Technical University of Munich
TUM School of Natural Sciences
Department of Physics
Observational Cosmology Research Group

MAX PLANCK INSTITUTE
FOR ASTROPHYSICS

Time Delay Inference using an LSTM Network

Elias Mamuzic

Tokyo, 5. August 2026

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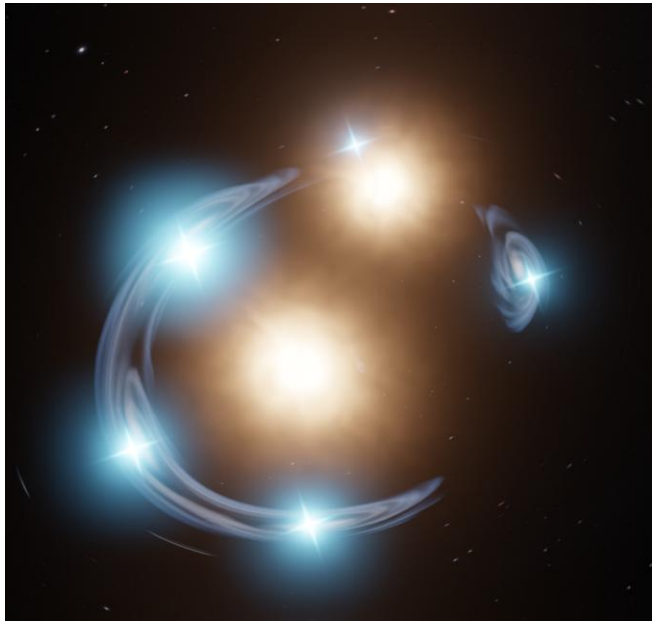
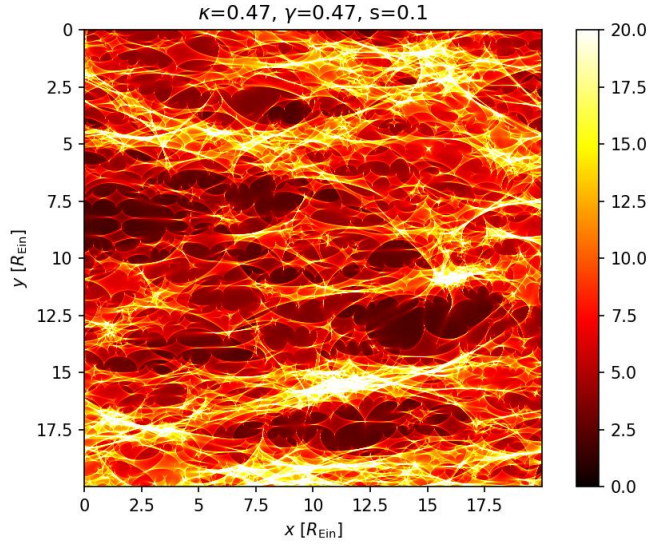
2nd year PhD student
Supervisor: Sherry Suyu



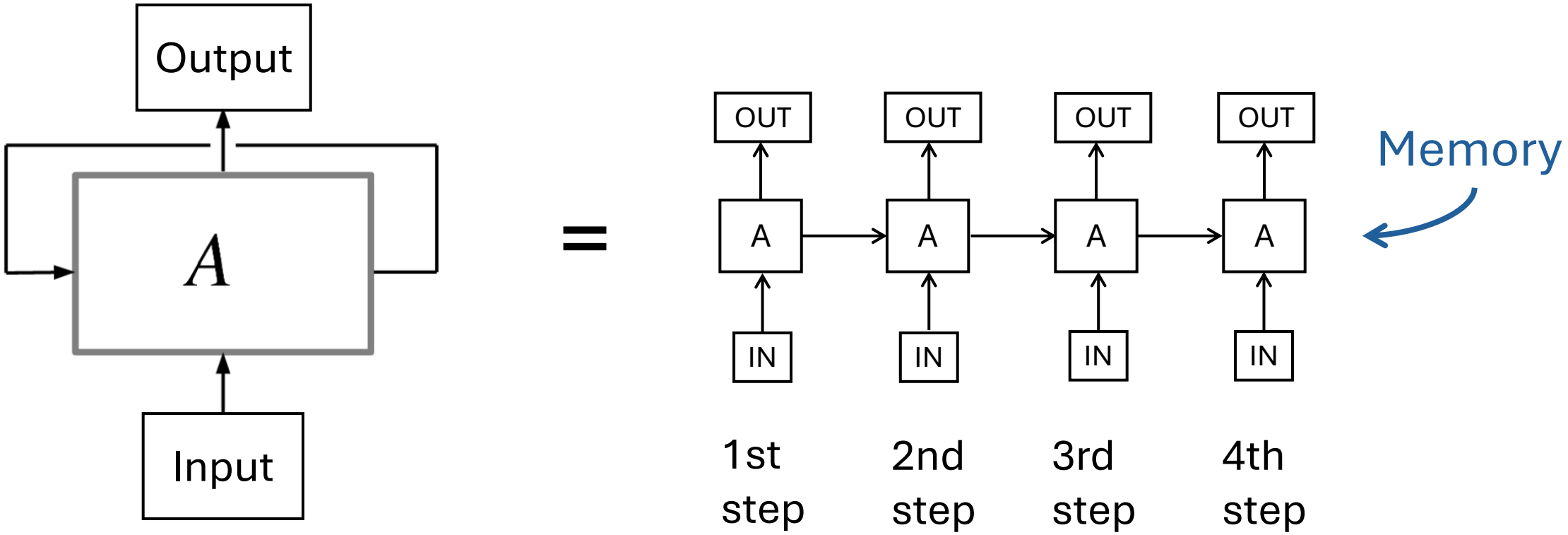
Lensed Supernovae

Lensed Tidal
Disruption Events

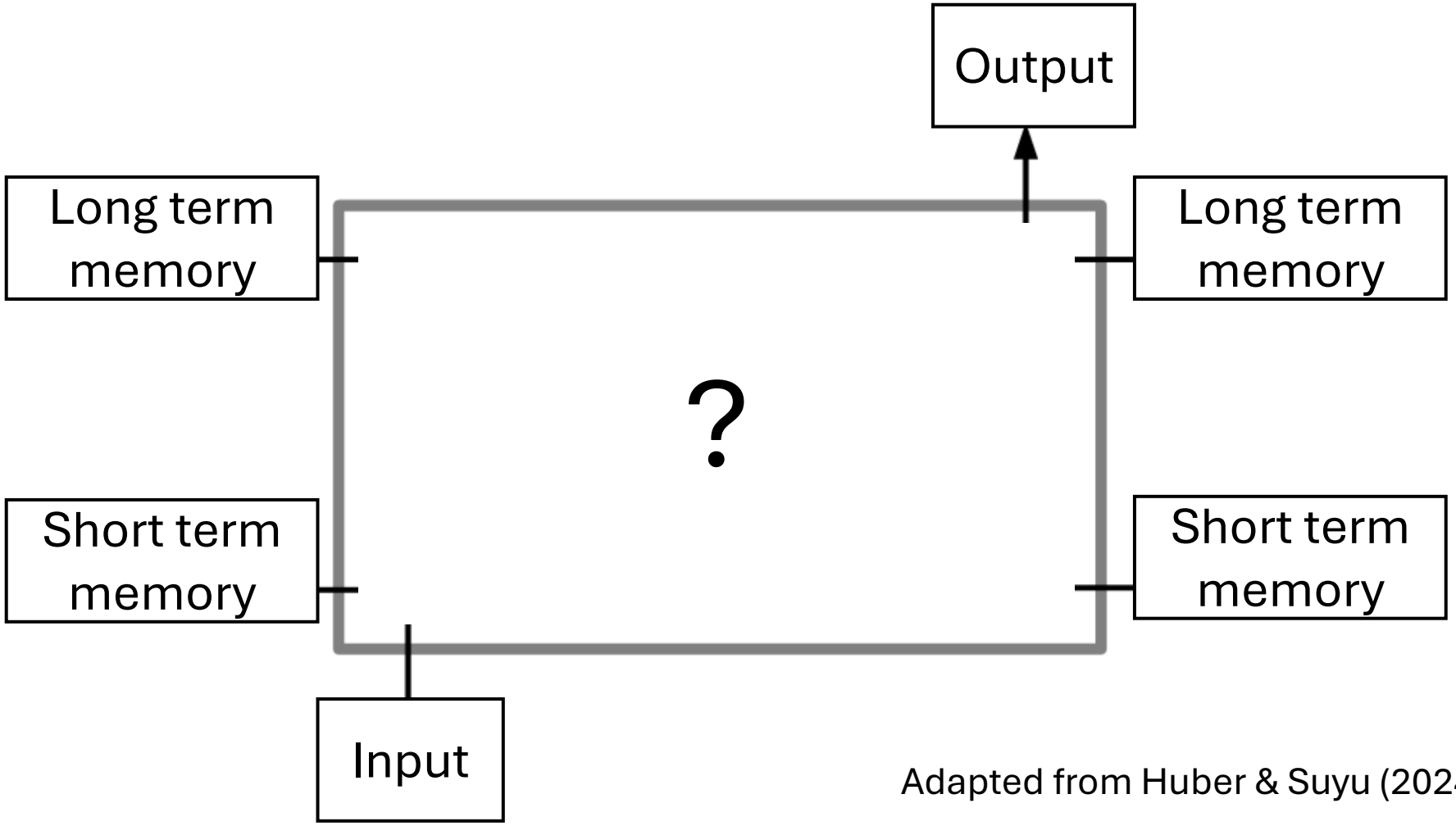


Microlensing

LSTM is a Type of Recurrent Neural Network

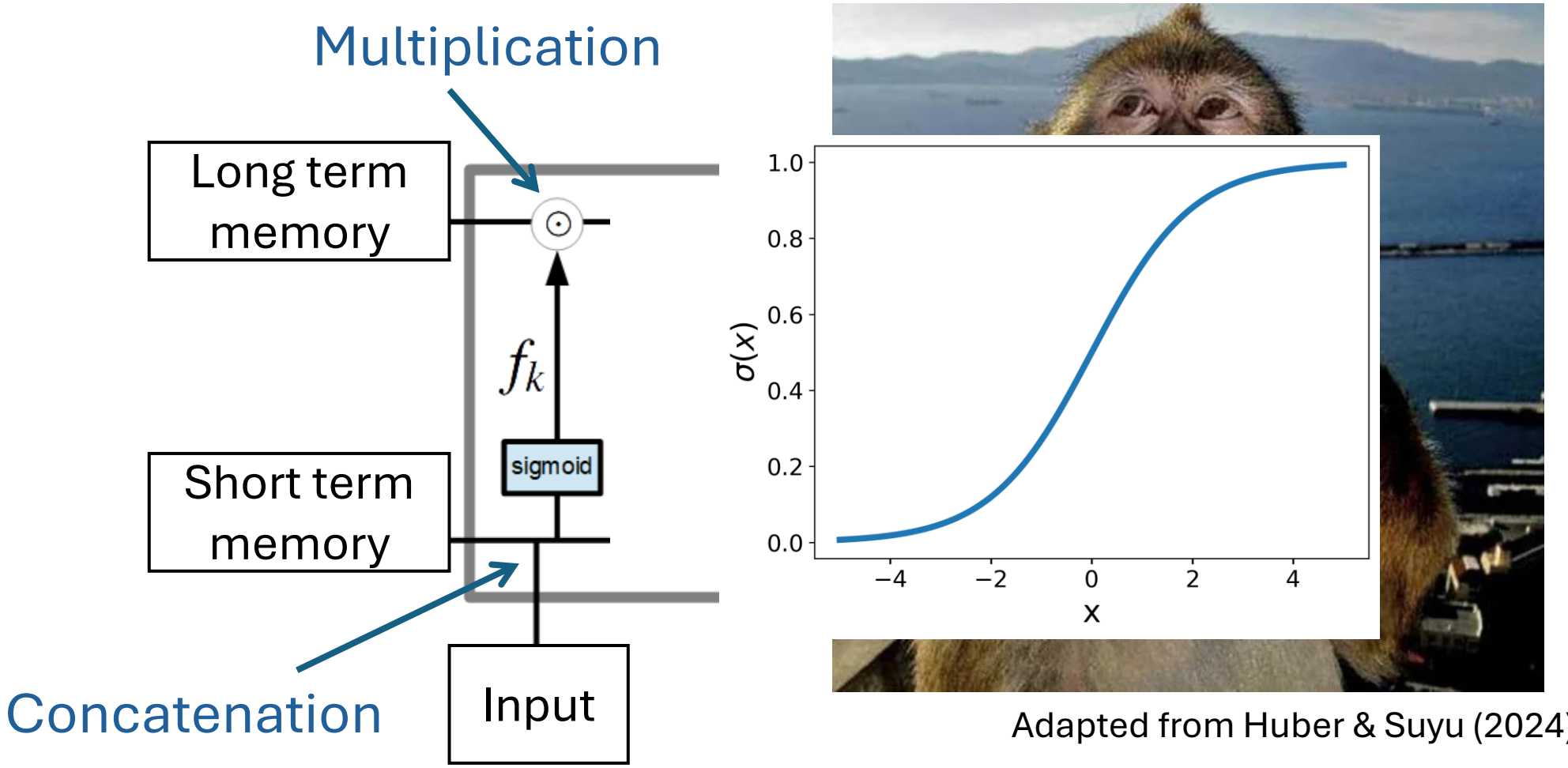


Long Short Term Memory Network



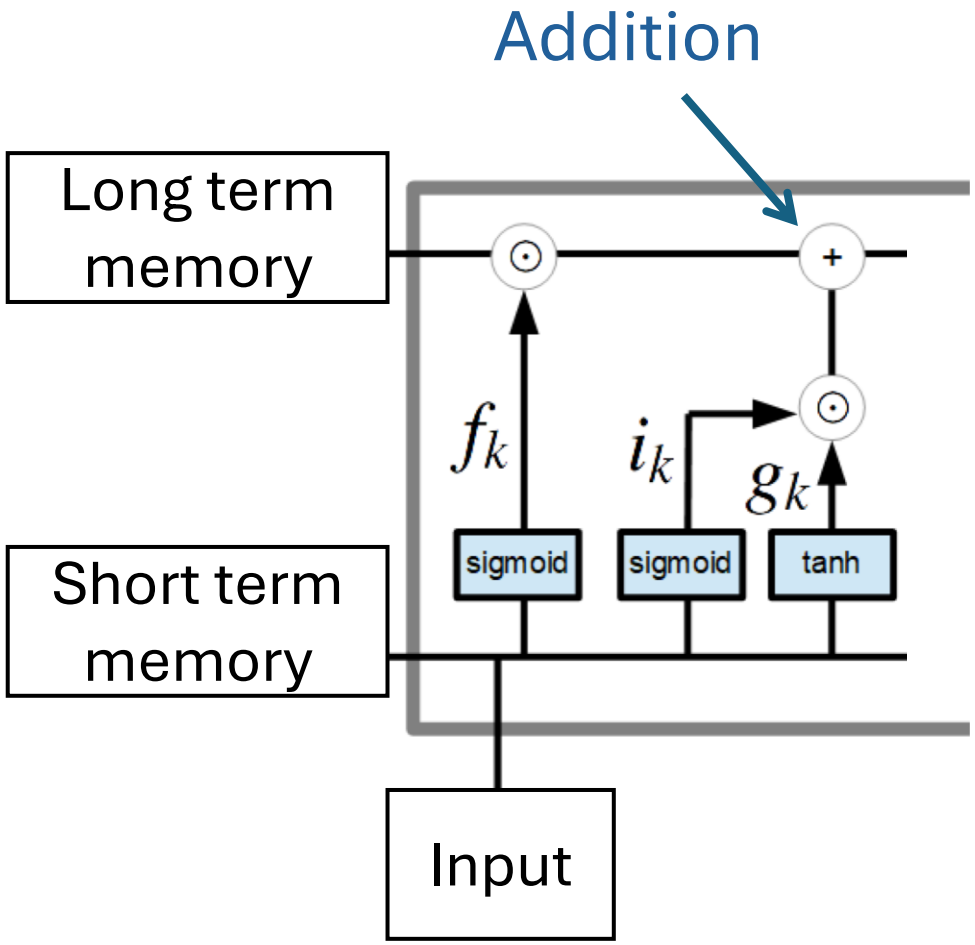
Adapted from Huber & Suyu (2024)

LSTM Network – Forget Layer



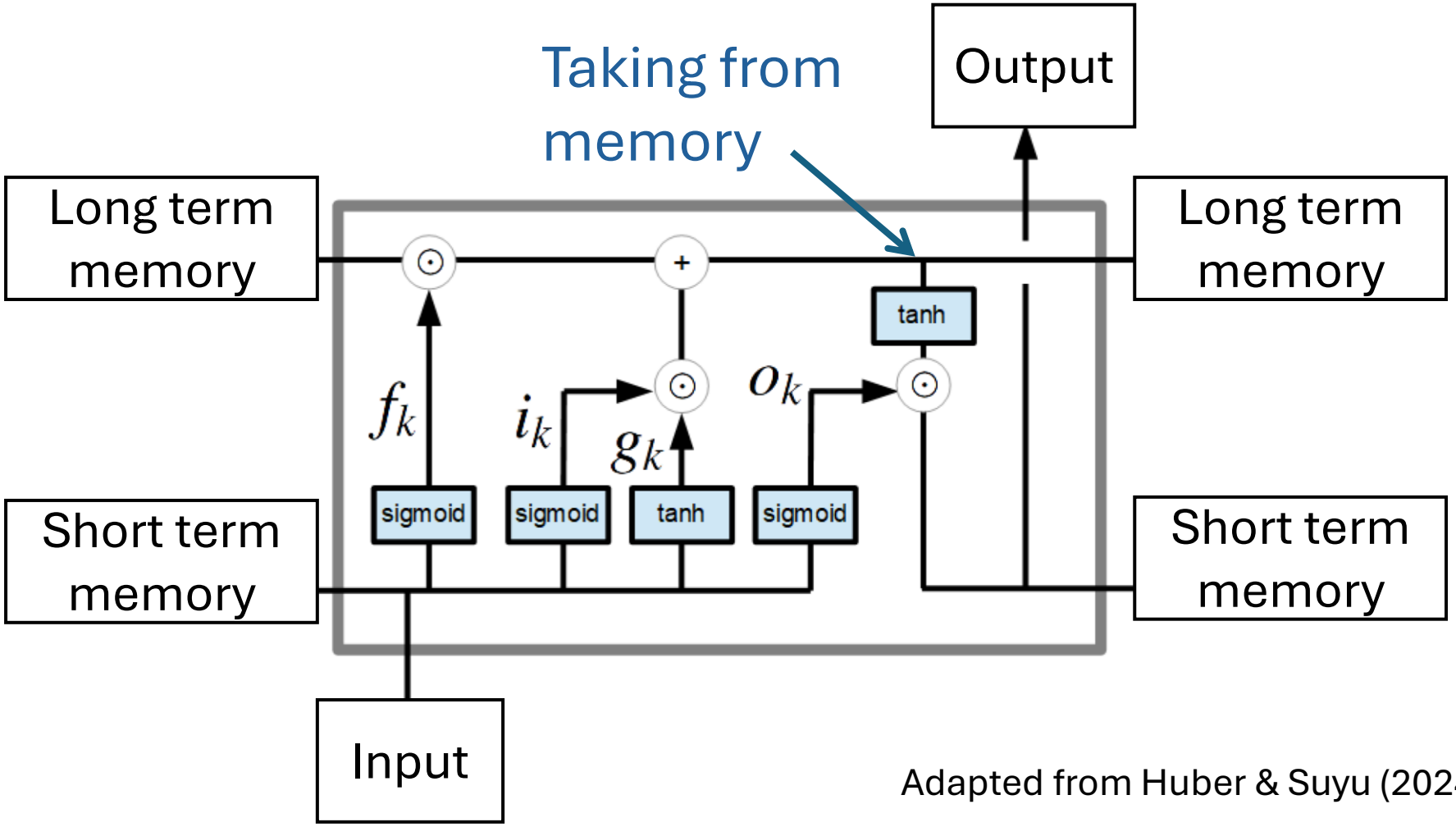
Adapted from Huber & Suyu (2024)

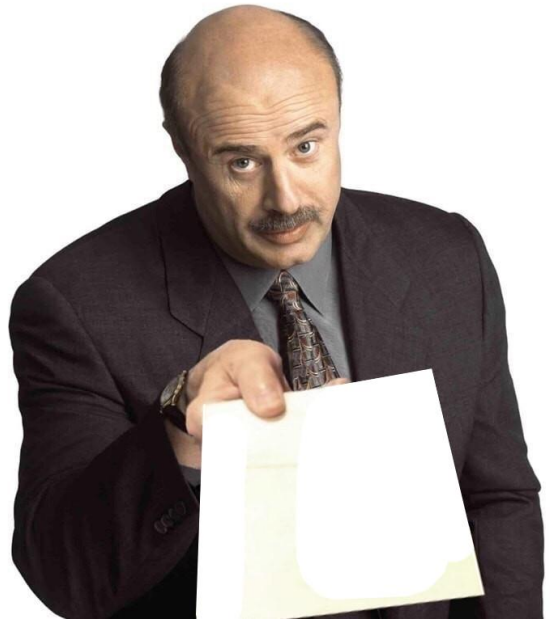
LSTM Network – Input Gate Layer



Adapted from Huber & Suyu (2024)

LSTM Network – Output Layer

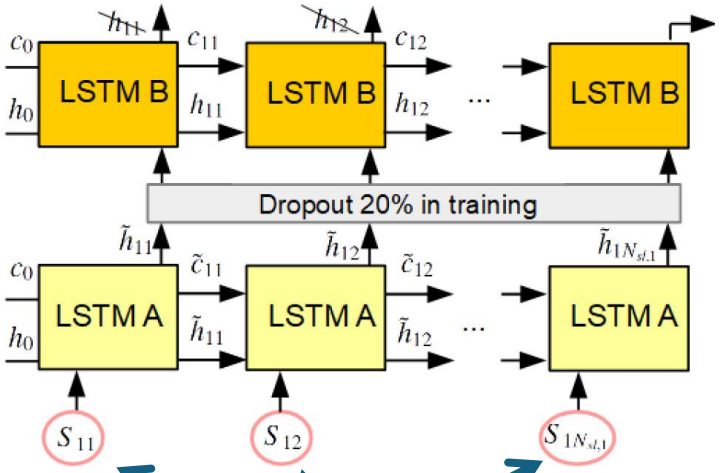




Adapted from Huber & Suyu (2024)

Siamese LSTM Network

Two LSTMs

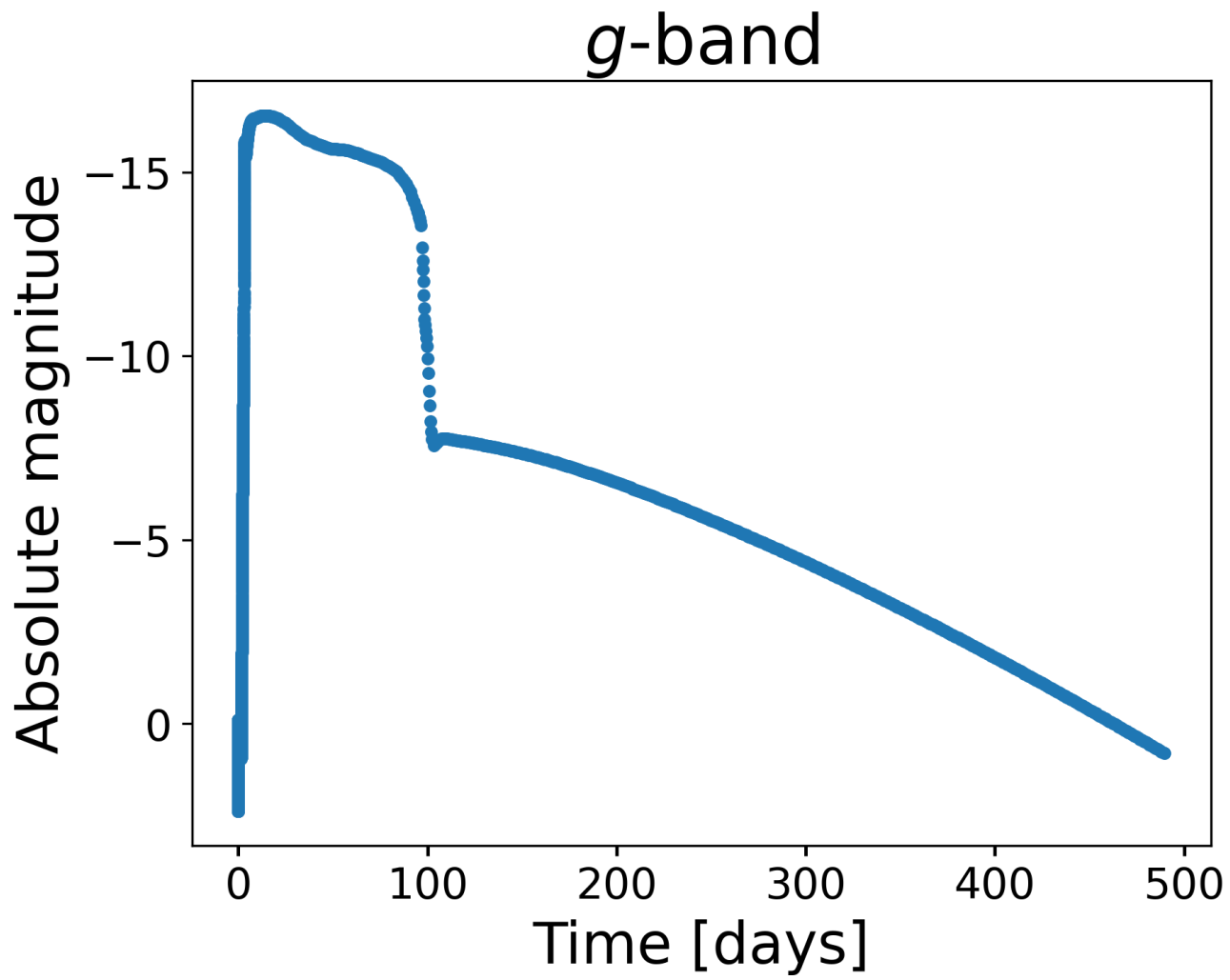


Same LSTMs applied to each lensed image

SN Light Curve

Huber & Suyu (2024)

Training Data

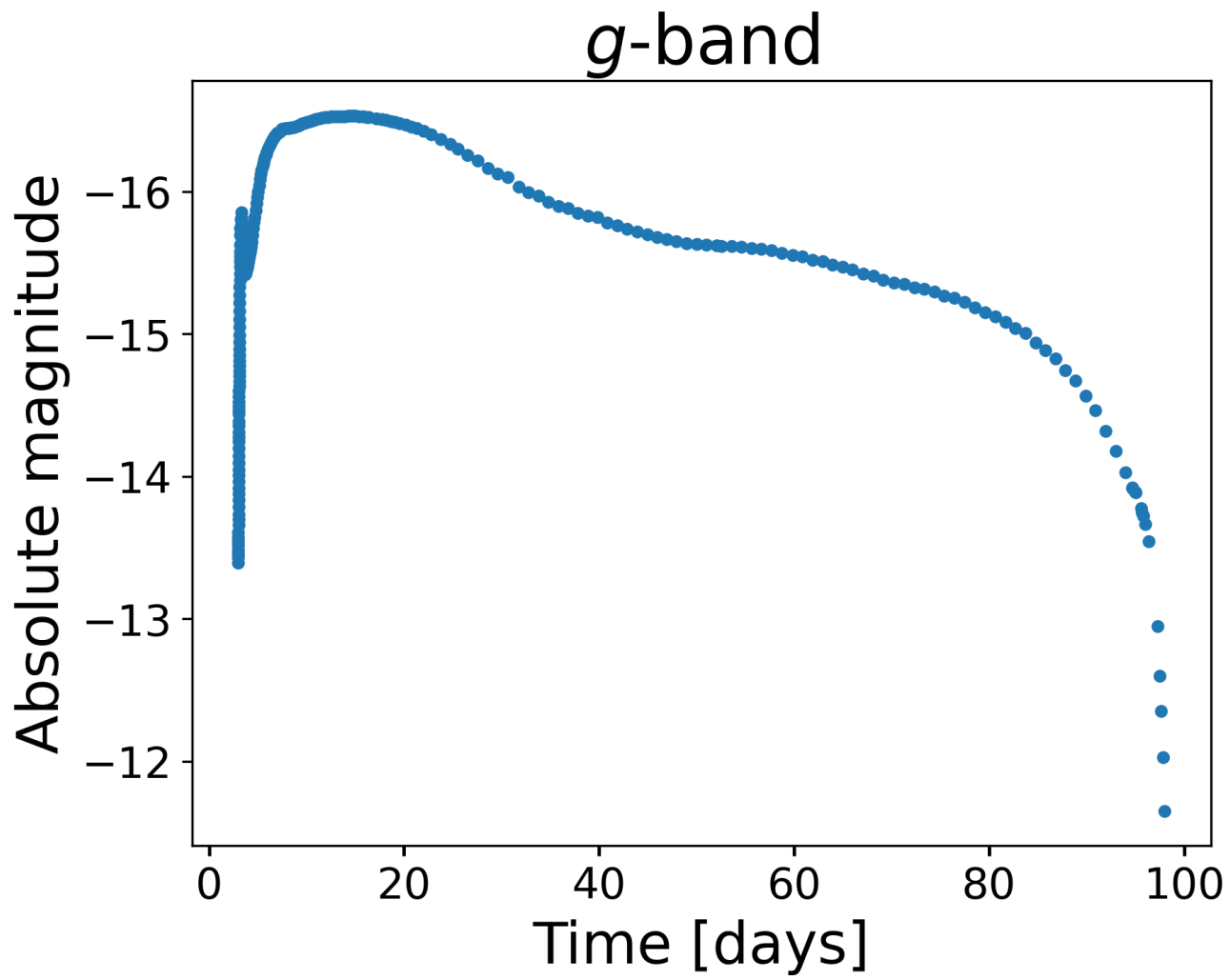


Synthetic SN IIP light-curve model set by Silva-Farfán et al. (2024) based on Moriya et al. (2018) using STELLA code

- Mass range: $10 - 18\ \mathrm{M}_{\odot}$
- Explosion energies: $0.5 - 2 \times 10^{51}$ erg
- Multiple wind velocities

Grupa Thesis (2025)

Training Data



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- Mass range: $10 - 18\ \mathrm{M}_{\odot}$
- Explosion energies: $0.5 - 2 \times 10^{51}$ erg
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Grupa Thesis (2025)

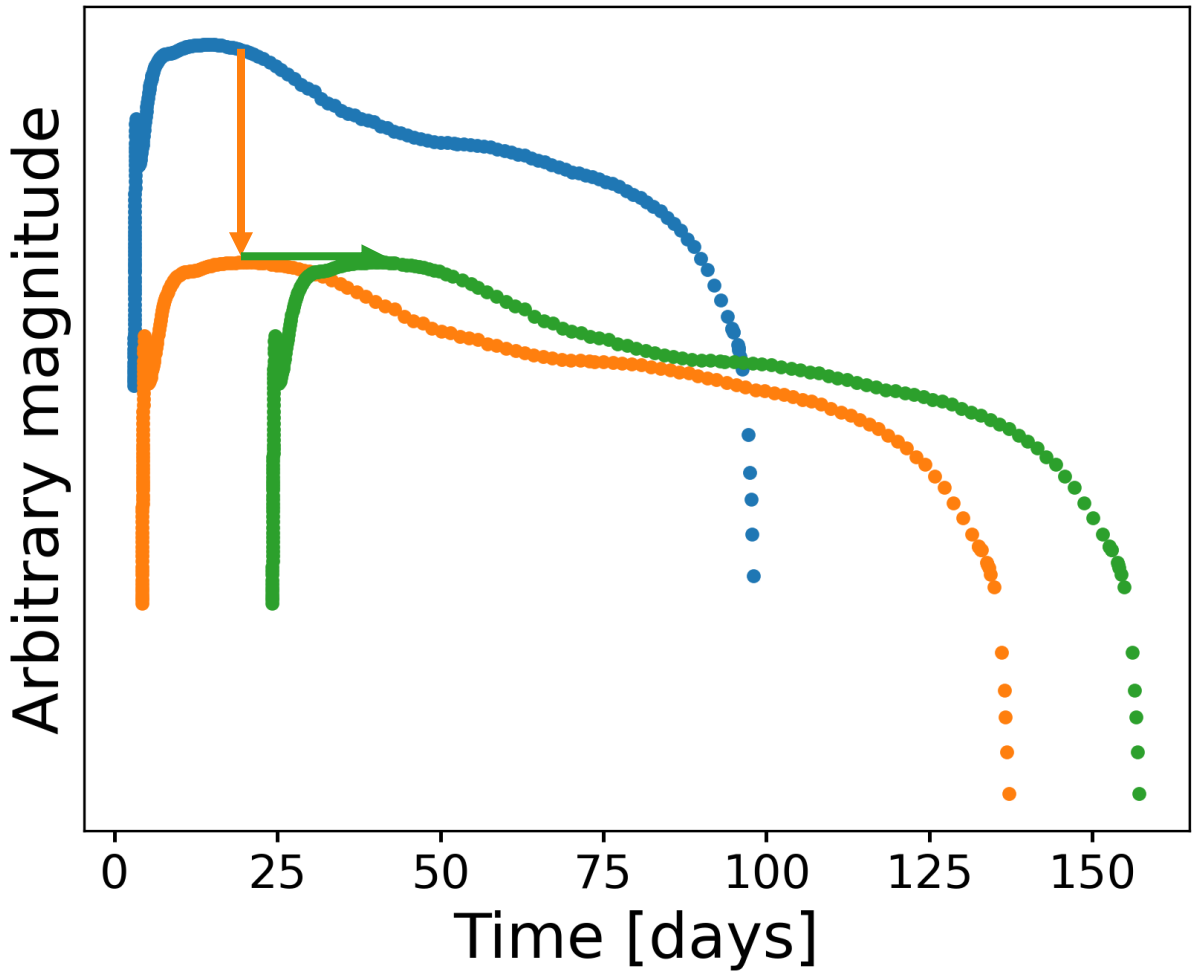
Training Data

Select lensed SN IIP form OM10 catalog

Oguri & Marshall (2010)

Source redshift

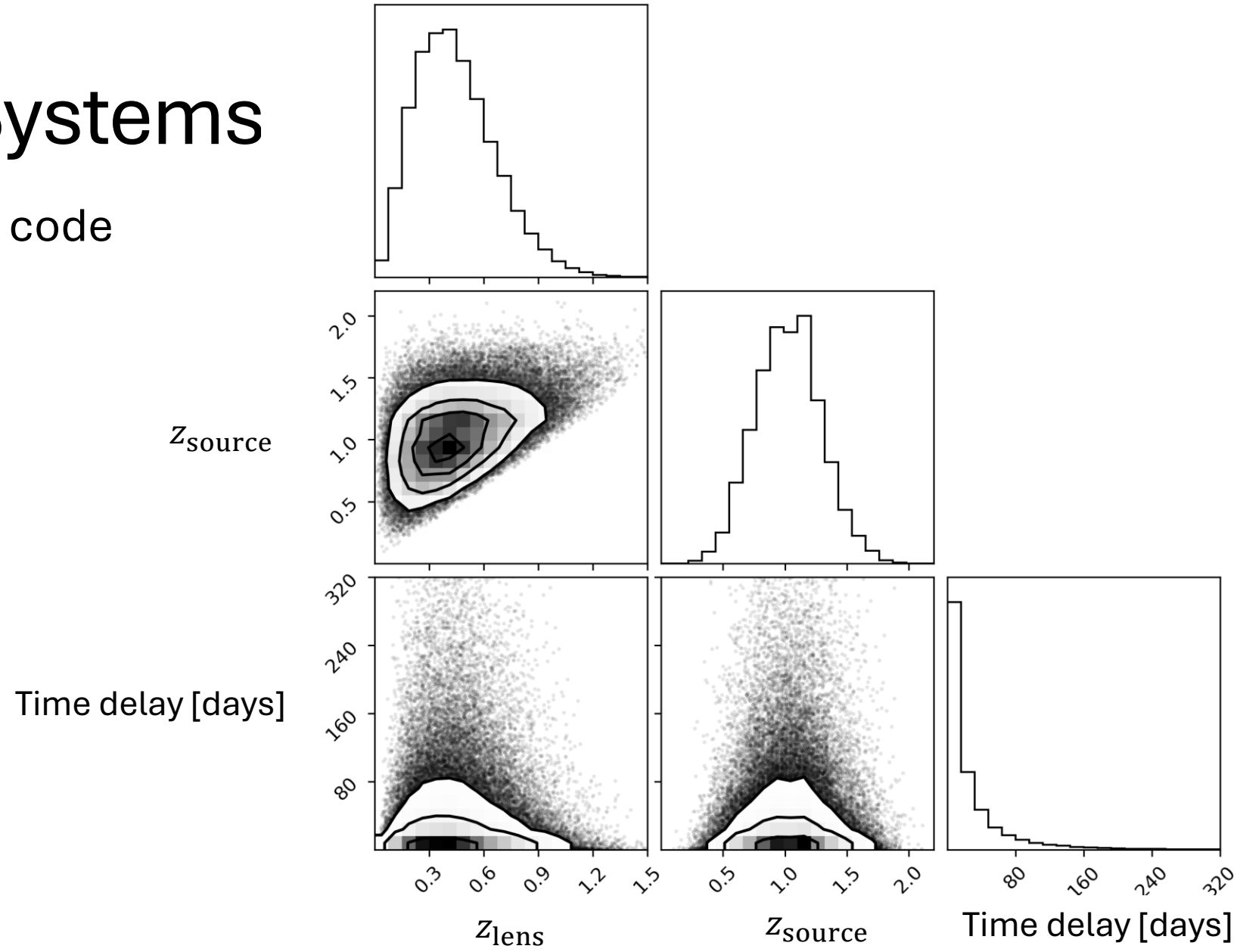
Time delay



Grupa Thesis (2025)

Lens Systems

from OM10 code



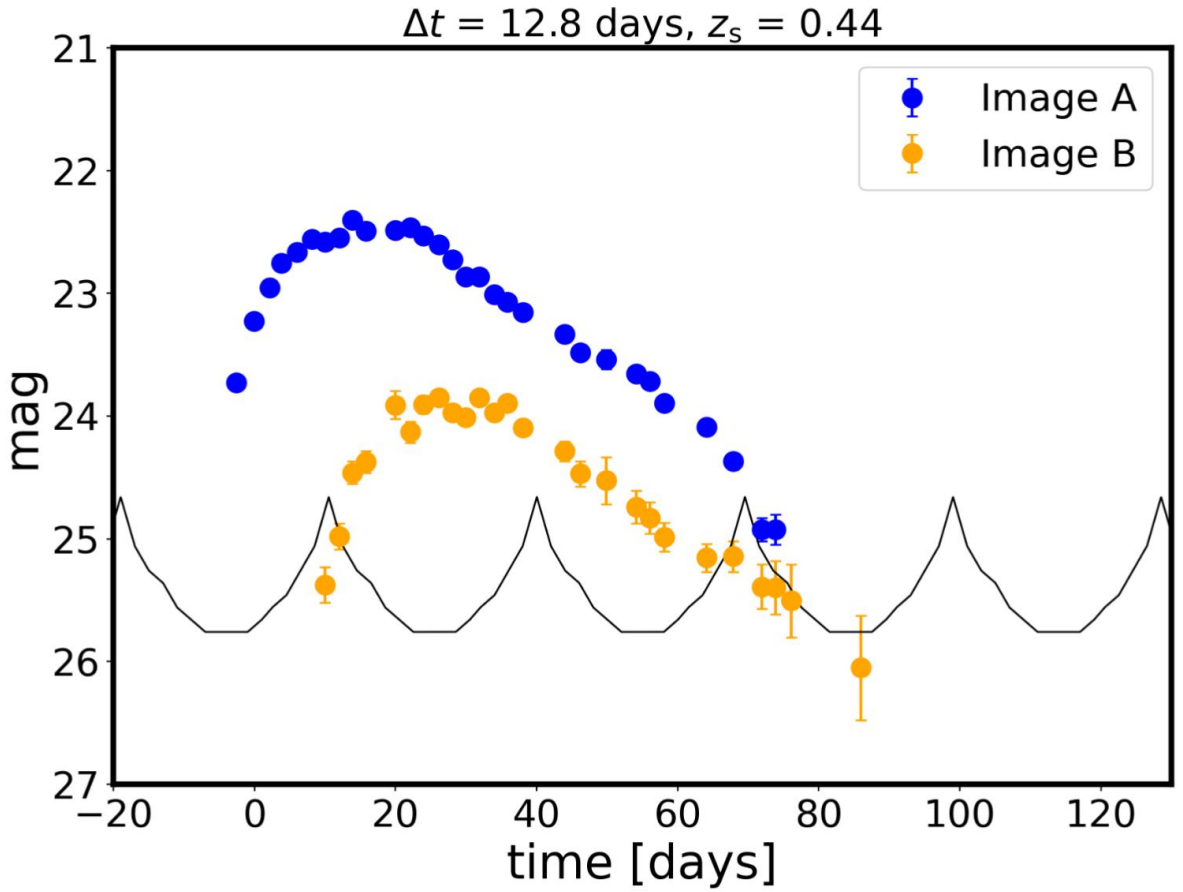
Training Data

Convert to 2 day cadence

Approximate K-corrections

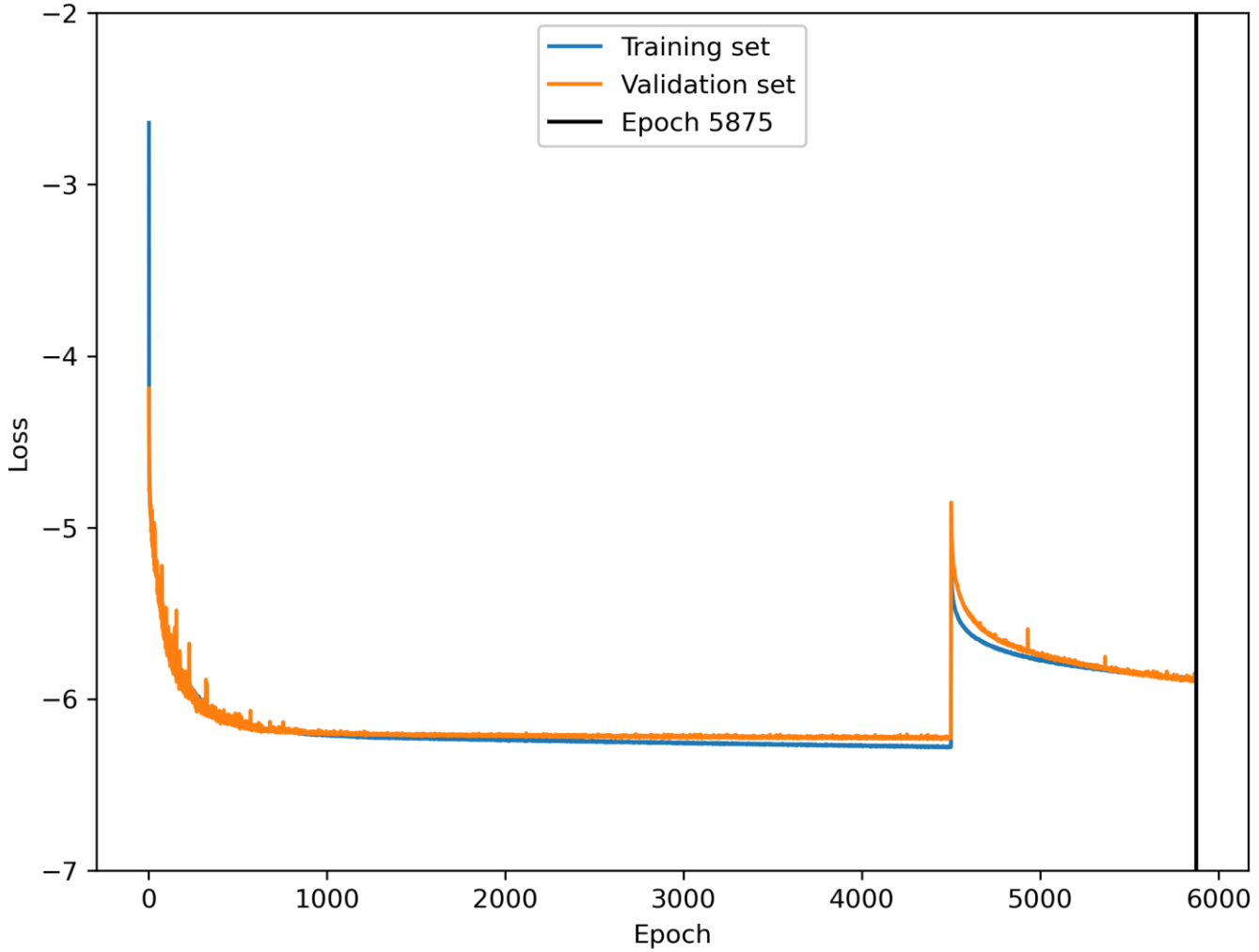
Simulate five sigma depth
➔ Shift data points
➔ Simulate uncertainty
Huber et al. (2022)

Simulate data loss ~25%



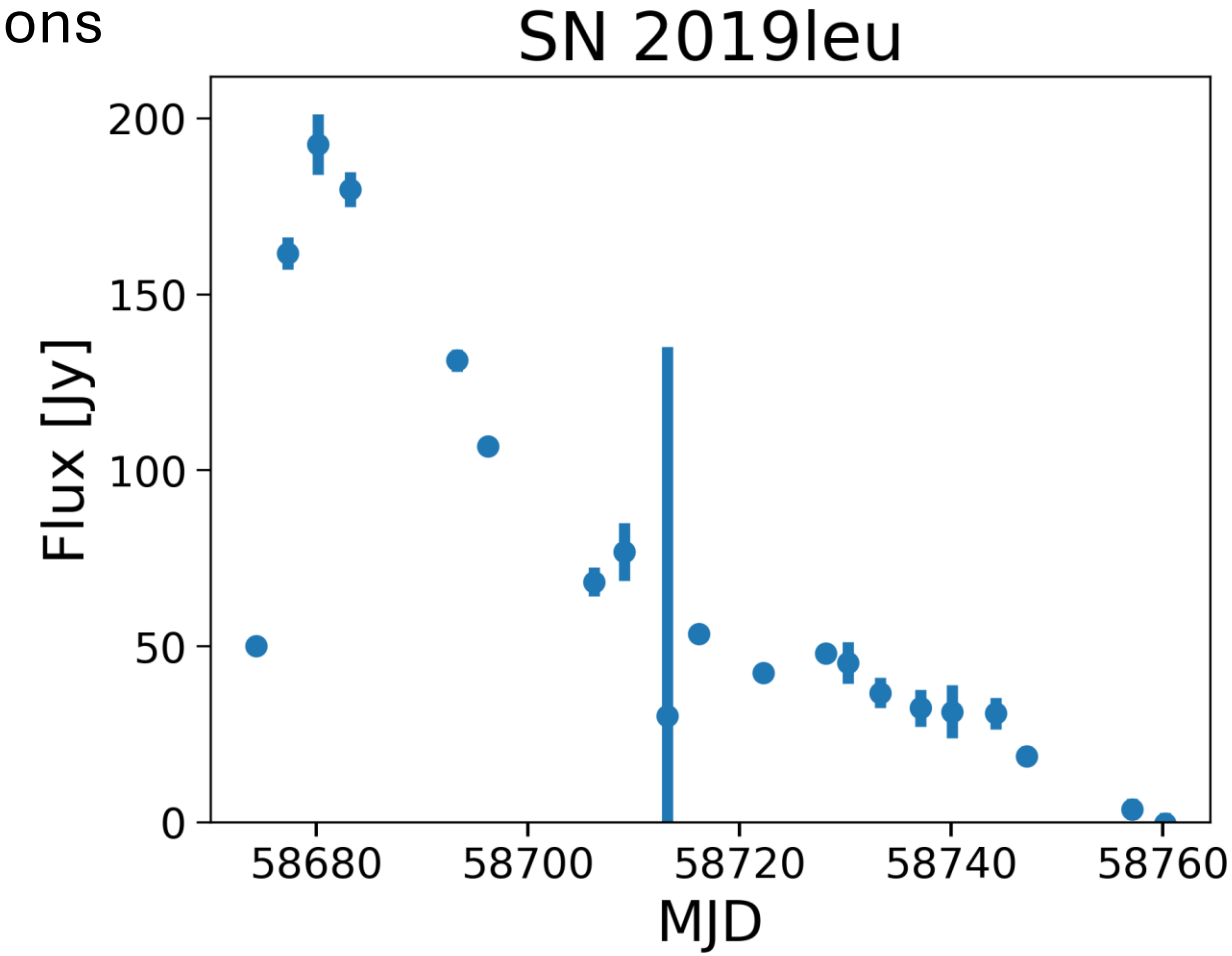
Grupa Thesis (2025)

Training the Network



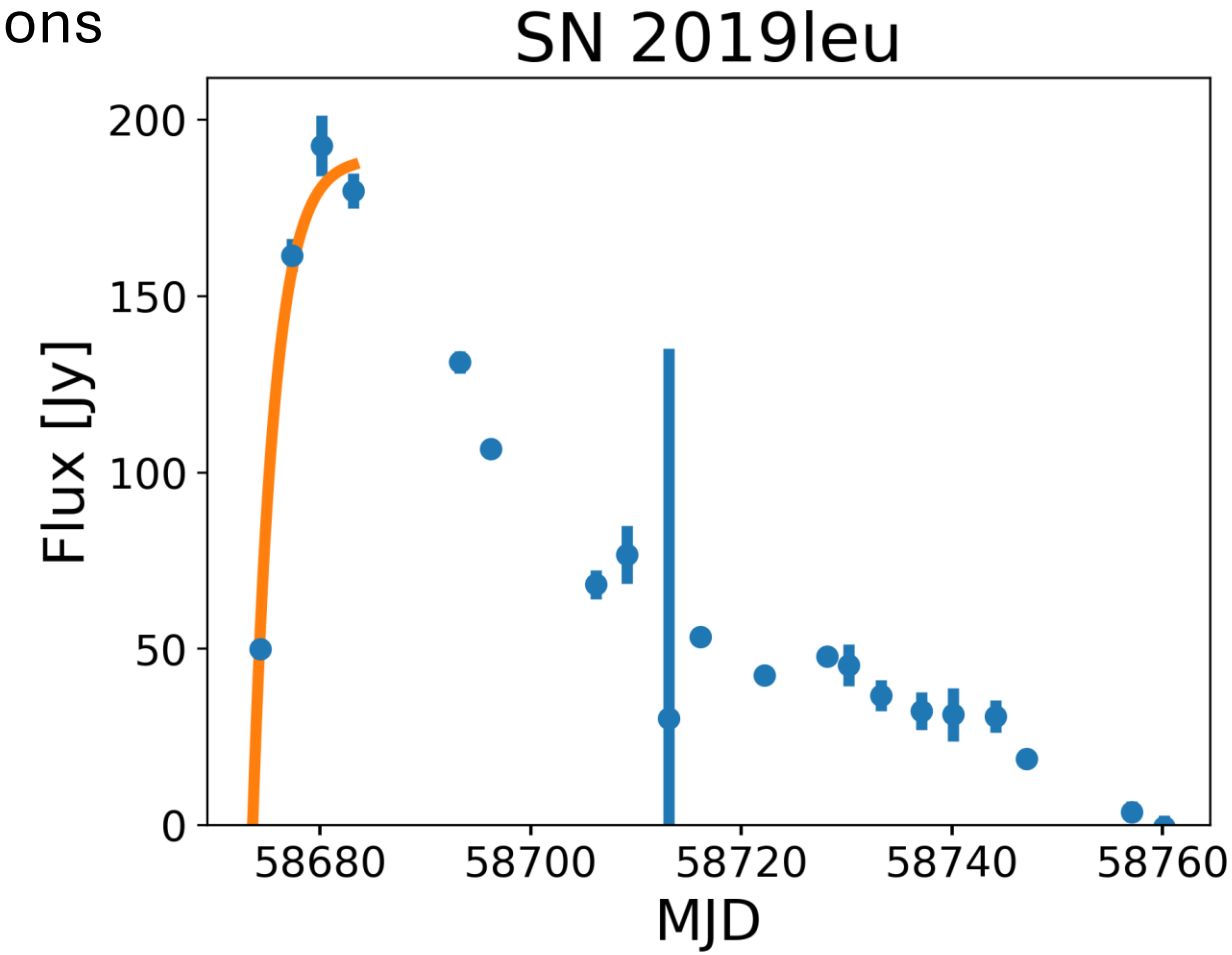
SN Light Curve

ZTF observations



SN Light Curve

ZTF observations

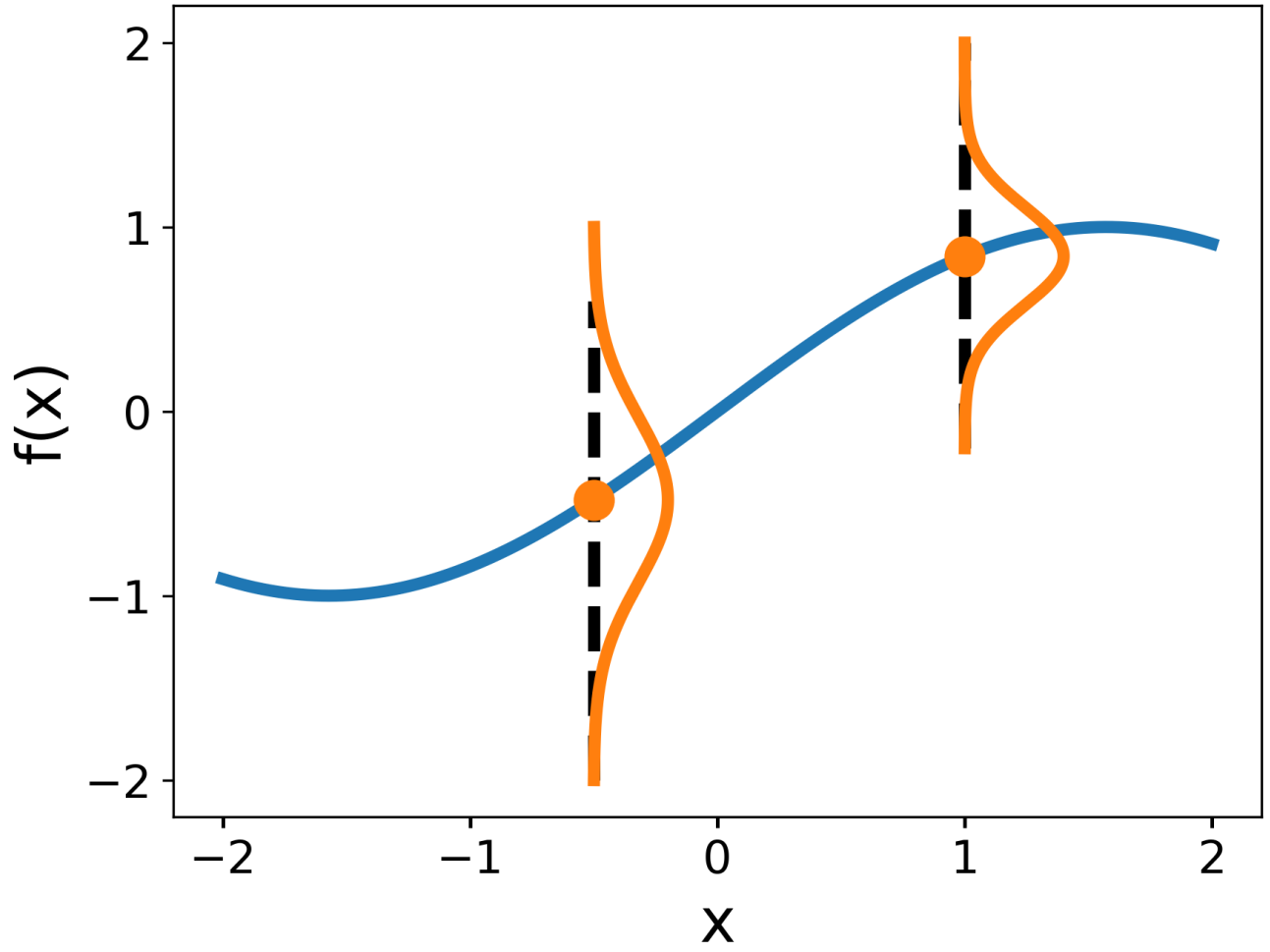


Exponential rise fit

$$A \cdot \left(1 - e^{-\frac{t-t_0}{t_r}}\right)$$

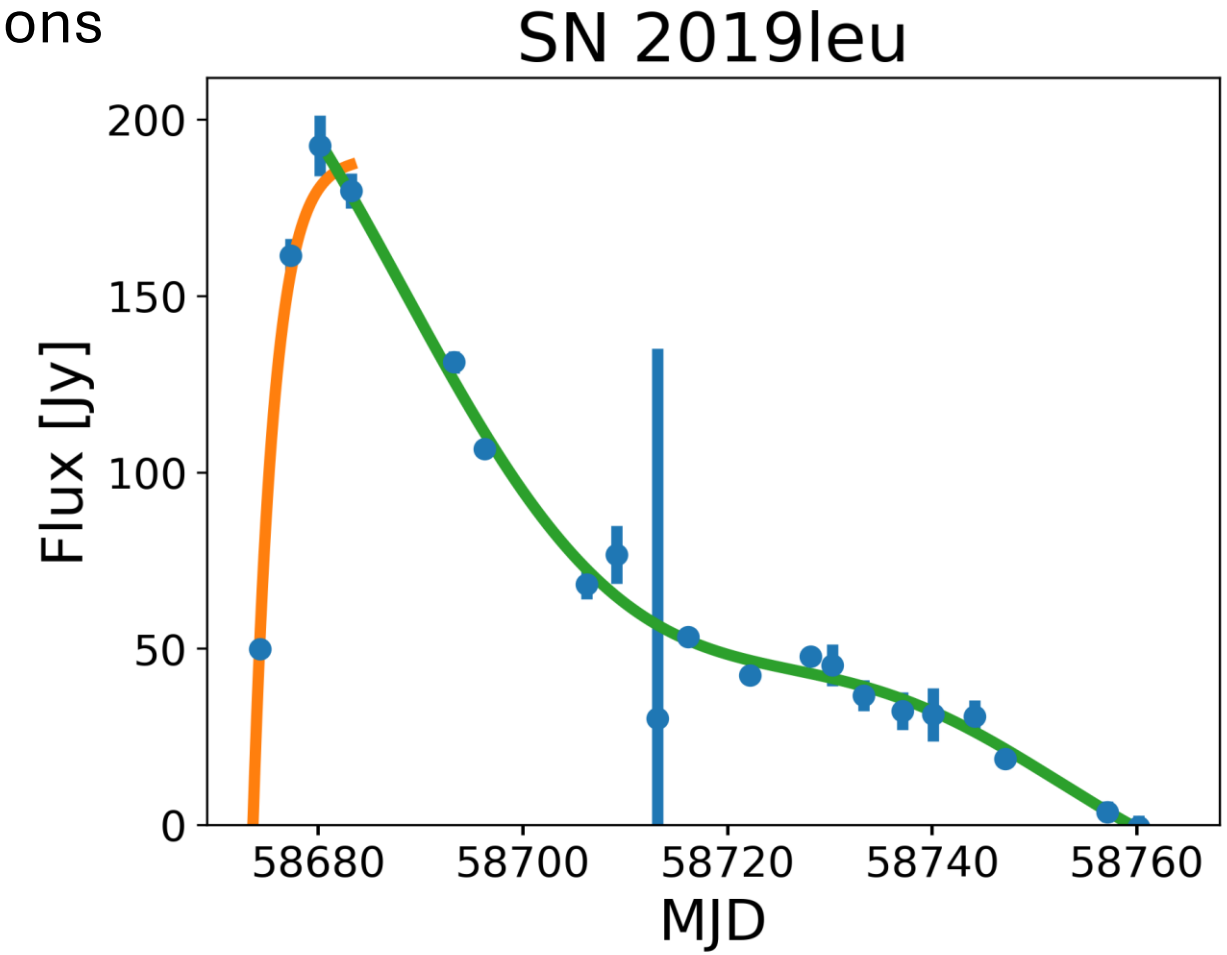
e.g. Csörnyei (2023)

Gaussian Process



SN Light Curve

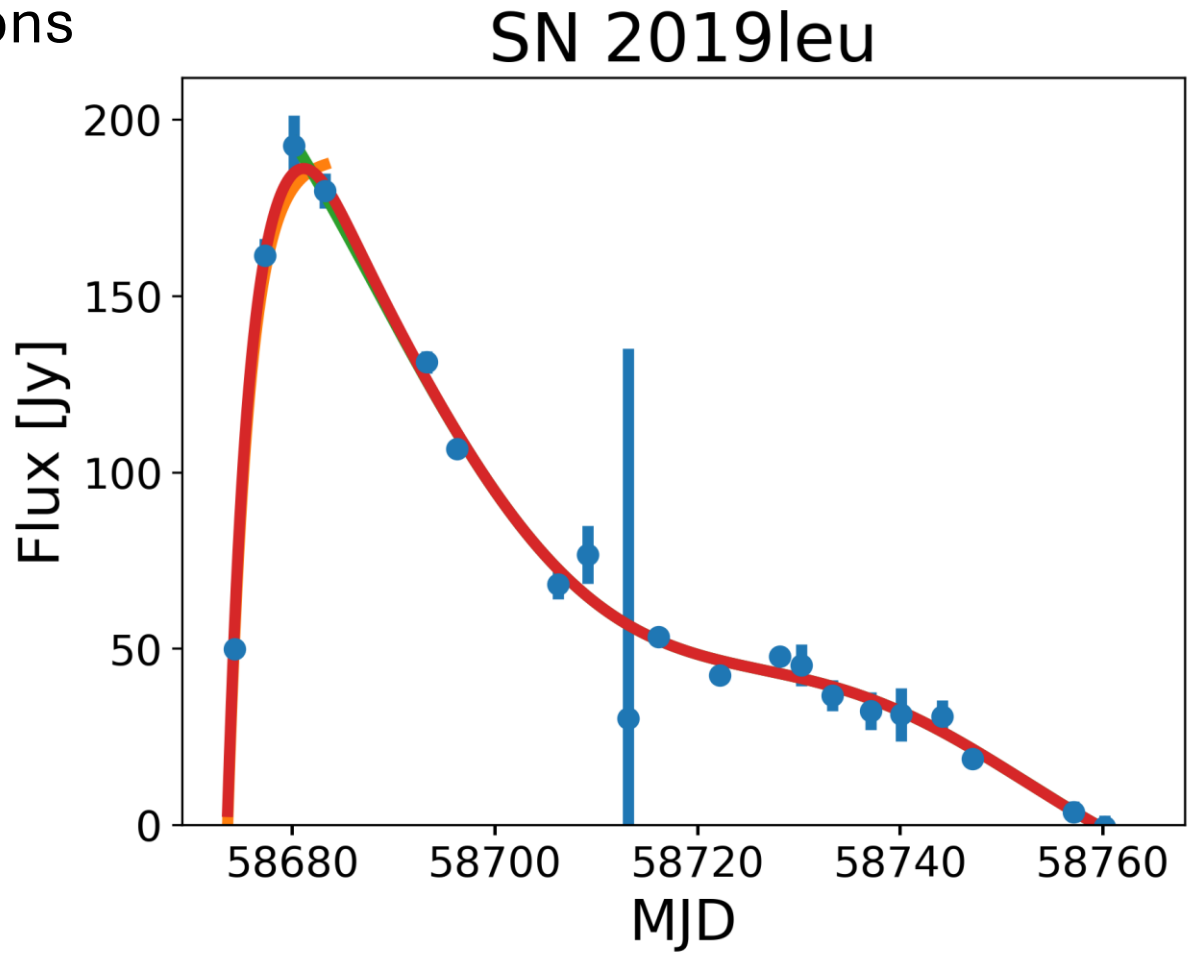
ZTF observations



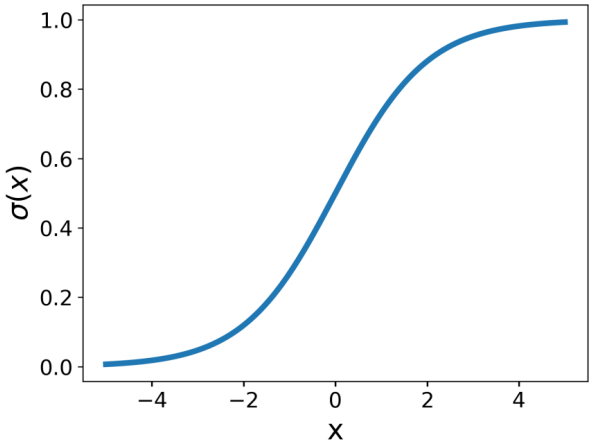
Fit decay with Gaussian Process

SN Light Curve

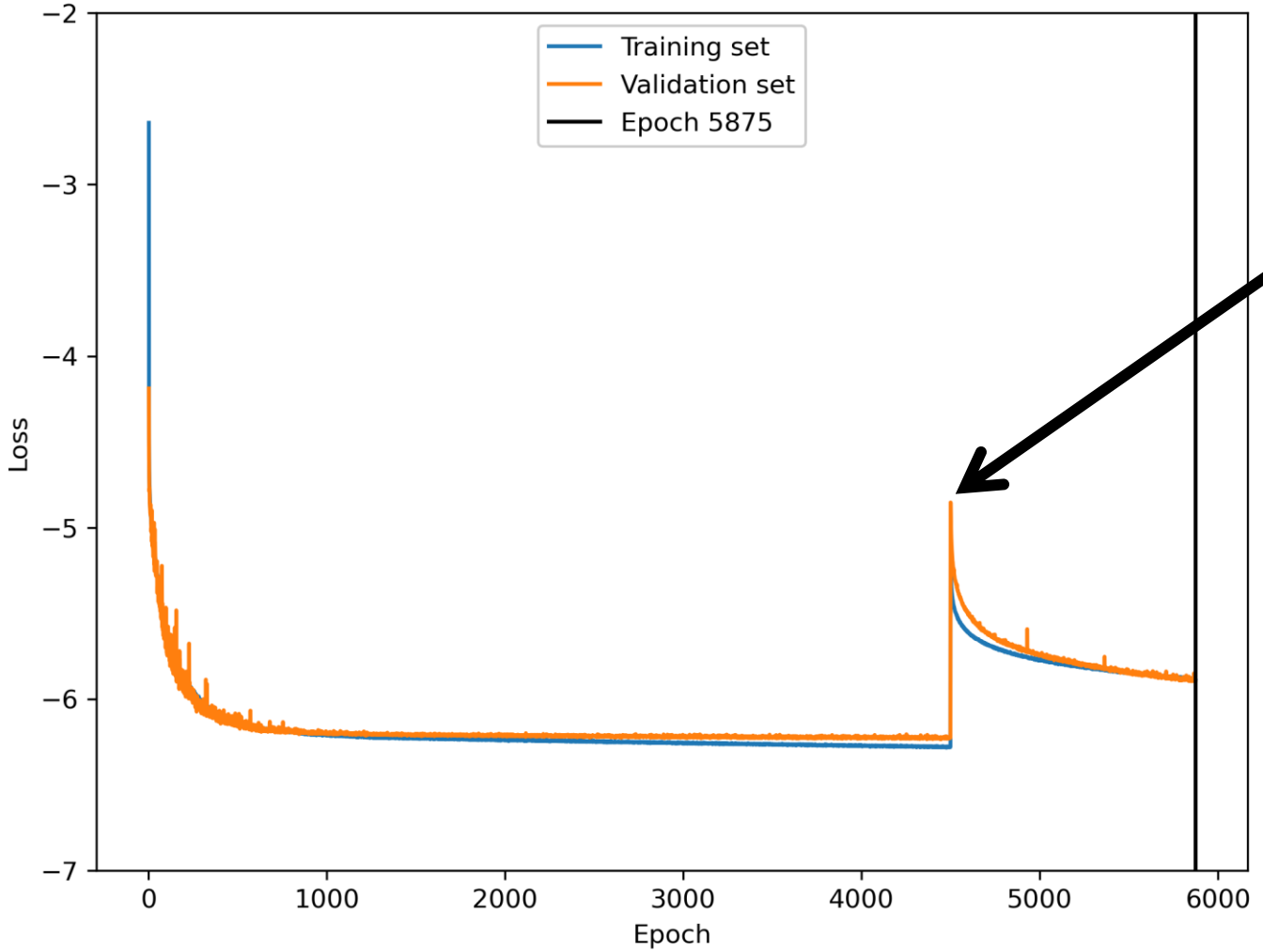
ZTF observations



Stitch with a smooth function

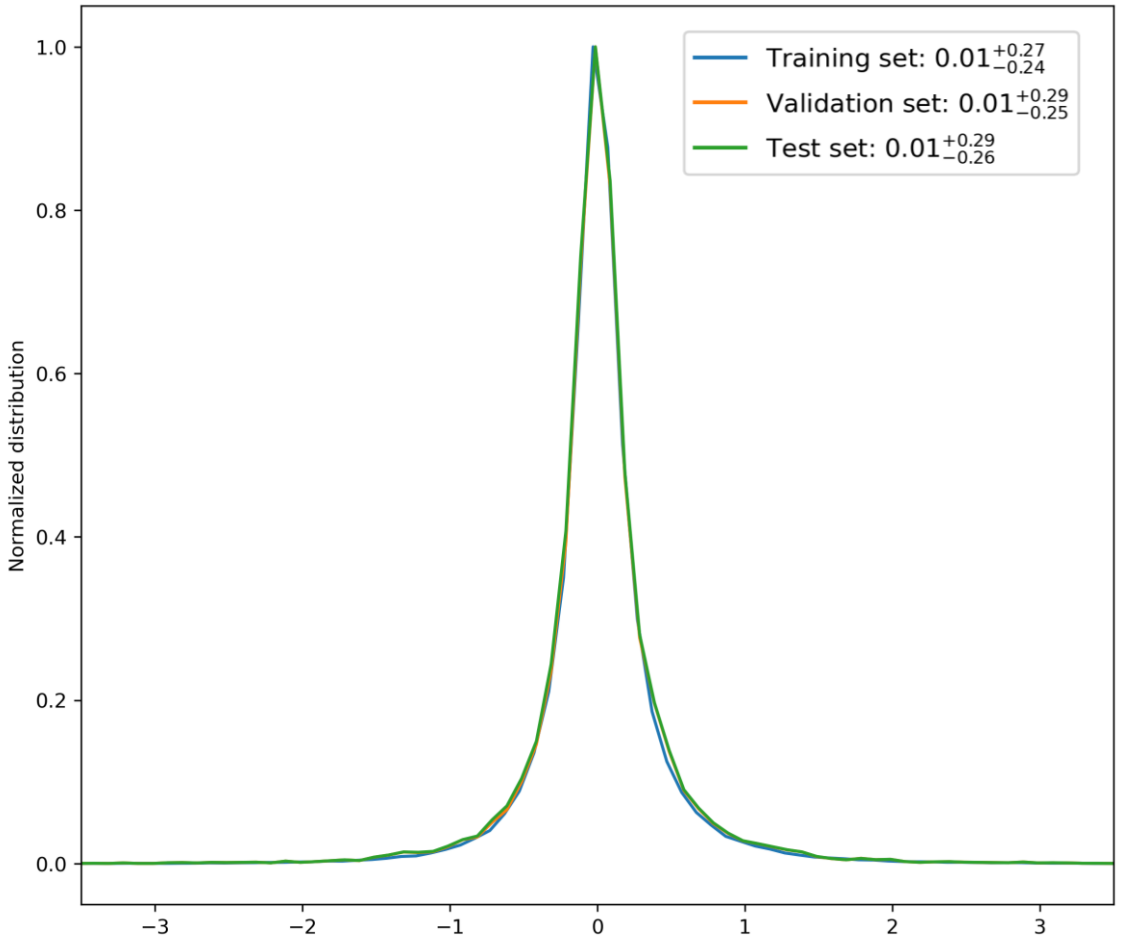


Training the Network



Add simulations based on 20 ZTF supernovae

After 5875 Epochs of Training

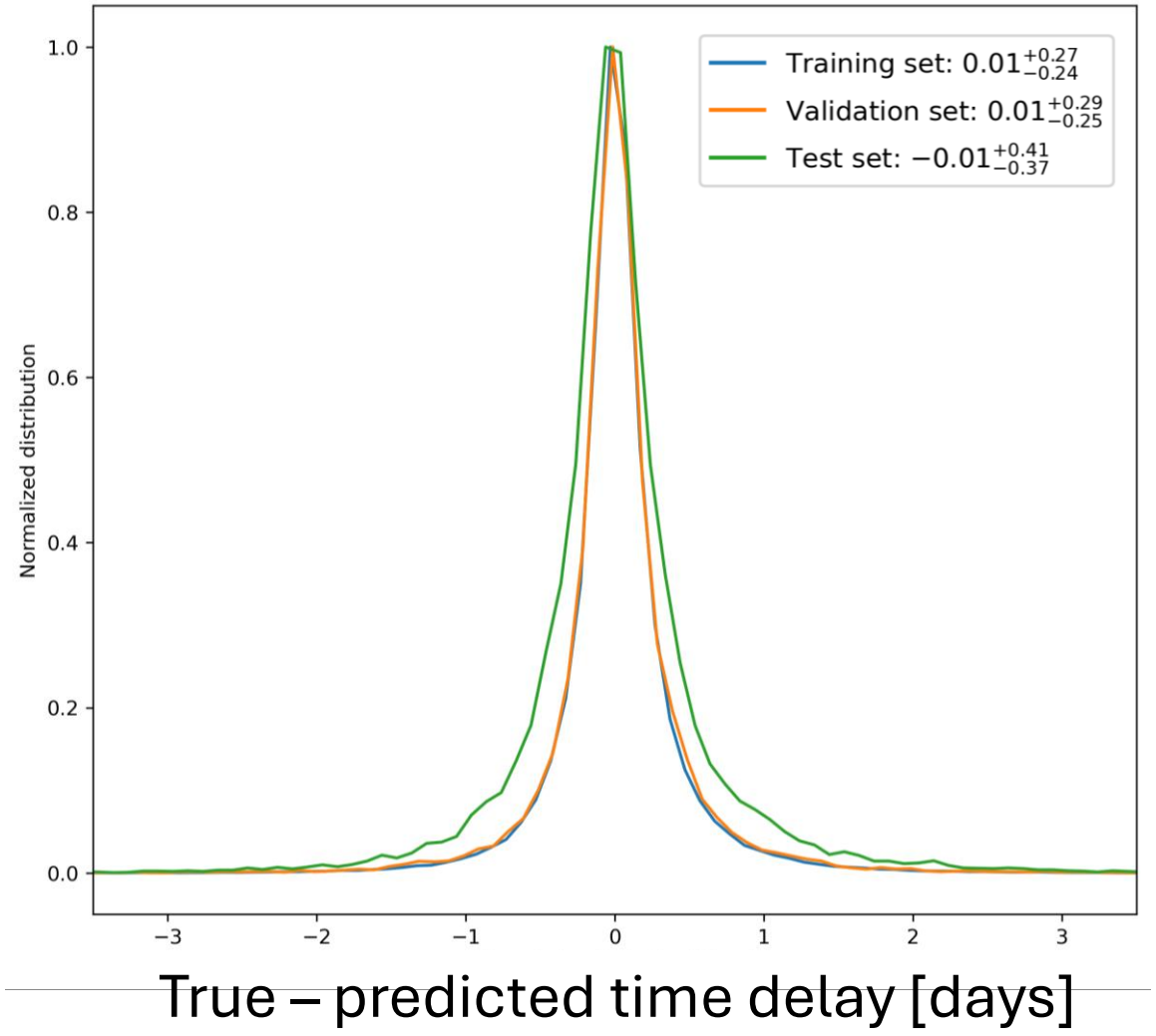


No overfitting

Small bias of 0.01

Standard deviation of $^{+0.29}_{-0.26}$

Having never seen this Data

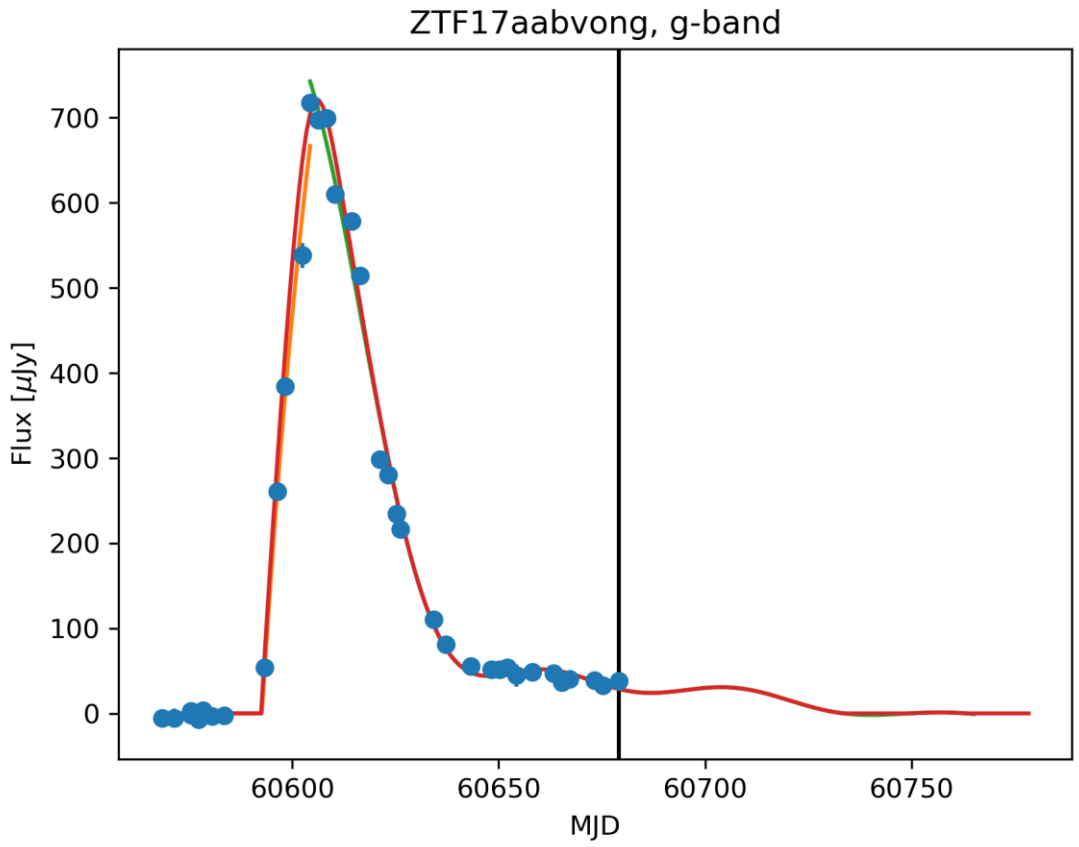


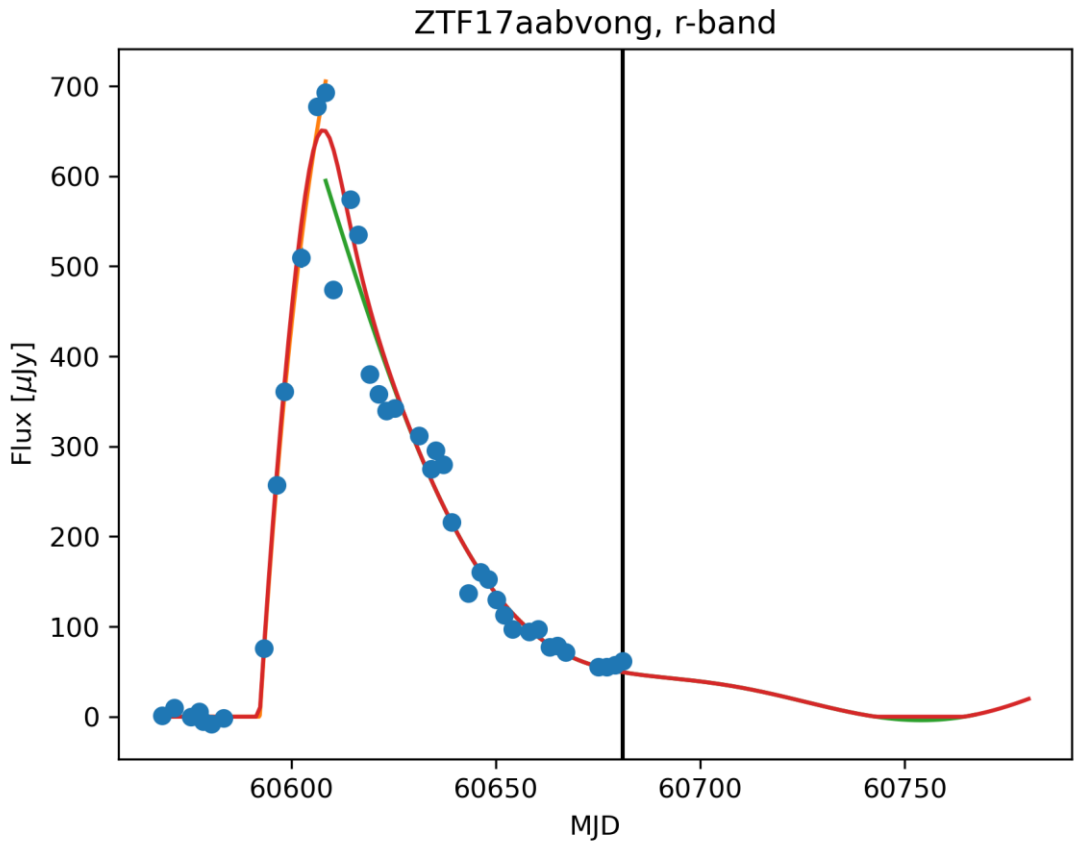
Testing on simulations based on 40 different ZTF SNe

Still performing at $-0.01\ ^{+0.41}_{-0.37}$

Expanding to all Types of SNe

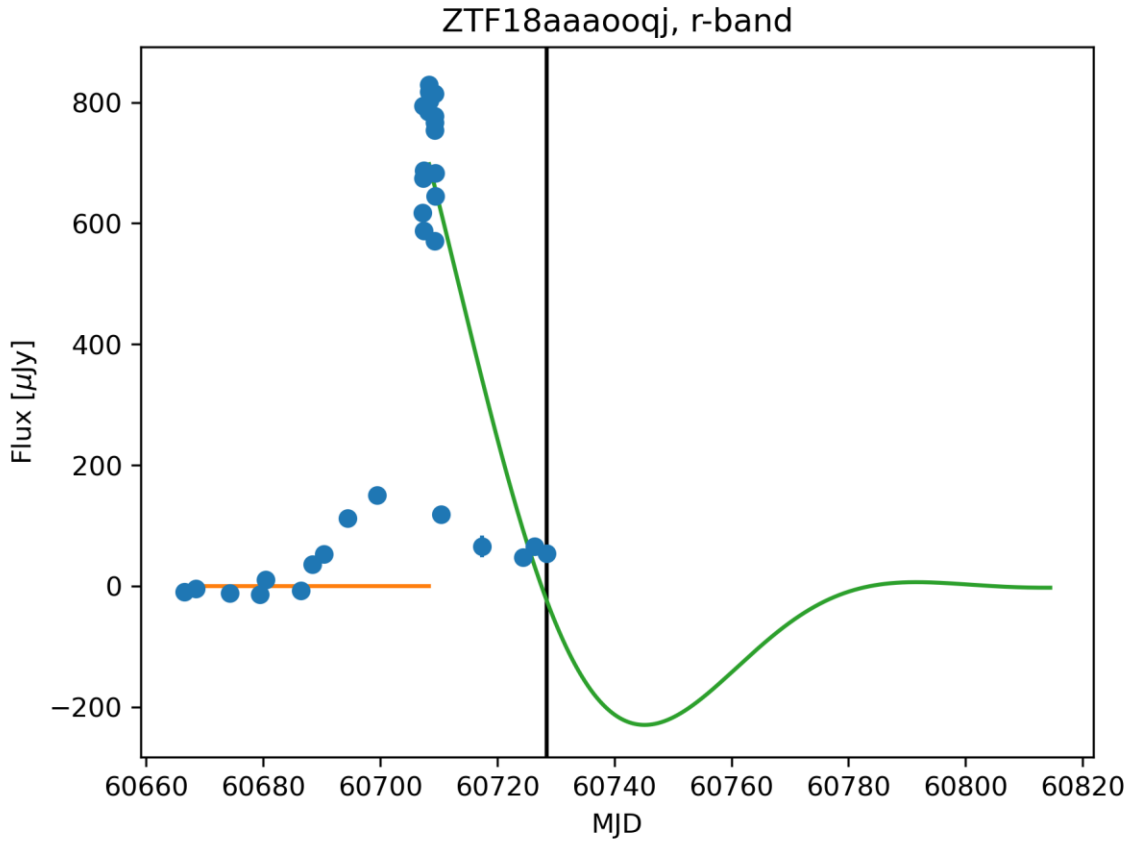
ZTF observations

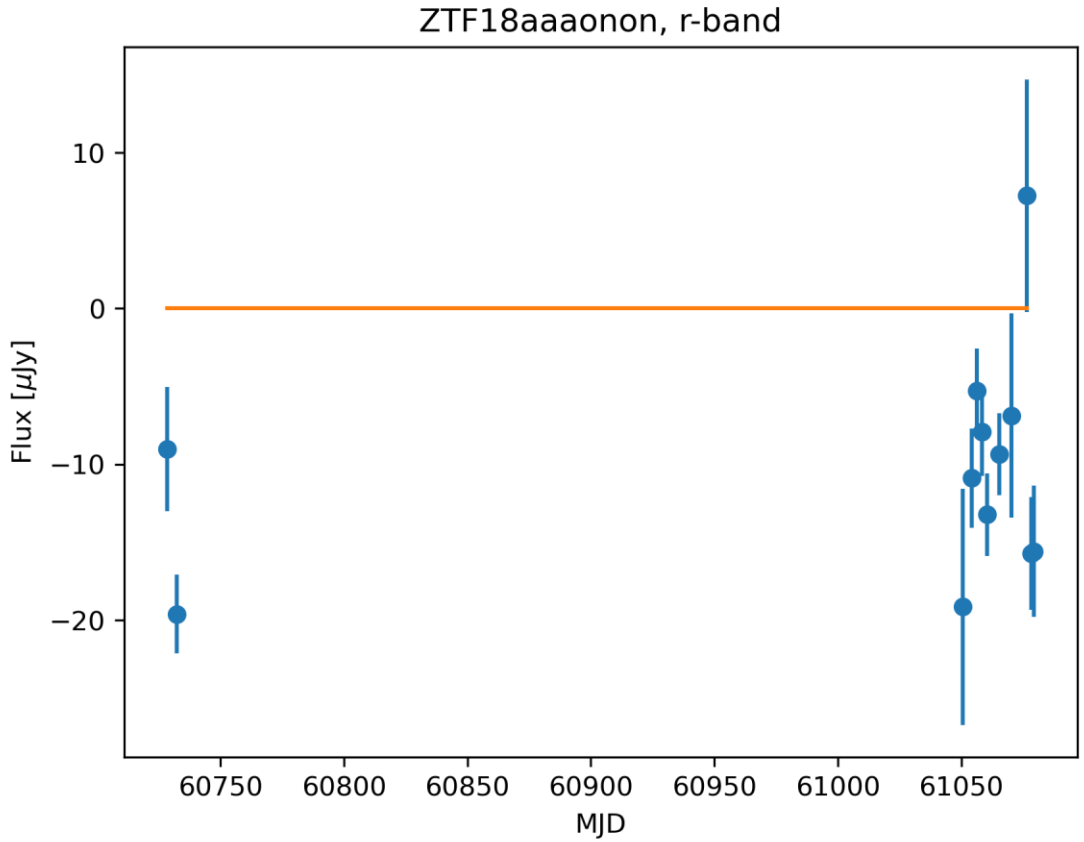




Expanding to all Types of SNe

ZTF observations





Training on all Types of SNe

True – predicted time delay [days]

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Conclusion

- LSTM performs very well on simulated SNe type IIP
  - On entirely simulated data and observation based simulations
- Generalizes very well
- Can (hopefully) expand to all SNe