Improving the detection capability of forming exoplanets in hyperspectral data with inverse problem approaches

Context & research background

Exoplanets are planets orbiting other stars than the Sun. Since their luminosity is orders of magnitude smaller than their host star, finding them and characterizing their properties is extremely challenging and necessitate very careful data analysis and data calibration. For years, astronomers have been using empirical calibrations to improve data quality, but recent publications led by data scientists have shown that an *inverse problem approach* with minimal empirical information can improve the data reduction, especially on 3D hyperspectral data produced by integrated field spectrographs, where each pixel of an image has an associated spectroscopic information. The approach does remove very efficiently systematic errors from the early data reductions steps, thus improving the full reduction chain. These improvements are key to allow the most advanced data algorithms to reveal their full potential, enabling reliable analysis of the spectroscopic signatures of exoplanets.

The latest and upcoming generation of integral field spectrographs such as MUSE, SINFONI and soon ERIS on the Very-Large Telescope (ESO, Chile) can disentangle the sparse spectral emission features of forming planets from the dominant stellar halo and promise to boost exoplanet detection capabilities **[1]**. In that context, the implementation of inverse problem approach on these data appear as a key step for lowering the false positive detection of these spectral features and for providing reliable information on the detected objects.

Objectives of the project & Description of work

The intern will start from an existing algorithm based on the inverse approach (PIC) and presently applied to low resolution integrated field spectrographs **[2]**. She/He will adapt it to the case of the higher resolution integral field spectrographs mentioned above. The supervisors will provide benchmark datasets - some including real exoplanets - reduced with the “traditional” empirical approach (already implemented) to estimate advantages and drawbacks of each approach. This internship offers to develop these approaches on such data for the first time and we therefore expect the work to identify the main leverage points in the method.

The internship will last from 3 to 5 months (to be discussed with the applicant). The work is intended to be introductory of a PhD thesis (funding secured) at the fringe between data science and astrophysics that will be opened in the fall of 2021.

We are looking for a master 2 student (of equivalent) with a strong background in signal processing and interests in astrophysics. The student will be part of a vibrant team of researchers from the Institut de Planétologie et d’Astrophysique de Grenoble and is expected to interact with data scientists from the CRAL (Lyon) laboratory.

References (list of the main bibliographic references related to the project proposal)

[1] *Original use of MUSE’s laser tomography adaptive optics to directly image young accreting exoplanets. Girard et al. 2020.* https://arxiv.org/pdf/2003.02145.pdf

[2] PIC: a data reduction algorithm for integral field spectrographs Application to the SPHERE instrument. *Berdeu et al. 2020*. https://www.aanda.org/articles/aa/abs/2020/03/aa36890-19/aa36890-19.html

Keywords

astrophysics, exoplanets, data reduction, inverse problem, linear algebra

Prerequisite

- master 2 or equivalent in data science and/or applied mathematics.
- enthusiasm to deal with open questions
- excellent programming skills (Python)
- ability for team work

Supervisors (with contact information)

Philippe Delorme, astronomer at IPAG :philippe.delorme@univ-grenoble-alpes.fr
Mickael Bonnefoy, CNRS researcher at IPAG : mickael.bonnefoy@univ-grenoble-alpes.fr

Location/Laboratory (with link to the website)

IPAG 414 rue de la piscine campus universitaire de Grenoble
https://ipag.osug.fr/

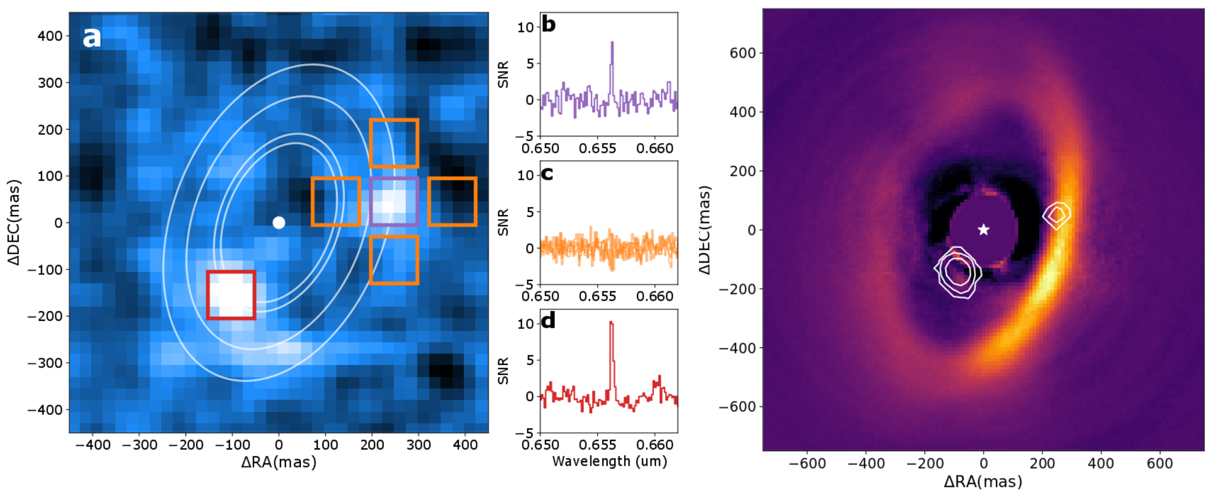

Figure 1: Left: detection of the light emitted by two forming exoplanets (white) orbiting the star PDS70 (at the center). The sparse emission of the planets (Hα, 656nm) shown here has been obtained from hyper-spectral data produced by the MUSE instrument. Right: image of the disk of gas and dust around the star revealed at sub-millimeter wavelengths. The planets are carving a large cavity within the disk while forming.