Bayesian Inference for Automated 3D CME Characterization and Uncertainty Quantification

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INTRODUCTION

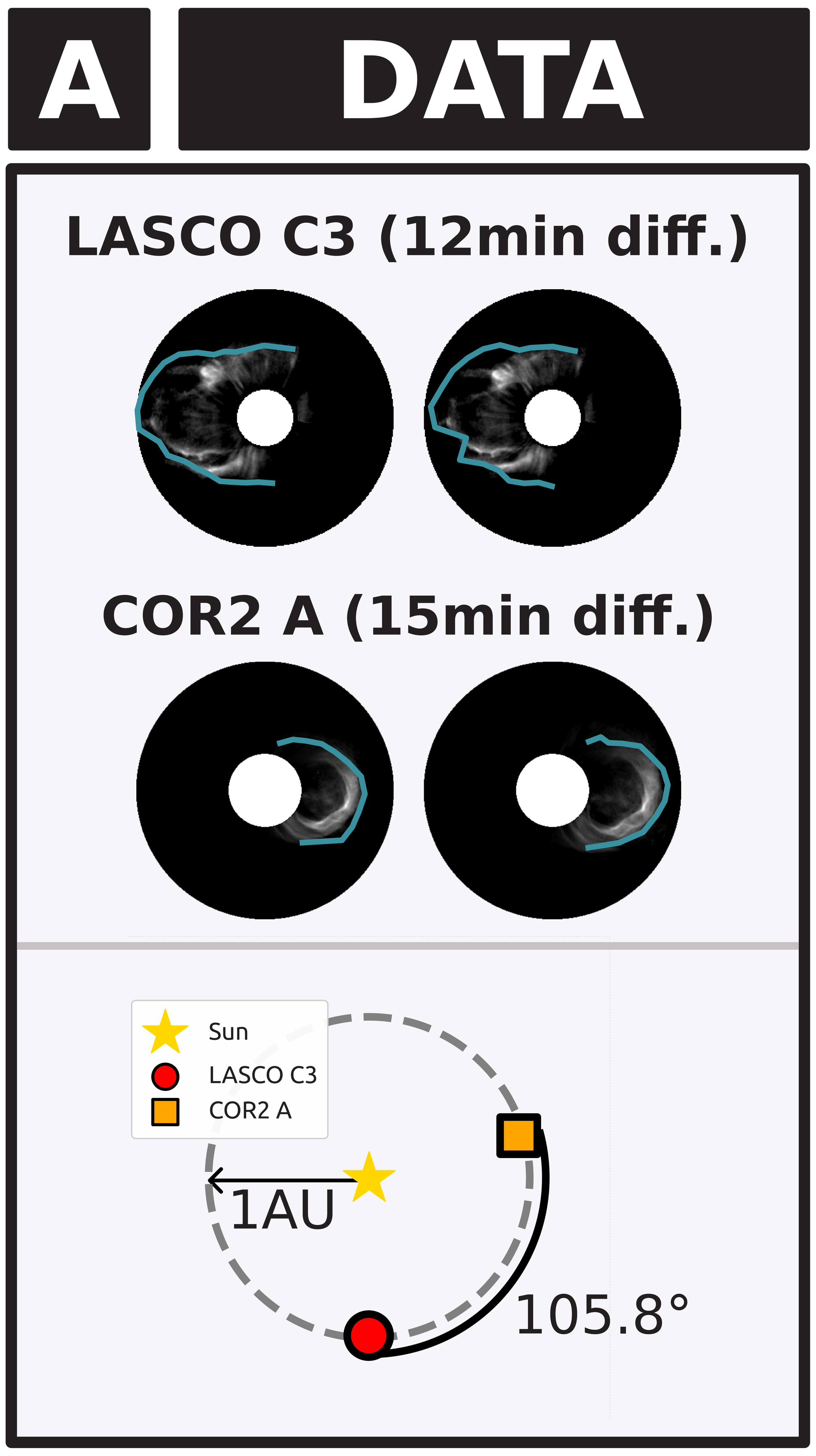
- The 3D kinematics of Coronal Mass Ejections (CME) is crucial for modeling its propagation.
- Current Time of Arrival (ToA) estimates suffer from persistent errors and under-dispersion.
- We present a method for reconstructing CMEs from coronagraph data.

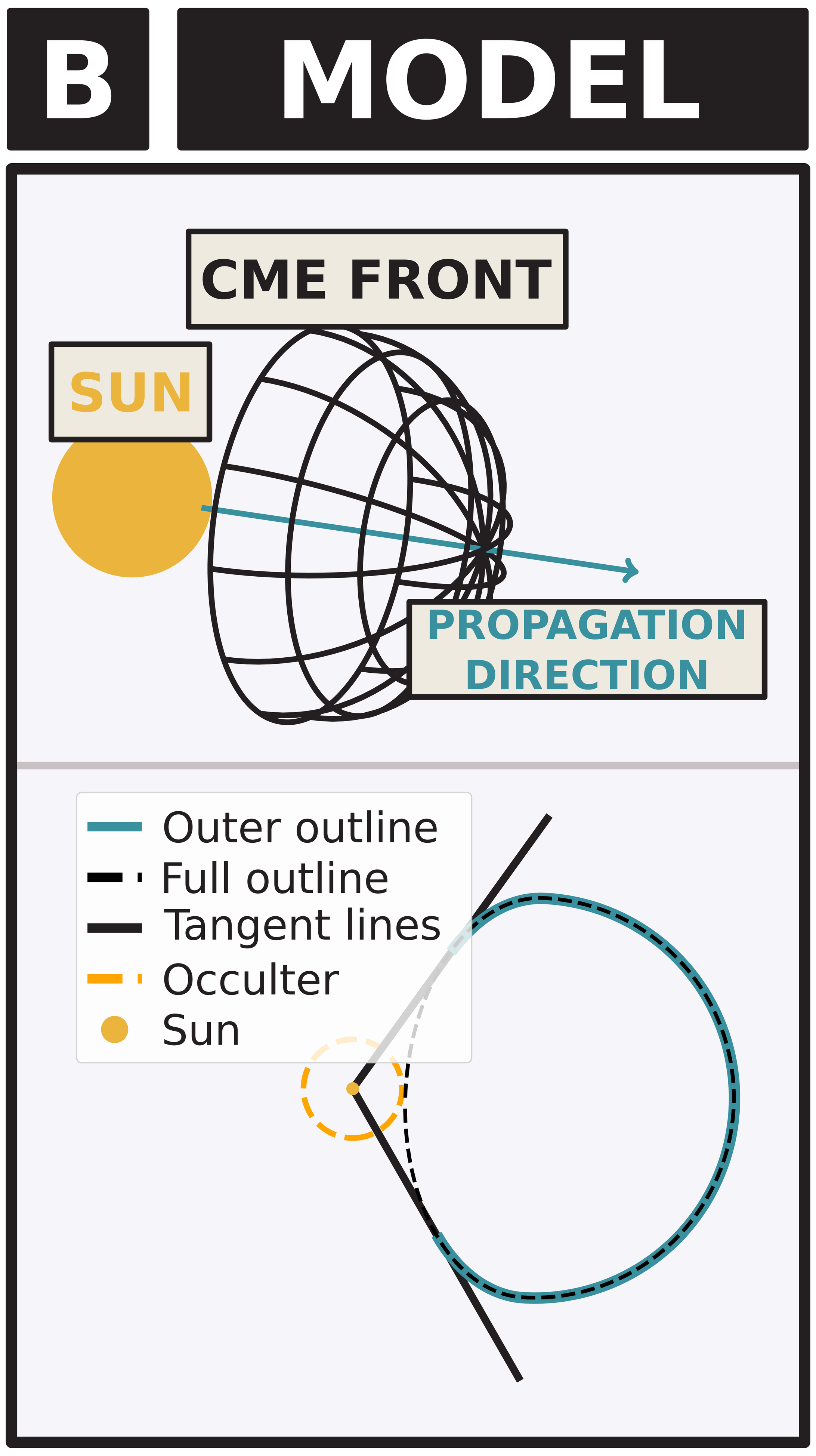
A DATA

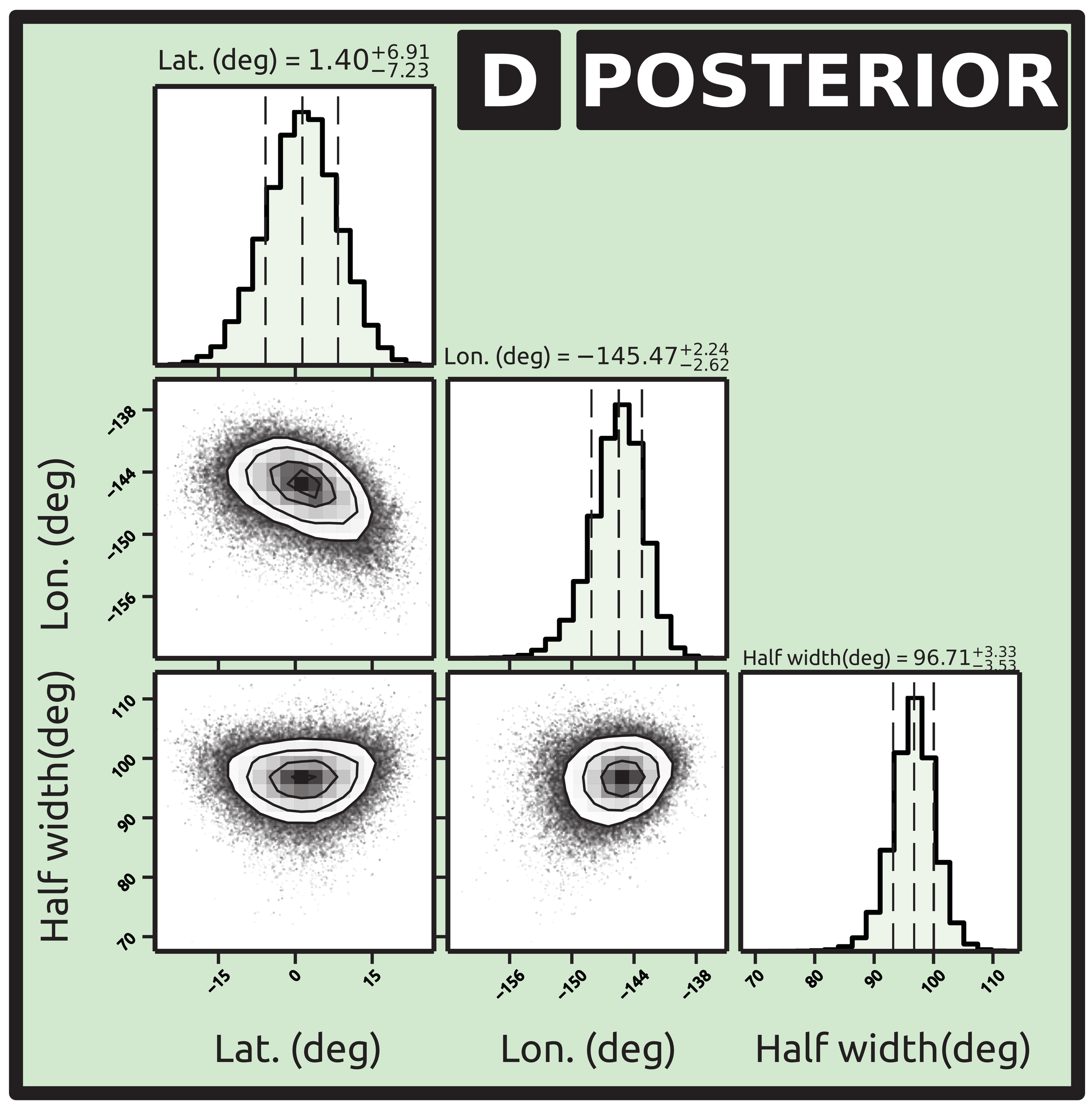
- Coronagraph images contain projected information on the CME structure.
- Multiple viewpoints provide complementary information.
- The reconstruction is based on the outer outline of the CME (blue lines) which can be measured in coronagraph images.

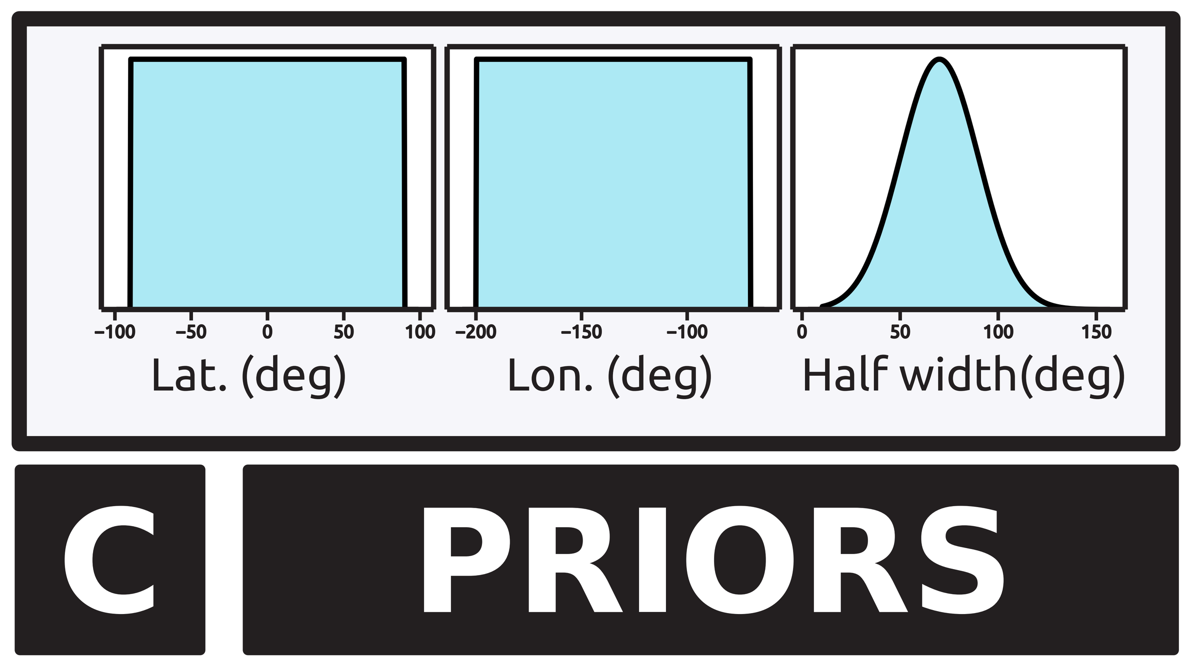
B MODEL

- An assumption on the 3D CME geometry is required.
- We use the full ice-cream cone model [1].
- The 3D geometry is projected and the outer outline extracted analytically.









C PRIORS

- In Bayesian inference, priors convey knowledge about model parameters before considering the data.
- They can informative (e.g. half-width, a narrow gaussian) or uninformative (e.g. latitude/Lat. with a flat prior).
- Priors allow incorporating physical knowledge of the system (e.g. use distribution of CME speeds as prior).

D POSTERIOR

- The posterior contains all the information about the model parameters after considering the data.
- It is a N-dimensional probability distribution (N = number of model parameters).
- It can be projected to 1D or 2D to visualize marginal distributions and correlations.

Samples from the posterior (grey) can be compared to the data (blue) to assess the model fit.

TAKEAWAYS

- Our Bayesian framework provides a robust method for the 3D reconstruction of CMEs from coronagraph data.
- It allows the characterization of model parameter uncertainties rigorously, regardless of the availability of multiple viewpoints.
- Posterior distributions can be directly sampled to propagate uncertainties and correlations into propagation models.

FUTURE WORK: Apply the framework to a large sample of CMEs and use the derived posterior distributions to drive ensembles of propagation models (e.g. HUXt). Investigate whether rigorous uncertainty quantification and correlations can improve distributions of arrival times.

References

[1] Hyeonock Na, Y.-J. Moon, and Harim Lee. Development of a full ice-cream cone model for halo coronal mass ejections. *The Astrophysical Journal*, 839(2):82, April 2017.