The Genesis of an EUV Wave

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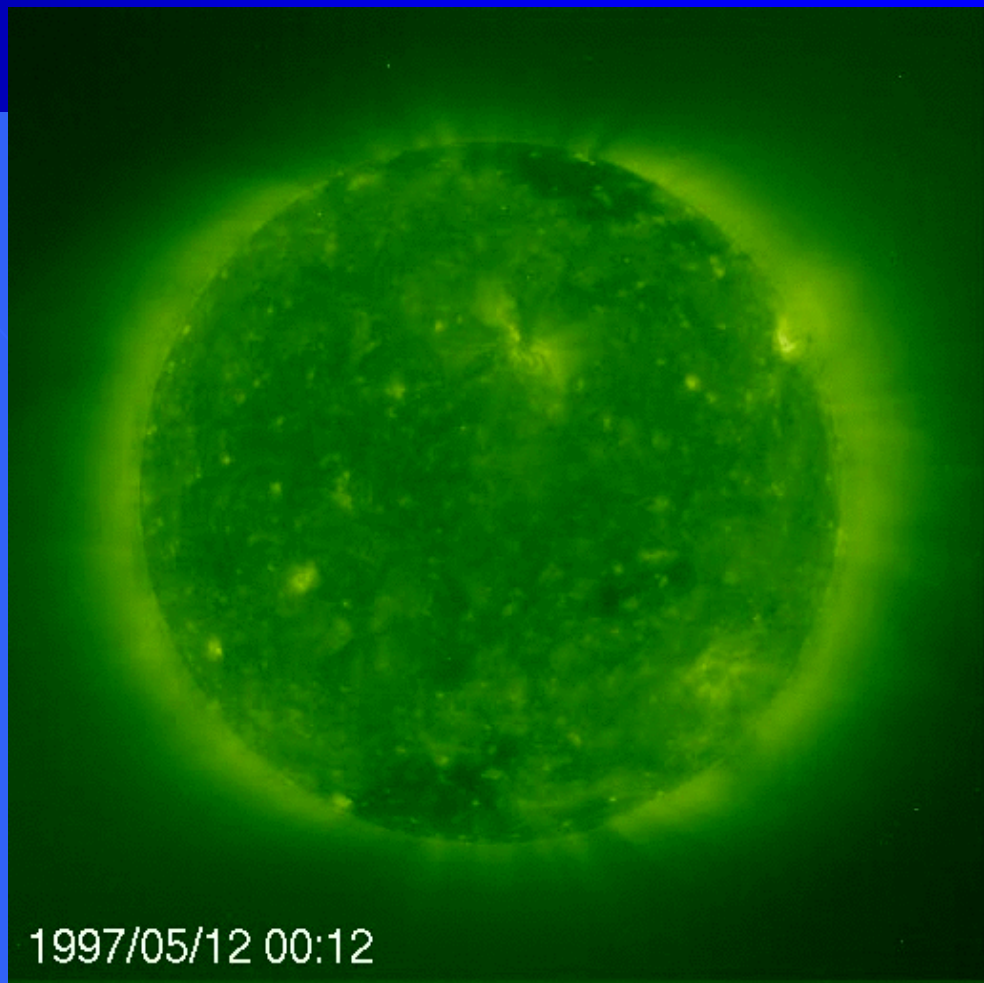
Overview & Rationalle

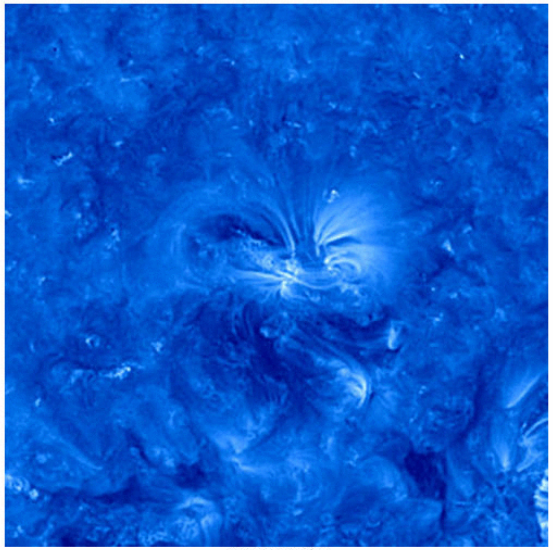
EUV waves (Moses et al. 1998;Thompson et al. 1999)
Propagating intensity fronts @ 200-300 km/s
Connection with CMEs (Biesecker et al 2002)

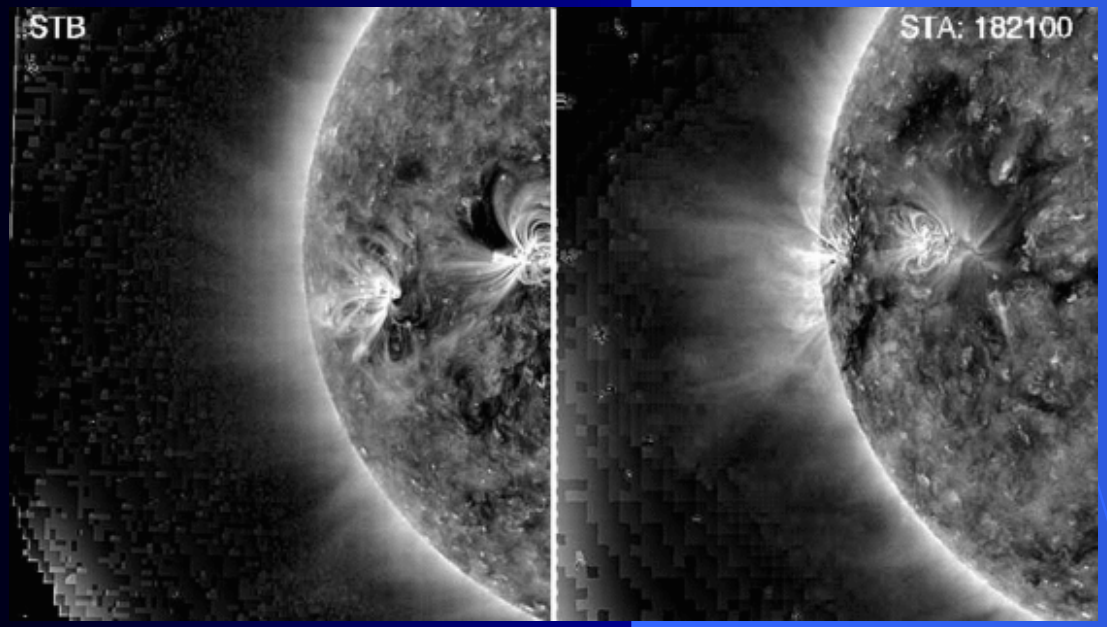
What drives these phenomena?



EUV Waves & early CMEs

Waves are first seen in the flanks of erupting cavities

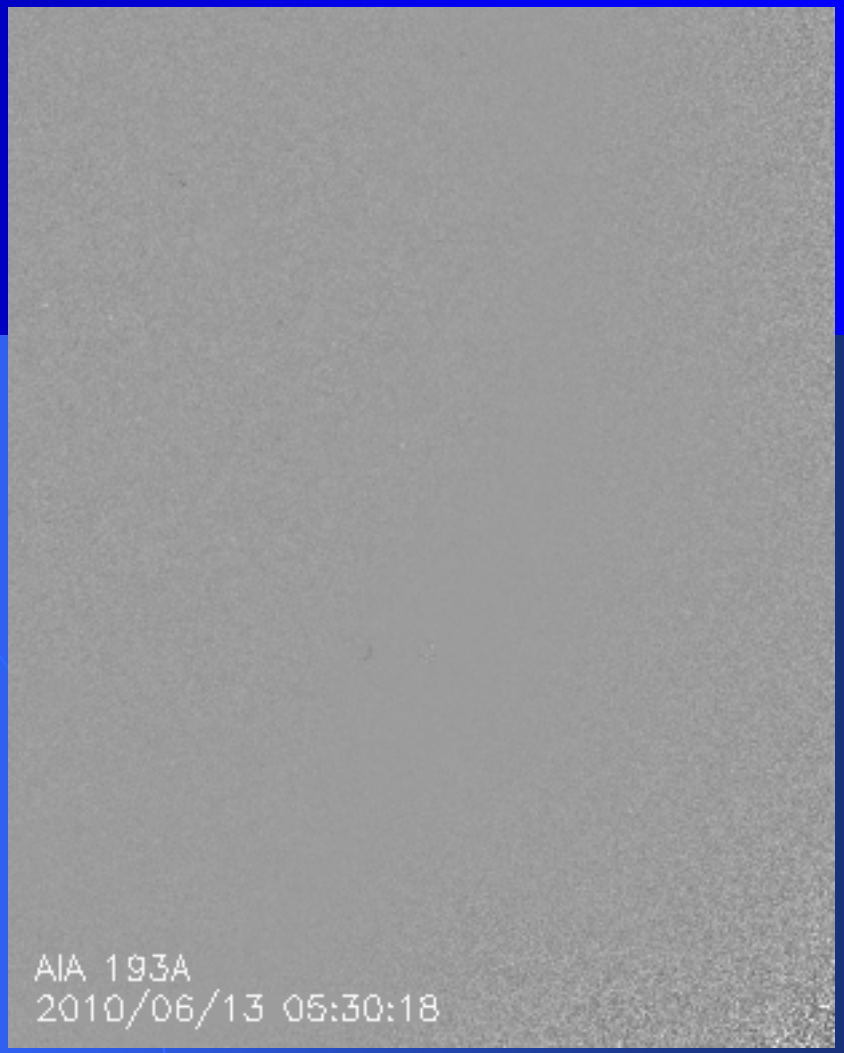




The Genesis of a CME-EUV Wave @ 12-s cadence

13-June-2010 ----- **separate driver & wave**

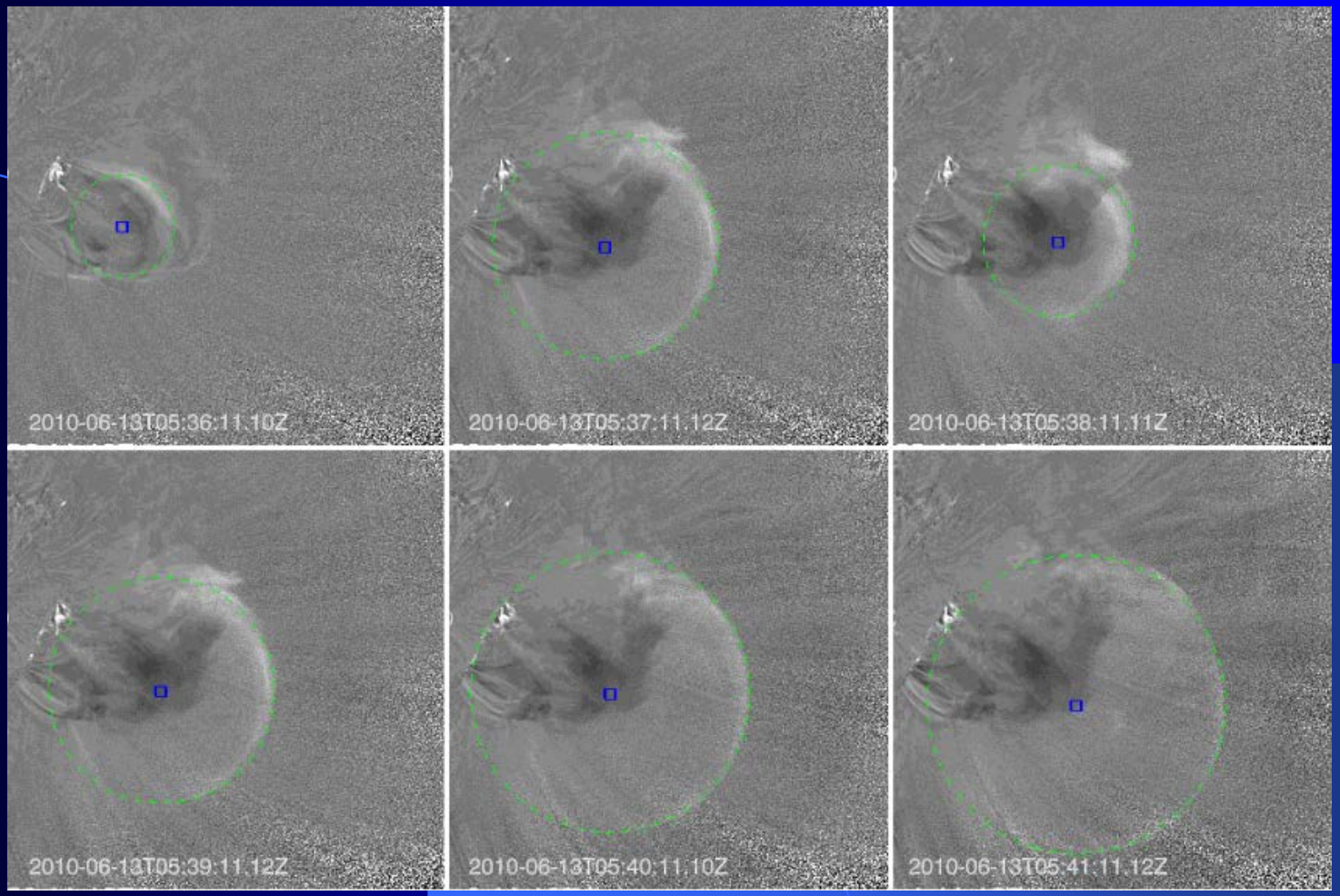
Base-ratio movie



Slow rise of loops→
Bubble formation →
Strong lateral expansion → wave

Without AIA we would have missed entire phases of the evolution!!!

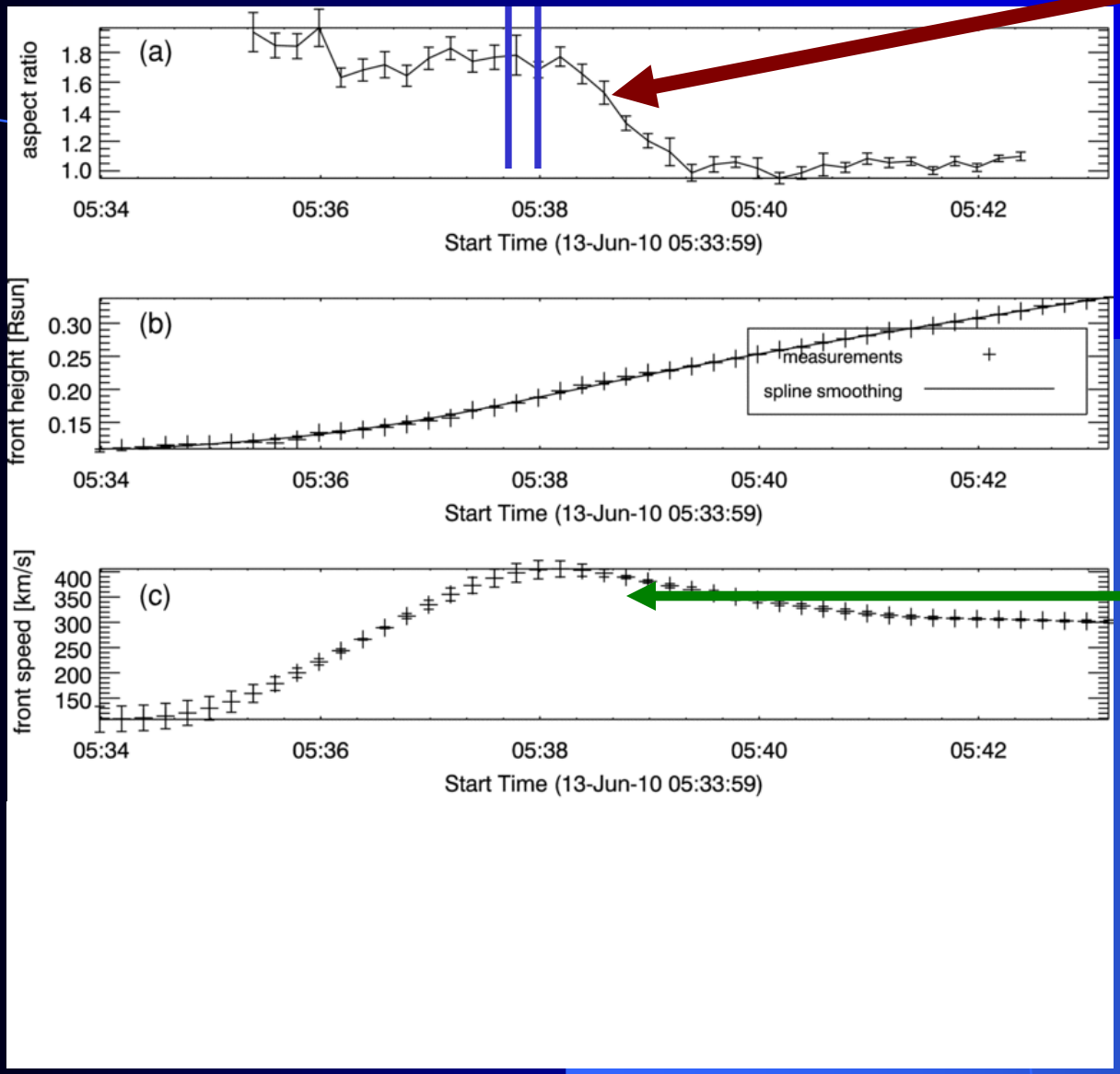
Cavity Measurements



Fit circles to the cavity → height & radius

Cavity Kinematics

EUV wave onset



Lateral over-expansion

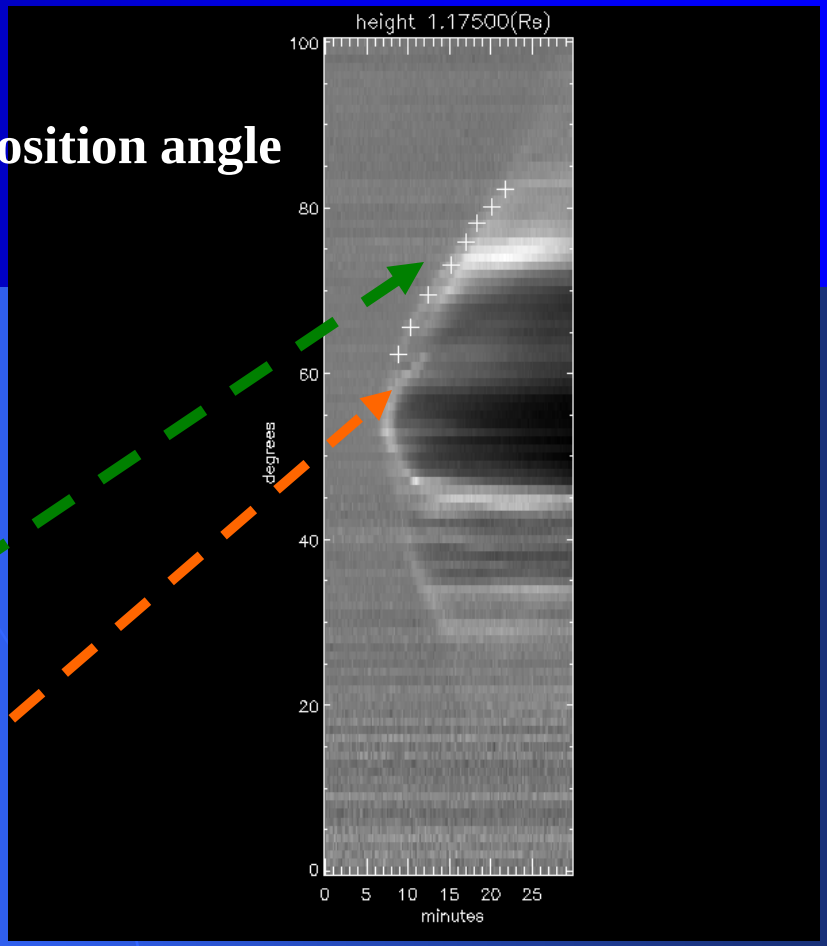
Aspect ratio=Height/radius

CME deceleration

Wave Kinematics @ 0.17 Rs

Map base-ratio
images into polar coordinates

Extract time-position angle plot
at r=0.17 Rs (~ height of EUV
waves from triangulations)



Position angle

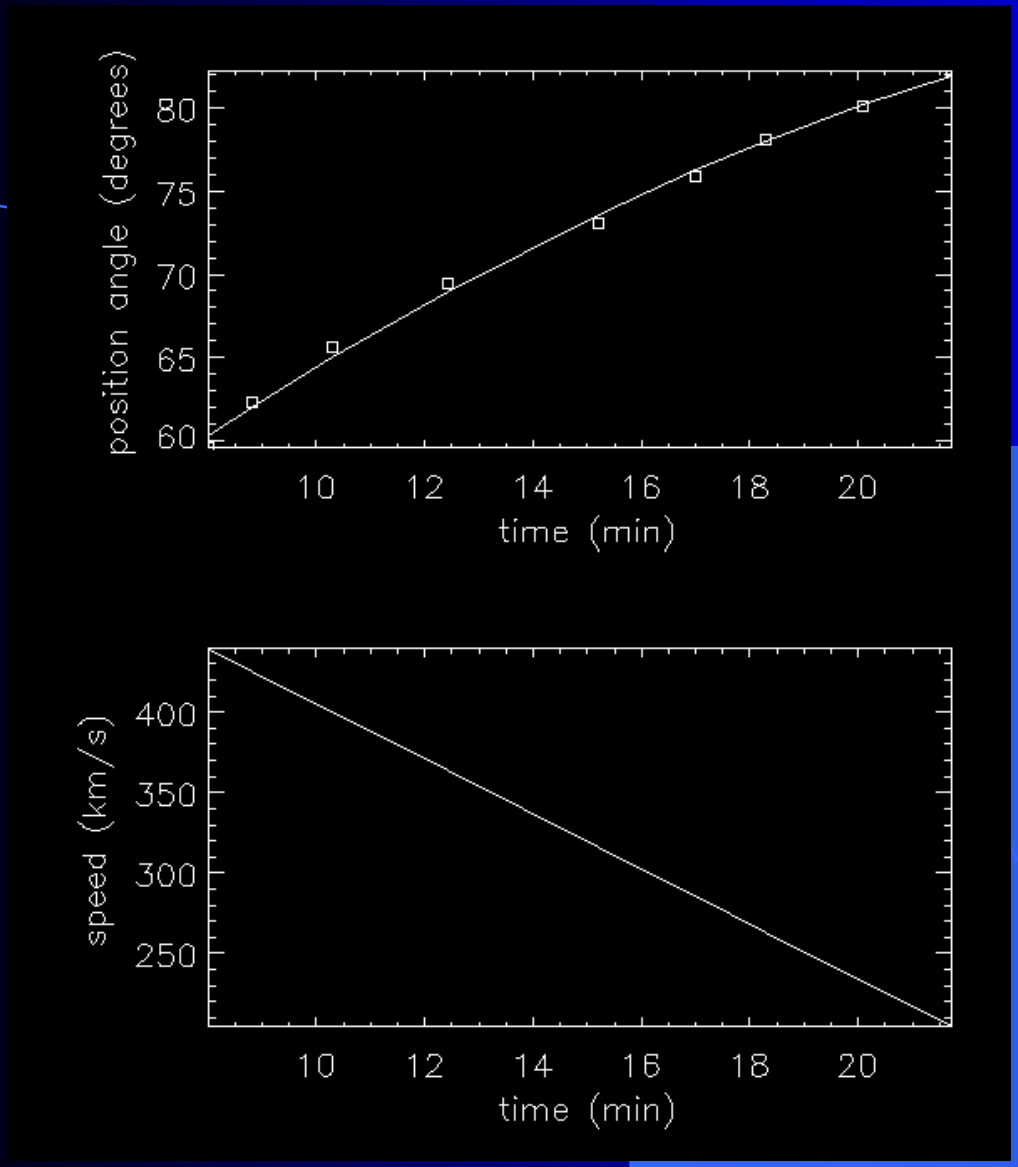
Select points along the wave

CME cavity

Wave detaches from CME cavity

time

Wave Kinematics



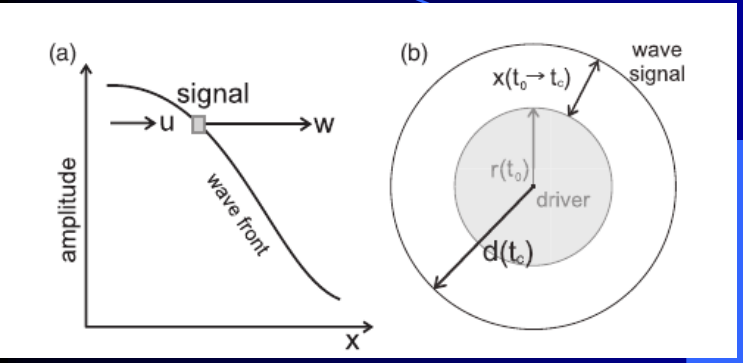
Fit a 2nd order polynomial to Time-PA measurements

Speed decreases from > 400 km/s to 200 km/s (~ fast-mode speed in quiet Sun)

driven wave (weak shock) becomes freely-propagating

A First-principles Model of Large-Scale Coronal Waves

(Temmer et al. 2009)



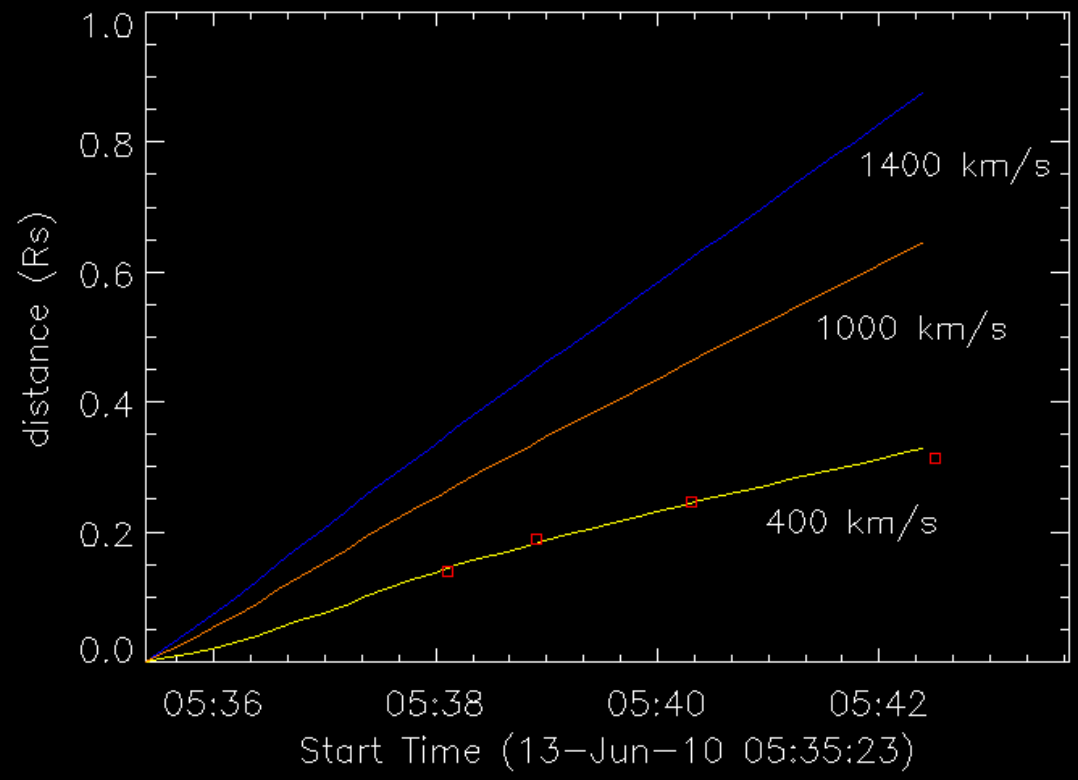
Expansion of source: height(t) & radius(t) drives a wave

Assume an Alfven speed

Wave amplitude evolution $f(d) = e^{-d/p}$

Ground Track of Wave (time-distance)

Wave Ground Tracks



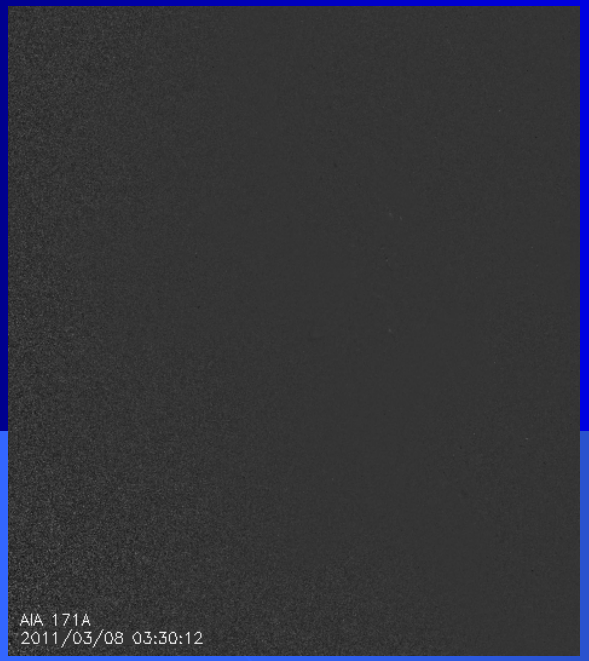
Solid lines: predicted r for various Alfven speeds

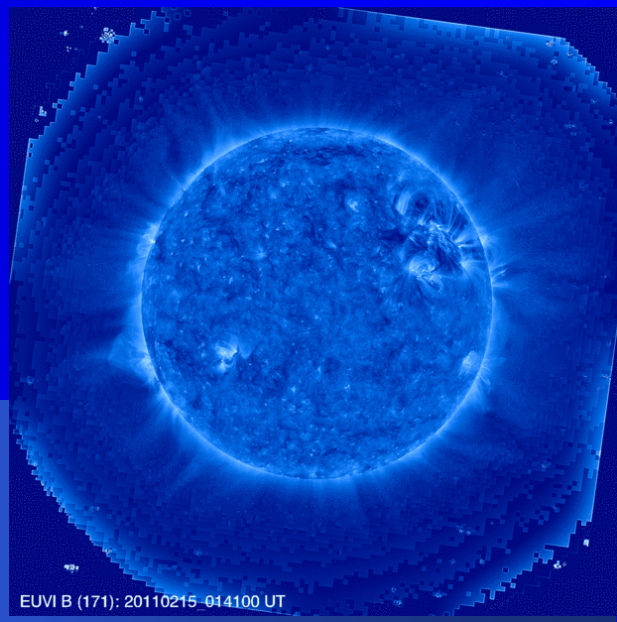
Boxes: wave r measurements

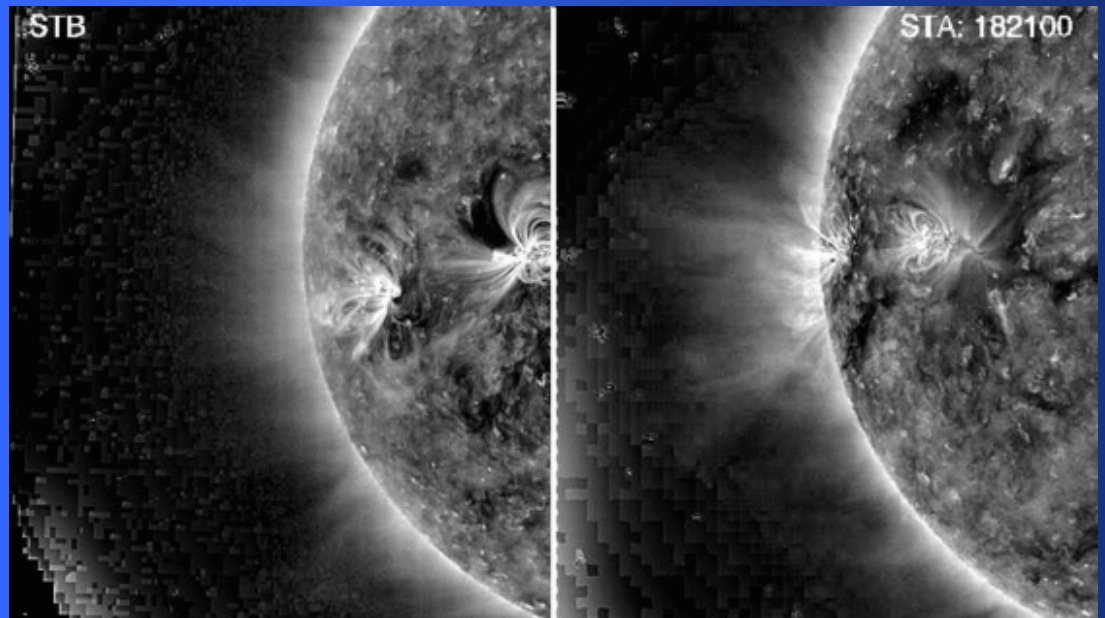
Propagation in low Alfven speed environment consistent w/ measurements → **CME flanks could generate the wave**

The Same Pattern is seen in Other Impulsive Events

Date	EUV Wave	SXR Flare
06/03/2007	▯	C 5.3
01/02/2008	▯	C 1.3
03/25/2008	▯	M 1.7
02/13/2009	▯	B 2.3
12/16/2009	▯ (weak)	C 5.3
01/17/2010	▯	▯ *(occulted)*
06/13/2010	▯	M 1.0
11/03/2010	▯	C 3.0
02/11/2011	▯	< B 3
02/15/2011	▯	X 2.2
02/24/2011	▯	M 3.5
03/08/2011	▯	M 1.5







Conclusions

High-res & cadence EUV observations of the genesis of CMEs and EUV waves shows that they tightly connected

Low-lying sets of loops → cavity → lateral expansion drives the wave

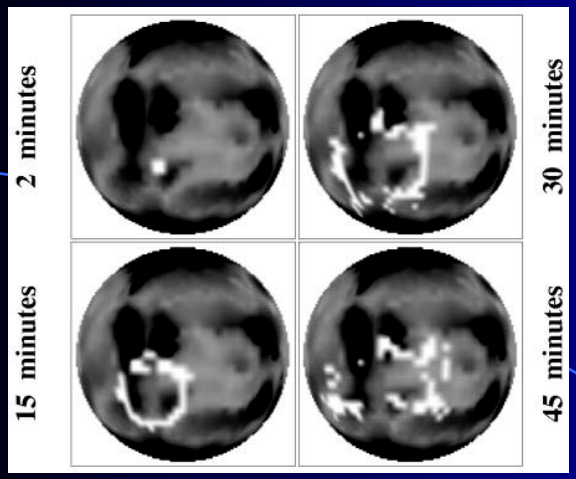
First principles data-driven model of EUV wave formation

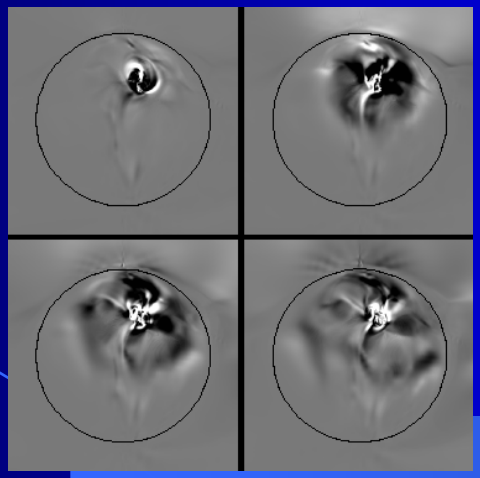
Based on observations of the both the CME driver and wave shows that CME flanks expansion is more probably driving the wave

Flux rope – Cavity Separation

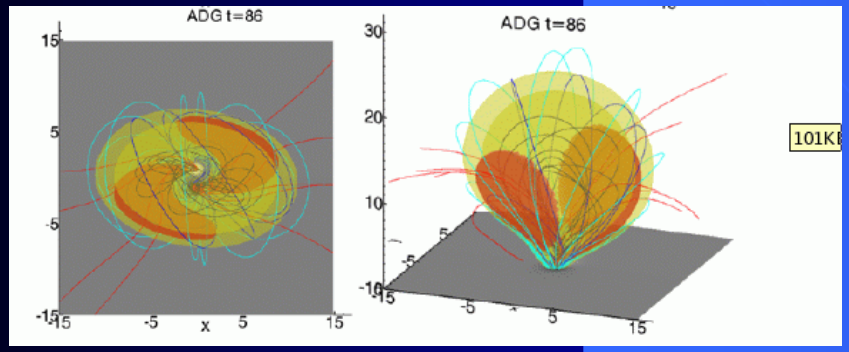
Red: 171 A ~ 0.8 MK
Green: 131 A ~ 10 MK

Physical Mechanisms: Waves, Pseudo-waves & Hybrids



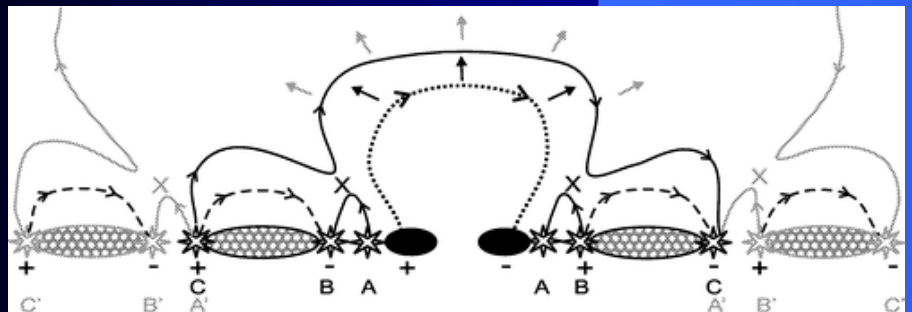


Fast mode wave:e.g. Thompson et al. 1998, Wang 2000, Ofman & Thompson 2002 Linker et al. 2008, Schmidt & Ofman 2010



Expanding flux rope (current & compression shells)

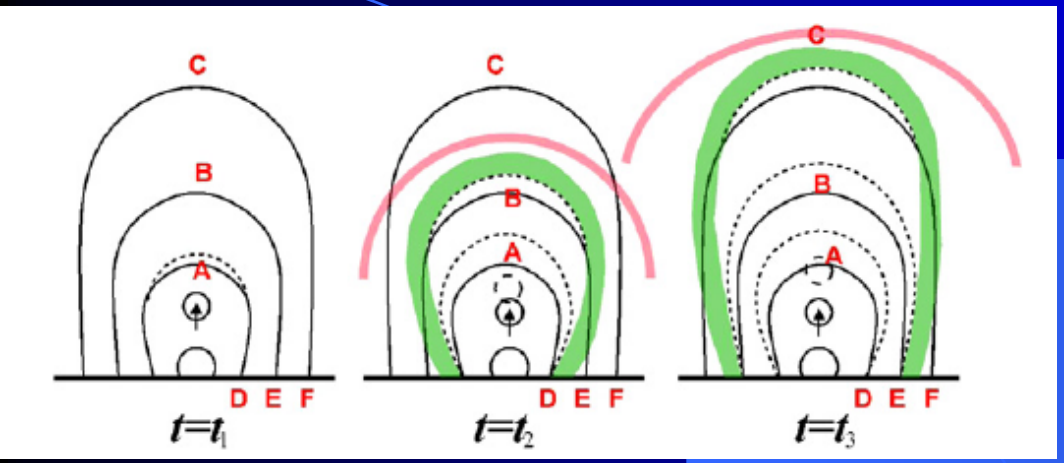
e.g. Delannee 1999, Chen et al. 2005,Delannée et al. 2008, 2010, Schrijver et al. 2011



Reconnection fronts:

e.g. Attrill et al. 2007

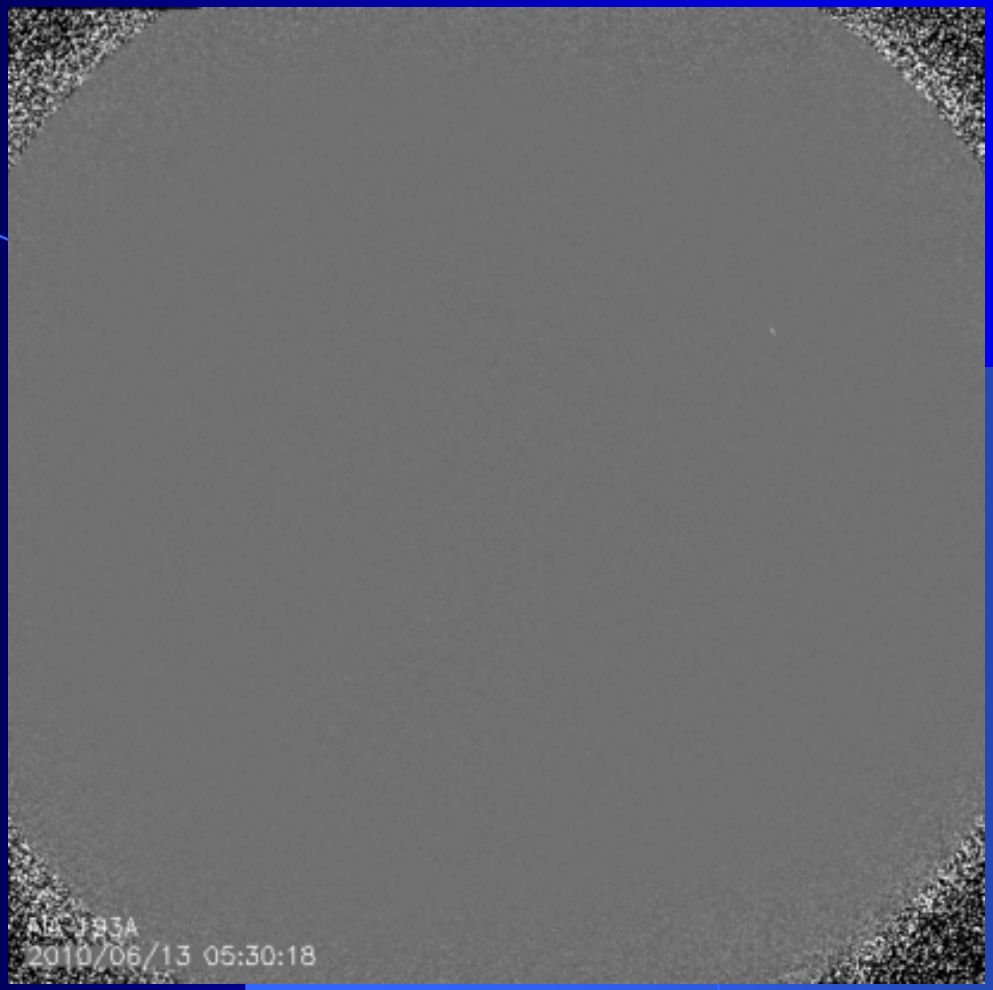
Physical Mechanisms: Waves, Pseudo-waves & Hybrids



Hybrid (wave& pseudo-wave):

e.g.Zhukov and Auchere 2004, Chen et al. 2005, Cohen et al. 2009 Poemel et al. 2010 Downs et al. 2011

Reconciling Waves and Pseudo-Waves



Diffuse shock front track: decceleration (true wave)
Bubble & bubble "termination" → pseudo-wave