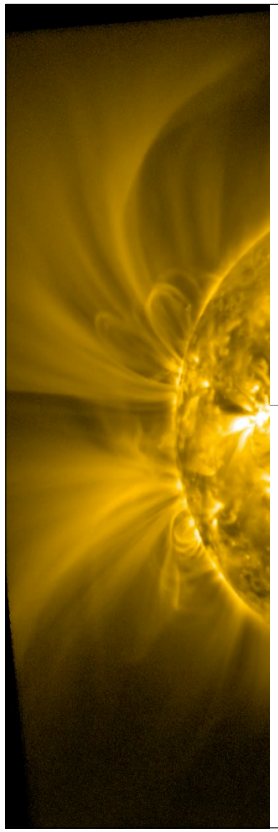
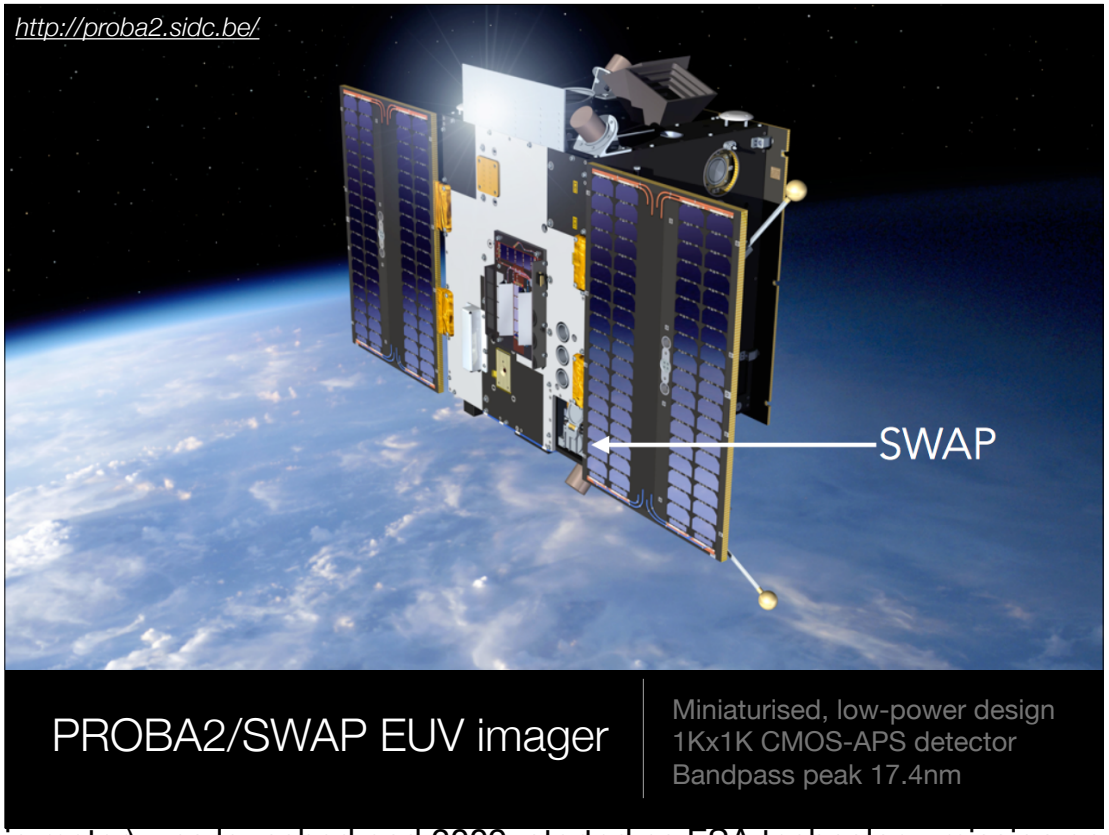


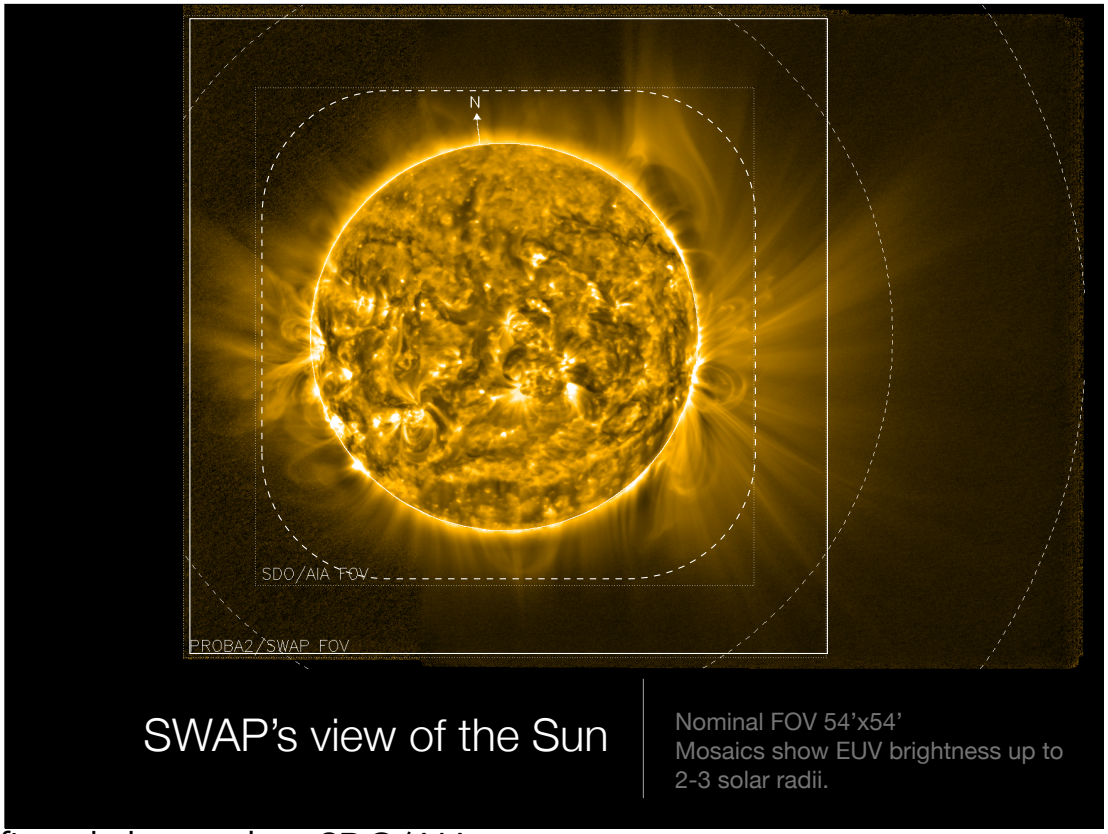
PROBA2/SWAP images of the EUV corona up to 2-3 solar radii

Can we close the gap in coronal magnetic field structure between 1.3 and 2.5 solar radii?

Anik De Groof *ESA/ESAC, Madrid, Spain*
Daniel B. Seaton
Laurel Rachmeler *Royal Observatory of Belgium, Brussels*
David Berghmans

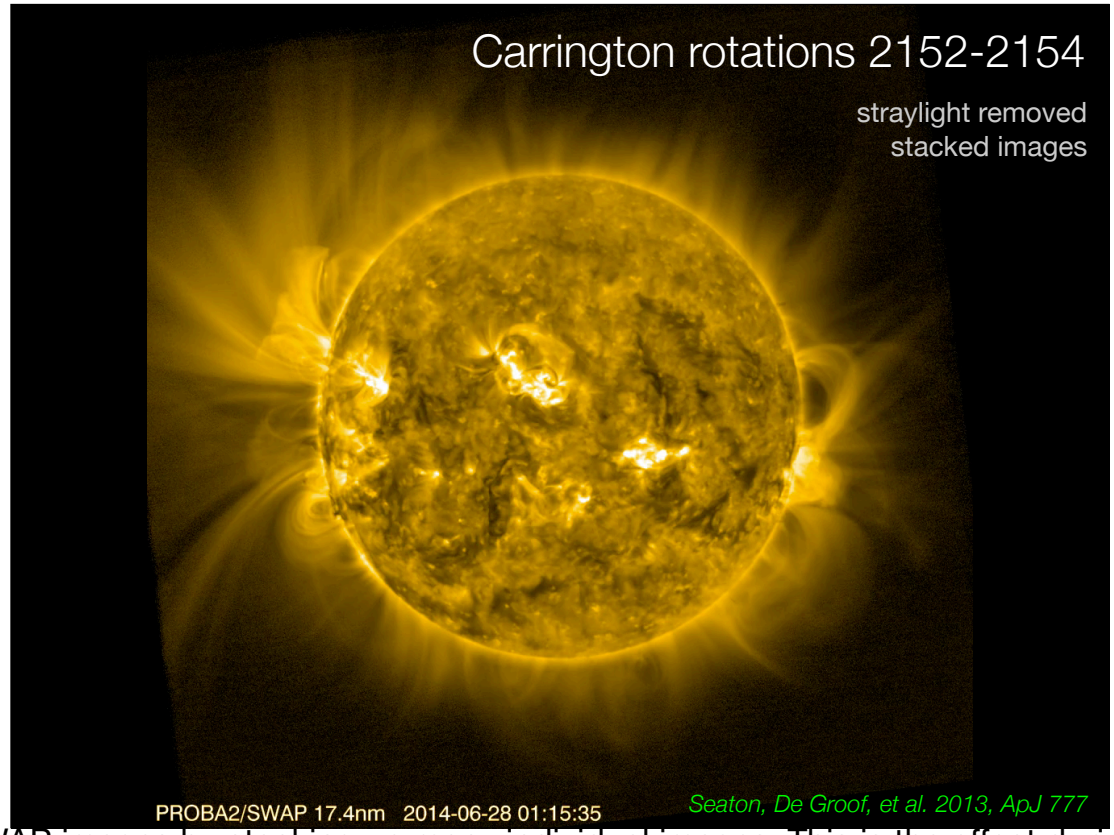


PROBA2 is mini-satellite (~1 cubic meter) was launched end 2009, started as ESA technology mission and got adopted later by ESA science and SSA.
SWAP is miniaturised EUV imager (~60cm long) using 1Kx1K CMOS-APS detector with one bandpass peaking at 17.4nm.



Nominal FOV is 54'x54', significantly larger than SDO/AIA.

SWAP can be commanded to do mosaic imaging to obtain an even larger FOV for special campaigns. This mosaic shows an extended fan-like structure present during November 2014.



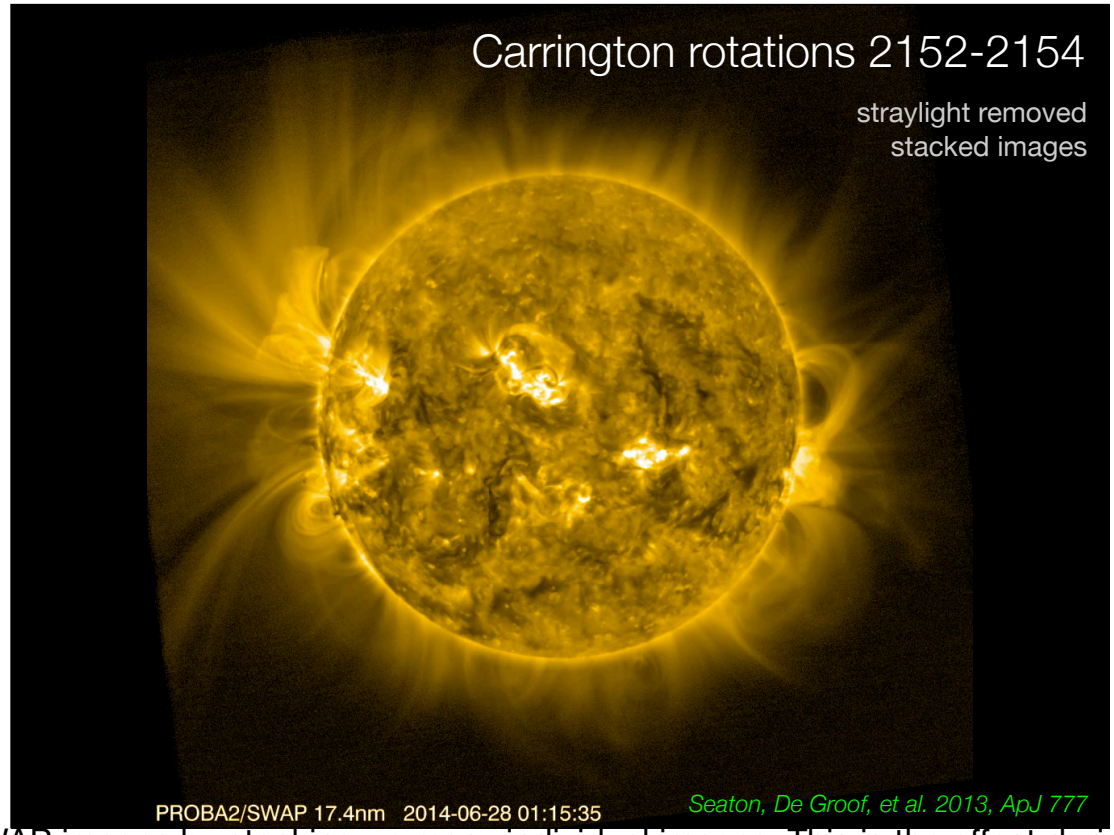
High-quality, deep-exposure SWAP images by stacking up many individual images. This is the effect during solar maximum!

SWAP monitored the extended corona (< 2 Rsun) over last 5 years (rising phase cycle 24)

There are different types of bright fan streamers:

1. related to (pseudo-)streamers (confirmed by CoMP and LASCO-C2)
2. bright fan streamers above ARs
3. extended, poleward curved streamers that are consistent over many rotations

Latter is main topic of this talk.



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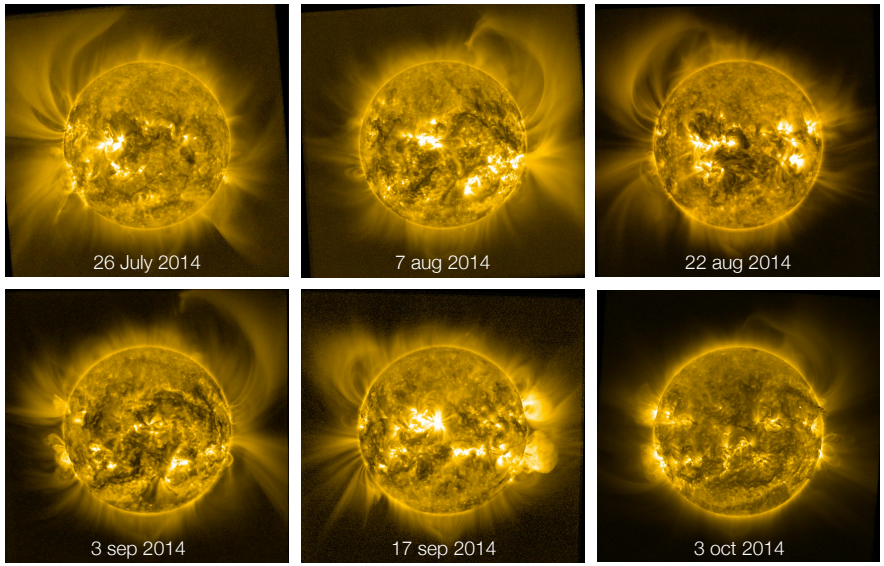
EUV coronal fans

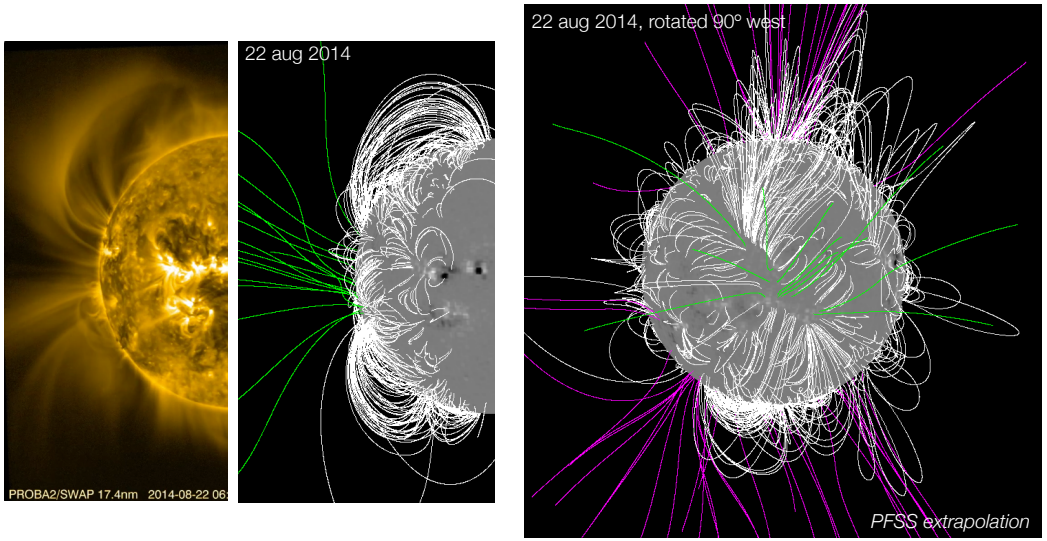
Extended, fan-shaped structures, persistent over many rotations. Example Jul ‘14-Jan ‘15 (CR 2152 -2160)



Fans reappear at limb with ~13.5 days period.

EUV coronal fans, curved polewards. Only seen when activity increased (starting 2011) and mainly (if not exclusively) in Northern hemisphere.

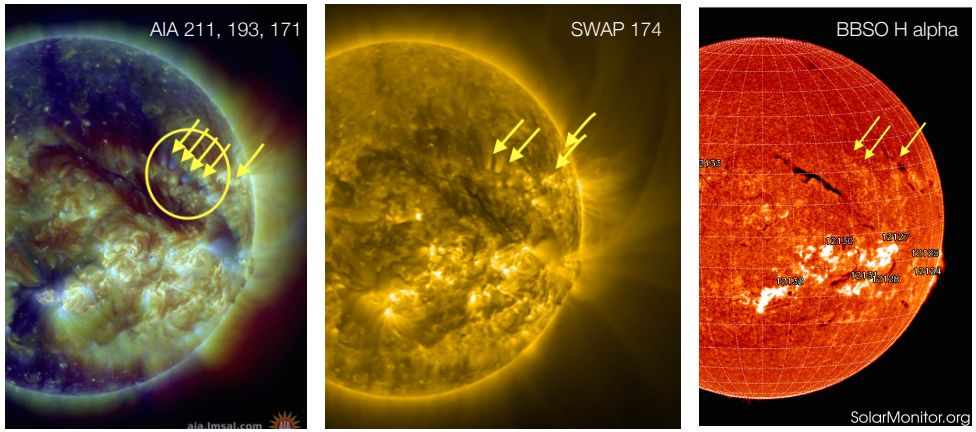
Coronal EUV fans: Magnetic structure



Fan sheet is formed at boundary of arcade of closed field lines and open field
In this particular case, a fan is formed curving both to North and South (latter short-lived)

Magnetic structure: sheet of open field lines overlying arcade of closed field that connects to pole.
PFSS too limited in reconstructing curvature coronal fan. However, the sheet of closed field lines and adjacent open field are always present.

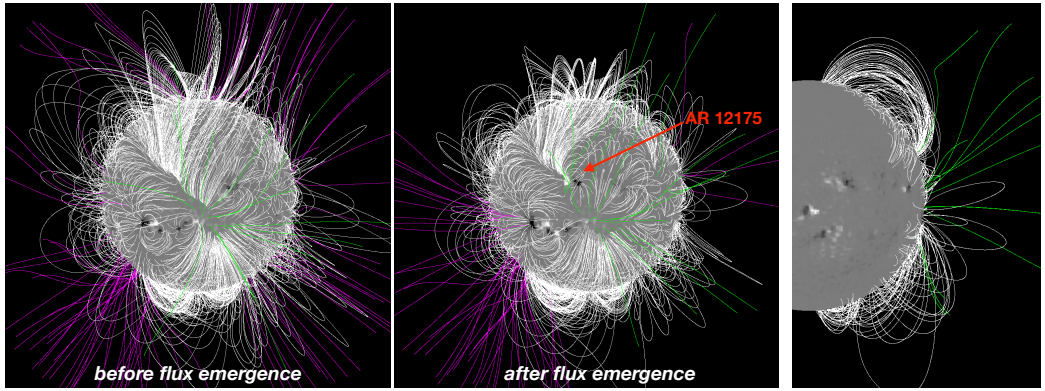
Coronal EUV fans: footpoint rooting



Fans are rooted in **magnetic regions without sunspots.**
Footpoints line up along a polarity inversion line, often linked to filaments.

Coronal EUV fans: Persistence & Breakdown

- EUV fans typically persist over several solar rotations. Fans disappear or break typically when **sunspots emerge** in the footpoint region



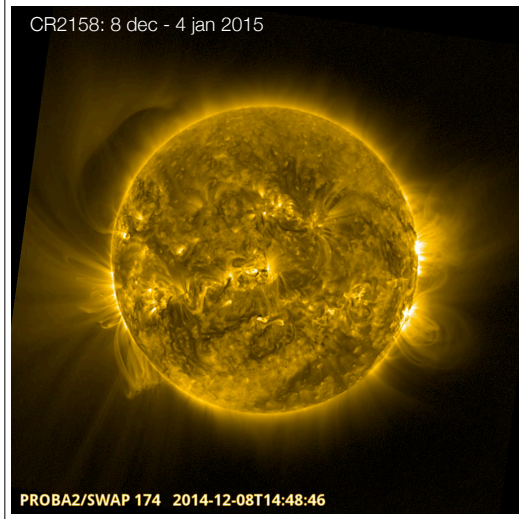
24 sep 2014: wide magnetic sheet at front

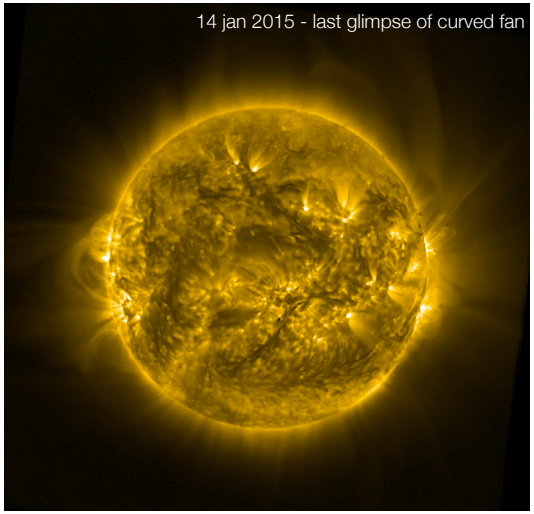
30 sep 2014 - rotated 90ºE: fan does not appear at W limb

3 oct 2014: Coronal fan **3 days later** at limb than expected

During Jul - Sep 2014, the coronal fan appeared every rotation at 270º carrington longitude.
Around 29 sep: Flux emergence breaks west part of the magnetic sheet.
Off-limb coronal fan appears 3 days later than expected at the west limb.
From then on, this ‘new’ fan located at 240º Carrington latitude rotates around with expected 28 days period.

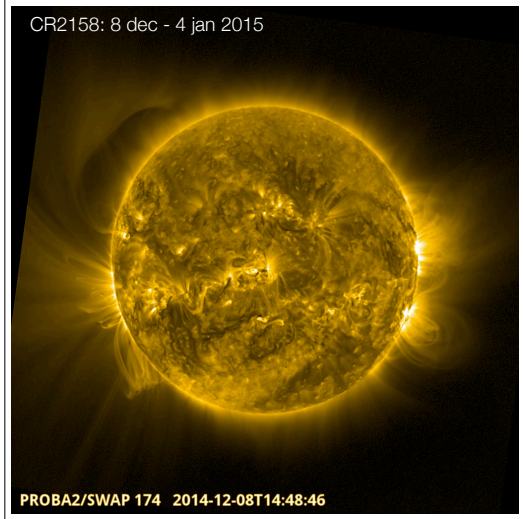
Coronal EUV fans: Persistence & Breakdown II

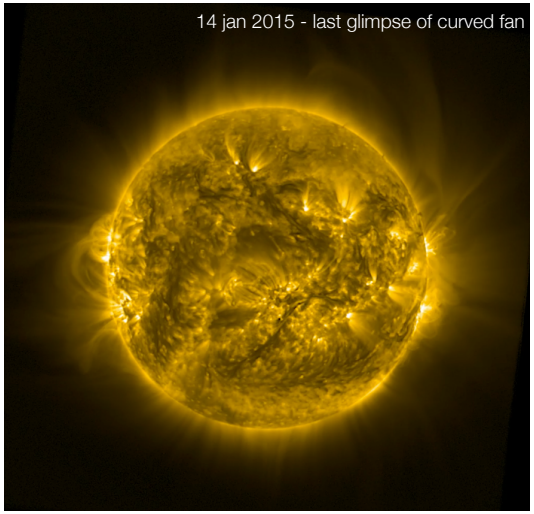




On 30 dec, a prominence erupts from behind the limb.
A few days later the coronal fan is still present but has more complex structure.
From 6 jan onwards, a new AR emerges in the region and the fan sheet is breaking down.

Coronal EUV fans: Persistence & Breakdown II





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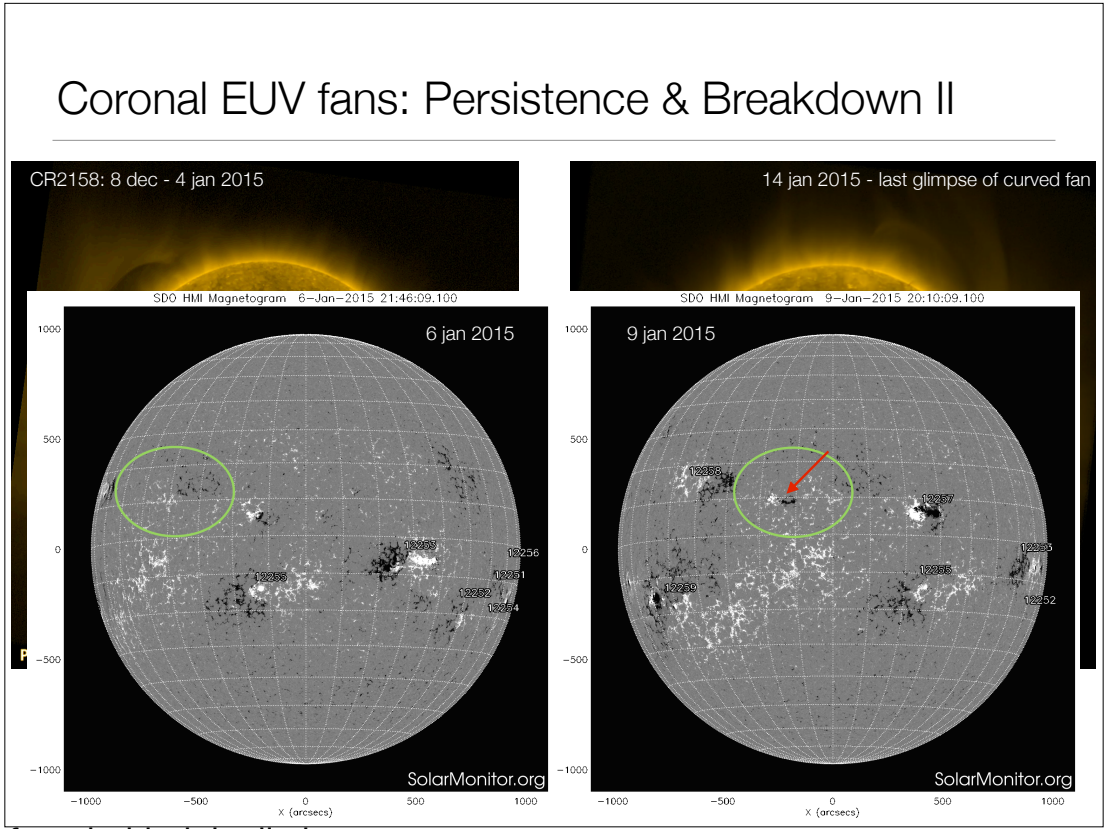

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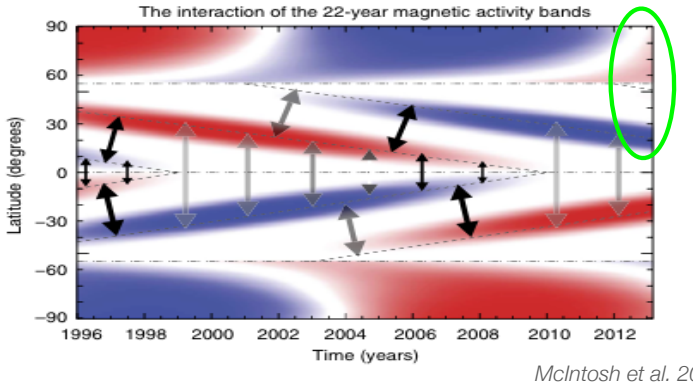
Coronal EUV fans along the solar cycle

- Extended EUV emission & presence of fans increased over rising phase Cycle 24. **No coronal EUV fans at solar minimum**.
  - Need of open field at low latitudes? Solar activity to heat them?
- All persistent EUV fans in **northern hemisphere**
  - Related to dominance of N activity, polar reversal?

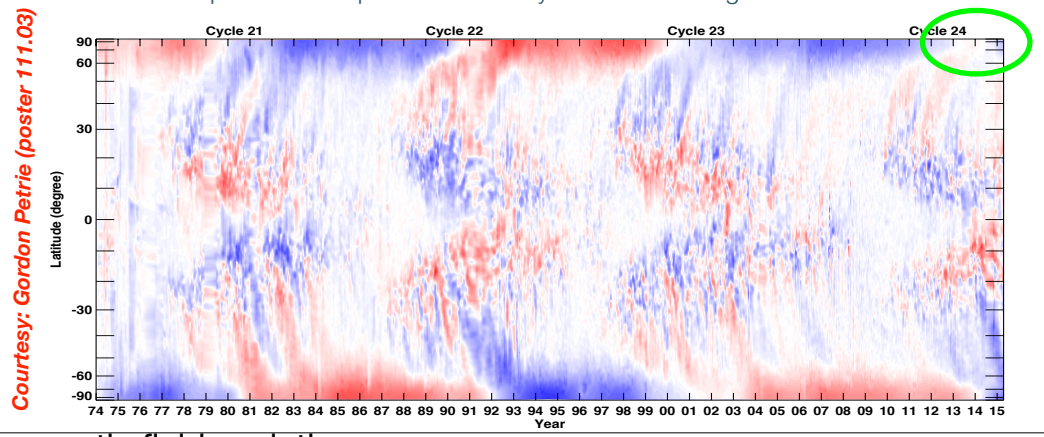


McIntosh et al. 2015, Ncomms 7491

EUV emission in extended solar corona increases with rise of solar activity (consistent with white light streamers)
No coronal EUV fans at solar minimum. First extended, long-lived coronal euv fans in 2011, most prominent ones in 2014.
All long-lived EUV fans in Northern hemisphere: why?
1 reason could be the dominance of activity in the North during Cycle24.
But more likely that the magnetic connection between activity belt and pole was only possible over the last few years in the North.

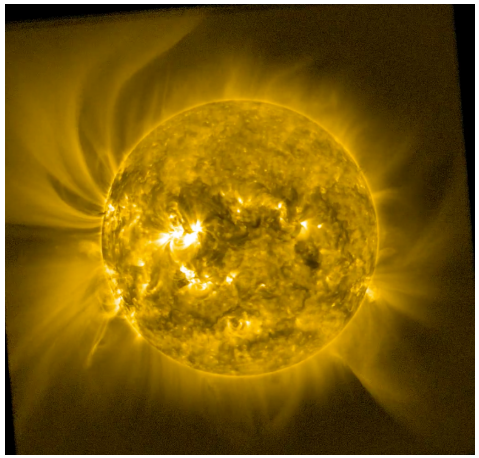
Coronal EUV fans along the solar cycle II

- Extended EUV emission & presence of fans increased over rising phase Cycle 24. **No coronal EUV fans at solar minimum**.
  - Need of open field at low latitudes? Solar activity to heat them?
- All persistent EUV fans in **northern hemisphere**
  - Related to dominance of N activity, polar reversal? Or rather to the weak fields at the north pole?! South pole reversal very sudden & strong CH

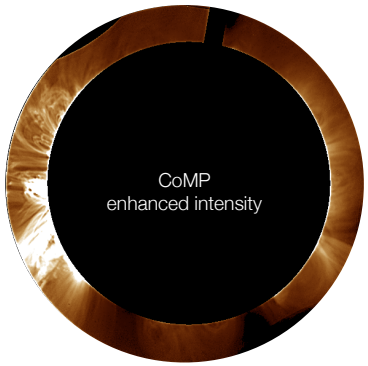


When looking more closely at the magnetic field evolution:
Northern pole has been very weak, allowing large scale loops connecting to the pole.
Southern pole was still negative up to 2014 and now suddenly flipped over. The current coronal hole is so strong that it may prevent any direct link with the activity belt.

SWAP vs CoMP intensity - 26 Jul 2014

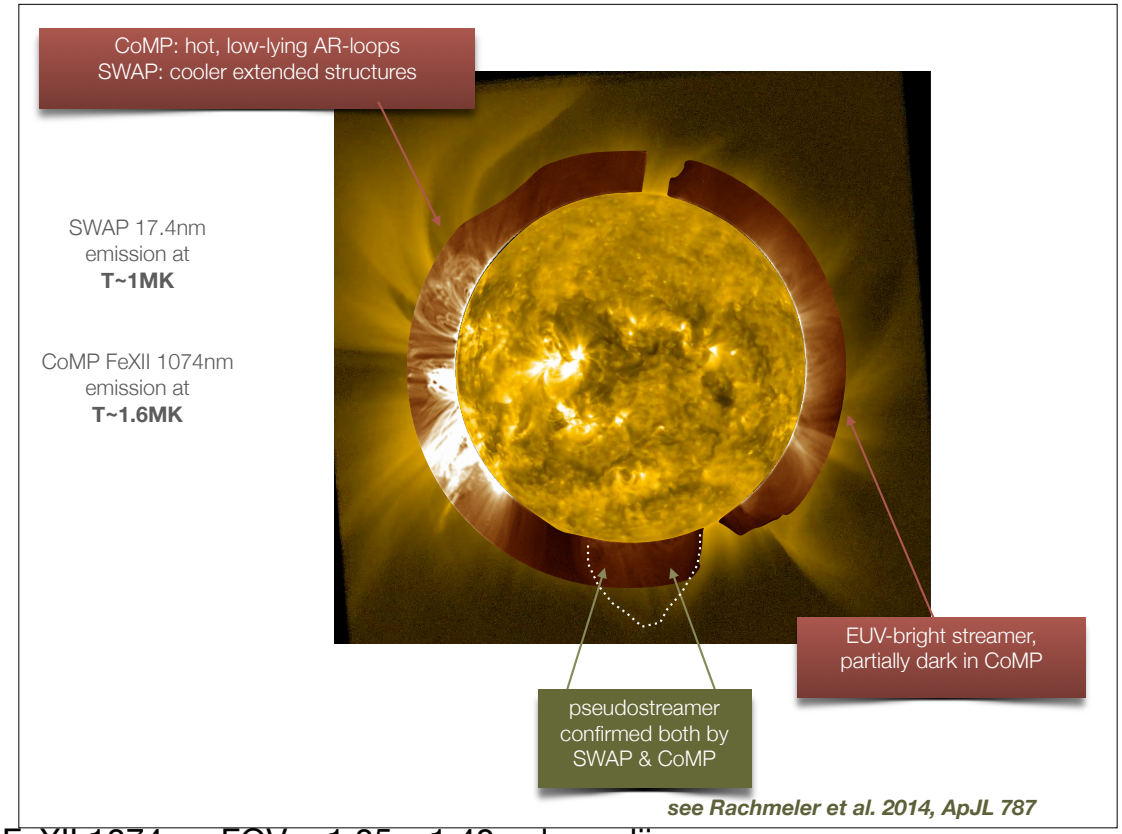


SWAP 17.4nm
emission at
T~1MK



CoMP FeXII 1074nm
emission at
T~1.6MK

CoMP measures forbidden line FeXII 1074nm FOV = 1.05 – 1.40 solar radii
= E-corona due to spectral emission lines produced by coronal ions = trace out magnetic field



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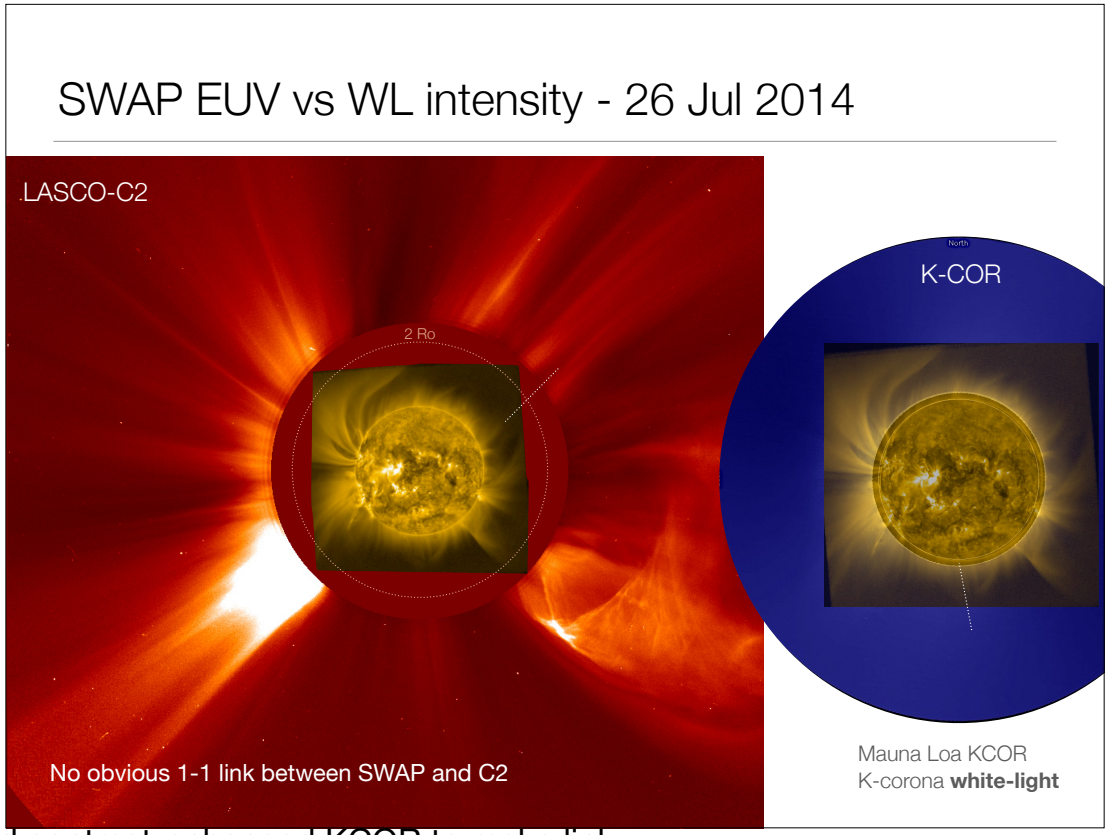
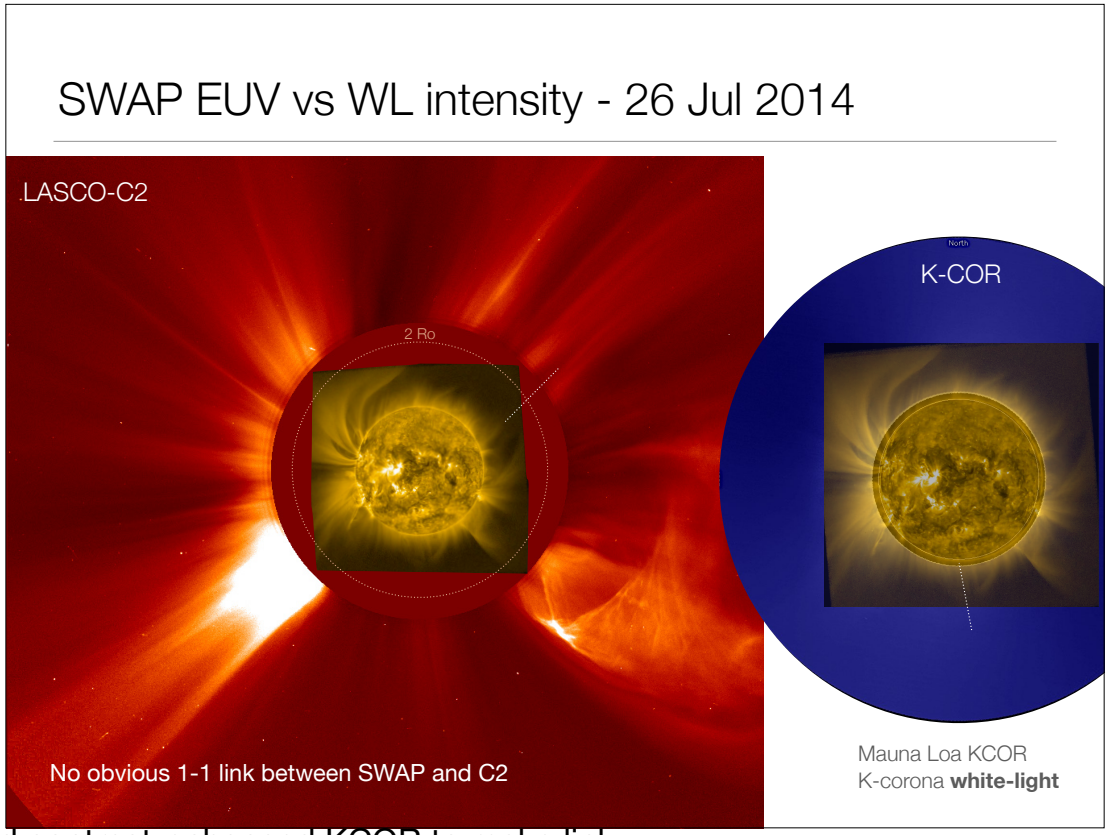


Link SWAP-C2 not obvious: need contrast-enhanced KCOR to make link

No obvious 1-1 link between the highly curved coronal EUV fans and WL streamers.



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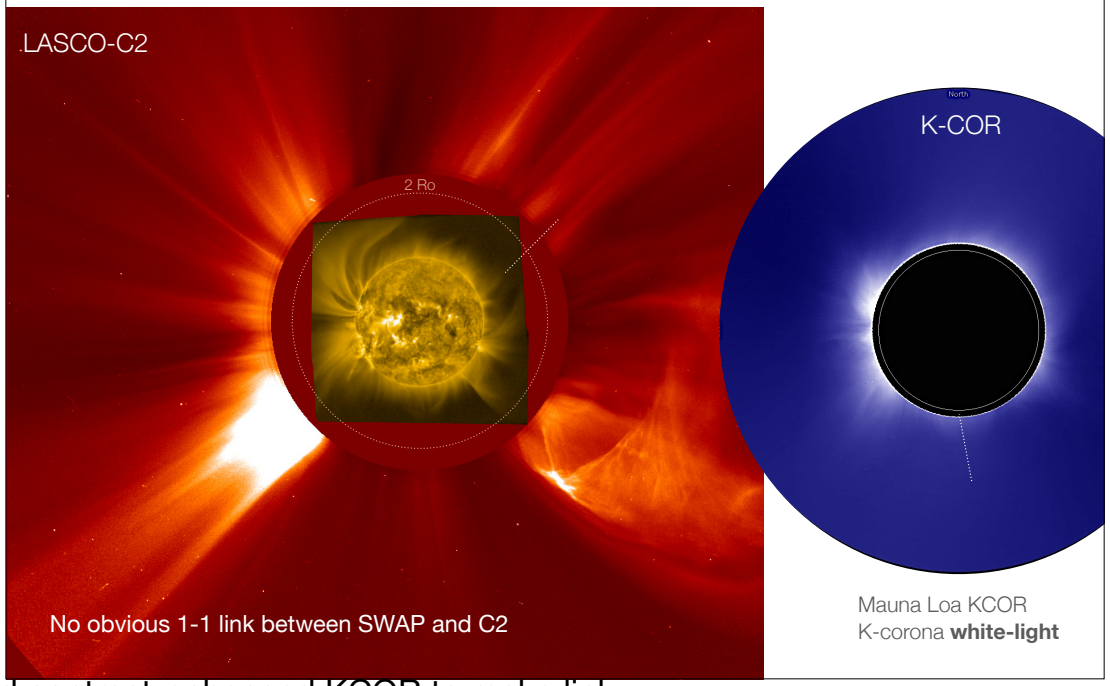

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(Preliminary) Conclusions

- SWAP revealed that 1-million-degree corona extends further than 2 R_o around solar maximum **and is clearly non-radial**
- Some persistent EUV streamers can be linked to double and/or pseudo-streamers
- Most-extended fans, curving towards the pole, don't have obvious 1-to-1 correspondence with WL(*). These typically trace open field lines, rooted in sunspot-less magnetic regions, overlying closed field.
- Question remains why they only appear in North during Cycle 24: related to magnetically weak North?

(*) pending analysis enhanced K-COR and eclipse images