CME propagation: where does aerodynamic drag "take over"?

Prasad Subramanian

Indian Institute of Science Education and Research (IISER), Pune, India

Collaborators

- Nishtha Sachdeva (PhD student, IISER Pune)
- Robin Colannino (Naval Research Lab, Washington, DC)
- Angelos Vourlidas (Applied Physics Lab/Johns Hopkins U)
- Volker Bothmer (U Goettingen)

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- The broad consensus is:
  - Driving - some sort of Lorentz ($\mathbf{J} \times \mathbf{B}$) force,
  - Drag - aerodynamic drag, due to “friction” of the CME with the surrounding solar wind
- The balance between driving and drag determines the CME trajectory, and important takeaways such as Earth arrival time, speed, etc.

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- i.e., For the most part, fast CMEs are only dragged down by the ambient solar wind - no driving
- Nicely confirmed using physical drag presciption (not ad-hoc constant $C_{\rm D}$!) - Subramanian, Lara & Borgazzi 2012 GRL

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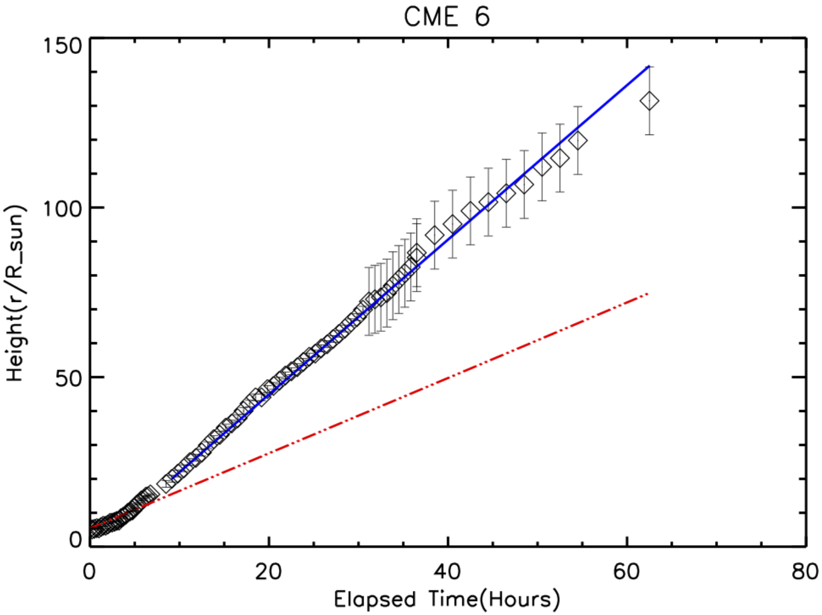
- ..when initiated from the first timestamp (as is usually done)

Drag only model fails when initiated from start



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No.	CME date	v_0(km/s)	$\widetilde{h}_0(R_\odot)$
1	Mar 19-23,2010	162	21.9
2	Apr 03-05,2010	916	5.5
3	Apr 08-11,2010	468	19.7
4	Jun 16-20,2010	193	15.2
5	Sept 11-14,2010	444	27.7
6	Oct 26-31,2010	215	20.1
7	Feb 15-18,2011	832	39.7
8	Mar 25-29,2011	47	46.5

Sachdeva et al 2015 ApJ

(Self and external) Lorentz forces

$$\rho_m \frac{d^2 R}{dt^2} = \frac{I^2}{4\pi^2 b^2 R^2}(L + \mu_0 R/2) - \frac{I B_{ex}(R)}{\pi b^2}$$

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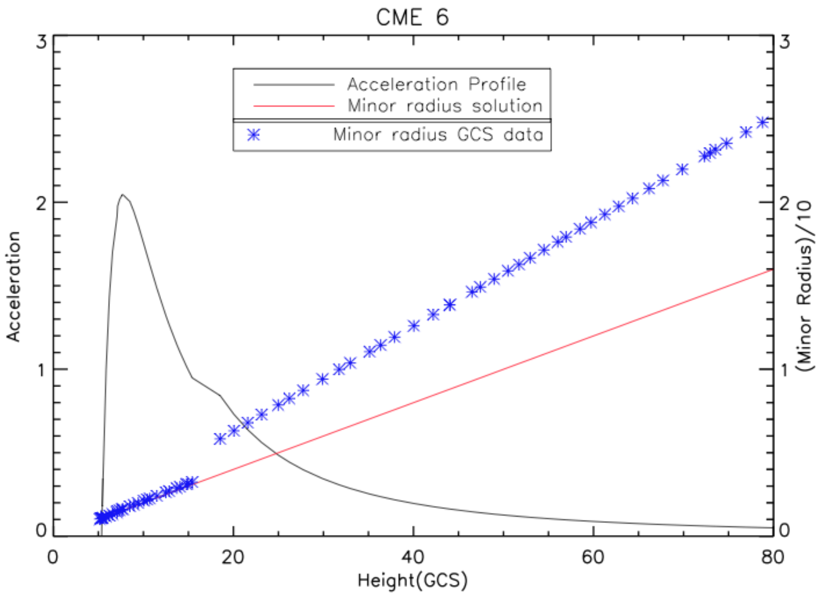
- Naturally predicts a peak in the Lorentz force; i.e., force dies down at large R


CME 6
Acceleration Profile
Minor radius solution
Minor radius GCS data
Acceleration
(Minor Radius)/10
Height(GCS)
0
1
2
3
0
20
40
60
80

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- ...so we are progressing towards a physically motivated understanding (not simply parametrization/fitting) of drag, as well as drive forces acting on CMEs
- Crucial for reliable time-of-arrival estimates
- Thank you for your attention!