A Brief History of Substellar Astrophysics

By Jim Liebert

The Brown Dwarf to Exoplanet Connection Conference 2017

Traditionally, spectral types of stars ranged from O to M. O stars, upwards of T_{eff} ~ 40,000K are of course the most massive. Massive stars can evolve through the Wolf Rayet phase. These objects show products of interior nuclear burning at their surfaces (atmospheres), the so-called WN, WC and WO types. Evolved stars of much lower mass can go through carbon-rich atmosphere phases -- R and N types. The most massive stars presumably wind up as supernovae, though the possibility exists that some may just collapse, ejecting very little or no mass. So much for high mass and evolved stars.

By the time later G spectral types are reached, the main sequence lifetimes exceed the lifetime of the Universe and certainly our Galaxy. The bottom of the main sequence for a very long time was the spectral type M8V, represented in the star Van Biesbroeck 10, a near neighbor of our Sun. Then Probst and Liebert (1983 ApJ, 274, 245) found that LHS2924 needed a later, M9V classification. They found that this M9V dwarf showed slightly weaker TiO (titanium oxide) molecular bands than vB10 showed. They speculated rather aimlessly as to why this was the case. In retrospect, this was the beginning of what became the L spectral class where TiO and other features in M dwarfs weaken and disappear. The physical properties of the M dwarf stars, and the definition of the M dwarf spectral types, are given in Kirkpatrick et al. (1993 ApJ, 402, 643, and Kirkpatrick and McCarthy (1994 AJ, 107, 333).

Shortly before the first discoveries of brown dwarfs, a conference was held in Garching, Germany, in August 1994, entitled "The Bottom of the Main Sequence -- And Beyond". Edited by Chris Tinney, contributors to this conference discussed the properties of late M dwarfs, and the first possible discoveries of substellar objects. The following year, the first certifiable substellar objects were identified. The first object later classified as a T dwarf was found by Nakajima et al. (1995, Nature, 378, 463), as a wide (common proper motion) companion to an M dwarf.

The first L dwarfs were discovered primarily in the Two Micron All Sky Survey (2MASS) and the Sloan Digital Sky Survey (SDSS). The former was an infrared sky survey (1.2, 1.6 and 2.2 microns -- JHK). A southern survey by Europeans, called DENIS, also explored some of this territory and discovered brown dwarfs. However, the vast majority emerged from 2MASS and SDSS. Eventually the spectral class of L dwarfs had to be defined -- Kirkpatrick et al. (1999 ApJ, 519, 802) -- based primarily on discoveries from 2MASS. The link between mass, T_{eff} and L spectral type was explored by Reid et al. (1999, ApJ, 521, 631). It was found that L dwarfs could last the lifetime of the Universe up to about L4V. Beyond or below that type, they had to be substellar. Of course substellar objects begin at earlier types and evolve through the M and L subtypes "on the way down." 2MASS could not identify early T dwarfs, since their JHK colors overlapped with those of stars.

A lot of the early history of L and T dwarf research is summarized in a conference "Ultracool Dwarfs, New Spectral types L and T," edited by H.R.A.Jones and Iain J. Steele, published by Springer in 2001. In a PhD thesis at Caltech, Adam J. Burgasser, collaborating in part with J.D. Kirkpatrick, gave the definition of the T spectral types. See also Burgasser et al. 1999 ApJ, 522, 65. Important reviews of this new field were published by Burrows et al. -- e.g. Rev.Mod.Physics, 73, 719. Here the relationships between mass, radius and age -- among other parameters -- are discussed.

Finally, the very end of the substellar sequence, at least in T_{eff}, was permitted by the Wide Infrared Sky Explorer (WISE) mission. Cushing et al. (2011 ApJ, 743, 50), introduced the Y spectral class and the first discoveries with WISE. The WISE mission can find only very near neighbors of the Sun that approach the T_{eff} of Jupiter, but generally without stellar companions. Brown dwarfs frequently have another brown dwarf as a companion, but almost never have a stellar companion. This is despite the fact that the first T dwarf (Nakajima et al. 1995) was found as the wide companion of an M dwarf.