AI-based approaches to data integration for Solar Orbiter instruments

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9th metis workshop, january 24-26 2024

museo diocesano di catania, catania, italy

credits

credits: people

solar physics and space weather people @MIDA:

- anna maria massone
- sabrina guastavino
- federico benvenuto
- emma perracchione (@POLITO)
- francesco marchetti (@UNIPD)
- paolo massa (@FHNW)
- andrea tacchino
- mattia rossi
- katia bahamazava (@POLITO)
- gianluca audone (@POLITO)
- edoardo legnaro
- anna volpara
- barbara palumbo
- fabiana cammattari
- margherita lampani
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- sam krucker (@FHNW)
- andrea battaglia (@FHNW)
- a gordon emslie (@WKU)
- gordon hurford (@berkeley)
- dario del moro (@tor vergata)

credits: money

ARCAFF
PI: a m massone

AIxtreme
PI: a m massone

SWESNET
subcontract

CORNERSTONE
PI: f benvenuto

solar orbiter contract

some tentative science

a tentative and personal list of open issues

solar flares:

- to what (quantitative) extent is it possible to predict whether an AR will produce a flare, and when, and of which class?
- which are the most effective precursors of a solar flare hidden in magnetograms and EUV images?
- which is the (quantitative) effectiveness of the acceleration mechanisms in a solar flare?

CMEs:

- is it possible to automatically detect and track a CME in a coronographic image?
- once a CME occures, how can one accurately and computationally determine its travel time from the sun to L1?
- how is it possible to compute the CME vital parameters in a detailed way using computation?

flares and CMEs:

- how can one distinguish in advance between a CME-triggering flare and a flare with no associated CME?
- are there physically explainable correlations between the parameters of CME-triggering flares and of the corresponding CMEs?

a tentative and personal general approach

ingredient 1: STIX data

- imaging approach: fourier
- spatial resolution: down to 7 arcsec
- temporal resolution: 1 sec
- spectral resolution: around 3 keV
- energy range: 4-50 keV
- database: 6000 events with at least 1000 counts at low energy

ingredient 2: metis data

(see this workshop)

ingredient 3: artificial intelligence:

- inverse problems approaches for image reconstruction from STIX data
- convolutional neural networks to detect and track CMEs in metis images
- physics-based neural networks to compute CMEs vital parameters
- featured-based machine learning to identify correlations between STIX and metis data

preliminary results: metis

see this workshop

preliminary results: image reconstruction for STIX

The Astrophysical Journal, 894:46 (11pp), 2020 May 1

MEM_GE: A New Maximum Entropy Me… X-Ray Vi…

Paolo Massa[1], Richard Schwartz[2], A Kim Tolbert[2], Anna M…
Federico Be…
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Received 2020 February 18; revised 2020 March 1…

A&A 668, A145 (2022)
https://doi.org/10.1051/0004-6361/202243907

Forward fitting

Anna Volpara[1], Paolo Massa[2], Emma Perracchione
Federico Benvenuto[1], Säm Krucker[5,7], Mi…

The Astrophysical Journal Supplement Series, 268:68 (10pp), 2023 October https://doi.org/10.3847/1538-4365/acf669

Unbiased CLEAN for STIX in Solar Orbiter

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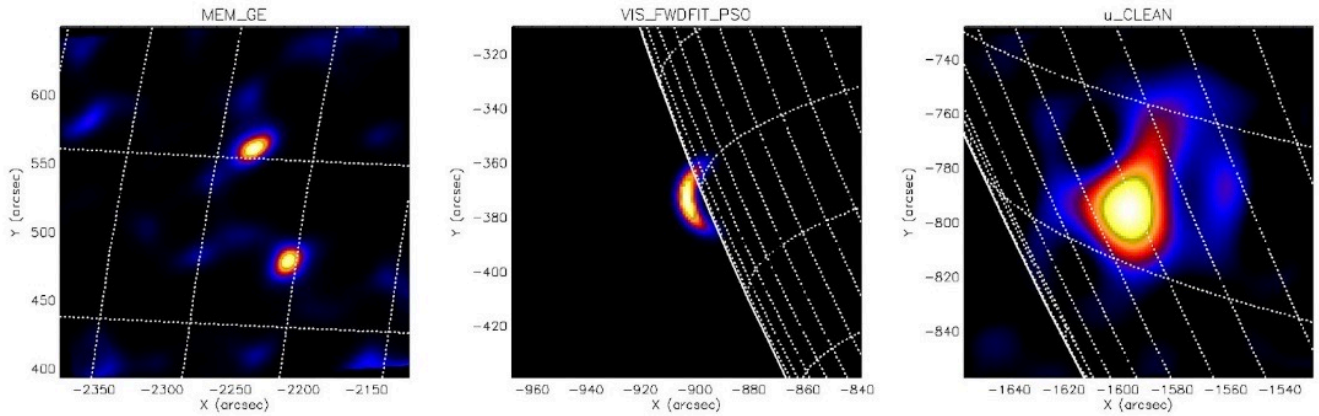
Received 2023 August 1; revised 2023 August 30; accepted 2023 September 2; published 2023 October 12



constrained maximum entropy

particle swarm optimization

automated CLEAN

preliminary results: flare forecasting

The Astrophysical Journal Letters, 904:L7 (7pp), 2020 November 20 https://doi.org/10.3847/2041-8213/abc5b7

Machine Learning as a Flaring Storm Warning Machine: Was a Warning Machine for the 2017 September Solar Flaring Storm Possible?

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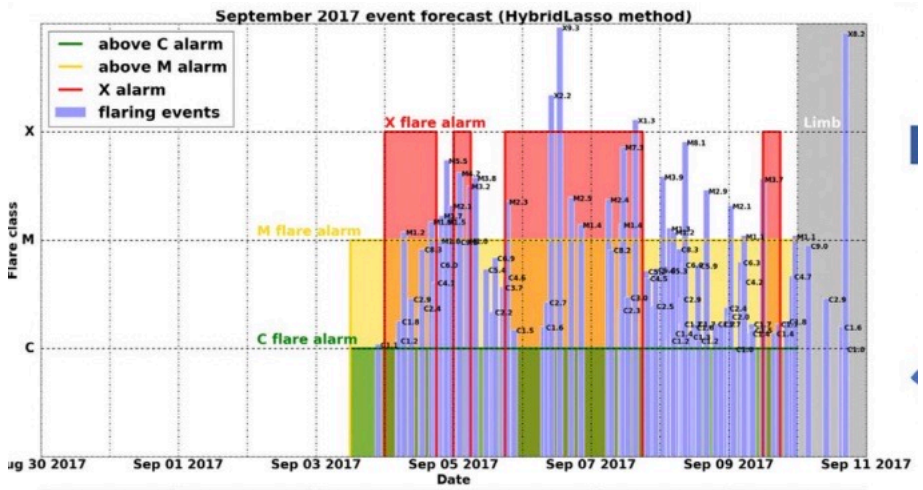

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Operational solar flare forecasting *via* video-based deep learning

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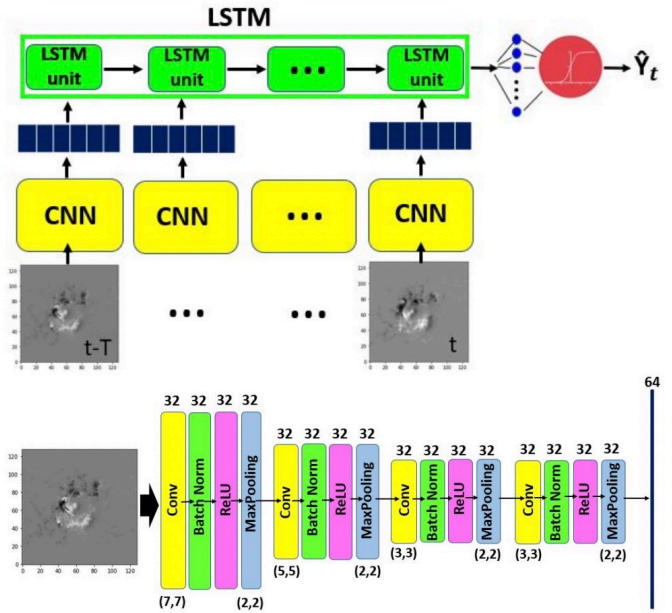
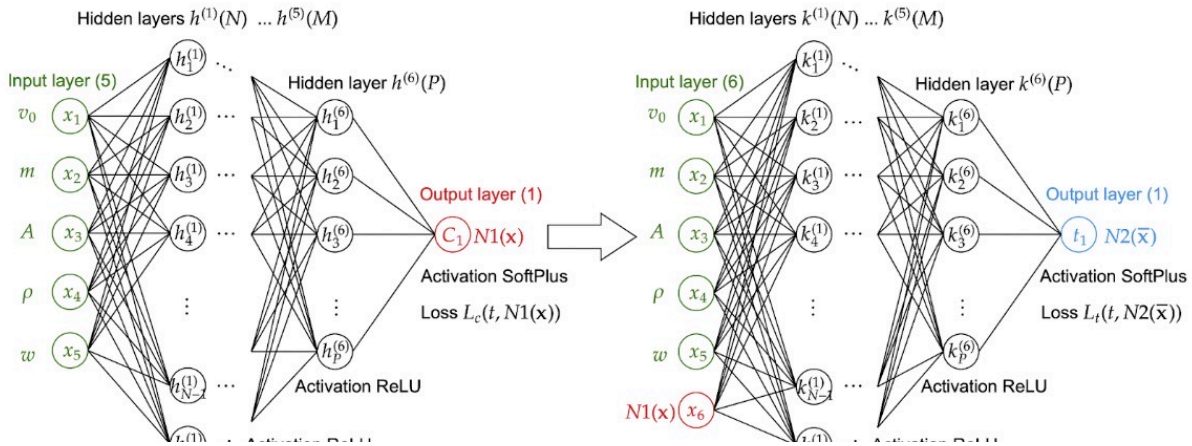
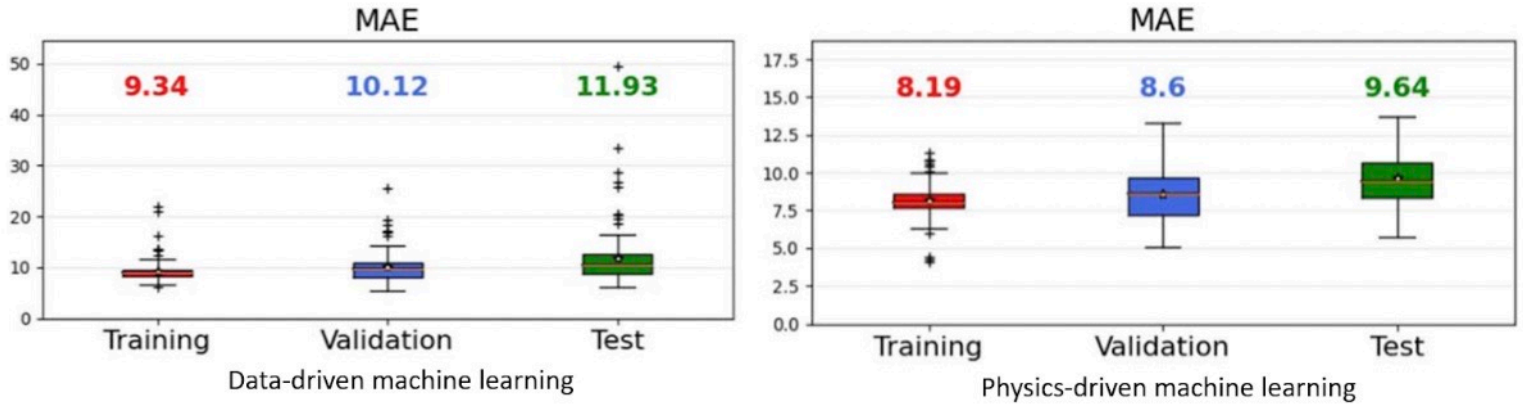


preliminary results: travel time prediction for CMEs

The Astrophysical Journal, 954:151 (9pp), 2023 September 10 https://doi.org/10.3847/1538-4357/ace62d

Physics-driven Machine Learning for the Prediction of Coronal Mass Ejections' Travel Times





comments

- still some issues concerning the calibration of the small STIX grids (work in progress at MIDA)
- model selection for acceleration mechanisms in solar flares
- few data from solar orbiter: transfer learning
- training phase in classification: score-oriented loss functions
- training phase in regression: design of physics-based loss functions
- value-weighted skill scores for performance assessment of AI approaches

MIDA in a nutshell
mida.unige.it

anna maria massone

HELCOMP

space weather national infrastructure

federico benvenuto

M3

MIDA
methods for image and data analysis

cristina campi, sara garbarino

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andrea tacchino

HoB
The portable AI

Spin off
Università degli Studi di Genova