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REMOTE SENSING THE CORONAL MAGNETIC FIELD USING SOLAR S-BURSTS

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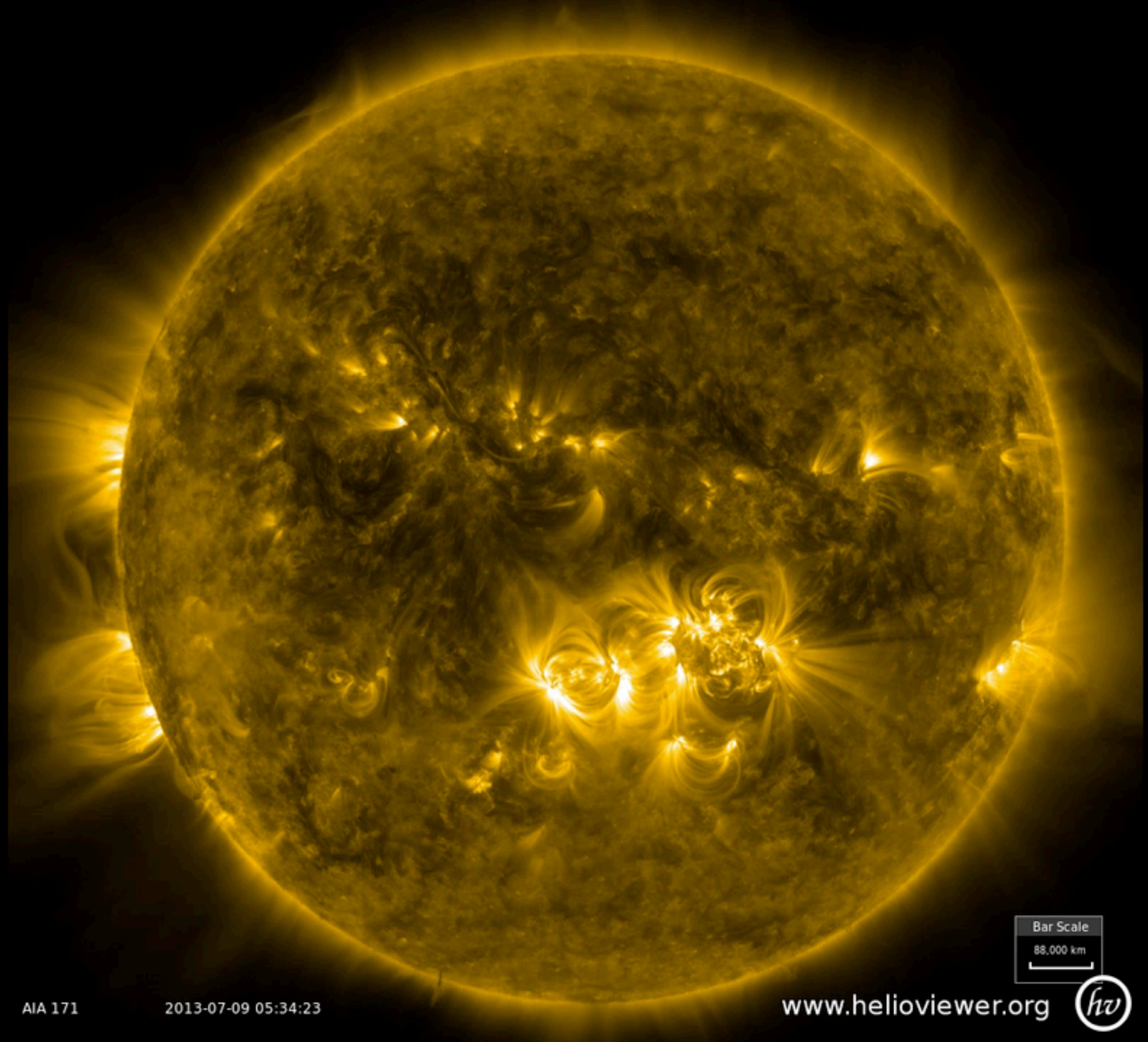
OUTLINE

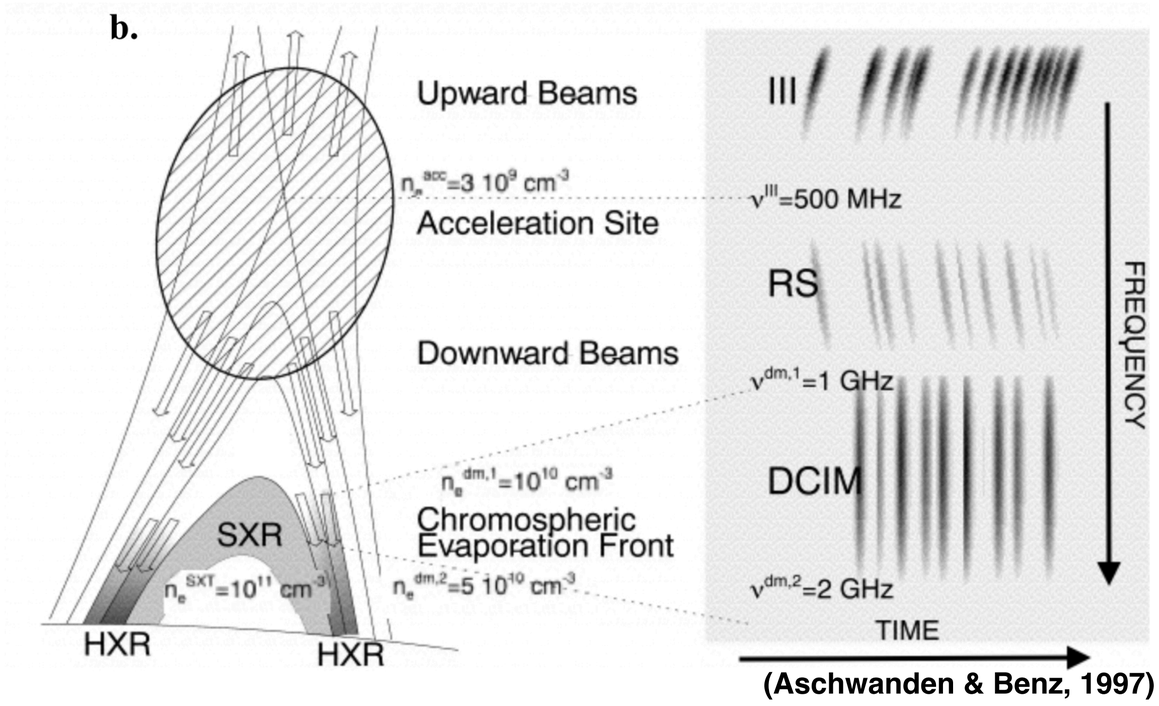
1. Solar radio emission and Solar Radio Bursts
2. Solar S-bursts
3. Motivation
4. Results
5. Conclusions


Bar Scale
88,000 km
AIA 171
2013-07-09 05:34:23
www.helioviewer.org

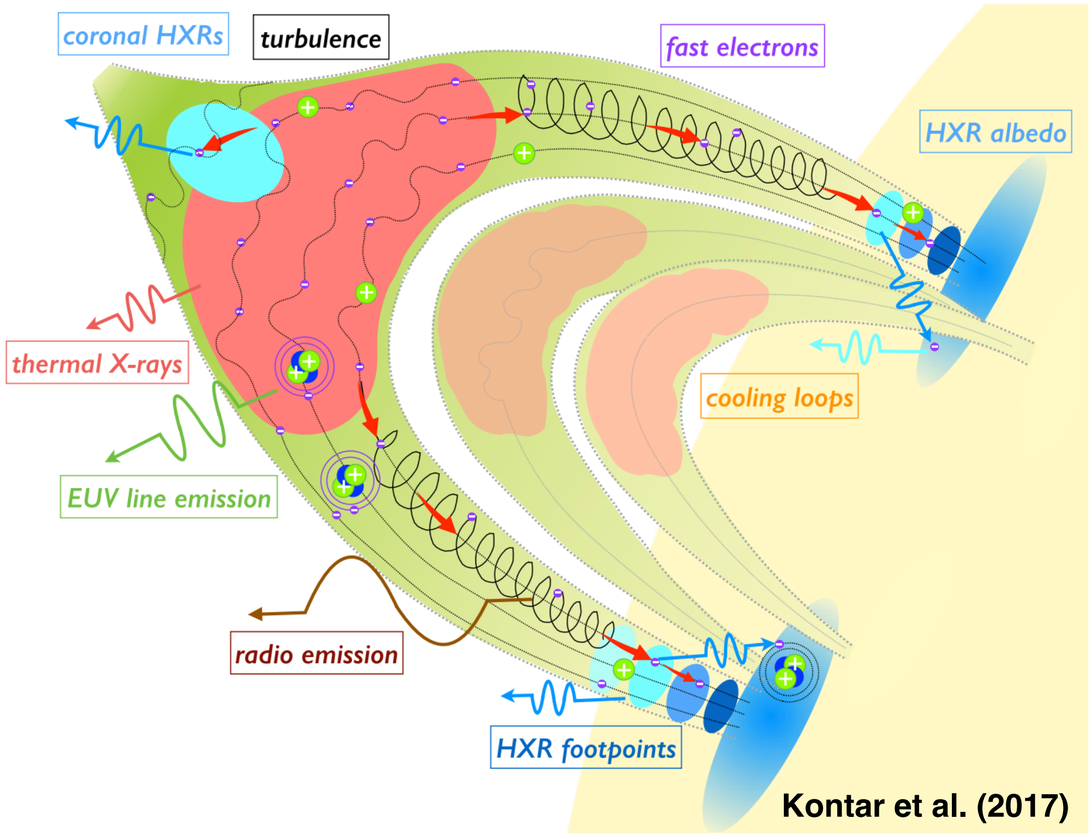
SOLAR RADIO EMISSION

Active regions are also associated with radio emission:

1. Gyrosynchrotron
2. Plasma Emission - $f_p \approx 9000\sqrt{N_e}$

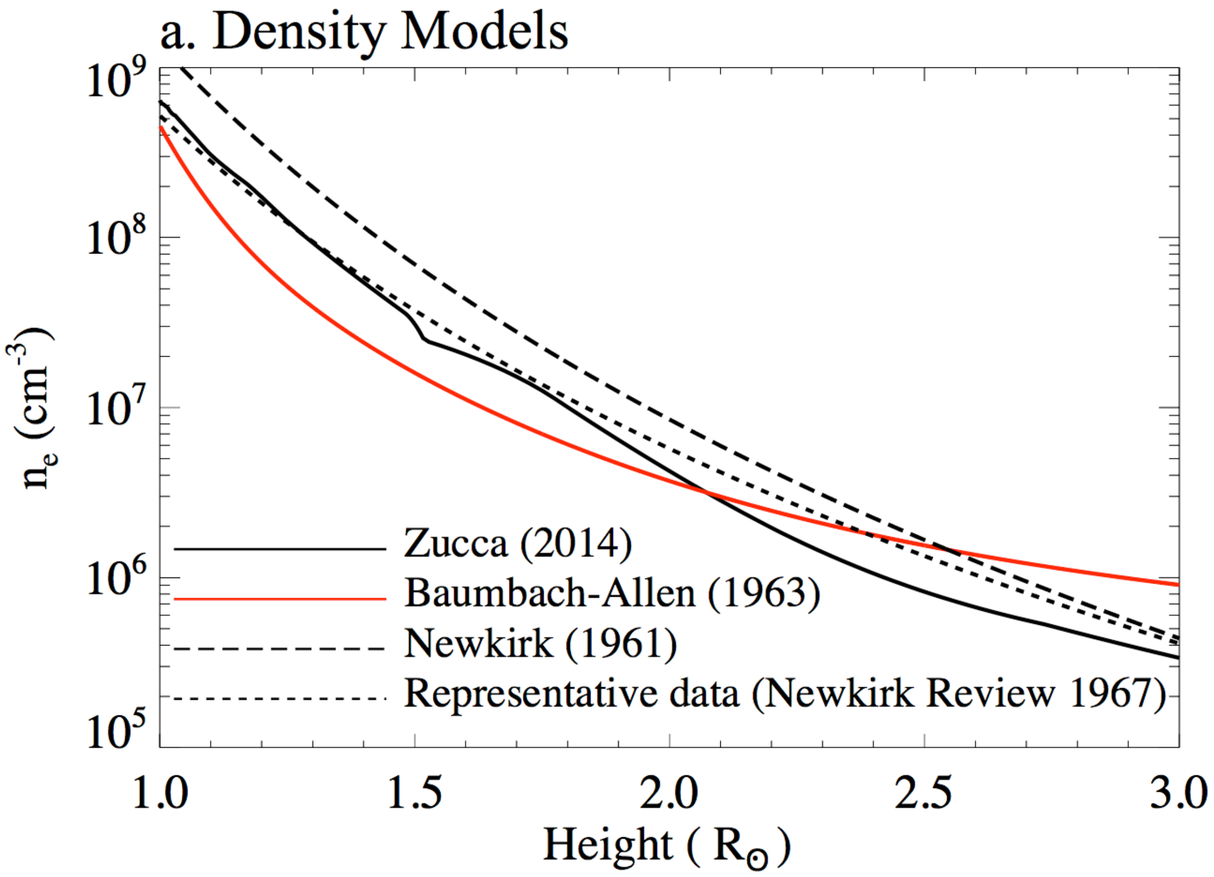


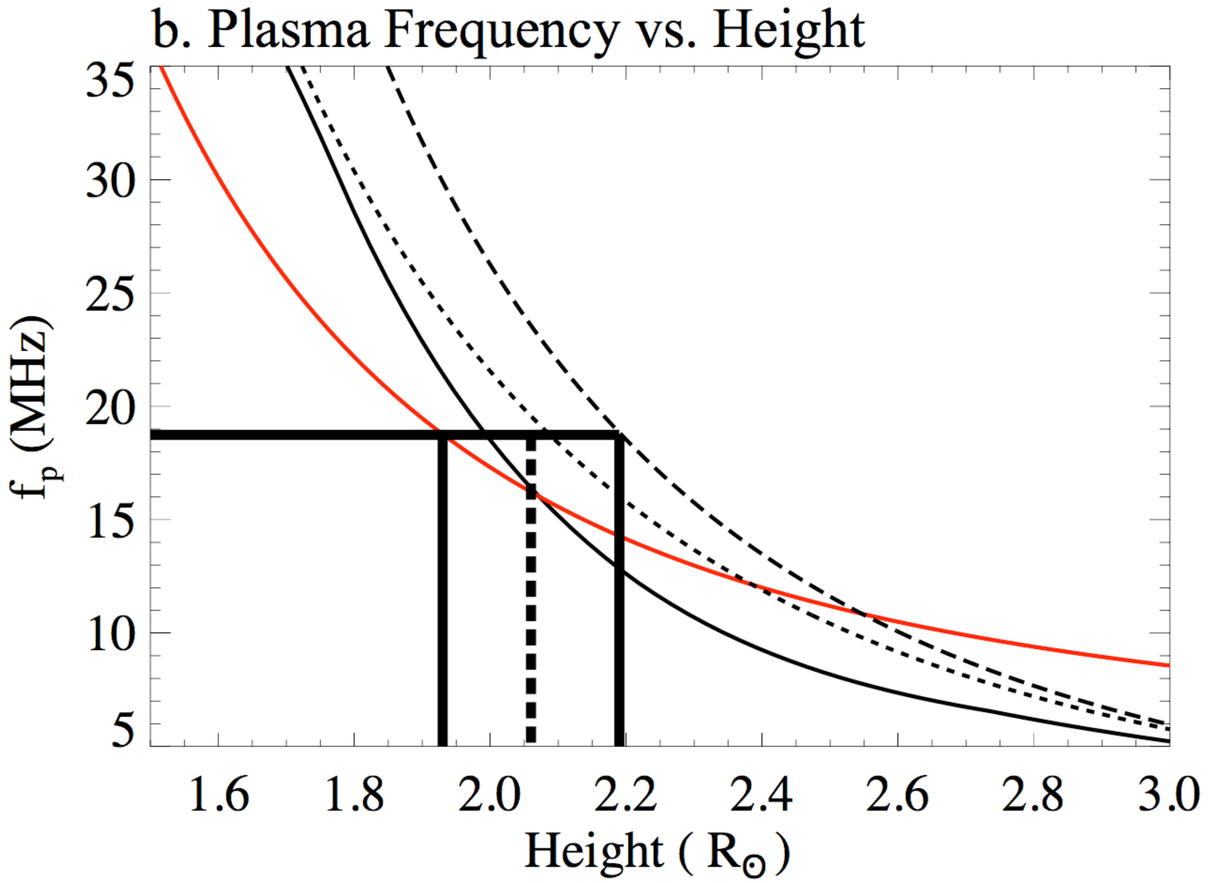
(Aschwanden & Benz, 1997)



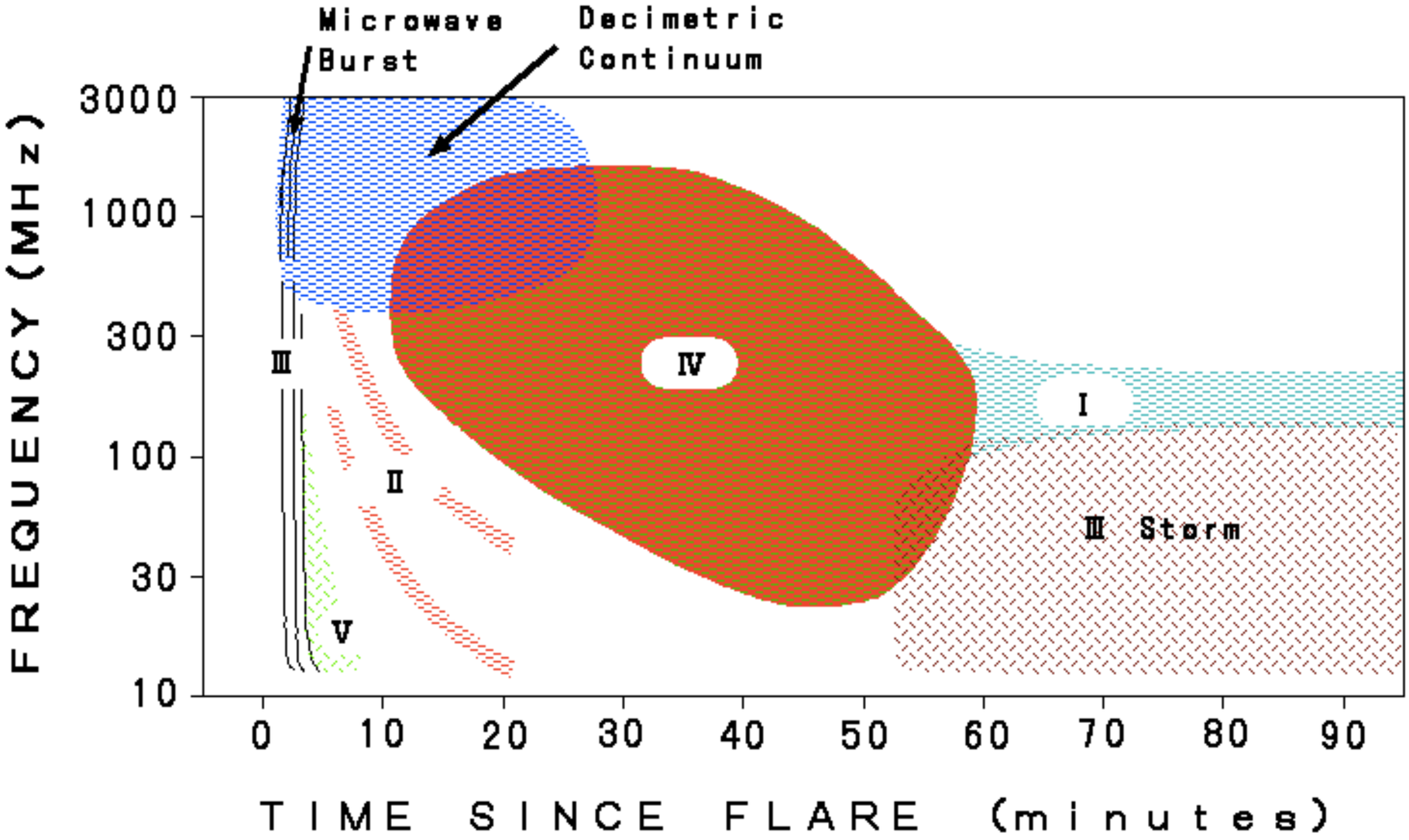
Kontar et al. (2017)

EMISSION AT THE PLASMA FREQUENCY





SOLAR RADIO BURSTS



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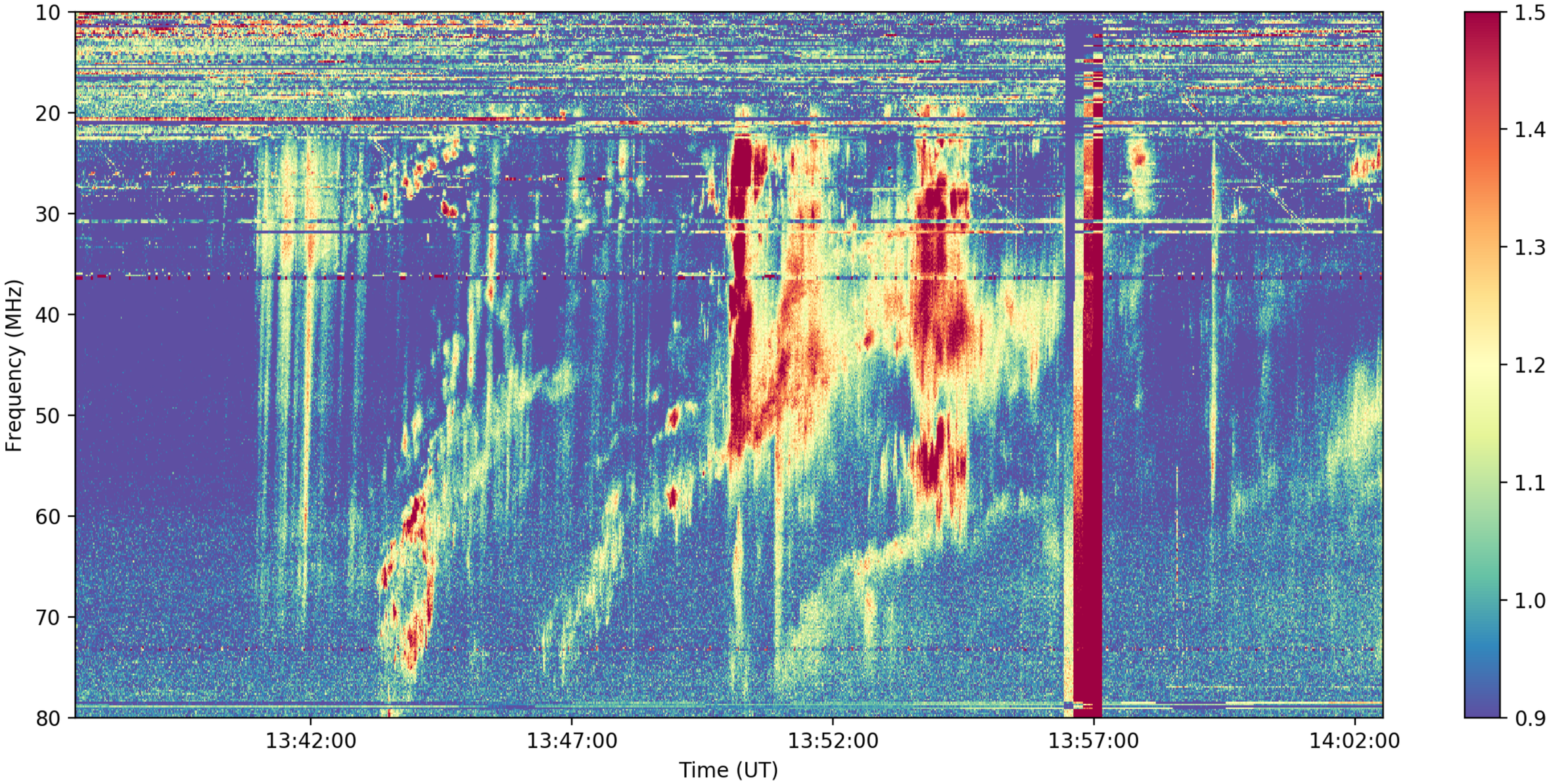
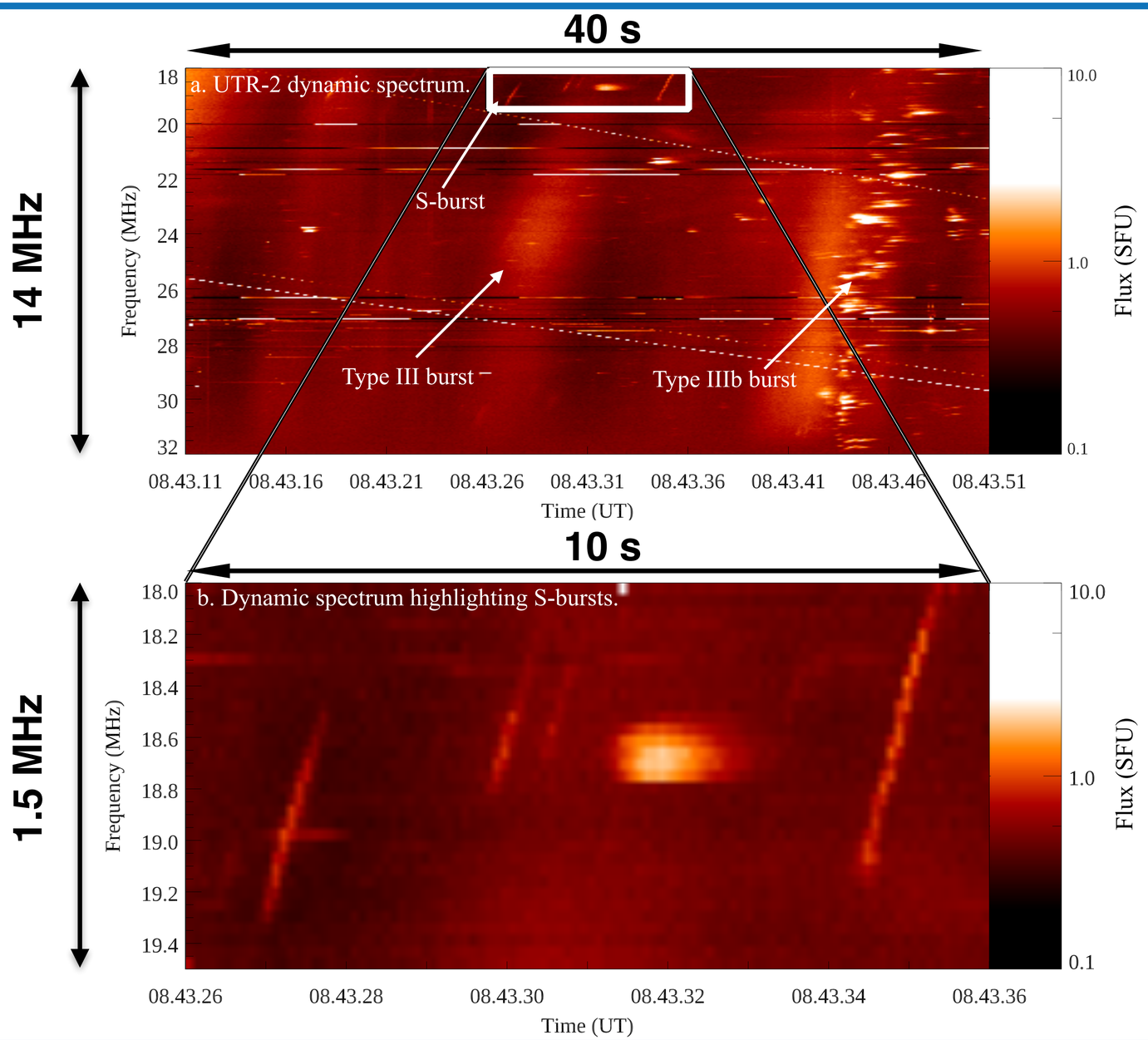


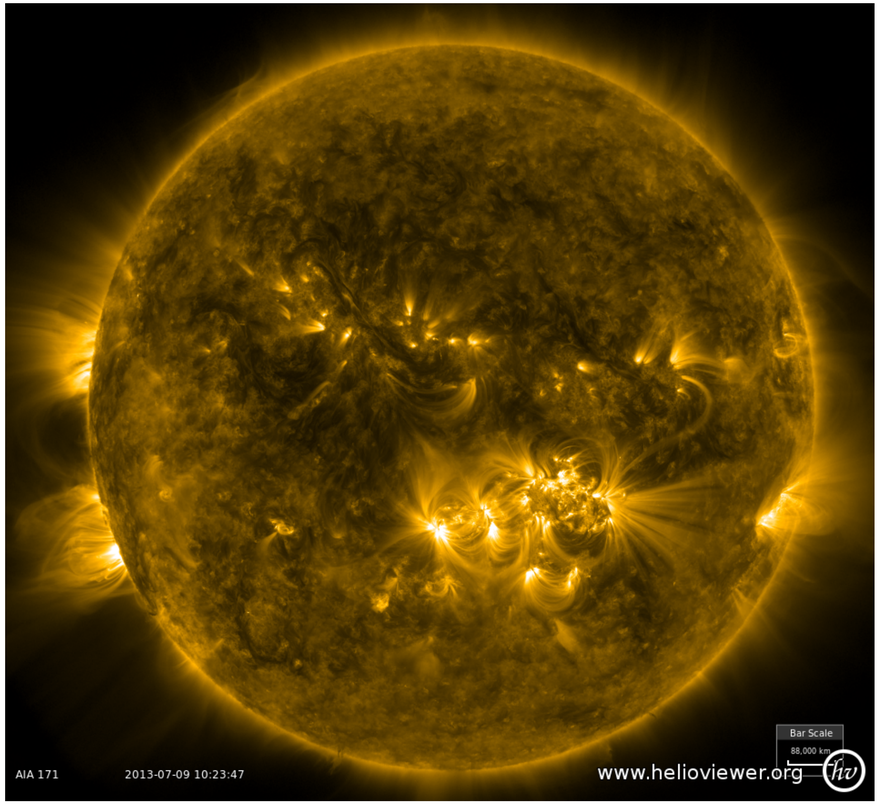
SOLAR S-BURSTS

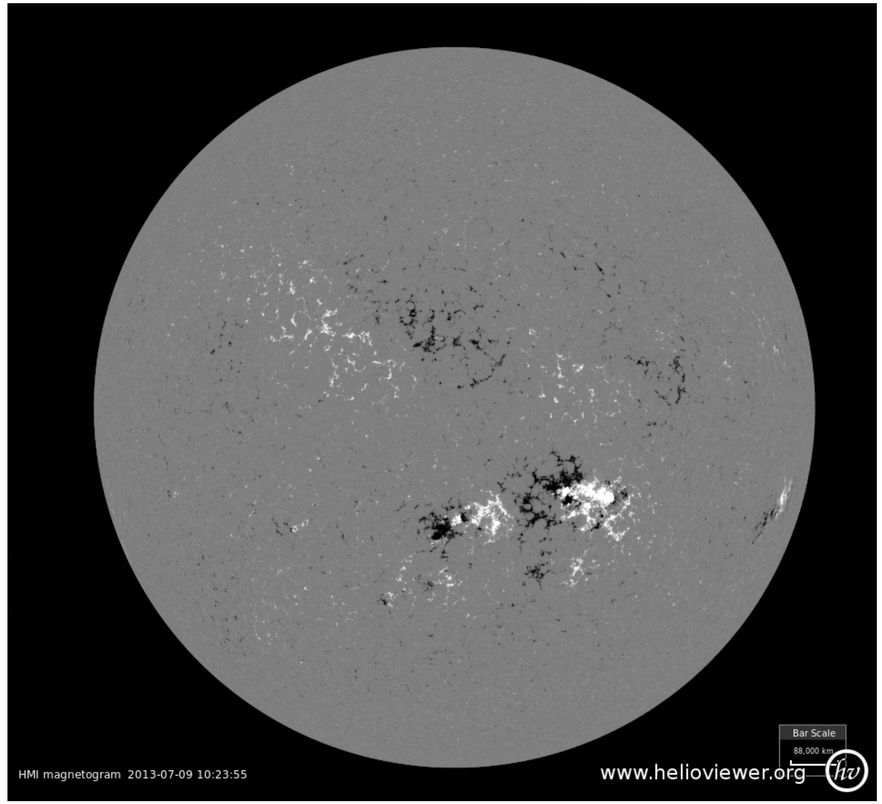


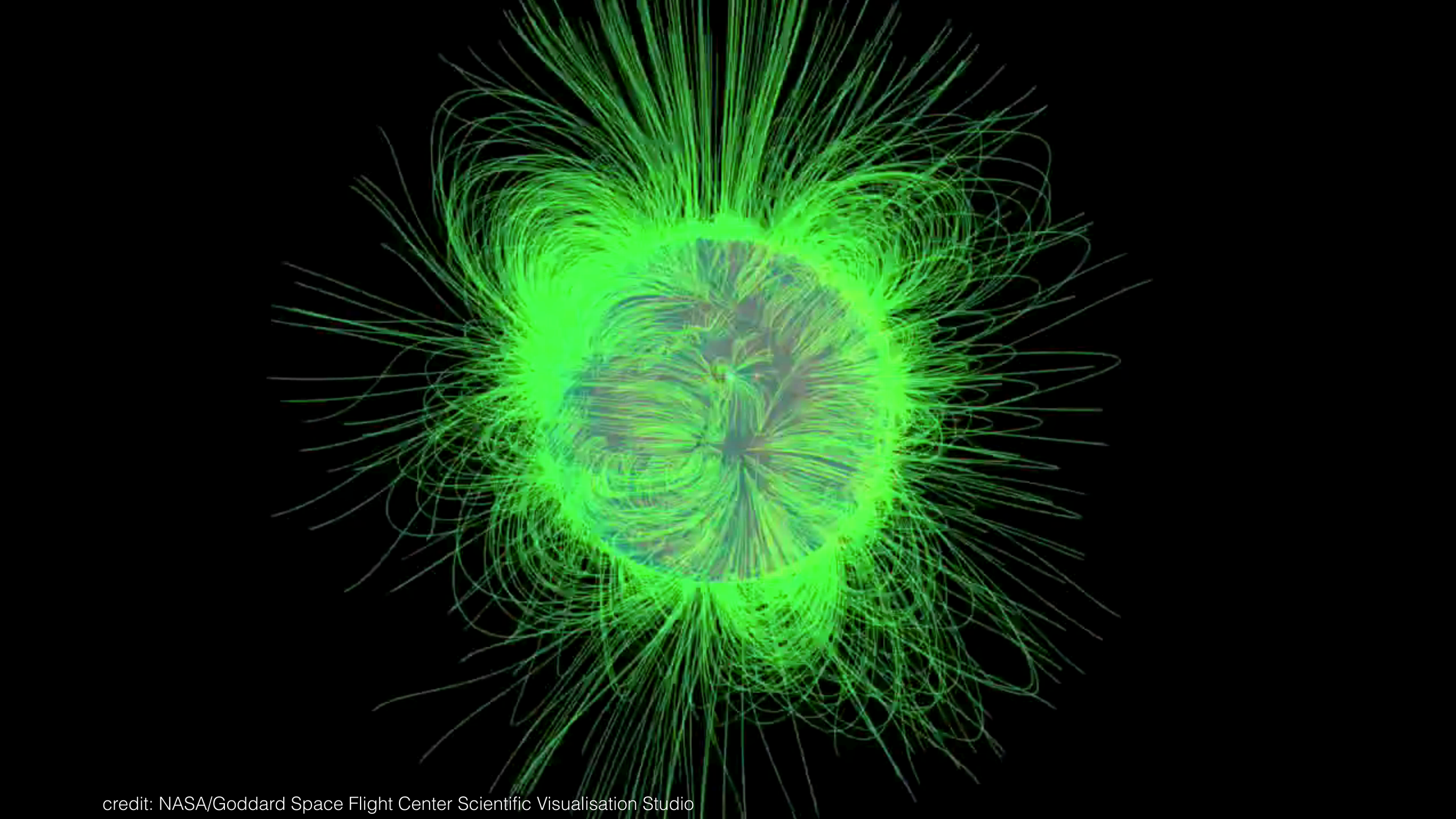
MOTIVATION

- A full understanding of solar radio emission is essential in order to work towards a complete model of solar energy release and flares.

- Investigate whether S-bursts can provide a potential diagnostic of the coronal plasma - e.g magnetic field strength.







credit: NASA/Goddard Space Flight Center Scientific Visualisation Studio

SCIENCE QUESTIONS

- What are the spectral properties of S-bursts?
- Do these observed properties align with any existing models?
- Can we extract information about the coronal plasma via observations of S-bursts?

INSTRUMENTATION

a. UTR-2

UTR-2

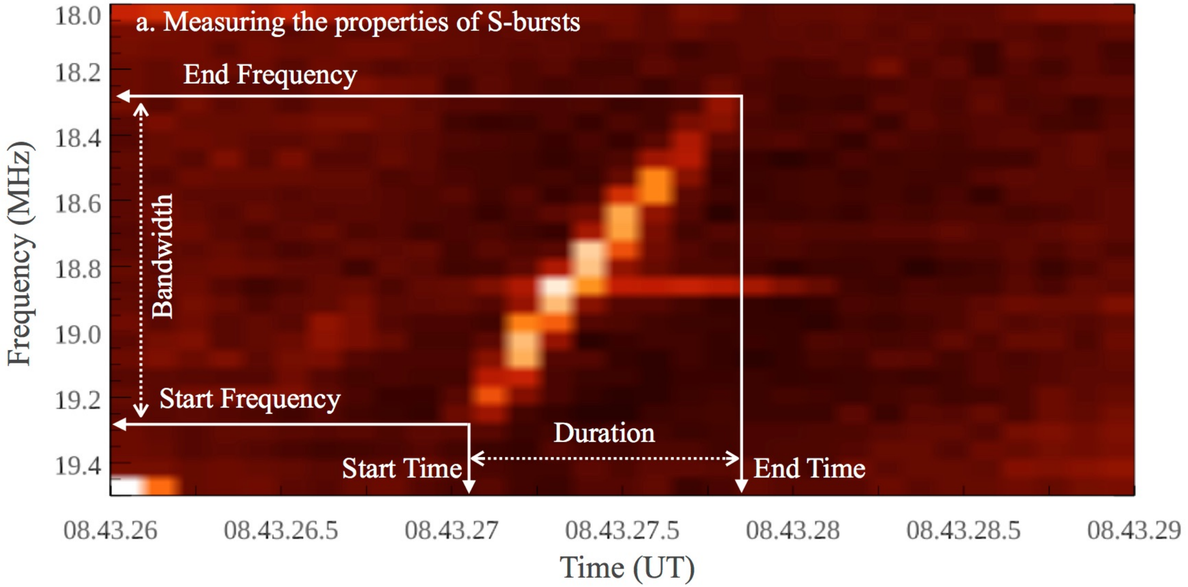
- Frequency Range: 8-32 MHz
- Time Resolution: 100 ms
- 2040 array elements (dipoles)
- Frequency resolution (4 kHz)
- Sensitivity ≥ 10 Jy

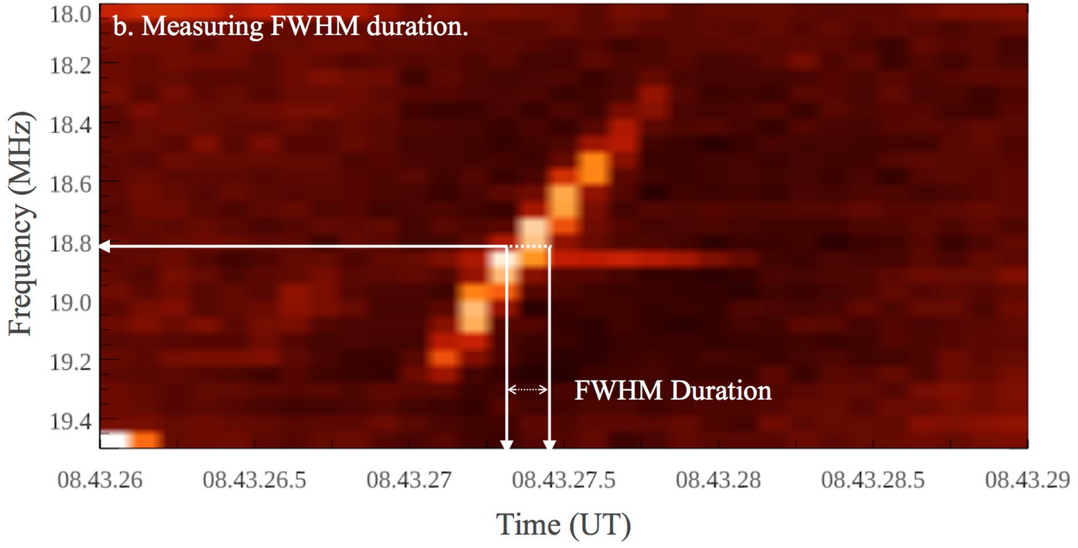
b. LOFAR

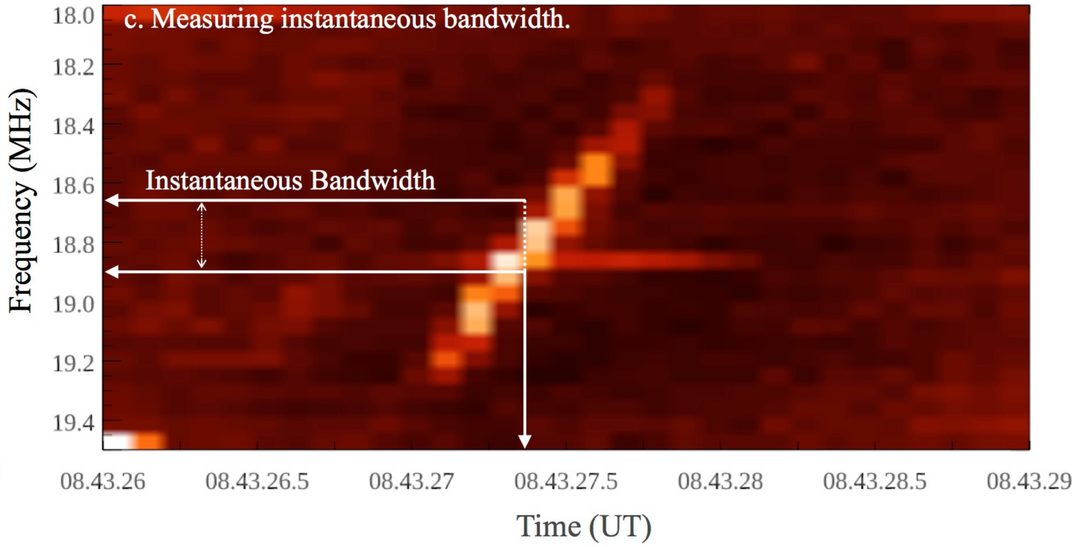
LOFAR

- Frequency Range: 10-90 MHz (LBAs)
- Time Resolution: 10 ms
- 7000 antennas (time of observations)
- Frequency resolution (12.5 kHz)
- Sensitivity ≥ 2.5 Jy

SPECTRAL PROPERTIES OF S-BURSTS







EMISSION MECHANISM UNDER INVESTIGATION

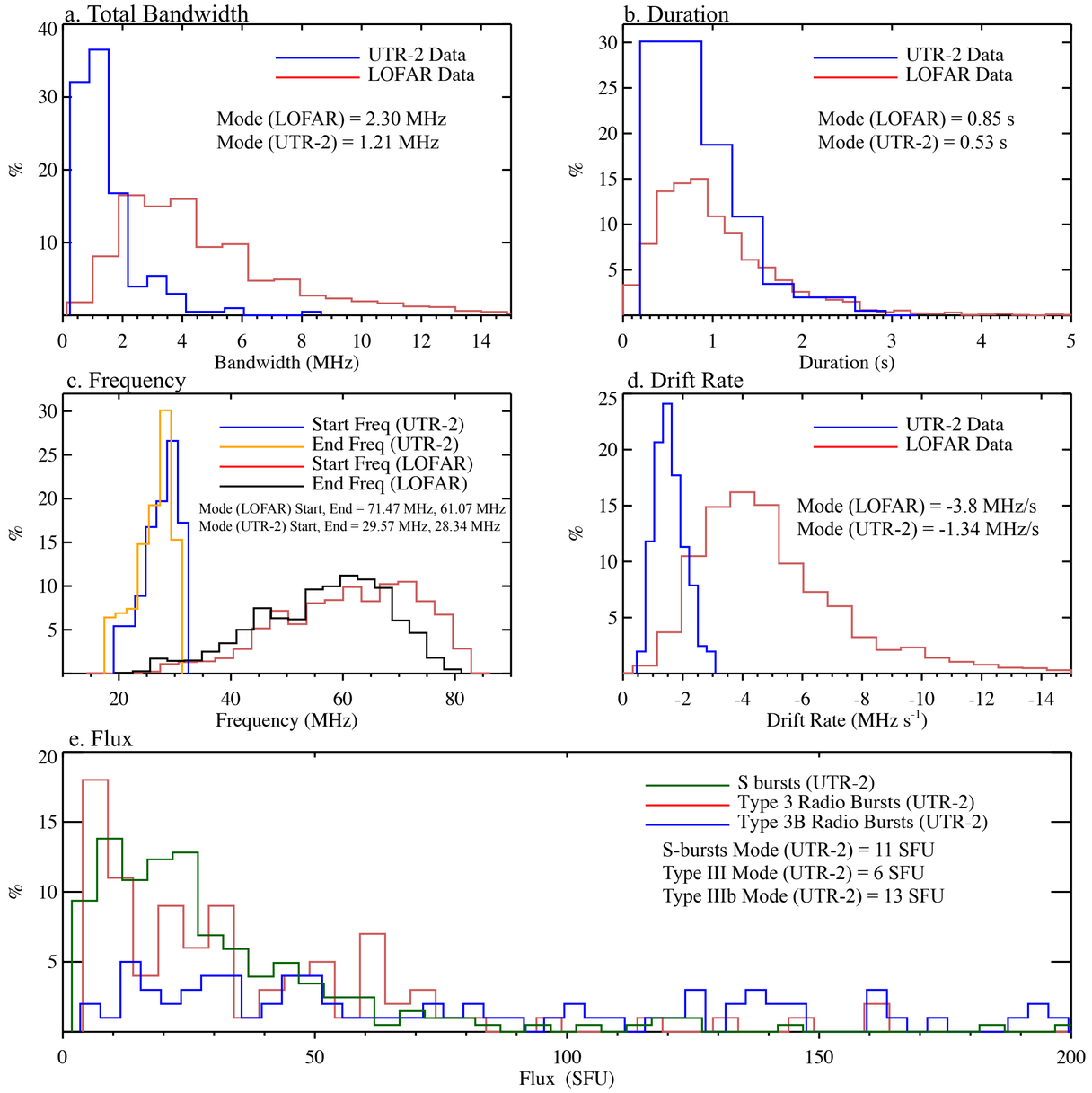
Melnik et al. (2010) model

1. Assumes S-bursts display long lasting sabre shaped features.
2. Assumes frequency is linearly proportional to instantaneous bandwidth.
3. Assumes dynamic source with a specific drift rate.
4. Assumes S-burst are generated in a turbulent environment.

$$B = \frac{\sqrt{8\pi m_e}}{e} f \sqrt{\frac{\Delta f}{f}} \frac{1}{sin\theta}$$

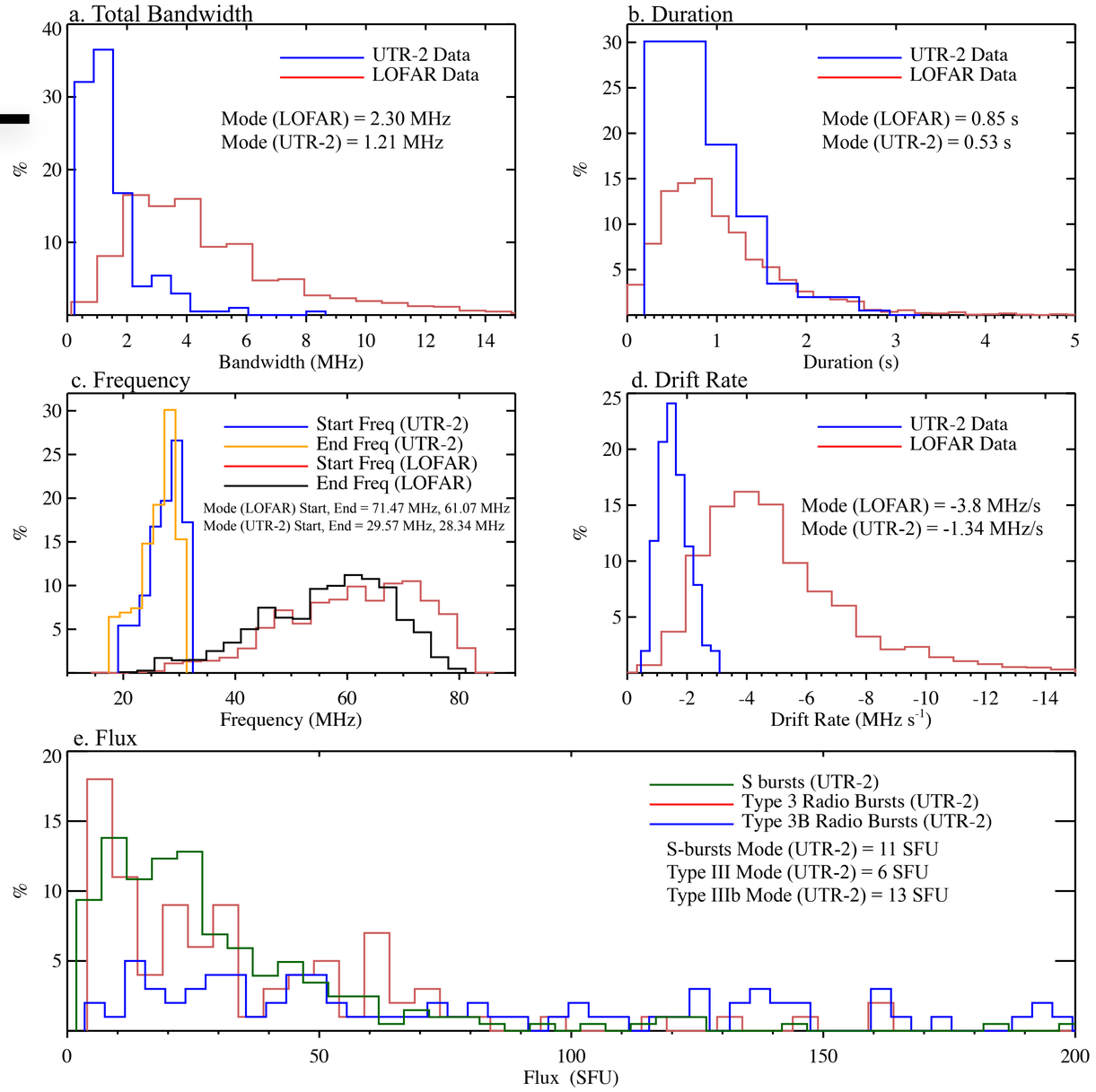
$$v_s = \frac{eB}{m_e} \frac{1}{4\pi f} c$$

RESULTS


a. Total Bandwidth
UTR-2 Data
LOFAR Data
Mode (LOFAR) = 2.30 MHz
Mode (UTR-2) = 1.21 MHz
%
Bandwidth (MHz)
b. Duration
UTR-2 Data
LOFAR Data
Mode (LOFAR) = 0.85 s
Mode (UTR-2) = 0.53 s
%
Duration (s)
c. Frequency
Start Freq (UTR-2)
End Freq (UTR-2)
Start Freq (LOFAR)
End Freq (LOFAR)
Mode (LOFAR) Start, End = 71.47 MHz, 61.07 MHz
Mode (UTR-2) Start, End = 29.57 MHz, 28.34 MHz
%
Frequency (MHz)
d. Drift Rate
UTR-2 Data
LOFAR Data
Mode (LOFAR) = -3.8 MHz/s
Mode (UTR-2) = -1.34 MHz/s
%
Drift Rate (MHz s-1)
e. Flux
S bursts (UTR-2)
Type 3 Radio Bursts (UTR-2)
Type 3B Radio Bursts (UTR-2)
S-bursts Mode (UTR-2) = 11 SFU
Type III Mode (UTR-2) = 6 SFU
Type IIIb Mode (UTR-2) = 13 SFU
%
Flux (SFU)

RESULTS

Wide range of total bandwidths.



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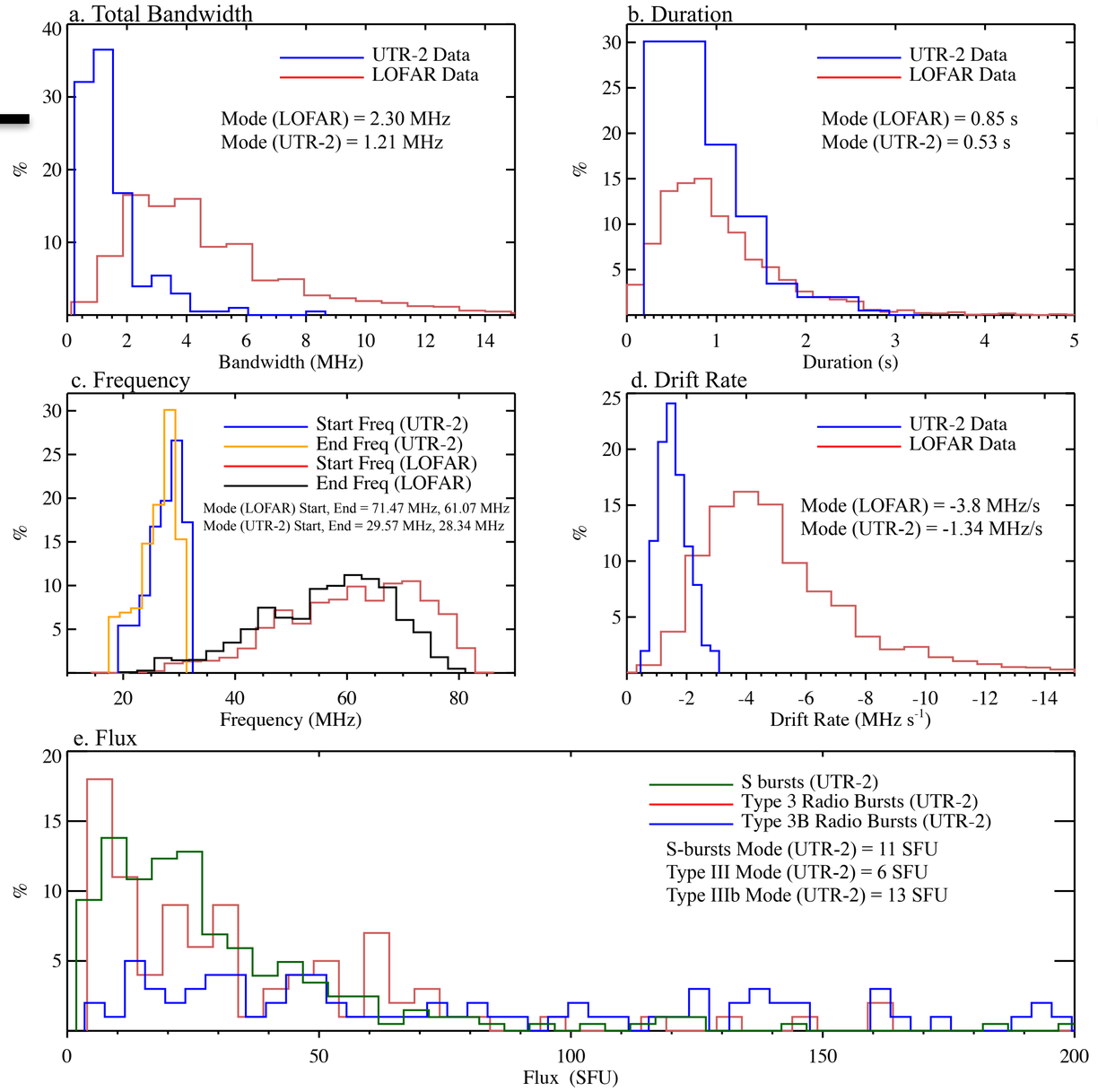
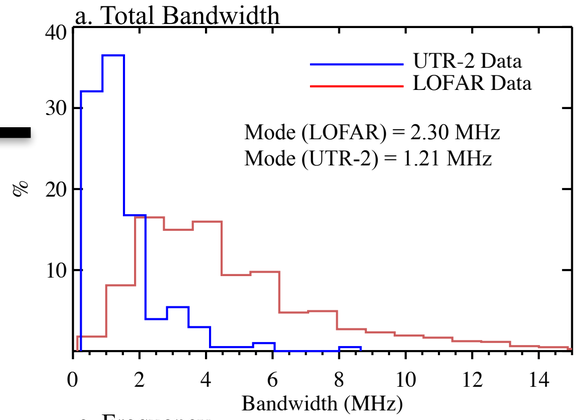
Wide range of total bandwidths.

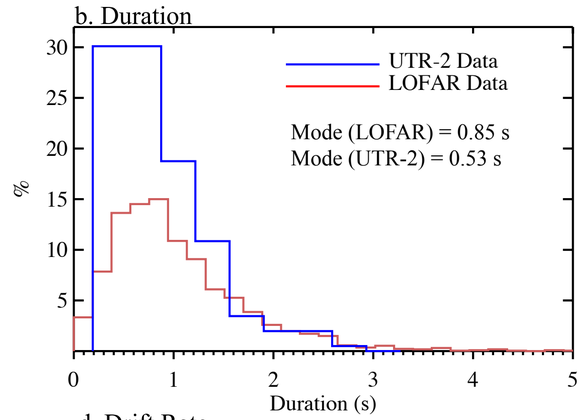


Durations < 1s.

RESULTS

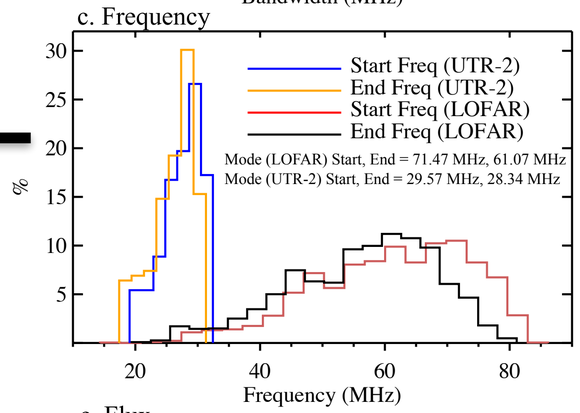
Wide range of total bandwidths.

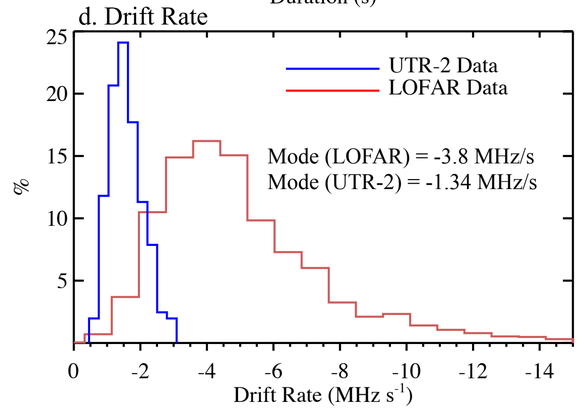


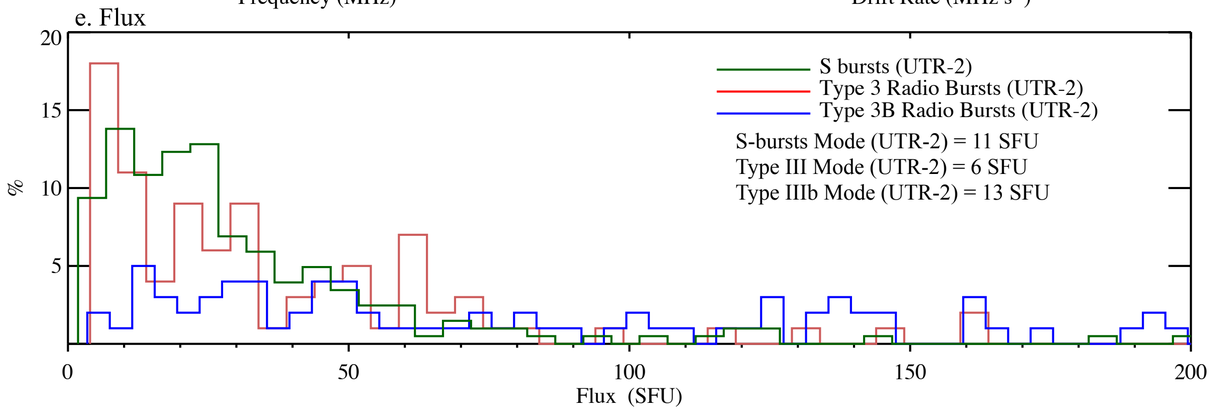


Durations < 1s.

Increase in number with increasing frequency .

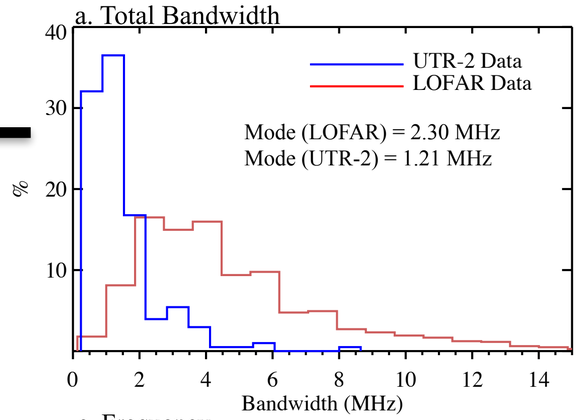


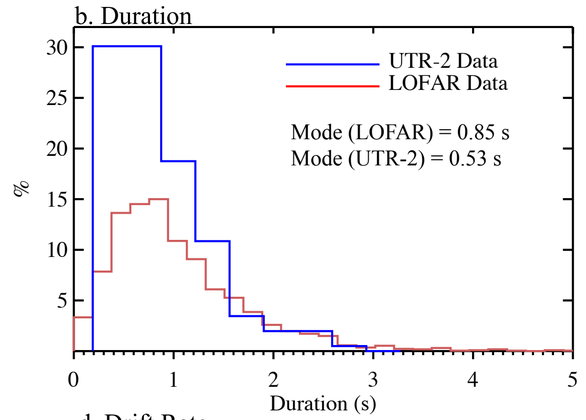




RESULTS

Wide range of total bandwidths.





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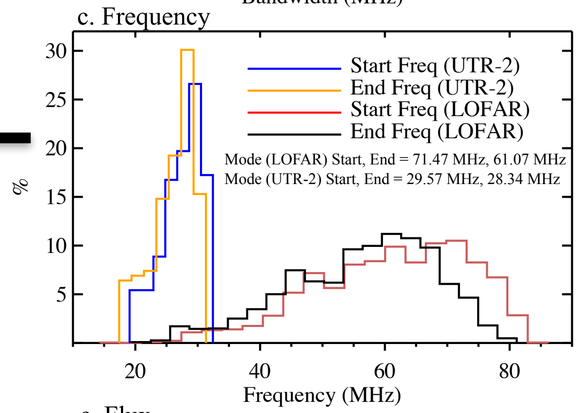
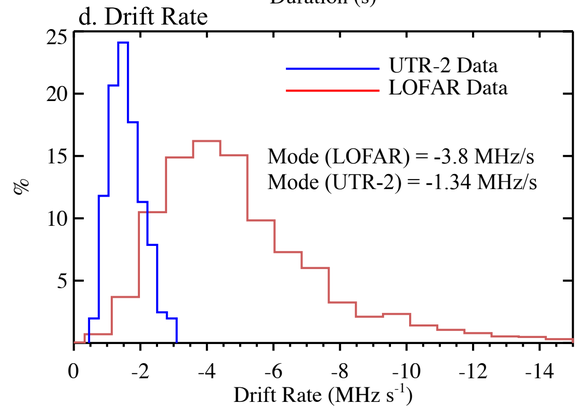
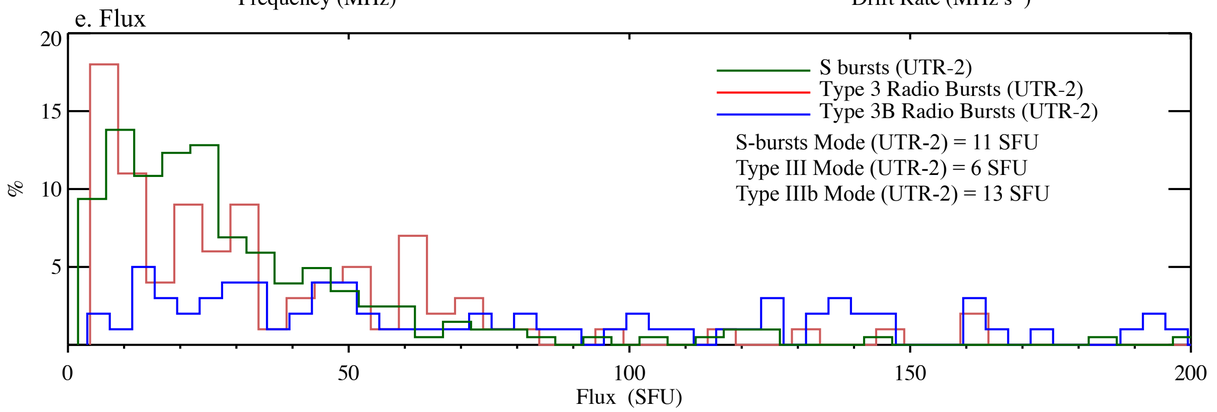


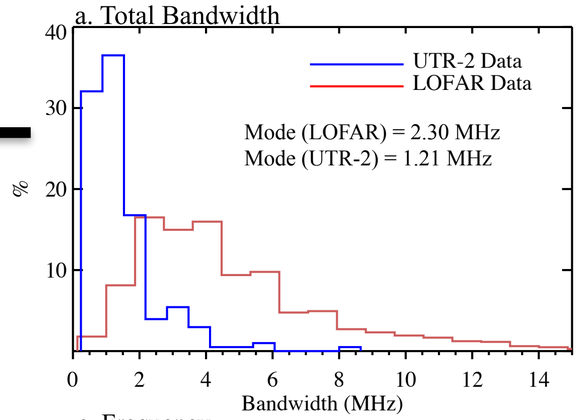


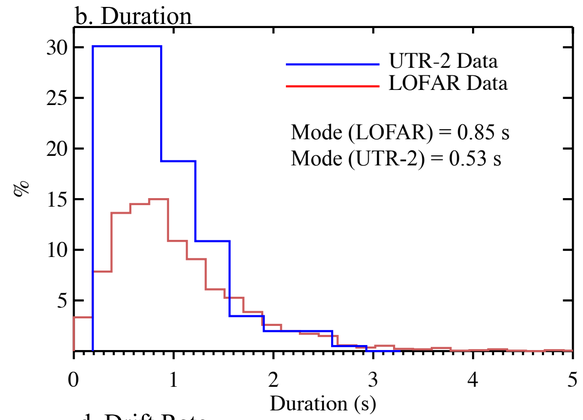
Negative drift rates.



RESULTS

Wide range of total bandwidths.





Durations < 1s.

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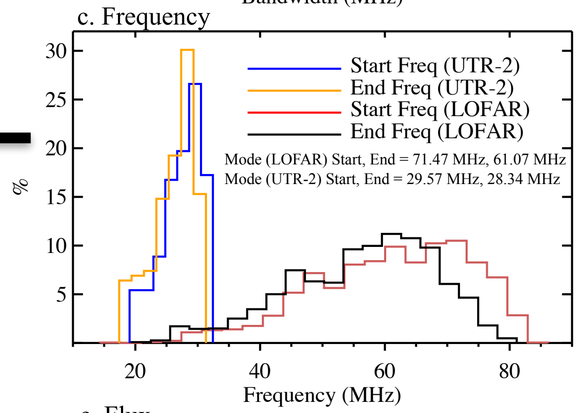
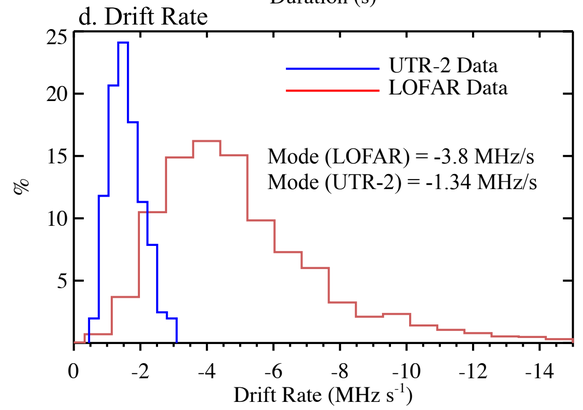
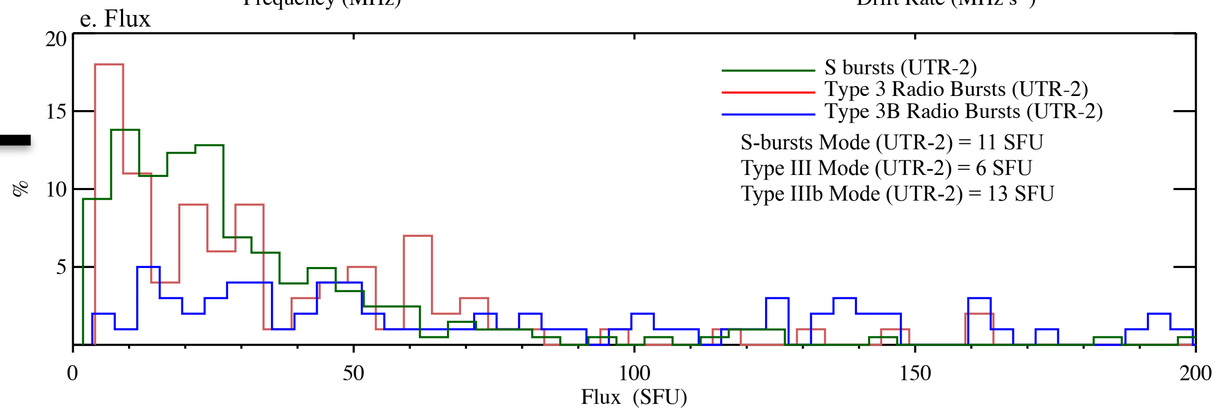


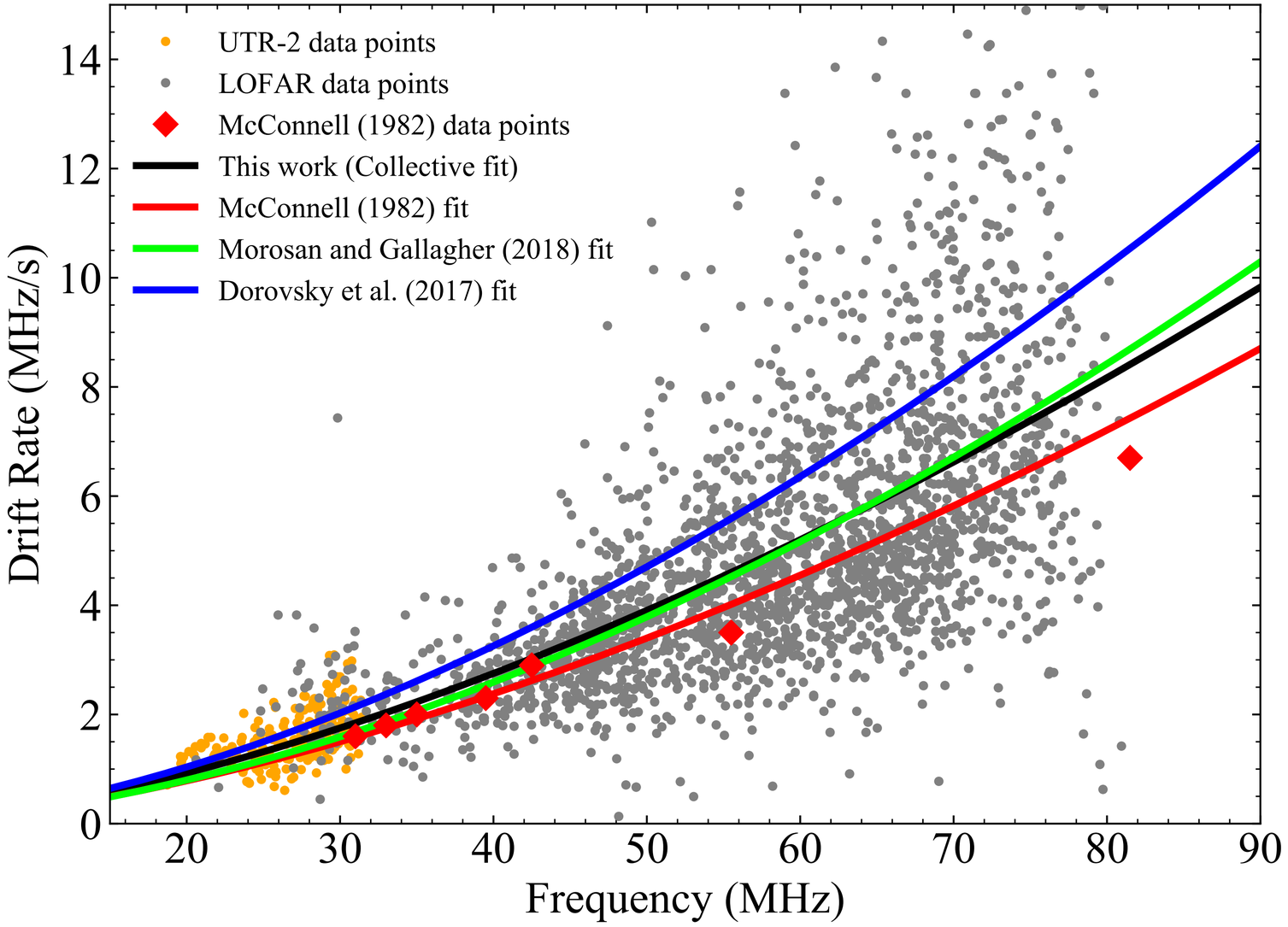


Negative drift rates.

Low flux values.



DRIFT RATE


UTR-2 data points
LOFAR data points
McConnell (1982) data points
This work (Collective fit)
McConnell (1982) fit
Morosan and Gallagher (2018) fit
Dorovsky et al. (2017) fit
Drift Rate (MHz/s)
Frequency (MHz)
0
2
4
6
8
10
12
14
20
30
40
50
60
70
80
90

DO THESE RESULTS SUPPORT ANY MODEL?

Melnik et al. (2010) Model

1. Assumes long lasting sabre shaped features.
2. Assume frequency is linearly proportional to instantaneous bandwidth.
3. Assumes dynamic source with a specific drift rate.
4. Assumes S-bursts are generated in a turbulent environment.

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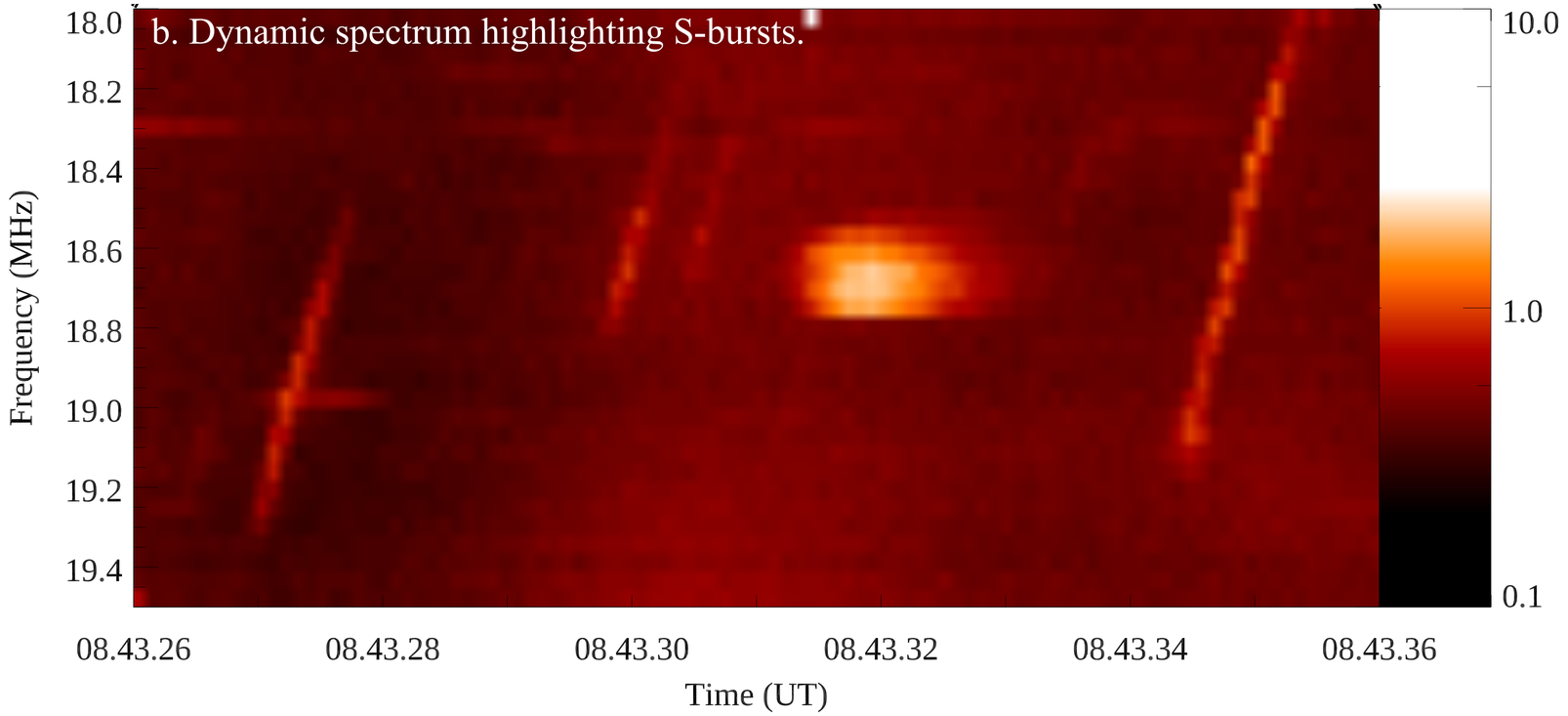

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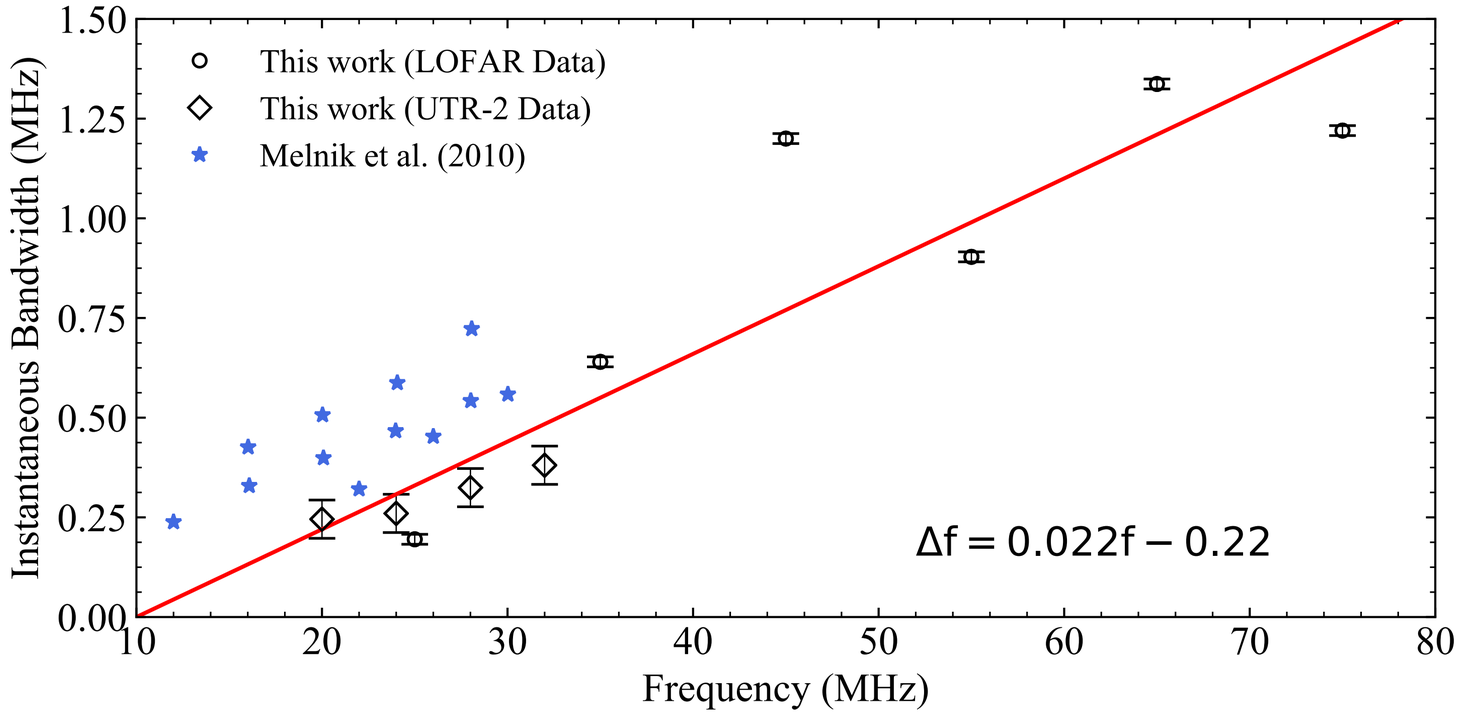

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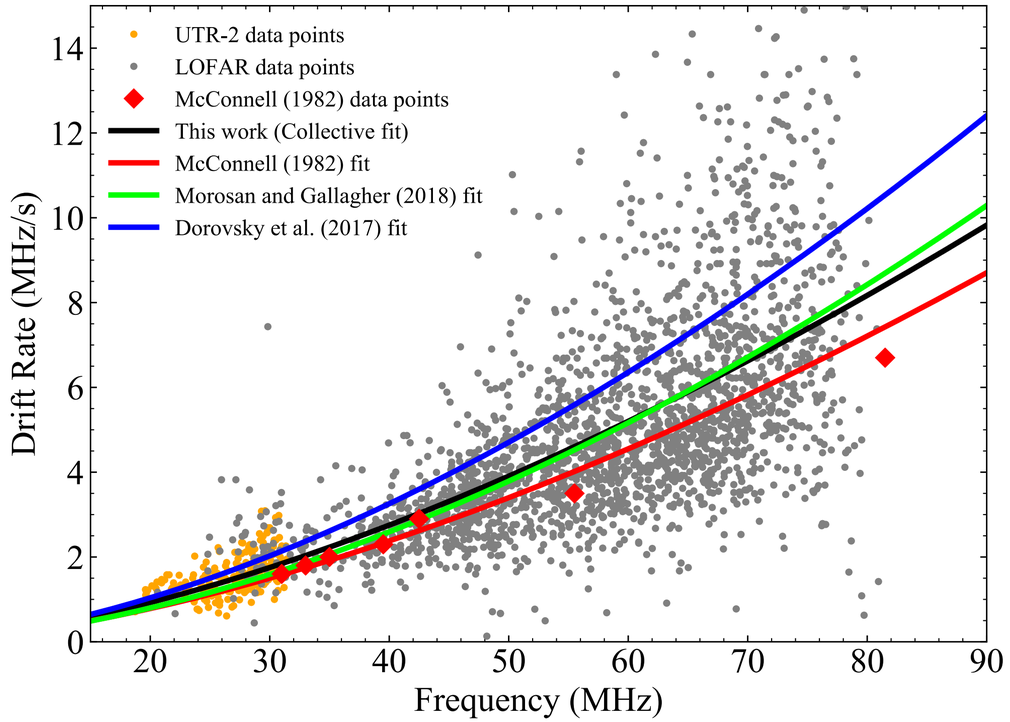

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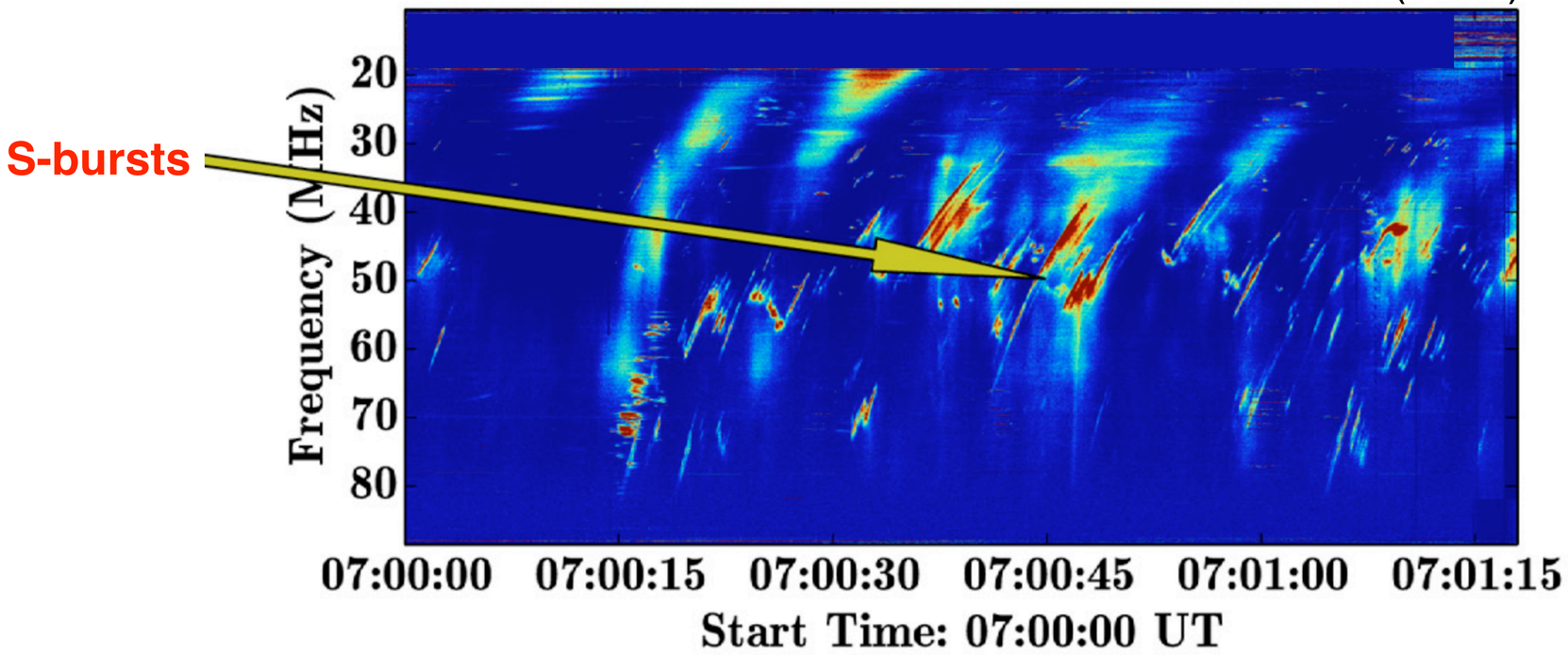
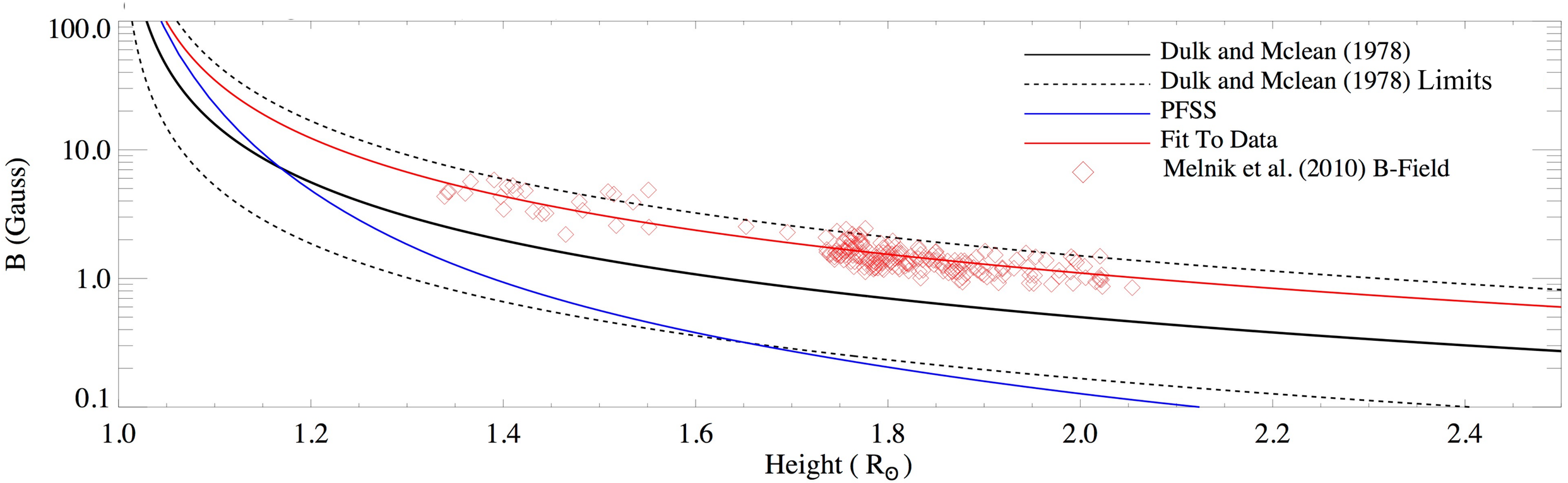
Morosan et al. (2015)



REMOTE SENSING THE CORONAL MAGNETIC FIELD



$$B = \frac{\sqrt{8\pi m_e}}{e} f \sqrt{\frac{\Delta f}{f}} \frac{1}{sin\theta}$$

SUMMARY

- Extensive analysis of spectral properties of over 3000 S-bursts were measured using UTR-2 and LOFAR.

- Melnik et al. (2010) model can account for the observed spectral properties of S-bursts.

- S-bursts can provide a proxy for measuring the coronal magnetic field.

- This work is currently published in the journal Astronomy and Astrophysics.