

A multimodal neural network for the study of gravitational lenses

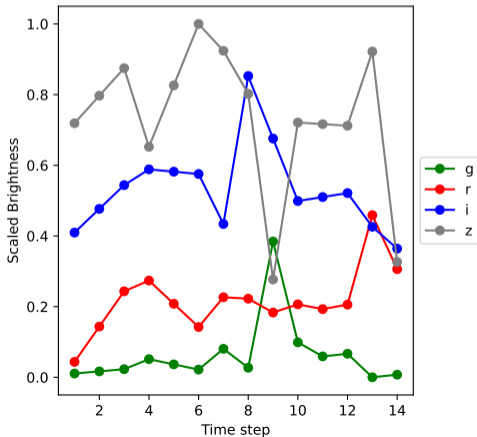
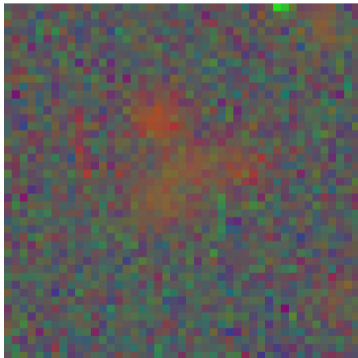


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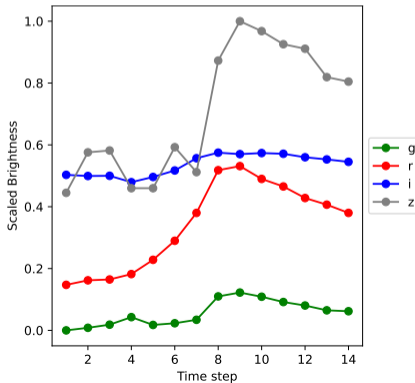
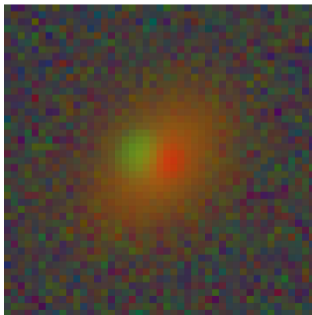
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11.07.2024

Discovering gravitationally-lensed supernovae given a $45 \times 45 \times 4$ image and 4 brightness time series

Multi-class single-label classification (No lens, Lens, LSN1a, LSNCC)

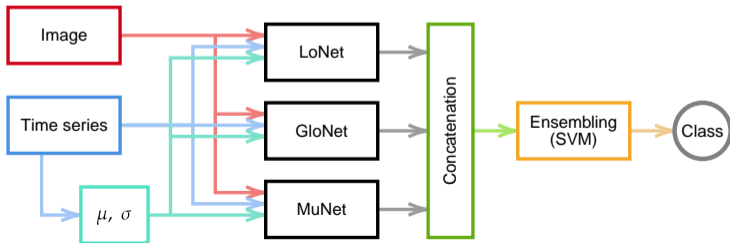


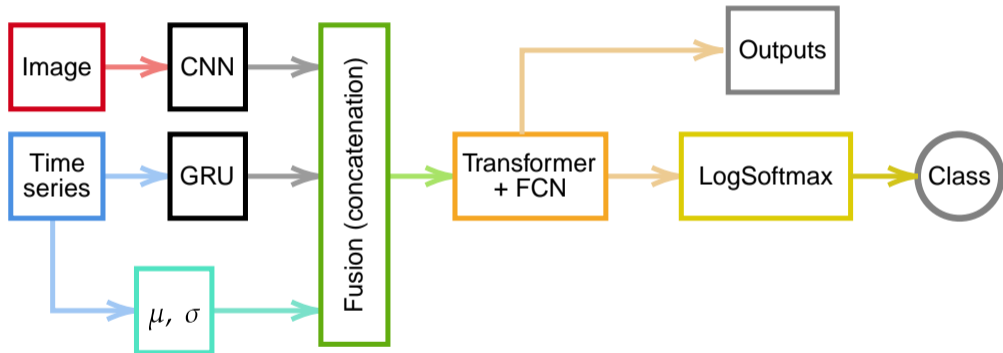
- Very **rare** phenomena (\implies training with simulated data)
- Huge **amount of data** from **future** astronomical surveys
- **Multimodality** \implies exploit both the **shape** of the object and its **time-dependent** behaviour (e.g., explosion of a supernova)

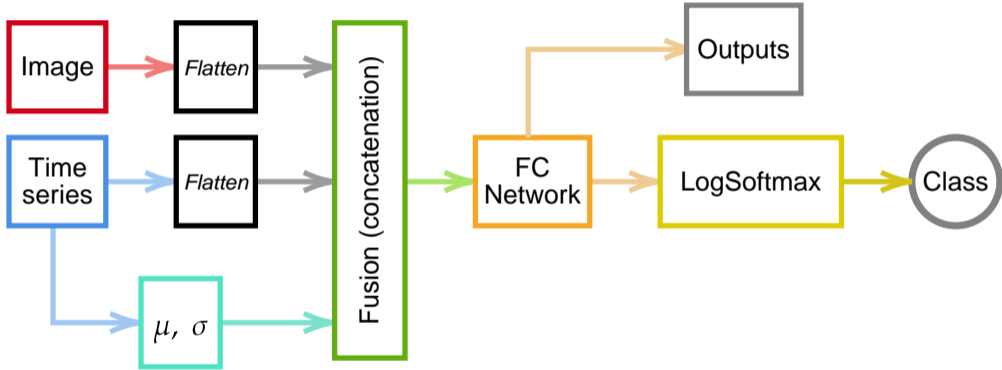


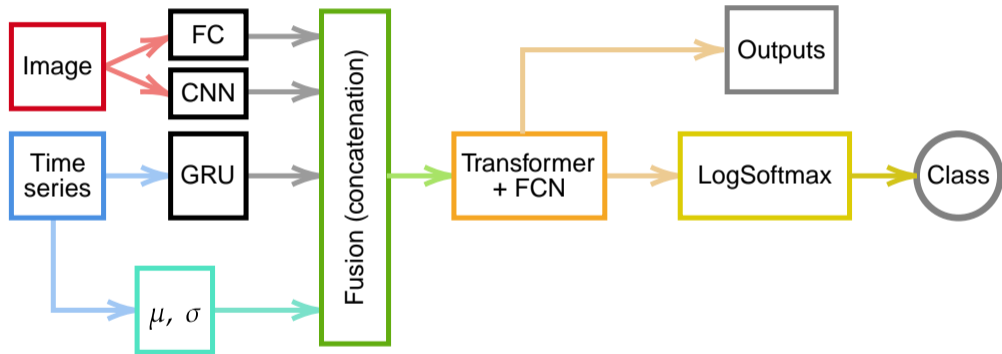
Ensemble of multimodal DL networks to exploit images and time series

- Implementation of **three** multimodal neural **networks** that focus either on local and global features
- Each network is **trained independently**
- Results are **ensembled** with SVM





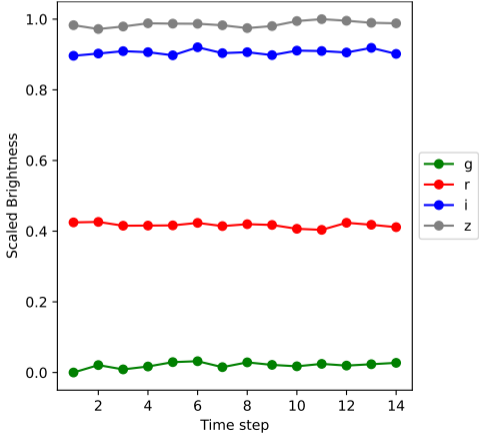
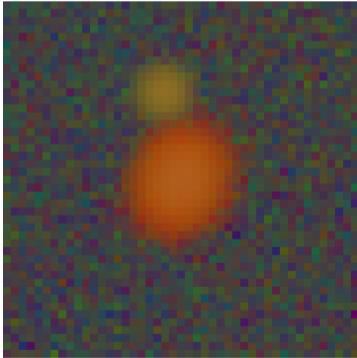




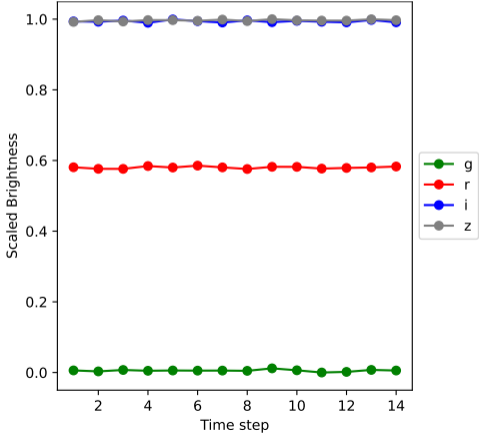
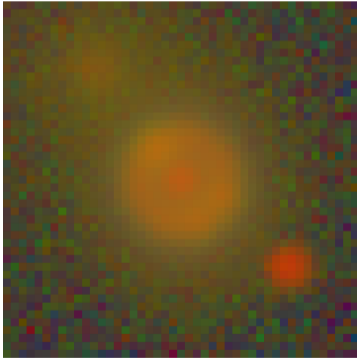
	DESI-DOT	DES-deep	DES-wide	LSST-wide
DeepZipper	77.1	58.6	51.7	74.3
DeepZipper II	78.9	57.4	49.8	70.7
STNet	85.1	58.4	82.5	84.3
LoNet (Ours)	87.0	67.5	85.8	87.2
GloNet (Ours)	77.2	62.3	76.8	76.8
MuNet (Ours)	87.9	67.9	86.5	88.5
DeepGraviLens (Ours)	88.7	69.6	87.7	88.8
Improvement	3.6	11.0	5.2	4.5

- Improvement wrt the **state of the art** (+3.6% to +11.0% accuracy)
- Improvement wrt **single modalities** (from +3.7% to +7.3% accuracy)
- Improvement wrt the **ensemble** of less than 3 multimodal networks (up to +12.0% accuracy)

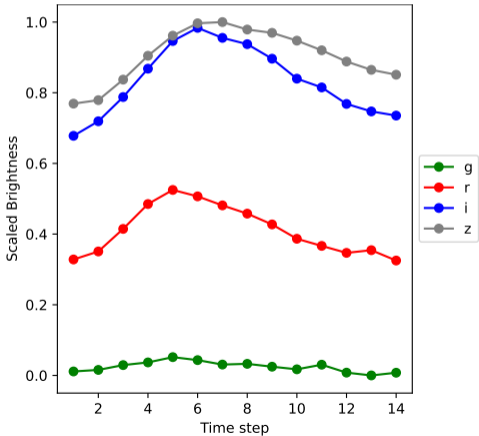
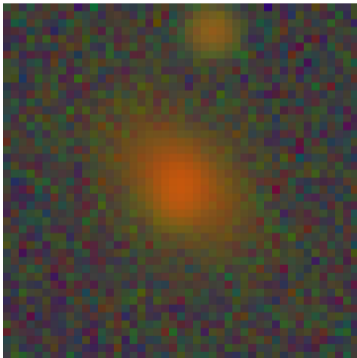
Not lensed body (correct prediction) Spherical geometry



Lensed body (correct prediction) Ring pattern, flat time series

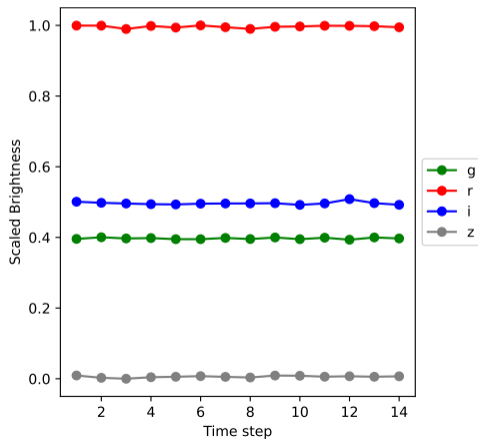
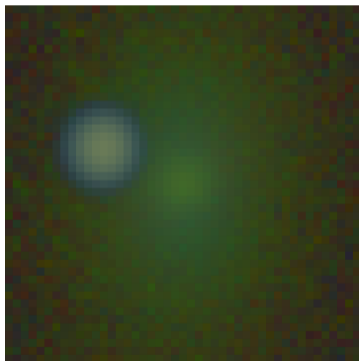


Lensed supernova (correct prediction) Elliptical shape, peak in the time series

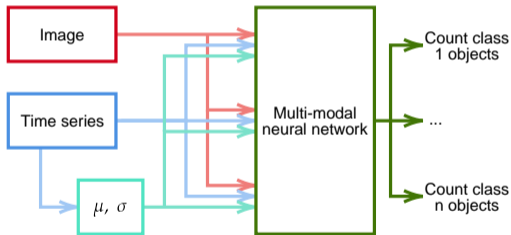


Lensed supernova (predicted as lens)

Halo, but **flat** time series!

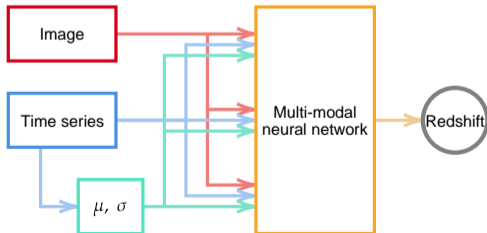


- Objects counting
 - Different types of objects in different quantities \Rightarrow counting problem with **ordinal regression**
 - Multi-input multi-output network



- Redshift estimation
 - Estimating redshift is usually **time-consuming**
 - Regression problem
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- Find an analytical description of gravitational lenses using Roulette amplitudes
 - Gravitational lenses can be approximated using the Roulette formalism (\rightarrow 2D Taylor expansion in polar coordinates)
 - Given an image, determine the Roulette amplitudes (\rightarrow Taylor expansion coefficients)

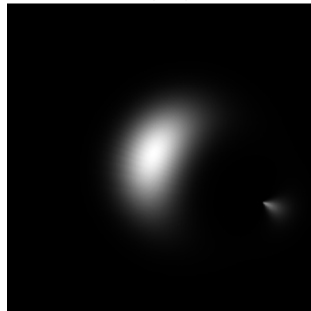
GT (Roulette amplitudes)



Reconstructed (ML)



GT (exact)



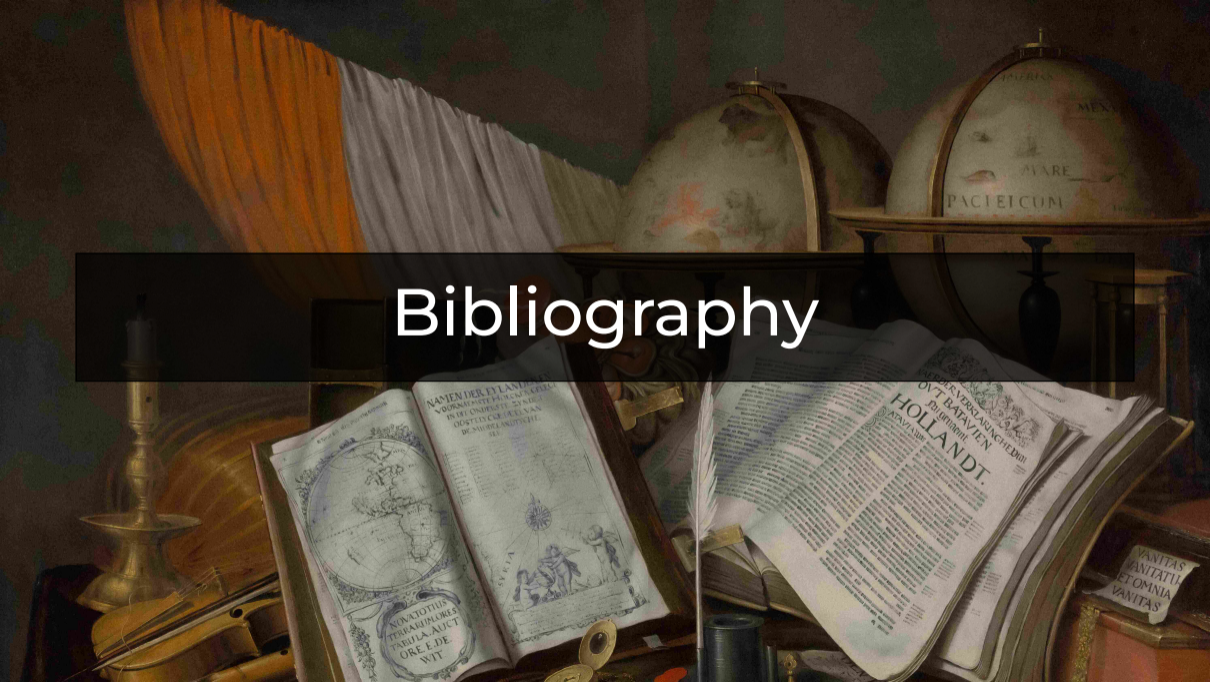


Thank you for the attention

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Bibliography



[VF23] **Nicolò Oreste Pincioli Vago e Piero Fraternali. “DeepGraviLens: a multi-modal architecture for classifying gravitational lensing data”.**
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<https://doi.org/10.1007/s00521-023-08766-9>.