A spectroscopic census of Brown Dwarfs observed by Gaia - completing the 3D picture.

Federico Marocco[1], Richard L. Smart[2], Hugh R. A. Jones[1], Avril C. Day-Jones[1], Ben Burningham[1], and David J. Pinfield[1]

1 – Centre for Astrophysics Research, Science and Technology Research Institute, University of Hertfordshire

2 – INAF/Osservatorio Astrofisico di Torino

1. Introduction: The ESA cornerstone mission Gaia will revolutionise astronomy observing objects as diverse as minor planets, stars, galaxies out to QSOs and impacting almost all areas of astronomy. 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 tangetial velocities at the level of 10-30 m/s [1]. 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. Therefore we aim to obtain a complete, mid-resolution spectroscopic census of all brown dwarfs that will be observed by Gaia.

2. Science goals: The goal of this project is to complete the medium resolution spectroscopic census of all known brown dwarfs that are within the Gaia magnitude limit. In Figure 1 we plot the distribution in equatorial coordinates (left panel) and J band magnitude (right panel) of the L/T dwarfs that we consider candidates for Gaia observation. We estimate this distribution is missing 25% of the objects due to incompleteness in the plane.

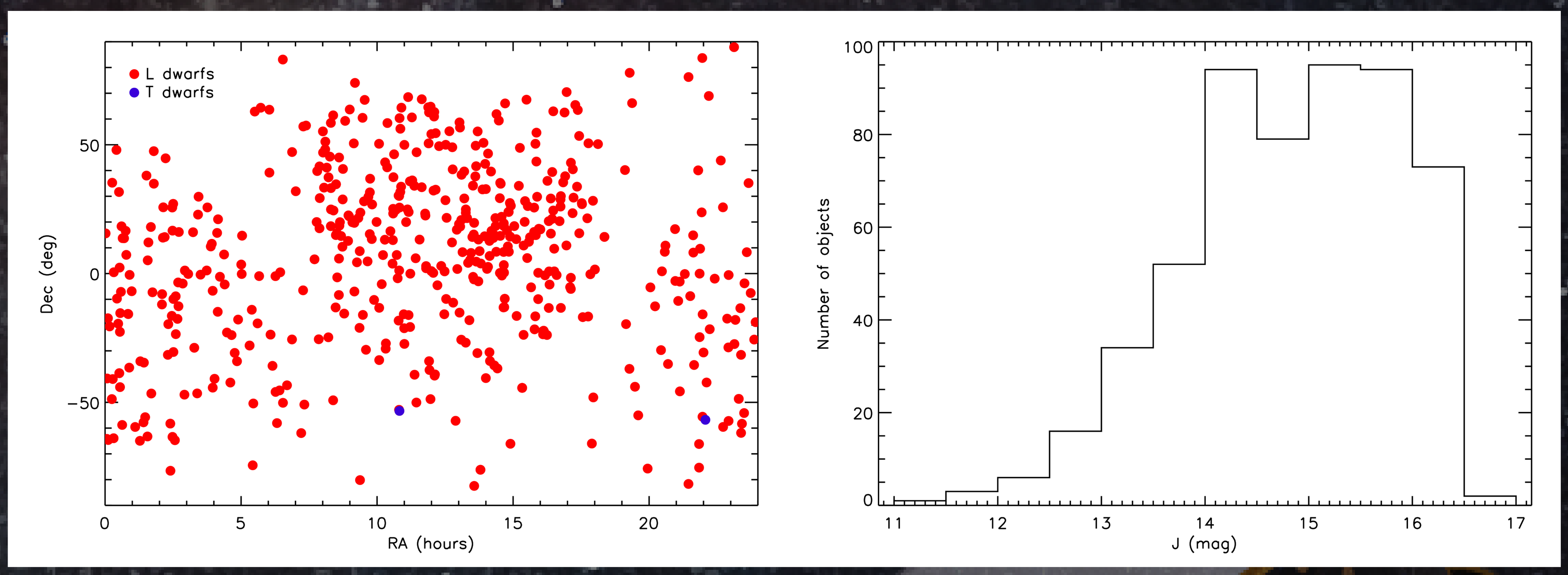

Figure 1: Left, the distribution of brown dwarfs that will be observed by Gaia in the RA – Dec plane. The 547 L dwarfs are plotted in red, and the 2 T dwarfs are plotted in blue. Right, the distribution in apparent J magnitude. The majority of the potential targets are within J of 13.5 and 16.5, making them ideal targets for high signal-to-noise ratio spectroscopy.

The spectra will be used to determine radial velocities, spectral indices, identify possible unresolved binaries, and further investigate the peculiar objects in the sample. Combined with the Gaia results this will be a incomparable dataset for many studies. Our knowledge of brown dwarf physical properties often comes from analysis of their spectra. A triangular shape to the H-band peak indicates youth [2], the FeHz, VO, K I and Na I indices can be used to indicate surface gravity [3], abundances can be estimated via comparisons with benchmark objects and model spectra and line broadening provides rotational velocities.

The holy grail for understanding brown dwarfs has been the associating of individual objects to main sequence stars. When this connection allows us to constrain physical parameters such as age or chemical composition these become benchmark systems. Gaia will find literally thousands of benchmark systems through the comparison of stellar kinematics and those of brown dwarfs seen, and also not seen by Gaia but observed in ground surveys.

Another fundamental contribution comes from members of young moving groups and associations, where the group constraint on the age helps us identifying and characterizing spectral features that are sensitive to surface gravity [3]. In this respect radial velocities with precisions of 1-2 km/s or better are key to identify moving groups members as the groups often overlap in kinematical parameter space [4].

3. Preliminary results: We conducted a preliminary feasibility test using a large sample of L and T dwarfs spectra obtained with X-shooter on the Very Large Telescope [5]. Using a simple cross-correlation technique we calculated "relative" radial velocities for the objects in the sample. An example of a cross-correlation function (hereafter CCF) obtained is shown in Figure 2. The CCF shows a clear sharp peak around -1 pix, highlighting the precision of the radial velocity obtained. The radial velocities have been measured relatively to one of the objects in the sample, that has been selected as "standard" because of its very high signal-to-noise ratio (hereafter SNR) spectrum. The results obtained are encouraging, as can be seen in Figure 3, where we plot the precision obtained as a function of the SNR of the spectra. Even with an SNR as low as 5, we can obtain a average precision of ~5 km/s. Increasing the SNR will allow us to achieve our precision goal of ~1km/s.

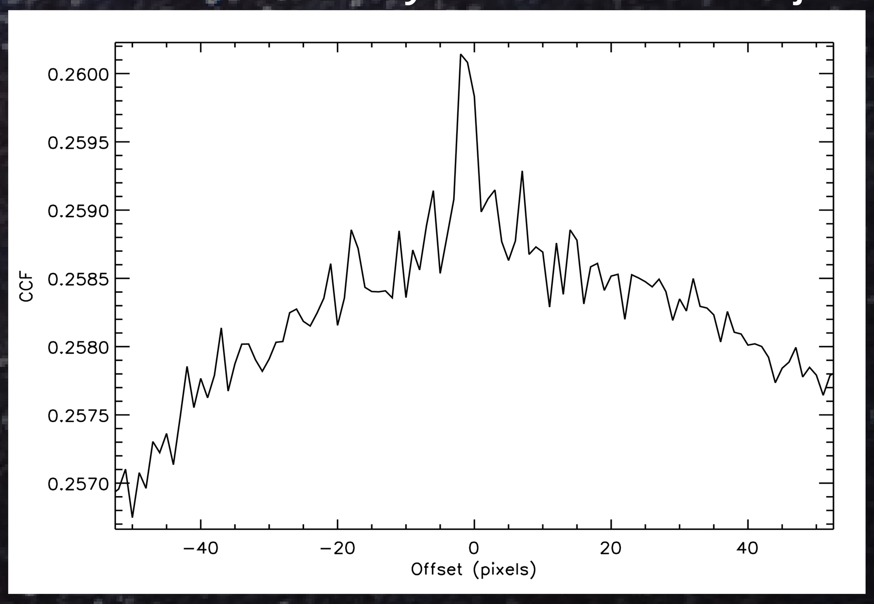

Figure 2: An example of a cross-correlation function (CCF) obtained for one of our targets. The offset is measured in pixels and then converted into a radial velocity using the wavelength dispersion of the instrument.

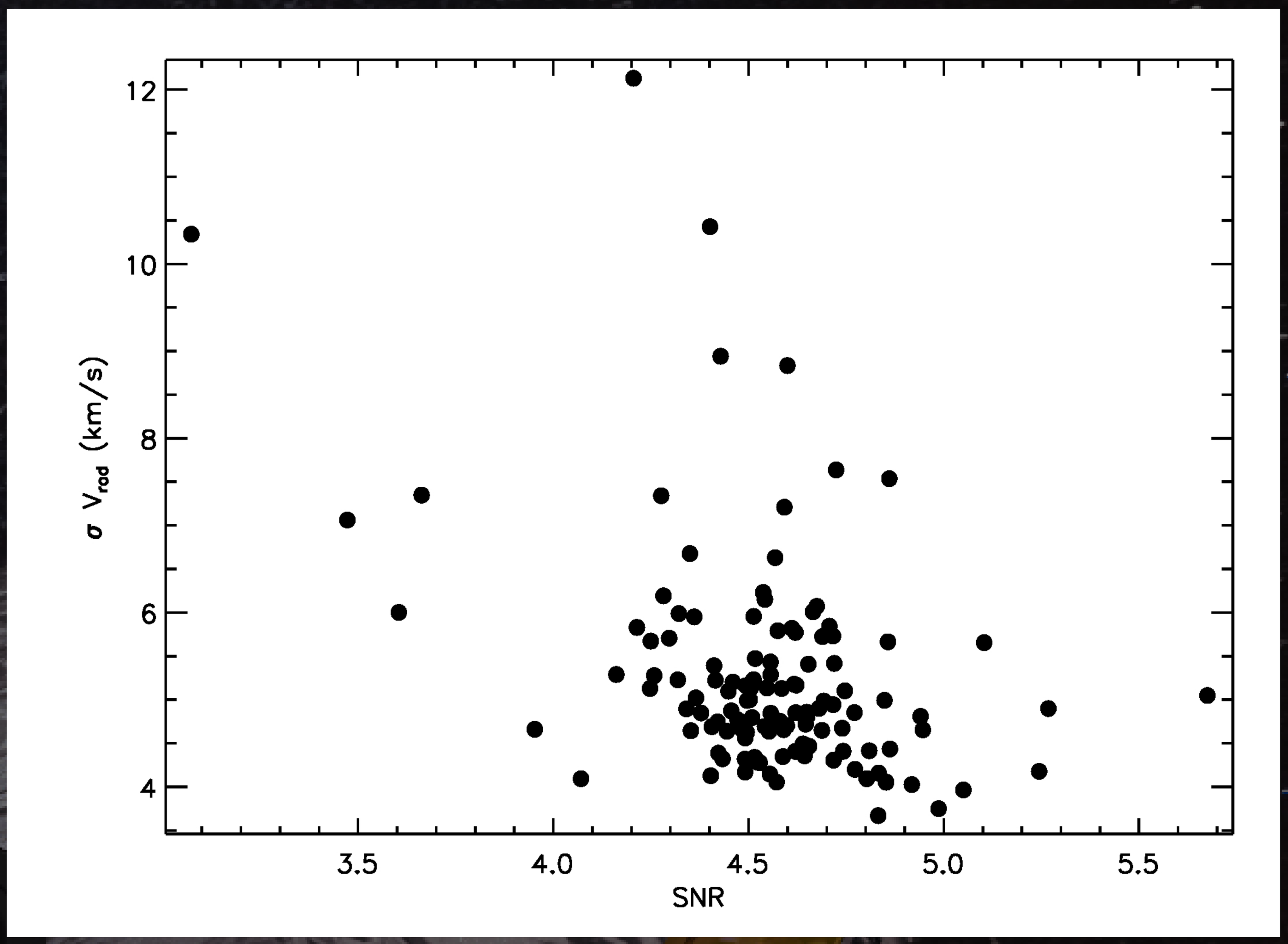

Figure 3: The distribution of the radial velocity precision obtained as a function of the signal-to-noise ratio (SNR) of the spectra. With a SNR as little as ~5 we can achieve radial velocity precisions of 4-6 km/s.

4. Conclusions & Future work: The preliminary results of our tests are encouraging. X-shooter seems to be an obvious choice to carry on part of the program. The next steps will be to test the stability of X-shooter (believed to be ~0.5 km/s, [6]) using the calibration data available on the ESO archive, and to explore the capability of different instruments, to complete the campaign on the "northern" targets. The possibility of using different data reduction techniques (e.g. using sky lines instead of arc lamps to improve the wavelength calibration) will also be explored.

References: [1] Sarro et al. 2013, A&A, 550, 40; [2] Lucas et al. 2001, MNRAS, 326, 695; [3] Allers & Liu 2013, ApJ, 772, 79; [4] Galvez-Ortiz et al. 2010, MNRAS, 409, 552; [5] Day-Jones et al. 2013, MNRAS, 430, 1171; [6] Vernet et al. 2011, A&A, 536, A105.

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