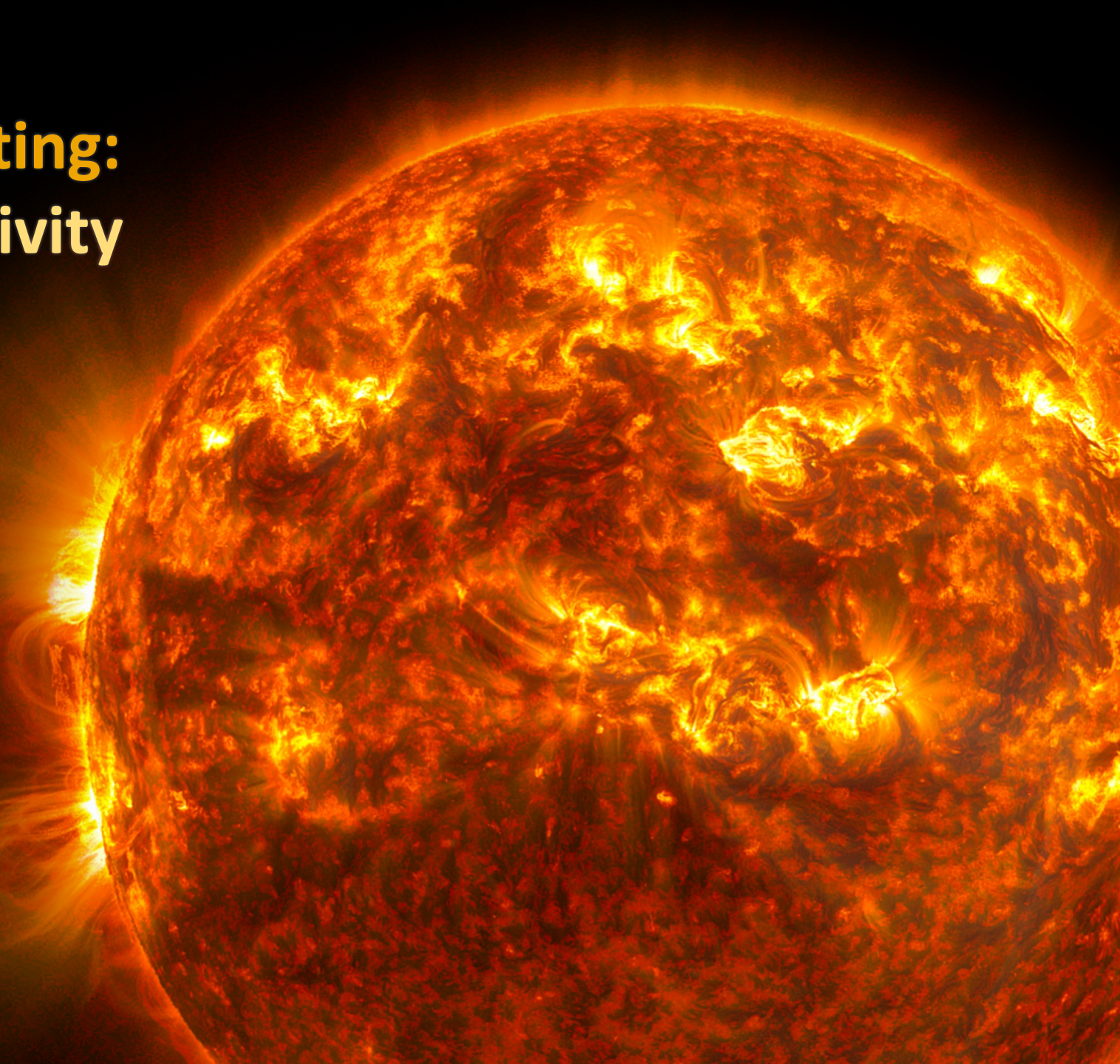
Solar Active Region Nesting: Impact on Magnetic Activity and Coronal Structure

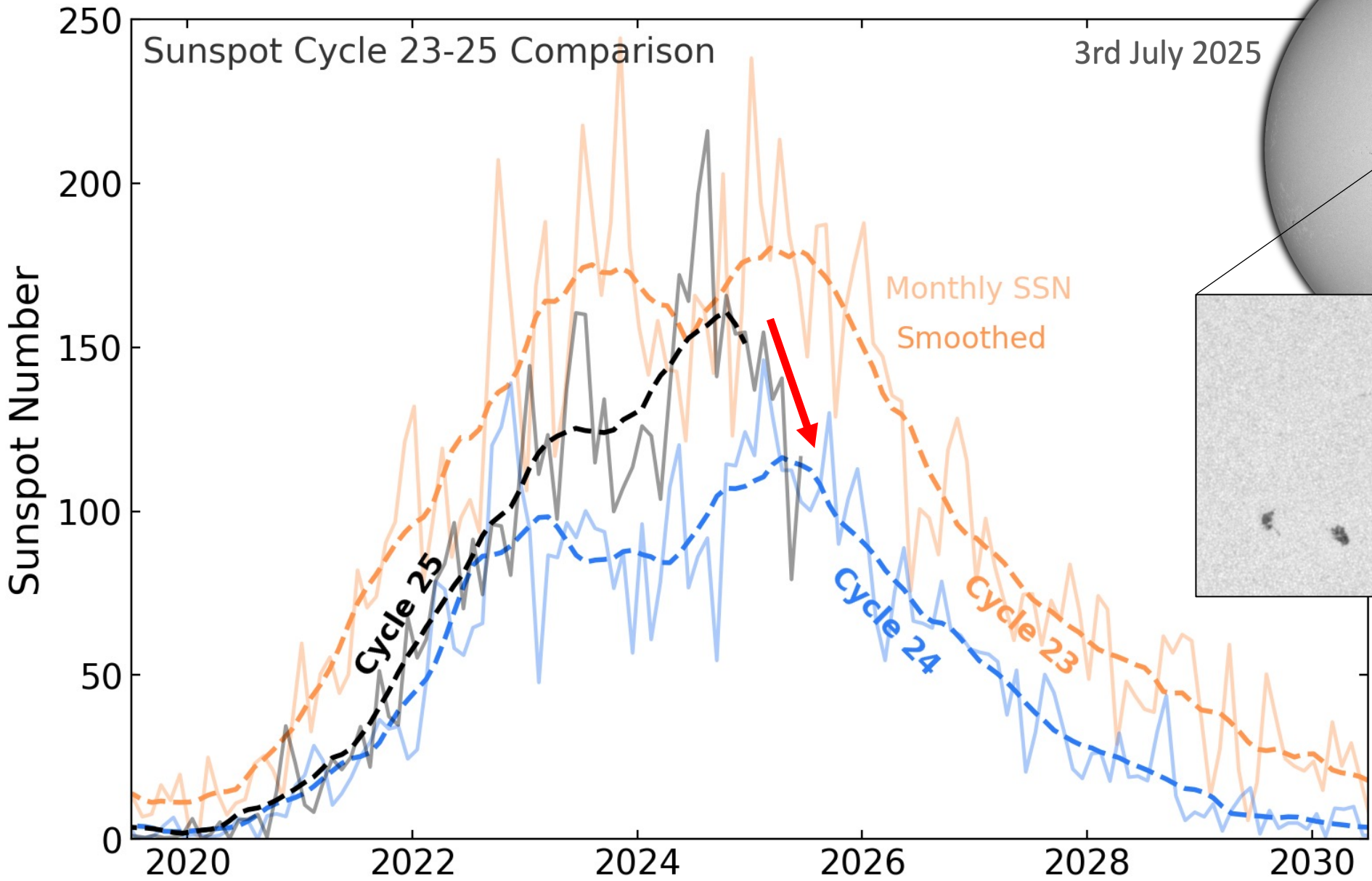
Adam J. Finley,
Sacha Brun, Antoine Strugarek & Barbara Perri
CEA Paris-Saclay, France

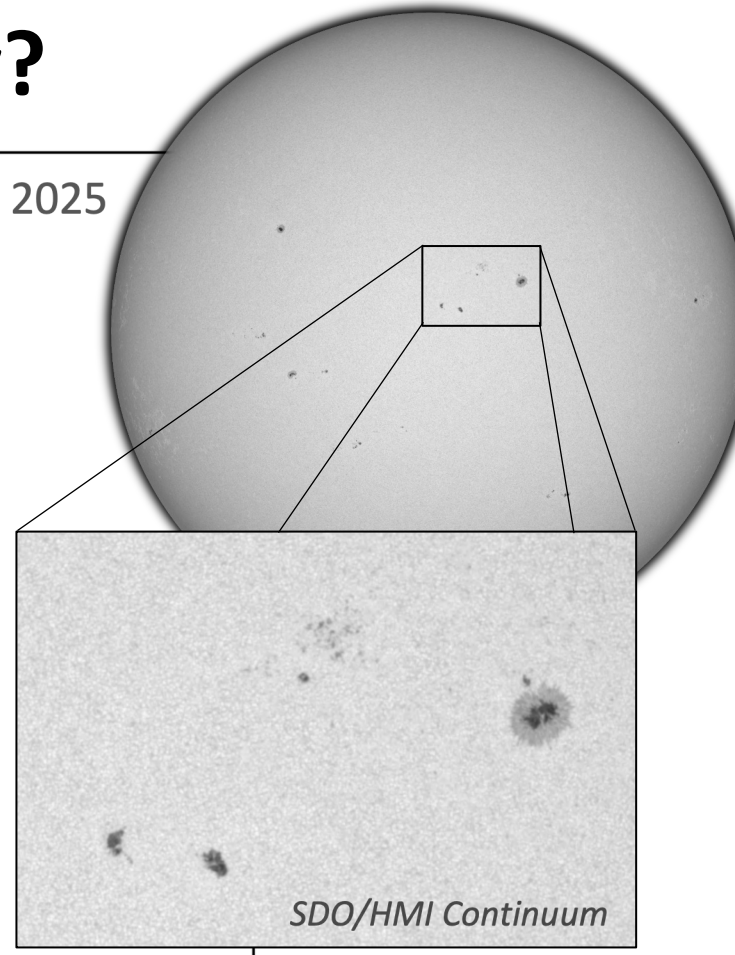
WholeSun Synergy Grant



UK NAM– Durham – July 2025

Sunspot Cycle 25: Passing Maximum Activity?

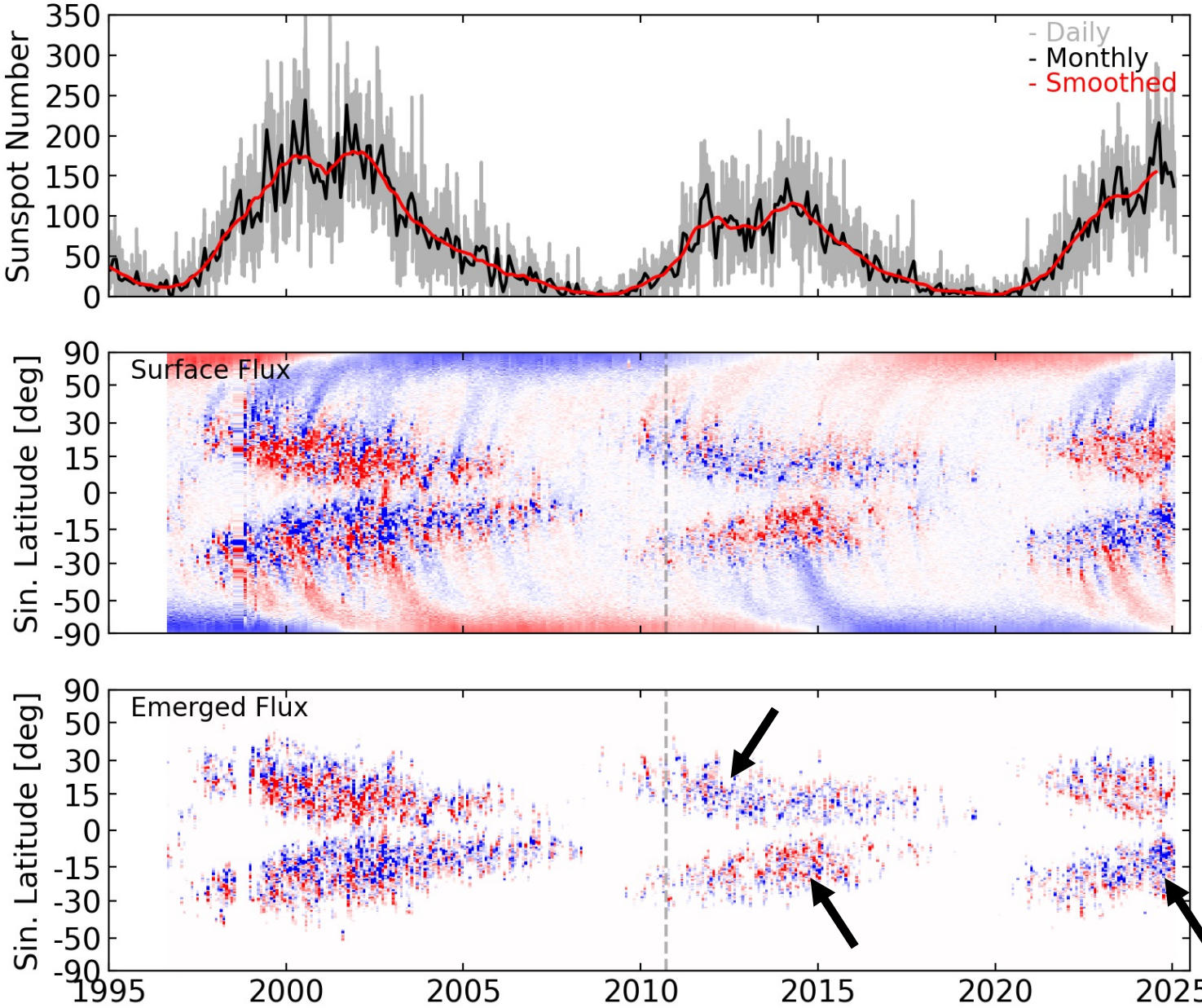




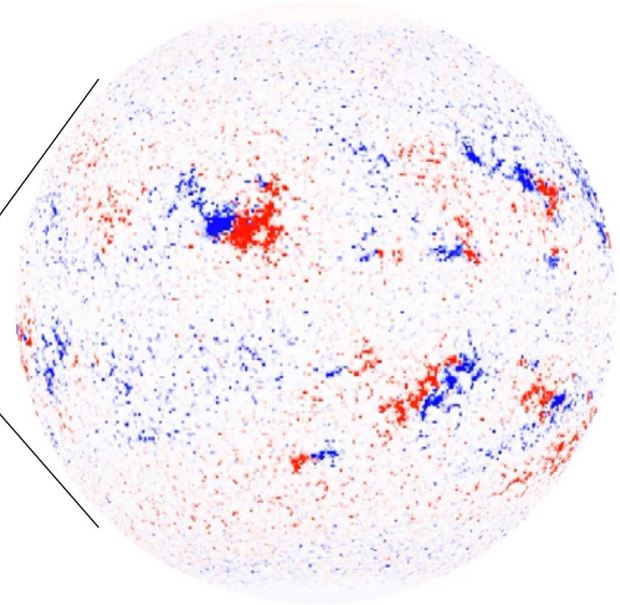
adam.finley@cea.fr

adamjamesfinley.github.io

Structure in Time and Latitude



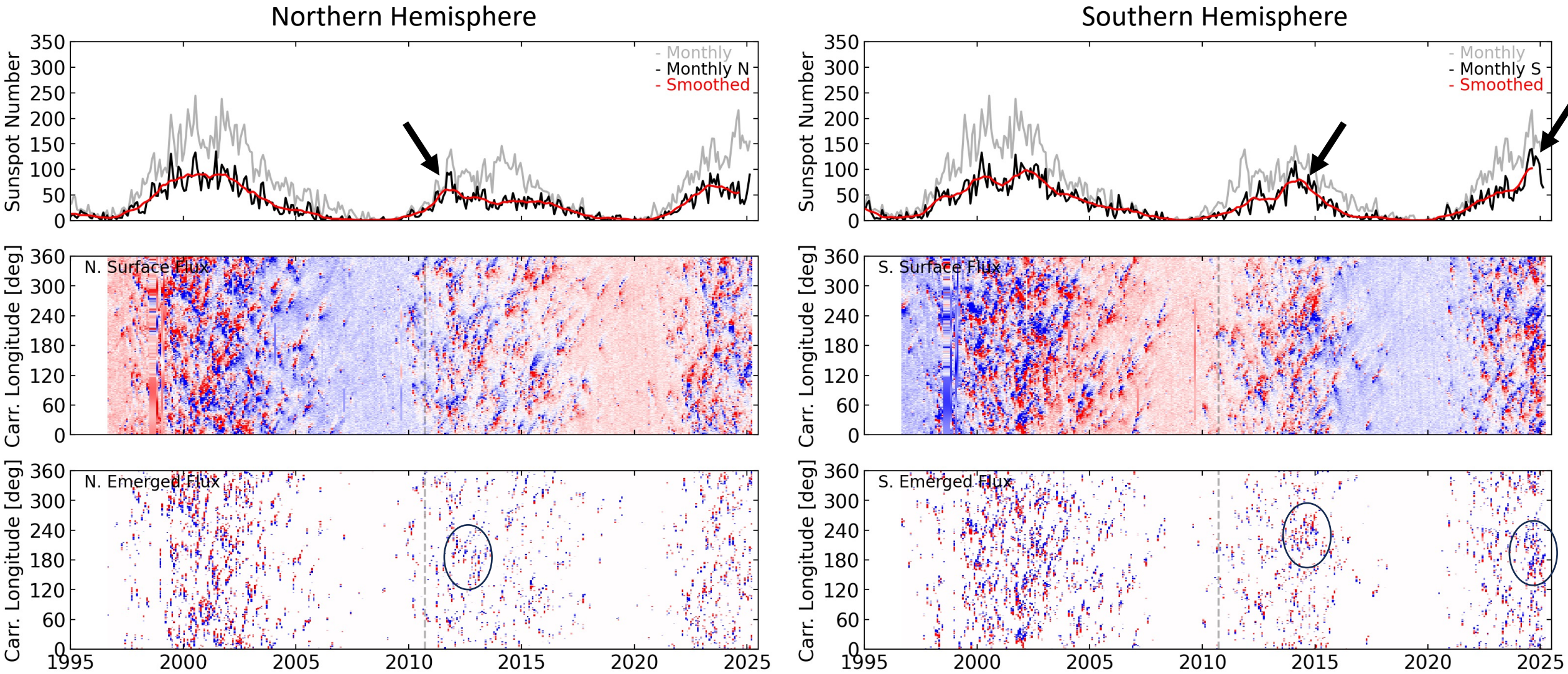
SOHO/MDI & SDO/HMI Magnetograms



adam.finley@cea.fr

adamjamesfinley.github.io

Structure in Longitude?



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adamjamesfinley.github.io

What is **Active Region Nesting**?

Up to **50% of flux emergence events** occur in close proximity to previously emerged active regions (Schrijver & Zwaan 2008).

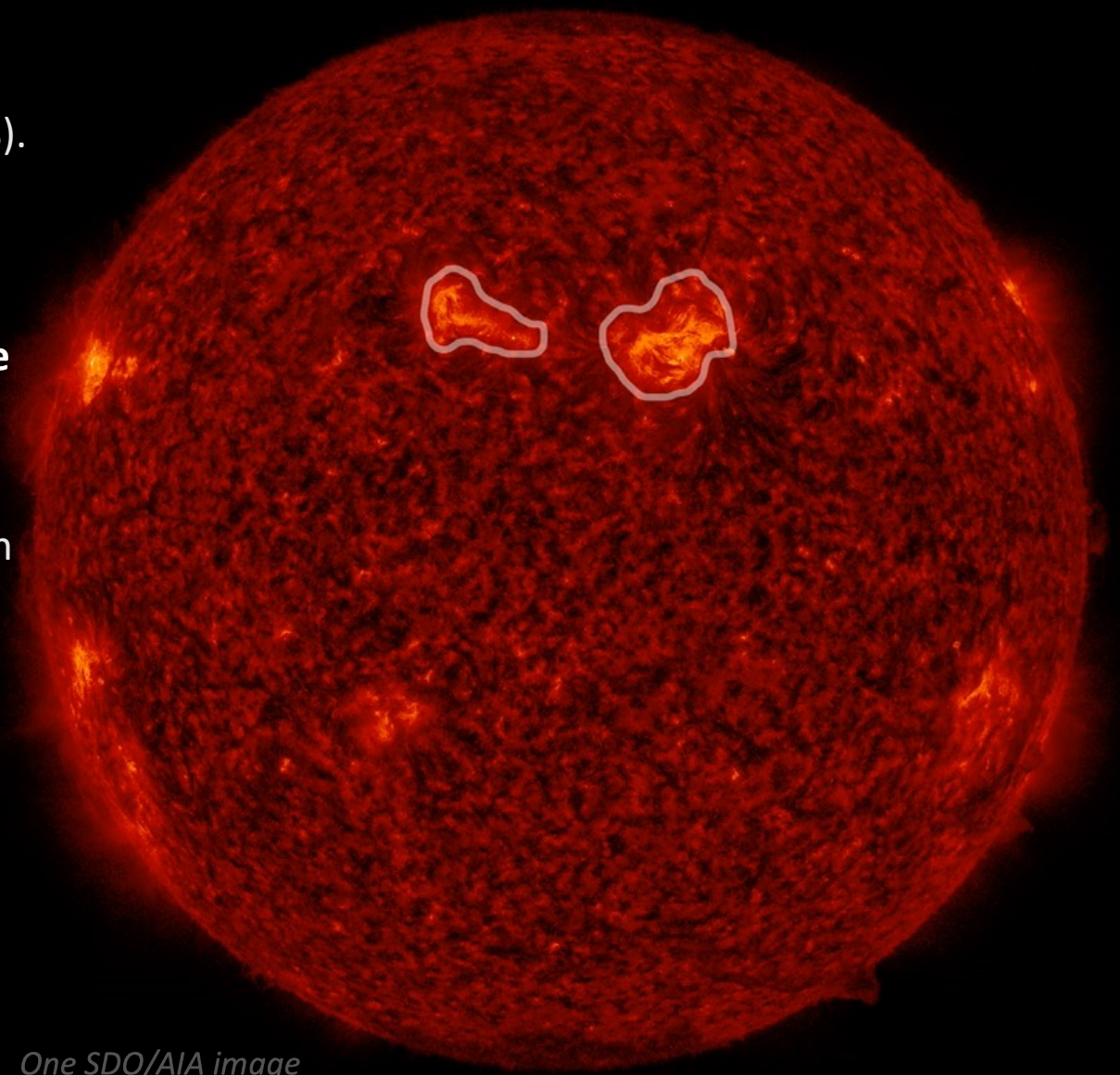
No clear definition in the literature; typically based on timescales for continuous activity.

Previous works point to **long-term (years to cycles) coherence** in the appearance of active regions (Berdyugina & Usoskin 2003).

Active longitudes are observed on other **Sun-like stars** (Breton et al. 2024) in photometry (Kepler, TESS, upcoming **PLATO**).

Broad Definition: Repeated flux emergence events that produce coherent activity over multiple solar rotations.

Could be linked to the flux emergence process itself, i.e., instabilities in the generation or storage of magnetic flux within the solar interior.



One SDO/AIA image per Carrington rotation (27.28 days)

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adamjamesfinley.github.io

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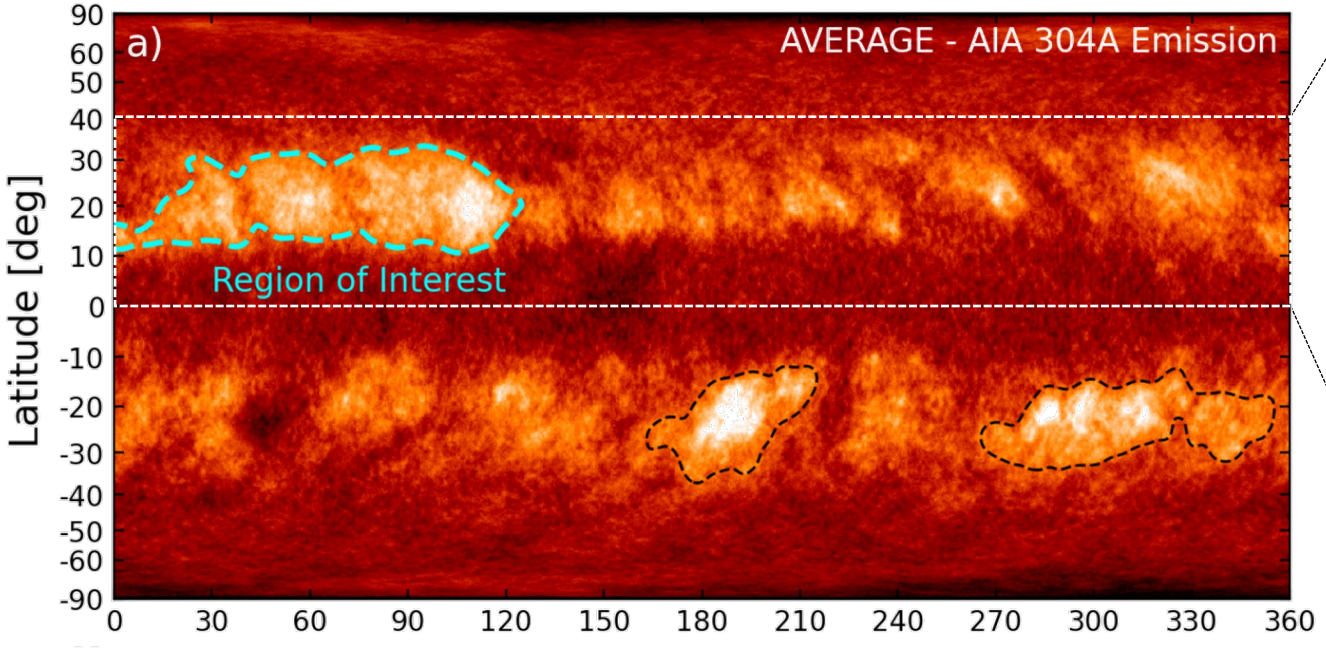

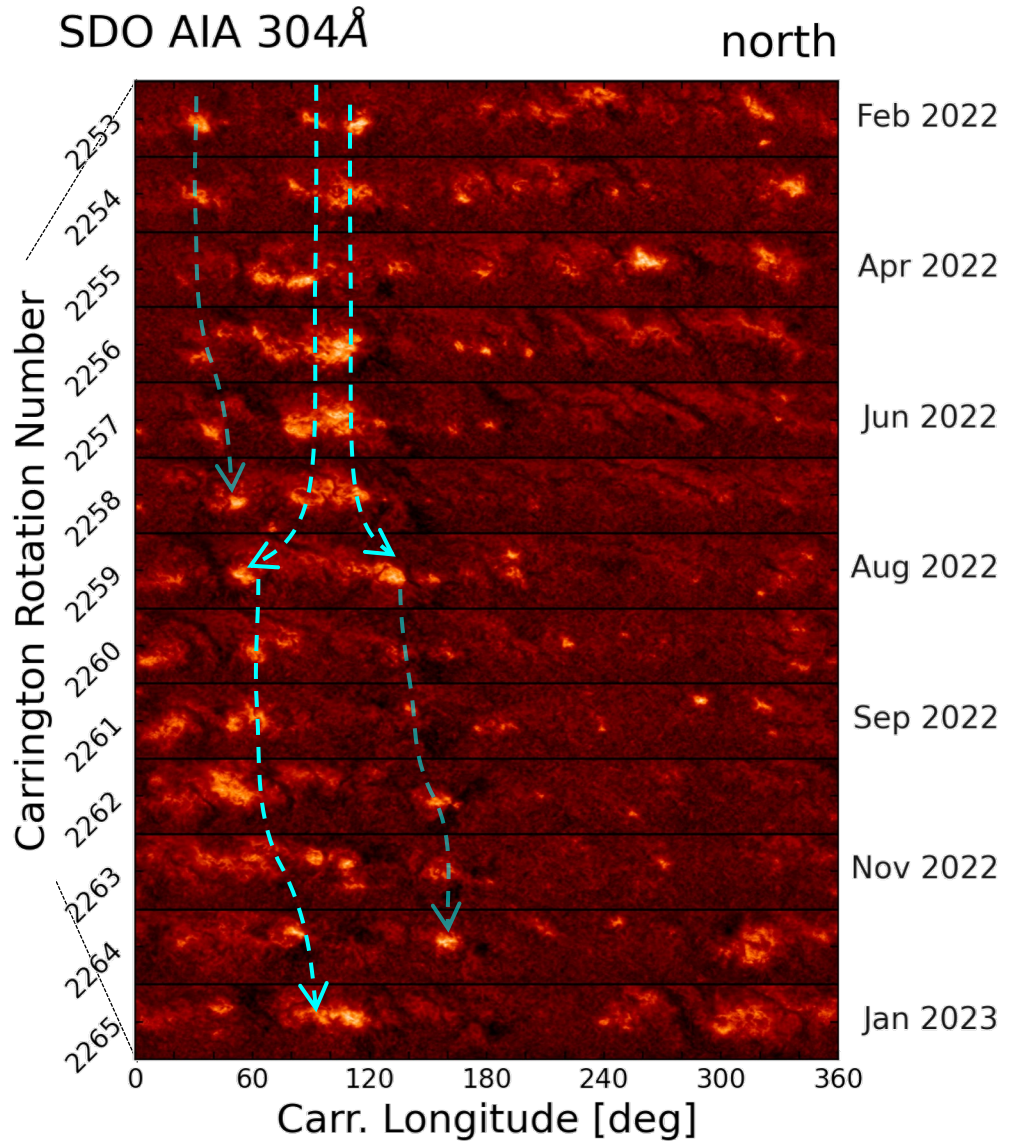

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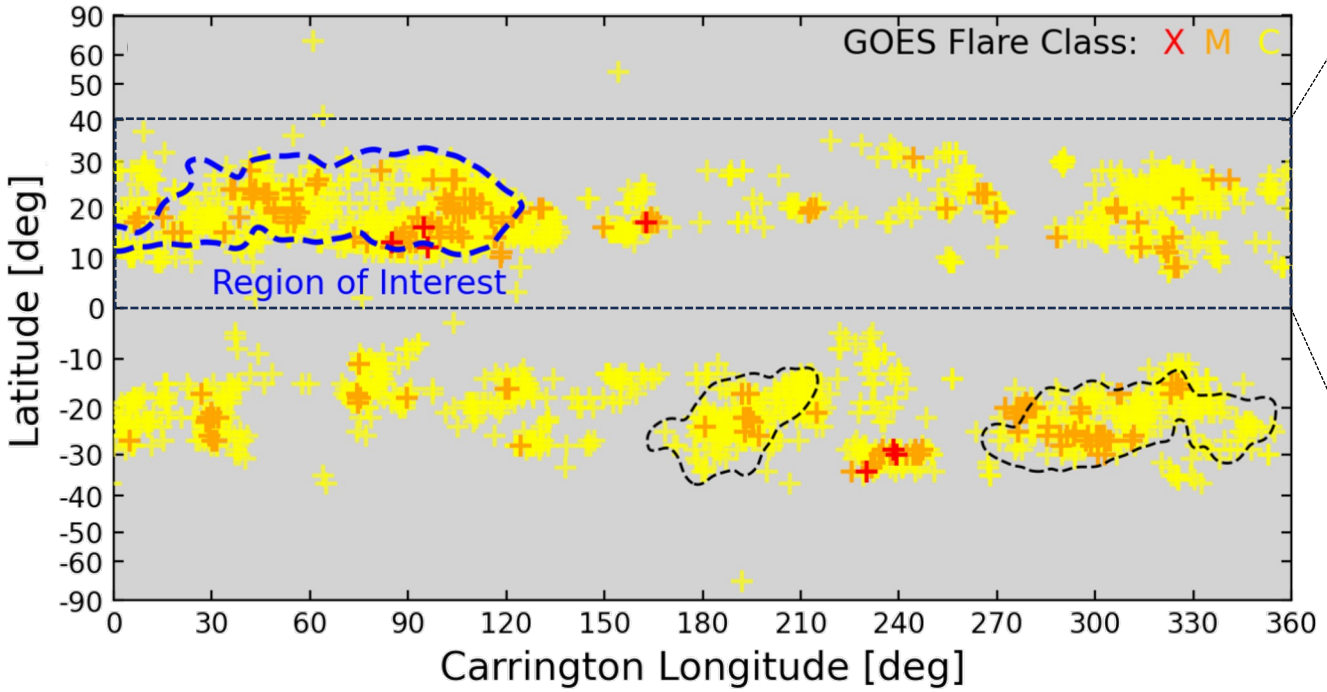

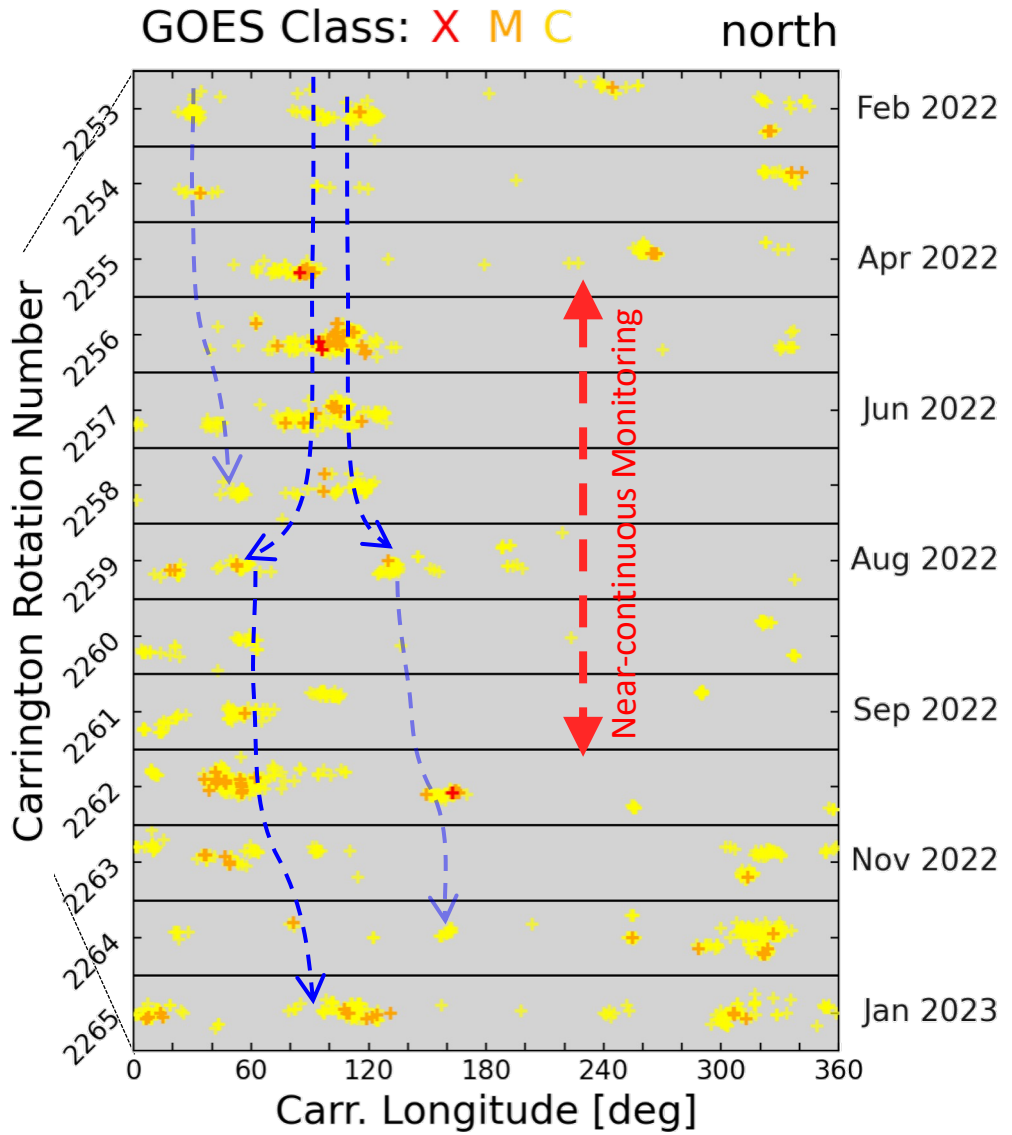

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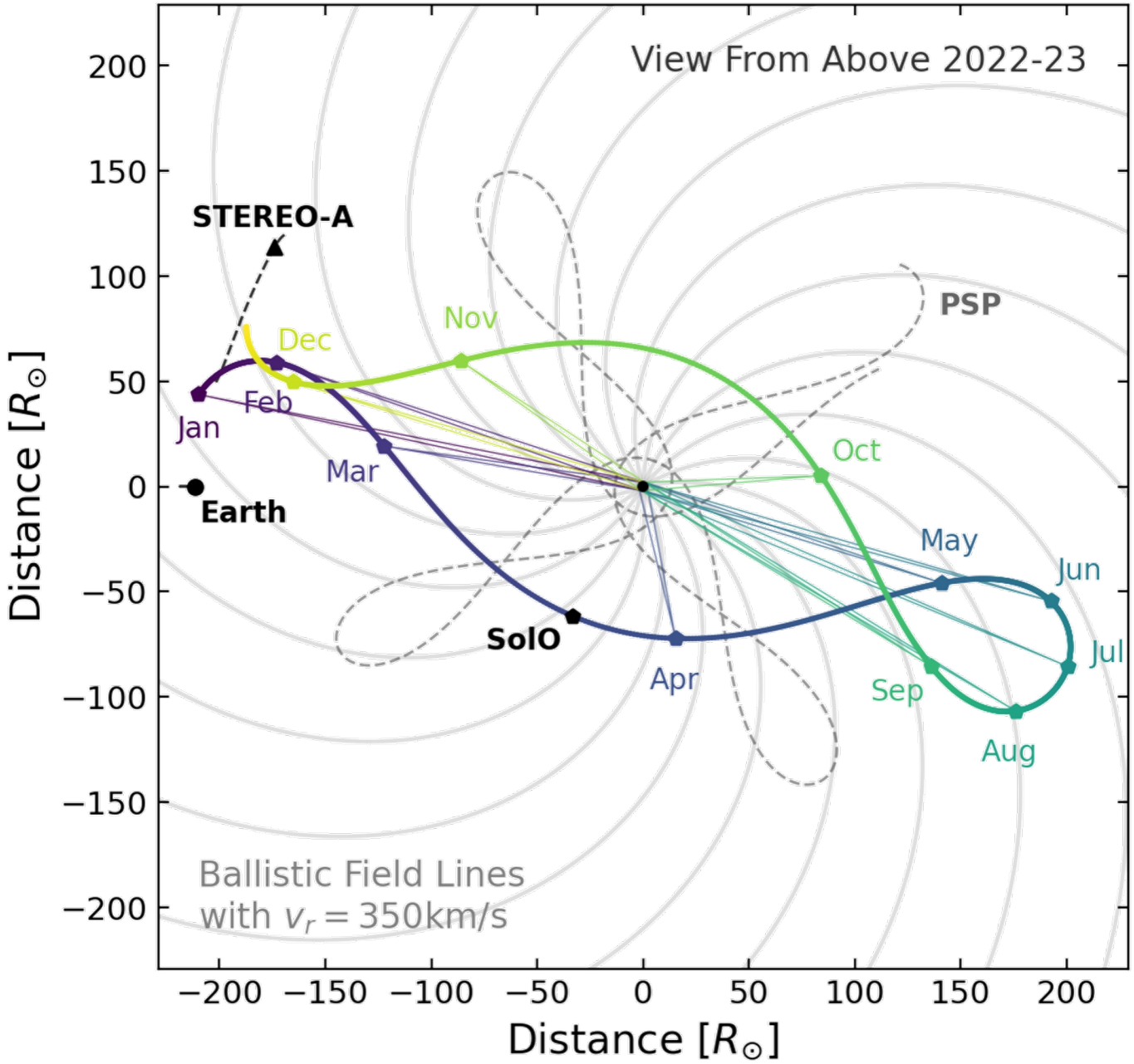
Relative Positions in 2022

Solar Orbiter

Earth:
SDO and GOES

STEREO-A



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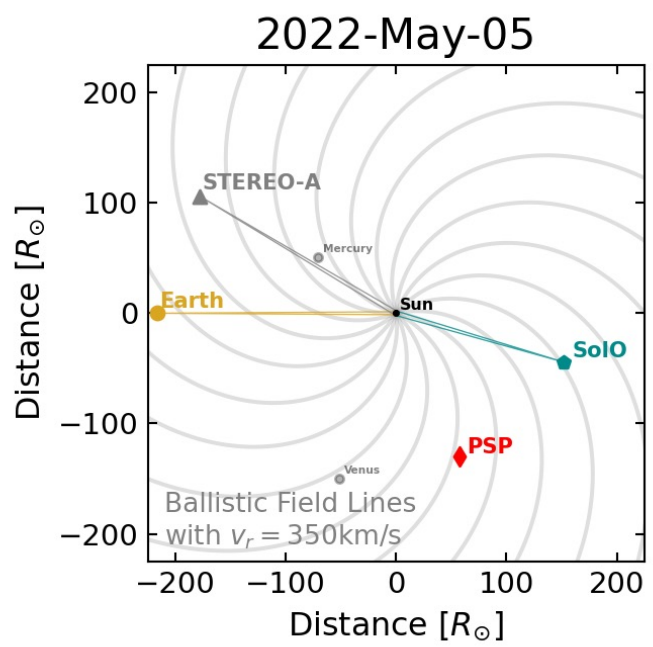

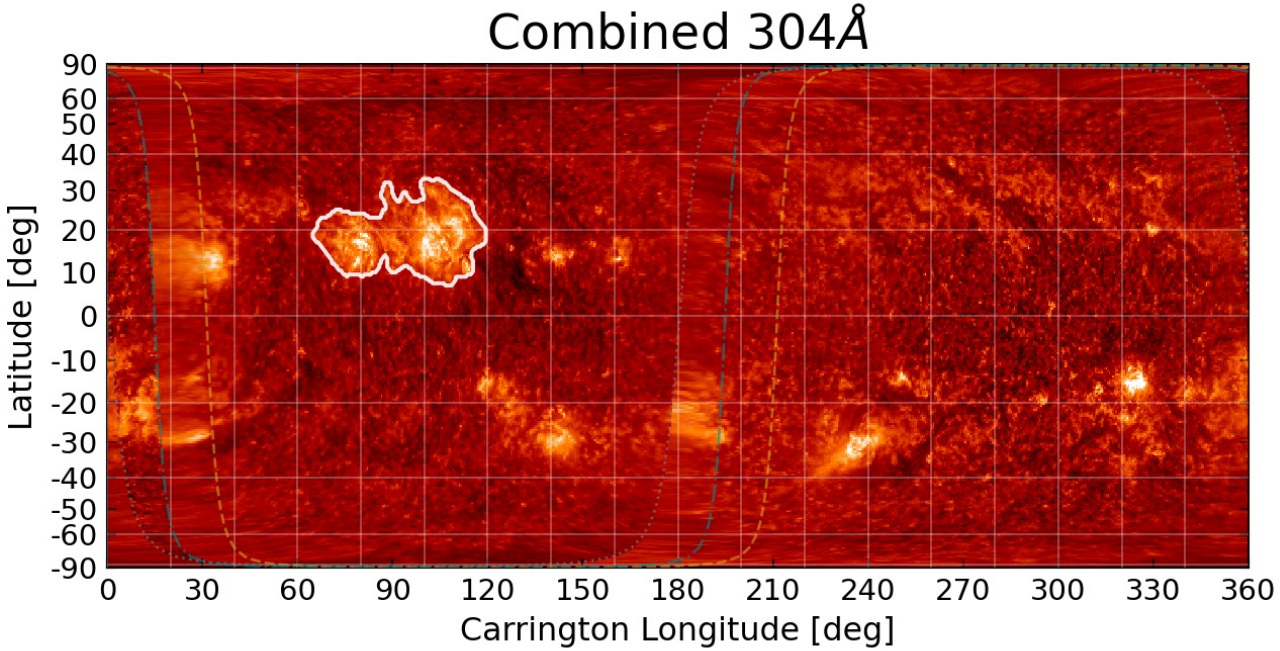

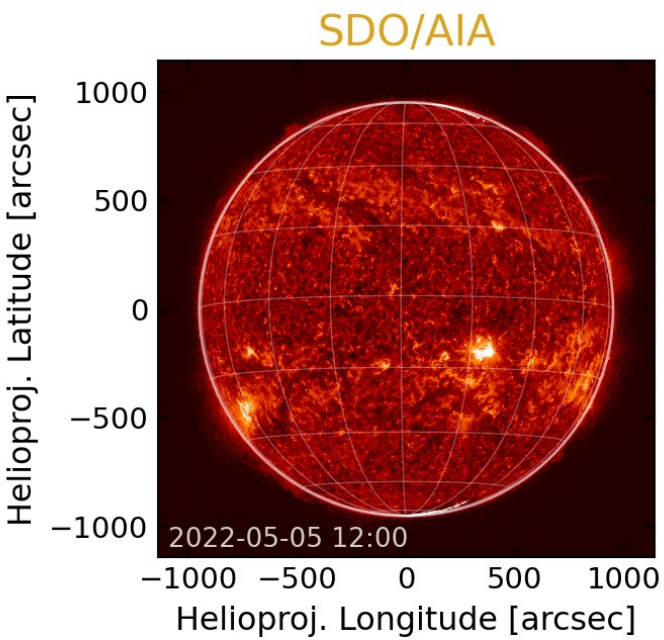

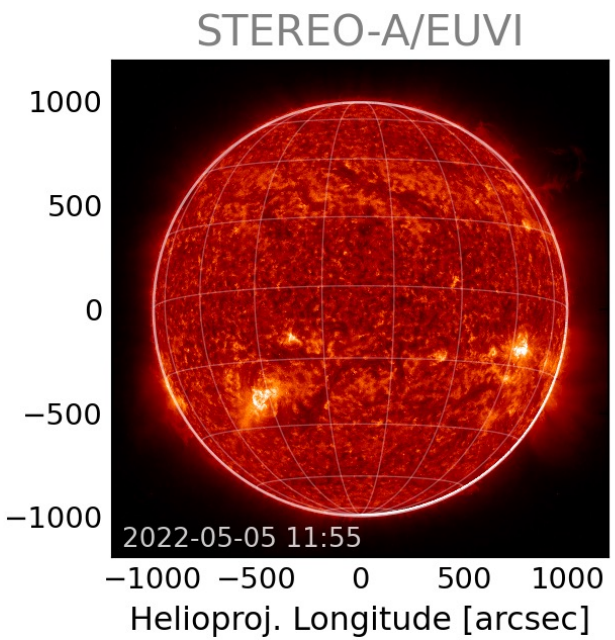

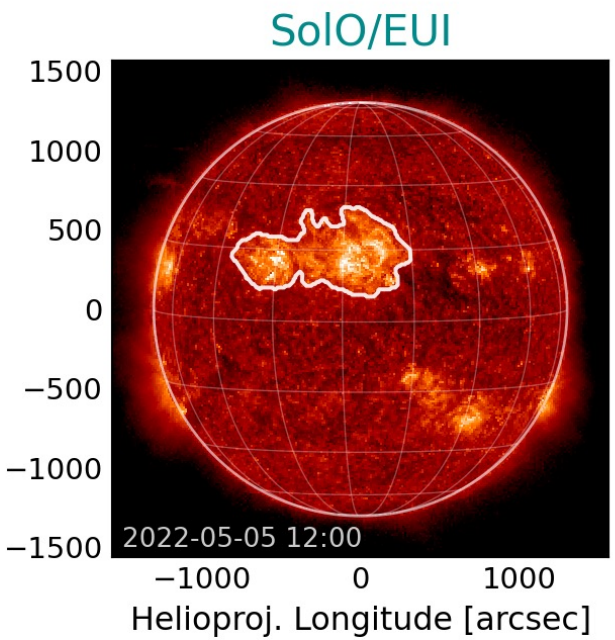

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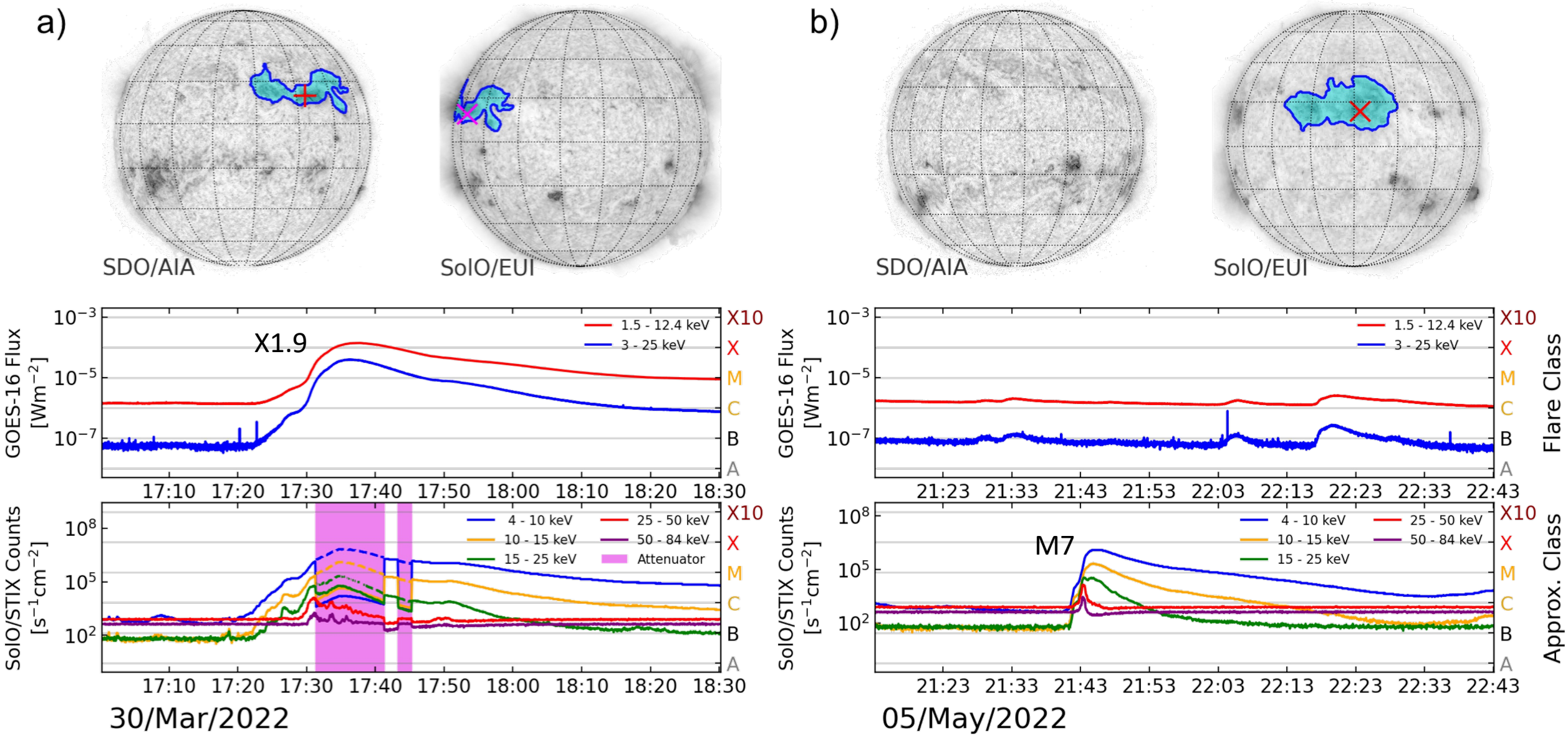

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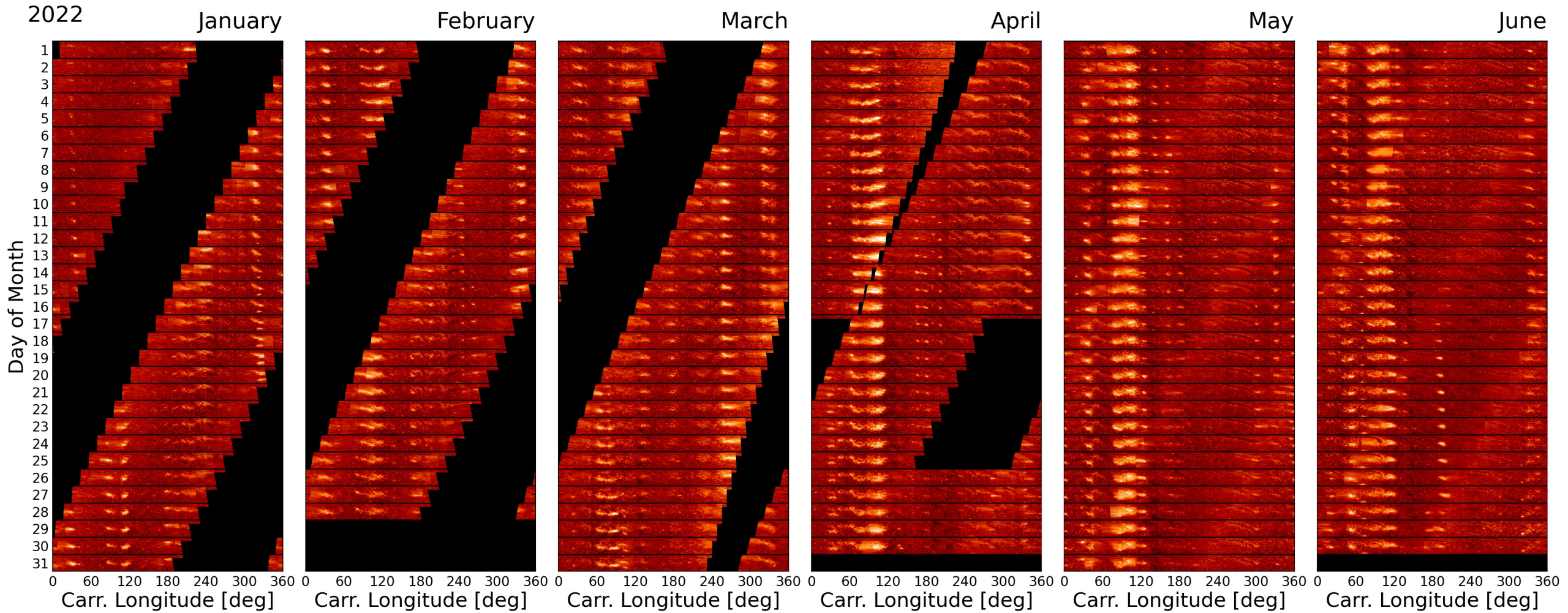

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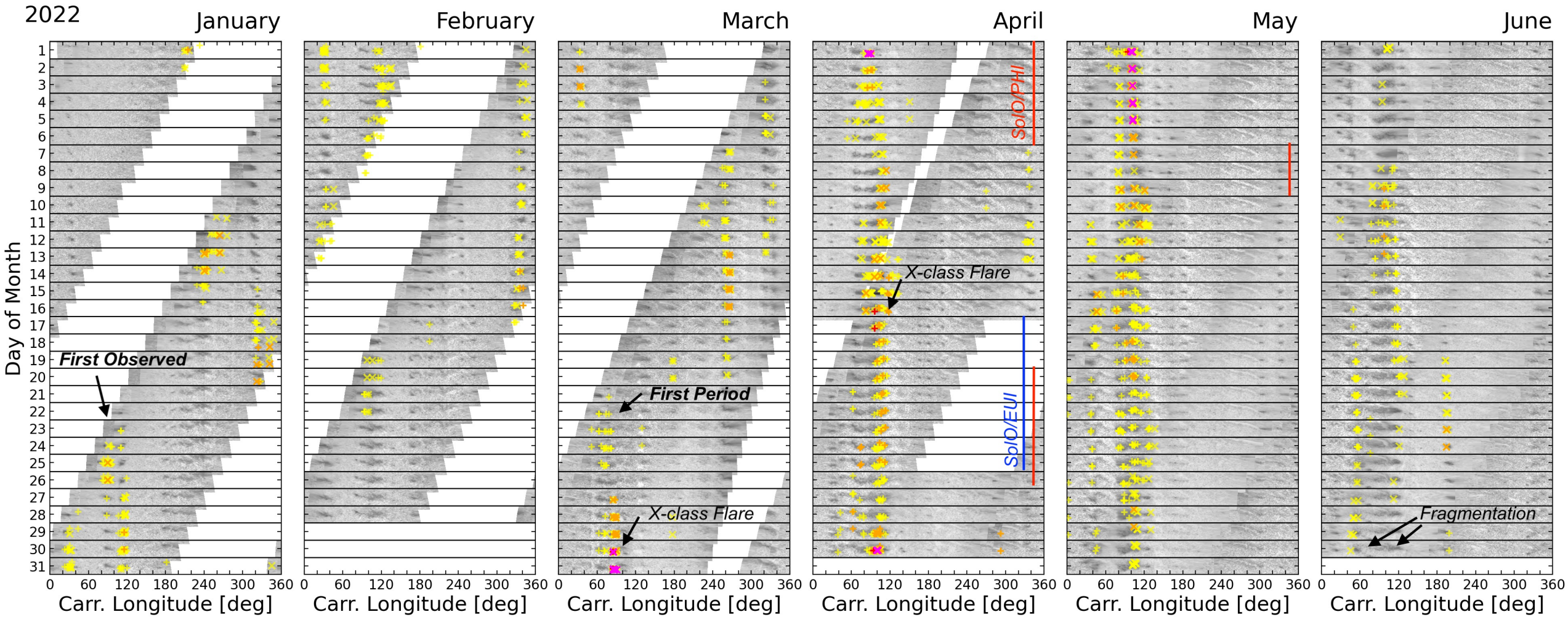

(far-side helioseismology can be used to fill the gaps)

Evolution of Solar Activity in the Northern Hemisphere (2022)

Greyscale -> EUV 304A Emission

Markers -> GOES and STIX Solar Flares (X M C class)

adam.finley@cea.fr

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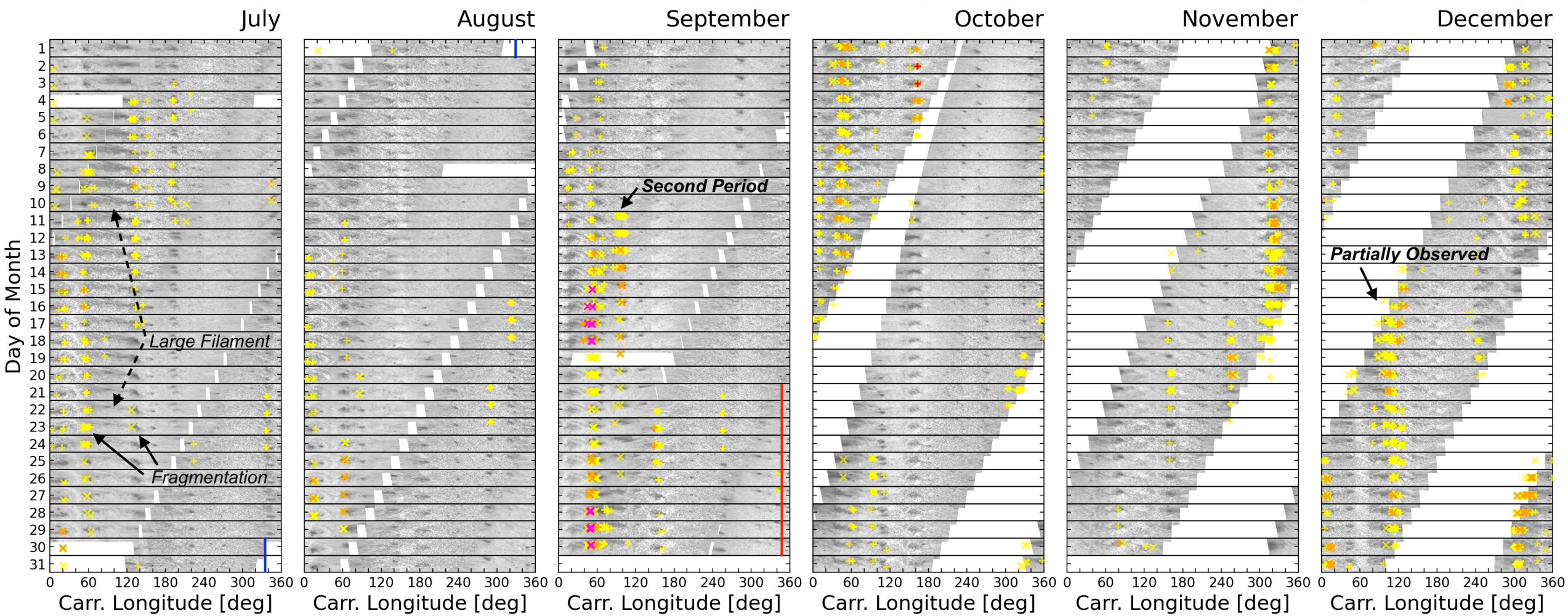

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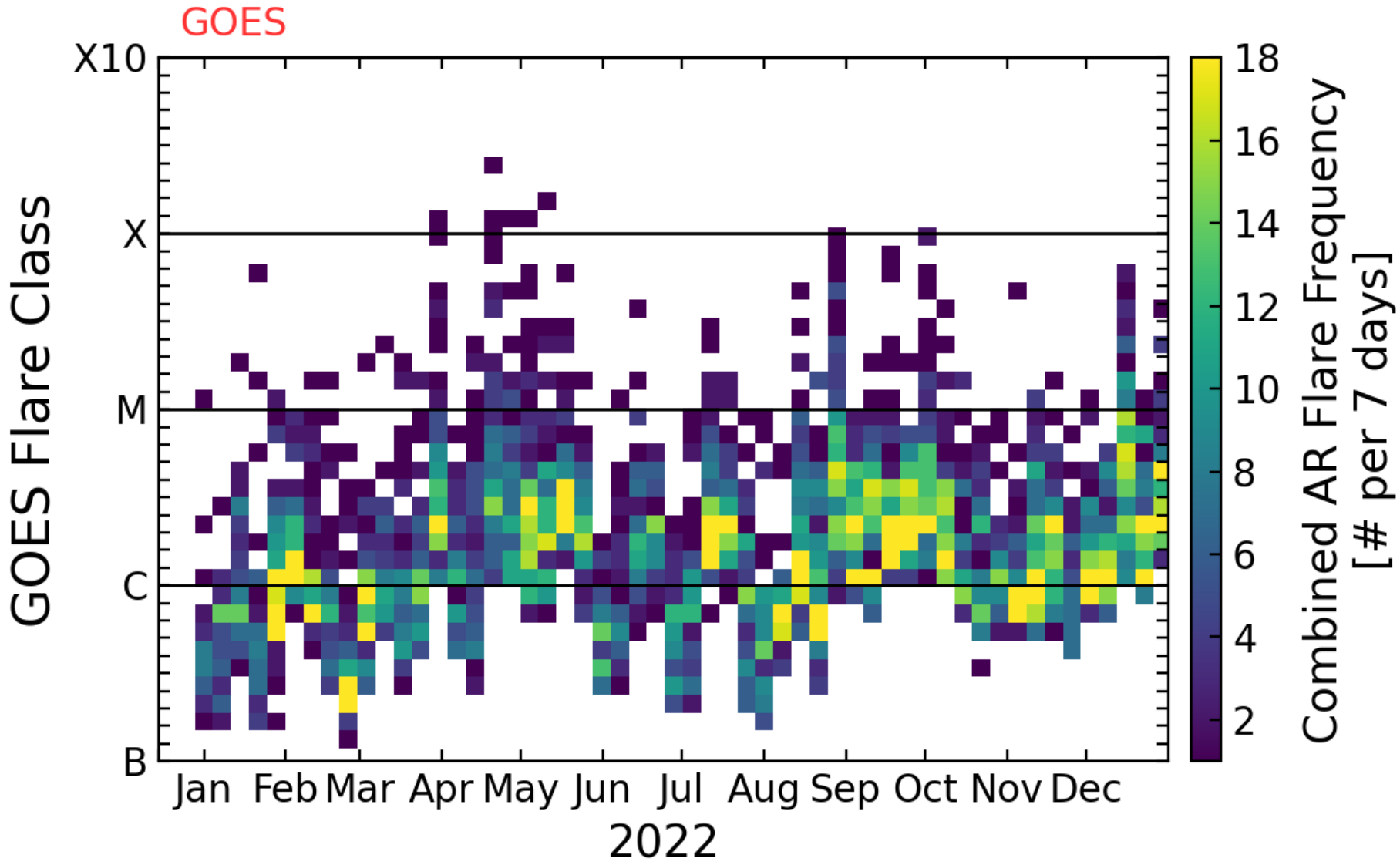
Combined Solar Flares from Nested Active Region



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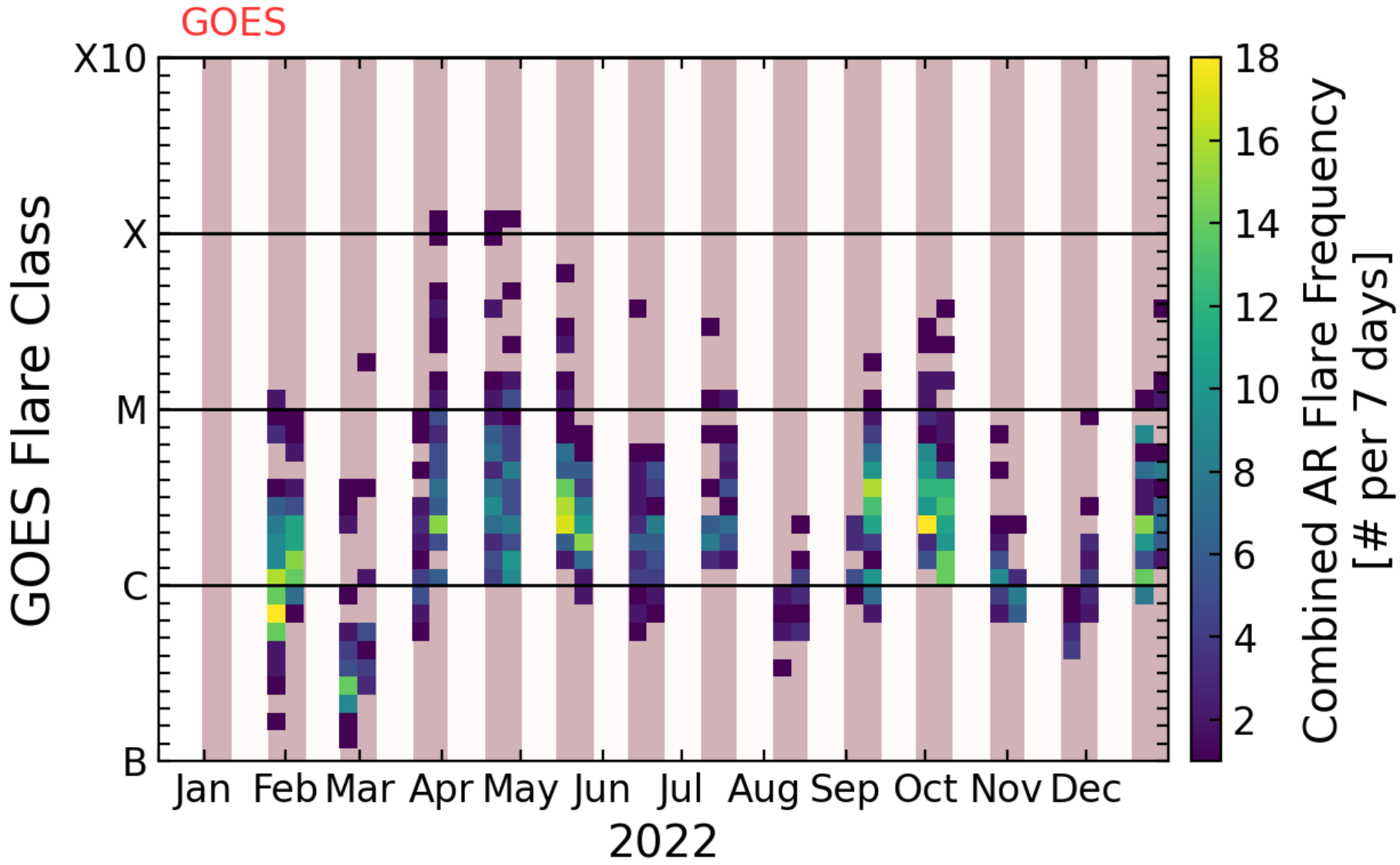

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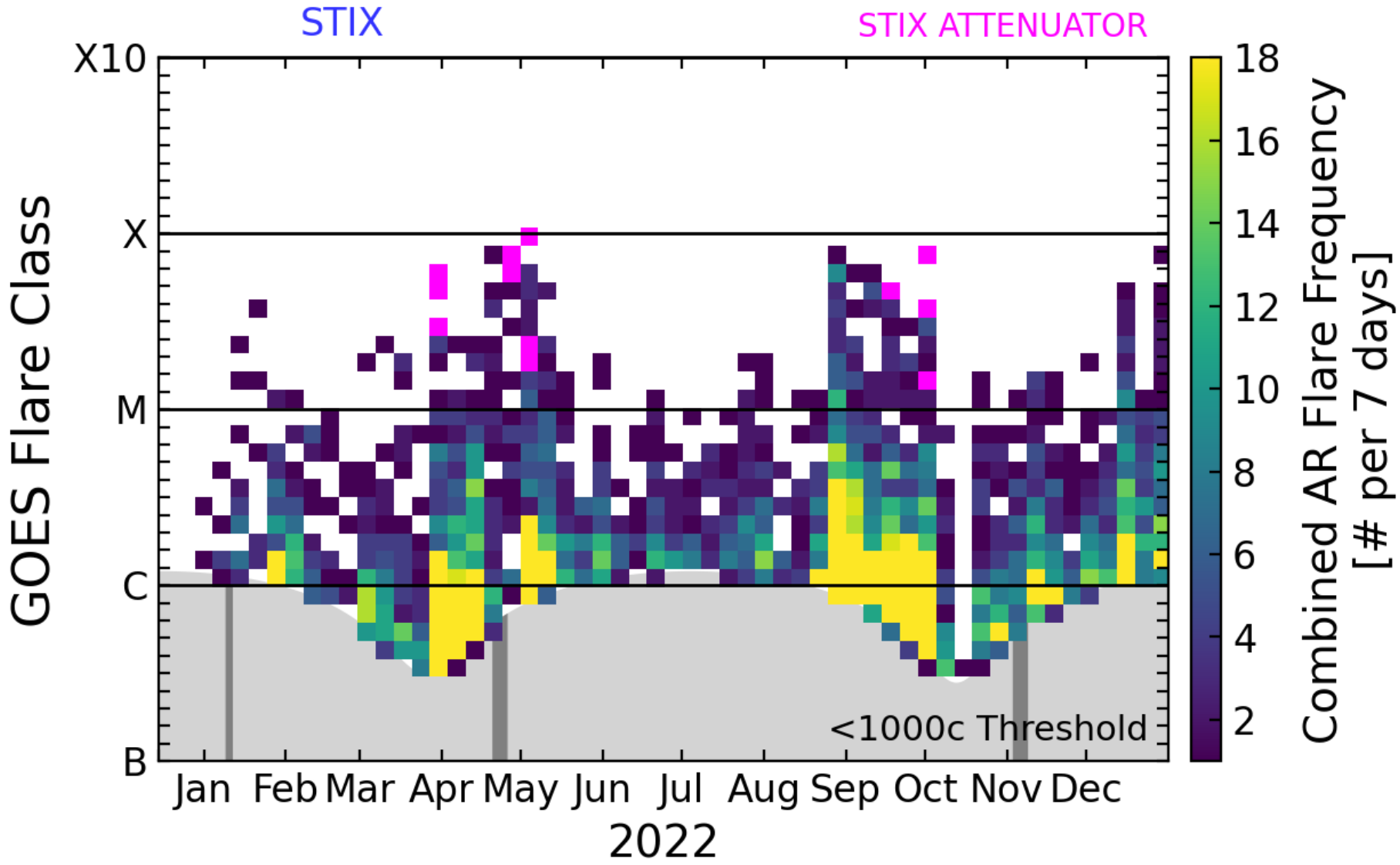

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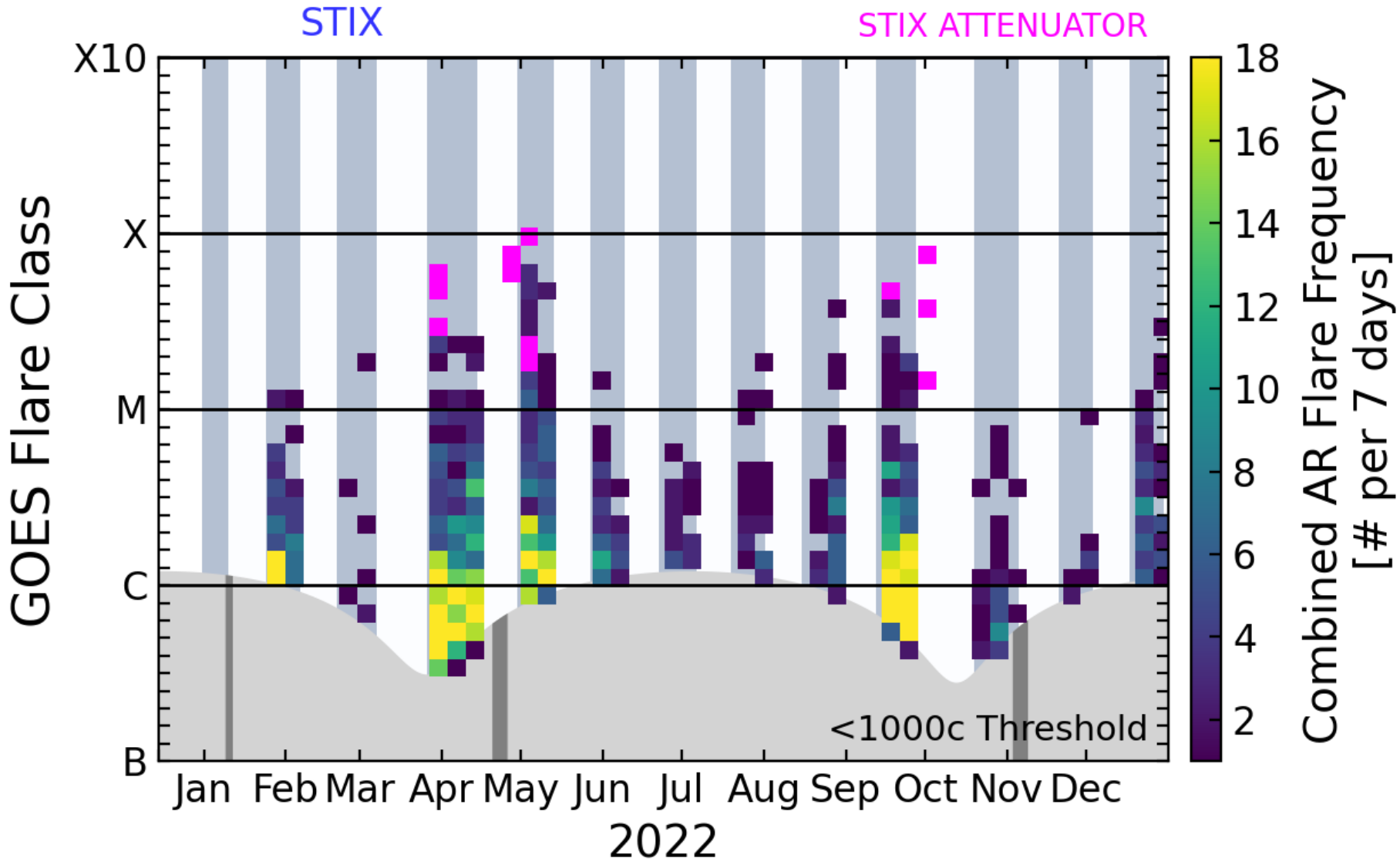

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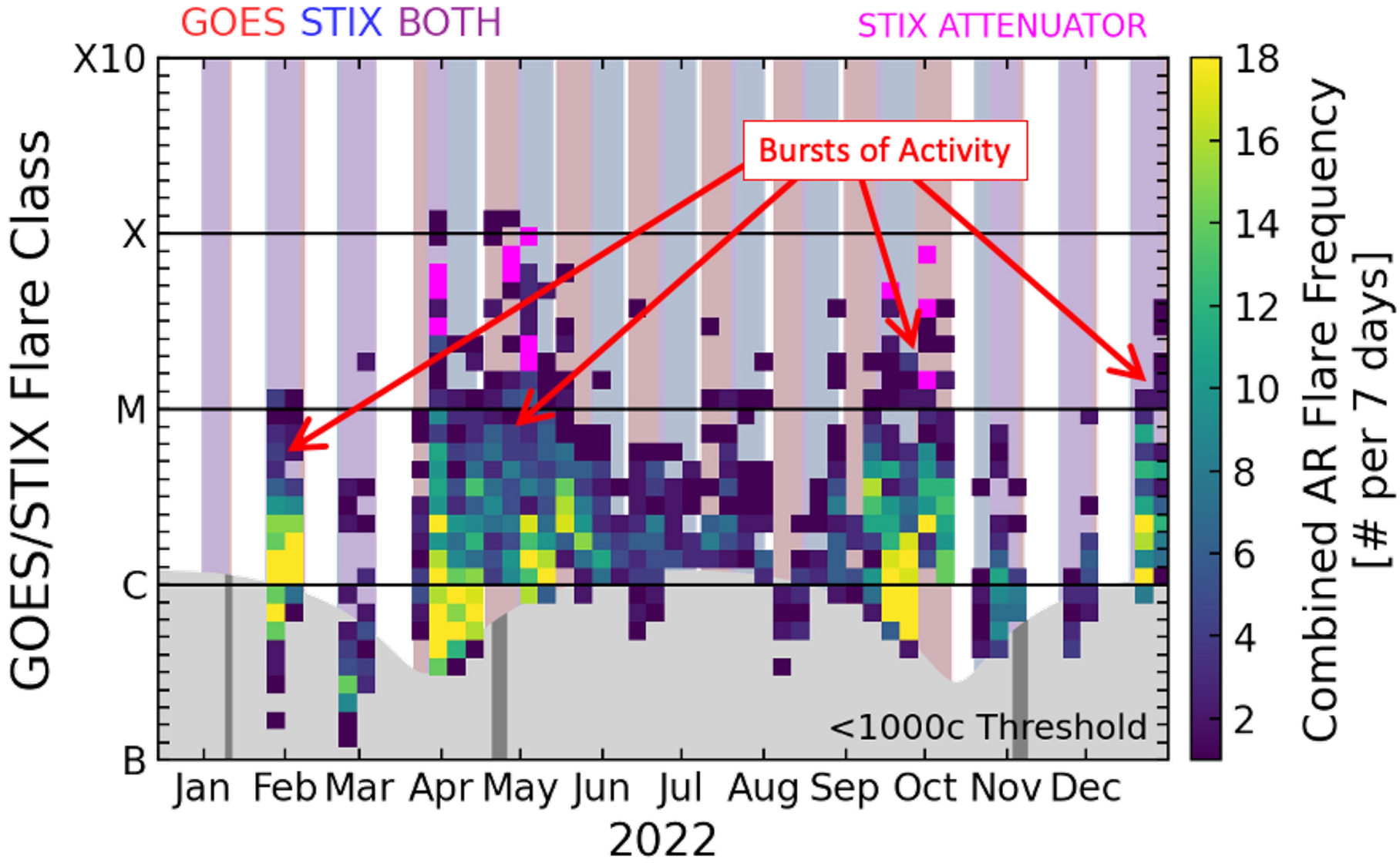

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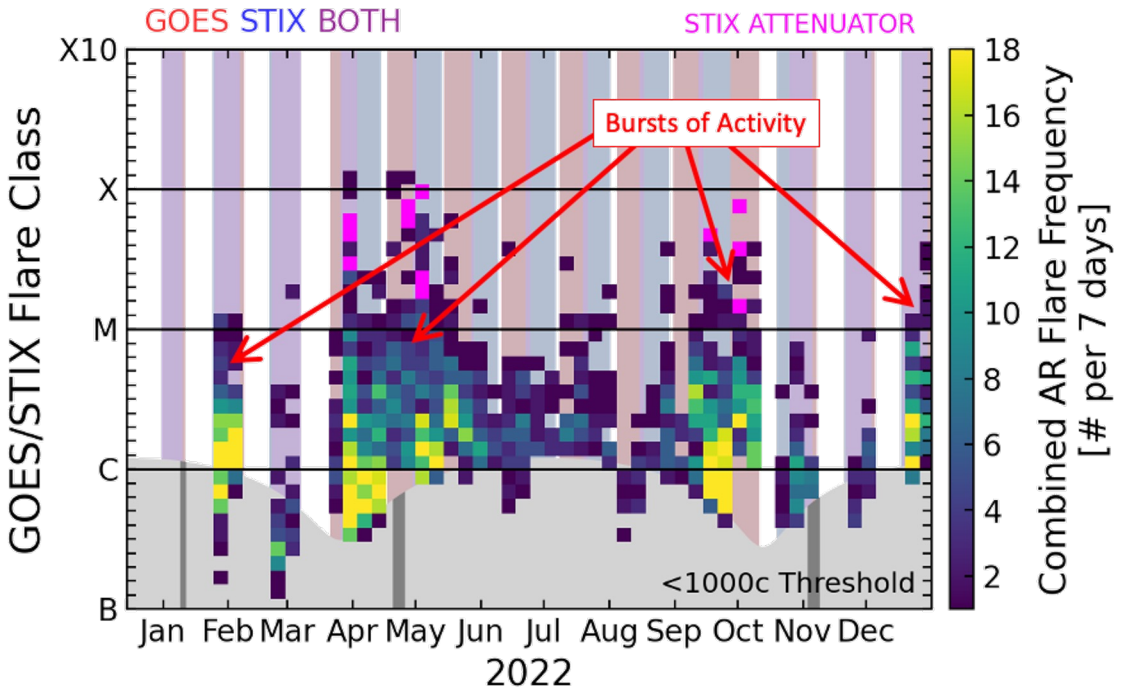

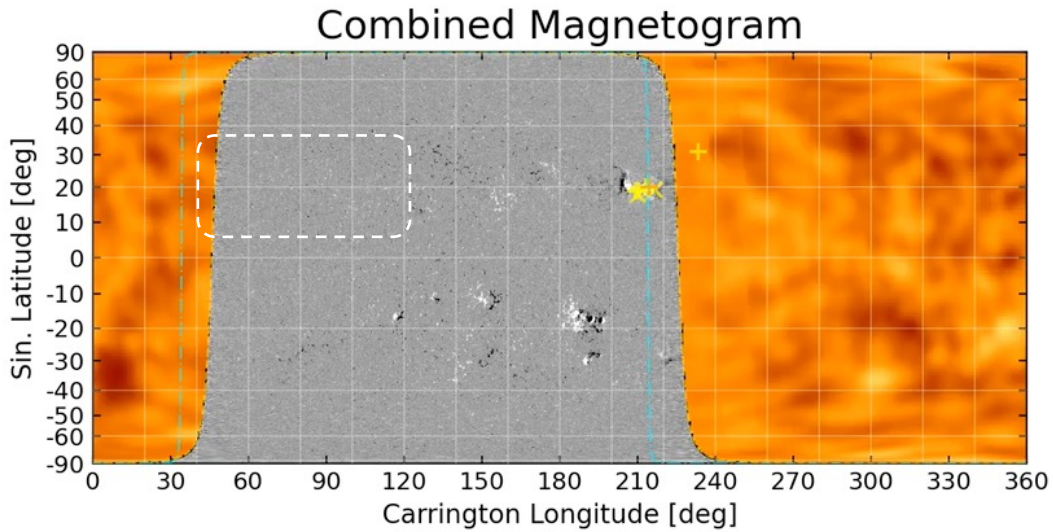

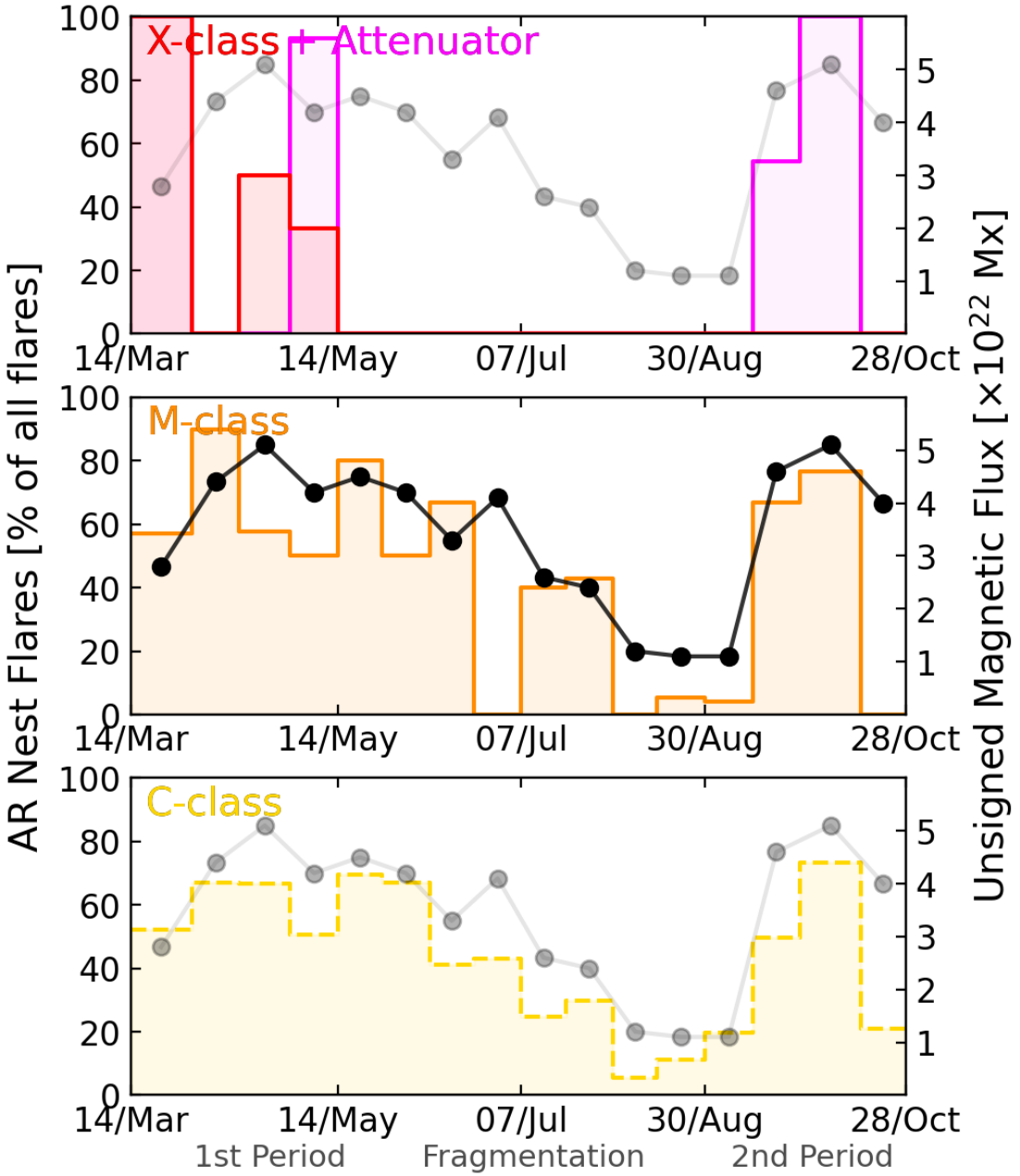

adam.finley@cea.fr

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adamjamesfinley.github.io

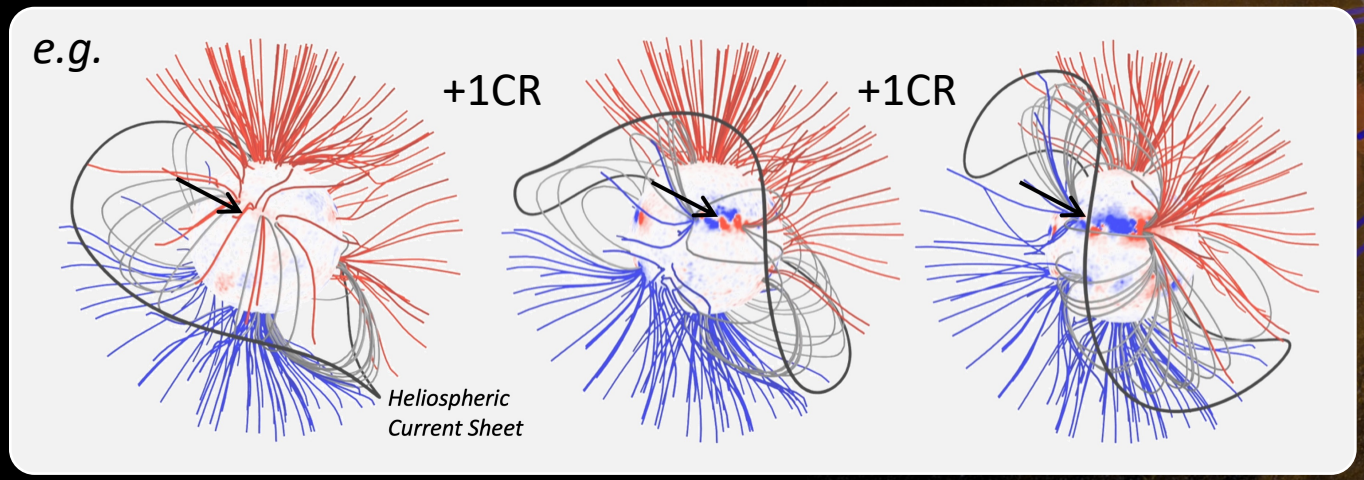
Coronal Structure above Active Nests

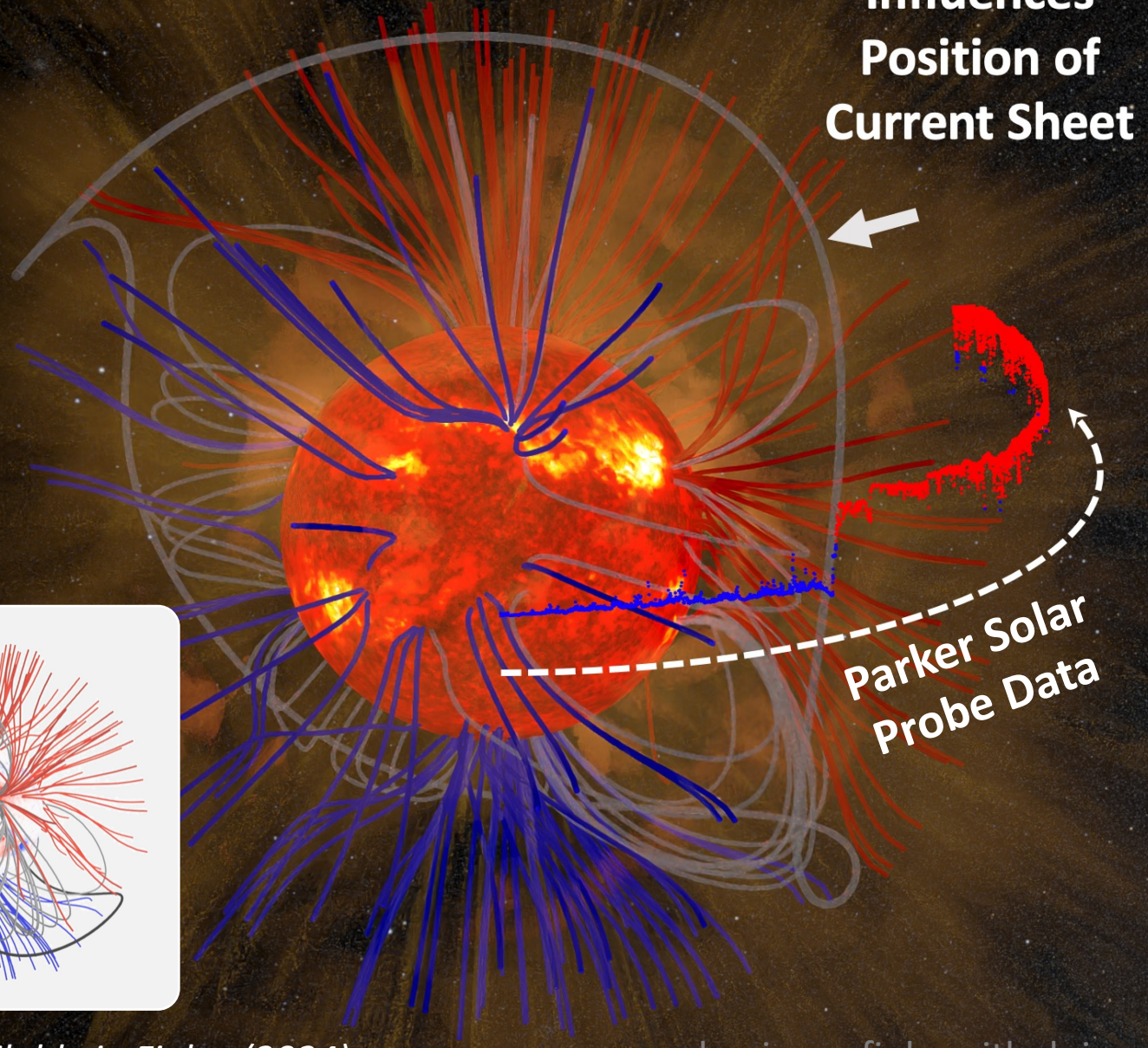
Repeated flux emergence events **contribute more effectively** to the Sun's large-scale magnetic field.

Strong influence on the heliospheric current sheet.

Can **anchor the current sheet** in place for several solar rotations (useful in predicting magnetic connectivity).

Could be visible on **other Sun-like stars** in spectropolarimetry (Zeeman-Doppler imaging)

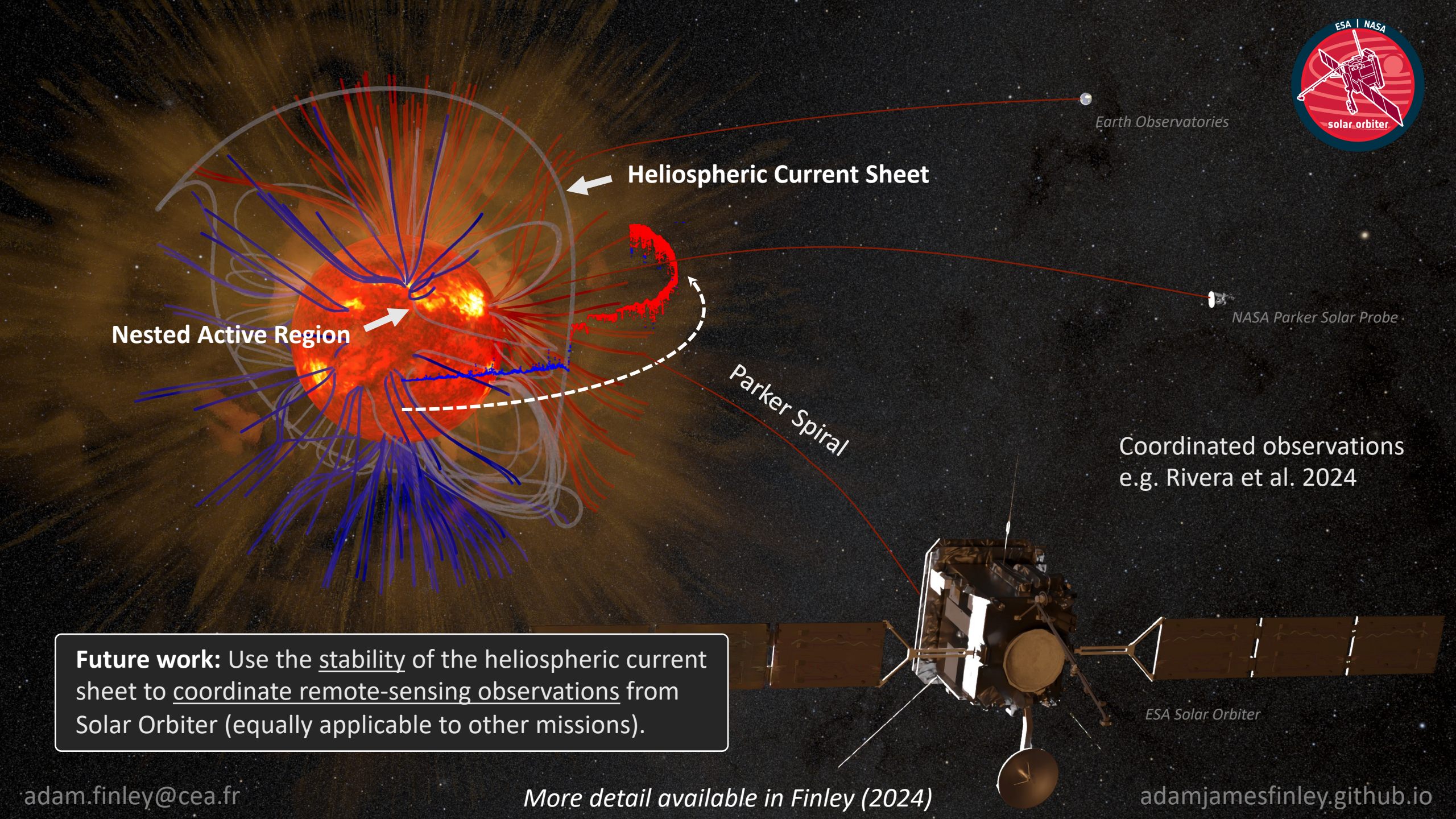




adam.finley@cea.fr

More detail available in Finley (2024)

adamjamesfinley.github.io



Future work: Use the stability of the heliospheric current sheet to coordinate remote-sensing observations from Solar Orbiter (equally applicable to other missions).

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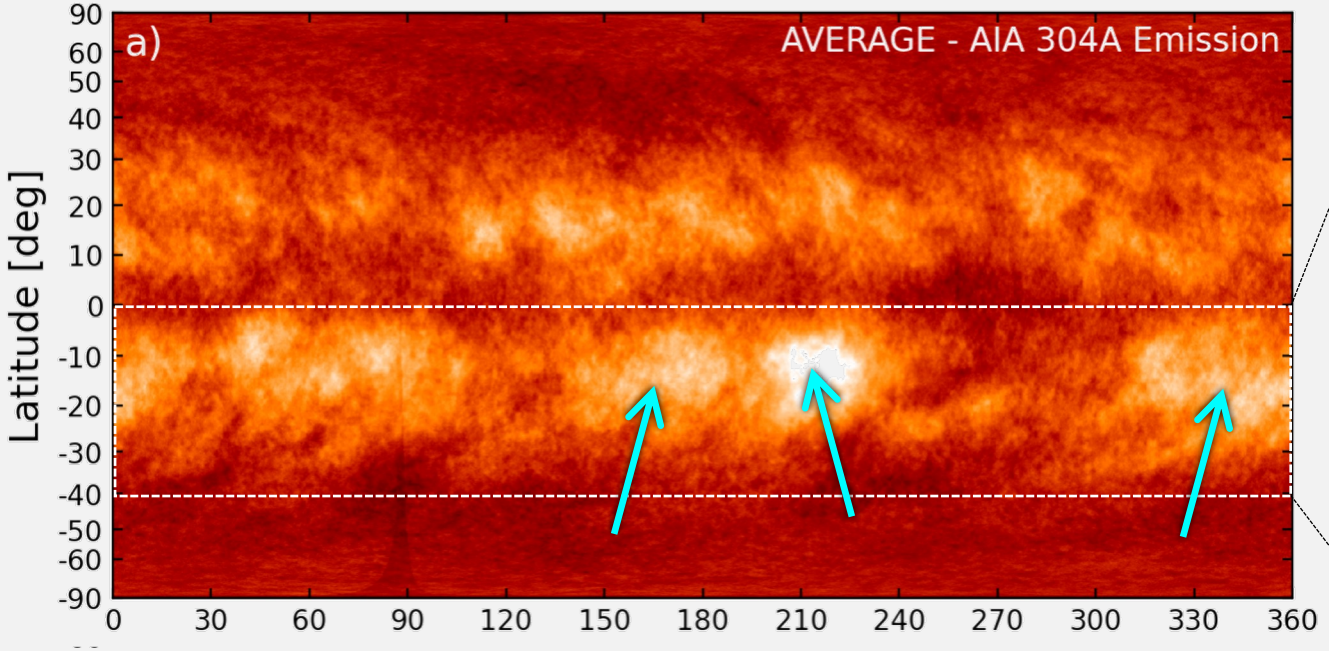
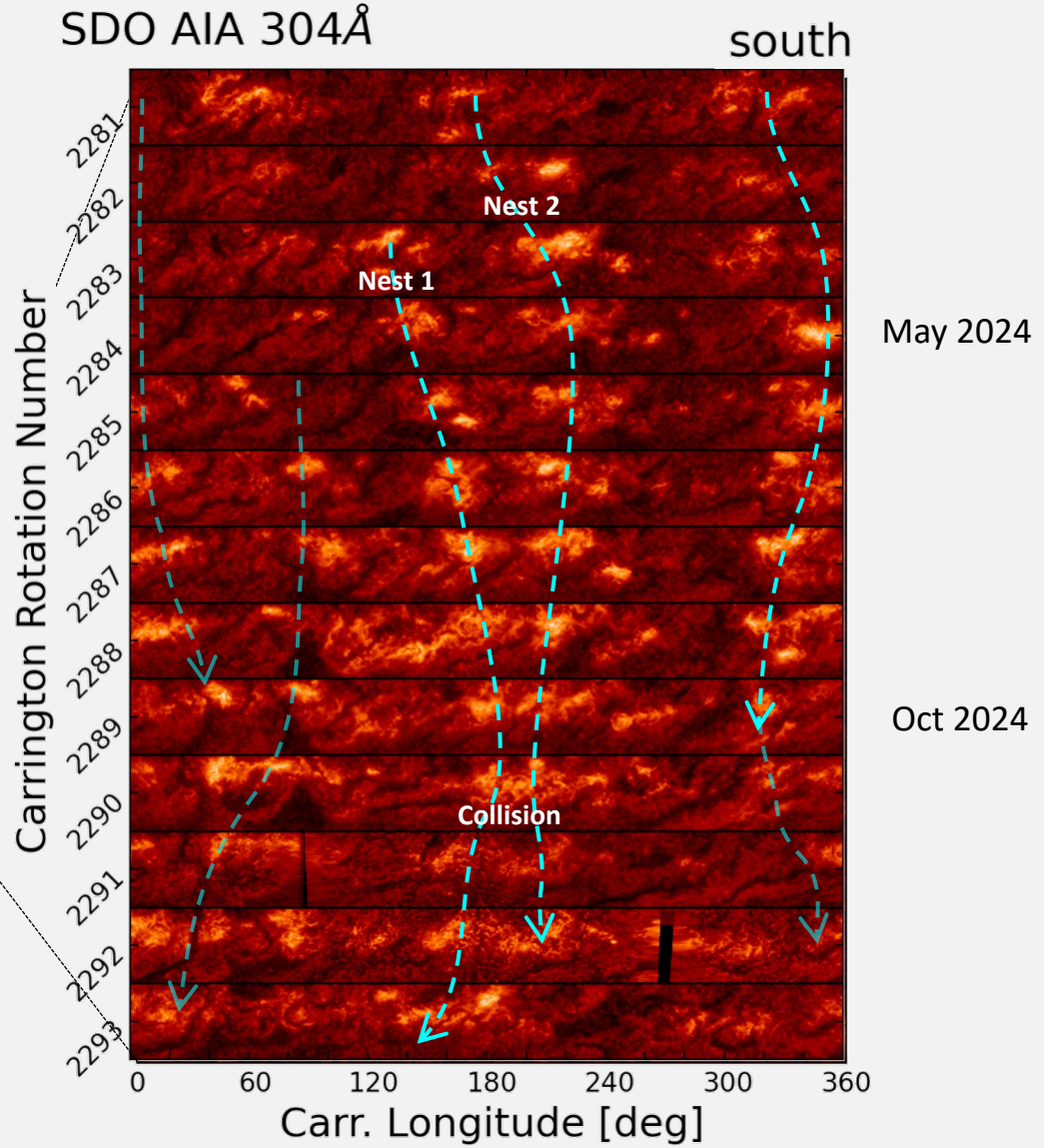
What about 2024?





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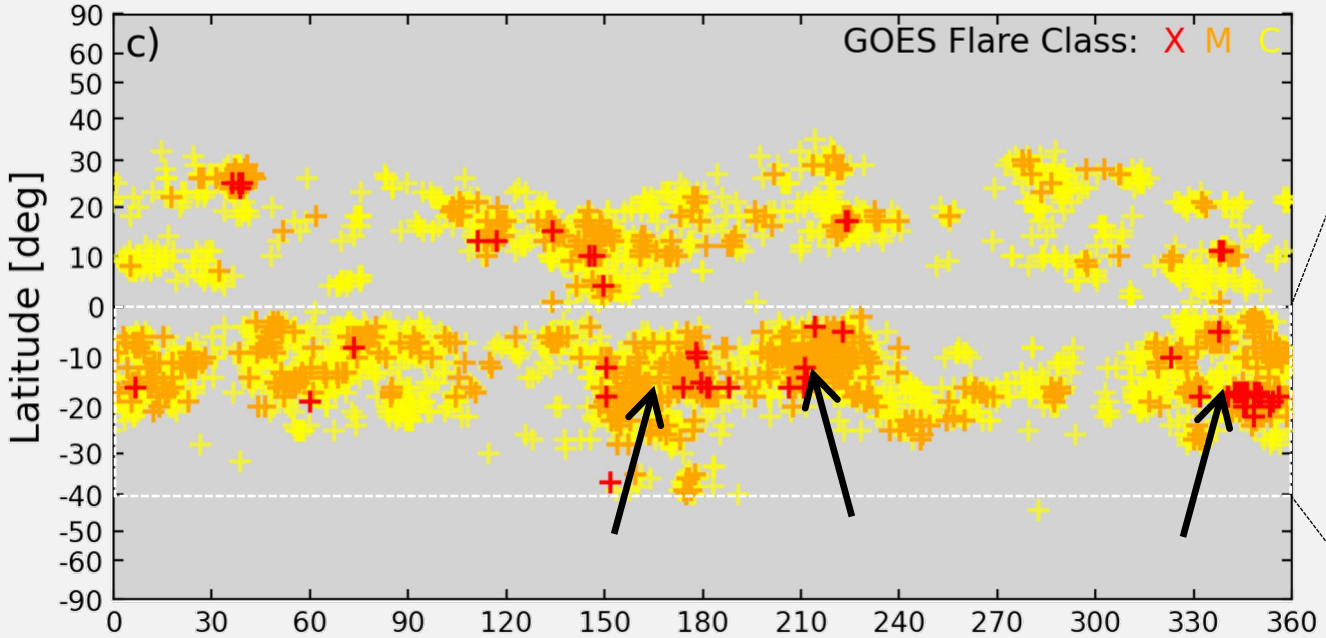

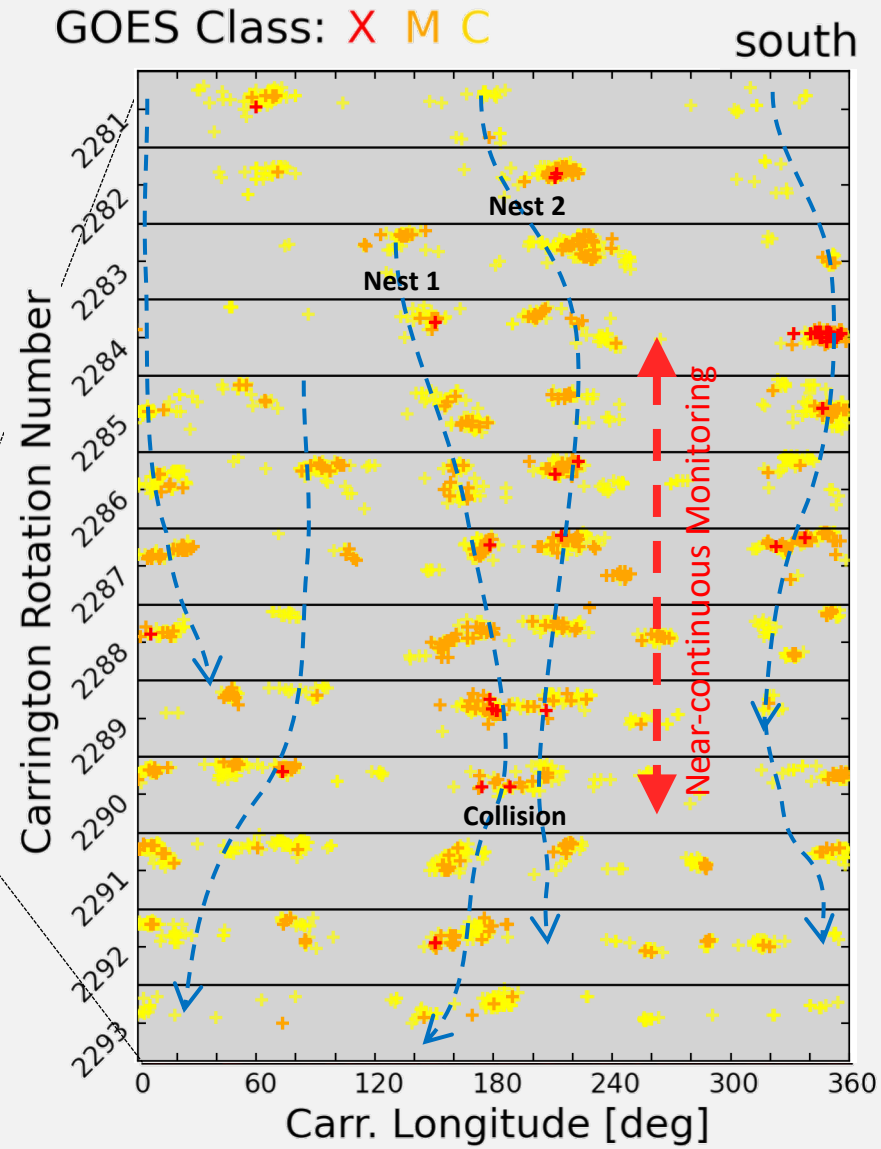

May 2024

Oct 2024

adam.finley@cea.fr

adamjamesfinley.github.io

Conclusions

Nested active regions are a **common feature** of solar/stellar dynamos. Previous works have shown that they can be **coherent** on long-timescales.

Some evidence that nested active regions have a **higher rate of flaring** than isolated regions (Finley et al. 2025); relating to their increased size and complexity.

Nesting plays a role in **shaping the Sun's large-scale** magnetic field (Finley 2024), and the **rotation** of the solar corona (Finley & Brun 2023).

Take home message: Short to medium term forecasting of space weather (solar flares and magnetic connectivity) would benefit from the improved identification and tracking of long-lived nested active regions.

A prolific solar flare factory
Nearly continuous monitoring of an active region nest with Solar Orbiter

Finley et al. 2025, A&A 697, A217

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