Ellerman Bombs in 1-D Radiative Hydrodynamics

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SOLARNET

F-CHROMA

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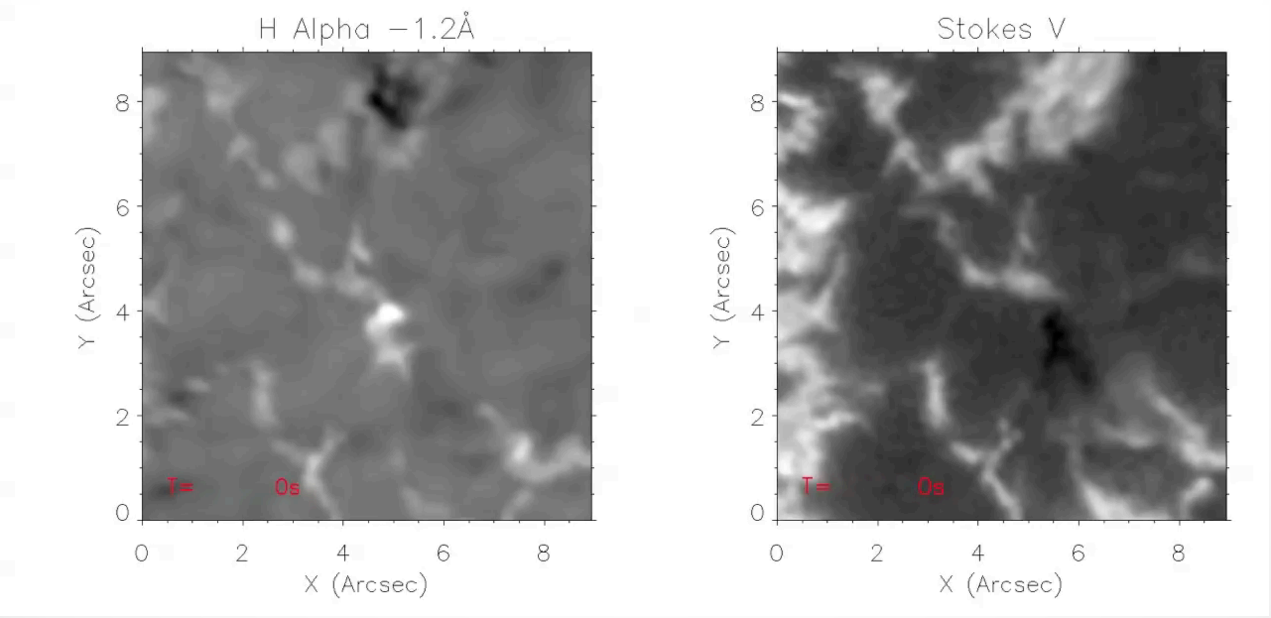
Ellerman Bombs

- Ellerman bombs (EBs) first identified as "Solar Hydrogen Bombs" in 1917 by Ferdinand Ellerman
- He noticed a brightening in the wings of Hα, Hβ and Hγ while leaving the line centre dark, lasting no more than a few minutes.
- EB energies are typically thought to range between 10^{24} – 10^{28} ergs.
- They are mainly found near Sunspots, active regions, or generally areas of increased magnetic activity.
- Recent studies using spectro-polarimetry show magnetic bipoles are observed in EB regions.
- Magnetic reconnection is the generally accepted driving mechanism now for EB ignition.



Reid et al. 2015

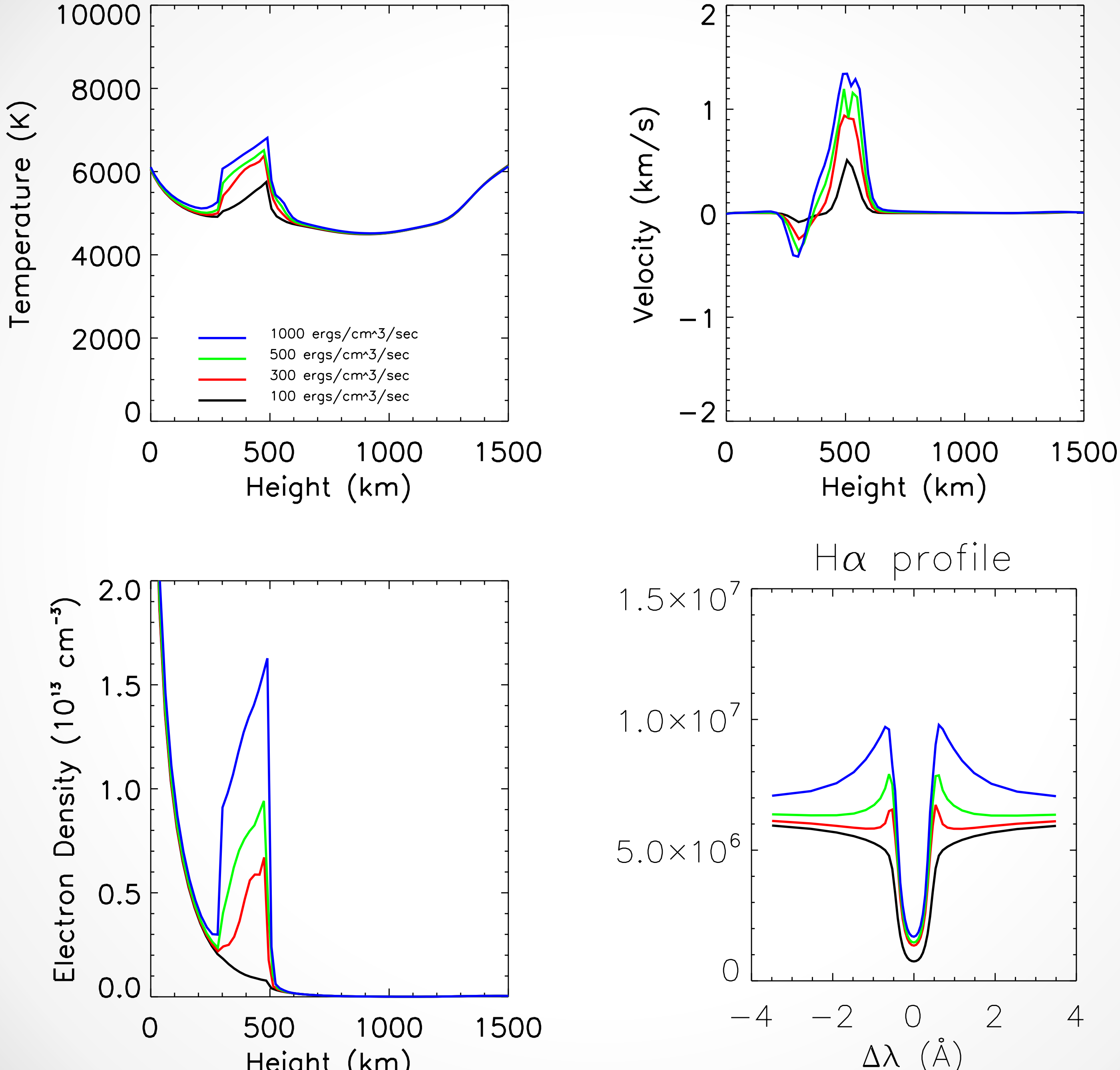
The RADYN code

- The RADYN code solves the equations of radiative hydrodynamics in 1 dimension and evolves them in time.
- A time dependent heating function can then be applied to an initial atmosphere.
- This function gives 2 free parameters in an attempt to model these lines;
    - Energy deposition rate
    - Location of energy deposition
- By computing the line profiles via the radiative transfer equation through the atmosphere, it will be possible to attain what energy deposition rate at which height best recreates EB-like line profiles.

Grid 1

- A grid of models was set up in order to investigate the energies needed in the photosphere to cause EB-like profiles.
- Heating is applied between 300 – 500 km above the photospheric floor, ranging between 100– 1000 ergs/cm^3/sec.
- This is calculated from estimates of the radiative losses from observed EBs, along with typical sizes and lifetimes (Georgoulis etal. 2002, Nelson etal. 2013a, Vissers etal. 2015).
- At this stage, we will focus on the H alpha response.

Grid Number	Energy Rate	Height (km)	Atmosphere	Comments
1	100 - 1000	300 - 500	Quiet Sun	300 - 700 ergs/cm^3/sec best fit EB profiles in Hα.
2	500	300 - 1000 (200 km step)	Quiet Sun	500 - 700 km best fit EB profiles in Hα and Ca II.
3	1000 - 1 x 10^6	300 - 500	Quiet Sun	All <10,000 K. Overwhelmed by continuum emission in all lines.
4	500	1000 - 2000 (200 km step)	Quiet Sun	Flare-like profiles in Ca & Hα. Good Mg II response.
5	500/1000	300 - 900 (200 km step)	Plage	500 - 700 km best fits EB Ca & Hα profiles. 700 - 900 km best fits IB Mg II profiles.
6	500/1000	1000 - 2000 (200 km step)	Plage	Flare-like profiles in all lines.
7	500	500 - 1000	Both	Strong line core enhancement in Ca, Hα. Weak Mg II response in QS atmosphere.
8	500	500 - 1200	Both	Ca in full emission, Hα strong enhancement. Good Mg II response in QS atmosphere.



Temperature (K)
10000
8000
6000
4000
2000
0
1000 ergs/cm^3/sec
500 ergs/cm^3/sec
300 ergs/cm^3/sec
100 ergs/cm^3/sec
0
500
1000
1500
Height (km)
Velocity (km/s)
2
1
0
−1
−2
0
500
1000
1500
Height (km)
Electron Density (10¹³ cm⁻³)
2.0
1.5
1.0
0.5
0.0
0
500
1000
1500
Height (km)
Hα profile
1.5×10⁷
1.0×10⁷
5.0×10⁶
0
−4
−2
0
2
4
Δλ (Å)

Grid 2

- Next, the correct height at which this energy is placed is needed.
- To do this, a second grid of models was created, which varies 500 ergs/cm^3/sec being deposited between 300 and 1000 km above the photospheric floor in 200 km steps.
- By varying the deposition location and by examining multiple wavelengths, it will be possible to attain a rough height estimate for these events.

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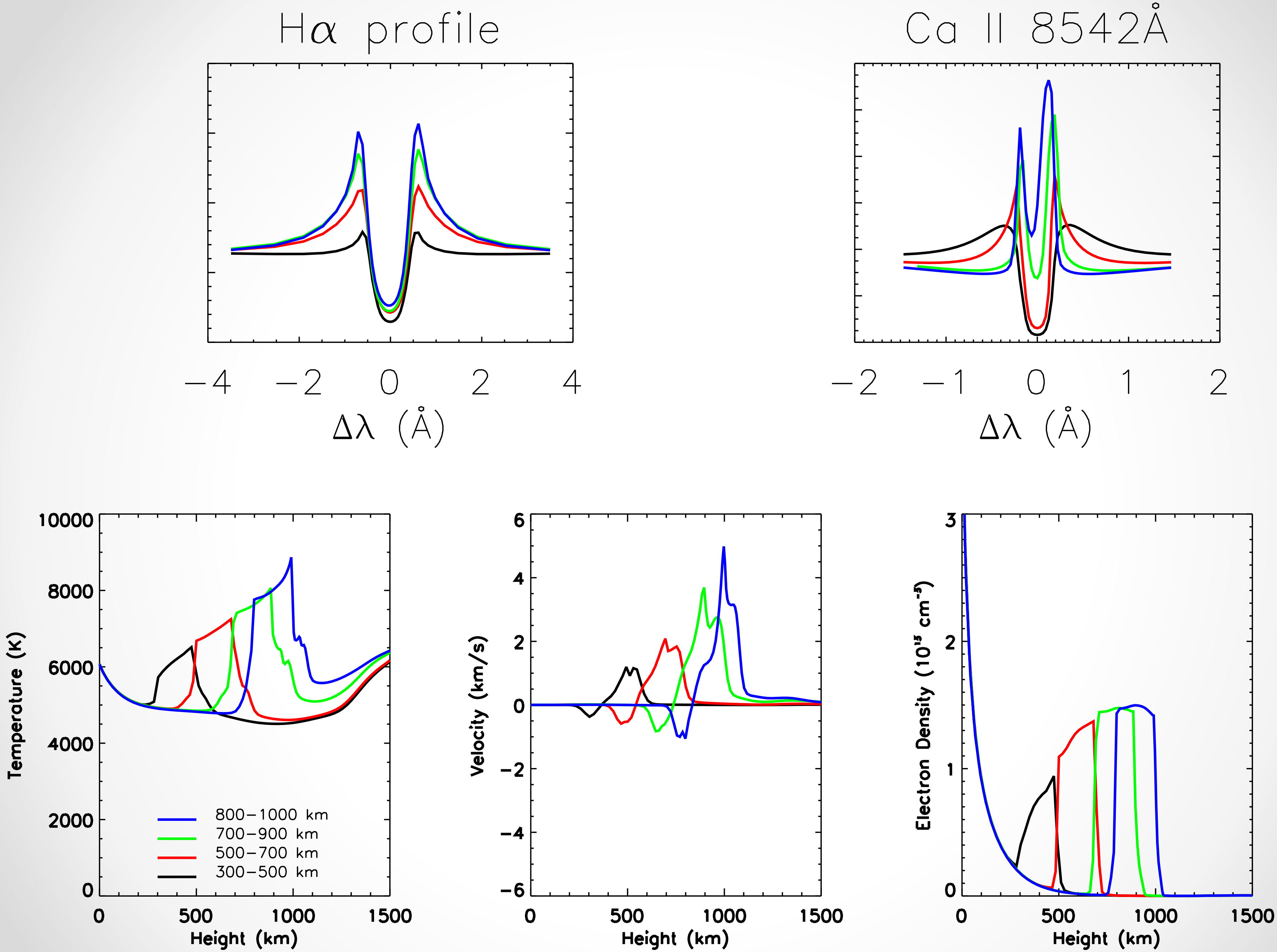
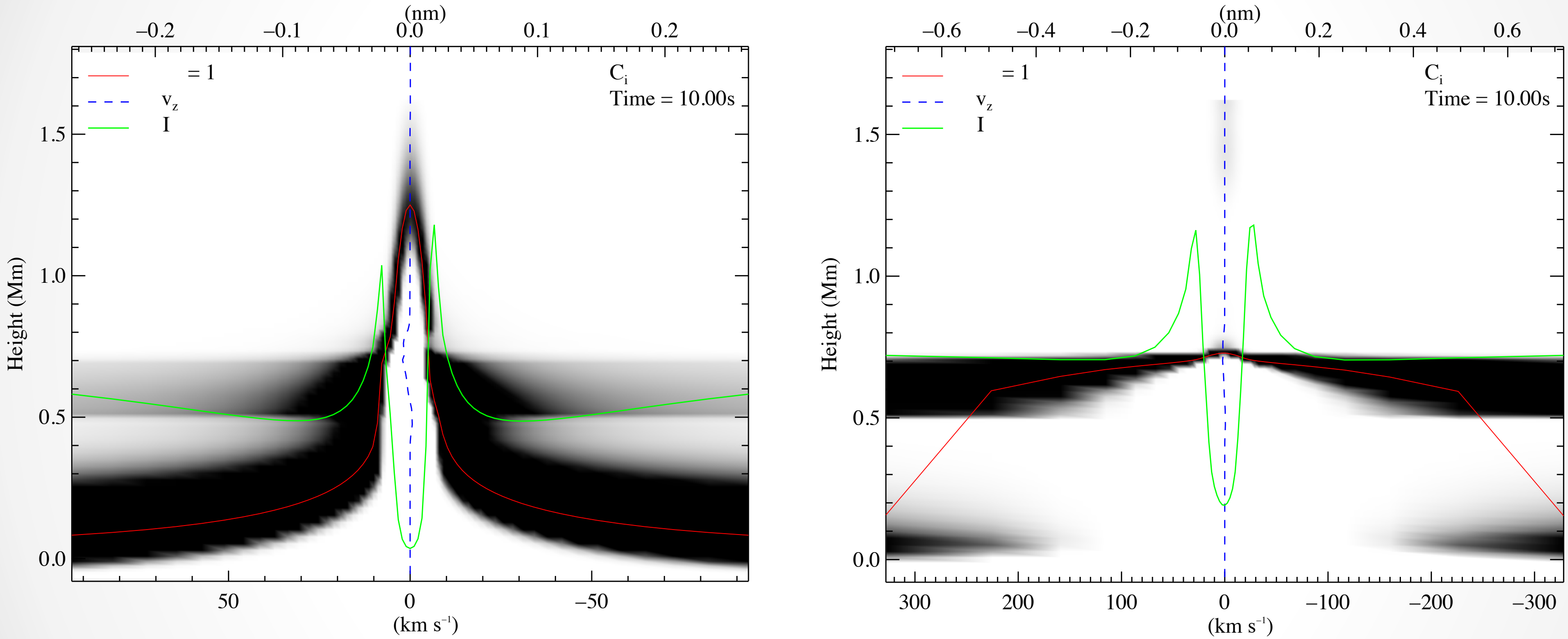
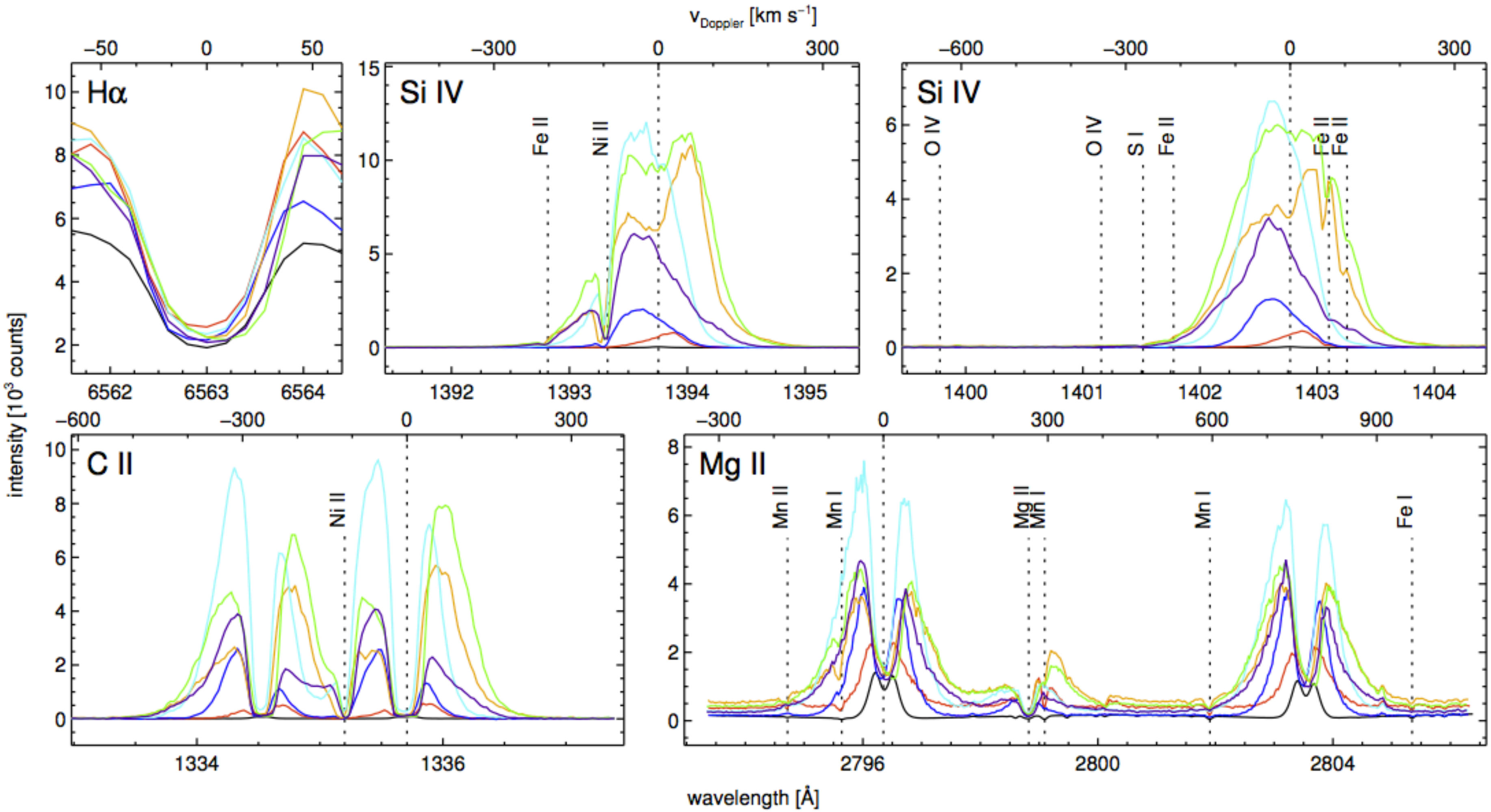


Hα profile
Ca II 8542Å
Δλ (Å)
Δλ (Å)
Temperature (K)
Velocity (km/s)
Electron Density (10¹⁵ cm⁻³)
Height (km)
Height (km)
Height (km)
800−1000 km
700−900 km
500−700 km
300−500 km



(nm)
−0.2
−0.1
0.0
0.1
0.2
= 1
v_z
I
C_i
Time = 10.00s
Height (Mm)
1.5
1.0
0.5
0.0
50
0
−50
(km s^{-1})
(nm)
−0.6
−0.4
−0.2
0.0
0.2
0.4
0.6
= 1
v_z
I
C_i
Time = 10.00s
Height (Mm)
1.5
1.0
0.5
0.0
300
200
100
0
−100
−200
−300
(km s^{-1})

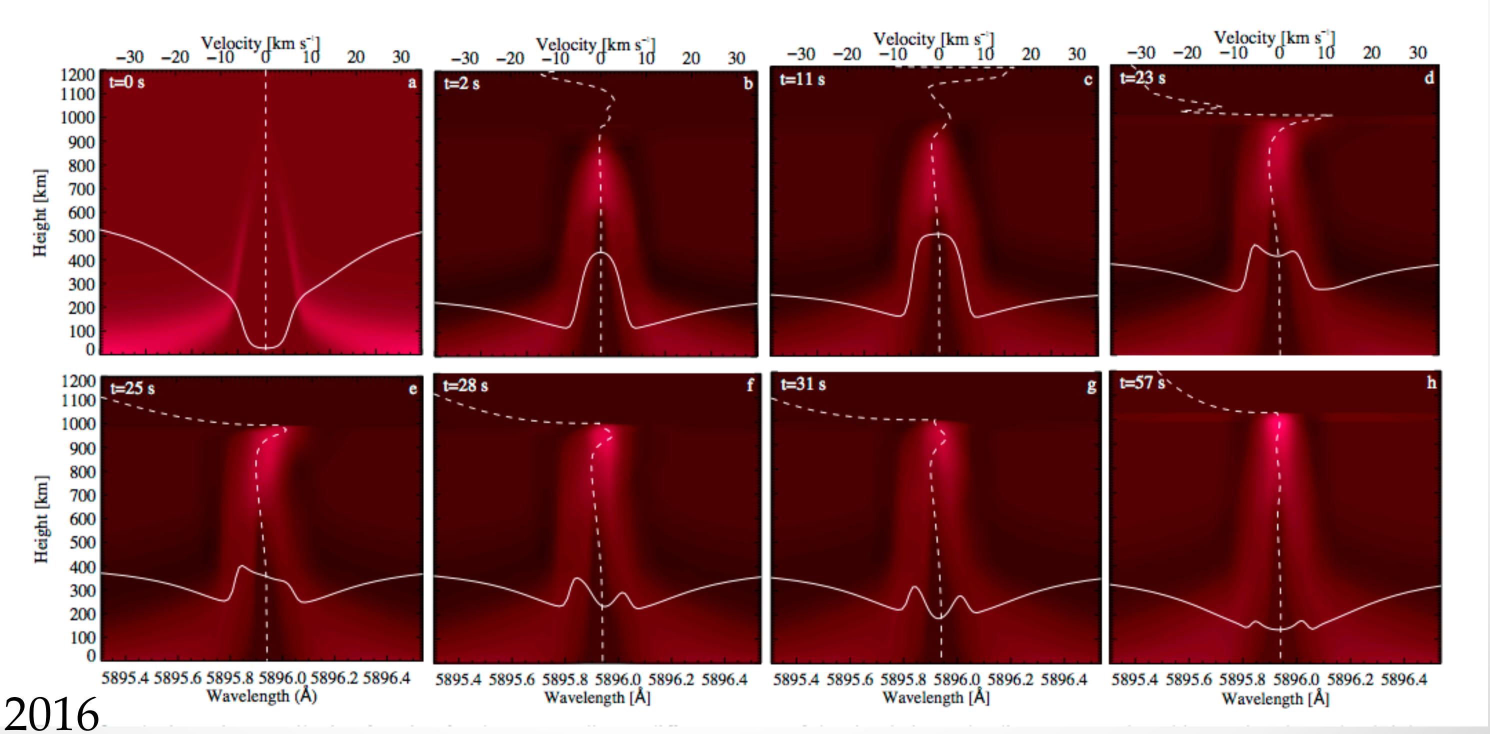
UV Bursts



Vissers etal. (2015)

Calculating the Mg II h & k line profiles.

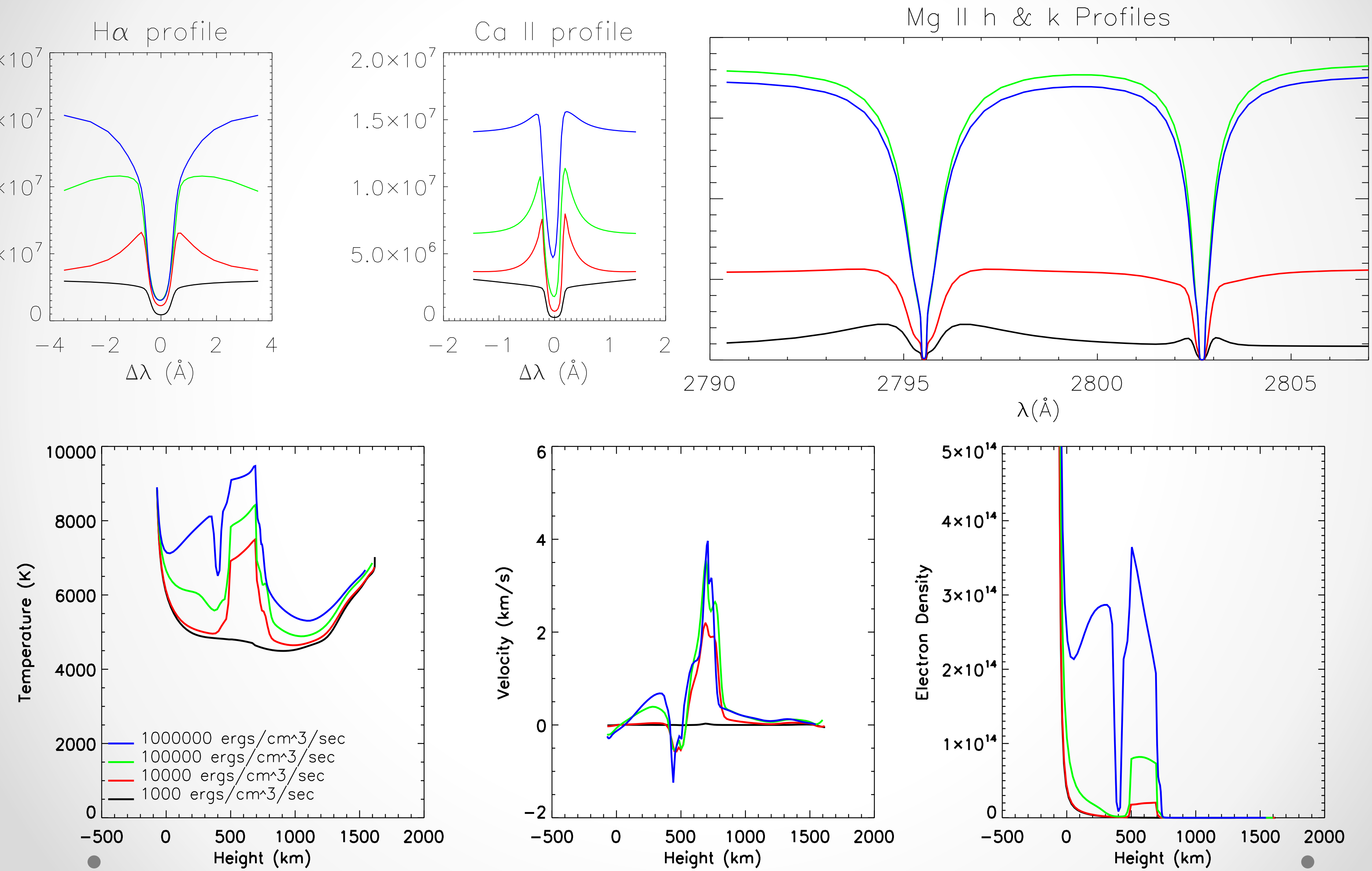
- RADYN calculates line profiles in complete redistribution (CRD), which is not suitable for resonance lines.
- Partial Redistribution (PRD) instead must be used. This is achievable by within the RH code.
- The RADYN outputs files could then be converted into RH format, at t=10s, calculating the Mg II h & k line profiles to compare with IRIS.



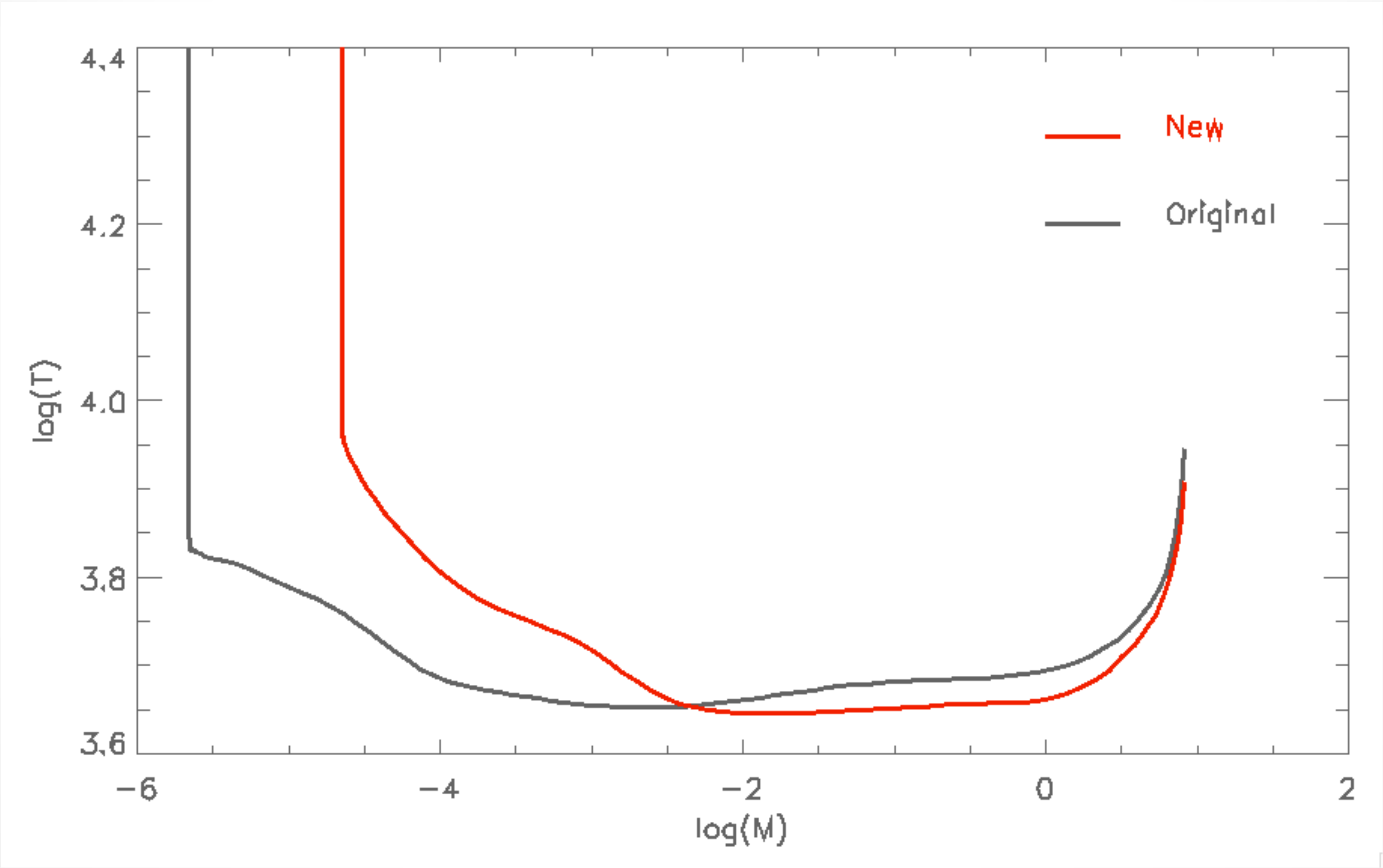
Kuridze etal 2016

Grid 3

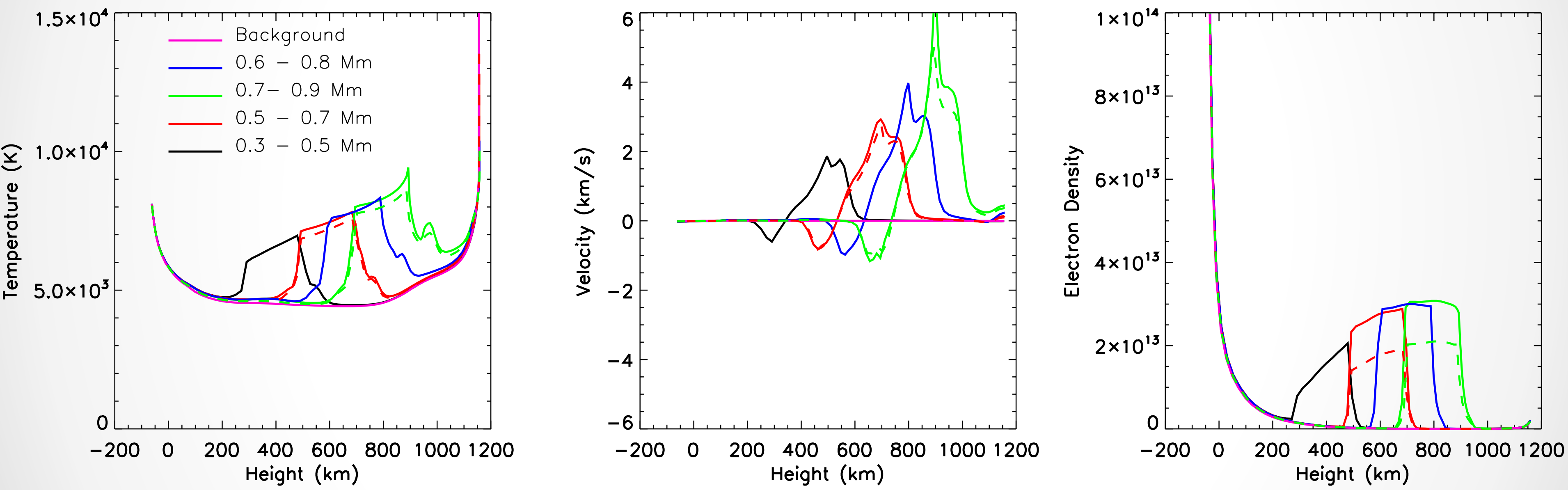
- With the previous models not showing any enhancement with Mg II h & k profiles, the energy deposition rate was changed to increase the energy logarithmically, from 1,000 – 1,000,000 ergs/cm^3/sec, in an attempt to recreate the 80,000 K photospheric temperatures.



Changing the initial atmosphere

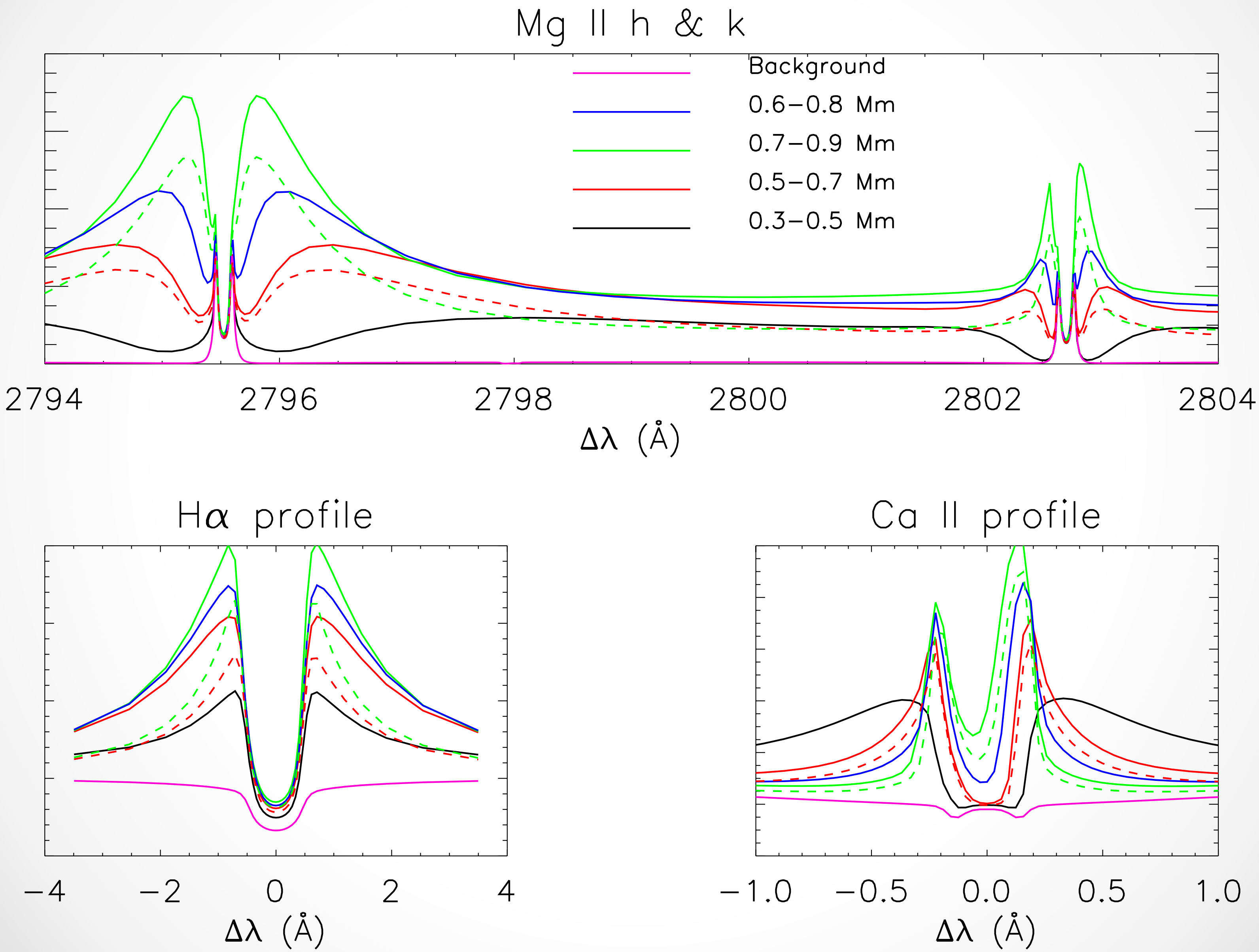


Grid 5



Background
0.6 – 0.8 Mm
0.7– 0.9 Mm
0.5 – 0.7 Mm
0.3 – 0.5 Mm
Temperature (K)
Height (km)
Velocity (km/s)
Electron Density

Grid 5


Mg II h & k
Background
0.6−0.8 Mm
0.7−0.9 Mm
0.5−0.7 Mm
0.3−0.5 Mm
2794
2796
2798
2800
2802
2804
Δλ (Å)
Hα profile
−4
−2
0
2
4
Δλ (Å)
Ca II profile
−1.0
−0.5
0.0
0.5
1.0
Δλ (Å)

Conclusions

- By only considering the Halpha and Ca II 8542 lines, we are able to re-create atmospheric conditions which replicate EB-like profiles.
- This occurs when 500 $ergs/cm^3/sec$ is deposited between 500 – 700 km above the photospheric floor.
- This does not however re-create recently observed IRIS signatures in Mg II h & k.
- The starting atmosphere was changed to a more active region environment in order to obtain more accurately shaped Mg II h & k profiles from the rest model.
- With the new model, IRIS-bomb signatures could be obtained by depositing the energy between 700 – 900 km, though this would only cause large core emission in Ca II 8542.
- This is due to the Mg II h & k line wings being formed at the same location as the Ca II 8542 line core.
- As such, we can reproduce EB like profiles in 2 of the 3 diagnostic lines, but not all 3 simultaneously.

Thanks!

- Special Thanks to:
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