Post-doc position – PEPR Origins

Multi-epoch recombination in high-contrast imaging techniques for exoplanet detection with HARMONI

Subject:

High-contrast imaging surveys performed in recent years (SHINE, GPIES) have revealed that formation mechanisms are not very efficient in producing giant planets with large separation (> 10 AU). Upcoming high contrast imaging instruments, including SPHERE+ on the VLT and HARMONI on the ELT, aim to probe the population of giant planets at separations smaller than 10 AU. Despite the anticipated improvements in contrast levels, detecting these planets (contrast > 10^6 at 50-100 mas) remains a formidable challenge.
To enhance the detection capabilities of these next-generation instruments, we have developed K-Stacker (Le Coroller, et al., 2015; Nowak et al., 2018; Le Coroller, et al., 2022), an algorithm (https://github.com/kstacker/) that allows to search for hidden planets (e.g. S/N < 2) in image series using a brute-force exploration of the possible orbital parameters (see Fig. 1).

The aim of this project is to assess the performance of K-Stacker in detecting young Jupiter like planets in images acquired by the HARMONI instrument. The project will include the automation of tests with extensive fake planet injections in simulated HARMONI images, aiming not only to determine detection statistics (true/false positive and negative rates) but also to evaluate the accuracy of the recovered orbital parameters. For planets detectable in each epoch, we will compare the orbital parameters found by K-Stacker against those derived from traditional MCMC methods on the positions of the planets. The postdoc will explore several potential enhancements to K-Stacker, such as integrating MCMC calculations (e.g., using emcee python module) for robust orbital parameter determination.
The candidate will also use K-Stacker to evaluate the best observing strategy, i.e., to find the optimal splitting of observations (e.g., number of observing epochs, spacing between each pose) to maximize the probability of detection of new planets in a minimum total exposure time with HARMONI. This work paves the way for the development of new algorithms required to detect planets like those in our solar system through reflected light: mature Jupiter previously identified via radial velocity with the Roman Space Telescope, and Earth-like exoplanets with NASA's Habitable Worlds Observatory.

The successful candidate will join the GSP team at LAM, which is involved in major international high-contrast imaging projects. Once K-Stacker optimized, the postdoc will be able to *re-run* the algorithm on archival data (e.g., Survey SPHERE SHINE) to search for new planets in the multi-epoch observations (e.g., HD 95086 c, etc.).

References:

Le Coroller, H. et al. 2015, "a new way of detecting … exoplanets …", ESS meeting #3, id.112.06. [link]
Nowak, M. et al. 2018, A&A, "K-Stacker: Keplerian image recombination…", 615, A144 [link]
Le Coroller, H. 2022, A&A, "Efficiently combining α CenA multi-epoch HCI data", 667, id.A142 [link]

Location:

Laboratoire d'Astrophysique de Marseille (équipe GSP)
Pôle de l'Étoile Site de Château-Gombert
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Position Duration: 1 Year

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Deadline for application: April 1st, 2025

Start date: September 1st, 2025 or earlier if available

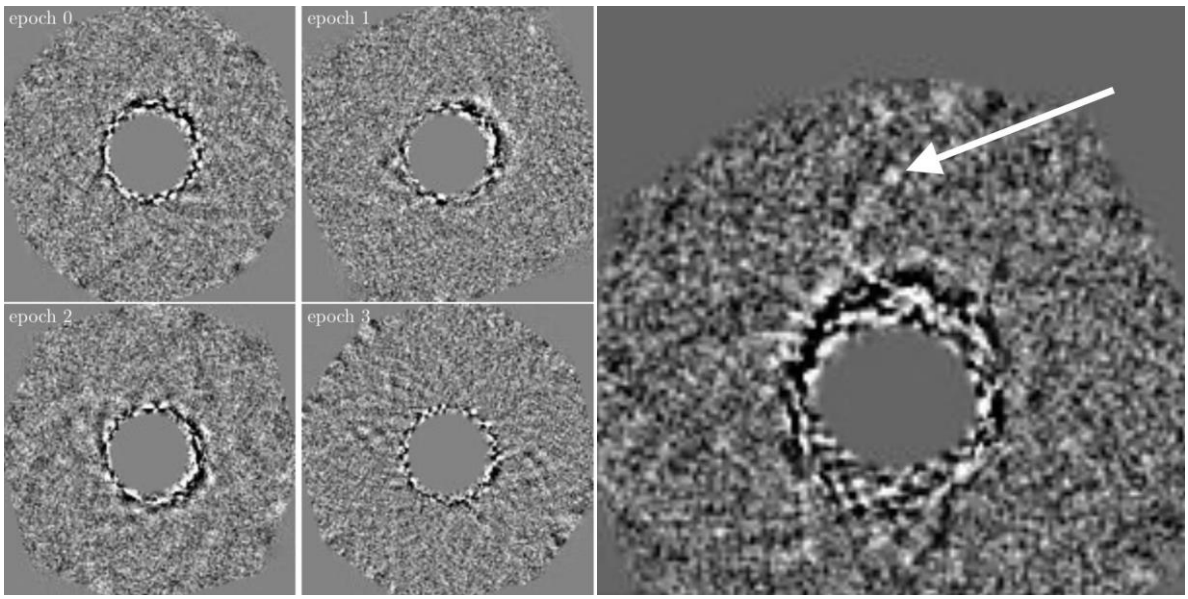

Fig.1 **Left:** Reduced (PCA-ASDI) HARMONI simulated images in which a planet with dmag=17 remains undetected in individual epochs at S/N ≃ 3. **Right:** The planet is successfully detected at S/N_KS = 6 by K-Stacker using the four reduced images shown on the left.