Stability Study of Coronal Cavities and Prominences

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ABSTRACT

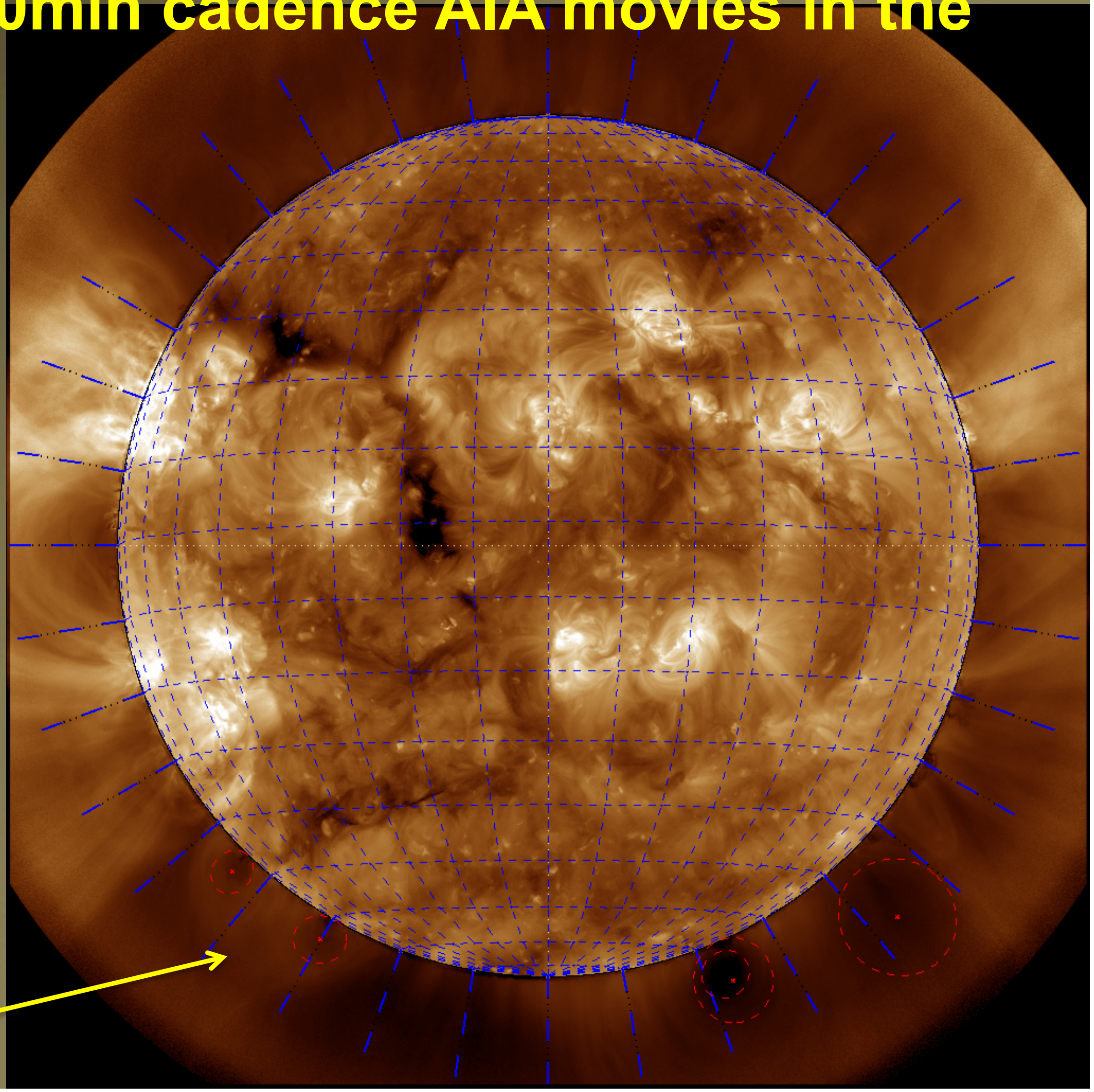
Prominence/cavity systems are large scale structures seen off the limb of the Sun that correspond to filament/filament channels seen against the solar disk. These large coronal systems can live for many weeks or even months and often end their life in the form of large eruptions.

We investigate the role of the surrounding large-scale coronal field in stabilizing these systems against eruption. In particular, we examine the extent to which the decline with height of the external coronal field can influence the evolution of prominence/cavity systems. At this purpose, we use observations from SDO/AIA and HMI during the rising phase of cycle 24.

OBSERVATIONS

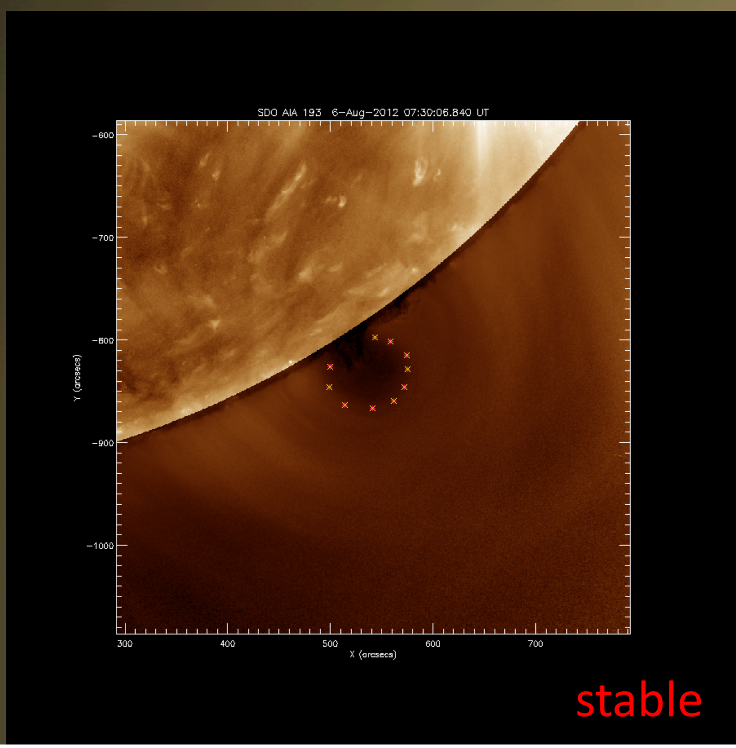
Coronal cavities are identified and divided in stable and eruptive using 30min cadence AIA movies in the 193A FeXII line.

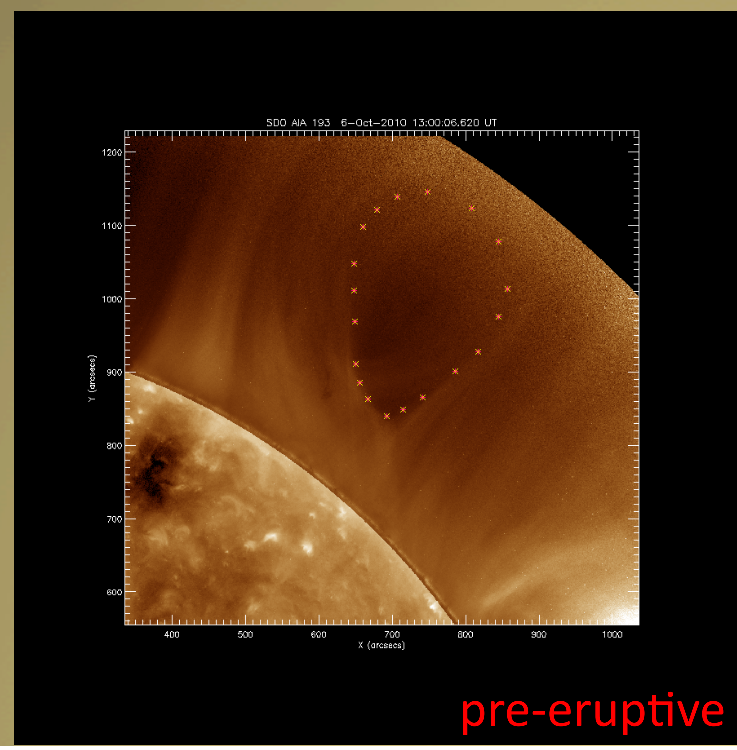
The cavity geometry is determined from an elliptical fit to points across the cavity boundary selected with an IDL widget tool. When a dark core is clearly identifiable inside a coronal cavity, the core is also fitted with an ellipse.



Our analysis confirms the previous findings *(Forland et al. 2013)* that the cavity morphology is a good indicator of when a coronal cavity is going to erupt: small, low-lying, round coronal cavities tend to be stable while tall, elongated or drop-shaped coronal cavities are more likely to erupt.

Examples of stable and pre-eruptive coronal cavities are shown below:





METHODOLOGY

We make the assumption that cavity/prominence systems are magnetic flux ropes and that the center of the dark cavity represents the location of the central axis of the corresponding flux rope.

The center of the cavity is usually located higher than the top of the associated prominence and we expect it to give a better estimate for the central axis of the flux rope than the prominence.

To derive the ambient coronal field, we use a PFSS extrapolation and use as boundary condition the HMI photospheric magnetic map closest in time to the measured cavity. The decay index is computed at the location of the cavity center and top.

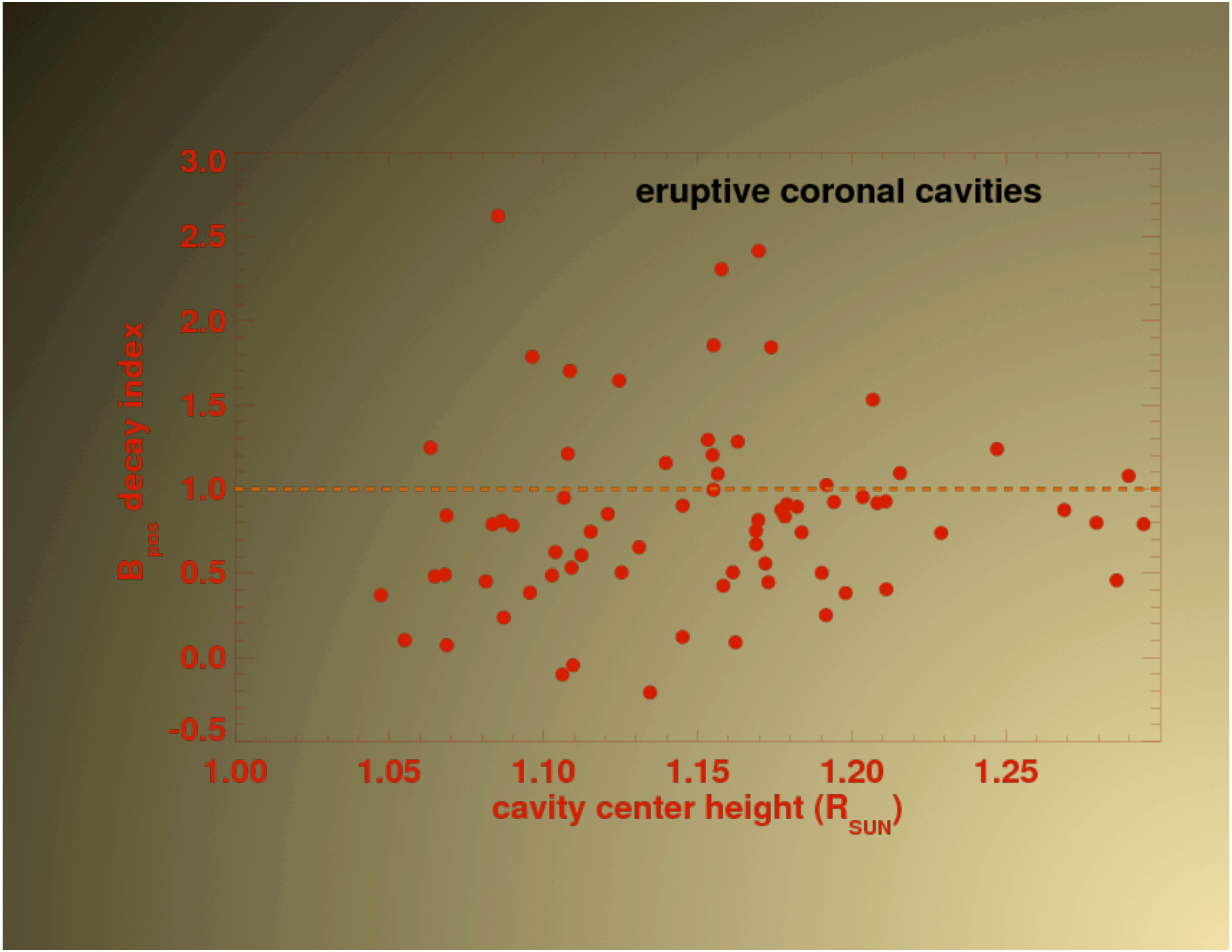
TORUS INSTABILITY

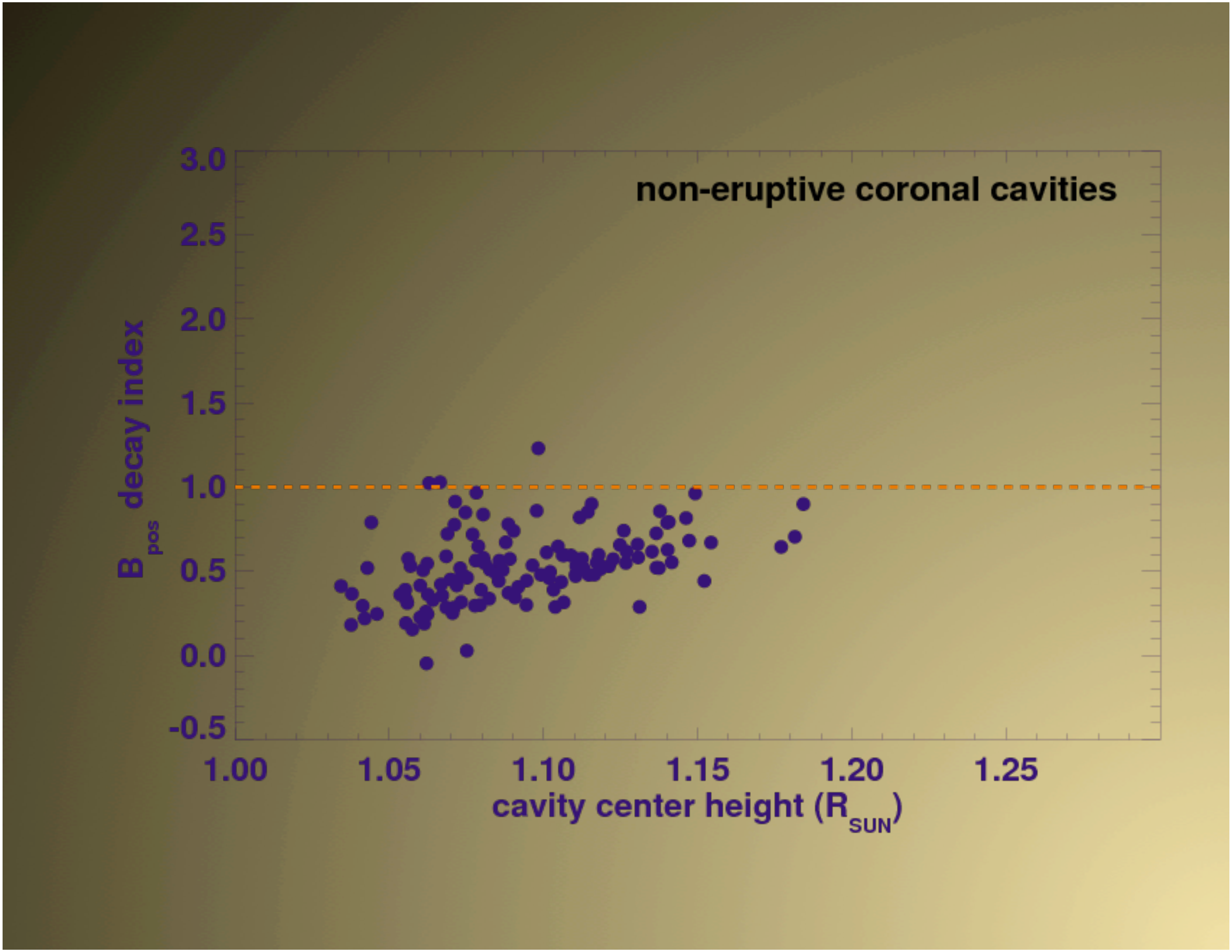
Because we measure cavities at the limb, we assume the corresponding flux rope system is located in the plane-of-the-sky and thus the "decay index of the potential field" is defined as:

$$\text{decay index} = - d \ln (B_{pos})/d \ln (h)$$

where B_{pos} is the component in the plane-of-the-sky of the potential field which produces the "strapping force" to our cavity system.

A torus instability is expected when the cavity system is located at a critical height h_c that corresponds to the location where the decay index of the external potential field is larger than a critical value.


eruptive coronal cavities
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
B pos decay index
1.00
1.05
1.10
1.15
1.20
1.25
cavity center height (R SUN)

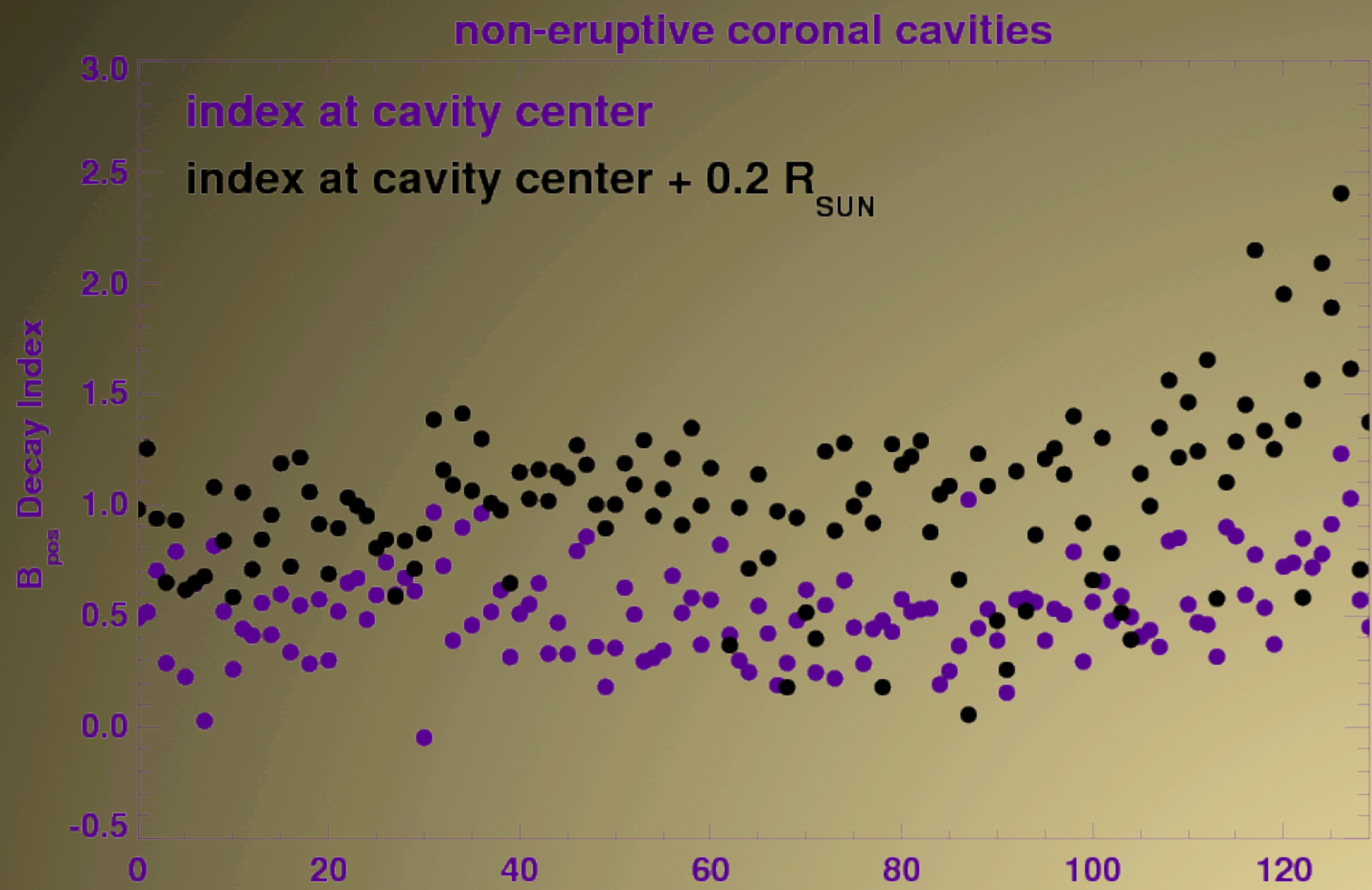


non-eruptive coronal cavities
B_{pos} decay index
cavity center height (R_{SUN})
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
1.00
1.05
1.10
1.15
1.20
1.25

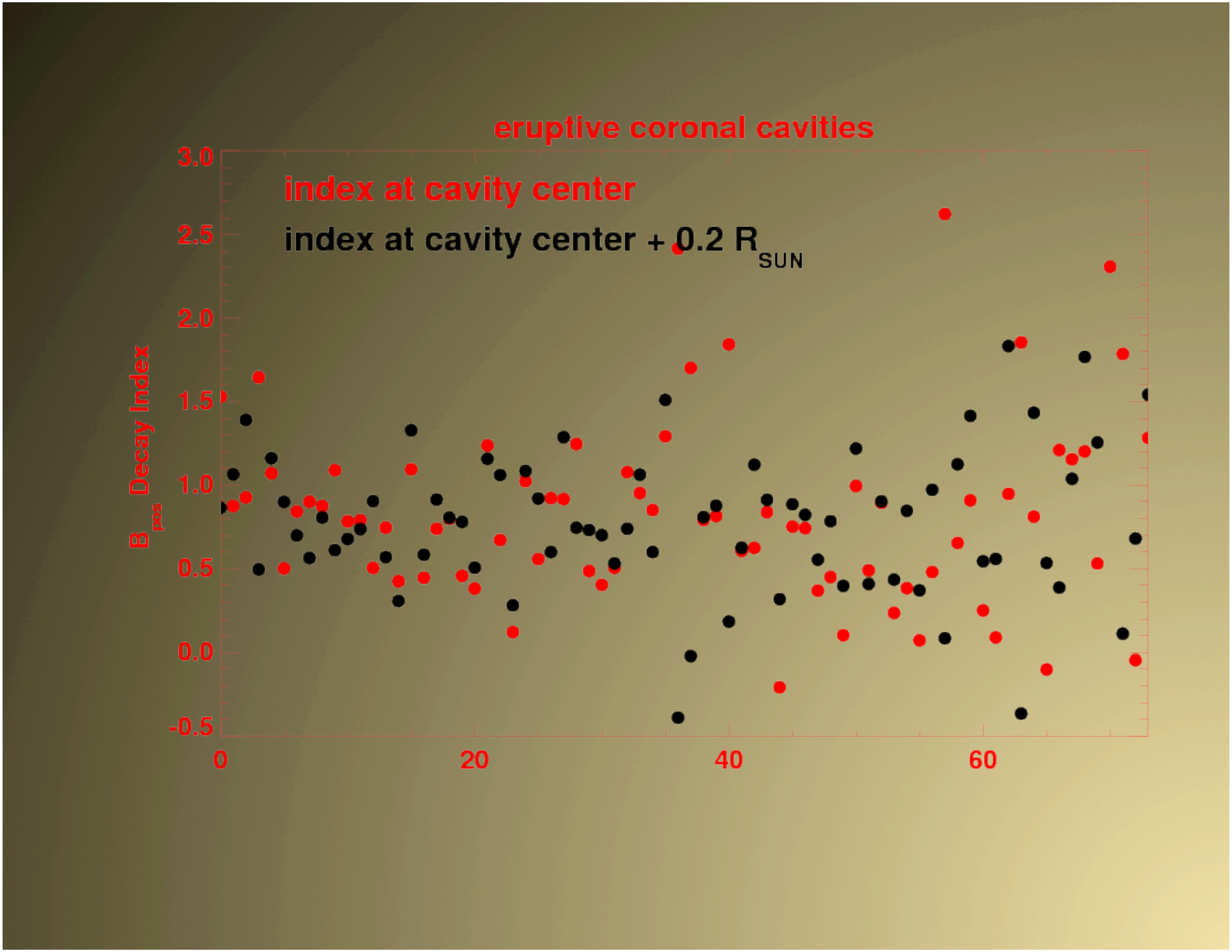
TOPOLOGY

We find that one of the main differences between eruptive and non-eruptive coronal cavities is the topology of the magnetic field above the cavity.

The magnetic field above stable coronal cavities shows a slow decrease and a positive decay index that monotonically increases with height. This is not the case for the large majority of eruptive coronal cavities. The decay index above pre-eruptive coronal cavities can decrease with height, stay almost stable, or even change sign. The small subset of pre-eruptive cavities for which the decay index gradually increases with height have a high index at the location of the cavity center.



non-eruptive coronal cavities
index at cavity center
index at cavity center + 0.2 R_SUN
B_pos Decay Index
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
20
40
60
80
100
120



eruptive coronal cavities
index at cavity center
index at cavity center + 0.2 R SUN
B pos Decay Index
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
20
40
60

TABLE OF RESULTS

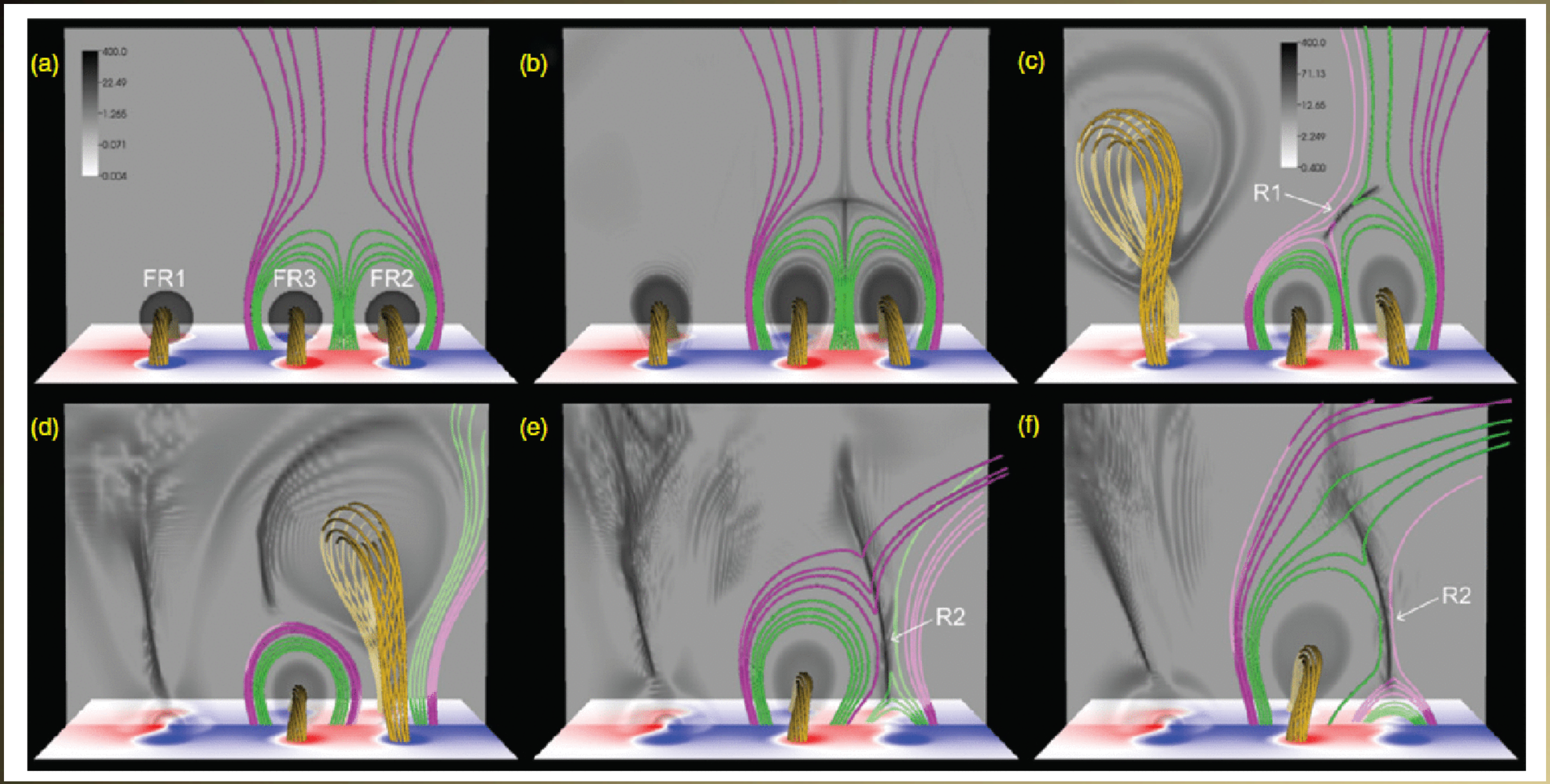
	NON-ERUPTIVE	ERUPTIVE
median decay index at cavity center	0.52	0.81
median decay index at cavity top	0.77	0.71
median center height	1.09	1.16
median top height	1.17	1.27

sympathetic eruptions, pseudo-streamers and null points:

We found several cases when a cavity eruption was observed shortly after another eruption nearby, in spite of a low decay index inside the cavity. For many of these events, the eruptive cavity was located under a pseudo-streamer or a null point was present just above the cavity. These are special locations where the value of the decay index is not a good indicator of the cavity stability.

Coronal observations -such as the linear polarization measured by the CoMP instrument at Mauna Loa- that can identify these topological features can help to locate regions where eruptions are more or less likely to occur (see S. Gibson's talk on Friday).

model for sympathetic eruptions



Török et al, 2011

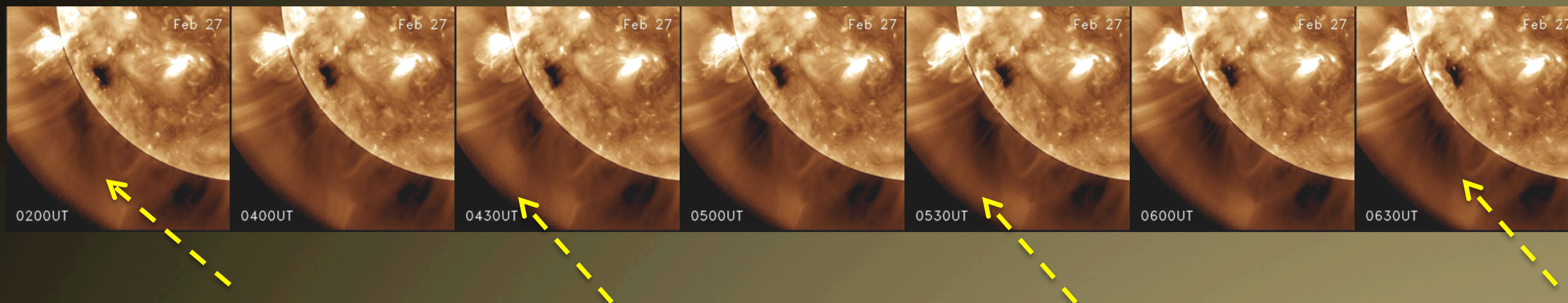
3D ideal MHD simulation of triple-eruption observed by SDO on August 2010. First, an eruption occurs near a pseudo-streamer, which triggers the eruption of one of the cavities under the pseudo-streamer, followed by the eruption of the other cavity. Note that the cavity closest to the location of the first eruption is the last one to erupt.

←

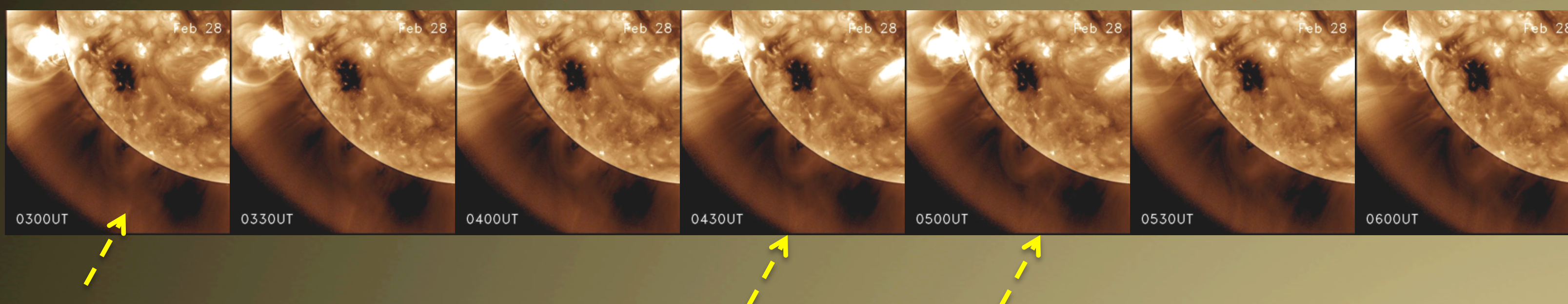
Triple-eruption observed at the SE limb on May 27-28 2012 which shows a similar topology and sequence of events. An eruption occurs N of the pseudo-streamer, followed by the eruption of the southernmost cavity and finally by the eruption of the northernmost cavity.

→

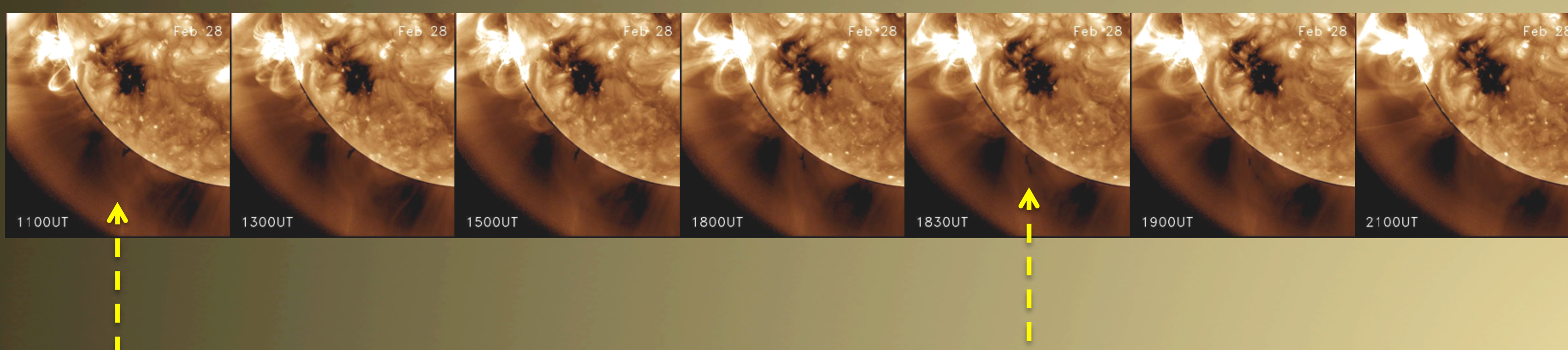
the first eruption occurs just N of the pseudo-streamer



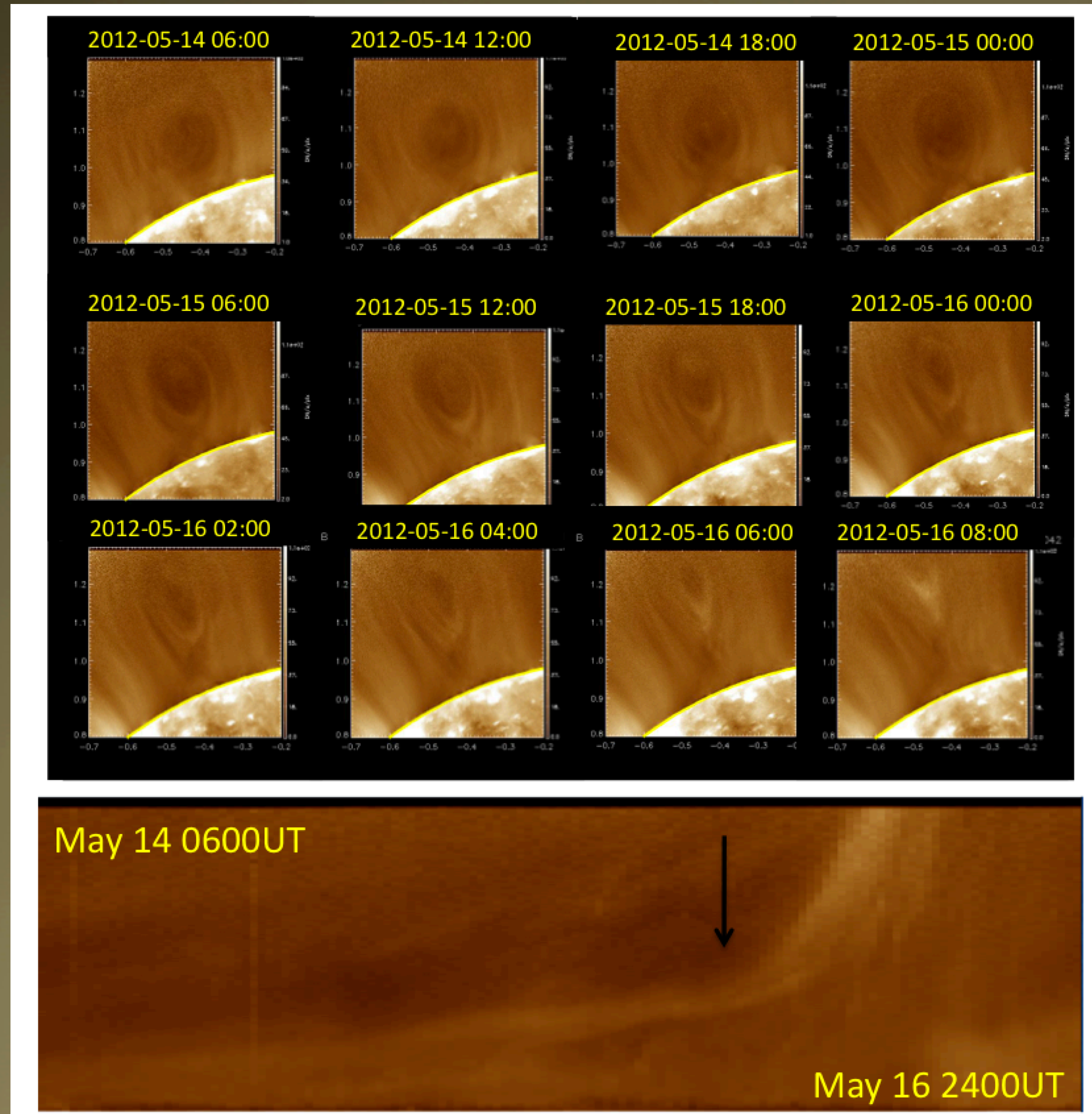
the southernmost cavity under the pseudo-streamer erupts first



the northenrmost cavity under the pseudo-streamer erupts last



A high decay index is not necessary for an eruption to occur. Other factors can affect the stability of the cavity system, such as an eruption occurring nearby which could open up field lines in the vicinity of the cavity, or new emerging magnetic flux.



For erupting cavities, the rapidly accelerating phase often (but not always) happens at heights where the decay index becomes > 1.0, as in the case above.

FINDINGS

- The decay index for coronal cavities systems, which are relatively weak magnetic regions, is lower than the decay index in active regions.

- The decay index varies significantly in value for both eruptive and non-eruptive cases and there is overlap between the two groups.

- Stable coronal cavities have a decay index ≤ 1.0

- Stable coronal cavities have, on average, a lower decay index than the eruptive ones.

- A high decay index is not a necessary condition for a coronal cavity to erupt.

- There is a subset of eruptive coronal cavities that have a very low decay index and are located in proximity of a null point or a local minimum in B_{pos}

- The magnetic field above stable coronal cavities has a simple topology and slowly decreases with height. In contrast, the magnetic field above eruptive cavities is more complex.

ACKNOWLEDGEMENTS

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