

The Source Locations of Major Flares and CMEs in the Emerging Active Regions

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Motivation

• The origin of major solar activities

- Where? When? How? One of the key problems in solar physics
- Strong field, high-gradient PIL [e.g, Schrijver, 2007]
- A recently proposed scenario: collisional shearing [Chintzoglou, 2019]
 - Emergence of different bipoles
 - **Collision** between nonconjugated polarities Compact PIL
 - Where the eruptions occur



Motivation

• The flux rope in the early emergence phase of NOAA AR 12673 is formed by **collisional shearing** between nonconjugated polarities [Liu, 2019]





Motivation

- Problems
 - Only a few cases
- How common is the "collisional shearing"?

- May get hints from the source PIL of the major eruption in emerging ARs

Sample

- 19 emerging ARs
 - Emerging on the visible solar disk
 - Producing at least 1 major eruption (M+ flare or CME) within $\pm 60^{\circ}$
 - Selected from a list of 423 emerging ARs observed by SDO/HMI [Kutsenko, 2019]
- What we studied
 - Source PILs of the first major eruptions (active PILs)
 - Evolution of the ARs since their births until the first major eruptions

Sample

No.	ARs			First major activities				Active PIL			
	NOAA	Flux emergence	onset^a	Flare			CME	Emergence	PIL	$\overline{L}_{CPIL} d$	\overline{S}^e
	No.	Time	Location	Start	Location	Class	Speed b	sequence c	type		
							$({\rm km~s^{-1}})$				
1	11081	2010-06-11T02:24	N24W32	2010-06-12T00:30	N23W43	M2.0	486	Seq	S+C	49.5 ± 12.8	61.7 ± 6.9
2	11158	2011-02-10T17:48	S20E47	2011-02-13T17:28	S19W03	M6.6	373	Sim	\mathbf{C}	62.7 ± 3.8	70.1 ± 1.1
3	11162	2011-02-17T14:00	N18E15	2011-02-18T10:23	N18E02	M1.0		Seq	С	87.5 ± 6.4	77.9 ± 4.2
4	11422	2012-02-18T10:00	N16E25	2012-02-19T08:41	N17E10	C1.0	238		S+E	11.7 ± 2.2	48.6 ± 7.2
5	11440	2012-03-20T04:00	S26W00	2012-03-21T12:38	S27W20	C2.9	387	Sim	S+C	24.9 ± 6.5	61.2 ± 4.3
6	11466	2012-04-20T21:24	N13E59	2012-04-27T08:15	N12W30	M1.0	365	Seq	S+C	22.3 ± 6.4	67.6 ± 5.8
7	11620	2012-11-24T23:00	S13W02	2012-11-27T21:05	S14W41	M1.0		Seq	С	60.1 ± 4.5	59.9 ± 1.7
8	11675	2013-02-15T22:12	N12E47	2013-02-17T15:45	N12E22	M1.9		Sim	С	39.4 ± 7.4	61.7 ± 3.4
9	11762	2013-06-01T03:36	S29E04	2013-06-03T07:03	S27W21	C9.5	429^{\dagger}	Seq	S+C	61.0 ± 7.3	36.1 ± 2.1
10	11776	2013-06-18T07:12	N11E15	2013-06-19T00:50	N10E03	C2.3	287	Sim	S+C	20.0 ± 1.6	59.5 ± 5.9
11	11817	2013-08-10T09:36	S22E44	2013-08-11T21:47	S20E25	C8.4	110	Sim	\mathbf{C}	69.1 ± 4.6	62.3 ± 2.0
12	11870	2013-10-13T05:00	S14E19	2013-10-16T15:03	S15W29	C1.8	514		S+E	4.3 ± 1.6	89.9 ± 15.9
13	11891	2013-11-05T12:48	S18E09	2013-11-08T09:22	S17W28	M2.3	207	Sim	С	41.8 ± 3.8	67.3 ± 2.4
14	11899	2013-11-15T15:24	N10E32	2013-11-23T02:20	N14W56	M1.1	406	Sim	\mathbf{C}	61.7 ± 6.5	55.8 ± 3.4
15	11928	2013-12-16T08:24	S16E31	2013-12-22T08:05	S19W51	M1.9	231	Sim	С	70.9 ± 5.7	61.8 ± 1.6
16	11946	2014-01-04T05:12	N09E49	2014-01-07T03:49	N07E08	M1.0		Seq	С	19.5 ± 3.4	54.7 ± 2.4
17	12017	2014-03-23T22:36	N03E53	2014-03-28T19:04	N11W21	M2.0	420	Seq	\mathbf{C}	44.3±2.1	58.2 ± 2.9
18	12085	2014-06-05T22:36	S20E39	2014-06-09T01:14	S20E00	C3.7	417	Seq	S+C	30.3 ± 5.8	62.9 ± 3.9
19	12089	2014-06-10T20:00	N18E32	2014-06-12T19:56	N17E05	M1.1		Sim	\mathbf{C}	30.5 ± 4.1	$63.0{\pm}11.2$

Result

- Three types of source PILs
 - cPIL-type: collisional PIL between the non-conjugated oppositesign polarities – *11 cases*
 - Conjoined cPIL/sPIL-type: mixed system of cPIL and self PIL (between conjugated polarities) – 6 cases
 - Conjoined sPIL/ePIL-type: mixed systems of sPIL and external PIL (between the AR and surrounding flux) 2 cases
 - No self PIL

• **Strong correlation** between the length of the PILs and magnitude of the flares

cPIL in AR 11891

50

40

30 20

10

0

-

-

-

Y (Mm)



Eruption in AR 11891



- M2.3 flare accompanied by a CME (05-Nov-2013)
- Initiated from the cPIL
 - Brightenings, mass eruption, ribbons, post-flare loops

Conjoined cPIL/sPIL in AR 11776

Y (Mm)



Eruption in AR 11776



- A CME accompanied by a C2.3 flare (19-Jun-2013)
- Initiated from the conjoined cPIL/sPIL
 - Brightenings, coronal dimmings, ribbons, post-flare loops

Conjoined sPIL/ePIL in AR 11422



- **Emergence** of a bipole near a pre-existing patch
- Separation between conjugated polarities
- Slight **collision** between PA and the Group of NE and NA
- Shorter collisional length



Eruption in AR 11422



- A CME accompanied by a C1.0 flare (19-Feb-2012)
- Initiated from the conjoined sPIL/ePIL
 - Brightenings, coronal dimmins, ribbons, post-flare loops

Correlation between collisional length and the flare magnitude

- Strong correlation between the collisional length and the flare magnitude
- Critical length for significant collision: 18 Mm



Conclusion

- For all active PILs, collision signature is found
 - Three types
 - 11 cPIL
 - 6 conjoined cPIL/sPIL
 - 2 conjoined sPIL/ePIL
 - The collision is significant at more than 84% (16/19) of the cases
 - Reference length for significant collision: 18 Mm
 - No single self PIL

• Strong correlation is found between the collisional length and flare magnitude

- With correlation coefficient ≥ 0.6 (99%) at various thresholds and averaging durations
- Collisional length: a promising indicator in forecasting the major eruption [Liu, et al, ApJ, 2021]