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Augmenting Supernova Training Sets Using Generative Adversarial Networks

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erc European Research Council
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Supernovae

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Type Ia

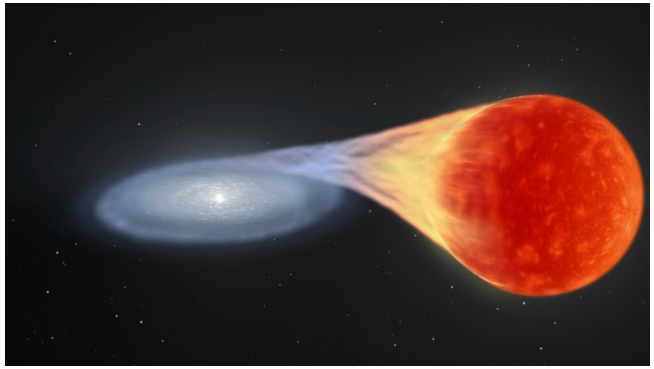
- White dwarf progenitor
- Standardisable candles

Core-collapse

- Massive star progenitor
- Very diverse properties

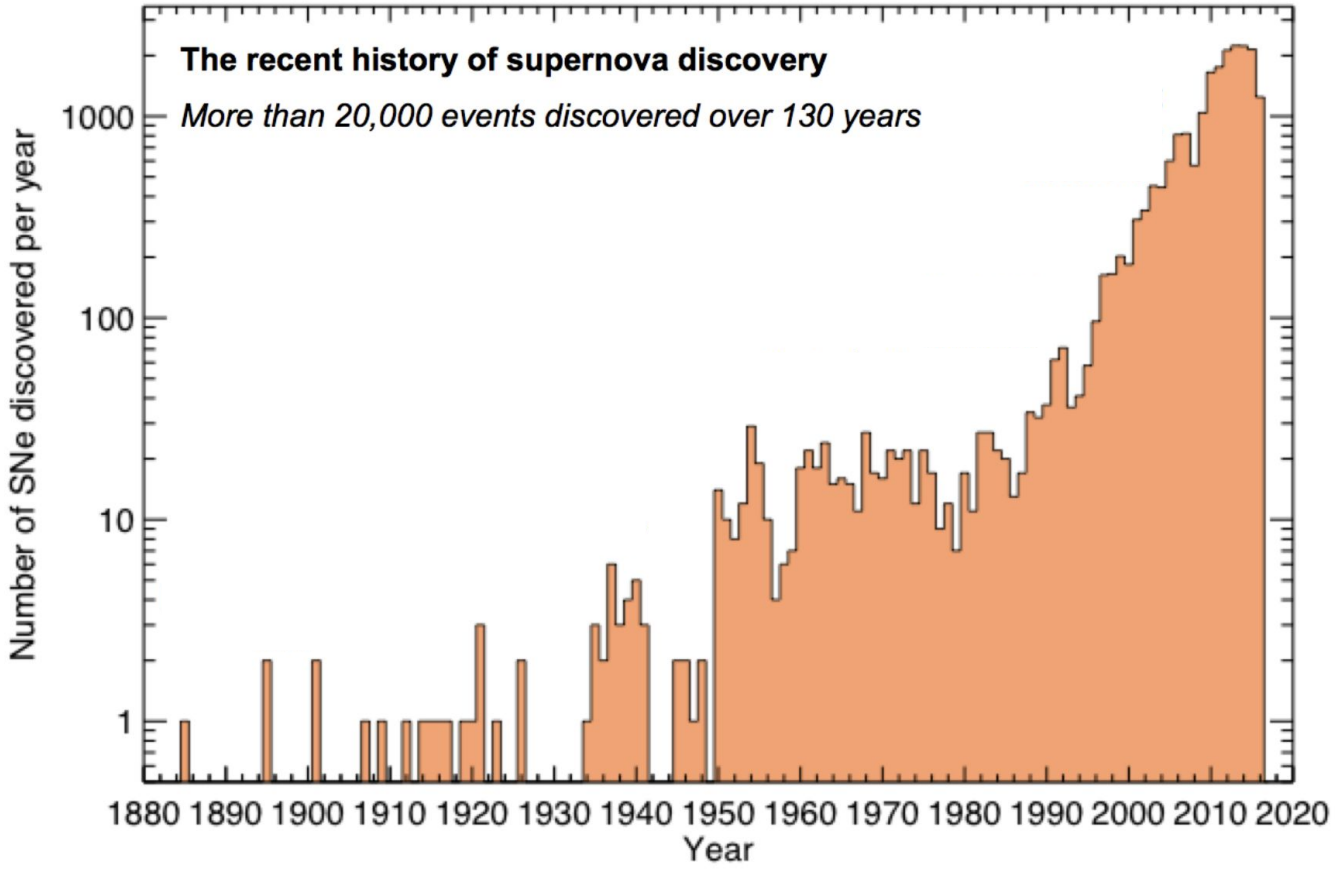
Significance of supernovae:

- Cosmologically useful
- Create and distribute heavy elements
- Influence their surroundings



Credit: Adriana Manrique Gutierrez svs.gsfc.nasa.gov

Supernovae



From 2024(ish):

Legacy Survey of Space and Time at Vera Rubin Observatory (LSST) - tens of thousands per year

Credit: Mark Sullivan

Supernova Classification

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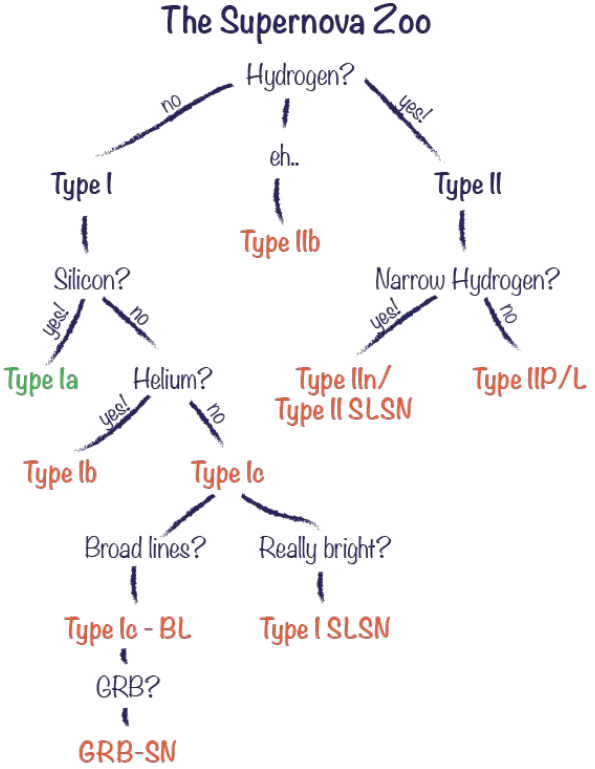
- Supernova classes defined based on spectral features
- High rate of discovery makes photometric classification vital
- For supernova cosmologists, classification is a simple binary Ia vs non-Ia problem
- For core-collapse astrophysicists, it is far more complex than that
- Machine learning-based classification techniques are being widely developed



Credit: Ashley Villar

Training on Simulations

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- Challenges with training on real data
  - Lack of training data
  - Biased training set
- Training on simulated data mitigates for the issues involved
- Limited by quality of simulations
  - Accurate simulations require good physical understanding of population
  - Supernovae are complex and diverse, simulations fail to reproduce full variability of population
  - Consistent drop in performance when applying models trained on simulations to real data

Generative Models

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- Generative models allow you to draw from the underlying distribution of your data without making any assumptions about it
- We can use generative models to create synthetic supernovae without knowing anything about the physics involved
- Generating synthetic training sets using generative adversarial networks (GANs) has been used to improve the performance of classification models, both within astronomy and beyond (e.g. Motamed+21, Garcia-Jara+22)

Generative Adversarial Networks (GANs)

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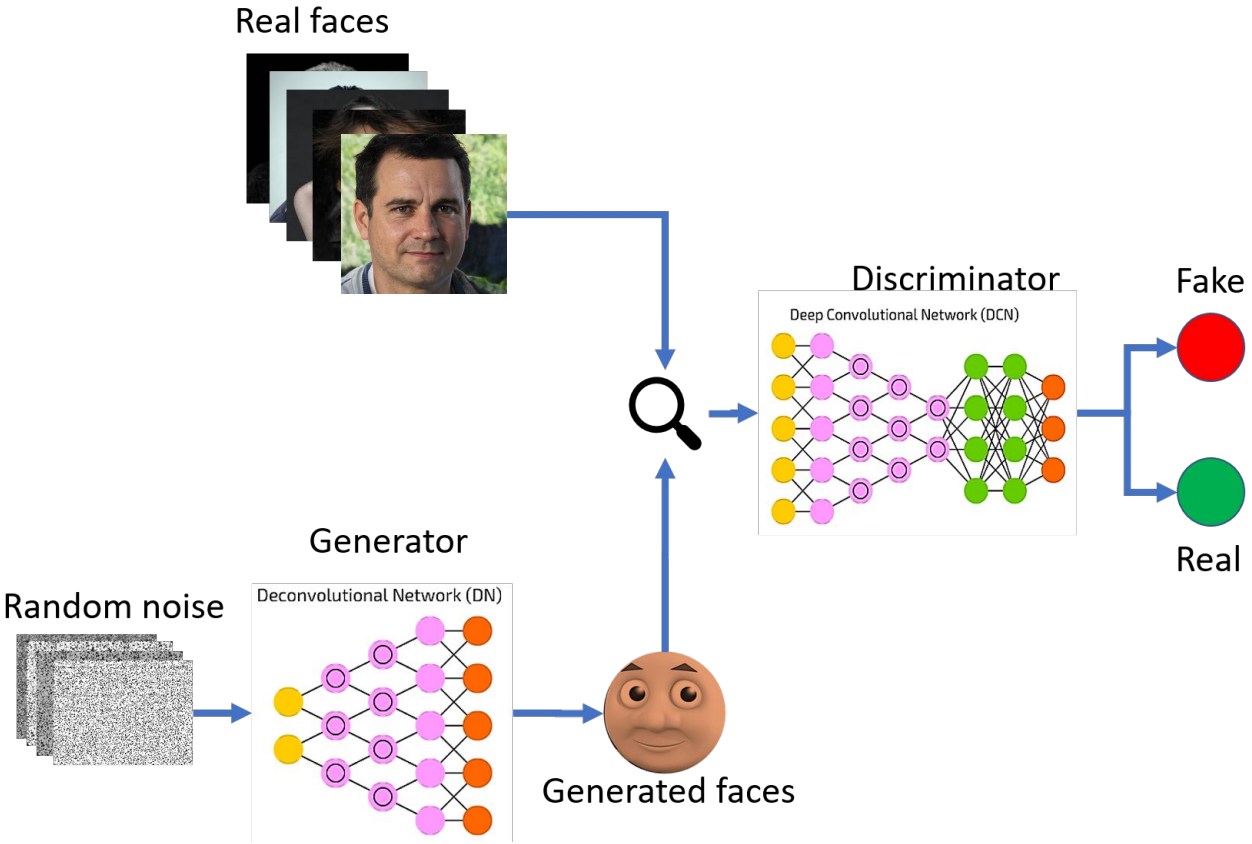

Application to Supernovae

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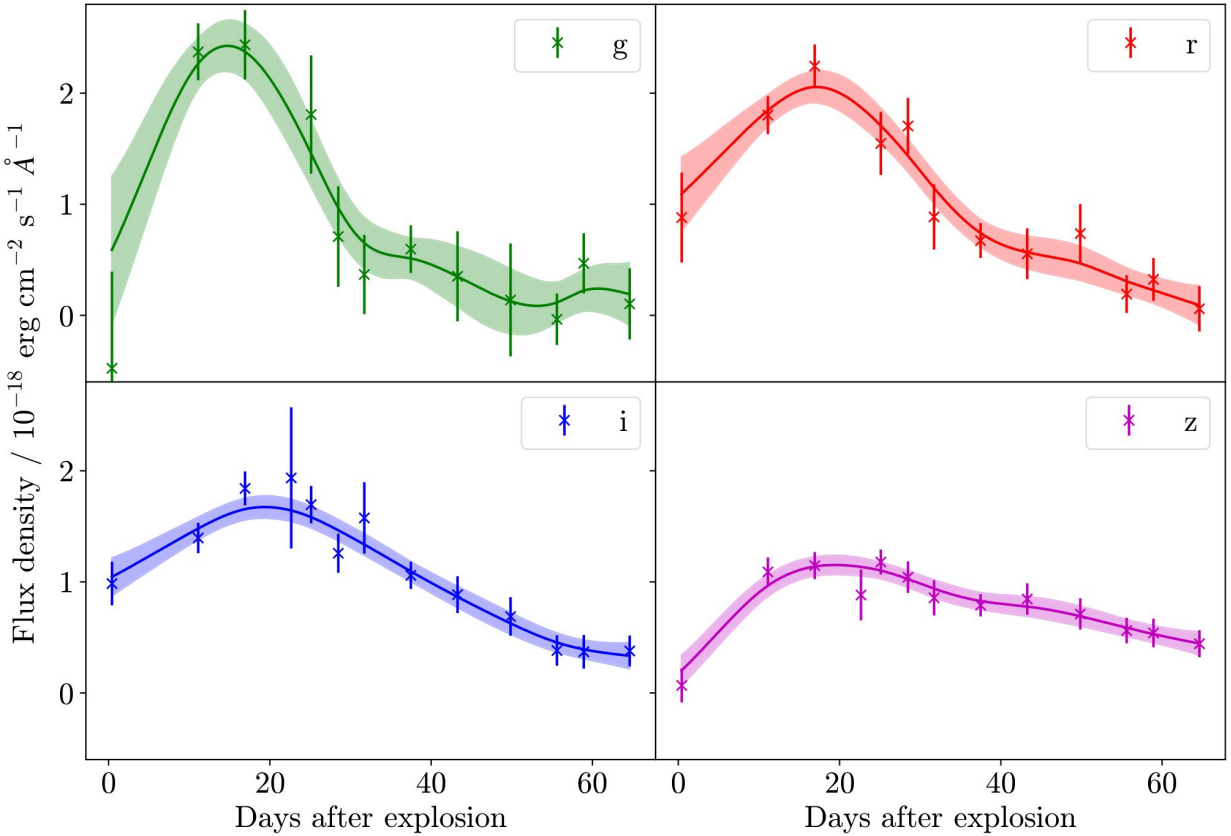

Application to Supernovae

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- Train a GAN using recurrent neural networks (RNNs) for both generator and discriminator, allows for variable length time series generation
- Phases and photometric data + uncertainties generated together as below

	g_t	r_t	i_t	z_t	g	r	i	z	g_err	r_err	i_err	z_err
1												
2												
⋮												
N												

Light Curve Examples (SNe II)

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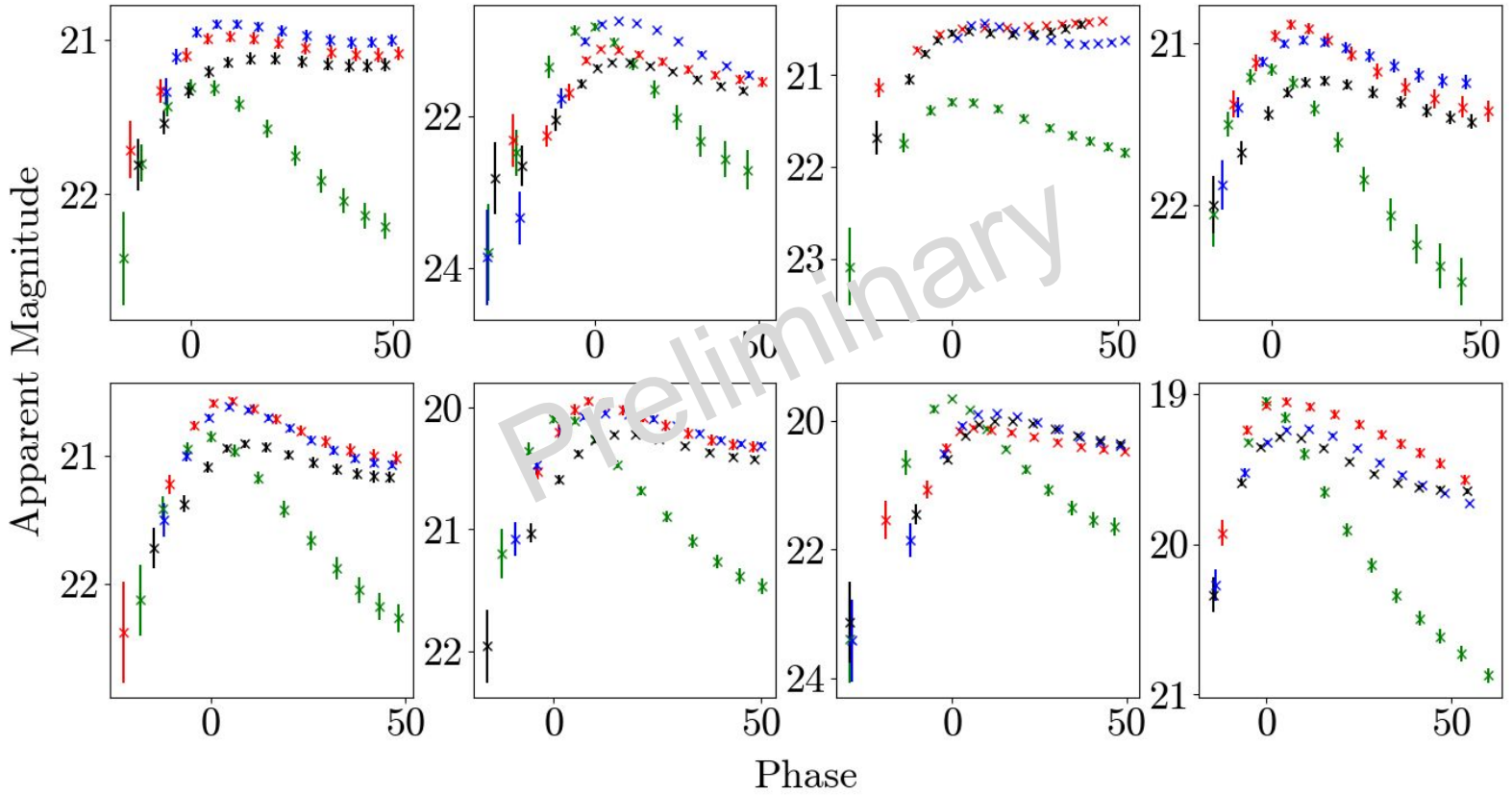

Peak Observed Brightness

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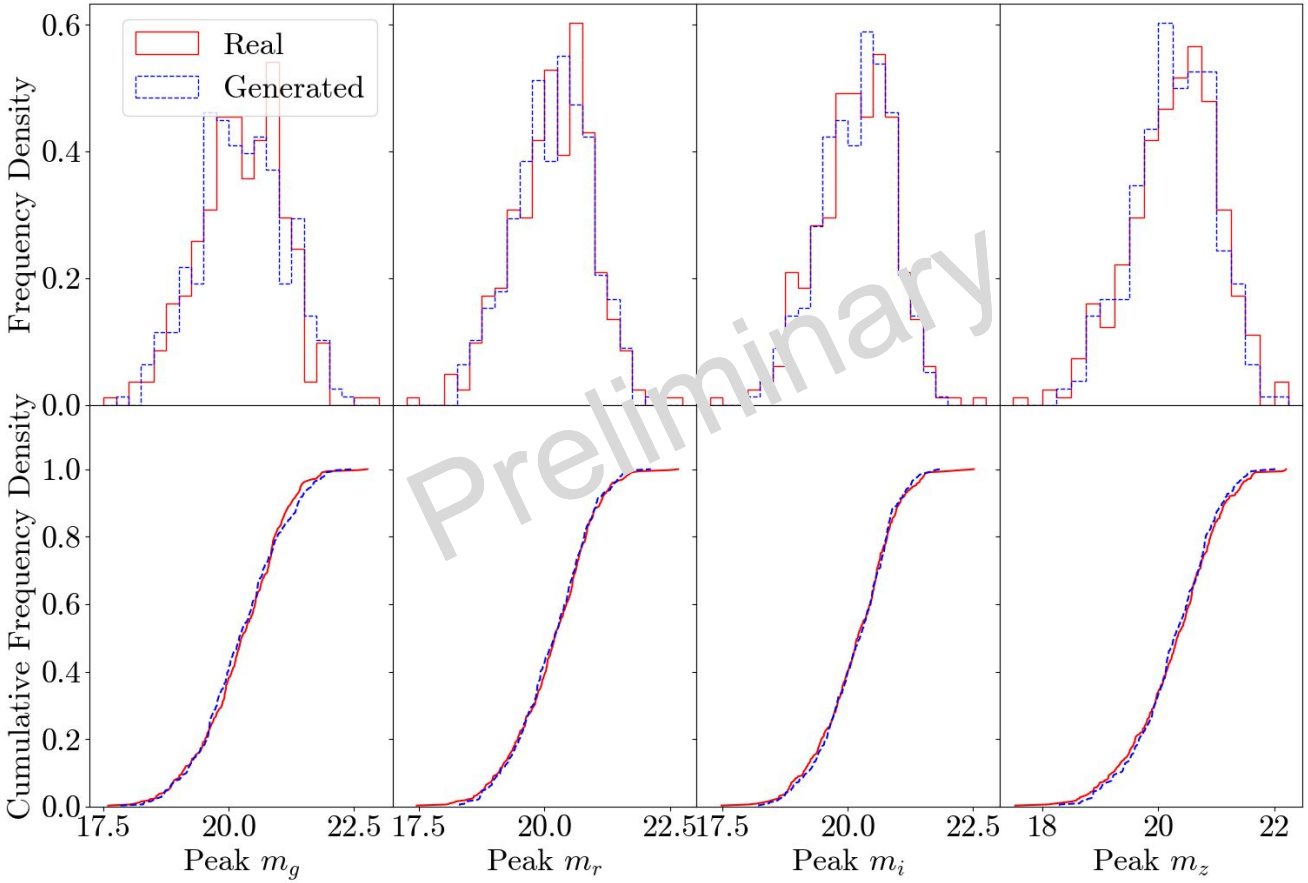

Light Curve Populations

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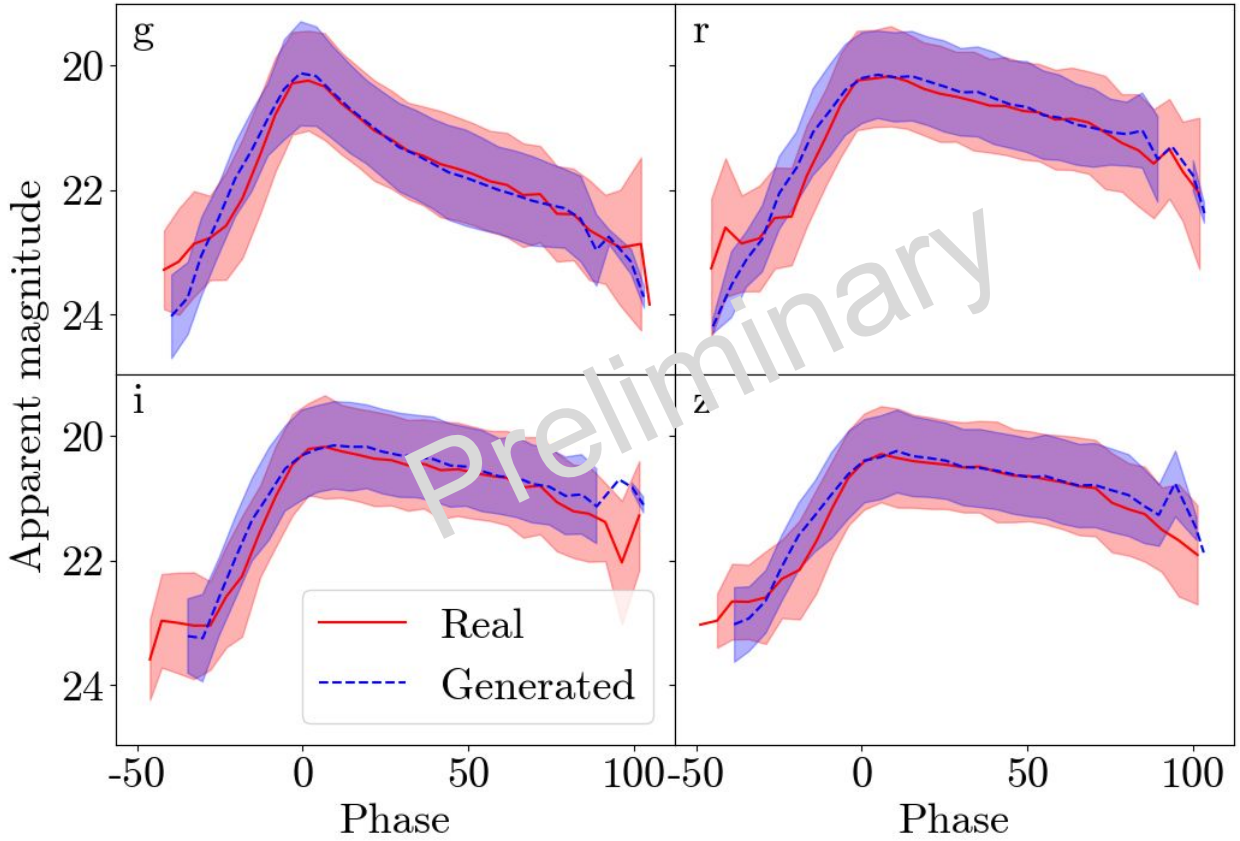

Augmenting Rare Supernova Classes

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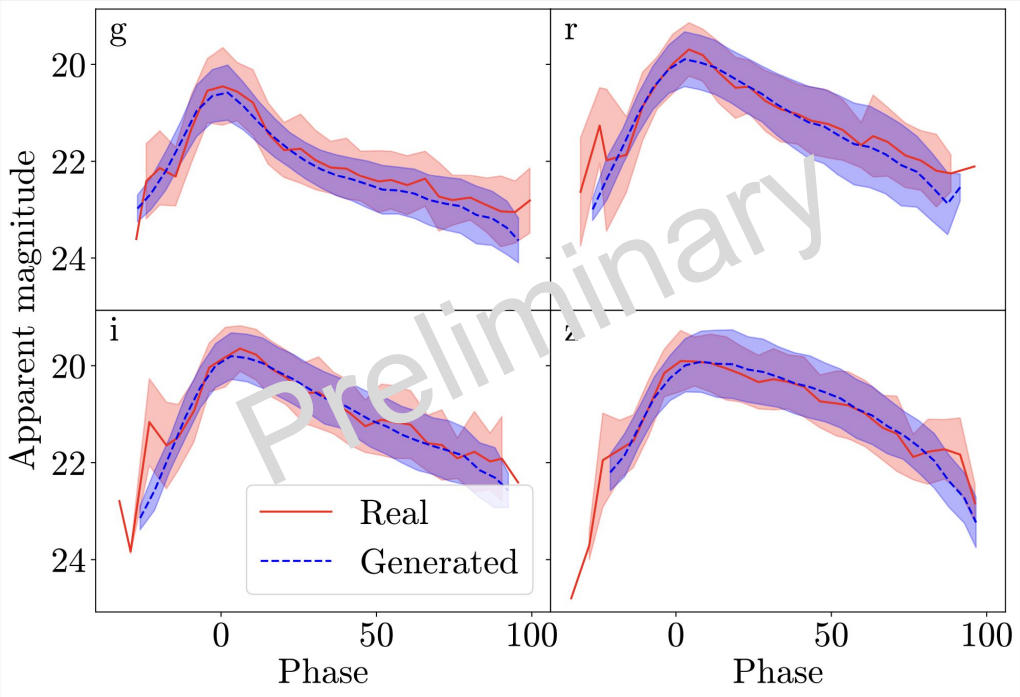
- Previous plots were for sample of ~350 simulated supernovae
- Training on a much smaller data set of ~30 supernovae still produces comparable results
- For rare SN classes with few examples, this approach has the potential to augment very sparse training sets



Summary

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- GANs have the ability to generate realistic supernova light curves, and the potential to improve the performance of photometric classifiers
- Improvements and future work:
  - Train a classifier with generated data and assess performance
  - Retrain on real data
  - Explore conditional models, allowing one model to generate all types of supernovae
  - Explore other types of generative model such as diffusion models