Detecting coronal mass ejections with machine learning methods

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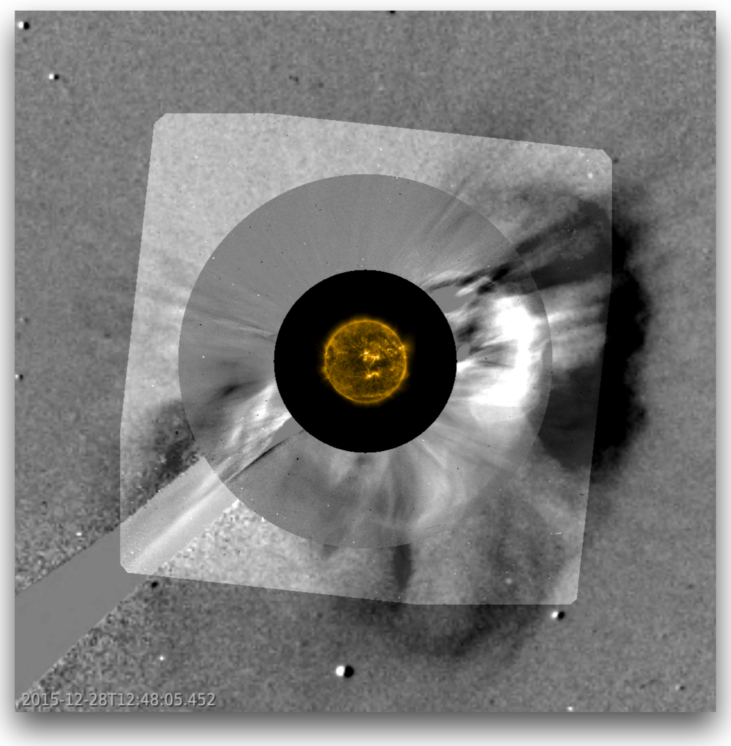
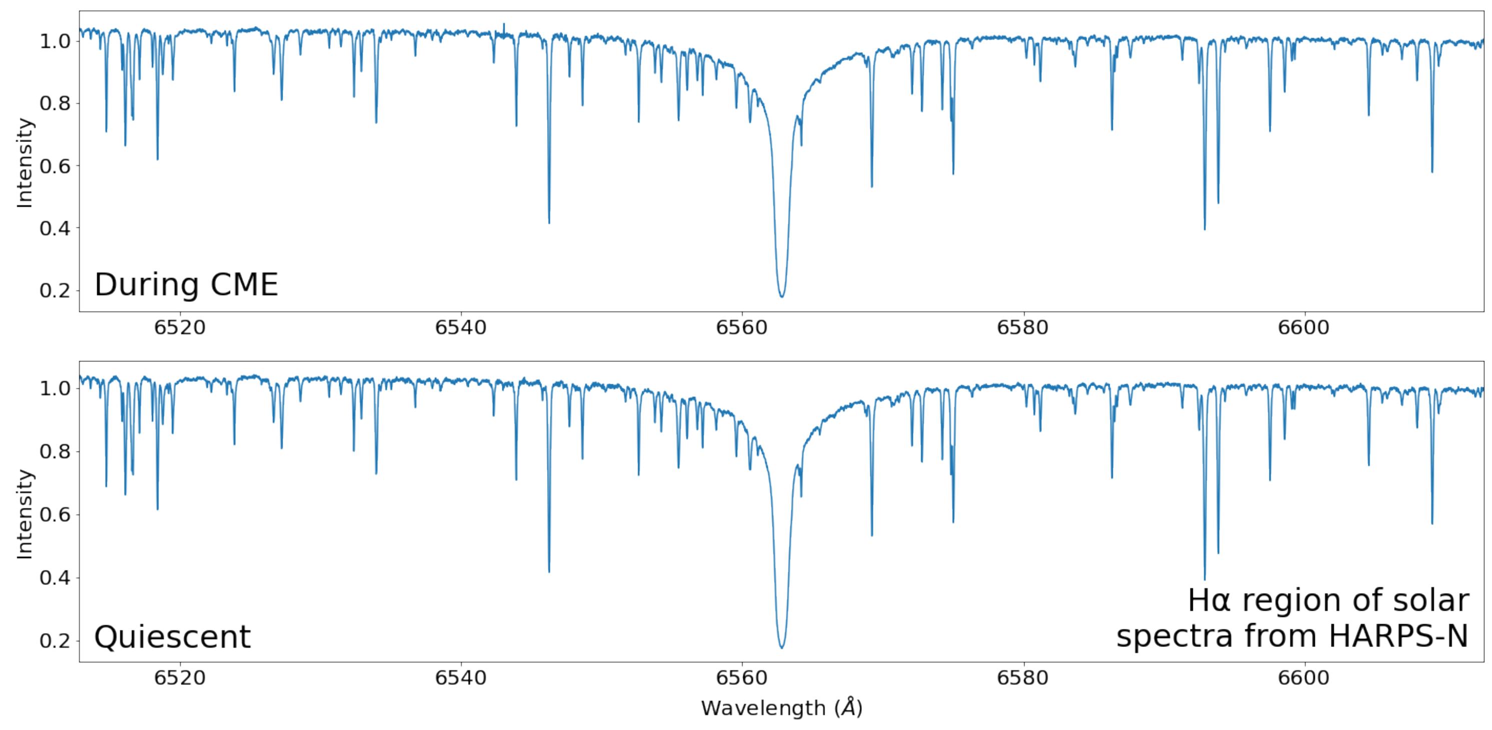
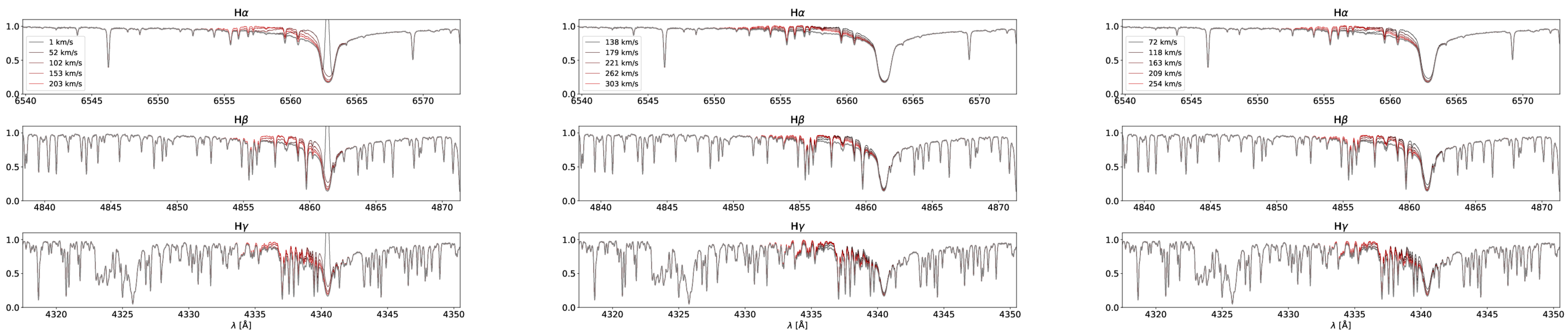
Flares on the Sun are often associated with ejected plasma: these events are known as coronal mass ejections (CMEs). These events, although are studied in detail on the Sun, have only a few dozen known example on other stars, mainly detected using the Doppler-shifted absorption/emission features in Balmer lines and tedious manual analysis. We present a possibility to find stellar CMEs with the help of high-resolution solar spectra.

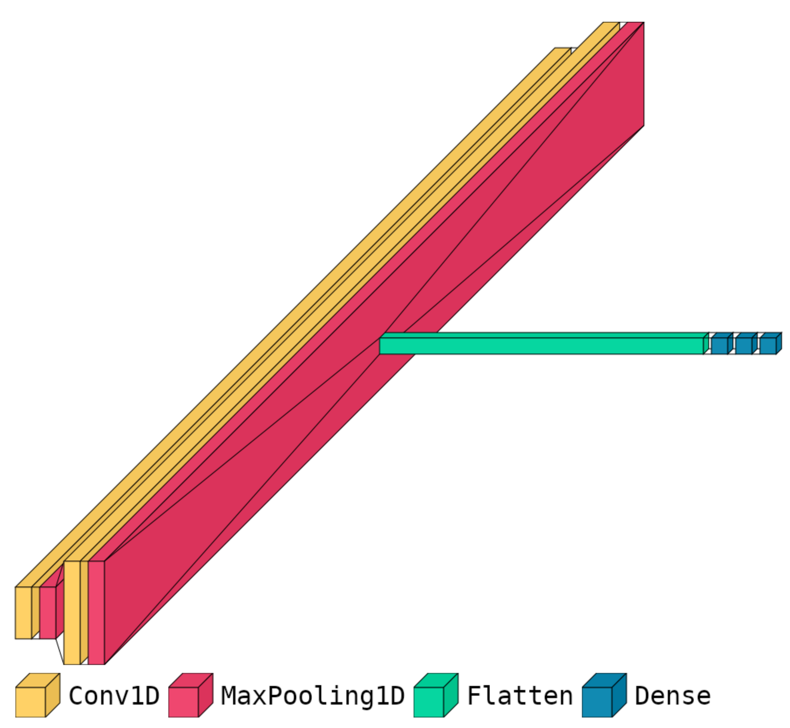




Unlike on stars, on our Sun, we have a detailed knowledge when CMEs occur from direct satellite observations (left: combined SDO&SOHO images). Could high-resolution, high-cadence sun-as-a-star observations help us to move forward? We are working on a neural network to identify solar CMEs using HARPS-N solar observations (right plot). This could help to find new tracers of CMEs, and the algorithm can be used to search for CME signals in archive data. The bad news is that solar CMEs show no obvious visual signatures, the most significant changes in the spectra are due to atmospheric lines.



To find out what kind of neural network architecture could be the optimal for this problem, we created a training set with artificial coronal mass ejections to have obvious signals. These have a typical mass of 5×10^{19}g, 1000 times larger than realistic values. The velocities of the artificial CMEs are realistic, with a maximum velocity of ~400km/s. This training set contains 50–50% spectra with/without CME signals.



After a set of trials, one of the best performing architecture – to our surprise – was one of the most basic runs, consisting only two `Conv1D` *layers with 16 and 32 filters, respectively, followed by two* `Dense` *layers with 32 neurons each.*

While the best runs achieved over 99% accuracy in both the train and validation set, this happened only:

- *on artificial data with events 5000x larger than realistic values*
- *where 50% of the spectra contained events*
- *using only 50.000 data points of the spectrum (the full dataset consists of more than 200.000 points)*

However, with a network that works consistently on the artificial training set, we could use transfer learning to use that weight file on the original scientific observations.

If our experiment is successful, and we can detect coronal mass ejections on the solar spectra, we can possibly finding new CME indicators, and determine what magnitude of CMEs are observable on other stars. The new algorithm can be also used to detect CMEs in archive stellar spectroscopic data.

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