
3CSD
Space Weather - Final Presentation
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1/12/2023
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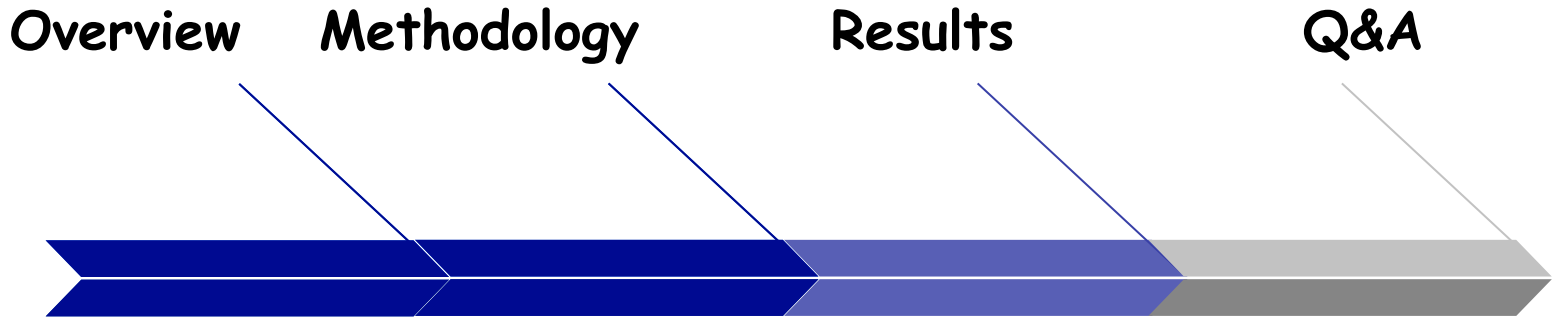
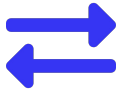
Outline



Why CSDs ?

Reduce space usage/HW cost

Reduce energy consumption



Less bandwidth usage

Why CSD ?

Reduce data traffic

Reduce latency

Boost performance

3CSD: Additional values

Why 3CSD ?


High NNs Accuracy


Less Inference Time


High Level Security


Streaming Inference


Increase Data Storage


User-Friendly Application


NNS/LILLIAN: Enhance Accuracy

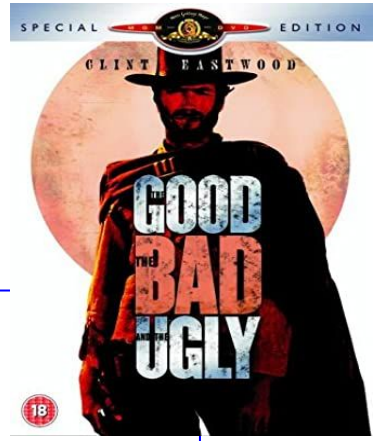

NNS/LILLIAN: Triage Sub-system


Efficient solutions for Multi Sensors


Subsystems Health check/failures

3CSD Architecture Design

Triage/Prediction Subsystem



OBC

Data Bus

ISP

IE

NNS Multistage

LILLIAN Multistage

Ensemble

EoFNets

FrCMENet

CMEEnets

SSD

Storage

Raw Data

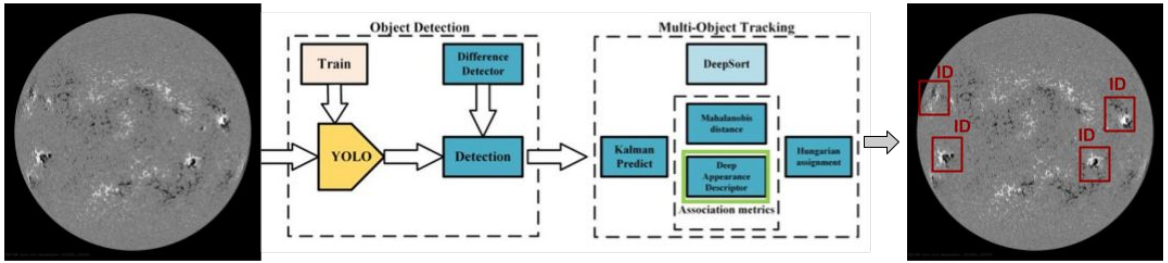
Imaging System

Triage/Detection Subsystem

Prediction Subsystem

NNS: Neural Network Supervisor
LILLIAN: LeveragIng Last-miLe data usIng context-based AutolabelliNg
ISP: Image Signal Processing
IE: Image Enhancement

Real Time Streaming - Detection/Tracking

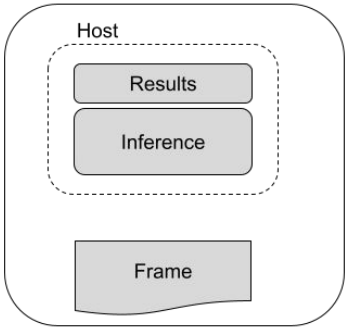


Video frame

Tracking algorithm

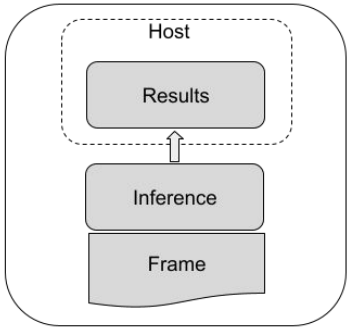
Tracking results

(a)



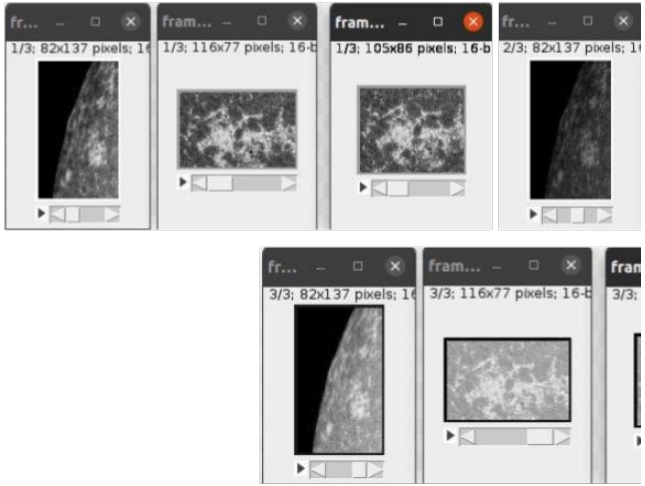
Conventional SSD

(b)



CSD

(c)



GSSD

Get Synchronised Solar Data tool to gather images and time series data

```
Loading CME features ...
     First C2 Appearance Date Time [UT]  ...                  Remarks
0                   2014/01/01 00:12:05  ...                  Only C2
1                   2014/01/01 00:36:05  ...              Poor Event
2                   2014/01/01 02:24:05  ...              Poor Event
3                   2014/01/01 02:48:07  ...      Poor Event; Only C2
4                   2014/01/01 05:12:05  ...                     NaN
...                                 ...  ...                     ...
2473                2014/12/31 04:48:05  ...         Very Poor Event
2474                2014/12/31 05:48:06  ...  Very Poor Event; Only C2
2475                2014/12/31 06:00:05  ...         Very Poor Event
2476                2014/12/31 17:00:06  ...              Poor Event
2477                2014/12/31 23:12:10  ...  Very Poor Event; Only C2

[2478 rows x 12 columns]
Loading LASCO Images ...
Files Downloaded:   1%|                | 126/10000 [03:22<5:06:11,  1.86s
22487189.fts:  54%|
22487192.fts:  18%|
22487190.fts:  75%|
22487193.fts:   0%|
22487188.fts:  43%|                | 911k/2.11M [00:07<00:13, 88.
```

- CME Features time series data
- Lasco Coronagraph (C2, C3) Images

```
Loading Solar Flare features ...
    event_starttime          event_peaktime     ... fl_goescls
---------------------- ---------------------- ... ----------
2011-01-01 00:17:00.000 2011-01-01 00:22:00.000 ...       B2.3
2011-01-01 00:49:00.000 2011-01-01 00:53:00.000 ...       B2.2
2011-01-01 00:49:00.000 2011-01-01 00:53:00.000 ...       B2.2
2011-01-01 18:11:00.000 2011-01-01 18:14:00.000 ...       B2.1
2011-01-01 18:11:00.000 2011-01-01 18:14:00.000 ...       B2.1
2011-01-01 19:37:00.000 2011-01-01 19:44:00.000 ...       B3.1
2011-01-01 21:52:00.000 2011-01-01 21:59:00.000 ...       B8.3
                    ...                     ... ...        ...
2011-01-04 09:43:00.000 2011-01-04 09:47:00.000 ...       B6.4
2011-01-04 19:42:00.000 2011-01-04 19:45:00.000 ...       B1.9
2011-01-04 23:39:00.000 2011-01-04 23:45:00.000 ...       B4.2
2011-01-05 23:23:00.000 2011-01-05 23:27:00.000 ...       B4.0
2011-01-05 23:23:00.000 2011-01-05 23:27:00.000 ...       B4.0
2011-01-05 23:50:00.000 2011-01-05 23:58:00.000 ...       B1.8
2011-01-05 23:50:00.000 2011-01-05 23:58:00.000 ...       B1.8
Length = 32 rows
Loading CME features ...
Files Downloaded: 100%|                | 10/10 [00:13<00:00,  1.34s/file]
Downloaded Files for 195 angstrom: ['data/GOES_SolarFlare_2011-01-01_2011-01-06/
efz20110101.131349', 'data/GOES_SolarFlare_2011-01-01_2011-01-06/Fits_Files/195/
350', 'data/GOES_SolarFlare_2011-01-01_2011-01-06/Fits_Files/195/efz20110103.011
S_SolarFlare_2011-01-01_2011-01-06/Fits_Files/195/efz20110104.011350', 'data/GOE
11-01-01_2011-01-06/Fits_Files/195/efz20110105.011348', 'data/GOES_SolarFlare_20
Files Downloaded: 100%|                | 10/10 [00:12<00:00,  1.23s/file]
```

- Solar Flare Features time series data
- Synchronised detected CME
- Solar flare images EIT SOHO wavelengths

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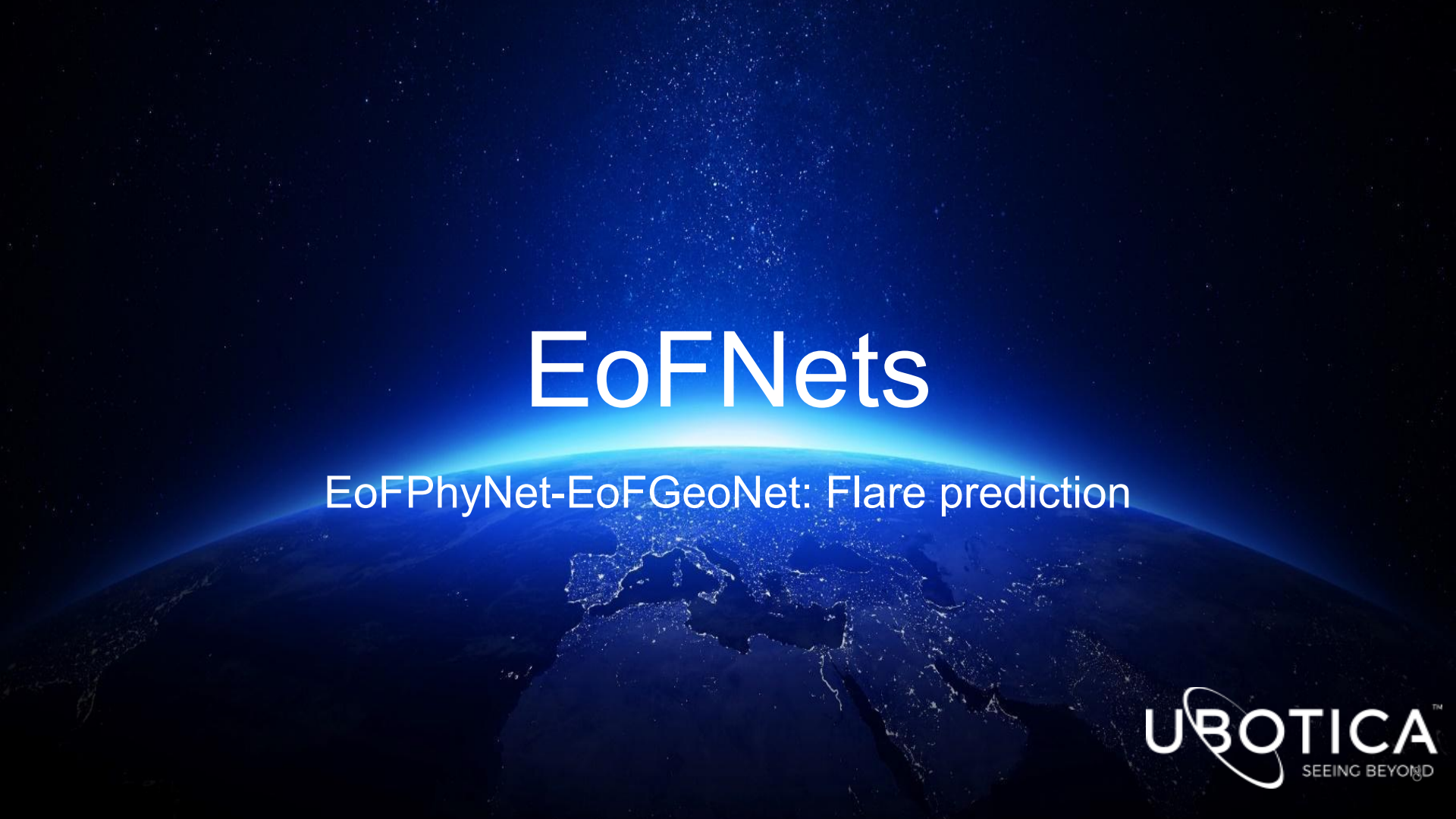
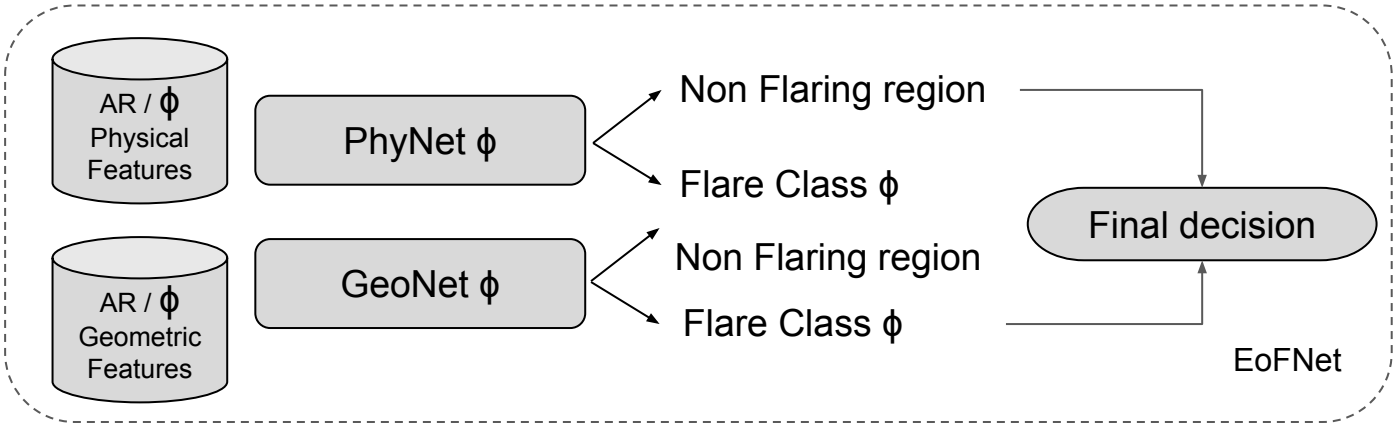
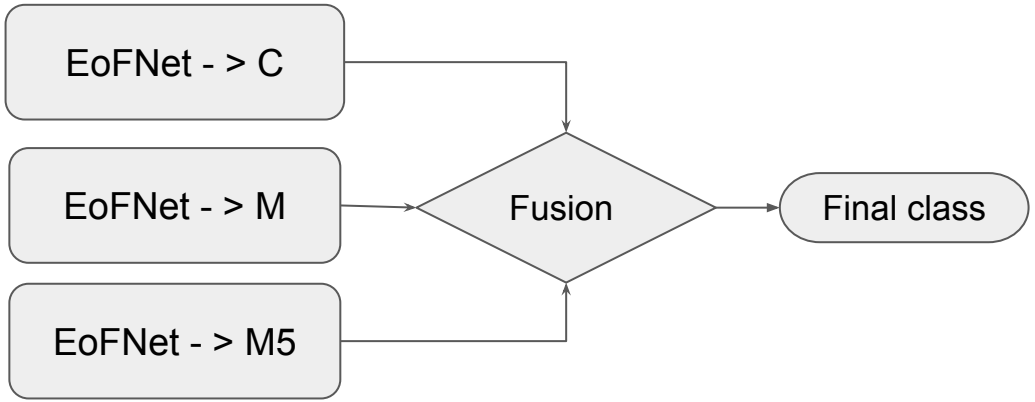
EoFNets

EoFPhyNet-EoFGeoNet: Flare prediction

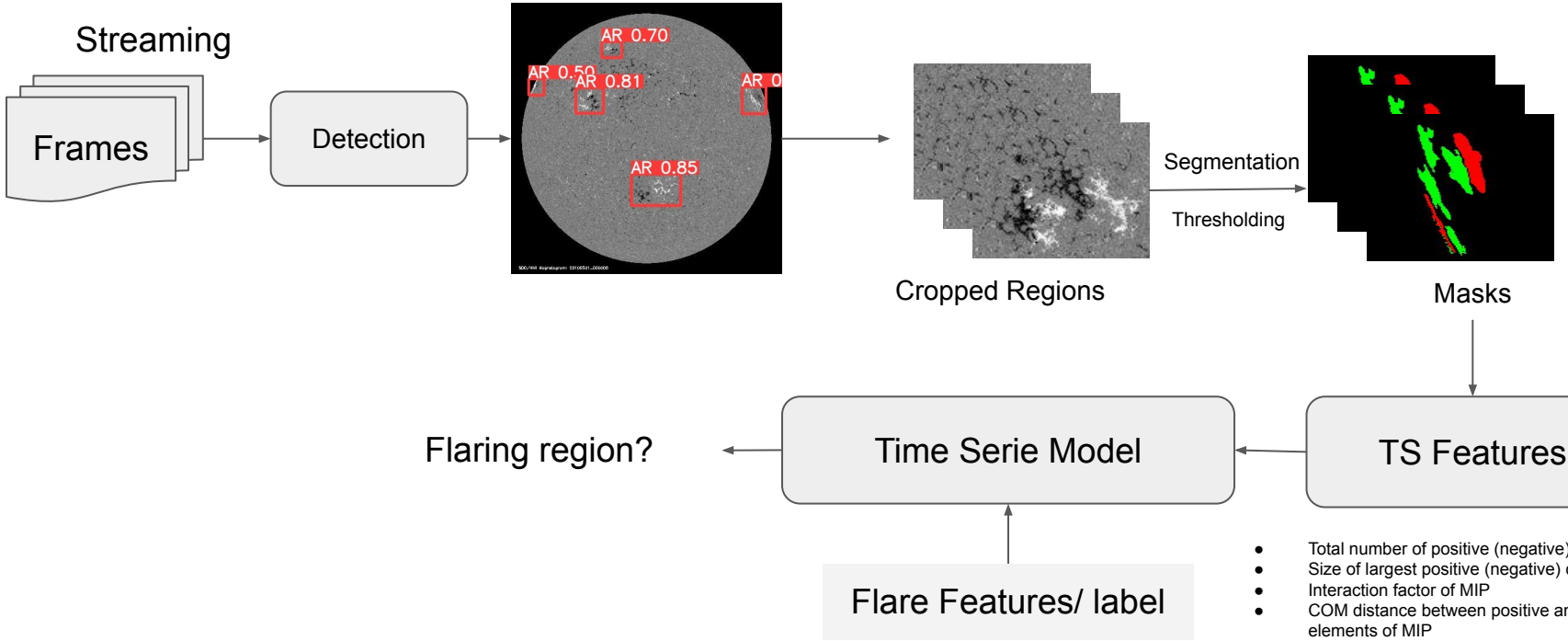


EoFNets - Stacked Nets





GeoNet: On board 3CSD



Reference: [Leveraging the Mathematics of Shape for Solar Magnetic Eruption Prediction]

EoFNets Evaluation

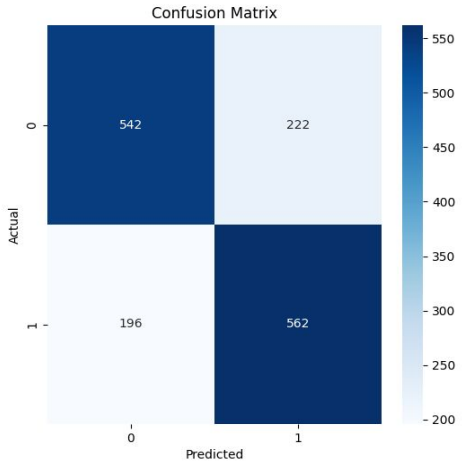


Fig.1: EoFPhyNet - Flare > C

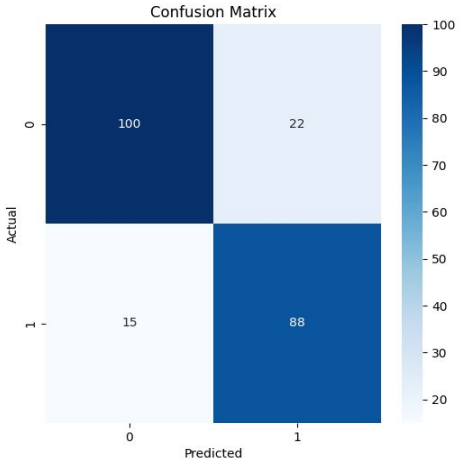


Fig.2: EoFPhyNet - Flare > M

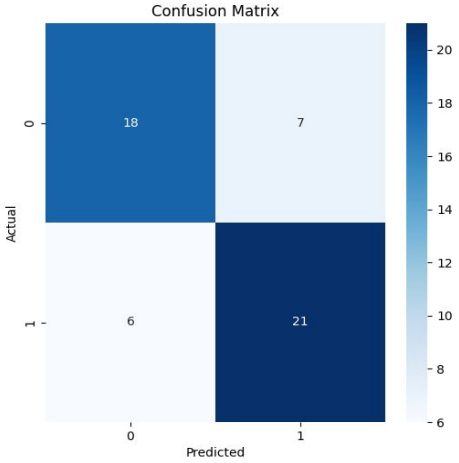


Fig.3: EoFPhyNet - Flare > M5

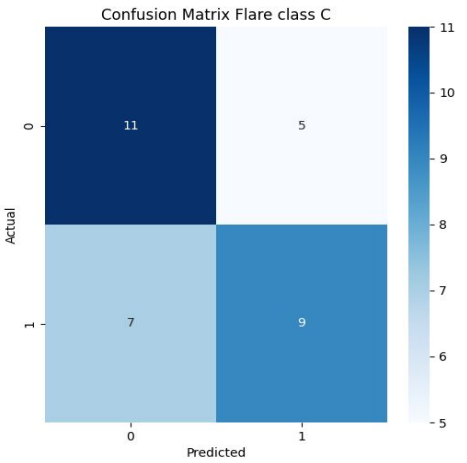
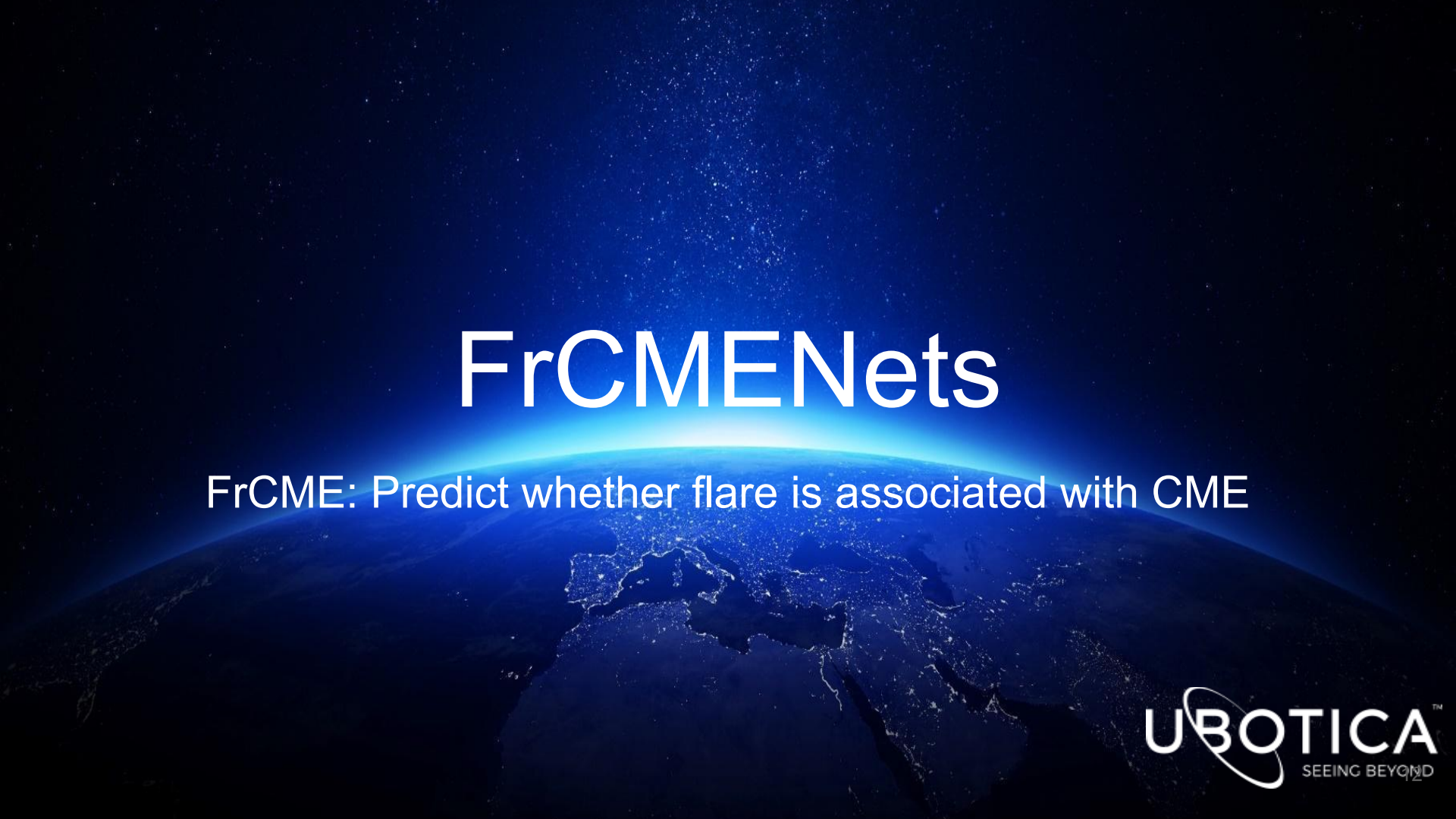


Fig.4: EoFGeoNet - Flare > C


FrCMENets
FrCME: Predict whether flare is associated with CME
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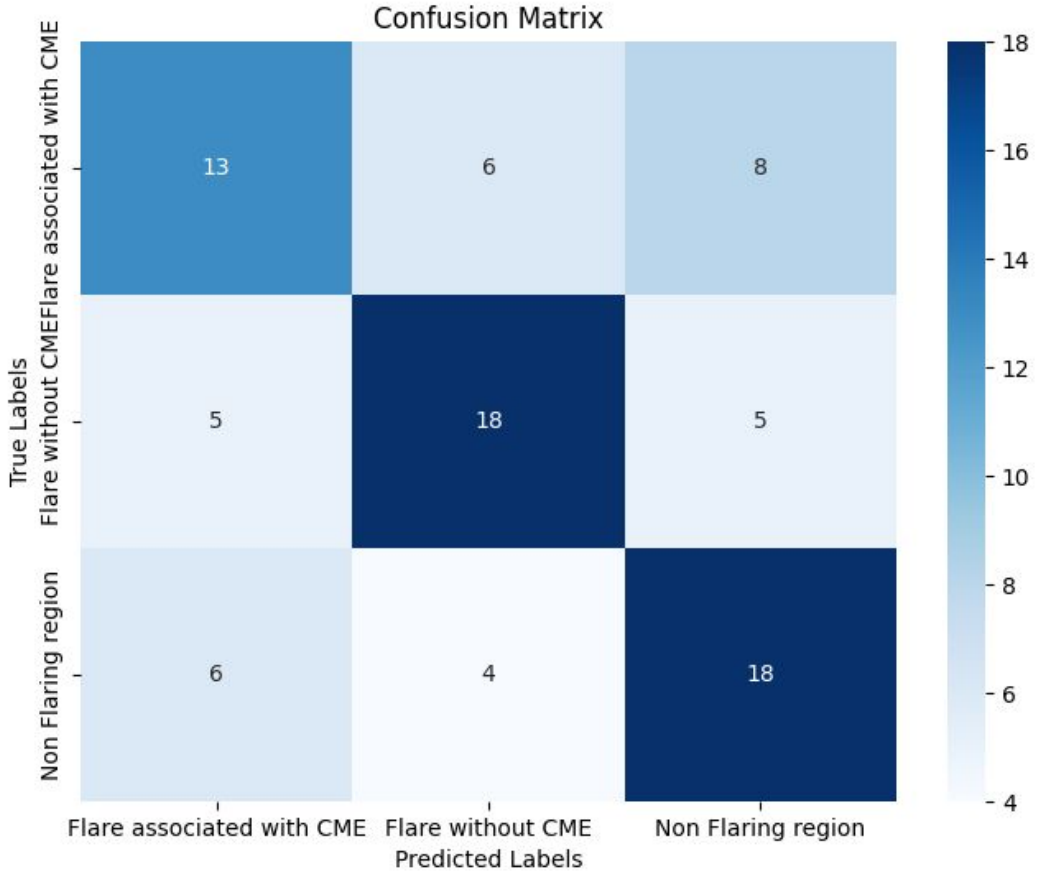
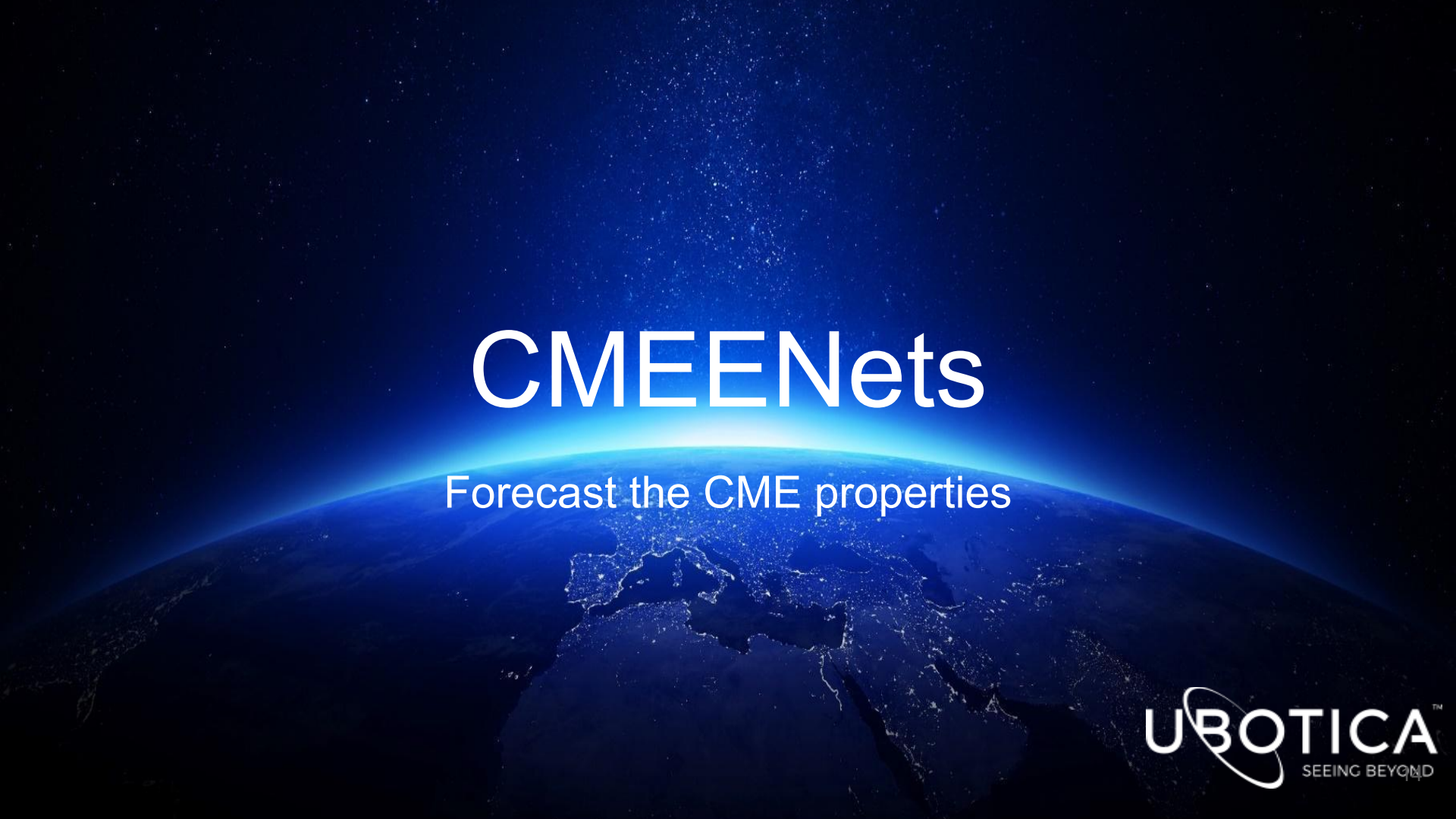
FRCMENet

- A Time series network that is able to forecast the solar flare and CME events by monitoring the evolution of Active region in a fixed window size (6 hours)




CMEENets
Forecast the CME properties
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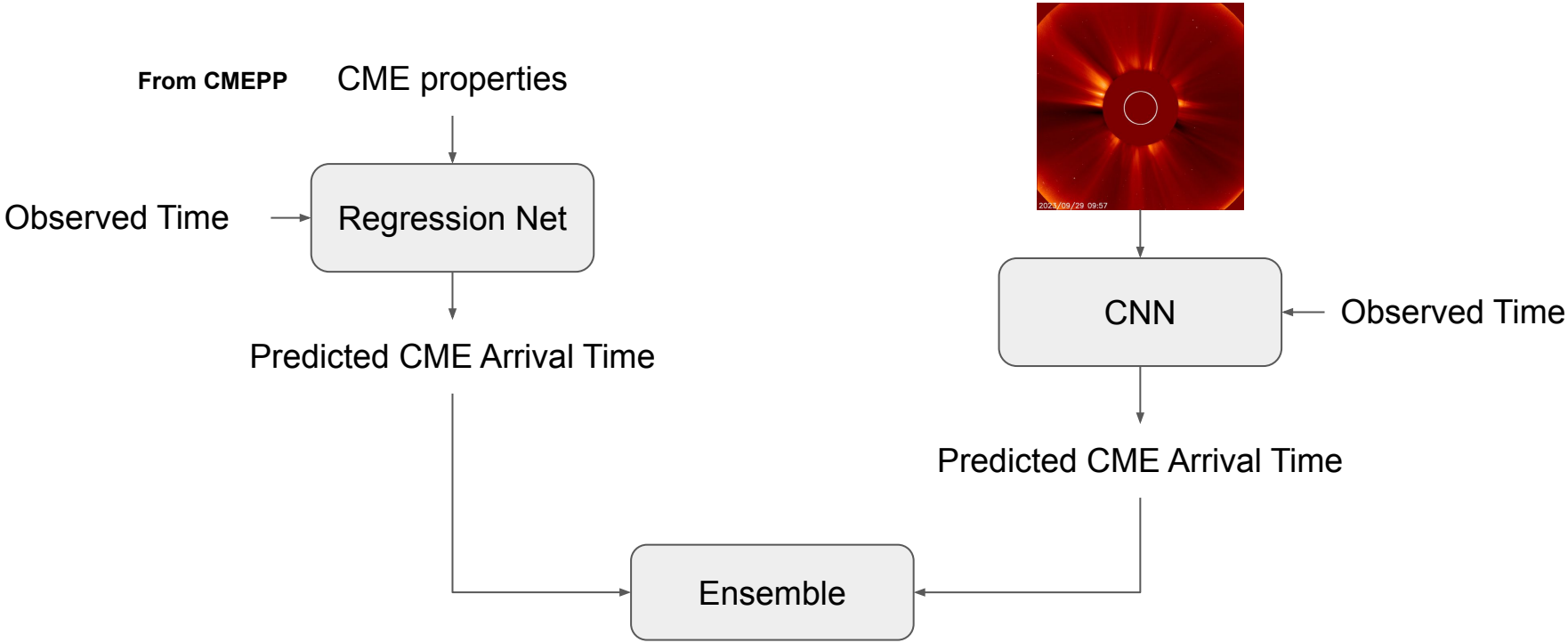
CMEENets

- CMEENets is a stack of networks is designed to forecast the CME properties
- CMEPP is a part of CMEENets designed to predict the CME Properties (direction, velocity, mass, etc) using the LASCO C2 and LASCO C3 dataset for ensemble
- CME-DyC: A classification network to classify CME independently based on each single CME property
- CMEAT is a network of Cabinets that is designed to estimate the observed CME arrival time using the LASCO images, the CME properties and the Observed time.

Predicting CME Arrival Time



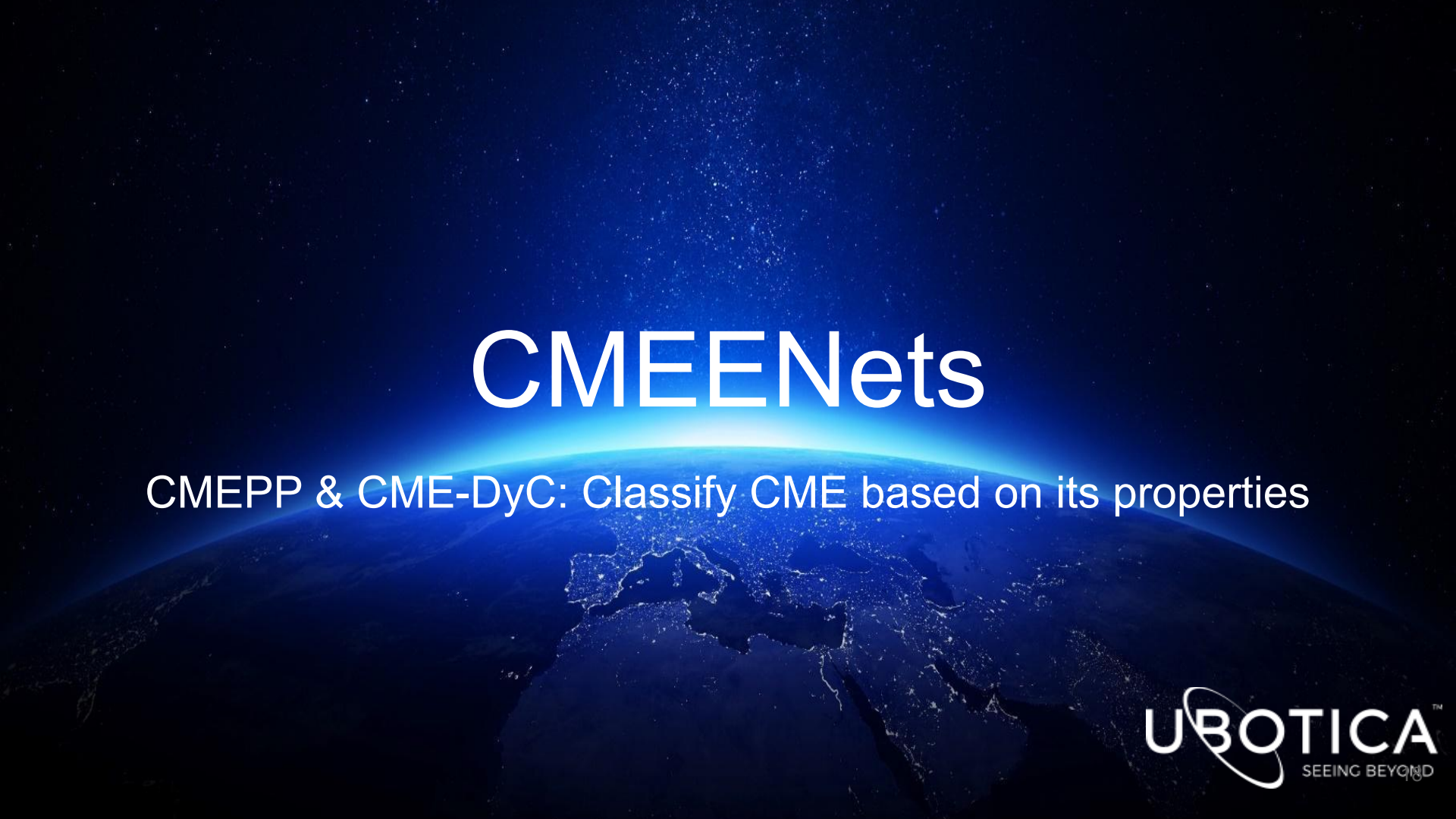
CMEENets - CMEAT

Label,Prediction
2014-01-09T00,2014-01-09T00
2014-01-09T00,2014-01-09T00
2014-01-09T04,2014-01-09T03
2014-01-09T04,2014-01-09T03
2014-01-09T04,2014-01-09T04
2014-01-09T04,2014-01-09T03
2014-01-09T04,2014-01-09T03
2014-01-09T04,2014-01-09T03
2014-01-09T04,2014-01-09T04
2014-01-09T04,2014-01-09T03
2014-01-09T04,2014-01-09T03
2014-01-09T08,2014-01-09T07
2014-01-09T08,2014-01-09T07
2014-01-09T00,2014-01-09T00
2014-01-09T00,2014-01-09T00
2014-01-09T00,2014-01-09T00

LASCO C3

Label, Prediction
2014-01-09T08,2014-01-09T08
2014-01-09T08,2014-01-09T07
2014-01-09T08,2014-01-09T07
2014-01-09T08,2014-01-09T08
2014-01-09T08,2014-01-09T07
2014-01-09T08,2014-01-09T08
2014-01-09T08,2014-01-09T07
2014-01-09T08,2014-01-09T08
2014-01-09T08,2014-01-09T07
2014-01-08T22,2014-01-08T22
2014-01-08T22,2014-01-08T22
2014-01-08T22,2014-01-08T22
2014-01-08T22,2014-01-08T22
2014-01-08T22,2014-01-08T21
2014-01-08T22,2014-01-08T22
2014-01-08T22,2014-01-08T21

LASCO C2


CMEENets
CMEPP & CME-DyC: Classify CME based on its properties
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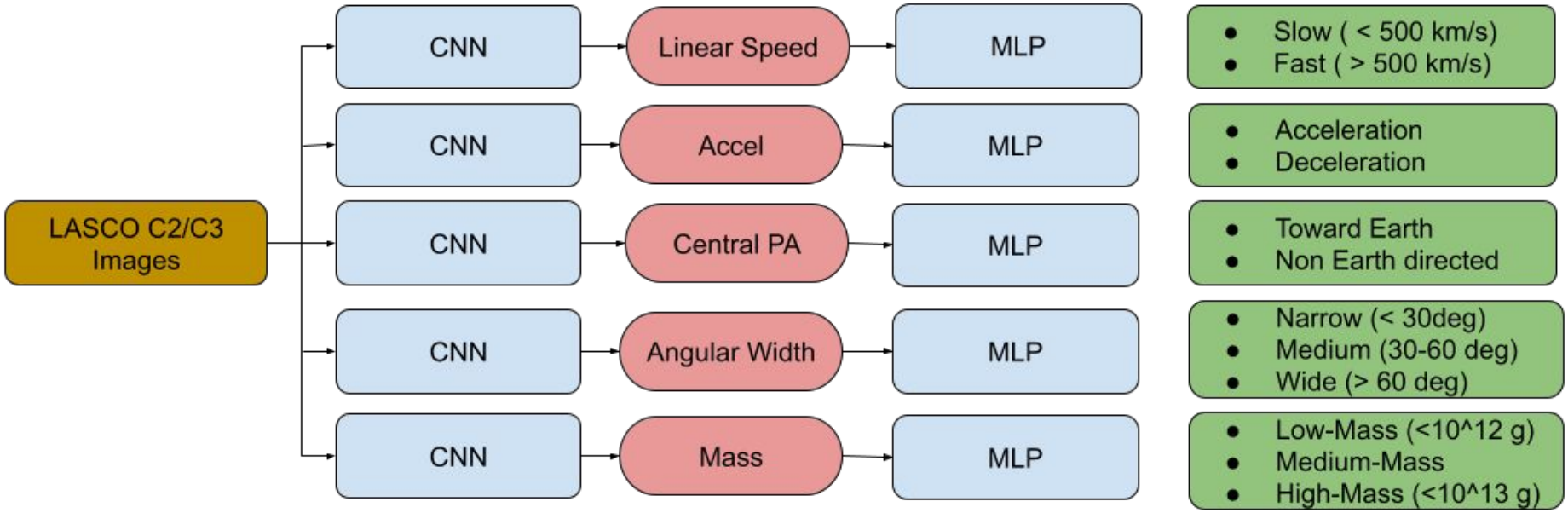
CME-DyC



CMEPP results

Central PA [deg]	Angular Width [deg]	Linear Speed [km/s]
119	60	161
119	60	161
119	60	161
119	60	161
119	60	161
119	60	161
140	105	539
140	105	539
45	33	467
45	33	467
45	33	467

Linear Speed [km/s]	Angular Width [deg]	Central PA [deg]
160.98	58.91	118.88
161.18	58.81	119.25
160.5	60.86	120.78
160.34	60.55	119.31
161.55	60.05	119.95
161.3	59.08	119.45
537.73	104.93	141.9
538.87	105.35	140.66
465.23	35.9	43.93
467.88	30.05	43.17
469.34	33.45	40.83

Central PA [deg]	Angular Width [deg]	Linear Speed [km/s]
236	61	377
236	61	377
236	61	377
236	61	377
236	61	377
301	72	403
301	72	403

Linear Speed [km/s]	Angular Width [deg]	Central PA [deg]
377.46	58.81	235.93
378.84	62.34	232.66
385.48	56.78	230.27
378.17	61.11	236.73
376.15	62	234.51
403.39	68.64	302.12
404	70.19	302.19

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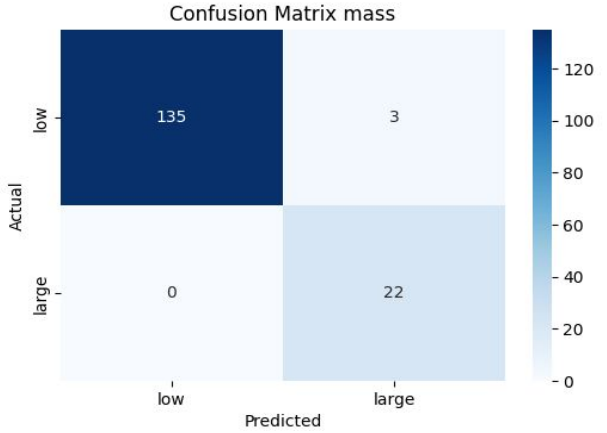
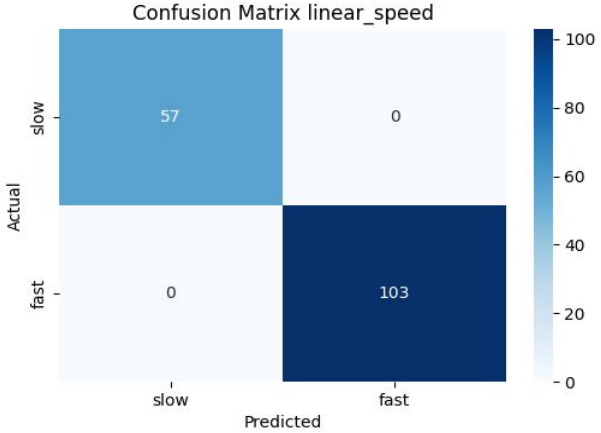
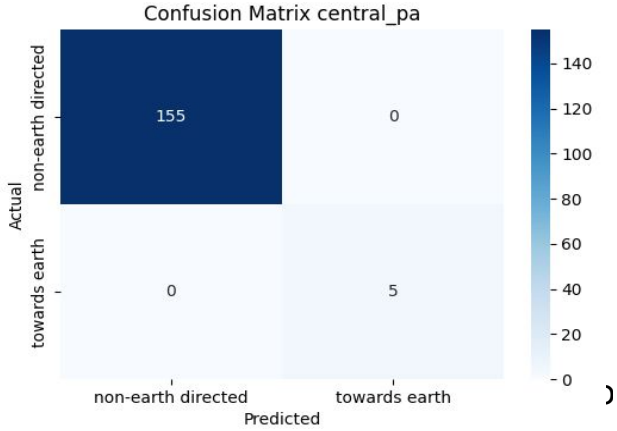
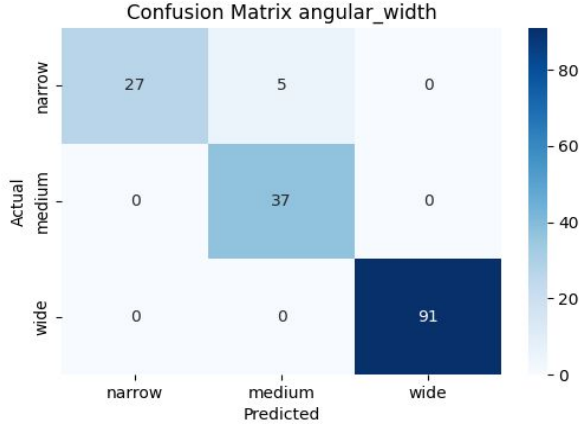
CME-DyC results









Summary

The 3CSD space weather features presented here are mainly divided into four main features:

- **Continuously monitoring** the sun in real time to swiftly detect and track solar events **like the evolution of the active regions and Coronal Mass Ejections (CMEs)**
- **EoFNets (Eye on Flare Networks)** represents the stack of two-time series networks (Physics-based features and Geometric based features) to predict whether the active region is flaring.
- **FrCMENets (Flare-related CME Networks)** is a time series network that is designed to **predict weather flares associated with CME using flare features**.
- **CMEENets:** The stack of three network to create an end-to-end CME monitoring and forecasting system
  - **CMEPP (CME Properties Prediction)** is dedicated to predicting the CME properties such as Central PA (deg), Angular Width (deg), and Linear speed (km/s) using LASCO C2 and LASCO C3 datasets.
  - **CMEATP (CME Arrival Time Prediction)** to predict the arrival time of CME that hits the Earth
  - **CME-DyC (CME Dynamic Classifier)** to classifier the observed CME based on its properties (mass, central pa, linear speed, etc)

Future work

- Enhance the capabilities of our time series predictors (EoFNets, FrCMENets, etc.)
- Considering the sunspot properties and evolution (e.g. using McIntosh classification) in the prediction of solar events.
- Consider the topology analysis in the active region tracking.
- Develop approach to retraining networks with less resources and high efficiency


Thank you
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