



# Applying Supervised Learning Methods for Metis Data Validation

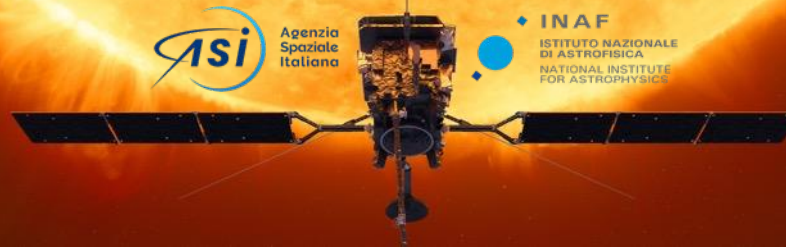
A. Burtovoi<sup>1</sup>, M. Romoli<sup>1</sup> for the Metis Team<sup>2</sup>

<sup>1</sup> University of Florence

<sup>2</sup> <https://metis.oato.inaf.it>

2nd Metis Science Meeting - 27-29 Jan 2025





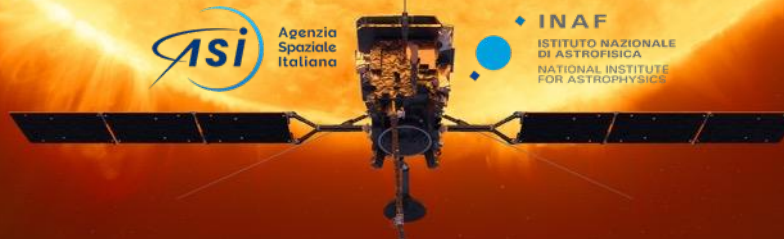
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# Metis Data Validation

Main activities:

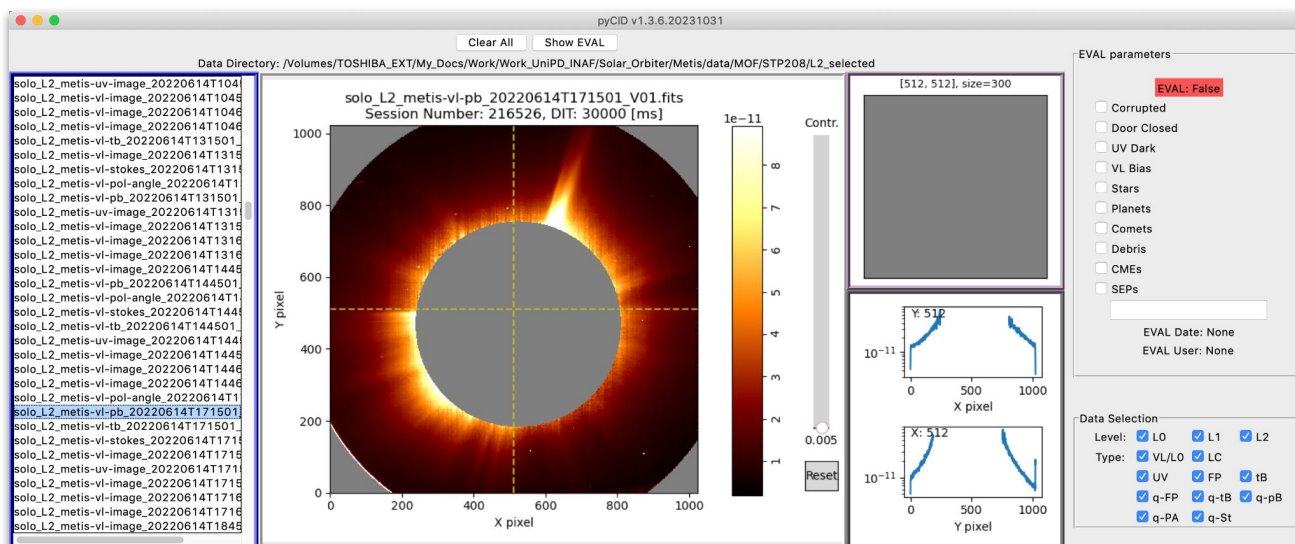
1. Missing data check

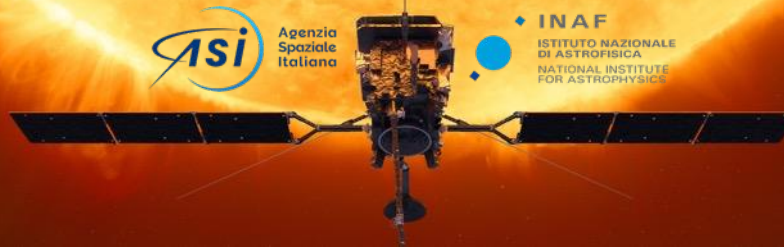


# Metis Data Validation

Main activities:

1. Missing data check
2. Visual examination of images (iCID or pyCID)

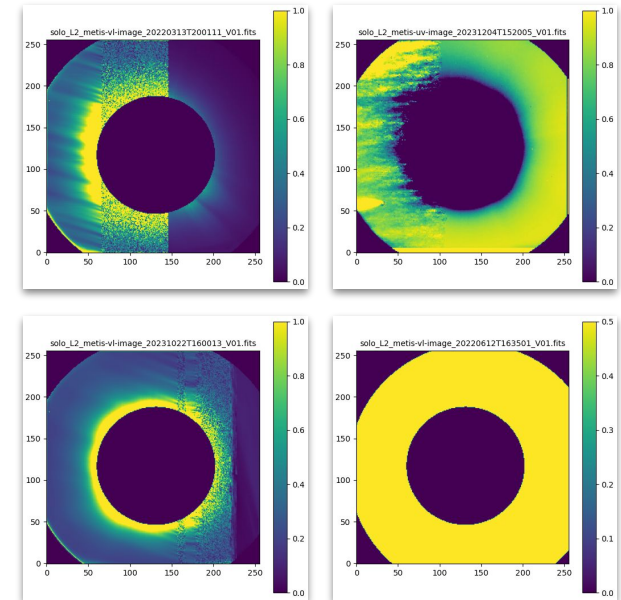




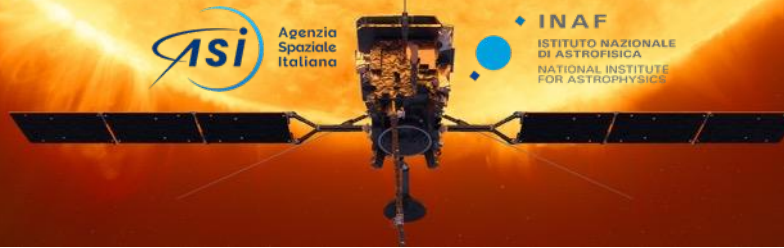
# Metis Data Validation

Main activities:

1. Missing data check
2. Visual examination of images
  - Corrupted images



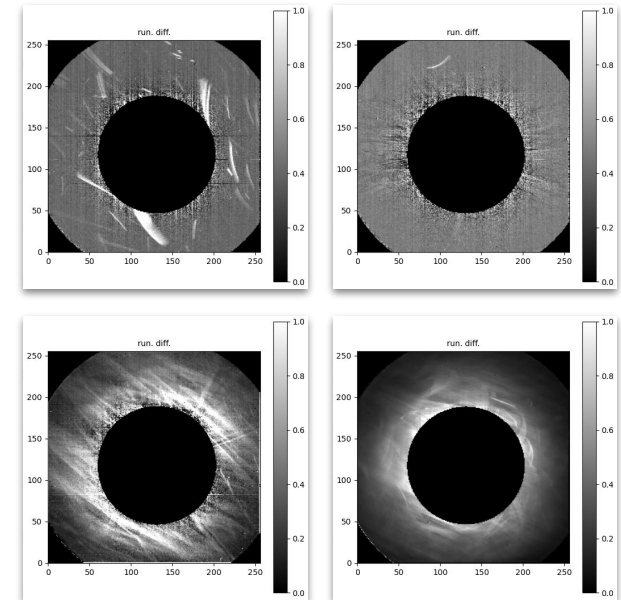


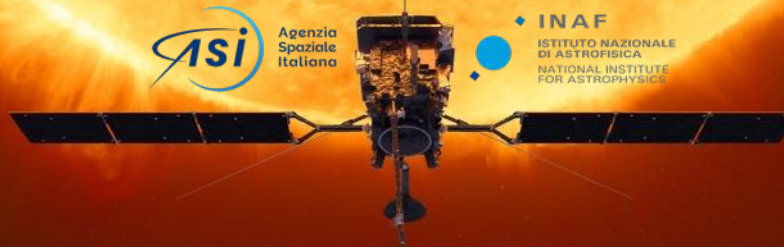


# Metis Data Validation

Main activities:

1. Missing data check
2. Visual examination of images
  - Corrupted images
  - Debris





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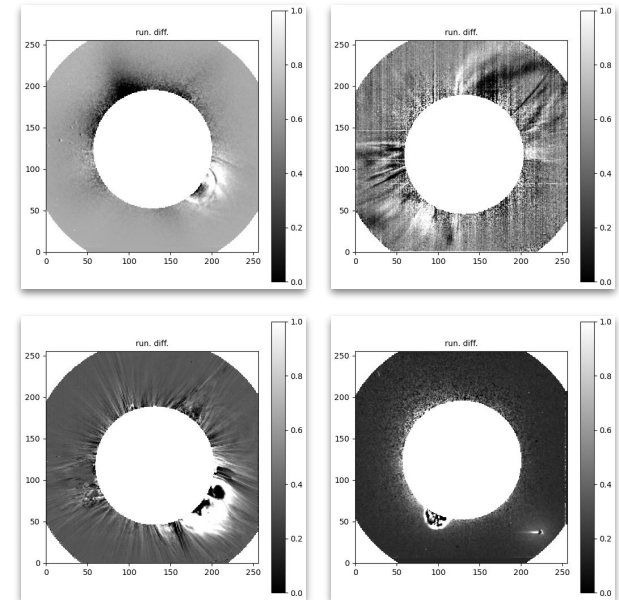
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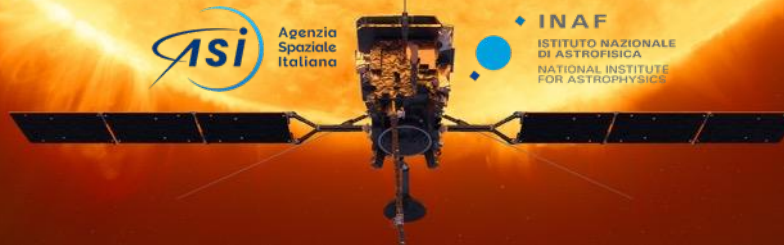


# Metis Data Validation

Main activities:

1. Missing data check
2. Visual examination of images
  - Corrupted images
  - Debris
  - CMEs





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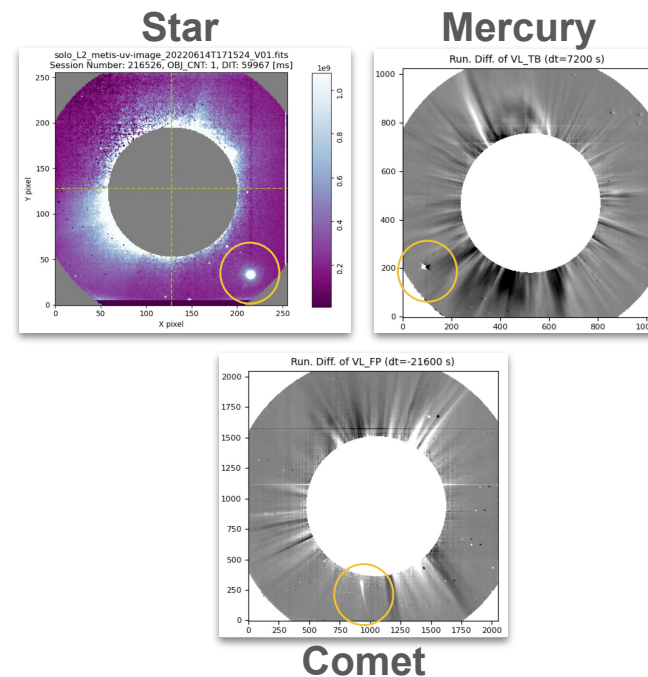
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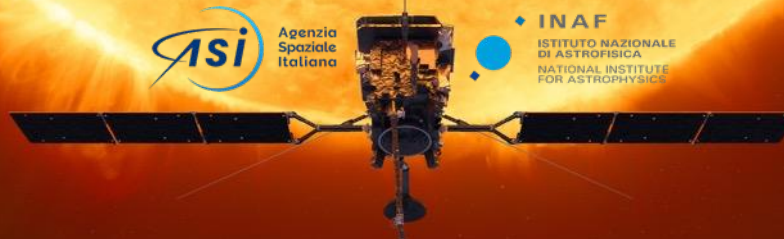


# Metis Data Validation

Main activities:

1. Missing data check
2. Visual examination of images
  - Corrupted images
  - Debris
  - CMEs
  - Stars
  - Planets
  - Comets

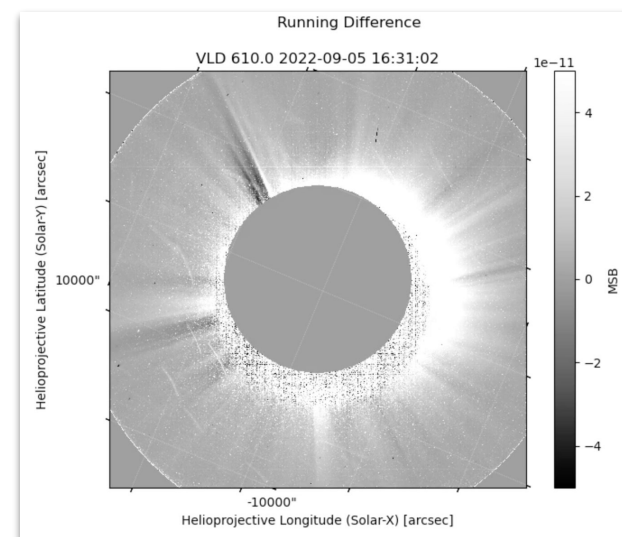




# Metis Data Validation

Main activities:

1. Missing data check
2. Visual examination of images
  - Corrupted images
  - Debris
  - CMEs
  - Stars
  - Planets
  - Comets
  - SEPs



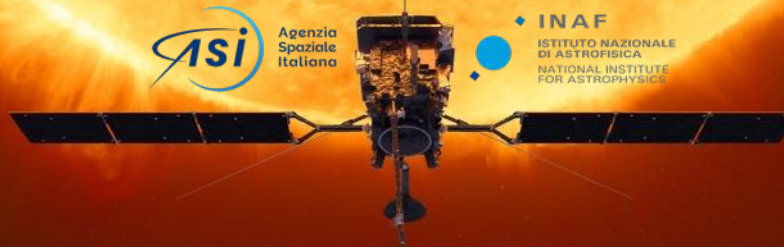




# Image Labeling

Visual examination → manual labeling → release\_global.csv

FILENAME	OBT_BEG	SESS_NUM	IS_CORRUPTED	DOOR_CLOSED	VL_BIAS	IS_DARK	CME	STAR	PLANET	DEBRIS	COMET	SEP	COMMENT	COMMENT1	PUBLICATION	EVALDATE	EVALUSER
solo_L2_metis-uv-image_20220612T163525_V01.fits	708366801.3821259	216321	False	False	False	False	False	True	False	False	False	False	47 Lib, HD142883, delta Sco, nu Sco			2024-01-07T21:14:31	aburtovoi
solo_L2_metis-uv-image_20220612T180525_V01.fits	708372201.3434906	216321	False	False	False	False	False	True	False	False	False	False	47 Lib, HD142883, delta Sco, nu Sco			2024-01-07T21:16:34	aburtovoi
solo_L2_metis-uv-image_20220612T193525_V01.fits	708377601.3048401	216321	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:16:45	aburtovoi
solo_L2_metis-uv-image_20220612T211523_V01.fits	708383599.1259003	216326	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:16:54	aburtovoi
solo_L2_metis-uv-image_20220612T224523_V01.fits	708389999.0874481	216326	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:25	aburtovoi
solo_L2_metis-uv-image_20220612T233516_V01.fits	708391992.8632855	216327	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:30	aburtovoi
solo_L2_metis-uv-image_20220612T234016_V01.fits	708392292.8811798	216327	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:43	aburtovoi
solo_L2_metis-uv-image_20220612T234516_V01.fits	708392592.8790741	216327	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:47	aburtovoi
solo_L2_metis-uv-image_20220612T235016_V01.fits	708392892.8769836	216327	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:52	aburtovoi
solo_L2_metis-uv-image_20220613T011502_V01.fits	708397978.2192078	216405	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:55	aburtovoi
solo_L2_metis-uv-image_20220613T051501_V01.fits	708412377.6537933	216410	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:17:59	aburtovoi
solo_L2_metis-uv-image_20220613T064501_V01.fits	708417777.6156311	216410	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:18:02	aburtovoi
solo_L2_metis-uv-image_20220613T091600_V01.fits	708426776.9864655	216415	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:18:04	aburtovoi
solo_L2_metis-uv-image_20220613T104500_V01.fits	708432176.9477539	216415	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:18:18	aburtovoi
solo_L2_metis-uv-image_20220613T131530_V01.fits	708441206.3227234	216420	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:18:24	aburtovoi
solo_L2_metis-uv-image_20220613T144530_V01.fits	708446606.2837067	216420	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:18:29	aburtovoi
solo_L2_metis-uv-image_20220613T171529_V01.fits	708455605.4716339	216425	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-08T12:25:28	aburtovoi
solo_L2_metis-uv-image_20220613T184529_V01.fits	708461005.4326477	216425	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco			2024-01-07T21:18:36	aburtovoi
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solo_L2_metis-uv-image_20220613T232322_V01.fits	708478398.3609467	216431	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-07T21:22:09	aburtovoi
solo_L2_metis-uv-image_20220613T232402_V01.fits	708478998.3587952	216431	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-07T21:23:13	aburtovoi
solo_L2_metis-uv-image_20220613T234522_V01.fits	708478998.3566437	216431	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-07T21:18:45	aburtovoi
solo_L2_metis-uv-image_20220613T235022_V01.fits	708479298.3544769	216431	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-07T21:18:48	aburtovoi
solo_L2_metis-uv-image_20220614T011527_V01.fits	708484403.7146912	216505	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-07T21:18:51	aburtovoi
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solo_L2_metis-uv-image_20220614T064526_V01.fits	708504202.7214355	216511	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-08T12:35:42	aburtovoi
solo_L2_metis-uv-image_20220614T091526_V01.fits	708513201.963923	216516	False	False	False	False	False	True	False	False	False	False	HD142883, delta Sco, nu Sco, HD144334, HD144844			2024-01-07T21:20:38	aburtovoi
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solo_L2_metis-uv-image_20220614T184524_V01.fits	708547400.110199	216526	False	False	False	False	False	True	False	False	False	False	delta Sco, beta1 Sco, nu Sco, HD144334, HD144844			2024-01-07T21:26:34	aburtovoi
solo_L2_metis-uv-image_20220614T203528_V01.fits	708554004.7732239	216531	False	False	False	False	False	True	False	False	False	False	delta Sco, beta1 Sco, nu Sco, HD144334, HD144844			2024-01-08T12:40:03	aburtovoi
solo_L2_metis-uv-image_20220614T204028_V01.fits	708554304.7710571	216531	False	False	False	False	False	True	False	False	False	False	delta Sco, beta1 Sco, nu Sco, HD144334, HD144844			2024-01-08T12:40:13	aburtovoi
solo_L2_metis-uv-image_20220614T204528_V01.fits	708554604.7688751	216531	False	False	False	False	False	True	False	False	False	False	delta Sco, beta1 Sco, nu Sco, HD144334, HD144844			2024-01-07T21:28:10	aburtovoi



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# Image Labeling

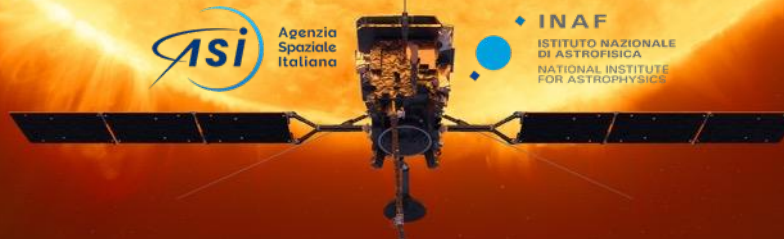
- Cruise Phase: examination of L0 images

(A. Burtovoi, A. Liberatore, C. Sasso, F. Frassati, F. Landini, G. Capuano, G. Jerse, G. Nicolini, G. Russano, L. Zangrilli, M. Giarrusso, M. Pancrazzi, M. Romoli, M. Uslenghi, P. Romano, S. Giordano, S. Guglielmino, V. Andretta)

- Nominal Phase: validation of L2 images

(A. Burtovoi, M. Giarrusso, and from STP201 on - A. Burtovoi)

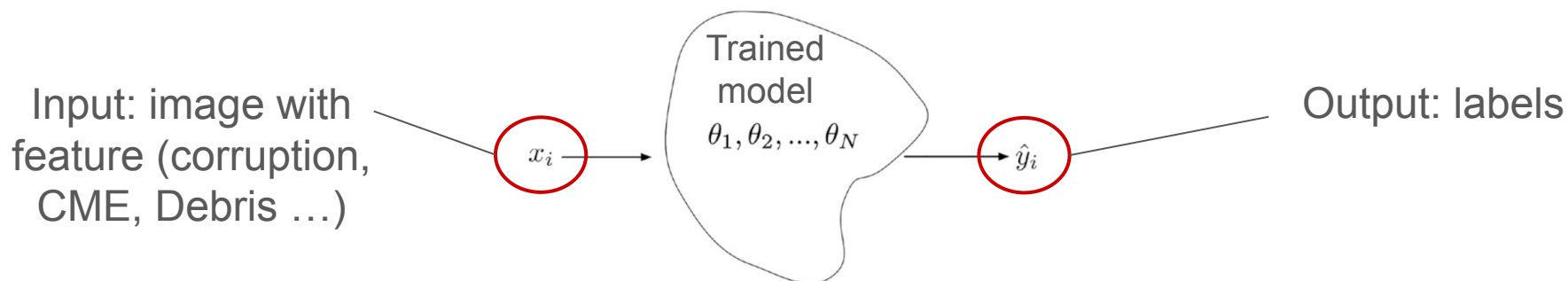
- In this work we used 131930 labeled L2 images (VL+UV)
  - from STP180 to STP300
  - from 2 Dec 2021 until 19 Mar 2024



# Metis Validation with Supervised Learning

- Supervised machine learning:

“Training a model from **features** and their corresponding **labels** (often human-made).”



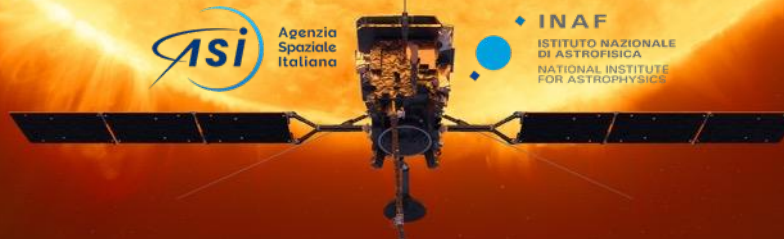
Adopted from U. Michelucci, *Applied Deep Learning with TensorFlow 2*, Springer Nature, 2022



# Metis Validation with Supervised Learning

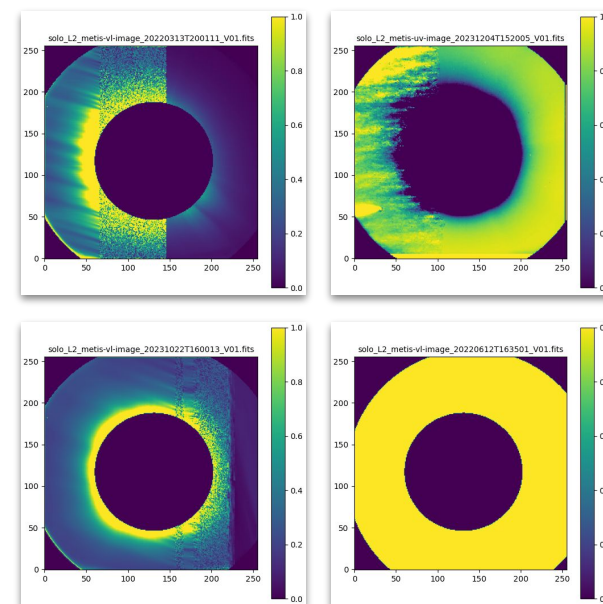
- Labeled images with bright features
  1. Corruption [188/92536 img-s]
  2. CMEs [11535/71876 img-s]
  3. Debris [9206/55122 img-s]
- Each class contains many images
- Preparation of the dataset:
  - Masking internal and external parts
  - Setting a fixed dynamic range
  - Normalization
  - Re-binning: 256x256 pixels
  - Setting “nan” pixels as 0
- Splitting dataset to training (50%) and testing (50%) subsets
- Algorithm: [C-Support Vector Classification](#) (SVC, from Python scikit-learn package)
- Calculating Confusion matrix and Accuracy (i.e. fraction of correctly predicted labels)

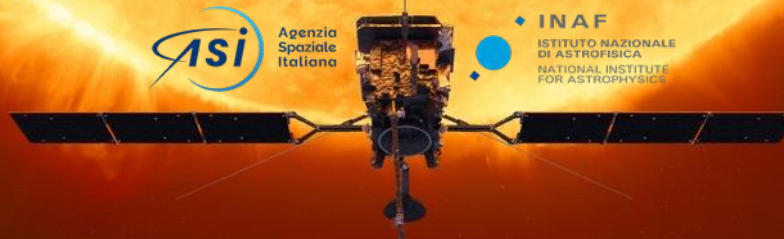




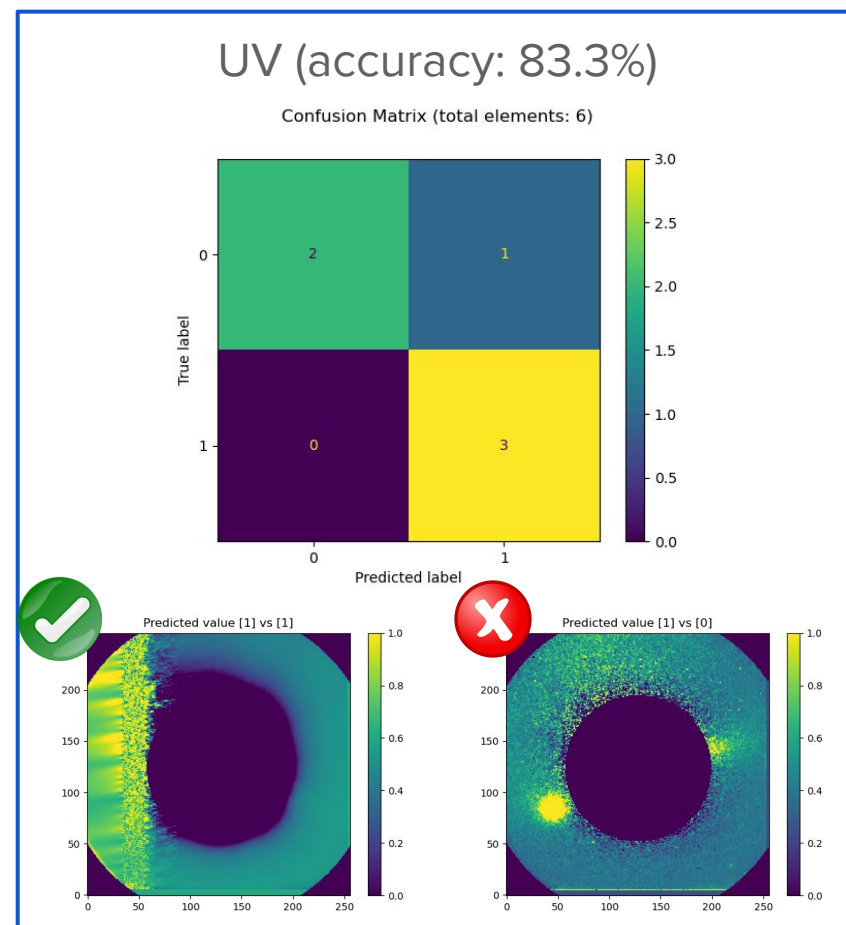
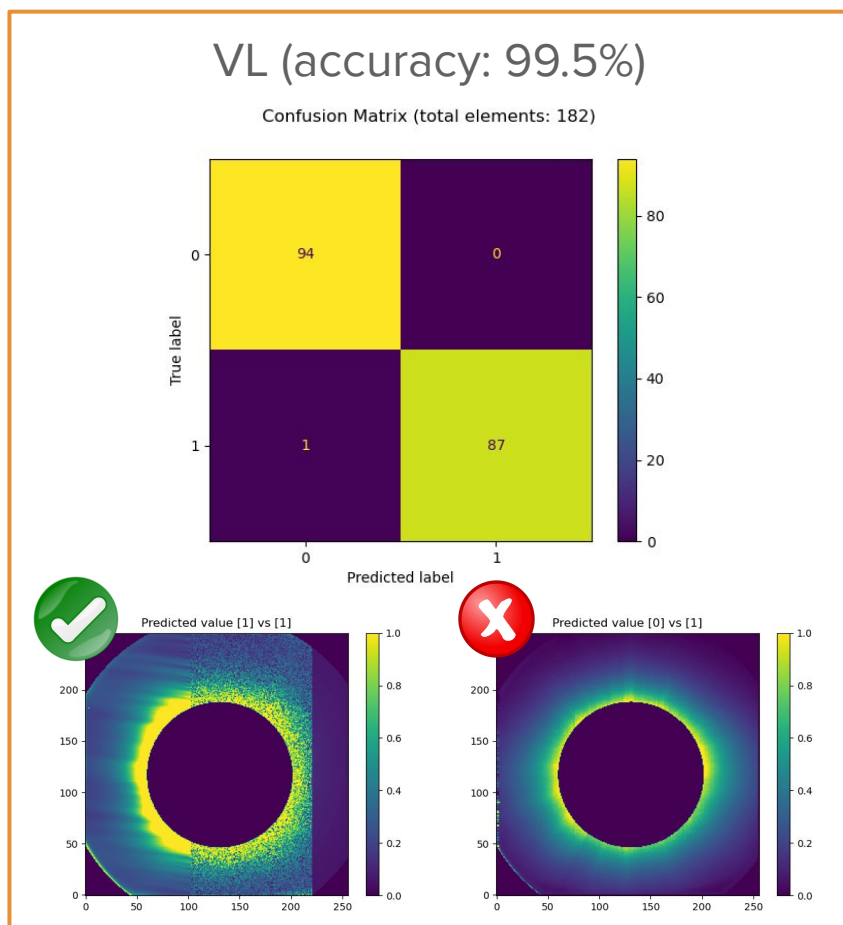
# Results: Corrupted images

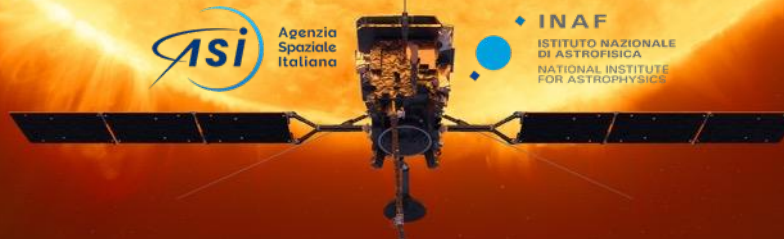
- Dataset
  - All VL products (except polar angle and Stokes images)
  - All UV images
  - Images without Debris
- No additional image processing



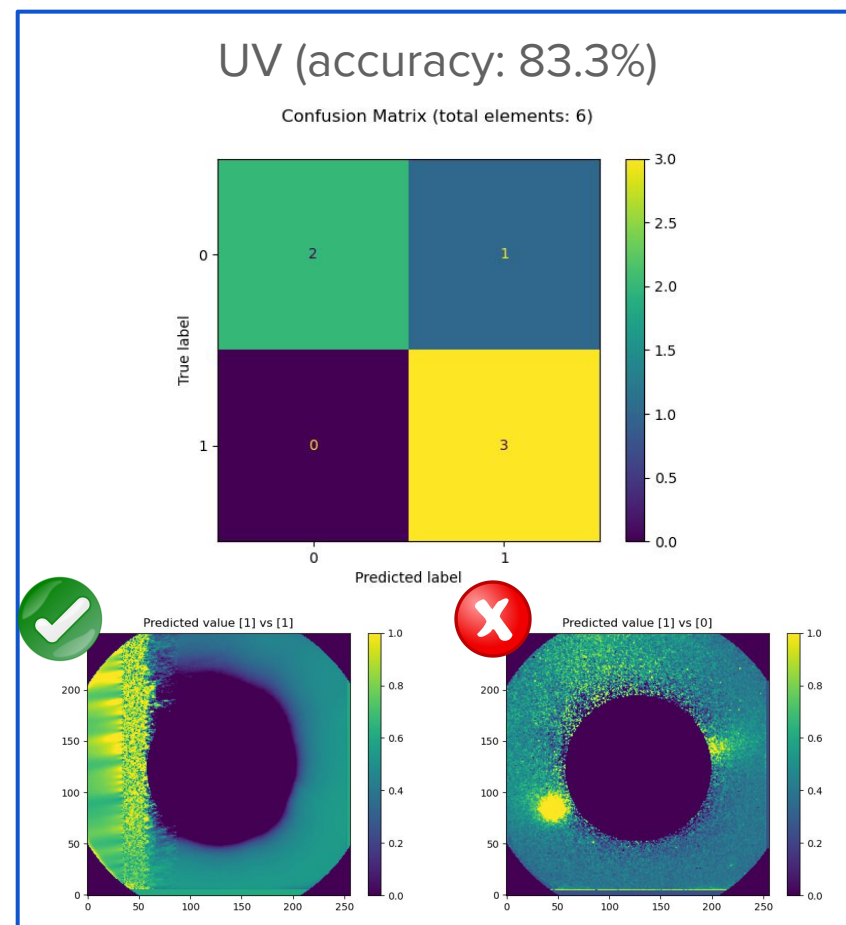
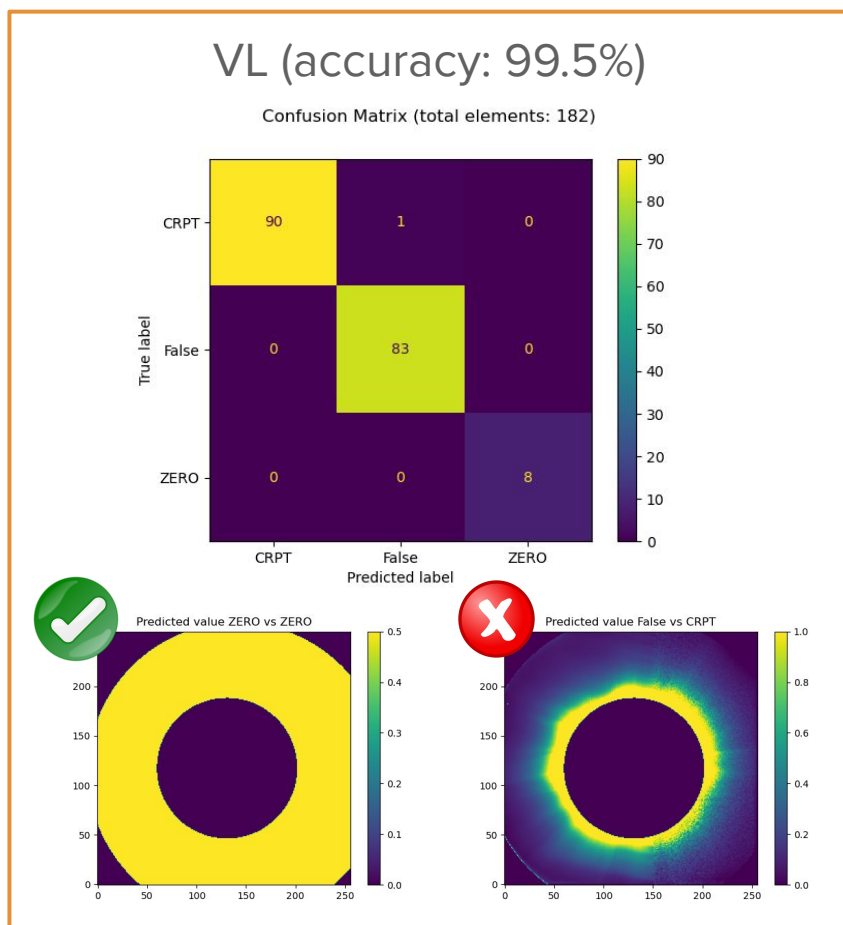


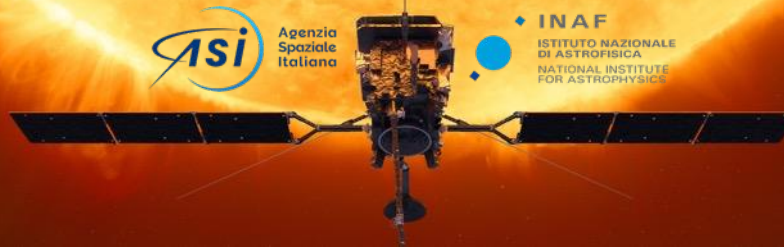
# Results: Corrupted images (2 classes)





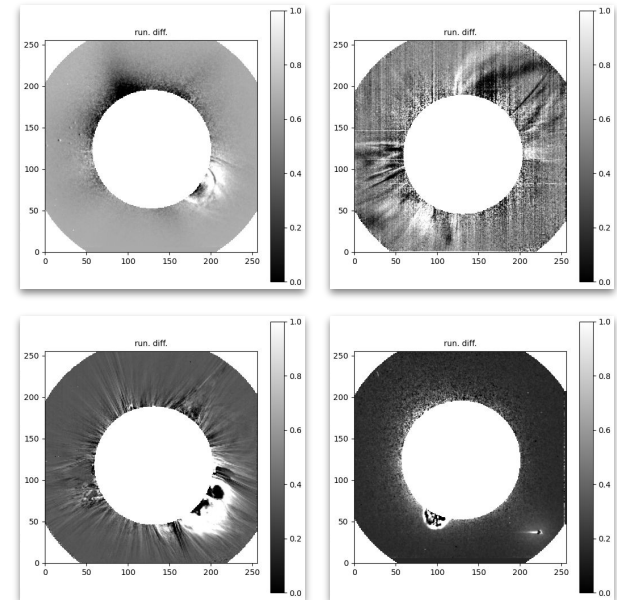
# Results: Corrupted images (3 VL classes)



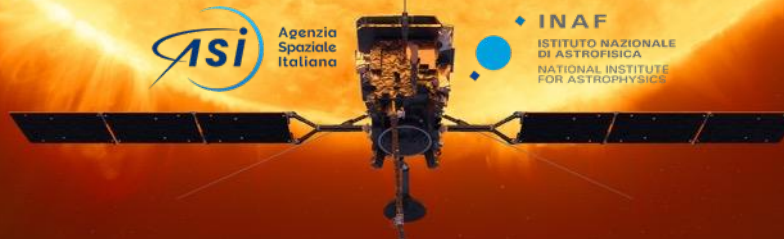


# Results: CMEs

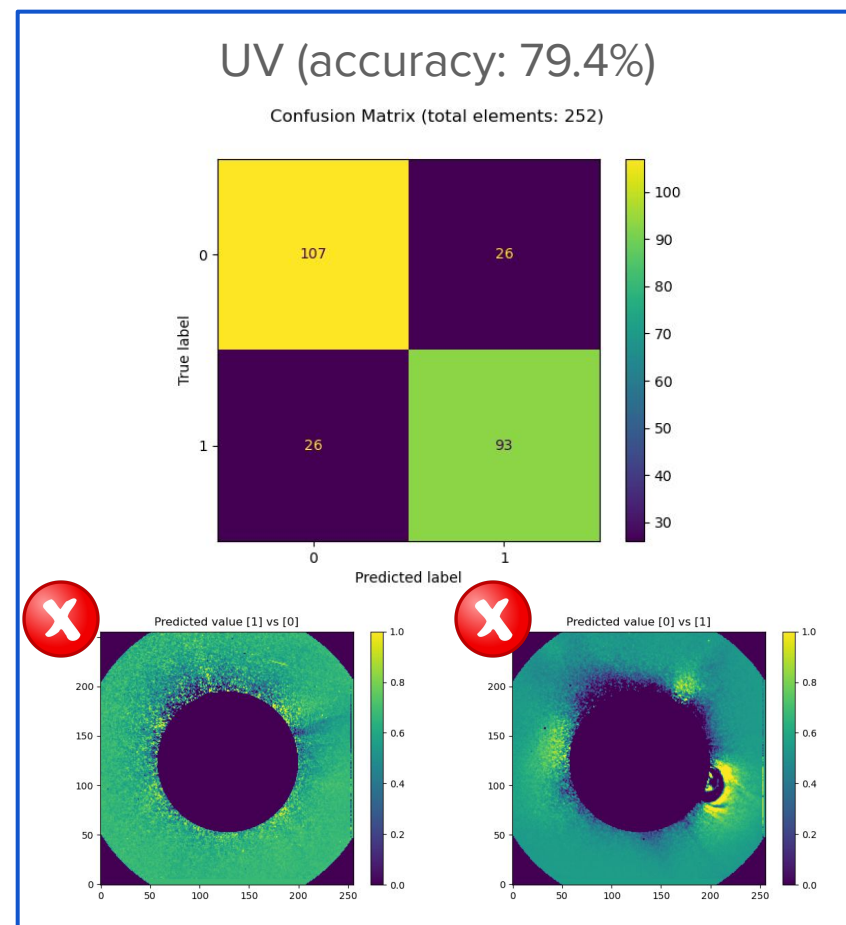
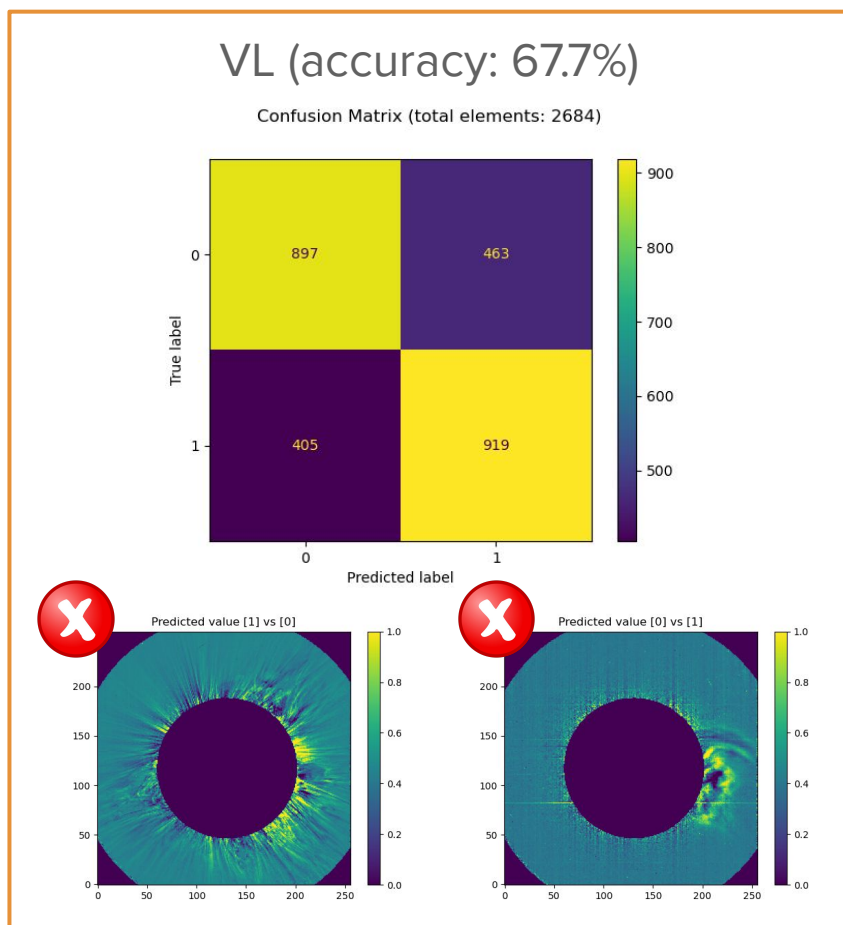
- Labeling work done by the Metis CME Catalog team (MeCCa, S. Giordano et al., <https://metisarchive.astro.unifi.it/cme/list>)
- Dataset
  - VL data: pB and B images from quadruplet observations
  - Manually selected UV data
  - No Corrupted images, no images with Debris
- Additional image processing:
  - Running difference
  - WOW image enhancement (F. Auchère et al. 2023, [sunpy link](#))

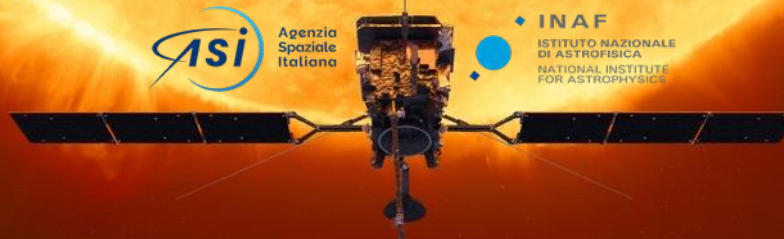




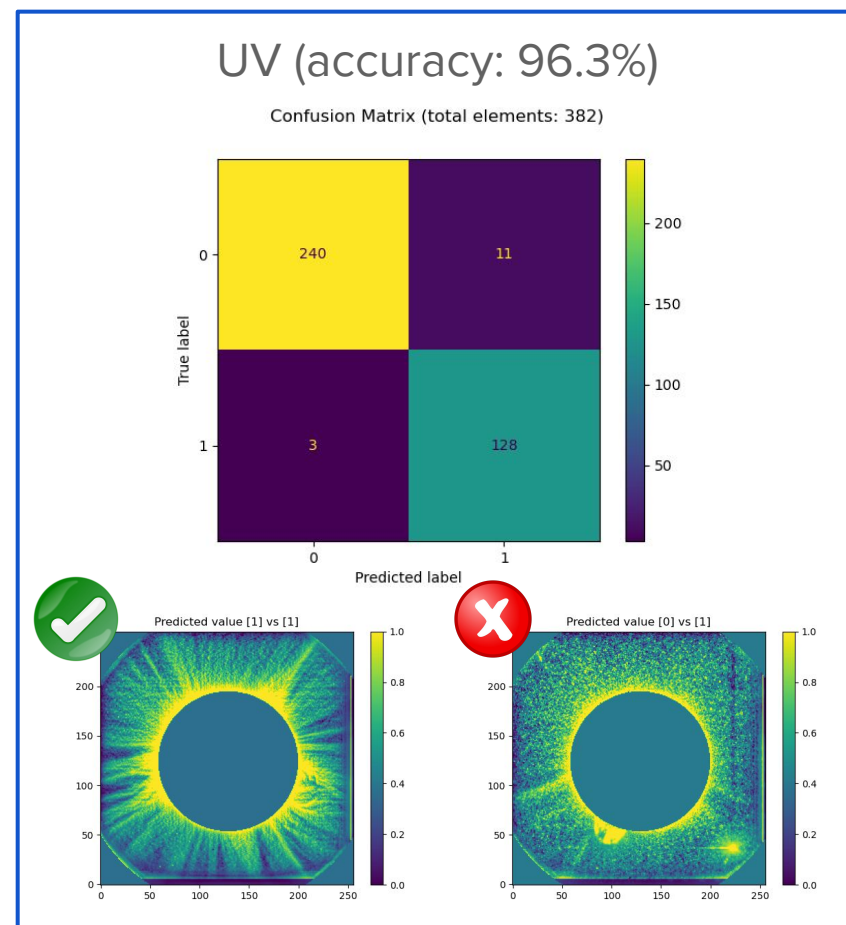
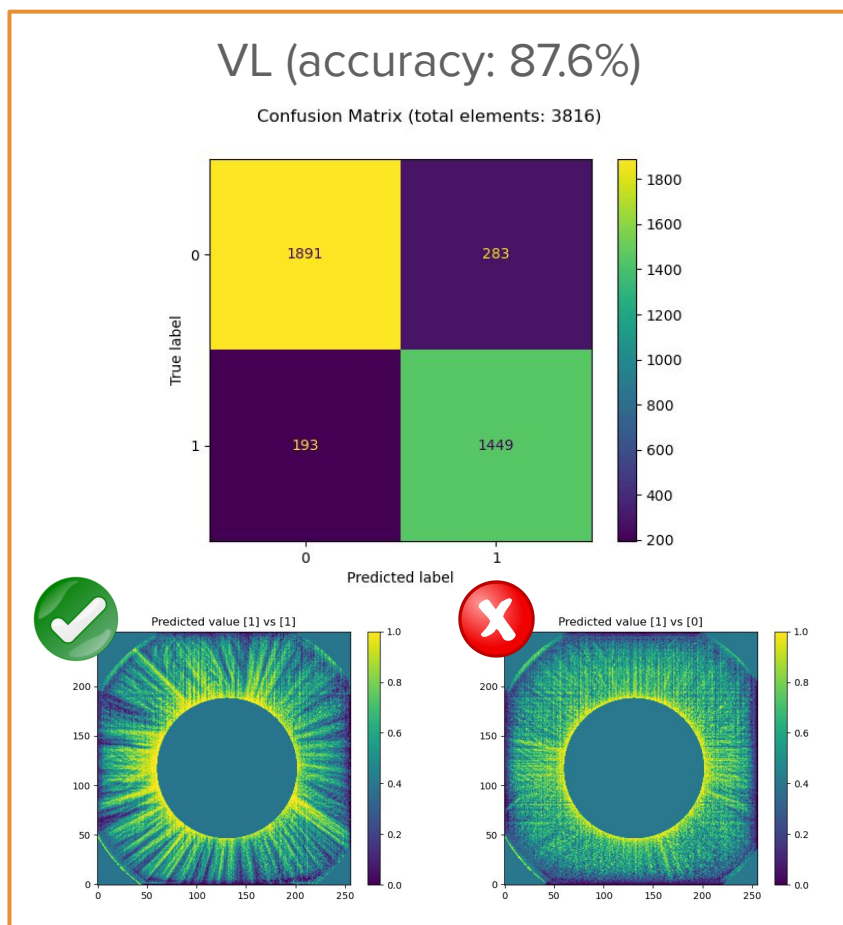


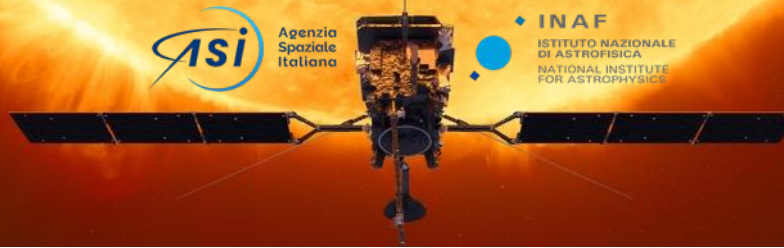
# Results: CMEs (running difference)





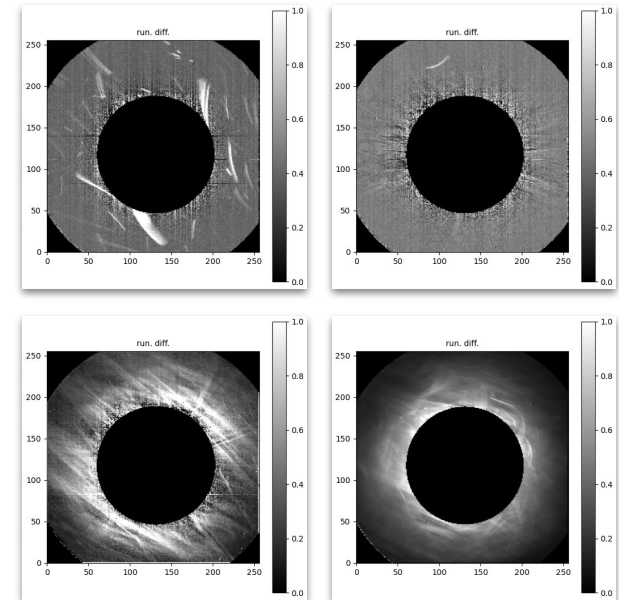
# Results: CMEs (WOW filter)

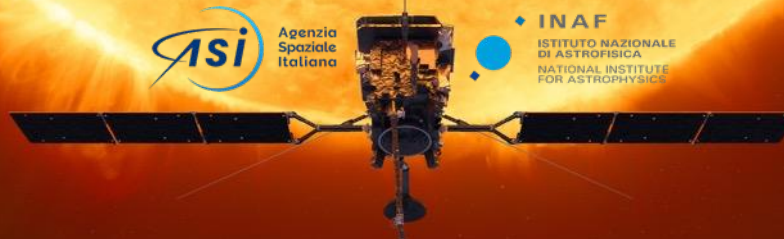




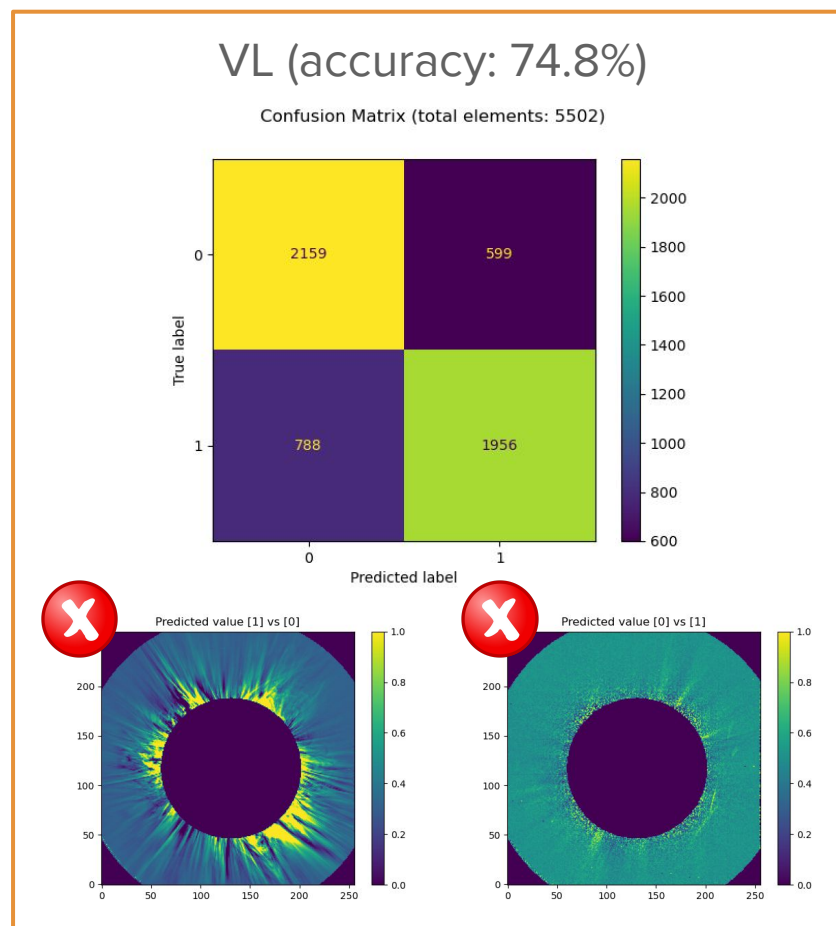
# Results: Debris

- Dataset
  - VL data: fixed polarisation data and total brightness data (for the moment no pB and B images from quadruplet observations)
  - No UV data: Debris are not visible in UV
  - No Corrupted images, no images with CMEs
- Additional image processing:
  - Running difference
  - WOW image enhancement (F. Auchère et al. 2023, [sunpy link](#))

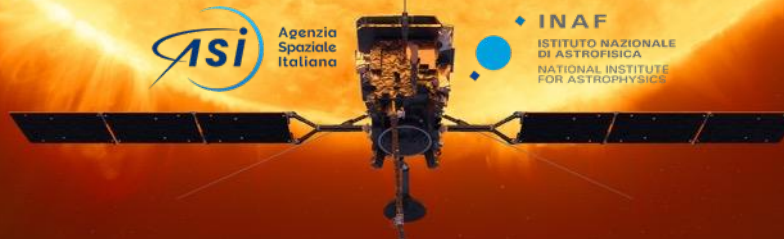




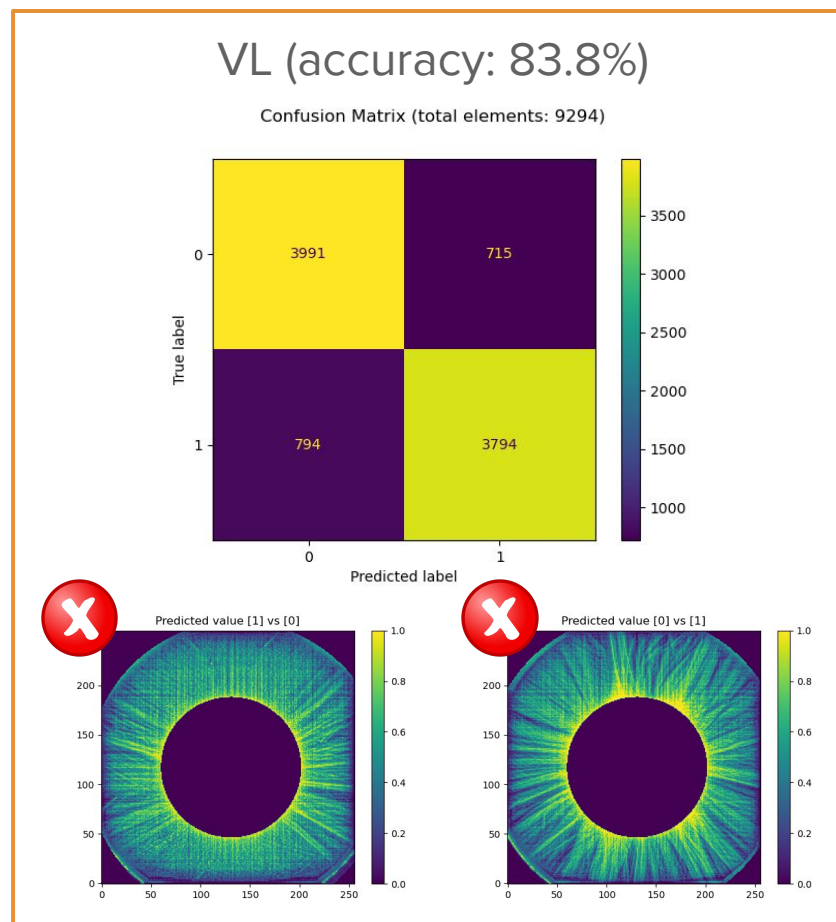
# Results: Debris (running difference)

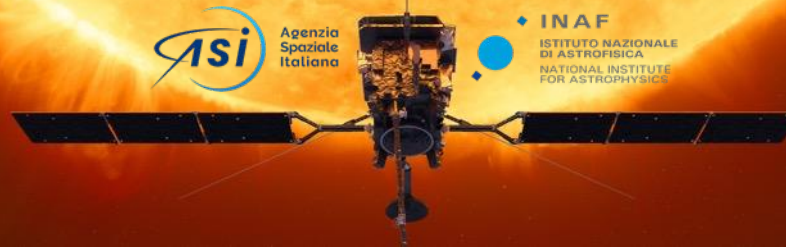






# Results: Debris (WOW filter)



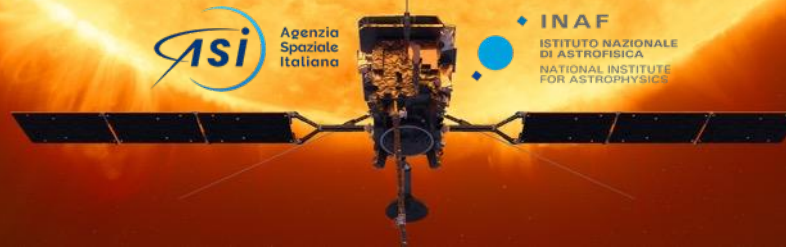


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## Conclusions

- SVC algorithm works well with Metis data (accuracy > 83%)
  - especially for the VL corrupted images with prominent features (accuracy > 99%)
- Model accuracy is can be lower for the UV data due to higher noise and/or lower number images
- Using WOW image enhancement improves the model accuracy for CMEs and Debris



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## Future Work

- CMEs:
  - VL data selection
  - Implement more detailed classification: halo CME, faint, bright, multiple etc...
- Debris:
  - Extend analysis to all types of VL images
  - Implement 3-type classification of debris: faint, bright and “overwhelming”
- Apply this algorithm to
  - the images with Comets and SEPs
  - unlabeled dataset (from STP301 on) in order to access it’s performance
    - checking manually “false-positive” cases
- Implement multiclass identification (e.g. CME + Debris)
- Model fine tuning and/or testing other algorithms



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*Thank you for your attention*

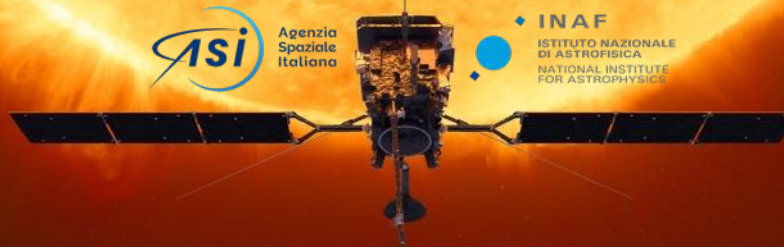




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## Backup slides



# Metis Validation with Supervised Learning

## An intuitive definition of learning

An algorithm that learns is typically nothing else than a **mathematical function** that depends on a set of parameters that are **tuned** hopefully in some smart way, to make the algorithm output as **close as possible** to some expected output.

Optimiser

Loss Function

Algorithm Type

*Adopted from U. Michelucci, Applied Deep Learning with TensorFlow 2, Springer Nature, 2022*