The Radio Sun

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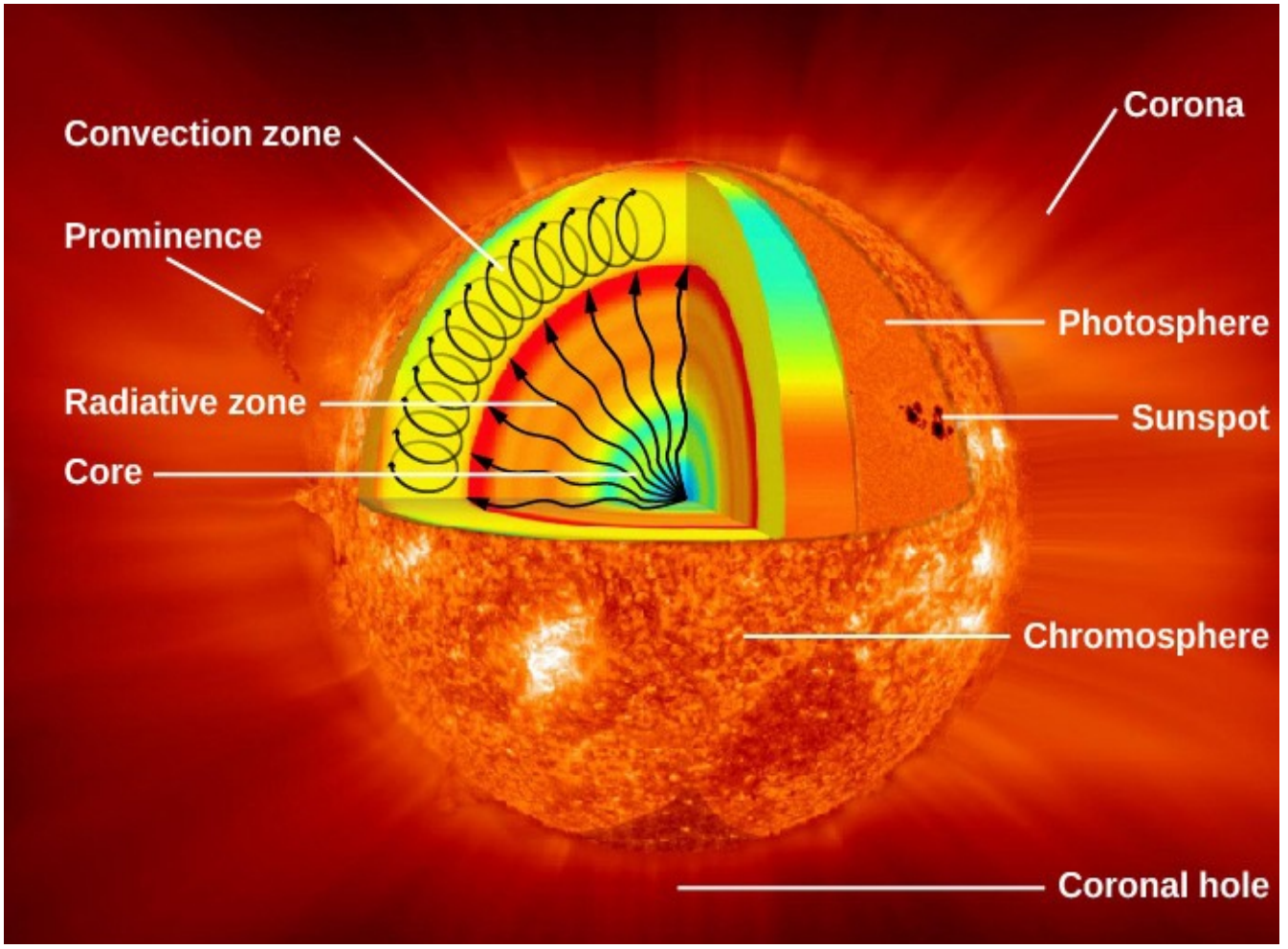
Radio Astronomy School, 2019

NCRA • TIFR

MWA
MURCHISON
WIDEFIELD
ARRAY

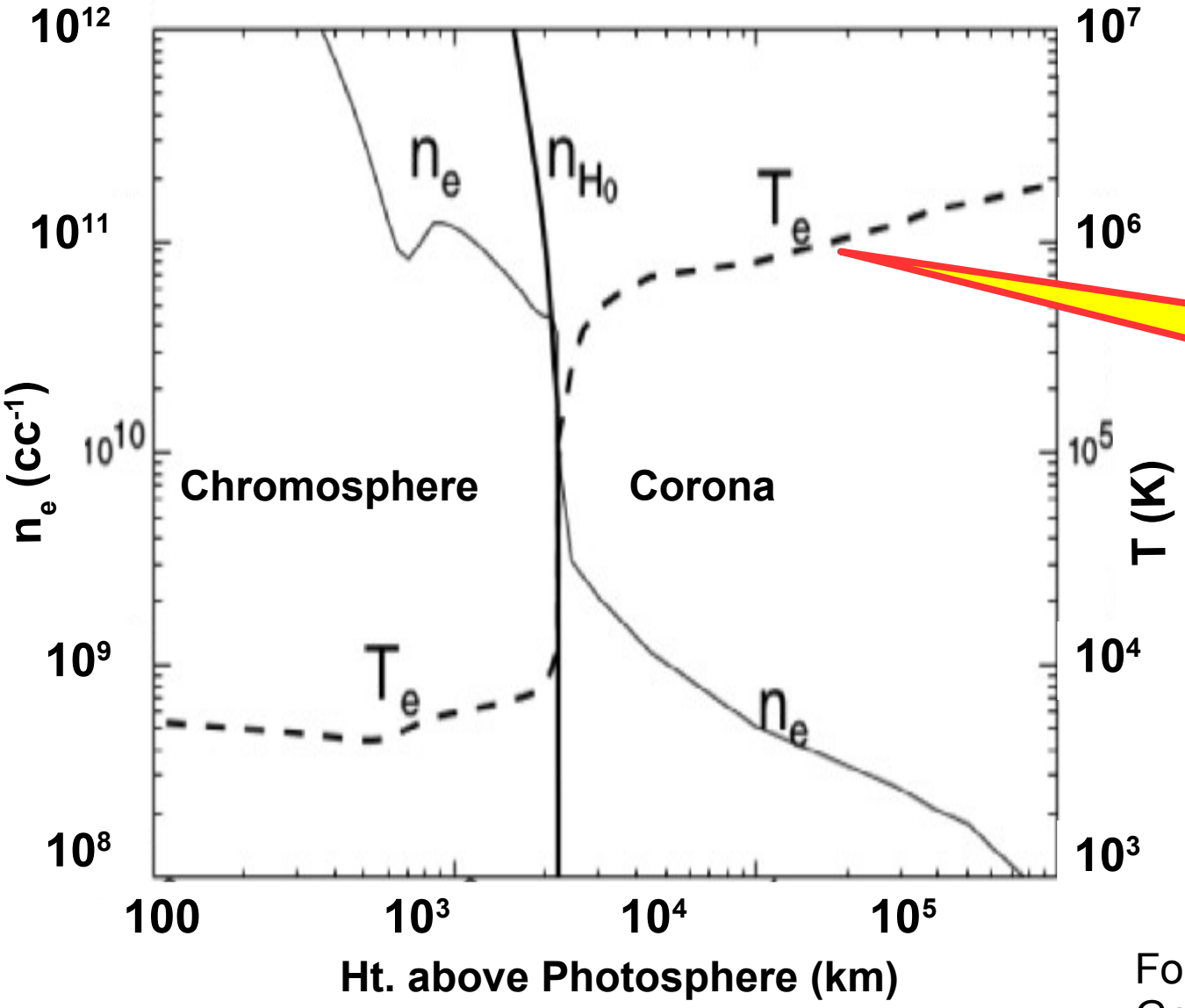
Introduction

- **Structure :**



- Radius = 700 Mm
- Core: 15 MK, 10^{26} cc^{-1}
  ~ 0.25 $R_\odot$
- Rad. Z: ~ 0.75 $R_\odot$
- Photo.: ~ 6000 K

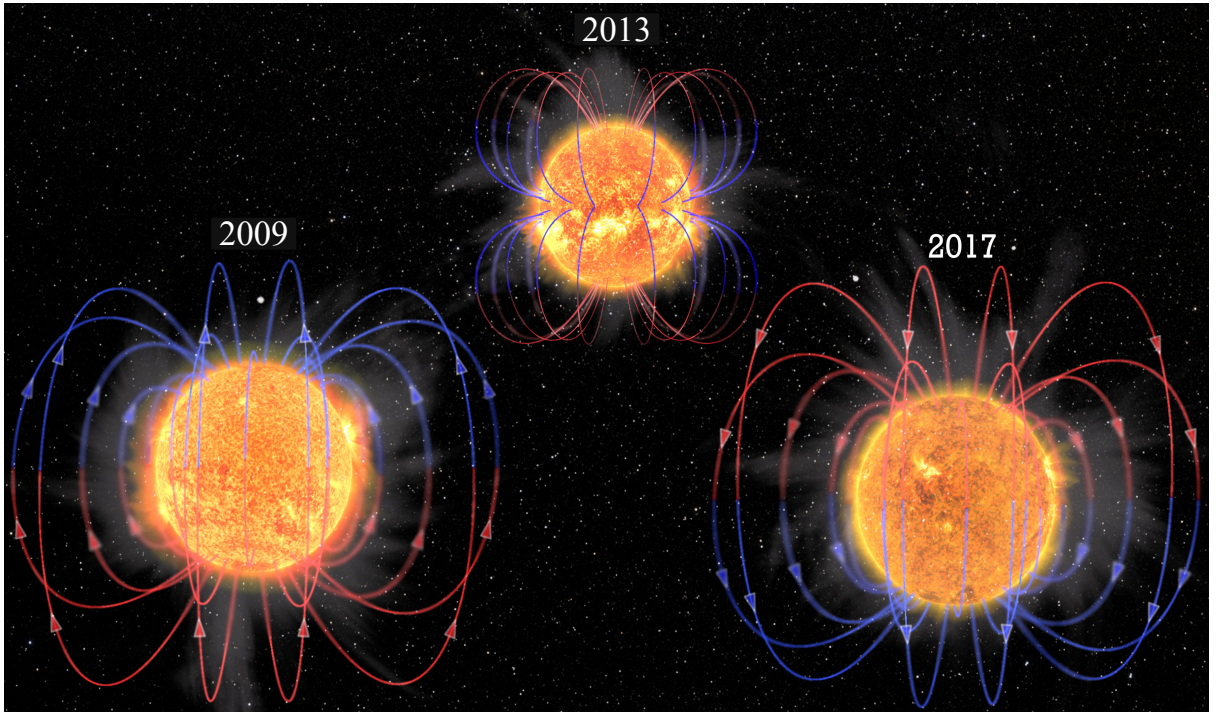
⭑ Atmosphere :



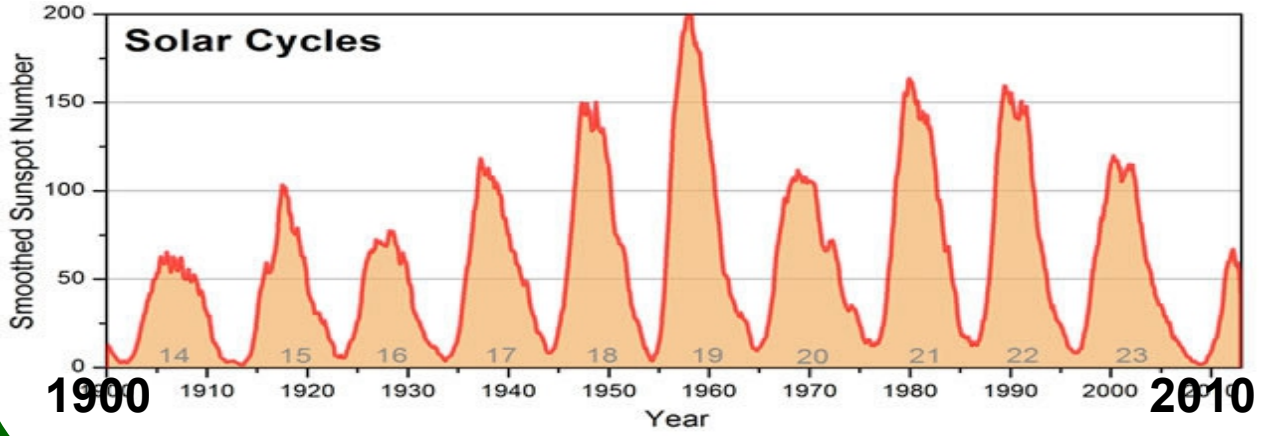
Coronal Heating Problem

Fontenla et al. 1990 & Gabriel, 1976

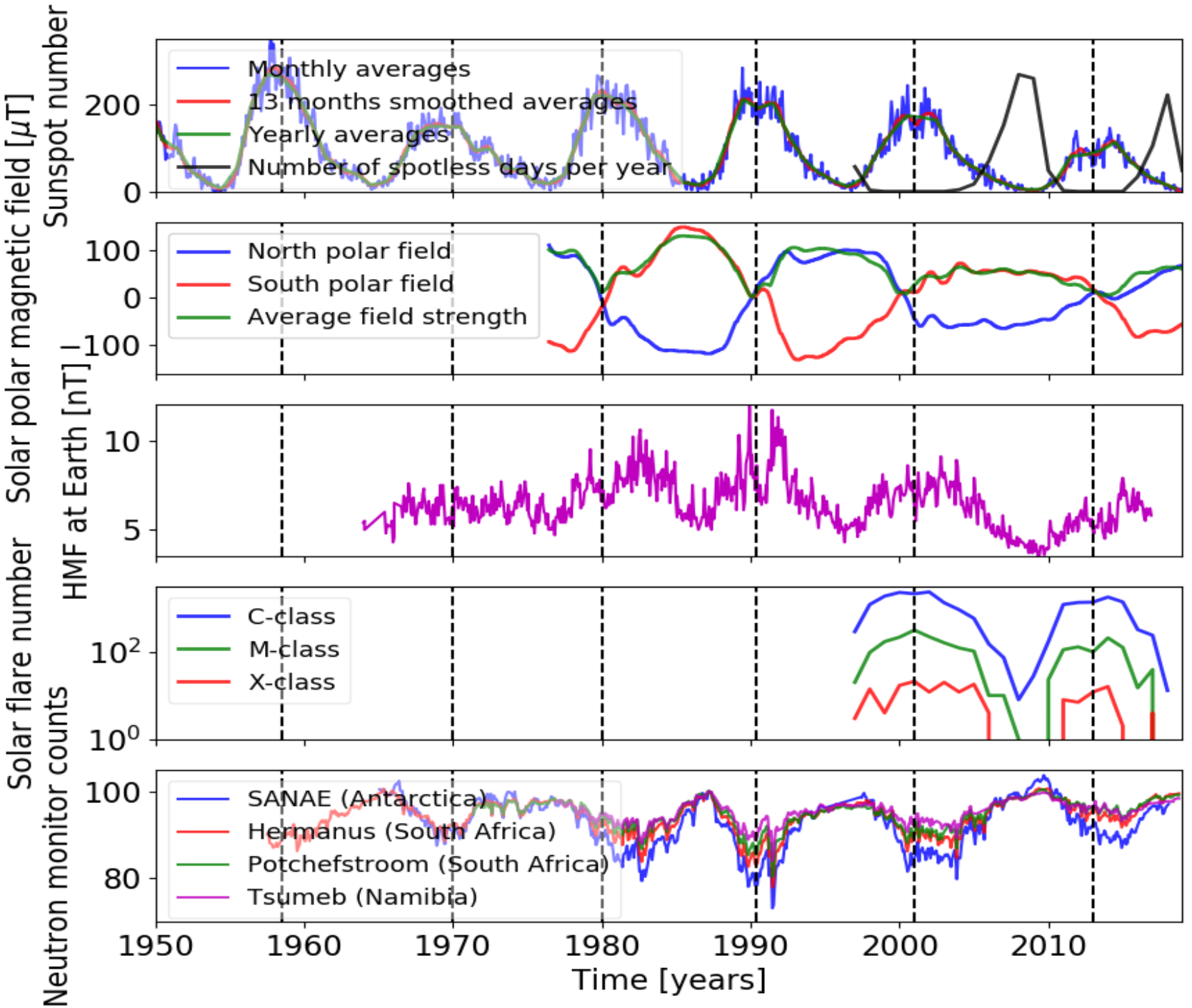
Magnetic field



- Dipolar field component flip ~ 11 yr.
- Sunspot no. & activity cycle oscillate.



Credits: NASA/GSFC/SVS & NOAA



Credits: https://ufarasuntalk.home.blog/2019/03/22/what-is-the-solar-cycle/

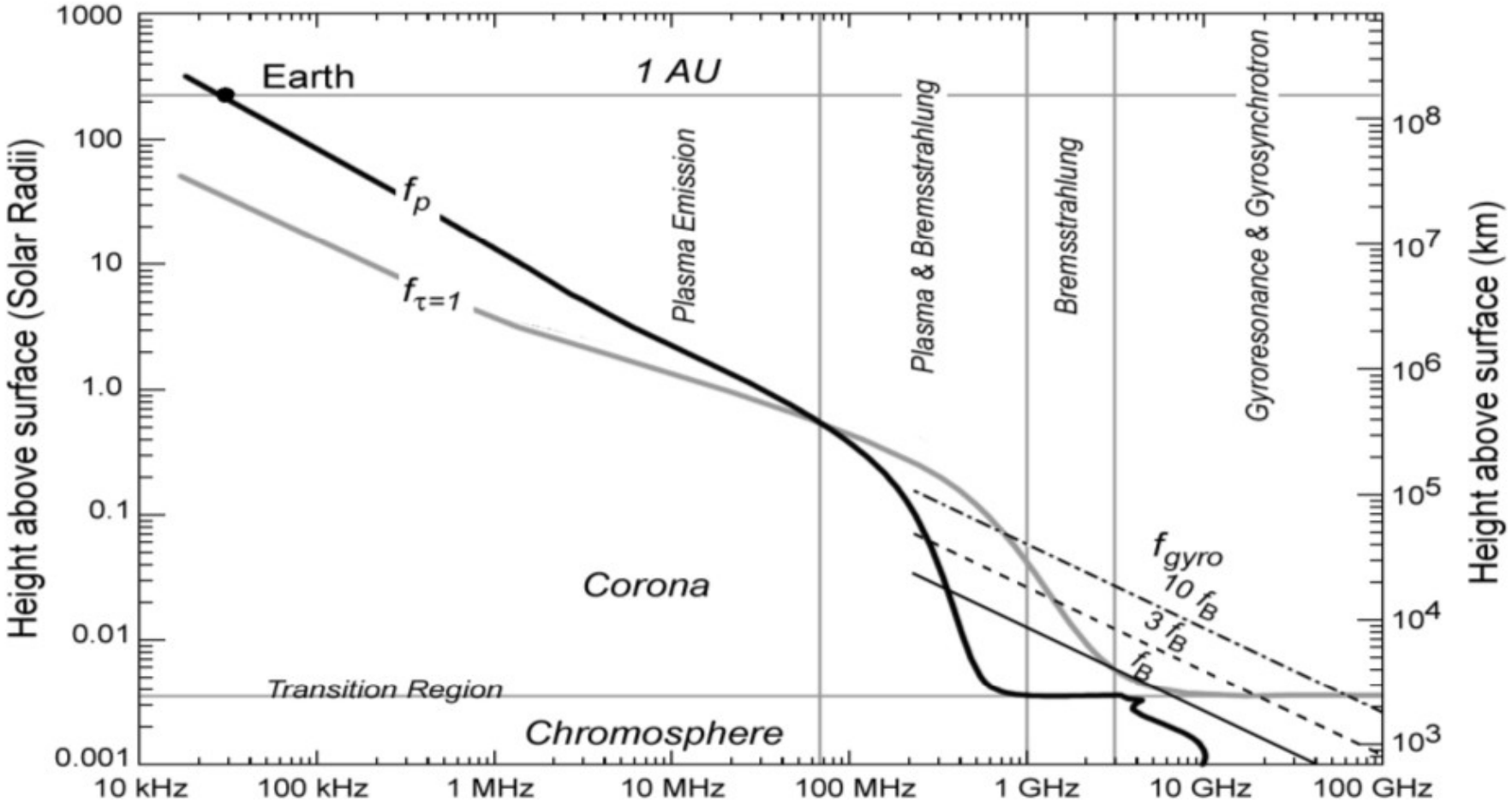


Table 1.1: The plasma-β parameter in the solar atmosphere.

Parameter	Photosphere	Cool corona	Hot corona	Outer corona
Electron density n_e (cm^{-3})	2×10^{17}	1×10^9	1×10^9	1×10^7
Temperature T (K)	5×10^3	1×10^6	3×10^6	1×10^6
Pressure p (dyne cm^{-2})	1.4×10^5	0.3	0.9	0.02
Magnetic field B (G)	500	10	10	0.1
Plasma-β parameter	14	0.07	0.2	7

Corona: The Metrewave Sun

- **Coronal plasma @ 1.1 – 2 $R_\odot$:**
  - *T ~ 2 MK, n_e ~ 10^8 cc*
  - ***Collisionless***
  - *B ~ O(0) – O(1) G.*
  - *$P_{gas}/P_B = \beta < 1$ → **Magnetically driven** (**Gary, 2001**)*
- **m-wave corona**
  - $$\nu_p \propto \sqrt{n_e} = f(\hbar) \;\; \tau_\nu \propto 1/\mu_\nu = \frac{1}{\sqrt{1 - \frac{\nu_p^2}{\nu^2}}}$$
  - *Thermal →* $T_B = T_e(1 - e^{-\tau_\nu})$, $\lim_{\nu \to \nu_p} T_B \to \infty$
  - *Non-thermal → Instabilities → coherent emission*
  - *Spectroscopic imaging* *Tomography*

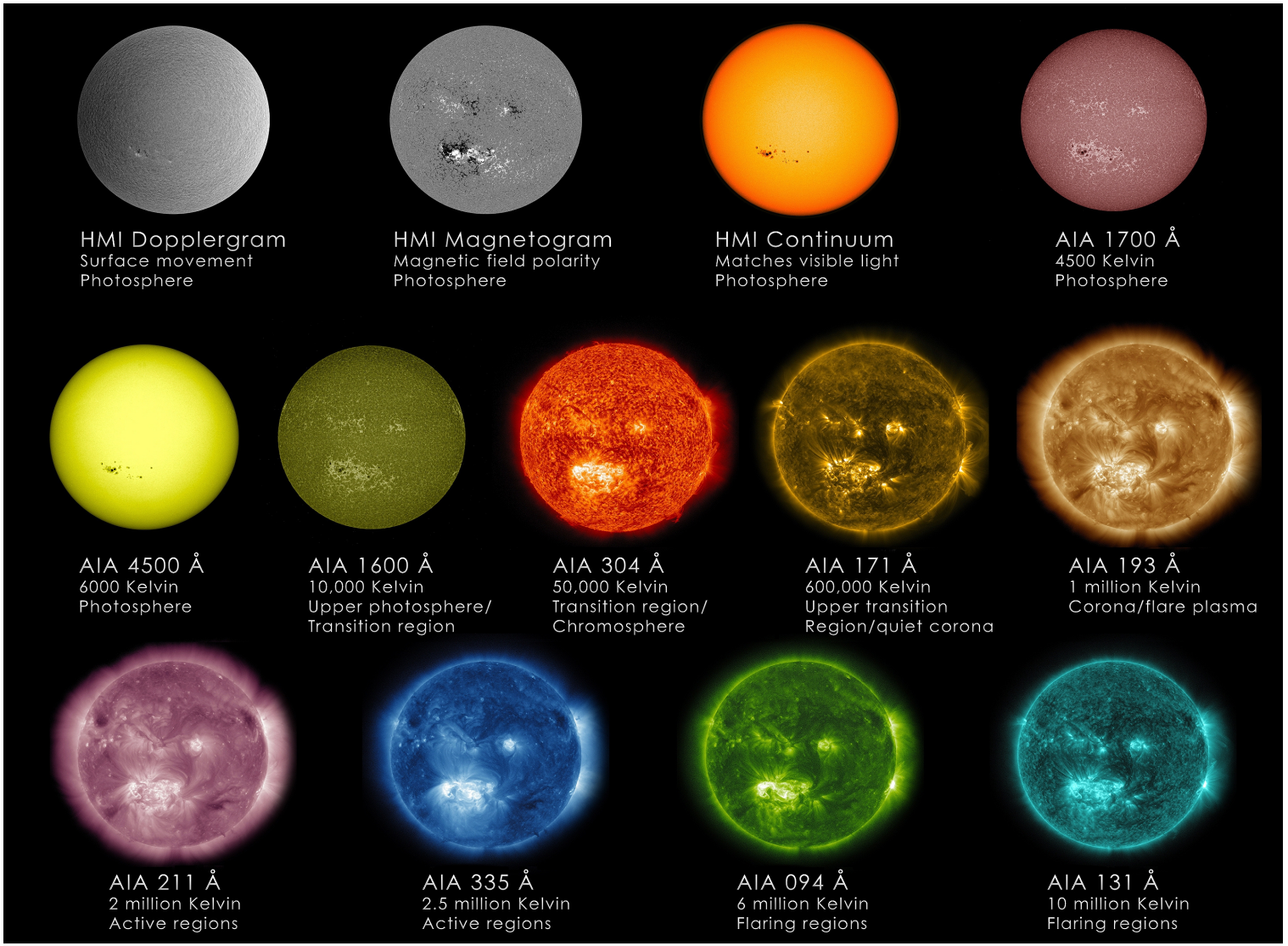
Problems & relevance

- **Problems:**
  - *Coronal Heating: Global & Local*
    - *Mechanism of energy derivation from B field.*
  - *Particle acceleration*
    - *Generation & propagation*

- **Relevance:**
  - *Coronal processes control the space weather.*
  - *SEPs and eruptive events disrupt power grids and damage satellites & affect astronauts.*
  - *Largest ever reported CME → $2 trillion loss today.*
  - *To predict space weather better.*

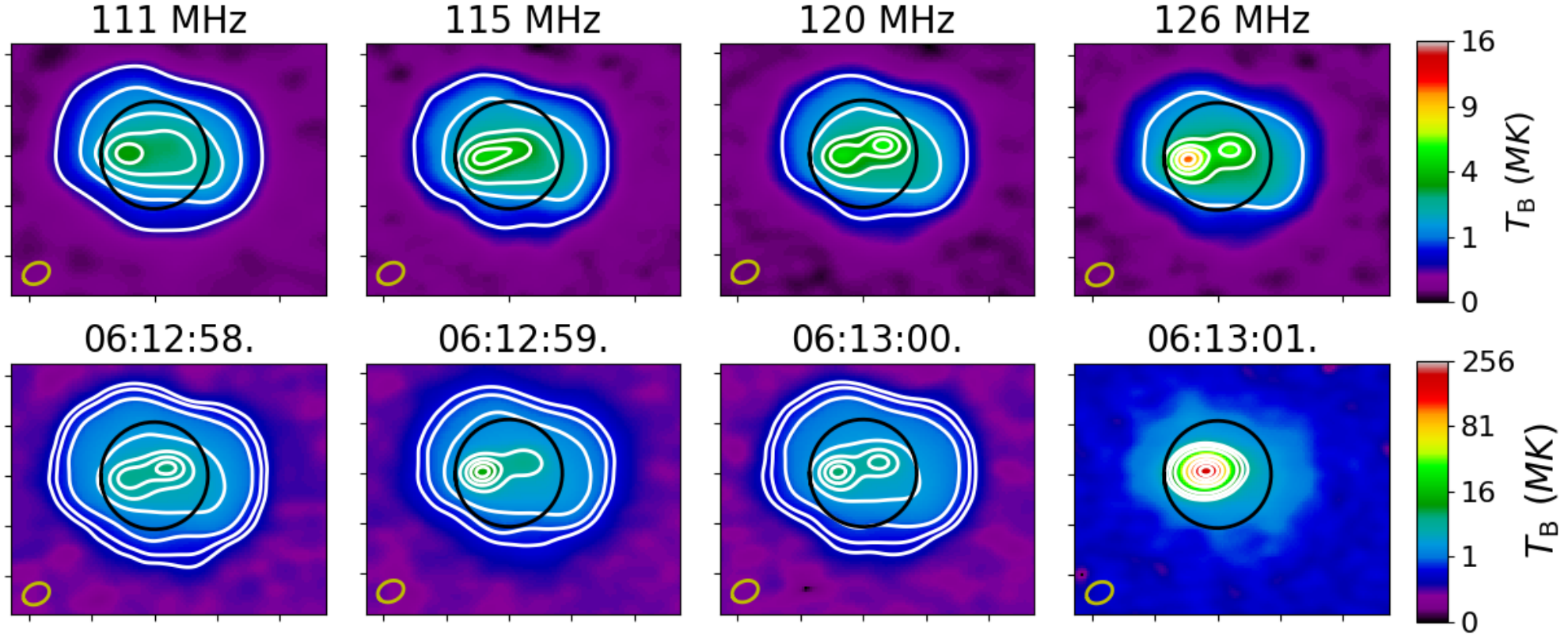
The approach

- **Multi-waveband snapshot imaging & B modelling**
  - *High energy imaging at ~ 10 s cadence → Thermal info*



Credits: SDO

Metrewave images → Non-thermal processes across 3D x & t. →



Top: 10% 30% 50% 70% 90% Bottom: 3% 5% 10% 30% 50% 70% 90%

Mohan, A. & Oberoi, D., 2017

Era of high DR snapshot spectroscopic imaging

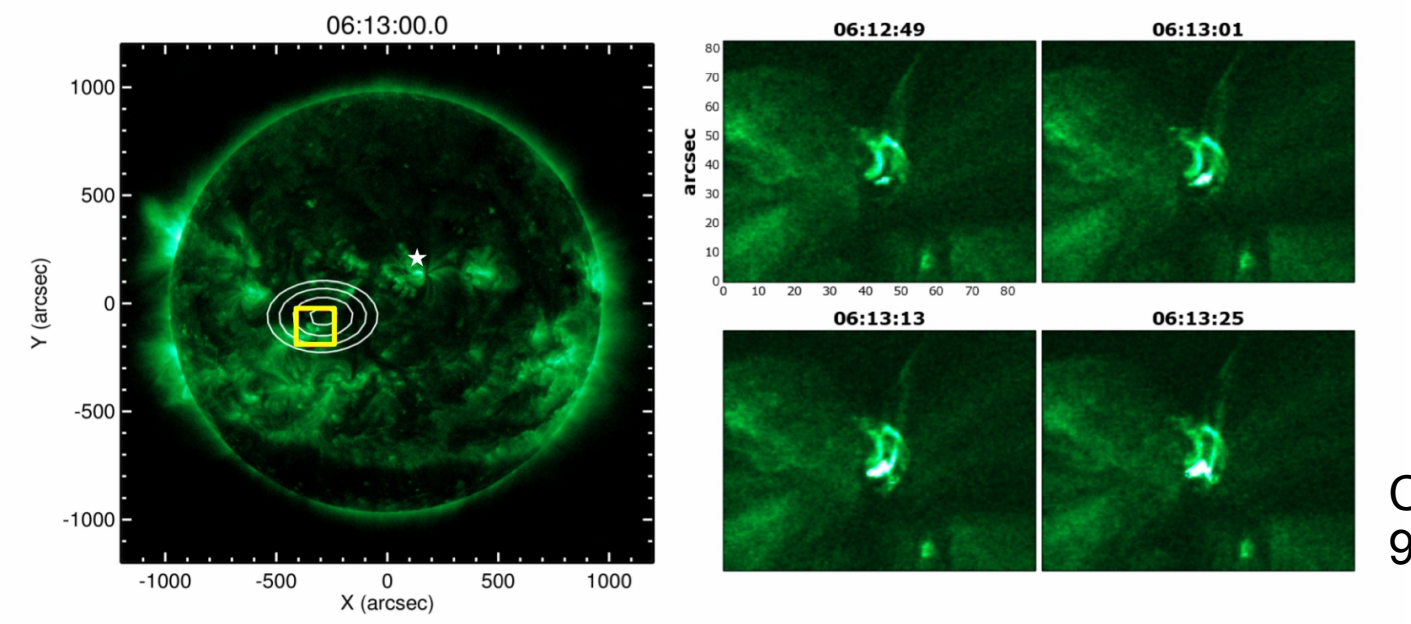
- Murchison Widefield Array (MWA) → SKA precursor
- Study fast varying processes in corona and propagation across ht.

$$\delta t \sim 1s; \delta\nu \sim 10kHz$$

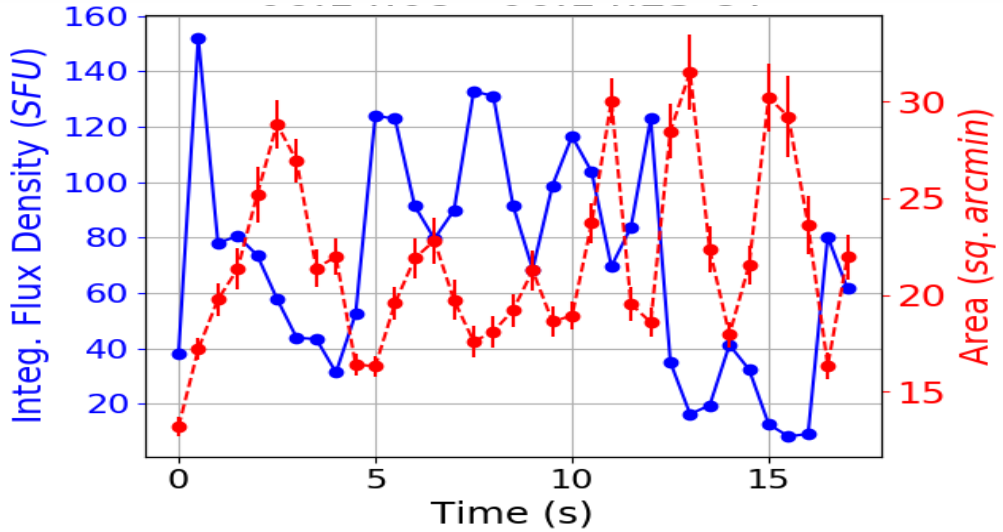
- DR → ~ 10^3 – 10^5
  - Continuous tracking of particle accl. & other non-thermal events.
  - Study simultaneous strong events.
  - Track eruptive events like CMEs with faint emission.
  - Quiet solar corona emissivity.
  - Explore coronal heating & particle accl. events better.

A few case studies

- **Discovery of fast QPOs in radio burst sources.**



Contours: 60, 80, 90, 95 & 98 % peak



- ~s scale QPOs in area anti-phased with flux density

Mohan, A. et al., 2019

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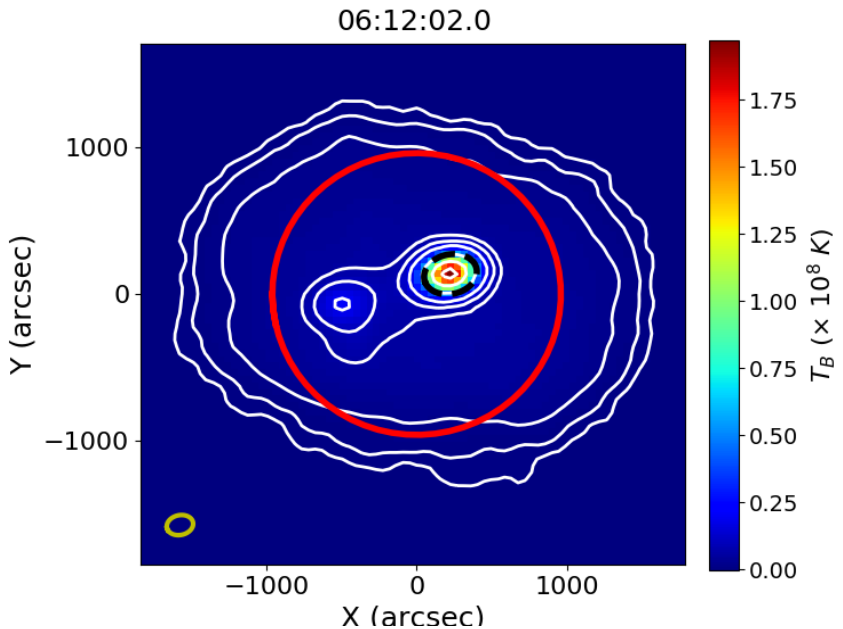
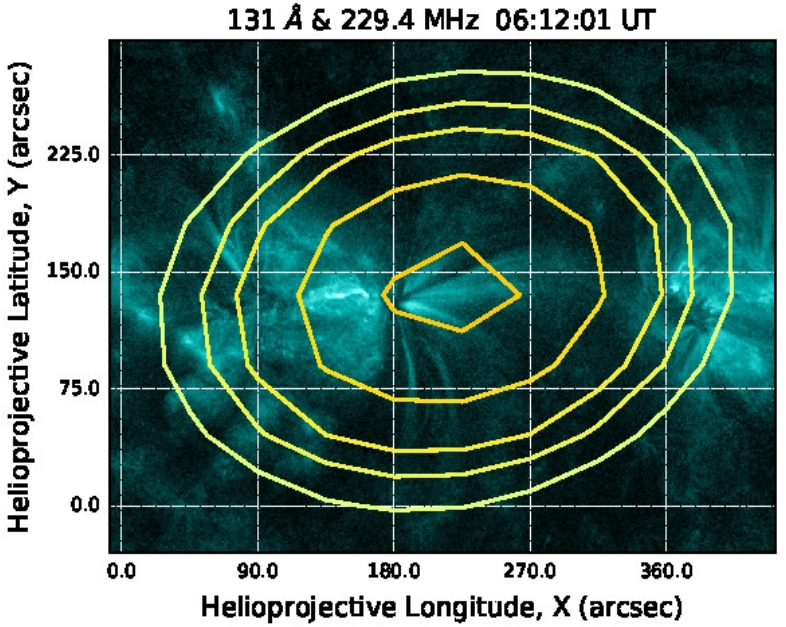
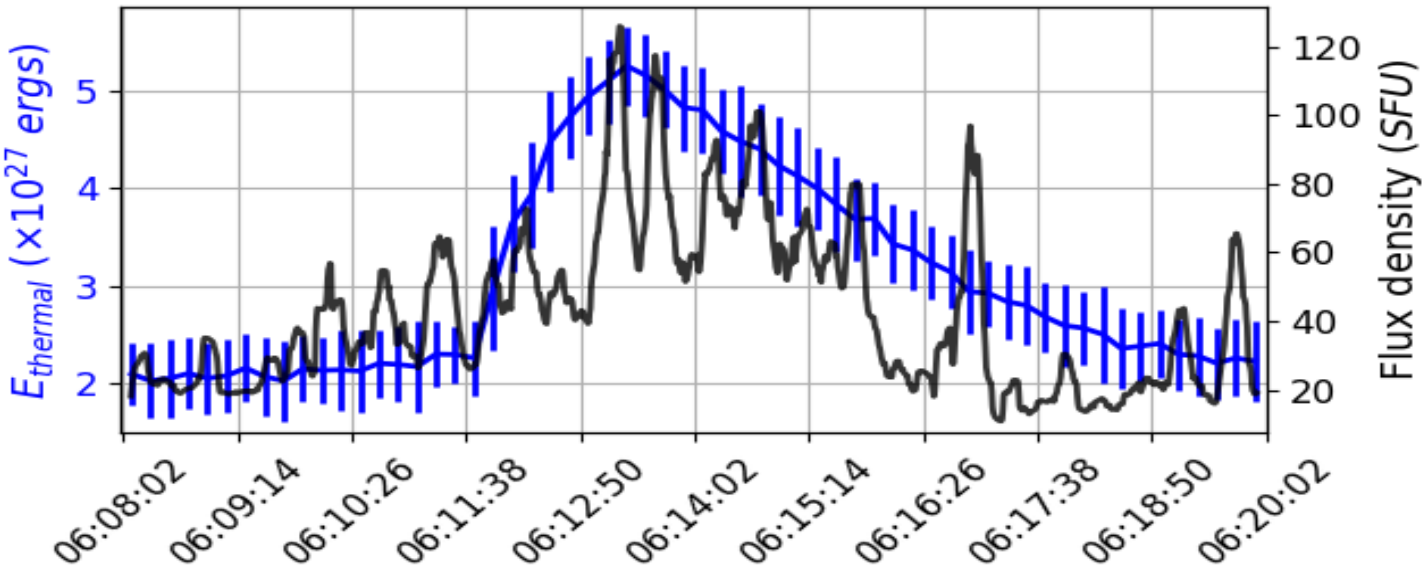
QP particle acceleration episodes → local coronal heating

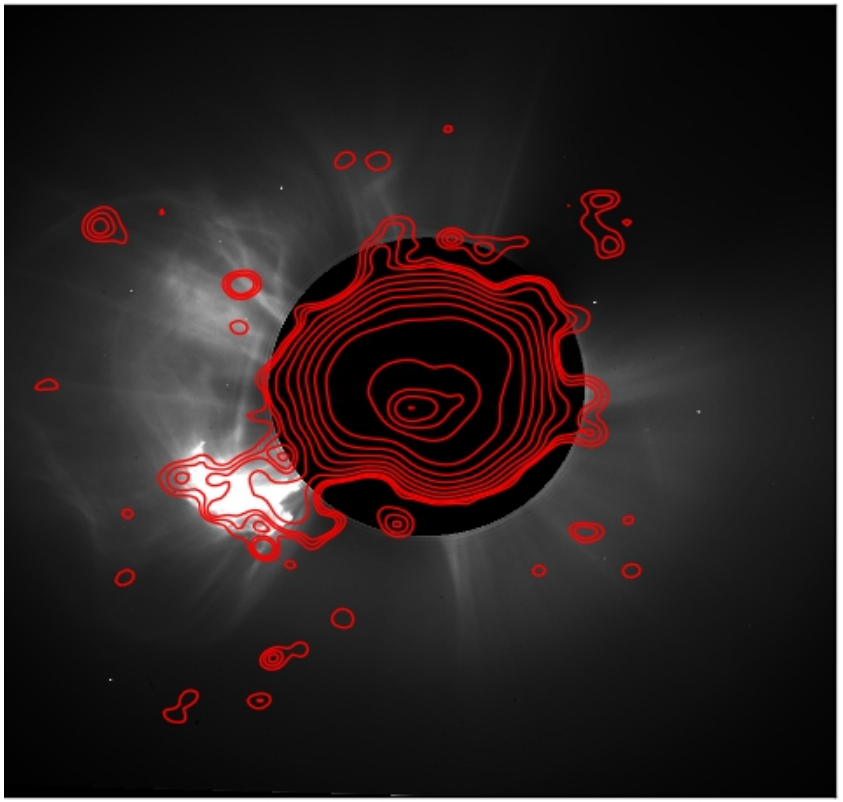


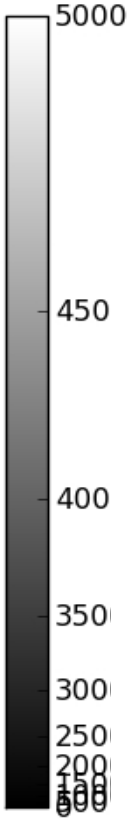


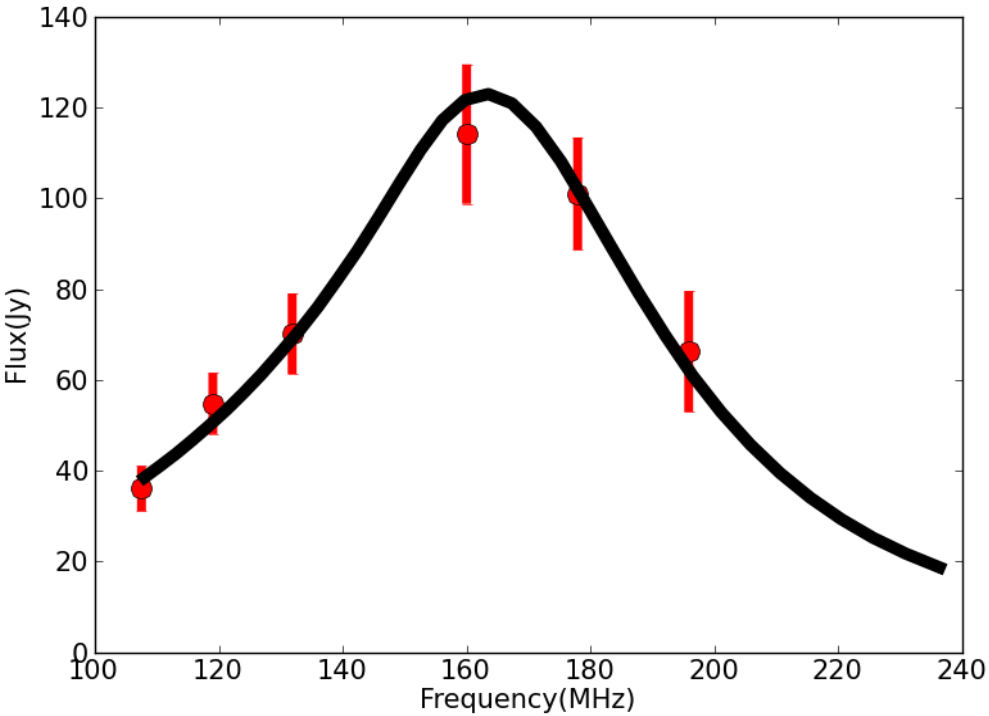


Mohan, A. et al., 2019

Radio CME







Thank You

Mondal, S. et al., in prep