Space Weather forecasting investigation using Virtual Reality

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Outline

- Background / Motivation
- Project: Approach and Challenges
- Results / Outcomes achieved so far
- Future Work

Background / Motivation

Space Weather: conditions on our Solar System due to activity detected on the surface of the Sun during its solar cycle.

- Solar wind
- Coronal Mass Ejections (CMEs)

Effect:

- Telecommunications
- Navigation
- Power distribution
- Astronauts on the ISS

Background / Motivation

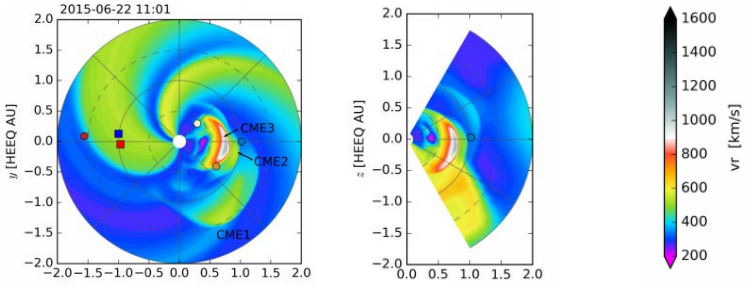
Remote sensing data → Develop sophisticated models → Accurate forecasts of Space Weather events

Data visualisation

The bridge between the quantitative information in the data and the human intuition and understanding

Current means:

- Typically focused on 2D graphs
- Quantities like the plasma velocity or density are plotted



Jens Pomoell and Stefaan Poedts. EUHFORIA: European heliospheric forecasting information asset J. Space Weather Space Clim. 2018, 8, A35

Background / Motivation

Virtual Reality: visualise the evolution of a solar event in a 3D environment:

- Contextualize simulation results ➡ get new insights - complex structures that may exist in 3 or more dimensions are lost when projected to a lower dimensionality display
- Support forecast model development ➡ prediction of the potential impacts on Earth,
- Navigate around a Coronal Mass Ejection ➡ increase knowledge about the propagation and unfolding of CMEs, which is not yet established

*Be **inside** the data, instead of around them*

Model: EUHFORIA – European heliospheric forecasting information asset

- STEREO (Solar Terrestrial Relations Observatory) mission (spacecraft A and B)

Measurements in specific positions ➡ Full 3D space

$$0.1\ AU < r < 2\ AU$$
$$-182.77° < longitude < 184.49°$$
$$3.58° < latitude < 175.6\ °$$

- Data for: plasma velocity, density, pressure, magnetic field

Note: 1 AU = 149600000 km

**CME-CME Interactions as Sources of CME Geo-effectiveness: The Formation of the Complex Ejecta and Intense Geomagnetic Storm in Early September 2017,* arXiv:1911.10817v1. Camilla Scolini, Emmanuel Chané, Manuela Temmer, Emilia K. J. Kilpua, Karin Dissauer, Astrid M. Veronig, Erika Palmerio, Jens Pomoell, Mateja Dumbović, Jingnan Guo, Luciano Rodriguez, Stefaan Poedts

Project

Input Data:

- KU Leuven scientists (they really liked the idea!)
- September 2nd – 9th 2017: intense solar activity
    - full 3D space data, every six hours *(00, 06, 12, 18)*
- Size **~1TB**

Approach: 3D Colour maps - closer to what the scientists are familiar with at the moment

Challenges:

- Data preparation - .npz to .csv, understanding their form, removing overlaps
- Achieve transparency without jeopardizing the amount of information depicted
- Performance – time for loading the data is not negligible

Project

Unity game engine – most widely used tool for AR/VR applications + **HTC Vive headset**

Requirement: *Accuracy*. **Not** a game implementation.

Results / Outcomes achieved so far

Equatorial plane:

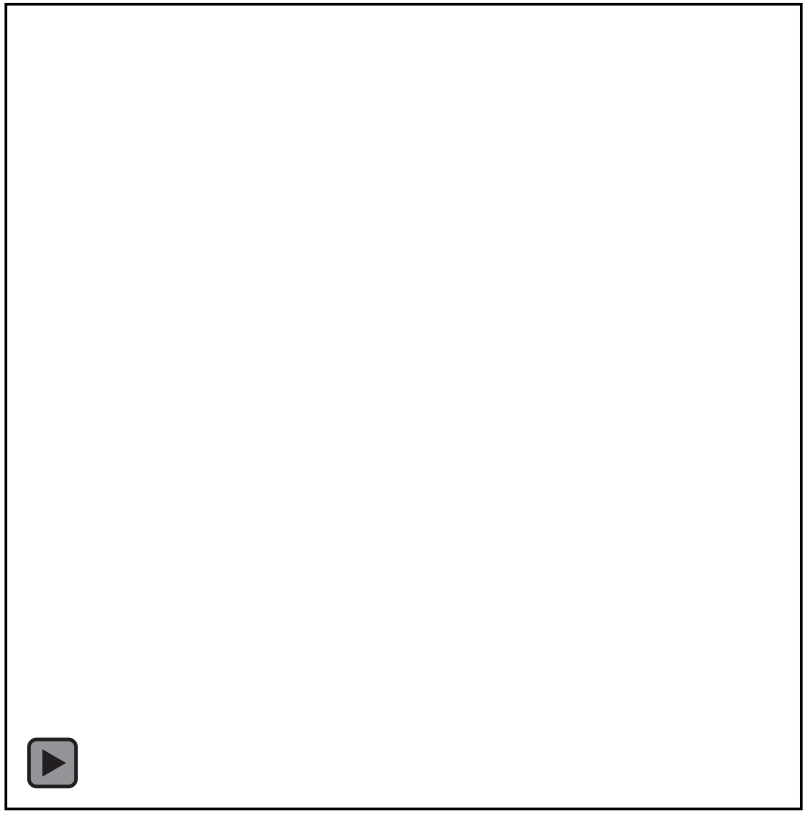
$latitude = 88.68\,°$

$\mathbf{0.1\ AU < r < 1.36\ AU}$

$-182.77° < longitude < 184.49°$

Plotting: Radial velocity [km/s]

Sampling: Every second radial



Results / Outcomes achieved so far

Equatorial plane:

$latitude = 88.68\,°$

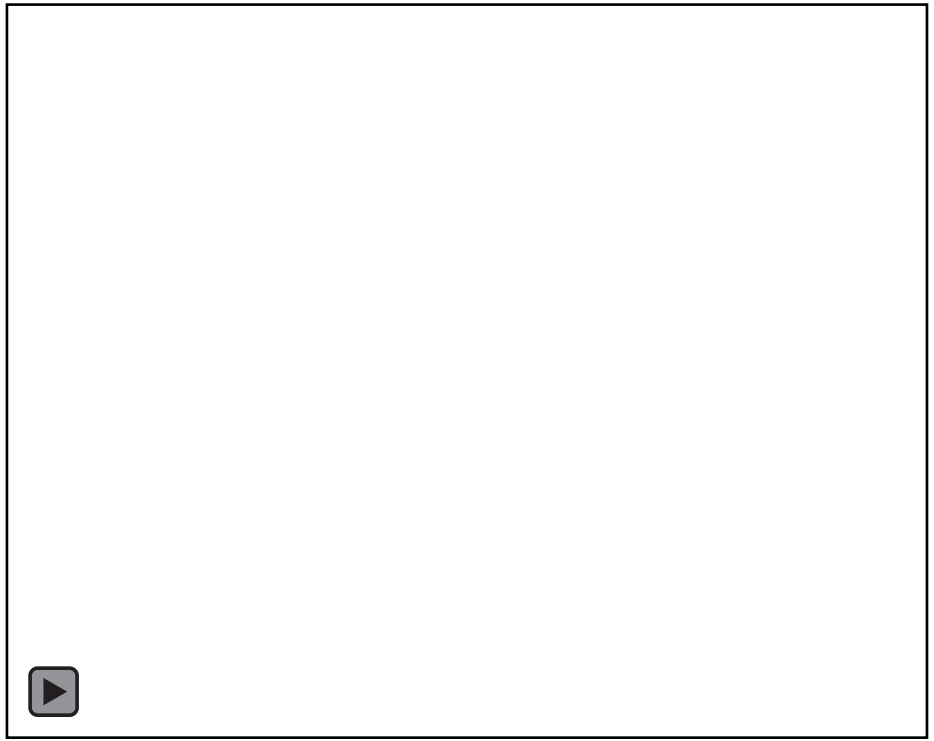
$\mathbf{0.1\ AU < r < 0.41\ AU}$

$-182.77° < longitude < 184.49°$

Plotting: Radial velocity [km/s]

Sampling: Every second radial

- Handling the plane
- Desired view angle
- Moving forward and backwards in time



Results / Outcomes achieved so far

Spherical shell:

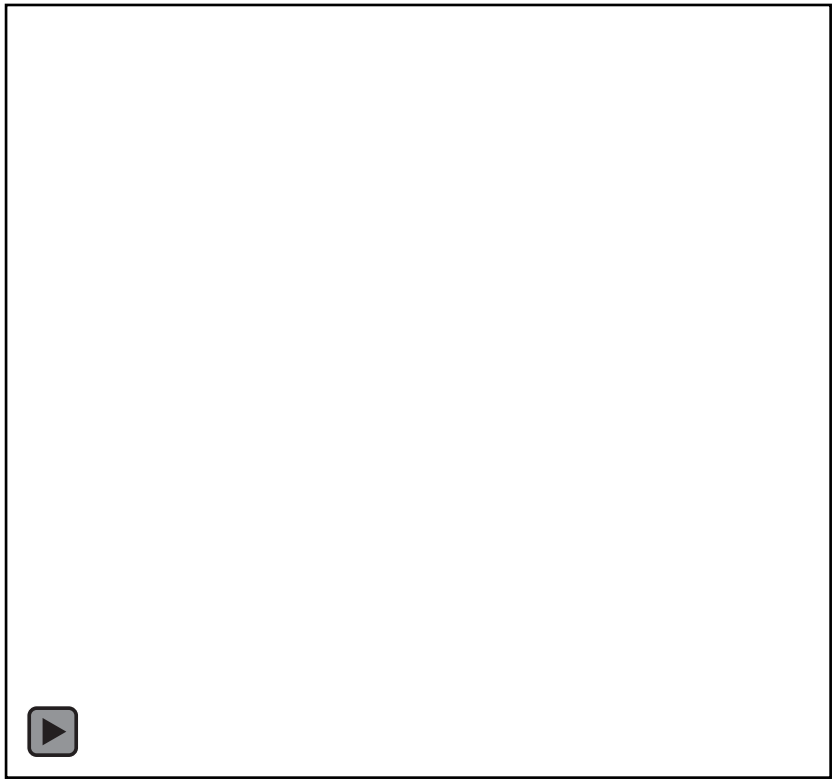
$3.58° < latitude < 175.6\,°$

$r = 0.1\,AU$

$-182.77° < longitude < 184.49°$

Plotting: Radial velocity [km/s]

Sampling: No sampling



Results / Outcomes achieved so far

Two spherical shells:

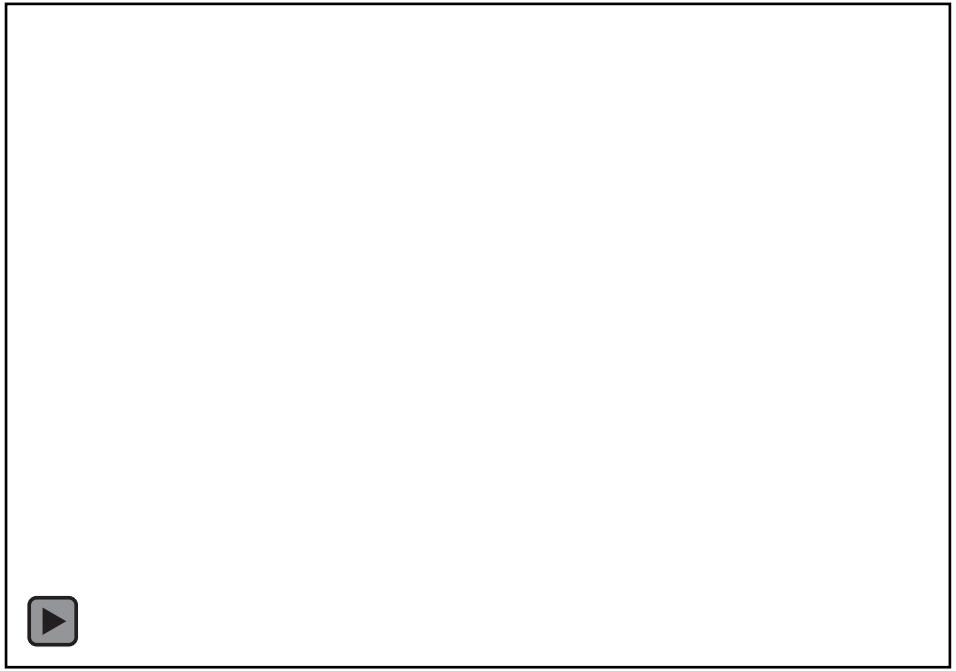
$3.58° < latitude < 175.6°$

$R_1 = 0.10\ AU,$

$R_2 = 0.18\ AU$

$-182.77° < longitude < 184.49°$

Plotting: Radial velocity [km/s]



Multiple spherical shells:

- Sampling 3D space
- Dealing with the info vs transparency balance

Results / Outcomes achieved so far

Four spherical shells:

$3.58° < latitude < 175.6°$

$R_1 = 0.10\ AU,$

$R_2 = 0.13\ AU,$

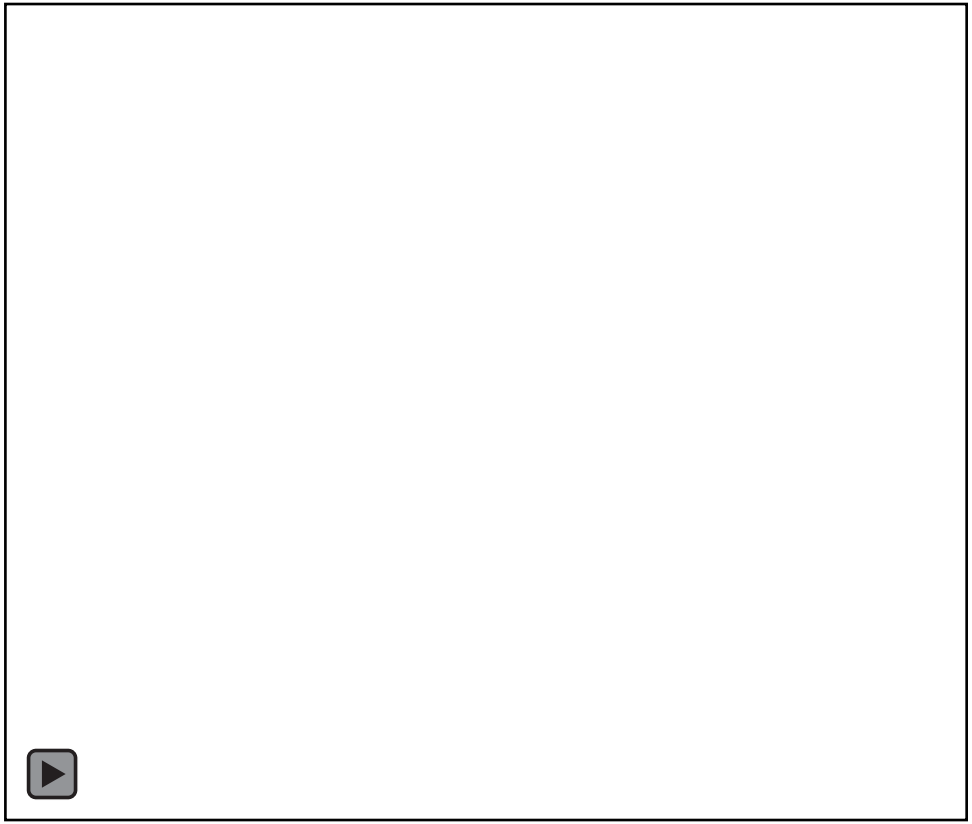
$R_3 = 0.16\ AU,$

$R_4 = 0.20\ AU$

$-182.77° < longitude < 184.49°$

Plotting: Radial velocity [km/s]

Sampling: No sampling



Future Work

- Further capabilities:
  - Filtering,
  - Grid cutting with hand controllers, …

- Add planets - Detailed visualisation of impact on Earth

- Visual comparison among different model parameters, different models

- Performance (input files, …)