ÖAW — AUSTRIAN ACADEMY OF SCIENCES

MODELLING CORONAL MASS EJECTION FLUX ROPES SIGNATURES USING APPROXIMATE BAYESIAN COMPUTATION: APPLICATIONS TO PARKER SOLAR PROBE

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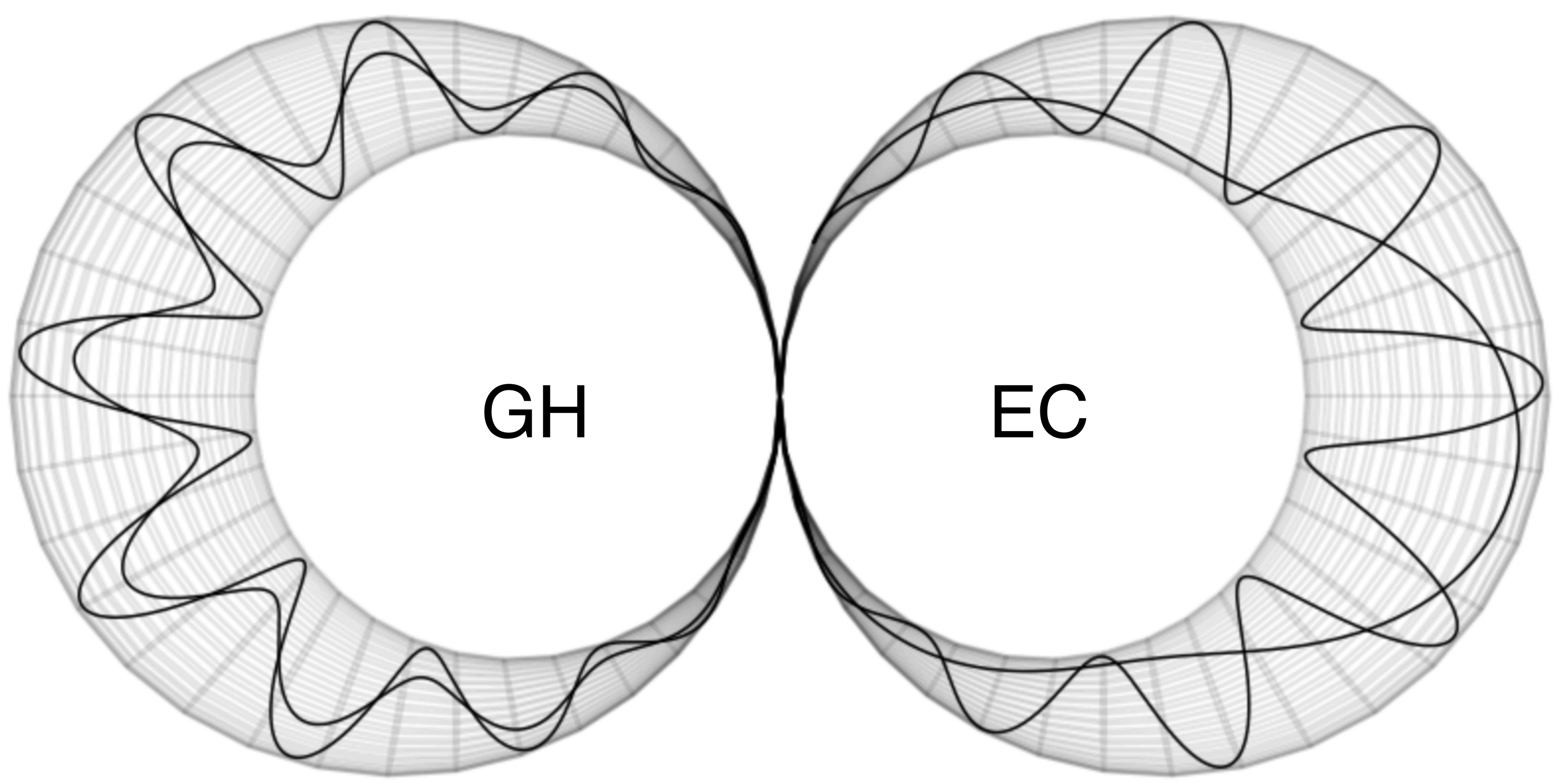
We present first results from the application of our 3D Coronal Rope Ejection Model (3DCORE) to in-situ magnetic field measurements from recent Parker Solar Probe fly by's. Our analysis attempts to reconstruct the 3D geometry of the observed flux rope, under the assumption of a torus-like global shape, and infer properties of the associated magnetic field. For the magnetic field which is inserted into our global shape we use two different analytical solutions and compare the results. The first is an analytical uniform twist model (like Gold-Hoyle) based on a toroidal shape [1] and the second is an elliptical-cylindrical model [2]. While we have performed extensive testing of our model and analysis tools for events at 1AU, the recent Parker Solar Probe fly by's provide use with the new and unique opportunity to test our approach to events observed extremely close to the sun.

3DCORE MODEL & ANALYSIS

The 3DCORE model is used to generate synthetic in-situ magnetic field measurements. This is achieved by combining a global 3D shape, currently a slightly modified torus, with a drag-based propagation model [3] and an analytical magnetic field model [1, 2]. This allows us to simulate in-situ measurements at any point within the heliosphere. Below we show the two used variants of our model for the analysis. Left: 3DCORE with the toroidal uniform twist model based on [1]. Right: 3DCORE with the elliptical-cylindric model based on [2]. In both cases we show two magnetic field lines at different distances from the flux rope core.

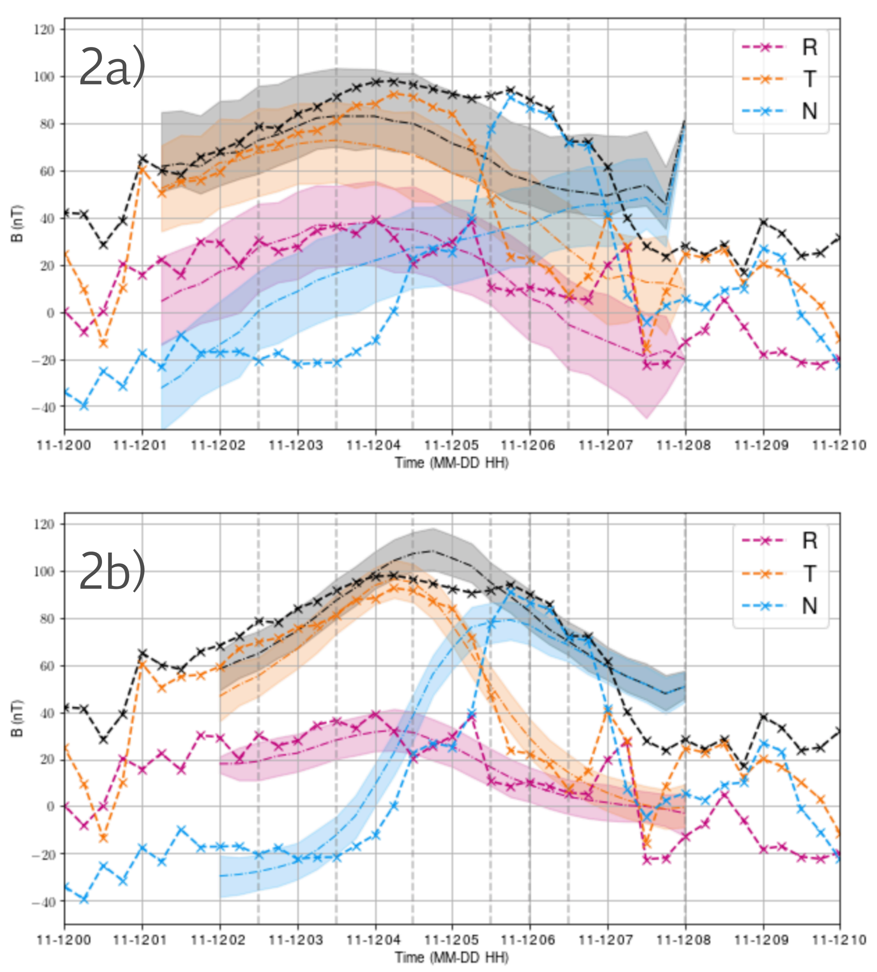
For the flux rope fitting procedure we use an Approximate Bayesian Computation (ABC) algorithm that generates an ensemble of solutions which represent an approximation of the posterior distribution.



We acknowledge funding by the Austrian Science fund (FWF): P31521-N27

FLUX ROPE FITTING

For our demonstration we chose to use an event that was observed by PSP on the 12th of November 2018. A detailed analysis of this event, including a fit using the original EC model can be found in [4]. We use some of the results from this paper as references for our own analysis.



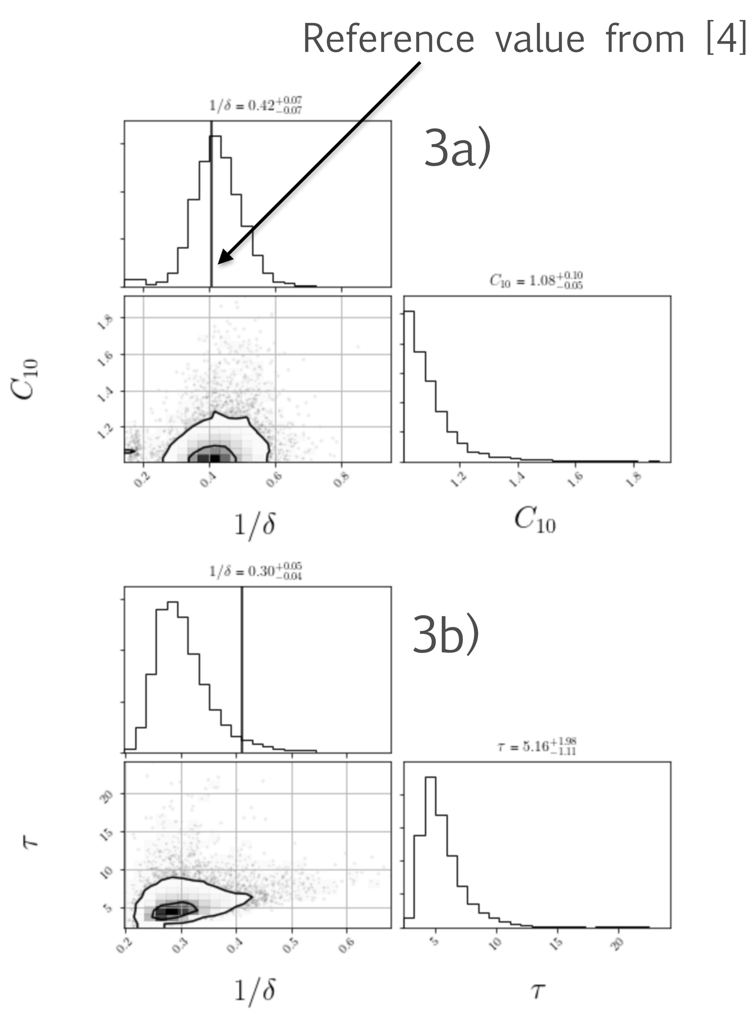


Figure 2a shows our fitting results using our implementation of the EC model and figure 2b shows the result using the uniform twist model It is important to note that we use a different error metric and slightly different time range for fitting with the EC model than what was used in [4]. The fitting is performed within the time range 02:30AM - 06:30AM.

We can additionally directly compare the resulting model parameters from our fits. In figure 3a we show the aspect ratio 1/δ and the twist parameter for the uniform twist model. In [2, 4] the aspect ratio is defined in the opposite way as the 3DCORE model (δ > 1 elliptical for 3DCORE, δ < 1 elliptical for EC). Figure 3b shows the aspect ratio and C10 parameter for the EC model. Both fits suggest a highly elliptical cross section with 1/δ either 0.25 or 0.42. The value given in [4] was 0.41 for the fit over the entire time range, which is very similar to our result using the same model. The uniform twist model suggests a twist parameter of approx 5 twists over the entire flux rope structure. At 0.26AU this corresponds to roughly 0.4 twists / AU. The fit for the EC model suggests a C10 parameter of 1.08, similar to the 1.02 value given in [4]. For this particular analysis we excluded values of C10 < 1 by choice of priors.

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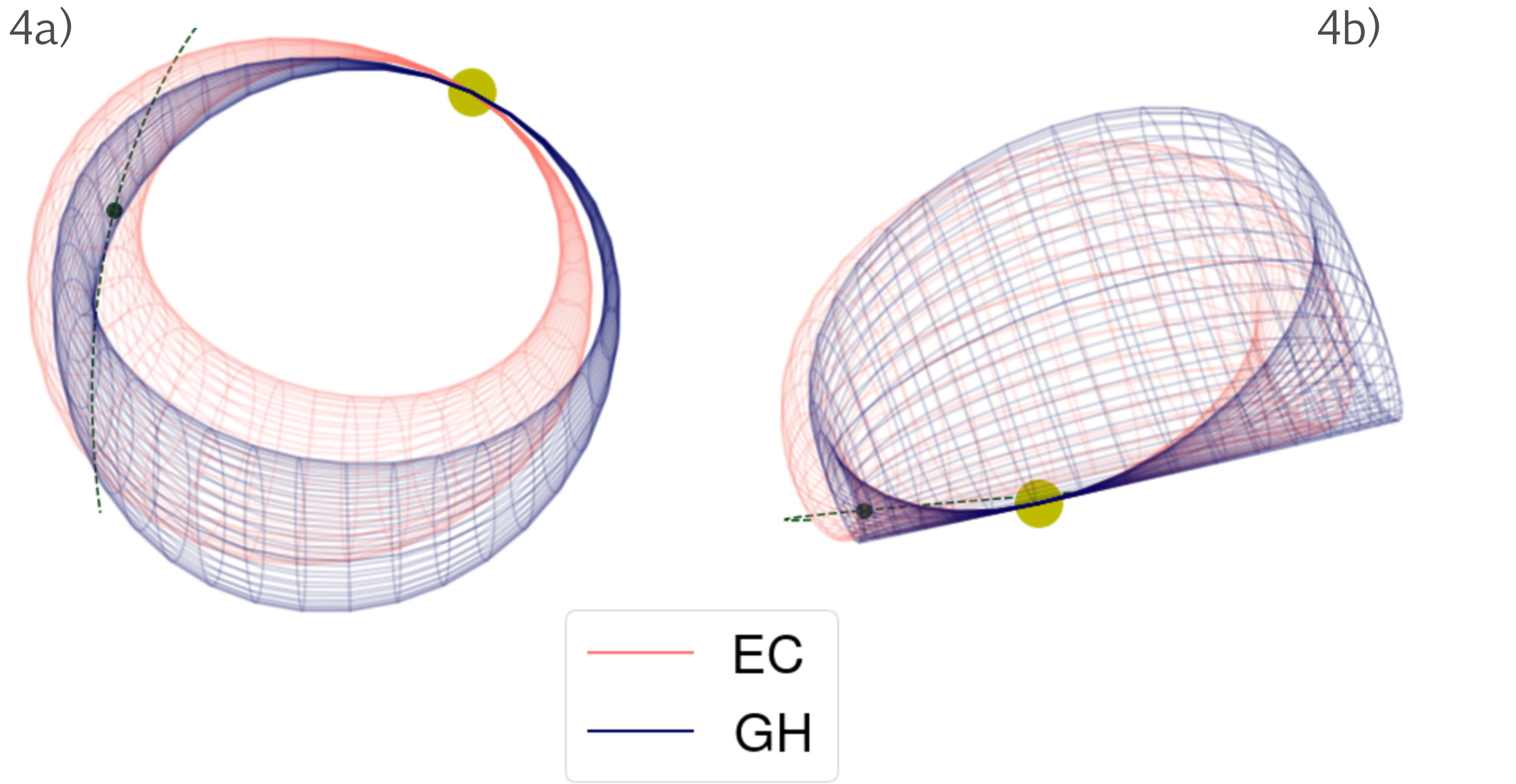
Scatter plot matrices generated using corner.py doi: 10.21105/joss.00024

3D RECONSTRUCTION

From the inferred geometrical parameters we furthermore attempt to perform a reconstruction of the 3D shape within our model. These reconstructions can, in theory, be compared with heliospheric imagers. In both cases the inference delivers longitude, latitude and inclination values with margins of error below 10°.



Figures 4a and 4b show the top and front view of our reconstruction for both models respectively. Additionally the Parker Solar Probe trajectory is plotted with dashed lines (200 hours of orbit for scale). In both cases, as we can see, the spacecraft intersects the flux rope at a large distance from the flux rope core. Additionally we can also attempt to infer the magnetic field strength of the flux rope core for both models. For the uniform twist model we achieve a result of 127 ± 6 nT and for the EC model we get 290 ± 18 nT (these values are taken at 04:00AM). The results in [4] vary between 95 and 203 nT.

DISCUSSION

The presented results are meant as a first demonstration of our ABC inference algorithm on Parker Solar Probe data in combination with our 3DCORE model. We were able to reproduce some of the previous results from [4] when using the same magnetic field model, now including estimates on the errors of the model parameters themselves. This opens up various new interesting ways in which we can assess the fitness of different magnetic field models and compare them with each other. Additionally we can infer the uncertainty that is present when fitting in-situ measurements and attempt to increase their accuracy. Future work will include fits to larger catalogs of CME's observed at 1AU in order to further assess the accuracy of our model. We currently have a paper in preparation, Weiss et al. 2020, in which we describe the implemented ABC algorithm and associated methods in detail.

2020

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