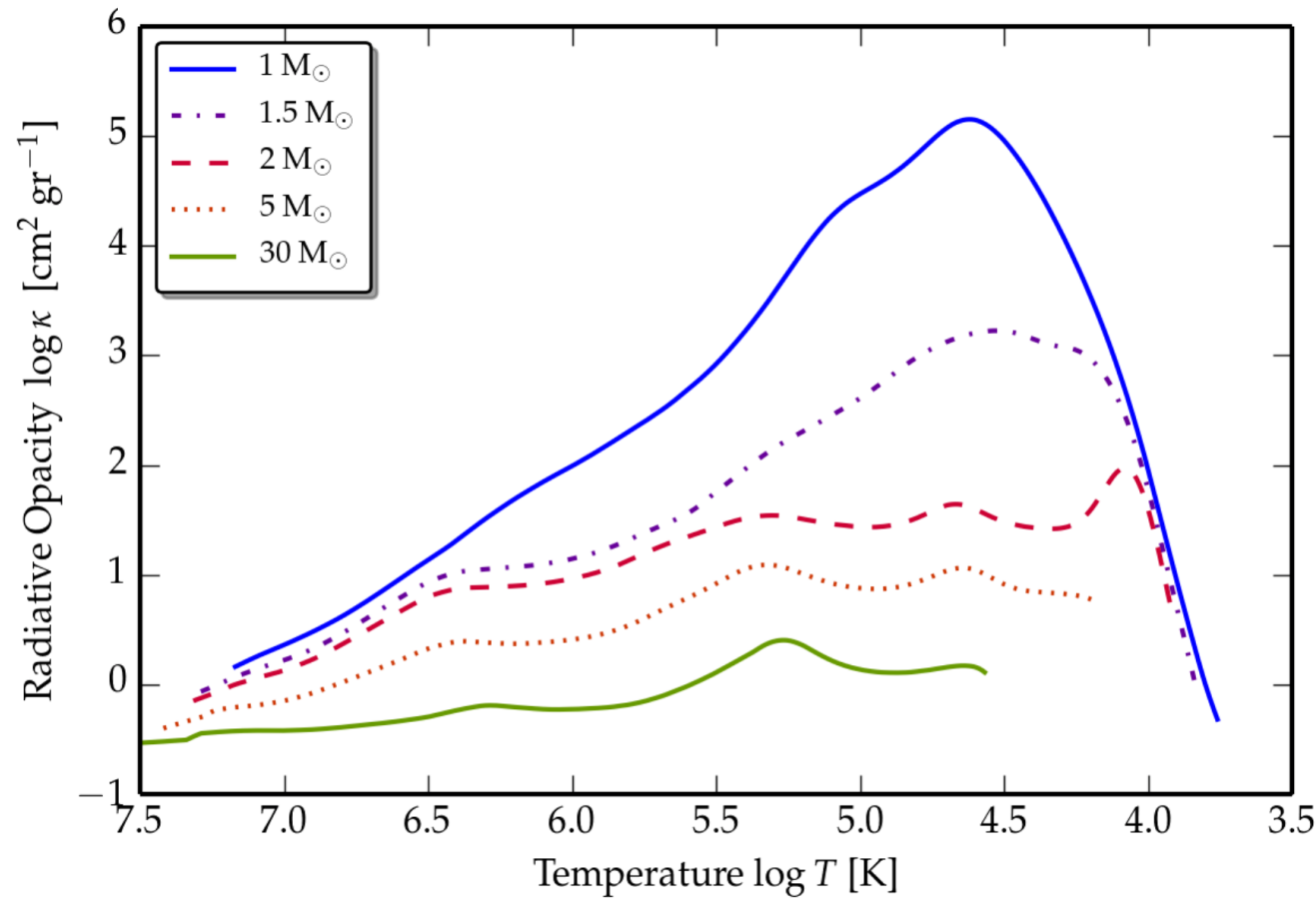


core

surface



$$\kappa_{\text{bf}} = \kappa_{\text{bf}}^{(0)} \rho T^{-3.5}$$

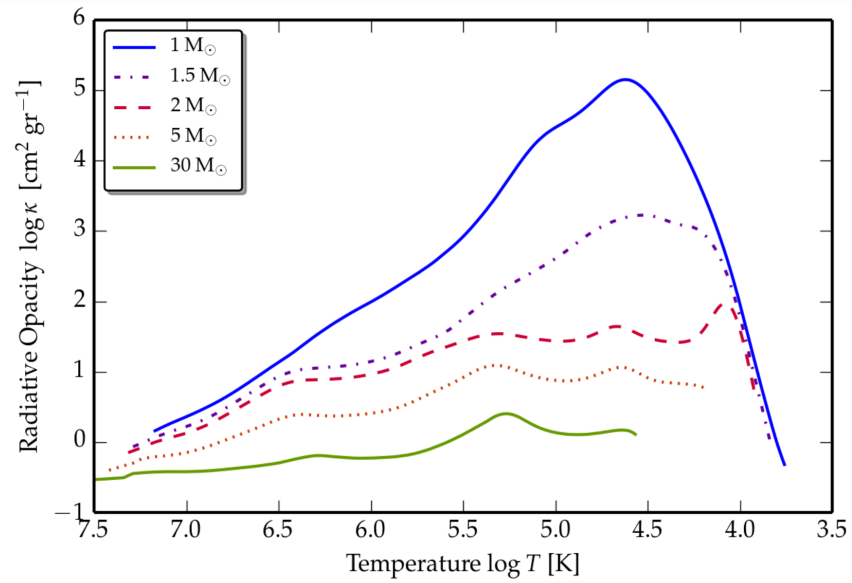
$$\kappa_{\text{ff}} = \kappa_{\text{ff}}^{(0)} \rho T^{-3.5}$$

$$\kappa_{\text{es}} = 0.200 (1 + X)$$

By increasing the initial mass of stars, the mean density of the stars decreases, and bound-free and free-free opacities that depend explicitly on density start losing their importance.

core

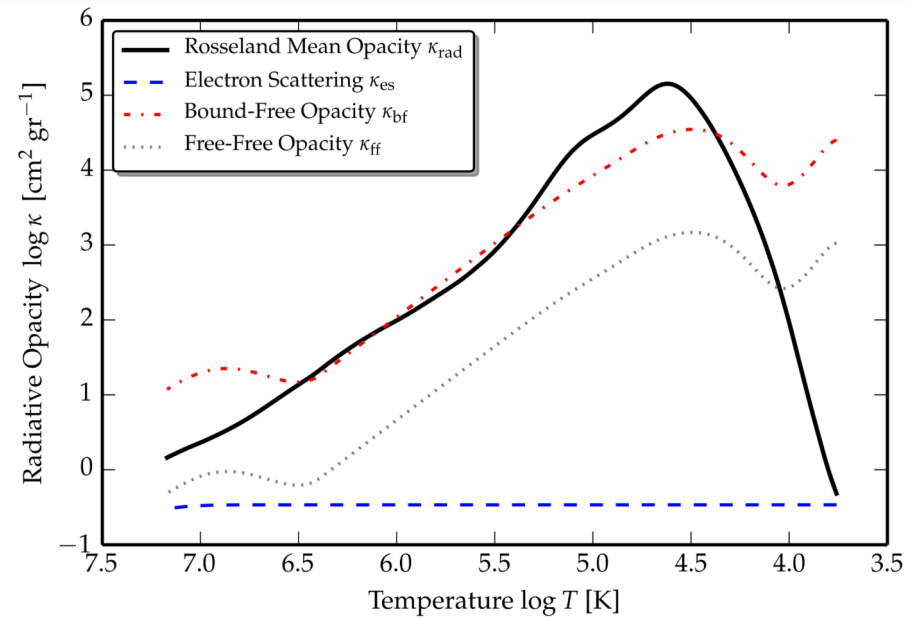
surface



$$\kappa_{\text{bf}} = \kappa_{\text{bf}}^{(0)} \rho T^{-3.5}$$

$$\kappa_{\text{ff}} = \kappa_{\text{ff}}^{(0)} \rho T^{-3.5}$$

$$\kappa_{\text{es}} = 0.200 (1 + X)$$

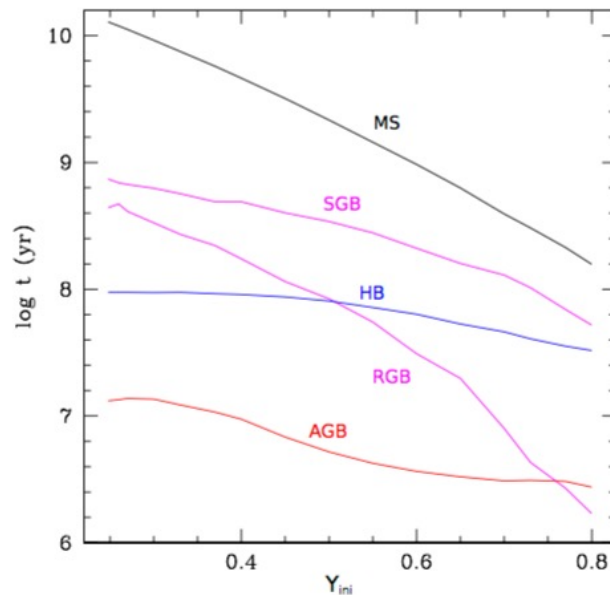


$$L = 4ac \left(\frac{Gm_H}{k} \right)^4 \frac{\mu^4 M^3}{\kappa}$$

Exemple: Etoiles riches en hélium

Modèle à $0.8 M_{\odot}$

Durée du temps de chaque phase en fonction de l'abondance initiale en He



Theoretical isochrones at 13 Gyr for different initial helium mass fractions Y_{ini} from 0.248 up to 0.7 (labels) and abundances of other elements varying accordingly. The color code represents the current stellar mass (in M_{\odot}) at 13 Gyr.

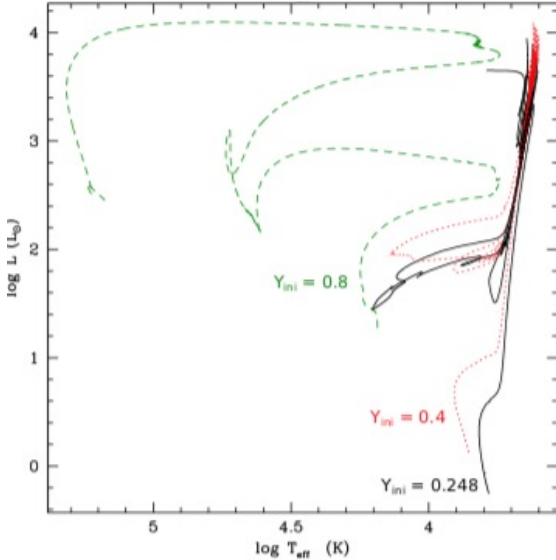
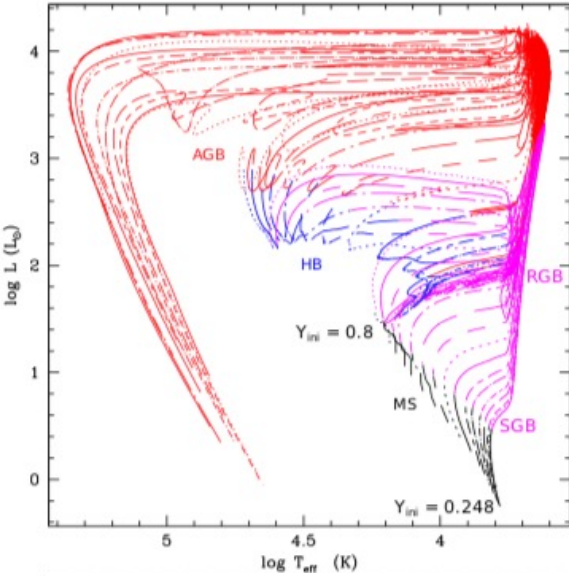
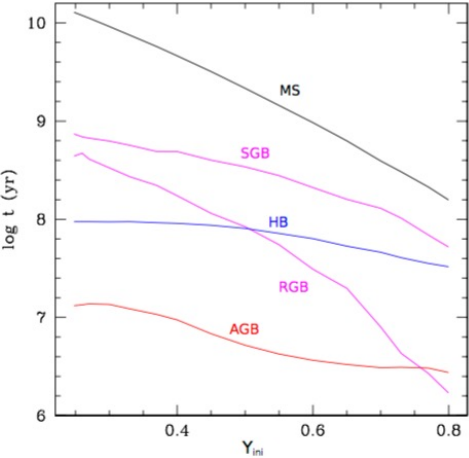
When the initial helium content is higher, the opacity due to Thomson scattering is reduced in the stellar interior, and the nuclear burning luminosity increases during the main sequence because of the greater mean molecular weight. Consequently, the evolution tracks are shifted towards higher luminosities and effective temperatures, and the main sequence lifetime is significantly shortened as shown

$$L = 4ac \left(\frac{Gm_H}{k} \right)^4 \frac{\mu^4 M^3}{\kappa}$$

Exemple: Etoiles riches en hélium

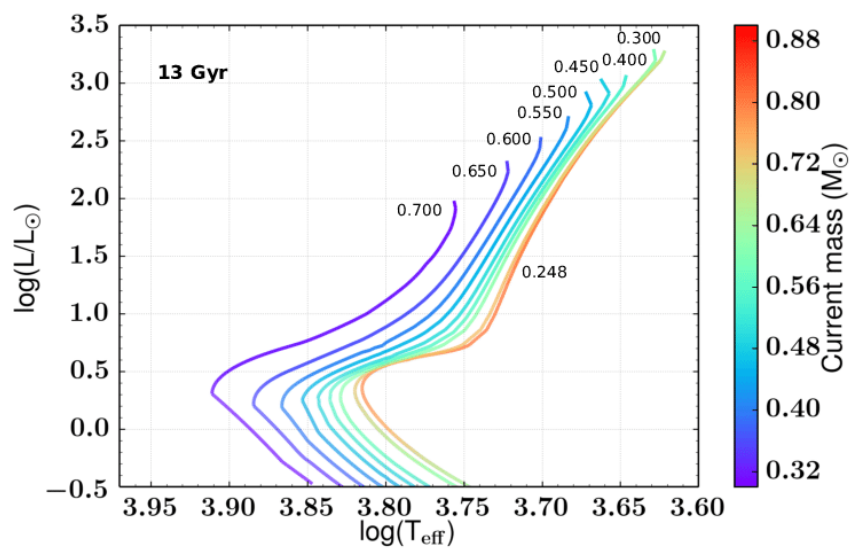
When the initial helium content is higher, the opacity due to Thomson scattering is reduced in the stellar interior, and the nuclear burning luminosity increases during the main sequence because of the greater mean molecular weight. Consequently, the evolution tracks are shifted towards higher luminosities and effective temperatures, and the main sequence lifetime is significantly shortened

Modèle à 0.8 M_⊙
 Durée du temps de chaque phase en fonction de l'abondance initiale en He



Exemple: Etoiles riches en hélium

Evolution from the zero-age main sequence to the RGB tip



Theoretical isochrones at 13 Gyr for different initial helium mass fractions Y_{ini} from 0.248 up to 0.7 (labels) and abundances of other elements varying accordingly. The color code represents the current stellar mass (in M_{\odot}) at 13 Gyr.

Model of the Sun (Kurucz 1979)

To compress the tables as much as possible, all quantities except temperature are given in log cgs units. The columns are mass cm^{-2} , Rosseland optical depth, continuum optical depth at 500 nm, geometric depth down from the first point, temperature, gas pressure, electron number density, atomic number density, mass density, Rosseland mass absorption coefficient, continuum mass absorption coefficient at 500 nm, radiation pressure, radiative acceleration (compare to $\log g$), and the fraction of the total flux carried by convection. A value of 0 in the table means an actual 0, not 10^0 . A label in the heading for each model tells whether the model was treated as purely radiative or radiative plus convective. The 40 depths listed in the table are the actual depths that were used in the calculation.

	MASS	TAU ROSS	TAU 500	TEFF	5770.	LOG G	4.44	LOG ABUND	.00	CONVECTIVE		P	ACC	CONV
				X	T	P	NE	NA	RHO	KAPPA ROSS	KAPPA 500	RAD	RAD	FRAC
1	-1.49997	0.0000	0.0000	0.0000	3054.4	2.9400	10.0976	15.3150	-8.3418	-2.2859	-2.2276	.1716	-.7501	-16.2348
2	-1.36788	-3.6538	-3.5954	6.4024	4329.1	3.0722	11.2206	15.2958	-8.3611	-2.2859	-2.2276	.1719	-1.2426	-22.7006
3	-1.28746	-3.5671	-3.5094	6.6398	4349.8	3.1526	11.2953	15.3740	-8.2828	-2.2167	-2.1650	.1721	-1.2367	0.0000
4	-1.23190	-3.5001	-3.4435	6.7508	4357.6	3.2082	11.3452	15.4288	-8.2280	-2.1698	-2.1210	.1722	-1.2077	0.0000
5	-1.18463	-3.4387	-3.3837	6.8272	4393.3	3.2553	11.3941	15.4724	-8.1845	-2.1268	-2.0864	.1723	-1.2132	0.0000
6	-1.12900	-3.3619	-3.3093	6.9030	4395.2	3.3109	11.4426	15.5278	-8.1290	-2.0802	-2.0413	.1725	-1.1935	0.0000
7	-1.06680	-3.2707	-3.2214	6.9748	4427.8	3.3733	11.5039	15.5870	-8.0699	-2.0252	-1.9934	.1727	-1.1746	0.0000
8	-.99779	-3.1638	-3.1188	7.0430	4447.8	3.4422	11.5680	15.6539	-8.0029	-1.9658	-1.9386	.1730	-1.1572	0.0000
9	-.92358	-3.0435	-3.0035	7.1064	4476.2	3.5164	11.6383	15.7254	-7.9315	-1.9014	-1.8801	.1734	-1.1350	0.0000
10	-.84501	-2.9113	-2.8768	7.1651	4504.3	3.5949	11.7122	15.8012	-7.8556	-1.8336	-1.8176	.1739	-1.1099	0.0000
11	-.76302	-2.7693	-2.7407	7.2192	4535.2	3.6770	11.7896	15.8803	-7.7766	-1.7625	-1.7523	.1746	-1.0816	0.0000
12	-.67862	-2.6199	-2.5974	7.2690	4566.9	3.7614	11.8691	15.9617	-7.6952	-1.6897	-1.6848	.1755	-1.0499	0.0000
13	-.59256	-2.4653	-2.4487	7.3148	4599.9	3.8474	11.9501	16.0446	-7.6123	-1.6158	-1.6157	.1768	-1.0146	0.0000
14	-.50563	-2.3074	-2.2966	7.3569	4634.3	3.9343	12.0322	16.1283	-7.5286	-1.5406	-1.5458	.1784	-.9731	0.0000
15	-.41827	-2.1473	-2.1424	7.3958	4670.7	4.0216	12.1149	16.2121	-7.4447	-1.4642	-1.4755	.1807	-.9245	0.0000
16	-.33063	-1.9855	-1.9866	7.4319	4709.4	4.1092	12.1984	16.2962	-7.3607	-1.3874	-1.4049	.1838	-.8735	0.0000
17	-.24272	-1.8224	-1.8295	7.4656	4751.2	4.1973	12.2826	16.3804	-7.2765	-1.3103	-1.3341	.1880	-.8199	0.0000
18	-.15450	-1.6581	-1.6714	7.4972	4797.4	4.2856	12.3681	16.4645	-7.1924	-1.2326	-1.2630	.1938	-.7637	0.0000
19	-.06584	-1.4924	-1.5122	7.5271	4850.1	4.3742	12.4556	16.5484	-7.1085	-1.1542	-1.1915	.2019	-.7058	0.0000
20	.02281	-1.3262	-1.3527	7.5554	4911.0	4.4628	12.5449	16.6316	-7.0253	-1.0755	-1.1200	.2130	-.6461	0.0000
21	.11131	-1.1598	-1.1931	7.5823	4982.8	4.5513	12.6371	16.7138	-6.9431	-.9961	-1.0482	.2281	-.5847	0.0000
22	.19922	-.9940	-1.0344	7.6078	5069.0	4.6392	12.7325	16.7942	-6.8627	-.9169	-.9765	.2485	-.5217	0.0000
23	.28649	-.8286	-.8763	7.6322	5174.0	4.7265	12.8330	16.8726	-6.7843	-.8362	-.9037	.2757	-.4564	0.0000
24	.37336	-.6626	-.7176	7.6557	5304.1	4.8134	12.9434	16.9487	-6.7082	-.7515	-.8258	.3116	-.3863	0.0000
25	.45895	-.4955	-.5576	7.6782	5467.3	4.8989	13.0715	17.0211	-6.6358	-.6656	-.7359	.3584	-.3029	0.0000
26	.53989	-.3283	-.3973	7.6992	5675.4	4.9799	13.2322	17.0898	-6.5711	-.5821	-.6200	.4177	-.1885	0.0000
27	.61227	-.1594	-.2361	7.7179	5934.0	5.0523	13.4408	17.1388	-6.5181	-.4966	-.4622	.4926	-.0185	0.0000
28	.66993	.0105	-.0749	7.7329	6300.7	5.1099	13.7384	17.1703	-6.4666	-.4224	-.2305	.5842	.2127	-2.2884
29	.71069	.1769	.0840	7.7440	6722.8	5.1508	14.0697	17.1828	-6.4241	-.3443	.0328	.6836	.4255	-.9992
30	.74213	.3447	.2442	7.7528	7085.6	5.1821	14.3377	17.1911	-6.4658	-.2727	.2496	.7796	.5485	-.5526
31	.76878	.5130	.4026	7.7605	7403.8	5.2087	14.5567	17.1982	-6.4587	-.2095	.4297	.8660	.5992	-.3146
32	.79286	.6798	.5580	7.7676	7891.3	5.2327	14.7419	17.2052	-6.4517	-.1585	.5853	.9388	.6017	-.1906
33	.81608	.8463	.7130	7.7747	7955.8	5.2560	14.9027	17.2131	-6.4437	-.1170	.8870	.7235	1.0012	.5885
34	.83937	1.0125	.8688	7.7818	8209.4	5.2794	15.0488	17.2222	-6.4347	-.0820	.8523	1.0569	.5708	-.0790
35	.86323	1.1786	1.0254	7.7893	8450.9	5.3032	15.1816	17.2324	-6.4245	-.0511	.9724	1.1078	.5507	-.0598
36	.88811	1.3459	1.1830	7.7972	8686.0	5.3282	15.3051	17.2443	-6.4125	-.0265	1.0873	1.1560	.5354	-.0343
37	.91397	1.5123	1.3398	7.8055	8916.3	5.3539	15.4213	17.2574	-6.3995	-.0137	1.1982	1.2015	.5104	-.0348
38	.94139	1.6788	1.4975	7.8143	9136.9	5.3815	15.5288	17.2729	-6.3840	-.0068	1.3032	1.2451	.4854	-.0118
39	.97057	1.8458	1.6569	7.8239	9369.1	5.4106	15.6371	17.2893	-6.3676	-.0012	1.4118	1.2874	.4573	-.0231
40	1.00167	2.0113	1.8166	7.8340	9578.8	5.4417	15.7333	17.3089	-6.3479	-.0000	1.5097	1.3300	.4612	-.0016

échelle
log!

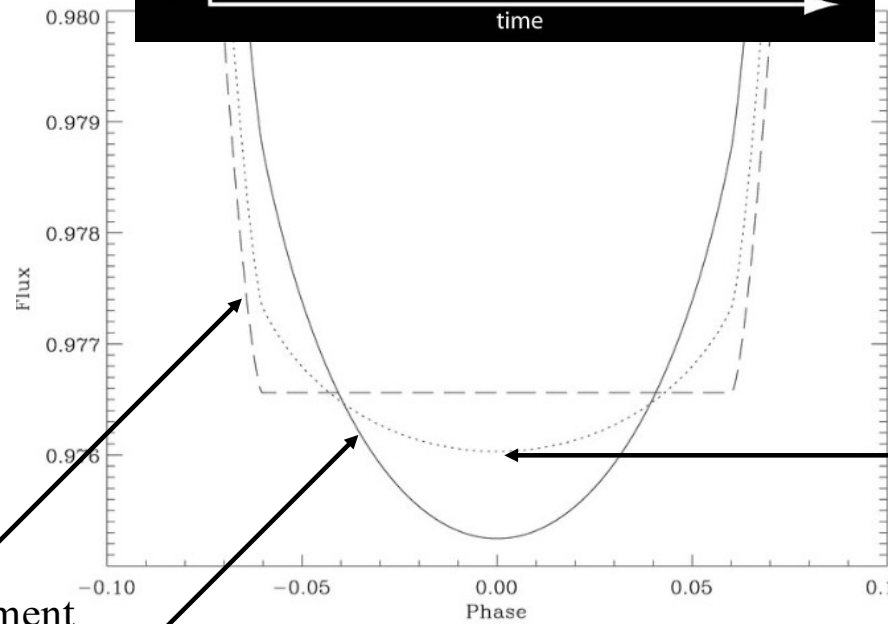
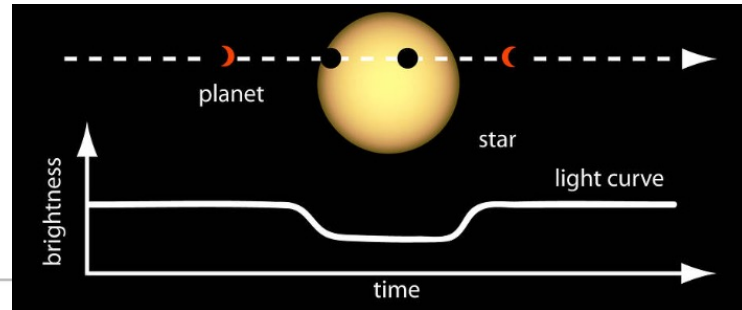
Model of a super giant star (Kurucz 1979)

TABLE 4
THE MODELS

	MASS	TAU		TEFF X	5500.		LOG G		0.00		CONVECTIVE		P RAD	ACC RAD	CONV FRAC
		ROSS	500		T	P	NE	NA	RHO	KAPPA ROSS	KAPPA 500				
1	-.38761	0.0000	0.0000	0.0000	3000.3	-.3893	7.7323	11.9934	-11.6635	-4.1046	-3.3399	.0865	-2.6844	-27.0123	
2	-.22215	-4.3268	-3.5621	10.9100	3765.6	-.2238	8.0766	12.0603	-11.5966	-4.1046	-3.3399	.0866	-2.8477	-29.3451	
3	-.06172	-4.1624	-3.4012	11.2337	3816.9	-.0632	8.2353	12.2150	-11.4419	-4.0797	-3.3373	.0868	-2.8742	0.0000	
4	.09200	-3.9979	-3.2464	11.4124	3867.2	.0906	8.3877	12.3631	-11.2938	-4.0517	-3.3340	.0869	-2.8817	0.0000	
5	.24067	-3.8327	-3.0958	11.5345	3915.9	.2393	8.5353	12.5064	-11.1505	-4.0203	-3.3298	.0872	-2.8864	0.0000	
6	.38470	-3.6673	-2.9491	11.6280	3964.2	.3835	8.6790	12.6452	-11.0117	-3.9846	-3.3244	.0875	-2.8897	0.0000	
7	.52497	-3.5007	-2.8053	11.7038	4013.3	.5239	8.8195	12.7803	-10.8766	-3.9435	-3.3177	.0879	-2.8824	0.0000	
8	.65991	-3.3347	-2.6658	11.7668	4064.7	.6588	8.9565	12.9096	-10.7472	-3.8969	-3.3092	.0885	-2.8735	0.0000	
9	.78968	-3.1691	-2.5302	11.8205	4118.0	.7887	9.0903	13.0339	-10.6230	-3.8447	-3.2986	.0892	-2.8674	0.0000	
10	.91489	-3.0032	-2.3979	11.8672	4172.3	.9139	9.2217	13.1534	-10.5034	-3.7875	-3.2856	.0902	-2.8623	0.0000	
11	1.03612	-2.8363	-2.2678	11.9086	4227.2	1.0350	9.3508	13.2689	-10.3880	-3.7254	-3.2698	.0915	-2.8573	0.0000	
12	1.15290	-2.6693	-2.1403	11.9455	4282.3	1.1520	9.4776	13.3802	-10.2767	-3.6586	-3.2507	.0932	-2.8511	0.0000	
13	1.26459	-2.5035	-2.0158	11.9785	4336.6	1.2636	9.6009	13.4864	-10.1705	-3.5887	-3.2281	.0952	-2.8435	0.0000	
14	1.37272	-2.3372	-1.8923	12.0086	4390.3	1.3720	9.7221	13.5894	-10.0675	-3.5151	-3.2015	.0979	-2.8300	0.0000	
15	1.47727	-2.1706	-1.7695	12.0361	4444.0	1.4765	9.8415	13.6887	-9.9662	-3.4382	-3.1705	.1012	-2.8094	0.0000	
16	1.57875	-2.0033	-1.6466	12.0616	4498.2	1.5781	9.9599	13.7849	-9.8720	-3.3578	-3.1347	.1056	-2.7844	0.0000	
17	1.67655	-1.8368	-1.5239	12.0851	4552.7	1.6759	10.0766	13.8775	-9.7794	-3.2751	-3.0940	.1111	-2.7501	0.0000	
18	1.77126	-1.6701	-1.4005	12.1069	4609.4	1.7706	10.1937	13.9668	-9.6901	-3.1886	-3.0477	.1183	-2.7084	0.0000	
19	1.86290	-1.5033	-1.2758	12.1273	4669.6	1.8622	10.3128	14.0528	-9.6041	-3.0981	-2.9948	.1277	-2.6603	0.0000	
20	1.95141	-1.3361	-1.1494	12.1463	4734.2	1.9507	10.4347	14.1353	-9.5216	-3.0030	-2.9349	.1400	-2.6041	0.0000	
21	2.03635	-1.1690	-1.0214	12.1641	4805.4	2.0354	10.5618	14.2136	-9.4433	-2.9014	-2.8664	.1560	-2.5369	0.0000	
22	2.11679	-1.0025	-.8921	12.1806	4887.2	2.1159	10.6983	14.2867	-9.3702	-2.7899	-2.7866	.1770	-2.4535	0.0000	
23	2.19226	-.8352	-.7606	12.1957	4985.6	2.1912	10.8505	14.3533	-9.3036	-2.6635	-2.6908	.2045	-2.3524	0.0000	
24	2.26091	-.6684	-.6278	12.2094	5104.6	2.2598	11.0228	14.4116	-9.2452	-2.5191	-2.5752	.2399	-2.2302	0.0000	
25	2.32138	-.5017	-.4937	12.2214	5252.7	2.3201	11.2225	14.4595	-9.1974	-2.3488	-2.4330	.2852	-2.0776	0.0000	
26	2.37239	-.3348	-.3581	12.2315	5436.9	2.3707	11.4538	14.4949	-9.1620	-2.1474	-2.2590	.3423	-1.8891	-15.8934	
27	2.41322	-.1676	-.2211	12.2398	5665.4	2.4111	11.7184	14.5171	-9.1397	-1.9119	-2.0496	.4129	-1.6641	-11.7676	
28	2.44392	.0003	-.0827	12.2462	5949.4	2.4411	12.0175	14.5252	-9.1317	-1.6340	-1.7996	.4984	-1.3922	-9.4069	
29	2.46531	.1680	.0554	12.2509	6289.4	2.4613	12.3377	14.5198	-9.1370	-1.3151	-1.5122	.5997	-1.0676	-6.8868	
30	2.47827	.3501	.2030	12.2539	6821.0	2.4723	12.7648	14.4903	-9.1666	-.8392	-1.0759	.7300	-.5761	-3.4201	
31	2.48334	.5179	.3379	12.2553	7434.8	2.4749	13.1726	14.4408	-9.2161	-.3059	-.5745	.8519	-.1430	-.6293	
32	2.48630	.6750	.4683	12.2561	7747.5	2.4758	13.3487	14.4105	-9.2464	-.0486	-.3268	.9345	-.1604	-.2772	
33	2.48925	.8481	.6186	12.2570	7977.0	2.4768	13.4636	14.3859	-9.2710	.1284	-.1533	.9973	-.2276	-.1388	
34	2.49196	1.0076	.7623	12.2579	8180.2	2.4781	13.5561	14.3623	-9.2946	.2767	-.0074	1.0427	-.2679	-.0704	
35	2.49494	1.1722	.9149	12.2589	8356.4	2.4796	13.6297	14.3401	-9.3168	.3974	.1129	1.0835	-.3202	-.0561	
36	2.49825	1.3368	1.0713	12.2602	8542.8	2.4814	13.6983	14.3160	-9.3409	.5115	.2285	1.1218	-.3378	-.0309	
37	2.50200	1.5023	1.2316	12.2616	8728.2	2.4836	13.7596	14.2905	-9.3664	.6156	.3345	1.1604	-.3567	-.0259	
38	2.50634	1.6686	1.3952	12.2635	8929.2	2.4861	13.8166	14.2623	-9.3946	.7142	.4361	1.2003	-.3562	-.0215	
39	2.51138	1.8343	1.5600	12.2657	9149.3	2.4891	13.8684	14.2312	-9.4256	.8029	.5292	1.2440	-.3364	-.0116	
40	2.51745	2.0009	1.7287	12.2687	9422.9	2.4923	13.9173	14.1936	-9.4633	.8822	.6191	1.2963	-.2829	-.0222	

To compress the tables as much as possible, all quantities except temperature are given in log cgs units. The columns are mass cm^{-2} , Rosseland optical depth, continuum optical depth at 500 nm, geometric depth down from the first point, temperature, gas pressure, electron number density, atomic number density, mass density, Rosseland mass absorption coefficient, continuum mass absorption coefficient at 500 nm, radiation pressure, radiative acceleration (compare to $\log g$), and the fraction of the total flux carried by convection. A value of 0 in the table means an actual 0, not 10^0 . A label in the heading for each model tells whether the model was treated as purely radiative or radiative plus convective. The 40 depths listed in the table are the actual depths that were used in the calculation.

Détection de planète par transit



Calcul théorique
sans assombrissement

optique

IR

Ehrenreich 2007