Sonora - Bobcat
Tables of brown dwarf and exoplanet evolution

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This directory contains tables of the evolution and photometry of brown dwarfs and self luminous extrasolar planets based on the model described in Marley et al. (2020, in prep.). This publication provides a detailed description of the physics included in the model. We intend that this and future models from our group will go under the general name “Sonora”, after the desert in southeastern Arizona and adjoining Mexico, while this particular generation of models is the “Bobcat” series.

The main differences with the previously published tables by Saumon & Marley (2008) are

- updated atmosphere models used as the surface boundary conditions, primarily involving improvements in the opacities of H_2, CH_4 and alkali resonance lines. The new atmosphere models are described in Marley et al. (2020, in prep.).

- including metals in the interior equation of state as an additional amount of helium. Currently, the evolution tracks are for solar metallicity and two other abundance cases ([M/H] = -0.5, 0.0, +0.5) and, in all three cases, solar C/O ratio. (defined relative to solar, so C/O=1 here) with cloudless atmospheres. Model spectra will be archived separately. This repository holds tables of the evolution and photometry of the model set as described below.

CONTENTS OF THE EVOLUTION TABLES

In each evolution subdirectory three tables give the evolution tabulated holding the mass, the age or the bolometric luminosity fixed, with file names ending with '_mass' (e.g. 'nc+0.0_co1.0_mass'), '_age', or '_lbol', respectively. A fourth table (nc+0.0_co1.0_mass_age) gives the mass and age as a function of T_{eff} and gravity.

All files are in ascii and contain the basic evolution parameters. As an example, the beginning of the file 'nc+0.0_co1.0_mass' is

```
 M/Msun   age(Gyr)  log L/Lsun  Teff(K)  log g  R/Rsun   log I
  24
 0.0005    0.0010     -5.361       631.   2.654  0.1743  49.4144
 0.0005    0.0020     -5.702       538.   2.716  0.1622  49.3782
 0.0005    0.0030     -5.912       485.   2.748  0.1565  49.3604
 0.0005    0.0040     -6.053       453.   2.768  0.1528  49.3488
 0.0005    0.0060     -6.216       419.   2.796  0.1481  49.3343
 0.0005    0.0080     -6.330       397.   2.815  0.1448  49.3243
 0.0005    0.0100     -6.413       381.   2.830  0.1423  49.3164
 0.0005    0.0150     -6.562       356.   2.858  0.1378  49.3014
 0.0005    0.0200     -6.679       337.   2.880  0.1344  49.2894
```

Column 1: mass is solar mass (adopted M_{sun} =1.989E+33 g)
Column 2: age in Gyr
Column 3: log (L_{bol}/L_{sun}) (log L_{sun}=33.5827 in erg/s/cm^2)
Column 4: T_{eff} in K
Column 5: log of gravity in cm/s^2
Column 6: radius in solar units (R_{sun}=6.9599E+10 cm)
Column 7: moment of inertia (log I in g cm^2)

Each block of lines is for one value of the mass/age/L_{bol} and is preceded by an entry giving the number of lines in the block (24 in the above example). The tables are limited to the following ranges:

$0.0005 < M/M_{sun} < 0.080$ $100 < T_{eff}$ (K) < 2400
1 Myr < age < 15 Gyr

Fine grids in mass, age and L_{bol} are used and, when necessary, an entry is provided outside these ranges to aid with interpolation and avoid extrapolation.

Note that the early evolution (age < 10 Myr or so) is sensitive to the initial condition of the model (see Baraffe et al. 2002, A&A 382, 563; Marley et al. 2007, ApJ 655, 561) and should be used with caution. These sequences correspond to a "hot start" initial condition.

TABLES OF FLUXES AND MAGNITUDES

The directory also contains tables of fluxes and of absolute magnitudes in a number of photometric systems commonly used in brown dwarf and exoplanet research (MKO, Keck, 2MASS, SDSS, WISE, Spitzer IRAC, etc). Fluxes and magnitudes for the full set of JWST filters is also included in separate tables. Magnitudes are computed on the Vega system (using the Vega spectrum of Bohlin & Gilliland 2004) or on the AB system (e.g. for SDSS). As an example, the beginning of the magnitude table nc_m+0.0_co1_mags is

```
Fluxes computed from the atmosphere models of Marley                /feb18_cloudless+0.5

MKO/UFTI Filter bandpasses are defined in ftp://ftp.jach.hawaii.edu/pub/ukirt/skl/filters
*** These are log(fluxes) (in mJy) computed for d=  10.00pc   ***

                                                |                    MKO
 Teff   log g   mass  R/Rsun   Y   log Kzz      Y         Z        J        H        K

 200.  3.000    0.52  0.1169  0.28 -99.00    -9.0089  -8.8190  -8.2531  -8.4935  -8.6650  -
 225.  3.000    0.55  0.1197  0.28 -99.00    -7.5622  -7.5969  -7.0288  -7.4282  -7.1015  -
 250.  3.000    0.57  0.1226  0.28 -99.00    -6.2790  -6.7217  -5.9553  -6.5584  -5.9426  -
 275.  3.000    0.60  0.1255  0.28 -99.00    -5.1265  -5.9089  -4.9558  -5.7989  -5.0739  -
 300.  3.000    0.63  0.1282  0.28 -99.00    -4.2515  -5.1839  -4.1040  -5.1139  -4.4067  -
 325.  3.000    0.65  0.1308  0.28 -99.00    -3.5965  -4.5340  -3.4168  -4.4745  -3.8608  -
 350.  3.000    0.68  0.1334  0.28 -99.00    -3.0931  -3.9901  -2.8737  -3.8954  -3.3957  -
 375.  3.000    0.70  0.1353  0.28 -99.00    -2.6832  -3.5352  -2.4366  -3.3980  -2.9941  -
```

Where columns to the right that correspond to other filters have been deleted here for clarity. Bandpasses are grouped by photometric systems indicated by the first line of the table header, delimited by vertical bars (|).

Column 1: T_{eff} in Kelvin
Column 2: log g (cm/s^2). In the spectrum files, g is in m/s^2
Column 3: Mass of the corresponding model, in $M_{Jupiter}$
Column 4: Radius of the corresponding model in R_{sun}
Column 5: Helium mass fraction Y

Column 6: log K_{zz}, the coefficient of eddy diffusion used to parametrize ver:cal transport. Models in chemical equilibrium are given a large negative value (-99), i.e. K_{zz}=0 cm^2/s
Column 7: MKO Y absolute magnitude
Column 8: MKO Z absolute magnitude
...
Column 14: 2MASS J absolute magnitude and so forth.
The masses and radii are obtained from the evolution sequences described in Marley et al. (2020; in prep.) and use the appropriate model atmospheres as surface boundary conditions for self-consistency.

The flux tables (e.g. nc_m+0.0_co1.0_flux) follow the same format, giving log (F) integrated over the bandpass with F in mJy at Earth for D=10pc.

CREDITS

If you use these tables in your research, please cite Marley et al. (2020, in preparation)

REFERENCES

Baraffe, I., Chabrier, G., Allard, F., Hauschildt, P.H., 2002, A&A 382, 563

Marley, M.S., Fortney, J.J., Hubickyj, O., Bodenheimer, P., & Lissauer, J.J. 2007, ApJ 655, 541 Saumon, D. & Marley, M.S. 2008, Astrophys. J. 689, 1327

INQUIRIES

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