Towards Autonomous Space Research

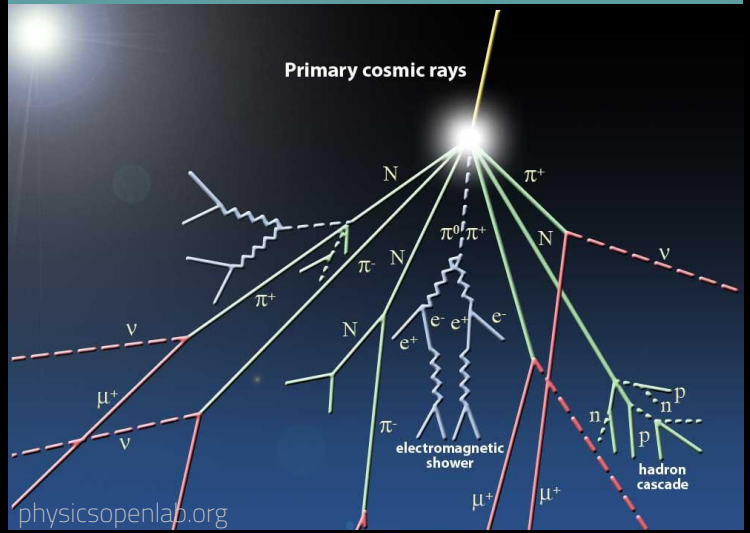
Šimon Mackovjak

Konferencia mladých astronómov / 10 Sep 2021 / Bezovec

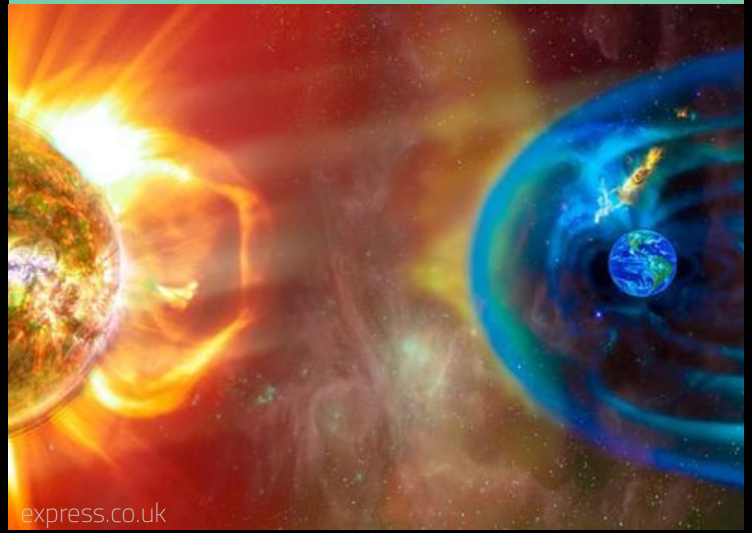
Credit: https://ourplnt.com

Main topics at **Slovak Academy of Sciences** in Košice

Cosmic rays



Space weather



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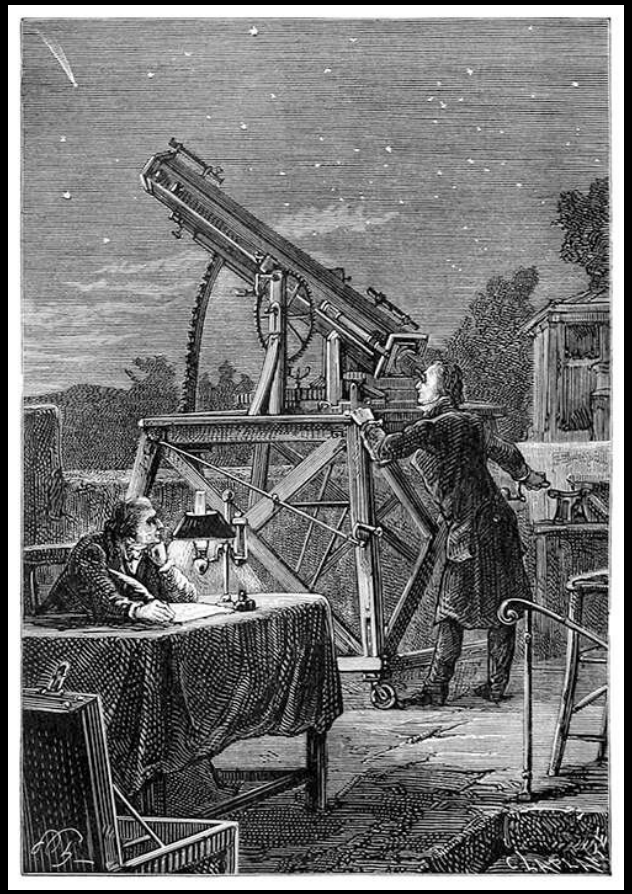
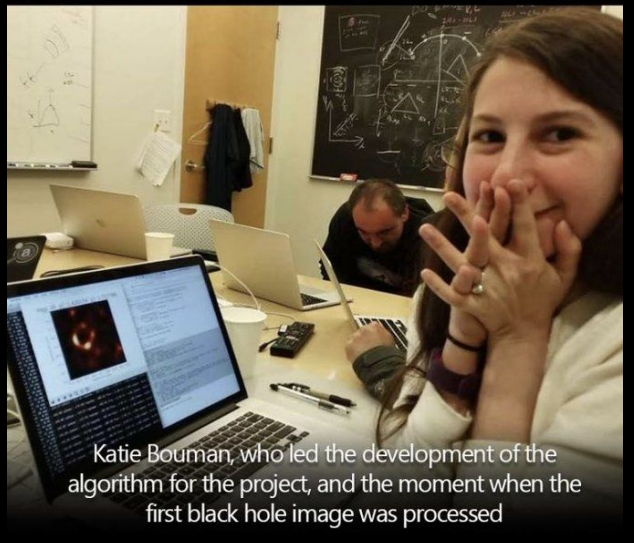
19th century



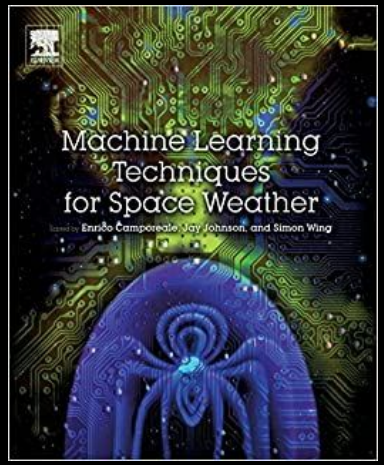
oldbookillustrations.com

21st century

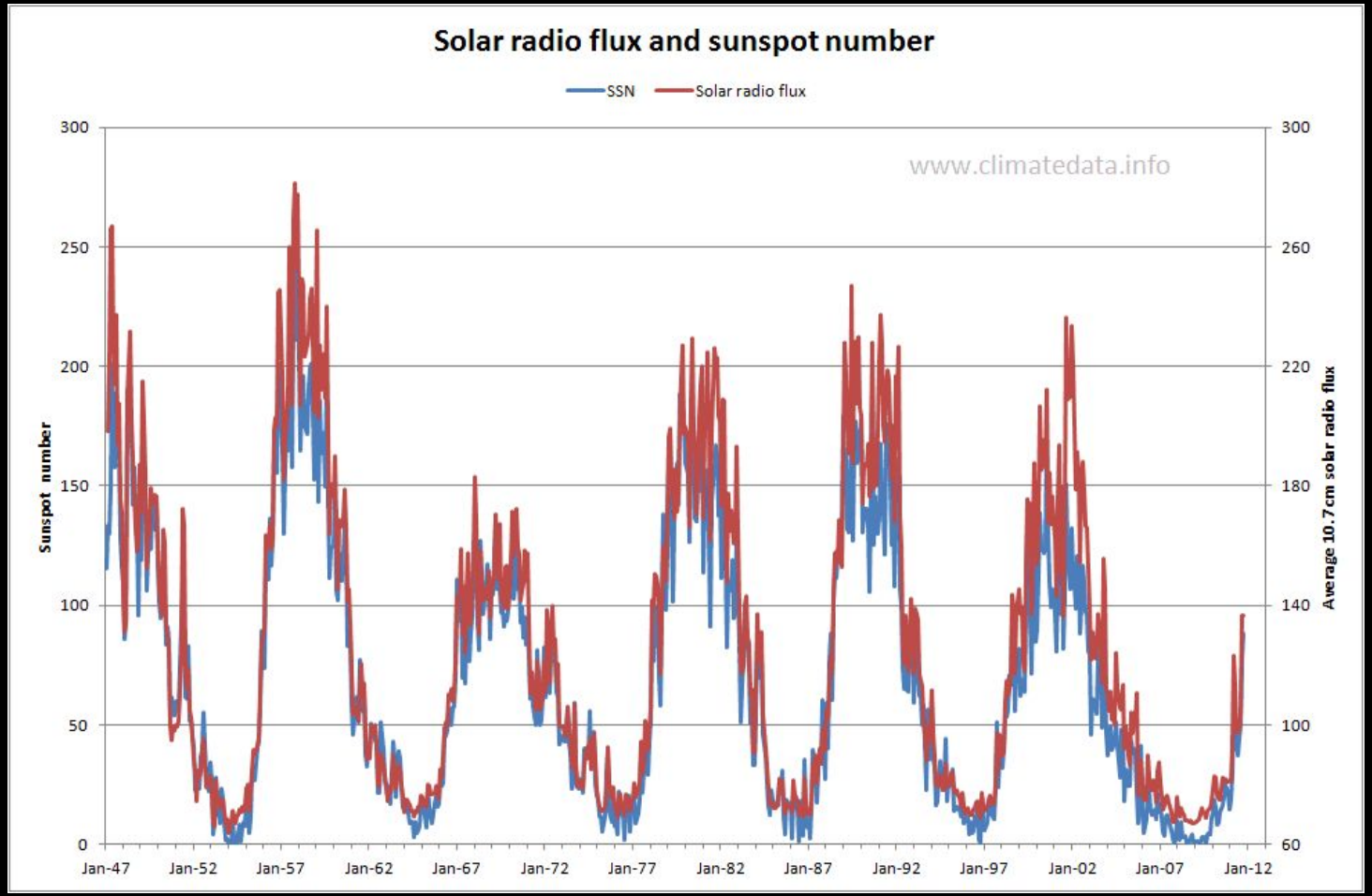


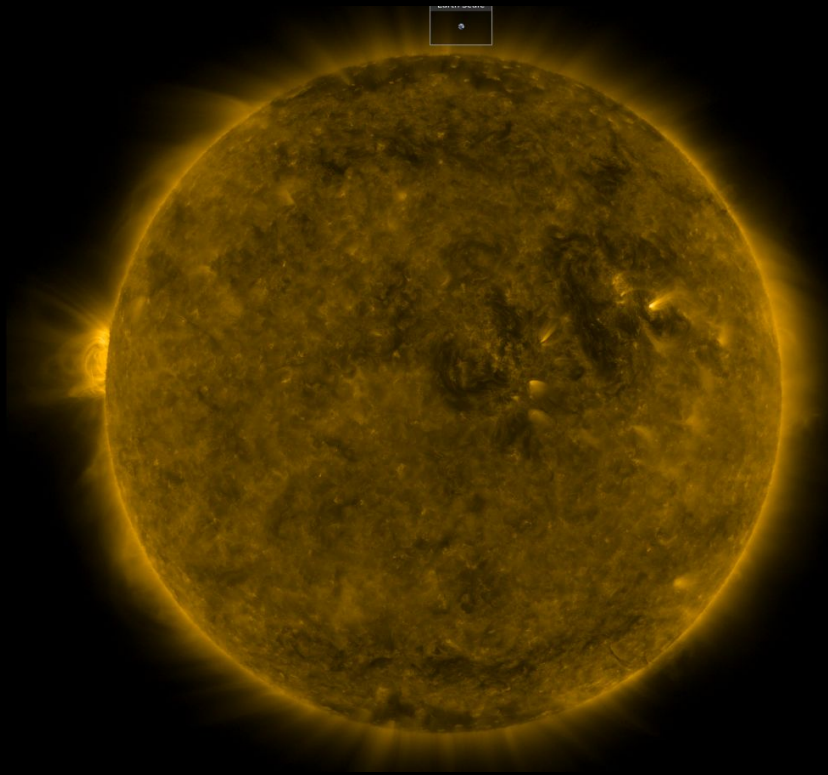
twitter.com

1) **Big data** are available (for free)
2) Great **computation power** is accessible (almost free)
3) Top **IT tools** can be used (for free)

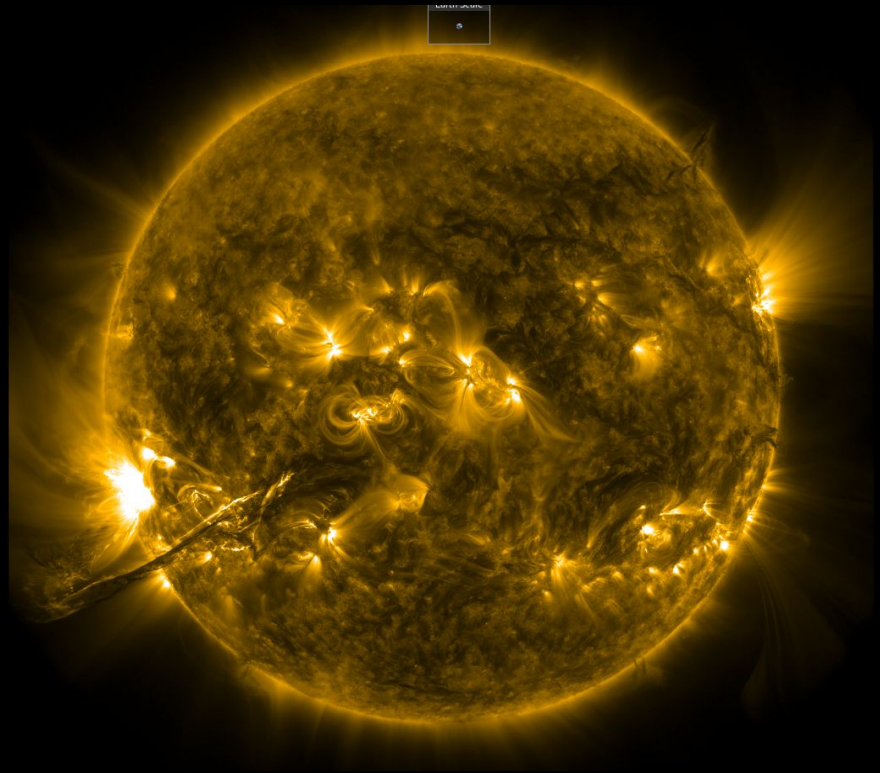


(Camporeale et al. 2019)


Solar radio flux and sunspot number
SSN
Solar radio flux
www.climatedata.info
Sunspot number
Average 10.7cm solar radio flux
300
250
200
150
100
50
0
260
220
180
140
100
60
Jan-47
Jan-52
Jan-57
Jan-62
Jan-67
Jan-72
Jan-77
Jan-82
Jan-87
Jan-92
Jan-97
Jan-02
Jan-07
Jan-12



Quiet Sun



Active Sun


EURÓPSKA
NOC
24.9.
2021
VÝSKUM-
NÍKOV
VEDECKÝ KURIÉR
KOZMICKÝ STRÁŽCA
ORGANIZÁTORI
SOVVA
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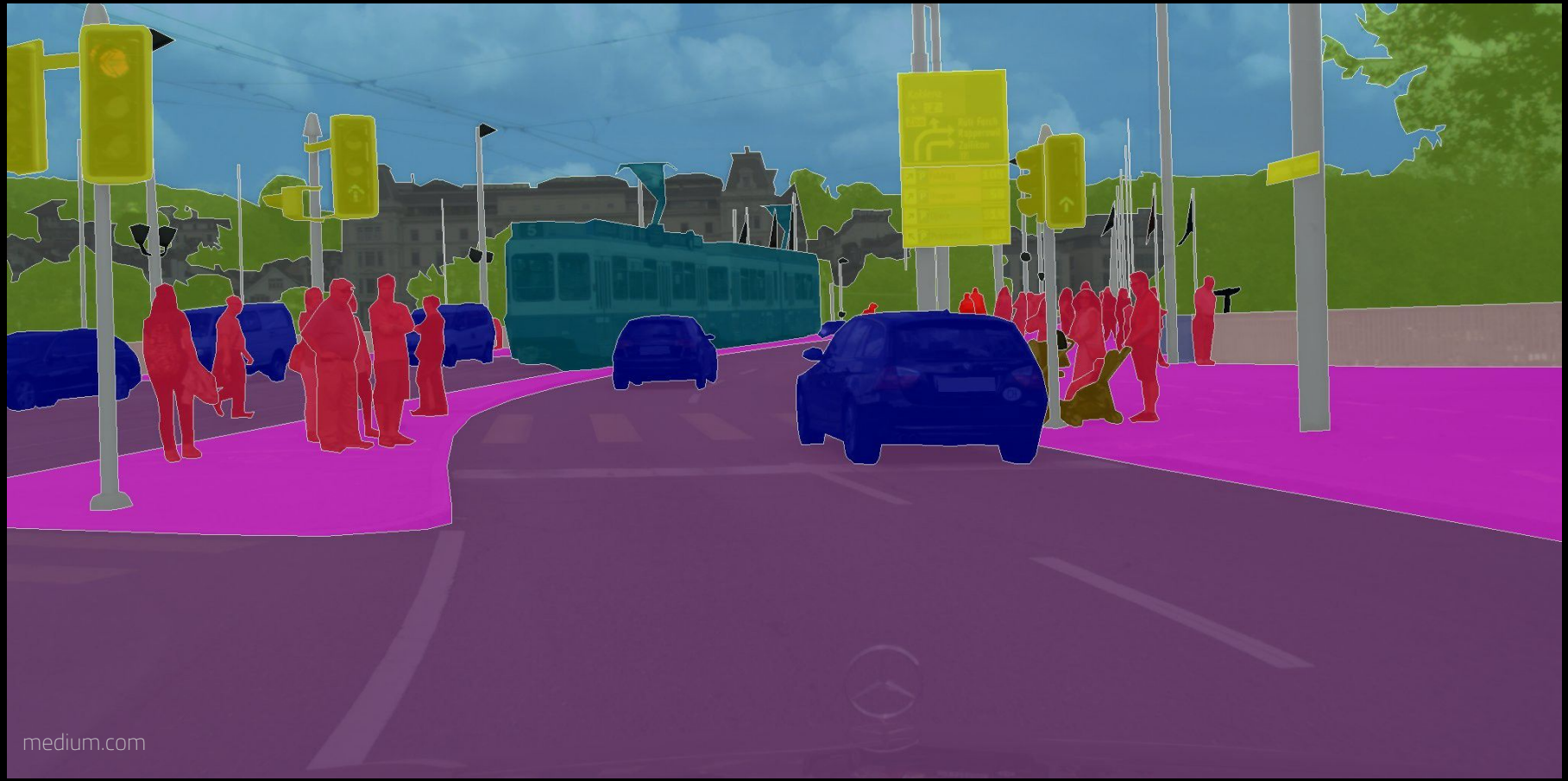
ENERGIOU


medium.com

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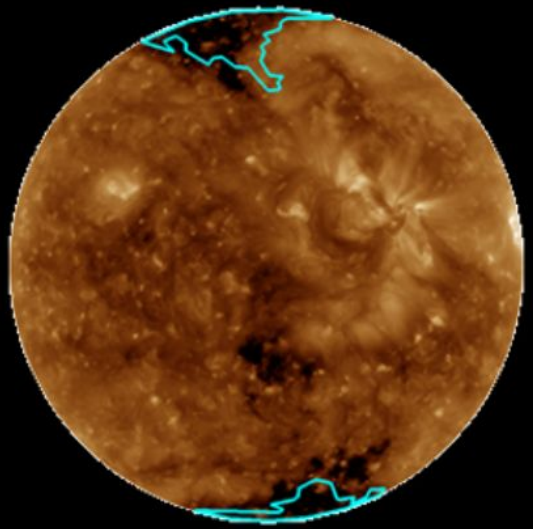
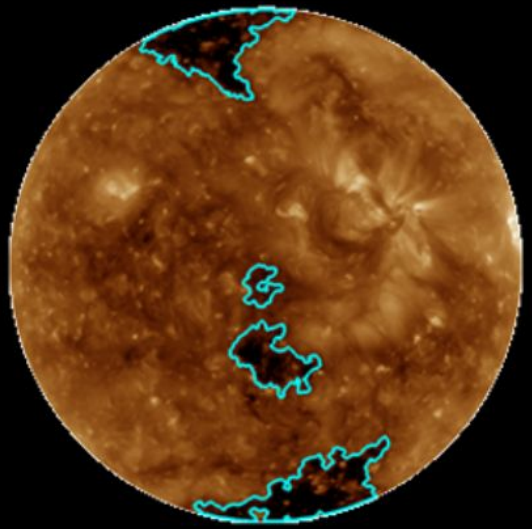
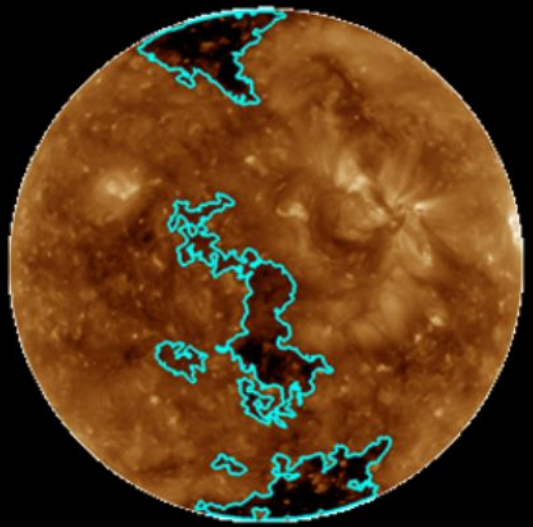
SPoCA



Region Growth



CHIMERA



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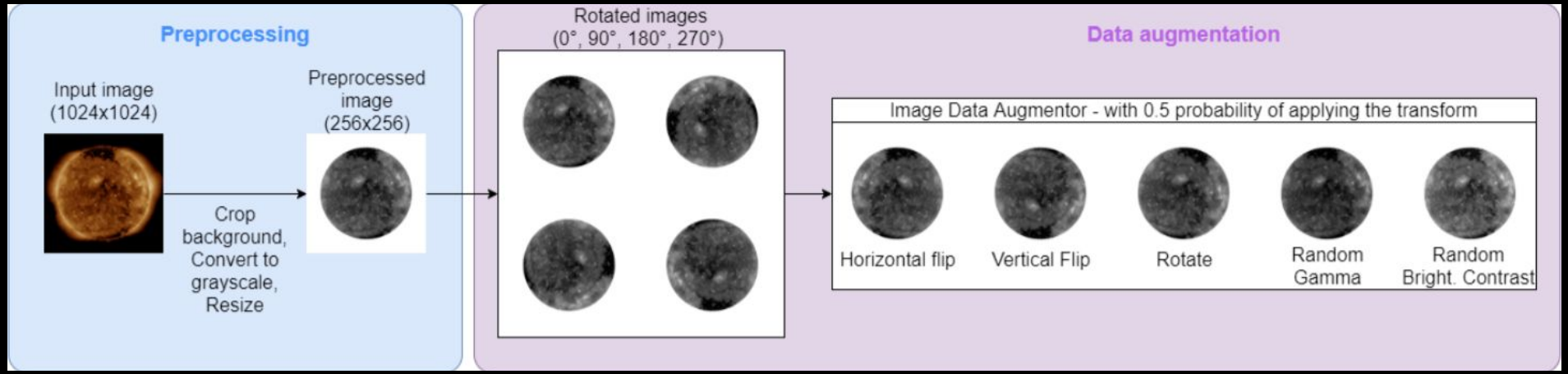

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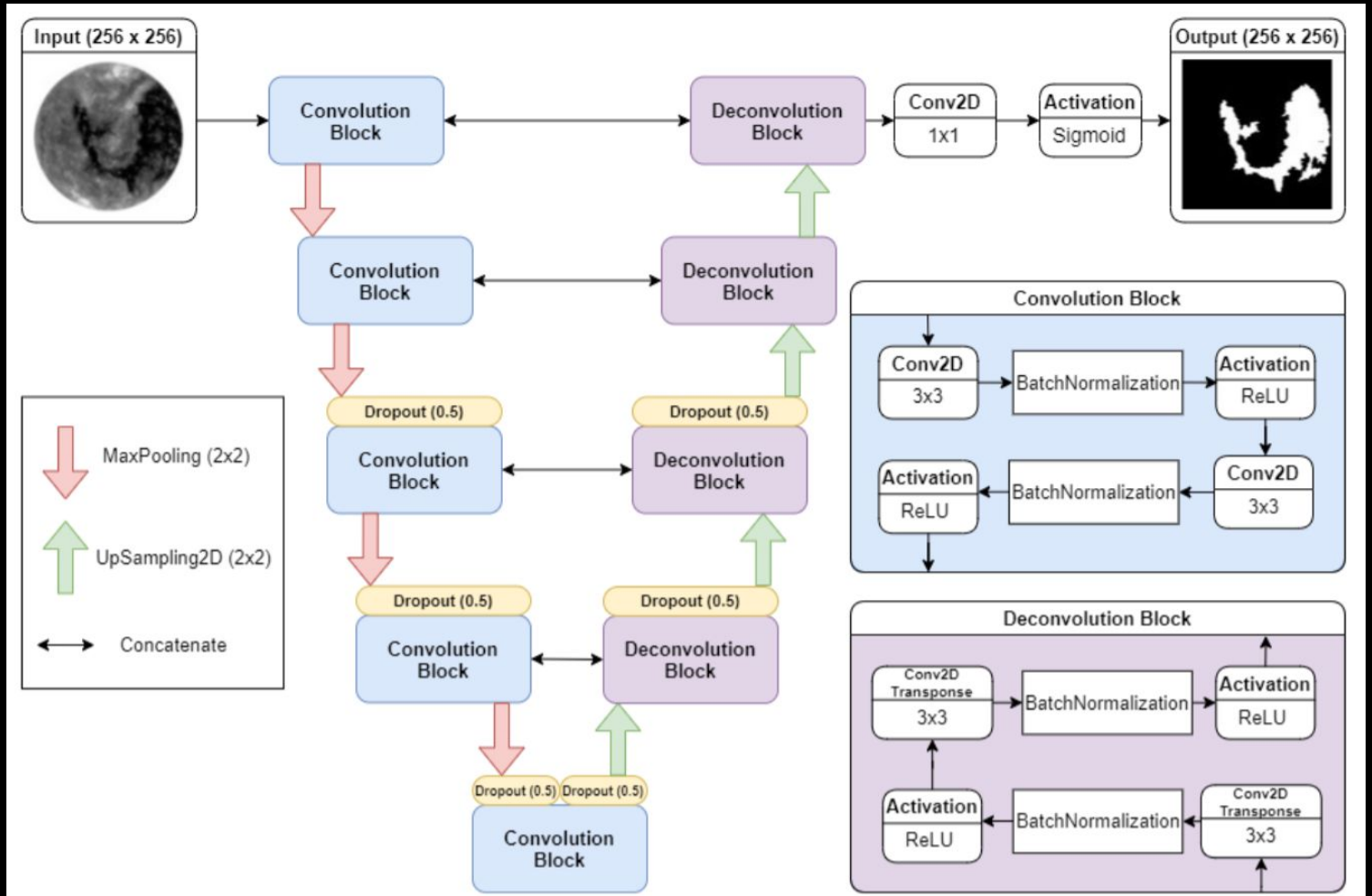
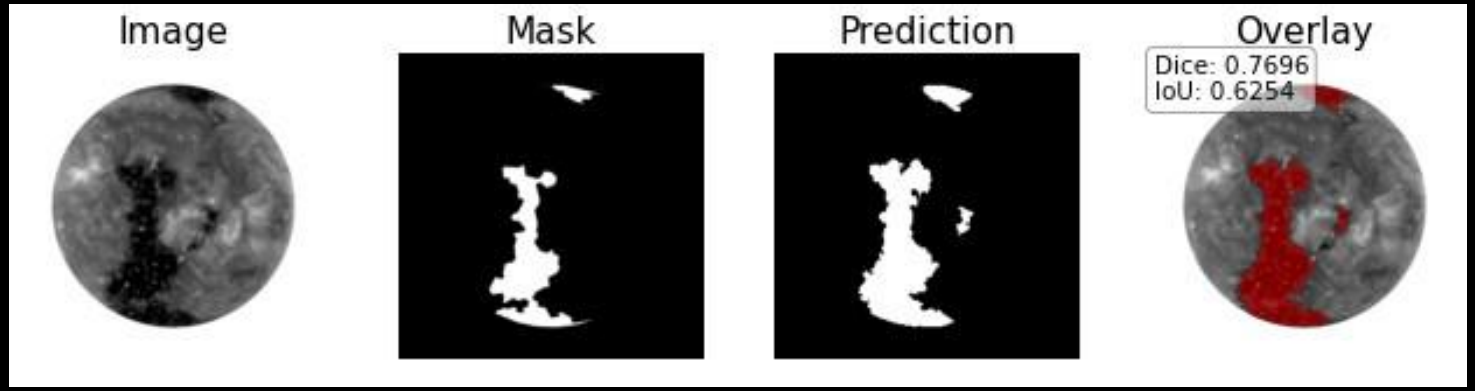
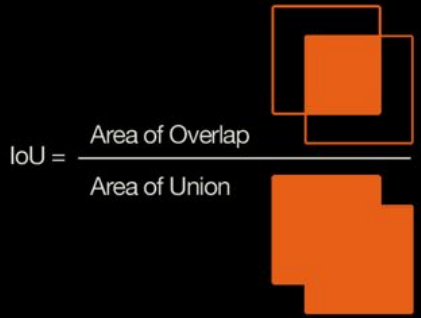
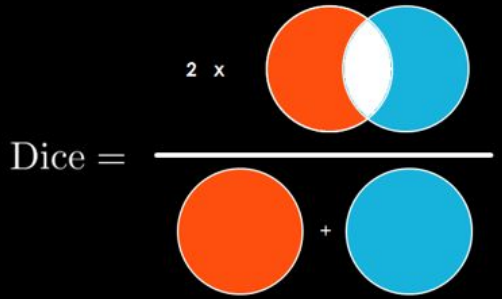




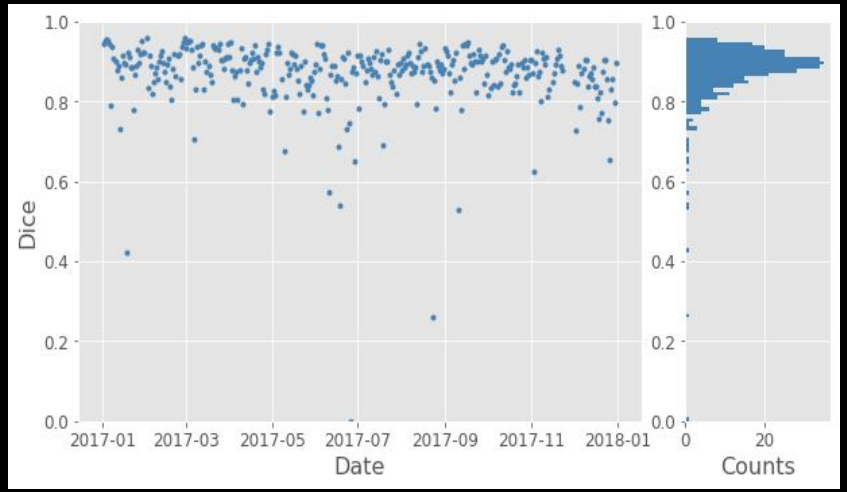


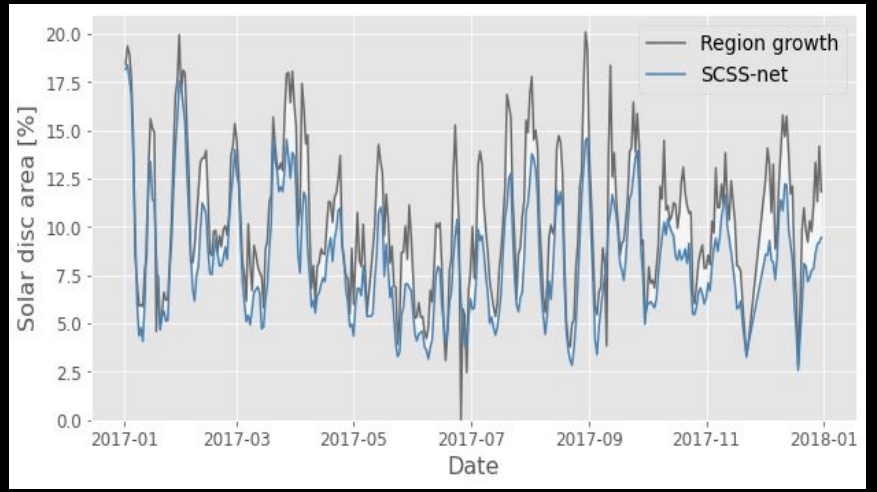


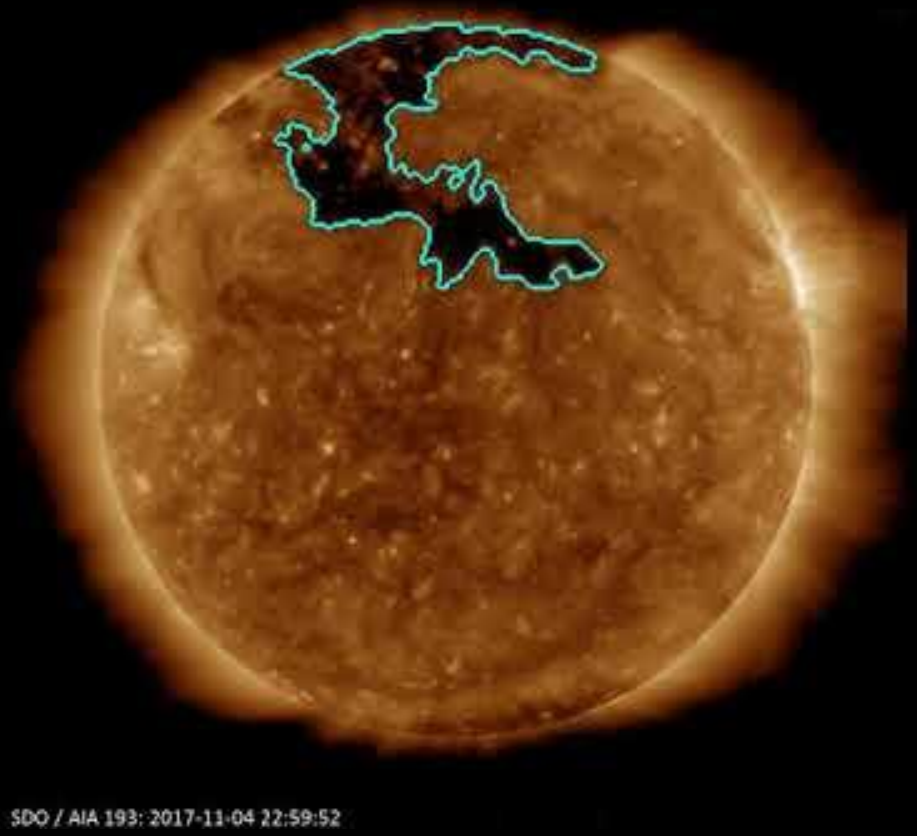
$$\text{IoU} = \frac{\text{TP}}{\text{TP} + \text{FP} + \text{FN}}$$

$$\text{Dice} = \frac{2\text{TP}}{2\text{TP} + \text{FP} + \text{FN}}$$

Train dataset	Test set	Dice	IoU
Custom	353	0.83	0.71
SPoCA	353	0.43	0.28
CHIMERA	353	0.85	0.73
Region Growth	353	0.88	0.78







Test dataset (SDO / AIA 193): 1 -12 / 2017

MNRAS 000, 1–11 (2021) Preprint 9 September 2021 Compiled using MNRAS LATEX style file v3.0

SCSS-Net: Solar Corona Structures Segmentation by Deep Learning

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Accepted 2021 September 03. Received 2021 August 11; in original form 2021 May 14

ABSTRACT

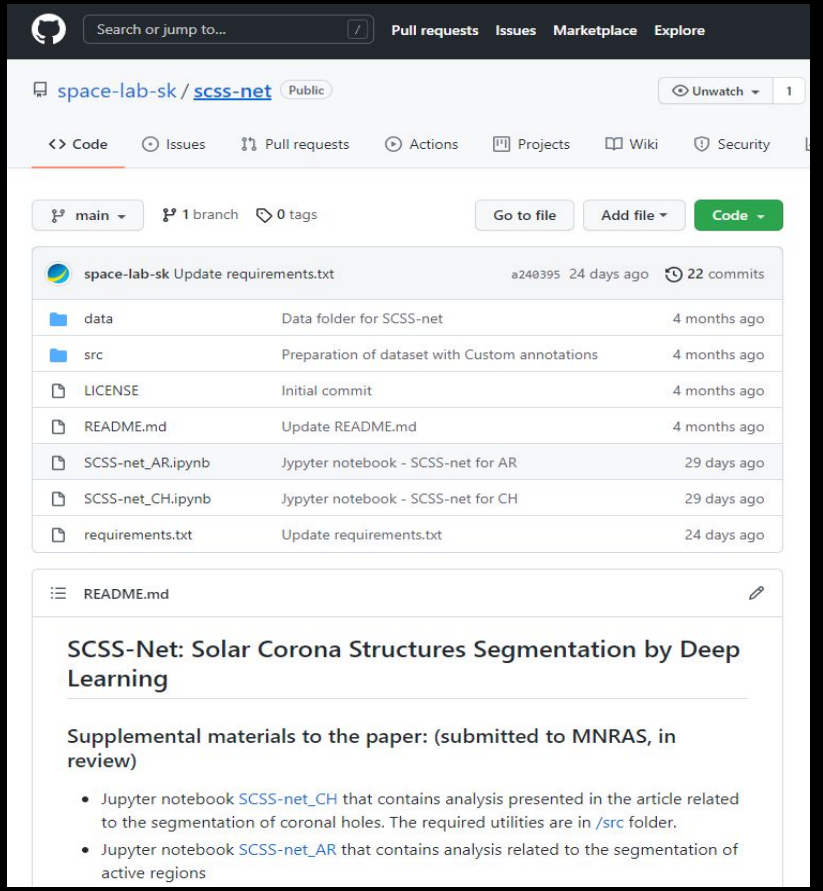
Structures in the solar corona are the main drivers of space weather processes that might directly or indirectly affect the Earth. Thanks to the most recent space-based solar observatories, with capabilities to acquire high-resolution images continuously, the structures in the solar corona can be monitored 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 EUV spectrum that is based on a deep learning approach utilizing Convolutional Neural Networks. The available input datasets have been examined together with our own dataset based on the manual annotation of the target structures. Indeed, the input dataset 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.

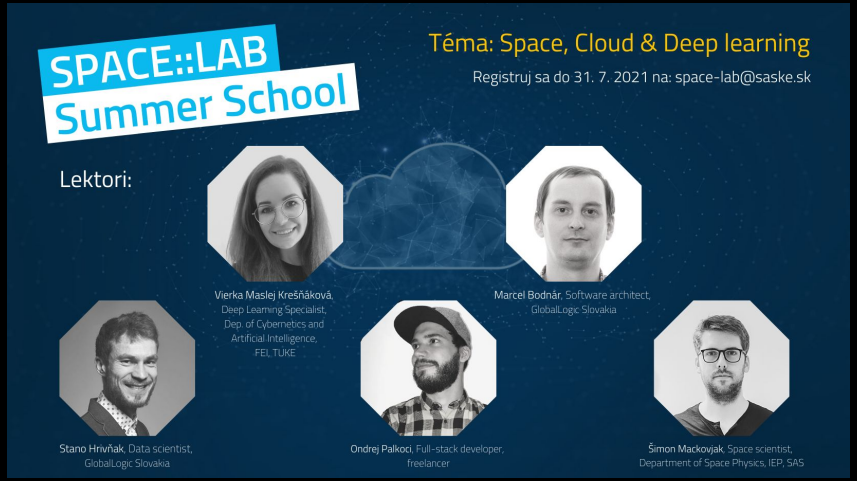
Key words: Sun: corona – methods: data analysis – techniques: image processing – software: development

1 INTRODUCTION

Solar activity has been quantified using various indices such as the sunspot number (Clette et al. 2014), the F10.7 index (Tapping 2013), coronal index (Rybanský et al. 2005), and others (Ermolli et al. 2014) over more than six decades. These indices represent integrated quantities for specific processes in the solar atmosphere as they are measured by ground-based instruments. Thanks to the most recent space missions such as e.g. SOHO (Domingo et al. 1995), Hinode (Kosugi et al. 2007), SDO (Pesnell et al. 2012), Solar Orbiter (Müller et al. 2013), and Parker Solar Probe (Fox et al. 2016), solar activity can be monitored in a much more detailed way. The temporal resolution in terms of seconds and spatial resolution down to hundreds of kilometers in multiple spectral bands enable individual events to be studied with particular consequences for Sun–Earth relations (Müller et al. 2020; Lörinčík et al. 2021a). However, the challenging task is to effectively process the huge amount of images that are automatically acquired with a very high resolution. This task rithms were introduced. The Spatial Possibilistic Clustering Algorithm (SPoCA) (Barra et al. 2009; Verbeeck et al. 2014) or Coronal Hole Identification via Multi-thermal Emission Recognition Algorithm (CHIMERA) (Garton et al. 2018) have been found to be very effective and are widely used in online solar data visualization tools[1, 2]. The SPoCA also provides entries for catalogues of coronal holes and active regions within the Heliophysics Events Knowledgebase (HEK) (Hurlburt et al. 2012) that is commonly used in the SolarSoft (Freeland & Handy 1998) and SunPy (The SunPy Community et al. 2020) frameworks. As will be presented later, these algorithms still have limitations for the precise segmentation of structures in the solar corona. Due to the advances in computer vision in recent years, approaches based on machine learning techniques are able to extend the standard methods (Aschwanden 2010). Conventional machine learning techniques as Support Vector Machine (SVM), Decision Tree, or Random Forest could improve the detection of coronal holes as they provide automated distinguishing

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

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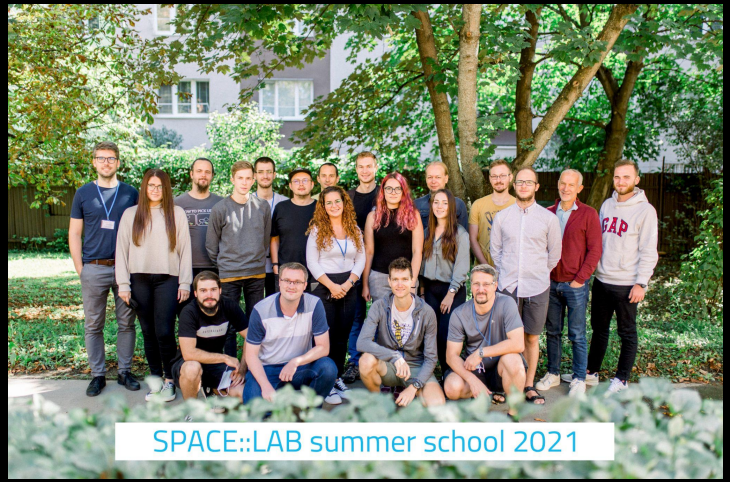
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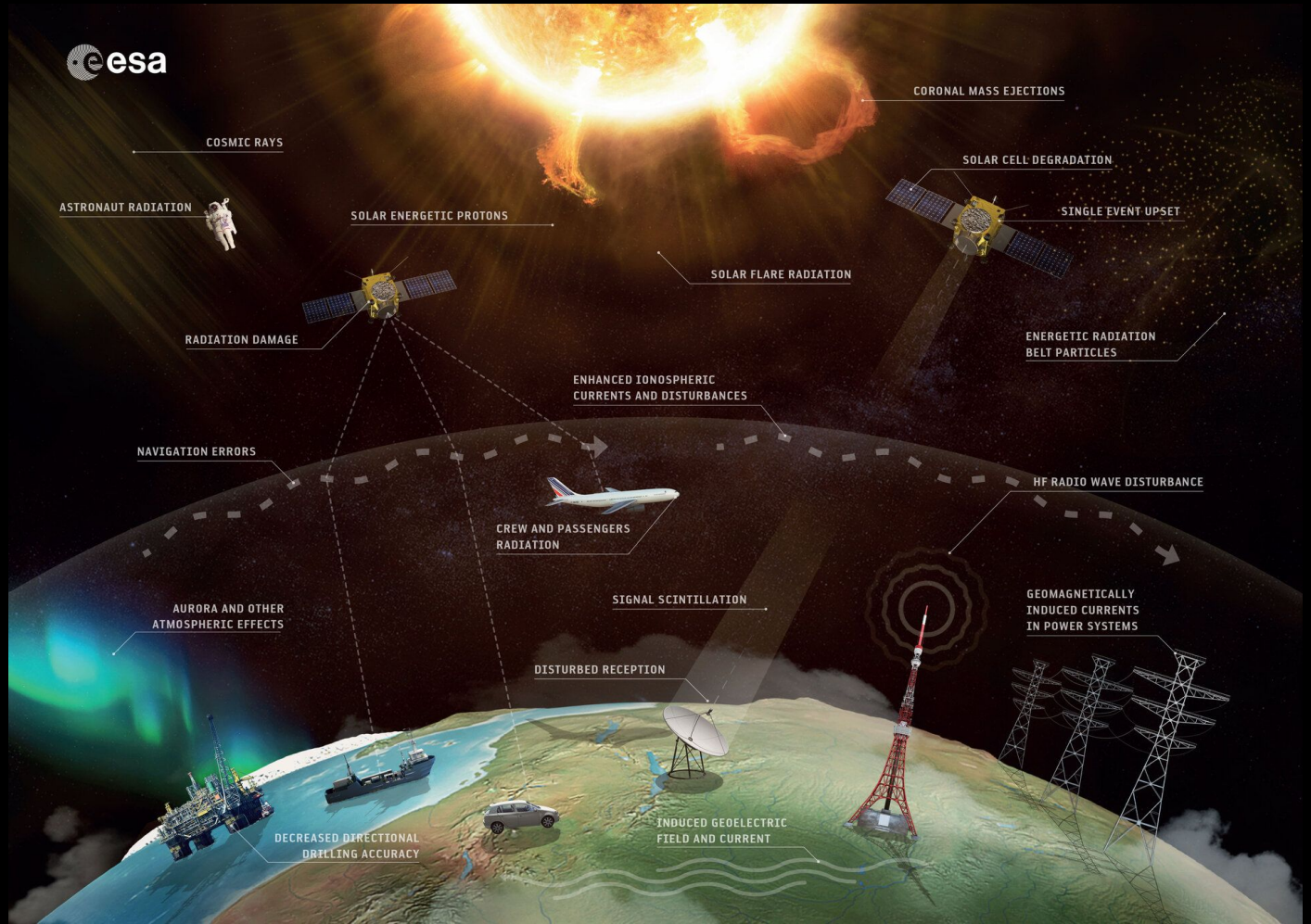

On the way towards autonomous space research:

1) Focus on domain & Define problem
2) Prepare data
3) Employ SW & AI tools
4) Catch the physics (!)
5) Wait for new discoveries

Priestor na spojenie

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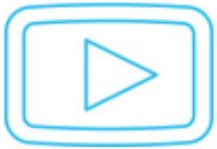

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