The Prevalence of O IV Density Diagnostics in UV Burst Spectra

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2018 Solar REU
2018/08/08

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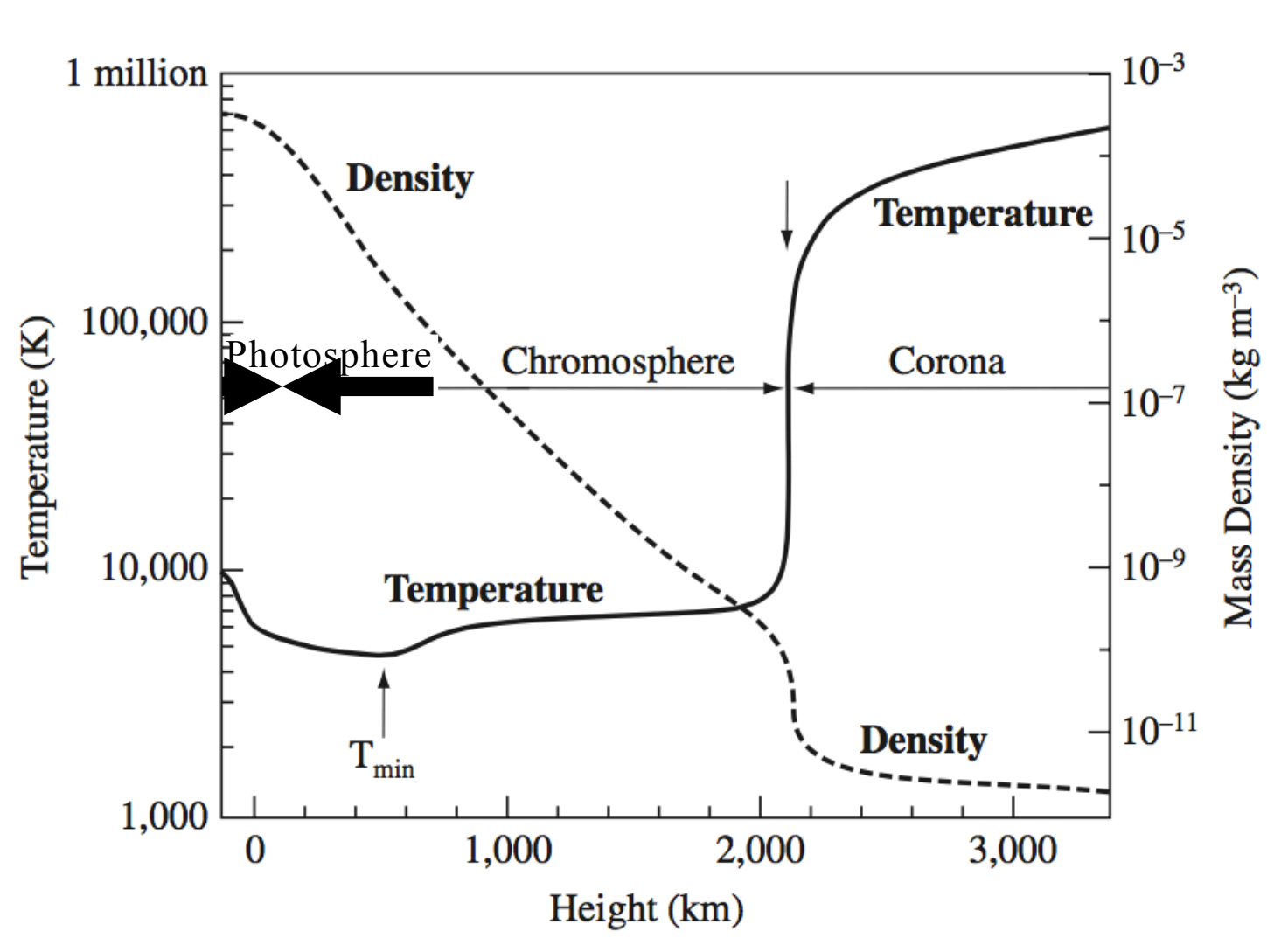
Quiet Sun Atmosphere Model

Vernazza et al. 1981



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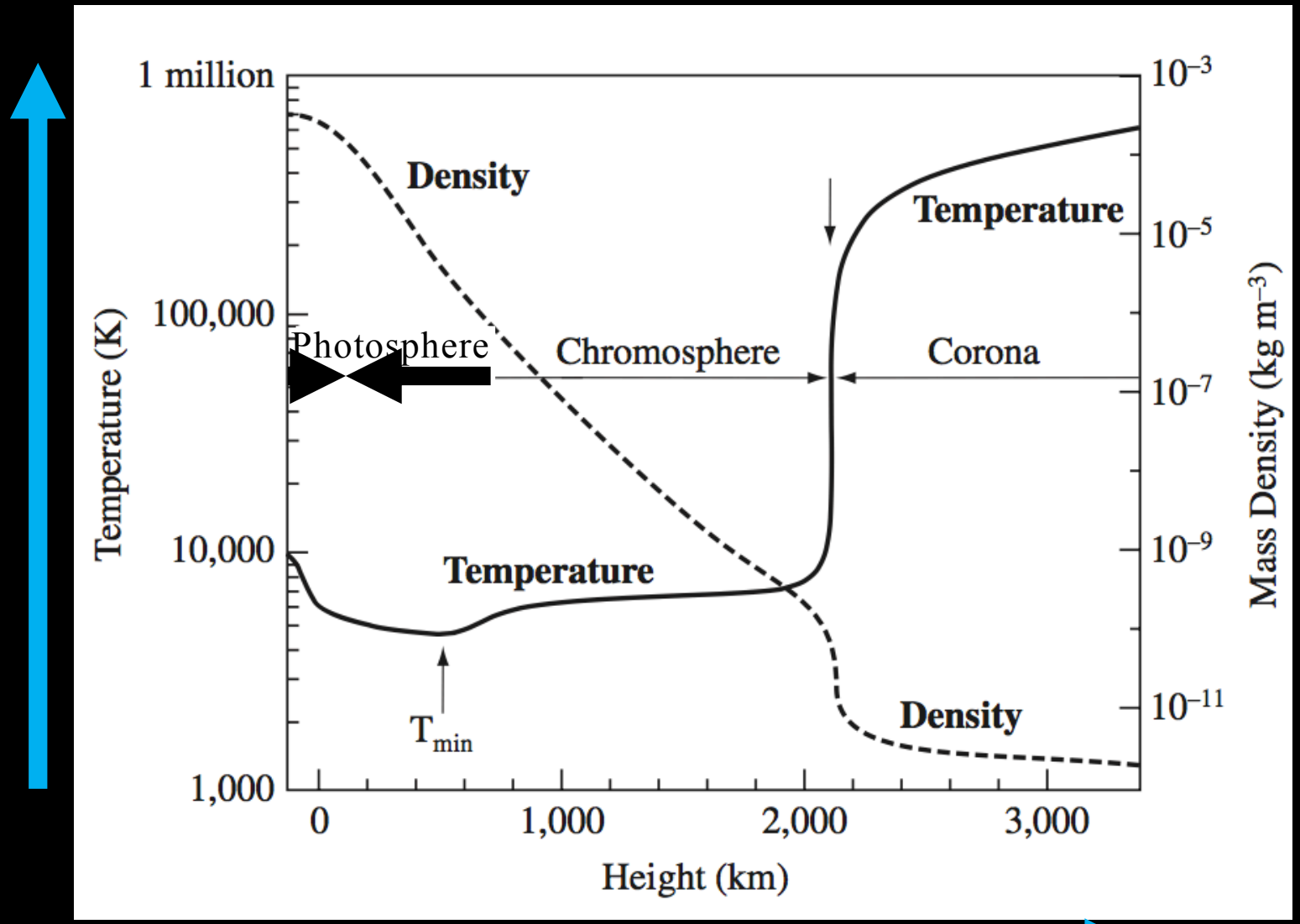

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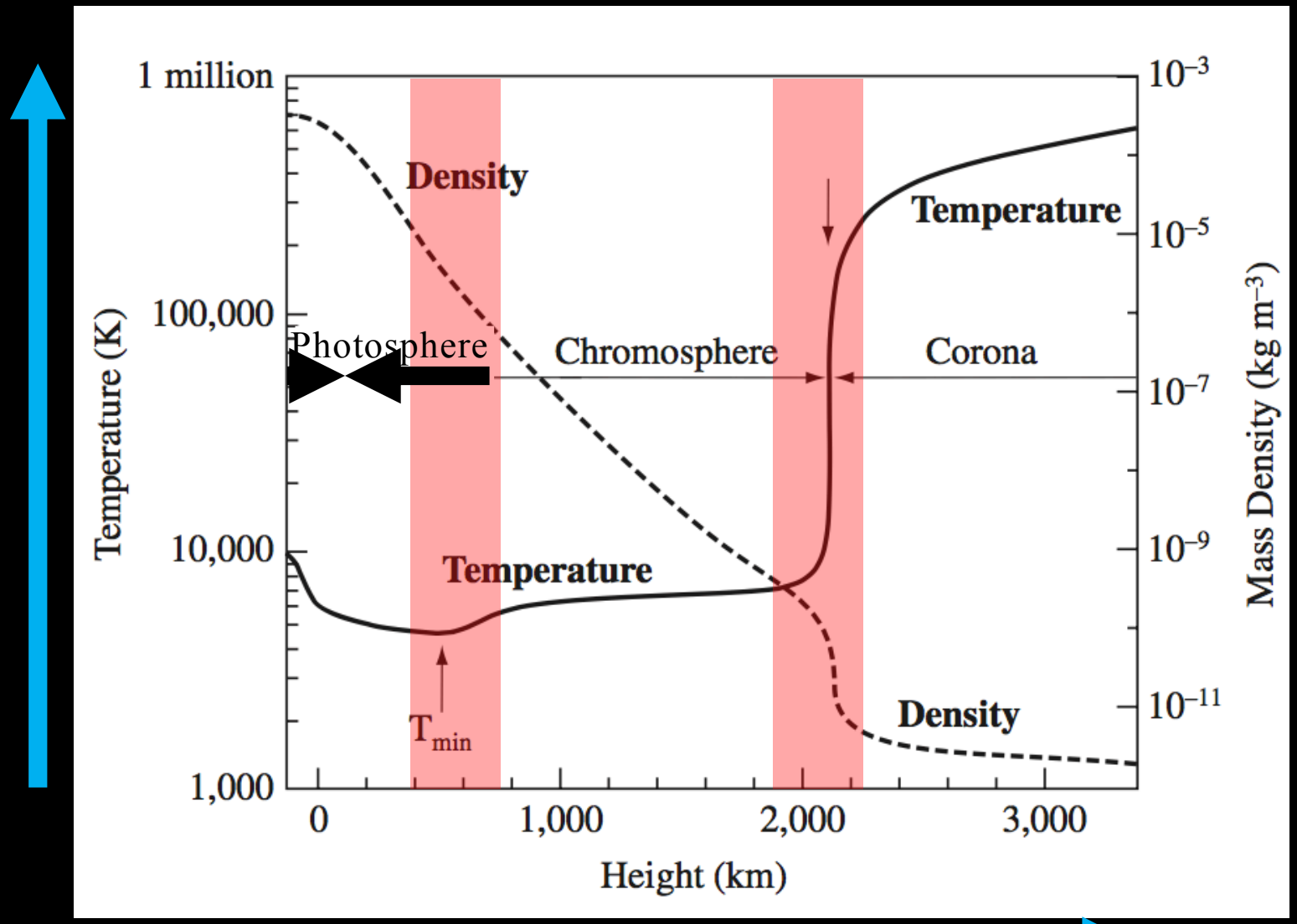
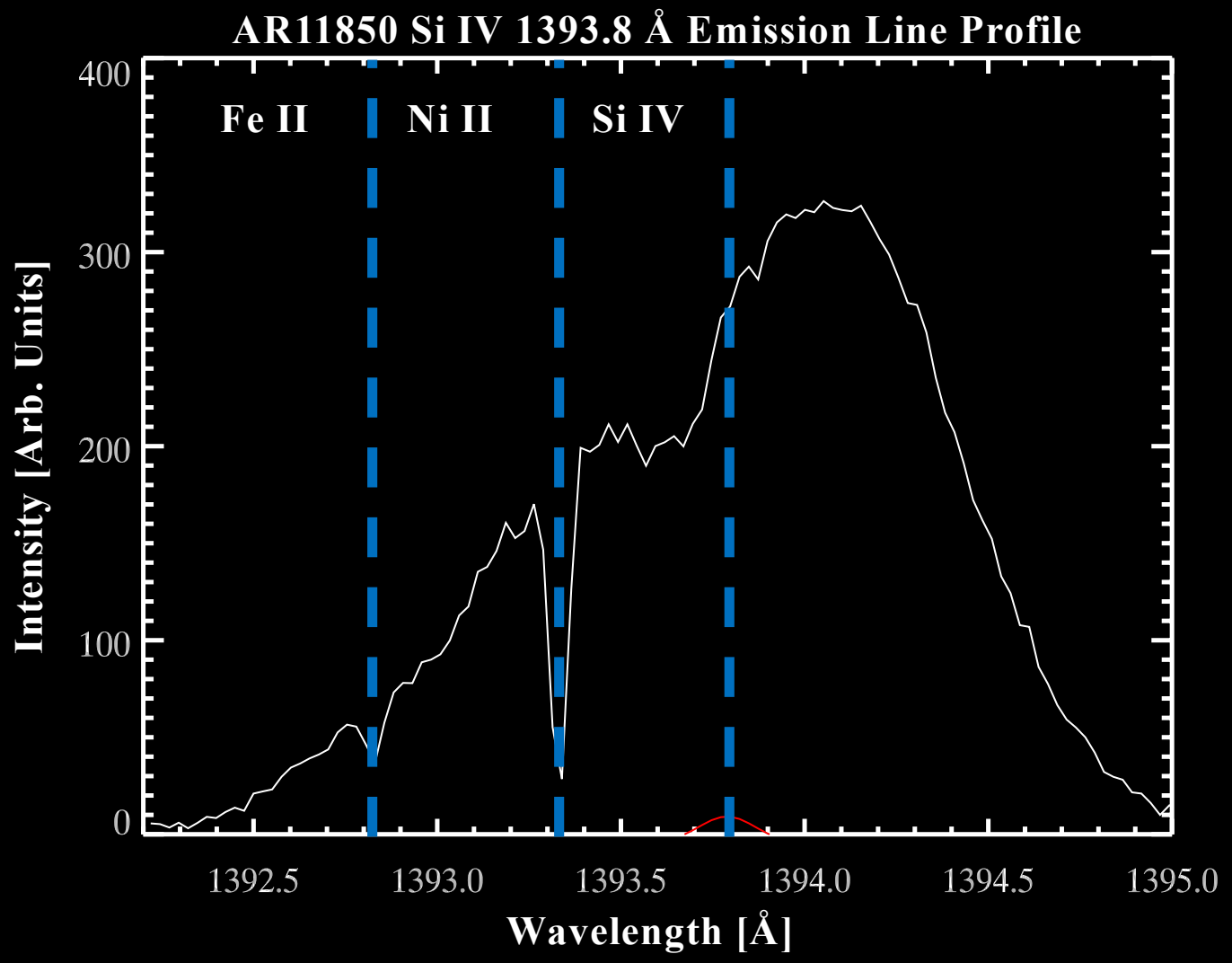
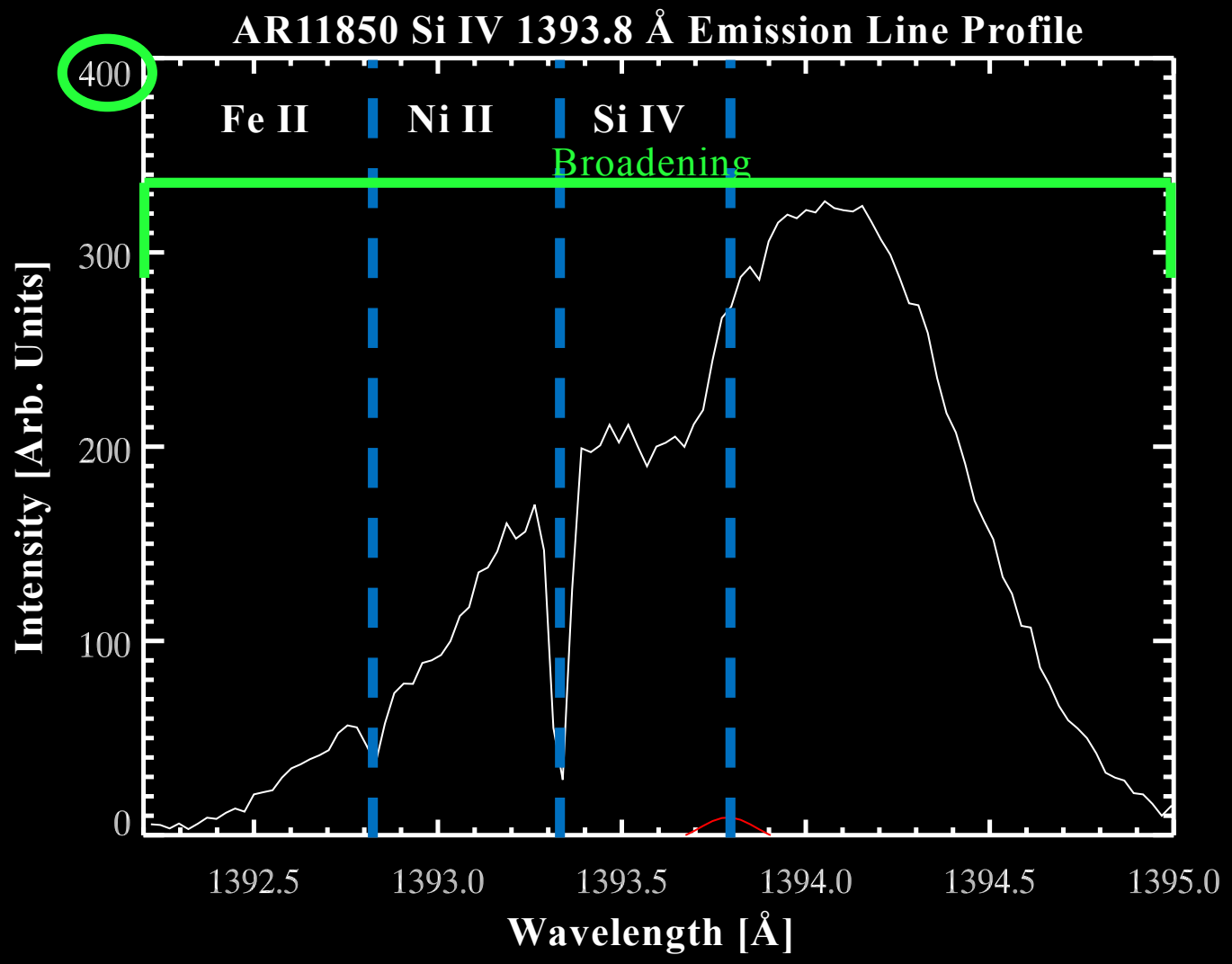


UV Bursts



- Compact, short-lived brightenings in active regions
- Observable properties:
  - Intensification and broadening/splitting of emission lines
  - Presence of optically thin Si IV emission lines
  - Presence of absorption features from cool metallic ions

UV Bursts



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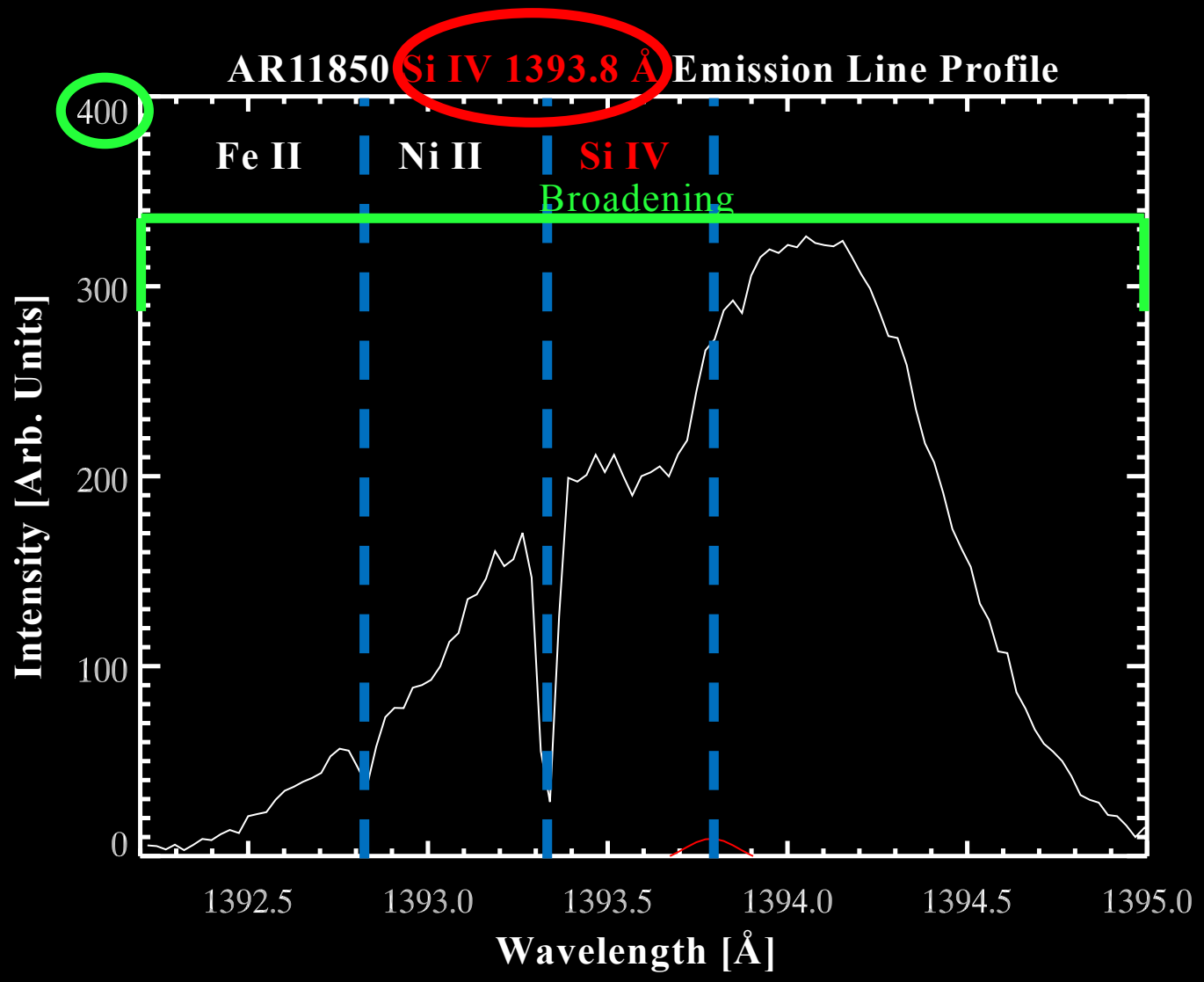

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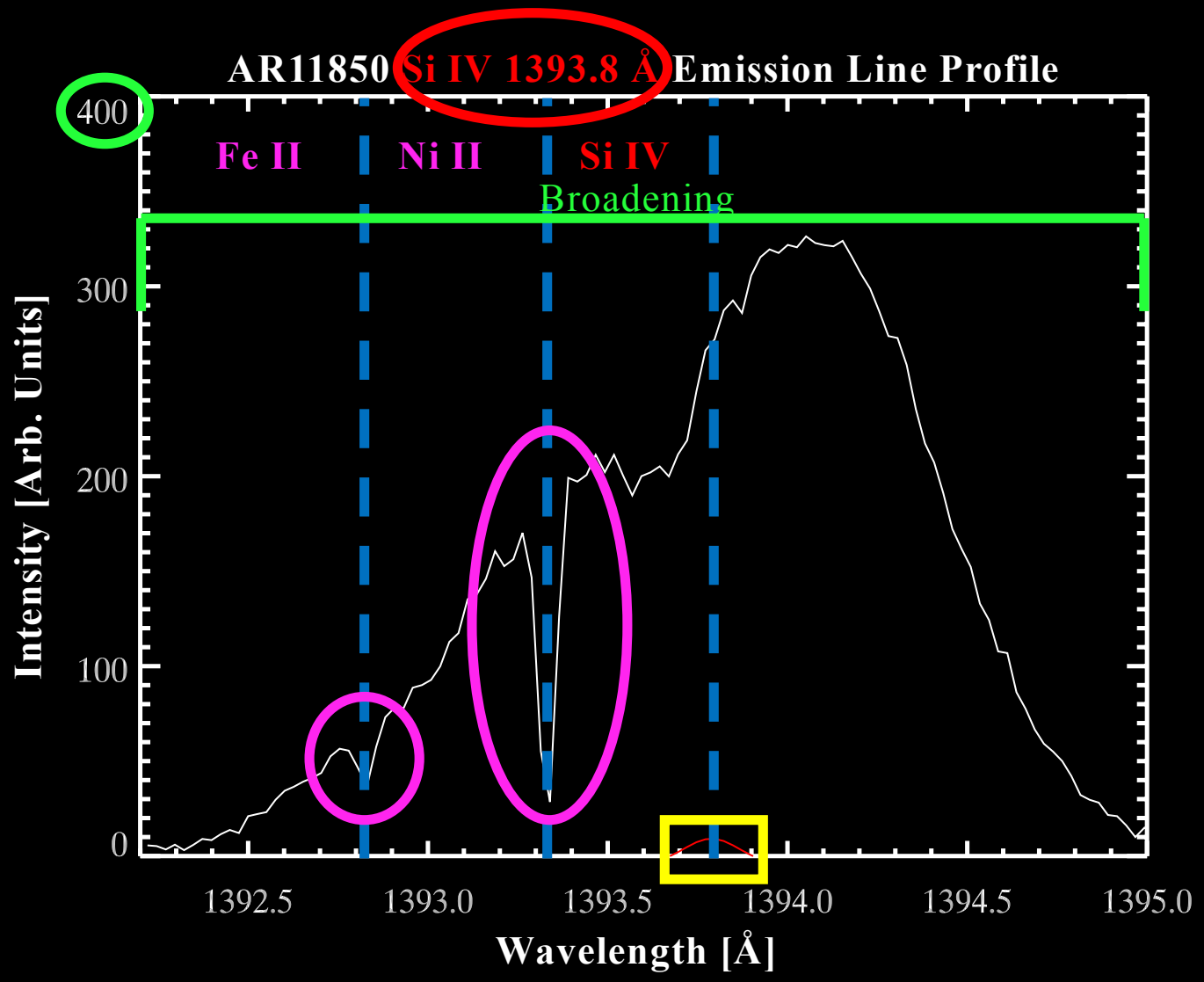

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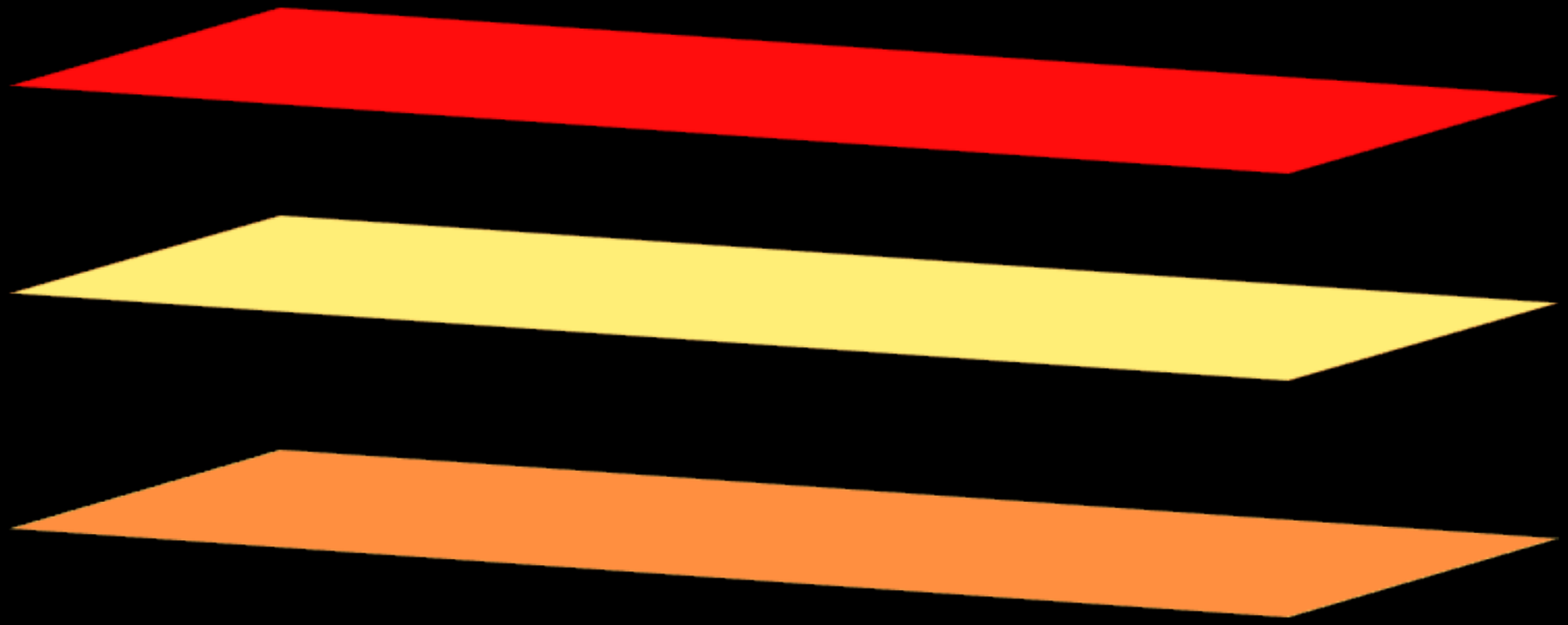
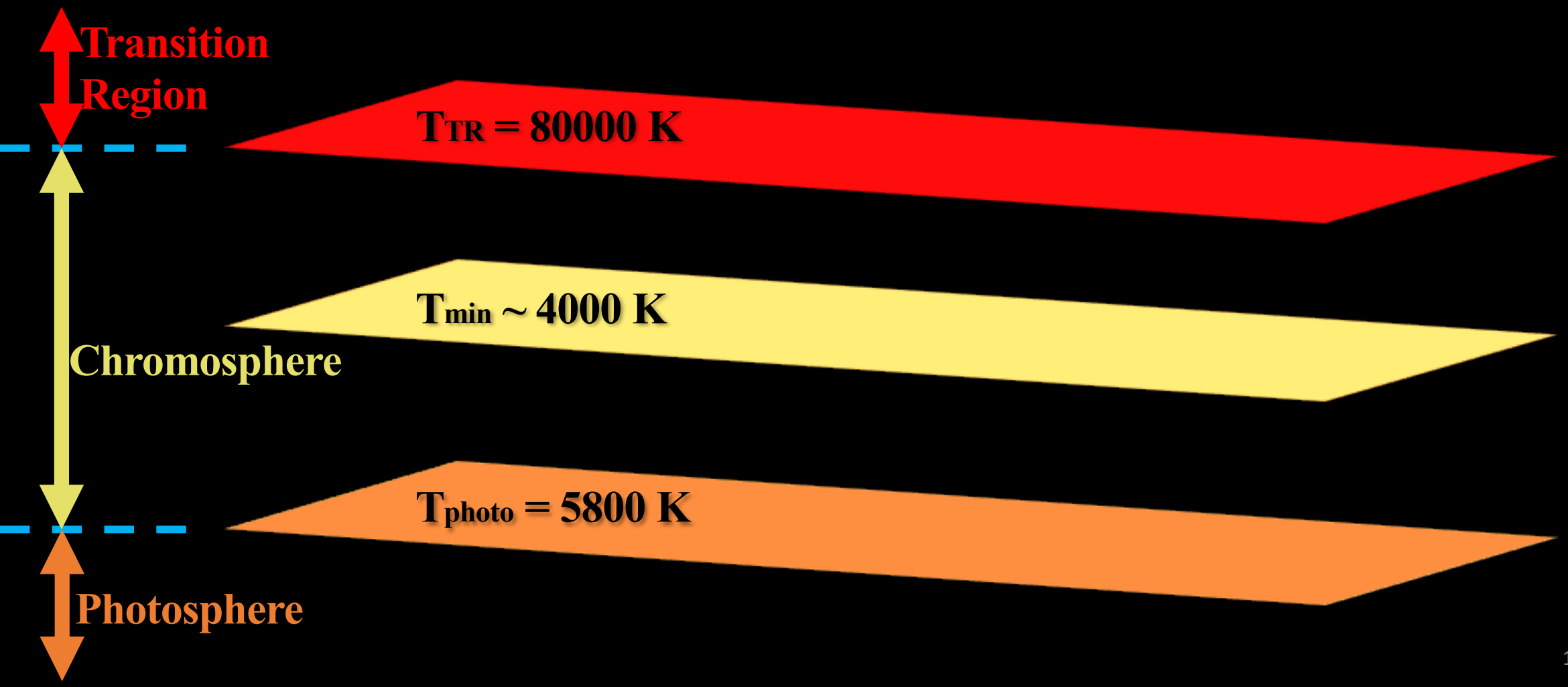
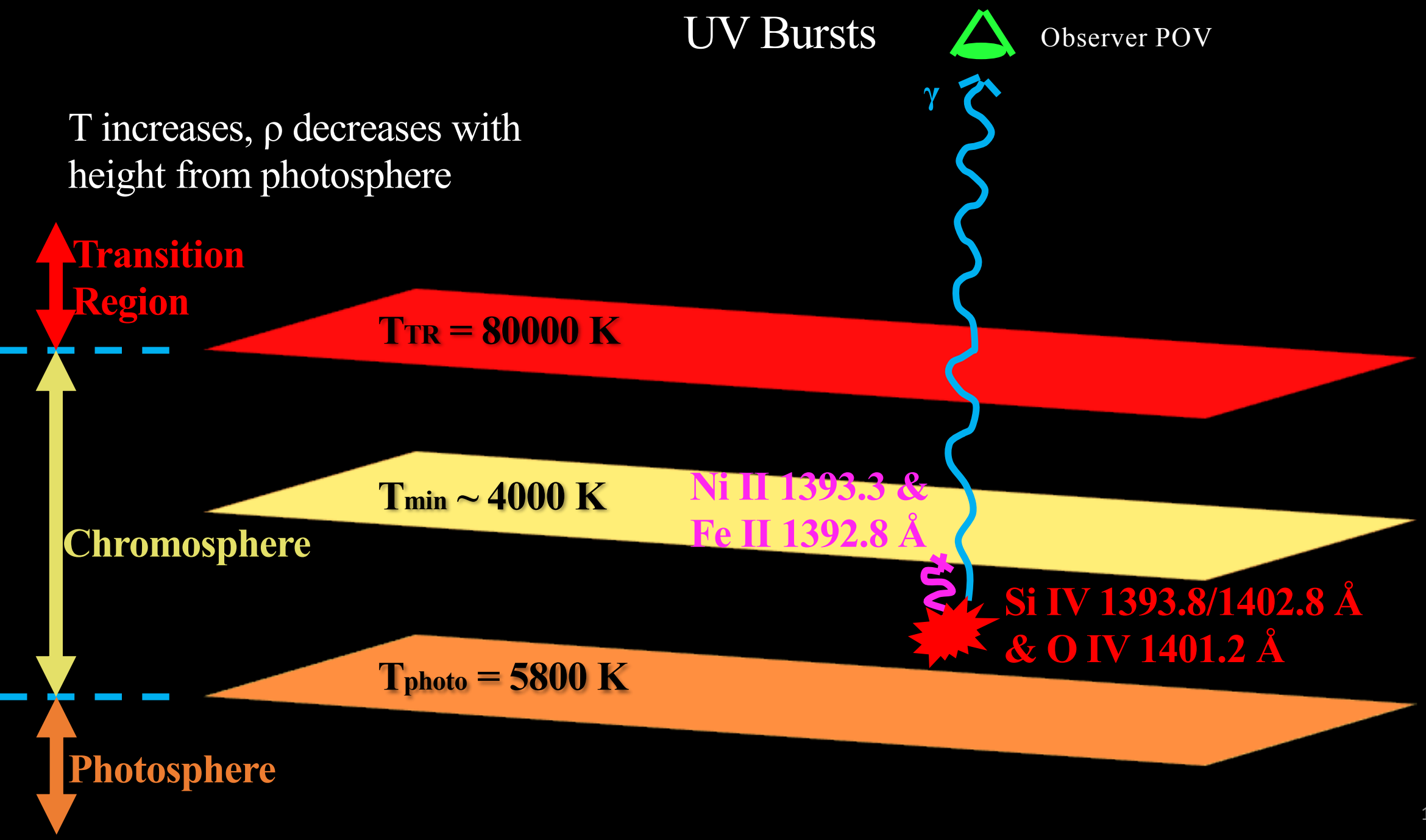


UV Bursts

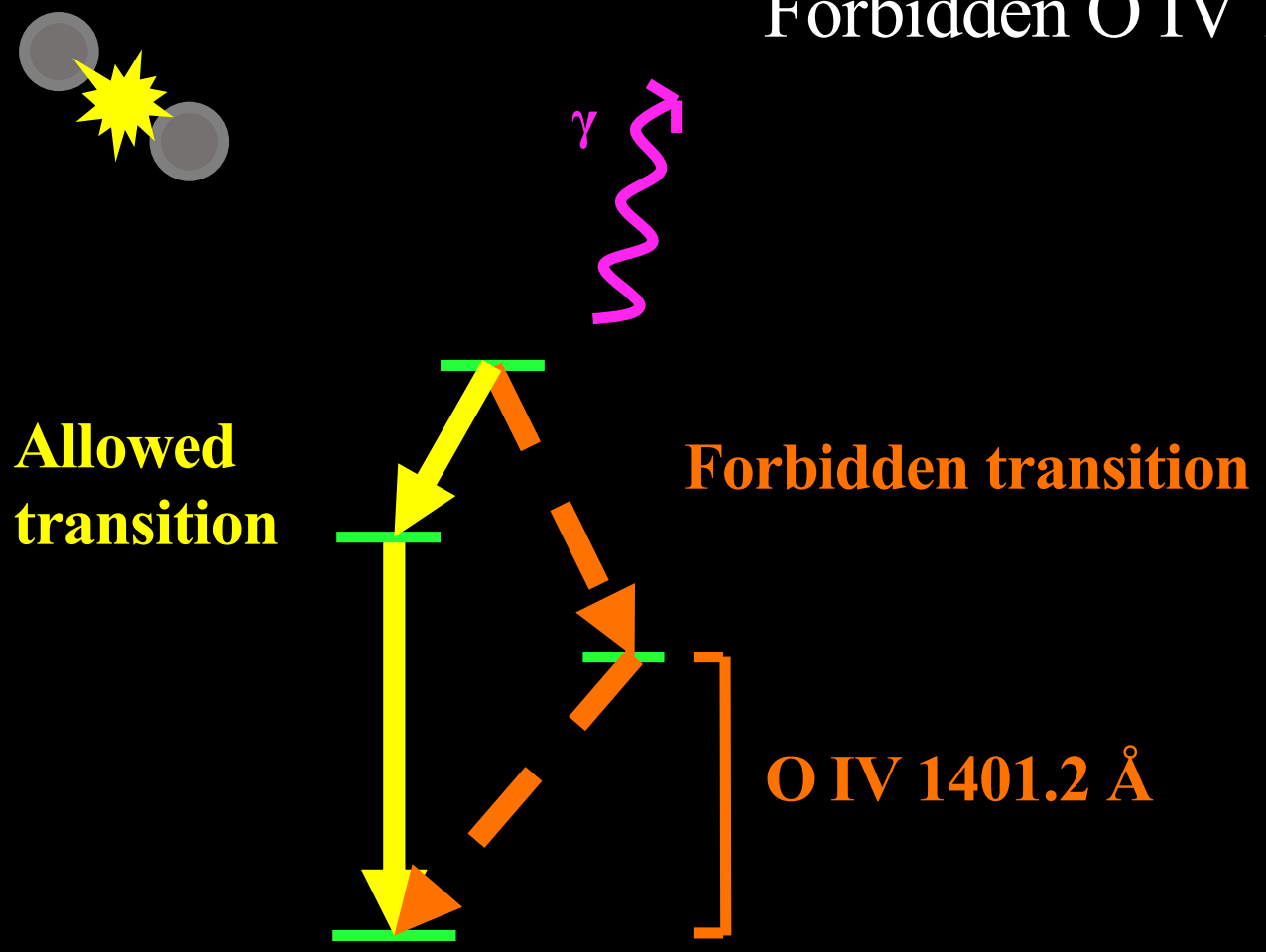
T increases, ρ decreases with height from photosphere



UV Bursts


Observer POV
γ
T increases, ρ decreases with height from photosphere
Transition Region
T_{TR} = 80000 K
T_{min} ~ 4000 K
Ni II 1393.3 & Fe II 1392.8 Å
Chromosphere
Si IV 1393.8/1402.8 Å & O IV 1401.2 Å
T_{photo} = 5800 K
Photosphere

Forbidden O IV Transition Line



- Electron density dependent
  - Too sparse: we'd never see it
  - Too dense: it gets extinguished
- Collisional de-excitation: particle collisions resulting in stolen angular momentum.
- Use resonance Si IV 1393.8 Å line and O IV 1401.2 Å line and take ratio of two to get electron density/altitude estimates

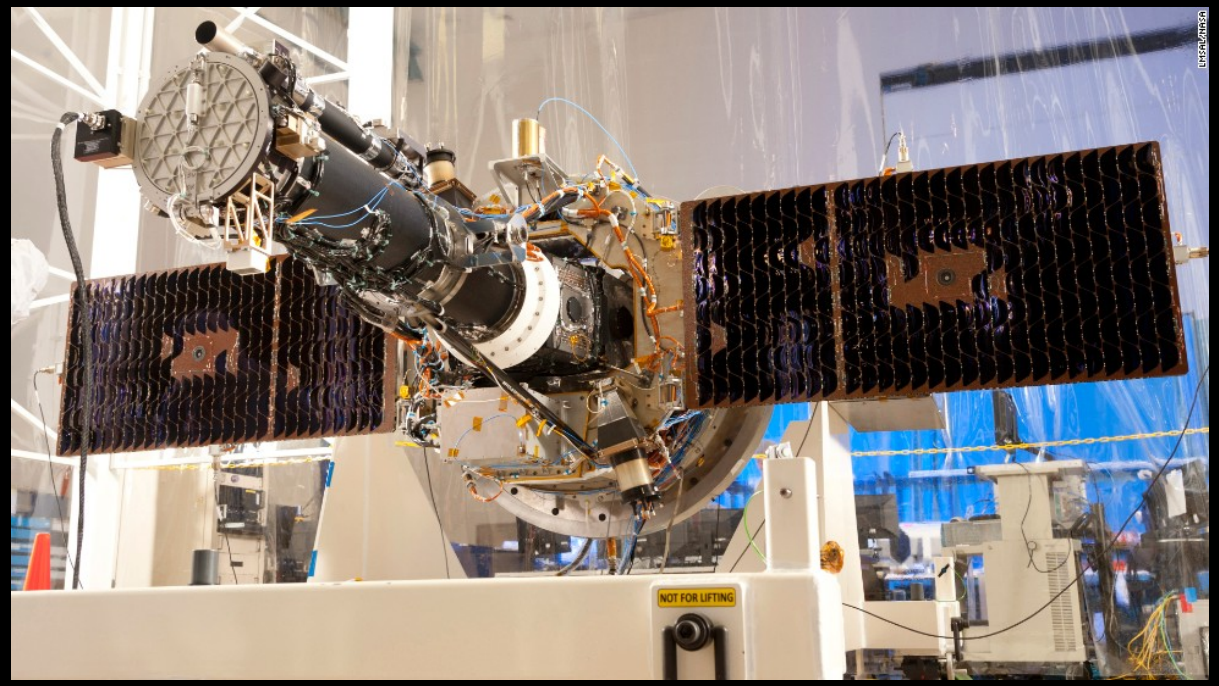
Importance of UV Bursts

- Narrow Picture: Figure out how often the forbidden O IV transition occurs in UV burst spectra, and use it to get electron density/altitude estimates.

- Intermediate Picture: Characterizing UV bursts to constrain the dynamics in the cool solar atmosphere.

- Big Picture: Do UV Bursts contribute to the heating of the solar atmosphere?

Interface Region Imaging Spectrograph (IRIS)

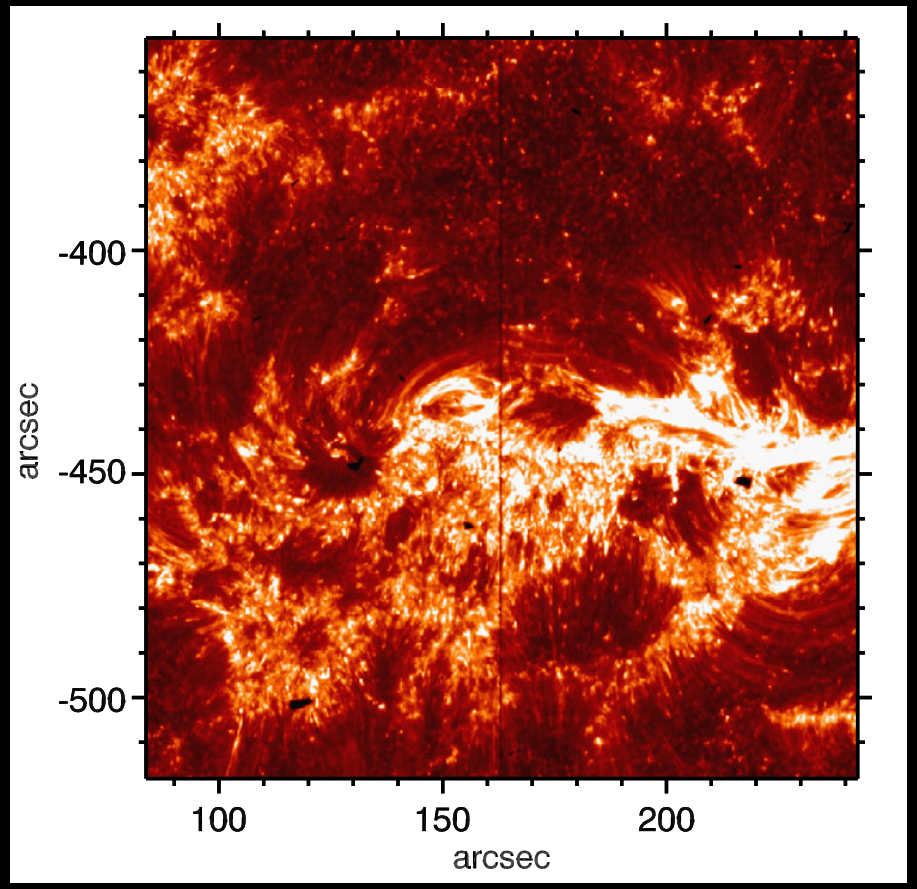


Mullen, CNN 2013

- Takes simultaneous imaging and spectroscopic data of upper chromosphere and transition region.
- Observes in FUV/NUV
- Images the Sun in four passbands:
  - 1330 Å C II (mostly upper chromosphere)
  - 1400 Å Si IV (transition region)
  - 2796 Å Mg II (upper chromosphere)
  - 2832 Å Mg II wing and continuum (photosphere and upper chromosphere)

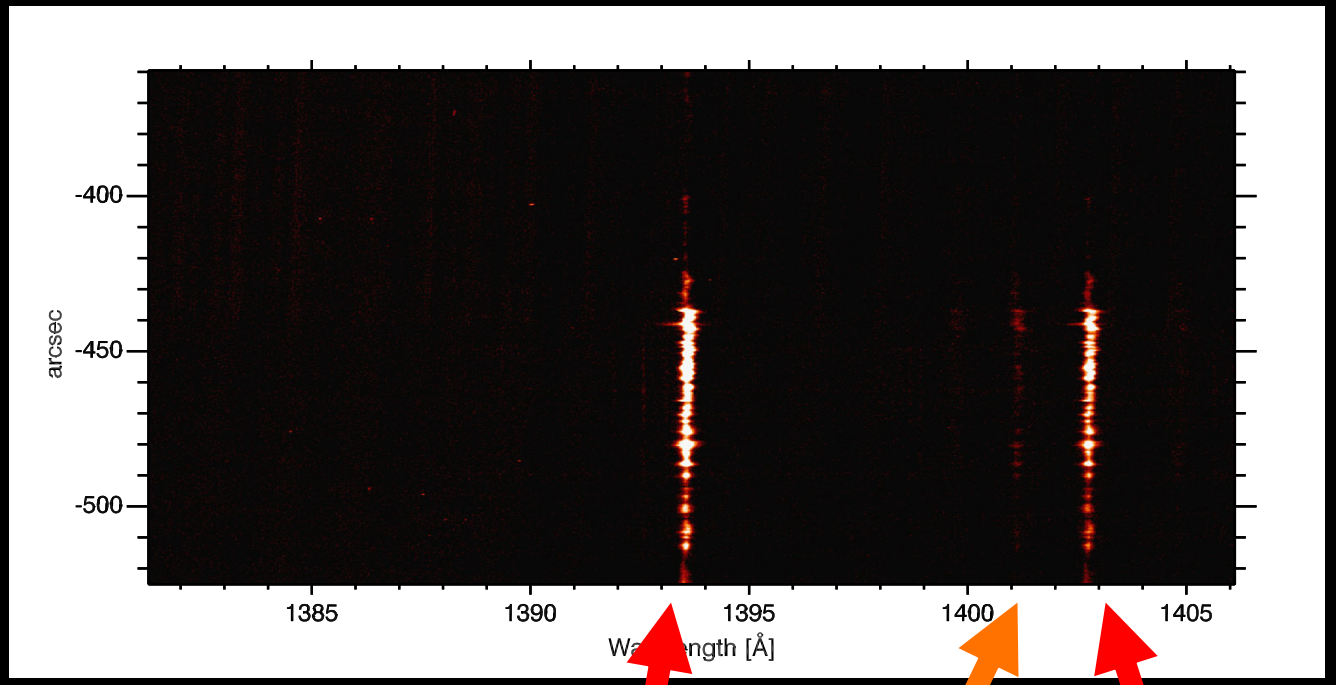
Interface Region Imaging Spectrograph (IRIS)

1400 Å SJI



B. De Pontieu et al. 2014

Full Si IV Spectra



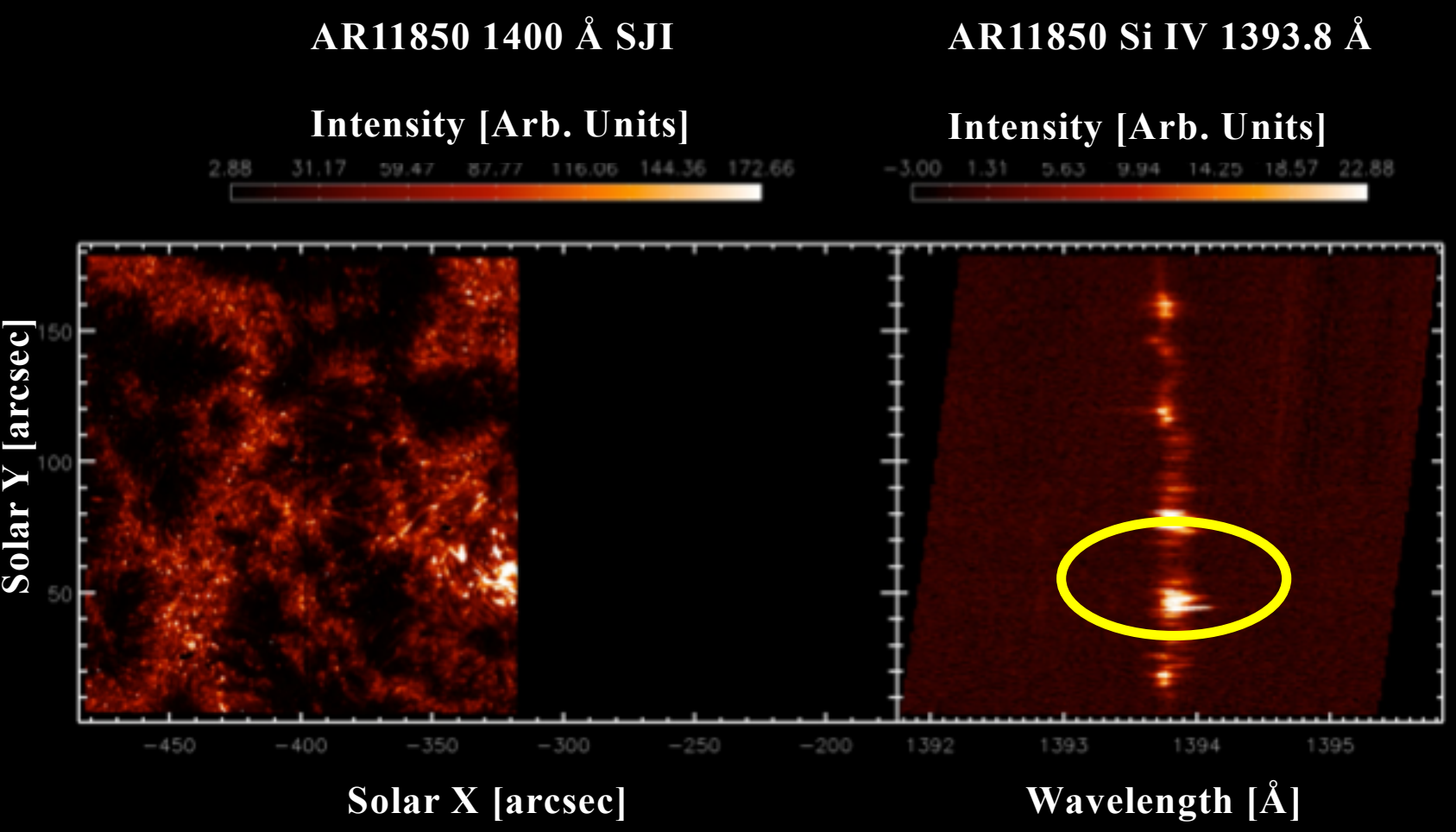
B. De Pontieu et al. 2014

Si IV 1393.8 Å

O IV 1401.2 Å

Si IV 1402.8 Å

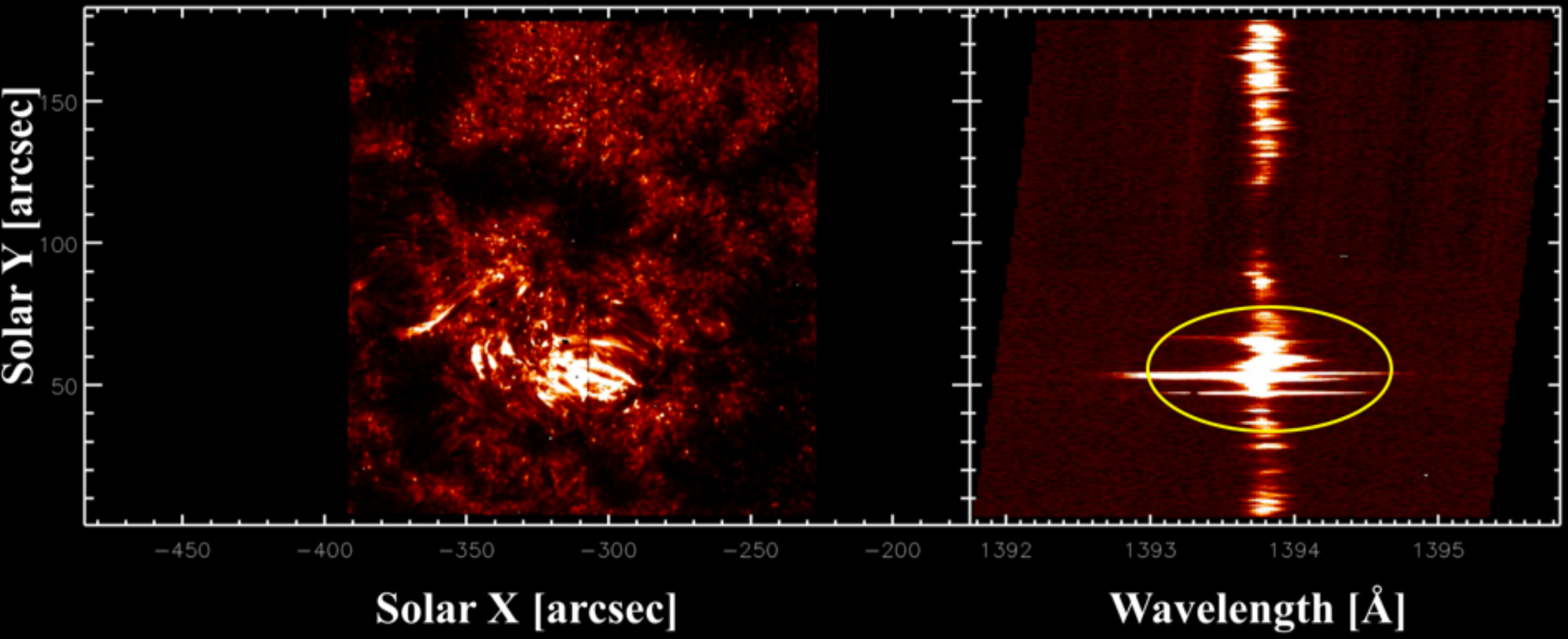
UV Burst Investigation Process



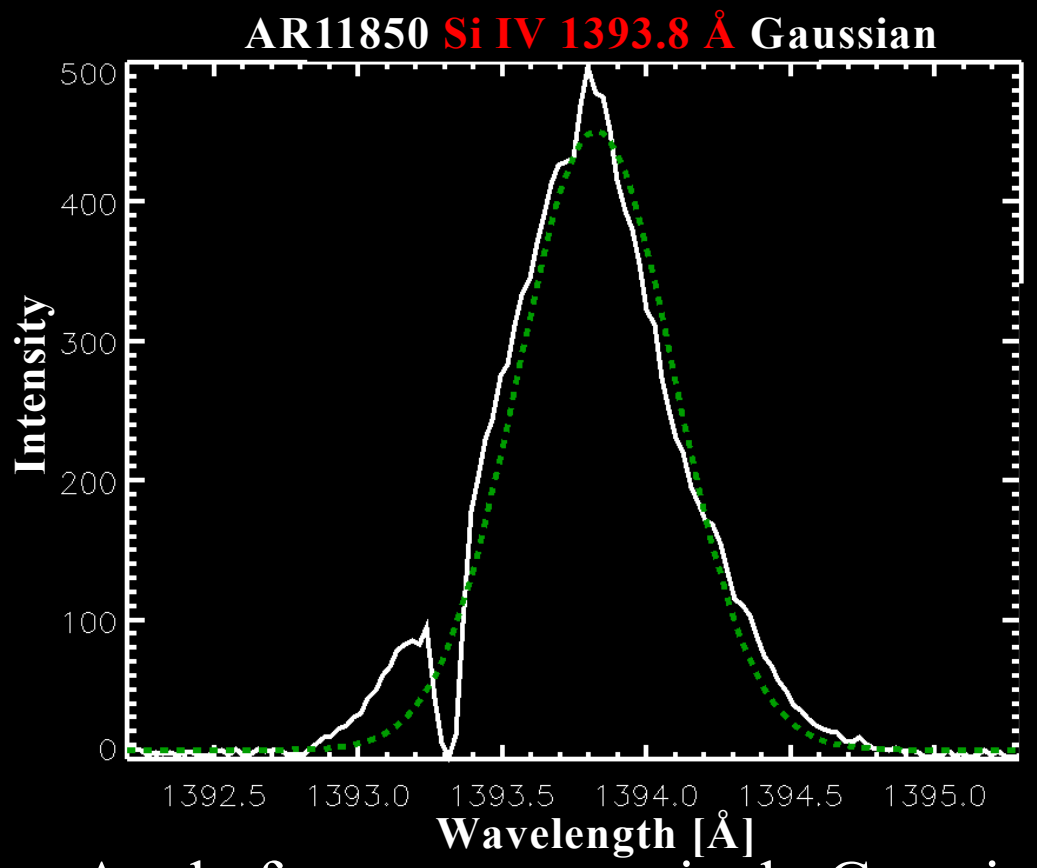
- AR11850 with nine observations from 24-27 September 2013.
- Detect bursts using Si IV 1393.8 Å line
  - 2x intensity
  - Absorption features
  - Broadening/splitting
- Use Si IV 1402.8 Å spectral window for analysis
  - Presence of O IV 1401.2 Å

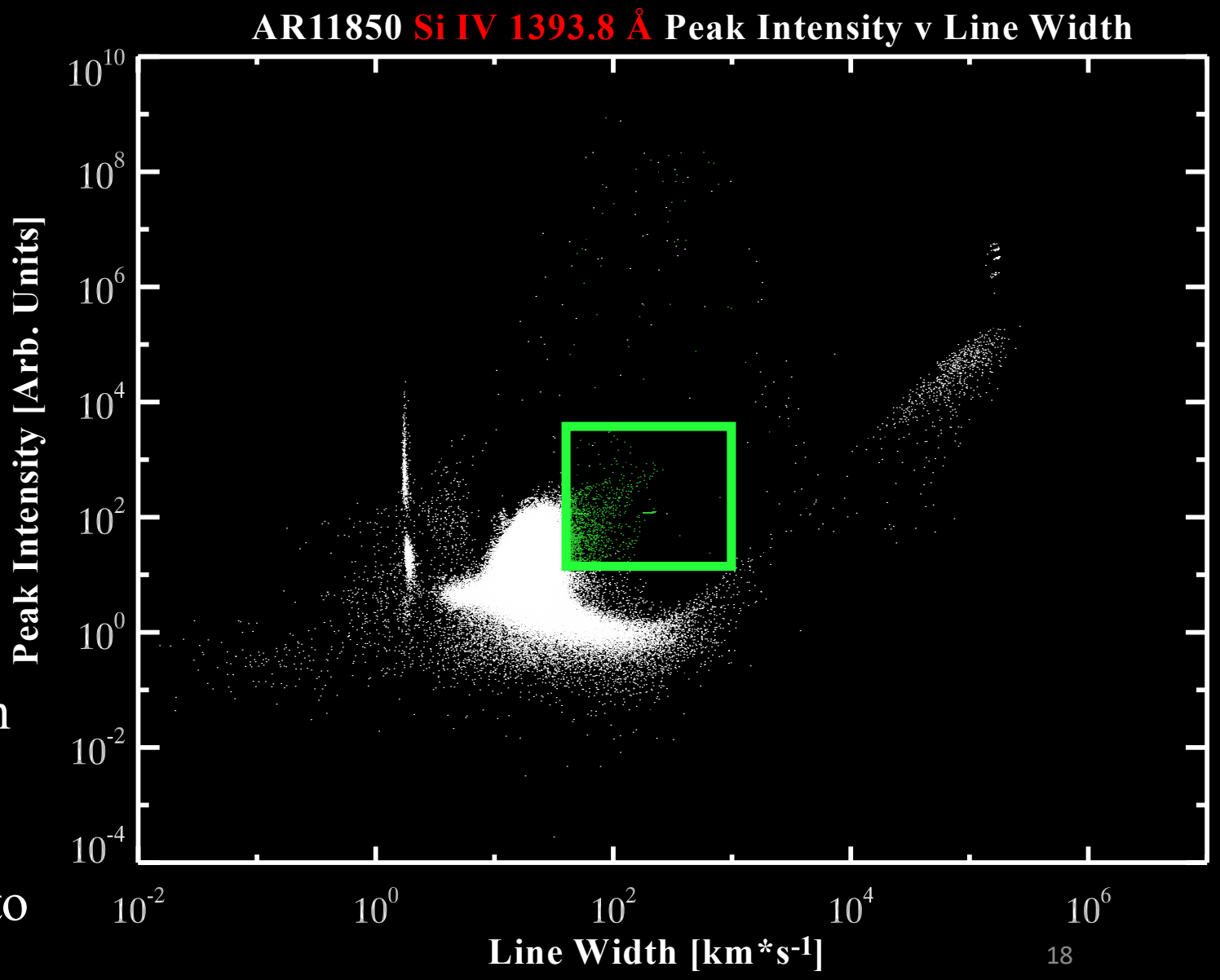
Credit: Chad synced the frames

IRIS Movie Close-Up



Detection and Isolation of UV Bursts

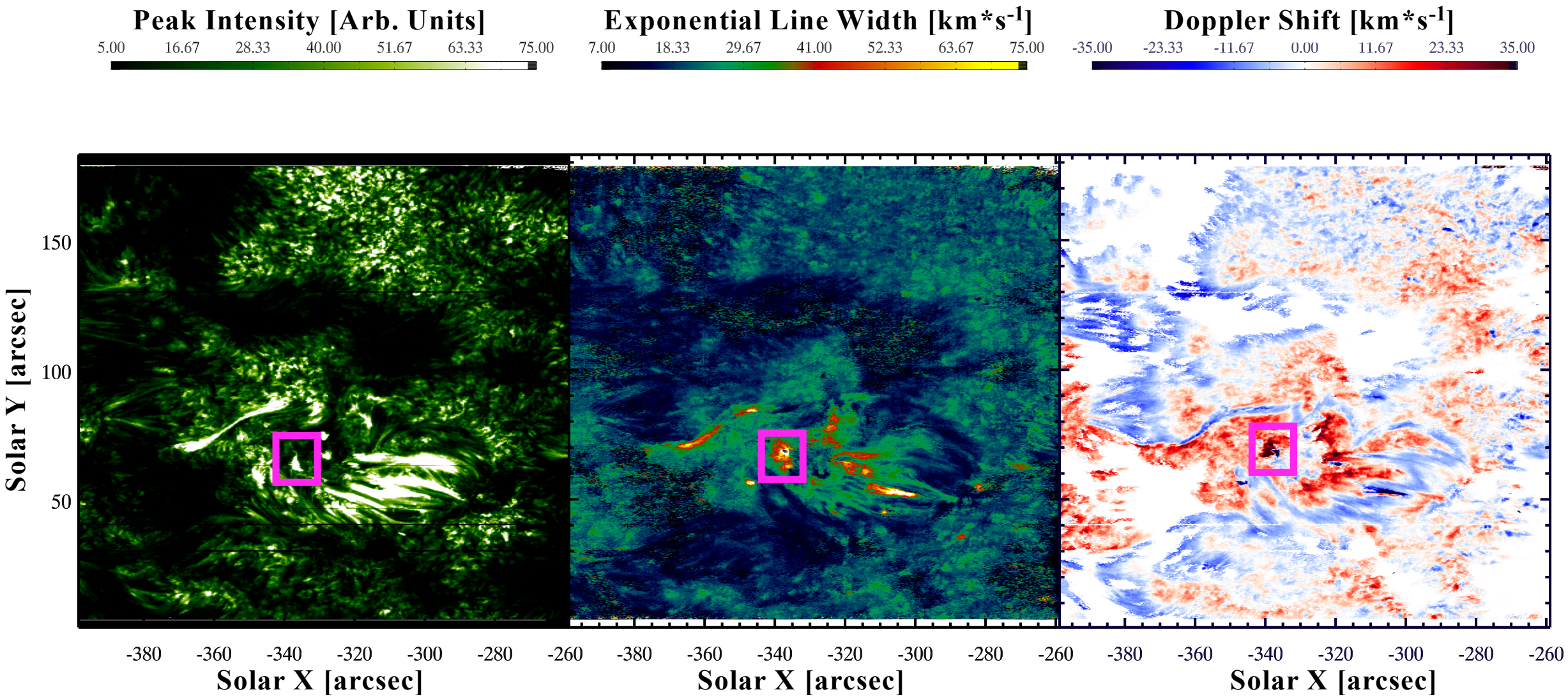




- Apply four-parameter single-Gaussian fits to Si IV 1393.8 Å spectra
- Plot peak intensity v line width
- Perform cuts in 4-D parameter space to isolate burst population

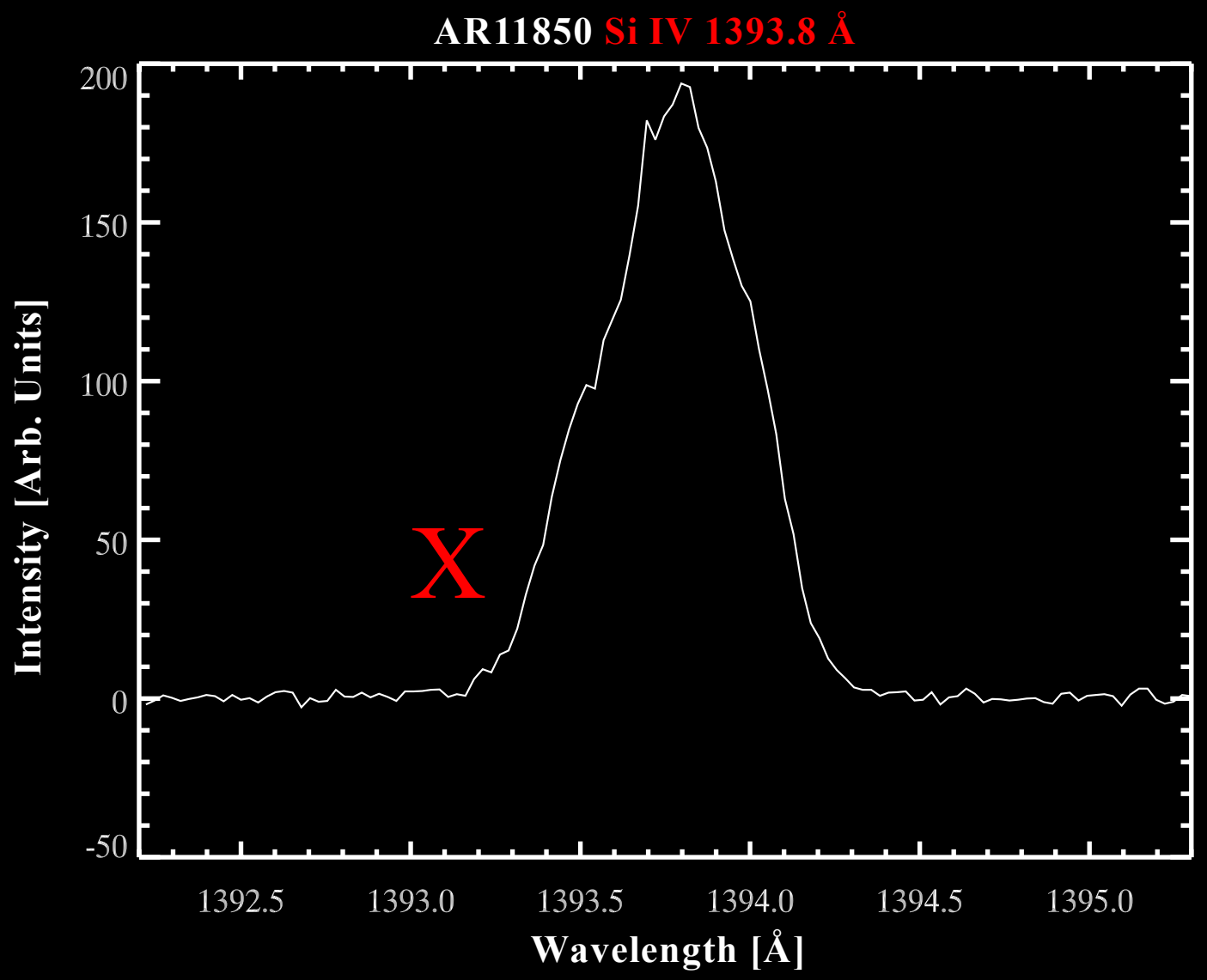
Parameter Maps

2013-09-24 T 05:09



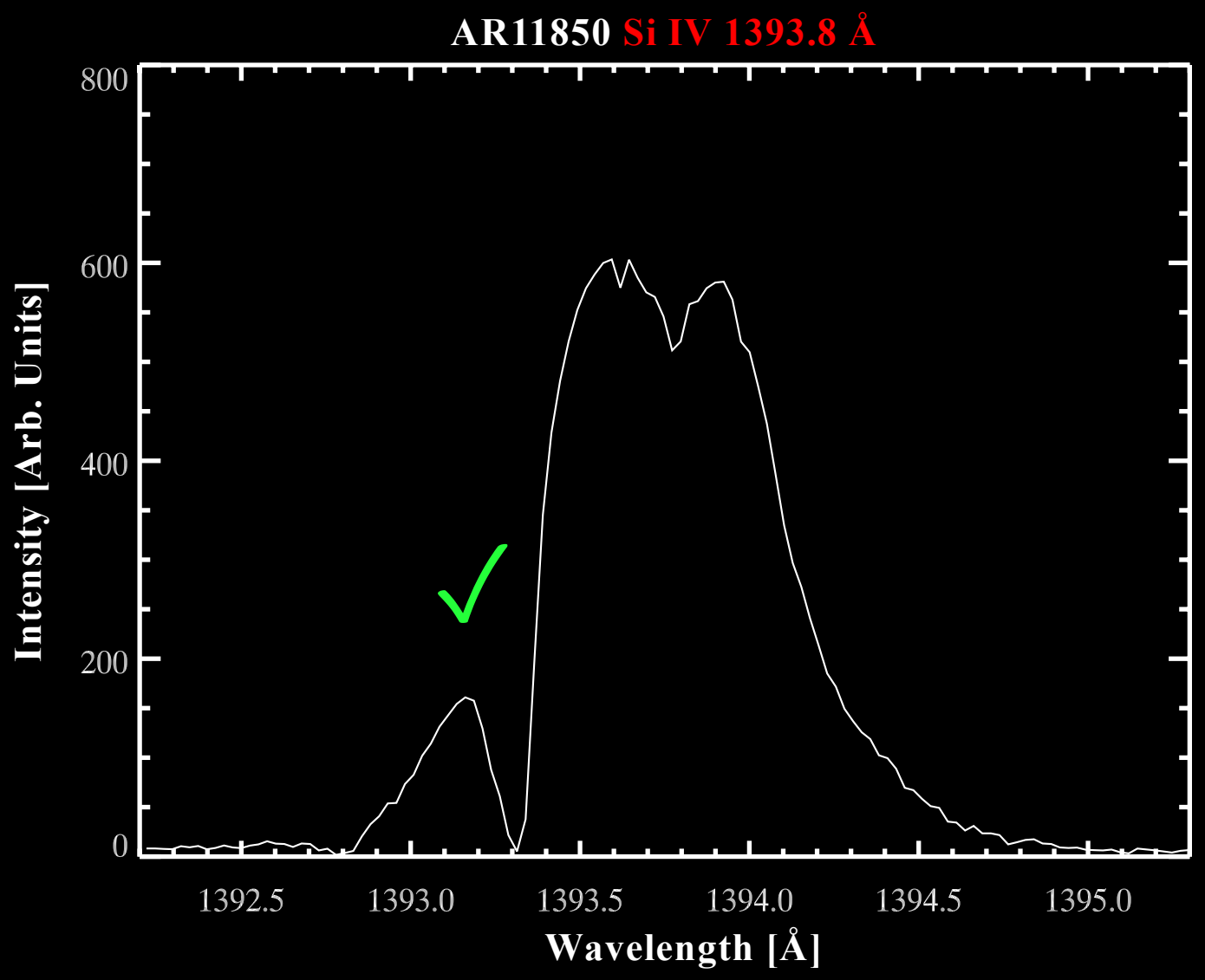
Credit: Chad despiked these maps

Manual Detection



- Manually inspect remaining spectra for signs of Ni II 1393.3 Å absorption.
- Every spectra with Ni II 1393.3 Å absorption is deemed a UV burst.

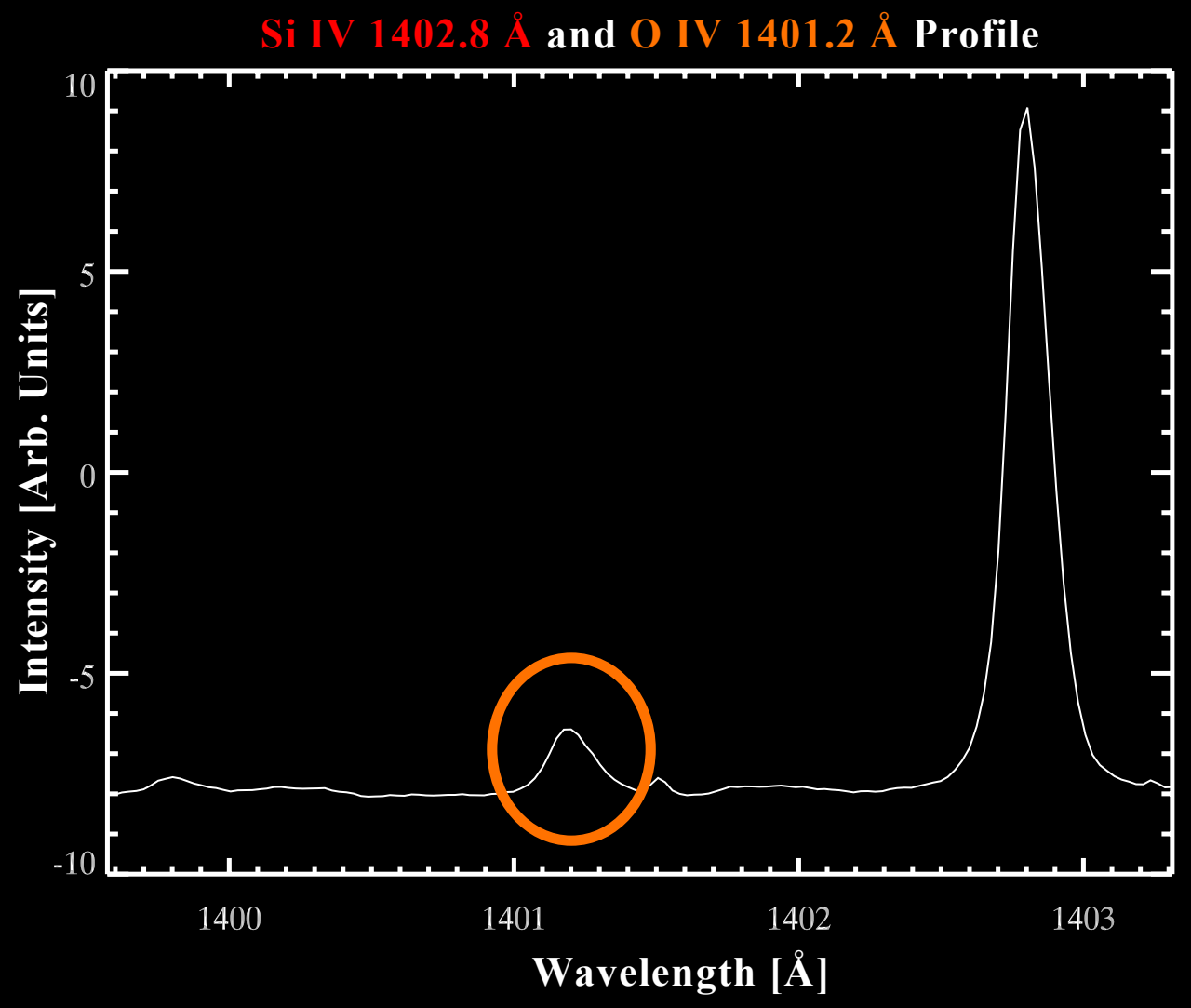
Manual Detection



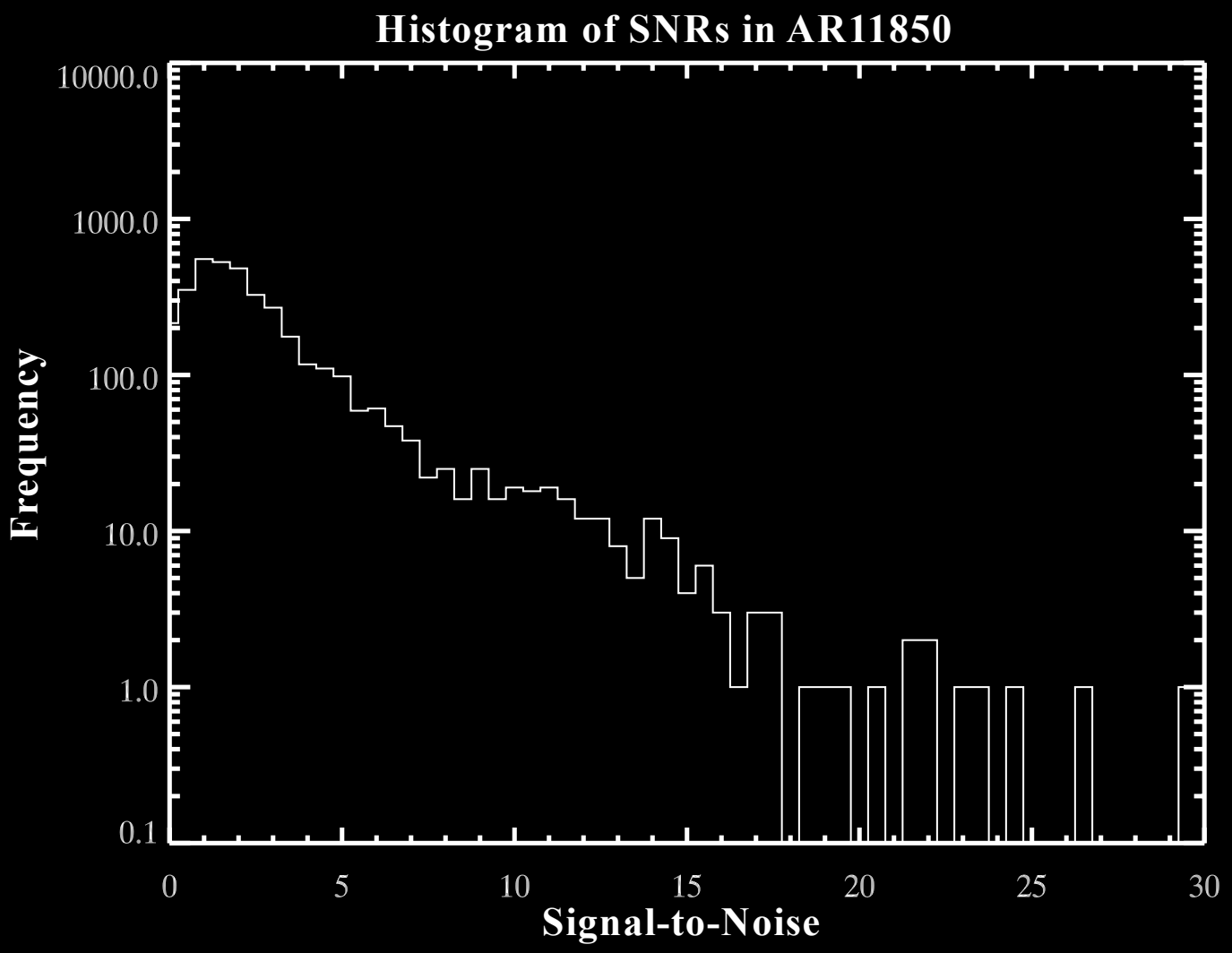
- Manually inspect remaining spectra for signs of Ni II 1393.3 Å absorption.
- Every spectra with Ni II 1393.3 Å absorption is deemed a UV burst.

O IV Detection

- Use resulting sample from manual inspection in Si IV 1402.8 Å window.
- Apply a cut to focus on O IV emission line
- Iterate through the sample applying four-parameter SGFs to each O IV line.



Histogram of Statistical Significance of O IV



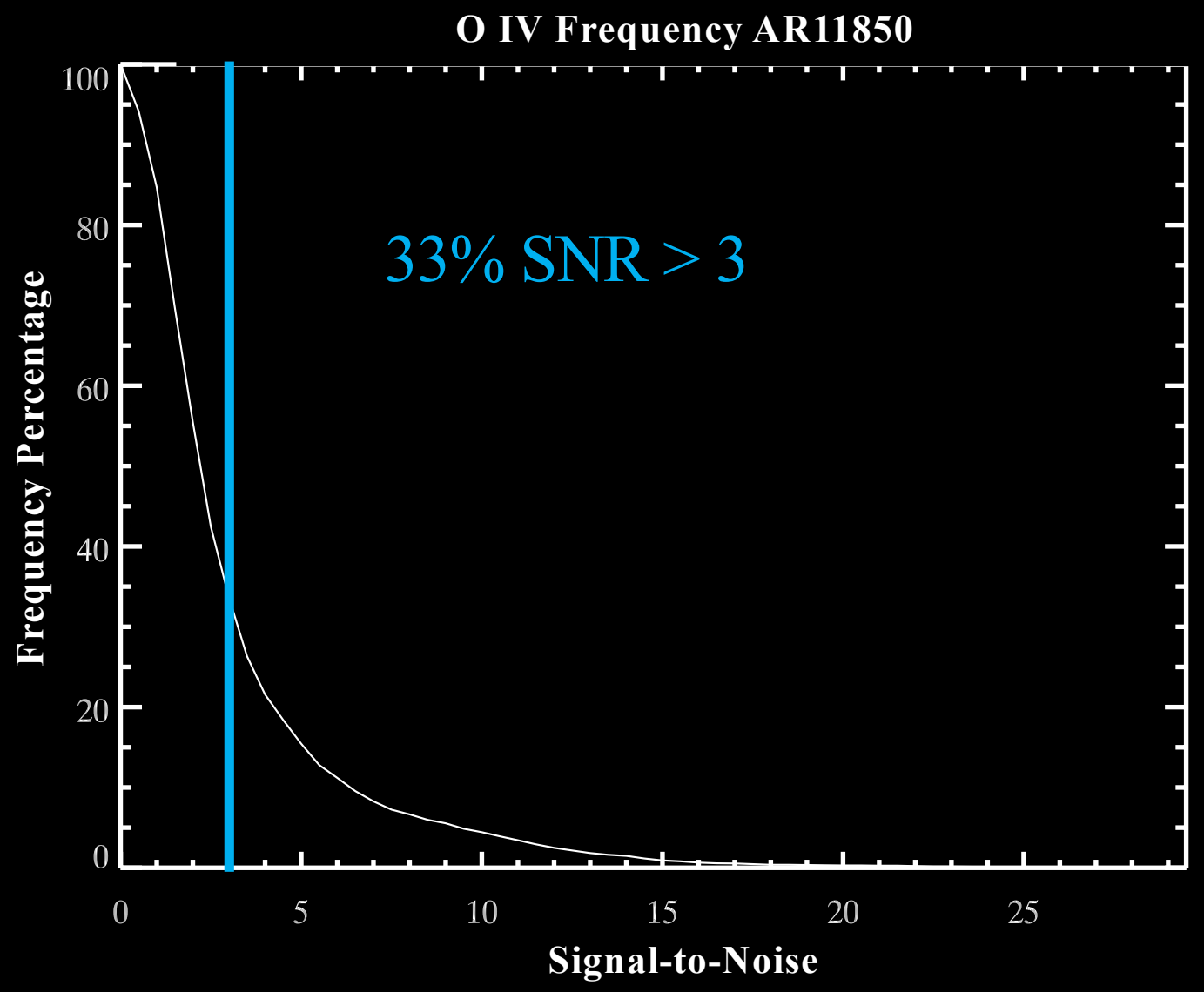
Total Integrated Intensity (TII)
= √2π*peak intensity*line width

- Measure total integrated intensity and their uncertainties using poisson and readout noise for each O IV line associated with a burst.
- Calculate SNRs for each observation.

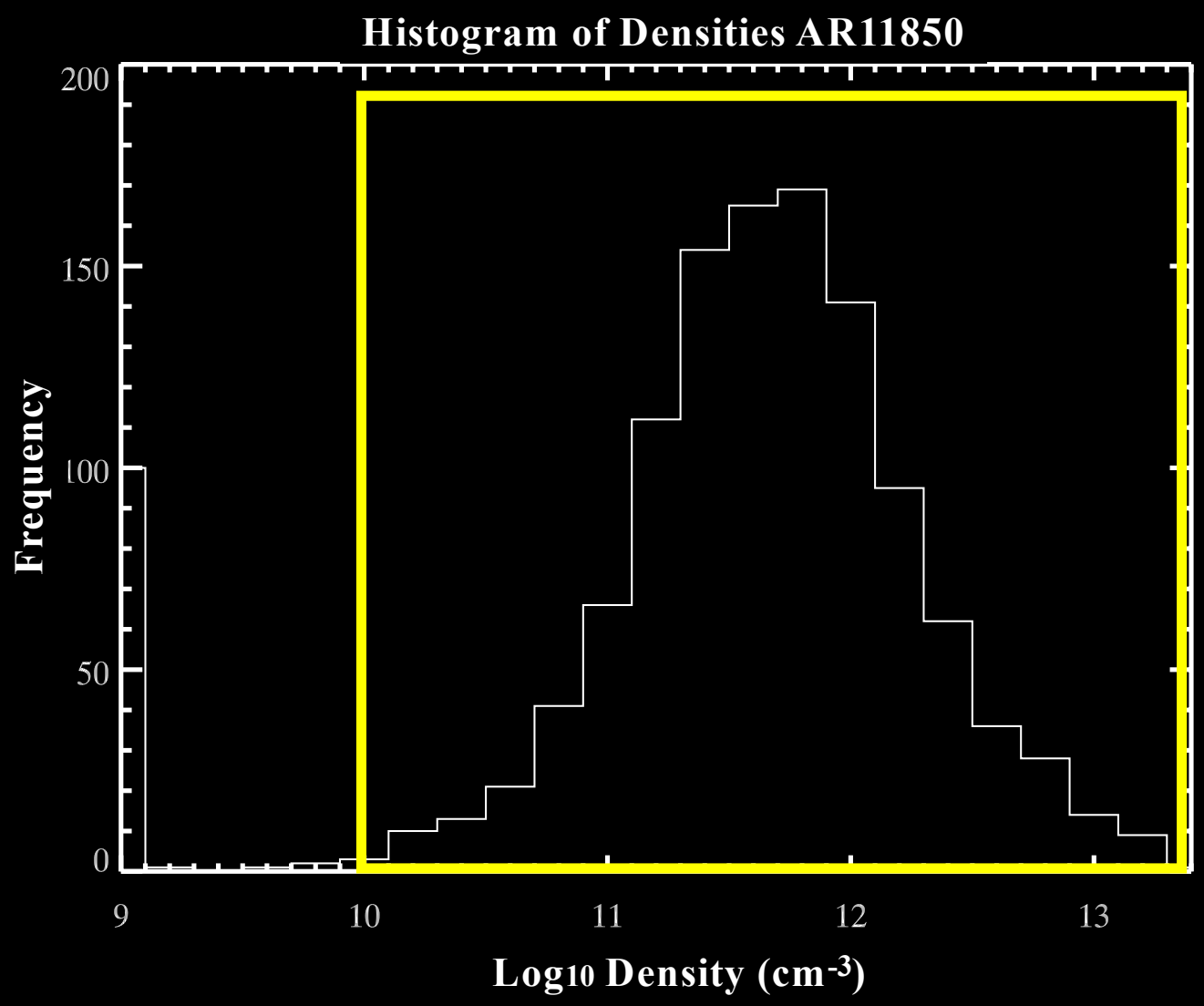
S/N = (TII/uncertainty TII)

Statistical Significance of O IV

- Plot the frequency over all SNRs to see distribution.
- O IV SHOWS UP ENOUGH TO MAKE GOOD ELECTRON DENSITY ESTIMATES



Density/Altitude Estimates



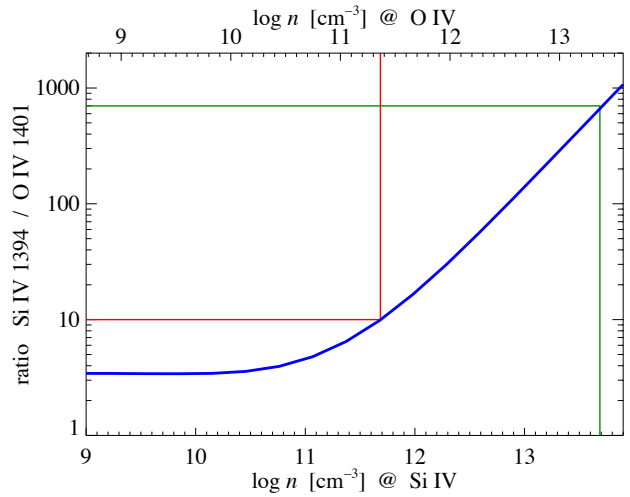


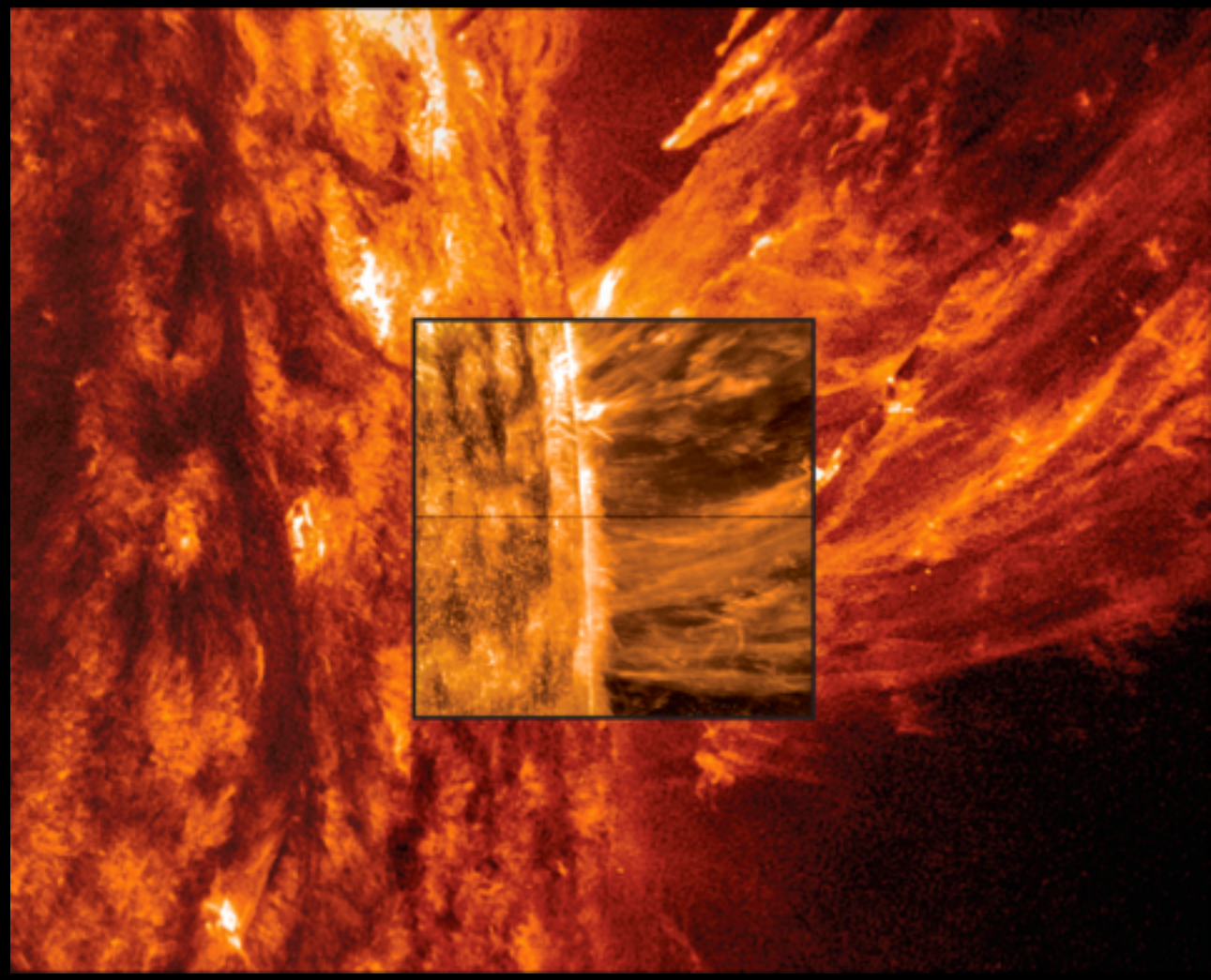
Figure S8. Density diagnostics from the ratio of Si IV to O IV. Predicted ratio assuming that both lines form at the same pressure. The straight lines indicate the ratios and densities associated with the lower limits of Si IV to O IV derived for the emerging loop (red) and bomb 1 (green) as listed in Table S2.

Peter et al., 2014

- Ratio/density diagnostic model adapted from Young et al. (2018) and Peter et al. (2014).
- O IV DIAGNOSTICS CLEARLY SHOWS CHROMOSPHERIC ELECTRON DENSITIES

Future Work

- Use model to get more precise altitude estimates
- Look at prevalence of O IV and S IV in other ARs with different exposure times

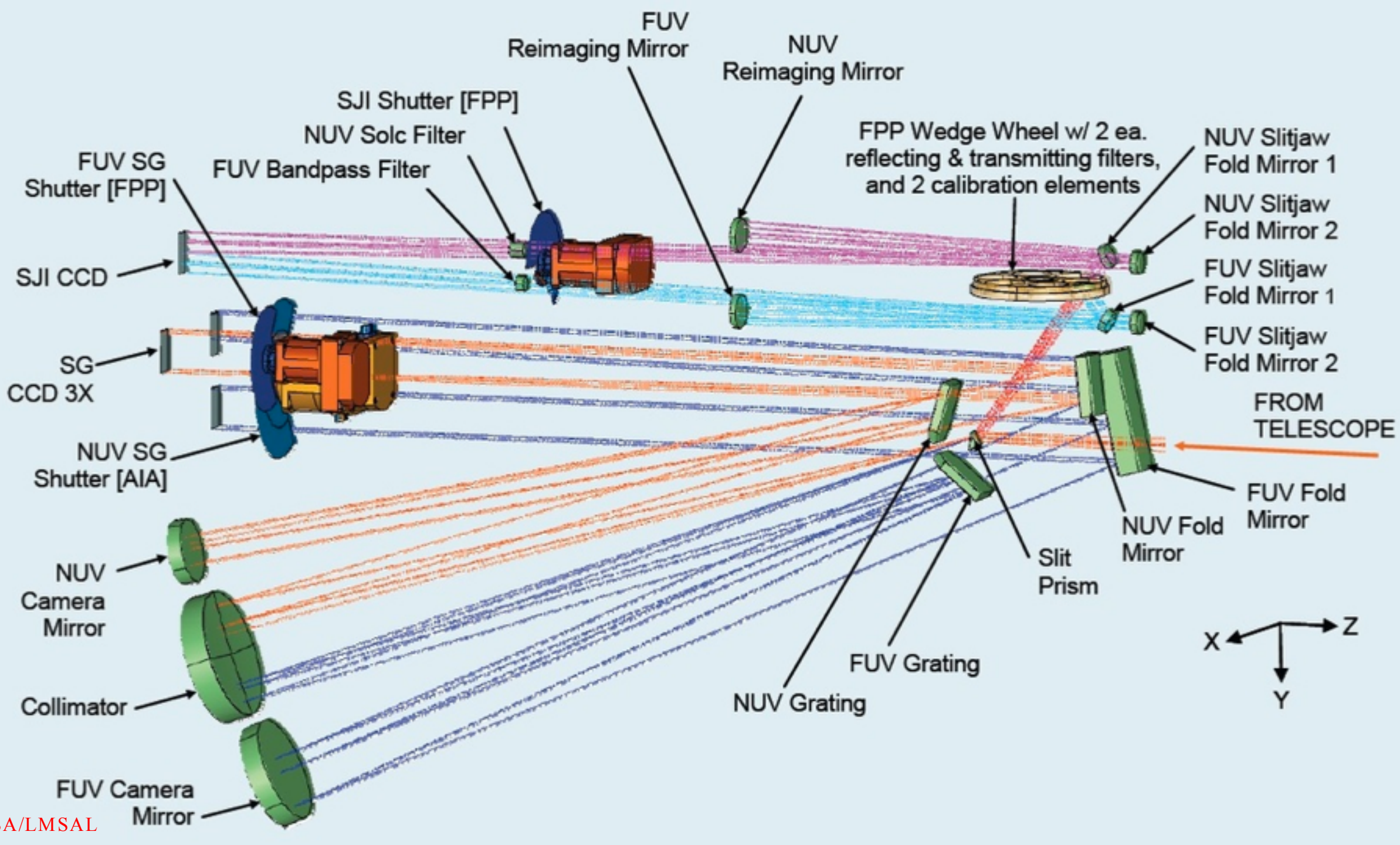


NASA, Lockheed Martin Solar & Astrophysics Laboratory

Acknowledgements

- NSF-REU Solar Physics program at SAO, grant number AGS-1560313.
- Dr. Kathy Reeves, Dr. Nishu Karna, Dr. Henry “Trae” Winters, Ken Wiley for the REU program.
- Chad and Ed for choosing me for this project and for providing guidance.

Back-Up Slides


FUV
Reimaging Mirror
NUV
Reimaging Mirror
SJI Shutter [FPP]
NUV Solc Filter
FUV Bandpass Filter
FUV SG
Shutter [FPP]
FPP Wedge Wheel w/ 2 ea.
reflecting & transmitting filters,
and 2 calibration elements
NUV Slitjaw
Fold Mirror 1
NUV Slitjaw
Fold Mirror 2
FUV Slitjaw
Fold Mirror 1
FUV Slitjaw
Fold Mirror 2
SJI CCD
SG
CCD 3X
NUV SG
Shutter [AIA]
FROM
TELESCOPE
FUV Fold
Mirror
NUV Fold
Mirror
Slit
Prism
NUV
Camera
Mirror
Collimator
FUV Camera
Mirror
FUV Grating
NUV Grating
X
Z
Y

NASA/LMSAL

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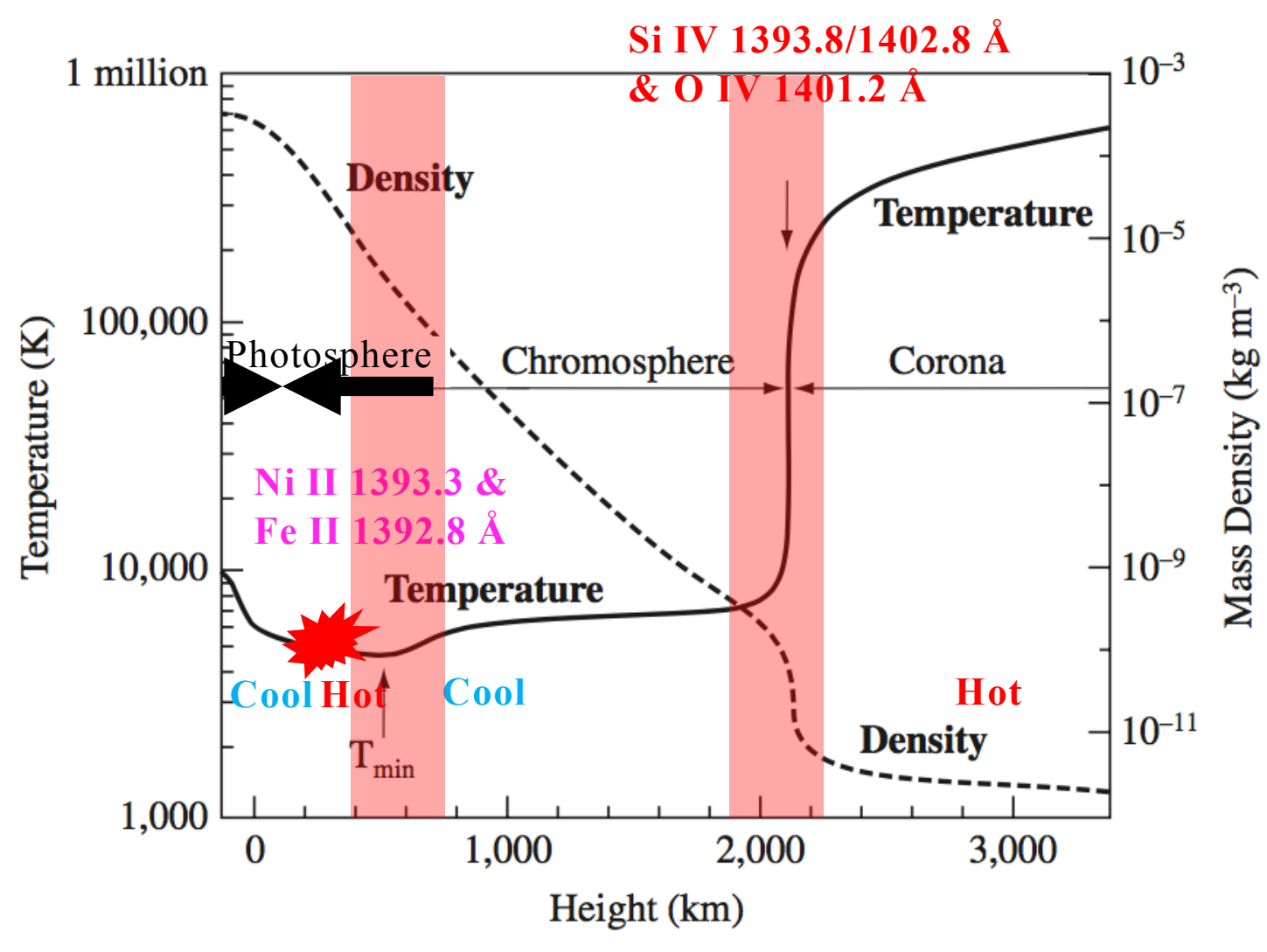
Vernazza et al. 1981



UVB Stats

Cut:

114443 – 2425
153943 – 2445
063943 – 2450
110943 – 2490
055943 – 2076, 2465, 2375
110943 – 1489
052432 – 2595
062443 – 2356
050945 – 2514
Total: ~25500

Manual Inspection (UVBs):

114443 – 657
153943 – 164
063943 – 362
110943 – 819
055943 – 210, 360, 200
110943 – 125
052432 – 378
062443 – 284
050945 – 318
Total: ~3800