THE QUEST FOR STELLAR CORONAL MASS EJECTIONS

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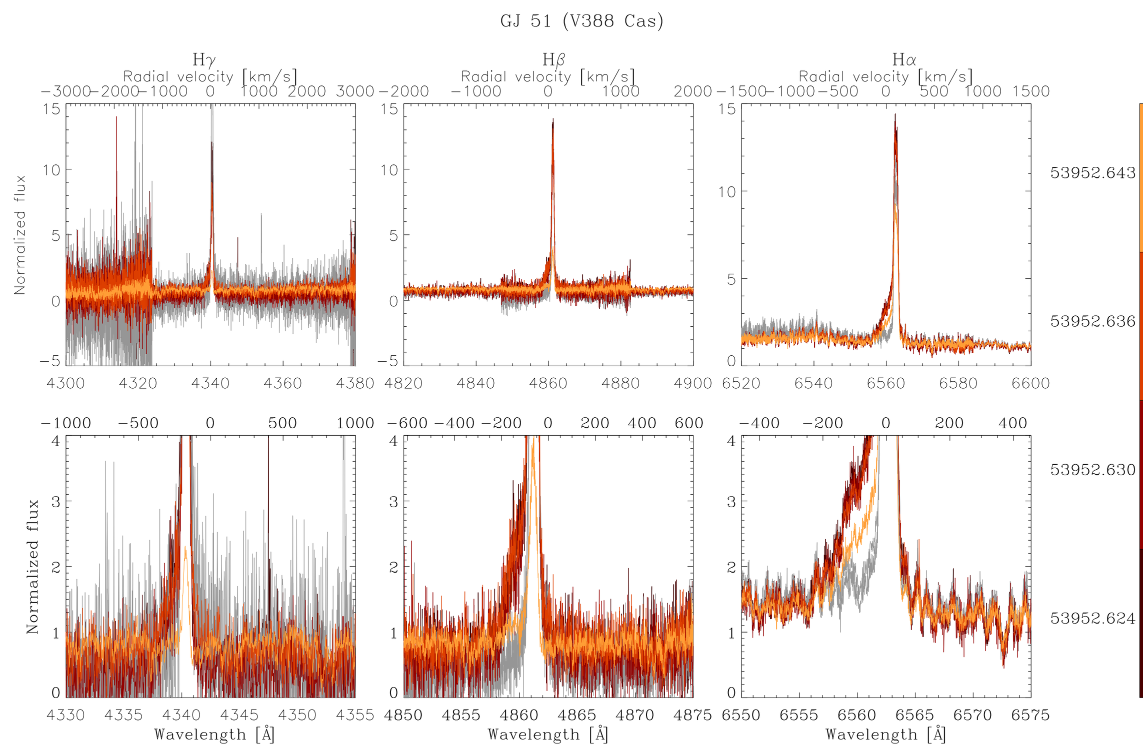
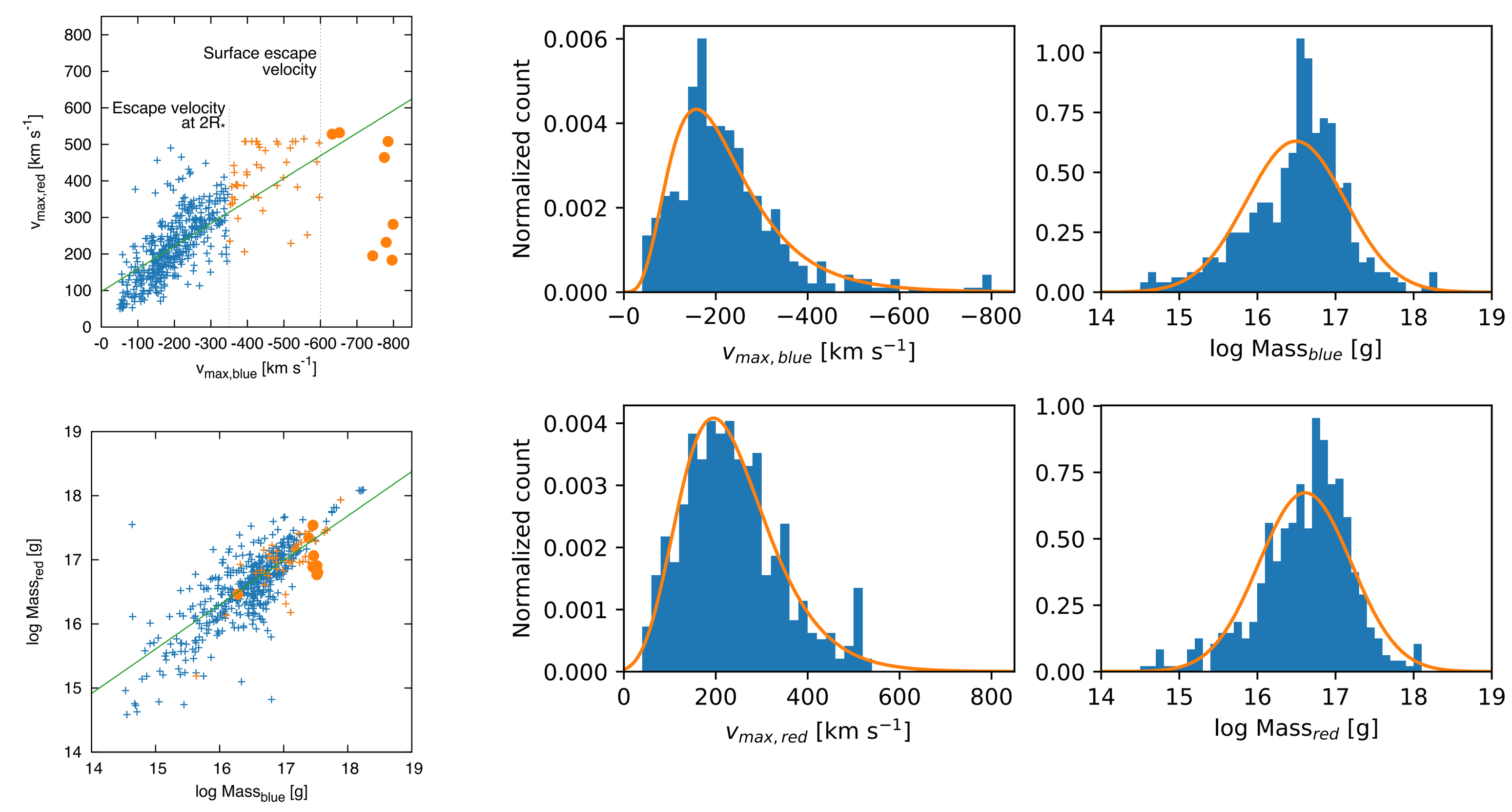
Flares and coronal mass ejections (CMEs) are the most prominent, most energetic events of stellar activity. These events can have high importance in exoplanet studies — they can erode or irreversibly alter the atmospheres of orbiting planets, rendering them uninhabitable. On the Sun, CMEs are studied in high detail, both by observation and modeling, and they are seen rather frequently: 0.5—6 CME/day. On other stars, however, there are only a handful of CMEs observed up to now.

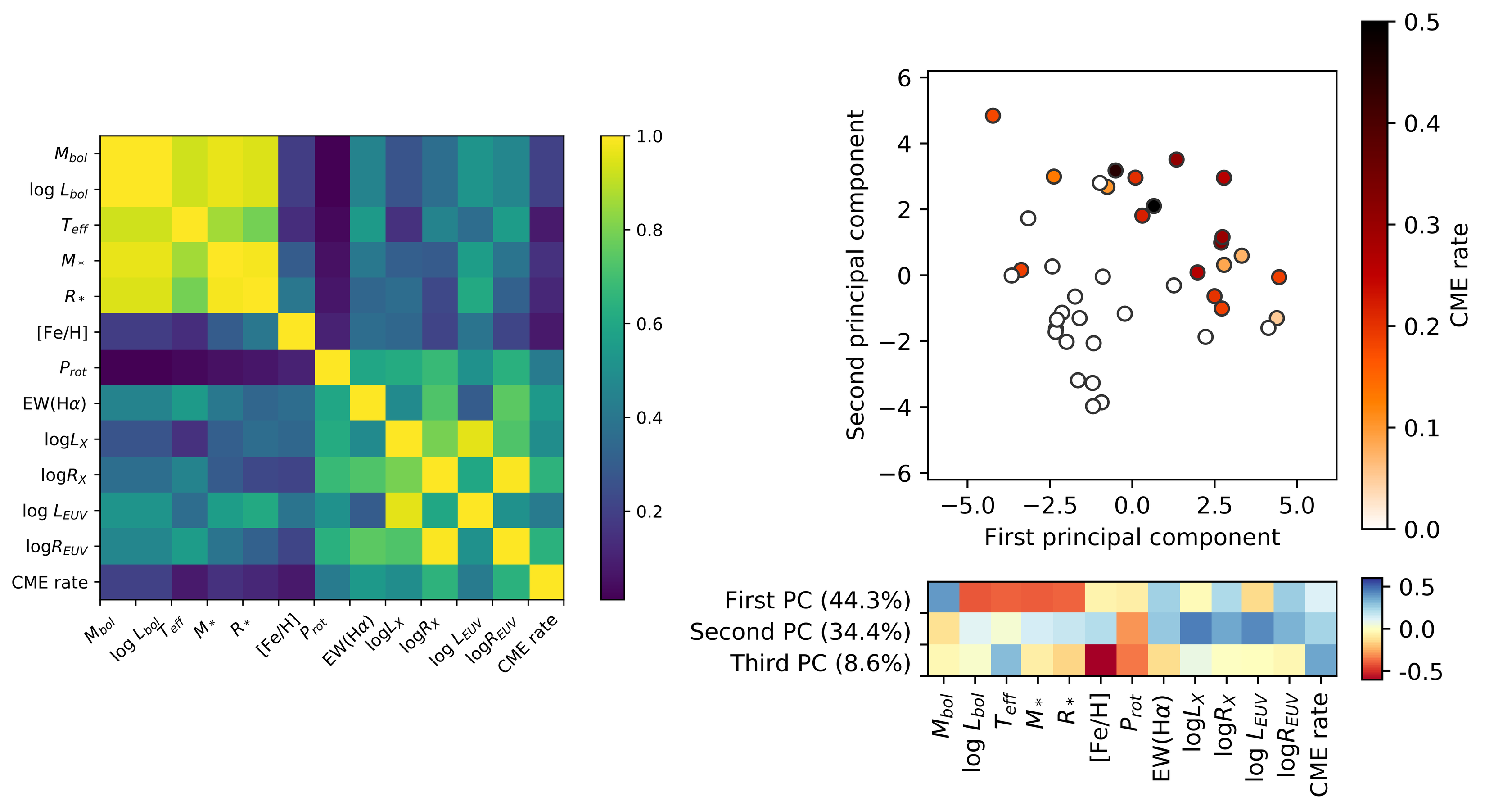
We present an extensive search of observational archives — the virtual observatory — in the hope of finding the missing events. Our initial target list was based on the list of single M-dwarfs within 15 pc from the PhD thesis of Odert (2016), the final analyzed data set consisted of more than 6300 spectra — about 1250 hours of observation, the largest such survey to date.



Coronal mass ejections can be detected due to their Doppler-shifted spectral signature, mainly in the Balmer-regions. We visually investigated the collected spectra in the Hα, Hβ and Hγ regions for line asymmetries. This plot shows an example of one of the stronger events on GJ 51. The spectra were fit to remove the symmetric quiescent flux, then again to have an fit the blue/red wing enhancements in order to estimate the velocities and masses of the ejecta.



Distribution of the maximum velocities and minimum masses derived from red/blue wing enhancements. We found that most of the events are under the escape velocities, one of the possible explanations is that most of the ejected material (60—70%) falls back on the surface. The typical measured maximum velocities seem to show a log-normal distribution with a peak at ~200km/s.



Statistical analysis of the line asymmetries. The correlation matrix (left) shows the obvious dependence between the physical parameters, and that the asymmetries are slightly correlated to the X-ray/EUV activity index and the Hα equivalent width. The correlation with X-ray/EUV luminosity and the anti-correlation with the rotation period are less significant.
In the right plot the result of the principal component analysis (PCA) is shown. This suggests that the main features of the first principal component (PC) are related mainly to stellar structure, while the features in the second PC are mainly related to EUV and X-ray activity indices. In this parameter space stars showing line asymmetries (filled circles) seem to form a cluster, indicating that fast-rotating late-type stars, and objects with high X-ray and EUV activity are the objects that host line asymmetries.

- Line asymmetries occur often on M-dwarfs. These could be linked to coronal mass ejections (CMEs), but other causes (e.g. opacity variations due to flares) are also possible.
- Event rates were in the order of 1.2—19.6 event/day (solar rates are 0.5–6 CME/day). These values are somewhat lower than expected from a scaled-up solar case (15—60 event/day), but this could be — at least partly — explained by observation effects.
- Asymmetries seem more frequent on cooler stars with stronger chromospheric activity, they seem to occur after reaching a threshold in chromospheric activity.
- If these phenomena are connected to CMEs, their maximal velocity is in most cases under the escape velocity, "successful" ejections seem to be rare (2–10%).
- This can be due to multiple reasons: projection effects, magnetic suppression blocking the eruptions, or that the accelerating, cooling material can be detected only in its early phase in Hα.

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