SPATIAL AND TEMPORAL ANALYSIS OF CORONAL RAIN WITH IRIS

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INTRODUCTION:

Coronal rain corresponds to the cool (10^3 - 10^5 K) and dense material seen in cold chromospheric or transition region lines, which falls toward the solar surface along coronal loops[1]. It is typically observed in flaring or active region loops.

Some Observational Facts:

- Coronal rain is formed when the heating is concentrated at the loop footpoint and for prolonged durations on the order of the radiative cooling time[2].
- Thermal instability sets in locally in a coronal loop that is in a global state of thermal non-equilibrium[3].
- Downward acceleration is typically much smaller (~1/3) than the effective gravity[4], probably caused by pressure restructuring[5].

Why Coronal Rain?

The properties of coronal rain are known to be strongly related to coronal heating, but the mechanisms behind its formation, dynamics and morphology are still hotly debated. In particular, it is unknown how widespread this phenomenon is over an active region.

DATA & METHOD:

We automatically detected coronal rain pixels using the Rolling Hough Transform (RHT) technique[6].

Date	: 06/02/2017
Instrument	: IRIS SJI (1400 Å and 2796 Å passbands)
Time sequence	: 07:28 UT and 12:55 UT
Cadence	: 43.1 s (1400 Å) and 32.2 s (2796 Å)
Spatial Sampling	: 0.3327 "/pixel
FOV	: 232"x182"
Raster step	: 64 (dense raster mode)

Scan the QR code for a movie of our coronal rain observation

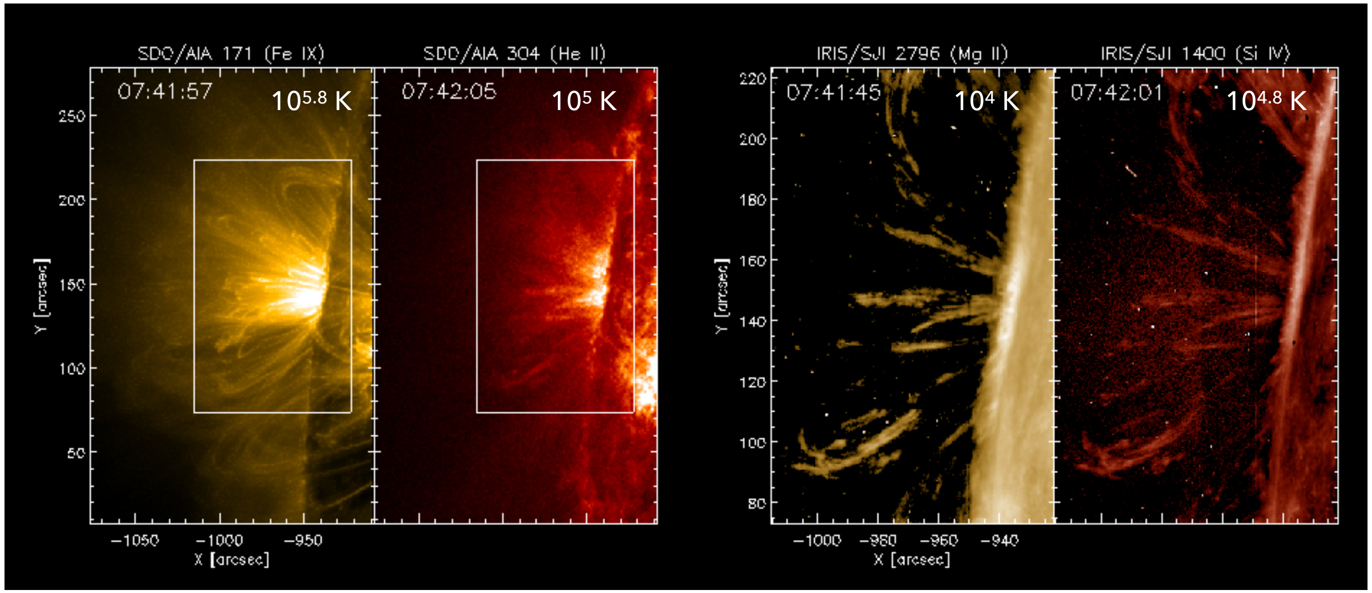


Figure 1. An active region at the East limb of the Sun on the 2nd of June 2017, co-observed by SDO/AIA and IRIS.

RESULTS:

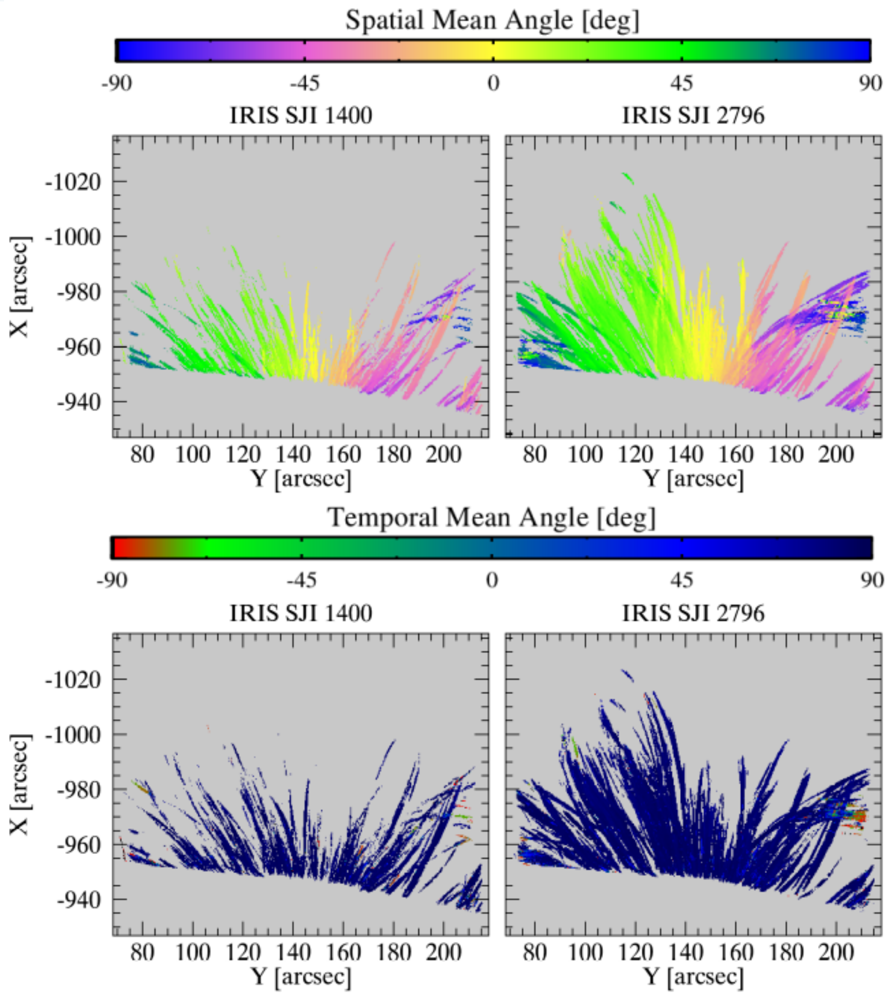


Figure 2. Average spatial (top) and temporal mean angle (bottom) maps.

The RHT method allows to obtain:

- Spatial mean angle (θ_{xy}) = inclination of the rain with respect to the vertical direction,
- Temporal mean angle (θ_t) = dynamical change along a trajectory.

- **Coronal rain is widespread over the active region.**
- **Coronal rain in chromospheric conditions is more extended.**
- **Downward motion is dominant.**

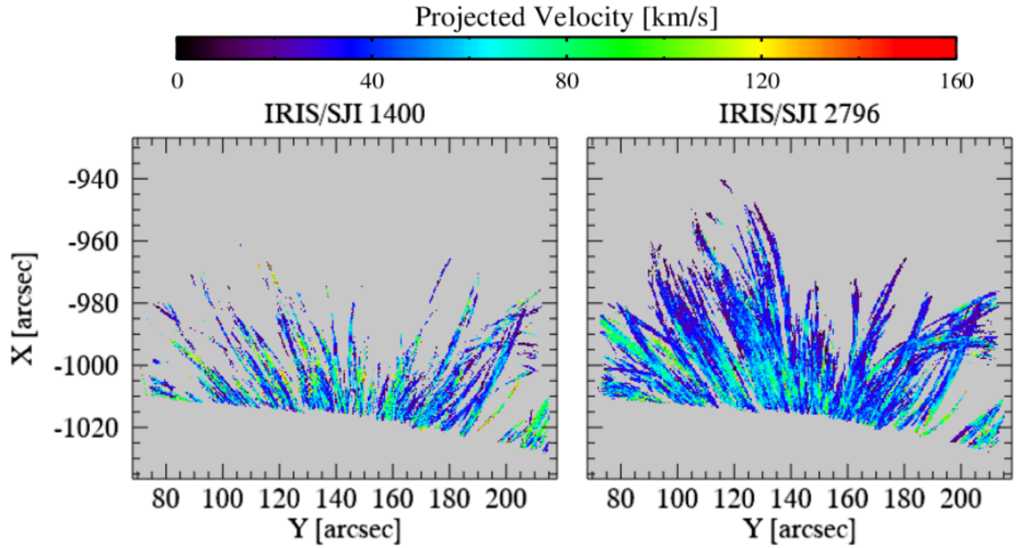
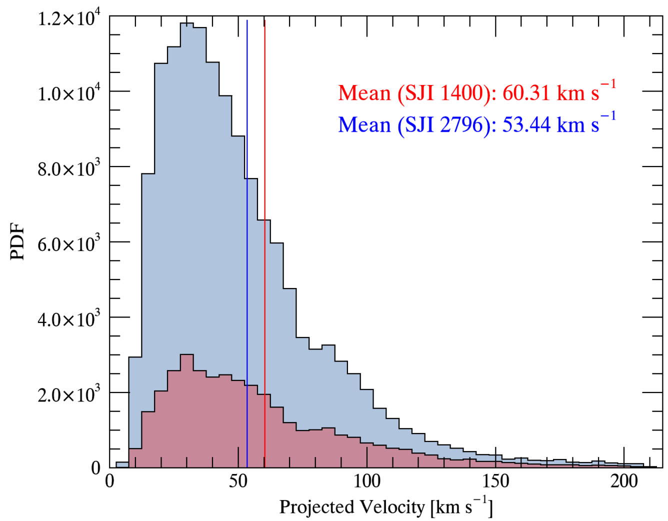


Figure 3. Average projected velocity maps.

- Tangential and Radial velocity maps are obtained from the temporal and spatial mean angles, which in turn provides the projected velocity:

$$v_p = \sqrt{v_{tan}^2 + v_{rad}^2}$$

- **Higher velocity values are found towards the active region centre.**



- **High velocity tails with peaks below 50 km/s, broadly consistent with previous results [4,5].**

Figure 4. 1D histogram distribution of projected velocity for SJI 1400 (red) and SJI 2796 (blue).

RESULTS:

- **Downward velocities are consistently lower than the free-fall velocity limit.**

- The contour plots show that the number of events detected in 2796 Å cover 1400 Å in all cases. On average, the heavier material (2796 Å) is not observed to fall faster than the lighter material (1400 Å), contrary to theoretical predictions [6].

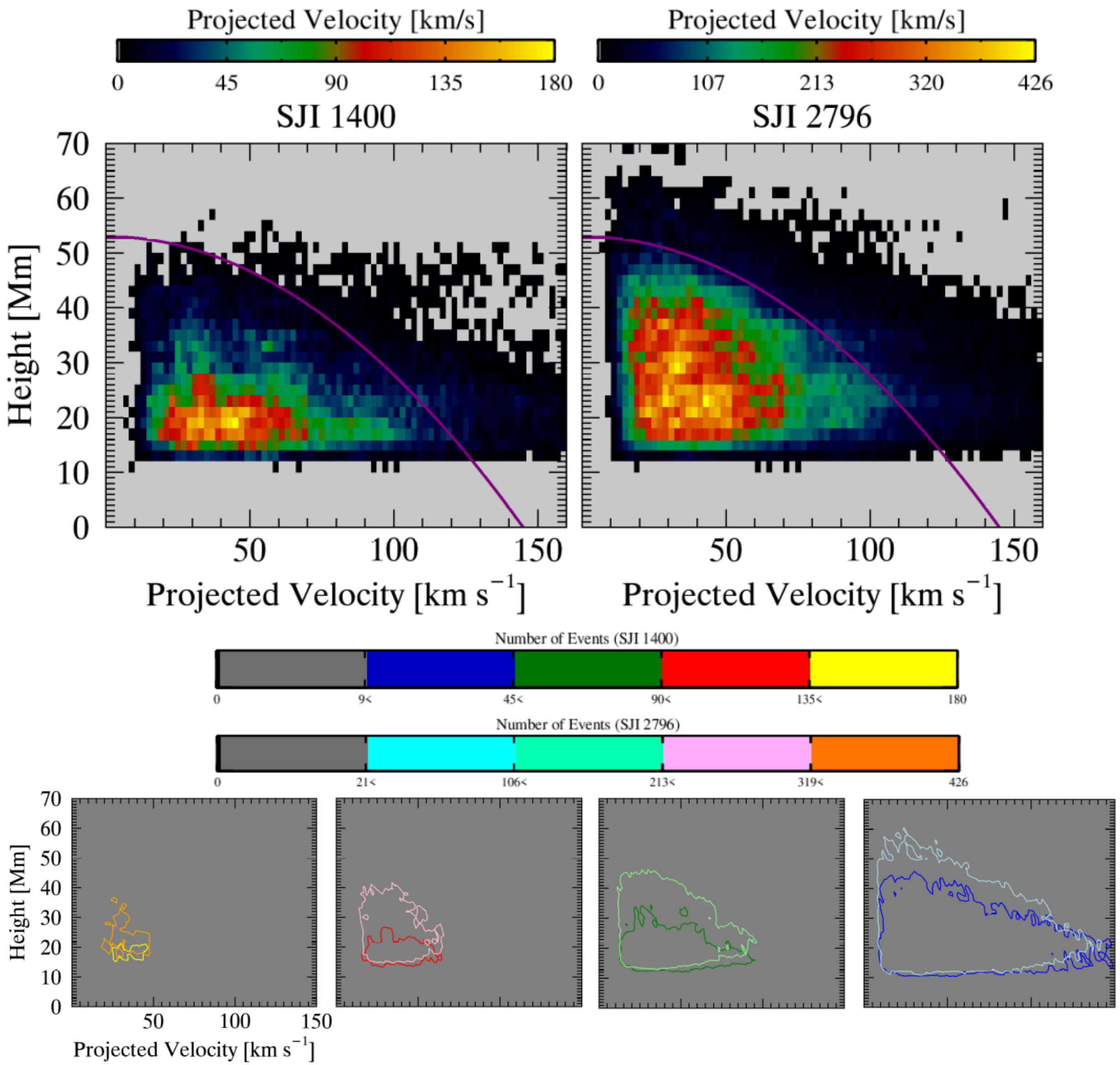


Figure 4. Two-Dimensional probability distribution functions (PDFs) (top) relative to height of projected velocity and their contour plots (bottom).

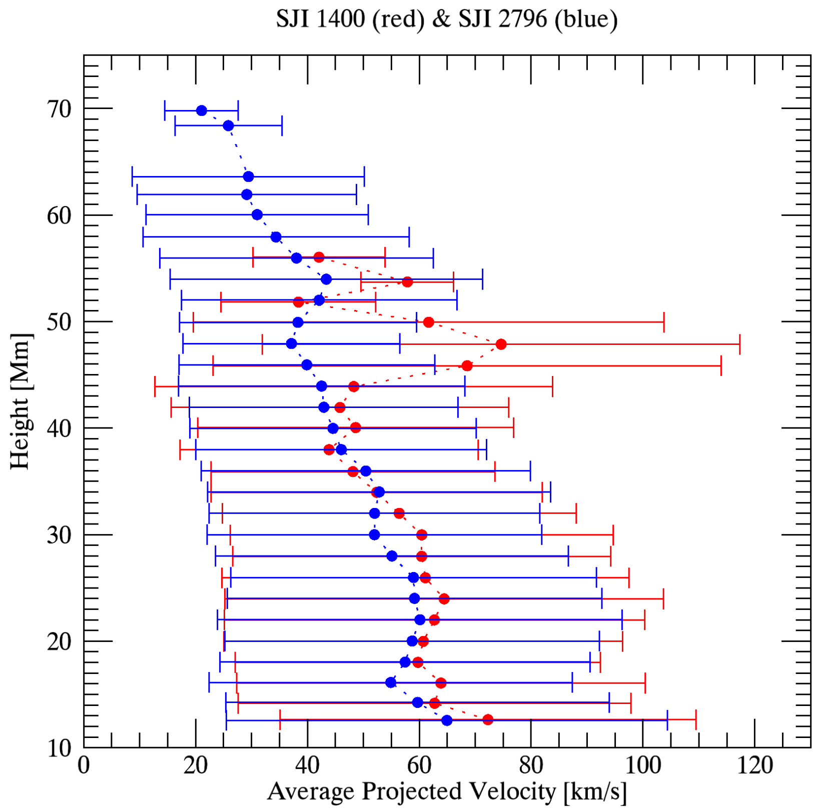


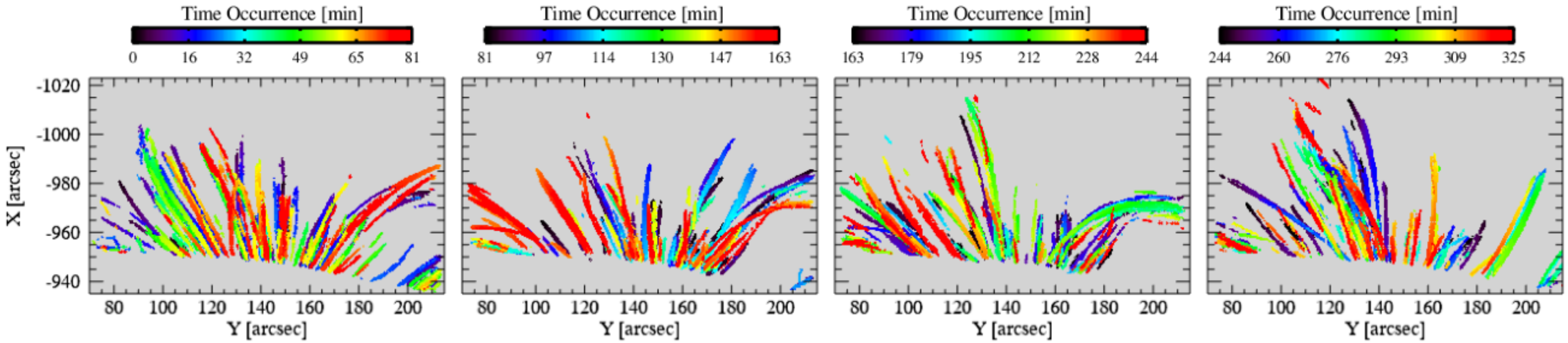
Figure 5. Average projected velocity at several heights, with 2 Mm binning.

- The 1400 Å velocity values appear slightly larger with stronger variation than the 2796 Å velocity values at almost all heights.

- A linear increase in velocity for both 2796 Å and 1400 Å Is observed between 20 and 50 Mm, With 1400 Å clumps being steadily 10-15 km s^{-1} faster.

RESULTS:

SJI 2796



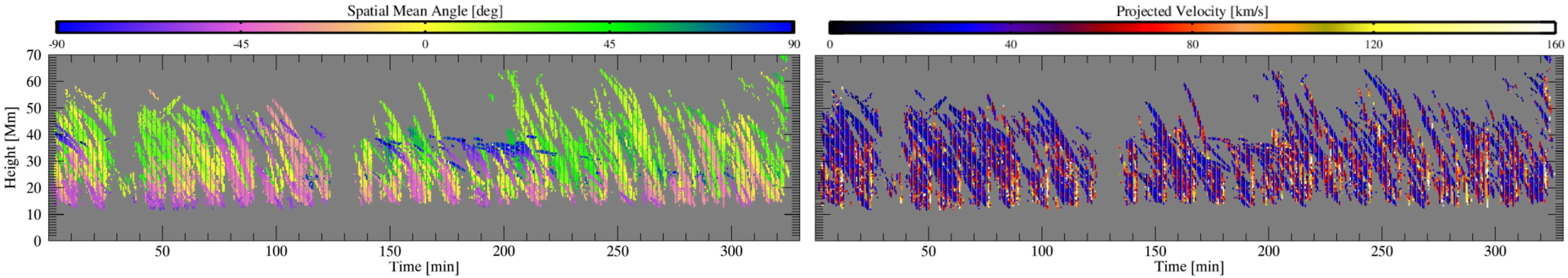


Figure 6. Space-time diagram of projected velocity (right) and spatial mean angle (left) for SJI 2796.

- The curved nature of coronal loops is clearly reflected in the rain trajectory
- A clear downward acceleration for each rain event (shower) is observed
- The duration of a rain event (shower) is ~10-20 min
- Rain shower width: 2 – 5 Mm
- A periodic occurrence for the rain events is observed (~10 min)
- Rain is continuously observed over the active region

DISCUSSIONS & CONCLUSIONS:

- Coronal rain dynamics are consistent with previous findings[4,5].
- Linear increase with lower height in velocity: combination of effective gravity and pressure restructuring[5] ?
- Rain in 1400 Å is observed to fall slightly faster (10-15 km/s) than that in 2796 Å, contrary to theory.
- Coronal rain is widespread across the active region, irrespective of the loop inclination, with minimal variation over the 4.5 hour duration of the observation. Showers occur periodically (10 min). However, raster motion may contribute to this periodicity.

➡ ***Prevalence of thermal non-equilibrium (TNE) over this active region.***

Future Work:

- AIA 304 analysis.
- Spectral properties: non-thermal broadening, Doppler velocity, and line opacity.
- Fourier and wavelet analysis of the imaging and spectra: short and long periodicities in the rain occurrence.
- Width of rain clumps and showers is under investigation.
- Estimate fraction of coronal volume under TNE and the contribution of coronal rain to the mass and energy cycle.

References:

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