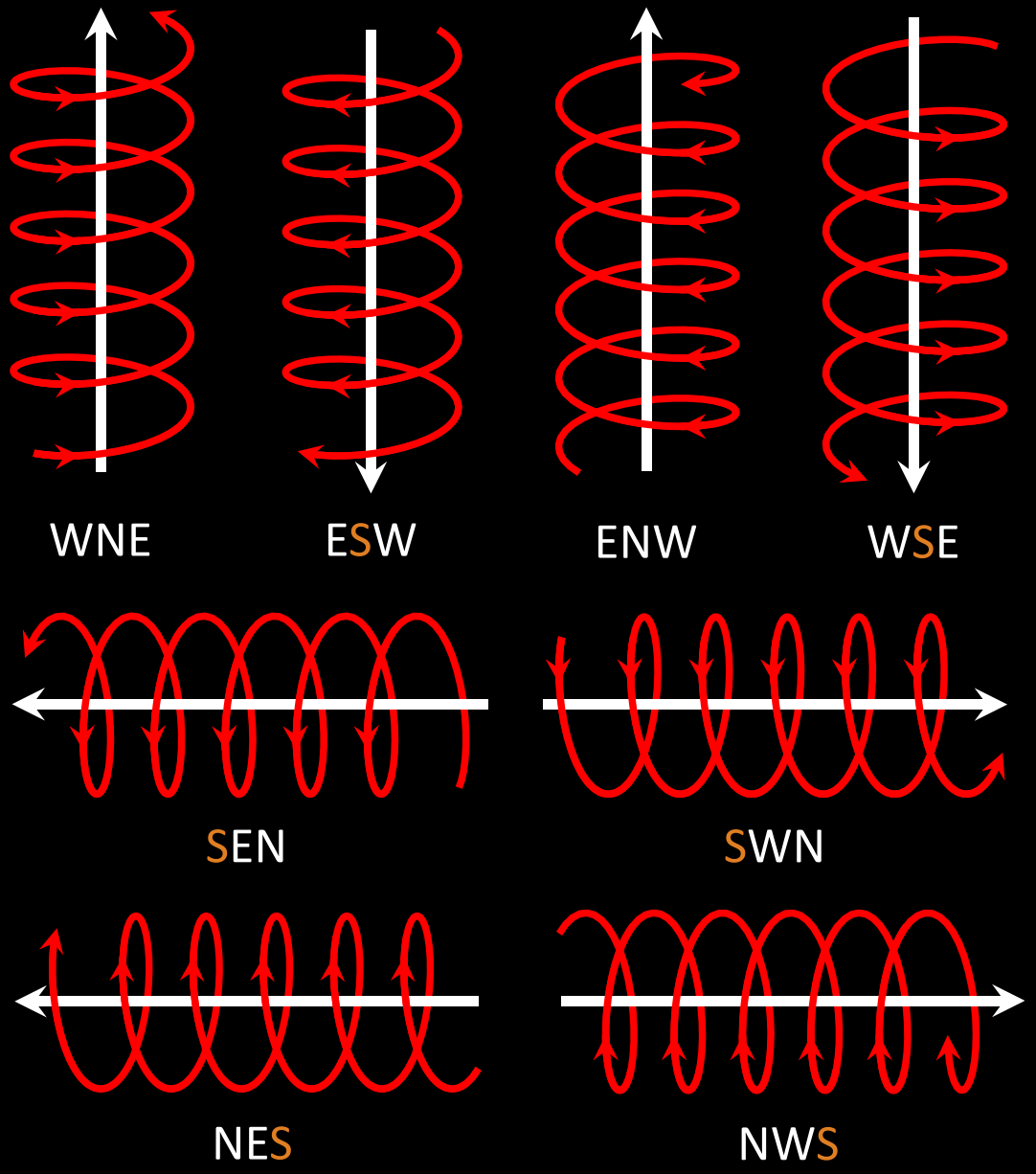
HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tracking the Magnetic Structure of Flux Ropes from Eruption to in-situ Detection

E. Palmerio • E. Kilpua • L. Green
A. James • J. Pomoell • G. Valori

ISSS • 6-10 June 2016 • L'Aquila, Italy

Flux Rope (FR) space weather perspective

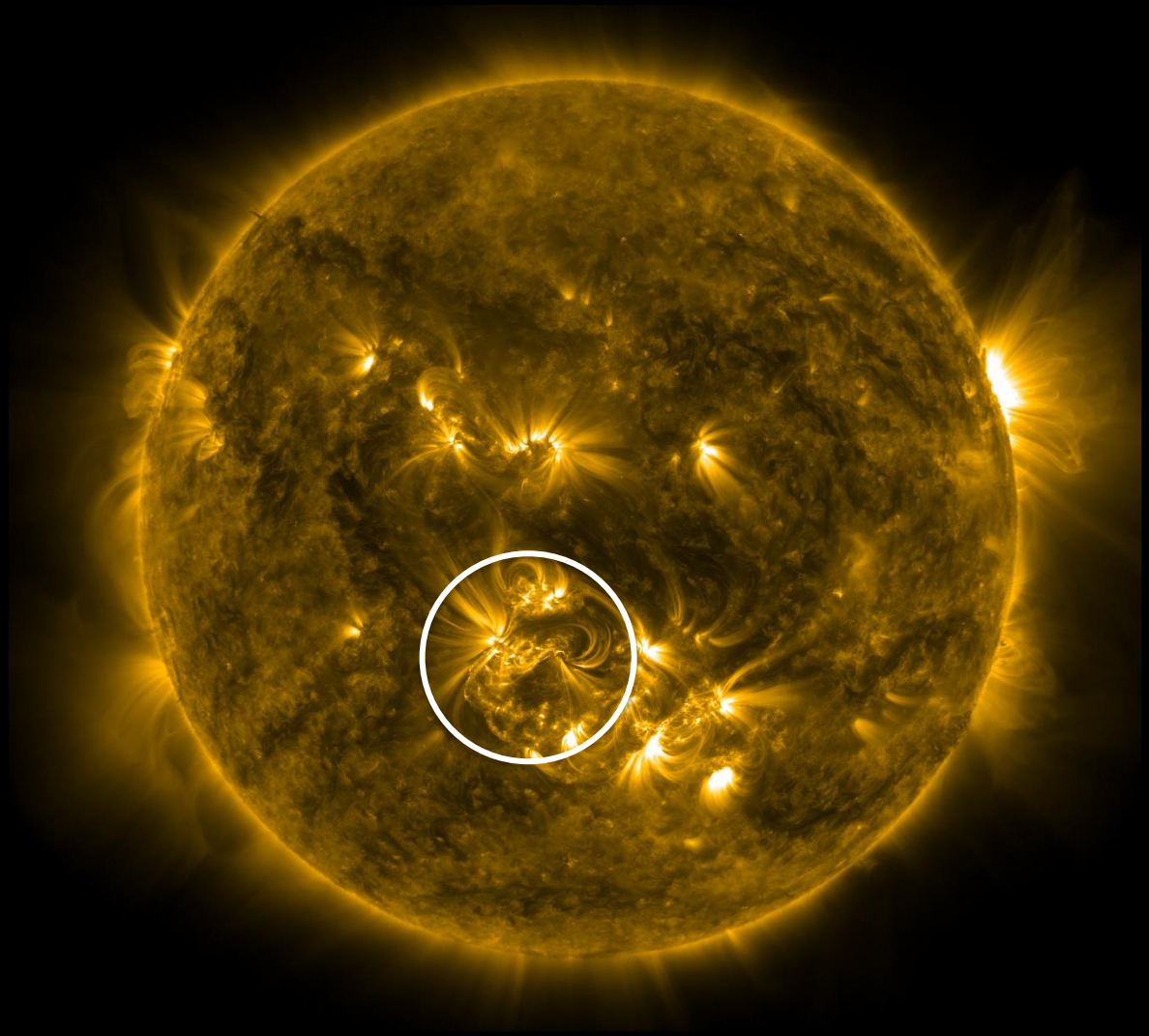


- The FR type determines the level of geoeffectivity
- What matters the most is the magnitude, duration and sign of the north-south component
- To improve long-term space weather forecasts, we want to predict in the solar wind
  - Tilt of the FR axis
  - FR helicity sign
  - FR axial field (direction)

← Different FR types

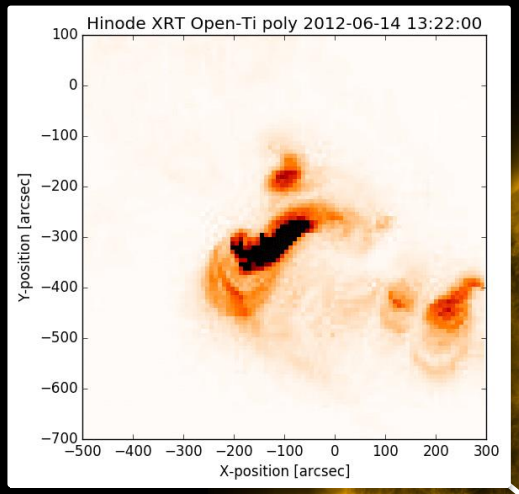
The CME on 14 June 2012: AR 11504

Eruption: around 13:30 UT



The CME on 14 June 2012: AR 11504

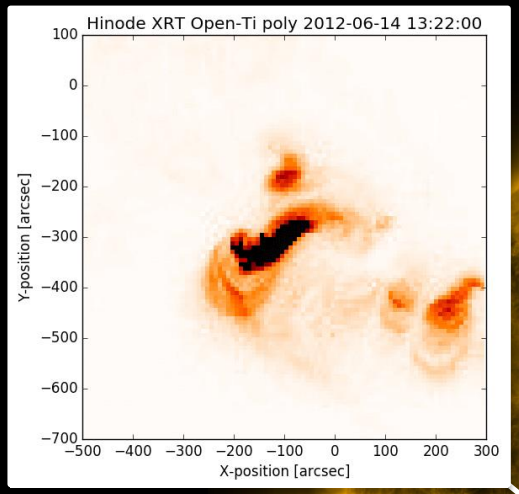
Eruption: around 13:30 UT



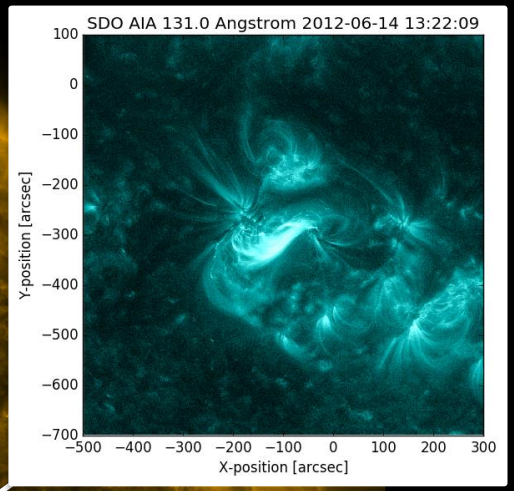
Soft X-ray
(XRT onboard Hinode)

The CME on 14 June 2012: AR 11504

Eruption: around 13:30 UT



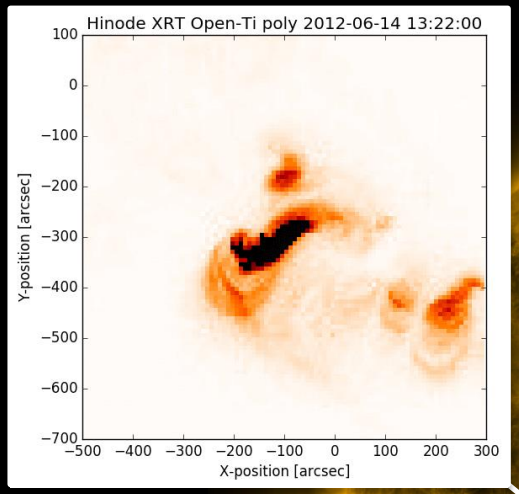
Soft X-ray
(XRT onboard Hinode)



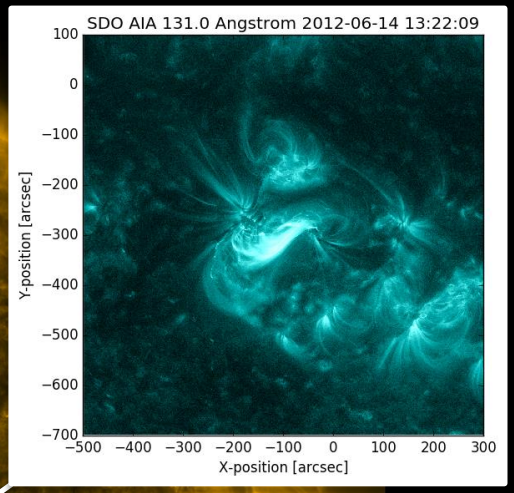
EUV 131 Å
(AIA onboard SDO)

The CME on 14 June 2012: AR 11504

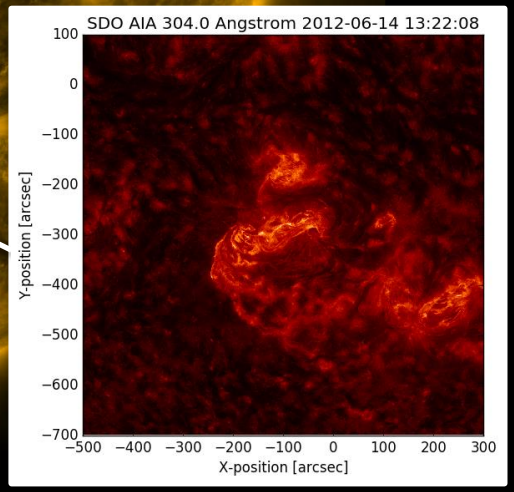
Eruption: around 13:30 UT



Soft X-ray
(XRT onboard Hinode)



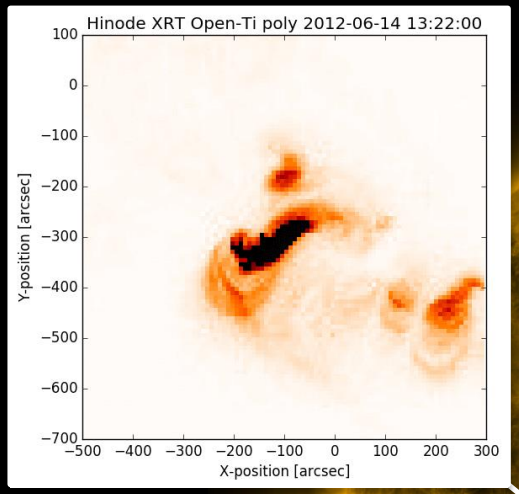
EUV 131 Å
(AIA onboard SDO)



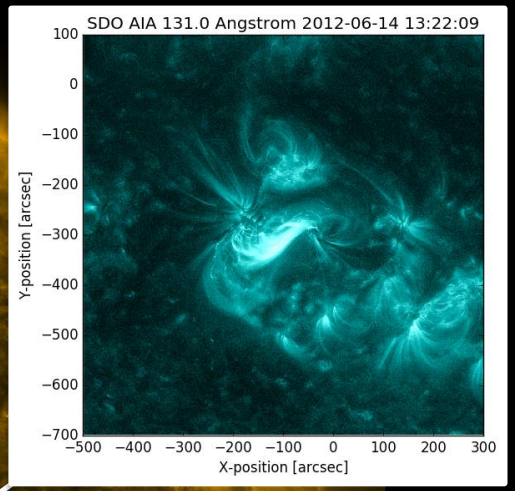
EUV 304 Å
(AIA onboard SDO)

The CME on 14 June 2012: AR 11504

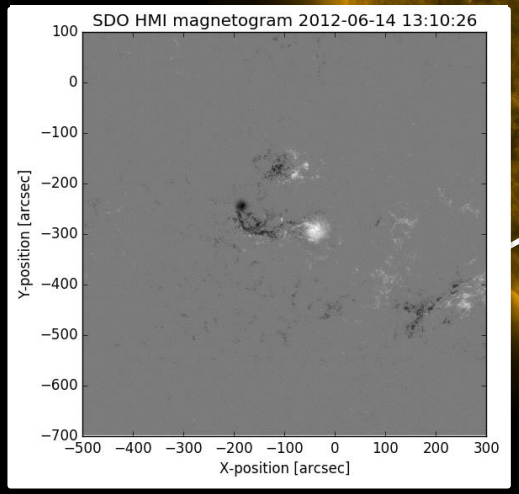
Eruption: around 13:30 UT



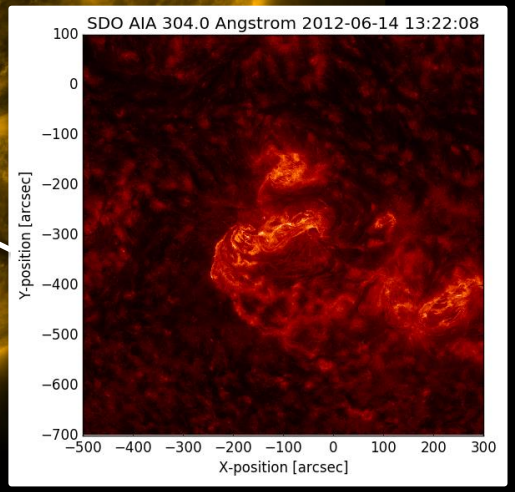
Soft X-ray
(XRT onboard Hinode)



EUV 131 Å
(AIA onboard SDO)



Magnetogram
(HMI onboard SDO)



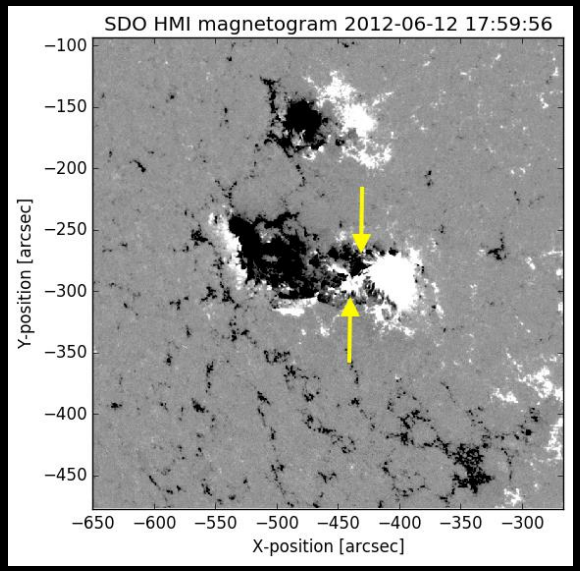
EUV 304 Å
(AIA onboard SDO)

Chirality of the FR

The chirality (“handedness”) of a FR can be inferred through various proxies, from the FR itself or from the source active region.

Chirality of the FR

The chirality ("handedness") of a FR can be inferred through various proxies, from the FR itself or from the source active region.

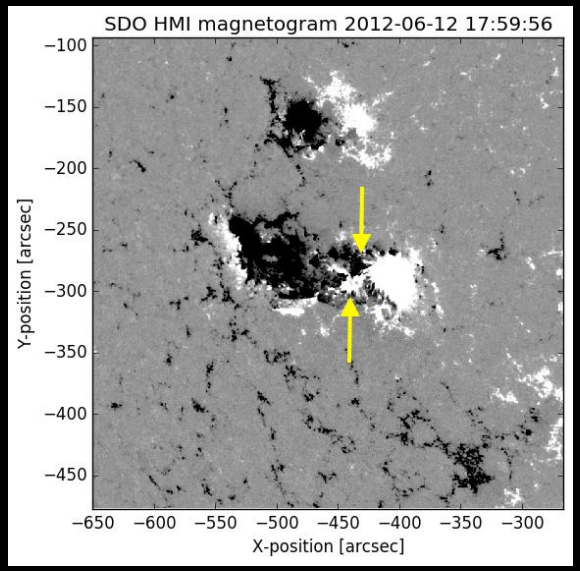


From LOS magnetograms: magnetic tongues (López Fuentes et al., 2000).

The leading magnetic polarity extends under the trailing one: RIGHT-HANDED active region

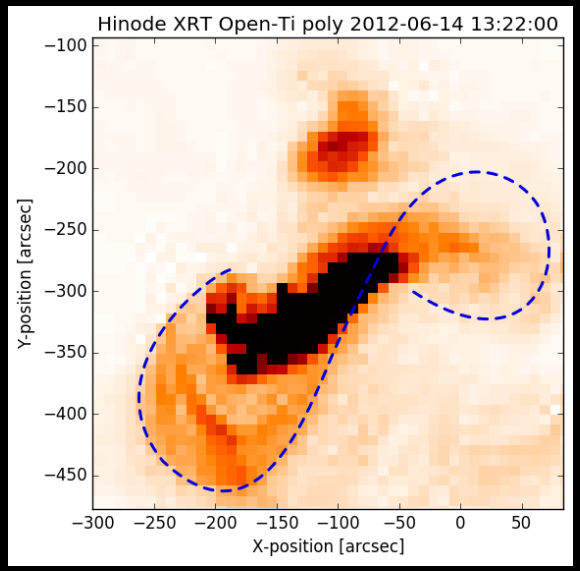
Chirality of the FR

The chirality ("handedness") of a FR can be inferred through various proxies, from the FR itself or from the source active region.



From LOS magnetograms: magnetic tongues (López Fuentes et al., 2000).

The leading magnetic polarity extends under the trailing one: RIGHT-HANDED active region



From soft X-rays: sigmoid (Pevtsov et al., 1997)

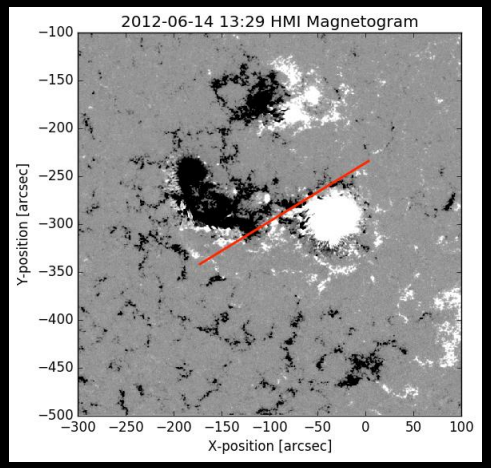
The sigmoid is shaped as a forward-S: RIGHT-HANDED flux rope

Tilt and axial field direction

The axis orientation of a FR can be considered more or less parallel to the polarity inversion line (PIL) of the source AR (Marubashi et al., 2015)

Tilt and axial field direction

The axis orientation of a FR can be considered more or less parallel to the polarity inversion line (PIL) of the source AR (Marubashi et al., 2015)

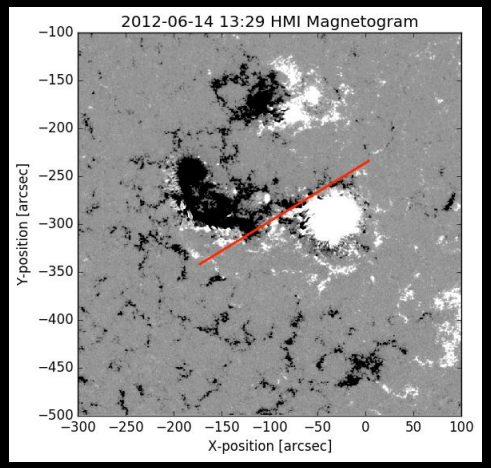


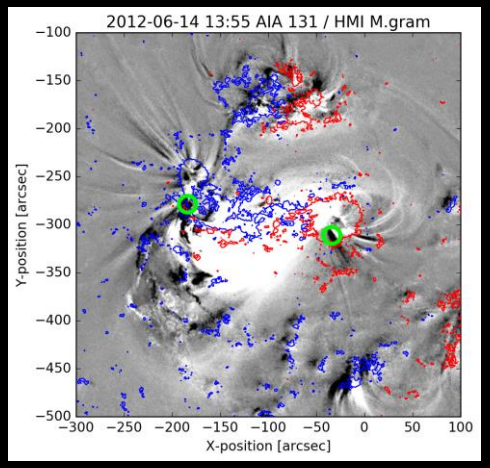
The PIL is inclined ≈ 35° in the YZ-plane: low angle to the ecliptic.

For an AR with right-handed chirality,
2 possible FR-types: NES and SWN

Tilt and axial field direction

The axis orientation of a FR can be considered more or less parallel to the polarity inversion line (PIL) of the source AR (Marubashi et al., 2015)





The PIL is inclined ≈ 35° in the YZ-plane: low angle to the ecliptic.

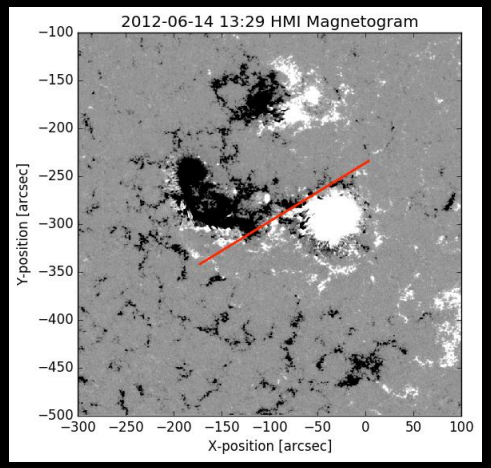
For an AR with right-handed chirality, 2 possible FR-types: NES and SWN

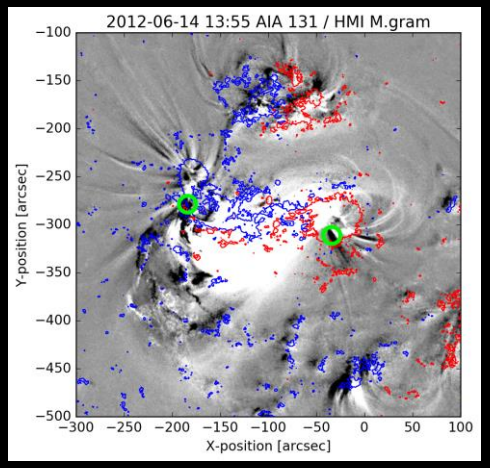
FR footpoints: the western one (right) is rooted to positive field, the eastern one (left) to negative field.

The axial field points EASTWARD.

Tilt and axial field direction

The axis orientation of a FR can be considered more or less parallel to the polarity inversion line (PIL) of the source AR (Marubashi et al., 2015)





The PIL is inclined ≈ 35° in the YZ-plane: low angle to the ecliptic.

For an AR with right-handed chirality, 2 possible FR-types: NES and SWN

FR footpoints: the western one (right) is rooted to positive field, the eastern one (left) to negative field.

The axial field points EASTWARD.

PREDICTION: FR is NES-type

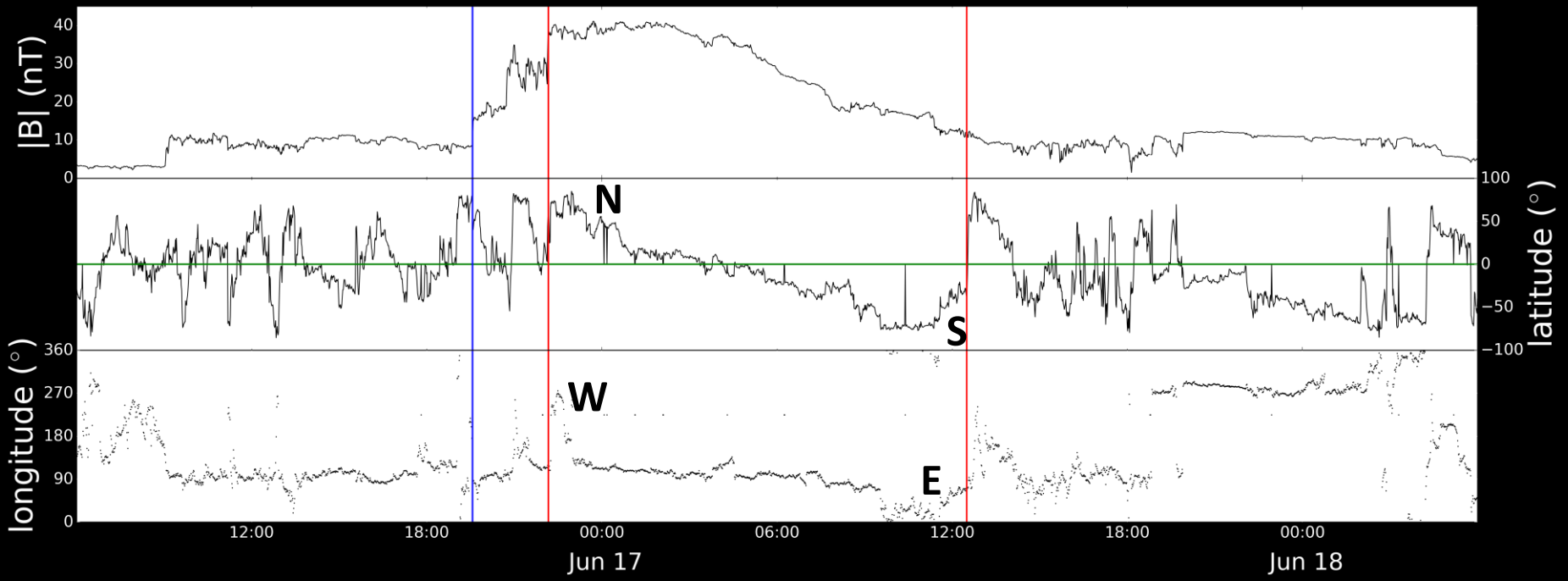
In-situ observation (Wind S/C)

latitude θ

$$q = \arctan\left(\frac{B_z}{\sqrt{B_x^2 + B_y^2}}\right)$$

longitude ϕ

$$f = \arctan\left(\frac{B_y}{B_x}\right)$$



In-situ observation (Wind S/C)

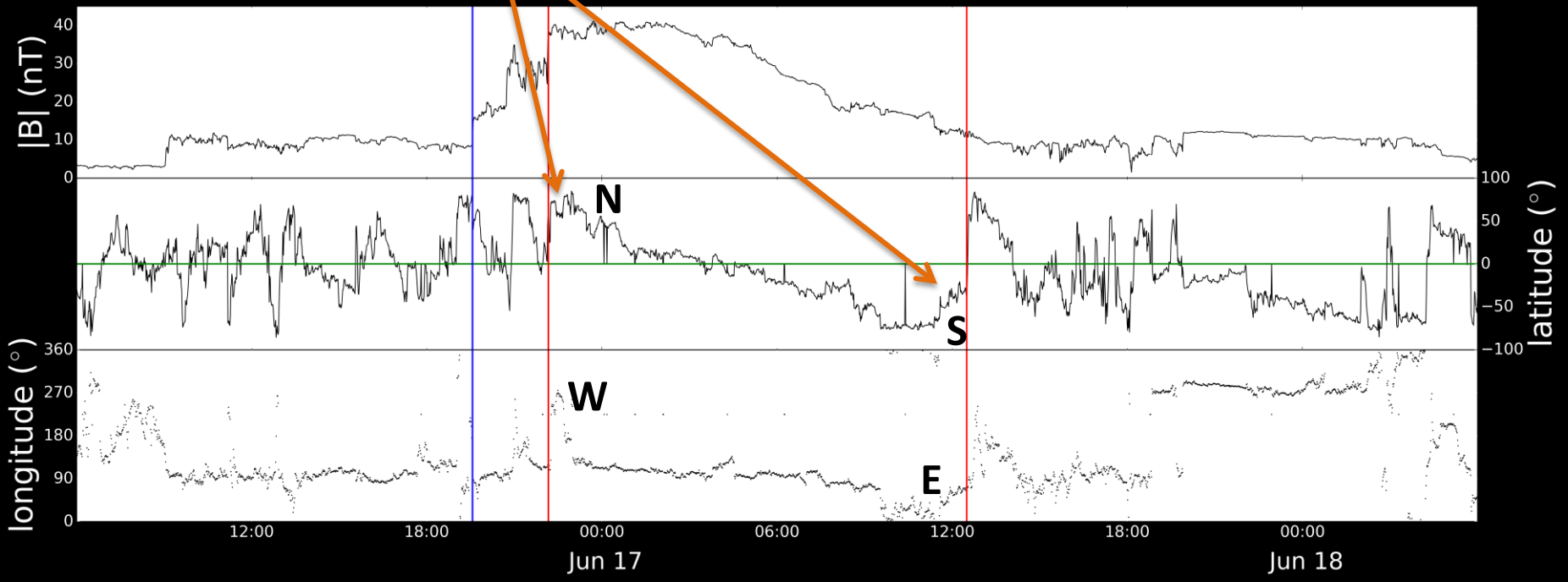
latitude θ

$$q = \arctan\left(\frac{B_z}{\sqrt{B_x^2 + B_y^2}}\right)$$

longitude ϕ

$$f = \arctan\left(\frac{B_y}{B_x}\right)$$

Smooth rotation in the NS-component and Δθ < 0:
the helical field is directed from North to South



In-situ observation (Wind S/C)

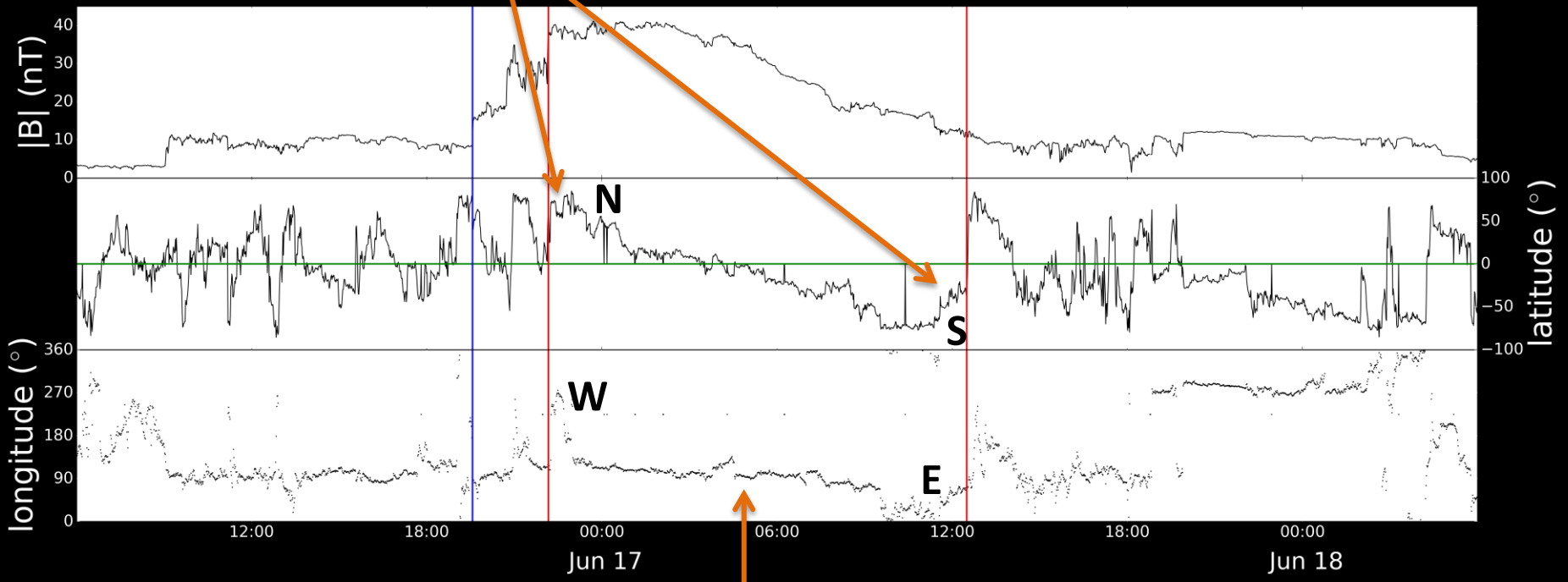
latitude θ

$$q = \arctan\left(\frac{B_z}{\sqrt{B_x^2 + B_y^2}}\right)$$

longitude ϕ

$$f = \arctan\left(\frac{B_y}{B_x}\right)$$

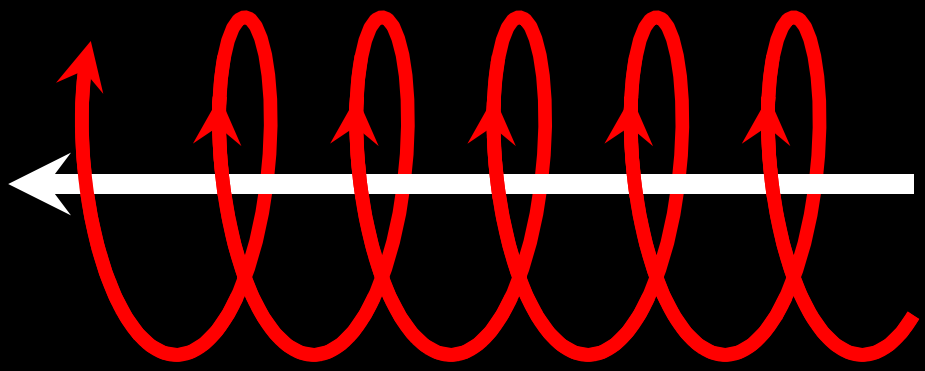
Smooth rotation in the NS-component and Δθ < 0: the helical field is directed from North to South



0° < ϕ < 180° at the center: the axial field is pointing to the East

Conclusions

- The remote-sensing predictions are confirmed by the in-situ observations: FR is NES-type
- This means that an eventual geomagnetic storm caused by a NES-type FR may start even one day later compared to a SEN-type FR
- Such remote-sensing predictions are necessary to improve space weather forecasts



NES

Thank you.