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# Going to the source: using topological measures to find early-warning signatures of flares

David MacTaggart

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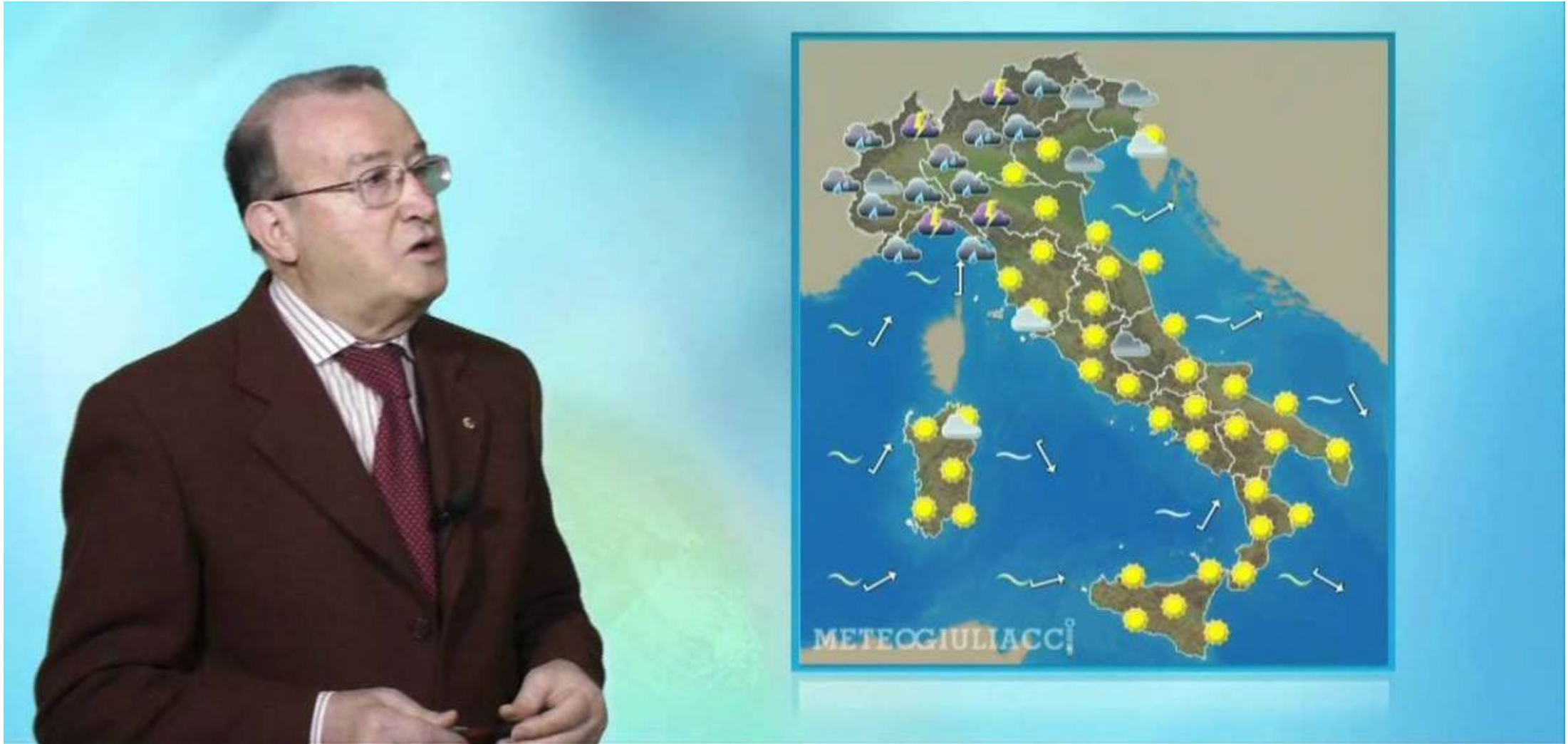
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A WORLD  
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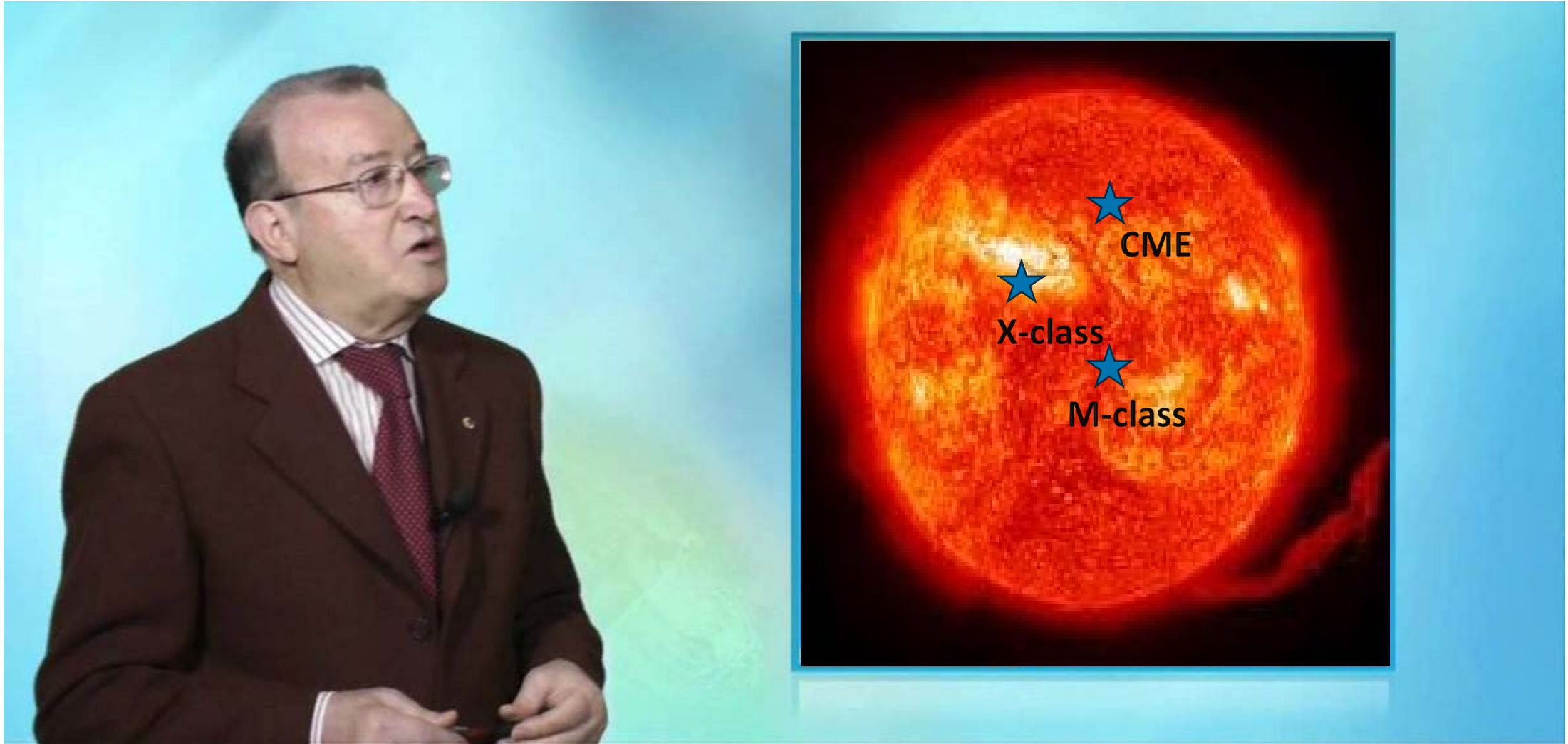
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## (Space) weather prediction





# (Space) weather prediction





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## The meteo-solar link

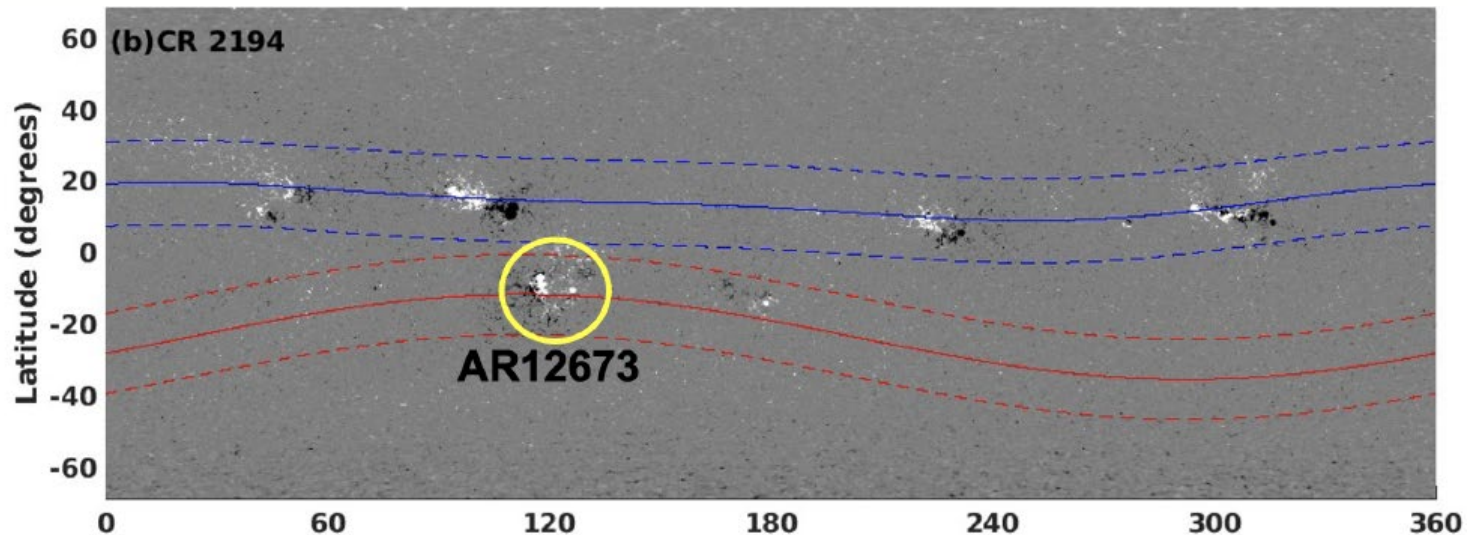
Behaviour on different scales determined by force balance.



# The meteo-solar link

Behaviour on different scales determined by force balance.

The synoptic (large) scale



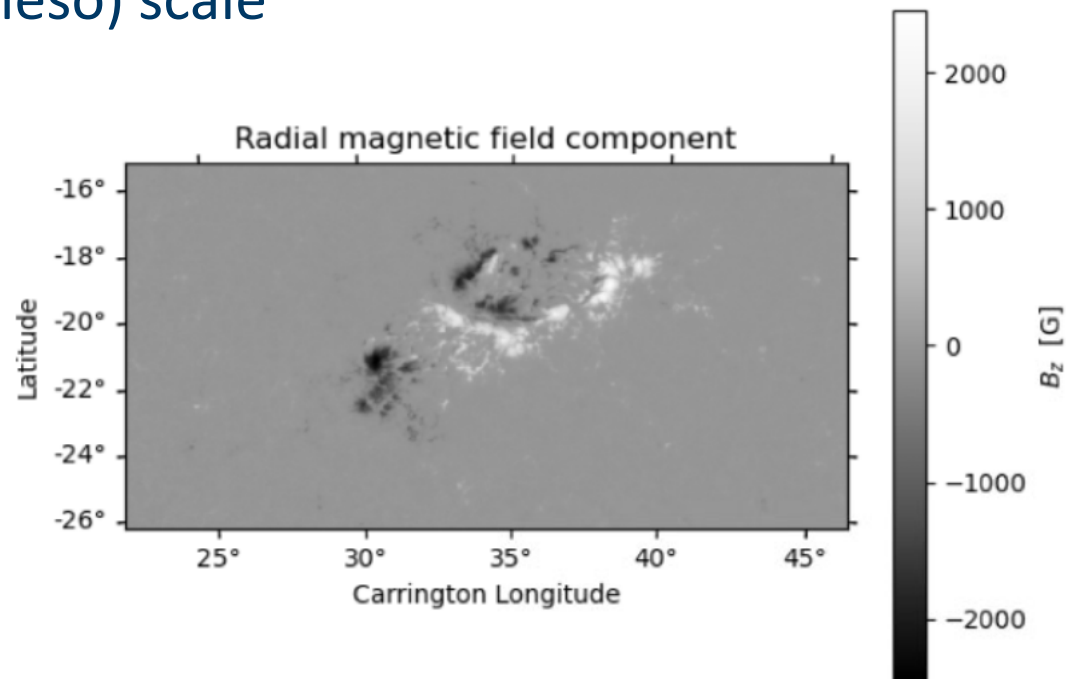
Raphaldini,..., MacTaggart 2023,  
submitted



# The meteo-solar link

Behaviour on different scales determined by force balance.

The active region (meso) scale

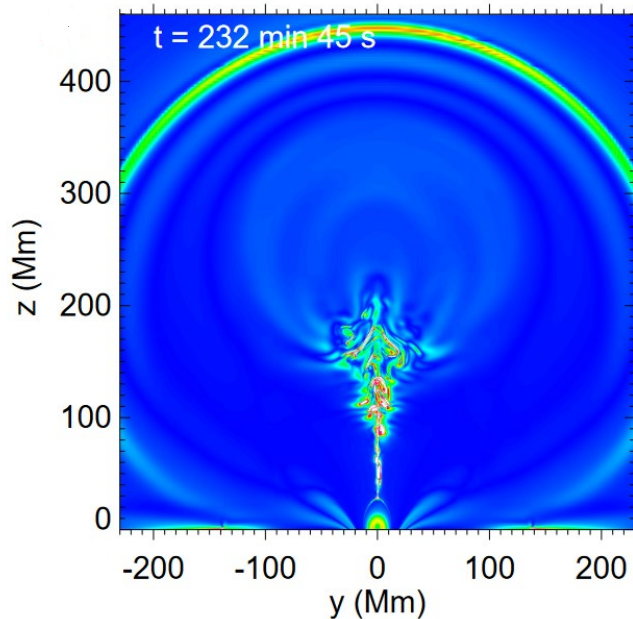


AR11158 from  
Alielden, MacTaggart, et al. 2023,  
RASTI, 2, 398

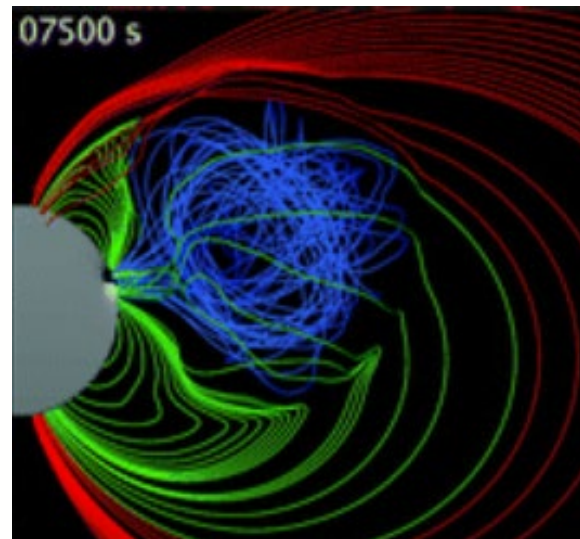


# Finding the key physics

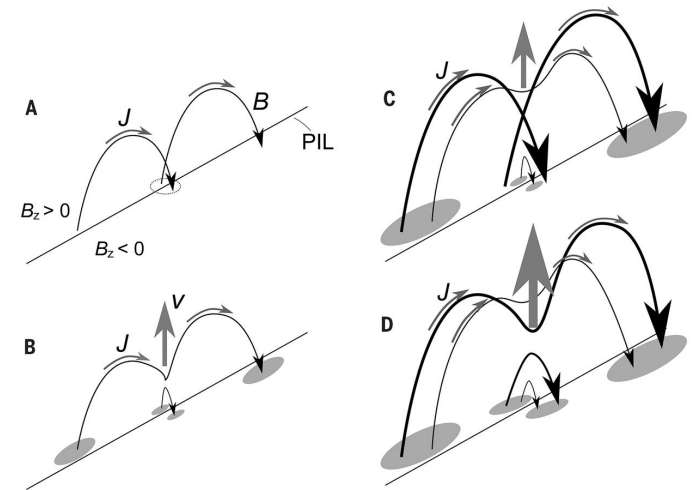
Many flare models depend fundamentally on *magnetic reconnection*



Tether-cutting/jet, from Jiang et al. 2021, Nat. Astro., 5, 1126



Breakout, from Lynch et al. 2008, ApJ, 683, 1192

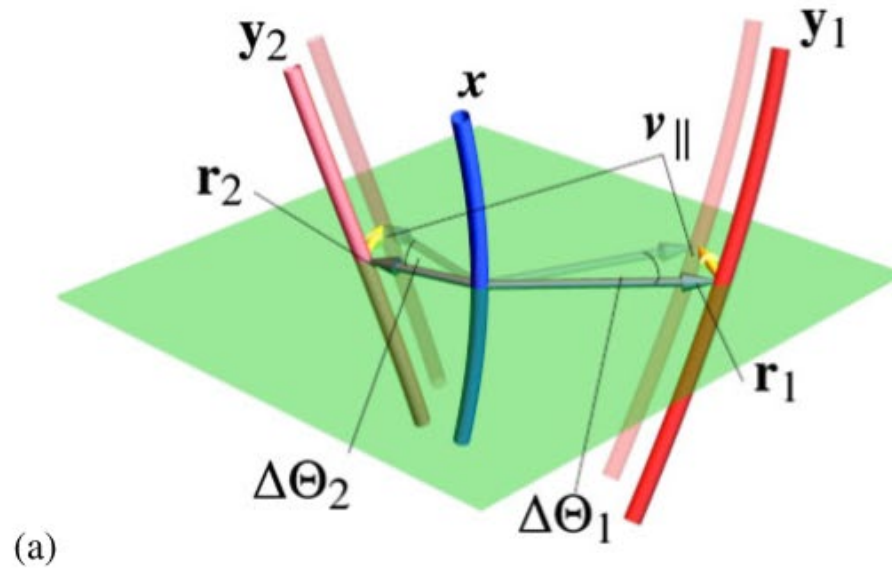


Double arc instability, from Kusano et al. 2020, Sci., 369, 587

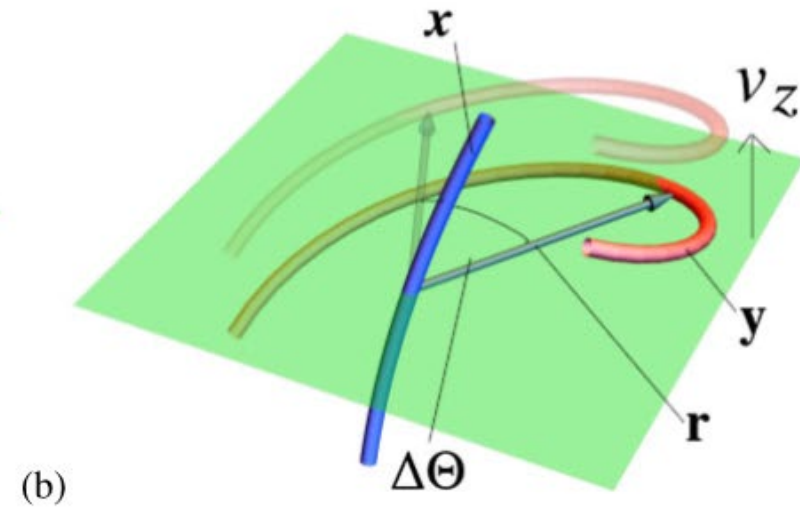


# Measuring the re-configuration

Topological changes due to reconnection have signatures at the photosphere



**braiding**



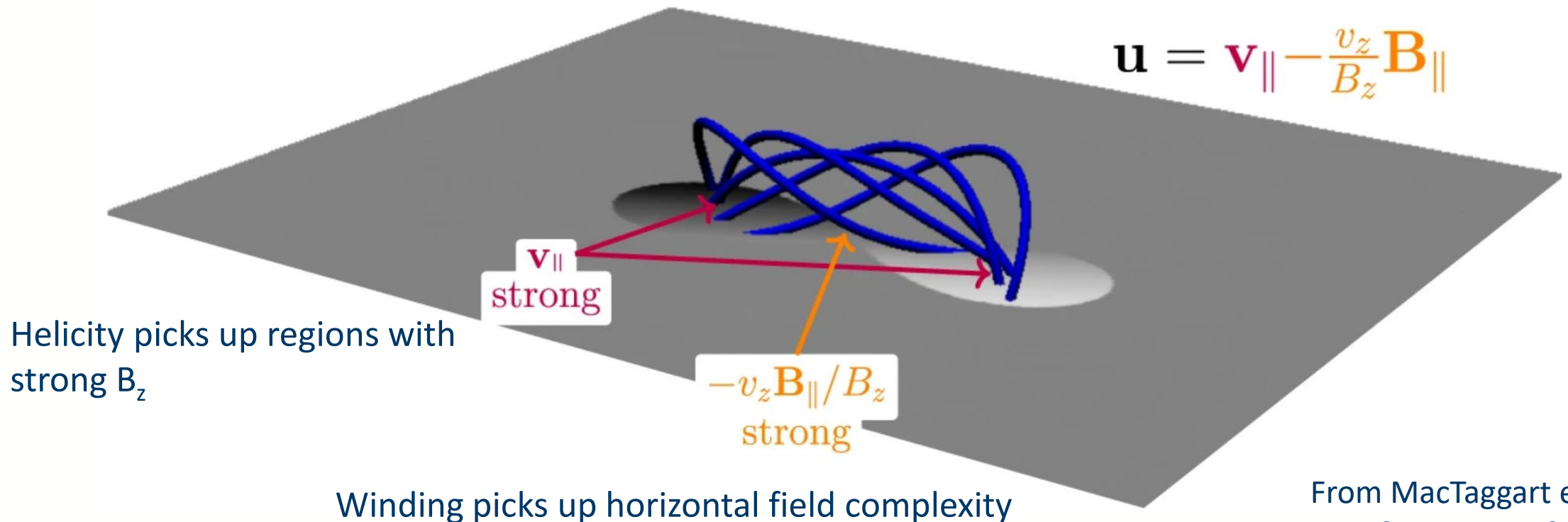
**emergence/submergence**





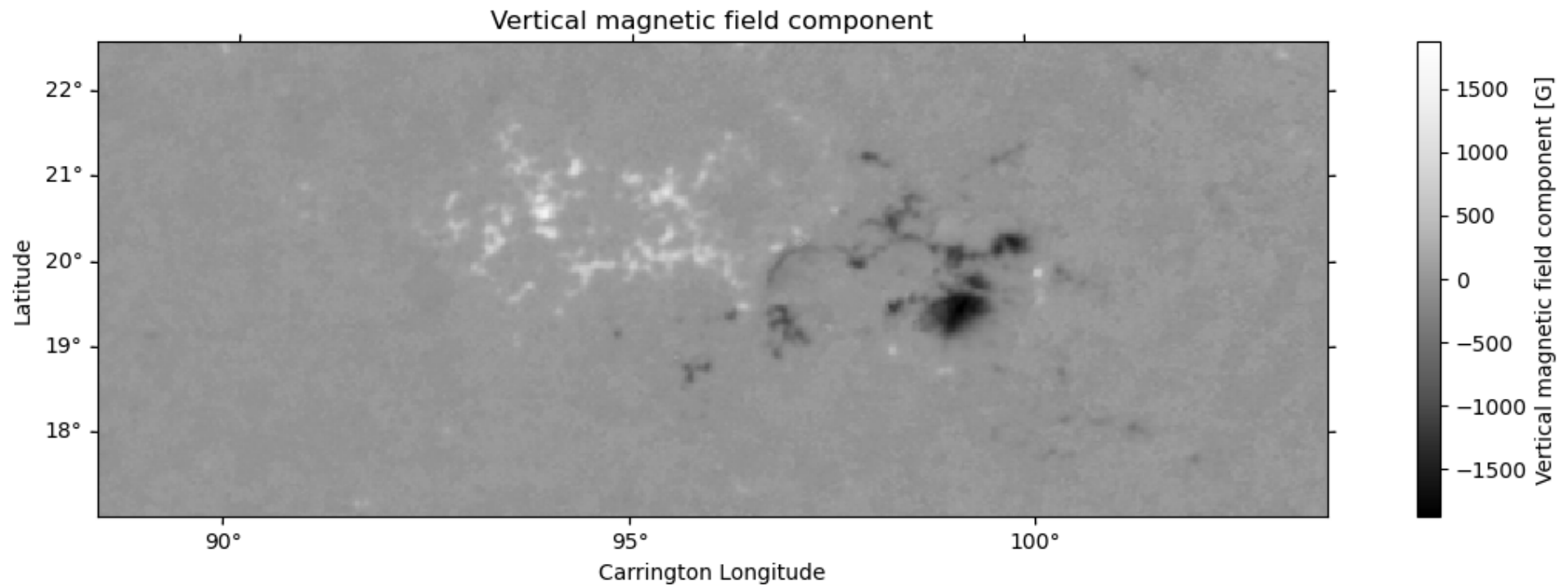
# Measuring the re-configuration

Key topological measures: Magnetic helicity and winding fluxes



# Example

## AR11318: Isolated bipolar region – 1 flare and 1 CME

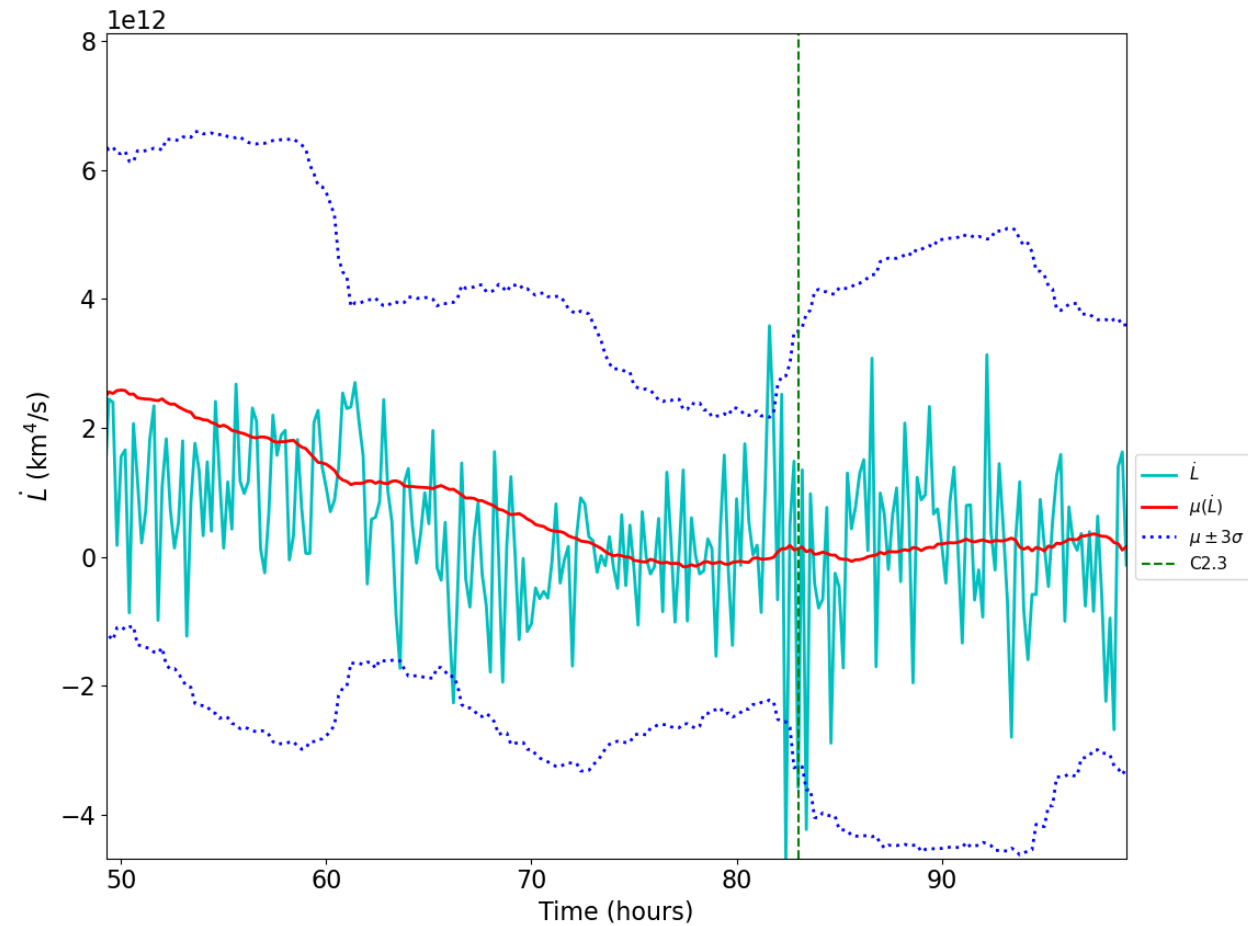


Magnetogram just before the flare



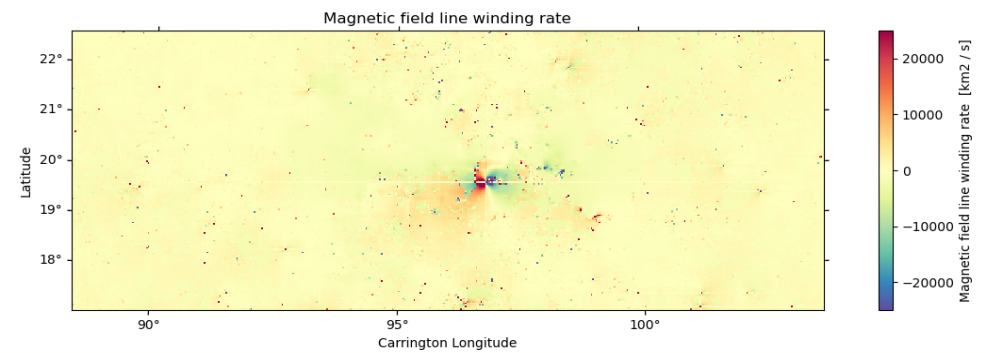
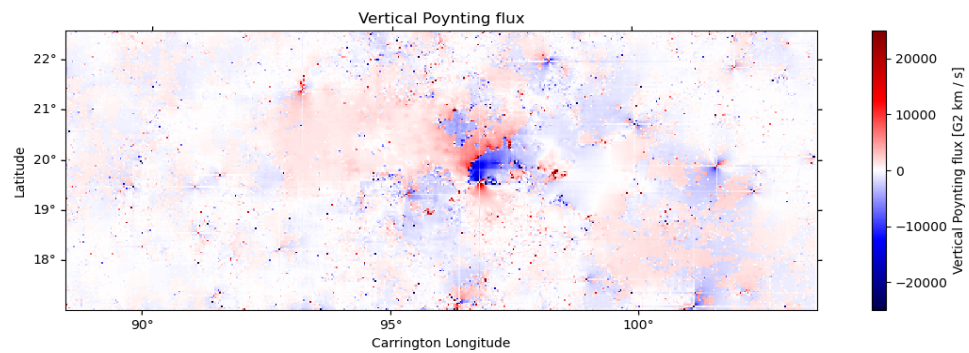
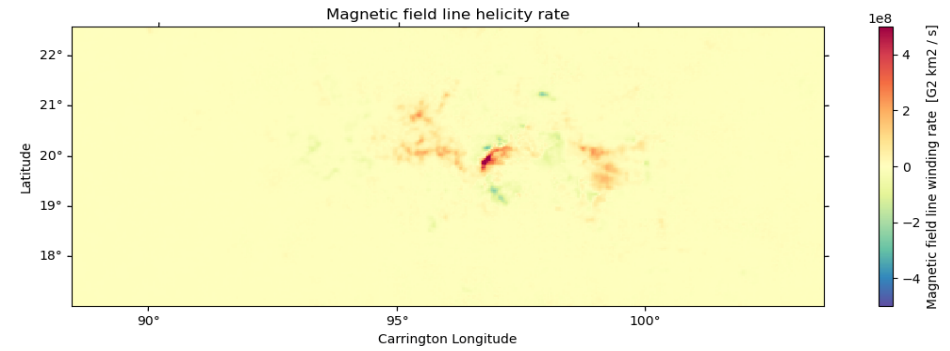
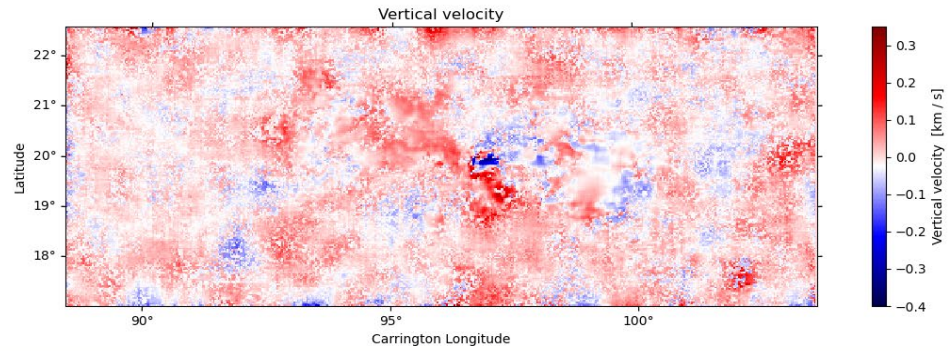
# Example: AR11318

## Magnetic winding signature in time





# Example: AR11318





## Summary

- Space weather (on the Sun) can be studied on different scales (synoptic, meso, etc.)
- Many flare models involve reconnection, leading to loops shrinking to the photosphere
- Magnetic winding can detect topologically non-trivial field moving at the photosphere
- Winding and other overlapping signatures can announce the onset of a flare or CME



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## Thanks to my collaborators

Chris Prior (Durham),

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Khaled Darwish (Aberystwyth)

Lyndsay Fletcher (Glasgow)

The more the merrier, please get in touch!



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Thank you for your attention

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