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# Near-future habitable exoplanets eclipse spectroscopy, and expected final number of cases challenge. The 'brown dwarf reserve'

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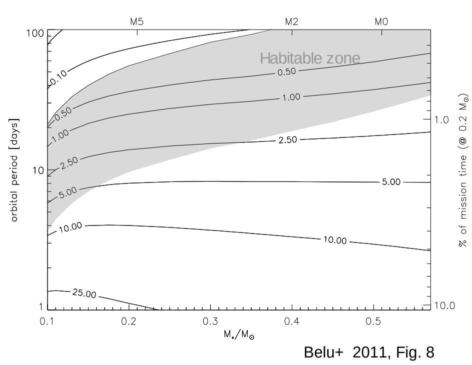
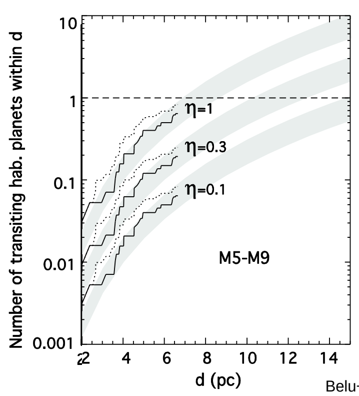
We present work conducted between 2009 and 2012 on the subject of nearby eclipsing habitable exoplanets eclipse spectroscopy, the possibly below unity final expected number of such cases, and, in order to solve this challenge, the extension of this science case to a class of primaries little considered until now: brown dwarfs (BDs). Based essentially on Belu+ A&A 2011 and Belu+ ApJ 2013, May,768:125.




Belu+ 2011, Fig. 8

**Figure 1**: S/N on the *detection* of the 9.6 µm $O_3$ band in a 1.8 Earth-radii super-Earth at 6.7 pc, summing the observations of all of the secondary transits available on average over the 5 year mission time of a 6.5 m space telescope. The S/N scales linearly with the square root of the number of summed eclipses (if no correlated noise), with the square of the planet's radius, with the brightness temperature depth, with the inverse of the distance in pc, and with the inverse of the resolution. (Abridged.)

See also for comparison extensive Deming+ 2009, and recent similar calculations by Tessenyi+ 2012 (for the latter, additional telescope sizes considered. As function of magnitudes).




Belu+ 2011, Fig. 19

**Figure 2**: Number of transiting systems receiving Earth's insolation, as a function of distance and mean number of habitable planets per star ($\eta_\oplus$), for the indicated range of dwarfs (derived from Figure 1). The dotted curves are based on the RECONS list. The solid curves results from rejecting stars with close companion source, stars already surveyed for transits and/or with eccentric planet in the habitable zone). The gray profiles are a $d^3$ fit (±σ) to the latter list. (Abridged.)

As in previous figure, see also for comparison recent similar calculations by Tessenyi+ (2012), but based on magnitudes.

Table 1

Total expected number of eclipsing habitable planets around the closest L, T and Y dwarfs (Belu+ ApJ 2013 May,768:125, Table 2)

| | | Dist.(pc) | $T$ (K) | $M/M_\odot$ | $R/R_\odot$ | $L/L_\odot$ (log) | Ref. | $HZ_{Roche}$ | $HZ_{asymp.}$ 1 Myr | $HZ_{asymp.}$ 10 Myr | *trans. prob.* 1 Myr | *trans. prob.* 10 Myr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WISE 1541-2250 | | 2.8[a] | *350* | *0.011* | *0.01* | -6.88 | | 0 | | | | |
| GJ 845 B | a | 3.6 | *1320* | *0.065* | *0.0805* | *-4.699* | | 1 | | 0.64 | | 0.030 |
| | b | | *910* | *0.050* | *0.0825* | *-5.232* | | 0.95 | | | | |
| SCR 1845-6357 B | | 3.85 | *950* | *0.039* | 0.091 | -5.1 | | 1 | | 0.27 | | 0.019 |
| UGPS 0722-05 | | *4.1* | *505* | *0.005* | 0.10 | *-6.13* | | 0.79 | | | | |
| DEN 0817-6155 | | *4.9* | *950* | 0.04 | 0.089 | -3.53 | | 0.98 | | | | |
| DEN 0255-4700 | | 5.0 | *1300* | 0.035 | *0.09* | -4.62 | | 1 | 0.55 | 0.74 | 0.023 | 0.033 |
| 2MASS 0939-2448 | A | 5.3 | *700* | *0.038* | *0.085* | -5.8 | | 0.52 | | | | |
| | B | | *500* | *0.024* | *0.09* | -6.3 | | 0 | | | | |
| WISE 1741+2553 | | 5.5[a] | | | | | | 0.79 | | | | |
| 2MASS 0415-0935 | | 5.7 | *947* | *0.01* | 0.12 | -5.0 | | 1 | 0.24 | 0.14 | 0.021 | 0.011 |
| GJ 229 B | | 5.8 | *950* | 0.038 | 0.094 | -5.2 | | 1 | | 0.08 | | 0.006 |
| GJ 570 D | | 5.9 | *948* | 0.019 | 0.11 | -5.0 | | 1 | 0.55 | 0.14 | 0.051 | 0.010 |
| SIMP J013656.5+093347.3 | | 6[b] | *1200* | 0.044 | 0.097 | -5.25 | | 0.96 | | | | |
| 2MASS 0937+2931 | | 6.1 | *950* | *0.054* | 0.08 | -5.33 | | 0.87 | | | | |
| WISE 0254+0223 | | 6.1[a] | 660 | 0.01 | 0.11 | -5.7 | | 0.95 | | | | |
| WISE 1738+2732 | | 7[c] | 350 | *0.019* | *0.093* | -6.94 | | 0 | | | | |
| | | (as of 2012 Jan) | | | | | | | | | 0.09 | 0.11 |
| | | | | | | | | **Expected #** | | | | |
| | | | | $\times 0.41\,^{+0.54}/_{-0.13}$ = | | | | **0.78** $^{+1}/_{-0.25}$ | | | **0.036** $^{+0.048}/_{-0.012}$ | **0.078** $^{+0.06}/_{-0.014}$ |
| | | | | | | | | **% probability of at least 1 occurrence** | | | | |
| | | | | | | | | **56** $^{+31}/_{-13}$ | | | **3.9** $^{+4.9}/_{-1.2}$ | **4.5** $^{+5.6}/_{-1.4}$ |

Notes:
$\boldsymbol{HZ}_{\mathbf{Roche}}$ is the habitable zone reduced by the Roche limit (Blake+2008 when applicable), and $\boldsymbol{HZ}_{\mathbf{asymp}}$ is the fraction from $HZ_{Roche}$ after asymptotic tidal migration of planets (Bolmont+ 2011). $\eta_\oplus = 0.41\,^{+0.54}/_{-0.13}$ is a recent observation based estimate (Bonfils+ 2013). Non-italic parameters (among photospheric temperature ***T***, mass ***M***, radius ***R*** and luminosity ***L***) are interpolated from model grids using the parameters (italics) from the reference. Note that the purpose of this table is to compute some ensemble averages; therefore the values of the BD parameters should not be reused for the study of individual objects, since the uncertainties on most parameters are quite large (e.g., spectroscopic/photometric distance estimates), and because of ongoing refined observations (e.g. parallaxes). (Abridged.). For recent such screening monitoring of the new 3rd closest system discovered in February 2013 (Luhman-16 AB), see Gillon+ 2013.

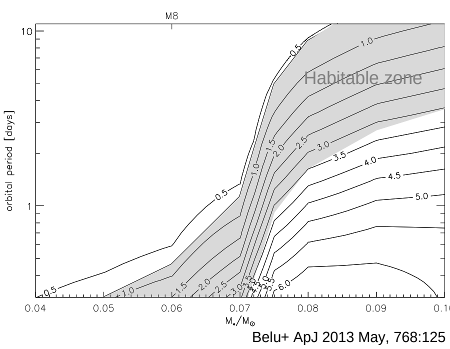



**Figure 3**: Same as Figure 1 but for a brown dwarf (BD) primary. Fiducial '$O_3$ substitute' spectral feature in the planet atmosphere at 10 µm considered, brightness temperature depth of 30 K and 0.1µm wide (i.e. $R$ = 100). The observations of 90 eclipses are summed for this result. The age of the BD is 10 Gyr (at younger ages the S/N naturally increases and lower mass BDs planets become charaterizable – see complete figure in reference).

## References

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