# NEXT-GENERATION CFHT SURVEYS: THE AMAKIHI PROJECT, WIDE SCIENCE FROM WIDE SPECTRA

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**Abstract.** The 3.6m Canada-France-Hawaii Telescope (CFHT) is well-known for its large surveys. The next generation of those surveys is in the preparation phase. It will consist of more than 1000 CFHT nights between 2027 and 2031. Part of the survey will make use of the combined spectropolarimetric suite of CFHT consisting of ESPaDOnS and SPIRou, coupled by the Wenaokeao/VISION device. The scientific objectives of the Amakihi project using these instruments include: exoplanet detection and characterisation around nearby cool stars and transiting candidates, the early stages of stellar and planetary formation, exoplanet atmospheres, various flavours of stellar physics, and galactic astronomy.

Keywords: surveys, exoplanets, stars, stellar formation, atmospheres, archeoastronomy, spectropolarimetry, CFHT

## 1 Introduction

The 3.6m Canada-France-Hawaii Telescope is located atop the Maunakea 4200m dormant volcano in Hawaii, a mountain of cultural significance (Cuby et al 2024) and of extraordinary atmospheric conditions for astronomy. CFHT has a long tradition of offering large amounts of nights for major surveys, ensuring homogeneity in the observing strategy and data processing. Currently, large surveys are conducted at CFHT using the wide-field optical camera Megacam and the near-infrared spectropolarimeter SPIRou. They will end in 2027. CFHT is now offering legacy-survey time for the next period, from mid-2027 to 2031. In this article, the survey project Amakihi is presented, which particularly aims at making the best use of this time with the instrument Wenaokeao/VISION.

## 2 Wenaokeao/VISION

ESPaDOnS and SPIRou are in the instrument suite of CFHT. They both are spectropolarimeters that measure the polarization of light in the stellar lines at high spectral resolution (resolving power 70000). ESPaDOnS is an optical spectrograph covering in one shot the 370-1030 nm wavelength range, while SPIRou is an infrared spectrograph covering 970 to 2500 nm. Details about these instruments can be found in Donati et al (2006) and Donati et al (2020). In addition to their high-resolution spectroscopic use, they both offer the possibility to measure the magnetic field of stars (generating polarization in stellar lines), as well as other processes (López Ariste et al 2025). In addition, SPIRou is stabilized in pressure and temperature and allows a high-precision measurement of the radial velocity (RV) of stars, optimal for the search for exoplanet through the gravitational pull on their host star (Donati et al 2020; Moutou et al 2024). Operating in the optical and near-infrared domains, they are sensitive to different processes at the surface of stars, and they see different lines. In the near-future, it will be possible to use them conjointly using the VISION or Wenaokeao concept.

VISION (a.k.a. Wenaokeao) consists in co-mounting the ESPaDOnS and SPIRou Cassegrain units to use them consecutively (using mirrors), or simultaneously (using dichroics). The device is being built at Observatoire Midi-Pyrénées and IRAP in Toulouse and will be installed and tested at the telescope mid 2026. SPIRou is positioned at the usual Cass focus, on the nIR beam emerging from a pair of tilted dichroics while ESPaDOnS is installed at a displaced Cass focus, on the optical beam featuring 2 reflections from tilted dichroics. The

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mirror mode allows observing either with SPIRou or with ESPaDOnS, with the goal of switching easily (if not frequently) from one instrument to the other. It offers some flexibility to the scheduling without modifying the actual instrument performances. When the dichroic mode is used, the blue part of the beam goes to ESPaDOnS, while the nIR part of the beam goes to SPIRou. Both instruments will be optimally co-aligned and guiding is also optimized.

The simultaneous use of ESPaDOnS and SPIRou has been identified as a strong scientific driver (Fig. 1). Using them both also increases their availability at the telescope, which is particularly beneficial when looking at evolving phenomena (like a planetary signal or magnetic field). In addition, the widest spectral range increases the science return (like for atmospheric signatures or sensitivity to faint polarized signals). In the following, we list the science objectives identified for the next CFHT survey to be proposed with VISION/Wenaokeao*. Evidently, other science topics than those presented here can be envisioned with this instrument, for which traditional PI time will be available and open to opportunities.

## 3 The Amakihi survey project

The science drivers of the Amakihi† project will be selected to make the best use of 1) the simultaneous observing in optical and nIR domains; 2) the long duration of the program; 3) at least one of the unique instrumental performances (spectropolarimetry sensitivity, velocimetric precision, high throughput). With these criteria in mind, we have defined four main scientific work packages, and two additionnal ones, if time allocation allows :

- The search for planets around the most nearby cool stars - The goal is to explore the architecture of evolved planetary systems, with a special focus on habitability and the temperate zone around nearby stars. Continuing on the SPIRou programs, we aim at contributing to planet occurrence statistics and to exoplanet population studies in the solar neighborhood, and at providing suitable targets for follow-up characterization investigations. For this, we'll conduct RV monitoring of nearby stars, characterize the star (rotation, activity, magnetism) and planets (mass, period, eccentricity) over timescale from day to years. The combination of optical and nIR studies are particularly important to distinguish stellar chromatic activity signatures from planetary achromatic signals (Carmona et al 2023). All stellar hosts will also be observed in spectropolarimetry, with an enhanced sensitivity due to the wide spectral range.

- The mass characterization of exoplanets transiting cool stars - By performing RV measurements on transiting exoplanet candidates, one can not only confirm their planetary nature, but also measure their true mass, their bulk density, and their orbital eccentricity, revealing for instance the wide diversity of the frequent super-Earth planets - telluric to ocean-like to gazeous internal structures. The fraction of mass present in the core and in water are of particular interest. Such constraints help understand the formation and migration scenarii. With a RV long-term follow-up, one can also search for longer periods planets, whatever their orbital inclination is, and better picture the full system. We will select transiting candidates identified by TESS, GAIA, and PLATO as well as the sample selected for the ARIEL survey. As previously, circular polarization will allow simultaneously constraining stellar activity and magnetism of stellar hosts.

- The formation of stars and planetary systems and the role of the magnetic field - VISION/Wenaokeao will be suited to study the magnetic fields of newborn stars as well as the magnetospheric accretion from their inner accretion discs. With the possible presence of short-period massive planets (that can be detected with their achromatic RV signature), we'll study the inner architectures of stellar systems in their early stages as well as the evolution of their magnetic fields. We'll also diagnose accretion / ejection patterns of these young stars, using multiple lines in the optical and nIR domains, in complement to what is done with interferometry. This will allow to further constrain magnetospheric accretion / ejection models, dynamo models of young stars, and planet formation models.

- The study of exoplanetary atmospheres - Transmission spectroscopy from ground-based telescopes and high-resolution spectrographs is highly complementary to current JWST exploring of exoplanetary atmospheres. With SPIRou, we have access to the exosphere in the HeI line as well as molecular lines in the

*The name chosen for this device by Hawaiian students means "the earliest glow of light".
†A Hawaiian native bird

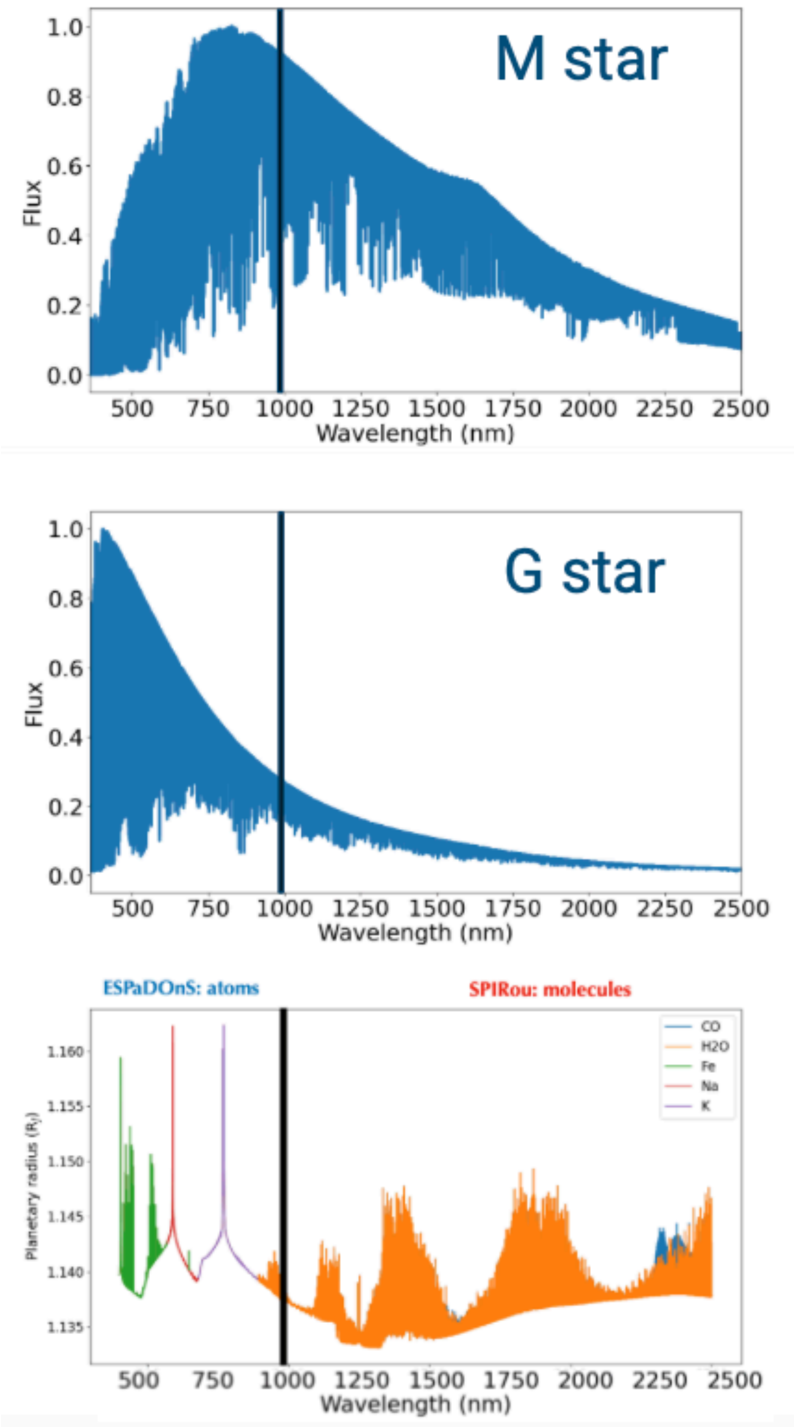


**Fig. 1.** Wenaokeao simulated spectral range for three types of objects: an M star, a solar-like star, and a giant exoplanet atmosphere, from top to bottom

stratosphere ($H_2O$, $CH_4$, TiO, and CO); in the ESPaDons range, we additionnally get atomic lines, and simultaneity is key due to seasonal variations, stellar activity, and the transit light source effect. The chemical mixing, formation history, and 3D atmospheric dynamics in giant planets will thus be investigated. This will help in particular to link these atmospheres with the interior structure and relate them to formation and evolution scenarios. We aim at probing all phases, i.e., day and night sides.

- The magnetic field of stars along the HR diagram - As a by-product to the planetary investigations, we will get spectropolarimetric information for free, and be able to detect, characterize, or place upper limits on all stellar magnetic fields. Magnetic fields affect all types of stars, at all evolution stages and can also be explored further, on stars unsuitable for planet search but with a general interest to investigate what processes lead to the onset and evolution of stellar magnetic fields. We'll investigate how magnetic fields modify stellar internal structure, internal dynamics, or atmospheres, and how magnetic fields influence stellar evolution after the main sequence, and shape stellar mass loss. A stellar sample throughout the HR diagram will thus be probed, exploring age, mass, rotation and multiplicity properties. Other physical processes generating light polarization can also be explored.
- Some questions of archeoastronomy - The study of stellar populations through galactic archeology is finally envisioned. For instance, very old and/or extremely metal-poor stars in the Milky-Way are direct fossils of the earliest epochs of star formation in the Universe and of our Galaxy's assembl. The brightest of those will be identified by Gaia and their chemodynamics can be constrained by high-res spectroscopy, with many lines of interest in the wide spectral range of Wenaokeao. In addition, Gaia identifies a wealth of binaries, including black holes orbited by low-mass stars, that yield unique information on binary star evolution; such long orbits are ideally monitored over a long-term survey.

Stellar and exoplanetary science being led by space missions, it must be noted that synergies are extended on all these topics with the following space observatories: i) TESS, since 2018, ii) PLATO, for which 20% of the South field and the Northern field are visible from Hawaii, iii) Gaia which DR4 will generate many new alerts for spectroscopic follow-up, iv) ARIEL for target selection during the preparation phase, v) JWST for complementary science, vi) the longer-term HWO, LIFE, ELT projects for which the best characterization of nearby systems will be essential.

## 4 Conclusions

ESPaDOnS and SPIRou have been used for an average 86 nights per semester in the last period from 2019 to 2025. This is also the minimum amount of nights required to explore all these fascinating scientific ideas with VISION/Wenaokeao, with a net gain in using both instruments simultaneously.

In conclusion, all interested colleagues from the France, Canada, Hawaii institutes are welcome to contribute to the project and are invited to contact us. The call for proposal is scheduled to be issued in the fall 2025 with a deadline in spring 2026. Operations should start in semester 2027B.

## References

Cuby J.-G., Matsuda C., Matsuda R. et al, 2024, SPIE 13094E, 19

Donati J.-F., Kouach, D., Moutou C. et al, 2020, MNRAS 498, 5684

Donati J.-F., Catala C., Landstreet J and Petit P., 2006, ASPC 358, 362

López Ariste A., Pilate Q., Lavail A. and Mathias P., 2025, A&A 699, 161

Carmona A., Delfosse X., Bellotti S. et al, 2023, A&A 674, 110

Moutou C., Ould-Elhkim M., Donati J-F. et al, 2024, A&A 688, 196