THE SEARCH FOR BROWN DWARFS WITH INFRARED SURVEYS

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Abstract. I compute the maximum number of observable brown dwarfs for various infrared surveys by combining the maximum possible Oort limit (0.1 "missing" M⊙pc⁻³) with all possible brown dwarf mass and age distributions. This approach shows what limits will be placed on the contribution of brown dwarfs to any possible "missing mass" if no brown dwarfs are observed. I consider brown dwarfs with masses of 0.01—0.08 M⊙ and ages of 10⁹—10¹⁰ years.

The full range of predicted numbers of brown dwarfs above ~ 6 times the noise of each of the below surveys is:

- IRAS Point Source Catalog |b| > 10°: 0.02—6
- IRAS Faint Source Catalog |b| > 10°: 0.05—16
- ISO (2 week 12 μm survey): 0.15—80
- SIRTF (2 week 12 μm survey): 2.50—1600
- WIRE (4 month 12 μm survey): 21.80—6000
- DENIS (half sky) |b| > 10°: 0.00—2000
- 2MASS (full sky) |b| > 10°: 0.00—8800

A failure to find brown dwarfs in the IRAS FSC would just barely rule out about half of the mass—age range for Oort limit total masses. A failure to find brown dwarfs in 2MASS/DENIS would rule out roughly the same mass—age range, but would set a limit of 0.1—0.01 times the Oort mass in that mass—age region. No limits would be set for the other half of the mass—age range since both IRAS and 2MASS/DENIS have insufficient sensitivity for brown dwarfs with T < 750 K.

A failure to find brown dwarfs with ISO would rule out almost all of the mass—age range for Oort limit total masses, but would not set a significantly lower limit to the brown dwarf mass limit. A failure to find brown dwarfs with SIRTF or WIRE would rule out the entire mass—age range for Oort limit total masses and set an upper limit of 0.1—0.001 times the Oort mass.

To date, about 18% of the IRAS FSC has been searched down to 6σ, and no brown dwarfs have been found. This sets a 95% upper limit of 3 in 18% of the sky, or 13 in the entire FSC for |b| > 10°. To begin to set useful limits from 2MASS or DENIS, approximately 400 square degrees need to be analyzed. To date, only a few square degrees of results from the 2MASS prototype camera have been examined, with no brown dwarfs found so far.

Key words: Brown Dwarfs—Missing Mass—2MASS—Near-infrared—DENIS

1. Introduction

For the last decade, brown dwarfs have always been just beyond the astronomer’s grasp. The simple cause of this is that brown dwarfs are hard to detect and our current technologies just border on having the sensitivity to detect...
them (see Stevenson 1991 for an up-to-date review).

Predictions of the number of brown dwarfs that can be observed at a given wavelength are complicated because all important brown dwarf parameters are unknown—their temperature, total luminosity, spectral distribution, mass function and age distribution. Even if one believes theoretical estimates of the first three of these parameters, the unknown mass and age functions result in widely varying predictions of the number of brown dwarfs. Because of this, previous predictions have been useful for getting gross estimates of the number of brown dwarfs that could possibly be seen, but are not very useful for setting limits to the space density of brown dwarfs if none are observed by a particular survey.

A more useful approach is to begin with a delta function age and mass distribution, and then consider all conceivable ages and masses. This is the clearest way of presenting the true range of the number of observable brown dwarfs for a given survey. Since any arbitrary age and mass distribution can be constructed from the combination of such delta functions, the predictions for arbitrary distributions can be obtained by using the results presented for delta functions. The advantage here is that such averaging can be done in the domain of the observable number of brown dwarfs, rather than by going back to the assumed age and mass functions.

2. Assumptions

I use the analytic radii and temperatures of Stevenson (1986) to describe the properties and evolution of brown dwarfs. Figure 1 shows the temperature of brown dwarfs as a function of mass and age from Stevenson’s formulae.

I consider the age range of $10^9$ to $10^{10}$ years for several reasons. Brown dwarfs much younger than $10^9$ years are probably absent in the solar neighborhood since they would be found only in star-forming regions. Second, young brown dwarfs are difficult to distinguish unambiguously from main-sequence stars since their temperatures are very similar. Theoretical models for these objects are also likely to be more suspect, since the collapse phase involves many more parameters than the cooling phase.

I consider the mass range from 0.01 to 0.08 $M_\odot$. The maximum mass of a brown dwarf is considered to be 0.08 $M_\odot$. Masses below 0.01 $M_\odot$ emit very feebly, and no instrument is likely to observe isolated such objects in the foreseeable future. If one assumes that star formation processes are independent of the minimum mass needed for a star to initiate fusion, then objects in this mass range should exist.

I take 0.1 $M_\odot$pc$^{-3}$ as the maximum possible amount of missing mass in the solar neighborhood. All of the predicted numbers scale directly with this number, so one can directly obtain the predictions for a different assumption.

Because all of the instruments observing at 12 $\mu$m observe over a wide