

# Optimizing exoplanet detection using coronagraphy and a digital micromirror device

Jainara Baptista Gaspar & Alexandre José Tuoto Silveira Mello

<sup>1</sup> Graduate Program in Physics and Astronomy, Federal University of Technology — Paraná (UTFPR)  
 e-mail: jainara@alunos.utfpr.edu.br

**Abstract.** In order to optimize telescopes used for detecting exoplanets, we use adaptive optics instrumentation to combine coronagraphy techniques, which aim to block the light from the main star so that fainter objects around it can be observed, with a DMD (Digital Micromirror Device), which acts as a dynamic adaptive mask to attenuate the diffraction halos caused by the suppression of starlight.

**Resumo.** A fim de otimizar telescópios que trabalham para a detecção de exoplanetas, utilizamos a instrumentação em óptica adaptativa para combinar técnicas de coronagrafia, que visa bloquear a luz da estrela principal para que seja possível observar objetos mais tênues ao seu redor, com dispositivo DMD (Digital Micromirror Device), que atua como máscara adaptativa dinâmica objetivando atenuar os halos de difração causados pela supressão da luz estelar.

**Keywords.** Instrumentation: adaptive optics

## 1. Introduction

Coronagraphy was initially developed to study and analyze the solar corona. Over time, its application has expanded and is now widely used to explore binary systems and distant exoplanets. In simple terms, a coronagraph works by introducing a mask that blocks direct starlight. However, the stellar light still produces a diffraction halo (known as the Point Spread Function (PSF)) that spreads around the stellar image. The goal of coronagraphy is not only to block the direct light but also to suppress the diffraction halo, which remains the main limitation to achieving high-contrast imaging (Kenworthy & Haffert 2025).

The masking used to suppress the diffraction halo is what we call “apodization,” which adjusts the PSF to provide better visualization of objects around the main star (Fig. 1). The DMD (Digital Micromirror Device) is a chip containing thousands of micro mirrors that functions as a dynamic apodizer in the telescope, i.e., with it, it is possible to manipulate the masks according to the required PSF, modulating the light intensity in each pixel and creating dynamic and specific patterns.

## 2. DMD and the Dark Speckle Method

Speckles are random interference patterns typically caused by atmospheric turbulence. The interference generated in the focal plane can be destructive (dark speckles) or constructive (bright speckles) (Boccaletti et al. 2001). The use of a DMD can help suppress these speckles by modifying the shape of the diffracted image, causing the speckles to move and spread out, thus reducing quasi-static speckles that might otherwise be mistaken for stellar companions.

## 3. Methodology

The combination of coronagraphic techniques with a DMD will be implemented through software simulation. To shape the PSF, we use a linear combination of Zernike polynomials. The desired PSF is defined, and the pupil mask is represented as a sum of Zernike modes. The resulting PSF is then computed using a Fourier Transform (Osborn et al. 2009). Determining the pupil pattern that produces a specific PSF is a nonlinear inverse problem with multiple local minima, making optimization challenging. Additionally, the continuous pattern must be converted into a binary format compatible with the DMD.

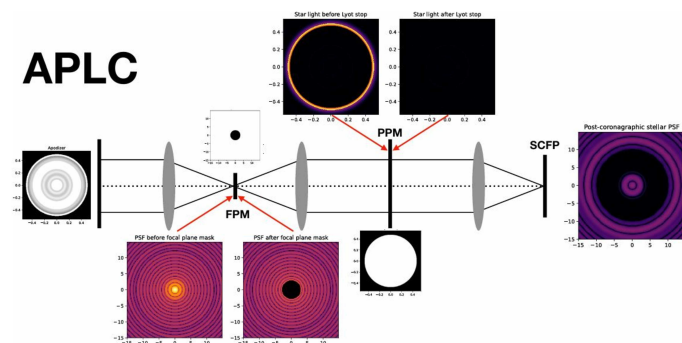
$$PSF = |\mathcal{F}P(x, y) \bullet M(x, y)|^2 \quad (1)$$

## 4. Expected results

With these adaptations, we expect to redistribute the diffracted light, thereby reducing both the diffraction halo and speckles in the PSF. This will increase the contrast between the main star and nearby faint companions. By using the DMD, we aim to achieve contrast levels on the order of  $10^6$  at angular separations of  $2 - 5\lambda/D$ , as illustrated in Fig. 2.

## References

- Boccaletti, A., Moutou, C., Mouillet, D., et al. 2001, A&A, 367, 371  
 Kenworthy, M. A. & Haffert, S. Y. 2025, ARA&A, 63, 179



**FIGURE 1.** Apodized Phase Lyot Coronagraph (Kenworthy & Haffert 2025).

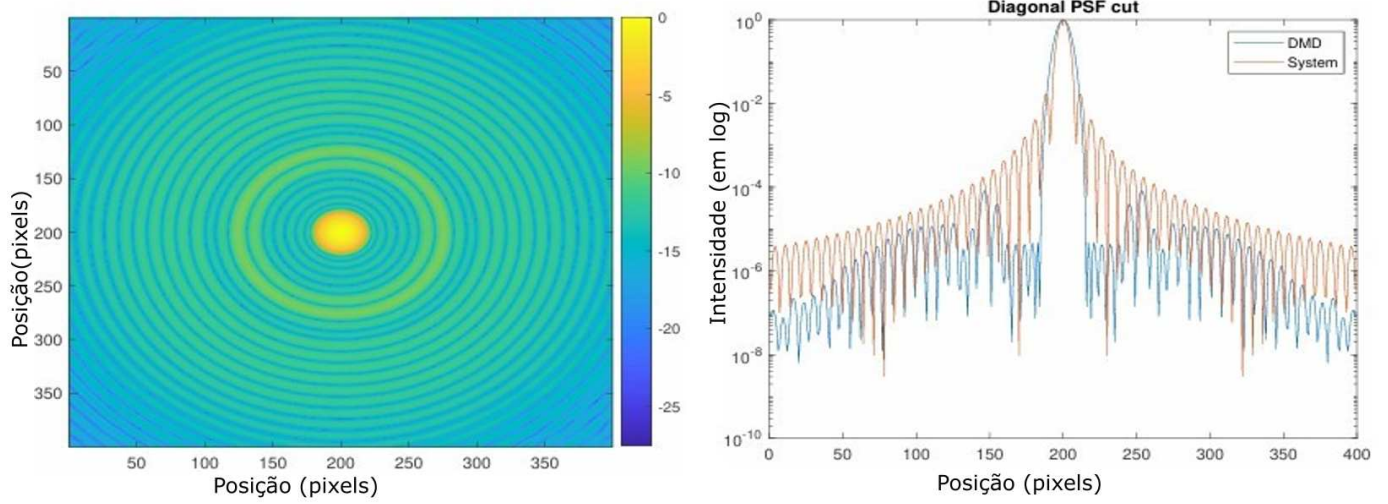


FIGURE 2. PSF coronagraph for the closed ring case (Mello 2025).

Mello, A. J. T. S. 2025, (Private Communication)

Osborn, J., Myers, R. M., & Love, G. D. 2009, Optics Express, 17, 17279