An Examination of Observed Coronal Structures through Automated Techniques Across Solar Cycle 24

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Background & Aims

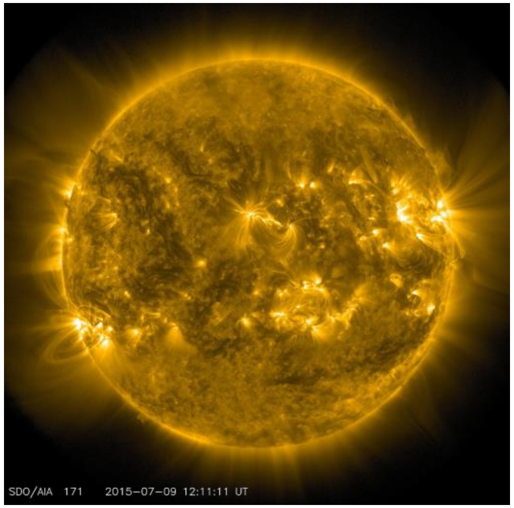
- The solar corona presents a difficult environment for solar physicists studying the properties and topology of coronal loops and their underlying magnetic structures. But techniques have been developed to trace and measure properties of coronal loops in various EUV wavelengths.

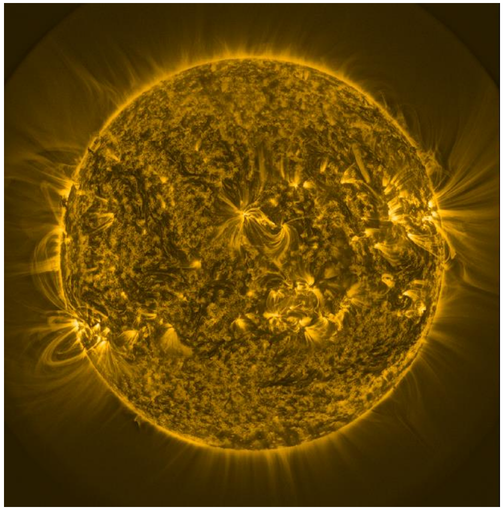
- Previous studies of coronal loop properties centered around single active regions of interest, wider trends tied to changes of the coronal magnetic field across the solar cycle missed. This work attempts to examine and quantify changes to coronal loops across solar cycle 24.

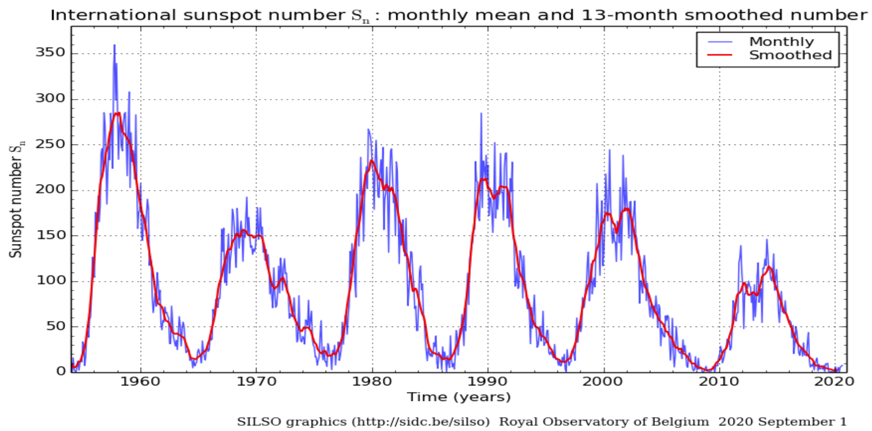
Dataset

- Using EUV data from NASA's SDO – AIA instrument, tens of thousands of coronal loops have been automatically detected and measured, and properties such as width and latitudinal position recorded.

- Tens of thousands of loop widths and positions have been identified in this way, and trends relating to North – South asymmetry and S.O.C power law loop width distributions analysed and outlined.







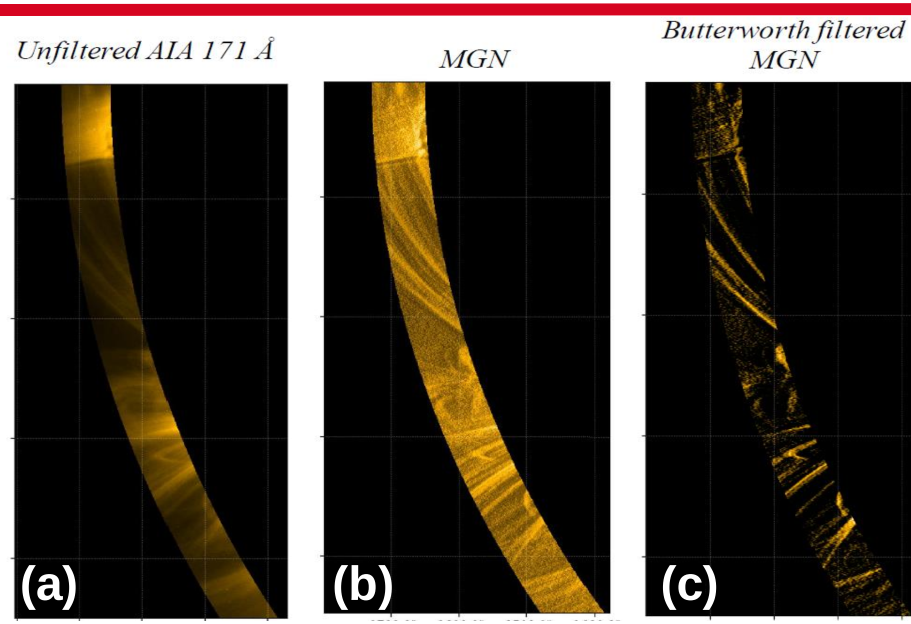
Tracing & Measurement – Algorithms and Annuli

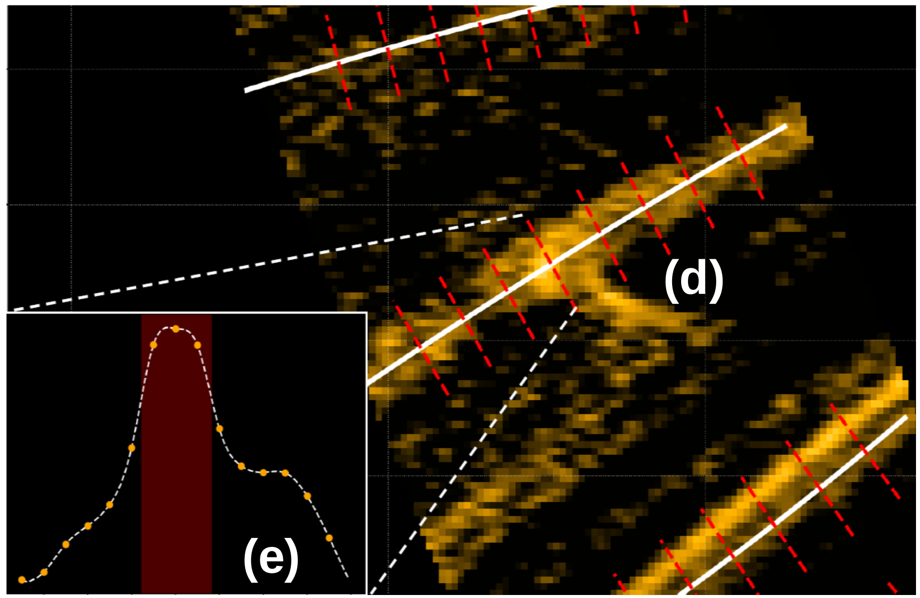
Image Filtering

- Limb loops are chosen for simple background to help aid automatic detection.
- Data taken from 171, 193, 211 and 304 Angstrom wavelengths from SDO AIA. **(a)**
- Annulus drawn from 1.05 to 1.10 solar radii to avoid emission from the foreground and background close to any imaged objects.
- Resulting image is filtered using MGN (Multi-Gaussian-Normalization, Morgan, H & Druckmüller (2014[1])) **(b)** to draw out local contrasts and then filtered again using butterworth/gaussian **(c)** filters to highlight edge geometry of loop structures.

Identification & Measurement

- Loop tracing and detection uses a modified OCCULT-2 algorithm (Markus Aschwanden et al., 2017)[2].
- Coordinates used to produce 8 cross sectional slices from identified structure. Average used for cross section. **(d)**
- Gaussian profiles fitted to average flux profiles, parameters of width and position extracted with associated uncertainties. **(e)**





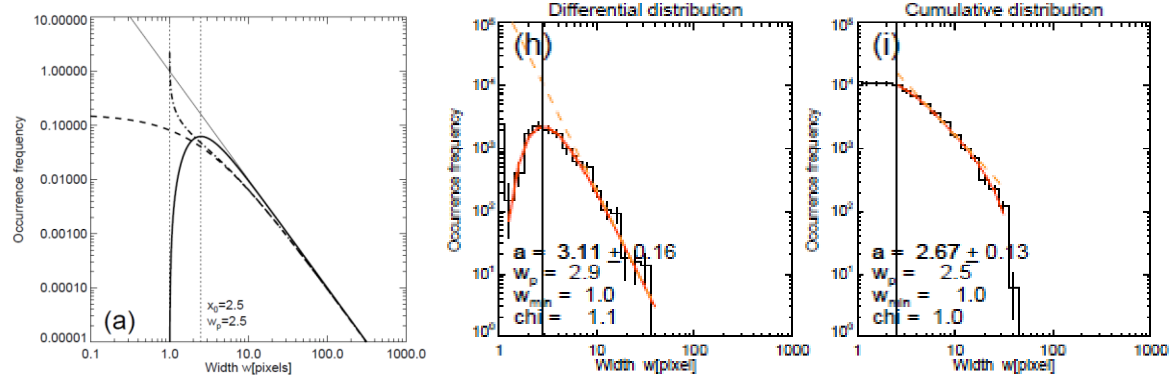
1. Morgan, H & Druckmüller, M. (2014). Multi-Scale Gaussian Normalization for Solar Image Processing. *Solar Physics*.
2. Aschwanden, M et al.. (2014). Optimization of Curvilinear Tracing Applied to Solar Physics and Biophysics . *Entropy*.

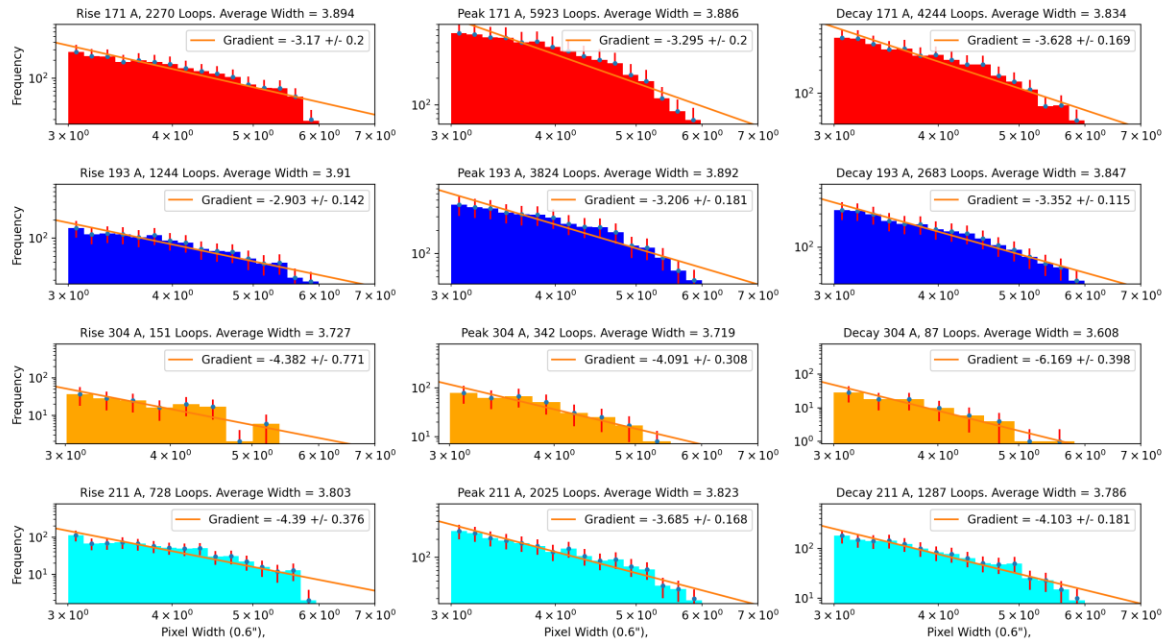
Width Frequency – S.O.C Variation Across Solar Cycle

Results – S.O.C Distribution & Variation

- Tens of thousands of loop widths from four EUV bands compiled into histograms.
- S.O.C (Self-Organized-Criticality)[2] describing cascading nonlinear local processes with characteristic power law distribution.
- Power law gradients describing frequency dependence on loop width constructed. Higher gradients indicate lower loop widths for a population and vice versa.
- "Ideal" S.O.C model indicated gradient around 2.5 expected for population. Observational active region population around 3.11
- Gradient varies from 2.9 to 4.39, indicating less wide structures than expected from model.
- Evidence of changing magnetic activity within the coronal field as solar cycle changes.

Figure (a), (h), and (i) from Aschwanden , M & Peter, H (2017)[1]





1. Aschwanden, M & Peter, H. (2017). The Width Distribution of Loops and Strands in the Solar Corona—Are We Hitting Rock Bottom?. *The Astrophysical Journal*.
2. Bak, P., Tang, C., & Wiesenfeld, K. 1987, Phys. Rev. Lett., 59, 381

Latitude Frequency– N-S Asymmetry Indicators Over Cycle 24

Results – Latitude Frequency & N-S Asymmetry

- Tens of thousands of coronal loop latitude positions recorded.
- Rise period – initial phase of solar sunspot increase. (2010 – 2012)
  Peak period – maximal period of solar sunspot activity. (2012 – 2015)
  Decay period – period of decreasing solar sunspot activity. (2015 – 2020)
- North – South loop asymmetry compared to daily and monthly sunspot averages.
- Normalized counts show good agreement, indicating that coronal loop activity is closely tied to sunspot activity.
- Indicates a strong connection between photospheric magnetic activity and coronal magnetic field behaviour.

Future Work

- Refining techniques, and extending survey to include polar regions/streamer structures.
- Applying technique to other datasets; Solar Orbiter + XRT – will benefit from increased wavelengths and spatial resolution.