A comparison of methods to derive Alfvénic Mach numbers for a CME-driven shock

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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 Alfvénic Mach number.
- Results and conclusions

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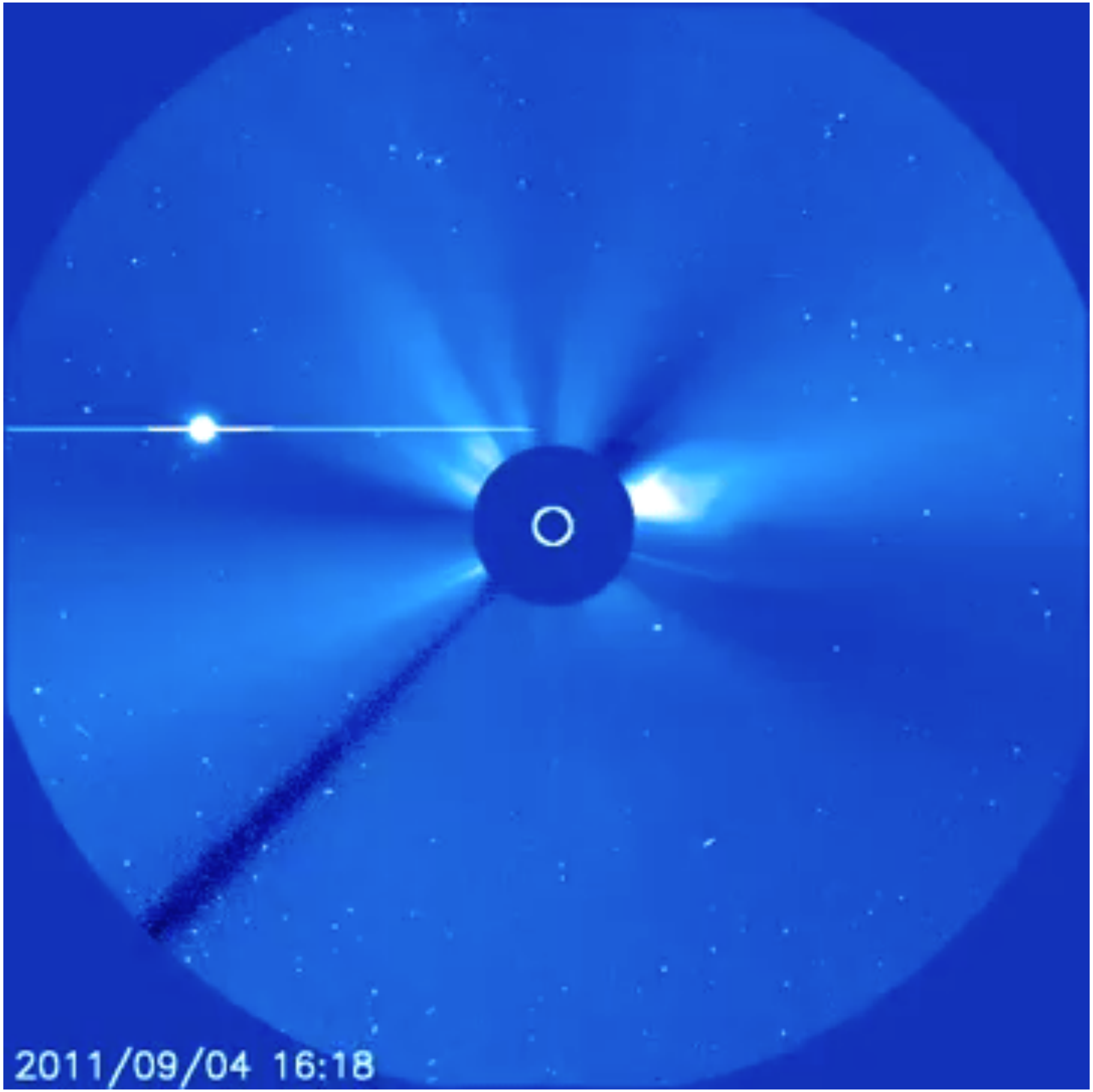
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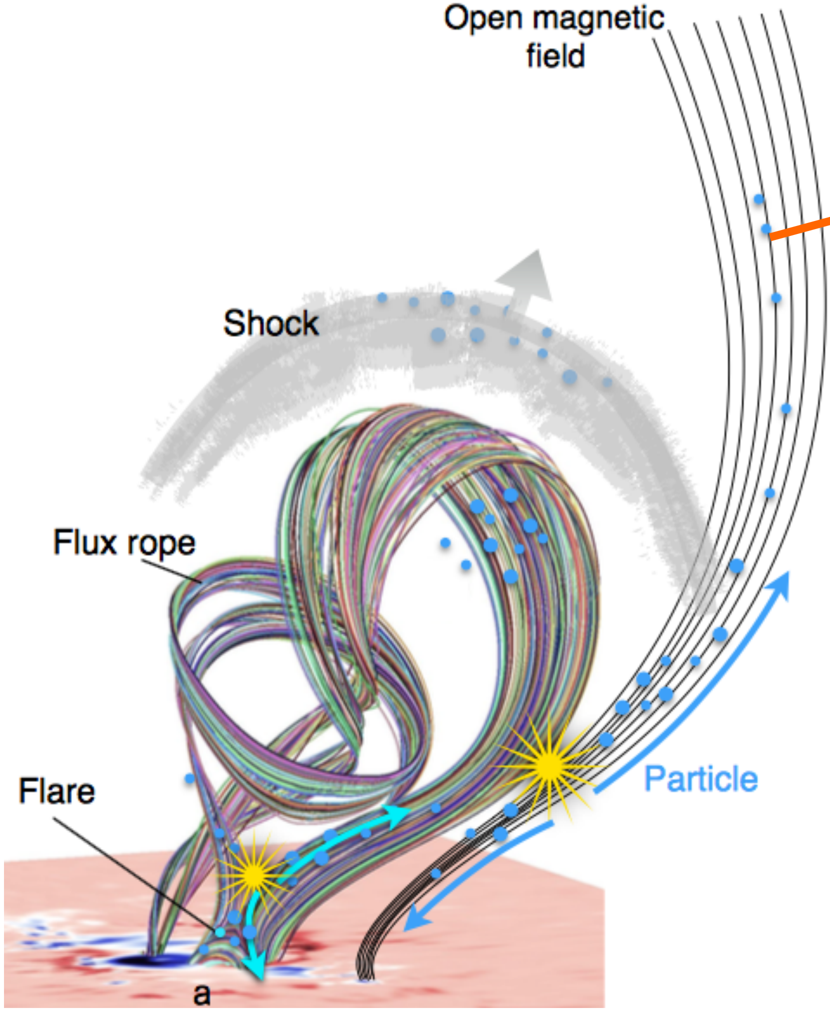
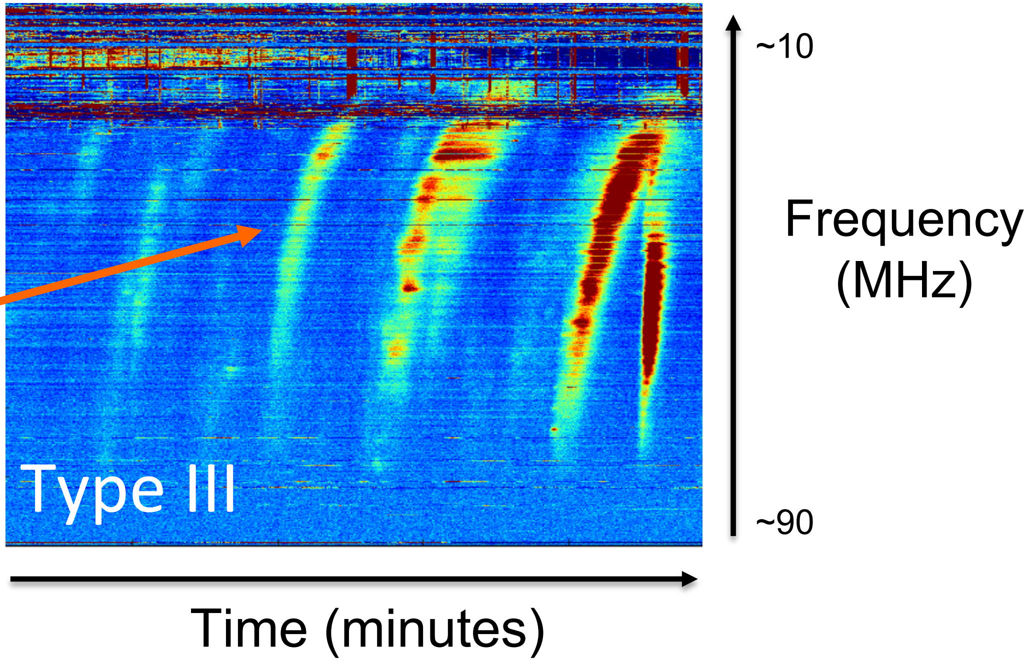
What are solar radio bursts?





Adapted from Amari et al. (2014)

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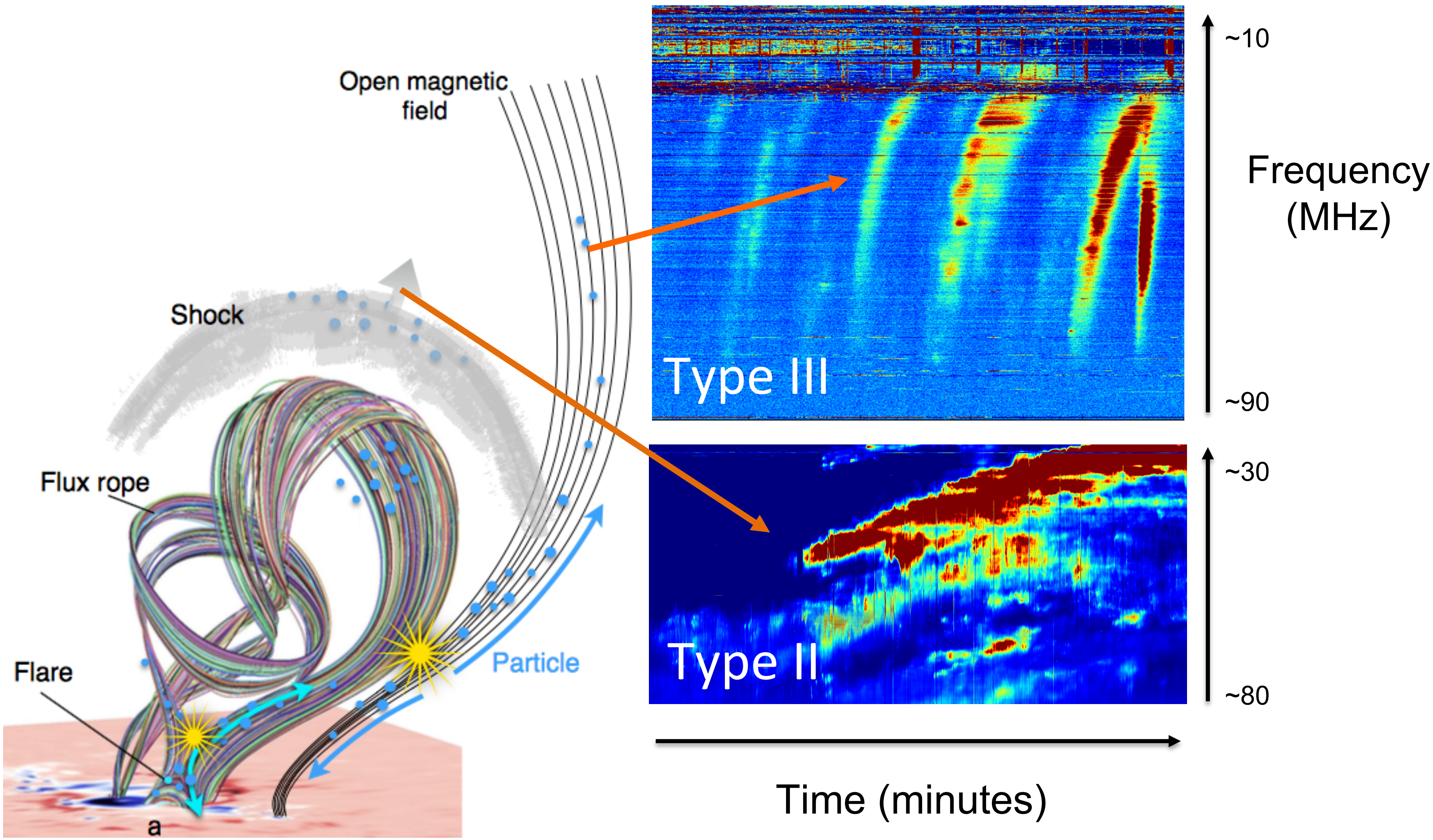
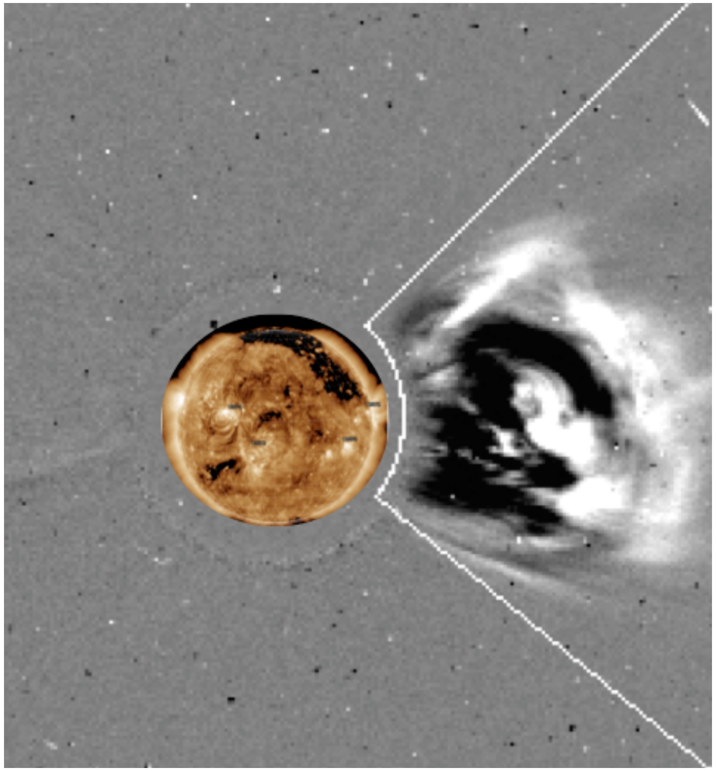
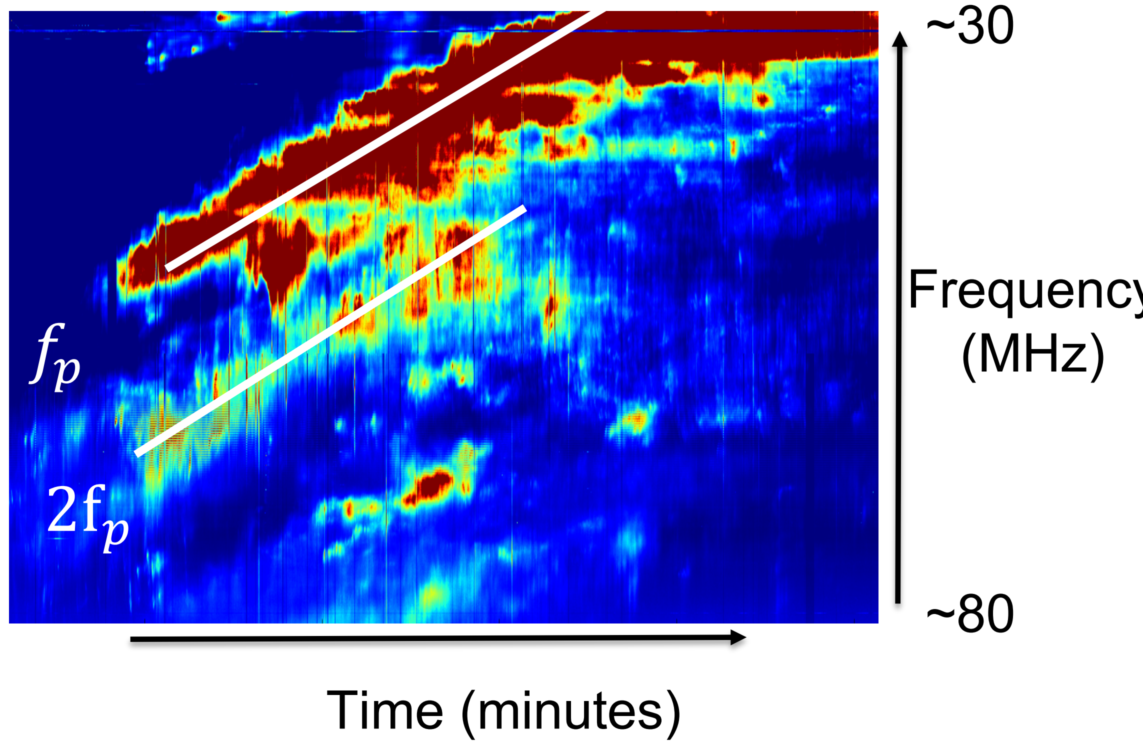
What are solar radio bursts?



Adapted from Amari et al. (2014)

What a Type II solar radio burst tells us?





$v_{\text{CME}} > v_{\text{Alfvén}}$

$f_p \rightarrow n_e \rightarrow h$

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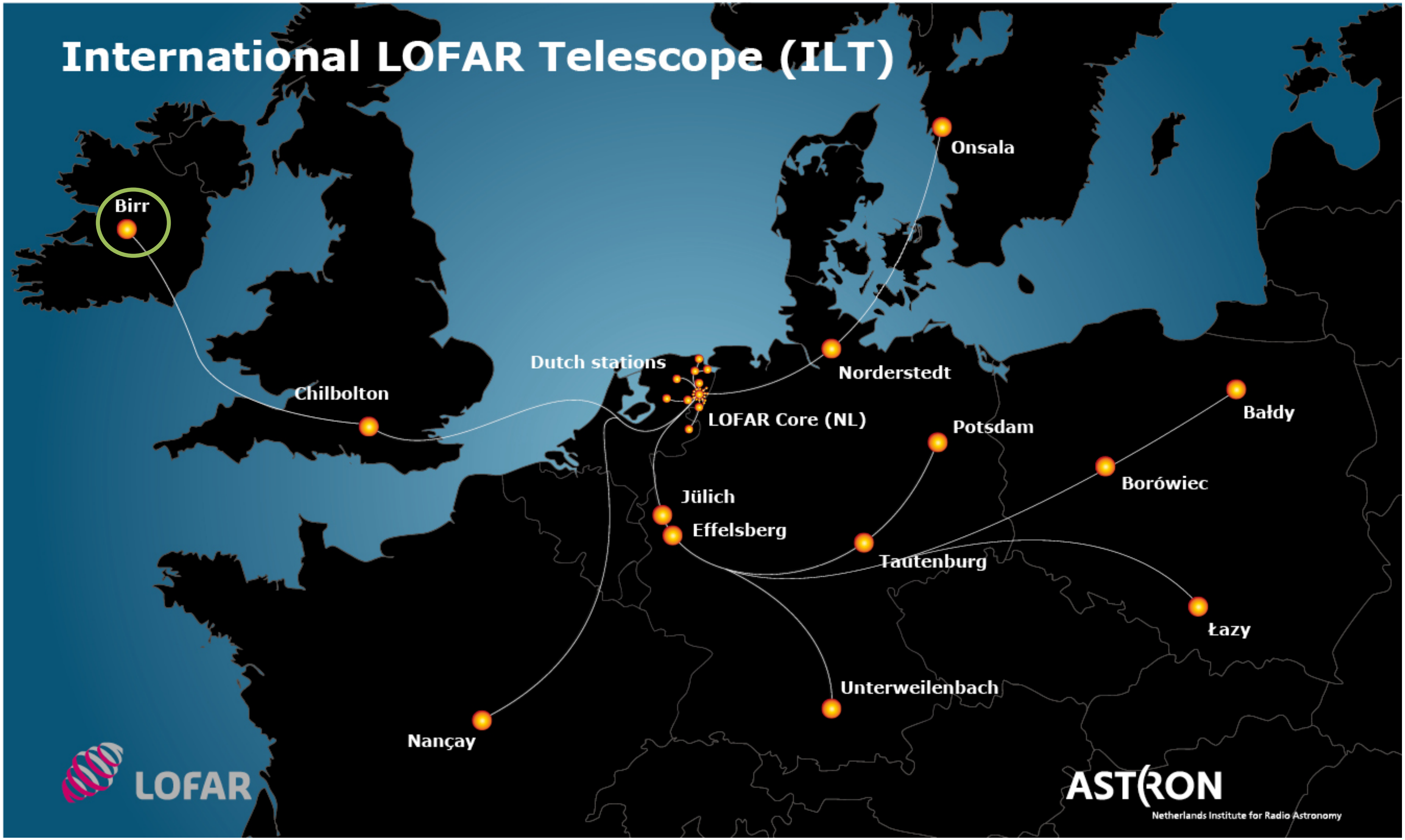
Low Frequency ARay (LOFAR)



Irish Low Frequency ARay (I-LOFAR)

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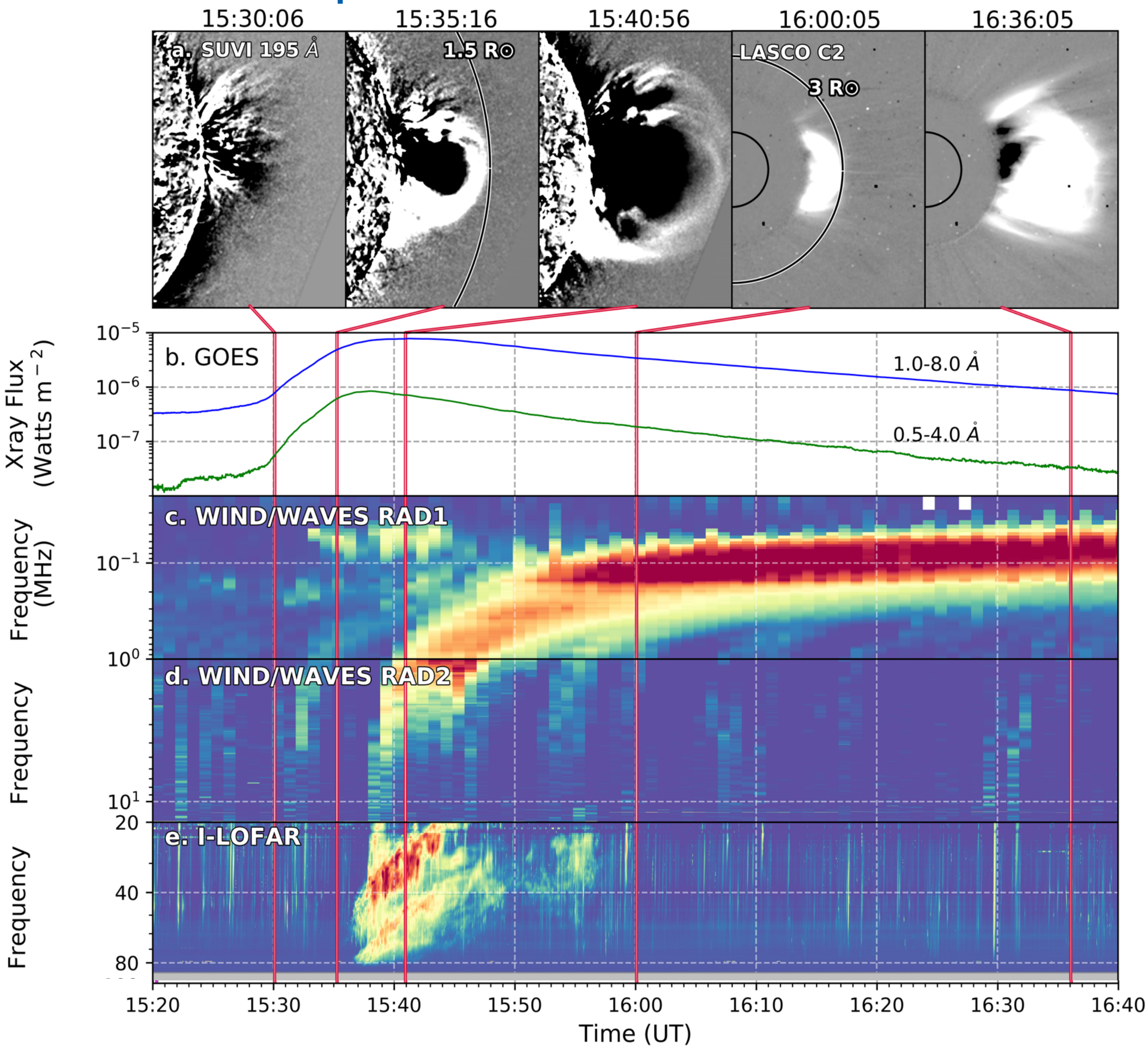
2 September 2017

EUV & Visible

X-ray

Radio



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Alfvénic Mach Number

Method 1 Standoff Distance

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

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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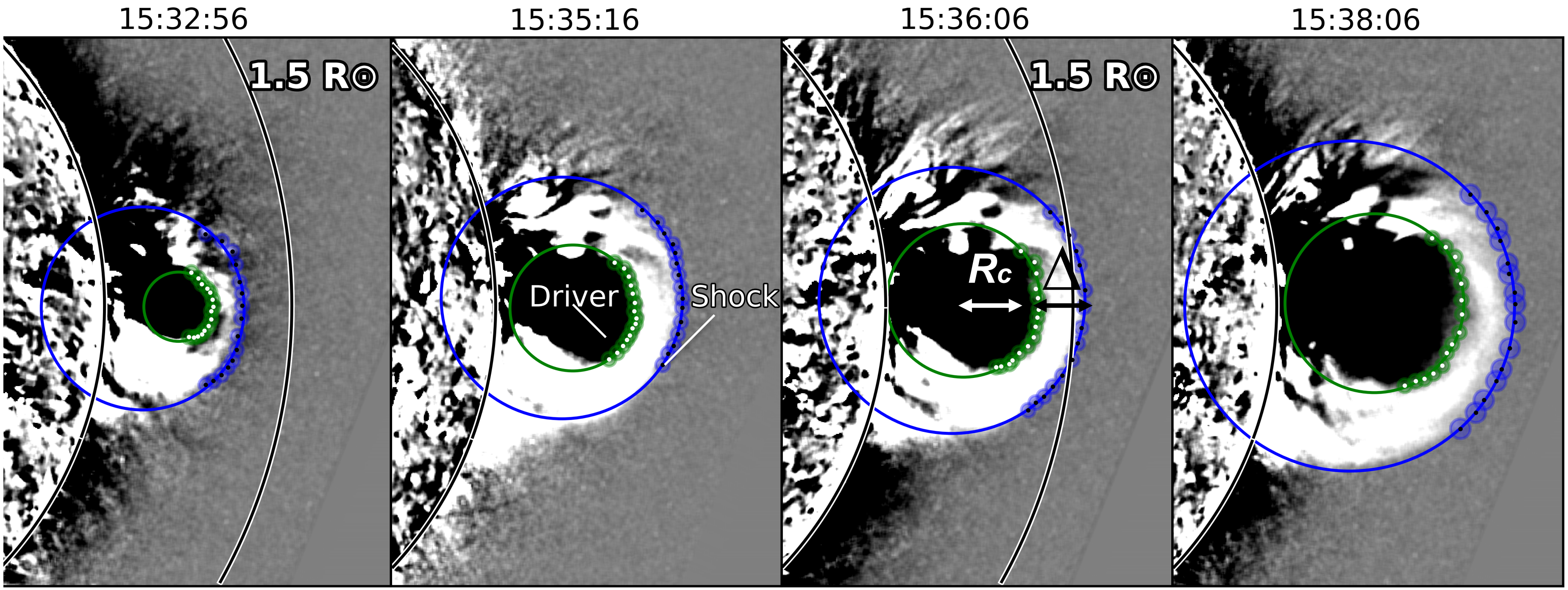
Method 1: Normalised Standoff Distance (δ)



$$\delta = \Delta / R_c$$

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

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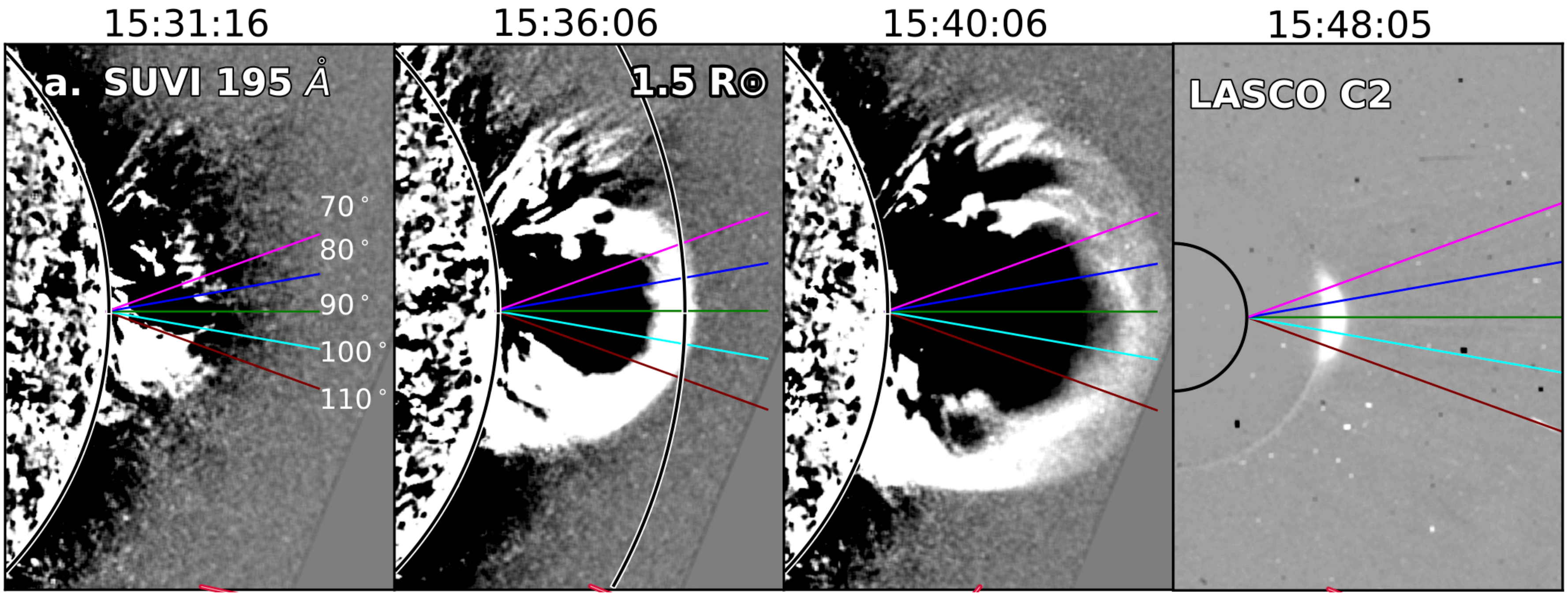
Method 2: CME speed to Alfvén speed Ratio



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

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

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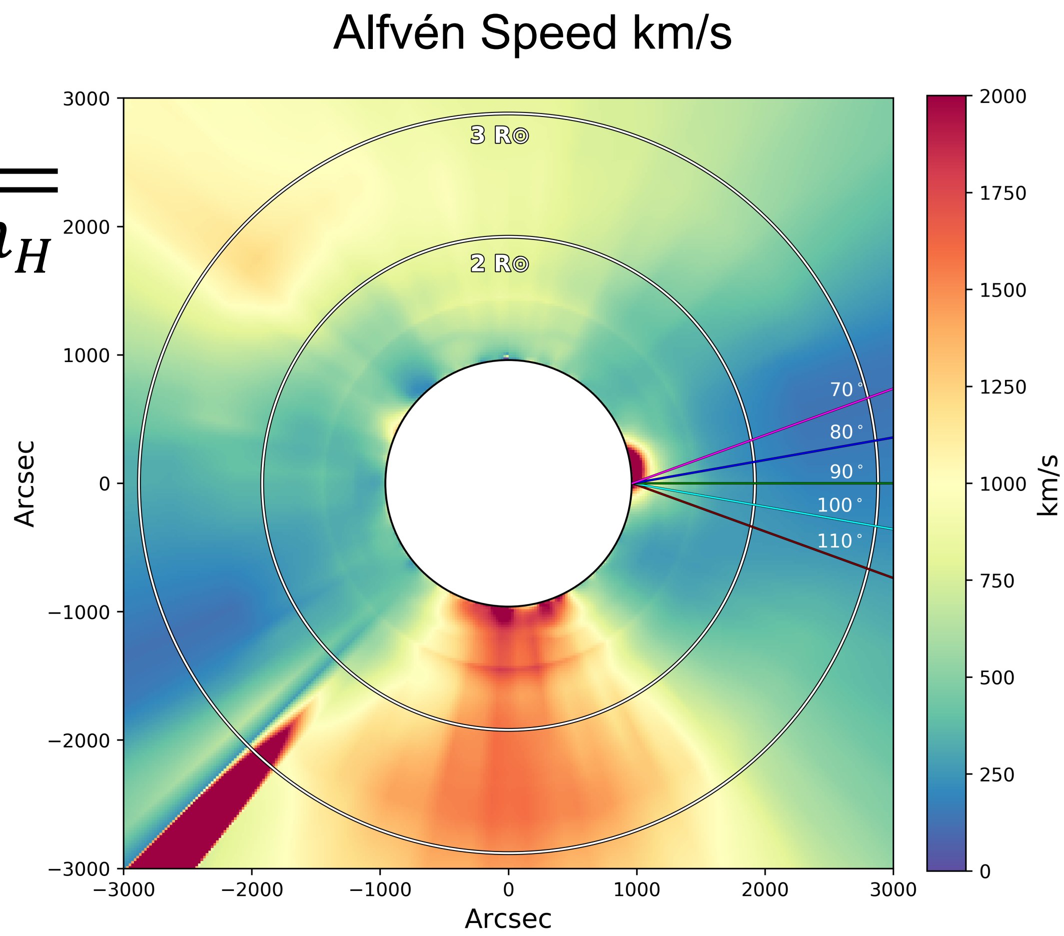
Method 2: CME speed to Alfvén speed Ratio

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

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



Zucca et al. 2014 Model

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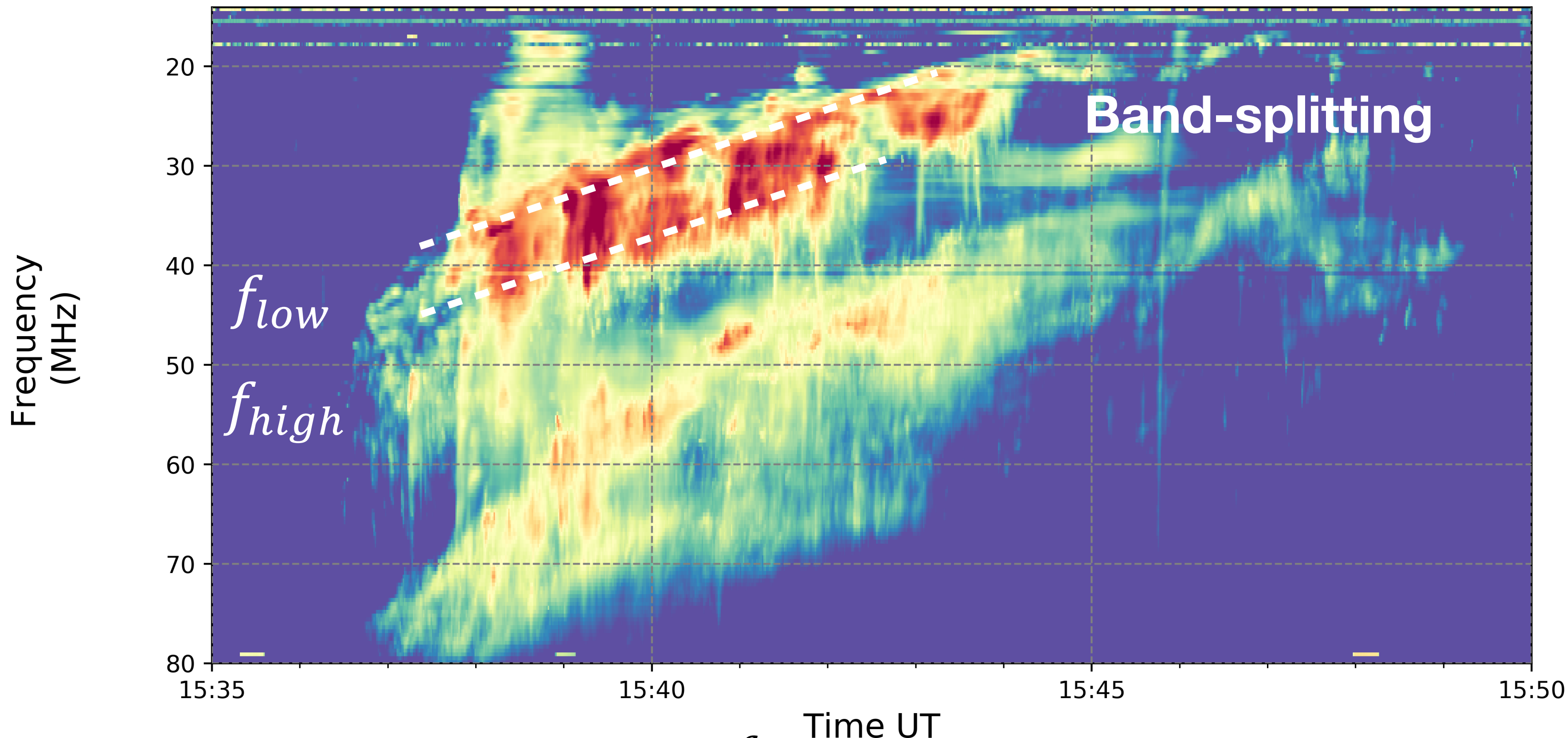
Method 3: Band-splitting



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

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

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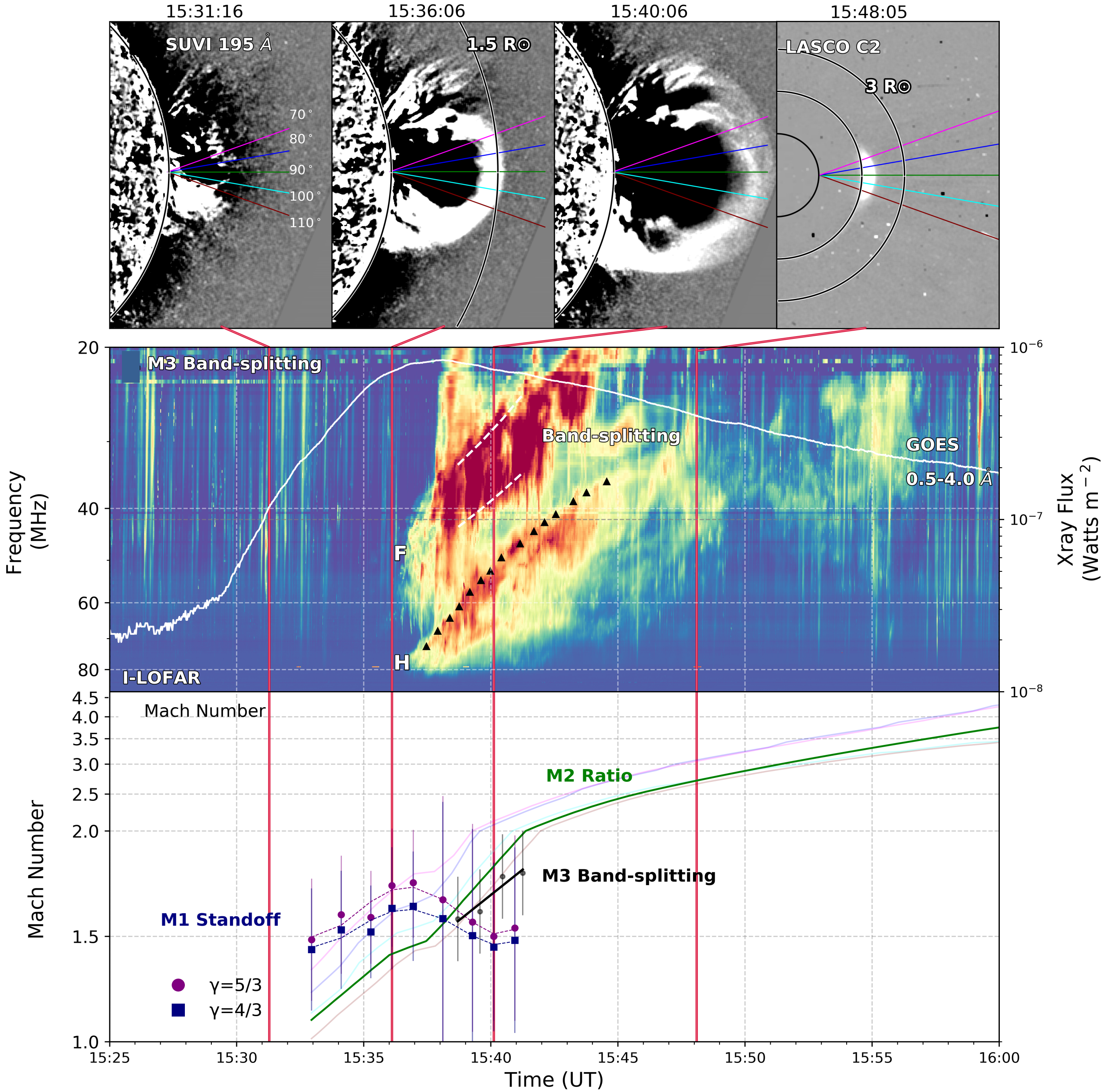
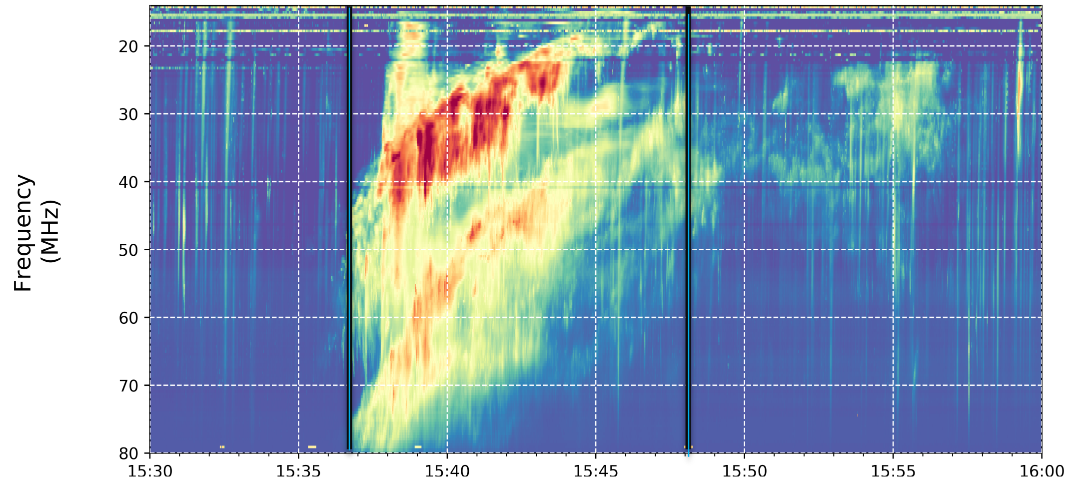
Comparison

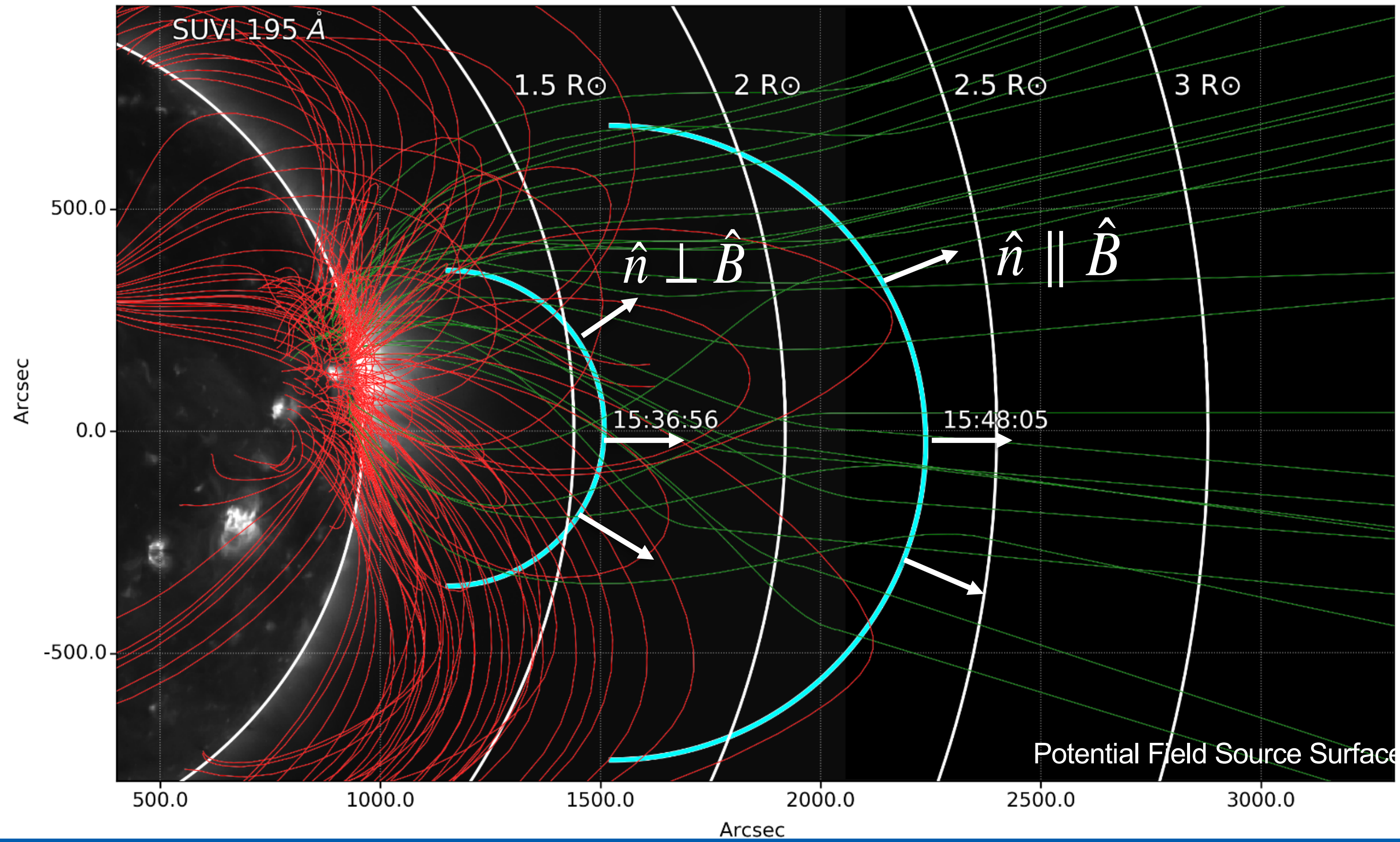
EUV & visible

Radio

Alfvénic Mach Number







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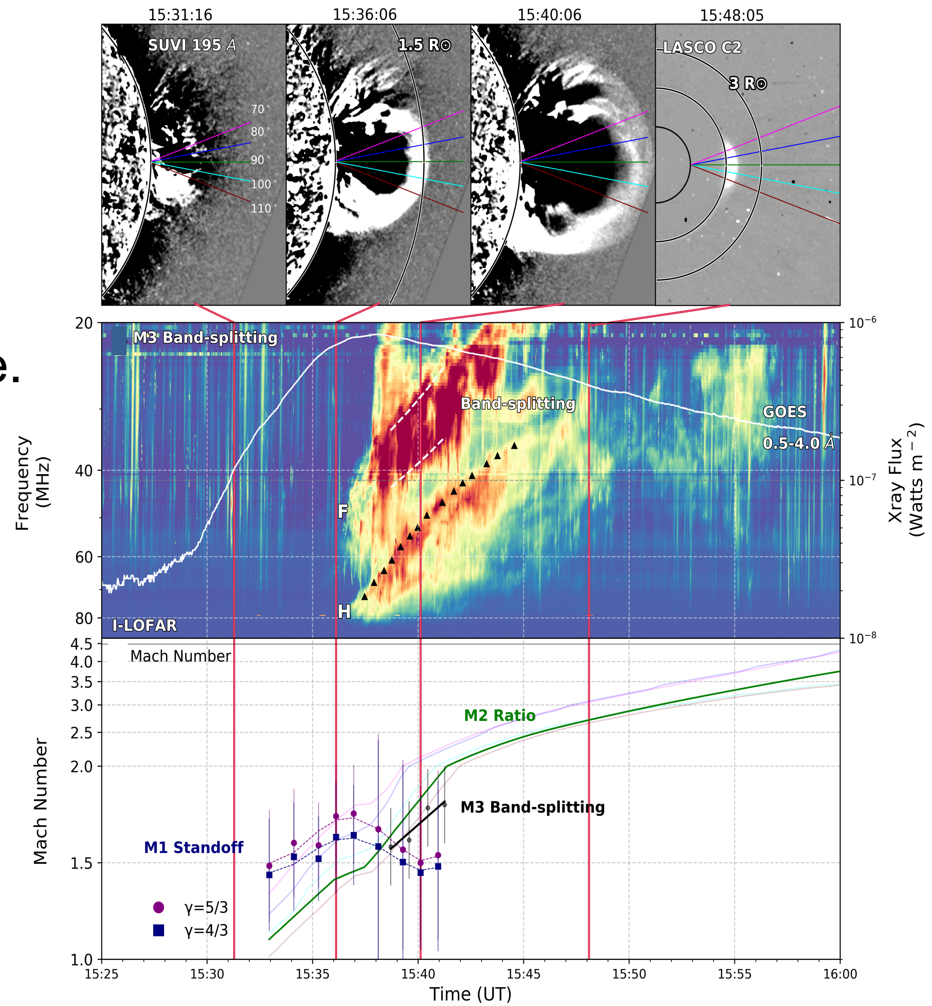
Conclusion

- First solar radio bursts observations by I-LOFAR.
- 3 methods to derive M_A are comparable.
- Type II emission begins $M_A \approx 1.6$ at $\sim 1.5R_\odot$ and ceases at $\sim 2R_\odot$
- Type II emission starts when quasi-perpendicular & ceases when quasi-parallel.



A comparison of methods to derive Alfvénic Mach numbers for a CME-driven shock, Maguire et al. A&A, 2019. (in prep.)