Statistical analyses of IRIS spectra to determine properties of supersonic downflows and IRIS bursts

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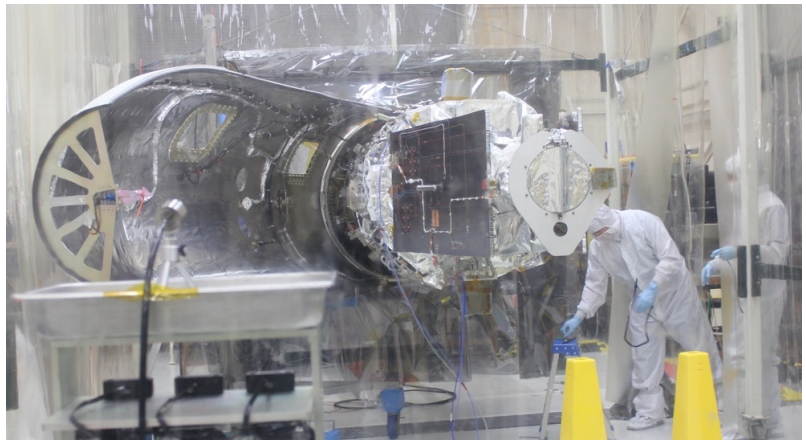
IRIS Data



IRIS:

- 2 spectral regions: FUV (1332-1406 Å) and NUV (2785-2835 Å)
- spectrograph with many observing modes (exposure times, raster length, pointing, ...)

Launched in 2013 → huge database of observations (> 60 TB)

→ ideal for statistical studies and thus machine learning

Science Questions

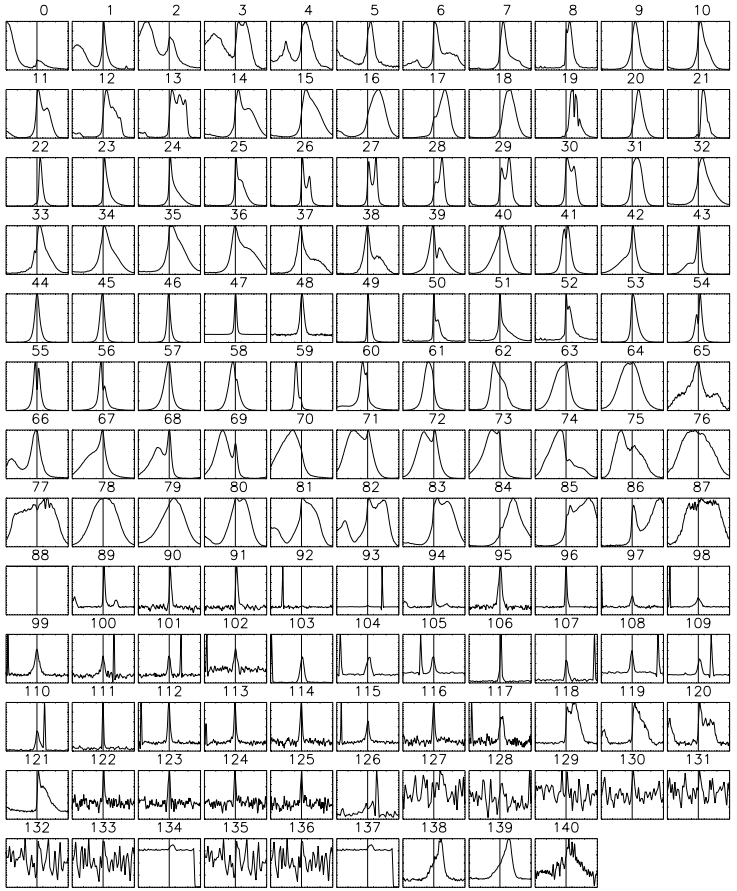
Examples of questions that can be answered with statistical studies:

- Do all flares share similar physics (meaning similar spectra)? Panos et al. 2018
- What are the velocities and densities of supersonic flows in the solar atmosphere?
- Do bursts in the lower solar atmosphere contribute to heating the corona?

IRIS Data

Analysis:

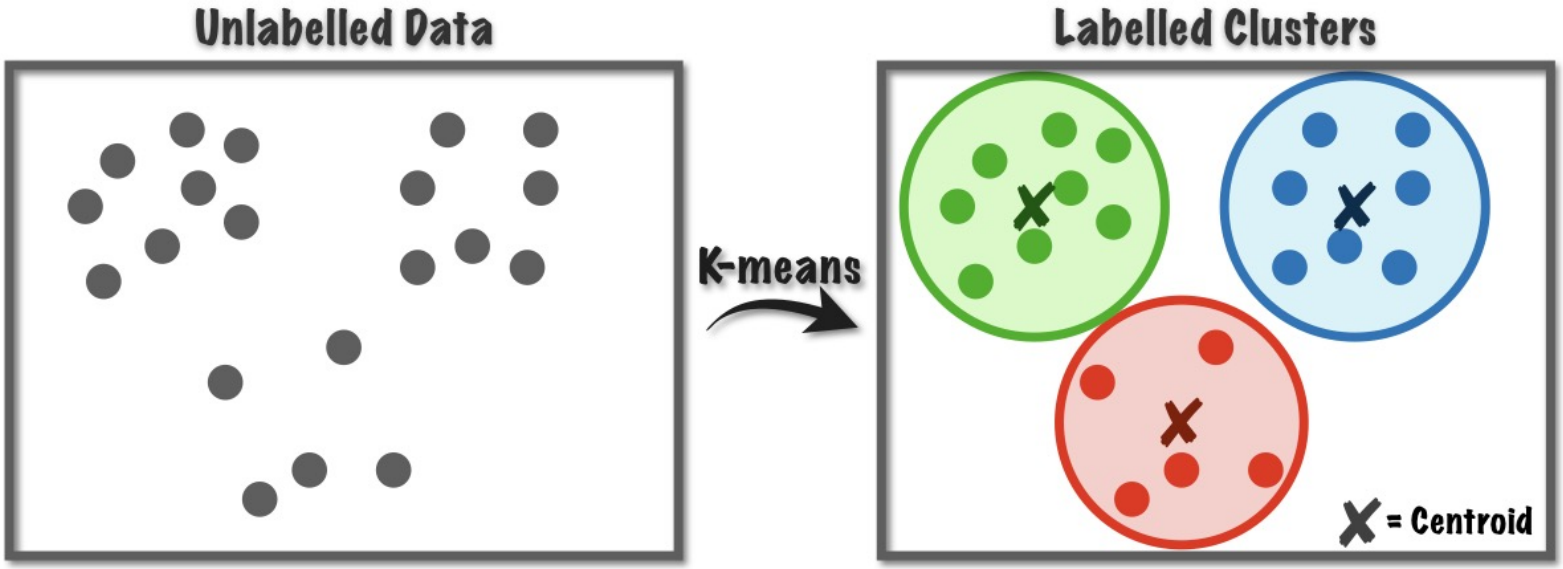
- we defined 200 types of different spectra
- we classified every IRIS spectrum to its most similar “type” (which takes about a month to run, considering the size of the IRIS database)
- afterwards, we can pick interesting ”types” of spectra and have large statistics for science.



How to classify spectra? k-means

Clustering algorithms can cluster similar data, i.e. find similar-looking spectra.

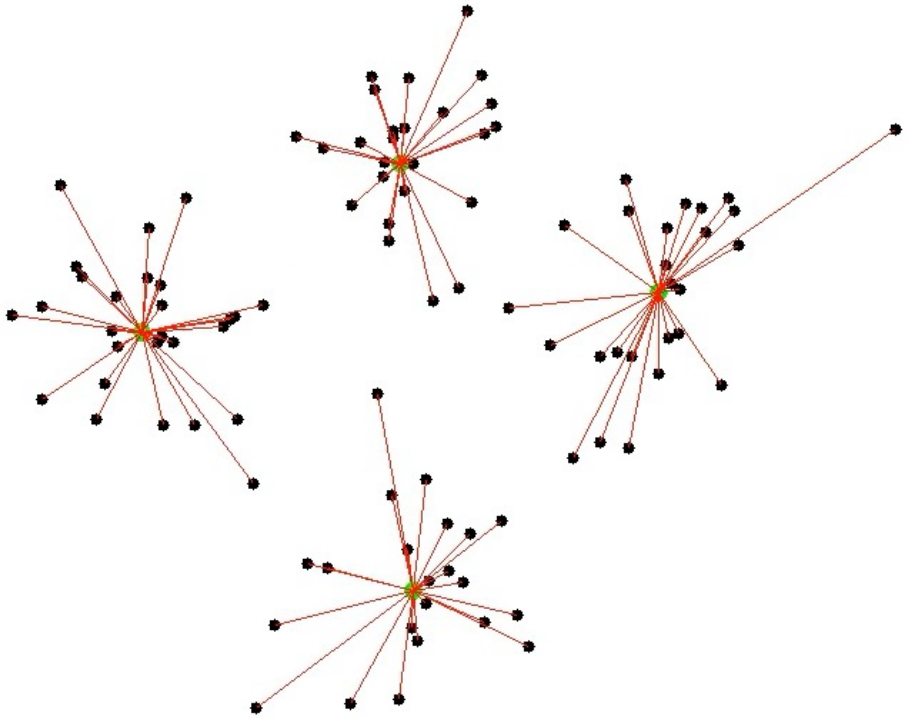
Each point could represent a different spectrum here.



k-means is a method to find clusters automatically
the “k” defines the number of clusters.

image source: https://towardsdatascience.com/k-means-a-complete-introduction-1702af9cd8c

Clustering of data

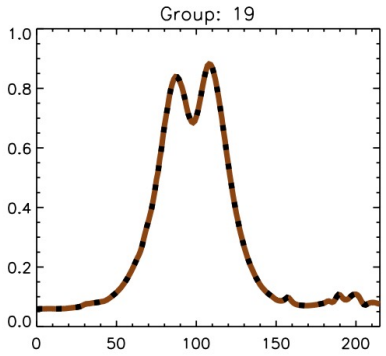


k-means is a method to find clusters automatically
the “k” defines the number of clusters.

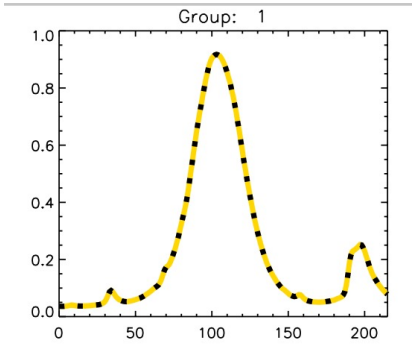
image source: https://shabal.in/visuals/kmeans/6.html

k-means with spectra: simple example

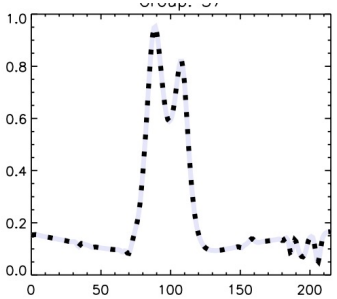
Assume there exist 2 groups of spectra:



and



Now go through each IRIS spectrum, calculate x=(group1-spectrum)^2 and y=(group2-spectrum)^2. If x < y then spectrum belongs to Group 1.



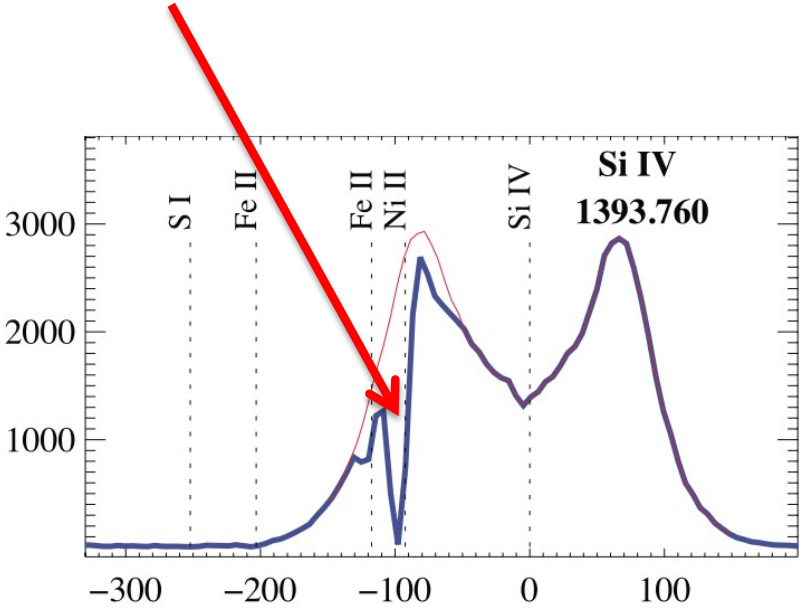
x=0.5
y=2
=> more similar to group 1

Analysis of IRIS bursts

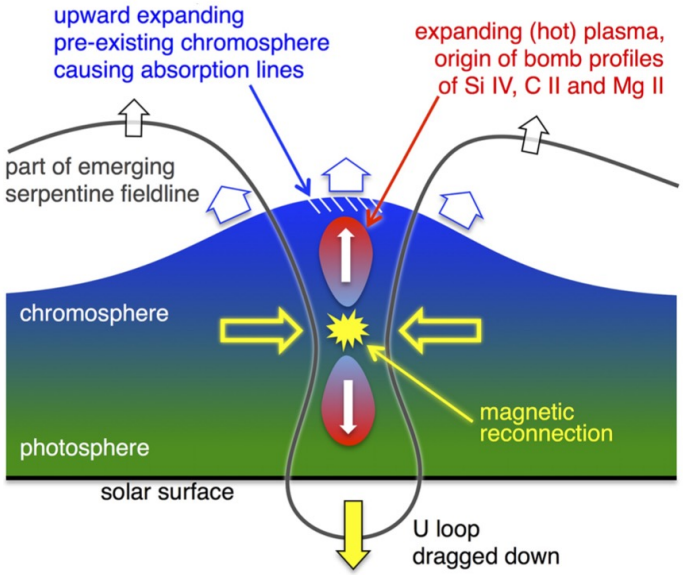
application: IRIS bursts

- first reported by Peter et al., Science, 346, 2014
- open questions: statistics, multi-line behavior, influence on coronal heating

spectra:
absorption lines superimposed on hotter lines

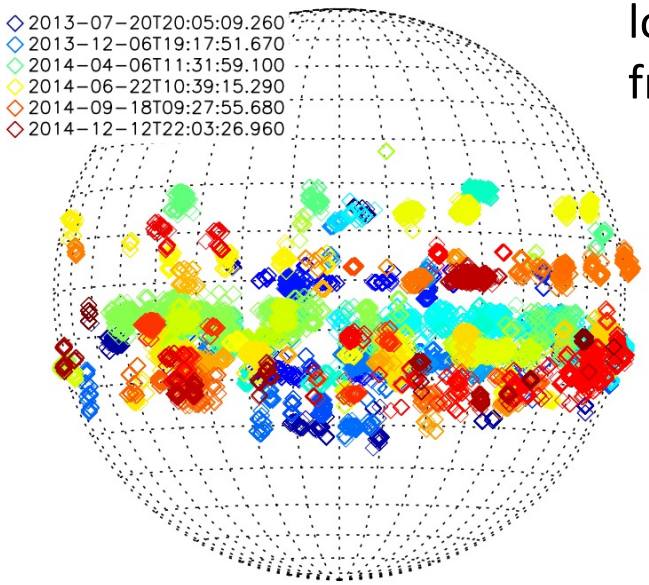


interpretation:
reconnection in the low atmosphere driving plasma flows



figures from Peter et al. 2014

Analysis of IRIS bursts



locations of all identified burst spectra from 2013+2014

Analyzed all 2013+2014 observations, classified 10^9 spectra to identify bursts.

Results:

- about 8% of obs. contain bursts, about 0.01 % of all IRIS spectra are bursts
- statistics on 101337 bursts

Analysis of IRIS bursts

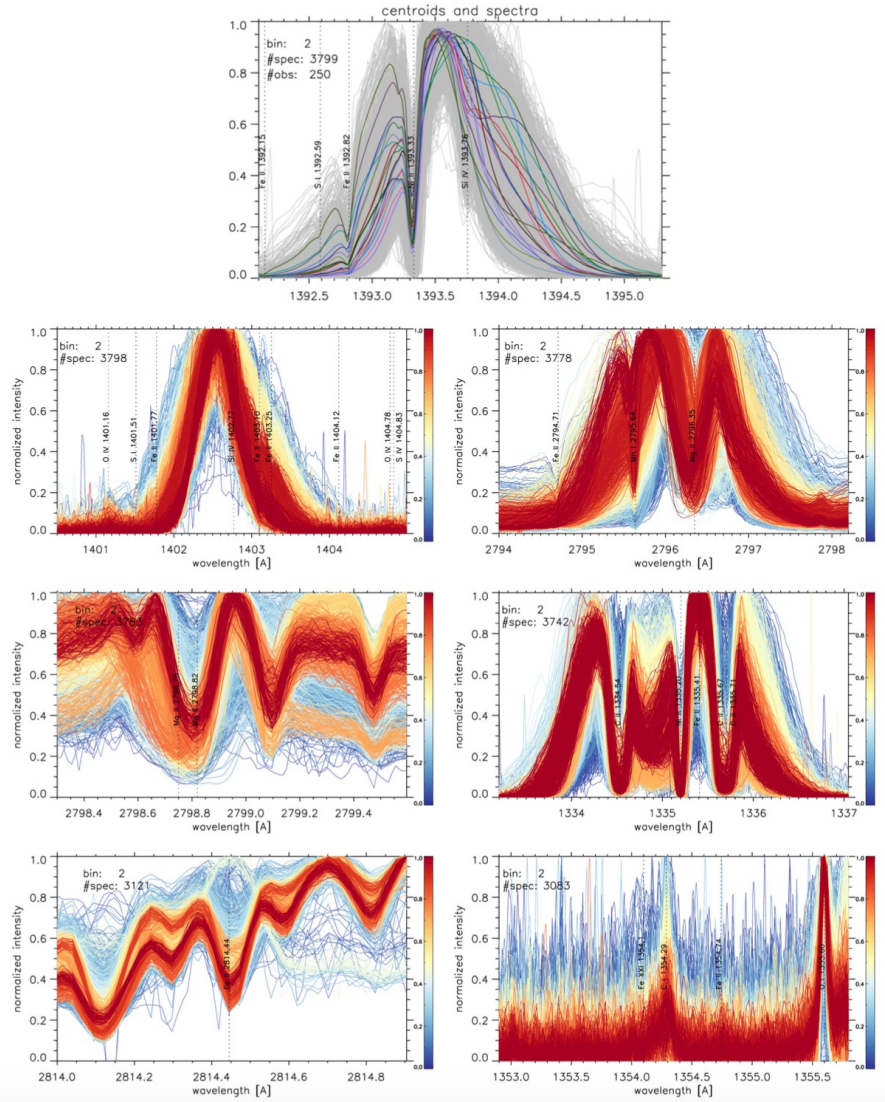
Results:

- multi-line behavior (constraints for modeling)

- IRIS bursts are statistically visible with similar properties and timings in the spectral lines Mg II, C II, and Si IV, but invisible in Fe XXI.

- no clear response to bursts in hot AIA passbands (94, 131, 171, 193, 211, 304, 335) => lower-atmospheric phenomenon.

- dataset is public and has been used for follow-up studies (Nelson & Kleint, 2022a, 2022b)

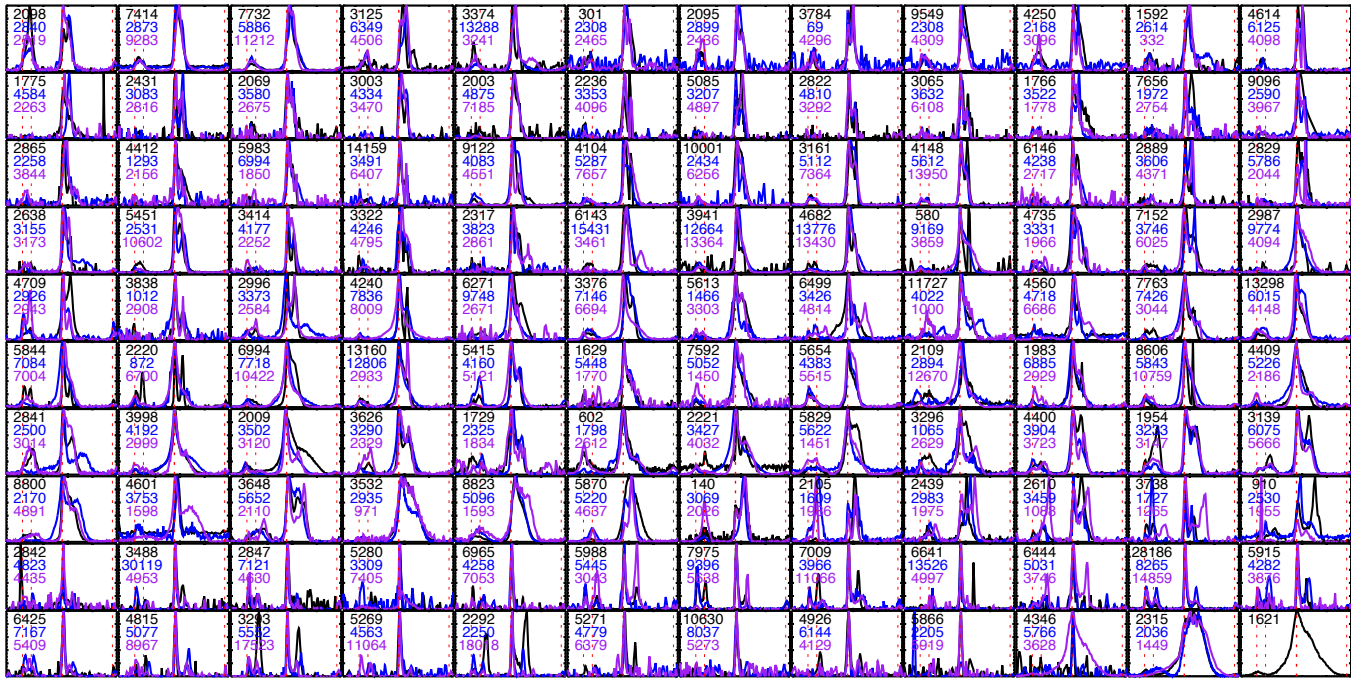


co-occurring spectra for a selected type of burst spectra (top panel)

Analysis of IRIS downflows

Analysis:

- similar to the burst study, but with different types of spectra. Analyzed all 2013-2018 observations.



Results:

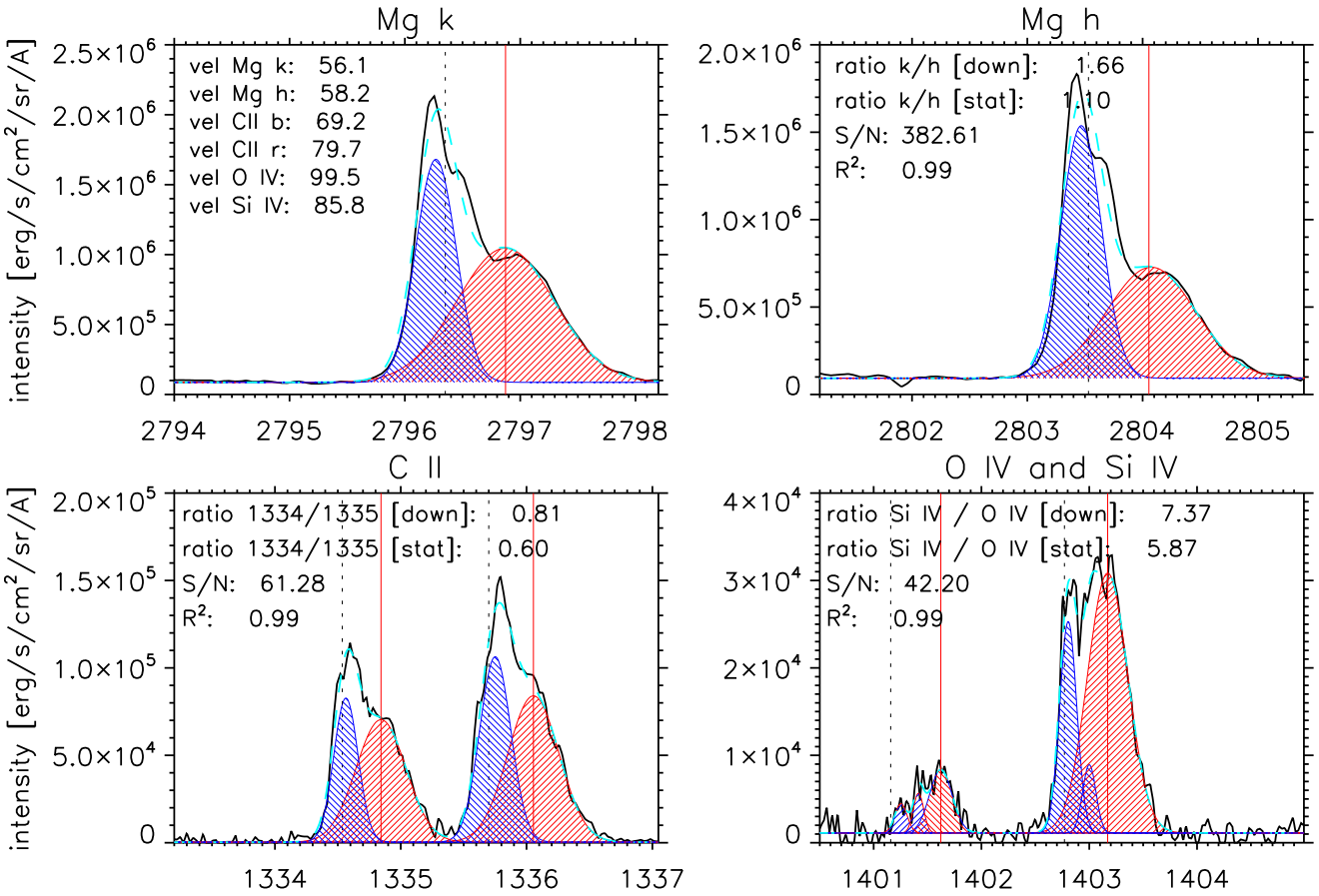
- about 15% of obs. contain downflows: found 1.8 million downflow spectra

Kleint et al., in prep.

Analysis of IRIS downflows

Analysis:

- identifying the downflow reliably is not so simple due to multiple components

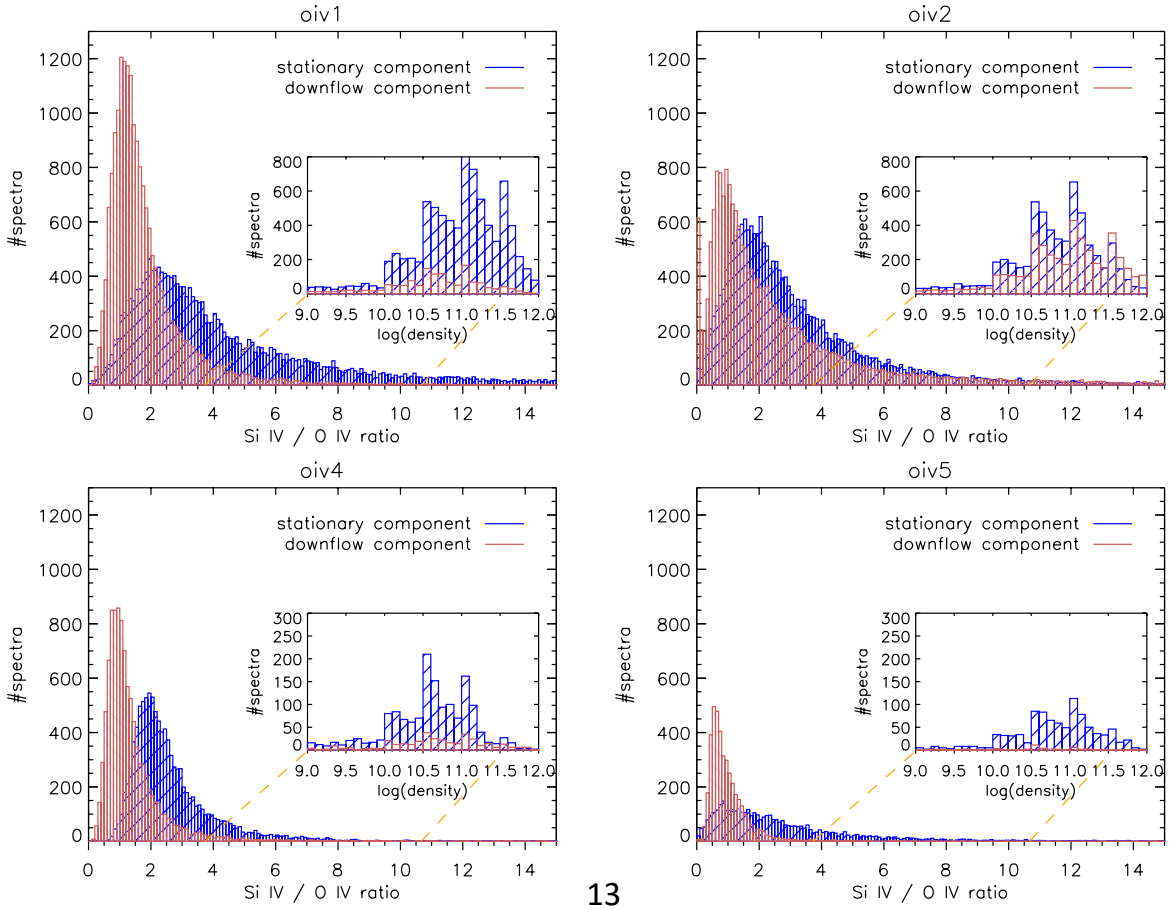


Kleint et al., in prep.

Analysis of IRIS downflows

Results:

- The velocity of downflows is highest at transition region temperatures, with the chromospheric Mg II line showing lower velocities by about 50 km/s and fewer observable downflows overall.
- The densities and opacities of the downflow component in the spectra are consistently lower than those of the stationary component.



Kleint et al., in prep.

Summary

Results:

- We created a pipeline to identify any type of spectrum from a large sample (any spectral line can be used).

- When applied to IRIS burst spectra, we found
  - no correlation to hot coronal AIA emission or Fe XXI => no coronal heating
  - similar properties and timings in Mg II, C II, Si IV (=the transition region)

- When applied to downflow spectra, we found
  - lower densities and opacities in downflows
  - velocity differences: the hotter the line, the higher the velocity