

7th **KAGRA** International Workshop

**Generating Kilonova Light Curves Using Autoencoder to Investigate the Properties of a Compact Binary Merging System**

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**國立清華大學**  
**NATIONAL TSING HUA UNIVERSITY**

**19<sup>th</sup> December, 2020**

## Collaborators



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**Dr. Daniel Williams**  
**Fergus Hayes**  
**Nicola De Lillo**



**UNIVERSITY OF**  
**BIRMINGHAM**

**Dr. Matt Nicholl**

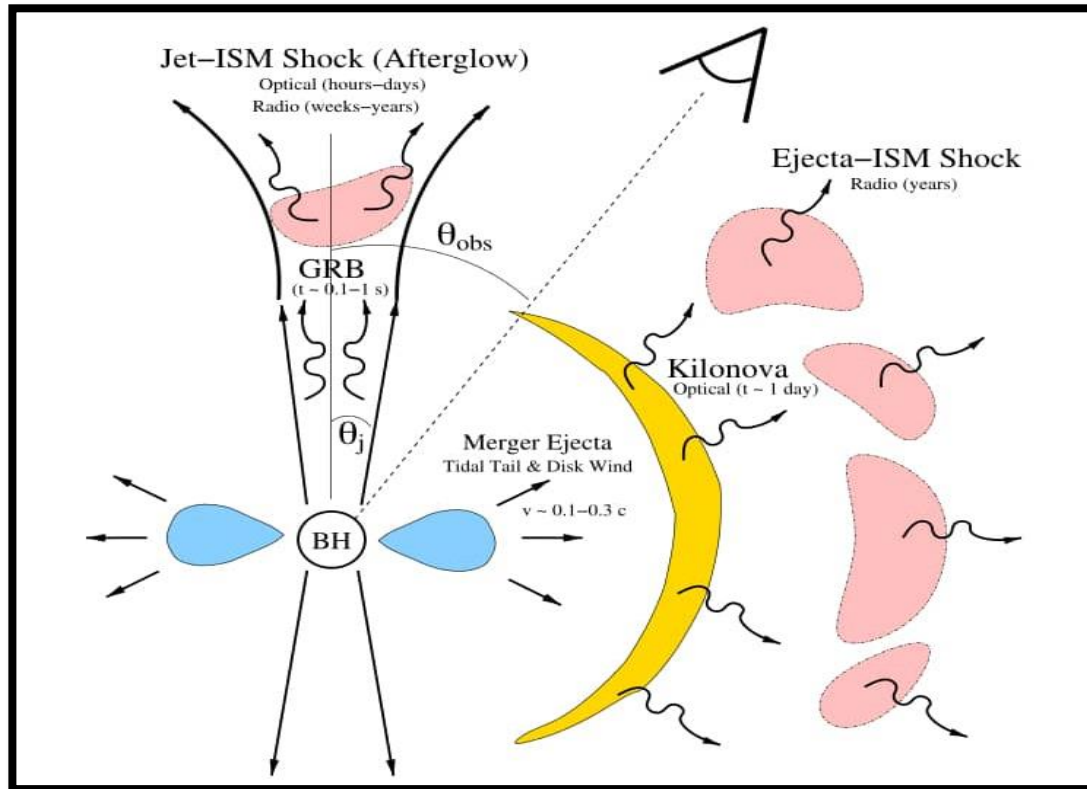
## Outline

- Background and Motivation
- Planning
- Data Used
- Roadmap
- Results
- Discussion



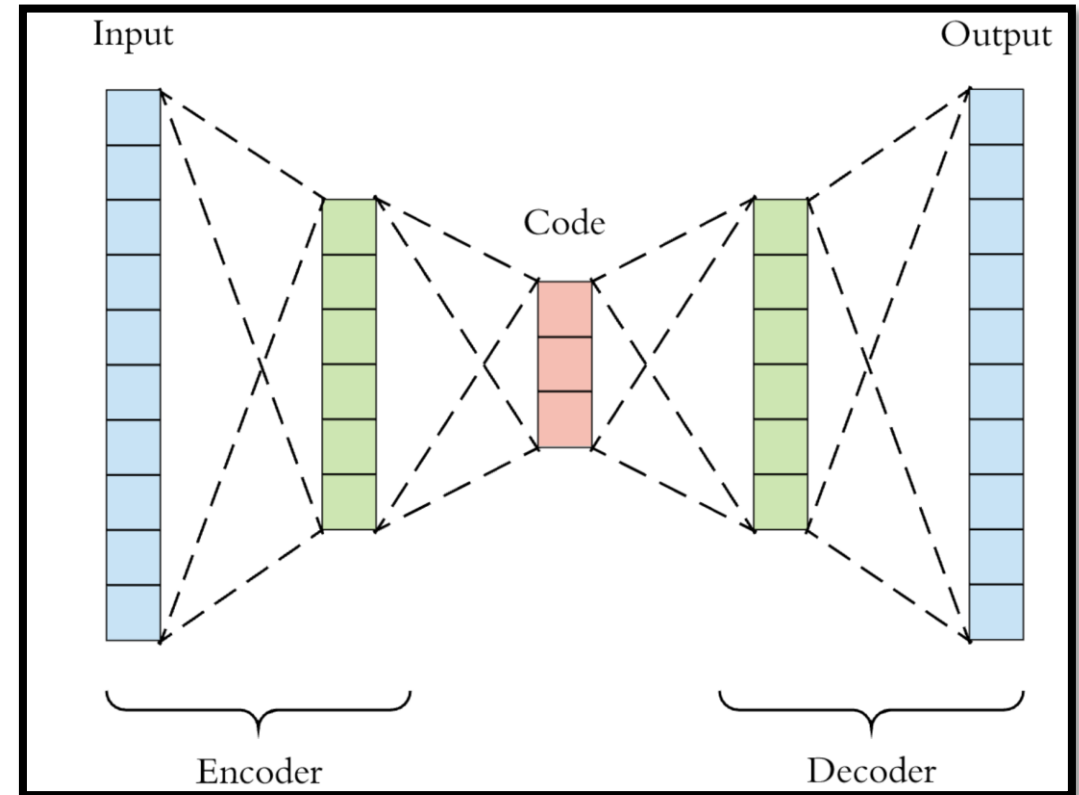
## Background and Motivation

**Kilonova:** Transient electromagnetic counterpart resulting from merger of NS-NS or BH-NS, powered by the radioactive decay of *r-process* nuclei.



Metzger and Berger 2012

**Autoencoder:** Unsupervised learning technique where neural networks are used for representation learning.



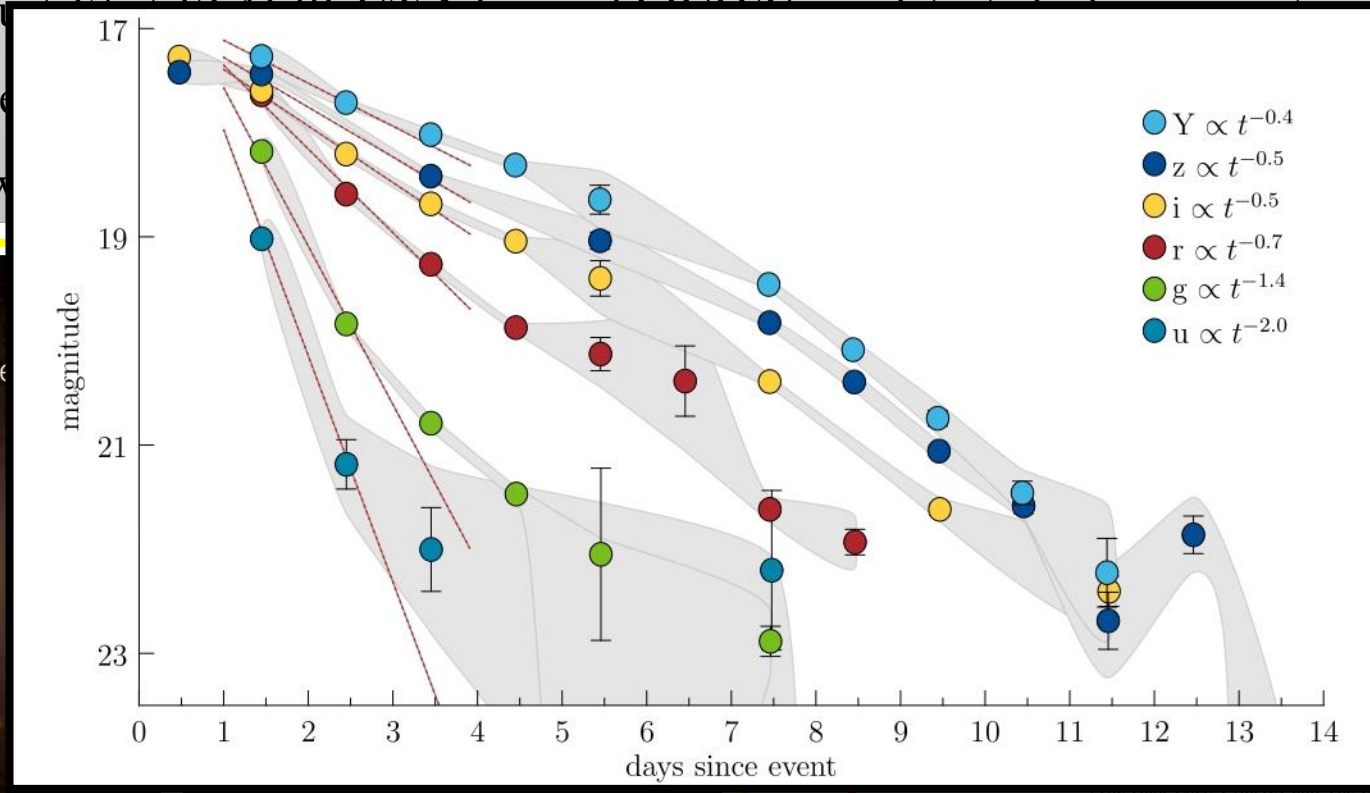
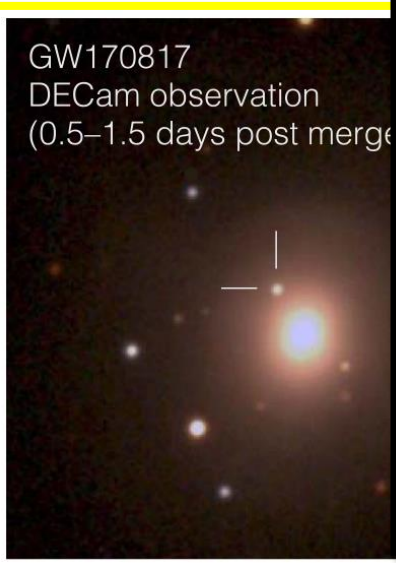
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## Background and Motivation

### Birth of Multi-Messenger Astronomy

- On 2017, August 17, 12:41:06 UTC, LIGO/Virgo detected a binary neutron star merger (GW170817)
- Alert was issued
- DECam followed

GW170817  
DECam observation  
(0.5–1.5 days post merge)



Binary neutron star merger (GW170817)

(Pulver et al.)

<https://doi.org/10.3847/2041-8213/aa9059>

#### Binary Neutron Star Merger LIGO/Virgo Counterpart Using the Dark Energy Camera

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NGC4993 *grz* color composites

Kilonova from follow up observation of GW170817

Follow up observations: HST, GS/F2, Swift/UVOT



## Motivation and Planning

### Looking For Some Answers

- How to relate the ejecta parameters with the kilonova (KN) light curves (LC) from the follow-up observations using autoencoder?
- Is it possible to generate KN LC based on certain ejecta parameters, hence helping in better parameter estimation?

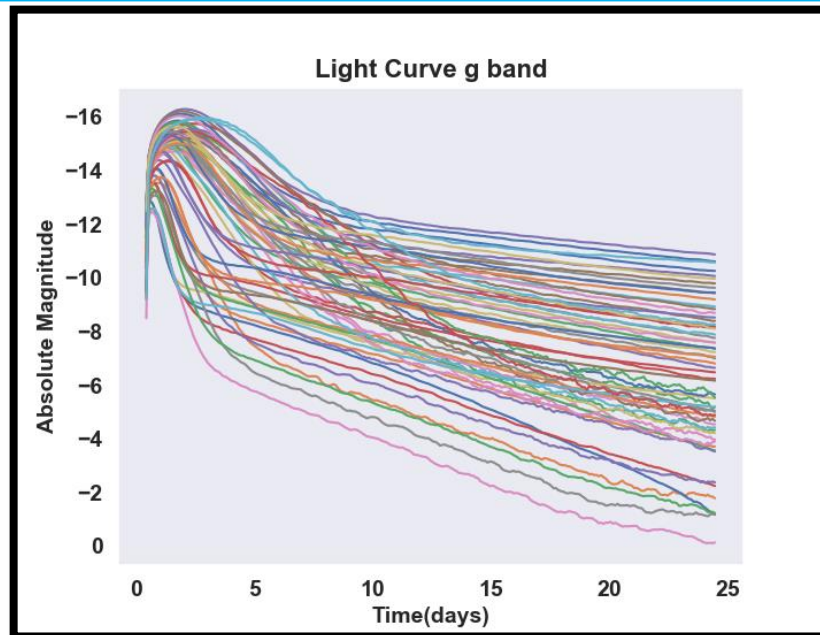
Build an autoencoder (AE) model of KN using some simulated data and reconstruct the LC, learn the physical parameters, use the model to extract KN LC from other data (if present).



## Data Used

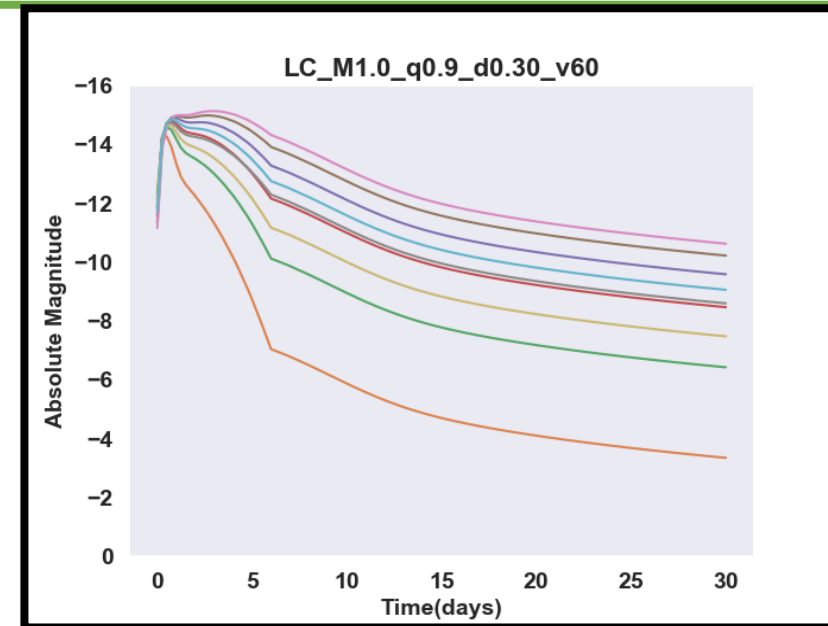
### Data 1

- Simulated LC using Kasen Model
- Each LC has its own dynamical ejecta properties
- Time, Absolute magnitude, ejecta mass, ejecta velocity, lanthanide fraction.
- LC curves are available in  $g, i, r, y$  and  $z$  bands of DECam.



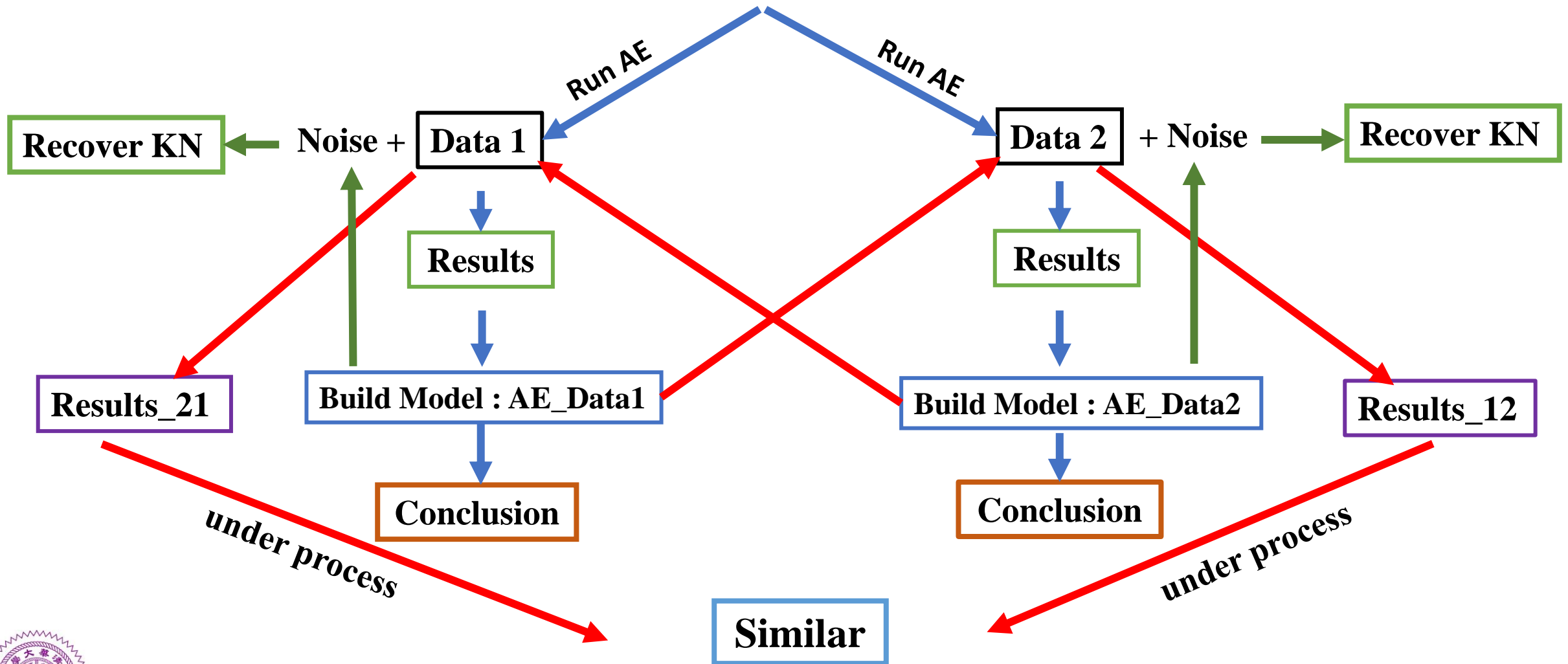
### Data 2

- Simulated from his own KN model.
- LC are generated based on chirp mass, mass ratio, viewing angle fraction of the ejected remnant disk.
- Each data set has a particular value for the above parameters and has values for *LSST* ( $u, g, r, i, z, y$ ), *PanSTARRS* ( $w$ ) and *ATLAS* ( $c, o$ ) bands.



# Roadmap

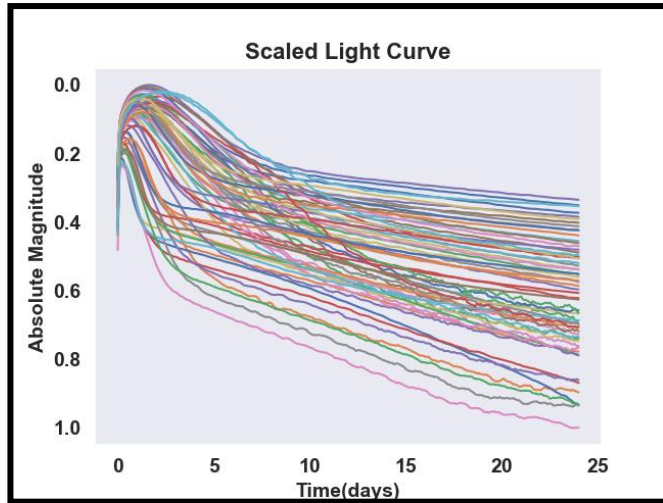
## Build The Autoencoder



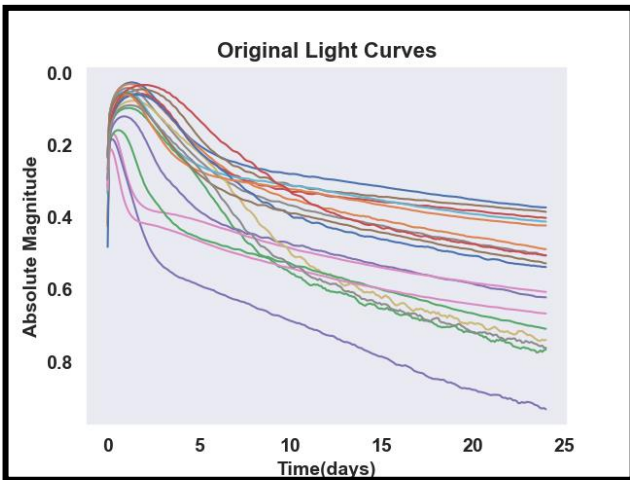


## From Data 1

### Input to AE



### Test Set of LC

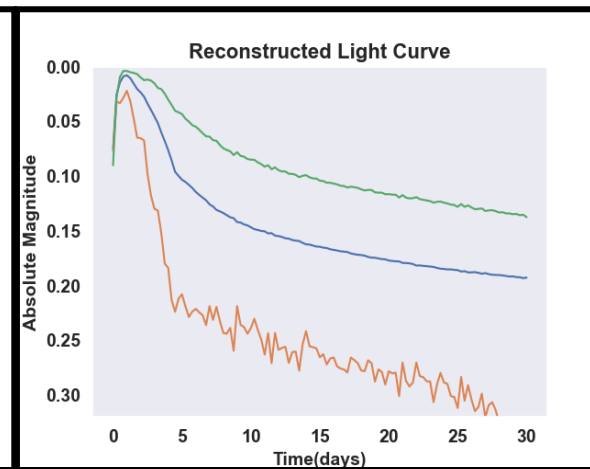
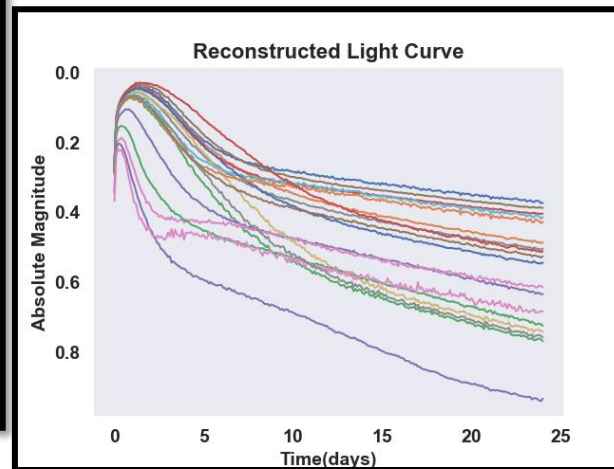


## Results

**For Data 1: Each LC has different ejecta parameters**

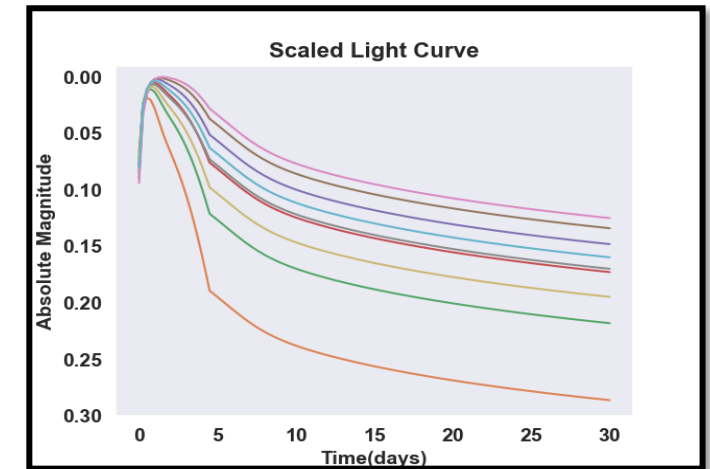
**For Data 2: Each LC corresponds to different band**

## Reconstructed Light Curve

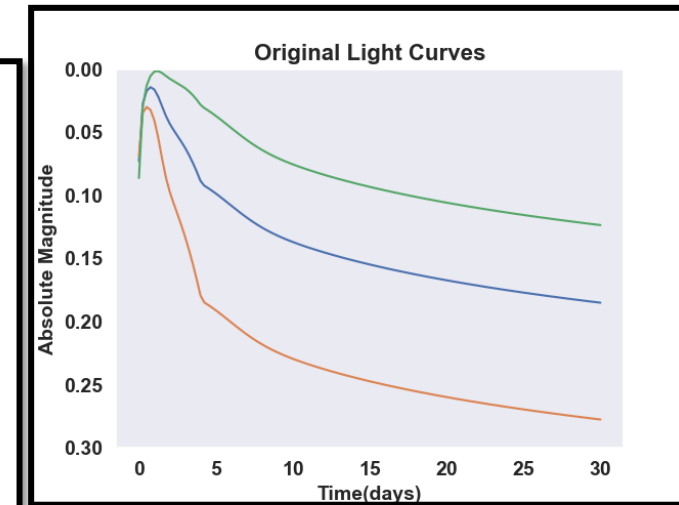


## From Data 2

### Input to AE

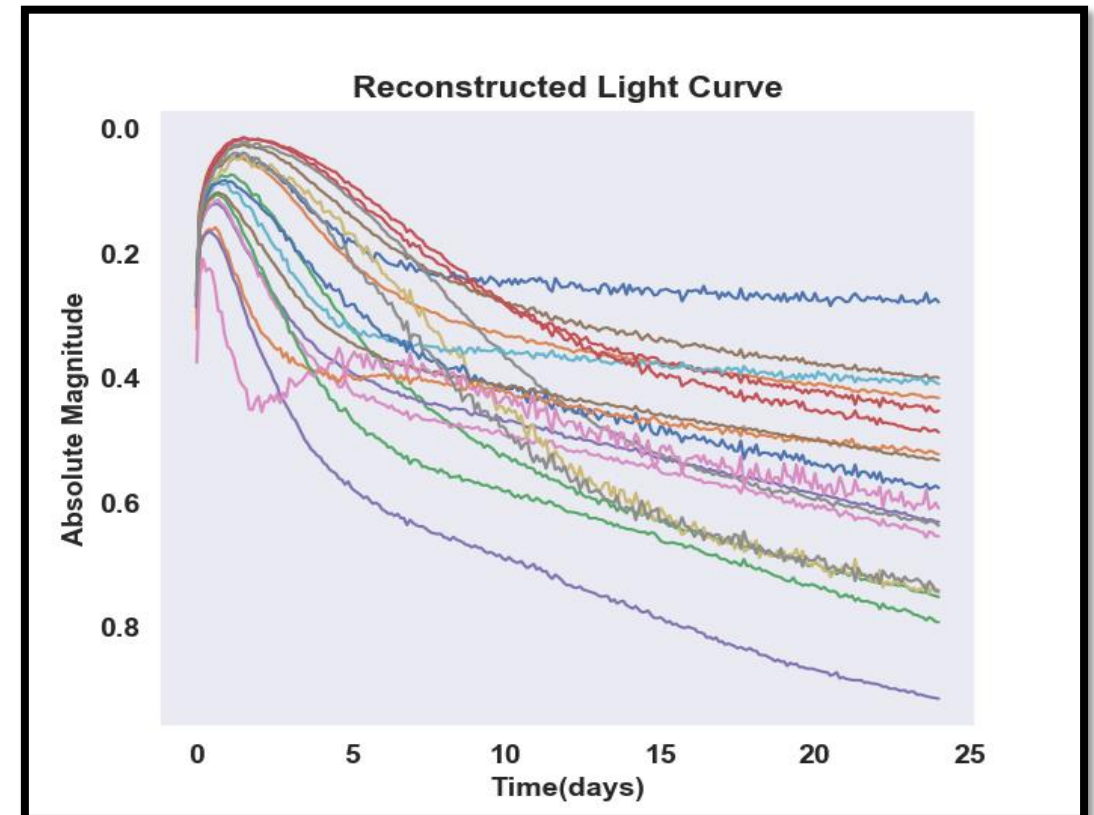
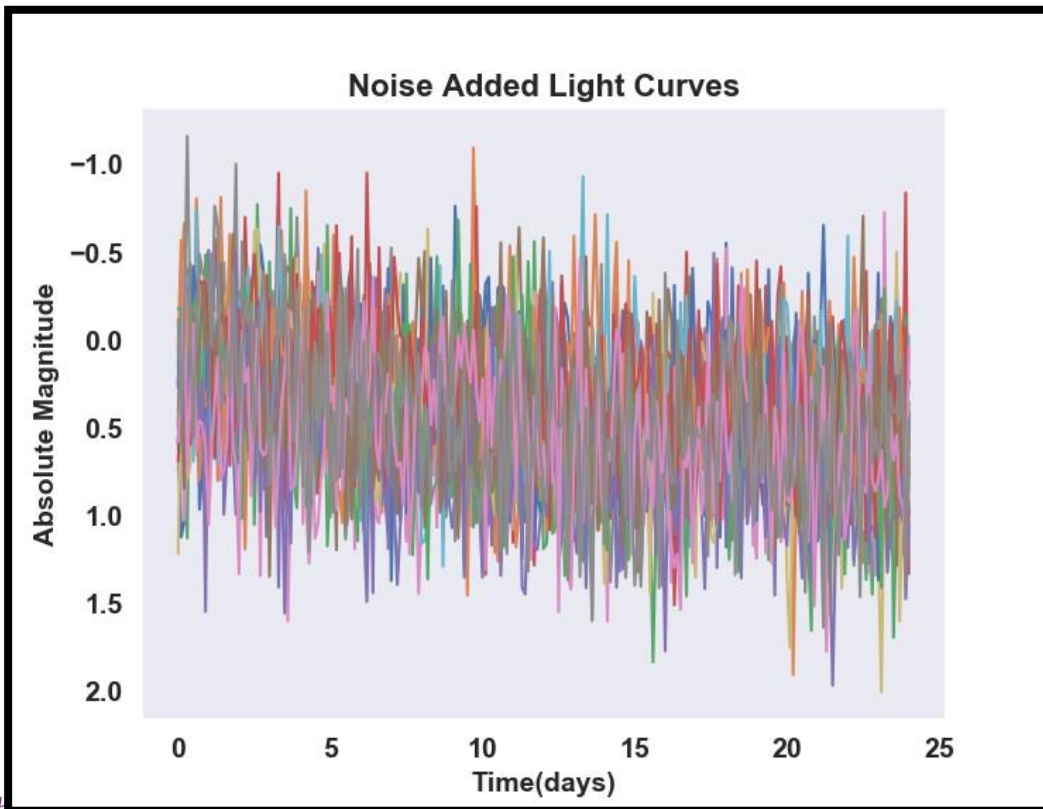


### Test Set of LC



## Model Test With Denoising Autoencoder

- To test the validity and accuracy of the model, denoising autoencoder has been used
- Random noise has been added to the data
- Model is run on it to extract the LC.



## Discussion

- Currently the autoencoder provides quite satisfactory results in reconstructing the LC
- In some cases there are still some issues in reconstructing LC
- Even though the noise added to the is not physical, but the recovery shows good results with the model-test run.
- The model built – AE\_data1 and AE\_data2 depends on the shape of the input.
- More realistic noise need to be added for achieving better physical significance.
- It is possible to recover hidden KN from a noisy data set.



## Future Works

- Make the autoencoder model more general.
- Add GRB afterglow data (generated with suitable time steps) to the autoencoder to perform the same analysis.
- Generate KN LC based on physical parameters (long term!!!)

**That's Great**

**I am Useless**

**Thank you for your Attention**

