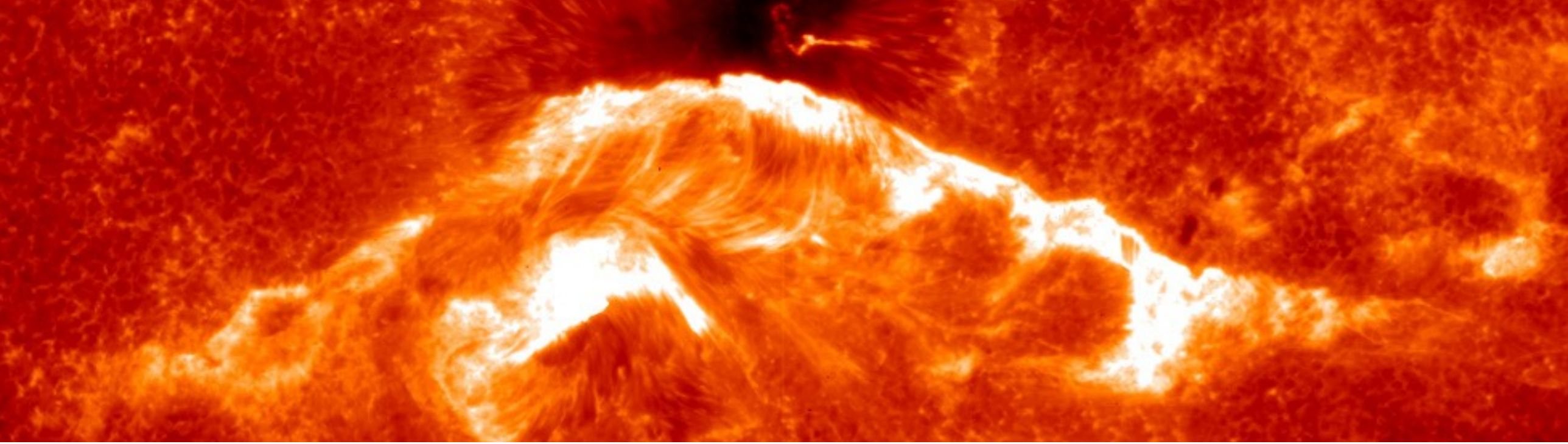
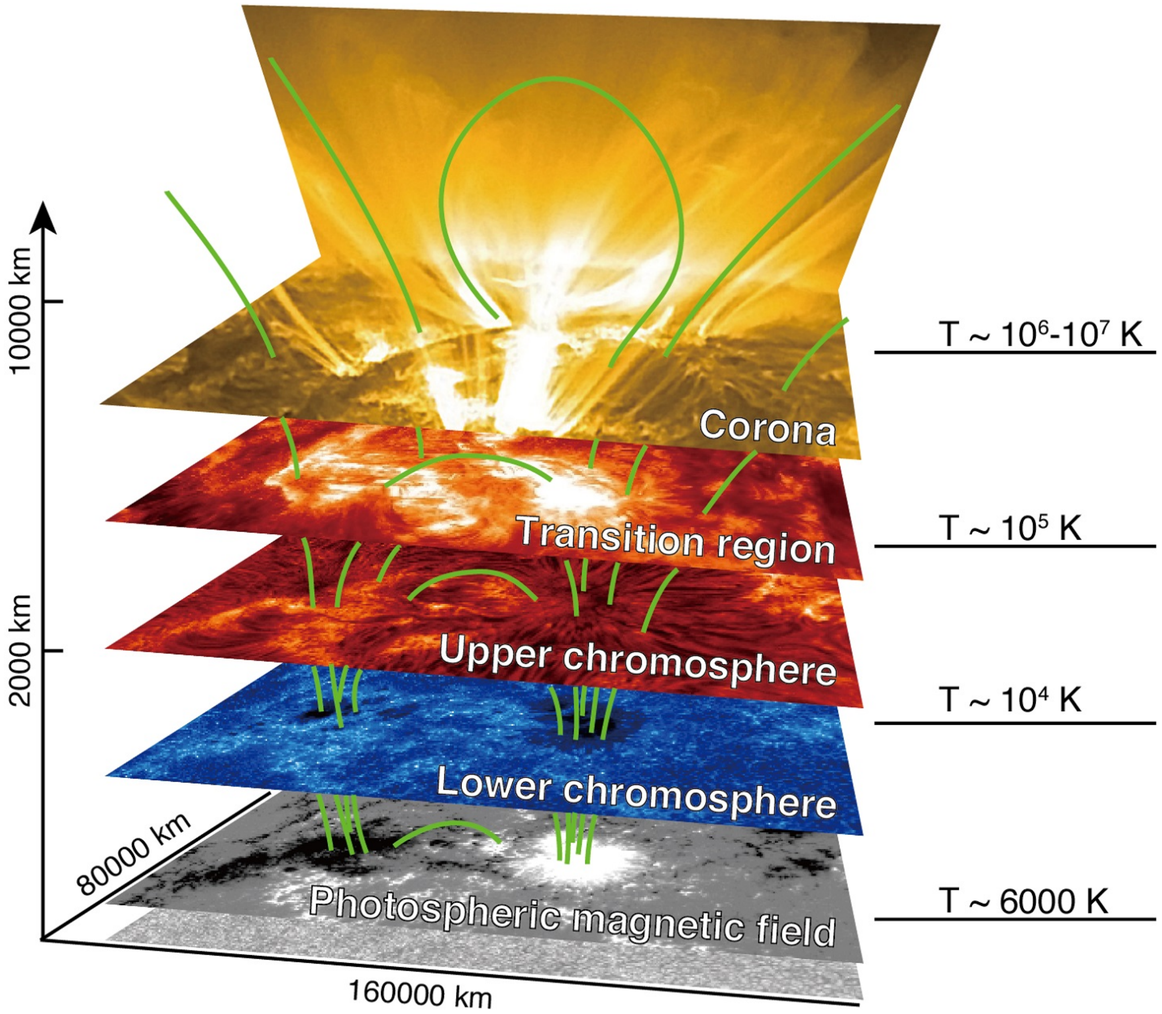


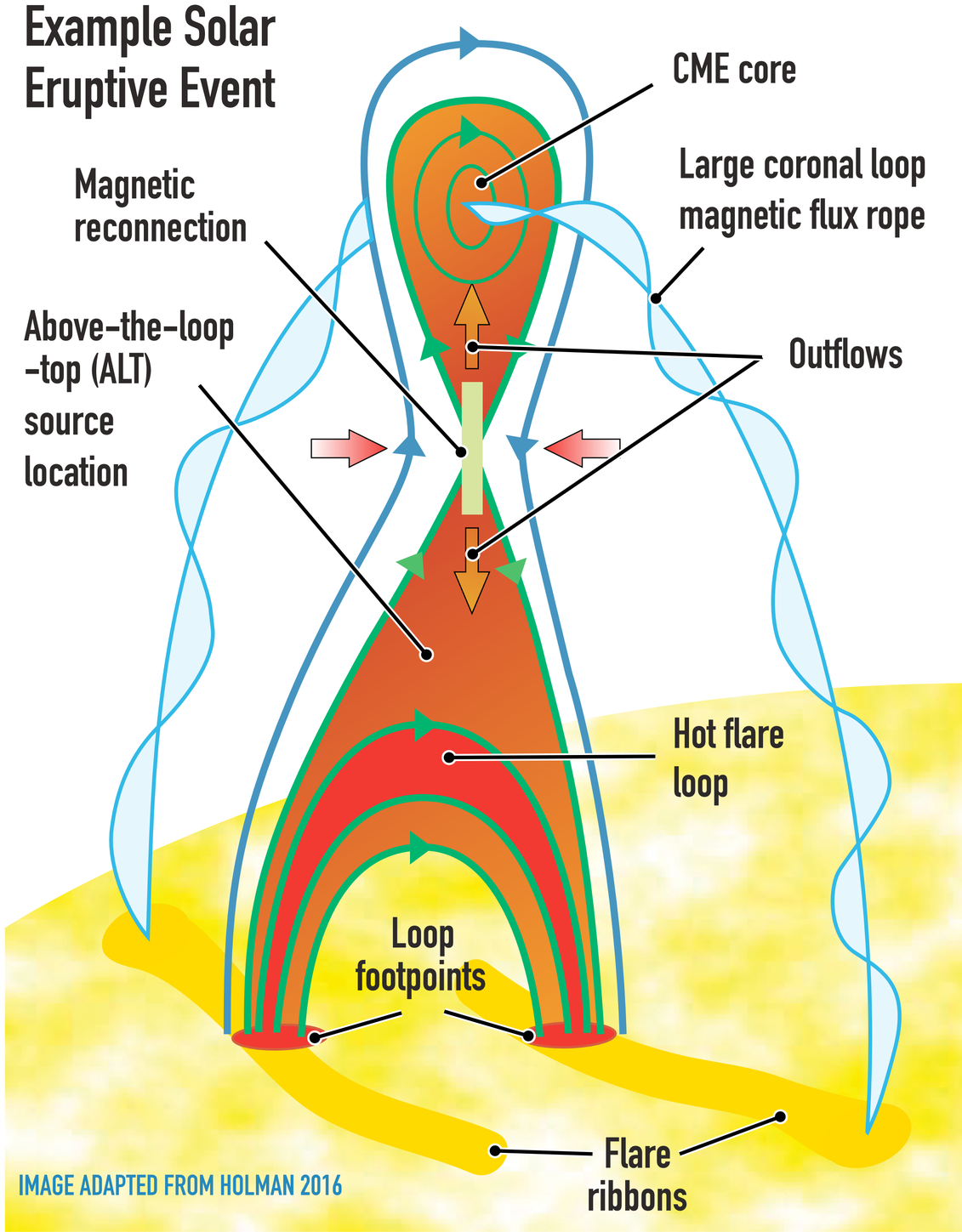
GRAHAM KERR (NASA/GSFC & CUA, HE/HIM)

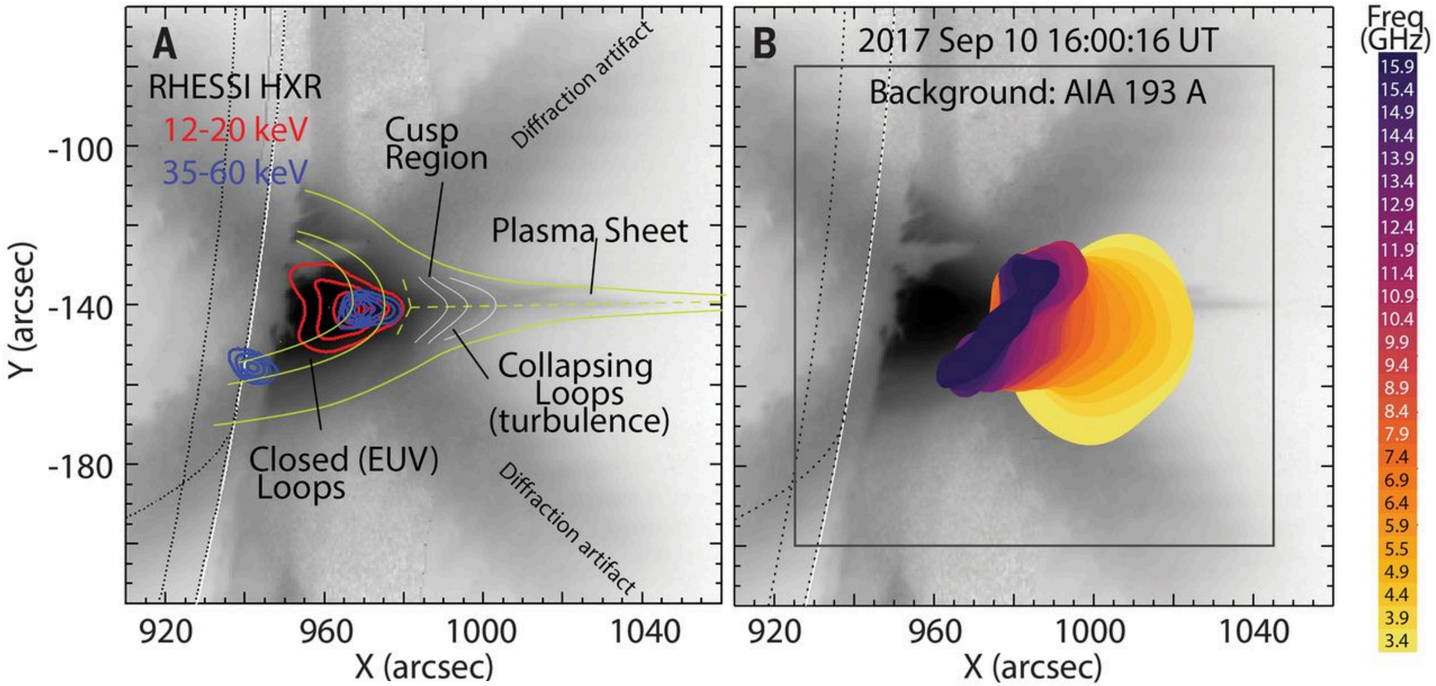
THE OPTICALLY THIN FLARING CHROMOSPHERE:

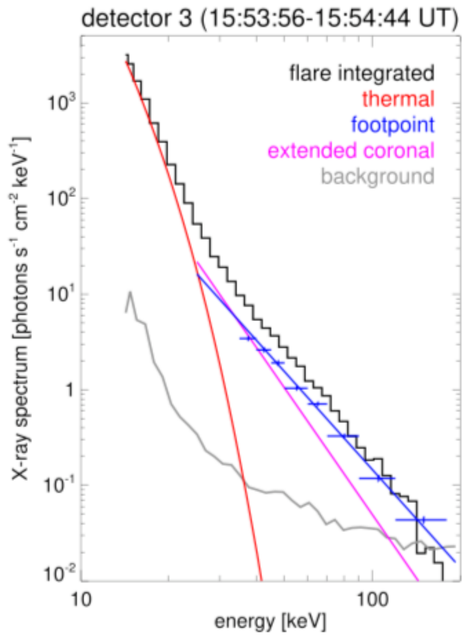
NONTHERMAL LINE WIDTHS FROM A CHROMOSPHERIC CONDENSATION

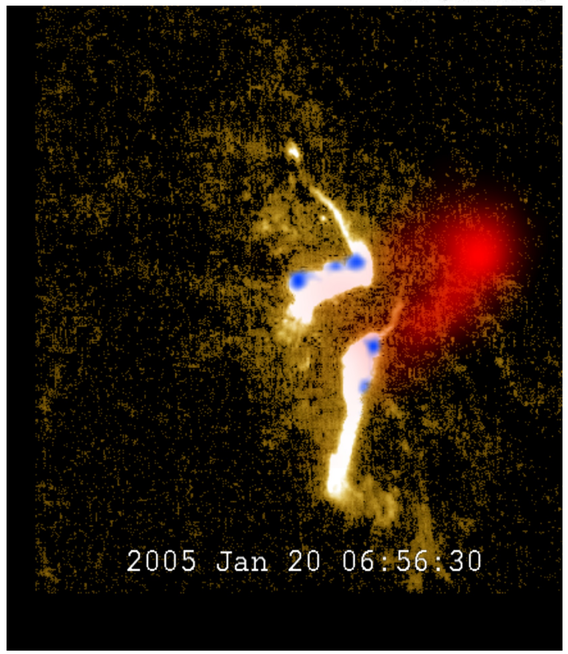
SOLAR FLARES



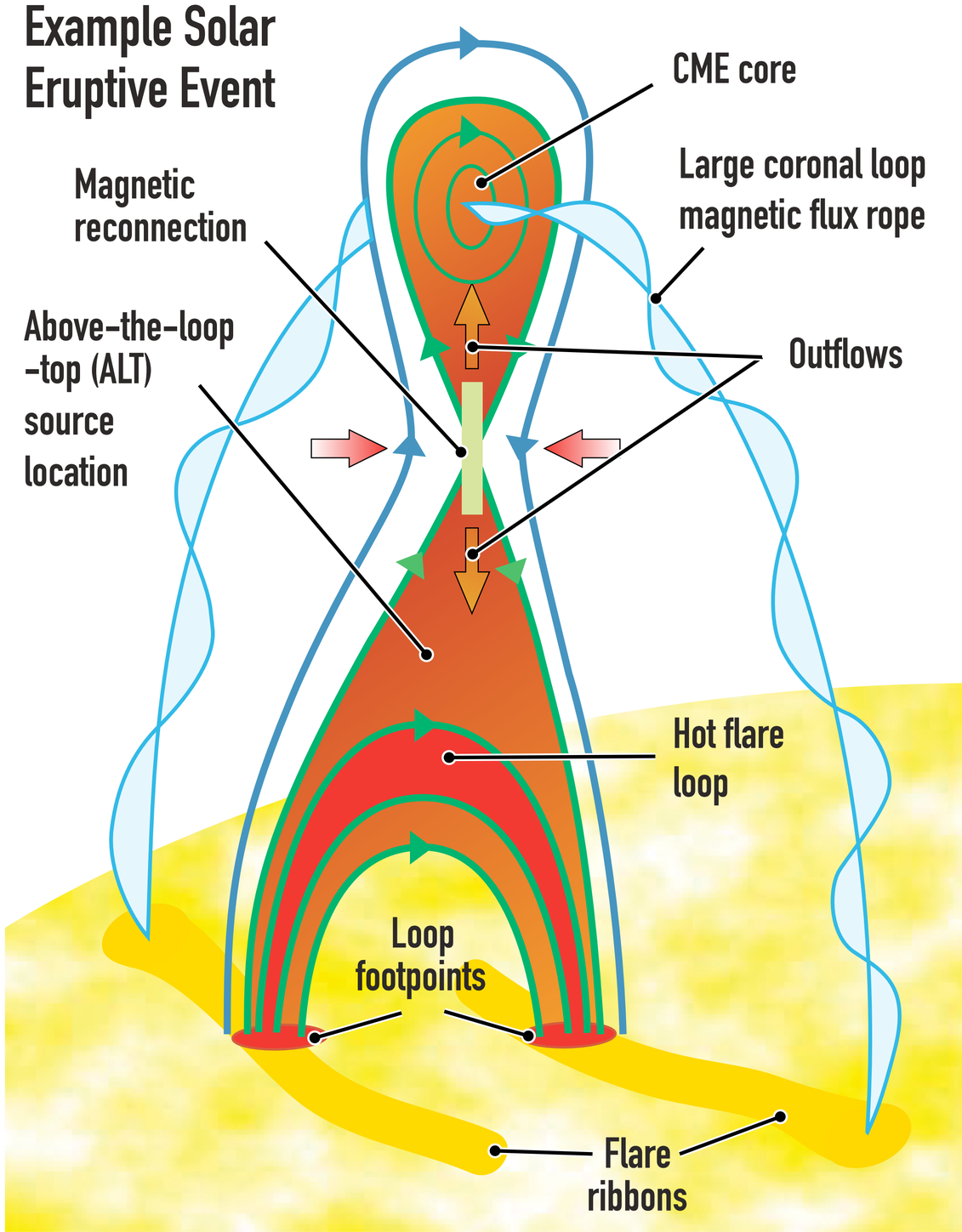




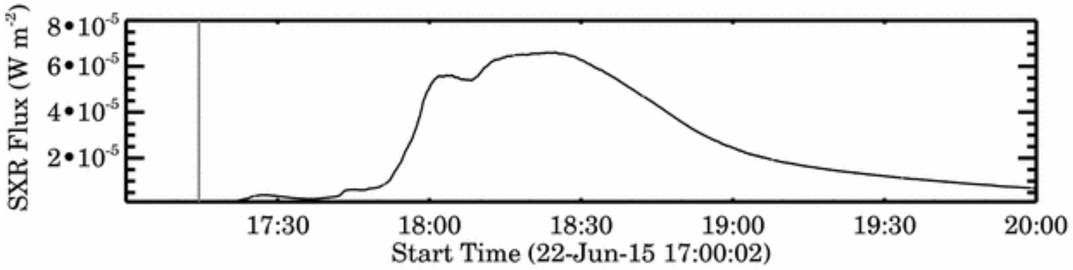


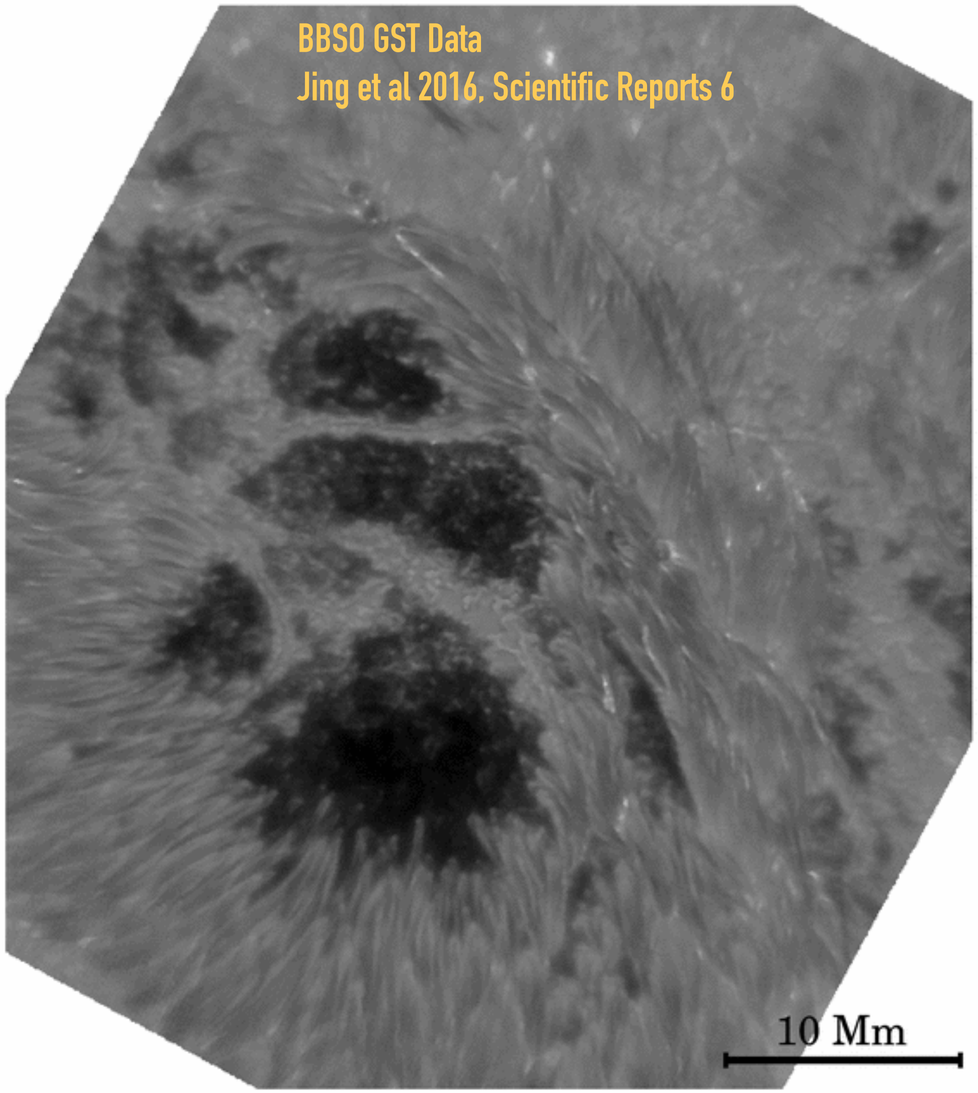


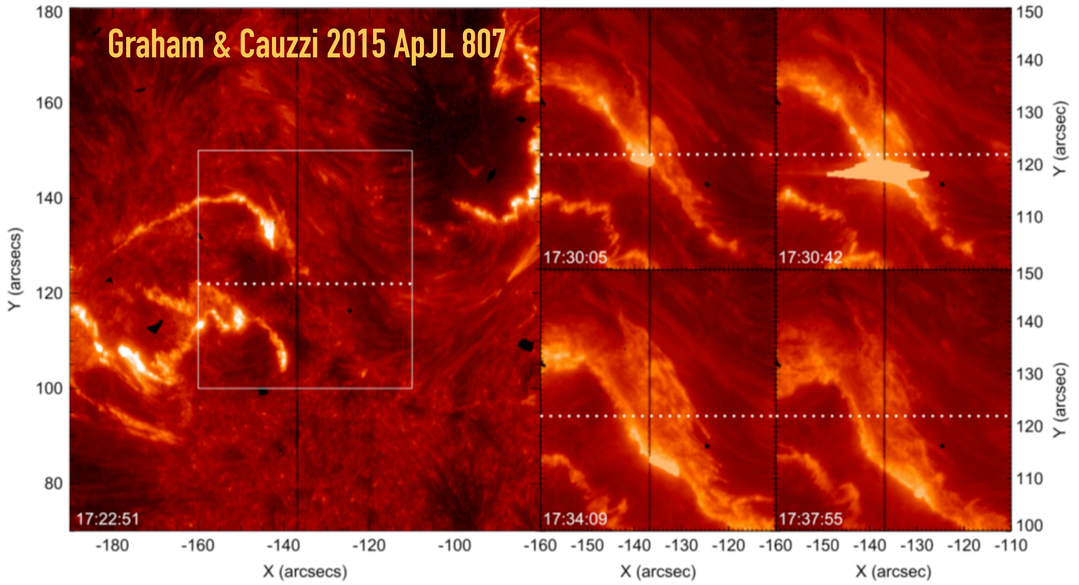
X-ray obs can be used to derive non-thermal electron distributions, which are then used to drive flare models.

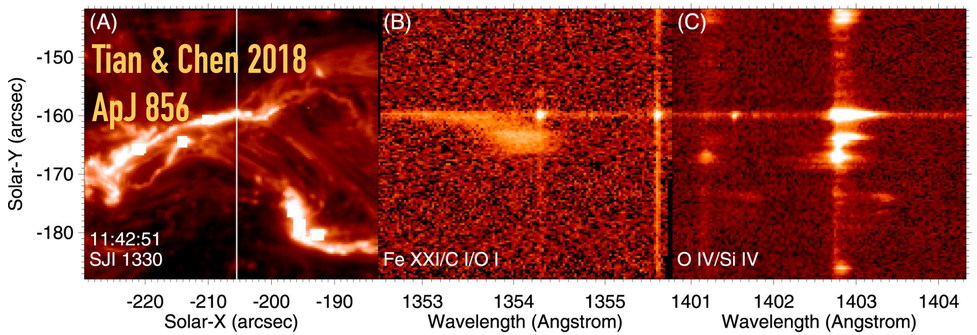


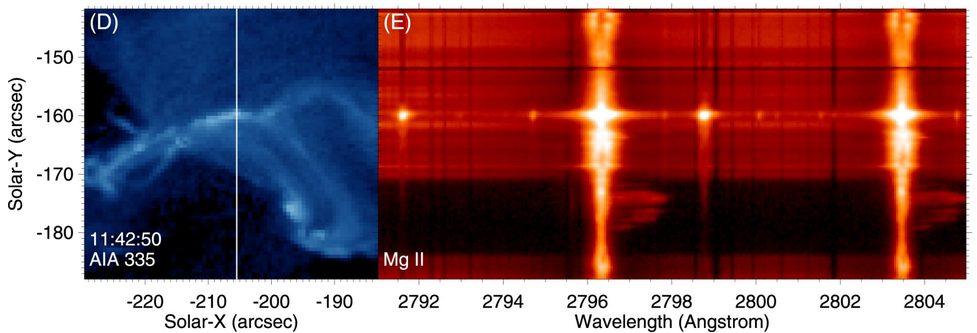
SOLAR FLARES







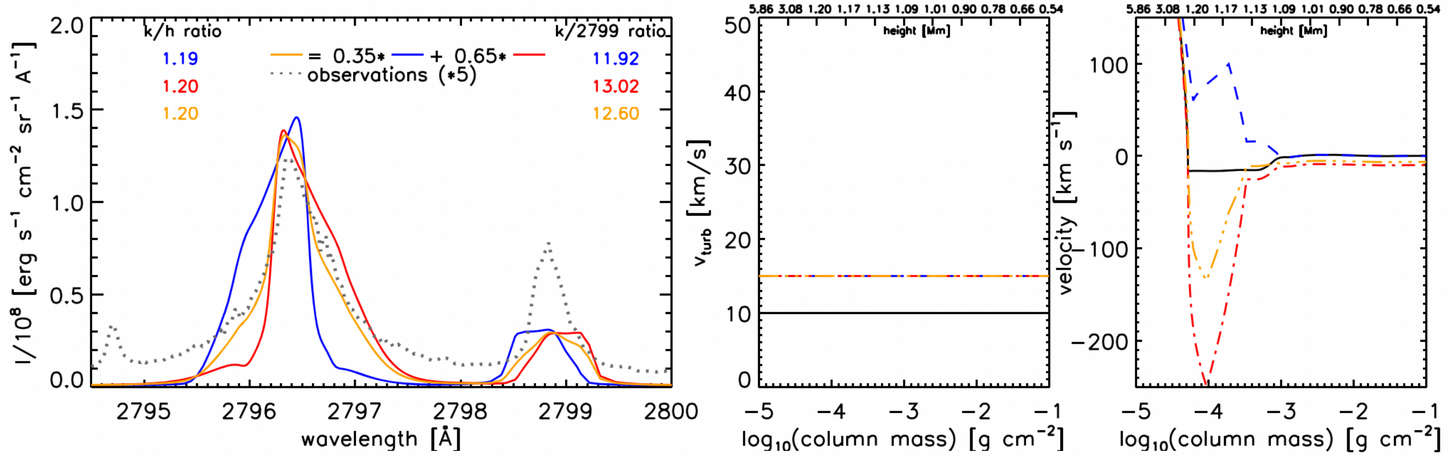




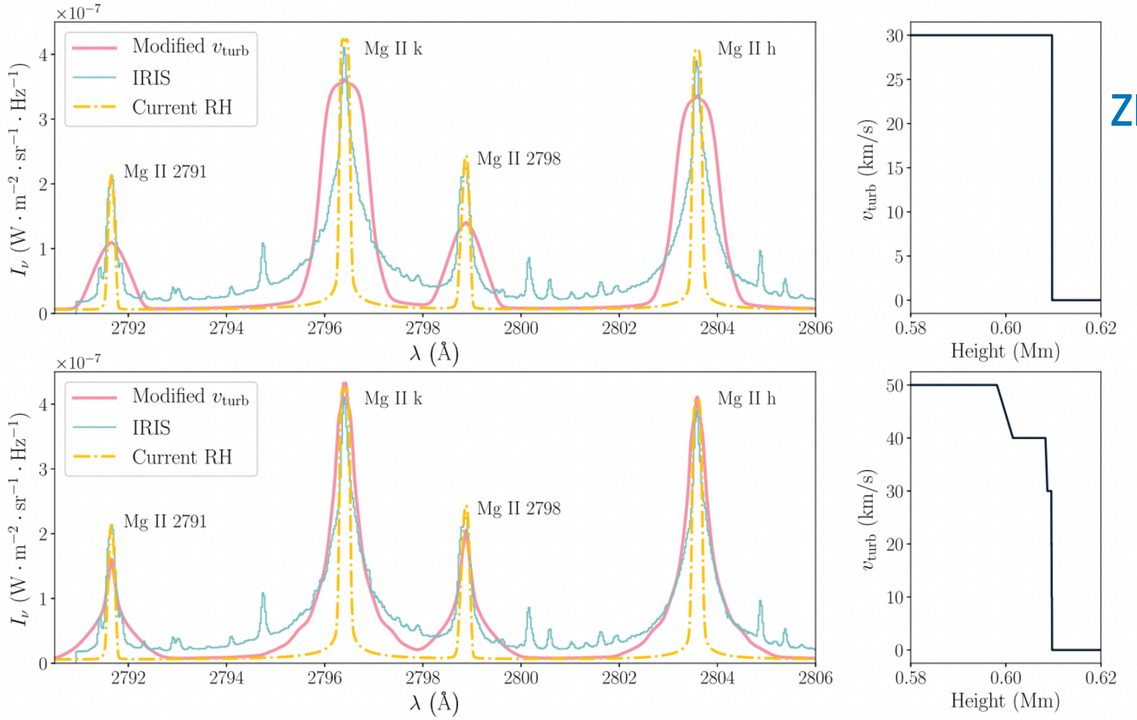
LINE WIDTHS ARE A PERENNIAL MODEL-DATA ISSUE

- Chromospheric and transition region lines are much broader in observations, than those forward modelled in flare simulations.
- Resolutions typical include exploring:
  - Extreme bi-directional flows (any evidence?).
  - Large amounts of microturbulent broadening, in the chromosphere, up to 30-50 km/s (any evidence?).
  - … other?

Rubio da Costa & Kleint 2017



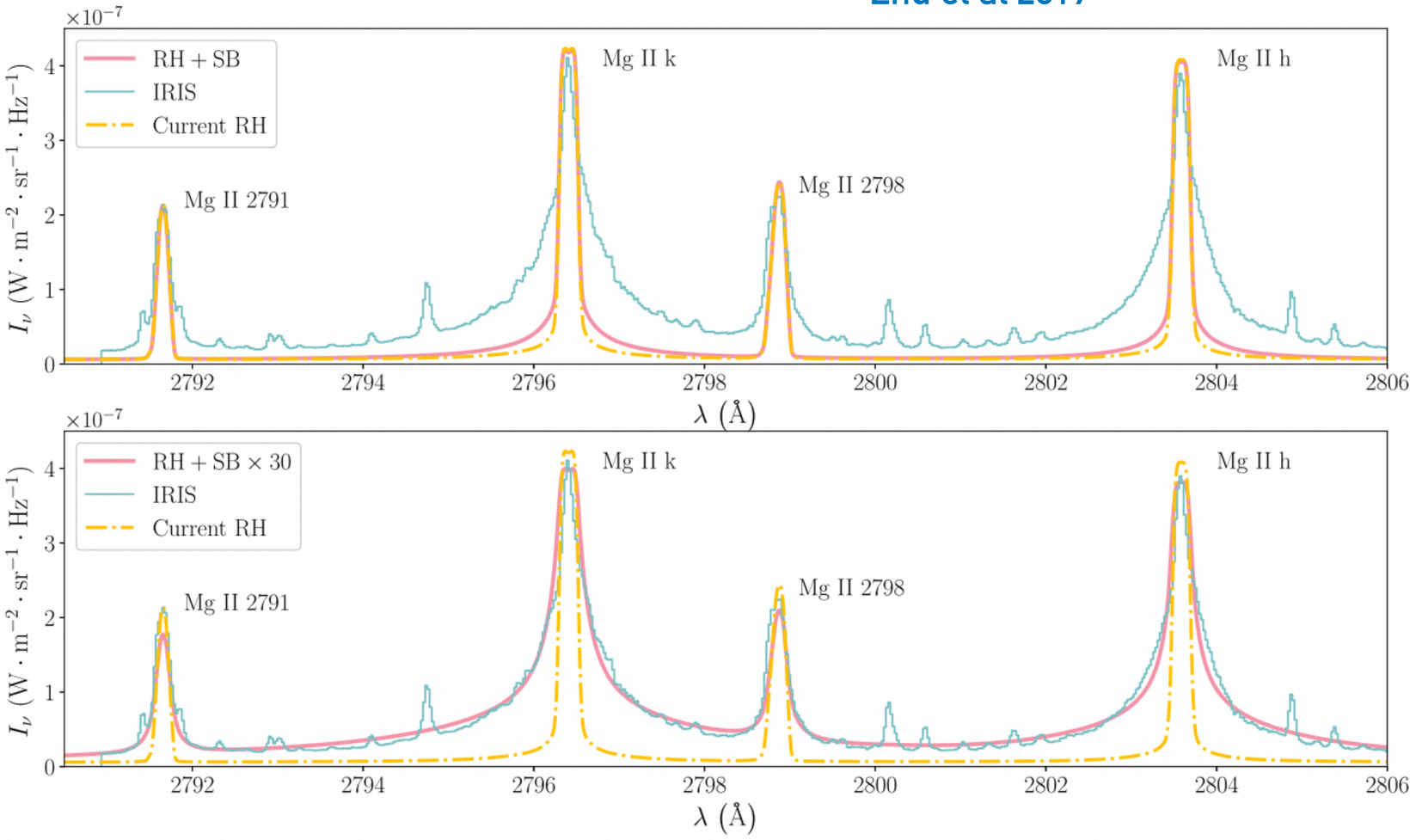
Zhu et al 2019



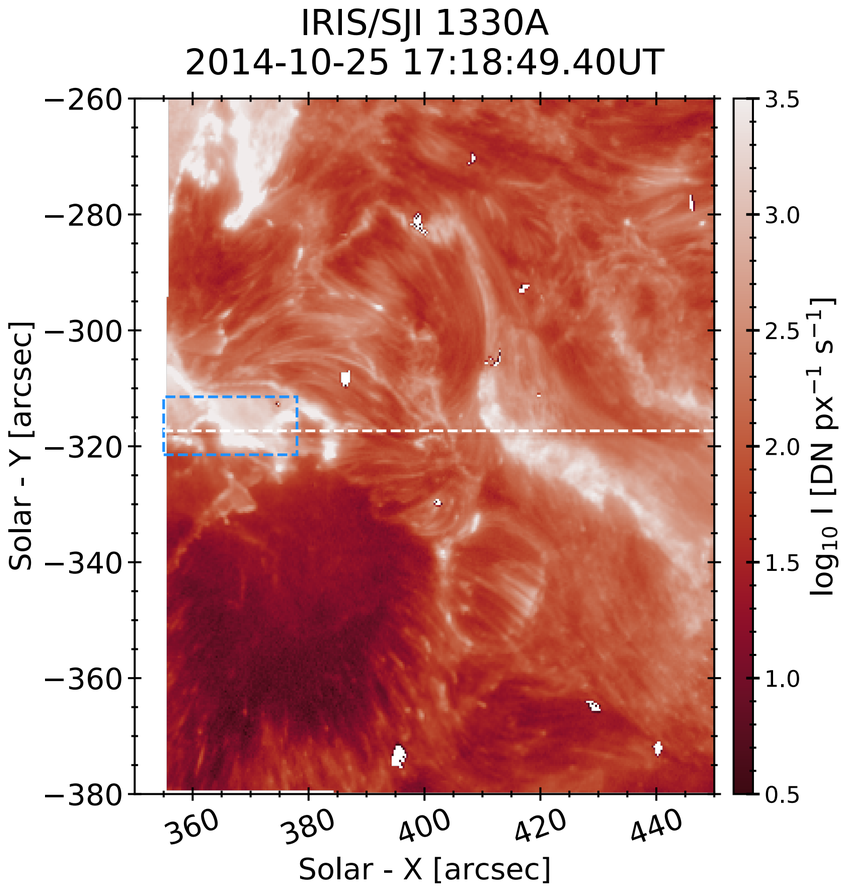
LINE WIDTHS ARE A PERENNIAL MODEL-DATA ISSUE

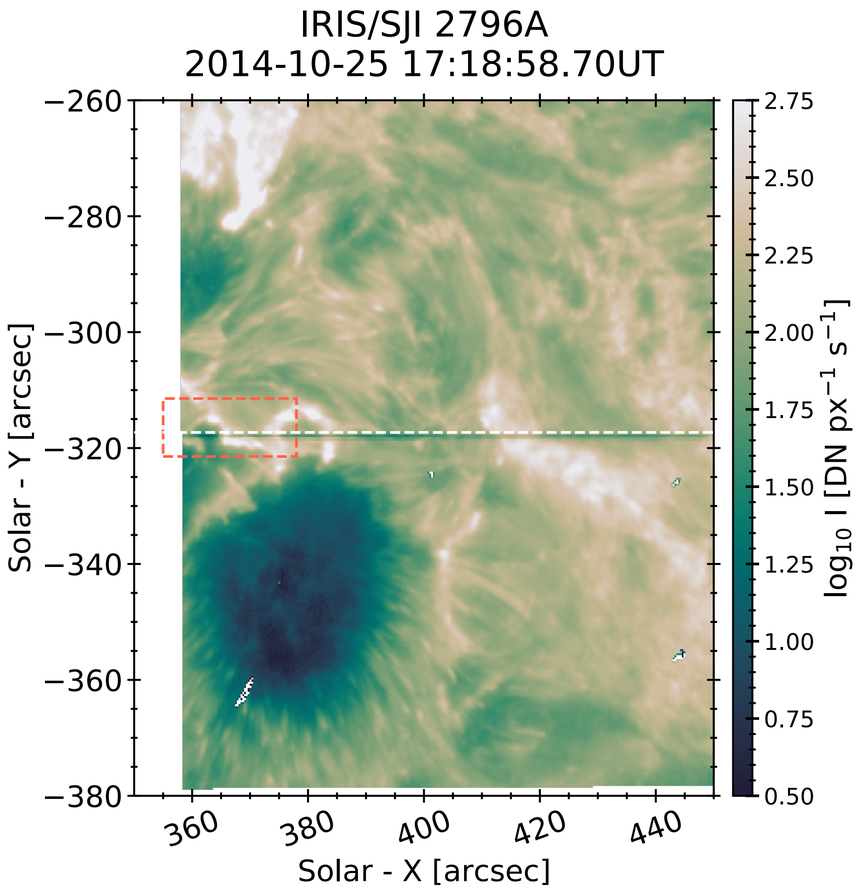
- Improved the treatment of Stark broadening for Mg II, using the STARK-B database broadens the lines but still not enough –another factor of 30x was needed!
- One possibility is that we are not heating the lower atmosphere sufficiently.

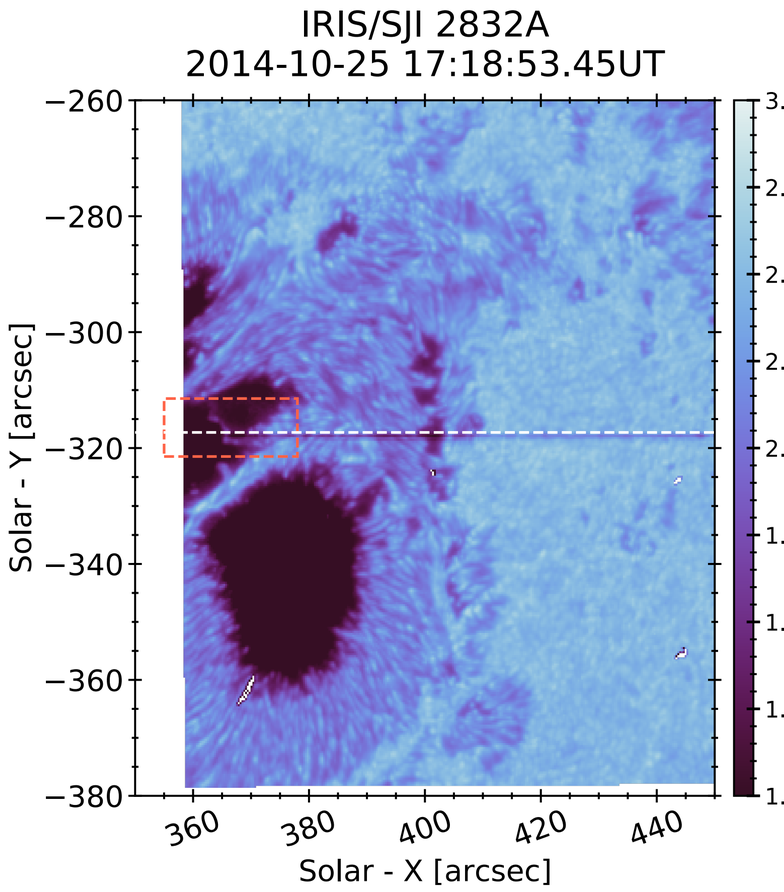
Zhu et al 2019



2014-OCTOBER-25 X1 CLASS FLARE







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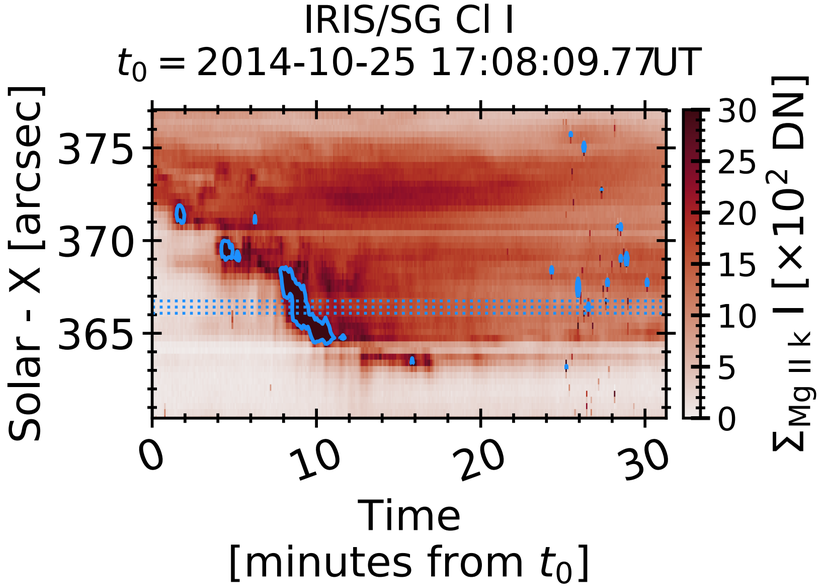

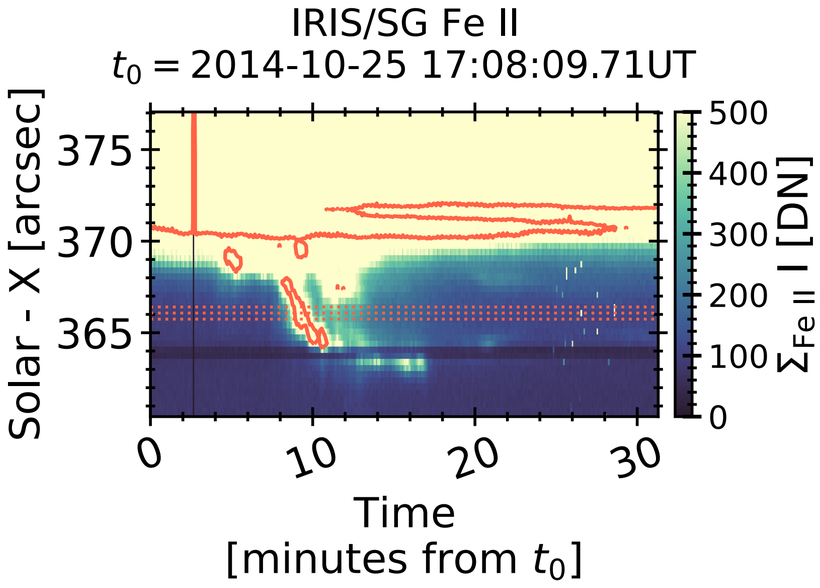

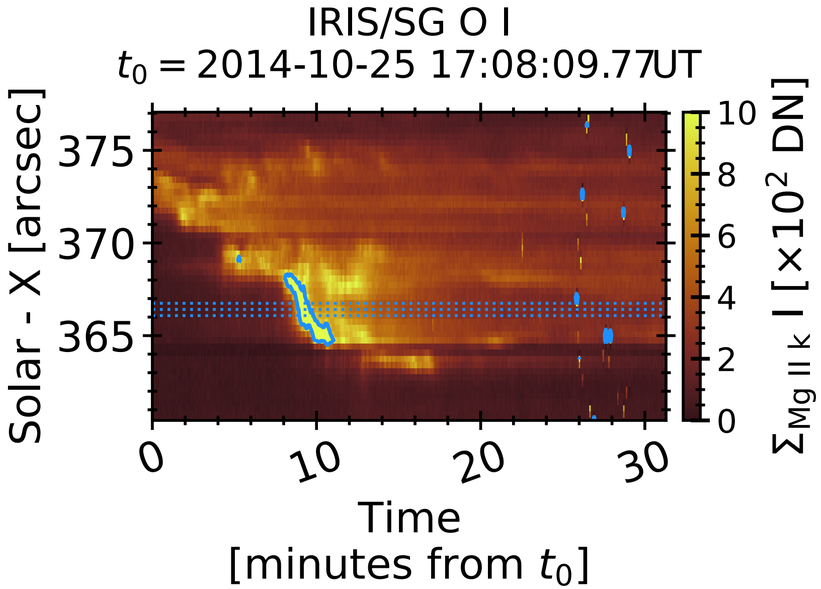

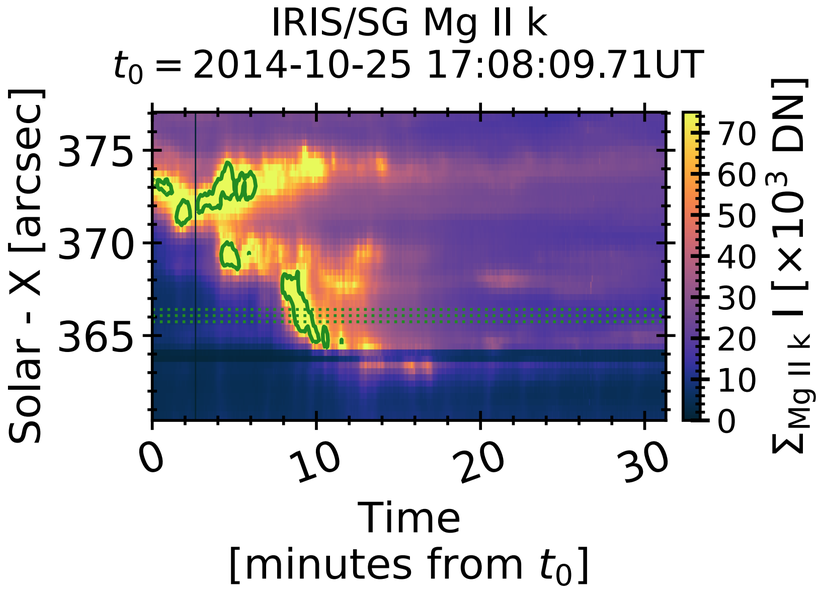

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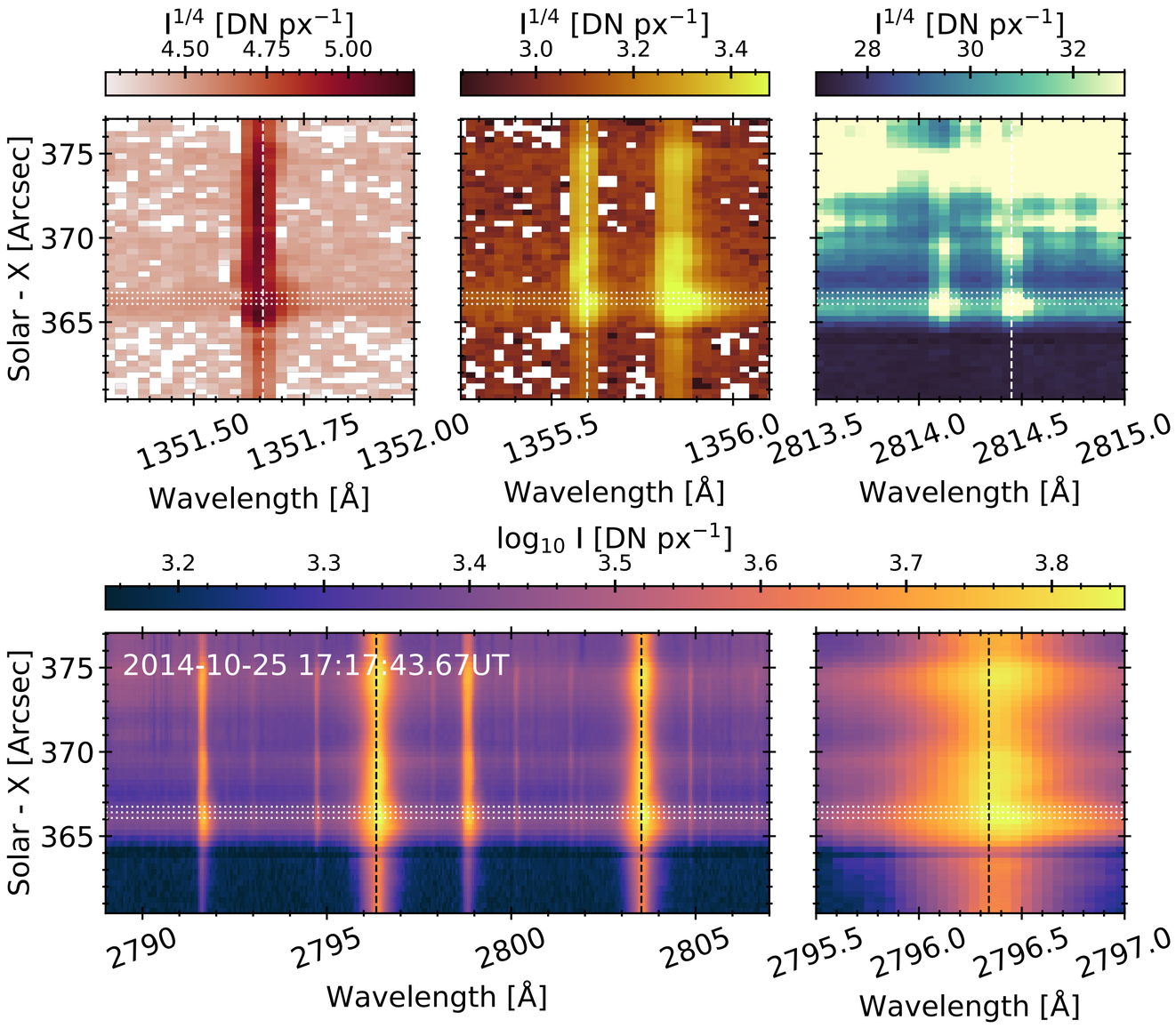

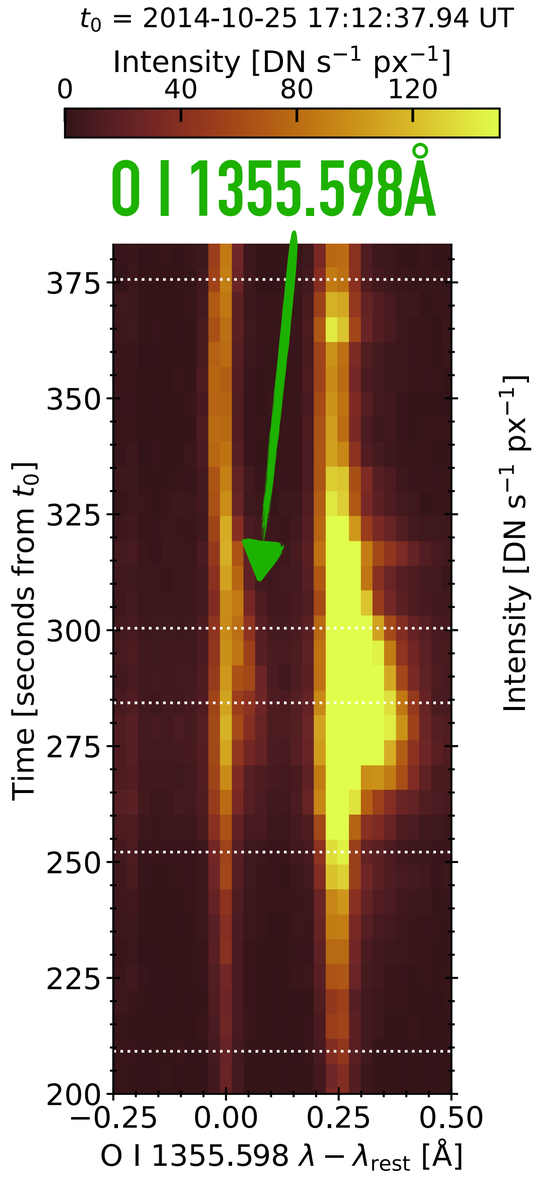

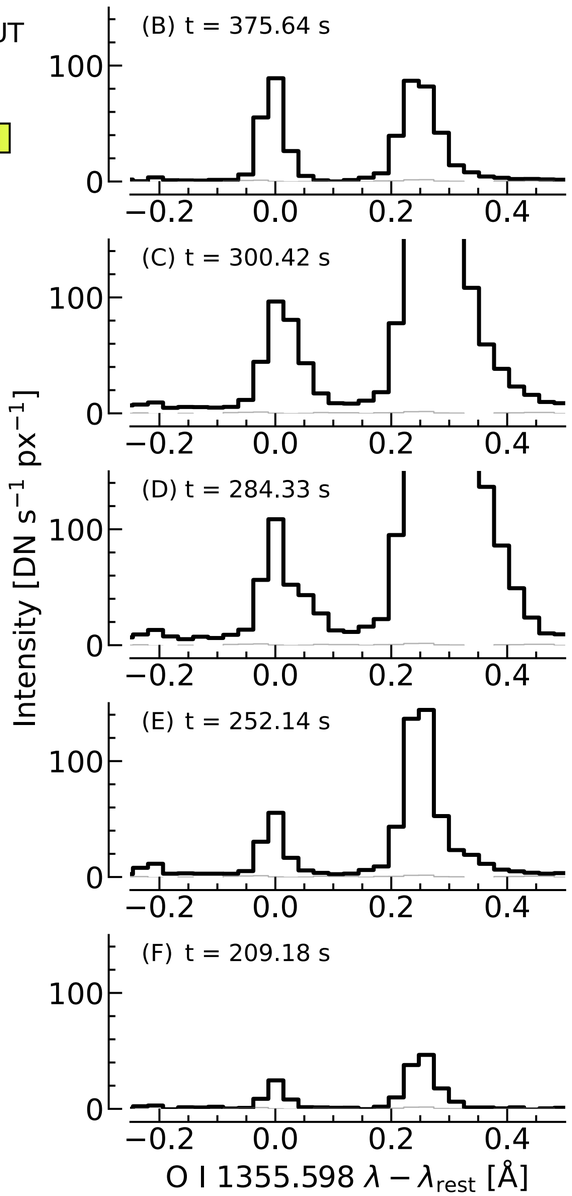

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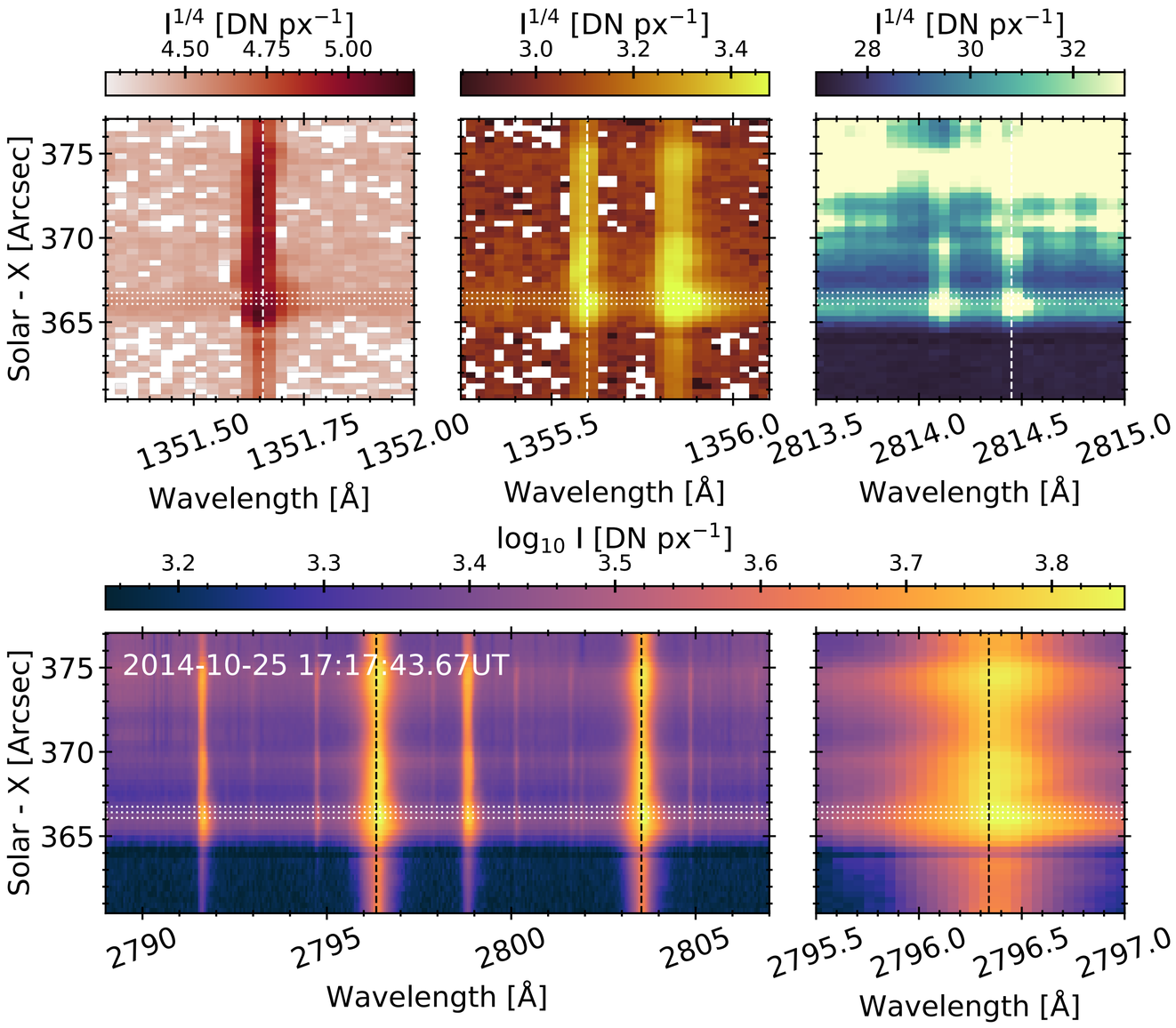

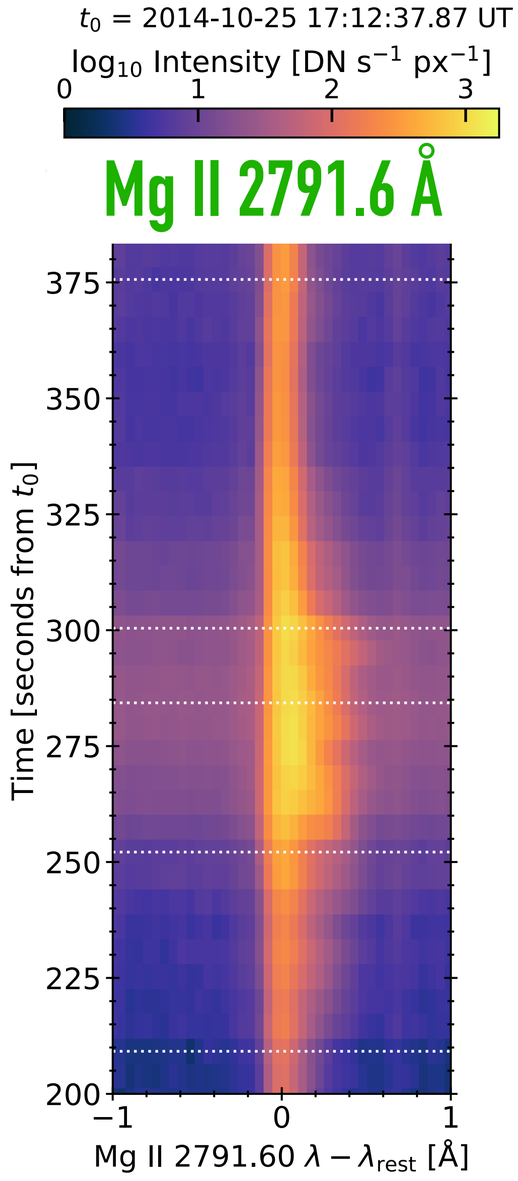

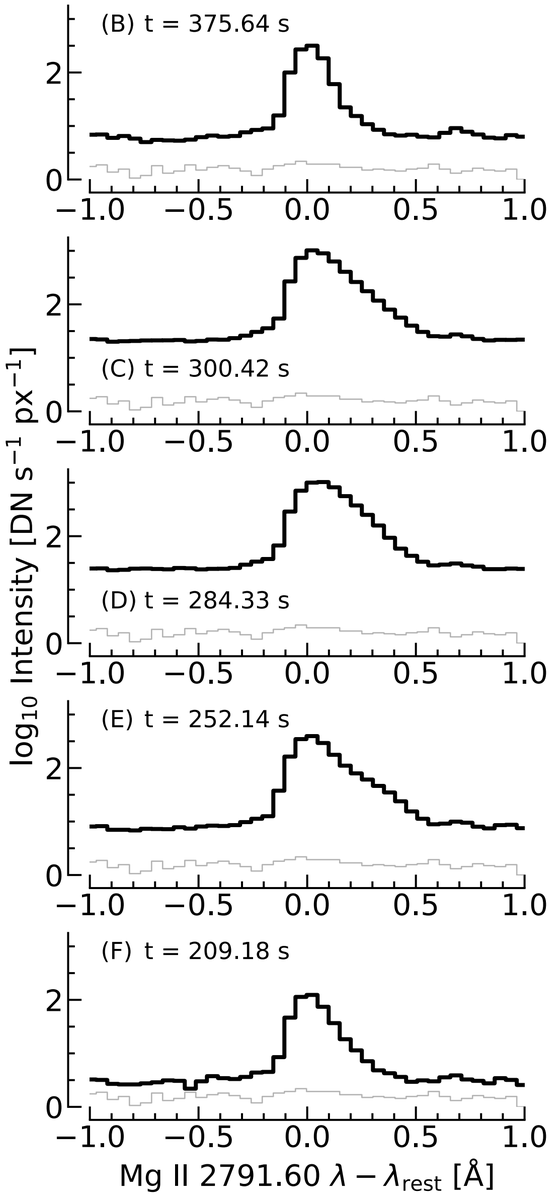

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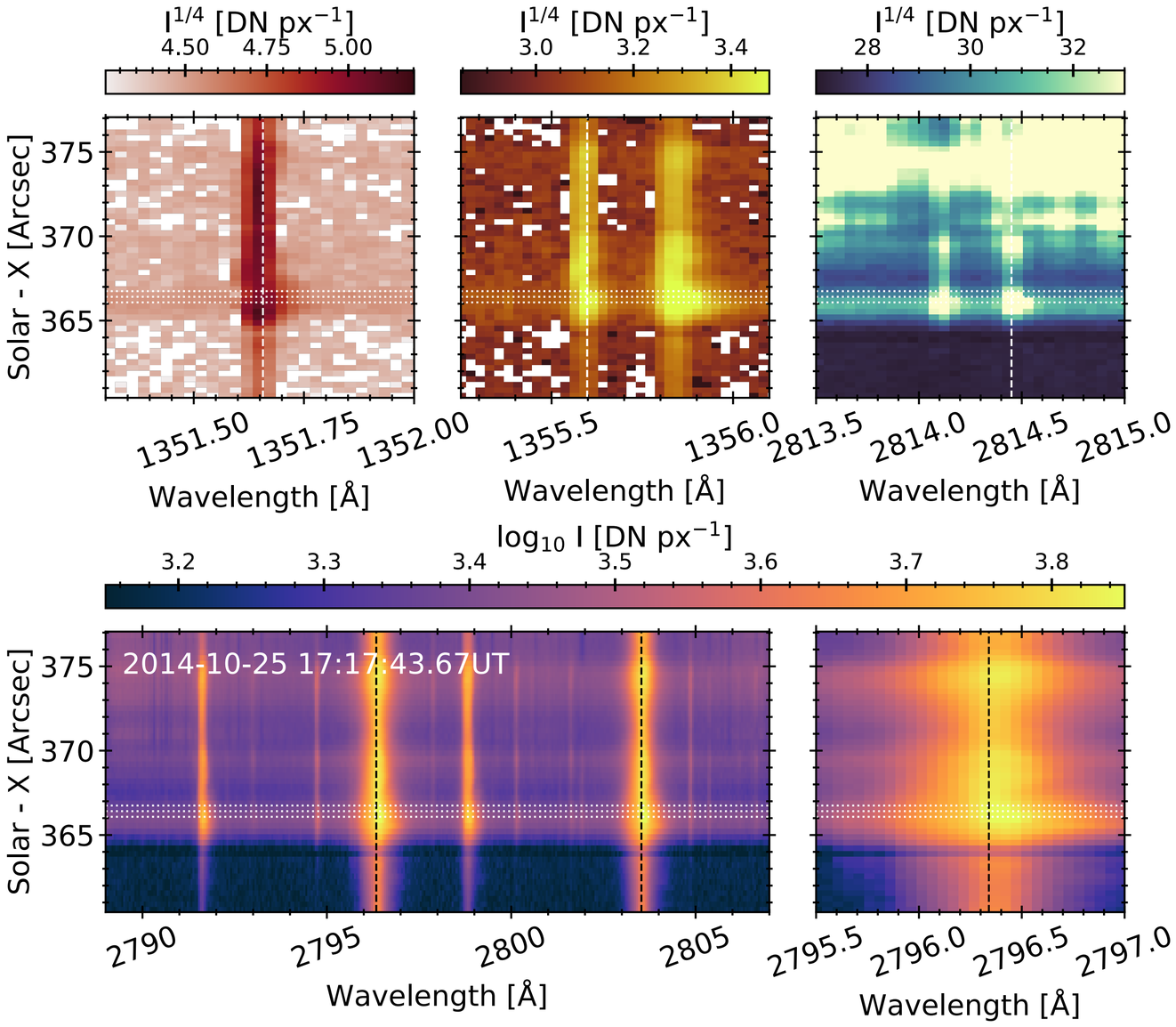

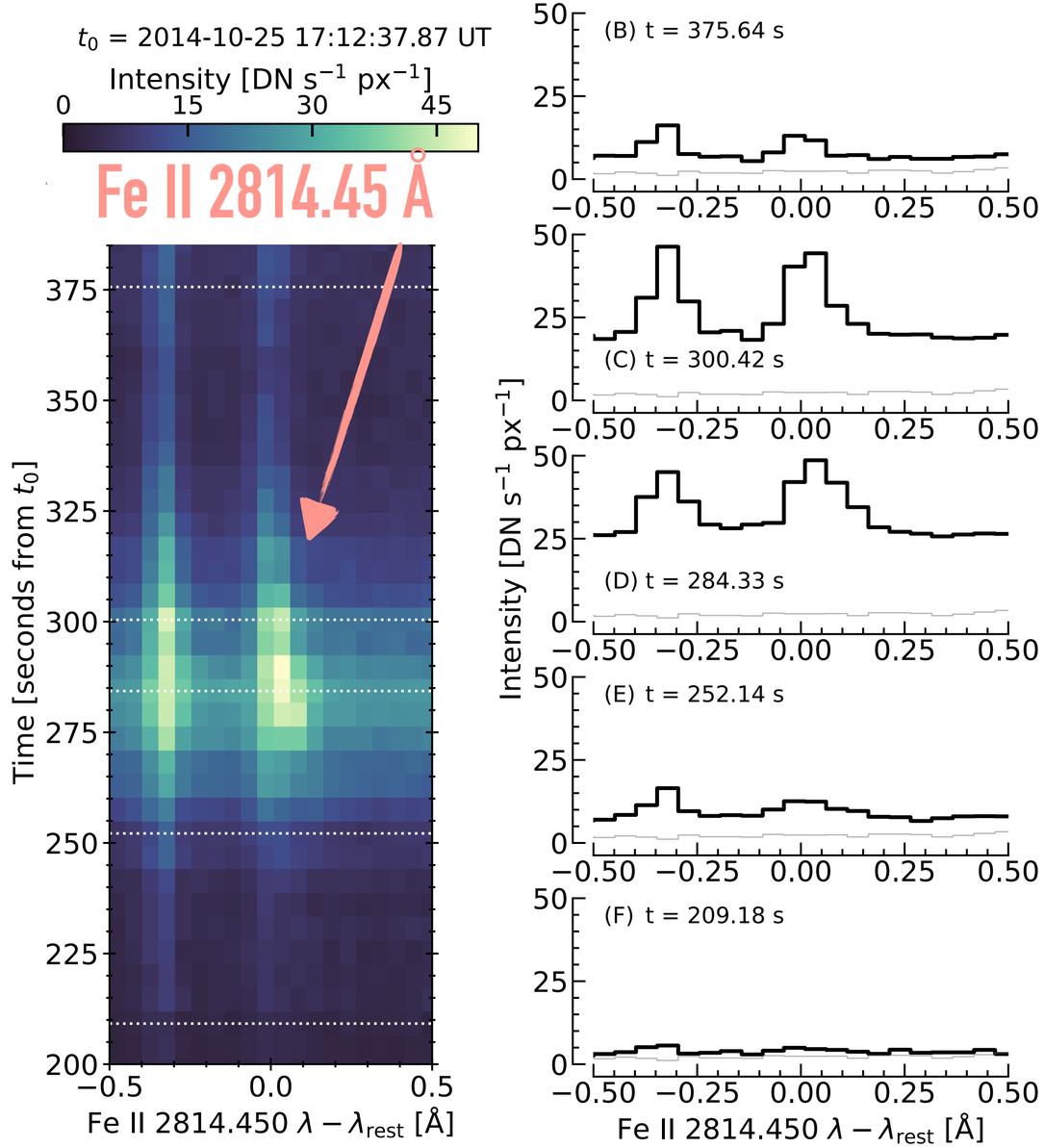

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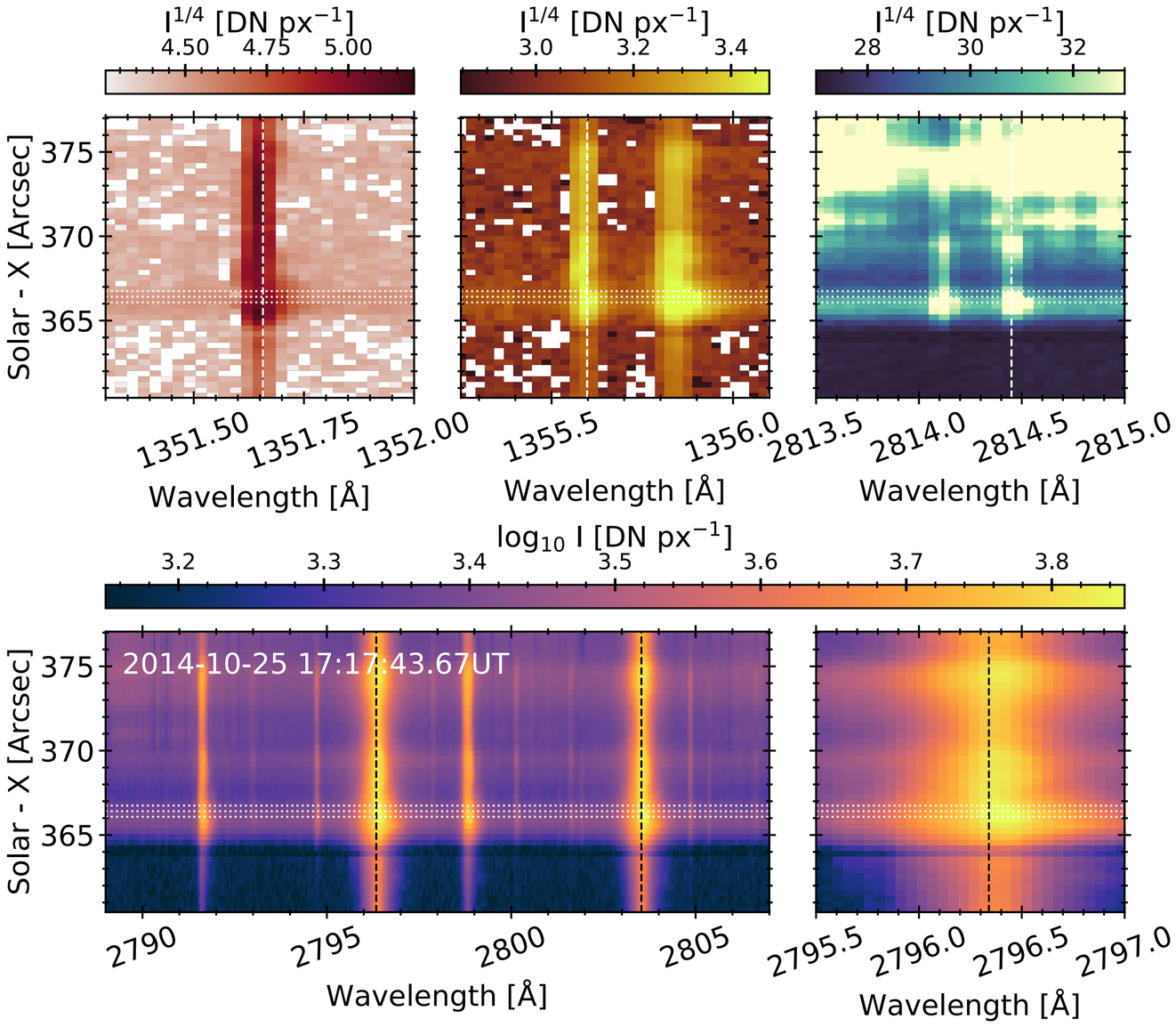
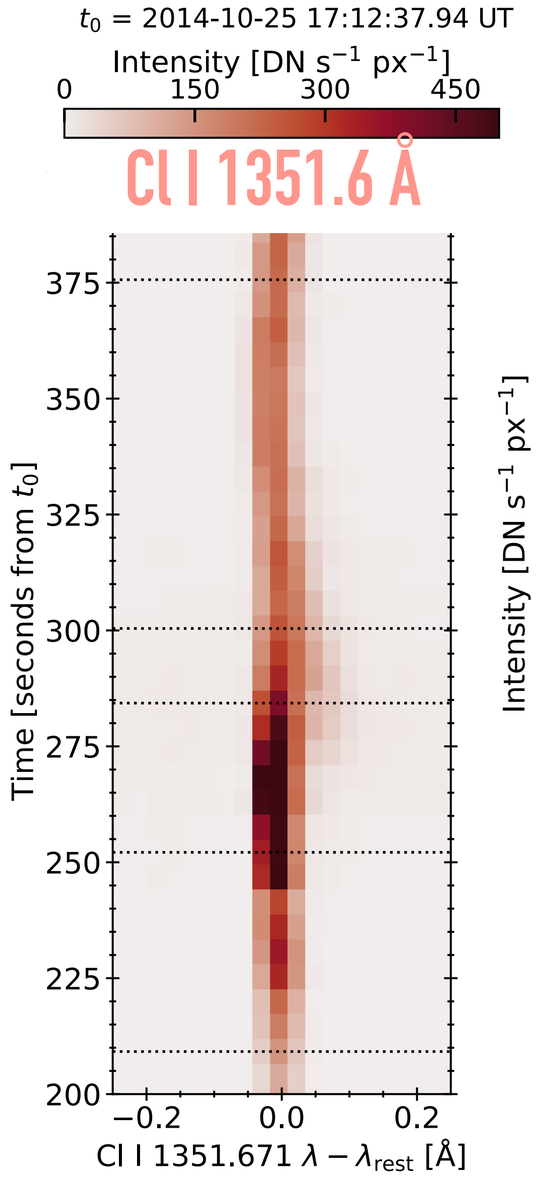
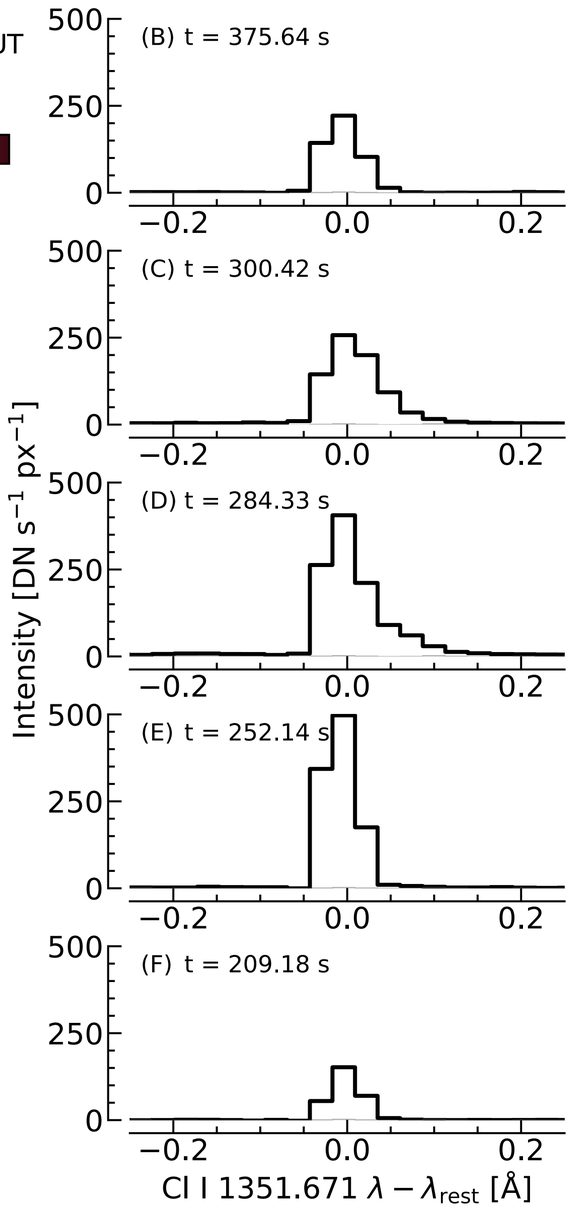
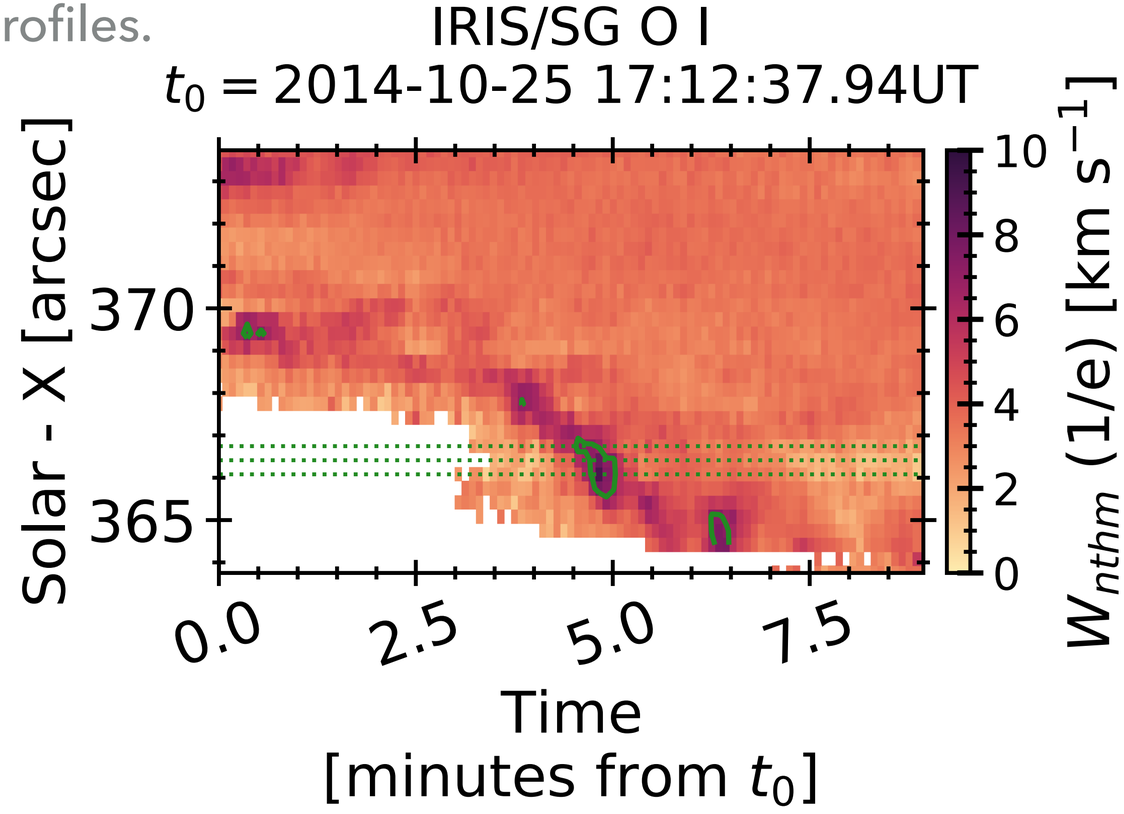






WHAT IS THE OBSERVED V_{TURB} ?

- Background values of v_{Nthm} ~ 2 - 3.5 km/s.
- Short lived (~30-90s) broadening, co-spatial with bright profiles.



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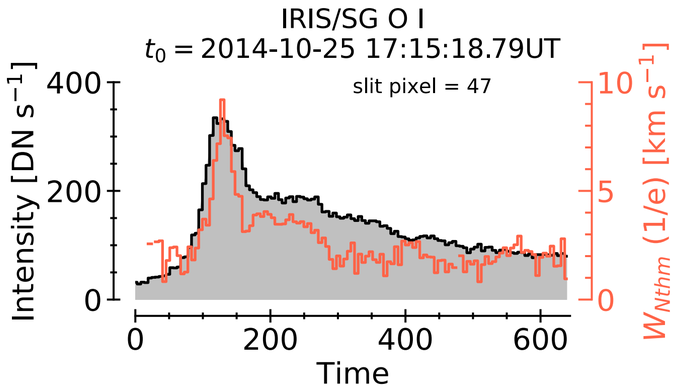

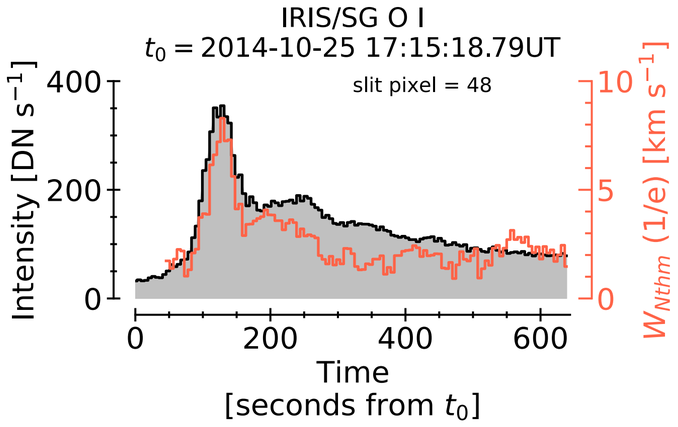

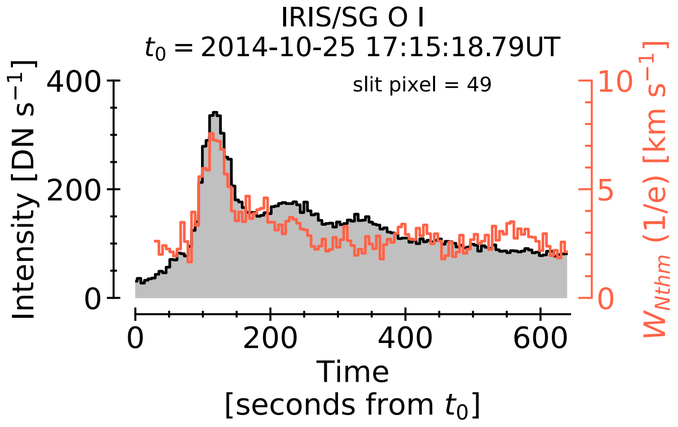

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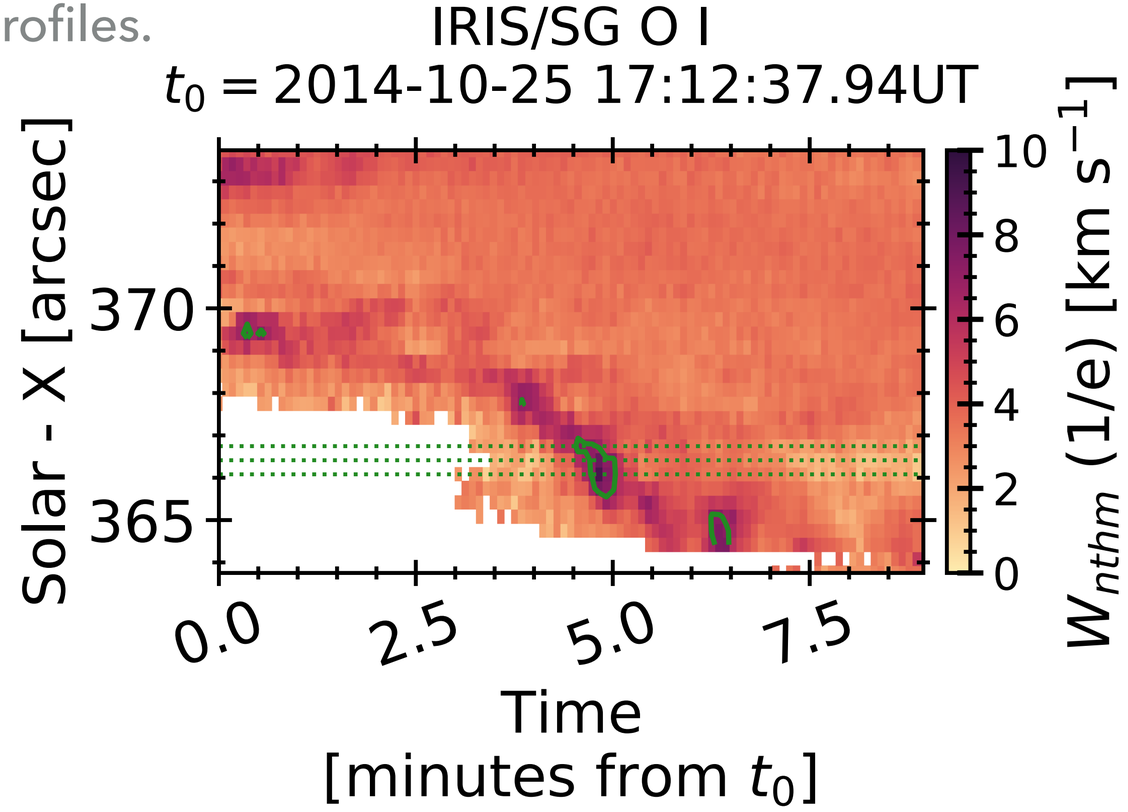

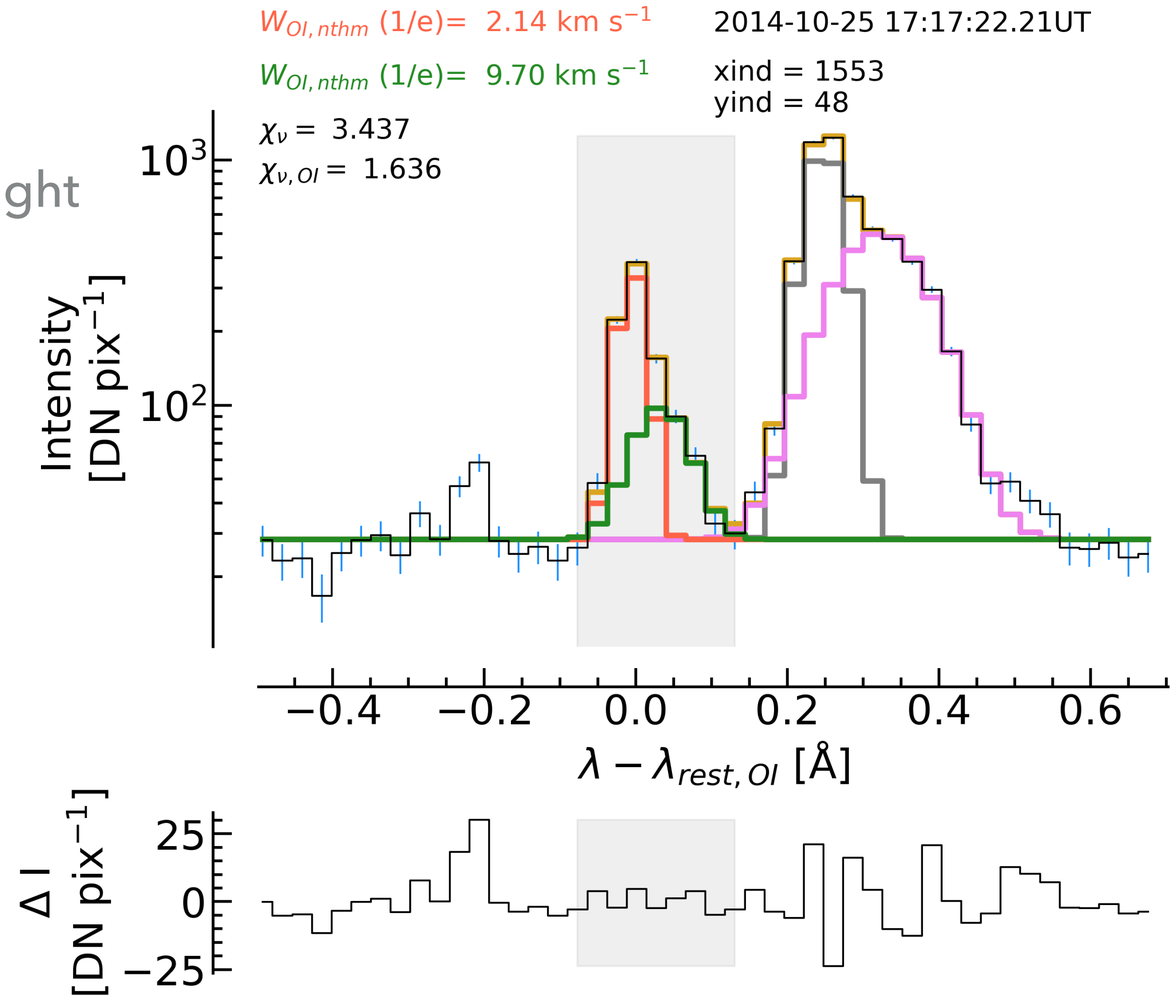

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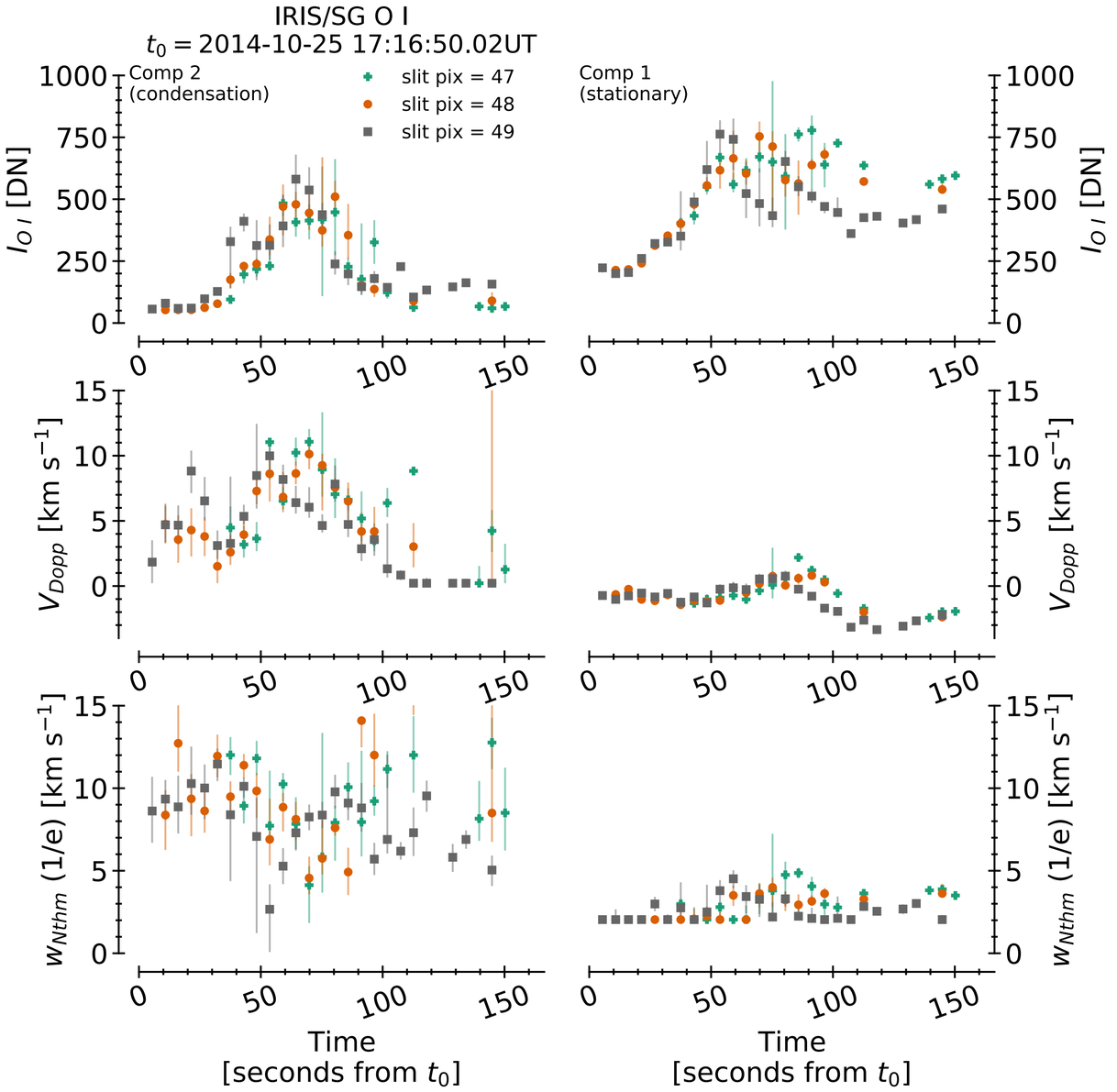
WHAT IS THE OBSERVED V_{TURB} ?

- Moderately redshifted second component; stationary component exhibits small red and blue shifts.
- Observed nonthermal width in the red wing component is ~5-12 km/s (typically 10 km/s).
- True for each of our assumed optically thin lines (Cl I, O I, Fe II).
- Stationary components only show very minor, if any, broadening – no strong broadening below the condensation?



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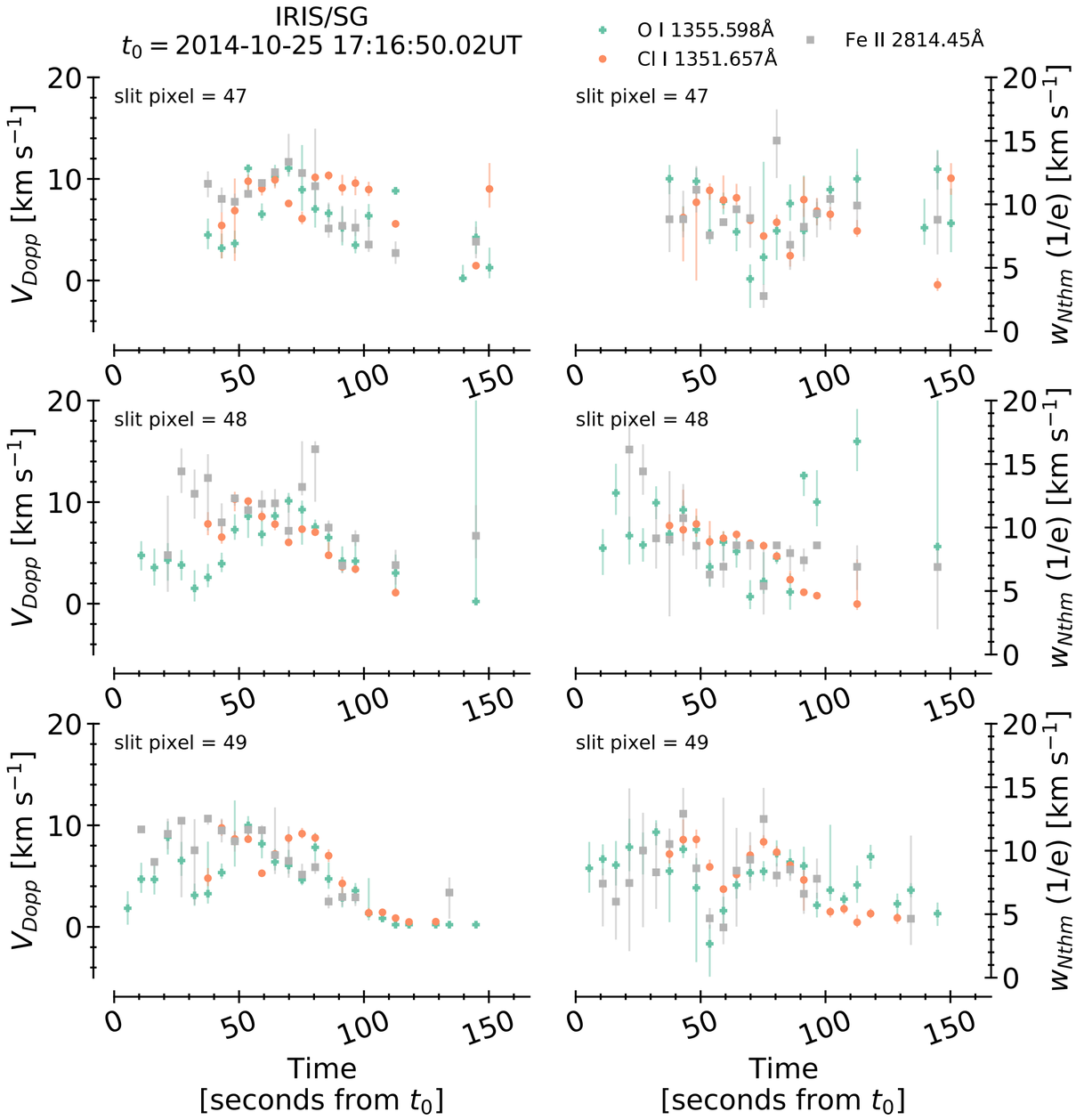
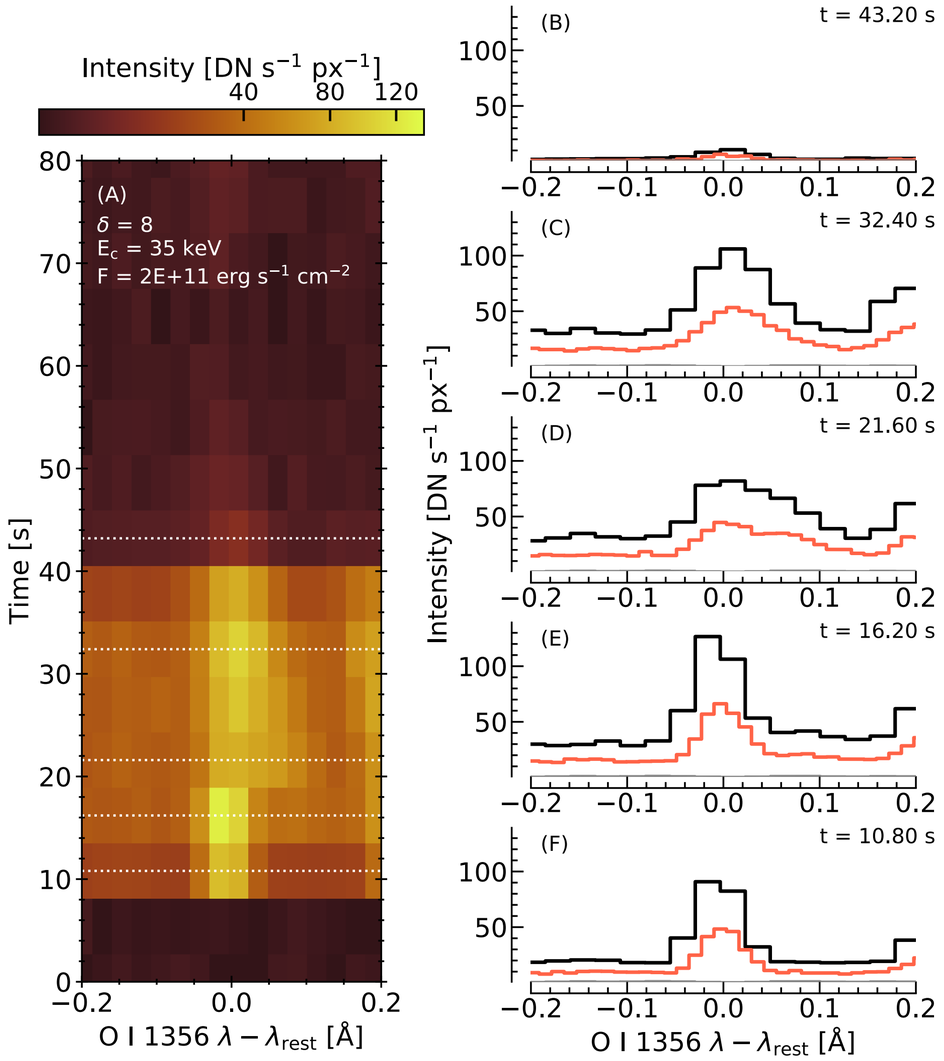
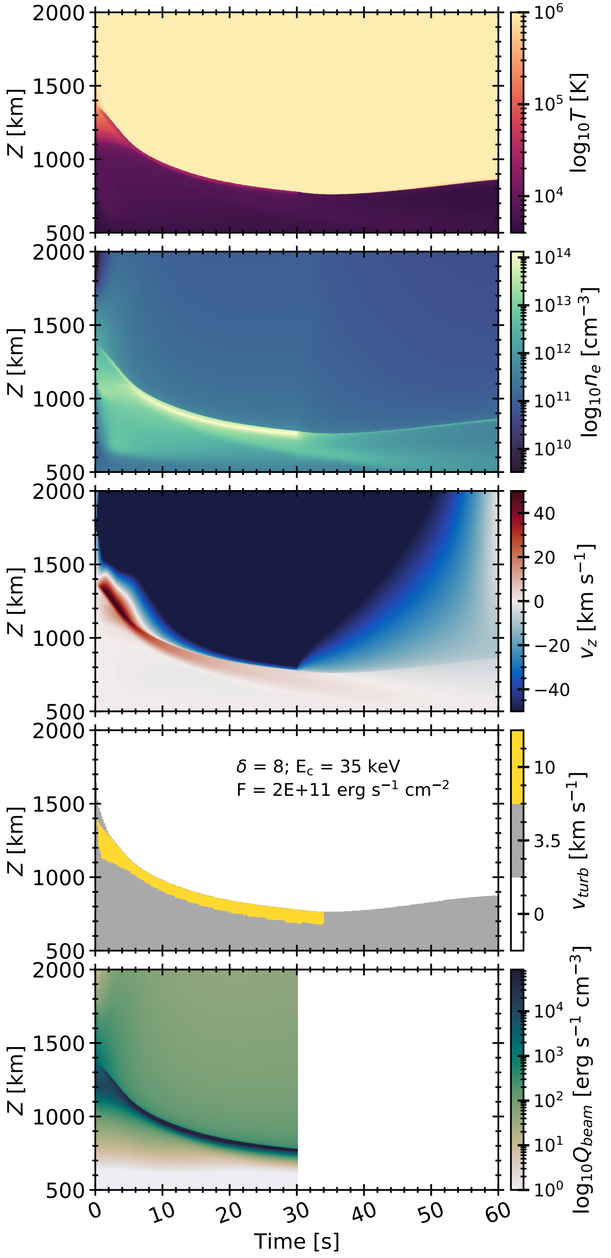


DATA-INSPIRED RADIATION HYDRODYNAMICS MODELLING

- Ran two RADYN flare simulations, with e-beam input from *Fermi* HXR analysis (only showing one of those here).
- When synthesizing IRIS lines with RH15D, imposed a micro-turbulence of 10 km/s within the condensation, guided by observations (assumes they form near Mg II).
- In the stronger flare both Fe II and O I exhibited prominent red wing components.





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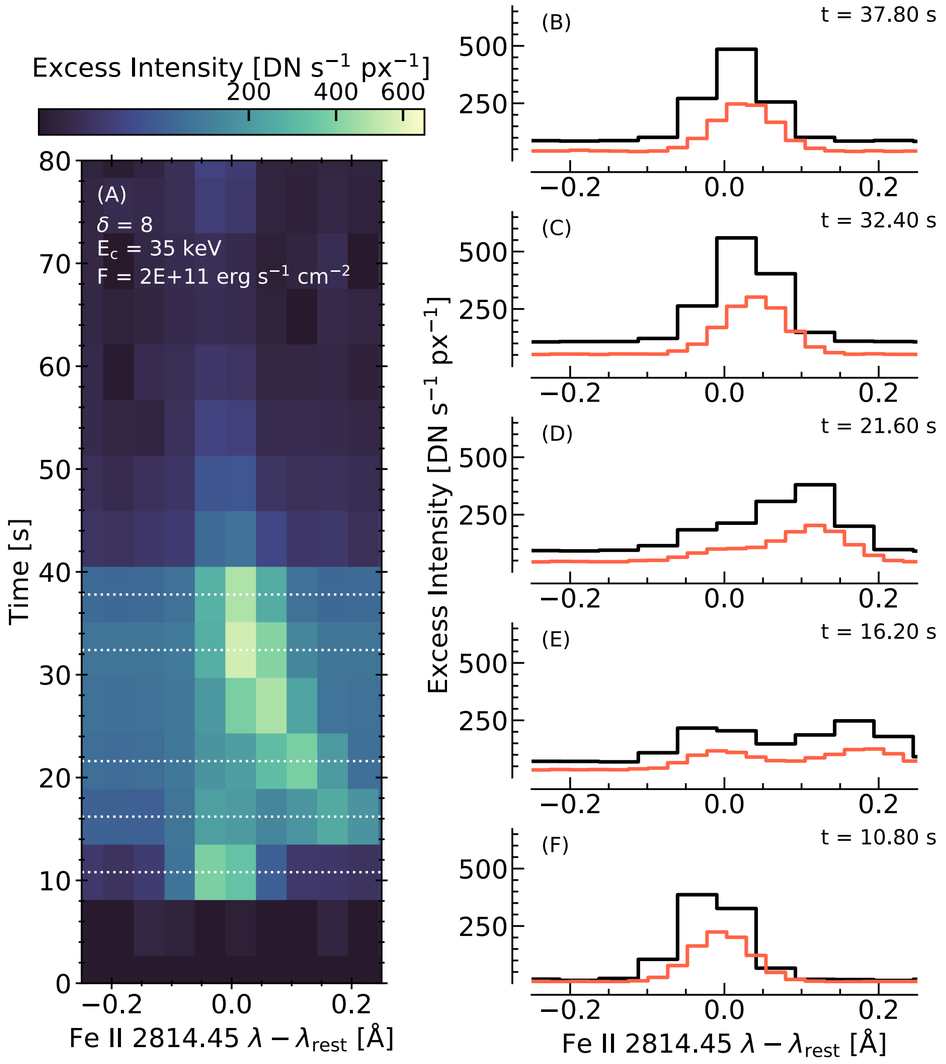

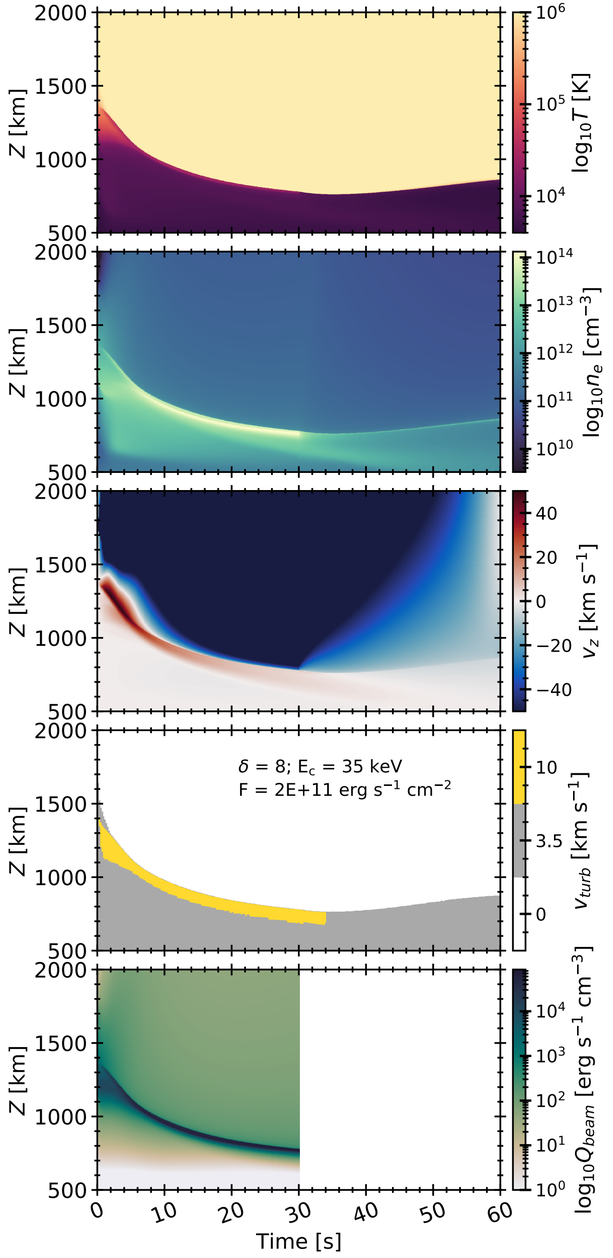

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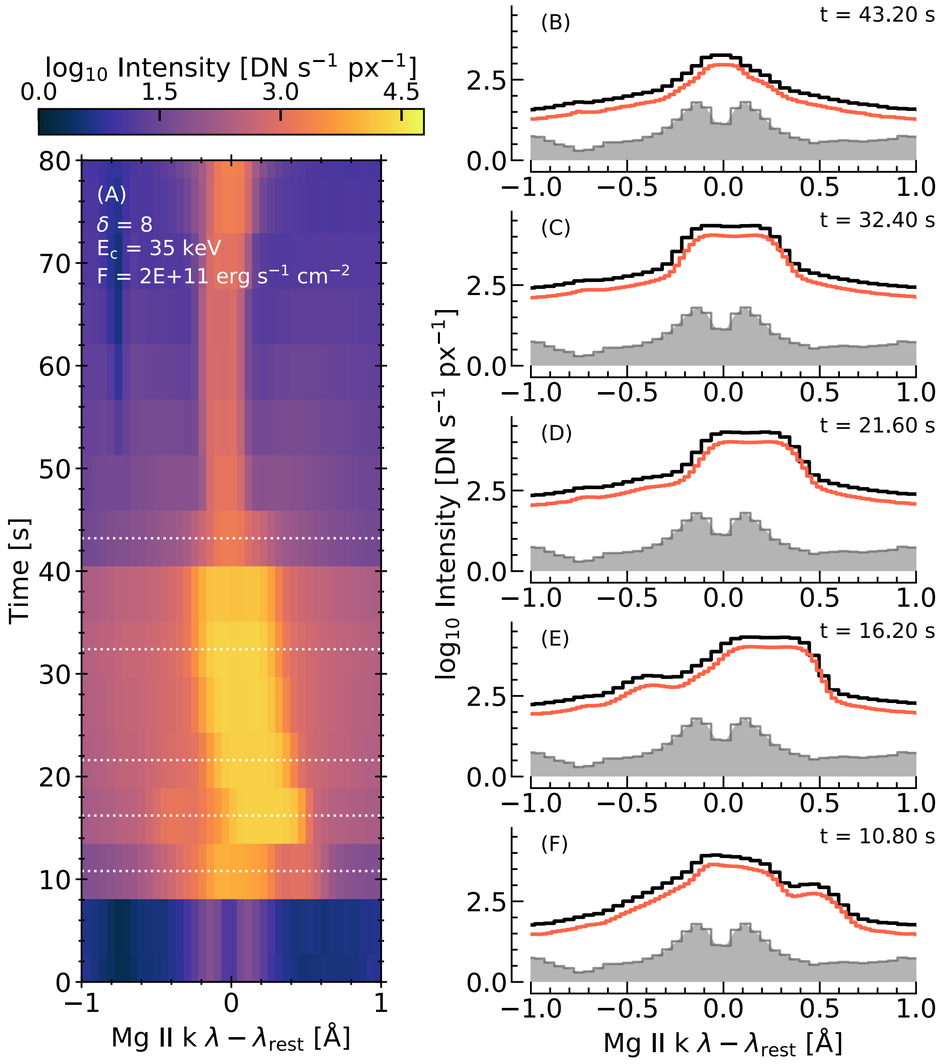
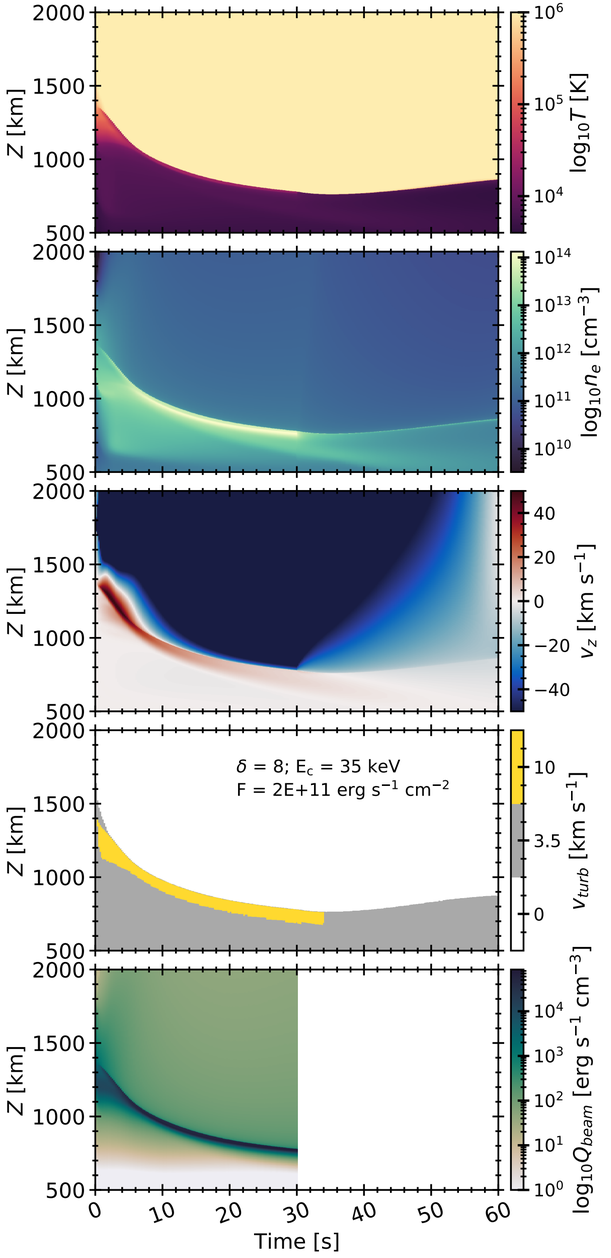
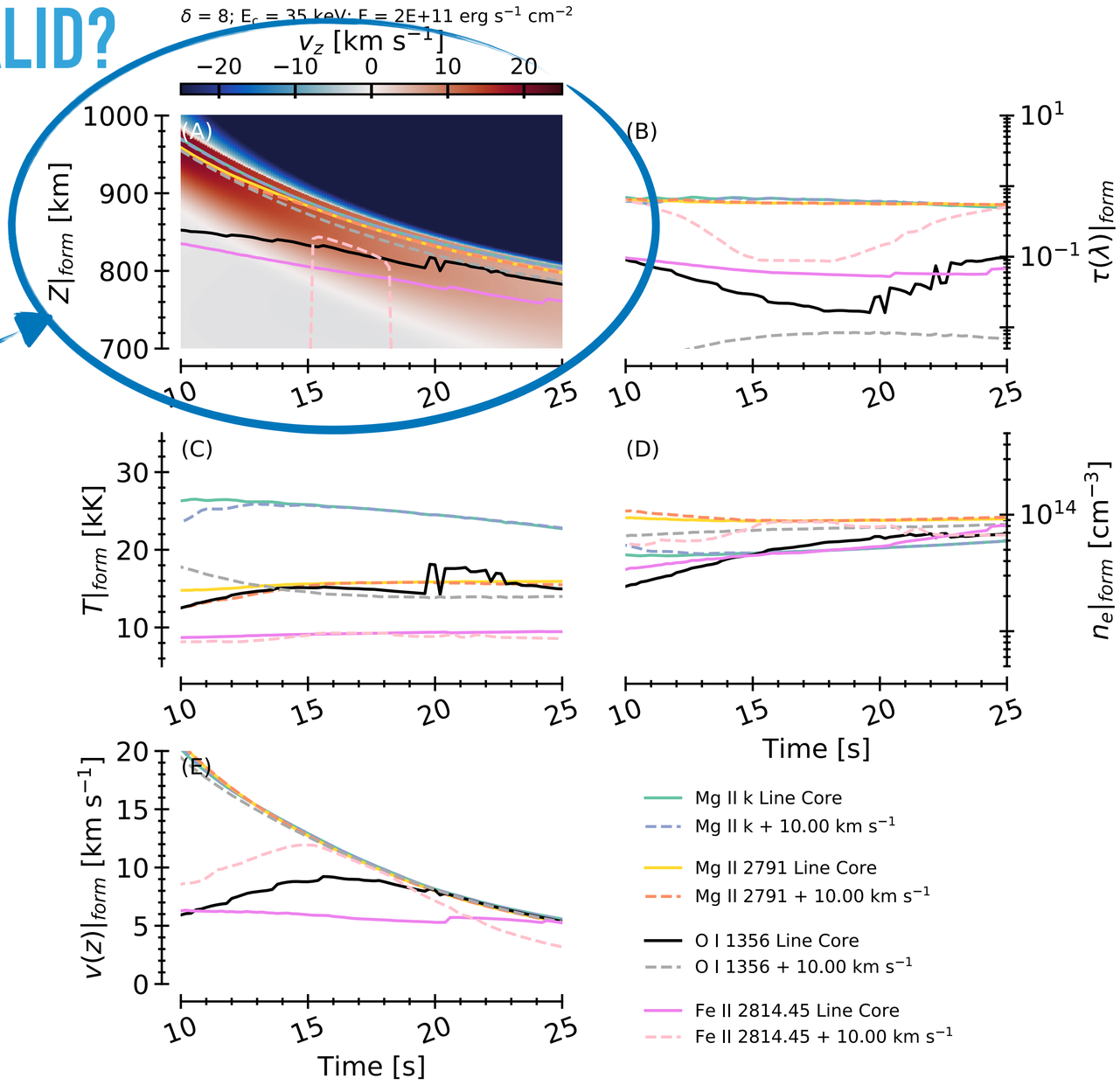




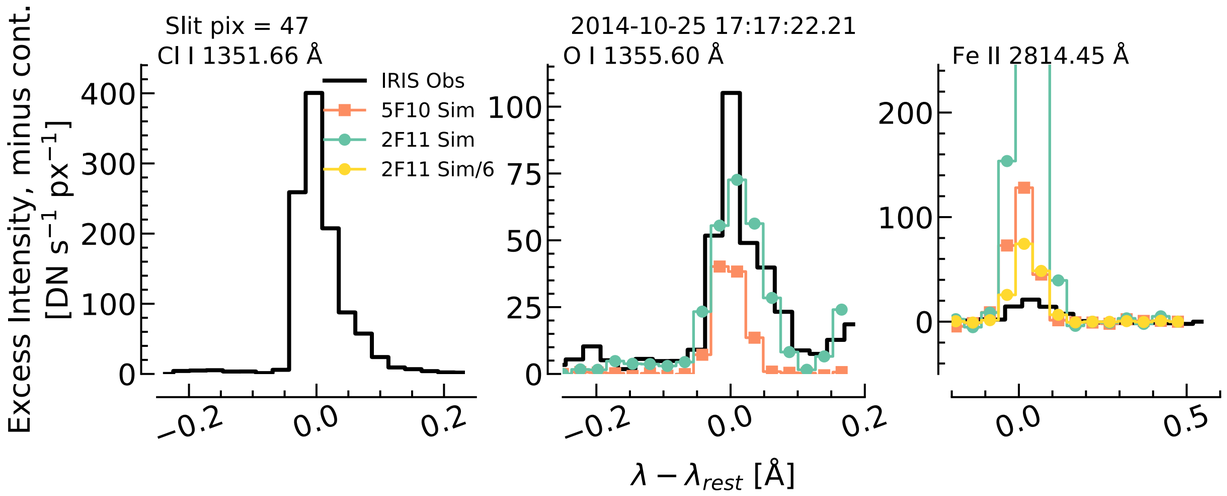
ARE OUR ANALYSIS ASSUMPTIONS VALID?

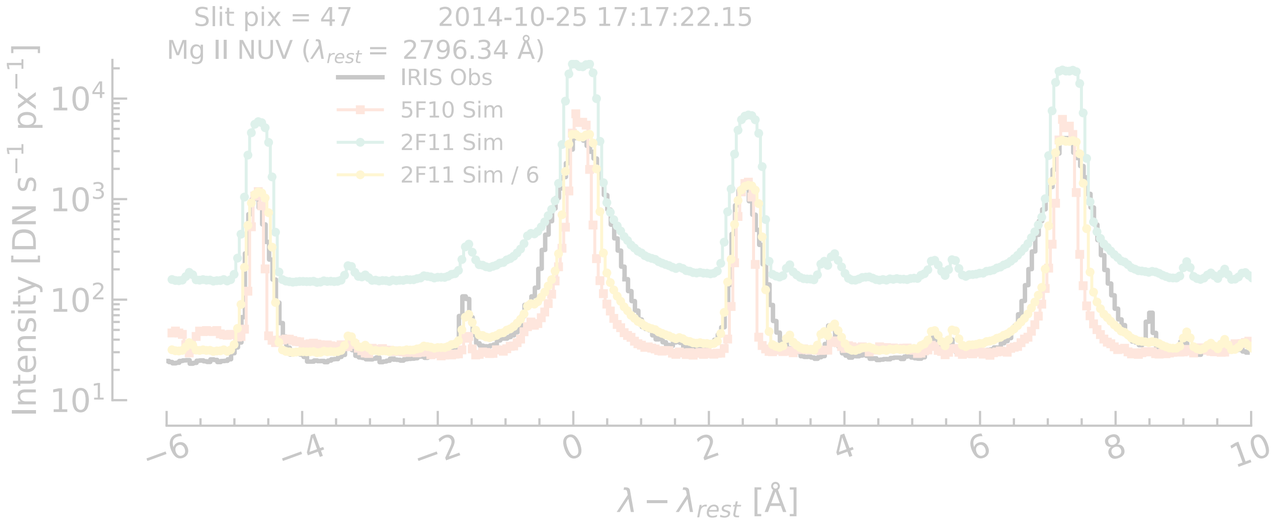
- O I line core and shifted component optically thin throughout.
- Fe II shifted component optically thin throughout, but core does suffer from some optical depth effect.
- Red wing components of both lines form nearby Mg II h & k lines, within the chromospheric condensation.



O I MODEL-DATA COMPARISON

- O I synthesis is pretty good!
- Fe II line core is too intense.
- Mg II NUV spectra's general shape is good, but too intense (x6).
- Mg II Line wings still too narrow, but we can't increase microturbulence deeper since we would see that in the O I line core.





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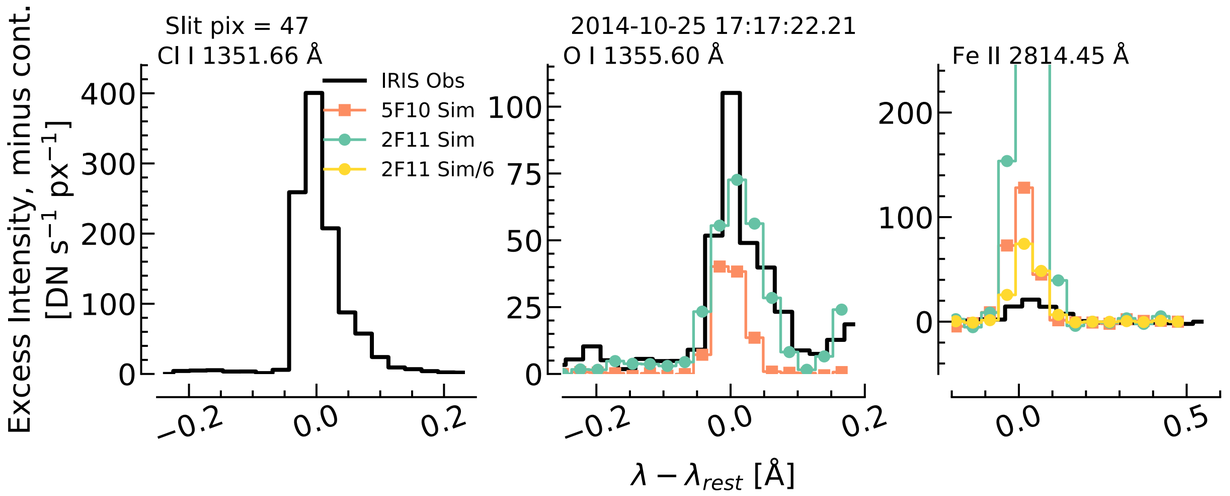

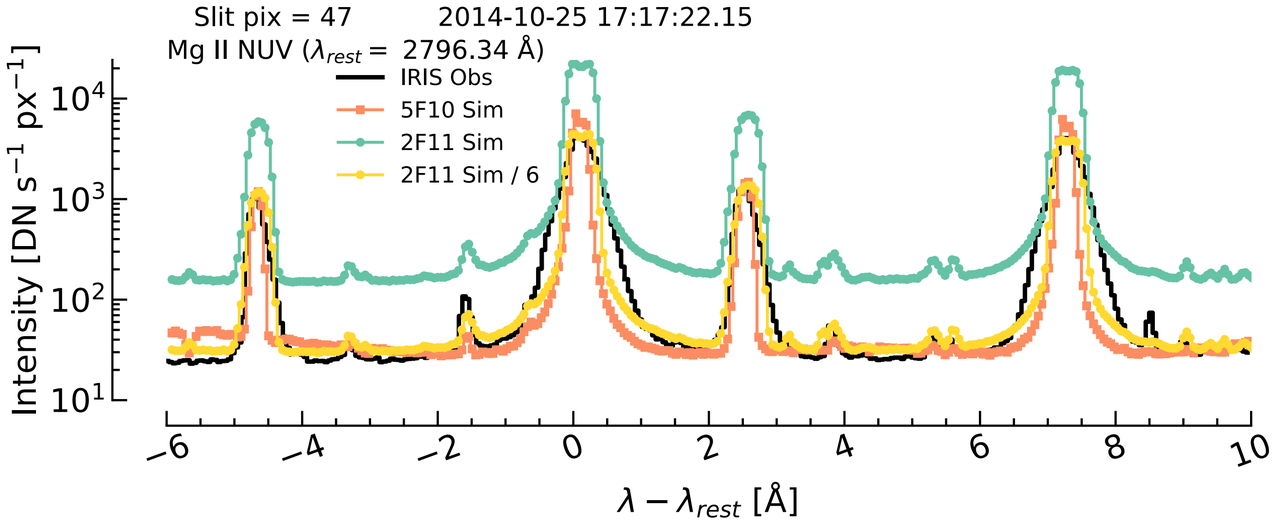

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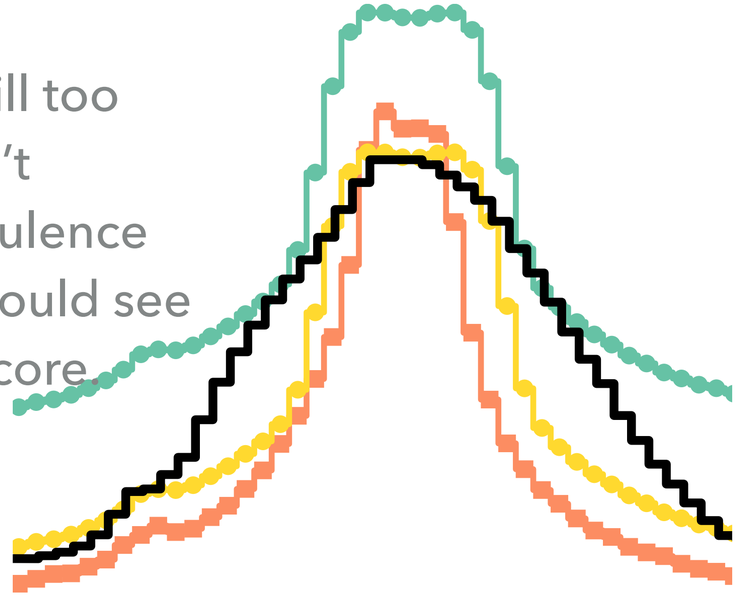
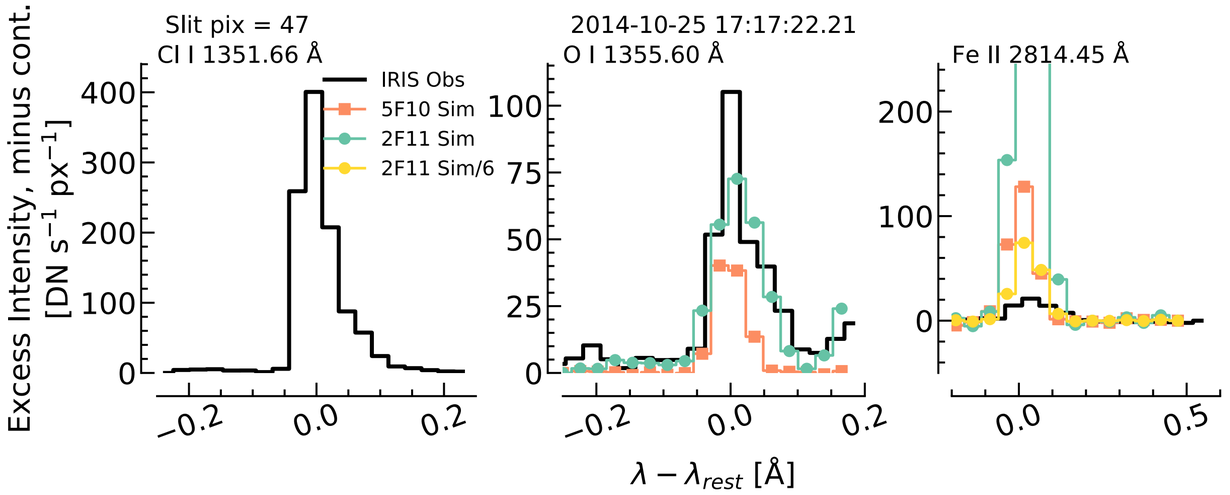
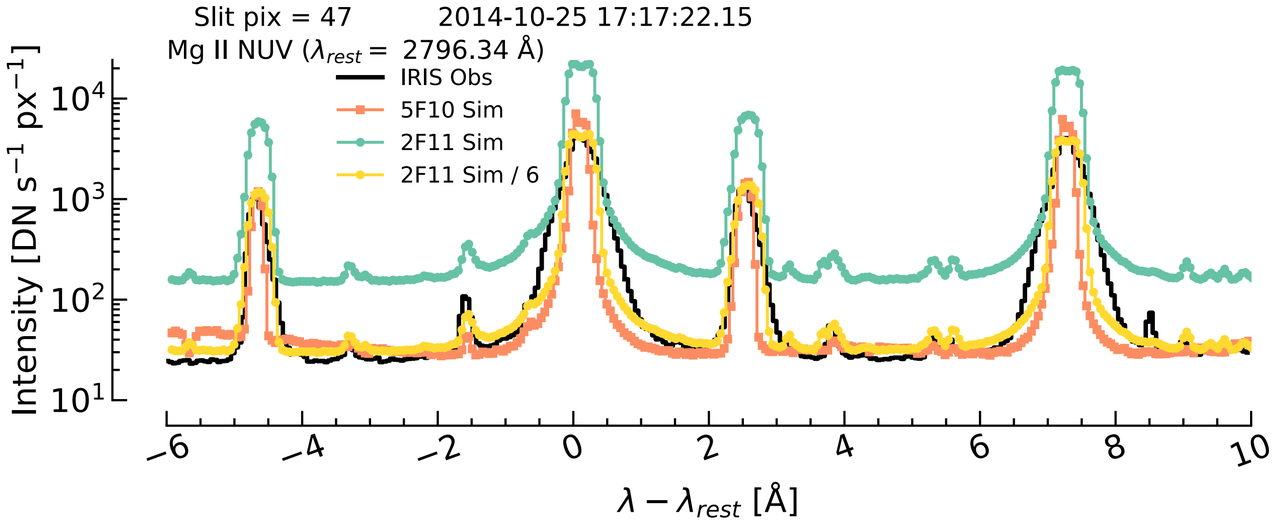
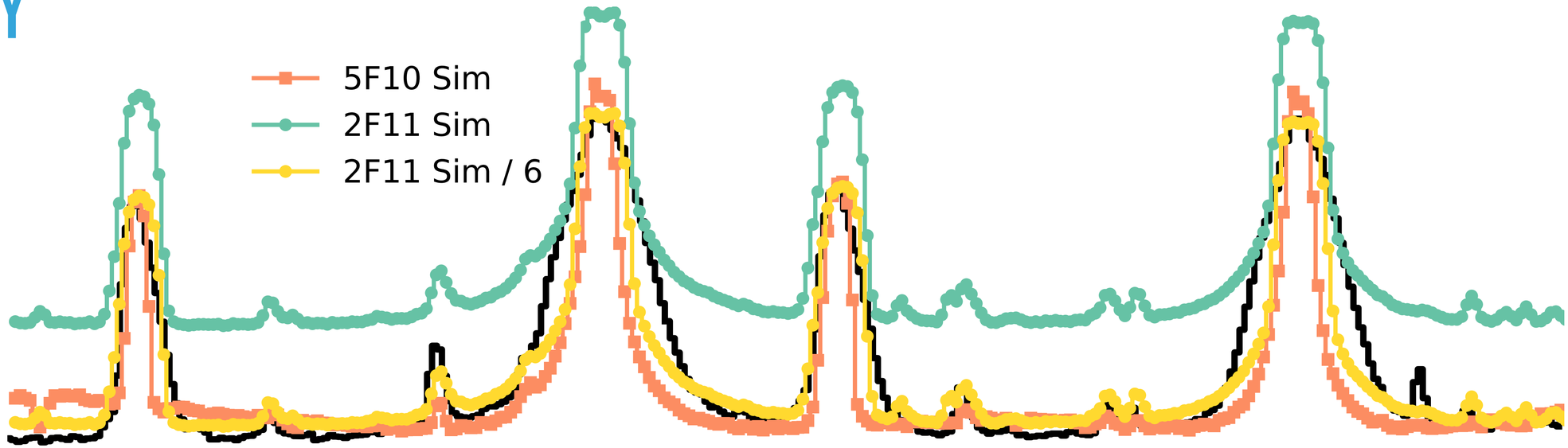
- Mg II NUV spectra's general shape is good, but too intense (x6).
- Mg II Line wings still too narrow, but we can't increase microturbulence deeper since we would see that in the O I line core.



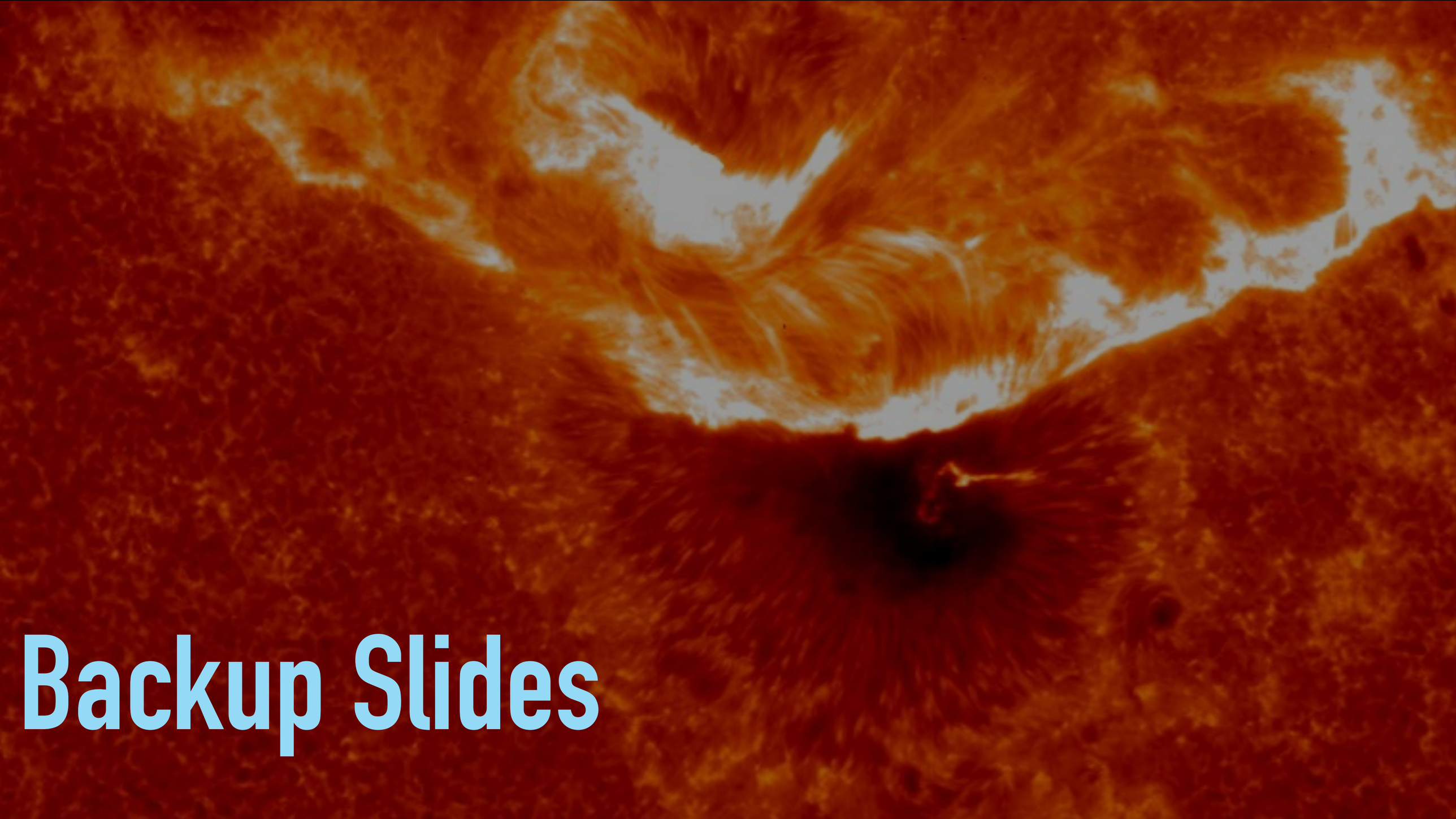




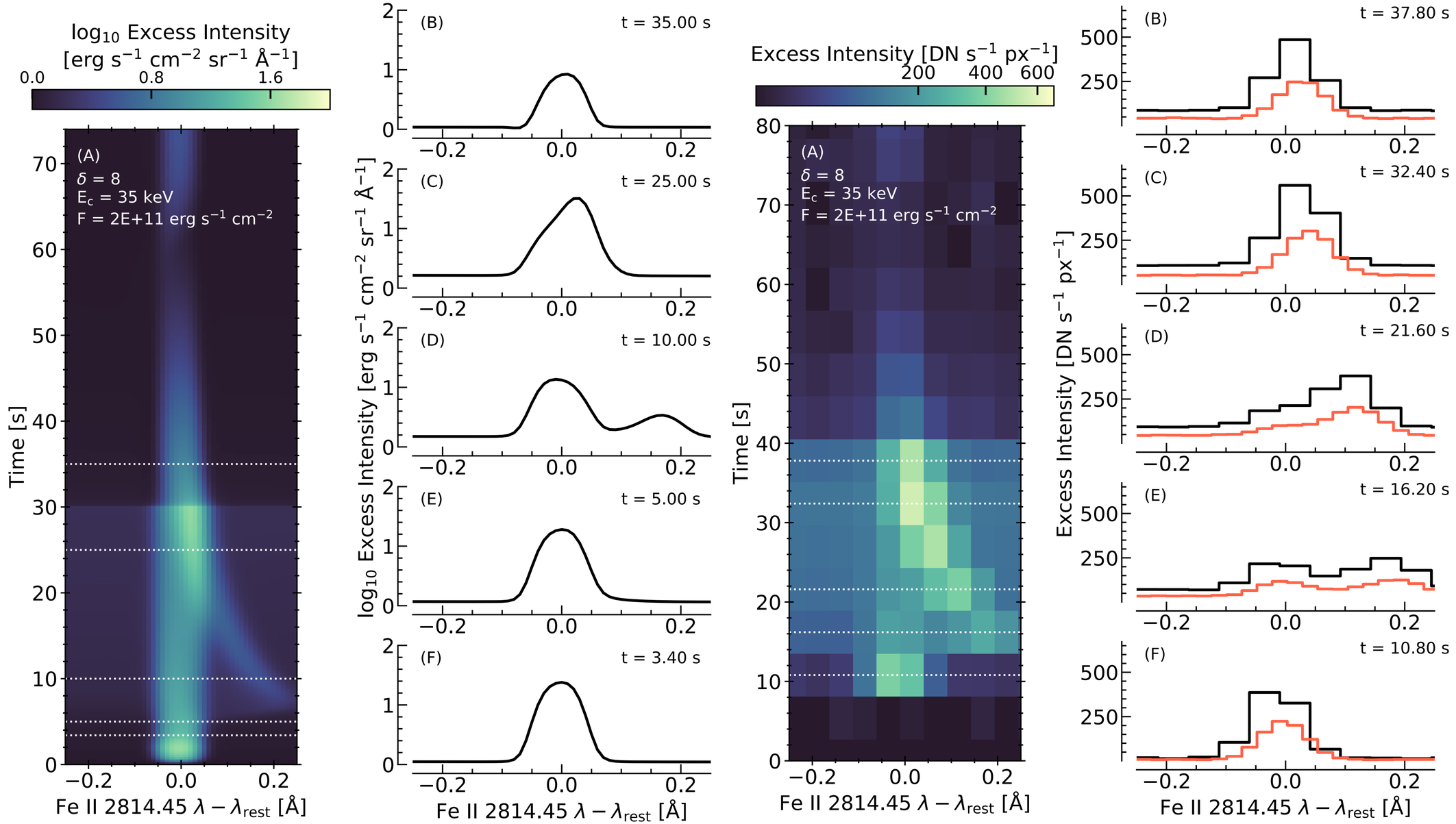
SUMMARY

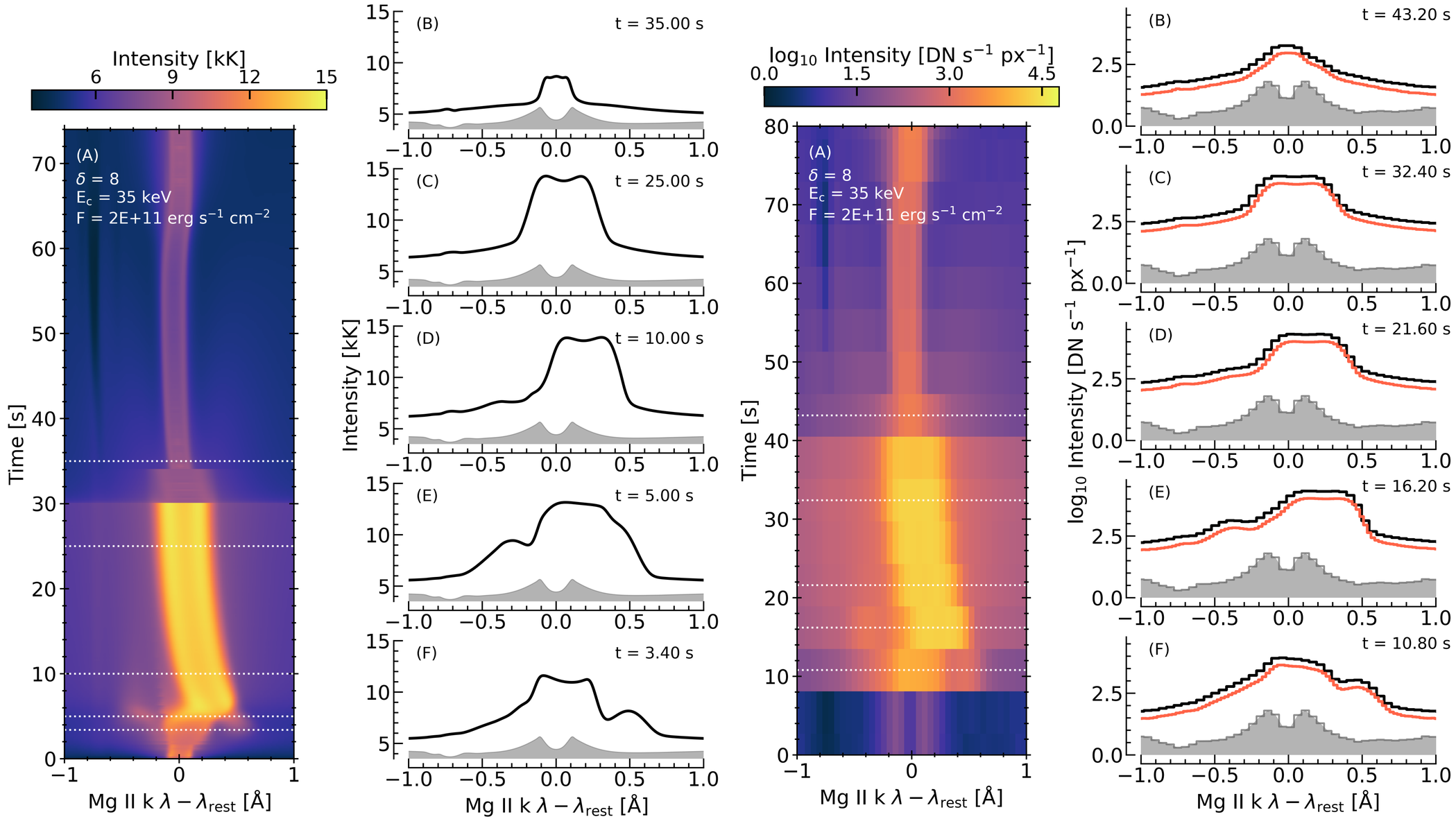


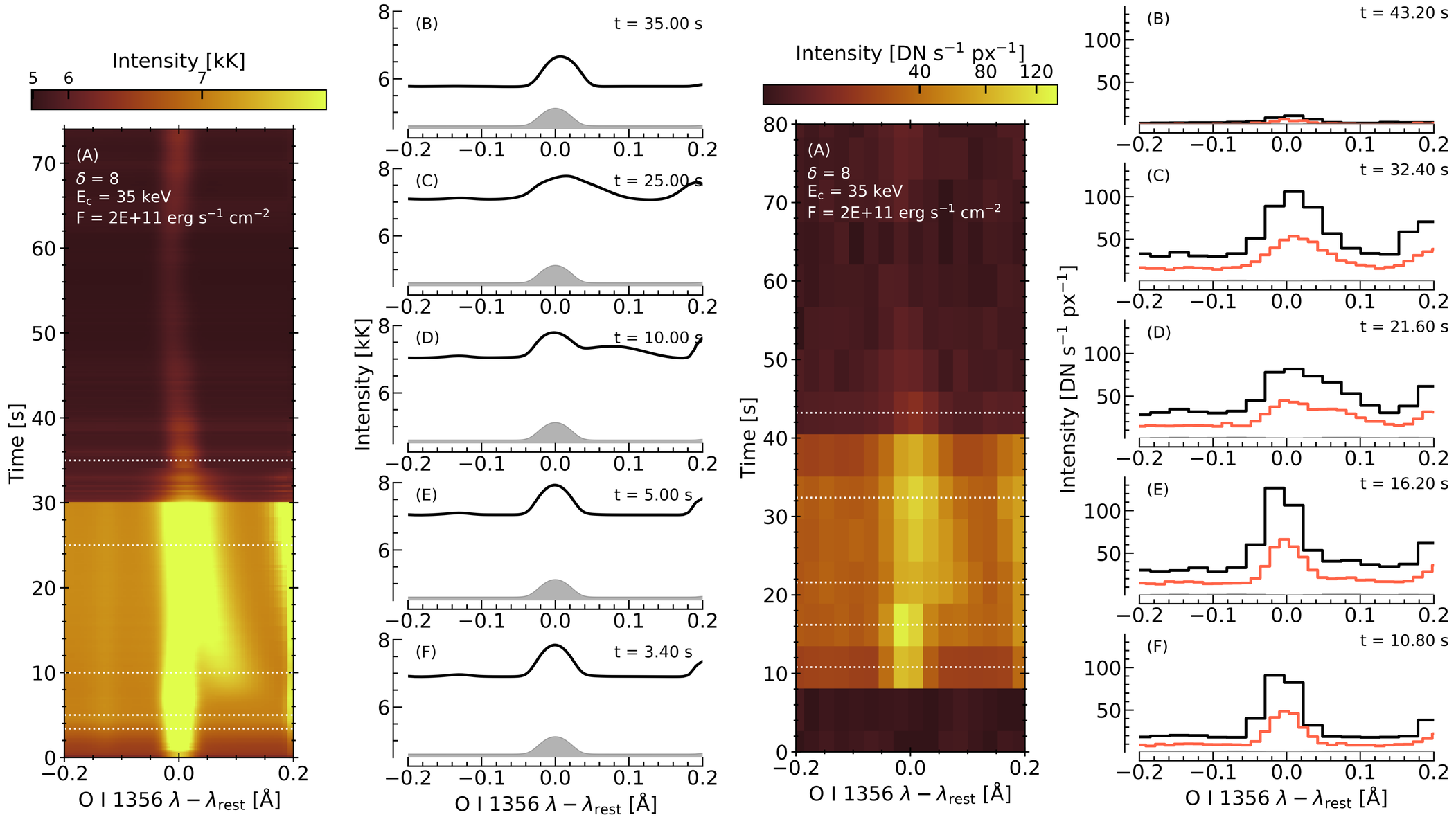
- Characterised upper limits of microturbulence in a chromospheric flare ribbon.
- O I, Cl I, and Fe II all exhibited red wing components, with nonthermal widths ~10 km/s. Stationary components showed only very modest nonthermal widths, and slight blue/red shifts.
- Lifetimes of the initial brightening/red wing components were 30-90s.
- Data inspired RHD modelling revealed a reasonably good model-data comparison, apart from Mg II line widths.
- Exploring missing ingredients from our models: nonthermal effects on Mg II formation and likely missing energy deposition at greater depths.



Backup Slides


log10 Excess Intensity
[erg s−1 cm−2 sr−1 Å−1]
0.0
0.8
1.6
(A)
δ = 8
Ec = 35 keV
F = 2E+11 erg s−1 cm−2
Time [s]
Fe II 2814.45 λ − λrest [Å]
(B)
t = 35.00 s
(C)
t = 25.00 s
(D)
t = 10.00 s
(E)
t = 5.00 s
(F)
t = 3.40 s
log10 Excess Intensity [erg s−1 cm−2 sr−1 Å−1]
Excess Intensity [DN s−1 px−1]
200
400
600
t = 37.80 s
t = 32.40 s
t = 21.60 s
t = 16.20 s
t = 10.80 s


Intensity [kK]
6
9
12
15
(A)
δ = 8
E_c = 35 keV
F = 2E+11 erg s^−1 cm^−2
Time [s]
Mg II k λ − λ_rest [Å]
(B)
t = 35.00 s
(C)
t = 25.00 s
(D)
t = 10.00 s
(E)
t = 5.00 s
(F)
t = 3.40 s
Intensity [kK]
log10 Intensity [DN s^−1 px^−1]
0.0
1.5
3.0
4.5
(A)
δ = 8
E_c = 35 keV
F = 2E+11 erg s^−1 cm^−2
Time [s]
Mg II k λ − λ_rest [Å]
(B)
t = 43.20 s
(C)
t = 32.40 s
(D)
t = 21.60 s
(E)
t = 16.20 s
(F)
t = 10.80 s
log10 Intensity [DN s^−1 px^−1]
Mg II k λ − λ_rest [Å]


Intensity [kK]
5 6 7
(A)
δ = 8
E_c = 35 keV
F = 2E+11 erg s^−1 cm^−2
Time [s]
O I 1356 λ − λ_rest [Å]
(B) t = 35.00 s
(C) t = 25.00 s
(D) t = 10.00 s
(E) t = 5.00 s
(F) t = 3.40 s
Intensity [kK]
Intensity [DN s^−1 px^−1]
40 80 120
(A)
δ = 8
E_c = 35 keV
F = 2E+11 erg s^−1 cm^−2
Time [s]
O I 1356 λ − λ_rest [Å]
(B) t = 43.20 s
(C) t = 32.40 s
(D) t = 21.60 s
(E) t = 16.20 s
(F) t = 10.80 s
Intensity [DN s^−1 px^−1]
O I 1356 λ − λ_rest [Å]