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Evolution of plasma parameters during the early acceleration phase of the June 13 2010 CME event

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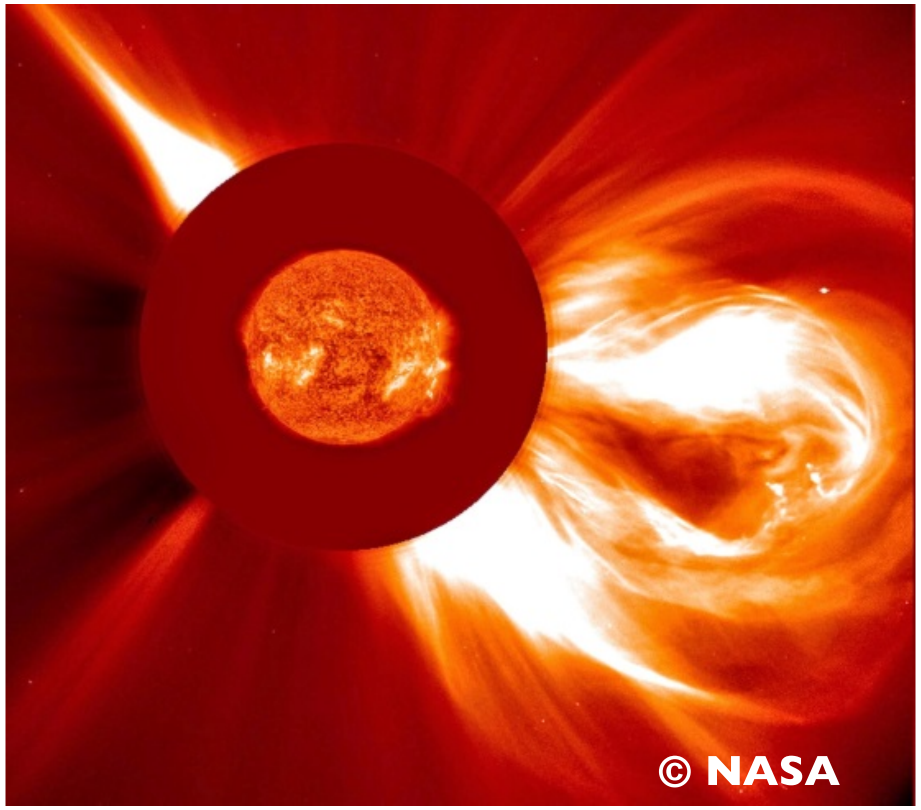
Coronal Mass Ejections

- Structures containing plasma and magnetic field expelled from Solar Corona
- Significant influence on IP space, space weather
- Earth`s magetosphere
  → geomagnetic storms[1,2]



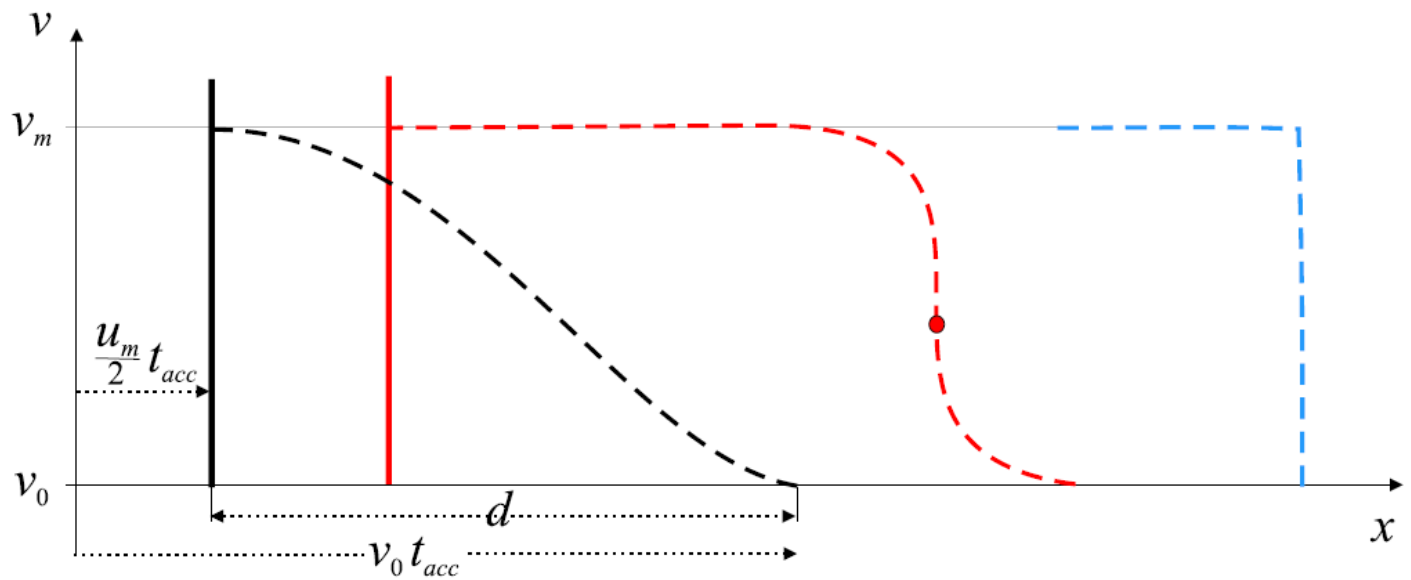
Characterizing their evolution

helps us understand their origins

CME Shocks

- Explosive expansion due to CMEs → acts as a 3D piston (Lulic+, 2013)
- If impulsive enough:
  - Perturbation is created
  - Nonlinear evolution of the wave front → perturbation steepens

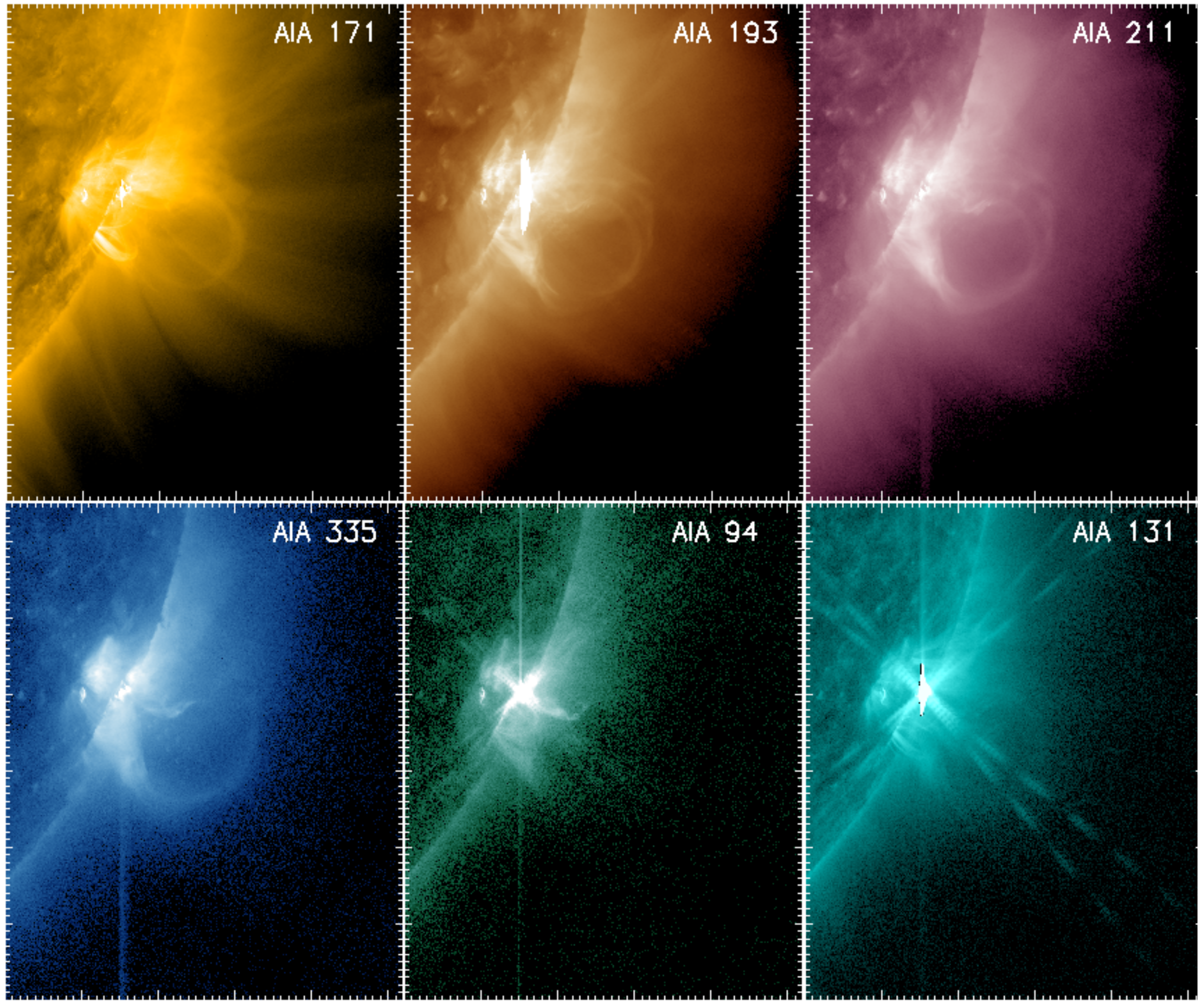
→ transformation into shock wave (Vršnak+, 2008)



B. Vršnak, E.W. Cliver, 2008

The event: 13 June 2010

- Well-studied event
- M1.0 flare, AR 11079
- Strong, short-lived acceleration (Patsourakos+, 2010)
- Type II radio burst (Ma+, 2011; Kozarev+, 2011)
  → indicates coronal shocks
- Very slow off-limb event



Method

- Data: SDO/AIA spacecraft
- Channels: 6 EUV (94 Å, 131 Å, 171 Å, 194 Å, 211 Å, 335 Å)
- Differential Emission Measure (DEM) technique
  by Hannah & Kontar, 2012

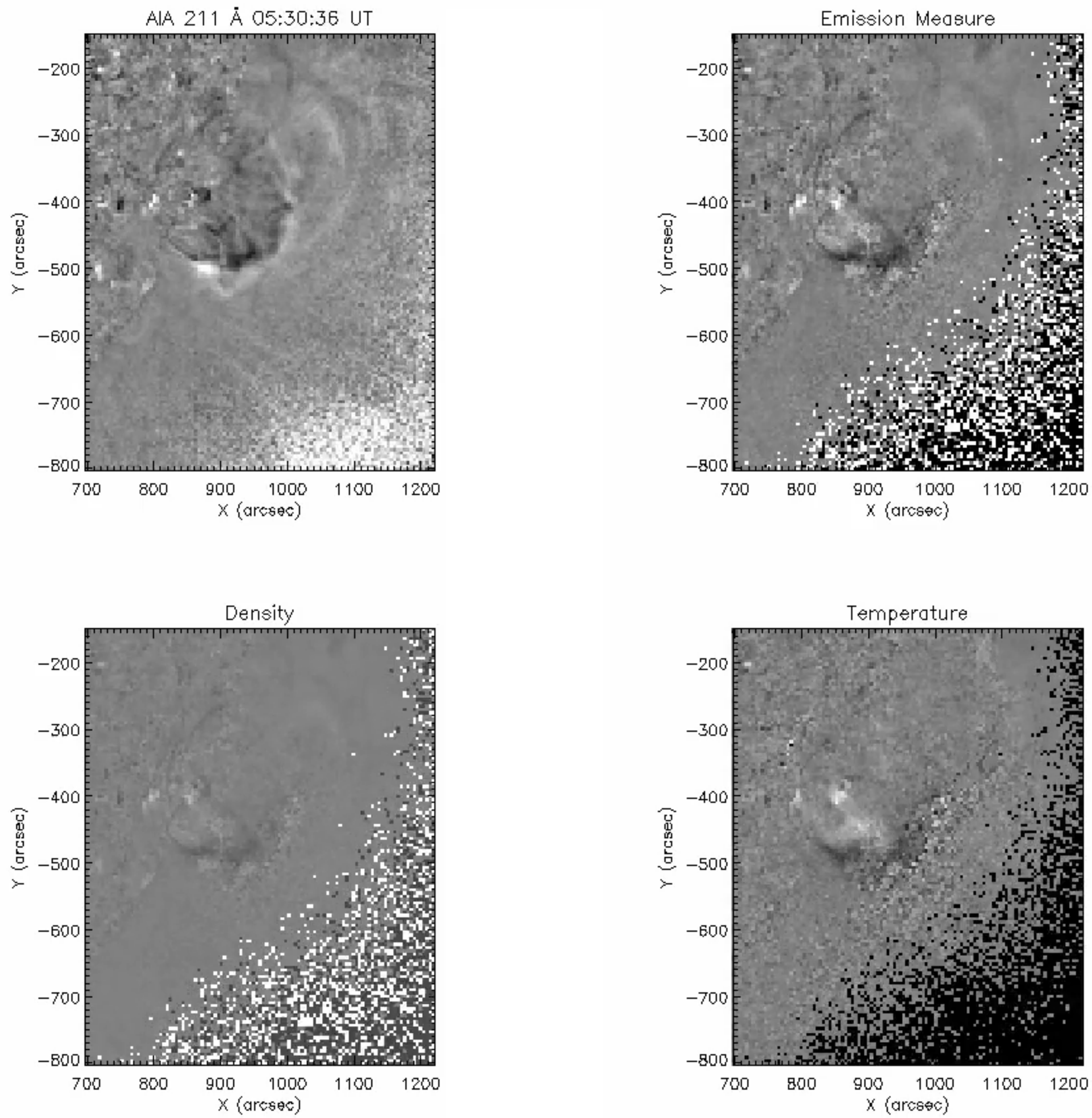
→ Plasma temperature: $\bar{T} = \frac{\int DEM(T)\ T\, dT}{\int DEM(T)\, dT}$

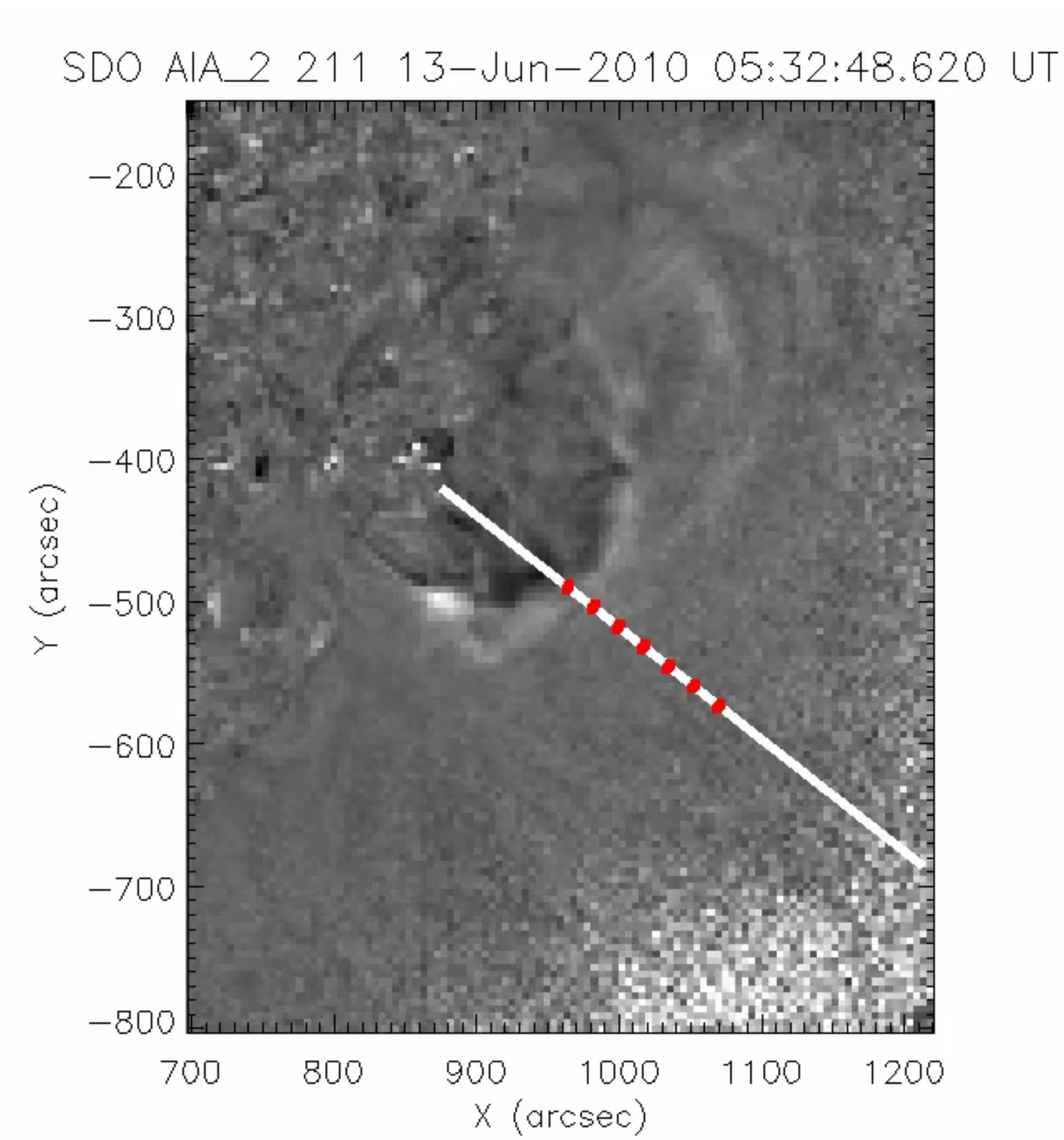
→ Emission Measure: $EM = \int DEM(T)\, dT$

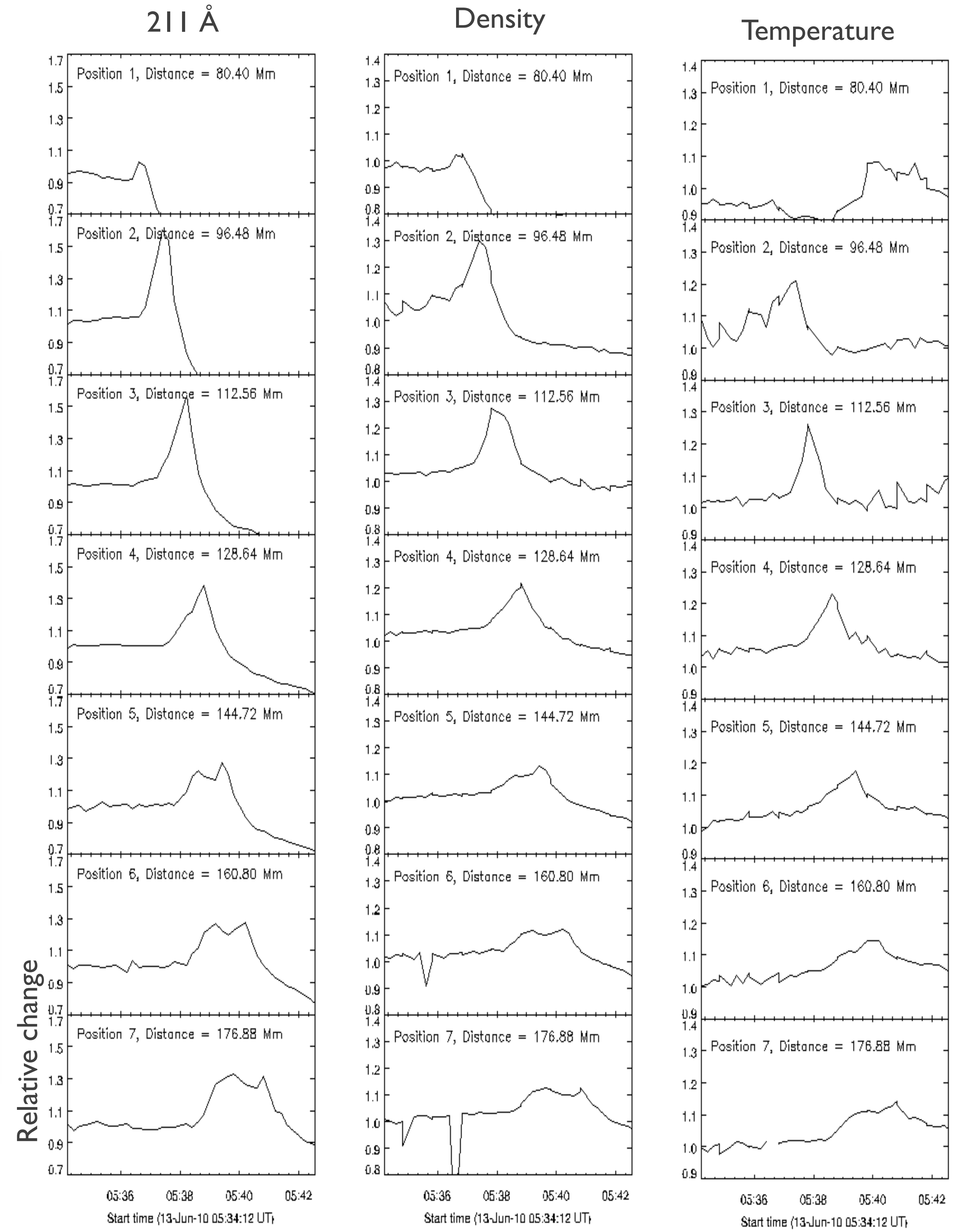
→ Plasma Density: $\bar{n} = \sqrt{\frac{\int DEM(T)\, dT}{H}} = \sqrt{\frac{EM}{H}}$

Calculated DEM maps

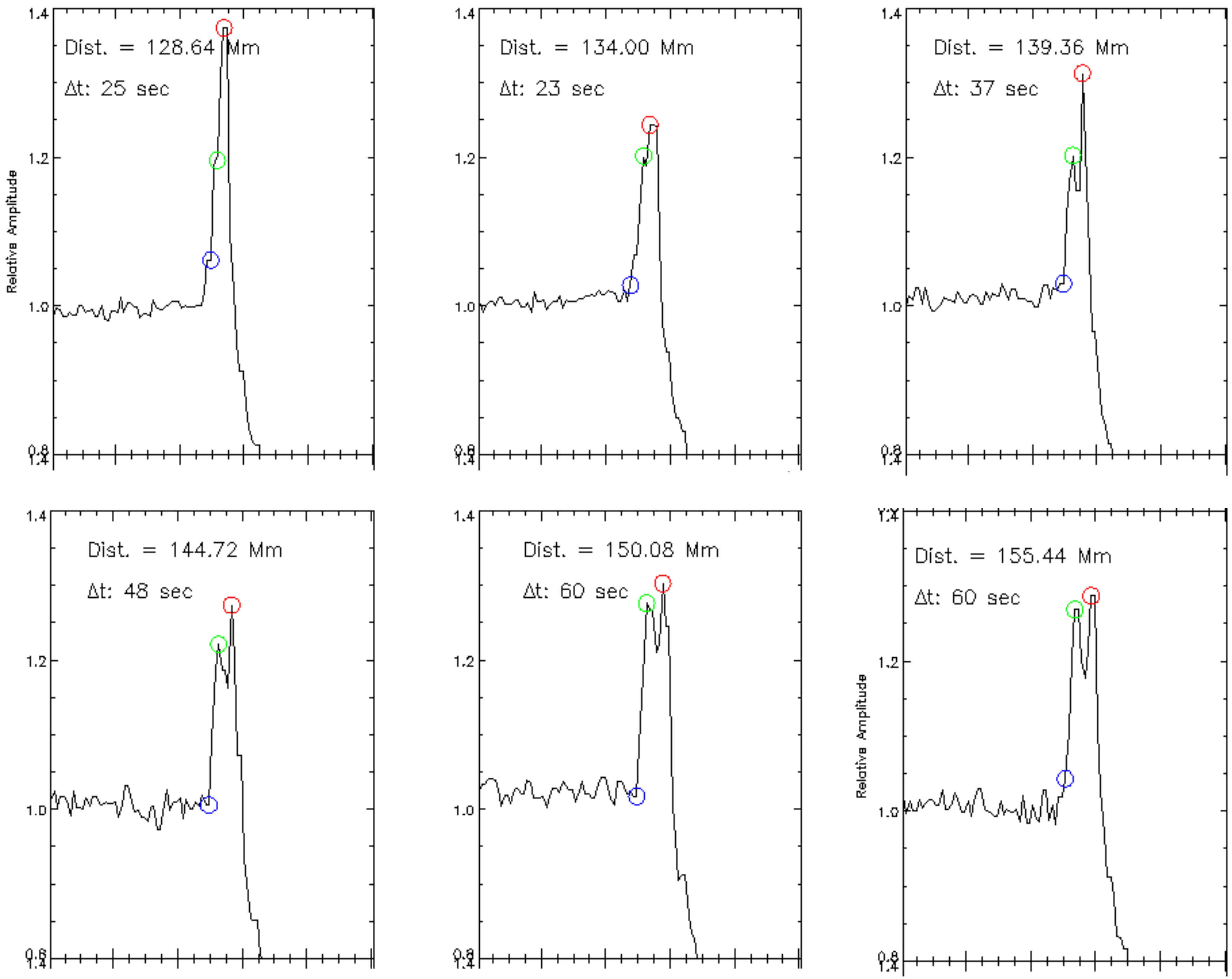
13/06/2010




SDO AIA_2 211 13−Jun−2010 05:32:48.620 UT
Y (arcsec)
X (arcsec)
−200
−300
−400
−500
−600
−700
−800
700
800
900
1000
1100
1200


211 Å
Density
Temperature
Relative change
Position 1, Distance = 80.40 Mm
Position 2, Distance = 96.48 Mm
Position 3, Distance = 112.56 Mm
Position 4, Distance = 128.64 Mm
Position 5, Distance = 144.72 Mm
Position 6, Distance = 160.80 Mm
Position 7, Distance = 176.88 Mm
05:36
05:38
05:40
05:42
Start time (13-Jun-10 05:34:12 UT)

Signature in 211 Å



Blue – CME shock (outer front)
Green – CME shock (peak)
Red – CME ejecta (peak)

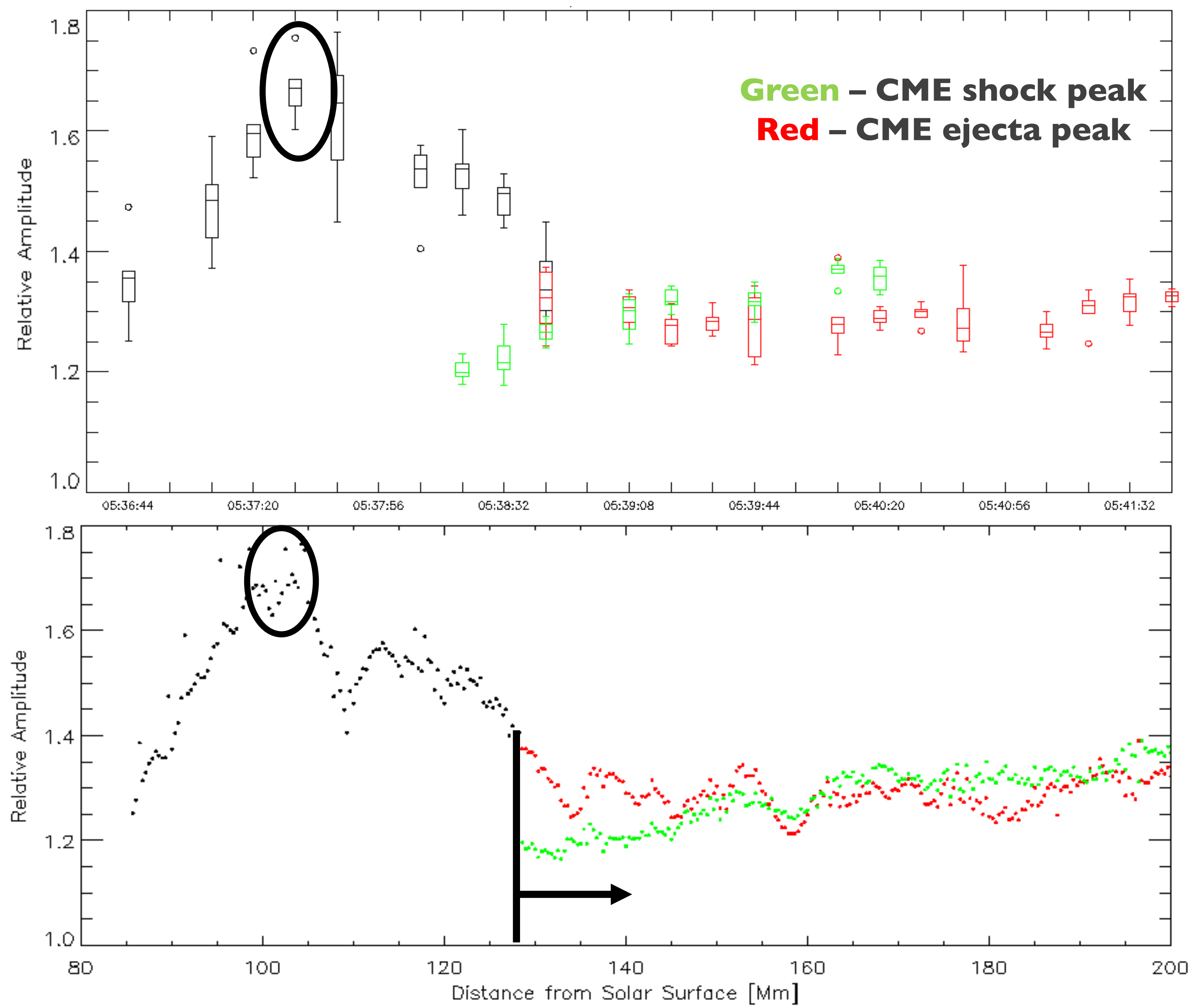
Signature in 211 Å

- Maximum amplitude increase: 60%

  at 105 Mm
  05:37:32

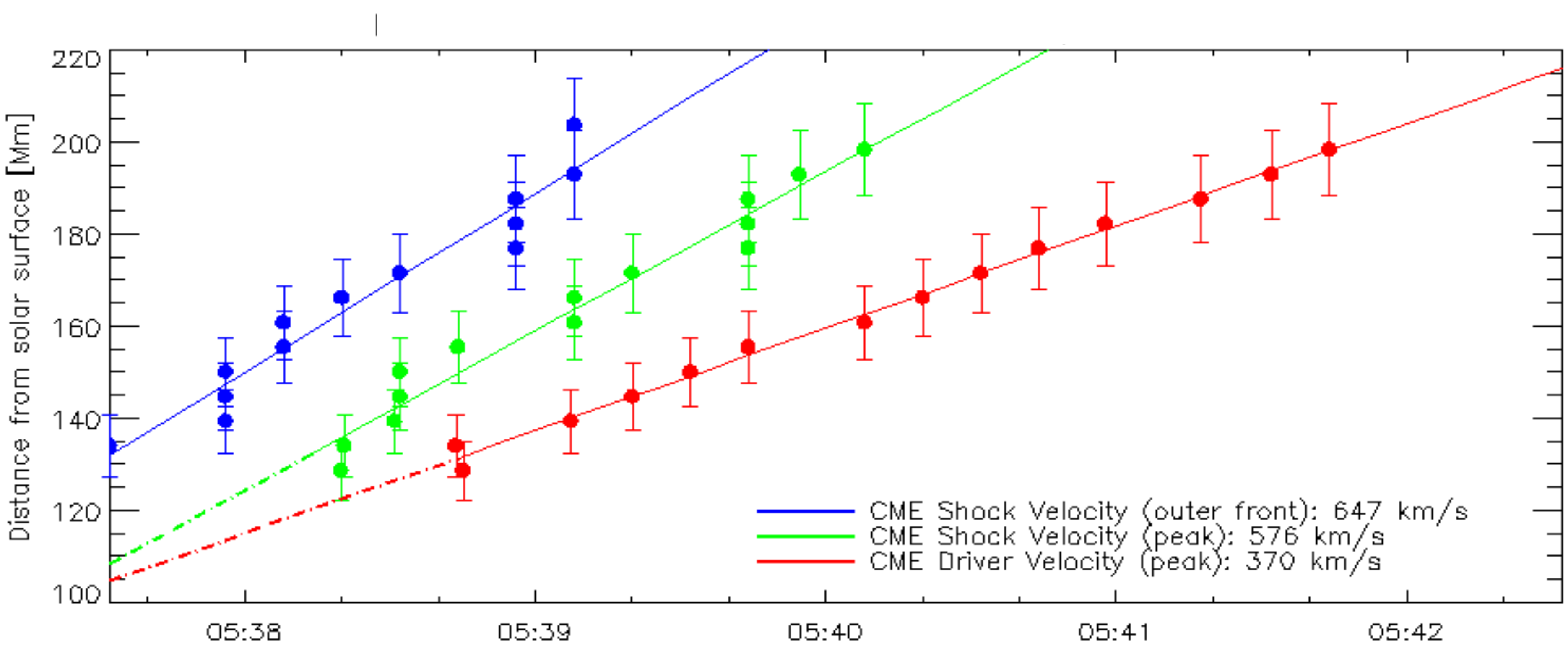
- 128 Mm onwards: clear double peak structure

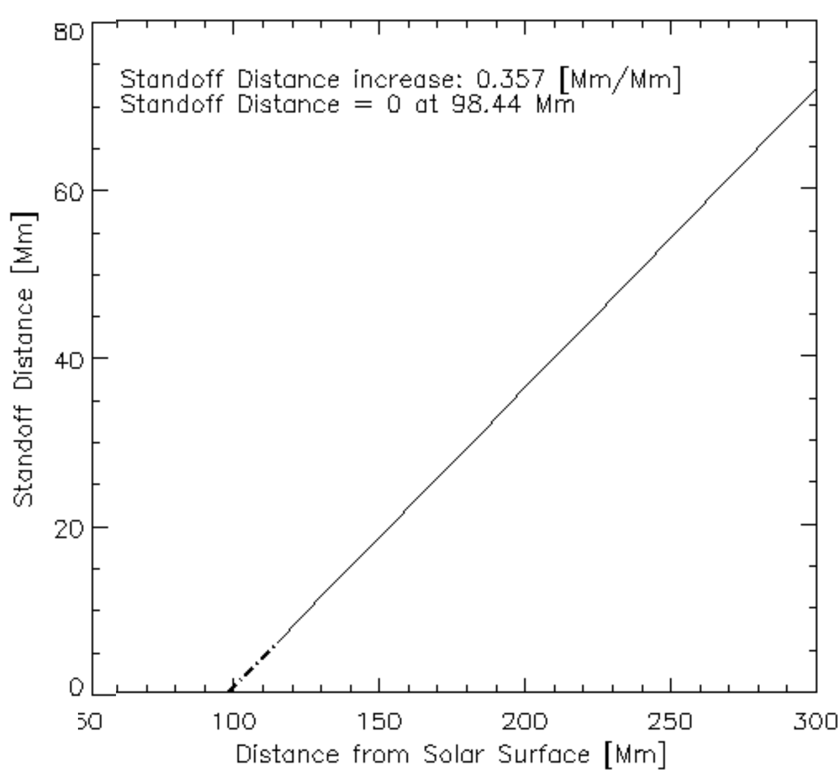
  → de-coupling



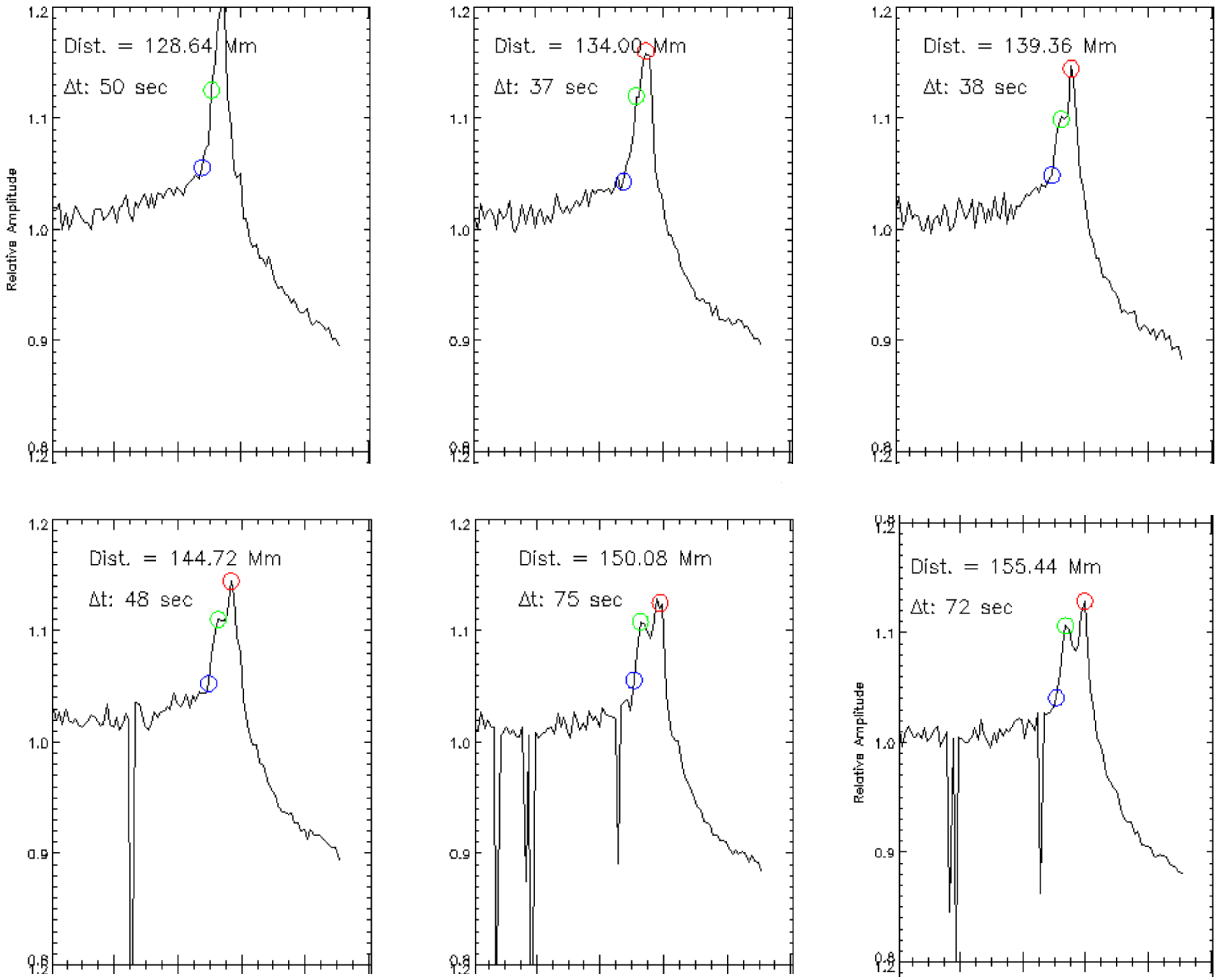
Signature in 211 Å

- CME ejecta velocity: 370 km/s
- CME shock velocity: 576 km/s
- Shock formation: 98 Mm from solar surface
- Standoff distance increase: 206 km/s (≙ 0.36 Mm/Mm)



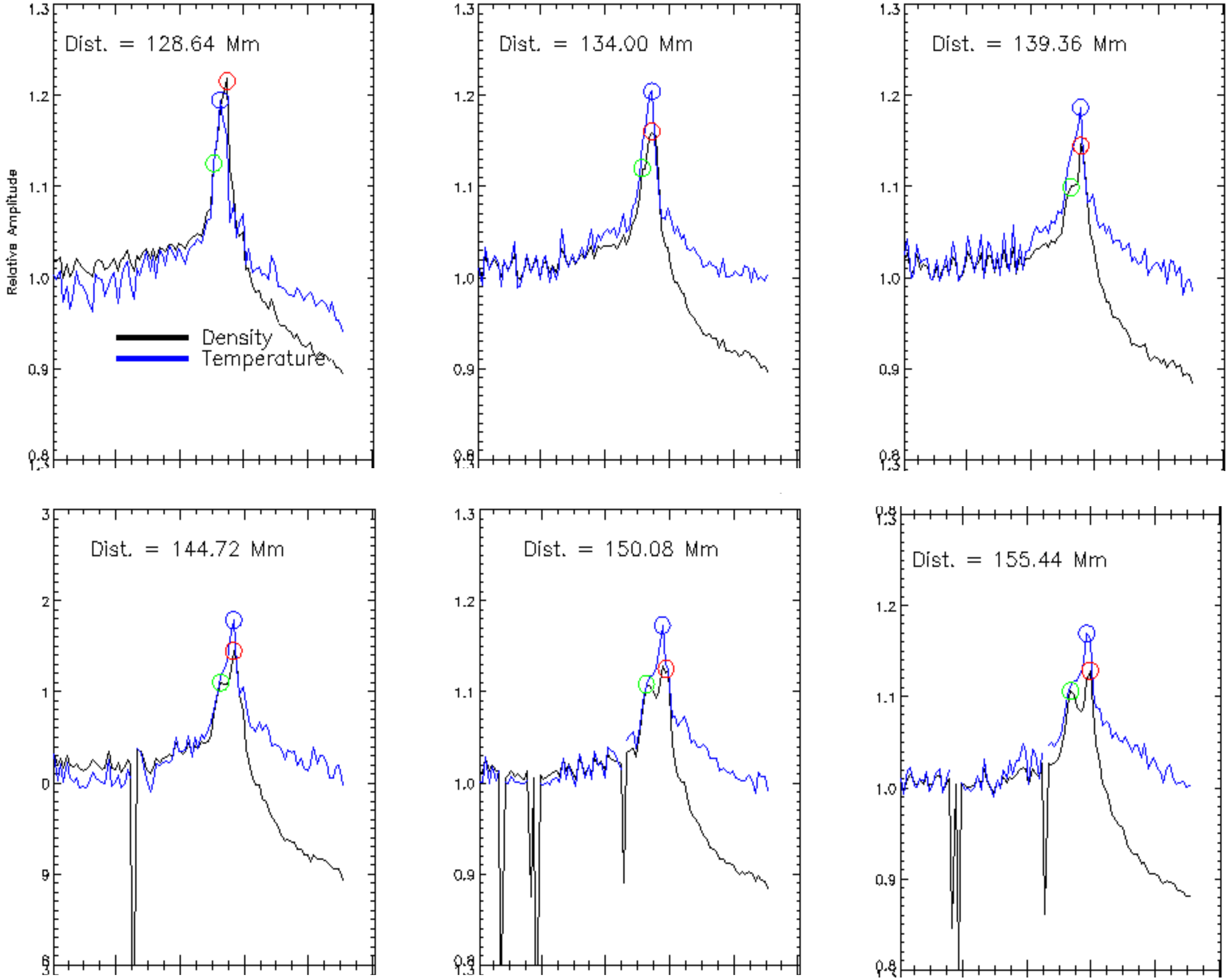


Density



Green – CME shock (peak)
Red – CME ejecta (peak)
Blue – CME shock (outer front

Density vs. Temperature



Green – CME shock, Density (peak)

Red – CME ejecta, Density (peak)

Blue – CME ejecta, Temperature (peak)

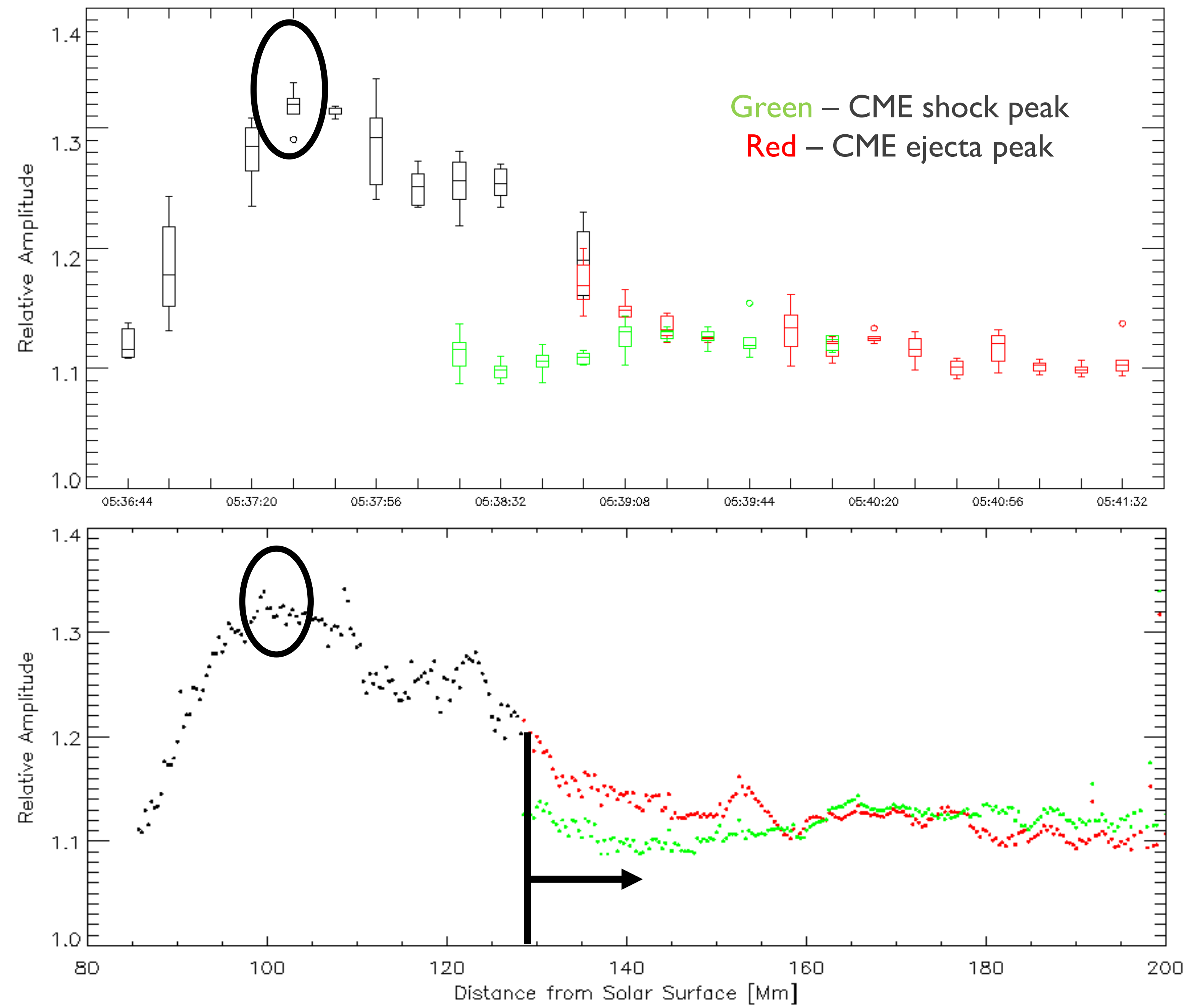
Density

- Maximum amplitude increase: 30%

  at 103 Mm
  05:37:32

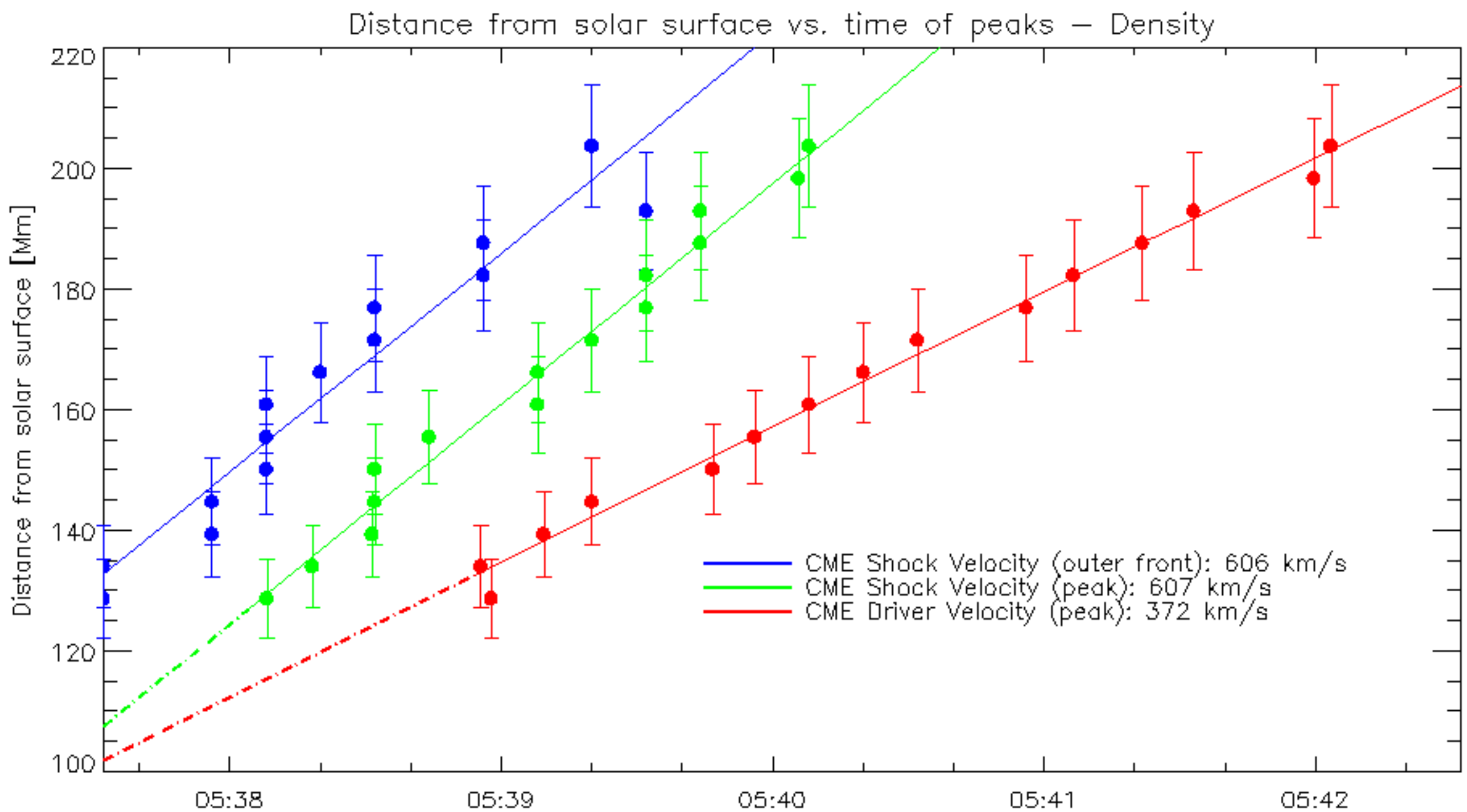
- 128 Mm onwards: clear double peak structure

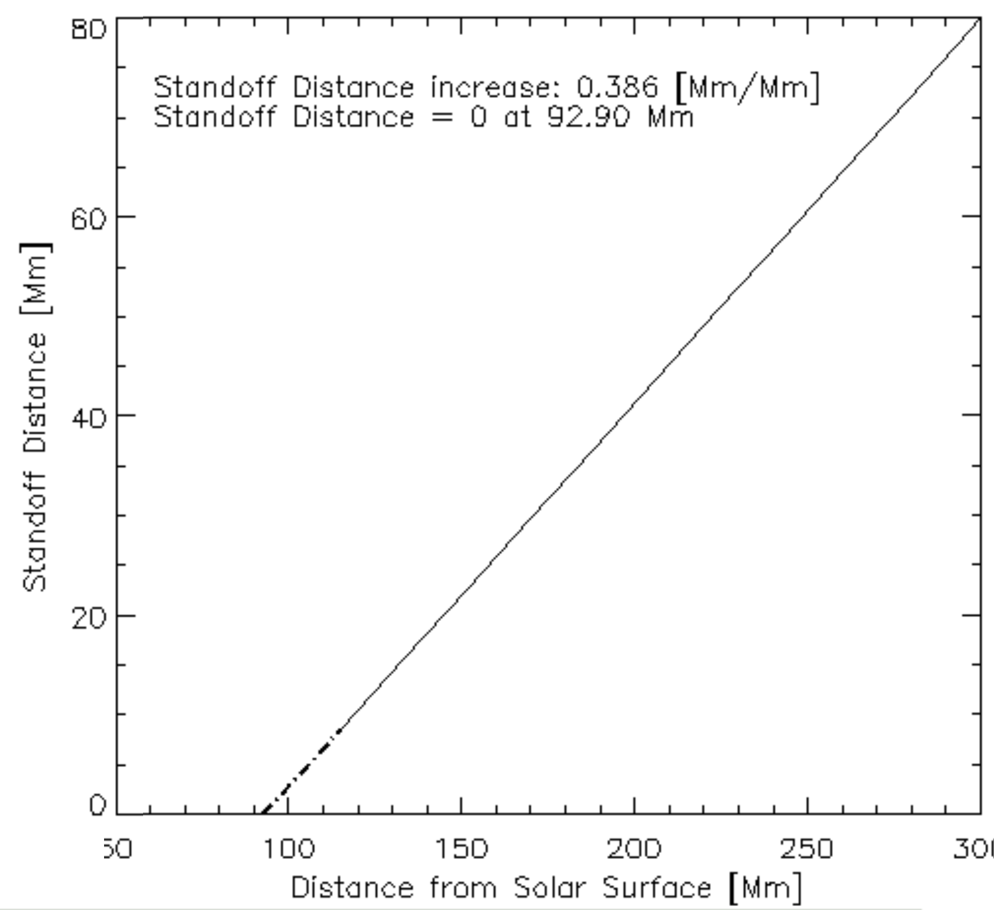
  → de-coupling



Density

- CME ejecta velocity: 372 km/s
- CME shock velocity: 607 km/s
- Shock formation: 93 Mm from solar surface
- Standoff distance increase: 234 km/s (≙ 0.39 Mm/Mm)





Summary

- CME shock velocity: ~600 km/s
- CME ejecta velocity: ~380 km/s
- Shock formation starts ~95 Mm from solar surface
- Maximum compression ratio of 1.3 at ~105 Mm from solar surface
- De-coupling low in the corona, ~128 Mm from solar surface
- Indication of piston-driven shock due to linear increase of standoff-distance

THANK YOU FOR YOUR ATTENTION