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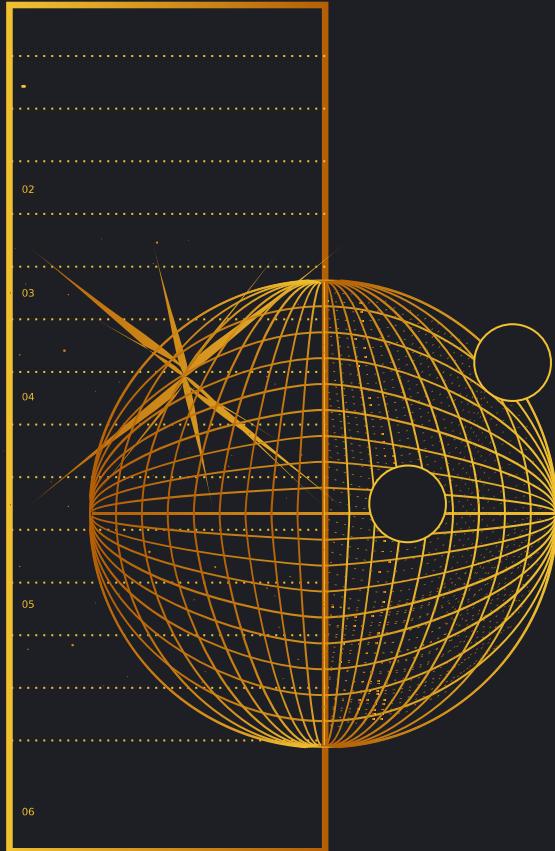
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PHYS 449/773 Final Project Presentation GALAXY CLASSIFICATION

Group Members: Yusuf Ahmed,
Alexander Caires, Jordan Ducatel,
Ashley Ferreira, Guillaume Hewitt

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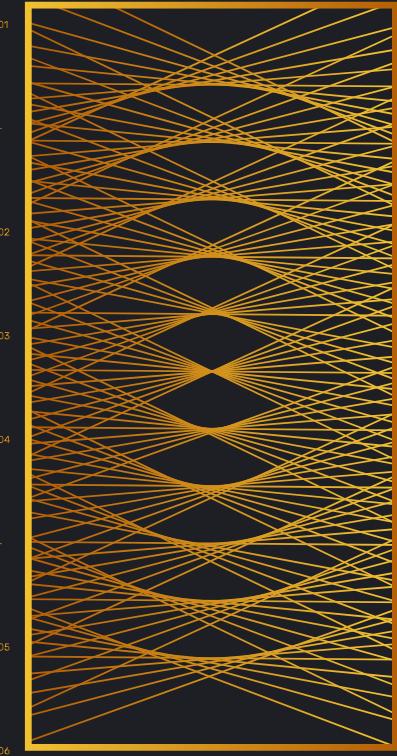
8



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| <u>INTRO</u> | 01. |
| <u>DATA</u> | 02. |
| <u>MODELS</u> | 03. |
| <u>RESULTS</u> | 04. |
| <u>CONCLUSIONS</u> | 05. |
| <u>OUTLOOK</u> | 06. |





01. INTRO

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M. K. Cavanagh, K. Bekki and B. A. Groves,

“Morphological Classification of Galaxies with Deep Learning: Comparing 3-way and 4-way CNNs”

MNRAS, 506-1, 659–676 (2021).

DOI: <https://doi.org/10.1093/mnras/stab1552>



Galaxy Morphologies



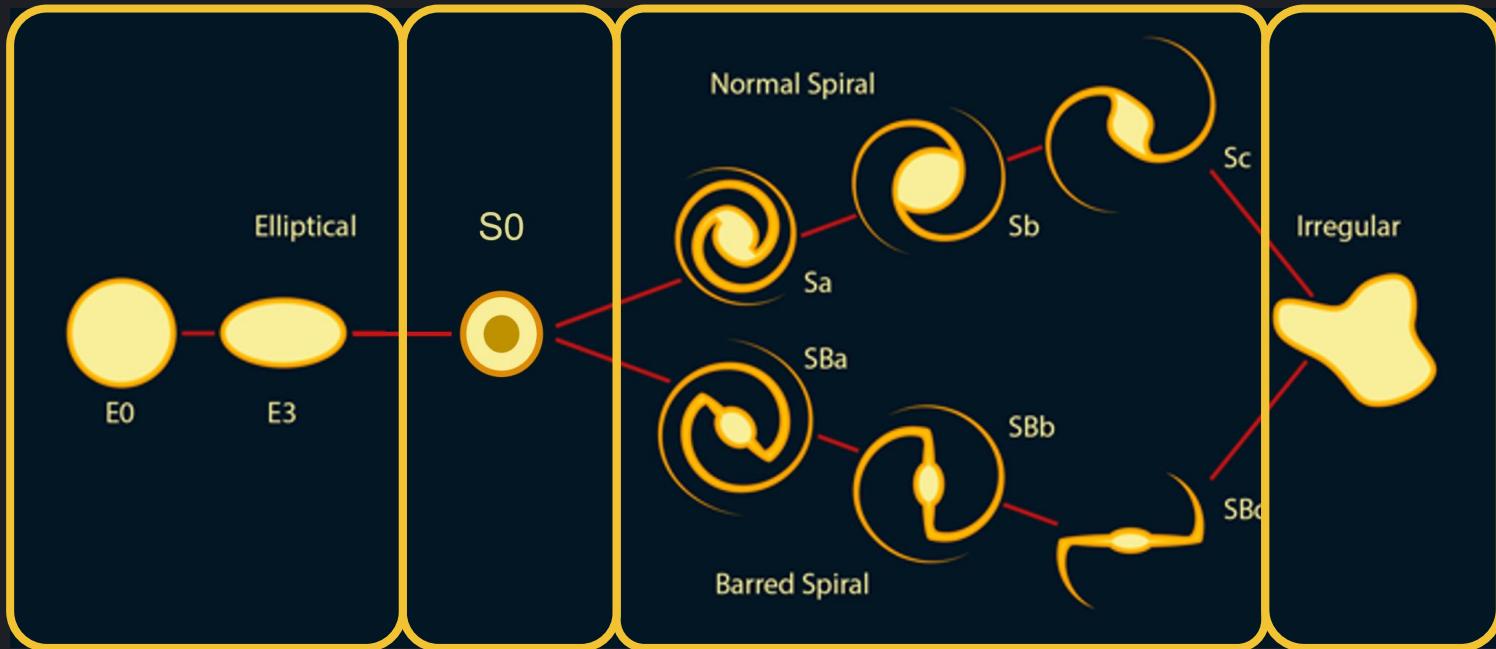
Learn about:

- Variety of Galaxies
- Evolution History
- Star Formation Rates, Scale and Mergers

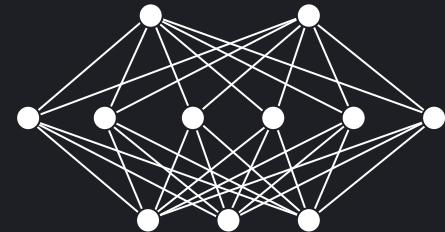
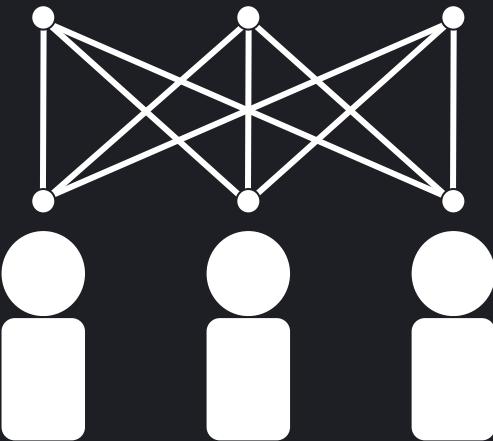


GALAXY CLASSES:

Nair et al. (2010) ApJS 186 427 DOI: 10.1088/0067-0049/186/2/427



Objective: Sort Galaxies



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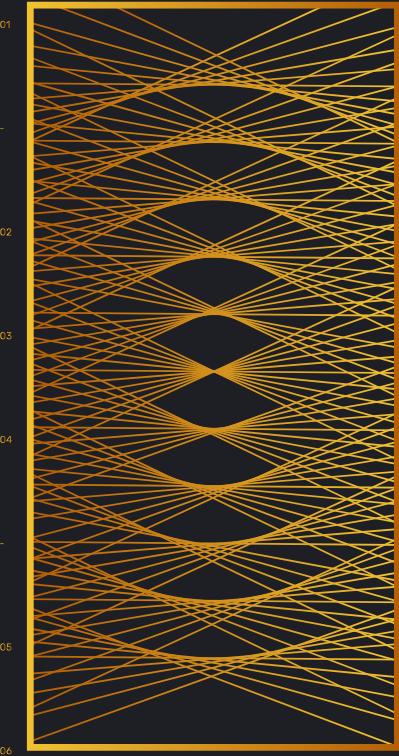
02

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02. DATA

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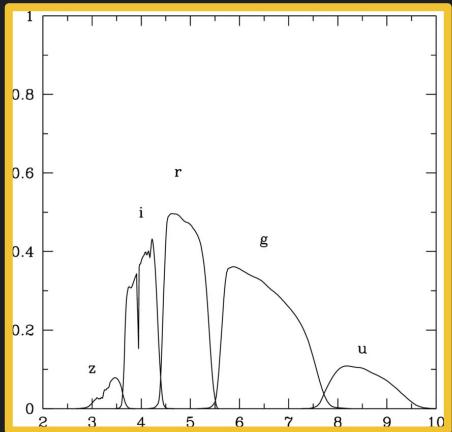
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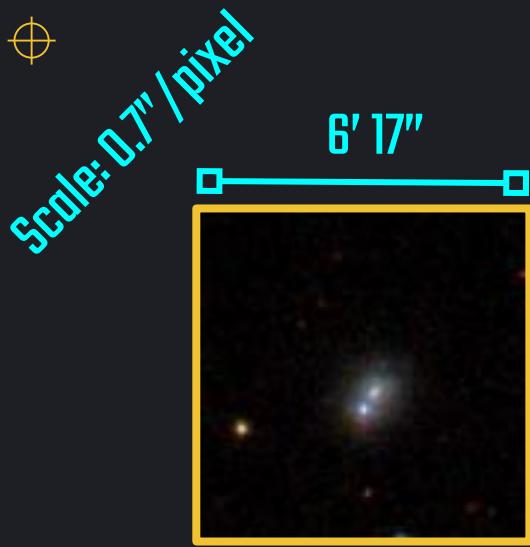
06



Sloan Digital Sky Survey (SDSS):

- 14,034 g-band Galaxy images





SDSS IMAGES



01

02

03

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05

06



Irregular



Lenticular



Spiral



Irregular



Elliptical



Spiral



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01

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06



Uneven Classes



SDSS CLASSES

ELLIPTICAL		2723
LENTICULAR		3215
SPIRAL		7708
IRREGULAR		388





DATA AUGMENTATION



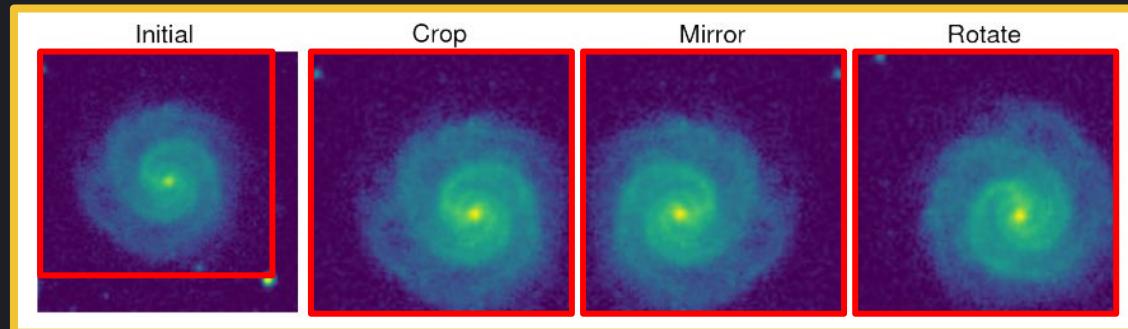
Crop image by each corner and center.
X5 more images



Rotate image by 90 deg
X4 more images



Flip/mirror image on
y=x axis
X2 more image



+ all images normalized





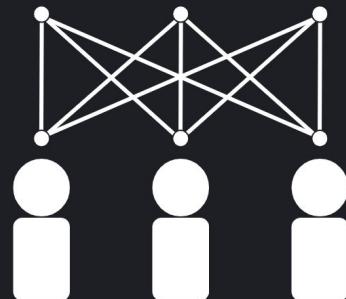
14,034 GALAXIES
561,360 Images

Classified into 4-way & 3-way classes



Galaxy Zoo - Galaxy 10

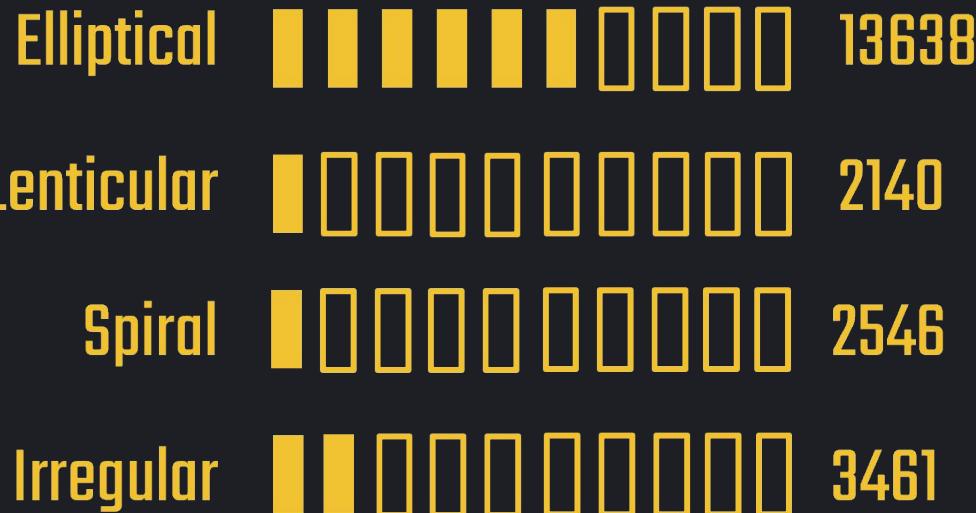
- **Crowdsourcing**
- **10 Classes \Rightarrow Reduced to 4 & 3**
- **21,785 Galaxy Images**
- **Lower Resolution**





Galaxy 10 CLASSES

Less uneven classes





Memory

Problem:

- Load all data at once $\Rightarrow \text{X}$ \Rightarrow Batches
- Small Batches $\Rightarrow \text{X}$ \Rightarrow Too Slow
- Large Batch $\Rightarrow \checkmark$ \Rightarrow Google Collab





PyTorch vs Keras



Paper:

Cavanagh *et al.* use Keras



Problem:

Struggle to load data batches in Keras

Solution:

Implement in PyTorch





03. MODELS

01

02

03

04

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01

02

03

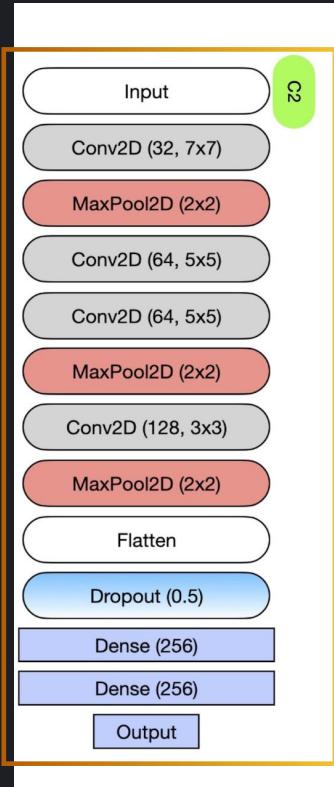
04

05

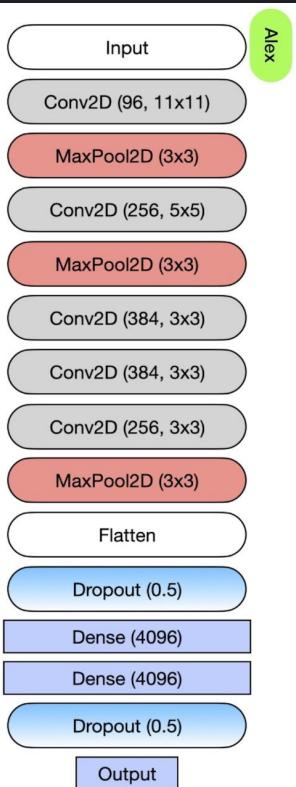
06

Their network and Our networks

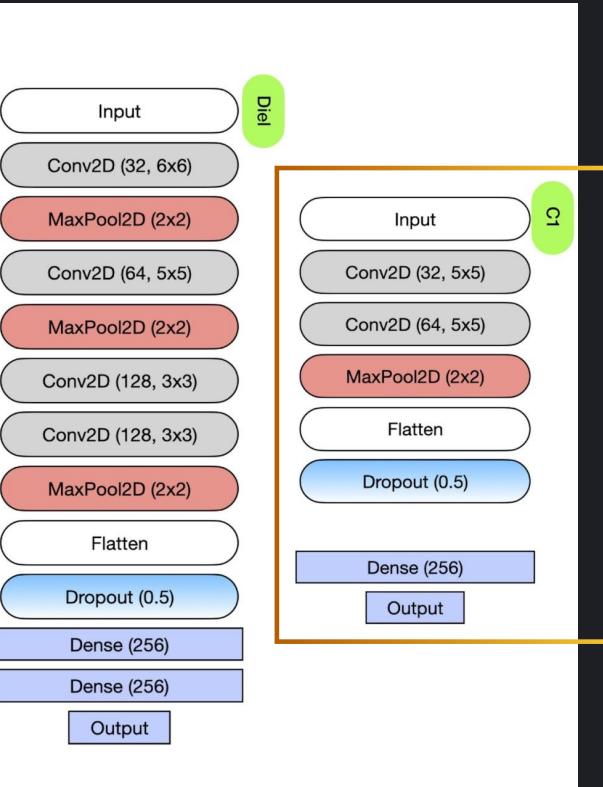
Adam



Alex



Adadelta

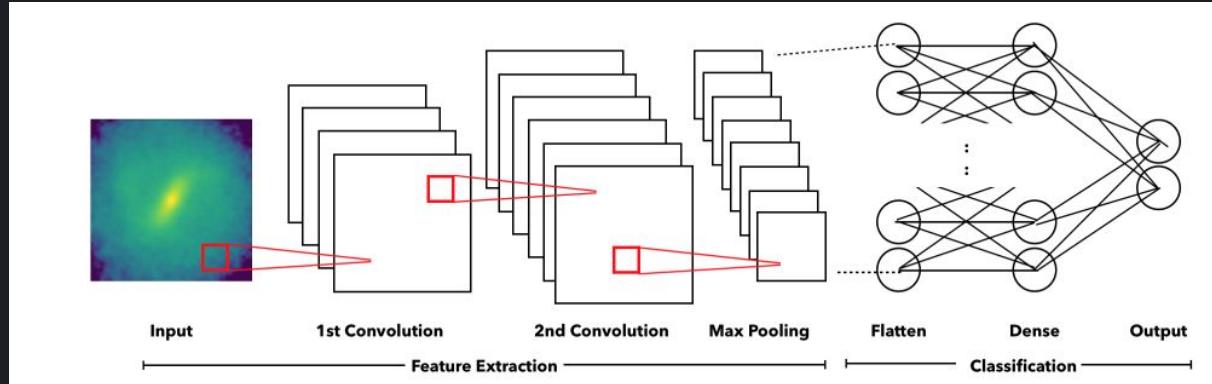


- C1, C2 developed by authors
- C2 new and improved model that performs best on both loss and accuracy
- Early stopping used to discourage overfitting and not waste compute resources

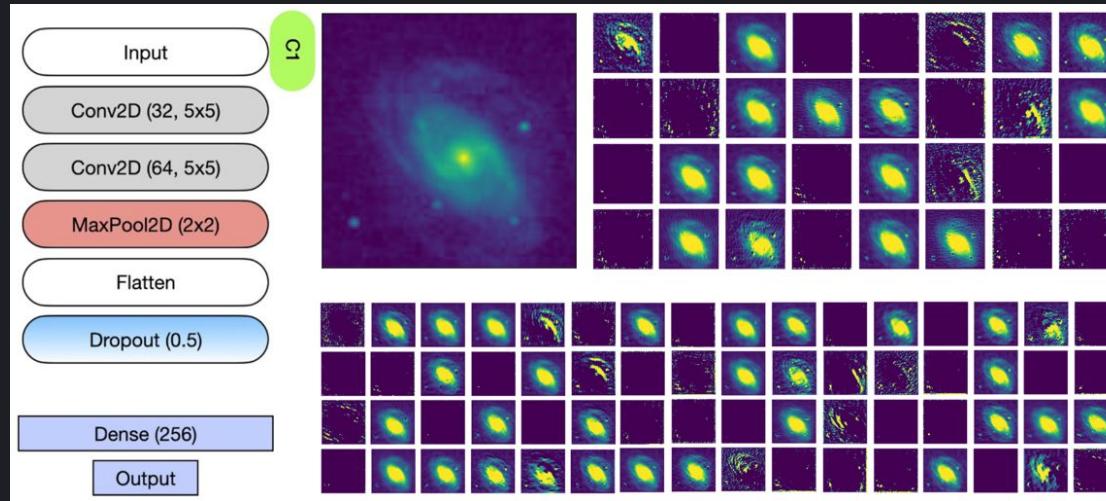


Cavanagh et al.

Feature Maps



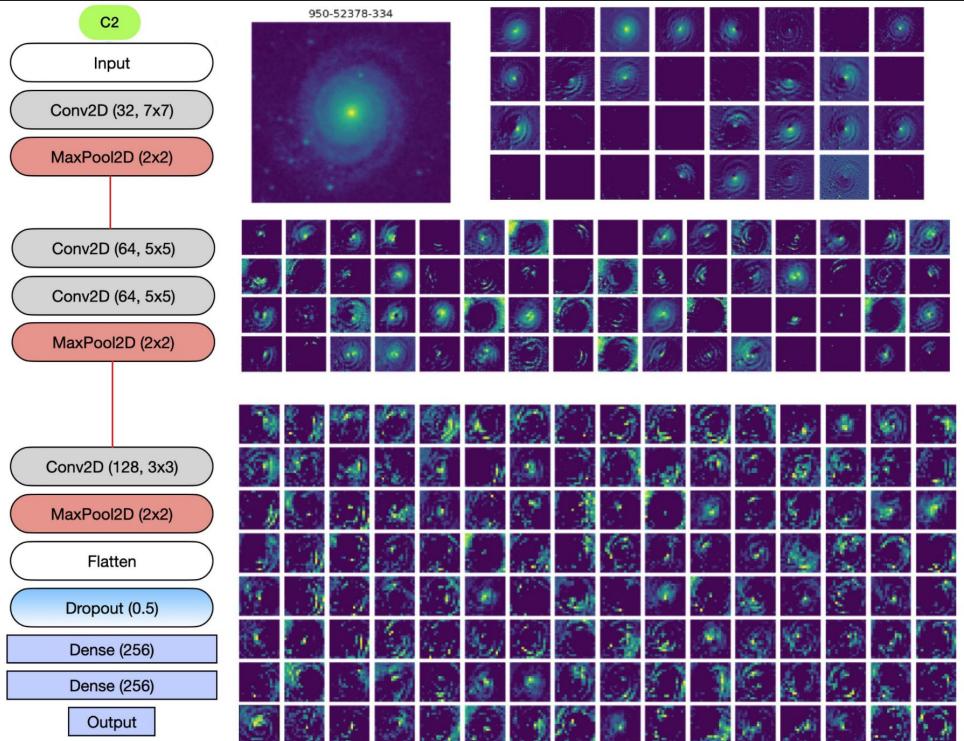
Our Plots



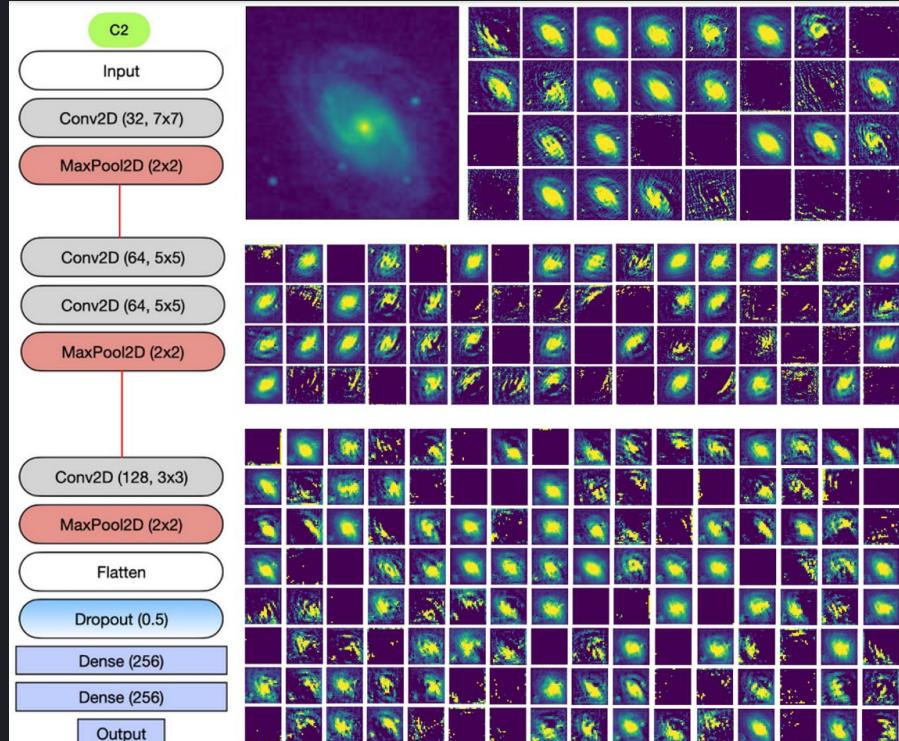


C2 Feature Maps

Cavanagh *et al.*



Our Plots



003-1040559

1250 003-77156.8

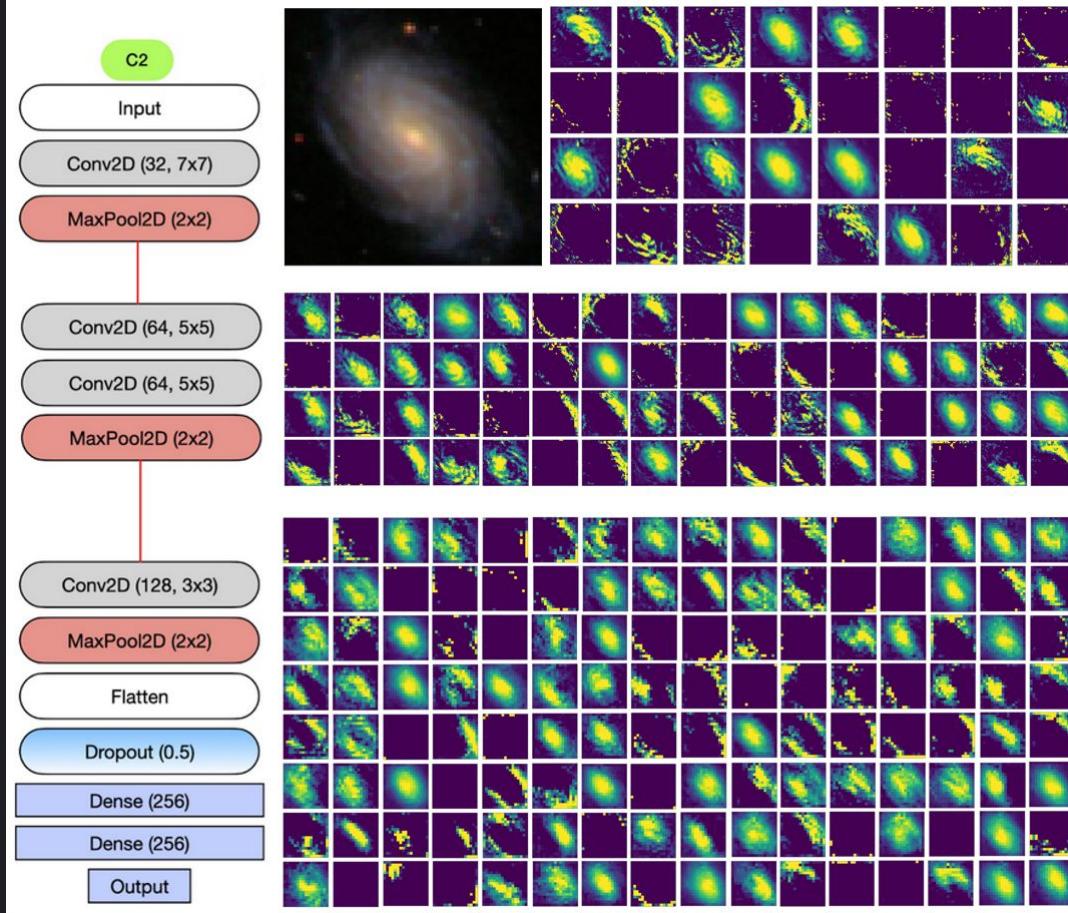
1760 0009-14563.7 73273

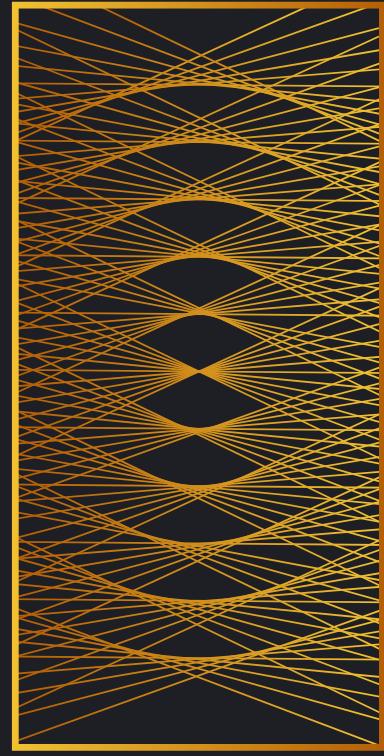


C2 Feature Maps with Galaxy10 data



Our Plots





04. RESULTS

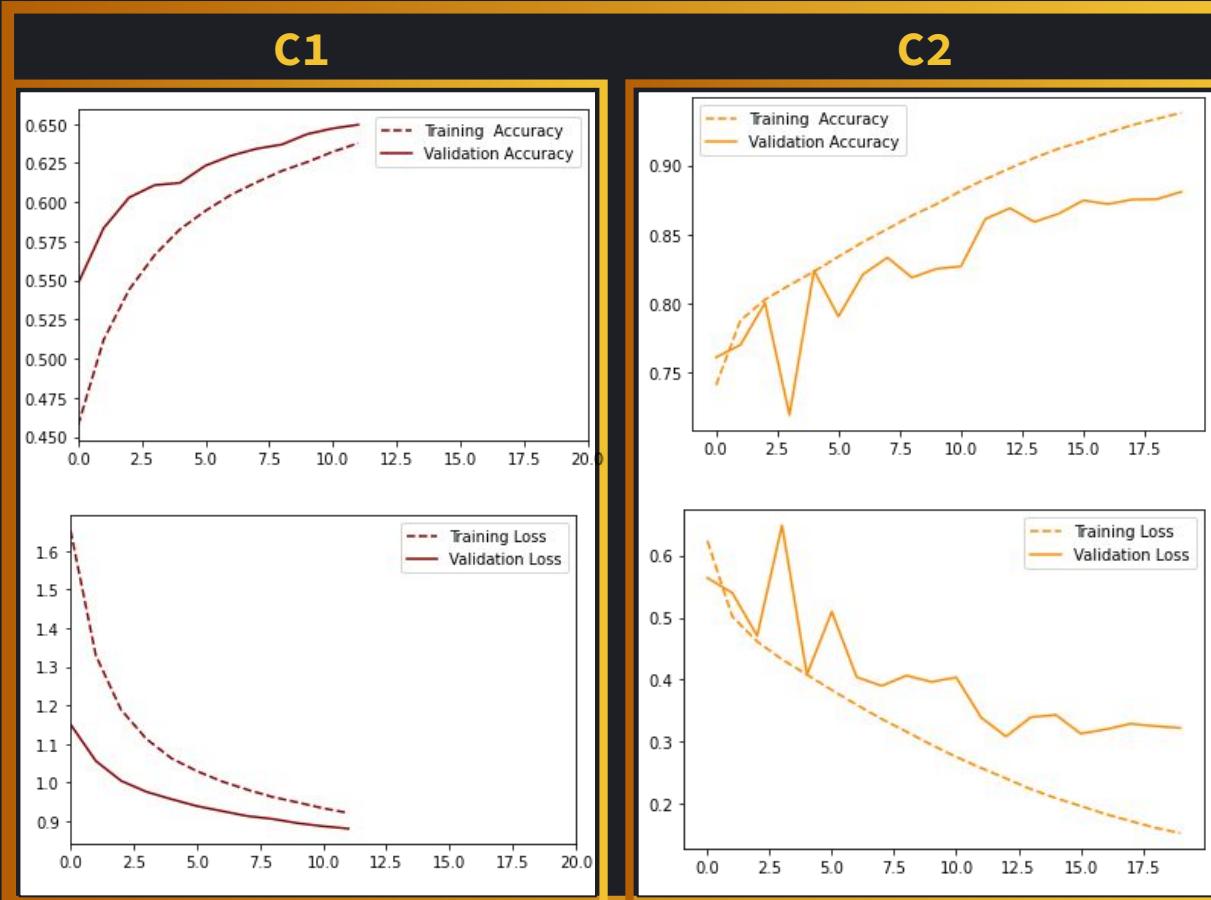
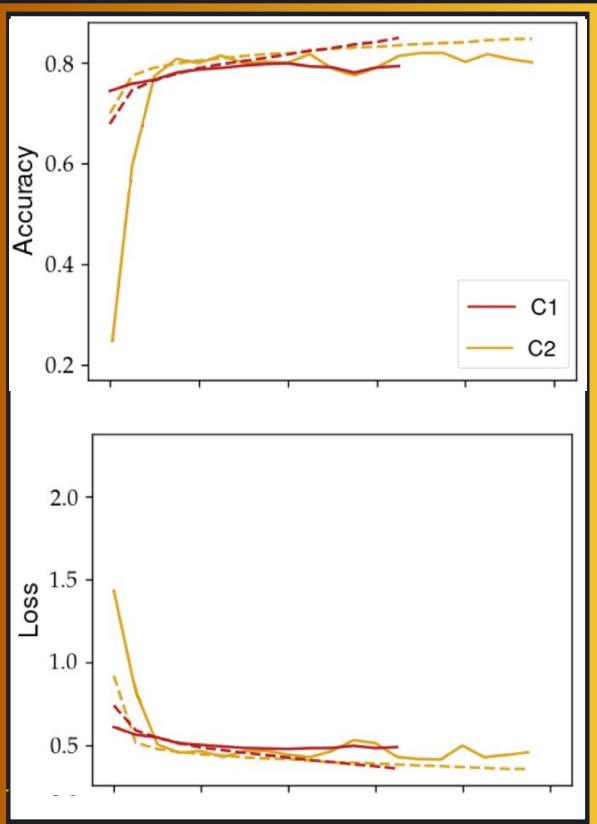


Cavanagh et al.

(561,360 images)

SDSS - Keras

Our Results
(300,000 images)



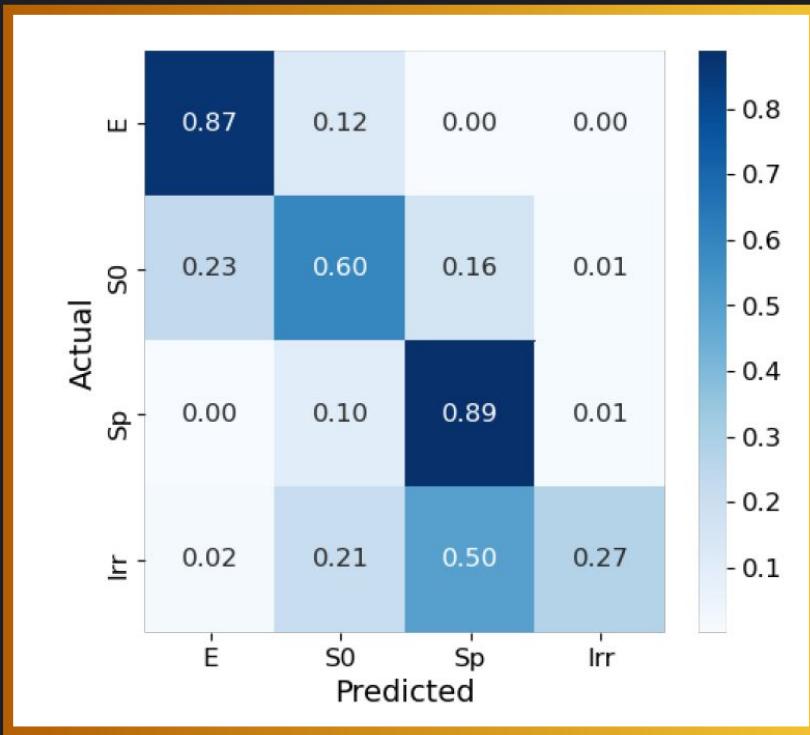


SDSS - Keras

Results from test set

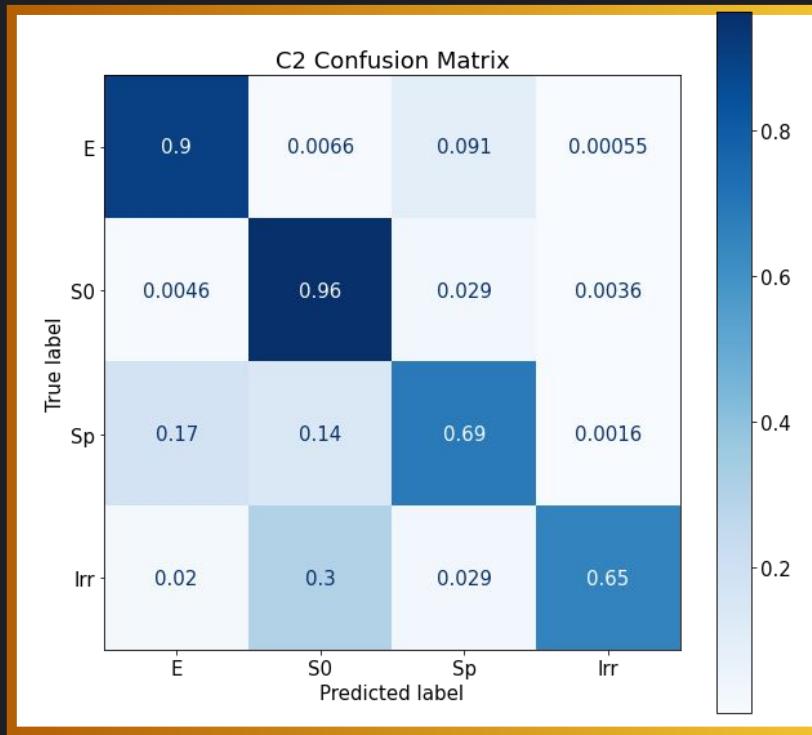


Cavanagh et al.
(561,360 images)



C2

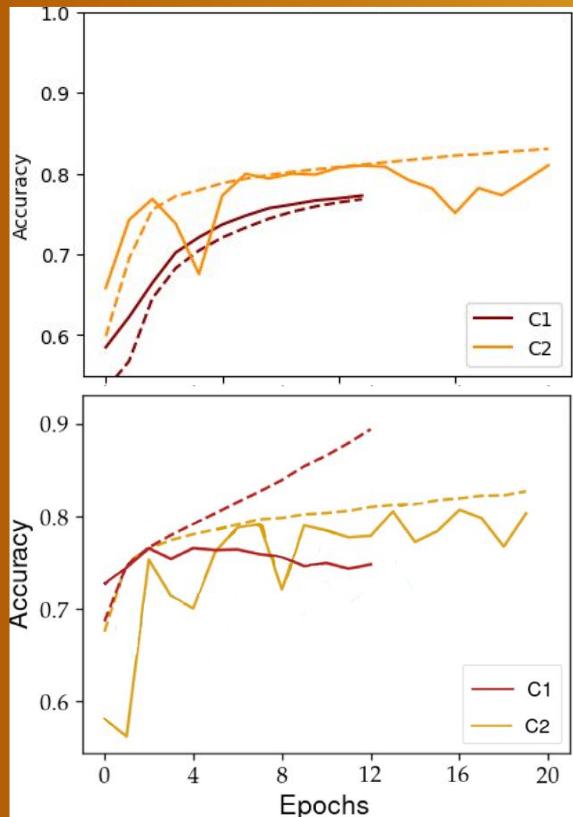
Our Results
(300,000 images)



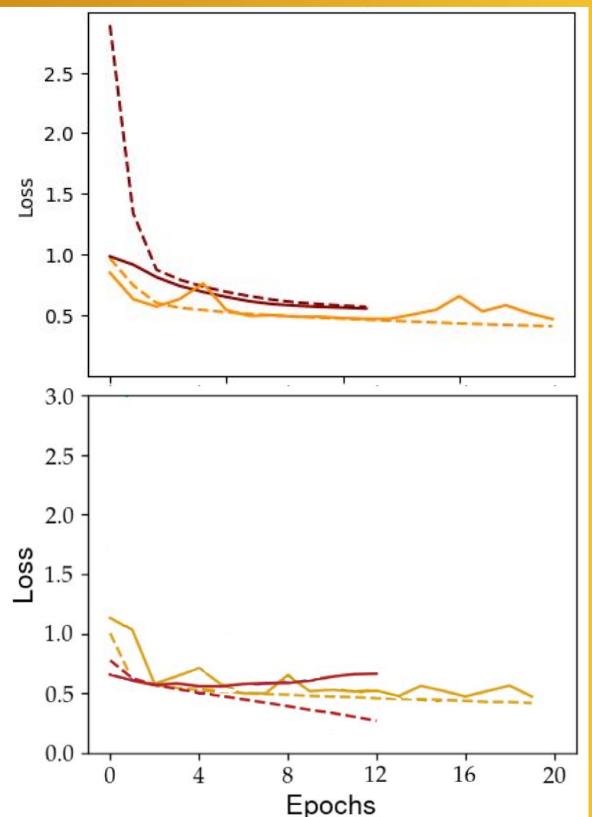


Our Results

Accuracy

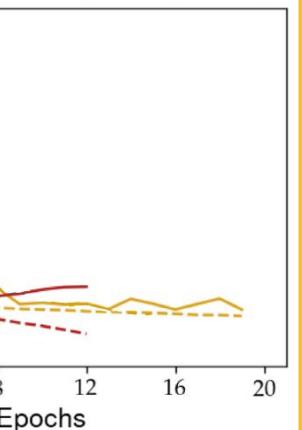
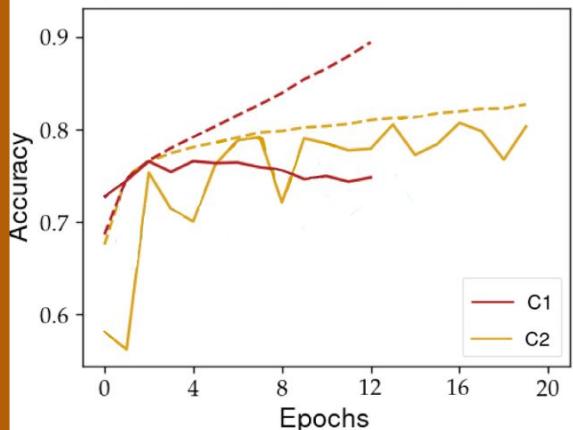


Loss



Cavanagh *et al.*

Accuracy



SDSS - PyTorch

4-Way Classification

(561,360 images)

— Validation
- - - Training



SDSS - PyTorch

Results from valid set

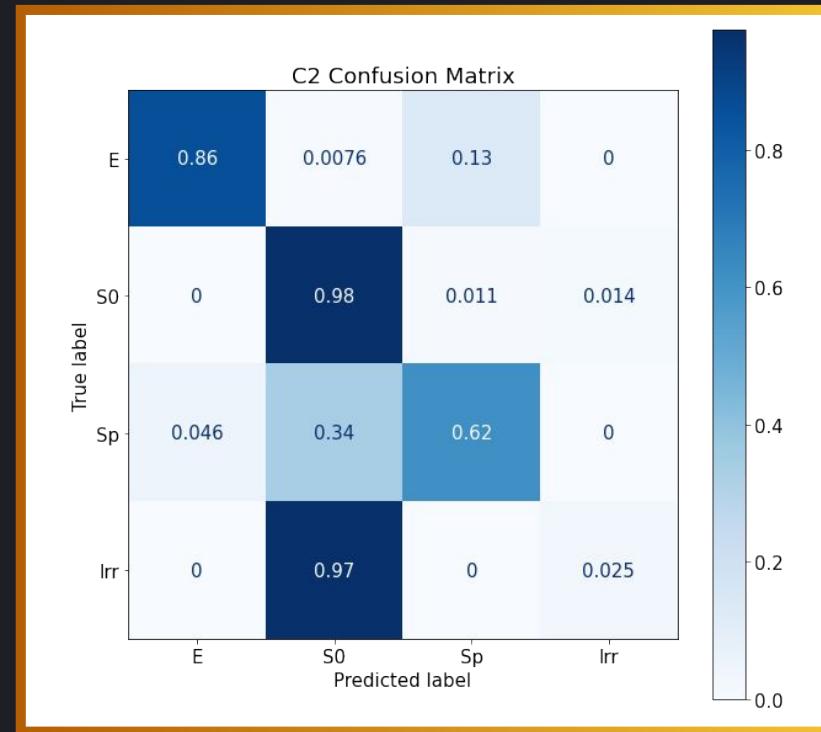
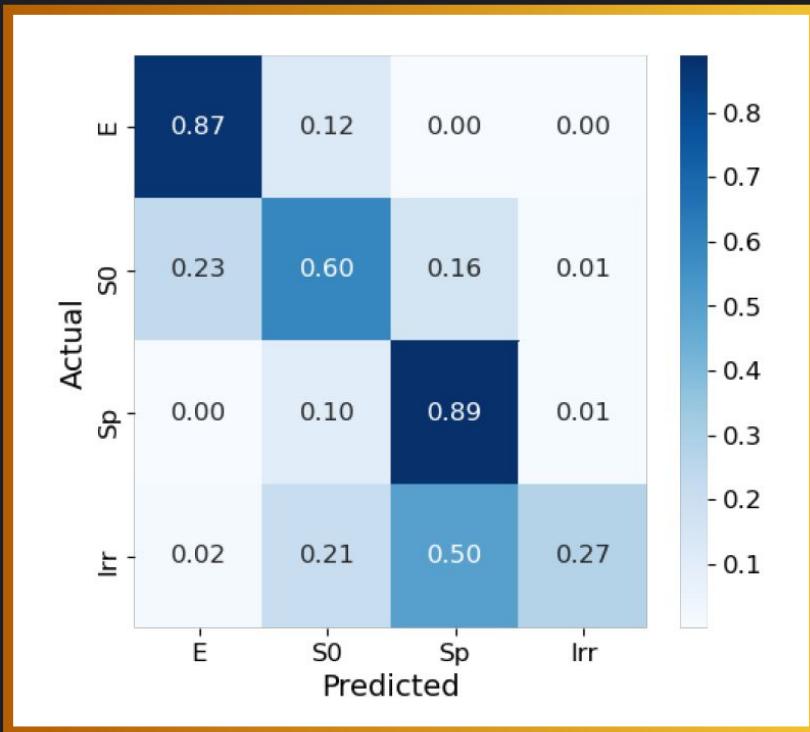
Cavanagh *et al.*

(561,360 images)

C2

Our Results

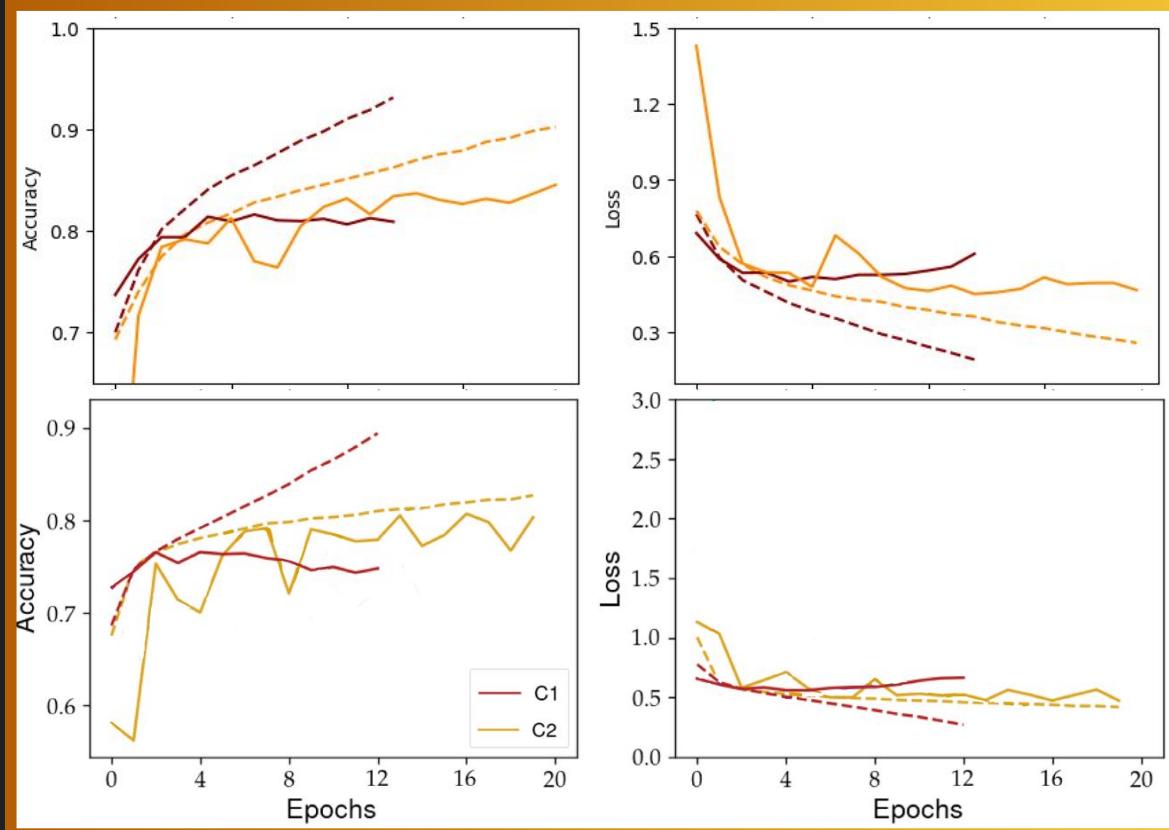
(561,360 images)





Our Results

Cavanagh *et al.*



Loss

Galaxy 10 - Keras

4-Way Classification

(21,785 images)

— Validation
- - - Training



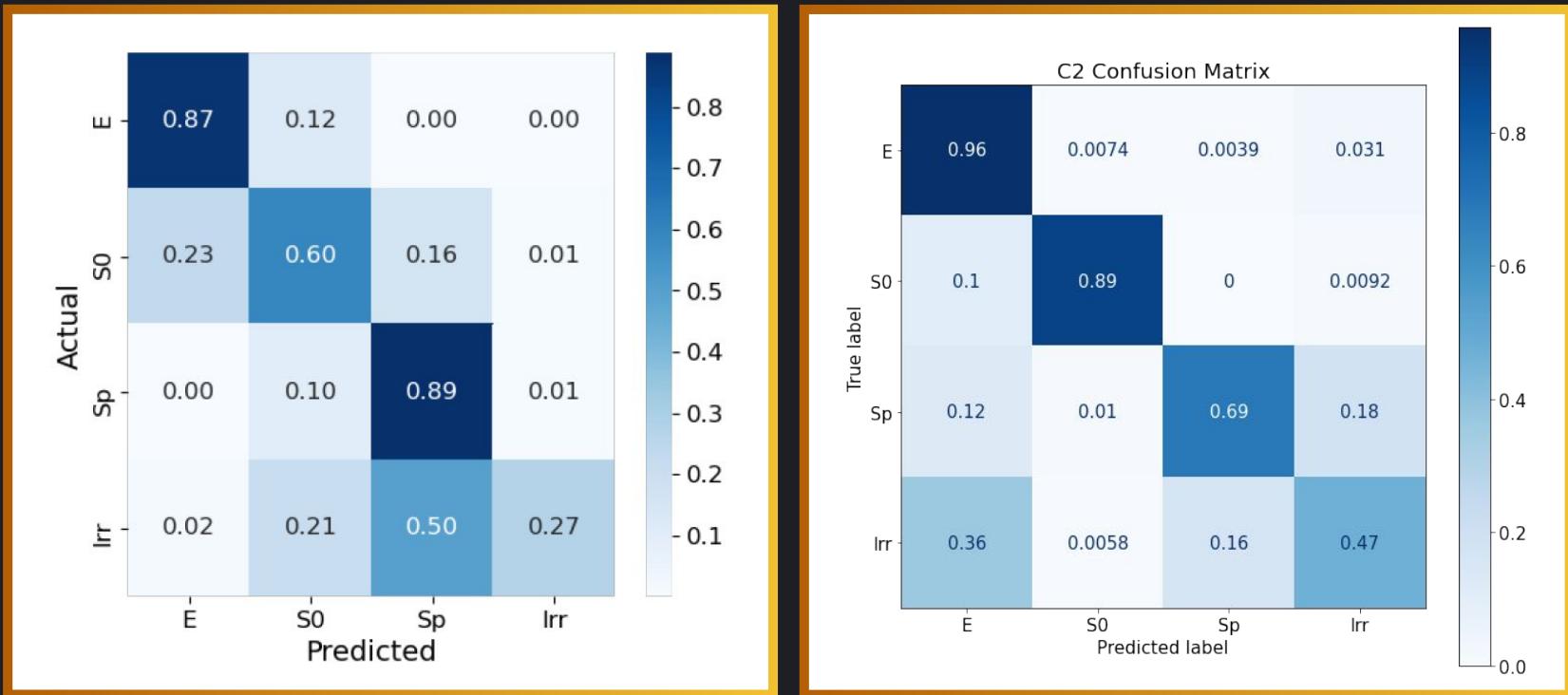
Galaxy 10 - Keras

Results from test set

Cavanagh *et al.*

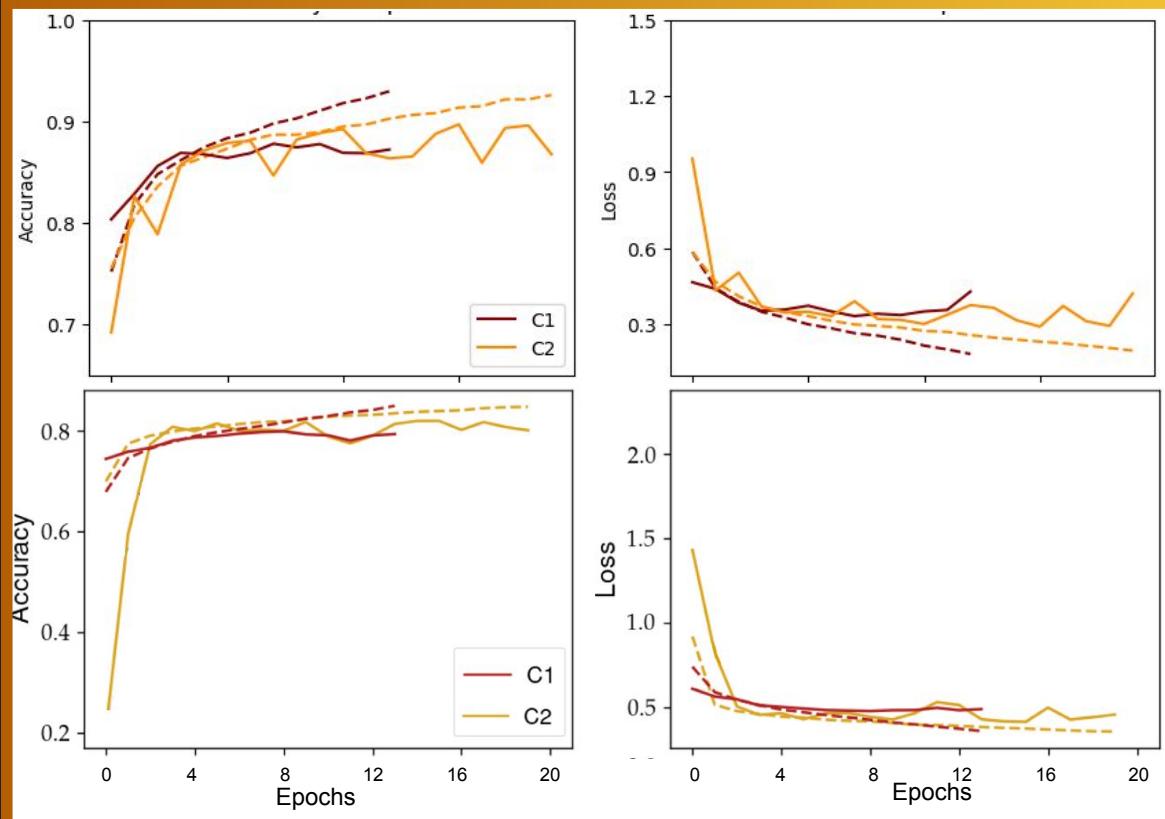
C2

Our Results



Accuracy

Loss



Galaxy 10 - Keras

3-Way Classification

(21,785 images)

— Validation
- - - Training



Galaxy 10 - Keras

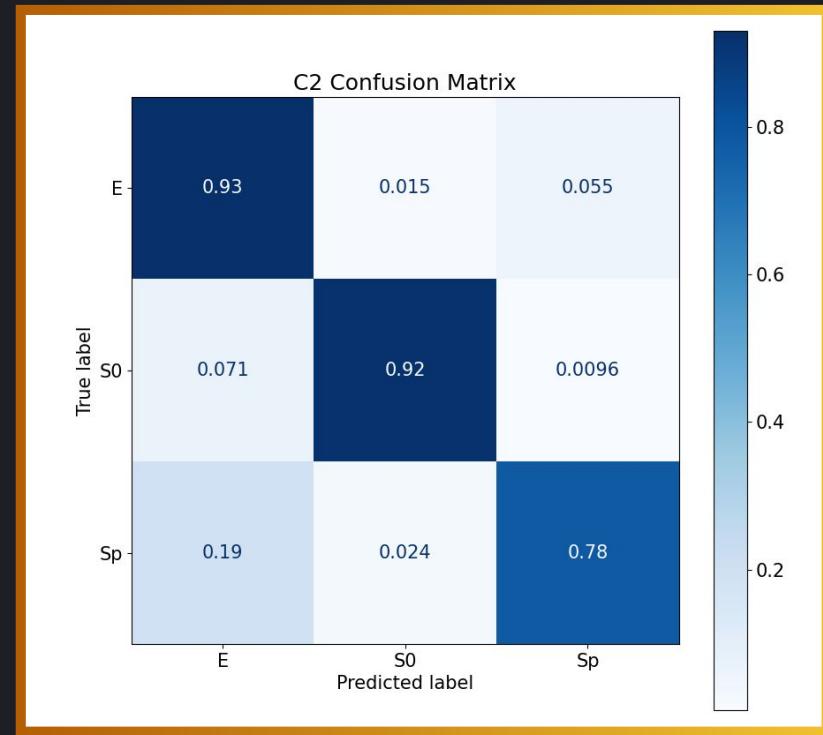
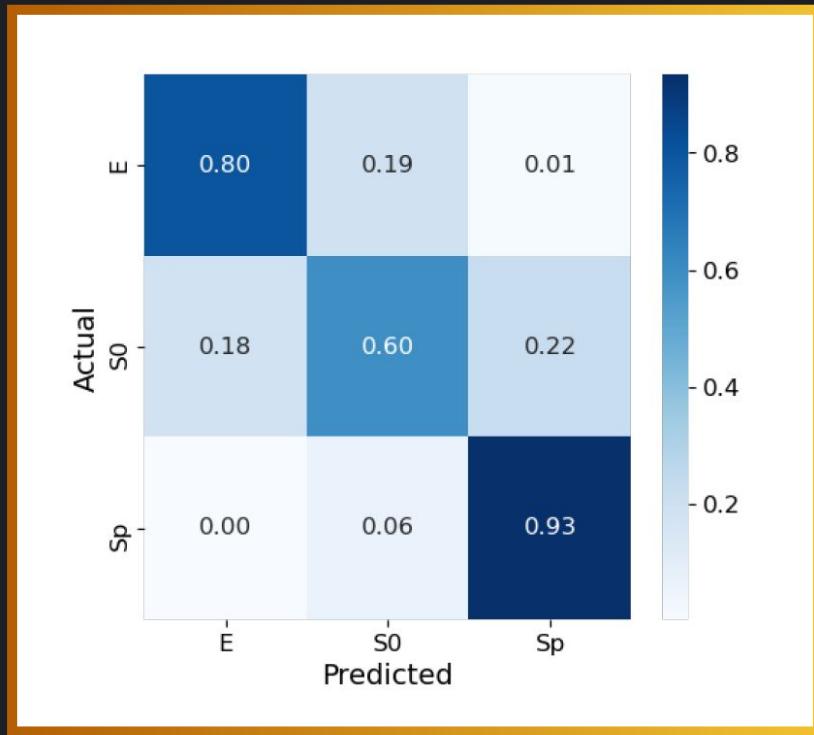
Results from test set

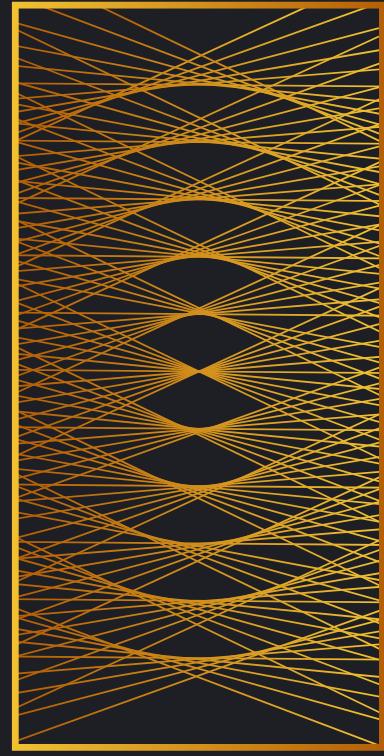


C2

Cavanagh *et al.*

Our Results





05. CONCLUSIONS

Overall Results

Network	#-Way	Data	Augment	Framework	Test Accuracy
C1	3	G10	No	Keras	87%
					80%
		Paper	Half		65%
			Full		75%
	4	G10	No	PyTorch	77%
					88%
		Paper	Half		84%
			Full		88%
C2	3	G10	No	Keras	81%
					81%
	4	Paper	Full	PyTorch	81%
					81%

Cavanagh et al.

Cavanagh et al.

Reproduced Results

Networks:

- AlexNet
- Dieleman
- C1
- C2

of Class:

- 2 Way
- 3 Way
- 4 Way

Keras:



Feature Maps:

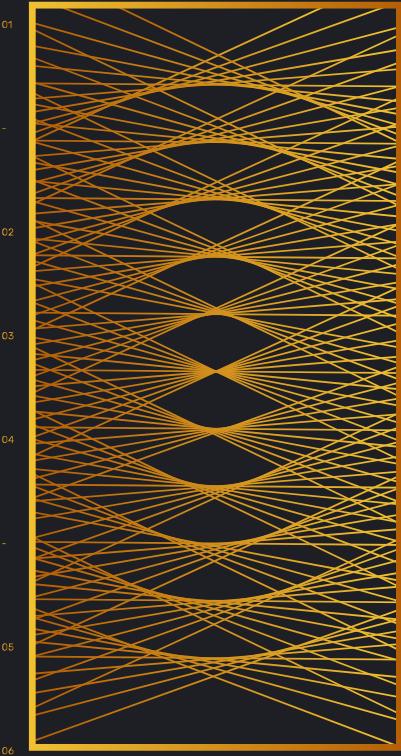


Galaxy Zoo Test:



Extra:

- PyTorch
- Galaxy 10 Train



06. OUTLOOK

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Future Directions

Balance classes, more rigorous testing

Is Simple Better?

Augmentation, regularization, g-band

Data Driven Labels?

Rethink old morphology classification schemes



GitHub Repo:

github.com/ashley-ferreira/PHYS449



CREDITS: This presentation template was created by [Slidesgo](#), including icons by [Flaticon](#), and infographics & images by [Freepik](#)





QUESTIONS & DISCUSSION

Thank you for your time and feedback





Overview of Appendix Slides

01. Our Hyperparameters

Detailed List

02. C1 CMs

C1 Classification
Confusion Matrices

03. Galaxy 10 Results

Direct Comparison
of 3-way and 4-way

04. Cavanagh *et al.* CMs

C2 Confusion
Matrices from Paper





01. Our Hyperparameters

Optimizer : Adam

Other than for SDSS Half Data
Keras where Adadelta was used

Learning Rate : 2e-4

Other than for SDSS Half Data
Keras where 1e-4 was used

Test/Train/Validation Split : 0.15/0.72/0.13

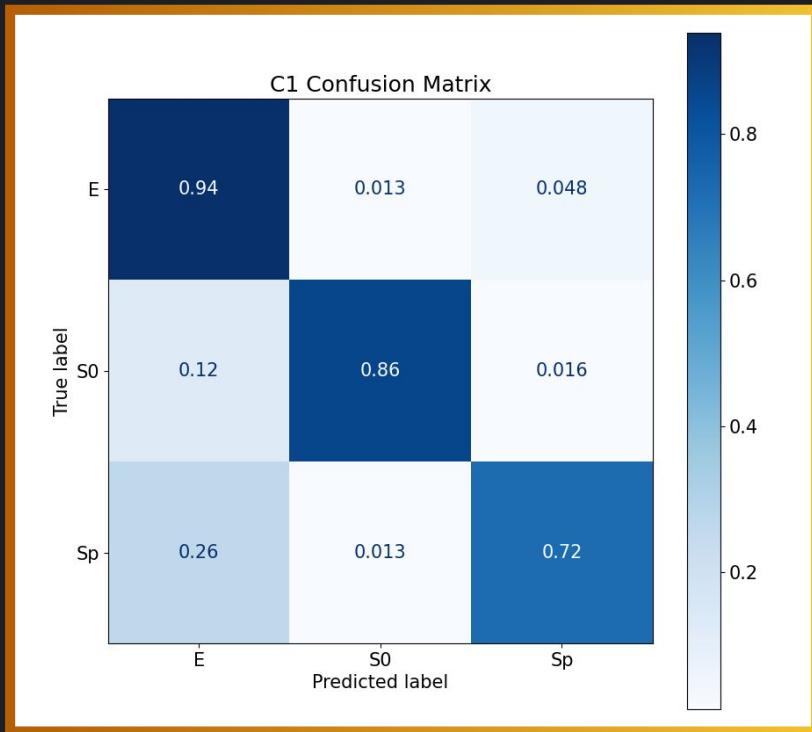
Other than for PyTorch implementation where
there are just a train and validation set
(which is also used for testing)

For both C1 & C2 in both Keras & PyTorch

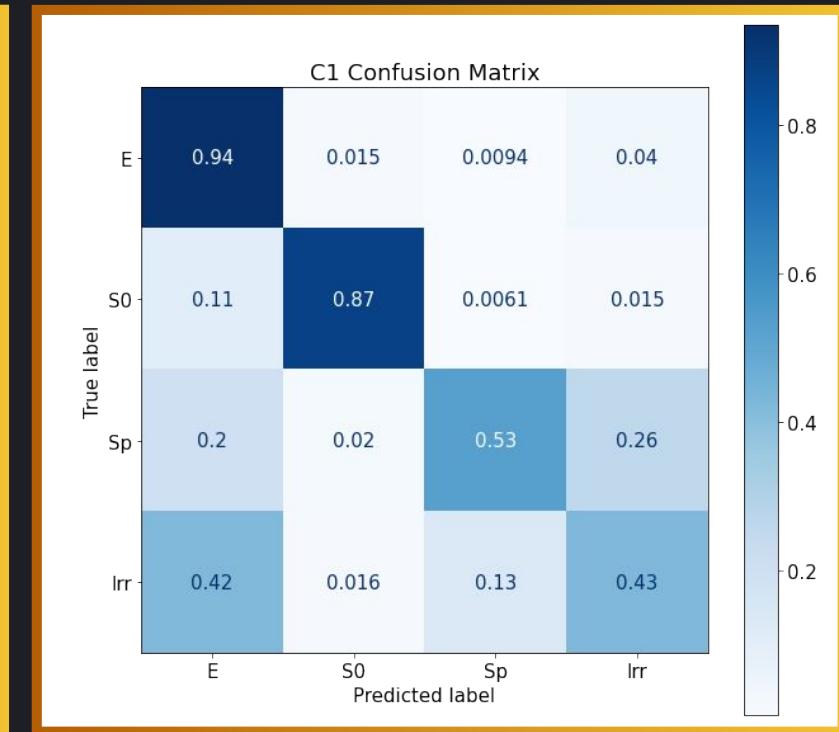


02. C1 CMs: Keras Galaxy 10 Data

Our Results 3-Way

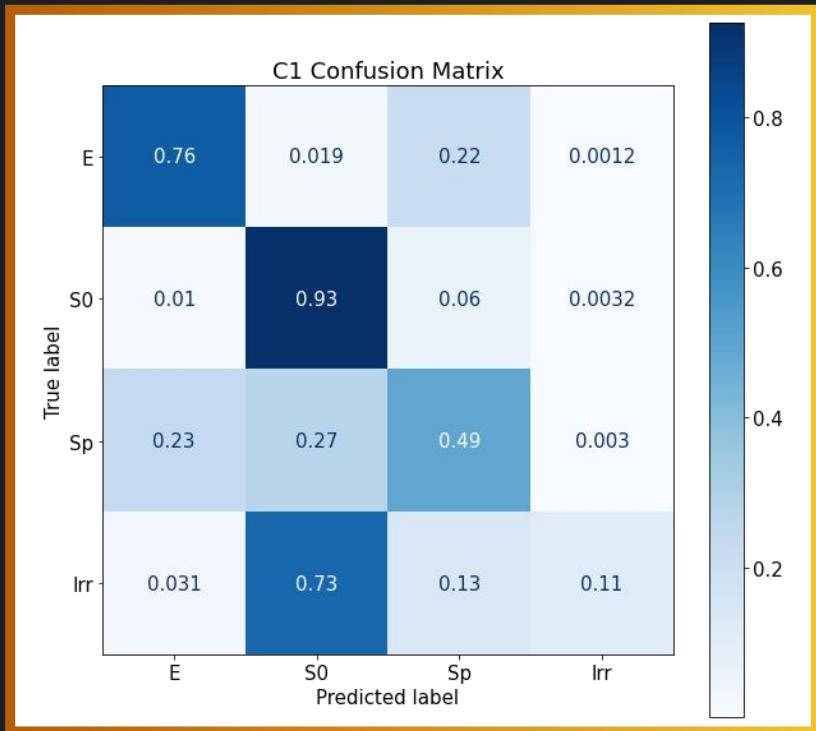


Our Results 4-Way

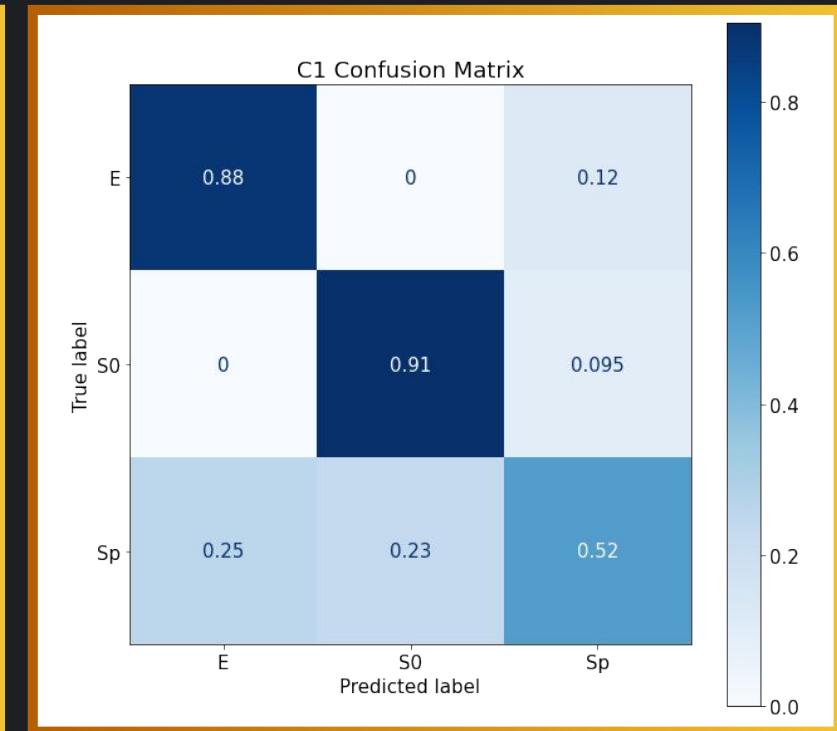


02. C1 CMs: SDSS

Keras Half Data



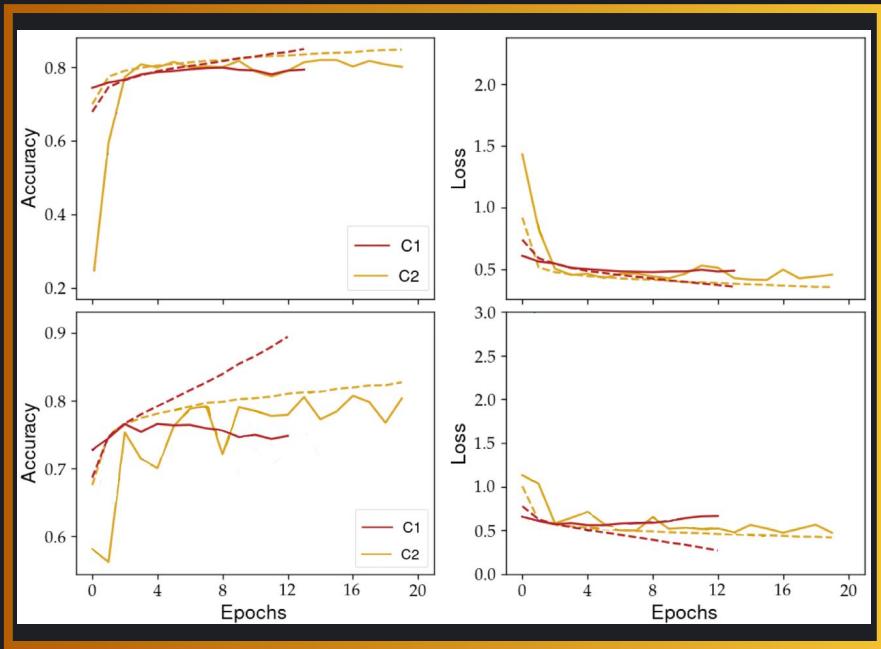
PyTorch Full Data Results



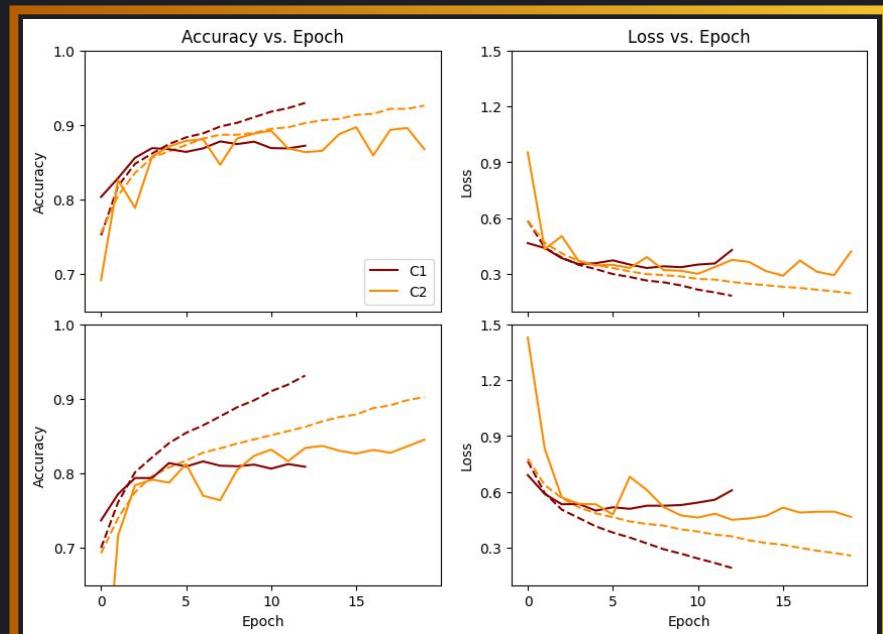


03. Galaxy 10 Results

3-way



4-way



003-1040559

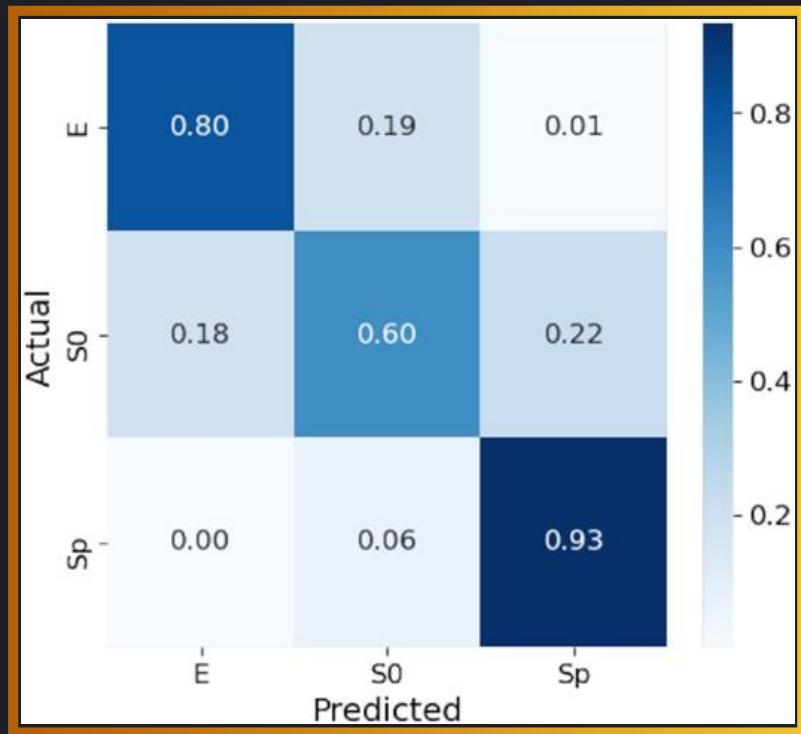
1250 003-77156.8

1760 0009-14563.7

73273

04. Cavanagh et al. CMs for C2, on test set

3-way classification



4-way classification

