Explosive Events in Magnetic Network

Jongchul Chae

Department of Astronomy and Space Science
Chungnam National University, Korea
and
Big Bear Solar Observatory, NJIT
1. What are they?

- Small-scale (~1 Mm), short-lived (~1 min), high-velocity (~100 km/s) events that are observed in transition region UV lines
- Originally discovered from HRTS experiments
2. Why are they important?

- They are many and ubiquitous on the Sun
- Small-scale magnetic energy release process
  - Magnetic reconnection
  - Shock
- Possibly important in coronal heating and solar wind driving
3. What have we learned from SOHO?

- Dynamical Property
  - Confirmation of bi-directional jet nature from spectral profiles, and spatial variations of Doppler shifts
  - Innes et al. (1997a)
  - Chae et al. (1998a)
3. What have we learned from SOHO?

- Temporal Behavior
  - Bursty and recurrent occurrence
  - Innes et al. (1997b)  Chae et al (1998a)
3. What have we learned from SOHO?

- **Magnetic Property**
  - weak fields of mixed polarity
  - Away from big flux concentrations
  - strong association with flux cancellation
  - flux cancellation precedes explosive events

Chae et al. 1998a

Ryutova and Tarbell 2000
3. What have we learned from SOHO?

- Association with H alpha upflow
  - typical size 2.5 arc sec
  - lifetime 1.4 min
  - speed up to 20 km/s, typically 5 km/s
  - birthrate 80 /s
  - recurrent behavior
  - Chae et al. (1998b)
  - Lee et al. (2000)
Spicules and Upflow Events

(a) Upflow Event

(b) Spicule

(c) Upflow Event

(d) Spicule
3. What have we learned from SOHO?

- Comparison with blinkers
  - associated, but not co-spatial
  - both kinds are in mixed polarity regions
  - blinkers comprise elementary brightenings that are similar to explosive events in size, lifetime, and spectral characteristics
3. What have we learned from SOHO?

Possible association with density enhancements

✓ Perez and Doyle (2000)
   cf. Harrison et al. (1999): blinkers are predominantly caused by increases in density or filling factor

Global energy contribution

✓ upward energy flux = $10^5-10^6$ cgs: seems to be enough for coronal heating
✓ net energy flux = $10^4-10^5$ cgs
   Winebarger et al. (1999)
   cf. coronal heating $3 \times 10^5$ cgs
   Withbroe & Noyes (1977)
4. How are they explained?

- Magnetic reconnection flow in transition region
  - Originally proposed by Dere et al. (1991)
  - Supported by: Innes et al. (1997), Chae et al. (1998a)
    - Bi-directional jet nature
    - Jet speed comparable to Alfvén speed in the transition region
    - MHD simulation (Innes & Toth 1999)
    - Association with flux cancellation if flux cancellation is a result of magnetic reconnection in the level of transition region
  - Challenged by:
    - Association with flux cancellation if flux cancellation is a result of low level magnetic reconnection
    - Association with H α upflow events
    - The existence of bright central spectral component in lines (Innes & Toth 1999)
4. How are they explained?

- Two-step magnetic reconnection
  - Chae (1999)
  - Flux cancellation = low level reconnection
  - H alpha upflow event = development of upward flow of low level reconnection
  - Explosive events = secondary reconnection driven by H alpha upflow
  - Supported by density enhancement
Two-Step Reconnection Model

- Step 1: Generation of Upflow Events
- Step 2: Generation of Explosive Events
4. How are they explained?

- Hydrodynamic cumulation
  - Tarbell et al. (1999), Ryutova & Tarbell (200)
  - Flux cancellation = low level reconnection
  - Shock waves are created by low level reconnection
  - Explosive events = a result of shock collision or explosive instability of negative energy waves
  - Possible to explain both brightenings and jets in the same context
5. Are they important in coronal heating?

Pros:
- numerous
- carry (kinetic) energy enough for coronal heating

Cons:
- Too cool (10^5 K) for coronal heating
- Too localized

Necessary conditions:
- Process to convert kinetic energy to heat for 10^6 K plasma
- Process to distribute heat over very large area
- High-frequency Alfven waves created by explosive events?
5. What should we learn from beyond Solar-B?

- The physics of magnetic reconnection responsible for flux cancellation
  - The atmospheric level of occurrence: photosphere or transition region?
  - Steady or bursty? If flux cancellation occurs in a bursty way, what’s the size, flux, and time scale of elementary process?
- The refined temporal and spatial relationships between flux cancellation, H alpha upflow events, and explosive events
- Possible existence of high-frequency MHD waves generated by explosive events