Explosive events: Jets, Eruptions and Splashes

Davina Innes
Explosive events are broad non-Gaussian wings in transition region lines. Many different forms. Mostly bright core with much weaker wings.

Symmetric

Evolving: blue - red - blue (15 s cadence)

SUMER O VI

SUMER Si IV (-/+200 km/s) and TRACE C IV (40” x 55”)

Innes (2001)
Explosive events at sites of emerging magnetic flux => signature of plasma accelerated by magnetic reconnection.

Velocity 100 km/s comparable to Alfvén speed in plasma with magnetic field strength 20 G and density $7 \times 10^{10}$ cm$^{-3}$

(Dere, Bartoe, Brueckner, Ewing & Lund 1991)
Structure of explosive events
footpoint jets

SUMER observations

Characteristics in Si IV:

- Blue often starts before Red
- Center does not move across Sun
- Blue often longer than Red
- Blue often faster than Red

Innes, Inhester, Axford & Wilhelm 1997
Relation to EUV brightenings

Explosive events coincide with brightenings at 304A caused by flux emergence and cancellation at supergranular cell junctions.

Innes & Teriaca 2012

28 June 2010
Coronal brightening at sites of flux cancellation and emergence. Long-lasting structure change due to flux emergence.
AIA images of explosive events

SUMER sit-and-stare
60 s exposure

Intensity
Intensity
Line width

Innes & Teriaca 2012

Line width > 80 km/s => explosive event
Eruptions at supergranular junctions

HMI magnetic field evolution at site of eruption
Flux cancellation – ring of fire

Convergence and cancellation at mixed polarity junction

Explosive events coincide with brightening.

Some are at the site of cancelling field.

The others may be at the other footpoint of the reconnecting field.

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Reconnection at loop footpoint
Jets

SOT Ca II observations near the limb on the edge of an active region (10”x10”)

Apparent Velocity - upflow jet 10 km/s
downflow blobs 35 km/s

Cartoon by Shibata et al. 1992

Singh, Isobe, Nishida & Shibata 2012
Splashes

SUMER sit-and-stare 60 s exposure

Line width $> 80$ km/s $\Rightarrow$ explosive event

Innes & Teriaca 2012
Almost invisible in AIA

Double explosive event

Explosive event strongest at northern bright point

Explosive event at both

171 A (0.7 MK)  304 A (0.05 MK)  O VI (0.3 MK)
Flow along small loop

Supergranule junction with weak magnetic field.

Main Brightenings
Time delay (AIA) = 50 s
Distance (AIA) = 4 arcsec
Flow velocity (SUMER) = 100 km/s

Semi-circular loop with length 5 Mm plasma at 100 km/s takes 50 s
“Splash”

Structure of southern brightening

Ring of bright 304A with bright 171A core
**Observation Summary**

**Transition region explosive events at**
1. Mixed-polarity supergranular junctions
2. Sites of flux emergence

Speed is roughly Alfven speed in transition region (up to 200 km/s)

Observations consistent with jet or loop flow

Flow along a loop may gives rise to a splash at the other end of the loop.
Reconnection jets
Petschek reconnection

Consider small segment of loops ($T \sim 10^4 \text{ K}$) with oppositely directed magnetic field that are driven close together. Reconnection starts at position of high current.

Jet plasma velocity equal $V_A$ in inflow region.

Jet head (fast shock) moves out with a speed inversely proportional to $\sqrt{\text{preshock density}}$.

$$T(\text{fast}) \sim 10^5 \left(\frac{V_A}{100}\right)^2 \text{ K km/s}$$

No line core emission

Image–Current Contours – Magnetic field (Innes & Tóth 1999) Arrows – Velocity
Regimes of reconnection

Lundquist Number (resistive diffusion time/Alfven time)

Formation of islands along Sweet-Parker current sheet. More energy goes into heating along the current sheet which may produce the observed core brightening.

Magnetic field and current density.

Bárta, Büchner, Karlický, Skála (2011)

Petschek reconnection probably doesn’t occur under transition region conditions

Huang and Bhattacharjee (2013)
Lundquist Number = Resistive diffusion time/ Alfvén time

\[ S = \frac{\mu_0 L V_A}{\eta} \approx 2 \times 10^12 \]

\[ \eta \approx 5 \times 10^{-7} \text{ ohm-m (Spitzer – underestimate)} \]

\[ L \approx 1 \times 10^7 \text{ m} \]

\[ V_A \approx 1 \times 10^5 \text{ m/s} \]

\[ \mu_0 \text{ (vacuum permeability)} \approx 1 \times 10^{-6} \text{ Ohm-s/m} \]

Effective plasma size

\[ \Lambda = \frac{L}{d_i} \approx 1 \times 10^7 \]

\[ L \approx 1 \times 10^7 \]

\[ d_i \text{ (ion skin depth)} = \frac{c}{\omega_{pi}} \approx 3 \times 10^8/3 \times 10^8 \]

\[ \omega_{pi} = 1.32 \times 10^3 Z (m_p/m_i)^{1/2} n_i^{1/2} \text{ rad/s} \]