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# The formation and evolution of a shock driven by coronal mass ejection in the low corona

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I-LOFAR Exploring the Radio Universe from Ireland
sfi Fondúireacht Eolaíochta Éireann Dá bhfuil romhainn Science Foundation Ireland For what's next
IRISH RESEARCH COUNCIL An Chomhairle um Thaighde in Éirinn

# Outline

- Shocks in the solar corona and their radio signature
- Study of 2 September 2017 CME and Type II radio burst
  - Compare three methods to derive Alfvén Mach number.
- Results and conclusions


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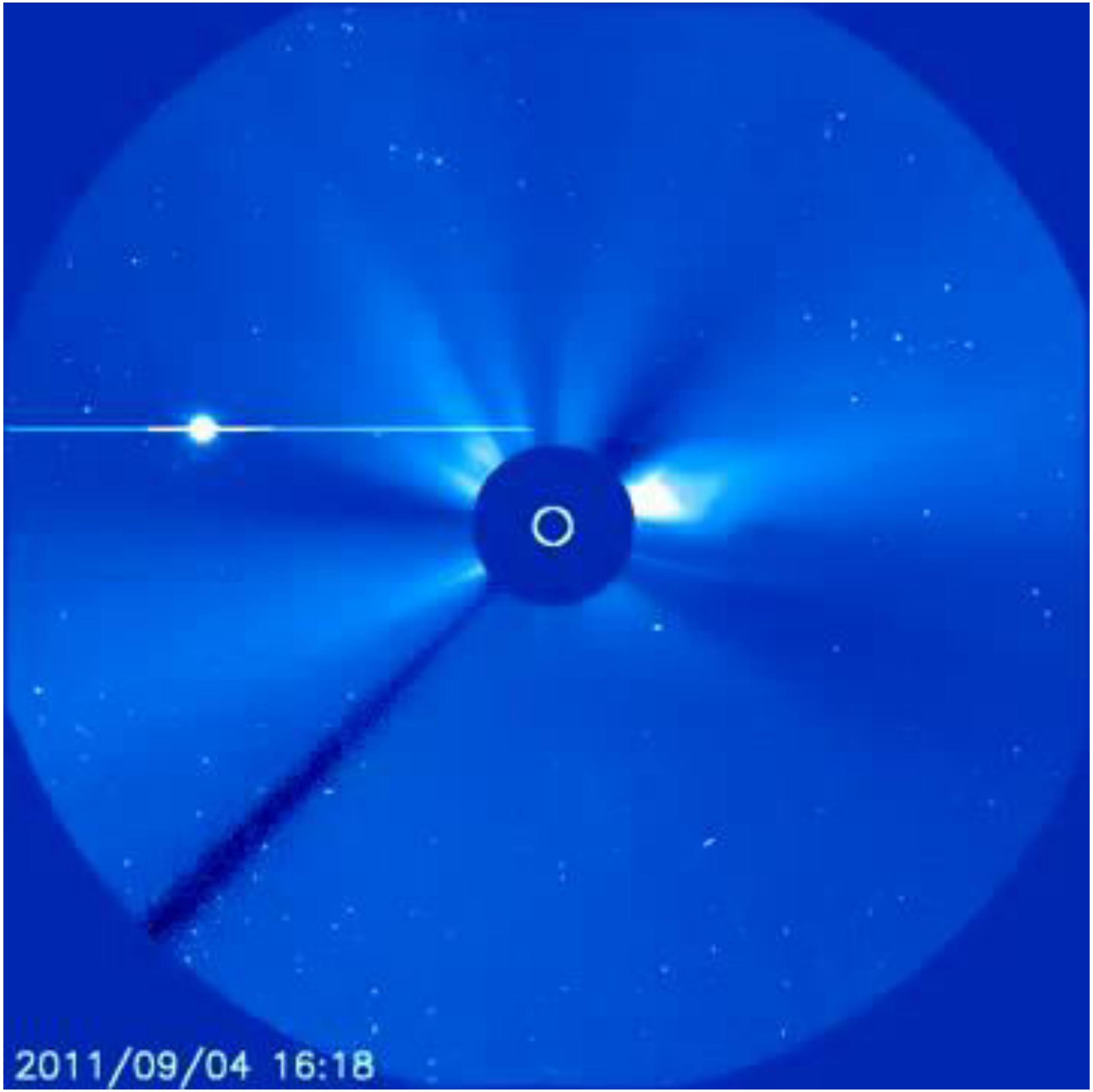



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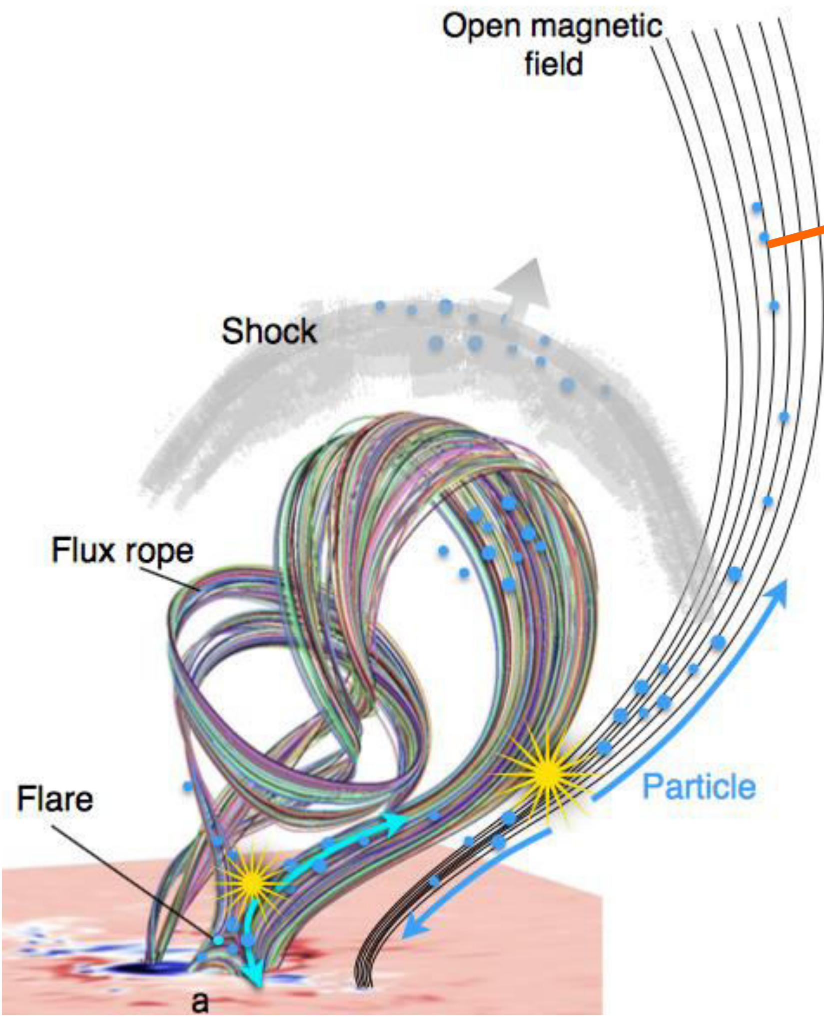
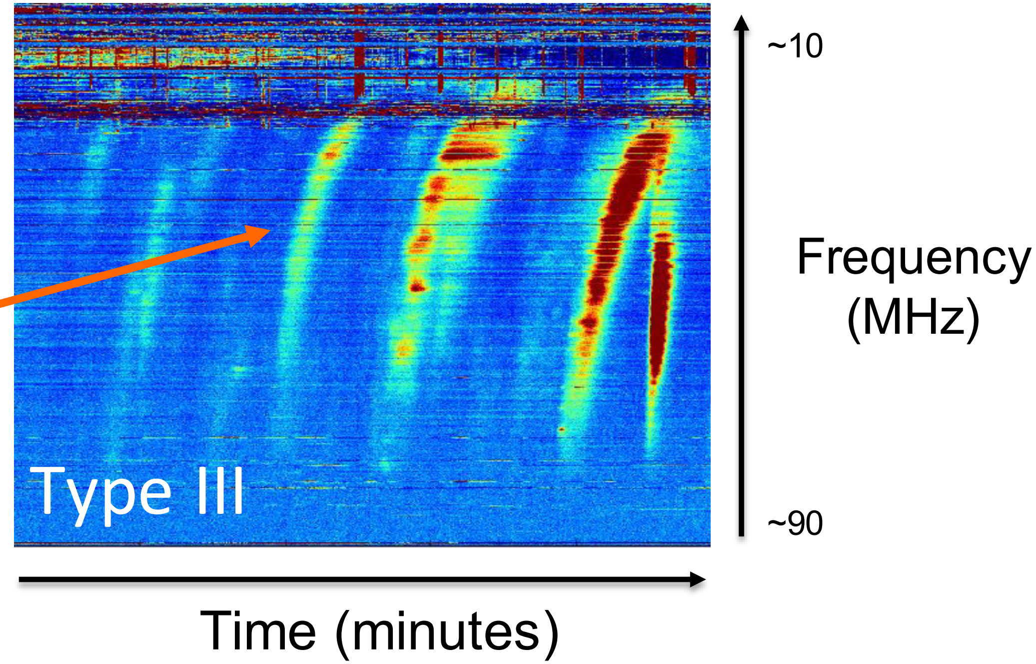
# What are solar radio bursts?




Adapted from Amari et al. (2014)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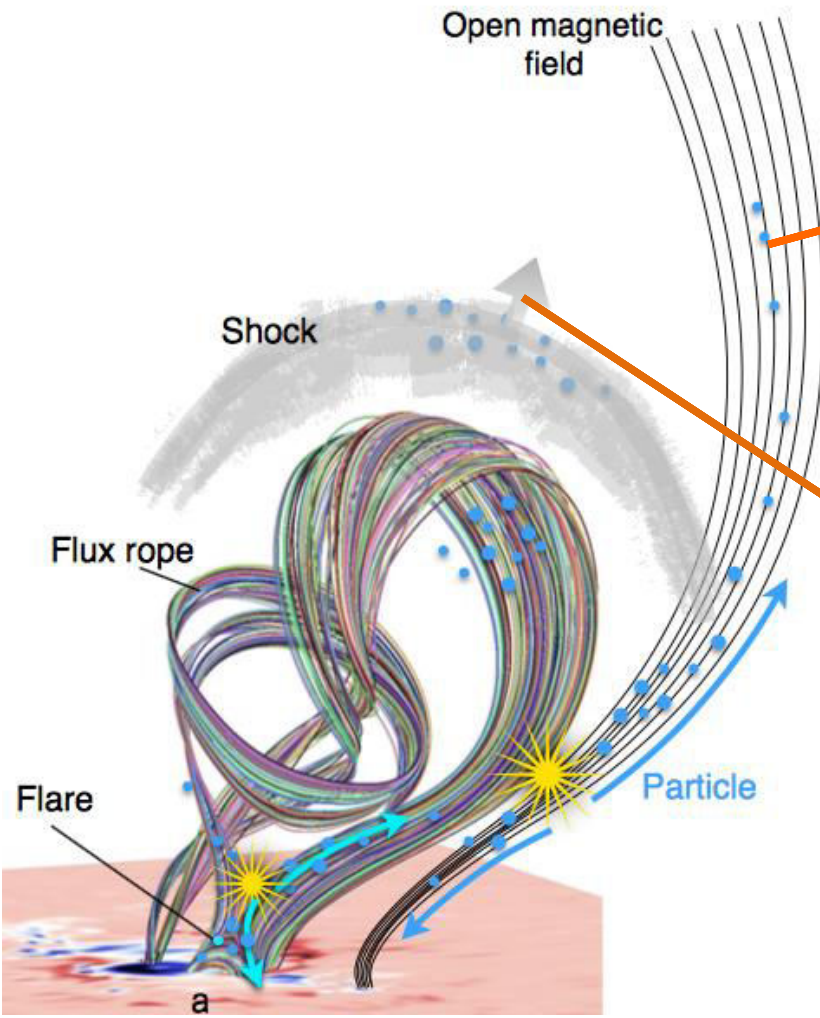
# What are solar radio bursts?

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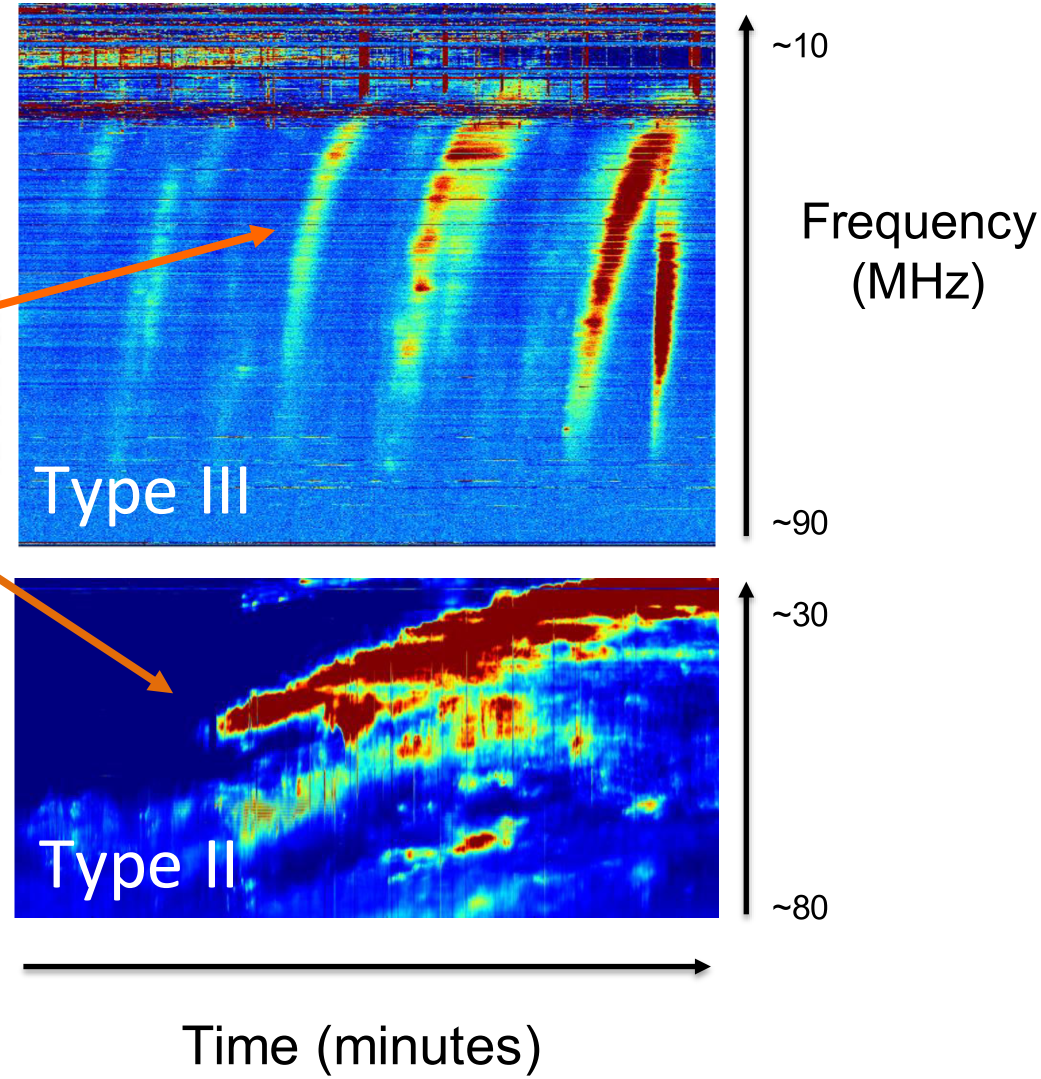



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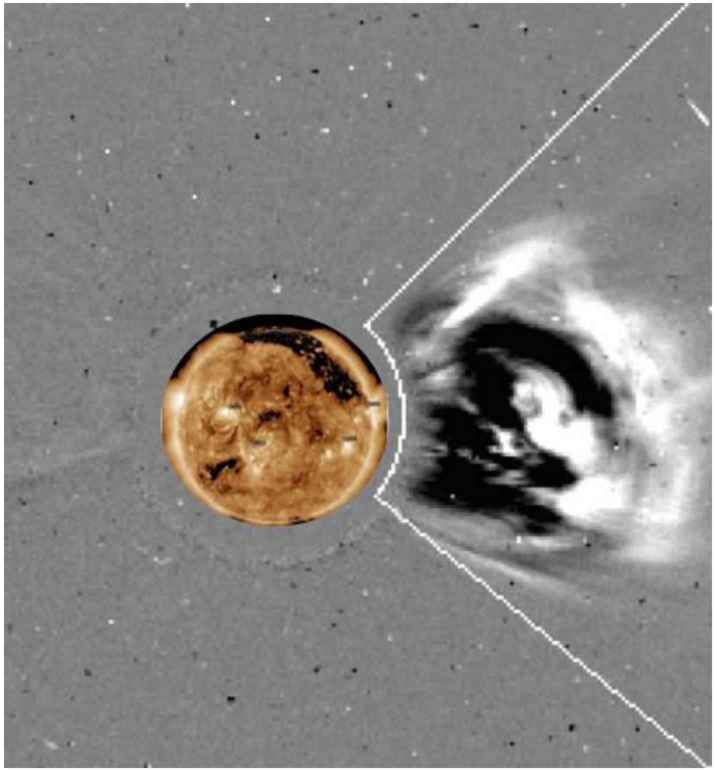
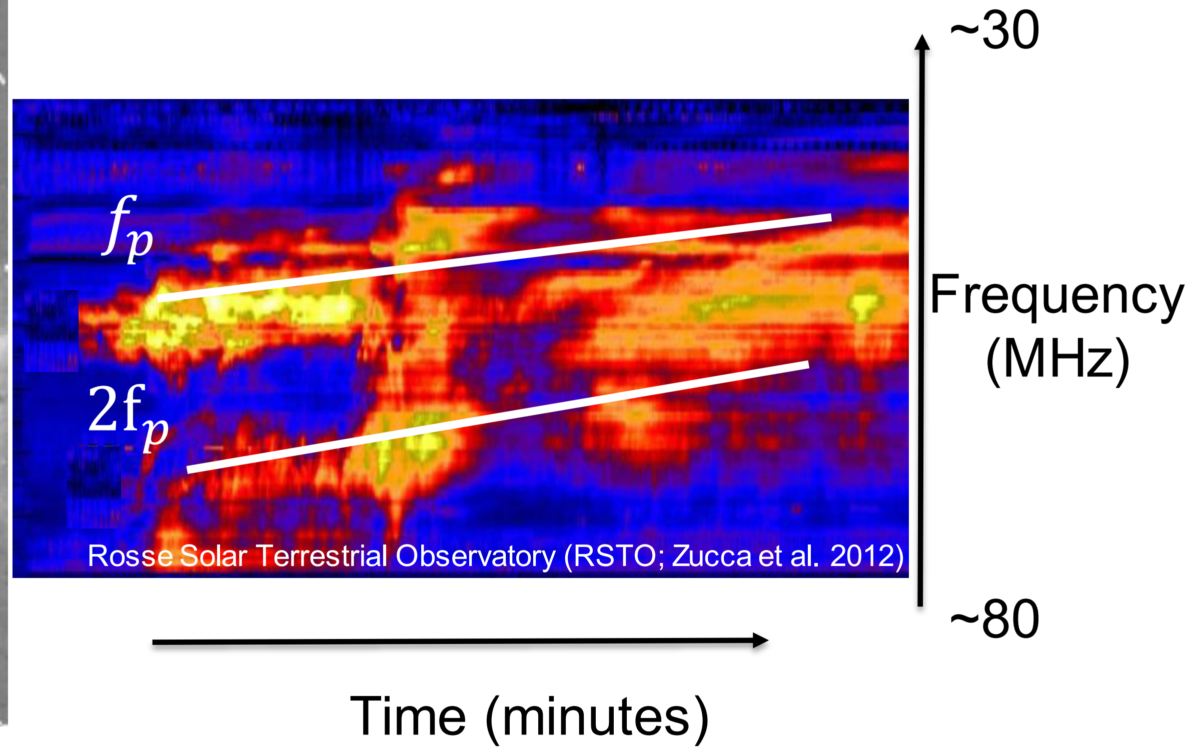
# Type II solar radio burst






$v_{CME} > v_{Alfvén}$

$f_p \rightarrow n_e \rightarrow h$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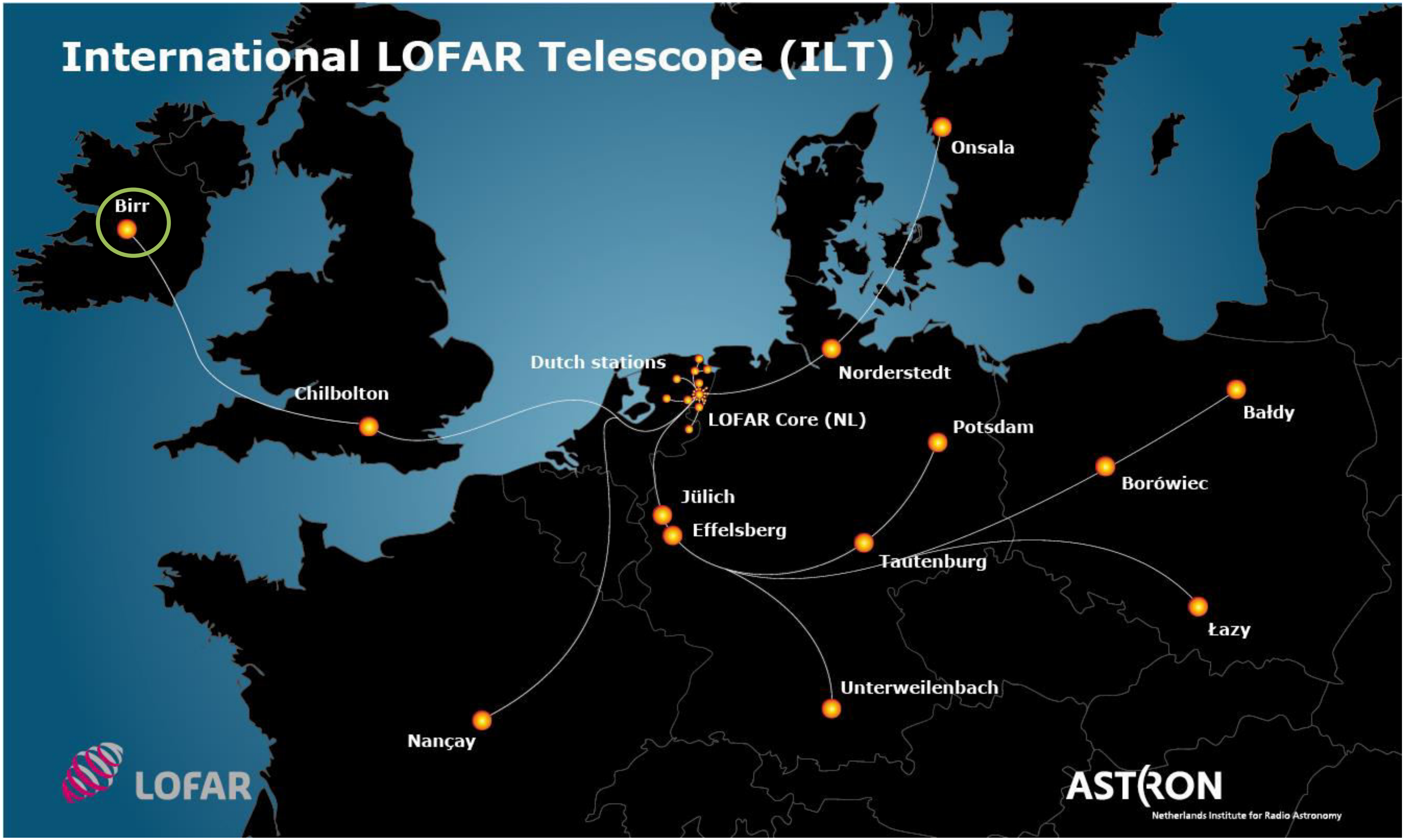
# Low Frequency ARay (LOFAR)



# Irish Low Frequency ARay (I-LOFAR)



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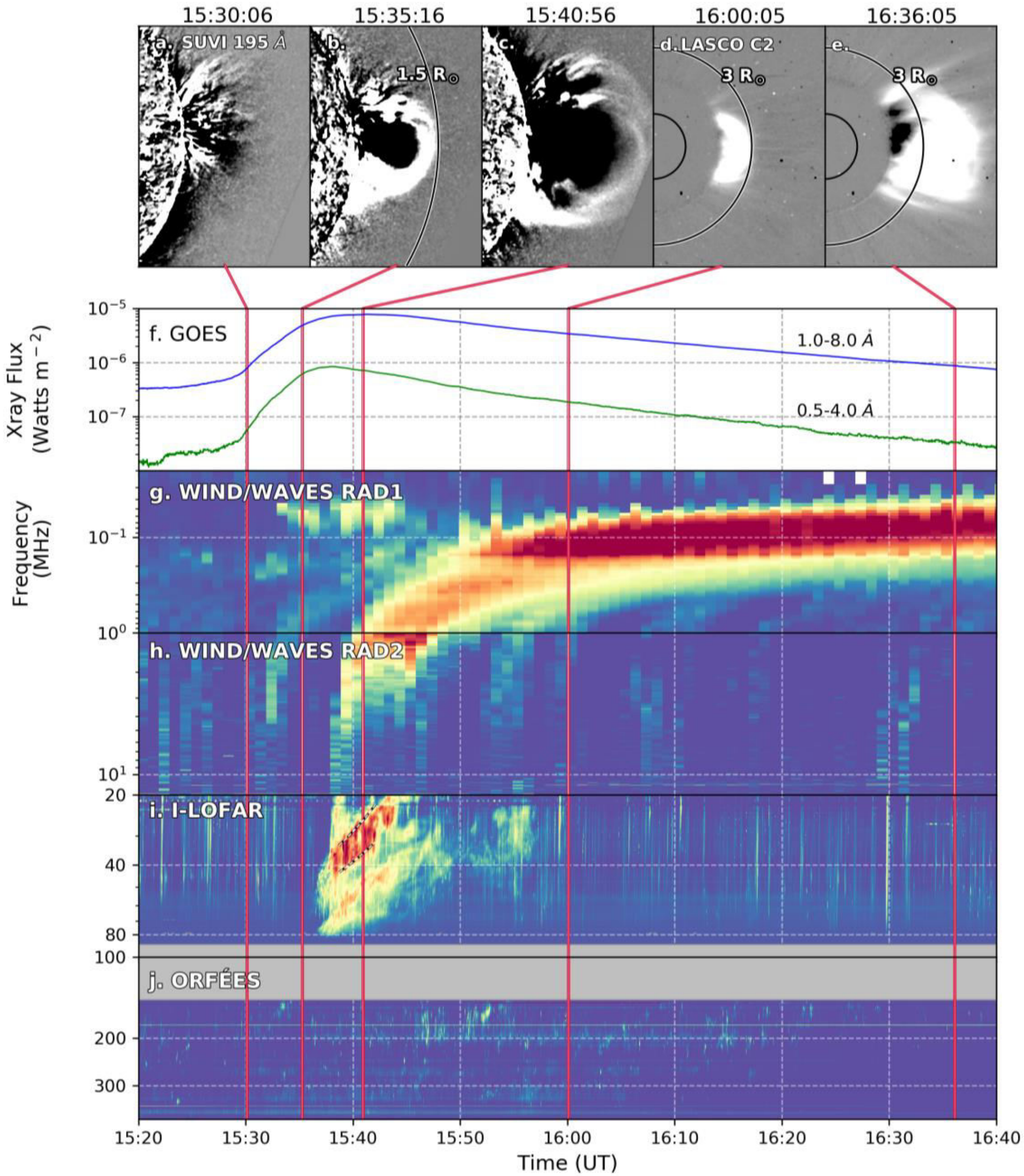
# 2 September 2017



# Alfvénic Mach Number

**Method 1** Standoff Distance

$$M_A = \sqrt{1 + [1.24\delta - \frac{(\gamma - 1)}{(\gamma + 1)}]^{-1}}$$

**Method 2** CME speed / Alfvén speed

$$M_A = v_{CME}/v_A$$

**Method 3** Band-Splitting

$$M_A = \sqrt{X(X+5)/2(4-X)}$$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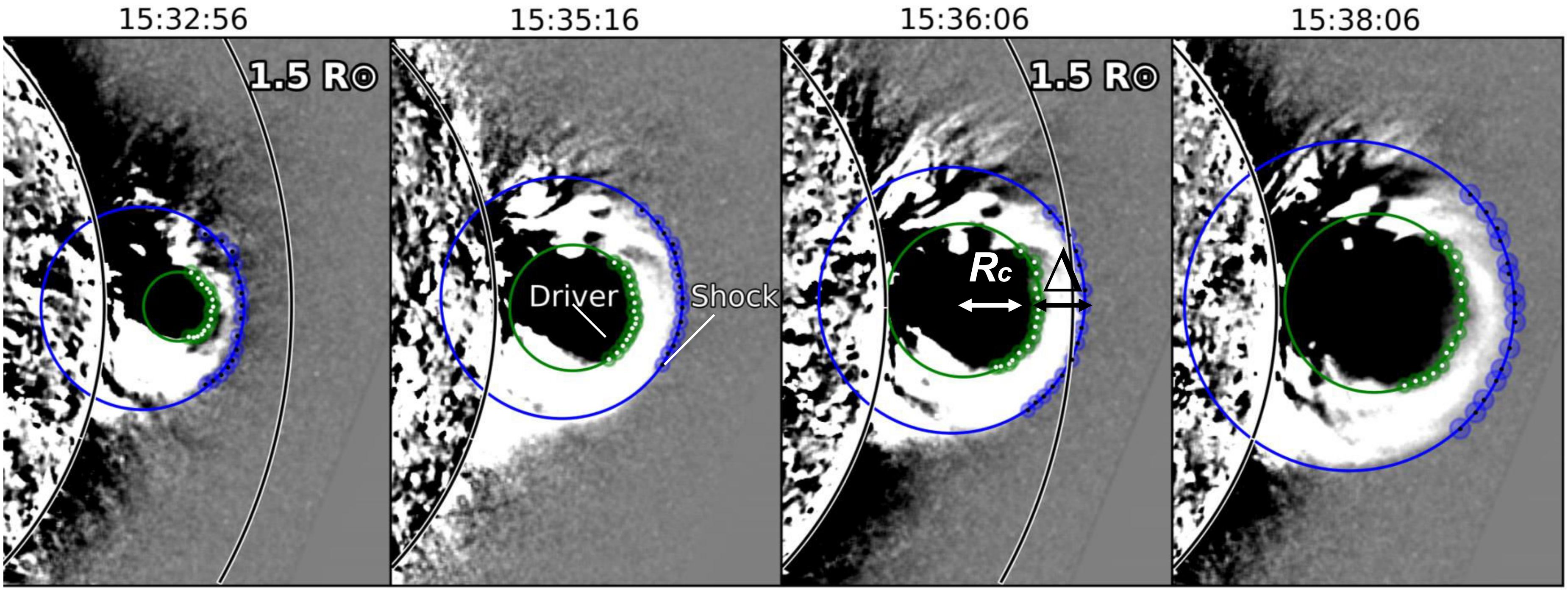
# Method 1: Normalised Standoff Distance (δ)




$$\delta = \Delta / R_c$$

$$M_A = \sqrt{1 + [1.24\delta - (\gamma - 1)/(\gamma + 1)]^{-1}}$$



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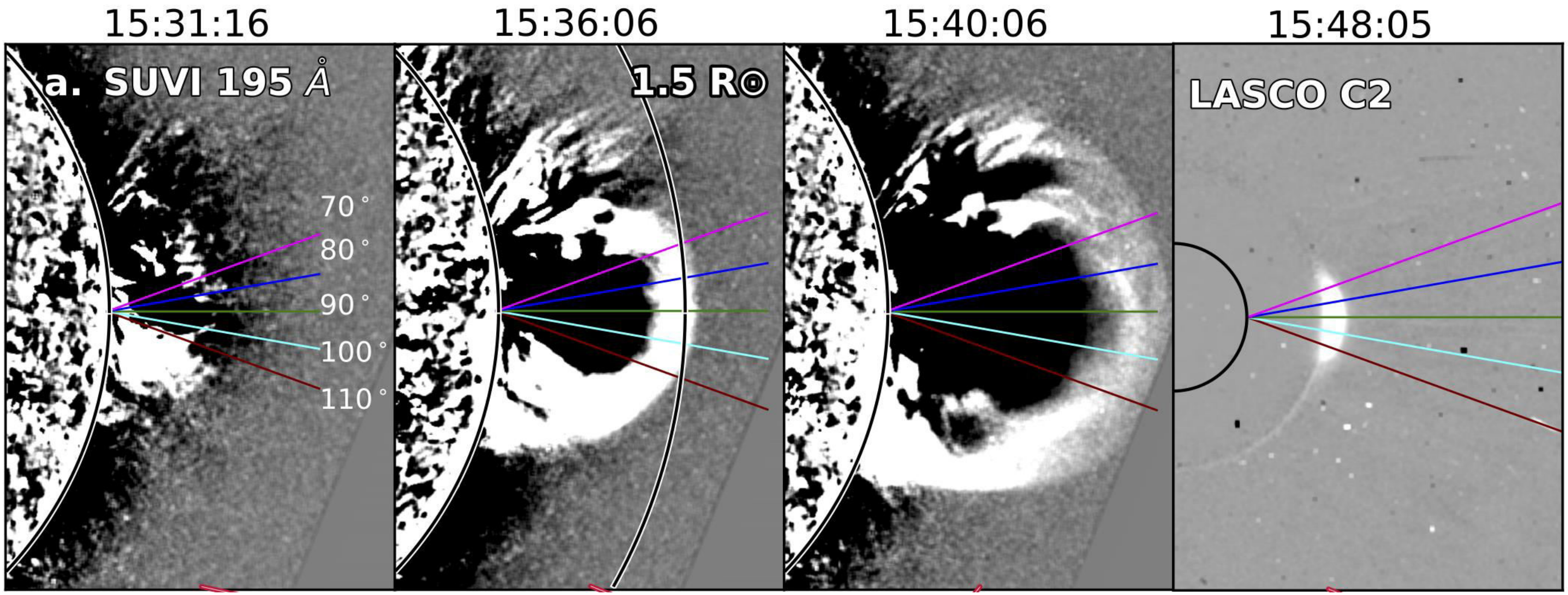
# Method 2: CME speed to Alfvén speed Ratio




$$v_{CME} = \frac{dh}{dt}$$

$$M_A = \frac{v_{CME}}{v_A}$$

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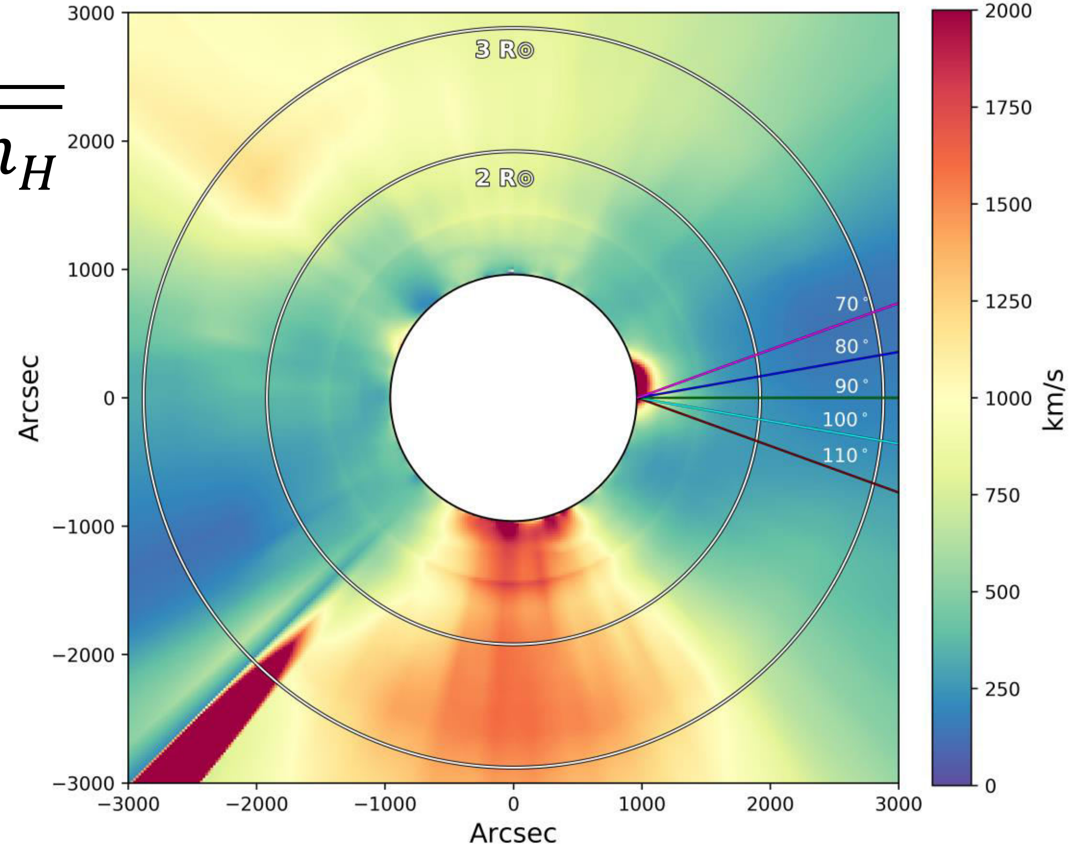
# Method 2: CME speed to Alfvén speed Ratio

$$v_A(x,y) = \frac{B(x,y)}{\sqrt{\mu_o n_e(x,y) m_H}}$$

$$M_A = \frac{v_{CME}}{v_A}$$

Alfvén Speed km/s




Zucca et al. 2014 Model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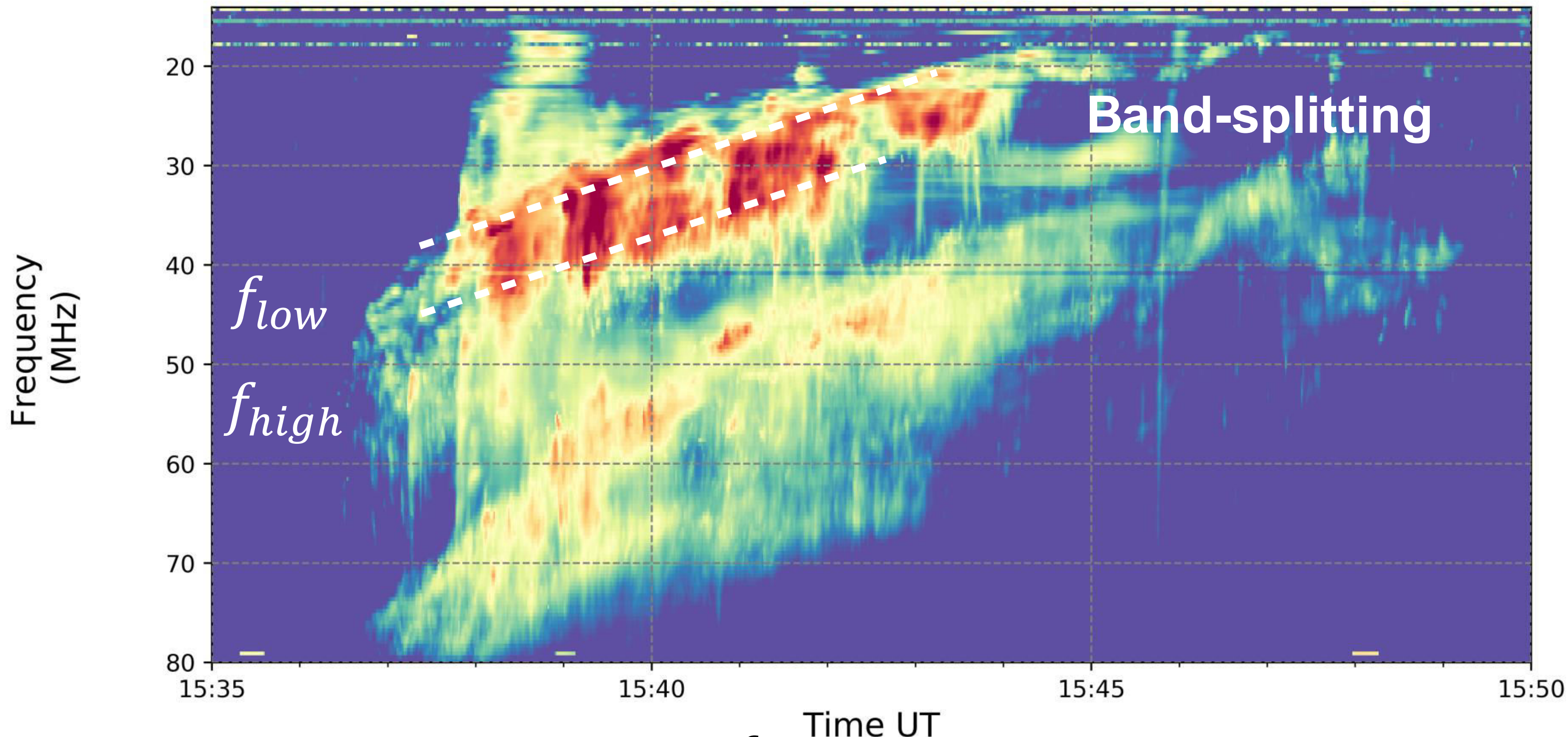
# Method 3: Band-splitting




$$X = \left(\frac{f_{high}}{f_{low}}\right)^2 = \frac{n_{downstream}}{n_{upstream}}$$

$$M_A = \sqrt{X(X+5)/2(4-X)}$$

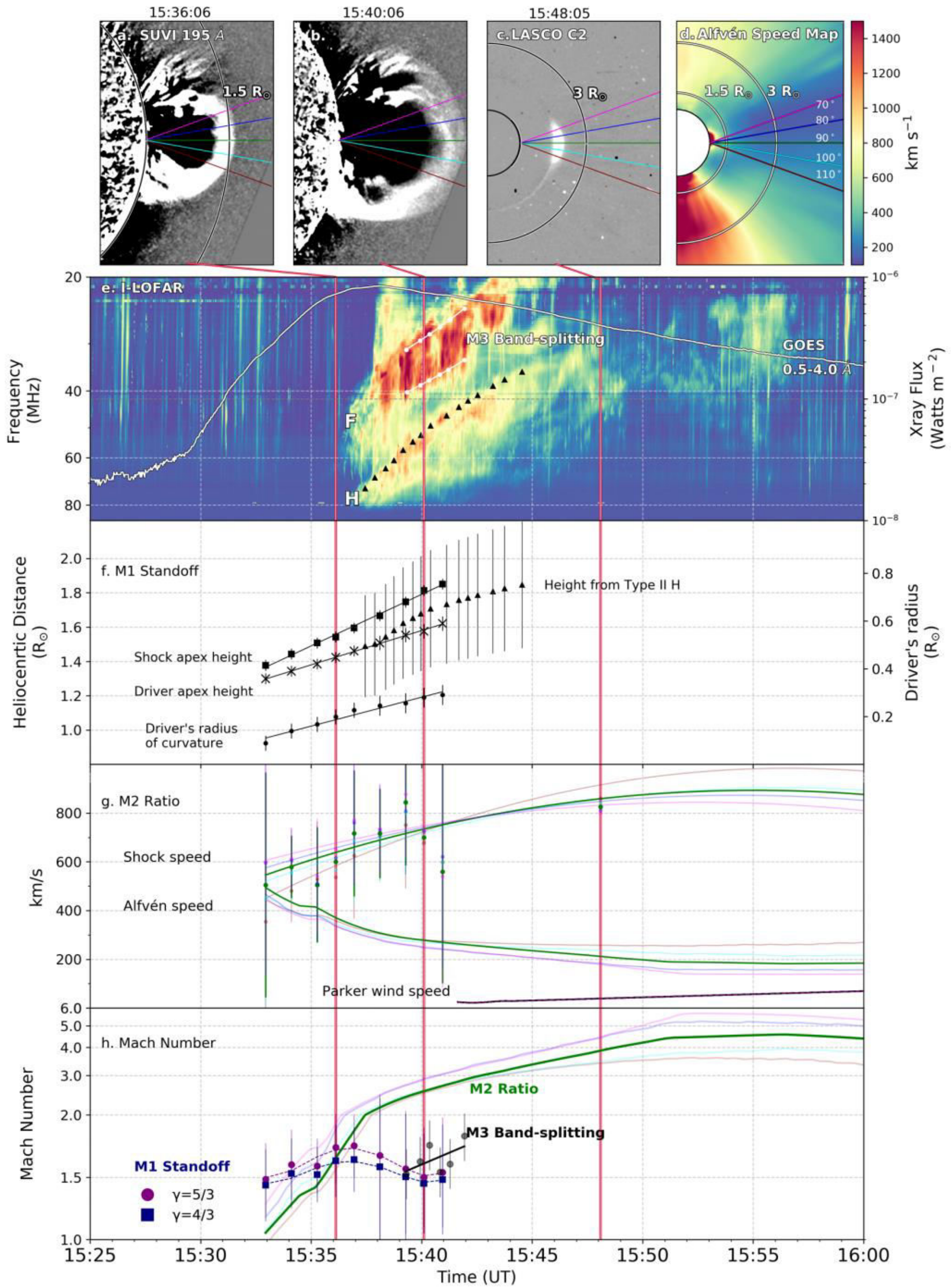
# Comparison

Band-splitting Method

Standoff Distance Method

Ratio Method

Alfvén Mach Number



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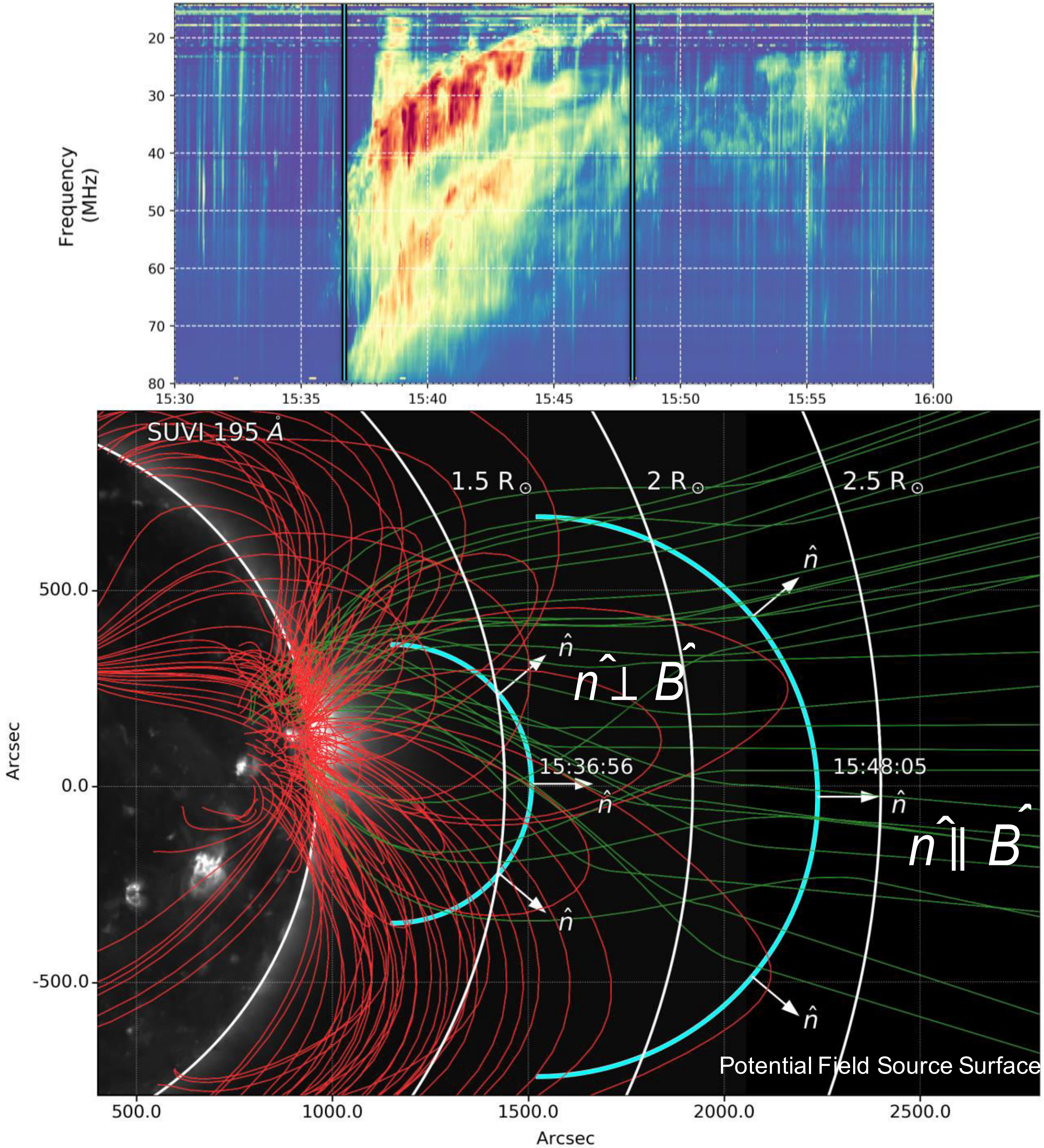




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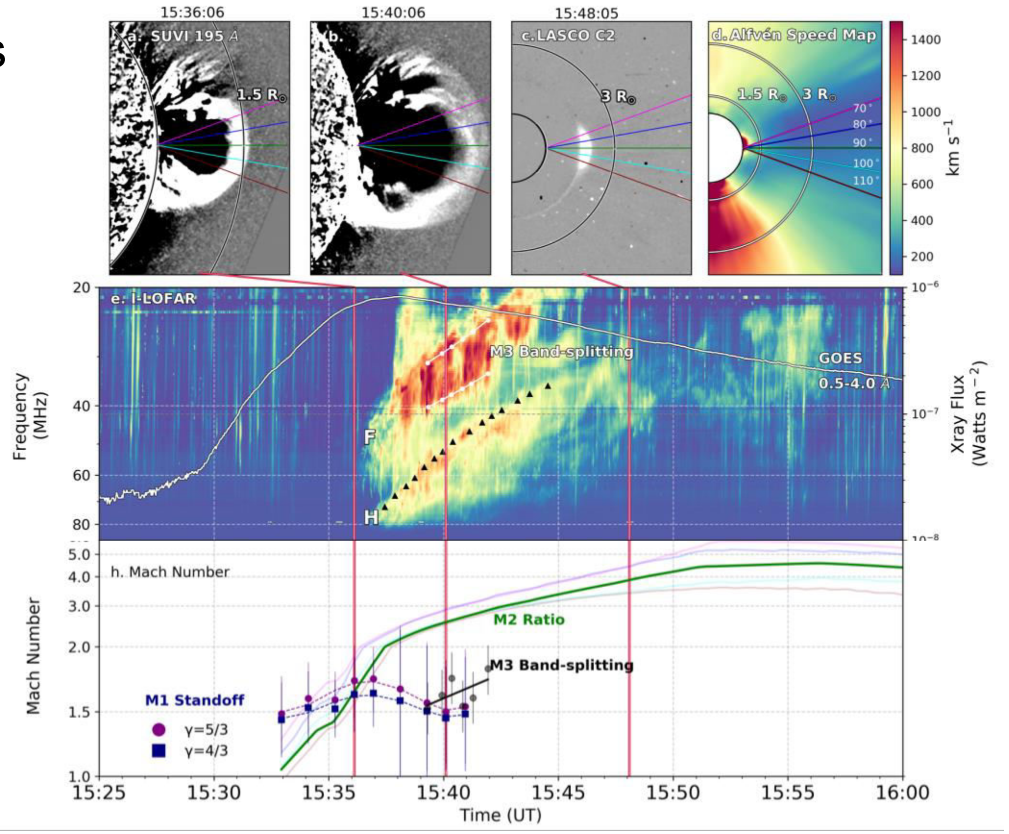
# Conclusion

- First solar radio bursts observations by I-LOFAR.
- 3 methods to derive $M_A$ consistent.
- Type II emission begins $M_A \approx 1.6$ at $\sim 1.5 R_\odot$ and ceases at $\sim 2.4\ R_\odot$
- Type II emission starts when quasi-perpendicular & ceases when quasi-parallel.




*The formation and evolution of a shock driven by coronal mass ejection in the low corona, Maguire et al. A&A, 2019. (submitted.)*