Rapid Generation of Kilonova Light Curves Using Conditional Variational Autoencoder

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XVIII International Conference on Topics in Astroparticle and Underground Physics 2023

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31st August, University of Vienna, Austria

Saha et al. (Submitted)

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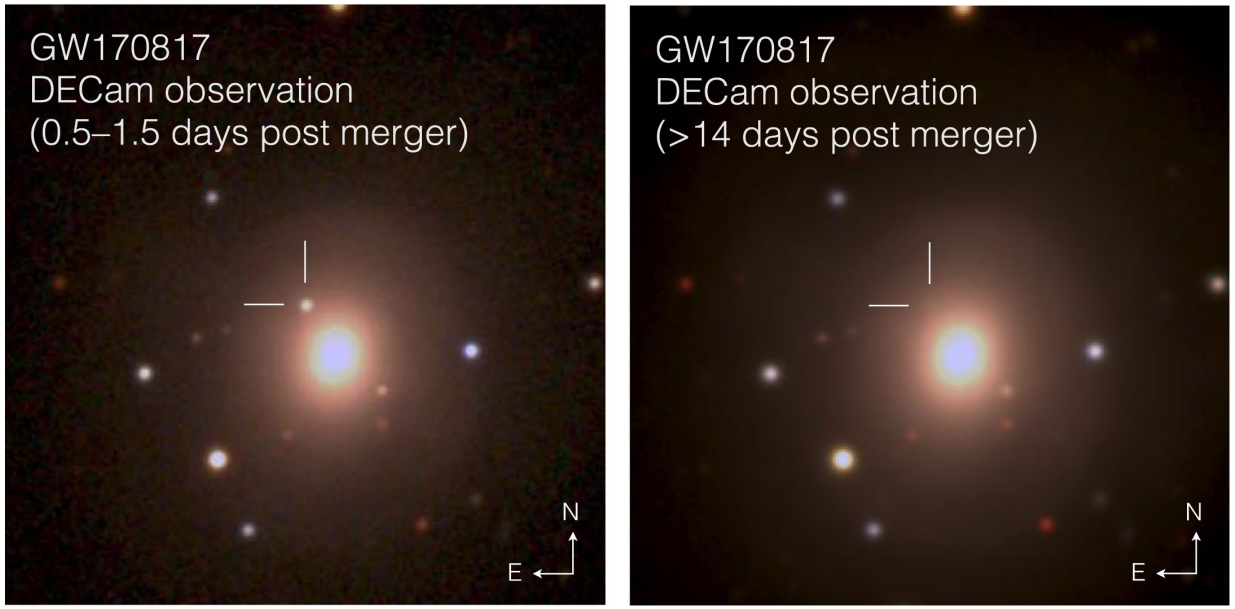
Outline

- Background
  - Kilonova
  - Conditional Variational Autoencoder
- Motivation
- Data & Methodology
- Current Results
- Summary

Kilonova

- Kilonova (KNe) is a thermal transient which is powered by the r-process, a radioactive decay of rapid neutron capture and observed as electromagnetic emission (EM) from the merger ejecta of two neutron star **(NS+NS)** or black hole and neutron star (NS+BH).
- This EM counterpart, further combined with gravitational waves(GW), can provide valuable insights and deeper understanding of the merger environment and its products.
- However, till now, there has been only one confirmed detection of KNe (GW170817) alongside GW.



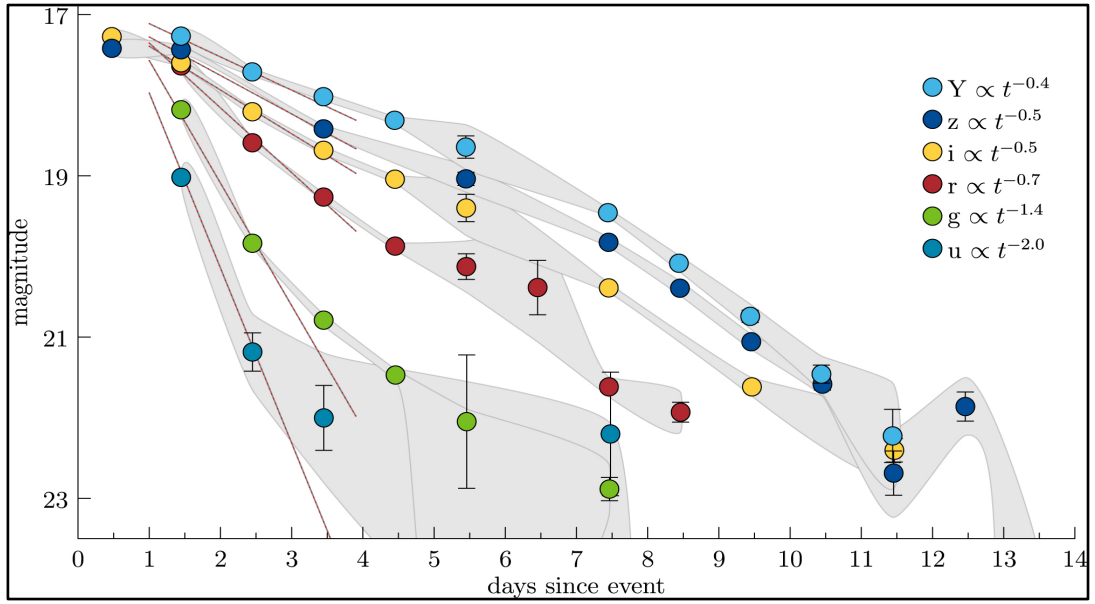
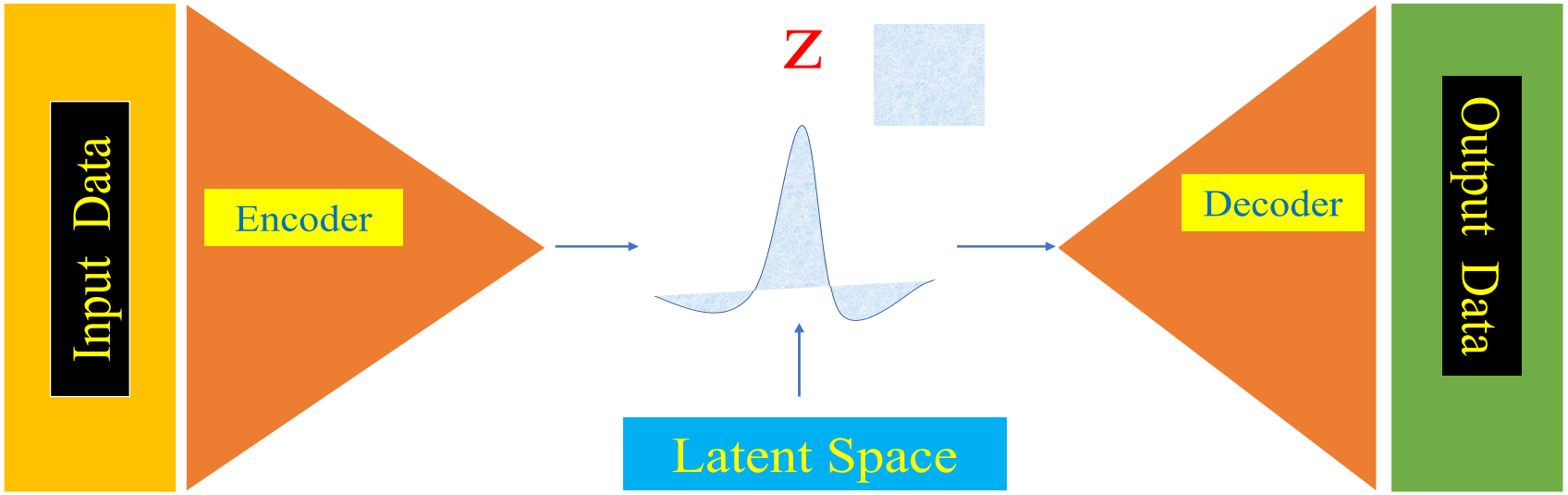


Image Credits: M. Soares-Santos *et al* 2017 *ApJL* **848** L16

Conditional Variational Autoencoder



Schematic diagram of the conditional variational autoencoder (CVAE) from input to data generation. In the figure, we have the probabilistic encoder Q(Φ) and the probabilistic decoder P(θ) and the latent space Z which represents the compressed input or encoded representation.

Motivation

Multi-Messenger Astronomy

Machine Learning

&

Generate Accurate Kilonova Light Curves Rapidly Using Less Computation Resources

Data & Methodology

Data

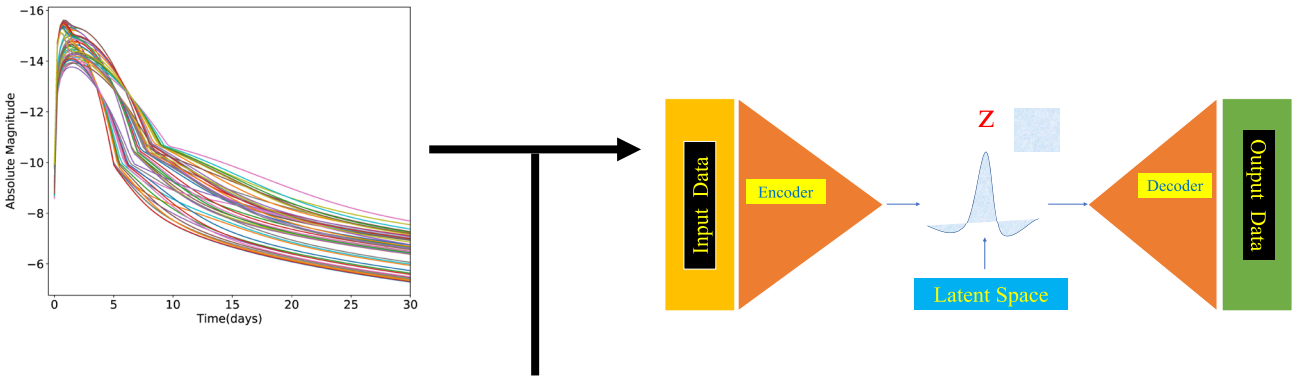
Data adopted from Matt Nichol's semi-analytic KNe model.
https://doi.org/10.1093/mnras/stab1523

- 529 KNe light curves
- Physical Parameters
  - Chirp Mass: **0.7-2.0 M_0**
  - Mass ratio: **0.5-1.0**
  - Fraction of remnant disk:**0.15-0.45**
  - Viewing angle from the pole:**0^0 – 90^0**

- Number of Physical Parameters Set: 529
- Filter Bands: u,g,r,y, i and z.

Methodology

Data set (529)= Training(401) + Test(64) +Validation(64)

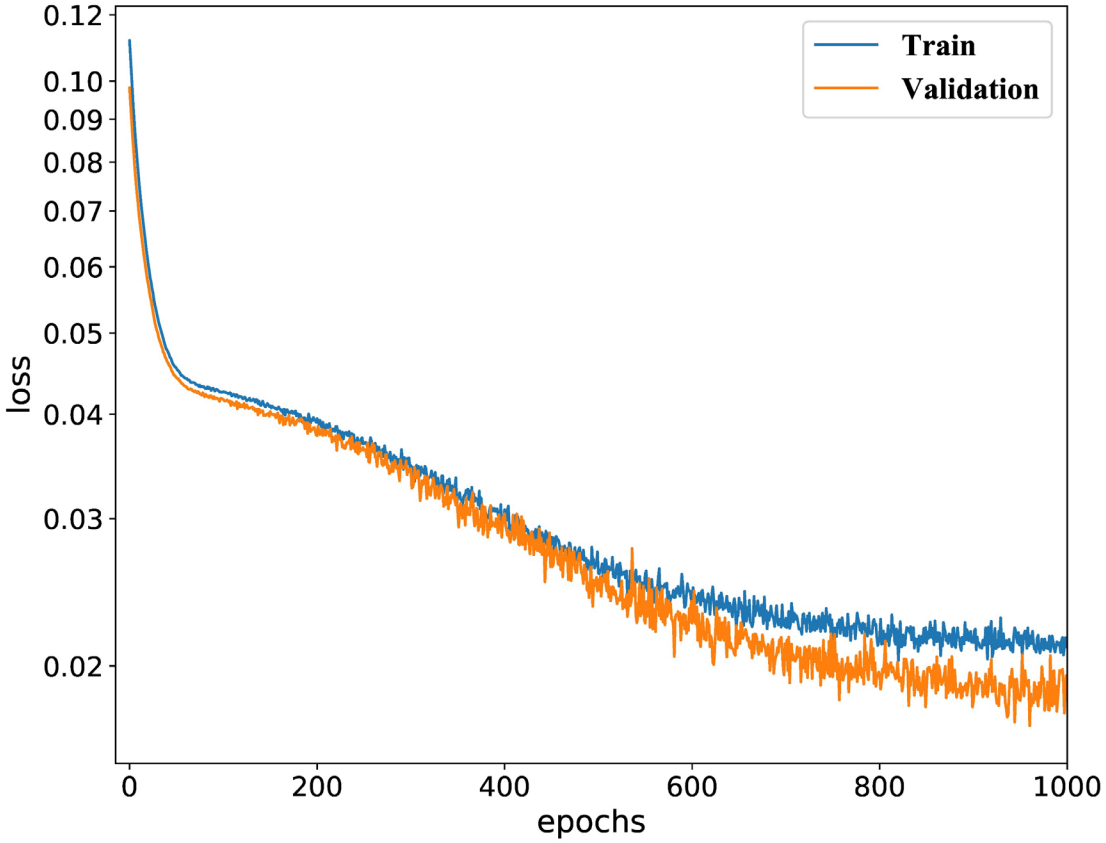


Train the light curves by conditioning them on physical parameters

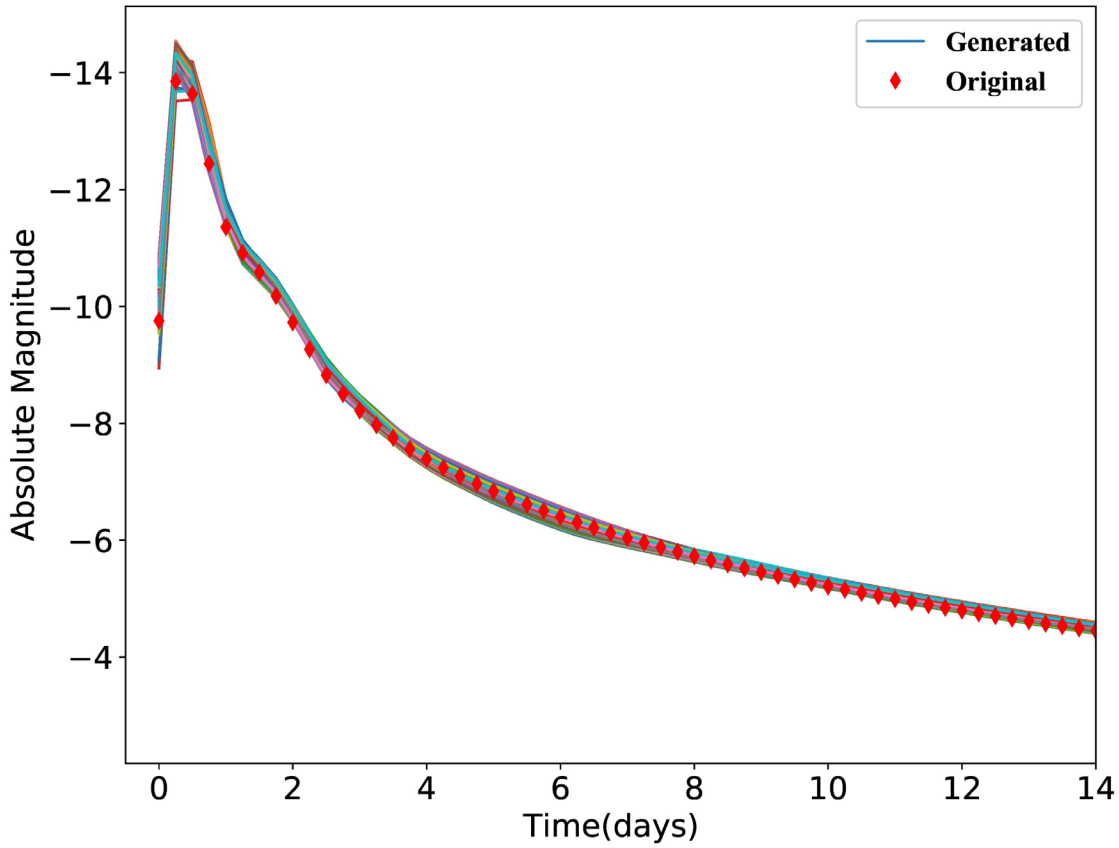
Check the performance of CVAE

Generate the light curves for the required values of physical parameters

Initial Performance-Check For CVAE

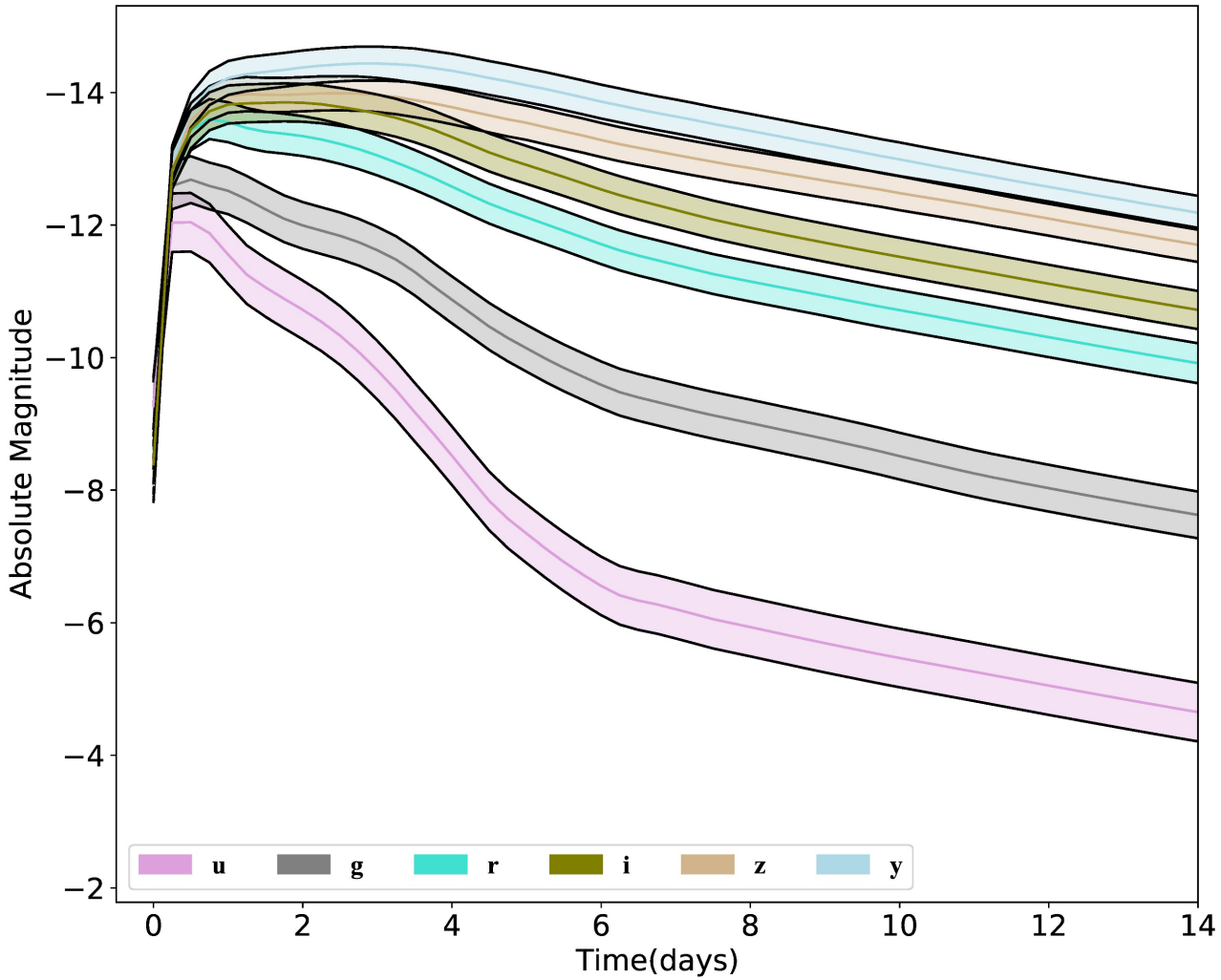


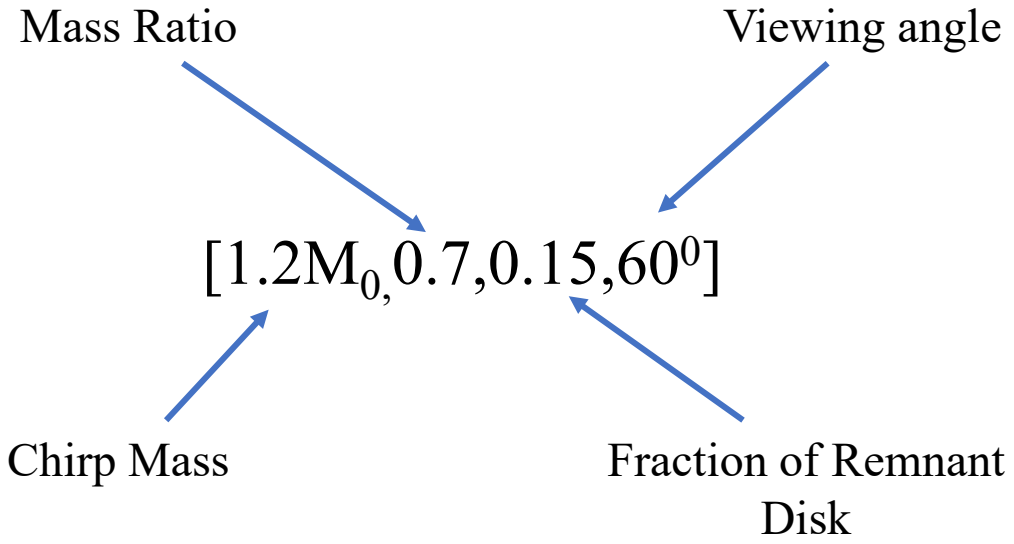
Obtained Loss Plot



True vs Generated Light Curves for $1.8M_0$ chirp mass, 0.7 mass ratio,0.15 fraction of remnant disk and 90^0 viewing angle

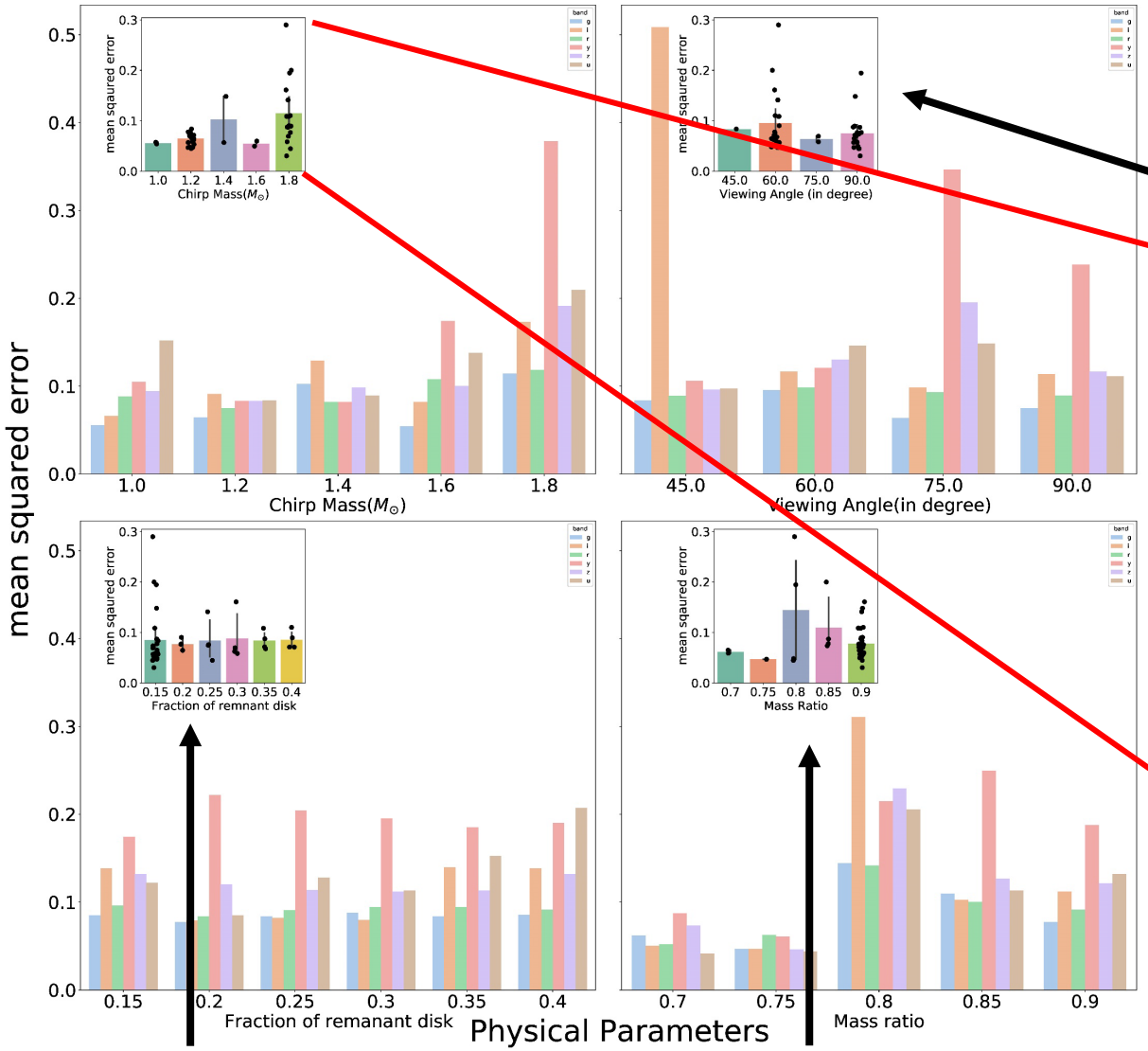
CVAE Performance-Check on Unseen Physical Parameter Set





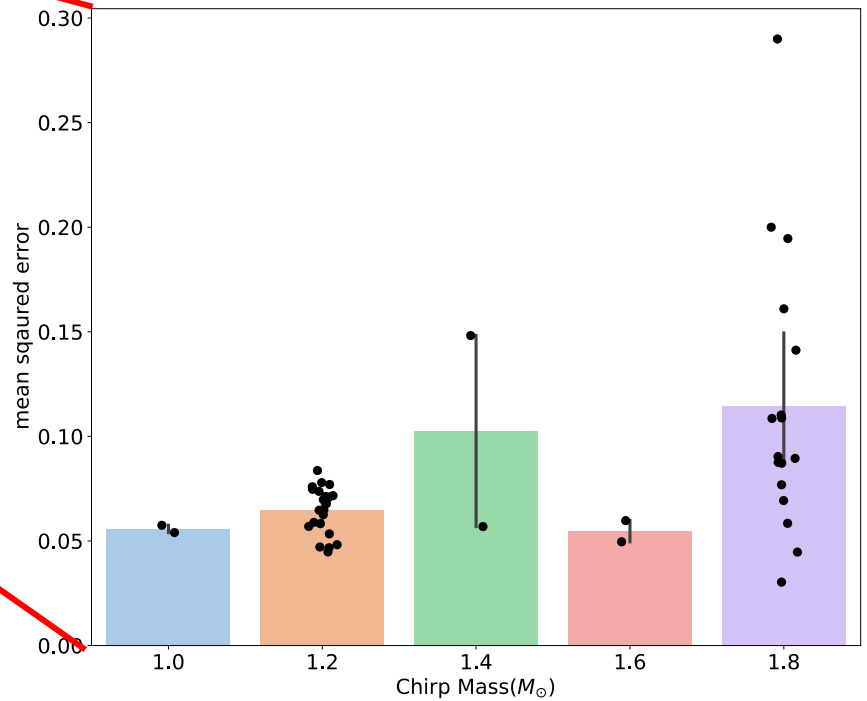
90% Confidence interval for the CVAE-generated light curves for the above physical parameter across different filter bands

CVAE Performance Over The Entire Parameter Space



Mean Squared Error Plots between the original and CVAE-generated light curves.

Viewing angle



CVAE Performance Over The Chirp Mass Parameter Space for g-band light curves

Fraction of Remnant Disk

Mass Ratio

Summary

1. Training time is ~20 mins and generation of light curves takes ~milli-seconds.
2. Calculated MSE is 0.015-0.08.
3. Performance across the parameter space is satisfactory.
4. Accelerating the existing method by 10^3 times.

Thank You For Your Attention
Questions and Comments