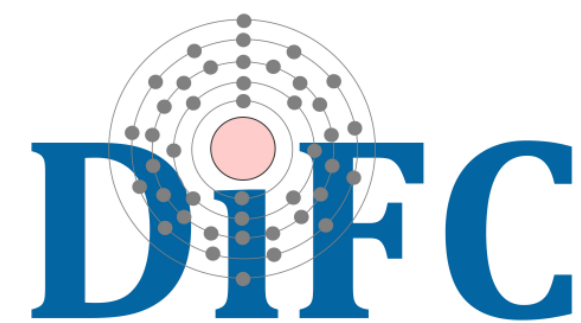# Identifying eruptive solar active regions for space weather warnings with S^2WARM
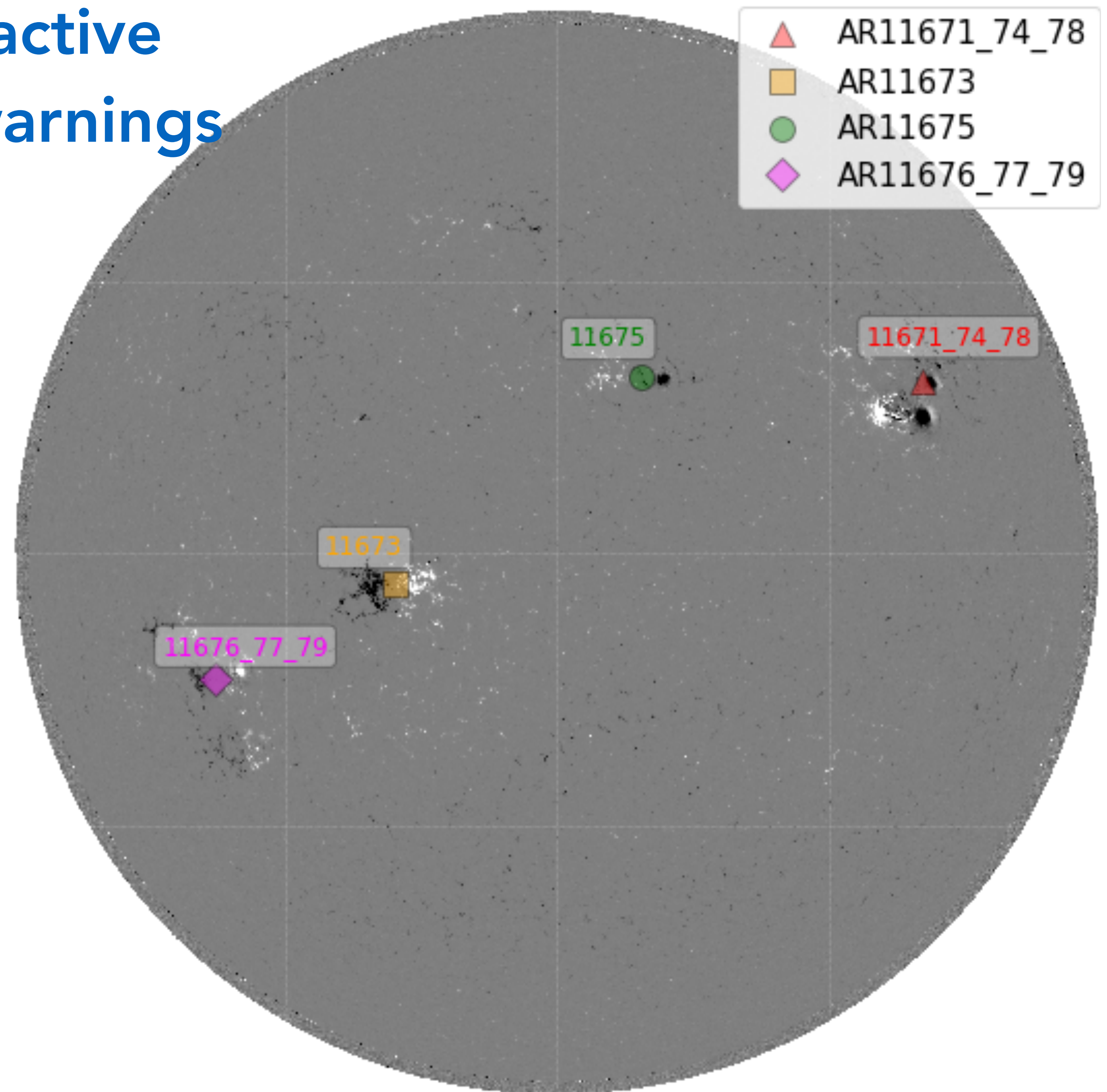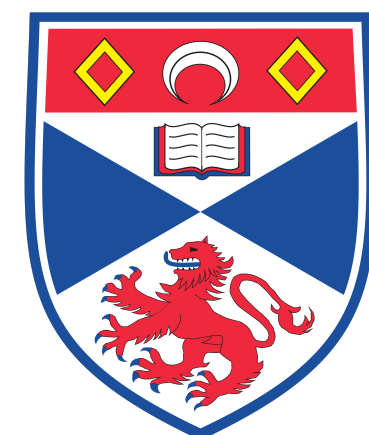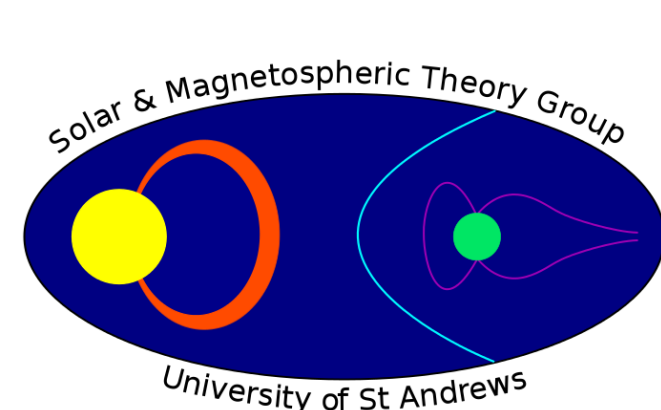
ESPM 2021   08/09/2021

Paolo Pagano
Università degli Studi di Palermo
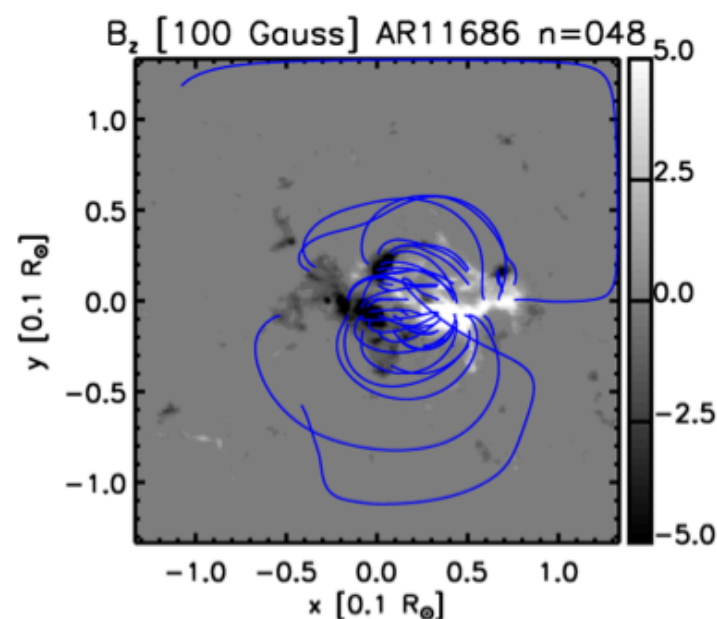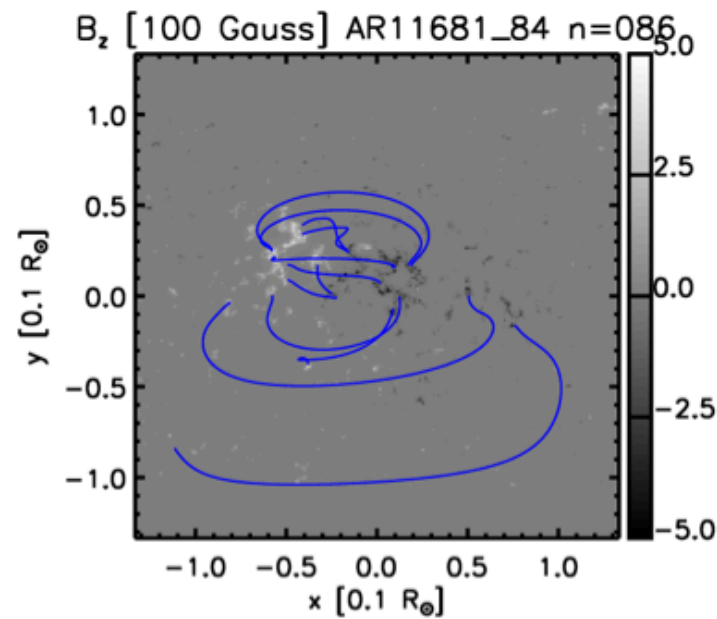
S. L. Yardley, D. H. Mackay
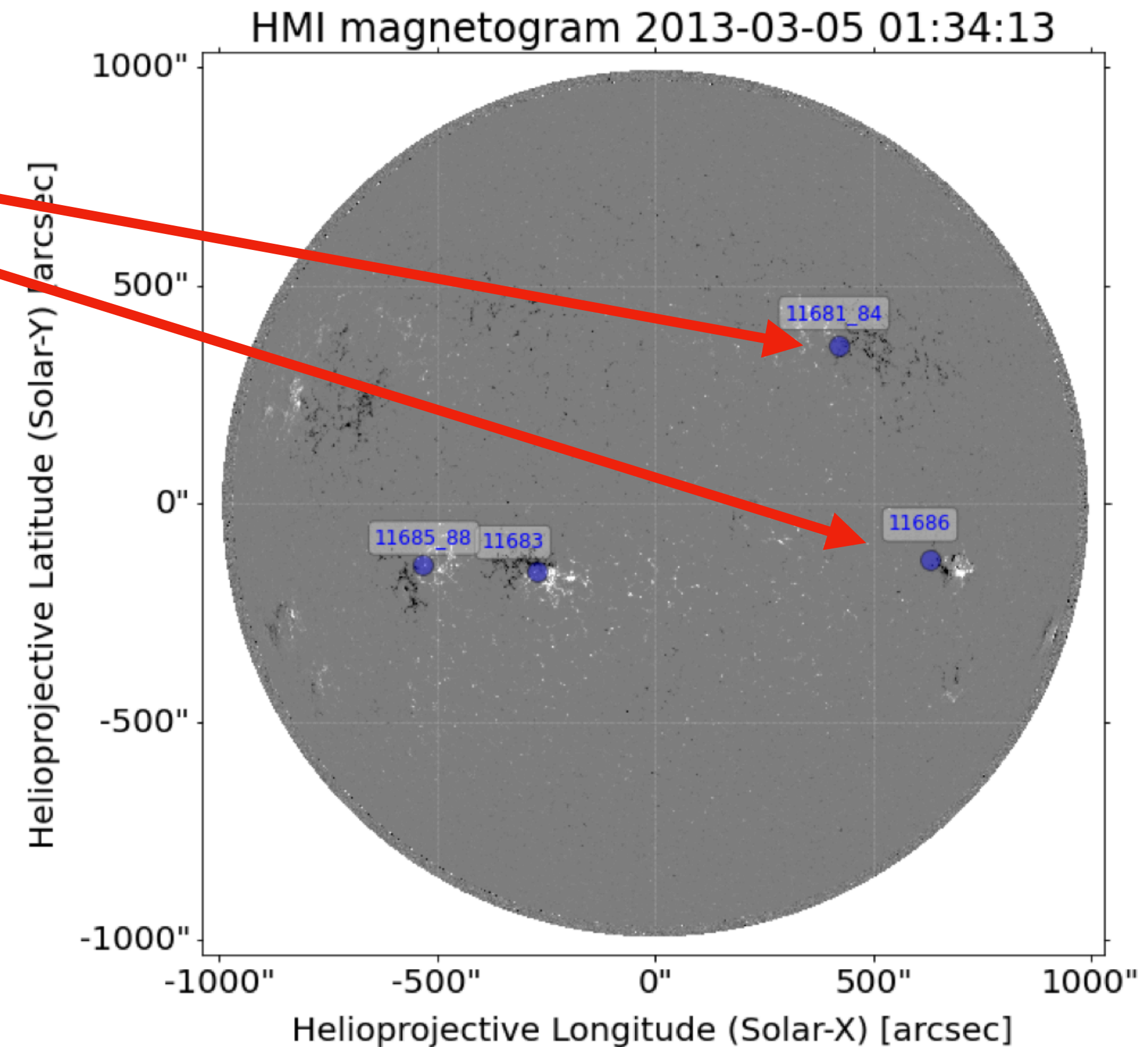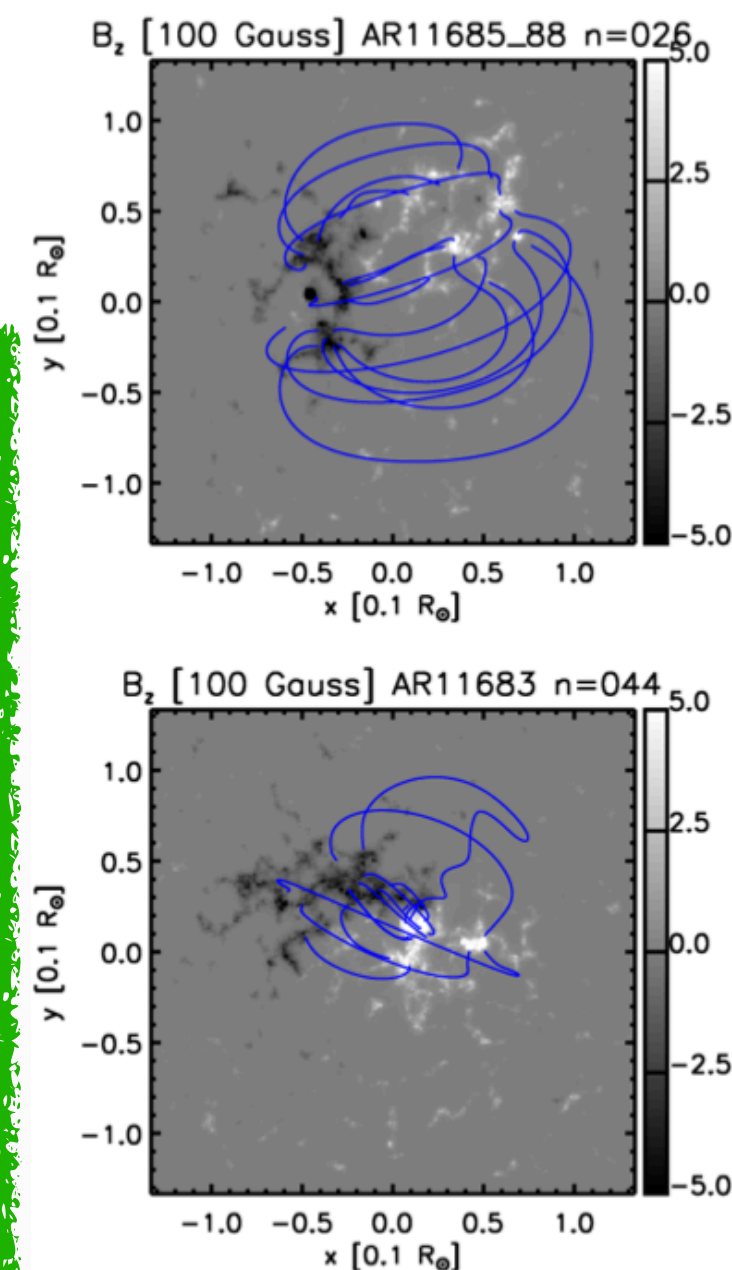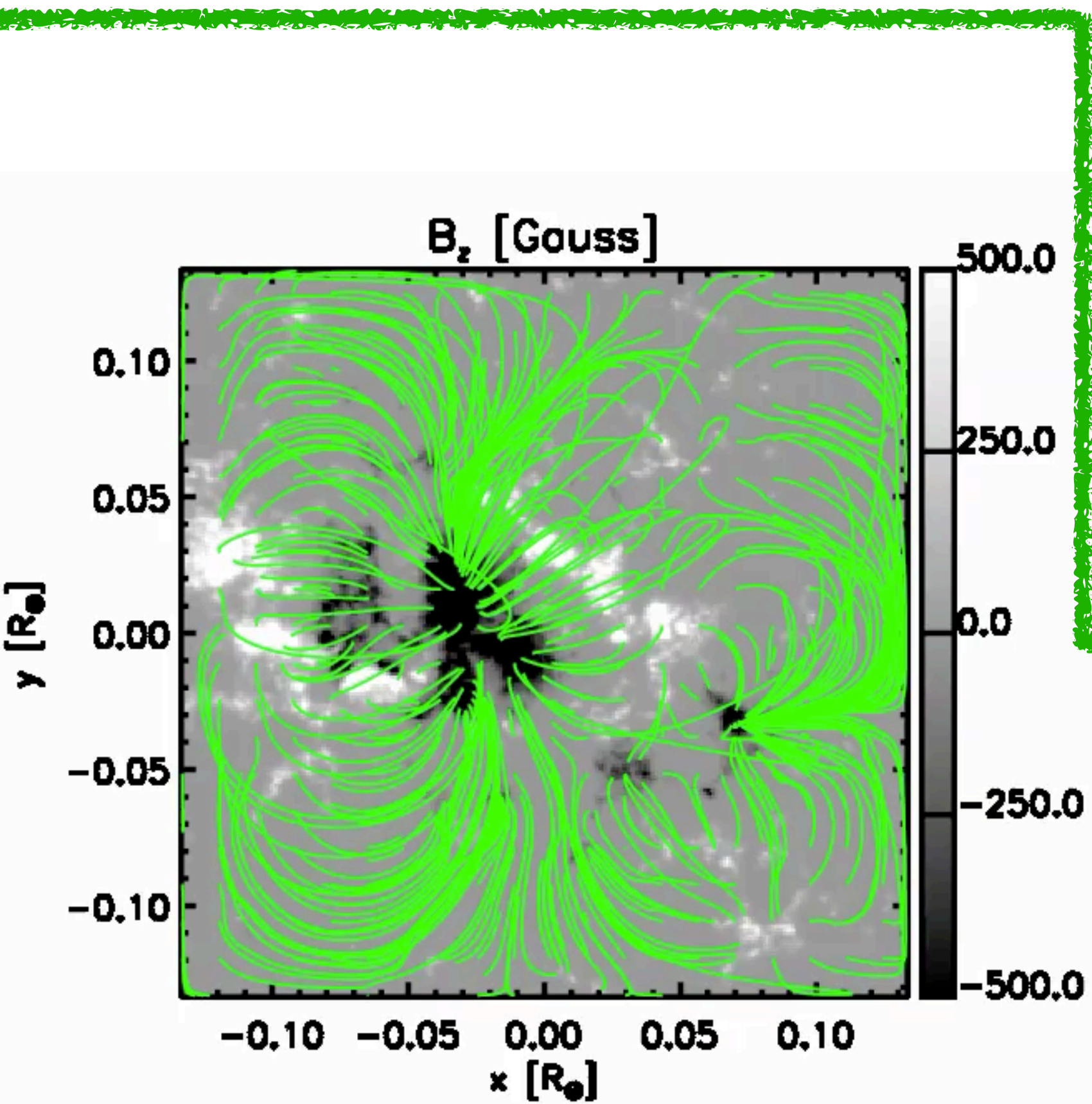
Acquisition of magnetograms and MF simulations

Modelling of:
Activity complexes
Isolated active regions

Mackay et al., 2011
- Dynamic reconstruction of the active region magnetic field
- Magnetofrictional model with evolving boundary conditions
- NLFF (initial conditions are potential and it evolves a non-potential field - ramp up phase)

Pagano et al., 2019a

$$\zeta(x, y, t) = \boxed{\omega} u \sigma$$

B twist

Lorentz force

Theoretical metric
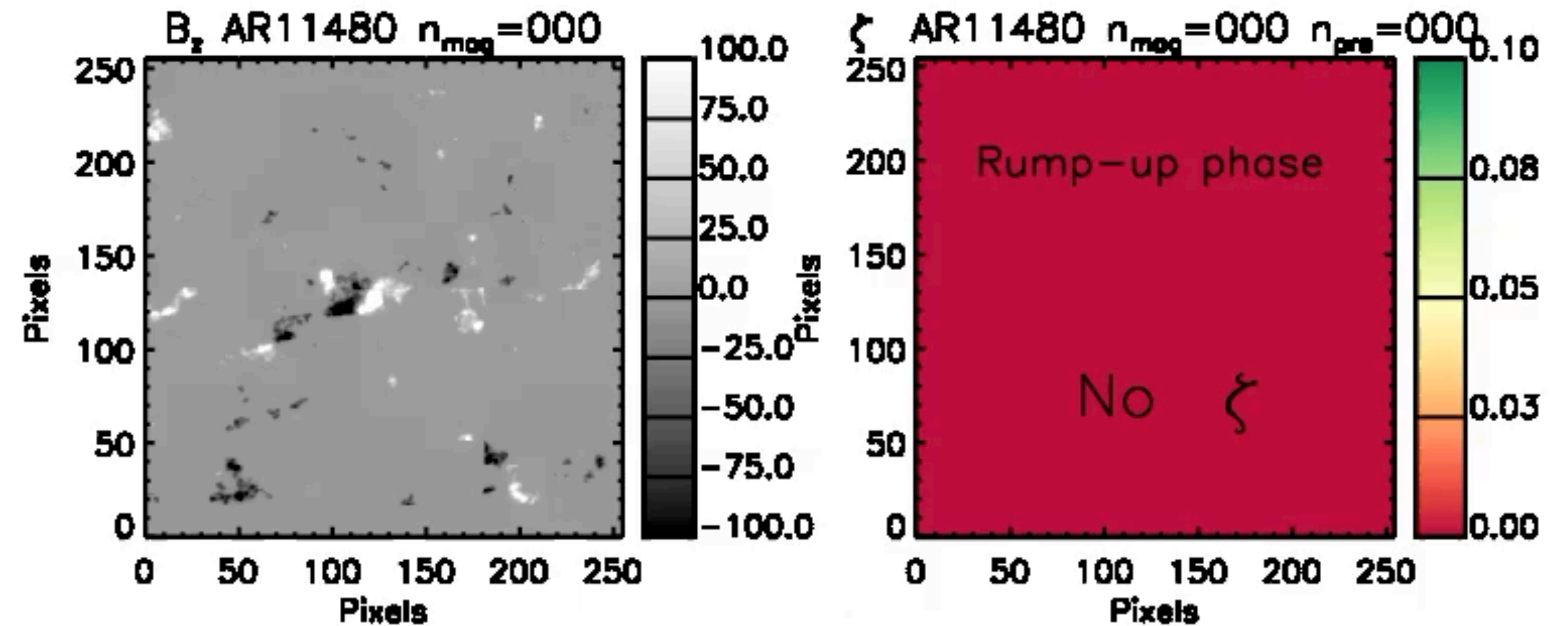
Pagano et al., 2019b

$$\Lambda(\zeta)$$

Operational metric

Ramp-up phase needed to develop non-potential field
Λ thresholds to identify eruptive/non-eruptive active regions

Application: 23 AR from 13/02/2013 to 26/03/2013

We also improved the metrics for:
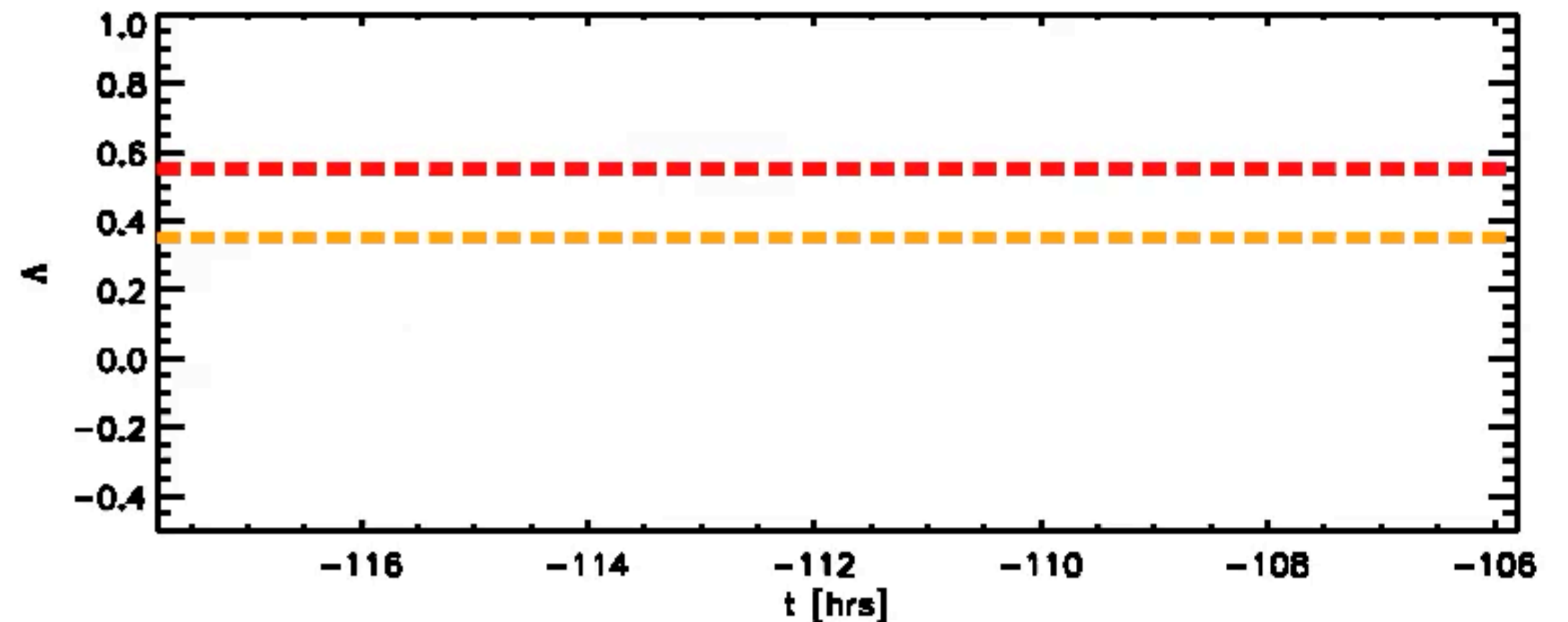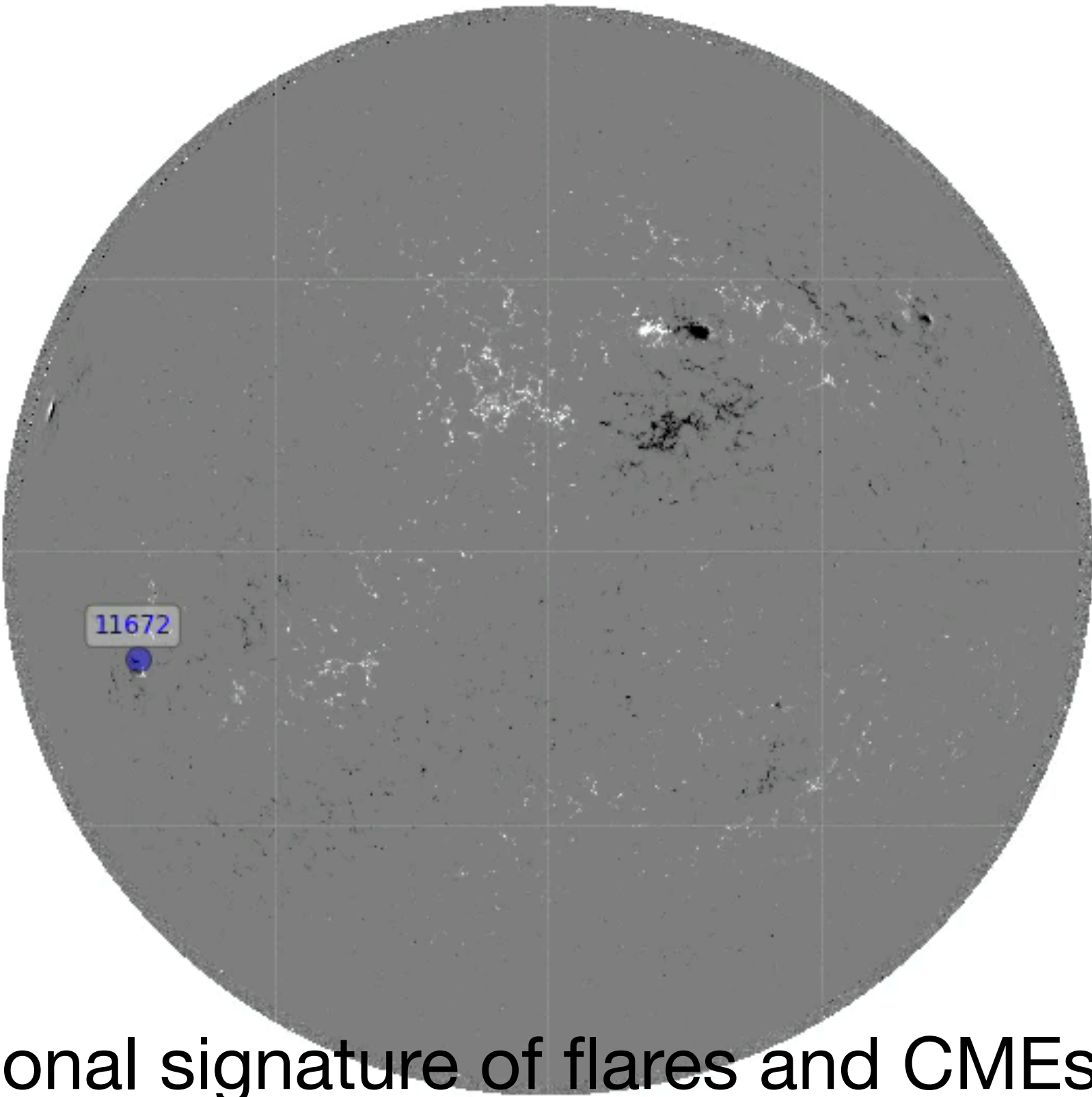
1. Magnetograms cadence. 96 mins is ok, as too high cadence unnecessarily computationally expensive

2. We can use shorter ramp up phase (11 instead of 35 magnetograms) when active regions emerge on the disk

3. Including the role of magnetic flux variations. Modified ζ, which make eruptions more likely.
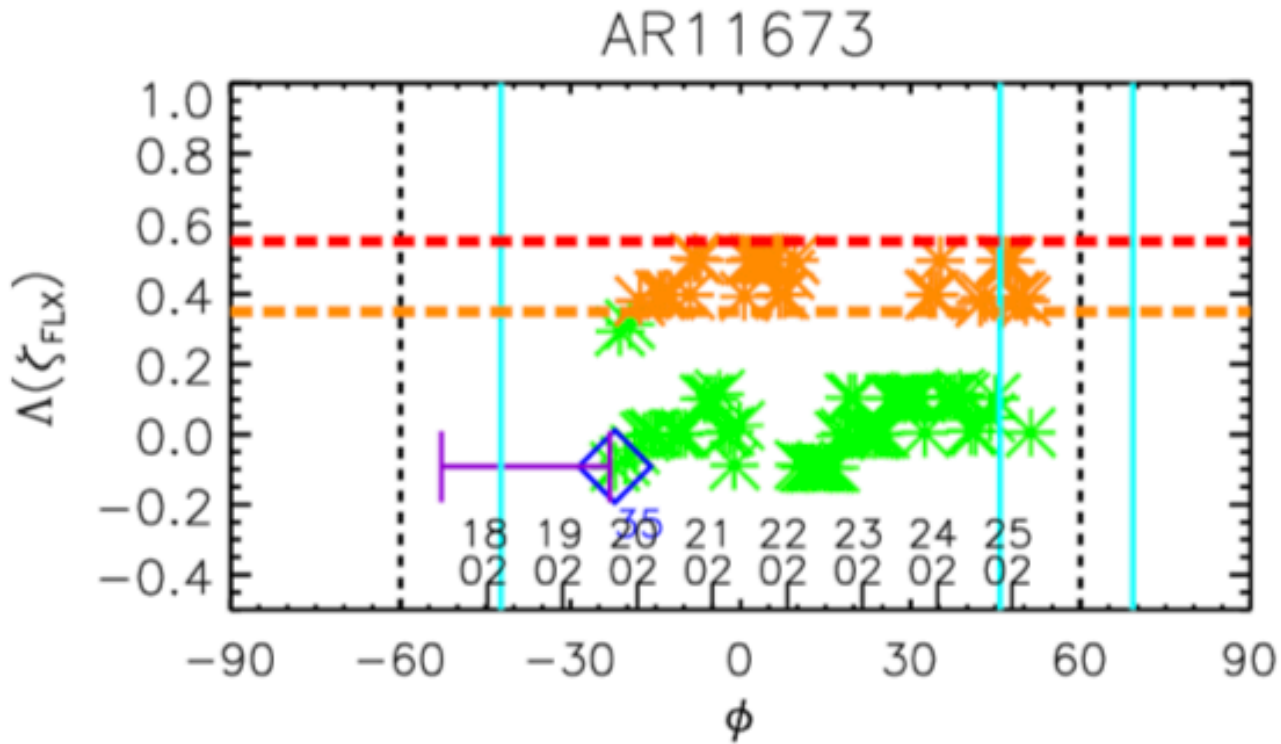
4. Add flares to the eruptions catalogue
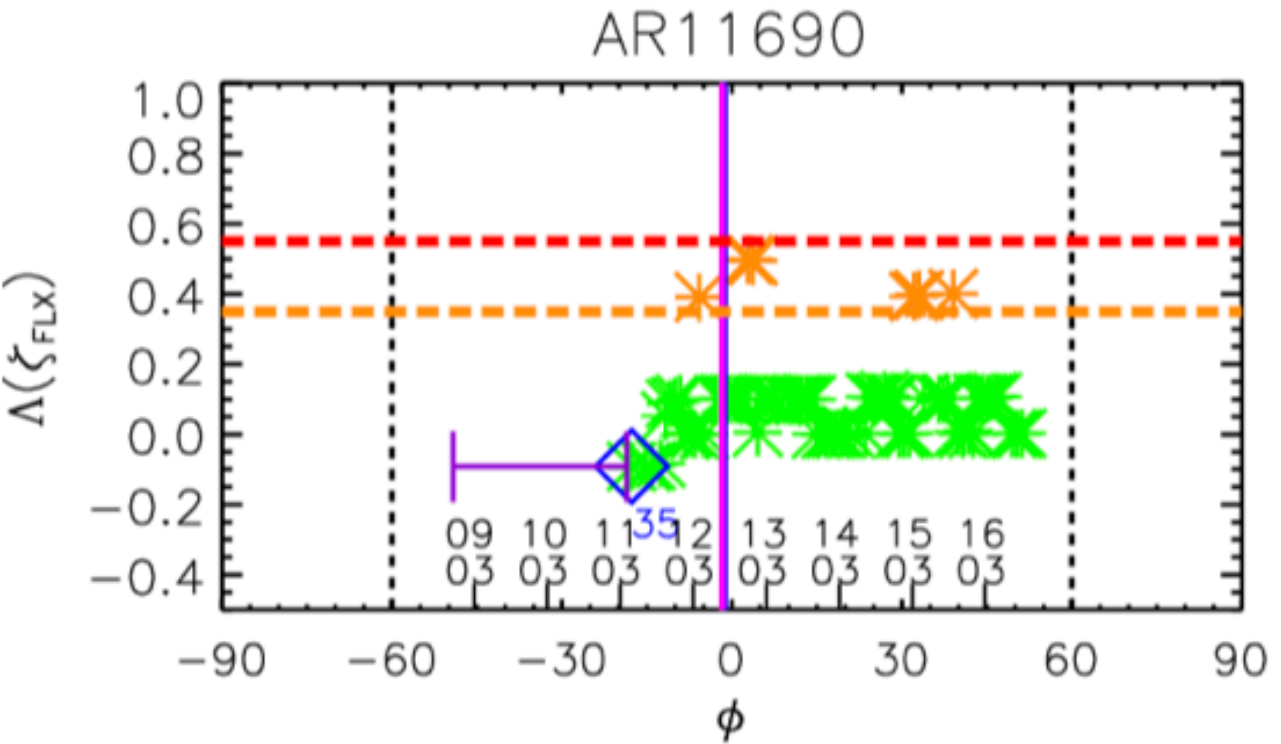
Benchmark with observational signature of flares and CMEs

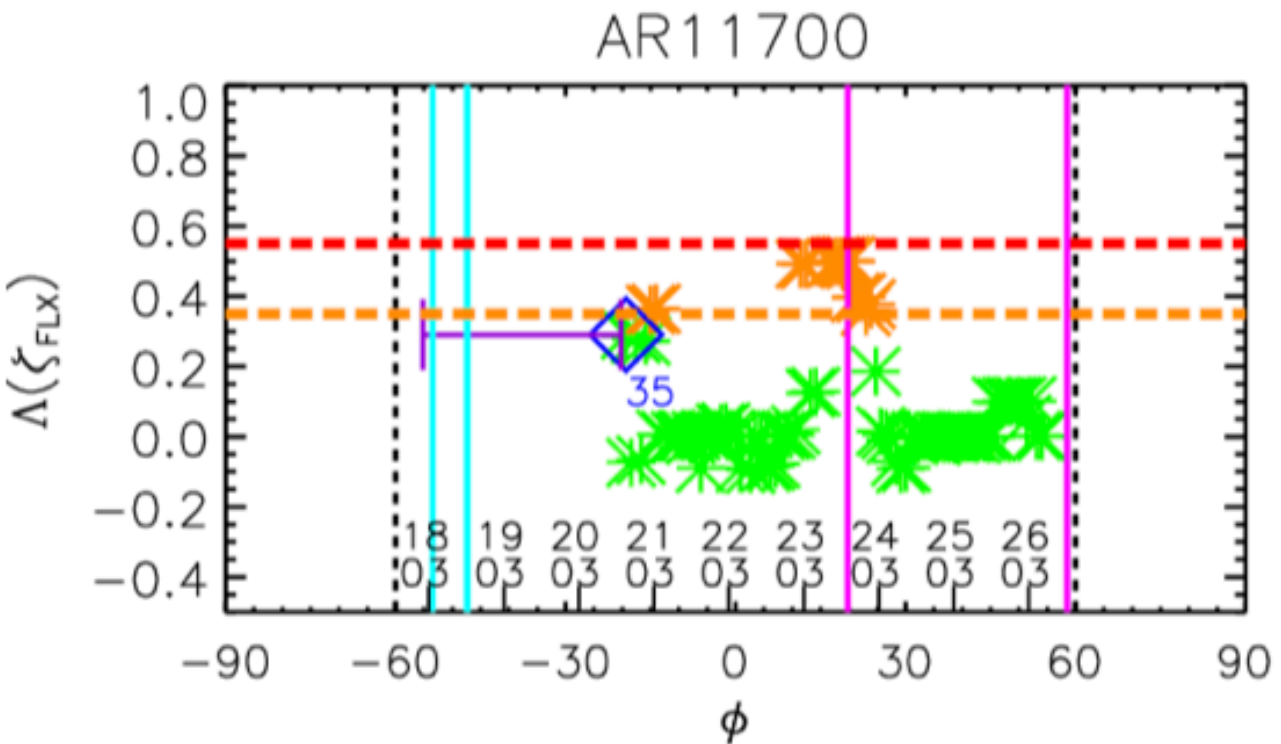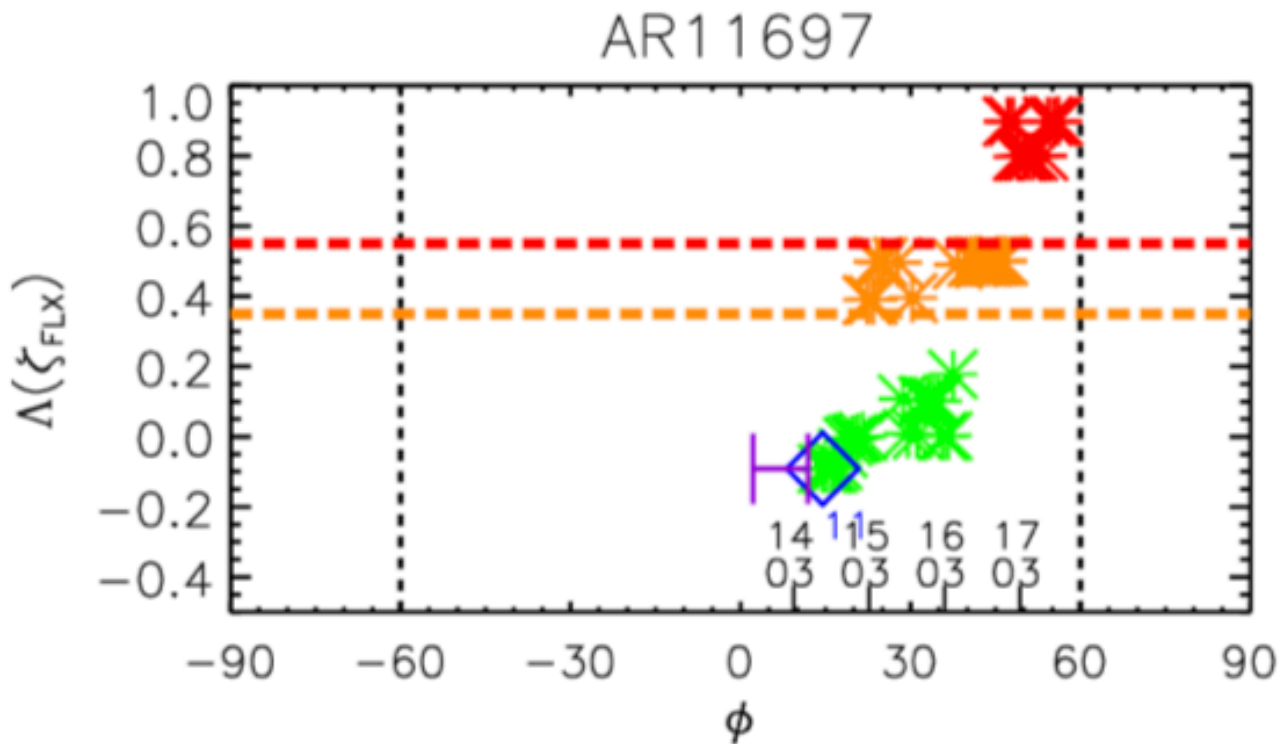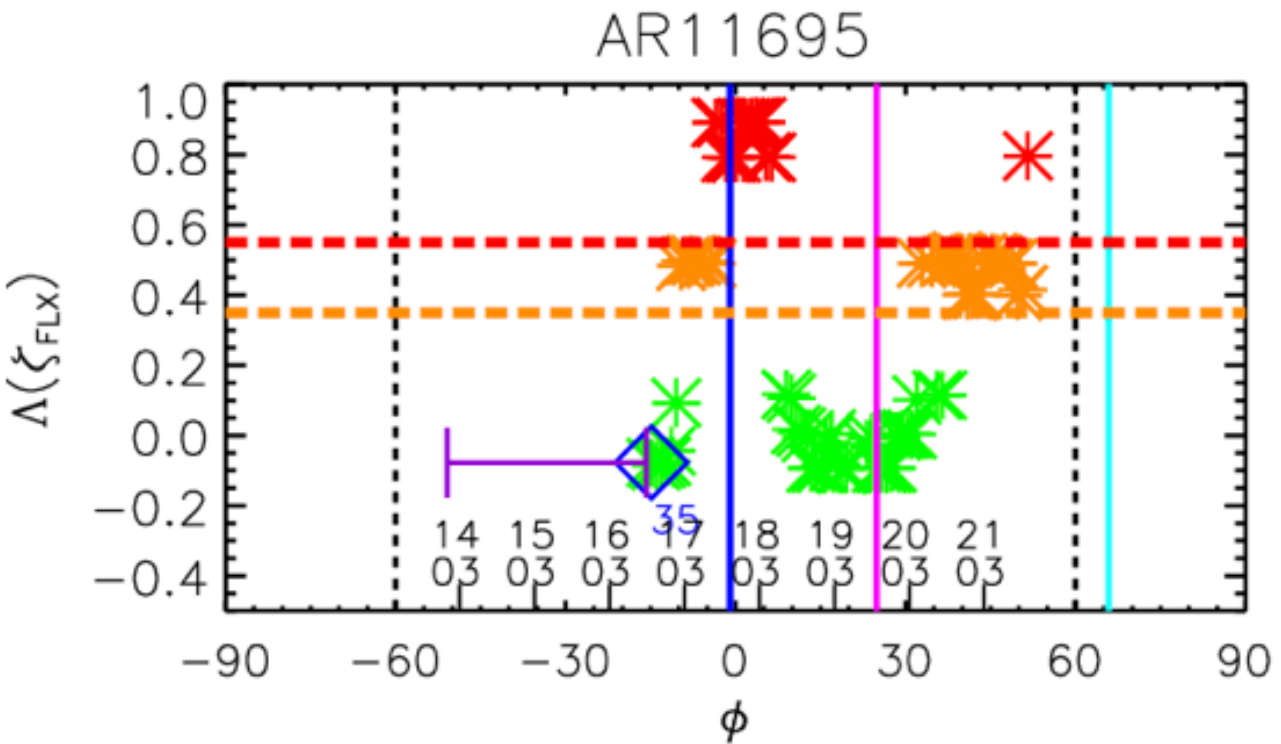| Active Region	Eruption/CME) Times (UT)	Eruption Signatures	Flare Times (UT)	GOES Flare Class
AR11671	-	-	19-02 10:09, 19-02 10:16, 19-02 13:19	C2.1, C2.2, B9.8
AR11672				
AR11673	-	-	18-02 04:23, 24-02 20:14, 26-02 14:42	B4.0, B9.8, B6.8
AR11674				
AR11675	17-02 15:30	A, D, FL, L	16-02 17:21, 16-02 22:59, 16-02 23:37	B3.9, B4.7, B5.3
			17-02 00:31, 17-02 01:00, 17-02 04:20	C1.0, B6.2, B5.6
			17-02 10:34, 17-02 15:13, 17-02 15:26	B3.8, C2.6, C2.5
			17-03 15:45, 17-03 17:59, 17-03 19:57	M1.9, B3.7, C1.0
			17-03 21:21, 18-02 02:36	B6.3, C1.0
AR11676				
AR11677				
AR11678	-	-	19/02 05:28, 19/02 06:49, 19/02 07:41	B5.4, B6.9, B8.7
			19/02 20:03, 20/02 05:32, 20/02 08:12	B8.8, B6.1, B5.8
			20/02 09:35, 20/02 10:41, 20/02 11:08	B6.2, B5.4, C8.2
			20/02 14:15, 20/02 14:52, 20/02 18:53	B7.2, C3.0, B8.1
			20/02 21:50, 21/02 03:07, 21/02 04:01	C1.7, C1.9, C2.0
			21/02 04:56, 21/02 08:54, 22/02 00:16	C2.5, B9.9, B5.6
			(22/02 12:14, 22/02 17:51, 22/02 20:53)	(C1.0, B8.3, B9.0)

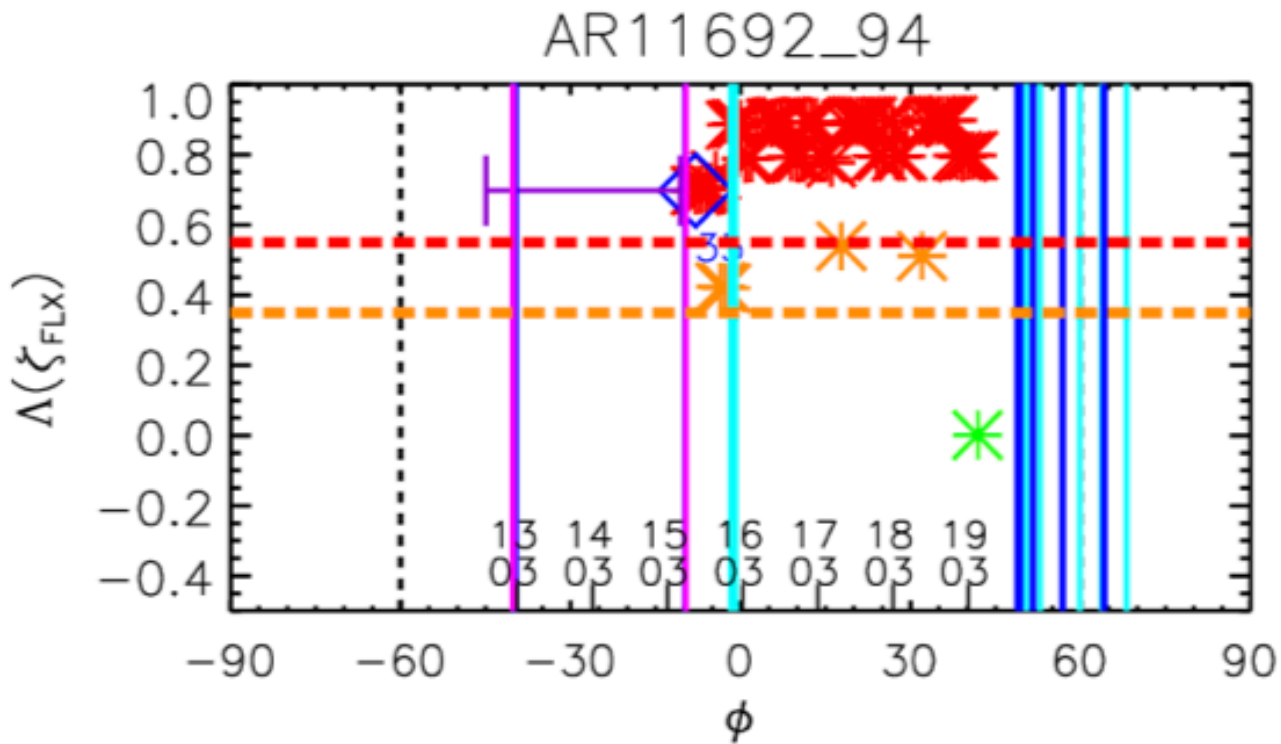# Does it work in this sample of 23 active regions?

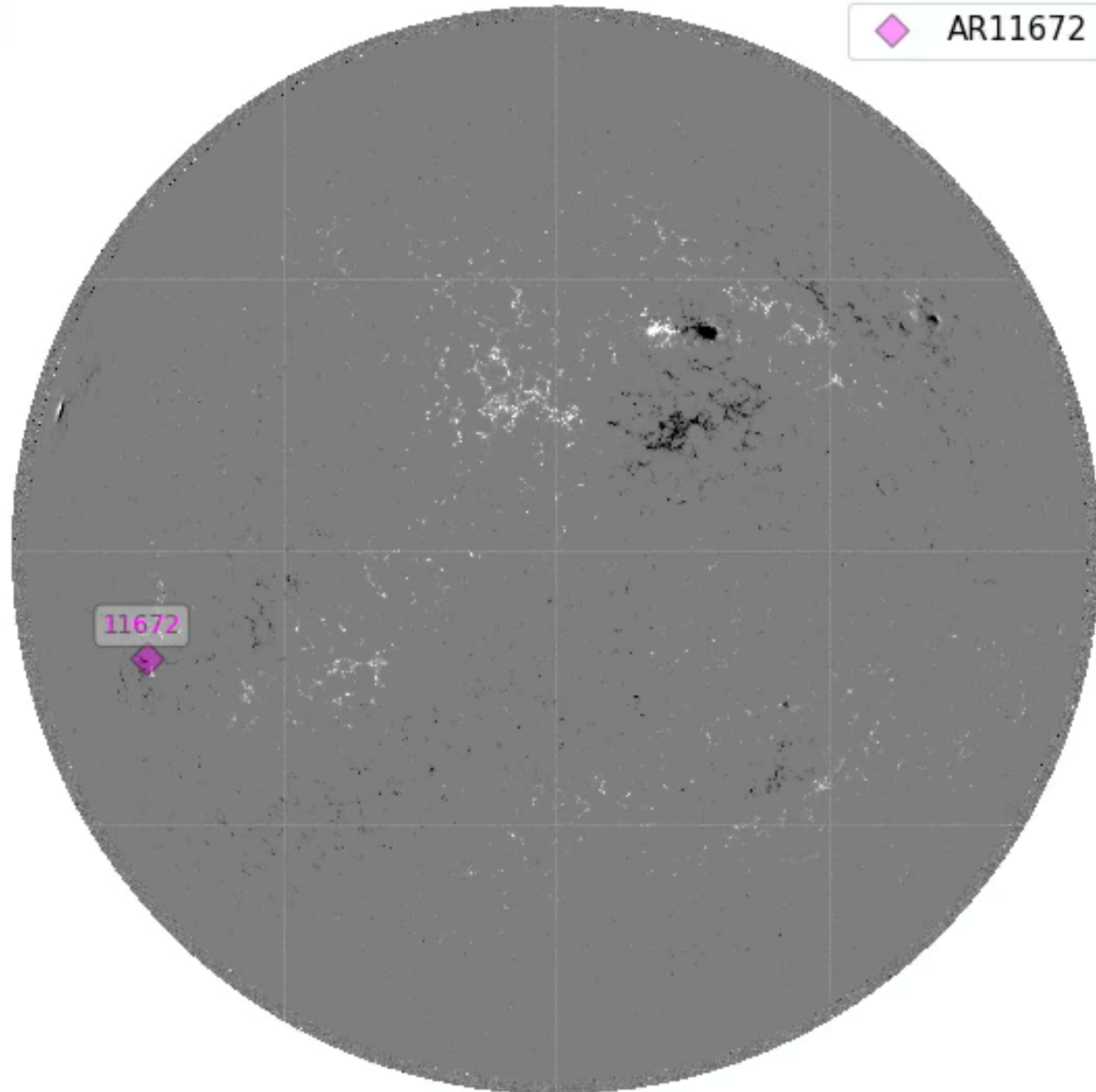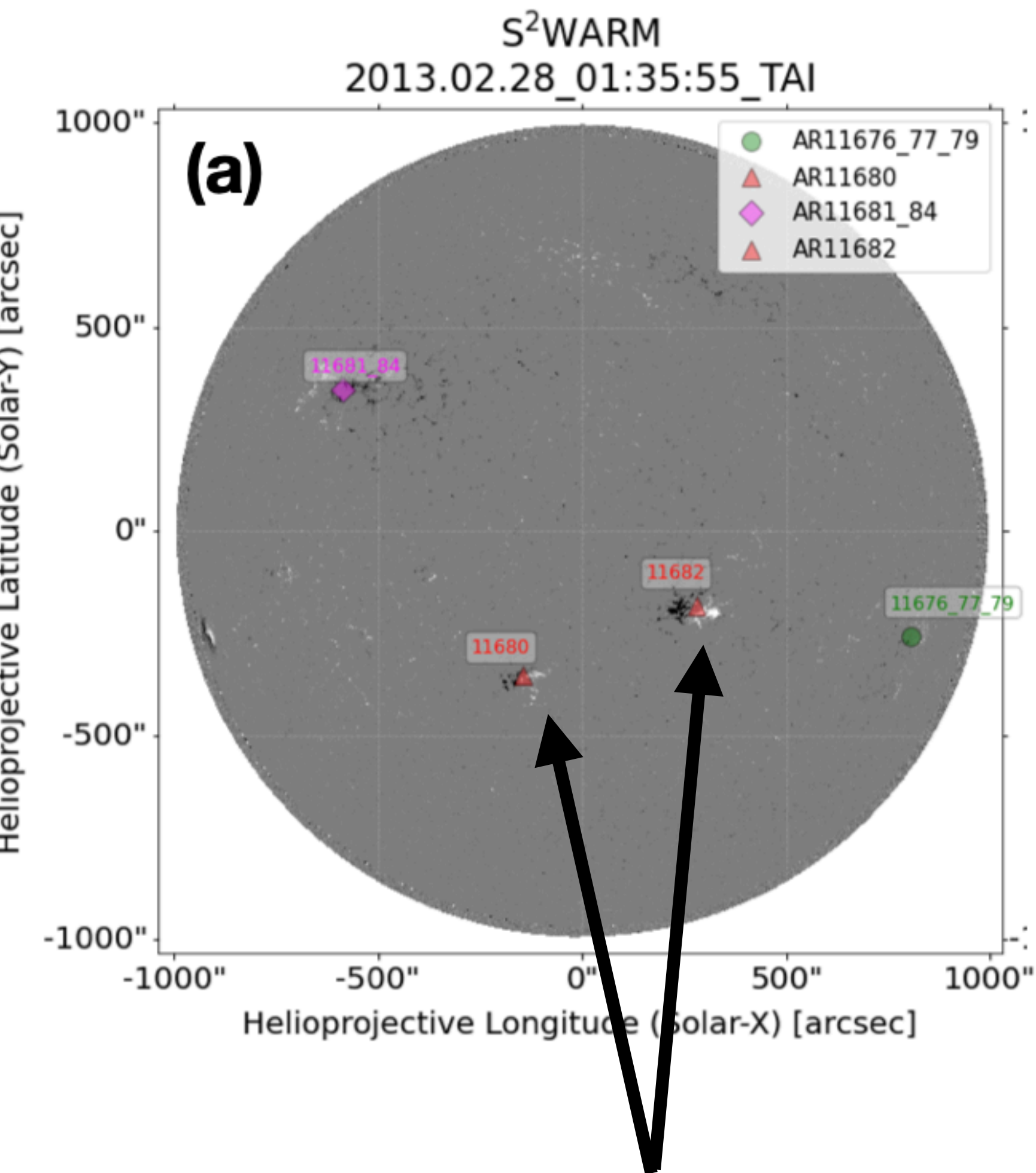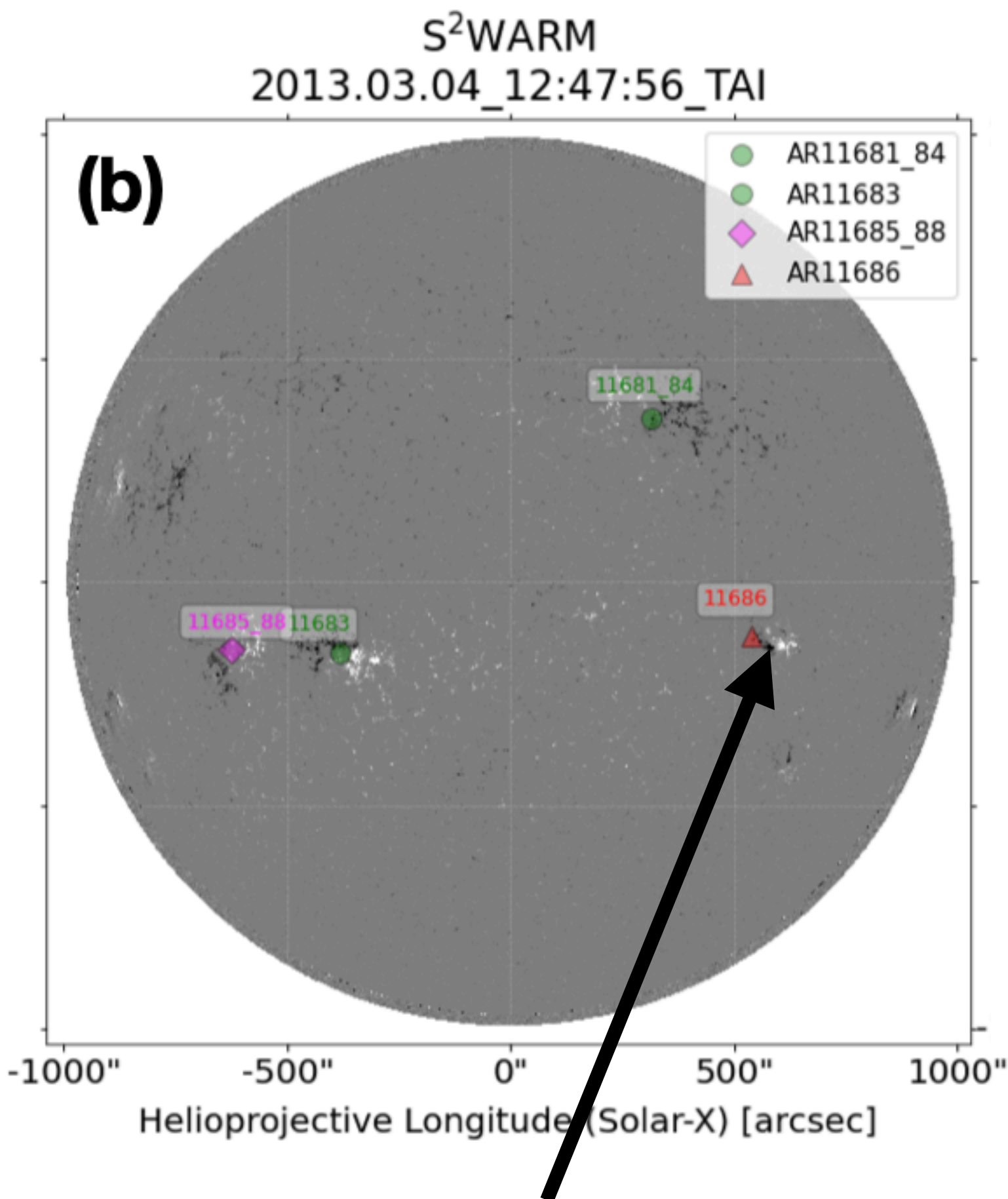| Category	$n(\%)$
Category 1, successful	**19 (83%)**
Category 2, uncertain	3 (13%)
Category 3, misleading	1 (4%)

Application
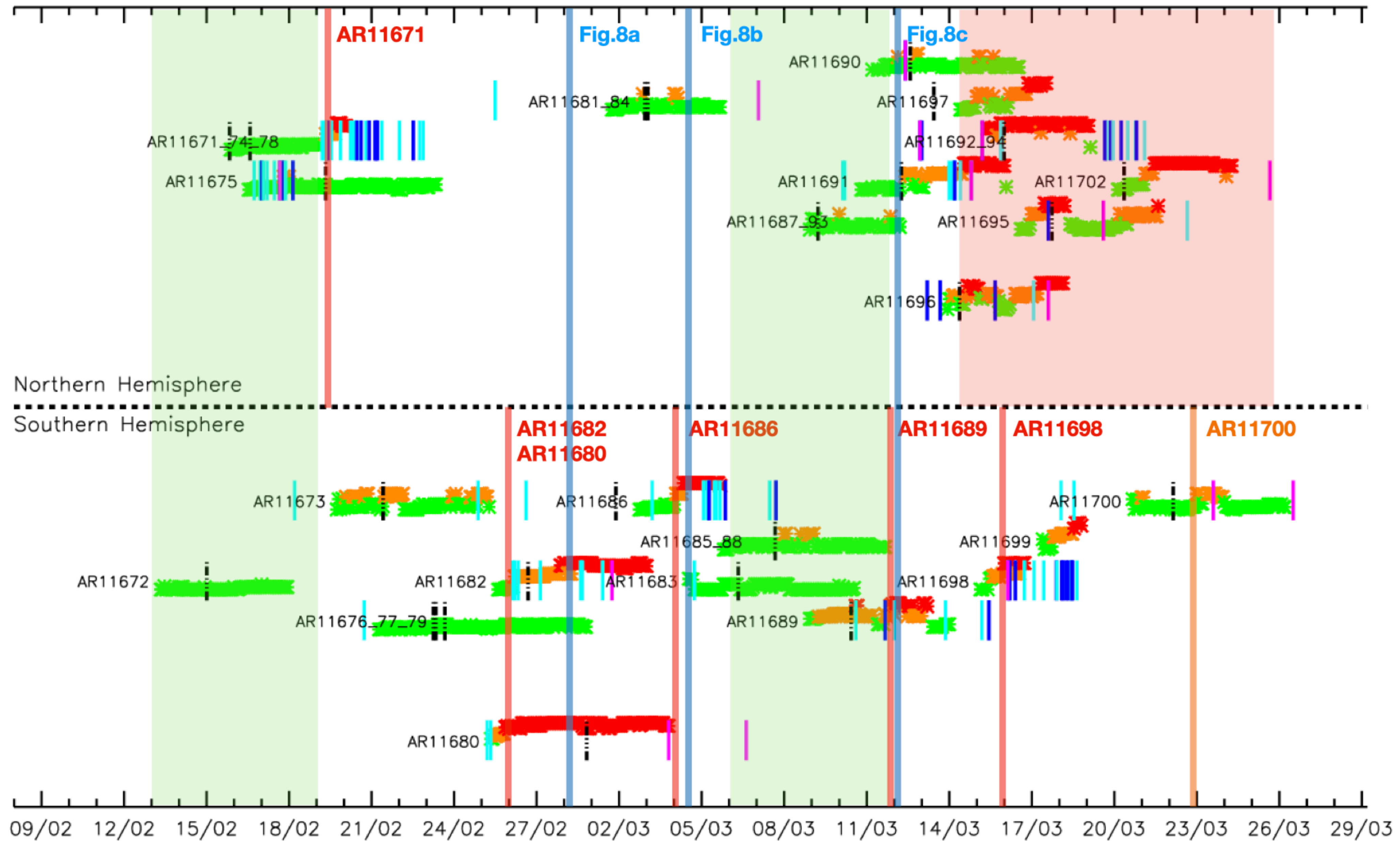
Application

Ramp-up phase
Non-eruptive
Amber risk
Eruptive

Identification of possible Earth directed CMEs

Follow ARs as they rotate behind (SO quadrature application)

It does not always work

S²WARM
2013.02.28_01:35:55_TAI

(a)

AR11676_77_79
AR11680
AR11681_84
AR11682

These will erupt

S²WARM
2013.03.04_12:47:56_TAI

(b)

AR11681_84
AR11683
AR11685_88
AR11686

This will produce a series of flares

S²WARM
2013.03.12_01:35:57_TAI

(c)

AR11687_93
AR11689
AR11690
AR11691
AR11696

This will erupt

This will not