Spectral continua in solar flares: blue, red or white ?

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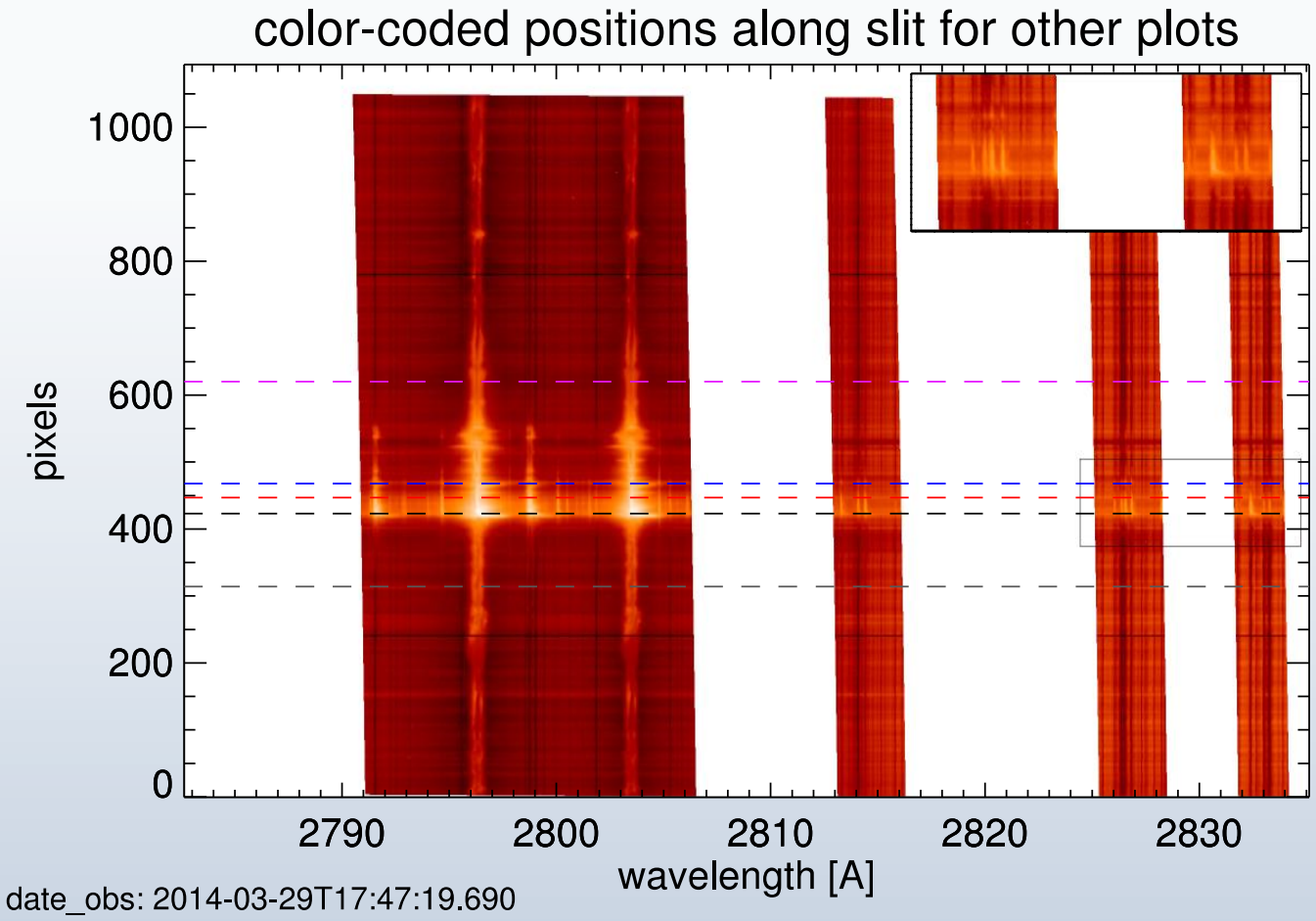
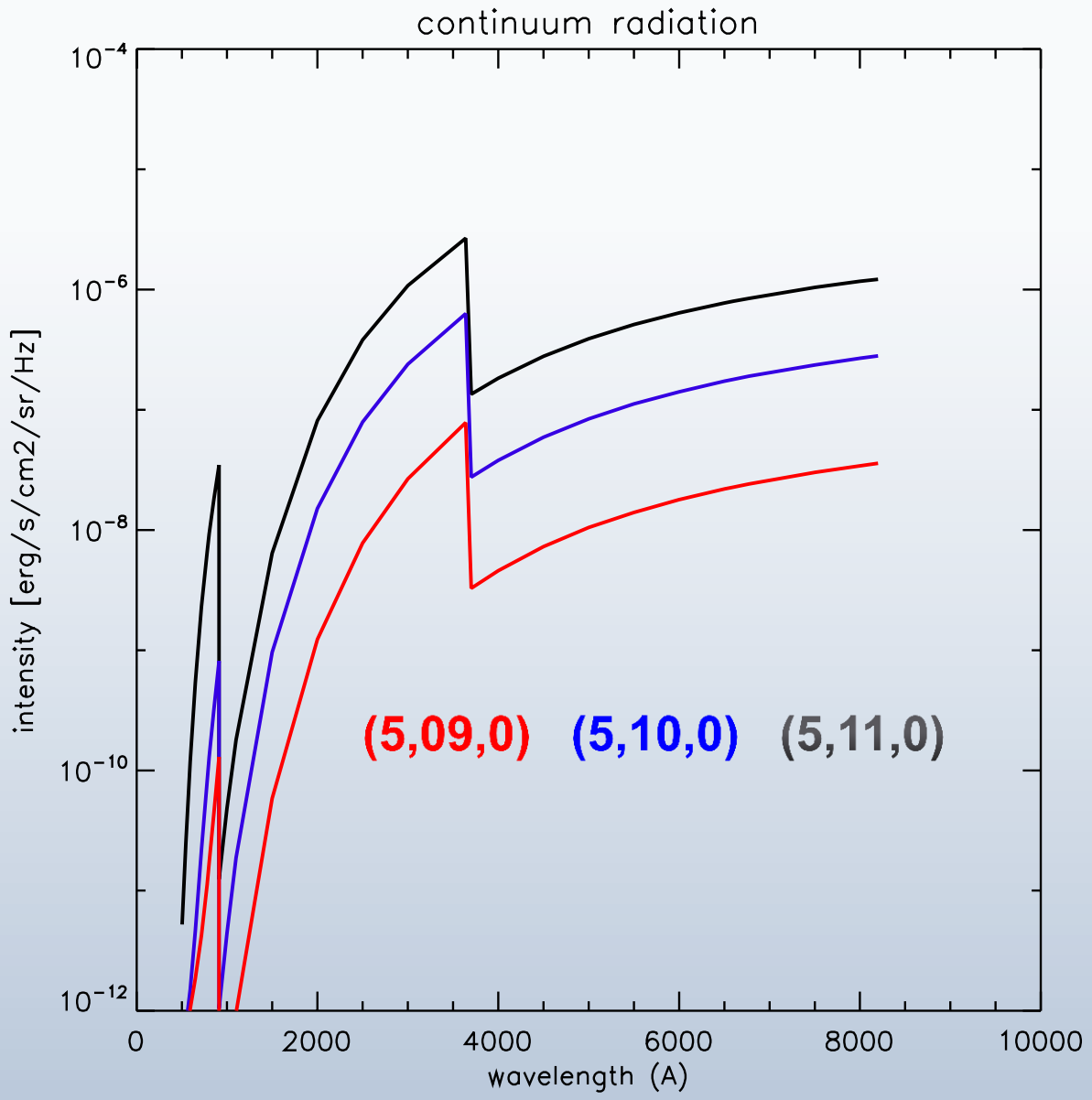
F-CHROMA

IRIS NUV spectra



Heinzel & Kleint (2014)

Static models of Ricchiazzi & Canfield (1983)

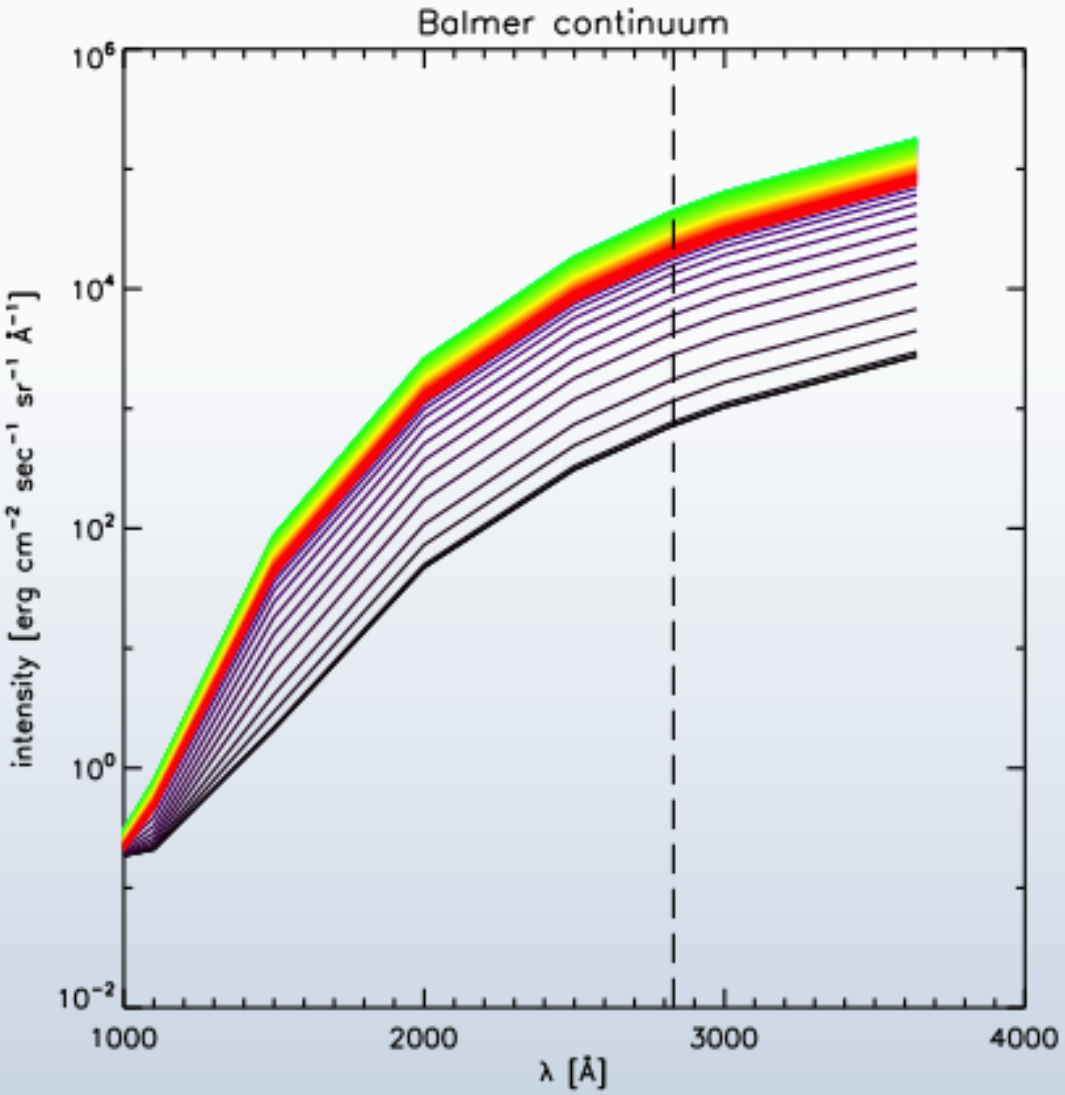


RC-model	Balmer enh. at 2830 A	Paschen enh. at 6000 A
E3	6.57E4	1.35E4
E4	3.17E5	5.82E4
E5	1.11E5	1.94E4
E6	2.78E5	4.70E4
E7	7.12E5	1.21E5
E12	9.41E4	1.79E4
E13	7.48E5	1.26E5
E14	1.74E6	3.60E5
E15	3.95E5	6.93E4

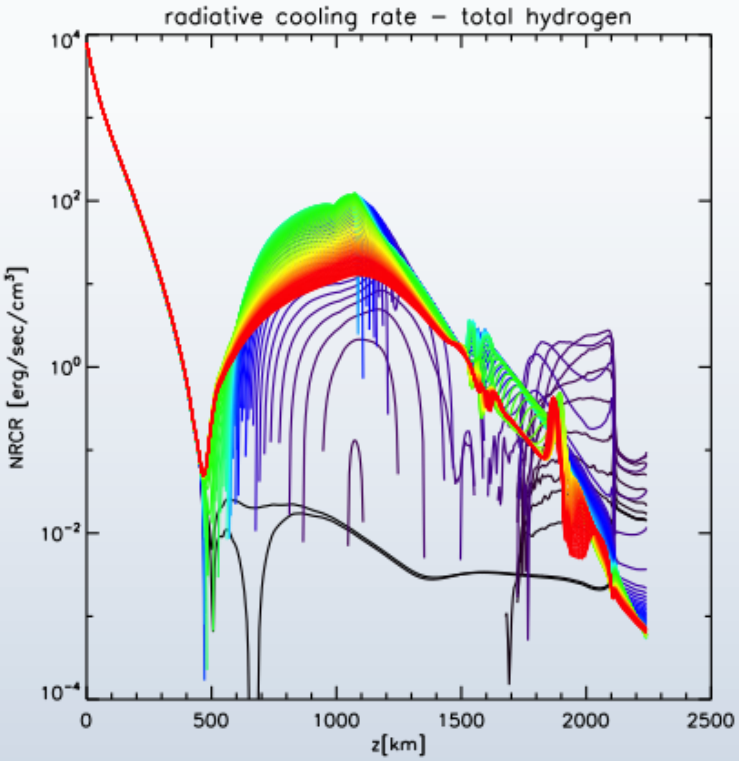
units are erg/s/cm2/sr/A

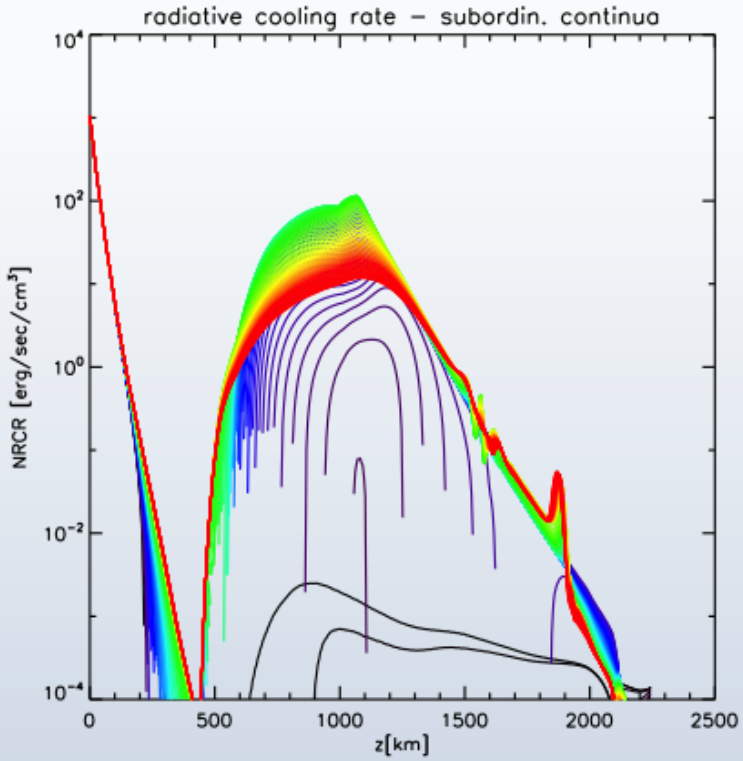
Balmer enh. as in Table 1 (Kleint et al. 2016)

photospheric continuum at 6000 A: 3.12E6 (Allen)

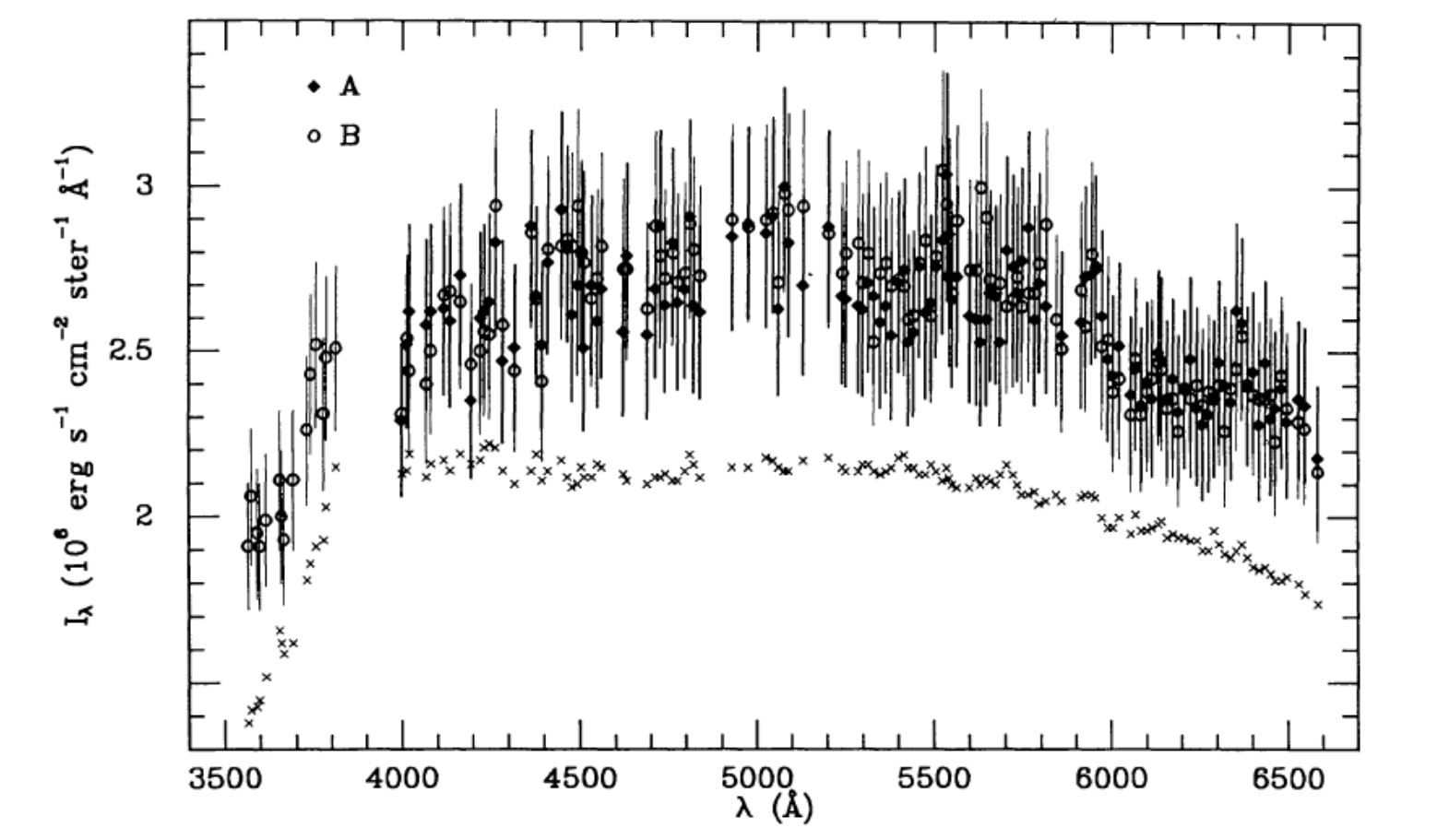


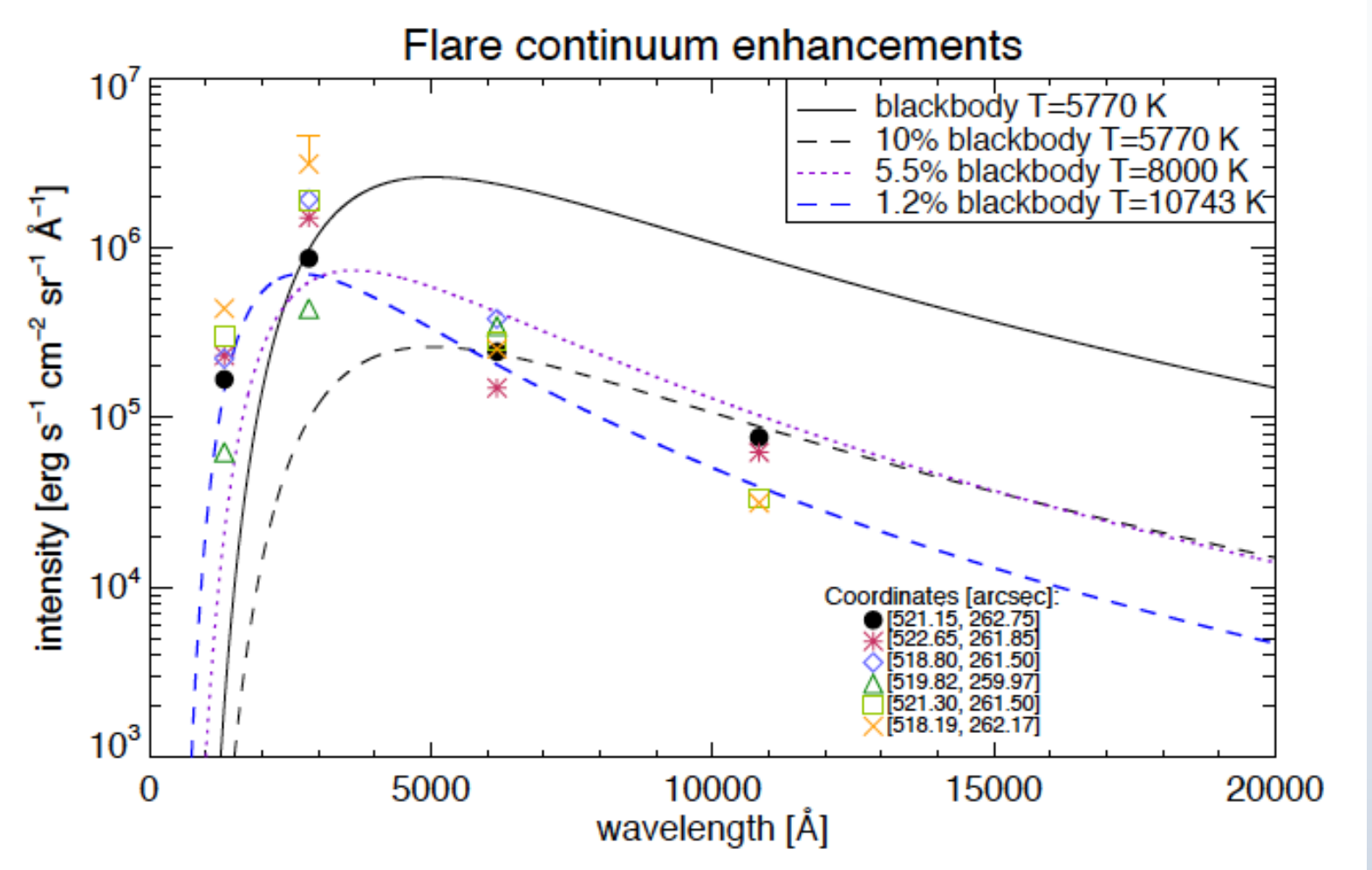
Flarix + MALI simulations


radiative cooling rate – total hydrogen
NRCR [erg/sec/cm³]
z[km]
10⁴
10²
10⁰
10⁻²
10⁻⁴
0
500
1000
1500
2000
2500

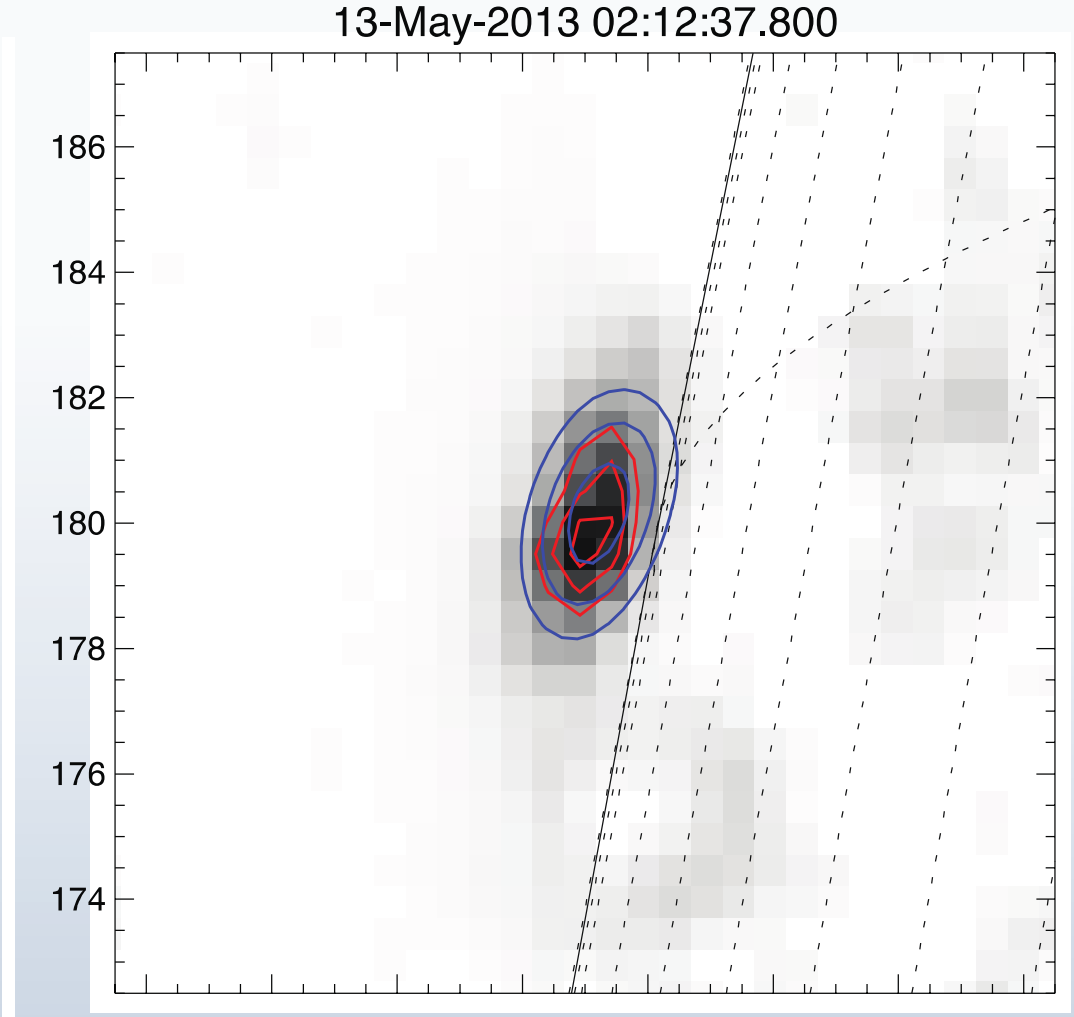

radiative cooling rate – subordin. continua
NRCR [erg/sec/cm³]
z[km]
10⁴
10²
10⁰
10⁻²
10⁻⁴
0
500
1000
1500
2000
2500

Solar white-light flare (WLF) – Mauas (1990)




Flare continuum enhancements
blackbody T=5770 K
10% blackbody T=5770 K
5.5% blackbody T=8000 K
1.2% blackbody T=10743 K
Coordinates [arcsec]:
[521.15, 262.75]
[522.65, 261.85]
[518.80, 261.50]
[519.82, 259.97]
[521.30, 261.50]
[518.19, 262.17]
intensity [erg s^{-1} cm^{-2} sr^{-1} Å^{-1}]
wavelength [Å]
10^7
10^6
10^5
10^4
10^3
0
5000
10000
15000
20000

Kleint+ 2016



Altitude above photosphere:
WL: 810 ± 70 km
HXR: 722 ± 122 km

Krucker+ (2015)

Off-limb emission at 6173 Å (SDO/HMI):

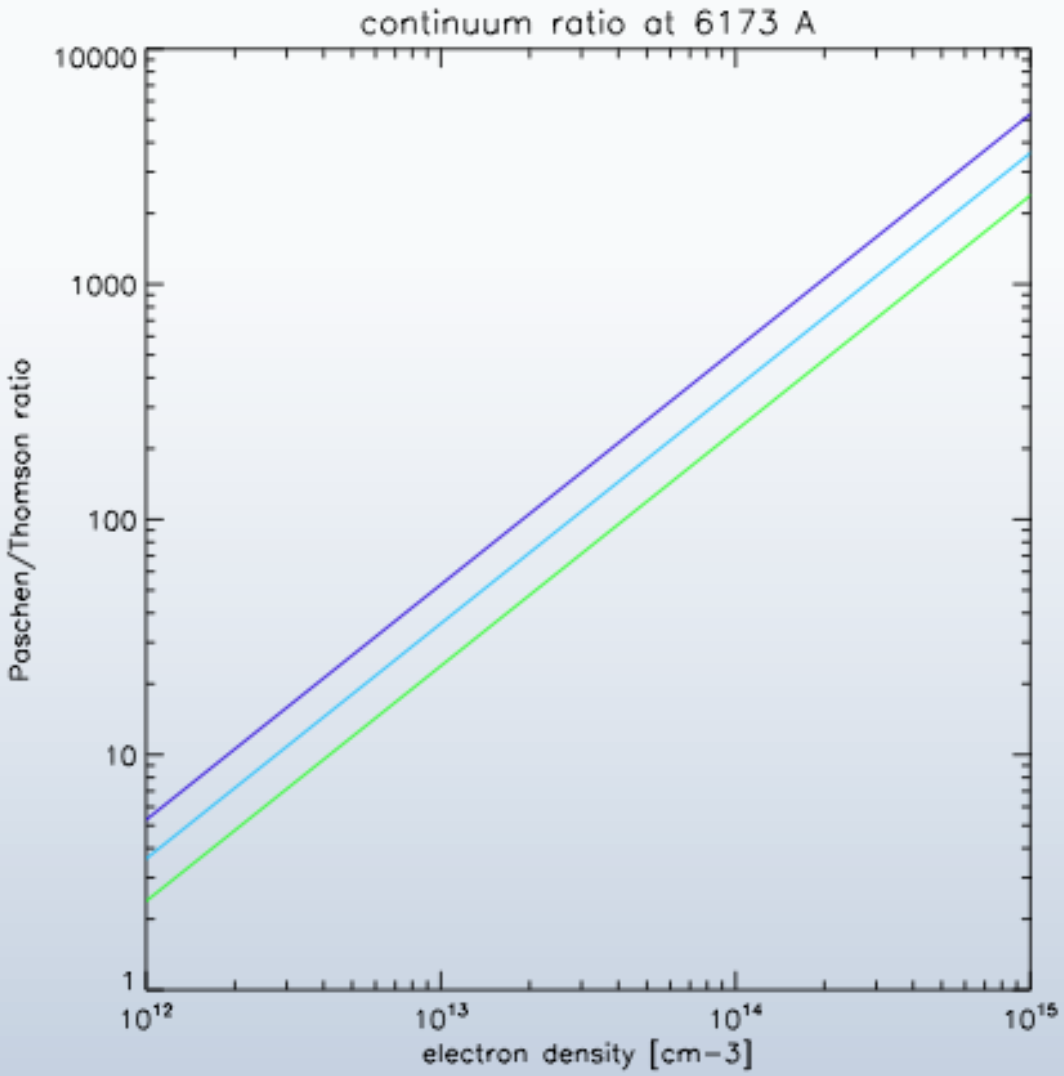
- **hydrogen recombination continuum (Paschen)**

$$\varepsilon_P = n_e^2 \; f(\lambda, T)$$

- **Thomson scattering on electrons ((polarized)**

$$\varepsilon_T = n_e \; \sigma_T \; J(\lambda)$$

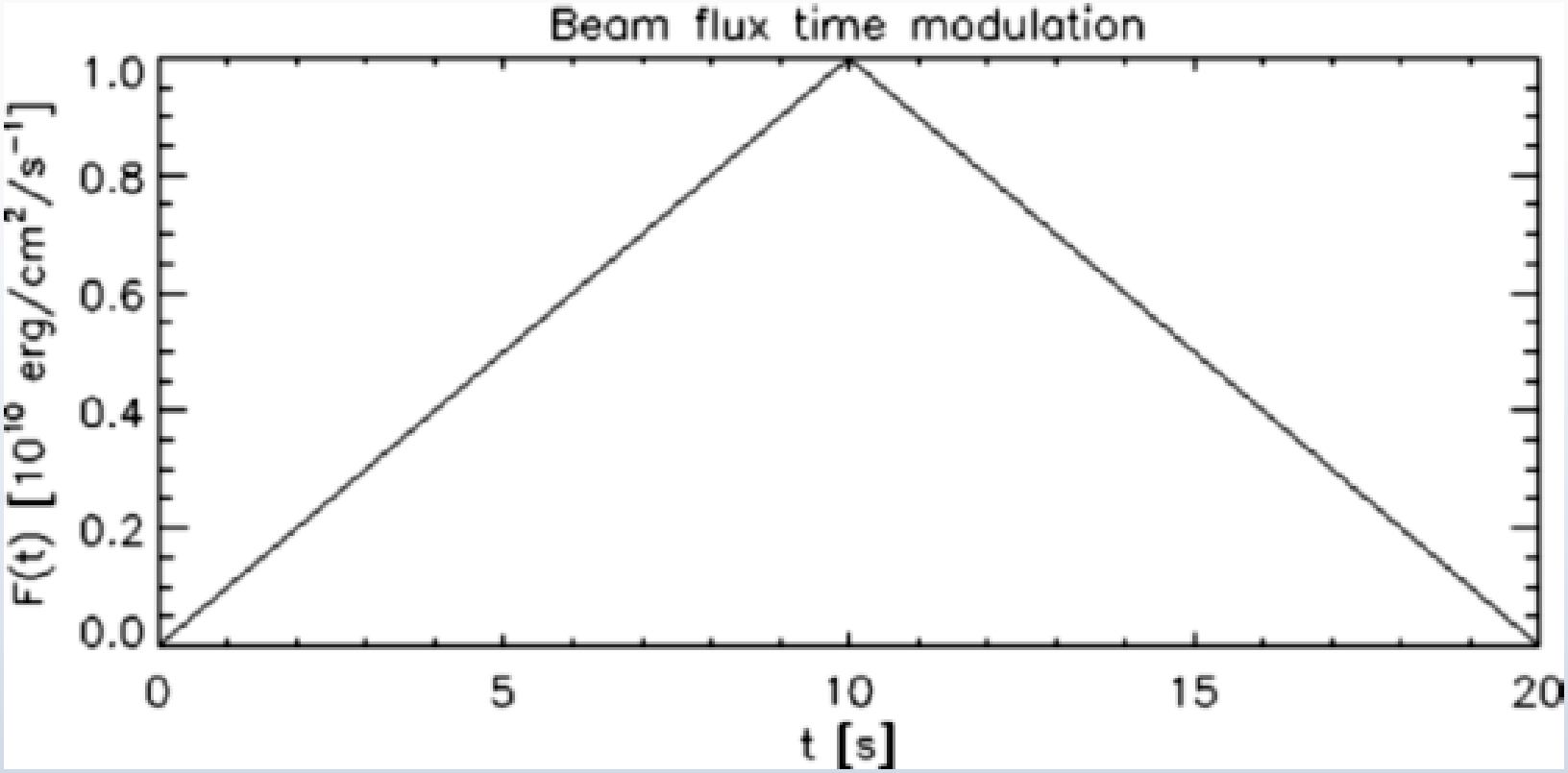
ratio $\varepsilon_P / \varepsilon_T$ is proportional to electron density

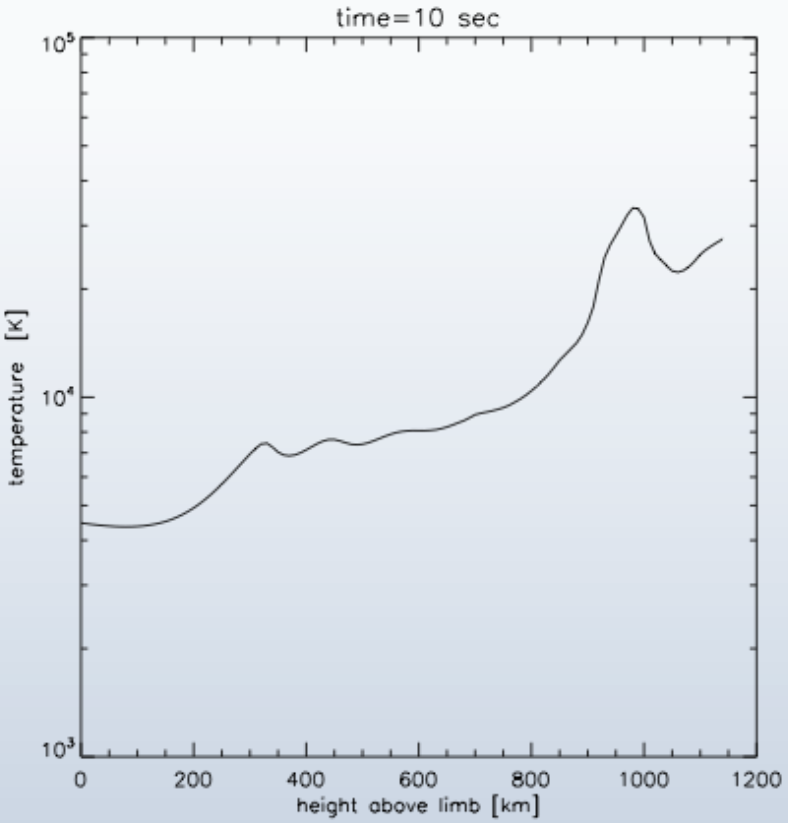

continuum ratio at 6173 A
10000
1000
100
10
1
Poschen/Thomson ratio
10^{12}
10^{13}
10^{14}
10^{15}
electron density [cm−3]

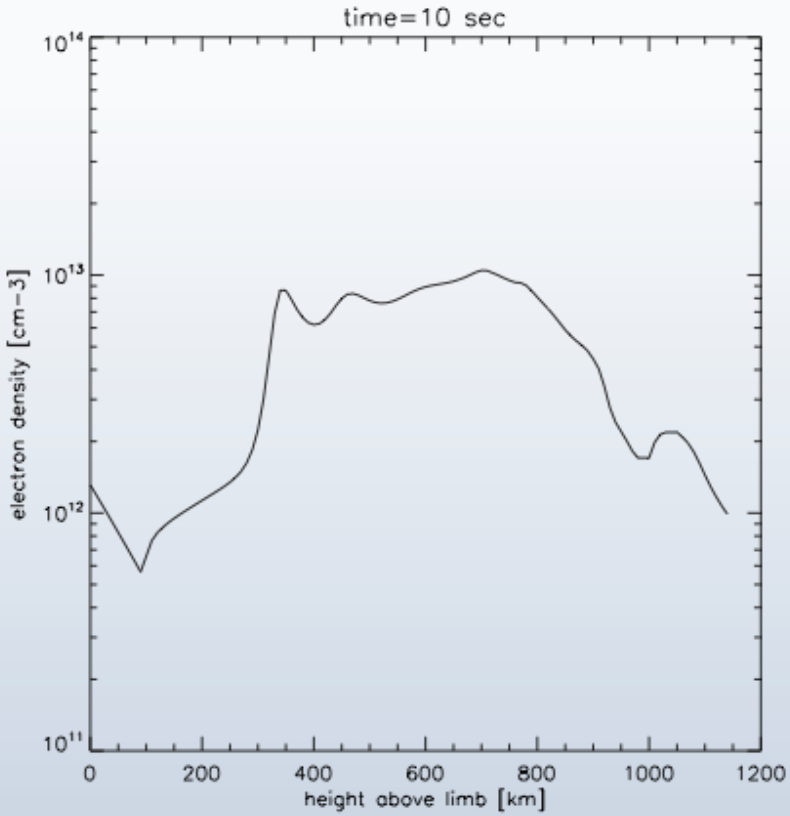
Flarix model was used to compute the off-limb emission:

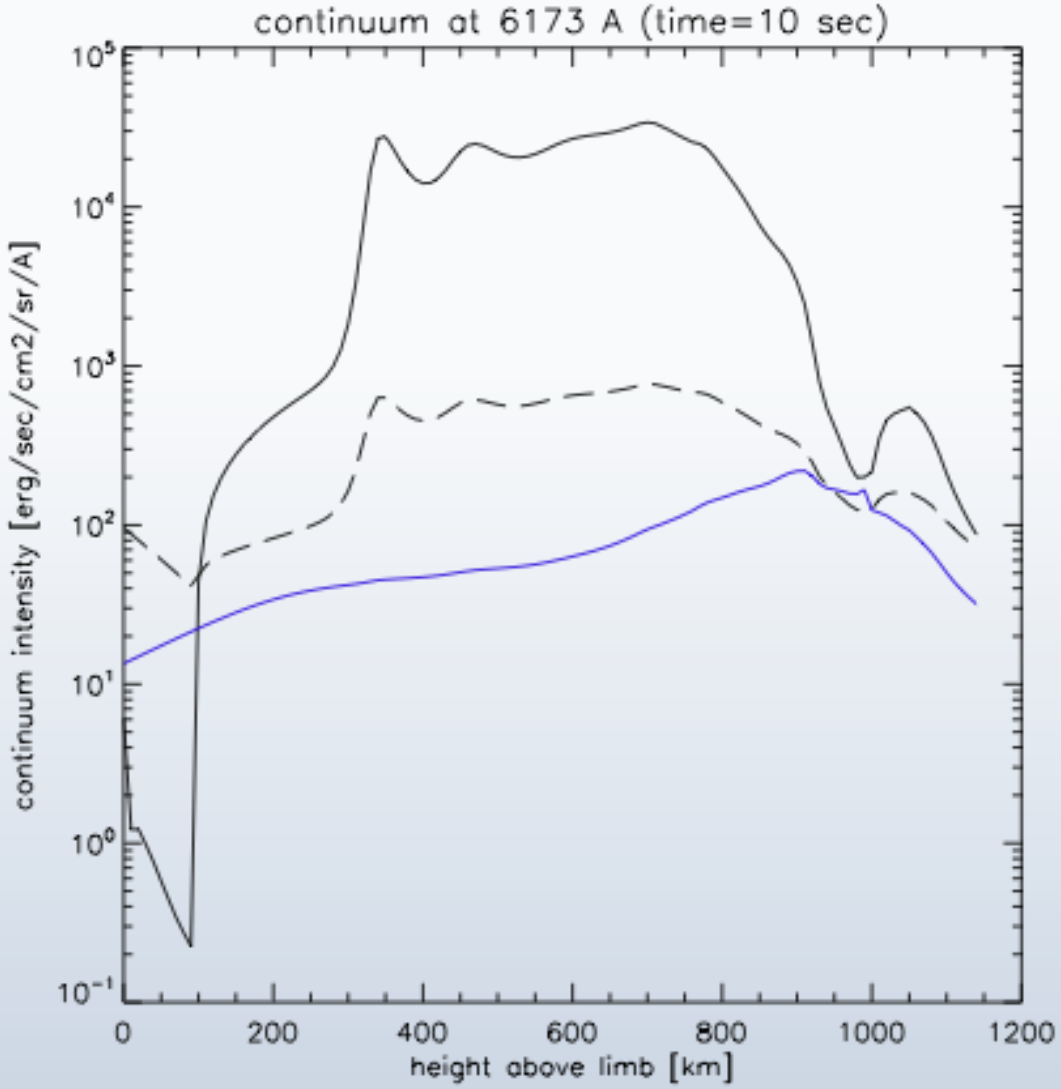
- **triangle beam pulse lasting 20 sec**
- **$\delta = 3$**
- **peak flux 10^{10} erg/sec/cm^2**
- **initial atmosphere VAL C**

- **optically-thick losses in non-LTE (HI, CaII, MgII)**
- **non-thermal collisional rates for H, CaII, MgII**


Beam flux time modulation
F(t) [10^10 erg/cm^2/s^-1]
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
t [s]


time=10 sec
temperature [K]
10^5
10^4
10^3
0
200
400
600
800
1000
1200
height above limb [km]

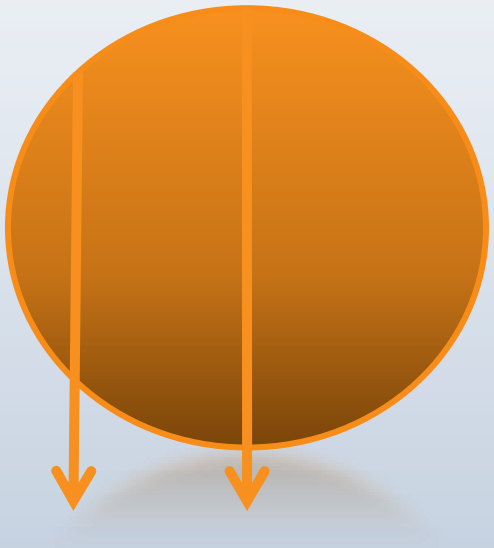

time=10 sec
electron density [cm-3]
10^{14}
10^{13}
10^{12}
10^{11}
0
200
400
600
800
1000
1200
height above limb [km]



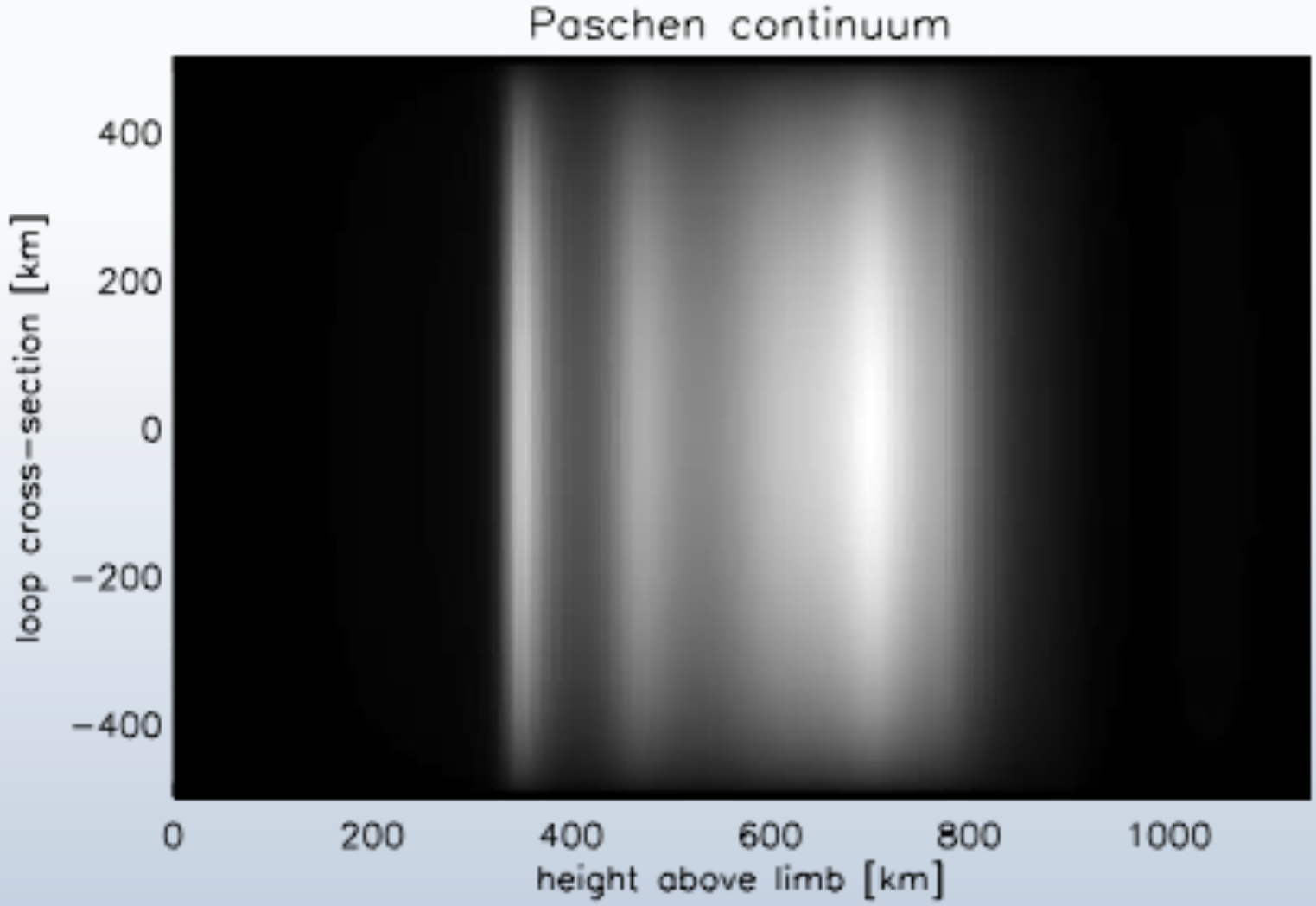
intensity along the loop axis for D=1000 km

1.5 D flare-loop model:

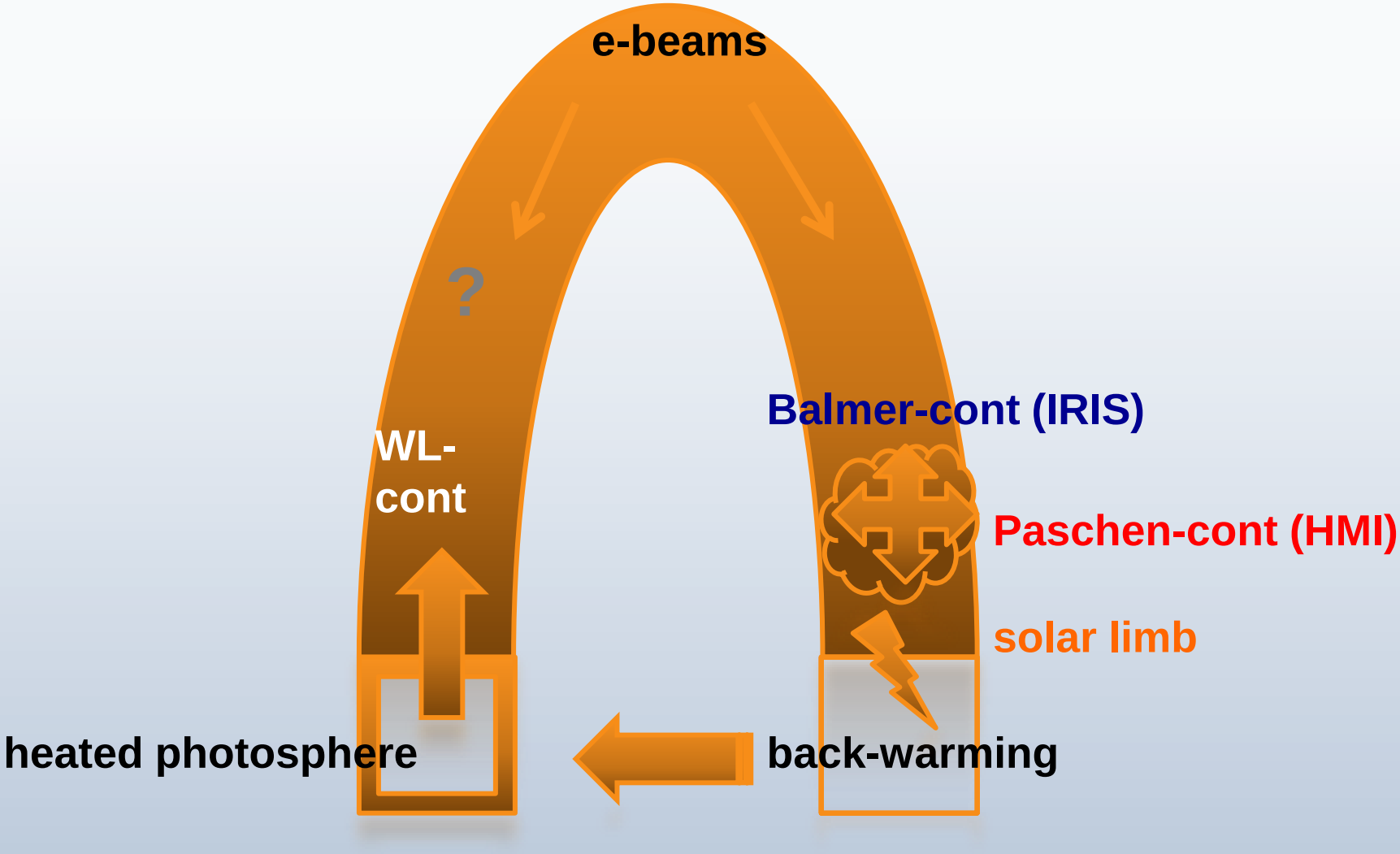
- **vertical variation of plasma parameters from Flarix (time-dependent)**
- **circular loop cross-section with uniform distribution of all parameters**



diameter 1000 km


Paschen continuum
400
200
0
−200
−400
loop cross−section [km]
0
200
400
600
800
1000
height above limb [km]

Flare-loop cartoon



Conclusions:

Depending on the emission mechanism, emitting layers (photosphere, chromosphere) and on the viewing direction (on-disk, off-limb), we see continua having different colors. So the so-called "white-light" flare is only part of the whole continuum story.