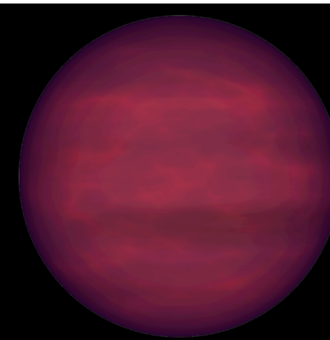
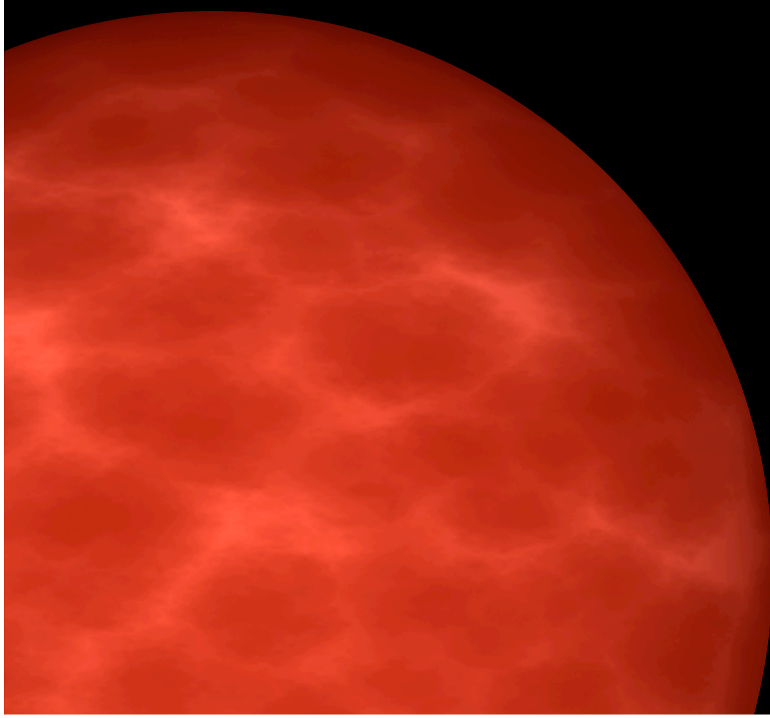
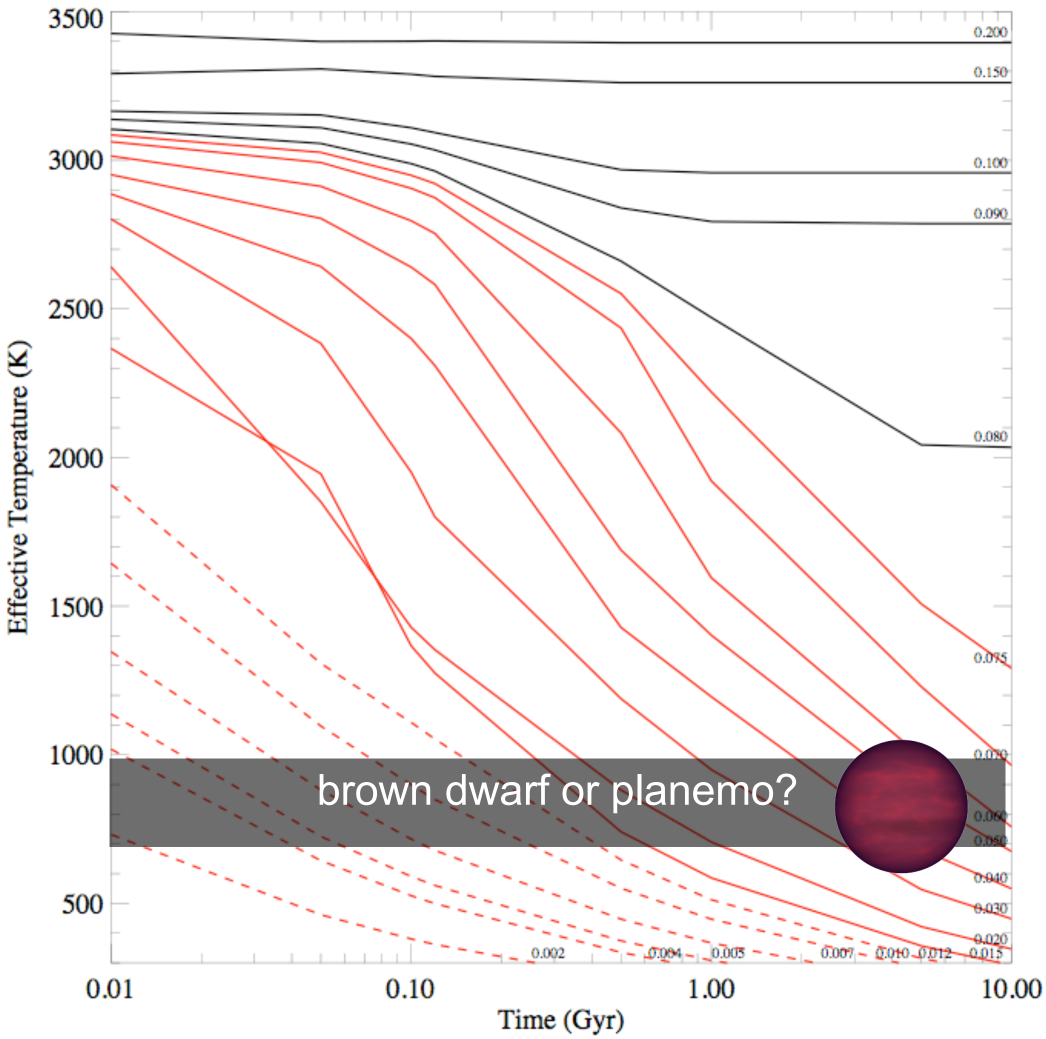


Gravity and Metallicity Effects in T Dwarf Spectra

Adam J. Burgasser (MIT)
Adam Burrows (UA)
J. Davy Kirkpatrick (Caltech/IPAC)



Brown dwarf artwork by Robert Hurt



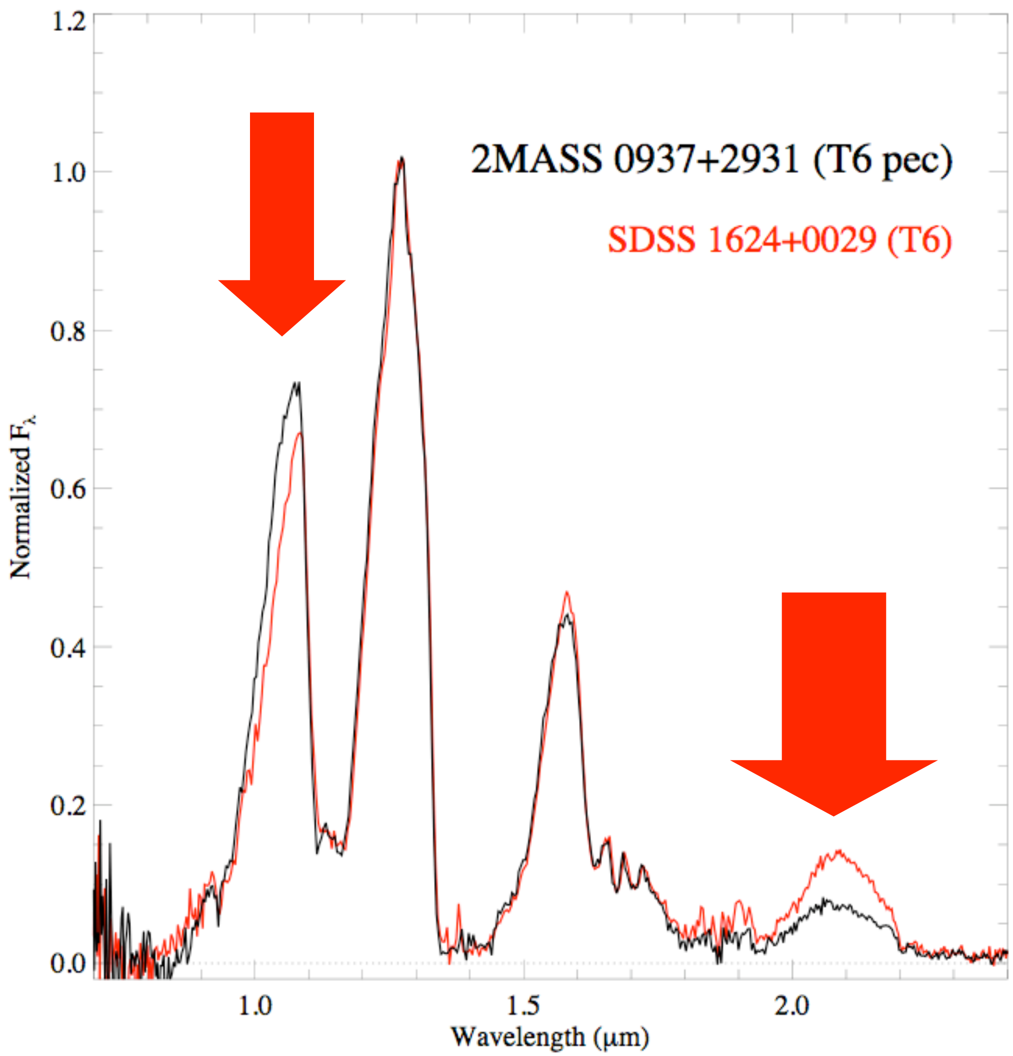
evolutionary models from Burrows et al. (2001)

> How do we explain differences between T dwarf spectra?

> How do we determine the physical properties of individual field brown dwarfs?

> How can we use T dwarfs to study Galactic properties/population?

2MASS 0937+2931: a Peculiar T Dwarf



Classified T6 on the basis of H_2O and CH_4 bandstrengths.

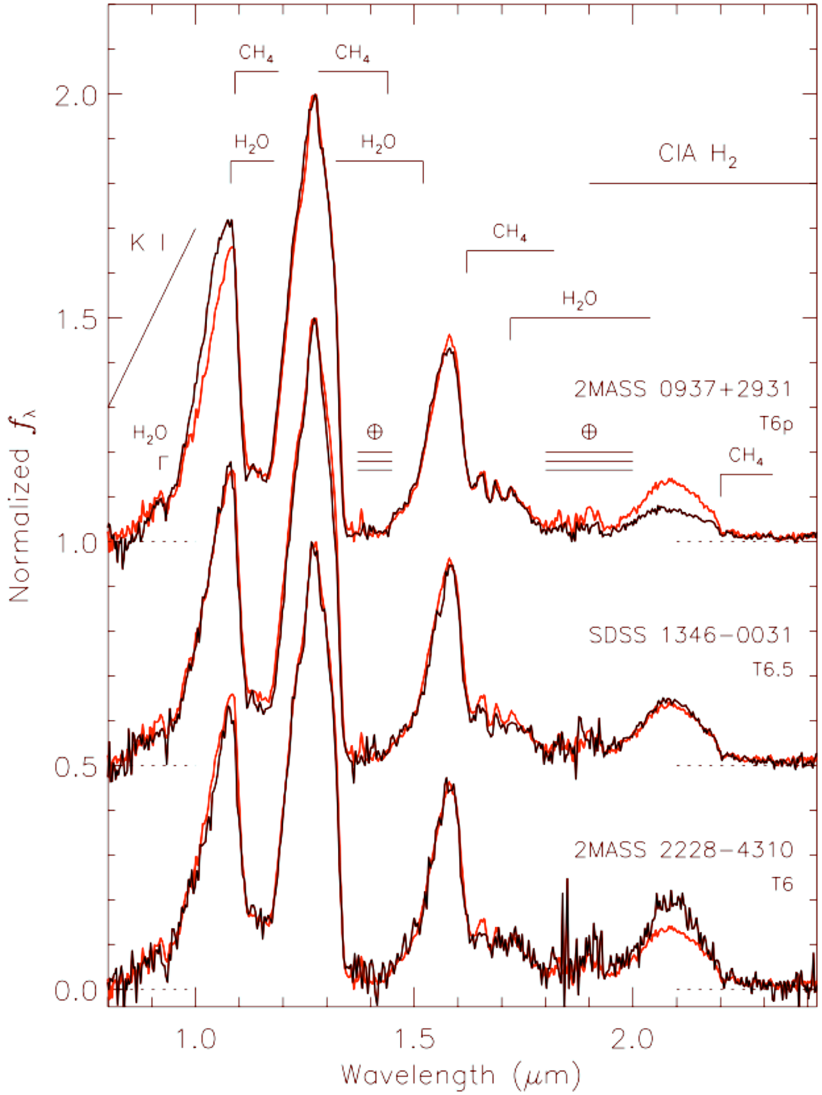
Clear discrepancies in Y- and K-band fluxes ⇒ peculiar

Indication of secondary parameter effects: g & Z

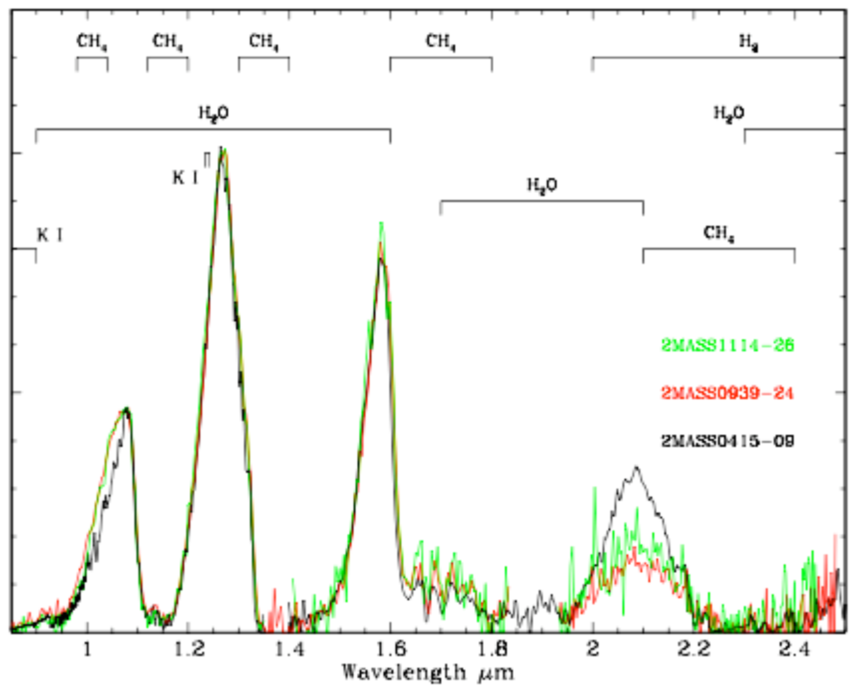
(N.B. V_{tan} = 47 km/s)

Burgasser et al. (2002,2003,2006); Knapp et al. (2004)

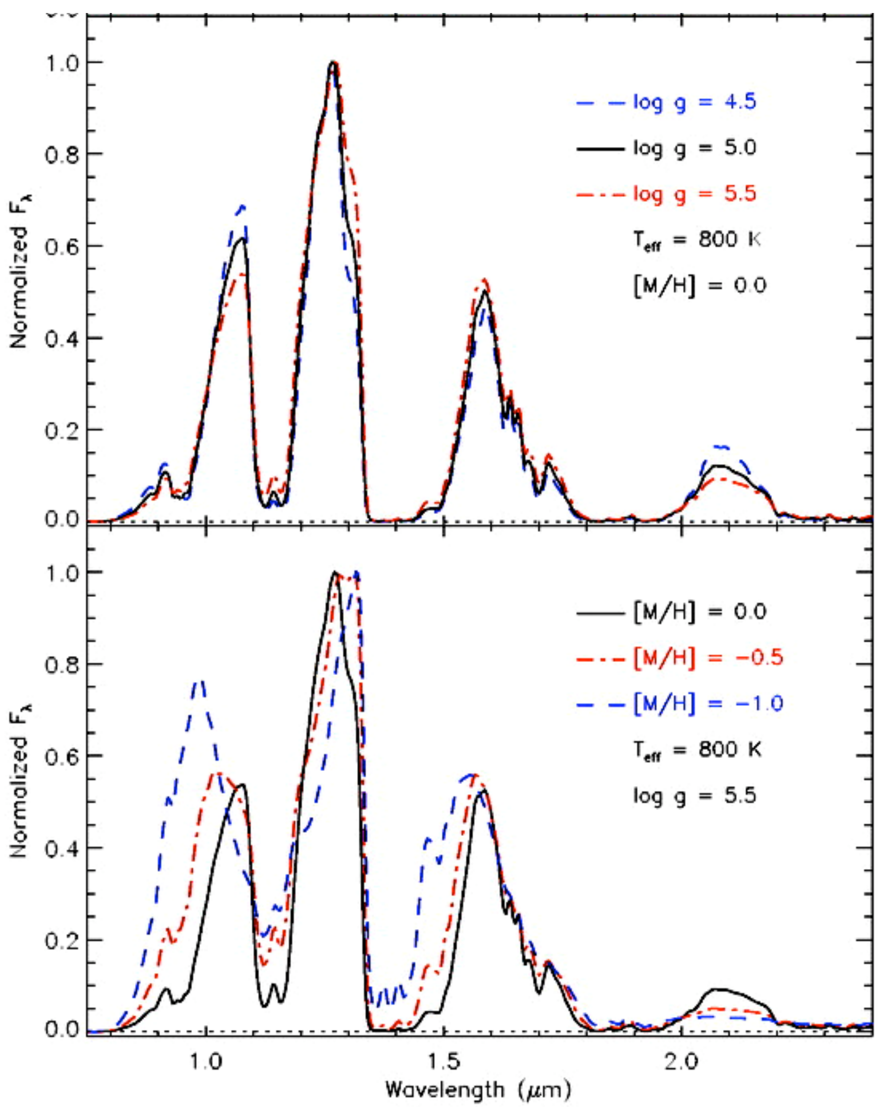
other examples…



Burgasser, Burrows & Kirkpatrick (2006)



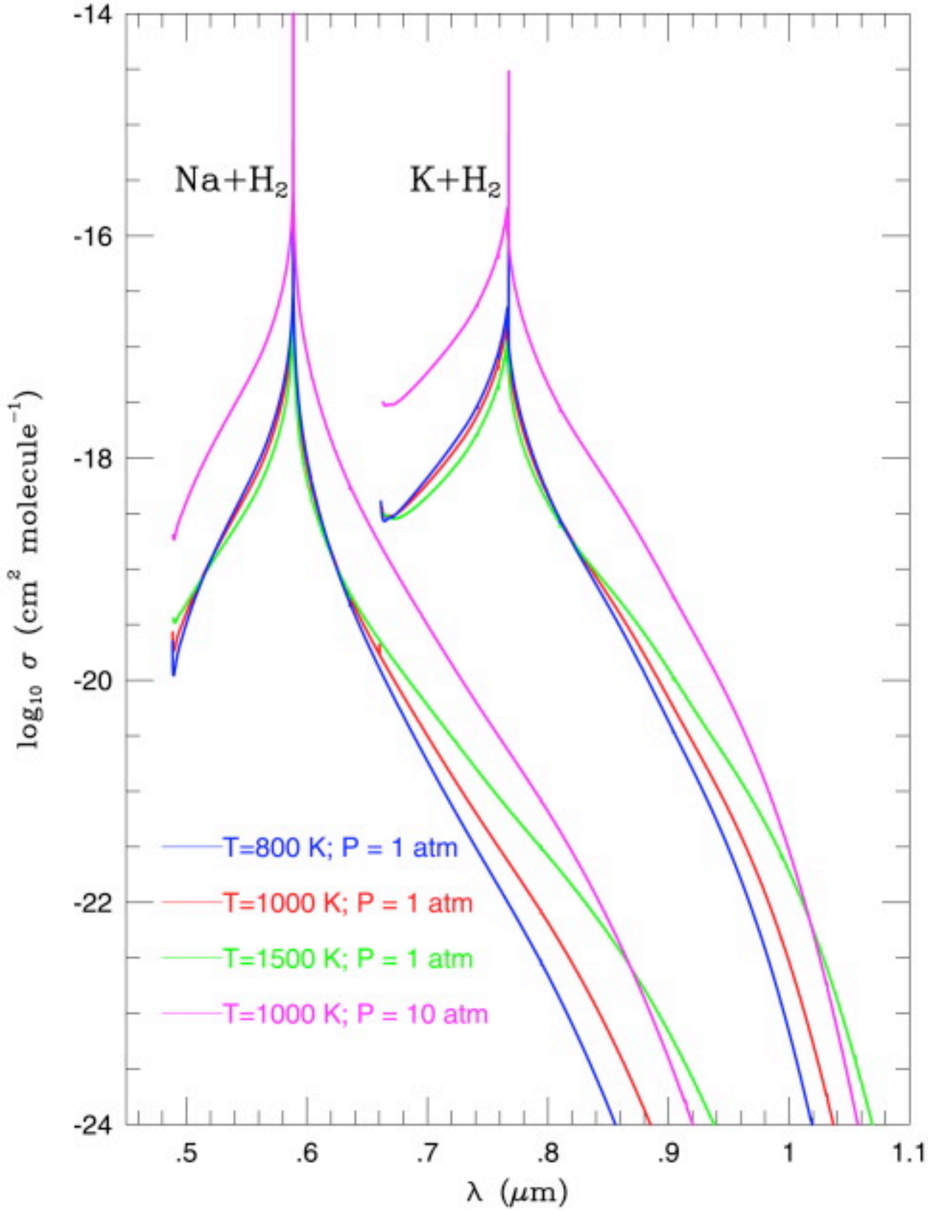
Leggett et al. (2007)



Burgasser, Burrows & Kirkpatrick (2006); see also Leggett et al. (2007)

Variations in spectra arise primarily in the strength of the 0.77 μm K I pressure-broadened wing and collision-induced H_2 absorption at ~2.1 μm

Arise primarily from changes in photospheric gas pressure in addition to relative molecular abundances ⇒ g & Z effects



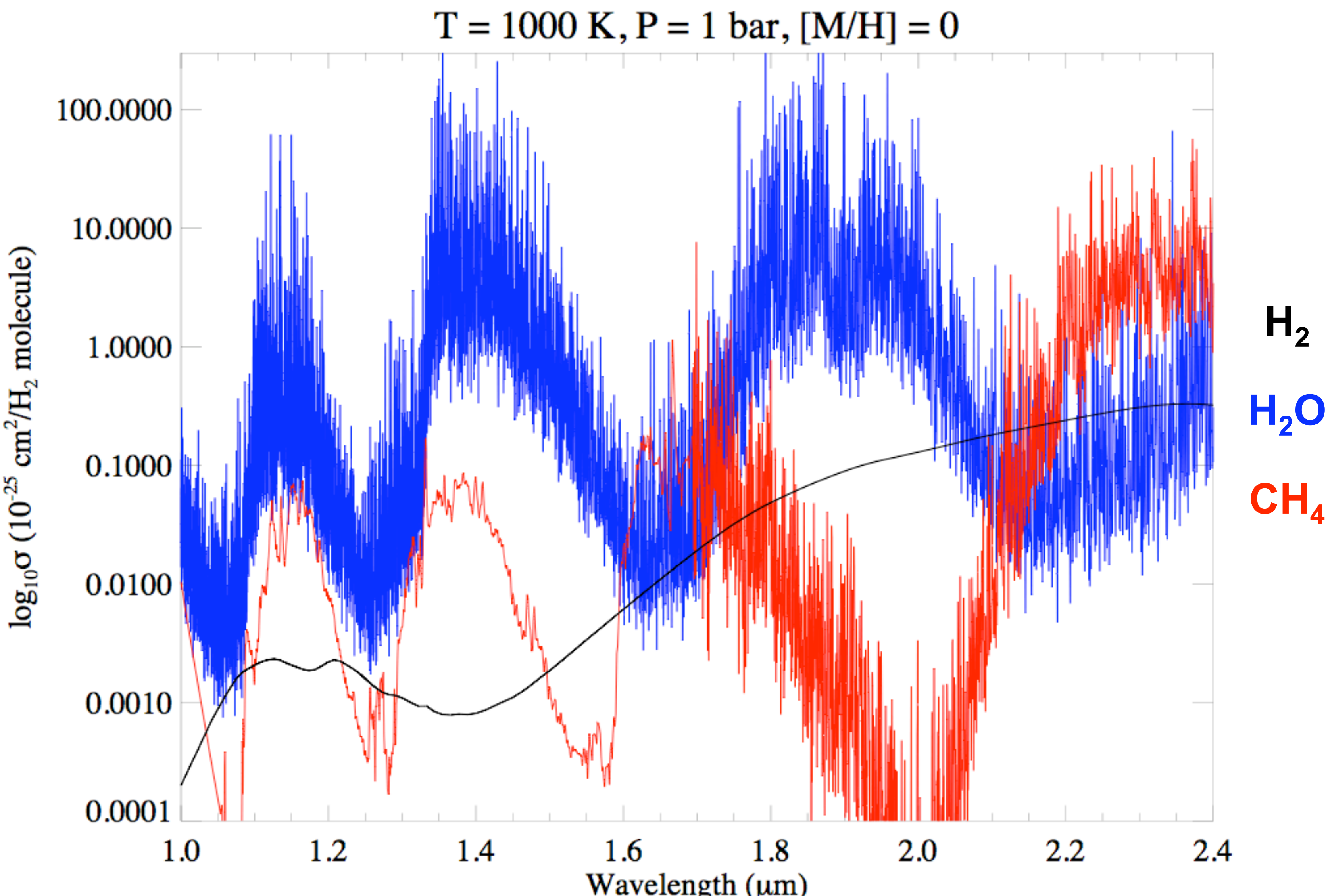
Burrows & Volobuyev (2003); see also Allard et al. (2003)

Na I & K I

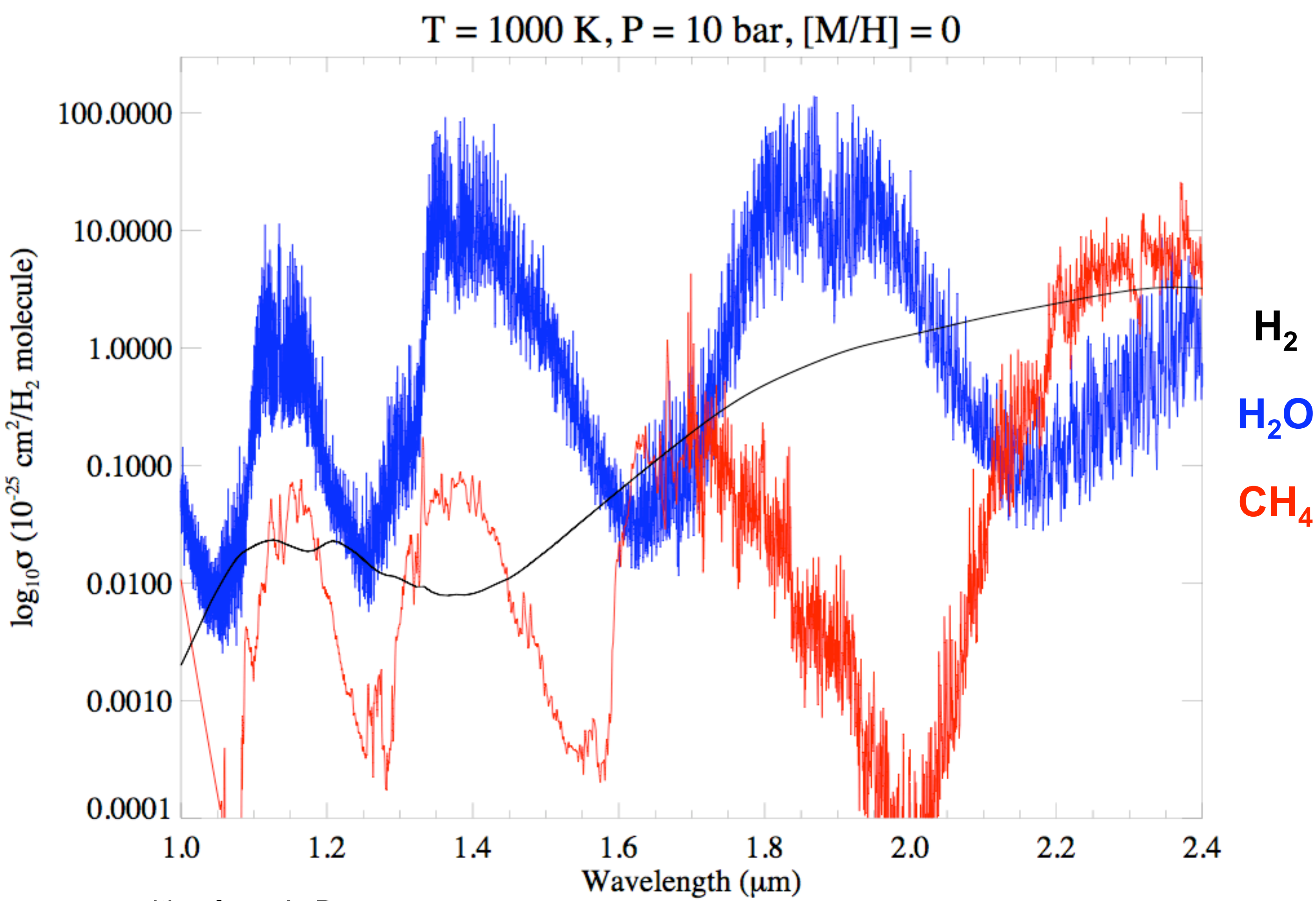
Pressure broadened wings of alkali lines are also influenced by increased gas pressure

Stronger opacity in core ⇒ steeper red wing

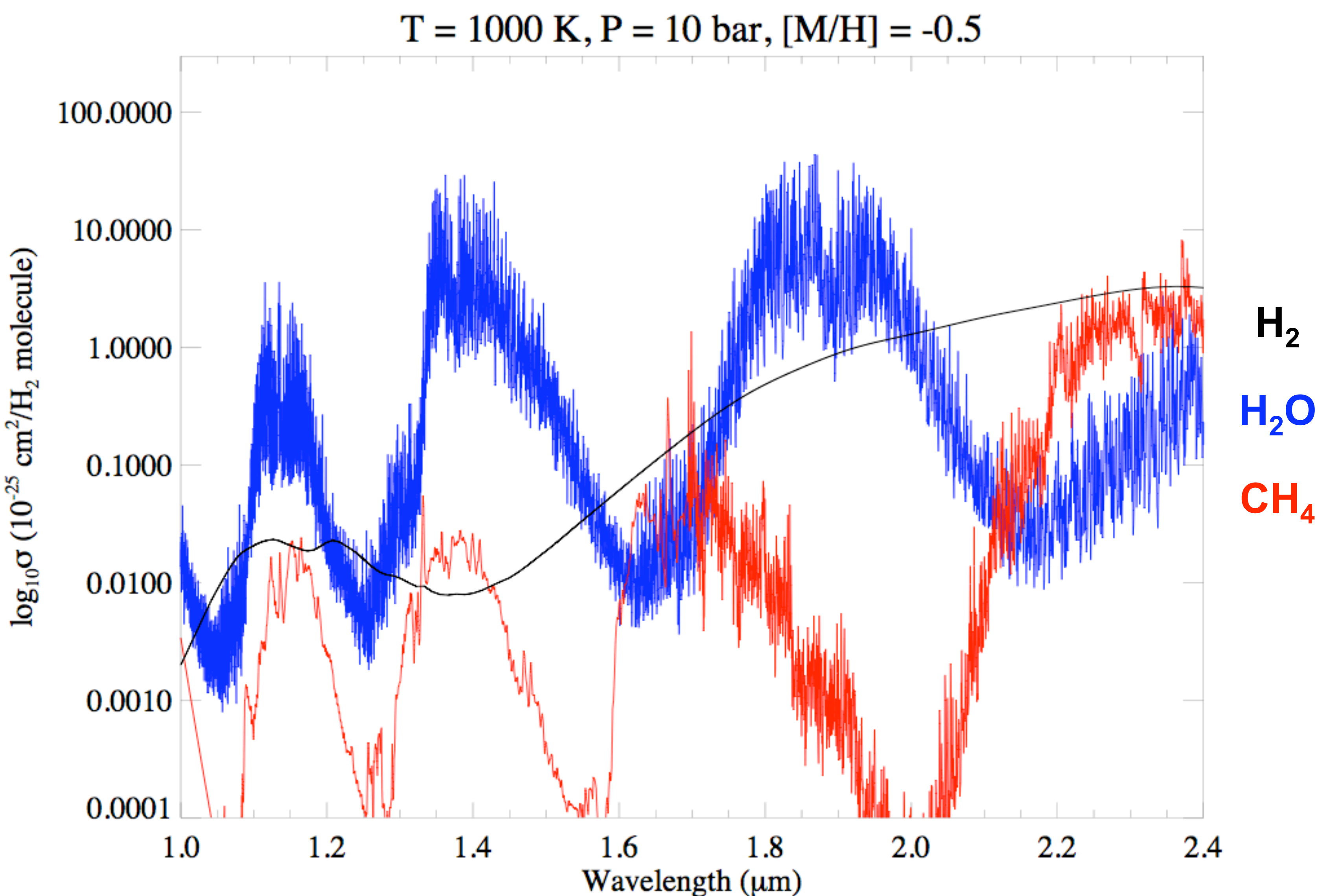
More in 069.05: Homeier et al. (next!)



opacities from A. Burrows



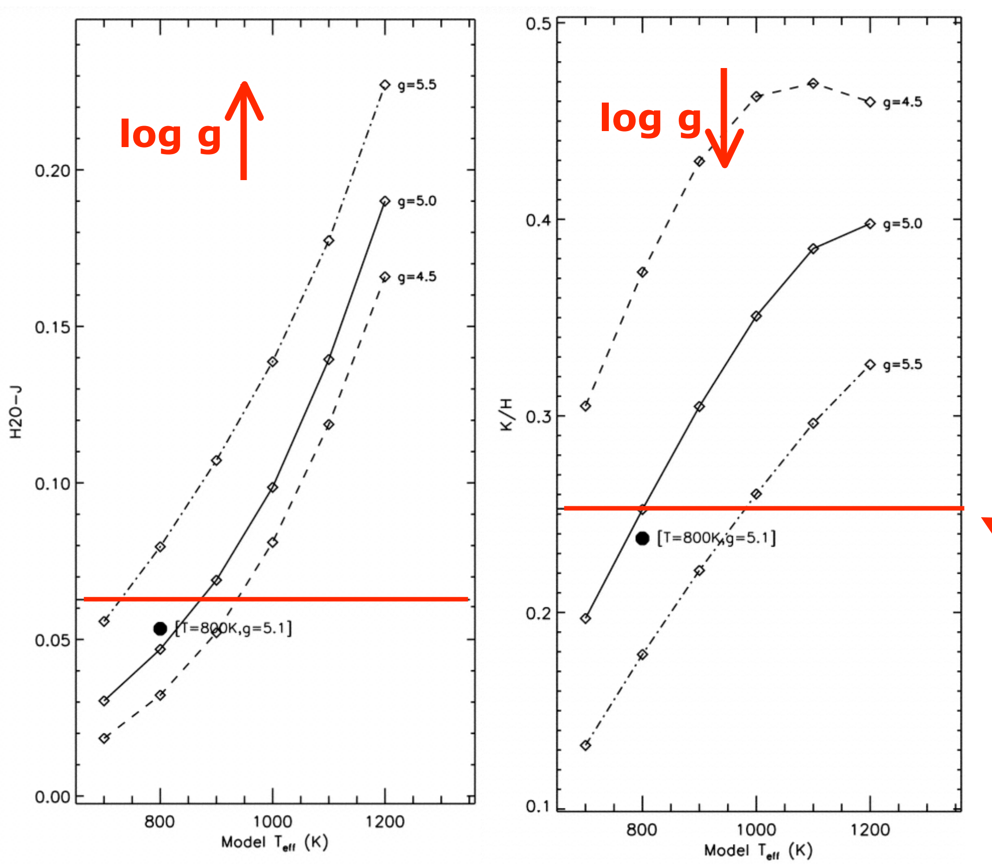
opacities from A. Burrows



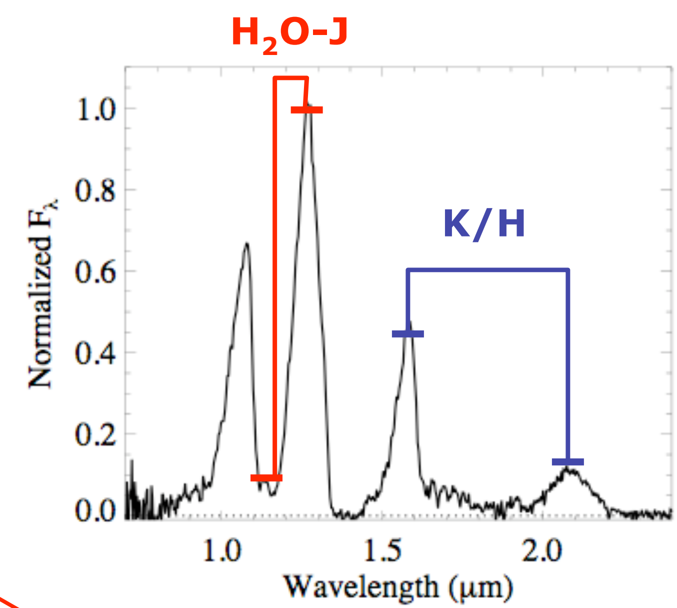
opacities from A. Burrows

The “BBK Method”

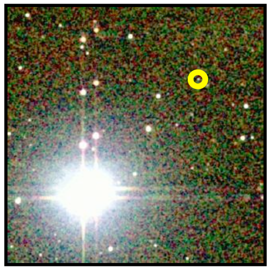
(Burgasser, Burrows & Kirkpatrick 2006)

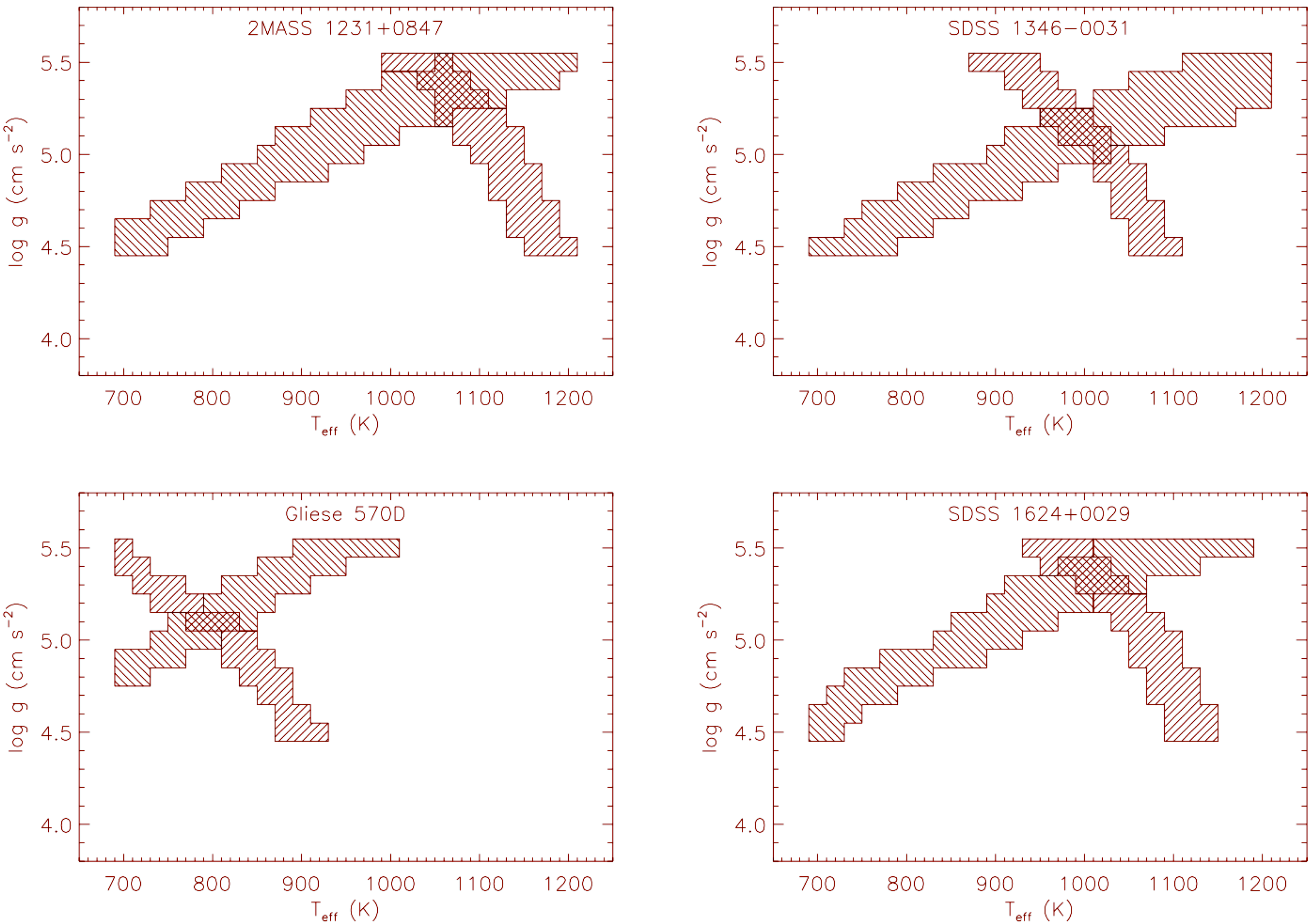


spectral models from Burrows et al. (2006)

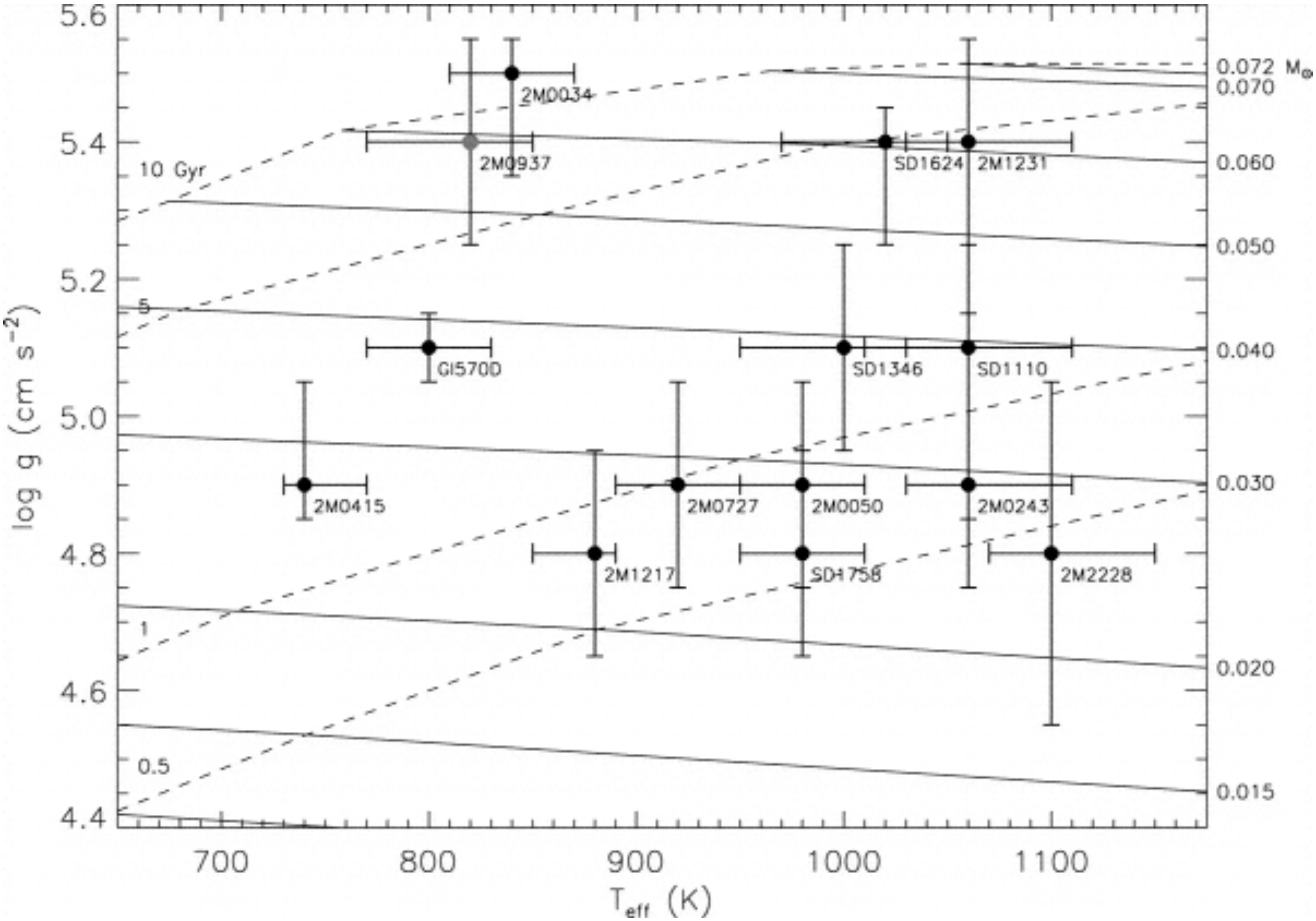


Calibrate to **Gliese 570D**, T7.5 companion to 2-5 Gyr, [M/H] = 0.09±0.04

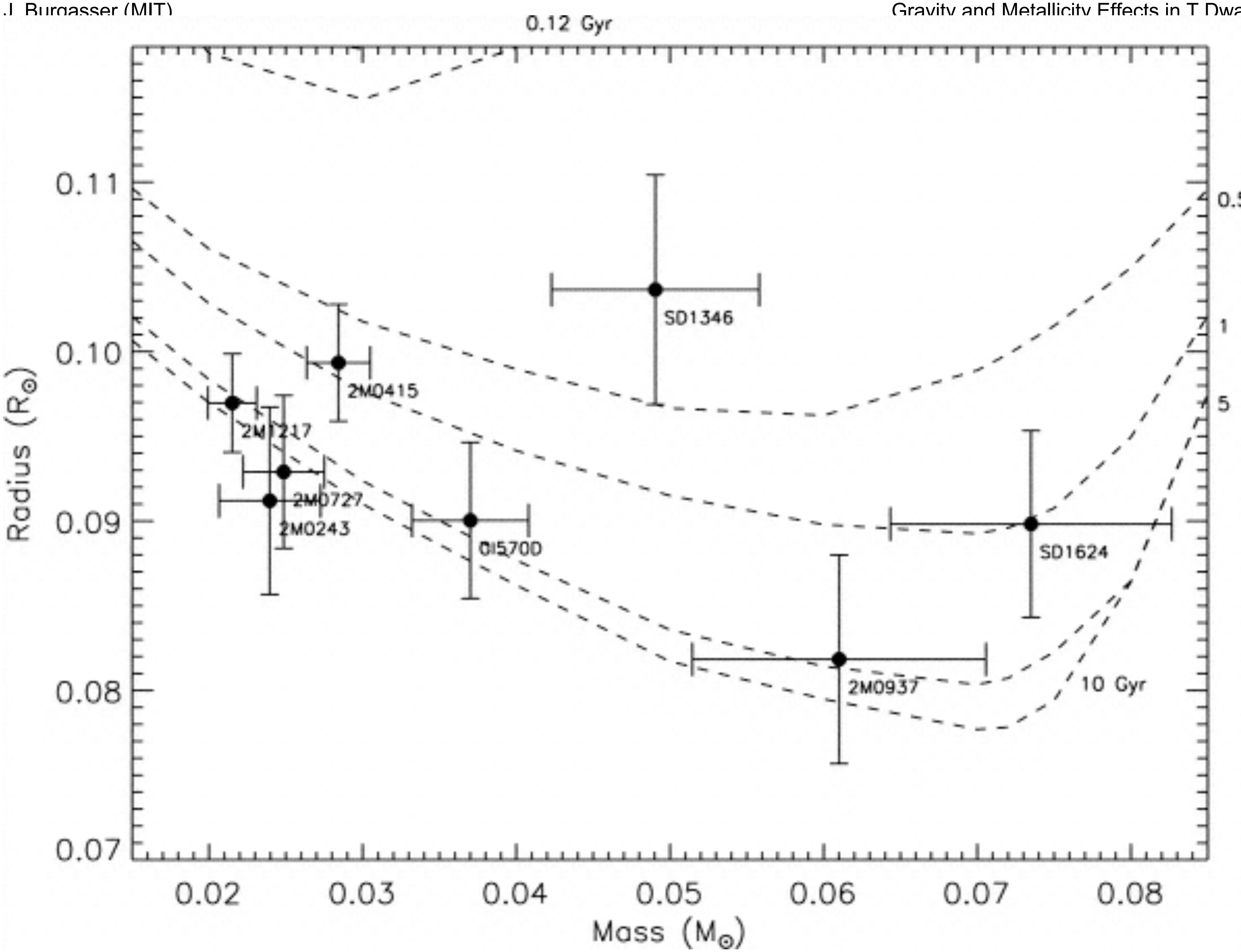




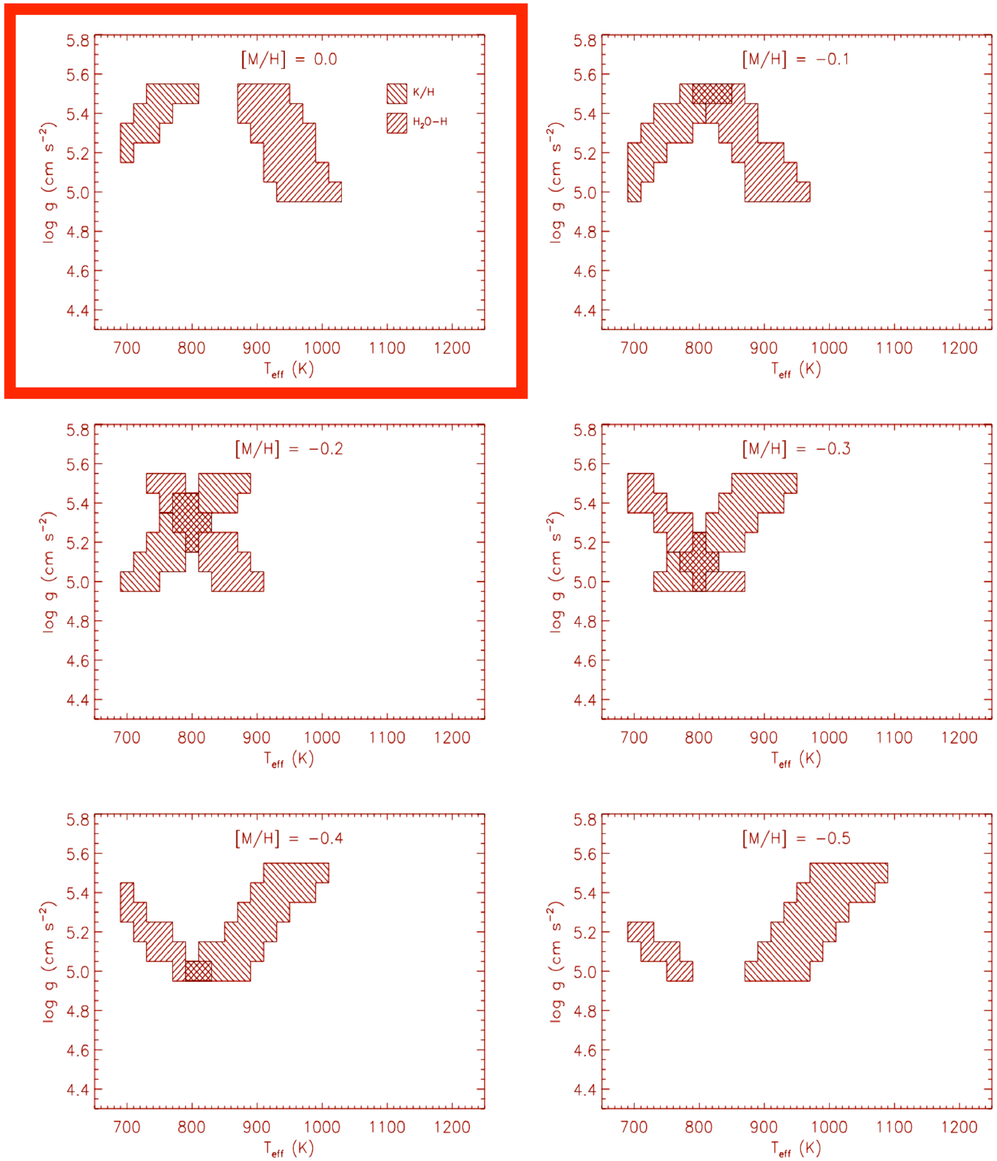
Burgasser, Burrows & Kirkpatrick (2006)



Burgasser, Burrows & Kirkpatrick (2006)



Burgasser, Burrows & Kirkpatrick (2006)

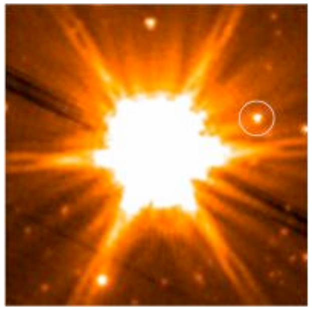


Burgasser, Burrows & Kirkpatrick (2006)

For 2MASS 0937+2931, solar metallicity models do not work.

Setting the metallicity to [M/H] = -0.4…-0.1 allows for constraints on T_{eff} and g for log g > 5.0 (age > 5 Gyr).

There is a degeneracy in gravity and metallicity diagnostics.



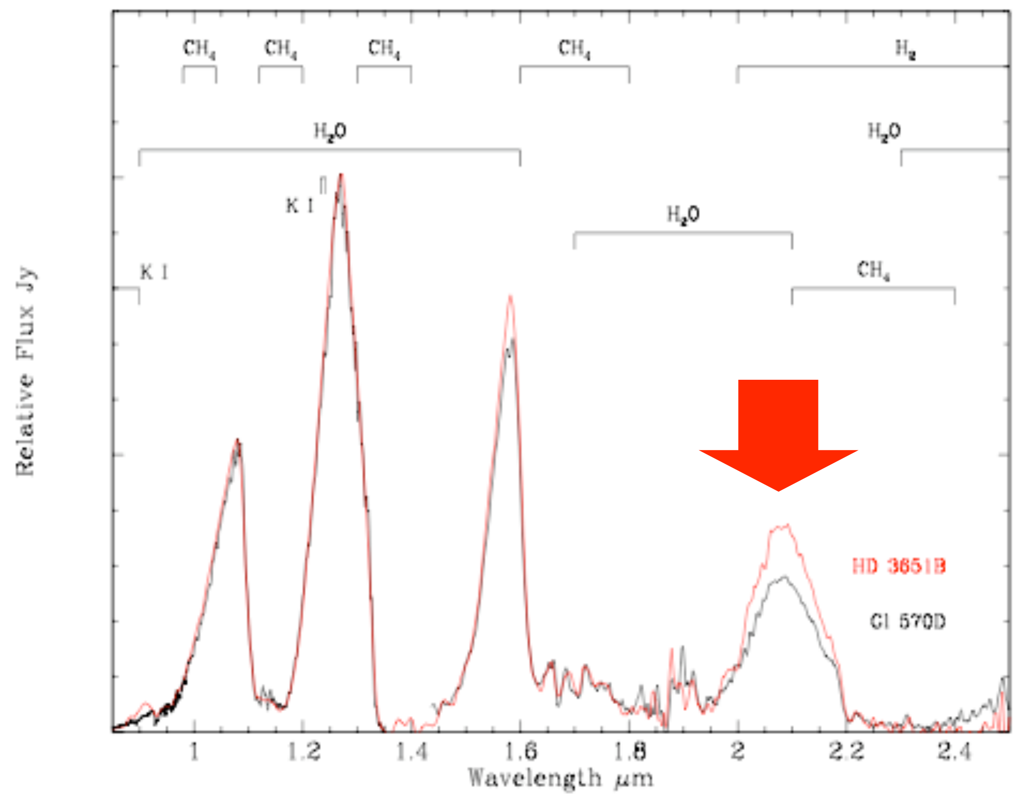
HD 3651B

(Mugrauer et al. 2006; Luhman et al. 2007)

T7.5 companion to nearby planet-hosting star - same SpT as Gliese 570D

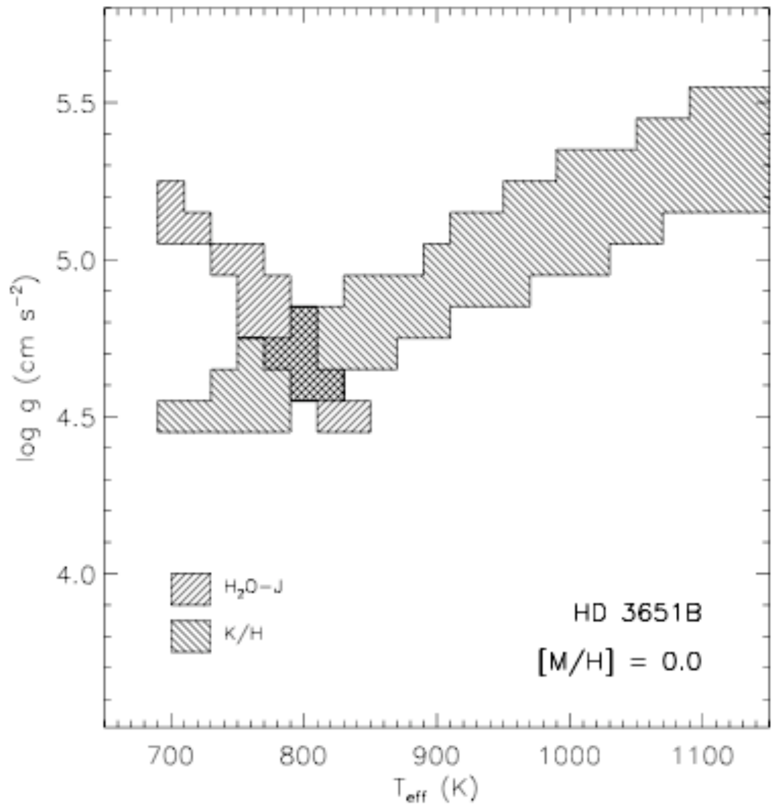
[M/H] = +0.12±0.04 (Santos et al. 2004) - more metal rich than Gliese 570A

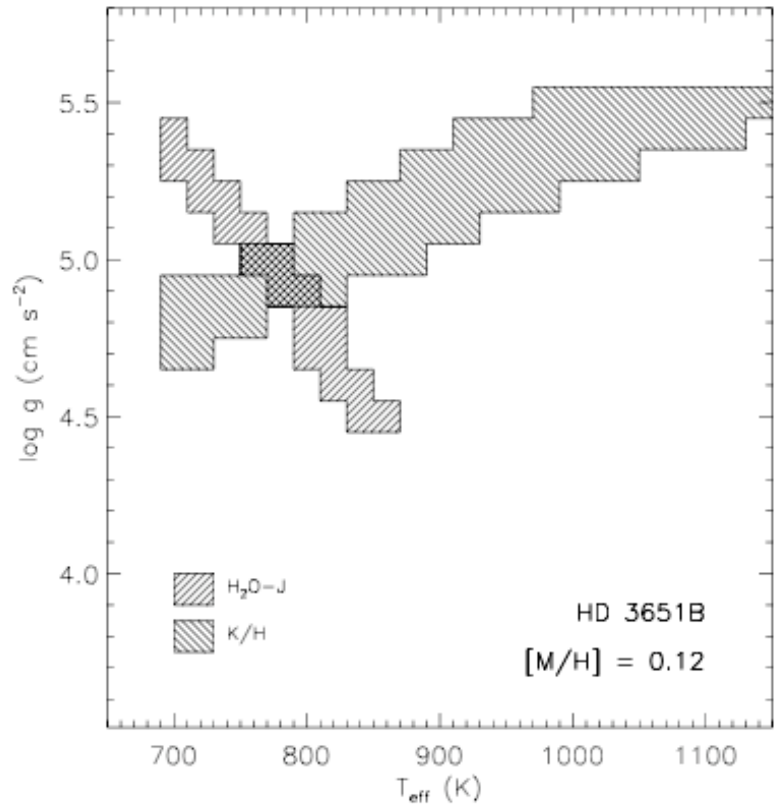
Age = 2-12 Gyr; ≈ 3x older than Gliese 570D (Liu et al. 2007)



Leggett et al. (2007); also see analyses by Burgasser (2007) and Liu, Leggett & Chiu (2007)

Burgasser (2007)



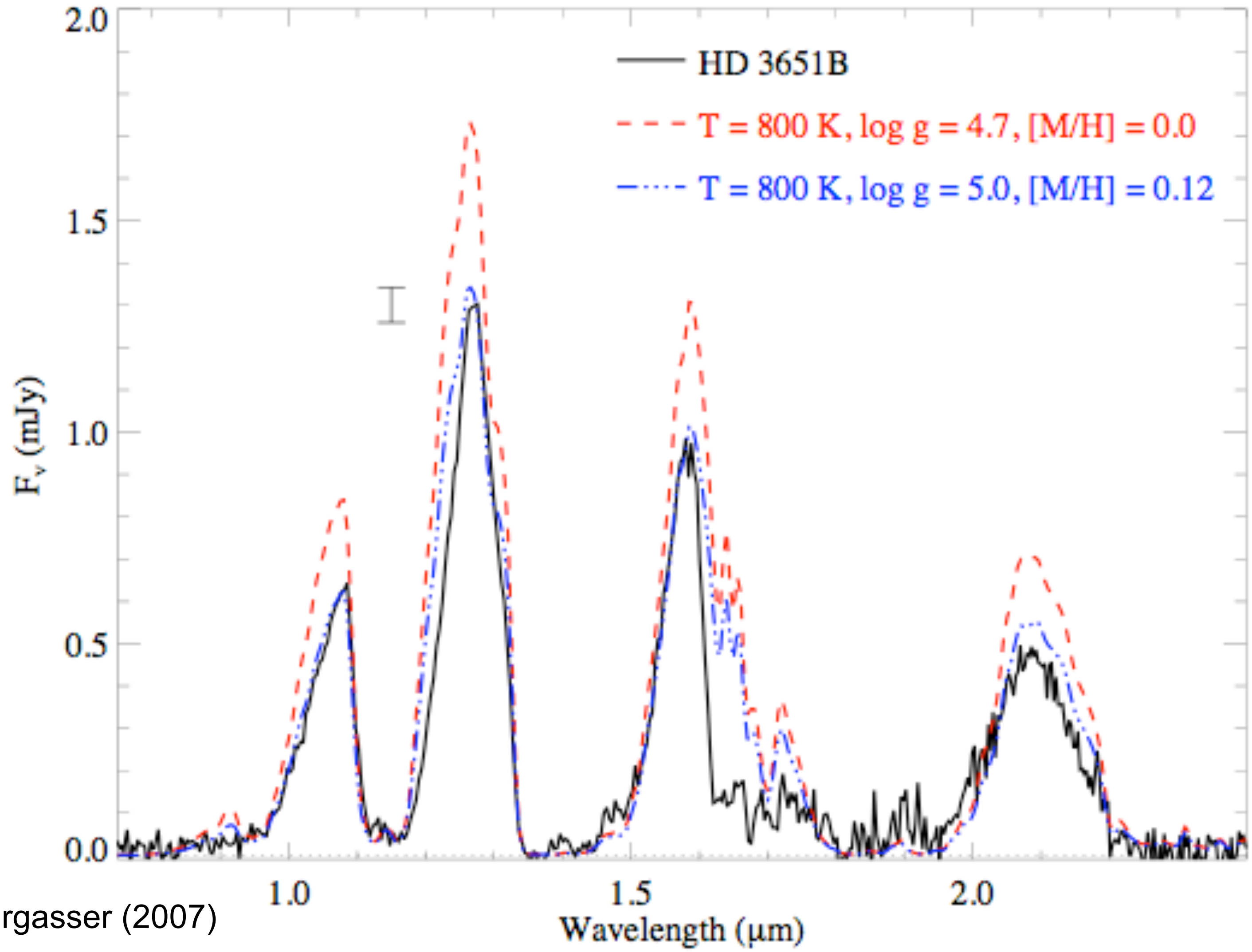


Assume [M/H] = 0:

T_{eff} = 810±30 K
log g = 4.7±0.2 cgs
M = 0.020±0.005 $M_{\odot}$
Age = 0.4-1.2 Gyr

Assume [M/H] = +0.12:

T_{eff} = 790±30 K
log g = 5.0±0.2 cgs
M = 0.032±0.008 $M_{\odot}$
Age = 1.0-3.7 Gyr



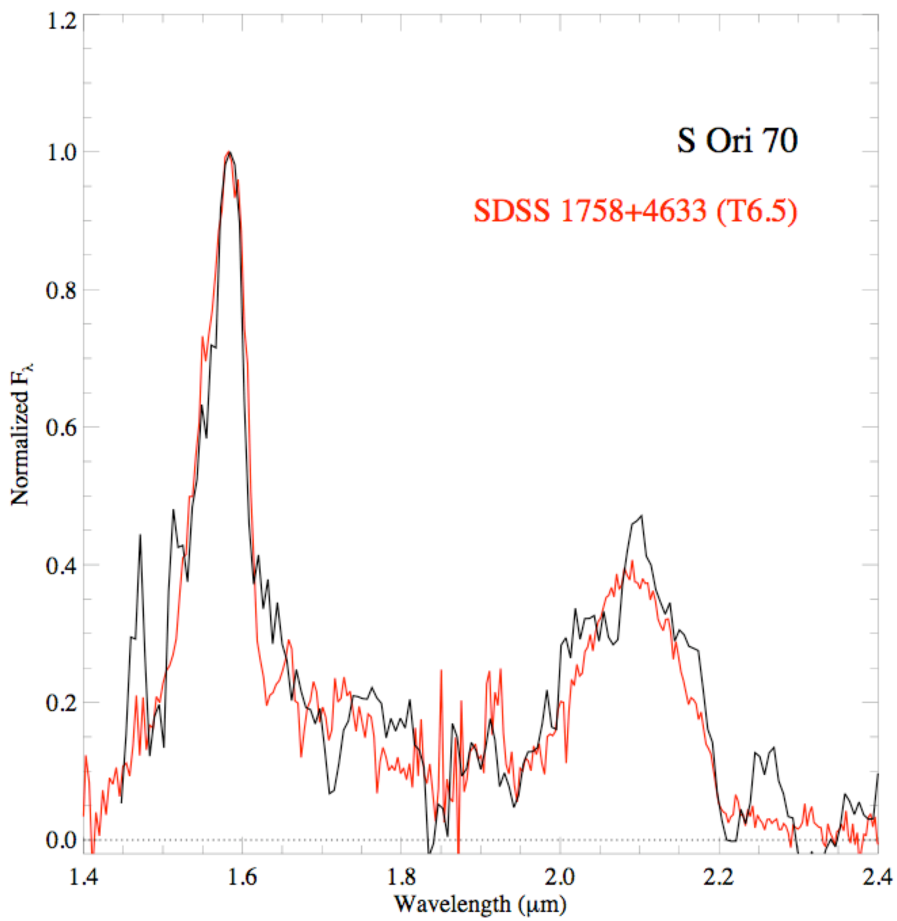
Burgasser (2007)

Examination of absolute fluxes can resolve gravity/metallicity degeneracy

Resolving Gravity/Metallicity Effects:

1. Measure absolute fluxes
2. Define (and calibrate) a third near-infrared diagnostic; e.g., K I wing, 1.25 μm K I lines
3. Identify spectral diagnostics at other wavelengths (optical ok, MIR not so good; Burgasser et al. 2003; Leggett et al. 2007)
4. Perfect spectral models (ongoing!)
5. Study "benchmark brown dwarfs"

low g T dwarfs: S Ori 70



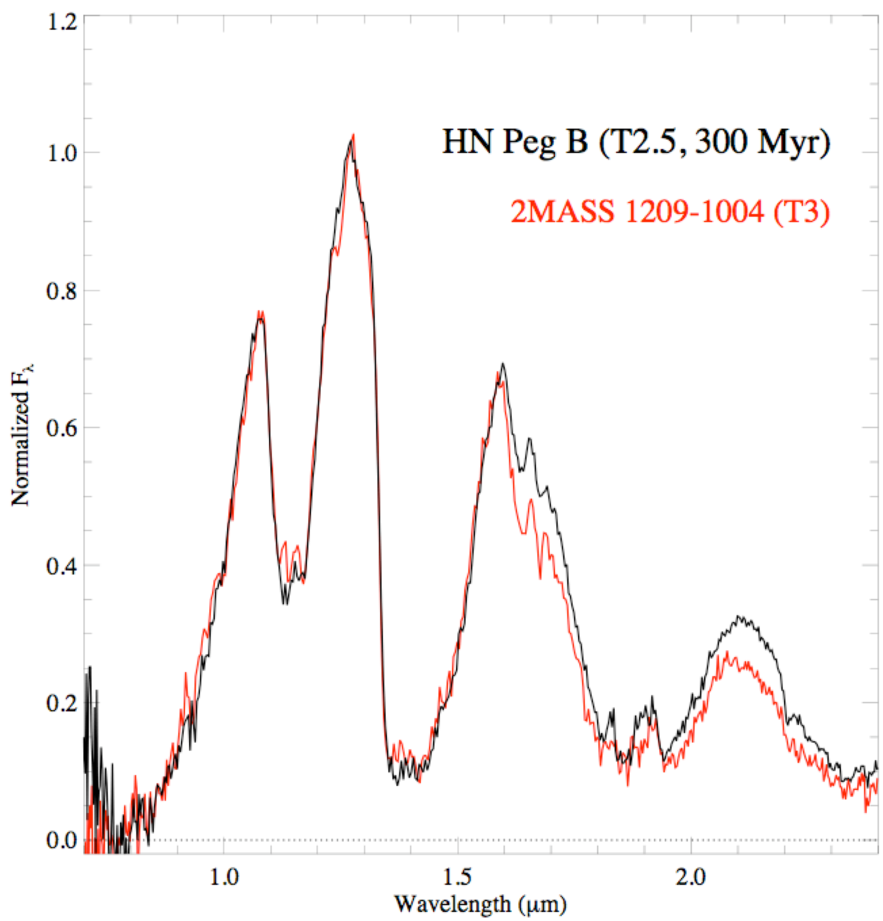
data from Zapatero Osorio (2002); Burgasser et al. (2006)

Faint T dwarf identified in direction of σ Orionis - potentially 1-8 Myr, 2-8 M_{Jup} (Zapatero Osorio et al. 2002; Martín & Zapatero Osorio 2003).

$(H-K)_{phot} = 0.64 \pm 0.25$ (Z02) ⇒ low surface gravity [but $(H-K)_{spec} = 0.25$]

Photometry, spectrum consistent with log g = 4.5-5.0 (cgs) field dwarf (Burgasser et al. 2004)

low g T dwarfs: HN Peg B



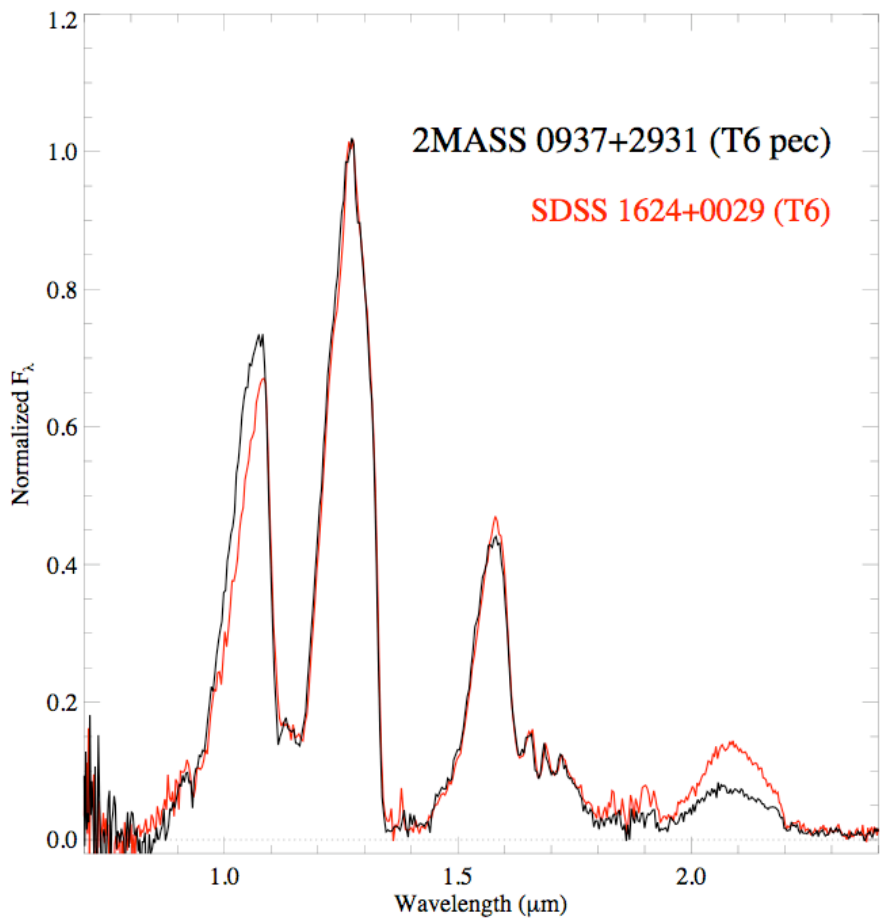
cf. Luhman et al. (2007)

T dwarf companion to 100-500 Myr HN Peg A (Luhman et al. 2007).

Redder J-K colors, weak 1.25 μm K I lines suggest low surface gravity effects

Empirical comparisons difficult - condensate clouds and high rate of unresolved multiplicity amongst early-type T dwarfs (Burgasser et al. 2006; Liu et al. 2006)

low Z T dwarfs: T subdwarfs?

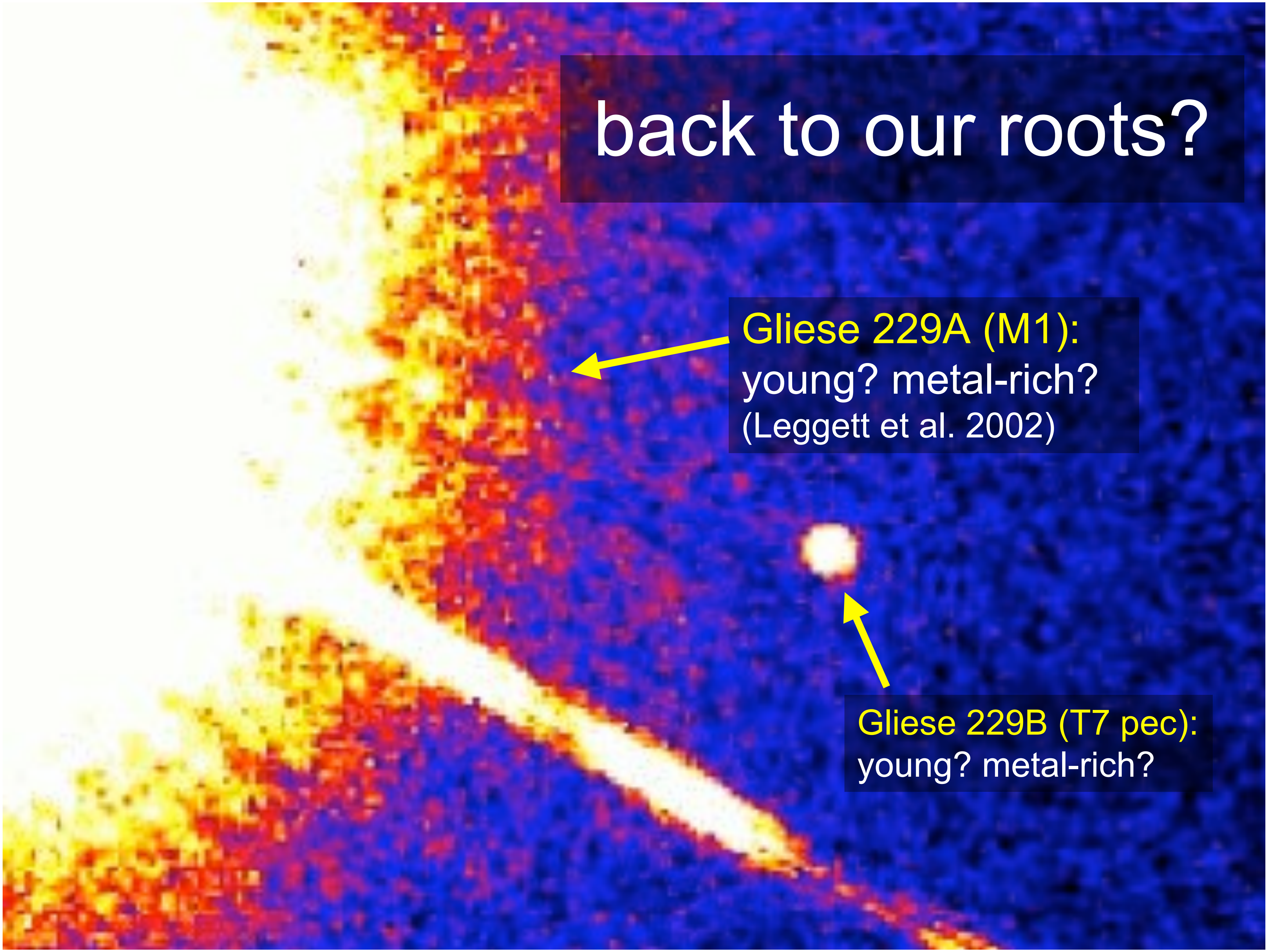


Most metal-poor T dwarf 2MASS 0937+2931 has *estimated* [M/H] = -0.4…-0.1

c.f. sdM: [M/H] = -1.2±0.3; esdM: [M/H] = -2.0±0.5 (Gizis 1997; Gizis & Reid 1997)

Suggestion: d/sdT6 subtype (Burgasser, Cruz & Kirkpatrick 2006)

see poster 017.07: Kirkpatrick et al.


back to our roots?
Gliese 229A (M1):
young? metal-rich?
(Leggett et al. 2002)
Gliese 229B (T7 pec):
young? metal-rich?

conclusions

- g & Z effects can be discerned in the low resolution NIR spectra of mid- and late-type T dwarfs
- features are associated with the H_2 (K-band) and red wing of the K I doublet (Y-band)
- fine gradations in both g & Z can be discerned
- calibration of g & Z effects is possible using T dwarf companions to main sequence stars
- not taking into account both g AND Z effects can lead to incorrect conclusions

for further reading…

- Burgasser, Burrows & Kirkpatrick (2006), "A Method for Determining the Physical Properties of the Coldest Known Brown Dwarfs", ApJ, 639, 1095-1113
- Burrows, Sudarsky & Hubeny (2006), "L and T Dwarf Models and the L to T Transition", ApJ, 640, 1063-1077
- Liebert & Burgasser (2007), "On the Nature of the Unique Hα-emitting T Dwarf 2MASS J12373919+6526148", ApJ, 655, 522-527
- Saumon et al. (2007), "Physical Parameters of Two Very Cool T Dwarfs", ApJ, 656, 1136-1149
- Burgasser (2007), "The Physical Properties of HD 3651B: An Extrasolar Nemesis?" ApJ, 658, 617-621
- Liu, Leggett & Chiu (2007), "The Late-T Dwarf Companion to the Exoplanet Host Star HD 3651: A New Benchmark for Gravity and Metallicity Effects in Ultracool Spectra", ApJ, 660, 1507-1516
- Leggett et al. (2007), "Physical and Spectral Characteristics of the T8 and Later-Type Dwarfs", ApJ, in press (astro-ph/0705.2602)