**1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)**

**Project title:**

## Retrieval of exoplanet atmospheric parameters

# 1. Project goals

Proper interpretation of extrasolar planet spectra requires both high signal-to-noise data and deep understanding of their physical and chemical conditions. Currently both are lacking. Given limitations of available and planned instrumentation, one of the ways of improving the results is to make best possible use of the available data.

Currently, most retrieval studies of planetary atmospheres begin with processed spectra, and ignore the time-domain covariances of the original light curves. That practice simplifies modelling but can bias abundances and ignore how noise and signal correlate across wavelengths and over time. This project will first make use of the existing frameworks of retrieval (like Taurex3) for a sample of exoplanets, which will increase as more data gets available from various telescopes, such as HST, JWST, VLT etc. over the course of PhD. A uniform catalogue will be published with the retrieved parameters.

Since the targets will be chosen as such that multi wavelength light curves are available for them, next step will be to elaborate and apply a new close-to-data approach that will let both wavelength and time constrain the atmosphere simultaneously. The atmospheric parameters will then be re-derived. Comparison studies will be made between both the approaches.

## 1.1. Outline

After detection of the first extrasolar planetary system (Wolszczan and Frail, 1992) and the first extrasolar planet orbiting a solar-type star (Mayor and Queloz, 1995) and successful implementation of transiting technique for detection of exoplanets (Charbonneau et al. 2000) the population of known exoplanets quickly reached into the thousands., and it is clear now that planets in our Galaxy are more numerous than the stars.

First observations of extrasolar planet atmospheres (Charbonneau et al. 2007, Richardson et al. 2007, Grillmair et al. 2007) opened yet another perspective: studies of physical conditions on extrasolar planets. Today, observations of extrasolar atmospheres, although challenging, are becoming a mature standard technique and open a perspective for in-depth studies of other worlds including their potential for life.

NCU is a partner in a world-wide collaboration undertaking construction and planning scientific exploitation of ANDES, the world's most advanced spectrometer for the world's largest ESO Extremely Large Telescope aiming at detection and characterisation of earth-analog exoplanet atmospheres. Also ESA's mission Ariel (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) will deliver thousands of exoplanetary atmospheres spectra in near future.

This project is meant as a step towards scientific exploitation of future instruments like ANDES and Ariel.

## 1.2. Work plan

Explore different open-source retrieval code (like Taurex3, Chimera etc.).
Make comparison study on their efficiency to select the best framework.
Apply at least one of the frameworks on a target list of exoplanets for retrieval studies. Publish uniform atmospheric catalogue.
Implement new methods to make use of the multi wavelength light curves for a better atmospheric retrieval (closed-to-data approach).
Compare the results with the traditional method.
Publish the results.

## *1.3.* Literature (max. 7 listed, as a suggestion for a PhD candidate preliminary study)


1. Welbanks et al., The Challenges of Detecting Gases in Exoplanet Atmospheres, arXiv preprint (arXiv:2504.21788)
2. Seager et al., Prospects for Detecting Signs of Life on Exoplanets in the JWST Era, arXiv preprint (arXiv:2504.12946)
3. Mugnai et al., 2024, Comparing Transit Spectroscopy Pipelines at the Catalogue Level: Evidence for Systematic Differences, Monthly Notices of the Royal Astronomical Society 531(1), 35–51
4. Changeat et al., 2024, Toward Atmospheric Retrievals of Panchromatic Light Curves: ExPLOR-ing Generalized Inversion Techniques for Transiting Exoplanets with JWST and Ariel, The Astronomical Journal 167(5), 195
5. Davey, J. J., et al. 2025, The Effect of Spectroscopic Binning on Atmospheric Retrievals, Monthly Notices of the Royal Astronomical Society, 536(3), 2618-2644


## 1.4. Required initial knowledge and skills of the PhD candidate

Knowledge: MSc in astronomy. English level B2 minimum.
Skills: Unix/Linux/MacOS system, Python programming, machine learning. Some cloud or HPC familiarity (AWS) is desirable.

## 1.5. Expected development of the PhD candidate's knowledge and skills

The PhD candidate is expected to become an expert in the field of bayesian modeling of data, high performance computing, and spectroscopy of exoplanetary atmospheres.