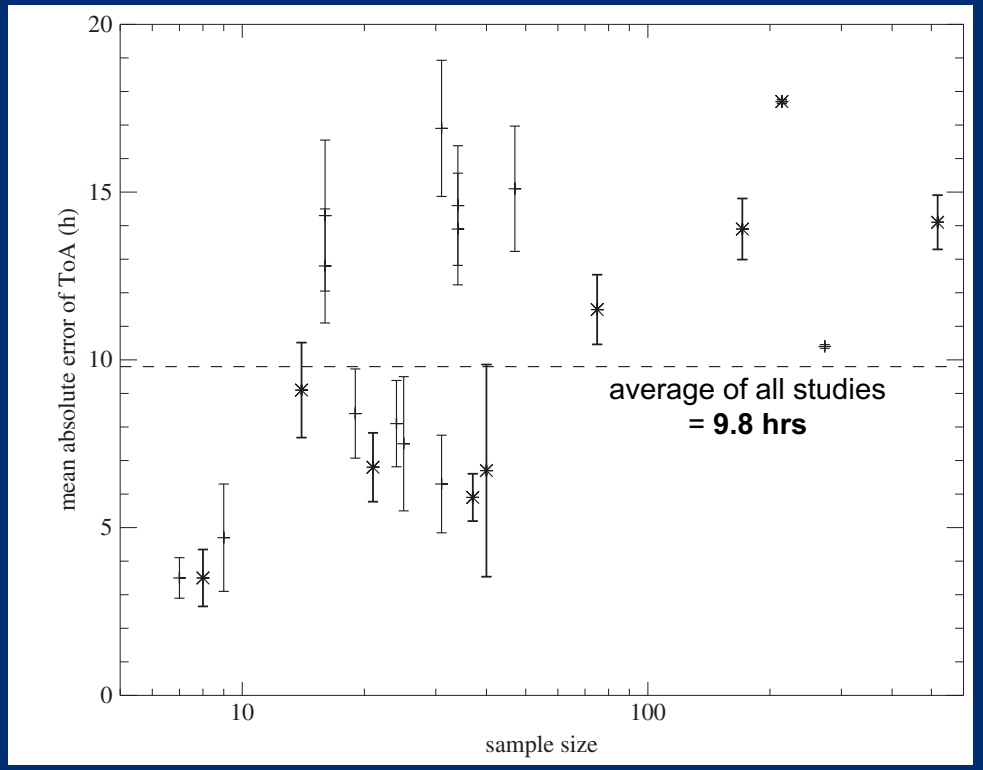
Predicting the Geoeffective Properties of CMEs: Status, Open Issues, and Path Forward

- Coronal Mass Ejections (CMEs) are the main drivers of terrestrial Space Weather
- Solar missions in the last 40 years have greatly advanced our understanding of the physical properties of CMEs.
- CMEs can now be imaged throughout the inner heliosphere yet their Time-of-Arrival (ToA) at Earth and their SpWx effects cannot be predicted reliably. Why is that?
- We identify several physical & modeling limitations:
  - CME size at 1 AU >> Earth
  - CME evolution above ~30 Rs is not understood
  - Modelling of the background corona and heliosphere is incomplete
  - Techniques from weather forecasting (e.g. data assimilation) are in their infancy in heliophysics modeling
- Path Forward:
  - Better observations (magnetograph at L5, off-Sun-Earth imaging
  - Improve modeling (include CME magnetic structure, data assimilation)
  - Consistent methodology to assess the effectiveness of prediction algorithms.



ToA mean absolute error vs. sample size for several studies. The error bars are the uncertainty in the mean value (σ/ N, N = sample size). The star symbols mark studies bssed on projected CME parameters.

Reliable Space Weather prediction requires targeted investment to improve observational and modeling capabilities and basic research

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