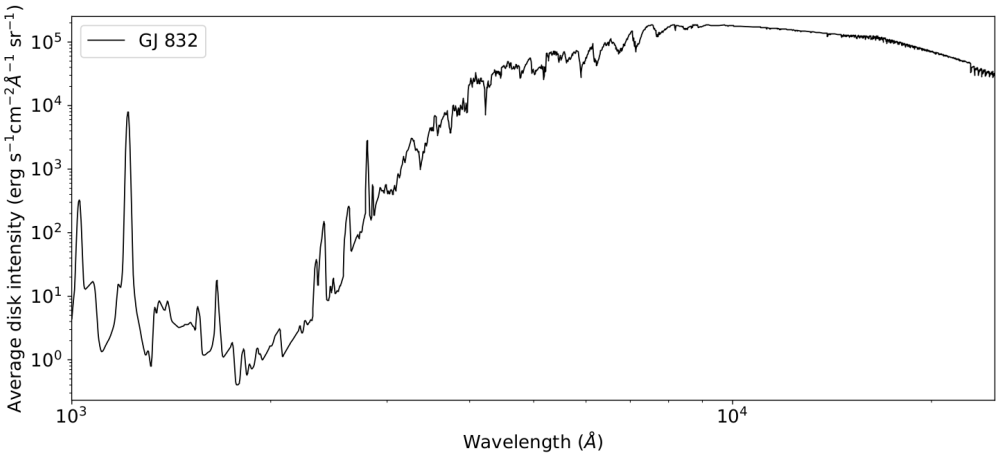
Stellar Models

Solar Focus Group Meeting 12
Dennis Tilipman
4/12/2019

Outline

- Why stellar models are important
- What is being done
- Our approach
- Our results and future work

Why stellar models are important



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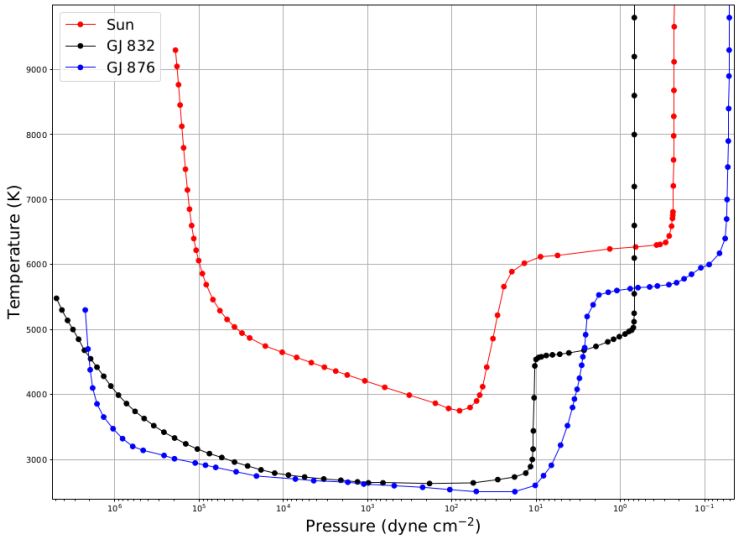
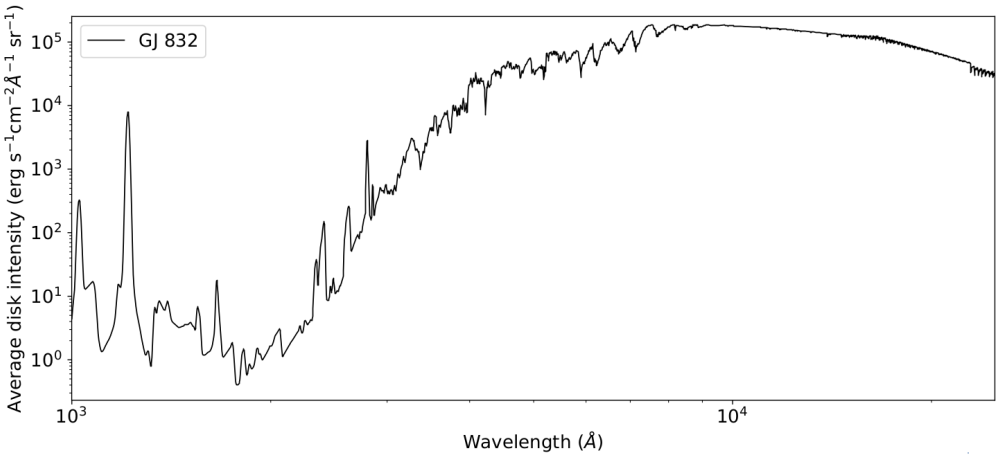
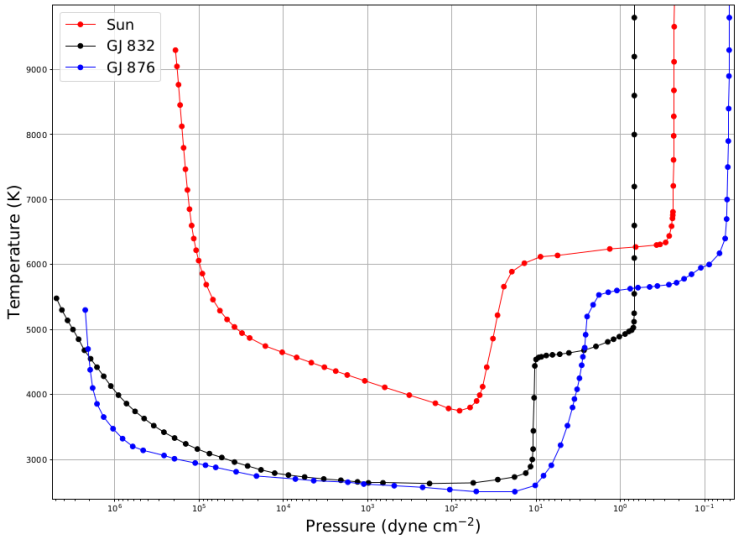


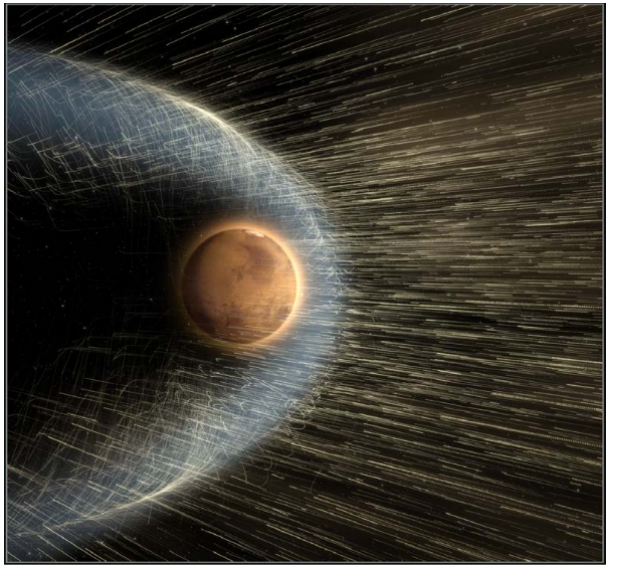
Why stellar models are important



1)

2)





What is being done

- Fitting of individual lines (Ca II H & K lines, Hα, etc.)
- Grids of star photospheres (e.g. PHOENIX) and their adaptations (e.g. TRAPPIST-1 model by Peacock et al. 2018)
- 3-D MHD simulations (e.g. STAGGER-grid)

Our approach

We study 1-D semi-empirical models of cool stars

```
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  2  5.048800000000e+007  8.000000000000e+004  3.026287e+010  2.631859e+010  1.323789e+009  2.764238e+010  5.200000e+005  0.000000e+000  4.320407e+003  0.000000e+000  4.310306e+003  1.000000e+000
  3  5.048600000000e+007  7.400000000000e+004  3.245389e+010  2.863584e+010  1.487252e+009  3.012310e+010  5.200000e+005  0.000000e+000  3.998201e+003  0.000000e+000  3.988973e+003  1.000000e+000
  4  5.048450000000e+007  6.600000000000e+004  3.614698e+010  3.237245e+010  1.621326e+009  3.399378e+010  5.200000e+005  0.000000e+000  3.536597e+003  0.000000e+000  3.529295e+003  1.000000e+000
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  6  5.048300000000e+007  5.000000000000e+004  4.759149e+010  4.304156e+010  1.942528e+009  4.498409e+010  5.200000e+005  0.000000e+000  2.507700e+003  0.000000e+000  2.503979e+003  1.000000e+000
  7  5.048240000000e+007  4.400000000000e+004  5.406746e+010  4.896869e+010  2.162652e+009  5.113134e+010  5.200000e+005  0.000000e+000  2.092670e+003  0.000000e+000  2.089968e+003  1.000000e+000
  8  5.048090000000e+007  3.800000000000e+004  6.244595e+010  5.675347e+010  2.597046e+009  5.935051e+010  5.200000e+005  0.000000e+000  1.670651e+003  0.000000e+000  1.668712e+003  1.000000e+000
  9  5.047930000000e+007  3.300000000000e+004  7.136934e+010  6.558521e+010  3.249092e+009  6.883430e+010  5.200000e+005  0.000000e+000  1.321573e+003  0.000000e+000  1.320129e+003  1.000000e+000
 10  5.047800000000e+007  2.800000000000e+004  8.244238e+010  7.854820e+010  4.098554e+009  8.264676e+010  5.200000e+005  0.000000e+000  9.848304e+002  0.000000e+000  9.838600e+002  1.000000e+000
 11  5.047680000000e+007  2.500000000000e+004  9.080286e+010  8.900730e+010  4.955459e+009  9.396275e+010  5.200000e+005  0.000000e+000  7.937532e+002  0.000000e+000  7.930092e+002  1.000000e+000
 12  5.047560000000e+007  2.200000000000e+004  1.020974e+011  1.015740e+011  6.195575e+009  1.077695e+011  5.200000e+005  0.000000e+000  6.147650e+002  0.000000e+000  6.142266e+002  1.000000e+000
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```

We use SSRPM – full NLTE radiative transfer code with 18,500+ levels, and 436,000 atomic lines, along with 20,000,000+ molecular lines from 20 molecules – to compute high-res synthetic spectra in all wavelengths

SSRPM heuristic

```
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```
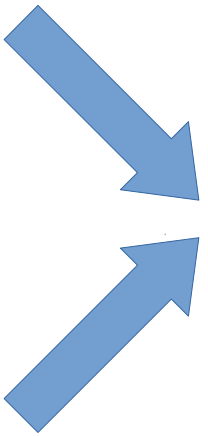

$$C_{1i} + A_{i1}V_{i1} = (C_{i1}\tilde{I} + A_{i1}\tilde{R}_{i1})\sigma_i + \sum_{j<i}[(C_{ij}\tilde{I} + A_{ij}\tilde{R}_{ij})\sigma_i - (C_{ji} + A_{ij}V_{ij})\tilde{I}\sigma_j] - \sum_{j>i}[(C_{ji}\tilde{I} + A_{ji}\tilde{R}_{ji})\sigma_j - (C_{ij} + A_{ji}V_{ji})\tilde{I}\sigma_i],$$

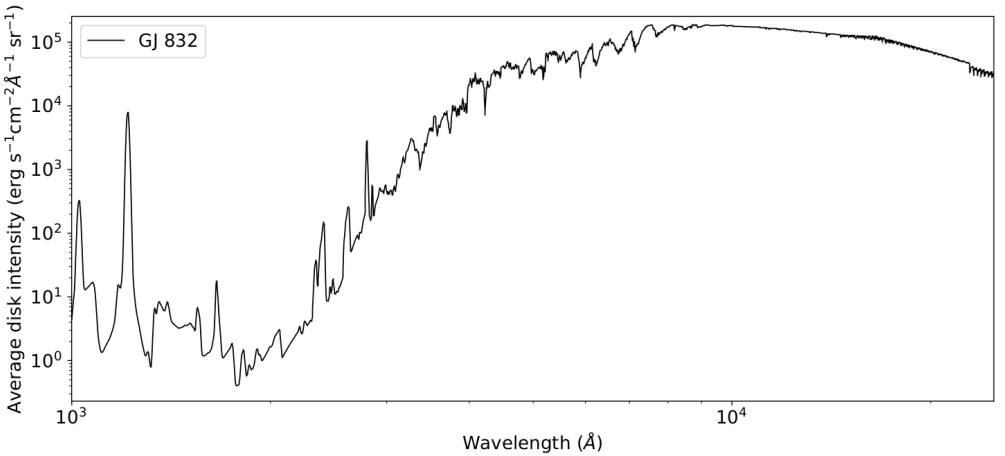


level populations

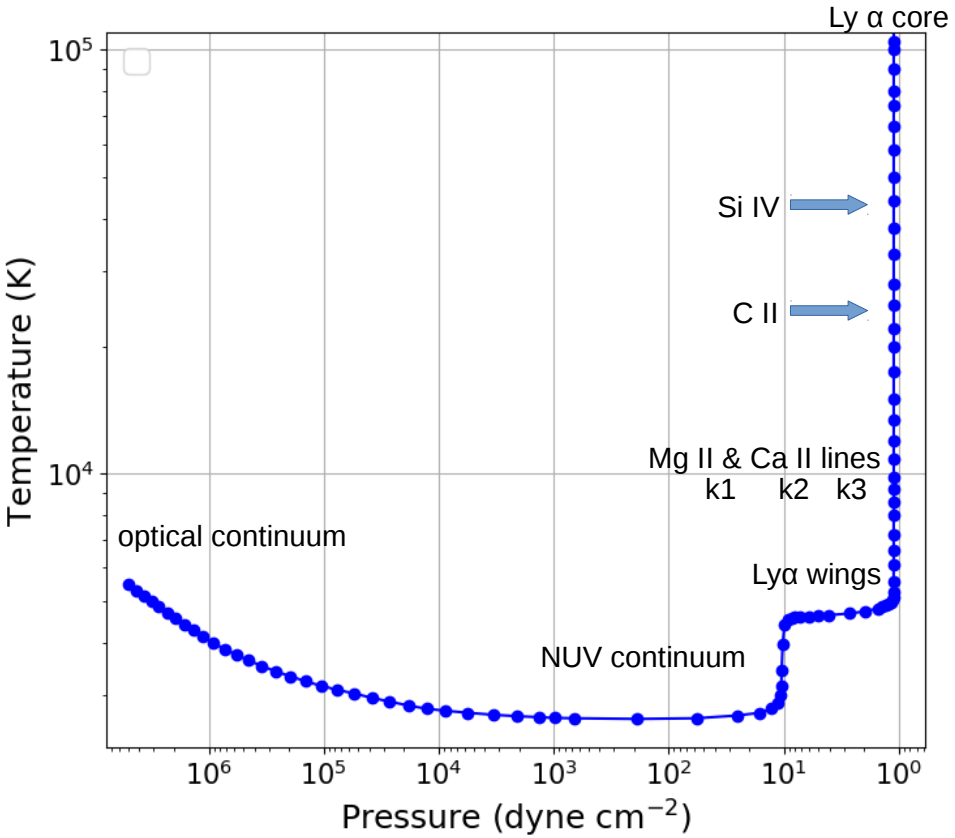
SSRPM heuristic

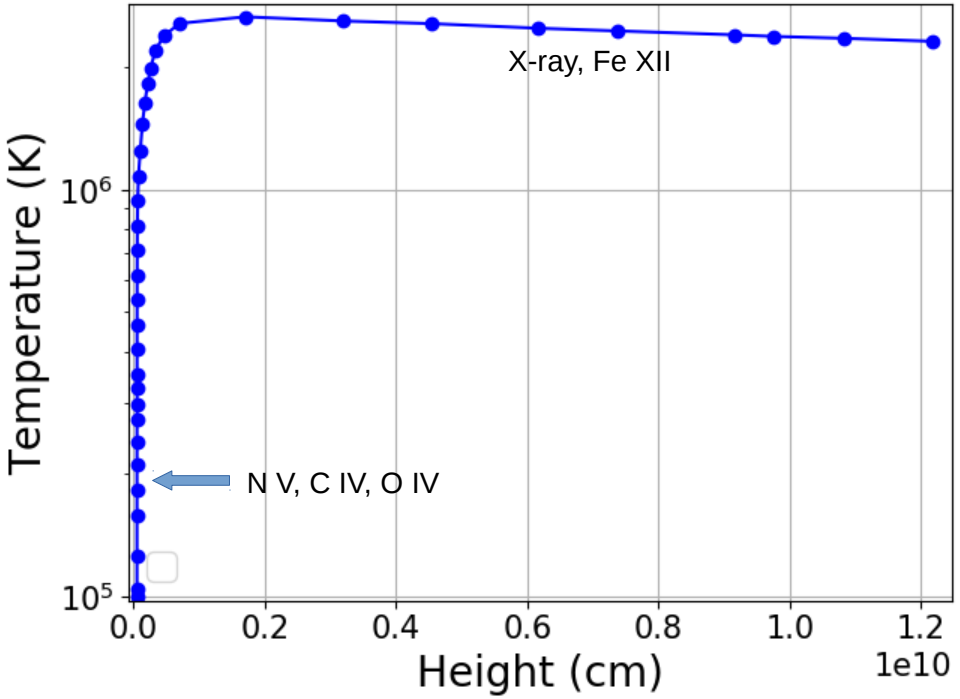
level populations

atomic database

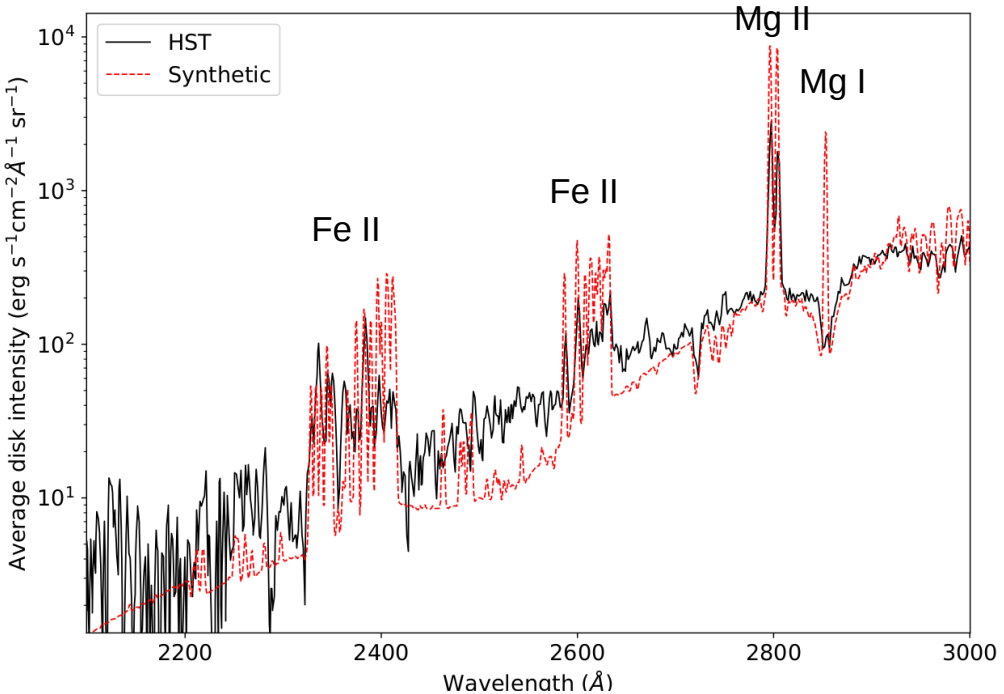


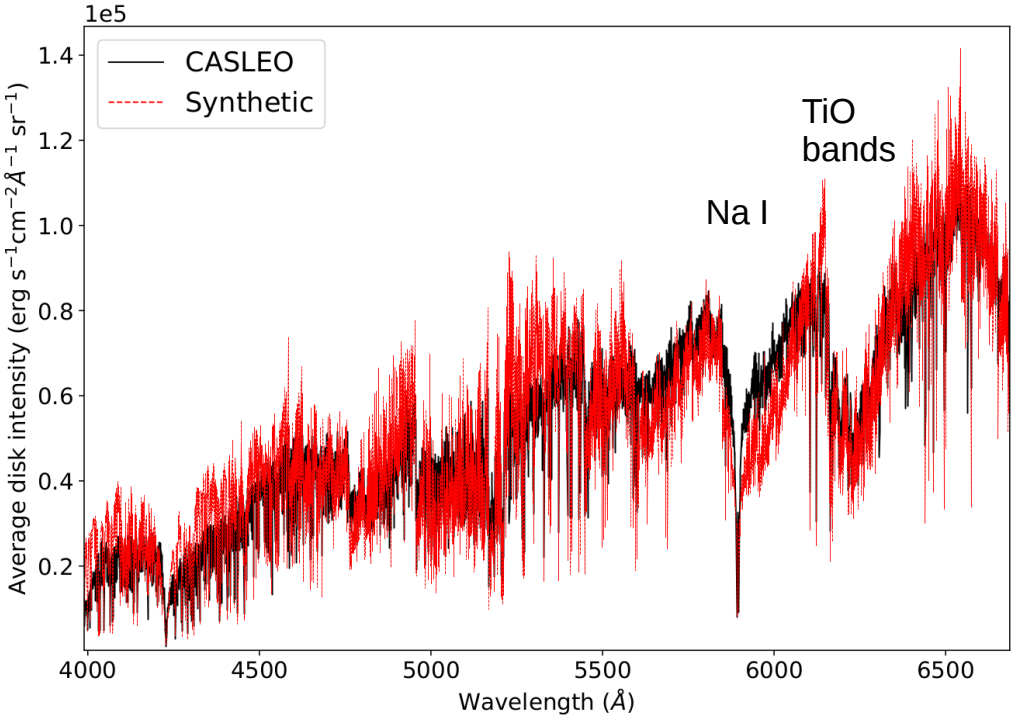
Getting the model right: GJ 832

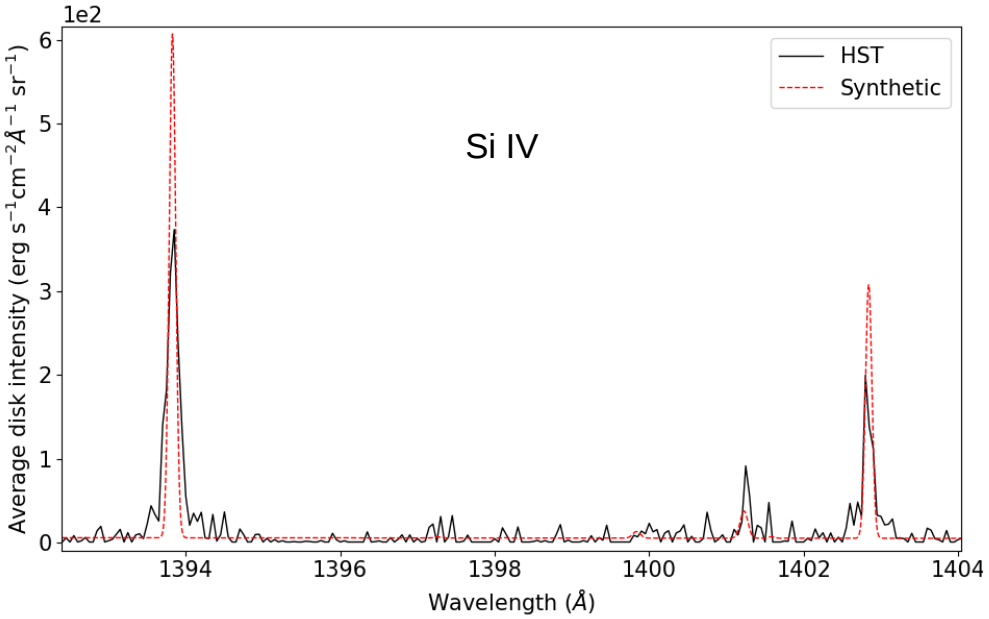


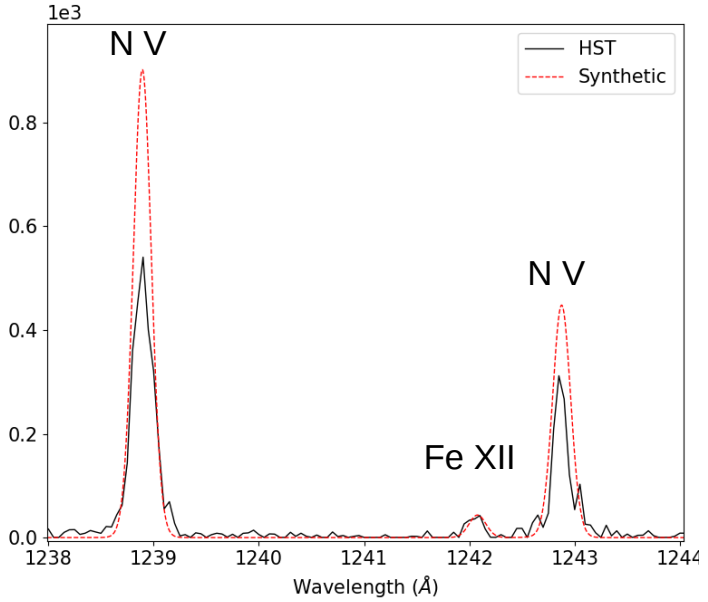


Some results: GJ 832





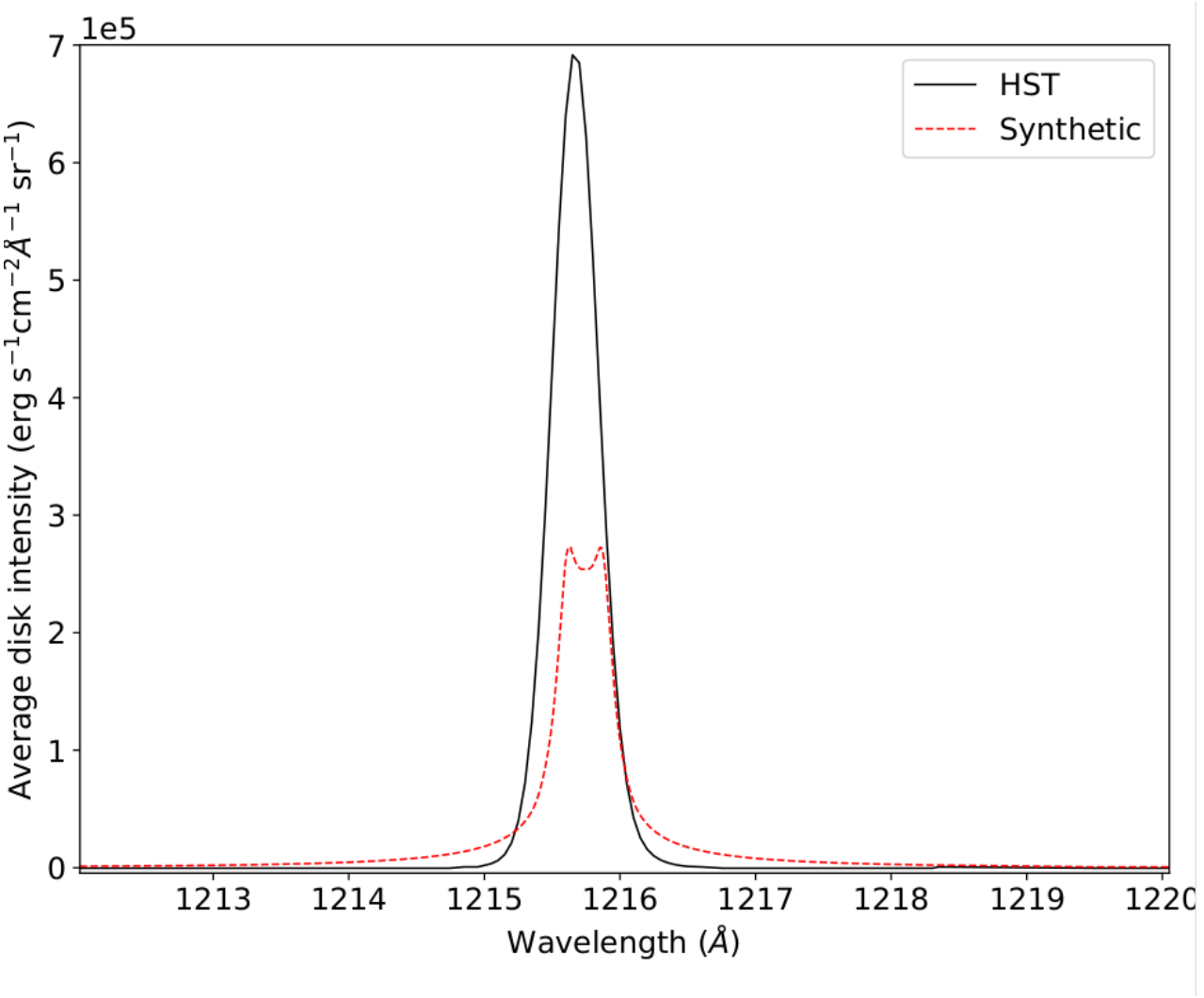




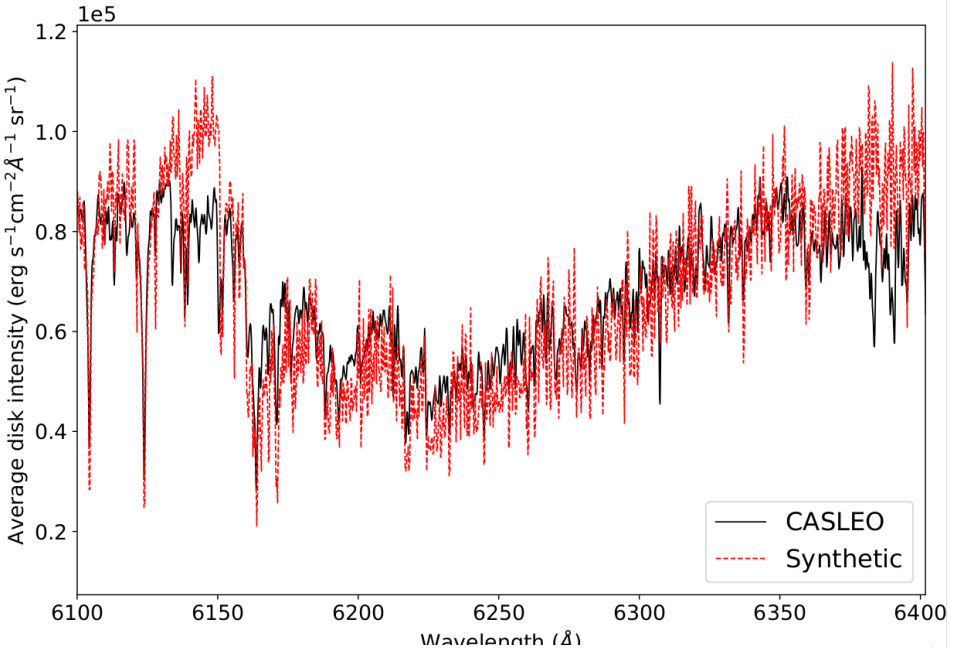
Ongoing and future work

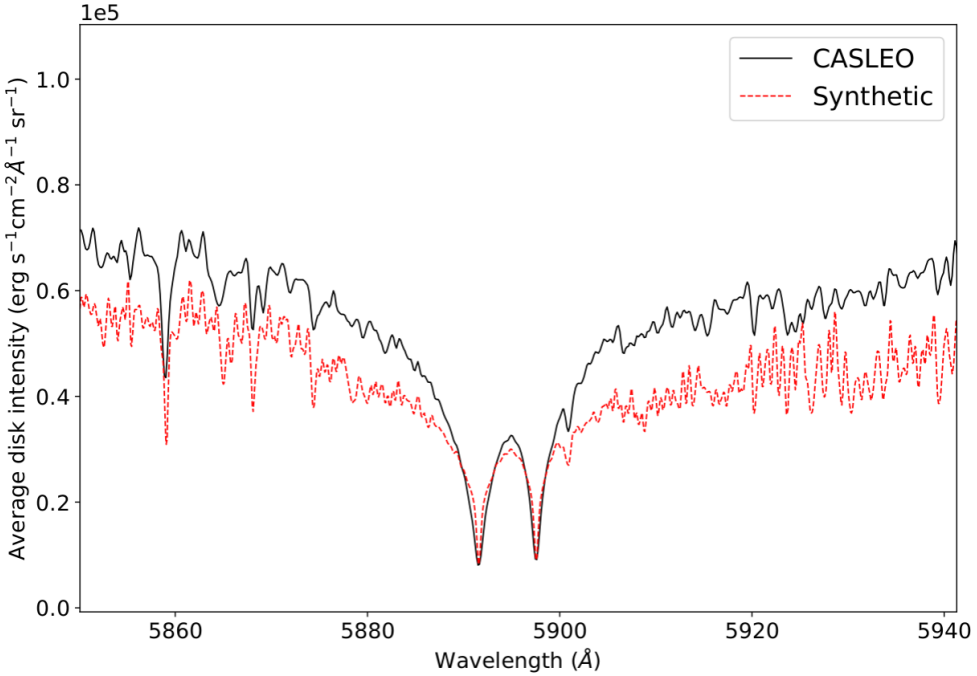
- We are currently finishing up the models of GJ 832 (M 2.5 dwarf) and GJ 876 (M 5 dwarf)
- Next up is creating a model for TRAPPIST-1 – ultra-cool M 8 dwarf
- Solve Mg I and Ly α problems
- Create a manual for SSRPM and make the code publicly available

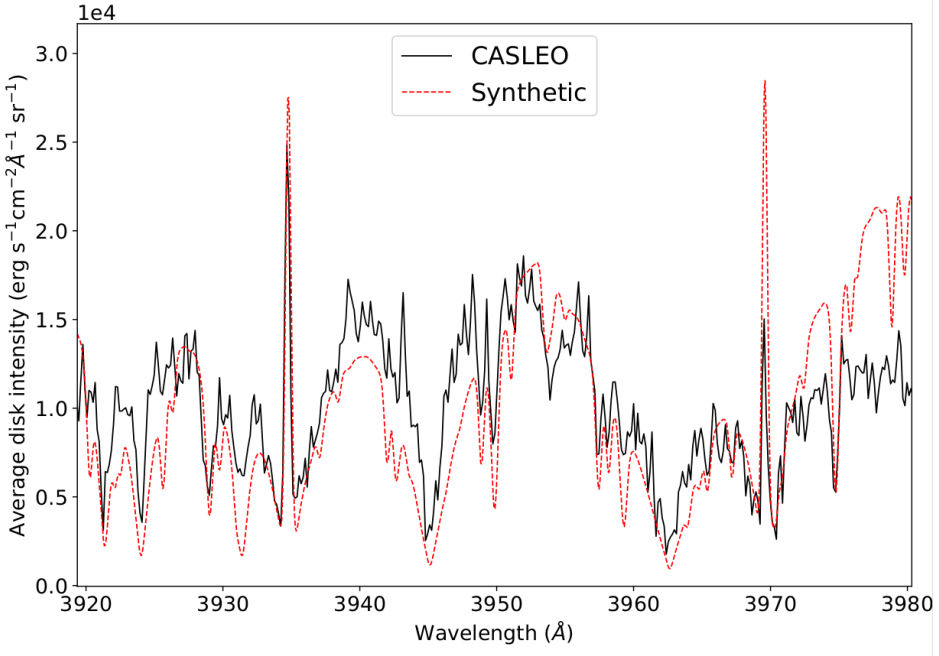
GJ 832 lines

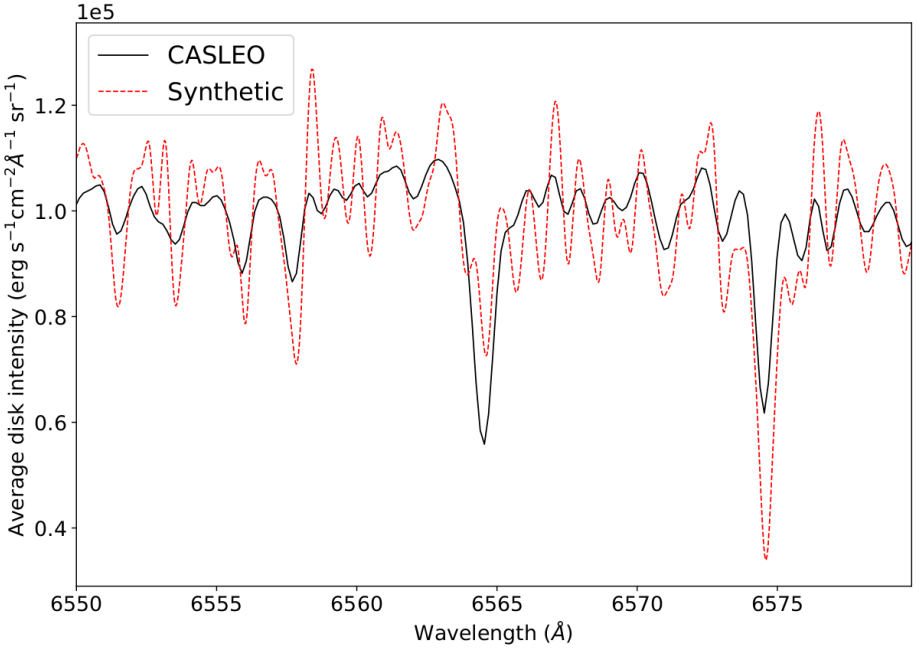

1e5
7
6
5
4
3
2
1
0
Average disk intensity (erg s^{-1}cm^{-2}Å^{-1} sr^{-1})
HST
Synthetic
1213
1214
1215
1216
1217
1218
1219
1220
Wavelength (Å)

GJ 832 lines

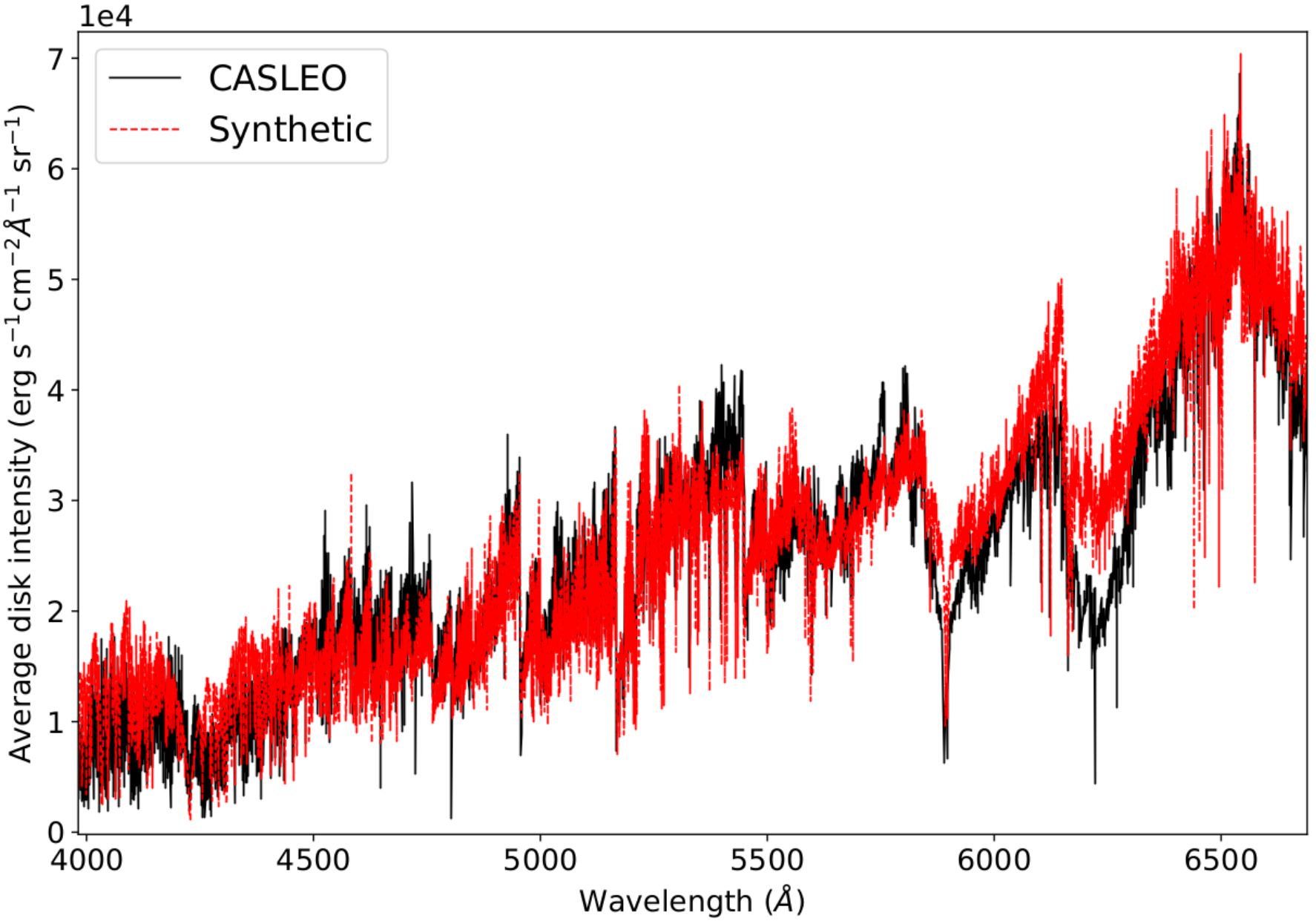

1e5
Average disk intensity (erg s^{-1}cm^{-2}Å^{-1} sr^{-1})
CASLEO
Synthetic
Wavelength (Å)


1e5
Average disk intensity (erg s^{-1}cm^{-2}Å^{-1} sr^{-1})
CASLEO
Synthetic
Wavelength (Å)

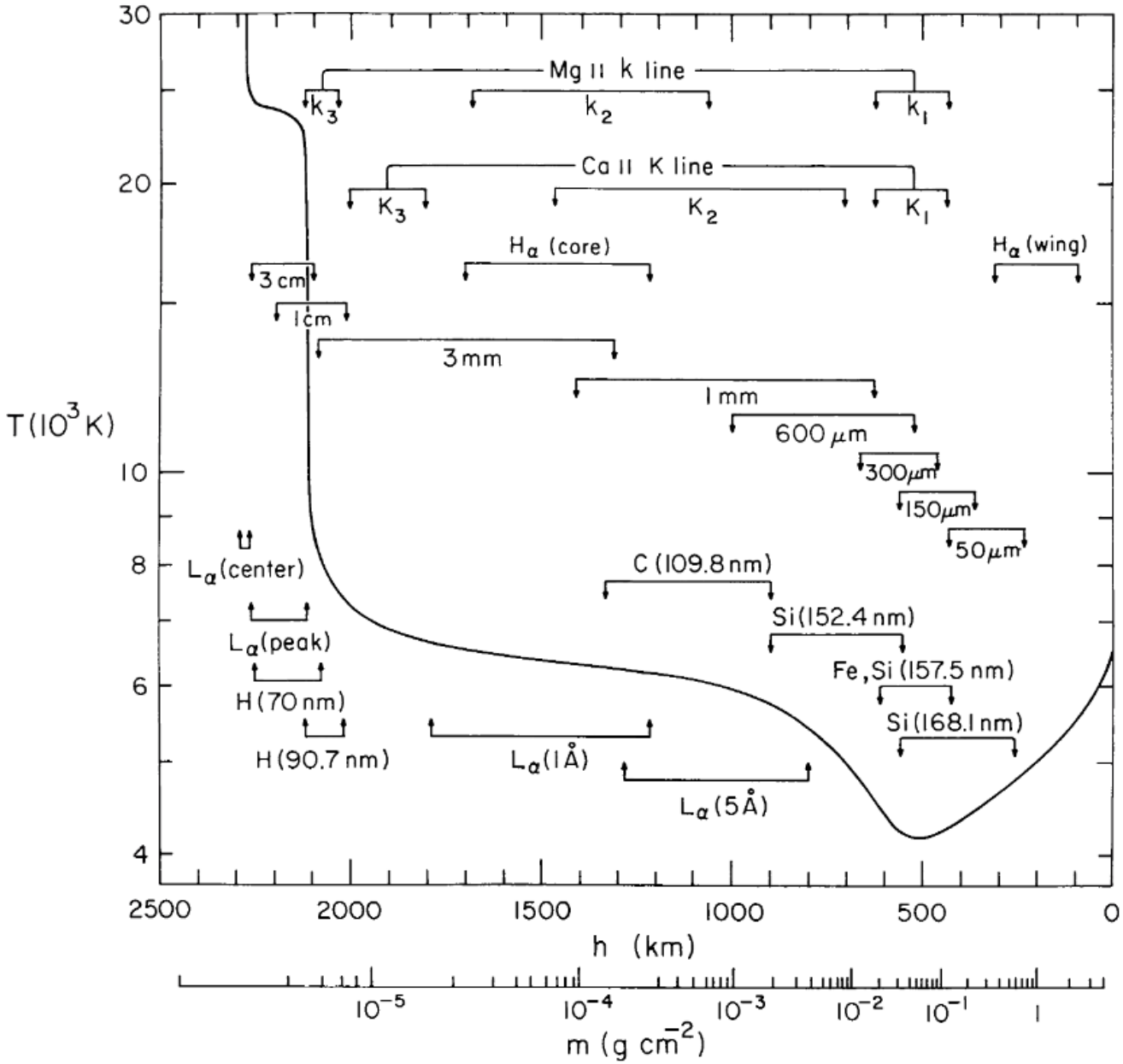

1e4
Average disk intensity (erg s^{-1}cm^{-2}Å^{-1} sr^{-1})
CASLEO
Synthetic
Wavelength (Å)


1e5
Average disk intensity (erg s^{-1}cm^{-2}Å^{-1} sr^{-1})
CASLEO
Synthetic
Wavelength (Å)

GJ 876


1e4
CASLEO
Synthetic
Average disk intensity (erg s^{-1}cm^{-2}Å^{-1} sr^{-1})
Wavelength (Å)
0
1
2
3
4
5
6
7
4000
4500
5000
5500
6000
6500

Getting the model right



Vernazza et al. 1981