The Impact of Sunspot Rotation on High Flare Energy Active Regions

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Motivation

Evershed, 1910: First observations of sunspot rotation.

Stenflo, 1969: Suggested sunspot rotation as mechanism to generate flare energy.

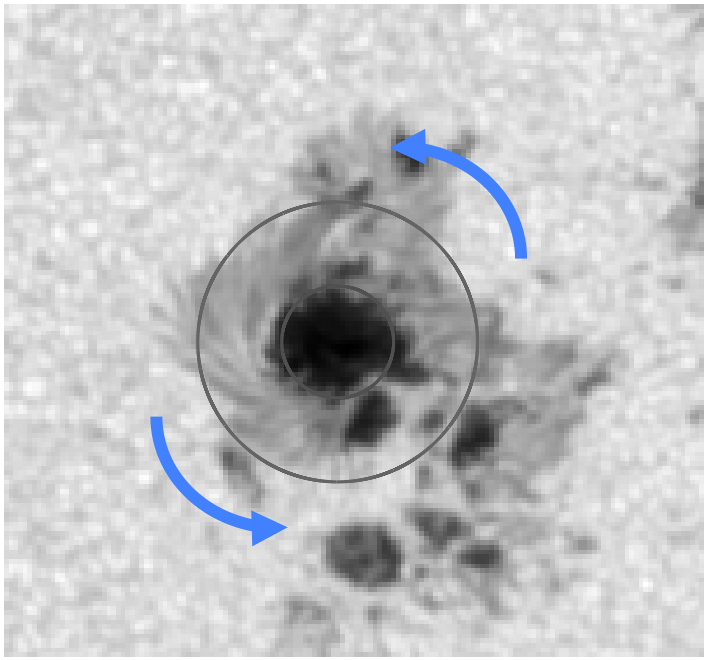
Brown et al., 2003:

- Seven sunspots studied using TRACE data.
- 150 – 200° rotation over 3 – 5 days.
- Six out of seven of these associated with flare events.

More recent work: Case studies, torsional oscillators, modeling, subsurface flows.

Sunspot Rotation

Rotation about the umbral centre of a sunspot.



What role does sunspot rotation play in X-class flare events?

X-class flare producing regions from April 2010 to May 2015:

26 X-class flare producing active regions.

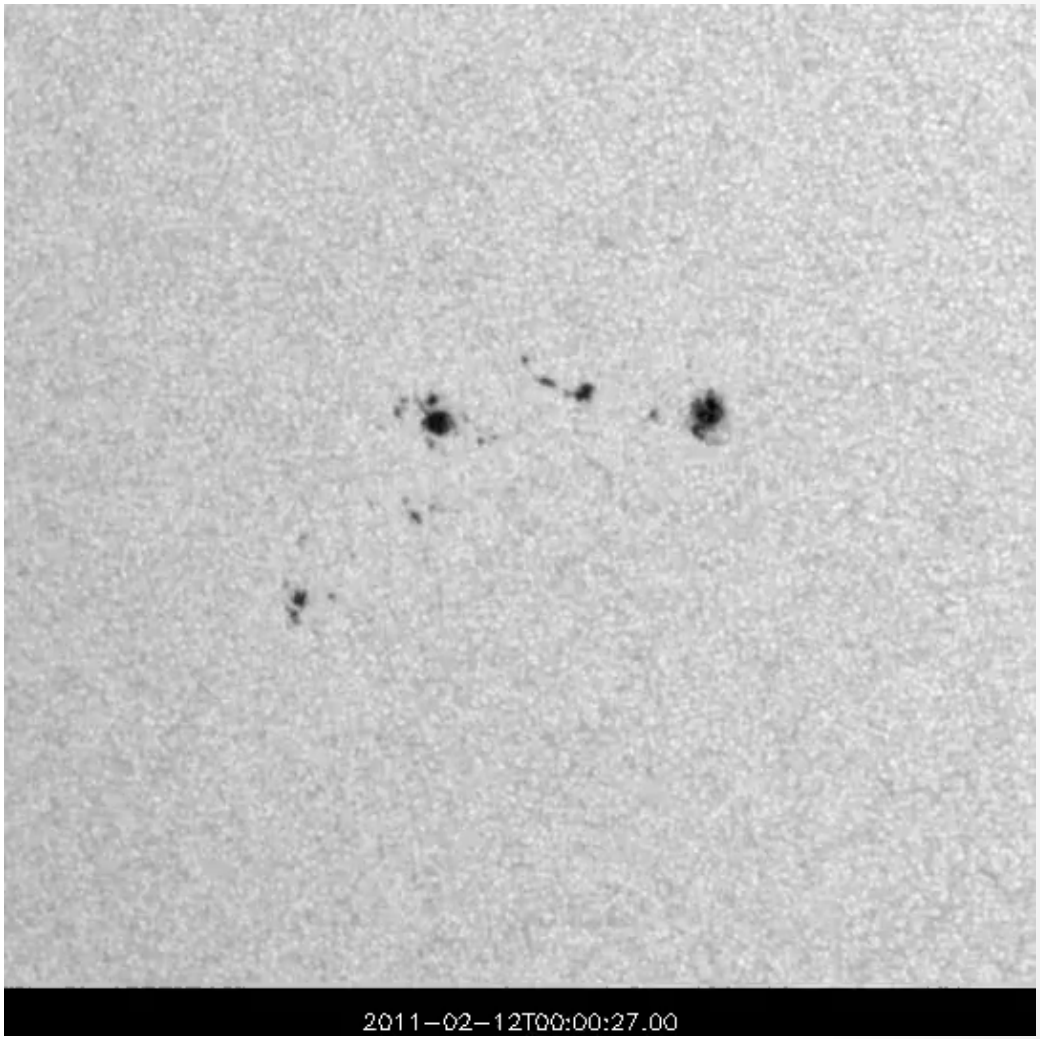
67 sunspots.

42 X-class flares.

Rotation properties of each sunspot are calculated.

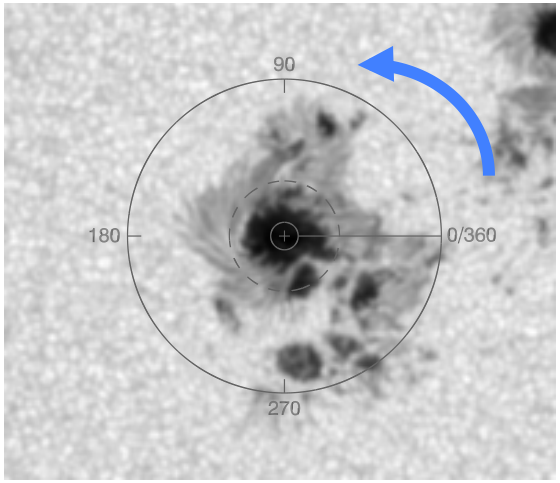
NOAA 11158

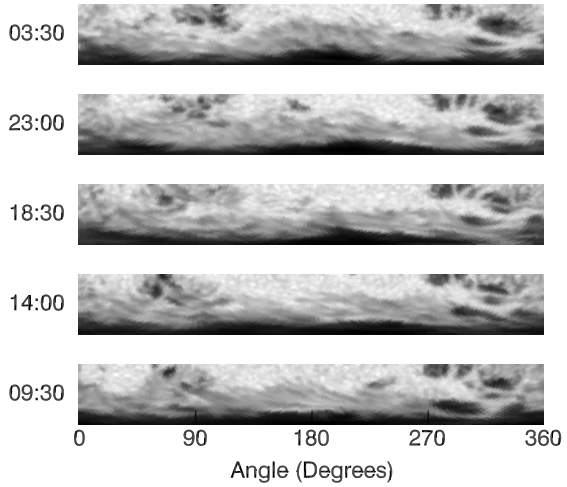
SDO/HMI white light images.



Analysis: The Method

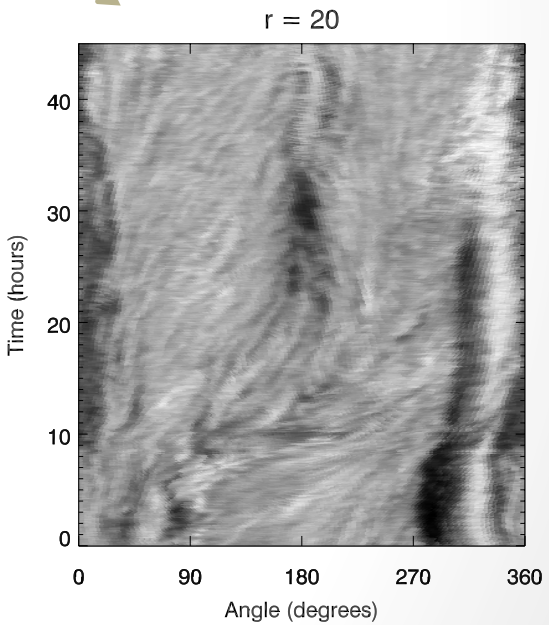
1. Begin with HMI Continuum clip of sunspot region.





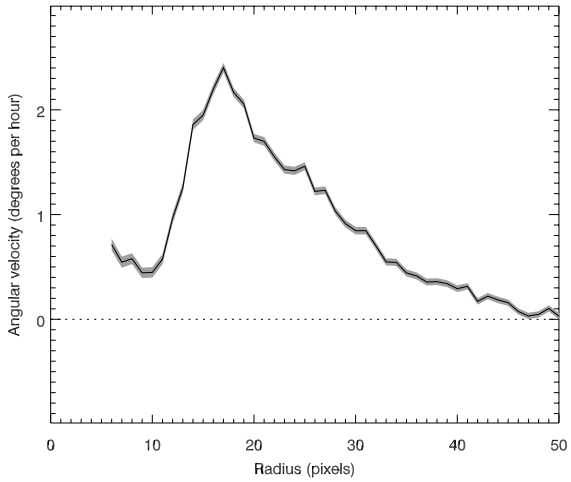
2. Anti-clockwise uncurling of annulus.

3. Radial slice taken at each point in time.

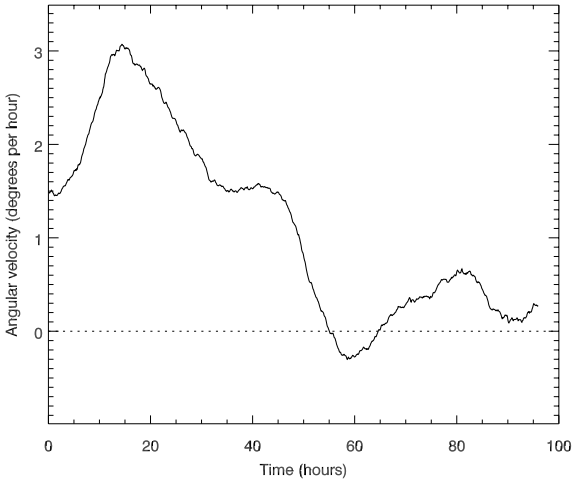


Analysis: The Output

1. Radial profile

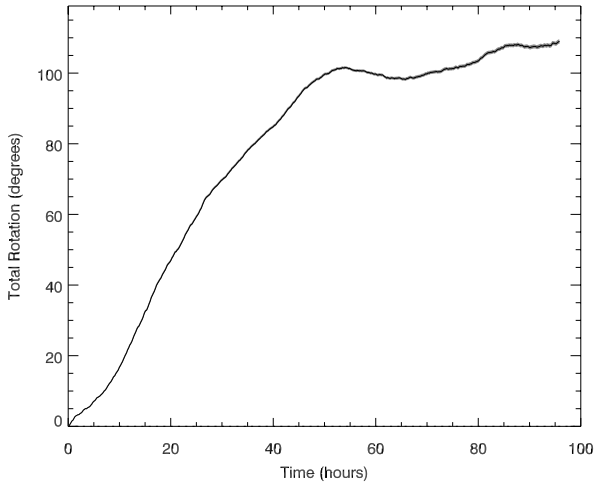


2. Velocity profile

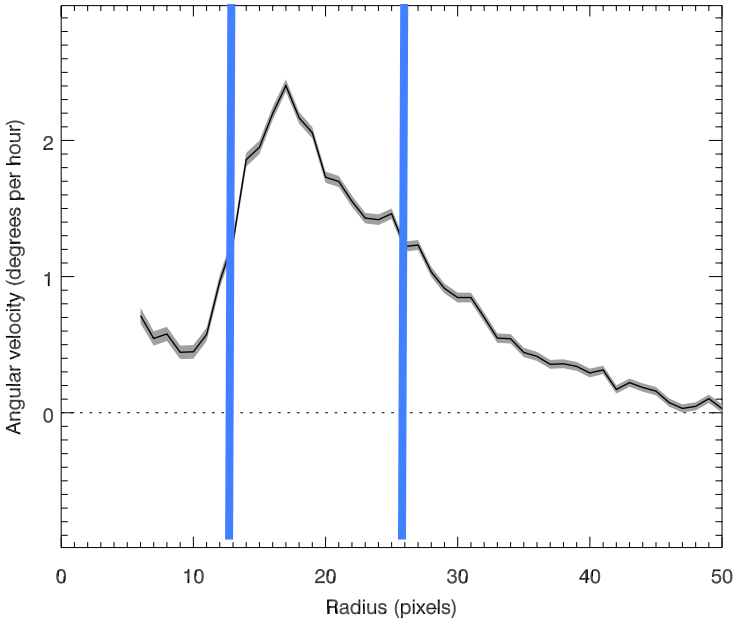


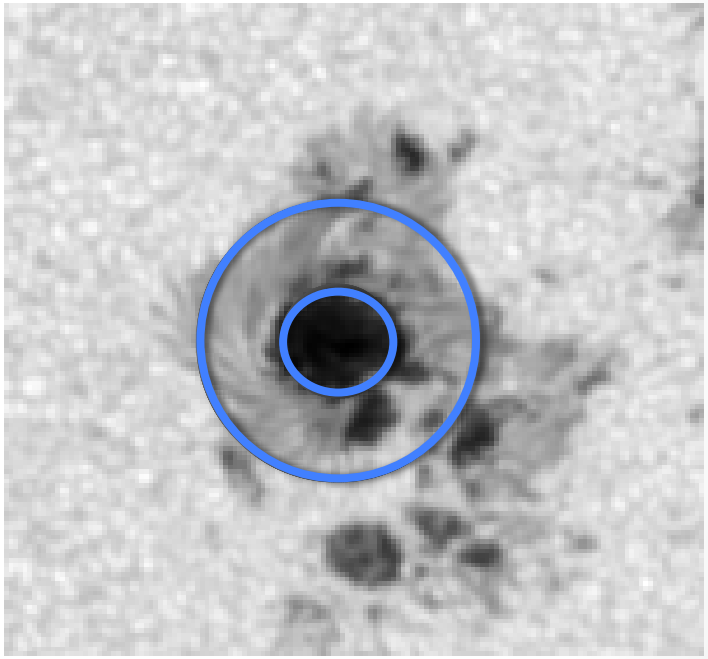
Integrate

3. Rotation against time



Analysis: Isolating the Penumbra



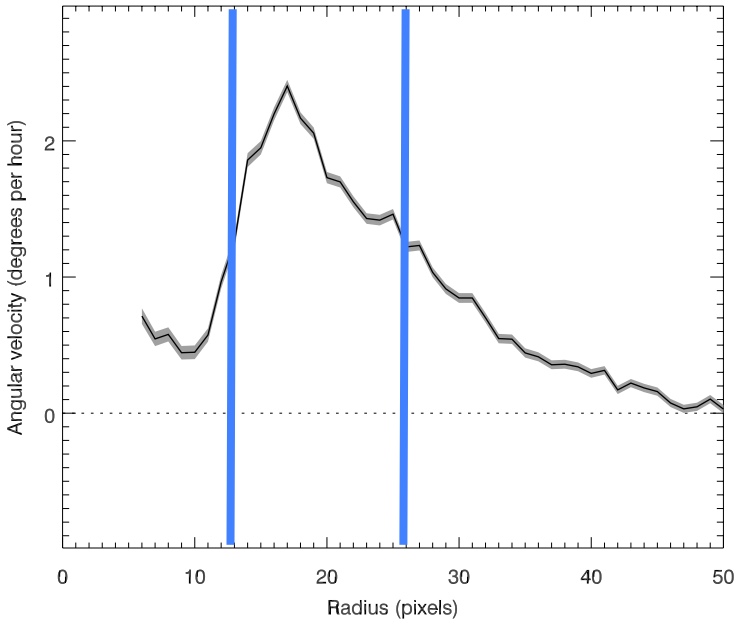


Significant Rotation

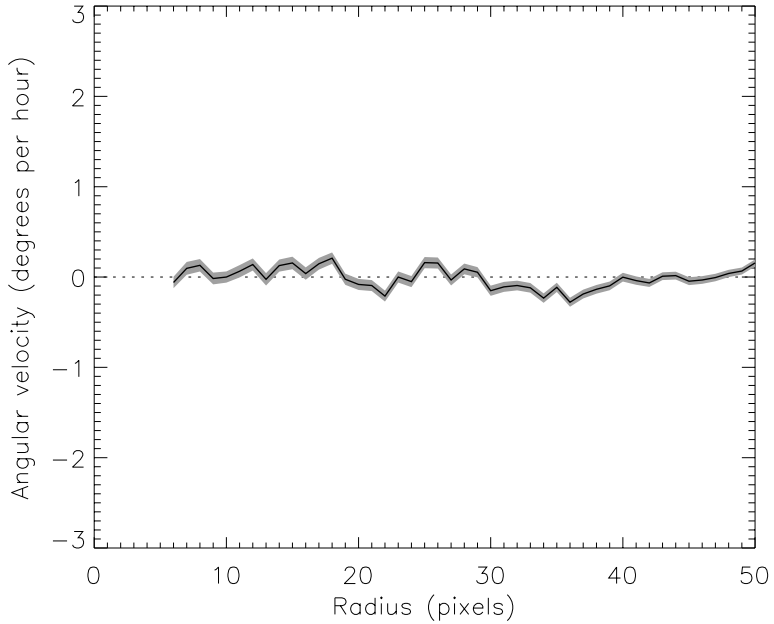
Kazachenko et al. (2009): 34° rotation enough to power M8.0 flare.

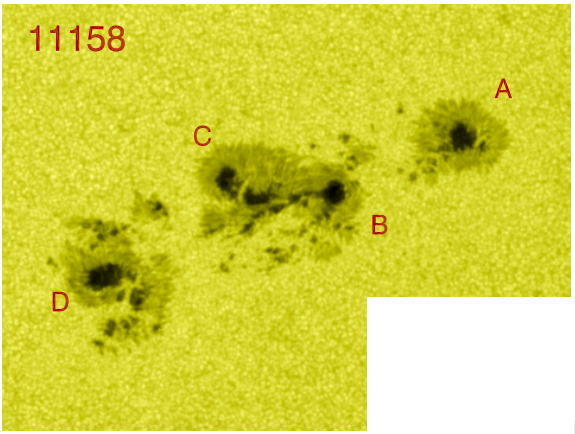
Sunspots with >30° rotation show a penumbral peak which we can isolate:

109° Maximum rotation:

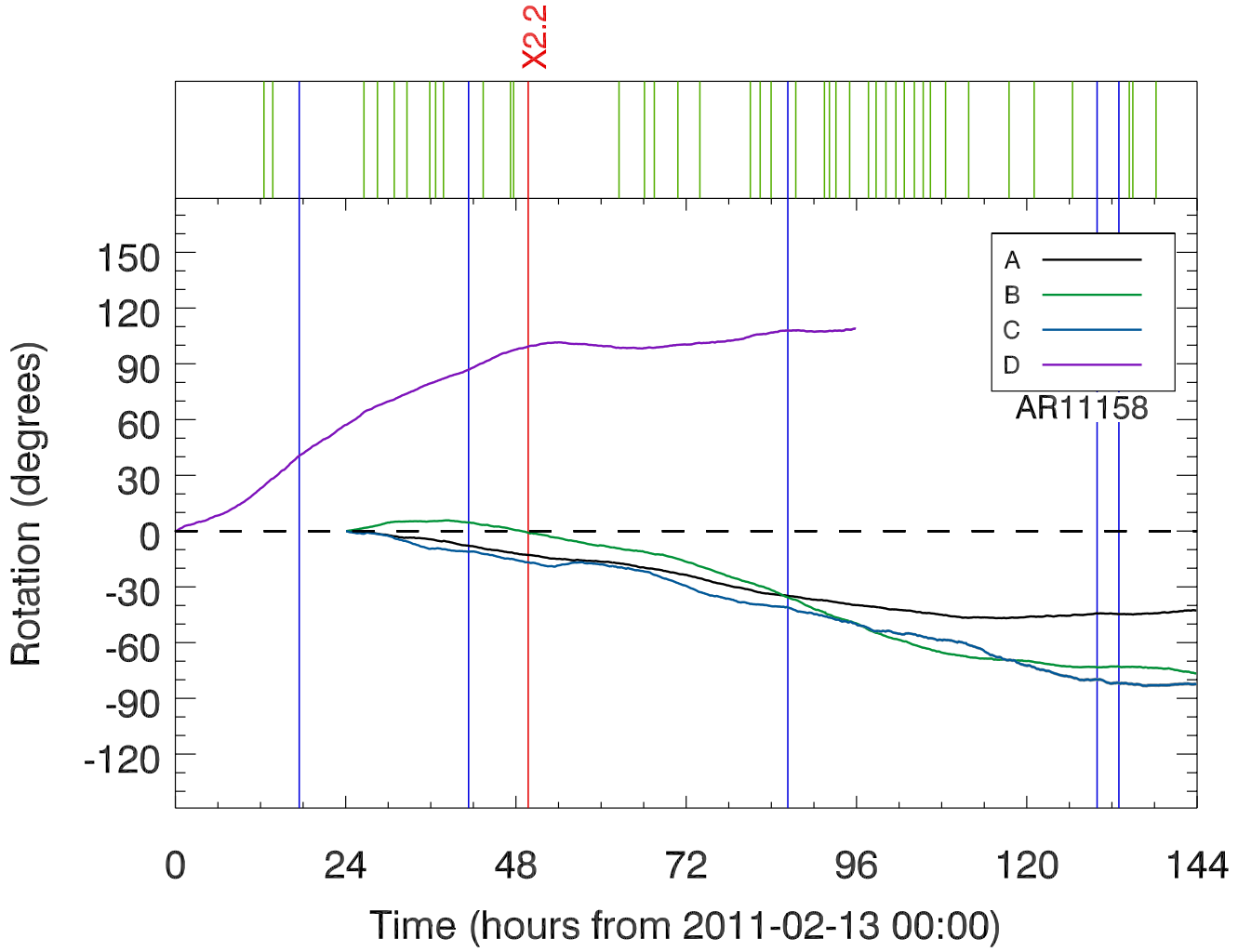


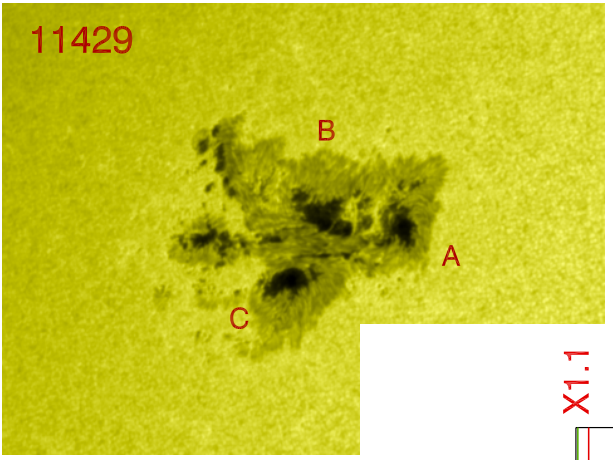
16° Maximum rotation:

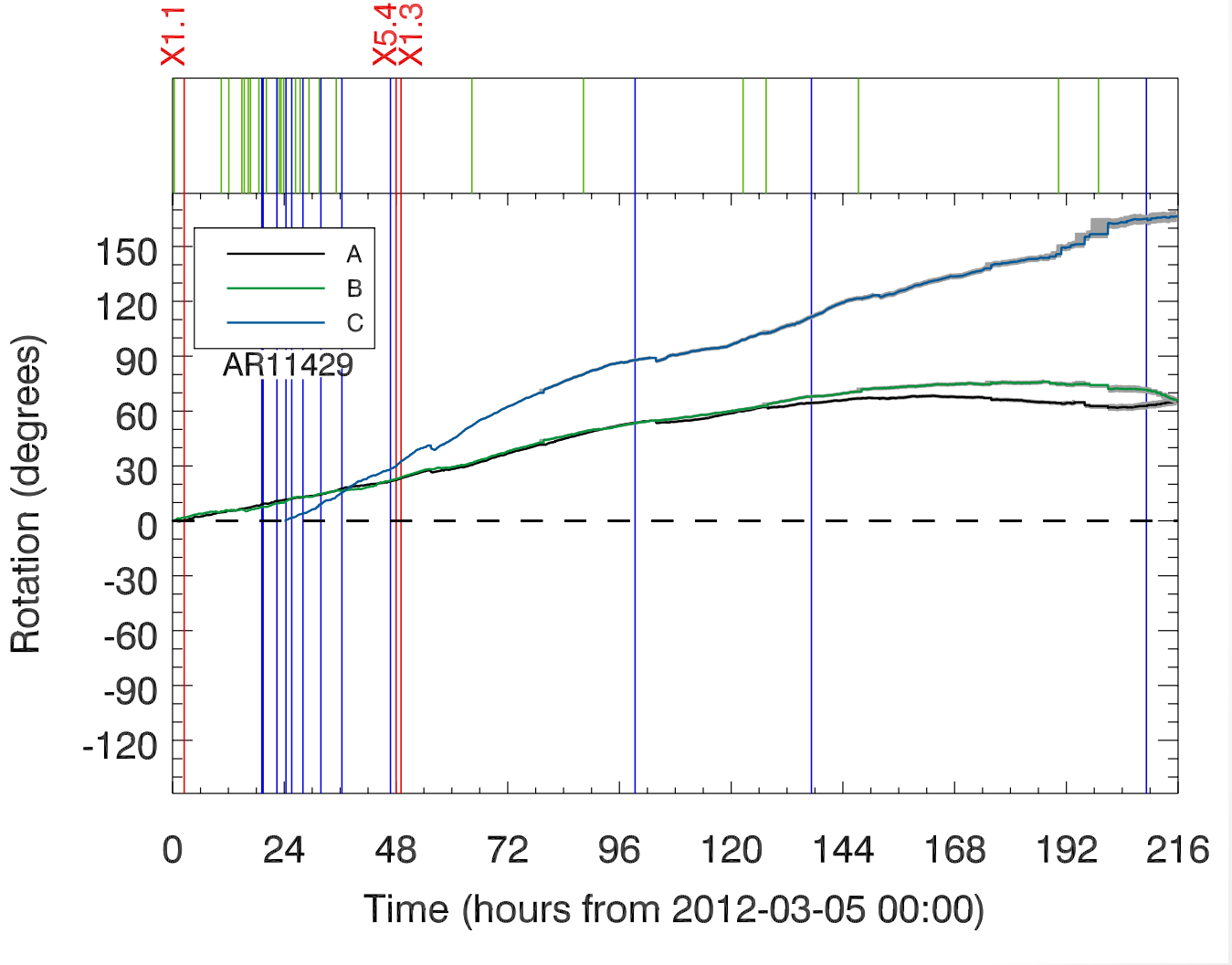


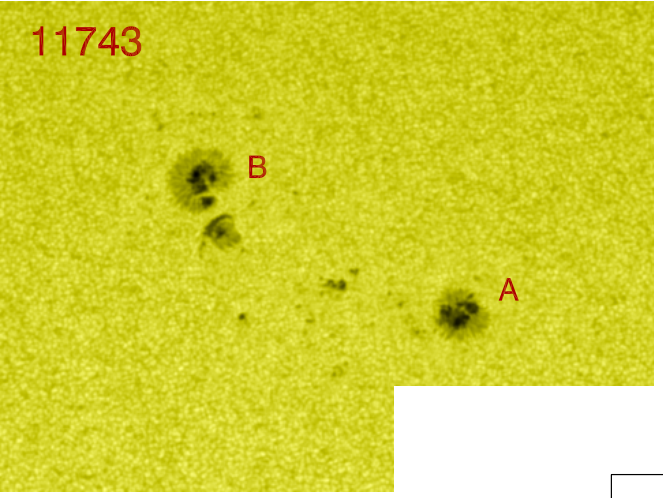


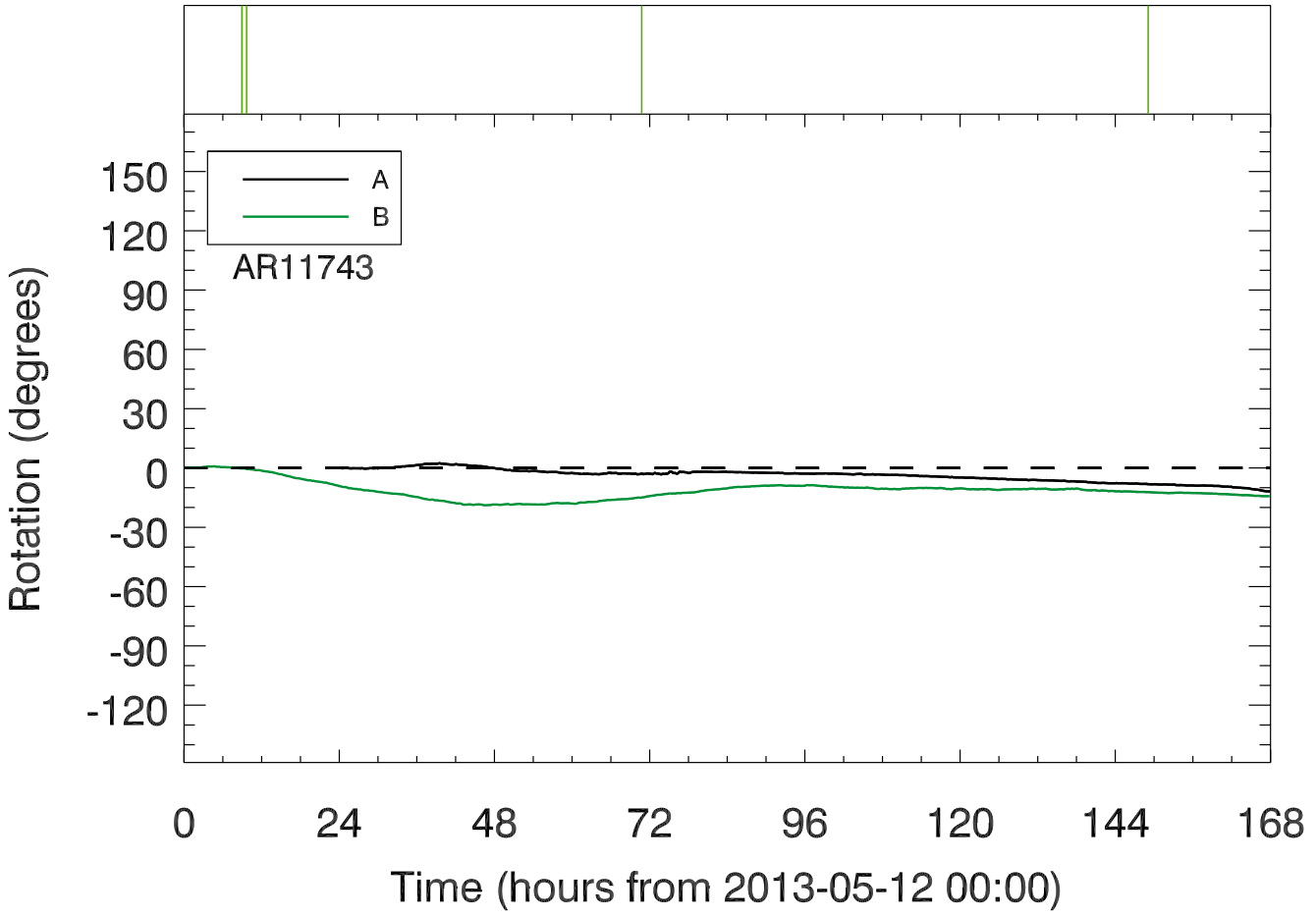
Results: Profiles




11429
B
A
C


X1.1
X5.4
X1.3
A
B
C
AR11429
150
120
90
60
30
0
-30
-60
-90
-120
Rotation (degrees)
0
24
48
72
96
120
144
168
192
216
Time (hours from 2012-03-05 00:00)


11743
B
A


A
B
AR11743
150
120
90
60
30
0
-30
-60
-90
-120
Rotation (degrees)
0
24
48
72
96
120
144
168
Time (hours from 2013-05-12 00:00)

Total Absolute & Net Active Region Rotation

Total absolute rotation: Total unsigned rotation of all sunspots in the region

Net rotation: Total signed rotation of all sunspots within the region.

For example: An active region with 3 sunspots:

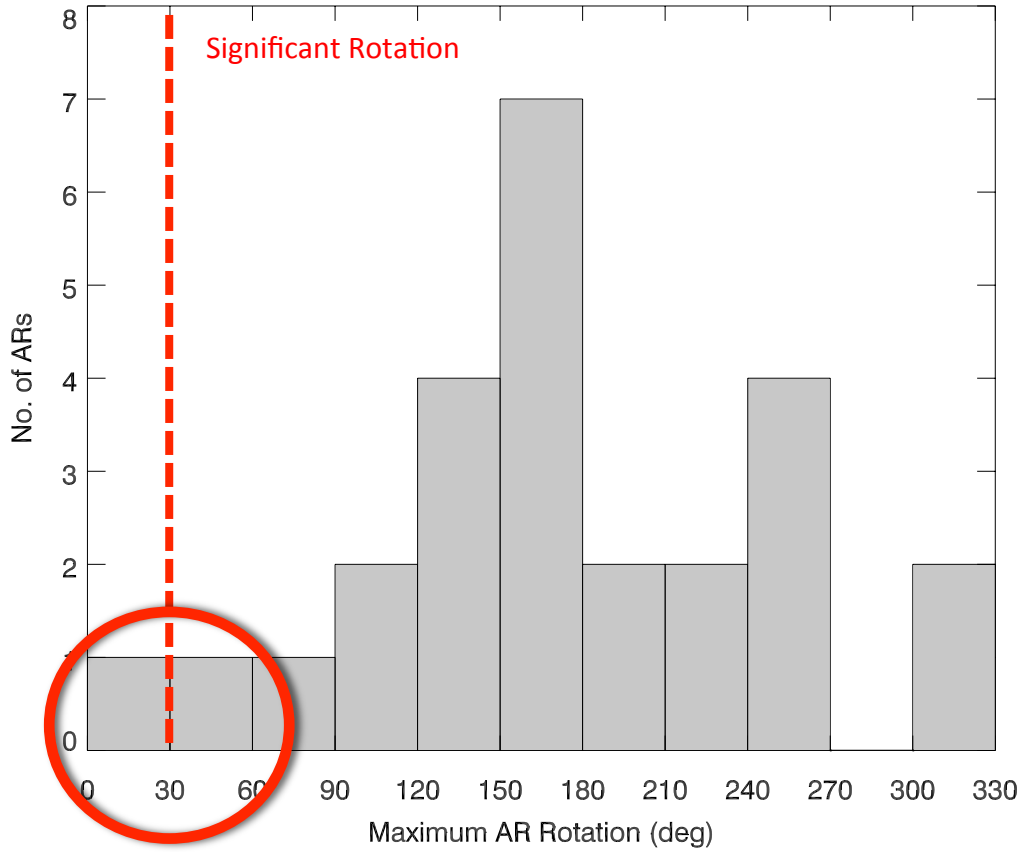
A: -50° rotation
B: 100° rotation
C: -25° rotation

Will have a total absolute rotation of 175°

And a net rotation of 25°

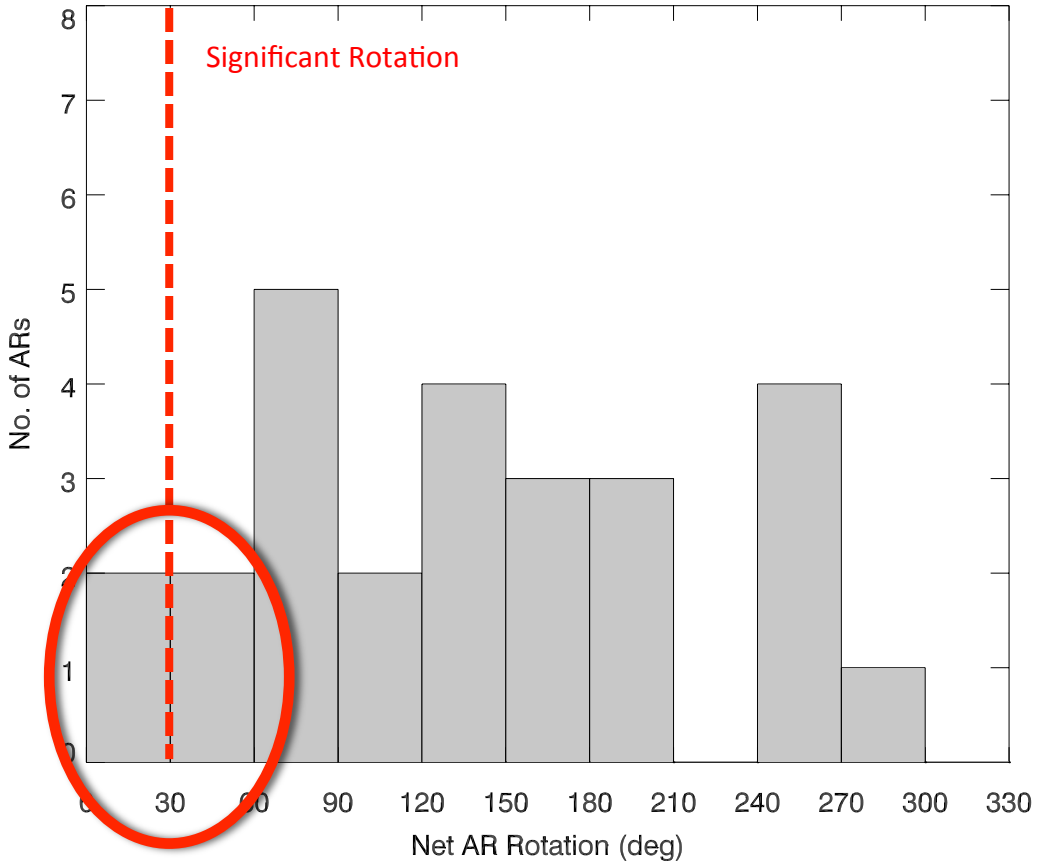
Total Absolute Active Region Rotation

Sum of sunspot rotation within each region neglecting direction of rotation.



Net Active Region Rotation

But the rotation direction can affect the magnitude of twist injected into flux tube.



Concluding Remarks

1. The sample is restricted to X-class flare producing regions only

2. 25 out of 26 active regions analysed contain <u>at least one</u> sunspot with significant rotation.

3. All active regions below 60° absolute and net rotation traverse the Eastern limb fully formed.

There is a strong relationship between high-flare energy regions and sunspot rotation.

Future Work

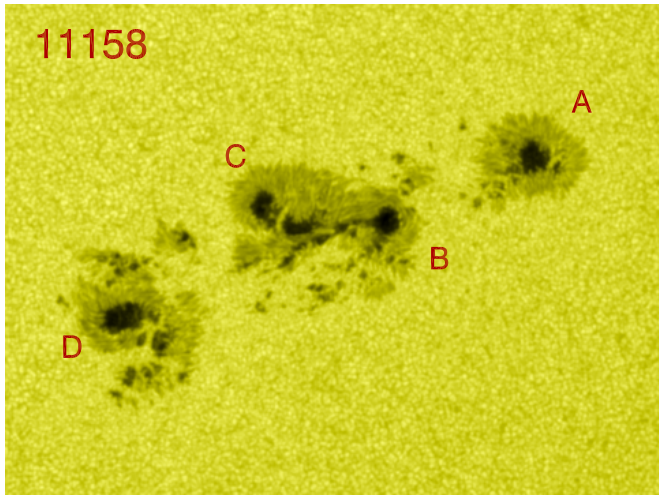
	High Rotation	Low Rotation
High Flare Energy	25	1
Low Flare Energy	?	?

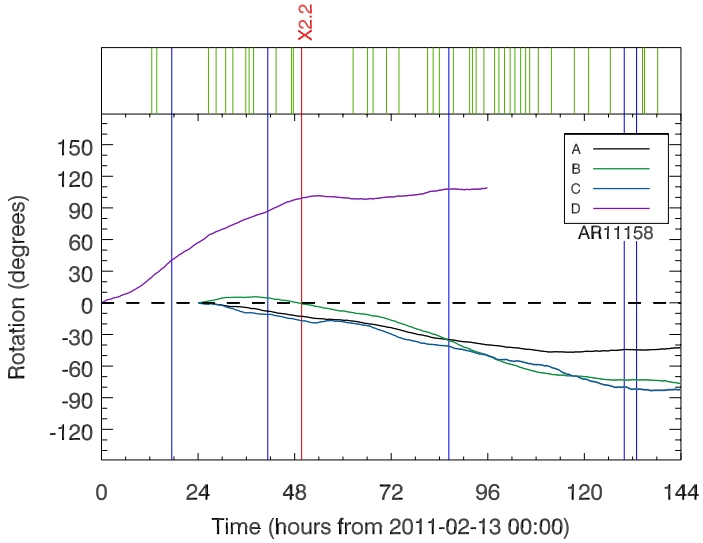
Thank you for listening.

Questions?

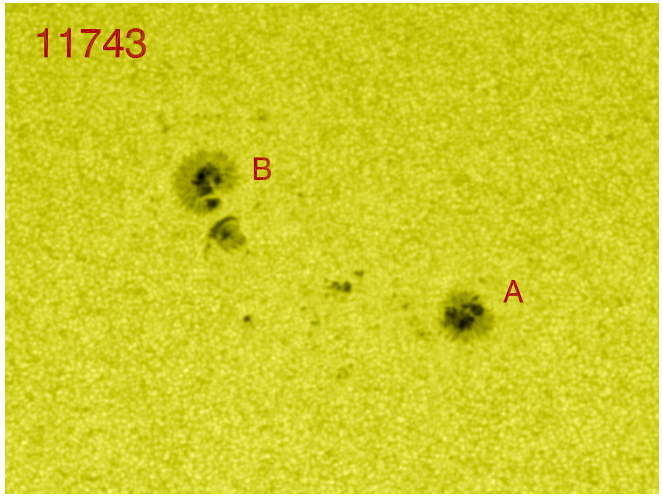
Results: For Comparison

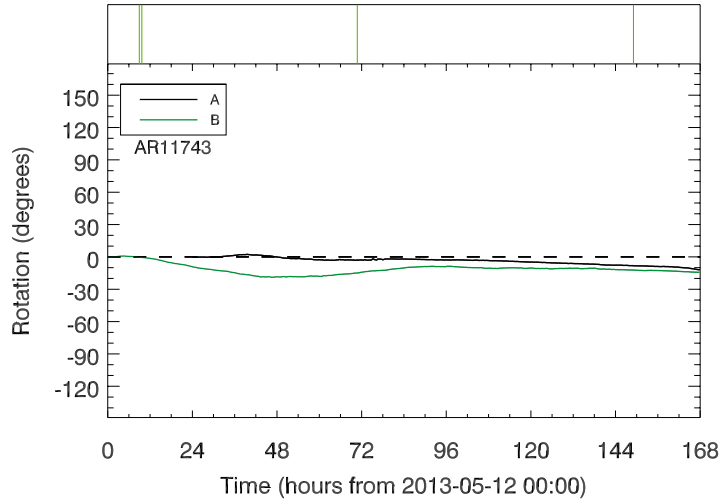
X-flare region:





Non-X-flare region:





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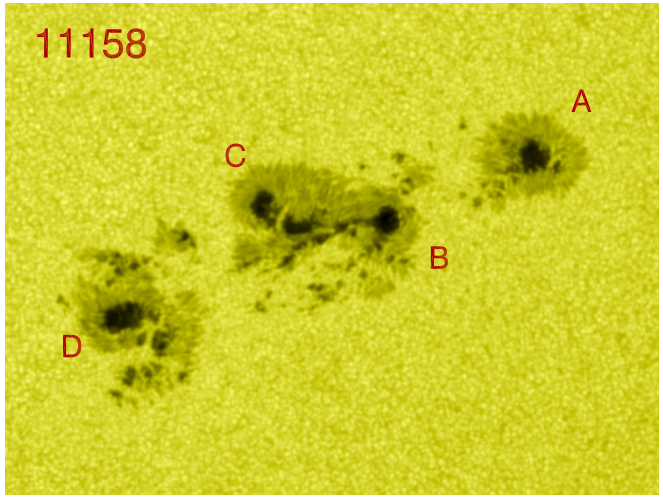

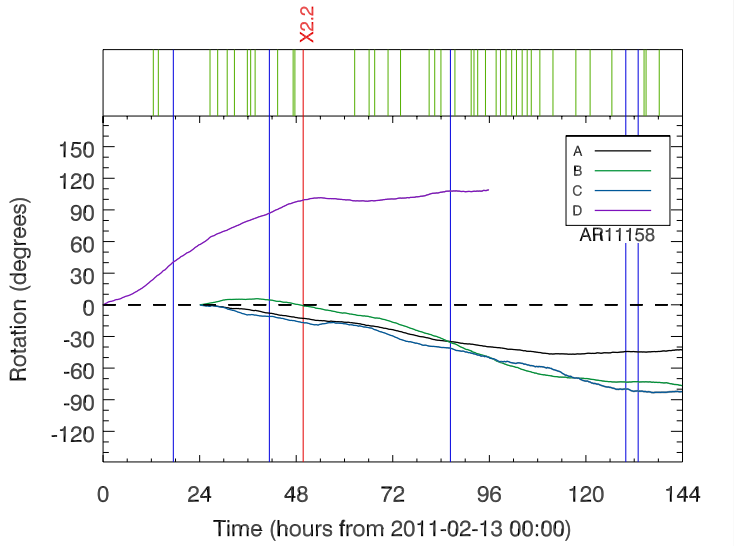

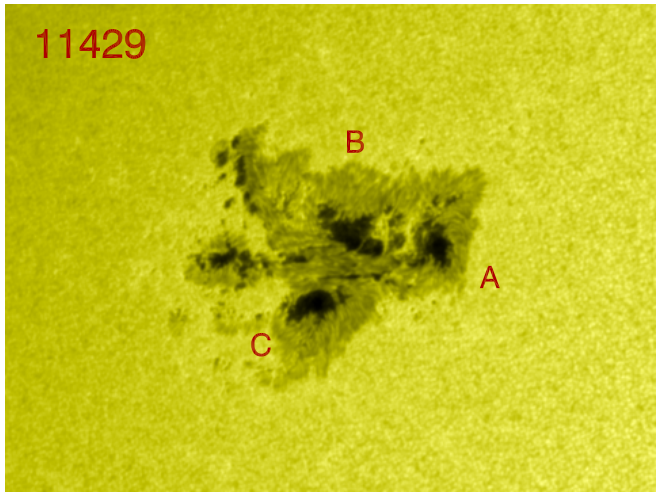

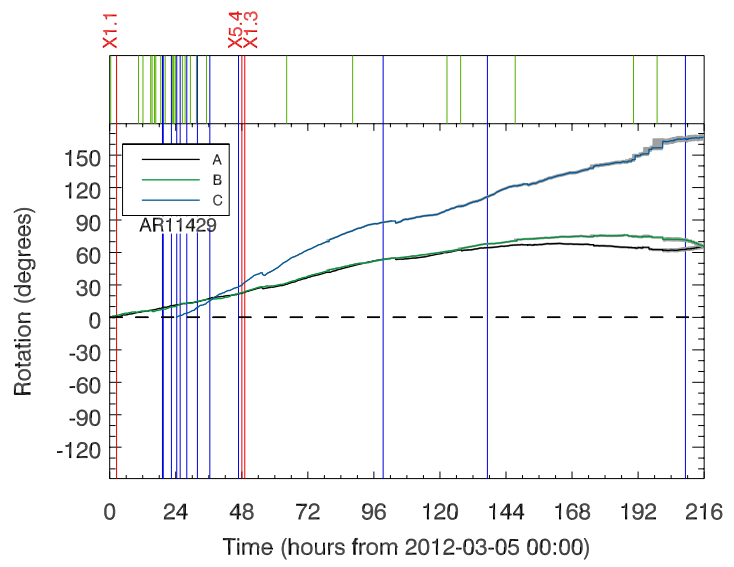

Rotation Mechanisms

Projection effect? Twisted flux tube emerging.

Re-balancing of twist? If energy is lost through a flare event, the flux tube may be seen to unwind.