Model atmospheres of cool dwarf stars

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Motivation/Goals

- understand atmospheres/spectra of M/L/T dwarfs
- parameter determination from observations
- Method: detailed numerical simulations
  - equation of state
  - radiative transfer (incl. scattering)
  - "full" atomic/molecular line database
  - dust formation/destruction model

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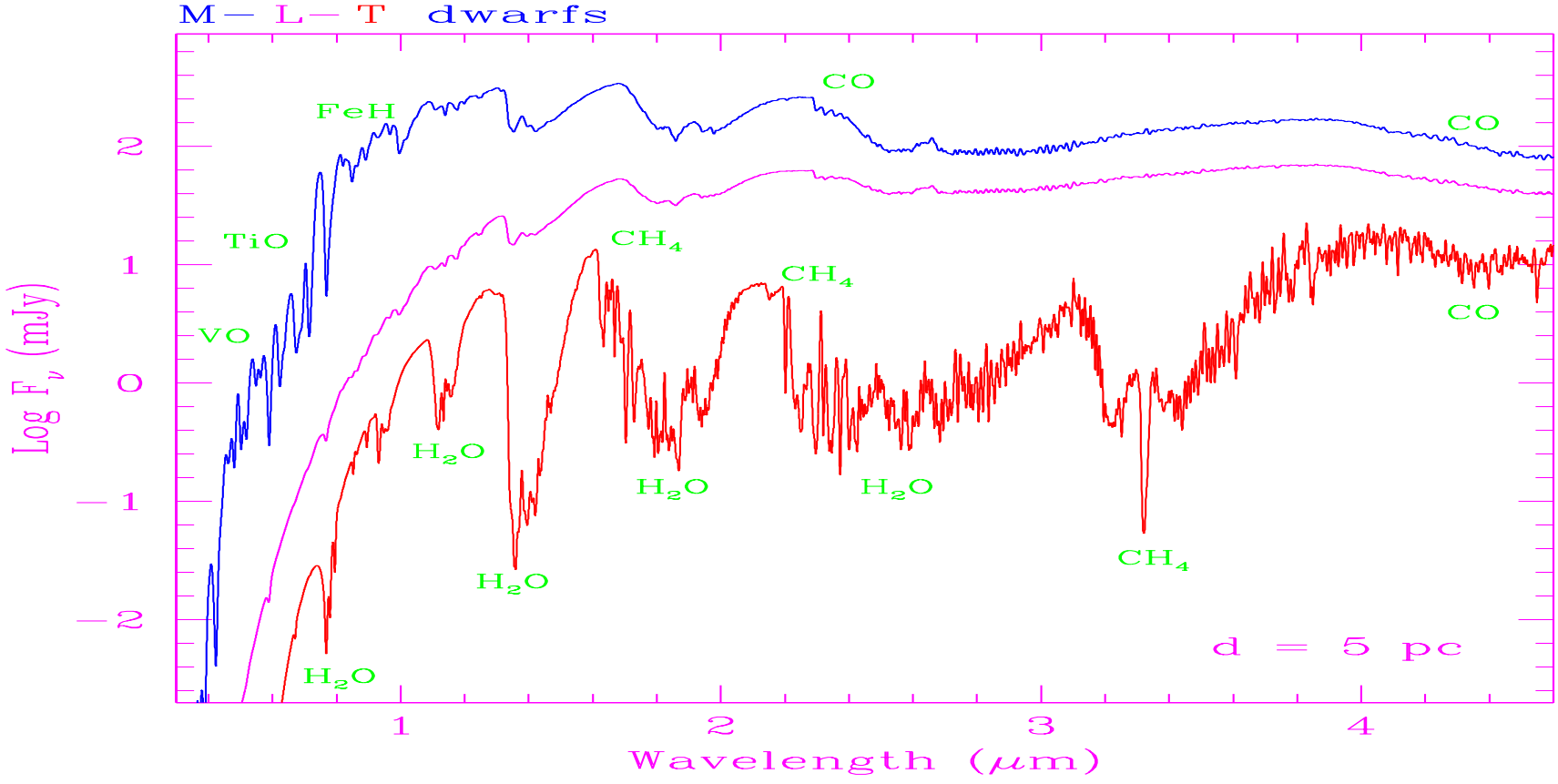
Results: Cool Atmospheres

- Trends (Allard et al, 2001)
  - $T_{\rm eff} = 2500, 1800, 1000\,{\rm K}$
  - age 5Gy (Chabrier et al, 2000)



PHOENIX version 16

- integrated /1D and /3D versions
- same micro-physics from 1D to 3D
- new EOS (ACES)
- dust formation/destruction $\rightarrow$
  DRIFT (Helling & Woitke)
- terrestrial conditions & planets (earth)
- cool to hot stars
- Novae, supernovae
- massively parallel
  - multi-stage domain decomposition
  - MPI
  - weak & strong scaling verified to 4k+ processes

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Dust formation/destruction

- directly couple DRIFT (Helling & Woitke) dust model to PHOENIX model atmospheres
  - PHOENIX $\rightarrow$ provides atmosphere structure $(T, P_g, \ldots)$
  - DRIFT $\rightarrow$ compute dust formation/destruction (cloud deck)
  - $\rightarrow$ feedback to PHOENIX
  - $\rightarrow$ new atmosphere structure
  - iterate to convergence

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DRIFT dust mode

- Helling & Woitke (2003, 2006)
- stationary solution
- nucleation rates for $(TiO_2)_N$ seeds
- 7 most important solids used (TiO_2, Al_2O_3, Fe, SiO_2, MgO, $MgSiO_3$, Mg_2SiO_2)
- mixing by convection + overshooting
- grain size distribution approximated

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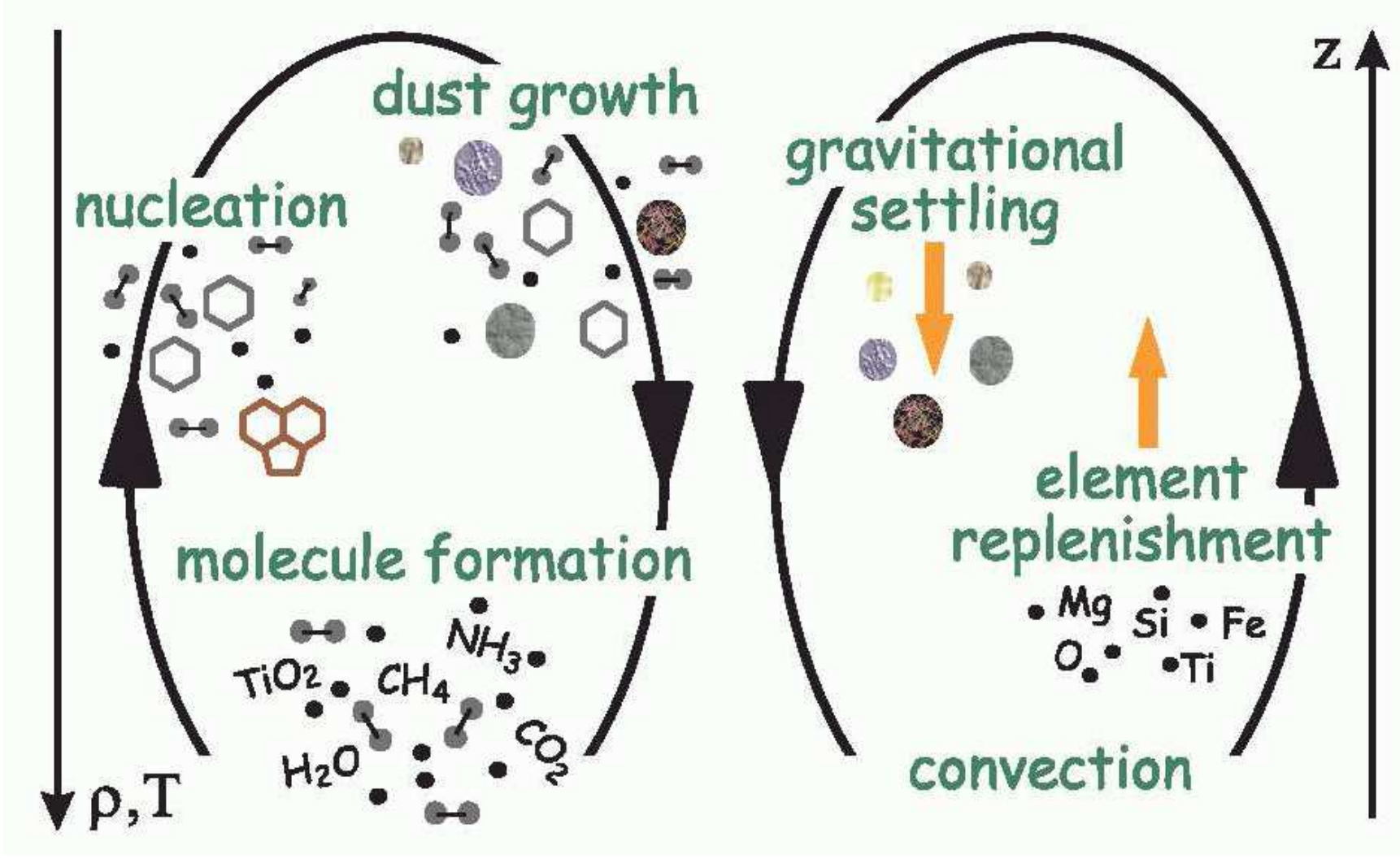
DRIFT dust mode



- Helling et al (2001)

DRIFT-PHOENIX models

- location of convection zone crucial for dust formation!
- considering feedback dust formation vs. atmosphere structure crucial
- cloud deck depends on model parameters

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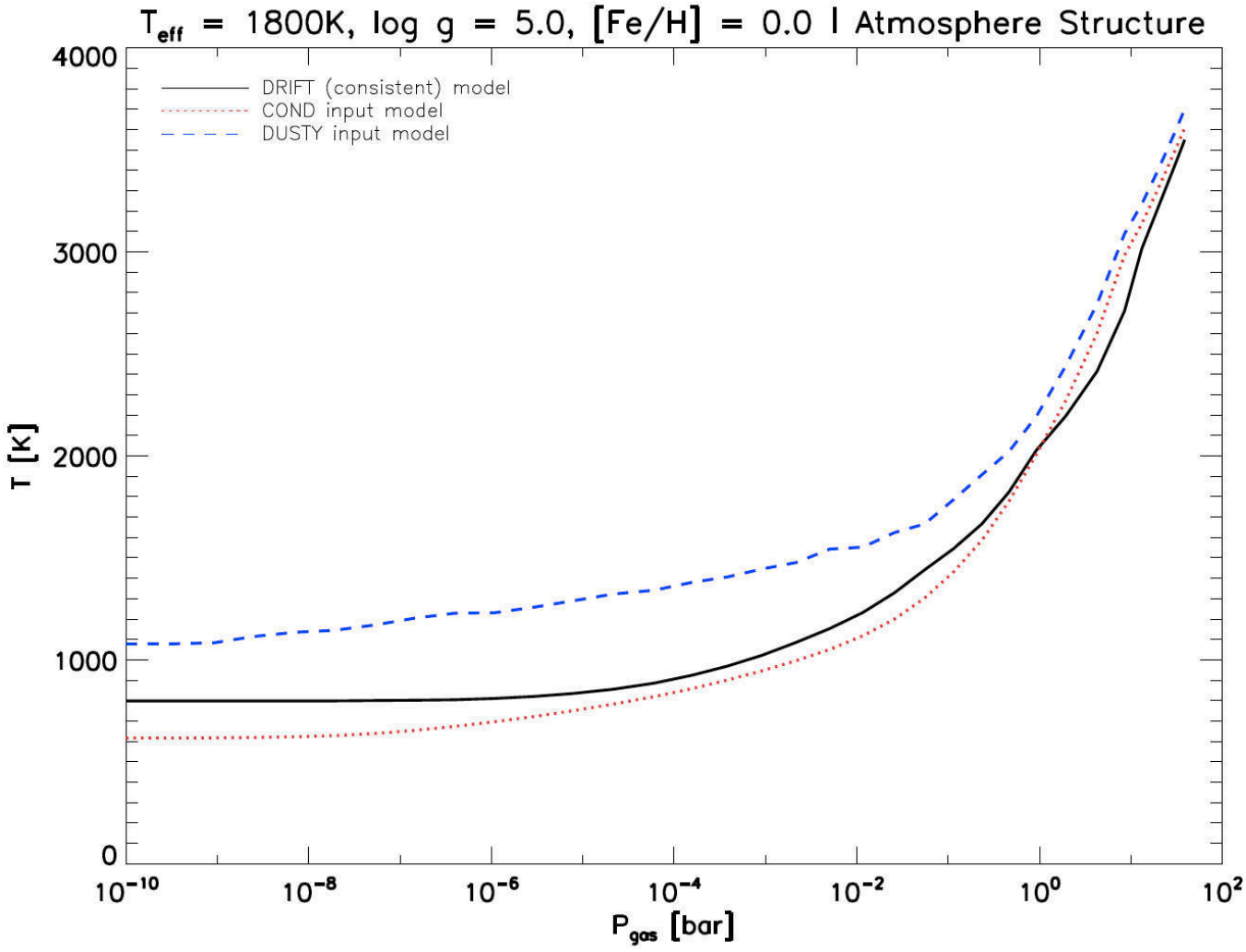
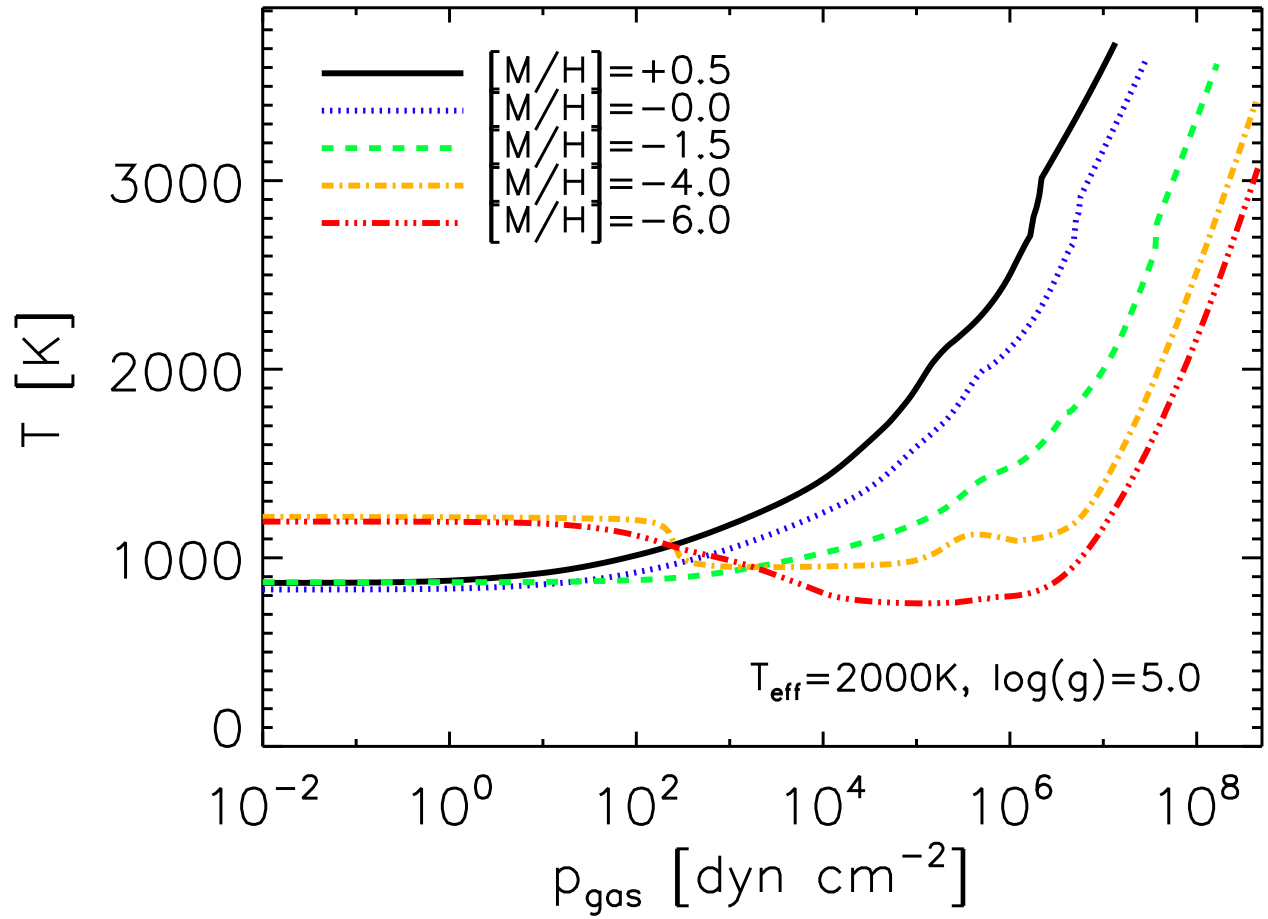
atmosphere structure feedback



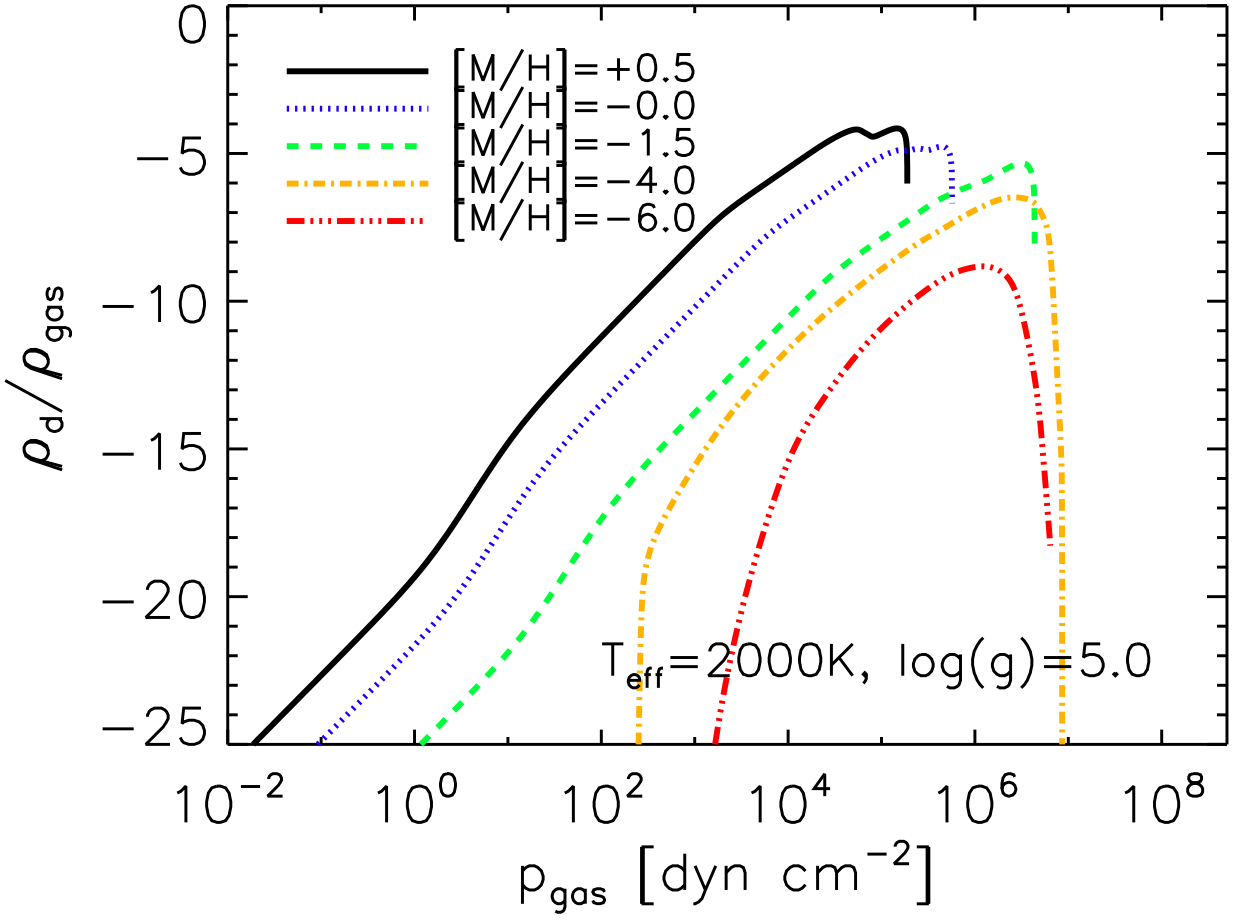
Dissertation M. Dehn (2007)

structures for different (M/H)



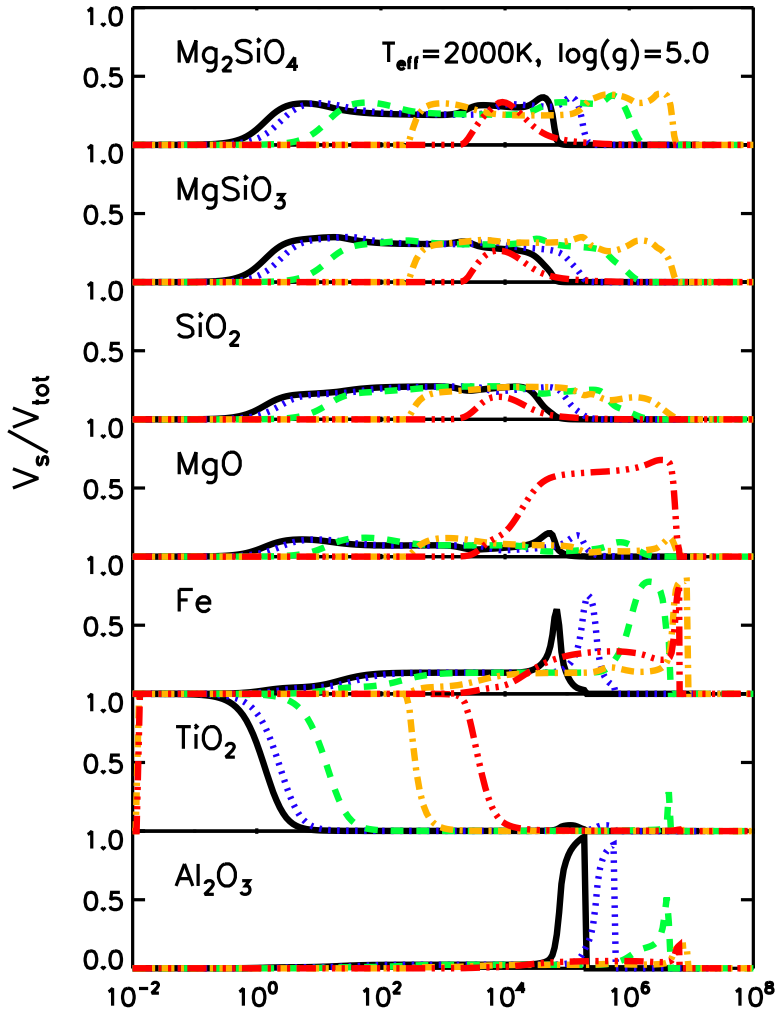
Witte et al (2009)

dust to gas mass ratios



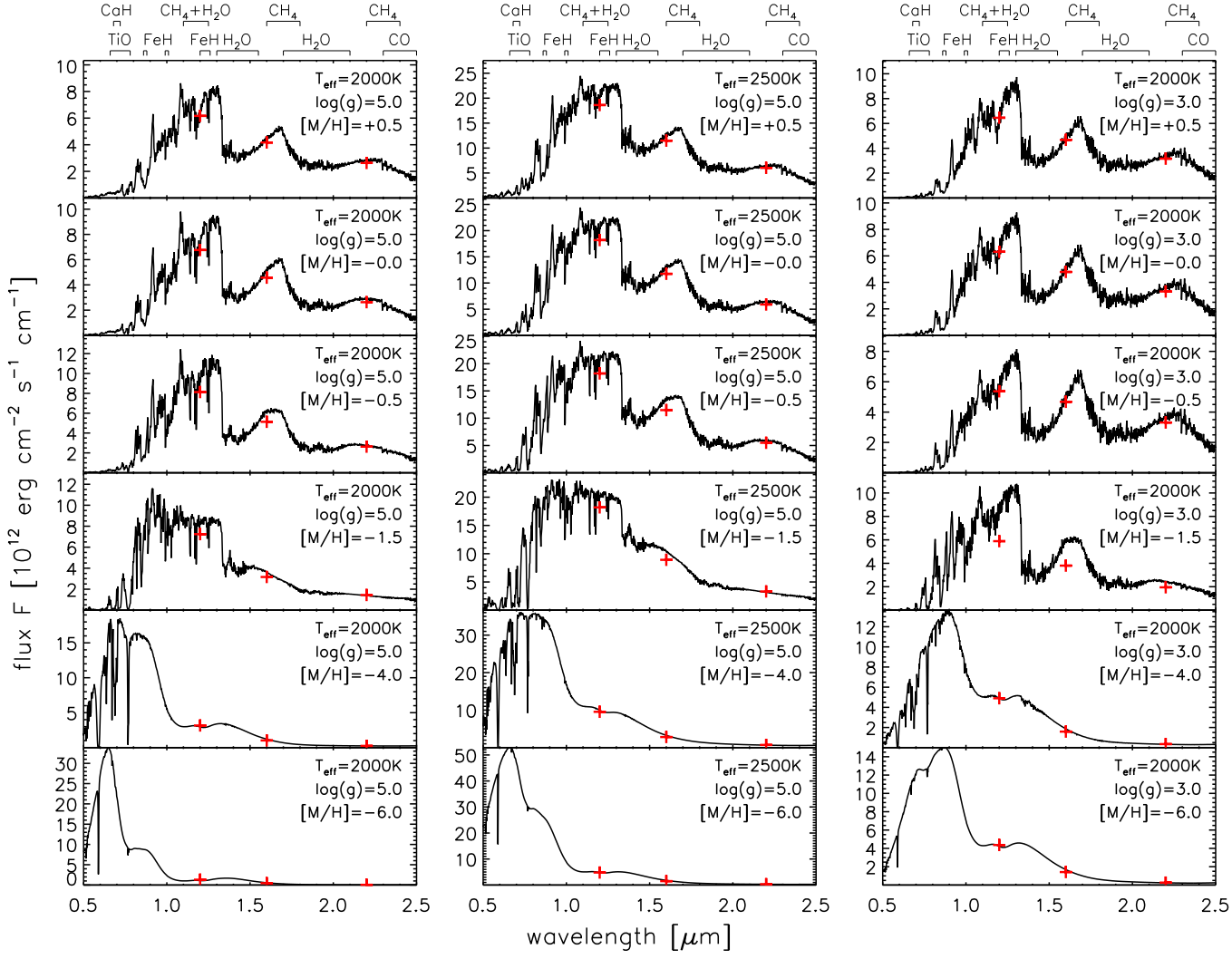
Witte et al (2009)

dust volume fractions



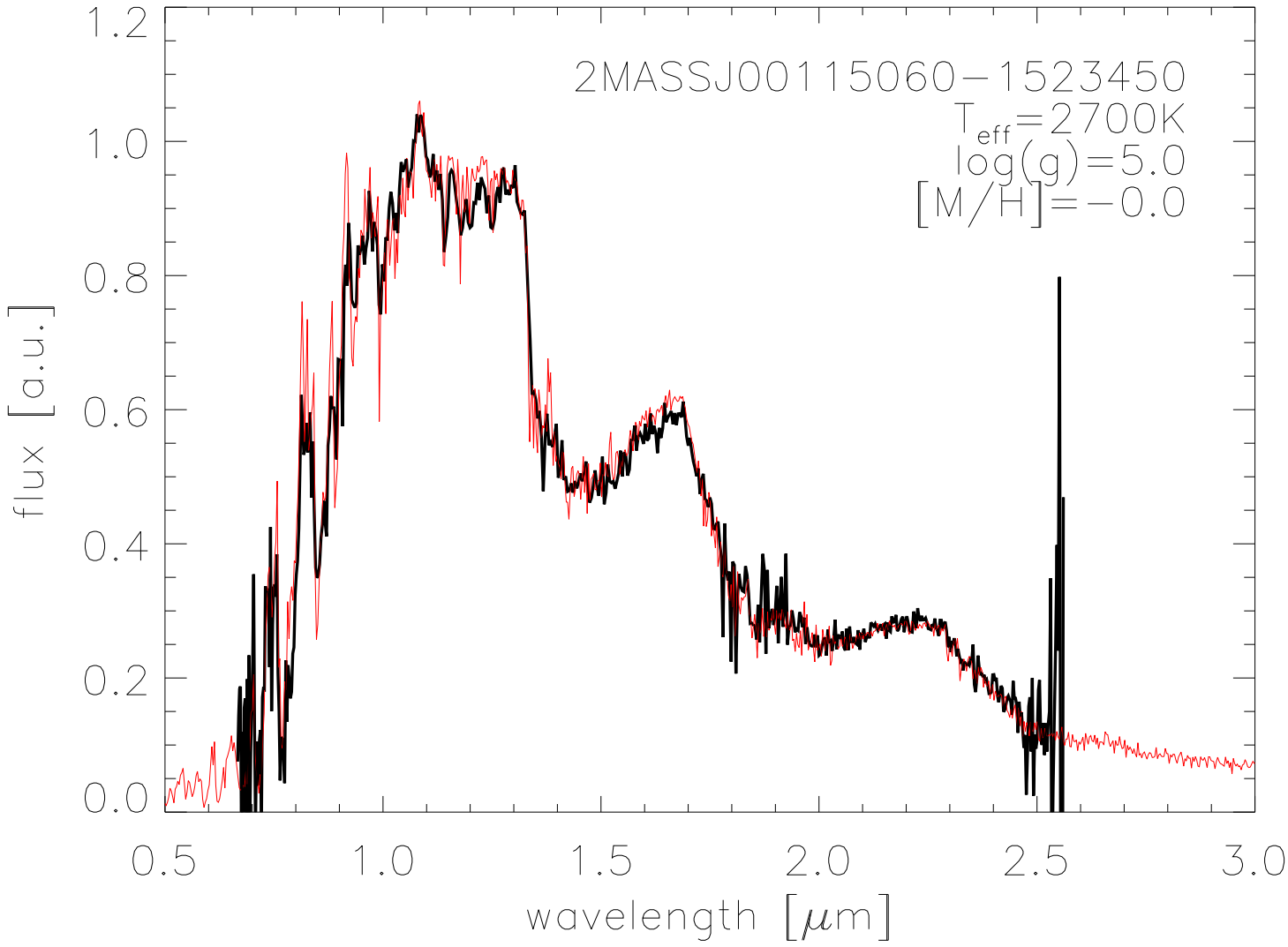
Witte et al (2009)

synthetic spectra



- Witte et al (2009)

Application: good fits



Witte et al, in preparation

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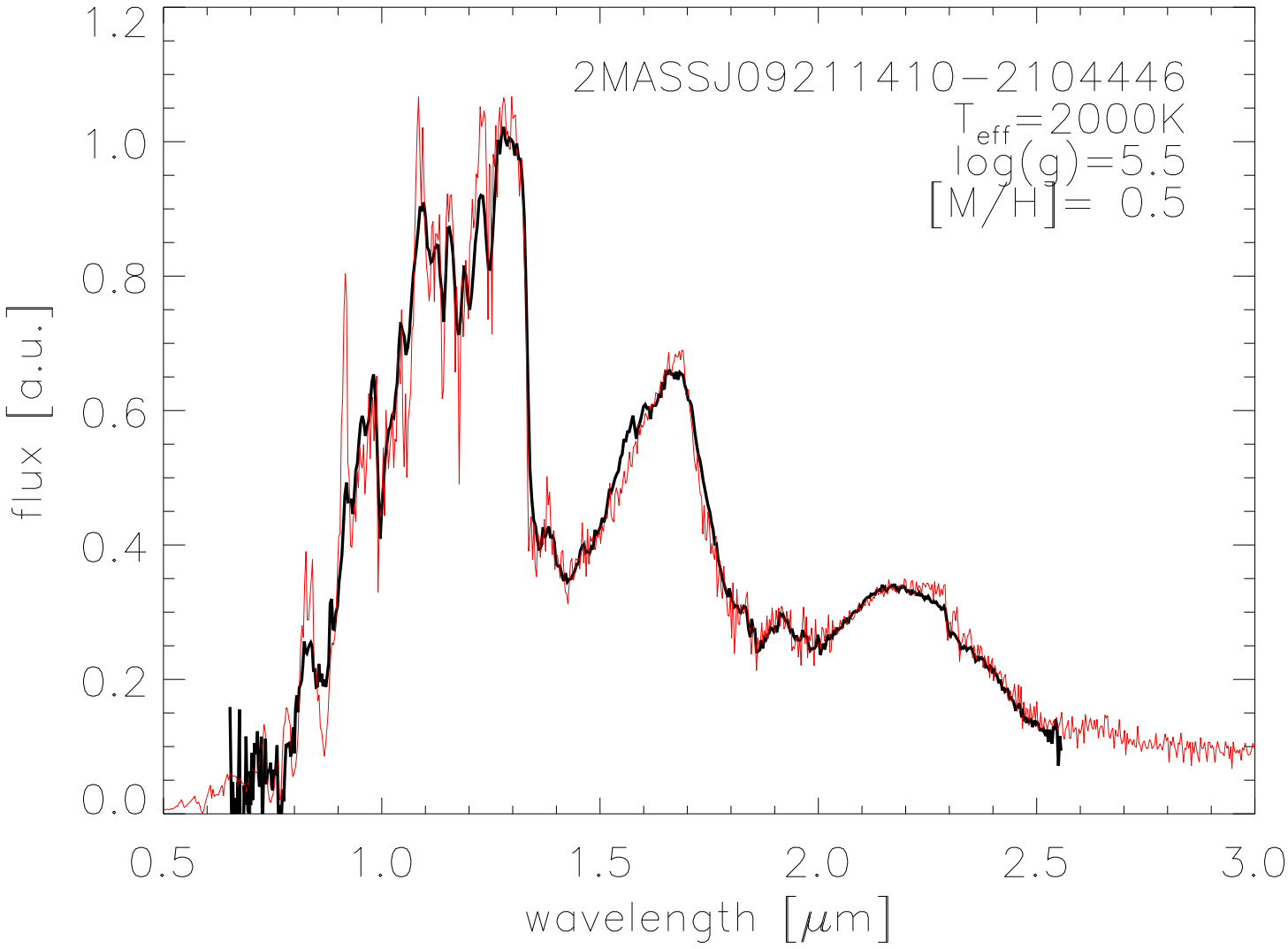

Witte et al, in preparation

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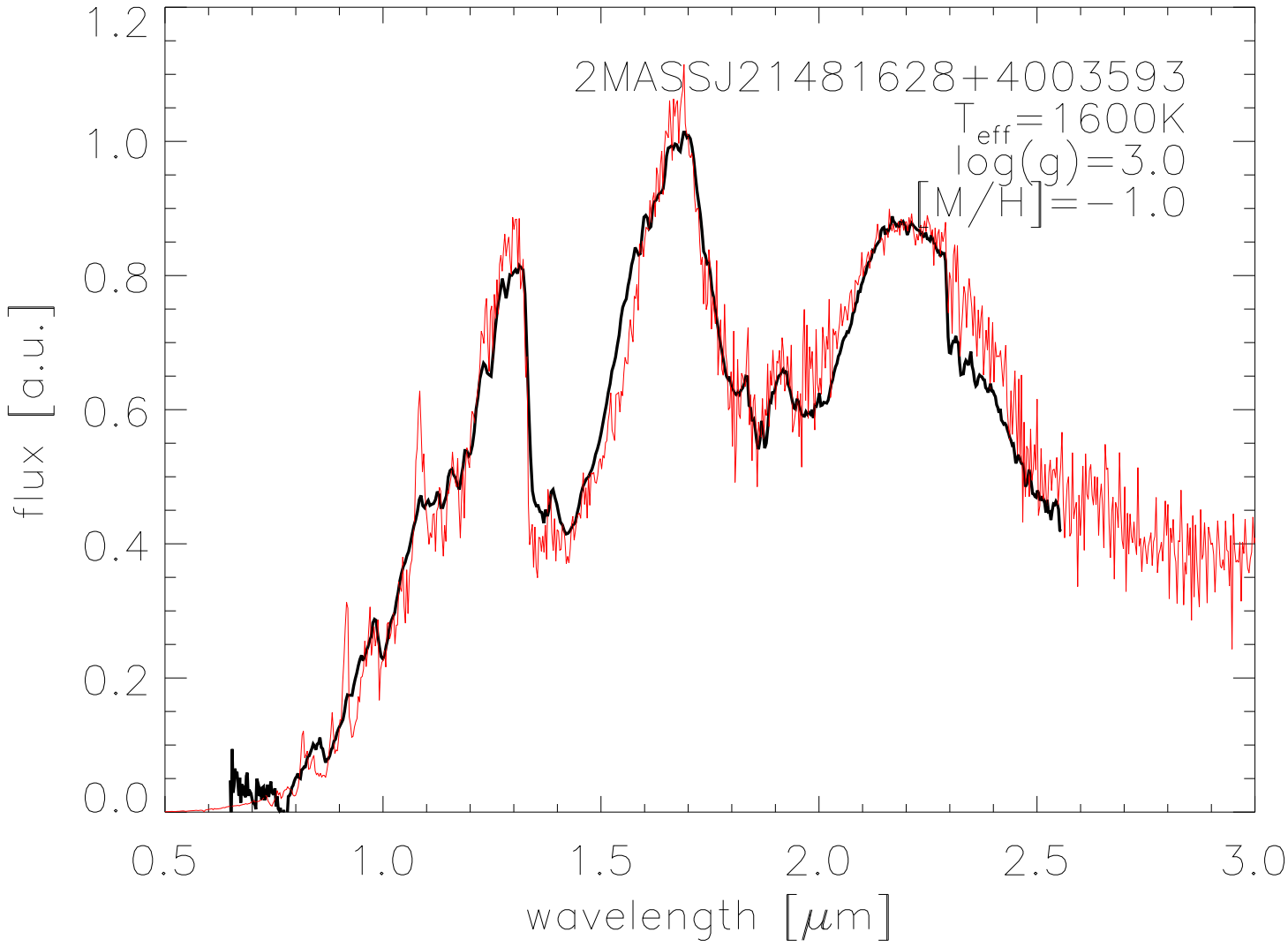

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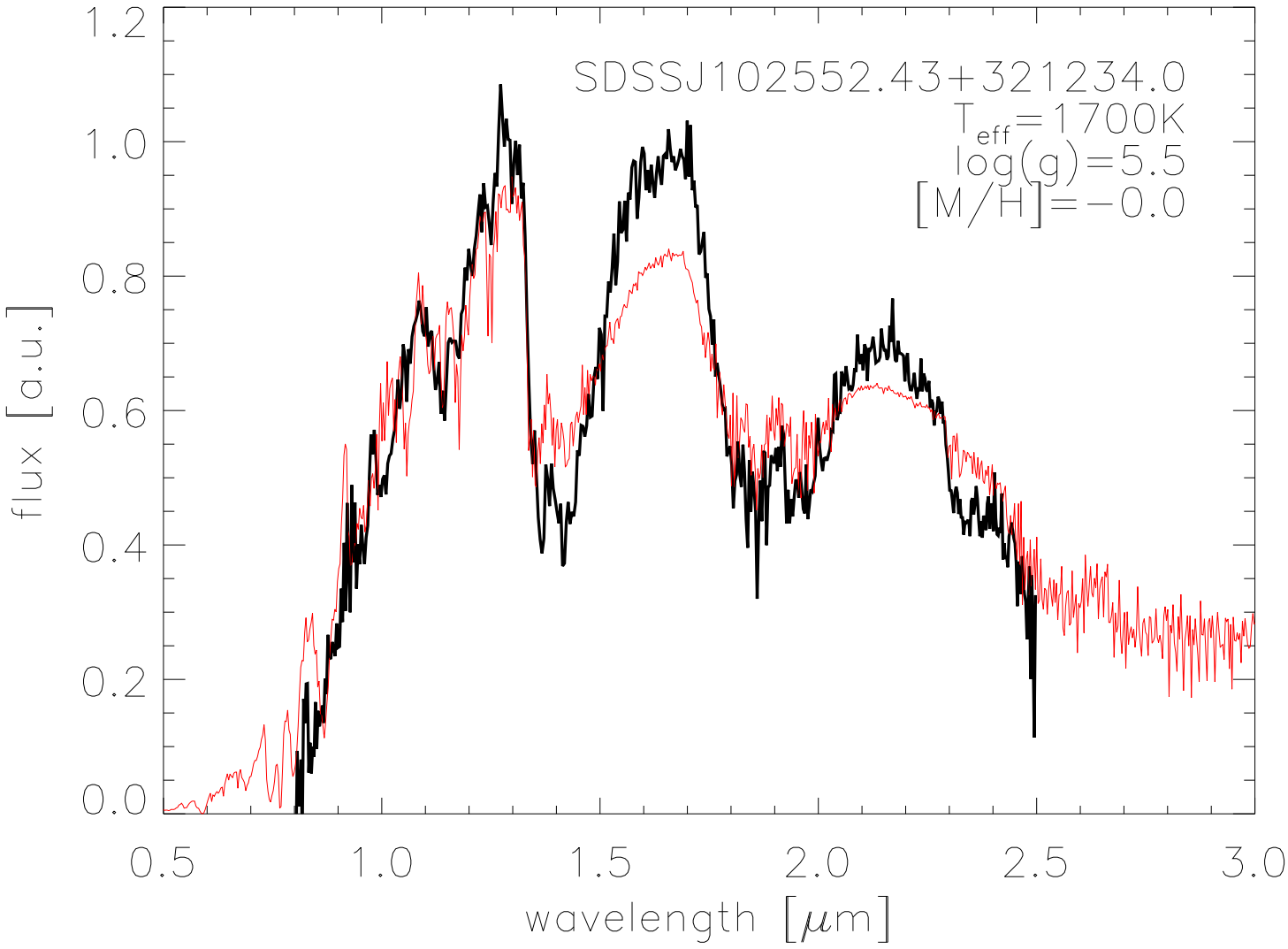
Application: bad fits



Witte et al, in preparation

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Conclusions

- current models generally describe spectra down to 1500 K
- consistent coupling of dust formation/destruction and atmosphere structure crucial
- also required: detailed alkali line profiles, very good gas phase equation of state, "complete" set of opacity sources, ...
- current models can be use to analyze observed spectra

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Future developments

- goal: consistent description M $\rightarrow$ L $\rightarrow$ T dwarf regime
- improved dust formation/destruction model
- eliminate more approximations/estimates
- better individual lines profiles needed
- 3D modeling
- ...

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