Accretion disc around white dwarfs

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Progress report

Most of astrophysical information comes from spectral lines, so what do the spectral lines tell us about accretion discs?

Long term target: disc tomography by means of spectral lines and their structure

The structure of the optically thin layers of the disc. What happens to the viscosity in this region? The interaction between the viscosity mechanism and line formation

The plan of the talk

- Brief Introduction: what do we want
- Basic Assumptions and Equ.
- The Shaviv-Wehrse code + improvments
- Results and comparison with previous works

Assumptions

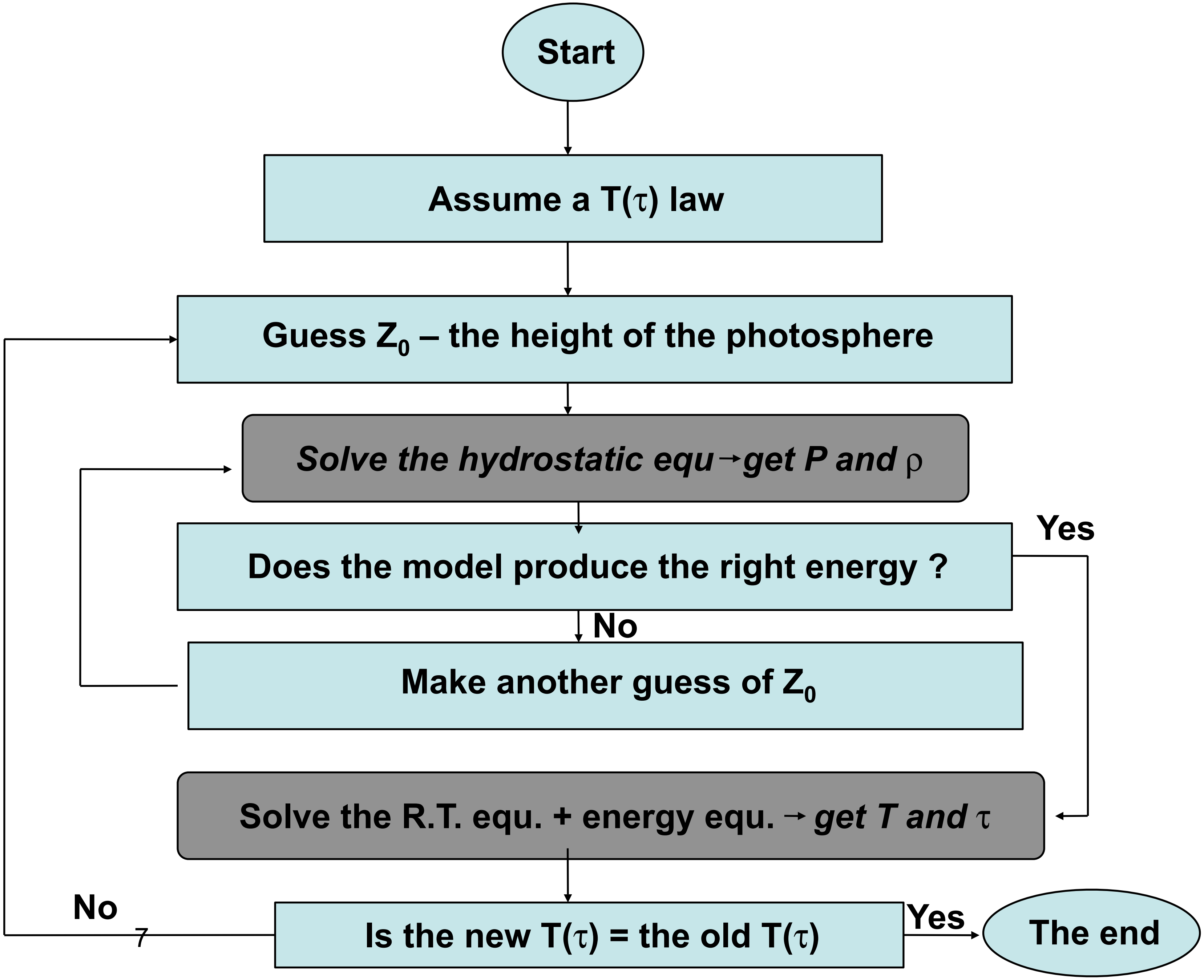
- concentric rings at a Keplerian angular speed
- disc is geometrically thin
- radial gradients << vertical gradients.
- Radiation from non-steady quiescent discs of dwarf-nova stars can be treated as being the sum of the emission of individual rings.
- We see the disk face on.

Governing Equations

- The hydrostatic equilibrium equation
- The energy balance equation
- The viscous energy generation
- The radiative energy flux and the radiative transfer equation. Two stream approximation with symmetry boundary conditions.

- Our model is based on the code of Shaviv and Wehrse 1991.

- The code <u>iterates</u> to find a self consistent model (hydrostatics + radiative transfer which satisfy the energy equation)
- Basic problem: location of photosphere is not known and must be iterated for. You cannot use a simple stellar atmosphere having the same effective temperature because gravity behaves differently.


Start
Assume a T(τ) law
Guess Z_0 – the height of the photosphere
Solve the hydrostatic equ→get P and ρ
Does the model produce the right energy ?
Yes
No
Make another guess of Z_0
Solve the R.T. equ. + energy equ. → *get T and τ*
No
Is the new T(τ) = the old T(τ)
Yes
The end

Improvements over the SW model

- The main improvements consist of using (modern) line opacities and improving the convective energy transport.
- Convection - mixing length approximation according to Paczynski(1969) rather than simple mixing length: basic effect-> better convergence

Opacities in the code

<u>Two schemes to calculate the opacities</u>

- "Atlas 12" subroutines written by R. Kurucz that calculates opacities and <u>few</u> of the line tables.

- Data from the Opacity Project – OPCD_2.1

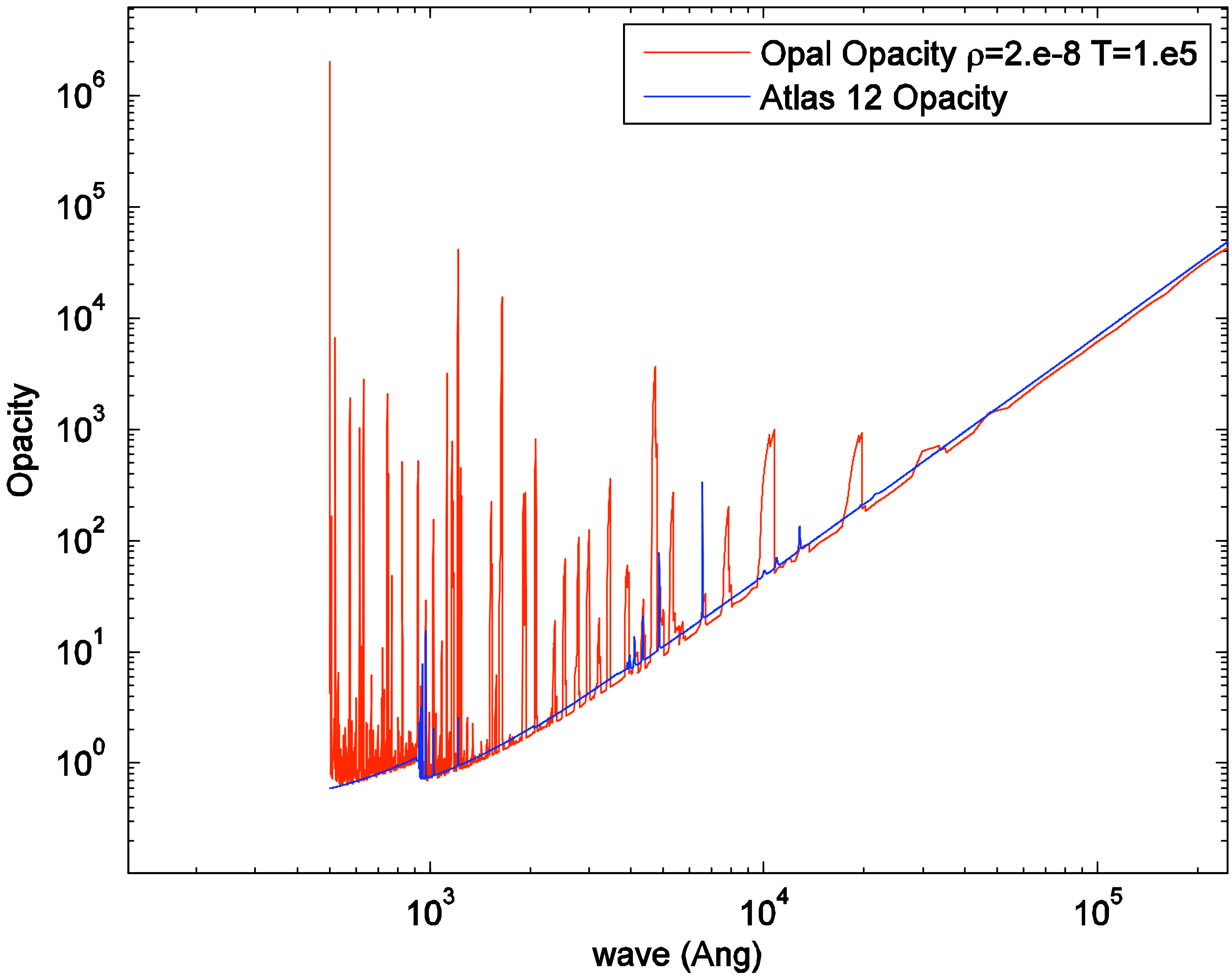
Tabulated opacities for a certain mixture at a chosen grid of wavelengths.

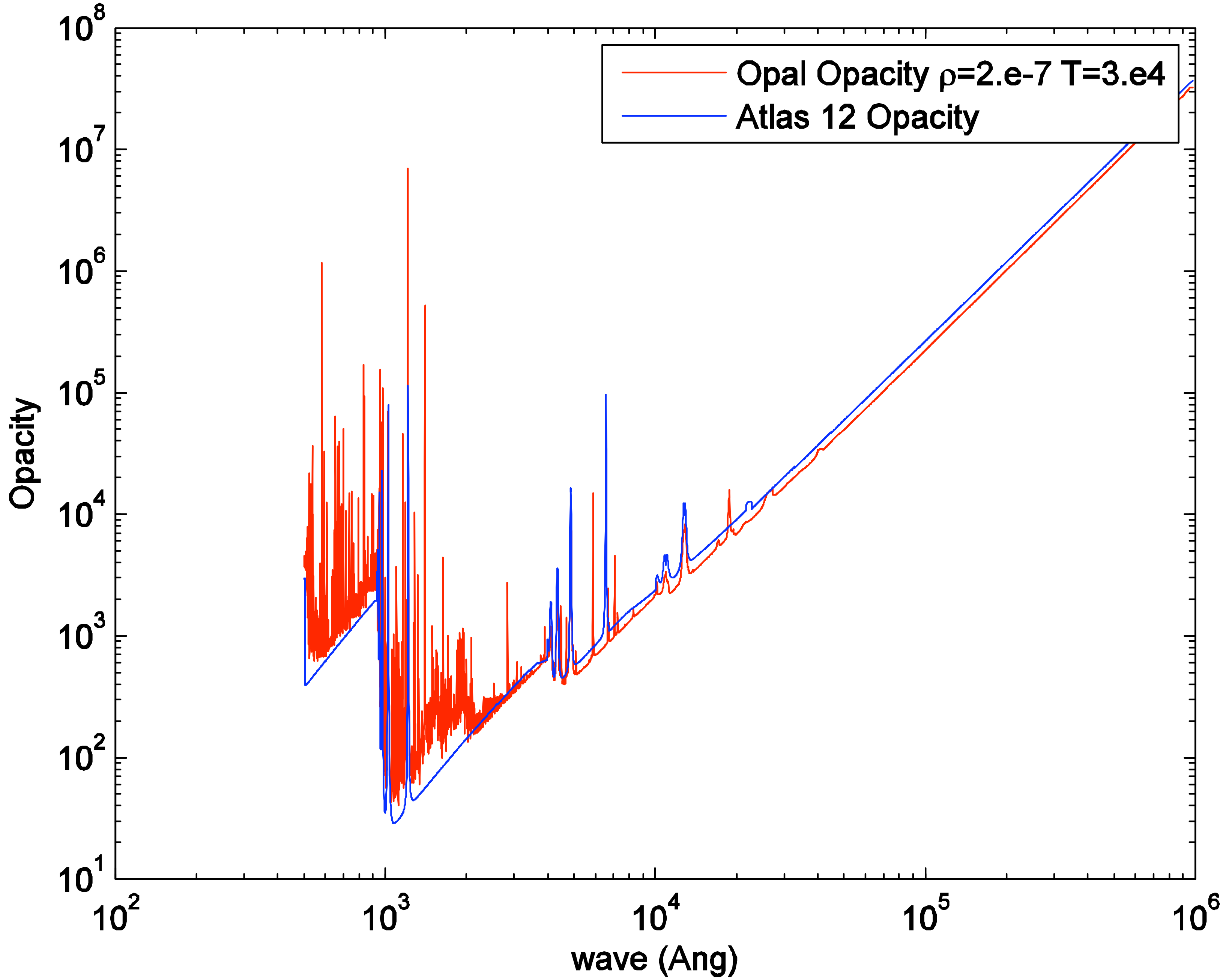
10,000 wavelength points, between 10^2-10^6 A.

Lowest Temp is 3160^o K

No (yet) molecular opacities.

Comparison between the two schemes of opacities





Opal Opacity ρ=2.e-7 T=3.e4
Atlas 12 Opacity
Opacity
wave (Ang)
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^2
10^3
10^4
10^5
10^6

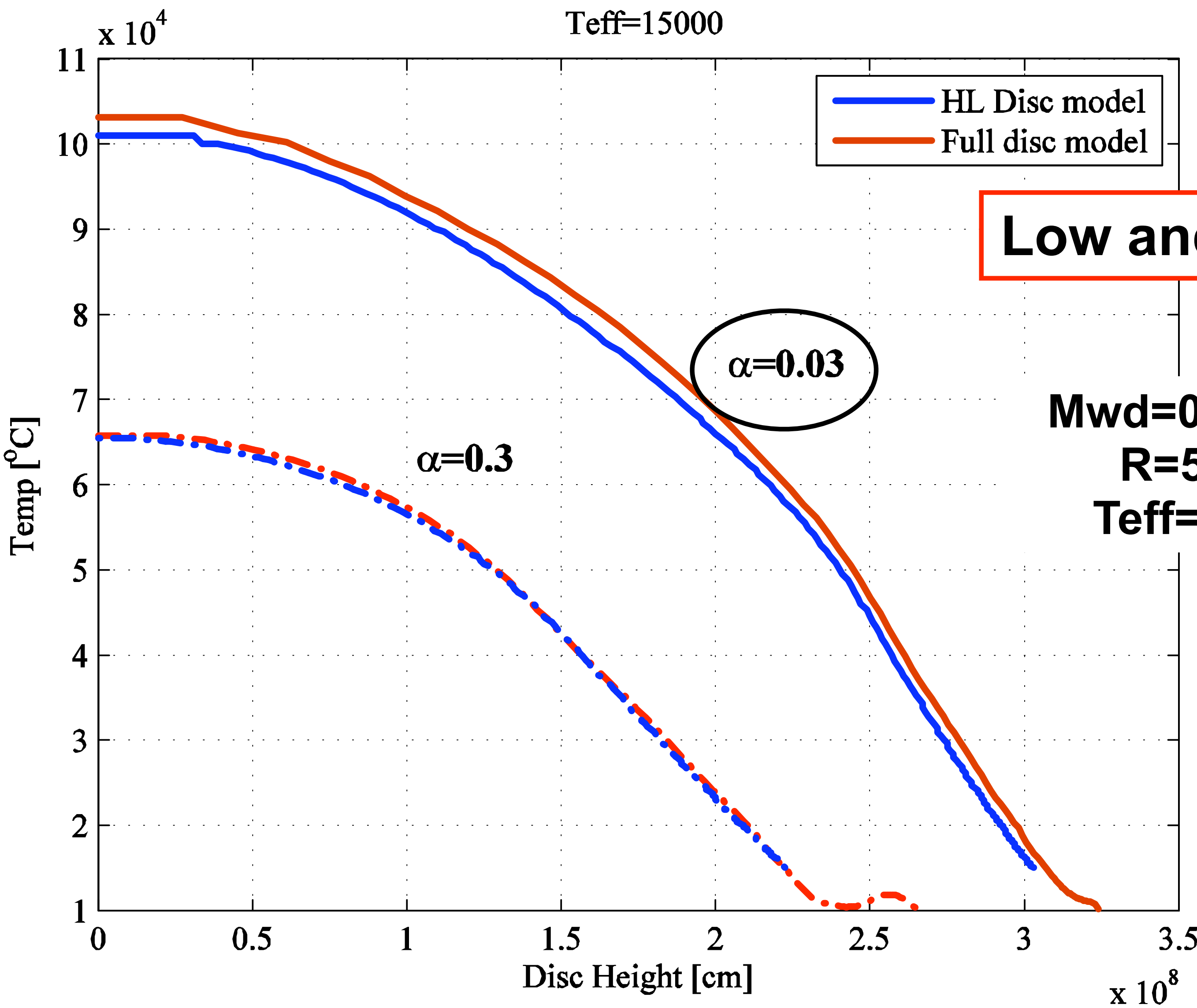
Next Goals

Use the time dependent code developed by J.M. Hameury, K. Menou, G. Dubus and J.P. Lasota for DN, Novae (HMDL)

together with a code that calculates radiative transfer → Spectrum

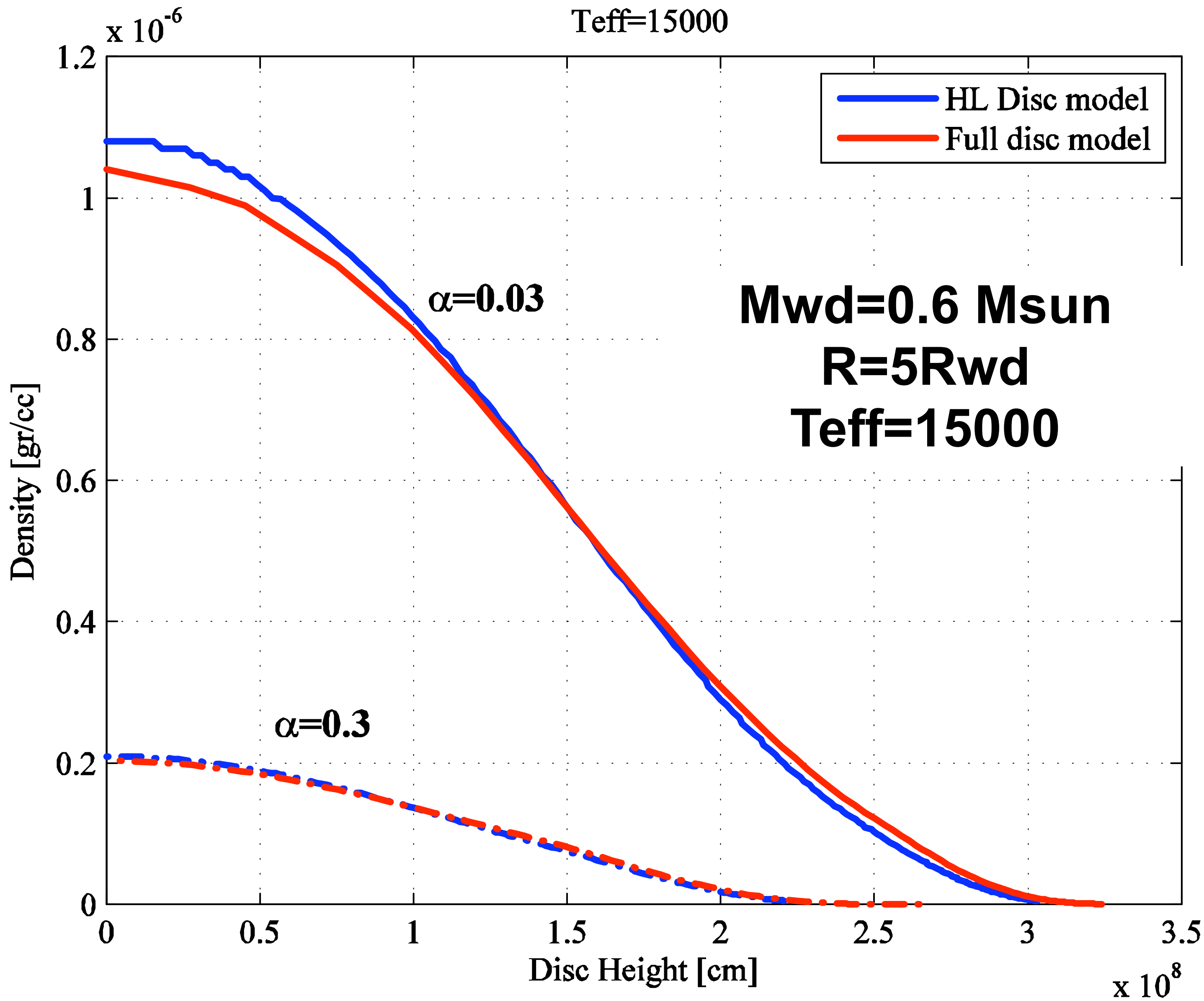
Observed the changes in the spectrum as function of time

Comparison with HMDL code

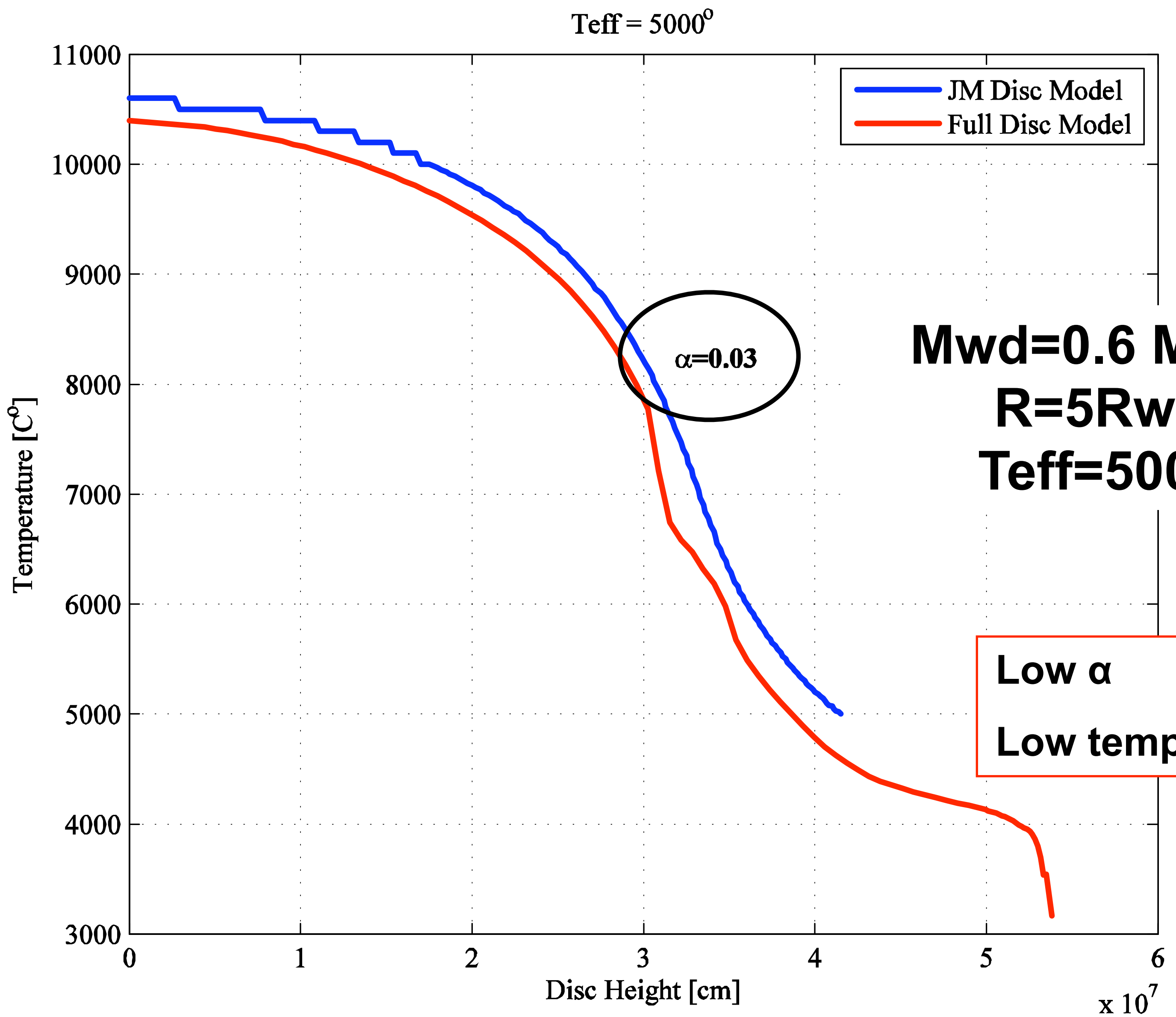


Low and high α

Mwd=0.6 Msun
R=5Rwd
Teff=15000



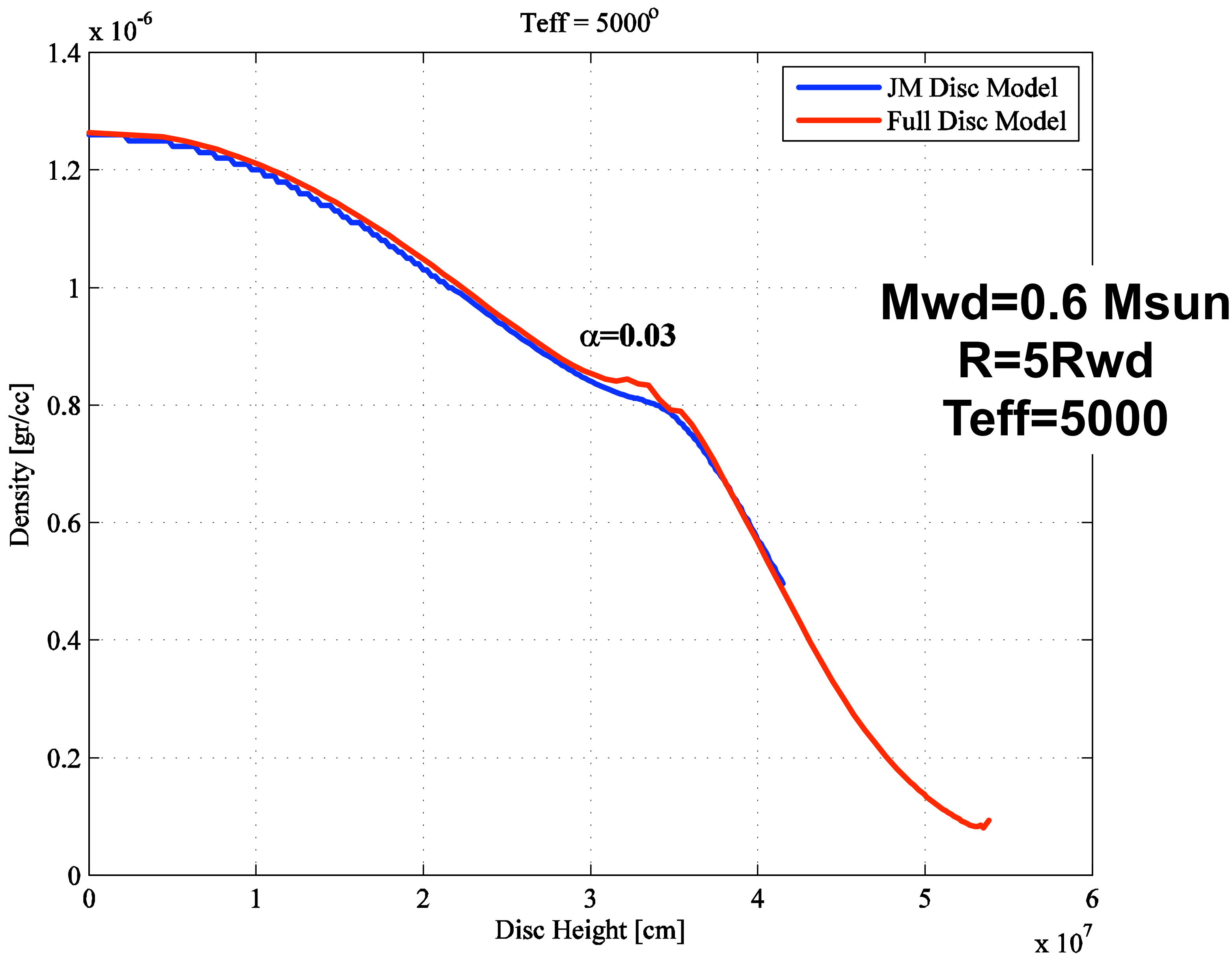
Teff=15000
x 10^-6
1.2
1
0.8
0.6
0.4
0.2
0
Density [gr/cc]
HL Disc model
Full disc model
α=0.03
α=0.3
Mwd=0.6 Msun
R=5Rwd
Teff=15000
0
0.5
1
1.5
2
2.5
3
3.5
Disc Height [cm]
x 10^8



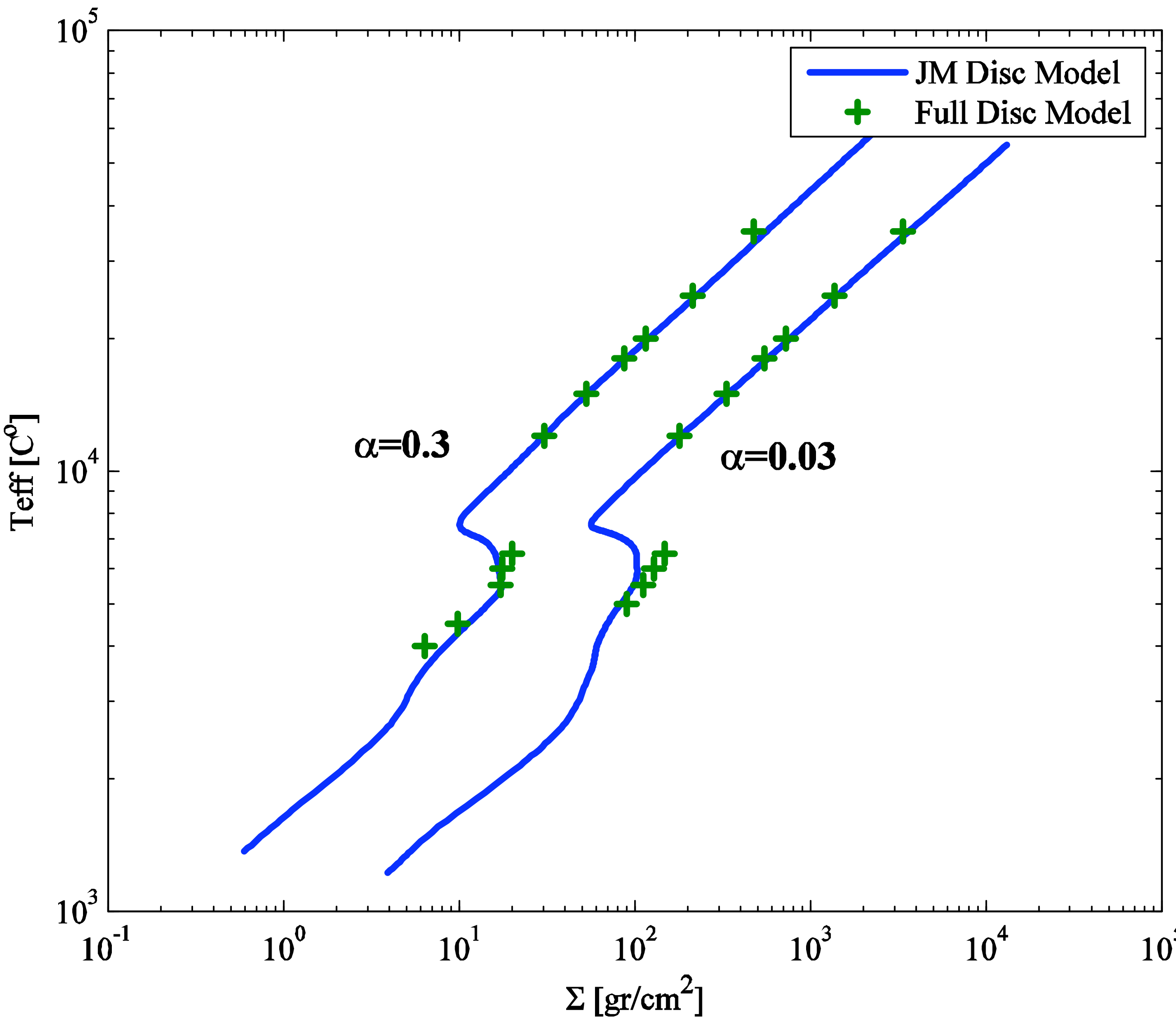
Mwd=0.6 Msun
R=5Rwd
Teff=5000

Low α

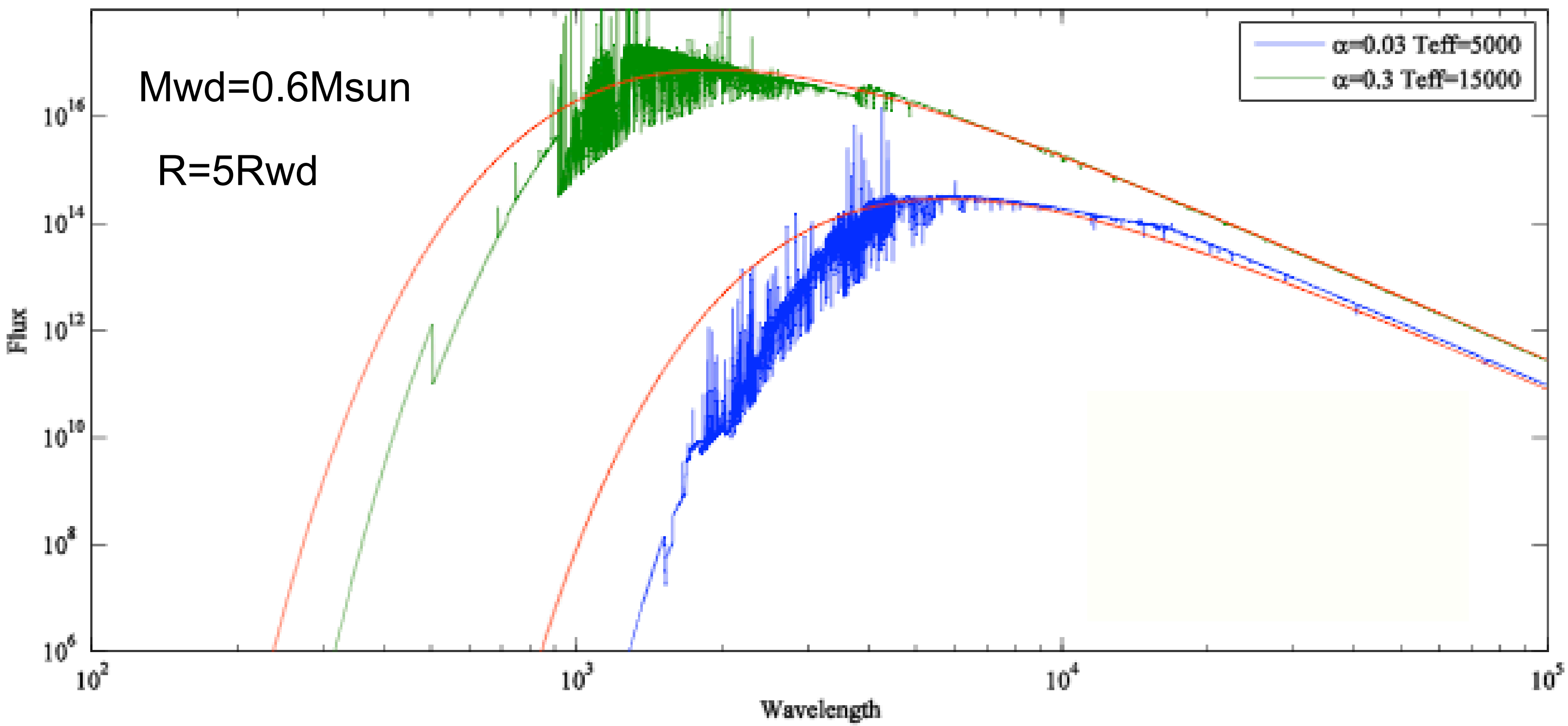
Low temperature

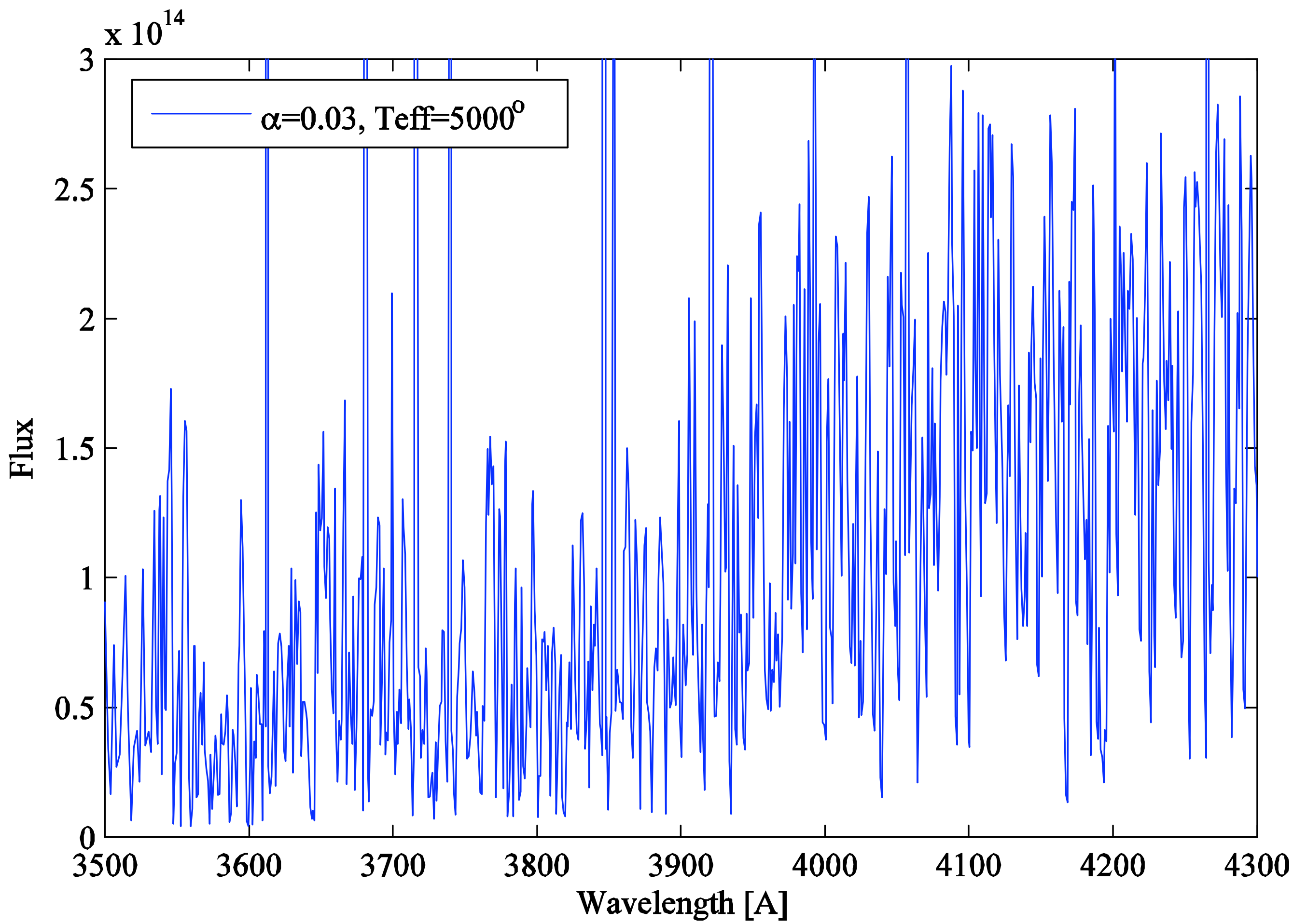

Teff = 5000°
x 10^-6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Density [gr/cc]
JM Disc Model
Full Disc Model
α=0.03
Mwd=0.6 Msun
R=5Rwd
Teff=5000
0
1
2
3
4
5
6
Disc Height [cm]
x 10^7

S-curve Comparison

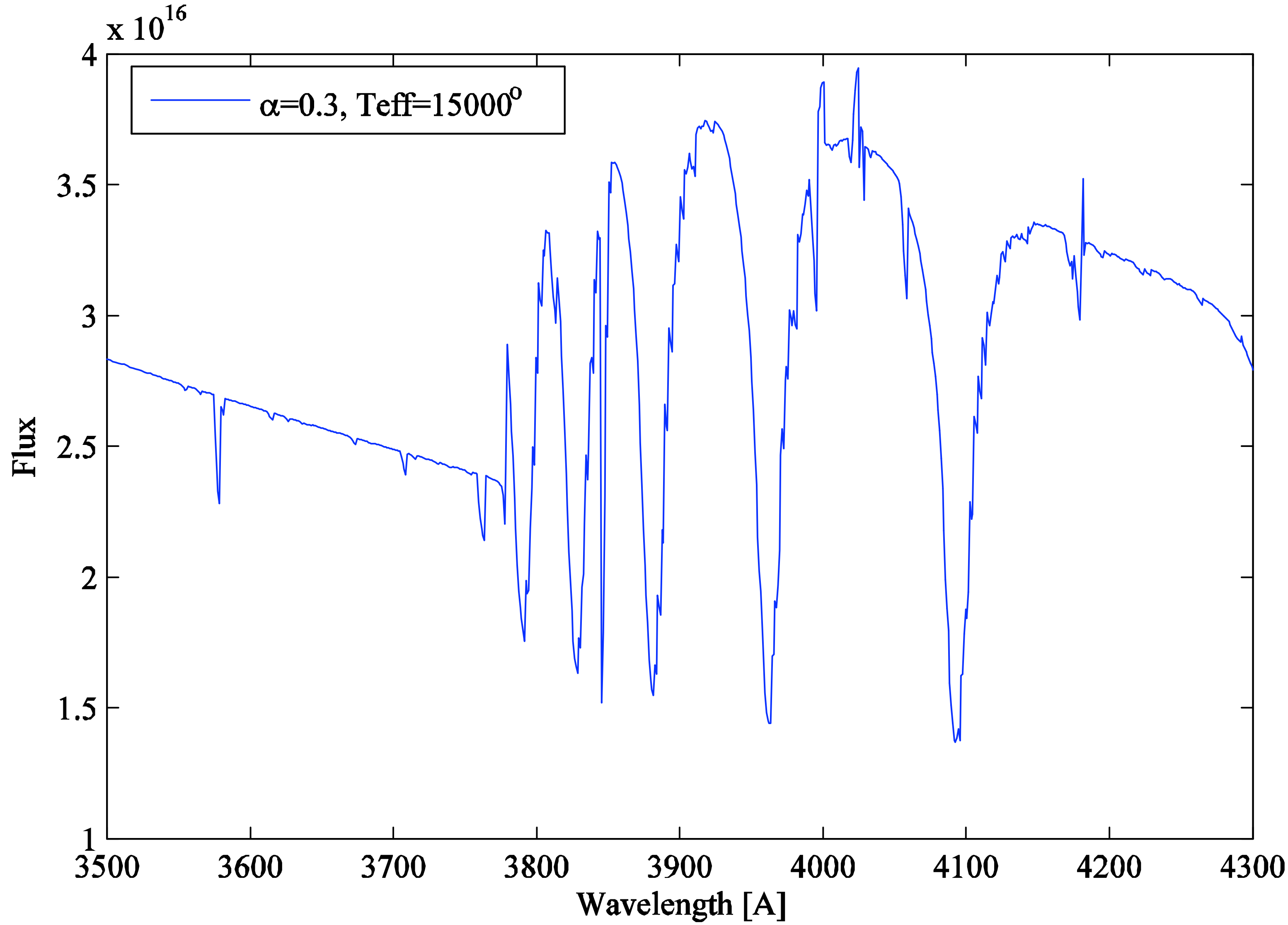


Spectrum – 1 Ring

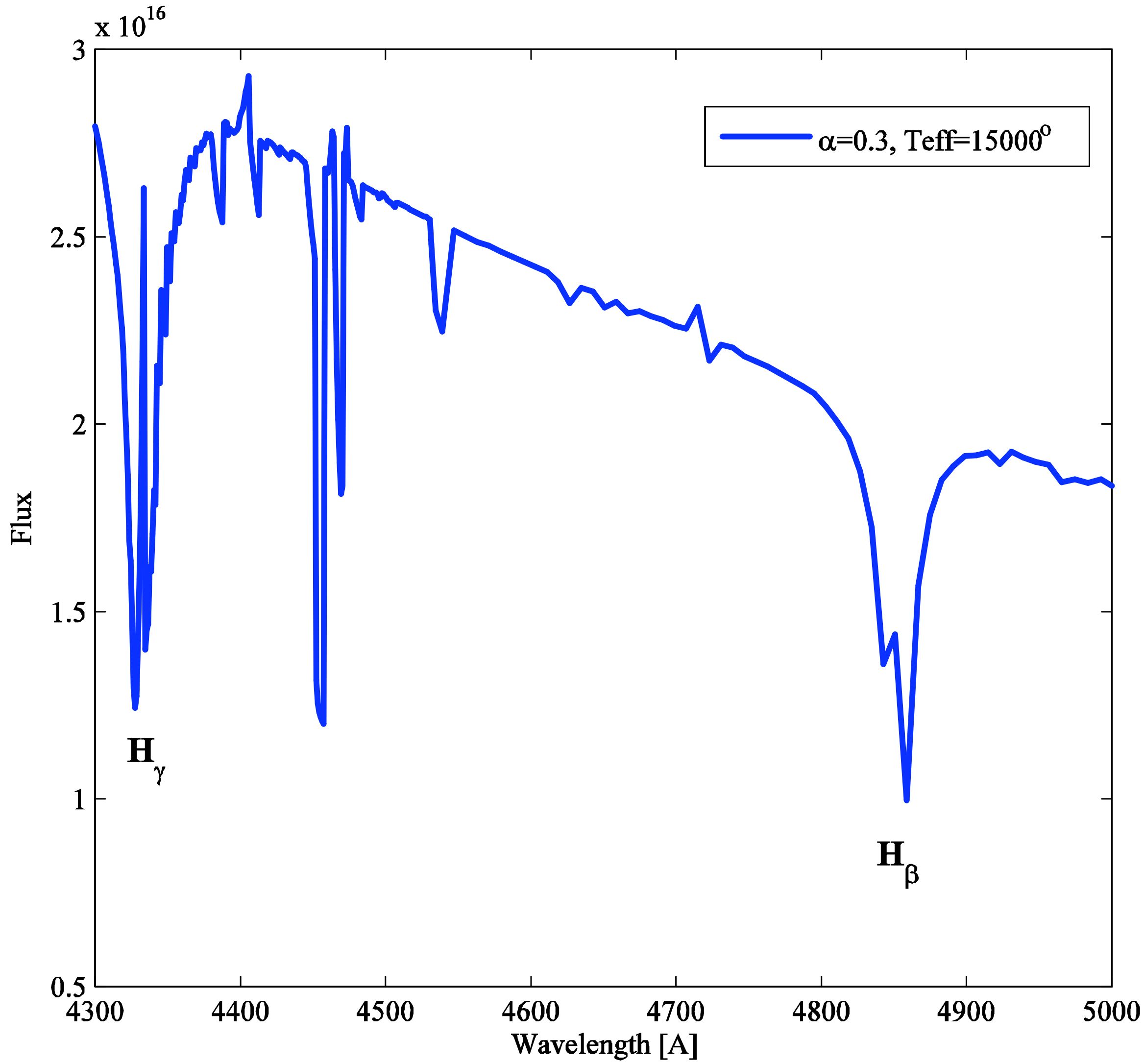




Cold Disc - Emission lines

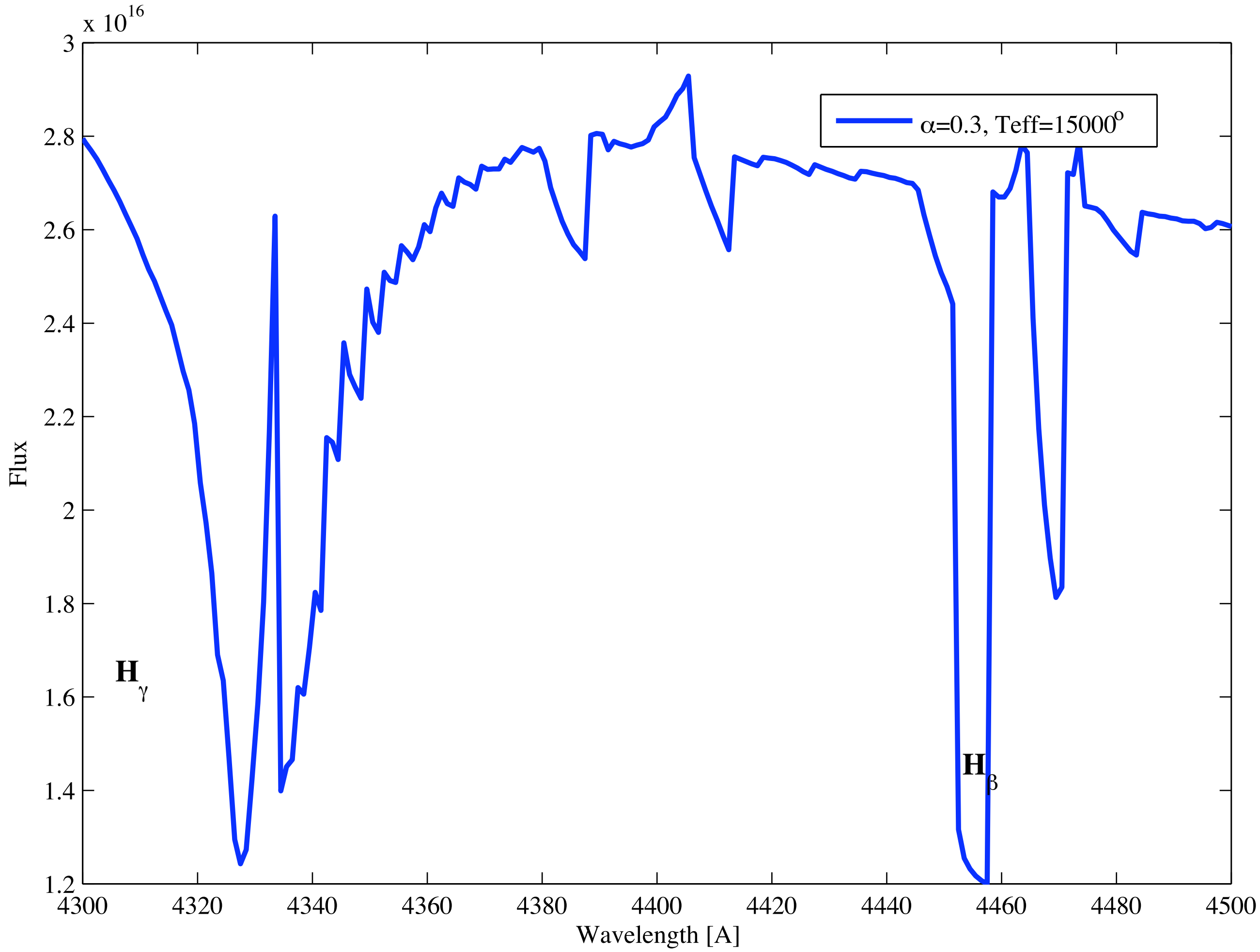


Hot Disc – Balmer jump, Absorption lines



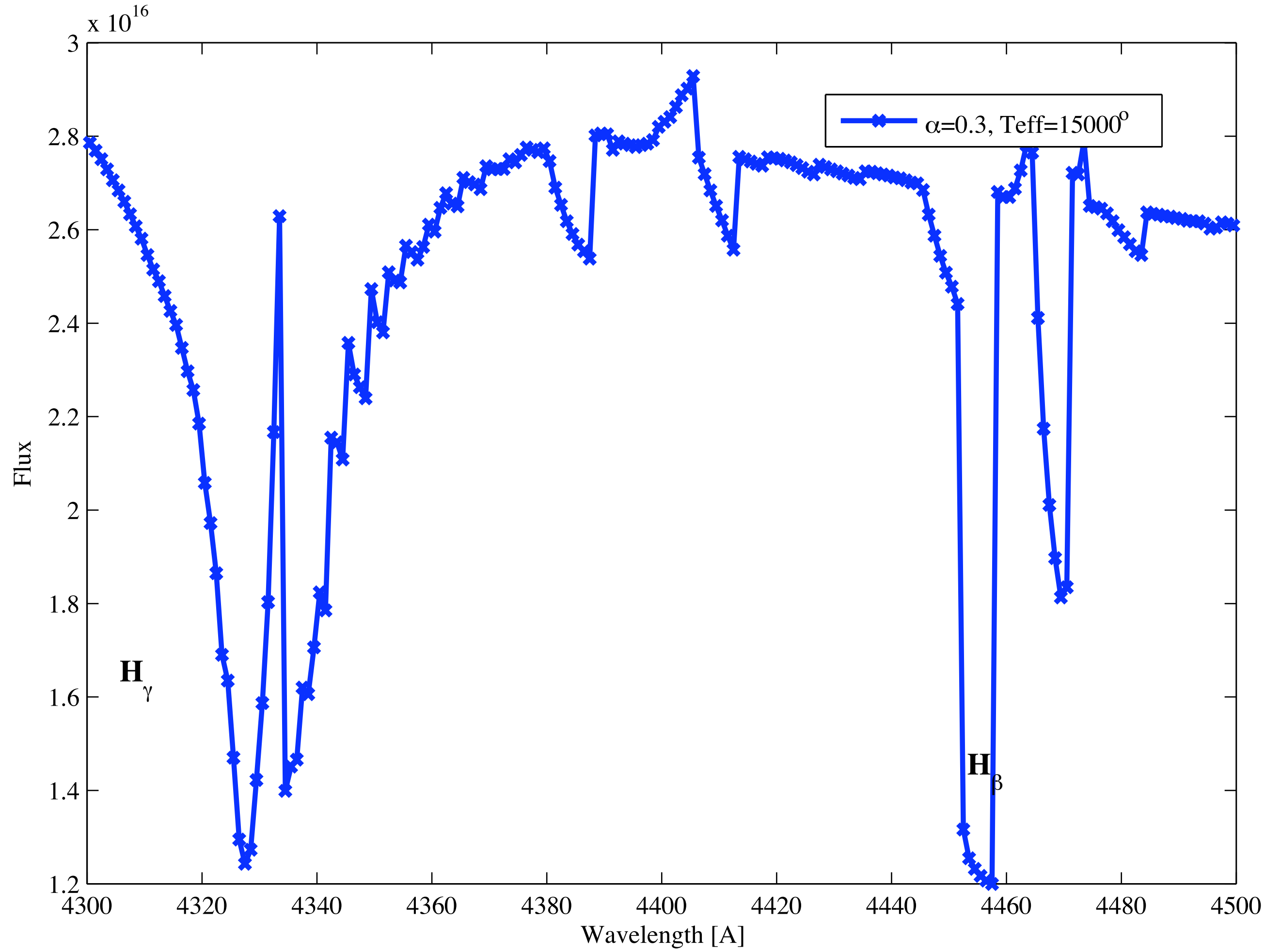
Hot Disc – Absorption lines (some have an emission line inside)

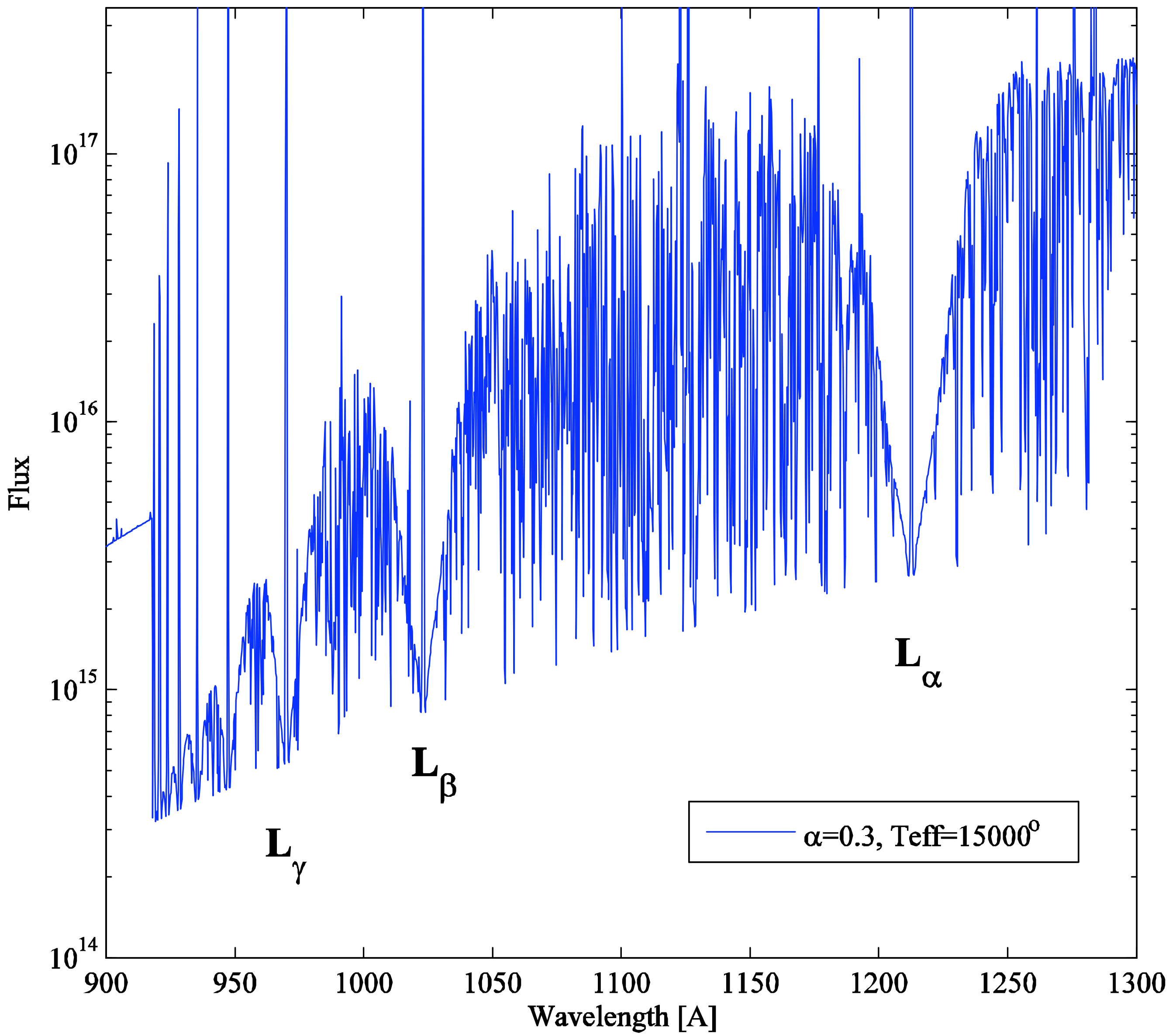
Some of the hydrogen lines show: emission in the line, strong asymmetry



 The obvious question: is it due to poor resolution in the calculation?

It is not due to poor resolution ....





Hot Disc

Narrow Emission lines inside wide absorption lines

Comparison with Wade and Hubeny accretion disc spectrum

Wade and Hubeney (1998) present a large grid of computed far- and mid-ultraviolet spectra (850-2000 A.) of the integrated light from steady-state accretion discs in luminous cataclysmic variables.

We use their parameters for the following comparison:

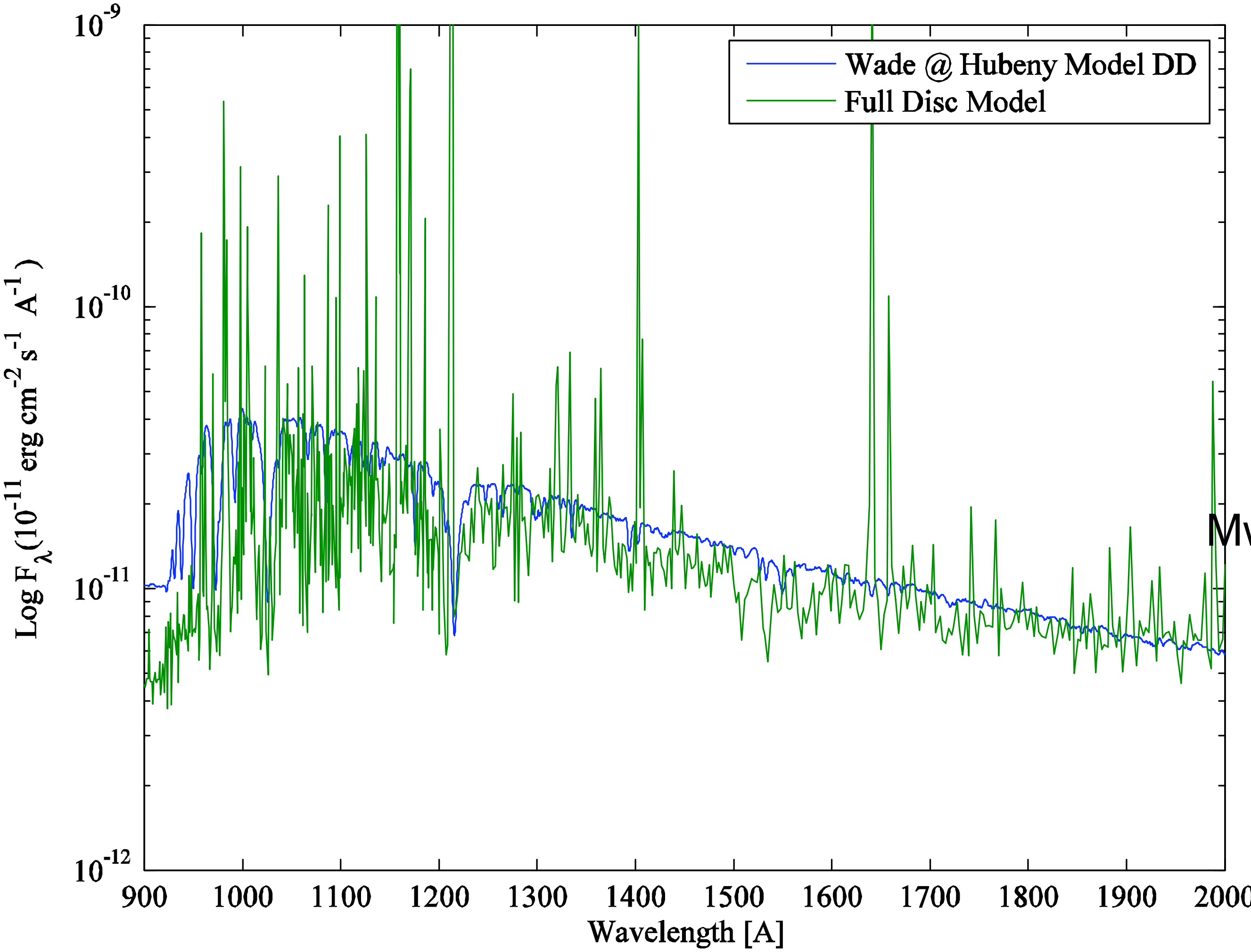
Wade and Hubeny 1998

- Solve the hydrostatic eq. per rings + enforced energy balance between radiative losses at the disc surface and heat generation due to viscosity.
- Solve the radiative transport eq. ($\Delta\lambda$=0.02A)
- Combine the disc spectrum from all the rings
- Convolution with a Gaussian instrumental broadening function and then re-sampled uniformly in wavelength.

Model DD

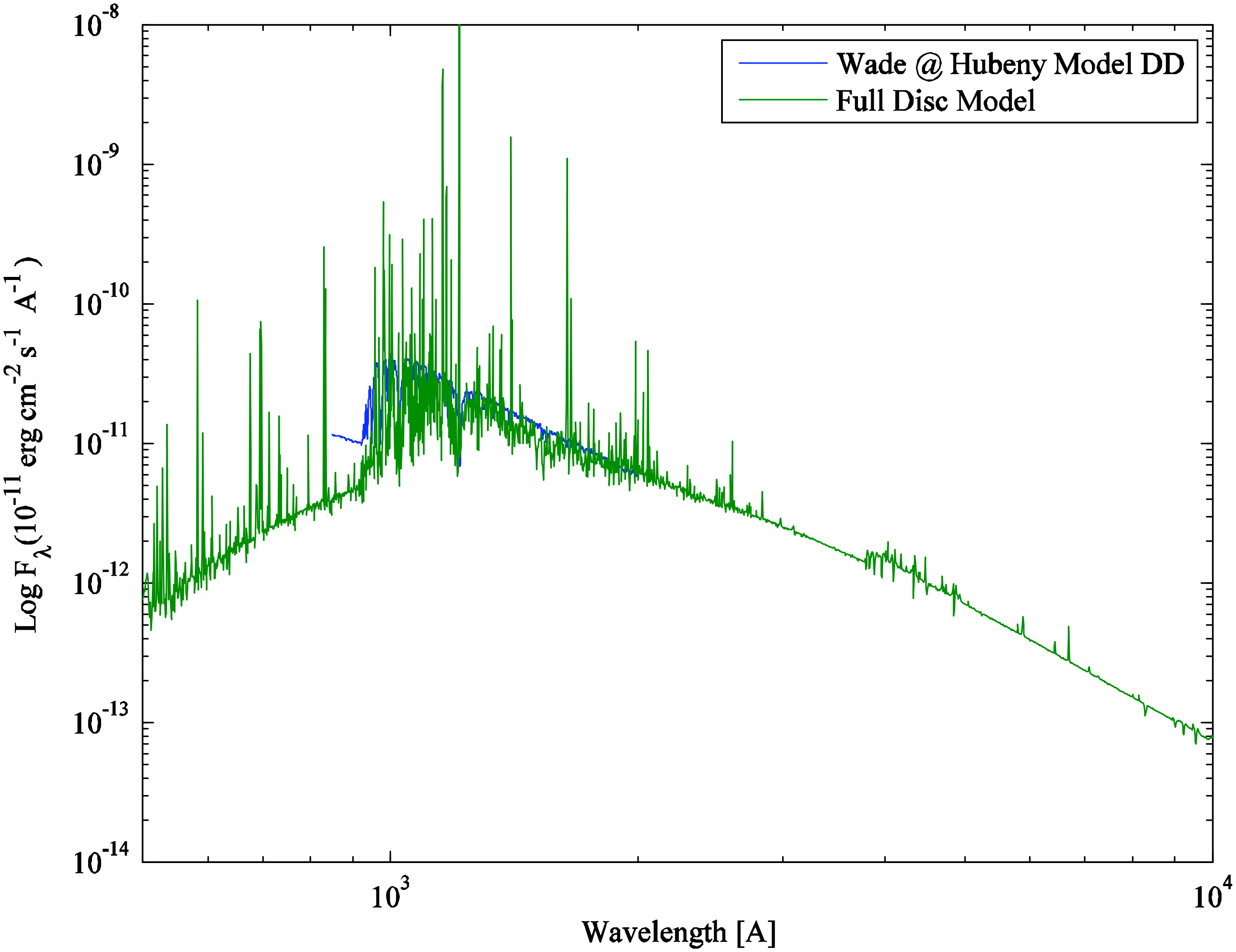
$$M_{wd} = 1 M_{sun}$$

$$Log(\dot{m}) = -8.5 M_{sun} Yr^{-1}$$

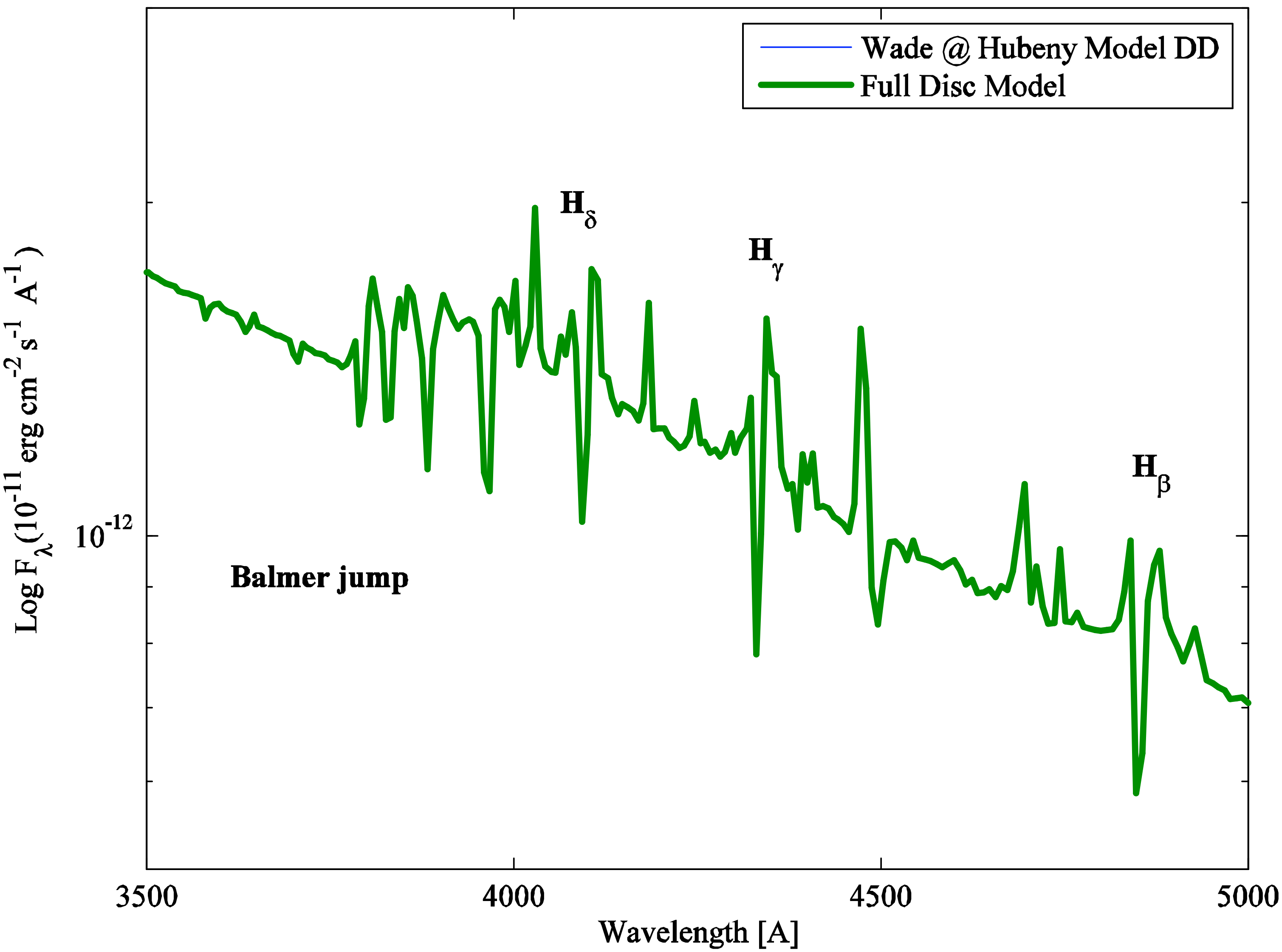


Mwd=1Msun

Accretion rate=$10^{-8.5}$ Msun/yr



Wade @ Hubeny Model DD
Full Disc Model
Log $F_\lambda (10^{-11}$ erg cm^{-2} s^{-1} A^{-1})
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{3}
10^{4}
Wavelength [A]

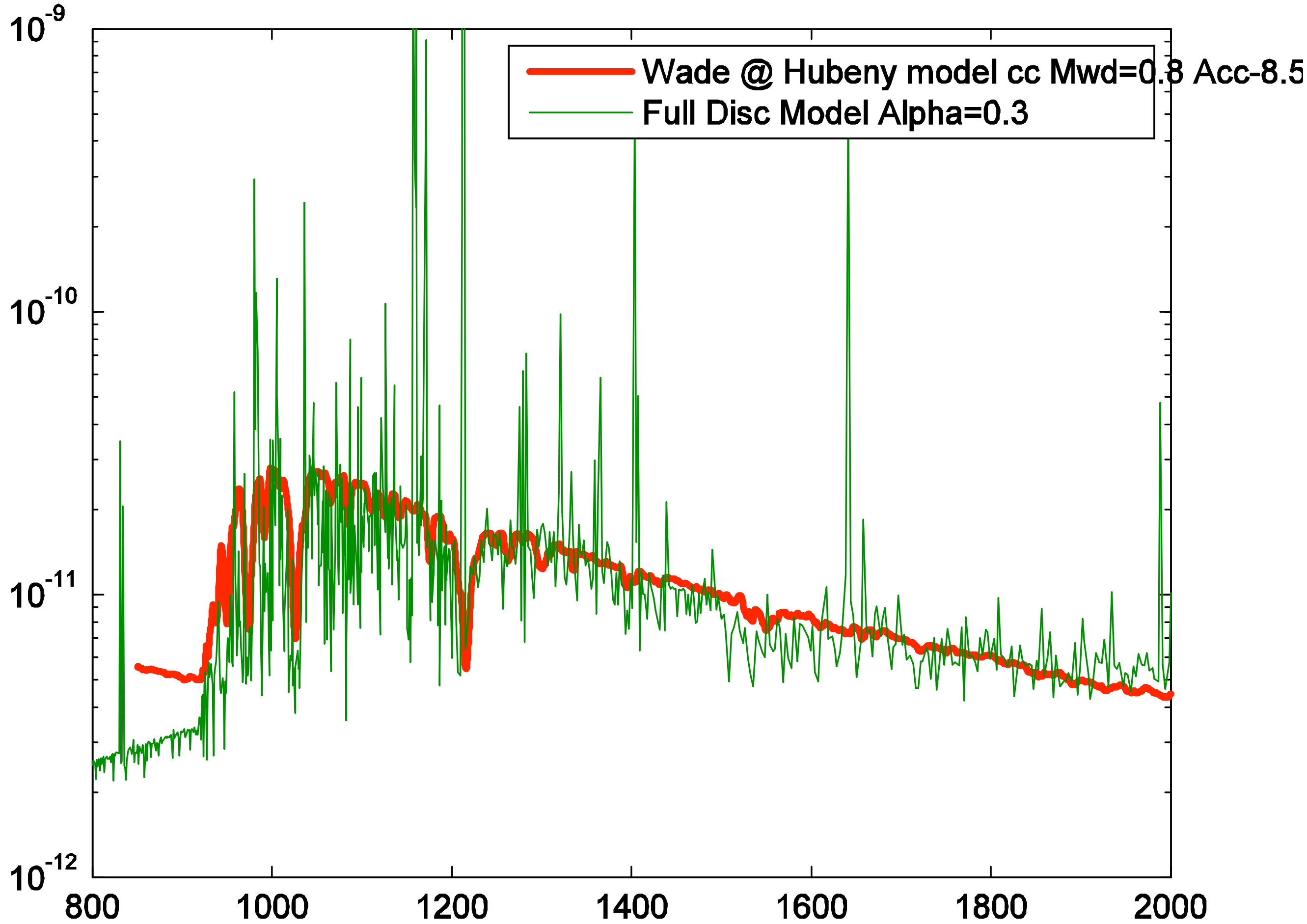

Wade @ Hubeny Model DD
Full Disc Model
H_δ
H_γ
H_β
Balmer jump
Log $F_\lambda (10^{-11}$ erg cm^{-2} s^{-1} A^{-1})
10^{-12}
3500
4000
4500
5000
Wavelength [A]

Model CC

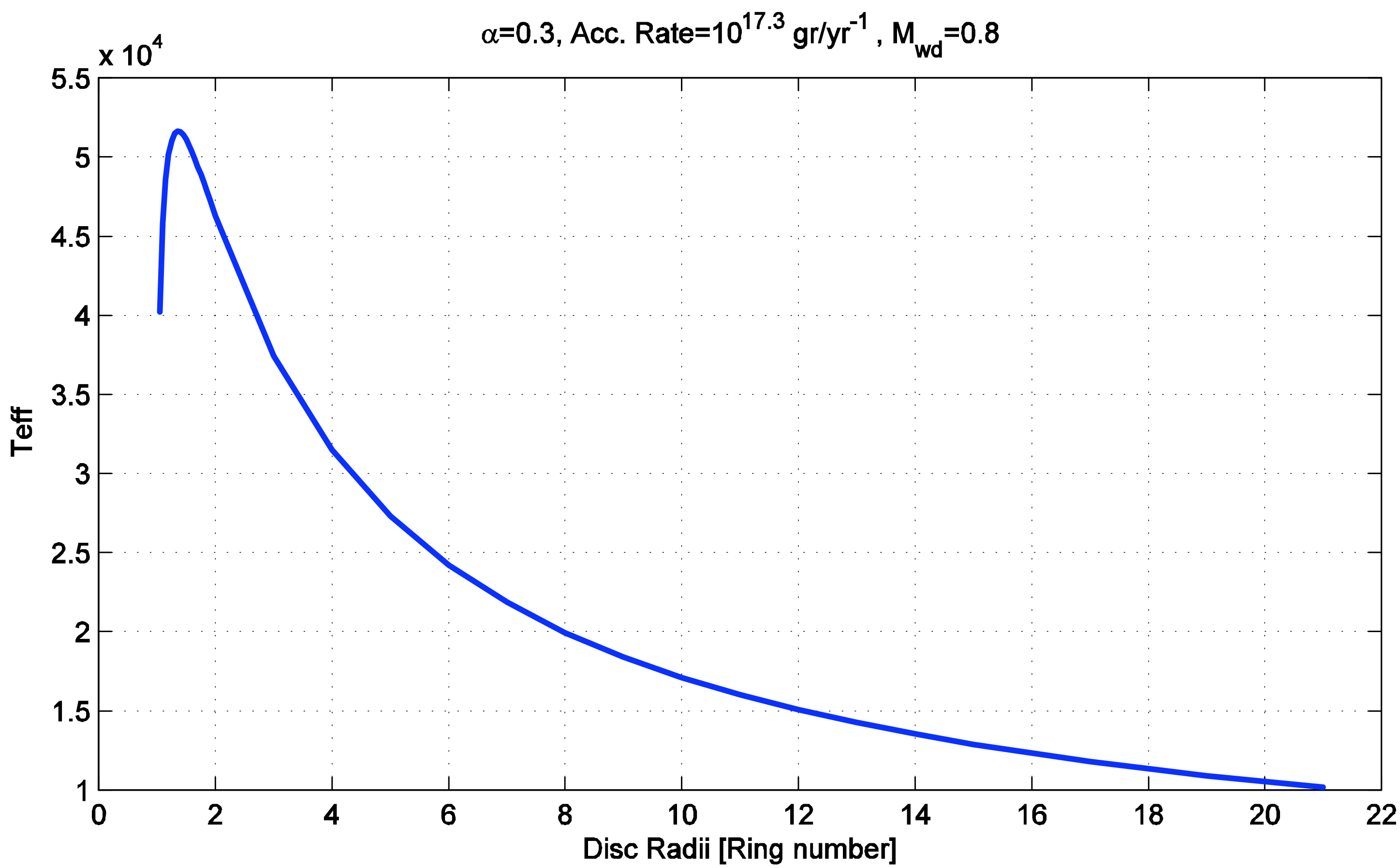
Mwd=0.8Msun

Non alpha viscosity

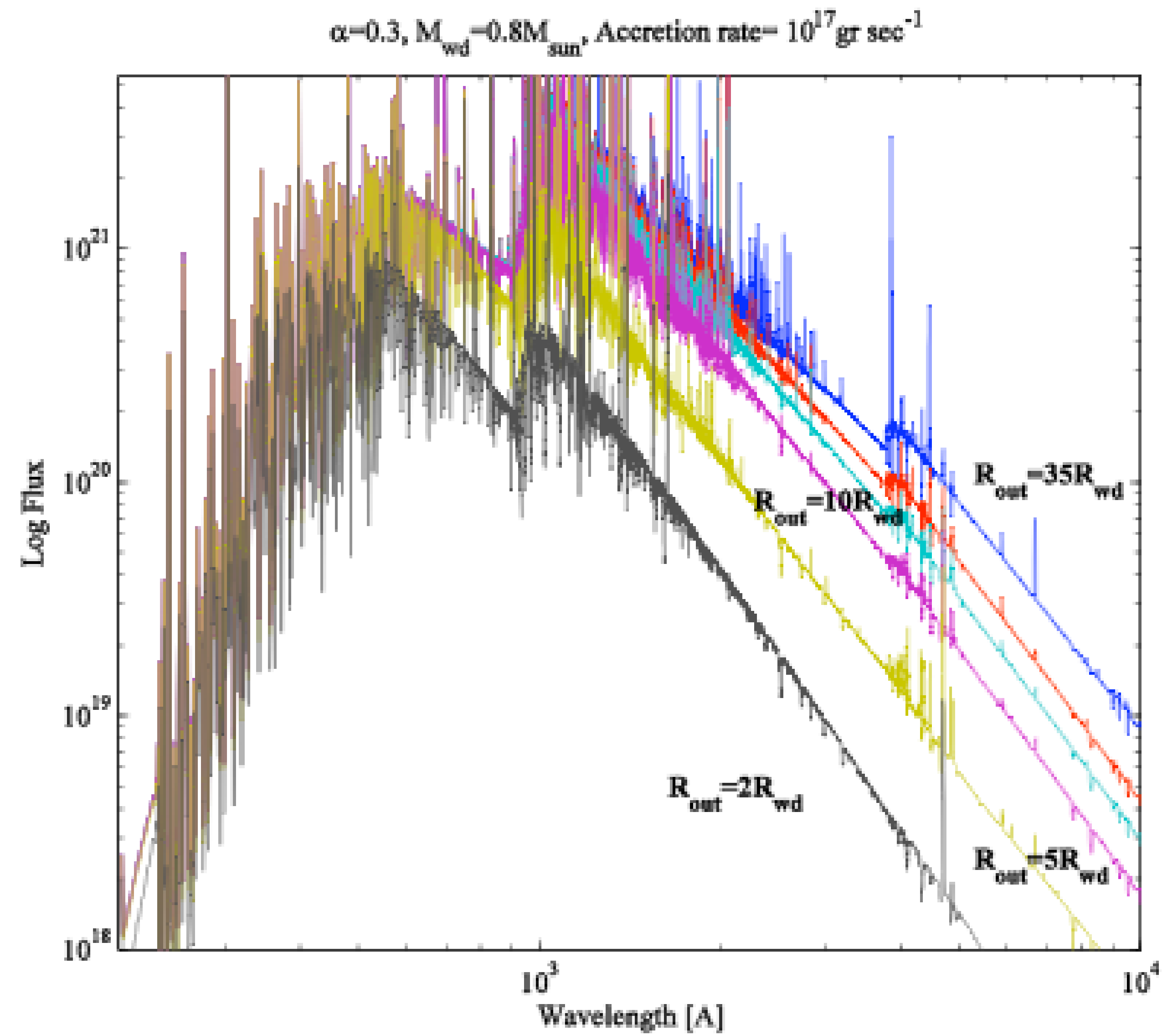
accetion rate=$10^{-8.5}$Msun/yr

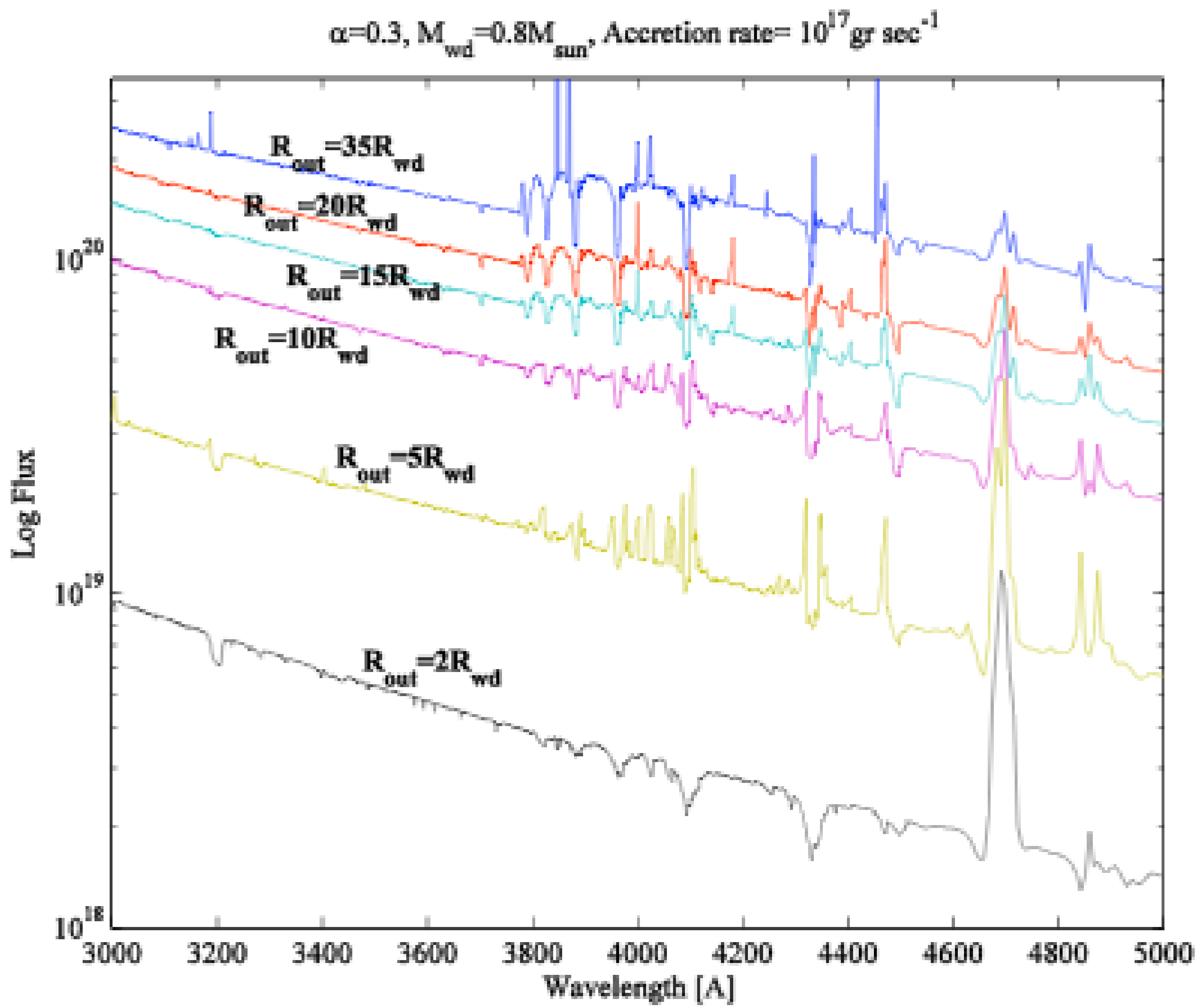


Full Disc Calculation-hot disc

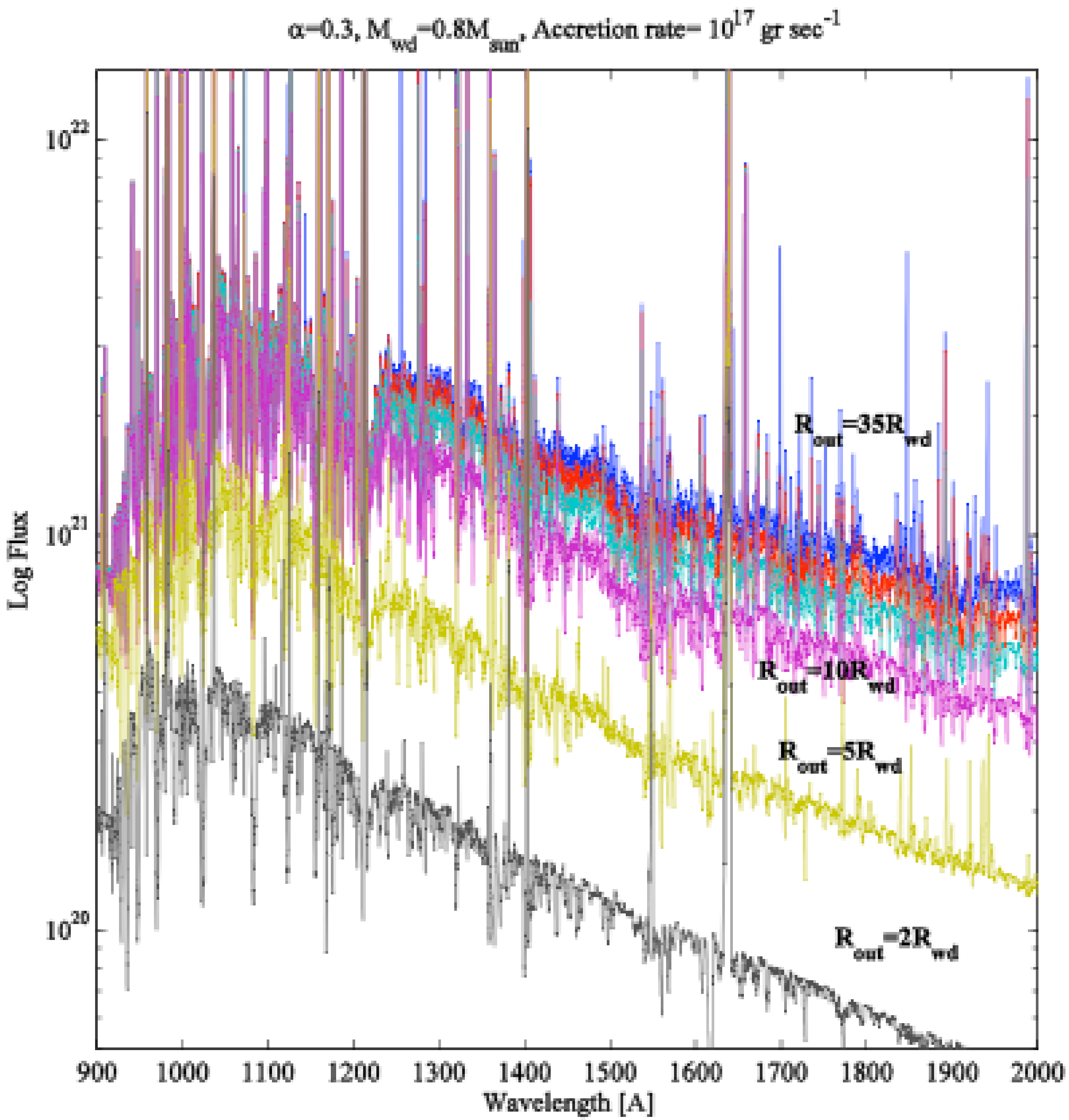


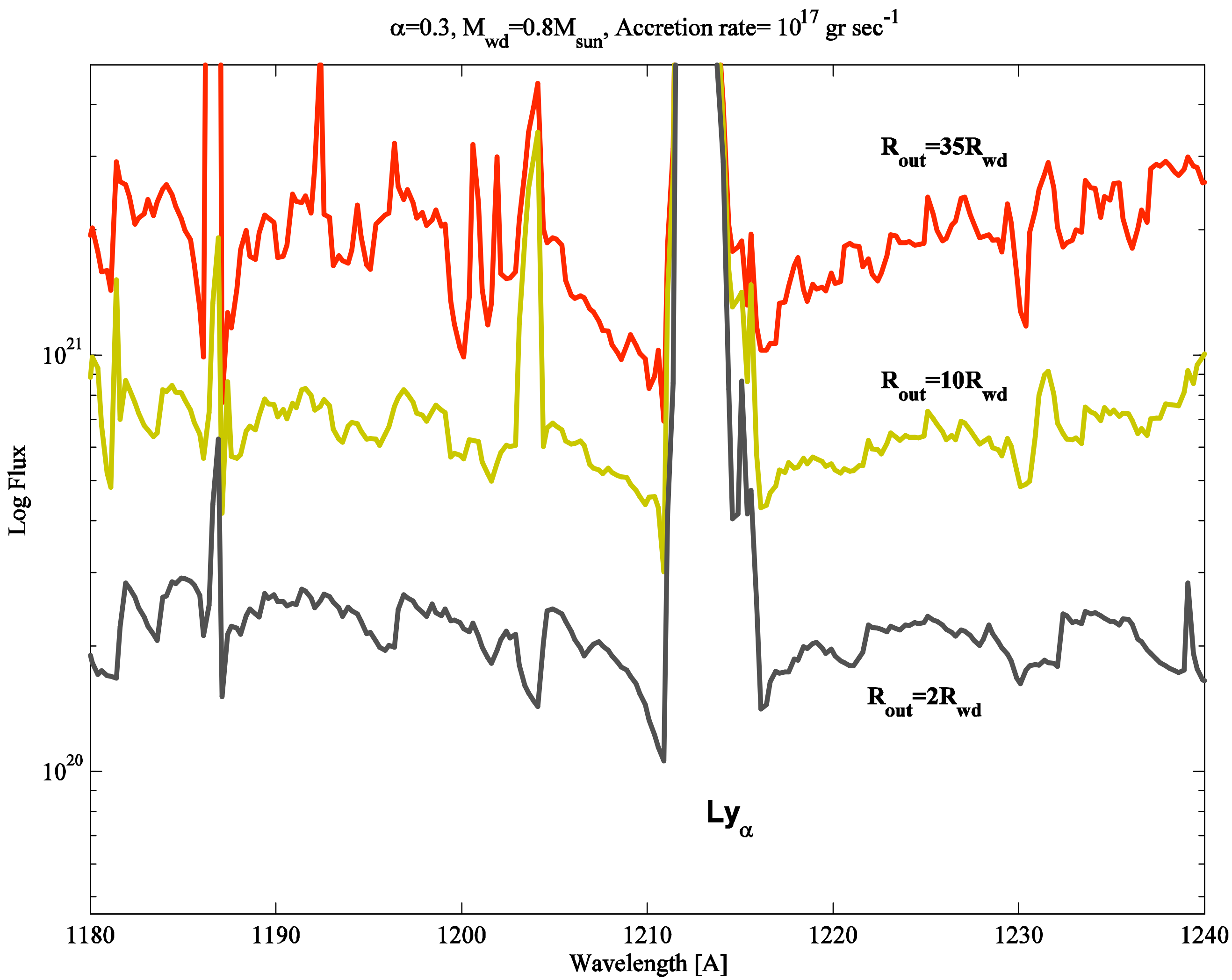
The effective temperature as function of the disc radii


α=0.3, M_wd=0.8M_sun, Accretion rate= 10^17 gr sec^-1
Log Flux
Wavelength [A]
10^21
10^20
10^19
10^18
10^3
10^4
R_out=35R_wd
R_out=10R_wd
R_out=2R_wd
R_out=5R_wd



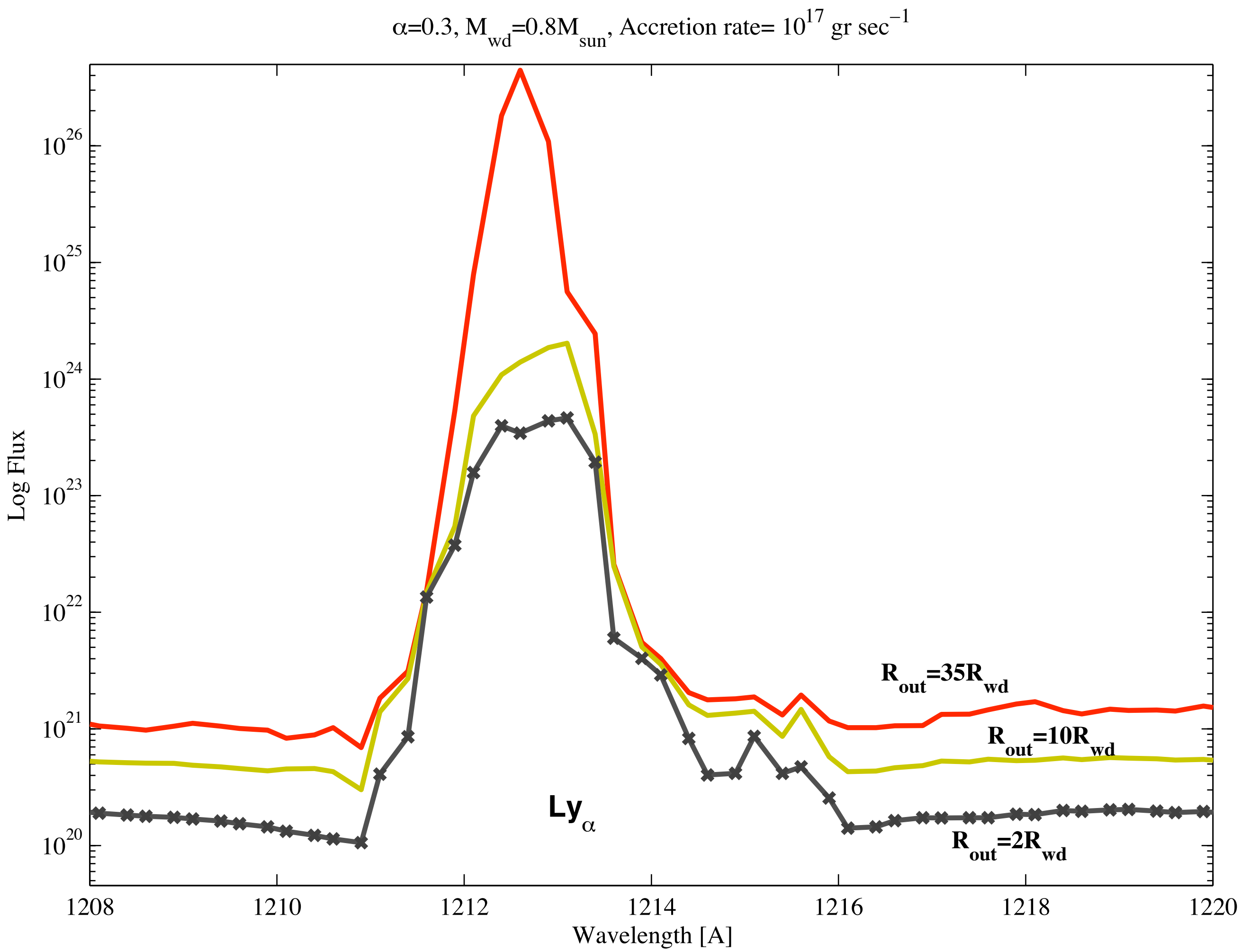
α=0.3, M_wd=0.8M_sun, Accretion rate= 10^17 gr sec^-1
R_out=35R_wd
R_out=20R_wd
R_out=15R_wd
R_out=10R_wd
R_out=5R_wd
R_out=2R_wd
Log Flux
10^20
10^19
10^18
3000
3200
3400
3600
3800
4000
4200
4400
4600
4800
5000
Wavelength [A]


α=0.3, M_wd=0.8M_sun, Accretion rate= 10^17 gr sec^-1
Log Flux
Wavelength [A]
R_out=35R_wd
R_out=10R_wd
R_out=5R_wd
R_out=2R_wd
10^22
10^21
10^20
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

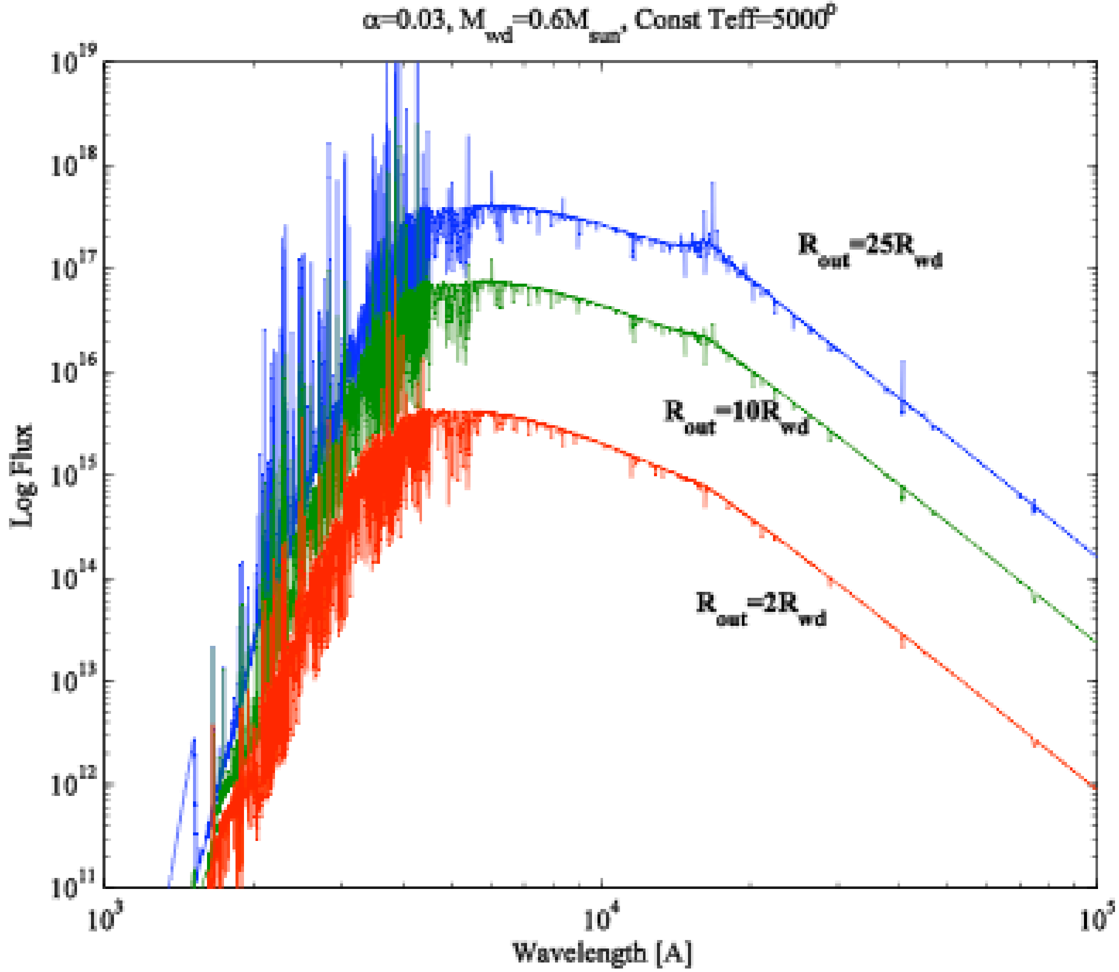


α=0.3, Mwd=0.8Msun, Accretion rate= 10^17 gr sec^-1
Rout=35Rwd
Rout=10Rwd
Rout=2Rwd
Lyα
Log Flux
10^21
10^20
1180
1190
1200
1210
1220
1230
1240
Wavelength [A]

Lyman alpha line has a complicated asymmetric shape



Full Disc Calculation- cold disc



What is the cause of the particular shape of the spectral line? Why such shapes appear in accretion discs and not in stars?

T(optical depth) is different.

For this reason it is very important to solve the hydrostatics and the radiative transfer equation properly for the conditions in the disc

Future work

- Compare with observations – cold disc spectrum versus DN spectrum
- Combine with time dependent code
- How the shape of the line varies with disc size and properties
- Disc in-homogeneities must have an effect on the disc
- Disc tomography
- Include expansion opacities

Happy Birthday from all of us

יום הולדת שמח – מזל טוב מכולנו

Joyeux Anniversaire!

Grattis pŒ fšdelsedagen

A Freilekhn Gebortstog!

Alles Gute zum Geburtstag!

Wszystkiego Najlepszego! or Wszystkiego najlepszego zokazji urodzin!
wszystkiego najlepszego z okazji urodzin