Research Networking Programmes

Short Visit Grant ☐ or Exchange Visit Grant ☒

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

***Proposal Title**:* A spectroscopic census of brown dwarfs observed by Gaia - completing the 3D picture.

Application Reference N°: 4641

1) Purpose of the visit

The purpose of my visit to the Osservatorio Astrofisico di Torino was to work with Dr. Richard L. Smart to investigate the feasibility and to define the observing and data reduction strategy for a spectroscopic follow-up of the brown dwarfs observed by Gaia, in order to measure accurate radial velocities. We estimate that Gaia will observe directly ~500 L0 to L4 dwarfs and a handful of L5 to T1 dwarfs, providing precision of 0.1-0.3 mas in parallax for these objects, distances with relative errors of 1-10% and tangential velocities at the level of 10-30 m/s (Smart et al., MemSAIt, in press). As these objects are very close, the perspective acceleration will change both the parallax and the proper motion over the time frame of the mission, leading to "astrometric" radial velocities with errors of 10-20 km/s. However, to fully exploit the extremely accurate and precise astrometric data, it is fundamental to obtain better radial velocities. The preparation of proposals to carry out the necessary observations was part of the aim of this exchange.

2) Description of the work carried out during the visit

We searched the literature to compile a list of all available radial velocity informations for the L dwarfs observed by Gaia. We found a total of 322 L dwarfs with radial velocity measured at different levels of precision. However only 40 of them have measurements with 1-2 km/s uncertainties (or better), which is the requirement for a full scientific exploitation of the Gaia data (see Marocco et al., MemSAIt, in press). The distribution of objects with measured radial velocity is also strongly biased towards the

northern hemisphere, where the majority of the previous efforts were focused (e.g. Schmidt et al. 2010, AJ, 139, 1808). There is therefore a clear need for a radial velocity follow-up of the southern population of L dwarfs, even more so considering that the majority of the nearby young associations are located in the southern sky, and these associations have been crucial in understanding the early evolution of L dwarfs.

Among the various facilities available in the southern hemisphere, the ideal choice for our intended project would be X-shooter, the echelle spectrograph mounted on the VLT. We therefore carried out a feasibility test, that proved that we can achieve the requested level of precision (Marocco et al., MemSAIt, in press).

During this exchange we refined our test, using a large sample of L and T dwarf spectra (Marocco et al., MNRAS, submitted). We focused in particular on an issue emerged when comparing the results of our study with data from the literature. The distribution of the measured radial velocities obtained in our preliminary test in fact had a lower dispersion compared to a previous result obtained by Schmidt et al. (2010, AJ, 139, 1808). We obtained a dispersion of 31.5 km/s while Schmidt et al. obtained a dispersion of 34.3 km/s. To understand and explain this discrepancy we assesed various possibilities. Telluric lines in the spectra could systematically shift our measurements towards lower values, but this possibility has been discarded since all of the wavelength regions affected by telluric absorption are not considered when measuring the radial velocity. The discrepancy could also be due to uncorrected instability of X-shooter. However this is very unlikely, as the instrument has been showed to be stable down to 0.5 km/s (Vernet et al. 2011, A&A, 536, 105). The most likely explanation seems therefore to be a geometric effect. Our sample is drawn from a smaller area of sky than the Schmidt's one, covering predominantly the northern galactic cap. The radial velocities of our objects are therefore dominated by the W component of their galactic velocity, which is known to have a narrower dispersion than the U and V components (Dehnen & Binney 1998, MNRAS, 298, 387). We tested this hypothesis using the Besançon Model of stellar population synthesis of the Galaxy (Robin et al. 2003, A&A, 409, 523). For O to M type dwarfs with $J < 18.1$ (which is the magnitude limit of our observed sample) we obtain a dispersion of 34.8 km/s when considering objects spread over the SDSS footprint (i.e. the area covered by the Schmidt's study) and a dispersion of 31.8 km/s when considering objects spread over the right ascension and declination limits of our study. Both numbers are in good agreement with the observed ones, and the measured difference between our sample and the Schmidt's one seems therefore to be due to a geometric effect.

X-shooter seems therefore to be the obvious choice to carry out our intended project, because it combines intermediate resolution ($R \sim 5000$-8000) with wide wavelength coverage and sufficient stability.

3) Description of the main results obtained

We compiled a preliminary list of L dwarfs visible to Gaia with measured radial velocity. The list has been made publicly available via the IPERCOOL wiki at http://db.oato.inaf.it/mwiki/index.php/Gaia_L_Dwarfs. This list will be continually updated as the Gaia data become available, allowing us to check and refine the transformation used to estimate the L dwarfs G magnitude. The preliminary list has already been the basis of an accepted proposal on the GTC, awarded 20 hours in filler mode on semester 2015A, to which both me and Dr. Smart have contributed. The observations are being carried out and the spectra obtained will be publicly available on the MAIA online database. The discrepancy between the results of our

earlier feasibility test and published results from the literature has been investigated and explained as a geometric effect, discarding possible instrumental effects or data analysis systematics. X-shooter has therefore been proven to be the ideal instrument to carry out our intended project.

4) Future collaboration with host institution (if applicable)

I will continue my fruitful collaboration with Dr. Smart and the Osservatorio Astrofisico di Torino. A large joint proposal is in preparation to be submitted to the CCI-ITP (P.I. Marocco) to follow-up the northern L dwarfs that will be observed by Gaia. Another proposal is in preparation to be submitted to the ESO/VLT (P.I. Smart) to follow-up the southern L dwarfs that will be observed by Gaia.

5) **Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)***

Part of the results obtained during this visit will be presented in the following publications:

Marocco, Smart, et al., A spectroscopic census of brown dwarfs observed by Gaia - completing the 3D picture, Memorie della Societa' Astronomica Italiana, in press.

Marocco, …, Smart, et al., A large sample of L and T dwarfs from UKIDSS LAS: peculiar objects, binaries, and space density, Monthly Notices of the Royal Astronomical Society, submitted.

The results obtained in this visit will also contribute to sections of a Gaia Data Processing and Analysis Consortium document (GAIA-C3-TN-OATO-RLS-009), focusing on the spectroscopic requirements for the Gaia L dwarfs. This document will be beneficial to the community as a reference for inteded complementary programs, and to foster new collaborations within and beyond the consortium.

6) Other comments (if any)