Modeling UV bursts

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Rosseland Centre for Solar Physics

Introduction

- What are UV bursts?

Wavelength:

Size:

Duration:

Intensity:

Motion:

No relation to flares:

(see the recent review by Young et al. 2018)

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- What are UV bursts?

Wavelength: UV => Ultraviolet $\lambda \in [465{,}1550]$ Å

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Motion: UV bursts track dynamics of photospheric magnetic features ($v \leq 10\ km/s$)

No relation to flares: Important to distinguish them from compact kernels related to flare ribbons

(see the recent review by Young et al. 2018)

Introduction

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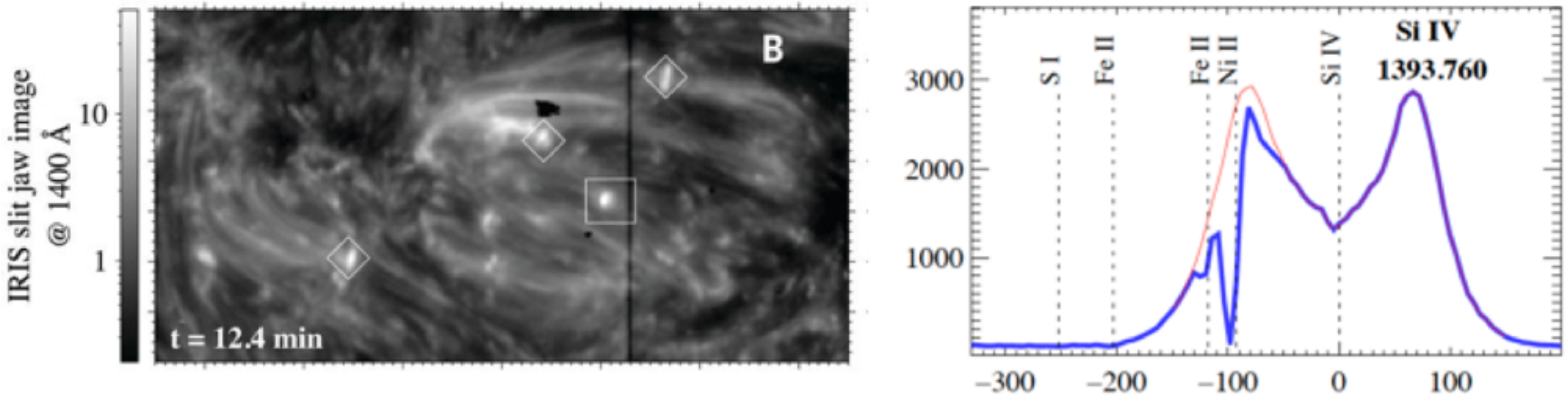
- How UV bursts look like?

  - Image: roundish compact bright structures in SJI 1400

  - Profile: Si IV lines are very wide and show narrow absorption lines superimposed



Peter et al. (2014)

Introduction

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- Where to find UV bursts?

Emerging flux regions (EFRs)

Moving magnetic features (MMFs)

Light bridges (LBs)

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Rosseland Centre for Solar Physics

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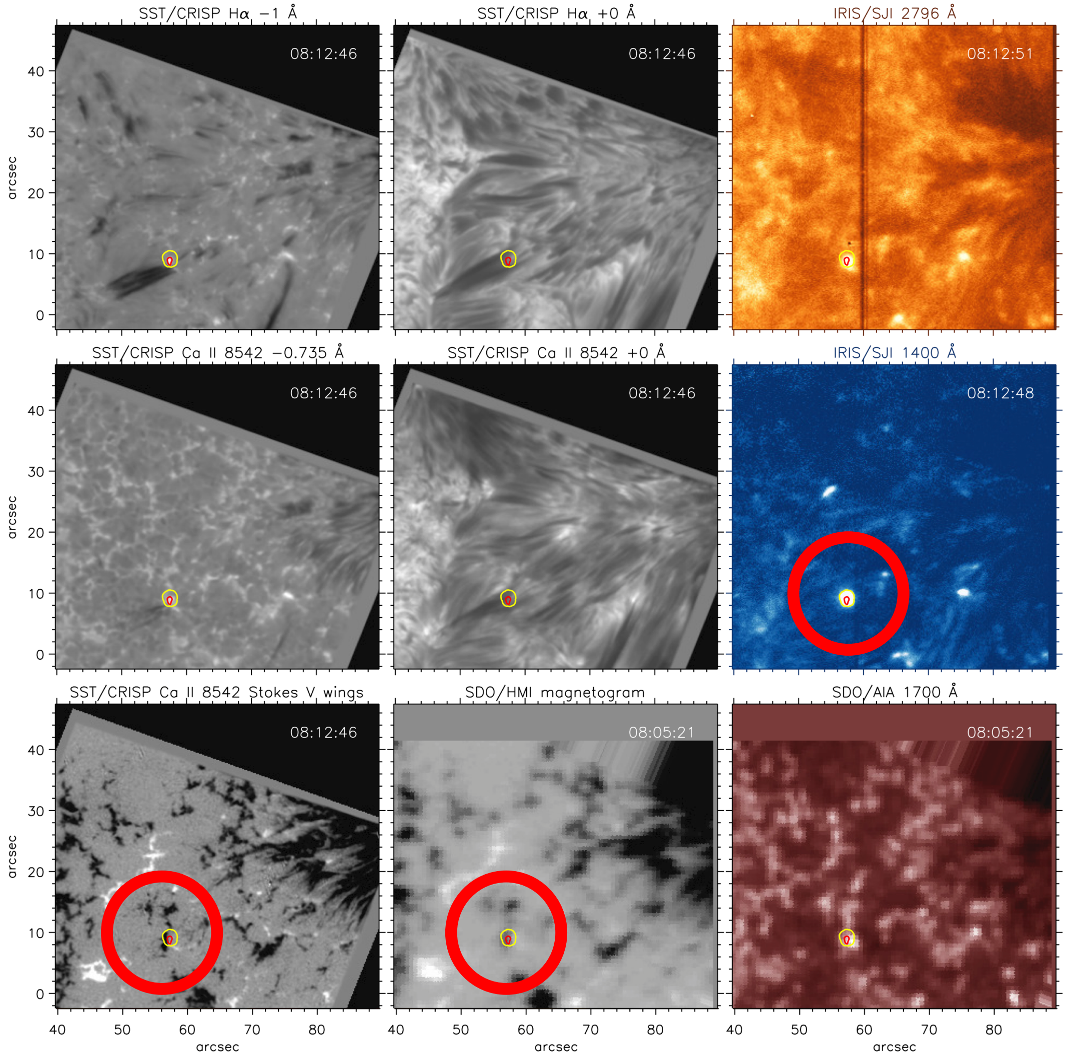

Ortiz et al. (accepted to be published, 2019)

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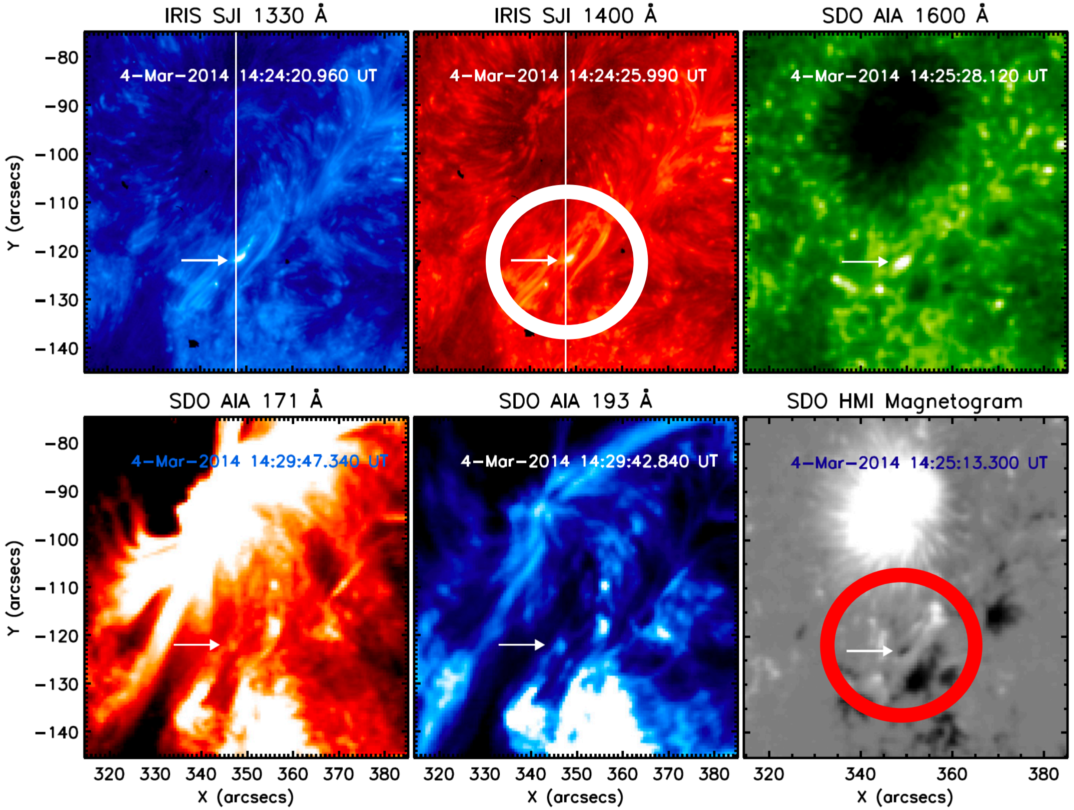

Gupta & Tripathi (2015)

Introduction

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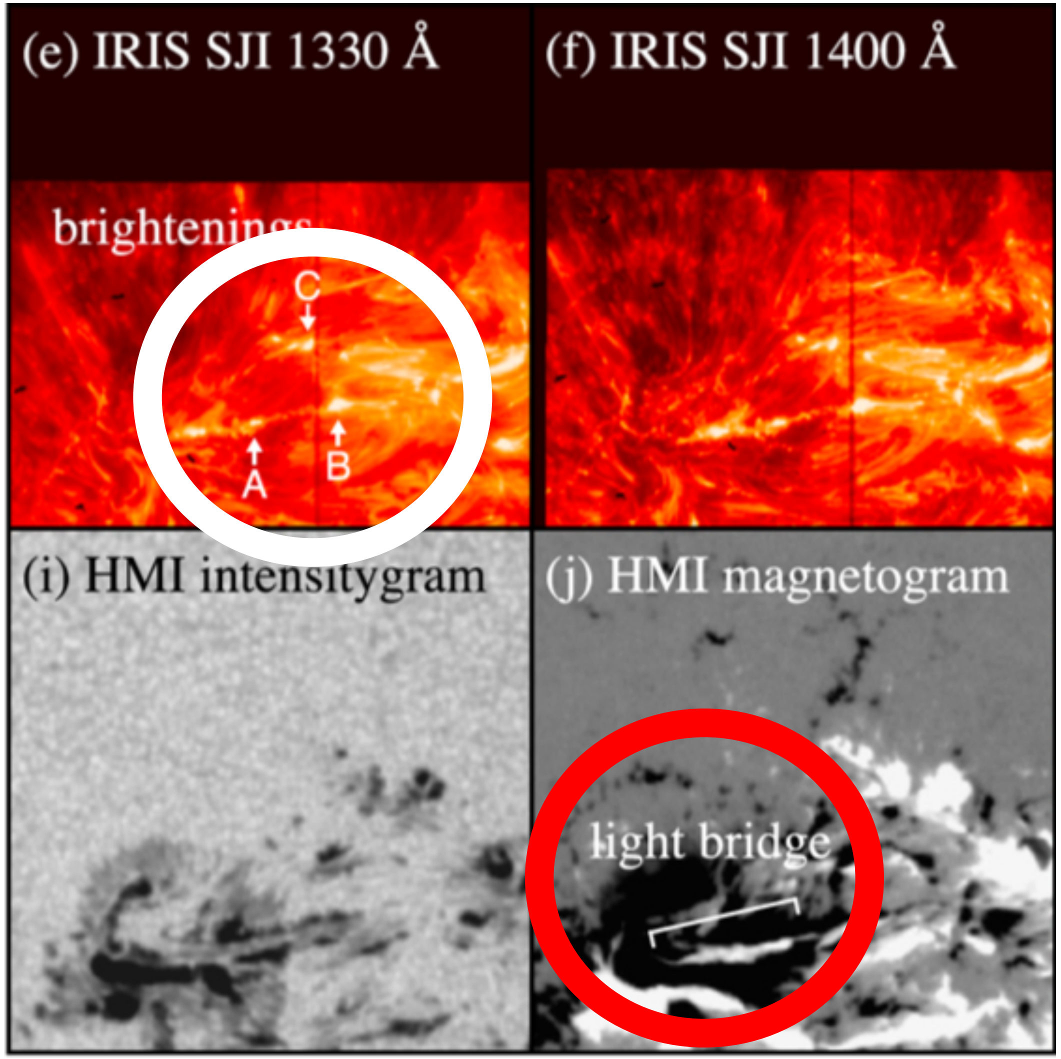


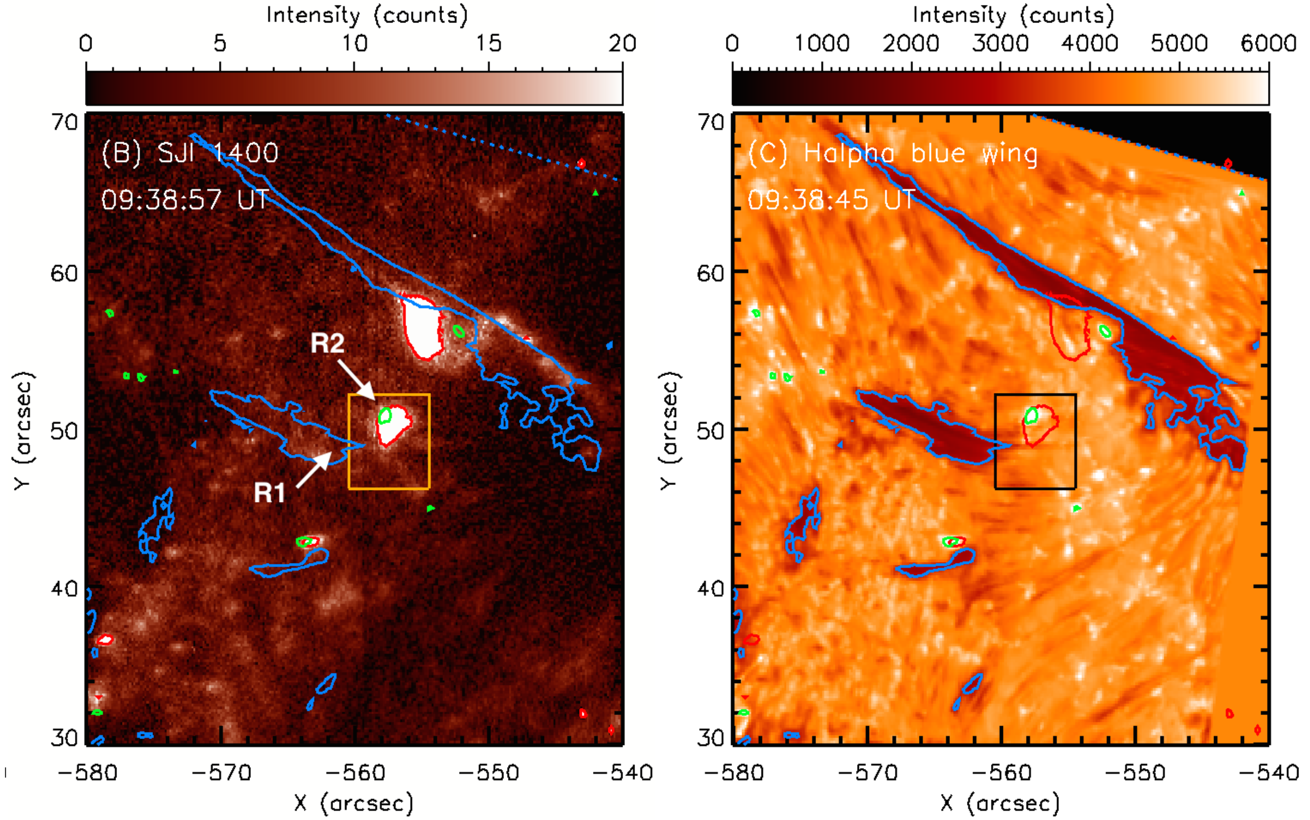
Toriumi et al. (2015)

Introduction

- Which phenomena are usually related to UV bursts?

  - Ellerman Bombs (EBs):
  substantial brightenings of the extended wings of Hα without core brightening

  - Surges:
  non collimated ejections of chromospheric plasma typically observed in Hα with velocities of ≤ 50 km/s



Nóbrega-Siverio et al. (2017)

Segmentation fault

Modeling UV bursts

- Addressing UV bursts from different theoretical perspectives

1D

2D

3D

Modeling UV bursts

- Addressing UV bursts from different theoretical perspectives

1D

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3D

Modeling UV bursts: 1D experiments

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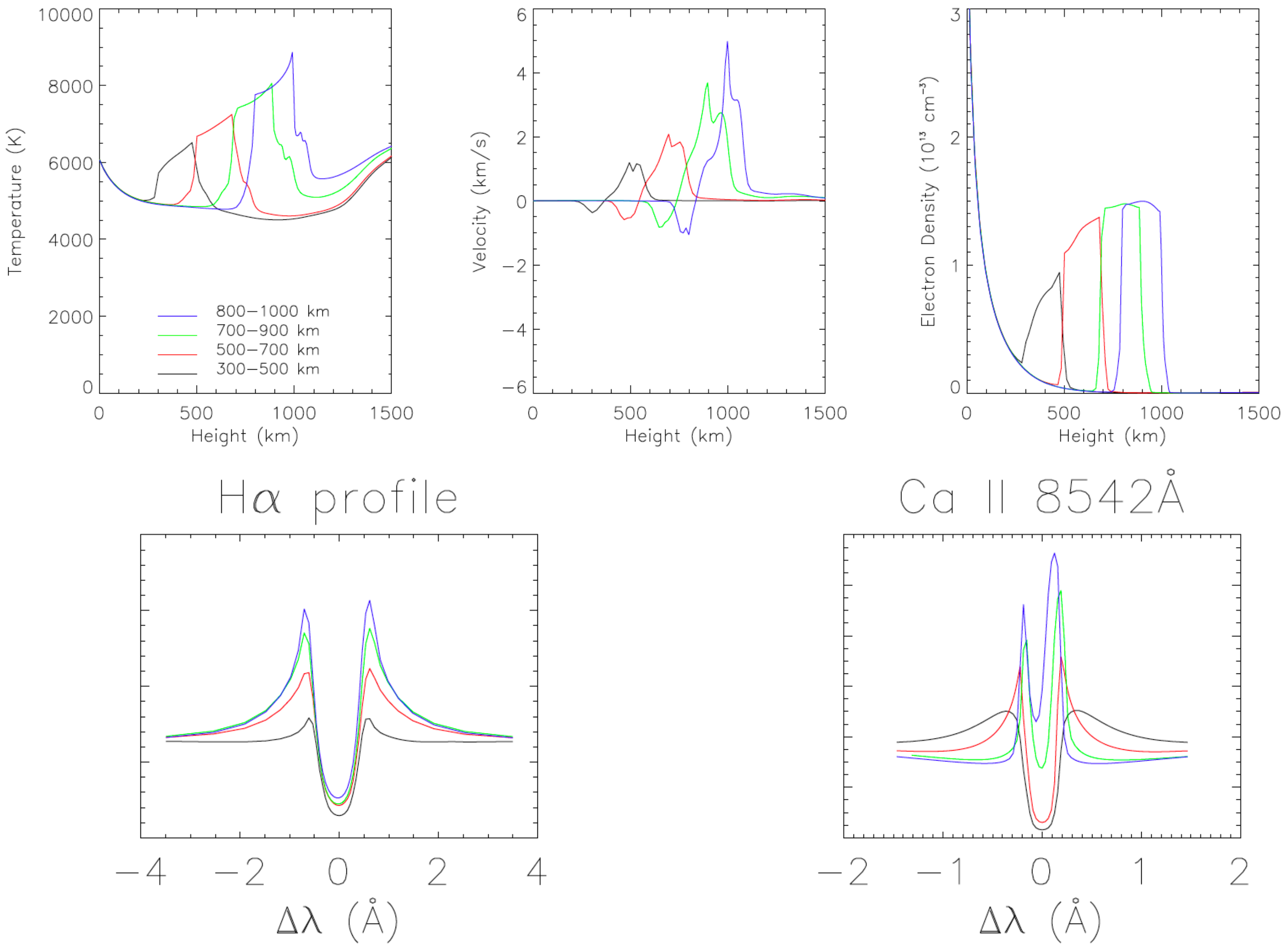
- **Could modified EB models produce UV emission?**

- Semi-empirical model by **Fang et al. (2017)** and radiative-hydrodynamic simulations by **Reid et al. (2017)** and **Hong et al. (2017a,b).**

- Scheme of these models:
  - Setting a 1D stratification for an EB model.
  - Synthesizing different lines (Hα, Ca II 8542, or Mg II h & k)

Modeling UV bursts: 1D experiments

- **Reid et al. (2017)**
- RADYN code (Carlsson and Stein, 1997) to get the stratification
- MULTI code (Carlsson 1986) to synthesize Hα and Ca II
- RH code (Uitenbroek 2001) to synthesize Mg II h & k



Reid et al. (2017)

Modeling UV bursts: 1D experiments

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- Scheme of these models:
  - Setting a 1D stratification for an EB model.
  - Synthesizing different lines (Hα, Ca II 8542, or Mg II h & k)

- Result:
  It was not possible to reconcile UV profiles with the profiles of EBs

Modeling UV bursts: 2D experiments

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- Addressing UV bursts from different theoretical perspectives

1D

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Modeling UV bursts: 2D experiments

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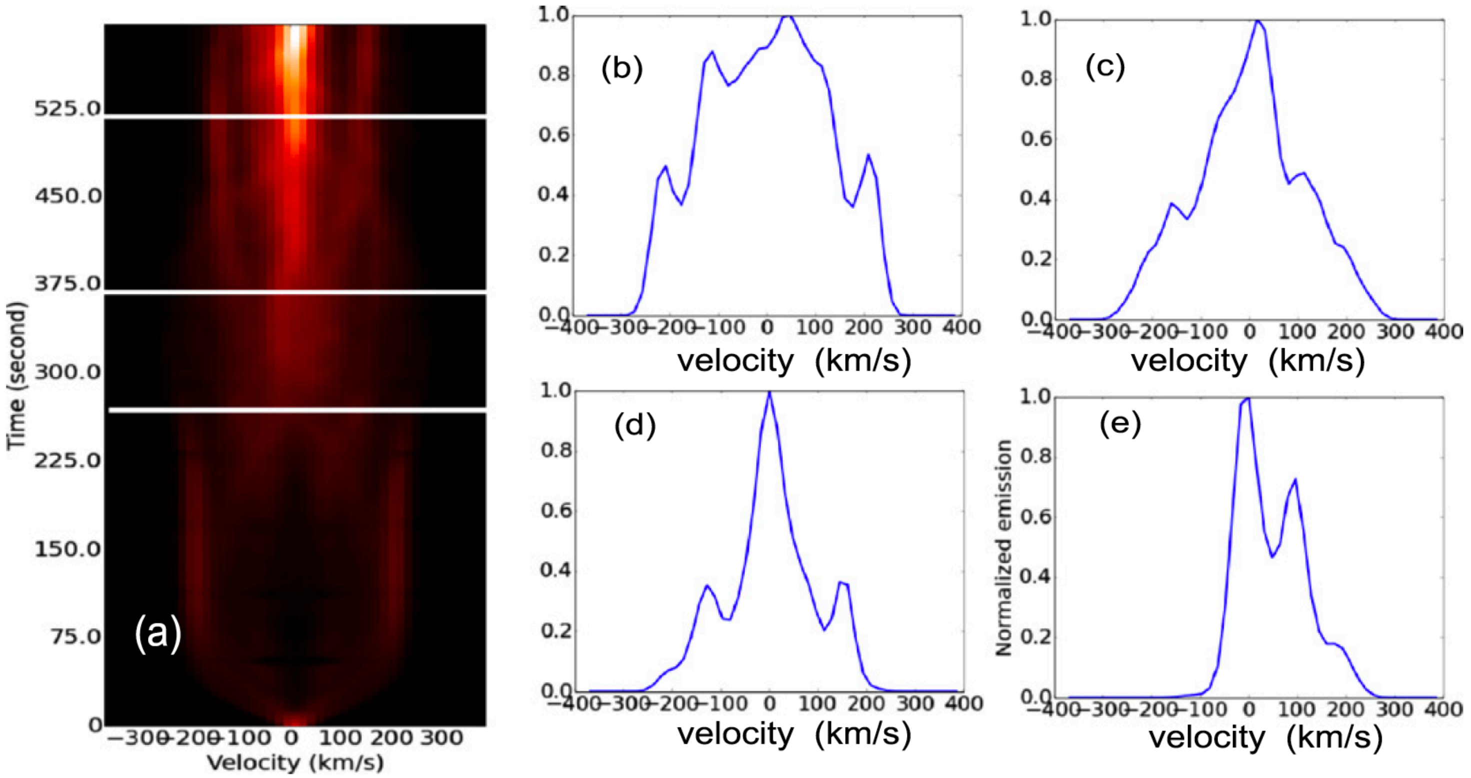
- **Innes et al. (2015)**

  - **Model**: Reconnection in the current sheet using the Athena code Stone et al. (2008)

  - **Aim**: To study the plasmoid instability during small-scale magnetic reconnection events in the Sun

  - **Result**: The Si IV profiles from *IRIS* observations can be reproduced with the multiple magnetic islands



Innes et al. (2015)

Modeling UV bursts: 2D experiments

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Other 2D models of reconnection in current sheets:

- **Ni et al. (2016)**: Single fluid. Radiation cooling, heat conduction and ambipolar diffusion included. Both the high temperature (8×10^4 K) and low temperature ($\sim10^4$ K) magnetic reconnection events can happen in the low solar atmosphere.

- **Ni and Lukin (2018), Ni et al. (2018)**: Multifluid using HiFi. Nonequilibrium ionization/recombination plays a critical role in the structure of the reconnection region. When β is lower than 0.0145, weakly ionized plasma can be strongly heated to above 2.5×10^4 K.

- **Peter et al. (2019)**: Model inspired in the observations by Chitta et al. (2017). Through a plasma-β study, the authors conclude that temperatures in the reconnection region should not reach values significantly above 10^5 K

None of these models contain forward modeling

Modeling UV bursts: 2D experiments

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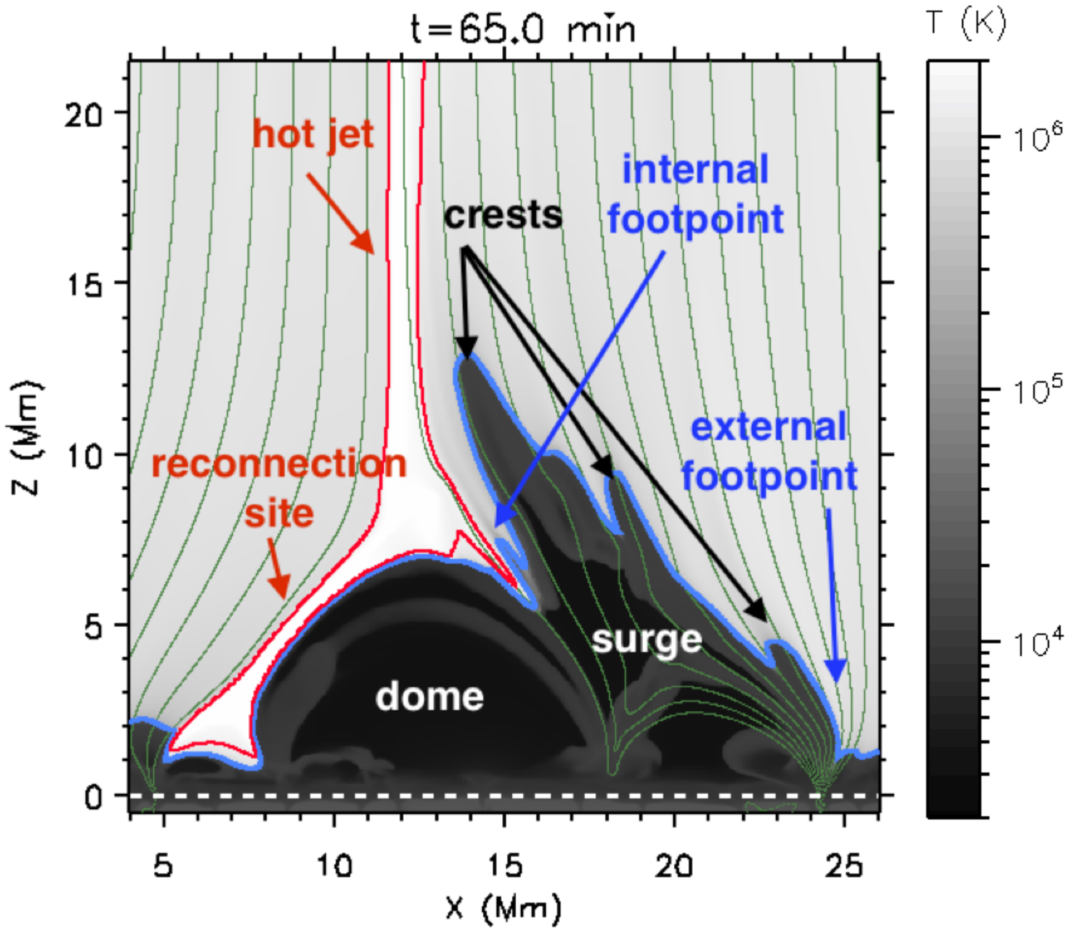
- **Nóbrega-Siverio et al. (2017)**

  - **Model**: Magnetic flux emergence experiment using the Bifrost code (Gudiksen et al. 2011)

  - **Aim**: To provide theoretical support to the relationship between UV bursts, surges and magnetic flux emergence

  - **Result**: Several features of IRIS observations can be obtained with this model



Nóbrega-Siverio et al. (2017)

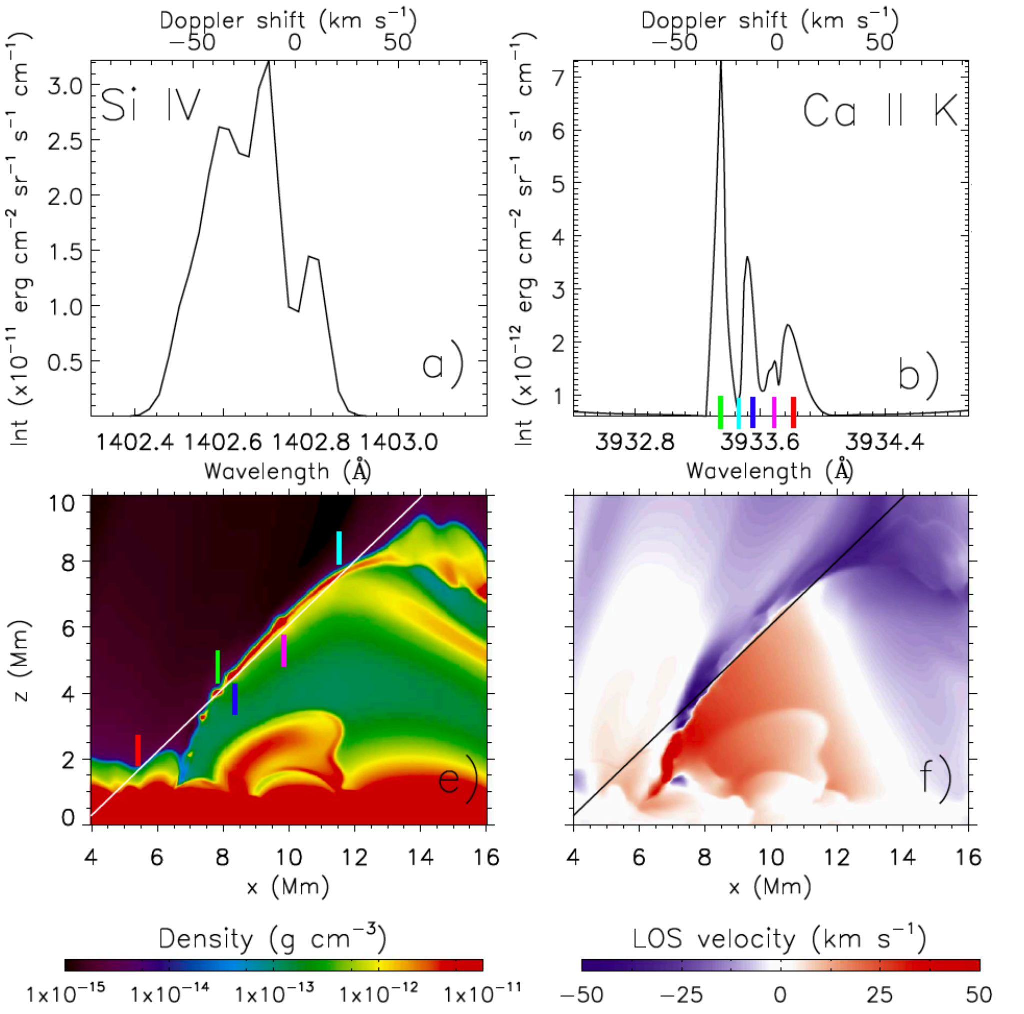
Modeling UV bursts: 2D experiments

- **Rouppe van der Voort et al. (2017)**

  - **Model**: Nóbrega-Siverio et al. (2017)

  - **Aim**: To exploit the capabilities of IRIS and SST/CHROMIS to study highly broadened line UV profiles with often non-Gaussian and triangular shapes and compare them with results from non-idealized numerical models

  - **Result**: Evidence of plasmoid instability in UV bursts in the low solar atmosphere supported by numerical experiments



Rouppe van der Voort et al. (2017)

Modeling UV bursts: 2D experiments

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- **Nóbrega-Siverio et al. (2018)**

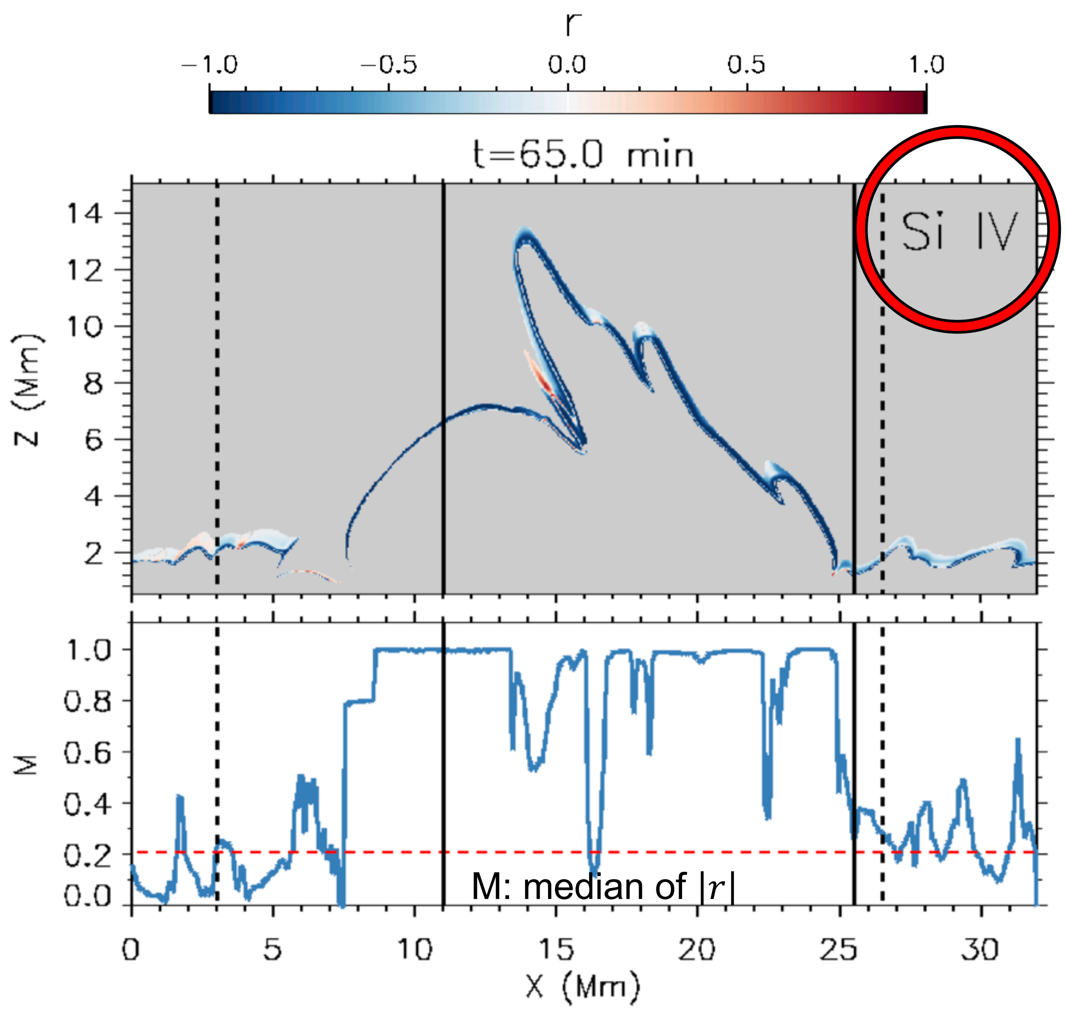
  - **Model**: Nóbrega-Siverio et al. (2017)

  - **Aim**: To study the NEQ ionization/recombination of Si IV and O IV

  - **Result**: The NEQ ionization has a massive impact on the reconnection site and the surge. The SE seriously underestimates the number density values

$$r = \frac{n_{SE} - n_{NEQ}}{n_{SE} + n_{NEQ}}, \; r \in [-1,1]$$

Gray mask: $\epsilon < 10^{-10}$ CGS



Nóbrega-Siverio et al. (2018)

Modeling UV bursts: 3D experiments

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- Addressing UV bursts from different theoretical perspectives

1D

2D

3D

Modeling UV bursts: 3D experiments

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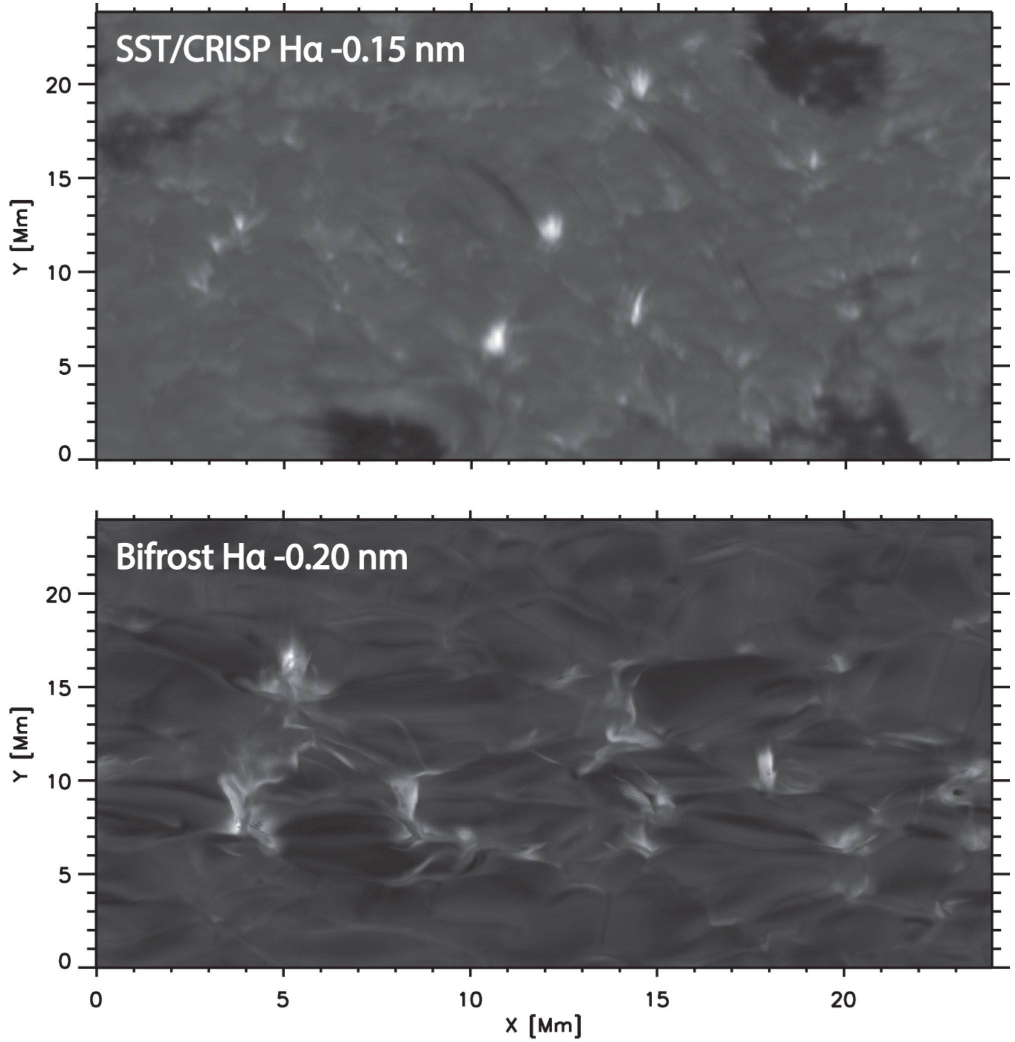
- **Hansteen et al. (2017)**

  - **Model**: Magnetic flux emergence experiment: non-twisted horizontal flux sheet emerges in a weekly magnetized corona using the Bifrost code (Gudiksen et al. 2011)

  - **Aim**: Getting new insights concerning EBs and UV bursts.

  - **Synthesis**:
    MULTI3D (Leenaarts and Carlsson 2009)
    RH1.5D (Pereira & Uitenbroek 2015)



Hansteen et al. (2017)

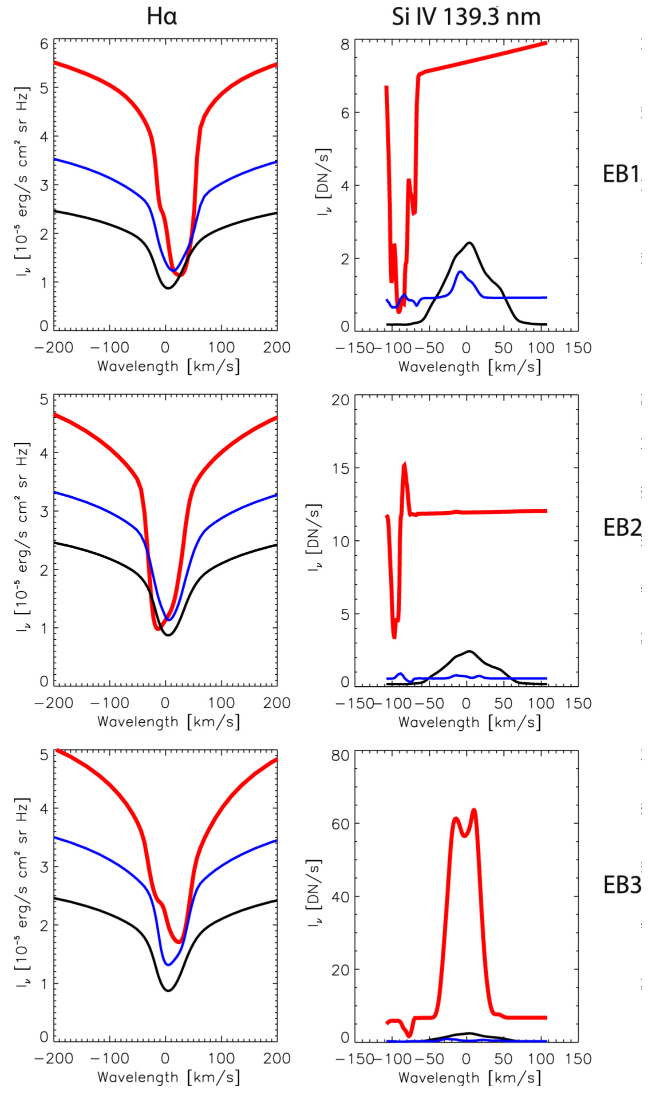
Modeling UV bursts: 3D experiments

- **Hansteen et al. (2017)**

  - **Results**:

    # Reconnection between emerging bipolar magnetic fields can trigger EBs, UV bursts and (nano/micro) flares.

    # First model that reproduced EB and UV burst profiles; however, not co-located.



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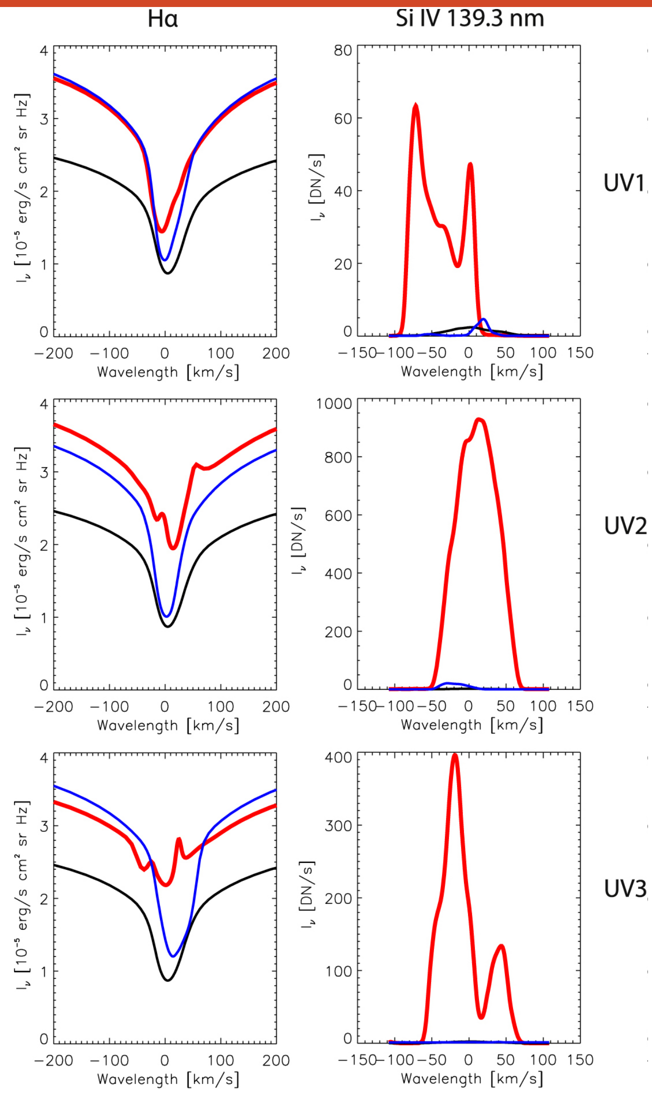


Hansteen et al. (2017)

Modeling UV bursts: 3D experiments

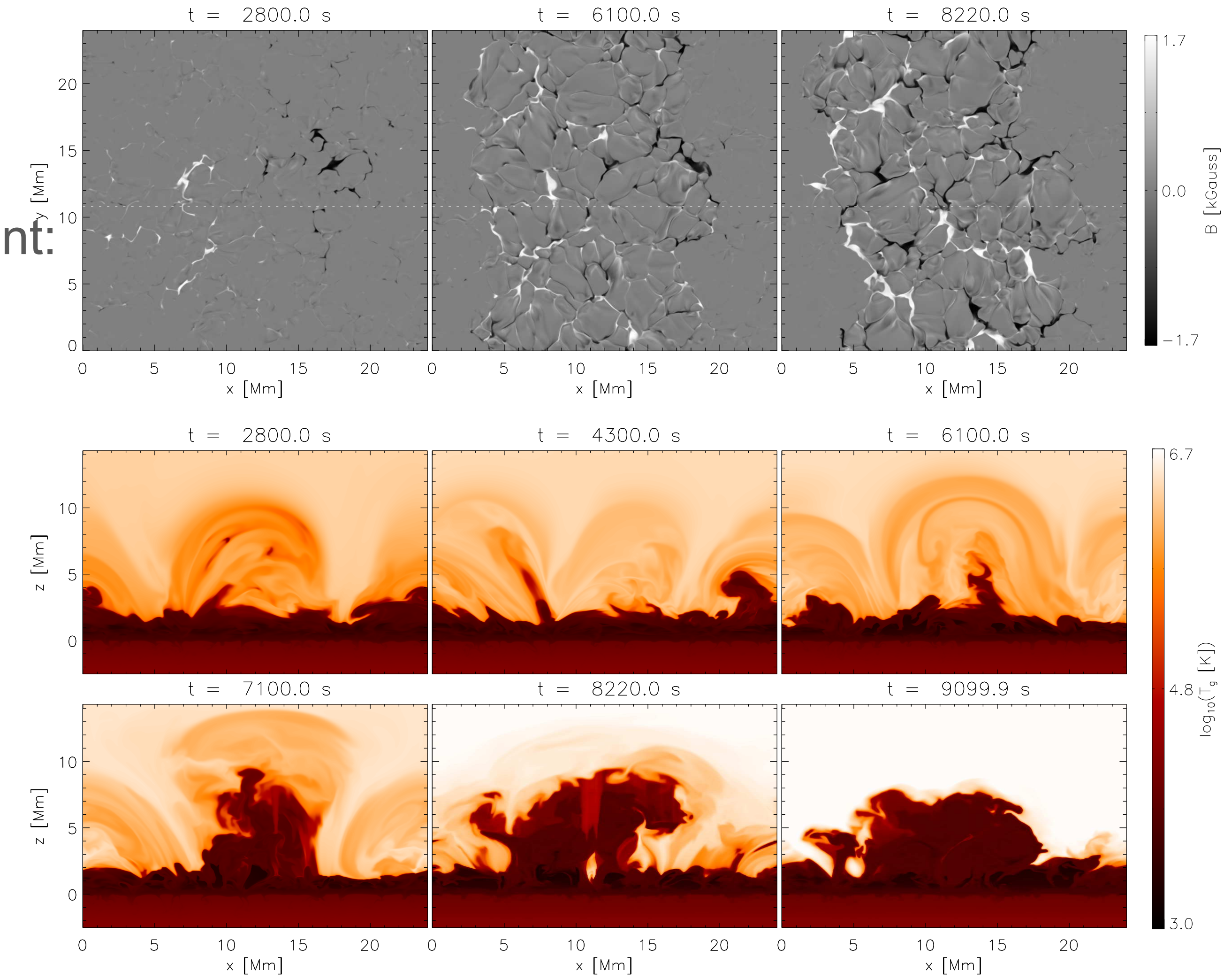
Rosseland Centre for Solar Physics

- **Hansteen et al. (2019)**

  - **Model**: Magnetic flux emergence experiment: untwisted horizontal flux sheet emerges in a strong magnetized atmosphere using the Bifrost code (Gudiksen et al. 2011)

  - **Aim**: Getting new insights concerning EBs and UV bursts.

  - **Synthesis**:
    MULTI3D (Leenaarts and Carlsson 2009)
    RH1.5D (Pereira & Uitenbroek 2015)



Hansteen et al. (2019)

Modeling UV bursts: 3D experiments

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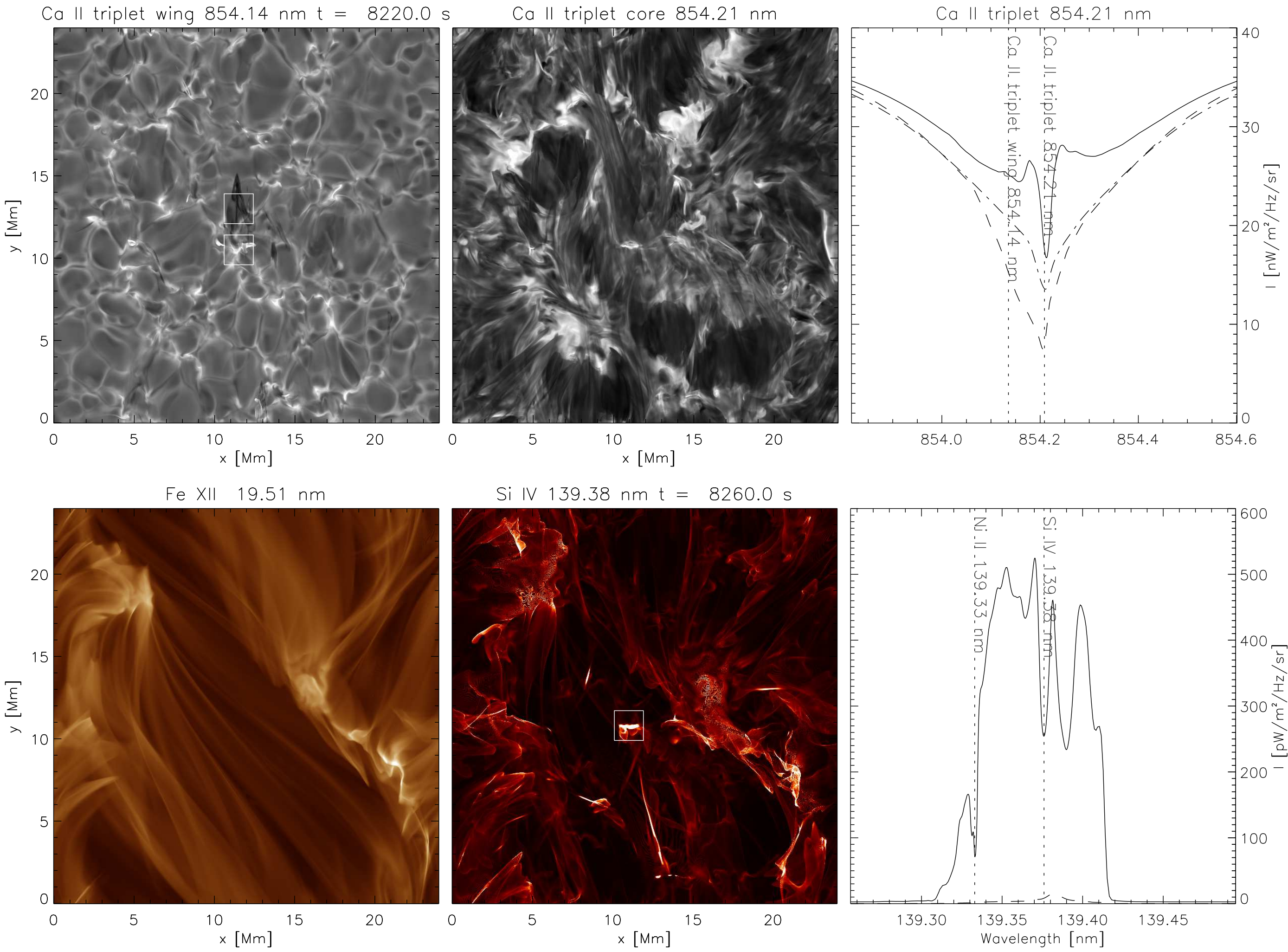
- **Hansteen et al. (2019)**

  - **Results**:

    # EB and UV burst profiles are found co-located as result of reconnection in a long current sheet that extends through the chromosphere

    # No compelling reasons to assume that UV bursts occur in the photosphere

    # Surges are also found related to the EB and UV burst.



Hansteen et al. (2019)

Conclusions

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- **UV burst models**

  - have allowed us to study essential physical mechanisms involved in the UV burst formation

    (non-stationary magnetic reconnection, plasmoid instability, heating,…)

  - have found many striking agreements with observations

    (relation to magnetic flux emergence, EBs and surges, explanation)

Conclusions

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- **Forward modeling**
  - links theory to observations via the spectral synthesis of our numerical data
  - is essential to provide theoretical support and interpret observations