Department of Space and Climate Physics,
Mullard Space Science Laboratory

Deriving large coronal magnetic loop parameters using LOFAR J-burst observations

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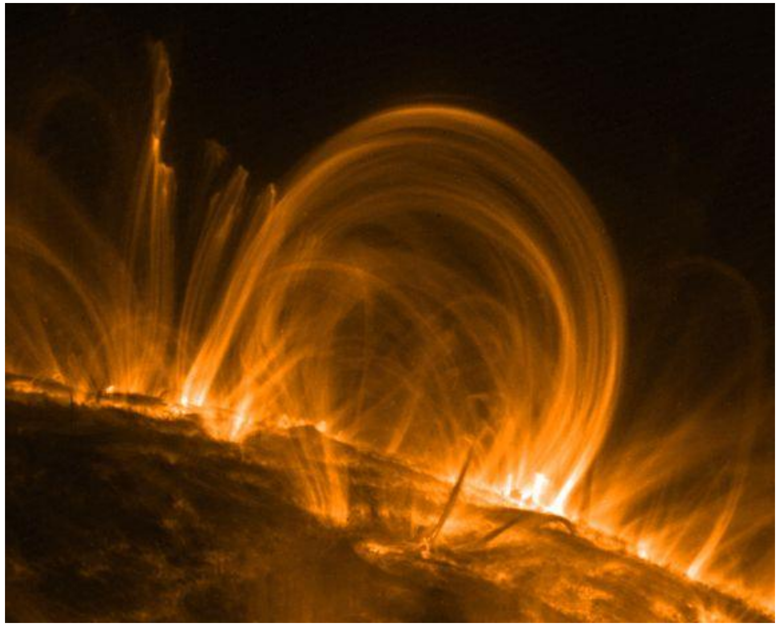

NASA Astronomy Picture of the Day (APD), 8TH Sep 2000

Photo of the Superterp, the heart of the LOFAR core (Haarlem et al 2013)

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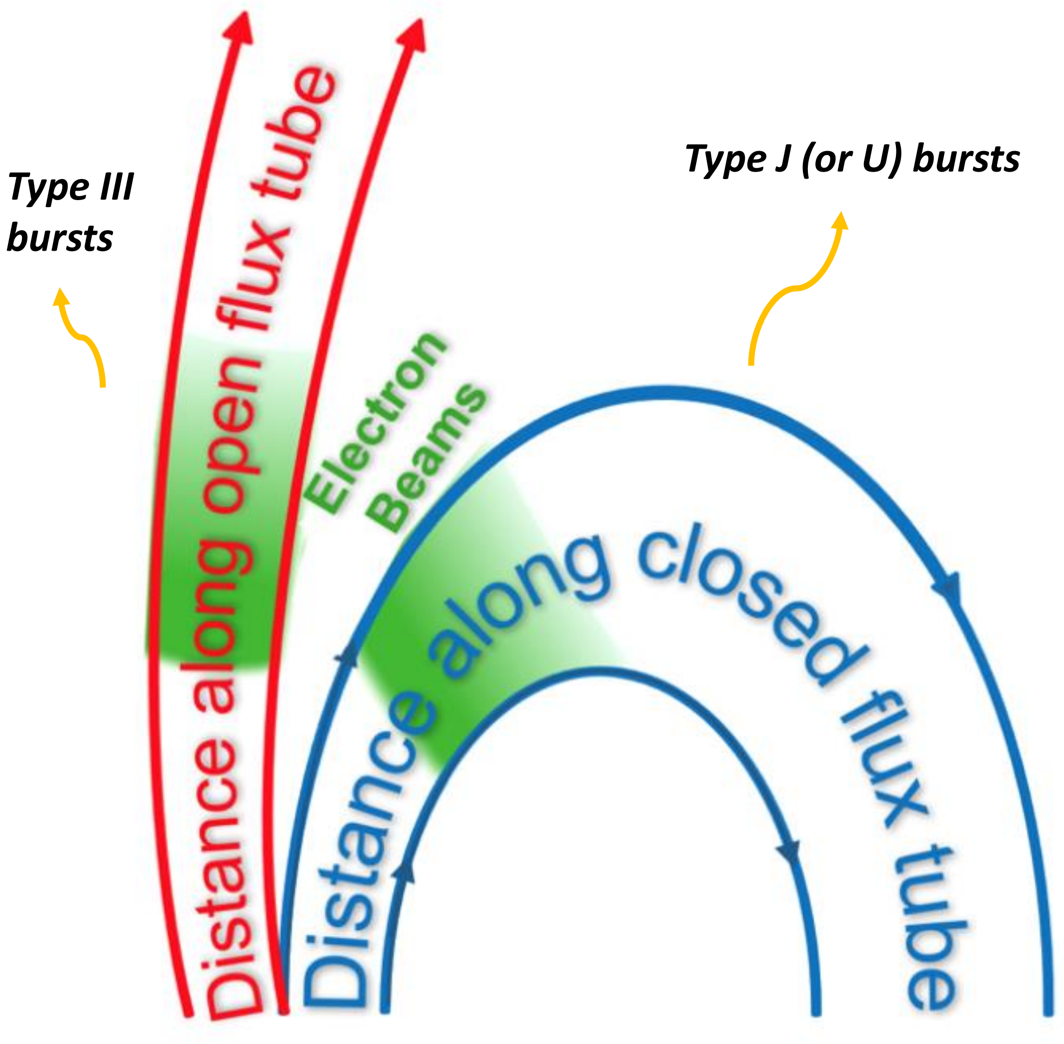
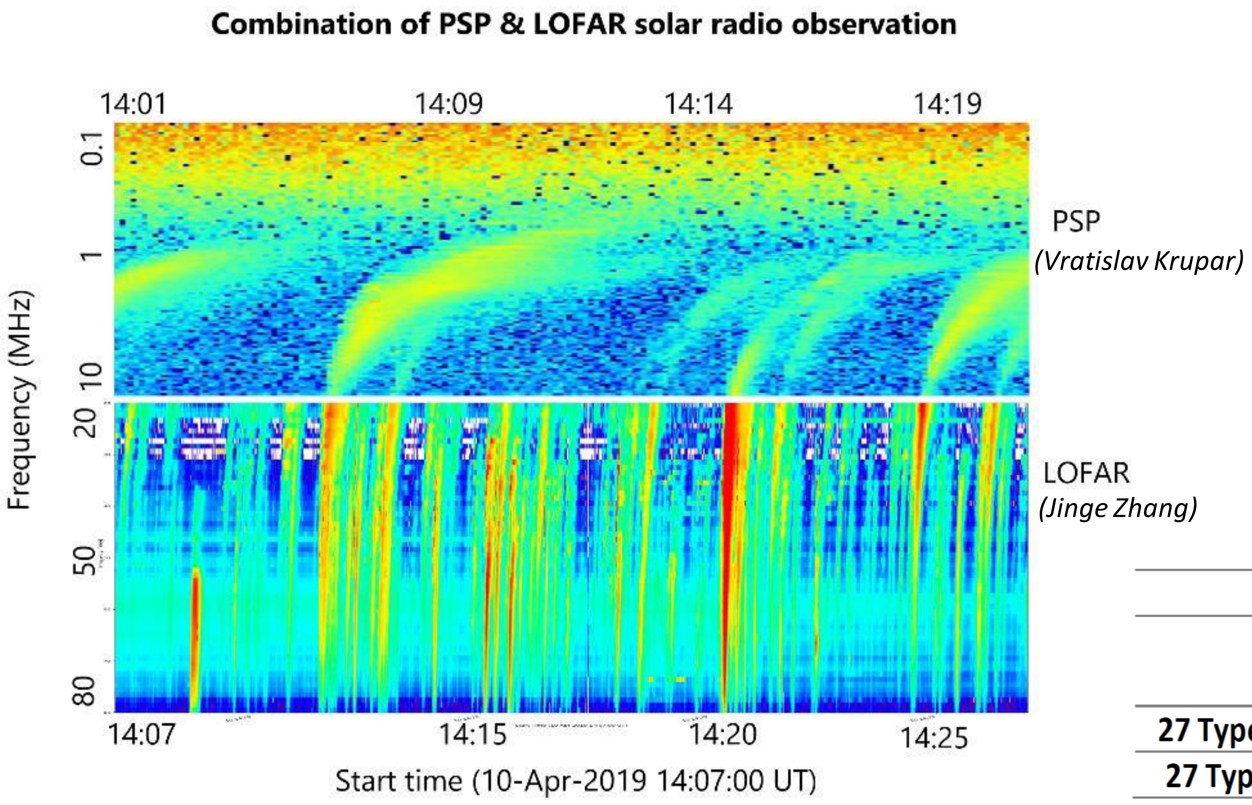
Analysing electron beam velocities

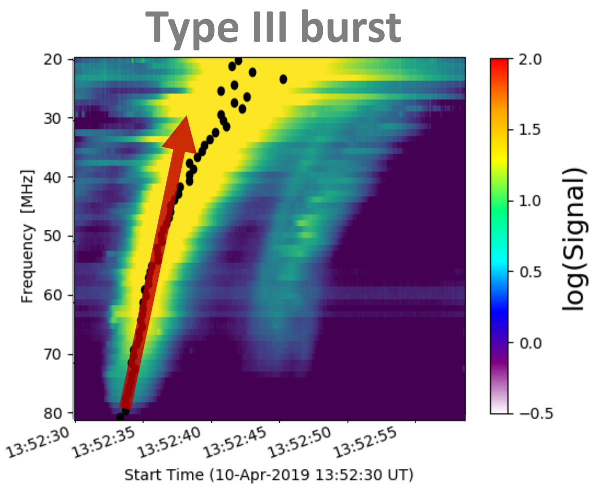


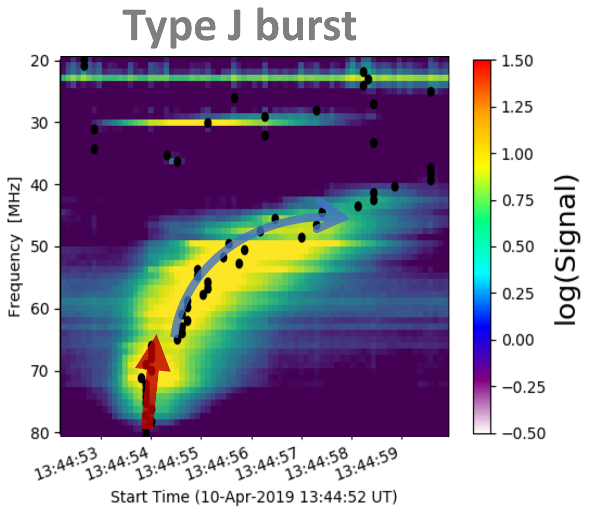
Reid and Kontar, 2017

- Exciter velocities of type III bursts from 0.15c to 0.3c (where c is the speed of light). **(e.g. Poquerusse (1994) ; Klassen et al. (2003))**
- Exciter velocities of type III bursts from 0.2 to 0.25c **(e.g. Labrum & Stewart (1970); Reid & Kontar (2017))**
- It is generally considered that type J and U's exciter velocities has the same order as type III bursts.
- **No statistical analysis of type III and type J bursts exciter velocities during one solar radio noise storm.**
- **Question: Whether the electron acceleration properties are different in 'open' and closed flux tubes?**

Analysing electron beam velocities







	Fundamental emission		Second-harmonic emission	
	Average velocity [c]	Standard deviation	Average velocity [c]	Standard deviation
27 Type III bursts	0.12	0.02	0.16	0.03
27 Type J bursts	0.13	0.03	0.17	0.04

Background electron density gradient

Drift rate ← $$\frac{df}{dt} = \frac{df}{dn}\frac{dn}{dr}\frac{dr}{dt}$$ → *Electron beam velocity*

$$\frac{d}{dn}\left(4\pi n_e e^2/m_e\right)^{1/2}$$

Type J bursts and type III bursts have similar average exciter velocities.

This means both type III and J electron beams experienced very similar acceleration process during the same solar activity.

Deriving loop parameters

- **Aschwanden et al. (1992)** determined coronal loop physical parameters and electron beam properties from three type U bursts observed by the Very-Large-Array (VLA) between 1300 to 1700 MHz. Therefore, loop height is relatively low, at around 0.18 $R_\odot$.

- **We determined large coronal loop's (with loop heights around 1.2 $R_\odot$) physical parameters by analysing type J bursts observed by the Low-Frequency-ARray (LOFAR) between 20-80 MHz.**

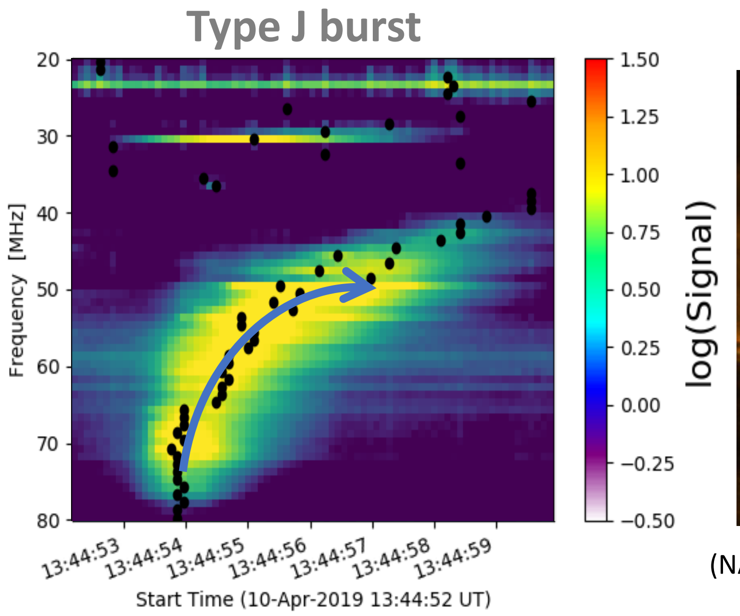
OBSERVED AND CALCULATED PARAMETERS FOR THREE TYPE U BURSTS ON 1989 AUGUST 13

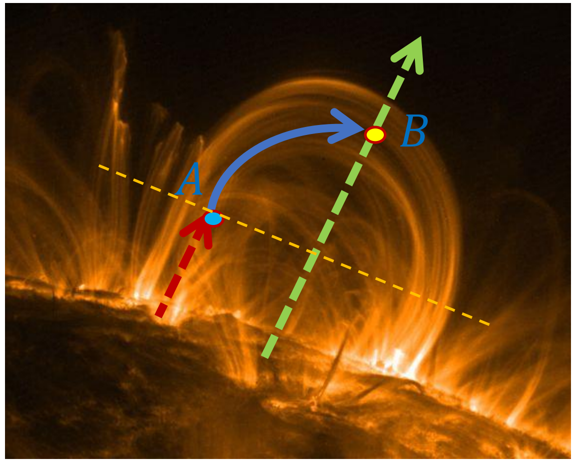
Parameter	U Burst 1	U Burst 2	U Burst 3
Observations			
Time of type U burst	1356:30 UT	1357:18 UT	1358:24 UT
Minimum frequency	1425 MHz	1375 MHz	1440 MHz
Maximum frequency	1700 MHz	1700 MHz	1700 MHz
Half-loop transit time	4.4 s	3.2 s	3.1 s
Harmonic Plasma Emission ($s = 2$)			
Plasma frequency	713 MHz	687 MHz	740 MHz
Electron density	6.3×10^9 cm^{-3}	5.9×10^9 cm^{-3}	6.8×10^9 cm^{-3}
Sakurai Magnetic Field Extrapolation			
Altitude of loop apex	130 ± 15 Mm	...	...
Half-loop length	200 ± 20 Mm	...	...
Magnetic field inner footpoint	1770 ± 30 G	...	...
Magnetic field outer footpoint	310 ± 20 G	...	...
Magnetic field apex	11 ± 2 G	...	...
Limits Implied from the Observed Frequency Range			
Maximum/minimum frequency ratio	>1.19	>1.24	>1.15
Loop height/scale height	>0.35	>0.42	>0.28
Density scale height	<360 ± 60 Mm	<300 ± 40 Mm	<460 ± 50 Mm
Temperature in loop	<7.9 ± 0.9 MK	<6.6 ± 0.8 MK	<10.0 ± 1.1 MK
Rosner-Tucker-Vaiana Law			
Temperature	7.0 ± 0.4 MK	6.7 ± 0.4 MK	7.2 ± 0.4 MK
Pressure	6.1 ± 0.4 dyn cm^{-2}	5.4 ± 0.3 dyn cm^{-2}	6.8 ± 0.4 dyn cm^{-2}
Density scale height	320 ± 20 Mm	310 ± 20 Mm	330 ± 20 Mm
Magnetic confinement	>12 G	>12 G	>13 G
Electron Beam			
Exciter velocity	42 ± 3 Mm s^{-1}	64 ± 5 Mm s^{-1}	53 ± 4 Mm s^{-1}
Kinetic energy	5 keV	10 keV	7 keV
Beam velocity/thermal velocity	4.4	6.2	5.2
Collisional deflection time	0.4 ± 0.1 s	1.4 ± 0.3 s	0.7 ± 0.2 s

Aschwanden loop height: 0.18 $R_\odot$

Aschwanden et al. (1992)

Deriving loop parameters





(NASA Astronomy Picture of the Day, 8TH Sep 2000)

We analysed 17 type J bursts in this burst storm and we derived exponential density models for each of them in form :

$$N_e(h) = N_0 \times e^{-h/H}$$

We use the density scale height for the coronal plasma in thermal equilibria, (Aschwanden et al 1992) given by:

$$H = \frac{(1+\alpha)}{\beta} \frac{k_b T_E}{m_p g_{sun}}$$

We use the Ideal gas law to estimate pressure:

$$P = n_e k_b T_E$$

We use plasma beta to estimate minimum magnetic field strength in solar corona:

$$\beta = 3.47 \times 10^{-15} \frac{n_e T}{B^2} < 1$$

Loop physical parameters we determined from 17 type J bursts are smaller in magnitude compared to **Aschwanden et al. (1992)** 's estimation for smaller loops:

Average loop height:1.2 $R_\odot$	VS	0.18 $R_\odot$

- We observe type J bursts in the lower frequency range, reflecting coronal loops in the higher solar corona.

Average density scale height:$2.4 \times 10^{10} cm$	VS	$3.6 \times 10^{10} cm$

- We have higher loop height/scale height ratio. Therefore, we use ideal gas law to estimate loop pressure.

Average loop top temperature:1.3 MK	VS	7.0 MK

- Loop temperature is lower in higher corona.

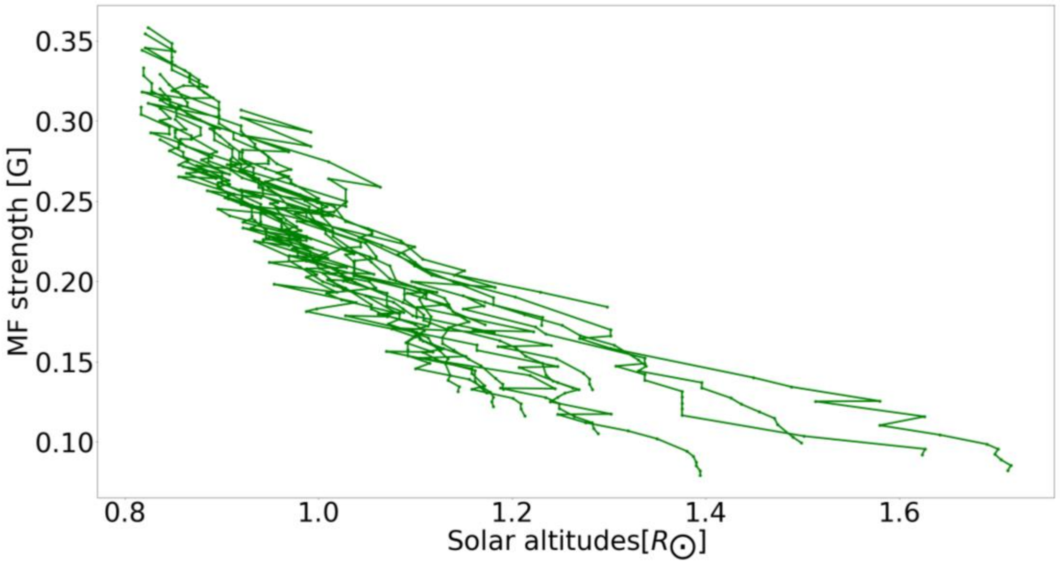
Average loop top pressure:$0.002\ dyn\ cm^{-2}$	VS	$6.1\ dyn\ cm^{-2}$

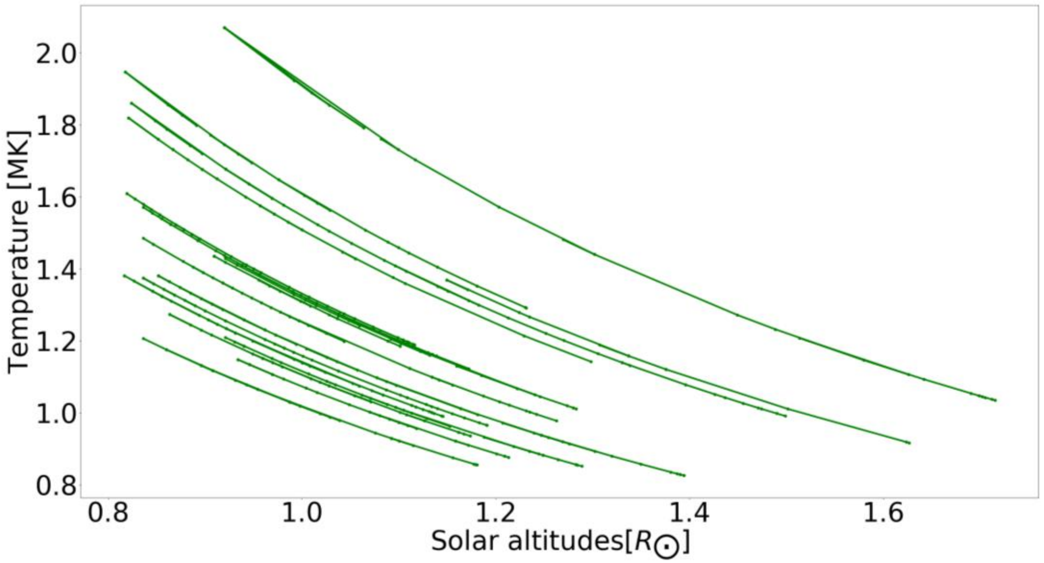
- Loop pressure is lower in higher corona.

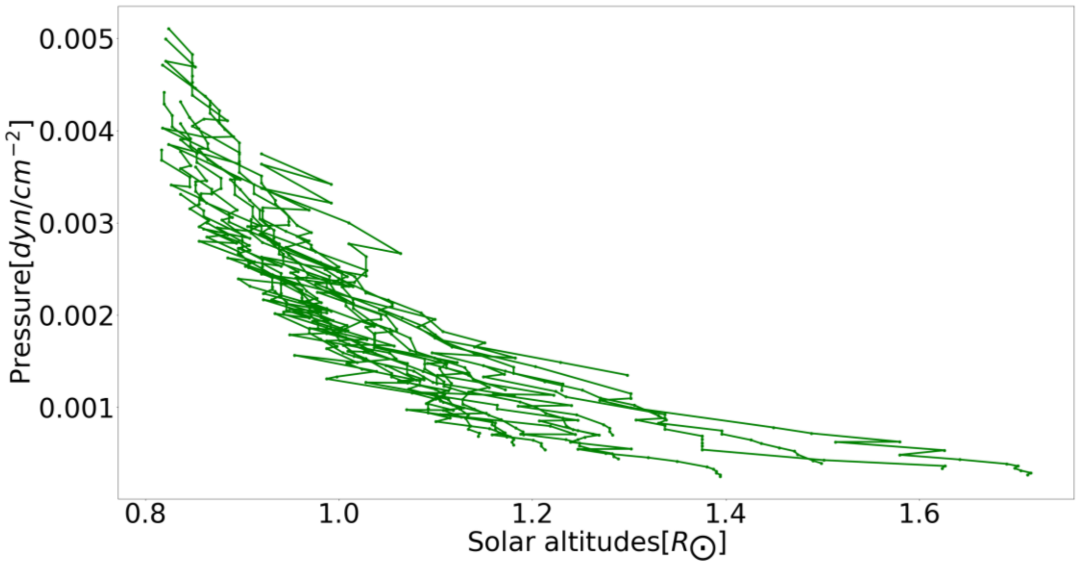
Average loop top MF strength:> 0.22 G	VS	> 12 G

- Loop magnitude strength is lower in higher corona.

Deriving loop parameters







- Loop top temperature between 0.8 to 2.0 MK.
- Loop top pressure between 0.0005 to 0.005 $dyn\ cm^{-2}$.
- Minimum loop top magnetic field strength between 0.1 to 0.25 G.
- **Loop temperature, pressure and magnetic field strength decrease while altitude increase.**

Summary

- Electron beams travel along open or closed flux tubes have very similar acceleration properties during the same solar activity.

- We derived large coronal loops' (loop height around 1.2 $R_\odot$) physical parameters from 17 type J bursts, we found:
  - ➢ Average loop top temperature: $1.3\ \mathrm{MK}$
  - ➢ Average loop top pressure: $0.002\ \mathrm{dyn\ cm^{-2}}$
  - ➢ Average loop top minimum magnetic field strength: $> 0.22\ \mathrm{G}$

- **Loop temperature, pressure and magnetic field strength decrease while altitude increase.**

Thank you for listening!

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