Multi-thermal nature of spicular downflows

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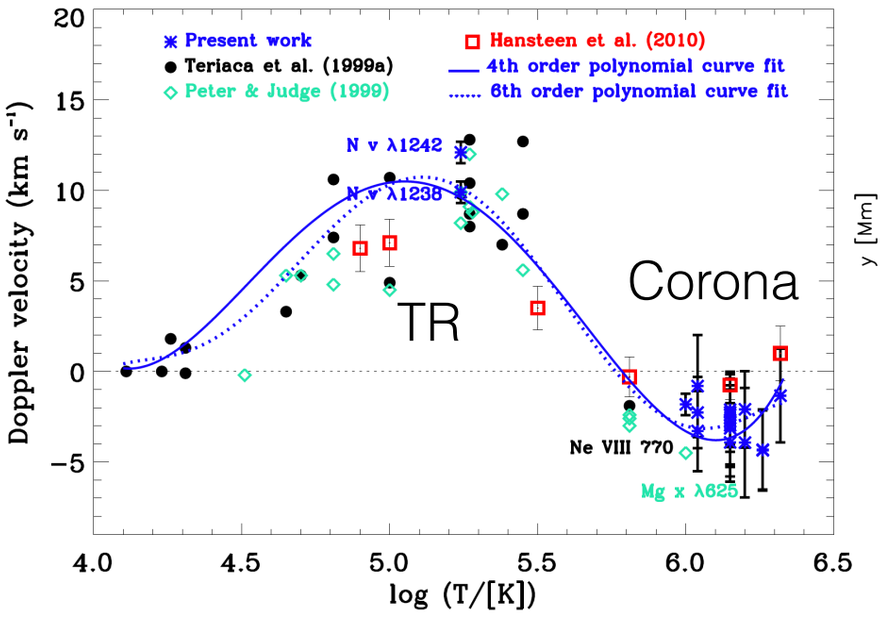
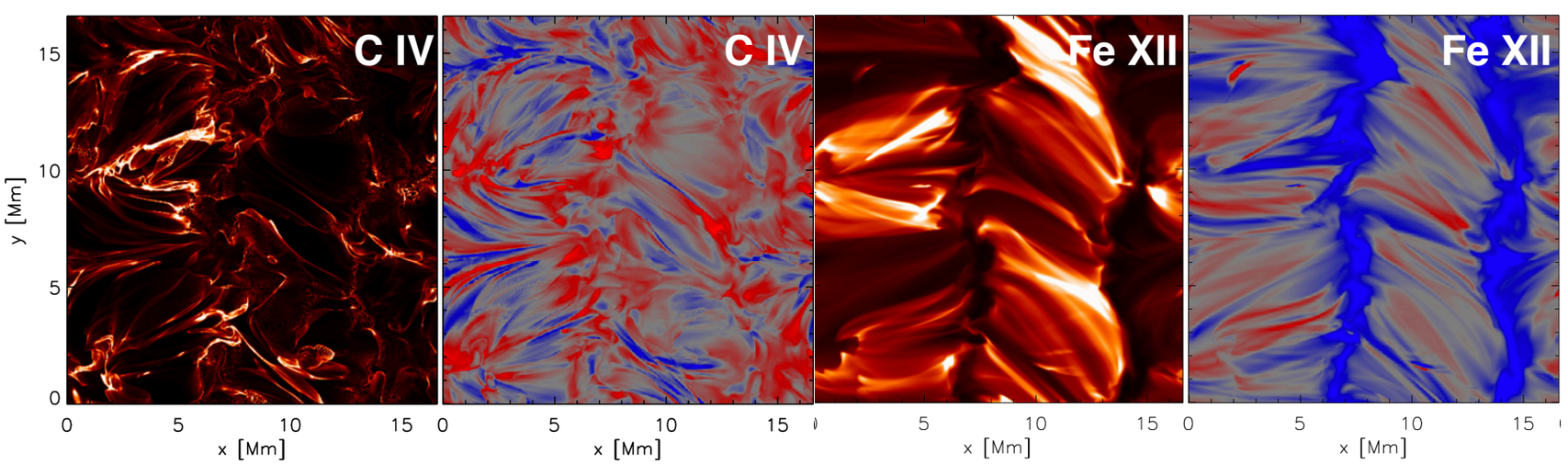
Downflows in the Transition Region (TR)



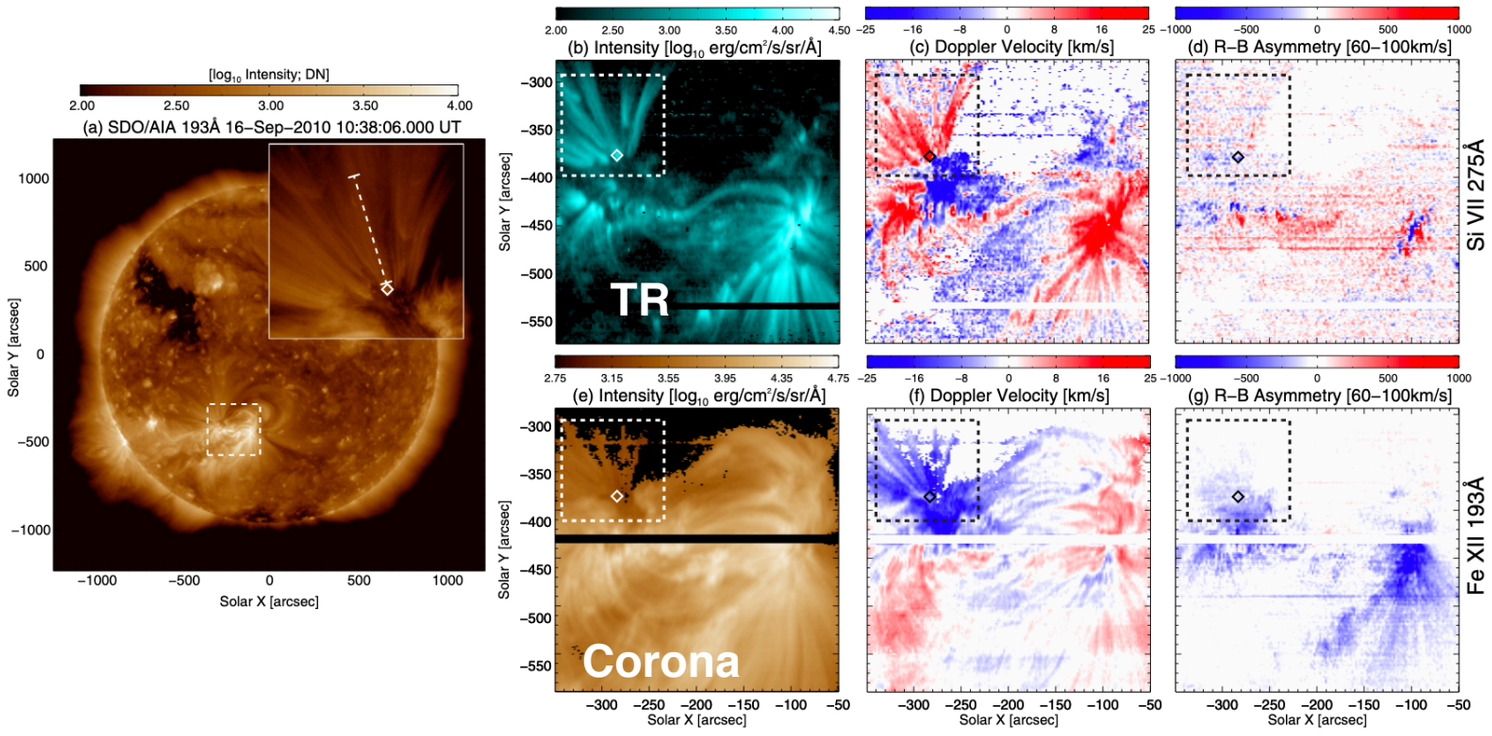


Average TR Dopplershift ~7 km/s and Coronal Dopplershift ~ -2.7 km/s

Hansteen et al. (2010).
Also see, Peter et al. (2006)

Dadashi et al. (2013); see also Peter and Judge (1999); Peter et al. (2004)

Rapid Episodic heating causing bi-directional flows

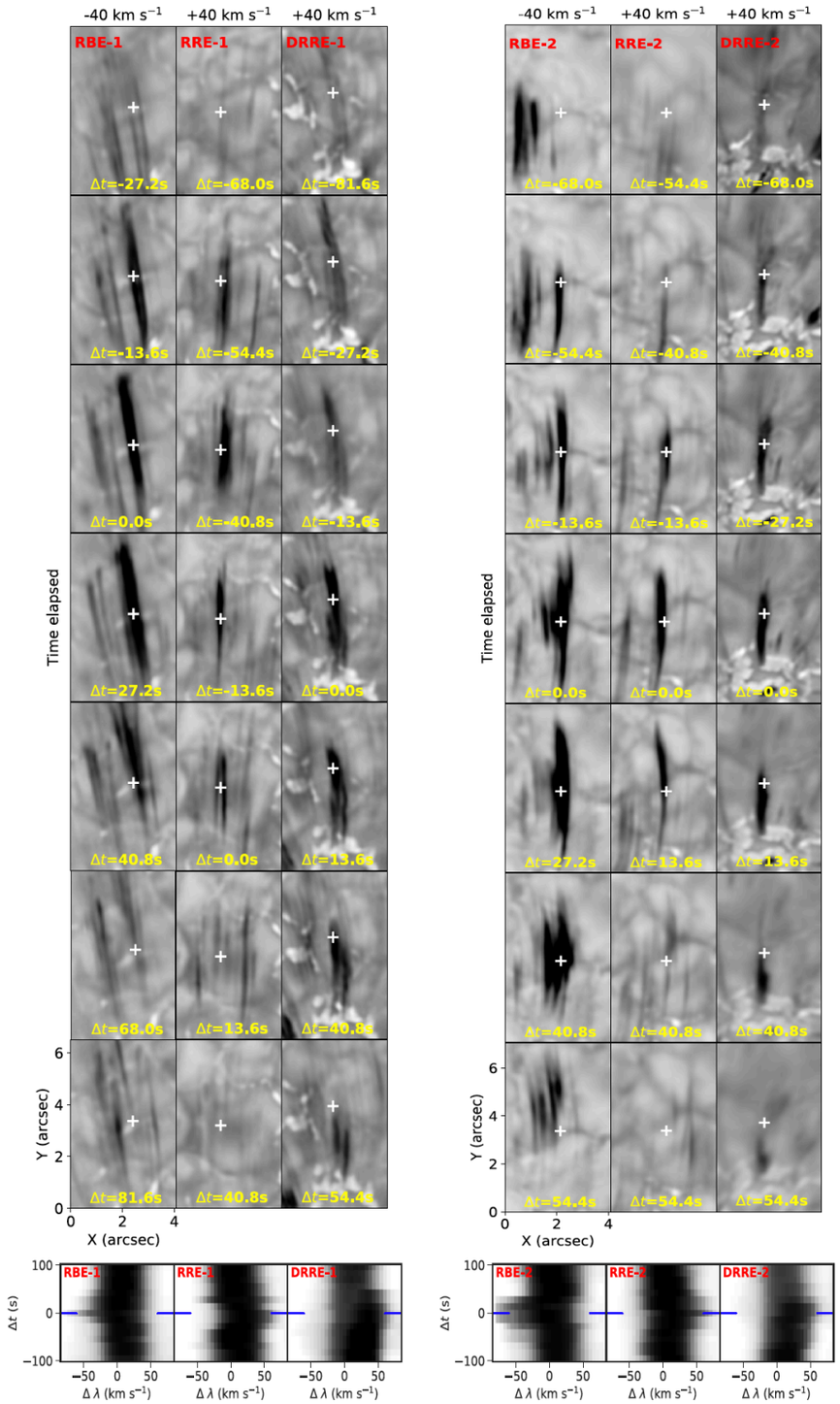


Downflowing spicular material

McIntosh et al. (2012)

- Agrees with Pneumann & Kopp (1977,1978), Athay & Holzer (1982).
- **But lacks unambiguous relation with spicules seen under high resolution.**

But what about the chromosphere?

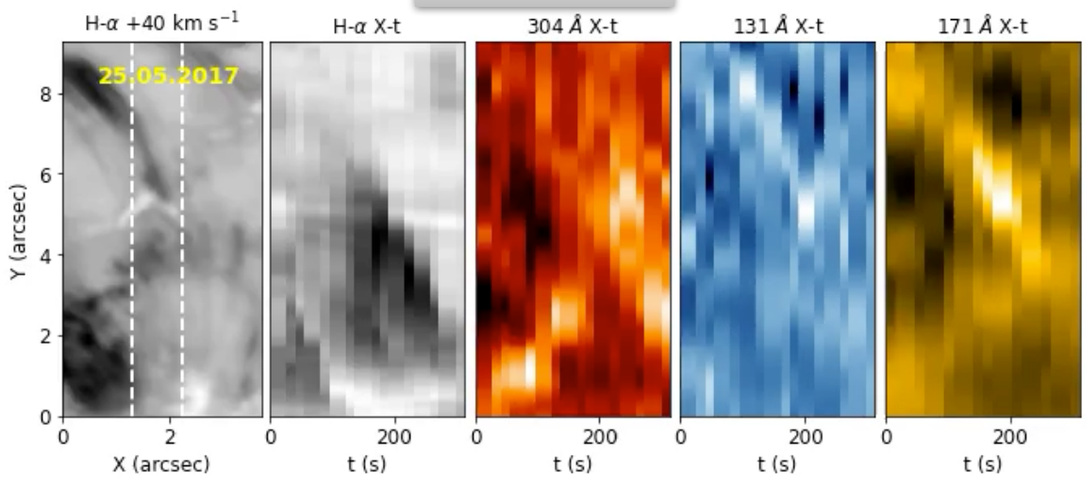


- **Bose et al. (2021a)** found ubiquitous presence of rapid downflows in the solar chromosphere.
- Statistical analysis performed on over 40,000 on-disk type-II spicular features.
- They are found to be the ***downflowing*** counterparts of the traditional rapid red (blue) shifted excursions (RBEs/RREs).
- Termed as **downflowing RREs**.

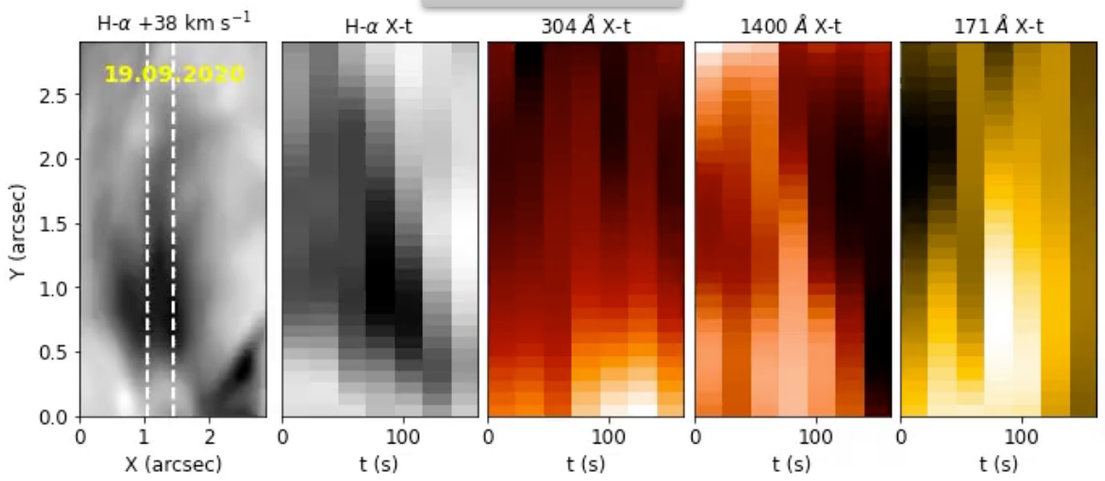
Bose et al. 2021a, also see Rutten et al. (2019)

Multi-thermal nature

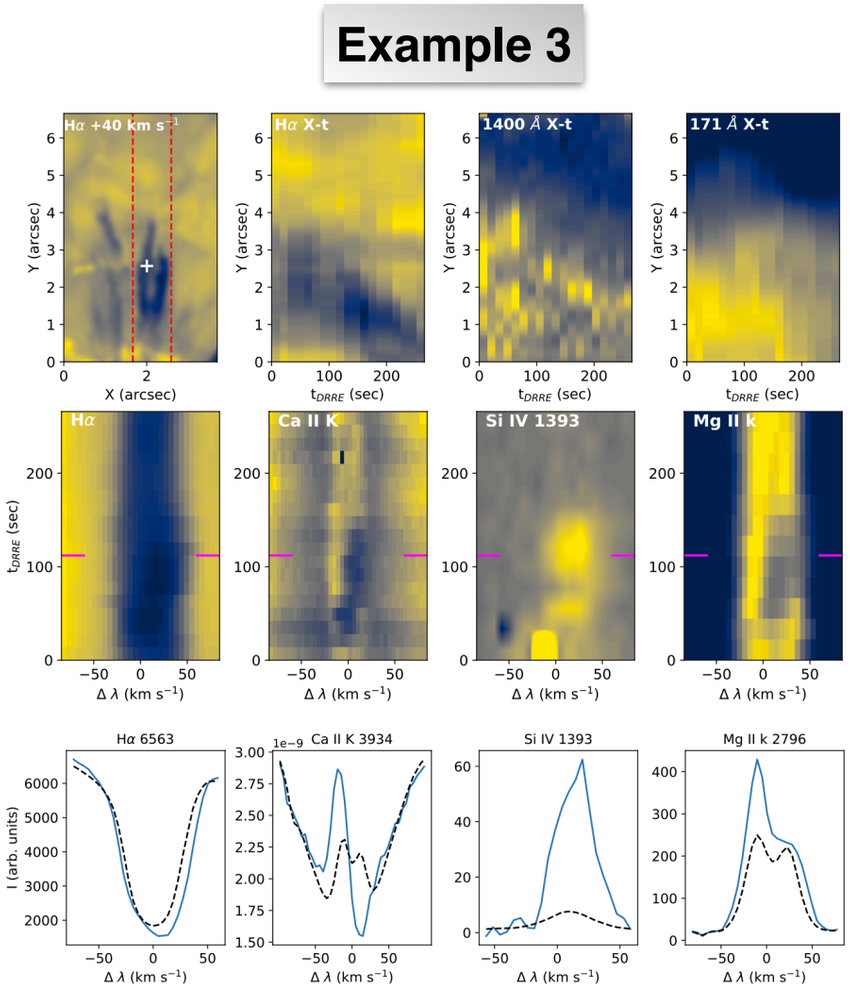
Example 1



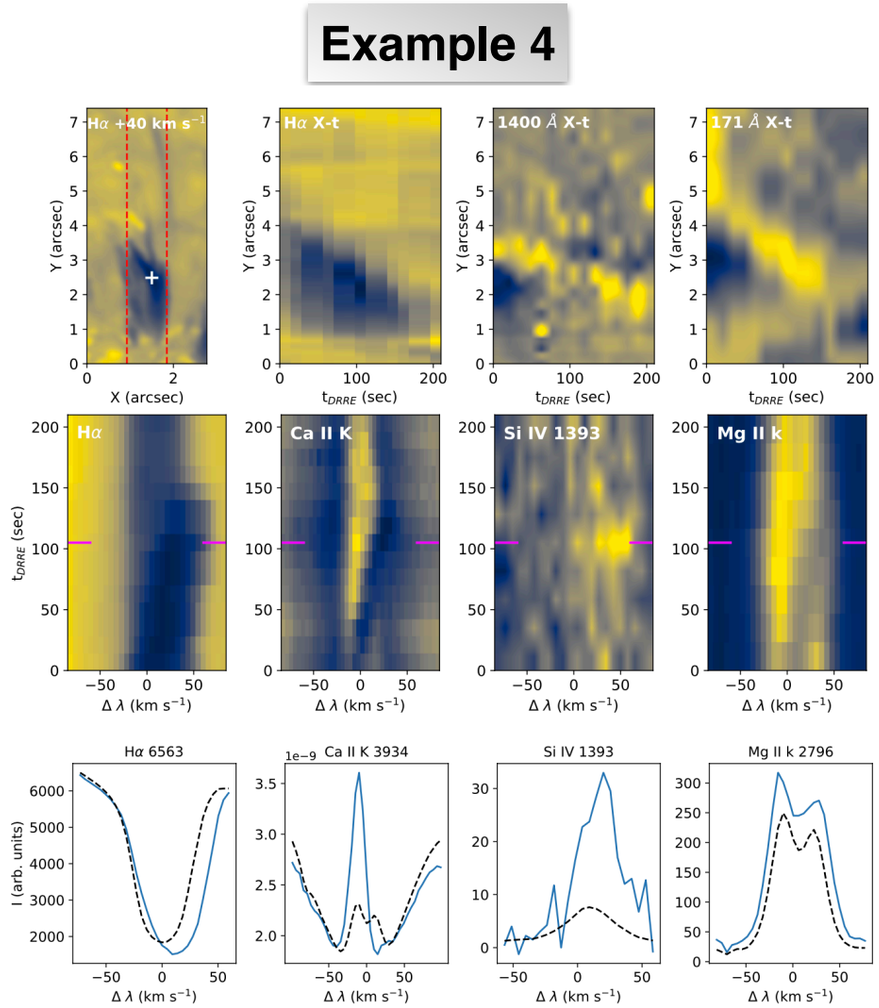
Example 2



Example 3

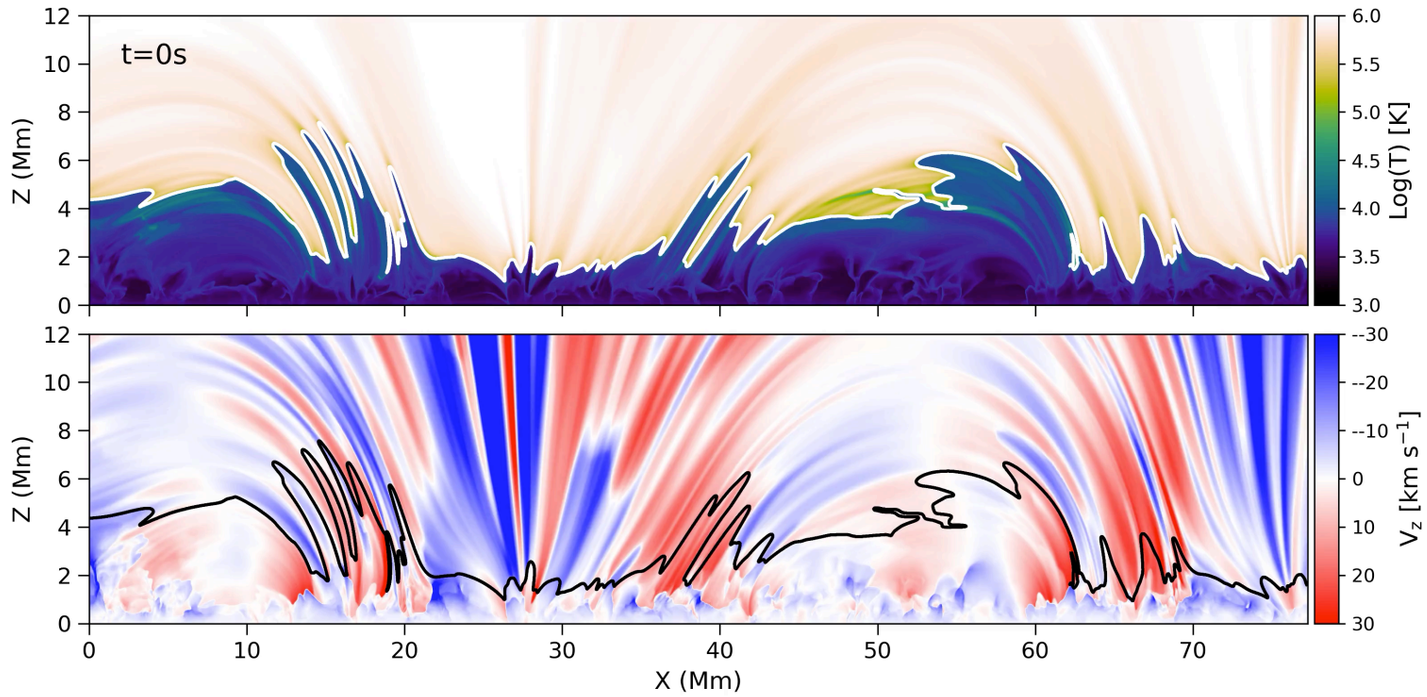


Example 4

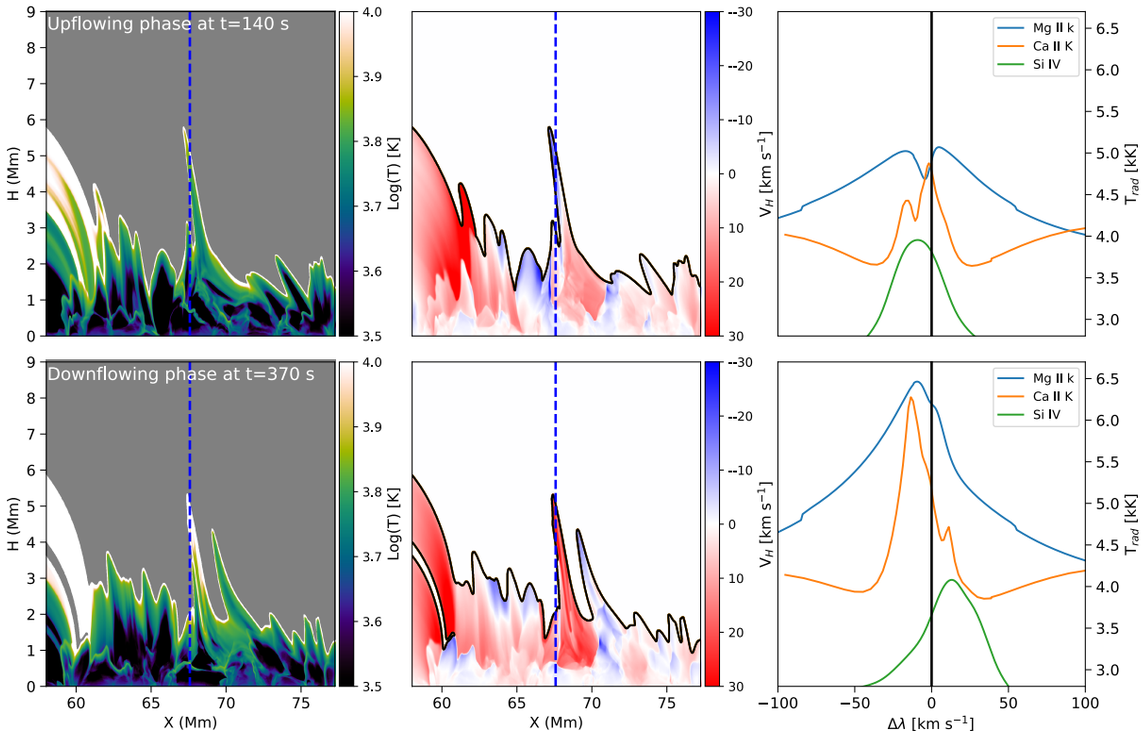


Comparison with an MHD simulation

Downflows following upflowing type-II spicules



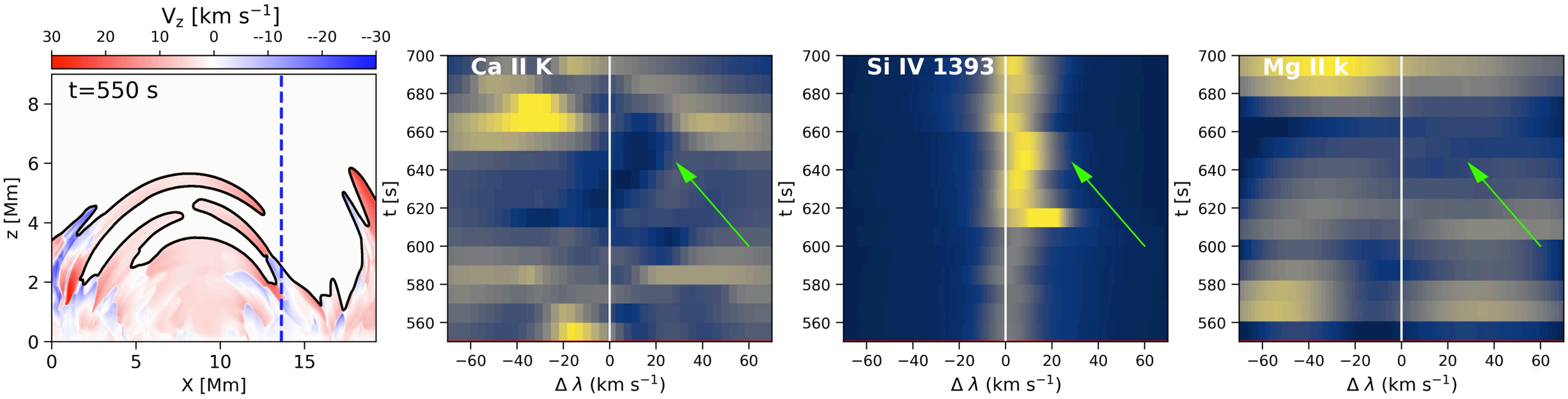
Martínez-Sykora et al. 2017



Bose et al. 2021b, arXiv: 2108.02153

Comparison with an MHD simulation

Downflows along a loop



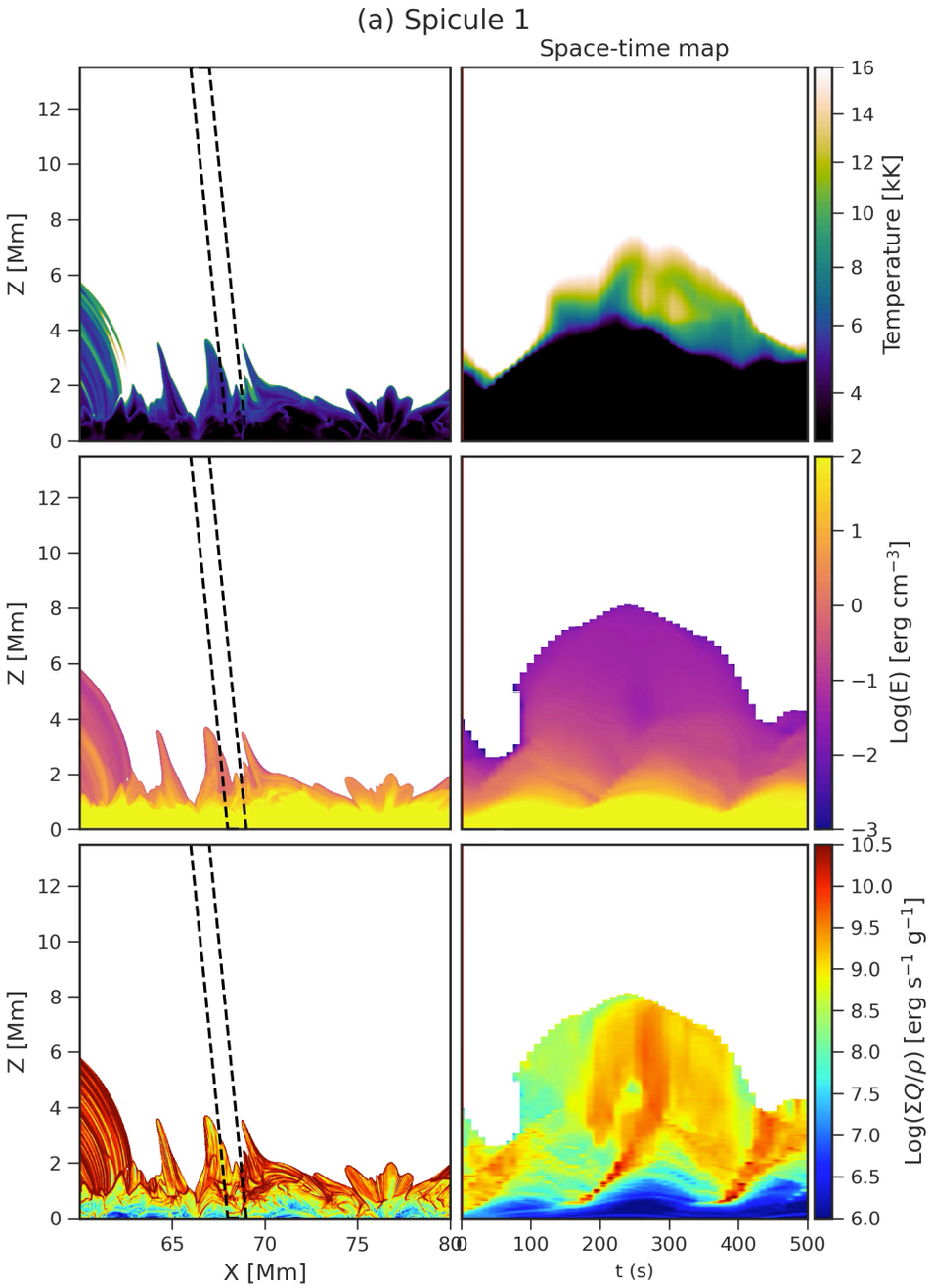
Bose et al. 2021b, arXiv: 2108.02153

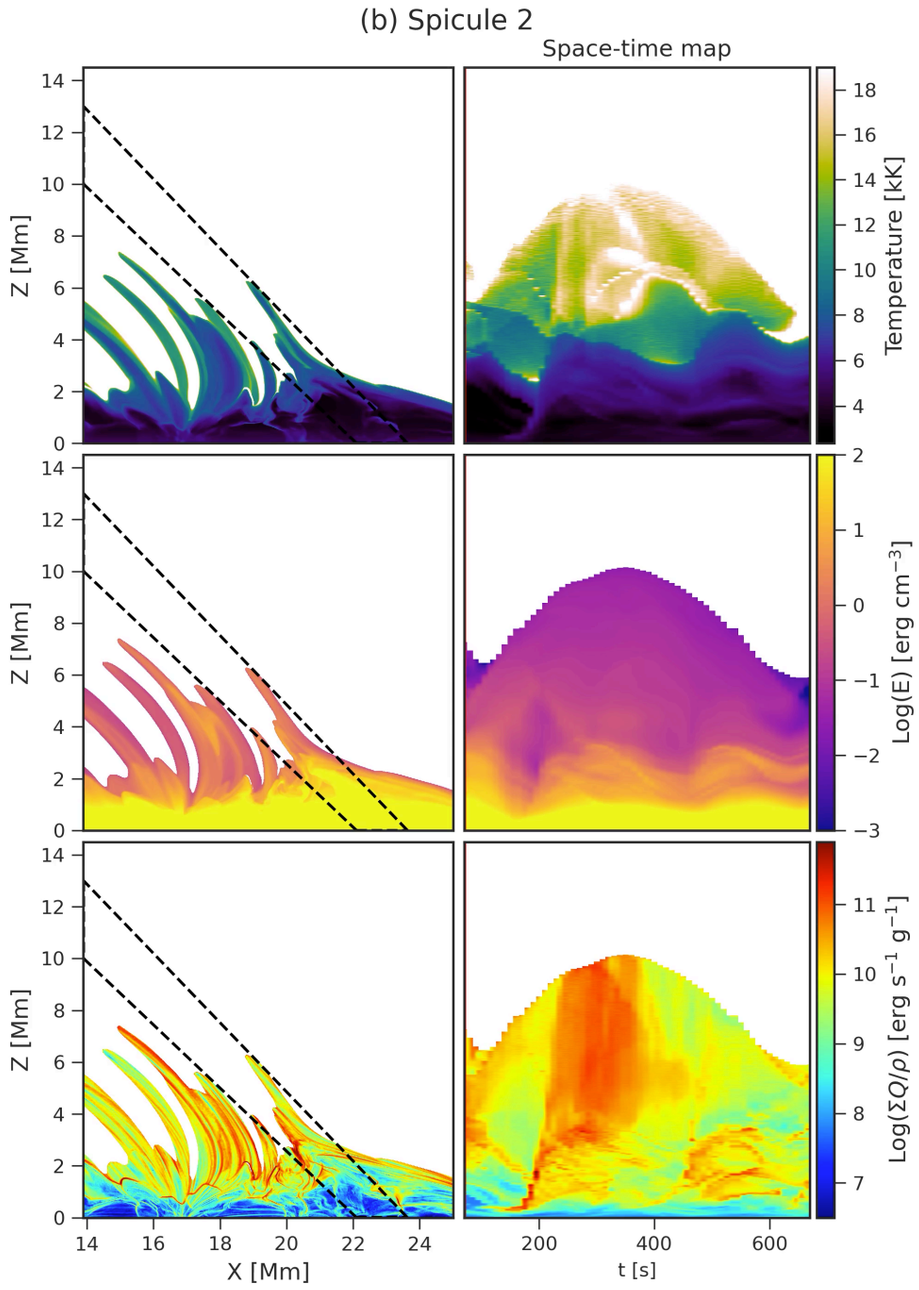
- Two major possibilities —

1. Downflows and up-flows are co-located.

2. Downflows *spatially displaced* and forms a part of a loop.

Solar atmospheric heating





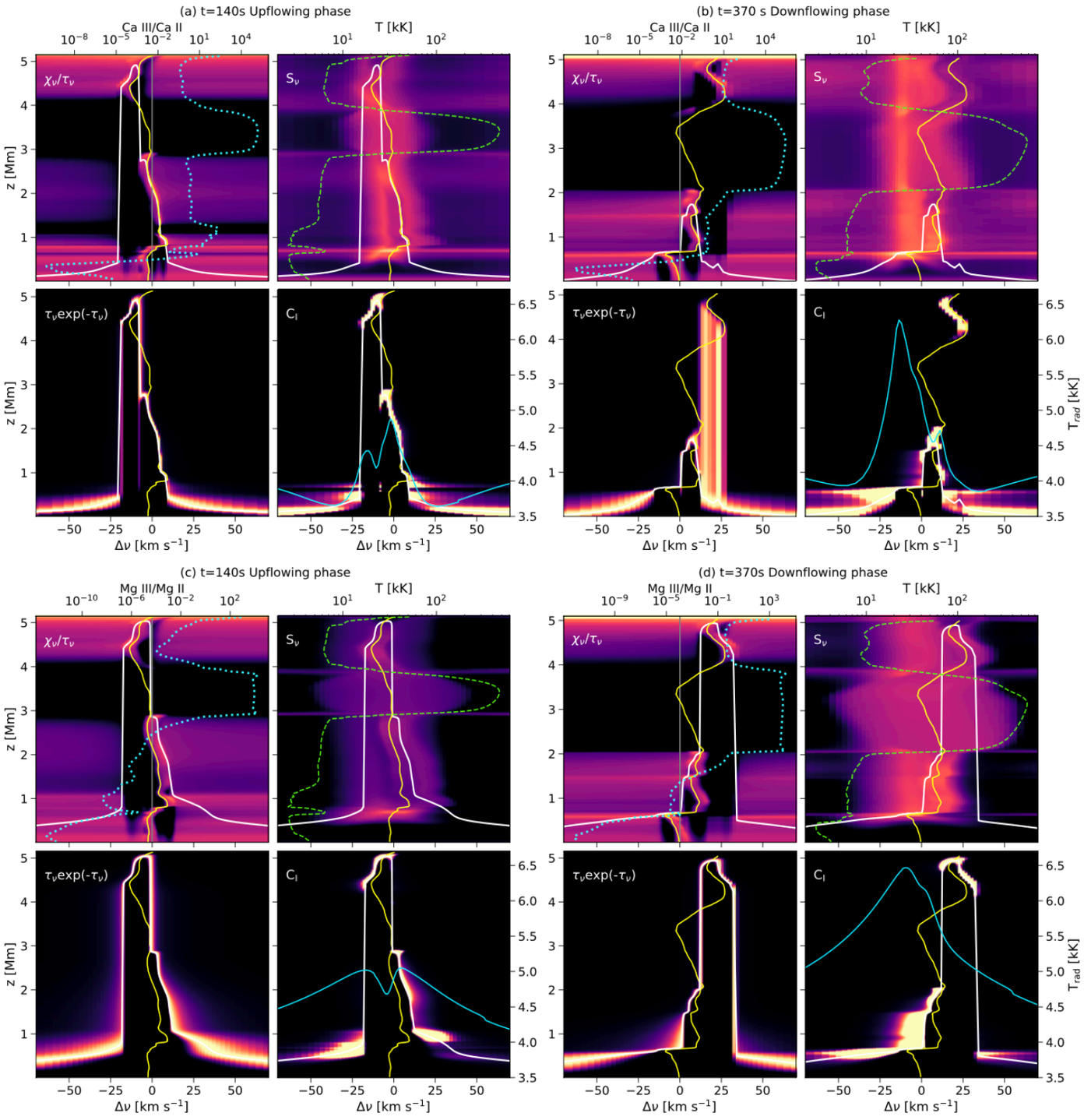
- ΣQ = Qjoule + Qamb + Qvisc + Qspitz +Qgenrad
- Downflows are found to be **hotter by 2—4 kK** in comparison with the upflows.
- **Ambipolar diffusion (Qamb)** plays a dominant role in heating.

Key findings and conclusions

- Ample occurrences of downflowing RREs in *different* datasets.
- Wide thermal coverage spanning the chromosphere to corona.
- Dopplershifts of the TR counterparts of downflowing RREs comparable with the average red-shifts observed in the TR.
- Distinctive match between simulations and observations.
- Ambipolar diffusion causes heating of the solar atmosphere during the downflows.

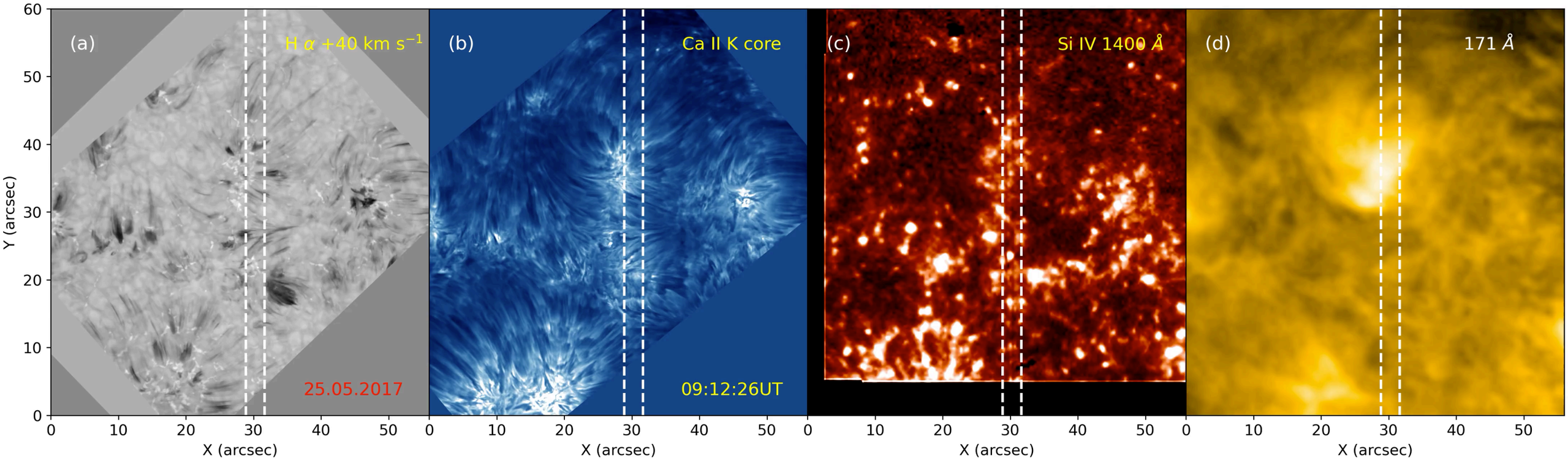
Extra slide

Contribution function analysis



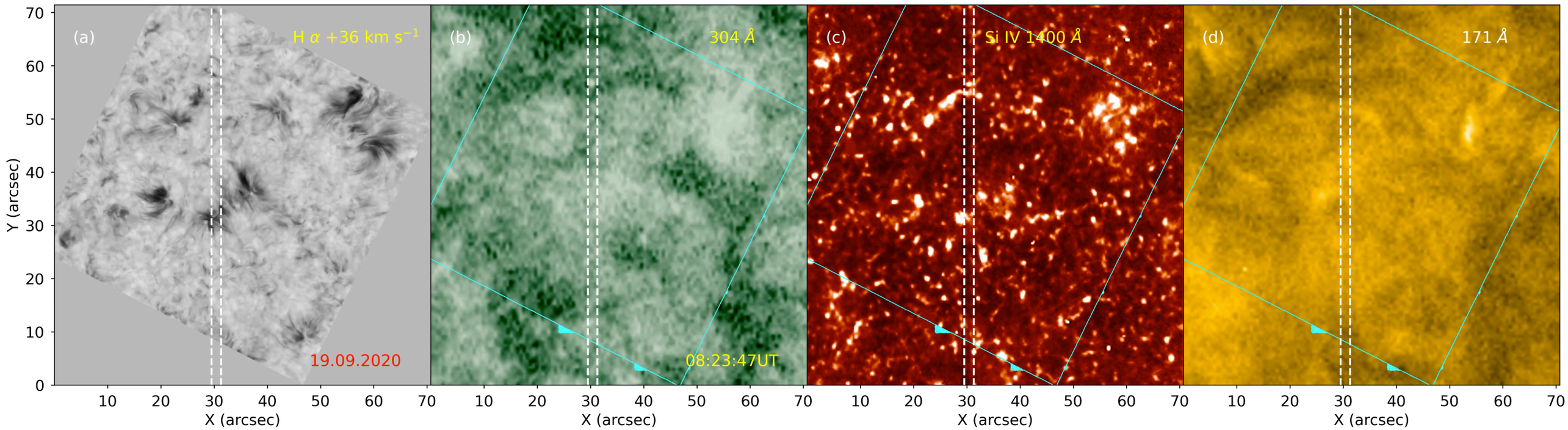
Observations— dataset 1

Enhanced network observed on 25.05.2017



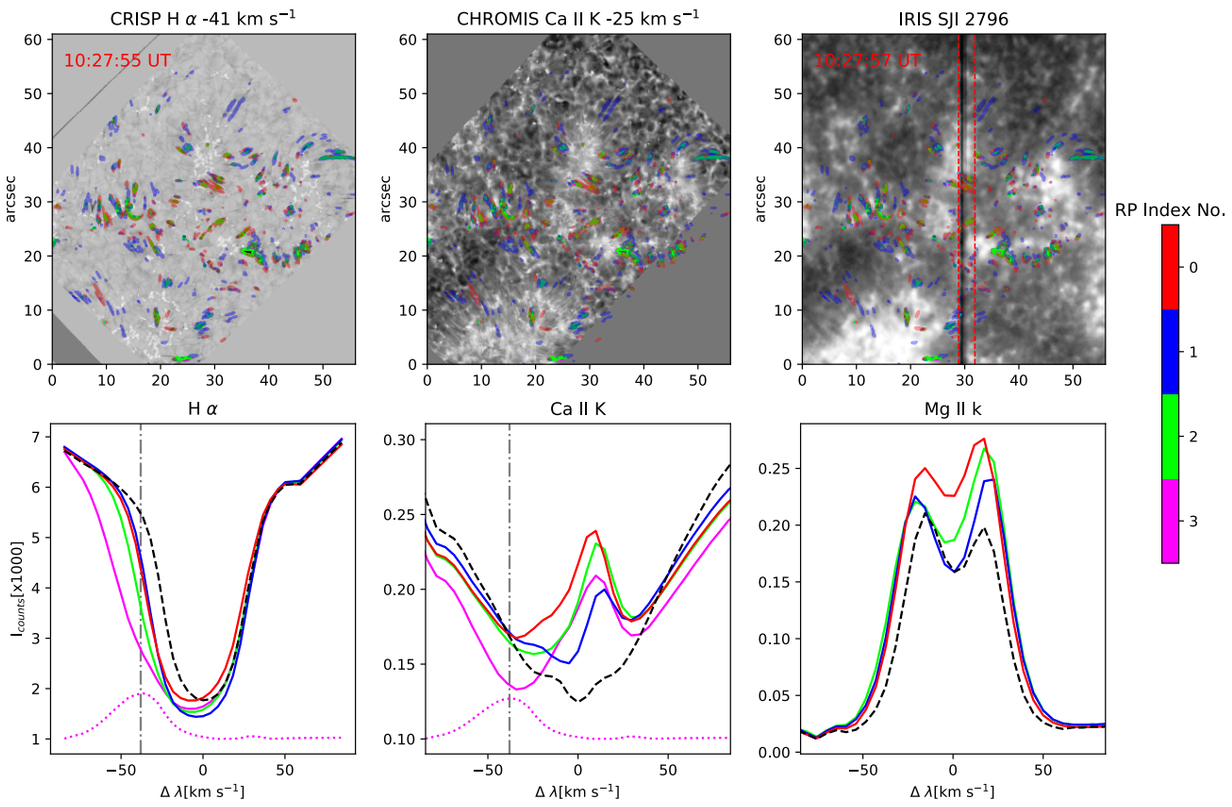
Observations— dataset 2

Quiet Sun observed on 19.09.2020

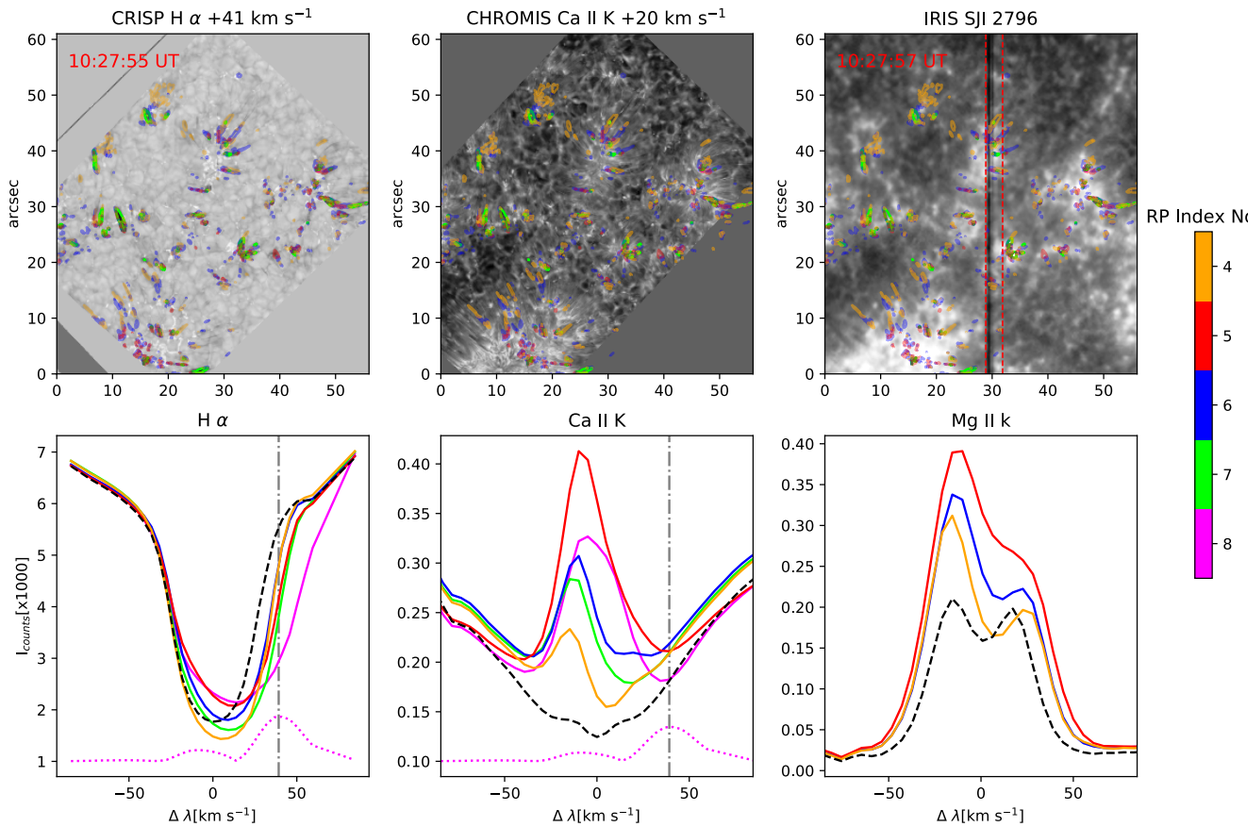


Heated returning counterparts?

RBEs



RREs/Downflowing RREs



Bose et al. (2019b)

Enhanced K2/k2 peak⟶Correlation with enhanced gas temperature (**Leenaarts et al. (2013), Bjørgen et al. (2018), Leenaarts et al. (2018)**)