

Automatic segmentation of different solar atmosphere structures by deep learning

Peter Butka¹, Šimon Mackovjak², Viera Krešňáková¹, Lenka Kališková¹

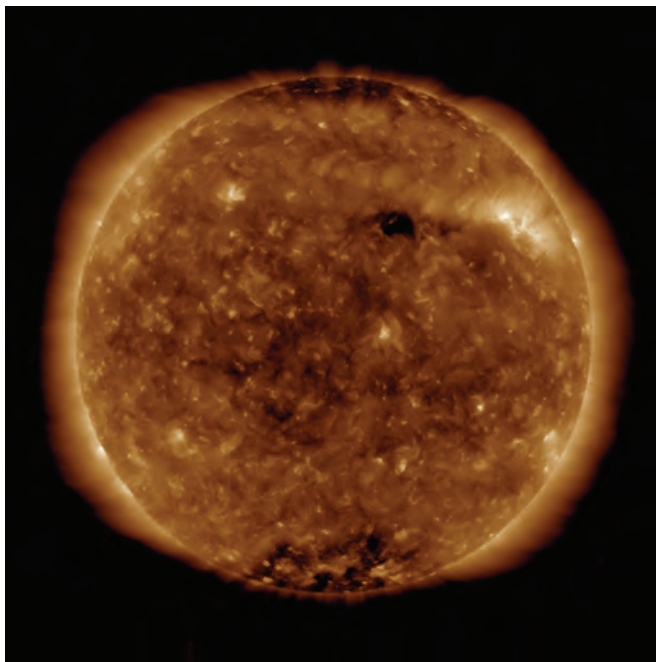
¹ Department of Cybernetics and Artificial Intelligence, Faculty of
Electrical Engineering and Informatics, Technical University of Košice

² Institute of Experimental Physics, Slovak Academy of Sciences

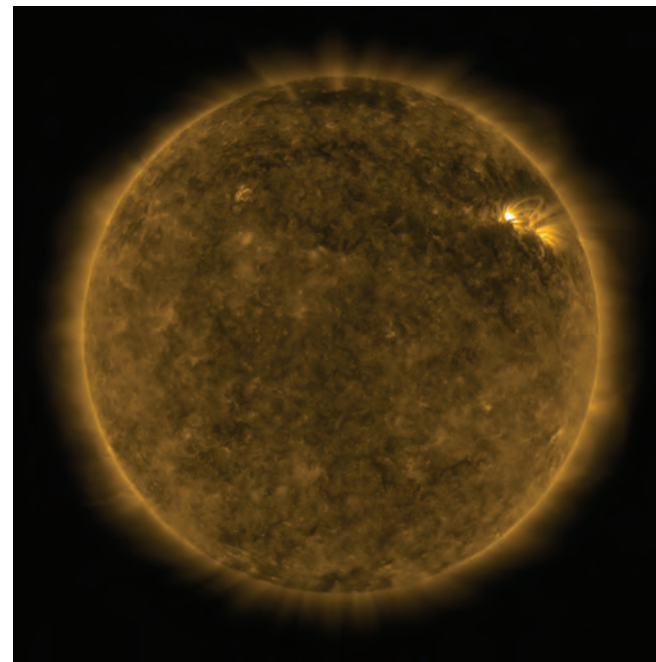
Bezovec 2023 - Conference of Young Astronomers

... 2 years ago, september 2021, Bezovec

- Automatic segmentation of objects in solar corona using Deep Learning
 - Using of own + existing annotations for coronal holes and active regions
 - Segmentation architecture based on U-Net
 - SDO (Solar Dynamic Observatory) / AIA (Atmospheric Imaging Assembly)

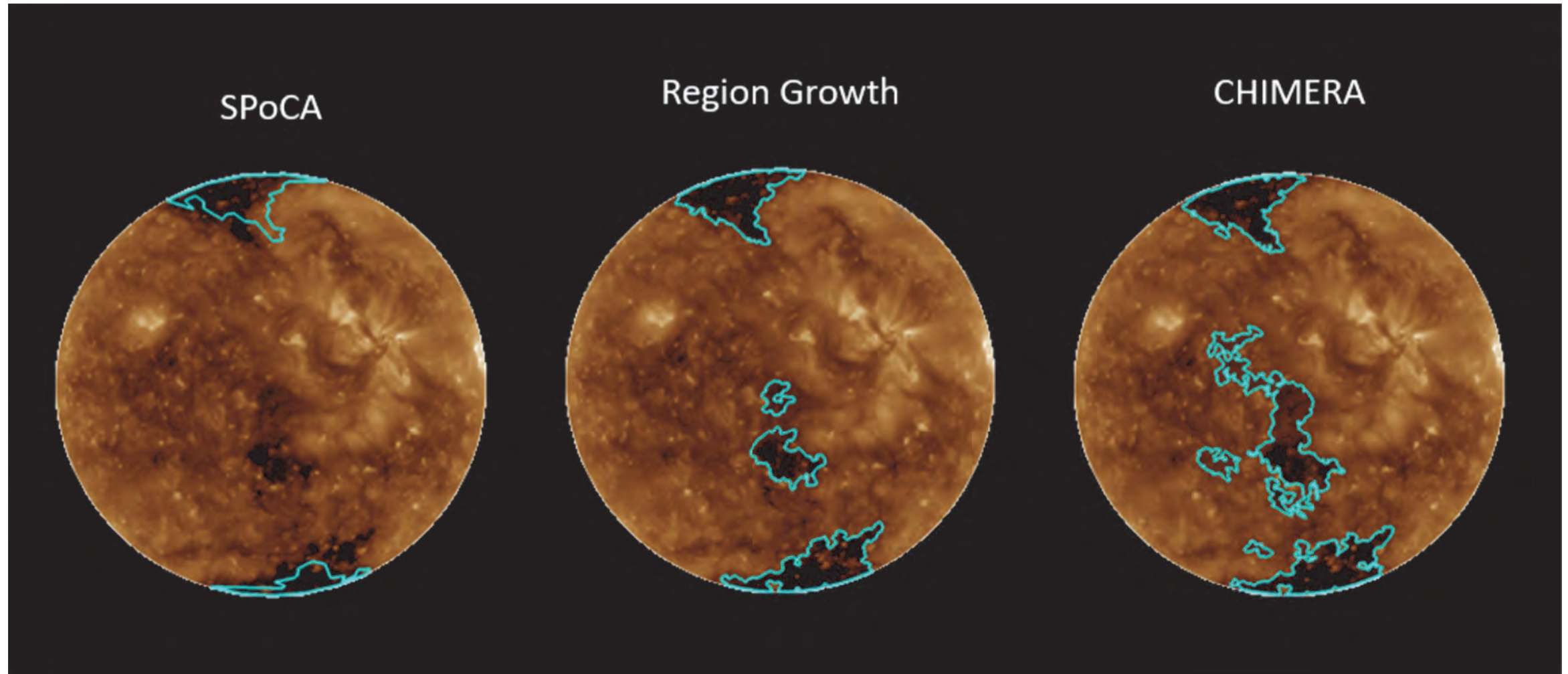


For coronal holes => 193Å

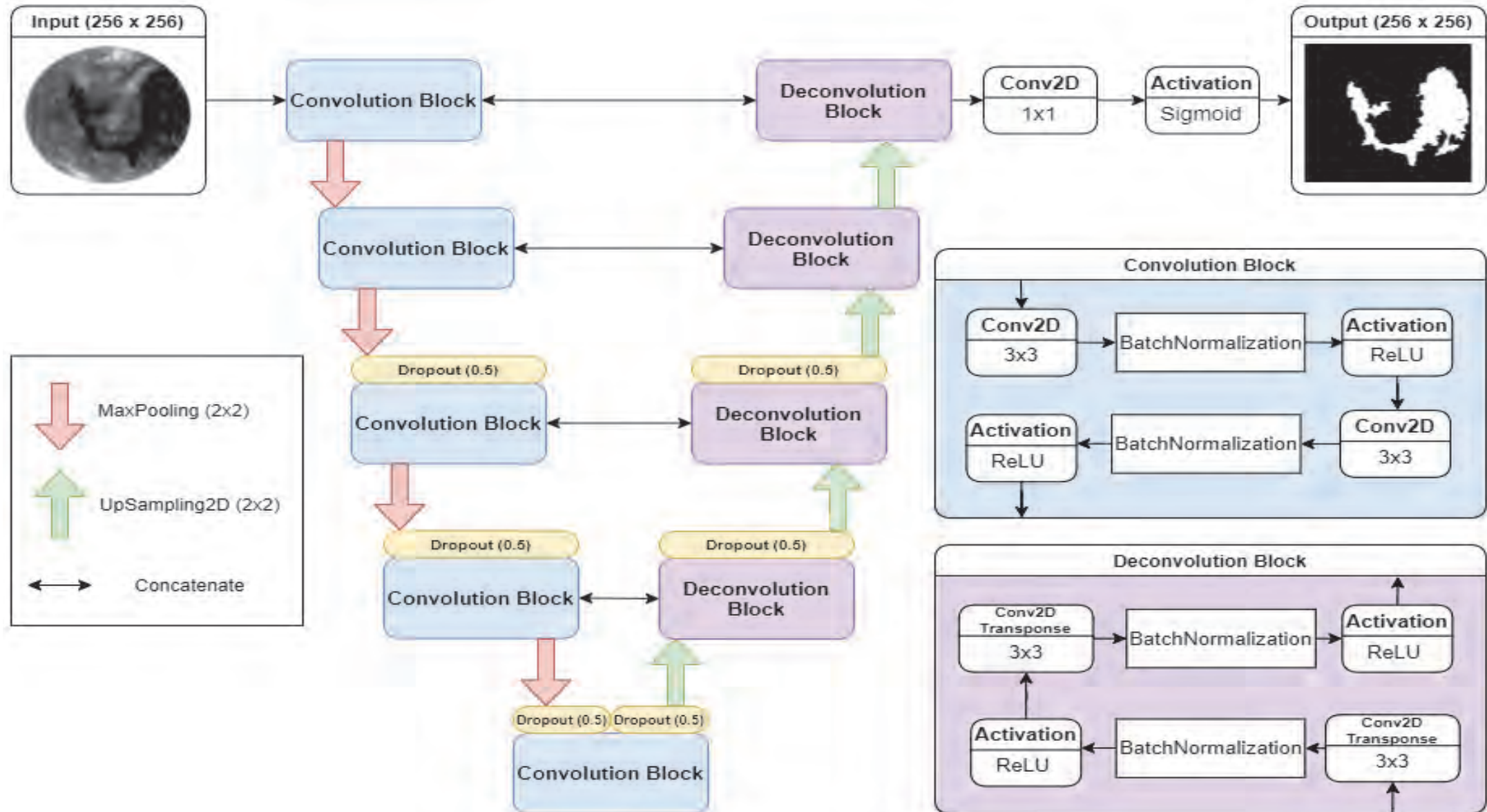


For active regions => 171Å

Existing annotations (products)

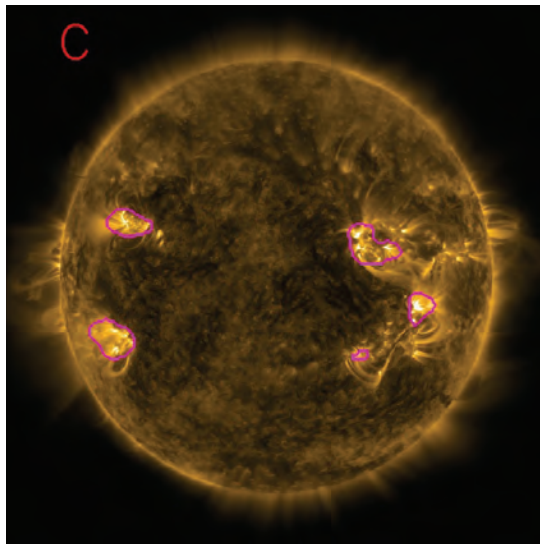
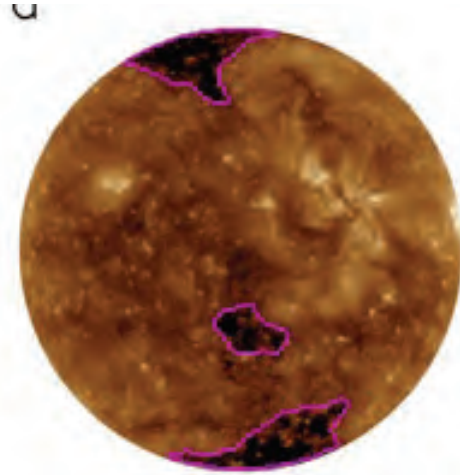


SCSS-Net (Solar Corona Structures Segmentation Network) – based on U-Net



Results

<https://github.com/space-lab-sk/scss-net>



Monthly Notices
of the
ROYAL ASTRONOMICAL SOCIETY
MNRAS **508**, 3111–3124 (2021) <https://doi.org/10.1093/mnras/stab2536>

SCSS-Net: solar corona structures segmentation by deep learning

Šimon Mackovjak¹,^{*} Martin Harman,² Viera Maslej-Krešňáková² and Peter Butka²

¹Department of Space Physics, Institute of Experimental Physics, Slovak Academy of Sciences, 040 01 Košice, Slovakia

²Department of Cybernetics and Artificial Intelligence, Faculty of Electrical Engineering and Informatics, Technical University of Košice, 042 00 Košice, Slovakia

Accepted 2021 September 3. Received 2021 August 11; in original form 2021 May 14

ABSTRACT

Structures in the solar corona are the main drivers of space weather processes that might directly or indirectly affect the Earth. Thanks to the most recent space-based solar observatories, with capabilities to acquire high-resolution images continuously, the structures in the solar corona can be monitored over the years with a time resolution of minutes. For this purpose, we have developed a method for automatic segmentation of solar corona structures observed in the EUV spectrum that is based on a deep-learning approach utilizing convolutional neural networks. The available input data sets have been examined together with our own data set based on the manual annotation of the target structures. Indeed, the input data set is the main limitation of the developed model's performance. Our *SCSS-Net* model provides results for coronal holes and active regions that could be compared with other generally used methods for automatic segmentation. Even more, it provides a universal procedure to identify structures in the solar corona with the help of the transfer learning technique. The outputs of the model can be then used for further statistical studies of connections between solar activity and the influence of space weather on Earth.

Key words: methods: data analysis – techniques: image processing – Sun: corona – software: development.

space-lab-sk / **scss-net** Public

Code Issues Pull requests Actions Projects Wiki Security

main 1 branch 0 tags Go to file Add file Code

File	Description	Last Commit
data	Data folder for SCSS-net	4 months ago
src	Preparation of dataset with Custom annotations	4 months ago
LICENSE	Initial commit	4 months ago
README.md	Update README.md	4 months ago
SCSS-net_AR.ipynb	Jupyter notebook - SCSS-net for AR	29 days ago
SCSS-net_CH.ipynb	Jupyter notebook - SCSS-net for CH	29 days ago
requirements.txt	Update requirements.txt	24 days ago

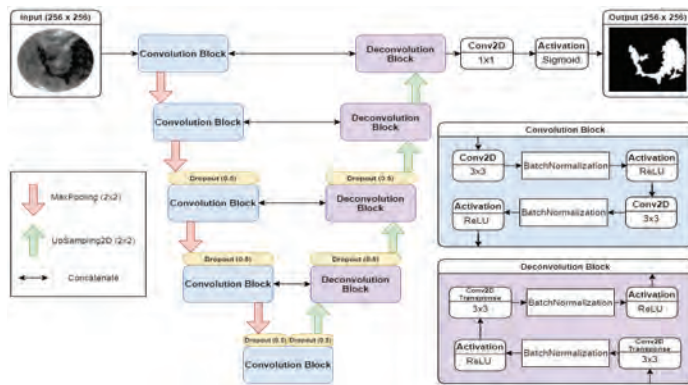
SCSS-Net: Solar Corona Structures Segmentation by Deep Learning

Supplemental materials to the paper: (submitted to MNRAS, in review)

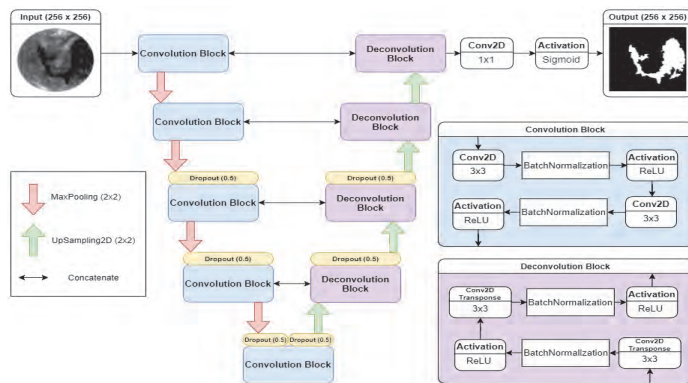
- Jupyter notebook *SCSS-net_CH* that contains analysis presented in the article related to the segmentation of coronal holes. The required utilities are in */src* folder.
- Jupyter notebook *SCSS-net_AR* that contains analysis related to the segmentation of active regions

Done 😊 ... and What now ? ...

Done 😊 ... and What now ? ...



Done 😊 ... and What now ? ...



Deep learning is nicely transferable approach

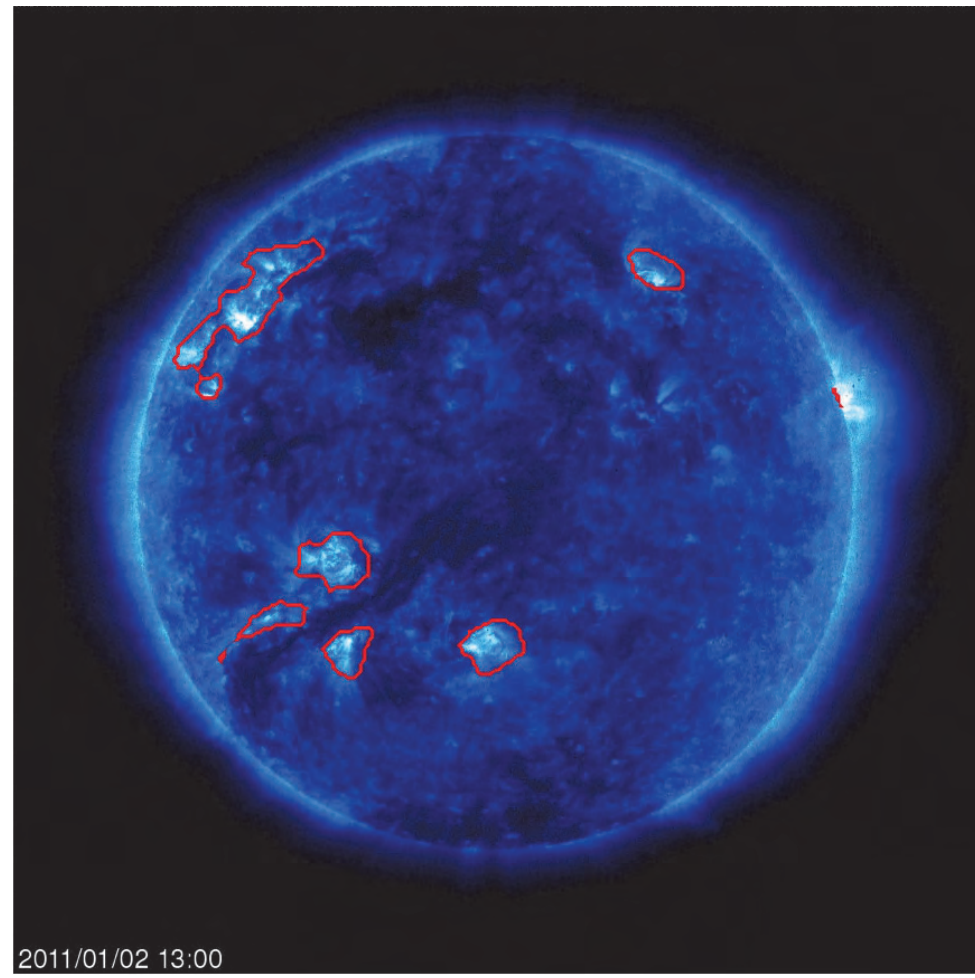
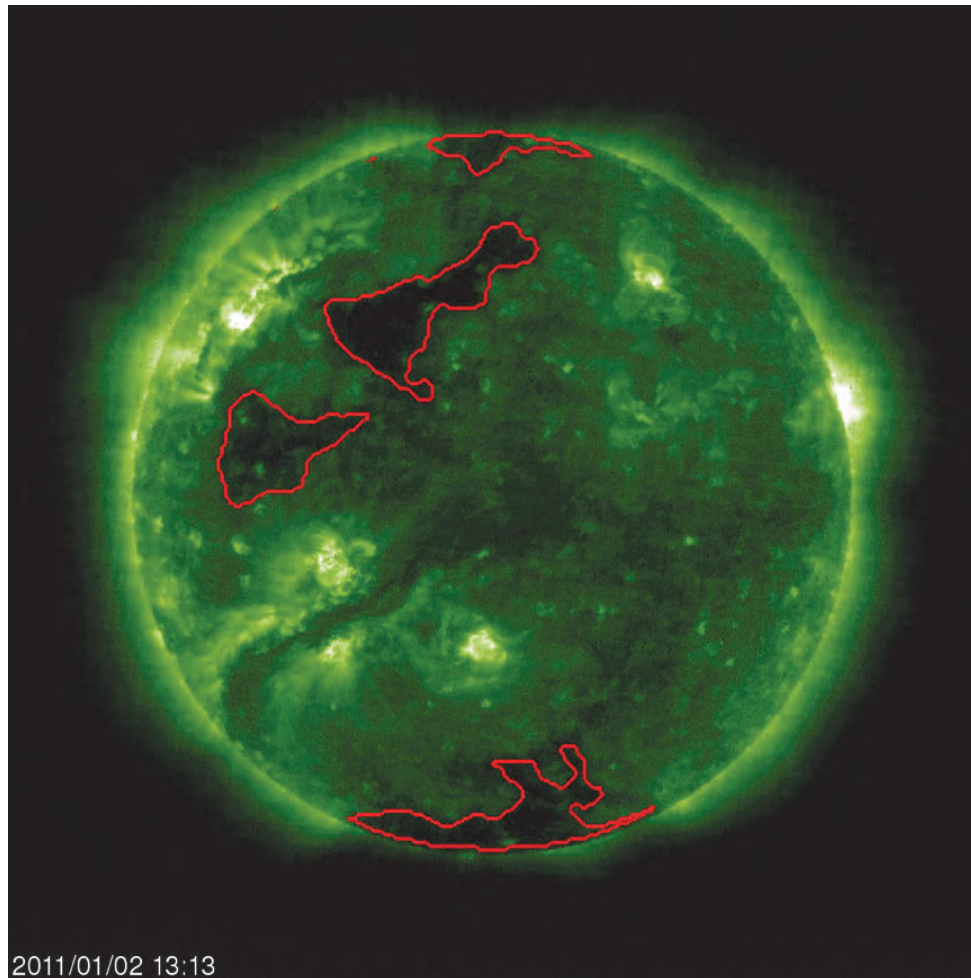
... SO ...

USE SCSS-Net AGAIN !!!

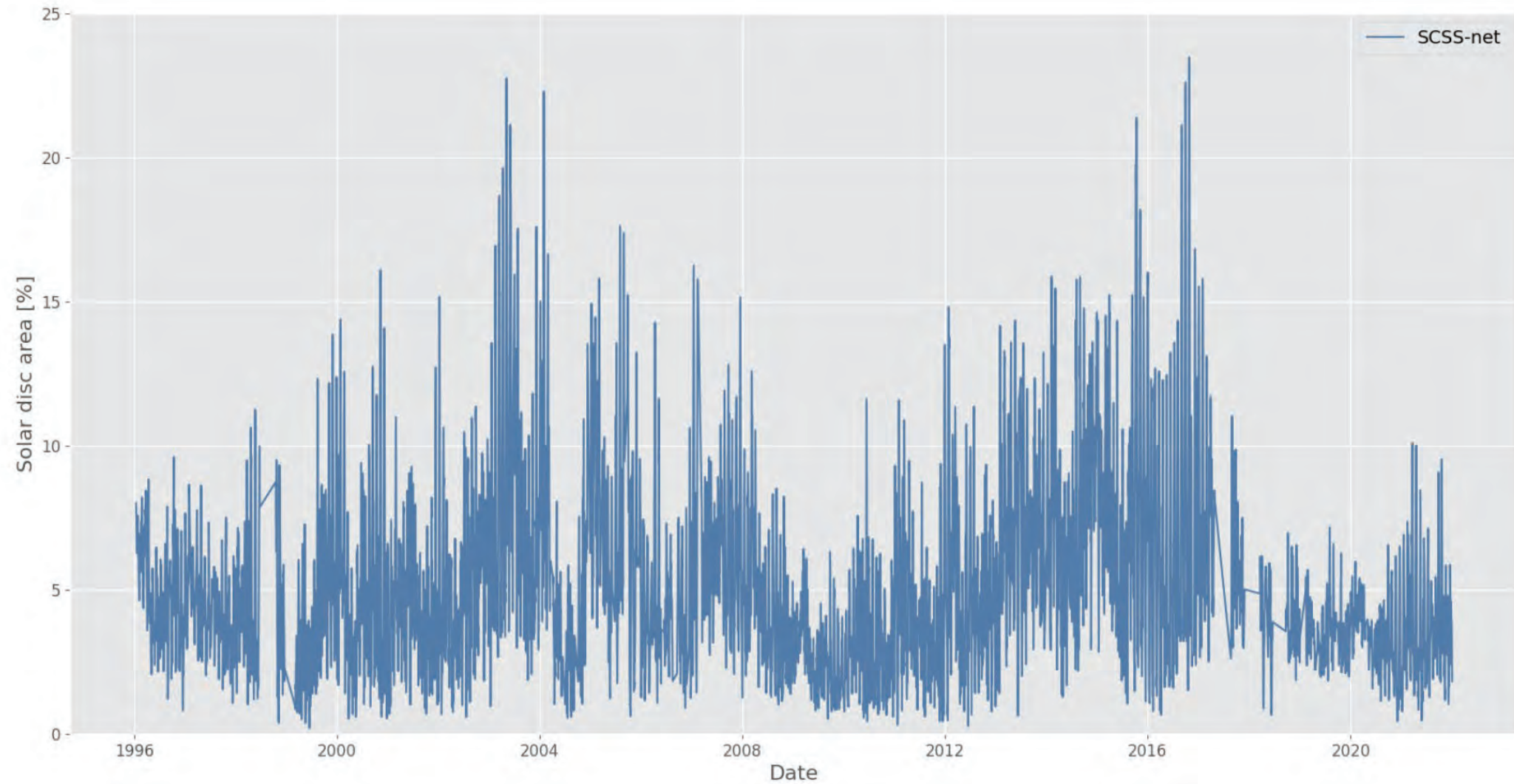
Use again, Part 1 – same task, but new data

- Bachelor thesis (Adam Majirský)
- Try it for new data = SOHO (Solar and Heliospheric Observatory)
- Possibility to extend segmentation results to longer period of time (data from 1996)
- Result
 - 25 years of annotations
 - Try videos for coronal holes and active regions
 - YOUTUBE SPACE::LAB ([youtube.com/@spacelabsk](https://www.youtube.com/@spacelabsk))

Use again, Part 1 – segmentation on SOHO

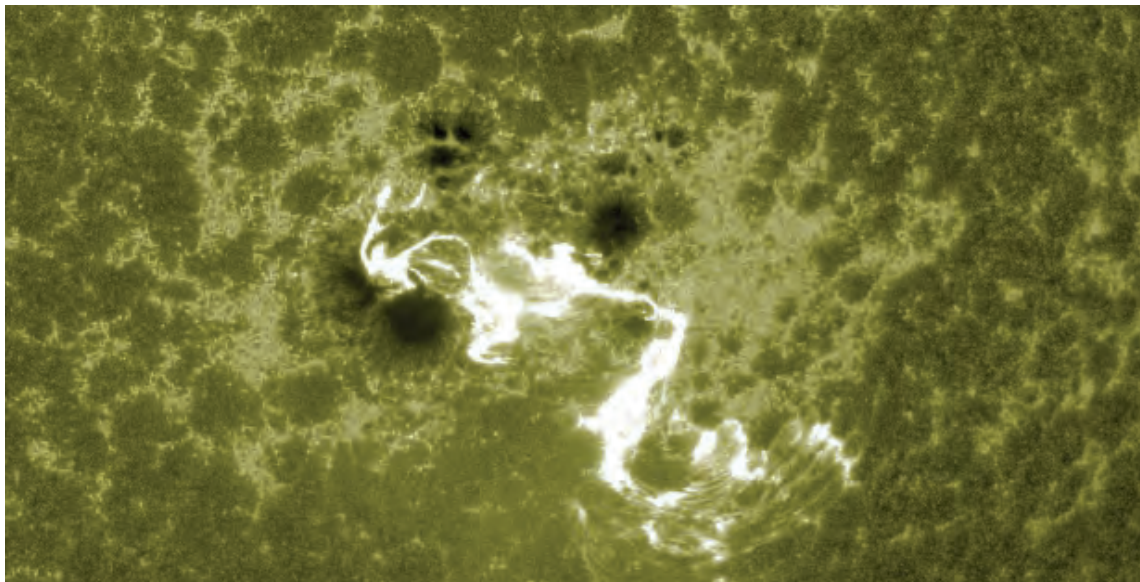


Use again, Part 1 – 25 years of CH annotations



Use again, Part 2 – different task

- Master thesis (Lívia Potočňáková)
- SCSS-Net in support of task to find specific type of **solar flare ribbons**
... **parallel structures indicates strong eruptions**
- Motivation and data on eruptions : Astronomical Institute in Ondřejov
- Input data for DL: SDO / AIA 1600 Å

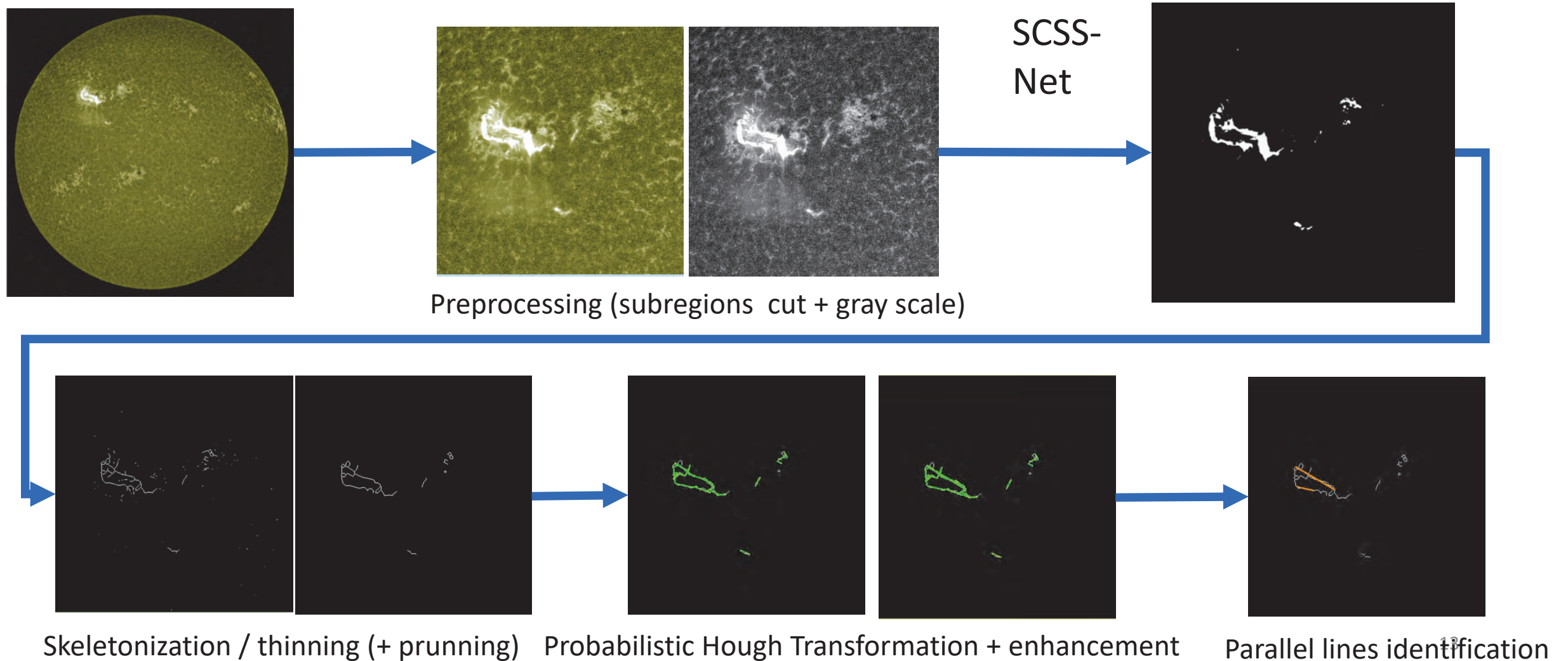


Catalogue of eruptions

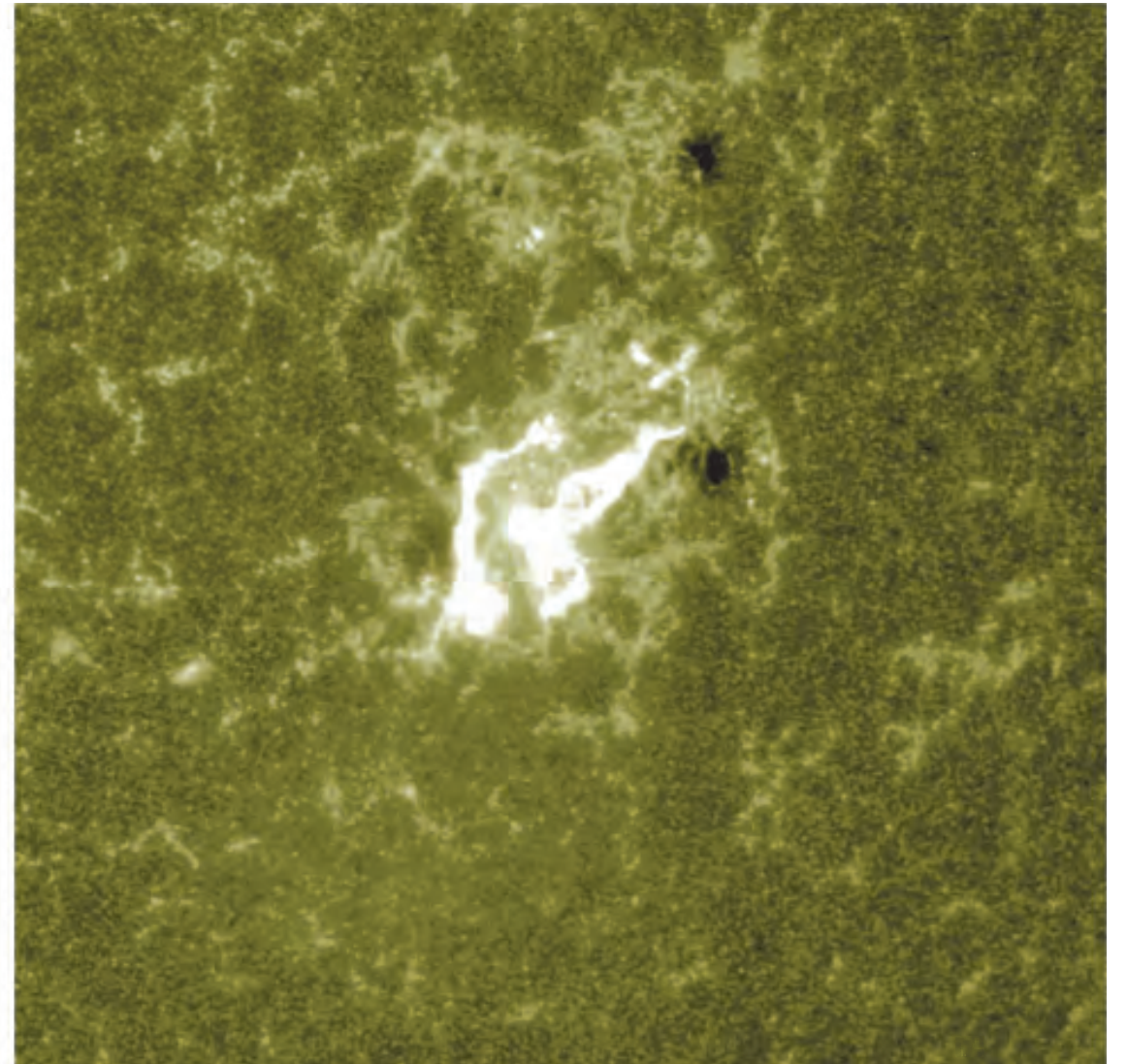
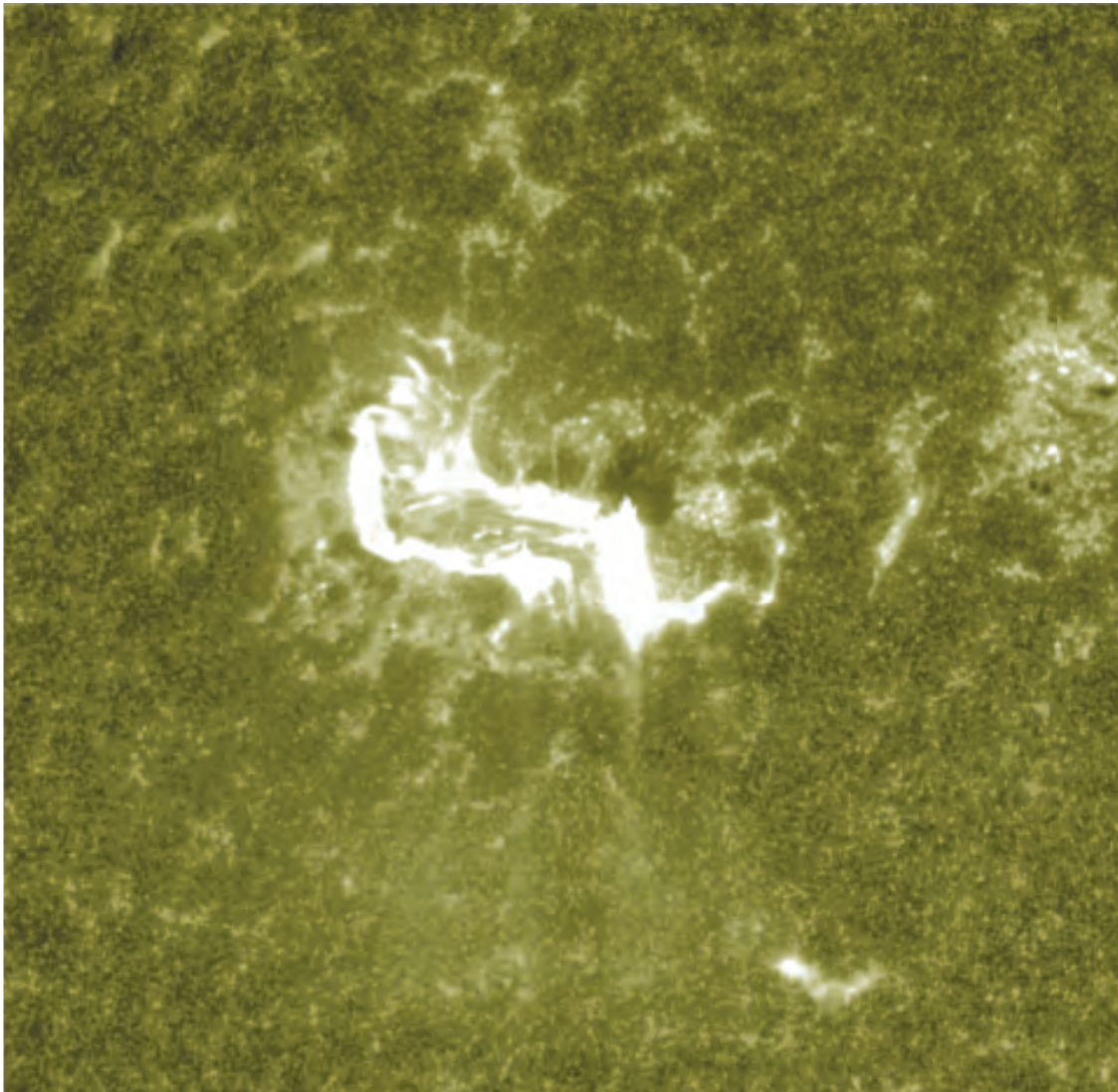
RibbonDB

(Kazachenko et al., 2017).

Processing of images – from original image to identified parallel flare ribbons



Examples of detected parallel flare ribbons



Use again ? ... Part 3

- We had some nice experimental results, code, paper, etc.
- What about to push it forward more => more product-like solution
- Inspiration:
 - ESA PECS SK-S2P study (**Astros**, IEP, ...) – SCSS-Net as possible service in S2P ?
 - ESA Space Weather Portal – SCSS-Net as service there

THE EUROPEAN SPACE AGENCY

Welcome to the ESA Space Weather Service Network
Please note that all ESA-SWE Services are under review/construction

Expert Service Centres / ESC Solar Weather

Solar Weather Expert Service Centre (S-ESC)

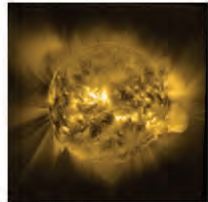
ESC Objectives | Contributions | Contributors

Mission Statement

The mission of the Solar Weather ESC (S-ESC) is to provide and develop the functionalities, capabilities and expertise in the domain of Solar Weather that are needed within the ESA SWE Network to achieve as a collaborative enterprise its mission of demonstrating and assessing the influences of Space Weather and informing and supporting end-users through the provision of accurate, reliable and timely products and (pre-)operational services, tailored to their requirements. The Solar Weather Expert Service Centre (S-ESC) thus provides, implements and supports the Solar Weather products and capabilities of the ESA SWE network. This includes the observation, monitoring, interpretation, modelling and forecasting of Solar Weather conditions with an emphasis on solar (sub-)surface and solar coronal features, events and processes that drive Space Weather in our solar system.

The source of most Space Weather perturbations can be directly linked to solar activity. Various solar phenomena and their manifestations in the solar wind need to be monitored in order to produce realistic Space Weather predictions. Solar flares, coronal mass ejections and coronal holes are all known to create space weather disturbances under certain conditions which can then in turn affect users' systems.

Phenomena such as these are ultimately driven by the Sun's magnetic field and are therefore regulated by the 11-year solar activity cycle, which is most obviously manifest in the sunspot cycle. High-quality data and state of the art computer modelling are essential tools to understand the processes and causality involved. This is greatly complicated by the fact that the near-Sun and near-Earth regions are rather better studied and understood than the ~150 million km of space in between them.

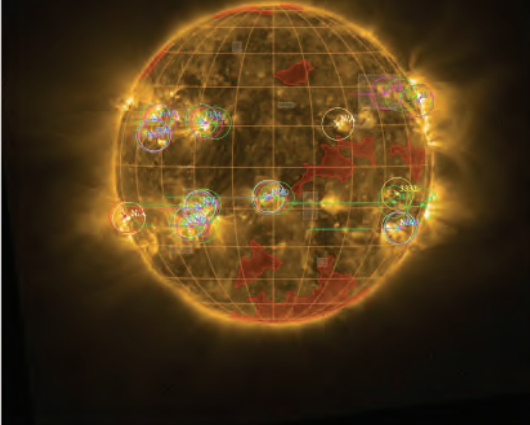


A stack of PROBA2/SWAP images, radially enhanced off-limb to show the extended corona in full wealth.
(© Proba2/SWAP - ESA and Royal Observatory of Belgium)

Solar Data

SIDC Solarmap

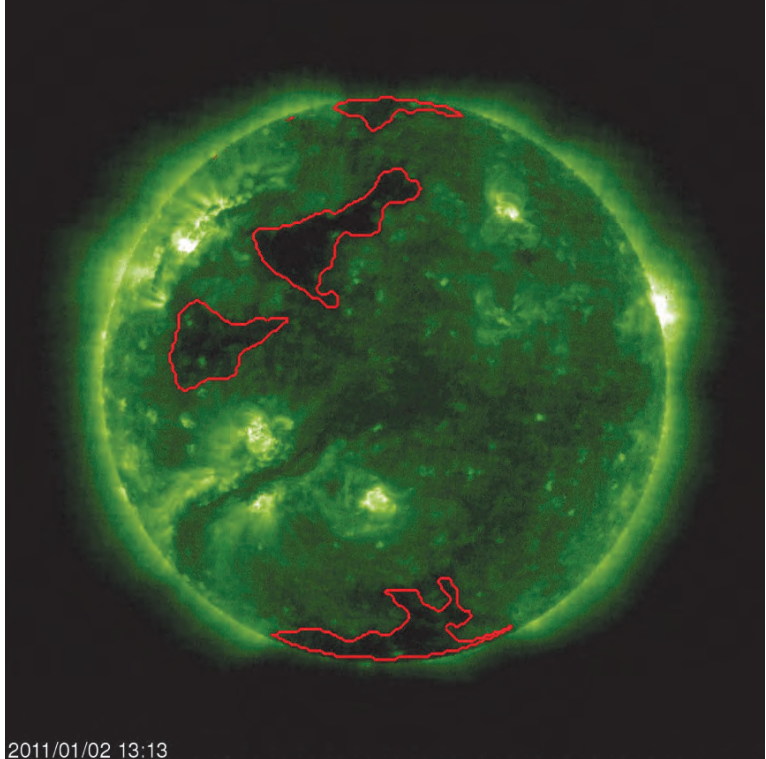
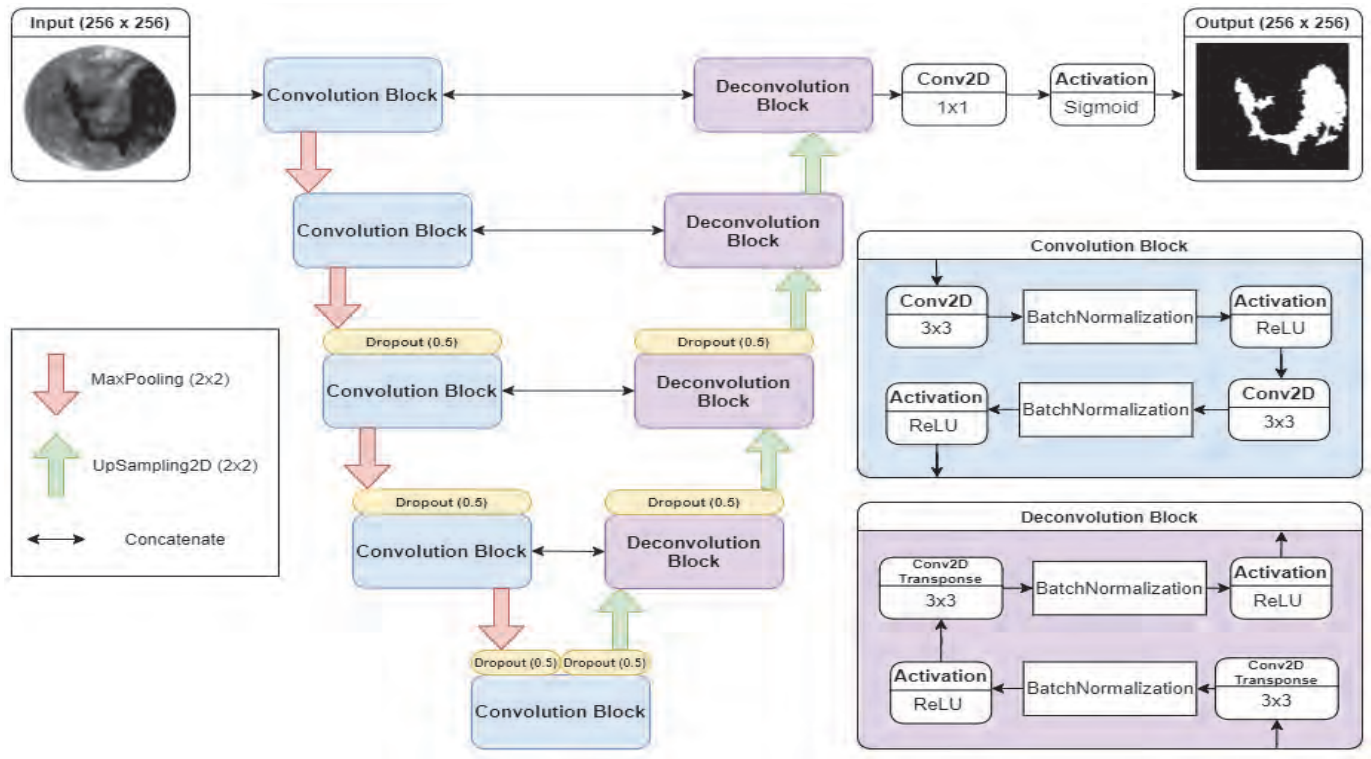
Range	2023-06-01 02:00:00 UTC
SCOPE-VIS0 Solar Monitor	2023-06-17 12:26:00 UTC
SIDC-Flare	2023-06-17 13:05:00 UTC
SIDC-PMCTF-Appara	2023-06-14 04:18:00 UTC
SCOPE-Appara	2023-06-17 00:00:00 UTC
SCOPE-Appara	2023-06-17 00:00:00 UTC
SCOPE-Appara	2023-06-18 02:00:00 UTC



Full product | Provided by: Solar Influences Data analysis Center

Use again, Part 3 – new project

- How to move towards potential service -> higher TRL
 - Who might help ? ... someone with long-term expertise in ESA SWE Portal => partners from Belgium with extensive experience in Solar Weather, ESA services, and ML/DL
 - Call: ESA RPA for Slovakia, 2023
 - Proposal: **SCSS-Net**
 - Proposal title: **Development of SCSS-Net: Solar Corona Structures Segmentation algorithm by deep neural networks**
 - Partners: **FEI TUKE + IEP SAS + ROB (Royal Observatory of Belgium)**
 - Goal: start with SCSS-Net as is, increase TRL to 3, try to fulfill as many requirements as possible in this stage, all towards the possible future use in ESA SWE Portal
 - Duration: 15 months
- ⇒ Current status of proposal => **recommended for implementation**
- [will start at the end of 2023 or start of 2024, after (hopefully successful) negotiation]



The story of SCSS-Net continues ...