Theory and the brown dwarf binary GJ 569Bab

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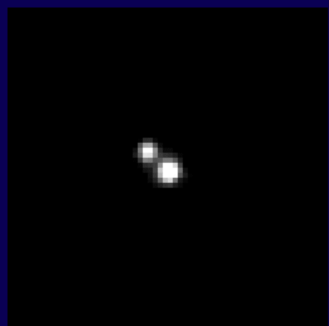
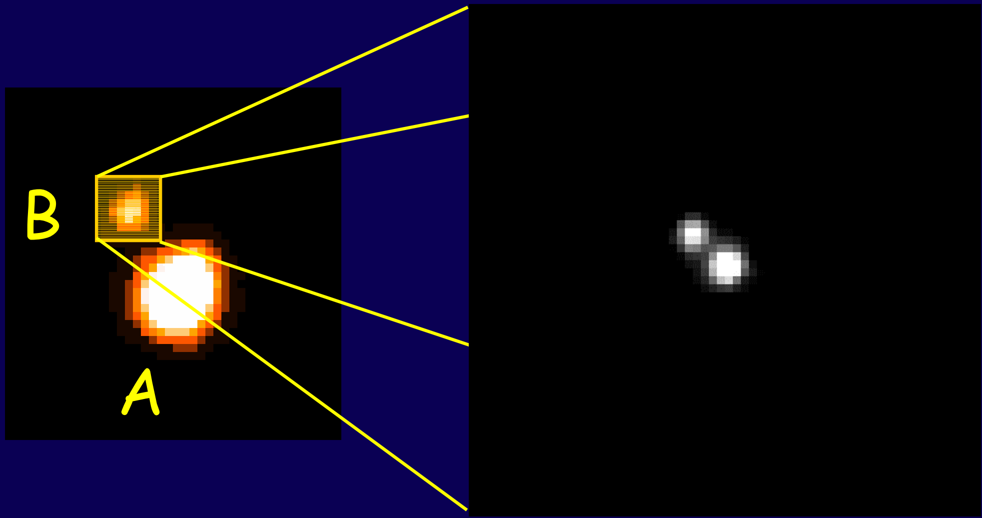


La Palma, June 2005

GJ 569: a triple system

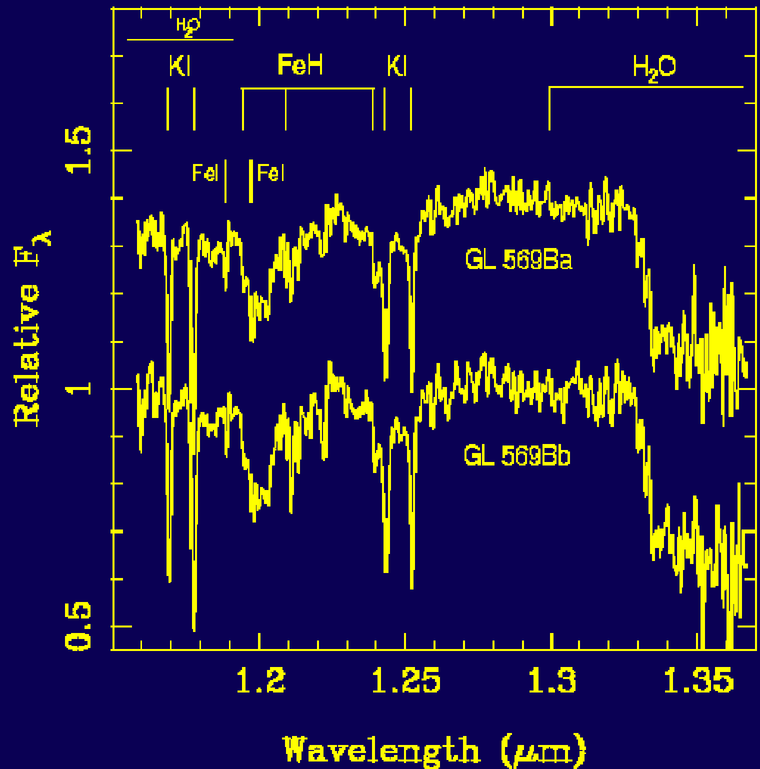


GJ 569B is
a proper motion
companion located
at 50 AU from
GJ 569A.

Forrest et al. (1988)

Keck AO images.
GJ 569B is resolved
into two objects of
spectral types M8.5V
and M9V, separated by
0.9 AU, and total mass
of 0.125 M_{sol}.

Martín et al. (2000); Lane et al. (2001)

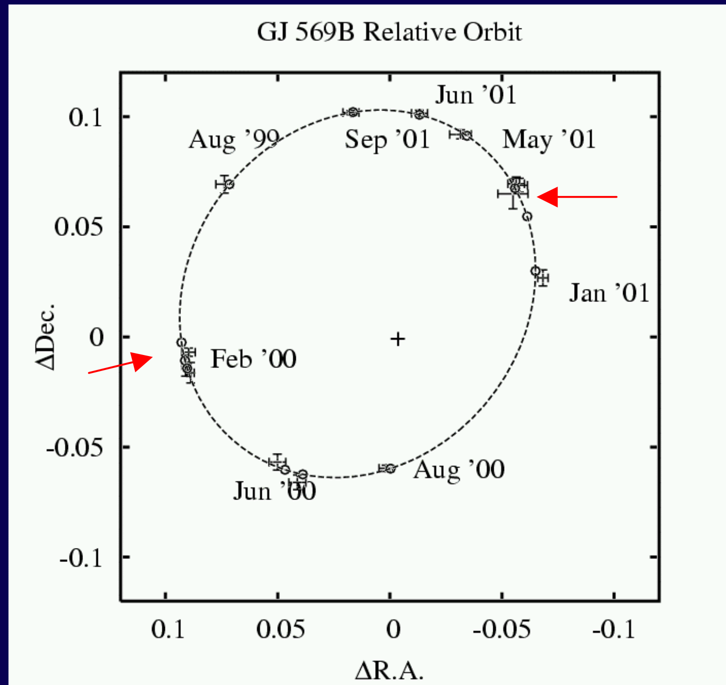


Keck AO NIRSPEC low -res
spectra.
T_{eff} ~ 2450, 2300 K.

Lane et al. (2001)

GJ 569B: the binary companion

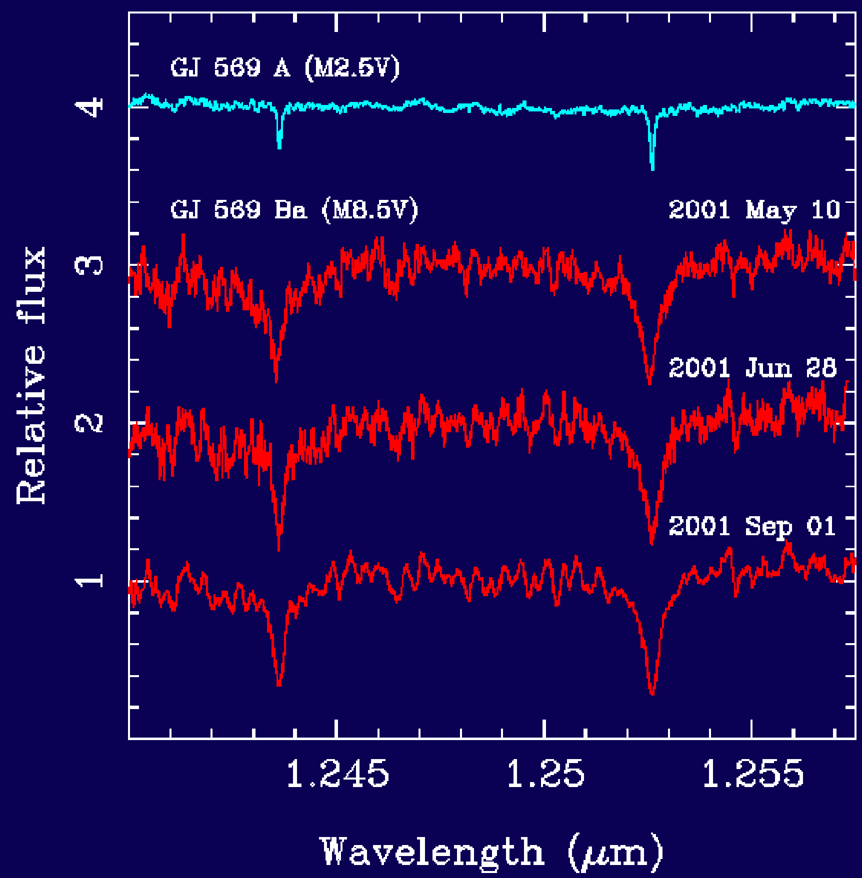
	Lane et al. (2001)	Zapatero Osorio et al. (2004)	Updated (2005)
P (days)	892 ± 25	876 ± 9	875.4 ± 8.0
e	0.32 ± 0.02	0.32 ± 0.01	0.316 ± 0.008
a (AU)	0.90 ± 0.02	0.90 ± 0.01	0.895 ± 0.009
i (deg)	34 ± 3	34 ± 2	33.6 ± 1.8
ω (deg)	76 ± 4	257 ± 2	257.4 ± 1.6
Ω (deg)	141 ± 4	321.5 ± 2.0	321.3 ± 1.9
Epoch (MJD)	51820 ± 4	51822 ± 3	51821.2 ± 3.0
Total mass (M_o)	0.123 ± 0.008	0.125 ± 0.005	0.1246 ± 0.004



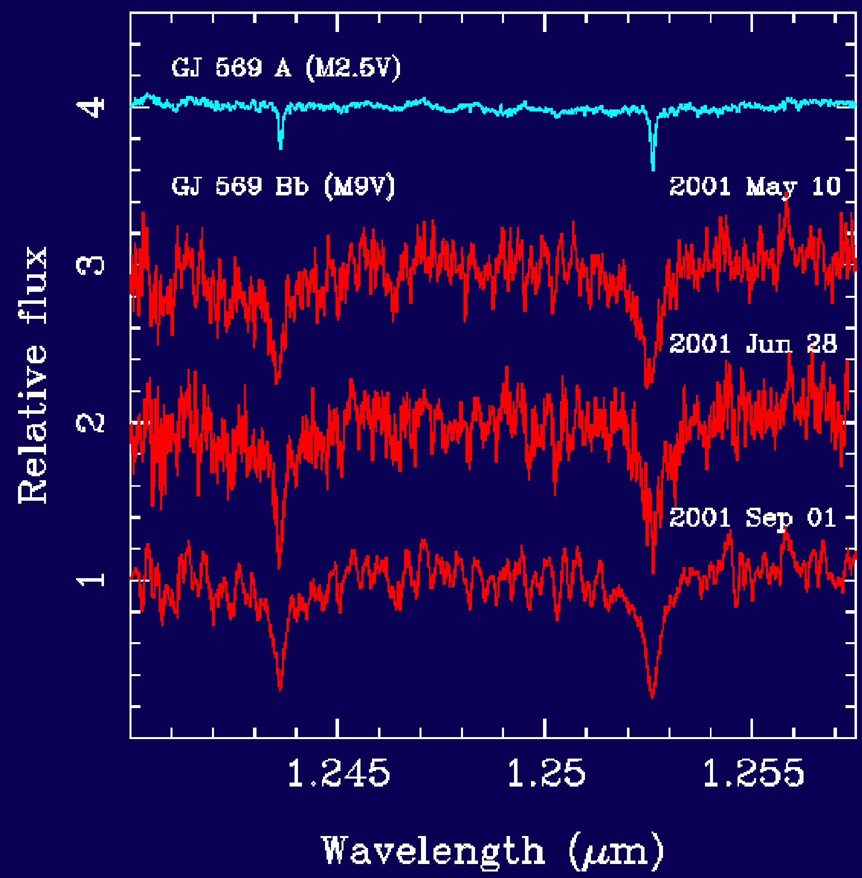
New data: Subaru, HST

GJ 569Ba and Bb: Keck AO NIRSPEC hi-res spectra

GJ 569Ba

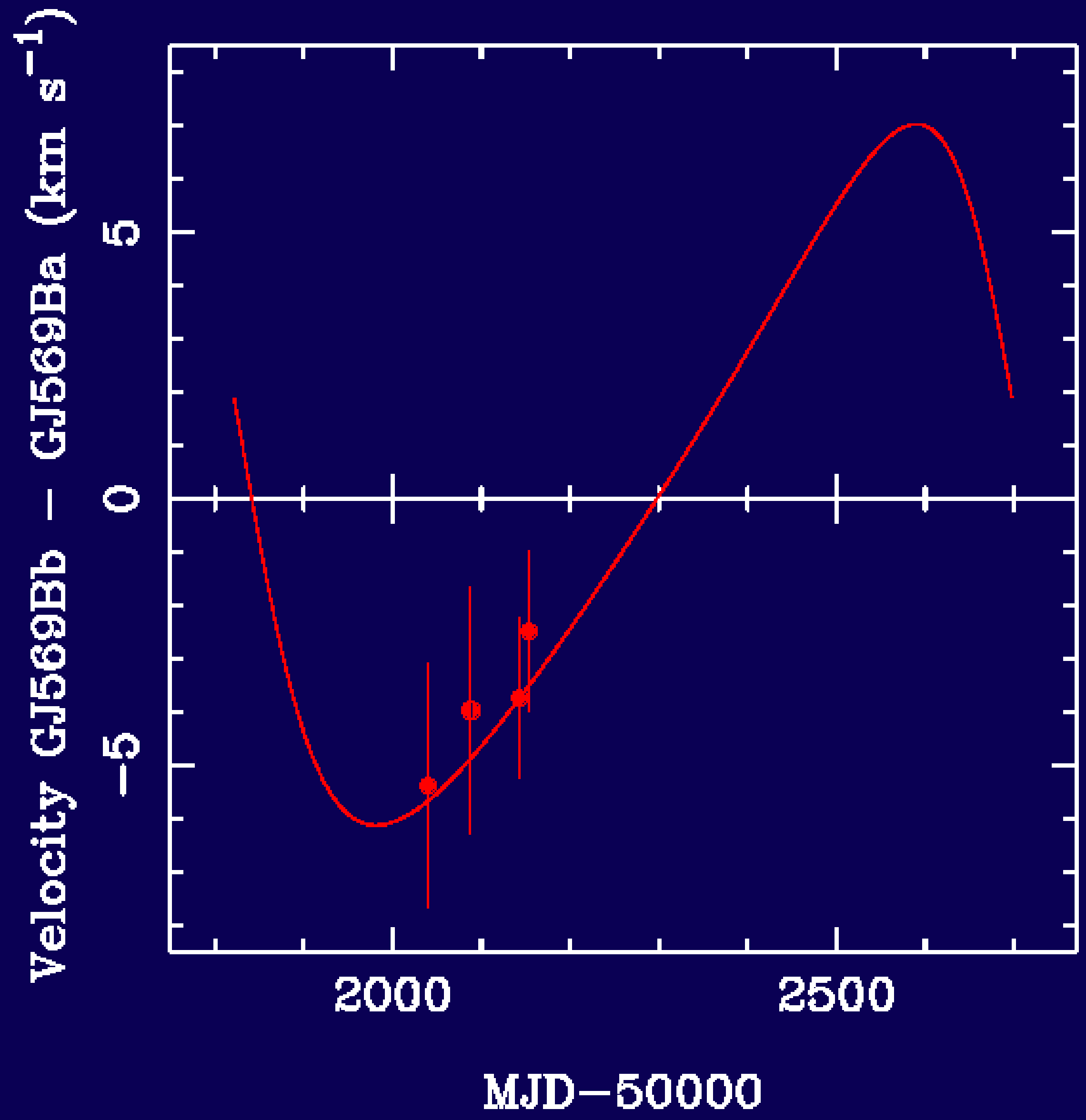


GJ 569Bb



Resolution = 22400

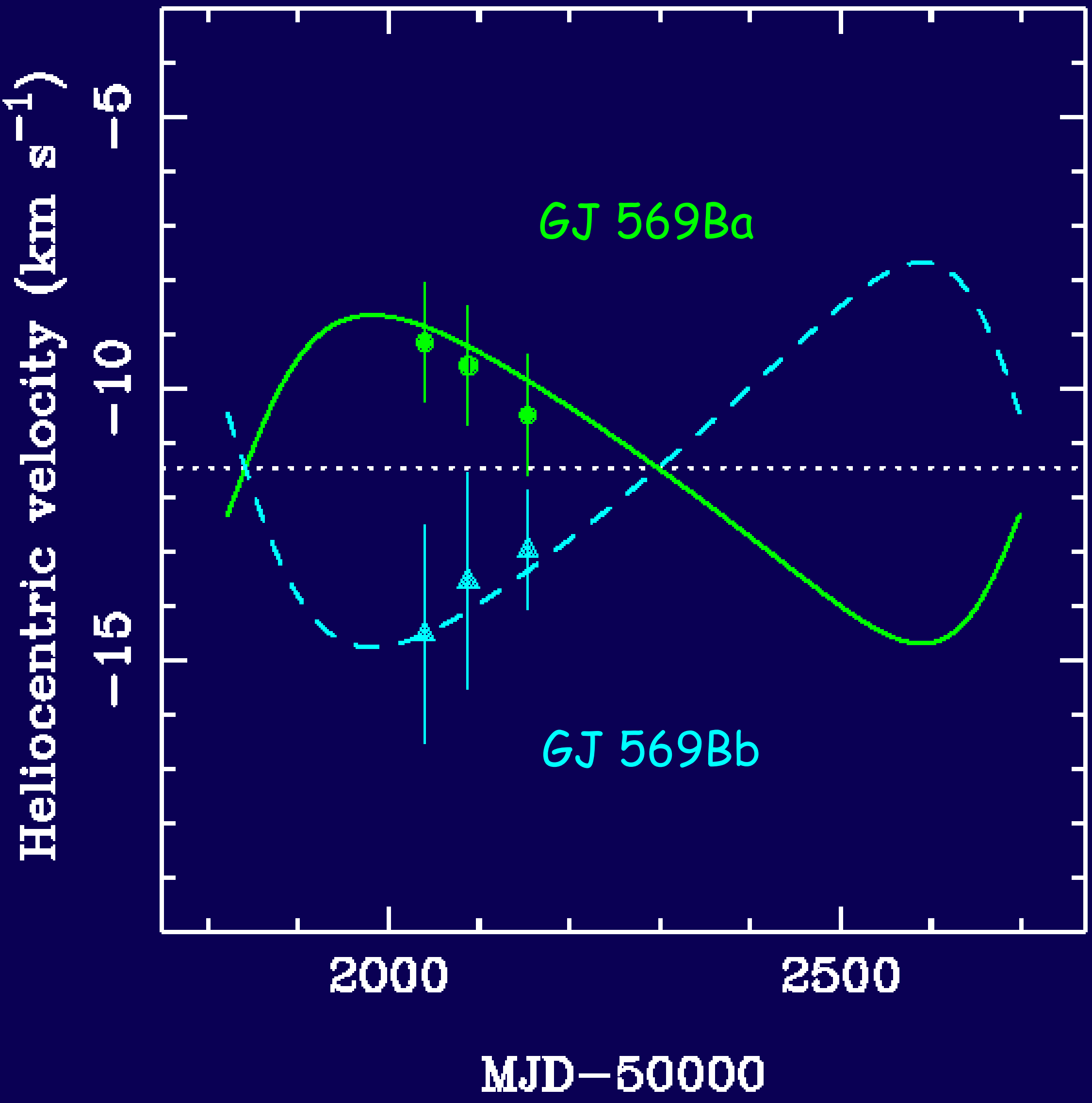
GJ 569Ba and Bb: velocities



The expected velocity curve, **based solely on the astrometric result,** is plotted as a red line.

The observed relative velocities and the curve are in very good agreement.

GJ 569Ba and Bb: velocities



The best fit to the unweighted velocity data yields:

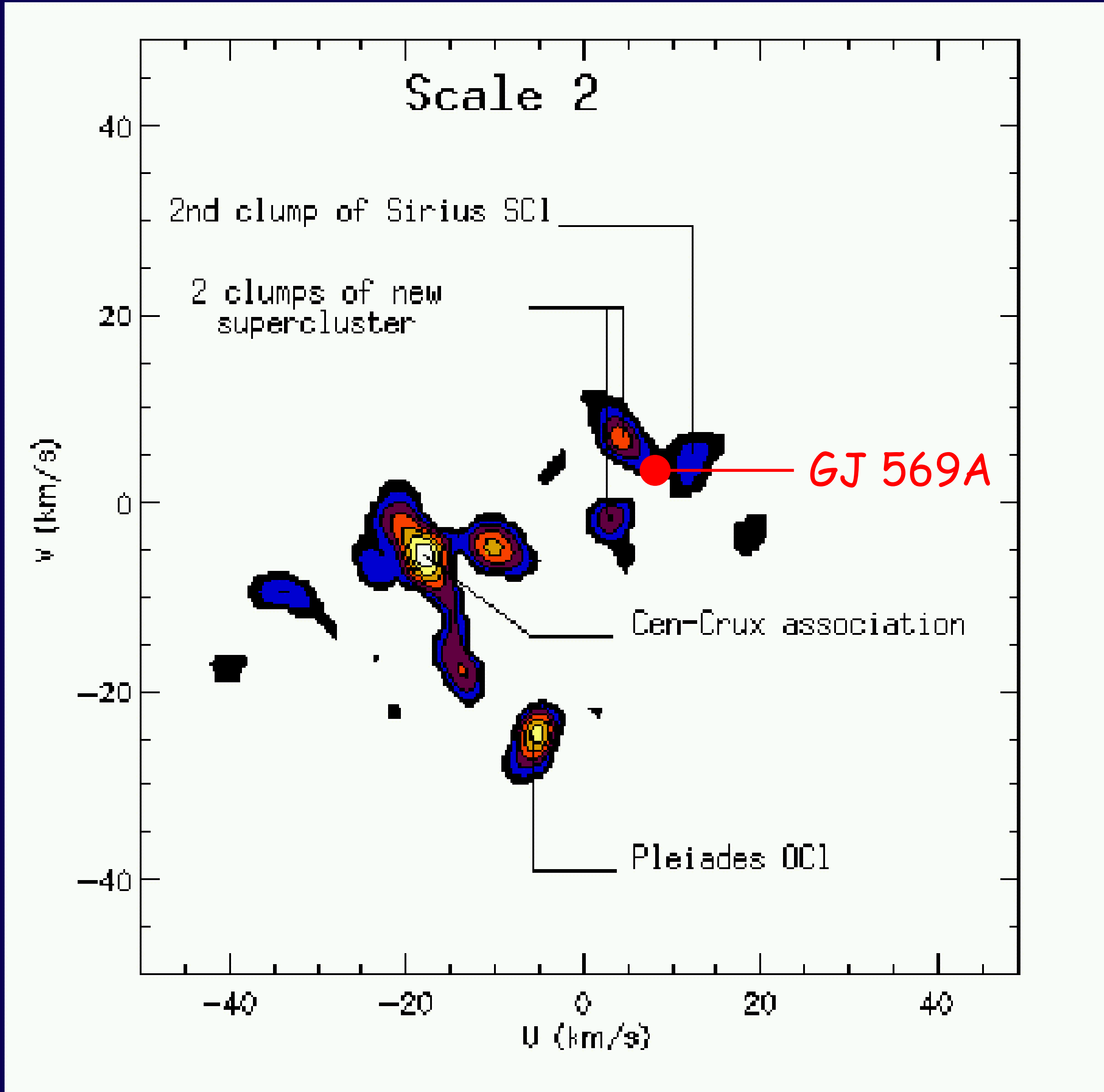
M (GJ 569Ba) = 0.068 ± 0.011 M_{sol}

M (GJ 569Bb) = 0.057 ± 0.011 M_{sol}

GJ 569Bb is the **first brown dwarf confirmed dynamically**, i.e., without any theoretical assumption.

Zapatero Osorio et al. (2004)

GJ 569: the age of the system

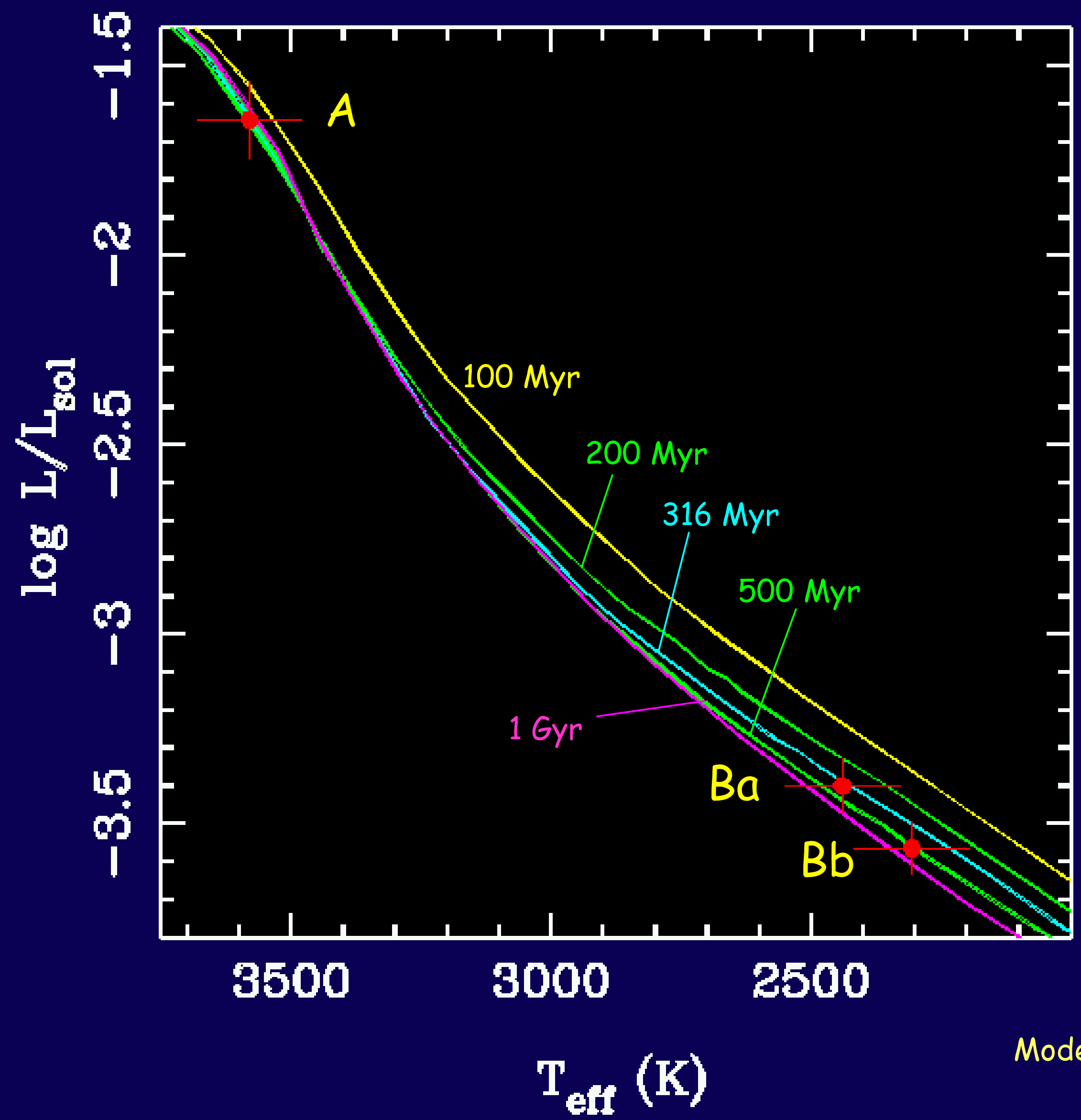


Chereul et al. (1999)

The galactic *UVW* velocities of GJ 569A are within 1σ the values of a known star cluster moving group, which has an estimated age of 300-800 Myr.

Additionally, the star GJ 569A exhibits many of the attributes of young stars (120-1000 Myr).

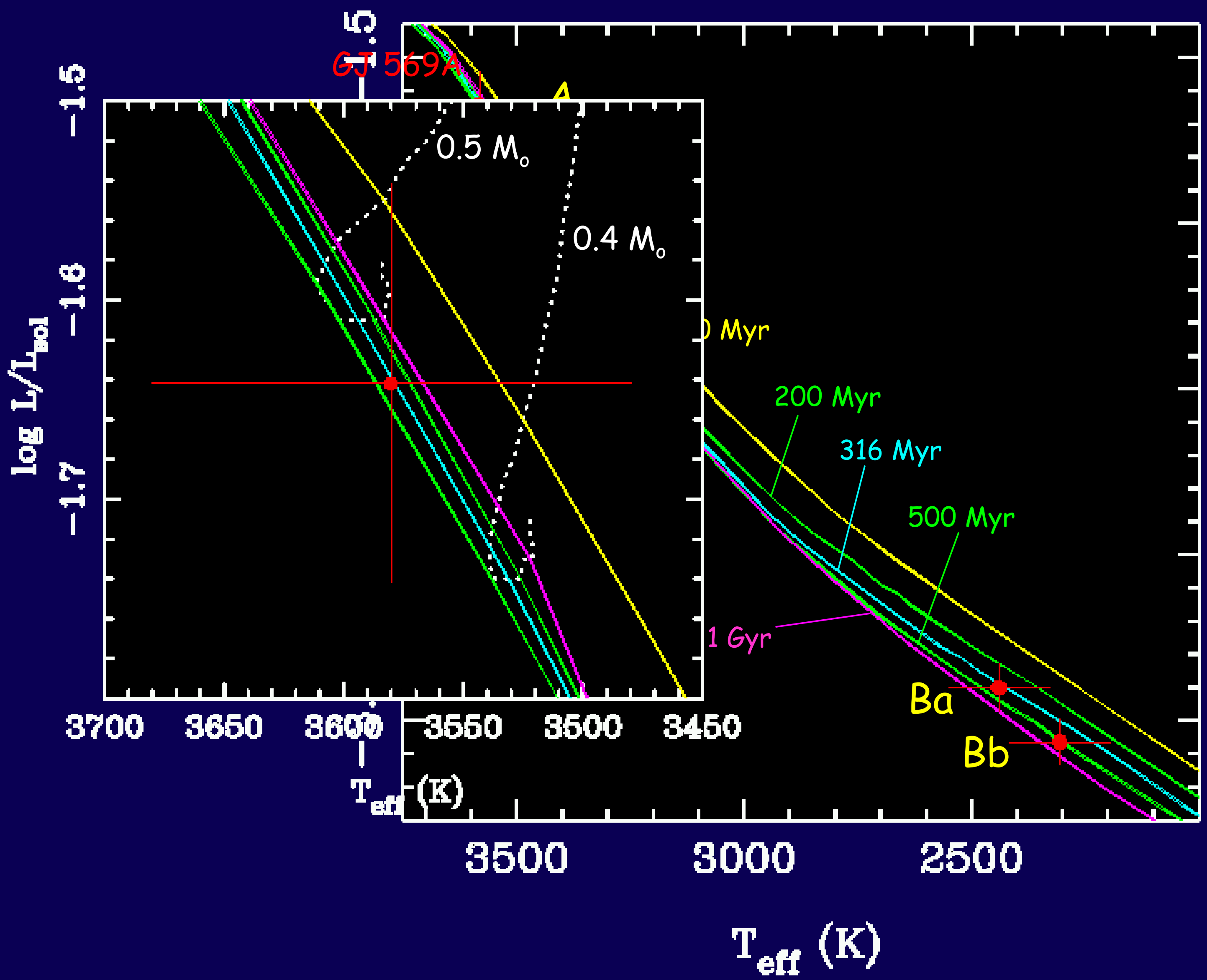
The triple system and evolutionary models



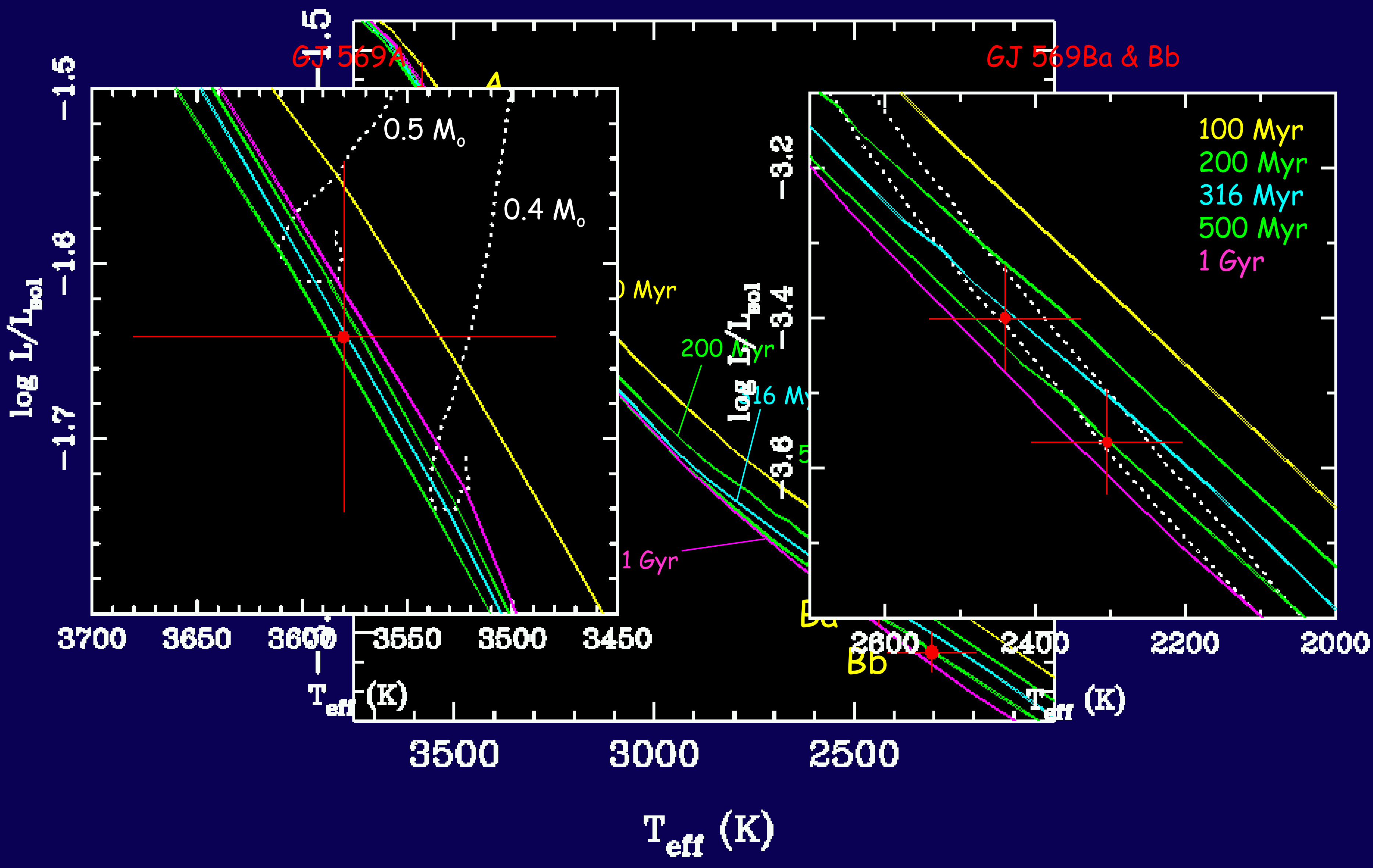
	log $L/L_\odot$	T_{eff} (K)	$M/M_\odot$
GJ 569A	-1.64	3580	0.44
GJ 569Ba	-3.40	2440	0.068
GJ 569Bb	-3.57	2305	0.057

Models by Baraffe et al. (2003)

The triple system and evolutionary models

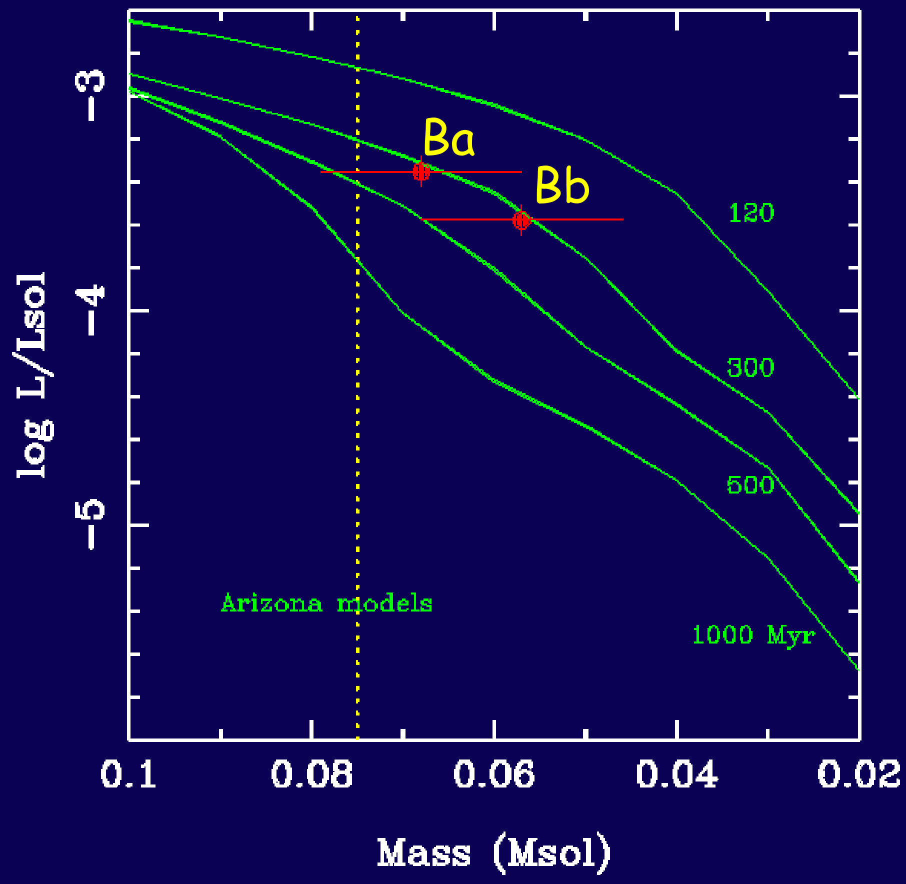


The triple system and evolutionary models

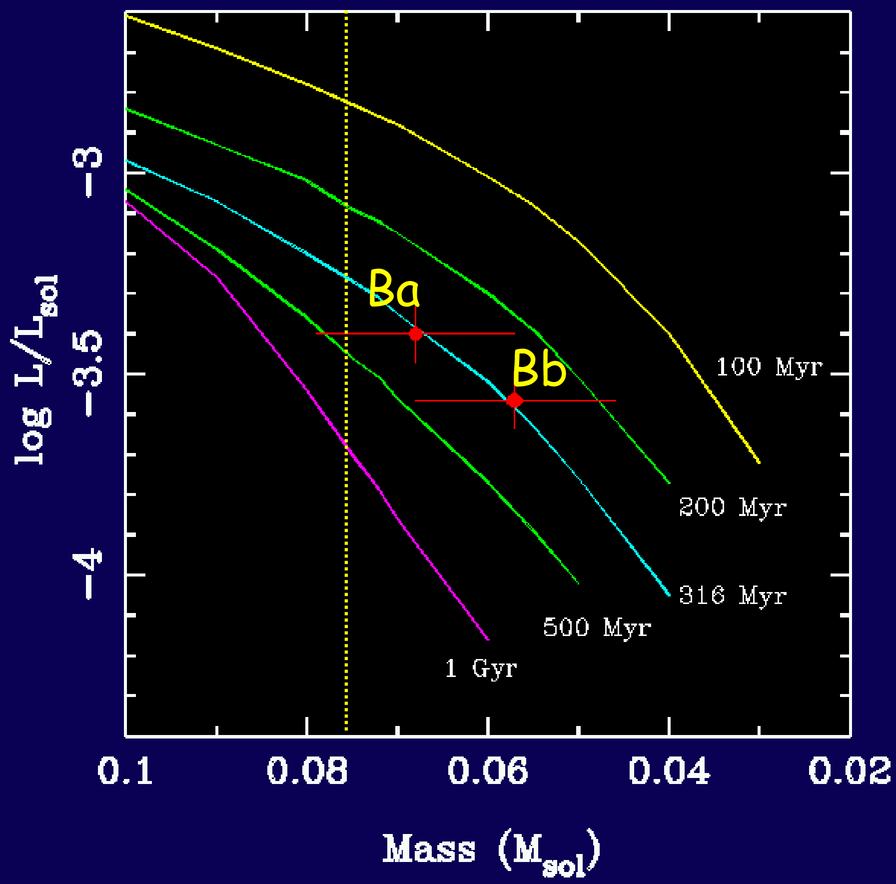


GJ 569Ba and Bb and evolutionary models

Burrows et al. (1997)



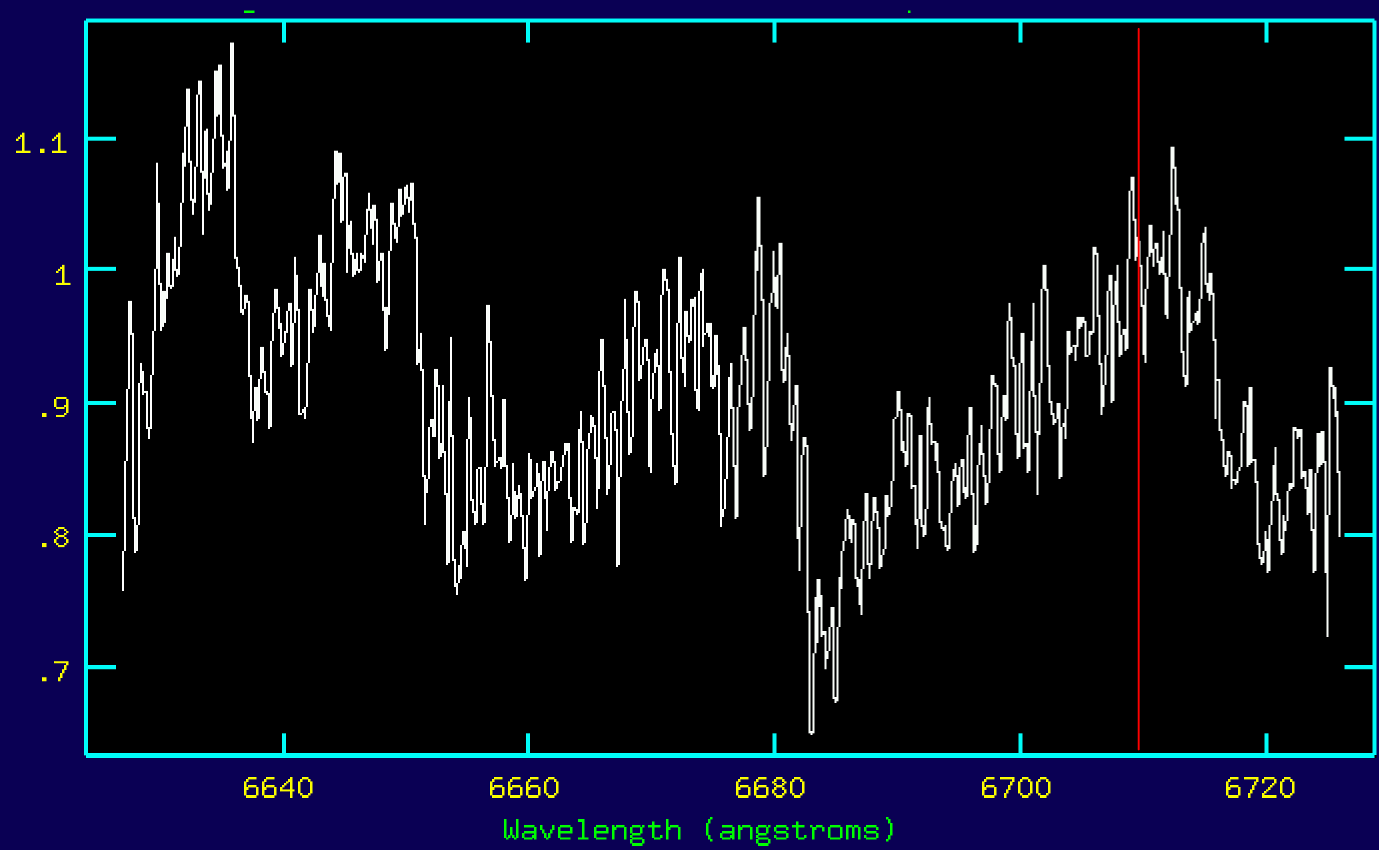
Baraffe et al. (2003)



Models nicely reproduce the substellar mass-luminosity relation of the binary *if* the system is about 300 Myr.

GJ 569Bab: Keck HIRES spectra

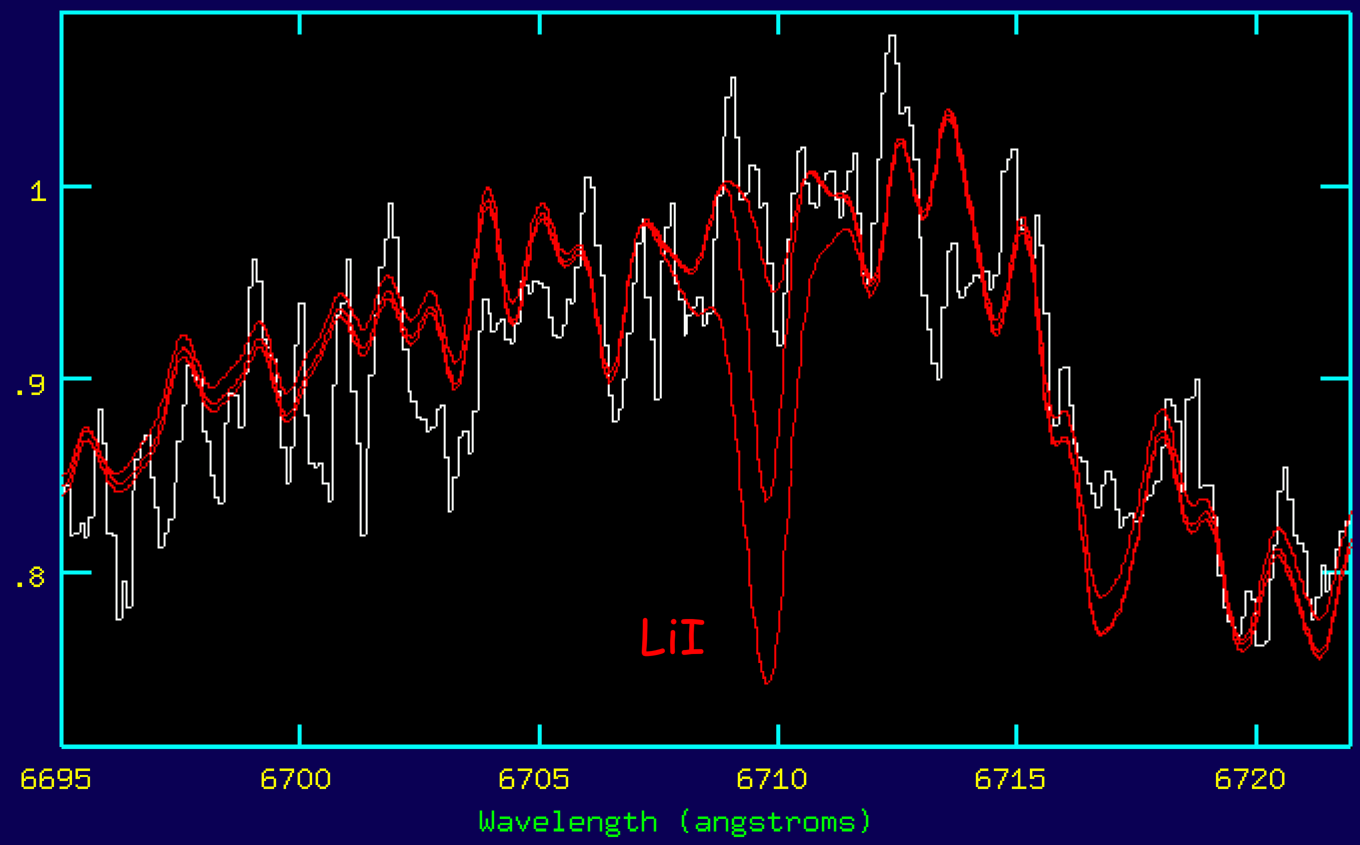
LiI of the combined optical spectrum



There is no strong LiI absorption feature (pEW < 0.05 A), suggesting that Li is significantly depleted in the atmosphere of GJ 569Ba.

GJ 569Bab: Keck HIRES spectra

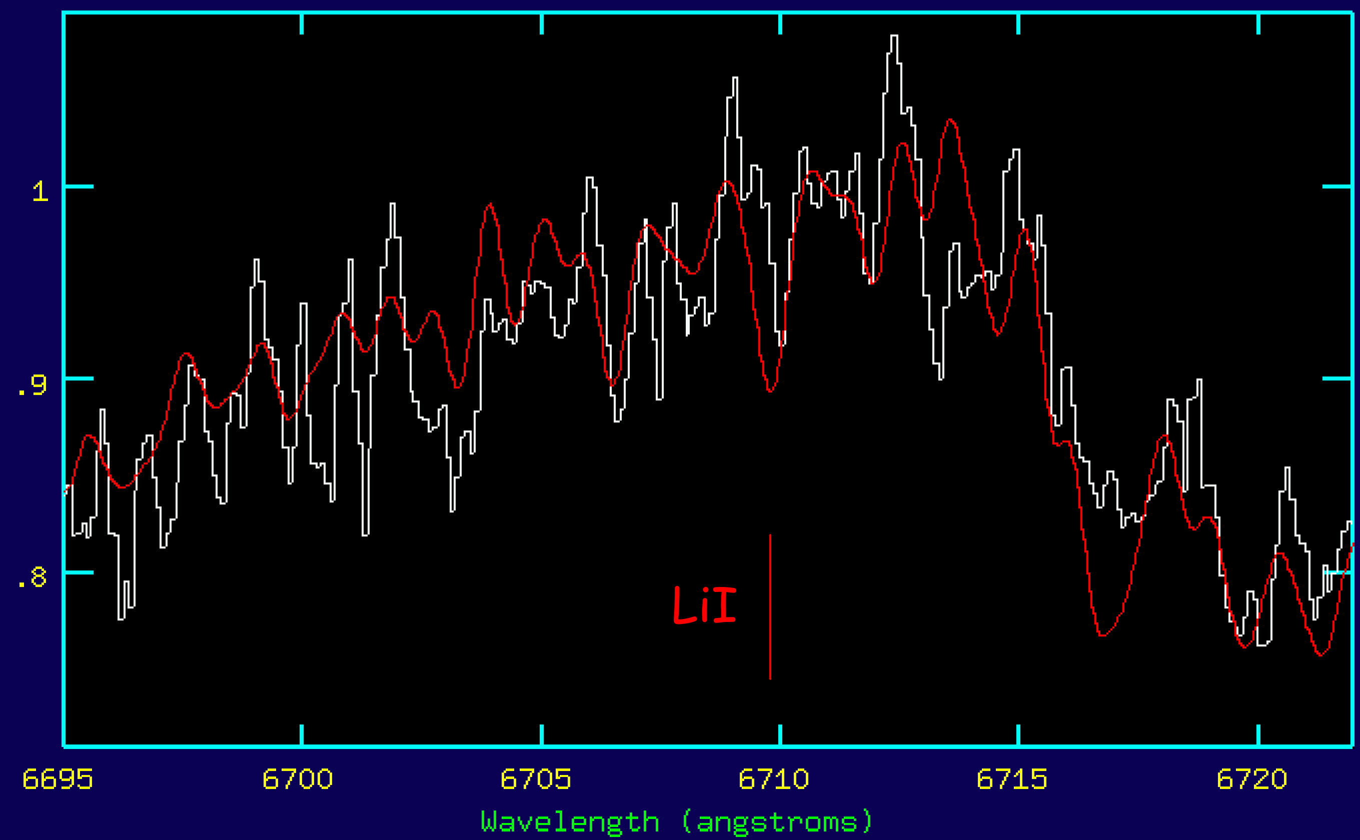
LiI of the combined spectrum



Models with high Li abundances in *GJ 569Bb* do not reproduce the observations.

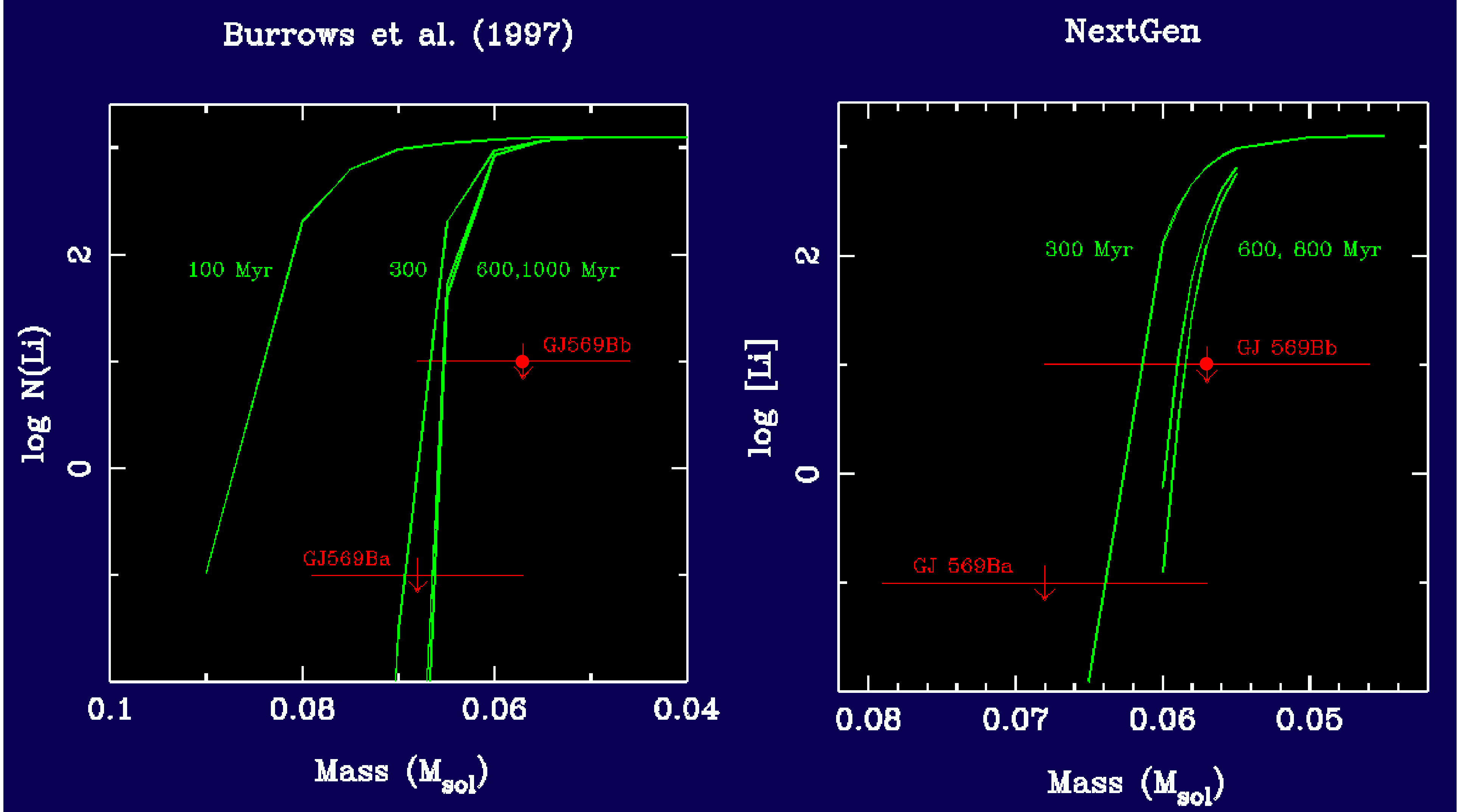
GJ 569Bab: Keck HIRES spectra

LiI of the combined spectrum



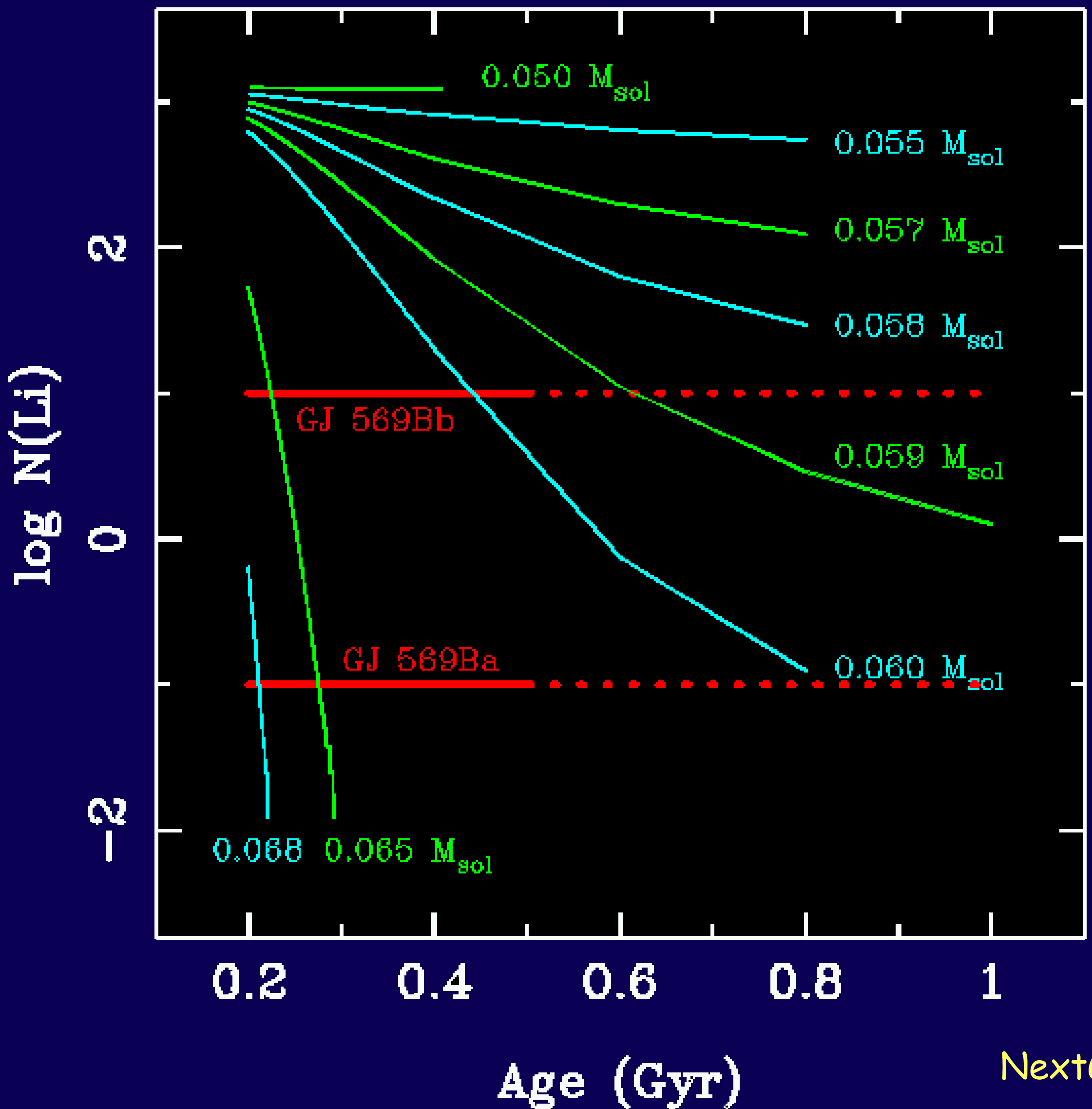
Model:
log Li (GJ569Ba) = -1.0 (four orders of magnitude of depletion)
log Li (GJ569Bb) = 0.0-1.0 (two-three orders of magnitude of depletion)

GJ 569Bab and lithium predictions



Smaller error bars in the mass determination are needed for a better test of the models.

GJ 569Bab and lithium predictions



NextGen models

Increasing list of nearby ultra-cool binaries …

All Known Resolved VLM Binaries[a]

Name	Sep. AU	Est. SpT_A/SpT_B	Est. M_A $M_\odot$	Est. M_B $M_\odot$	Est. Period[b] yr
PPL 15[a]	0.03	M7/M8	0.07	0.06	5.8 days
Gl 569B	1.0	M8.5/M9.0	0.063	0.06	3
SDSS 2335583-001304	1.1?	L1?/L4?	0.079	0.074	3
2MASSW J1112256+354813	1.5	L4/L6	0.073	0.070	5
2MASSI J1534498-295227	1.8	T5.5/T5.5	0.05	0.05	8
2MASSW J0856479+223518	2.0	L5?/L8?	0.071	0.064	8
DENIS-P J185950.9-370632	2.0	L0/L3	0.084	0.076	7
HD130948B	2.4	L2/L2	0.07	0.06	10
2MASSW J0746425+200032	2.7	L0.5/L2	0.082	0.078	12
2MASSW J1047127+402644	2.7	M8/L0	0.092	0.084	11
DENIS-PJ035726.9-441730	2.8	L2/L4	0.078	0.074	12
2MASSW J0920122+351742	3.2	L6.5/L7	0.068	0.068	16
LP415-20	3.5	M7/M9.5	0.095	0.079	15
2MASSW J1728114+394859	3.7	L7/L8	0.069	0.066	19
LHS 2397a	3.9	M8/L7.5	0.090	0.068	22
2MASSW J1426316+155701	3.9	M8.5/L1	0.088	0.076	19
2MASSW J2140293+162518	3.9	M9/L2	0.092	0.078	22
2MASSW J2206228-204705	4.4	M8/M8	0.092	0.092	22
2MASSs J0850359+105716	4.4	L6/L8	0.05	0.04	30
2MASSW J1750129+442404	4.8	M7.5/L0	0.095	0.084	25
DENIS-P J1228.2-1547	4.9	L5/L5	0.05	0.05	34
2MASSW J1600054+170832	5.0	L1/L3	0.078	0.075	29
2MASSW J1239272+551537	5.1	L5/L5	0.071	0.071	31
2MASSI J1553022+153236	5.2	T7/T7.5	0.040	0.035	43
2MASSW J1146345+223053	7.6	L3/L4	0.055	0.055	63
2MASSW J1311391+803222	7.7	M8.5/M9	0.089	0.087	51
2MASSW J1127534+741107	8.3	M8/M9	0.092	0.087	57
LP475-855	8.3	M7.5/M9.5	0.091	0.080	58
DENIS-P J0205.4-1159	9.2	L7/L7	0.07	0.07	75
2MASSW J2101349+175611	9.6	L7/L8	0.068	0.065	82
2MASSW J2147436+143131	10.4	L0/L2	0.084	0.078	83
2MASSW J1449378+235537	11.7	L0/L3	0.084	0.075	100
DENIS-P J144137.3-094559	13.5	L1/L1	0.079	0.079	124
2MASSW J2331016-040618	15.0	M8.0/L7	0.093	0.067	159
Eps Indi B	2.6	T1/T6	0.047	0.028	15 (McCaughrean et al. 2004)

0.146 M_{sol}
Bouy et al. (2004)

Table from Close et al. (2003)

Conclusions

- Current state-of-the-art substellar evolutionary models exhibit good performance in the regime of high brown dwarf masses if GJ 569 is about a few hundred Myr.

- Close binary brown dwarfs will provide an excellent test to evolutionary models in the next decade.