CANADA-FRANCE-HAWAII TELESCOPE

Donati

No code

The SPIRou Legacy Survey (SLS)

Semester : 2018B - 2022A

Science Cat. : Solar system and exoplanets

Abstract

Detecting and characterizing exoplanets, especially Earth-like ones located at the right distance from their host stars to lie in the habitable zone, is a major goal in our quest to understand the emergence of life. M dwarfs are key targets in this quest. Beyond largely dominating the population of the solar neighborhood, they host several planets per star and can reveal how planet formation behaves at the lower-mass end of the main sequence, yet only constrained to date by observations of early-M types.

Similarly, studying the early evolutionary stages of low-mass stars and their planets is key for understanding how worlds both like and unlike our Solar System are born, and comes as a logical twin to the exploration of nearby planetary systems. Magnetic fields play a major role in these phases, but only fragmentary information is currently available on the fields of newborn stars and their surrounding discs, and on their impact on star / planet formation.

To achieve a breakthrough on these two forefront science goals, we propose to conduct a dedicated CFHT Large Programme with SPIRou called the SPIRou Legacy Survey, for a total of 400 CFHT nights over 8 consecutive semesters (2018b-2022a).

Telescopes

Telescope	Observing mode	Instruments
CFHT	QSO Regular	SPIRou (LP only)

Applicants

Name	Affiliation	Email	Country		Potential observer
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		Country	France

Requested Time (exposure + overheads) in hours (in nights for Classical)

2800.0

Overall scheduling requirements

The program requires monitoring. Typically one observation per night.

Proprietary Exception Request

see requests on proprietary periods and wishes for target protections in Sec 5.4 of the SLS justification

Observing runs

Run	Instrument	Seeing	Config	Details
A	SPIRou (LP only)	0.60 - 1.00" (SPIRou (LP only))	Observing mode: Polarimetry Read-out mode : Default	standard configuration The program requires monitoring. Typically one observation per night.

Targets

Field	RA	Dec	Epoch		Runs	Moon	Seeing Lower	Seeing Upper	S/N	Magnitude	Diameter	Comments
04-08 RA	06:00:00.00	+00:00:00.0	J2000		A	any						17 nights for 2018b
08-12 RA	10:00:00.00	+00:00:00.0	J2000		A	any						2.5 nights for 2018b
12-16 RA	14:00:00.00	+00:00:00.0	J2000		A	any						0.5 nights for 2018b
20-24 RA	22:00:00.00	+00:00:00.0	J2000		A	any						6 nights for 2018b
16-20 RA	18:00:00.00	+00:00:00.0	J2000		A	any						0 night for 2018b
00-04 RA	02:00:00.00	+00:00:00.0	J2000		A	any						5 nights for 2018b

The SPIRou Legacy Survey / SLS

1. Planetary systems of M dwarfs and the formation of new worlds

1.1. General context

Detecting and characterizing exoplanets, especially Earth-like ones located at the right distance from their host stars to lie in the habitable zone (**HZ**, where liquid water can pool at the planet surface), is a **major goal in our quest to understand the emergence of life** (Gaidos & Selsis 2007); standing as one of the most exciting areas of contemporary astronomy, it motivates ambitious space missions and ground-based projects (TESS, JWST, ELTs[1]) aimed at unveiling these new worlds yet to be discovered and at searching for the potential presence of biomarkers in their atmospheres. Up to now, two main complementary techniques have been used in this aim, both very successful at revealing an incredible diversity of exoplanets and planetary systems around many types of stars. Velocimetry, measuring radial velocities (**RVs**) of stars and the periodic changes that probe the presence of orbiting bodies, yields lower limits on planet masses, while photometry, identifying planet candidates transiting their host stars, yields planet radii. For exoplanets detected with both techniques, one can constrain their true masses and their bulk densities / compositions vs planet masses (Lissauer et al 2014, see Fig 1; Weiss & Marcy 2014). This opens a new era of comparative planetary science encompassing thousands of new planets beyond those of our Solar System, with great potential for testing planet formation models (Alibert & Benz 2017) and for habitability studies (Leconte et al 2015).

M dwarfs are key targets in this quest; beyond being by far the most abundant population of the solar neighborhood, they are known to host multiple planets per star on average (Dressing & Charbonneau 2015; Gaidos et al 2016) especially at later spectral types (Gillon et al 2017), only a small fraction of which have been discovered so far. Moreover, M dwarfs feature smaller radii and closer-in HZs than Sun-like stars. This renders their HZ planets far easier to detect (than those of Sun-like stars) by boosting their transit depths (by 11x and 45x for M4 & M6 dwarfs respectively) and RV wobbles (by 4x to 8x for M4 & M6 dwarfs respectively), by reducing their orbital periods and by increasing their transit probabilities. In particular, M dwarfs will reveal **how planet formation behaves at the lower-mass end of the main sequence,** expected to strongly vary with mass (Alibert et al 2011, see Fig 2) and yet only constrained to date by observations of early-M types. Thanks to their relative proximity and small radii (yielding favorable planet-star brightness ratios), M dwarfs are also by far the best candidates for future characterization of their HZ planets' atmospheres with future facilities such as JWST and later-on ELTs, whereas similar planets around Sun-like stars will remain out of reach of such studies for at least several decades. Velocimetric surveys are critical in this respect; transiting planets are indeed rare enough (Gillon et al 2017; Dittman et al 2017) that HZ planets in the closest solar neighborhood in reach of ELTs (Snellen et al 2015) can only be unveiled through velocimetry (Anglada-Escudé et al 2016; Bonfils et al 2018).

However, monitoring M dwarfs with existing high-precision velocimeters like HARPS on the 3.6m ESO telescope is tricky given their intrinsic faintness at visible wavelengths, and is mostly limited to early-M types, preventing a deep exploration of the Solar System neighborhood to detect significant samples of HZ Earth-like planets (Bonfils et al 2013), especially at later spectral types. Observations in the near-infrared (**nIR,** 1-2.5 µm), where M dwarfs emit most of their light, are essential for this quest. M dwarfs are also notorious for their magnetic activity, hampering planet detectability through the spurious RV jitter that activity generates (Newton et al 2016). Modeling the activity of M dwarfs and the underlying magnetic fields is thus crucial for filtering out the RV jitter and for maximizing our efficiency at detecting low-mass planets (Haywood et al 2014; Hébrard et al 2016, 2018). Again, observations in the nIR, where the RV jitter is expected to be smaller than in the optical (Reiners et al 2010; Crockett et al 2012), are ideal in this respect. Furthermore, investigating magnetic fields of M dwarfs, featuring largely or fully convective interiors, and the underlying exotic (non-solar) dynamo processes (Morin et al 2010, 2011), is essential to characterize the activity and winds of these stars and their impact on the habitability of HZ planets (Vidotto et al 2013).

Similarly, studying the **early evolutionary stages of low-mass stars and their planets** - as they form from collapsing dense pre-stellar cores that progressively flatten into large-scale accretion discs and eventually settle as young suns orbited by planetary systems (André et al 2009) - is key **for understanding how worlds both like and unlike our Solar System are born**, and comes as a logical twin to the exploration of nearby planetary systems (Morbidelli 2018). Investigating pre-main-sequence (**PMS**) phases, in which central young stars feed from surrounding planet-forming accretion discs, is especially critical in this respect. Following a phase where they massively accrete from their discs (as class-I protostars, aged 0.1-0.5 Myr, see Fig 3 left panel) while still embedded in dust cocoons, newly-formed protostars end up clearing out their dust envelopes once bright enough to do so (at ages 0.5-10 Myr), becoming classical T-Tauri stars (**cTTSs** / class-II PMS stars) when still accreting from their planet-forming discs, then weak-line

[1] ELT stands as a generic acronym for 25-40m class next-generation telescopes such as ESO's ELT, the TMT and the GMT

T-Tauri stars (**wTTSs** / class-III PMS stars) after they have mostly exhausted their discs.

Magnetic fields play a major role in these phases. By controlling accretion, triggering outflows and jets, and producing intense X-rays, fields critically impact the physics of PMS stars and their discs, and largely dictate their angular momentum **(AM)** evolution (Shu et al 2007; Bouvier et al 2007; Güdel et al 2010). They can force PMS stars to spin down by coupling them to their discs (Romanova et al 2011; Zanni & Ferreira 2013), as well as alter disc dynamics and planet formation (Johansen 2009; Baruteau et al 2014). To quantitatively assess the effect of these fields on star / planet formation and further improve the gyrochronometry of young low-mass stars (Gallet & Bouvier 2016), **one critically needs observational constraints on the large-scale fields** that control the star / disc coupling and the loss of AM, and on how these fields relate to the observed diversity of accretion modes (Cody et al 2014; Sousa et al 2016; Blinova et al 2016). However, despite recent progress (Johns-Krull 2007; Johns-Krull et al 2009; Donati et al 2013, 2015, see Fig 3 right panel), **our knowledge of stellar magnetic fields of PMS stars** (especially late-K and M ones) **is still fragmentary**, reflecting mostly the faintness of young stars in the visible, which drastically limits their accessibility even to the most sensitive existing instruments.

At the heart of our two topics (planetary systems of M dwarfs & magnetized star / planet formation) is **the study of close-in planets orbiting within a few 0.1 au of their host stars**, both for mature low-mass dwarfs hosting a surprisingly large occurrence rate of such bodies (Howard et al 2012; Muirhead et al 2015) and for young stars whose close-in giants (Johns-Krull et al 2016; Donati et al 2016, 2017; Yu et al 2017) are expected to have a major dynamical impact on the early architecture of planetary systems. Characterizations of close-in planets around stars across a wide range of masses and evolutionary stages - both PMS and MS - will reveal how planets grow, migrate and survive the formation stage, then settle into the observed systems.

1.2. Key questions

To achieve a breakthrough on our two forefront science goals, we propose to conduct a dedicated CFHT Large Programme with SPIRou called the **SPIRou Legacy Survey (SLS), for a total of 400 CFHT nights over 8 consecutive semesters.** The SLS aims at harvesting observational material of unprecedented precision on a large sample of M dwarfs and PMS stars, by pushing SPIRou to its ultimate performance, and with which we will address the following key questions:

(i) **Q1**: **How diverse are planetary systems of nearby M dwarfs, how frequently do the lowest-mass stars harbor close-in, and in particular, HZ Earth-mass planets?** How does this diversity evolve with the host-star mass down to the brown-dwarf limit - **a mostly unexplored mass range thus far**?

(ii) **Q2: How does the density, structure and bulk composition of low-mass transiting planets change with planet mass and stellar irradiation, in particular for those located in the HZ for which very few data exist?**

(iii) **Q3: What are the as-of-yet undetected systems, soon to-be discovered** (eg by TESS), **that are best suited for characterizations** (eg of planetary atmospheres) with future facilities (eg, JWST, ELTs)?

(iv) **Q4: What kind of magnetic fields do largely- and fully-convective M dwarfs generate as they spin down to low activity levels for which almost no data are available? How do their fields and associated activity impact planet detectability and habitability?**

(v) **Q5: What types of magnetic fields do low-mass PMS stars** (and their accretion discs if relevant) **host,** in particular the youngest and strongly-accreting stars, for which very few magnetic observations exist? **How do these fields change as stars and planets evolve?**

(vi) **Q6: How do such fields impact accretion/ejection processes and star/planet formation, and what is their role in the formation and survival of close-in planets, especially hot Jupiters (hJs)** known for their huge dynamic impact on the early architecture of planetary systems?

In practice, **the SLS consists of 3 interrelated surveys**, the SLS Planet Search (**SLS-PS**), the SLS Transit Follow-up (**SLS-TF**) and the SLS Magnetized PMS star-planet formation (**SLS-MP**), outlined in Sec 2.

2. A Legacy survey of M dwarfs and PMS stars with SPIRou

2.1. The SPIRou revolution

Addressing Q1-6 requires an efficient instrument carrying out precision velocimetry (Q1-3) and spectropolarimetry (Q4-6). **SPIRou at CFHT was optimized for this purpose and offers both capabilities in the nIR**, a spectral range in which M dwarfs and PMS stars are the brightest. This is especially true for late-M dwarfs and embedded class-I protostars, brighter by >3 orders of magnitudes in the nIR than in the visible and almost entirely out of reach of older generation instruments (HARPS or ESPaDOnS). Furthermore, the enhanced Zeeman effect in the nIR also boosts the spectropolarimetric sensitivity by ~6x, making SPIRou much more efficient and sensitive than ESPaDOnS and HARPS to both large-scale and small-scale magnetic fields (through polarization and Zeeman broadening of spectral lines respectively).

Thanks to its unique combination of (i) a wide simultaneous spectral domain (0.98-2.35 µm, YJHK bands), (ii) a high throughput (>10% in H and K bands, where RV and polarimetric contents are largest), (iii) a RV precision of 1 m/s and a resolving power of 70k, and (iv) polarimetric capabilities, **SPIRou will outperform all existing instruments for our science goals**, including nIR competitors (eg Carmenes, HPF or IRD, which lack the K band & polarimetry, CRIRES+ whose single-exposure domain is far smaller).

With its unrivaled capacity at characterizing magnetic activity of M dwarfs and PMS stars while simultaneously monitoring their RVs, **SPIRou is best equipped for optimally filtering RV curves** from activity jitters. This is a key asset, as activity jitters, often exceeding 1 m/s for M dwarfs (Bonfils et al 2013) and 1 km/s for PMS stars (Donati et al 2015) in the visible, are expected to contribute to RV curves of most SLS targets, even in the nIR where jitters are likely 2-3x smaller (Reiners et al 2010; Crockett et al 2012).

2.2. Census and statistics of planetary systems around nearby M dwarfs : the SLS-PS component

M dwarfs represent 80% of the stellar population in the solar neighborhood and are known to host more planets than higher-mass stars (2.5 planets/star with periods <6 months on average for early-M dwarfs, Bonfils et al 2013, Dressing & Charbonneau 2015; Gaidos et al 2016, and likely more for the latest M dwarfs, Gillon et al 2017), implying that exoplanets closest to our Solar System orbit mostly M dwarfs. If we however consider the 140 stars (100 systems) closest to the Sun (within 6.6 pc) and above a declination of -30°, only 11% of them (15 stars[2]) are currently known to host planets. This demonstrates that **the vast majority of the hundreds of planets in the close neighborhood of the Solar System** (within 15 pc) **still remains to be discovered**. The main goal of the **Planet Search component of the SLS (SLS-PS)** is to detect and characterize (ie, measure the orbital periods and derive lower limits on the masses for) a large fraction of these missing planets / systems, with an extensive survey of 100 nearby M dwarfs with SPIRou.

The first aim of the SLS-PS is to address Q1 by carrying out a **large census and statistical study of the planet population around nearby M dwarfs and in particular on the less-explored lowest-mass stars**. We will focus on close-in and / or HZ Earth-mass ones, and document their diversity with respect to those of our Solar System. By unveiling the modal architectures of planetary systems, ie, where planets of different masses tend to cluster, around M dwarfs of various spectral types, this study will reveal **how sensitive planetary formation is to the mass** (in the range 0.1-0.4 $M_{\odot}$) **and temperature** (in the range 2600-3700 K) **of the central object, and therefore to the initial conditions in the proto-planetary disc** (disc mass & density, Keplerian velocity, ice limit). Simulations suggest that planetary systems significantly change from early to late-M dwarfs (Alibert et al 2011, see Fig 2) though detailed and extensive observations are still lacking to either confirm or refute this theoretical claim. By using SPIRou to detect and characterize 80-100 new planets, the SLS-PS will provide the community with a statistically significant sample of tens of planetary systems in the close neighborhood of the Solar System, making it possible to achieve a major step forward in our understanding of how systems like ours form and evolve into maturity.

Our SLS-PS observations will yield accurate measurements of the occurence of Earth-like (ie, 1-5 $M_{\oplus}$) planets of mid- to late-M dwarfs, especially those located within the HZ, to be compared with prior estimates in the specific case of early-M dwarfs using HARPS and Kepler data (of ~0.5 Earth-like planet per M dwarf with half of them in the HZ, Bonfils et al 2013; Dressing & Charbonneau 2015; Kopparapu et al 2013, for typical HZ width and planet mass / radius relation, Kopparapu et al 2017). Similarly, studying the distribution of close-in planets, whose density was found to be unusually high in the Kepler sample compared to the Solar System (especially for intermediate-size planets in the range 1-4 $R_{\oplus}$, Muirhead et al 2015; Gaidos et al 2016), has the potential to reveal which of the several mechanisms invoked so far for the formation of planetary systems and the early evolution of their dynamic architecture best explain observations (Mulders et al 2015; Fulton et al 2017; Gaidos 2017).

Monte-Carlo simulations of realistic observations, following Cloutier et al (2018a, see Fig 4 left panel), including the activity jitter and its filtering through Gaussian Process Regression (GPR, Haywood et al 2014), indicate that the SLS-PS survey of a sample of 100 M dwarfs with 200 visits per star over 4 yr **should lead to the detection of 80-100 planets, 40% of them being Earth-mass planets and 10% of them HZ Earth-mass planets,** thereby improving the planet population currently known around M dwarfs in the immediate vicinity of the Solar System by a factor of at least 4x, and by over a factor of 2x that of HZ Earth-mass planets around M dwarfs. In particular, we will **determine the minimum-mass vs period distribution of M-dwarf planets**, constrained by no more than 14 planets as of yet (Bonfils et al 2013), whereas only the radius-period planet distribution of early-M-dwarfs is currently known (from Kepler data, Dressing & Charbonneau 2015). The SLS-PS will also probe the occurrence rate of sub-Earth-mass planets

[2] Namely YZ Cet, LHS 1723, Gl 229, Gl 273, Gl 411, Gl 447, Gl 581, Gl 625, Gl 628, Gl 687, Gl 876 with declinations above -30°, and Gl 674, Gl 832, Proxima Cen and Kapteyn's star that are hardly accessible or out of reach from CFHT

with orbital periods shorter than 10d. The discovery of the Kepler-42 system, with 3 Mars-sized planets in close orbit around an M5 dwarf among the very small sample of late-M dwarfs 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 higher probabilities of transits (of a few %) for further studies with transit surveys.

All planets detected with the SLS-PS, and especially HZ Earth-like planets, will be photometrically monitored from the ground (with ExTrA or NGTS; Bonfils et al 2015; Wheatley et al 2018) or from space (with CHEOPS, Fortier et al 2014), to **determine which are transiting** once their ephemeris and transit windows are known with sufficient accuracy. This task will be especially useful for detecting transiting planets with orbital periods >20 d (ie, those located in the HZs of early- to mid-M dwarfs) that TESS will find difficult to detect given its operation mode on 27-d windows of continuous monitoring. We will also carry out dynamical studies to test the orbital stability of the detected Keplerian bodies and estimate, eg, whether planets are locked in specific orbital resonances and whether dynamical tides drove their evolution.

The SLS-PS will also serve as a pioneering exploration to **pin down the very best planet candidates for future detailed characterizations of their atmospheres with JWST and eventually ELTs** (Q3). In the particular case of transiting planets, transmission spectroscopy secured in and out of transit phases with JWST will reveal the chemical composition of the planet atmospheres, and the potential presence of biomarkers such as ozone or methane, presumably tracing biological processes at the planet surfaces (Rauer et al 2011, Beichman et al 2014). Transiting planets in the immediate vicinity of the Sun, ie, bright enough for JWST transmission spectroscopy, are however rare (Dittman et al 2017), with at best a few HZ Earth-like planets expected to be accessible. Later on, ELTs will offer unique opportunities for studying atmospheres of non-transiting planets by looking for absorption signatures associated with the planet orbital motion, providing information on the chemical composition and the thermal profile of the atmosphere (Birkby et al 2013), with techniques similar to those implemented for probing the atmospheres of a handful of close-in giant exoplanets so far (Snellen et al 2010; Brogi et al 2012; De Kok et al 2013). Even more ambitious and promising are techniques combining high-resolution spectroscopy and high-contrast imaging, potentially able to disentangle spectra of planets from those of their host stars, and to unveil O_2 lines as biomarkers in the atmospheres of HZ planets (Snellen et al 2015).

Finally, the SLS-PS will yield a wide, legacy-type, homogeneous collection of high-S/N high-resolution nIR spectra for most types of M dwarfs, providing fresh opportunities to **improve atmospheric models of very-low-mass stars**, for which several key physical aspects (opacities, atmospheric chemistry) are either missing or speculative (Rajpurohit et al 2016; Artigau et al 2018).

With its state-of-the-art velocimetric precision, large spectral domain and high throughput, **SPIRou is the most efficient instrument for this programme,** thanks to its access to the K band in particular, which almost doubles the RV content for mid- to late-M dwarfs (SPIRou science case; Artigau et al 2018).

2.3. Characterization and follow-up of transiting planets : the SLS-TF component

Exoplanets transiting their host stars are sensitive probes of their internal structures and atmospheres as well as powerful tools to study the dynamic of their orbits, hence the effort devoted to photometric surveys from both space and ground aimed at detecting such planets around low-mass stars for detailed characterization and follow-up. The main goals of such studies are (i) **to constrain the mass-radius diagram of low mass planets** that will revolutionize our understanding of their internal structure and bulk composition (Q2) and (ii) to provide key mass measurements of the best planets amenable to atmospheric characterization with JWST and with SPIRou itself through high-resolution spectroscopy (Brogi et al 2018, Q3). **Ground-based spectroscopy is key to this quest**.

Kepler achieved a spectacular success in determining planet statistics, but was not been designed to detect Earth-like twins bright enough for further atmospheric characterization, most candidates being too faint for RV surveys. Among future transit surveys, TESS (Ricker et al 2015), to be launched in April 2018, is the most promising. Focussing on bright nearby targets, it will carry out a nearly all-sky survey in a nominal 2-yr mission, monitoring on a 27-d timespan 200,000+ targets at a 2-min cadence, and 100x more at a 30-min cadence. TESS should discover hundreds of Earth-like & super-Earth planets candidates, in addition to thousands of icy & gas giant candidates. As most super-Earth candidates that TESS will detect will orbit around M dwarfs, fewer than 30% of them will be accessible to optical RV follow-up (Sullivan et al 2015, see Fig 4 right panel). Ground-based surveys such as ExTrA (Bonfils et al 2015), NGTS (Wheatley et al 2018), TRAPPIST (Gillon et al 2017) and MEarth (Nutzman, & Charbonneau 2008) are expected to unveil their own sample of transiting planets. Several promising planets transiting M dwarfs detected with Kepler and K2 are also waiting for a precise velocimetric follow-up in the nIR.

With its high throughput and wide nIR spectral range, SPIRou will be the most efficient RV instrument to monitor the best planet candidates orbiting M dwarfs visible from CFHT, to establish or reject their planetary nature and measure their masses with an accuracy of better than 20%. Knowing in advance (from transit data) the periods and inclinations of planetary orbits, allows for an improved planet detection sensitivity and enhanced mass precision, especially for multiple systems predicted to be frequent around M dwarfs (Dressing & Charbonneau 2015).

We propose to carry out a **RV follow-up of the ~65 most interesting transiting planets around M dwarfs**, the majority to be uncovered by future photometric surveys. The **Transit Follow-up component of the SLS (SLS-TF)** is focused on measuring the masses of ~50 small (1-4 $R_\oplus$) planets with an accuracy of 20%, in order to investigate whether the radius valley observed for FGK hosts (Fulton et al 2017; van Eylen 2018) also applies to M dwarf hosts. We will also target the best ~15 new icy and gas giants (the majority from TESS) amenable for atmospheric characterization with JWST, including the few northern rocky HZ planets to be scrutinized by JWST and ELTs for biosignatures in their atmospheres (Q3). The atmospheric signal strength inferred from transit spectroscopy scales as $T_{eq}/(\rho_p \mu R_s^2)$ where T_{eq} is the planet equilibrium temperature, ρ_p the planet bulk density, μ the mean molecular weight and R_s the radius of the host star. Interpreting transit spectroscopy data thus requires a constraint on the planet mass (the planet radius being relatively well known) in order to lift the degeneracy between the composition of the atmosphere (μ) and the planet bulk density (ρ_p).

Our program features the Trappist-1 system (Gillon et al 2017) that will be monitored at favorable conjunctions when the RV signal exceeds 10 m/s to (i) better constrain the TTV-derived masses of all 7 planets, (ii) characterize the stellar activity of the host and (iii) secure a very-high-S/N average spectrum that will provide key constraints on the fundamental parameters of the host. We will also observe K2-33 (David et al 2016) to determine its mass and further constrain existing models of planetary formation.

2.4. Using spectropolarimetry to characterize the magnetic fields and activity of M dwarfs, enhance the detectability & study the habitability of planets

By carrying out all observations of the SLS-PS and SLS-TF surveys in spectropolarimetric mode, we will be able to detect and monitor the Zeeman signatures of most M dwarfs in our sample, and thus characterize their dynamo-generated magnetic fields (through tomographic techniques such as Zeeman-Doppler Imaging, **ZDI**, Donati & Landstreet 2009) as well as the temporal evolution of these fields throughout the full timespan of the SLS. This will first allow us to address Q4 by documenting **how magnetic fields of largely- and fully-convective M dwarfs** (including their bistable behavior, Morin et al 2010, 2011) **vary with masses and rotation rates**, thereby providing observational guidance to dynamo models in a parameter space where few constraints are available so far (see Fig 5). This may even reveal for the first time whether fully convective stars undergo **solar-like magnetic cycles** as suggested from radio observations (Route 2016). We will also address this issue theoretically using 3D numerical simulations to investigate how large-scale dynamos are affected by changes in the internal structure (Gastine et al 2013), the aspect ratio of the convective zone, the differential rotation profile, and the Rossby number (measuring the relative strengths of inertial to Coriolis forces and approximated by the ratio of the rotation period to the convective turnover time).

Alongside this analysis, we will model the activity of all targets using different tools including GPR (Haywood et al 2014, Cloutier et al 2018a) and innovative tools based on tomographic imaging (Hébrard et al 2016, 2018) in order to **filter out their RV curves down to photon-noise precision and hence maximize the SLS sensitivity to low-mass planets** (Q4). As the RV activity jitter is known to reach several m/s at visible wavelengths even for relatively inactive M dwarfs (Bonfils et al 2013; Hébrard et al 2016, 2018), filtering it efficiently is key for planet detection even though the jitter amplitude is expected to be significantly smaller in the nIR (Reiners et al 2010). With its spectropolarimetric capabilities allowing the best characterization of the magnetic field driving the activity jitter (Haywood et al 2016), SPIRou is best equipped among competitors (Carmenes, CRIRES+) to achieve the most accurate filtering.

Last but not least, we will tackle Q4 by extrapolating the magnetic fields of the host stars (inferred from our magnetic maps, Jardine et al 2002) to estimate with reasonable precision **the magnetospheric environment in which the detected planets orbit**. We will then assess the impact of the observed fields, winds and coronal mass ejections of M dwarfs on the orbital evolution and habitability of M dwarf planets, via numerical simulations of stellar winds and star / planet interactions using 3D MHD codes, especially for short-period and HZ Earth-like planets that are most prone to suffer from such interactions (Jardine et al 2013; Vidotto et al 2013; Strugarek et al 2015). This will yield quantitative lower limits on the magnetic fields HZ Earth-like planets detected with SPIRou must host to be adequately shielded from the activity of the host stars and its potentially devastating effects for the emergence of life at their surfaces.

We stress that all these studies will come as a **free by-product of the SLS-PS and SLS-TF observations** and will require no additional visits to the surveyed targets.

2.5. Magnetized star / planet formation: the SLS-MP component

The second main goal of the SLS is to explore **the impact of magnetic fields on star / planet formation**. By linking forming stars to their discs, by controlling the star / disc coupling and the associated loss of AM

(Bouvier et al 2007), and by altering disc dynamics and planet formation (Baruteau et al 2014), **magnetic fields play a major role throughout the early life of stars and their planets.** To quantitatively assess the effect of these fields on star / planet formation and address Q5 and Q6, one critically needs observational constraints on magnetic fields of PMS stars at various formation stages, from young embedded class-I protostars, to class-II stars (cTTSs) still feeding from their accretion discs, and class-III ones (wTTSs) that have mostly exhausted their discs. Evidence that planet formation is ongoing and information on how fields are able to affect the processes shaping the architecture of planetary systems is also essential.

Pioneering explorations with the MaPP and MaTYSSE programmes (using mostly ESPaDOnS at CFHT) revealed that magnetic fields of cTTSs and wTTSs stars **reflect the internal structures of the forming stars**, getting weaker and more complex when stars are no longer mainly convective (Gregory et al 2012; Donati et al 2013, see Fig 6). Using novel techniques to filter out the extreme activity that wTTSs trigger, MaTYSSE was also able to **disclose the presence of young hJs** for two wTTSs (Donati et al 2016, 2017, see Fig 7; Yu et al 2017), demonstrating not only that planet migration resulting from planet-disc interactions is efficient at generating hJs, but also that magnetospheric cavities can save migrating hJs from falling into their host stars (Lin et al 1996). **Despite this progress, our understanding of magnetized star / planet formation is still inadequate.** Time is ripe for an ambitious study of PMS stars, exploiting the enormous boost in sensitivity (of up to 10 mag) that SPIRou will yield with respect to ESPaDOnS, and allowing us to access a much broader and more diverse sample of PMS stars than previously possible. This study is called the **Magnetized PMS star / planet formation component of the SLS (SLS-MP).**

More specifically, the SLS-MP will feature a spectropolarimetric investigation of 60 accreting PMS stars, including a **pioneering exploration of 15 class-I protostars** whose reputedly strong fields (Johns-Krull et al 2009) have unknown topologies. As the missing link between the youngest class-0 protostars whose fields are surveyed with ALMA / NOEMA at mm wavelengths (Maury et al 2010), and the more evolved cTTSs scrutinized with optical instruments (eg, ESPaDOnS), class-I protostars are key for fingerprinting the impact of magnetic fields on star / planet formation. They will tell us **how dynamo processes** (Gregory et al 2012) **and magnetospheric accretion** (Romanova et al 2008; Blinova et al 2016) **behave when accretion is both stronger and more episodic than that occurring on cTTSs**, and how stars react to this process (Q5, Baraffe & Chabrier 2010; Feiden 2016). The 45 additional program targets will include medium to strong accretors with massive discs or very-low-mass cTTSs for which very few spectro-polarimetric observations exist so far, and will sample the full range of masses (0.3 to 1.5 $M_\odot$), ages (0.1 to a 10 Myr), accretion rates (10^{-9} to 10^{-6} $M_\odot$/yr) and modes (Cody et al 2014; Sousa et al 2016). For this study, we will visit all sample stars 20x throughout their rotation cycles so that rotational modulation can be disentangled from intrinsic variability, strong in accreting PMS stars. We will also use these data to **probe fields in the innermost regions of the surrounding discs**, expanding on the only result so far (Donati et al 2005) and bringing fresh input for accretion discs and planet formation / migration models (Shu et al 2007).

Building on the discovery of young hJs with MaTYSSE (Yu et al 2017) and a young planet with K2 (David et al 2016), the SLS-MP will explore a sample of 60 wTTSs to **detect and characterize hJs at early evolutionary stages with unrivaled efficiency**, offering an innovative way of investigating planet formation and planet / disc interactions (Q6, Baruteau et al 2014). We will simultaneously characterize the fields of the observed wTTSs to **complete our magnetic panorama of young Sun-like stars** (still sparse for wTTSs, Hill et al 2017) and reveal how these fields change with mass and age, at ages similar to those of cTTSs but with no impact from accretion (Q5). This goal requires observing a large sample with many visits/star (~40) to secure statistically reliable conclusions on the occurence of young hJs, and meaningful constraints on planet formation / migration models. Ongoing surveys with ALMA and SPHERE (and soon GRAVITY), investigating outer discs and searching for distant giant planets, will ideally complement our results.

For all stars, we will use ZDI to infer brightness distributions and magnetic topologies at the surfaces of stars, and maps of accretion spots in the accreting PMS stars (Donati et al 2013, 2016). We will then extract the main properties of their large-scale fields, ie (i) the overall magnetic energy, (ii) the fractional energy in their poloidal components, and (iii) the degree of axisymmetry of their poloidal component (Donati & Landstreet 2009; see Fig 6), to **investigate how fields and the underlying dynamo respond to the evolutionary changes in the structure of PMS stars** as they evolve along Hayashi tracks (Gregory et al 2012; Emeriau & Brun 2017). In the case of cTTSs, we will study whether accretion impacts dynamo processes, and find out how non-stationary dynamo fields modify accretion processes and star formation. Working out how rotation rates respond to large-scale fields and accretion rates will provide missing information on **how magnetic fields control the AM evolution of cTTSs** (Gregory et al 2012; Davies et al 2014) and reveal which of the various physical mechanisms invoked (magnetospheric accretion / ejection; Romanova et al 2011; Zanni & Ferreira 2013; X-winds; Mohanty & Shu 2008; accretion-powered winds; Matt et al 2012) can explain observations best (Ferreira 2013). Last but not least, we will investigate the extent to which our magnetic characterization of TTSs can be used to further constrain theoretical evolutionary models of PMS stars (Gregory et al 2012; Feiden 2016) and thereby fingerprint star formation.

For accretion discs, we will apply the technique previously devised for successfully detecting and characterizing the large-scale field of FU Ori (Donati et al 2005), the only protostellar accretion disc in the innermost regions of which a mainly vertical kG field was found at ~0.05 AU from the central protostar. Class-I protostars and actively accreting cTTSs are the best potential targets for this study.

For wTTSs and weakly-accreting cTTSs, we will apply our activity-filtering techniques based on ZDI and GPR to **reveal the potential presence of hJs** (Yu et al 2017), and assess if (and to which extent) hJs are more frequent around TTSs than around mature stars. From the orbital elements of the detected hJs, we will confirm whether they result from disc migration (for low-eccentricity systems) or from planet-planet scattering. By comparing the derived orbital distances with the typical sizes of magnetospheric gaps inferred from our observations of accreting PMS stars, we will assess the role of the magnetic fields in the survival of hJs (Lin et al 1996; Mulders et al 2015). We will further exploit our results with simulations of migrating hJs including realistic fields, magnetospheric gaps and their secular changes with time, to constrain type-II migration and assess the impact of tidal forces as young stars contract and spin up to the MS (Bolmont & Mathis 2016), then predict their orbital fate and compare with the well-constrained population of mature hJs (Wright et al 2012). We will finally study how these fields affect the AM evolution of wTTSs through winds (Réville et al 2016), and how much they impact the atmospheres of hJs (Vidotto et al 2015).

With its polarimetric capabilities and high overall throughput, **SPIRou is clearly the only instrument capable of tackling this forefront observational challenge on star / planet formation**.

3. The SPIRou Legacy Survey and science consortium

3.1. Observing samples and strategies

For the SLS-PS, the main goal is to characterize the multiple-planet systems, both for the closest M-dwarfs (for future studies with ELTs) and for a large sample of nearby mid- to late-M dwarfs to pin down statistical properties of planets and planetary systems around the lowest-mass stars. To achieve this goal, a large number of visits for each star is required to characterize activity and disentangle RV signatures of multiple planets. In practice, **we will survey a sample of 100 M dwarfs,** most of them having spectral types ranging from M3.5 to M7 and moderate to low activity levels (ie rotation periods >10d), with 200 visits per star for a total of 20000 visits. SLS-PS stars were selected from the catalog of the closest M dwarfs, keeping those whose merit factor for nIR velocimetry is highest (Moutou et al 2017; Fouqué et al 2018). Each star will be visited 50x per season at an average rate of 1 visit per night throughout its visibility window, with the full survey requiring 4 yr to reach completion. For each visit, we will acquire one circular polarisation sequence, with an exposure time yielding S/N ratios per 2.28 km/s bin ranging from 230 for a M0V dwarf down to 140 for a M7.5 dwarf, adequate for securing a RV precision of 1 m/s (Figueira et al 2016, Artigau et al 2018) and for detecting polarized Zeeman signatures and Zeeman broadening in line profiles.

Our SLS-TF sample of 65 stars will include candidates that prove to be genuine planets after the first few visits. A 5σ mass detection is predicted to occur on average after 65 visits (min: 30, max: 250) per star for a total of 4200 visits. The planet candidates will be selected among the closest late-K and M dwarfs observed by TESS (southern targets from 2018.5 to 2019.5 and northern ones on the following year), K2 and other ground-based photometric surveys. Each star will be monitored from the time they are selected until a 5σ mass detection is secured for the largest planet in a given system. As for the SLS-PS, we will acquire one circular polarisation sequence per star per visit, with exposure times yielding RV precisions of ~1 m/s.

A large sample size is key for our SLS-MP survey. This is mandatory for assessing how magnetic fields and their impact on star formation change with parameters such as masses, ages, accretion rates / modes, and rotation rates. This is also critical in order to investigate the frequency of young hJs around PMS stars (unlikely to be much larger than a few %) and their orbital properties. We chose **a sample of 120 PMS stars**, including 15 class-I stars and 45 cTTSs (some with disc mass estimates from ALMA and water detection from Spitzer) that we will visit 20 times throughout their rotation cycles (as required for imaging accreting stars exhibiting significant intrinsic variability, Donati et al 2013), and 60 wTTSs to be monitored 40 times throughout their cycles (20 visits for mapping their fields and 20 more to reliably detect their hJs if present, Yu et al 2017). The selected PMS stars are clustered in star forming regions closest to the Sun (Taurus, ρ Oph, Lupus, TWA) sampling ages from a few 0.1 to 10 Myr. For each star, the full series of observations will be secured in a single season; for the wTTSs around which a hJ is found, a new data set will be collected on a later season to confirm the detection, at the expense of sacrificing one star in the wTTS sample. Each visit will yield a circular polarisation spectrum with a S/N ratio of 150 per 2.3 km/s bin, adequate for carrying out the various steps that the data modeling requires.

3.2. Expected results from prior studies and simulations

To quantify the science output of the SLS-PS, we carried out a realistic simulation on our sample of M dwarfs with planetary systems consistent with prior literature results (Bonfils et al 2013; Dressing & Charbonneau 2015), including activity jitter from both star spots and magnetic fields, jitter filtering through GPR and visibility windows for CFHT (Cloutier et al 2018a, see Fig 4 left panel). We find that most planets with RV semi-amplitudes >1 m/s are safely detected by the SLS-PS. Altogether, **the SLS-PS simulation predicts a yield of 80-100 detected planets, 40% of them being Earth-mass planets and 10% of them HZ Earth-mass planets;** among them, 6 are expected to be adequate targets for future ELT characterization (Snellen et al 2010, 2015). The latest versions of our data analysis tools (planet modeling, jitter filtering, magnetic characterization), already used for studies published in the literature (Bonfils et al 2018; Cloutier et al 2018a; Hébrard et al 2016, 2018), are fully functional and ready to be applied on SLS-PS data.

Similar detailed simulations were carried out for the SLS-TF (Cloutier et al 2018b). The synthetic TESS sample (Sullivan et al. 2015, see Fig 4 right panel) was used as input catalog to assess the observing time needed to secure 5σ mass measurements of various planet samples, eg small planets near ~2 $R_\oplus$, H/He-rich icy & gas giants amenable to atmospheric characterization with JWST and a few rocky planets in the HZ of M dwarfs. This simulation methodology is similar to that used for the SLS-PS; it includes all realistic noise sources (photon, activity jitter, unseen planets, systematics due to, eg, telluric residuals). These simulations allow for a realistic planet yield and provide valuable guidelines and objective criteria for selecting SLS-TF targets from new planet candidates unveiled by TESS and other surveys. Optimal selection of the TESS targets yield a sample of ~65 stars, with typically one detected planet per system.

The SLS-MP relies on detecting and characterizing magnetic fields of PMS stars using ZDI, in order to investigate in a quantitative way their impact on star / planet formation. Pioneering explorations of cTTSs and wTTSs with ESPaDOnS at CFHT within the MaPP and MaTYSSE Large Programmes (Donati et al 2013, 2015) demonstrate that this can be achieved using time series of spectropolarimetric observations of high-enough quality (ie, S/N~150) to ensure polarized Zeeman signatures and Zeeman broadening in line profiles of cTTSs are detectable, both within accretion regions and the quiet photosphere (Johns-Krull 2007; Donati et al 2013). First observations of a class-I protostar (Johns-Krull et al 2009) suggest that these techniques are applicable provided the stellar spectrum is not too strongly veiled. From these results we will reveal how fields change along evolutionary tracks of different masses (see Fig 6), how they relate to and impact mass accretion from the inner disc, and how AM evolution is affected in the process. Discovering close-in giant planets of TTSs is another major goal of the SLS-MP. Given detections secured so far, we can logically expect to detect several more with our ambitious survey. Jitter filtering based on GPR, which already proved to be successful in the optical (Donati et al 2017; Yu et al 2017), will perform even better at nIR wavelengths where RVs suffer less from activity (Crockett et al 2012).

3.3. Time needed to complete the survey

With average exposure times of ~4 min for the M dwarfs of the SLS-PS, ~10 min for those of the SLS-TF, and ~11.5 min for the PMS stars of the SLS-MP (see Sec 6 for a list of all targets with their respective exposure times), the SLS requires a total of **400 nights over 8 semesters** (including 30 s overheads per visit per star) that split as follows :
* **200 nights** (1400 hr) **for the SLS-PS**, for carrying out 20000 visits of 100 M dwarfs;
* **100 nights** (700 hr) **for the SLS-TF**, for carrying out 4200 visits of 65 stars, mostly M dwarfs;
* **100 nights** (700 hr) **for the SLS-MP**, for carrying out 3600 visits of 120 PMS stars.

Over the 4 yr that the survey will last, the SLS represents **an average observational effort of 100 nights / year, in line with the CFHT Board decision of 2014 December** which concluded:

> « The Board unanimously agreed that the second call for LP's should occur one year before SPIRou's first light on the telescope in order to facilitate the early start of a Large Survey Program amounting to at least 300 nights over the first three years with this instrument. »

We propose the 400 SLS nights to be split into 217 and 183 nights for the F and C agencies respectively, as outlined in Sec 6.5.

3.4. The SPIRou science consortium

The SLS consortium involves 140+ scientists worldwide and includes in particular the core SPIRou science team who proposed the instrument, secured its funding, closely followed its design, construction and validation, and developed optimal tools for data reduction and velocimetric / spectropolarimetric analyses. The SLS consortium is deeply rooted in the vivid Franco-Canadian collaboration, born decades ago with the construction of CFHT and grown strong and extremely fruitful with many coordinated science and instrumental projects, including ESPaDOnS and WIRCAM that inspired both SPIRou and the SLS. The consortium (see Appendix for a full list) also gathers collaborators from other CFHT partners (Taiwan, Hawaii) and institutes involved in the construction / funding of SPIRou (Brazil, Genève, Porto, Dublin).

4. Figures & references

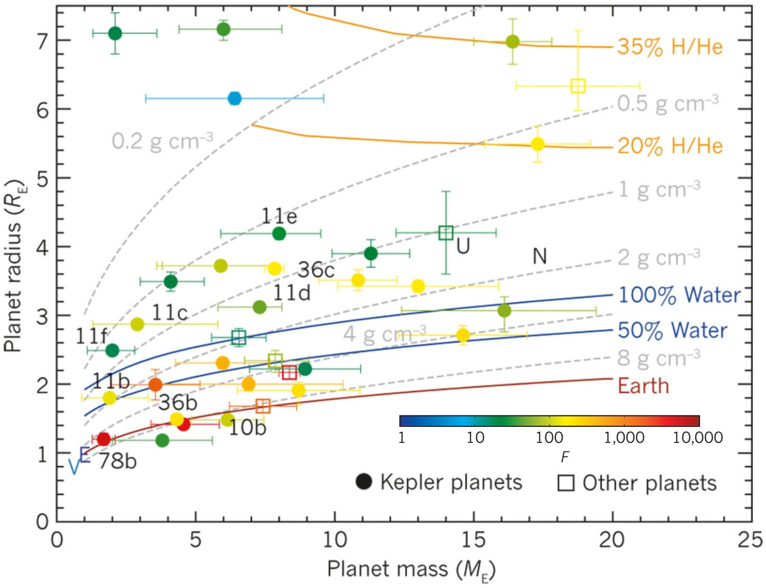

Fig 1: Mass-radius diagram for transiting exoplanets with measured masses lower than 20 M⊕ (symbols & error bars) with model curves for different compositions. Planets are color-coded by the incident bolometric flux they receive (Lissauer et al 2014), With such studies, the bulk composition of the detected planets (and of their atmospheres for gas giants) can be characterized. Note that relative error bars on Kepler planet masses are 20% at best, and that smallest planets receive at least 100x more flux from their stars than the Earth from the Sun.

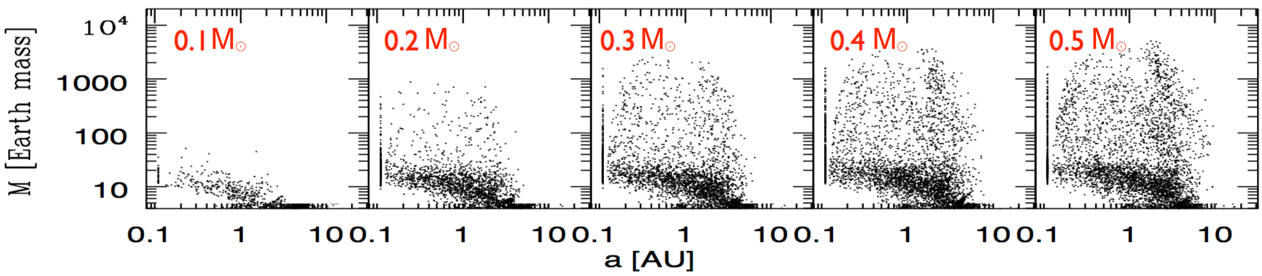

Fig 2: Simulated planet populations assuming various masses of the central star, in the range 0.1-0.5 M⊙. Predicted planet populations are expected to strongly vary for M dwarfs of different masses / spectral types (Alibert et al 2011).

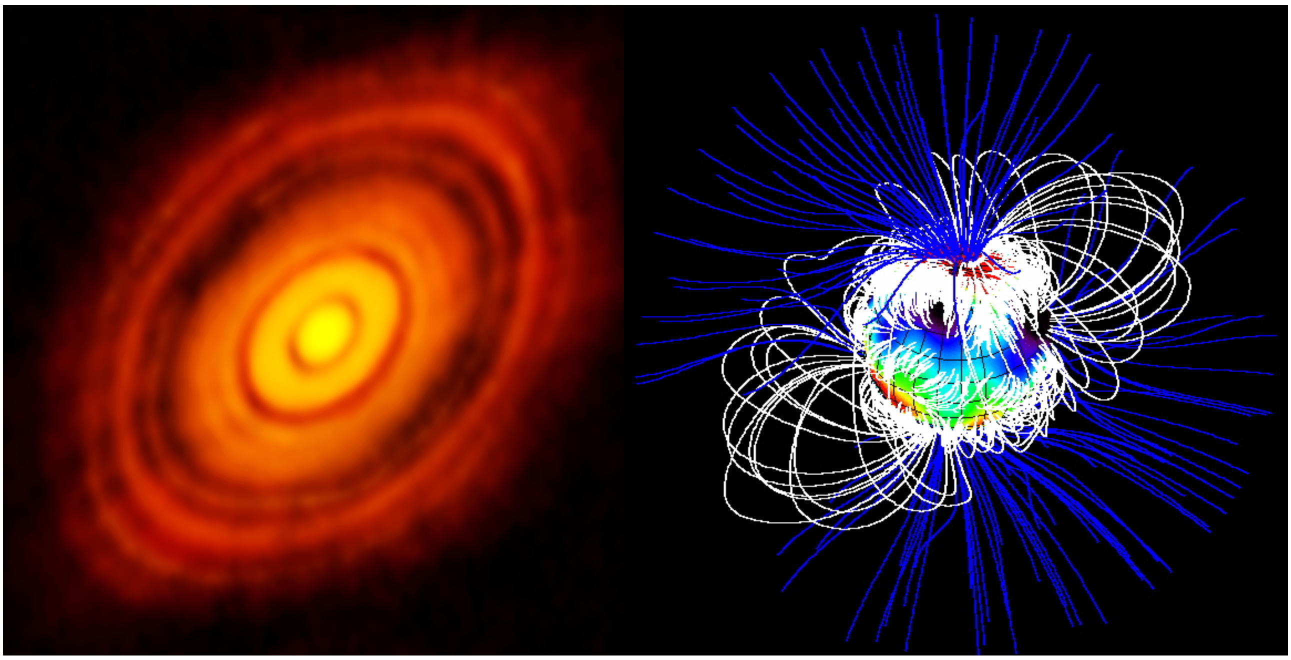

Fig 3. Left panel: The class-I protostar HL Tau and its accretion planet-forming disc as seen with ALMA - a critical evolutionary stage for understanding how worlds like our Solar System are born. **Right panel:** The cTTS V2129 Oph and its magnetic field as inferred from ESPaDOnS spectropolarimetric data; the field carves a magnetospheric gap at the heart of the accretion disc and funnels material from the inner disc to the stellar surface (**click** for an animation).

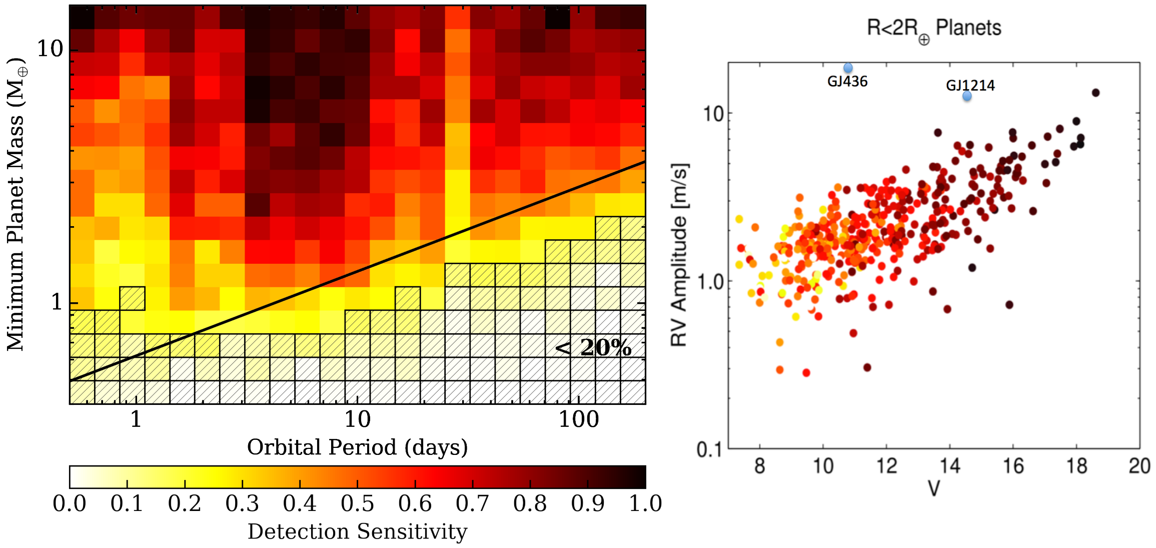

Fig 4. Left panel: Detection efficiency of a simulated realistic SLS-PS survey with SPIRou at CFHT, showing that most planets with a RV semi-amplitude >1 m/s (full line for a mid-M dwarf of mass 0.25 $M_\odot$) are detected (except for those with orbital periods close to 1d) despite the activity jitter plaguing the data. Hashed bins indicate zones where this efficiency is <20%. The predicted planet yield for a SLS-PS survey of 100 M dwarfs with 200 visits per star is 80-100 planets, ~40% of them being Earth-mass (ie, 1-5 $M_\oplus$) planets and 10% of them HZ Earth-mass planets (Cloutier et al 2018a). **Right panel:** Simulated population of transiting Earth-like planet candidates to be detected by TESS. Planet candidates with highest RV amplitudes orbit the coolest M dwarfs (faintest at visible wavelengths). As for the SLS-PS, the SLS-TF should detect most planets with RV semi-amplitudes of >1 m/s (Sullivan et al 2015).

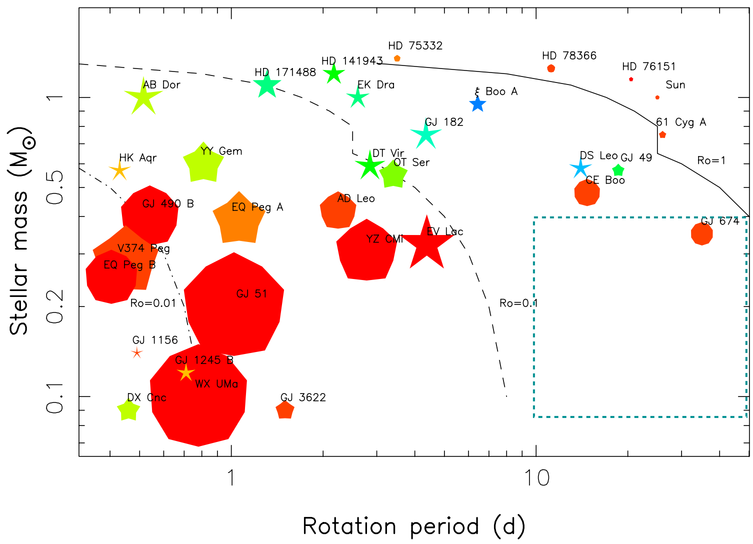

Fig 5: Magnetic properties of low-mass stars vs stellar masses and rotation periods. Symbol sizes scale up with relative magnetic fluxes; colors illustrate field configurations (red to blue for poloidal to toroidal fields); shapes depict the degree of axisymmetry of the poloidal field (decagon and stars for axisymmetric and non-axisymmetric fields). The sharp transition in the field properties at ~0.5 $M_\odot$ shows that magnetic fields can probe the internal structures of low-mass stars. Lines of constant Rossby number (Ro, with dynamo strength increasing with 1/Ro) are added on this plot (updated from Donati & Landstreet 2009). The dotted blue rectangle depicts the sparsely observed region to be explored with the SLS-PS.

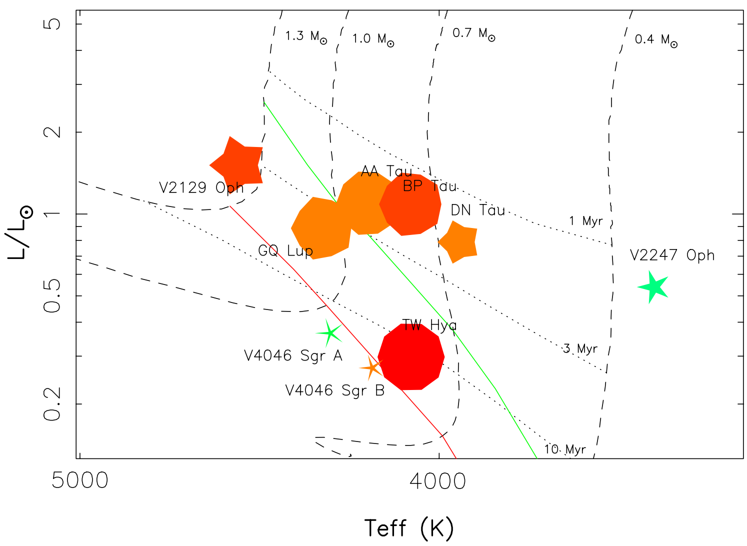

Fig 6: Same as Fig 5 in a HR diagram, for a small sample of cTTSs observed with ESPaDOnS at CFHT. Evolutionary tracks for masses 0.4-1.3 $M_\odot$ and isochrones for ages 1-10 Myr are shown. Ages at which cTTSs are no longer fully- and largely-convective are depicted as a green and red line (from Donati et al 2013). As for M dwarfs, it suggests that magnetic fields can probe internal structures of forming stars. The SLS-MP will produce a much denser version of this plot, extending both to lower masses and younger ages, and adding accretion rates and modes as an additional dimension.

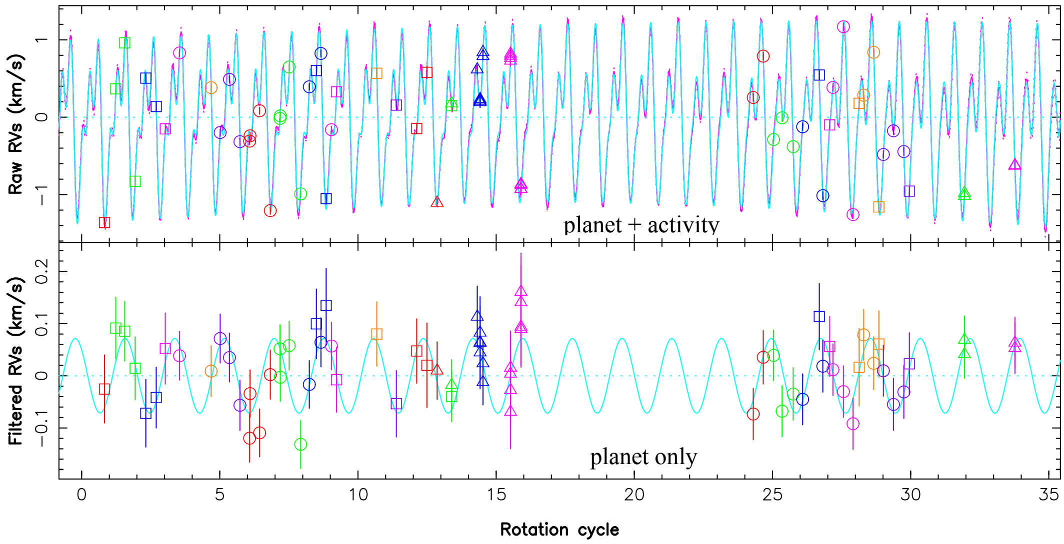

Fig 7: Raw (top) and activity-filtered (bottom) RVs of the wTTS V830 Tau vs rotation cycle, as derived from ESPaDOnS data (open symbols, 1σ errors). The cyan lines depict the curve that ZDI & GPR predict (top) and the planet signal inferred from the filtered RVs (bottom), with rms RV residuals as low as 0.04 km/s. This demonstrates that hJs of wTTSs can be reliably detected despite the huge activity levels of forming stars (from Donati et al 2017).

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5. Technical justification

5.1. Feasibility & exposure times

Regarding the SLS-PS component, the extensive simulations carried out with an adequate level of physical realism (both for the instrument response and RV precision, and for the jitter expected from stellar activity) demonstrate that our programme is feasible, and reliably quantifies the results we can expect in terms of planetary yield (Cloutier et al 2018a, see Fig 4 left panel). For the SLS-TF component, the planet candidates, whenever validated after the first few measurements, will be characterized for their masses using the planet orbital periods and the stellar rotation periods as a modeling input, yielding improved GPR fits of the activity jitter (eg Haywood et al 2014) and enhanced precision on planet masses compared to cases when periods are not known a priori (as for the SLS-PS targets).

The exposure times documented in the target list for each visit (see Sec 6.2) are those required to reach S/N ratios per 2.28 km/s bin, ranging from 230 for a M0V dwarf, down to 140 for a M7.5 dwarf, and are expected to yield a photon-noise RV accuracy of 1 m/s (Figueira et al 2016, Artigau et al 2018) for slowly-rotating stars like those of our sample. The exposure times also agree with those computed with the current version of the SPIRou Exposure-Time Calculator (**ETC**)[3]. For each sample star, we will carry out 200 visits, at a typical rate of 50 visits per season over the 4 yr of the SLS, to ensure we are able to characterize multi-planet systems. **Integrating exposure times over all targets and all visits yield a full survey time of 200 nights including overheads** (30s per visit and per star) for the SLS-PS (see Sec 6.2). For the few very bright stars, we have taken into account saturation limits and the minimum time of 2 readouts per sub-exposure.

Most stars in the SLS-TF sample will be M3V with H~8. With an average exposure time of ~10 min per visit to reach the required S/N (of ~200 per 2.28 km/s bin for M3V dwarfs) and ~65 visits on average per star to secure a 5σ mass measurement, **the SLS-TF survey of 65 stars requires 4200 visits or 100 nights**.

Regarding the SLS-MP component, pioneering programmes exploring magnetic fields of PMS stars with ESPaDOnS at CFHT (MaPP and MaTYSSE in particular) demonstrated that this is feasible. The boost in magnetic sensitivity that SPIRou will bring thanks to the enhanced Zeeman effect at nIR wavelengths ensures that our programme is not only feasible, but will permit an unprecedented level of magnetic characterization, giving access to maps of both small-scale and large-scale fields by combining information from polarized and unpolarized line profiles. Similarly, activity jitters being smaller in the nIR than at optical wavelengths (Crockett et al 2012), RV signatures of potential hJs will be comparatively easier to detect, ensuring that techniques which proved successful when applied to optical spectra (Donati et al 2017; Yu et al 2017) will work even better on SPIRou data. Despite being more challenging, measuring fields in the inner regions of accretion discs (from Zeeman-sensitive emission or absorption lines specifically formed in the disc whenever detected) for a few class-I or class-II objets was proved feasible at optical wavelengths (Donati et al 2005) and will be easier in the nIR (thanks to the higher magnetic sensitivity) for FU Ori-like targets whose spectrum comes mostly from the disc; the success of this experiment on a few new targets will depend on the abundance and relative strength of disc lines in their spectra at the time of our observations, which we will assess through initial snapshots observations of a small sample to ensure that the few ones we will monitor are the best candidates for our exploration.

The exposure times documented in the target list for each visit (see Sec 6.3) will yield average S/N ratios of ~150 per 2.28 km/s velocity bin (in agreement with the SPIRou ETC). This is adequate to model the magnetic fields and activity of PMS stars, both for filtering their RV jitters (smaller in the nIR) and for reliably investigating the potential presence of hJs. We will carry out 20 visits per target for class-I protostars and cTTSs to map their fields and accretion regions, with all visits for a given star within a typical time span of 1 month. We will aim for 40 visits for wTTSs, ie 20 visits for mapping their fields and 20 additional ones for filtering their activity and looking for hJs. Again, we will carry out all visits in a single season to maximise the efficiency of activity filtering, and will take another series of 40 spectra (at the expense of sacrificing a sample star) for the few wTTSs around which a hJ is detected from the first series. Altogether, **integrating exposure times over all targets and all visits yield a full survey time of 100 nights including overheads** (30s per visit and per star) for the SLS-MP (see Sec 6.3).

All visits will be carried out in polarimetric mode for all 3 SLS components, in order to collect both unpolarized (Stokes I) and circularly-polarized (Stokes V) spectra of our targets. In practice, this means

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[3] Output of the March 2018 SPIRou ETC for a few typical stars from our target lists (see Sec 6). Note that the ETC gives S/N ratios per 4.2 km/s bins, ie 1.36x larger than the S/N ratios per 2.28 km/s bins quoted in our proposal.

* GJ 3148 (M3, aim S/N=270 per 4.2 km/s): Computed snr:267,etime:290,teff:3100,magh:7.3,seeing:0.6,h2o:1.0,airmass:1.0
* GJ 3877 (M7, aim S/N=200 per 4.2 km/s): Computed snr:207,etime:1004,teff:2500,magh:9.3,seeing:0.6,h2o:1.0,airmass:1.0
* HL Tau (class-I, aim S/N=200 per 4.2 km/s): Computed snr:240,etime:290,teff:4500,magh:7.5,seeing:0.6,h2o:1.0,airmass:1.0
* TWA 35 (wTTS, aim S/N=200 per 4.2 km/s): Computed snr:210,etime:892,teff:2700,magh:9.1,seeing:0.6,h2o:1.0,airmass:1.0

that all exposures will consist of a sequence of 4 subexposures, each taken with a different configuration of the quarter-wave retarders (Donati et al 1997, 2018). This will ensure in particular that we will be able to perform a magnetic analysis of all SLS stars, including those of the SLS-MP and SLS-TF, allowing us to monitor in detail the magnetic activity of our targets and to implement novel techniques for filtering the activity jitter (Hébrard et al 2016, 2018). For the SLS-PS and the SLS-MP components, we aim for one visit per night per star, with a target list that varies between A and B semesters (and from one year to the next in the case of the SLS-MP). For the SLS-TF component, the sampling will be optimized with the known orbital periods of the candidates, and will typically range from 2 visits per night to 1 visit every 2-3 nights.

For all programmes, we will use standard calibrations series (darks, flat fields, Fabry-Perot and U-Ne frames) recorded at the beginning of the night. Moreover, all stellar exposures on the science channels collected throughout the observing nights will be recorded simultaneously with Fabry-Perot spectra on the reference channel. This will ensure in particular that **our RV reference frame is stable at 1 m/s rms or better** on both the short- and long-term, as required for both SLS-PS and SLS-TF programmes. If needed, we may also use a small fraction (<1%) of the full SLS time to complete our library of telluric spectra to be built as part of the forthcoming SPIRou Technical Commissioning and Science Verification slots.

5.2. Data reduction & analysis

Data reduction will be carried with the nominal SPIRou Data Reduction Software (**DRS**).

Deriving high-precision RVs from SPIRou spectra over long time series for the SLS-PS and SLS-TF components requires in particular to (i) monitor the instrumental drift with spectral lamps, (ii) assess the RV content of stellar spectra for different spectral types with optimized lists of spectroscopic lines from which RVs are derived through cross-correlation techniques, and (iii) mitigate the impact of telluric lines moving with respect to stellar spectra. With the large RV data set collected with the SLS, we will be able to optimize these RV measurements and thereby improve the SPIRou pipeline as experience with the instrument and knowledge of its on-sky performances builds up with the collected data.

Polarized spectra for all SLS components will be derived following the same technique extensively used for ESPaDOnS (Donati et al 1997), whose robustness is now well established after 1.5 decades of successful science operation.

Data analysis will be carried out using reference tools and techniques (such as periodogram analysis, GPR, ZDI, MCMC) already tested and extensively used over the last decade for many detailed studies involving data collected with previous similar instruments (eg HARPS, ESPaDOnS, Sophie) and published in the refereed literature (eg Bonfils et al 2013, 2018; Morin et al 2010, 2011; Yu et al 2017) .

5.3. Sensitivity to reduced data acquisition rate or evolving instrumental performances

Nights with moderate weather will be dedicated to the brightest targets, for which we can easily increase exposure times to reach the desired S/N ratios without losing too much time. Dependency of the RV precision with water vapor column will be assessed during Science Verification and at the beginning of the survey, when the library of telluric spectra will be available. From our simulations of telluric line correction and given typical water vapor conditions at Maunakea, we expect our RV programmes to be feasible at least 80% of the time. Whenever adequate, we will also reallocate time within the SLS-TF and dedicate a small fraction of the overall SLS-TF time to monitoring transits of well-known hJs or hot Neptunes (eg GJ 436, GJ 1214, whose atmosphere will be scrutinized later on with JWST), given that this programme is more resilient than the core SLS-TF programme to moderate seeing conditions (or to limitations in RV precision).

Laboratory tests already demonstrated that SPIRou is compliant with scientific specifications. In particular, SPIRou reaches an absolute RV precision of 0.3 m/s over periods of 24 h, which bodes well to meet sub-m/s performance on the sky. Our simulations of the SLS-PS and SLS-TF surveys (Cloutier et al 2018a, 2018b) assume a noise floor of 1 m/s, corresponding mostly to telluric subtraction using methods tested on synthetic spectra (to be validated on sky during the SPIRou Technical Commissioning and Science Verification slots). In the unlikely even that telluric subtraction is less effective than expected from our tests, we predict a planet yield reduction of ~25% for both the SLS-PS and SLS-TF (Cloutier et al 2018a, 2018b) for a RV precision limited to 2 m/s rms instead of the nominal one (1 m/s). The SLS-MP is visually unaffected by similar limitations in RV precision, given the large activity levels of PMS stars.

5.4. Data management plan

The work associated with the SLS is divided into 5 Work-Packages (**WPs**), either specific to each SLS component, or transverse to several ones. More specifically, we will have:

(i) **WP1**, in charge of the SLS-PS, including target selection, planet detection and characterization, detection limits & statistics, photometric follow-up (coordinators: X Delfosse, C Moutou & E Artigau);

(ii) **WP2,** in charge of the SLS-TF, including target selection, planet characterization, complementary observations (coordinators: G Hébrard & R Doyon);
(iii) **WP3,** in charge of the SLS-MP, including target selection, magnetic tomography, detection of disc fields, activity filtering & the search for hJs, complementary observations & modeling (coordinators: J Bouvier, JF Donati & S Alencar)
(iv) **WP4,** in charge of tools common to both SLS-PS & SLS-TF, including DRS & RV optimization, jitter filtering, dynamics of planetary systems, star-planet interactions, HZs (coordinator I Boisse);
(v) **WP5,** in charge of tools common to the whole SLS, including spectral classification, large-scale fields of low-mass stars, atmospheric characterization from telluric lines (coordinator J Morin).

The 5 work packages are already functional, with survey preparation and target selection for WP1 & 3, and RV optimization for WP4, among the main tasks carried out so far. A dedicated wiki site (https://spirou-legacy.irap.omp.eu) was setup to document progress and results. Activity will ramp up as the first spectra are collected starting in 2018b. We plan to have regular science workshops throughout the 4 yr of the SLS to share the data analysis and results as data are being collected.

The whole work is coordinated within each WP by the WP coordinators, and at the SLS level by the WP coordinators, forming the SLS Executive Board (SLS-EB); in particular, the SLS-EB will ensure that all components of the SLS remain optimally phased with other projects on relevant science topics (eg JWST, ALMA, SPHERE, GRAVITY), will organise / manage collaborations with other observing teams (eg TESS, IRD on Subaru, CARMENES on CalarAlto) if possible and whenever productive, and will readjust the respective size of each SLS component if needed. The SLS-EB will also decide regarding the evolution of the target catalogs and protection lists (see below).

The SLS will naturally implement **a data-access policy** to ensure that all SLS coIs have equal access to the raw and reduced data; in practice, coIs will need to register on a password protected portal to become Registered Users (**RUs**) and gain access to the data while certifying at the same time that they will (i) comply to the publication policy (see below) and (ii) commit not to export SLS data to non-RUs. The SLS will also come with **a publication policy** to ensure collaborative rather than competitive work within the team. All analyses of the SLS data will be performed within the respective individual WPs and coordinated by the team in charge, with coIs undertaking studies regularly informing other WP members of their goals and progresses for these members to get the opportunity of providing their expertise and of participating to the modeling efforts. Resulting publications will explicitly include all WP members involved in the analyses as coauthors, in an order reflecting their respective level of implication.

Due to the nature of the programmes being carried out (survey of a large sample and / or long-term monitoring), we request **the proprietary time of the SLS data to be extended to the duration of the SLS plus one year**. This would give the SLS science team enough time to conduct final analyses; only the full data set coupled to a thorough study can reveal the full architecture of planetary systems along with accurate stellar characterizations, and yield a detailed view of how magnetic fields impact star / planet formation (see Fig 6). Data sets completed and published before the end of the survey will be made public at the time of their publication; for the SLS-PS component, we also propose to publicly release one spectrum per observed star after 3 semesters, once most stars of the sample have each been visited a few tens of times. We also request **the metadata to have the same proprietary period as the data**. Although we plan to have an open target list so as to deter inefficient observation duplications (see below), some confidentiality, eg on the sampling or the quality of the RV data, is required in these extremely competitive research fields.

We recall here that the SLS science team was built through repeated calls to the CFHT community and already gathers most experts on the SLS main topics (see full list in the Appendix); scientists from the CFHT community interested in contributing to the SLS work, and not yet members of the SLS science team, are welcome to contact the SLS-EB to propose their participation, outlining their suggested involvement.

The survey strategy we will carry out for the SLS-PS and SLS-TF components, based on long-term monitoring and requiring a large number of visits per star to detect weak RV signals, calls for optimization by preventing a duplication of observations between different programmes. **We thus suggest both SLS-PS and SLS-TF target lists to be protected from exact duplication while the selected targets are being observed within the SLS.**

Note that our target catalogs (and thereby protection lists) are likely to evolve throughout the first few semesters of the SLS. The new planet candidates that TESS will discover will trigger regular updates of the SLS-TF target list (handled by the SLS-EB in coordination with the TESS science team to avoid duplicating efforts); similarly, nearby M dwarfs to be revealed by the forthcoming GAIA results may be added to our SLS-PS sample if beneficial for the survey. **Our revised target catalogs / protection lists will be published on the CFHT web page a few weeks prior to the biannual CFHT deadlines for proposals** to ensure an optimal use of SPIRou time and no duplication of observations.

6. Target lists & RA distribution

6.1. Target selection

For the SLS-PS component, our sample mixes two different sets of M dwarf stars (see Sec 6.2). The first set, about half the size of the full sample, includes all closest M dwarfs up to 7 pc, except for targets with declinations <-30°, for binary stars with angular separation <2" and for the most active dwarfs with rotation periods shorter than 4 d. This group includes in particular the M dwarfs that will be most accessible and hence the best candidates for future follow-up studies of planet properties and atmospheres with ELTs. The second set gathers nearby mid- to late-M dwarfs whose merit function for planet detection[4] is highest (Moutou et al 2017). We are left with **a full list of 100 M dwarfs** for which we will carry out 200 visits per star (each visit yielding a S/N ratio per 2.28 km/s bin ranging from 230 for a M0V dwarf down to 140 for a M7.5 dwarf, and yielding a photon-noise RV accuracy of 1 m/s, Figueira et al 2016; Artigau et al 2018) to detect and characterize their planetary systems in agreement with our programme (see Secs 2.2 and 5.1), bringing the full survey time to 200 nights including overheads. The (protected) target list will slightly evolve with time depending on results obtained with other instruments working on similar research fields (eg GAIA, CARMENES, see Sec 5.4).

For the SLS-TF component, the full sample is not known yet and will largely depend on the candidate planets to be discovered by TESS during its survey, starting with southern targets from mid 2018 to mid 2019, then concentrating on northern targets from mid 2019 to mid 2020. The initial target list that we provide includes 14 interesting targets that are already available, mostly from K2 (see Sec 6.4). **We anticipate most** (though not all) **of these targets to be replaced by TESS candidates as they are being discovered**. Note that targets in our initial list are on average significantly fainter than those to be discovered with TESS, hence the higher average number of observing nights per target that they require (5.5 night per target instead of 1.5 for TESS candidates) and the lower RV precision (2 m/s rms) that we aim at for half of them (expected to exhibit a high activity level, eg K2-33). The very interesting planets / systems of Trappist-1, K2-33, K2-135, K2-136 and K2-155 are among the targets we will start observing during the first few semesters of the SLS-TF irrespectively of TESS's fate and performances.

Our initial sample also includes 9 bright transiting systems that could be observed during one transit to study their atmosphere through high-resolution spectroscopy, a very powerful and emerging technique for exoplanet atmospheric characterization (eg Snellen et al. 2010; Brogi et al. 2018). In addition to being ideal for early release of high-impact SPIRou results, these observations are also well resilient to reduced RV performance and / or moderate seeing conditions (see Sec 5.3).

Given TESS's schedule, we will provision 6 nights for the first semester (when only a few candidates will be available), 10 nights for the second one and 14 nights per semester for all following 6 semesters (for a total of 100 nights). The (protected) target list for each semester will be updated and optimized a few weeks before the biannual CFHT deadlines for proposals (see Sec 5.4).

For the SLS-MP component, the target list includes **~120 of the most interesting class-I, cTTSs and wTTSs targets to be observed with SPIRou** that are currently known at the time of submission (see Sec 6.3). More specifically, it includes ~15 of the brightest class-I stars in 2 main Star Forming Regions (**SFRs**) and ~45 cTTSs in 3 main SFRs (Taurus, ρ Oph, Lupus) with a wide variety of accretion modes and rates, for which we will carry out 20 visits per star to diagnose their magnetic and accretion properties. It also features ~60 wTTSs in 3 main SFRs (Taurus, ρ Oph and TWA) with a wide range of spectral types, for which we will perform 40 visits per star (20 visits to derive their magnetic fields and 20 additional visits to investigate the potential presence of hJs). This list includes a small fraction of the most interesting MaPP and MaTYSSE targets (eg V830 Tau, TAP 26 & LkCa 4 for wTTSs, or V2129 Oph & TW Hya for cTTSs), for which we find it essential to perform a full nIR analysis enhancing the optical studies carried out so far, and wish to extend the long-term monitoring of their magnetic fields and accretion modes / rates whenever relevant. Exposure times are set to yield S/N ratios of ~150 per 2.28 km/s bin, adequate for the planned tomographic imaging and jitter filtering studies (see Secs 2.5 and 5.1). The target list will evolve with time to optimise its relevance with respect to the most recent discoveries in star / planet formation (eg with results from the ongoing extensive surveys with ALMA and SPHERE, and the forthcoming ones with GRAVITY then JWST, see Sec 5.4).

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[4] This merit function is defined as the flux received from the star in the H band, times the semi-amplitude of the RV signature that a 3 $M_\oplus$ planet orbiting in the HZ would generate.

6.2. Target list for the SLS-PS

star	ST	H (mag)	t_{exp} (s)	d (pc)
GJ 1002	M5.5V	7.79	312	4.8
GJ 1006A	M4V	7.32	245	15.1
Gl 15A	M1.5V	4.48	67	3.6
Gl 15B	M3.5V	6.19	89	3.6
GJ 1012	M4V	7.50	290	13.3
Gl 48	M2.5V	5.70	67	8.2
GJ 1026	M2V	7.09	268	15.9
Gl 54.1	M4.5V	6.75	134	3.7
Gl 83.1	M4.5V	6.97	178	4.5
GJ 3148	M3V	7.32	290	13.6
Gl 102	M4V	7.91	446	9.4
Gl 105B	M4V	6.79	156	
Teegarden's star	M7V	7.88	268	3.8
GJ 3192A	M3V	6.56	134	6.7
GJ 1057	M5V	8.21	513	8.6
Gl 166C	M4.5V	6.28	89	5.0
Gl 169.1A	M4V	6.01	67	5.5
2M 04425586+2128230	M3.5V	7.40	290	
Gl 179	M3.5V	7.21	245	12.4
GJ 3323	M3.5V	7.07	223	5.4
LHS 1731	M3V	7.24	268	9.3
Gl 205	M1.5V	4.15	67	5.6
GJ 3356	M3.5V	7.19	245	12.4
2M 05363846+1117487	M4V	7.69	357	
Gl 213	M4V	6.63	134	5.8
GJ 3378	M3.5V	6.95	201	7.5
Gl 229	M1V	4.39	67	5.8
2M 06165372-0518037		7.19	268	
Gl 251	M3V	5.53	67	5.5
Gl 273	M3.5V	5.22	67	3.8
2M 07495087-0317194	M3.5V	7.46	312	
GJ 1103A	M4.5V	7.94	424	8.8
GJ 1105	M4V	7.13	201	8.3
Gl 299	M4V	7.93	446	6.8
Gl 300	M4V	6.96	178	8.0
GJ 3506	M2.5V	7.29	290	13.0
2M 08401597+3127068	M3.5V	7.56	335	11.1
Gl 317	M3.5V	7.32	268	15.3
GJ 1119	M4.5V	8.03	446	9.9
Gl 338B	M0V	4.04	67	6.3
GJ 1125	M3.5V	7.18	245	10.0
Gl 362	M3V	6.73	178	11.7
GJ 1129	M4V	7.54	312	11.0
LP 847-48	M3V	7.43	335	10.8
GJ 3612	M3.5V	7.39	290	13.2
GJ 1134	M4.5V	8.01	446	10.3
GJ 3622	M6.5V	8.26	424	4.6
Gl 402	M4V	6.71	134	6.9
Gl 408	M2.5V	5.76	67	6.7
Gl 411	M2V	3.64	67	2.5
Gl 412A	M1V	5.00	67	4.9
GJ 1148	M4V	7.07	201	11.0
Gl 445	M3.5V	6.22	89	5.2
Gl 447	M4V	5.95	67	3.4
GJ 1151	M4.5V	7.95	424	7.7
GJ 3707	M3.5V	7.14	223	12.8
Gl 480	M3.5V	6.94	201	14.0
LHS 2613	M4V	7.50	290	10.6
Gl 486	M3V	6.67	156	8.1
GJ 3801	M4V	7.21	223	9.1
Gl 526	M1.5V	4.78	67	5.4
L 762-51	M3.5V	7.19	245	11.3
GJ 3820	M4V	7.76	379	10.8
Gl 553.1	M3.5V	7.26	268	10.9
Gl 555	M3.5V	6.26	89	6.3
GJ 9492	M1.5V	6.73	201	11.0
GJ 3877	M7V	9.32	1004	7.1
Gl 581	M2.5V	6.10	89	6.3
Gl 609	M4V	7.65	335	
Gl 617B	M3V	6.30	112	10.7
Gl 625	M1.5V	6.06	112	6.5
Gl 628	M3V	5.37	67	4.3
Gl 643	M3.5V	7.06	223	6.5
GJ 3988	M4.5V	8.19	535	9.5
GJ 3992	M3.5V	7.04	201	12.0
Gl 669A	M3.5V	6.71	156	10.7
Gl 687	M3V	4.77	67	4.5
Gl 699	M4V	4.83	67	1.8
GJ 1227	M4V	8.05	491	8.2
GJ 4063	M3.5V	6.53	134	
GJ 4071	M4.5V	7.81	379	11.0
Gl 725A	M3V	4.74	67	3.5
Gl 725B	M3.5V	5.20	67	3.5
2M 18481752+0741210	M5V	8.26	535	7.2
Gl 729	M3.5V	5.66	67	2.9
Gl 752A	M2.5V	4.93	67	5.9
GJ 1256	M4.5V	8.08	468	9.9
HIP 103039	M4V	6.52	112	5.7
Gl 810A	M4V	7.64	335	12.9
2M 21462206+3813047	M4V	7.47	290	6.7
TYC 3980-1081-1		5.86	67	8.3
Gl 843	M3.5V	7.50	312	12.8
Gl 849	M3V	5.90	67	8.8
GJ 4274	M4.5V	7.64	312	7.3
Gl 873	M3.5V	5.55	67	5.0
Gl 880	M1.5V	4.80	67	6.9
GJ 4333	M3.5V	6.77	156	10.9
Gl 905	M5.5V	6.25	67	3.2
GJ 1289	M3.5V	7.45	312	8.1
Gl 908	M1V	5.28	67	5.9
total stars	**100**			
visits / star	**200**			
total integration (nights)	**176**			
total overheads (nights)	**24**			
total time (nights)	**200**			

6.3. Target list for the SLS-MP

class I protostar	ST	K (mag)	t_{exp} (s)	SFR
HL Tau	K5	7.41	290	Taurus
IRAS 04263+2426	K7	8.05	513	Taurus
L1551 IRS 5	K3-M3	9.26	1427	Taurus
IRAS 04016+2610		9.20	1360	Taurus
IRAS 04385+2550		9.20	1360	Taurus
GY 214		7.14	223	ρ Oph
GY 378		8.71	959	ρ Oph
L1689 SNO2 N		7.56	335	ρ Oph
WLY 2-51		8.99	1115	ρ Oph
WLY 2-63		9.22	1383	ρ Oph
VSSG 17	M2	9.02	1160	ρ Oph
BKLT J162636-241554	M0	9.59	1570	ρ Oph
Haro 5a IRS		8.00	491	Orion
HH 381 IRS		8.30	669	Cygnus
V512 Per		8.17	513	Perseus

cTTS / class II	ST	K (mag)	t_{exp} (s)	SFR
AA Tau	K7	8.05	468	Taurus
BP Tau	K7	7.74	357	Taurus
CI Tau	K7	7.79	379	Taurus
CW Tau	M3	7.13	201	Taurus
DF Tau	M3	6.73	134	Taurus
DG Tau	K7-M0	6.99	178	Taurus
DN Tau	M0	8.02	468	Taurus
DO Tau	M1	7.30	245	Taurus
DQ Tau	M0	7.98	446	Taurus
DS Tau	K5	8.04	468	Taurus
FP Tau	M4	8.87	1004	Taurus
FY Tau	K7	8.05	468	Taurus
GI Tau	K6	7.89	401	Taurus
GK Tau	K7	7.47	268	Taurus
GO Tau	M0	9.33	1539	Taurus
IP Tau	M0	8.35	650	Taurus
IQ Tau	M0	7.78	379	Taurus
RY Tau	K1	5.40	67	Taurus
UZ Tau	M1	7.47	268	Taurus
V410 X-ray 6	M4.5	9.10	1249	Taurus
V807 Tau	K7	6.96	178	Taurus
V927 Tau	M5.5	8.77	914	Taurus
LkCa 15	K5	8.16	535	Taurus
JH 223	M2.8	9.49	1570	Taurus
CoKu Tau 3	M1	8.41	669	Taurus
RW Aur	K1/K5	7.02	178	Auriga
WSB 60	M4.5	9.32	1539	ρ Oph
SR 9 (V2129 Oph)	K5	7.21	223	ρ Oph
SR 10	M2	8.90	1026	ρ Oph
SR 12 (V2247 Oph)	K4/M2	8.41	669	ρ Oph
SR 13	M3.75	8.00	446	ρ Oph
SR 24N	M0	7.55	290	ρ Oph
AS 205 A (V866 Sco)	K5	5.78	67	ρ Oph
Sz 71	M1.5	8.63	803	Lupus
Sz 74	M3.5	7.43	268	Lupus
Sz 82	K5	7.74	357	Lupus
Sz 83	K7	7.14	201	Lupus
Sz 118	K5	8.69	847	Lupus
EX Lup	M0	8.50	714	Lupus
GQ Lup	K7	7.10	201	Lupus
RU Lup	K7	7.10	201	Lupus
RY Lup	K1	6.98	178	Lupus
RXJ 1615-3255	K7	8.56	758	Lupus
TW Hya	K6	7.30	245	TWA
FU Ori		5.16	67	Orion

wTTS / class III	ST	K (mag)	t_{exp} (s)	SFR
CoKu Tau 4	M1.5	8.66	825	Taurus
CoKu LkHA 332 G2	K7	8.23	558	Taurus
HBC 427	K7	8.13	513	Taurus
Hubble I 4	K7	7.29	245	Taurus
Herbig Anon 1	M0	7.46	268	Taurus
DI Tau	M0	8.39	647	Taurus
FF Tau	K7	8.59	781	Taurus
HP Tau G3	K7	8.80	937	Taurus
IW Tau	K7	8.28	580	Taurus
UX Tau B	M1	8.92	1048	Taurus
VY Tau	M0	8.96	1093	Taurus
V410 Tau	K3	7.63	312	Taurus
V819 Tau	K7	8.42	669	Taurus
V826 Tau	K7	8.25	580	Taurus
V827 Tau	K7	8.23	558	Taurus
V830 Tau	K7	8.42	669	Taurus
V836 Tau	K7	8.60	781	Taurus
V928 Tau	M0.5	8.11	491	Taurus
V1075 Tau	K6	8.85	1004	Taurus
V1195 Tau	K7	7.75	357	Taurus
V1207 Tau	K5	8.80	959	Taurus
V1304 Tau	M1	9.05	1204	Taurus
V1306 Tau	M1.5	9.25	1427	Taurus
V1335 Tau	M0	9.02	1160	Taurus
V1347 Tau	K6	8.28	580	Taurus
LkCa 1	M4	8.63	803	Taurus
LkCa 4	K7	8.32	602	Taurus
LkCa 5	M2	9.05	1204	Taurus
LkCa 7	K7	8.26	580	Taurus
LkCa 11	M2	8.69	847	Taurus
LkCa 14	M0	8.58	781	Taurus
LkCa 21	M3	8.45	691	Taurus
TAP 26	K7	9.27	1472	Taurus
TAP 41	K7	8.85	1004	Taurus
TAP 45	K7	9.31	1516	Taurus
TAP 57	K7	8.13	513	Taurus
V583 Aur	K5	8.42	669	Auriga
Oph 22	M3	9.06	1204	ρ Oph
GY 380	K7.5	8.13	513	ρ Oph
VSS II-23/WLY 2-10	K5.5	8.33	624	ρ Oph
GSS 20/WLY 2-13	K5.5	8.32	602	ρ Oph
VSSG 3	K6	8.69	847	ρ Oph
VSSG 19	M2	9.12	1271	ρ Oph
TWA 2A	M2	6.71	134	TWA
TWA 3B	M4	6.71	134	TWA
TWA 6	K7	8.04	468	TWA
TWA 7	M3	6.90	156	TWA
TWA 8A	M3	7.43	268	TWA
TWA 8B	M5	7.66	335	TWA
TWA 9A	K5	7.85	401	TWA
TWA 9B	M3	9.15	1316	TWA
TWA 10	M2	8.19	535	TWA
TWA 12	M2	8.05	468	TWA
TWA 13A	M1	7.49	290	TWA
TWA 13B	M1	7.46	268	TWA
TWA 20	M2	8.41	669	TWA
TWA 23	M3.5	7.75	357	TWA
TWA 25	M0	7.31	245	TWA
TWA 35	M5	8.72	892	TWA
Sz 121	M4	9.03	1182	Lupus

total class I & class II	**60**
total class III	**60**
total stars	**120**
visits / class I & class II	**20**
visits / class III	**40**
total integration (nights)	**96**
total overheads (nights)	**4**
total time (nights)	**100**

6.4. Initial target lists for the SLS-TF (will evolve with TESS discoveries)

star (1 m/s RV goal)	**ST**	**H (mag)**	**t_{exp} (s)**	**d (pc)**
Trappist-1	M8V	10.70	3033	12
Kepler-16	K5V	9.10	2832	61
Kepler-138	M1V	9.70	3300	66
K2-21	K7.5V	9.60	3903	65
K2-135	K6V	7.40	580	30
K2-136	K5.5V	8.50	1628	59
K2-155	K6V	7.40	580	30
star (2 m/s RV goal)	**ST**	**H (mag)**	**t_{exp} (s)**	**d (pc)**
Kepler-1651	M1V	10.00	1093	69
K2-26	M1V	10.80	2275	93
K2-33	M3V	10.30	1182	145
K2-83	M0V	11.00	2988	
K2-123	M0V	11.30	3947	
K2-174	K5V	9.50	1026	
K2-199	K5V	9.60	1115	
total stars	**14**			
visits / star	**65**			
total integration (nights)	**76**			
total overheads (nights)	**1**			
total time (nights)	**77**			
star (transit monitoring)	**ST**	**H (mag)**	**t_{exp} (hr)**	**d (pc)**
GJ 436	M3V	6.30	1.5	10
GJ 1214	M4.5V	9.10	1.5	15
GJ 3470	M2V	8.20	5.5	25
K2-25	M4.5V	10.70	3.6	46
HD 189733	K0V	5.60	3.6	20
WASP-69	K4V	7.50	4.5	50
HAT-P-1	G0V	8.90	5.6	139
WASP-80	K7V	8.50	4.2	60
WASP-107	K6V	8.80	3.8	
total integration (nights)	**5**			

6.5. Time distribution over semesters 2018b-2022a

The following table summarizes how time (in observing nights) is distributed between semesters for the SLS as a whole (and for F and C agencies), as well as for each SLS component. The first semester is shorter, being carried out in shared risk mode. The SLS-TF ramps up as TESS discoveries will come out, whereas the SLS-MP requires higher time on B semesters when Taurus targets are best visible.

semester	SLS (F)	SLS (C)	SLS	SLS-PS	SLS-TF	SLS-MP
2018b	17	14	**31**	15	6	10
2019a	21	17	**38**	20	10	8
2019b	29	25	**54**	25	14	15
2020a	28	23	**51**	28	14	9
2020b	33	29	**62**	28	14	20
2021a	28	23	**51**	28	14	9
2021b	33	29	**62**	28	14	20
2022a	28	23	**51**	28	14	9
total	**217**	**183**	**400**	**200**	**100**	**100**

6.6. RA distribution in 2018

The following table summarizes how time (in observing nights) is distributed across RAs for the SLS as a whole, as well as for each SLS component

RA	SLS	SLS-PS	SLS-TF	SLS-MP
16-20	**0**	0	0	0
20-24	**6**	2	4	0
00-04	**5**	5	0	0
04-08	**17**	5	2	10
08-12	**2.5**	2.5	0	0
12-16	**0.5**	0.5	0	0
total	**31**	**15**	**6**	**10**

Appendix. SLS science team

We include below the full list of 140+ SLS participants (coIs and additional contributors), with work-package coordinators in bold face and affiliated coIs in italics.

Country	Institute	Team members
France	IRAP/OMP/UPS, Toulouse	**Donati**, Yu, Klein, Kulenthirarajah, Hill, Carmona, Folsom, Baruteau, Jouve, Petit, Ferrière, Cang, *Charbonnel*
	IPAG/OSUG/UGA, Grenoble	**Delfosse**, **Bouvier**, Bonfils, Alecian, Forveille, Dougados, Ménard, Mignon, Lagrange, Meunier, Ferreira, Bonnefoy, Babusiaux, Beust, *Duchêne*
	LAM/Pythéas/AMU, Marseille	**Boisse**, Santerne, Deleuil, Hobson, Grosso
	IAP, Paris	**Hébrard**, Lecavelier
	SAp/AIM/CEA, Saclay	Brun, Strugarek, Hennebelle, Mathis, Maury
	LESIA/OP, Meudon	Widemann, Bézard, Coudé du Foresto, Doressoundiram, Zarka
	LERMA/OP, Paris	Cabrit, Dormy, Petitdemange
	IMCCE/OP, Paris	Laskar
	IPSL/LMD, Paris	Forget
	LUPM, Montpellier	**Morin**, Palacios
	ENS, Lyon	Allard
	UTINAM, Besançon	Reylé
	IAS, Orsay	Ollivier
	OCA, Nice	Guillot
	OAB, Bordeaux	Selsis
Canada	UdeM, Montréal	**Doyon**, **Artigau**, Cloutier, Malo, Lafrenière, Albert, Bastien, Benneke, Boucher, Weiss, Cook, Rameau, Gagné
	McGill, Montréal	Cumming, Cowan, *Lee*
	UofT, Toronto	Menou, Valencia
	York Univ, Toronto	Jayawardhana
	NRC & UVic, Victoria	Marois, Venn
	UWO, London	Metchev
	RMC, Kingston	Wade
	BU, Sherbrooke	Rowe, Nelson
	UBC, Vancouver	Matthews
International	CFHT	**Moutou**, Fouqué
Brazil	UFMG, LNA, UFRN, UFRGS	**Alencar**, Martioli, Dias Do Nascimento, Alves-Brito
Taiwan	ASIAA	Shang, Lai, Gu
Hawaii, USA	UH	Gaidos
Switzerland	Obs Genève	Udry, Lovis, Pepe, Bouchy, Ségransan
Portugal	CAUP	Figueira
Ireland	DIAS, Dublin	Ray, *Vidotto*
Additional contributors (w/o access to SPIRou data)		**UK**: Cameron, Gregory, Jardine, See, Davies **Portugal**: Santos, Faria, Correia, Palmeirim, Ulmer-Moll **Brazil**: Castilho, Neves, Saito, Vasconcelos, Gregorio-Hetem, Rodrigues, Cerqueira, Galli **Switzerland**: Alibert, Dumusque, Ehrenreich, Bourrier, Hara, Allart, Nielsen, Audard **Taiwan**: Takami, Wang, Liu **Hawaii**: Huber **ESO**: Hussain, Manara **Italy**: Venuti, Zanni **Hungary**: Kospal **Russia**: Grankin **Argentina**: Diaz **Chili**: Astudillo-Defru **USA**: Dragomir **Spain**: Crouzet

Students involved

Student	Level	Applicant	Supervisor	Applicant	Expected completion date	Data required
the SLS science team	Doctor	Yes	Jean-Francois Donati	Yes	2019/12	Yes
the SLS science team	Doctor	Yes	Dr Rene Doyon	Yes	2019/12	Yes
the SLS science team	Doctor	Yes	Isabelle Boisse	Yes	2019/12	Yes
the SLS science team	Doctor	Yes	Jean-Francois Donati	Yes	2020/12	Yes
the SLS science team	Doctor	Yes	Xavier Delfosse	Yes	2020/12	Yes

Linked proposal submitted to this TAC: No

Linked proposal submitted to other TACs: No

Any other expenditure

Relevant previous Allocations: Yes

MaTYSSE LP (510hr)

Related Publications

selection of recent papers only:

Artigau et al 2018, AJ in press (arXiv:1803.07646)
Bonfils et al 2018, A&A in press (arXiv:1711.06177)
Cloutier et al 2017, 2017, AJ 153, 9
Cloutier et al 2018, 2018, AJ 155, 93
Donati et al 2016, Nature 534, 662
Donati et al 2017, MNRAS 465, 3343
Donati et al 2018, Handbook of Exoplanets (arXiv:1803.08745)
Fouque et al 2018, MNRAS 475,1960
Hébrard et al 2016, MNRAS 461, 1465
Hill et al 2017, MNRAS 472, 1716
Moutou et al 2017, MNRAS 472, 4563
Yu et al 2017, MNRAS 467, 1342

Observing run info :

Run: A calibration info: standard calibration series at the beginning of each night (see Sec 5.1 of SLS justification)

backup strategy: see Sec5.3 of SLS justification for the backup program

see Sec6 of the SLS justification for the full target list

see Appendix of the SLS justification for the full list of the SLS science team

ETC - CFHT - Version of March 2018. We give below the ETC output for a few typical stars from our target lists (GJ 3148, GJ 3877, HL Tau, TWA 35, see Sec 6 of SLS justification). Note that the ETC gives S/N ratios per 4.2 km/s bins, ie 1.36x larger than the S/N ratios per 2.28 km/s bins quoted in our proposal.

* GJ 3148 (M3, aim S/N=270 per 4.2 km/s):
  Computed snr:267,etime:290,teff:3100,magh:7.3,seeing:0.6,h2o:1.0,airmass:1.0
* GJ 3877 (M7, aim S/N=200 per 4.2 km/s):
  Computed snr:207,etime:1004,teff:2500,magh:9.3,seeing:0.6,h2o:1.0,airmass:1.0
* HL Tau (class-I, aim S/N=200 per 4.2 km/s):
  Computed snr:240,etime:290,teff:4500,magh:7.5,seeing:0.6,h2o:1.0,airmass:1.0
* TWA 35 (wTTS, aim S/N=200 per 4.2 km/s):
  Computed snr:210,etime:892,teff:2700,magh:9.1,seeing:0.6,h2o:1.0,airmass:1.0