Photometric redshifts of Kilo-Degree Survey quasars by deep learning techniques

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QUASAR

- Galaxies exhibit broader spectral energy distribution – Active galaxies
- Central region is called Active Galactic Nuclei (AGN)
- **Quasi-stellar radio sources/Quasars/QSOs -most luminous category of AGN**
- Luminosity is hundreds of times greater than those of non-AGN galaxies.

How to estimate Redshift?

Spectroscopic way

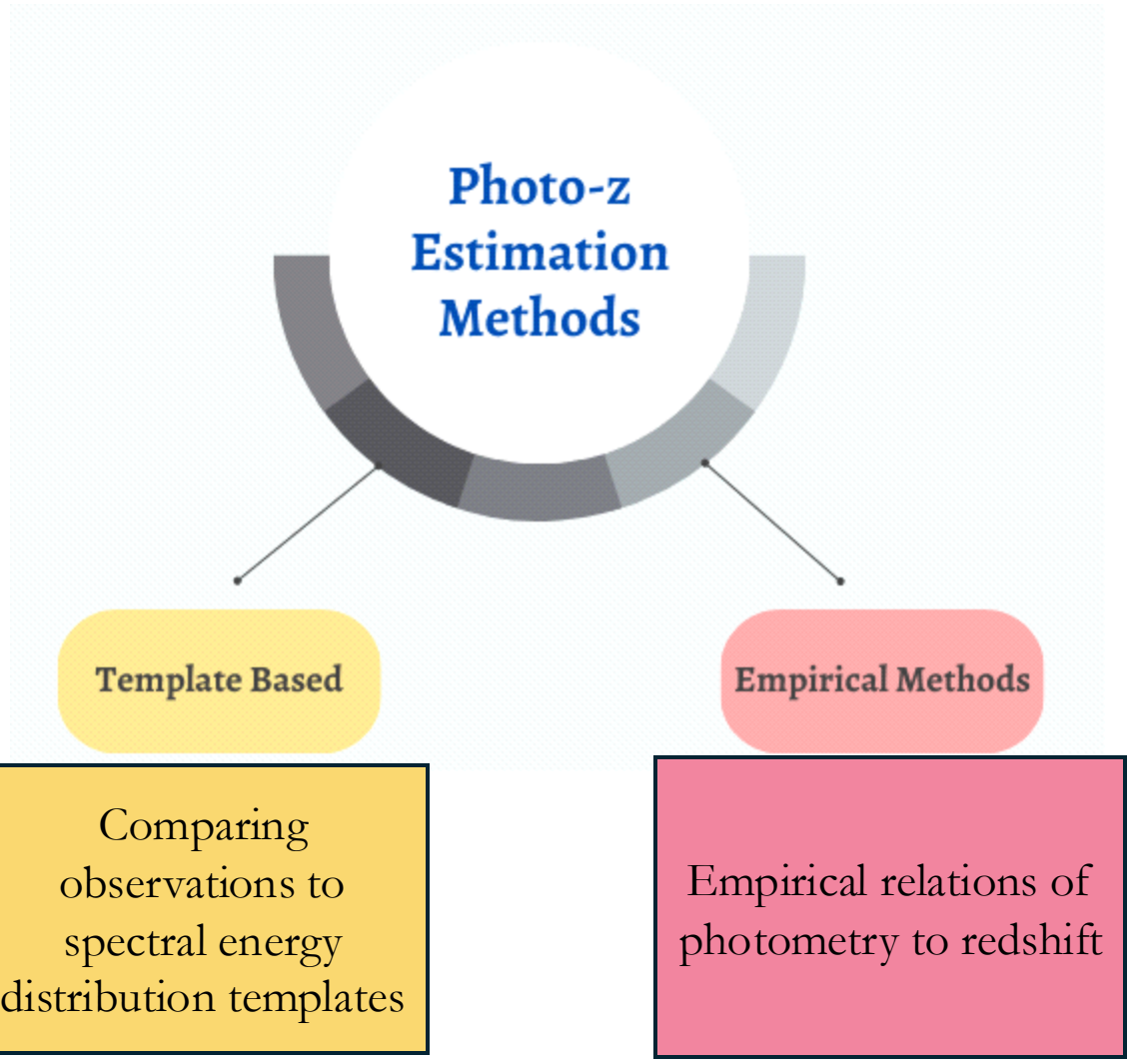
- Measuring the shift in spectral lines
- Spectroscopic redshifts (Spec-zs).

Photometric Way

- Based on observed **photometric quantities.**
- Mapping of photometric space into redshift space.
- Photometric redshifts (Photo-zs)

- The measurable quantities or characteristics of an object's light.
- Derived from the object's intensity or flux measurements.
- Magnitudes and colours

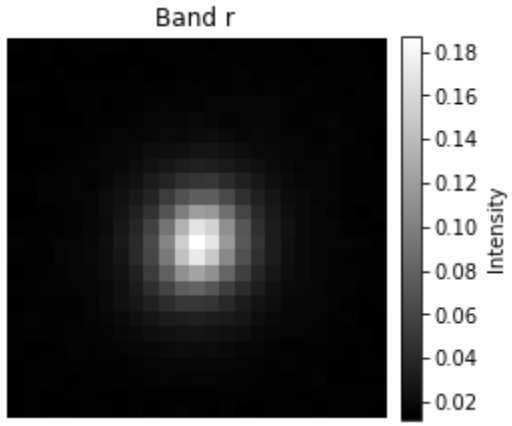
Photo-z estimation methods



Deep learning based estimation is an empirical method.

Input data

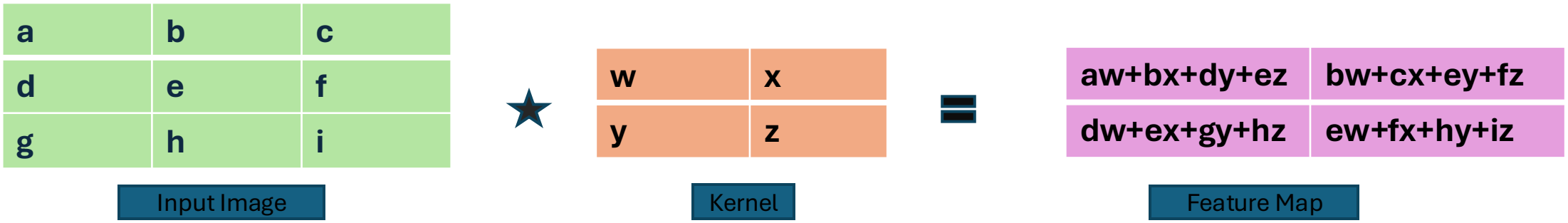
- Kilo-Degree Survey (KiDS) is a weak lensing survey.
- Quasar catalogue in KiDS DR4 *(*Nakoneczny et al. (2021, A&A, 649, id.A81; arXiv:2010.13857)
- Input images are quasar cutouts
- Model is trained by quasar **images**, their corresponding spectroscopic redshifts (spec-zs).
- Images are supplement with **9-band magnitudes** (u, g, r, i, Z,Y,J,H, and Ks)
- Cutout size = (25,25,4)
  - Height = 25 pixels
  - Width = 25 pixels
  - Number of bands = 4; (u, g, r and, i)



(RA,DEC)=(83.4,-1.2),
Spec-z=0.98

Convolution Neural Network (CNN)

- Small matrix of weights – Kernel/Filter
- Convolved with input data to extract features such as edges, corners etc. of input data.

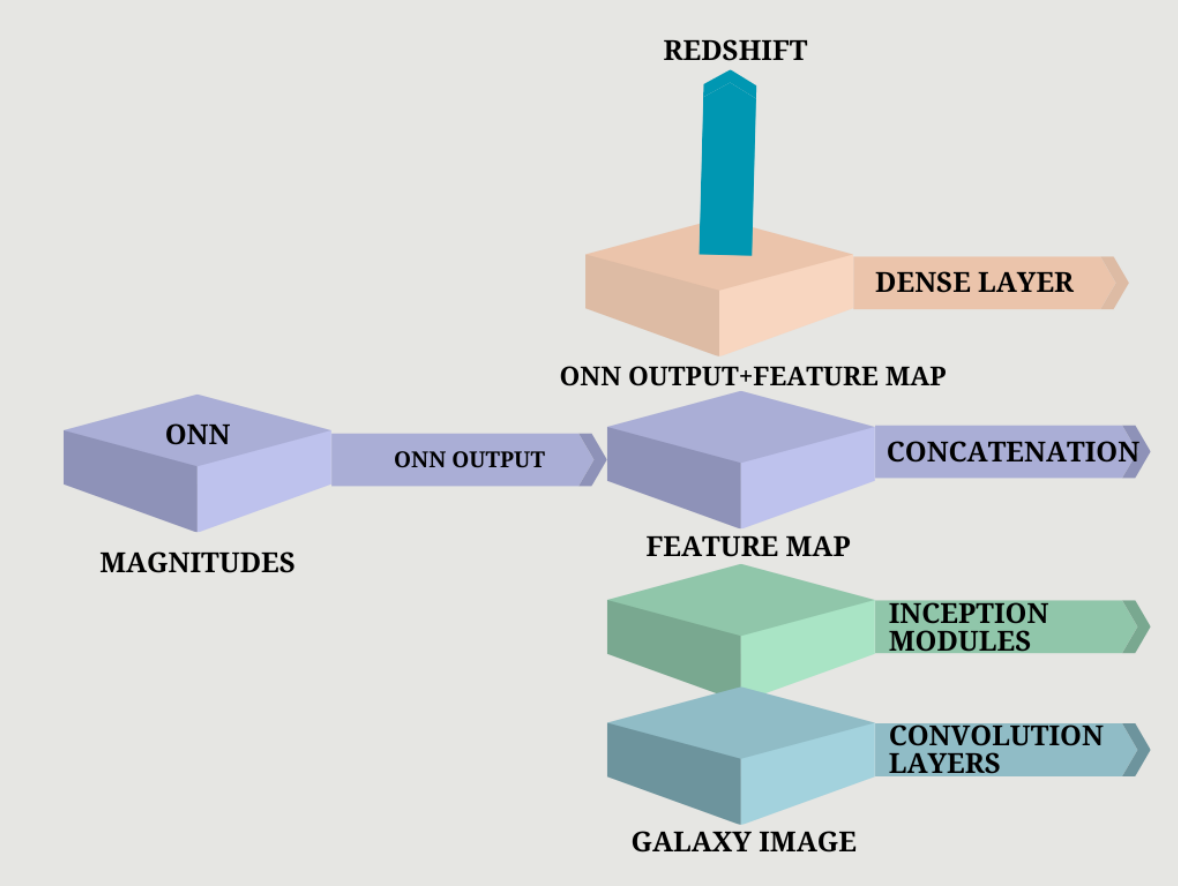


- Activation function is applied in feature map to introduce non-linearity into the network.

Hybrid-z

- Treated as a regression problem.
- Developed a deep learning model based on Inception.
- Hybrid of two types of network:
  - CNN
  - Ordinary Neural Network (ONN)

- This model uses two inputs:
  - 4-band images
  - 9-band Magnitudes



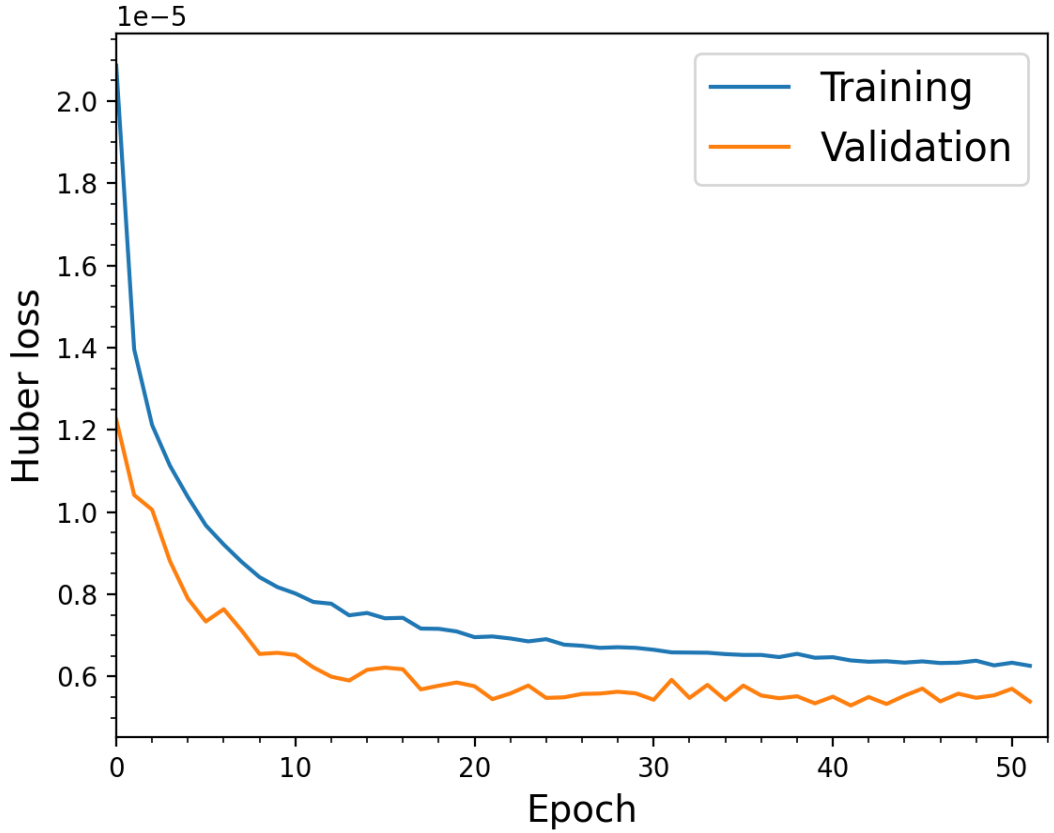
Training

- Network predicts redshift.
- This predicted redshift is compared with the true redshift by loss function.
- Huber loss function is used.
- It is the combination of Mean Squared Error (MSE) and Mean Absolute Error (MAE).

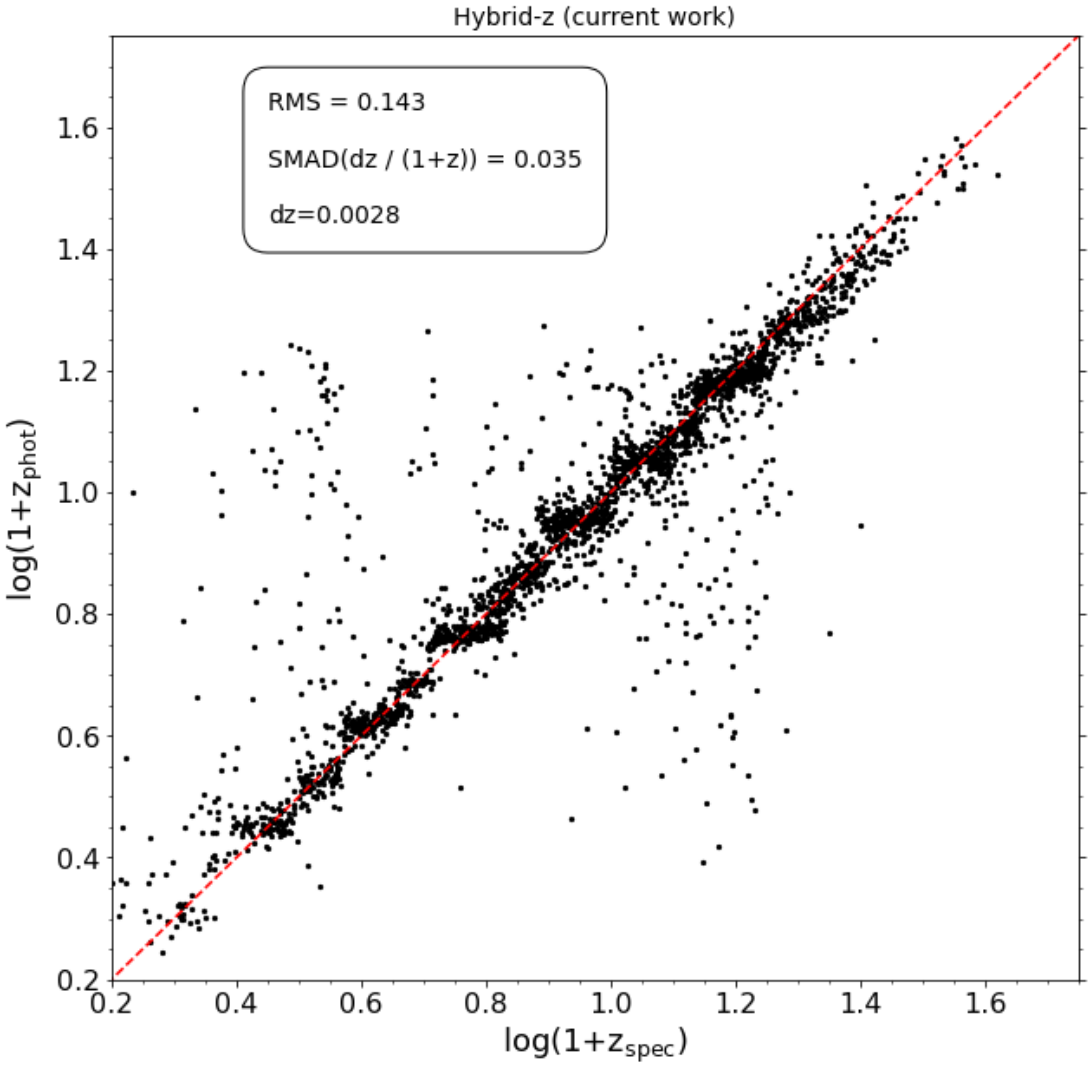
$$L_h = \begin{cases} \frac{1}{2}(e)^2, & |e| \leq \alpha \\ \alpha(|e| - \frac{1}{2}\alpha), & \text{otherwise} \end{cases}$$

  - e= true redshift – predicted redshift
  - α is a hyperparameter that determines the transition between MSE and MAE

- During training, the network tries to minimize this loss function by adjusting the weights.
- Training : Validation: Testing = 80:10:10



Result



Model	dz	SMAD	RMS
ONN (*Nakoneczny et al. (2021)*)	0.041	0.041	0.138
Hybrid-z (current work)	0.003	0.035	0.143


Thank you