Galaxy Mergers: Identification and Classification

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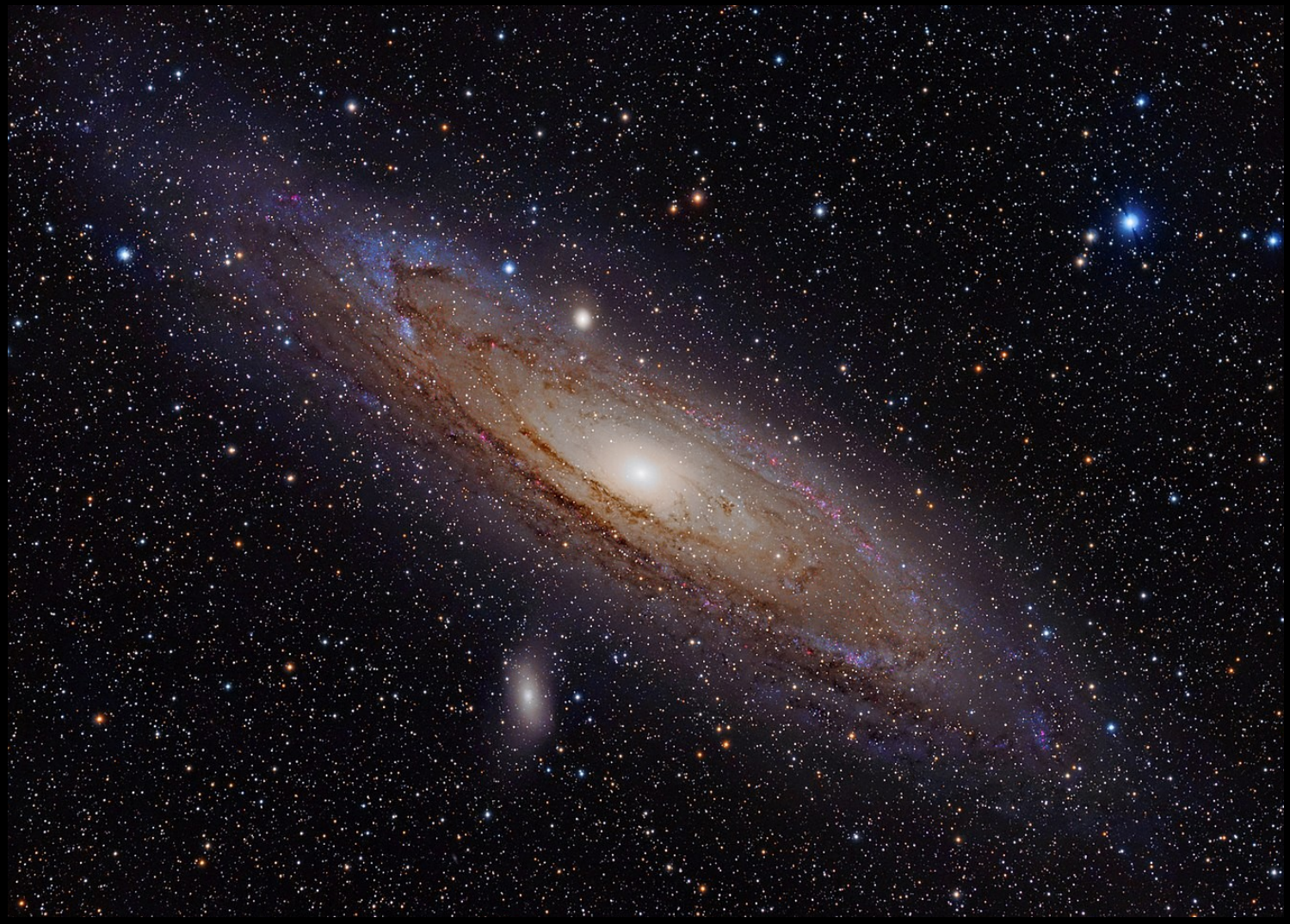
Why should we even care?

Why should we even care?

- Galaxy mergers underpin our current understanding of galaxy evolution
- All galaxies have, or will have, merged at some point
- Mergers change star-formation rates and accretion onto supermassive black holes

- It will happen to us...

Why should we even care?



Identifying Mergers

- Close Pairs
  - Galaxies close on the sky and in redshift
  - Requires expensive spectroscopic observations

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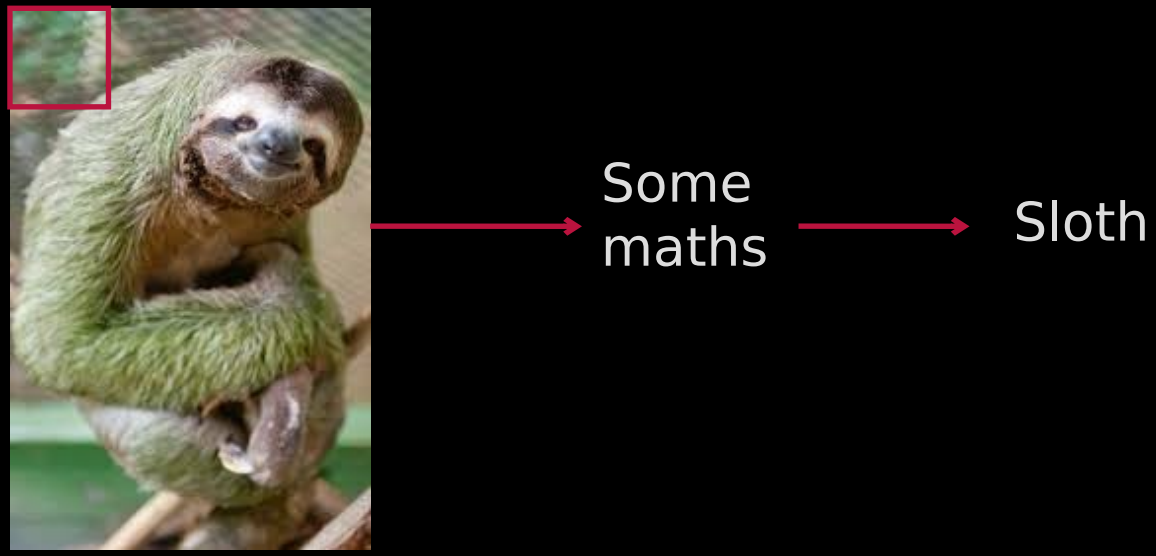
  - Galaxies close on the sky and in redshift
  - Requires expensive spectroscopic observations
- Morphological Statistics (CAS, Gini, $M_{20,}$ etc.)
  - Simple to obtain
  - Not always reliable, need high quality observation
- By eye
  - Hard to reproduce, not scalable

Deep Learning

- Basically a series of matrix multiplications

$$\max(0, \mathbf{wx}+b)$$

  - Just a lot of them
- Image classification is typically done with Convolutional Neural Networks (CNN/ConvNet)



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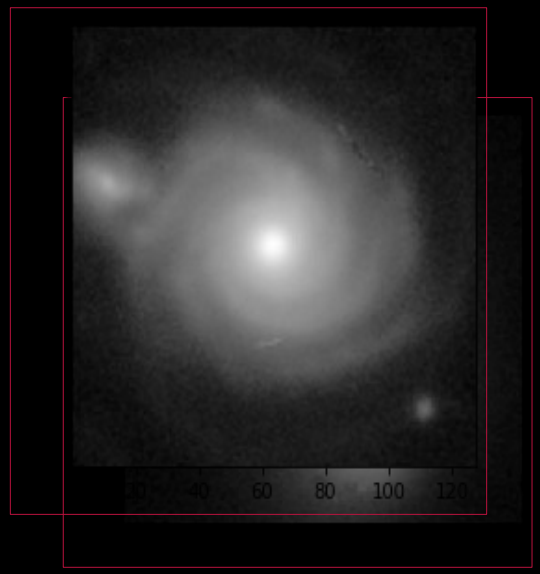
Some maths → Merger

Why Deep Learning?

- Vera C. Rubin Observatory and Euclid expect billions of galaxies (~1e9 galaxies)
- Human classification – 30 per minute
  - 555 000 man hours (~63 years)
- Deep Learning – 475 per minute
  - 35 000 GPU hours (~4 years)
- Reproducable
- Does not need expensive observations

North Ecliptic Pole



CNN

C	A	S
2.877	0.326	0.021
2.450	0.238	...

DNN

DNN

Merger	Non-merger
0.852	0.148
0.625	...

Pearson et al. 2022a

North Ecliptic Pole

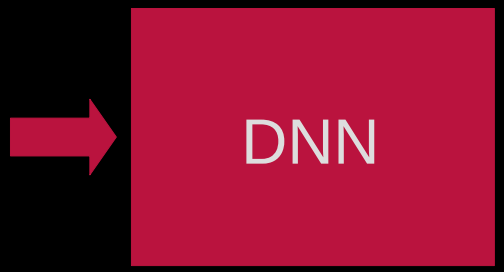
Redshift	Statistic	Value
z < 0.15	Accuracy	0.884
	Recall	0.863
0.15 < z < 0.30	Accuracy	0.850
	Recall	0.790

Redshift	Total Galaxies	Non-merger	Merger Candidate	Confirmed Merger
z < 0.15	6965	5488	1477	251
0.15 < z < 0.30	27 299	18 581	8718	1858

Pearson et al. 2022a

Photometry

u	g	u-g
16.378	14.502	1.876
20.797	8.779	...



Merger	Non-merger
0.001	0.999
0.739	...

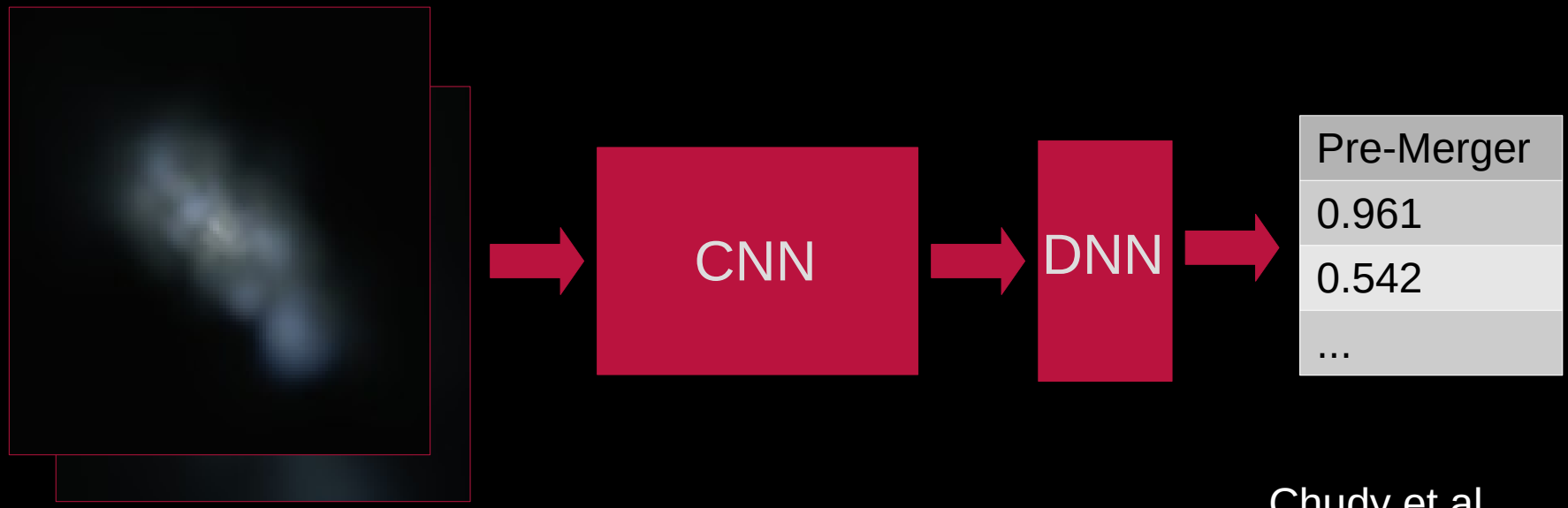
- “Reference” accuracy of 0.690
- Best accuracy of 0.887 with Fiber + error

- Demonstrated, for the first time, just photometry can be used to identify galaxy mergers

Suelves et al. 2022

Classification

- Pre-merger – galaxies that will “soon” merge
- Post-merger – galaxies that have “recently” merged
- Lack truth – Simulated galaxies (Illustris TNG)



Chudy et al.

Classification

- Beyond pre/post-merger
- Time before or after a merger
- Lack truth – Illustris TNG
  - Lack time resolution – continue simulation

C	A	S
2.877	0.326	0.021
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CNN

DNN

DNN

Merger Time
-43
152

Pearson et al. 2022b

Future Plans

- NEP mergers
  - Environmental dependance
  - AGN enhancement
    - SFR not greatly enhanced (Pearson et al. 2022a)
- Photometry mergers
  - Test with other data
- Merger classification
  - SFR/AGN enhancement at different stages

Summary

- Brief overview of identification methods
- Shown the power of deep learning
  - Images, Photometry, Images + morphology
- Generate catalogues ready for science
- Sneak peak of what we can do soon with these cutting edge techniques