Diagnosing coronal loop dynamics

Outline

- Introduction
- Temporal variation
  - Loops at different temperatures
  - Hot upflow and cool downflow
- Diagnostic of coronal loop
  - Doppler velocity
  - Magnetic field extrapolation
  - Disturbance from photosphere
  - Pressure estimated from density
Top view

- Non-flaring active region on disk observed with AIA
- Hot loops in compact core
- Cool loops are extended
Side view

- Non-flaring active region at the limb
- Hot core and cool outer shell
Sporadic downflow

Sporadic downflow in cool emission

Darkenings in the corona
Apparent upward motion
Cooling in the corona

- Enhancement in cool emission coincided with darkening in corona.
  ➔ Cooling of coronal plasma
Time distance plots

- Falling of cool dense blobs in AIA-304 (51 km/s)
- Diffuse plasma (<1 MK) followed in AIA-171. Brightening at the bottom
- Continuous upward pattern in the corona in AIA-193. 82 km/s
- Increased after the falling cool plasma.
Lightcurve

- A dip in AIA-193
- Increase in cool emission (171&131)
- Cooling from 1 MK
- AIA-335 does not show related variation.
Simulation by H. Peter

Constant density

- AIA 211 [6.27] * 60
- AIA 193 [6.18] * 20
- AIA 171 [5.91] * 20
- AIA 131 [5.72] * 300
- AIA 304 [4.92] * 50

Constant pressure

- AIA 211 [6.27] * 60
- AIA 193 [6.18] * 20
- AIA 171 [5.91] * 20
- AIA 131 [5.72] * 100
- AIA 304 [4.92] * 1
Footpoint of loop system

- Doppler velocity indicates downflow at 0.6 MK, upflow at 1 MK
Time distance plot

- Apparent flow towards the footpoint in AIA-171
  35 – 43 km/s
- Continuously diverging motion in AIA-193
  57 – 88 km/s
- Enhanced after the cool flows
Interpretation

- Apparent motions are interpreted as plasma flow: continuous hot upflow & sporadic cool downflow
- Cooling of coronal plasma at loop apex decrease in AIA-193, increase in AIA-171&131
- Cool dense plasma falls down along the loop
- Coronal loop is emptied after the falling
- The upflow at 1 MK from the footpoint is enhanced
Magnetic field extrapolation

- An active region near the disk center.
- Linear force free field extrapolation from MDI magnetogram
- Determine an optimum $\alpha$ by comparing with TRACE image (Wiegelmann et al. 2005)
Temperature

- Hot loops in the core of active region
- Cool loops outside forms a fan structure above sunspot
Dopper velocity

- Downflow in the cool fan structure
- Upflow in hot emission, left part of the sunspot.
A hot loop in the core

- Enhancement of bluewing in leading sunspot (−35km/s)
- Redwing enhanced on the other end (+20km/s)
- Flow from the leading sunspot to following region
A cool loop

- Redshift in fan structure (+31km/s)
- Blueshift in the following region (–29km/s)
- Flow from the following region to the leading sunspot
Density diagnostic

- Density inferred from Fe XII line pair (186/195)
- Flow tendency from high density (O) to low density (X)
- Pressure imbalance between footpoints determines the flow?
Chromospheric activities

- Moving magnetic features outside the sunspot correspond to upflow in hot emission
- Magnetic field perturbation on the left side – hot loop
- Less activity on the right side – cool fan structure
3D Structure

- Cool loops are located higher than hot core loops
- Magnetic field strength rapidly decreases with height
Plasma $\beta$ along the loop

- Magnetic field extrapolation
- Electron density hydrostatic case $n = n_0 \exp(-h/H)$
- Plasma $\beta$ can be close to unity at loop apex
- Breakup of magnetic loop in non-flaring active regions?
Summary

- Perturbations at the footpoint cause heating
- Flow induced by pressure imbalance
- Coronal condensation (in long loops)
- Sporadic cool downflow
- Continuous hot upflow
Movie on disk