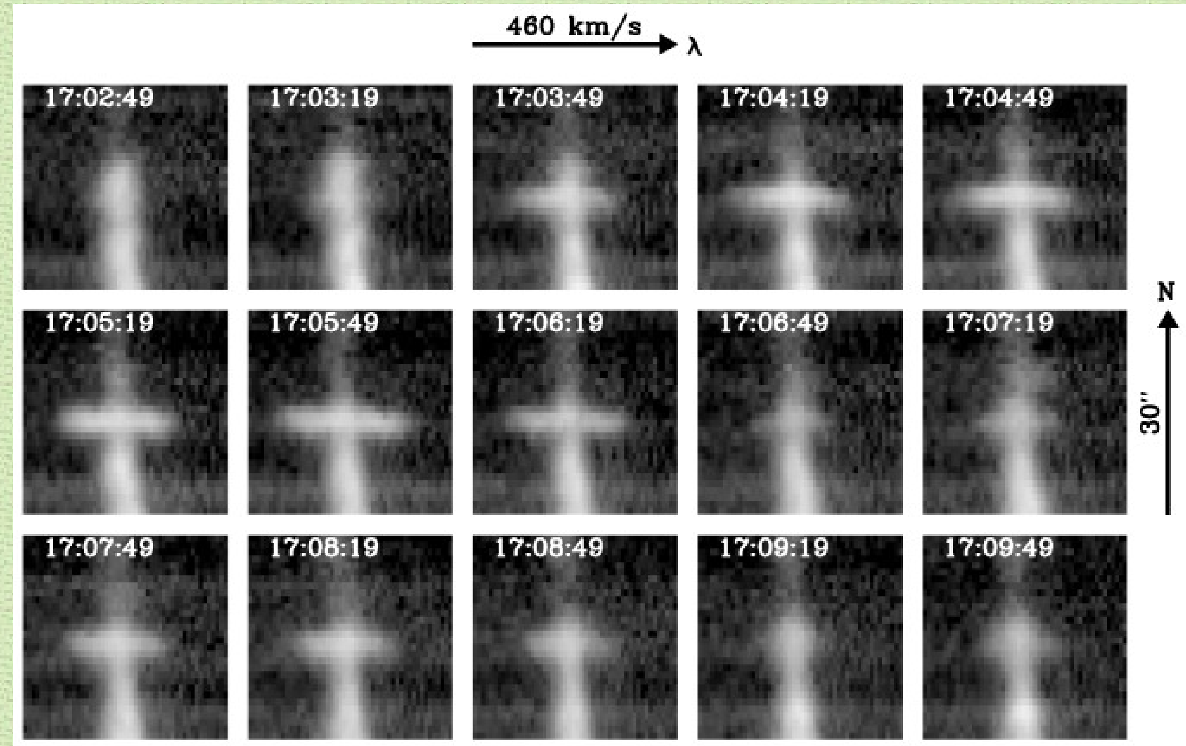
Explosive Events in Magnetic Network

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?

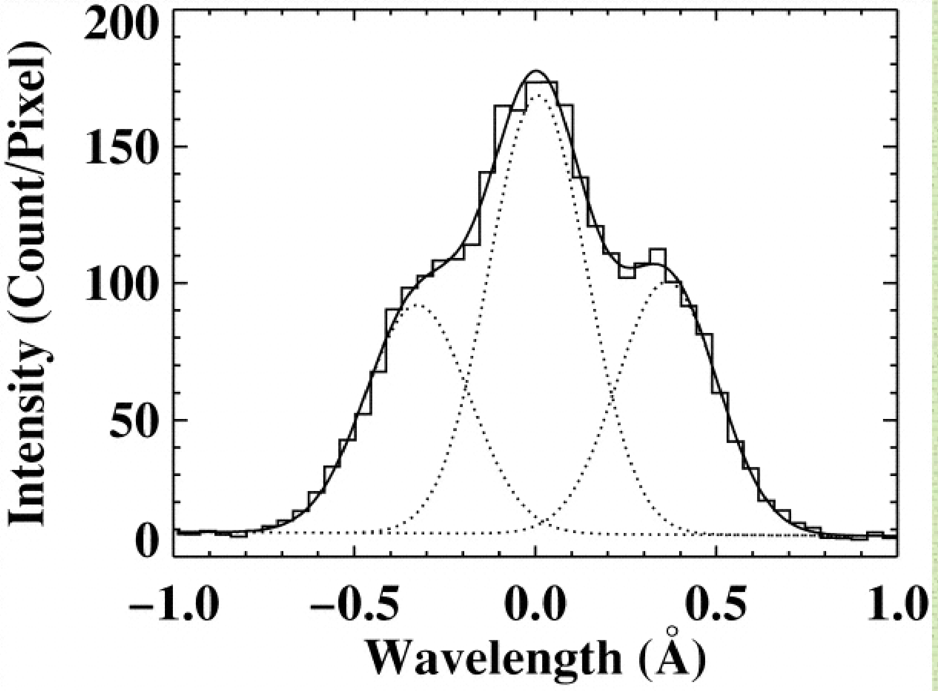
- They are many and ubiquitous on the Sun
- Small-scale magnetic energy release process
  - ✓ Magnetic reconnection
  - ✓ Shock
- Possibly important in coronal heating and solar wind driving

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)

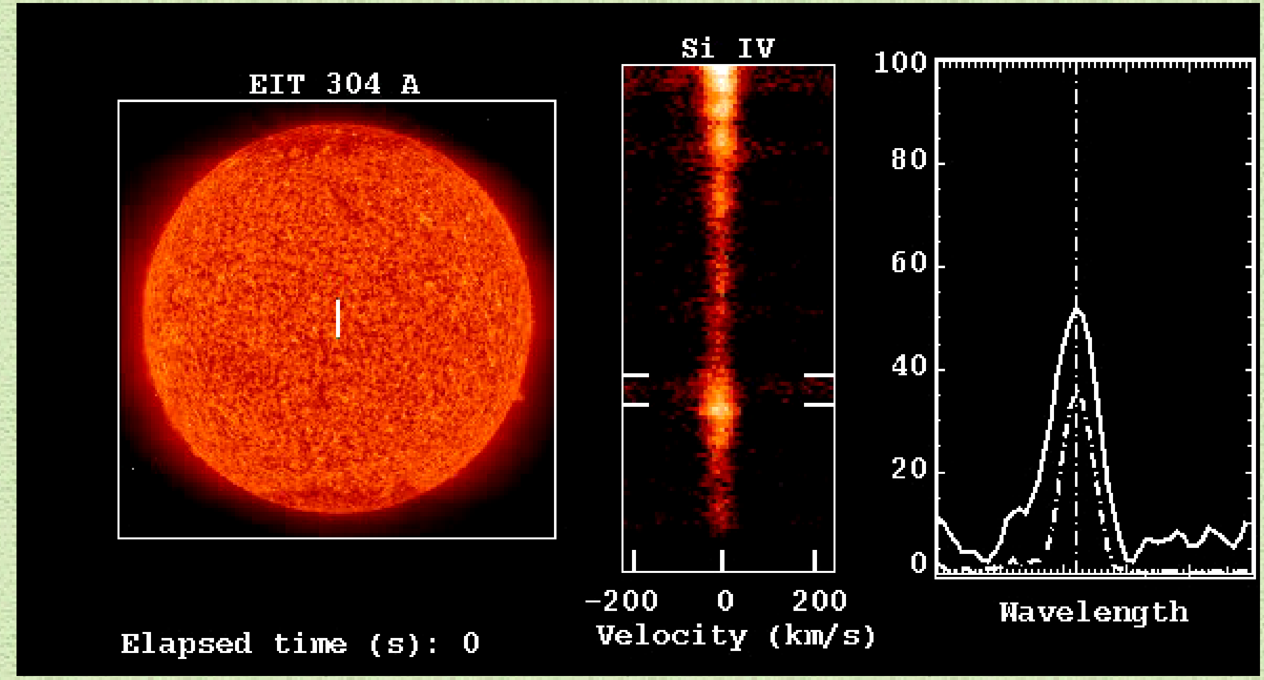
    Chae et al. (1998a)



3. What have we learned from SOHO?

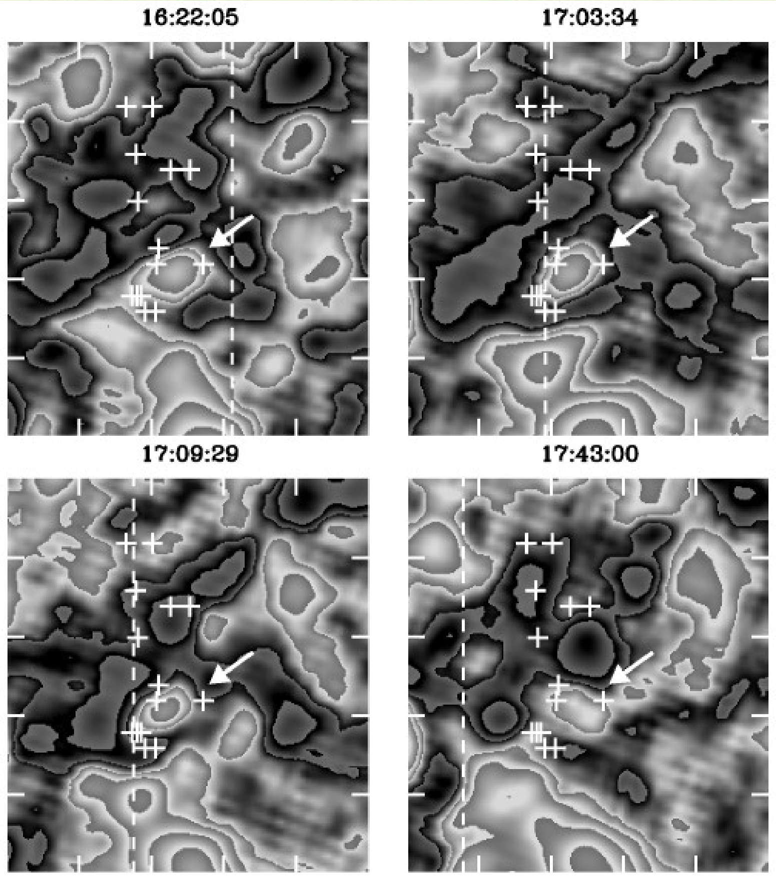
- Temporal Behavior
  - ✓ Bursty and recurrent occurrence

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 Chae et al. 1998a
  - ✓ flux cancellation precedes explosive events Ryutova and Tarbell 2000

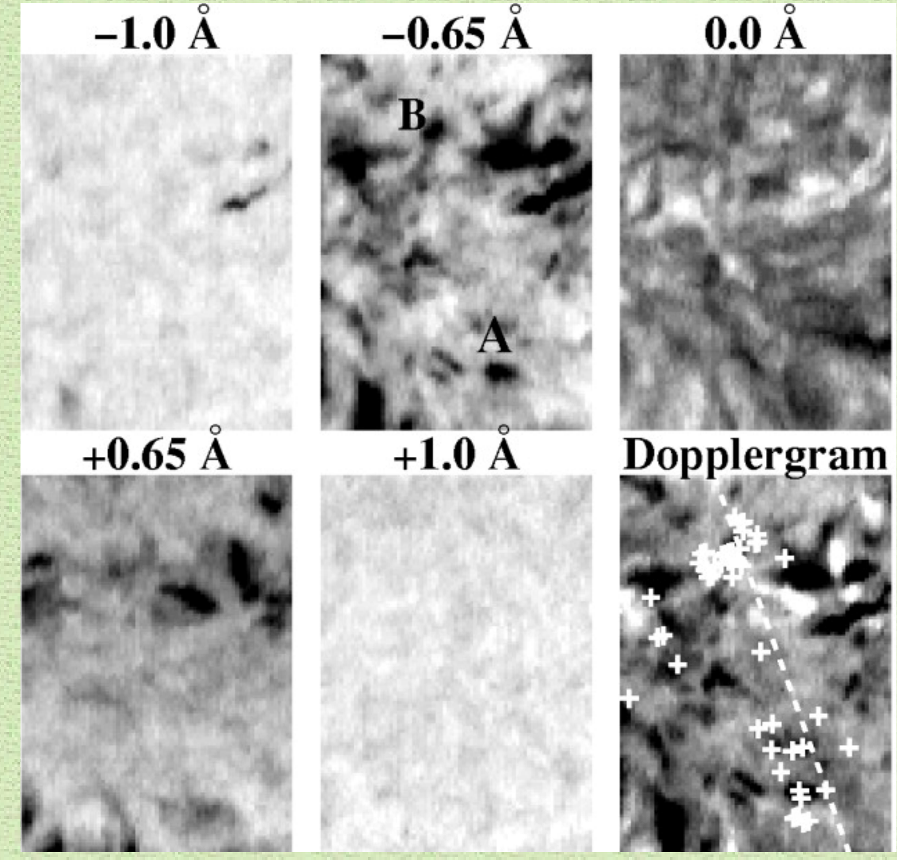


3. What have we learned from SOHO?

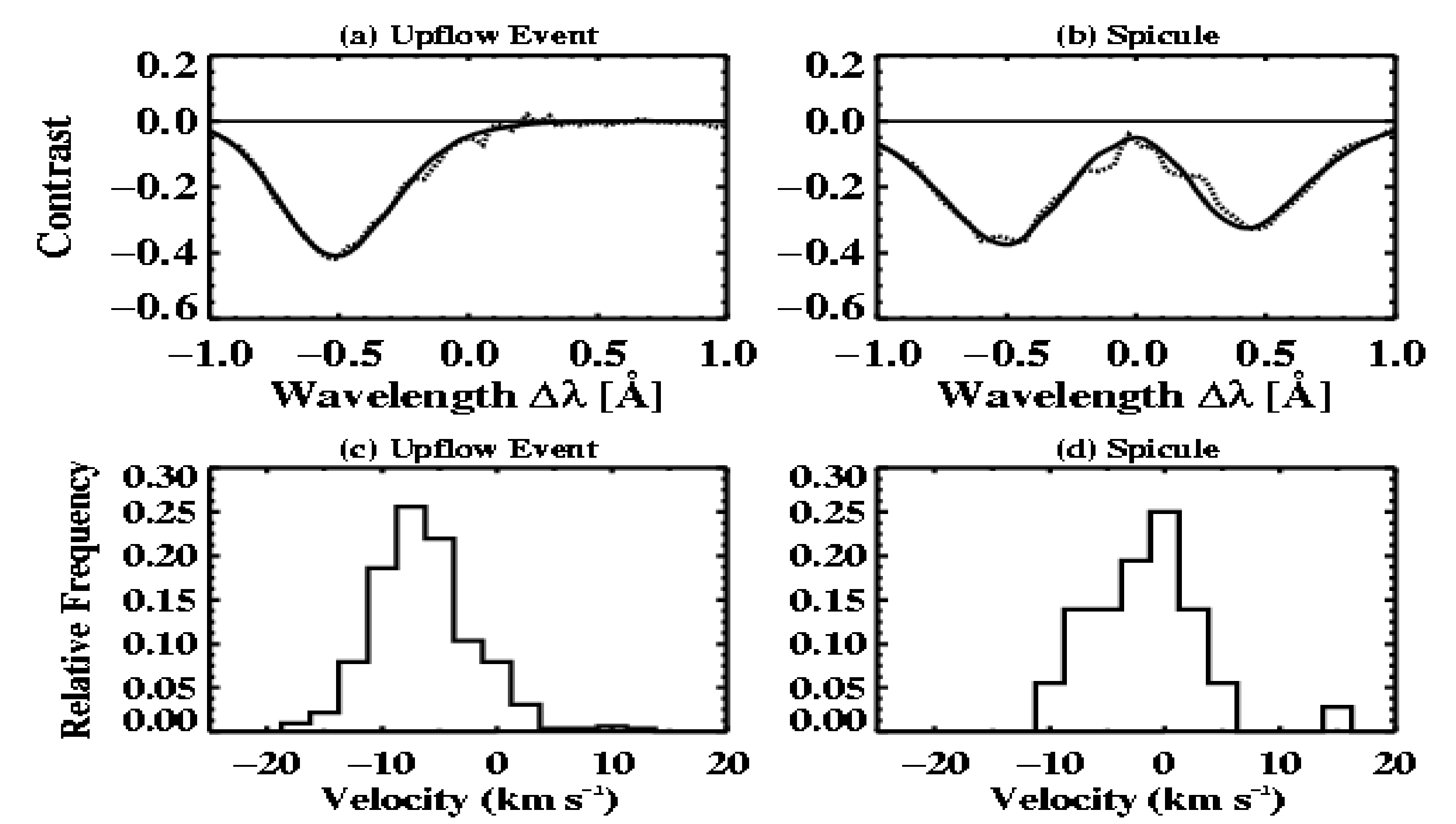
- Association with H alpha upflow
  - ✓ typical size 2.5 arc sec
  - ✓ lifetime 1.4 min
  - ✓ speed up to 20 km/s, typically 5 km/s
  - ✓ birthrate 80 /s
  - ✓ recurrent behavior

    Chae et al. (1998b)

    Lee et al. (2000)

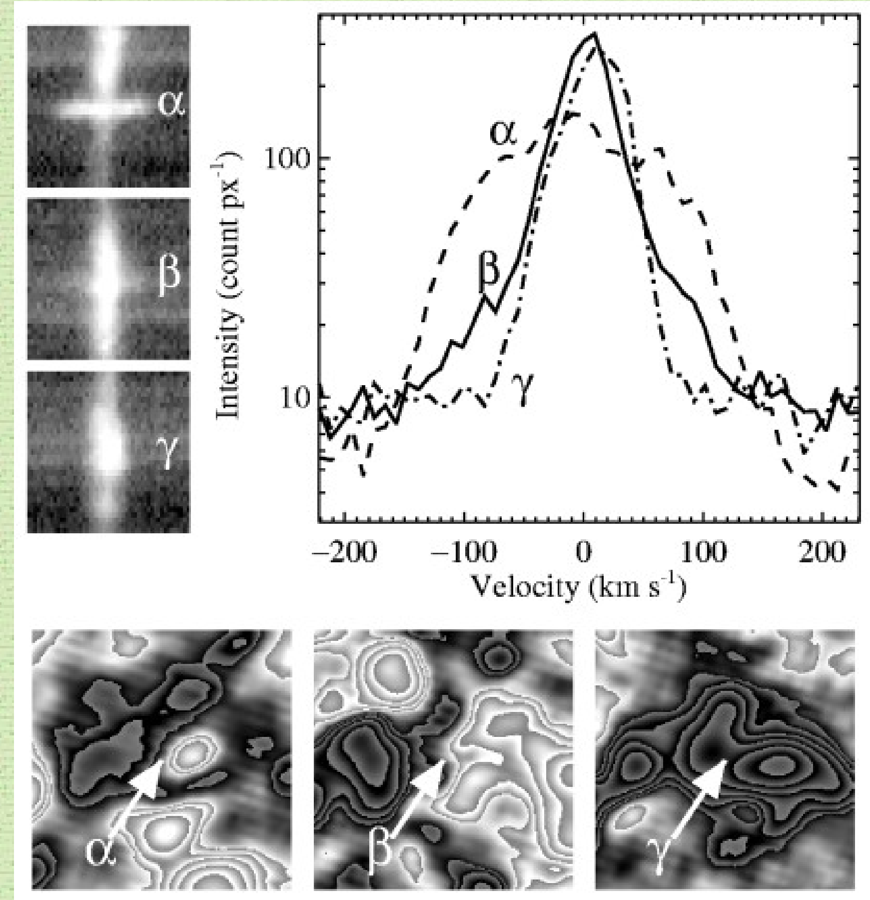


Spicules and Upflow Events



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. cornal heating 3 x 10^5 cgs

    Withbroe & Noyes (1977)

4. How are they explained?

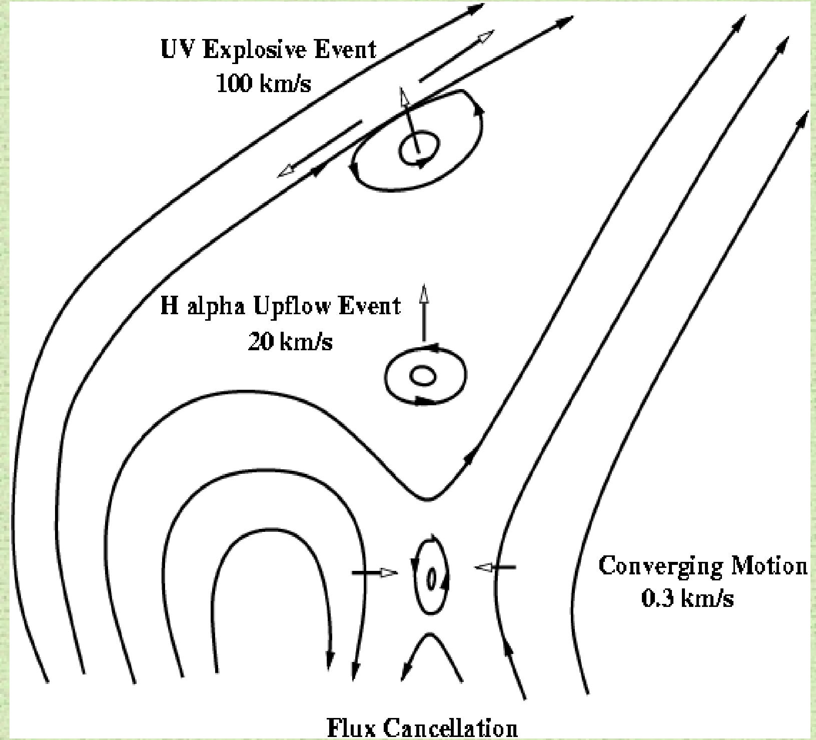
- Magnetic reconnection flow in transition region
  - Originally proposed by Dere et al. (1991)
  - Supported by: Innes et al. (1997), Chae et al. (1998a)
    - Bi-directional jet nature
    - Jet speed comparable to Alfven speed in the transition region
    - MHD simulation (Innes & Toth 1999)
    - 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 alpha 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