

USING STEREO-HI BEACON DATA TO PREDICT CME ARRIVAL TIME AND SPEED WITH THE ELEVOHI MODEL

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OVERVIEW

Current situation:

- The Ellipse Evolution Model based on Heliospheric Imager observations (ELEvoHI) allows for prediction of CME arrival time and speed. An elliptical CME front is assumed and combined with drag-based model fitting (Rollett et al., 2016, Amerstorfer et al., 2018).
- Science data from the STEREO HI instruments forms the basis for creating the input for ELEvoHI. This data is made available with a latency of 2 - 3 days, making real time predictions impossible. Real-time data from the STEREO Space Weather Beacon is available, but not currently used.
- ELEvoHI and the STEREO software routines necessary for performing data reduction on HI images are written in IDL and thus currently only available to people who have purchased an IDL license.

OVERVIEW

Future goals:

- STEREO-A is now again in a position where it can observe the Sun-Earth line, allowing for the observation of earth-directed CMEs. Preparing STEREO beacon data in a way that makes it usable for ELEvoHI would expand its capabilities to include real-time predictions. The current favorable spacecraft position means that predictions about arrival time and speed could be made in advance and later verified once the CME arrives at Earth.
- Reproducibility and collaboration are at the heart of science. By rewriting the STEREO HI data reduction software in Python and making the programs that produce the input for ELEvoHI available to everyone, it is ensured that every person interested in reproducing our research is able to do so. Using an open-source language like Python enables more people to partake in our work, regardless of whether they are in possession of an IDL license.

PROCESS

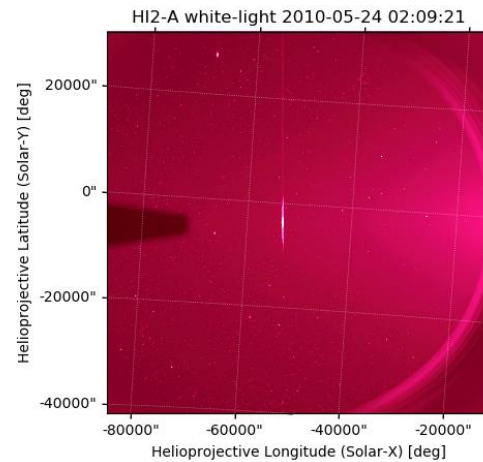
Obtaining input for ELEvoHI:

- SECCHI Prep is the IDL program that handles the data reduction for STEREO science and beacon data. A comparable program is not available in any open-source language. To obtain the correct input files for ELEvoHI, several data reduction steps must be performed and first implemented in Python.
- First, basic data reduction is done. This includes bias subtraction, flat fielding, the correction for the shutter-less readout , etc..
- CMEs are not visible even after these procedures have been performed. This is due to the bright light of the solar corona making CMEs appear almost invisible. Therefore, running difference images are produced. Images are subtracted from their successors, eliminating the influence of the corona while enhancing the visibility of the CME.
- ELEvoHI uses, among other parameters, time-elongation values as its input. These are obtained by tracking the propagation of the CME by hand. To this end, so-called Jplots are used.
- Jplots are created from running difference images. The ecliptic line of each time step is cut out. These cut out frames are then assembled next to each other, making it possible to follow the CME on its trajectory.

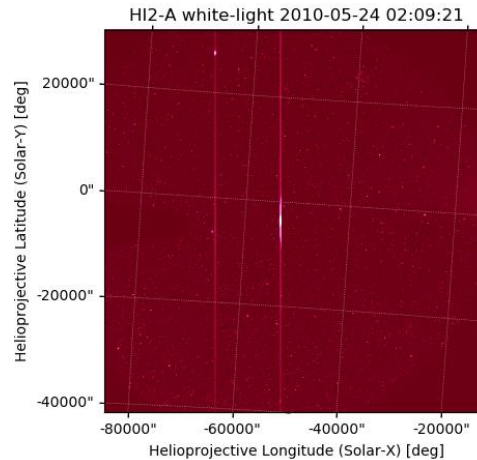
PROCESS - EXAMPLE IMAGES

Raw image

Science (STEREO-A HI-2)

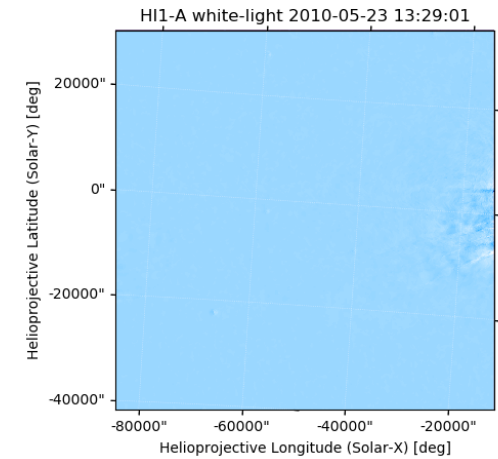


Data reduced image

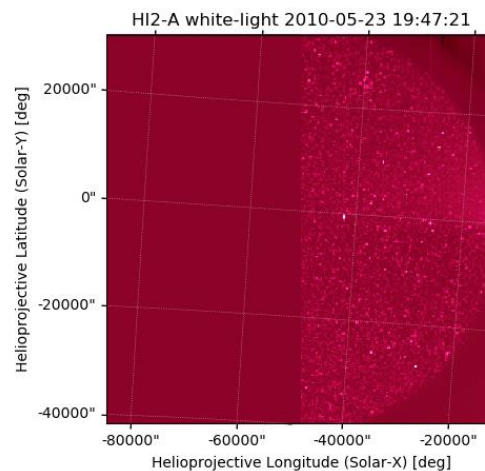
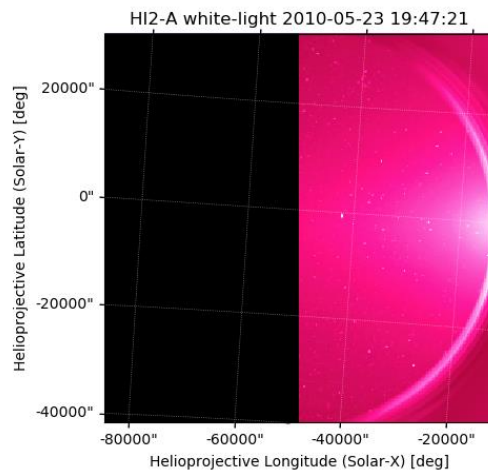


Running difference image

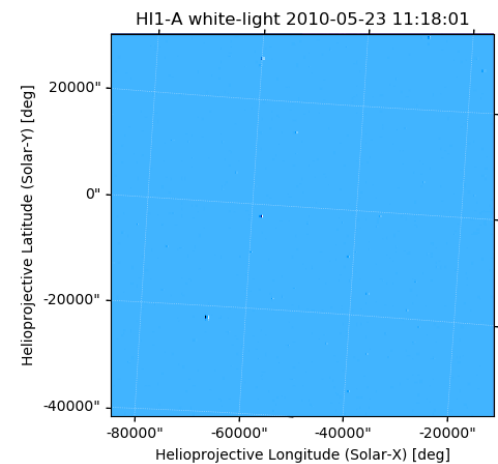
Science (STEREO-A HI-1)



Beacon (STEREO-A HI-2)



Beacon (STEREO-A HI-1)



CHALLENGES

Software:

- All software routines for the STEREO mission are only available in IDL. Some functions that solar physicists take for granted in IDL do not yet have a counterpart in Python or another open-source language. Translating these routines and functions is a time-consuming task.
- The functionality of the IDL programs must be reproduced exactly to ensure comparability of the results. This requires extensive testing with different inputs.

Data:

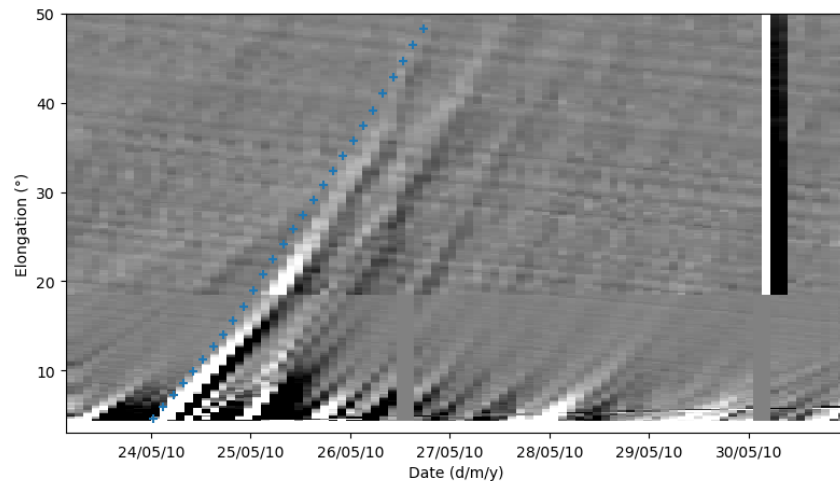
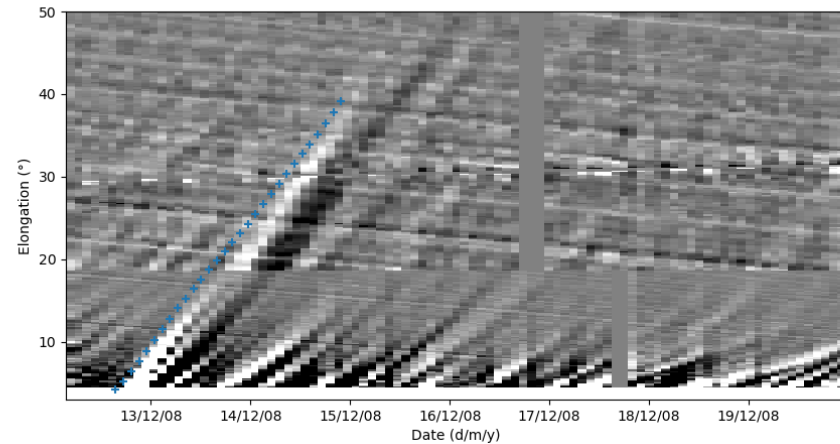
- Beacon data is highly compressed and binned, making the image quality worse than that of science data. This makes tracking the CMEs in Jplots more difficult since the spatial resolution is worse.
- Beacon data is downlinked in real-time, but there are often gaps in the telemetry. This leads to large time gaps in Jplots, which in turn further complicates the manual tracking of CMEs.

RESULTS (SO FAR)

- Data reduction and creation of running difference images are possible using the Python program. The created Jplots, on the other hand, do not yet behave as they do in IDL.
- There appear to be shifts between HI-1 and HI-2 beacon images that do not appear when using the corresponding IDL program.
- The entire Jplot appears to be slightly shifted along the time-axis for science images.
- Assuring that the code is of high quality and usable by everyone is the highest priority, thus more work is necessary to replicate the IDL results. Due to these circumstances, the actual science goal of comparing the predicted arrival time and speed between science and beacon data has not yet been achieved.
- Once the programs are finished, an analysis of the errors in the prediction of arrival time and speed using science and beacon data is planned.

RESULTS (SO FAR)

- Jplots created from STEREO-A HI images for the events launched on 12.12.2008 (above) and 23.05.2010 (below).
- The time-elongation profile obtained by manual tracking in IDL is depicted using blue crosses
- A clear difference is visible between these tracks and the CMEs as they are visualized in the Python version



REFERENCES

- T. Rollett et al., ElEvoHI: A Novel CME Prediction Tool for Heliospheric Imaging Combining an Elliptical Front with Drag-Based Model Fitting, The Astrophysical Journal, 2016, doi: [10.3847/0004-637X/824/2/131](https://doi.org/10.3847/0004-637X/824/2/131)
- T. Amerstorfer et al., Ensemble Prediction of a Halo Coronal Mass Ejection Using Heliospheric Imagers, Space Weather, 2018, doi: [10.1029/2017SW001786](https://doi.org/10.1029/2017SW001786)