AGN Variability-Informed Photometric Redshifts for Large Time-Domain Surveys

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CONTEXT

- AGN photometric redshift estimation using only SED colors is highly degenerate due to smooth continuum, host galaxy contamination, variability, dust effects, and degeneracies in color-redshift space.
- AGN variability is shaped by accretion physics and modulated by cosmological time dilation, making it inherently redshift dependent. We use this property to derive a variability-based redshift likelihood.

VAR-PZ

Satheesh-Sheeba et al. 2026a (accepted)

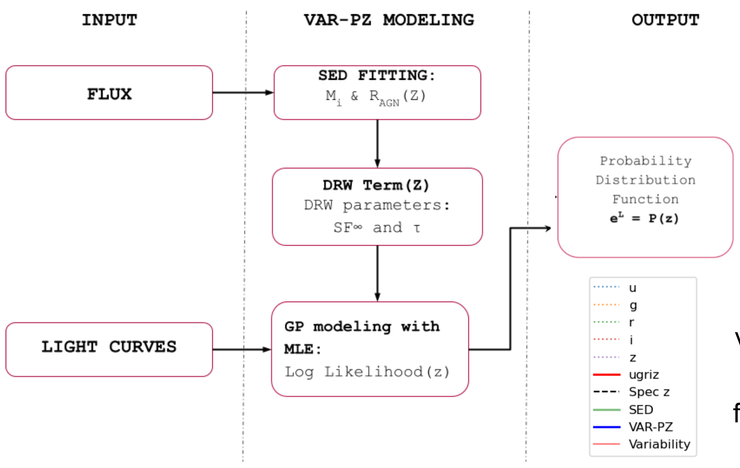
- Modeling the AGN variability as a Damped Random Walk (DRW)

$$\log_{10} f = A + B \log_{10}\left(\frac{\lambda_{\mathrm{RF}}}{4000\,\text{Å}}\right) + C\,(M_i + 23)$$

DATA &METHODOLOGY

- 9210 Qsos from MacLeod et al. 2010
- Uses CELERITE to model the light curves through gaussian process.
- Mi, AGN_flux fraction is obtained through SED modeling

WORK FLOW



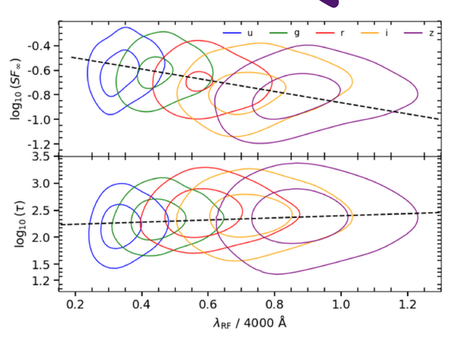


Fig. 1. The distribution of the variability parameters, SF∞ and τ, in the observed frame, measured from the ugriz bands as a function of rest frame wavelength.

APPLICATION

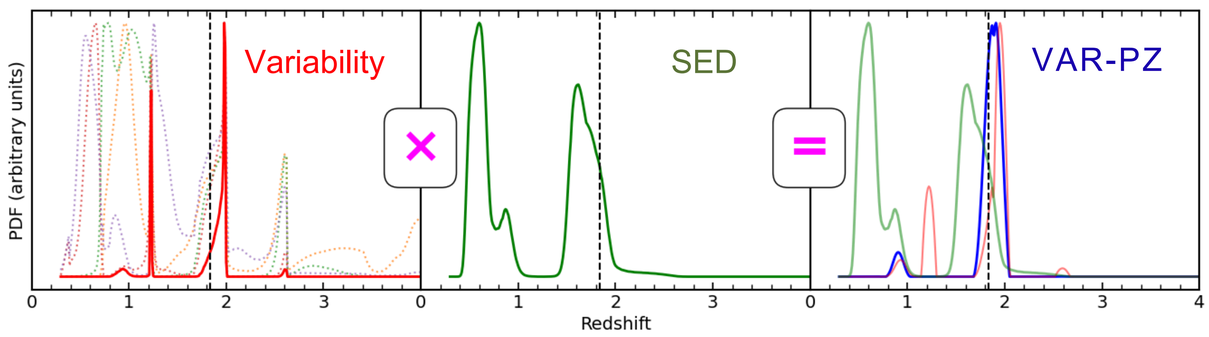


Fig. 2. Photo-z priors from VAR-PZ along with vSED fitting PDF, and the combined posterior. Vertical dashed lines mark the spectroscopic redshift.

RESULTS

- 10 % reduction in the outlier fraction using SDSS light curves
- LSST like simulations show that VAR-PZ will be able to reduce the outlier fraction from 32% (SED-alone) to 15% (SED+Variability) at the end of the survey.

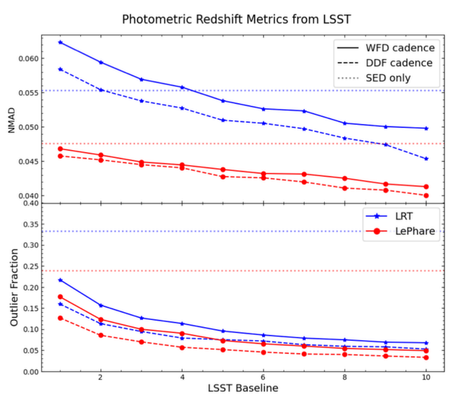


Fig. 3. The evolution of photo-z precision and outlier fraction for our parent sample as a function of the LSST temporal baseline.

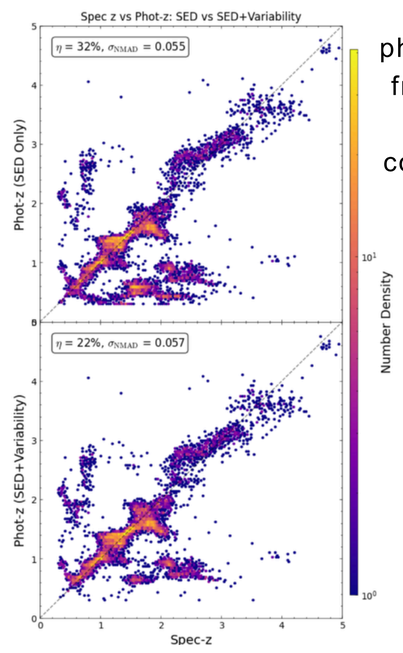


Fig. 4. Comparing photometric redshifts derived from SED fitting using LRT, independently (top) and combined with our variability model (bottom), against spectroscopic redshifts.

REFERENCES

- Assef et al. 2010
- MacLeod et al. 2010
- Suberlak et al. 2021
- Salvato et al. 2009, 2011, 2019
- LSST Science Collaboration. 2009
- Kelly et al. 2009
- Ivezic et al. 2019

VAR-PZnn

Satheesh-Sheeba et al. (forthcoming)

- A machine learning architecture to estimate AGN photo-zs from the ALeRCE light curve classifier features.
- Fully Connected Neural Network that combines photometric colors and AGN variability features.

DATA

- ~72,000 sources classified as AGN/QSOs by the ALeRCE light curver classifier
- Subsample with ~53k AGNs with NIR photometry from UKIDSS
- Spectroscopic redshifts (True labels) from SDSS DR19 and DESI DR1
- Optical colors: Pan-STARRS “griz”
- NIR colors: UKIDSS “YJHK”
- MIR colors: catWISE “W1, W2”
- Variability features: ZTF forced photometry

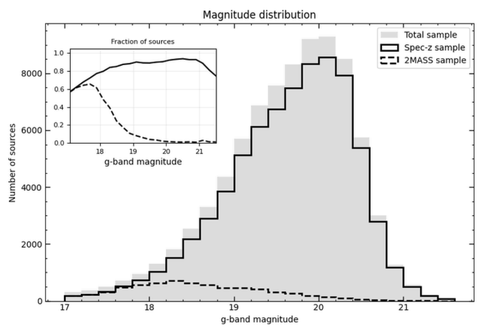


Fig.1. Distribution of the samples used our analysis as a function of their brightness.

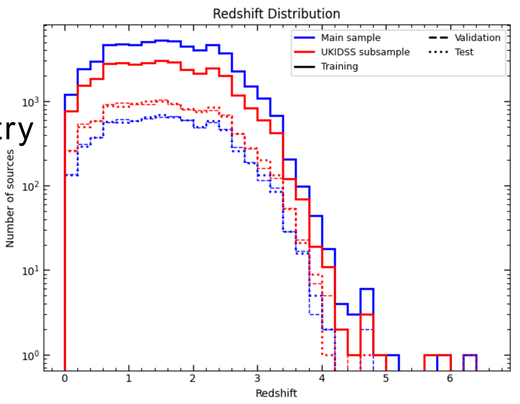
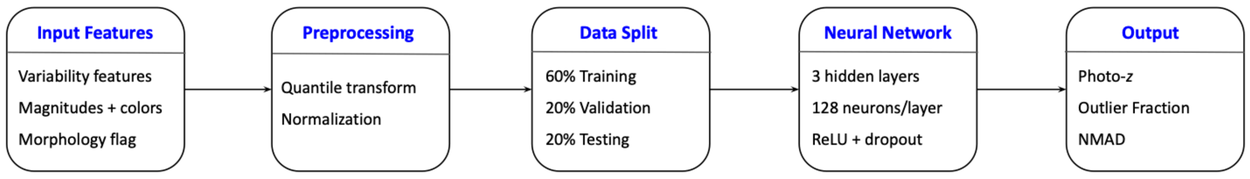


Fig. 2. Redshift distributions of the training, validation, and test samples adopted in our analysis.

MODEL ARCHITECTURE



RESULTS: Comparing variability features with and without NIR photometry

Fig.3. Performance of our photo-z estimator model using AGN variability features combined with PS1 +UKIDSS photometry (left) and PS1+UKIDSS+WISE photometry (right).

REFERENCES

- Arévalo et al. 2026
- Sánchez Sáez et al. 2021, 2023
- Saxena et al. 2024
- Salvato et al. 2009, 2011, 2019
- Brescia et al. 2019
- Shirley et al. 2025 (submitted)
- Foster et al. 2021

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