Evolution of Coronal Cavities leading to CMEs

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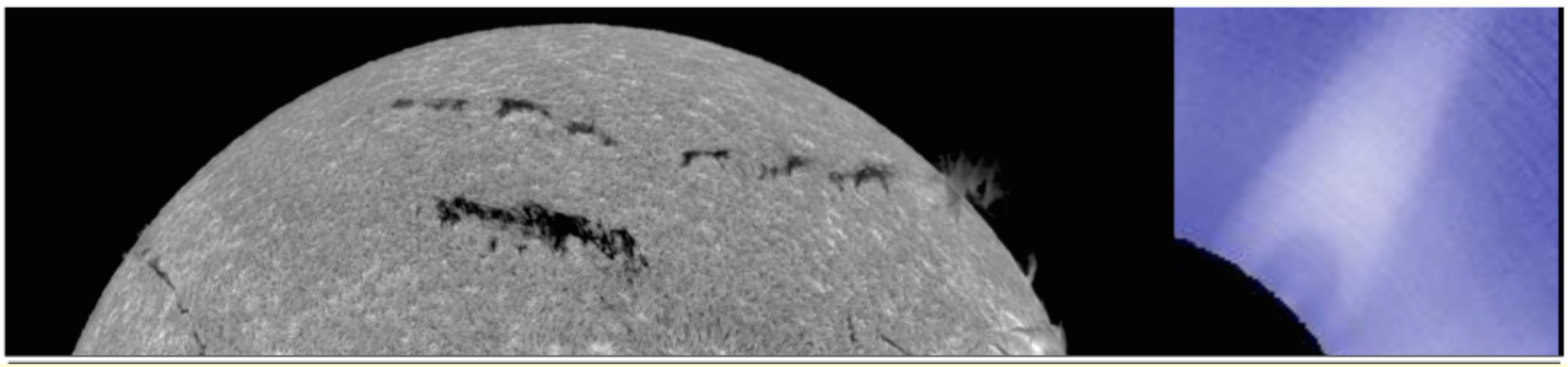
Outline

- Introduction
- Motivation of study
- Observations of the morphological evolution of a coronal cavity during eruptive phase (SWAP/Proba2 observations)
- Pre-eruptive stability condition of the cavity in the context of torus instability
- Results

Coronal Cavity

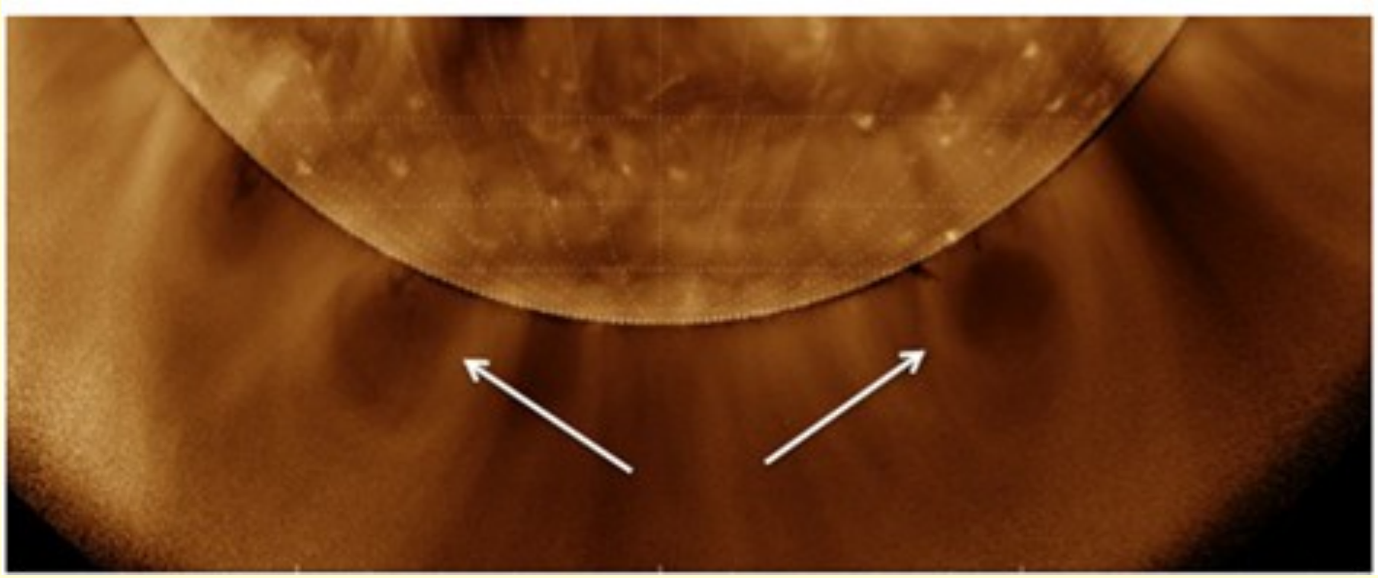
Cavities appear as dark features over the solar limb and are believed to be the density depleted cross-sections of the magnetic flux ropes, where the magnetic field strength attains a much higher value compared to the background corona. Cavities may last for days or even weeks and evolve as the dark core part of the CME during the eruptive phase.
(Low and Hundhausen, 1995; Gibson and Fan, 2006)



PCF observed in Hα by BBSO on July 2002 (right): White light cavity observed by MLSO/MK4

[Gibson 2017]

EUV Cavity observed from AIA 193 channel on 29 May 2013



[Karna et al. 2017]

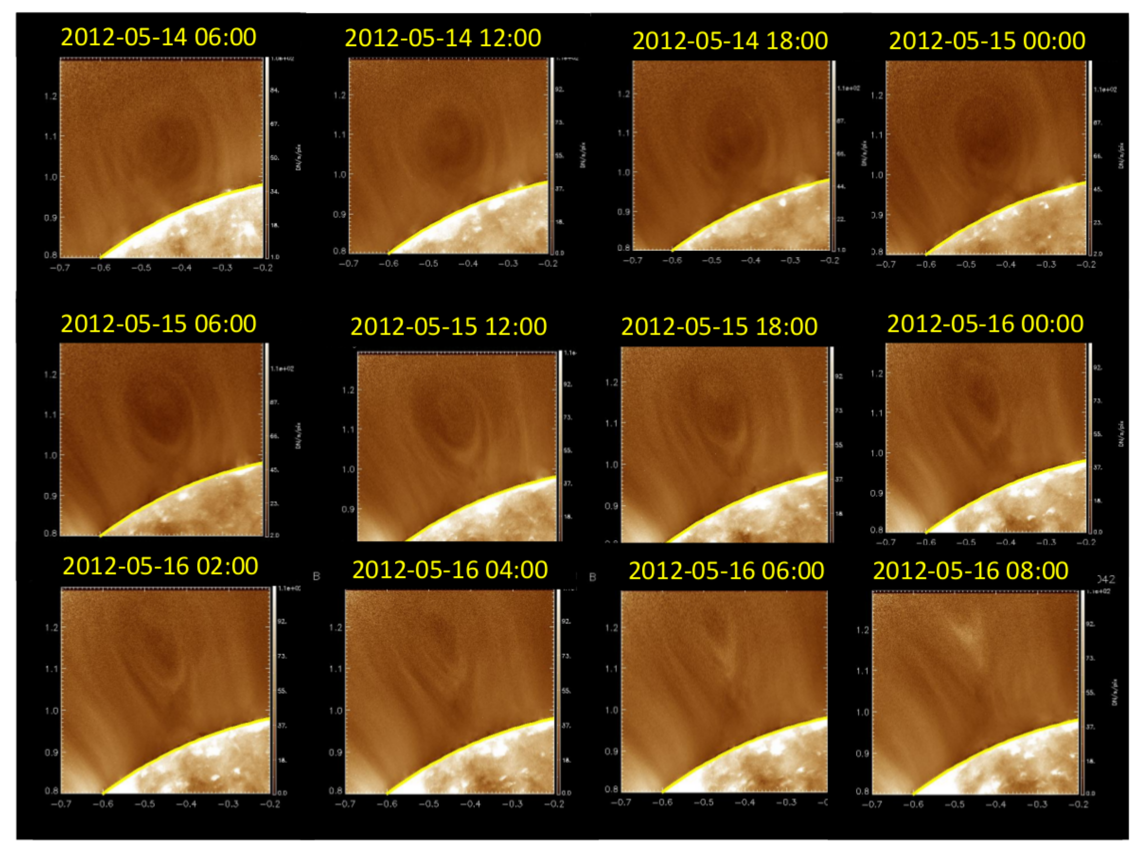
Morphological pre-cursors for cavity eruption:

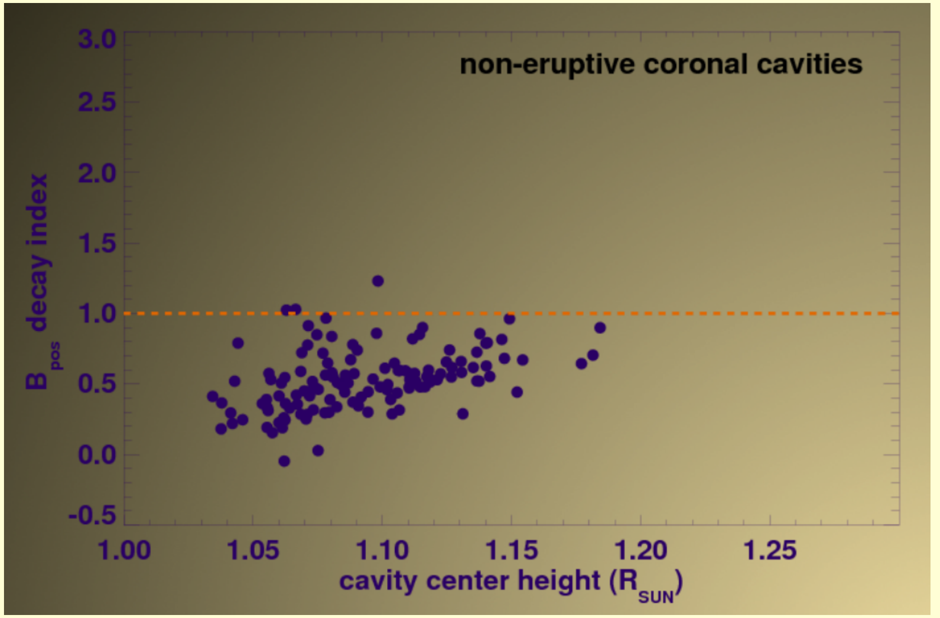
Cavity morphology can be observed as semi-circular, elliptical or tear-drop shape.

Forland et al. 2013, identified 129 cavities during June 2010 to December 2019 from the data obtained from AIA 193 channel

Of these 129 cavities, 28 % were eruptive.

61% of all the eruptive cavities have been found to be in tear-drop shape before the eruption.





Stability study of coronal cavities:

Decay index values for the non-eruptive cavities at the height of its centroid mostly lie below the 1.0 value. (de Toma & Gibson 2018)

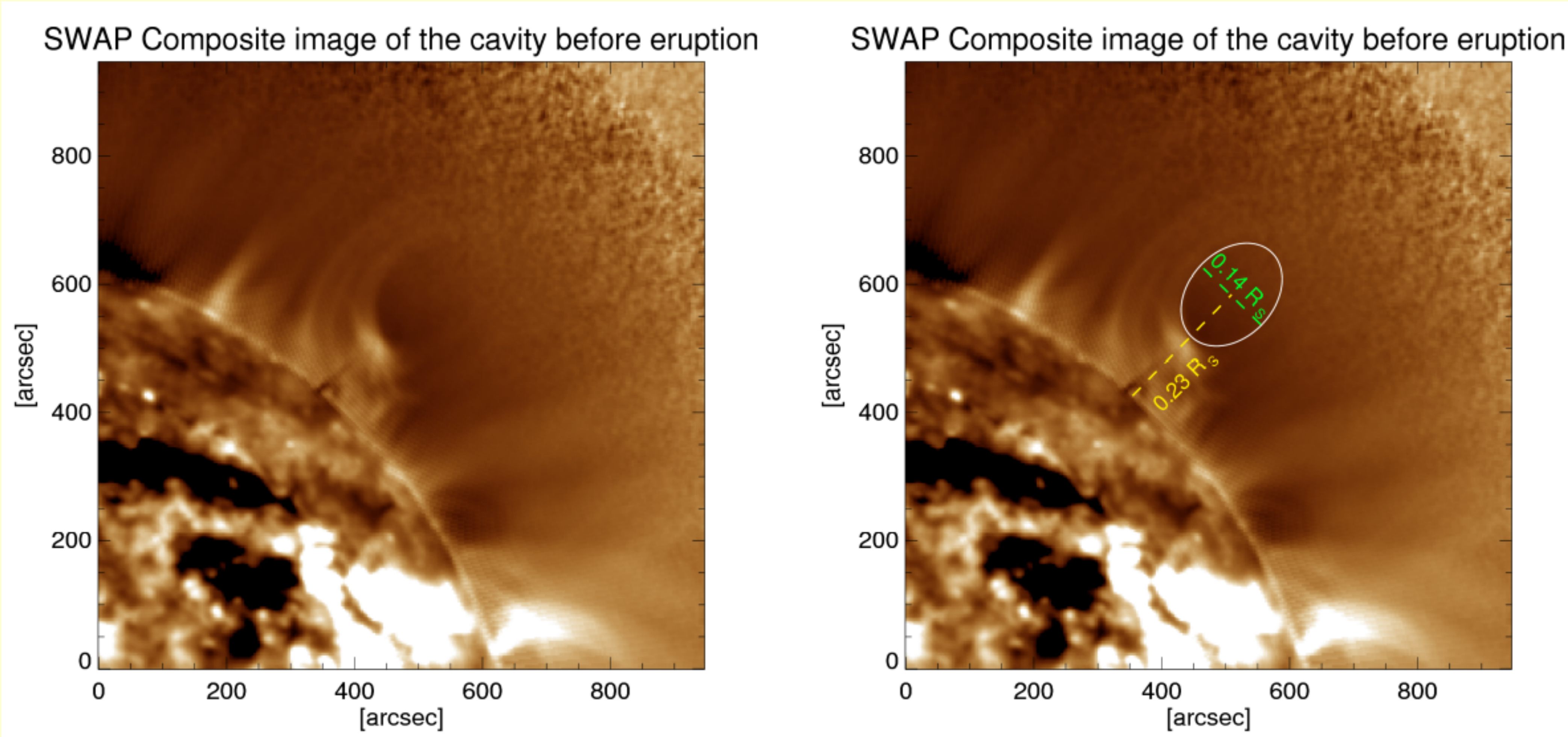
Motivation

Continuous tracking of an eruptive coronal cavity starting from its EUV counterpart in lower corona up to the white-light cavity morphology seen in LASCO C2/C3 field-of-view has not been studied earlier due to the observational gap between 1.3 to 2 solar radii. The extended field-of-view of SWAP/PROBA2 EUV Imager fills the observational gap between 1 to 2 $R_{S.}$ Therefore, it enables us to track the complete morphological evolution of the coronal cavity in order to address the following key problems regarding the initiation mechanism of CMEs at lower corona

- The initiation height of the CME
- Morphological pre-cursor of CME initiation
- Correspondence between the EUV cavities seen in lower corona and the white light cavities seen during the CME eruption
- Self-similar expansion of CMEs: Starting from the initiation height whether the CMEs exhibit self-similar expansion or not. If not, then what is the critical height above which it shows the self-similar expansion.
- Role of ideal MHD instabilities to trigger the CME eruption

13 June 2010: Cavity morphology as seen in SWAP before eruption

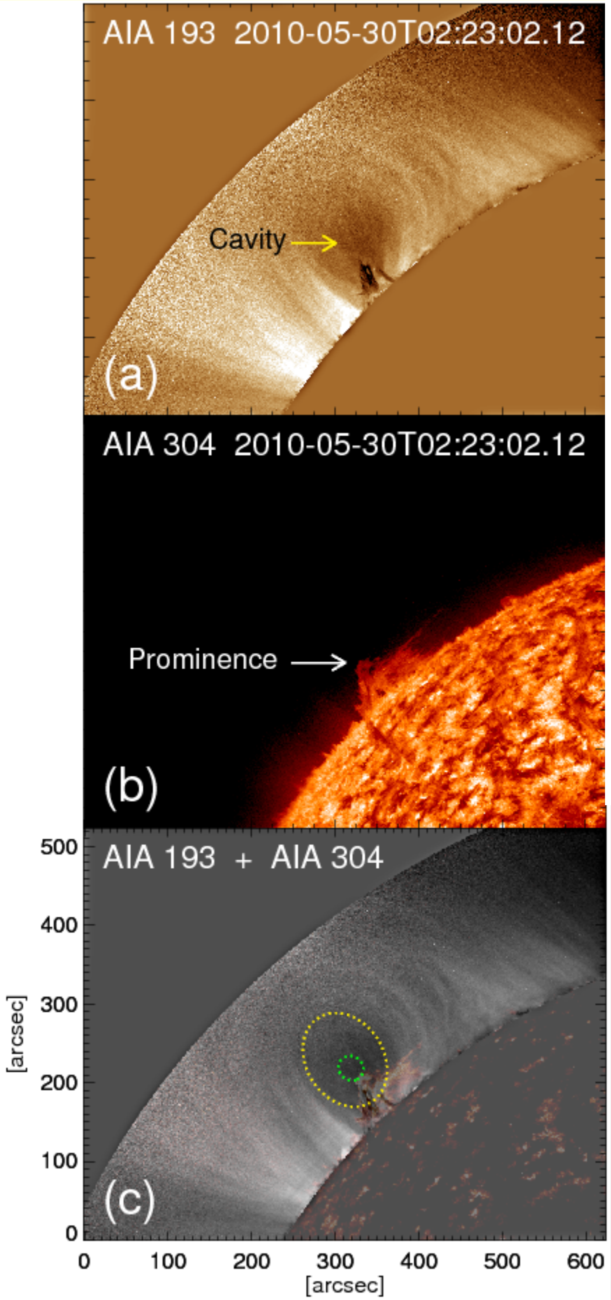
Eruption time – around 06:30 UT on 13 June, 2010
Location - North-West solar-limb

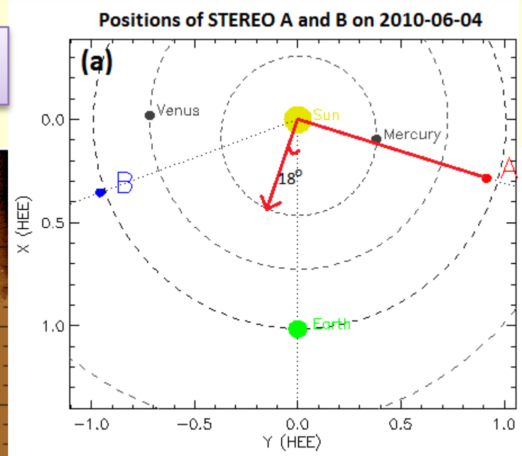


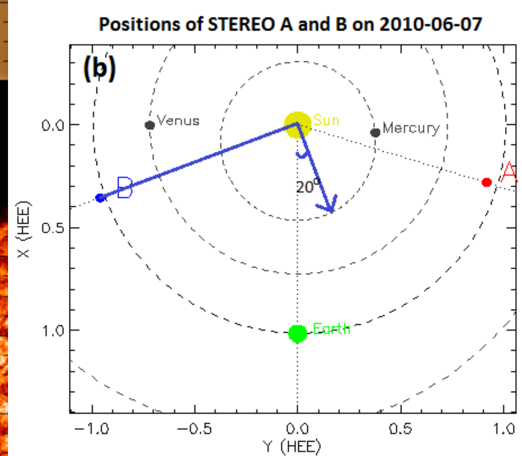
Axis height of the cavity is near about 1.23 solar radii prior to eruption

Evolution of the cavity during quiescent phase

East limb



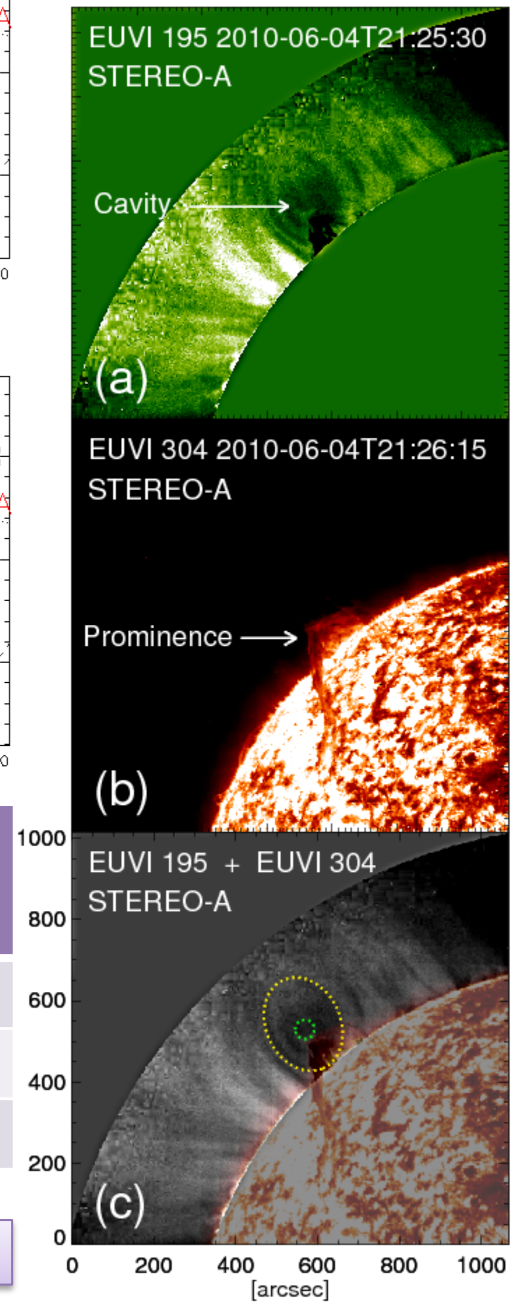




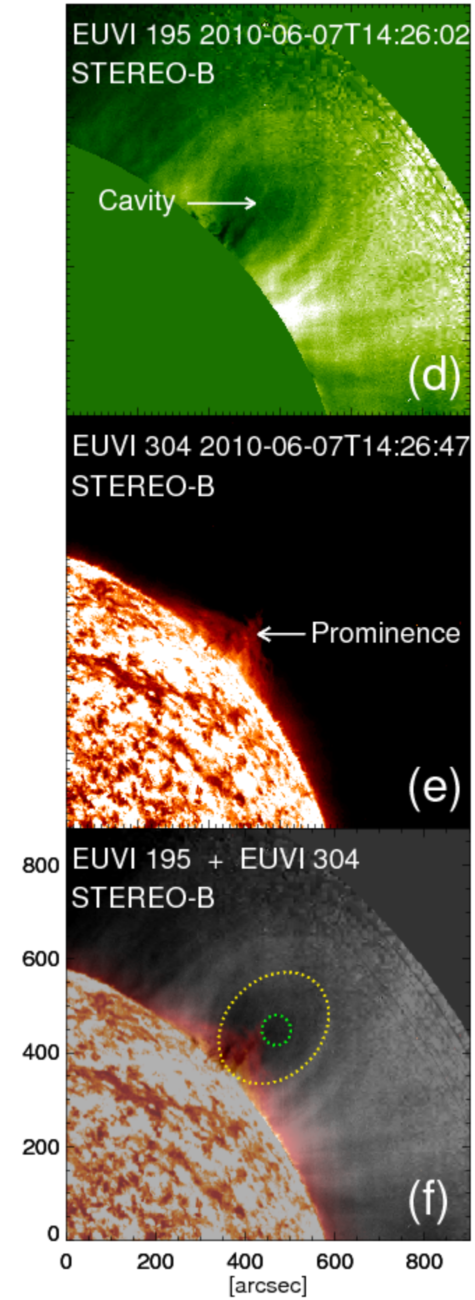
Longitude w.r.t CM	Cavity centroid height (R_S)
90°	1.10
18°	1.13
-20°	1.17

Shape is ~ circular

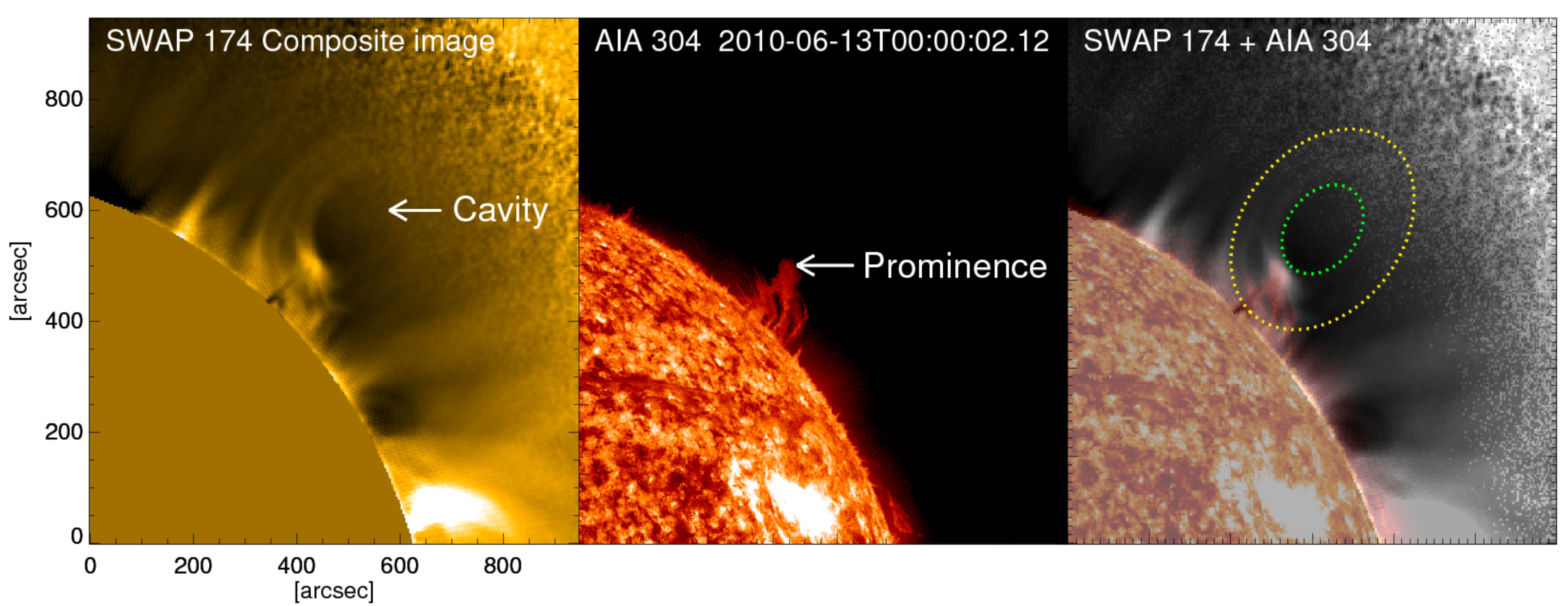
POS along 18° east from central meridian



POS along 20° west from central meridian



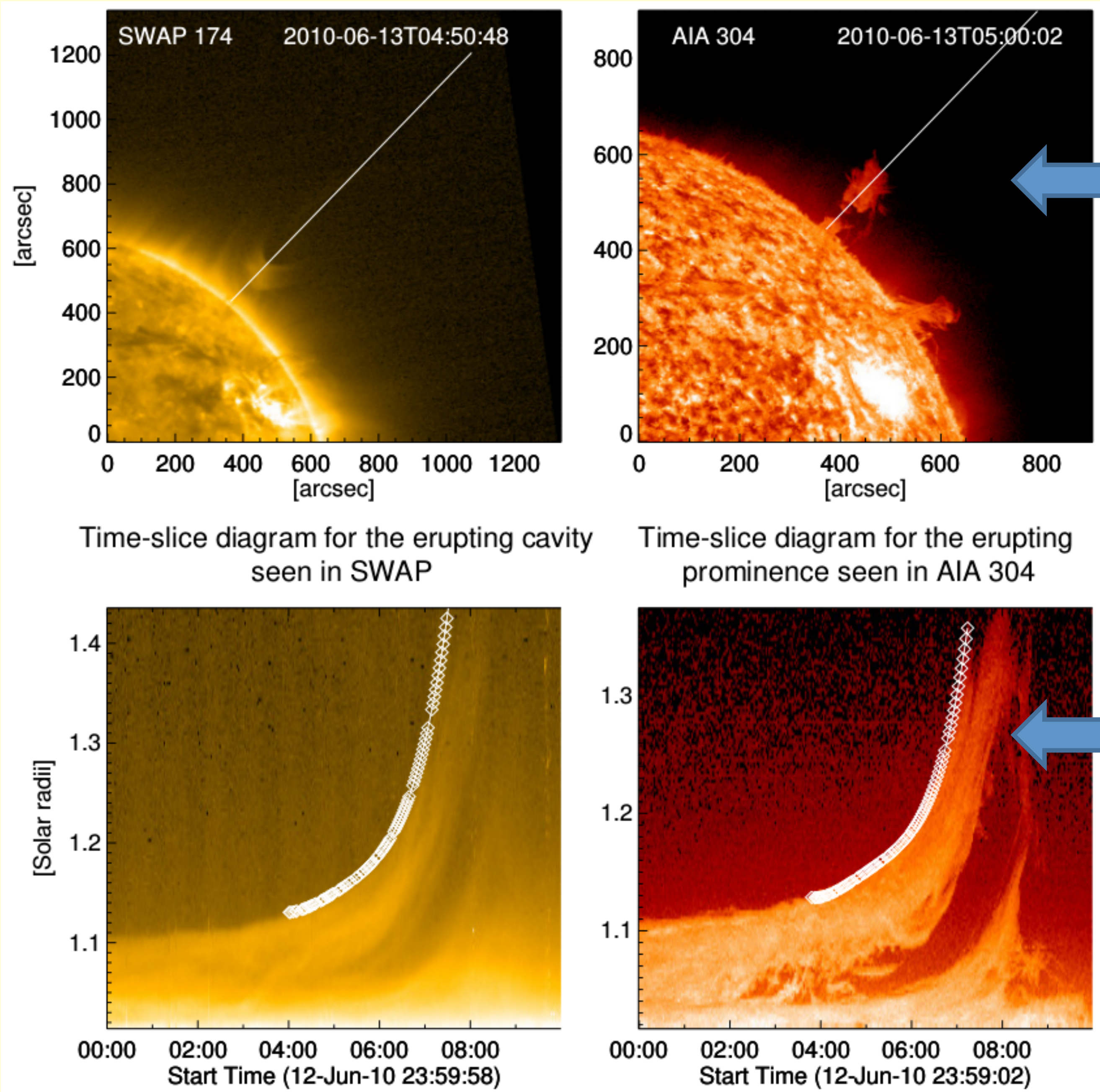
Overlap of coronal cavities seen in SWAP and the prominence material seen in AIA 304



The top of the prominence material and the lower-most part of the cavity coincide well.

Do they maintain this trend during the eruption also ?

Spatial relationship between prominence and cavity during eruptive phase

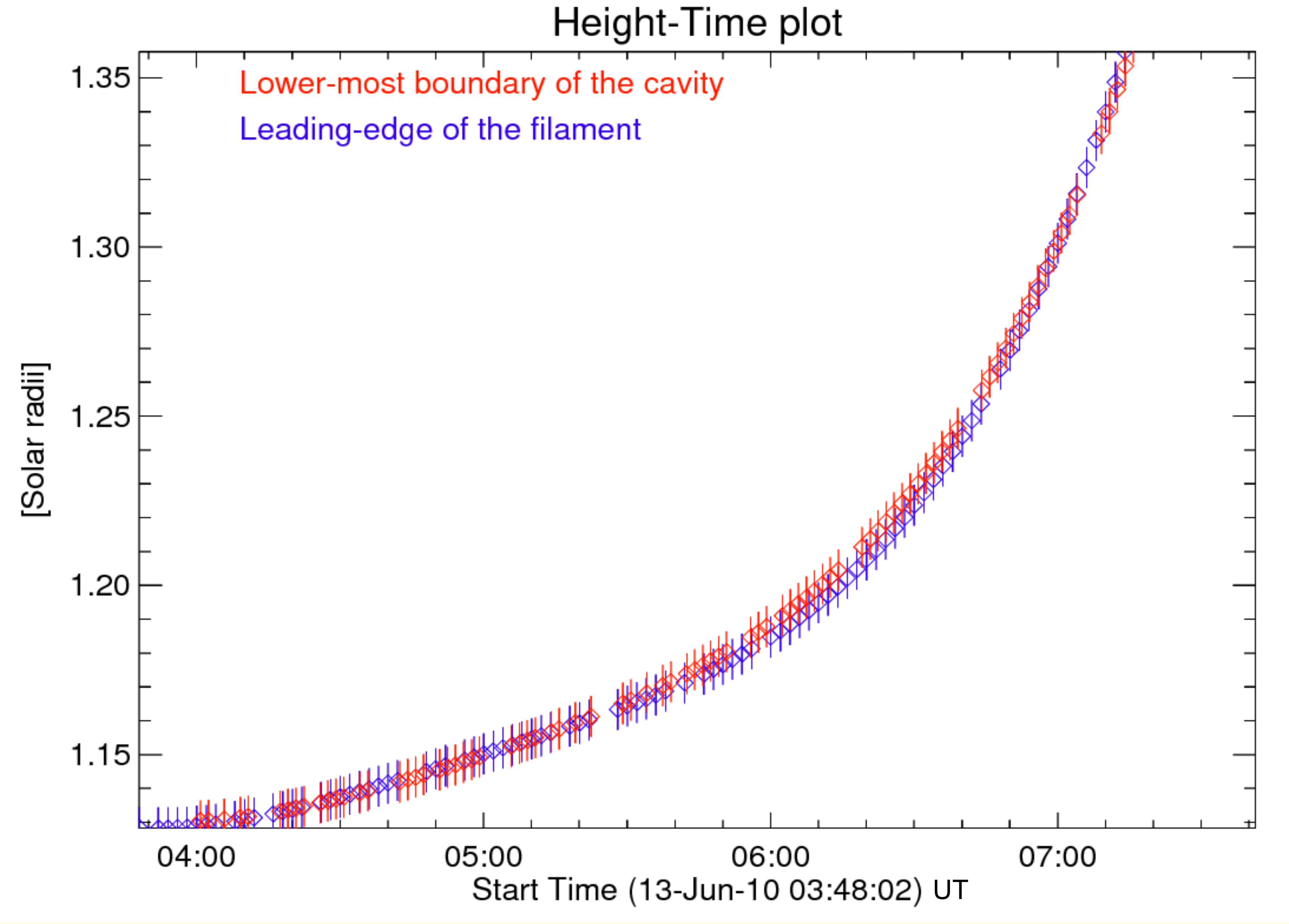


Positions of the slits on SWAP and AIA images along which the height-time profile for the lower-most boundary of the cavity and the top-most part of the prominence have been evaluated

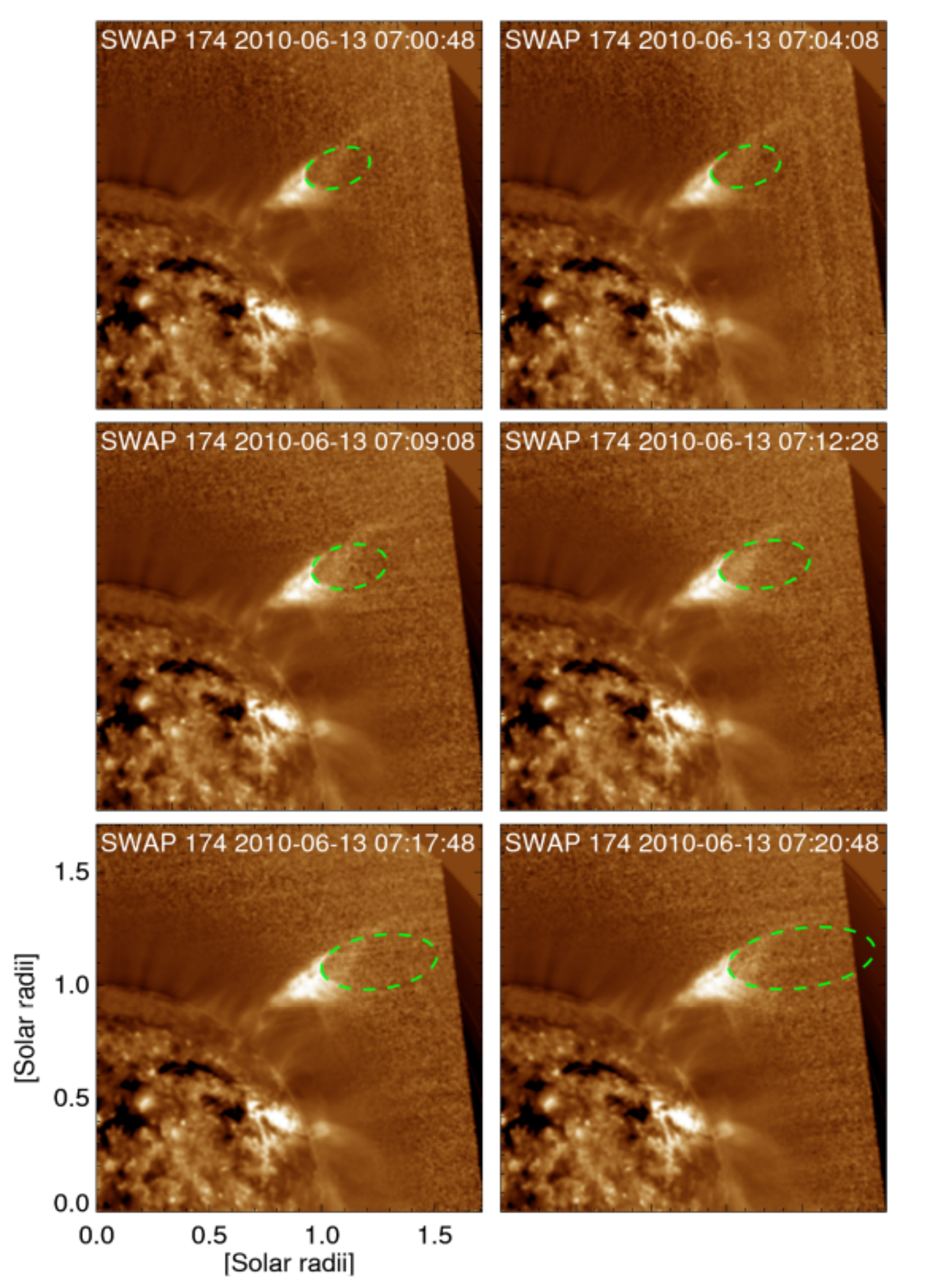
Both the slits are taken along the same position angle

Height-time plot for the lower-most boundary of the cavity and the top-most part of the prominence

Do these two height-time profiles match with each other?



The two height-time profiles almost coincide. The bottom boundary of the cavity and the top most part of the prominence lie in a same boundary.



Geometrical fitting to the cavity morphology in different time-steps during its eruptive phase within SWAP field-of-view

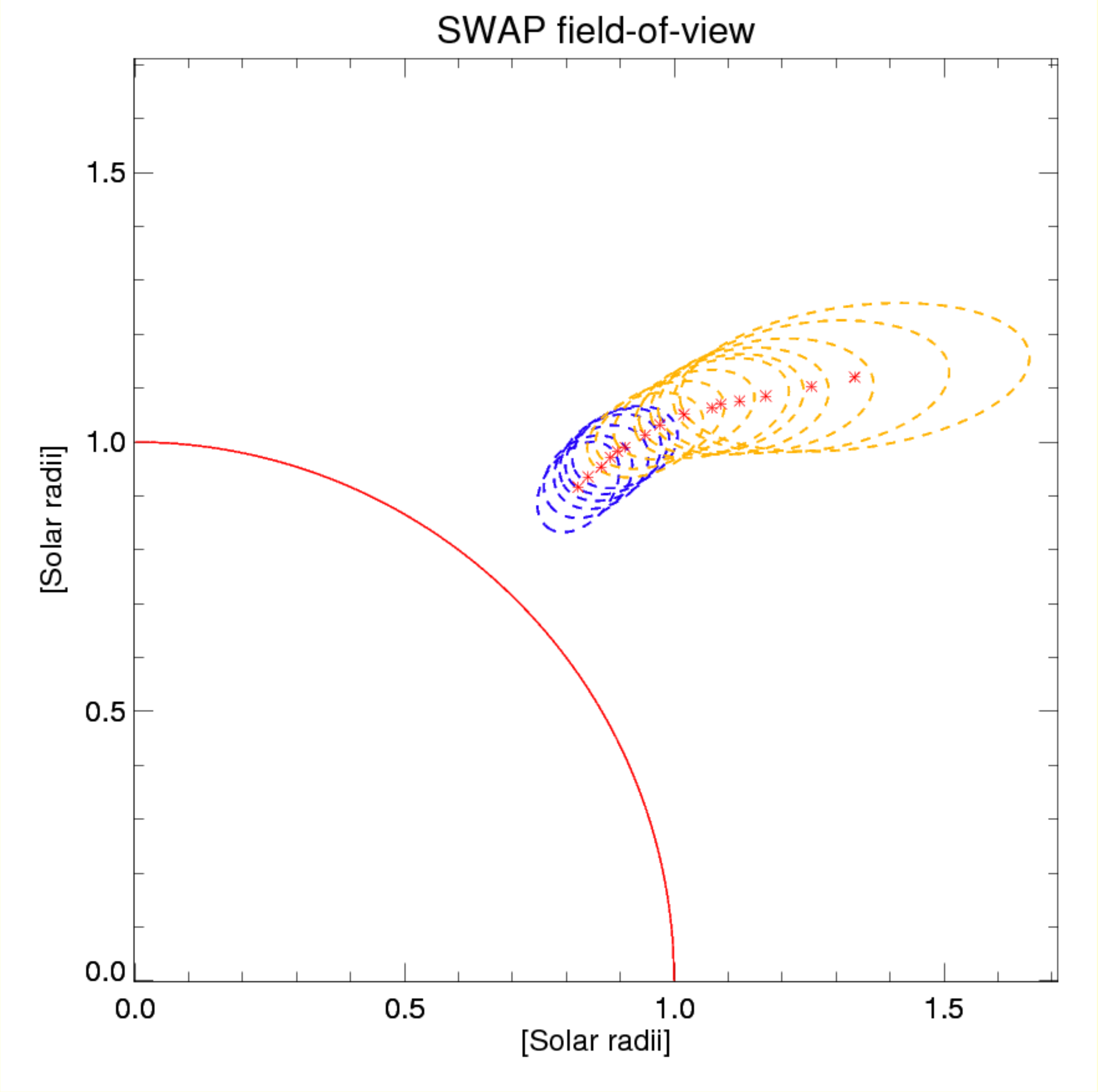
In the AIA (17.1 nm) field-of-view we could track the evolution of the cavity only up to 1.35 solar radii

The extended field-of-view of SWAP(17.4 nm) gave an unique opportunity to track the cavity up to 1.7 solar radii

Evolution of the cavity in SWAP field-of-view

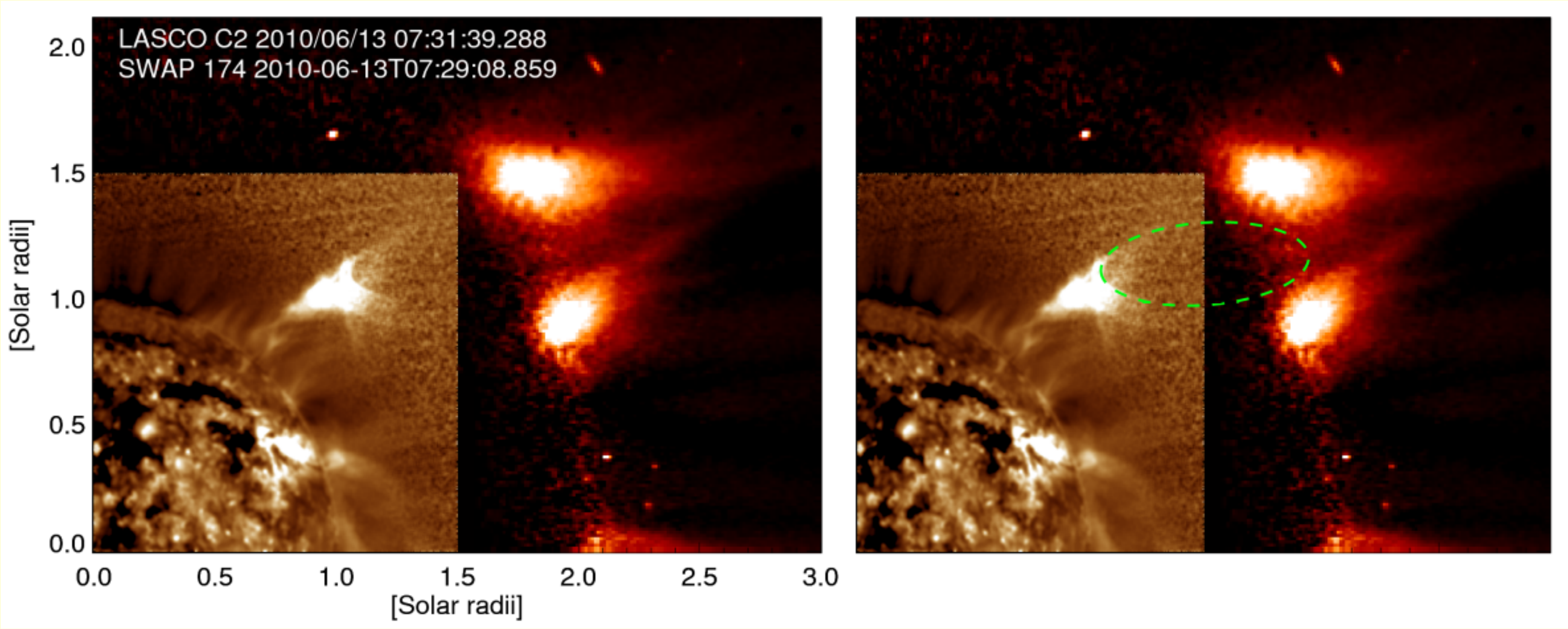
Non-radial motion at about 1.3 solar radii

Position angle changes from 310 to 270 degrees



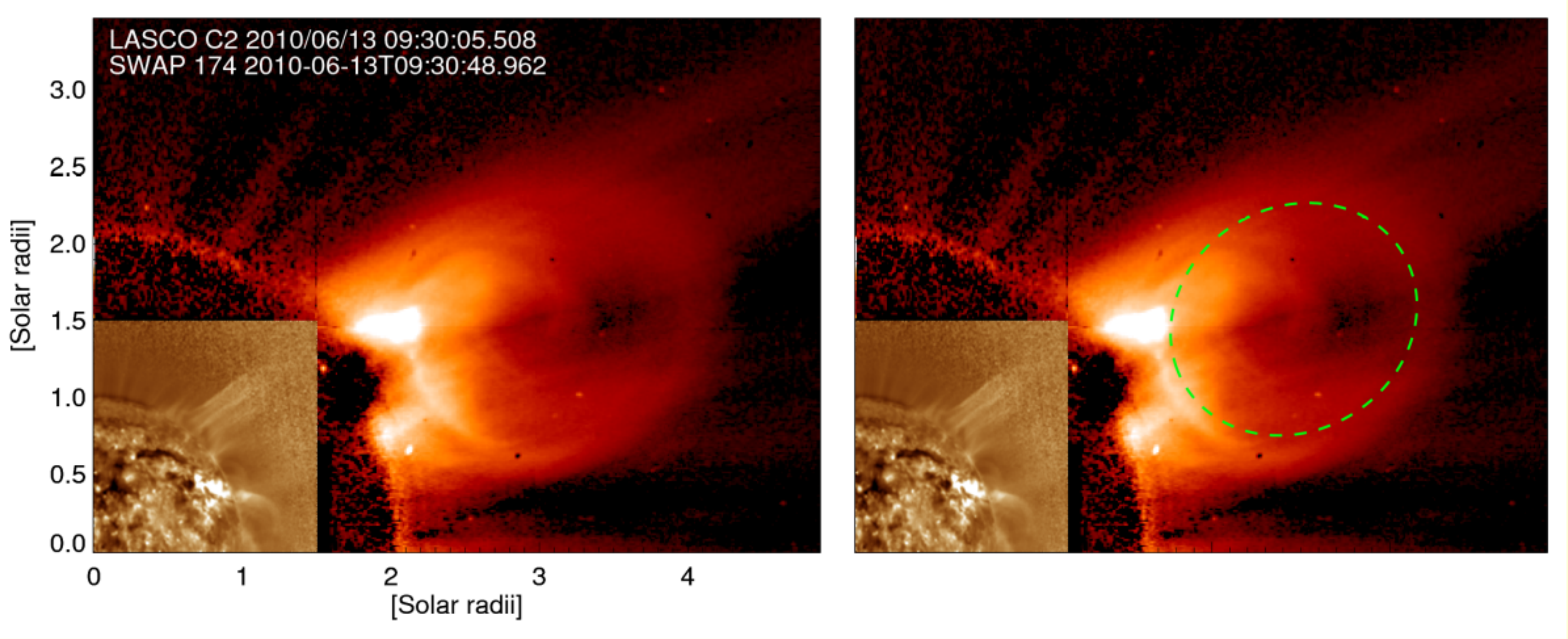
Fitting the cavity morphology in SWAP + LASCO C2 field-of-view (2-6 Rsun)

07:30 UT

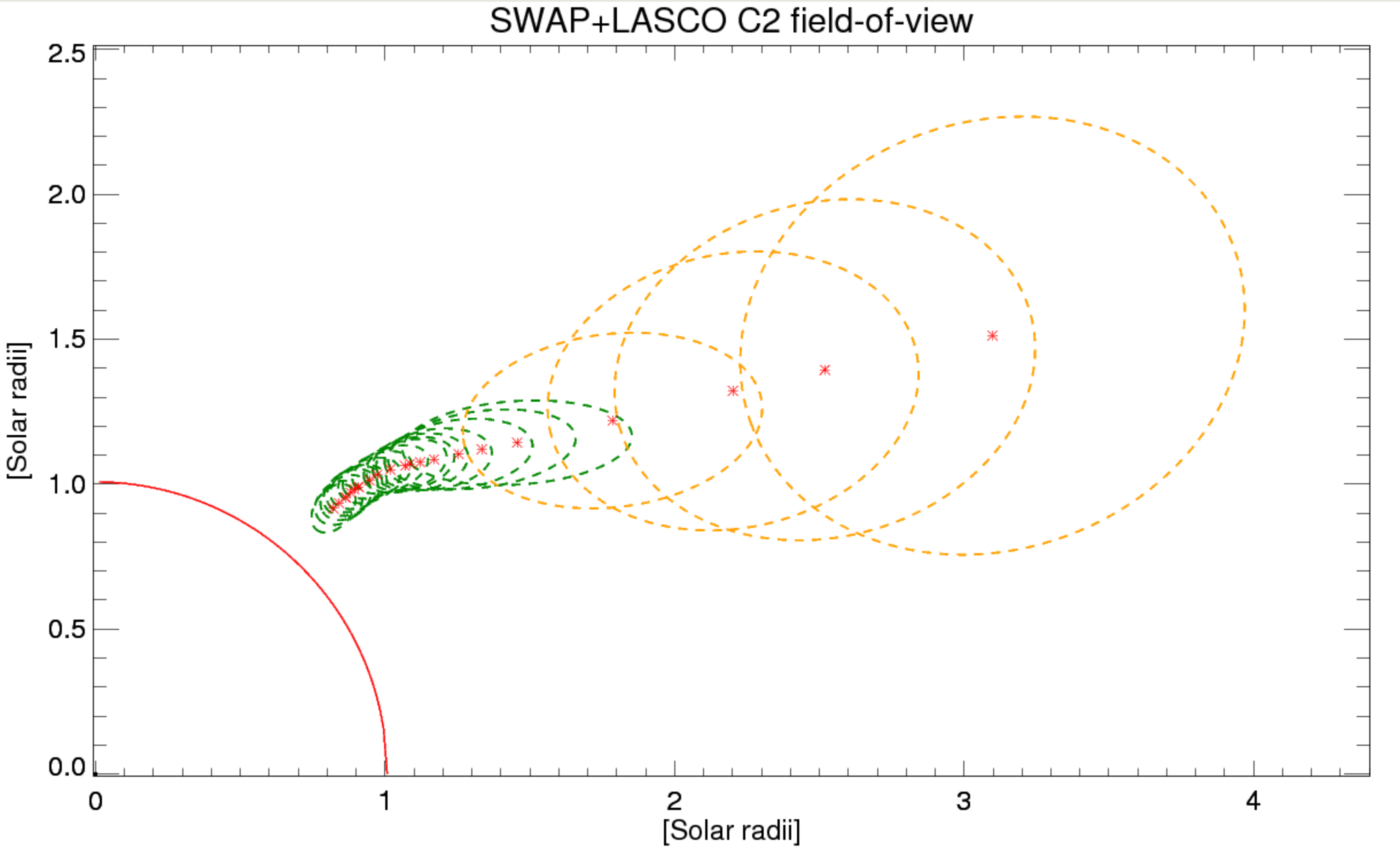


Fitting the cavity morphology in SWAP + LASCO C2 field-of-view

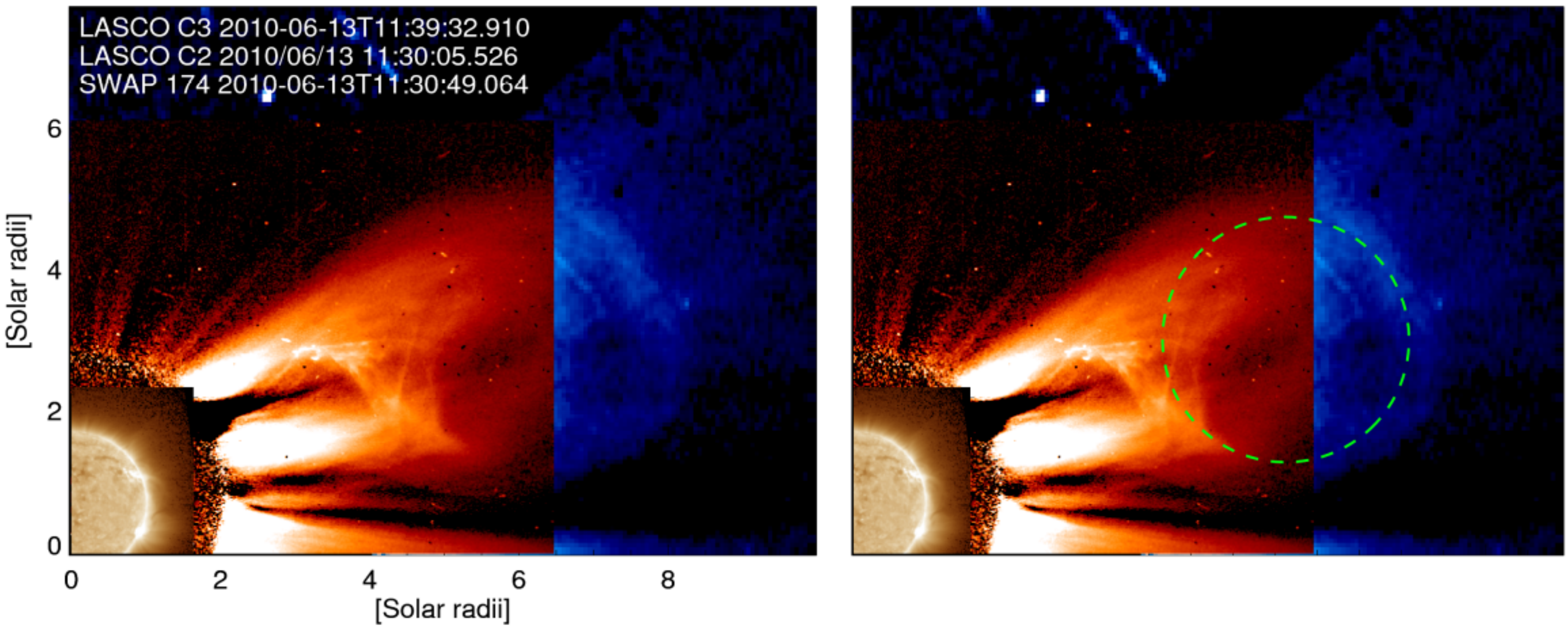
09:30 UT



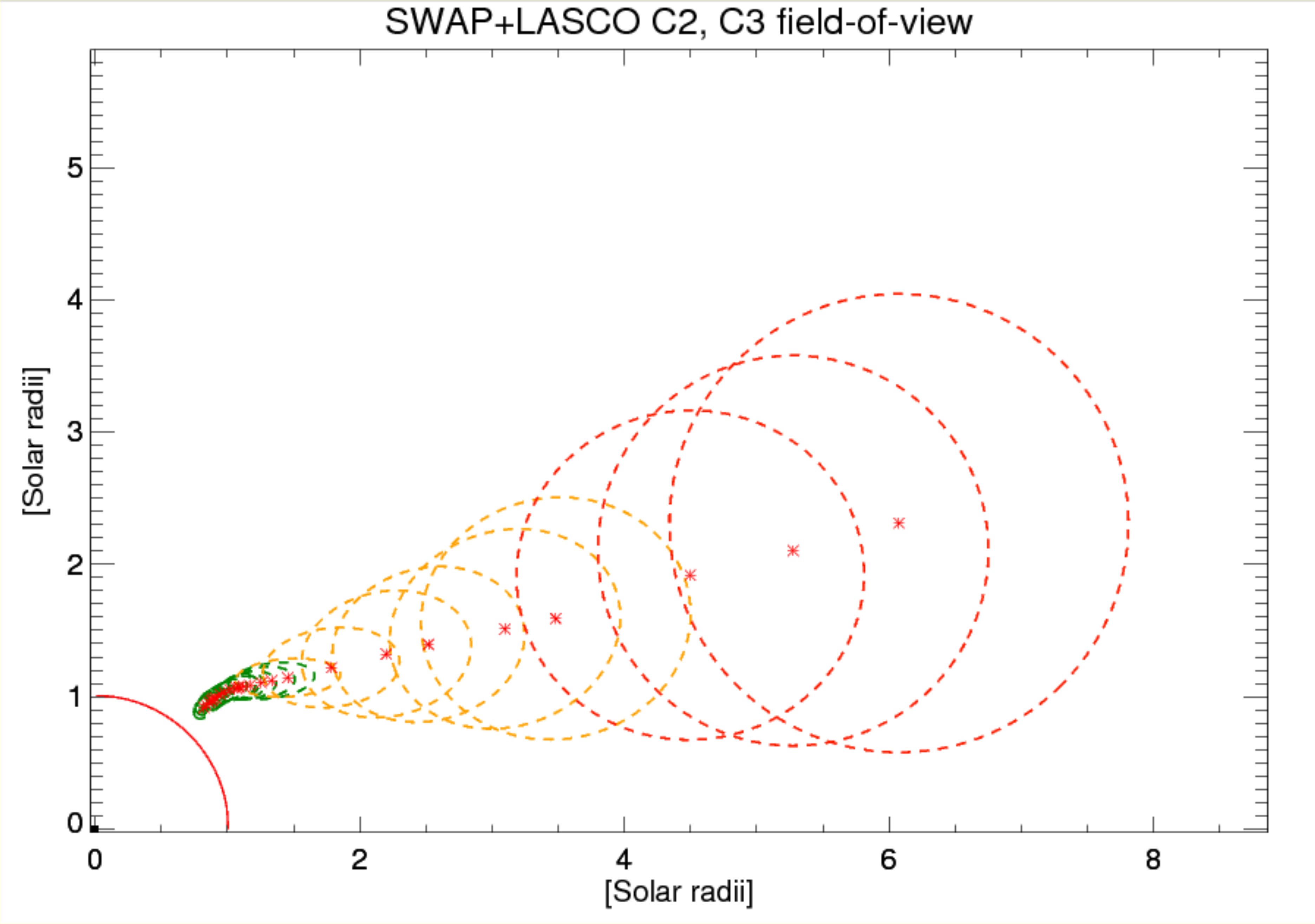
Evolution of the cavity in SWAP + LASCO C2 field-of-view



Fitting the cavity morphology in SWAP + LASCO C2 + C3 field-of-view (3-30 Rsun)

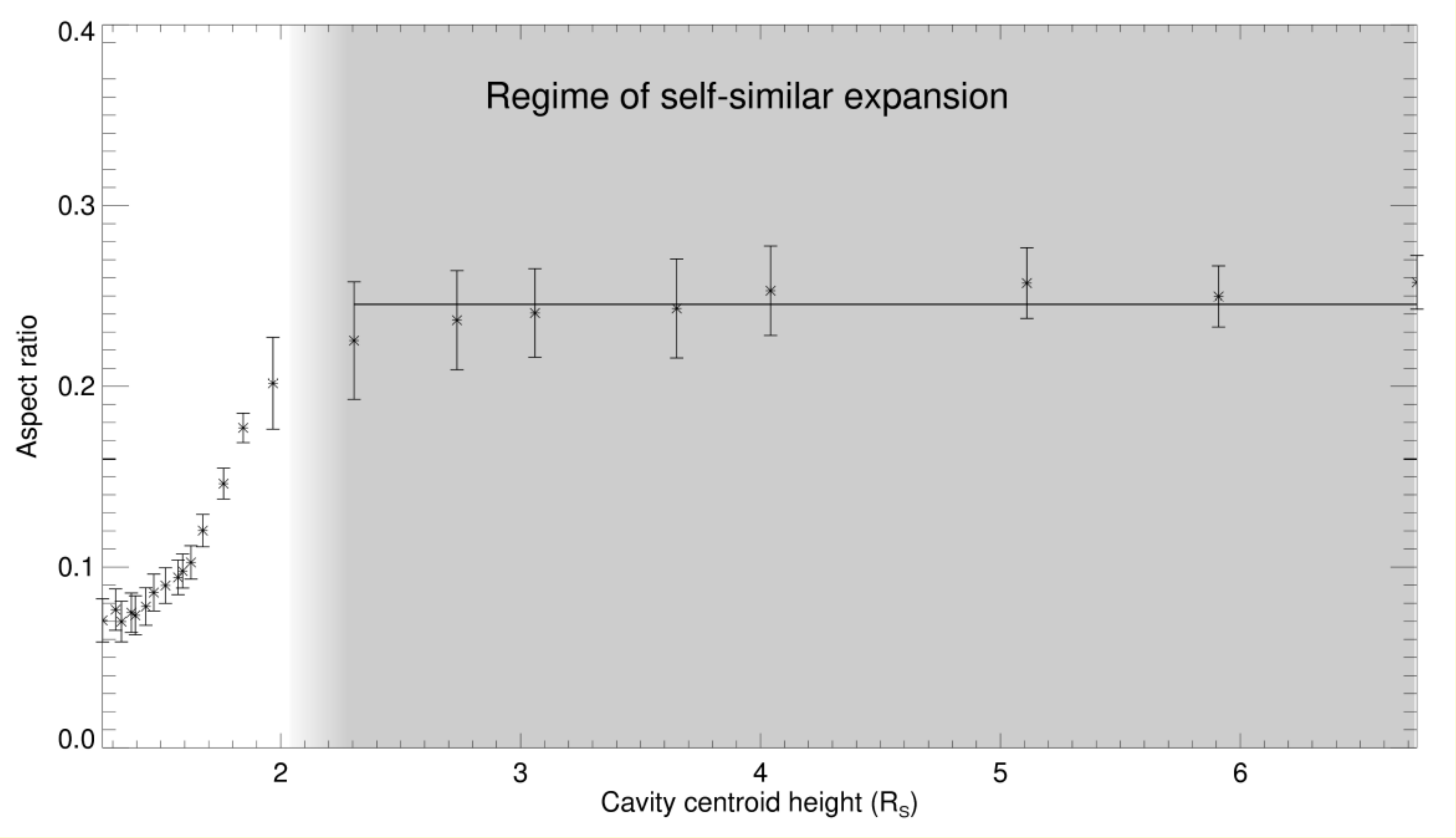


Evolution of the cavity in SWAP + LASCO C2 + C3 field-of-view

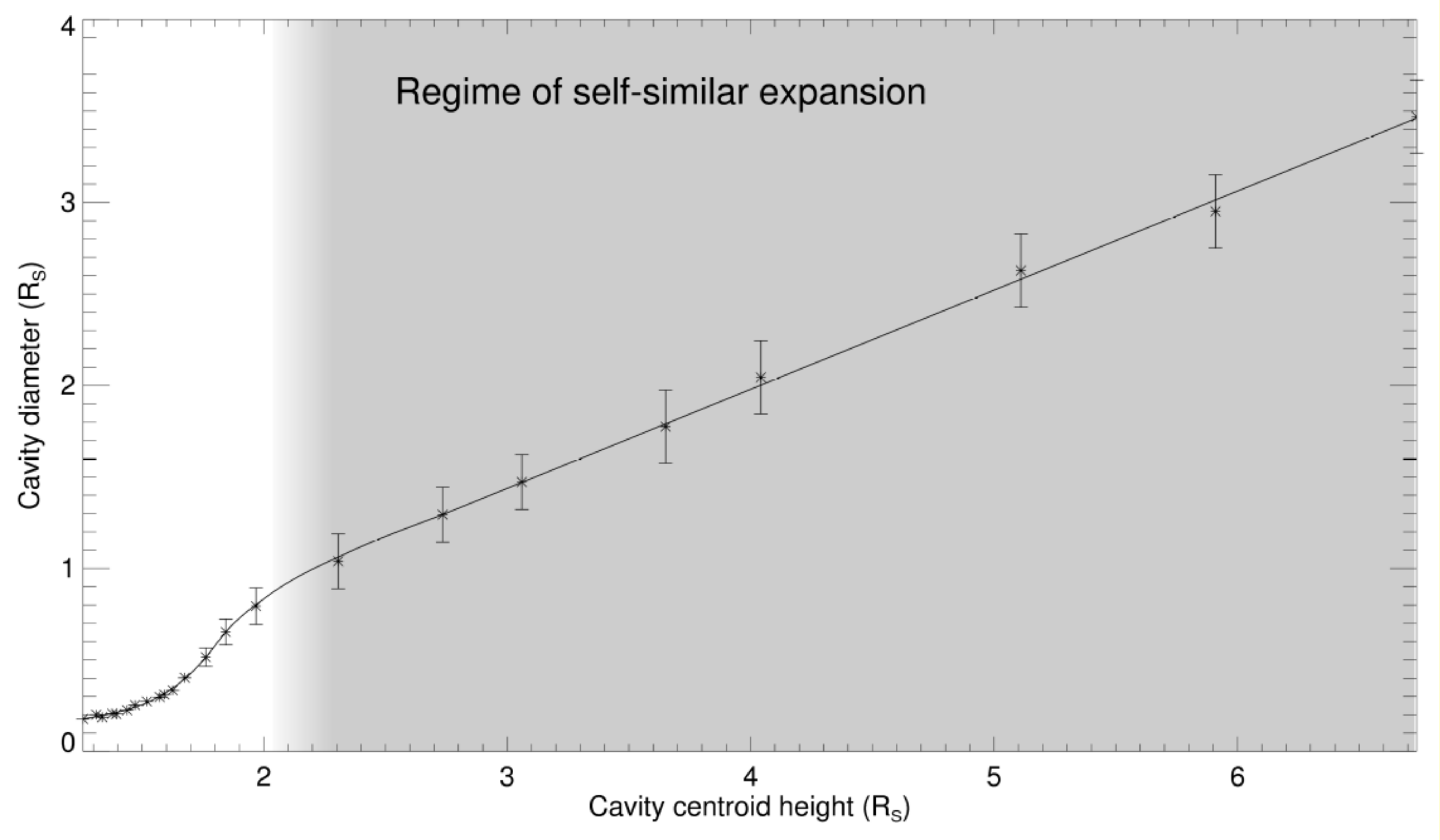


Aspect ratio vs height of the cavity-centroid plot

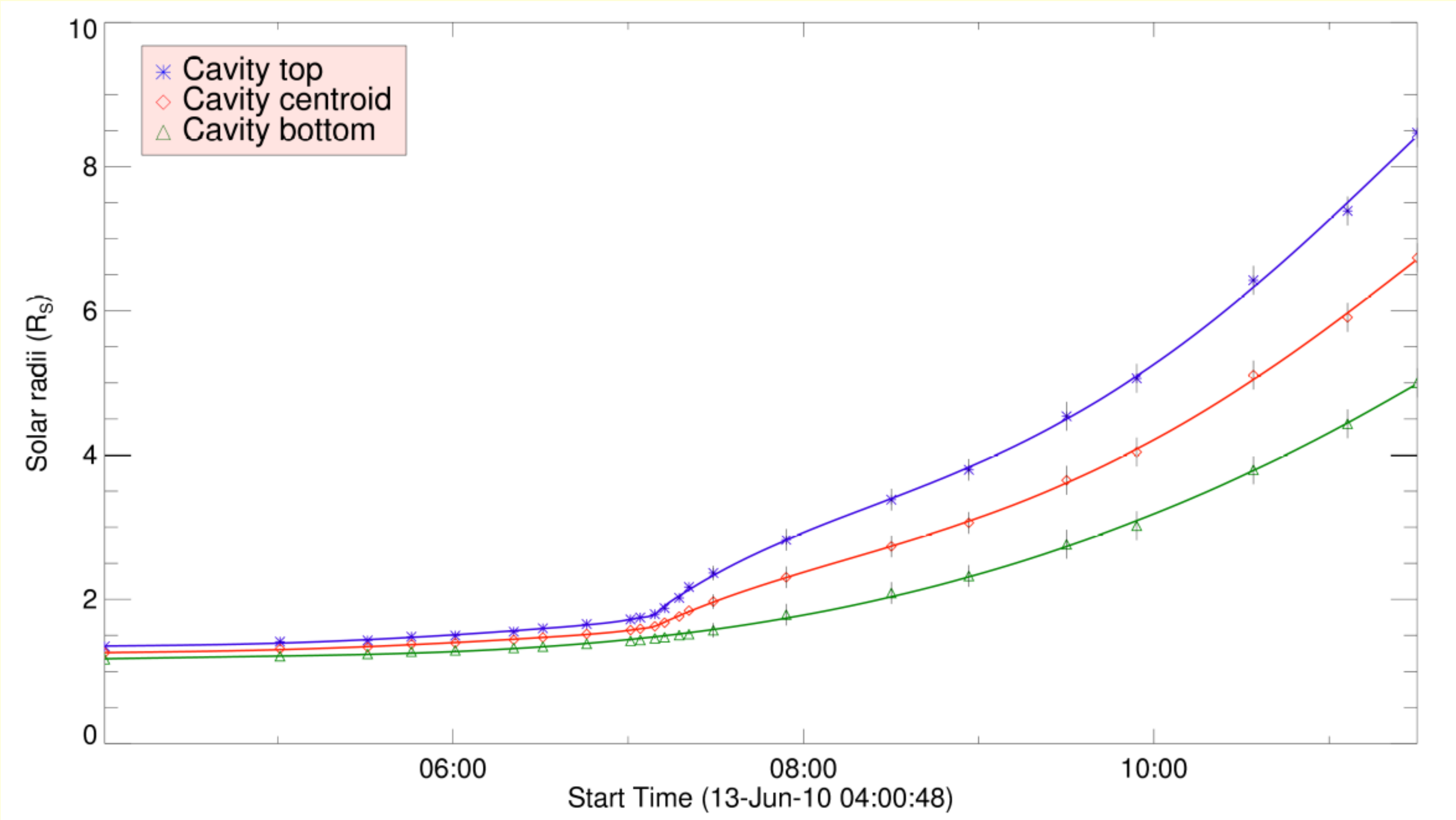
Aspect ratio: Ratio of Radius of cross section and the centroid height



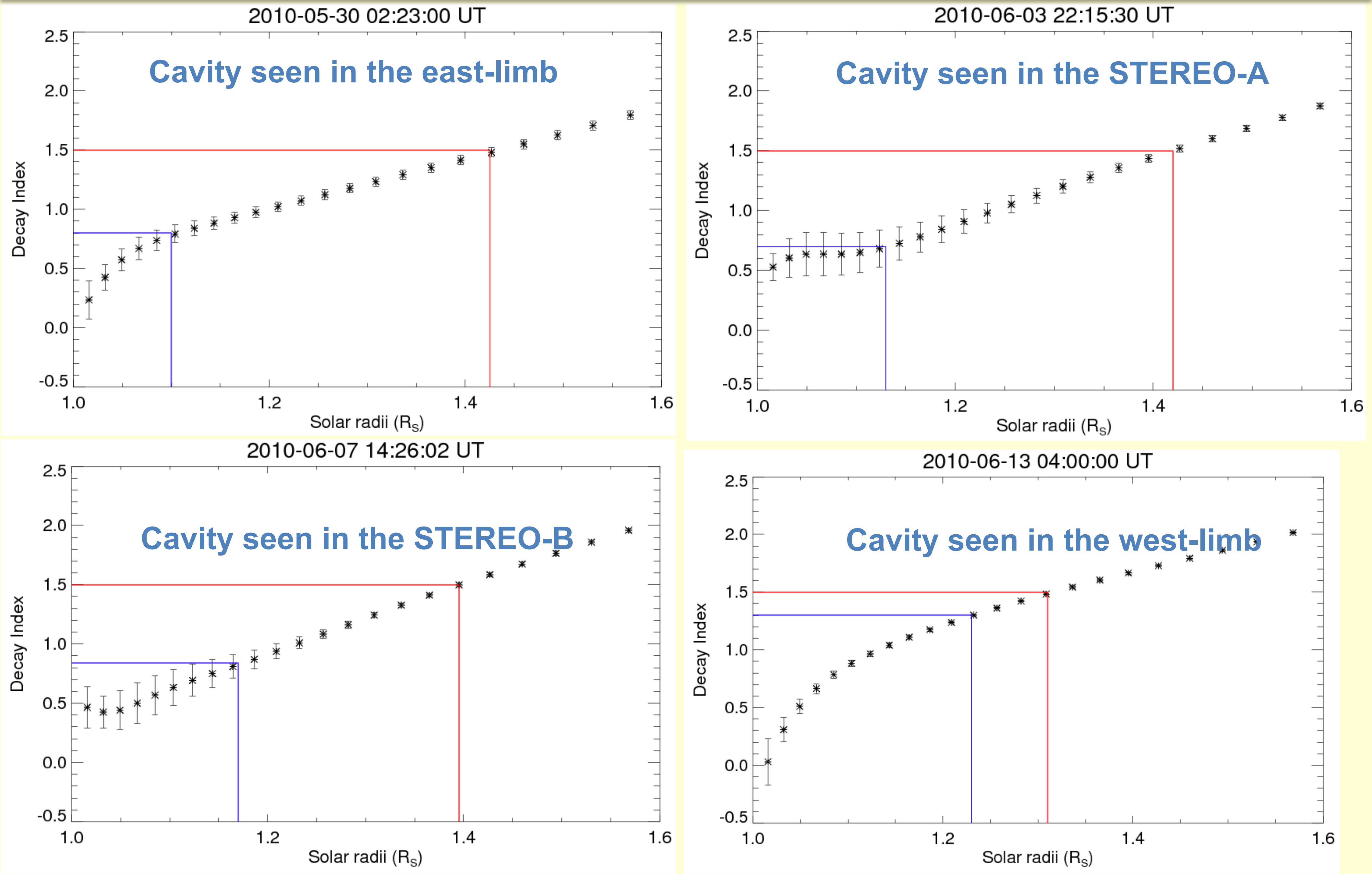
Cavity diameter vs height of the cavity-centroid plot



Height-time plot for individual cavity top, bottom and centroid



Decay Index profiles for four different dates during the quiescent phase



Results

We have studied the morphological evolution of an erupting coronal cavity starting from its initiation in the lower corona up to the LASCO C2/C3 field-of-view.

- The height-time profiles for the top of the prominence material and the lower-most part of the cavity almost coincide.
- Up to almost 1.3 solar radii in SWAP field-of-view, the cavity exhibits non-radial motion. After approx. 1.3 solar radii, it maintains same position angle (270^0).
- Up to almost 4 Rsun (LASCO-C2), the cavity morphology is best fitted with an ellipse. In LASCO C3 field-of-view the cavity morphology attains almost circular shape.
- After near about 2 solar radii, the cavity maintains a constant value of aspect ratio (approx. 0.25) and thus exhibits self-similar expansion.
- In the quiescent phase, the cavity centroid height slowly rises from 1.10 to 1.23 R_S during its passage on the visible solar disc from May 30 to June 13, 2010 and its initial circular shaped morphology gradually expanded and evolved into elliptical shape prior to the eruption from the western solar limb.
- The cavity centroid undergoes acceleration after crossing the critical decay index value.

THANKS!!