# Using spatially resolved solar flare data to assess spectral signatures of physical phenomena in stellar data

Supervisors: Malcolm Druett, Alexander Pietrow, Adur Pastor Yabar

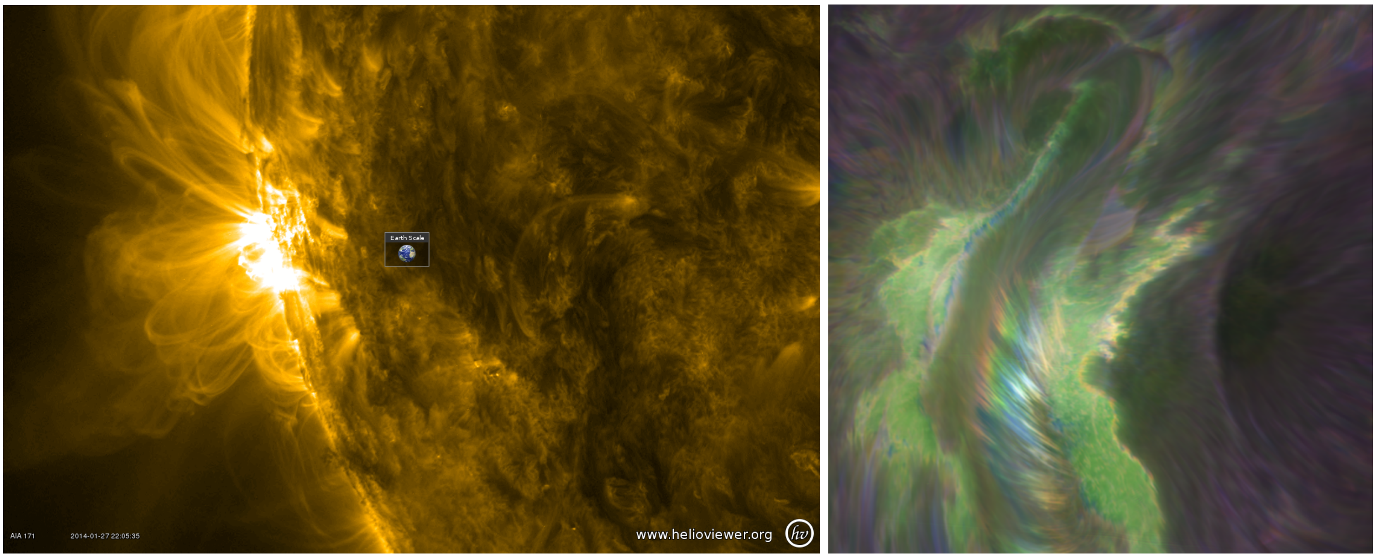


Figure 1: Left: a solar flare viewed from the side in hot coronal line (around 1 MK) with the AIA instrument aboard the Solar Dynamics Observatory satellite. Right: a solar flare viewed from above in a cooler chromospheric line (around 11000 K) with the Swedish Solar Telescope (SST) using the COCOPLOT software of Druett, Pietrow et al.

## 1 Project introduction

**This opportunity is for an 8 week paid summer internship in astronomy research hosted at the Centre for mathematical Plasma Astrophysics (CmPA) in the Department of Mathematics at KU Leuven.**

You will learn and use a variety of techniques to inspect *solar data*, in the context of interpreting signatures from *stellar flares*, occurring elsewhere in the galaxy. You will gain knowledge of several recently developed techniques to improve on previous "sun-as-a-star" works, and a network of contacts via a supervision team of scientists from top European research institutes.

For day-to-day interactions your main contact and supervisor will be Dr. Malcolm Druett (KU Leuven, Belgium). You will also receive support form experts in Germany (Dr. Alexander Pietrow, AIP Potsdam), and Sweden (Dr. Adur Pastor Yabar, Stockholm University) and analyse data from world leading solar instruments (e.g. The Swedish Solar Telescope).

We aim to publish the results in the peer-reviewed Astronomy and Astrophysics journal with the intern as first author. You will be given advice on academic writing by three experienced researchers. A back-up plan means that a partially successful project can still be included into another paper with the intern as a co-author. If a publication is achieved this will not only provide an outstanding basis for a future research career, but also the opportunity to apply for funding to present your research at an academic conference.

This proposal is suitable for a strong BSc graduate or MSc student with some understanding of spectral line formation and astronomical observations. The dates of the project can be agreed upon to be flexible to summer plans, e.g. split into 2 blocks, a shifted start date, or some fraction of remote working. **To express your interest please contact malcolm.druett@kuleuven.be**. Funding for this project comes from the ERC Prominent project, with thanks to Prof. Rony Keppens.

# 2 Solar and stellar flares

Solar flares are the most energetic events in the solar system. Magnetic energy can be built up in the field of the Sun until the field lines become unstable and rapidly reconnect into a more relaxed state. This reconnection causes the release of the stored energy at the reconnnection point (see a reconnection x-point in fig.2 right: the green field line with flow velocities indicated by blue and red arrows). This ejects plasma, radiation, and other energy in upwards and downwards directions. The upward ejecta and radiation form dramatic space-weather events that impact satellites, power grids, and the Earth's atmosphere. The downward ejected energy impacts the lower atmosphere of the Sun, causing a large number of flare phenomena including

- The brightenings shown in the figures.
- Ribbon formation at the bases of the loop footpoints. This corresponds to the little red circles at the bases of the flare model picture and the green patches to either side of the flare loops that can be seen in fig.1 right.
- Chromospheric evaporation, which are hot upflows of plasma from the lower atmosphere, often observable as Doppler shifted, asymmetric emission.
- Filament eruptions, i.e. the eruption of the twisted rope running along the flare length in the model diagram.

The flares observed from our Sun are also orders of magnitude weaker than those detected from stars elsewhere in our galaxy, detected only through brightenings of their emission across the electromagnetic spectrum. The Sun offers us a unique opportunity to associate such spectral signatures with physically observable phenomena such as those listed above, but the strengths and spatial extents needed for such phenomena to be manifested in long-exposure, spatially unresolved stellar data are not clearly understood. Your project will use recent advances in sun-as-a-star modelling to address this.

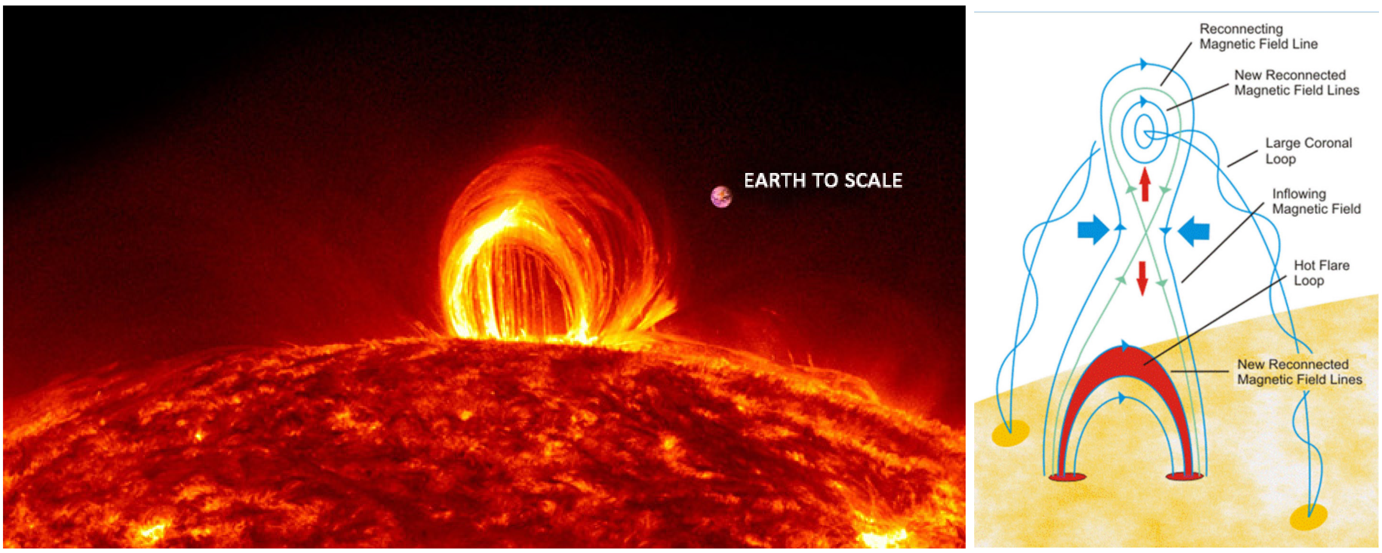


Figure 2: Left: a solar flare viewed from the front. Right: compare the hot loops seen (left) to the cross section through the model of a solar flare (right). Reconnection of the magnetic field lines above these loops has released stored magnetic energy which is converted into a variety of forms, and heats up the loops at the base of the flare, shown in red.

## 3 Project timeline

| Activity | Main Supervision |
|---|---|
| **Week 1** | |
| Reading: Otsu et al. (Pseudo-sun-as-a-star) | Druett |
| Introduction to analysing solar data with python | Druett/Pietrow |
| Introduction to spectral lines | Druett |
| Introduction to solar observations | Pietrow |
| Introduction to stellar observations | Peitrow |
| **Week 2** | |
| Reading: Pietrow et al., HARPS data paper (true sun-as-a-star) | Pietrow |
| Introduction solar flares | Druett |
| Associating flares phenomena with spectral signatures | Druett |
| Integrating Field Of View spectra | Independent |
| **Week 3** | |
| Reading: Pietrow et al., NESSI code | Pietrow |
| Using NESSI to generate sun-as-a-star data | Pastor Yabar/Pietrow |
| **Week 4** | |
| Comparing Findings for this flare with HARPS results | Druett/Pietrow |
| Repeating procedure for other flares | Druett |
| **Week 5** | |
| Interpreting results | Druett |
| **Week 6** | |
| Artificiality scaling flares, what flaring area coverage is required to see certain phenomena | Pietrow/Pastor Yabar |
| **Weeks 7 & 8** | |
| Writing paper | Druett |