Energetics of CMEs

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Subramanian, P., Vourlidas, A., 2007, to appear in A&A, astro-ph/0701160

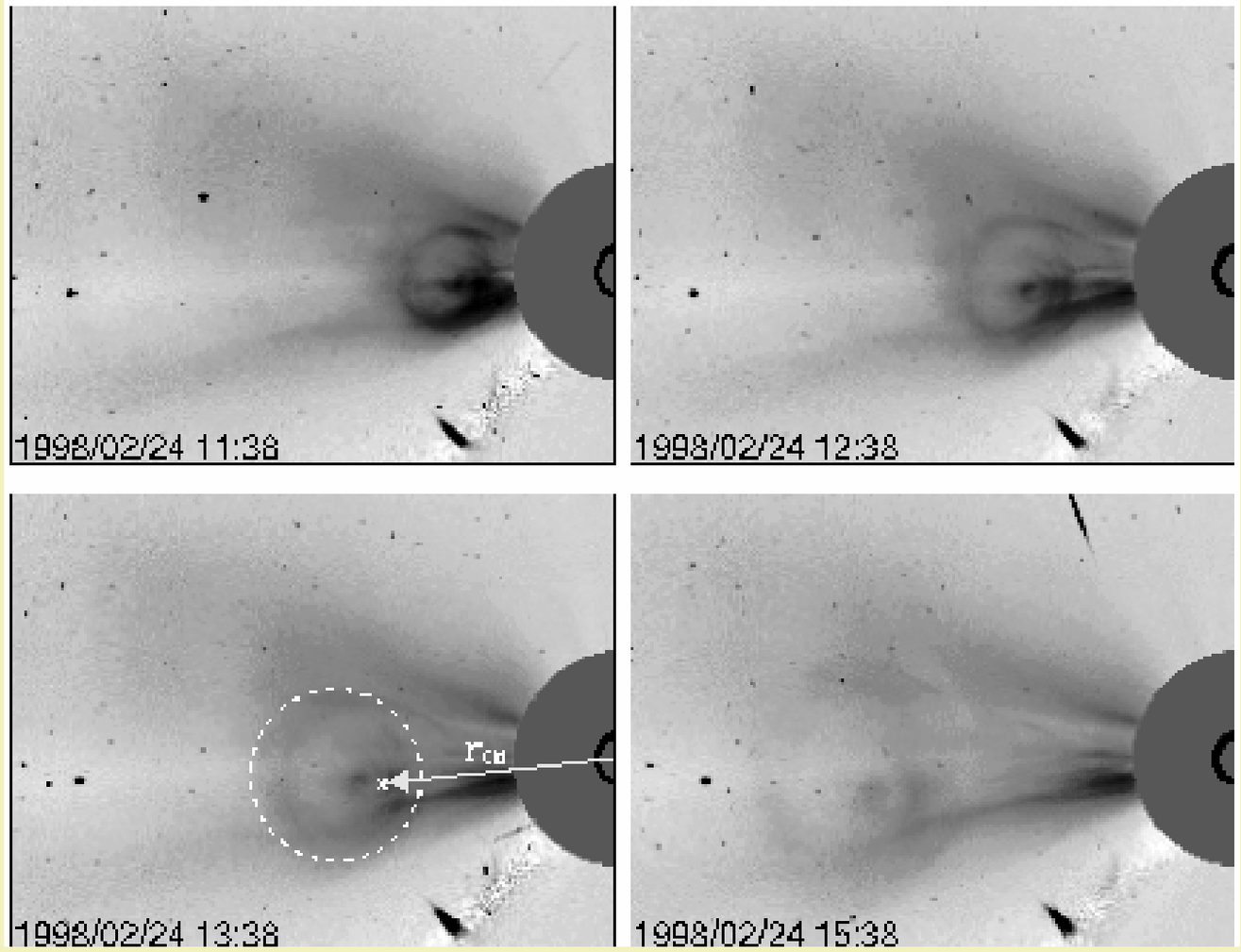
How are CMEs driven?

(distinction between initiation and "driving" $\sim$ 2–30 $R_\odot$)

- By coupling to ambient solar wind, (i.e., does the solar wind mostly "drag" them along)

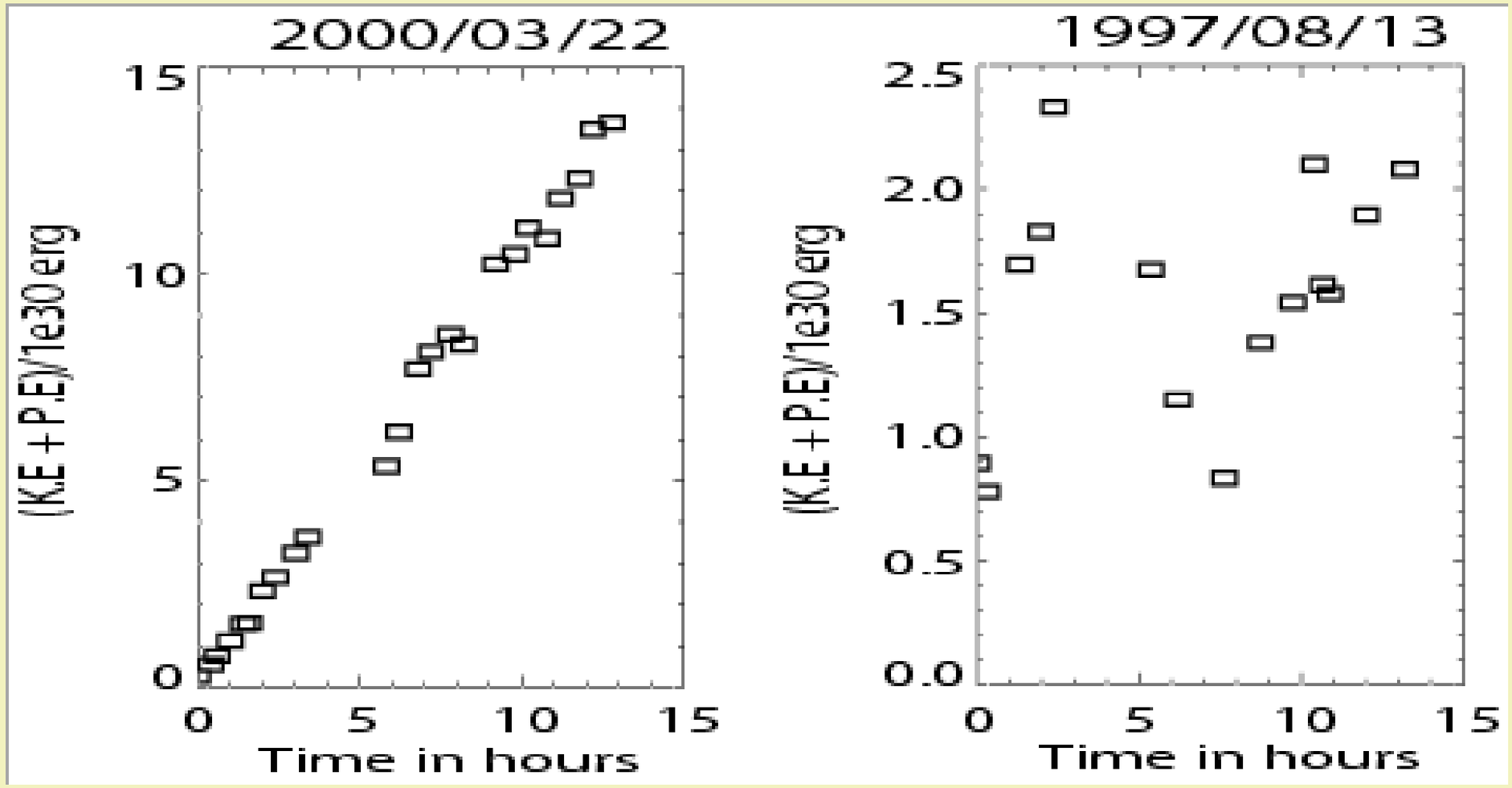
- or by release of magnetic energy associated with advected magnetic field?

Method



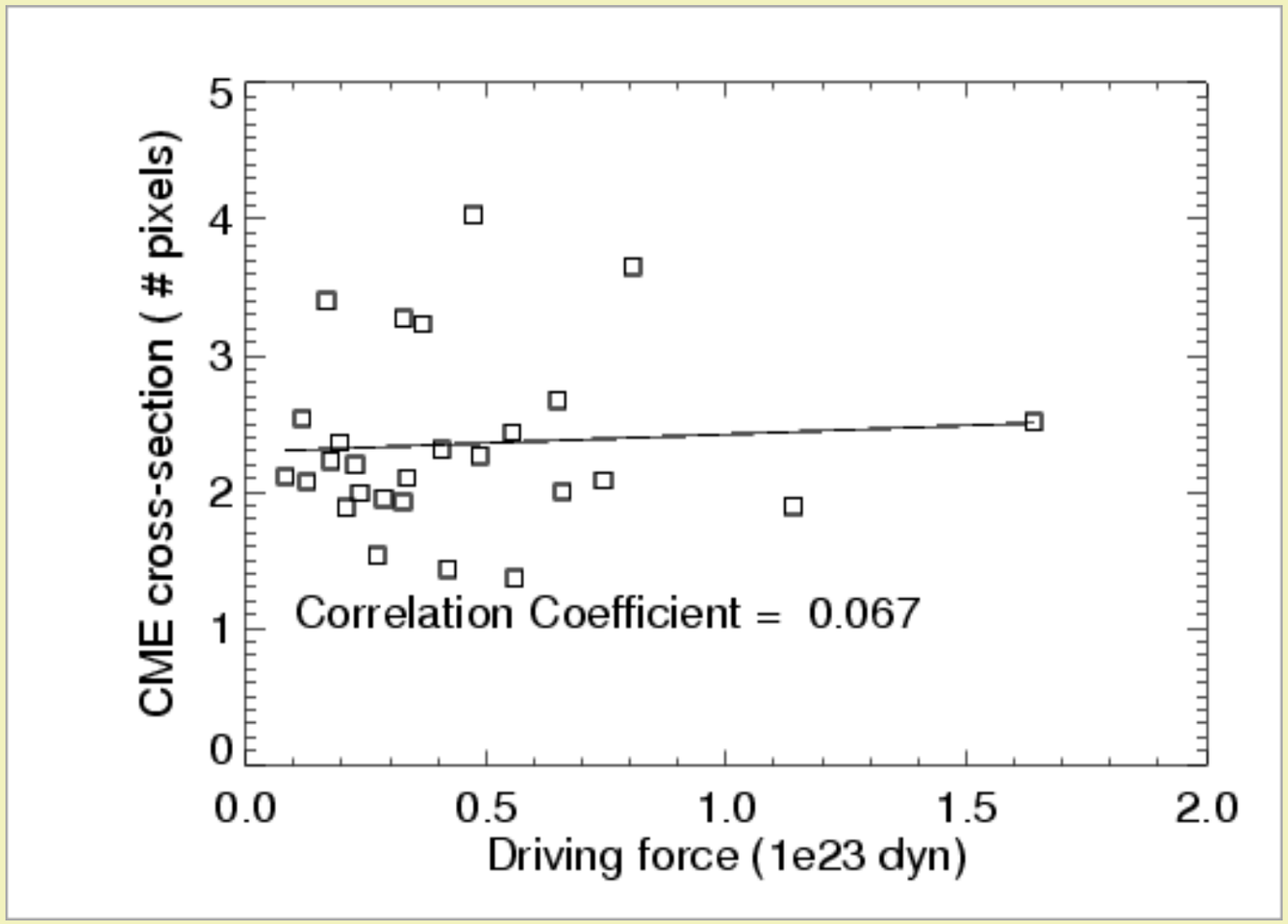
Examine energetics from mass images of 39 (best) flux-rope CMEs during 1996-2001.

"Driven" CMEs



Consider only the driven CMEs (69% of CMEs in sample).

Dragged along by solar wind?



At large Reynolds nos. “drag”/propelling force $\propto$ cross-sectional area.

Available magn energy: upper limit

Bastian et al. (2001): from obs of "radio CME": CME magnetic field 0.1–1 G. We use 0.1 G.

Available driving power

$$\widetilde{P_M} = \frac{d}{dt}\,\widetilde{E_M} = \frac{B^2}{8\,\pi}\,\frac{d}{dt}\,l\,A\,.$$

Compare w/ required driving power P_D?

$$\text{Average } \frac{\widetilde{P_M}}{P_D} \simeq 10 \pm 1$$

Available magn energy: lower limit

Assume flux to be frozen en route sun to earth. Estimate flux from near-earth magnetic clouds.

$$P_M = \frac{d}{dt}\, E_M = \frac{1}{8\,\pi}\, (\overline{B.A})^2\, \frac{d}{dt}\, \frac{l}{A}\,.$$

Compare with required driving power P_D:

$$\text{Average } \frac{P_M}{P_D} \simeq 0.74 \pm 1.3$$

Conclusions

• Not much evidence for solar wind "dragging" CMEs along; driving force not $\propto$ cross-sectional area.

• On the other hand, CME magnetic fields can provide 74% (lower limit) to 10 times (upper limit) the power required to drive them.

• Open question: how can magnetic energy be converted into (directed) kinetic energy? Easier to dissipate magnetic energy into heat via reconnection. Maybe $\vec{J} \times \vec{B}$ forces due to misaligned currents/fields.