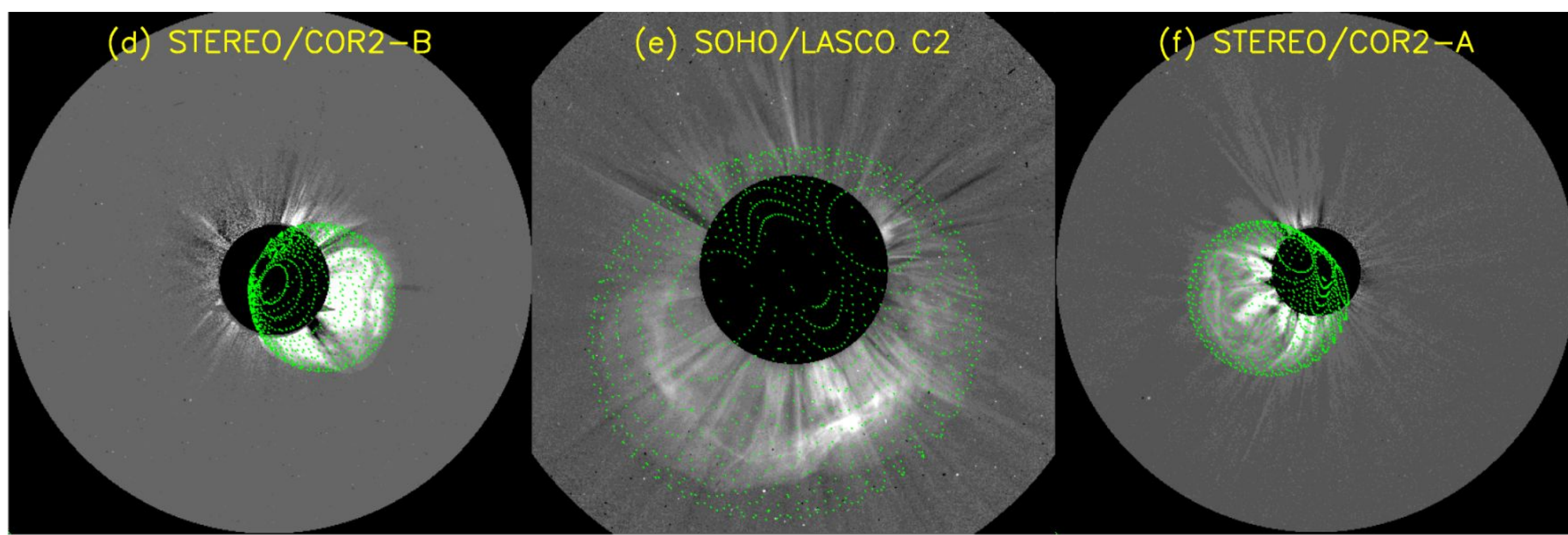


We need to talk about spherical CMEs

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Introduction

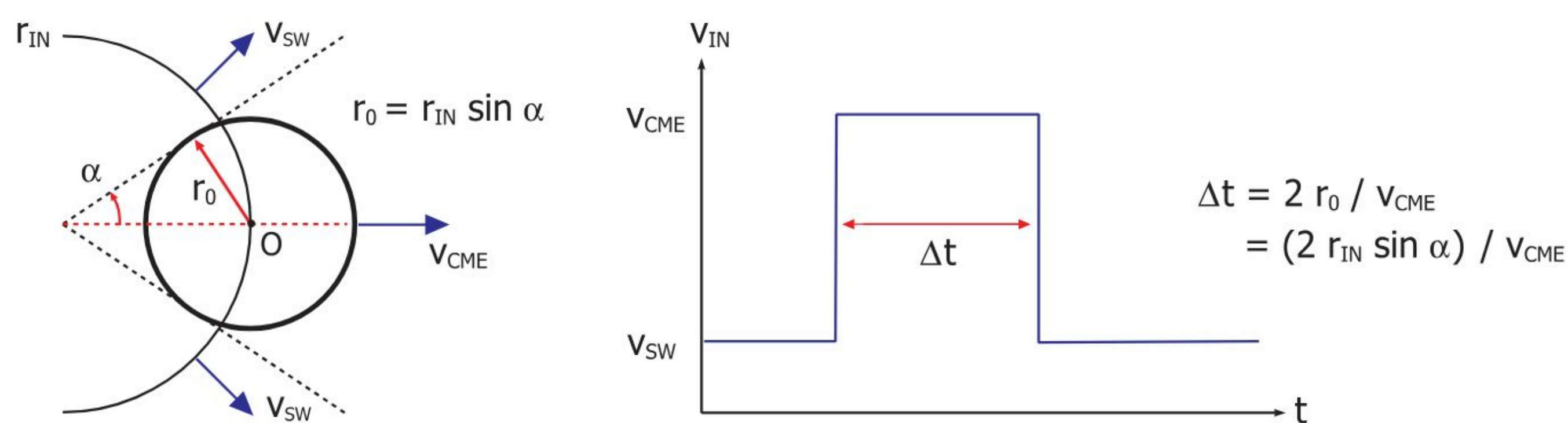
The arrival of CMEs at Earth is typically forecast using dynamical solar-wind models – such as Enlil and EUHFORIA – with “cone-model” estimates of CME properties derived from coronagraph observations:



Adapted from Zhong et al., 2021.

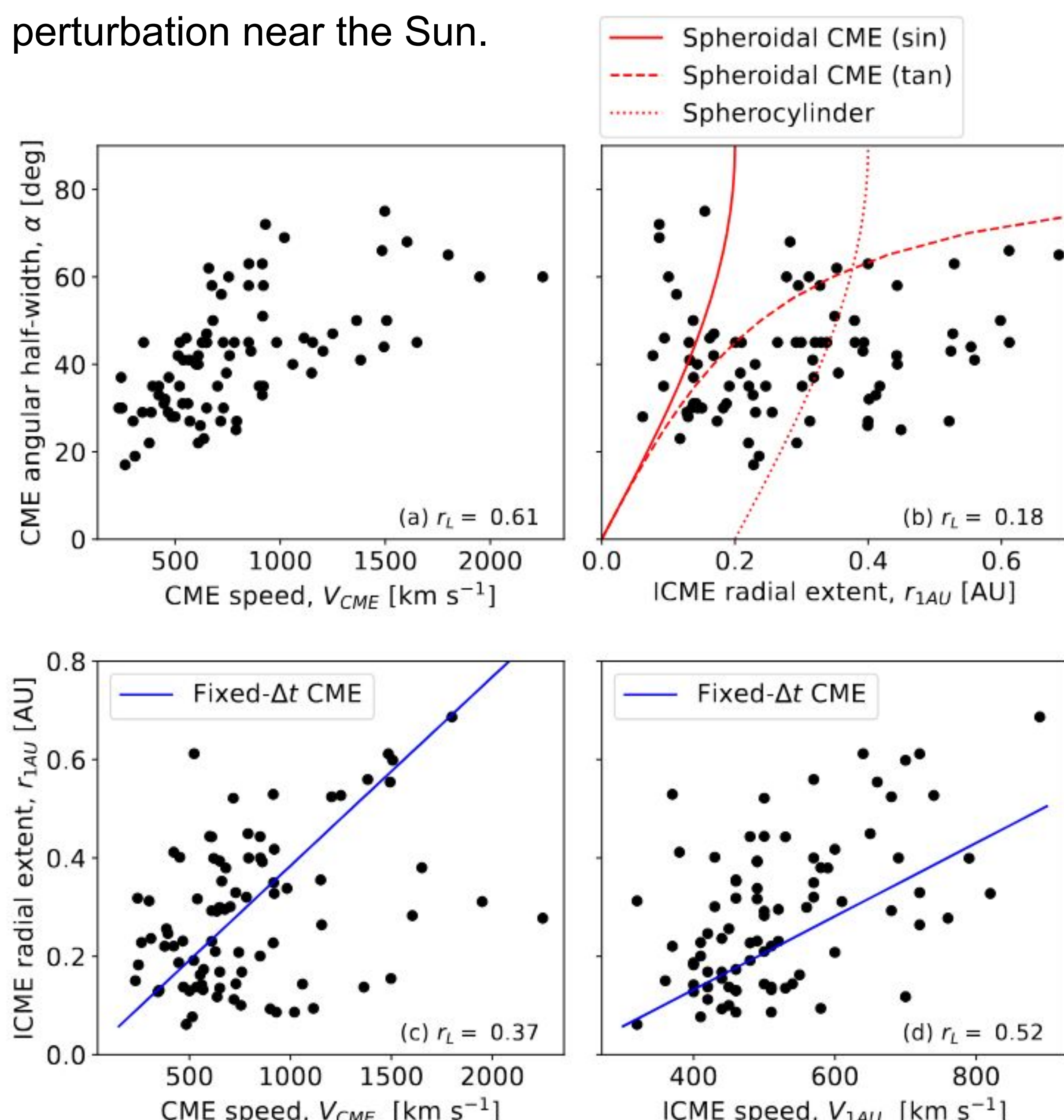
CMEs in solar-wind models

For space-weather forecasting, the speed, direction and size of a cone-model CME is used to characterise a speed and/or density at the inner boundary of a solar wind model. This is typically a spheroidal perturbation. The duration of a spheroidal perturbation at the inner boundary is a function its angular width and speed:



CMEs in reality

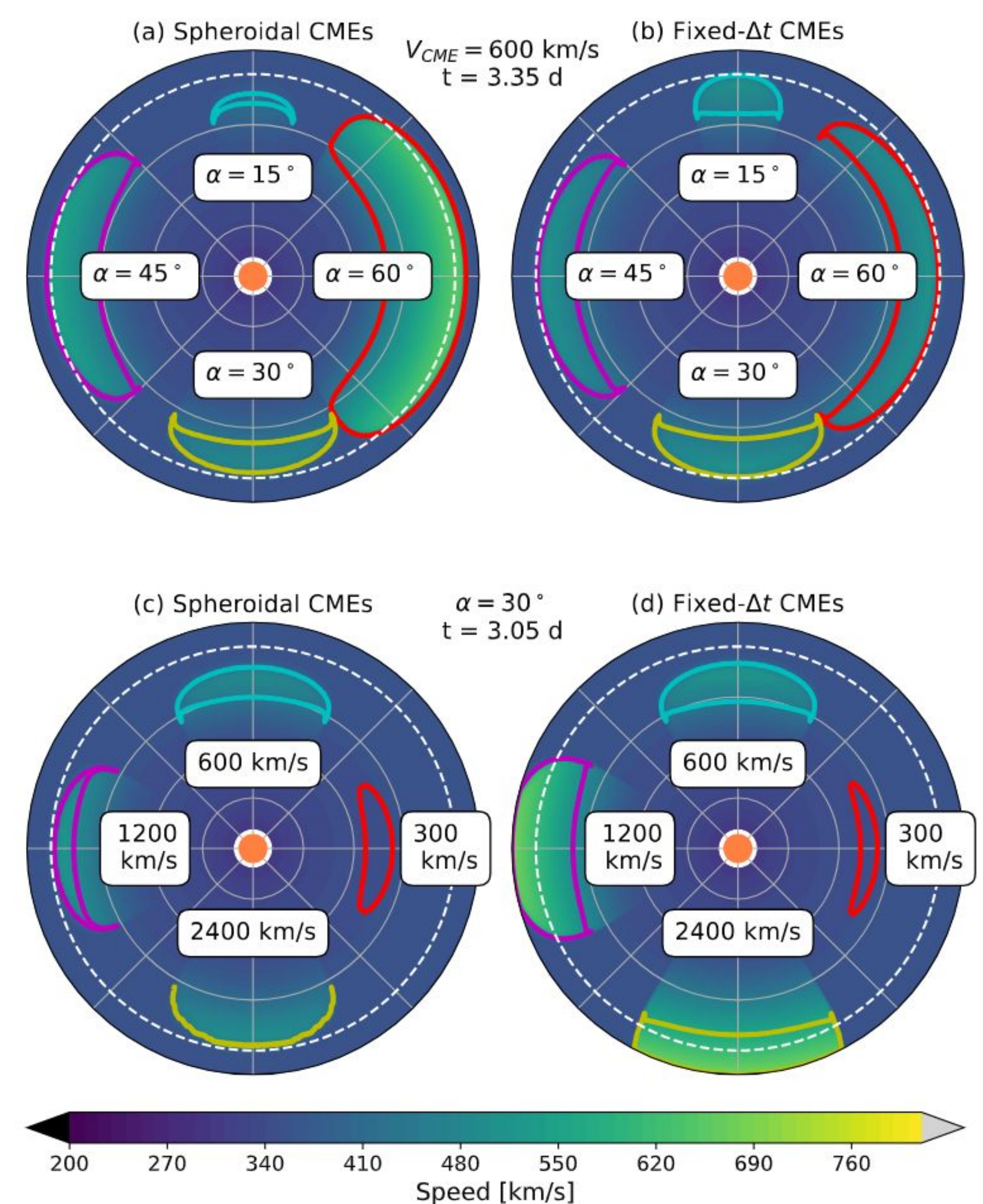
Observations of CMEs do not show evidence of any relation between CME duration and speed or angular width. Observations suggest faster CMEs expand more. This implies a fixed duration for a perturbation near the Sun.



The observed relations between different CME properties near the Sun and the resulting ICME properties near the Earth,

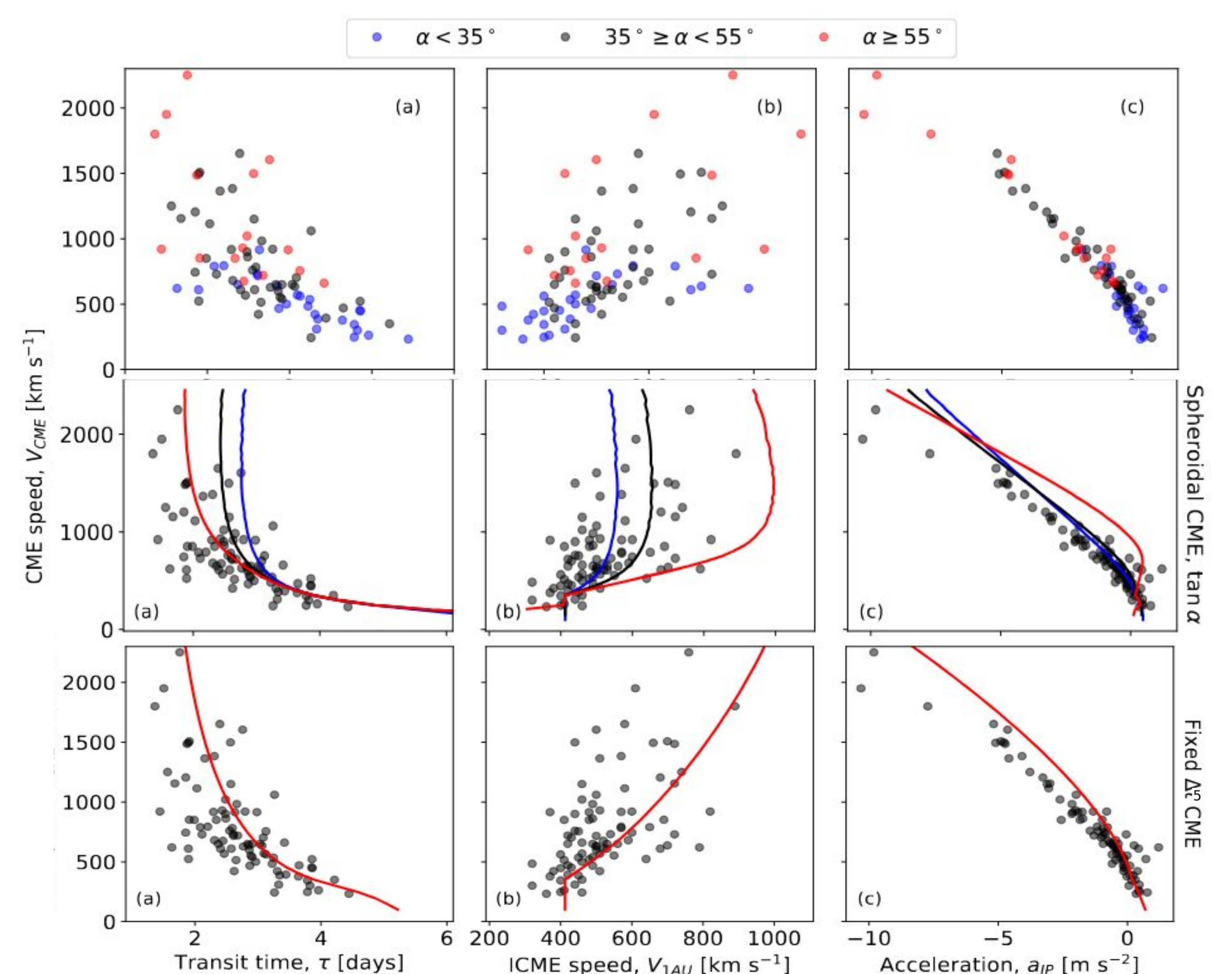
Effect on transit times

Spheroidal CMEs have increased “mass” with increased angular width, and reduced “mass” with increased speed. Thus wide spheroidal CMEs arrive earlier than narrow ones. And faster spheroidal CMEs decelerate faster, meaning transit time plateaus rapidly.



Simulation results for spheroidal and fixed-duration (expanding) CMEs

Observed and model transit times



Observed and model CME transit times, arrival speeds and acceleration as a function of initial CME speed. CME angular widths are shown as different colours

The bottom line

- Solar wind forecasting represents CMEs as spherical perturbations
- This implies the perturbation size increases with CME angular width and decreases with CME speed
- No such relations are observed
- Spherical CMEs result in shorter transit times and higher arrival speed with increased angular width. This is also not observed.
- Fixing the CME duration (meaning fast CMEs expand more) largely alleviates these issues