More observations

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HELIOPHYSICS | HELIOPHYSICS ONBOARD

Can we improve the nowcasting of space weather events by having AI onboard a spacecraft?

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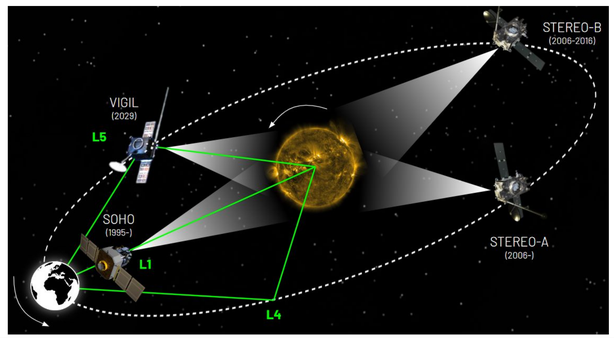
CHALLENGE AND OPPORTUNITY

Motivation: Extracting the direction and density of Coronal Mass Ejections (CMEs) is crucial for **predicting CME impacts** but challenging from 2D observations. The upcoming **ESA VIGIL mission** will provide a much needed extra viewpoint to enable triangulation and 3D reconstruction - but can combining onboard and ground based processing save valuable time when a CME is approaching?

Aim: Improve **CME nowcasting** with ML methods by increasing data throughput onboard (task-aware compression), and 3D CME reconstruction on Earth (using NeRFs).

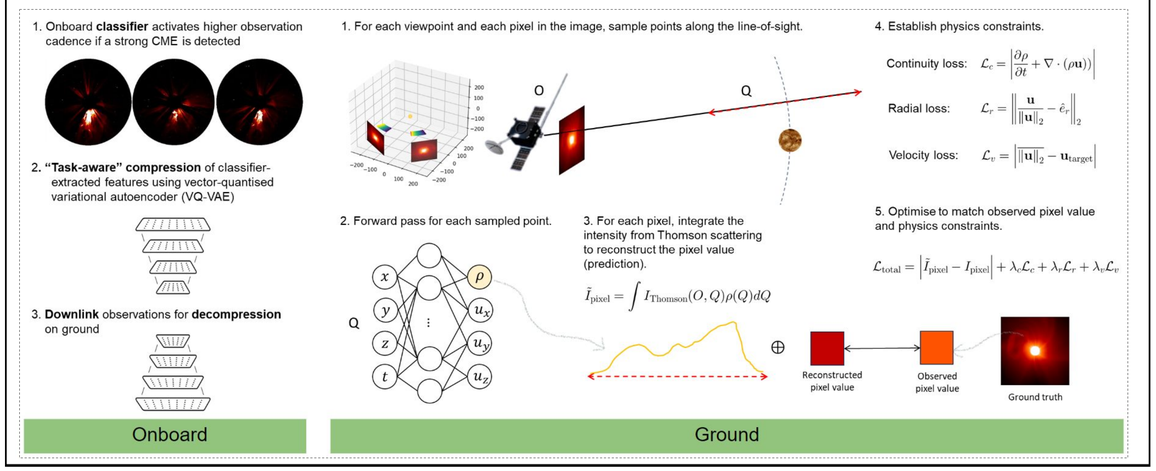
Advantage:

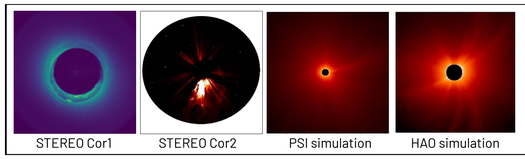
Automatic 3D CME reconstruction for better CME reaction time on Earth.



Methodology

CME-aware compression performed onboard; downlinked observations used for **3D reconstruction** and CME parameter estimation using **Physics-informed Neural Radiance Field (PINNeRF)** on ground.





Data

Training on coronagraph data from simulations and proxy observation data from the STEREO mission.

OUTCOMES

ICARUS

Onboard compression

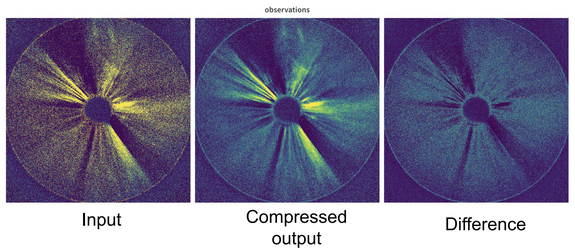


Figure 1: Example output from Cor2 with resulting compression from pretrained model, alongside the mean squared difference - tested on Myriad Compute Stick and Unibap Spacecloud Testbed

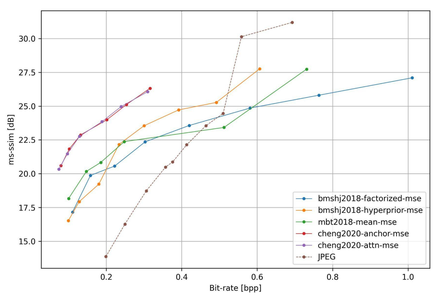


Figure 2: Model comparison of Vector-Quantized Variational Autoencoder based algorithms vs JPEG with STEREO images

3D reconstruction visualisation available here!

3D CME reconstruction

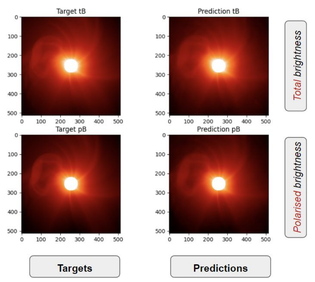


Figure 3: Coronagraphic image (2D) reconstruction of the PINNerF model

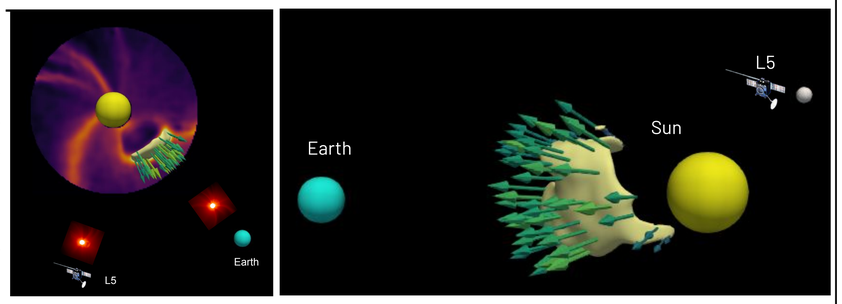


Figure 4: Velocity and density field snapshot of a simulated CME (reconstructed from observations from L5 and the Earth)

NEXT STEPS

- **Data fusion**: make use of different types of data (e.g. EUV)
- Investigate the tolerance of noise level in simulation data for model training to bridge the gap from **simulated to real observations**
- Include more **sophisticated architectures and training schemes** (e.g., neural compression)
- **Deploy** on the VIGIL satellite

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