The SPIRou Legacy Survey

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Approved and accepted by	**Date**

KEY WORDS – SUMMARY

Summary	This document describes the various aspects of the SPIRou Legacy Survey (SLS), starting from an overview of the science case to the technical feasibility and to the details of the project management
Keywords	SPIRou Legacy Survey (SLS), SLS Steering Group, SLS Science Consortium, SLS Work-Packages, SLS Data Processing center, SLS Registered Users, SLS Data Access Policy, SLS Publication Policy

MODIFICATIONS

Issue	Rev.	Date	Modified pages
1	0	28/04/14	Preliminary FDR version
1	1	16/05/14	Version submitted to the SSC, the SAC and the BoD

DISTRIBUTION LIST

REFERENCE DOCUMENTS

N°	Name	Reference – Version
RD1	Science Case	SPIROU-2000-IRAP-RP-00503
RD2	Monte-Carlo simulations of RV surveys	SPIROU-2100-UDM-TN-00698

1. Executive summary

1.1. Scope and coverage

SPIRou is the new near-infrared (nIR) spectropolarimeter / velocimeter for CFHT. SPIRou aims in particular at becoming world-leader on two forefront science topics, (i) the quest for habitable Earth-like planets around very-low-mass stars, and (ii) the study of low-mass star & planet formation in the presence of magnetic fields. The science programs that SPIRou proposes to tackle are forefront, ambitious and timely – ideally phased in particular with complementary space missions like TESS and JWST.

The amount of observing time required to complete the two main science goal of SPIRou is large. In this context, SPIRou only makes sense if coupled to a SPIRou Legacy Survey (SLS) of ~500 CFHT nights on a timescale of 5 yr starting with the commissioning of SPIRou, and focussed mostly on both main science goals. The current plan is to divide the SLS into three main components, two of them being dedicated to exoplanets around M dwarfs, and one focussed on large-scale magnetic felds & young hot Jupiters of class-I-III protostars.

The observations comprising the SLS are in particular intended to achieve the following objectives: (a) accomplish selected large-scale community-defined scientific programs and (b) provide the community with an extensive, homogenous, well characterized, and high quality database having the potential for a wide range of long-lasting scientific applications. This makes the SLS very similar to its predecessor – the CFHTLS w/ MegaCam.

We describe herein an overview of the general scientific context and immediate objectives of the SLS and demonstrate its technical feasibility. We also present a first proposition of the SLS structure and management, as well as of the Data Access and Publication Policies. We finally propose a schedule for converging from this first version to a mature SLS proposal that can be approved by the CFHT BoD in 2014 Dec after iteration with the CFHT SAC and the SLS science consortium at large.

1.2. Glossary

CFHT	Canada-France-Hawaii Telescope
nIR	near InfraRed
RV	Radial Velocity
HZ	Habitable Zone
ESO	European Southern Observatory
cTTS	classical T Tauri stars
wTTS	weak-line T Tauri stars
hJ	hot Jupiter
SFR	Star Forming Region
SSC	SPIRou Steering Committee
SLS	SPIRou Legacy Survey
SLS-PS	SPIRou Legacy Survey – Planet Search

SLS-TF	SPIRou Legacy Survey – Transit Follow-up
SLS-MP	SPIRou Legacy Survey – Magnetic Protostar / Planet survey
SLSSC	SPIRou Legacy Survey Science Consortium
SLSSG	SPIRou Legacy Survey Steering Group
SLSDA	SPIRou Legacy Survey Data Access policy
SLSPP	SPIRou Legacy Survey Publication Policy
SLSDP	SPIRou Legacy Survey Data Processing center
SLSWP	SPIRou Legacy Survey Work Package
SLS-RU	SPIRou Legacy Survey – Registered User status
CADC	Canadian Astronomy Data Center
LP	Large Program

2. Science background

We start by recalling the science background underlying the two main goals of SPIRou, to which the SLS is devoted.

2.1. Detecting exoplanets around low-mass dwarfs

The first main goal of the SLS is to **search for, and to characterize, exo-Earths orbiting low-mass stars – with a particular interest for planets located in the habitable zone (HZ) of their host stars.**

Since the pioneering discovery of a giant planet around 51 Peg (Mayor & Queloz 1995), about 1,600 extra-solar planets have now been detected, revolutionizing planetary science by placing our unique solar system into a much broader context and making the study of exoplanetary systems as one of the most exciting areas of astronomy today. Identifying habitable Earth-like planets and searching for biomarkers in their atmospheres is among the main objectives of this new century's astronomy, motivating ambitious space missions (e.g., JWST, TESS, CHEOPS, PLATO). SPIRou will play an essential role in providing a few of the very best targets for a planet characterization program with the JWST, and in allowing us to estimate the frequency of habitable planets in the solar neighborhood.

Among the various techniques developed to detect exoplanets, velocimetry and transit photometry are very efficient and complementary. Whereas RV studies look for Doppler shifts induced by orbiting planets in the spectrum of their host stars, giving access in particular to the planet mass, long-term photometric monitorings search for regular occultations caused by planets transiting the visible stellar disc, yielding the planet radius. In most cases, RVs are mandatory to establish the planetary nature of the transiting candidates. For exoplanets detected with both techniques, one can estimate their densities and thus constrain their bulk compositions. Transiting planets also allow numerous key investigations, including atmospheric studies, either in absorption (through transits) or in emission (through occultations), dynamic analyses from possible timing variations, or obliquity measurements.

In this context, much interest has been focused on low-mass M dwarf stars, around which **habitable super-Earths are much easier to detect**. To be considered potentially habitable, planets must be within the proper range of orbital distances where liquid water can be stable on their surface. This constraint also imposes limits on the atmospheric pressure at the planet surface, and thus indirectly on the planet mass. The range of orbital distances for HZs also strongly depends on the mass (and thus on the temperature) of the host star, with lower temperatures moving HZs closer in. A habitable exo-Earth around an M dwarf thus produces a much larger RV wobble (4x to 8x for M4 and M6 dwarfs, respectively) compared to the same planet orbiting a Sun-like star. A 1m/s RV precision is sufficient to detect habitable telluric planets around M dwarfs. In addition, the much shorter orbital periods (of order of weeks) vastly decrease the timescale over which observations must be collected with such accuracy. This is the way that the first likely habitable super-Earths were discovered (Udry et al 2007; Mayor et al 2009; Delfosse et al 2013; Bonfils et al 2013a).

Planetary photometric transits are also much deeper for M dwarfs as a result of their smaller stellar radii – by 11x and 45x for M4 and M6 dwarfs, respectively. The orbital periods being shorter, transits of habitable planets are also more frequent for M dwarfs, as well as more likely in the case of habitable planets first detected with RVs. A prime goal in coming years will be to discover exo-Earths and super-Earths whose **atmosphere can be scrutinized and characterized** in the future, with instruments such as the JWST or the E-ELT. Since atmospheric characterization primarily requires as deep an atmospheric transit as possible on the one hand, and as bright a star as possible on the other hand (in the nIR, where absorption from atmospheric molecules mostly concentrates), M dwarfs are optimal targets for this quest. Today, only a handful of bright transiting systems have been discovered - most being giant gaseous planets - but many more are expected with forthcoming space missions like TESS or PLATO. As the most promising candidates from TESS and PLATO for characterization with the JWST will orbit M-dwarfs, nIR velocimeters like SPIRou will be essential to validate the planet candidates and measure their masses.

In addition, statistical properties of planets around M dwarfs (compared to those around FGK-type stars, which are the most numerous hosts of known exoplanets) can provide key information on planetary formation, and in particular on the sensitivity of planet formation to initial conditions in the protoplanetary disc. M dwarfs vastly dominate the stellar population in the Solar neighborhood and are likely hosting most planets in our Galaxy; this makes such studies even more crucial.

Finally, pioneering studies with HARPS at the ESO 3.6m demonstrated that super-Earths with orbital periods <100 d are more numerous around M dwarfs than around Sun-like stars, with an occurrence frequency close to 90% (Bonfils et al 2013b); moreover, about half of these super-Earths are potentially located in the HZs of their host stars. The newest results from Kepler fully confirm these estimates (Gaidos 2013; Kopparapu et al 2013). Only a few have been detected today, mainly in the optical domain using existing velocimeters such as HARPS, capable of reaching a RV precision of 1 m/s for only the ~100 brightest M dwarfs. This is clearly insufficient, either to have a realistic chance of detecting several transiting habitable super-Earths, or to achieve a proper statistical survey of rocky exoplanets around M dwarfs. **Making such observations in the nIR domain** where these targets are brighter **is mandatory** to detect, characterize, and study a large number of such planets, whose existence is known.

M dwarfs however suffer from higher activity than FGK stars with similar rotation rates. This activity (spots, plages, magnetic fields) tends to generate spurious signals in RV curves (activity jitter) and thus to limit the RV sensitivity to low-mass planets. This limitation is significantly smaller in the nIR than in the visible, giving SPIRou an additional advantage over existing instruments. Moreover, modeling this activity and the underlying magnetic field, and filtering out its effect on RV curves, will allow to regain RV sensitivity, to maximize planet detection rates and to efficiently reject false positives. **Spectropolarimetry carried out simultaneously with precision velocimetry offers a novel and potentially quite efficient way of performing this filtering.**

2.2. Magnetic fields & star / planet formation

The second main goal of the SLS is to explore **the impact of magnetic fields on star and planet formation**, by detecting and characterizing magnetic fields of various types of young stellar objects (e.g. classical T Tauri stars, embedded class-I protostars, young protostellar accretion discs). This quest will expand the pioneering surveys carried out in the framework of the studies with the optical spectropolarimeter ESPaDOnS at the CFHT. Studying how Sun-like stars and their planetary systems form comes as a logical complement to the direct observation of exoplanets. Within the last decades, **this research field underwent major observational and theoretical advances**, for instance by clarifying the crucial role of magnetic fields, not only on the gravitational collapse of giant molecular clouds (e.g Hennebelle et al 2008a), but also on the formation of accretion discs and pre-stellar cores (e.g. Hennebelle et al 2008b) from which stars and their planetary systems are born.

At an age of ~1 Myr, low-mass protostars emerge from their dust cocoons, most often surrounded by a massive accretion disc in which planets form and migrate. This is the so-called «classical T Tauri» (cTTS or class-II protostar) stage – one of the best studied phase of stellar formation thanks to its relative accessibility to existing optical instruments. Observations suggest in particular that magnetic fields of cTTSs are strong enough (i) to disrupt the central regions of the surrounding accretion discs, thereby generating magnetospheric gaps at the heart of the discs, (ii) to guide the plasma from the discs to the stars along discrete magnetospheric accretion funnels, and (iii) to drastically slow-down their rotation rates by magnetically coupling stellar surfaces with the inner edges of the accretion discs (e.g. Bouvier et al 2007).

Spectropolarimetric observations secured with ESPaDOnS in the optical domain enabled to disclose, for a small sample of ~10 cTTSs with masses <1.5 M_{sun}, the large-scale magnetic topologies that link low-mass protostars to their accretion discs, and to demonstrate that **this topology strongly relates to the internal structure of the protostar** and thus to both its age and mass (e.g. Donati et al 2013). When the protostar is young enough and has a low-enough mass to be fully convective, its large-scale magnetic topology is dominated by a strong dipolar-like field roughly aligned with the stellar rotation axis – thereby providing a quantitative explanation of the physical star/disc coupling mechanism through which the protostar is strongly spun down (e.g. Zanni et al 2013). These observations are however still rather sparse as a result of the relative faintness of cTTSs at optical wavelengths. Moreover, younger class-I protostars (with ages <1 Myr), for which magnetic fields are expected to have an even bigger evolutionary impact, are still out of reach of existing instruments, their dust cocoon hiding them completely from view at optical wavelengths.

Studying the more evolved class-III protostars that have mostly dissipated their accretion discs (the so-called "weak-line T Tauri" stars or wTTSs) allows one to investigate **how different their large-scale fields are from those of cTTSs protostars that are still surrounded by their accretion discs** (called classical T Tauri stars / cTTSs), and from those of mature main-sequence stars; being the missing link in our knowledge of magnetic topologies of low-mass stars, wTTSs should reveal the kind of magnetospheres with which Sun-like stars initiate their unleashed spin-up as they contract towards the main-sequence. Observations carried out with ESPaDOnS are presently ongoing, but again limited to a small sample of stars.

Extending such observations to the nIR domain is the most logical step forward. The targets are brighter in the nIR than in the optical, while the Zeeman effect is stronger at longer wavelengths. **Spectropolarimetric observations with SPIRou will thus allow us to survey larger samples**, including in particular fainter, younger, and/or more embedded targets.

3. Immediate objectives

We now outline in more details the science programs of the SLS.

3.1. Detecting exoplanets around low-mass dwarfs

By giving access to a much larger sample of stars than existing instruments, SPIRou will considerably expand our chances to **detect and characterize Earth-like planets** in the HZ of low-mass stars, and to achieve a proper statistical survey of rocky exoplanets around M dwarfs. SPIRou will also crucially contribute to the forthcoming extensive photometric surveys of **transiting planets around M dwarfs.** We thus propose that the search for Earth-like exoplanets around low-mass dwarfs to be carried out within the SLS consists of 2 main components:

- a systematic RV monitoring of nearby M dwarfs, referred to as the SLS Planet Search (SLS-PS);
- a RV follow-up of the most interesting transiting planet candidates uncovered by future photometry surveys (mostly from space, e.g., with TESS, but also from the ground, e.g., with NGTS and ExTrA), referred to as the SLS Transit Follow-up (SLS-TF).

We detail both SLS components below.

3.1.1. RV monitoring of nearby M dwarfs

By 2017, the number of known habitable super-Earths will still be fairly small – in particular for those orbiting the nearest stars, i.e., the only ones for which atmospheric characterization with the JWST will be feasible in practice. Only large surveys can provide a high enough number of detections to carry out a proper characterization of habitable super-Earths. We thus propose to carry out an ambitious and extensive RV monitoring capable of:

- identifying **several tens of habitable Earth-like planets** in the immediate neighborhood of the Solar System, i.e., orbiting nearby M dwarfs;
- determining the **fraction $\eta_\oplus$ of habitable Earth-like planets** around M dwarfs to a goal accuracy of ~10-15%.

To reach this aim, we need a **systematic survey of ~360 nearby M dwarfs** of different masses, with typically 55 visits per star (each visit providing a spectrum w/ S/N~170 and yielding an average RV measurement at a precision of ~1 m/s – see RD1) – **requiring in total ~300 CFHT nights** (see Sec 4).

Monte Carlo simulations (see RD1 & RD2) demonstrate that the SLS-PS will detect **~290 new exoplanets**, including ~200 with masses <5 $M_\oplus$ and ~35 of them lying in the HZ. By breaking down the full stellar sample in 0.5-dex bins in orbital period and mass, the SLS-PS will provide occurrence rates of Earth-like planets in each mass / period bin with a ~20% accuracy. In particular, **the SLS-PS will enable to determine the frequency of habitable Earth-like planets around M dwarfs $\eta_\oplus$ to an accuracy of ~16%.** Lowering further our estimate of $\eta_\oplus$ down to ~12% will require expanding our observing sample up to ~600 M dwarfs – for another ~300 CFHT nights. We propose to achieve this second exploration phase later on and outside the SLS per se, once the SLS-PS survey is nearing completion and using the results of the SLS-PS to optimize the science return of the full survey.

By providing improved statistics on planets around M dwarfs, the SLS-PS will also provide fresh information on planetary formation, and in particular on the sensitivity of planet formation to initial conditions in the protoplanetary disc. The SLS-PS will also probe, for the first time in RV studies, the occurrence rate of **sub-Earth-mass planets with orbital periods shorter than ~10 d.** The recent discovery of the

KOI-961 system, with 3 Mars-sized planets in close orbit around an M5 dwarf among the very small sample of late-Ms in the Kepler field, indicates that such worlds are likely to be very common (Muirhead et al 2012). Furthermore, the very tight orbits of these planets imply high probabilities of transit (of order ~10%).

All planets detected with the SLS-PS, and especially Earth-like planets located in the HZ, will be photometrically monitored from the ground (e.g., with ExTrA) or from space (e.g., with CHEOPS), to determine which are transiting once their ephemeris and transit windows are well known. This task will be especially useful for **detecting transiting planets with orbital periods >20d**, i.e., those located in the HZ of early- to mid-M dwarfs, that TESS will have difficulties to detect given its operation mode on 27-d windows of continuous monitoring.

Last but not least, the polarimetric capabilities of SPIRou will also be very useful to **study the activity and magnetic cycles of the host stars**, known to be significant in M dwarfs, and their impact on RV curves. Securing simultaneously polarimetric and RV data will allow us to model both the large-scale magnetic topologies and the associated activity (whose large-scale distribution relates to that of the magnetic field), giving new options for filtering RV curves from the activity jitter and for enhancing further the sensitivity of SPIRou to low-mass planets. Studying large-scale magnetic topologies of M-dwarfs will also be very informative on **how dynamo processes behave in fully-convective bodies**, and how such dynamo fields can either degrade or improve habitability depending on whether they anchor in stars or in planets.

3.1.2. RV follow-up of transiting planet candidates uncovered by future photometry surveys

Exoplanets transiting their host stars are especially interesting as sensitive probes of their internal structures and atmospheres – hence the effort recently devoted to photometric surveys from both space and ground, aimed at detecting transiting planets around low-mass dwarfs. **Ground-based nIR spectroscopy is essential to this quest** – spectroscopy being mandatory to validate the planetary nature of all transiting objects detected around low-mass dwarfs through photometric monitoring (and discard false detections, e.g., caused by background eclipsing binaries) and to measure their mass from the RV amplitude of their host dwarfs' orbital motion.

Among the 3,500+ planet candidates yet found by Kepler, only a few tens have been validated and characterized through RV measurements – the vast majority of candidates orbiting stars that are too faint for current RV surveys (e.g., Santerne et al. 2013). The goal of future photometric surveys is thus to detect planet candidates around brighter stars, with a specific emphasis on nearby M dwarfs. Among them, the TESS space mission, to be launched in 2017 and predicted to detect ~300 super-Earths, is the most promising. Since most super-Earths detected with TESS will orbit around M dwarfs, and less than ~30% of them will be accessible to optical RV follow-ups (Deming et al. 2009), **SPIRou will be the best and most efficient RV instrument** to monitor in the nIR the best candidates visible from CFHT, to confirm or reject their planetary nature and to determine their masses.

We thus propose, for this second component of the SLS (the SLS-FT), to carry out **a RV follow-up of the ~75 most interesting transiting planet candidates** uncovered by future photometry surveys including TESS and ExTrA – for a total of ~75 CFHT nights (see Sec 4). Monte Carlo simulation (see RD1 & RD2) demonstrate that, with 55 visits per star and with S/N~170 spectra per visit, SPIRou has the capacity to validate and characterize Earth-mass planets orbiting mid-M dwarfs. **The SLS-FT will**

mostly concentrate on the TESS & ExTrA planet candidates with orbits closest to their HZs – to select the best ones to be scrutinized in the future by the JWST or the E-ELT for spectral signatures of biomarkers in their atmospheres. Again, we propose the SLS-FT to be followed by a second phase (outside of the SLS per se) to bring the full follow-up sample up to ~150 planet candidates – for another ~75 CFHT nights. The SLS-FT will also be complemented through additional PI or Large Programs (LPs), e.g., to study orbital obliquities of transiting planets via the Rossiter-MacLaughlin effect.

Several members of the SPIRou team are also members of the TESS Follow-up Observing Program (TFOP) Working Group at the request of D. Latham (Chief Mission Scientist). Simulations estimating more precisely the statistics of planet candidates that TESS will detect (in terms of magnitude, mass and period) are ongoing, and will soon confirm the key role that SPIRou can play in the validating process.

3.2. Spectropolarimetric monitoring of class-I, -II, and -III protostars

With a much higher magnetic sensitivity than ESPaDOnS, thanks to both the increased nIR brightness of protostars (especially in K) and the enhanced Zeeman effect at larger wavelengths, SPIRou will provide a much deeper and more systematic access to large-scale fields of class-I, -II and -III protostars. More specifically, it will allow (i) to survey much larger sample of class-II and -III protostars (cTTSs and wTTSs) than the very limited one currently accessible with ESPaDOnS, and (ii) to **extend for the first time this study to the brightest class-I protostars** thanks to the K band coverage. Observing large-enough samples, and in particular larger samples than those explored in the pioneering surveys with ESPaDOnS, is essential to clearly establish **how the large-scale magnetic topologies of protostars depend on stellar mass, age and rotation rate**; sampling the whole parameter space with ~4-5 points per parameter typically suggests samples of 50-100 stars of each type.

SPIRou will also have the power to **detect hot Jupiters (hJs) orbiting around wTTSs** and thus to verify whether hJs are either much more or much less frequent around low-mass protostars than around mature Sun-like stars (~1% of which showing hJs) – yielding a direct observational test of the formation and migration of hJs by allowing to estimate the relative fraction produced through disc migration (acting during the formation stage) and that attributable to interactions / scattering (occurring much later). Once again, given the low detection probability expected here (~a few % at most), a large enough sample of 100-200 wTTSs is needed to secure statistically significant results.

We thus propose the third component of the SLS, called the Magnetic Protostar / Planet survey (SLS-MP), to be dedicated to the **spectropolarimetric monitoring of ~20 class-I & ~40 class-II and ~80 class-III protostars** and their accretion discs, selected in the 3 closest star forming regions (e.g., Taurus/Auriga, TW Hya Association, ρ Ophiuchius), for a total of ~125 nights. For class-I protostars, the SLS-MP survey will bring completely new information; despite being carried out on a small sample with limited ability to diagnose how the field topology depends on the various parameters, it will nevertheless provide the same kind of science breakthrough than that brought by ESPaDOnS for cTTSs. For class-II and -III protostars, the SLS-MP sample will be 3-4x larger than that already explored with ESPaDOnS, allowing a **much finer diagnostics on how the field varies with stellar parameters**. As for the 2 other components of the SLS, we also proposed the SLS-MP to be followed by a second phase (outside of the SLS-MP), aiming for a full extended sample of ~40 class-I, ~80 class-II and ~150 class-III protostars in a total of 5 nearby SFRs (for another ~125

CFHT nights) to further improve the statistical significance of our conclusions. The results of the SLS-MP will be used to prepare and to optimize this second survey phase. The SLS-MP will complement ALMA observations of pre-stellar (class-0) cores and of their magnetic fields, and will bring one of the key missing pieces in our understanding of star / planet formation.

Technically speaking, the SLS-MP data will be used to infer brightness distributions and large-scale magnetic topologies, as well as maps of accretion regions whenever relevant, at the surface of protostars of various masses (typically ranging from ~0.3 to ~1.5 M_{sun}), ages (from ~0.1 up to ~10 Myr) and rotation rates (from ~0.5 to ~10 d), thus providing new observational constraints and **guidance to future theoretical and numerical models of star-disc interactions** capable of explaining self-consistently the early stages of the observed rotational evolution of low-mass stars of various masses (e.g. Bouvier et al 2007). These data will offer at the same time the opportunity to study dynamo processes in forming stars, and their similitudes / differences with respect to those operating in mature stars with presumably similar internal structures.

Looking for periodic RV fluctuation of wTTSs once their RV curves are largely filtered out from the activity jitter (down to a level of ~50 m/s, using the reconstructed brightness and magnetic distributions) **may reveal the presence of hJs** – producing typical peak-to-peak RV amplitudes of 0.1-1 km/s on periods of a few days. Even if yielding only one detection, the SLS-MP data will provide observational confirmation that disc migration is a viable mechanism for generating hJs. The proposed extension of the SLS-MP will further improve our chances to detect hJs and therefore the statistical significance of our results.

The SLS-MP will also allow one to study the inner regions (typically within 0.5 AU) of accretion discs of class-I and -II protostars, from the specific signatures these discs generate in the nIR spectrum, and to provide new observational material on their physical properties (density, departure from Keplerian rotation, magnetic field), by using techniques such as Doppler tomography of accretion discs (e.g., Marsh & Horne 1990). Looking for periodicities in these signatures can potentially inform on the presence of migrating hJs in the inner disc regions. The SLS-MP observations will nicely complement contemporaneous ALMA observations revealing the properties (including magnetic field) in the outer disc regions (typically beyond 1 AU).

3.3. Additional science with the SLS data

Although dedicated to the two science goals described above and to tightly connected topics (e.g., the activity and magnetic topologies of M dwarfs), the SLS data will also be very useful for a variety of other science programs of high interest for the whole community. To mention juste one example, by providing a wide and homogeneous set of nIR spectra for all types of M dwarfs, the SLS data will give the opportunity to check theoretical atmospheric models of cool and very cool stars in much more details than what is currently possible, and to expend the still largely incomplete data bases of atomic and molecular lines in the nIR domain. The SLS data will also allow to investigate a number of molecular species (and their evolution with time) in the Earth atmosphere (through the modeling of telluric lines) that are critical for long-term studies of the Earth global warming.

4. Technical feasibility

4.1. Detecting exoplanets around low-mass dwarfs

To demonstrate the technical feasibility of both the SLS-PS and SLS-TF surveys, realistic Monte-Carlo simulations were carried out (see RD2), using as input a comprehensive list of ~360 M3-M7 dwarfs with nIR magnitudes and spectral types. The sample considered for these simulations is directly taken from both Lepine et al 2013 (J<9, northern hemisphere, spectroscopic confirmation) and Lepine et al 2011 (all sky, J<11, photometry only). Most northern targets (except for the few ones later than M6.5) are drawn from Lepine et al (2013) and thus have spectroscopic confirmation. The assumed planet distribution is consistent with the results of Bonfils et al (2013).

For each target and each visit, integration is carried out until photon noise on the RV estimate is equal to 1 m/s, i.e., until the S/N in the spectrum is 170 per 2 km/s spectral bin. This corresponds to average integration times of ~7 min per star and per visit. With ~55 visits per star for the SLS-PS, we ensure that the detection probability of planets is 100% for all planets with RV semi-amplitudes K>1.5 m/s and 70% for those w/ K=1 m/s; increasing the number of visits up to 70 per star for the SLS-FT survey will ensure that all candidate planets down to K=1 m/s can be validated with a 96% probability. This yields **total survey times of ~300 and ~75 CFHT nights for the SLS-PS and SLS-TF respectively** (counting 8 hr / night in average).

We finally obtain that the SLS-PS will detect ~290 planets, ~200 of them being Super-Earths, ~55 of them being located in the HZ and ~35 of them sharing both characteristics (see RD2). The SLS-TF will be able to validate all candidate planets detected by photometric surveys down to at least K=1 m/s and up to about half of them down to K=0.5 m/s – tuning the number of visits on the expected amplitude of the RV signal and programming them at optimal timings given the ephemeris inferred from the photometric data.

The final target list of the SLS-PS survey will aim at two main goals: optimizing the detection of planets in the HZ on the one hand, and covering the full mass range of M dwarfs on the other hand (to probe different conditions of planetary formation). Observations with ESPaDOnS are being planned to complement information from the existing catalogs of M dwarfs. In addition to this, GAIA and the MEarth collaboration will soon provide parallax measurements for the vast majority of the closest M-dwarfs, as well as rotational period for a large fraction of them – thus providing us with all we need to finalize our SLS-PS target selection. For the SLS-TF component, the targets will be the best planet candidates detected with photometric surveys, that we will select in collaboration with the photometric survey teams.

4.2. Magnetic fields & star / planet formation

The technical feasibility of the SLS-MP survey is **straightforwardly inferred from those of the MaPP and MaTYSSE Large Program** (LP) surveys. The targets of the SLS-MP will be selected among the 3 closest and best known star forming regions (SFRs) – namely Tau/Aur, TWA and ρ Oph. Regarding class-I protostars, we will observe ~20 of them, which essentially means selecting most targets brighter than K=12 in these 3 SFRs. Regarding class-II and -III protostars, we will respectively select ~40 and ~80 of the best ones brighter than K=10, sampling as evenly as possible the intervals of mass and age (and rotation rate in the case of wTTSs) that we want to probe for this survey.

For such observing programs, MaPP and MaTYSSE demonstrated that one needs **circular polarization spectra with S/N~100 per 2 km/s velocity bins** to be able to detect the Zeeman signatures probing the large-scale magnetic topologies of low-mass protostars with enough precision on their strengths and shapes. This means average integration times of ~1 hr for class-I protostars, and of ~10 min for class-II and -III protostars. Moreover, 25 visits per star are typically needed to properly cover at least 2 rotation cycles and to reliably disentangle rotational modulation from intrinsic variability (usually quite significant in accreting protostars). This implies a total survey time of ~65 nights for class-I protostars, and another ~60 nights for class-II and -III protostars, hence **~125 CFHT nights for the whole SLS-MP**.

The target list of the SLS-MP survey will be finalized at a later stage, again using ESPaDOnS to complement the information already available from existing catalogs of protostars.

5. Management of the SLS

We now describe how the SLS will be managed in practice.

5.1. The SLS Science Consortium (SLSSC)

The science program of the SLS will be carried out by a SLS Science Consortium (SLSSC) gathering over ~100 scientists from 10+ countries (see preliminary list in Appendix A). The SLSSC includes in particular a strong French and Canadian core team, illustrating the fruitful collaborative expertise built up over the last few decades of shared observing effort at CFHT, but also involves more recent CFHT partners such as Brazil and Taiwan. It also includes a small number (6-8) experts from the non-CFHT countries Switzerland and Portugal, as a return for (and in proportion to) their active involvement in the design and construction of SPIRou. A potential participation from IfA/UH to the SLS is being investigated.

Altogether, more than 20 research institutes (e.g., IRAP/OMP/UPS, IPAG/OSUG/UJF, LAM/Pythéas/AMU, IAP, LESIA/OP, SAp/AIM/CEA, LERMA/OP, IAS, LUTH/OP, IMCCE/OP and LATMOS/IPSL in France; UdeM, UL, NRC, UofT, UWO and UBC in Canada; LNA, UFRN and UFMG in Brazil, ASIAA in Taiwan) are already part of the SLSSC, with additional contributions from Switzerland (OG) and Portugal (CAUP). Persons from the CFHT community (from countries/institutes investing cash, manpower and/or observing nights into SPIRou and/or the SLS) and interested in joining the SLSSC will be welcome to do so at any time.

Practically speaking, we propose that all members of the SLSSC have equal access to the raw and processed SLS data provided they formally agree to comply with the SLS Data Access and Publication Policies (SLSDA and SLSPP, see below) and to thereby become Registered Users (RUs). The number of RUs from non-CFHT partners (Switzerland and Portugal) is limited to a total of 6-8 (4-5 from OG and 2-3 from CAUP), reflecting their financial & manpower investment in the design & construction of SPIRou. Should an existing CFHT partner decide to quit CFHT, the number of RUs from this partner to the SLSSC will also be limited in proportion to its contribution to SPIRou.

The SPIRou kickoff science meeting scheduled for 2014 September 22-25 will initiate iterations with the community on the definition and coordination of the SLSSC, to update its composition and to nominate its representatives. All members of the CFHT community will be able to join the SLSSC provided that they explicitly agree with the Data Access and Publication Policies defined in sec 6.2 and 6.3.

5.2. The three SLS components

As described in Secs 3, we propose the SLS to be divided into 3 main components:

- SLS Planet Search (SLS-PS) dedicated to the RV monitoring of ~360 nearby M dwarfs, for a total amount of ~300 nights;
- the SLS Transit Follow-up (SLS-TF), dedicated to the RV follow-up of ~75 transiting planet candidates uncovered by future photometric surveys such as TESS, for a total of ~75 nights;
- the SLS Magnetic Protostar / Planet survey (SLS-MP), dedicated to the spectropolarimetric monitoring of ~20 class-I and ~120 class-II and -III protostars and their accretion discs, for a total of ~125 nights.

Each survey component is supervised by coordinators, one in the case of the SLS-TF and SLS-MP, and 2-3 for the larger-scale SLS-PS. These coordinators will be nominated by the SPIRou Steering Committee (SSC) upon a proposition from the SLSSC representatives.

5.3. The SLS Steering Group (SLSSG)

The progress of the SLS will be monitored by a SLS Steering Group (SLSSG), who will regularly inform the SAC on the advances of the survey effort with respect to the initial predictions. We suggest that the SLSSG typically includes 7-8 members, in particular:

- the 4-5 coordinators of the 3 components of the SLS;
- one CFHT representative;
- one person from the SLS Data Processing center (see below);
- one member from the SLSSC at large.

The last 3 members of the SLSSG will also be nominated by the SSC upon a proposition from the SLSSC representatives.

5.4. The SLS Science Workpackages (SLSWP)

The three components of the SLS will be divided into a number of SLS Science Workpackages (SLSWPs) that can be either specific to each SLS component, or transverse to several or even all SLS components. We propose below a tentative splitting of the SLS into ~15 SLSWPs as a basis for discussion during the SPIRou kickoff science meeting of 2014 September 22-25.

For the first component of the SLS:

- **WP1.1**: organize the RV monitoring of ~360 M dwarfs and derive RV curves w/ adequate sampling; determine orbital distance and minimum mass of detected planets, focussing on low-mass planets in the HZ;
- **WP1.2**: identify M dwarfs showing long-period or multi-periodic RV variations requiring additional observations and organize follow-up outside of the SLS;

- **WP1.3**: organize photometric follow-up of detected planets to identify transiting ones;

For the second component of the SLS:

- **WP2.1**: organize RV follow-up of ~75 planet candidates detected by photometric surveys (in particular TESS) to validate planetary nature; build-up a list of confirmed transiting planets, including those detected in WP1.2, with estimates of masses, radii and densities;
- **WP2.2**: organize complementary observations with CHEOPS and JWST for finer characterization of the transiting planets, and of their atmospheres for transiting planets in the HZ; compare with theoretical models of planet atmospheres to interpret potential detections of biomarkers;

For both the first and second components of the SLS:

- **WP3.1**: filter activity jitter from RV curves by using simultaneous spectropolarimetry and by looking for correlations between spot distributions and large-scale magnetic topologies;
- **WP3.2**: determine frequency occurrence of planets around M dwarfs and of their orbital properties, focussing especially on low-mass planets in the HZ; compare with theoretical models of planetary formation;
- **WP3.3**: study exoplanet internal structures & compare w/ observations; study stability of multi-planet systems & compare w/ observations;

For the third component of the SLS:

- **WP4.1**: monitor Zeeman signatures of ~20 class-I, and ~120 class-II and -III protostars in order to derive their surface brightness distributions and large-scale magnetic topologies, as well as accretion maps whenever relevant, using Zeeman-Doppler imaging;
- **WP4.2**: organize multi-wavelength follow-up on accreting protostars to better understand magnetized accretion processes in low-mass protostars and to clarify its impact on the formation of Sun-like stars; compare w/ predictions of theoretical models;
- **WP4.3**: filter-out activity jitter from RV curves of class-III protostars to detect hot Jupiters (hJs) around young low-mass stars; estimate the frequency occurrence of hJs around young protostars and compare w/ theoretical models;
- **WP4.4**: look for specific spectroscopic & spectropolarimetric signatures from accretion discs of class-I and -II protostars; determine properties of the innermost disc; look for potential periodicities tracing disc inhomogeneties and planet formation;

For all 3 components of the SLS:

- **WP5.1**: update stellar parameters from sets of recorded spectra, using a specific automatic spectral classification tool, optimized for both M dwarfs and low-mass protostars;
- **WP5.2**: investigate how large-scale fields vary with stellar parameters among M dwarfs and low-mass protostars; compare w/ theoretical dynamo models of fully-convective and non-fully-convective stars;
- **WP5.3**: model telluric lines in reduced spectra and derive atmospheric properties (e.g., column densities of atmospheric molecules, wind speeds) and their evolution with time; compare with similar data obtained at other sites (e.g., CSO, ESO).

The exact number of WPs, their respective contours and the teams in charge (including the coordinators) will be settled at a later stage, after discussing and iterating with the SLSSC at large.

5.5. The SLS Data Processing center (SLSDP)

The SLSSC will implement a SLS Data Processing center (SLSDP) to provide the SLSSC with the ultimate version of the processed data – taking into account all corrections to ensure optimal RV and polarimetric precisions. Over the full duration of the SLS, the SLSDP will regularly release, no later than 3 months after the end of each semester, the processed SLS data, including both the most recent data and the previously released data with improved processing / telluric subtraction / RV and polarimetric accuracies. The SLSDP will also provide CFHT with regular updates of the SPIRou DRS.

5.6. Project schedule

The detailed definition of the SLS will take place through iterative phases with the SLSSC, the SSC and the CFHT SAC and BoD in 2014. The initial document, available at the SPIRou FDR (in late April 2014), will be submitted to the SSC and then to the following SAC (late May 2014) and BoD for information / comments. After discussing with the SLSSC at large in 2014 September 22-25 (to propose names for coordinators of the 3 components of the SLS and to converge on a mature set of SLSWPs with well-identified teams), a new version of this document will be released, and submitted to the SAC for further comments (late November 2014). The final version of the SLS document will be presented to the SSC and the CFHT BoD at the end of 2014 for final approval.

Once the SLS is officially approved, it will be widely advertised within the whole CFHT community through an offer to join the SLSSC. All teams will then start working on the various WPs, starting with a second pass on the target lists for WP1.1, WP2.1 and WP4.1 and all the preparation work that goes with it, e.g. pre-SPIRou survey work w/ ESPaDOnS to secure additional information and homogenous data on the future SPIRou targets, in order to select the most promising ones to be observed as soon as SPIRou gets on the sky. This documentary work and accompanying studies will take place throughout most of 2015 and 2016.

The SLS in itself will take place between 2017 and 2022, in ideal conjunction with the launch of TESS (in 2017) and JWST (in 2018). The SLSSG will regularly follow the progress of the SLS and will potentially suggest (depending on the secured results) slight changes in the observing strategy to optimize the overall science return of the SLS.

6. Data access, release & publications

We give more details below on the conditions to be agreed upon before gaining SLSSC membership. This applies to all eligible members of the CFHT community willing to join the SLSSC as well as to the pre-identified members of the non-CFHT community from Switzerland and Portugal.

6.1. The SLS Registered User (SLS-RU) status

Only registered individuals will have access to the proprietary SLS data. The eligibility of individuals to receive proprietary access to the SLS data includes:

- all persons engaged in astronomical research residing in France, Canada, Hawaii, Brazil and Taiwan (as long as these countries are CFHT partners and agree to contribute to the SLS) – including students, post-doctoral fellows and employed professional astronomers at Universities and Research Institutes (persons from IfA/UH may also be eligible if IfA/UH chooses to bring an additional ~90 nights to the full SLS survey time);
- members of the CFHT scientific staff;
- professional astronomers employed at Research Institutes or Universities outside of Canada or France, but who are directly or indirectly supported by either NRC or CNRS, or another French or Canadian agency (e.g., a French Astronomer at ESO, a Canadian astronomer at JAC).
- individuals who do not fit the stated eligibility criteria but nevertheless believe they may be eligible to be included in the SLS community may apply for authorization to register, stating their argument, to the CFHT Executive Director, who will decide upon advice from the SLSSG.

Previously registered users whose status changes to one that no longer fits the stated eligibility criteria will normally be removed from the list of authorized users (their registration will be revoked). Such individuals may appeal to the CFHT Executive Director, stating their reasons to continue as a registered user of the SLS, who will decide upon advice from the SLSSG.

The CFHT Executive Director is charged with administering a system of registering eligible persons to become users of the SLS data. The registration form will contain a statement of the obligations associated with access to the data, especially regarding the SLS Data Access Policy (SLSDA) including the proprietary nature of the data, and the SLS Publication Policy (SLSPP).

6.2. The SLS Data Access Policy (SLSDA)

The SLS is based on the concept that all members of the SLSSC have equal access to the raw and processed data obtained at the CFHT and released by the SLS Data Processing center (SLSDP). Access to the SLS data will be via registration as a SLS Registered User (RUs). The raw and reduced data will be made available to all RUs simultaneously. Individuals in charge of reducing and releasing the SLS data will not undertake science analysis in advance of the release to the SLSSC.

The SLSDP will setup a password-secured website for providing access to the raw and reduced data to the whole SLSSC. The CADC will also offer a password-protected access to the data released by the SLSDP. The raw data distributed to the SLSSC will include all stellar frames as well as all calibration data used for the processing. The processed data will include both the non-telluric-subtracted and telluric-subtracted spectra with wavelengths referring to the Solar-System Barycentric frame, and corrected from all known residual instrumental contributions to the RV signal. RV measurements and Zeeman signatures derived from processed spectra with reference cross-correlation tools will also be released with the processed spectra.

The raw and processed data released by the SLSDP will be proprietary within the SLSSC for a period of 12 months after each release of the SLSDP. The RV and polarimetric information associated with the processed data will remain proprietary with the SLSSC for an additional period of 12 months, whereas the processed intensity spectra (with RV and polarimetric information removed) will be made available to the whole CFHT community through the CADC. The full data released by the SLSDP (including RV and polarimetric information) will be made available by the CADC to the whole CFHT community 24 months after the initial release by the SLSDP. RUs agree to protect the proprietary rights of the SLS community by individually not exporting proprietary data to persons other than RUs or of making public the data in digital form. The export of SLS proprietary data to external members of a scientific collaboration is permitted only upon the explicit authorization from the CFHT Executive Director, upon advice from the SLS Steering Group.

6.3. The SLS Publication Policy (SLSPP)

All scientific analyses of SLS data and the resulting publications will be performed within the respective WP by the team in charge – with publications explicitly including all members of the WP as coauthors (in an order left to the appreciation of the WP team). The results from all scientific analyses of SLS data remain the exclusive property of the WP team.

Appendix A: Preliminary list of the SLSSC

This list was derived from that of the SPIRou science team and already includes a large fraction of the CFHT community potentially interested by the SLS. It will be updated during the forthcoming iteration phases, in particular the SPIRou science meeting scheduled for 2014 September. Once the SLS is officially approved, it will be widely advertised within the whole CFHT community through an offer to join the SLSSC.

Country	Institute	Team members
France	IRAP/OMP/UPS, Toulouse	Donati, Baruteau, Jouve, E Hébrard, Petit, Ferrière, Dintrans
	IPAG/OSUG/UJF, Grenoble	Delfosse, Bonfils, Bouvier, Forveille, Ménard, Barthélémy, Dougados, Delorme, Lilensten
	LAM/Pythéas/AMU, Marseille	Boisse, Bouret, Deleuil, Bouchy, Santerne
	IAP, Paris	G Hébrard, Lecavelier, Terquem
	SAp/AIM/CEA, Saclay	Brun, Hennebelle, Mathis, Fromang
	LESIA/OP, Meudon	Widemann, Bézard, Lellouch, Fouchet, Doressoundiram, Zarka, Coudé du Foresto
	LERMA/OP, Meudon	Cabrit, Dormy, Petitdemange
	IMCCE/OP, Meudon	Laskar, Boué
	LUTH/OP, Meudon	Zahn, Mazevet
	LATMOS, Paris	Leblanc
	LUPM, Montpellier	Martins, Morin, Lèbre
	IAS, Orsay	Ollivier, Bordé, Baudin
	ENS, Lyon	Baraffe, Chabrier, Allard
	UTINAM, Besançon	Reylé
	OCA, Nice	Morbidelli, de Laverny, Recio Blanco, Guillot, Crida
Canada	UdeM, Montréal	Doyon, Artigau, Lafrenière, Bastien, Dufour
	McGill Univ, Montréal	Cumming
	UofT, Toronto	Menou, Valancia, Wu
	McMaster, Toronto	Pudritz
	York Univ, Toronto	Jayawardhana
	NRC, Victoria	Bohlender, Marois
	UWO, London	Metchev
	RMC, Kingston	Wade
	UBC, Vancouver	Matthews
International	CFHT	Moutou, Malo, Fouqué
Brazil	LNA	Martioli, Castilho
	UFRN	Diaz
	UFMG	Alencar
Taiwan	ASIAA	Wang, Takami, Lai
Switzerland	Obs Genève	Pepe, Udry, Lovis, XXX, (YYY)
Portugal	CAUP	Figueira, Santos, (ZZZ)