Observation of Ellerman Bomb emission features in He I D3 and He I λ10830: observations and modelling

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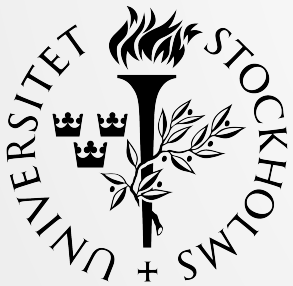
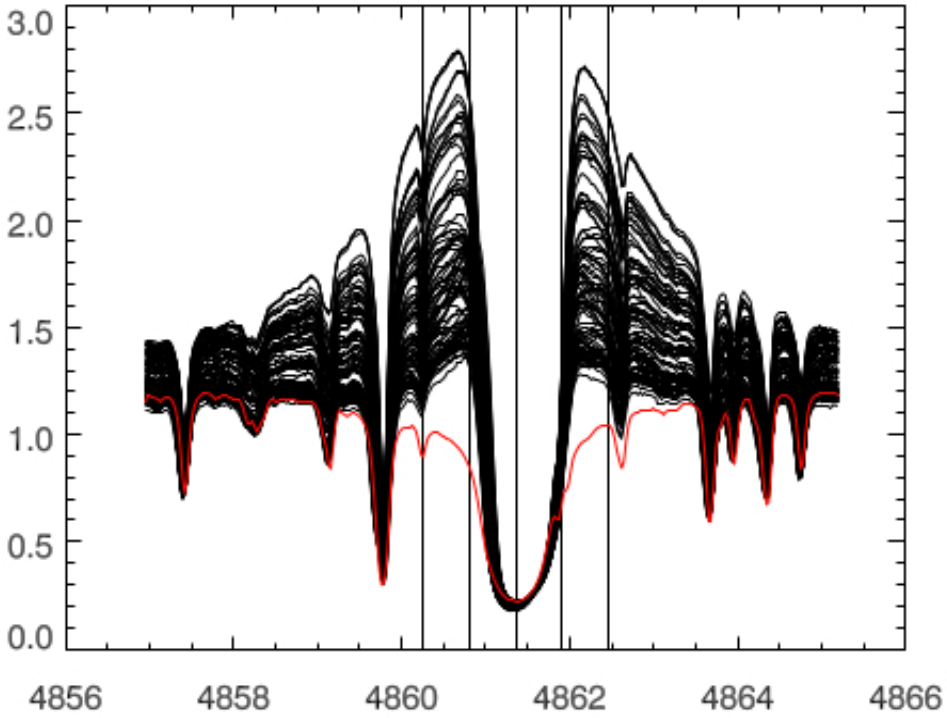


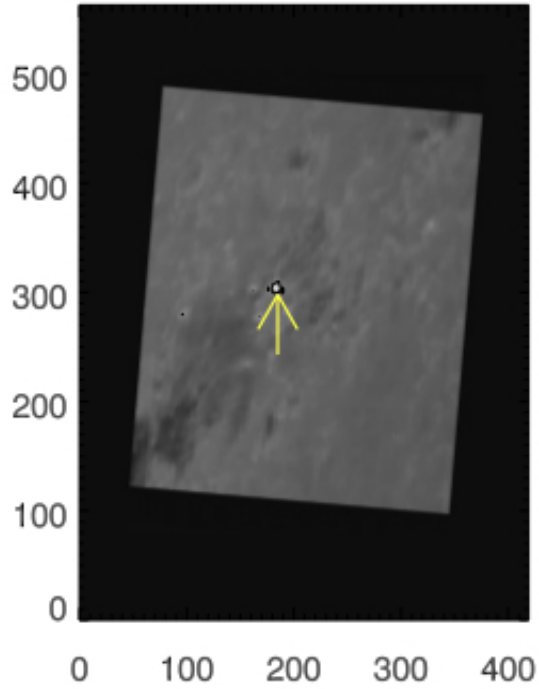
In collaboration with: J. Joshi, J. de la Cruz Rodríguez, J. Leenaarts, A. Asensio Ramos

Stockholm University

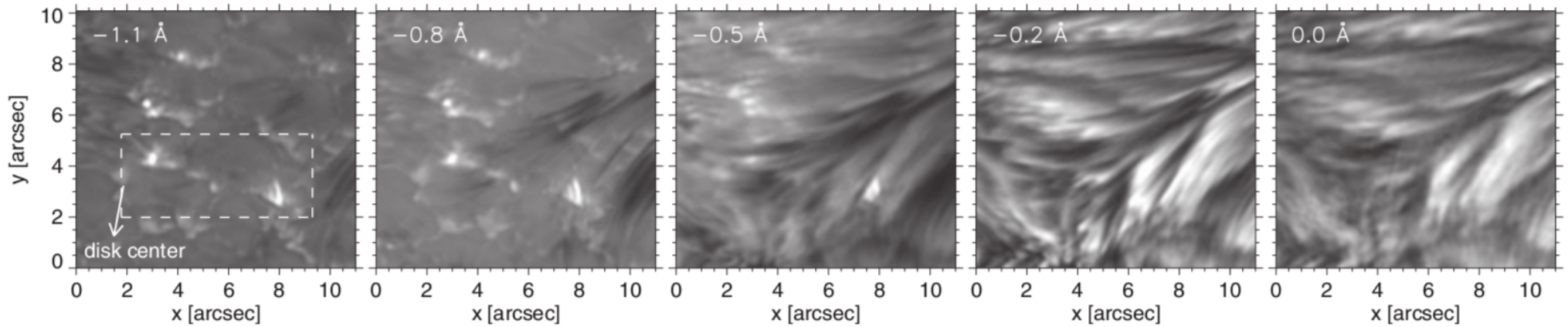
Ellerman Bombs

- Emission in the wings of hydrogen Balmer lines
- Line core unaffected

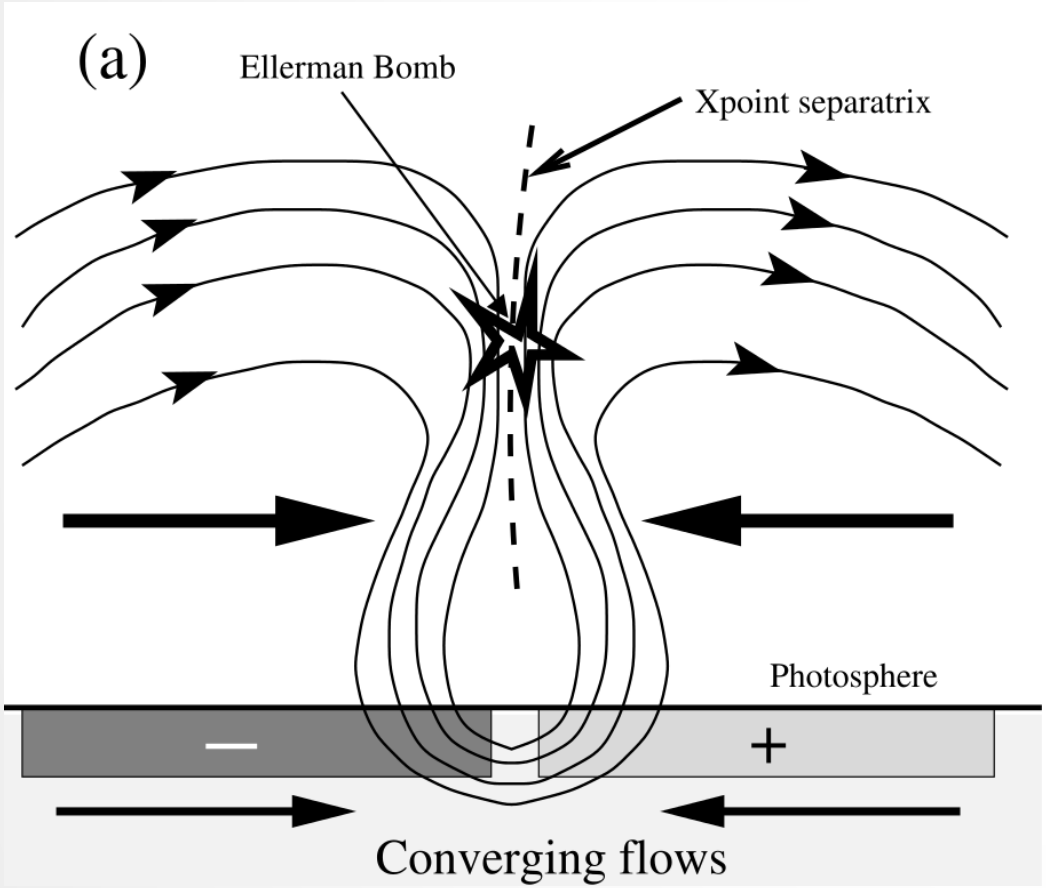




Watanabe et al. 2011



Common believes about Ellerman Bombs (until 2014)... BUT



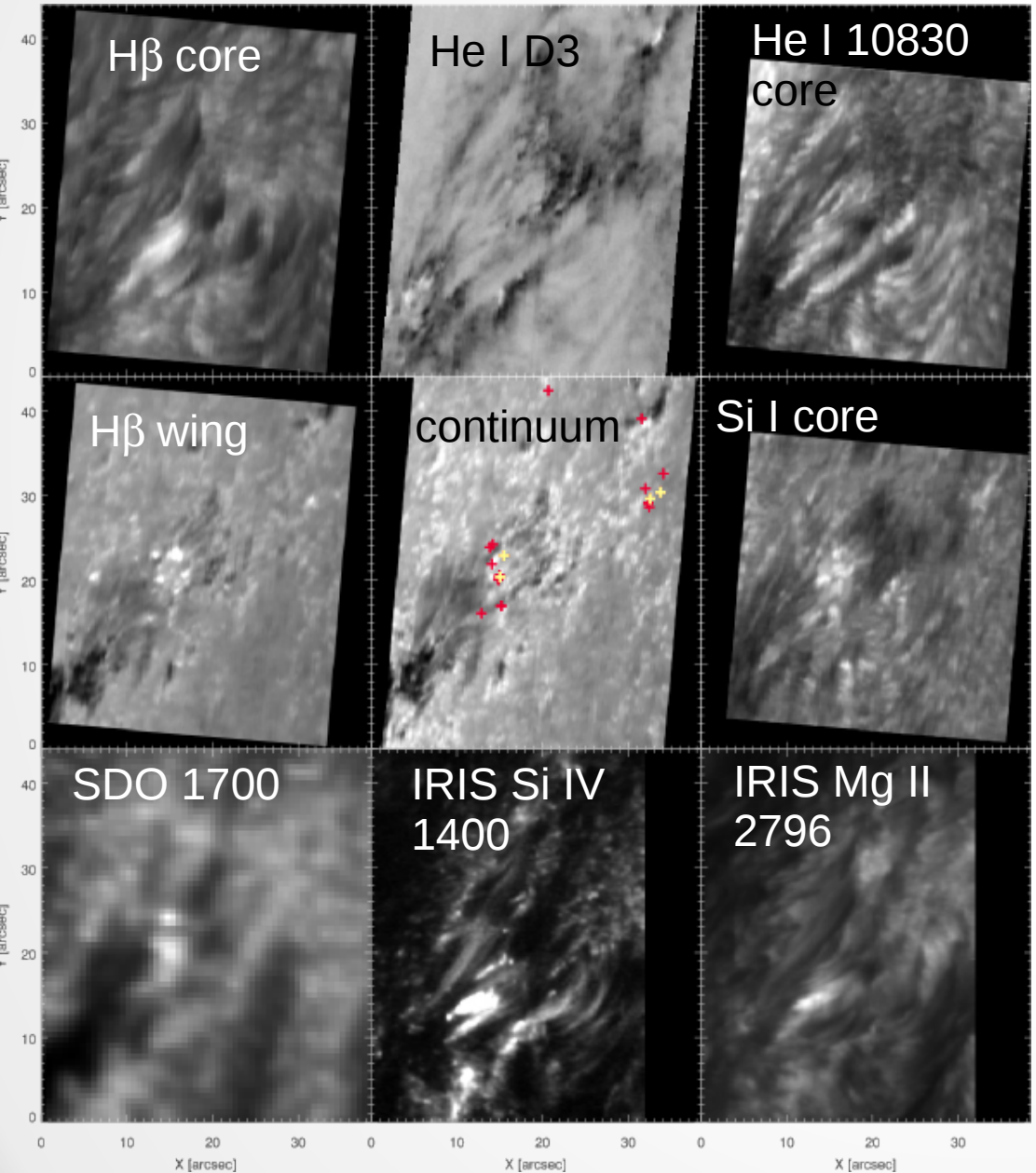
Georgoulis et al. 2002

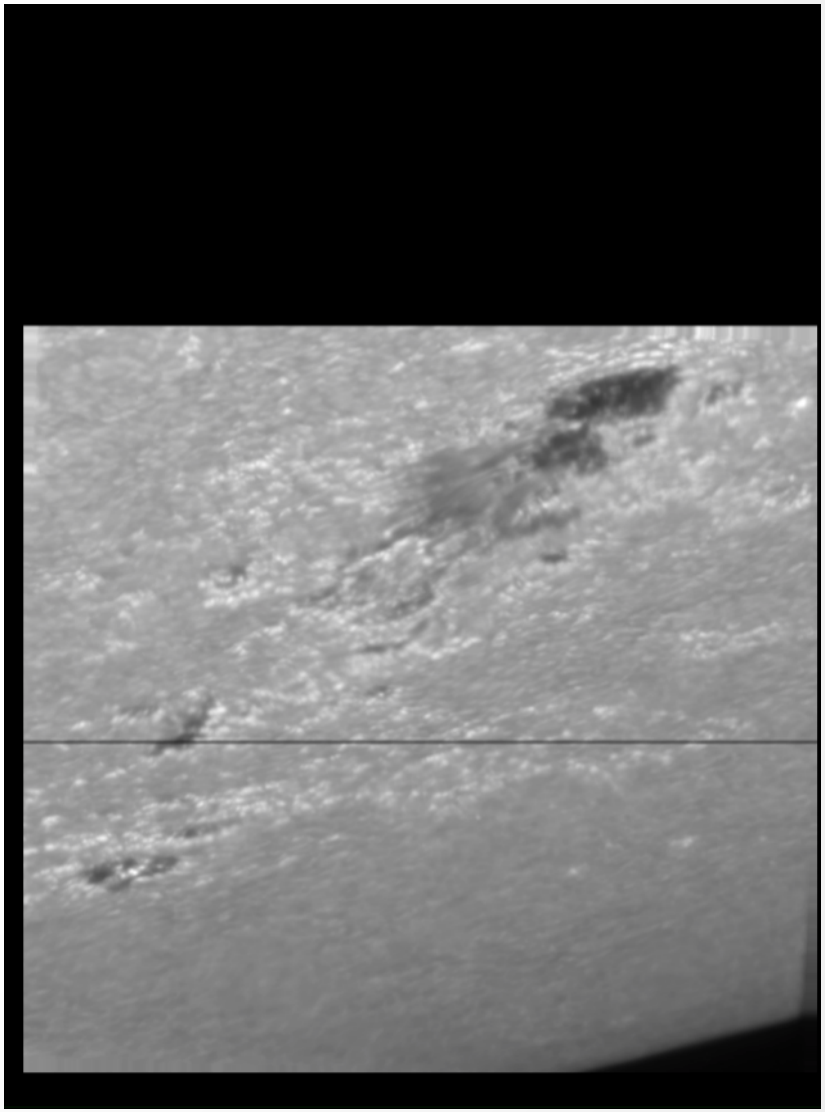
- In flux emergence regions: converging flows in the photosphere bend the magnetic field lines, reconnection
- Presence of bi-directional jets
- EBs are photospheric events (Rutten et al. 2013)
- Temperature enhancements of 1000-4000K above photospheric 6000 K

BUT

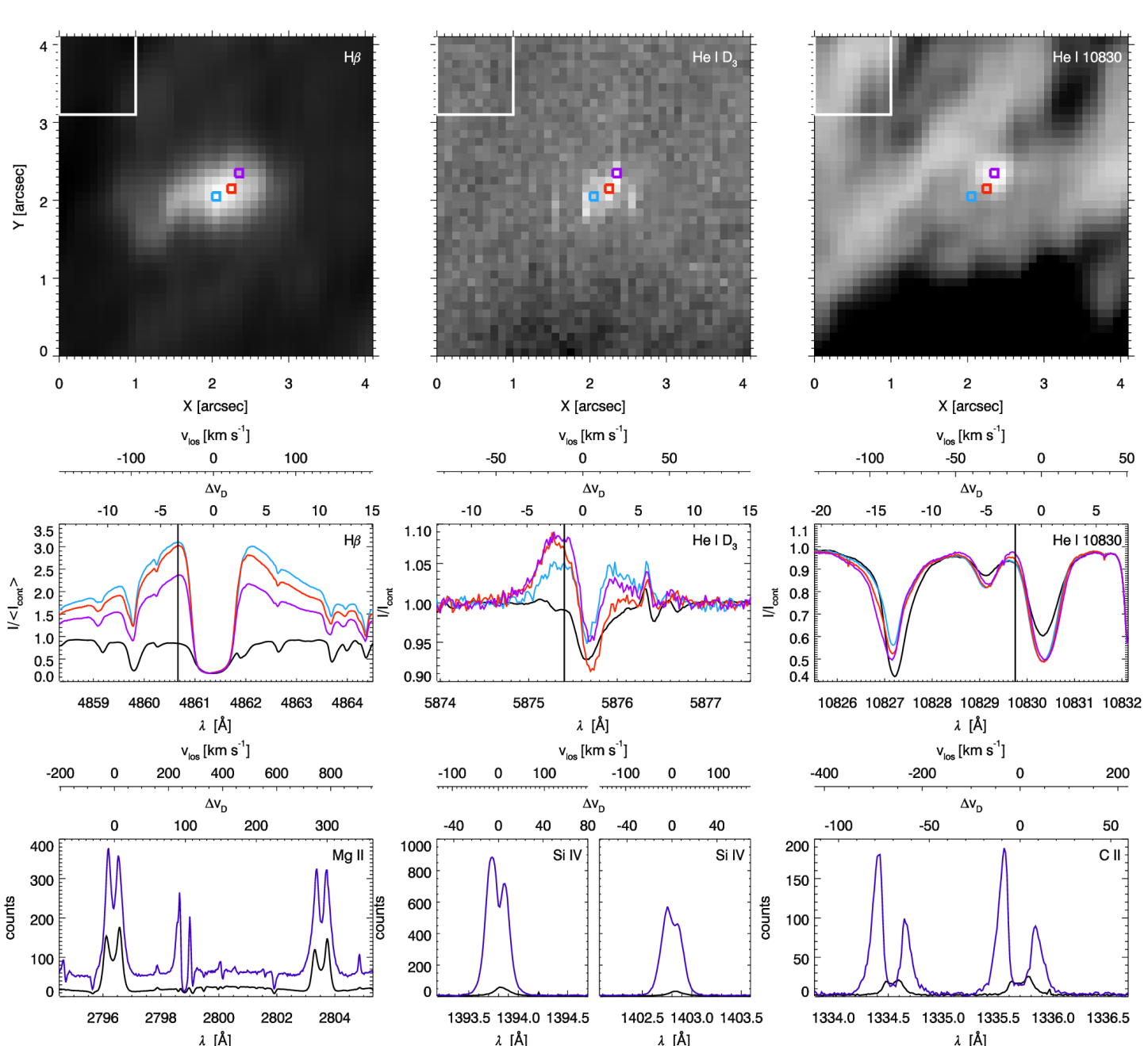
- Peter et al. 2014: photospheric “IRIS” bombs with T ~ 10^5 K
- Vissers et al. 2015, Kim et al. 2015, Tian et al. 2016, Libbrecht et al. 2017: IRIS bombs are related to Ellerman bombs in some cases

Aug 2015: First infrared observations at the SST





Ellerman Bomb spectra



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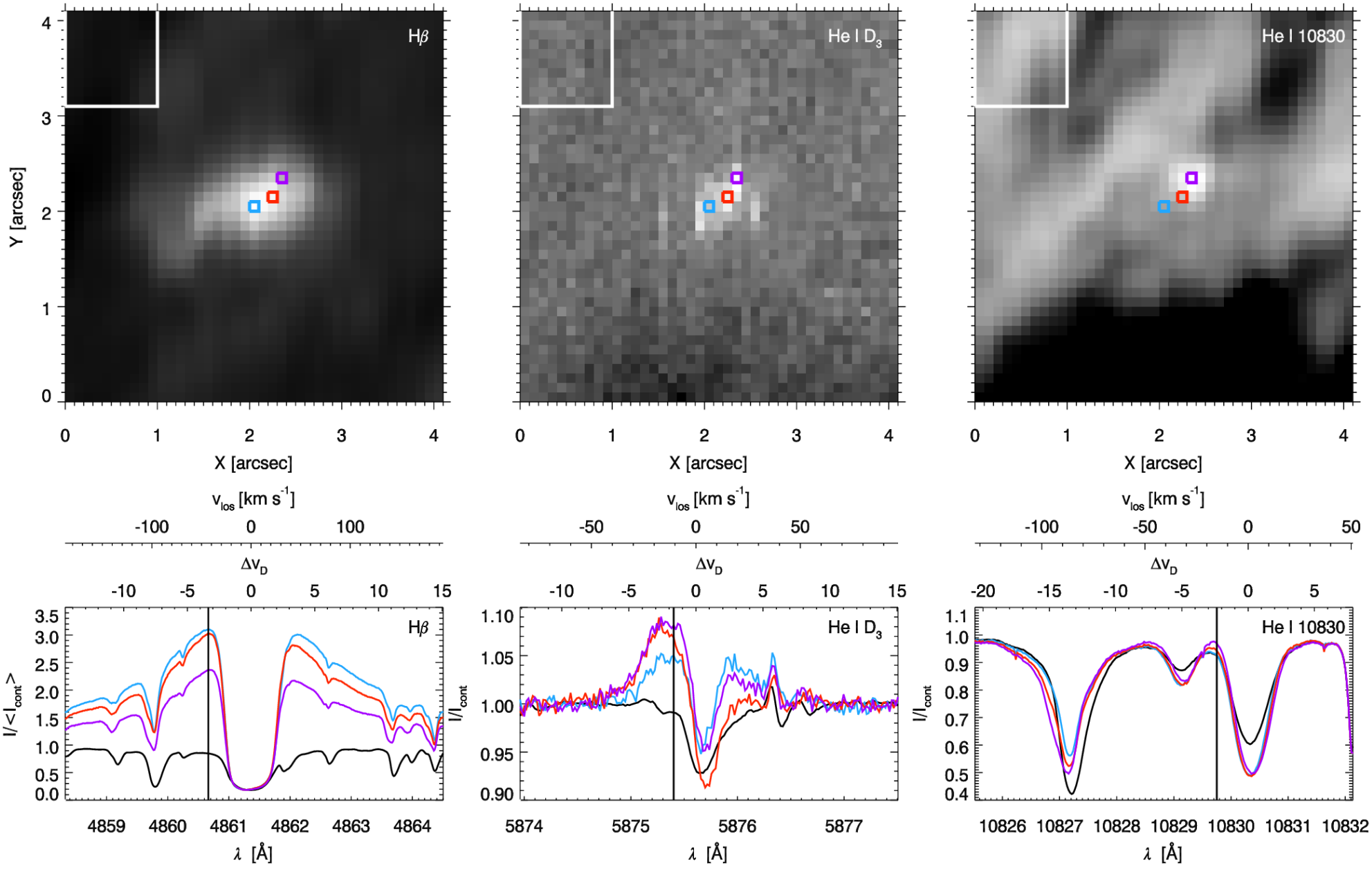

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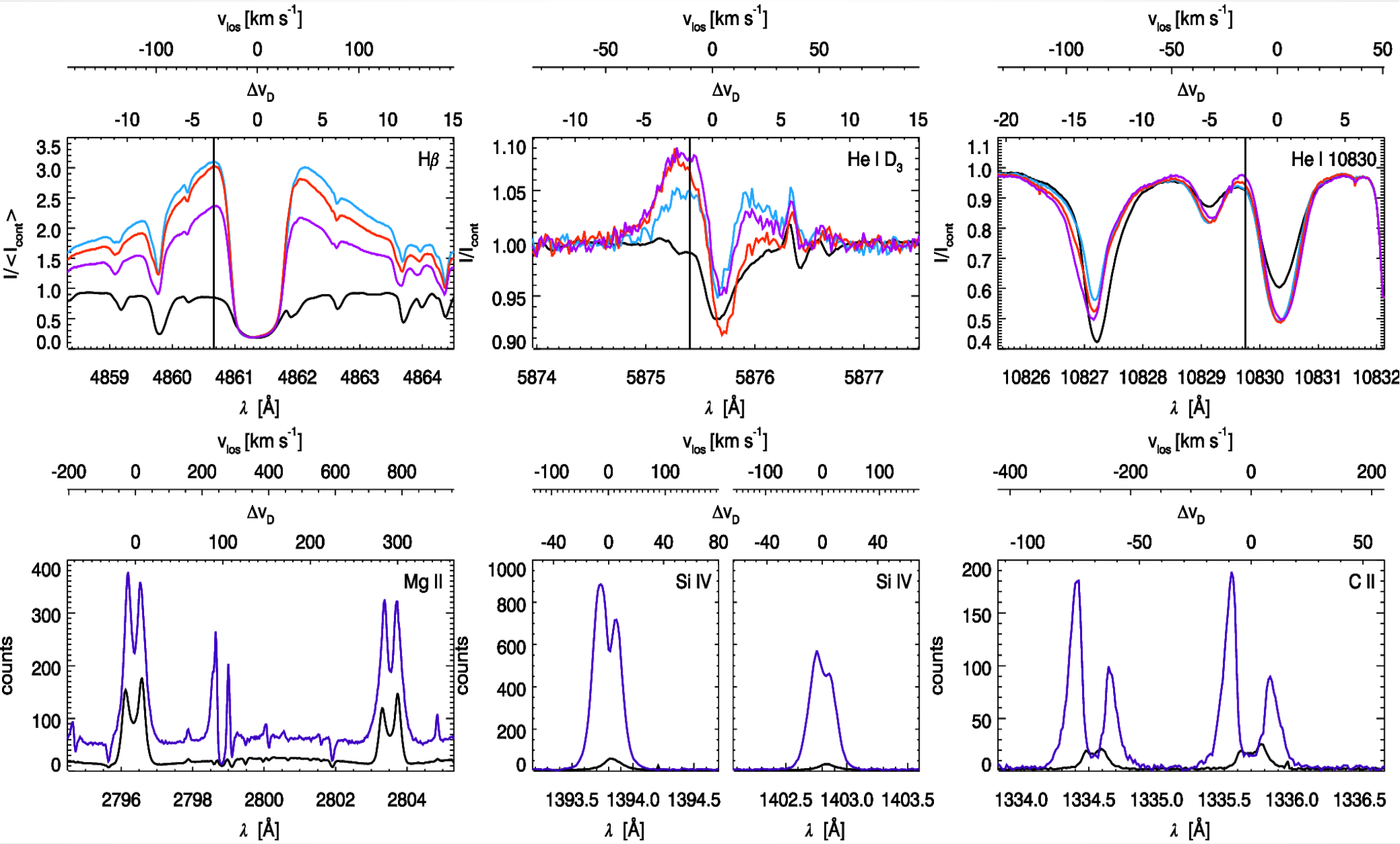

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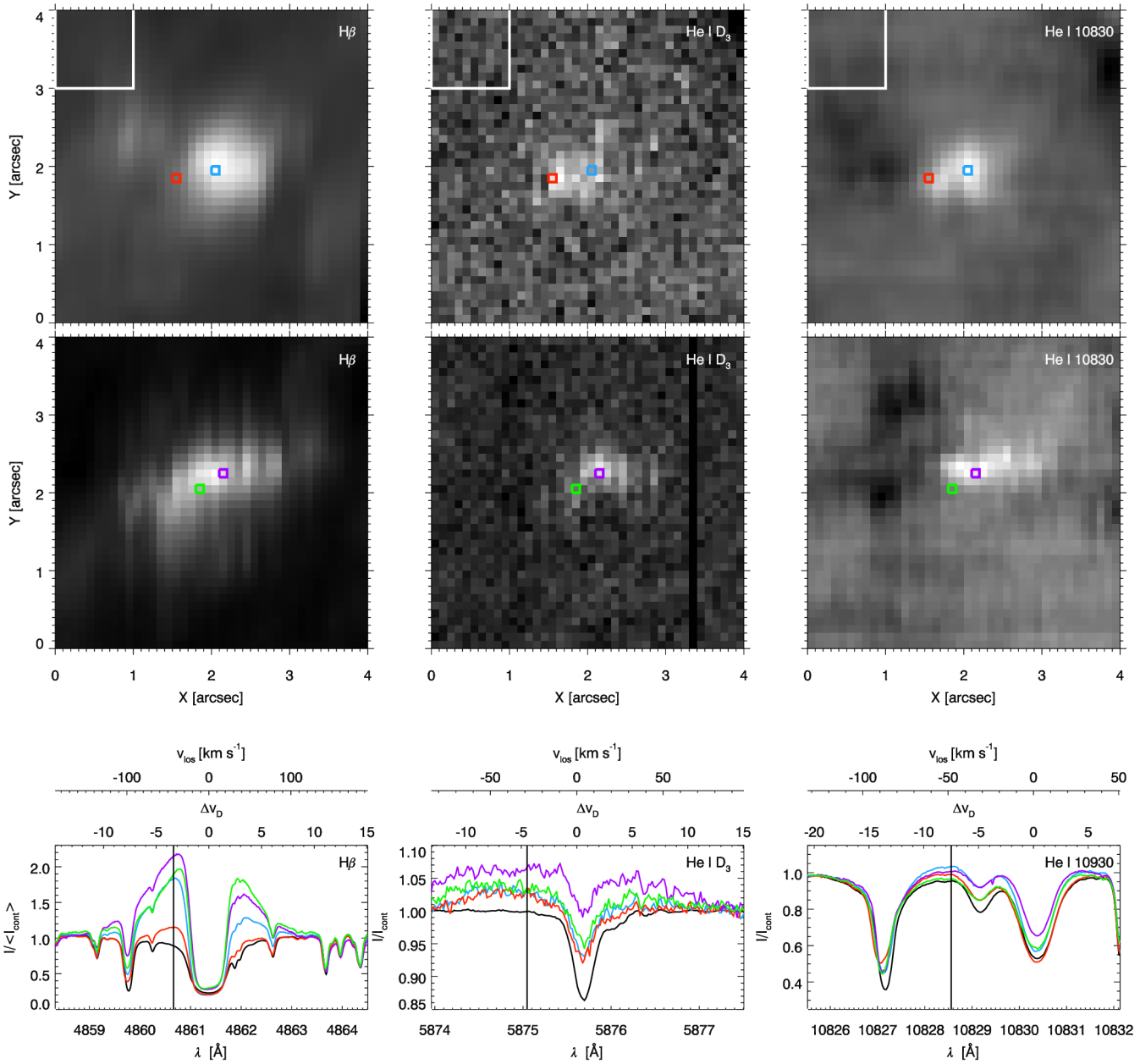

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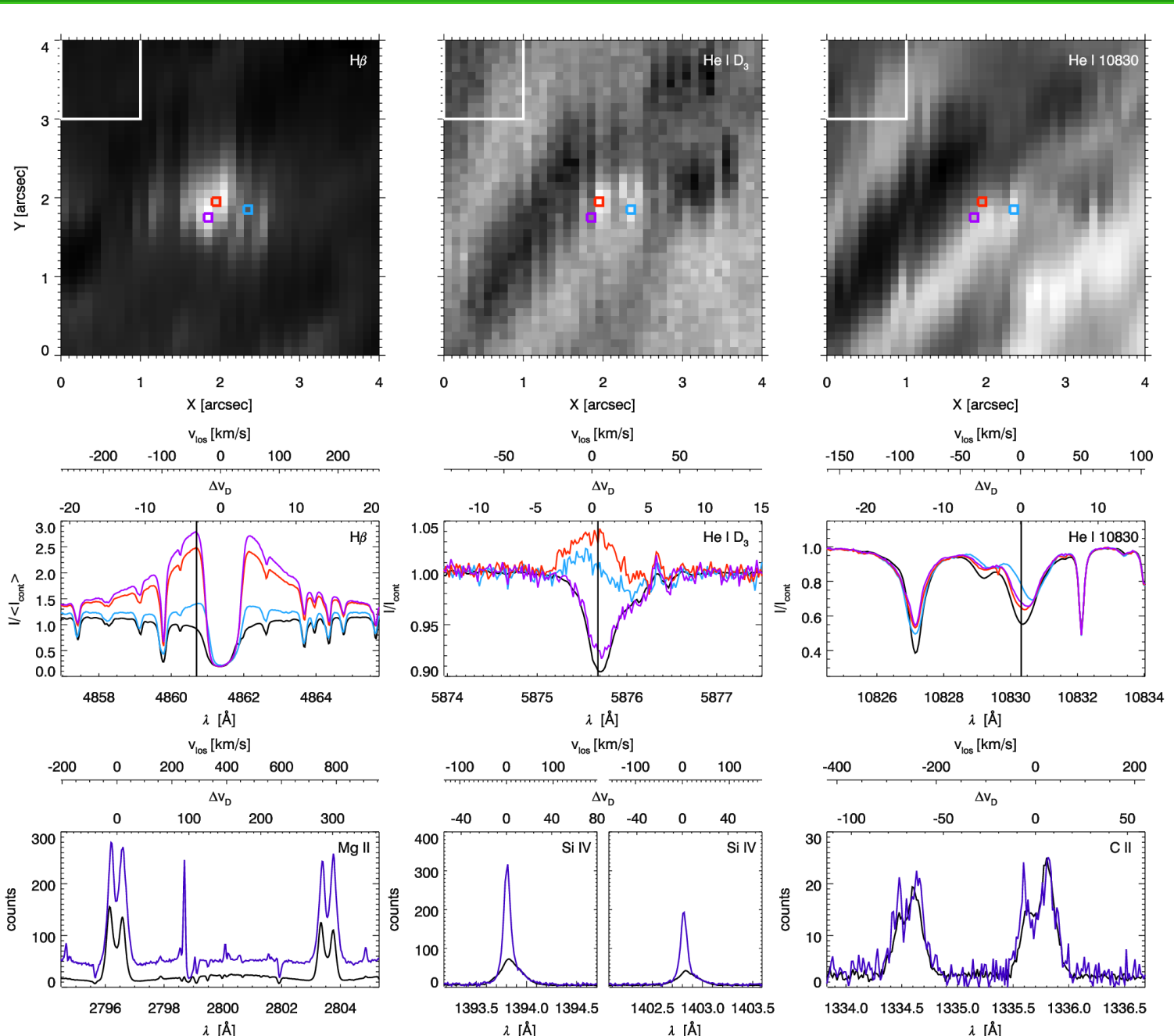
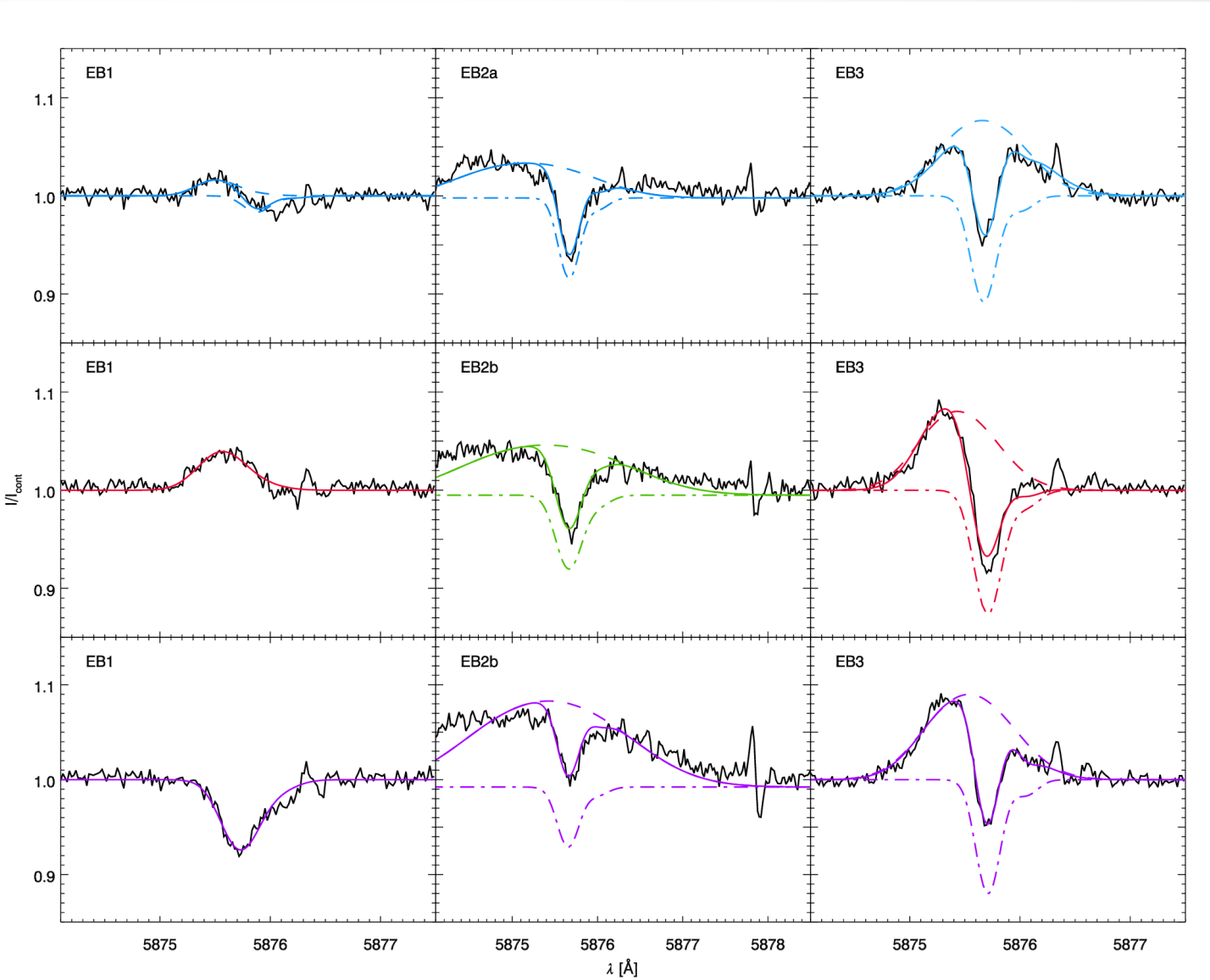


Fit components with Hazel

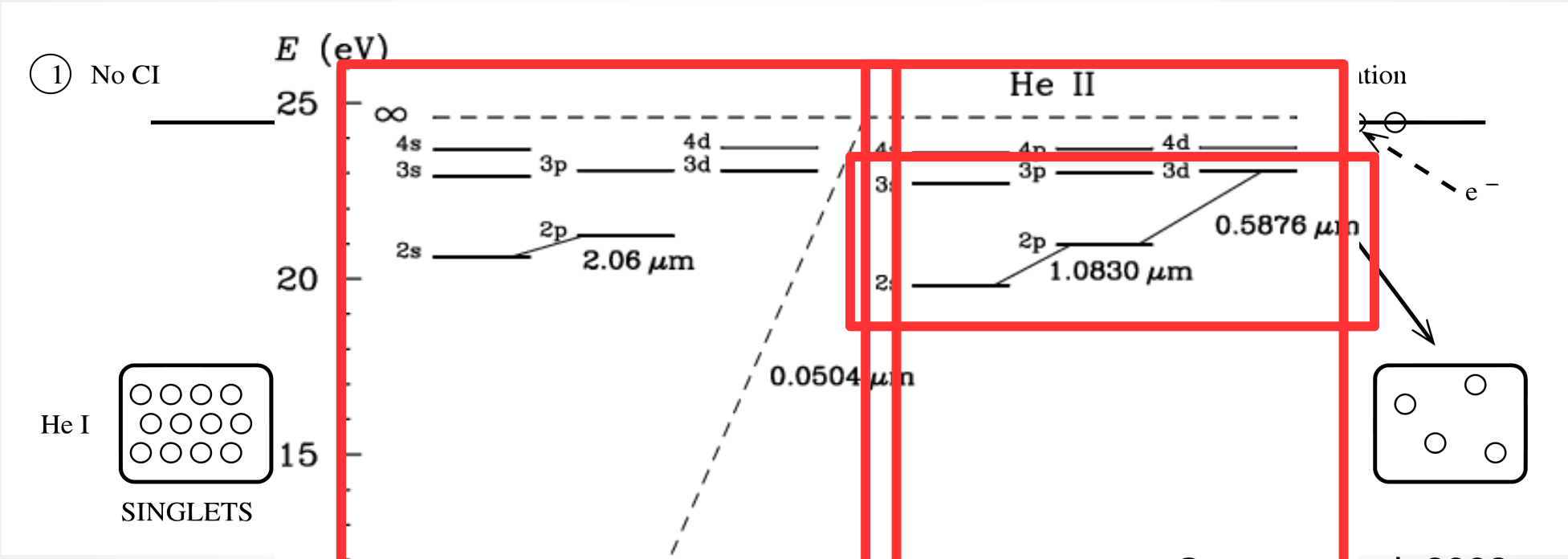
- HeLiX+ vs. Hazel
- Milne-Eddington vs. slab geometry
- Filling factor vs. stacked slabs
- Generally: very broad and slightly blueshifted emission component, “normal” absorption component



Why does the Helium emission occur?

We have to populate the neutral helium triplet levels!

Line formation



Centeno et al. 2008

- Normally in active regions: level population & line opacity linked to EUV radiation from corona and transition region (see also Leenaarts et al. 2016)
- But in the EB case: we need a different mechanism!

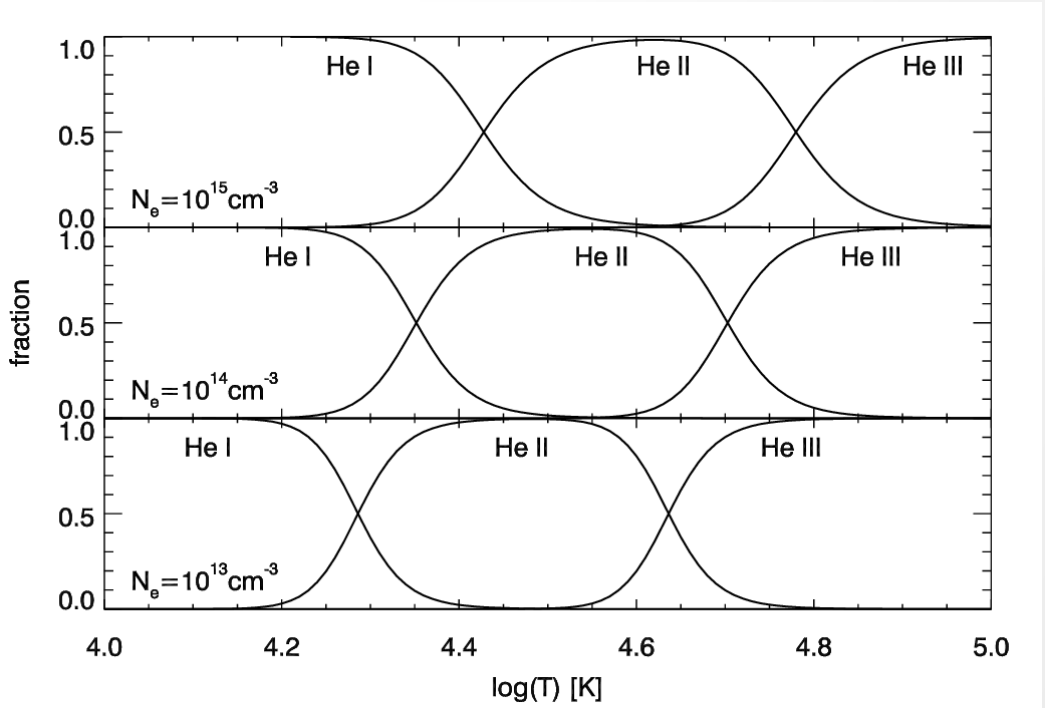
Why does the emission occur?

We have to populate the neutral helium triplet levels!

- Not due to EUV from corona or transition region
- The levels have to be populated either by locally produced EUV radiation
- Or by collisions
- In both cases → we need very high temperatures (and/or density) !

Why does the emission occur?

- In both cases ⟹ we need very high temperatures (and/or density) !
- Upper limit for temperature estimate from assuming all broadening is due to thermal Doppler motions : $T \sim 10^5$ K
- Lower limit for temperatu
  e.g. LTE, Saha, $T \sim 2.10^4$ K
- Are these high temperatu

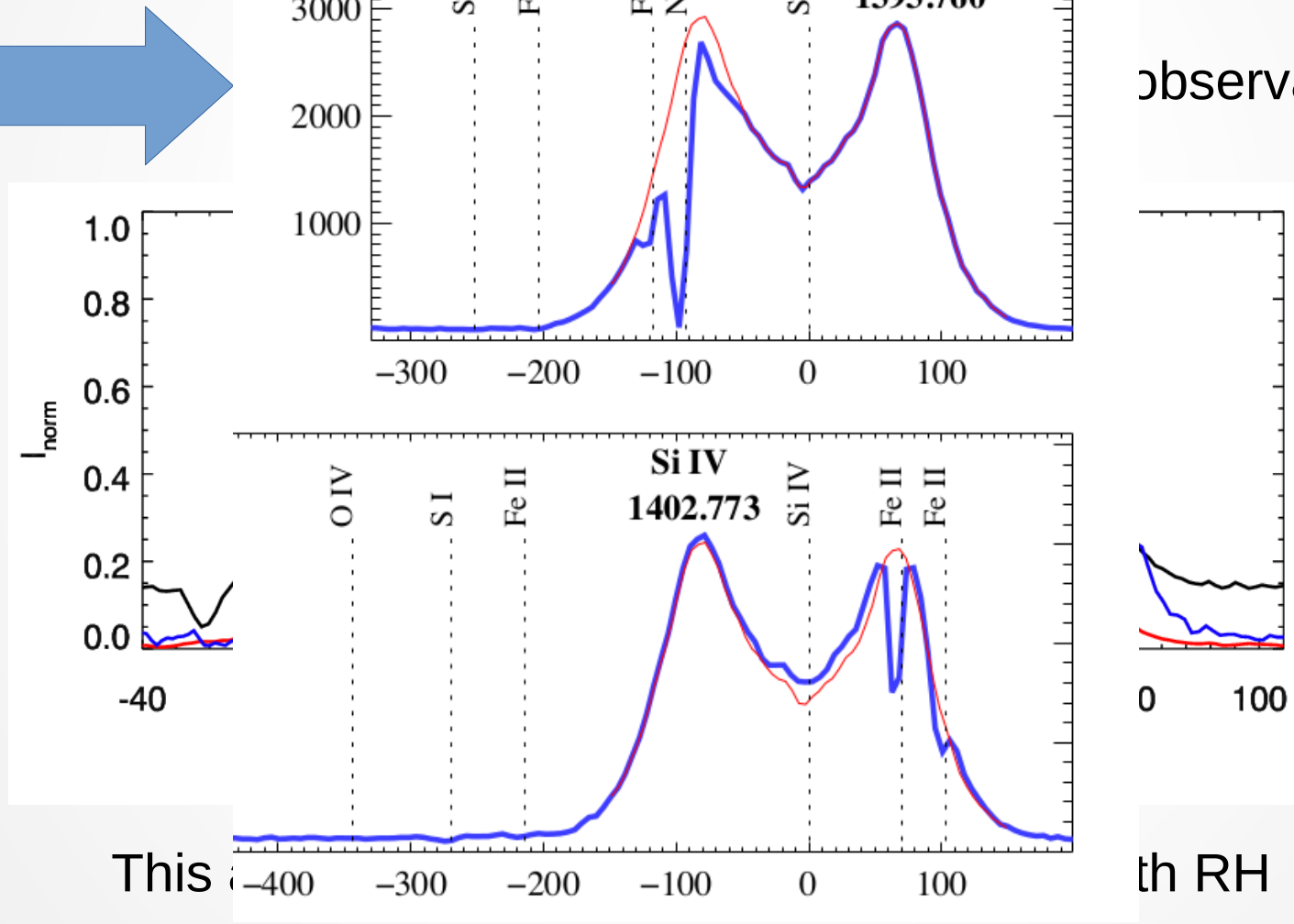


Why does the emission occur?

- Are these high temperatures realistic?
- **Peter et al. 2014**: photospheric IRIS bombs with T ~ 10^5 K, interprets broadening of Si IV lines as bi-directional jets, EBs?
- **Vissers et al. 2015, Kim et al. 2015, Tian et al. 2016**: combine Balmer line diagnostics with IRIS profiles and confirm that IRIS bombs correspond to EBs in some cases
- **Rutten 2016**: EB visibilities in ALL diagnostics are compatible with T ~ 1 – 2 x 10^4 K
- **Libbrecht et al. 2017 (A&A, accepted)**: Ellerman bombs have a signature in IRIS lines AND in He I D3 and He I 10830, T ~ 2 x 10^4 – 10^5 K

Interpretation of Si IV

- Si IV line cen optically thin and a reversal in

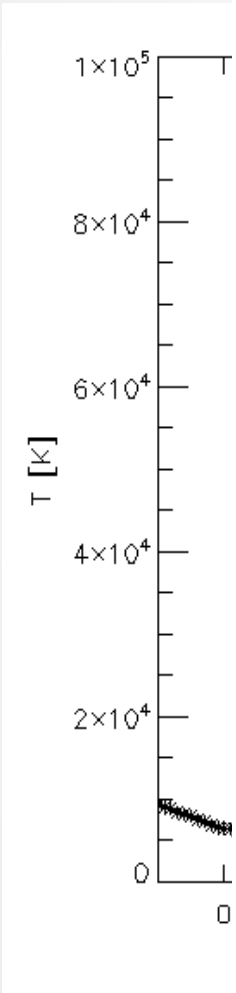


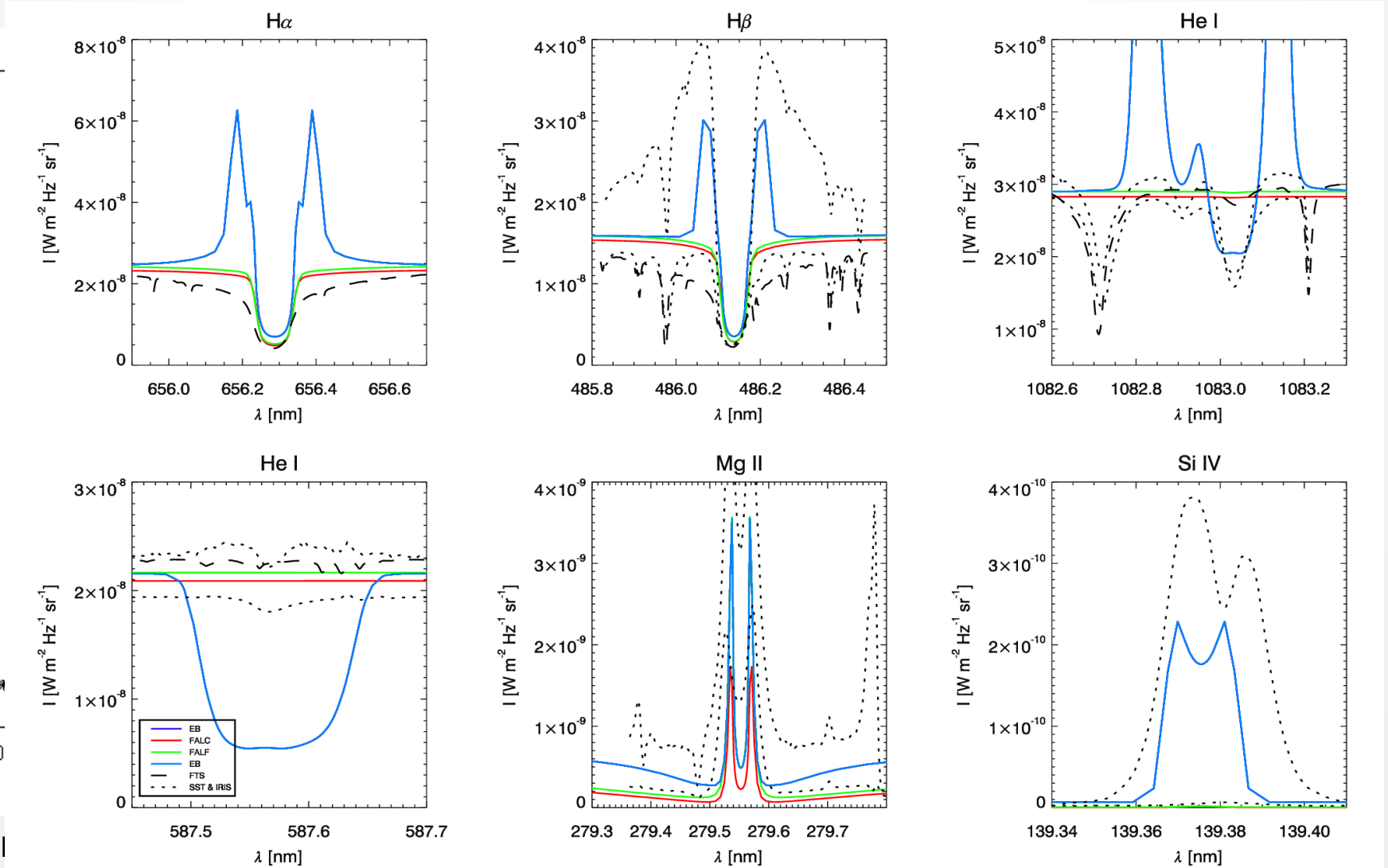
observation

This th RH

Interpretation of Si IV 1400

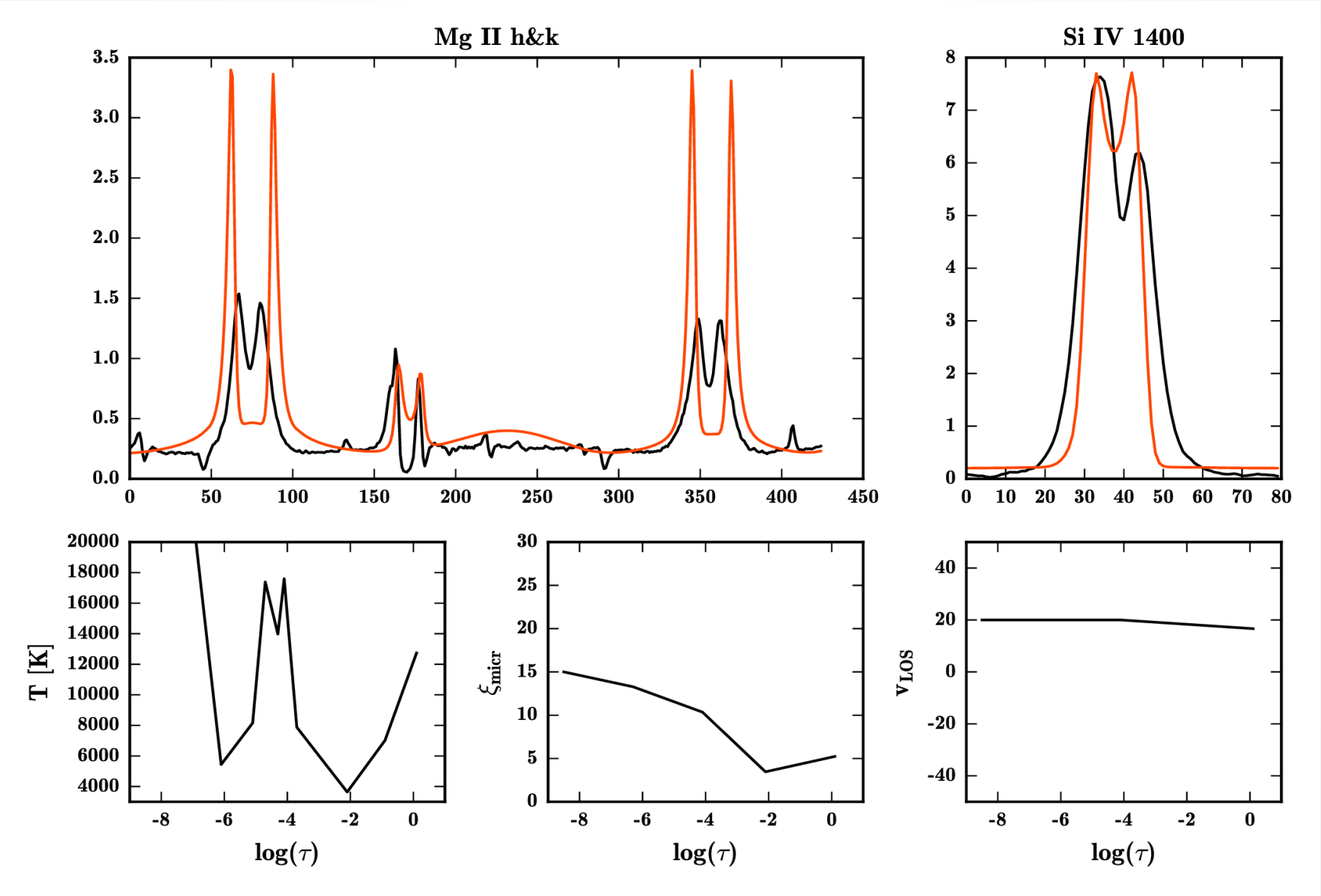
Observing neutral helium in emission, Si IV and other IRIS lines, adds a strong constraint to modelling!





In collabo

Inversion of EB IRIS profiles with STIC



In collaboration with Gregal Vissers, Jaime de la Cruz Rodríguez

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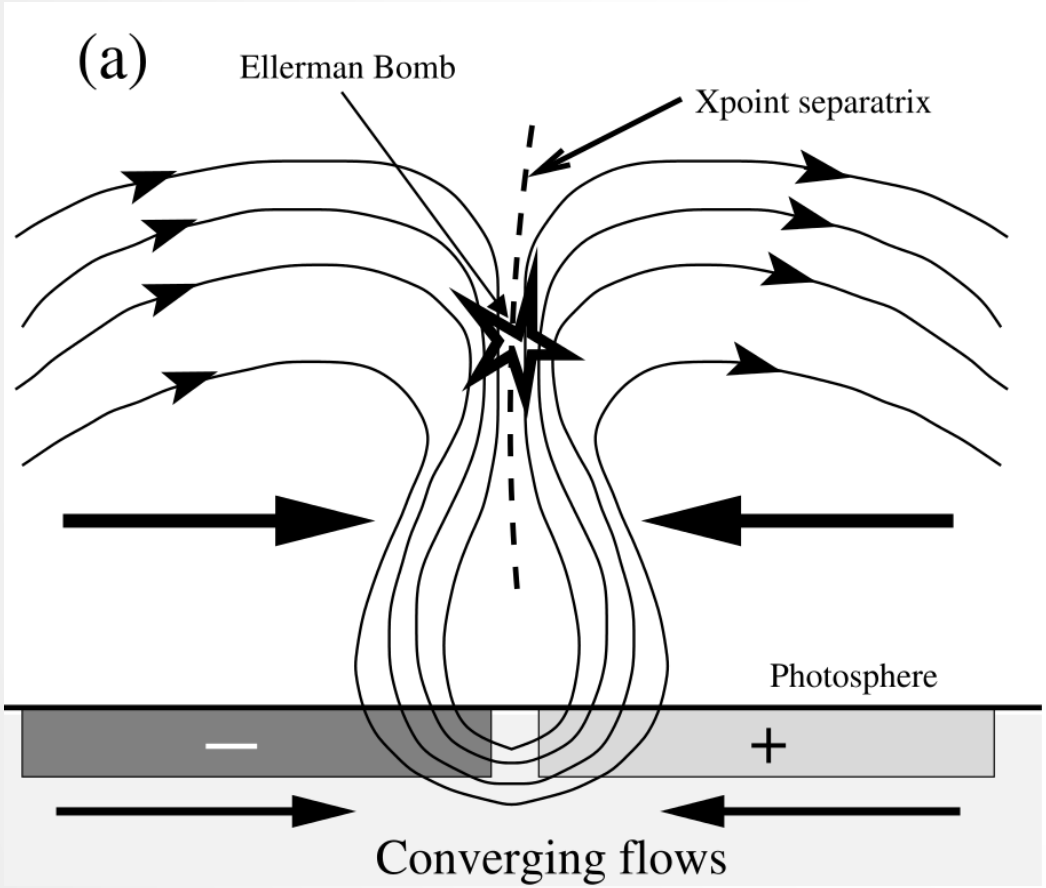

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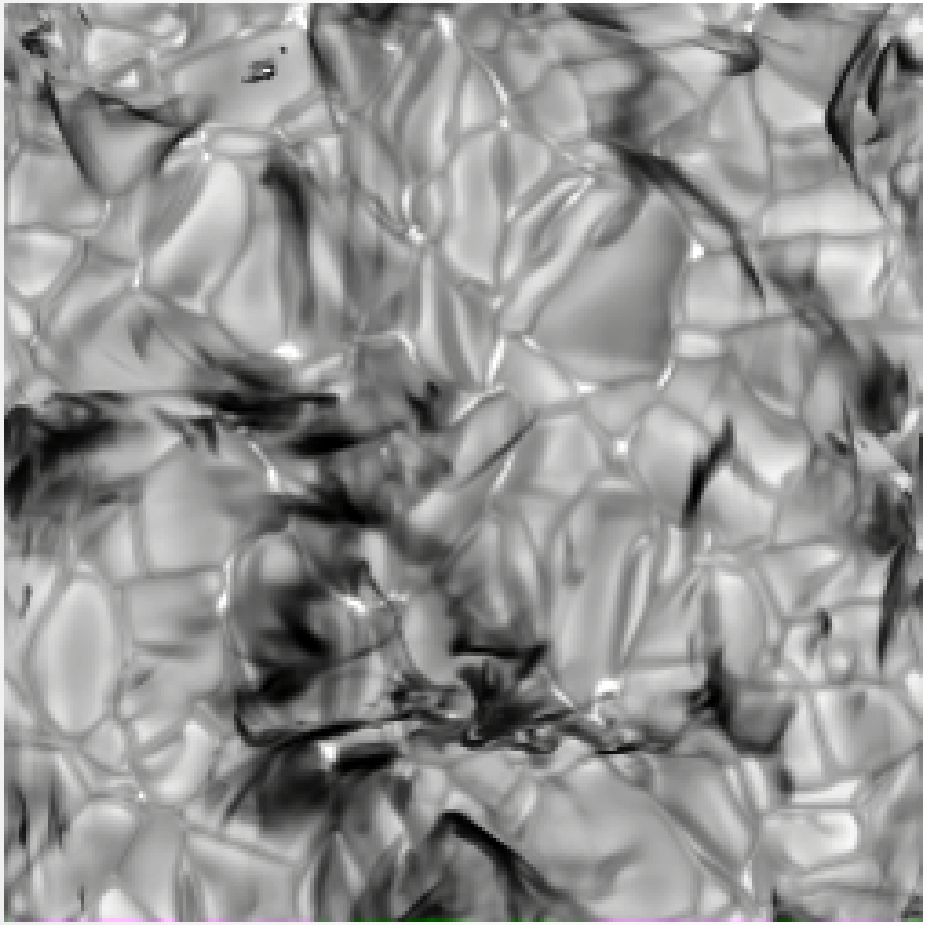
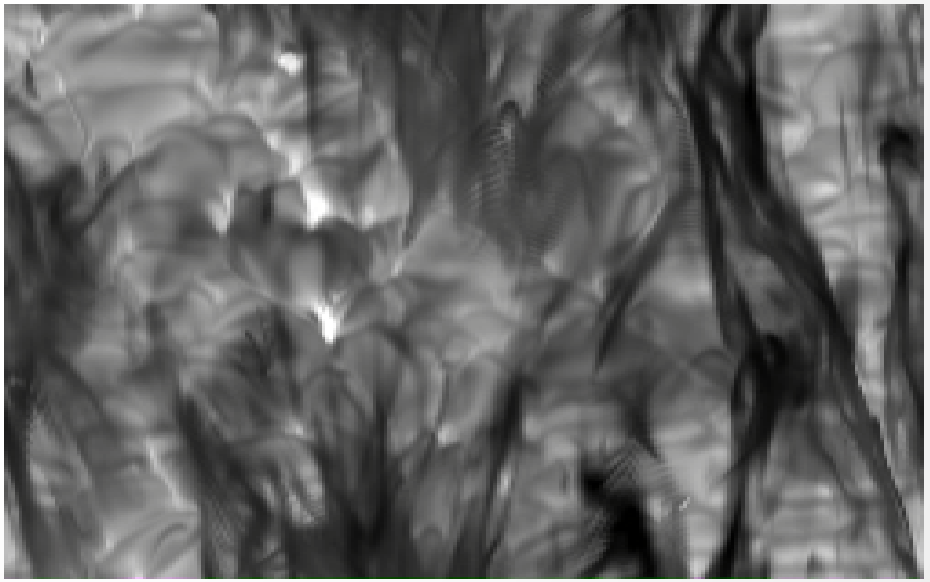
Synthetic helium spectra with Multi3D

He I 10830 scan through wavelength



μ=1

Synthesis of Hα, Mg II h&k, Si IV:
see Viggo's talk tomorrow



μ=0.33

In collaboration with Viggo Hansteen, Jorrit Leenaarts

Synthetic helium spectra with Multi3D

He I D3 scan (continuum corrected!) through wavelength

μ=1

μ=0.33

In collaboration with Viggo Hansteen, Jorrit Leenaarts

Summary

- We observe EB emission in He I D3 and He I 10830
- The emission component is very broad and slightly blue-shifted
- We roughly estimate the EB temperatures between
  T ~ 20 000 – 100 000 K
- Si IV 1400 emission can be generated at temperatures of
  T ~ 20 000 K

Thank you for your attention!