The Substellar Subdwarf Gap

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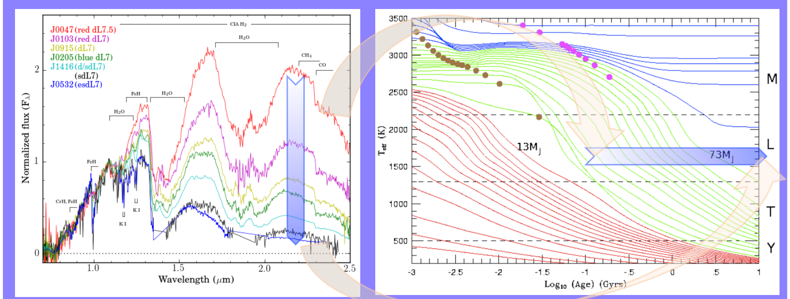
I. Introduction

Brown dwarfs (BD), so called ‘failed stars’, do not have enough mass to maintain stable hydrogen fusion. However, it is a challenge to distinguish normal massive field BD from low-mass stars without knowing their age. Since BD keep cooling down shortly after their formation while low-mass stars keep shining, thus there will be an effective temperature (T_{eff}) gap between BD and low-mass stars, substellar subdwarfs gap (SSG). Very old massive BD (of the Halo, ~10 Gyr) would have a lot lower T_{eff} than stars just above hydrogen burning minimum mass (HBMM), thus distinguishable. L subdwarfs are a mixture of metal deficient low-mass stars and BD located beside the SSG. Eleven L subdwarfs have been identified (e.g., Burgasser et al. 2003; Burgasser 2004; Sivarani et al. 2009; Cushing et al. 2009; Lodieu et al. 2010, 2012; Zhang et al. 2013 in prep).

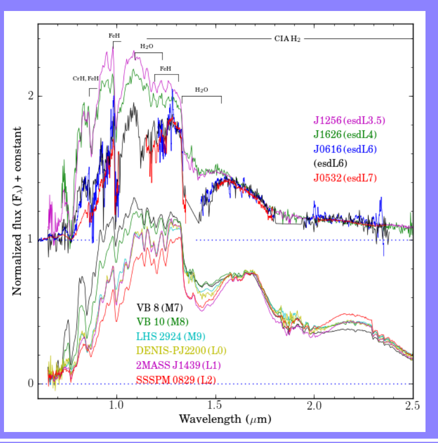
II. Evolution of BD

The SSG is predicted by evolutionary models. The right-hand figure below shows the evolutionary tracks of low-mass stars, BD and exoplanets (Burrows 2001). The left-hand figure below shows a sequence of spectra of L7 type BD. Metal hydrides (e.g. FeH) and collision-induced H2 absorption (CIA H2) are strengthening, metal oxides (e.g. CO) are weakening and absent from top to the bottom spectra. Similar slope of optical spectra indicates similar T_{eff} (1500-1700 K), while large variation of NIR spectra indicates different metallicity and gravity. The sequence is also indicated in the right-hand plot with an blue arrow. They have very different mass from 20 to 80 M_{jup} and age from 0.1 to 10 Gyr.



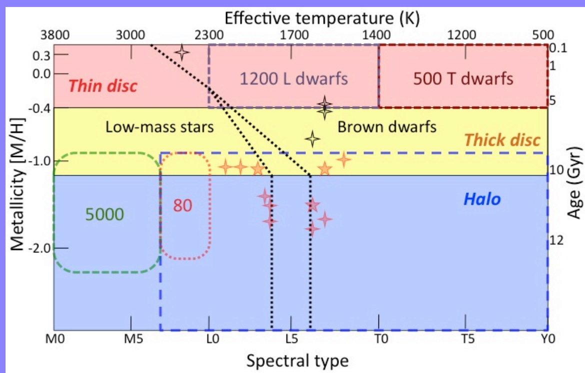
III. Signature of substellar subdwarfs

The esdL7 type 2MASS J0532 (Burgasser et al. 2003) have model predicted mass just below the HBMM, thus the first brown dwarfs of the Halo. The esdL4 type 2MASS J1626 (Burgasser 2004) has very different spectral features from 2MASS J0532 (e.g. depth of H2O bands at 1.15 and 1.4 um). Spectra of late-type M to early-type L dwarfs at the star – BD boundary also have very different features. Figure below shows that flux peak shifting from Y to J band and H2O band at 1.4 um are strengthening from late M to early L. The same thing happened between 2MASS J1626 and 2MASS J0616 (Cushing et al. 2009). They are both extreme L subdwarfs with only 1-2 subtype difference. Large difference of 1.4 um H2O absorption band might represents very different physical conditions of lowest mass stars and massive BD. The 2MASS J1626 and 2MASS J0616 should have a large difference of T_{eff}, thus the SSG might between esdL4 and esdL6, although massive BD with higher metallicity could have earlier spectral types. 2MASS J1756 was claimed to be a sdL1 subdwarfs by Kirkpatrick et al. (2010). It is actually not a subdwarf because the 2.3 CO band presented in its spectrum, but a metal-poor ~L3 type BD, because it has much deeper 1.4 um H2O band than a L1 dwarf. It is indicated in up right figure.



IV. The substellar subdwarfs gap

The figure below shows spectral type, T_{eff}, metallicity and age of Galactic populations of low-mass stars and BD. Red, yellow and blue shaded areas indicate thin disc, thick disc and halo populations respectively. Black dotted lines indicate the SSG. 11 known L subdwarfs are indicated as red stars. 4 black open stars are Teide 1 and 3 mildly metal-poor BD. Since different evolutionary models have slight different prediction of HBMM, thus different SSG. It is possible to test evolutionary and atmosphere models by measure the location of the SSG.



The location of the SSG in the figure below is estimated based on a small sample. But our sample is increasing, another 43 L subdwarf candidates have been followed up. A large number of L subdwarfs around SSG could be identified in current and future large scale surveys (e.g. VISTA, Gaia, Euclid, LSST).

V. Conclusions

SSG is exists between halo low-mass stars and BD, which have strong metal hydrides (e.g. 1 um FeH), absent metal oxides (e.g. 2.3 um CO) and enhanced CIA H2 in their spectra. Deep H2O absorption bands at 1.15 and 1.4 um could be used as an indicator of substellar subdwarfs. SSG could be used to test theoretical models.

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