The Multimodal Universe:
Enabling Large-Scale Machine Learning with 100 TB of Astronomical Scientific Data

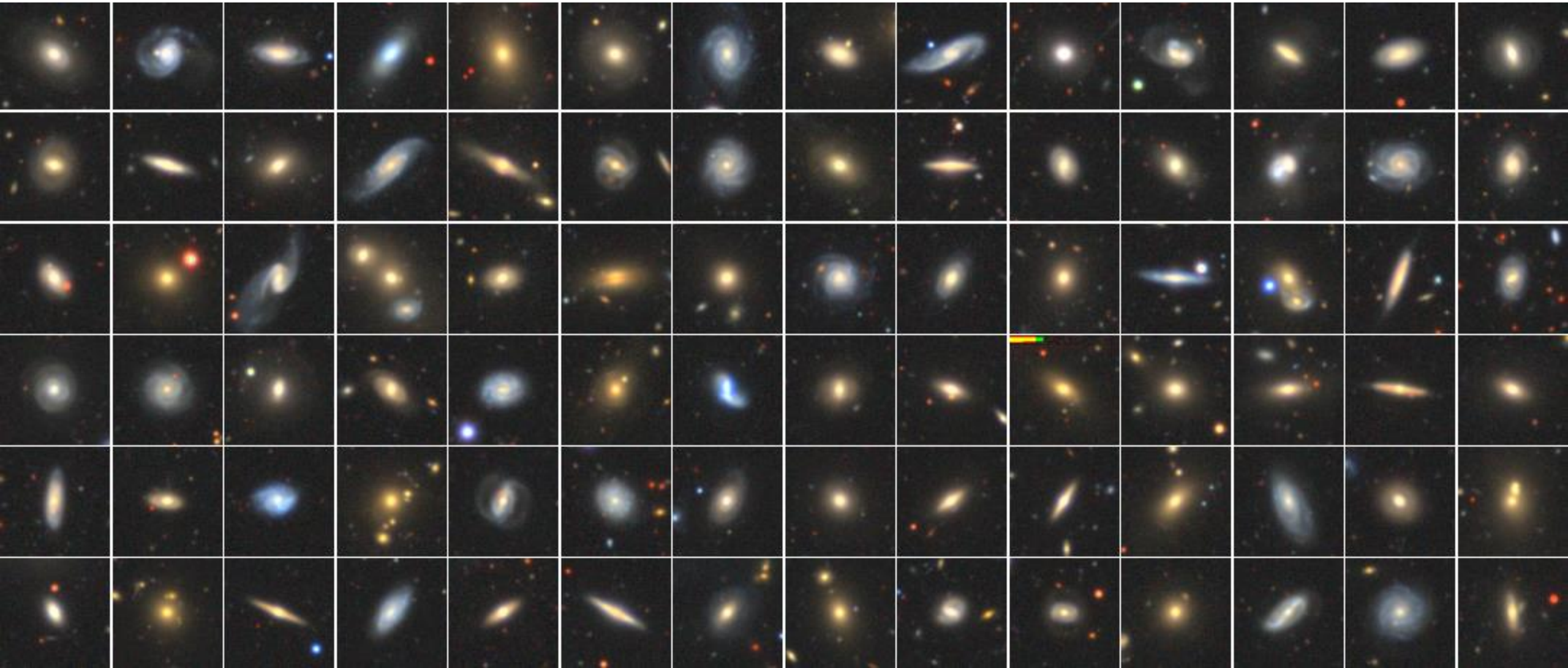The Multimodal Universe Collaboration

NEURAL INFORMATION PROCESSING SYSTEMS

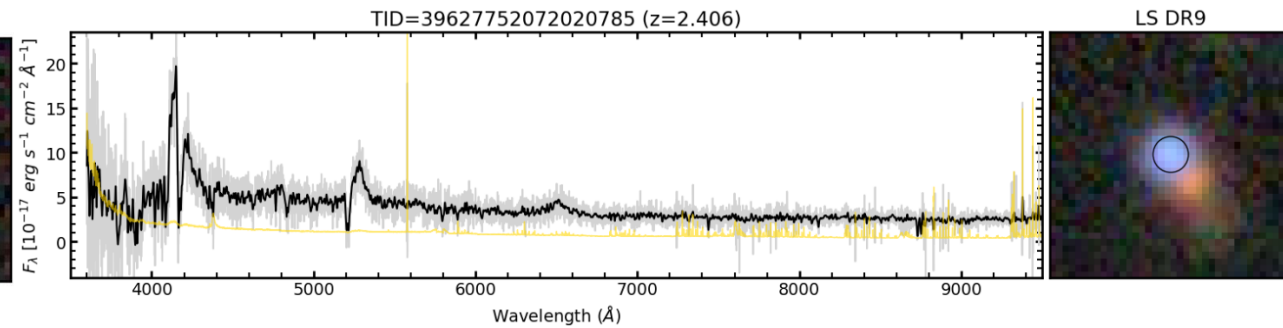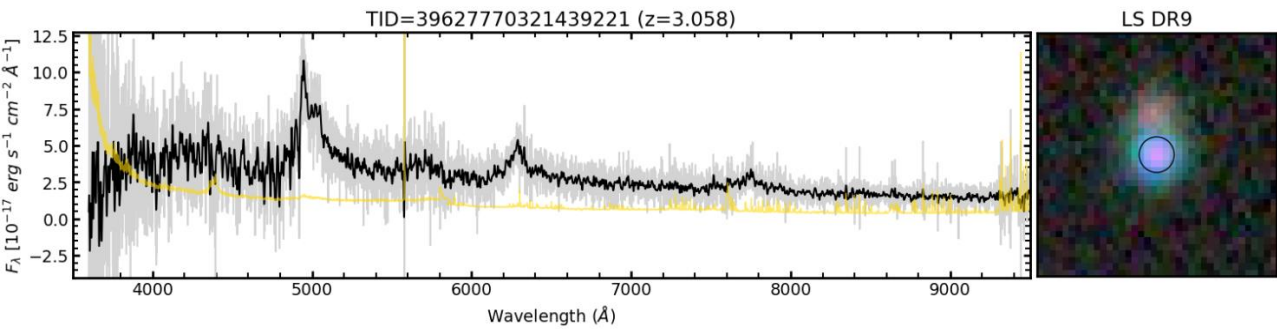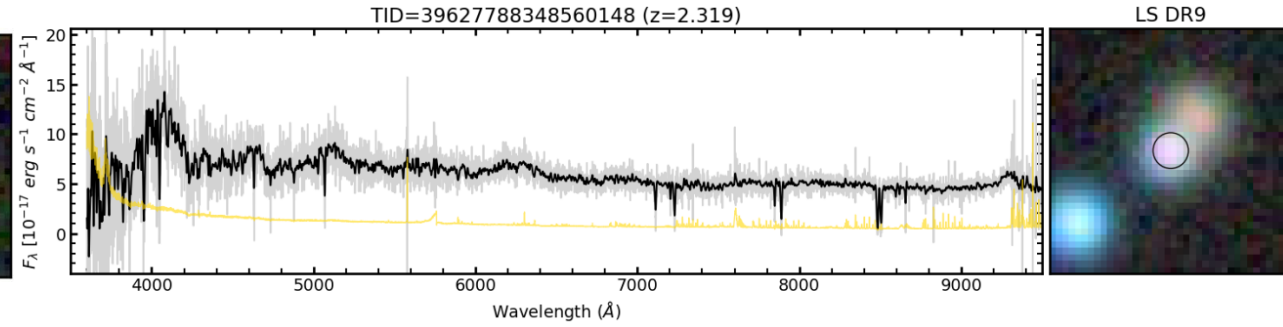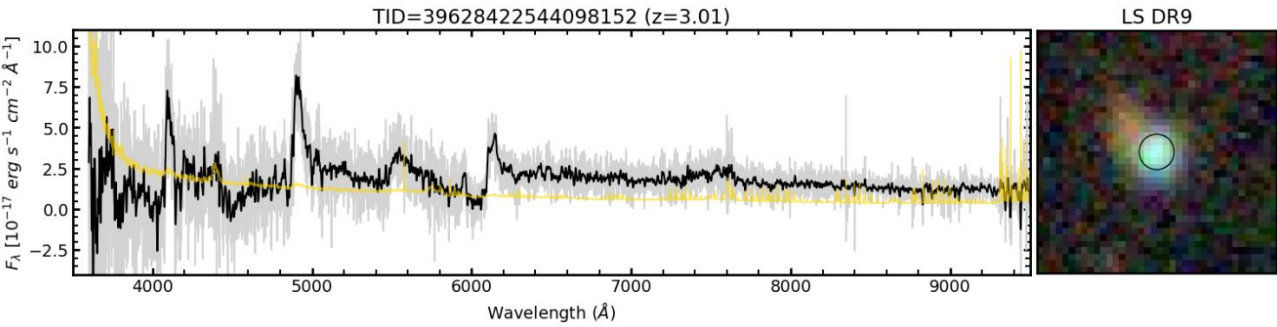Wed, Dec 11, 16:30-19:30 PST (Poster Session 2)

Imaging

DESI Legacy Imaging Surveys

Spectra

DESI Spectra

DESI Collaboration (Juneau et. al. 2024)
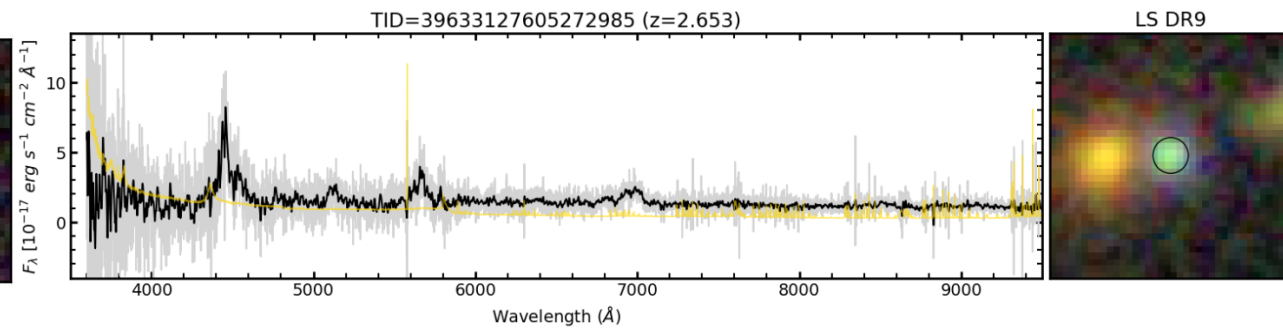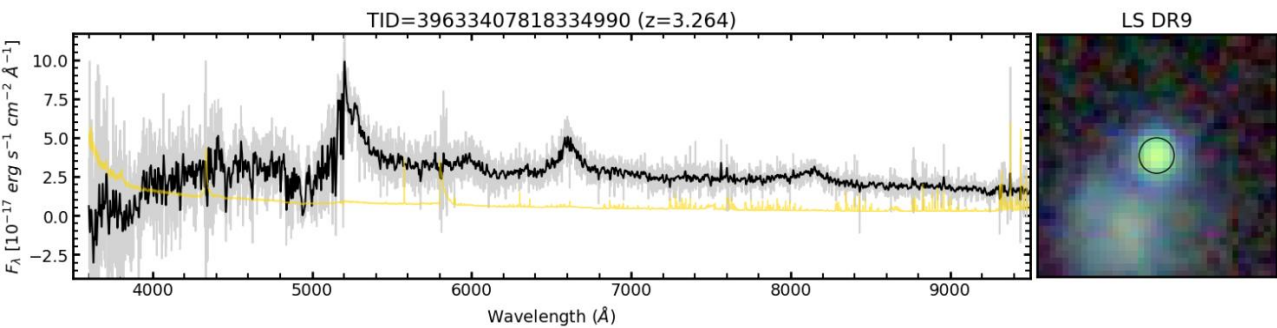
Hyperspectral

MaNGA
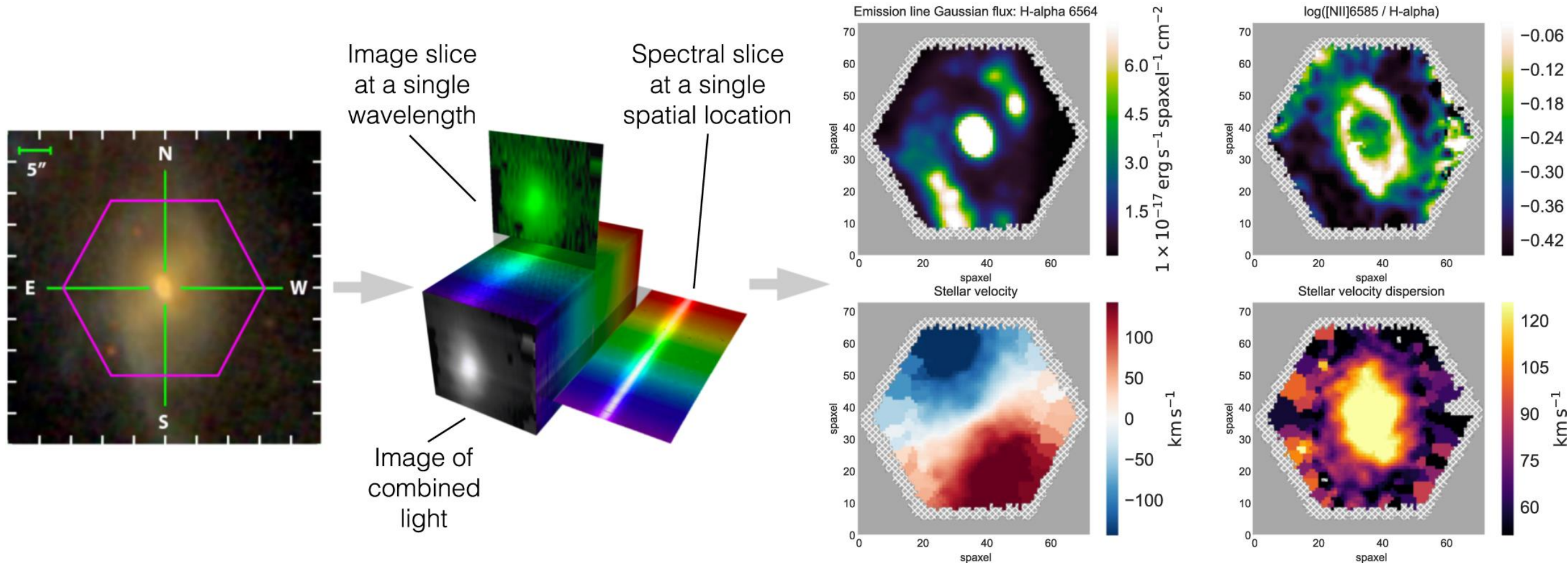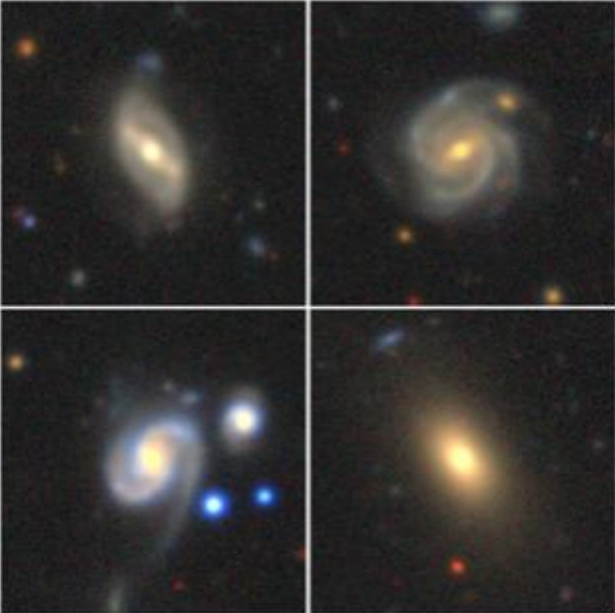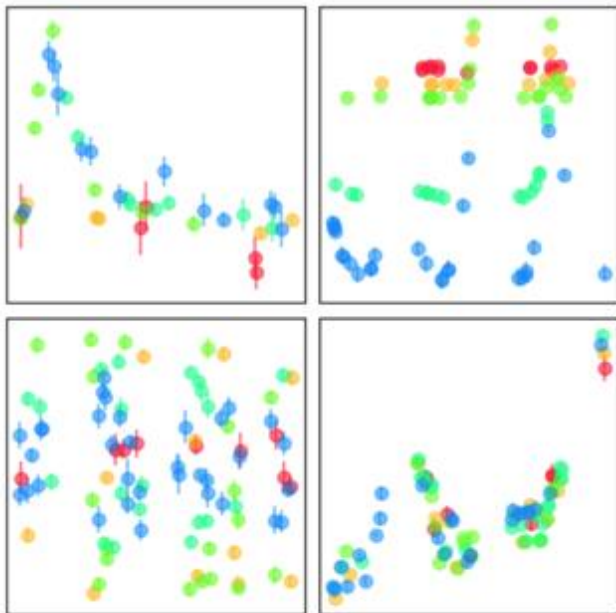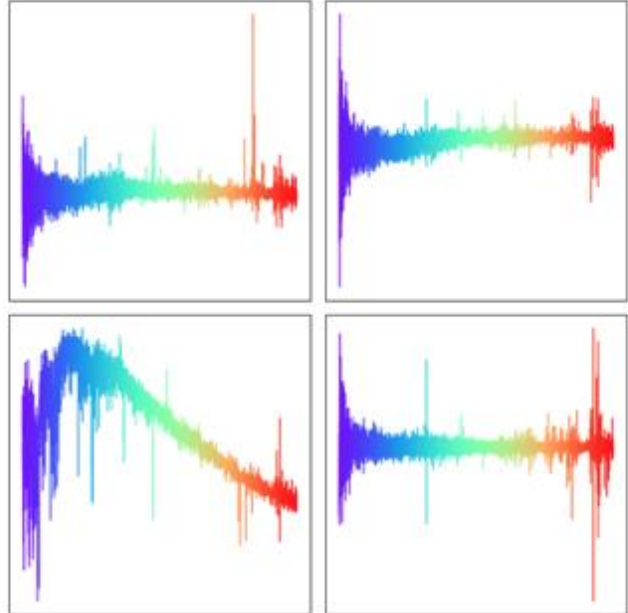
Time Series

PLAsTiCC
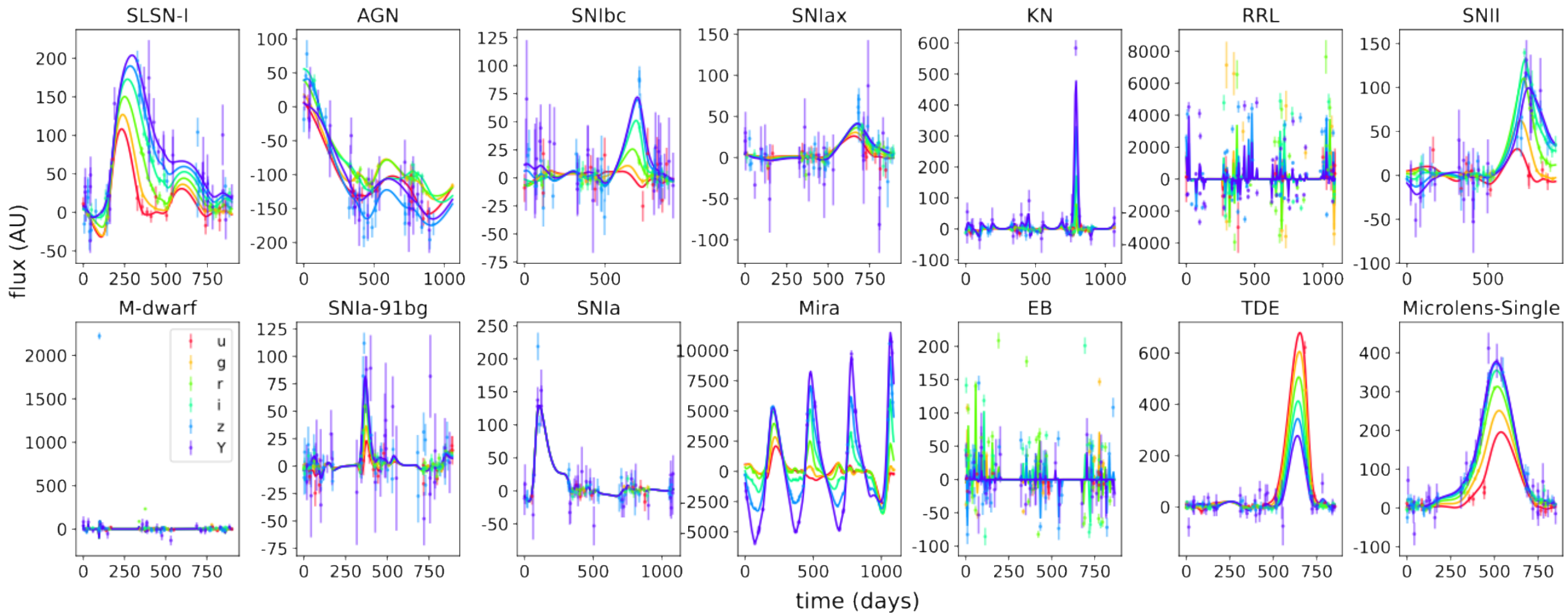
The Multimodal Universe

	Images	Time-Series	Spectra
# examples	140M	4.5M	225M
Description	images in a variety of wavelength ranges, including optical and infrared	multivariate time-series of flux + uncertainty in different wavelength ranges	flux as a function of wavelength
Tasks	galaxy classification, physical property estimation	time-series classification, redshift estimation	physical property estimation
Examples			

Framework
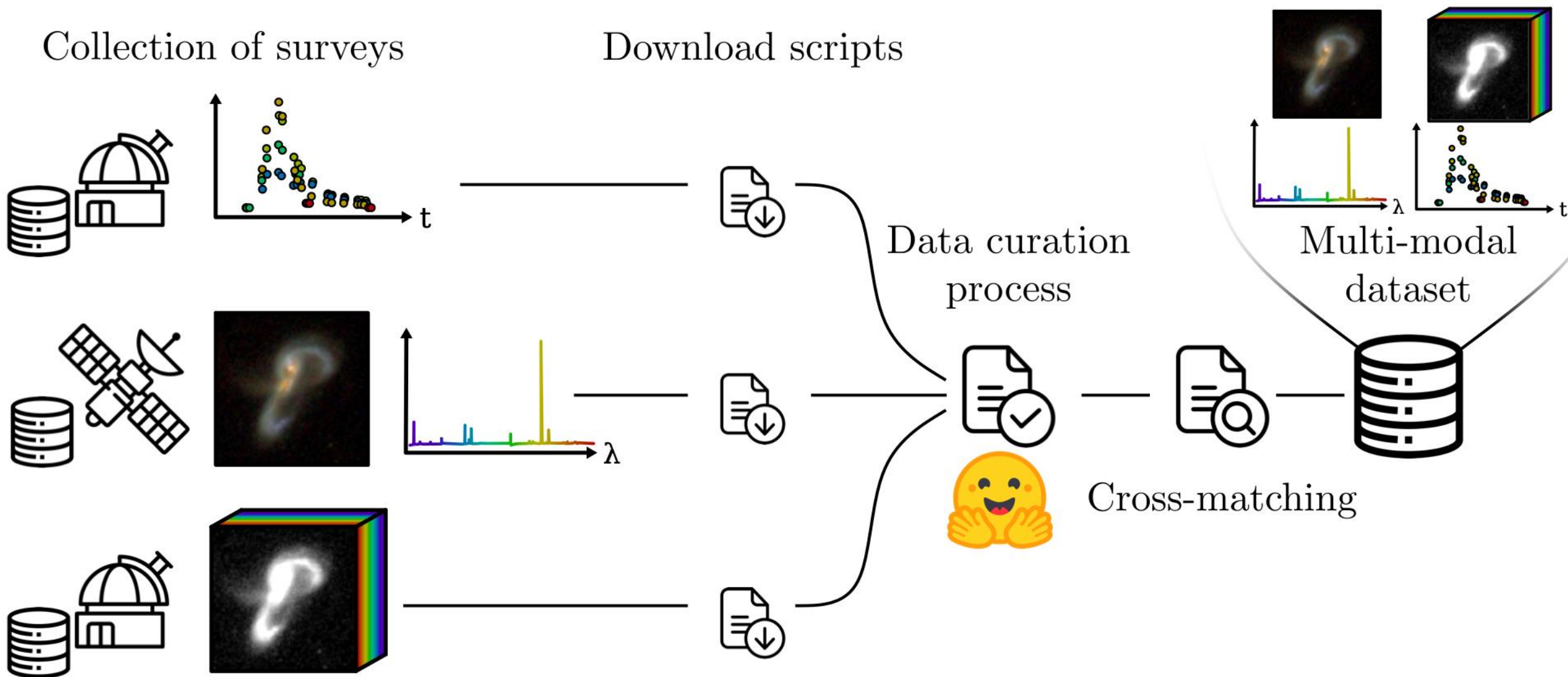
Benchmarks

Benchmarks
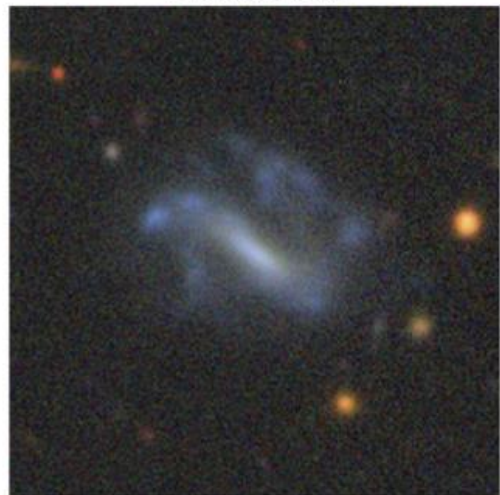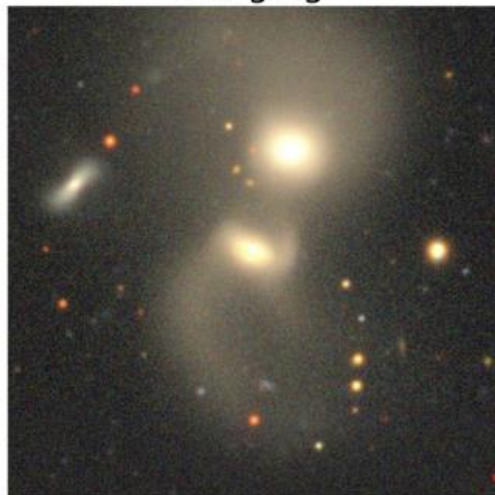
Disturbed · Merging · Round Smooth · In-between Round Smooth · Cigar Round Smooth
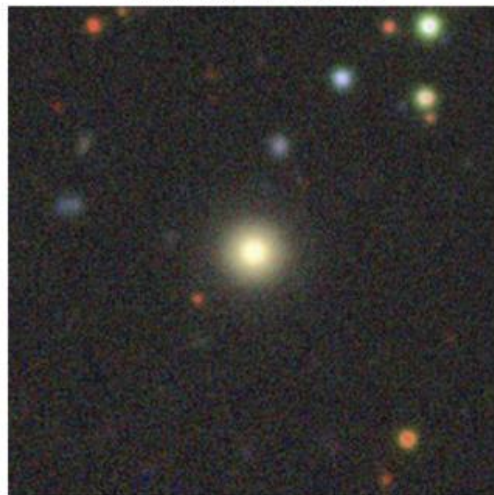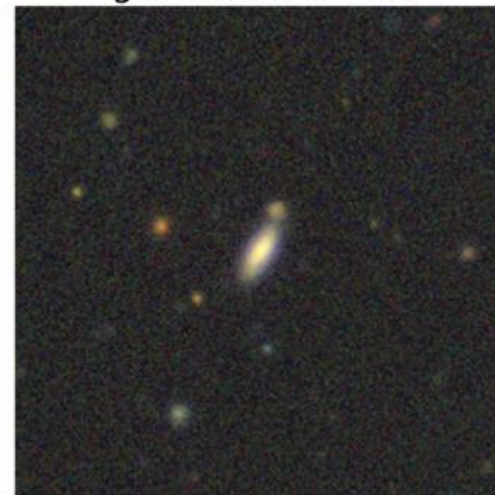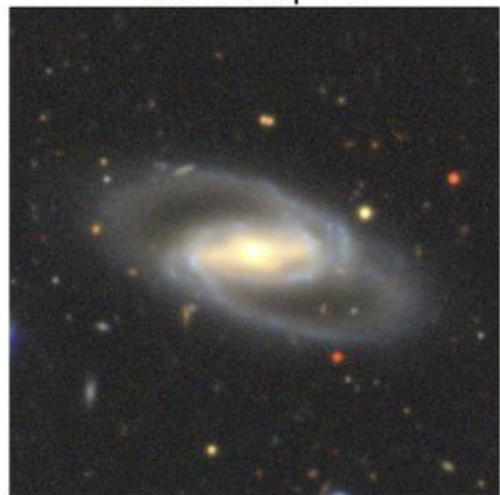
Barred Spiral · Unbarred Tight Spiral · Unbarred Loose Spiral · Edge-on without Bulge · Edge-on with Bulge
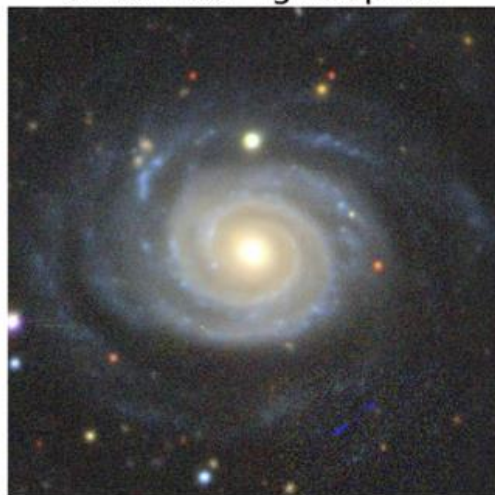
Benchmarks

Table 3: Top-1 Accuracy on the Galaxy10 DECaLS morphology classification dataset.

Pretraining	Model	Top-1 Accuracy
	EfficientNetB0	**80.9** $\pm$0.1 %
No pretraining	ConvNext-nano [144]	75.6 $\pm$1.8 %
	ResNet18	73.9 $\pm$0.9 %
	DenseNet121	73.5 $\pm$2.4 %
Galazy Zoo	ConvNext-nano [144]	**89.3** $\pm$0.1 %
ImageNet-12k	ConvNext-nano [144]	83.9 $\pm$0.3 %

Benchmarks

Table 4: Model R^2 performance comparison for predicting galaxy properties from different observational data modalities.

Modality	Source Survey	Model	Z_{HP}	$\log M_*$	Z_{MW}	$t_{age,MW}$	sSFR
Image	Legacy Surveys	ResNet18	0.771	0.725	0.381	0.210	0.405
		DenseNet121	0.774	0.734	0.414	0.267	0.446
		EfficientNetB0	0.697	0.645	0.395	0.260	0.421
Spectrum	DESI	Conv+Att [104]	0.982	0.871	0.659	0.488	0.679
Photometry	PROVABGS	MLP	0.696	0.681	0.383	0.308	0.343

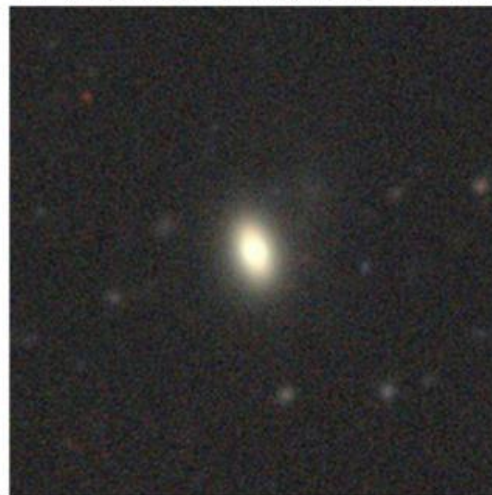| No pretraining | | ResNet18 | | | | | |
		DenseNet121	75.3 ±...				
Galazy Zoo	ConvNext-nano [144]	**89.3** ±0.1 %					
ImageNet-12k	ConvNext-nano [144]	83.9 ±0.3 %					

Round Smooth

In-between Round Smooth

Cigar Round Smooth

Barred Spiral

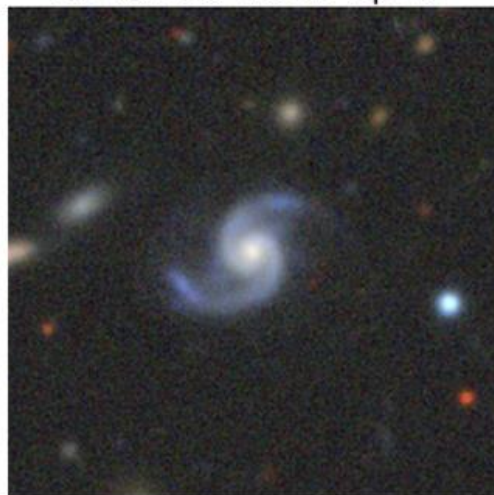# Benchmarks

Table 4: Model R^2 performance com... observational data modalities.

Modality	Source Sur...
Image	Le...
Spectrum	
Phot...	

Table 5: Results for astronomical time-series tasks. The performance of each model on the associated metric for the task is shown in the **Performance** column. Avocado is a Random Forest architecture while Connect Later is a transformer architecture.

Source Survey	Task	Metric	Model	Performance
				0.985
				0.90
			BTSbot [119, 120]	77.4
	Transient Candidate Identification	AUC	Random forest	79.9
		AUC	Avocado [20]	0.247
BTS	SN Ia classification	Accuracy	Connect Later [117]	
YSE	14-way classification	Accuracy	Connect Later [117]	
	14-way classification	RMSE		
PLAsTiCC	Redshift estimation			

		$t_{age,MW}$	$sSFR$
.581		0.210	0.405
0.414		0.267	0.446
0.871	0.395	0.260	0.421
0.681	0.659	0.488	0.679
	0.383	0.308	0.343
...eNet121	73.5		
ConvNext-nano [144]	**89.3 $\pm$0.1 %**		
ConvNext-nano [144]	83.9 $\pm$0.3 %		

Benchmarks

Table 6: R^2 performance of zero-shot prediction of galaxy properties from image and spectrum following the strategy described in [112]. AstroCLIP embeddings following the strategy described in [112].

Modality	Source Survey	Z_{HP}	$\log M_*$	Z_{MW}	$t_{age,MW}$	$sSFR$
Image	Legacy Surveys	0.801	0.737			
Spectrum	DESI	0.986	0.879	0.432	0.240	0.405
				0.584	0.441	0.435
						0.643

Table 5: Results for astro... associated metric for the tas... Forest architecture while Conv...

Source Survey	Task		Performance
BTS	Transient Candidate Id... SN Ia classification		
YSE	14-way classification	ConvNext-nano [144]	**89.3** ±0...
PLAsTiCC	14-way classification Redshift estimation	ConvNext-nano [144]	83.9 ±0.3 %

...vs. The performance of each model on the ...**Performance** column. Avocado is a Random ...er architecture.

Model		Performance
BTSbot [119, 120]		0.985
Random forest		0.90
Avocado [20]		77.4
Later [117]		79.9
Later [117]		0.247

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