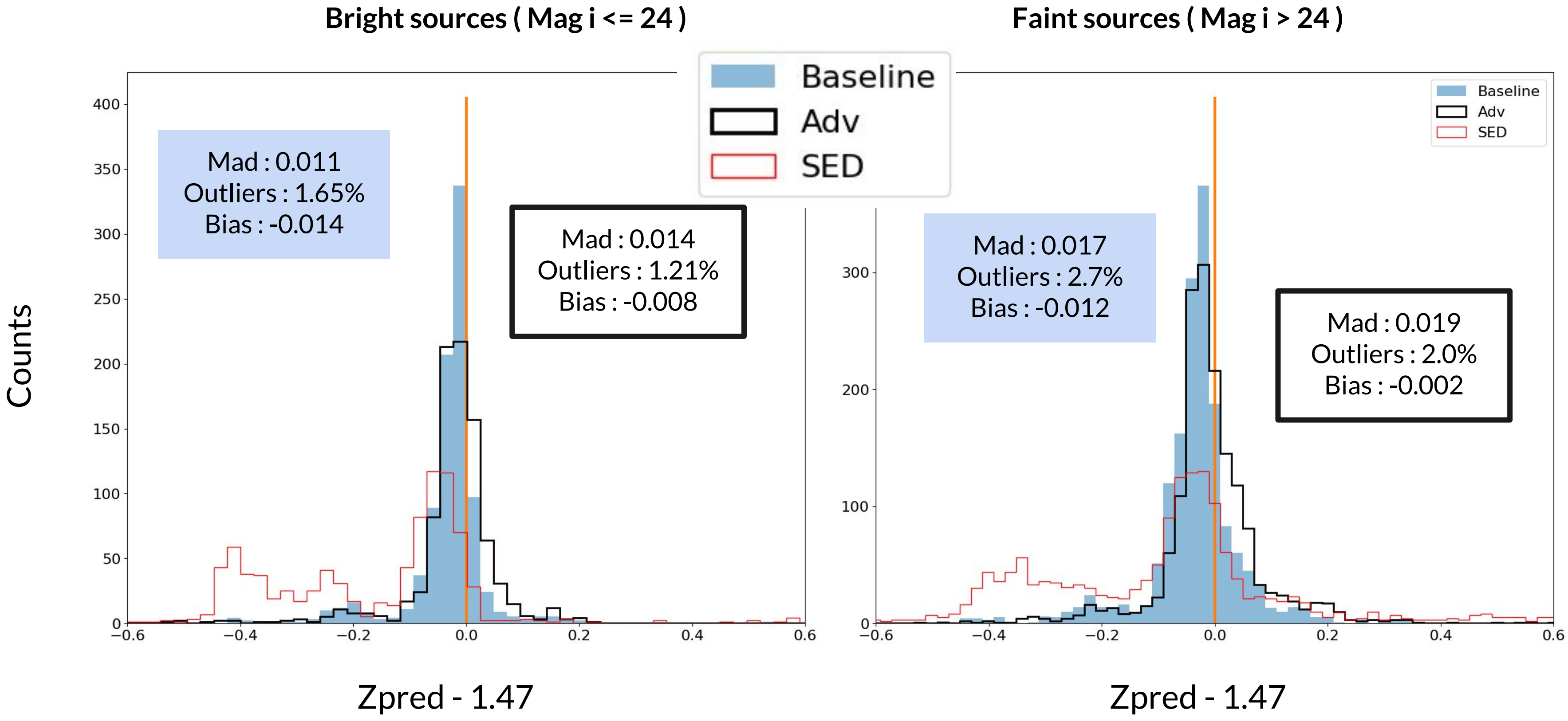
Domain Matching With Adversarial Training

Faint Sources Inference (24 <= i <= 26.5)



Independent Test on [OII] Emission Line Galaxies at Z = 1.47 on XMM field

Selected with a narrow band filter



Key Takeaways

- Integrating multimodality when designing deep network framework for Photo-Z estimation can help

- We can estimate Photo-Z using the ***ugrizy*** bands with a precision ~ σ 0.01 for sources brighter than ***mag i = 24***

- It's challenging to have training labels for sources fainter than ***mag i = 24***. Domain matching can help with this !