Brown Dwarfs

After all this time talking about stars let's talk about not-stars!

The Initial Mass Function

If you remember, the initial mass function (IMF) tells you the distribution of stars when they were created. Most authors find a peak in the IMF near 0.5 $M_{\odot}$, but the lower mass end becomes difficult to measure, because the stars are so faint.

One piece of evidence about the shape of the IMF at the low end comes from "Recons," the Research Consortium on Nearby Stars. They did a census of all stars within about 10 parsecs. They found about 20 stars of Solar mass, 10 that are significantly more massive than the Sun, and 300 that are significantly less massive. They also found 50 brown dwarfs. So, of the 380 objects, they identified, 50 were brown dwarfs, or 13%. If this sample is representative, there would be about 25 billion brown dwarfs in the Milky Way. That's a lot!

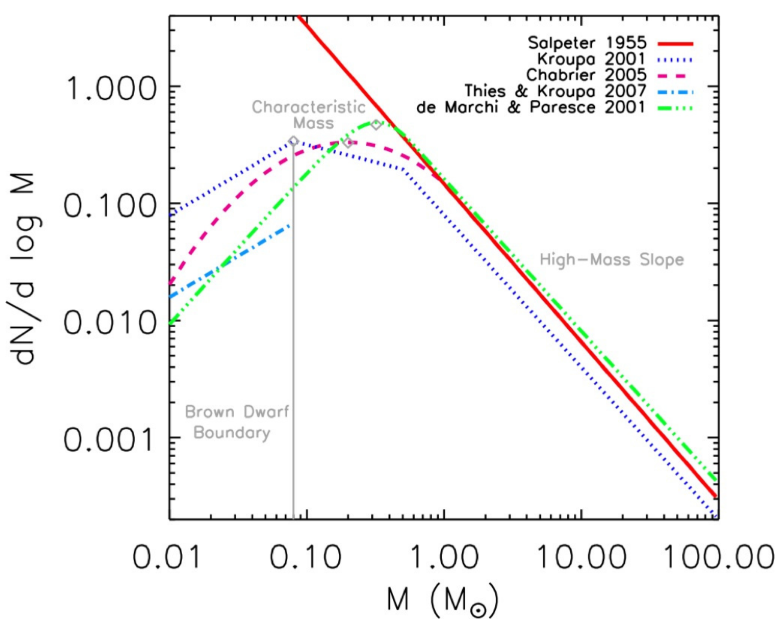

Figure 1: The Initial Mass Function.

Brown Dwarf Definition

A brown dwarf is a "failed star," a star that cannot sustain fusion of hydrogen into helium. This sets an upper mass of 80 times that of Jupiter, or 0.08 $M_{\odot}$. For the lower mass, we have decided that it is 13 times the mass of Jupiter, or 0.012 $M_\odot$. Anything lower mass than that we call a planet. If it's not orbiting another star, it's a free-floating planet.

Brown Dwarf Detections

Brown dwarfs have only been directly detected in the past few decades, with the creation of sensitive infrared telescopes.

Because they are cool, the light from brown dwarfs peaks in the infrared. Anything cooler than about 2300 K must be a brown dwarf. But, how can we estimate temperatures? With colors! If a longer wavelength filter records more intensity than a shorter wavelength filter, the difference in intensity (the color) reveals that the temperature is low.

We can also use something called "proper motion." All stars in the Milky Way orbit about the Galactic center. But, the closer a star is to the Sun, the faster it **appears** to be moving. This is the same effect that we witness all the time. A plane taking off zips across our field of view, but a plane high in the sky takes much longer to pass overhead even though both are traveling at roughly the same speed. It's a similar effect to that of parallax, where nearby stars shift in position more than distant stars. The apparent motion of a foreground star relative to background stars is called proper motion, and is usually measured in milli-arcseconds per year. Unlike parallax, however, high proper motion indicates a near distance, but it does not prove it.

We can use proper motion to identify the candidate nearest stars. If the star has a high proper motion and is also faint, it is likely a brown dwarf, and its faintness is due to a low luminosity.

Barnard's Star has the largest proper motion known. It is a small red dwarf star at a distance of just 1.83 pc. The star is named after E. E. Barnard, an American astronomer who in 1916 measured its proper motion as 10.3 arcseconds per year.

A third brown dwarf detection method is looking for lithium emission. In the Big Bang, a little lithium was produced. Stars are formed from this material, and therefore have a little bit of lithium. Lithium is easily destroyed in the core of stars, however, by combining with a proton to produce two alpha particles. Low-mass stars are fully convective, so Li anywhere in the star is transported to the core, where it is destroyed. Stars therefore are deficient in lithium, and the amount of lithium they are formed with decreases over time.

If Li is detected, therefore, the star must either be young (and therefore it hasn't had time to destroy it), relatively massive (not fully convective), or a brown dwarf.

Brown Dwarf Properties

Sizes

Like white dwarfs, brown dwarfs are also supported by electron degeneracy pressure (this is also what supports the gas giant planets). Without a large source of fusion, something must support them! Just like white dwarfs, as you add mass to a brown dwarf, its radius decreases. The decrease isn't large, however, and to first order all brown dwarfs are the same physical size, that of Jupiter.

Temperatures

Brown dwarfs cool over time. The youngest BDs have surface temperatures basically the same as those of very low mass stars, maybe 2300 K.

Classes

Astronomers love to classify things! Brown dwarfs are no exception.

Spectral class M
Some classify the smallest of the nominal spectral types, class M, as brown dwarfs if they have a spectral class of M5.5 or later; they are also called late-M dwarfs.

Spectral class L
The defining characteristic of spectral class M is an optical spectrum dominated by absorption bands of titanium(II) oxide (TiO) and vanadium(II) oxide (VO) molecules. However, L dwarfs, are defined in the red optical region of the spectrum not by metal-oxide absorption bands (TiO, VO), but by metal hydride emission bands (FeH, CrH, MgH, CaH) and prominent atomic lines of alkali metals (Na, K, Rb, Cs).

Spectral class T
Whereas near-infrared (NIR) spectra of L dwarfs show strong absorption bands of H2O and carbon monoxide (CO), the NIR spectrum of class T dwarfs is dominated by absorption bands from methane (CH4), features that were found only in the giant planets of the Solar System and Titan. Theory suggests that L dwarfs are a mixture of very-low-mass stars and sub-stellar objects (brown dwarfs), whereas the T dwarf class is composed entirely of brown dwarfs.

Spectral class Y
In 2009, the coolest-known brown dwarfs had estimated effective temperatures between 500 and 600 K, and have been assigned the spectral class T9. The spectra of these objects have

absorption peaks around 1.55 micrometres. Delorme et al. have suggested that this feature is due to absorption from ammonia and that this should be taken as indicating the TY transition, making these objects of type Y0. However, the feature is difficult to distinguish from absorption by water and methane, and other authors have stated that the assignment of class Y0 is premature.

Fusion

Although brown dwarfs cannot fuse hydrogen into helium, they can fuse deuterium. Deuterium fusion combines a proton with deuterium to make ^3He. This is a step on the proton-proton chain. A star must have 13 times the mass of Jupiter for deuterium fusion, which sets the lower mass limit for brown dwarfs.