

Artificial Intelligence & Astrophysics

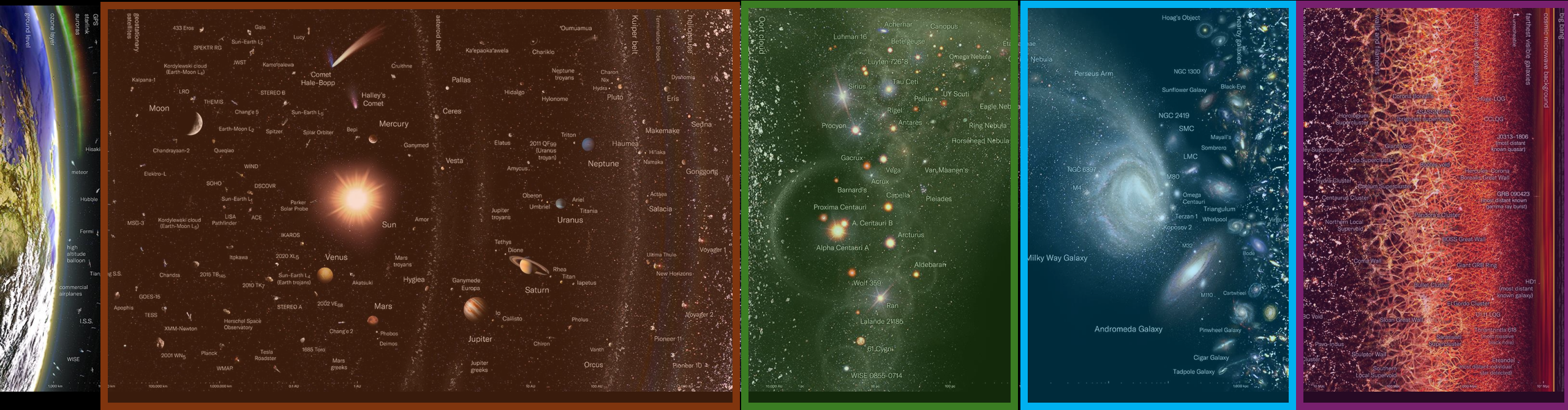
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INAF

ISTITUTO NAZIONALE
DI ASTROFISICA

Astrophysics is about large distances



Solar System and Planetary Science (incl. exoplanets)

Stellar astrophysics

Galaxy Evolution

Cosmology

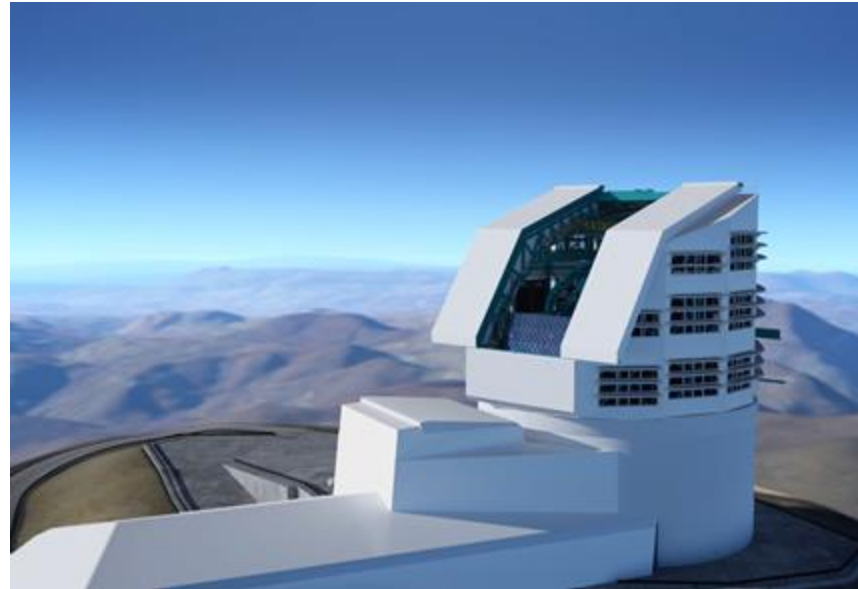
log scale

... and large numbers

2026

Future

Human Memory ~ 1 Gb
1 Tb = 2 Books



Vera Rubin Observatory,
will observe half of the night sky,
will produce ~ 20 Tb/night
In 10 years will produce 500 Pb of data



Square Kilometer Array,
will produce 1 Million Tb of
raw data per *second*

Outline

1

Process (huge) multi-D data
Classical Computer Vision, multi-modal data

2

**Accurate Inference
(with errors!)**
Normalizing flows/ invertible networks

3

**Are our theoretical models
good enough?**
Domain adaptation

4

Accelerate Discovery
Replace astronomers by machines
...

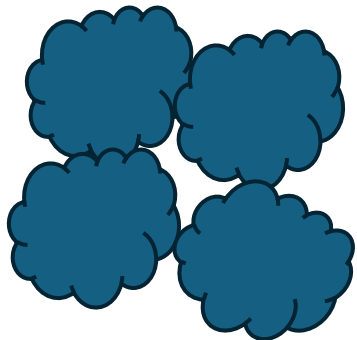
1

Analysis of 3D data-cubes

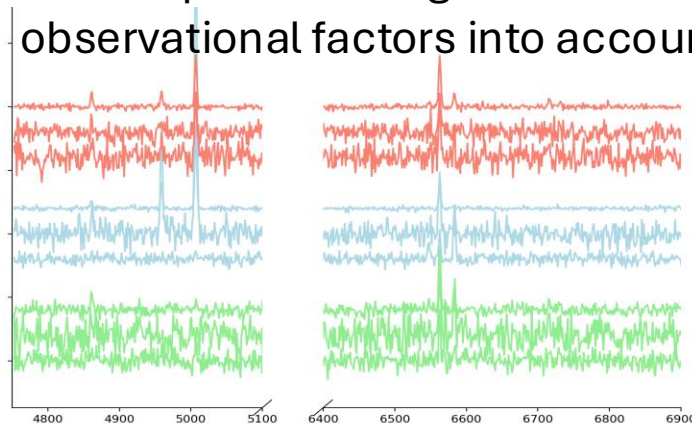
Typical data:
 $\sim 10^6$ spatial elements
 $\sim 10^3$ spectral elements



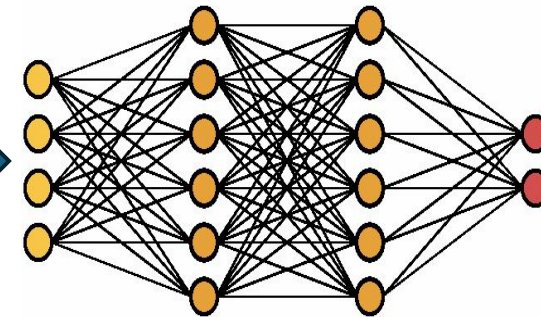
Theoretical model of an astrophysical plasma



Model spectra taking observational factors into account



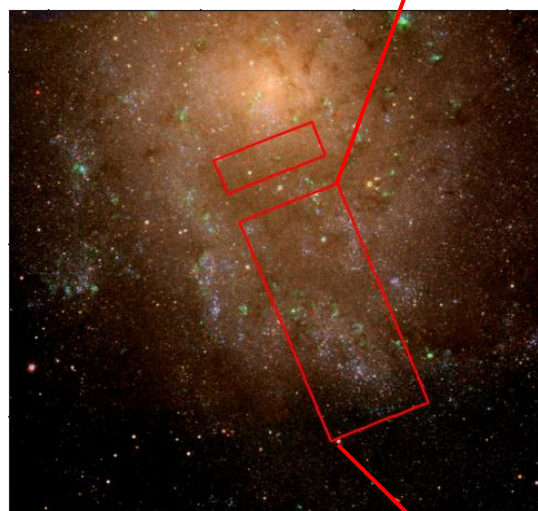
Classification (e.g. different kinds of nebulae)
Segmentation



1

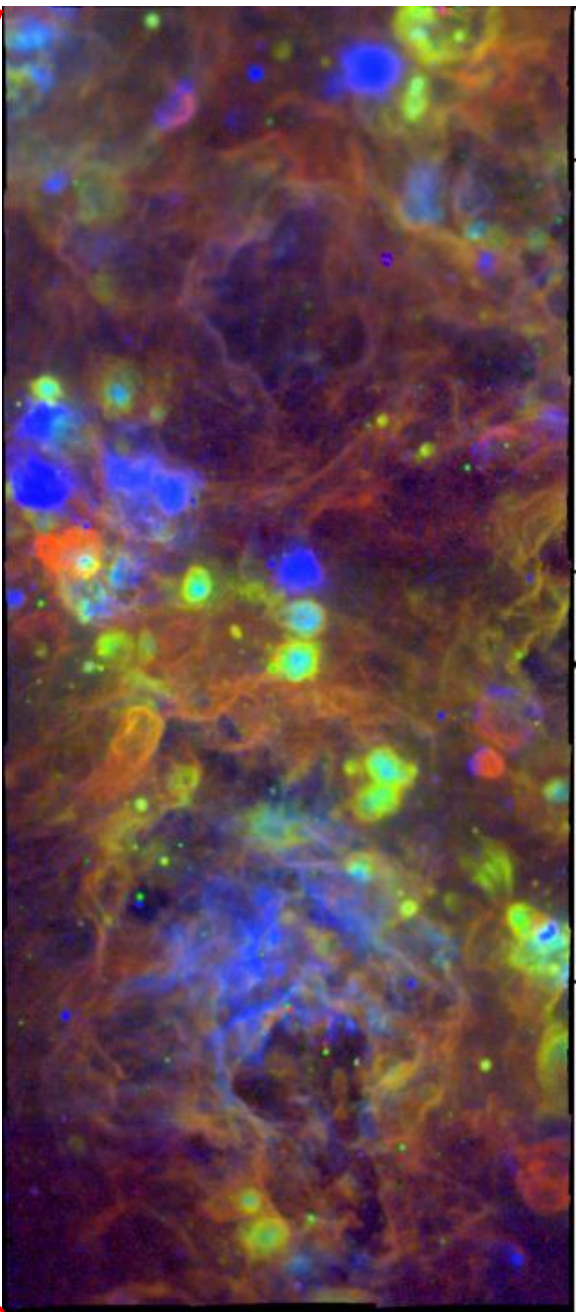
A case study of M33

Bracci+(in prep)

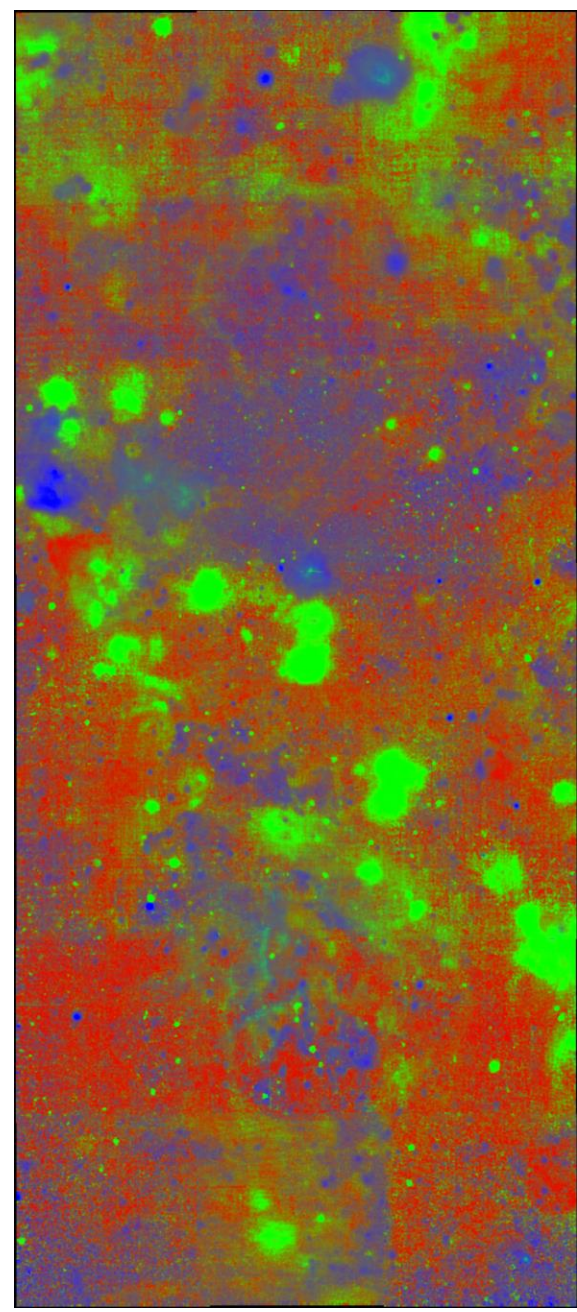


Nearby galaxy M33
24 MUSE pointings (PI Cresci)
➤ 2×10^6 spectra

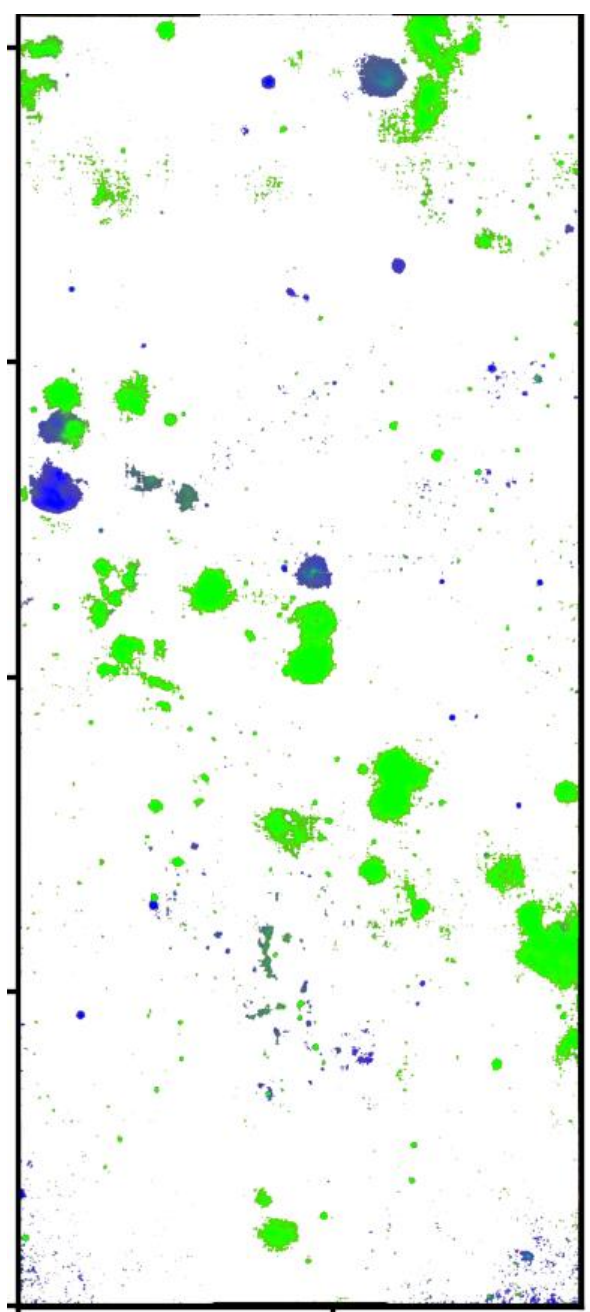
MUSE data, H α [SII] [OIII]



ML classification, HII SNR/DIG PNe



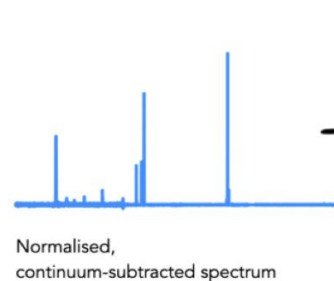
Segmentation



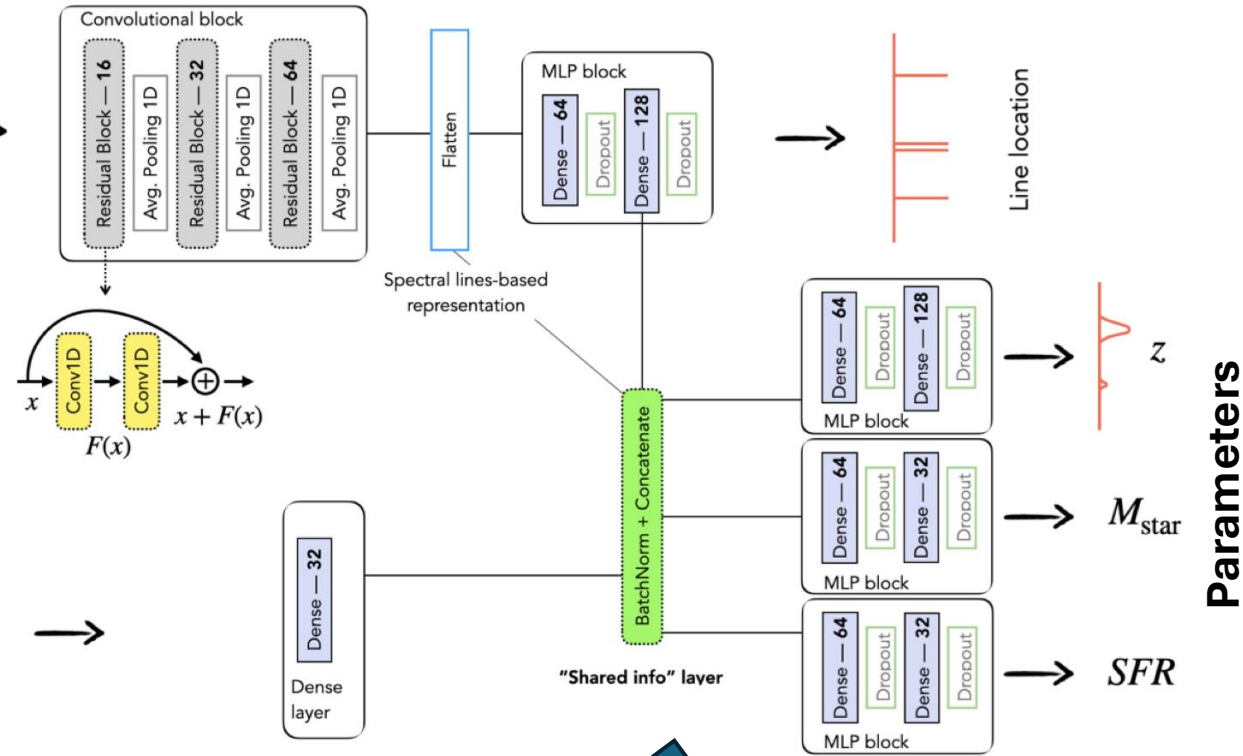
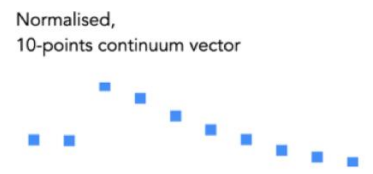
1

Going multi-modal

Spectra

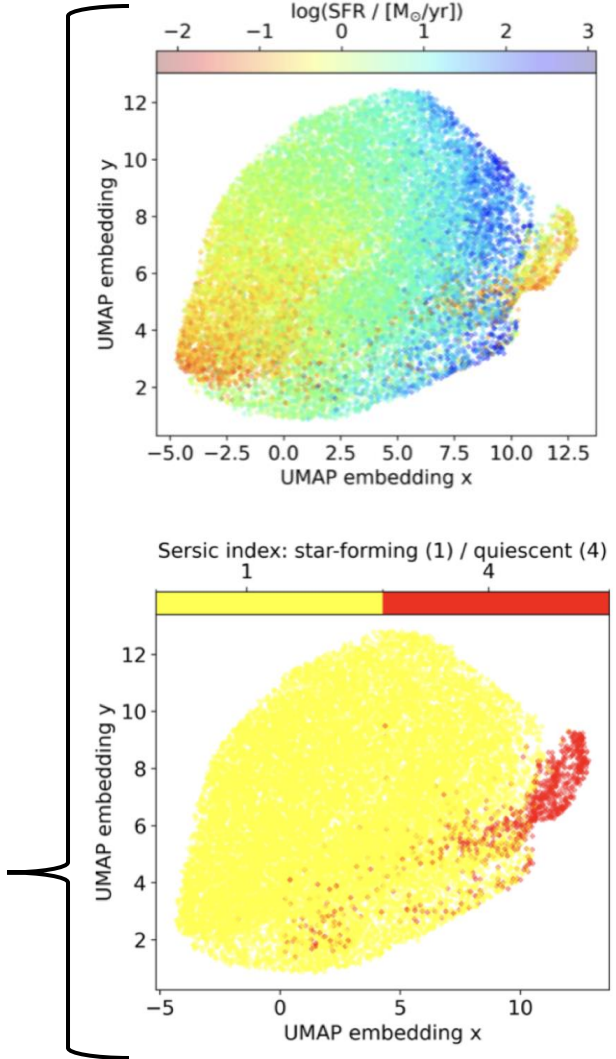


Imaging data

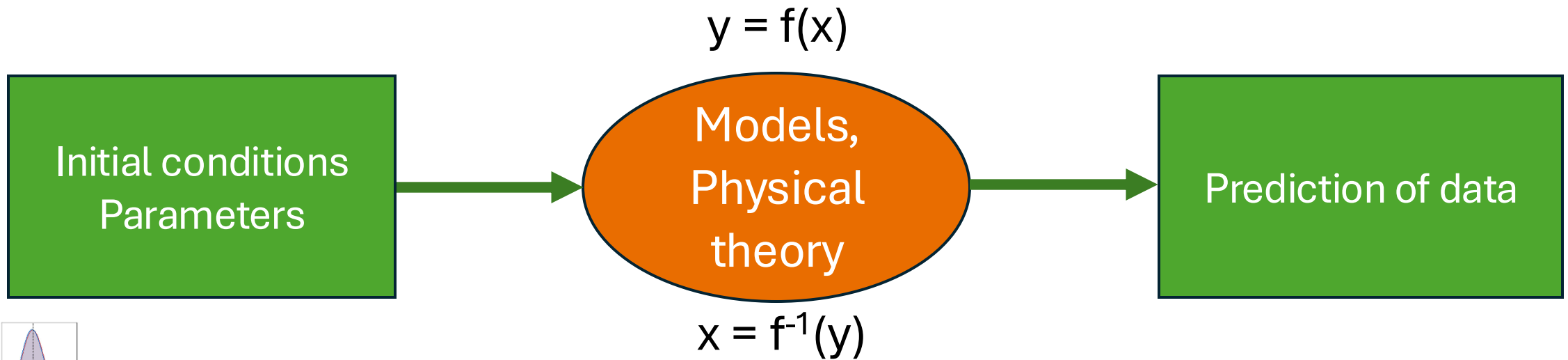


Low-dimensional representation of data

Parameters

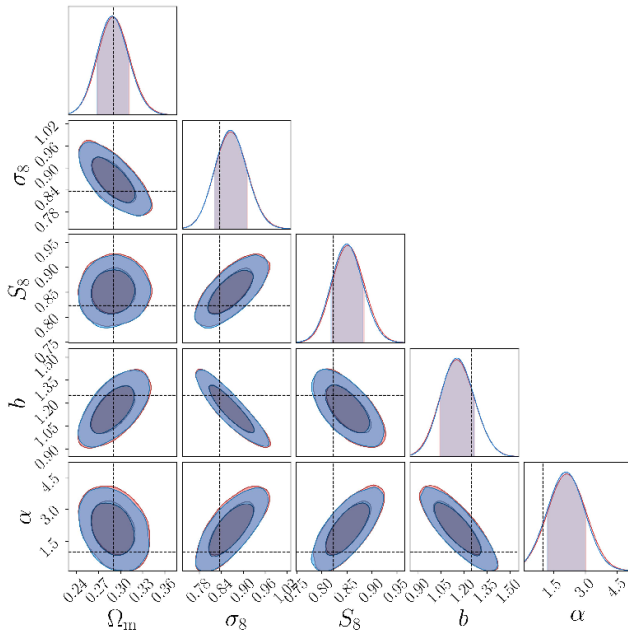
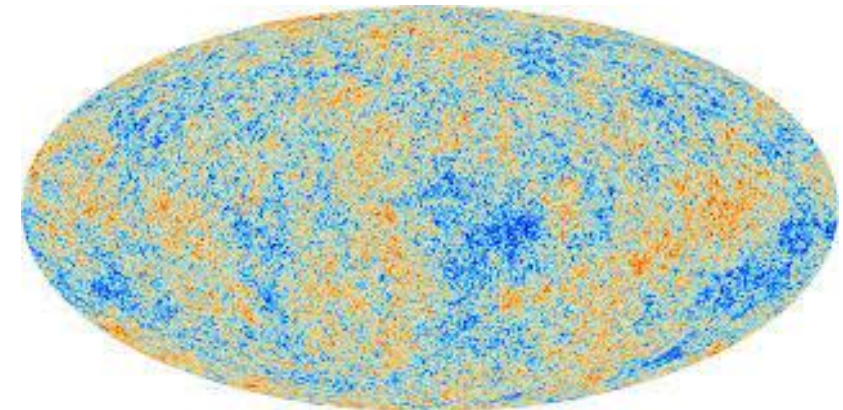


The Inverse Problem

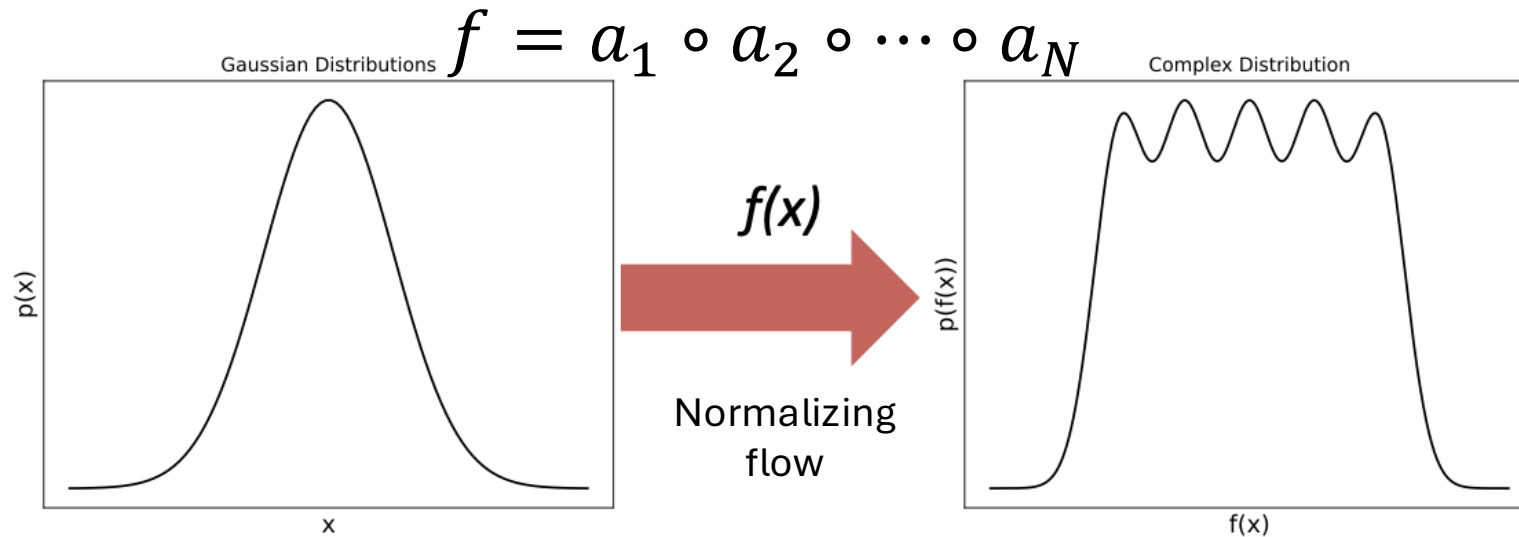


The Inverse Problem

A typical approach requires writing the likelihood and exploring a high-dimensional parameters space (e.g. with MCMC)

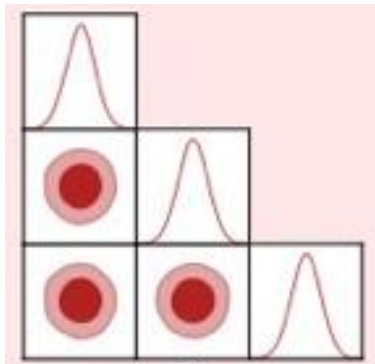


Inference with invertible normalizing flows

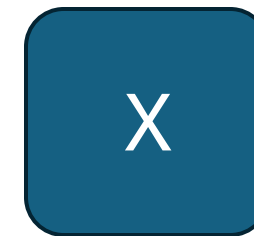
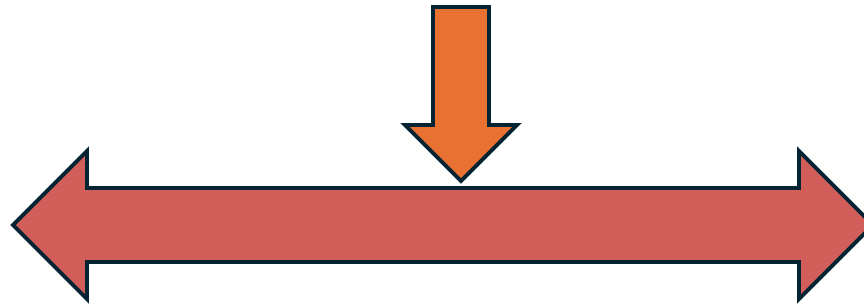


Conditional normalizing flow

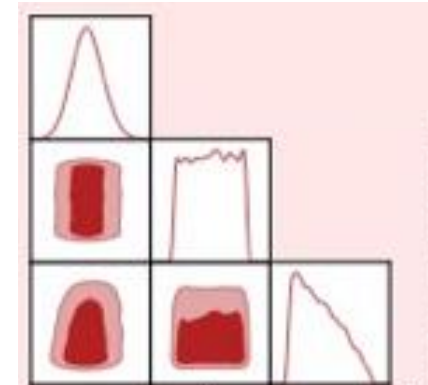
Data



Latent Space

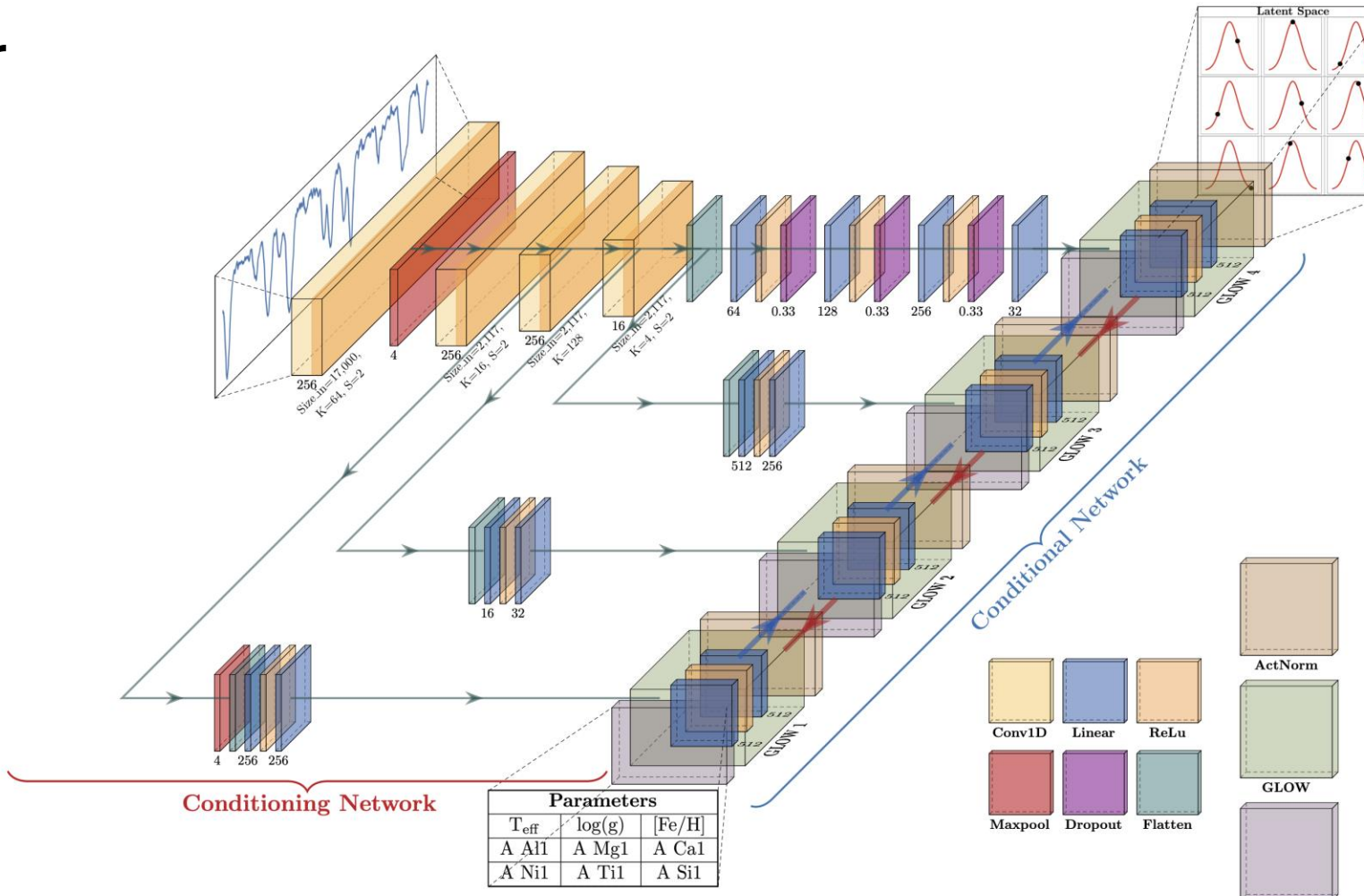
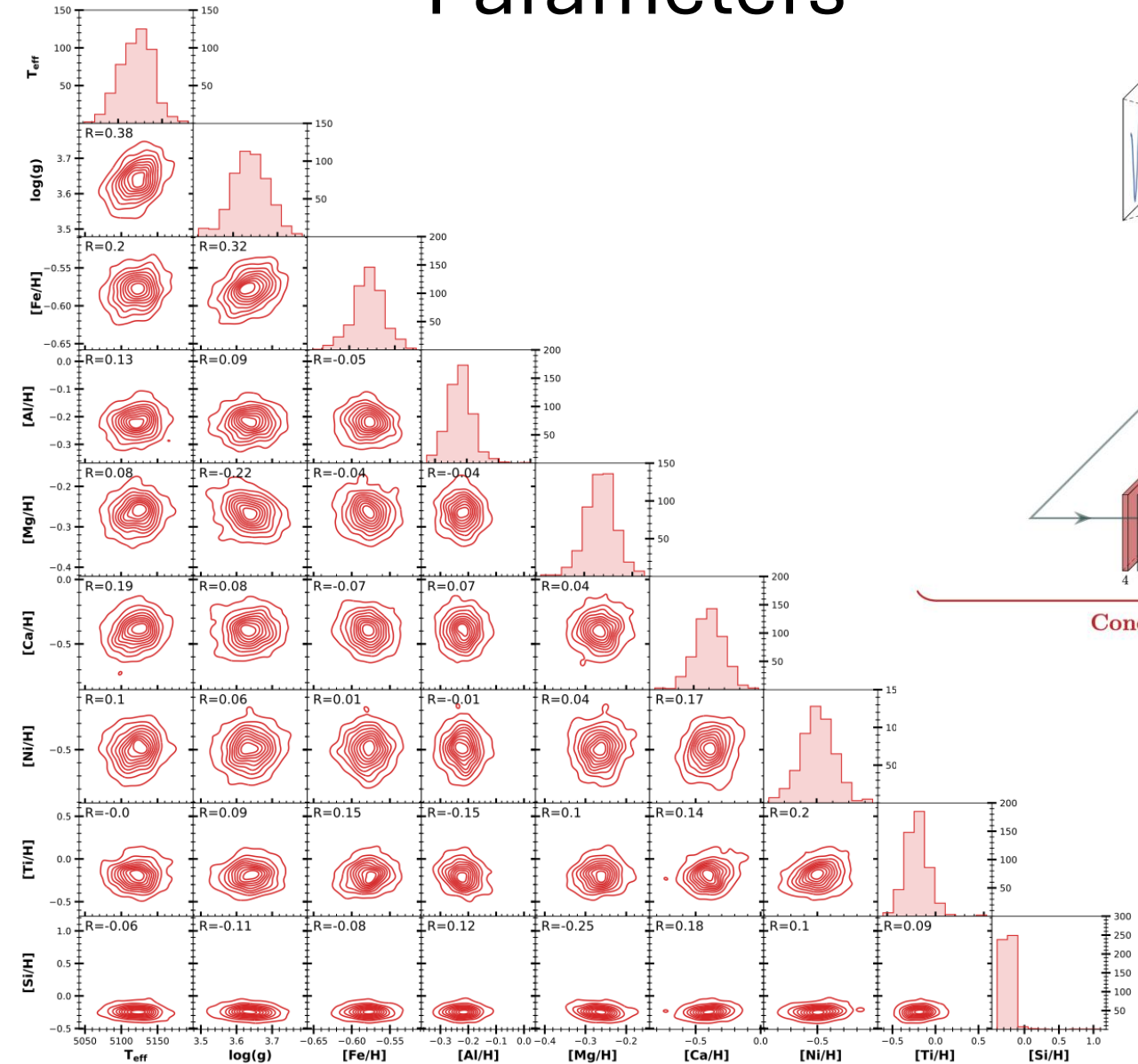


Parameters



2

Inferring Stellar Parameters



Candebat+24

Can I really train just on theory?

Theory

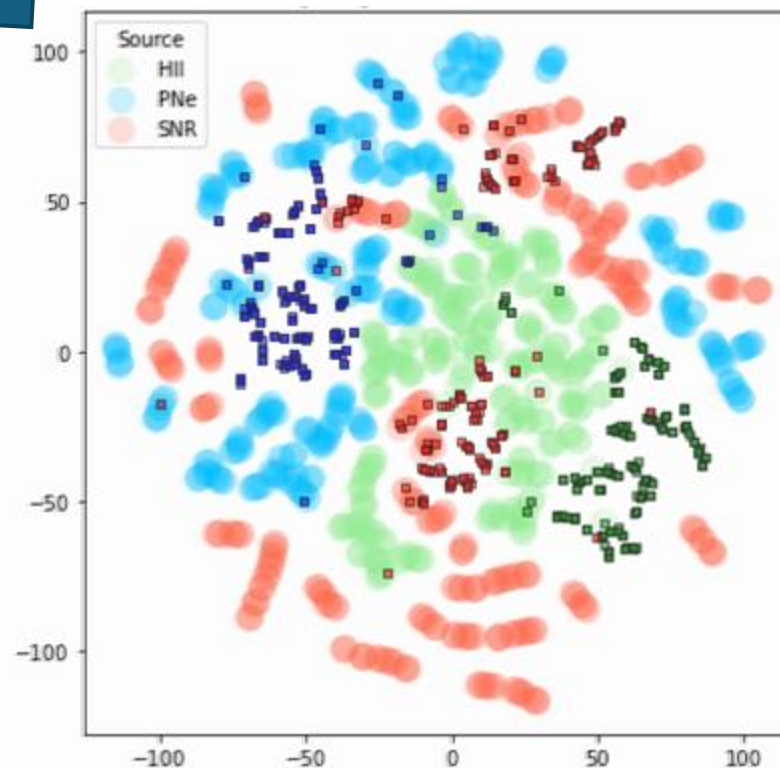
e.g. photoionisation models,
videogames



- Imperfect modelling of observational effects
- Missing or unknown physics
- Other simplifying assumptions

Data

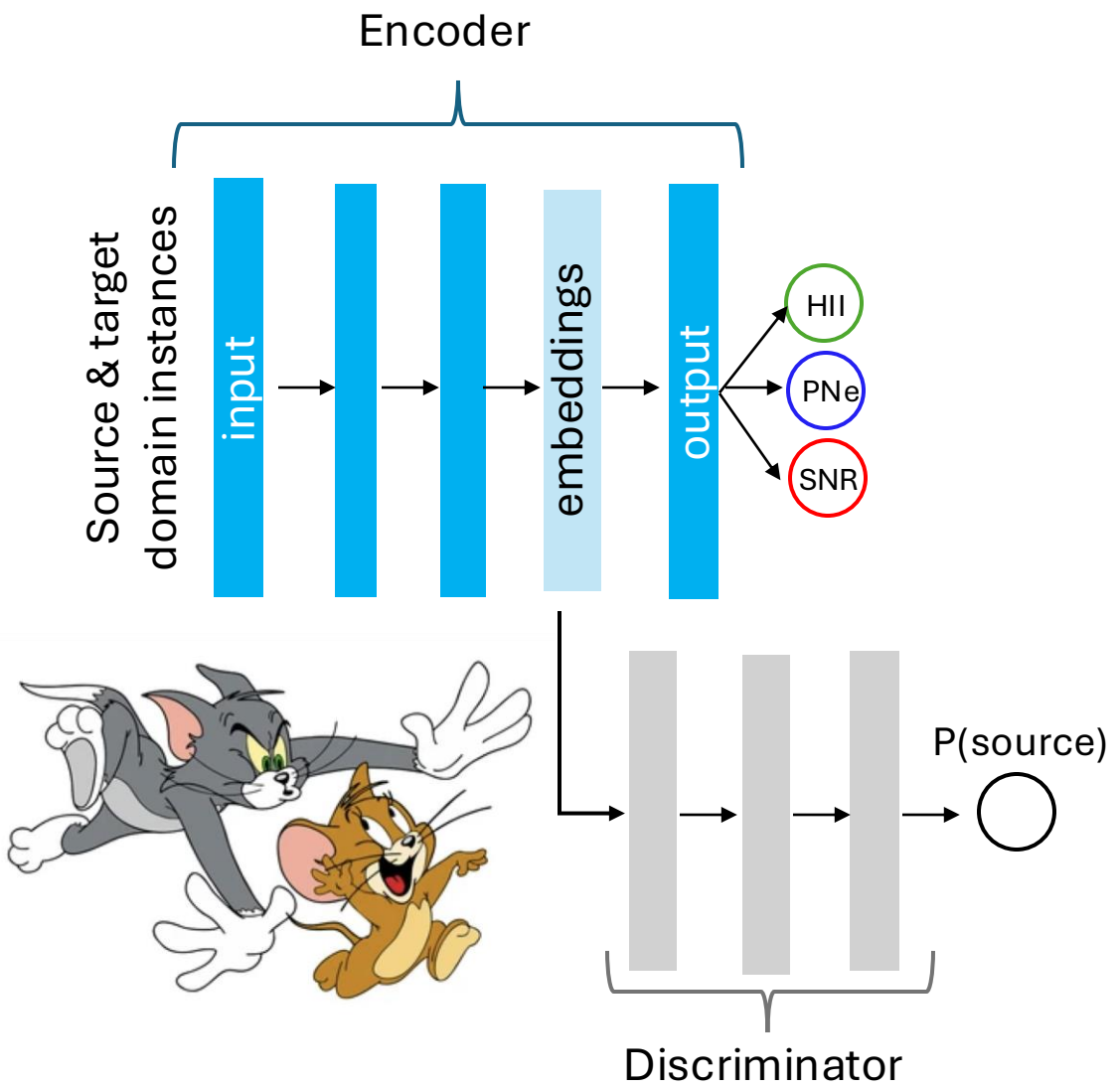
e.g. spectra of observed nebulae,
real images



Domain Adaptation

Aligns the low-dimensional representations of the two “domains”

A Domain Adversarial Neural Network



		Theory			Data		
		f1 = 0.98, acc= 0.98			f1 = 0.68, acc= 0.80		
ANN True	HII	98	2	0.5	99	0.1	0.5
	PN	3.6	96	0	5	95	0
	SNR	0.1	0	1e+02	43	13	44
		HII	PN	SNR	HII	PN	SNR
		f1 = 0.83, acc= 0.83			f1 = 0.67, acc= 0.89		
DANN True	HII	57	36	7.3	89	2.5	8.7
	PN	2.3	96	1.8	0	94	6.3
	SNR	0	2.3	98	5	9.8	85
		HII	PN	SNR	HII	PN	SNR
		Predicted			Predicted		



Accelerating Discovery

arXiv > astro-ph

Astrophysics (since April 1992)

For a **specific paper**, enter the identifier into the top right search box.

- **Browse:**
 - [new](#) (most recent mailing, with abstracts)

All the Astronomy paper on ArXiv +
Open-Source LLM



👤 Spaces

👤 kiyer/pathfinder

👍 like 22

🟢 Running on CPU UPGRADE

Prompt: Hello, what is the effect of Supernova explosion in galaxies?
can you guide me through recent literature?

ADS Link	Relevance	date	cites	title
2016arXiv160406071B	0.969	2016-04-01	0	A supernova feedback implementation for the astrophysics
2014IAUS...296..273W	0.956	2014-01-01	15	Supernovae and the Galactic Ecosystem
2006astro.ph...3174S	0.931	2006-03-01	0	Impact of Supernova Explosions on Galaxy Formation
2020MNRAS.493.4700L	0.911	2020-02-01	37	Supernova feedback and the energy deposition in molecu
1999ApJ...513..142M	0.884	1998-01-01	933	Starburst-driven Mass Loss from Dwarf Galaxies: Efficie
2017hsn...book.2313P	0.882	2016-09-01	3	The Effects of Supernovae on the Dynamical Evolution of
1998ApJ...500...95T	0.868	1997-06-01	385	Energy Input and Mass Redistribution by Supernovae in t
2006APh....25..183E	0.807	2006-01-01	98	The anisotropy of galactic cosmic rays as a product of :
2008A&A...486L..35G	0.763	2008-05-01	140	Direct simulations of a supernova-driven galactic dynam

To understand the effects of supernova (SN) explosions in galaxies, we can break down the question into several key components:

- 1. Definition of Supernovae:** Supernovae are explosive events that occur at the end of a star's life cycle, particularly for massive stars. They release an enormous amount of energy and can outshine entire galaxies for a short period.
- 2. Impact on the Interstellar Medium (ISM):** Supernovae significantly influence the ISM, which is the matter that exists in the space between stars in a galaxy. The energy and momentum from supernova explosions can compress and heat the surrounding gas, leading to the formation of shock waves. These shock waves can trigger star formation in nearby regions by compressing gas clouds.
- 3. Role in Galaxy Formation:** According to recent literature, including the studies mentioned in the provided documents, supernovae play a crucial role in the development of galactic structures. They can affect the dynamics of the ISM and contribute to the formation of features such as superbubbles—large cavities in the ISM created by the collective effects of multiple supernovae.

Conclusions

- ML is be key to analyse the huge flow of data from current and future astronomical facilities.
- Invertible architectures can capture degeneracies and perform Bayesian inference
- If we train on theoretical simulations we need to bridge the gap to real data
- We are just starting to consider the potential benefits (&risks) of LLMs for tasks beyond data analysis

