

A million stars* isn't cool.
You know what's cool?

A million stars* isn't cool.
You know what's cool?

A billion stars*.

—(fictionalized) Sean Parker

*original quote about dollars not stars

Vera C. Rubin Observatory

Legacy Survey of Space and Time (LSST)



credit: RubinObs/NOIRLab/SLAC/NSF/DOE/AURA/A. Pizarro D.

A Billion Stars and Galaxies – Oh My! AstroAI Needs SkAI

**An (Incomplete) Summary of New Initiatives at the
NSF-Simons AI Institute for the Sky (SkAI)**

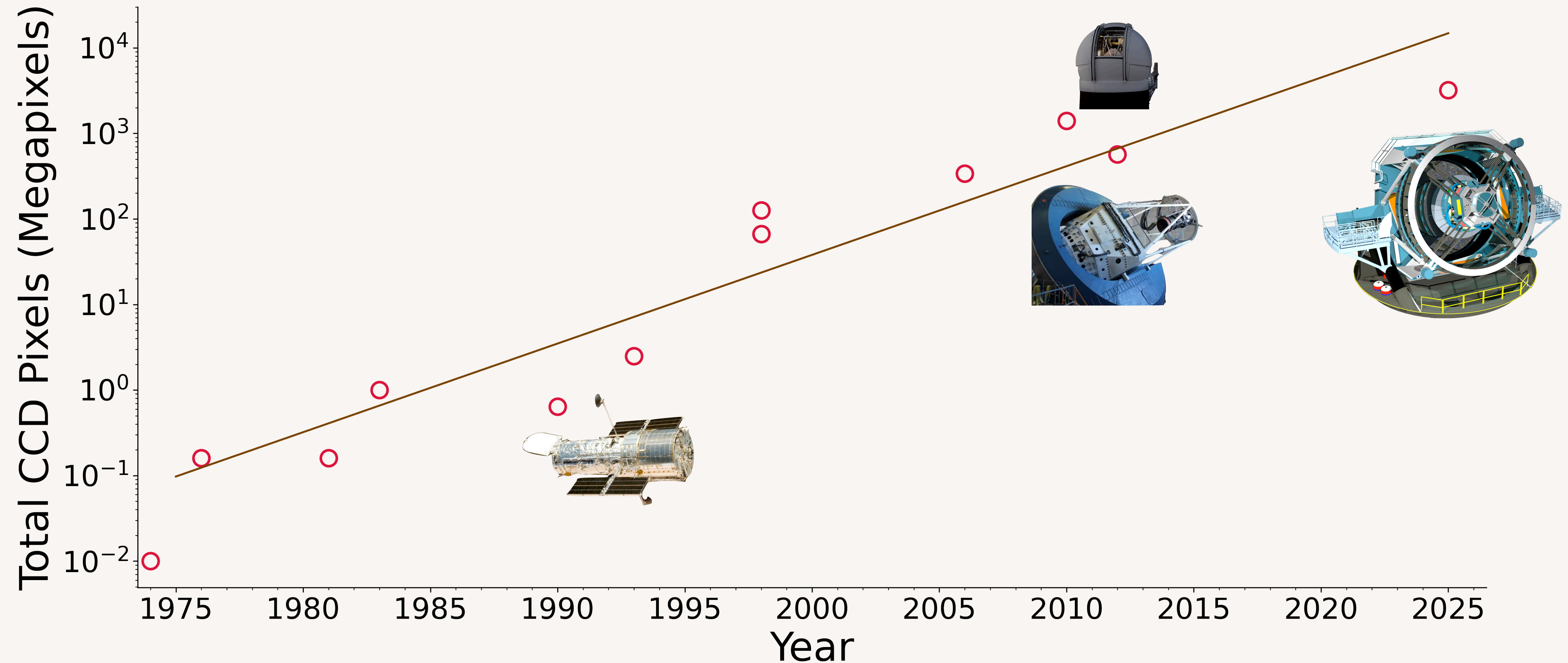
Adam A Miller

Northwestern, CIERA, SkAI

6th Global Research Platform Workshop
15 September 2025

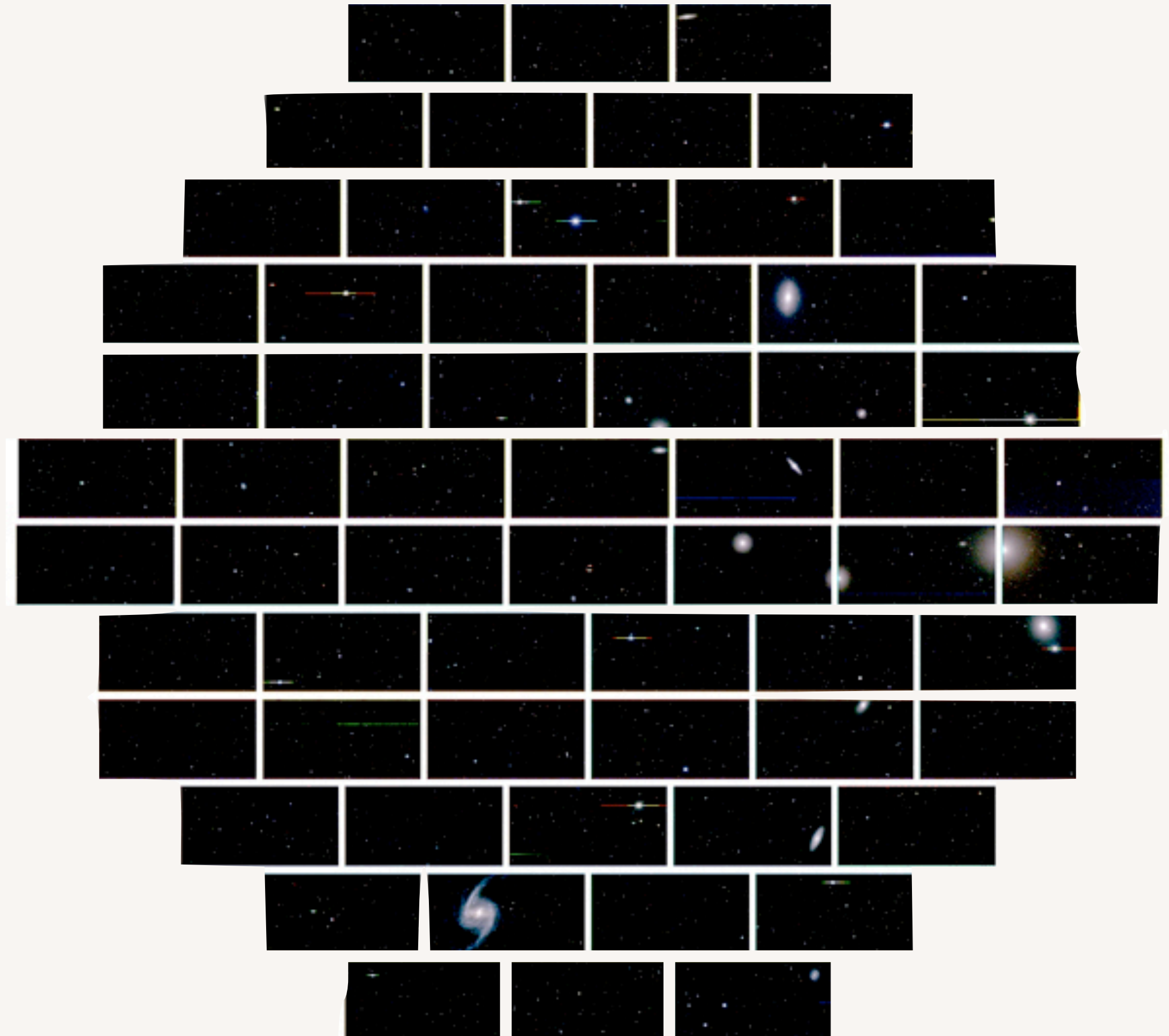
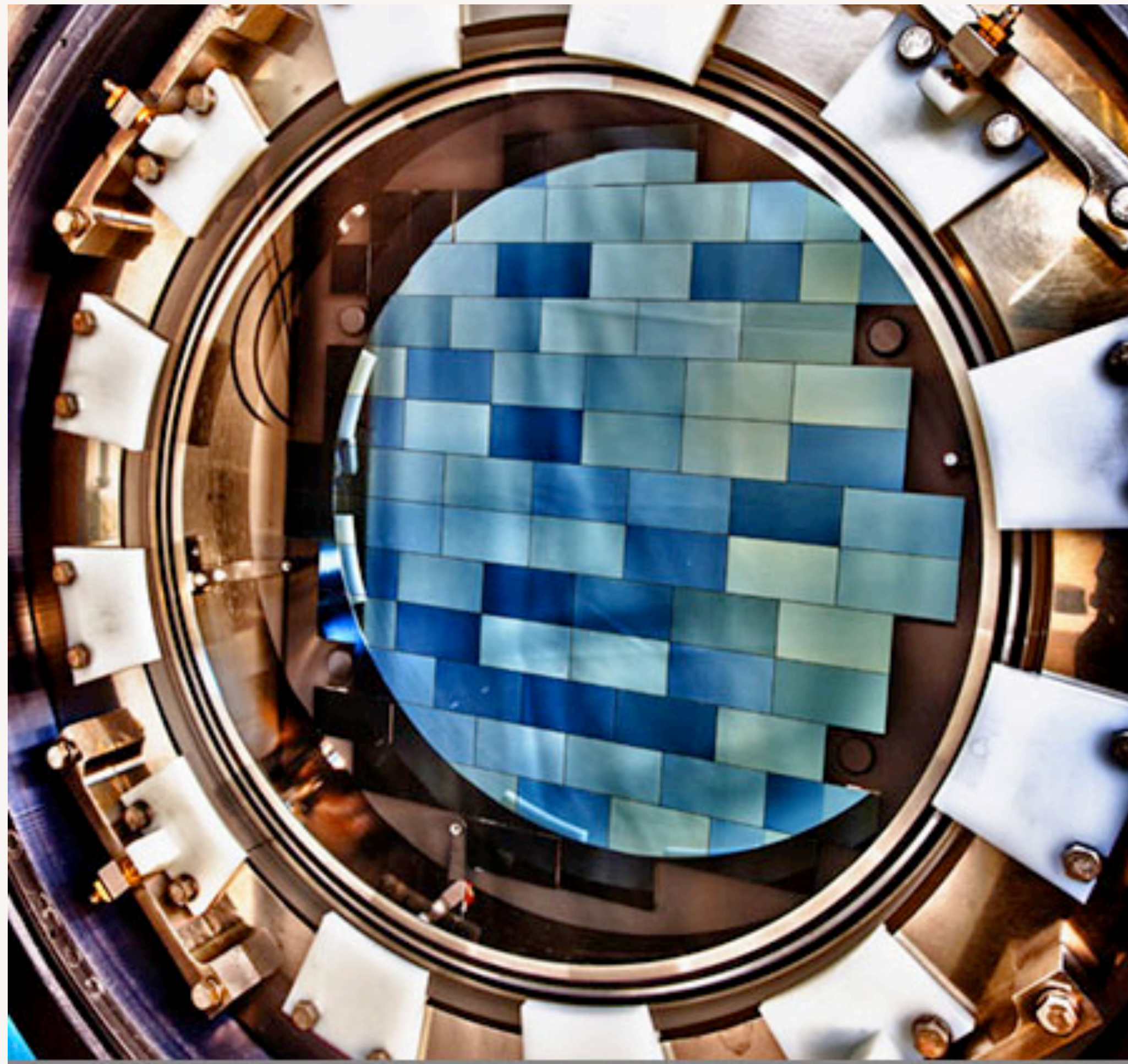
“Moore’s Law” of CCDs

Every ~decade pixels increase by factor of ~10x



Mosaic Multiple Detectors

Enables fast readout



credit: Dark Energy Survey Collaboration

Vera C. Rubin Observatory

Legacy Survey of Space and Time (LSST)



Cerro Pachon, Chile

8.4 m telescope

3.4 Gigapixels

20 TB/night

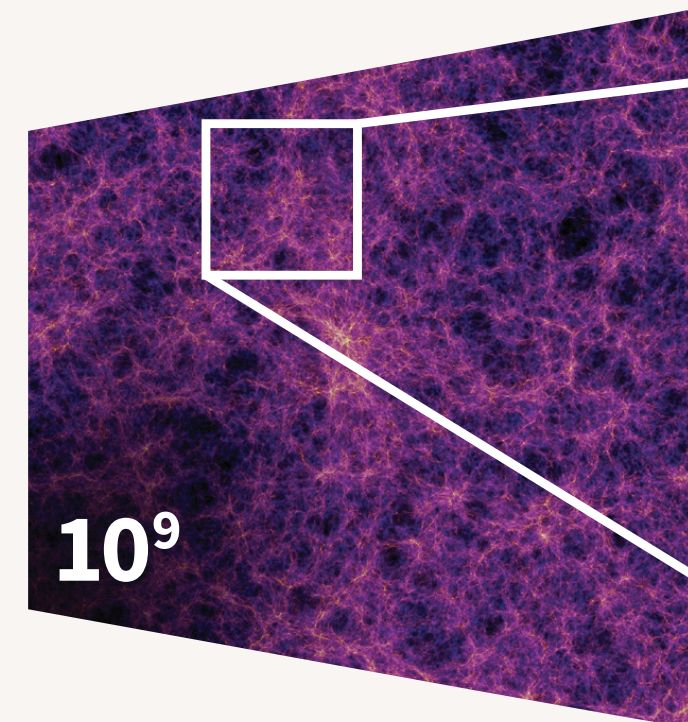
10 year survey

SkAI Institute

Developing AI solutions for Rubin and other surveys

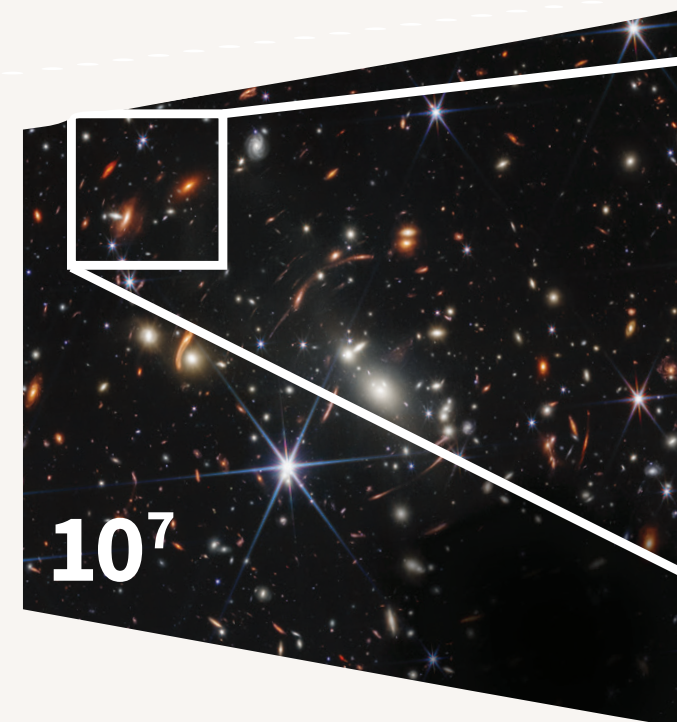


Funded by the U.S. National Science Foundation and the Simons Foundation



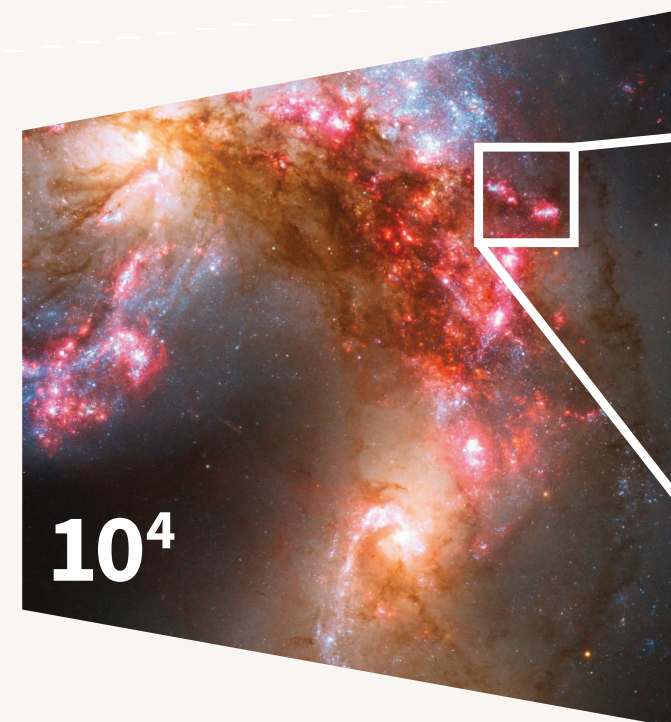
10^9

Cosmology and the
Early Universe



10^7

Galaxy Formation
and Evolution



10^4

10^{-13}

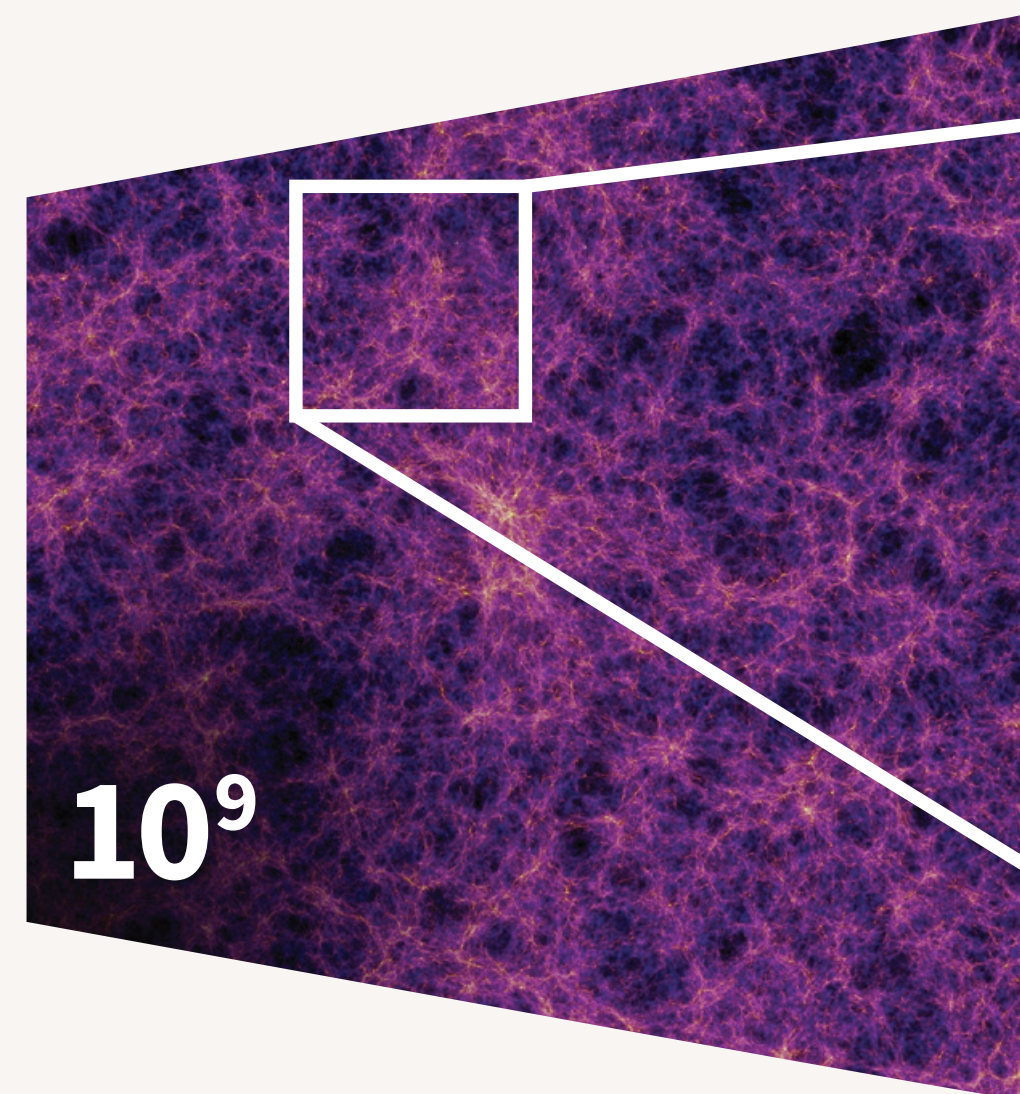
Stars, Compact Objects
and their Transients



credit: SkAI/NCSA

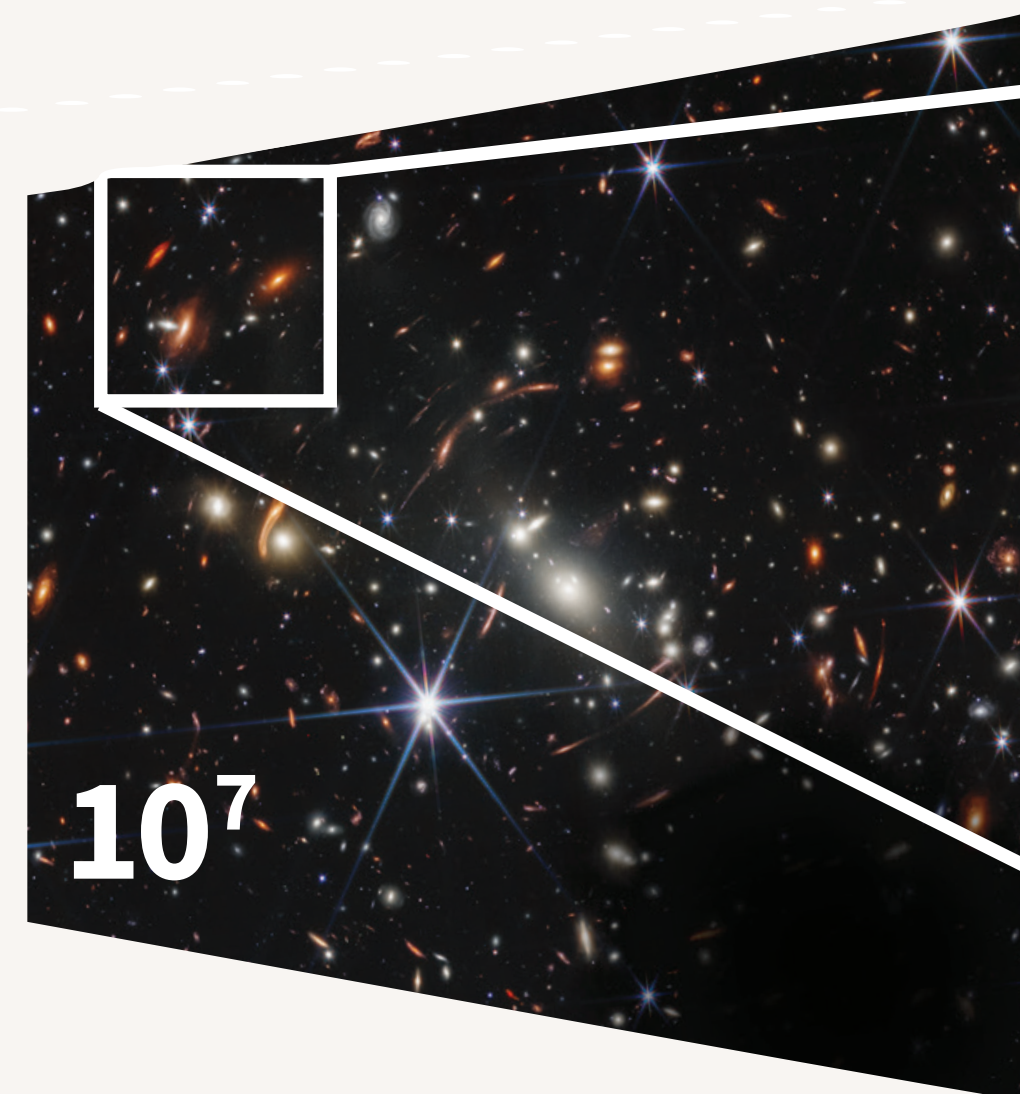
SkAI Institute

Bridging scales across astrophysics



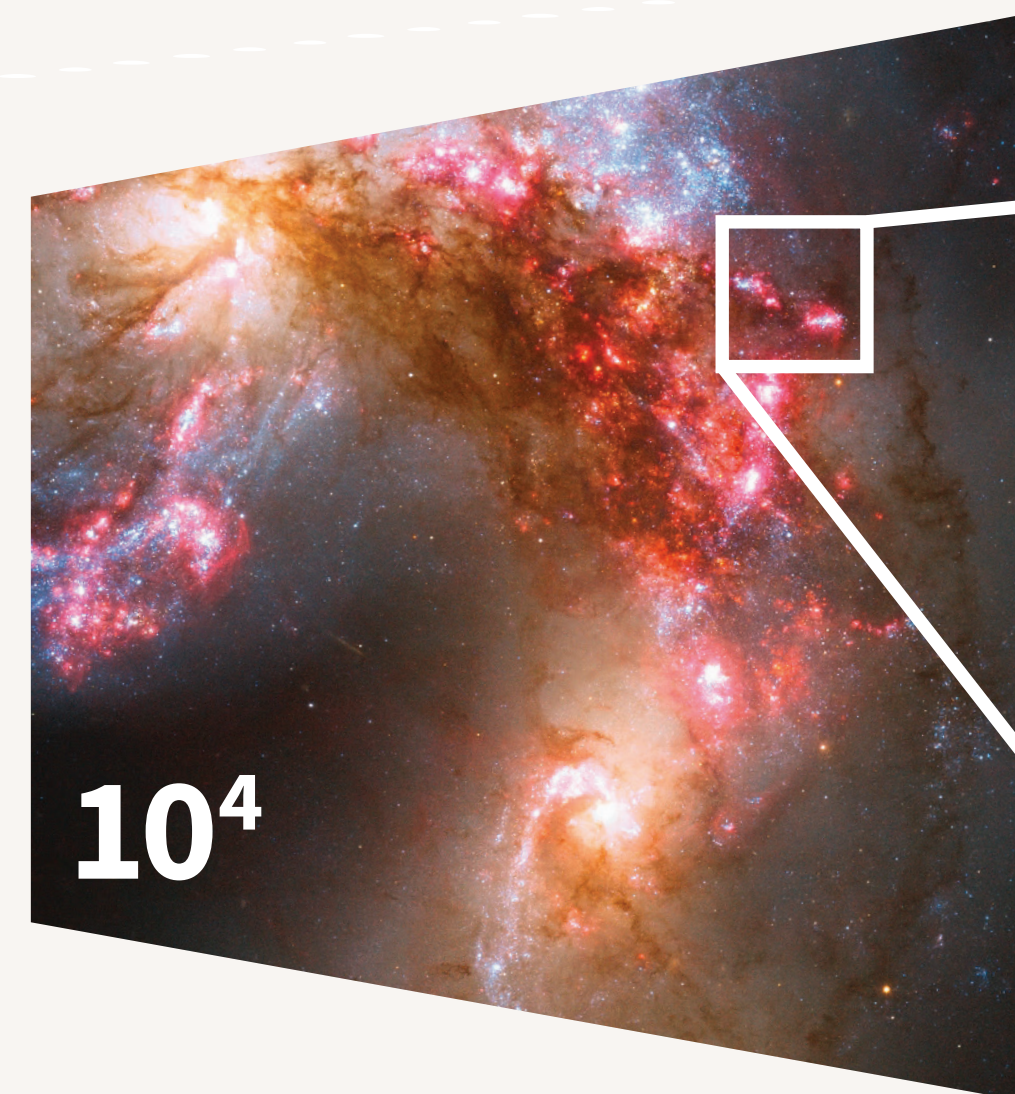
10^9

Cosmology and the
Early Universe



10^7

Galaxy Formation
and Evolution



10^4



10^{-13}

Stars, Compact Objects
and their Transients

SkAI Institute

Bridging scales across astrophysics and AI

Astrophysics

Stars, Compact Objects,
and their Transients

Galaxy Formation and
Evolution

Cosmology and the
Early Universe

Foundational AI

Generative Models

Astrophysics-Informed
and Interpretable
Architectures

Uncertainty
Quantification

SkAI Institute

Bridging scales across astrophysics and AI

Astrophysics

Research Pillars

Foundational AI

Stars, Compact Objects,
and their Transients

Galaxy Formation and
Evolution

Cosmology and the
Early Universe

Enhanced Inference from
Cosmic Survey Data

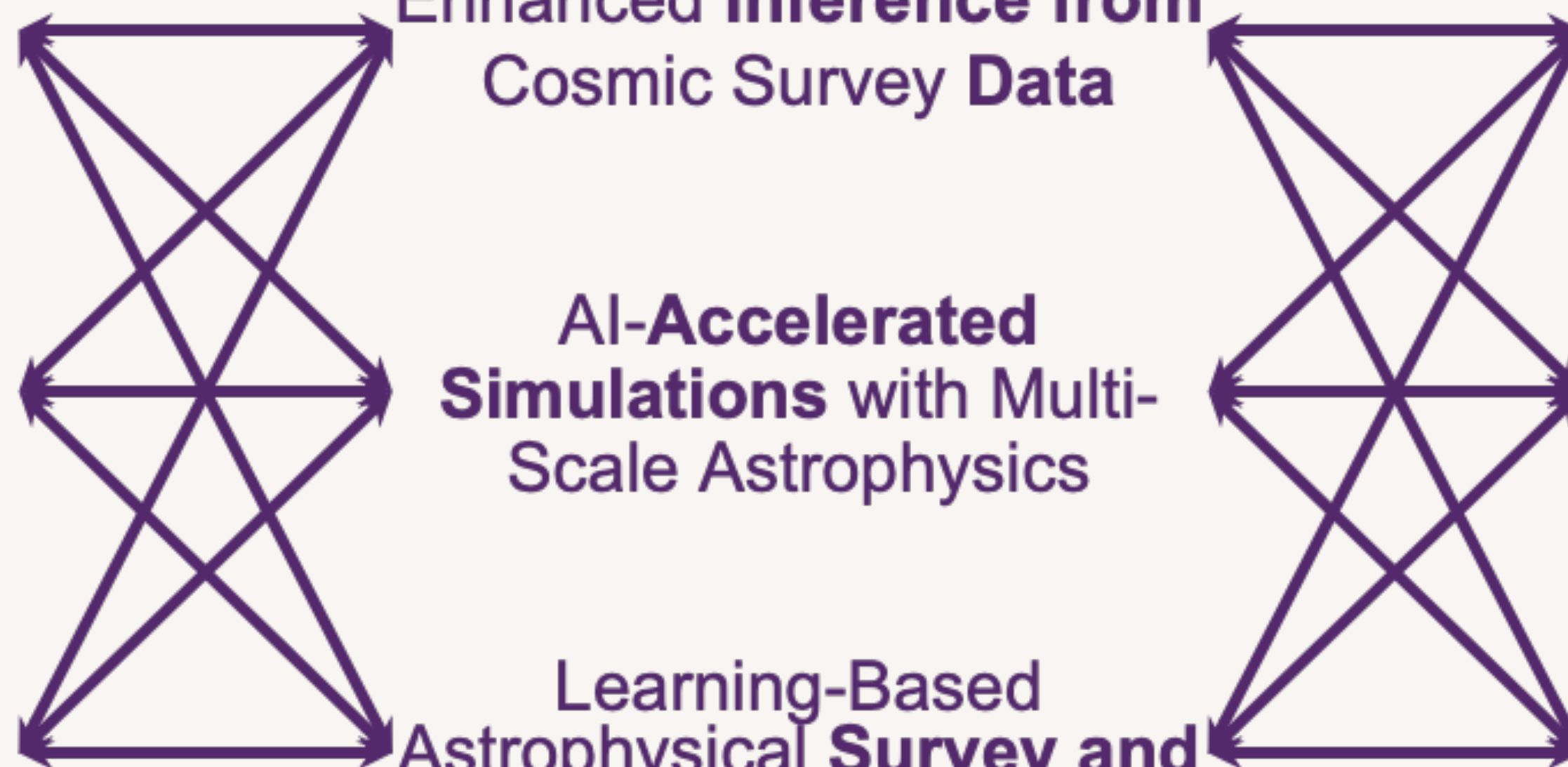
AI-Accelerated
Simulations with Multi-
Scale Astrophysics

Learning-Based
Astrophysical Survey and
Instrument Design

Generative Models

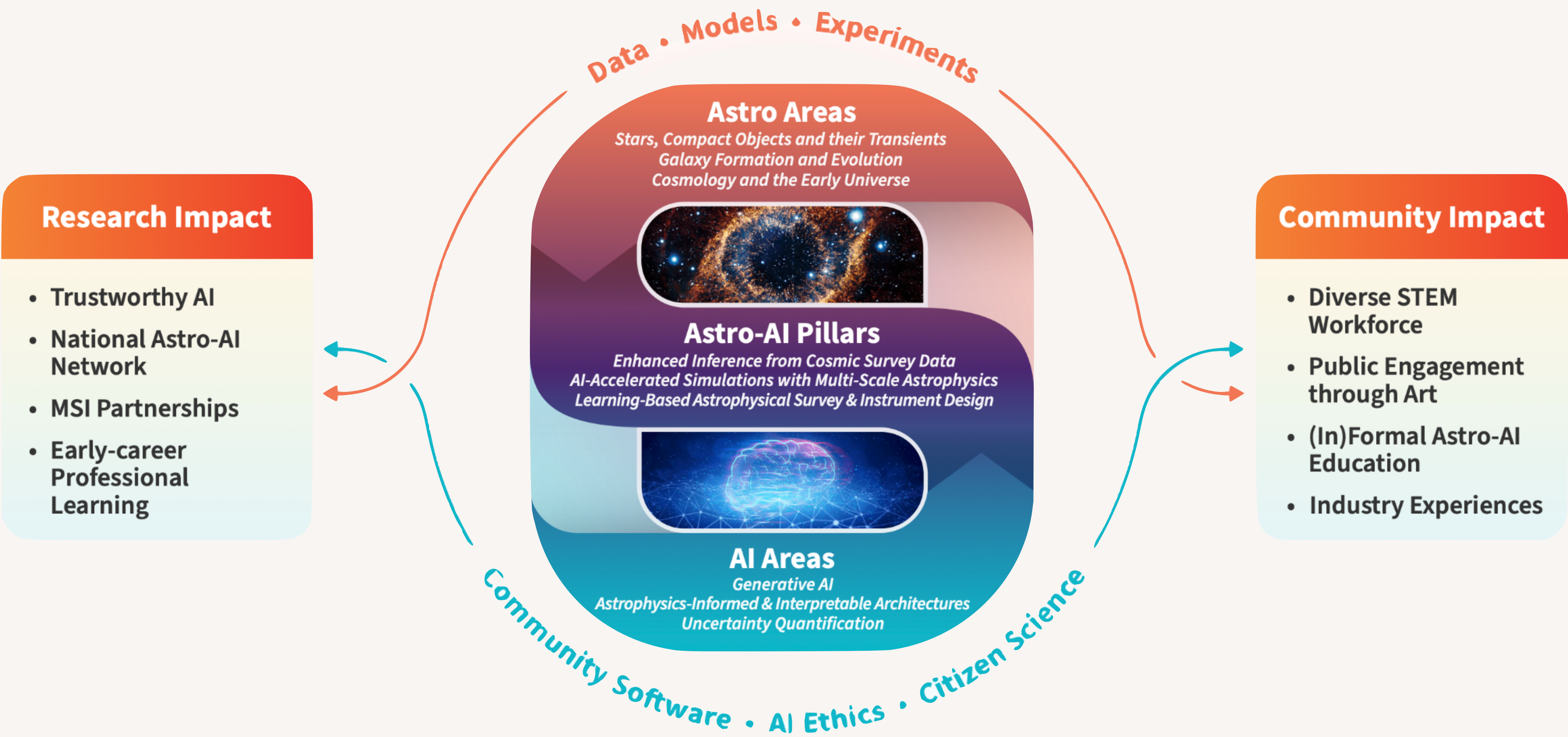
Astrophysics-Informed
and Interpretable
Architectures

Uncertainty
Quantification



SkAI Institute

Overview



SkAI Institute

Nationwide collaboration

Lead Institutions



Partner Institutions



Satellite Network



Art Partners

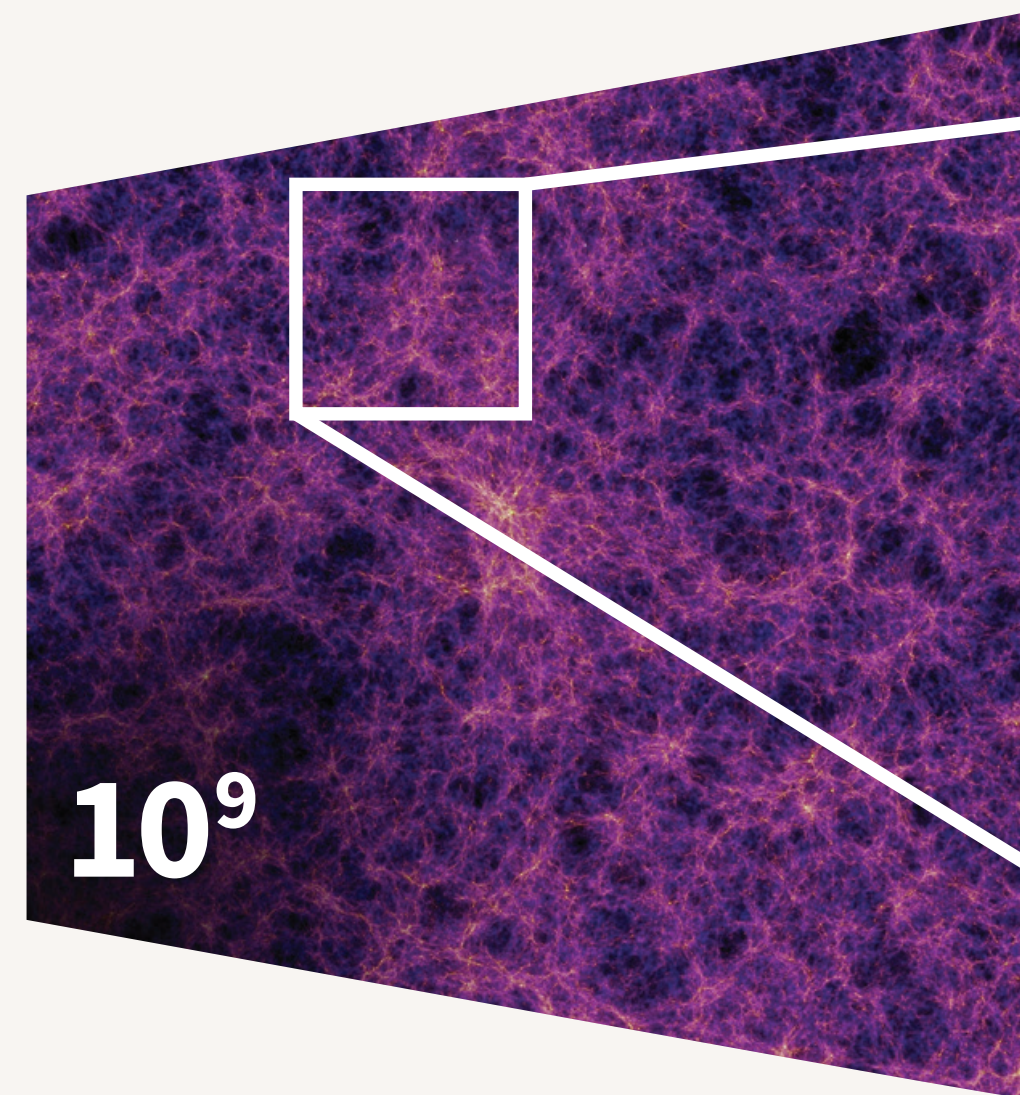


SkAI: a Geographic and Community Hub

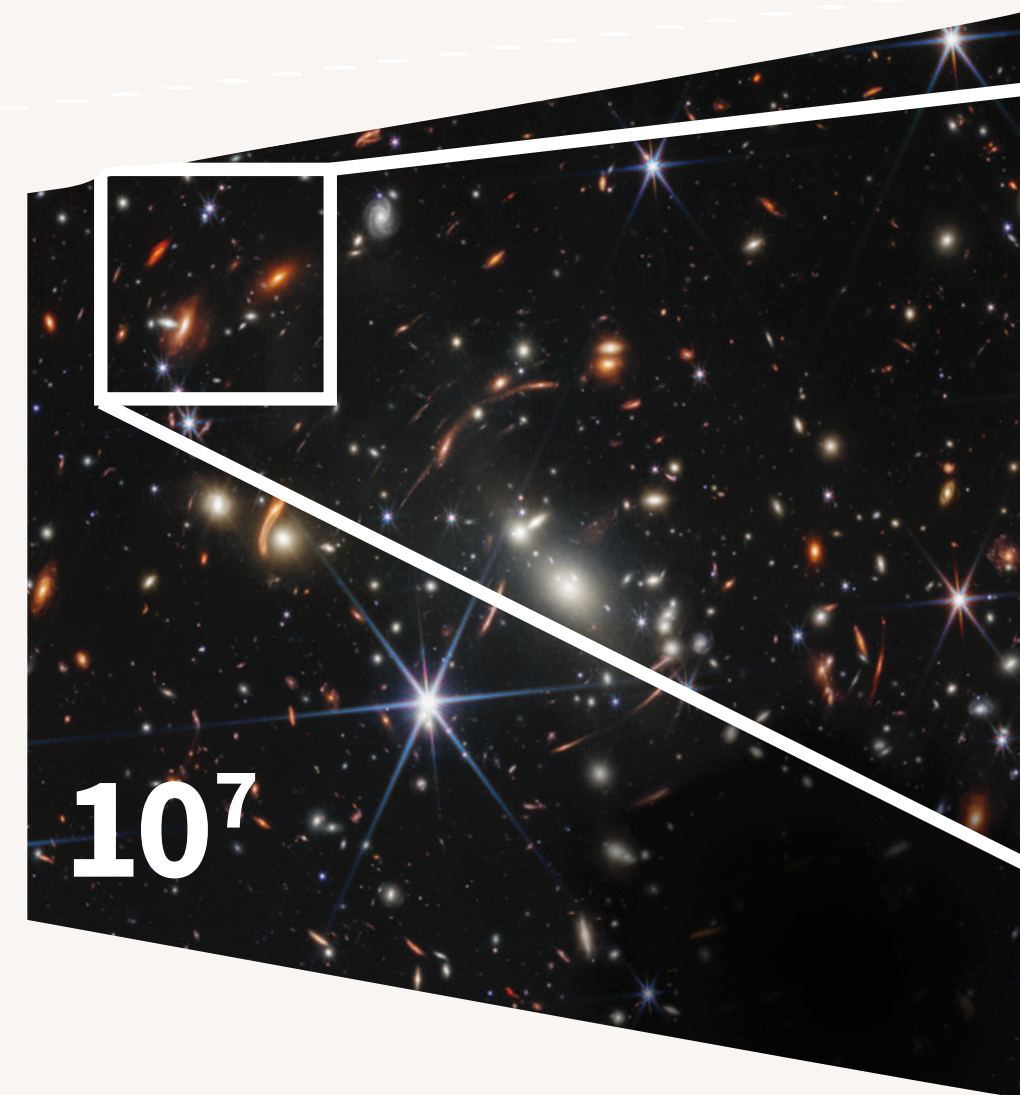


SkAI Focus: Multi-scale Astrophysics

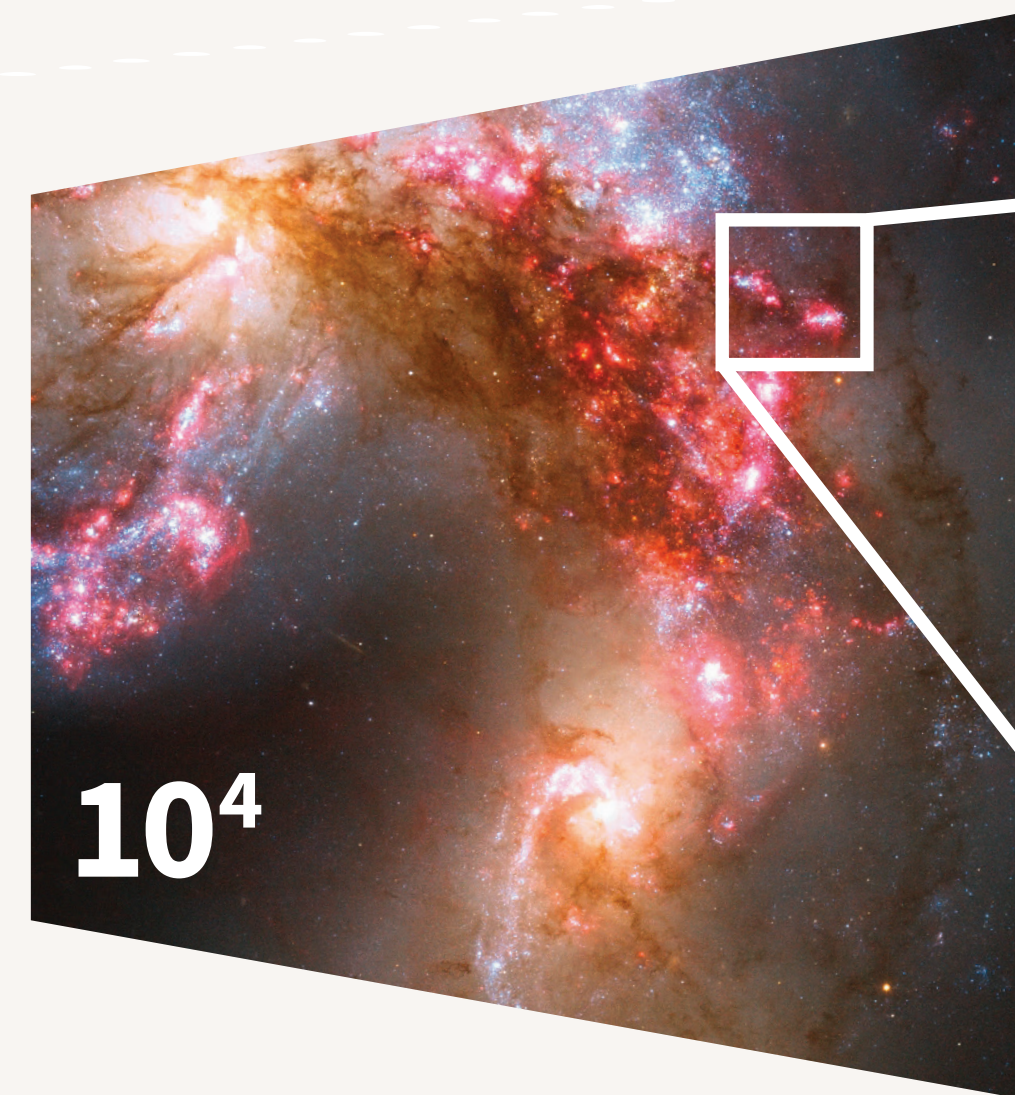
Orders of magnitude in space and time



Cosmology and the
Early Universe



Galaxy Formation
and Evolution



Stars, Compact Objects
and their Transients

Observations of Galaxies

Uncertainty quantification



Emma Alexander
(NU CS)



Tjitske Starkenburg
(NU astro)

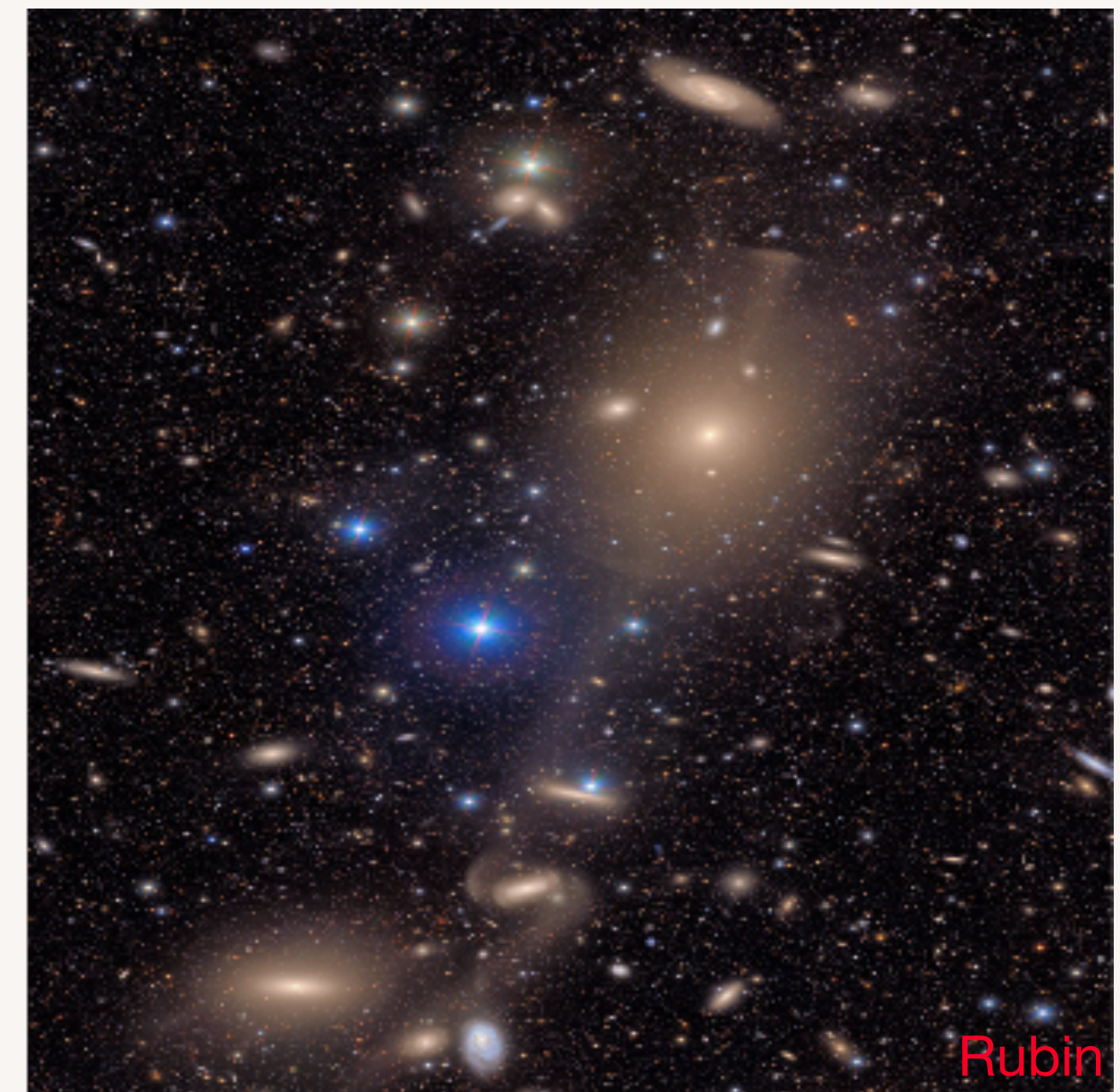
weak lensing



strong lensing

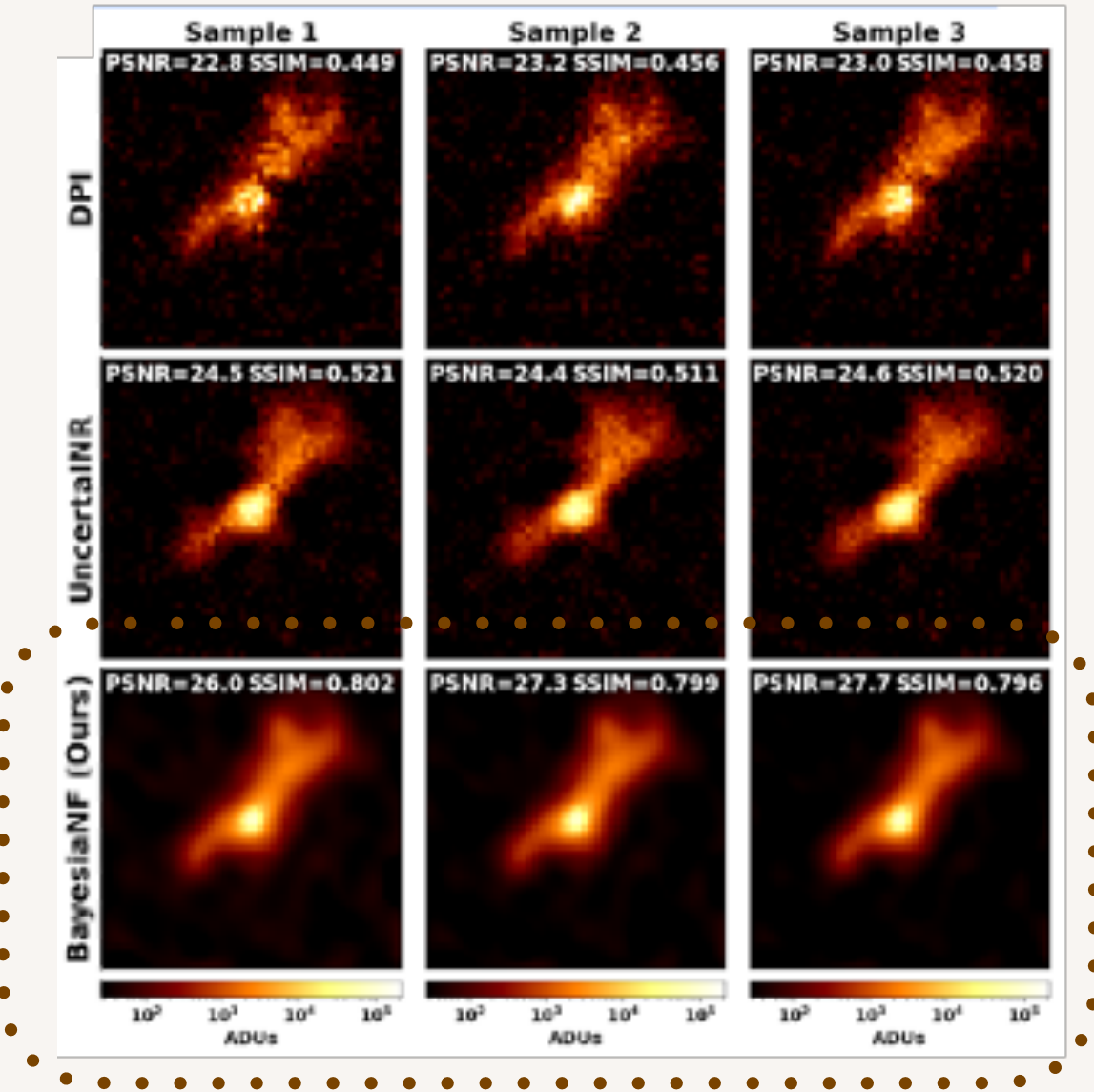


low surface brightness

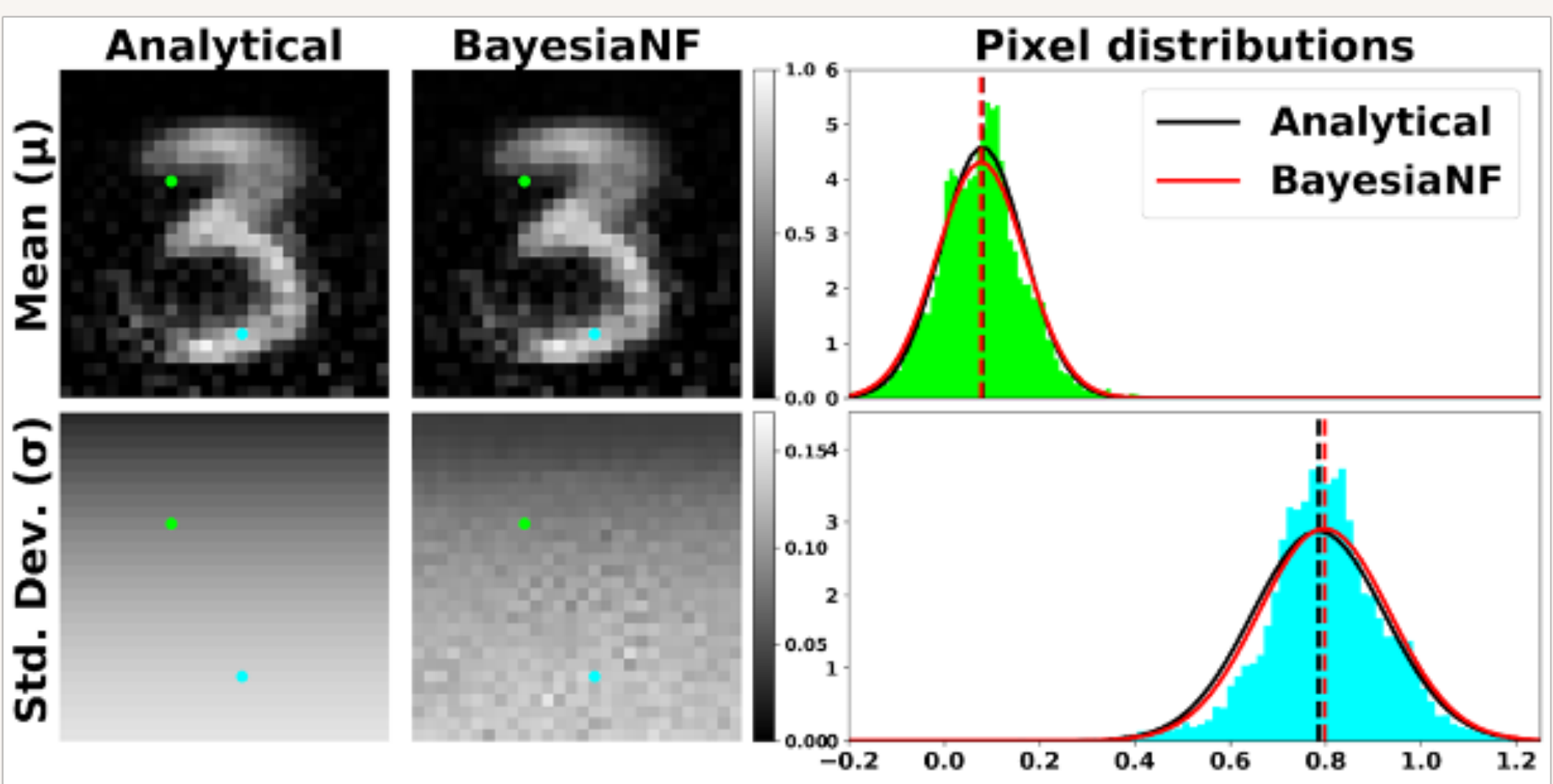


Observations of Galaxies

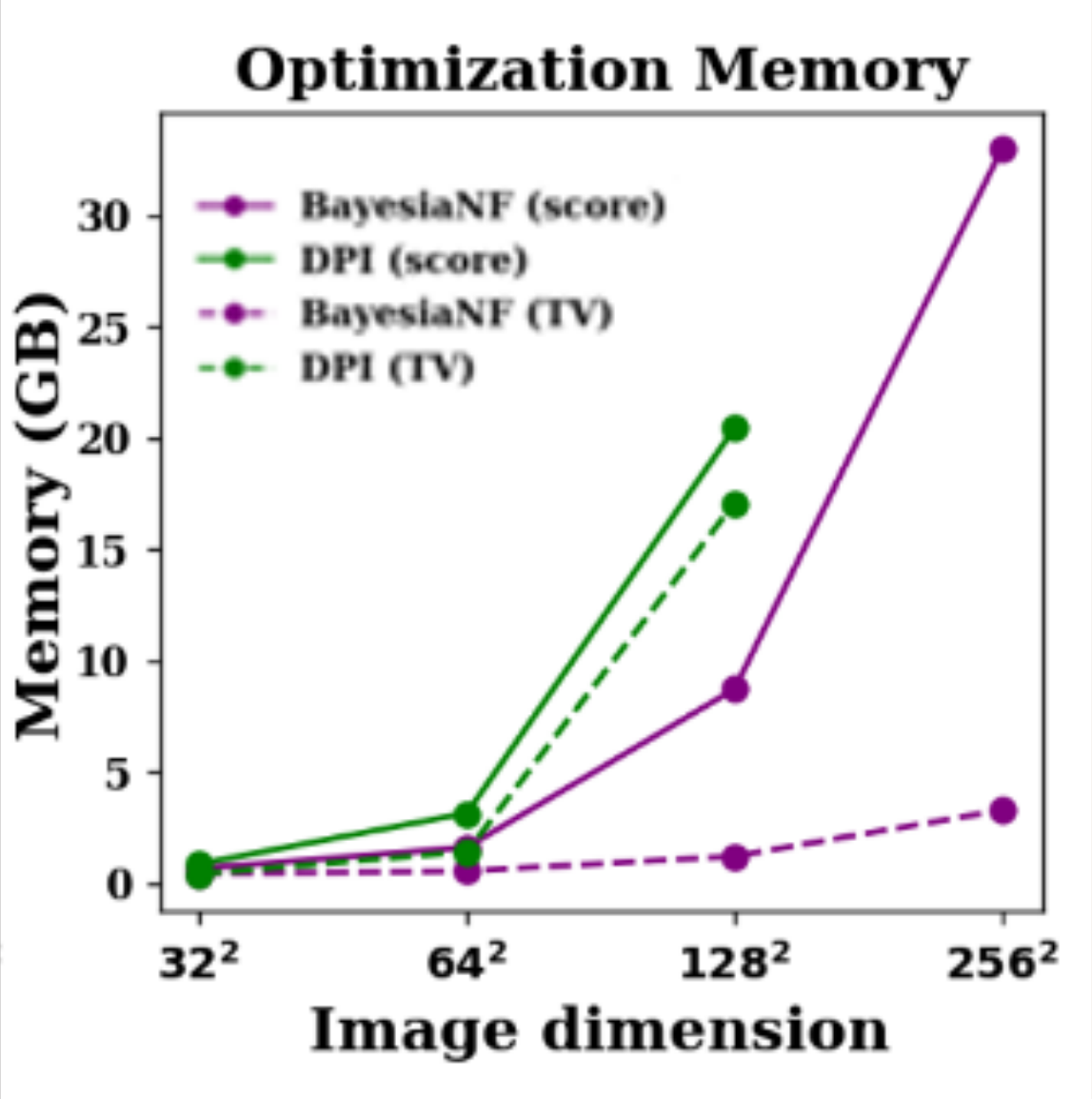
image quality



uncertainty quantification



scalability



Simulations of Stars

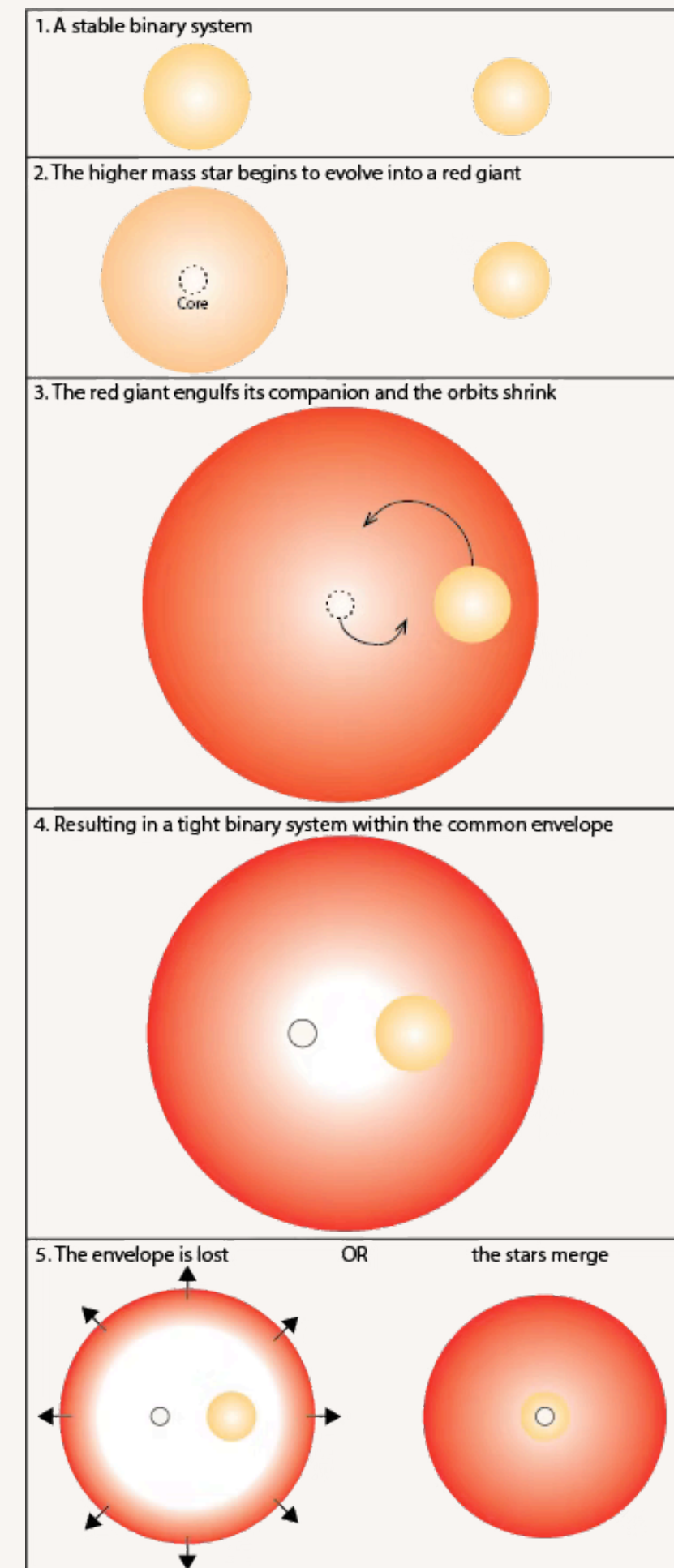
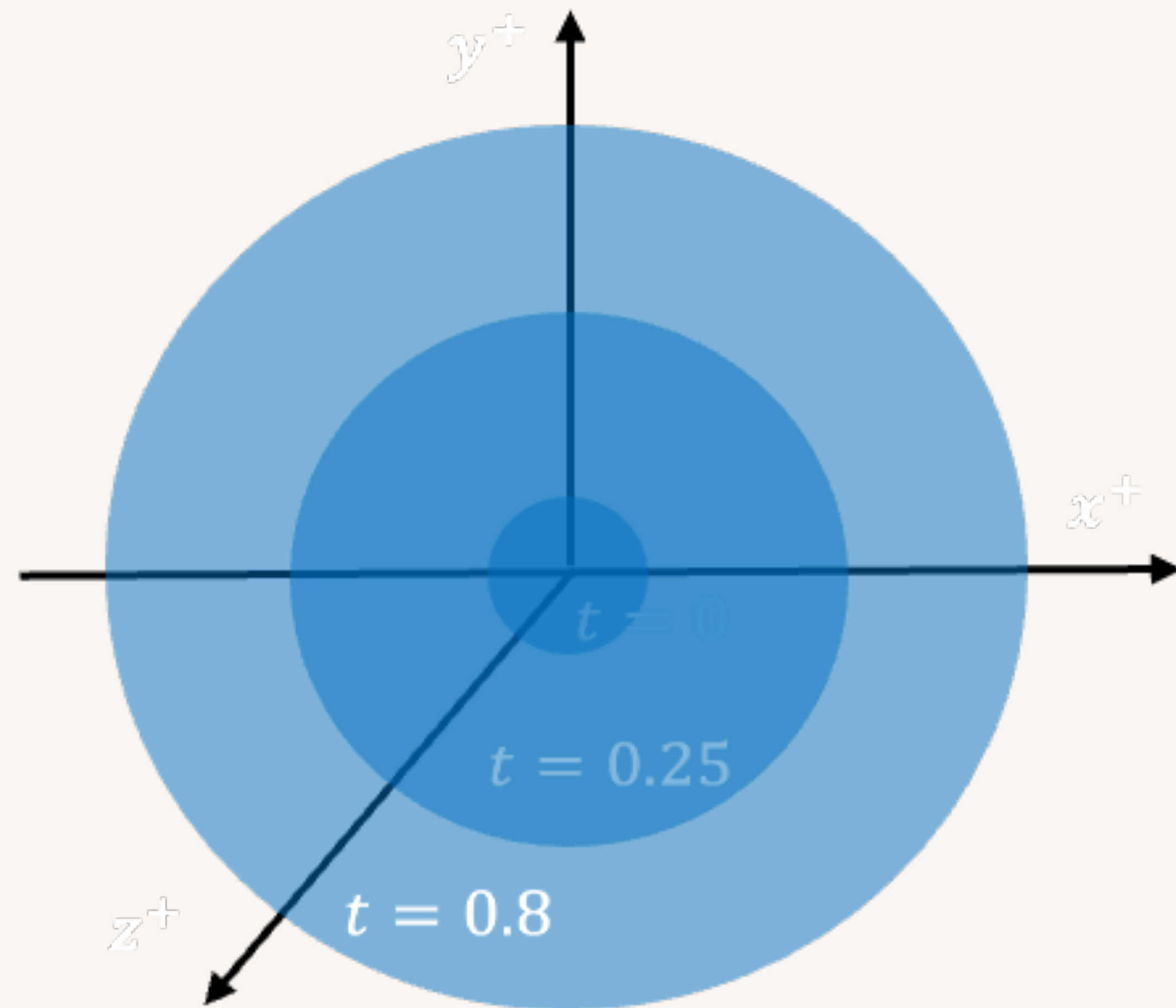
Astrophysics-informed neural networks



Vicky Kalogera
(NU astro)



Aggelos Katsaggelos
(NU CS)



single stars

4 coupled ODEs/PDEs

M, ρ, L, T as a function of r, t

+microphysics

binary stars

2 stars + orbit

mass transfer

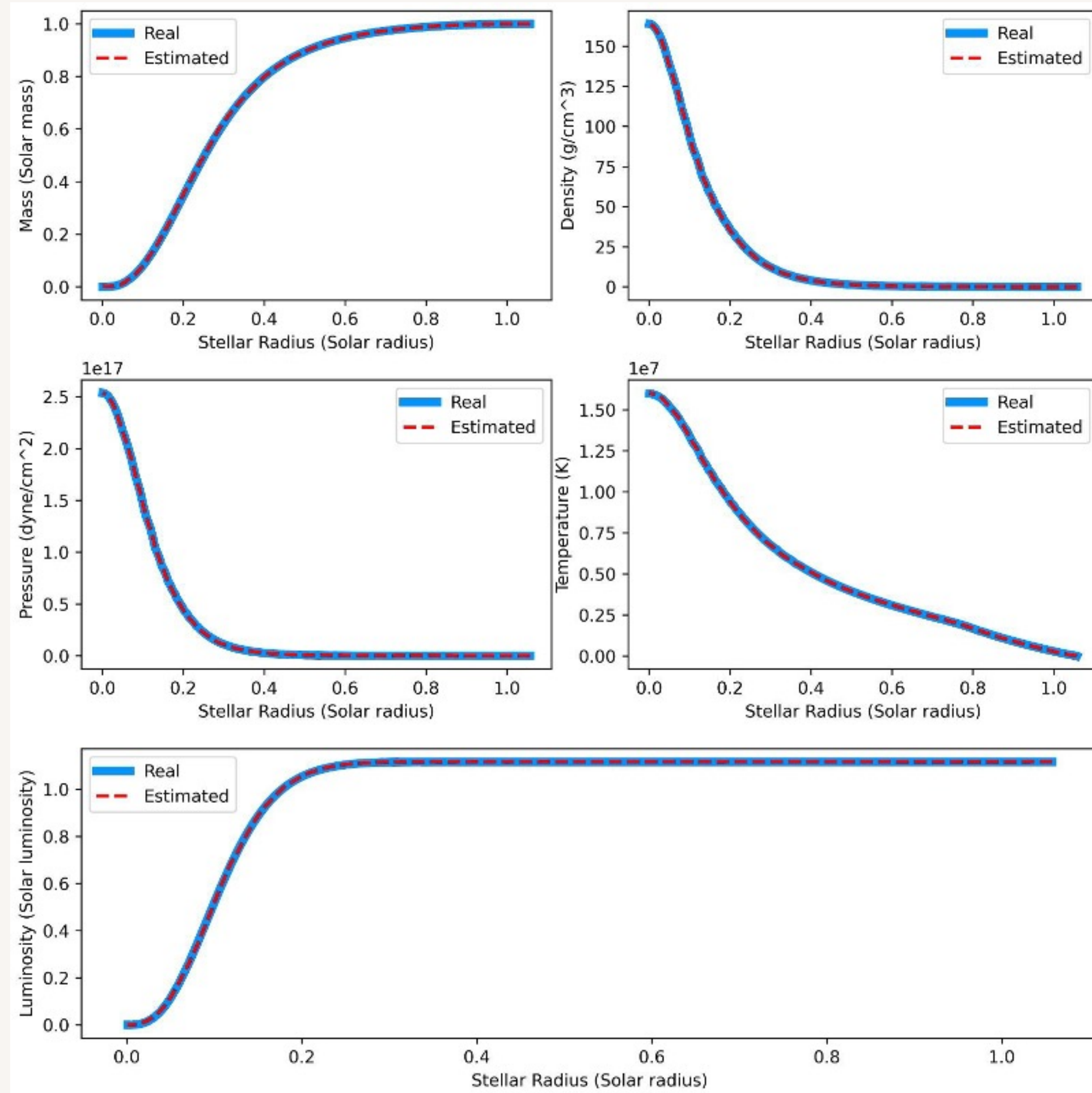
Simulations of Stars

Astrophysics-informed neural networks

PINNs replicate single stars
loss incorporates PDEs, BCs, & training data

can simulate stars without training sims
(currently less accurate)

(soon) accelerated models beyond SOTA



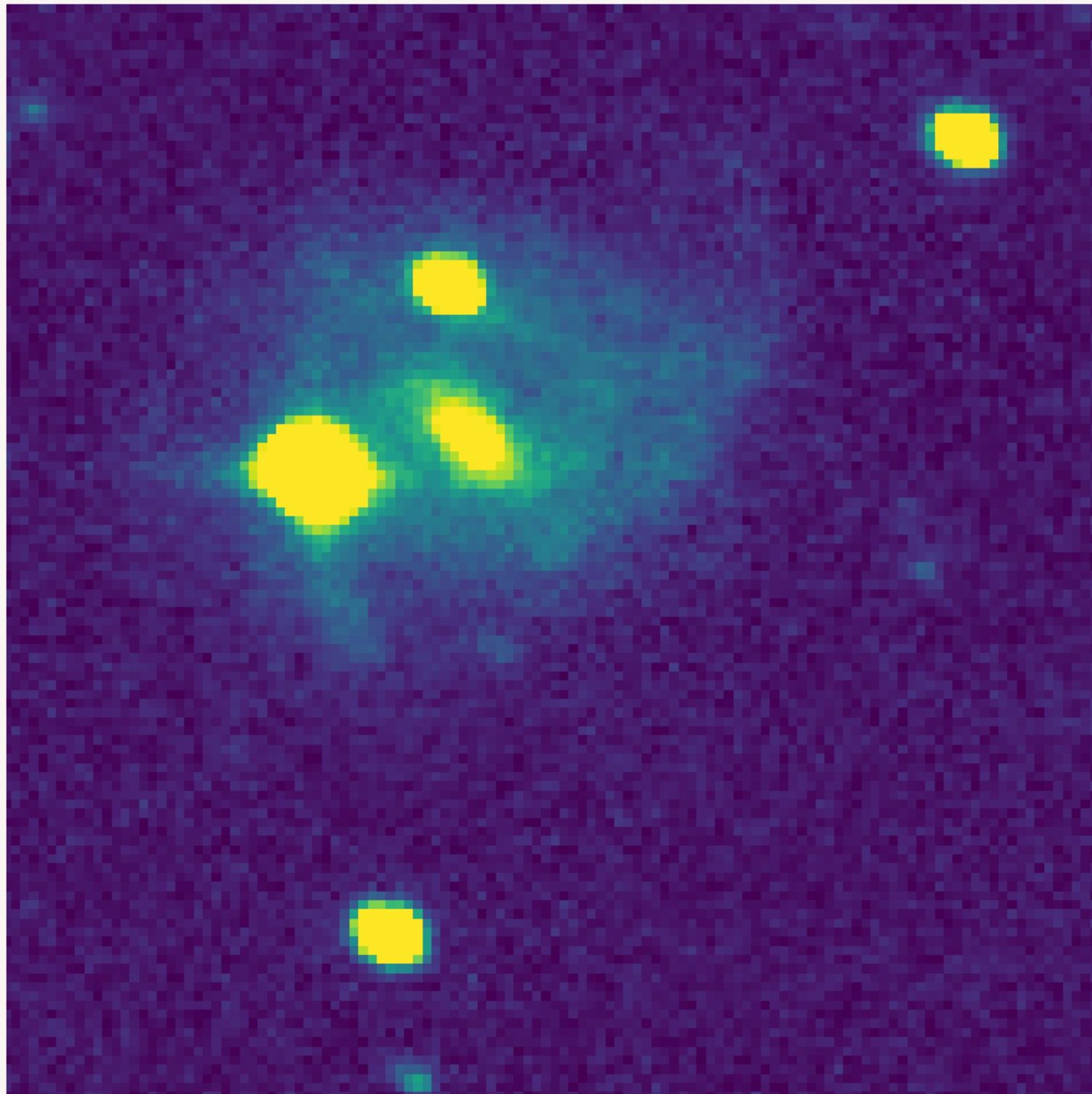
Need Many Images to Detect Faint Sources

Repetition opens up the time domain

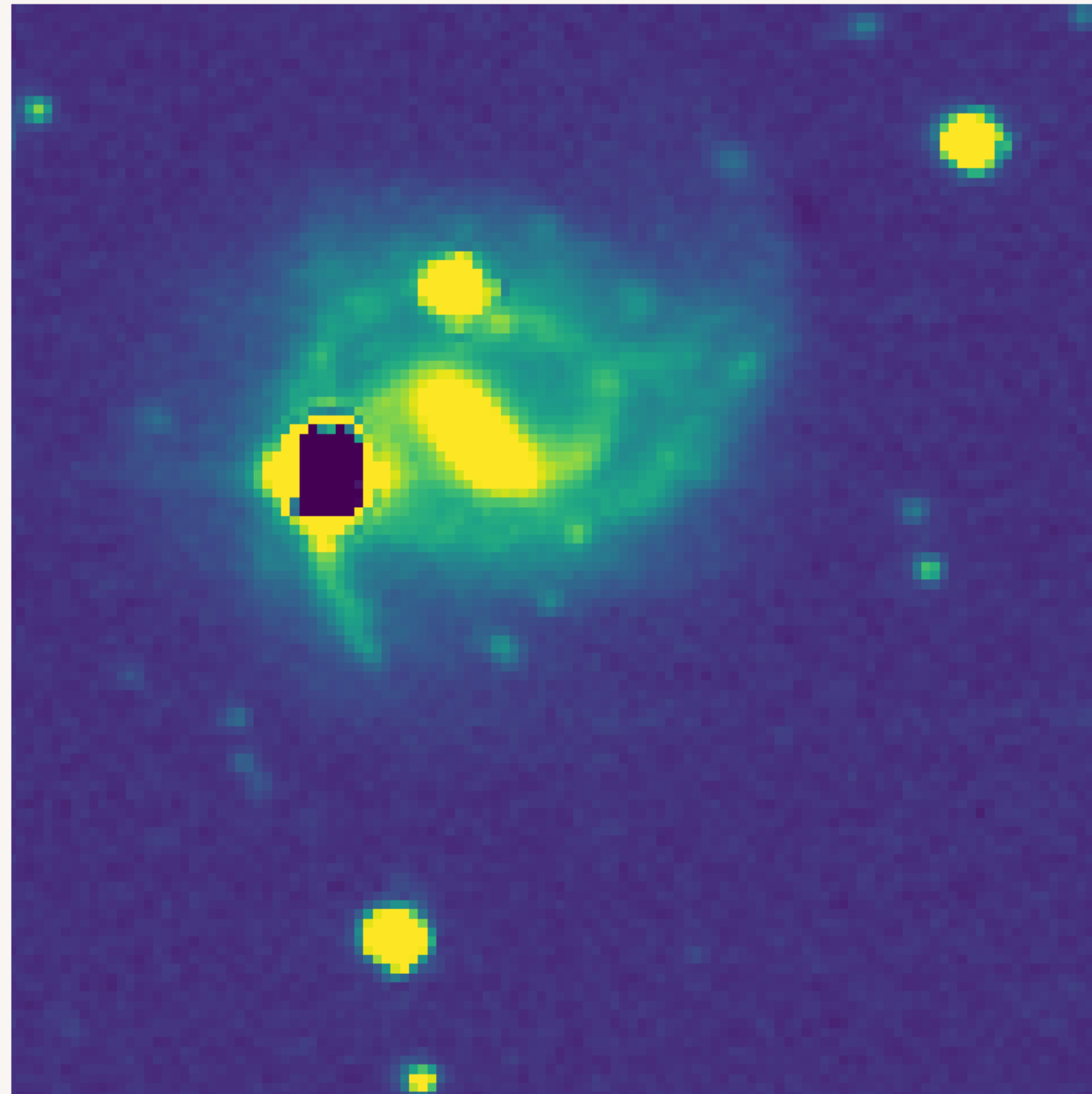


Observations of Exploding Stars

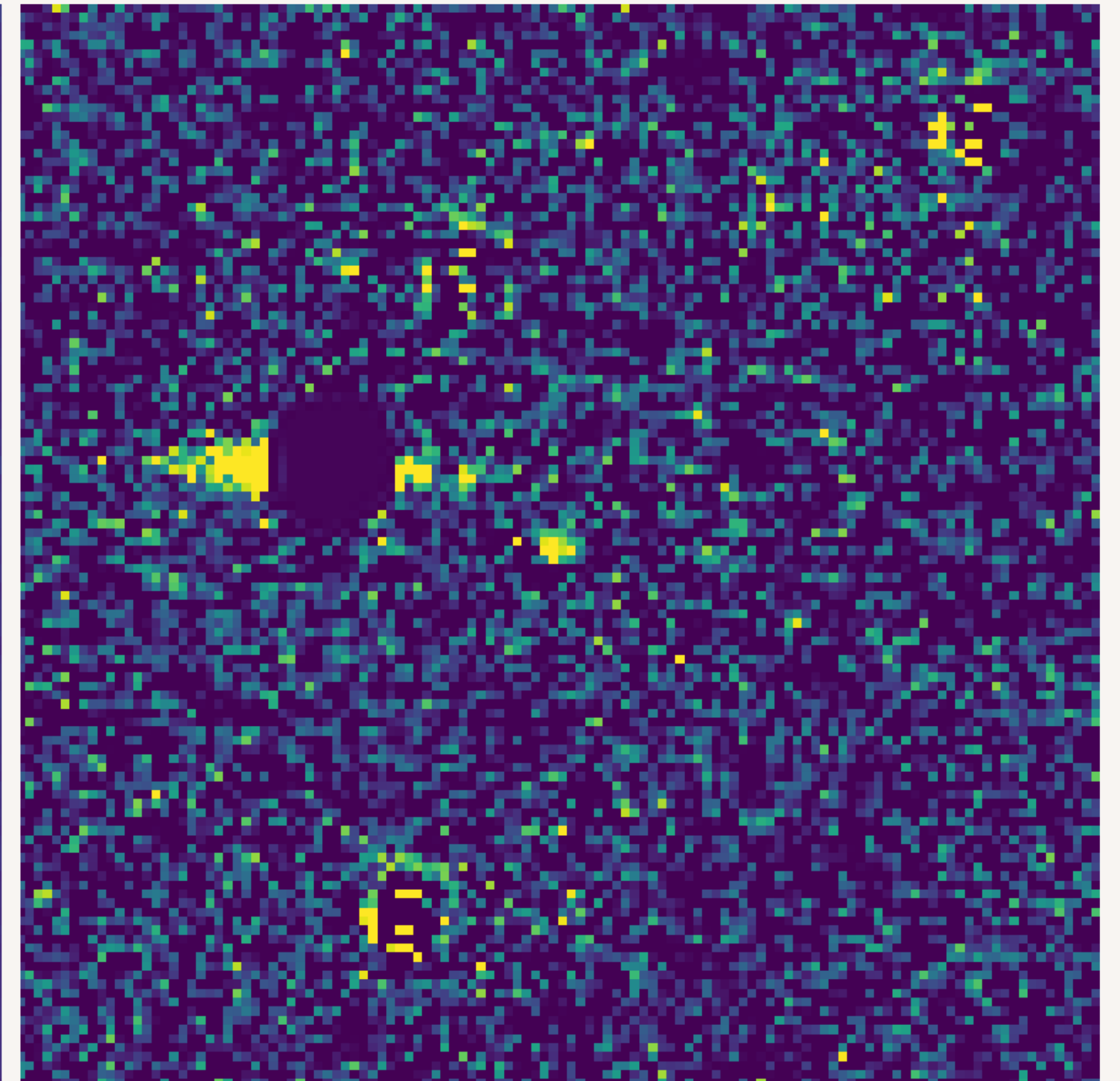
Image subtraction



new image



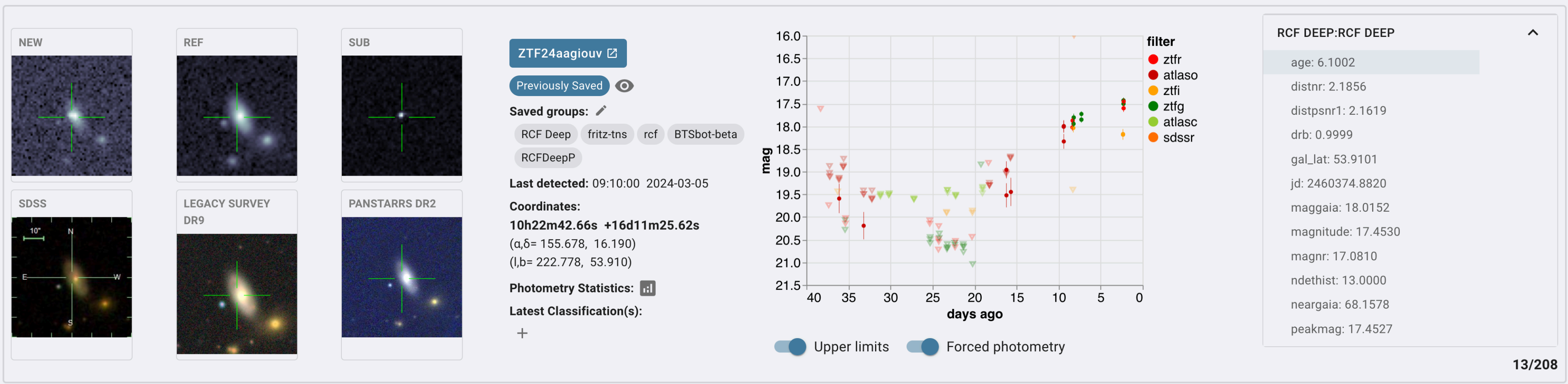
historical reference



“subtraction”

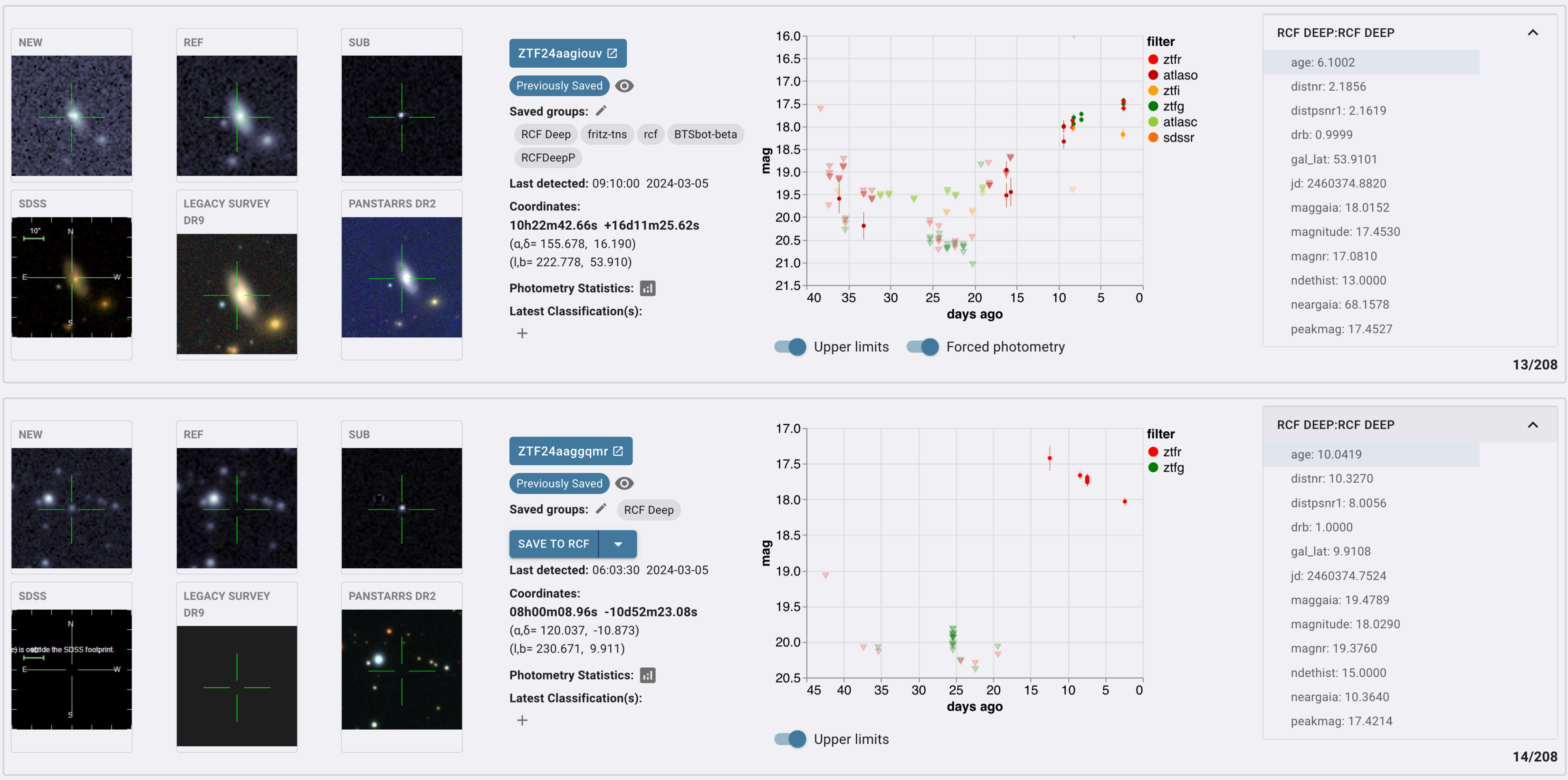
Automating Discovery

ZTF Bright Transient Survey



Automating Discovery

ZTF Bright Transient Survey



ZTF24aagiouv

Previously Saved

Saved groups: RCF Deep fritz-tns rcf BTSbot-beta RCFDeepP

Last detected: 09:10:00 2024-03-05

Coordinates: 10h22m42.66s +16d11m25.62s (α,δ= 155.678, 16.190) (l,b= 222.778, 53.910)

Photometry Statistics:

Latest Classification(s):

mag

days ago

filter: ztfr, atlaso, ztfi, ztfg, atlasc, sdssr

Upper limits, Forced photometry

RCF DEEP:RCF DEEP

age: 6.1002

distnr: 2.1856

distpsnr1: 2.1619

drb: 0.9999

gal_lat: 53.9101

jd: 2460374.8820

maggai: 18.0152

magnitude: 17.4530

magnr: 17.0810

ndethist: 13.0000

neargaia: 68.1578

peakmag: 17.4527

13/208

NEW

SDSS

REF

SUB

LEGACY SURVEY DR9

PANSTARRS DR2

ZTF24aaggqmr

Previously Saved

Saved groups: RCF Deep

SAVE TO RCF

Last detected: 06:03:30 2024-03-05

Coordinates: 08h00m08.96s -10d52m23.08s (α,δ= 120.037, -10.873) (l,b= 230.671, 9.911)

Photometry Statistics:

Latest Classification(s):

mag

days ago

filter: ztfr, ztfg

Upper limits

RCF DEEP:RCF DEEP

age: 10.0419

distnr: 10.3270

distpsnr1: 8.0056

drb: 1.0000

gal_lat: 9.9108

jd: 2460374.7524

maggai: 19.4789

magnitude: 18.0290

magnr: 19.3760

ndethist: 15.0000

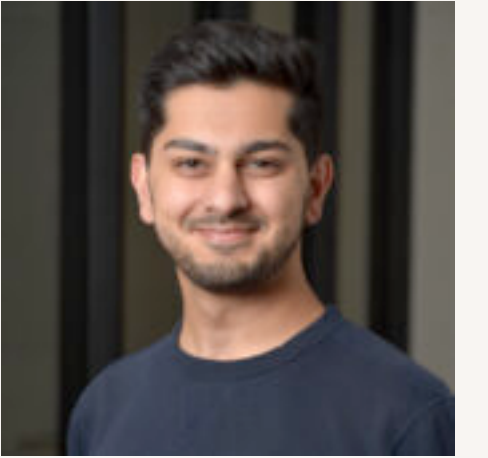
neargaia: 10.3640

peakmag: 17.4214

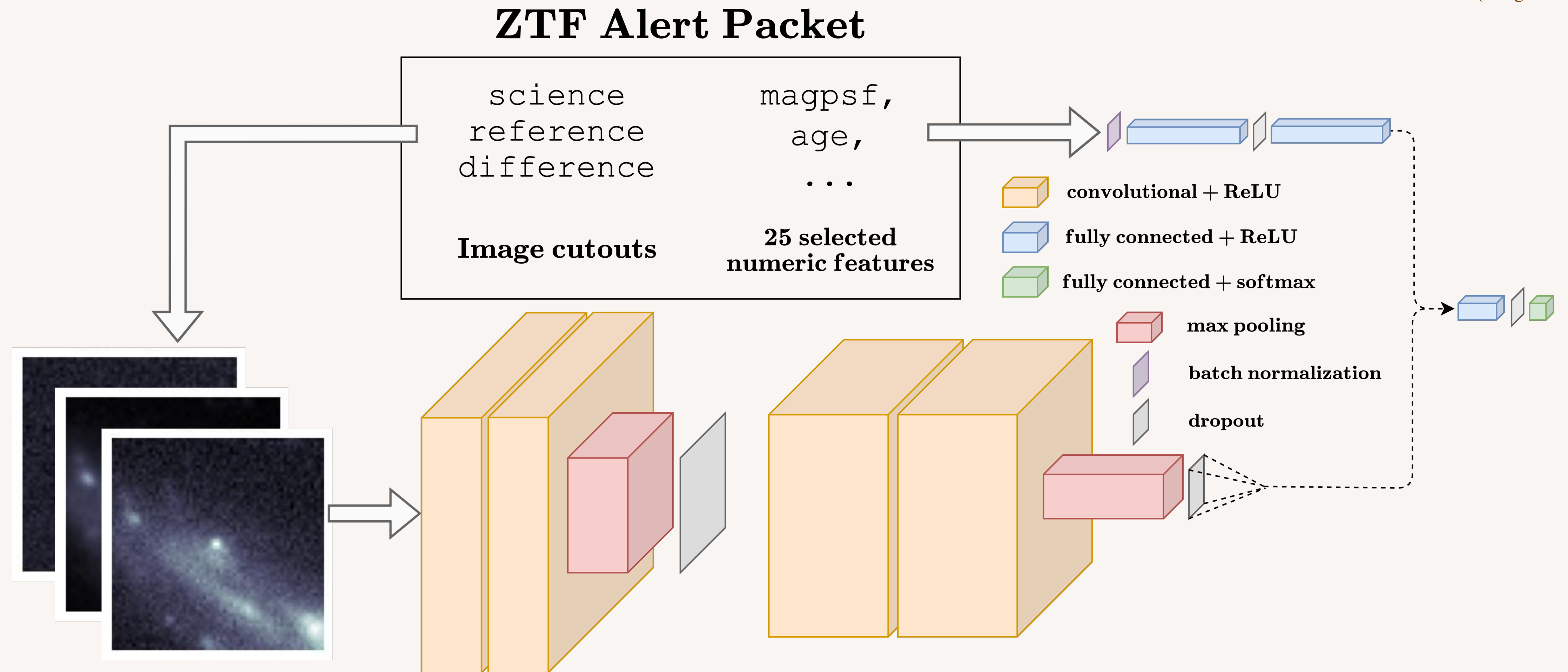
14/208

Automating Discovery

BTSbot — Can ML identify supernovae?



Nabeel Rehemtulla
(NU grad student)



SN 2023tyk

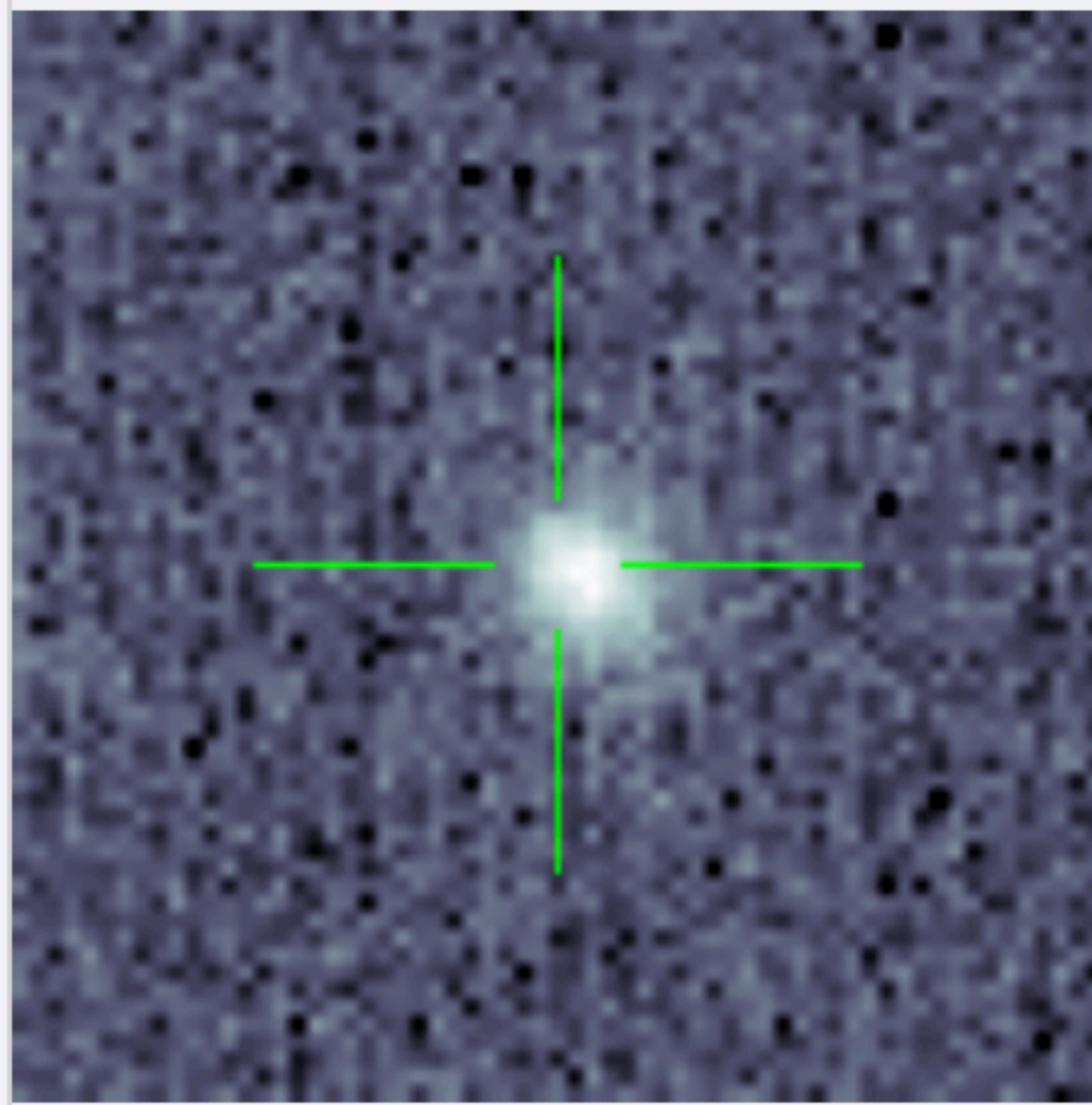
First-ever automated detection, ID, spectrum, classification + public report

☆ ZTF23abhvlji

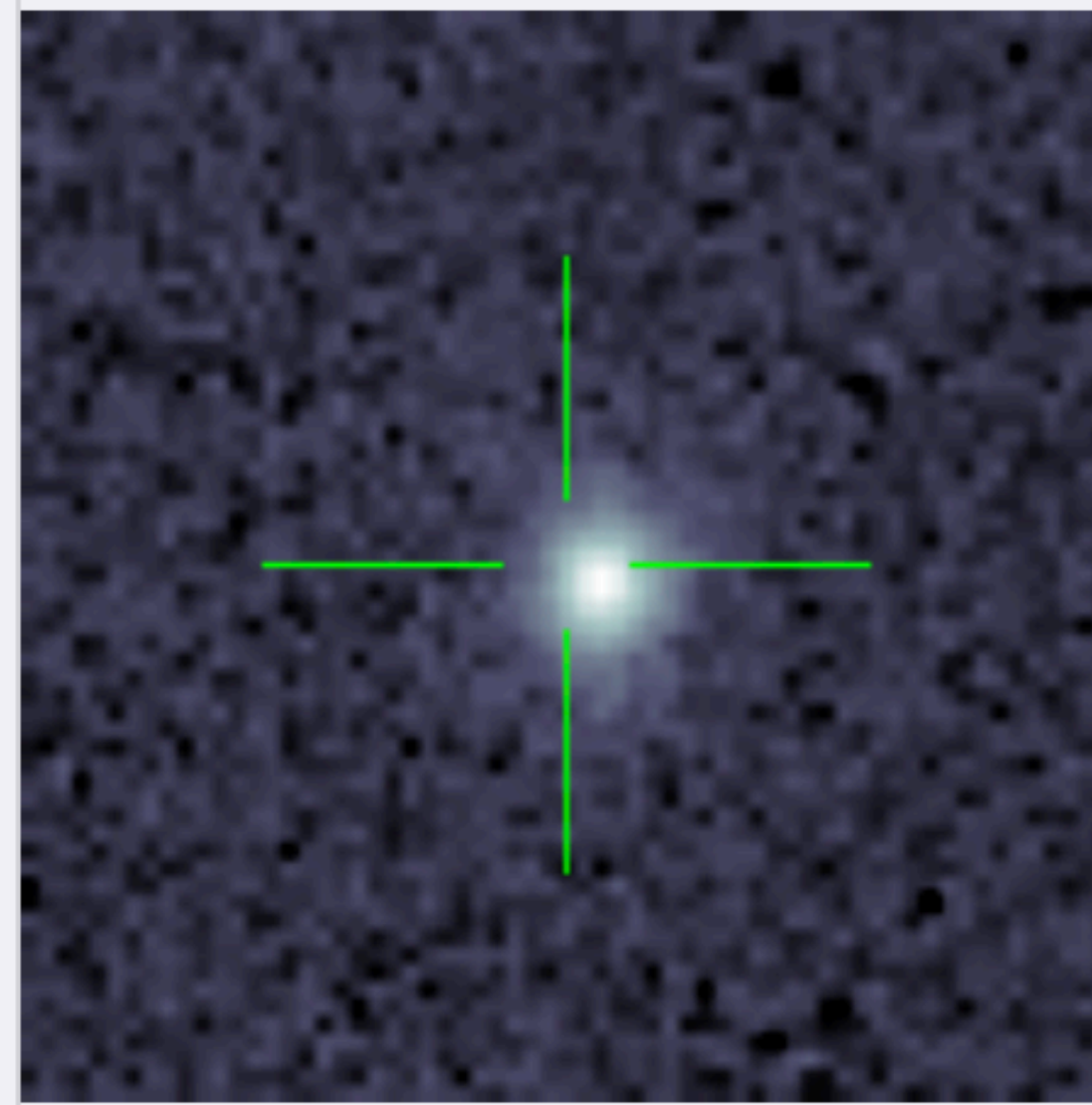
la

Redshift: 0.0562 ± 0.0001   DM: 37.071 mag D_L : 259.52 Mpc

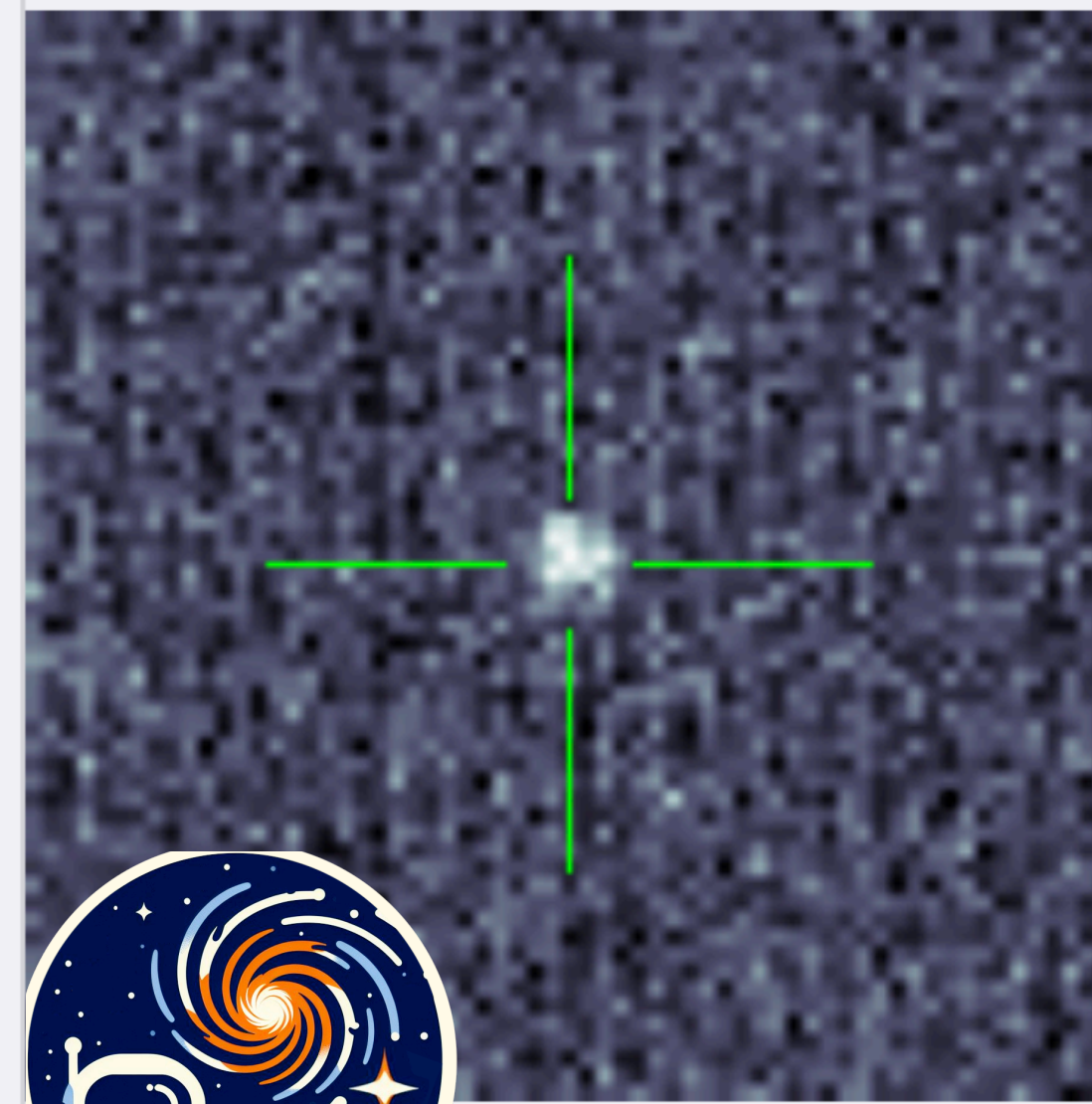
NEW



REF



SUB

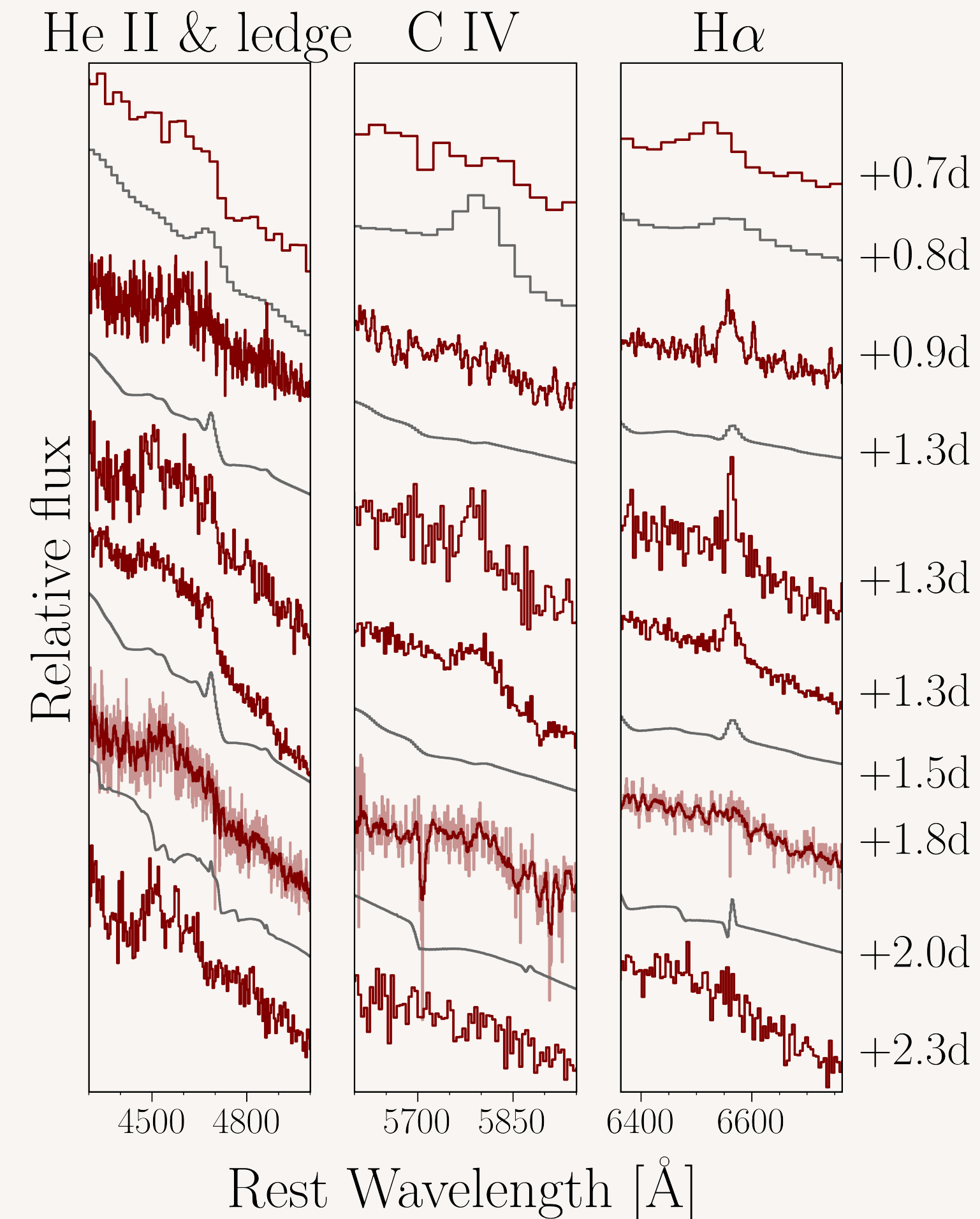
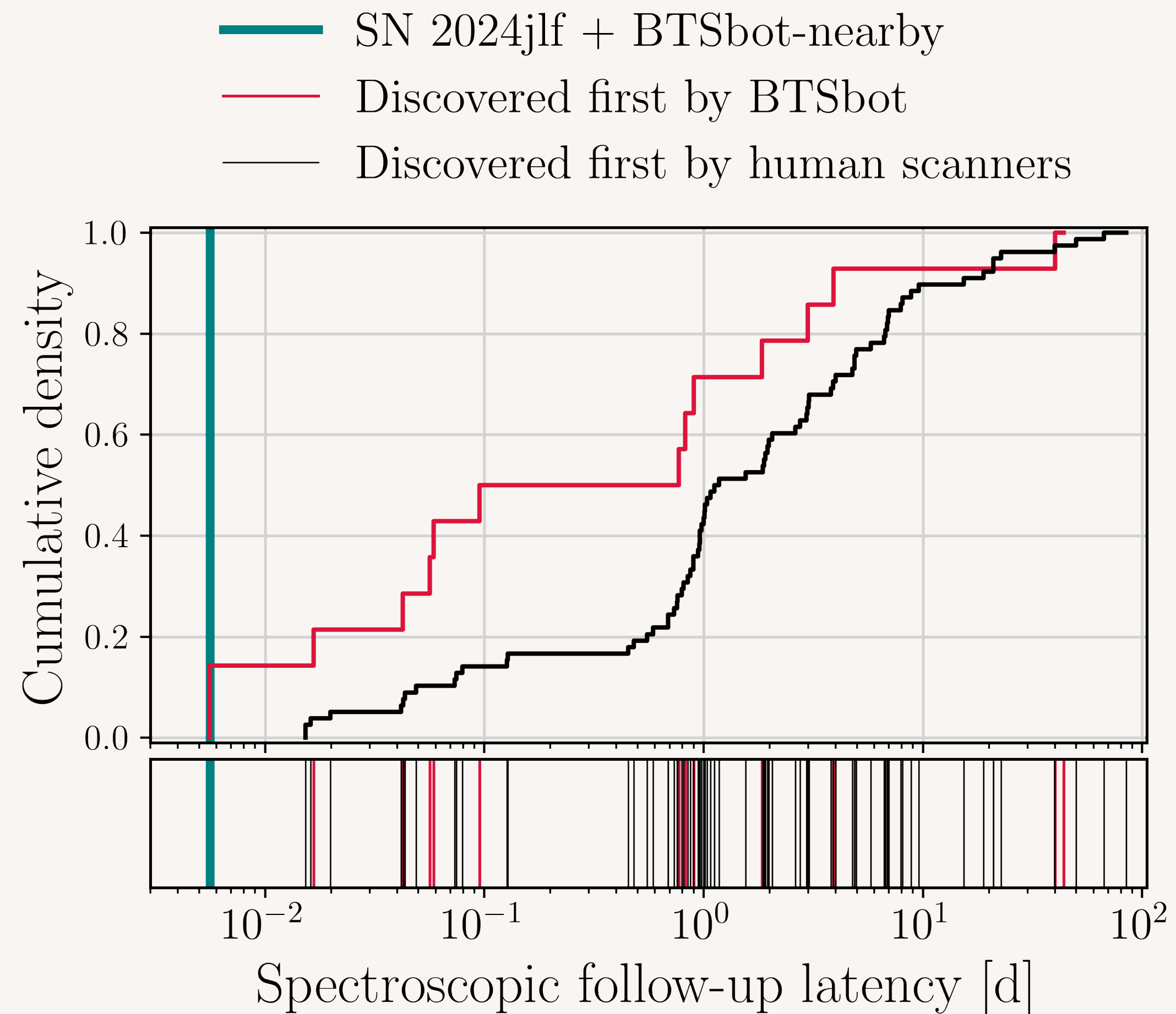


LEGACY SURVEY DR9



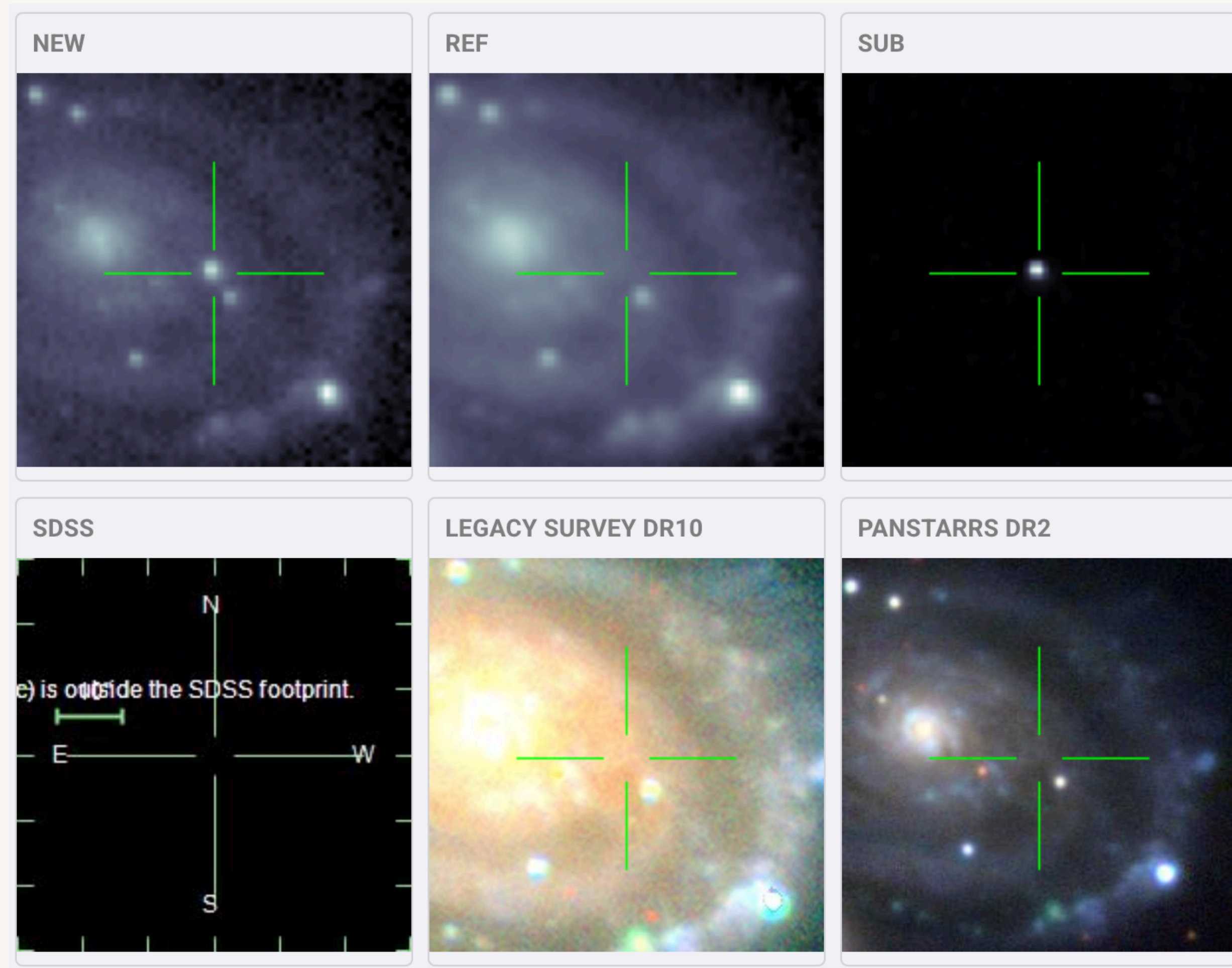
SN 2024jlf

Automation enables *fast* follow-up



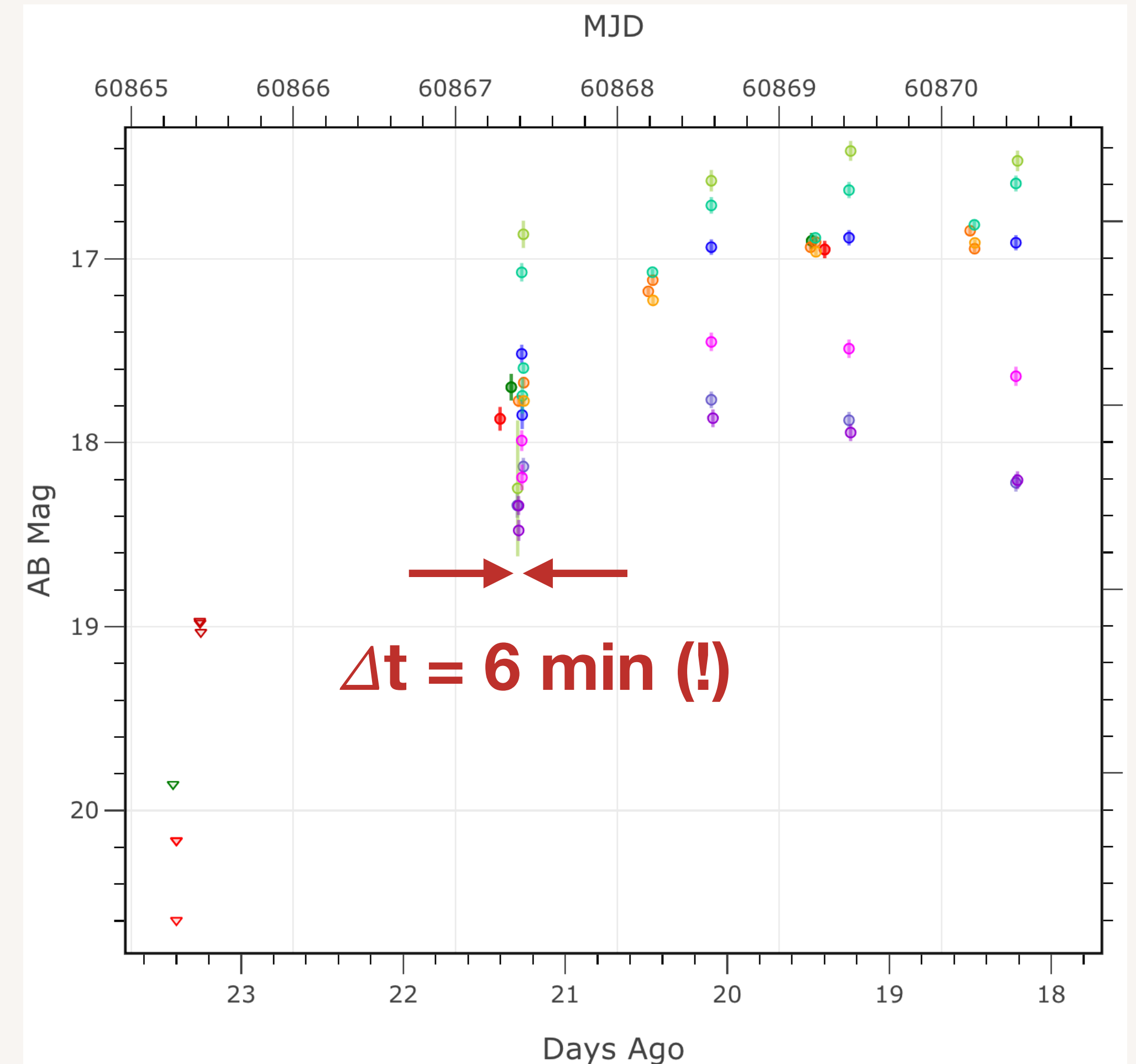
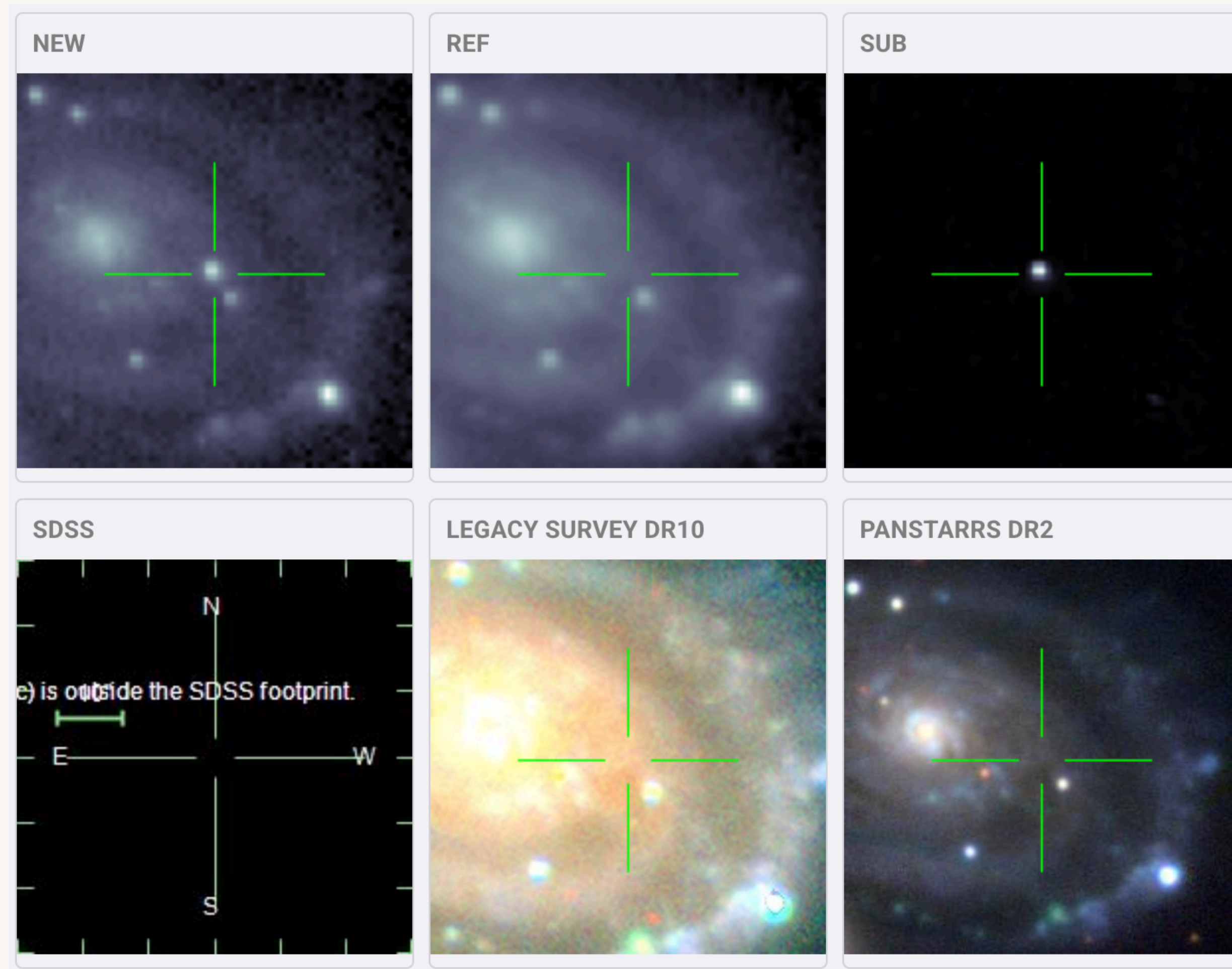
SN 2025qtt

Automation enables *fast* follow-up (from space)



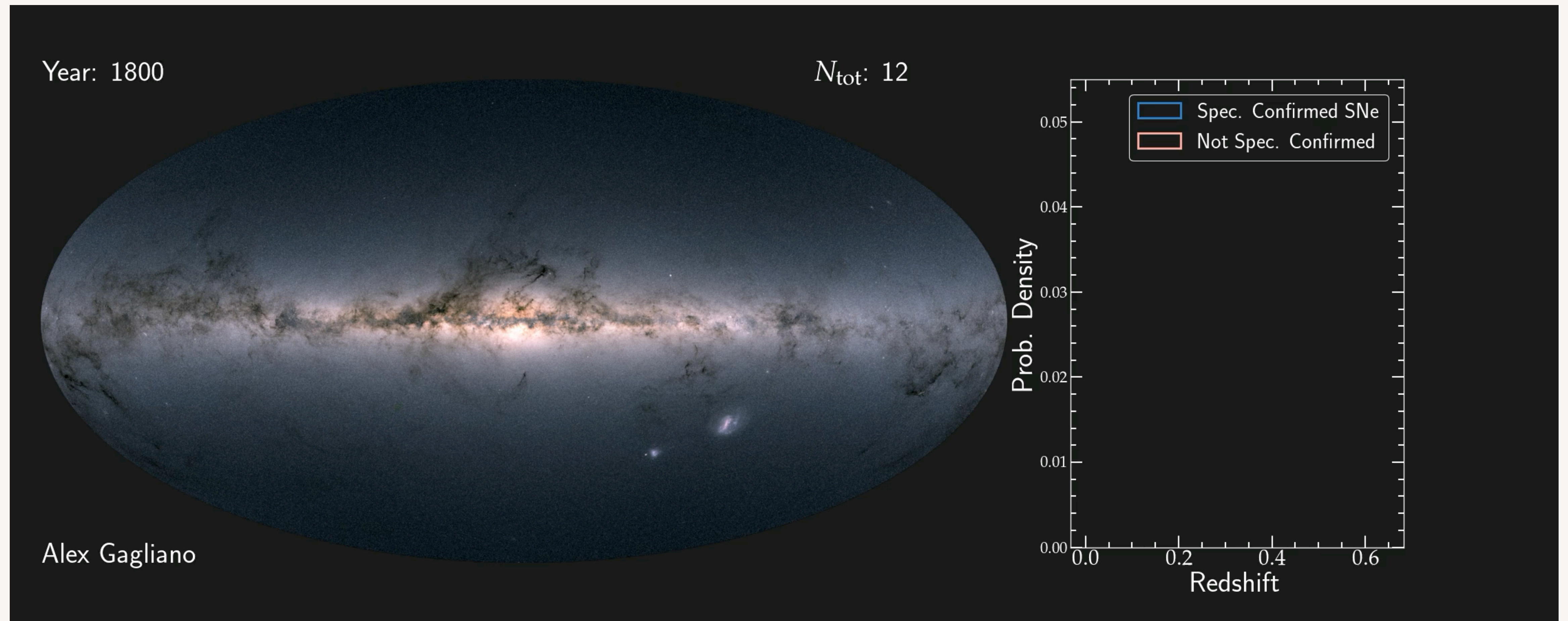
SN 2025qtt

Automation enables *fast* follow-up (from space)



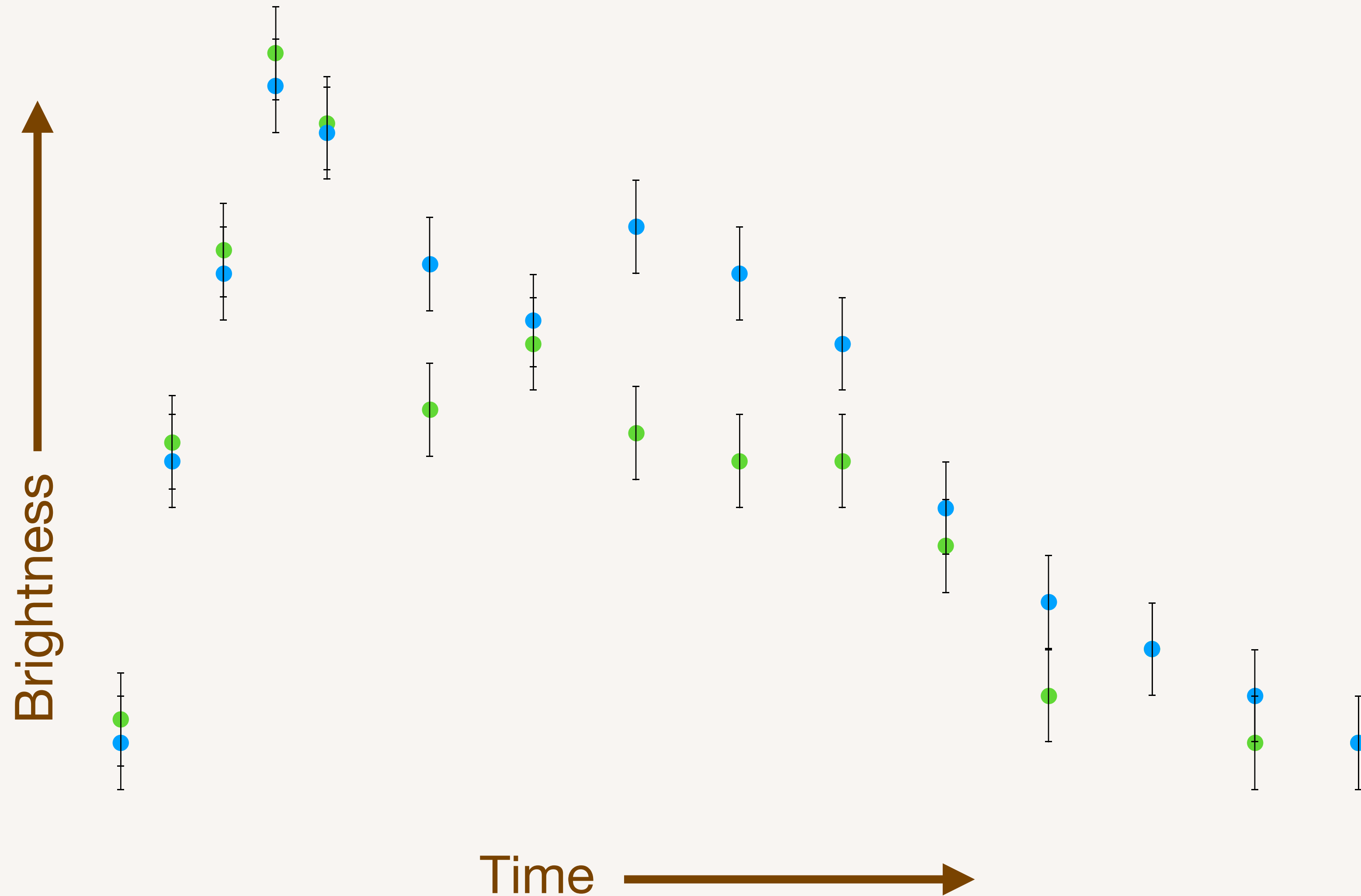
LSST Supernova Deluge

~2000 new discoveries every night



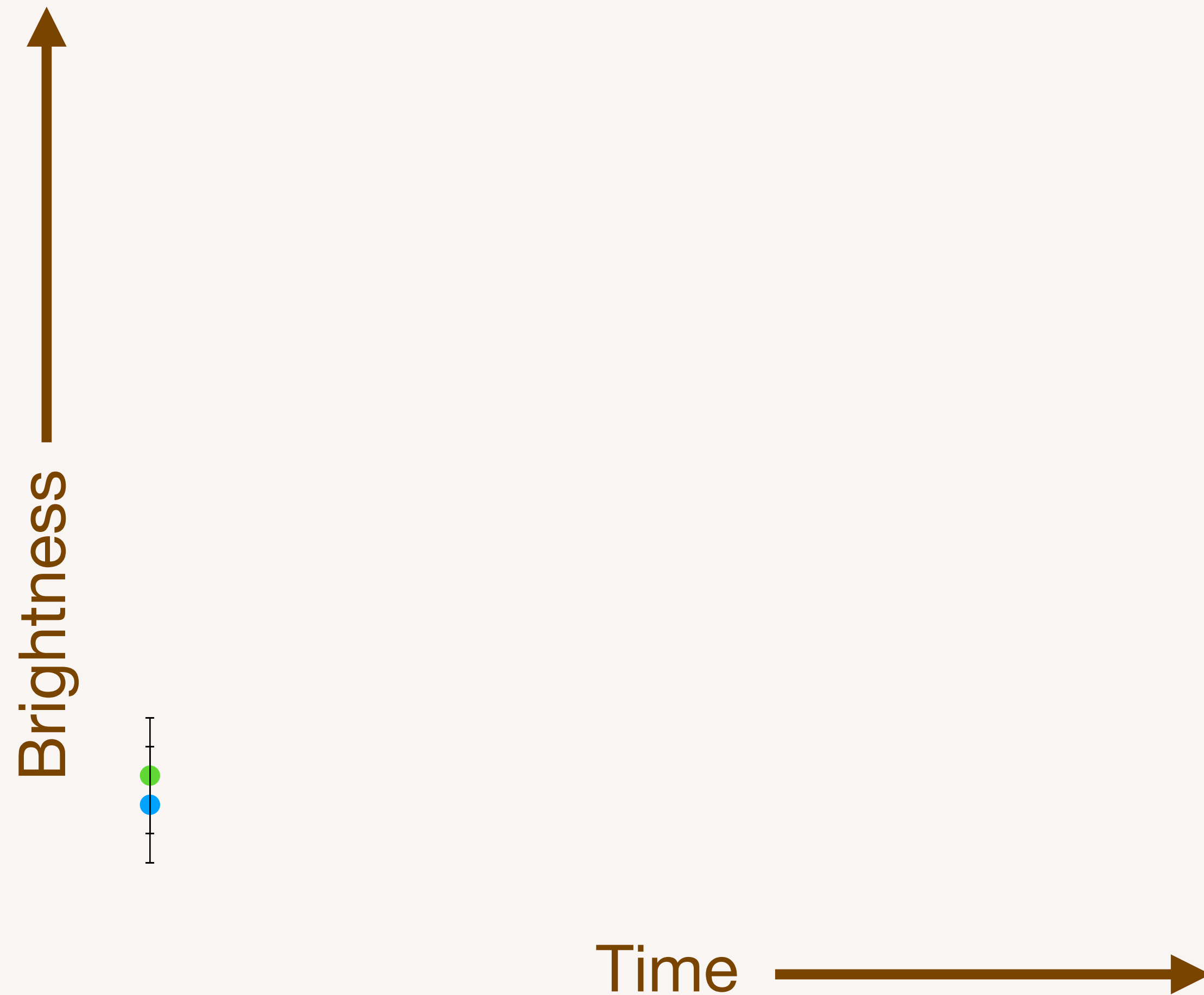
Supernova Time Series

Light curves encode some, but not all information



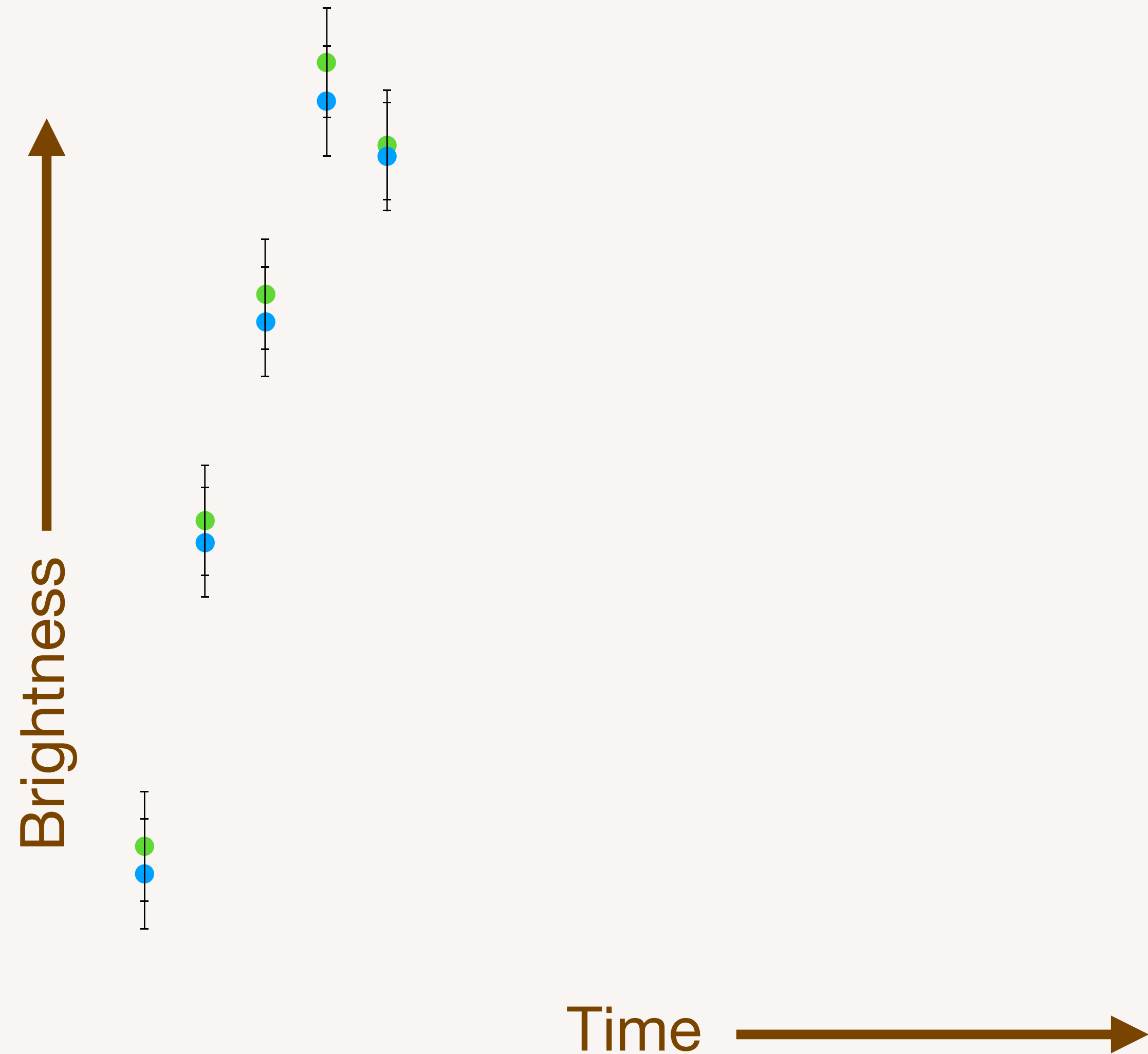
Supernova Time Series

Early classifications are extremely valuable



Supernova Time Series

Early classifications are extremely valuable

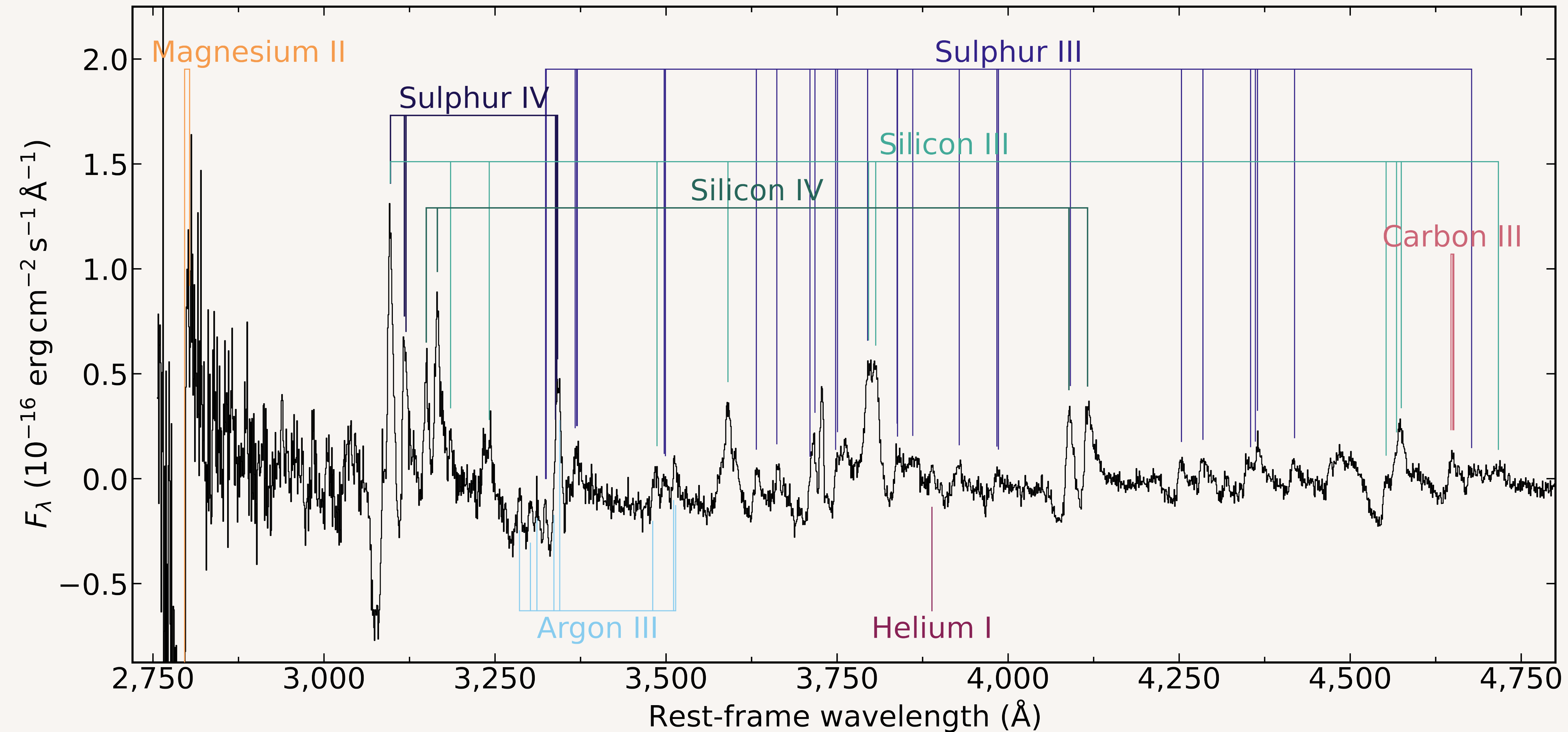


Supernova Discoveries

New/rare sources highlight gaps in our knowledge

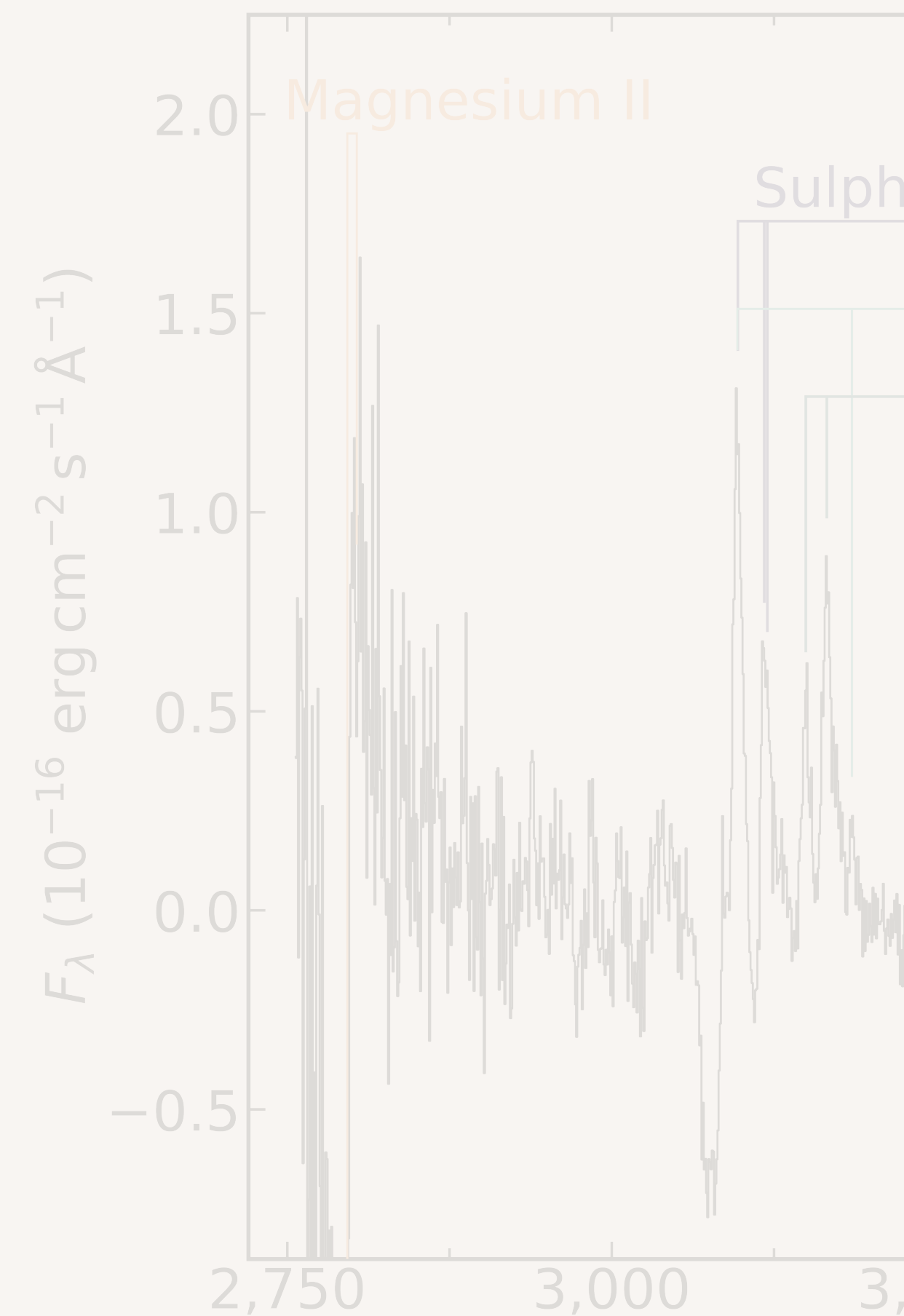


Steve Schulze
(NU research associate)



Supernova

New/rare sources h

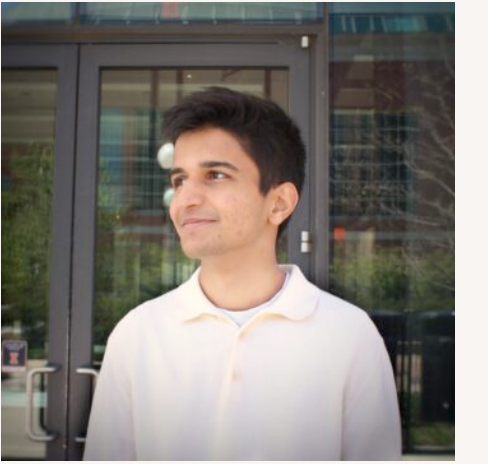


Steve Schulze
(NU research associate)

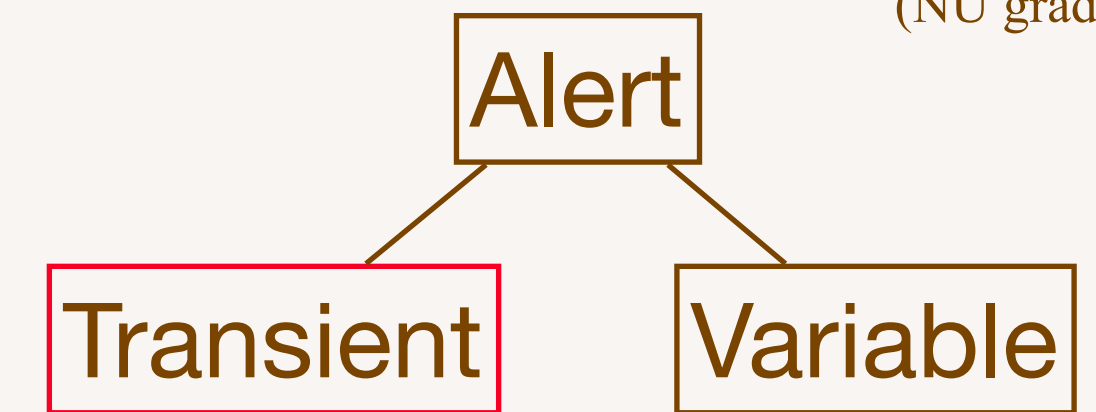
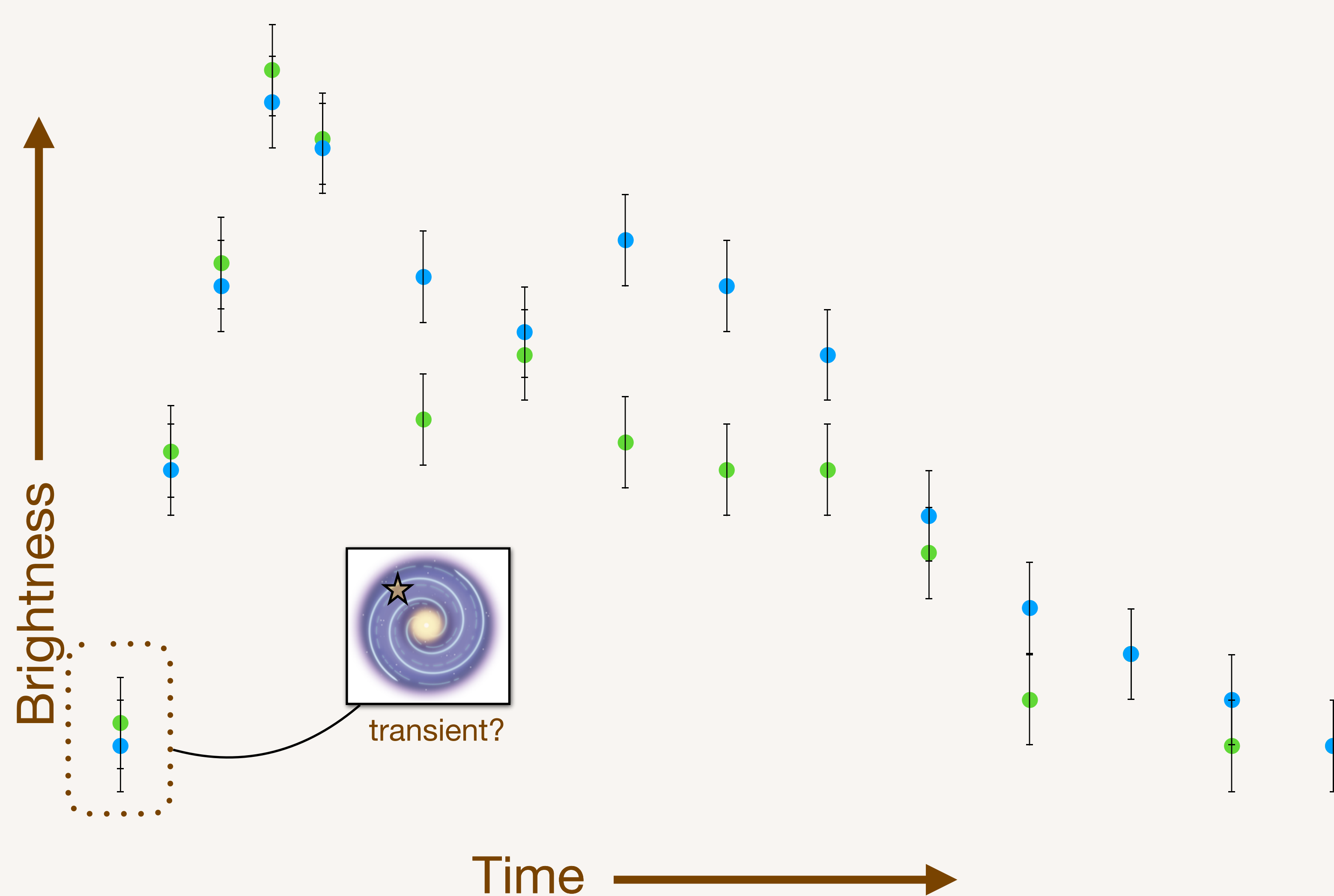


Hierarchical Real-Time Classification

Classification becomes more granular with time

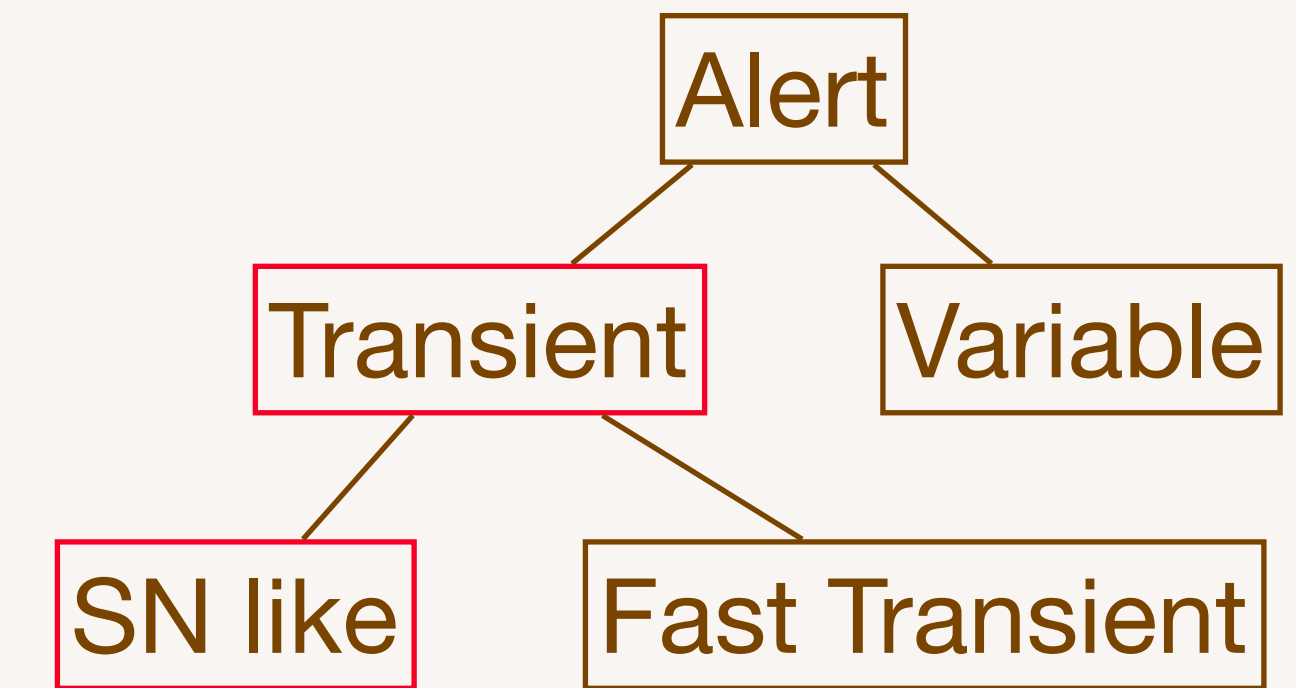
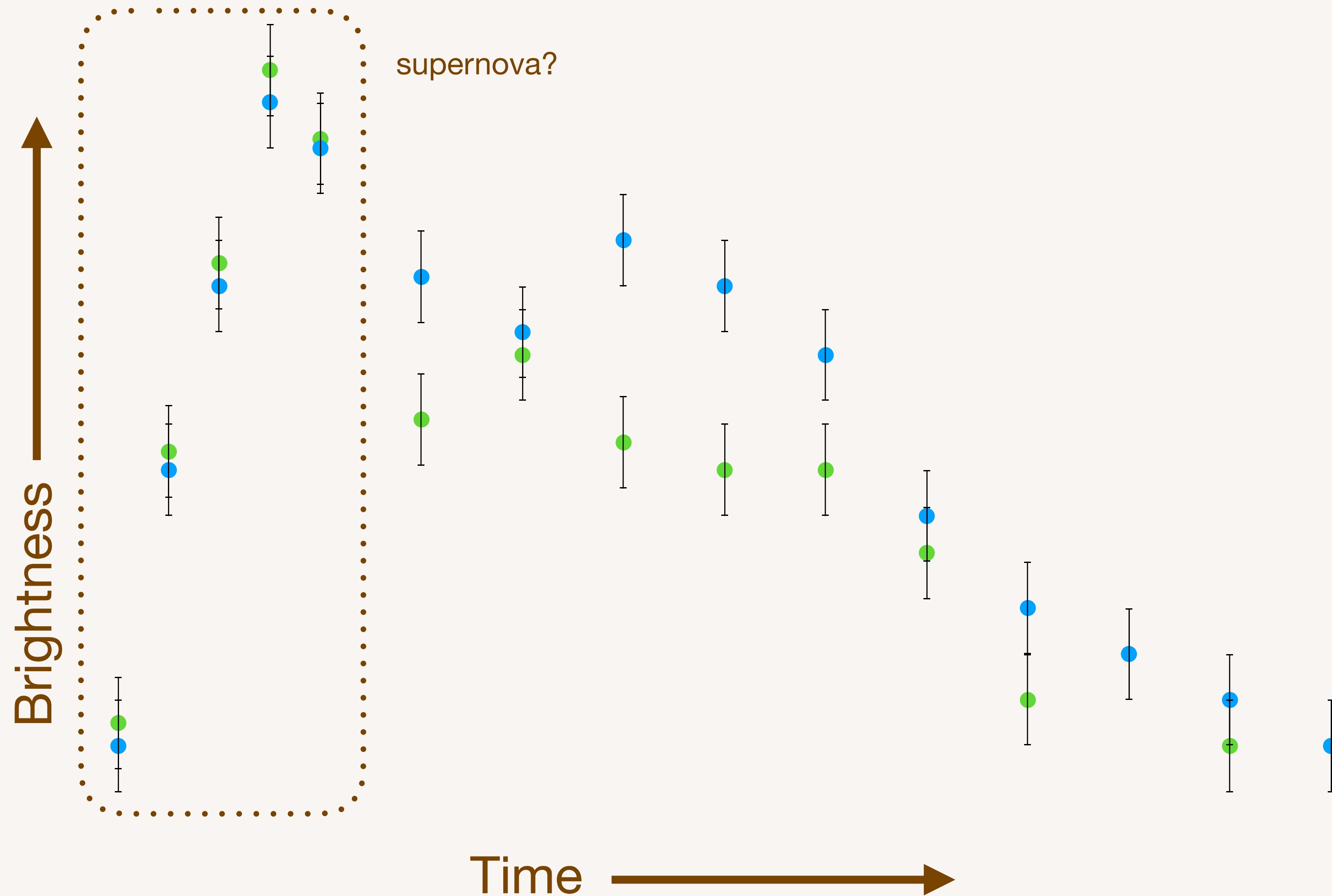


Ved Shah
(NU grad student)



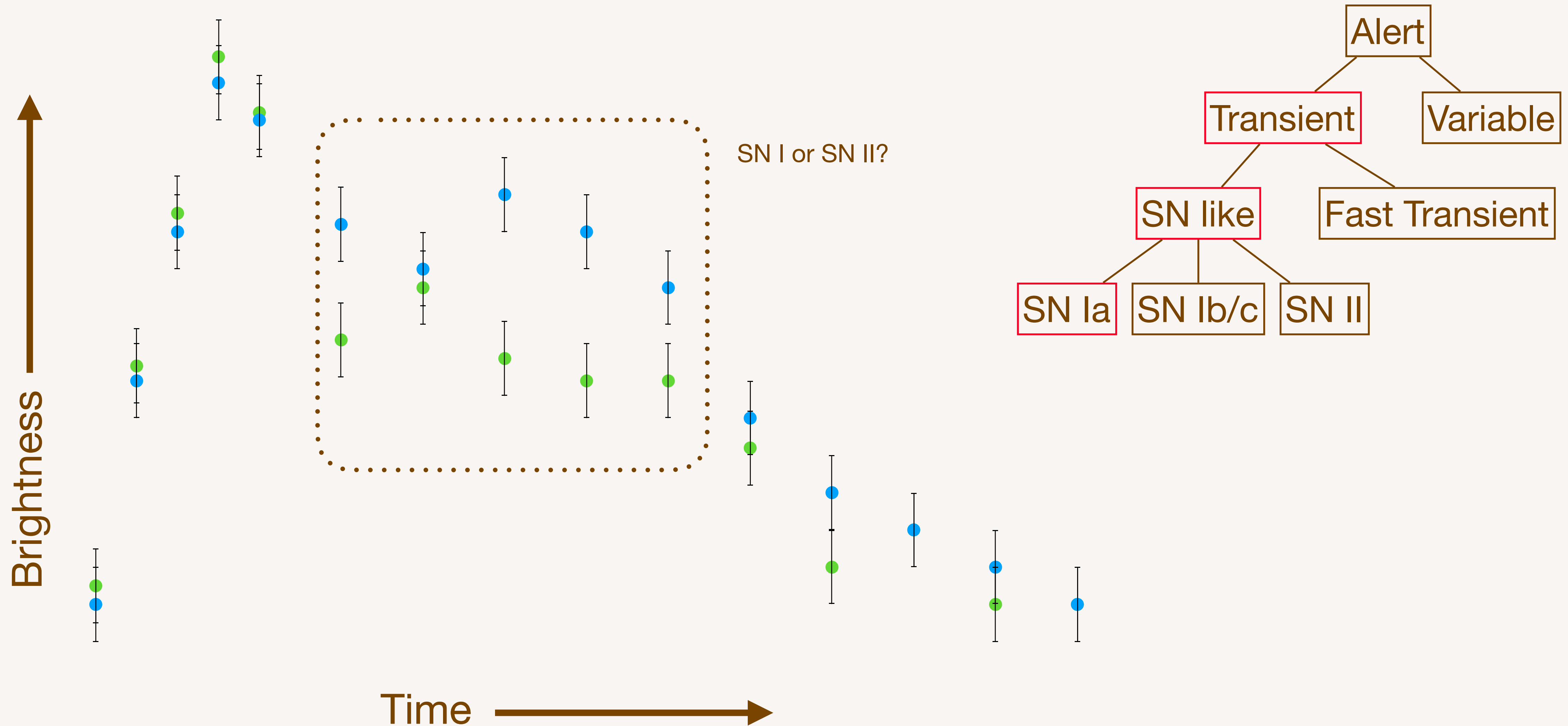
Hierarchical Real-Time Classification

Classification becomes more granular with time



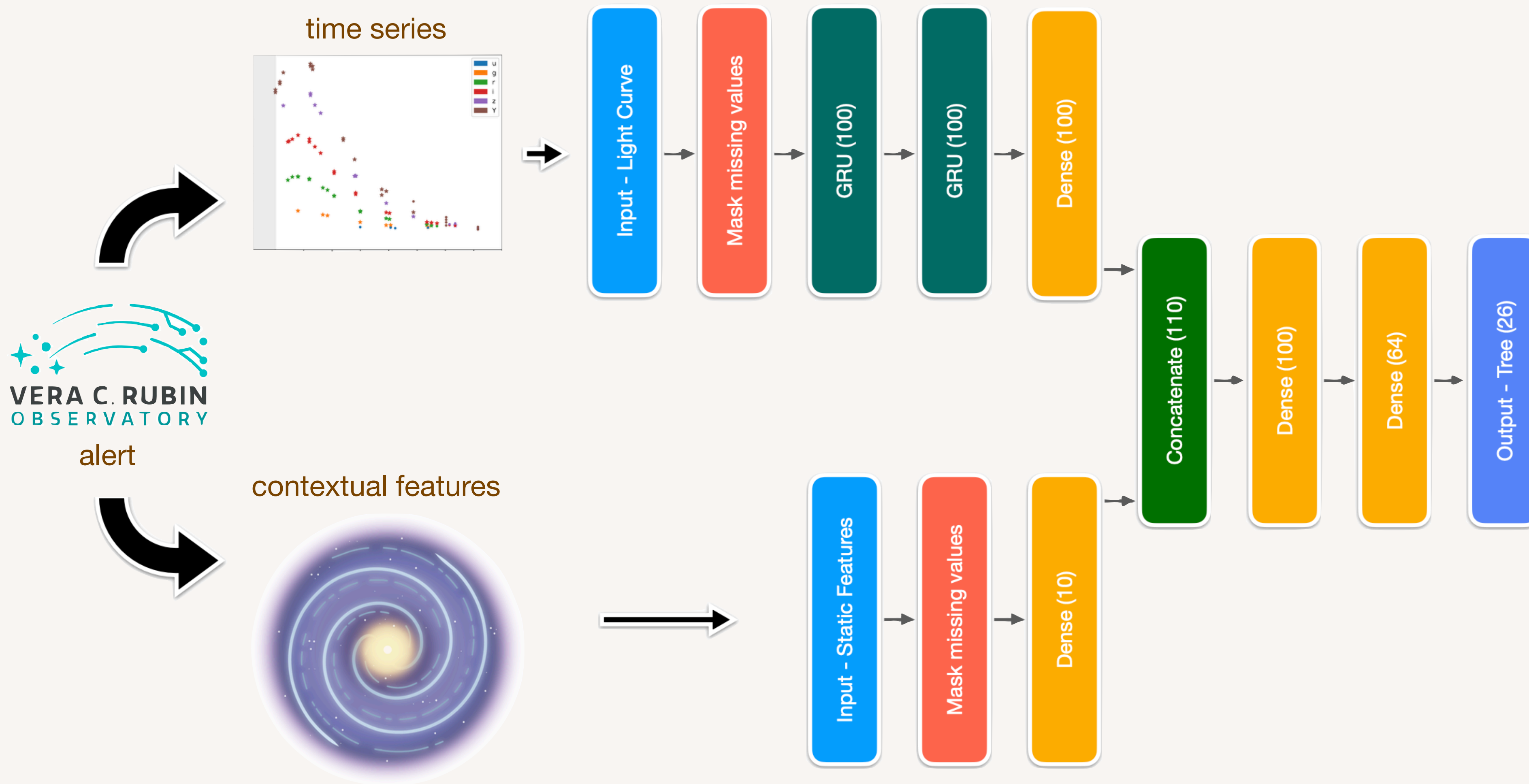
Hierarchical Real-Time Classification

Classification becomes more granular with time



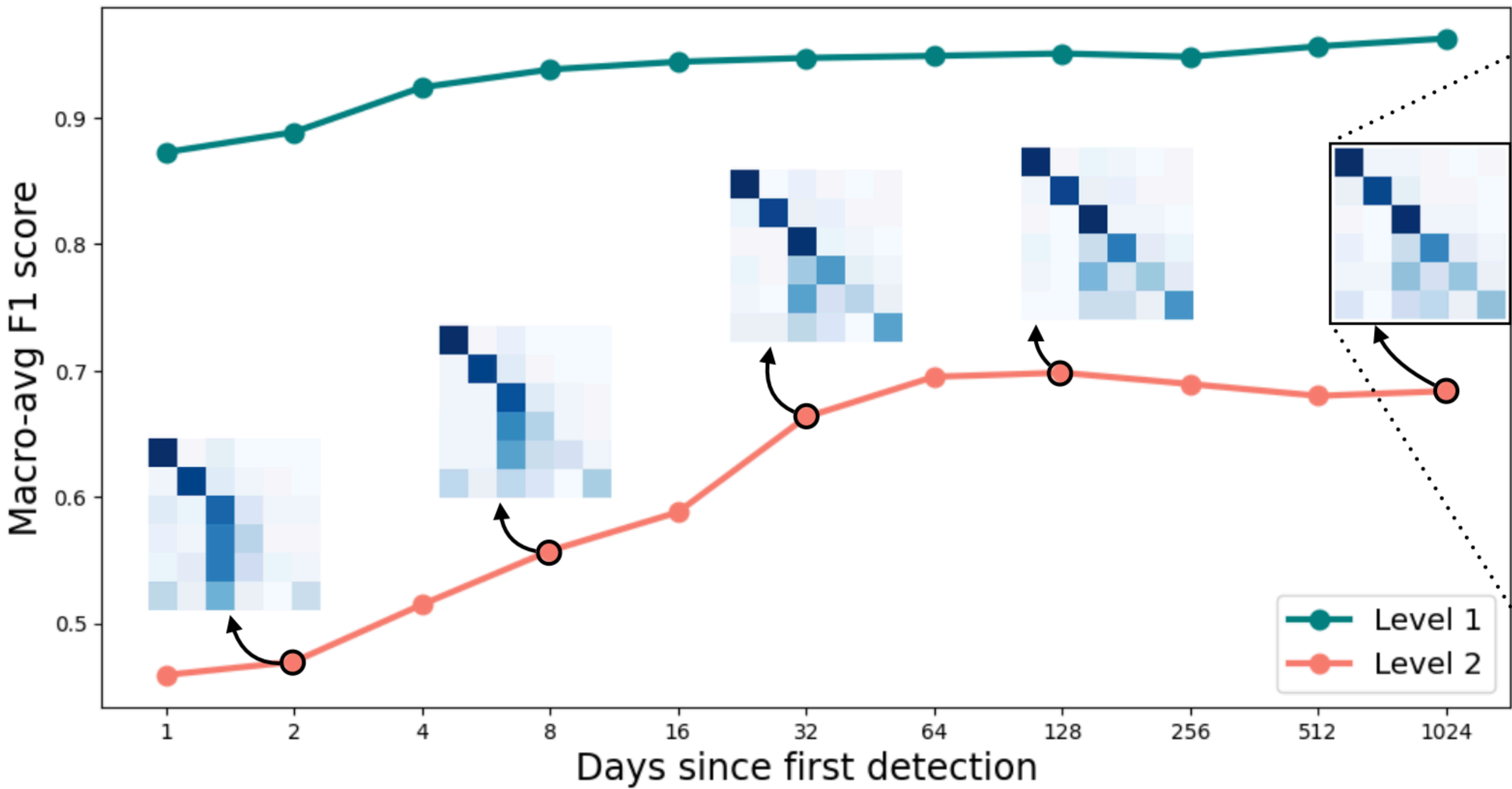
Hierarchical Real-Time Classification

Multimodal using time series and galaxy information



Hierarchical Real-Time Classification

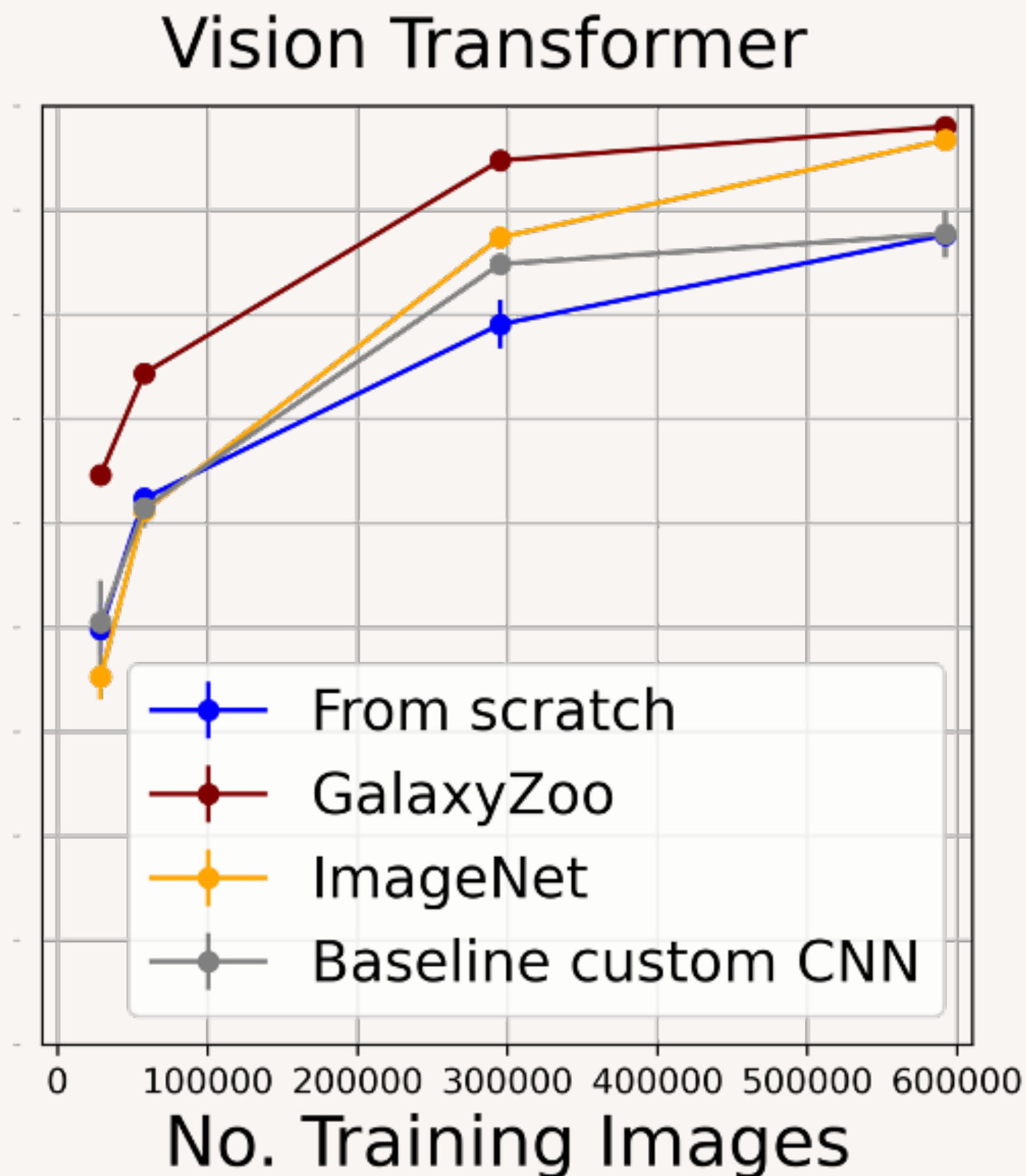
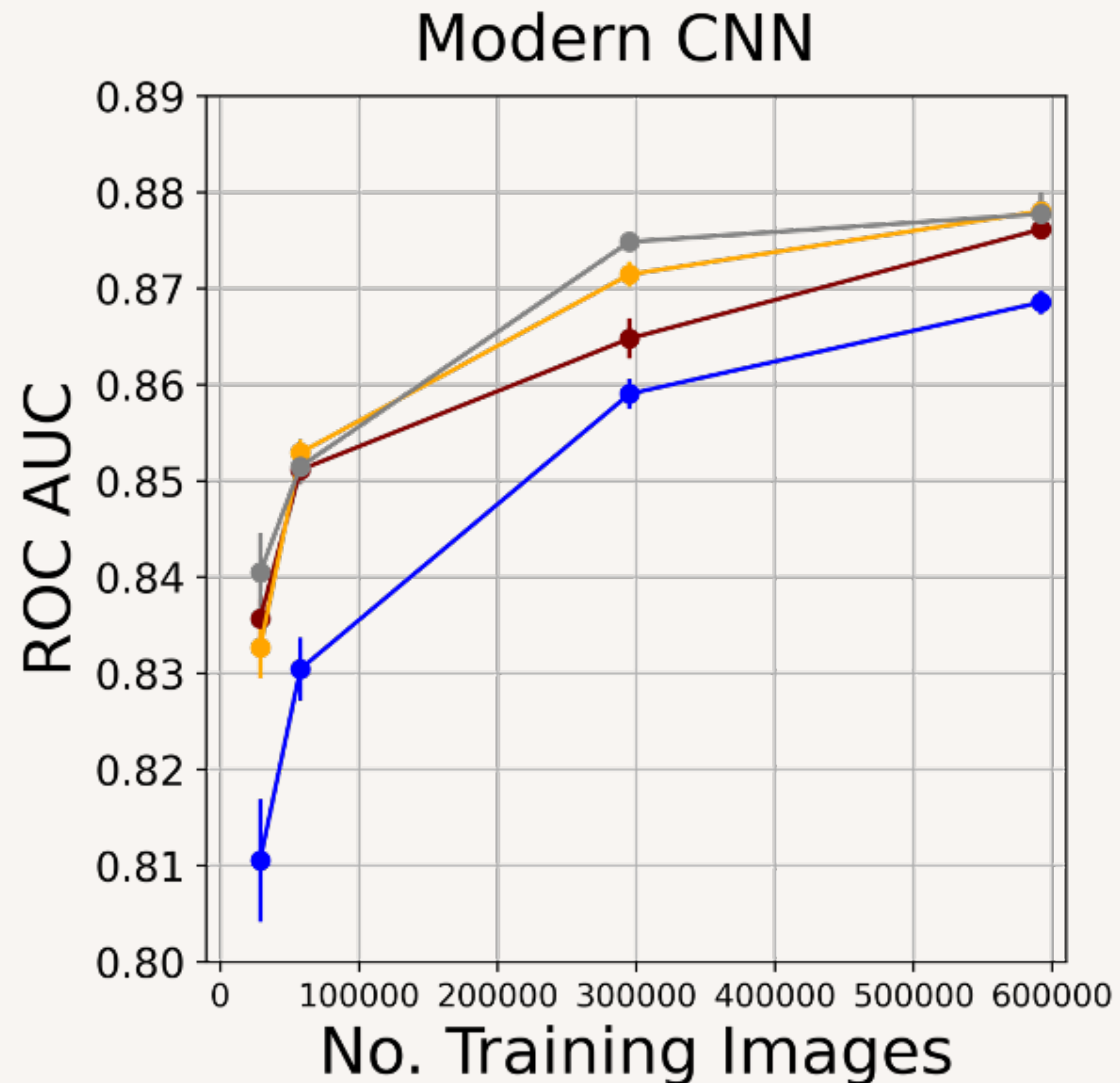
Performance on real observations



Trigger+1024 days							
True Label	AGN	0.94	0.02	0.03	0.01	0	0.01
	CV	0.06	0.85	0.07	0.01	0.01	0
	SN-Ia	0.01	0	0.93	0.02	0.03	0
	SN-II	0.05	0	0.2	0.63	0.09	0.04
	SN-Ib/c	0.02	0.02	0.38	0.16	0.36	0.06
	SLSN	0.12	0	0.19	0.25	0.06	0.38
		AGN	CV	SN-Ia	SN-II	SN-Ib/c	SLSN
Predicted Label							

Vision Transformers For Multimodality

Can we improve BTSbot?



Can Foundational AI Classify Variables?

StarEmbed



Han Liu



Qinjie Lin



Adam Miller



Ved Shah



Hong-Yu Chen



Weijian Li



Nabeel Rehemtulla



Padma Venkatraman



StarEmbed

Representing light curves with time series foundation models

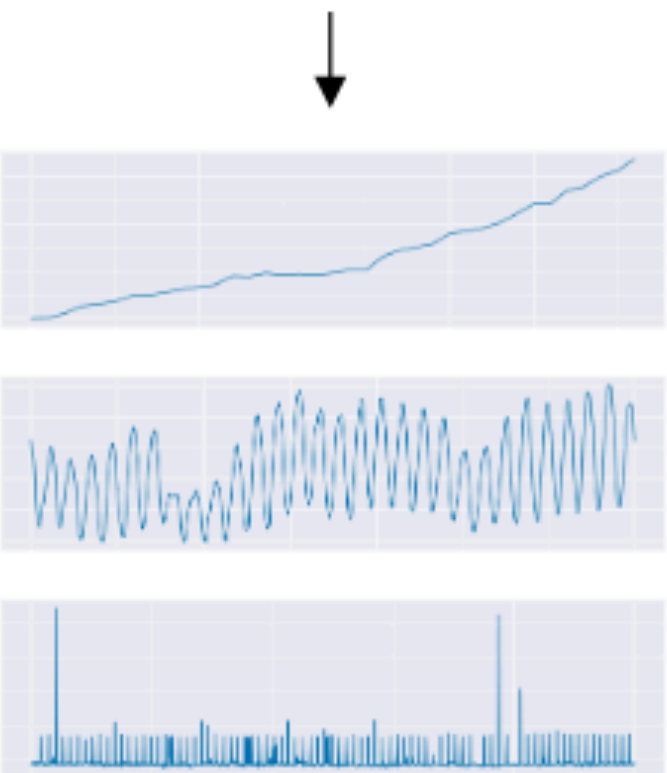
Unified Training of Universal Time Series Forecasting Transformers

Gerald Woo^{1,2} Chenghao Liu¹ Akshat Kumar² Caiming Xiong¹ Silvio Savarese¹ Doyen Sahoo¹

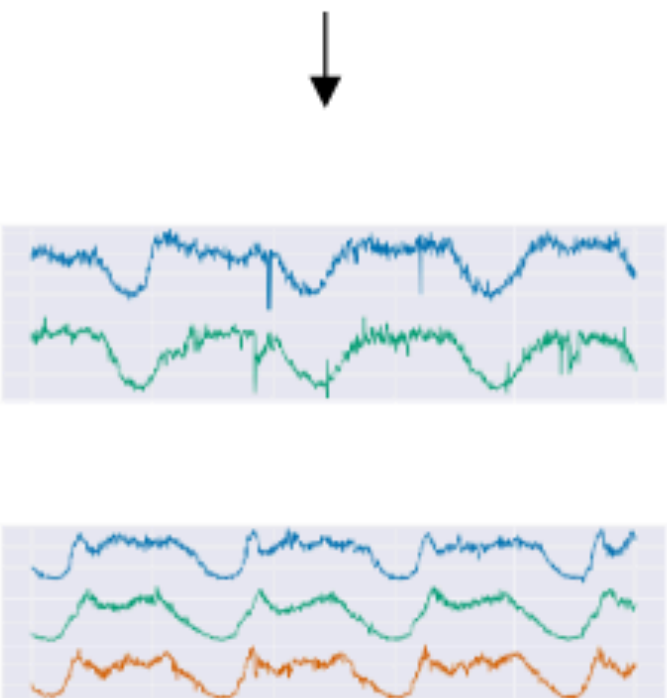
Multiple Domains



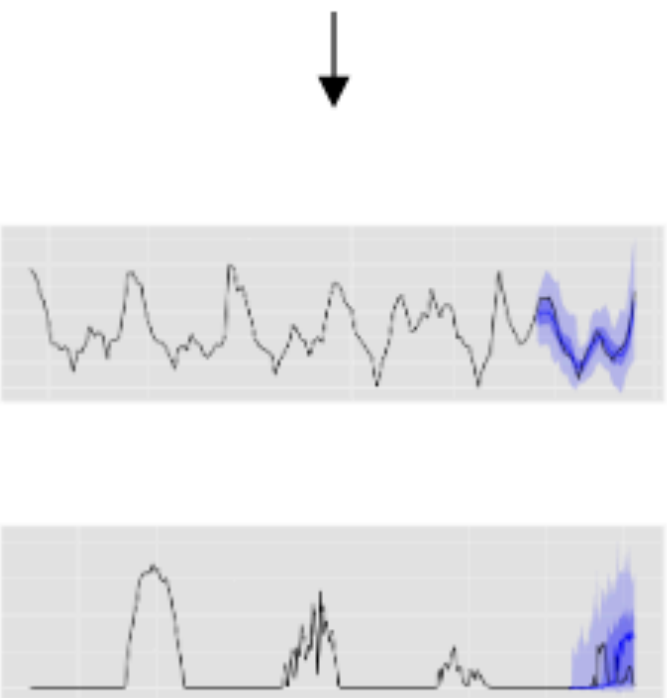
Universal Forecaster



1) Multiple Frequencies



2) Any-variate Forecasting



3) Varying Distributions

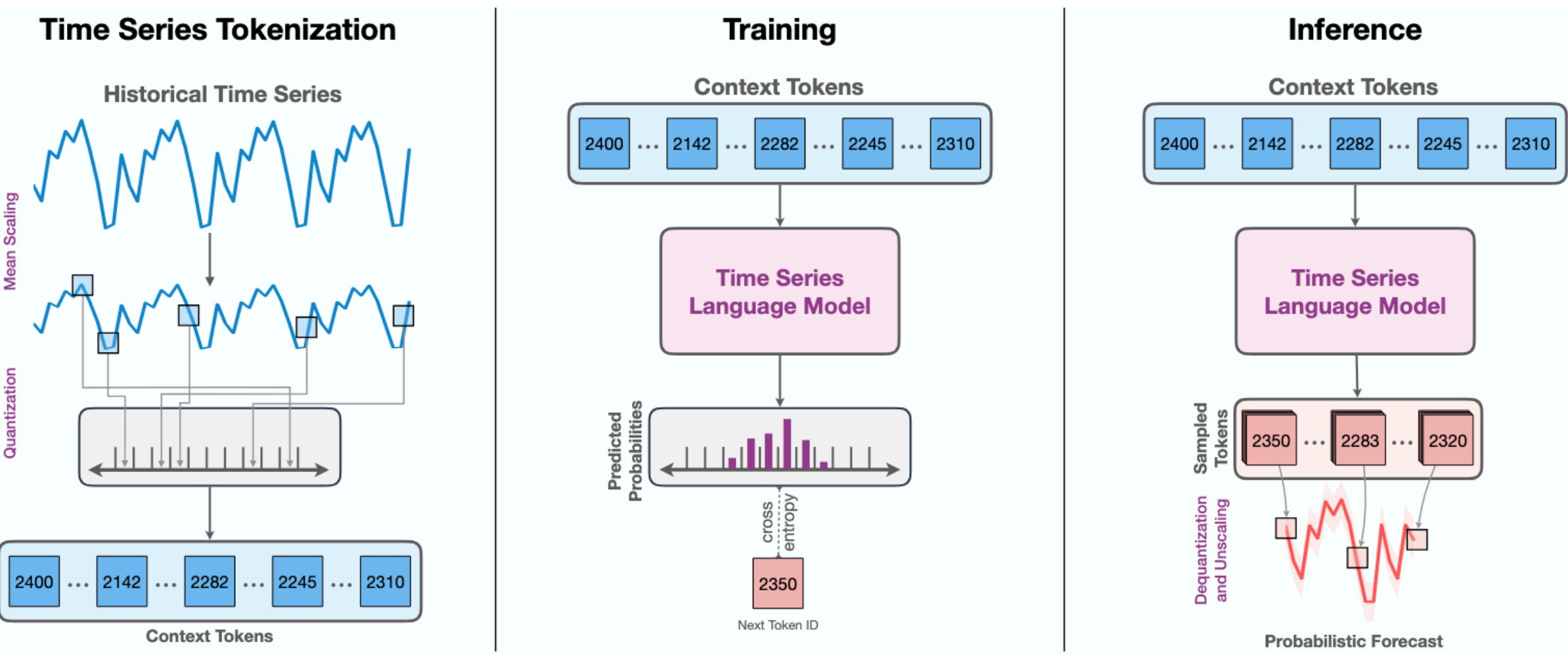
Chronos: Learning the Language of Time Series

Abdul Fatir Ansari^{1*}, Lorenzo Stella^{1*}, Caner Turkmen¹, Xiyuan Zhang^{3†}, Pedro Mercado¹, Huibin Shen¹, Oleksandr Shchur¹, Syama Sundar Rangapuram¹, Sebastian Pineda Arango^{4†}, Shubham Kapoor¹, Jasper Zschiegner[†], Danielle C. Maddix¹, Hao Wang^{1,5†}, Michael W. Mahoney^{2,6†}, Kari Torkkola², Andrew Gordon Wilson^{2,7†}, Michael Bohlke-Schneider¹, Yuyang Wang¹
{ansarnd, stellalo}@amazon.com

¹AWS AI Labs, ²Amazon Supply Chain Optimization Technologies, ³UC San Diego, ⁴University of Freiburg, ⁵Rutgers University, ⁶UC Berkeley, ⁷New York University

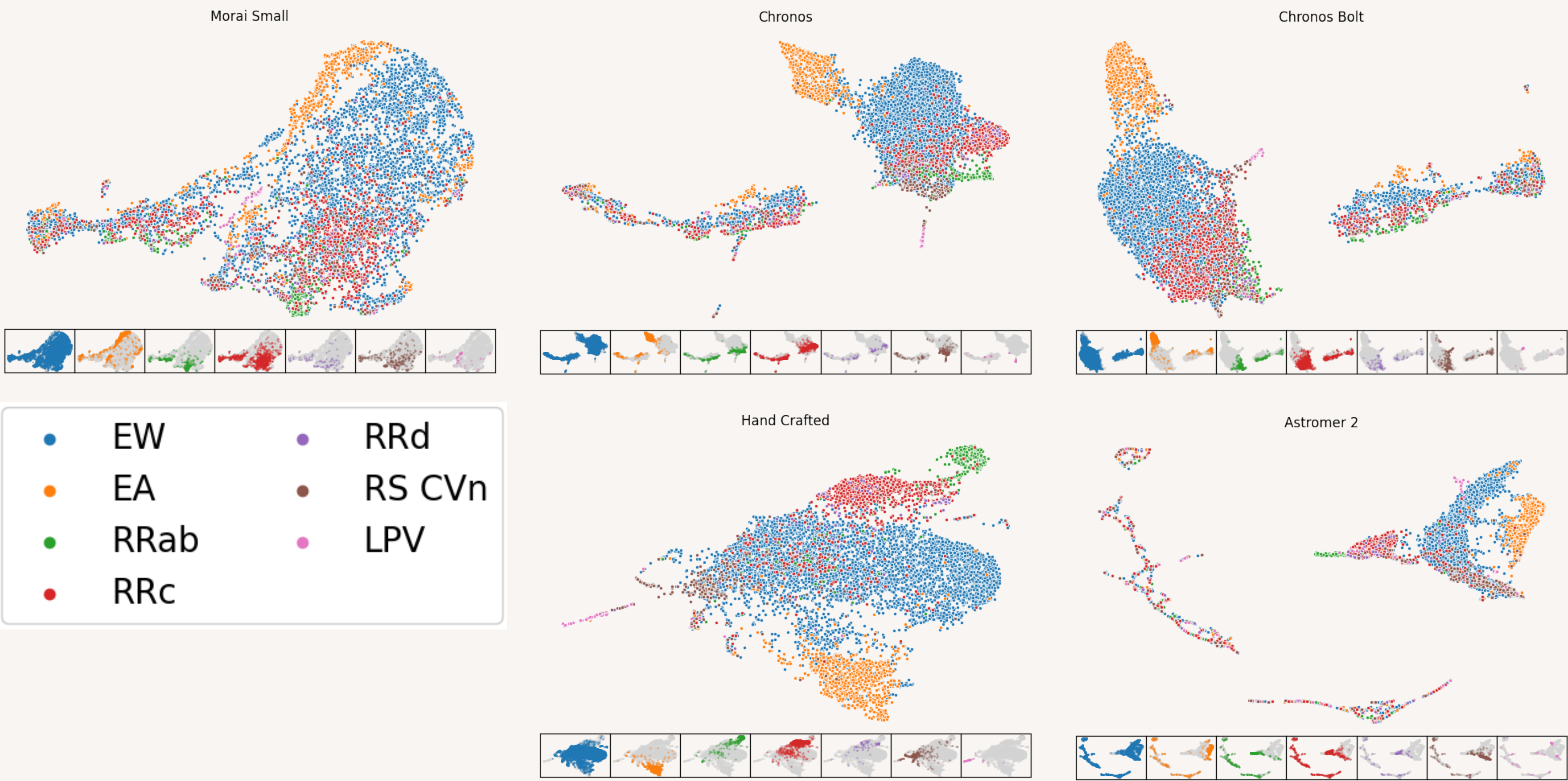
Reviewed on OpenReview: <https://openreview.net/forum?id=gerNCVqqtR>

Code and Pretrained Models: <https://github.com/amazon-science/chronos-forecasting>



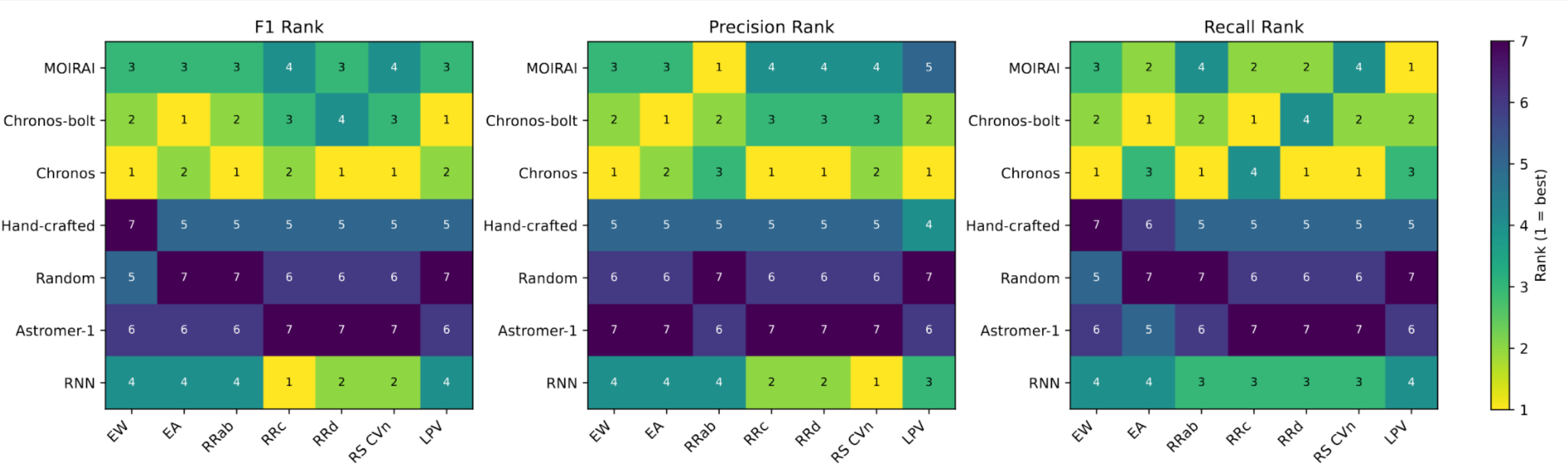
StarEmbed

Representing light curves with time series foundation models

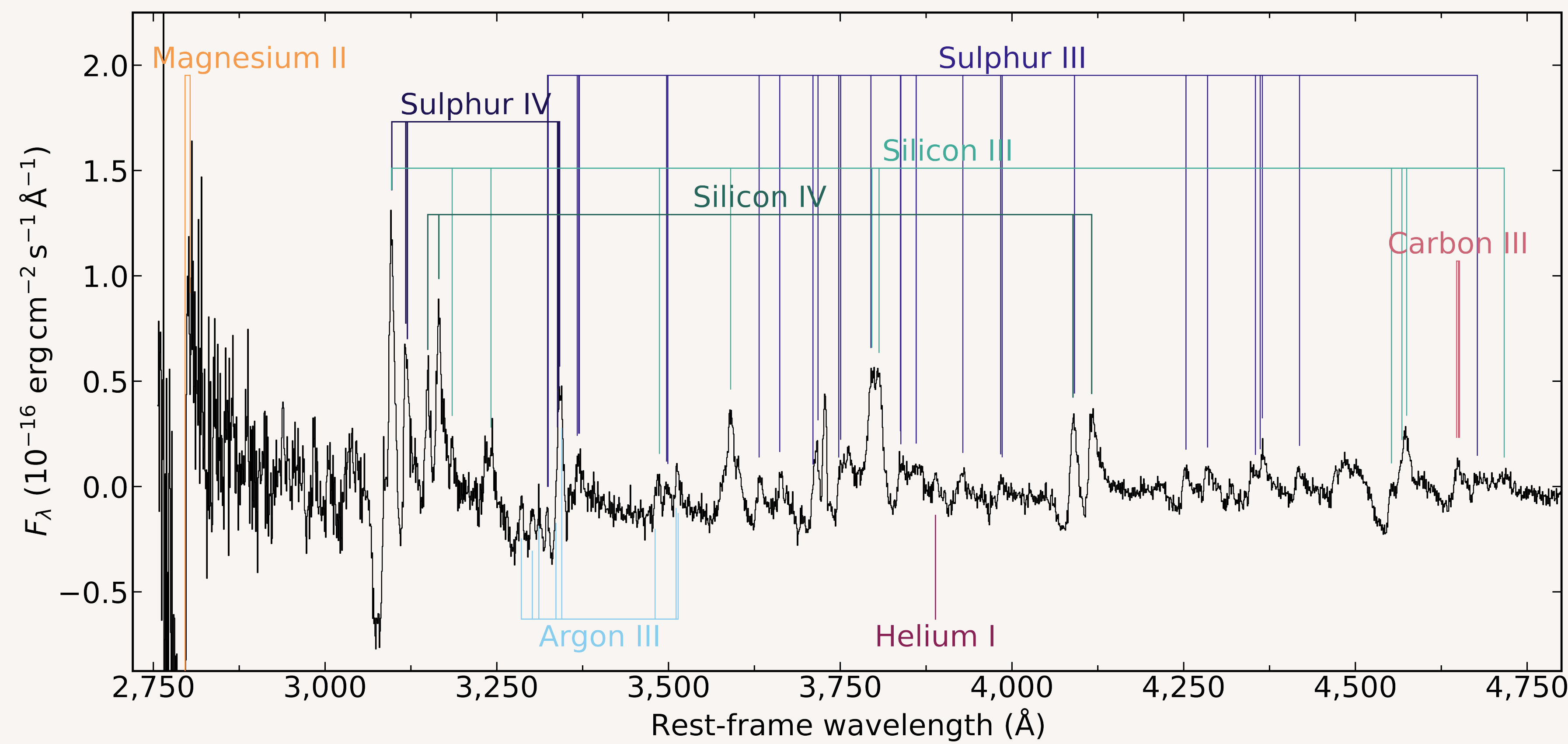


StarEmbed

Classification performance



Conclusions



Universe is very big

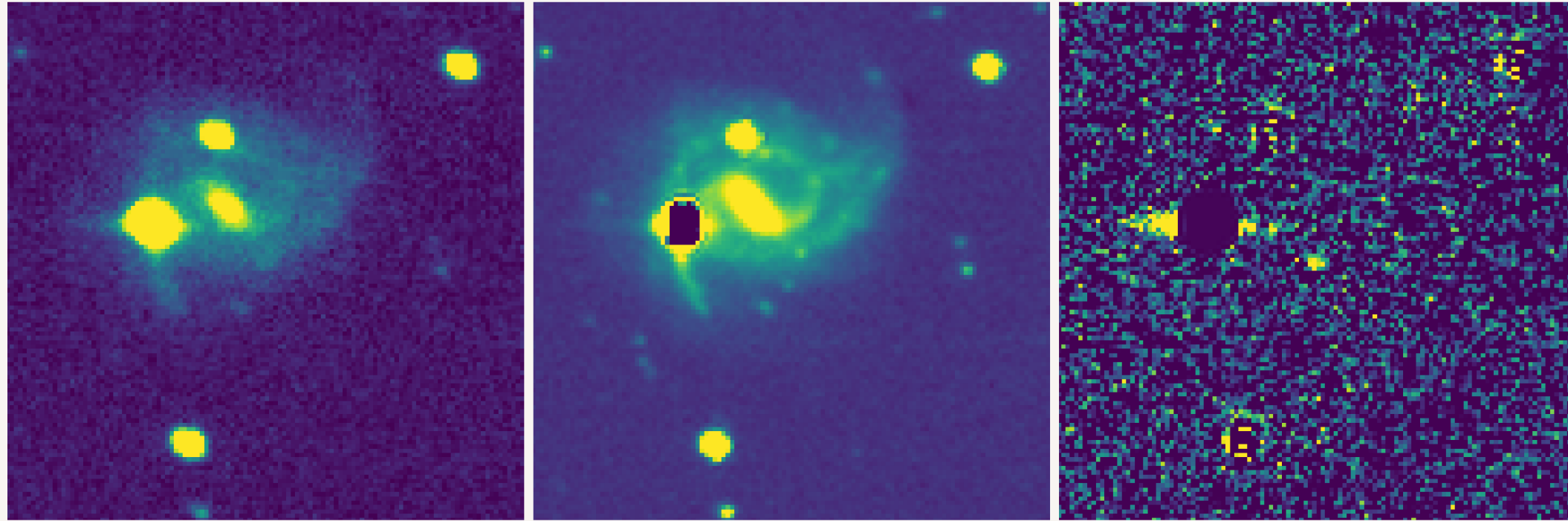
Conclusions



Universe is very big

Data rates are rapidly exploding

Conclusions



Universe is very big

Data rates are rapidly exploding

AI will be needed for new discoveries



Conclusions



Universe is very big

Data rates are rapidly exploding

AI will be needed for new discoveries

SkAI Institute
nexus for new astro+AI research



Funded by the U.S. National Science Foundation and the Simons Foundation