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

Virginie Batista
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)
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)
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.
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**: Saad Taleb
- **Next: Master 2 internship + PhD**: focused on de-trend systematics from the astrophysical signal, using AI (e.g. GAN).
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
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
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
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**
- Radius
- Temp
- H2O
- CO2
- CO
- CH4
- NH3

*Journée ARIEL France - Jeudi 18 janvier 2024 at Institut d’Astrophysique de Paris*
Starting from the Ariel Data Challenge Baseline

Convolutional Neural Network (CNN) + DNN

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