NUdata

Newcastle University

UKRI Science and Technology Facilities Council

CASTING A DEEPER NET: DETECTING BLACK HOLES WITH OPTICAL SURVEYS

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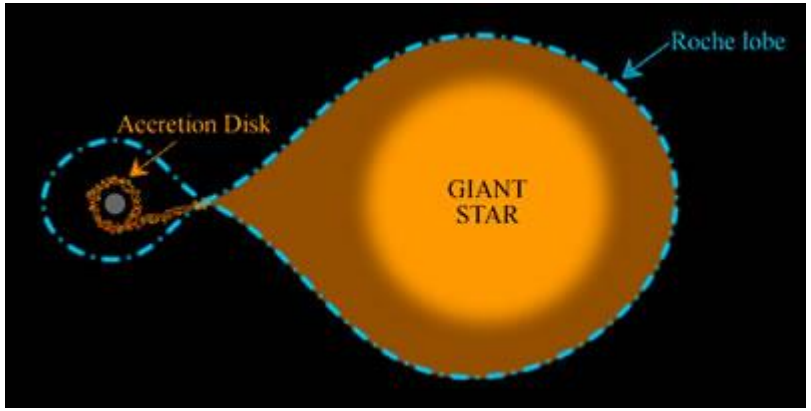
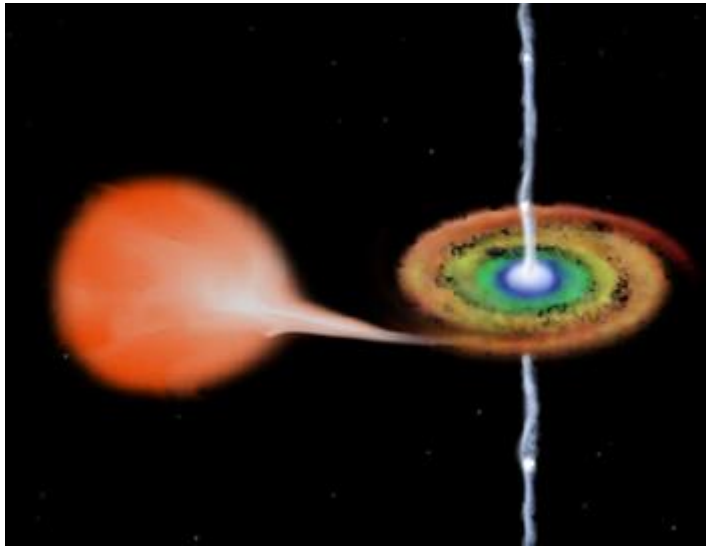
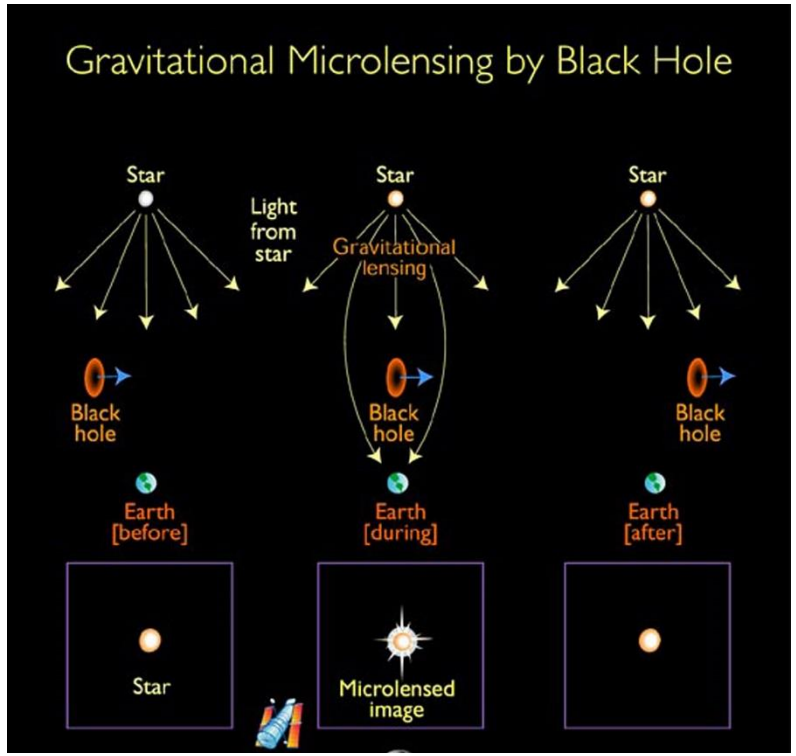
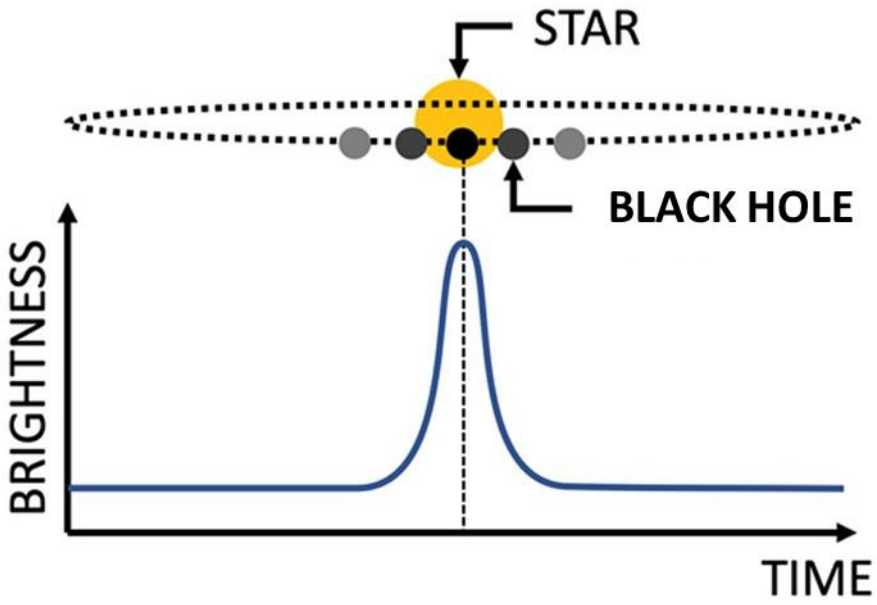
WHAT DOES A BLACK HOLE LOOK LIKE?

We can observe the effects of accretion in narrow binaries
We can track the orbits of nearby stars
Occasionally, we observe microlensing









Chance alignment is rare – self-lensing offers repeated measurements!

PARAMETER SPACE

Binary system parameters

- Lens mass
- Star mass
- Star radius
- Orbit period
- Inclination (HIGH)
- eccentricity

MS star parameters

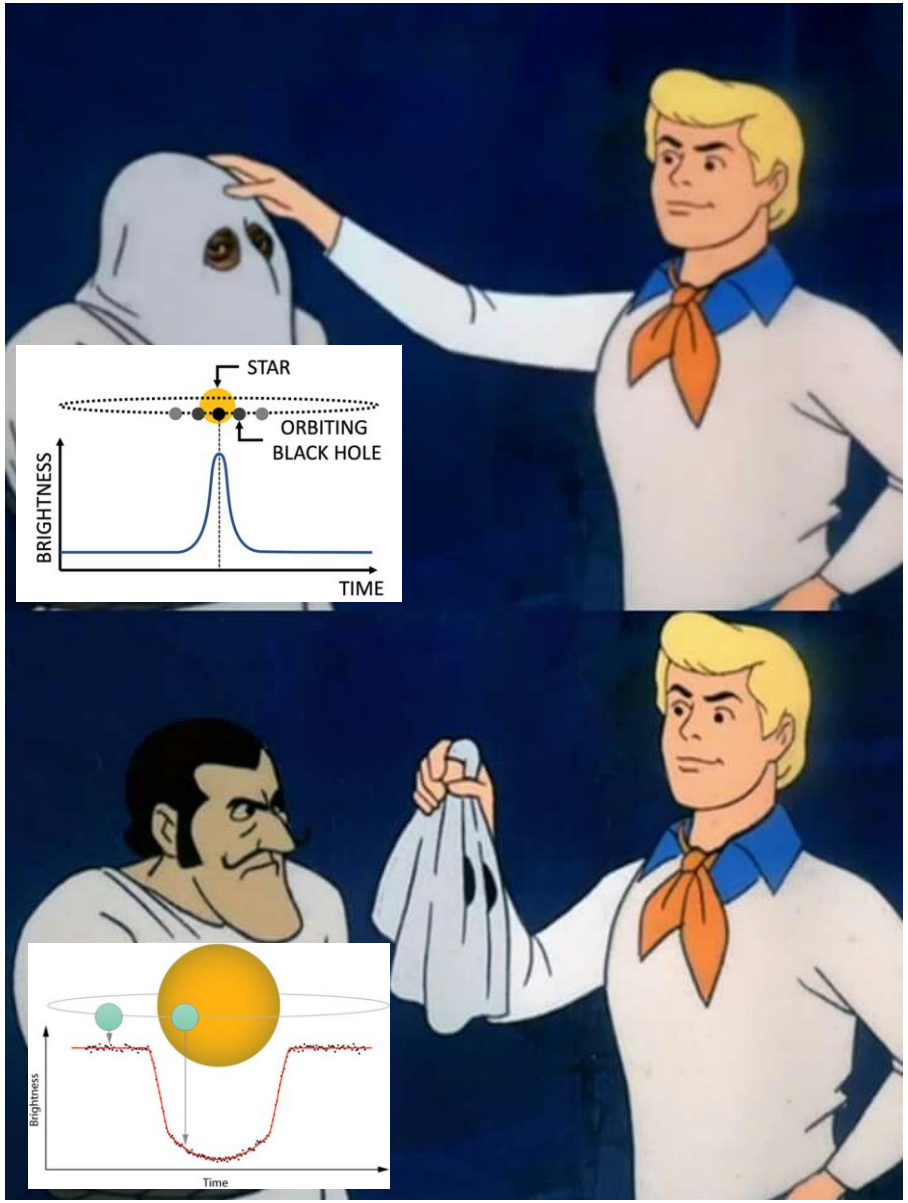
- Surface gravity
- Effective temperature
- Metallicity
- Velocity

THE PHYSICS

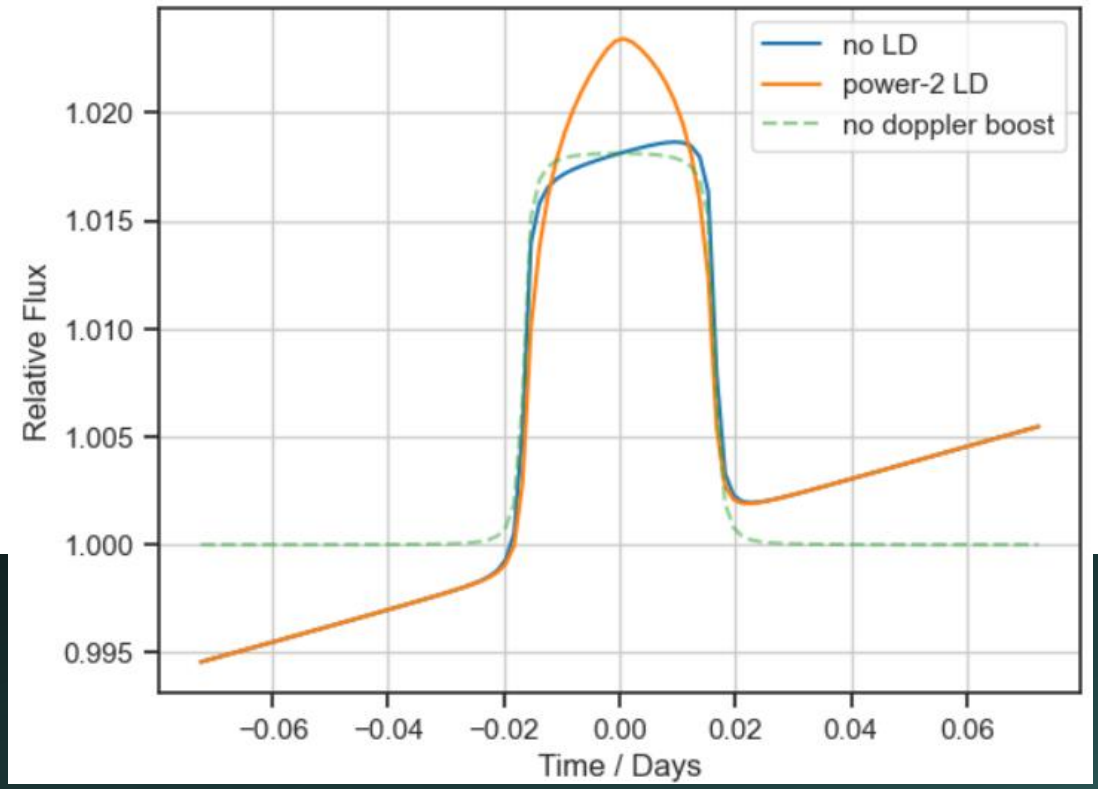
Keplerian orbits
Tidal distortion
Doppler boosting
Limb-darkening

MS star parameters

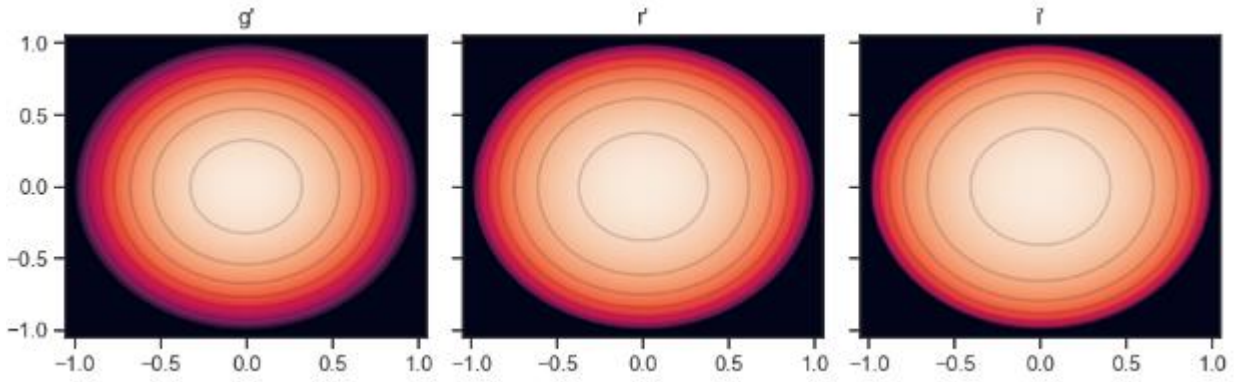
- Surface gravity
- Effective temperature
- Metallicity
- Velocity

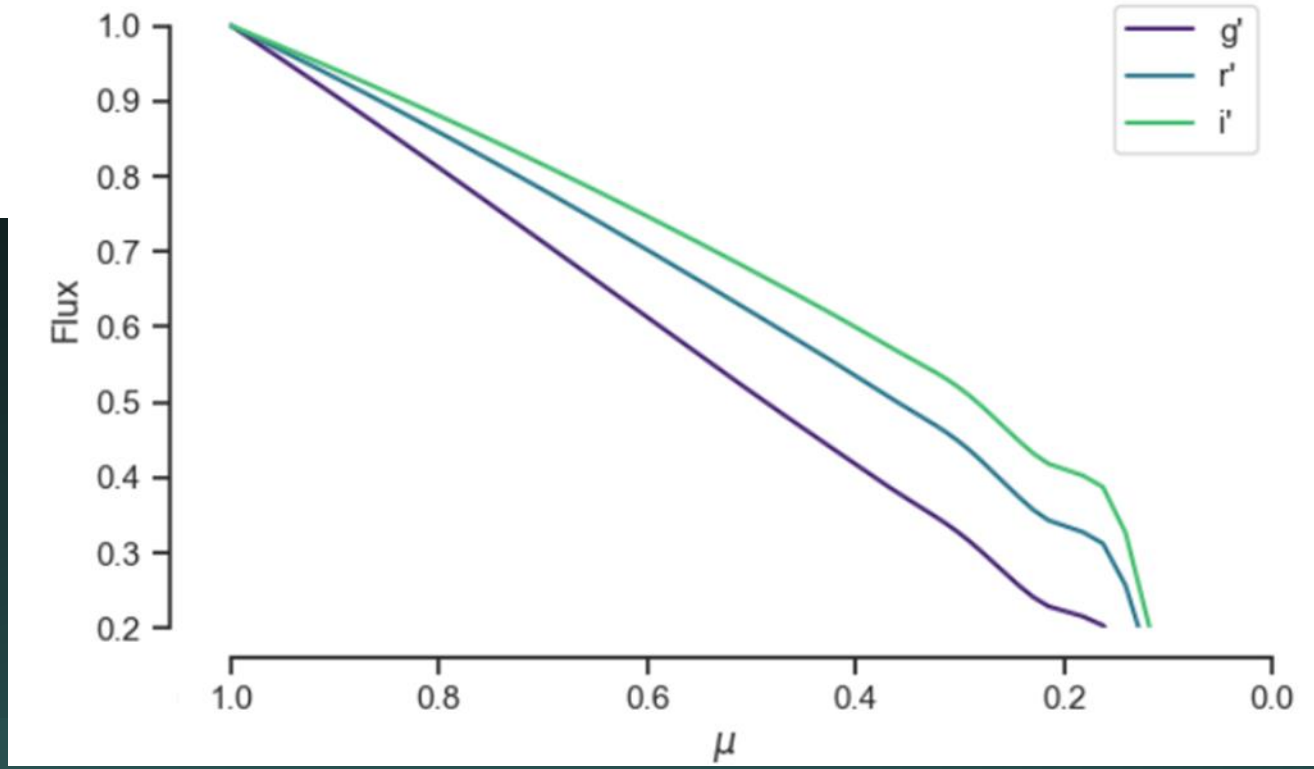


SINGLE BAND PHOTOMETRY

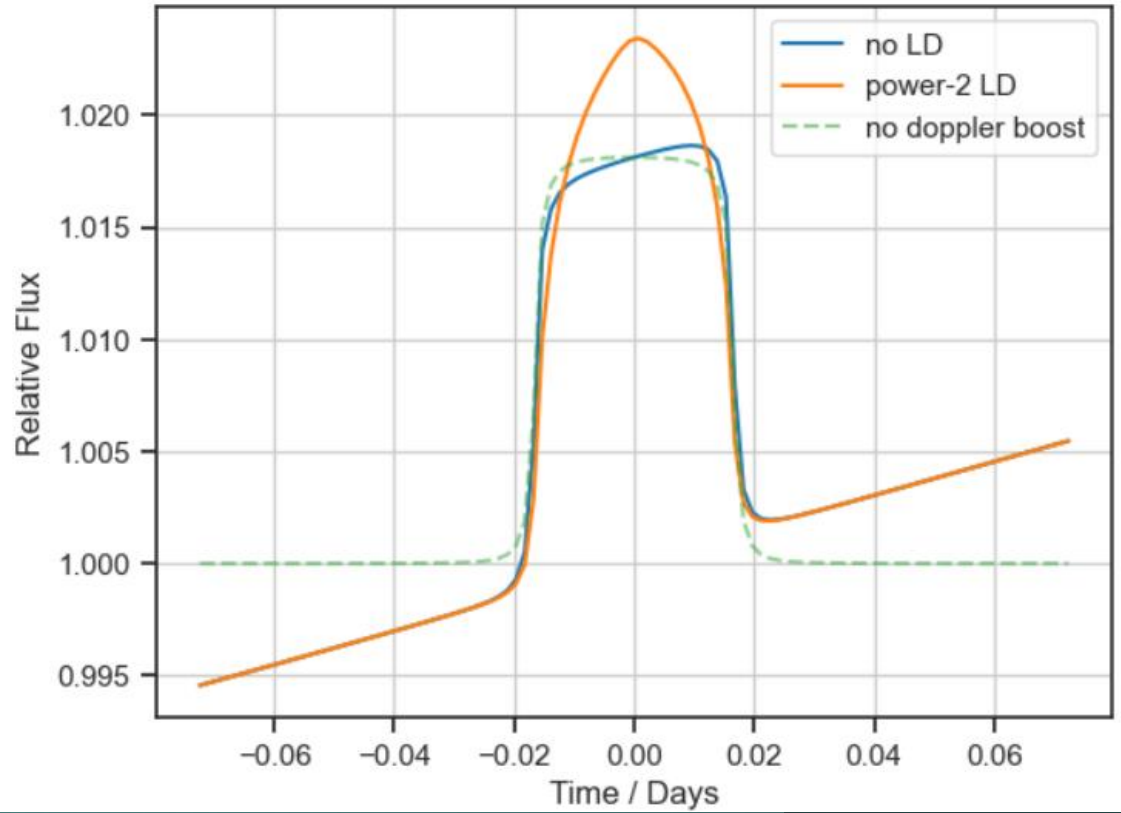


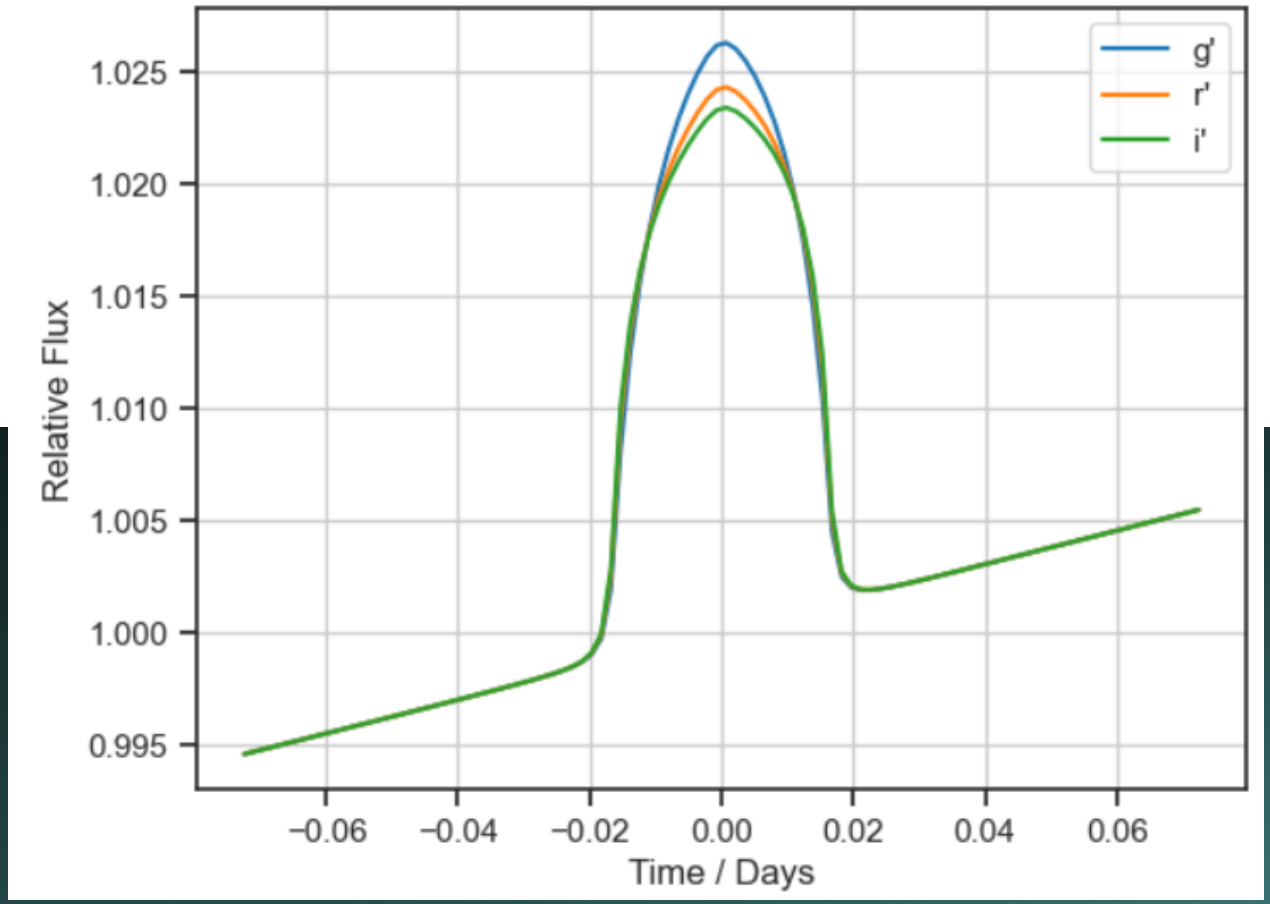
MULTI BAND PHOTOMETRY





MULTI BAND PHOTOMETRY

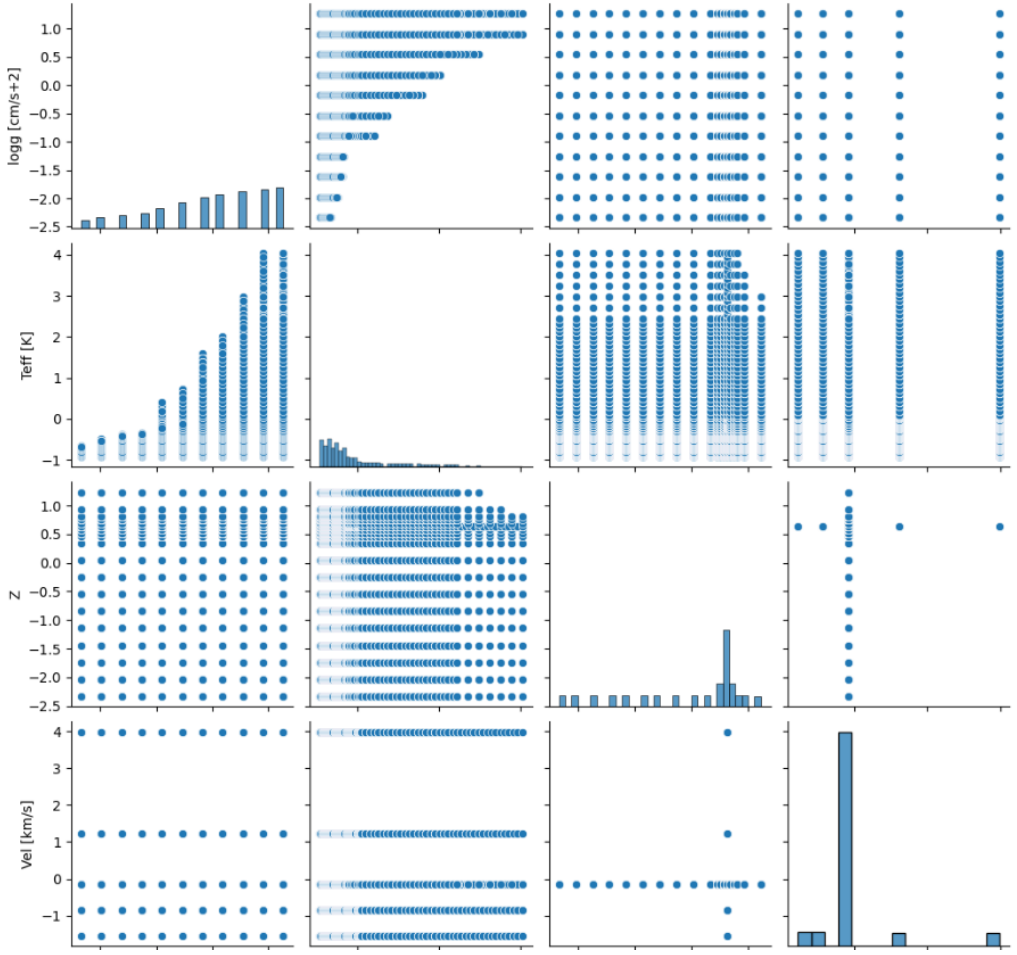


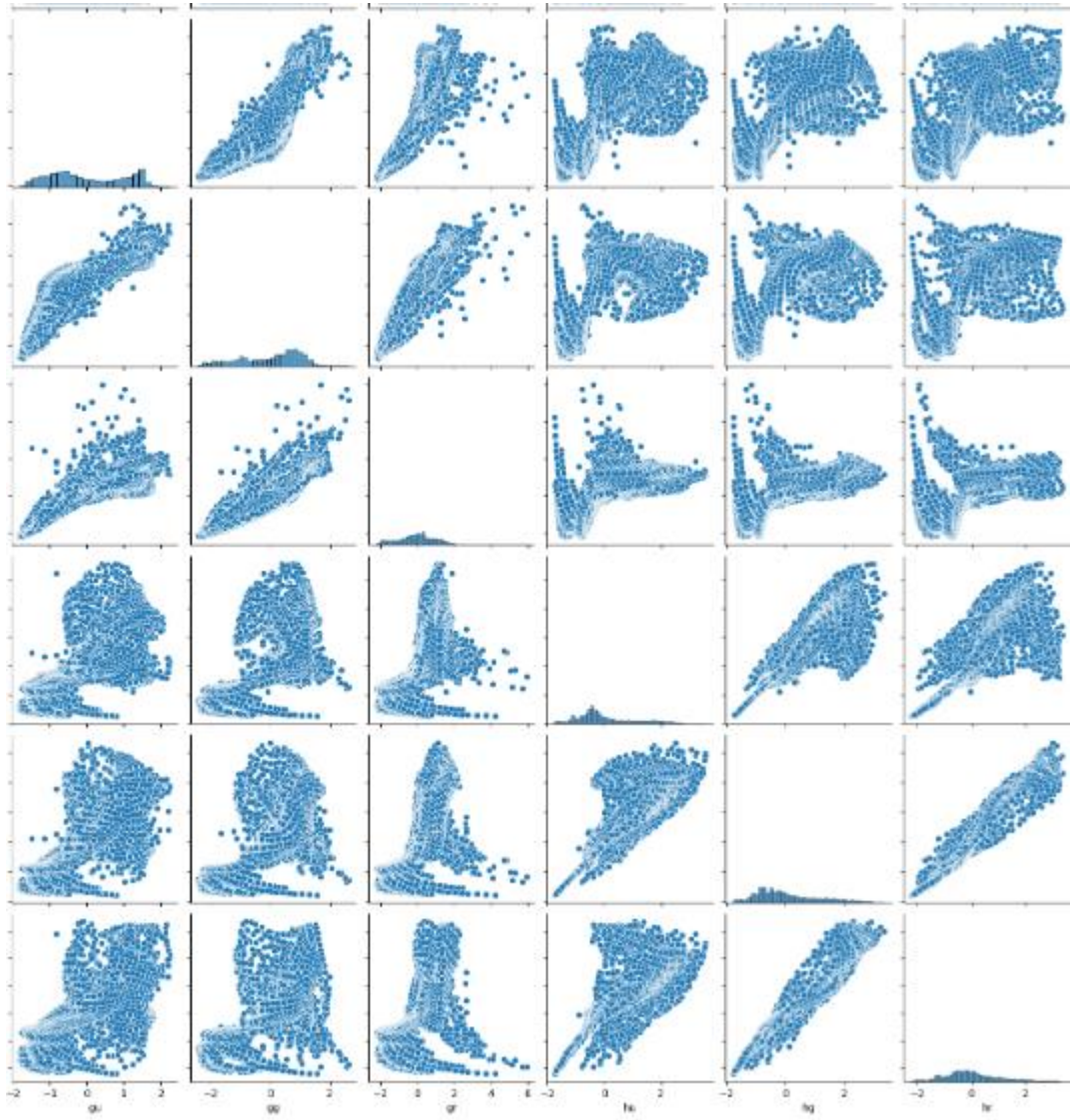


THE PROBLEM

Power-2 limb-darkening coefficients for the uvby, UBVRIJHK, SDSS ugriz, Gaia, Kepler, and TESS photometric systems

A. Claret, J. Southworth





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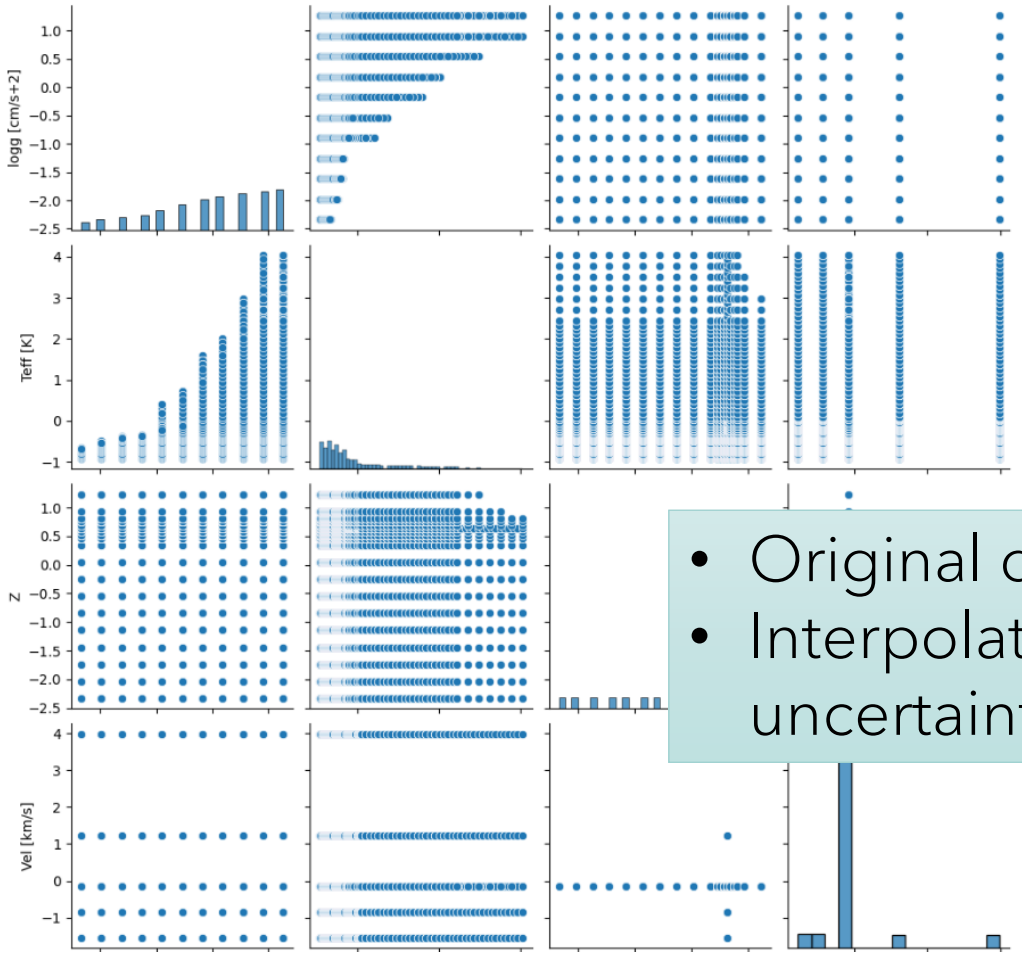
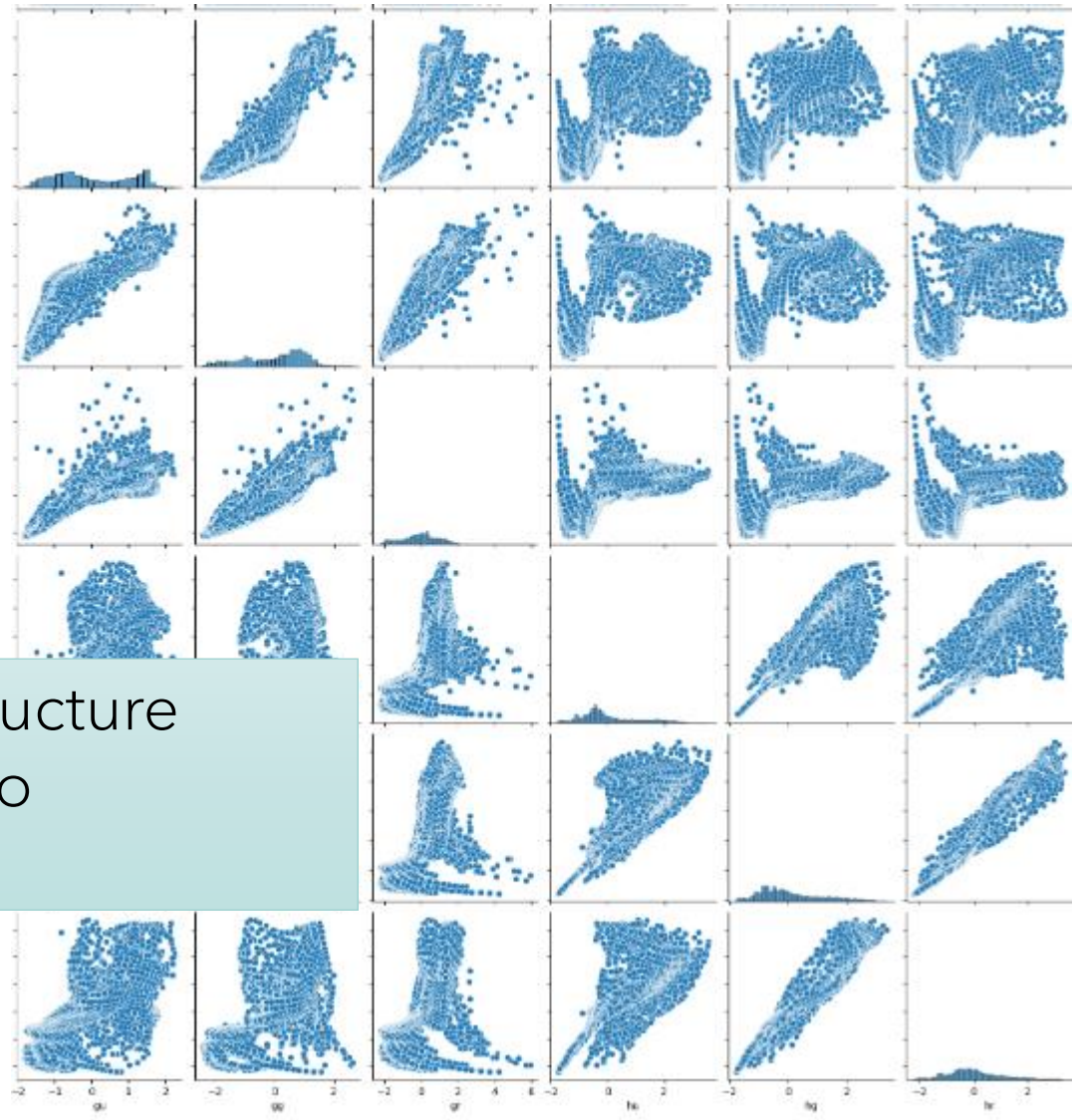
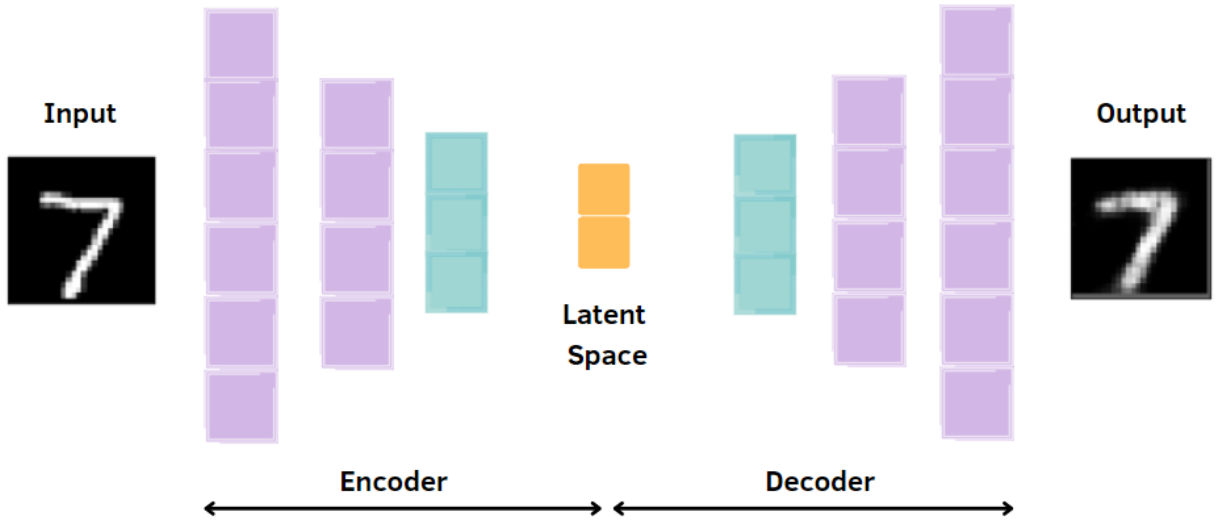




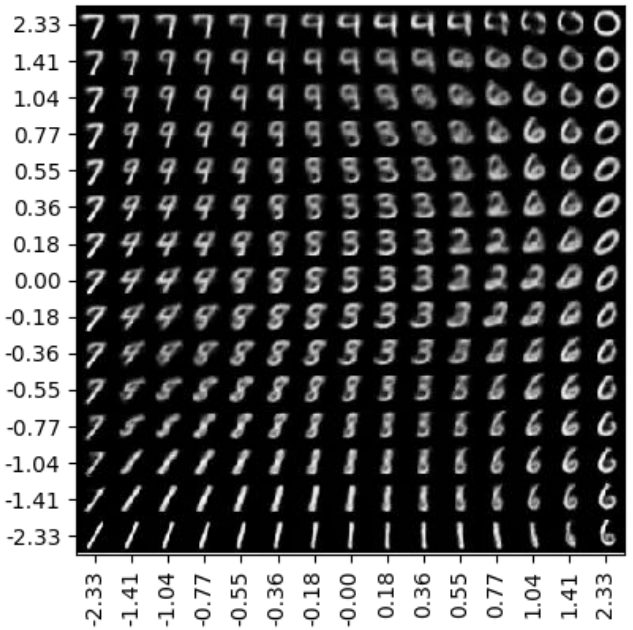
- Original data structure
- Interpolating into uncertainty

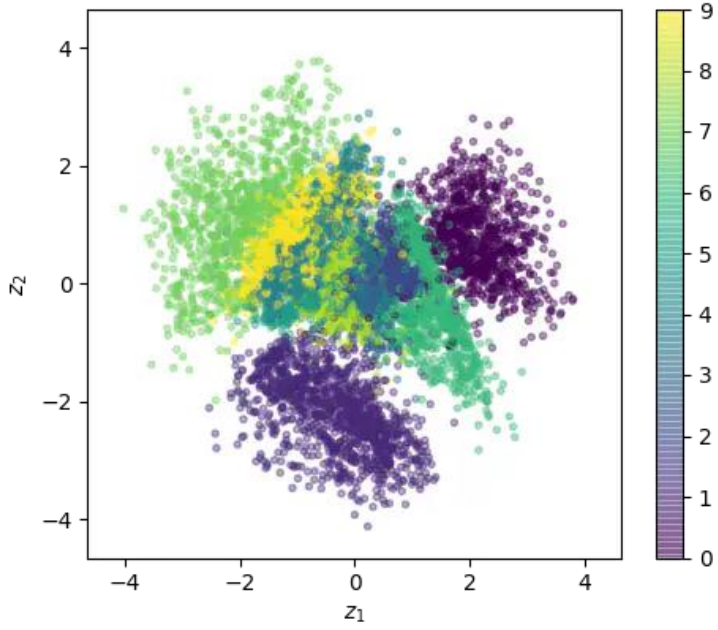
AUTOENCODERS



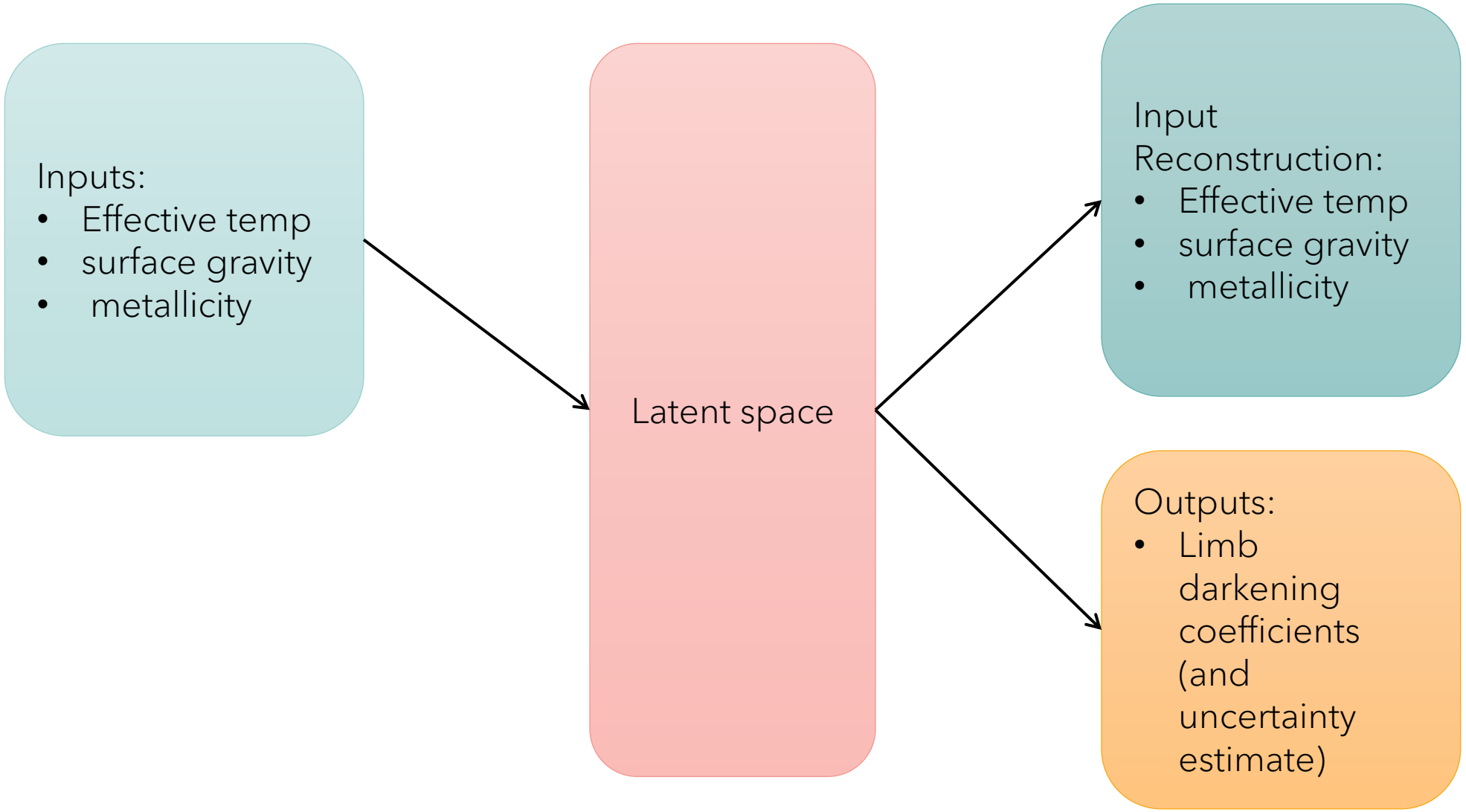
WHY?

- Capture the underlying data structure
- Sampling methods introduce stochasticity
- Uncertainty estimates via inference





VAE REGRESSION



OPTIMISATION

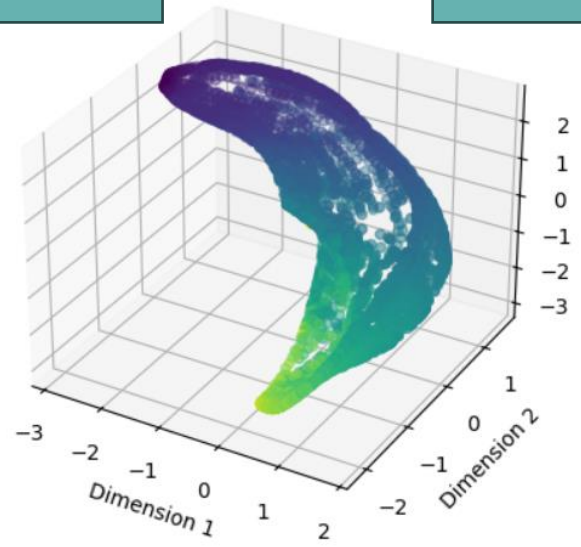
$$\mathcal{L} = \mathcal{L}_{reconstruction} + \mathcal{L}_{KL} + \mathcal{L}_{regression}$$

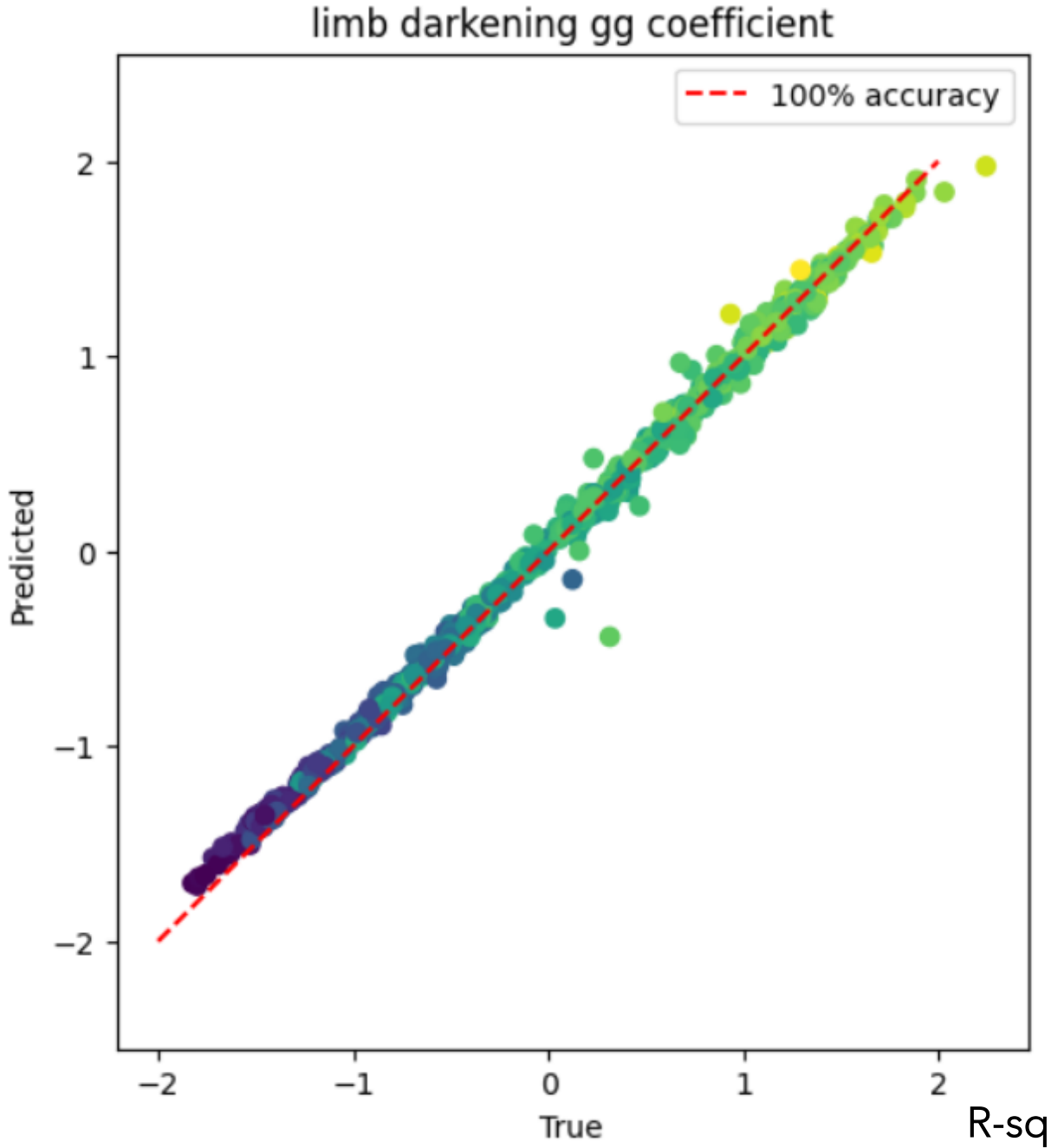
autoencoder

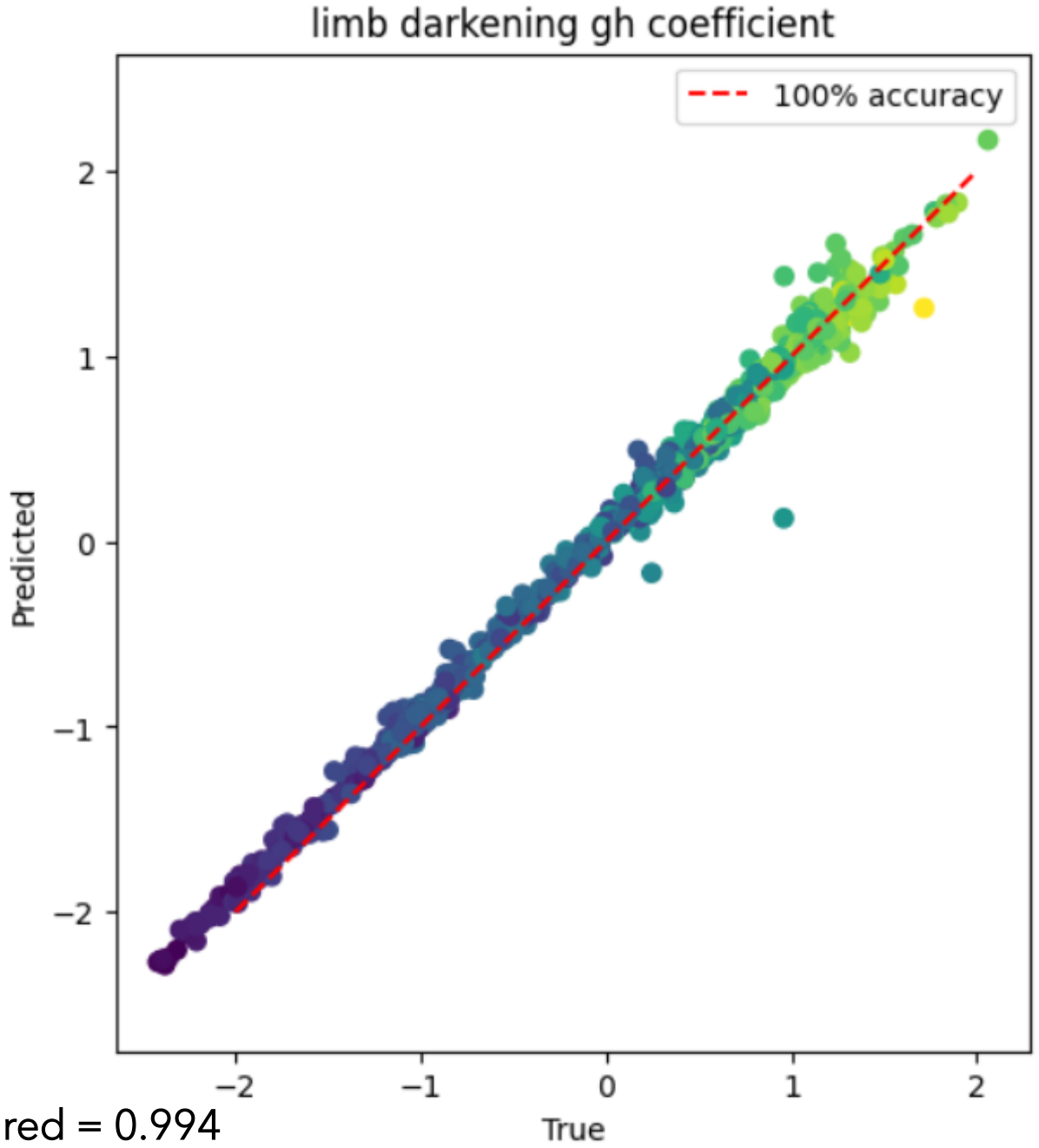
Latent space

regression

The relative weight of each loss term can (and should) be changed!

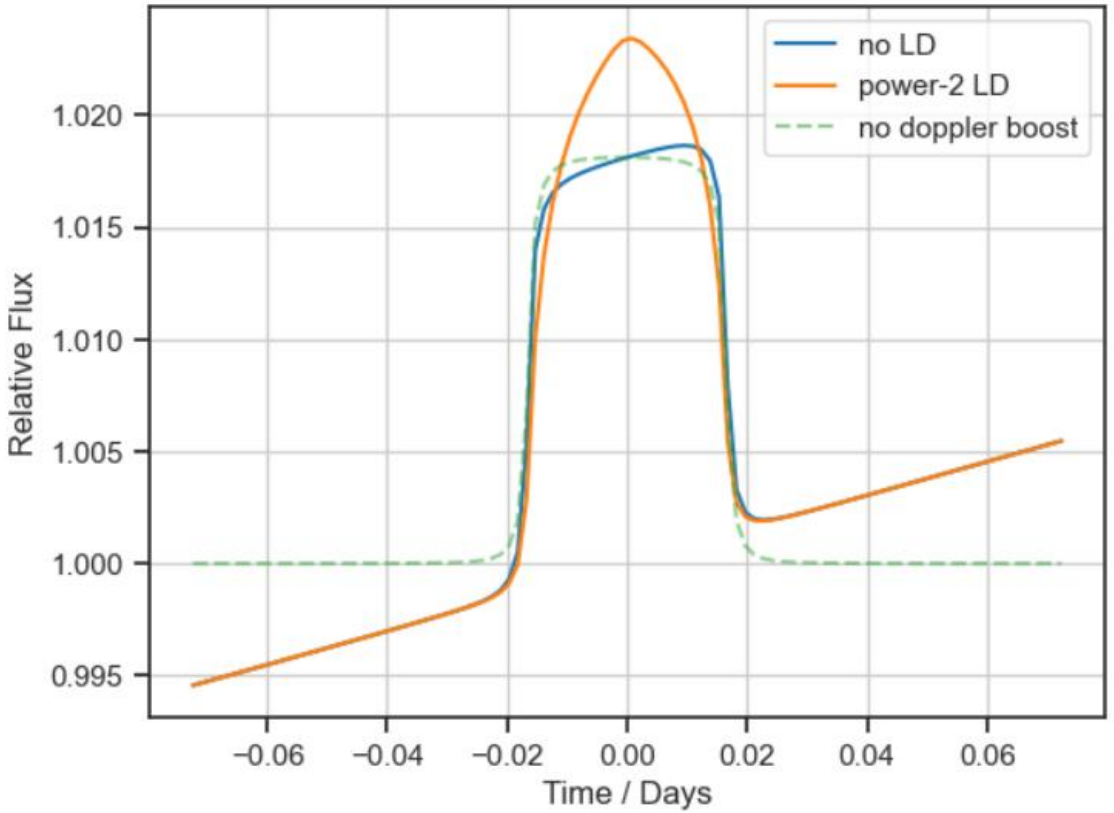


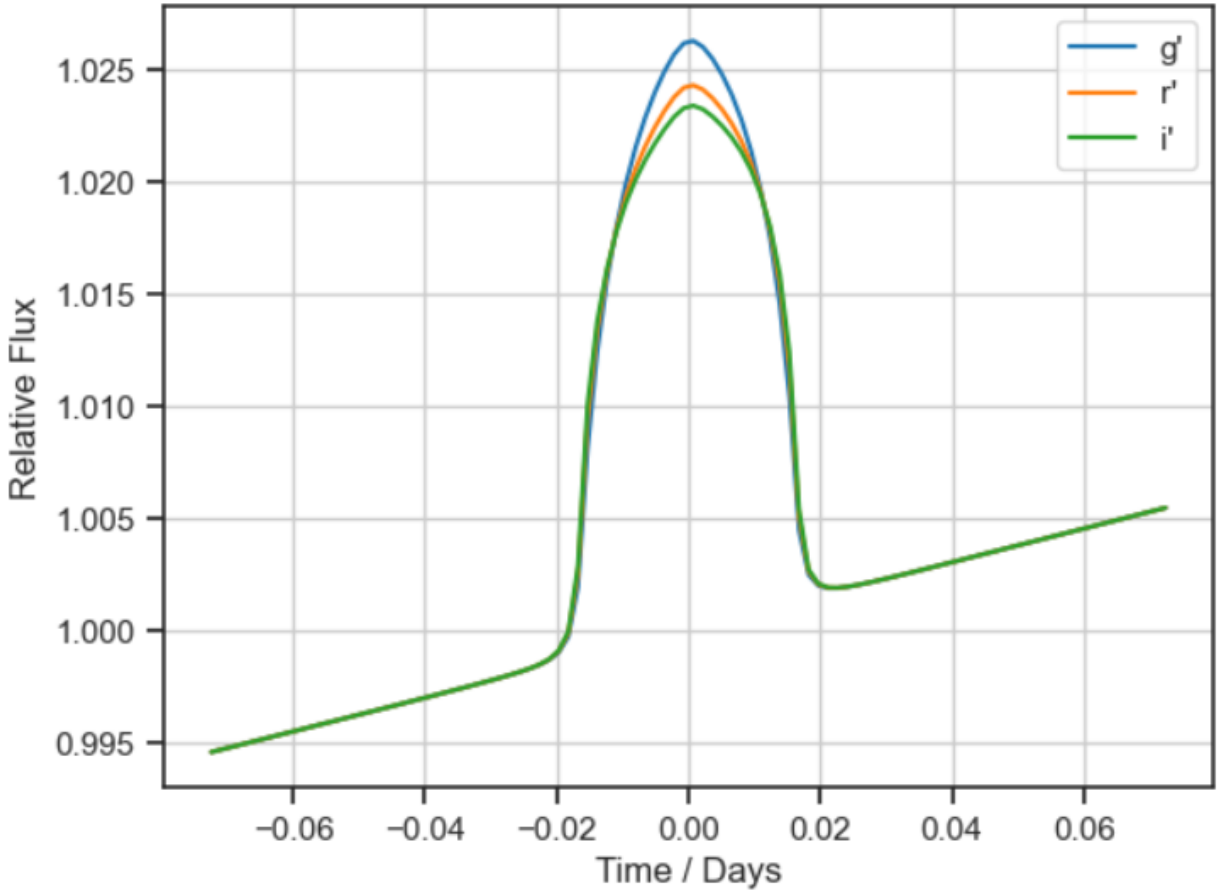




R-squared = 0.994

MULTI BAND PHOTOMETRY





SUMMARY

- Toolkit design is a data problem due to survey sizes
- Periodicity and multi-band photometry potentially increases constraining power through repeat measurement
- VAE regression allows us to capture underlying data structures and estimate uncertainty from astrophysical simulations