Can we emulate the LSST detection pipeline using neural nets?

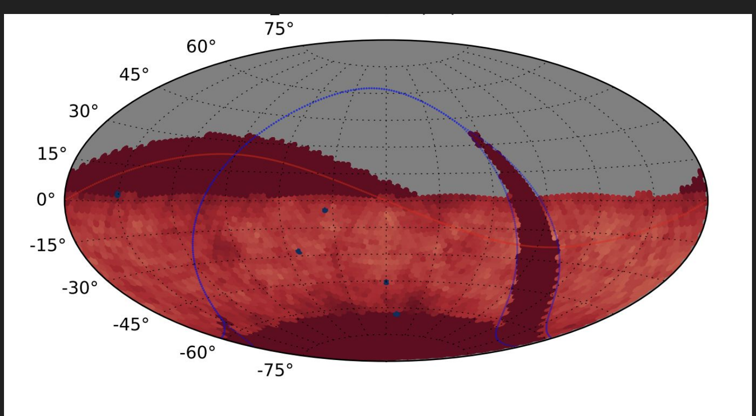
Paxton Scott

Outline

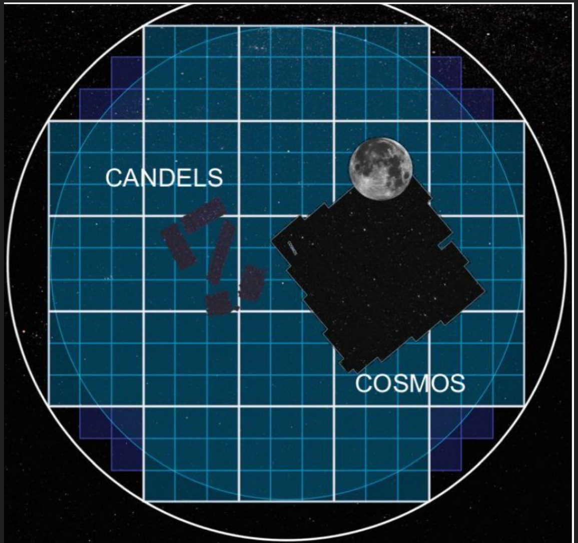
1. **Rubin Observatory/LSST overview**
2. Emulation project outline
3. Data and model results
4. Next Steps
5. Questions

Rubin Observatory/LSST

- Rubin Observatory will conduct 10 year Legacy Survey of Space and Time (LSST)
- Two of the dark energy probes:
    - Weak lensing
    - large scale structure



LSST Observing Strategy (2018)



The problem: overlapping galaxy images (blending)

- LSST looks deeper (further back in time)
- More overlapping galaxies images

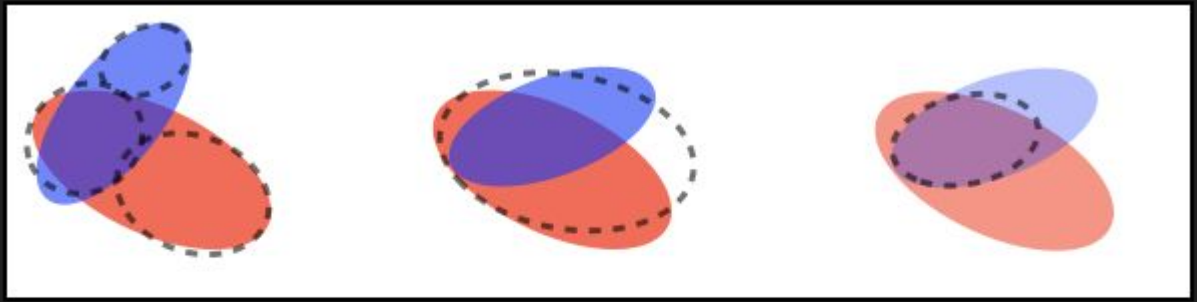


Image from Sowmya Kamath’s thesis defense

Shredded blends

Unrecognized blends

Blending induced detections

- Blending can introduce bias in measurements for weak lensing and large scale structure

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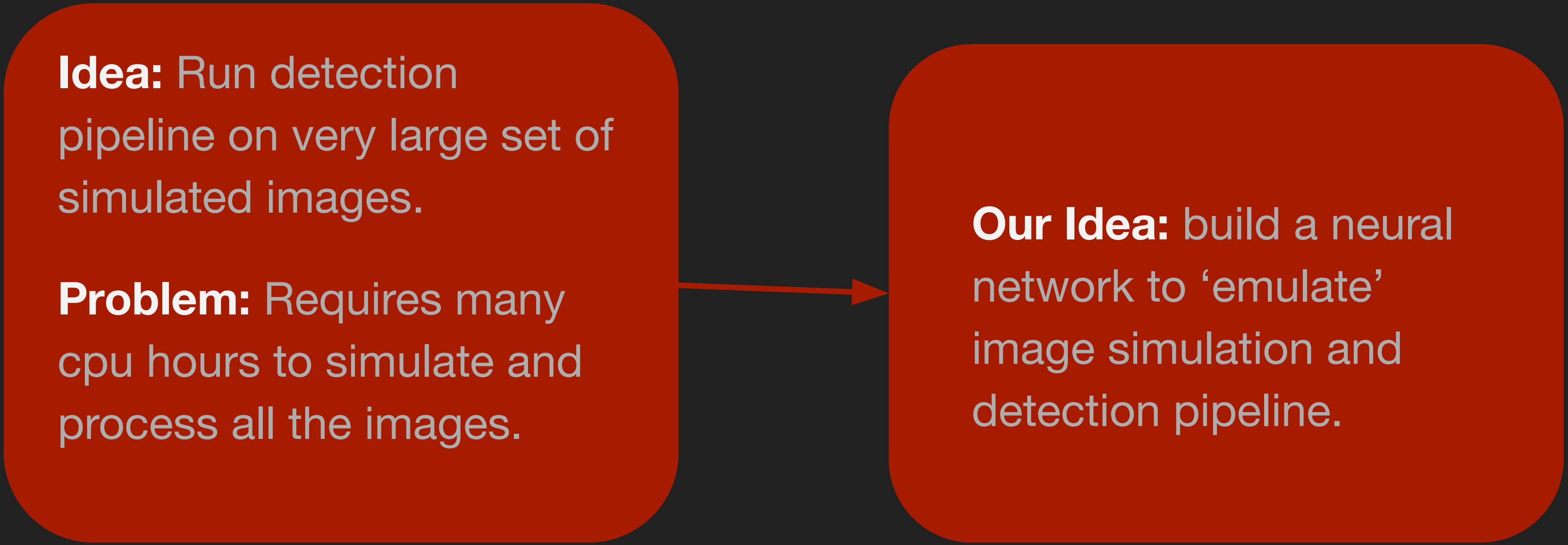
Question: How to estimate bias introduced by blending?



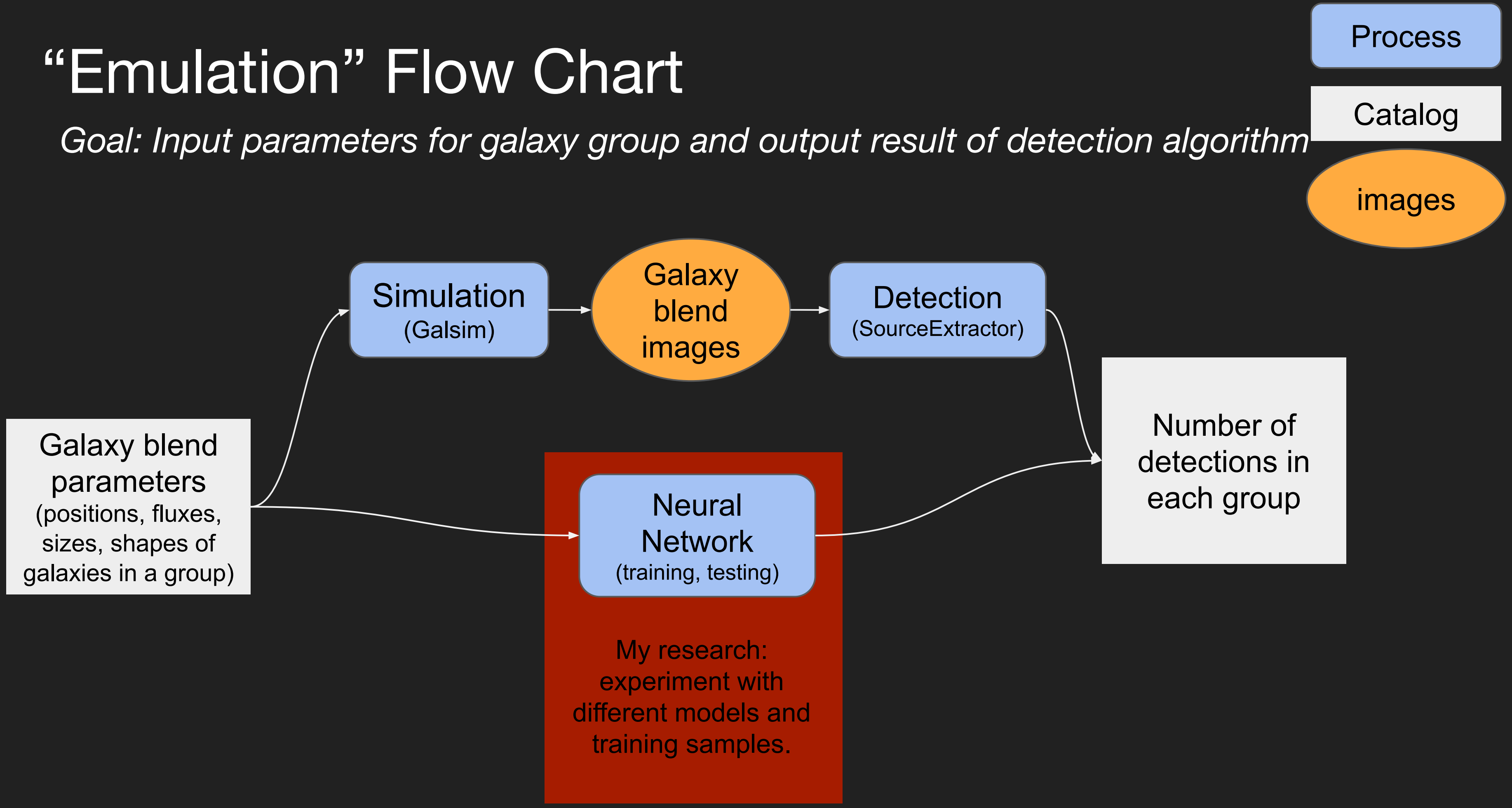
Idea: Run detection pipeline on very large set of simulated images.

Problem: Requires many cpu hours to simulate and process all the images.

Our Idea: build a neural network to ‘emulate’ image simulation and detection pipeline.

“Emulation” Flow Chart

Goal: Input parameters for galaxy group and output result of detection algorithm


Process
Catalog
images
Galaxy blend parameters (positions, fluxes, sizes, shapes of galaxies in a group)
Simulation (Galsim)
Galaxy blend images
Detection (SourceExtractor)
Number of detections in each group
Neural Network (training, testing)

My research: experiment with different models and training samples.

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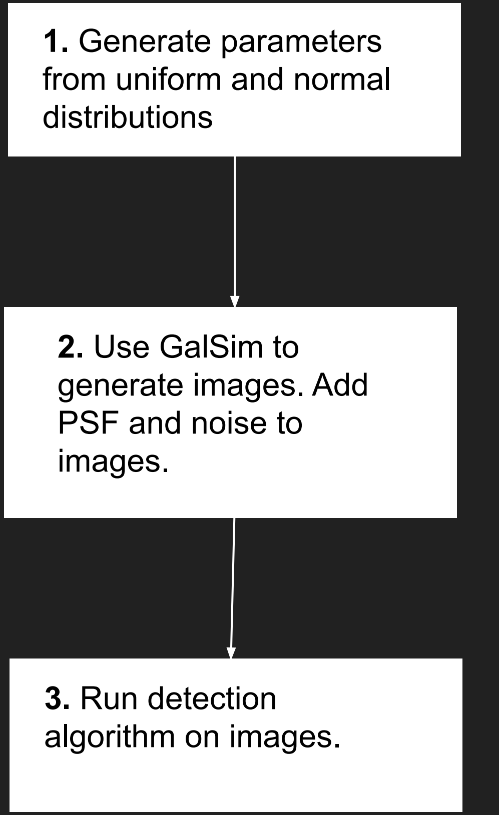
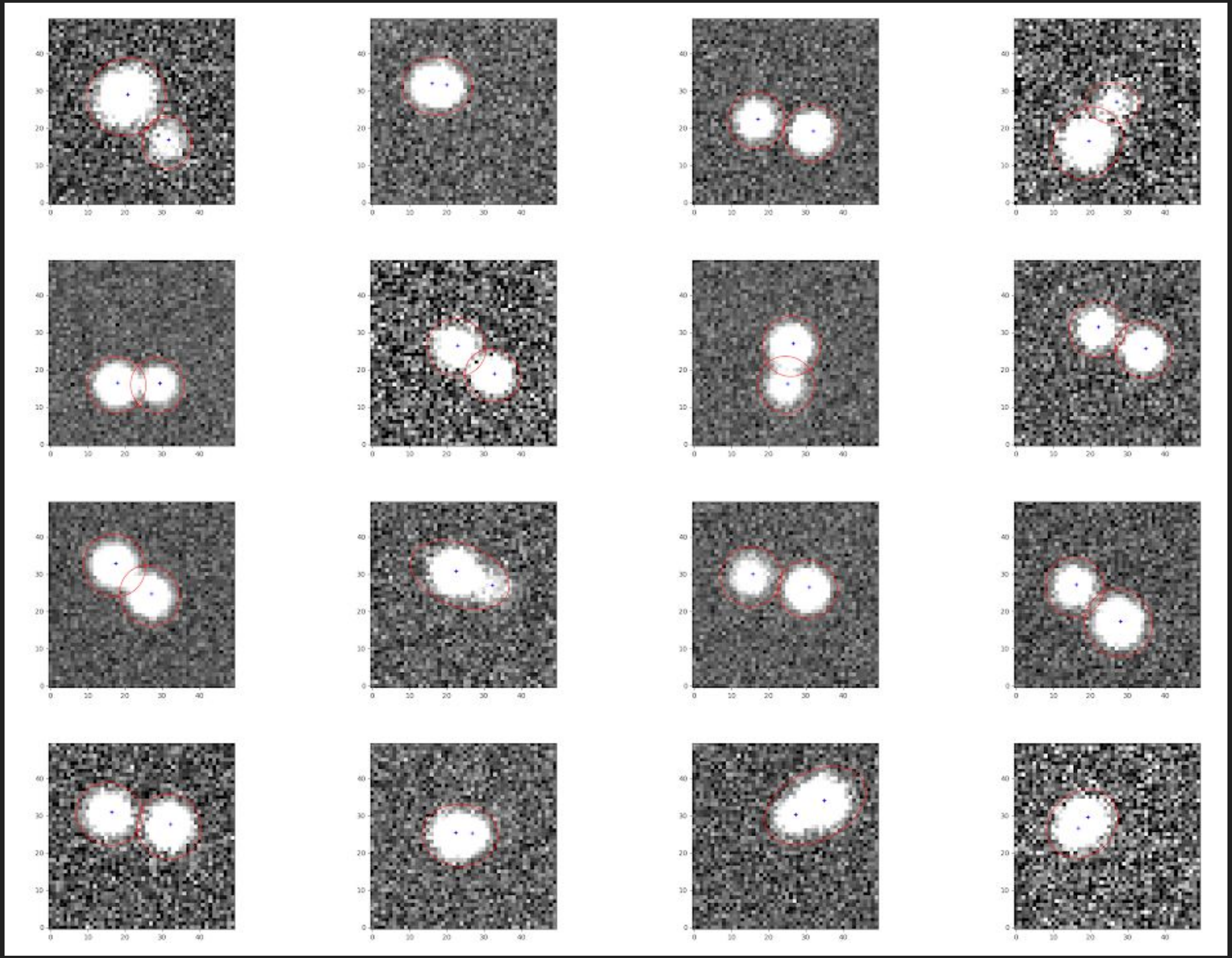
Training Data



1. Generate parameters from uniform and normal distributions

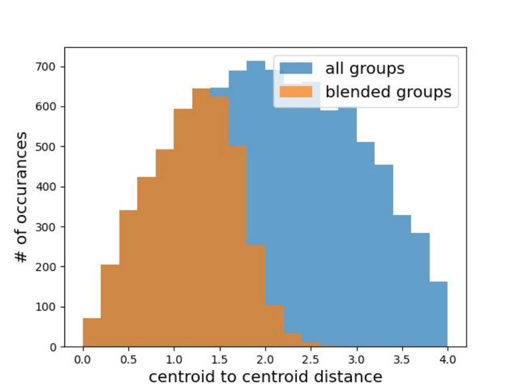
2. Use GalSim to generate images. Add PSF and noise to images.

3. Run detection algorithm on images.

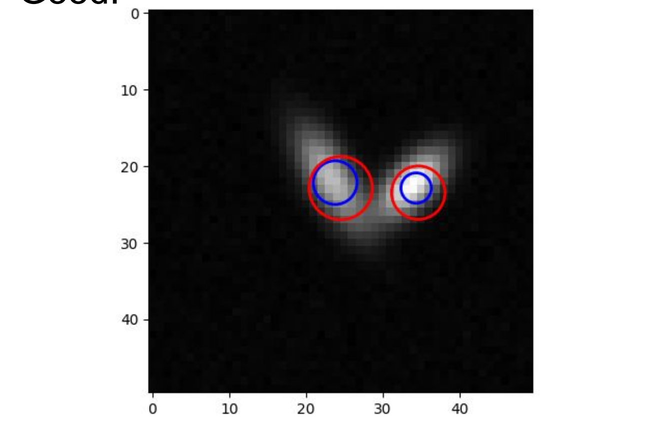


Binary classification

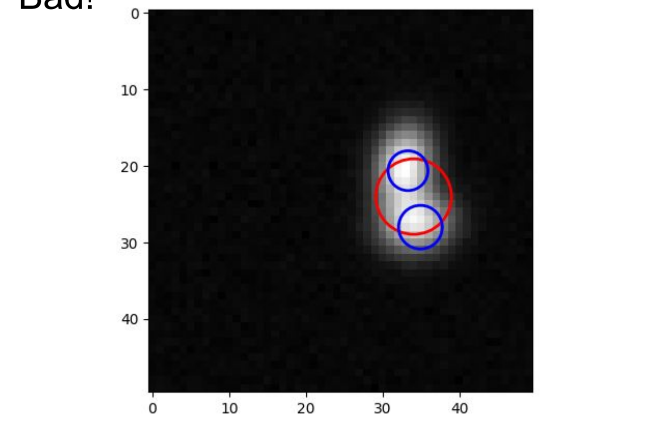
- Simple problem
- familiarize myself with PyTorch
- Output deblended (good) or unrecognized blend (bad)
- **97%** accuracy vanilla neural net
- **94%** accuracy using only euclidean distance



Good!



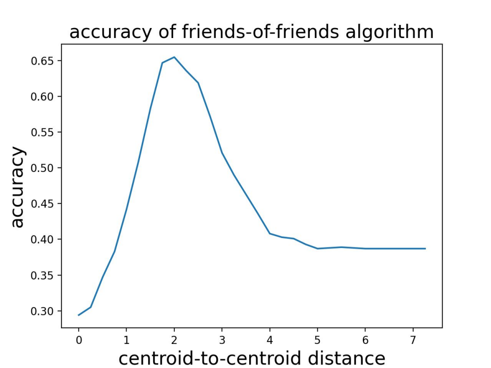
Bad!



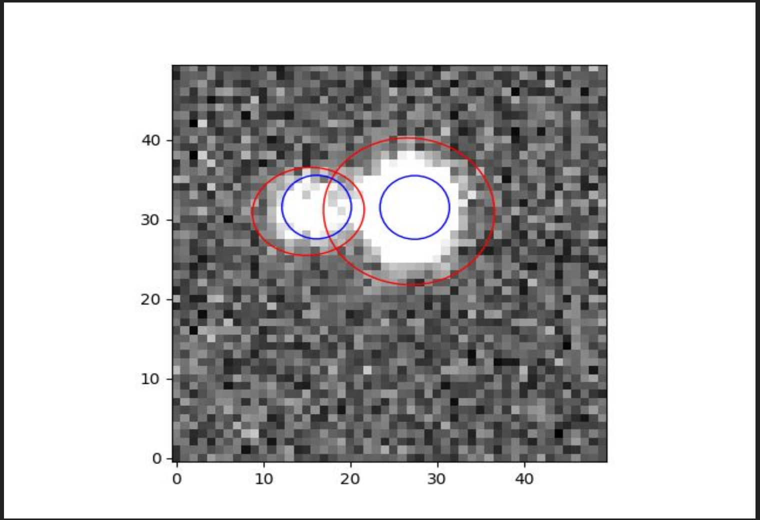
Multiclass classification

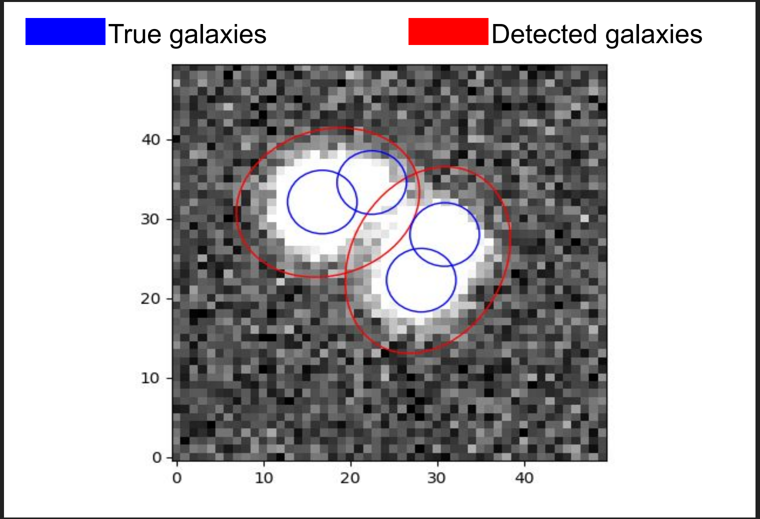
- 1-5 possible galaxies
- Predicts number detected
- Simple architecture
- More complex problem
- **85%** accuracy

65%
Accuracy (classical distance based algorithm)



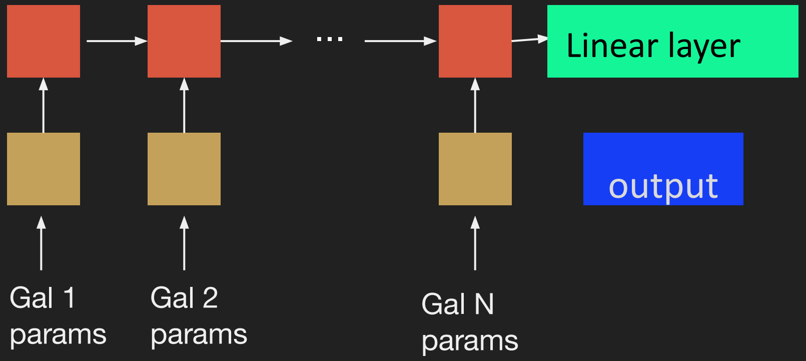
- Padding concern (neural net takes in constant dimension input)



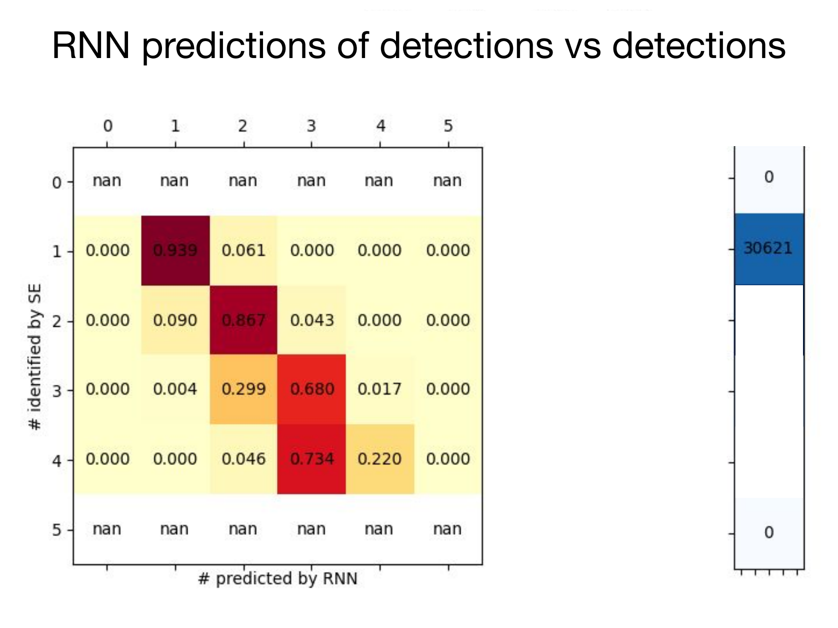


Multiclass classification - recurrent neural net

- RNN solved padding concern
- Variable sized input
- 87% accuracy
- Model assumes sequential order

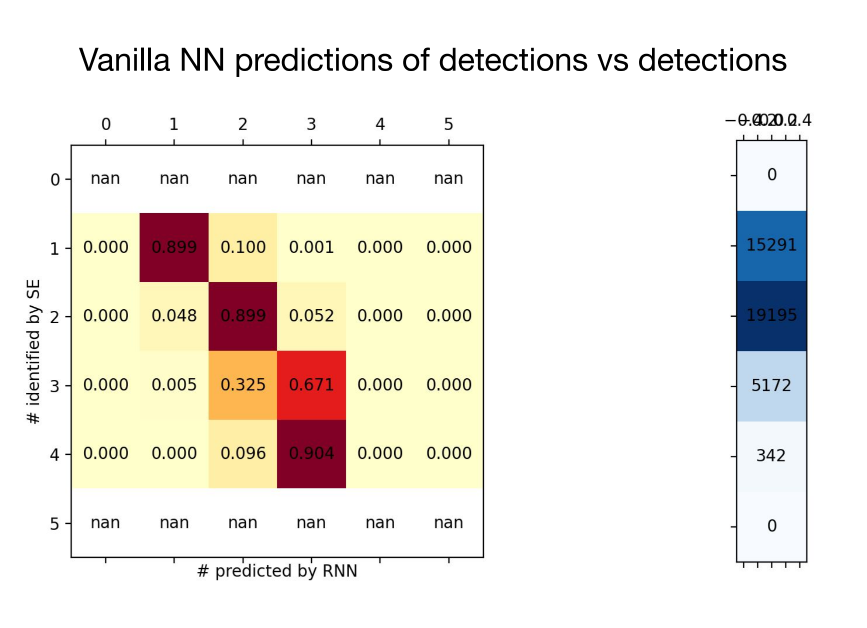


Accuracy matrices



RNN predictions of detections vs detections

# identified by SE \ # predicted by RNN	0	1	2	3	4	5
0	nan	nan	nan	nan	nan	nan
1	0.000	0.939	0.061	0.000	0.000	0.000
2	0.000	0.090	0.867	0.043	0.000	0.000
3	0.000	0.004	0.299	0.680	0.017	0.000
4	0.000	0.000	0.046	0.734	0.220	0.000
5	nan	nan	nan	nan	nan	nan



Vanilla NN predictions of detections vs detections

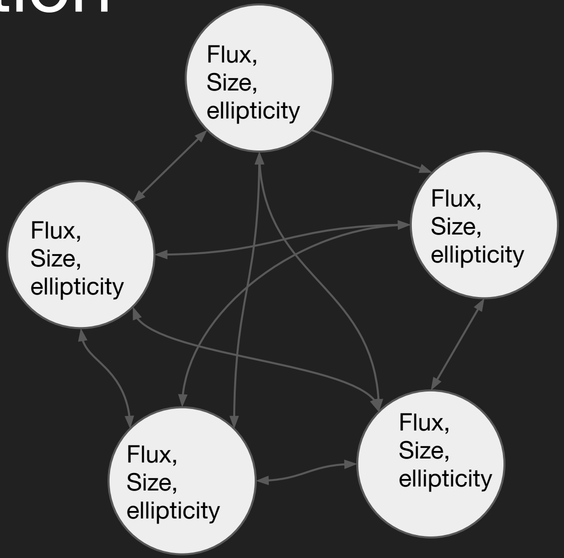
# identified by SE \ # predicted by RNN	0	1	2	3	4	5
0	nan	nan	nan	nan	nan	nan
1	0.000	0.899	0.100	0.001	0.000	0.000
2	0.000	0.048	0.899	0.052	0.000	0.000
3	0.000	0.005	0.325	0.671	0.000	0.000
4	0.000	0.000	0.096	0.904	0.000	0.000
5	nan	nan	nan	nan	nan	nan

RNN: 87%

Vanilla NN: 85%

Graph Neural Network - Classification

- Idea: model for neural net should reflect our knowledge about the problem
- Assumes permutation invariance



↕ weight=distance
between centroids

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Next steps

- Continue work on the graph based neural network
- Ultimately use neural net to measure the bias of unrecognized blends on two point correlation functions

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