AstroFiT
Astrophysical Flow Instabilities and Turbulence

COMPARING INTERPLANETARY AND IN-SITU PROPERTIES OF CME DRIVEN SHOCKS

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CME DRIVEN SHOCKS

- High CME speeds in the corona suggest that shocks can be driven at those locations
- Indirect indication of shock existence are present in radio type II burst, deflected streamers, and SEP events
- *Hildner (1975)* and *Dulk (1976)* identified "forerunners " in coronagraph images - ambiguous
- First direct detection of CME-driven shock in LASCO images (*Vourlidas, 2003*) confirmed by MHD simulations

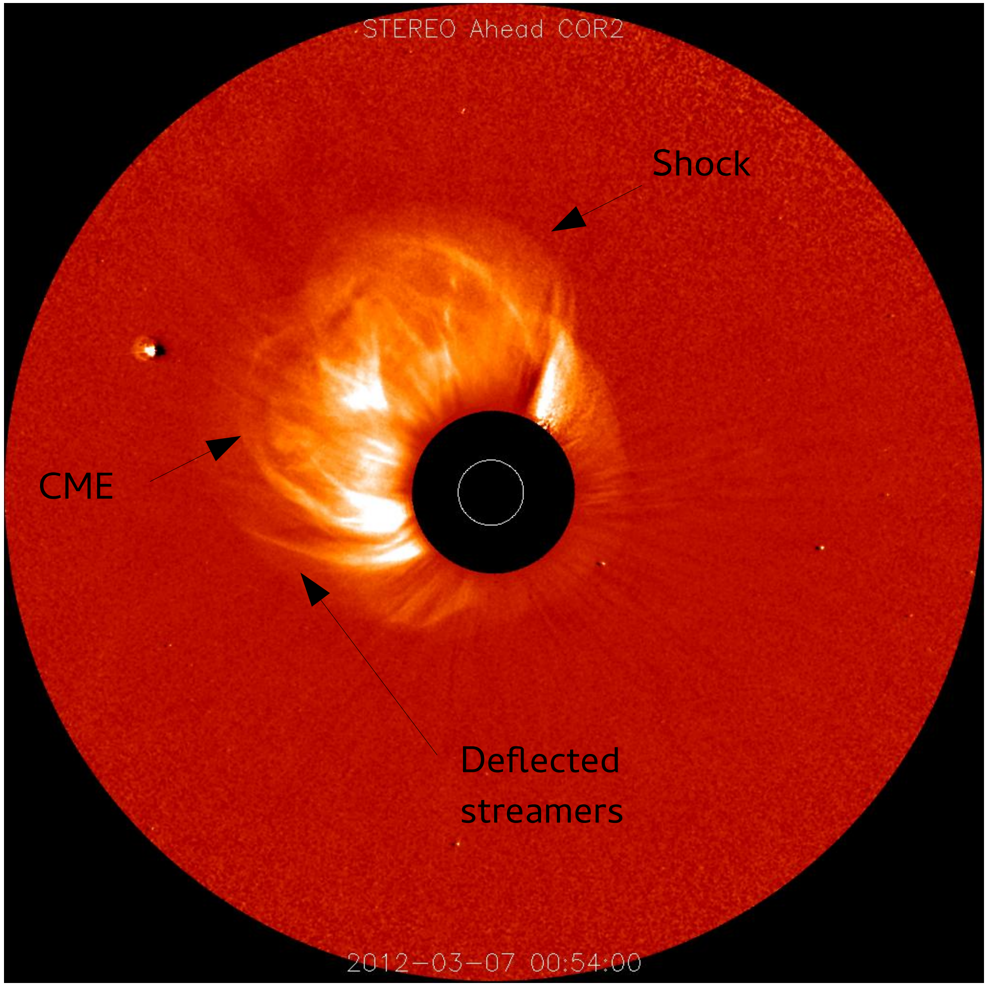


Image credit :NASA

Detectability of CME driven shocks in white light images depends on the ratio between density compression and background corona (*Vourlidas,2006*)

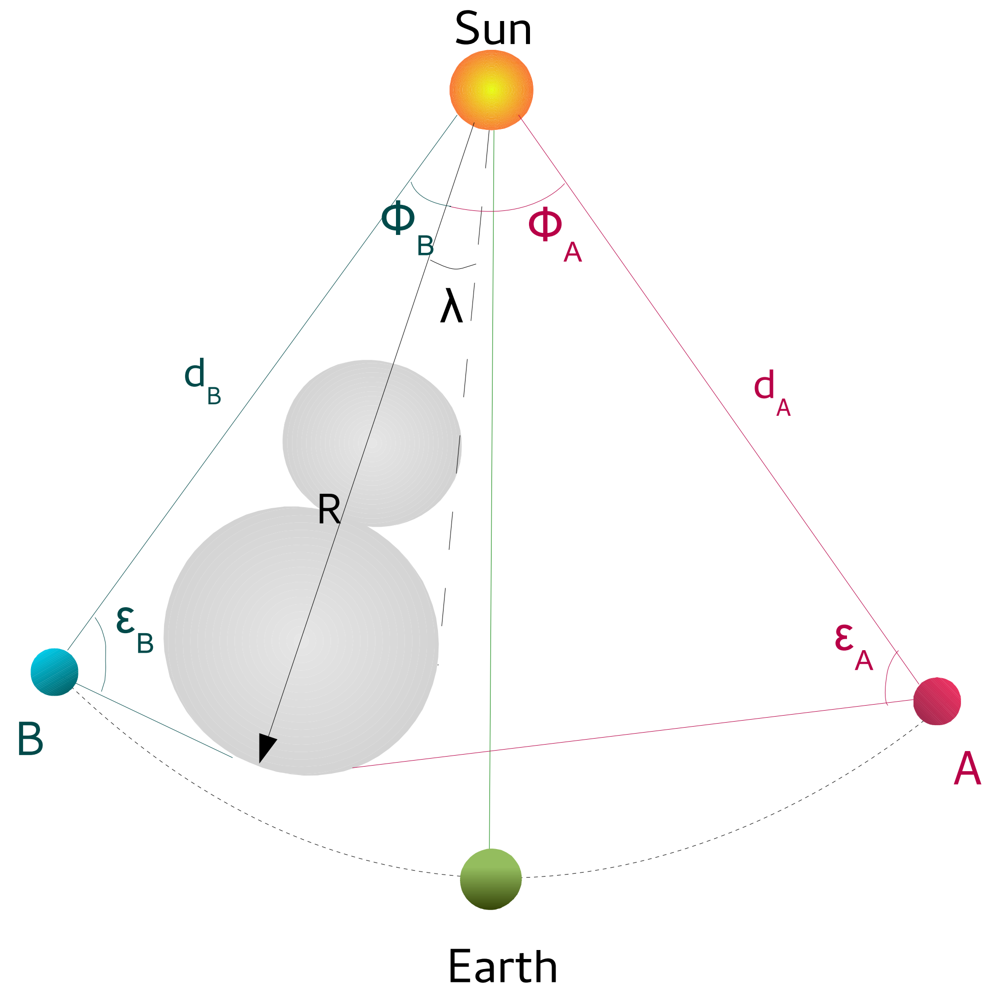
GOALS

- Study the interplanetary evolution of fast CMEs
- Determine the CME-driven shock properties from analysis of remote sensing observations
- Compare to in-situ measurements
- Compare to simulations (Prof. J. Buechner, Dr. J. Skala)

THE STEREOSCOPIC SELF SIMILAR EXPANSION MODEL

- A geometrical model for the CME is required to convert the measured elongation angles in radial distances (Sheeley, 1999)
- Davies et al (2012): CME as circular front expanding self similarly (i.e. with constant angular half width)
- Davies et al (2013): extend the model to stereoscopic observations of CMEs. For each spacecraft i, at fixed time:

$$R_{SSSEM} = d_i \frac{\sin(\epsilon_i)(1+\sin(\lambda))}{\sin(\lambda)+\sin(\epsilon_i+\Phi_i)}$$



- With λ as a parameter we have two equations in the unknowns R and Φ_i.

→ We can determine distance and direction of a CME at all times!

ON THE SHOCK LOCATION – MODELS

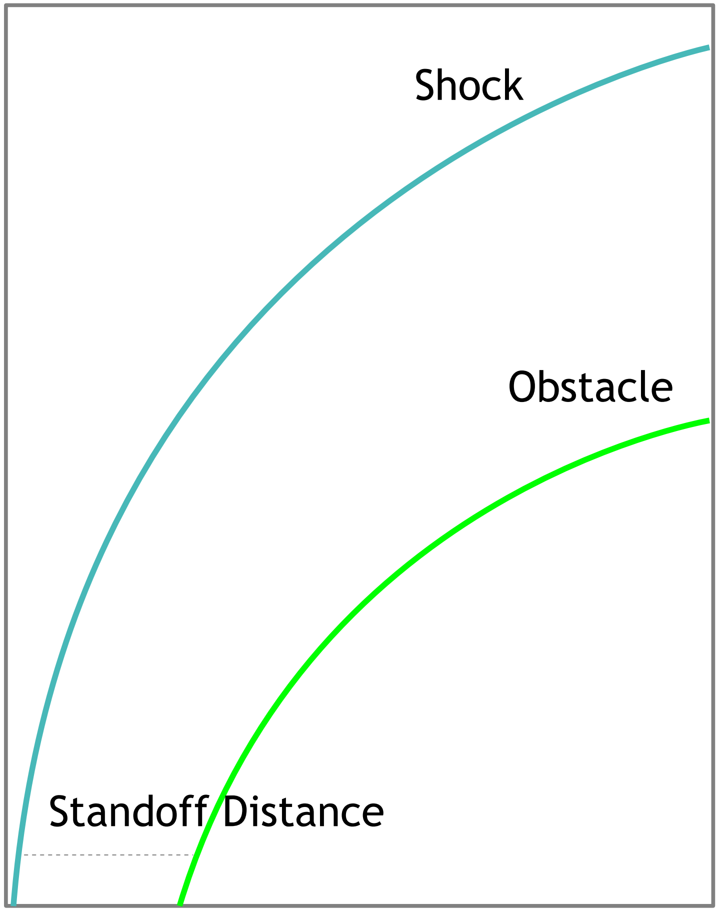
- *Farris and Russel (1994)* adapt the relation between normalized standoff distance and compression developed by *Seiff (1962)* and *Spreiter et al (1966)* to work in the low M regime, and for application to CMEs

$$\frac{\Delta}{R_C} = 0.81 \frac{\rho_u}{\rho_d}$$

- From HD relations the compression ratio can be expressed as a function of the Mach Number, so that

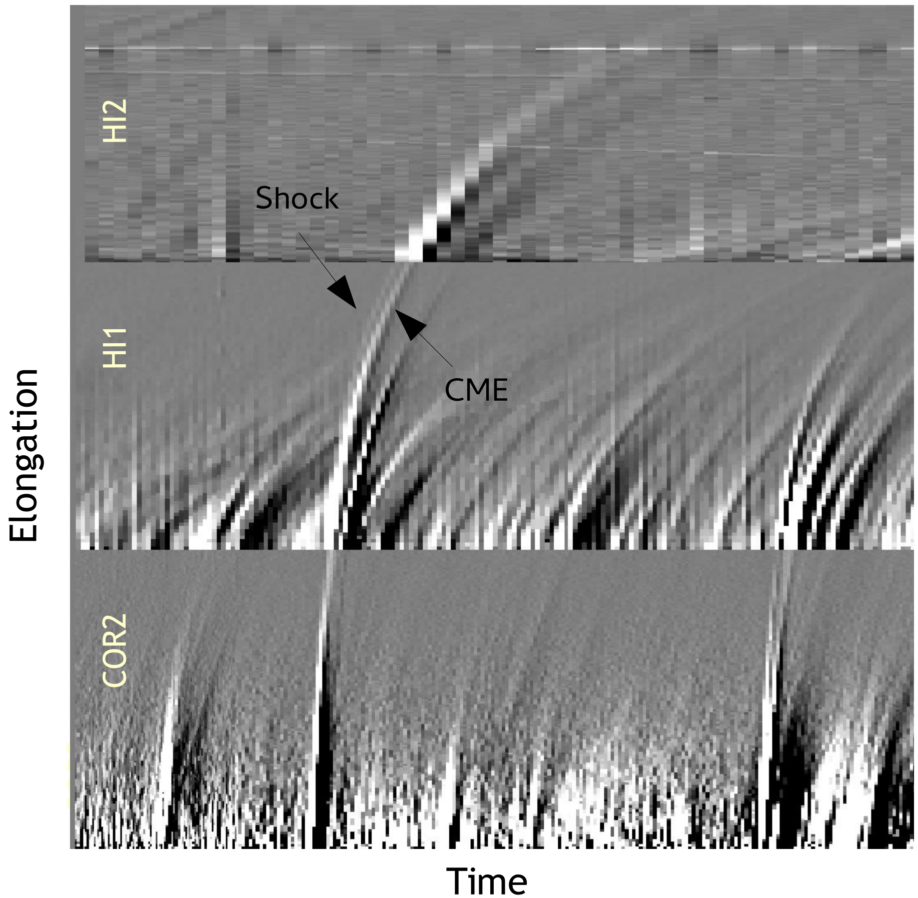
$$\frac{\Delta}{R_C} = 0.81 \frac{(\gamma - 1) M^2 + 2}{(\gamma + 1)(M^2 - 1)}$$

- The above relation is valid in the high M_A regime, with $M \rightarrow M_A$ the sonic Mach Number . In the low M_A regime it provides a good first approximation for $M \rightarrow M_A$ (*Fairfield et al., 2001*)



ON THE SHOCK LOCATION – APPLICATIONS

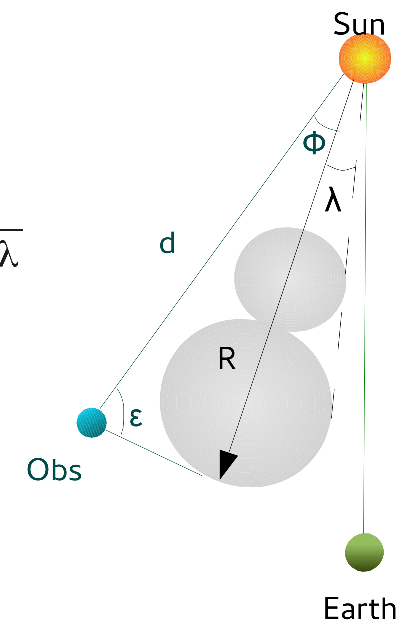
- We apply the SSSEM to 5 fast, Earth directed (4) events for which CME and shock are distinguishable in remote sensing observations and j-maps (for both STEREO A and B)



- Time elongation profiles of the CME and the shock yield the time evolution of the standoff distance

- The radius of curvature of the CME is derived from the model as

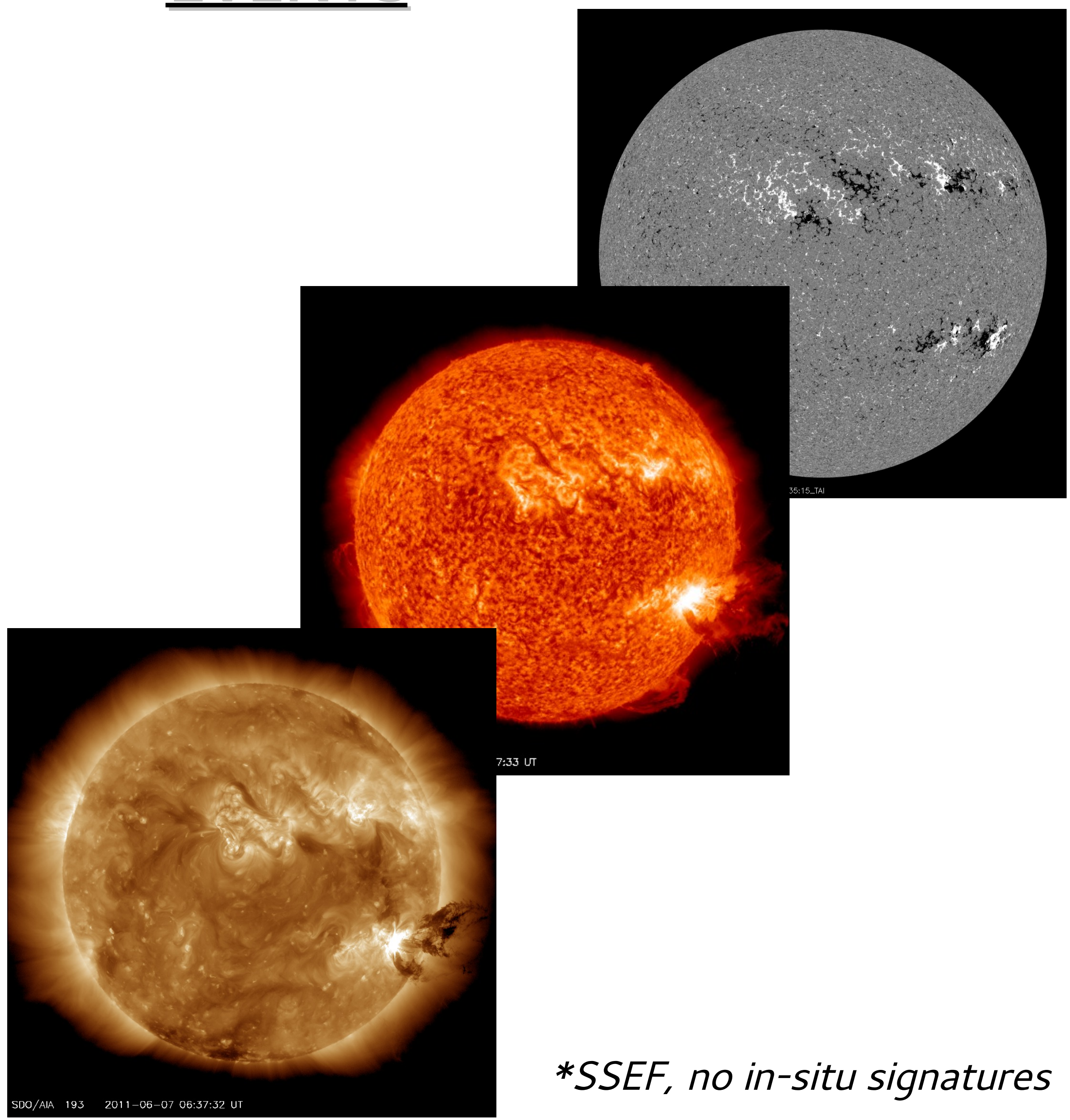
$$R_C = R_{SSSEM} \frac{\sin\lambda}{1+\sin\lambda}$$



- It is possible to derive the time profile of the Mach number and the compression ratio during the CME evolution towards Earth. Extrapolation at L1 and comparison to in-situ

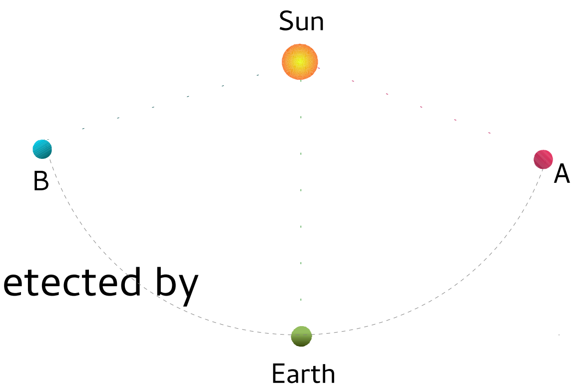
EVENTS

- 2010-Apr-03
- 2011- Jun-06*
- 2011-Aug-03
- 2012-Jul-12
- 2013-Mar-15

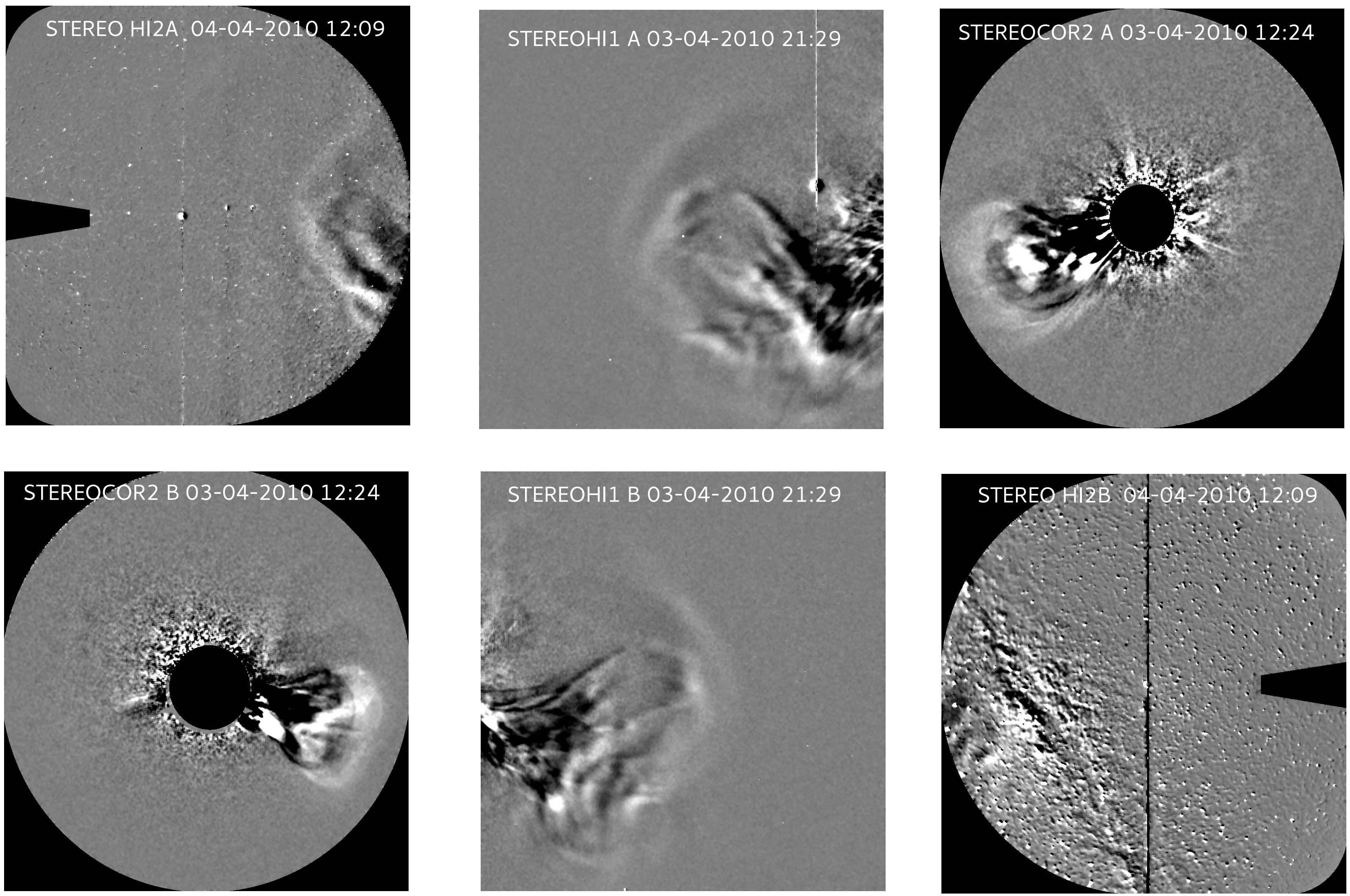


SSEF, no in-situ signatures

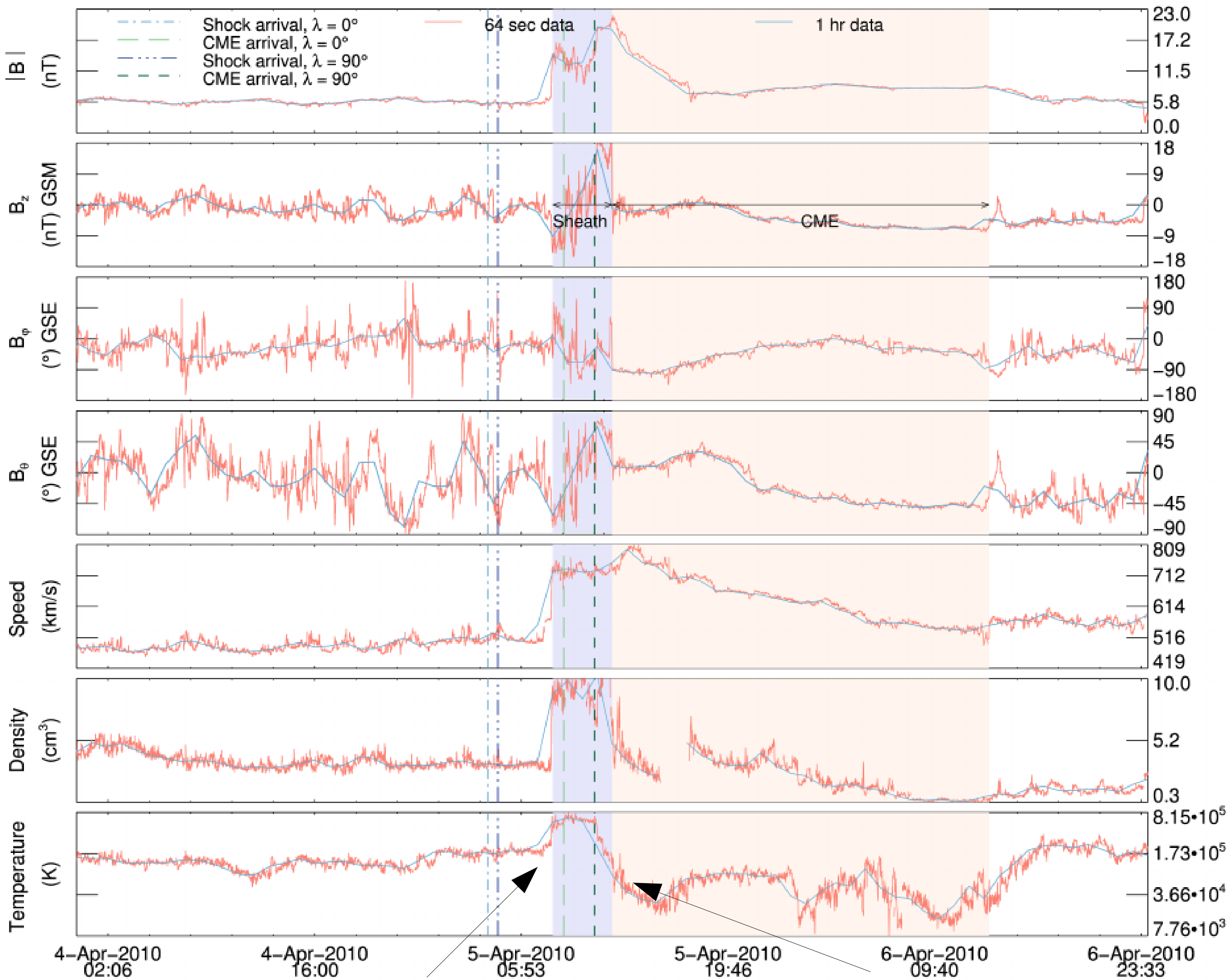
03 04 2010 CME



- Originated from NOAA AR11059 (S23W05) associated to a B7.4 flare detected by GOES at 09:04 UT



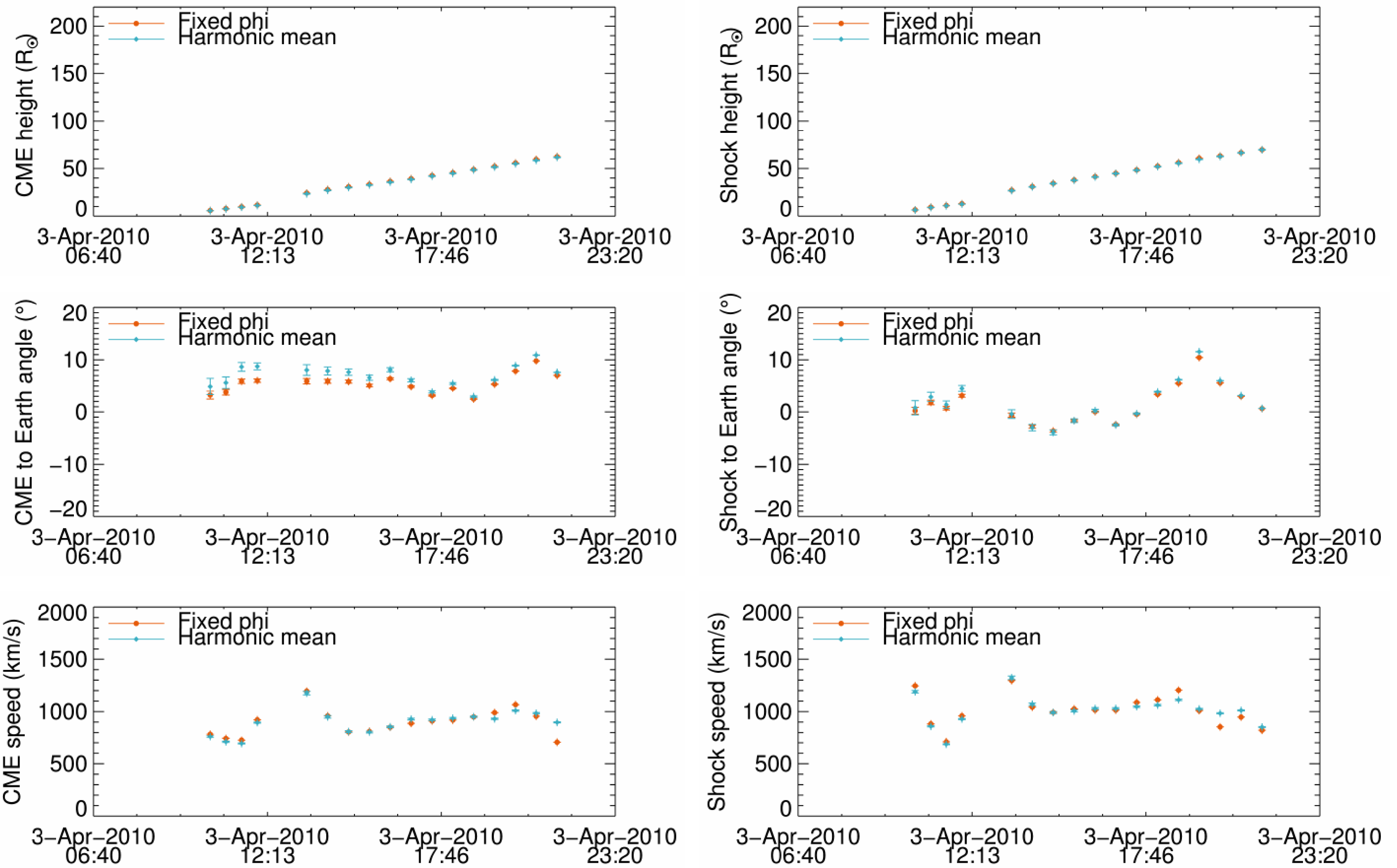
05 04 2010 IP SHOCK



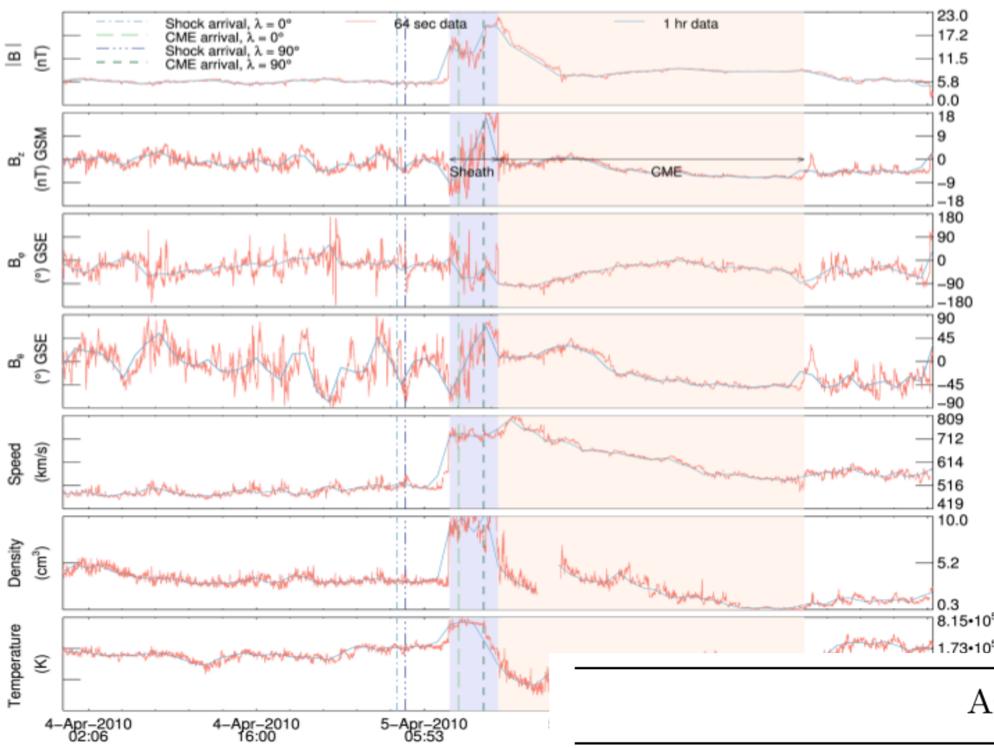
Shock
t_A ~08:00:00

CME
t_A ~12:00:00

CME AND SHOCK KINEMATICS



CME AND SHOCK ARRIVAL TIMES

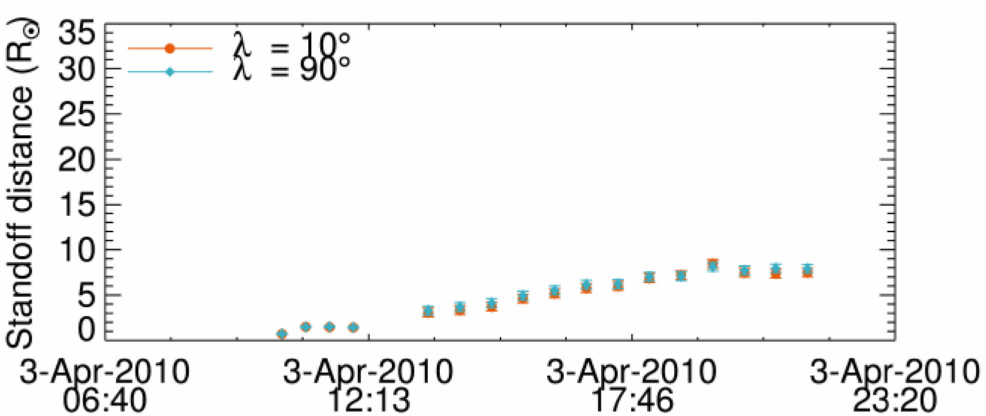


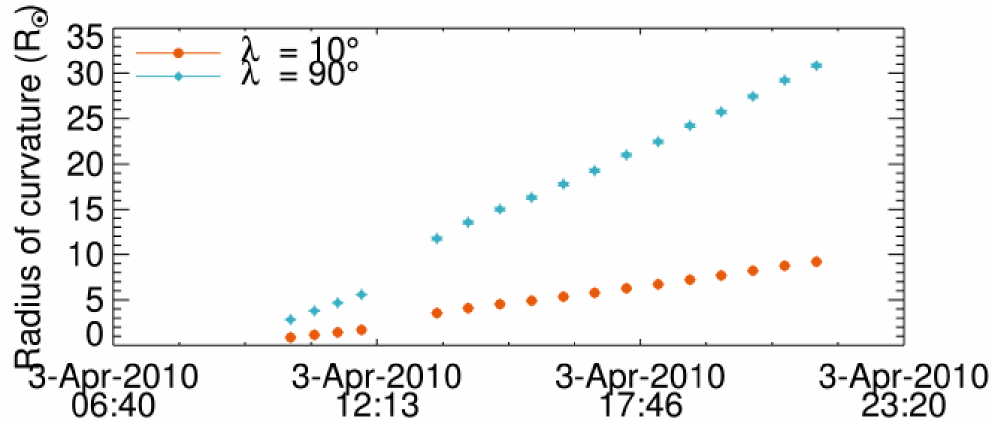
	ACE+EUVI	1st degree fit $\lambda = 0°$	1st degree fit $\lambda = 90°$
CME eruption time	*3-Apr-2010 09:04*	*3-Apr-2010 08:24*	*3-Apr-2010 08:32*
Shock arrival time	*5-Apr-2010 07:56*	*5-Apr-2010 00:26*	*5-Apr-2010 00:19*
Shock arrival speed	*750 km/s*	*1025 km/s*	*1033 km/s*
CME arrival time	*3-Apr-2010 12:24*	*5-Apr-2010 05:24*	*5-Apr-2010 06:05*

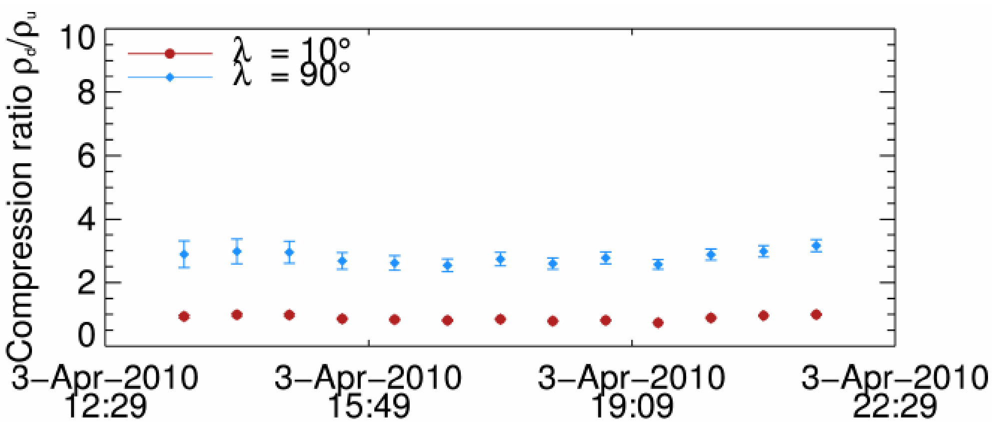
	ACE+EUVI	2nd degree fit $\lambda = 0°$	2nd degree fit $\lambda = 90°$
CME eruption time	*3-Apr-2010 09:04*	*3-Apr-2010 08:27*	*3-Apr-2010 08:12*
Shock arrival time	*5-Apr-2010 07:56*	*5-Apr-2010 03:38*	*5-Apr-2010 04:19*
Shock arrival speed	*750 km/s*	*867 km/s*	*851 km/s*
CME arrival time	*3-Apr-2010 12:24*	*5-Apr-2010 08:44*	*5-Apr-2010 10:48*

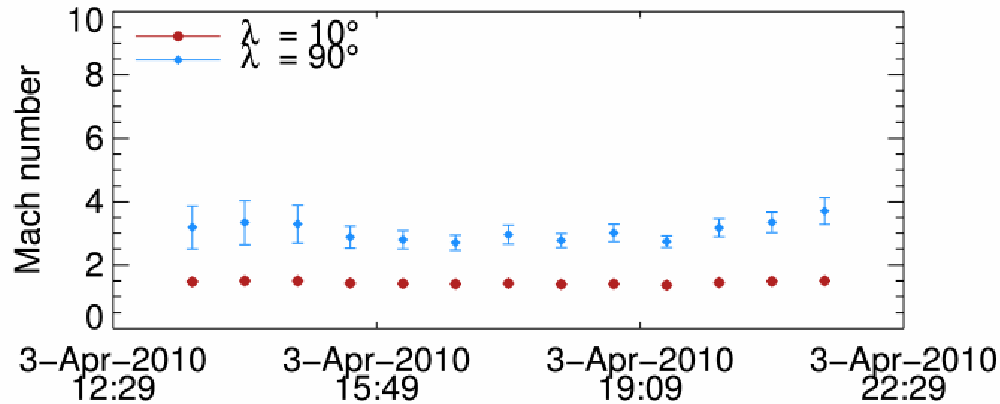
SHOCK PARAMETERS

$$R_C = R_{SSSEM} \frac{\sin\lambda}{1+\sin\lambda}$$





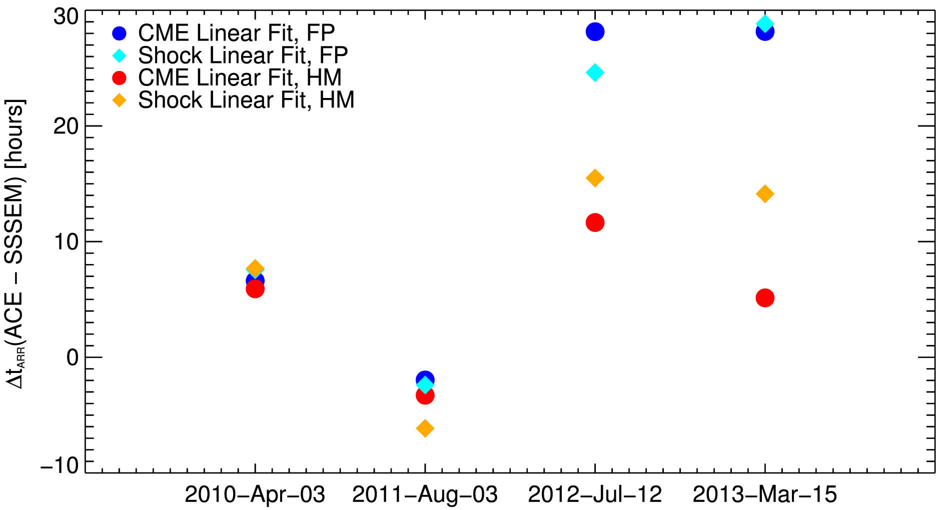


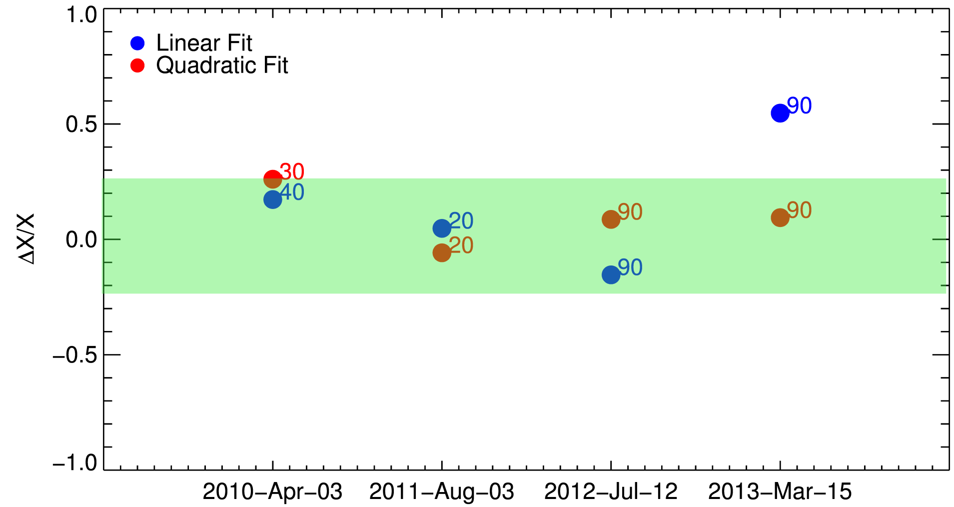


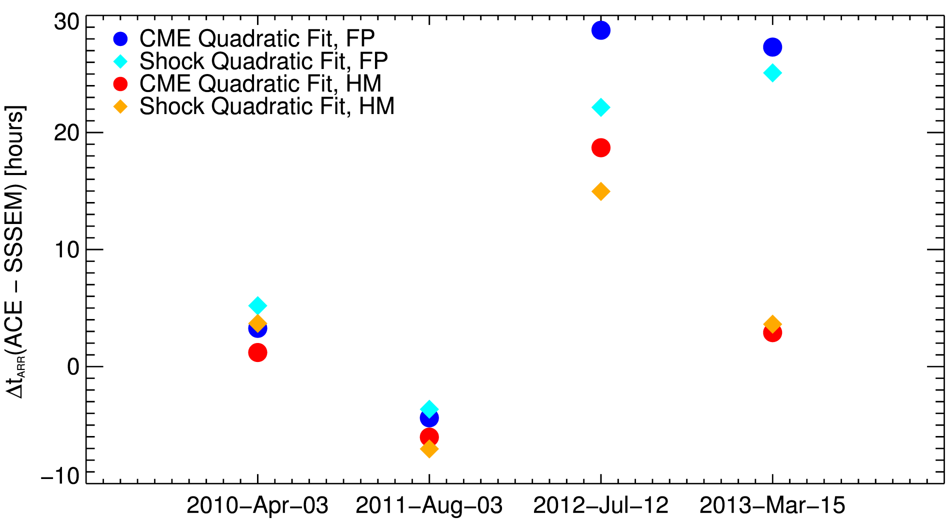
$$\frac{\Delta}{R_C} = 0.81 \frac{\rho_u}{\rho_d}$$

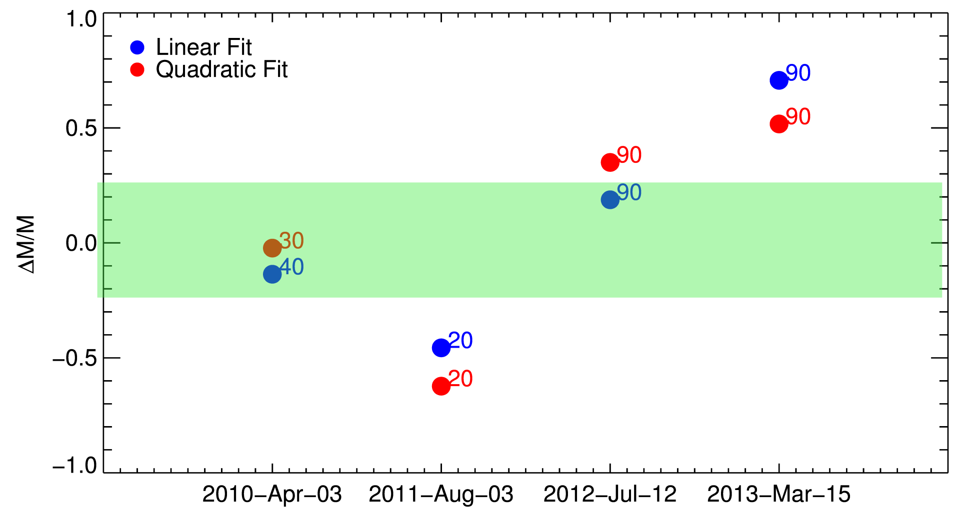
$$\frac{\Delta}{R_C} = 0.81 \frac{(\gamma-1)M^2+2}{(\gamma+1)(M^2-1)}$$

IN–SITU EXTRAPOLATION









CONCLUSIONS

- We presented the analysis of the observations of a fast CME and its associated shock:
  - Time series of white light images allowed to determine the CME and the shock kinematics and arrival times.
  - The shock compression ratio and Mach Number are obtained in the HI1 field of view.
  - Extrapolation of the shock parameters to 1 AU and comparison with in-situ
- Future work:
  - Include GCS modeling to improve the accuracy in the determination of shock parameters
  - Comparison with numerical simulations of CME initiation (prof J. Buechner, Dr. J. Skala)