**PROGRAMME BLANC**

**ÉDITION 2010**

**DOCUMENT SCIENTIFIQUE**

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ACRONYMS:

AU: Astronomical Units
BD: Brown Dwarf
CA: Core-Accretion models
CFHT: Canadian-France-Hawaiian Telescope
DI: Direct Imaging
EGP: Exo-Giant Planet
GI: Gravitational instability
GPI: Gemini Planet Finder
HZ: Habitable zone
MS: Main Sequence
PRIMA: The Phase Referenced Imaging and Micro-arcsecond Astrometry Project
PUE'O: The CFHT Adaptive Optics Bonnette
SAFIR: Software for Analysis of Fourier Inter-spectrum Radial-velocity
SPHERE: Spectro-Polarimetric High-contrast Exoplanet Research
RV: Radial Velocity
VLT: Very Large Telescope
VLTI: Very Large Telescope Interferometer
1. **Contexte et positionnement du projet / Context and positioning of the proposal**

How giant exo-planets (EGPs) form, evolve and are structured is one of the biggest challenges of modern astronomy. This major goal is directly connected to the ultimate search for Life over the Horizon 2020-2030. Nevertheless, several astrophysical (formation, evolution, dynamics, structure and atmosphere), biological (bio-markers) and technical (new technologies developed for next generation of instrumentation) steps must be carried out in that perspective. We need to understand how EGPs are formed and structured, how they evolve and interact as they will completely shape the planetary system architecture and therefore the possibility to form telluric planets capable to host Life. In that perspective, we led an extremely successful ANR05 program, ‘Exo-planets at Horizon 2008’, dedicated to the interpretation of multi-technique observations of EGPs. We now propose to fully exploit this rich expertise to enter a phase of systematic search and characterization that will offer invaluable constraints for theories of EGP formation, evolution and atmosphere.

Since the discovery of the first EGP around the star 51 Peg (Mayor & Queloz 1995), our understanding of the origin and properties of EGPs has fundamentally evolved. The existence of Hot Jupiters has revealed the premise of an unexpected variety of planetary systems. Planetary systems are not rare and their occurrence actually depends on the host star properties such as the metallicity, the mass or the multiplicity. Multiple planetary systems have been discovered. The atmosphere and the structure of giant irradiated planets have even been probed and studied. Finally, the ultimate performances of current instrumentation led to the discovery of telluric planets, and super-Earths possibly located in the habitable zone (where liquid water is expected to be found on the planet surface). The success of these discoveries relies on the development of complementary observing techniques to probe various physical and chemical properties of EGPs, around different classes of stars and at various locations. The radial velocity (RV) technique is nowadays the most successful one to detect close-in EGPs at short periods (P < 10 yrs; < 5 AU). The concept of this indirect method consists in measuring the periodic reflex motion of the EGP host stars with precise Doppler spectrographs. More than 350 EGPs have been identified with this technique, mainly around main-sequence solar-type stars (Udry & Santos 2007). These discoveries led us to reconsider our understanding of planetary formation. Several intrinsic limitations to that technique (mass indetermination, absence of atmosphere characterization or limitation to the close-in environment) remain. Complementary methods must be used to enlarge our current view. The Transit technique is a second method that consists in detecting the shadow of an EGP on its host star. The first transit observation has been obtained by Charbonneau et al. (1999). This technique enables the measurement of EGP radii. Combined with RV measurements to derive the mass, the EGPs density can be measured to study their internal structure. From space, the spatial mission CoRoT (launched in December 2006) has enabled the detection of 7 transiting planets, including CoRoT 7b, a 20 hour orbiting super-Earth (Léger et al. 2009). Additional indirect techniques such as micro-lensing and astrometric wobbling offer interesting perspectives for the study of telluric planets and masses determination. They are sensitive to the outer regions of planetary systems. At longer periods (P > 10 yrs; > 5 AU), Direct Imaging (DI) offers the unique ability to enable fast detection and characterization through the analysis of actual planetary photons.
Current instrumentation on very large telescopes is limited to the identification of EGP\'s around young stars. Young giant planets are hotter, brighter and easier to detect than their older counterparts. In 2011, new generation of spectro-imagers will enable to survey systematically a consequent sample of nearby stars. Systematic detection and characterization of EGP\'s will lead to the observation of in-situ planetary formation in large proto-planetary disks and the determination of the EGP\'s physical and atmosphere properties (mass, luminosity, effective temperature and chemical composition) by the use of planetary interior & atmosphere models.

On a competitive international scene with on-going planet search surveys at Gemini, Keck and Subaru telescopes or in the perspective of the Gemini planet finder instrument, our project of ANR10-GuEPARD aims at strengthening our leadership in the field of detection and characterization of EGP\'s. Although intensive searches are now devoted to telluric planets, fundamental questions remain to be answered about their formation and evolution processes and the physics of their interior and atmosphere. During our ANR05 program, data processing and analysis tools have been developed and demonstrated. Our expertise has been more than confirmed with the discovery of the first planetary mass companion in direct imaging (see Fig 1, Chauvin et al. 2004, 2005ab; Bonnefoy et al. 2010; Lagrange et al. 2009c), of the first close-in EGP\'s to intermediate-mass stars (Galland et al. 2006), and the characterization of the impact of stellar activity on RV surveys (Desort et al. 2007; Lagrange et al. 2009c). We want now to initiate a phase of systematic multi-techniques observations and characterization of the environment of nearby stars. In the perspective of the next generation of planet finder instruments (SPHERE and ESPRESSO at VLT), we will fully exploit our experience to provide invaluable constraints to model the large variety of properties for EGP\'s, including their frequency, their physical and orbital characteristics (distribution of mass, period and eccentricity). We will probe the diversity of the planetary

Fig. 1: Left, Composite image of brown dwarf 2M1207 and its planetary mass companion in H (blue), Ks (green) and L’ (red). The companion appears clearly distinguishable in comparison to the color of the brown dwarf 2M1207 (Chauvin et al. 2004, 2005a). Right: Beta Pictoris b saturated L’ images. North is up and East is to the left. A candidate companion is clearly detected at a PA of 32 degrees, i.e., along the North East side of the disk, at a separation of about 0.41” from the star (Lagrange et al. 2009ab).
systems, study the evolution of their properties with the star characteristics (metallicity, lithium abundance, multiplicity, age and mass) and witness the first phases of planetary formation and evolution directly inside the planetary disks.

2. DESCRIPTION SCIENTIFIQUE ET TECHNIQUE / SCIENTIFIC AND TECHNICAL DESCRIPTION

2.1. ÉTAT DE L’ART / BACKGROUND, STATE OF THE ART

Stars and brown dwarfs share similar rapid formation mechanisms. Turbulent fragmentation of molecular clouds may deliver (over $10^5$ years) proto-stellar embryos with a wide range of masses, many of which are too low to support hydrogen burning and will end as brown dwarfs. Similarly, disc fragmentation is likely to deliver low-mass proto-stellar embryos. These proto-stellar embryos may undergo competitive accretion (as a result of which some of them evolve to higher mass) and dynamical interactions (as a result of which some of them are ejected before they reach H-burning masses). None of these mechanisms is mutually exclusive, and in the most advanced simulations of cluster formation, collapse and fragmentation, disc fragmentation, competitive accretion and dynamical ejection all occur concurrently. At the end, it is finally well accepted that star and brown dwarf mechanisms are capable of forming isolated and binary objects down to the planetary mass regime as observed in young, nearby associations. Several stars and brown dwarfs will end-up with a circumstellar disk inside which planetary formation will take place.

Two competitive planetary formation scenarii are currently debated. Giant planets are expected to form over a few million years, either by core accretion plus gas capture (CA; Pollack et al. 1996) or disk fragmentation driven by gravitational instabilities (GI; Cameron 1978). With the number of detected close-in planets regularly increasing, the statistical properties of the derived orbital elements (period, planet mass and eccentricity) and the stellar-host characteristics (metallicity, multiplicity, mass and age), provide crucial constraints for testing models predictions. At close-in (< 5 AU) physical separations, RV, transit and micro-lensing techniques are nowadays the best suited. The planet occurrence frequency has been determined (7.5 ± 1.5% for $M_\text{sini} > 0.5 M_{\text{Jup}}$, a < 4.8 AU; Naef et al. 2004, Udry & Santos 2007), confirming that planet formation is not rare. The bimodal aspect of the mass distribution is the most obvious evidence of different formation mechanisms for (sub-)stellar binaries and planets. The period-mass distribution indicates a paucity of massive close-in planets well reproduced by planetary migration mechanisms. It reveals also a promising niche of massive planets at longer periods, ideal for DI campaigns. The planet-metallicity correlation derived from the chemical characterization of the planet hosts, favors CA as the main mechanism responsible for the formation of close-in giant planets. Transit observations have revealed large amount of heavy elements in Hot Jupiter interiors which corroborates these conclusions (Guillot et al. 2006). Nevertheless, the CA scenario encounters difficulties to form very massive (> $6 M_{\text{Jup}}$) planets (Matsuo et al. 2007). The well-known planet-metallicity correlation may not be present for the highest mass planets (Rice et al. 2003). Finally, this mechanism has difficulties explaining the recent discoveries of planetary mass companions at wide (> 20 AU) orbits. The CA timescales become long and the disk surface density low.
GI as well as binary stellar mechanisms could actually operate at wide orbits, leading to different physical and orbital distributions of giant planets (Boley et al. 2009). Additional mechanisms of inward/outward migration or planet-planet interactions have been propose and could modify the giant planet orbital properties. Consequently, there is a real need to reveal the physical and orbital properties of the EGP population at all orbit (see Fig. 2), to study their diversity and the evolution of their properties with the stellar ones. The recent discoveries of wide orbit planetary mass companions Fomalhaut b (Kalas et al. 2008), HR8799 bcd (Marois et al. 2008) and Beta Pictoris b (Lagrange et al. 2009b) have shown that DI of EGPs is now possible, on close-by young systems, providing the luminosity is not larger than about 12 magnitudes and/or angular separation is greater than 0.4 arcseconds. Gains in contrast and separations are expected in the next generation AO instruments (e.g VLT/SPHERE and Gemini/GPI in the same baseline) and represent the next observing challenge to fully describe the properties of outer planetary systems.

In addition to the origin, evolution and architecture of planetary systems, fundamental questions remain about the internal and atmospheric properties of EGP’s themselves. The use of transmission and emission spectroscopy to probe the outer layers of strongly irradiated giant planets has been particularly successful in the IR, with the discovery of the molecules of water, methane, carbon monoxide and dioxide in the atmosphere of the planet HD 189733b (Tinetti et al., 2007, Swain et al., 2008, 2009). However, the presence of cloud layers, thermal inversions, and a strong variability of the depth of molecular bands likely due to dynamical mixing has been revealed by these authors, stressing the need for more realistic modeling of extra-solar planetary atmospheres. While numerous models have been developed for the study of Hot Jupiter transits and brown dwarfs, no weather model -- except for our work for brown dwarfs in the frame of ANR05 (Freytag et al. 2010) -- has been

Fig. 2: Mass (minimum mass for RV planets) and distance to the star given for all sub-stellar companions detected up to now. The techniques used for their discoveries are shown. The DI technique appears unique to explore the population of EGPs at wide orbits (> 5 AU).
published. The extension of brown dwarf weather model to 3D models with rotation and, when necessary impinging radiation, will allow the extension to the planetary regime (lower surface gravity and effective temperatures, composition). Future individual detection and characterization of wide orbit EGPs will offer an unprecedented way of testing improved grids of synthetic spectra, colors accounting for cloud formation and dynamical mixing, corresponding isochrones and therefore our understanding of physical and chemical properties of EGPs.

2.2. **Objectifs et caractère ambitieux/novateur du projet / Rationale highlighting the originality and novelty of the proposal**

Based on our rich expertise in the domain of DI and RV observing techniques, of interpretation and analysis tools and of simulation of stellar activity and planetary atmospheres, we want first to understand the processes of planetary formation and evolution at wide orbits. It implies to unveil for the first time the properties of the population of giant planets located at wide orbits. We will derive the occurrence, the mass, period and eccentricity distributions, as well as the dependency of these properties on the primary star characteristics (mass, age, metallicity, presence of circumstellar gas or dust and multiplicity). We have seen that CA alone cannot explain the recent discoveries of wide orbit giant planets. Additional mechanisms such as GI, stellar processes or planet-planet interactions could be at work, but how? Our expertise in high contrast instrumentation (CFHT/PUE'O, CRIRES, NACO and SINFONI) and the perspective of SPHERE, the European planet finder instrument, position our project into an ideal configuration. We have the competences and the opportunity to optimally exploit the current and next generation of high contrast instruments to extensively study the properties of the outer population of giant planets. The determination of their physical and orbital properties will provide us with invaluable constrains to answer several fundamental questions: Are they various formation mechanisms that operate at different disk location? What is their respective efficiency? How does it depend on the stellar properties (mass, metallicity and multiplicity) and the disk properties (mass)? Can we form circum-binary planets? What is the timescale for planetary migration? Is planet scattering efficient? How frequent are multiple systems at wide orbit? At short periods, RV searches for planets have been mostly focused on quiet solar-type GK stars. We want to study the impact of the star masses on the occurrence of short period planets. In 2004, we developed a method and software to extract the RV from the spectra of massive stars, which harbor much less spectral lines than solar-type stars (or evolved stars) and which have higher projected rotational velocities. We showed that conversely to what was assumed, planets indeed could be detected around such stars, despite their generally high rotational velocities, depending however on their level of activity (Galland et al. 2005). In 2010, we enter into a new phase in which we will survey these stars and search for planets with periods in the range 1–100 days. Our aim is to test whether or not short-period planets can be present around massive stars and survive during the main-sequence (MS) lifetime. If planets are present with such periods, we will determine their characteristics (masses, eccentricities, distances) and compare to those of planets orbiting dwarfs with smaller masses; in particular, it will be interesting to see if there is any gap, as observed in the case of solar-type stars in the 10–100 days period region (for solar-type stars, 70% of the planets with periods shorter than 100 days have periods shorter than 10 days).
Detecting planets at close separations (hot Jupiters) from massive stars will allow answering fundamental questions: how the rate of close-in planets around massive stars compares with that around less massive stars? Are migration processes more efficient in more massive disks? Are the processes that stop the inward migration at early stages of planet evolution more efficient? Is there a correlation between the presence of short-period planets and the spectral distribution of the irradiation received by close-in planets? What are the timescales of close-in planet destructions over the MS and post MS timescale (if the absence of such planets around G–K sub-giants is confirmed)? Are massive MS stars hosting planet over/under metallic? How efficient is the pollution of the star photosphere by planets? Note that to this respect, as noticed by Li, Lin and Liu (2008), the stars with spectral types earlier than F8 are the best targets to study the metallicity pollution as their convective envelope is more shallow than lower-mass stars. **We want also to study the first phases of planetary formation.**

Using the unique capabilities of the SAFIR software, we will search with HARPS for giant planets around young stars, in stellar associations (TW Hya, BPic, TucHor and AB Dor moving groups) aged 10-70 Myr. Coupled with the deep imaging, this will able to fully characterize the presence of giant planets at both short and large periods, which has never been done so far. This will help to test the timescales associated to giant planet formation in general. Using DI, we will even be able to witness directly EGPs inside their circumstellar disk to study in detail the planet – disk interactions, the system architecture and dynamical stability. In that perspective, we will therefore have to **further characterize the impact of the stellar activity.** In RV surveys, in the case of massive stars, it limits the detection of giant planets, and in the case of solar or later type stars, it limits the detectability of less massive telluric planets. During the previous years, we have performed a study of the impact of (magnetically induced) stellar spots on the detectability of planets. The most detailed simulations have shown (Desort et al, 2007) that depending on their characteristics (size, location, temperature), and depending on the star properties (inclination), spots can produce RV variations quite similar to those induced by planets, which is a potential problem of growing importance as lower and lower mass planets are being and will be searched at both short and long periods with next generation RV instruments. To further investigate the impact of spots on the detection of Earth mass planets in the Habitable Zone (HZ; where liquid water can be found) in a real case, we have performed a complete simulation of the RV
variations expected from a solar type star, seen edge-on if covered by spots identical to the ones of the Sun, as observed during one entire, 11 yr solar cycle. Our simulation takes full benefit from the SAFIR code we developed for our RV studies. We could show (Lagrange, Desort & Meunier, 2010) that during solar-like high-activity period of the star, Earth mass planets would not be found. During the periods of low activity, only very intensive surveys (star observed twice a week over several years) could lead to a positive detection with the next generations of RV instruments on the VLT (ESPRESSO) or on the ELT (CODEX). If we consider, in addition to the spots, the bright structures (plages, network) present at the Sun surface, as well as convection, we showed that an Earth mass planet orbiting the Sun in the HZ would not be detected with the next generation instruments, and with the knowledge and tools available today (Meunier, Desort & lagrange, 2010). As the Sun is considered as a quiet star (not much active), these unexpected results show that definitively much more efforts should be devoted to the study and characterization of the stars activity than what is done today if one wishes to unambiguously detect Earth mass planets in the HZ of solar type stars in the forthcoming decade. Given these rather pessimistic results obtained, it is mandatory to further explore the impact of activity related parameters (spots, bright structures, convection) in patterns possibly different from those of the Sun and around different types of stars (earlier or later types stars), seen in different geometrical configurations. This should allow to quantitatively identify the best candidates for Earth mass planets searches, based on simulations. This is our objective for the coming years.

Finally, we want to understand the physics of EGP in the light of their formation mechanisms. A great advantage of the direct imaging technique is the capacity to resolve the planet photons. Our objective is the individual characterization of the internal (luminosity, mass, radius) and atmospheric (composition, surface temperature and cloud coverage) properties of the EGPs, directly imaged as already investigated by Vigan et al. (2009, 2010). Orbital characterization linked to the disk geometry will help constraining the planet dynamical masses. One can also think to the direct imaging of EGP already detected by RV. The observed planet luminosity and derived masses will be compared to evolutionary model predictions to test the impact of the initial conditions of formation on the evolutionary predictions of the planet properties.

Fig. 4: A snapshot of our 2D Radiative Hydrodynamics model (W350 x H80 Km**2) for brown dwarfs at Teff=1800K and logg=5.0, where the entropy in coded in green to illustrated the convective motions of the internal convection zone, and the dust concentration is coded in red (Freytag et al. 2010, in press).
Spectroscopy of the planetary radiation will provide very rich information, such as the species present in the atmosphere of EGPs. The presence of water, carbon-dioxide and monoxide, methane and ammonia are of special interest to characterize the atmospheric conditions (abundances, pressures and temperatures). Direct spectroscopy will enable the study of the cloud coverage and the physical processes at work such as the cloud formation and sedimentation, the convective overshooting effects, the dynamical mixing, and the impact of rotation. Time-variability in the planet’s flux and/or spectra might also be expected due to seasonal variations. Several results have been obtained during the successful ANR05, that enabled to take into account the effect of convective motions in the atmosphere of cool brown dwarfs and planets (see Fig. 4). New grids of model atmospheres have been offered to the community (via the web simulator: [http://phoenix.ens-lyon.fr/simulator](http://phoenix.ens-lyon.fr/simulator)). However, extension to 3D RHD models with stellar irradiation and rotation is still mandatory to offer a complete grid of models covering the BD and planet atmospheres.

3. **PROGRAMME SCIENTIFIQUE ET TECHNIQUE, ORGANISATION DU PROJET / SCIENTIFIC AND TECHNICAL PROGRAMME, PROJECT MANAGEMENT**

3.1. **PROGRAMME SCIENTIFIQUE ET STRUCTURATION DU PROJET / SCIENTIFIC PROGRAMME, SPECIFIC AIMS OF THE PROPOSAL**

Our ANR10-GuEPARD project is structured according 3 main tasks, subdivided for two of them in terms of sub-tasks (the GuEPARD tasks diagram is shown in Fig. 5). The main purpose is to support the exploitation and the interpretation of our current and future observing programs of direct imaging (TASKs 1a and 1b) and radial velocity (TASK 2a and 2b). It therefore implies the support for the development of simulation and interface tools to optimally exploit all the pertinent information from DI and RV observations (TASKs 1c and 2c resp.). We also propose to support the theoretical efforts initiated during our ANR05 aimed at modeling the dynamical atmosphere of giant planets to optimize the characterization of all brown dwarf and giant planets directly imaged during our project (TASK 3). It will improve our understanding of the physical processes at work in their cool atmospheres.

**TASK 1 – DIRECT IMAGING OF WIDE ORBIT GIANT PLANETS**

*Sub-Task 1a: LAOG/IPAG direct imaging surveys*

A first part concerns the support to our current and future DI programs conducted at LAOG/IPAG with the NACO, CFHT/PUEO and SINFONI instruments dedicated to the search for EGPs around different classes of targets. As we mentioned earlier, this technique offers the great advantage to enable a rapid detection and characterization of EGPs, to provide detection performances independent of the target mass, age or evolutive status, to give access the EGPs orbit inclination, finally (using photometry and spectroscopy) to provide theorists with constraints for the internal properties and atmosphere models. Since
2002, we have initiated several DI programs previously supported by our ANR05 project and that led to key results over the international scene.

A first program concerns the young, nearby stars, which are very favorable targets for the direct detection of the lowest mass companions. They are gathered in several groups (TW Hydrae, β Pic, Tuc-Hor, Cha, AB Dor, Columba and Carinae), sharing common kinematics, photometric and spectroscopic properties (see Torres et al. 2008). With typical contrast of 10-15 magnitudes for separations beyond 1.0 - 2.0 arcseconds (50-100 AU for a star at 50 pc), EGP's down to 1-2 Jupiter masses are detectable with NACO. In 2004, we have obtained the first detection of a planetary-mass companion to a young brown dwarf (2M1207; Chauvin et al. 2004, 2005; see Fig. 1). Planetary mass companions were also detected around young, nearby stars, such as AB Pic (Chauvin et al. 2005; Bonnefoy et al. 2010). Our NACO survey of 88 young, nearby stars which represent the largest one to date in the southern hemisphere enabled to derive a first upper limit of the giant planet frequency as a function of the semi-major axis at relativel y wide orbit (> 40 AU; see Chauvin et al. 2009). We have initiated a 2-yrs programs (PI: Chauvin, 10 nights) focused on the search of wide orbit planets around 50 young, nearby stars taking advantage of the new high contrast angular differential imaging modes offered by the NACO. Special care will be given to survey a sub-sample of young, nearby stars composed of young dusty stars, i.e stars surrounded by proto-planetary and debris disk, to test the disk-planet interaction models and the late stages of planetary system formation.

To test the evolution of the EGP population with the primary mass, we will perform systematic NACO deep images of intermediate-mass A–F dwarfs from our HARPS sample (see detail below). As these targets are generally older than Fomalhaut, HR 8799 or Beta Pictoris, the detection limits associated to the deep images generally fall in the BD or low-mass stars domain rather than in the EGP range, especially at very close distances to the stars (5–50 AU). The present statistic on this class of target is however very poor. The situation is relatively similar for very low mass and nearby stars. We will intensify our current search for planets in the close vicinity of very nearby late type stars at an unprecedented dynamical range (allowing the detection of planets with masses as low as 1-3 M_Jup down to 2 AU). This will boost the search for close-in Jupiter mass planets around later type stars, as detection in imaging requires only 2 observations spread over typically 1-2 years, whereas RV detection requires several years of monitoring.

In recent years, we have conducted the largest and deepest search for substellar companions to stars with close-in giant planets detected by RV at physical separation down to 5 AU. This led us to image the environment of 43 systems, characterize completely 32 of them and reveal 5 true companions. We initiated a monitoring of the orbital motion of three systems to derive the system dynamical properties and study their impact on the inner planetary system. Prolific results have been continuously published to study moreover the dynamical stability and history (Chauvin et al. 2006; Lagrange et al. 2006, Chauvin et al. 2007, 2010, in prep). Our goal is to systematically explore the outer part of planetary systems host by nearby (< 50 pc) stars recently found selected according to their distance, discovery date and planet eccentricity.
Sub-Task 1b: SPHERE scientific exploitation

This second sub-task is dedicated to the support for the exploitation of the forthcoming SPHERE planet finder instrument, including the NACO-reconnaissance Large observing program and the upcoming SPHERE guaranteed time and open time observing programs. SPHERE will be offered in early-2012 to the ESO community (SPHERE first light fall 2011). The prime objective is the discovery and study of new planets orbiting stars by direct imaging of the circumstellar environment. The challenge consists in the very large contrast of luminosity between the star and the planet (larger than 12.5 magnitudes or \( \sim 10^5 \) flux ratio), at very small angular separations (100 mas, i.e 5 AU for a star at 50 pc), typically inside the seeing halo. The whole design of SPHERE is therefore optimized towards high contrast performance in a limited field of view and at short distances from the central star. Based on our NACO expertise, we want to optimize our future exploitation of the SPHERE instrument by coordinating the efforts of the LAOG/IPAG and LAM institutes, main French contributors of the SPHERE project.

This coordinated work already starts with the NACO-reconnaissance Large Program which has been proposed in the perspective of the future SPHERE NIRSUR survey that will observe a sample of 300 to 600 stars. The NACO program can be seen as a preparatory mission designed to obtain pre-deep imaging observations of a large fraction of the SPHERE sample. The main objective is to survey the high-priority stars that were never observed with high contrast instruments. A total of 110 young and intermediate-old nearby stars have been selected according to their declination (delta < +25 deg), their age (< 200 Myr), their distance (d < 100 pc) and their R-band brightness (R < 9.5) and will be observed from Dec 2009 to Dec 2011 to provide invaluable constraints for the identification of false alarms and massive stellar or substellar companions to the SPHERE targets. The results will complete a DI database of already 80 stars observed with similar detection performances and will already offer before the SPHERE first light, the largest and deepest survey of nearby stars. The LAOG/IPAG and LAM institutes are significantly involved into the observation preparation, execution and the data reduction analysis and final interpretation, in collaboration mainly with the Padova INAF and MPIA Heidelberg institutes.

The SPHERE NIRSUR survey which represents the main fraction of the guaranteed time that will be given to the SPHERE consortium represents a total of 200 observing nights. The LAOG/IPAG and LAM institutes will be involved at more than 40% for the observing preparation, execution, analysis and publication. The main mode will combine the IRDIS dual imaging in H band with imaging spectroscopy using the IFS in the Y-J bands. This configuration will permit to benefit simultaneously from the optimal capacities of both dual imaging over a large field (out to 5" radius) and spectral imaging in the inner region (out to at least 0.7" radius). In complement to preparatory work, it will allow to reduce the number of false alarms and to confirm potential detections obtained in one channel by data from the other channel. We want here to reinforce the coordination of the LAOG/IPAG and LAM institutes to optimally prepare and exploit the NIRSUR survey, again for a systematic study of the wide orbit EGP population and of their orbital, physical and atmosphere properties. Of course, this will naturally lead us to develop collaborative approach for SPHERE open time observing programs in the continuation of our NACO programs and devoted to young and/or dusty stars, RV exo-planet host, intermediate-mass stars and low mass stars.
**Sub-Task 1c: Data processing and analysis tools**

To prepare and exploit the DI programs reported above, a key part of our project is to intensify the current efforts aimed at developing and improving DI data analysis techniques. The use of new and innovative high contrast imaging and spectroscopic modes (AO-assisted lucky imaging, differential imaging, interferential coronagraphy, sparse mask aperture, 3D spectroscopy...) opens completely new perspectives that force us to re-think our way of processing and interpreting DI observations. These tools are mandatory, first to prepare our DI observations, schedule them and adapt our strategy in real time based on the observing conditions. A second step concerns the development of automatic tools to perform cosmetic reduction and signal extraction adapted to the differential imaging techniques used. Similar development can be imagined for the reduction and the spectral extraction adapted to long-slit and 3D-spectroscopy. A third step will be devoted to the image quality determination and selection to enable a rapid and robust image selection. The estimation of the detection performances including the simulations of fake companion in our observations will be essential. Finally, a last step concerns interpretation tools to estimate the probability of false alarms estimation based on galactic population models, the determination of the companion physical and atmosphere properties based on up-to-date evolutionary and atmosphere models (TASK 3). We propose in addition to develop Monte-Carlo simulations to test statistical properties of the EGP orbit distribution and compare them to the predictions of giant planet population synthesis models.

**TASK 2: RADIAL VELOCITY OF CLOSE-IN GIANT PLANETS AROUND ACTIVE STARS**

**Sub-Task 2a: Impact of the star masses on the occurrence of short period EGPs**

We propose here to enter a new phase of systematic research of EGPs around massive stars. Observations of A-F main sequence stars will be carried out at ESO Chile with HARPS (Large Program allocated) and at OHP with SOPHIE to search for short period giant planets over at least 2-3 years. We will then directly benefit from our important investment during the 4 four years in characterizing the suitable targets. At least 50 nights will be devoted to this program, leading to a large amount of data to reduce and analyze. Data will be reduced using the SAFIR software. We will use and further develop our simulation tools (see below) to be able to disentangle the stellar activity from the planetary signatures. The statistics of short planets found around these stars - the first ones ever obtained- will be compared to that around solar or less massive stars, and will be discussed in the frame of planet formation and evolution (see objectives above). In parallel, we will characterize the candidates already identified. Several associated publications are then expected.

**Sub-Task 2b: Search for short period EGPs around young stars**

Similarly we will perform (with HARPS) dedicated monitoring of young stars in close associations to search for giant planets with periods up to 100 days (or more if possible). The work description is quite similar to the previous on in the case of the main sequence stars, except that even more efforts will be devoted to the characterization and removal of the comparatively higher- level of activity. For these objects we will perform as much as possible simultaneous photometric observations, so as to better constrain the activity.
**Sub-Task 2c: Activity simulation**

Over 2010-2013, we want to further explore the impact of activity related to the parameterization of the spots and plages temporal and spatial distributions and the simulation of their RV, photometric and astrometric variations. For any star, seen on any inclination, we will use the data available for the Sun as a basic pattern, but with the possibility to tune each parameter (e.g. spot distribution sizes, temperatures, convection levels, differential rotation, etc), according to the current knowledge on these parameters for the considered stellar type. This will require a bibliographic work on the stars properties and on the transposition to the edge-on sun-like star to other type stars and other configurations, and new software developments. We will also compare observations in spectroscopy and photometry of different spectral types stars with simulations. Finally, we will study also the impact of the differential rotation. We anticipate that the whole study will last 3 years, with nevertheless already identified milestones, and associated publications. They will be dedicated to 1) the parameterization of the spots & plages temporal and spatial distributions; inclusion of differential rotation; application to solar type stars: simulations of their RV, photometric and astrometric variations 2010-2011; 2) the application to other stellar types (later and earlier) over 2010 and 2013; the impact of the convection; 3) the observations (spectroscopic & photometric) of different spectral types & comparison with simulations over 2011 and 2013.

**TASK 3: DYNAMICAL ATMOSPHERES OF GIANT PLANETS**

EGPs and BD properties can be estimated by the confrontation of photometric and spectroscopic observations with predictions of Interior and Atmosphere synthetic models. However, their predictions have to be extended down to planetary masses and young ages. Cloud formation and new molecular opacities have been considered by Allard et al. (2001) for the treatment of the line and dust transfer, and Allard et al. (2003) for the construction of the cloud model for brown dwarf atmospheres. Models include condensation, sedimentation, and convective overshooting effects based on 2/3D RHD simulations (Ludwig et al. 2006). Rotation can also affect the distribution of clouds on the planetary surface. RHD atmospheric simulations with irradiation and rotation are needed to determine more realistic conditions for the formation of clouds in planetary and brown dwarf atmospheres. In the frame of ANR05, the work has concentrated on enabling the CO5BOLD RHD atmosphere code to explore the parameter regime characteristic for brown dwarfs. This included the production of detailed binned non-grey gas opacity tables, a 2-bin and a multi-size-bin dust model (for Forsterite) with simplified dust opacities, modified boundary conditions and numerical settings appropriate for the nearly incompressible flows in cool dwarfs. A large range in effective temperatures from 2800K down to 700K at a surface gravity of 5.0 dex has been covered in local 2D models. We demonstrated the influence of the underlying convection zone onto the atmosphere by "classical" overshoot and gravity waves, as well as convective motions within the dense cloud layers in objects cooler than 2500K. There is a strong interaction between the microphysical processes (dust formation, dust opacities) and the macroscopic flow (Freytag, Allard, Ludwig, Homeier & Steffen 2010, in press).
GuEPARD (ANR10)
Coordinator: G. Chauvin
Partners: LAOG/IPAG, LAM & CRAL
TASK Coordinators: G. Chauvin, C. Moutou, A.-M. Lagrange & F. Allard

Fig. 5: Project Management of the ANR-2010 GuEPARD, “Giant Exo-Planets Atmospheres, oRigin and Dynamics” gathering 3 partners, the LAOG/IPAG institute as coordinator-Partner and the LAM and the CRAL. The project is then subdivided in three main tasks dedicated to: (1) Detecting and characterizing EGP’s at wide orbits using DI based on the development of adapted tools for imaging and spectroscopy Analysis (TASKs 1a, 1b and 1c); (2) Detecting and characterizing close-in EGP’s using RV and based on the development of simulation tools to take into account the stellar activity (TASKs 2a, 2b and 2c); and (3) Models for dynamical Atmospheres (TASK 3).
This flow has been parameterized as a function of atmospheric depth, and used in Phoenix to define the diffusion coefficient of dust and generate a new grid of model atmospheres, synthetic spectra, and isochrones for brown dwarfs (Allard et al., in preparation for April 2010), which is currently available on the web simulator developed for the distribution of the model predictions to the community [http://phoenix.ens-lyon.fr/simulator]. We want now to extend this work for the development of 3D RHD models of EGPs (with stellar irradiation) and rotation including a cloud model and up-to-date Phoenix opacities for the computation of up-to-date grids of model atmospheres and synthetic spectra accounting for the RHD information (the velocity field, the diffusion coefficient, the cloud surface distribution, etc.), the extension to the regime of planetary masses (internal entropy corresponding to less than 200K), and the improvement of the web simulator to allow the computation of irradiated atmospheres and planetary interior and evolution tracks online.

**COLLABORATIONS: DYNAMICS AND POPULATION SYNTHESIS OF GIANT PLANETS**

In close relation with the topics investigated in this application, but without requested support for it, we want to mention two collaborative studies. The first one concerns the development of dynamical tools (Orbital fit and N-body simulations) that will be covered by Hervé Beust (LAOG/IPAG). The objectives are: 1/ to develop a powerful least-square code to perform combined orbital fits using both RD and DI data; 2/ using N-body codes to study the dynamics and probing the evolutionary history as well as the stability of multiple stellar; 3/ studying the dynamics and the stability of planetary systems. The second collaborative study concerns the giant planet population synthesis simulations that will be covered by Yann Alibert (Obs. Besançon/Beome). The objectives are to provide the up-to-date outputs of the models of giant planet formation that extends the core-accretion model of Pollack et al. (1996). These models include migration, disc evolution and gap formation. Their results will be directly compared with the detection performances of DI and RV surveys to constrain the present model initial conditions and assumptions.

**3.2. COORDINATION DU PROJET / PROJECT MANAGEMENT**

The ANR10-GuEPARD project is a 4-year project starting on October 2010. It gathers 3 French public institutes and partners: the LAOG/IPAG, the LAM and the CRAL (see description part 5.1). A total of 9 permanent staff are involved with 2 associated post-docs and 3 expected PHD students. A total manpower of 8 FTE is requested to fulfill 3 post-doc positions of 2 years each and one IR2 CDD position. The ANR10-GuEPARD project will be coordinated by G. Chauvin (LAOG/IPAG). Ten percents of his time is specifically dedicated to the project management and coordination task. The project coordination follows the subdivision in terms of tasks reported in Fig. 5: Direct Imaging (TASK 1), Radial Velocity (TASK 2) and Dynamical atmosphere (TASK 3). The temporal evolution of the project is reported in Fig. 6.

The DI task will be coordinated by G. Chauvin and C. Moutou (LAM) over 2010-2014. The first sub-task 1a) that concerns current and forthcoming LAOG/IPAG observing programs will be coordinated by G. Chauvin in collaboration with A.-M. Lagrange (LAOG/IPAG). It concerns on-going NACO and SINFONI observing programs. Collaborating projects with the LAM are foreseen. The two remaining sub-tasks 1b) and 1c) that concern the SPHERE
exploitation and the development of high contrasts imaging and spectroscopic tools will be coordinated by G. Chauvin and C. Moutou in collaboration with J.-L. Beuzit (SPHERE PI; LAOG/IPAG), D. Mouillet (SPHERE PS; LAOG/IPAG), M. Deleuil (LAM) and C. Gry (LAM). One post-doc position of 2 years is requested at LAOG/IPAG and one post-doc position of 2 years at LAM.

The second RV task will be coordinated by A.-M. Lagrange over 2010-2013. The first two sub-tasks concerning the RV observing programs of intermediate-mass and young stars. They will be conducted in collaboration with G. Chauvin. The activity simulation subtask will be coordinated with N. Meunier (LAOG/IPAG). One post-doc position of 2 years is requested at LAOG/IPAG over 2010 and 2012.

Finally, the third task concerning the modeling of dynamical atmosphere of EGPs will be coordinated by F. Allard (CRAL) over 2010-2014. One IR2 position of 2 years is requested at CRAL. A collaborative work is foreseen to provide us with interpretation tools already available (dynamics & giant planet population model) and developed by H. Beust (LAOG/IPAG) and Y. Alibert (Obs. Besançon). Regular meeting are foreseen, especially for the follow-up of the various DI and RV observing programs (preparation, execution and completion). Finally, a mid-course and a final meeting are foreseen to review and control the progress of each task and each sub-task of the ANR10-GuEPARD project.
3.3. Description des travaux par tâche / Detailed description of the work organised by tasks

Tâche 1 / Task 1: Deep Imaging of wide orbit giant planets

Starting: Oct 2010
Length: 4 years
Coordinator: Gael Chauvin (LAOG/IPAG) and Claire Moutou (LAM)
Permanents: Gael Chauvin (LAOG/IPAG, 40%), Claire Moutou (LAM, 50%), Anne-Marie Lagrange (LAOG/IPAG, 40%), David Mouillet (LAOG/IPAG, 20%), Jean-Luc Beuzit (LAOG/IPAG, 10%), Magalie Deleuil (LAM, 20%) and Cécile Gry (LAM, 20%).
Temporary positions: One PhD student to be recruited between 2010 and 2014 at LAOG/IPAG (50%) and one at LAM (50%). One Del Luca Post-doc (LAOG/IPAG, 2 FTE, 50%) and one CNES post-doc (D. Ehrenreich, LAOG/IPAG, 0.4 FTE, 20%).
ANR manpower support: One DI post-doc position at LAOG/IPAG (2 FTE; 100%) and 1 DI post-doc position at LAM (2 FTE; 100%).
Total manpower: 192 personnes.mois (16 FTE)

Objectives: The purpose is to support the preparation, observations and interpretation phases of current and upcoming DI programs dedicated to detect and characterize EGP at wide orbits (P \(>\) 10 yrs; > 5 AU). It concerns individual detection and characterization the determination of the EGP frequency and statistical properties.

Program & Methods:

- Proposals writing: every 6 months during 4 years.
- Observing preparation & Monitoring
  
  Starting: Oct 2010 (NaCo, SINFONI), Jun-2011 (SPHERE)
  Length: 1.5 yrs (NaCo, SINFONI), 3 yrs (SPHERE)

  (1) Target and Deep Imaging Data Catalogs. Creation of a database of all nearby stars (young, dusty, early-type, exoplanet-hosts stars), to identify and gather potential targets in an homogeneous database collecting all necessary information to optimize their information. This target catalog will be complemented by a database gathering all current DI detection limits of previous DI survey. The purpose is to adapt our target selection based on detection limits achieved with other Telescopes and instruments.

  (2) Optimized definition of the target sample for the detection and characterization of EGP at wide orbits, using various criteria (distance, age, primary mass, IR excess, planets detected by RV survey) and previous observations in DI.

  (3) Choice of the best observing modes (coronagraphy, spectral or angular differential imaging, observing wavelength, long-slit spectroscopy or 3D spectroscopy for spectral characterization) based on the latest development of high contrast modes at ESO (pupil stabilization).

  (4) Observing strategy that will follow a three steps sequence: 1) Faint sources identification in the star environment, 2) Follow-up observations of candidate companions to confirm that it is commoving and 3) Spectroscopic characterization to confirm the discovery of cool atmosphere EGP or BD companion.
(5) **Building observing sequences** for service or visitor modes observations using ESO available tools to prepare all DI observations with NACO, SINFONI & SPHERE (starting early-2012) instruments at the VLT in the southern hemisphere.

(6) **Monitoring of on-going observations**, estimation of the data quality & observing conditions. Quick-look to check of the detection performances.

- **Reduction and data analysis**
  
  *Starting*: Oct 2010 (NaCo, SINFONI), Jan 2012 (SPHERE)
  *Length*: 1.5 yrs (NaCo, SINFONI), 2.5 yrs (SPHERE)
  
  (1) **Based on data imaging and spectroscopic tools**, characterization of individual systems observable: relative photometry, relative astrometry and spectral properties.
  
  (2) **Ultimate detection limits estimation**.
  
  (3) **Status identification** of each companion candidate (background or foreground contaminant or commoving companion) based on photometry and multi-epochs astrometry. We will also conduct the spectral characterization for confirmed commoving companions and orbital follow-up.

- **Surveys Interpretation**
  
  *Starting*: Oct 2010 (NaCo, SINFONI), Jun 2012 (SPHERE)
  *Length*: 2 yrs (NaCo, SINFONI), 2 yrs (SPHERE)
  
  (1) **Physical and chemical properties characterization** of detected companions based on evolutionary and atmosphere models predictions and last development from F. Allard atmosphere Grids (see TASK 3).
  
  (2) **Dynamical interpretation** (evolution, orbital fit) of astrometric observations of EGP\'s and exo-planet host binaries in co. Combination of RV and DI programs.
  
  (3) **Statistical analysis** using Monte Carlo simulations and Giant Planet population model synthesis to constrain the frequency of EGP\'s at wide orbits, and the physical (mass) and orbital (period, eccentricity) distributions.

- **Publication and public release.**
  
  *Starting*: Oct 2010 (NaCo, SINFONI), Jun 2012 (SPHERE)
  *Length*: 2.5 yrs (NaCo, SINFONI), 2 yrs (SPHERE)
  
  The last step is the presentation of individual discoveries and characterization as well as the complete survey interpretation. Most important results will publicly released.

- **Software support Requirements.**
  
  *Starting*: Oct 2010; *Length*: 4 yrs
  
  We plan to develop automatic imaging an spectroscopic analysis tool dedicated to NaCo, SINFONI and SPHERE aimed at providing for imaging and spectroscopy: detection performances (testing various detection limit techniques, fake planet simulations and contamination calculation), determination of the companion candidates properties (relative astrometry and photometry), interpretation of the companion internal properties and atmosphere based on up-to-date atmosphere grids and evolutionary tracks, orbital fit in case of resolved orbital motion, finally statistical tools to interpret the complete survey detection performances.

**TÂCHE 2 / TASK 2 : RADIAL VELOCITY OF CLOSE-IN GIANT PLANETS AROUND ACTIVE STARS**

*Starting*: Oct 2010
Length: 3 years  
Coordinator: Anne-Marie Lagrange (LAOG/IPAG)  
Permanent: Anne-Marie Lagrange (LAOG/IPAG, 40%), Nadège Meunier (LAOG/IPAG, 20%) and Gael Chauvin (LAOG/IPAG, 30%)  
Temporary positions: One PhD student to be recruited between 2010 and 2014 (50%)  
ANR manpower support: one RV + activity post-doc position (2 FTE, 100%).  
Total manpower: 75 personnes.mois (6 FTE)

Objectives: Observation and characterization of EGPs at short orbits (< 5AU) around young and/or early-type stars and to conduct more realistic and complex activity, pulsation and sun from outside simulations.

Description & Methods:

- **Proposals writing:** every 6 months during 2 years.
- **Observing preparation & Monitoring:**
  
  **Starting:** Oct 2010; **Length:** 2 yr  
  We want to fully exploit our ESO Large Program dedicated to the extensive search for EFPs around AF stars with HARPS. 50 nights will be devoted to this program, leading to a large amount of data to reduce and analyze. We will monitor precisely the candidates already identified. It has to be noticed that so far the candidates found have periods larger than 150 days, so confirmations take at least one year. During the period 2010-2012, we expect a wealth of results from these surveys. This will reward from our important and early investment, both in observations and simulations, in this search for planets around massive MS stars. The second objective is to look for EGPs around stars in close and young (a few to a few dozens of Myrs) associations. These stars are particularly interesting as giant planets at large separations can be imaged with today instruments. we will perform (with HARPS) dedicated monitoring to search for giant planets with periods up to 100 days (or more if possible). The work description is quite similar to the previous on in the case of the main sequence stars, except that even more efforts will be devoted to the characterization and removal of the -comparatively higher- level of activity.

- **Reduction and data analysis.**
  
  **Starting:** Oct 2010; **Length:** 2.5 yr  
  Data reduction and analysis as soon data arrive. The analysis will be done for individual objects and also globally at the end of the surveys. Update and maintaining the RV database on early type and young stars regularly during the surveys. Data will be reduced using the SAFIR software. We will use and further develop our simulation tools (see below) to be able to disentangle the stellar activity from the planetary signatures.

- **Activity Simulation.**
  
  **Starting:** Oct 2010; **Length:** 3 yr  
  We will explore the impact of activity related parameters (spots, bright structures, convection) in patterns possibly different from those of the Sun and around different types of stars (earlier or later types stars, young active stars), seen in different geometrical configurations. (1) We want to study the parameterization of the spots and plages temporal and spatial distributions and the simulation of their RV, photometric and astrometric variations. For any star, seen on any inclination, we will
use the data available for the Sun as a basic pattern, but with the possibility to tune each parameter; (2) we will test the impact of convection over 2011 - 2013; (3) we will compare our simulations with observations of different types of stars over 2011-2013; Finally, (4) we will study also the impact of the differential rotation.

- **Publication and public release:**
  
  _Starting:_ Oct 2010  
  _Length:_ 2.5 yr  
  Regularly for individual cases, as well as synthesis at the end of the surveys.

**Tâche 3 / Task 3: Dynamical Atmospheres of Giant Planets & BDs**

- **Starting:** Oct 2010  
- **Length:** 4 years  
- **Coordinator:** France Allard (CRAL)  
- **Permanent:** France Allard (CRAL, 50%)  
- **ANR manpower support:** 1 full time Dynamic Atmosphere IR2 position for 2 years (2 FTE)  
- **Total manpower:** 48 personnes.mois (4 FTE)

**Objectives:** Development of 3D RHD models of EGPs (with stellar irradiation) and rotation including a cloud model and up-to-date Phoenix opacities for: (1) the computation of up-to-date grids of model atmospheres and synthetic spectra accounting for the RHD information (the velocity field, the diffusion coefficient, the cloud surface distribution, etc.), (2) the extension to the regime of planetary masses (internal entropy corresponding to less than 200K), and (3) the improvement of the web simulator to allow the computation of irradiated atmospheres and planetary interior and evolution tracks online.

**Description & Methods:** Based on the work achieved with the ANR05, we will update our codes to take into account:

- **Dust opacities.**  
  _Starting:_ Oct 2010; _Length:_ 1 yr  
  The use of frequency-dependent dust opacities (in the framework of the existing gas opacity scheme) and the application of the (already developed) multi-size-bin dust scheme should result in even more realistic temperature profiles of the atmospheres. The inclusion of (a few) further dust species, that form at lower or higher temperature than Forsterite, would allow to study the interaction of multiple (connected?) dust cloud layers. The cooler the objects the more important scattering becomes over absorption, in particular for the case of irradiated objects. The current treatment within COSBOLD should be improved accordingly.

- **2D RHD extension to planets: Extension 700K to 100K**  
  _Starting:_ Oct 2010; _Length:_ 2.0 yr  
  We will extend from 700K to 100K in steps of 100K, and in surface gravity from logg=5.0 to 3.0, the current set of 2D RHD model atmospheres with forsterite clouds, accounting for the progress achieved in dust opacities, i.e. we will explore additional dust species (water ice for instance) and account for a more accurate non-grey description of the dust scattering and absorption cross-sections. To allow this we will focus on the implementation of an account for scattering in the RHD code CO5BOLD.
The models include impinging radiation from the star. We will use this capacity to compute 2D RHD simulations for Hot Jupiter cases, as well as more distant planets.

- **Phoenix Atmosphere Grid including RHD mixing and impinging radiation**
  
  *Starting*: Oct 2011; *Length*: 2.5 yr
  
  As in our brown dwarf work, the RHD velocity field will be parameterized and used in the Phoenix models to generate grids of model atmospheres of planetary mass objects including impinging radiation, which will be made available via the web simulator. But we also intend to use Phoenix to compute the spectral signatures of variability using the thermal structures and dust distribution (spatial and grain size distributions) from the RHD models. Such models will be a real advance in the field for relatively low cost, where global models are available which however do not resolve the convection cells, and which will rely on a credibility established on the more readily observable VLM and brown dwarfs objects. This is a credibility which most often lacks for current models of exo-planets.

- **Parallelization.**
  
  *Starting*: Oct 2010; *Length*: 1 yr
  
  A full parallelization of CO5BOLD is necessary. Parallelization currently relies on Open-MP, restricting CO5BOLD to relatively few processors on shared-memory machines. We have worked out a scheme that would allow the code to run on distributed memory machines, which is straightforward for the hydrodynamics part but highly non-trivial for the non-local radiation transport. We plan to start the implementation (in collaboration with Matthias Steffen, Potsdam).

- **Extension to 3D RHD models.**
  
  *Starting*: Mar 2011; *Length*: 2.5 yr
  
  Although 2D models show qualitatively a similar behavior as 3D models, a realistic quantitative description of the surface and variability properties require the computationally expensive step to three dimensions. 3D models will allow, for instance, the inclusion of (f-plane) rotation to study the role of global flow patterns caused by rotation and its influence on the surface granulation and cloud distribution. We also plan to use the full capacities of CO5BOLD and proceed from the local models described above (that cover only a small part of the total surface of the object) to global models (that comprise the entire object). This is only possible for young, low mass (low-gravity) objects where the scales of the surface granulation are comparably large. With these models we will be able to investigate the exchange flows between the day side and the night side of a planet, while more realistically determine the surface granulation and cloud distribution.

- **Interior & evolutive tracks:**
  
  *Starting*: Mar 2013; *Length*: 1.5 yr
  
  Based on the up-to-date grid of Phoenix model atmospheres, the calculation of the isochrones tracks will be estimated and provided on the web simulator.

### 3.4. Calendrier des tâches, livrables et jalons / Planning of tasks, deliverables and milestones

The planning of the three tasks of our ANR10-GuEPARD project is shown on Fig. 6.
Fig. 6: Gantt diagram of the ANR10-GuEPARD project
4. STRATEGIE DE VALORISATION DES RESULTATS ET MODE DE PROTECTION ET D’EXPLOITATION DES RESULTATS / DATA MANAGEMENT, DATA SHARING, INTELLECTUAL PROPERTY AND RESULTS EXPLOITATION

- **Results publication.** All Members of the project have skills and experience for a timely exploitation of the results from the DI and RV observing programs: (1) individual detection and characterization and (2) Statistical interpretation of the complete surveys to test planetary formation and evolution mechanisms. Data will be shared inside the project and analyzed and published before their public release. ESO observations will be public after one year, whereas ESO-GTO SPHERE data will be public after 1.5 years. Results will be published in reviews with referring comity (Astronomy & Astrophysics, and Science).

- **World coverage.** All published results will be presented in national (yearly Société Française d’Astronomie Meeting) and above all international conferences and workshops (Spirit of Lyot Conference-2010, IAU international General Assembly and meetings, Cool stars conferences, Planet & Protopstar 2011…). Three missions per year for equivalent permanent positions and post-doc positions are planned to optimize the presentation and the coverage of our different results in France and abroad. In the context of the development of planetary atmosphere, New grids of model atmospheres have been offered to the community (via the web simulator: [http://phoenix.ens-lyon.fr/simulator](http://phoenix.ens-lyon.fr/simulator)) and will be constantly updated based on last simulation results.

- **Public release.** In addition, for important discoveries, they will be released to the press via the public relation services of ESO, CNRS and UJF. We have the experience of such events with the presentation of key discoveries in the past, including results supported by our previous ANR-2005 (NT05-4-44463). We can refer to the image of giant planet to a young brown dwarf (Chauvin et al. 2004; 2005), released to the public by ESO: ESO-PR 23/04 “Is This Speckle of Light an Exo-planet?” and ESO-PR 12/05 “Yes, It is the image of an Exoplanet”. And also released by the CNRS: CP-10-09-2004 ‘Première Image d’un Exo-planète’. More recently, the discovery of probable planet in the Beta Pictoris Disk (Lagrange et al. 2008) has been publicly released by ESO, CNRS and Joseph Fourier University at the same time on November 21 2008: “A probable planet imaged in the 8 Pictoris disk”.

- **Prospective.** Thanks to the combined use of Radial Velocity and Deep Imaging, this multi-techniques project will offer a complete vision of the occurrence of giant planets at all orbits. It will strengthen our leadership in the field and enrich our expertise to fully exploit the capabilities of upcoming instrument like SPHERE or ESPRESSO at VLT. Moreover, our results will enable the creation of Deep Imaging and Radial Velocity database (target observed, detection performances, contaminant or companion identification) combined with Nearby Stars Database (stellar properties). They will be used for upcoming instrumental projects using alternative observing techniques: GAIA and VLTI/PRIMA (astrometry), Kepler and THESIS (transit), WISE (wide field imaging) or in the perspective of the preparation of future DI and RV surveys at the horizon 2015-2030: ELT/EPICS, ELT/CODEX, JWST/MIRI,
TPF/Darwin. Finally, dynamical atmosphere simulations will also provide the community with spectra, isochrones for the future transit and imaging instruments dedicated to the characterization of giant planets.

5. **Organisation du partenariat / Consortium organisation and description**

5.1. **Description, adéquation et complémentarité des partenaires / relevance and complementarity of the partners within the consortium**

- **“Institut de Planétologie et d’Astrophysique de Grenoble (LAOG/IPAG)”, coordinator-Partner:** the LAOG/IPAG institute, involving experts in the field of Detection and characterization of EGPs using different observing techniques. They are known on the international scene thanks to major breakthrough discoveries and the development of dedicated instruments. For years, the LAOG/IPAG institute has been involved into the development of several deep imaging instruments (ADONIS, NaCo, SPHERE). J.-L. Beuzit and David Mouillet are respectively the Principal Investigator and the Project Scientist of the SPHERE second generation instrument of the ESO-VLT. Our team gathers also experts who have largely proven their expertise to conduct and scientifically exploit observing programs using two successful techniques for detecting and characterizing giant planets: the Deep Imaging and the Radial Velocity techniques. Anne-Marie Lagrange and J.-L. Beuzit have conducted several successful Radial Velocity programs in collaboration with the Geneva Observatory dedicated to late dwarfs, solar-type stars and more recently early-type stars. Gaël Chauvin has been leading several Deep Imaging programs at ESO and CFHT dedicated to the search for very faint companions. In addition, Experts in dynamical atmosphere & structure of EGPs models (F. Allard; CRAL; see below), dynamical simulations (H. Beust; LAOG/IPAG) and giant planet formation (Y. Alibert; Obs. Besançon), are also part of the project to exploit optimally all pertinent information obtained from radial velocity and deep imaging surveys. The LAM is already an important partner in the context of the SPHERE project and expert in the study of exoplanets (see below). Consequently, all skills are gathered in this project to successfully carry out a global multi-techniques study to detect and characterize giant planets at all orbits. This project will provide invaluable constraints for our understanding of the formation and evolution processes of EGPs and BDs as well as their structure and atmospheres. The defined project coordination will guaranty its success.

- **“Laboratoire d’Astrophysique de Marseille (LAM)”, Partner 2.** The LAM includes researchers working on the detection and study of extrasolar systems. They have developed an expertise in transit photometry from space, leading the operations and ground-based support of the CNES mission CoRoT (M. Deleuil, C. Moutou, P. Barge), in radial-velocity measurements of solar-type stars, for planetary detections and mass determination of CoRoT candidates (C. Moutou). M. Deleuil is leading a group on stellar parameter determination and has developed all skills necessary to derive fundamental parameters of the star and planets from the measurements. The LAM is
responsible for the conception, realisation and integration of one focal instrument of SPHERE (M. Langlois, now at CRAL and K. Dohlen, LAM). C. Moutou is CoI of the SPHERE instrument and scientific responsible of the Target Data Base, developed at LAM in support for the Guaranteed Time Observations of the SPHERE consortium. On direct imaging projects including NACO and SPHERE, the LAM and LAOG/IPAG teams work closely together and want to strongly consolidate this link in preparation to the operations of the SPHERE survey, and beyond. A particular interest is given at LAM to the characterization of extrasolar planets: 1) follow-up observations using a variety of techniques to constrain the system -optical and infrared photometry, spectroscopy, radial velocity, spectropolarimetry; 2) system modelling to derive fundamental parameters and errors. Planetary formation using MHD physics (P. Barge) and star-planet interactions (C. Moutou) are also developed at LAM.

- « Centre de Recherche d’Astrophysique de Lyon (CRAL)”, Partner 3: The third partner of the project is the CRAL which has been leader for years in the modeling of the structure and atmosphere of low mass stars, brown dwarfs, and extrasolar planets. In the frame of current and upcoming deep imaging instruments, NaCo, SINFONI and SPHERE, F. Allard improved existing classical models to dynamical weather models, and start extending the computations to sub-jovian planets (less than 100K) for the treatment of convection and turbulence, and with P. H. Hauschildt (Hamburg Univ.) to adapt static (1D and 3D) radiative transfer models. RHD atmospheric simulations with irradiation and rotation are needed to determine more realistic conditions for the formation of clouds in planetary and brown dwarf atmospheres. Their team gathers experts in that specific field, who will enable an optimal use of new grids of model atmospheres, synthetic spectra and interior models, in collaboration with Isabelle Baraffe (Exeter Univ.), for (1) the physical and chemical characterization of EGPs and BD companions and (2) the use of model predictions considering their intrinsic limitations.

5.2. Qualification du coordinateur du projet / Qualification of the project coordinator

At ESO, Gaël Chauvin was actually in charge of two Large observing program with NaCo at VLT dedicated to the search for Giant Planets around young, nearby stars and exoplanet host stars that led to significant results (Three ESO Press Releases) and publications (9 first author publications) over the past-years. The team was actually formed by a collaboration between UCLA (B. Zuckerman, I. Song), ESO (C. Dumas), LAOG (A.M. Lagrange, D. Mouillet, J.L. Beuzit) and Geneva (M. Mayor, S. Udry, A. Eggenberger). Despite an extreme competition, major breakthroughs were obtained and rapidly published. The team has been seen as one of the most competitive internationally in that specific field dedicated to finding and characterizing giant planet in deep imaging. This experience strongly confirmed his abilities to conduct an international collaboration to the complete exploitation of the NaCo surveys. Since April 2007, he has started a permanent position at the LAOG to pursue in collaboration with A.M. Lagrange several on-going programs that recently led to the detection of probable planet in the β Pictoris disk (Lagrange et al. 2008). These results confirmed his developing expertise and motivation to push the present techniques and instrument performances to
exploit all the available information from high contrast observations. He is currently co-directing a thesis in the specific area of cool companion’s characterization using 3D-spectroscopy assisted by AO in collaboration with F. Allard (CRAL) that gave already promising astrophysical results. He has therefore proven his potential ability to supervise students (PhD, master) given a defined guideline. Finally, as member of the VLT/SPHERE scientific groups, he is in charge with S. Desidera (Padova/Italy) of coordinating the preparation of the SPHERE GTO near-infrared survey of more than 200 nights dedicated to a systematic search of EGP’s and BDs to nearby stars. He has therefore developed the competences to place his own work in the frame of future projects and developments to coordinate a 4 years ANR project gathering the LAOG/IPAG, LAM and CRAL partners.
5.3. Qualification, rôle et implication des participants / Contribution and qualification of each project participant

**PARTENAIRE 1: LAOG**

<table>
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<tr>
<th>Partenaire</th>
<th>Nom</th>
<th>Prénom</th>
<th>Emploi actuel</th>
<th>Personne.mois</th>
<th>Rôle/Responsabilité dans le projet 4 lignes max</th>
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<tr>
<td>Coordonné/responsable</td>
<td>Chauvin Gaël</td>
<td>CR2</td>
<td>34.8</td>
<td>Coordinator of the whole project Coordinator for TASK 1 Contribution to TASK 2a DI programs at LAOG/IPAG SPHERE exploitation and tools RV survey of young stars</td>
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**Autres membres**

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<th>Emploi actuel</th>
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<tr>
<td>Lagrange Anne-Marie</td>
<td>Meunier Nadège</td>
<td>Astronome-Adjoint</td>
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<td>Contribution to TASK 2c Activity simulation</td>
<td></td>
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<tr>
<td>Mouillet David</td>
<td>Beuzit Jean-Luc</td>
<td>CR2</td>
<td>4.8</td>
<td>Contribution to TASK 1 SPHERE Principal Investigator DI programs at LAOG/IPAG SPHERE exploitation and tools</td>
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**PARTENAIRE 2: LAM**

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<tr>
<td>Coordonné/responsable</td>
<td>Moutou Claire</td>
<td>CR1</td>
<td>24</td>
<td>Co-Coordinator for TASK 1b and 1c SPHERE exploitation and tools</td>
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**Autres membres**

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<tr>
<td>Deleuil Magali</td>
<td>Gry Cécile</td>
<td>Professeur</td>
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<td>Contribution to TASK 1</td>
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<tr>
<td>Kry</td>
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<td>Astronome</td>
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**PARTENAIRE 2: CRAL**

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<tr>
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<td>DR2</td>
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<td>Coordinator for TASK 3 Dynamical Atmosphere</td>
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6. JUSTIFICATION SCIENTIFIQUE DES MOYENS DEMANDEES / SCIENTIFIC JUSTIFICATION OF REQUESTED BUDGET

6.1. PARTENAIRE 1 / PARTNER 1 : LAOG/IPAG

Personnel / Staff
- 2 years of ANR Deep Imaging post-doc (2 FTE)
- 2 years of ANR Radical Velocity + Activity post-doc (2 FTE)

Missions / Missions
- Permanent staff: (2 FTE for 5 permanent staff)
  - Conference: 2 missions/years * 2 persons * 4 years * 2 kEuros = 32 kEuros
  - Collaboration: 3 missions/years * 2 persons * 4 years * 0.5 kEuros = 12 kEuros
- Two ANR-Post-Docs:
  - Conference: 2 missions/years * 2 persons * 2 years * 2 kEuros = 16 kEuros
  - Collaboration: 3 missions/years * 2 persons * 2 years * 0.5 kEuros = 6 kEuros
- Two Doctorants:
  - Conference: 1 mission/years * 2 persons * 3 years * 2 kEuros = 12 kEuros
  - Collaboration: 1 mission/years * 2 persons * 3 years * 0.5 kEuros = 3 kEuros

Dépenses justifiées sur une procédure d’autres dépenses charges externes/ External expense
- Computers, data storage.
  - Permanent staff: 2*4 kEuros = 8 kEuros
  - ANR-Post-Docs: 2*4 kEuros = 8 kEuros

6.2. PARTENAIRE 2 / PARTNER 2 : LAM

Personnel / Staff
- 2 years of ANR Deep Imaging post-doc (2 FTE)

Missions / Missions
- Permanent staff: (1 FTE for 3 permanent staff)
  - Conference: 1 mission/years * 1 persons * 4 years * 2 kEuros = 8 kEuros
  - Collaboration: 3 missions/years * 1 persons * 4 years * 0.5 kEuros = 6 kEuros
- One ANR-Post-Doc:
  - Conference: 2 missions/years * 1 persons * 2 years * 2 kEuros = 8 kEuros
  - Collaboration: 3 missions/years * 1 persons * 2 years * 0.5 kEuros = 3 kEuros
- One Doctorant:
  - Conference: 1 mission/years * 1 persons * 3 years * 2 kEuros = 6 kEuros
  - Collaboration: 1 mission/years * 1 persons * 3 years * 0.5 kEuros = 1.5 kEuros

Dépenses justifiées sur une procédure d’autres dépenses charges externes/ External expense
- Computers, data storage.
  - Permanent staff: 4 kEuros
  - ANR-Post-Doc: 4 kEuros
6.3. PARTENAIRE 3 / PARTNER 3 : CRAL

Personnel / Staff
- 2 years of ANR Dynamical Atmosphere IR2 position (2 FTE)

Missions / Missions
- **Permanent staff**: (1 FTE for 1 permanent staff)
  - Conference : 1 missions/yr * 1 person * 4 yrs * 2 kEuros = 8 kEuros
  - Collaboration : 3 missions/yr * 1 persons * 4 yrs * 0.5 kEuros = 6 kEuros

Dépenses justifiées sur une procédure d'autres dépenses charges externes/ External expense
- Computers, data storage.
  - **Permanent staff**: 8 kEuros
  - IR2 : 8 kEuros
7. ANNEXES

7.1. REFERENCES BIBLIOGRAPHIQUES / REFERENCES

Freytag B., Allard F., Ludwig et al. 2010, in press
Kalas, P.; Graham, J. R.; Chiang, E. et al. 2008, Science, 322, 1345
Mayor & Queloz 1995, Nature, 378, 355
Torres C. Quast, G., Melo C. 2008, Handbook of Star Forming Regions, Volume II
Vigan, Moutou, Langlois, 2010, soumis à A&A
7.2. Biographies / CV, Resume

Biographies / CV, Resume
Gaël Chauvin
Address: Born on September, 5th 1976 in Grenoble (France)
10 Rue Humbert II single
38000 Grenoble

Education and Degrees:
2003: PHD Thesis from Grenoble Joseph Fourier University (France).
2000: Master of Astrophysics, with honors
1994 : Scientific ‘Baccalauréat’ with honors

Positions :
2007- : Researcher at Laboratoire d’Astrophysique de l’Observatoire de Grenoble (LAOG).
Chargé de Recherche 2ème Classe
2007: Fellowship position at the European Southern Observatory.
ESO support astronomer to the NACO, SINFONI, ISAAC and FORS1/2 instruments at the VLT. Member of the ESO AO group and especially involved into the NACO instrument.
Title: “Study of the circumstellar environment to search for substellar objects and circumstellar disks [Joseph Fourier University, Grenoble] Participation to the integrating and tests phases of the NAOS adaptive optics instrument. Creation of a detection performance estimator dedicated to AO instruments. Observing programs to search for low mass companions, using high contrast and high angular resolution instruments. Observations with ADONIS SHARPII, PUEO/KIR (CFHT) and NACO (VLT).
“Moniteur” at Grenoble Joseph Fourier University. Teaching physics at the Joseph Fourier University, Grenoble for more than 192-hr over my three years of PhD.

Scientific activities :
Research topics: study and search for extra-solar planetary systems as main topic. Direct imaging detection and characterization of faint companions to nearby stars, brown dwarf companion and EGP's
Leader of two main collaborations dedicated to the direct search for and the characterization of brown dwarfs and planets 1) to young, nearby stars (LAOG-UCLA-Gemini-IPAC-ESO) and 2) to planetary hosts (LAOG-Obs. Geneve-ESO). Strong experience in coronagraphy and differential imaging, long-slit and integral field unit spectroscopy coupled to adaptive optics system.
- Member of the VLT/SPHERE scientific Group, instrument of second generation at the VLT. System of Extreme-AO coupled to high contrast instrumental techniques to survey a large number of nearby stars and to detect and to characterize systematically giant planets.- -
Publications: 25 papers published or in press in refereed journals.
committees and management of science:
member of the ESO fellowship selection panel (2006)
ESO panel adviser for the telescope time (2009 - 2010)
responsible for public & schools visits and communication at LAOG and member of the communication committee of the Grenoble Observatory

languages:
French (native), English (fluent), Spanish (fluent), Italian (read, spoken), German (read, spoken)

PhD student:
Mickael Bonnefoy (co-direction with A.M. Lagrange, LAOG)

key publications:
Anne-Marie Lagrange
Address:
16, Rue Boileau
38700 LA TRONCHE
FRANCE

Education and Degrees:
1994 : Diploma: "Habilitation à diriger des recherches"
Mention "Très Honorable".
1985 : Diploma from Ecole Polytechnique
1979 : Baccalauréat série C, mention TB.

Positions :
2007- : Researcher at Laboratoire d' Astrophysique de l' Observatoire de Grenoble (LAOG).
2004-2006 : Deputy Director at Institut National des Sciences de l’Univers ; Deputy Director at Département des Sciences de l’Univers, CNRS. Head of the Astronomy Division.
2004- : "Directeur de Recherche" 1st class at CNRS
2000-2003 : "Directeur de Recherche" 2nd class at CNRS. Work at Laboratoire d’Astrophysique de l'Observatoire de Grenoble (LAOG).
"Chargée de Mission” at Institut National des Sciences de l’Univers (INSU), and at Département des Sciences de l’Univers, CNRS, Paris.
1994-1999 : "Chargée de Recherche” 1st class at CNRS (LAOG).
"Chargée de Mission” at l’INSU (19999) Institut National des Sciences de l’Univers (INSU), and at Département des Sciences de l’Univers, CNRS, Paris.
1990-1994 : "Chargée de Recherche” 2nd class at CNRS (LAOG).
1989-1990 : Post-Doctorate at ESO (European Southern Observatory), Garching (D)
1983-1985: Ecole Polytechnique
1982-1983: Military Service

Awards:
1994 : Bronze medal, CNRS
1997 : Prize DIGITAL/SFSA (Société française des Spécialistes de l’astronomie)
2003 : Prize Deslandres from Académie des Sciences
2004 : Grenoble J Fourier University medal
2005 : Prize of Cino del Duca fundation
2007 : Prize ARRI (« Prix du Rayonnement International » )
2009 : Prix Dargelos de l’Ecole Polytechnique

Scientific activities :
Research topics: study and search for extrasolar planetary systems as main topic. Also, comets, interstellar medium and stellar studies. Leader of the team "Planetary Systems" at LAOG (1992-2003)
Organisation and co-organisation of colloquium/symposia; edition and co-edition of books
Project Scientist (1997-2002) of the NAOS Adaptive Optics System for the ESO Very Large Telescope
"Principal Investigator" (2002-2003) of the Phase A of the "Planet Finder" (now SPHERE) project for VLT
Publications: 105 papers published or in press in refereed journals.

Board memberships:
Member of the Board of the Canada France Hawaii Telescope (2004-2006)
Member of the Board of the Institut de Radio Astronomie Millimétrique (2004-2006)
Member of the Board of the THEMIS solar Telescope (2004-2006)
Member of the Board of the EISCAT Association (2004-2006)
Member of the Board of OPTICON (2004-2006)
Member of the Board of ASTRONET (2005-2006)

Committees and Management of Science:
Member of the Time Allocation Committee for the Hubble Space Telescope 1996.
Member of the ESO VLTI « Steering Committee » (1997-2006).
Member of the French WG on prospective on R&D in Astronomy (1999)
Member of the VLTI Science demonstration team (2001-2003)
Coordinator of the FP6 Eranet in astronomy Astronet (2005-2006)
Member of the ESO DG Search Committee (2006)
Member of ESA SSAC (2007-2008)

Languages:
French (native), English (fluent), Spanish (read, spoken), German (read)

PHD students:
Patrice Corporon
David Mouillet
Jean Charles Augereau
Gael Chauvin
Franck Galland (co-direction with M Mayor, Geneve)
Morgan Desort
Jean François Sauvage (codirection with G Rousset, ONERA)
Mickael Bonnefoy (codirection with G Chauvin, LAOG)

Key publications:
Desort, M.; Lagrange, A.-M.; Galland, F., Beust, H., 2008, in press, ASTRO-PHarXiv:0809.3862, "Extrasolar planets and brown dwarfs around A-F type stars V. A planetary system found with HARPS around the F6IV-V star HD 60532"
Claire Moutou
Address:  
203 rue Albert Einstein  
13013 Marseille

Born on December 18th, 1969 in Paris  
Married, one child

Education and Degrees:
1993: Master of Astrophysics of University Paris VI

Positions:  
2002-: Researcher at Laboratoire d’Astrophysique de Marseille (LAM). Chargée de Recherche 1ère Classe  
1999-2001: Fellowship position at the European Southern Observatory.  
ESO support astronomer to FORS, ISAAC, UVES at the VLT at Paranal for 2 yrs. Member of the Instrumentation group in Garching on the NACO instrument in 2001.  
1997-1998: Assistant researcher at Observatoire de Haute Provence with A. Labeyrie. Assistant researcher at Observatoire de Haute Provence with A. Labeyrie. “PAHs in the interstellar medium”.

Scientific activities:  
Research topic: detection and characterization of extra-solar planetary systems, fundamental parameters and atmospheric observational properties  
CoI of CoRoT and responsible for the follow-up operations of CoRoT transiting planet candidates  
Radial-velocity activities: detection of new systems around solar-type stars, observations of transiting planets, with OHP/SOPHIE and ESO/HARPS  
CoI of VLT/SPHERE and member of the scientific Group, instrument of second generation at the VLT. PI of star-planet interaction studies: spectropolarimetric observations of hot Jupiter systems, analysis and interpretation of tidal and magnetic interactions  
Publications: 98 publications in refereed journals.

Committees and Management of Science:  
- Member of the CNRS Comité National (2005-2008)  
- Member of the science council of CoRoT  
- Member of the science council of “programme national de planétologie”  
- Member of the science council of Observatoire de Haute Provence  
- ESO Panel Adviser for the Telescope Time (2009)

Languages:  
French (native), English (fluent), Spanish (read, spoken)

PHD student:  
Arthur Vigan (co-direction with M. Langlois, LAM/CRAL)  
Alexandre Santerne (co-direction with F. Bouchy, IAP/OHP)  
Rim Farès (co-direction with J.-F. Donati, LATT)

Key publications:  
- Moutou, Mayor, Lo Curto et al., 2009, A&A 496, 513: The HARPS search for southern extra-solar planets. XV. Six long-period giant planets around BD -17 0063, HD 20868, HD 73267, HD 131664, HD 145377, and HD 153950
- Moutou, Hébrard, Bouchy et al., 2009, A&A 498, L5 Photometric and spectroscopic detection of the primary transit of the 111-day-period planet HD 80606 b
- Vigan, Moutou, Langlois, 2010, soumis à A&A: Photometric exoplanet characterization with angular and spectral differential imaging
France Allard

Address: Born on June, 11th 1963 in Montreal (Canada)
5b, Rue Baudrand
69540 Irigny
FRANCE

Education and Degrees:
2004 : Diploma: "Habilitation à diriger des recherches"
1990 : PHD Thesis from Ruprecht-Karls-Universität Heidelberg. Mention "Honorable".
1986 : M.Sc. Physique, Université de Montréal
1985 : B.Sc. Physique, Université de Montréal
1982 : Diplôme d’études secondaires, Laval Ouest.

Positions:
2008-: "Directeur de Recherche" 2ième Classe at CNRS.
1998-2008 : "Chargée de Recherche" 1ère Classe at CNRS.
1997-1998 : "Chargée de Recherche Associée" at CNRS.
1996-1997 : Chercheur Associée, Department of Physics, Wichita State University.
1994-1995 : Sessional Lecturer, Department of Geophysics and Astronomy, U.B.C.
1990-1993 : Boursière Post-doctorale, Département de Physique, Université de Montréal.

Scientific activities:
Research topics: modeling the atmospheres of very low mass stars, brown dwarfs and extrasolar gaseous planets as main topic. Also, low temperatures opacities.
Organisation and co-organisation of colloquium/symposia; edition and co-edition of books, web sites
Publications: 102 papers published or in press in refereed journals.

Committees and Management of Science:
Membre de l’instance European Southern Observatory (ESO) : Membre du « Observing Programmes Committee »
Membre de l’instance scientifique ou administrative de groupe de travail conjoint PNP/ASHRA/PNPS exoplanètes
Membre de l’instance scientifique ou administrative de Bureau de la Société Française d’Astronomie et d’Astrophysique
Membre de l’instance European Interferometric Initiative Radiative Transfer Working Group
Membre de l’instance Groupe de travail du projet SPHERE
Membre de l’instance Conseil scientifique du Programme Origine des Planètes et de la Vie (OPV)[CNRS]

Languages:
French (native), English (fluent), German (correct)

PHD students:
Jimmy Paillet

Key publications:
7.3. IMPLICATION DES PERSONNES DANS D’AUTRES CONTRATS / INVOLVEMENT OF PROJECT PARTICIPANTS TO OTHER GRANTS, CONTRACTS, ETC …

*(un tableau par partenaire)*

*Cf. § 5.3*

Mentionner ici les projets en cours d’évaluation soit au sein de programmes de l’ANR, soit auprès d’organismes, de fondations, à l’Union Européenne, etc. que ce soit comme coordinateur ou comme partenaire. Pour chacun, donner le nom de l’appel à projets, le titre du projet et le nom du coordinateur.

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<th>Part.</th>
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<th>Personne . mois</th>
<th>Intitulé de l’appel à projets Source de financement Montant attribué</th>
<th>Titre du projet</th>
<th>Nom du coordinateur</th>
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