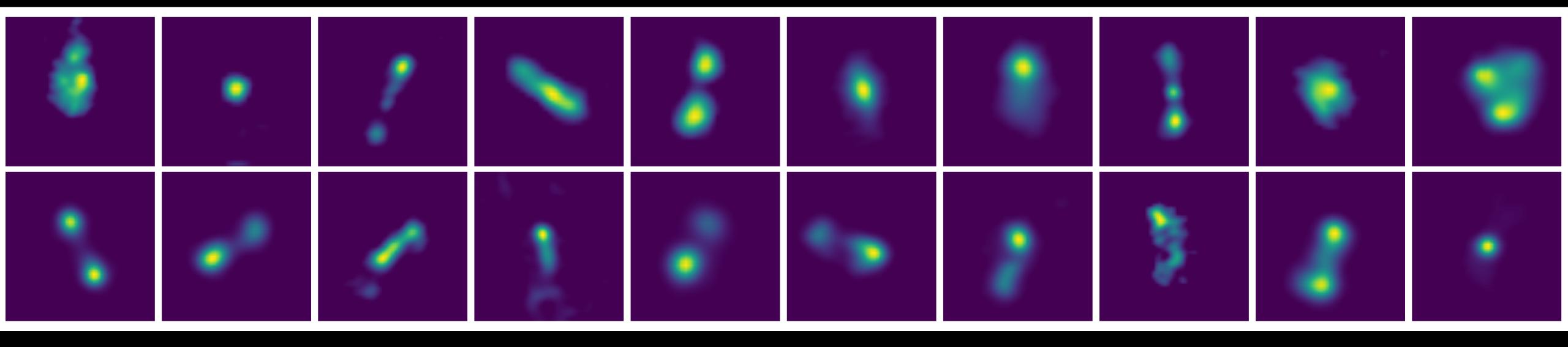
Classification of radio sources through self-supervised learning

Nicolas Baron Perez, Marcus Brüggen, Gregor Kasieczka, and Luisa Lucie-Smith

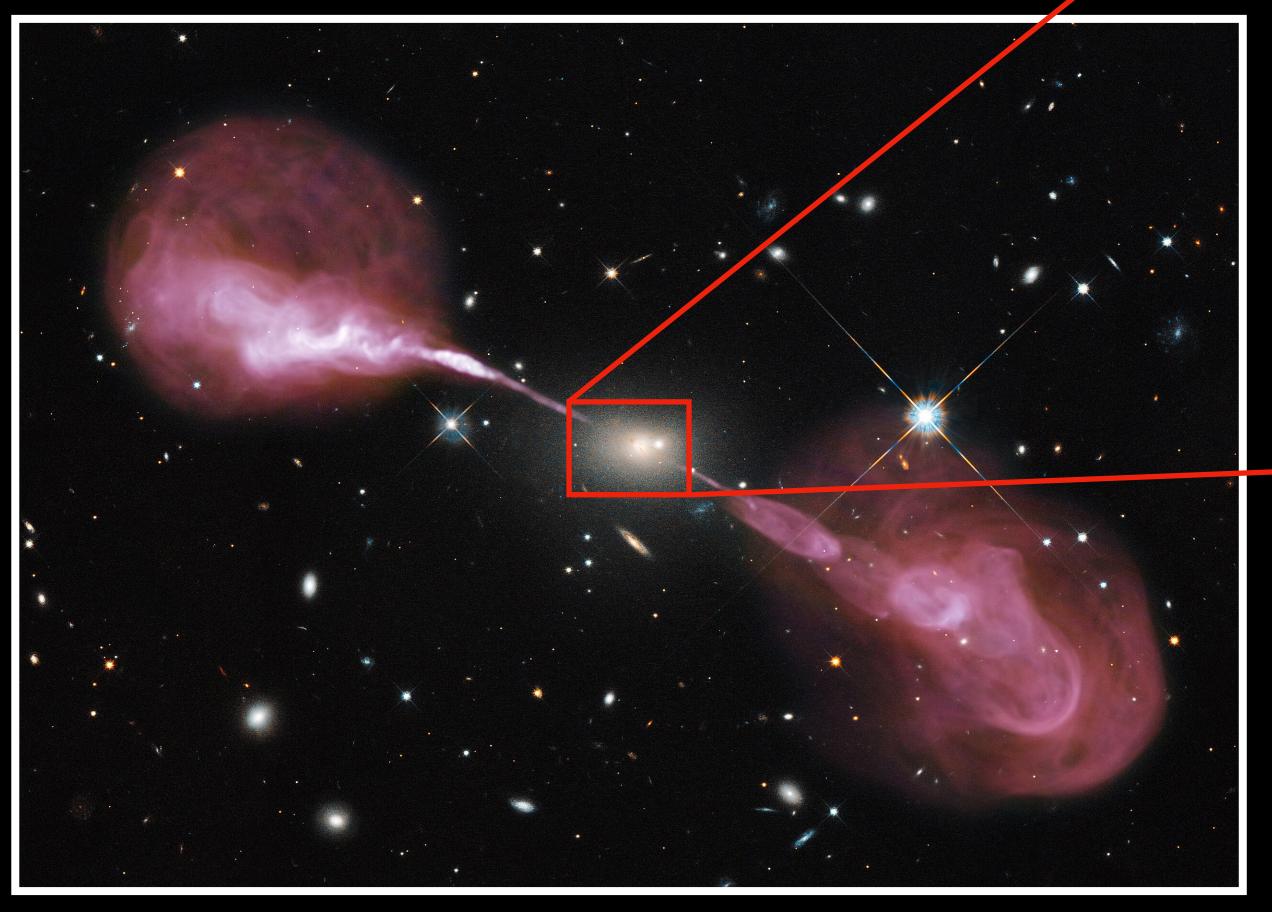
arXiv:2503.19111

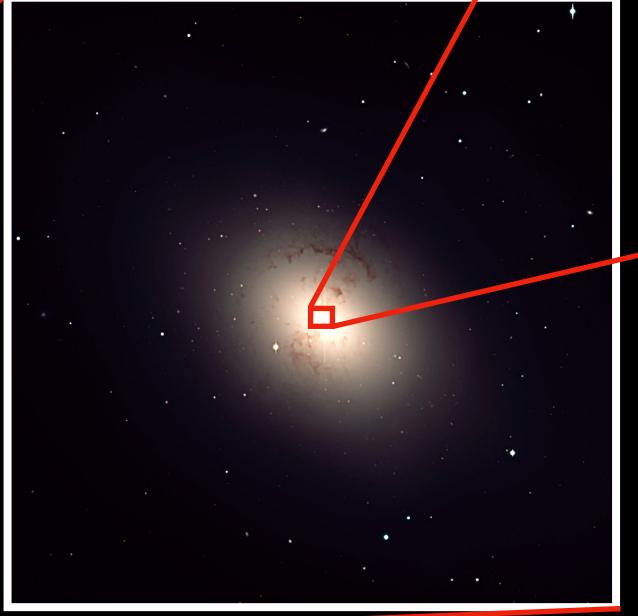


ntroduction

Radio Galaxies

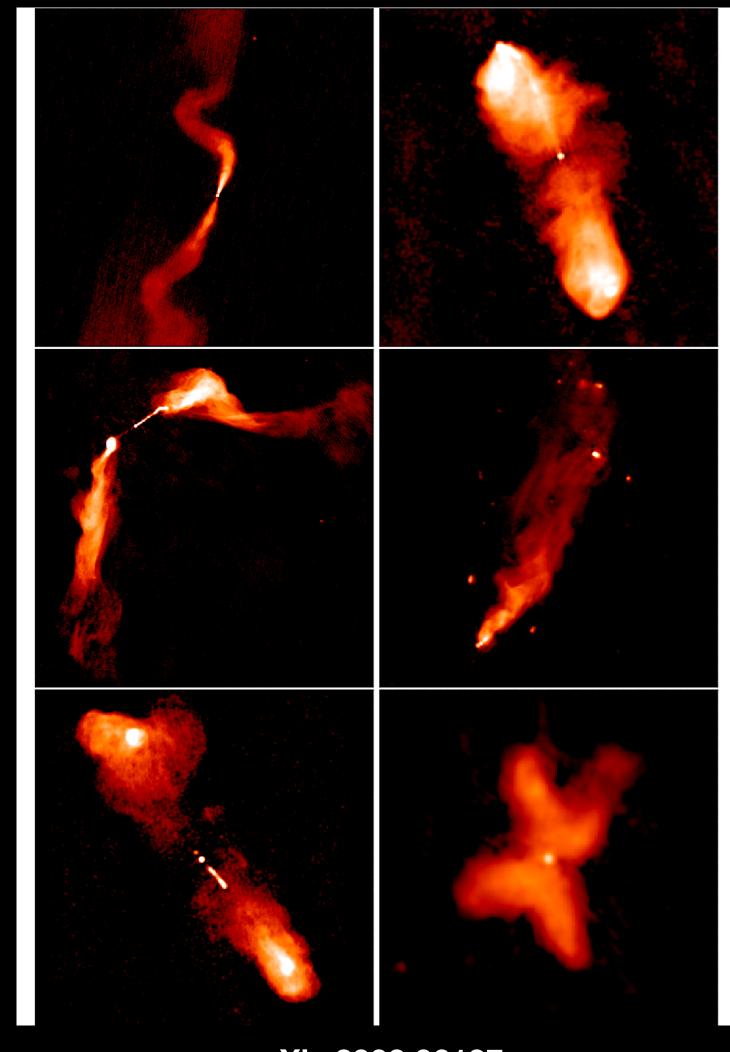




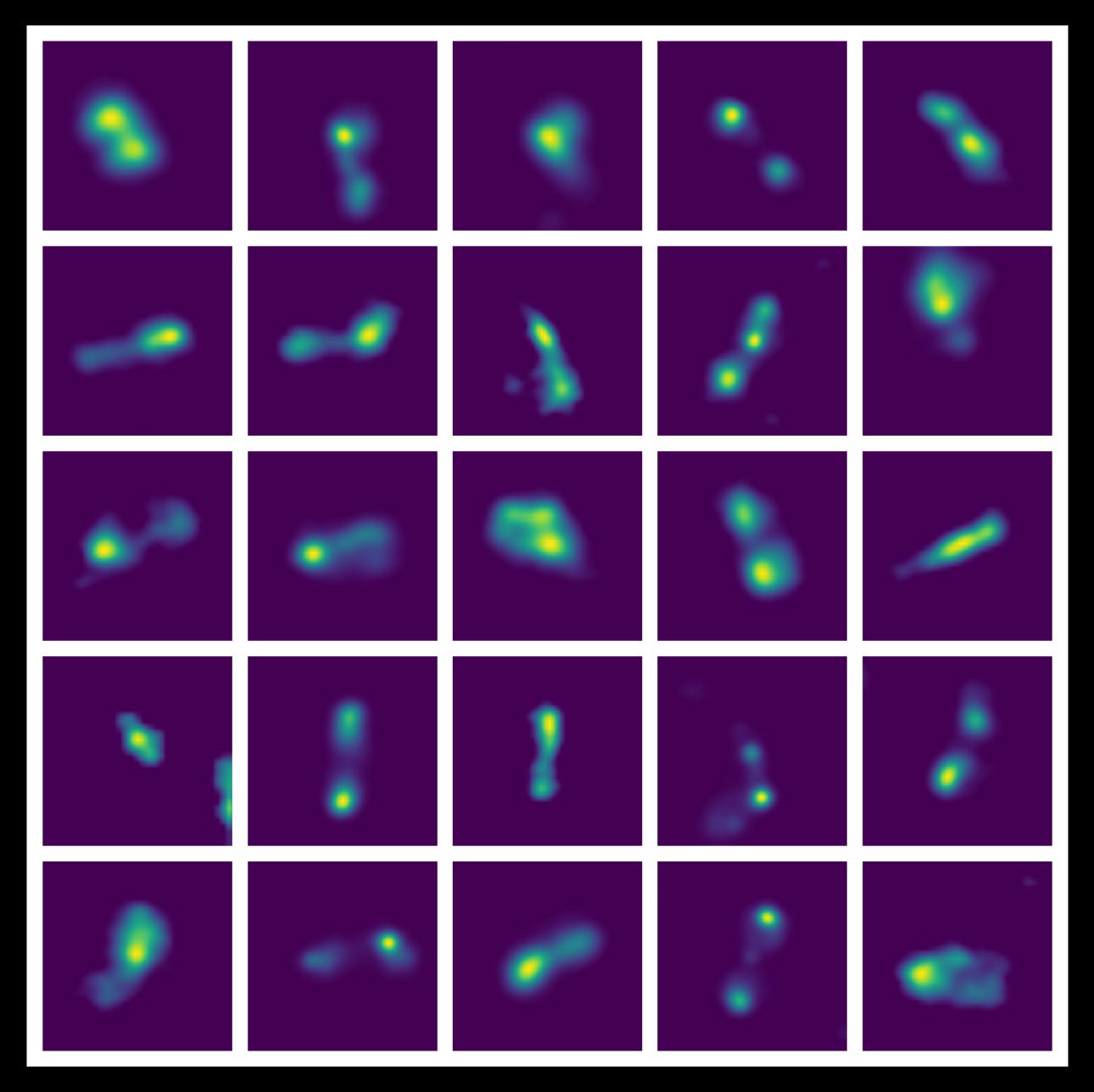


©: eso.org, science.org, wikipedia.org

Radio Galaxies



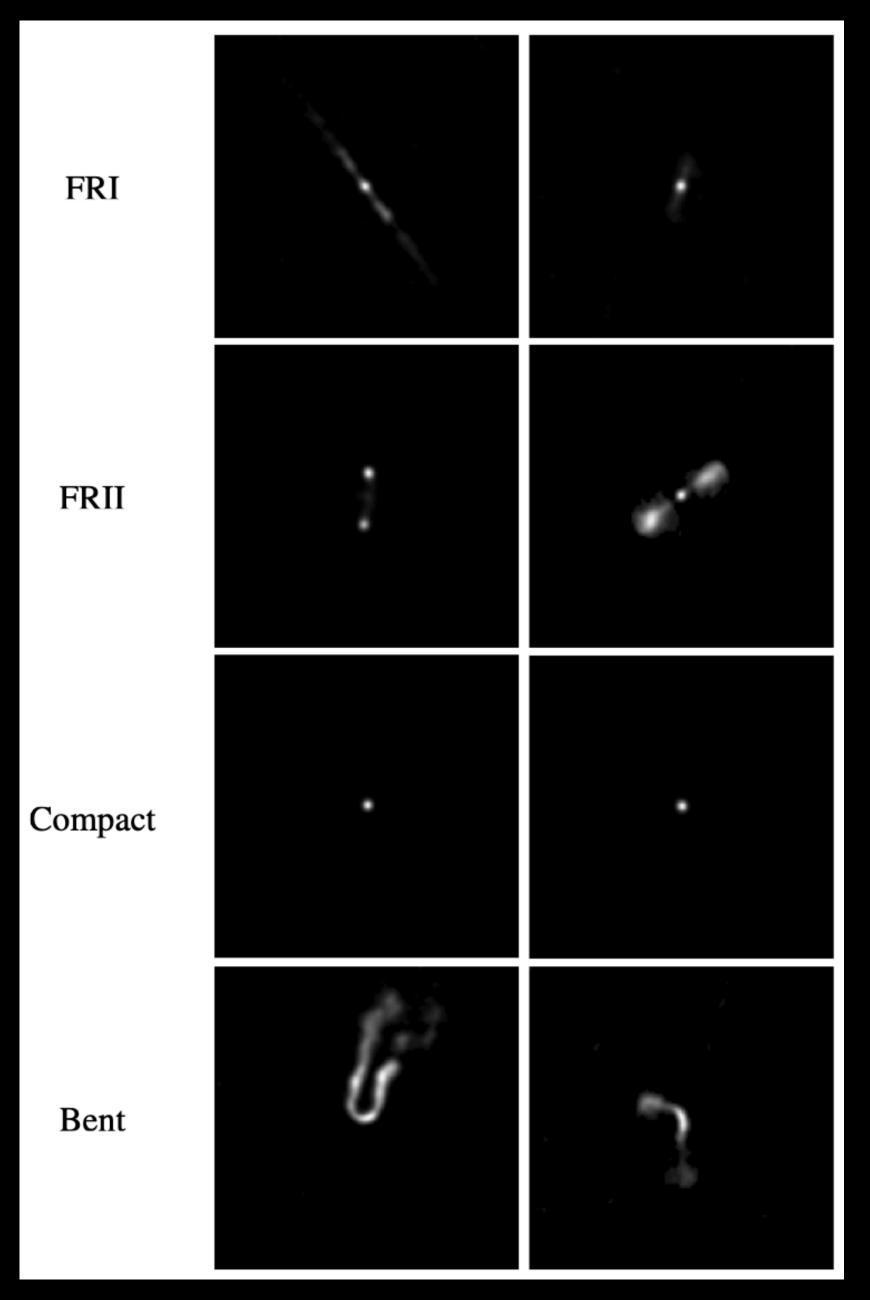
arXiv:2003.06137



Motivation

Can we classify radio sources without labels?

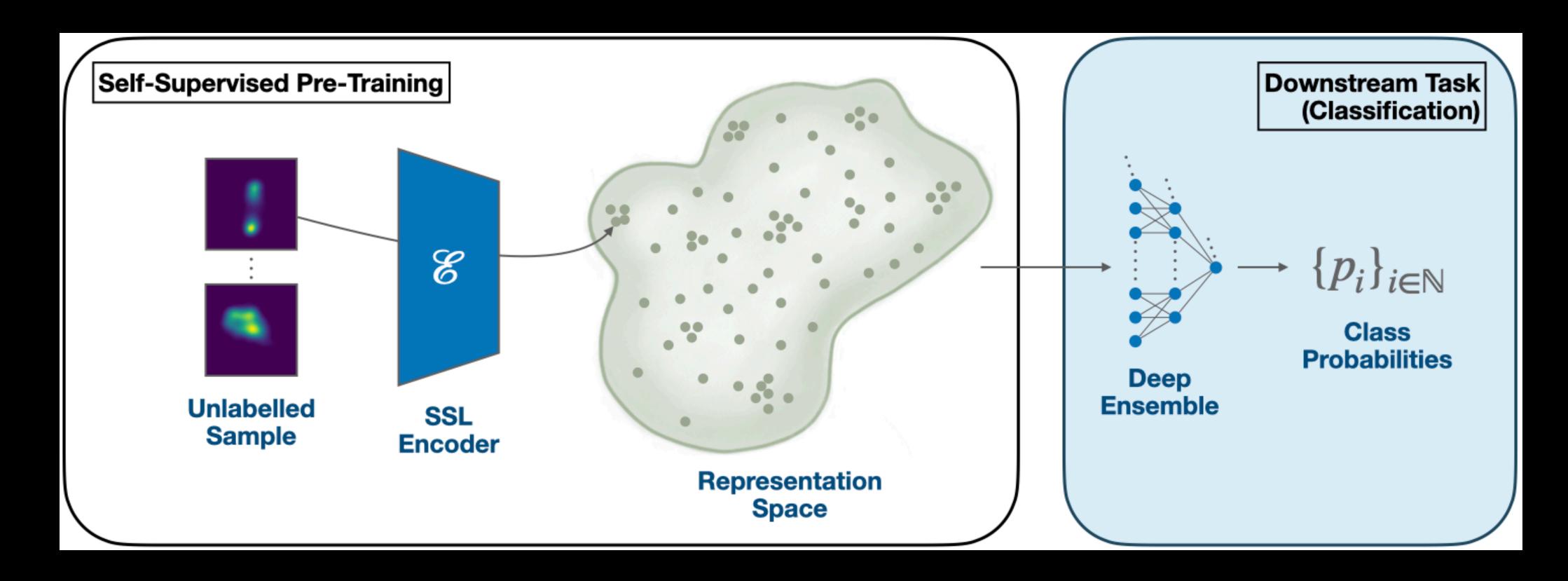
- Lack of theoretical models or simulations
- Differing and possibly inadequate classification schemes
- Possible discovery of new morphologies



Method

SSL Approach

- 1. Learn a representation space that encodes image similarity
- 2. Create a small labelled subsample that describes the morphological variety
- 3. Provide class probabilities for the dataset

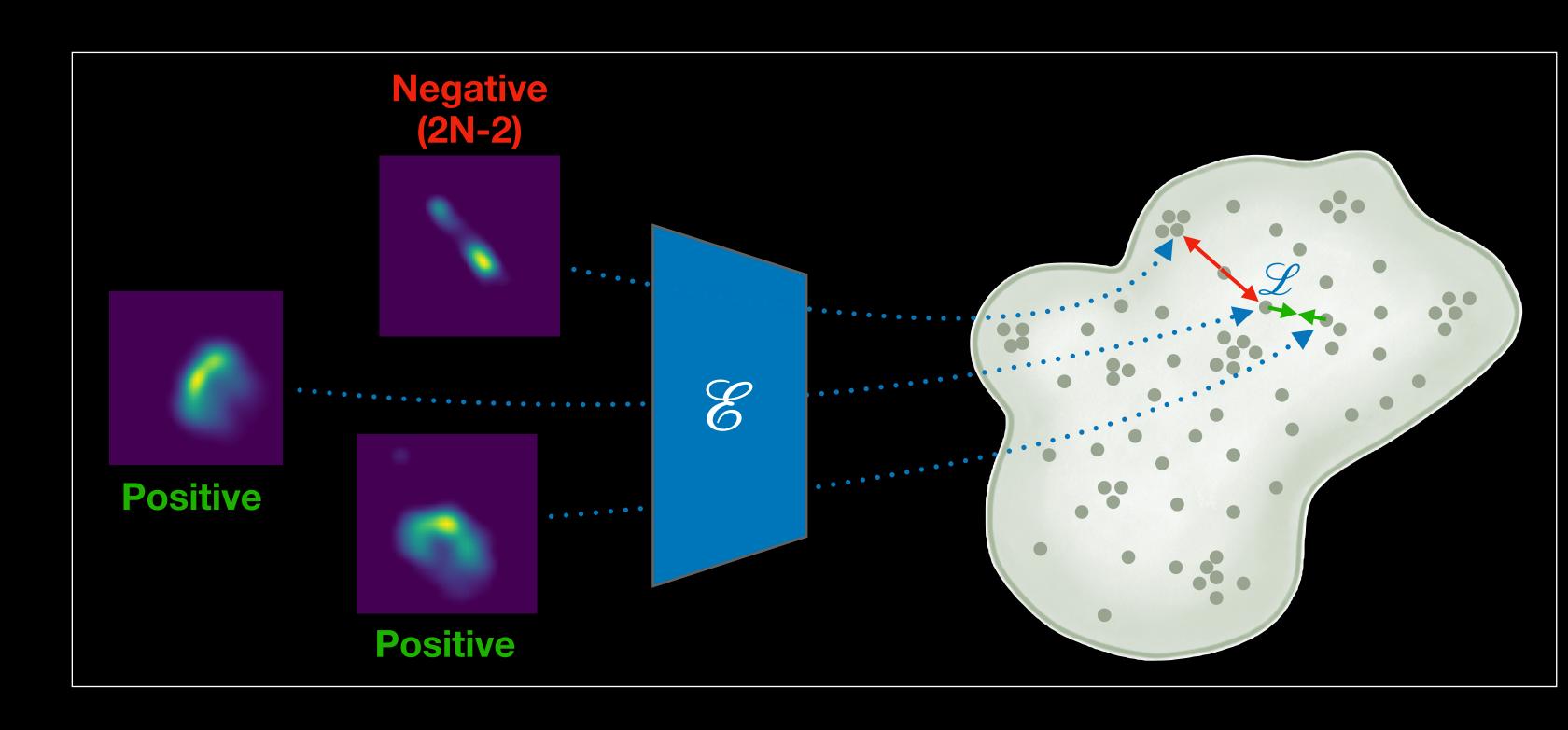


1. Representation Space

Contrastive Learning

Dataset:

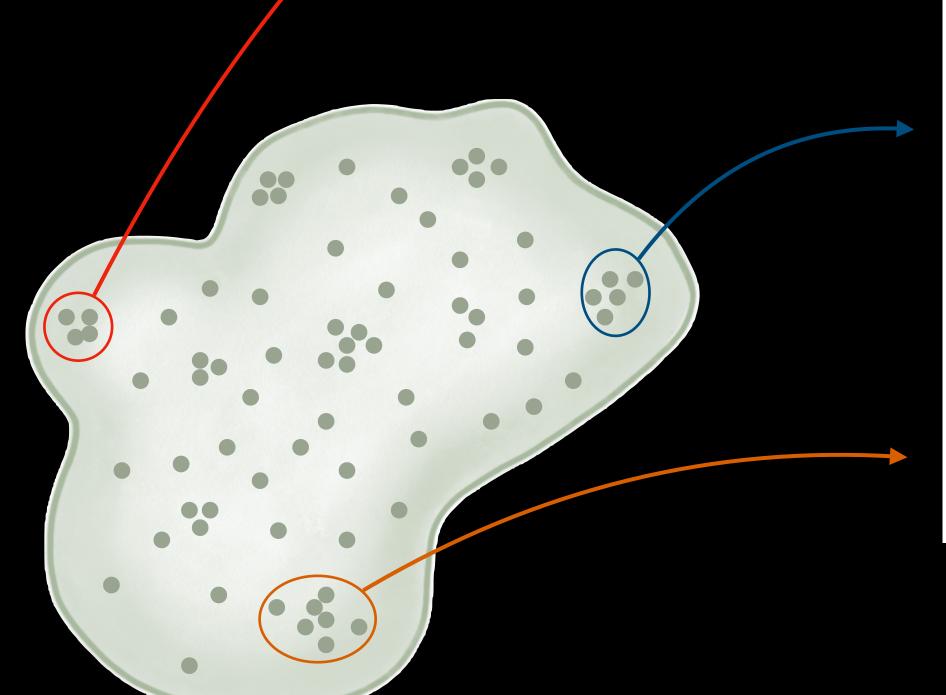
42 230 sources

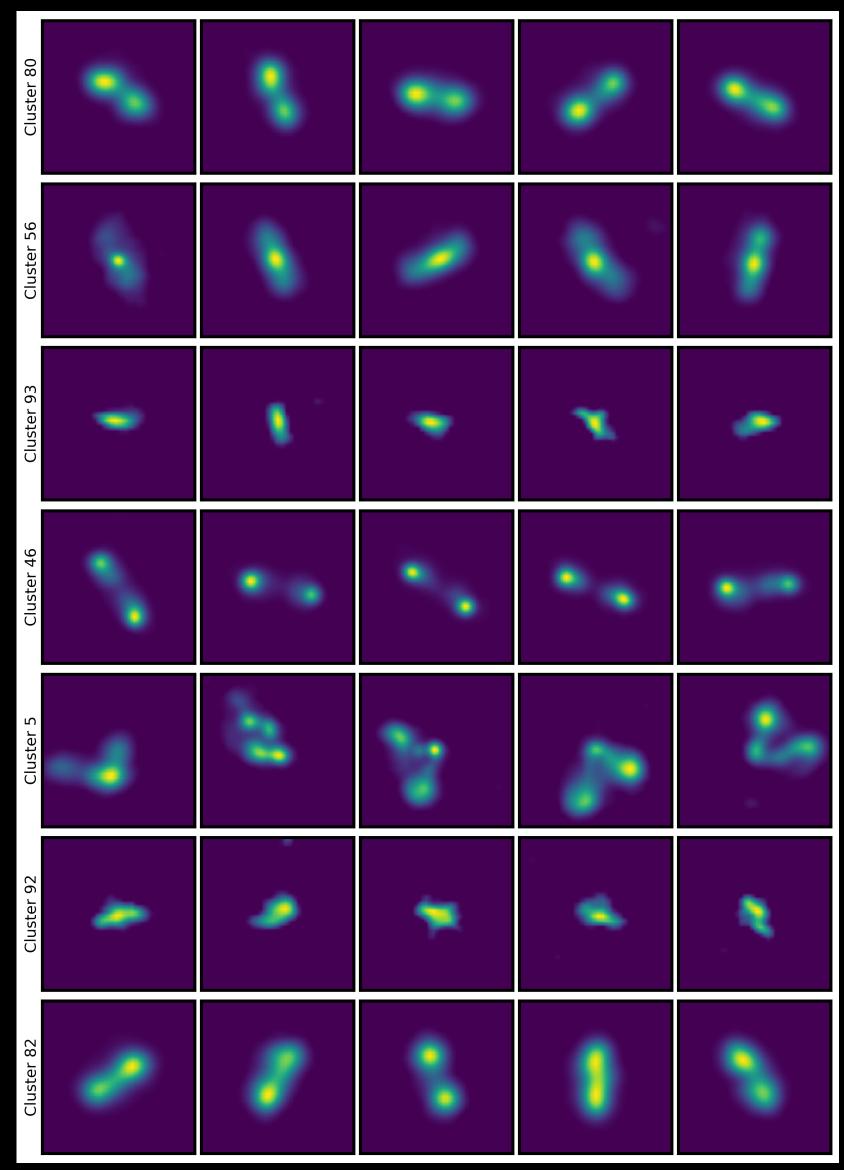




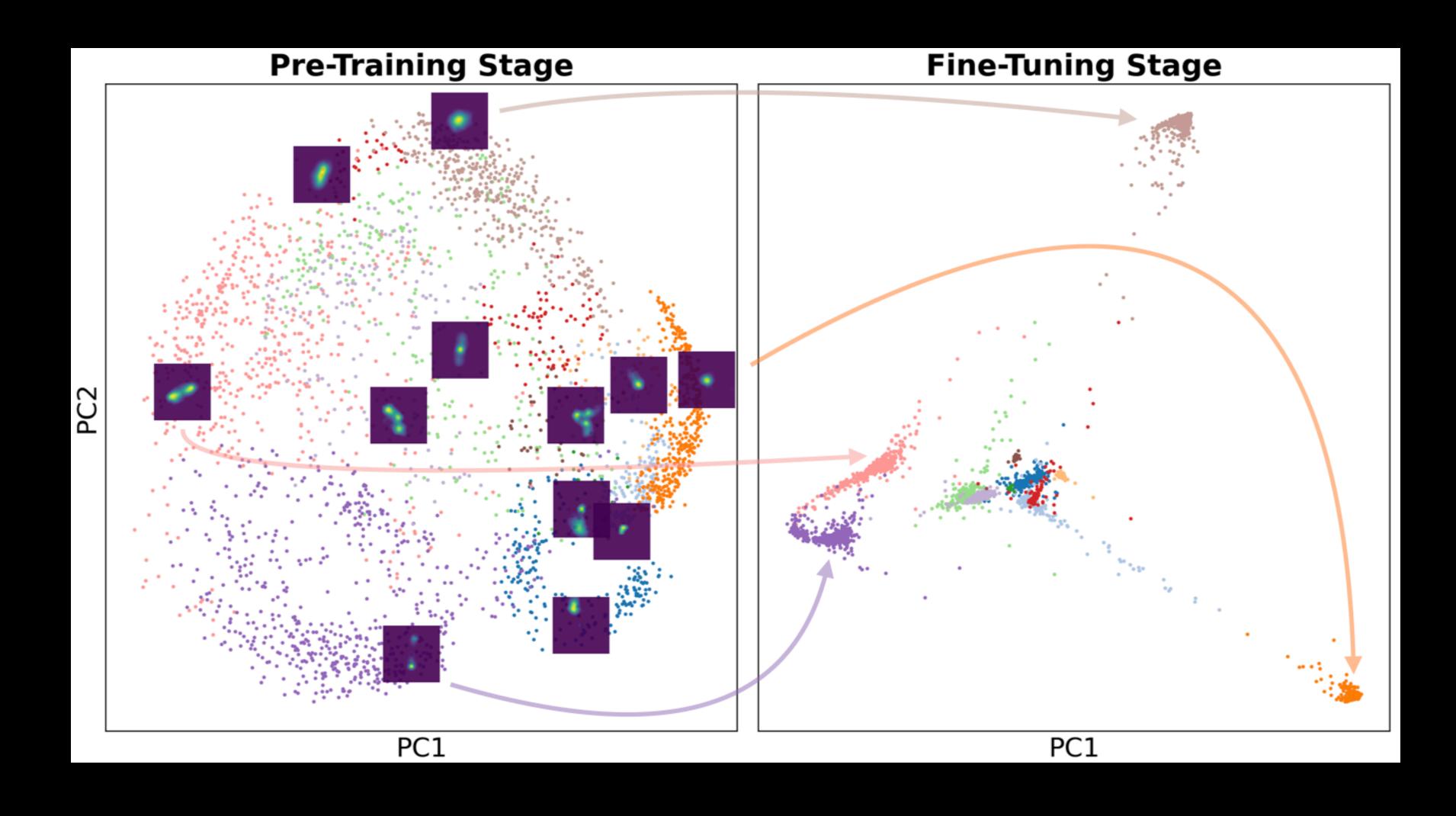
2. Subsample labelling Clustering

- Labelled subsample:
 - 12 classes
 - 2920 sources



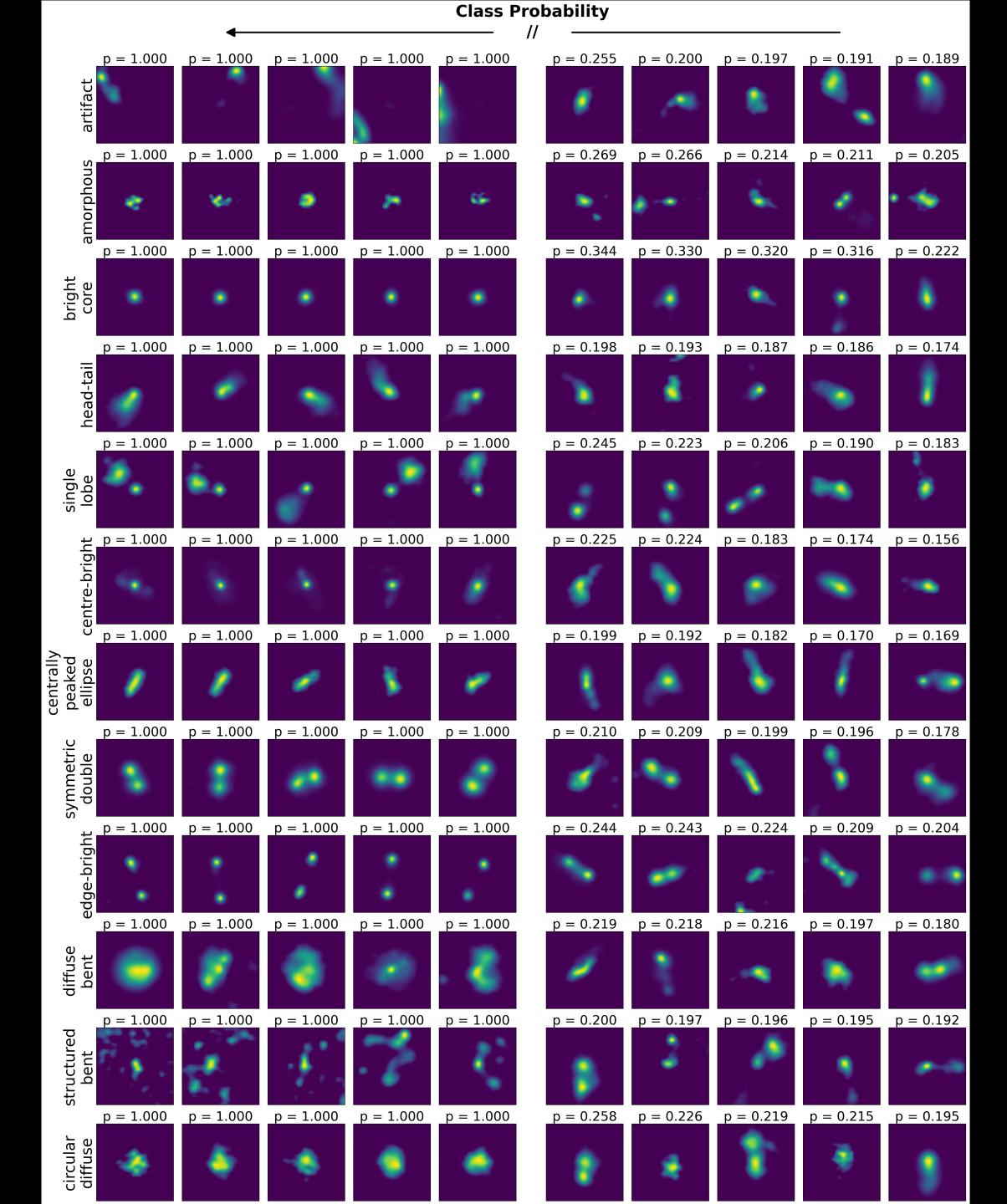


3. Fine-Tuning Supervised Classification



Results

Results Classification



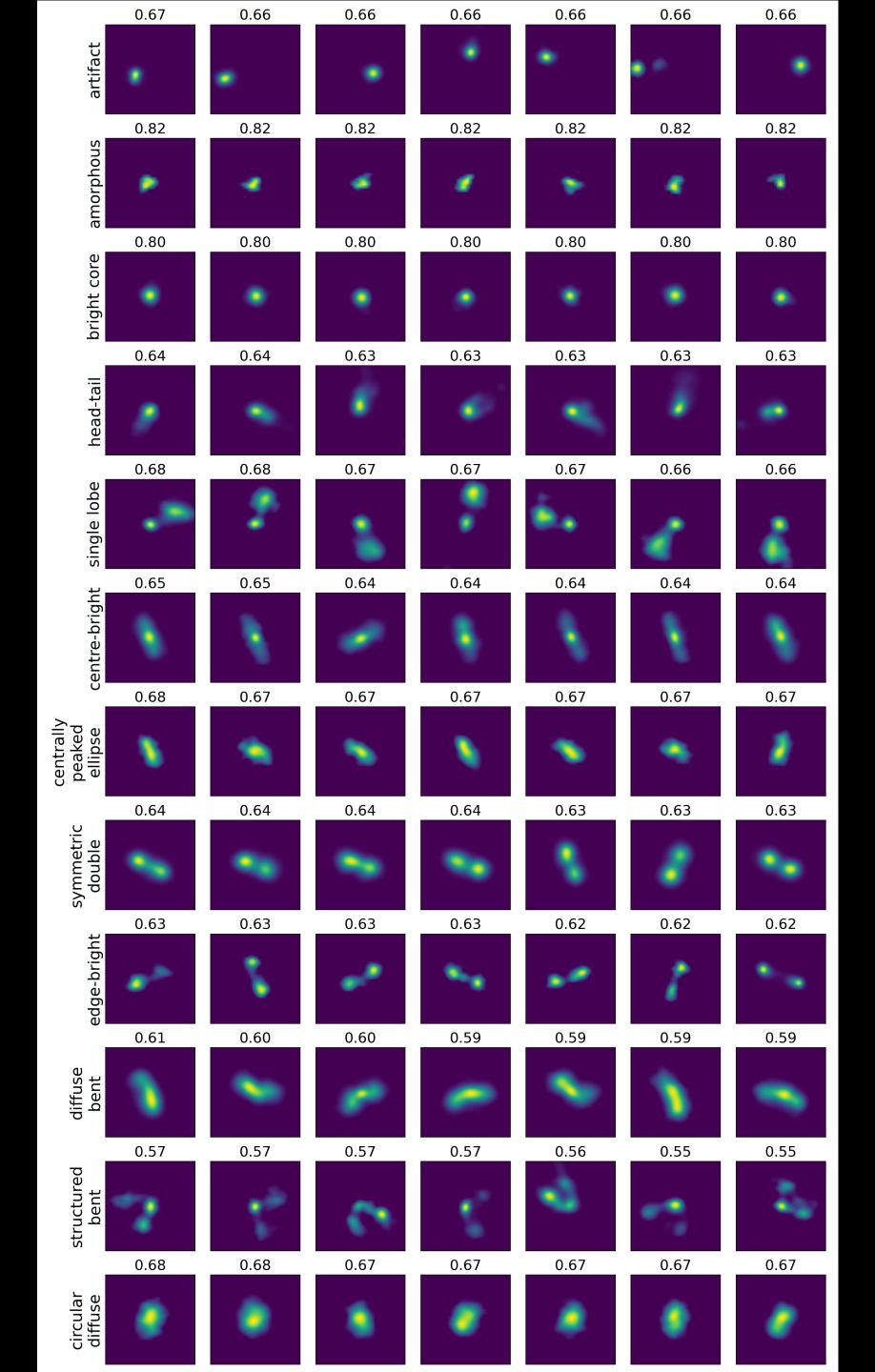
Conclusions



- The morphological similarity was successfully encoded in the representation space
- The required effort for survey classification was significantly reduced
- A new classification scheme based on the geometric appearance was proposed



The method still requires human intervention

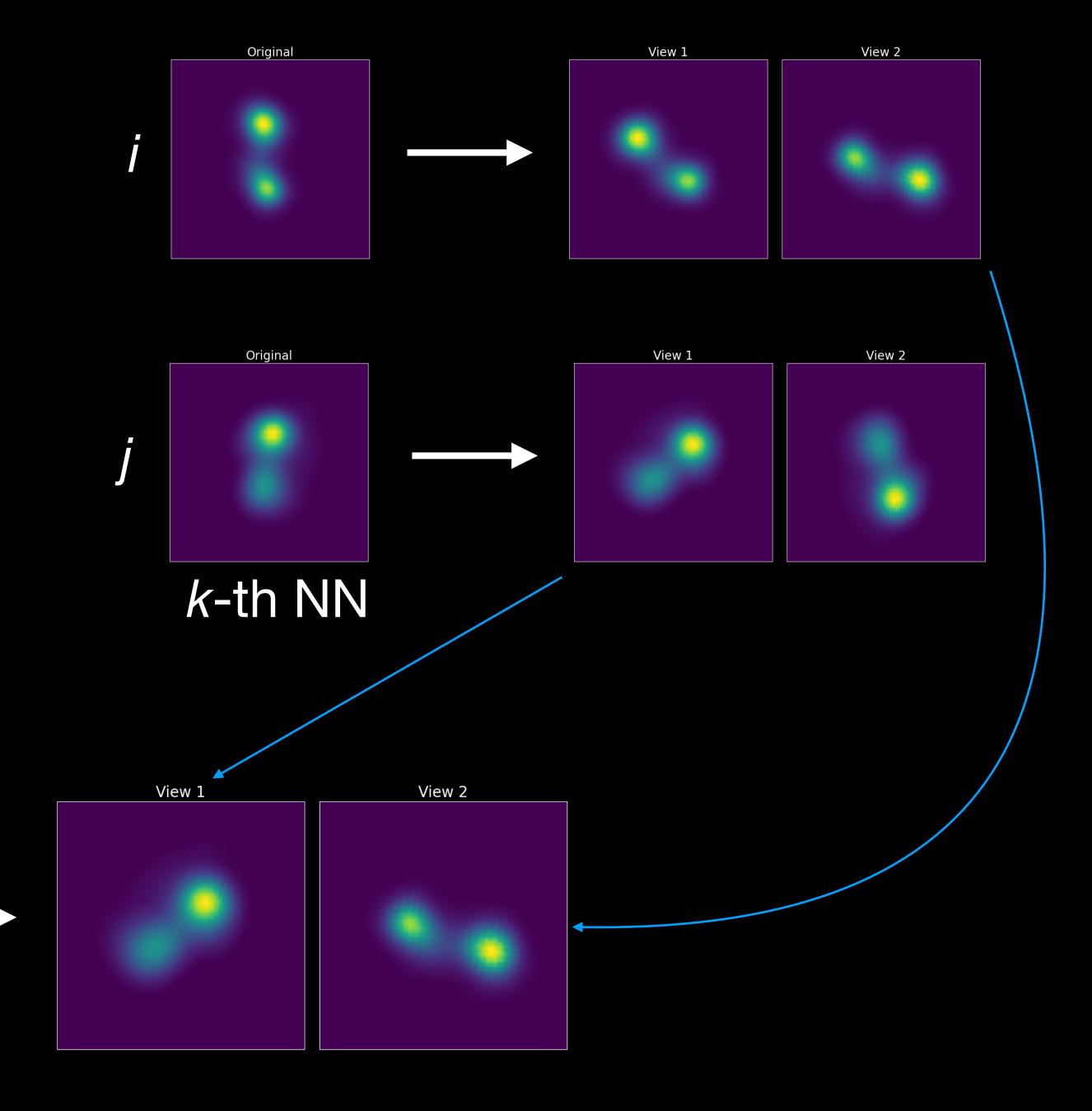


Thank you.

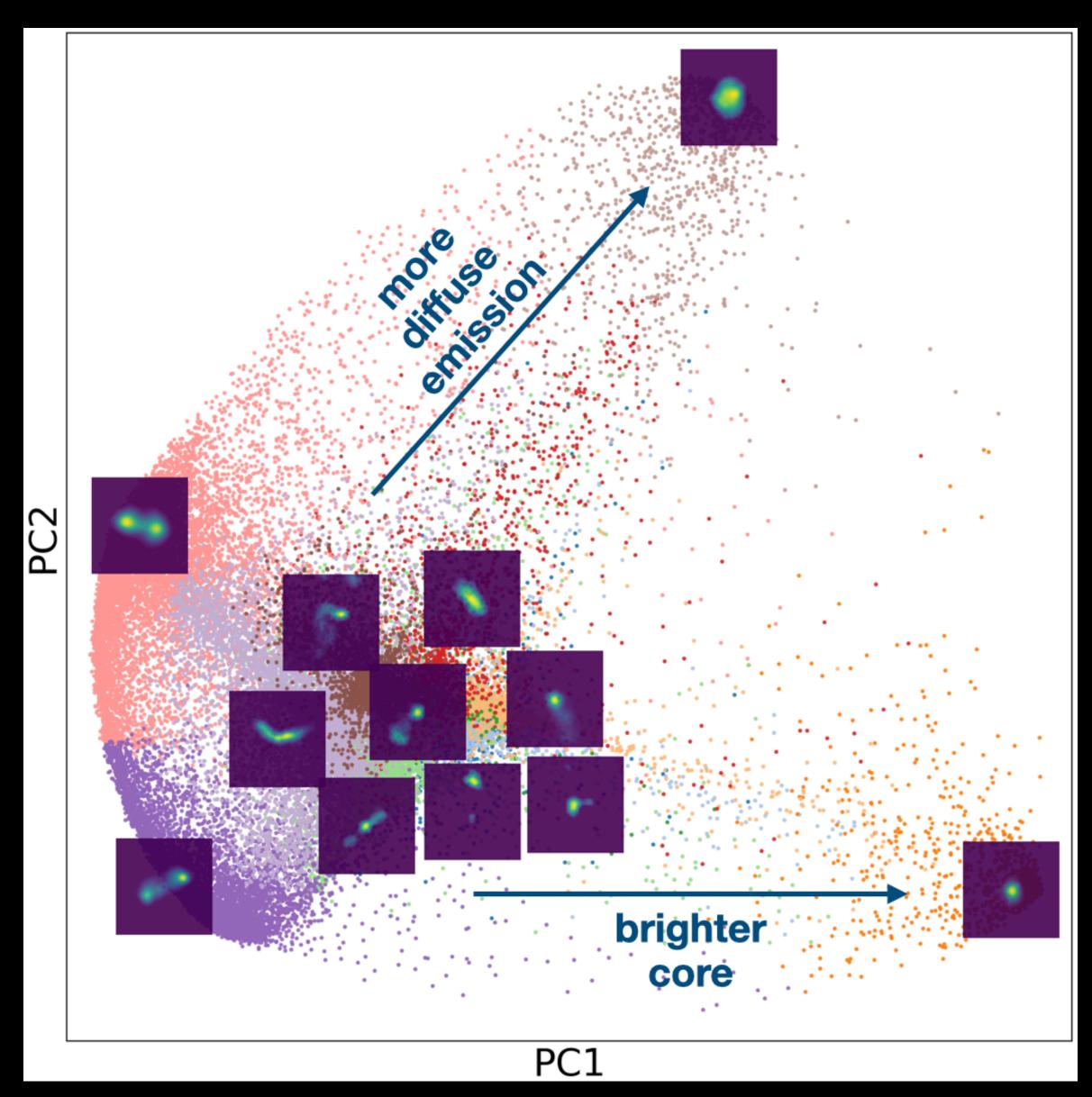
Representation Space Random Structural View

Original

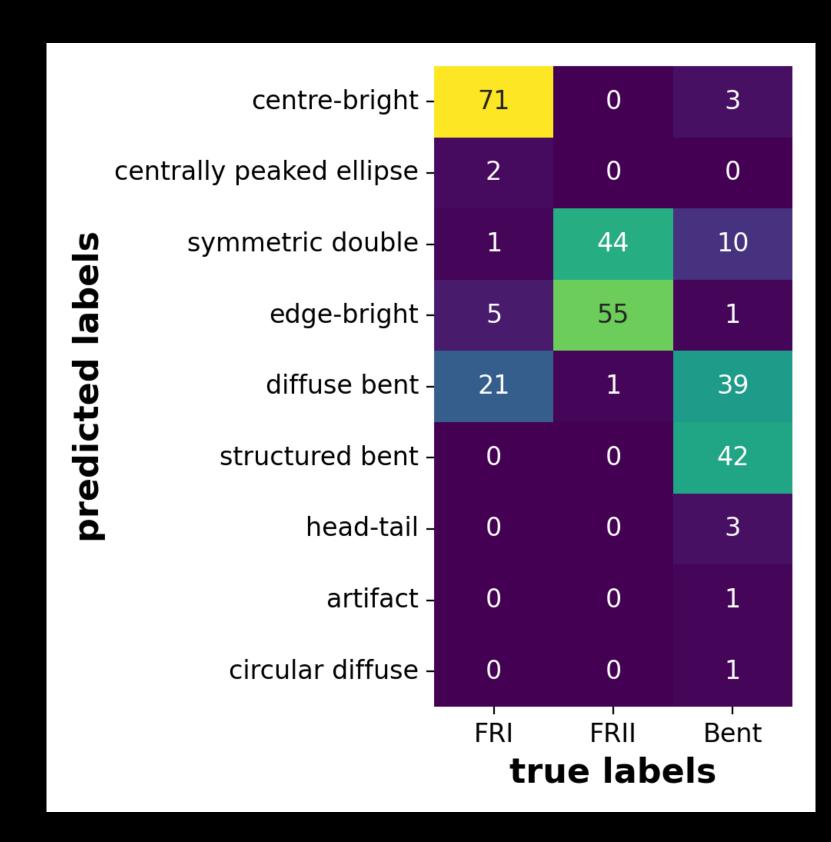
New random augmentation based on image similarity



Representation Space



EvaluationVisual Classification



Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9
(99.8%)	(95.9%)	(83.8%)	(93.8%)	(58.2%)	(97.2%)	(99.3%)	(100.0%)	(93.3%)	(99.9%)
	•	**	8	7	•	•	1	4	3
Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9
(92.8%)	(54.5%)	(100.0%)	(63.5%)	(51.7%)	(60.0%)	(99.3%)	(99.6%)	(95.6%)	(84.9%)
			~	4	Q:	*	•	3	
Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9
(66.1%)	(65.6%)	(100.0%)	(97.8%)	(99.5%)	(38.8%)	(99.8%)	(71.1%)	(37.5%)	(92.7%)
1	•	V	~		γ	6		1	5
Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 9	Pred: 10
(68.4%)	(99.8%)	(99.5%)	(68.3%)	(99.9%)	(100.0%)	(99.0%)	(60.8%)	(77.7%)	(99.9%)
15	5	3	.83	•	•	.	5	•	4
Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10
(78.4%)	(99.6%)	(100.0%)	(99.8%)	(45.4%)	(63.5%)	(51.7%)	(99.8%)	(50.7%)	(50.4%)
1			23	*	2	$\sigma^{\mathbf{a}}$	₹.	•	4
Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10
(90.8%)	(99.8%)	(95.9%)	(100.0%)	(97.5%)	(100.0%)	(97.6%)	(99.8%)	(85.4%)	(100.0%)
•	2	4		7	.1	a a	%	• •	>
Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10
(76.8%)	(100.0%)	(94.7%)	(100.0%)	(100.0%)	(100.0%)	(97.9%)	(99.4%)	(100.0%)	(77.0%)
-	-	\mathcal{C}_{-}		0		$J_{\frac{n}{2}}$	A	å	•
Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10	Pred: 10
(100.0%)	(98.9%)	(70.5%)	(97.4%)	(97.5%)	(99.4%)	(70.3%)	(59.5%)	(93.0%)	(99.5%)
Ą			e de la composition della comp	*	-3	1	4	45	
Pred: 10	Pred: 0	Pred: 3	Pred: 3	Pred: 3	Pred: 5	Pred: 5	Pred: 5	Pred: 7	Pred: 7
(99.9%)	(93.8%)	(99.8%)	(98.6%)	(99.7%)	(59.6%)	(94.0%)	(64.2%)	(93.9%)	(61.2%)
		4		•		•	•	4	<
Pred: 7	Pred: 7	Pred: 7	Pred: 7	Pred: 7	Pred: 7	Pred: 7	Pred: 7	Pred: 8	Pred: 11
(96.8%)	(95.6%)	(74.9%)	(55.3%)	(59.2%)	(96.2%)	(67.6%)	(100.0%)	(93.2%)	(42.5%)
	1	4	3	•		15		1	

EvaluationVisual Classification

• F1 score

Class	p ≤ 85%	Entire sub-set	p ≥ 99%	
artifact	0.22	0.59	0.77	
amorphous	0.31	0.67	0.92	
bright core	0.00	0.63	0.85	
head-tail	0.17	0.36	0.59	
single lobe	0.22	0.48	0.83	
centre-bright	0.40	0.73	0.91	
c. p. ellipse	0.33	0.42	0.70	
symmetric double	0.41	0.64	0.87	
edge-bright	0.54	0.65	0.81	
diffuse bent	0.40	0.47	0.59	
structured bent	0.26	0.51	0.67	
circular diffuse	0.53	0.66	0.80	
Macro average	0.37	0.60	0.80	