Finding Low Surface Brightness Galaxies with CNNs

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ASTR 502 Term Project

May 4th, 2022

Based on Tanoglidis et al. 2021, A&C, 35, 100469

Low Surface Brightness Galaxies

- Low Surface Brightness Galaxies (LSBGs) have central surface brightnesses lower than the typical sky background (> 22 g-band mag/arcsec^2).
- LSBGs lie at the low end of the luminosity function, and are thus expected to be among the most numerous of galaxies.
- They test structure and galaxy formation at small scales, and are crucial for constraining the galaxy-halo connection as well as galaxy evolution.

Finding LSBGs

- Deep surveys such as DES have begun to find large populations of LSBGs
- In practice, sorting true LSBGs from artifacts is very difficult
- Next-gen surveys such as Rubin/ LSST will require this process to be automated

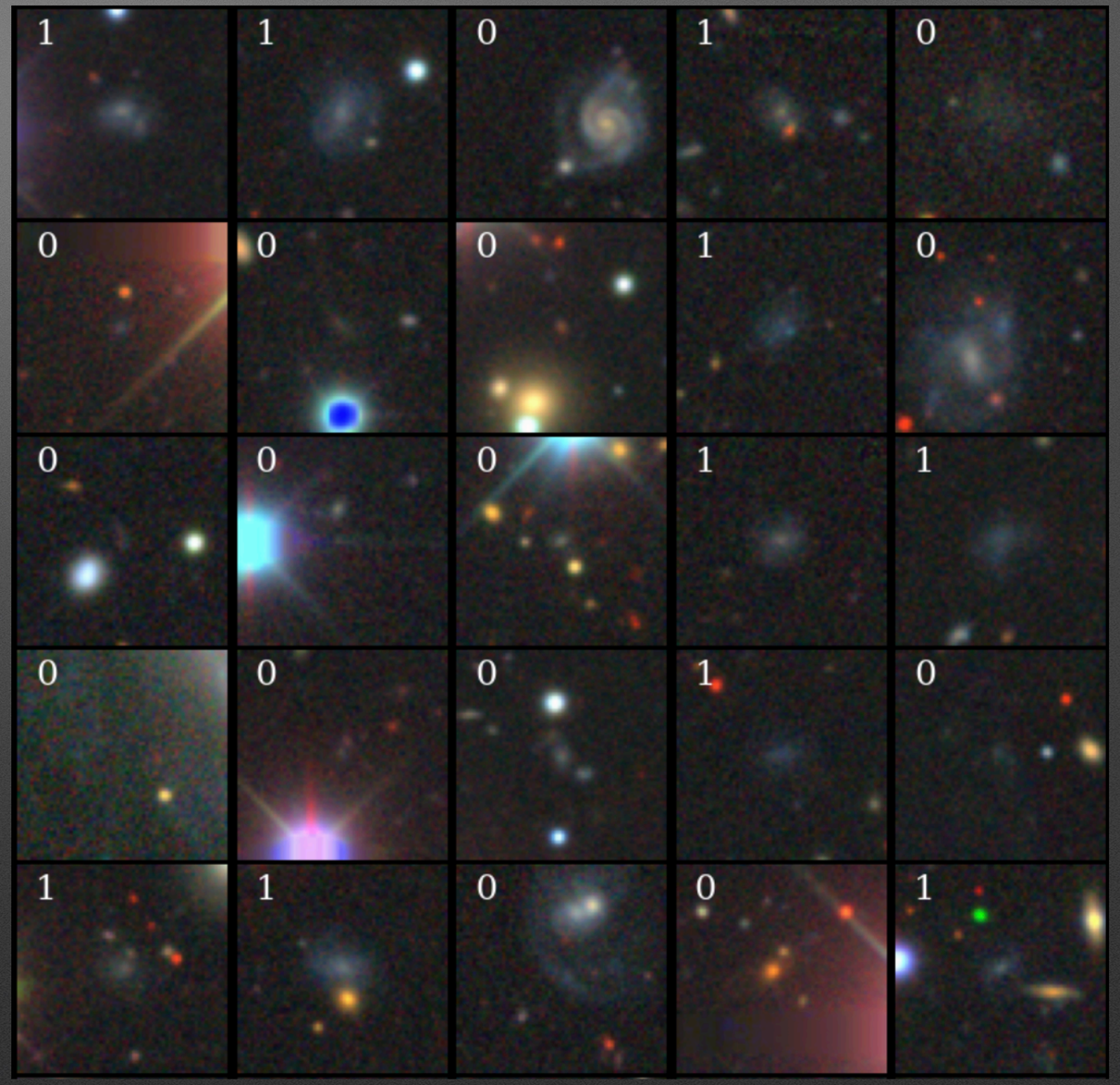
THE DARK ENERGY SURVEY

LSST Legacy Survey of Space and Time

Goal: Train a CNN to classify between LSBGs and Artifacts, then determine whether the model can be applied to datasets from different surveys with little to no retraining

DES Dataset

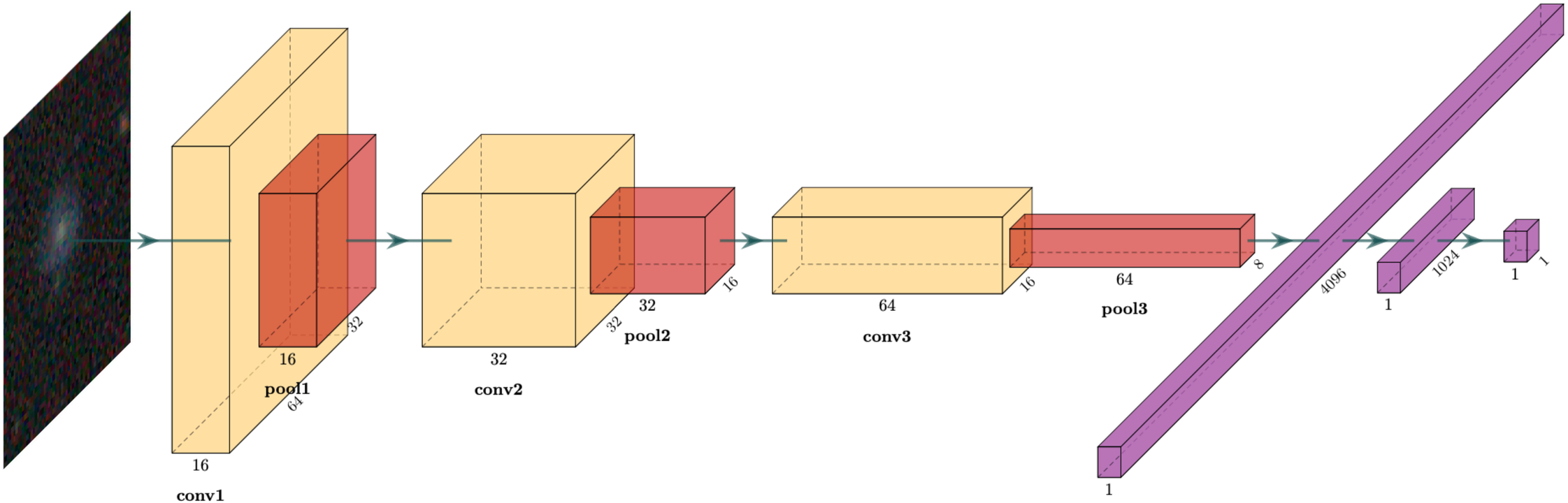
- All images are 64x64x3 (g, r, z band channels) cutouts from the DES, centered on the LSBG candidate
- Labels are 0 (artifact) or 1 (LSBG), and are assigned based on visual confirmation
- 20,000 LSBG and 20,000 Artifact images (40,000 total):
  - 30,000 training
  - 5,000 validation
  - 5,000 test



DeepShadows CNN Architecture

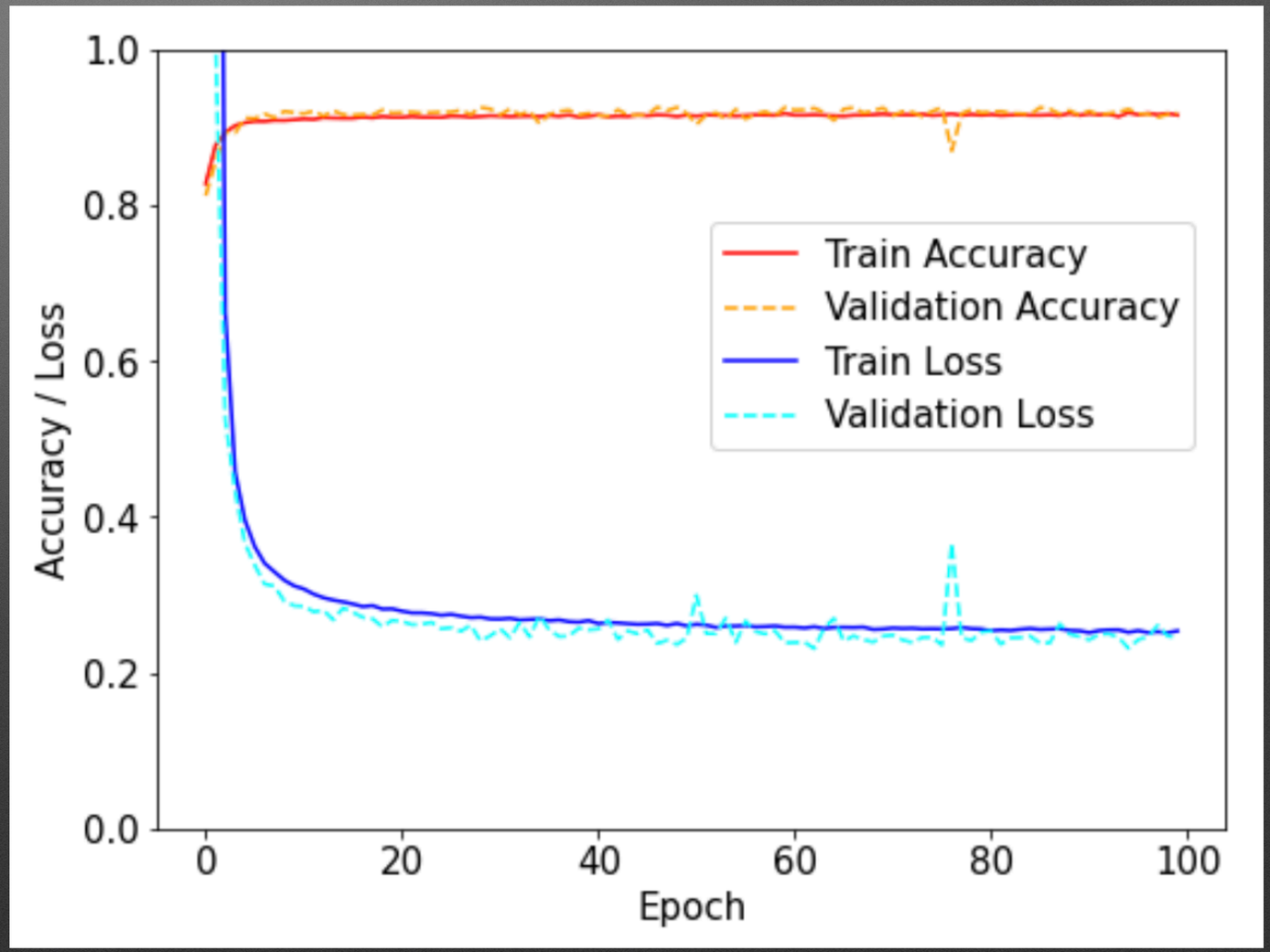
Layers	Properties	Stride	Padding	Output Shape	Parameters
Input	$64 \times 64 \times 3^a$	-	-	(64, 64, 3)	0
Convolution (2D)	Filters: 16	1×1	Same	(64, 64, 16)	448
	Kernel: 3×3	-	-	-	-
	Activation: ReLU	-	-	-	-
	Reg: L2 (0.13)	-	-	-	-
Batch Normalization	-	-	-	(64, 64, 16)	64
MaxPooling	Kernel: 2×2	2×2	Valid	(32, 32, 16)	0
Dropout	Rate: 0.4	-	-	(32, 32, 16)	0
Convolution (2D)	Filters: 32	1×1	Same	(32, 32, 32)	4640
	Kernel: 3×3	-	-	-	-
	Activation: ReLU	-	-	-	-
	Reg: L2 (0.13)	-	-	-	-
Batch Normalization	-	-	-	(32, 32, 32)	128
MaxPooling	Kernel: 2×2	2×2	Valid	(16, 16, 32)	0
Dropout	Rate: 0.4	-	-	(16, 16, 32)	0
Convolution (2D)	Filters: 64	1×1	Same	(16, 16, 64)	18496
	Kernel: 3×3	-	-	-	-
	Activation: ReLU	-	-	-	-
	Reg: L2 (0.13)	-	-	-	-
Batch Normalization	-	-	-	(16, 16, 64)	256
MaxPooling	Kernel: 2×2	2×2	Valid	(8, 8, 64)	0
Dropout	Rate: 0.4	-	-	(8, 8, 64)	0
Flatten	-	-	-	(4096)	-
Fully connected	Activation: ReLU	-	-	(1024)	4195328
	Reg: L2 (0.12)	-	-	-	-
Fully connected	Activation: Sigmoid	-	-	(1)	1025

DeepShadows CNN Architecture



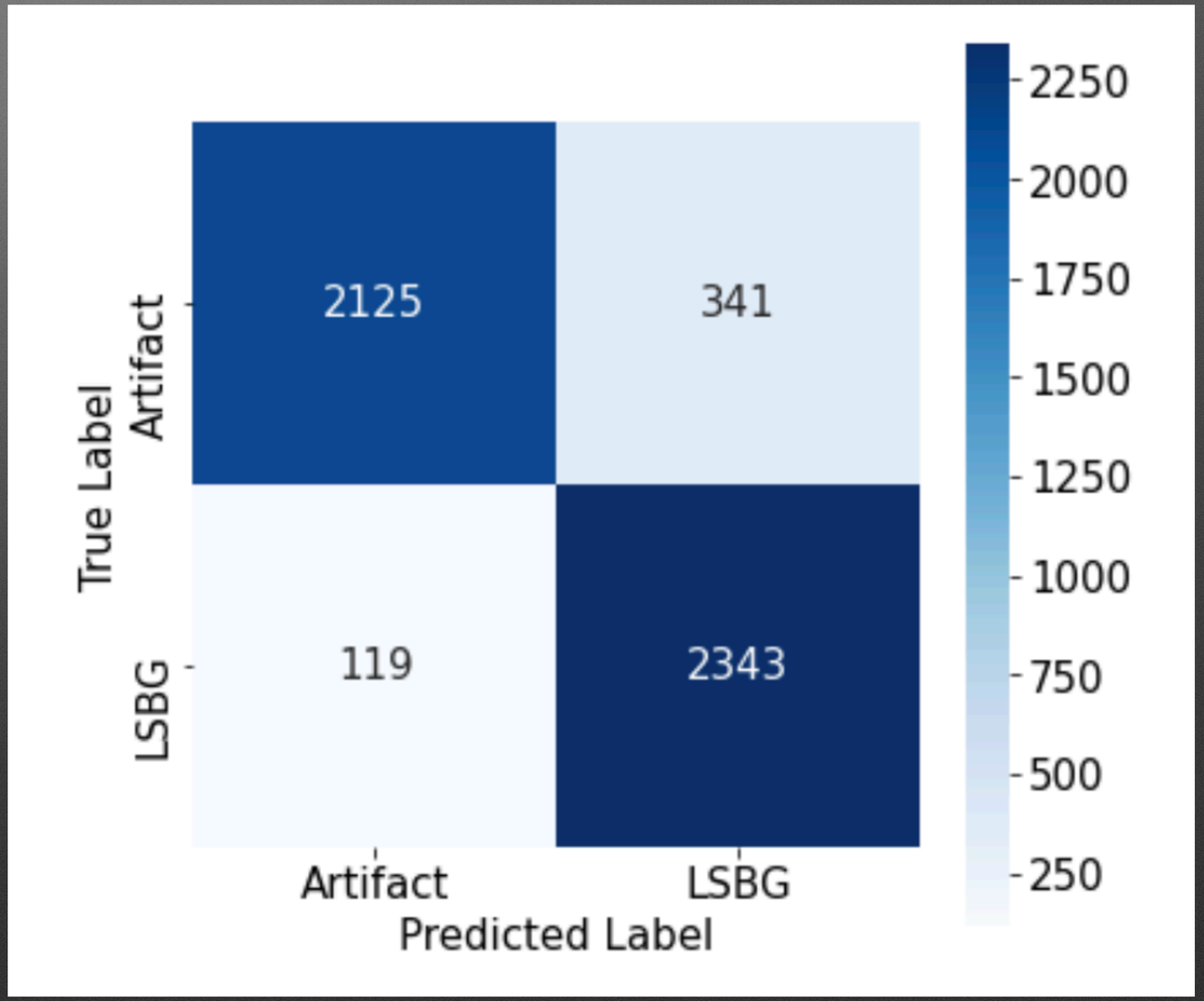
Training

- Batch Size = 64
- Number of epochs = 100
- Binary cross-entropy loss
- Optimizer is Adadelta, lr=0.1



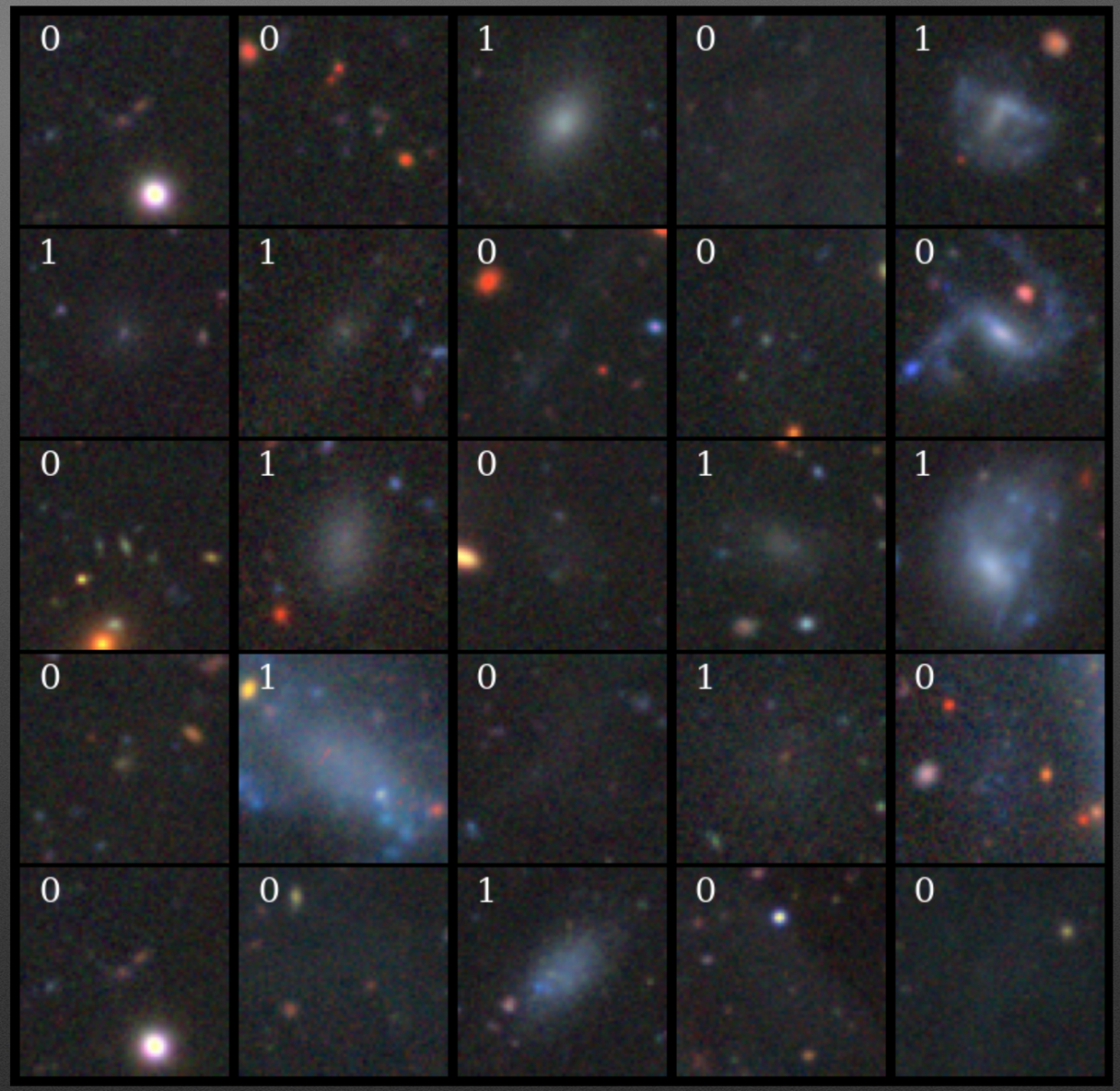
Testing

- After training, the validation accuracy is 91.74%
- The test accuracy is 91.17%



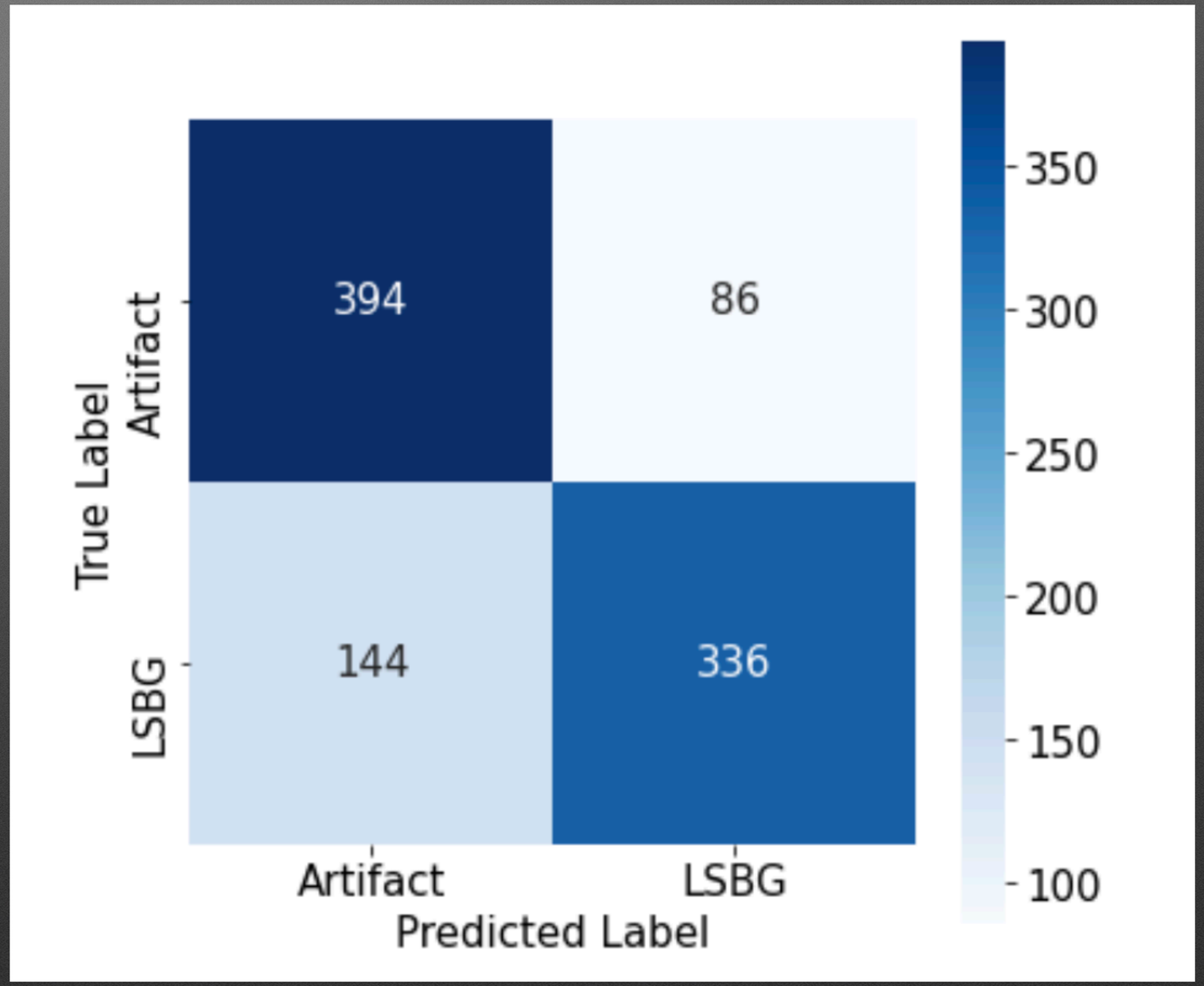
Transfer Learning

- Training data is expensive!
- Can we apply this model to other surveys without entirely re-training it?
- Additional dataset of 640 LSBGs and 640 Artifacts from the Hyper Suprime-Cam Subaru Strategic Program (HSC SSP):
  - 320 Training
  - 960 Test



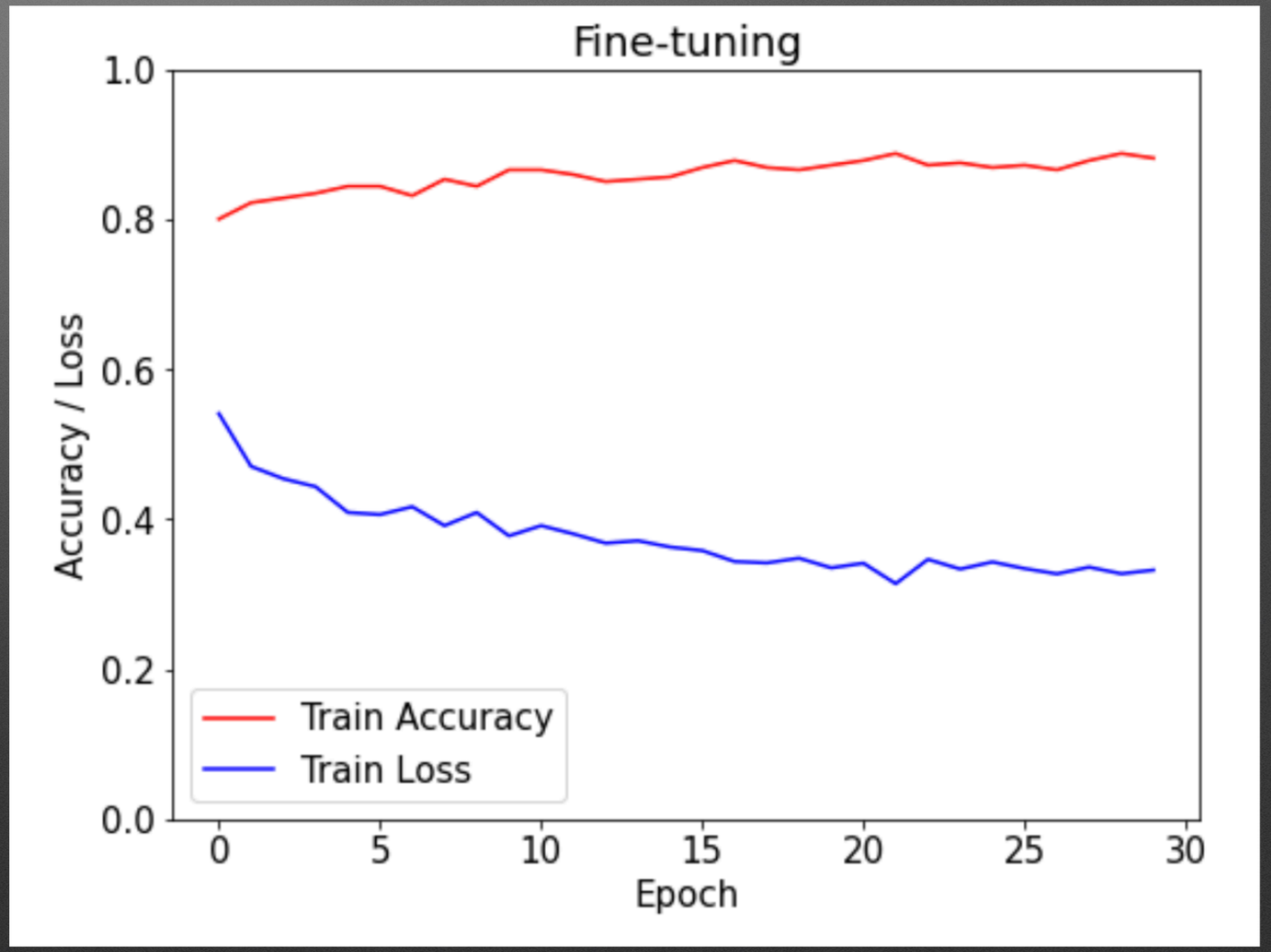
No Further Training

- Applying the DES-trained DeepShadows to the HSC test set with no adjustments gives a test accuracy of 76.04%



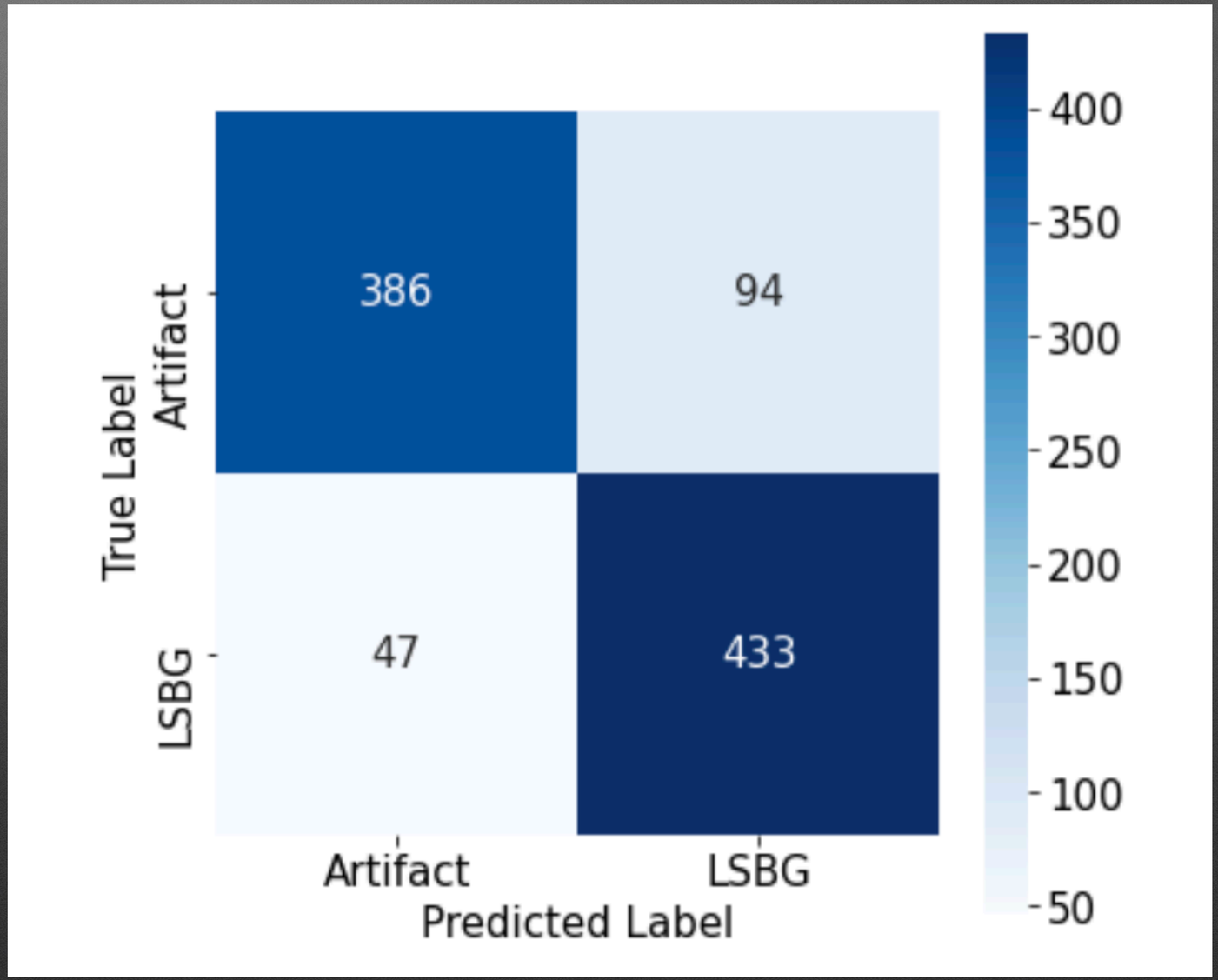
Re-Training (Transfer Learning)

- Quick re-training with the 320-image HCS training set
- Batch Size = 32
- Number of epochs = 30
- Binary cross-entropy loss
- Adadelta, lr=0.005



After Transfer Learning

- After quickly fine-tuning on a small HSC training set, the model achieves 85.31% accuracy on the HSC test set.



Summary

- DeepShadows is a relatively simple CNN designed to separate LSBGs from artifacts.
- When trained with an expensive DES dataset, DeepShadows achieves an accuracy of 91.17%
- Applying the trained network to data from HSC achieves an accuracy of 76.04%
- After transfer learning, the network achieves an accuracy of 85.31% on the same HSC dataset.
- If you’re able to obtain a sufficiently large observational training set, CNN’s show promise for automating source classification in next-gen surveys.