A *k*-NN Method to Search Brown Dwarfs with *Spitzer*/IRAC

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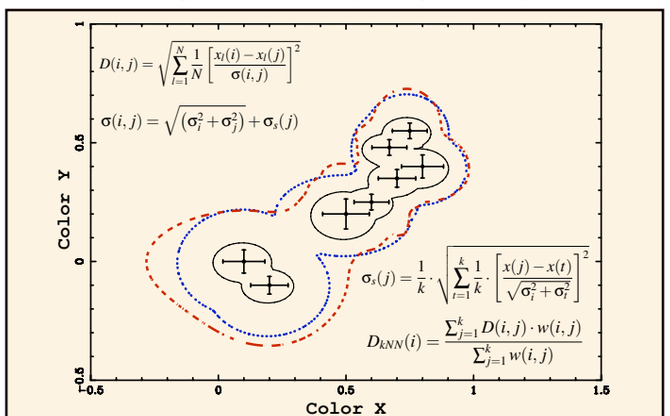
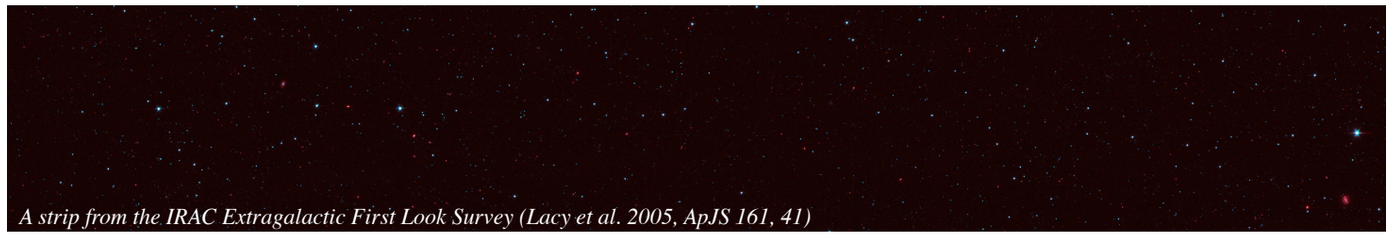
We have developed a statistical technique, based on the *k*-Nearest Neighbor (*k*-NN) method, for the photometric classification of astronomical sources. We present here the application of the method for the search of L and T brown dwarfs using infrared photometry from *Spitzer*/IRAC and 2MASS.

The k-NN method (Fix & Hodge 1951) is a nonparametric classifier, used in fields as diverse as pattern recognition, unsupervised machine learning and life sciences, capable to automatically classify large sets of data based on their distances from a class of "templates". In this paper, we present an adaptation of the k-NN method to the spectro-photometric classification of astronomical sources. For each source we derive a "distance" in a multidimensional color and magnitude space, from a set of template sources. If the distance from the *k* nearest templates is less than a certain threshold value, the source is likely to be of the same class of the templates. The distance is normalized on the photometric uncertainty of the source and templates, and a "sparseness factor" σ_s is added to take into account how well the target class is sampled by the templates.



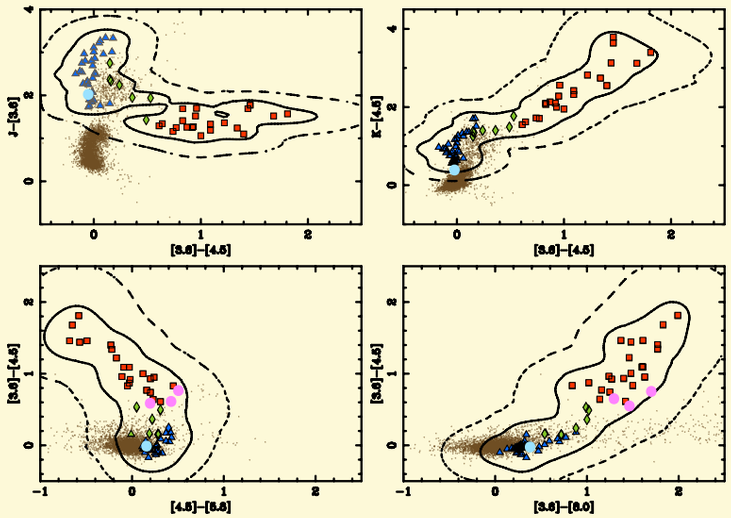
Template sources in a 2-color space. The solid line encloses a 1-NN region around the templates.The two template sources at the bottom are isolated enough to form a separate region. Once the sparseness factor $\sigma_s(j)$ is included in the metric, the two regions coalesce (dotted line). For *k*=3 and larger the region becomes smoother and less dependent on the colors of individual templates (red dashed line). In the more general case, a metric can be defined with an arbitrary number of colors and magnitudes, allowing automatic classification in multiple photometric bands.



A strip from the IRAC Extragalactic First Look Survey (Lacy et al. 2005, ApJS 161, 41)

Searching for Brown Dwarfs in the Spitzer First Look Survey

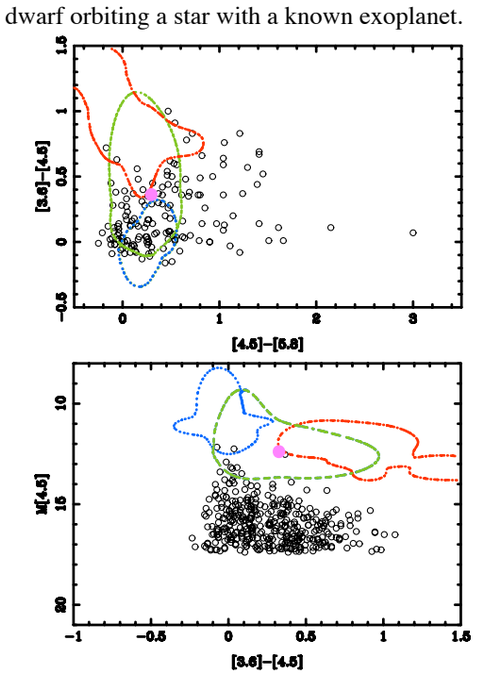
The figure below shows the colors of brown dwarfs of spectral type L (triangles), T<4 (diamonds) and T≥4 (squares) in the near-IR J and K bands, and in the photometric system of *Spitzer*'s InfraRed Array Camera (IRAC), as measured by Patten et al. (2006). These colors are unique because brown dwarfs present prominent molecular features such as CH_4, H_2O, NH_3 and CO in this wavelength range. The brown dots represent sources from the *Spitzer* Extragalactic First Look Survey (XFLS, Lacy et al. 2005).



We have applied our k-NN method to search for L and T brown dwarfs in the XFLS. The contours represent the *k*-NN regions for *k*=5 and for a threshold distance of 1 (solid line) and 2 (dashed line). The search was optimized to maximize the completeness of the result and minimize the number of false candidates, using a Monte Carlo simulation based on a subsample of the whole survey. The maximum efficiency is obtained in the search of late T dwarfs (T≥4) using both near-IR and IRAC colors. In that case the *k*-NN method is able to eliminate over 99.7% of the XFLS sources. Remaining sources can be eliminated by comparison with optical colors. The search returned 1 L dwarf candidate and 9 T dwarf candidates, currently undergoing spectroscopic verification. The large symbols in the plots show the colors of the best L dwarf candidate (cyan) and 3 of the best T dwarf candidates (purple), according to the *k*-NN metric.

Searching for Low Mass Companions around Nearby Stars

We have also applied our *k*-NN method to search for brown dwarf companions to nearby stars. In this case the search is facilitated because a candidate companion is required to have the same distance of the primary star. This allows to use absolute magnitudes as additional constraints. The search has already produced positive results with the discovery of a T2.5 dwarf companion of the young star HN Peg B, and a T7.5 dwarf companion of the star HD 3651 (Luhman et al. 2006). This last system is notable because it is the first case of a brown dwarf orbiting a star with a known exoplanet.



The plot compares HN Peg B (purple symbol) compared to background stars and the *k*-NN regions for L (blue), early T (green) and late T (red) brown dwarfs.