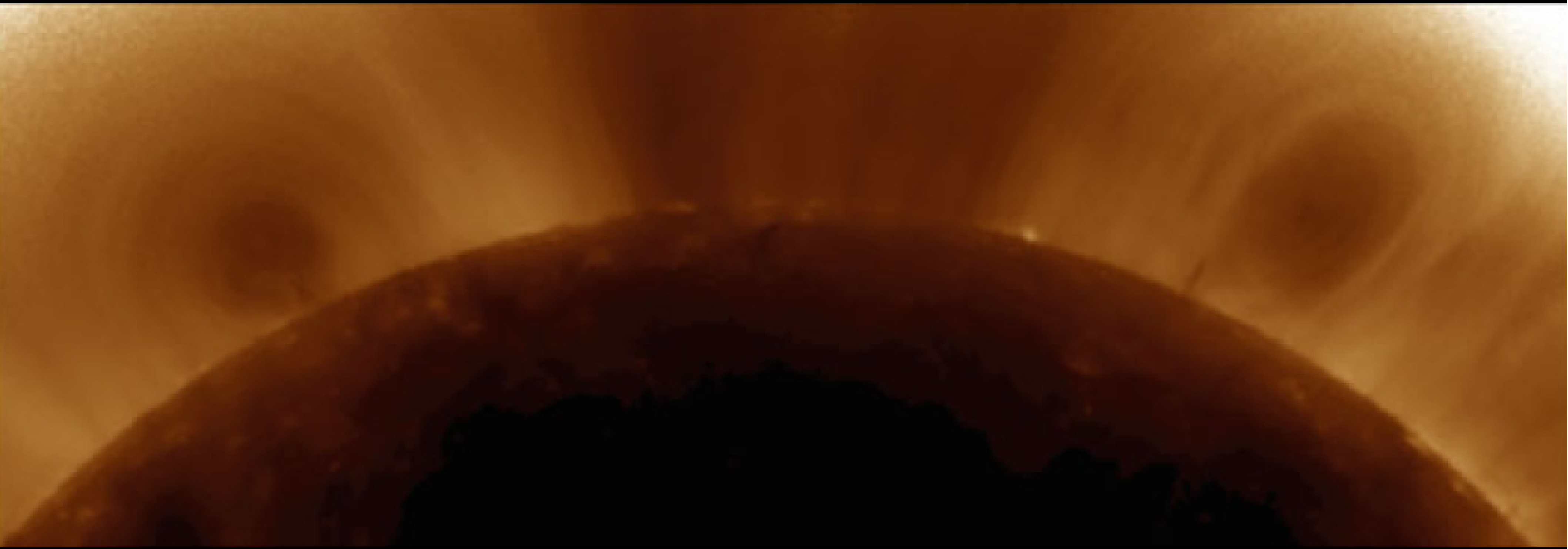
Lifecycle of a large polar coronal Pseudostreamer/cavity system



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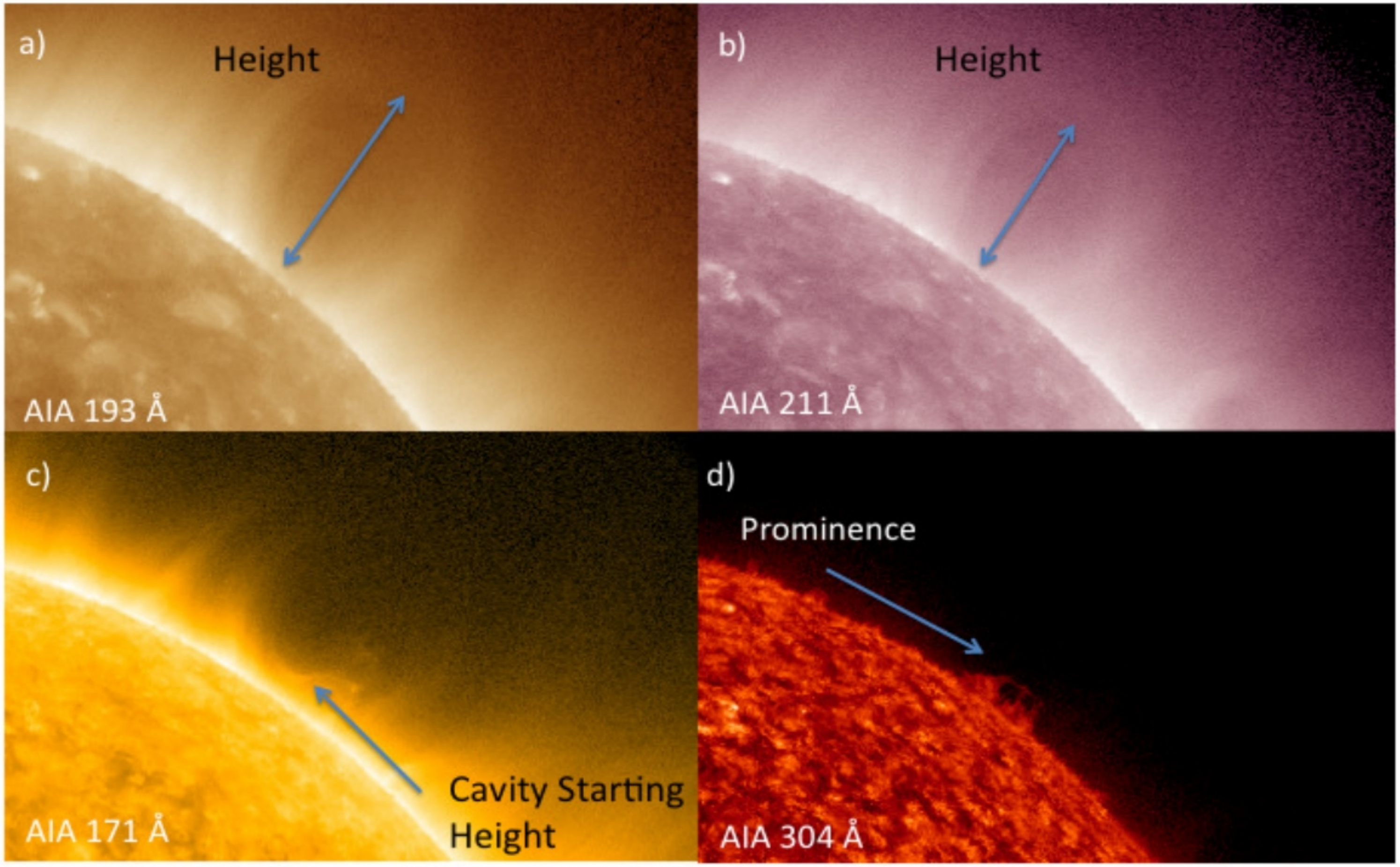
Cavities



- Dark and elliptical features : Density depletion ~30 %;
  → above photospheric neutral lines
- Surrounds solar prominences/ are surrounded by a streamer/PS
- Ubiquitous in the solar corona, Long quiescent lifetime ~ weeks or even longer
  → ideal for tomography !!!

Some Open Questions

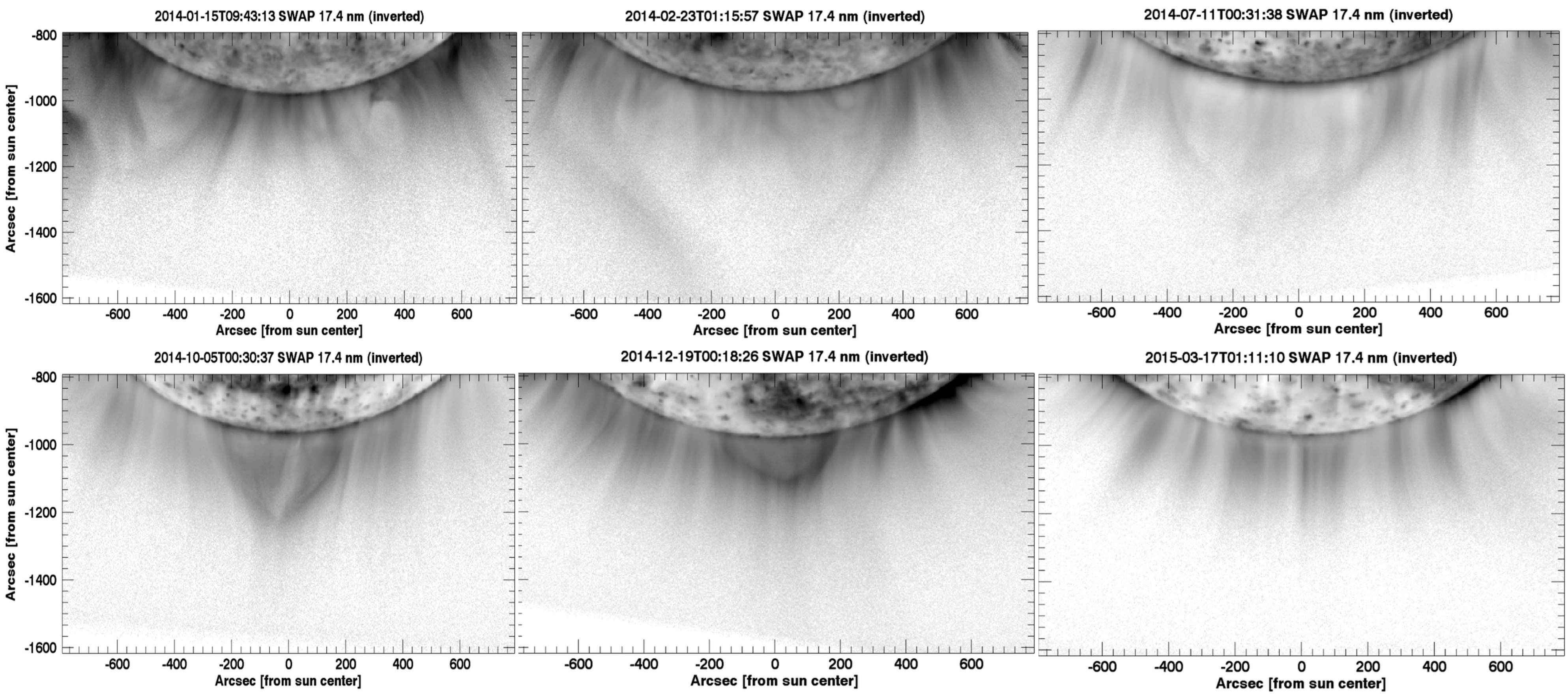
- Prominences/cavities association ?
- Trigger for their eruption ?
- Processes for cavity stability ?
- Morphology White light vs EUV cavities ?
- Cavity temperature?
  Relative to the surrounding streamer/PS ?
  (Cf Gibson 2010, Schmidt 2011, Reeves 2012 & Kucera 2012)
- Nature of multithermal variations of cavity ?

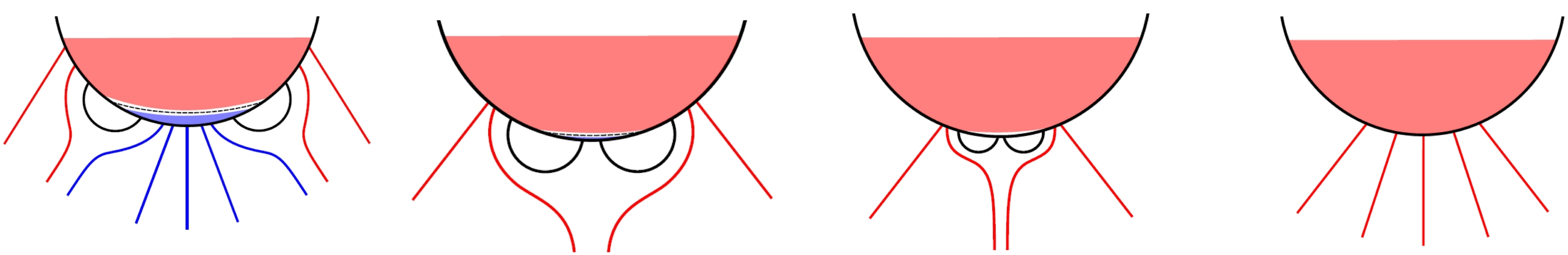
How ?

By tracking the ***3D formation, evolution*** and disappearance of a pseudostreamer/cavity system using ***Tomography***

Tomography + DEM → ***3D plasma parameters*** and their evolution over the whole life-cycle of the system

Proba2/SWAP 174Å





Rachmeler & Guennou 2016

What can be deduced from UV observations ?

- General case : intensity of an optically thin plasma in a waveband b

$$I_b = \frac{1}{4\pi}\int_0^{\infty} R_b(T_e(l))n_e^2 \mathrm{d}l$$

Thermal properties

$$I_b = \frac{1}{4\pi}\int_0^{\infty} R_b(T_e)\xi(T_e)\mathrm{d}\, T_e$$

$$\xi(T_e) = \sum_{s=p(T_e)} n_e^2 \frac{ds}{dT_e}$$

Differential emission Measure

Geometrical properties

$$I_b = \frac{1}{4\pi}\int_0^{\infty} e(x,y,z)\,\mathrm{d}l$$

$$e(x,y,z)$$

Plasma emissivity

$$\left.\begin{array}{ll} \text{DEM} & \rightarrow T_e, n_e \;/\; \cancel{x, y, z} \\ \text{Tomography} & \rightarrow x, y, z \;/\; \cancel{T_e, n_e} \end{array}\right\} \begin{array}{c} \text{Coupling Tomography/DEM} \\ \checkmark\; x, y, z \;/\; T_e, n_e \end{array}$$

Solar Rotational Tomography (SRT)

$$I_b = \frac{1}{4\pi}\int_0^\infty e(x,y,z)\,\mathrm{d}l \; + \; \text{Noise} \qquad \text{with} \qquad e = R_b(T_e)n_e^2$$

$$I = He + n$$

Data

Noise

Projection matrice

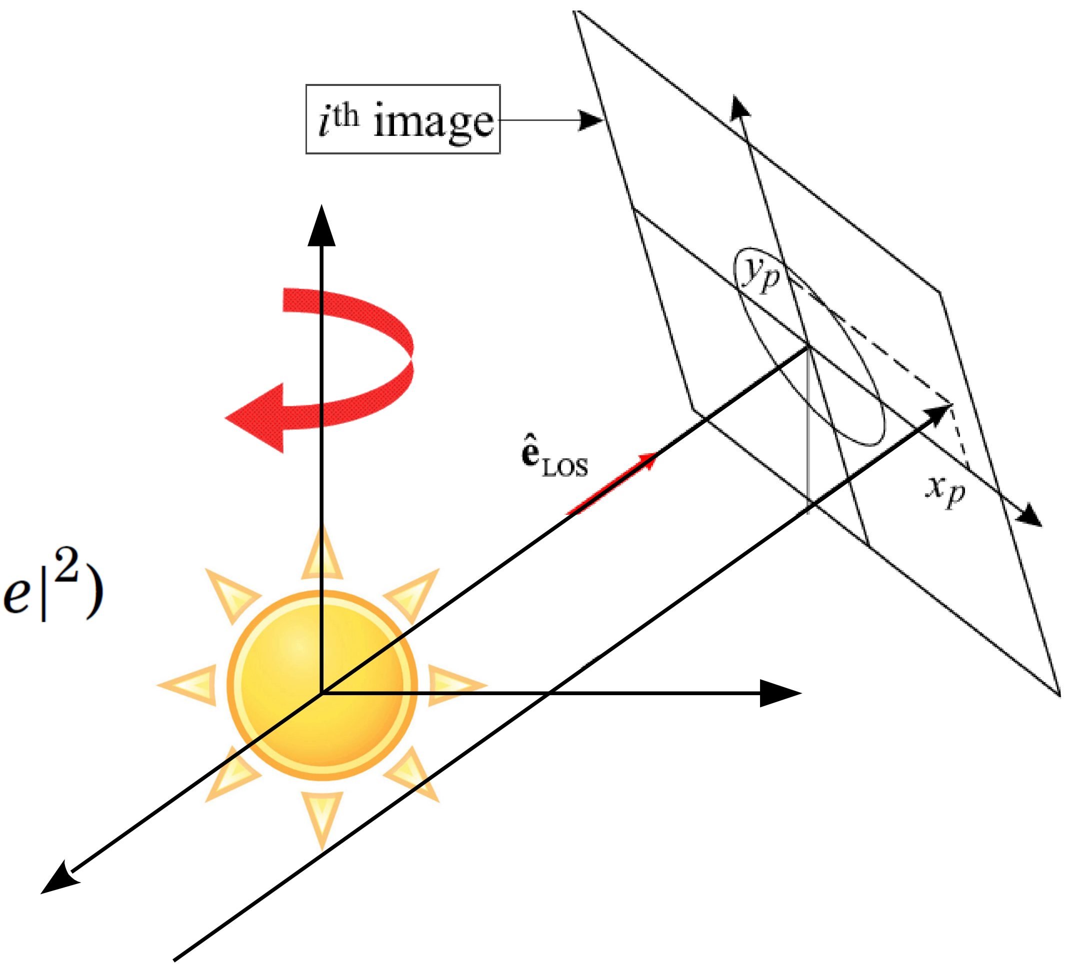
+

1 solar rotation

+

$$e = \arg\min(|I - He|^2 + \lambda|De|^2)$$

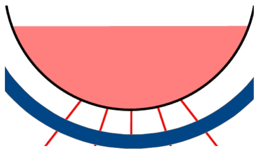
3D reconstruction
of the emissivity



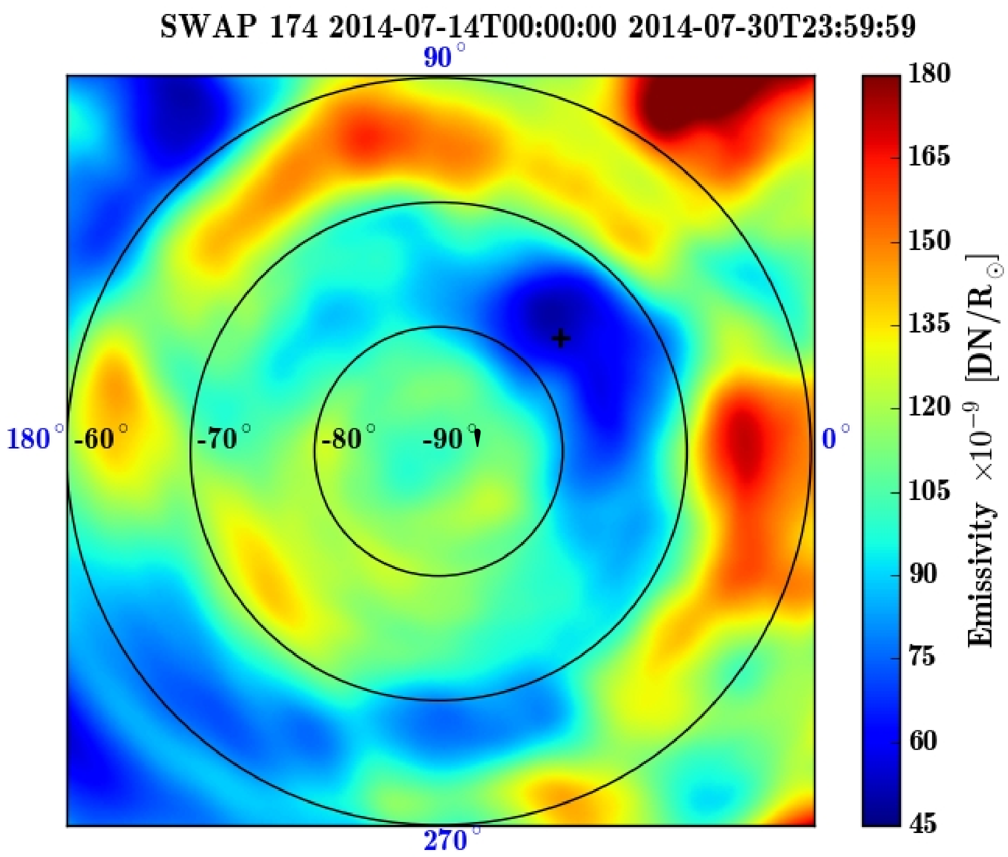
TomograPy (Barbey, Guennou et al. 2011)

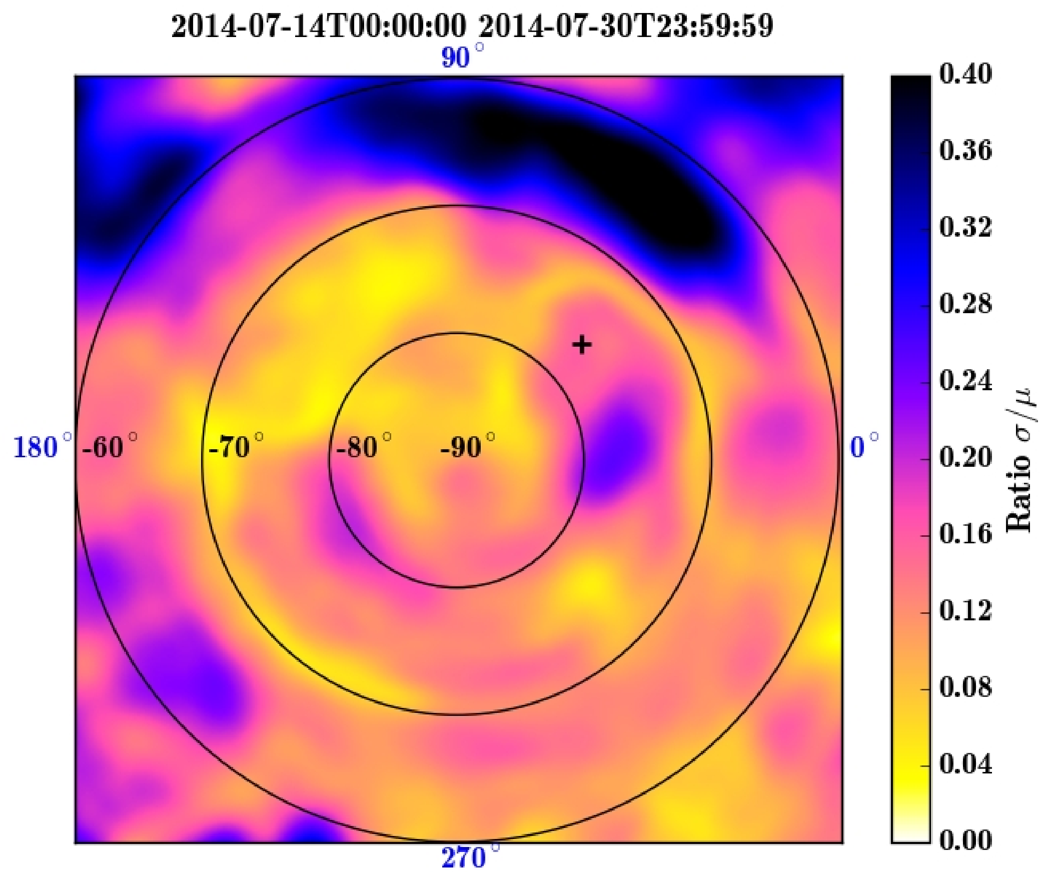
(Siddon 1975)

Morphological properties & Evolution



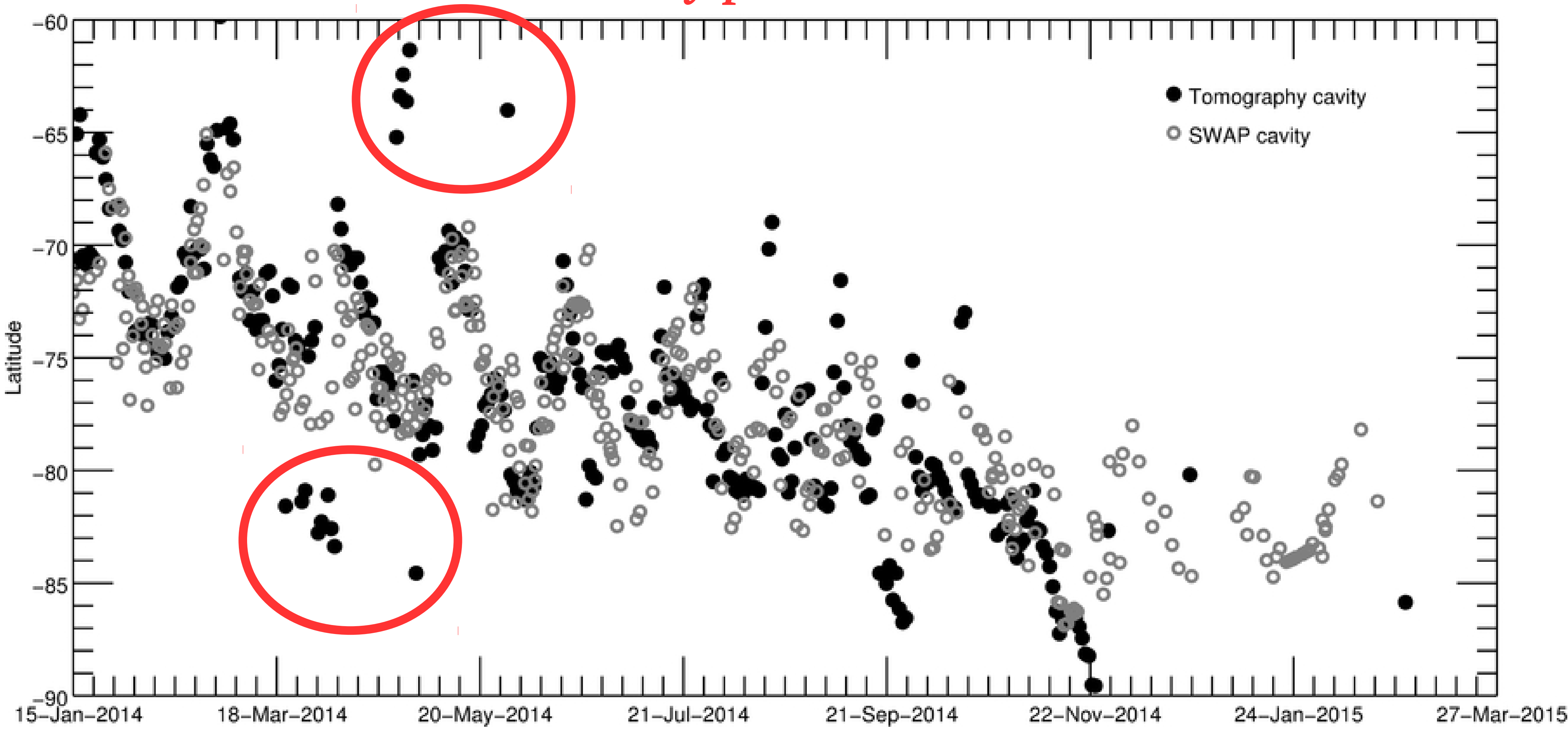
Polar caps at 1.05 Rsol ~ 35 000km above the surface





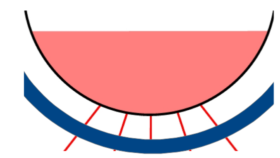
Comparison tomography/data

Cavity position



Good agreement between tomographic reconstruction & data !
Except two periods : high dynamic & high B-angle that complicates reconstructions

AIA reconstructions



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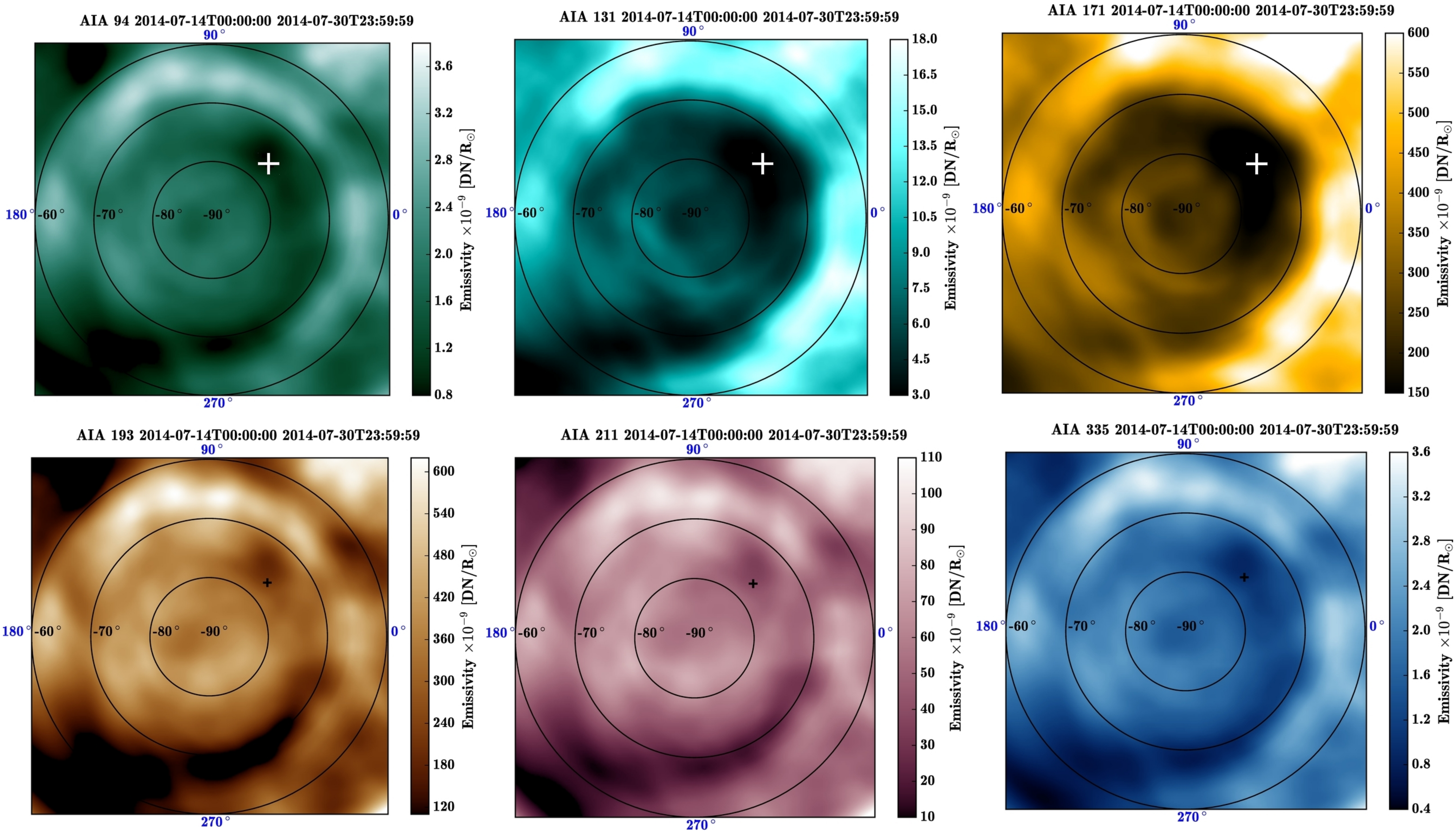
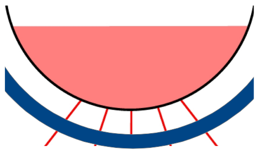


Temperature evolution



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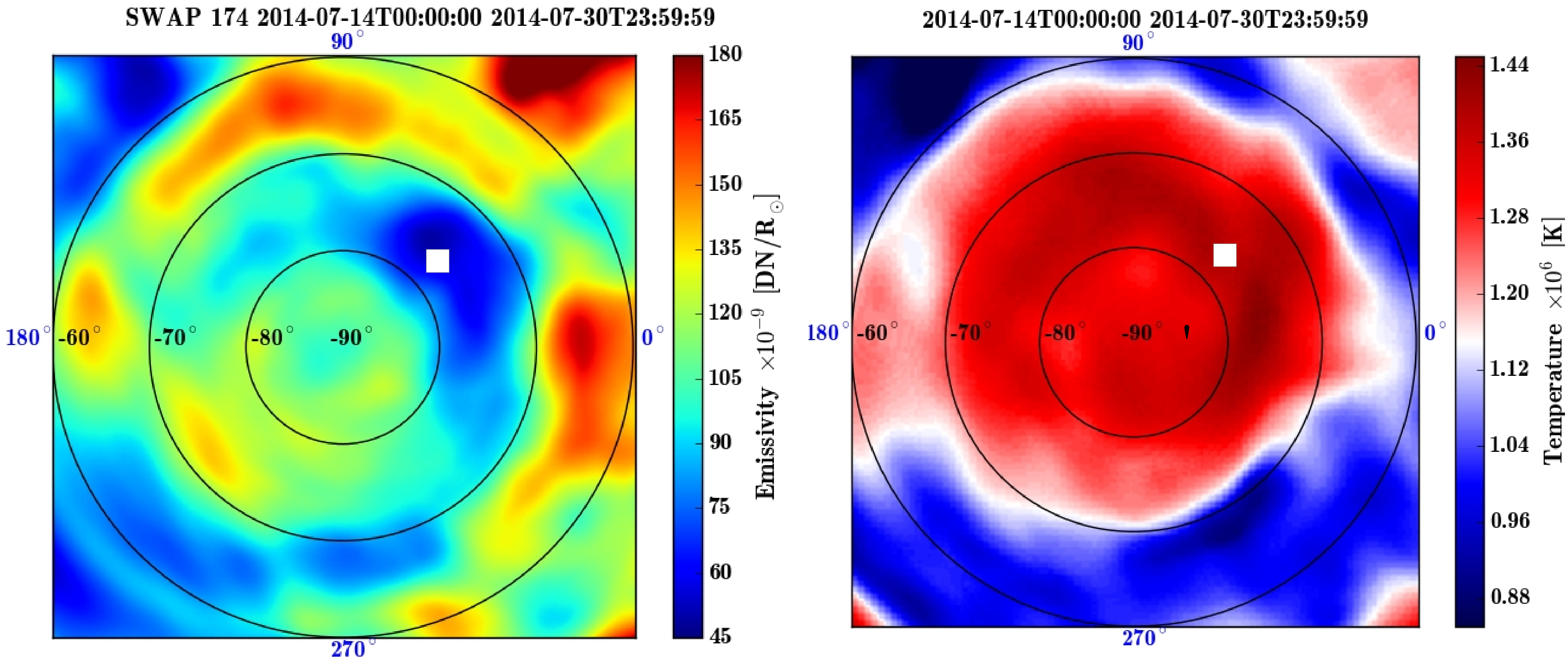
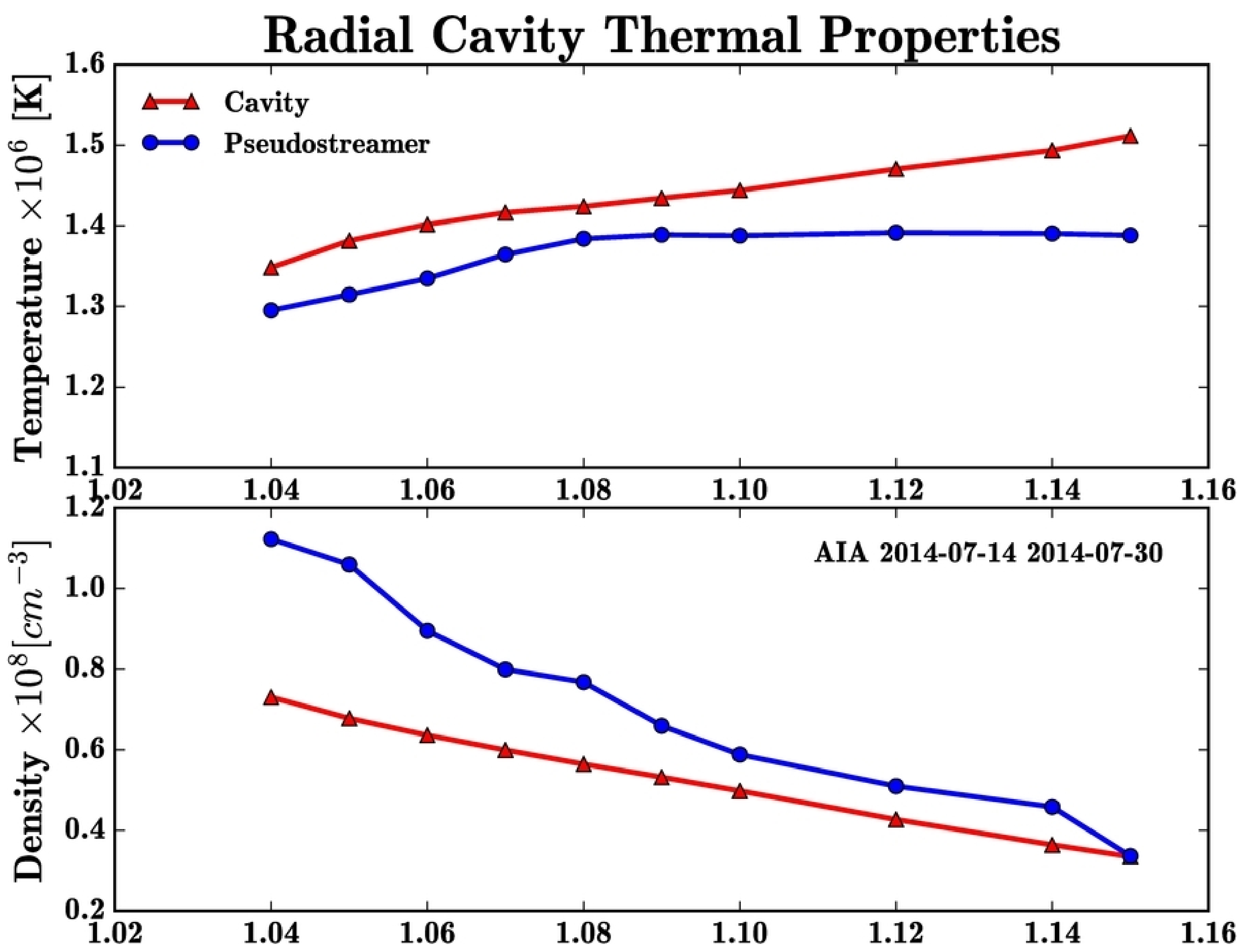


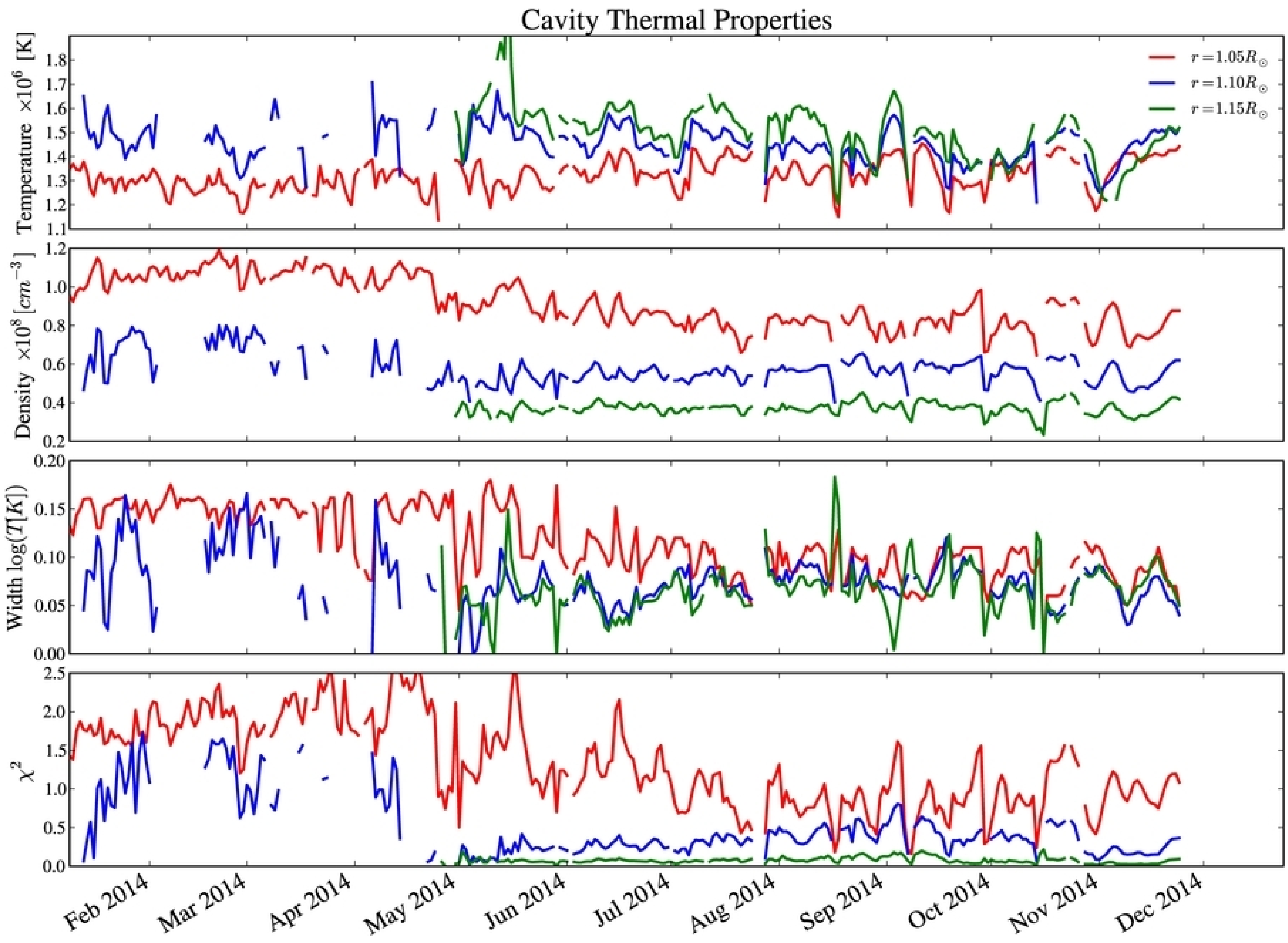
Similar temperature PS/Cavity, higher than open magnetic field domain

Evolution with height



Cavity temperature is slighlty above that of the pseudostreamer

Time evolution of cavity properties



Conclusions

- Cavity depletion ~ 20-40% depending of the height,
- Cavity density depletion decreases with height, from a maximum of about 40% at the cavity lower boundaries to approximately 0% at the cavity top,
- The cavity density slowly decreases with time as the pseudostreamer shrinks,
- The volume enclosed within the pseudostreamer is systematically hotter than the surrounding open field line plasma,
- The cavity temperature is essentially at similar or slightly higher temperatures than the pseudostreamer and remains really stable
- No cavity hot cores was observed over the year of data, consistent with Vial 2015
- Two regimes in cavity density and thermal distribution are observable during the pseudostreamer lifetime : January-June 2014 highest cavity density and high thermal width. June -December : opposite behavior.

Thank you

Local DEM inversion

- The emissivity in each voxel can now be recasted as

$$e_{b,i} = \int_0^\infty R_b(T_e, n_e)\xi_{loc,i}(T_e) d\log T_e,$$

With the local DEM defined as

$$\xi_{loc,i} = n_e^2(T_e) dV_i / d\log T_e \qquad [\mathrm{m}^{-3}.\mathrm{K}^{-1}]$$

- The local DEM is completely ***analogous*** to the classical DEM, except that the integration volume is reduced to the voxel volume (see Frazin 2009).

- We estimated the local DEM by a simple least-square inversion :

$$\chi^2 = \min\left[\sum_{b=1}^{N_b}\left(\frac{e_{b,i}^{\mathrm{tomo}} - e_b^{\mathrm{synth}}(T_c, n_e, \sigma)}{\sigma_{b,u}^2}\right)^2\right],$$

And we imposed the solutions to be Gaussian

$$\xi_{loc,i} = n_e^2(T_e)\mathcal{N}(\log T_e - \log T_c)$$

$$\text{with } \mathcal{N}(\mathrm{x}) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{x^2}{2\sigma^2}\right).$$

Guennou et al 2012a,b

Data processing

SWAP data

fully calibrated IDL p2sc prep routine (dark current, subtracts the flat field, PSF, corections)

high signal-to-noise images → 100 minutes of data + median-stacked= single frame (Halain et al. 2013 and Seaton et al. 2013).
Suppresses short-time-scale dynamics of the Sun

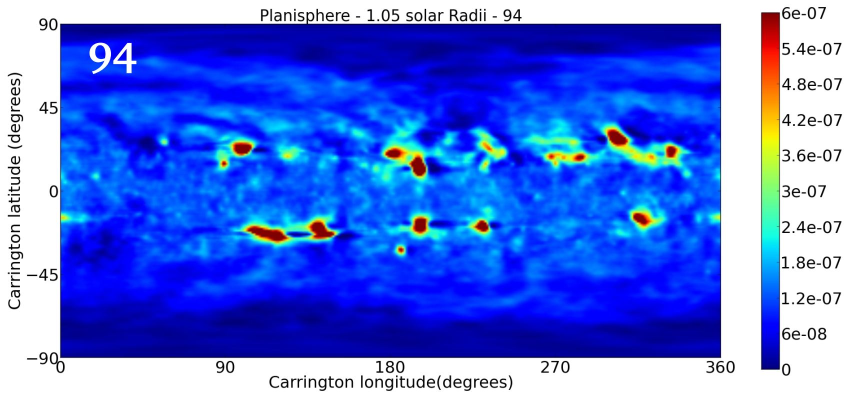
For each tomographic inversion, 17 days of data at a cadence of 100 minutes (totalling approximately 240 median-stacked frames) were used.

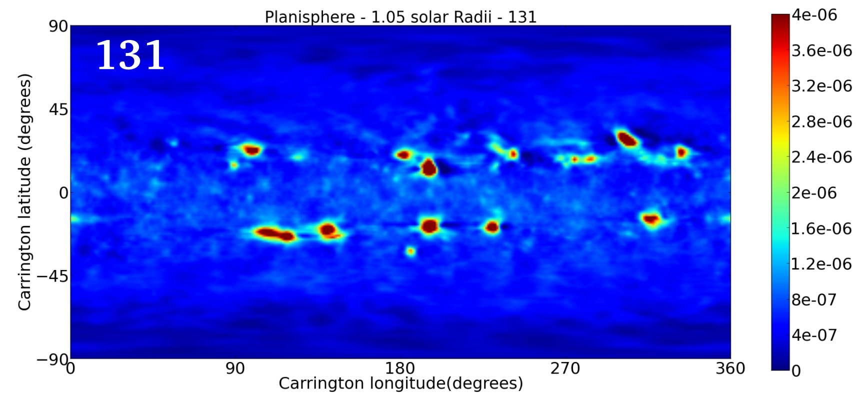
AIA data : For each waveband, the data were first rotated, translated,scaled and normalized, using a Python Then, 10 images (1 frame per minute) were averaged together to create a single frame with high signal-to-noise ratio.

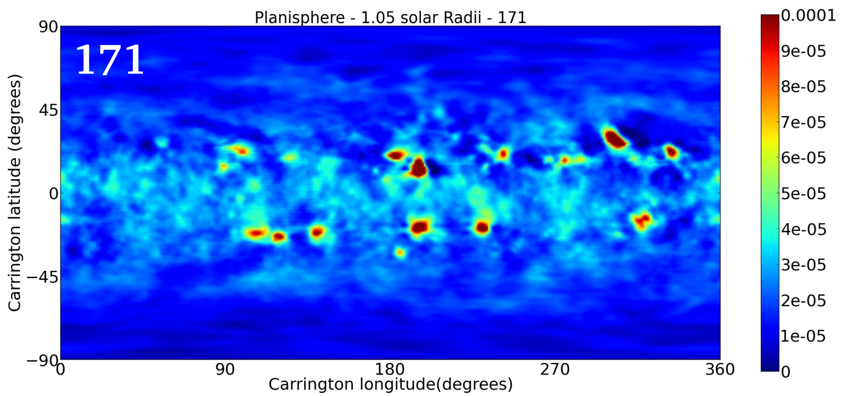
For each tomographic inversion,
17 days of data at a cadence of 2 hours (totalling approximately 204 averaged frames) were used.

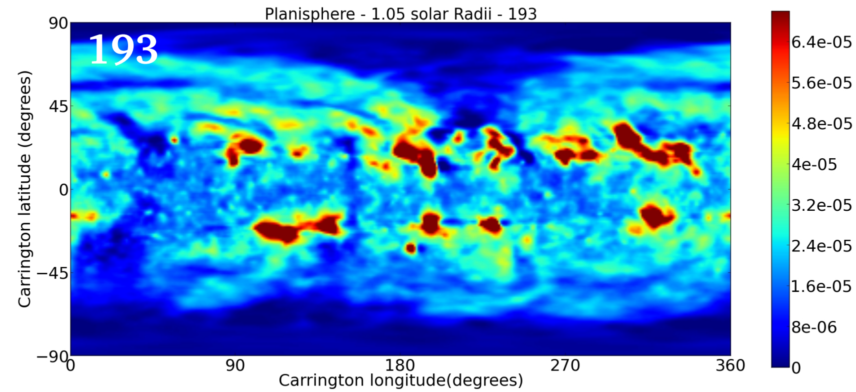
Rachmeler & Guennou 2015

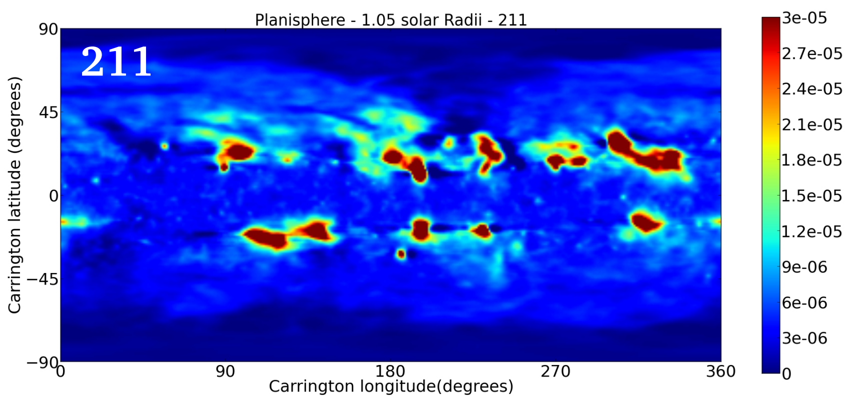
Carrington maps

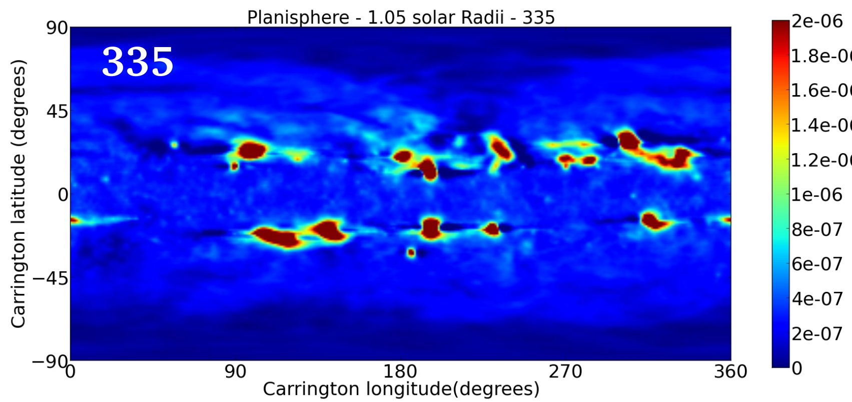




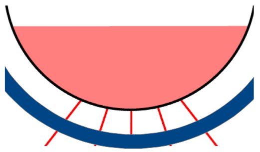




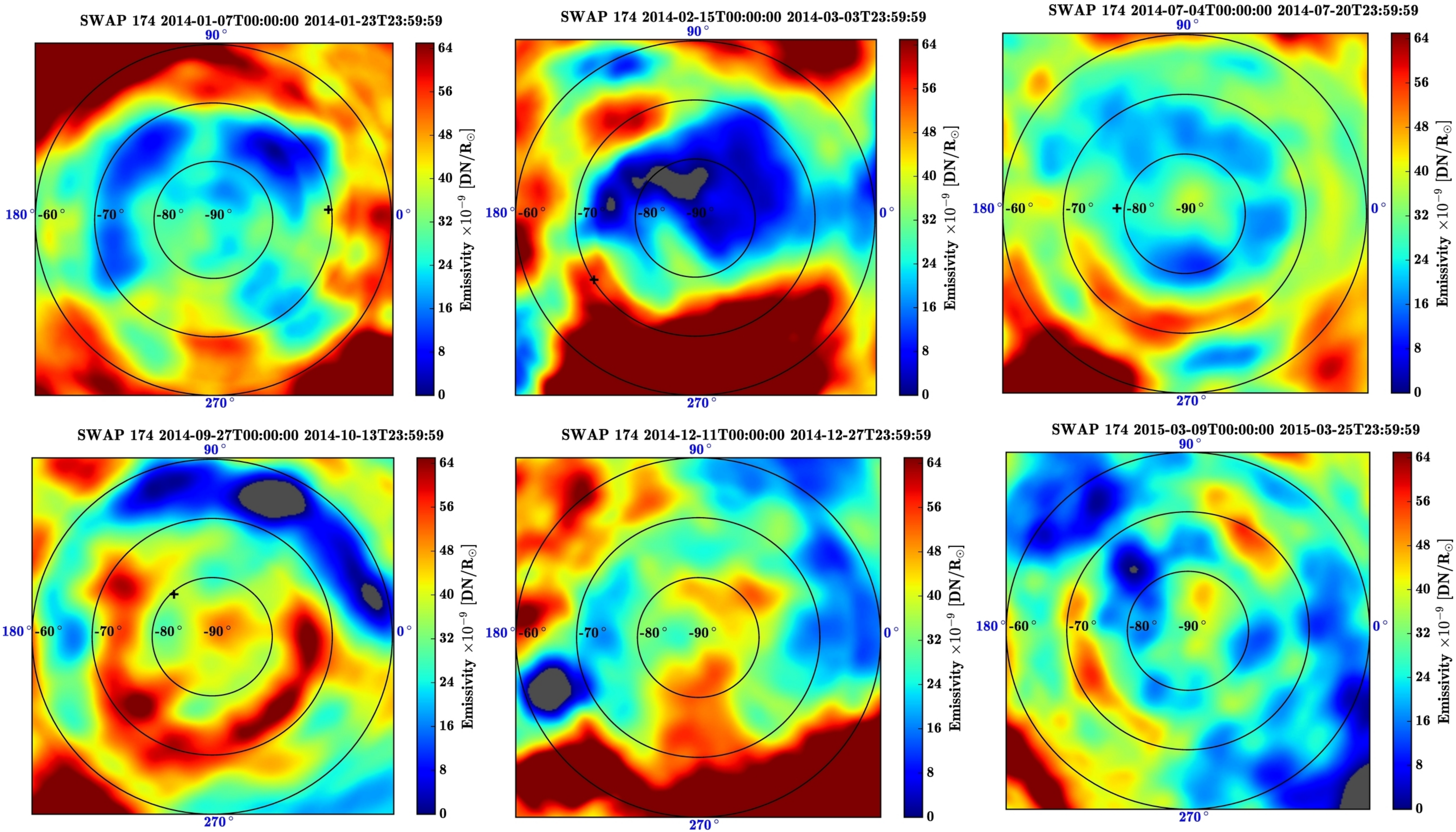




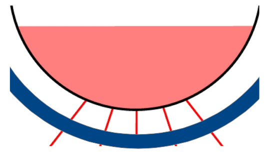
Morphological properties & Evolution



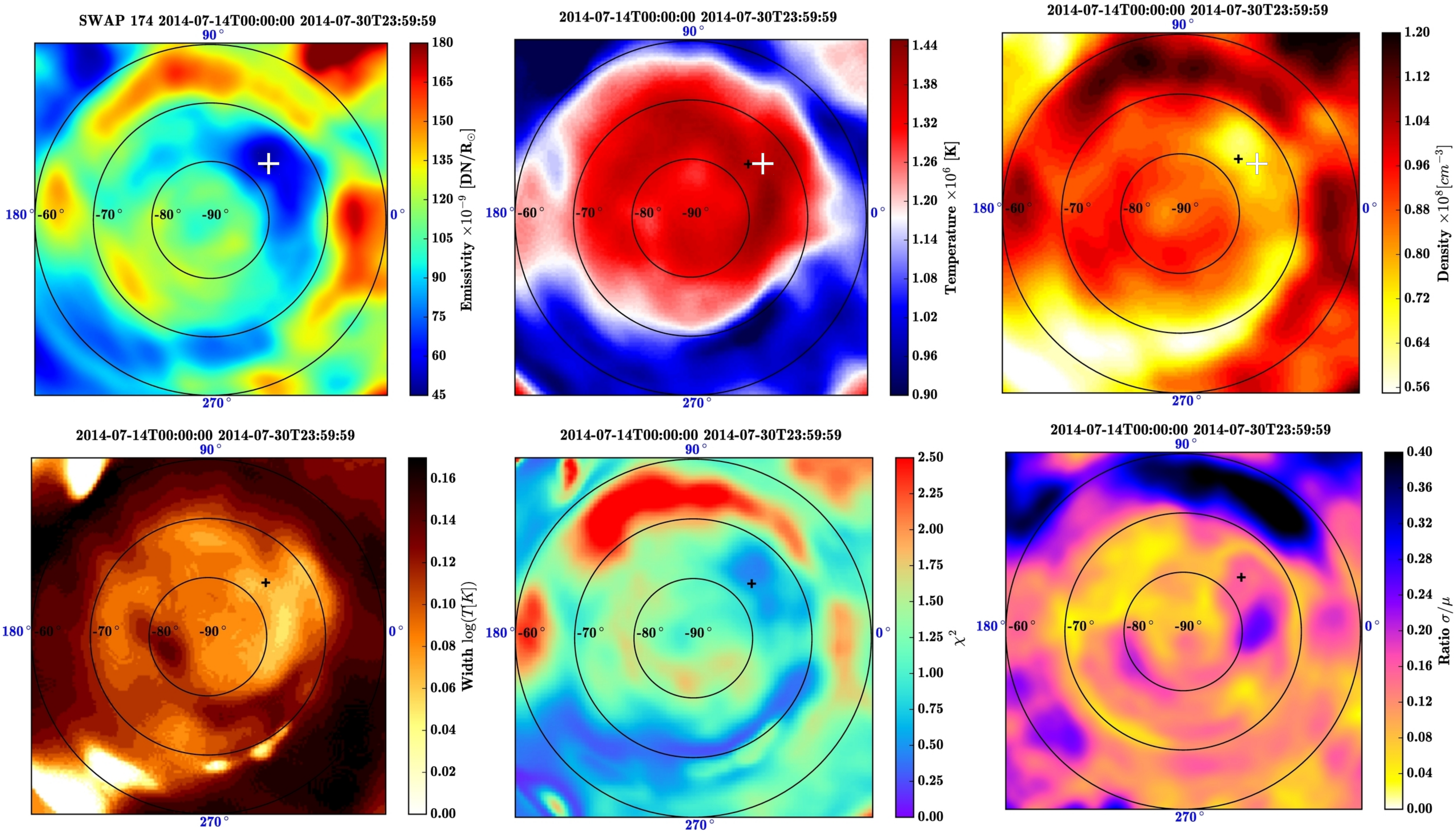
Polar caps at 1.10 Rsol ~ 70 000km above the surface



Example : the Bastille day reconstruction



Polar caps at 1.05 Rsol ~ 35 000km above the surface



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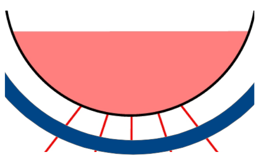

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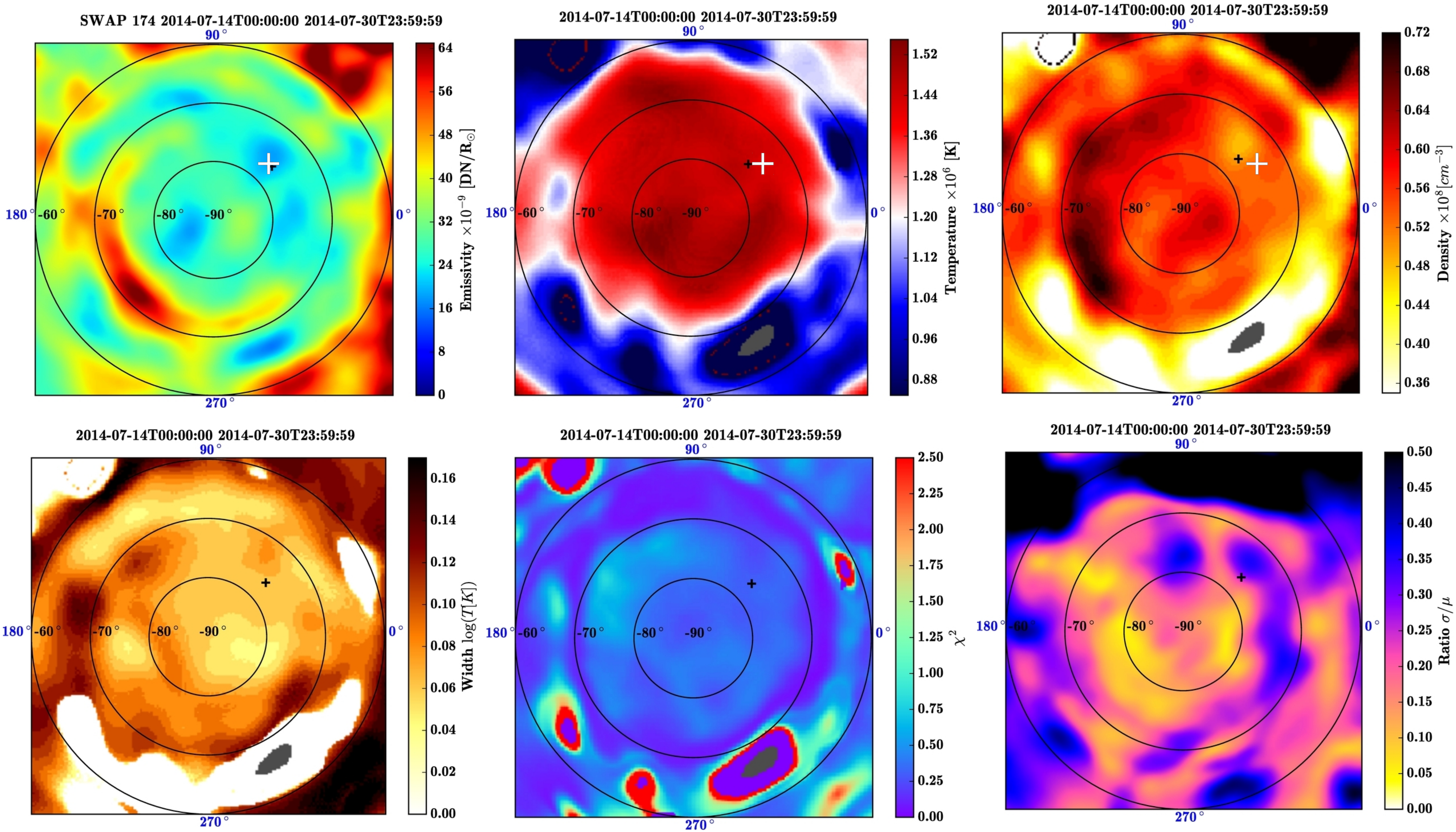
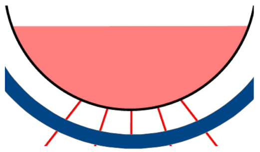


AIA reconstructions



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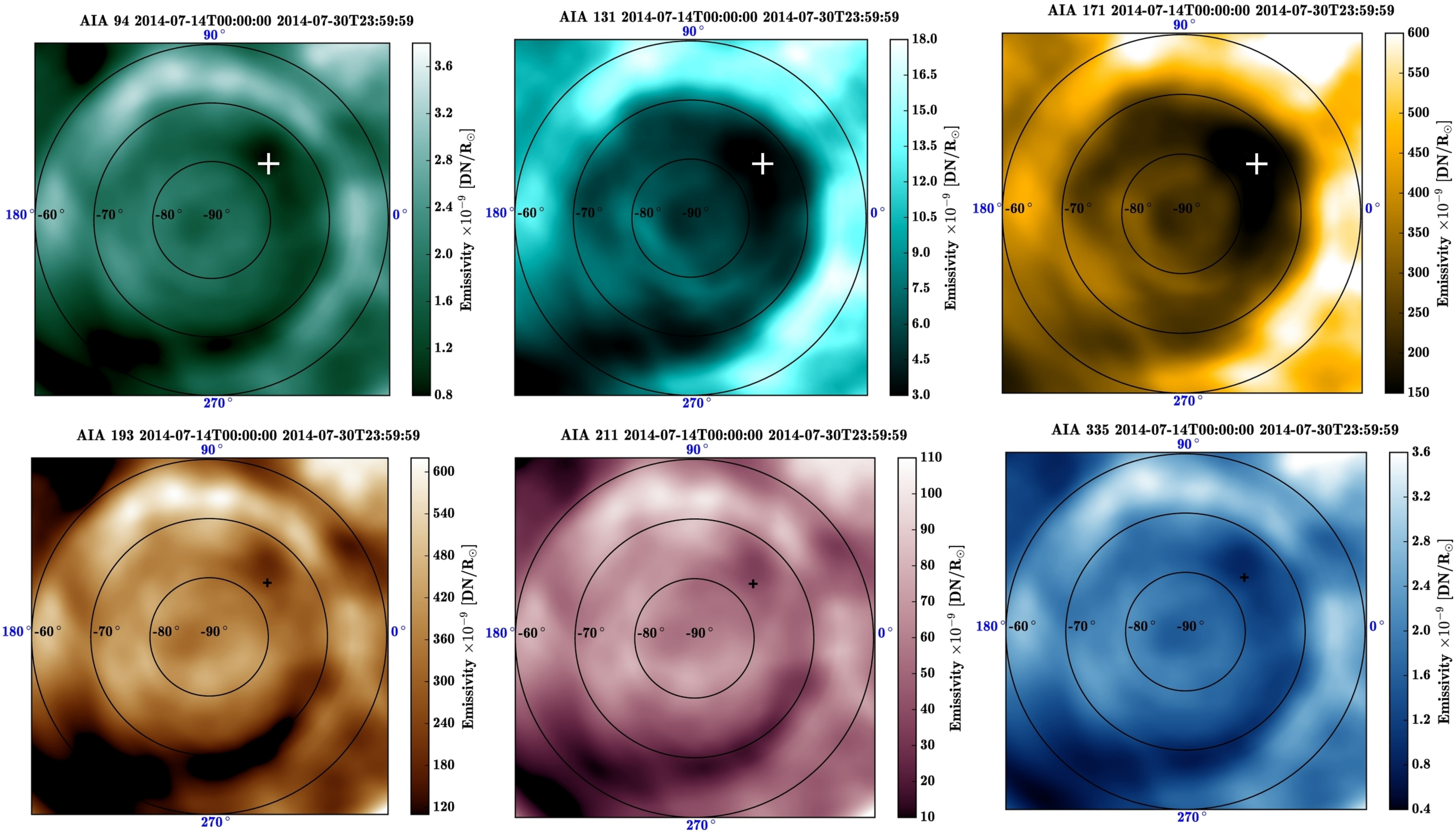

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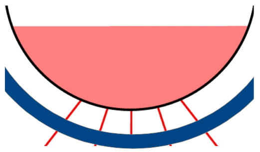

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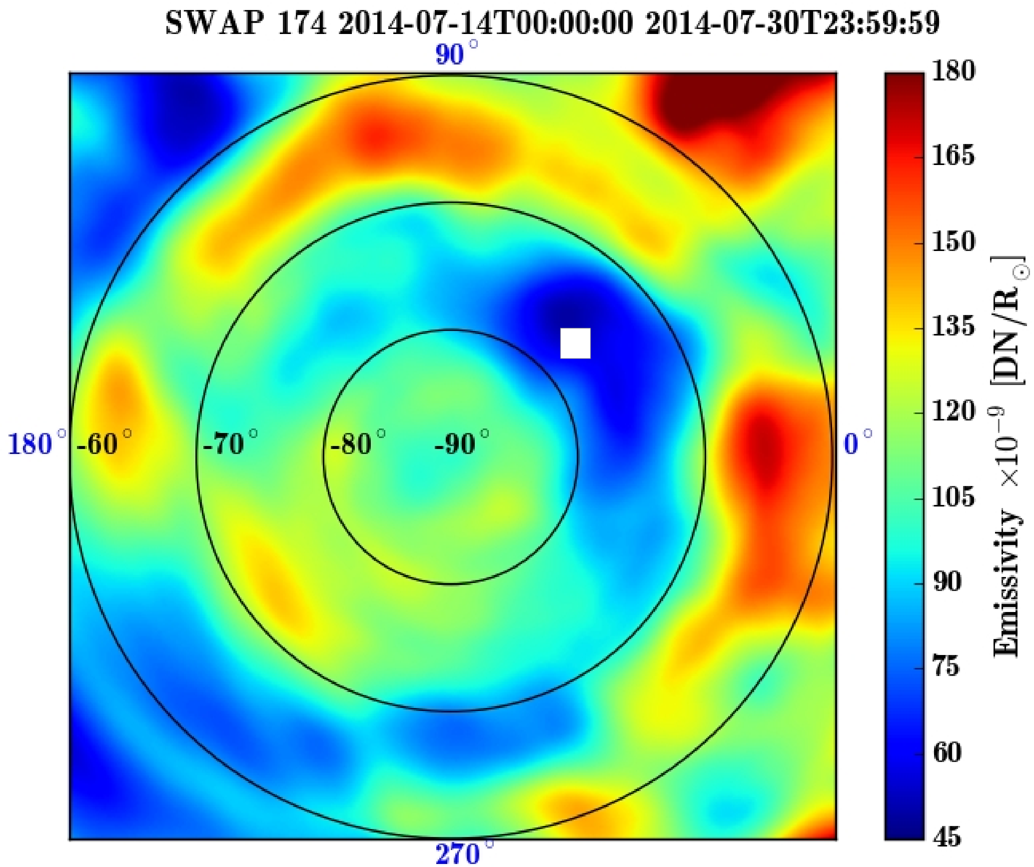
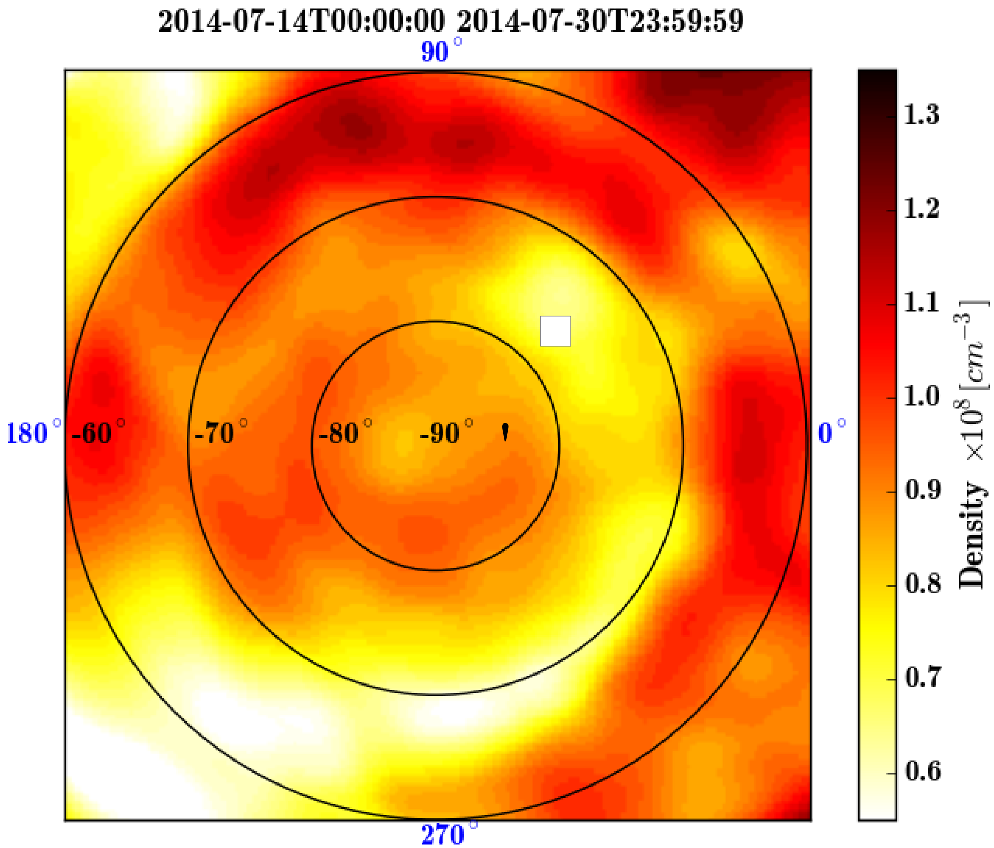




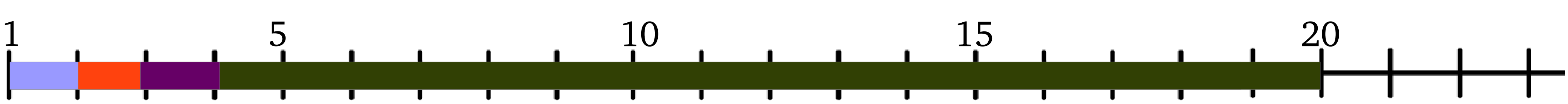
Cavity density depletion ~ 20-40 % at its base

Tracking the time evolution

Biggest source of error in SRT → dynamic nature of the corona

- ***South pole*** → use ***half a rotation*** of data
- ***Differential solar rotation*** → 17 day window to ensure 180° coverage
- Instead of modeling the temporal evolution → We ***shifted by one day at a time*** for a total time coverage of approximately a year
  - If a structure is really ***stable*** → *observable in various sucessive reconstructions*
  - We compute ***standard-deviation maps*** through sucessive reconstructions to detect the stable structures

Tomographic inversions :
443 cubes/wvl for a total covering ∼15 months of data



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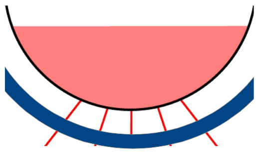

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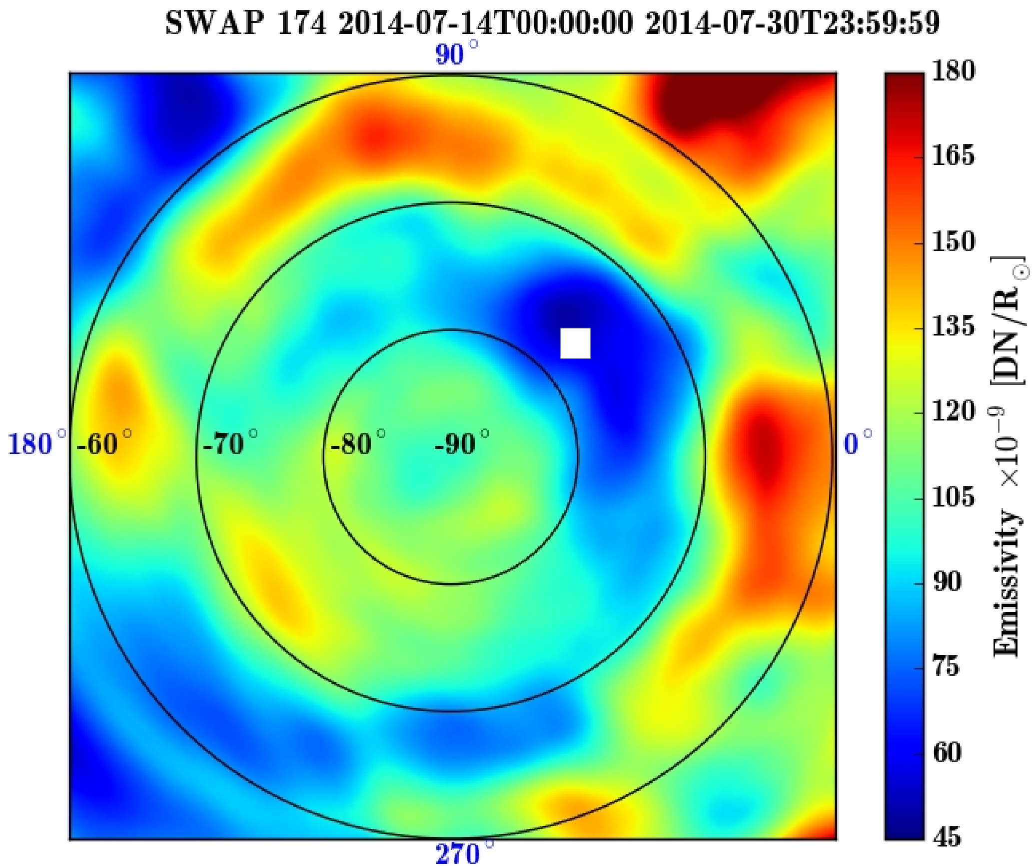

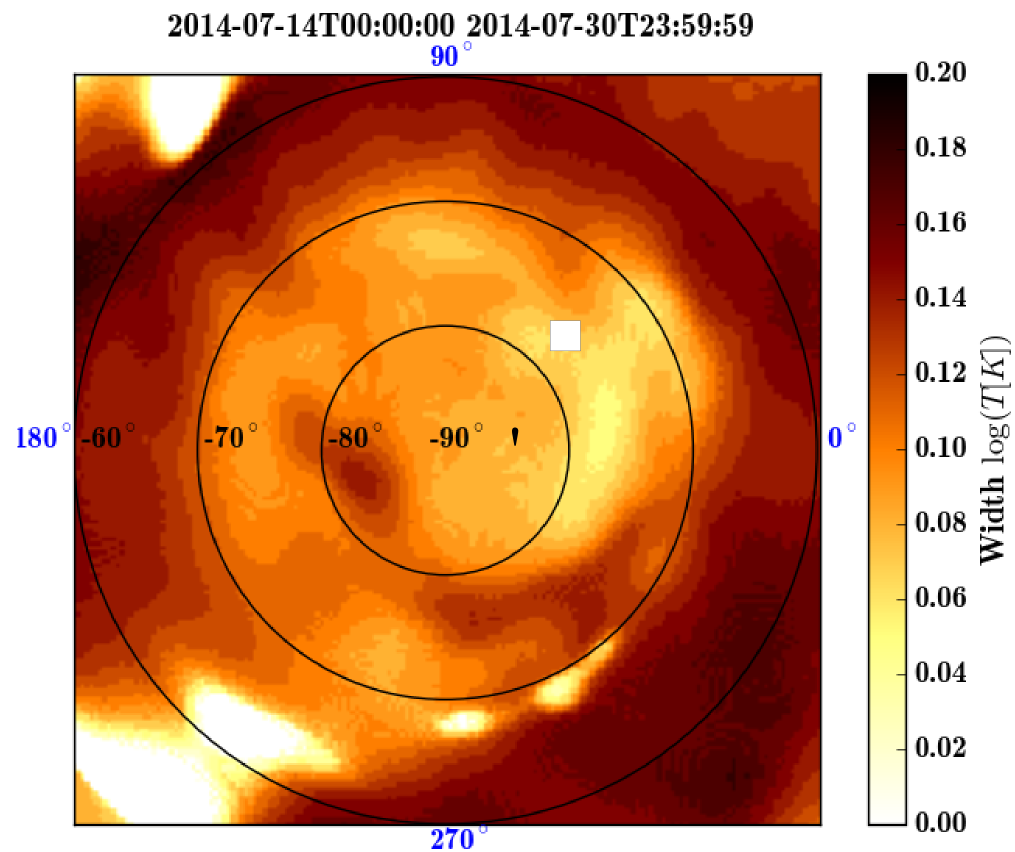

Two regimes in the cavity thermal width :
lower vs higher width for half of the cavity lifetime