



Machine Learning and AI technics to model planetary atmospheres: contribution of IAP in the French landscape

Virginie Batista



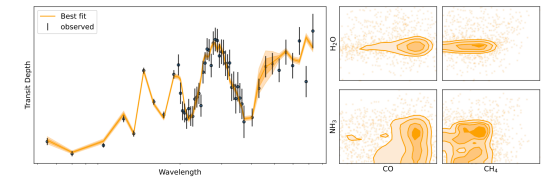
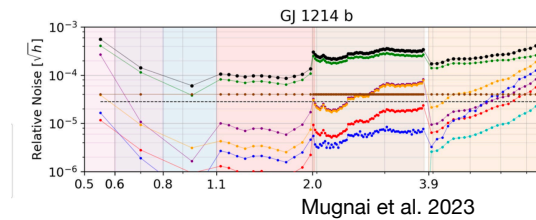
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AI in the context of ARIEL and its applications to Planetary Atmospheres

Use of AI has increased drastically within the last few years in astrophysics.

In the context of exoplanet and Ariel, among many other things, AI can be useful for:

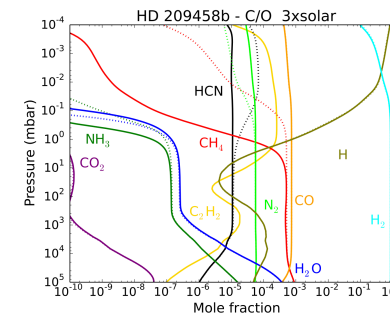
- Data de-trending (instrumental noise)
- Instrument noise simulations
- Faster retrievals for atmospheric characterization
- Generative models (e.g. chemistry, radiative transfer, etc)



Yip et al. 2022



Yip et al. 2022



Venot et al. 2019



CNES supporting AI developments in French labs

- Monthly meeting between CNES, IAP, IAS, LISA, LESIA, CEA in 2022 to discuss AI applications for ARIEL activities



- **February 16th, 2023: AI training day** organized at IAP with Orphée Faucoz and Denis Standarovski (CNES AI experts)



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Ariel School: Biarritz Ares III School 2023

Increasing AI content in the Ariel School organized by Pierre Drossart, and J.-P. Beaulieu in coordination with CNES, focused on atmospheric retrievals and Machine Learning:

- **4 AI lectures** given by:

Orphée Faucoz and Denis Standarovski (CNES),

Ingo Waldmann (UCL),

Katia Matcheva (University of Florida).

- **1 training session** by Orphée Faucoz and

Denis Standarovski.



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IAP AI working group

IAP new working group in 2023 with common interest in developing AI technics in the context of the ARIEL mission:

- **3 researchers:** J.-P. Beaulieu, Pierre Drossart, Clément Ranc
- **2 PhD Students:** Emilie Paneck and Alice Maurel
- **1 research engineer:** Virginie Batista
- **1 engineering internship from June to October 2023** dedicated to the Ariel Data Challenge 2023: Saad Taleb
- **Next: Master 2 internship + PhD** focused on de-trend systematics from the astrophysical signal, using AI (e.g.GAN).



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Keeping up to date with the literature

Explainable Artificial Intelligence (XAI): Concepts, Taxonomies, Opportunities and Challenges toward Responsible AI
Alejandro Barredo Arrieta^a, Natalia Díaz-Rodríguez^b, Javier Del Ser^c,
Siham Tabik^g, Alberto Barbado^h, Salvador Garcia^g, Sergio
Richard Benjamins^h, Raja Chatila^f, ...

ExoGAN: Retrieving

Random Forests applied to High Precision Photometry Analysis
JESSICA E. KRICK,¹ JONATHAN FRAINE,² JIM INGALLS,¹ AND CROSSMARK

Neural networks as an alternative to Bayesian
Retrieving exoplanet transmission spectra

You Need
Chalmer IRAC.
Jakob Uszkoreit*
Google Research
usz@google.com

To Sample or Not To Sample:
Retrieving Exoplanetary Spectra with Variational Inference and Normalising Flows
KAI HOU YIP¹, QUENTIN CHANGEAT¹, AHMED AL-REFAIE¹ AND INGO P. WALDMANN¹
¹ University College London
Received 2020

Searching for Exoplanets

Kyle A. Pearson
Lunar and Planetary Institute

Armed CNN for exoplanet lightcurves

Neural Networks for Exoplanetary Atmospheric Retrieval
MOLLY D. O'BEIRNE⁵, SIMONE ZORZAN⁴, GIADA N. ARNEY⁷, AND DANIEL ANGERHAUSEN
MOLLY D. O'BEIRNE⁵, SIMONE ZORZAN⁴, GIADA N. ARNEY⁷, AND DANIEL ANGERHAUSEN
Waldmann¹, and Ingo P. Waldmann¹
¹ University College London
Gower St. Bloomsbury, London WC1E 6BT, UK; mario.morvan.18@ucl.ac.uk, n.nikolaou@ucl.ac.uk,
ingo.star@ucl.ac.uk
accepted 2020 January 7; published 2020 February 17

Short-term Memory Networks
Chalmer IRAC.
Jakob Uszkoreit*
Google Research
usz@google.com

Accurate Machine Learning Atmospheric Retrieval via a Neural Network Surrogate Model for Radiative Transfer

MICHAEL D. HIMES¹, JOSEPH HARRINGTON², ADAM D. COBB³, ATILIM GÜNEŞ BAYDIN³,
FRANK SOBOCZENSKI⁴, MOLLY D. O'BEIRNE⁵, SIMONE ZORZAN⁶, DAVID C. WRIGHT¹, ZACCHAEUS SCHEFFER¹,
SHAWN D. DOMAGAL-GOLDMAN⁷ AND GIADA N. ARNEY⁷

Reduced
M. Nixon
Institute of Astronomy, University of Cambridge

An Ensemble
KAI HOU YIP
Adam D. Cobb^{1,10}, Atılım Güneş Baydin¹, Yarin Gal

Interpretable
Bovino⁵, G. Picogna^{1,2}, and B. Ercolano^{1,2}

retrievals
ate Model
[0000-0002-0355-2076]
, and Katia



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Online courses with Fidle CNRS Univ. of Grenoble

Following online Fidle course + training sessions:

<https://gricad-gitlab.univ-grenoble-alpes.fr/talks/fidle/-/wikis/home>

Programme

1 History, Fundamental Concepts	2 High Dimensional Data CNN	3 High Dimensional Data CNN	4 Demystify mathematics for neural networks.	5 Training strategies Evaluation	6 Sparse data (text) Embedding
7 Basic Regression DNN	8 Basic Classification DNN	9 PyTorch A small detour with PyTorch .	10 «Attention is All You Need» Transformers	11 Graph Neural Network GNN	12 Autoencoder networks AE
13 Variational Autoencoder VAE	14 Project session «My project in 180 s»	15 Generative Adversarial Networks GAN	16 Diffusion Model Text to image	17 AI, Law, Society and Ethics	18 Model and training optimization Resource efficiency
19 Jean-Zay GPU acceleration	20 Physics-Informed Neural Networks PINNS	21 Deep Reinforcement Learning RL	22 What will be tomorrow's AI Review & perspectives!		

Formation
Introduction Deep Learning

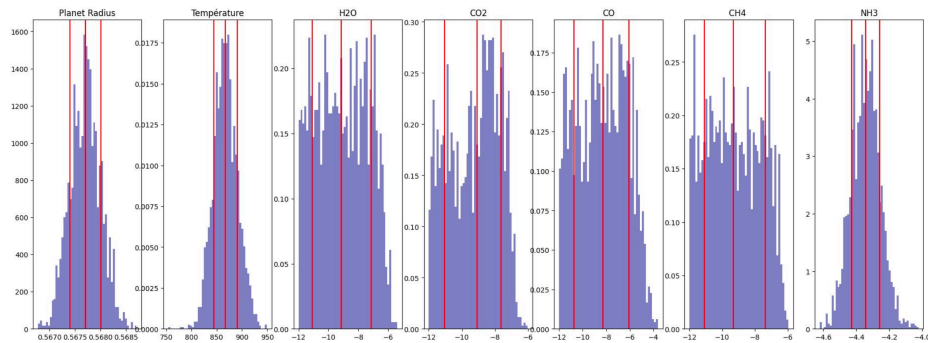
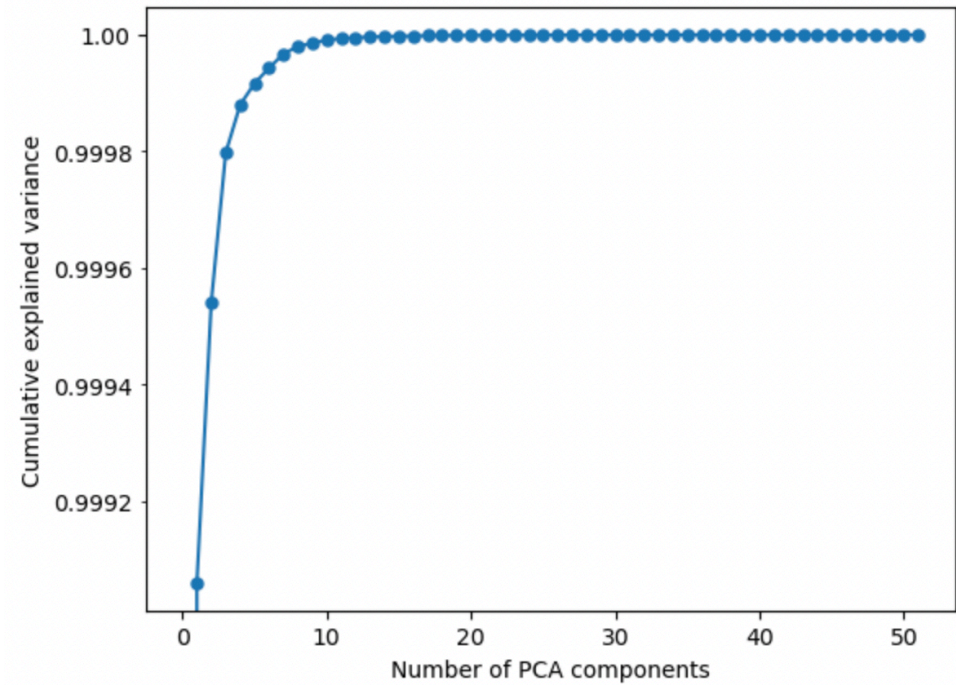
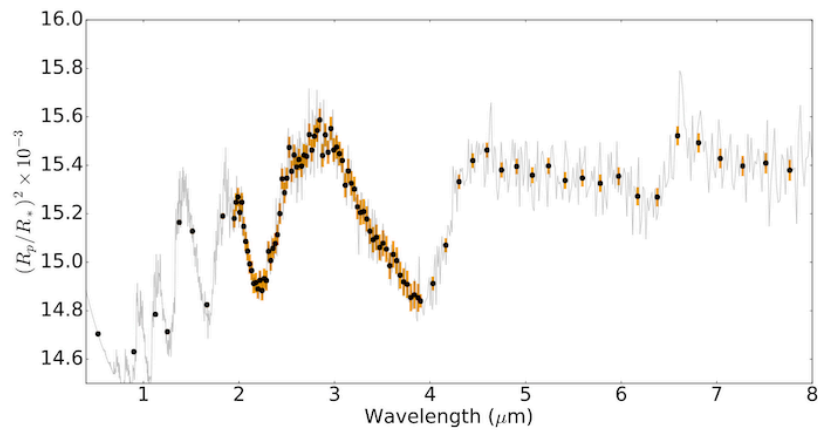
Présentation de saison, 2022/23



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Training sessions: e.g. PCA analysis on ADC2023 database

6766 supervised data (Yip et al. 2022)



PC1 = 0.99905

PC2 = 0.0005

PC3 = 0.00025

1st component
strongly dominates

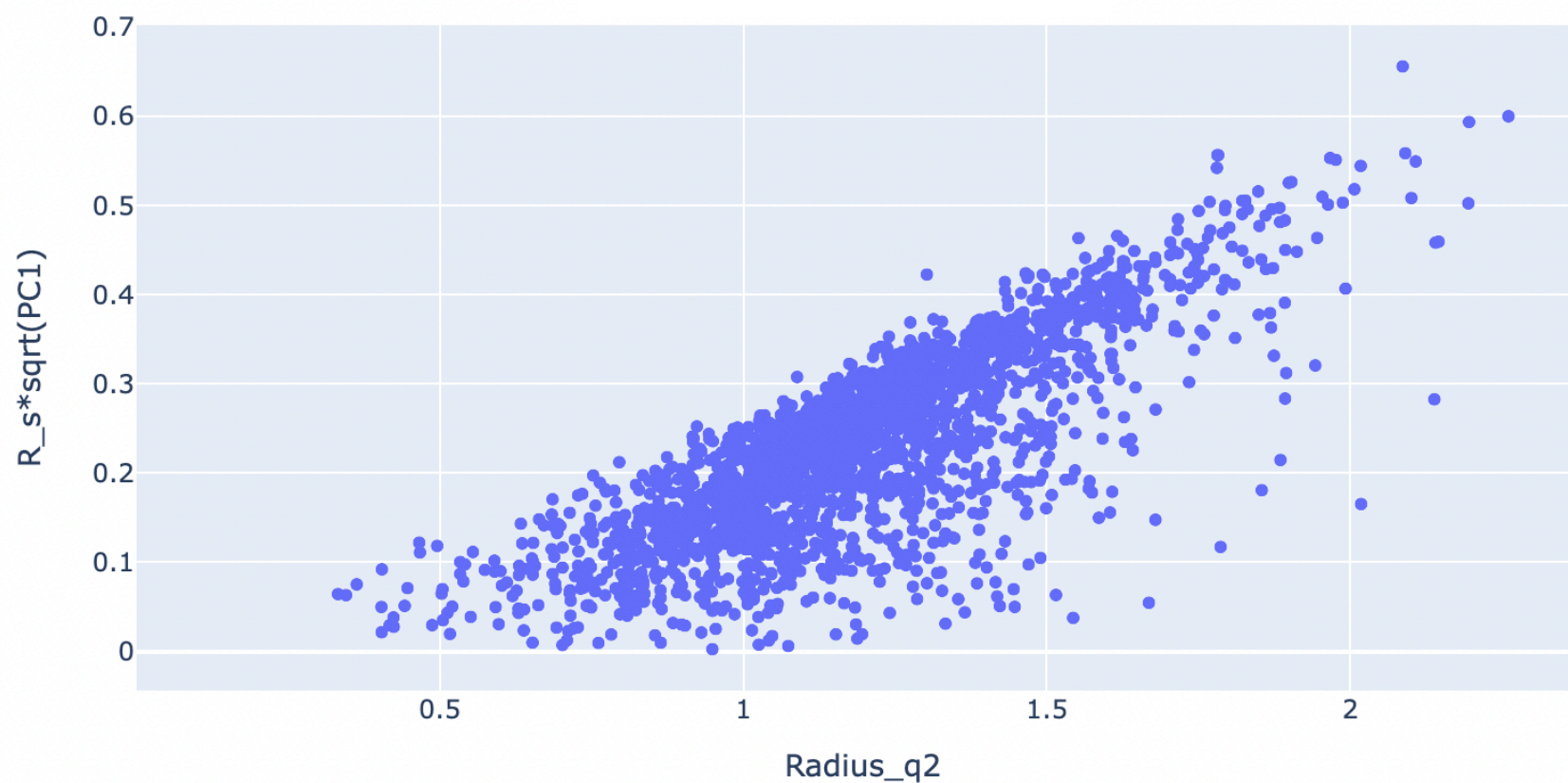


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PCA analysis on ADC2023 database: 1st component PC1



$$R_S \sqrt{PC1} \sim R_P$$



PCA analysis on ADC2023 database: other components

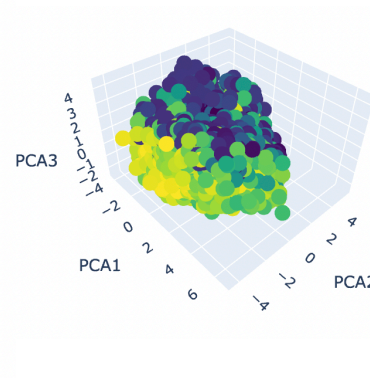
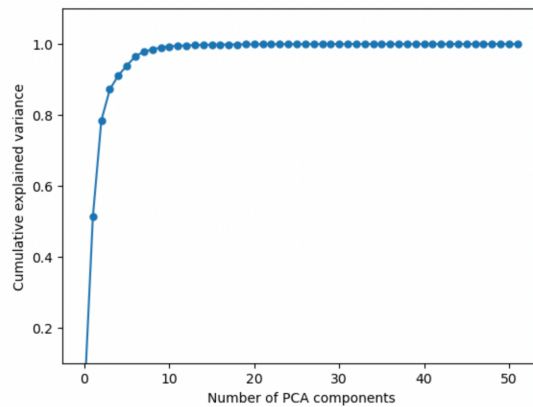
To express other PCA components, remove PC1 from the spectrum and do a second PCA on the residuals:

New components

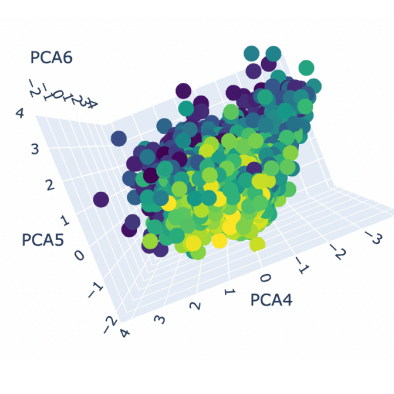
PC1 = 0.513

PC2 = 0.272

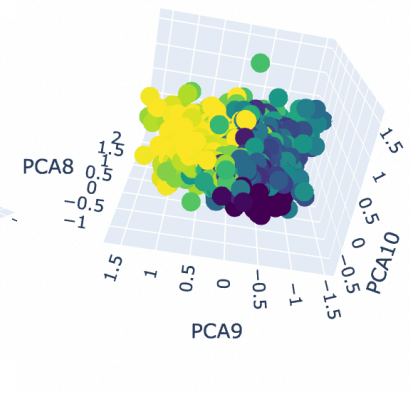
PC3 = 0.088



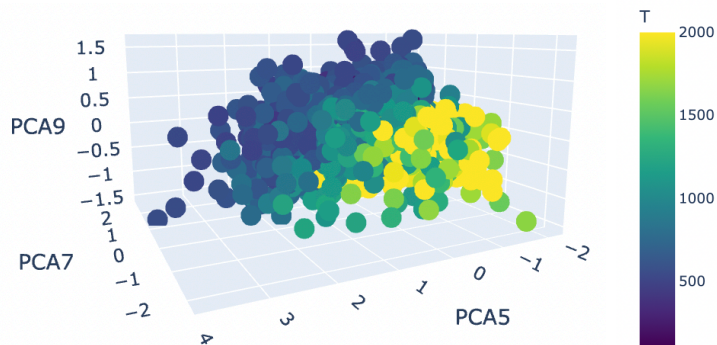
H₂O



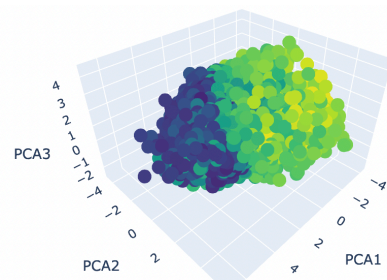
CO₂



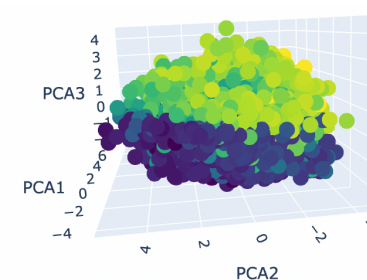
CO



Temperature



CH₄



NH₃



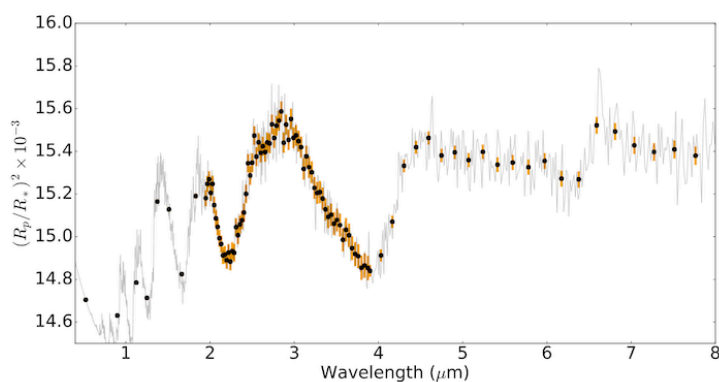


Participation to the Ariel Data Challenge 2023 (ADC23)

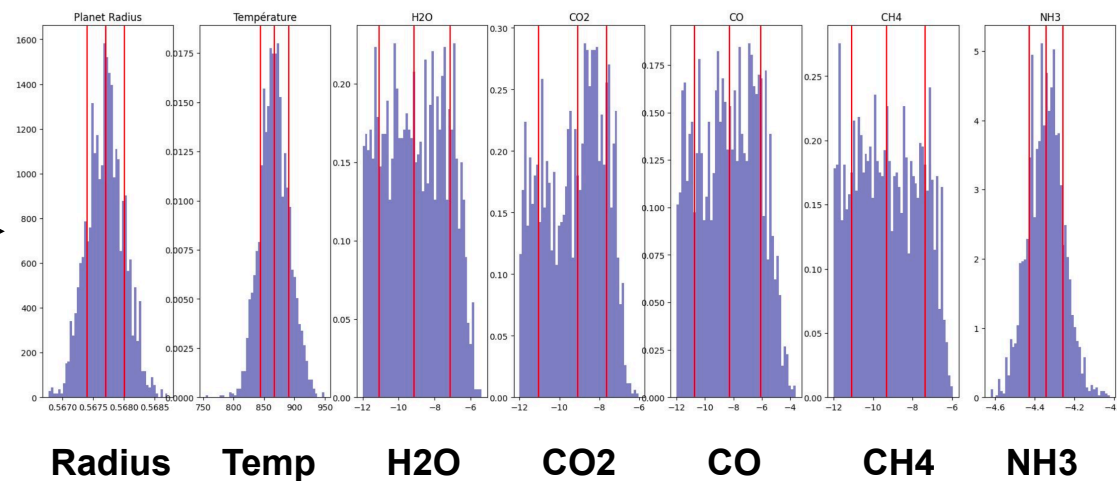


Engineering internship from June to October 2023 with **Saad Taleb (INSA Haut de France)**

to work on **Ariel Data Challenge 2023** - Deadline June 18th => **Short !**



Inputs

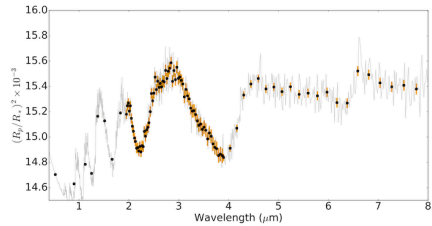


Radius Temp H2O CO2 CO CH4 NH3

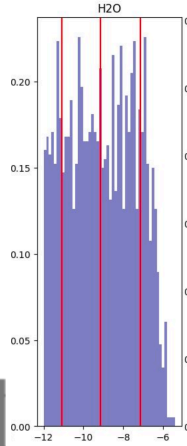
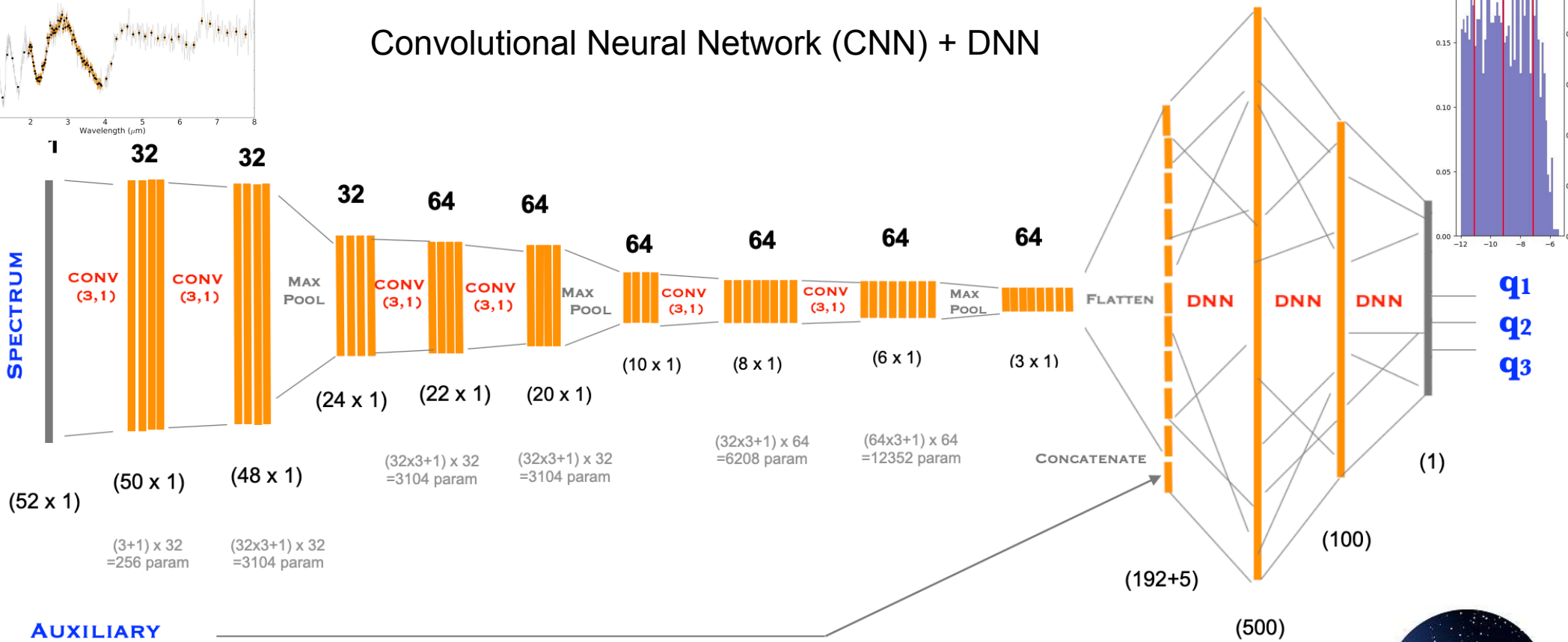
Outputs

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Starting from the Ariel Data Challenge Baseline



Convolutional Neural Network (CNN) + DNN

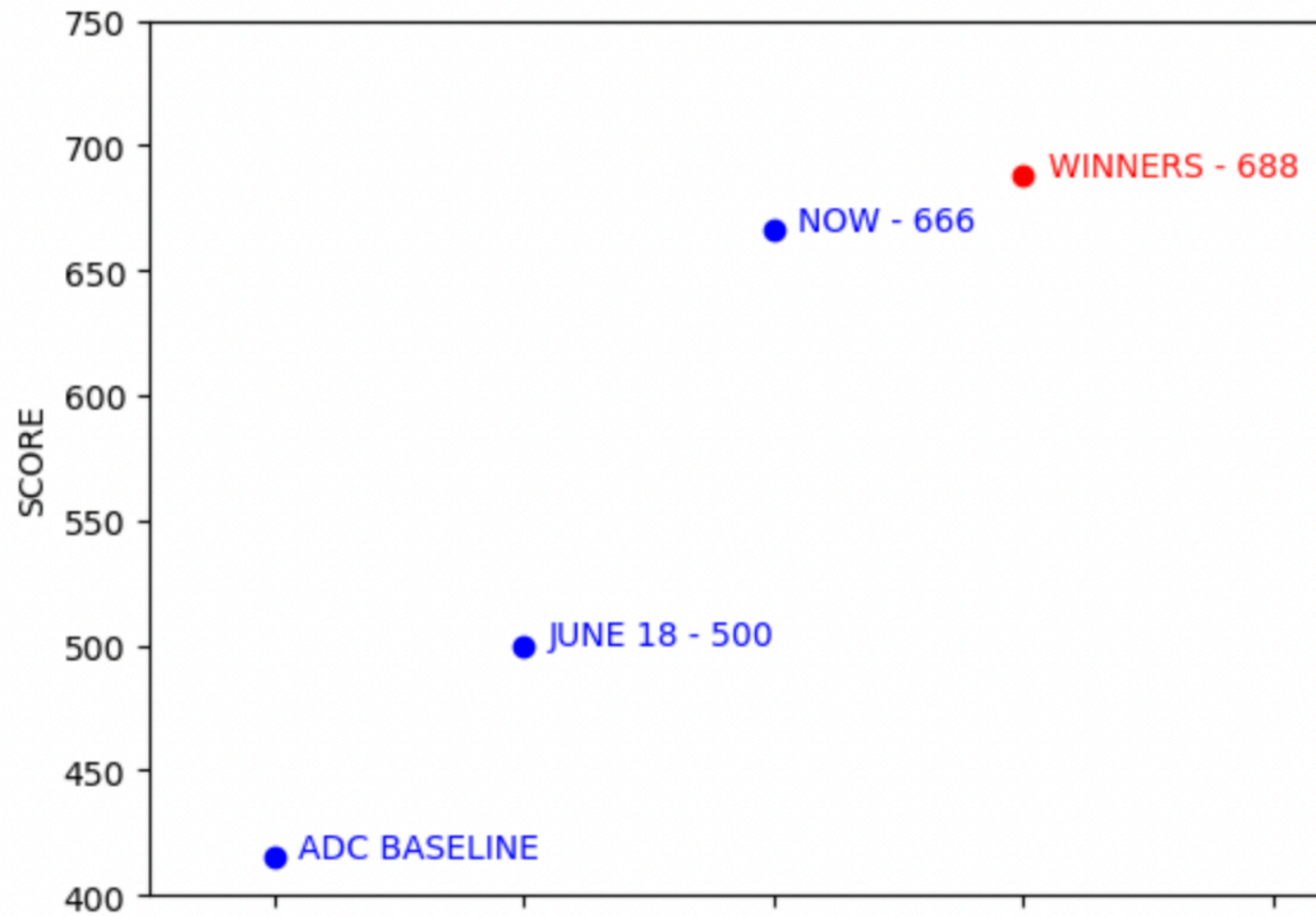


Score on test data between 0 and 1000 - Baseline score ~ 415

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Score



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Conclusion and future projects



- **The Ariel Data Challenge provided a very useful Database for practicing**
- **IAP/CNES project to create a new Data Challenge in 2024** for French universities.
- **Master M2 internship + PhD starting in 2024 at IAP** under the supervision of Pierre Drossart, J.-P.

Beaulieu and Orphée Faucoz (CNES):

- Exploring AI approaches to de-trend systematics associated with the instrumental and astrophysical noise (e.g. variability of the host star, cosmic rays, jitter, photon noise, etc)
- Generating Ariel L3 data with GANs
- Testing Deep Learning approaches on a large sample of JWST/NIRSPEC data.

