Temperature of coronal streamers through the solar activity cycle

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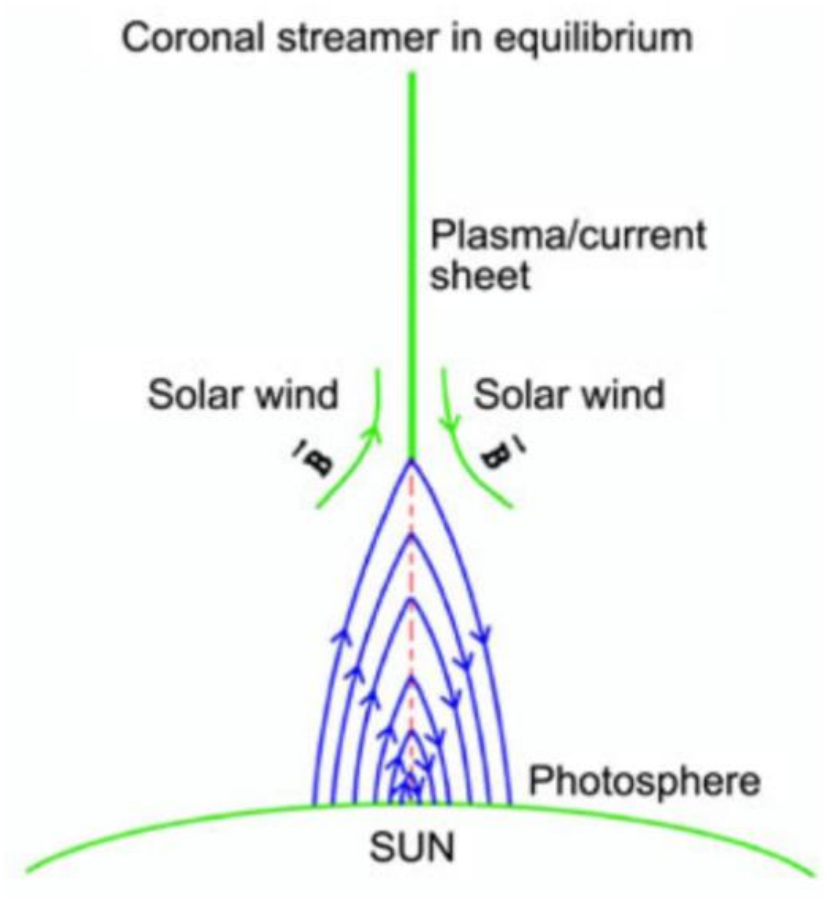
Coronal streamers

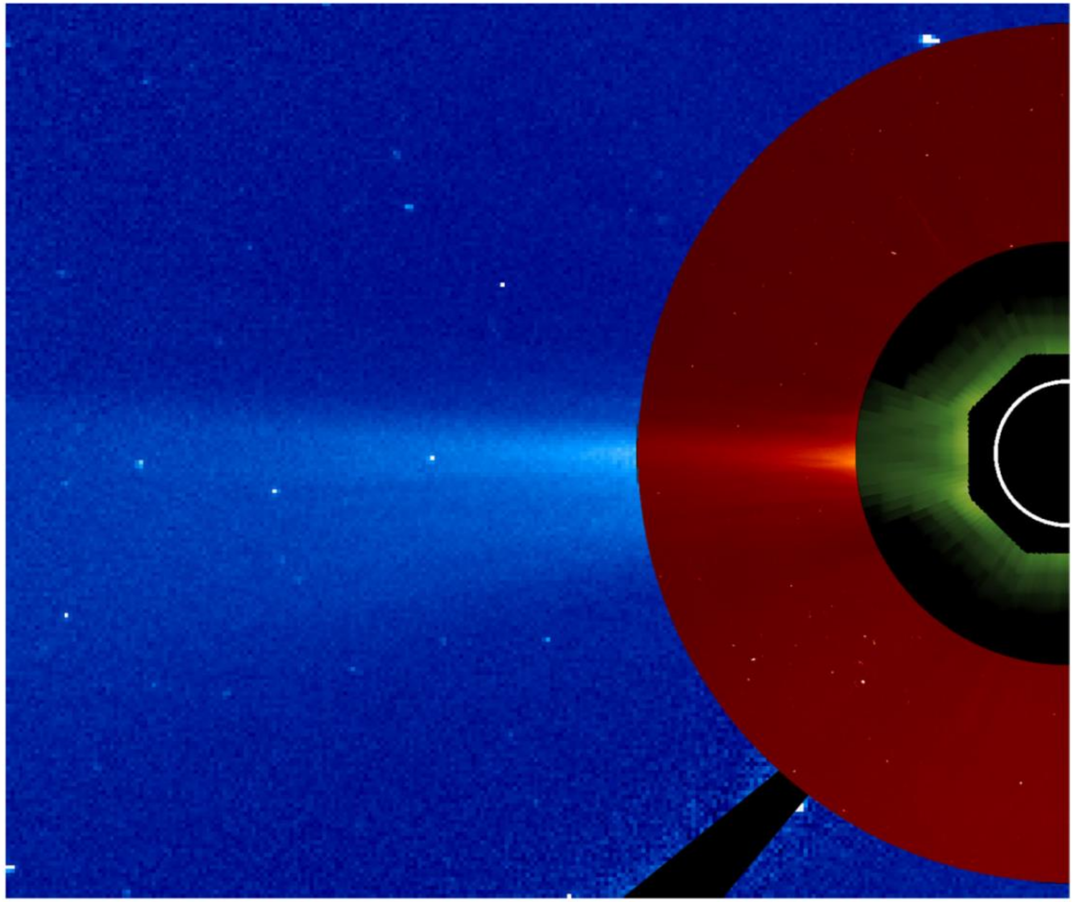
- Cusp structure below ~2-3 R
- Cusp is located above the magnetically-closed arcades and below bright streamer stalk (plasma sheet)
- Heliospheric current sheet embedded in the plasma sheet (Koutchmy & Livshits 1992)
- Bright above the cusp, due to presence of a dense solar wind plasmas
- Coronal streamers are a important source of slow solar wind (Wang i in. 2000)
- Magnetic field configuration of a streamer can strongly affect associated solar wind (Li et al. 2006).



Chen (2013)

Coronal streamer time evolution

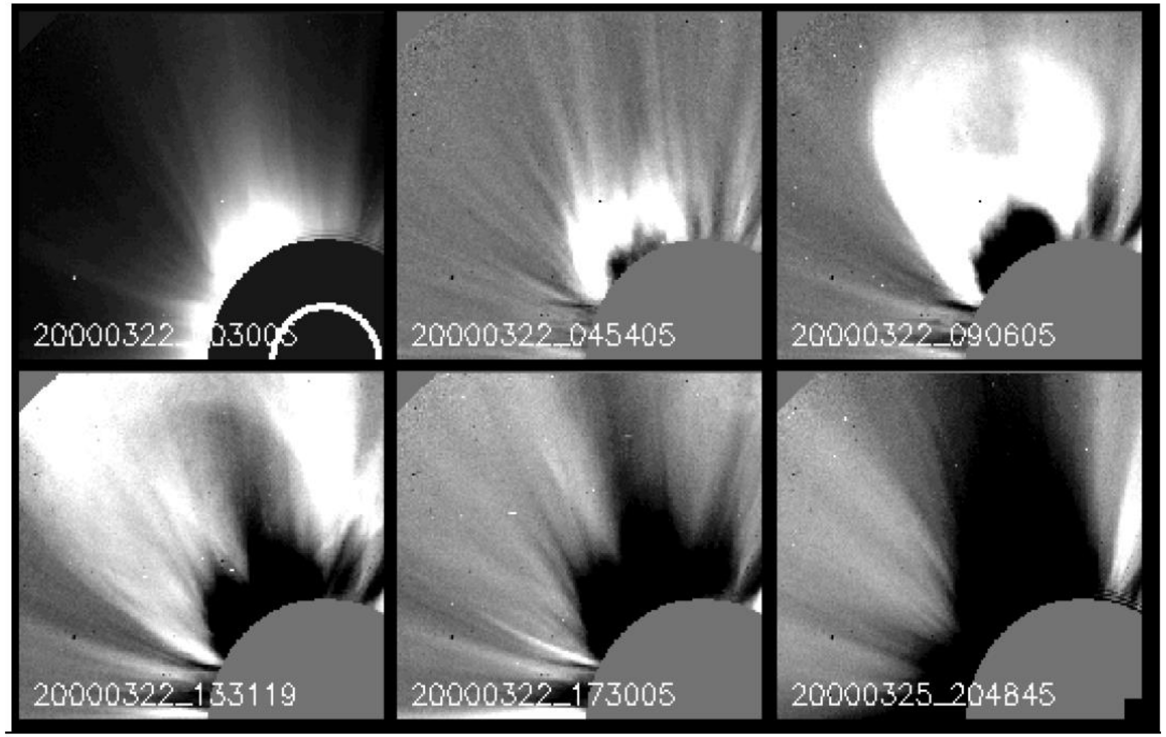
- Coronal streamers are quiescent coronal structures.
- Can exist longer than one solar rotation
  - Small unstable streamers are usually connected with active regions (Morgan & Habbal 2010)
- Small activity of streamers is often seen by coronographs.
- Additionally, streamer structure can evolve (Sheeley & Wang 2007):
  - Diffusion
  - Gradual explanation
  - Disturbance and reconstruction
  - Disconnection of plasma sheet



Antonucci et al. (2020)

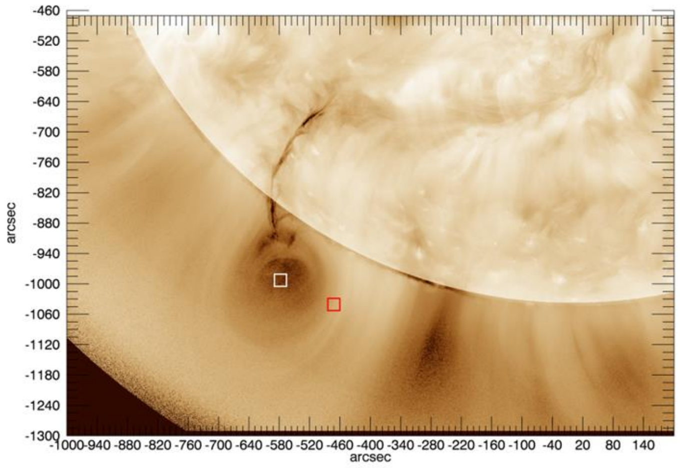
Streamers are connected with CMEs

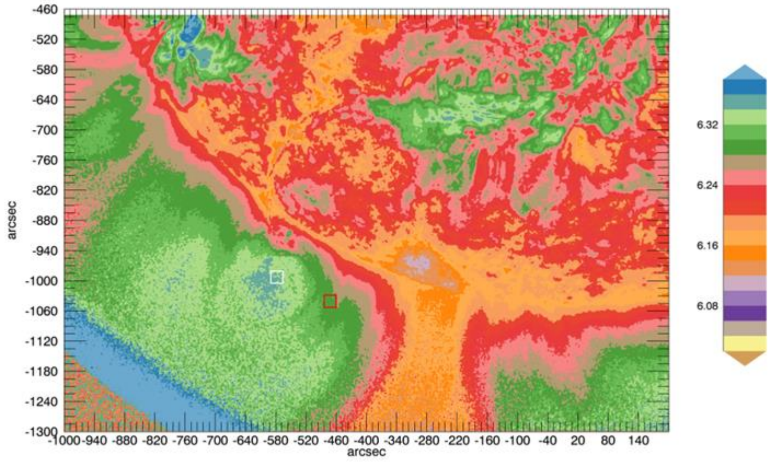
- ~60% - ~70% CMEs is connected with coronal streamers



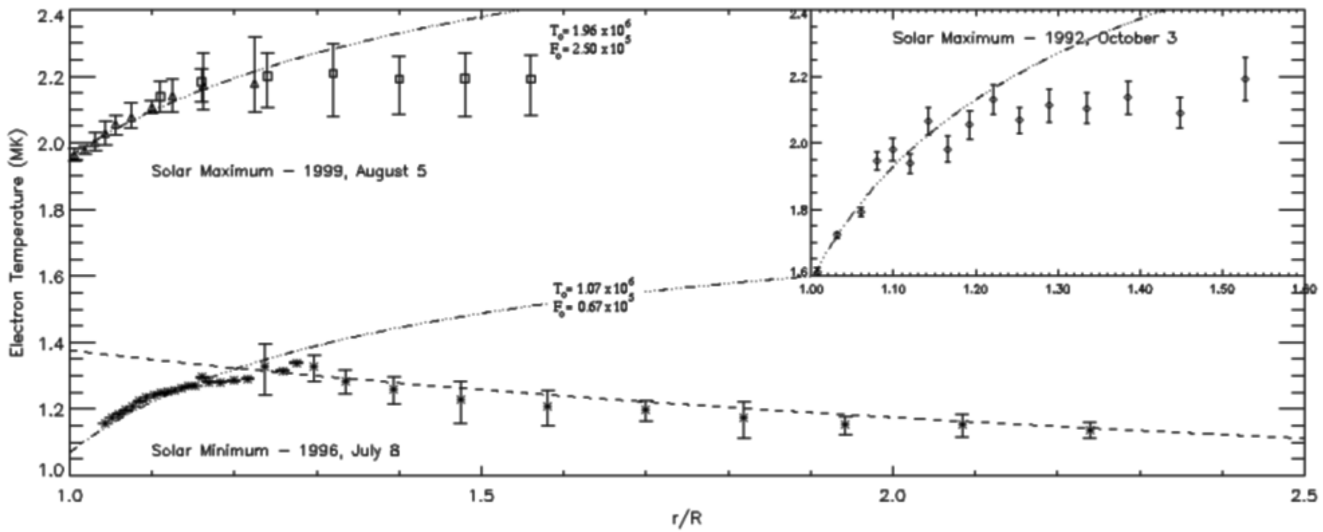
Vourlidas & Webb (2018)

Temperatures and it’s variations through the solar cycle

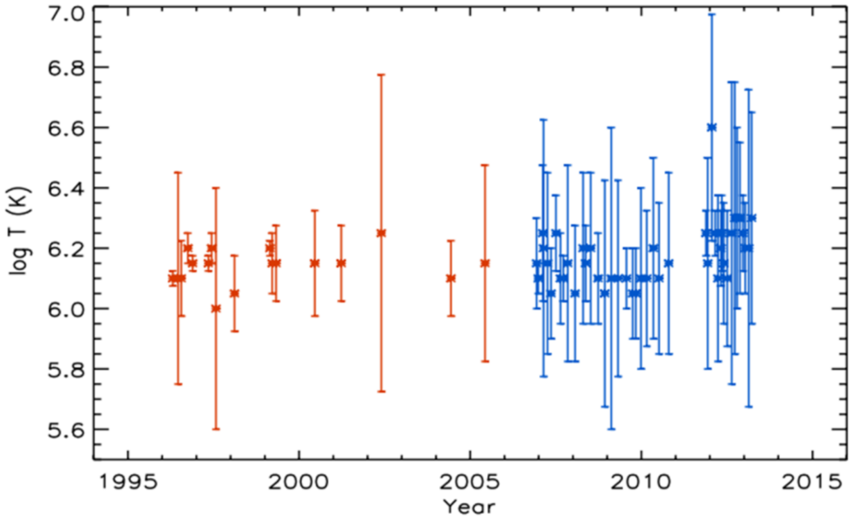




Bąk-Stęślicka et al. (2019)



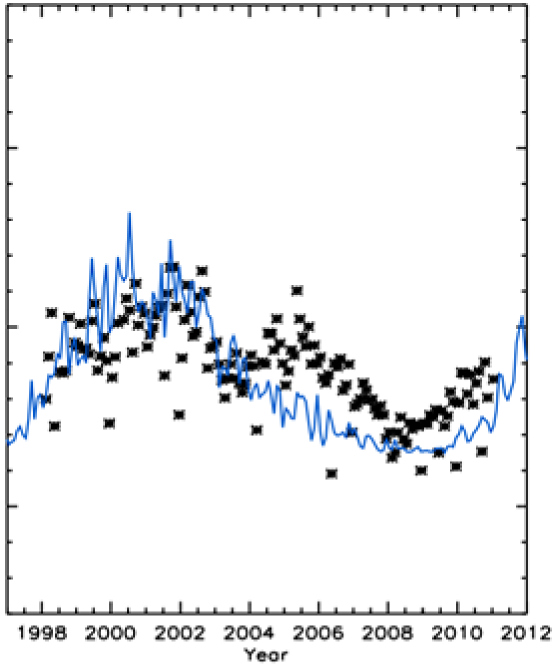
Foley et al. (2002)



Landi & Testa (2014)

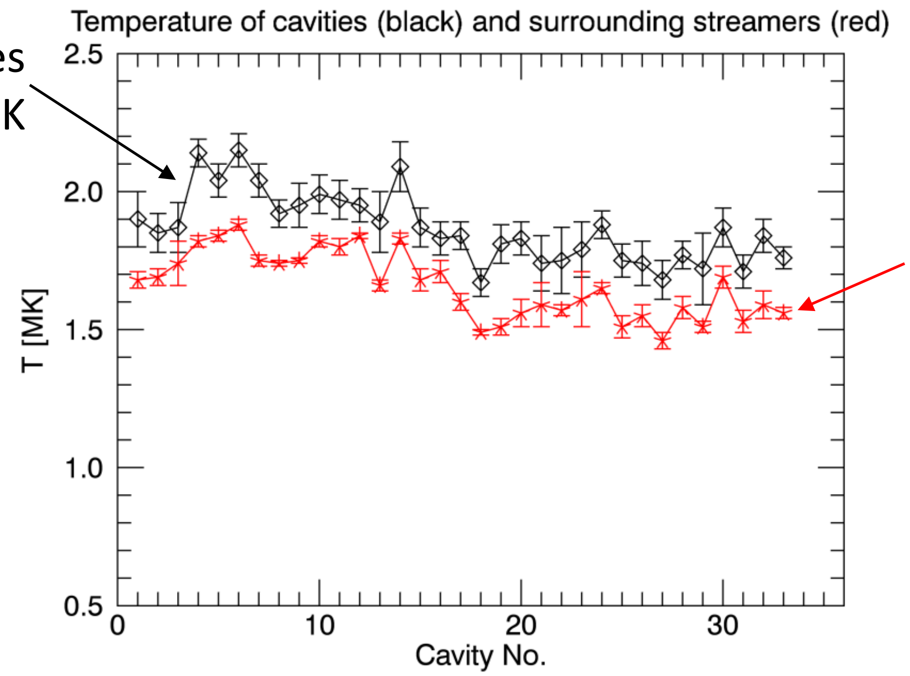
Temperatures and it's variations through the solar cycle

Coronal electron temperature inferred from the O 7+ /O 6+ as measured by ACE/SWICS from 1998 to 2011



Landi & Testa (2014)

cavities
1.85 – 2.15 MK



streamers
1.67 – 1.88 MK

Bąk-Stęślicka et al. (2019)

Data & methods

- 33 streamers
- AIA/SDO data (94, 131, 171, 193, 211, and 335 Å)
- Deconvolved data (Grigis, Su & Weber , 2011)
- Data normalized and integrated over 4 pixels

Two method of DEM analysis:

- xrt_dem_iterative2.pro (Weber et al. 2004)

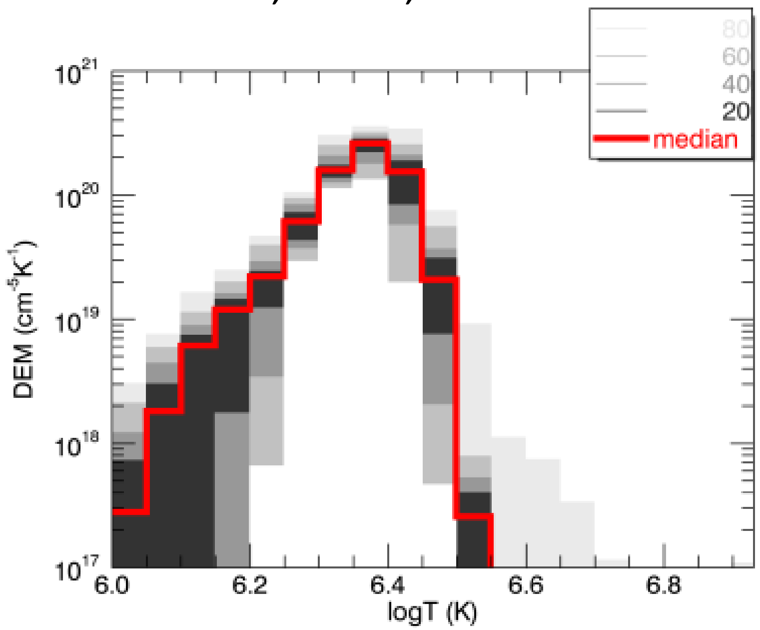
No.	Date	T_{CAV_A} [MK]	T_{CAV_B} [MK]	T_{STR_A} [MK]	T_{STR_B} [MK]
1	2 Jan. 2012 19:30	1.86 ± 0.24	1.90 ± 0.10	1.72 ± 0.19	1.68 ± 0.03
2	3 Jan. 2012 19:30	[a]1.85 ± 0.29	1.85 ± 0.07	1.73 ± 0.15	1.69 ± 0.03
3	4 Jan. 2012 19:30	1.85 ± 0.13	1.87 ± 0.09	1.72 ± 0.18	1.74 ± 0.08
4	19 Mar. 2012 19:30	2.18 ± 0.14	2.14 ± 0.05	1.87 ± 0.07	1.82 ± 0.02
5	20 Mar. 2012 19:30	2.02 ± 0.09	2.04 ± 0.06	1.90 ± 0.07	1.84 ± 0.02
6	30 Oct. 2012 19:30	2.21 ± 0.13	2.15 ± 0.06	1.93 ± 0.07	1.88 ± 0.02
7	15 Dec. 2012 19:30	2.07 ± 0.17	2.04 ± 0.06	1.79 ± 0.07	1.75 ± 0.02
8	18 Dec. 2012 19:30	1.98 ± 0.09	1.92 ± 0.05	1.78 ± 0.05	1.74 ± 0.01
9	19 Dec. 2012 19:30	1.95 ± 0.14	1.95 ± 0.08	1.79 ± 0.05	1.75 ± 0.01
10	3 Jan. 2013 19:30	2.07 ± 0.13	1.99 ± 0.07	1.86 ± 0.07	1.82 ± 0.02
11	4 Jan. 2013 19:30	1.99 ± 0.19	1.97 ± 0.07	1.86 ± 0.11	1.80 ± 0.03
12	25 Jan. 2013 19:30	2.02 ± 0.11	1.95 ± 0.06	1.89 ± 0.06	1.84 ± 0.01
13	19 Feb. 2013 19:30	1.85 ± 0.19	1.89 ± 0.11	1.70 ± 0.04	1.66 ± 0.02
14	5 Jun. 2015 19:30	2.21 ± 0.20	2.09 ± 0.09	1.91 ± 0.06	1.83 ± 0.02
15	15 Aug. 2017 19:30	[a]1.92 ± 0.27	1.87 ± 0.06	1.70 ± 0.36	1.68 ± 0.04
16	16 Aug. 2017 19:30	[a]1.81 ± 0.27	1.83 ± 0.06	1.76 ± 0.42	1.71 ± 0.04
17	17 Aug. 2017 19:30	1.89 ± 0.19	1.84 ± 0.05	1.65 ± 0.09	1.60 ± 0.03
18	19 Aug. 2017 19:30	[a]1.68 ± 0.23	1.67 ± 0.05	1.54 ± 0.10	1.49 ± 0.01
19	20 Aug. 2017 19:30	1.79 ± 0.43	1.81 ± 0.07	1.55 ± 0.08	1.51 ± 0.03
20	26 Sep. 2017 19:30	1.84 ± 0.28	1.85 ± 0.06	1.62 ± 0.13	1.56 ± 0.05
21	27 Oct. 2017 19:30	1.68 ± 0.25	1.74 ± 0.10	1.57 ± 0.19	1.59 ± 0.08
22	28 Oct. 2017 19:30	1.69 ± 0.23	1.75 ± 0.12	1.63 ± 0.09	1.57 ± 0.02
23	8 Nov. 2017 19:30	1.77 ± 0.52	1.79 ± 0.10	1.59 ± 0.34	1.61 ± 0.10
24	8 Nov. 2017 19:30	1.95 ± 0.17	1.88 ± 0.05	1.70 ± 0.27	1.65 ± 0.02
25	17 Nov. 2017 19:30	1.74 ± 0.66	1.75 ± 0.06	1.54 ± 0.50	1.51 ± 0.04
26	23 Nov. 2017 19:30	[a]1.71 ± 0.23	1.74 ± 0.08	1.60 ± 0.18	1.55 ± 0.04
27	25 Dec. 2017 19:30	[a]1.69 ± 0.32	1.68 ± 0.07	1.50 ± 0.12	1.46 ± 0.03
28	31 Dec. 2017 19:30	1.81 ± 0.24	1.77 ± 0.05	1.63 ± 0.17	1.58 ± 0.04
29	3 Jan. 2018 19:30	1.65 ± 0.32	1.72 ± 0.13	1.56 ± 0.07	1.51 ± 0.02
30	13 Jan. 2018 19:30	1.87 ± 0.20	1.87 ± 0.07	1.72 ± 0.16	1.69 ± 0.04
31	14 Jan. 2018 19:30	1.73 ± 0.22	1.71 ± 0.06	1.57 ± 0.17	1.53 ± 0.04
32	20 Feb. 2018 19:30	1.91 ± 0.10	1.84 ± 0.06	1.63 ± 0.10	1.59 ± 0.05
33	17 Mar. 2018 19:30	1.82 ± 0.14	1.76 ± 0.04	1.61 ± 0.05	1.56 ± 0.02

DEM analysis

- To obtain uncertainties we used a Monte Carlo method. We ran a code 100 times, each time perturbing the observed flux with random noises.
- These median DEM profiles were used to calculate the DEM-weighted average temperature for each binned pixel in the map
- This allowed us to determine the average temperature of the cavity and surrounding streamer. The average temperature was determined in a box of 5x5 binned pixels (20x20 original pixels).

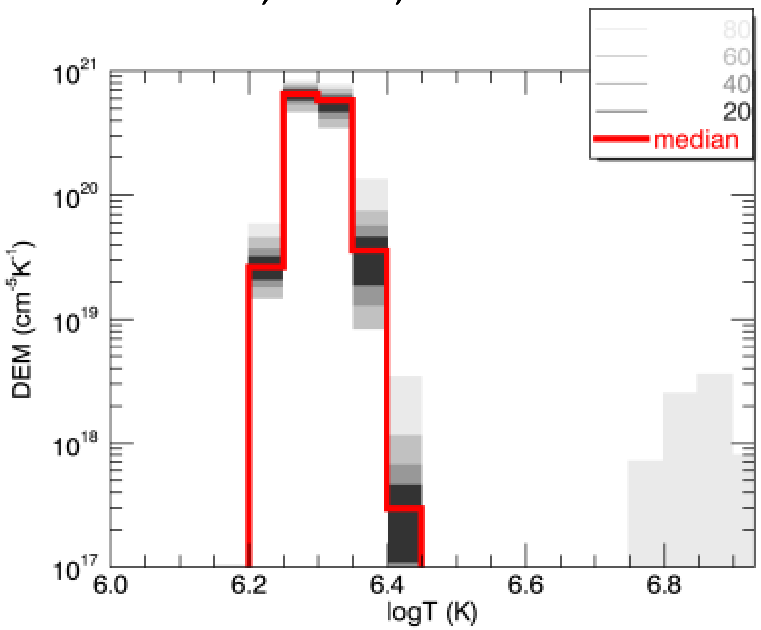
Cavity

$2{,}15 \pm 0{,}06$ MK



Streamer

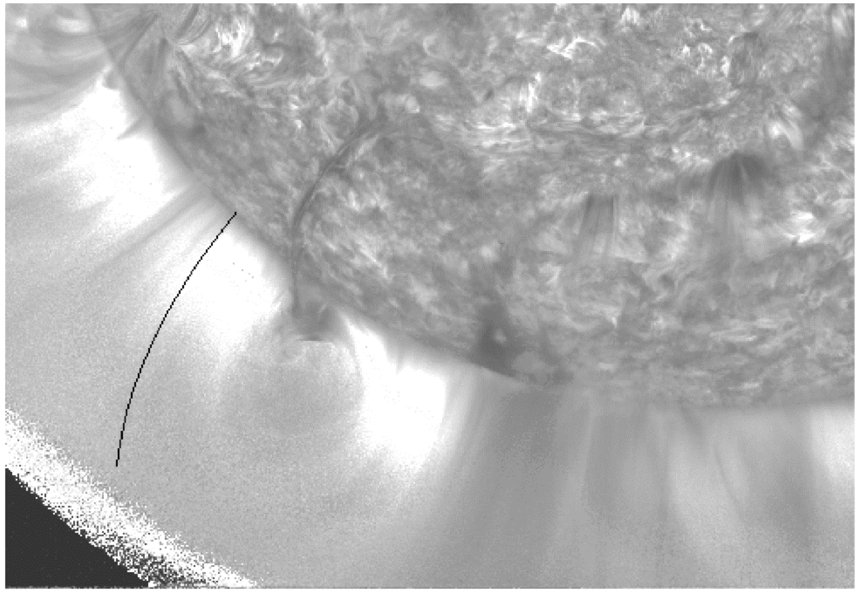
$1{,}88 \pm 0{,}02$ MK

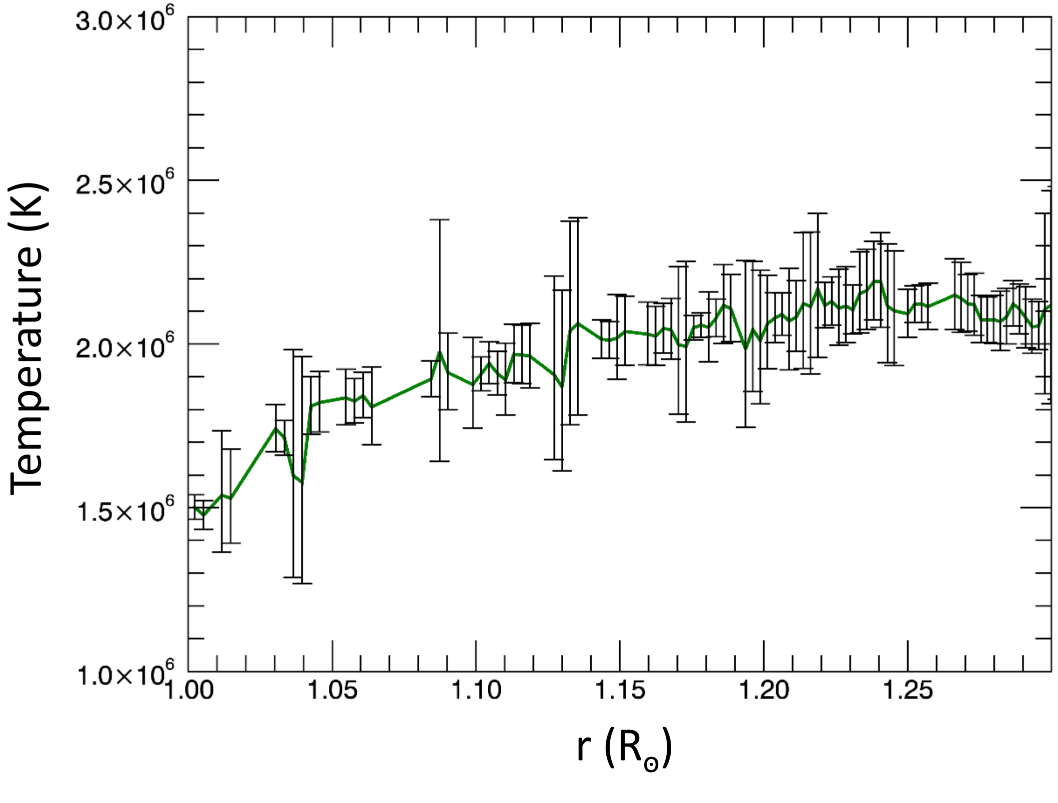


Temperature height profiles

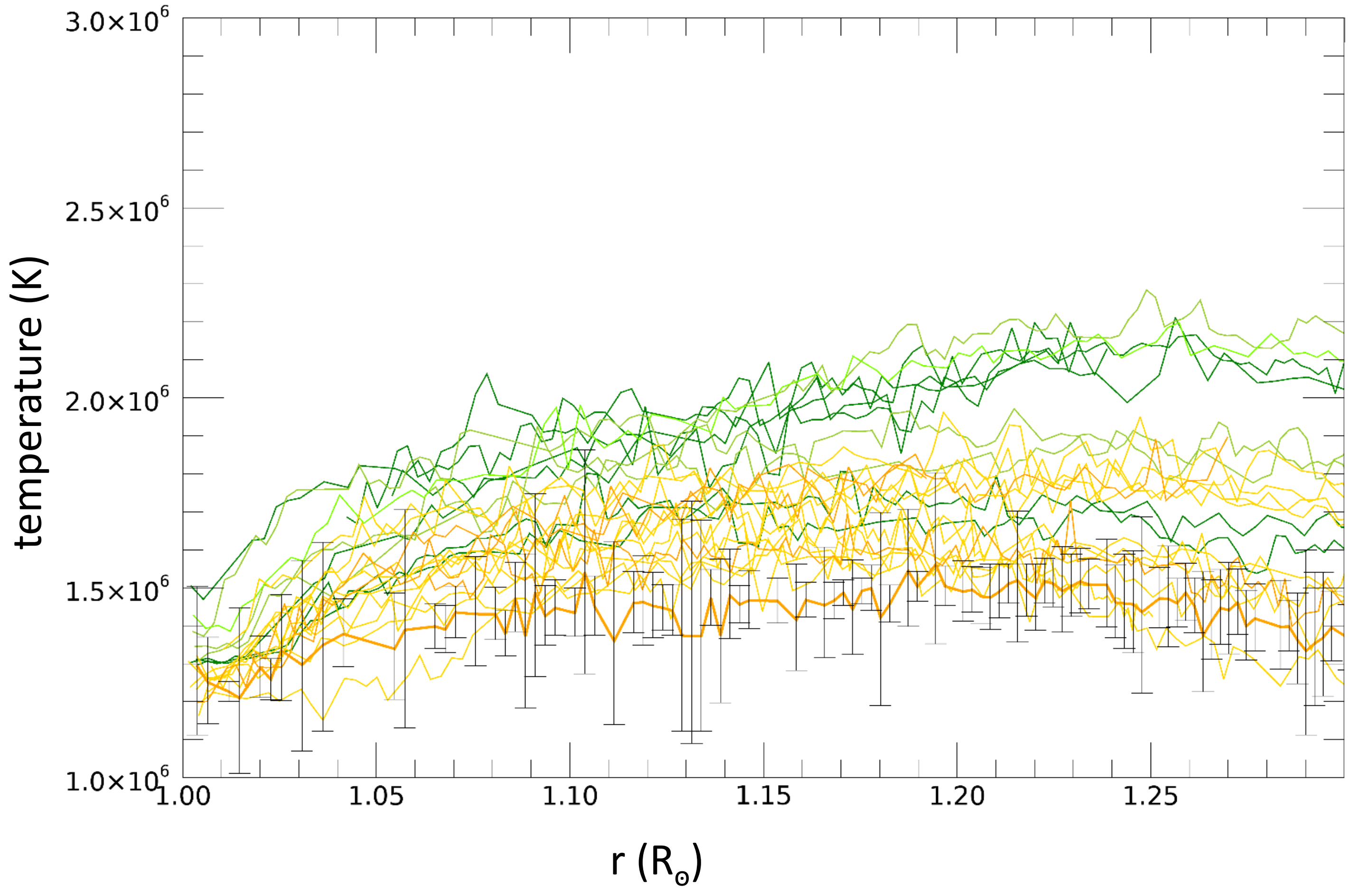
- xrt_dem_iterative2.pro (Weber et al. 2004)
- Images integrated over 4 pixels
- Average temperatures obtained from 9 pixels

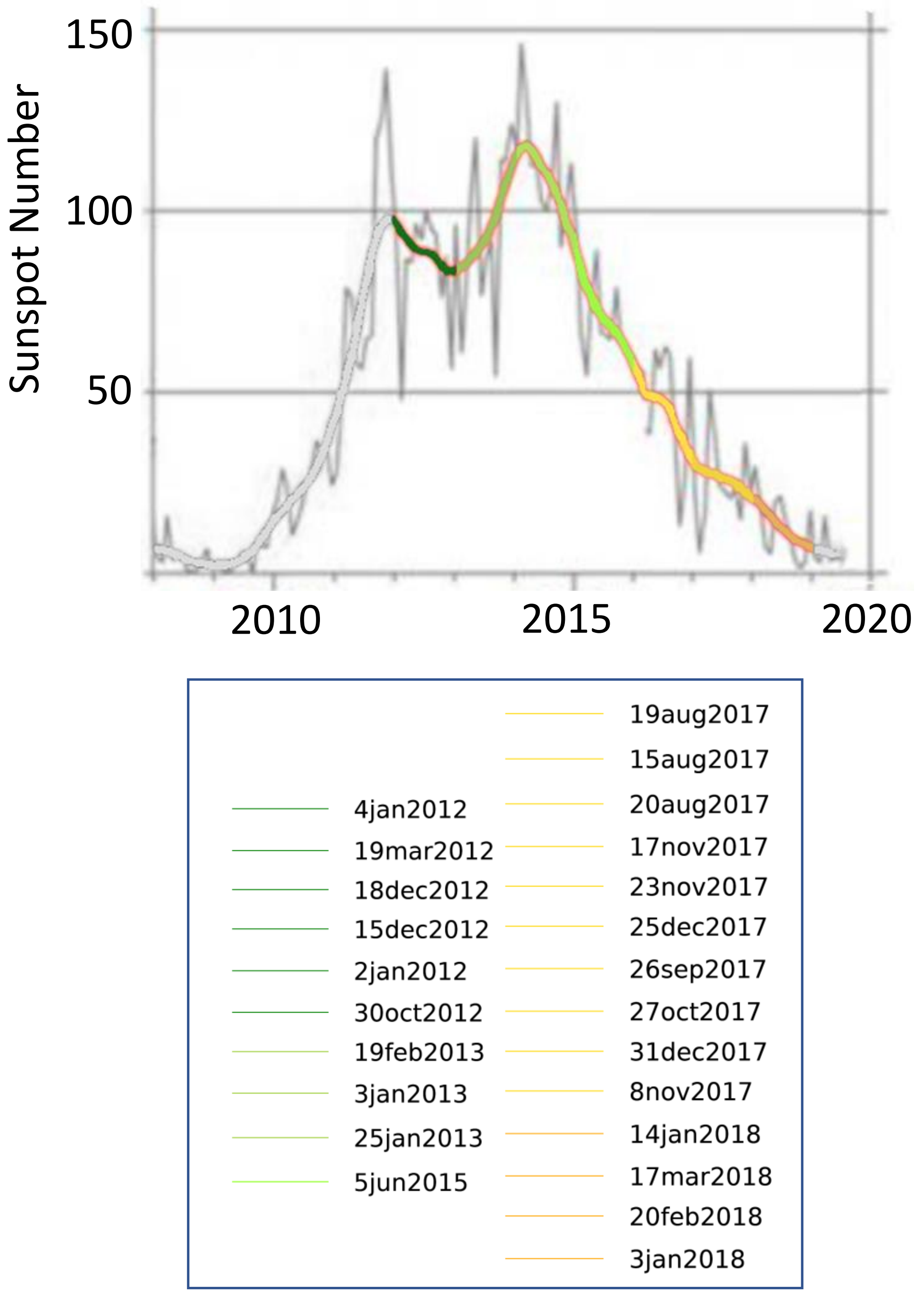
Oct 30, 2012





Change with the cycle





Conclusions

- Changes of streamers temperature with height agrees with previous measurements
- Noticeable change of streamers temperature (up to ~0.6 MK) during solar activity cycle
- Streamers are hotter at their core with the temperature dropping at their boundary
- Temperature of cavities is higher (~0.2 MK) then surrounding streamer