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Assessment of **acoustic holography** parameters from the solar **far side** as a proxy of **magnetic activity** on the Sun's **near side**

[Preliminary results of my B.Sc. Physics thesis]

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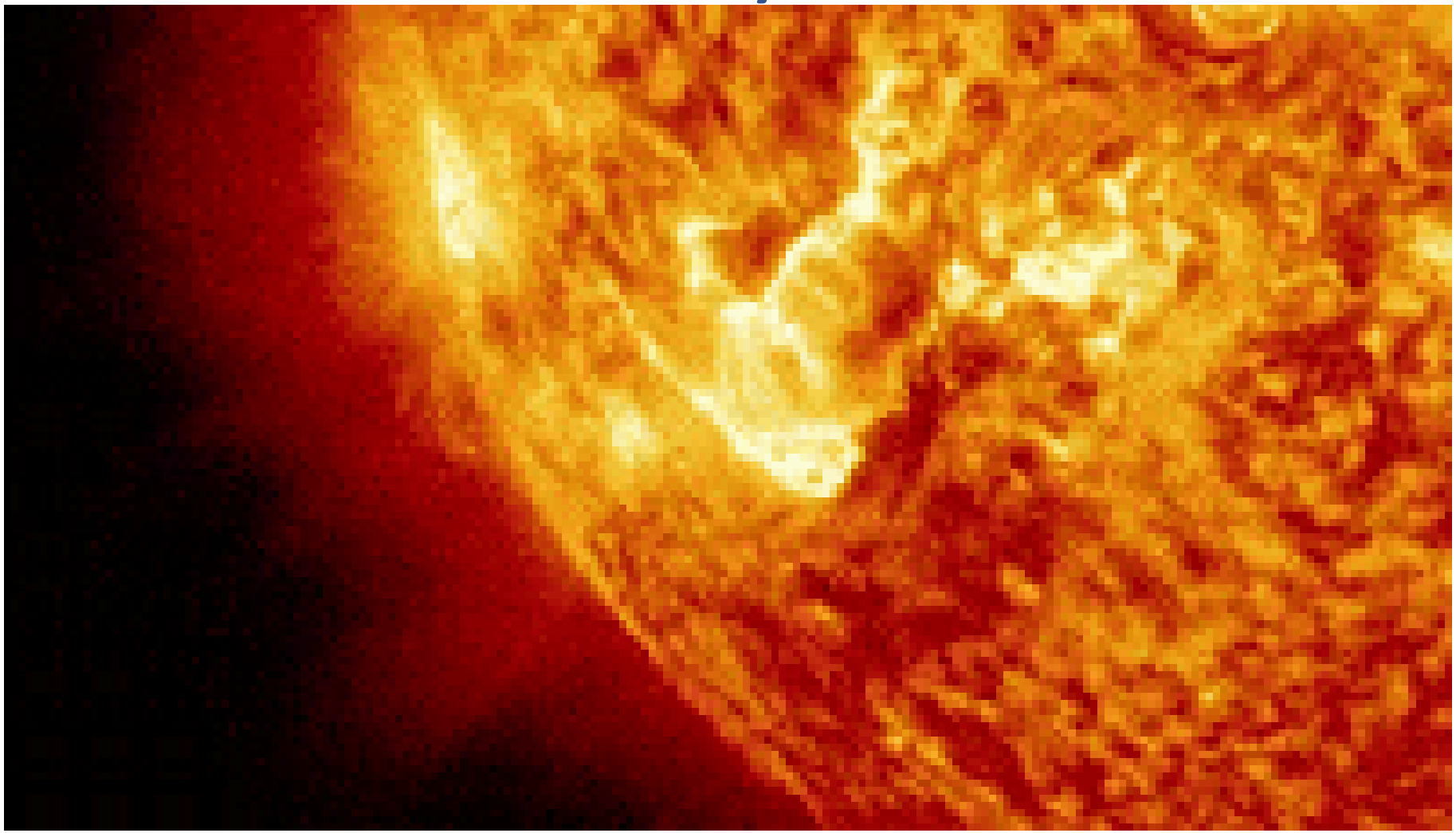
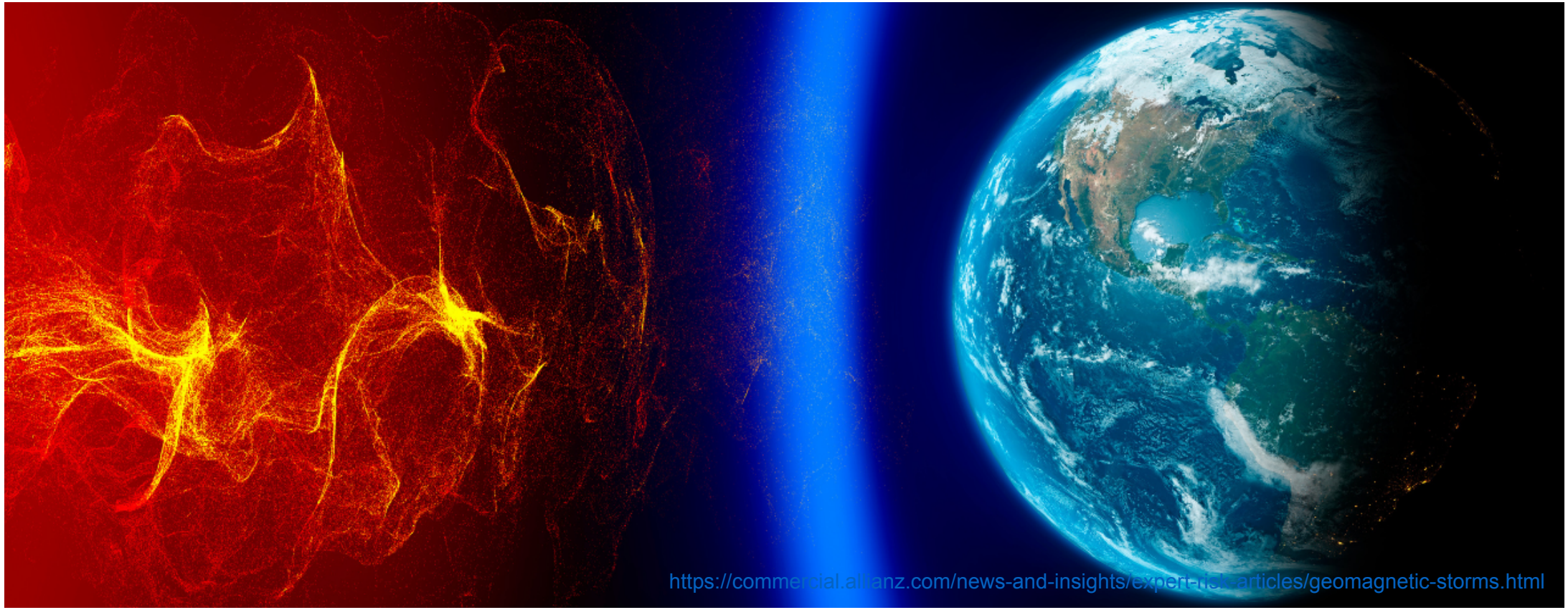
The Sun hosts the most powerful eruptions in the solar system



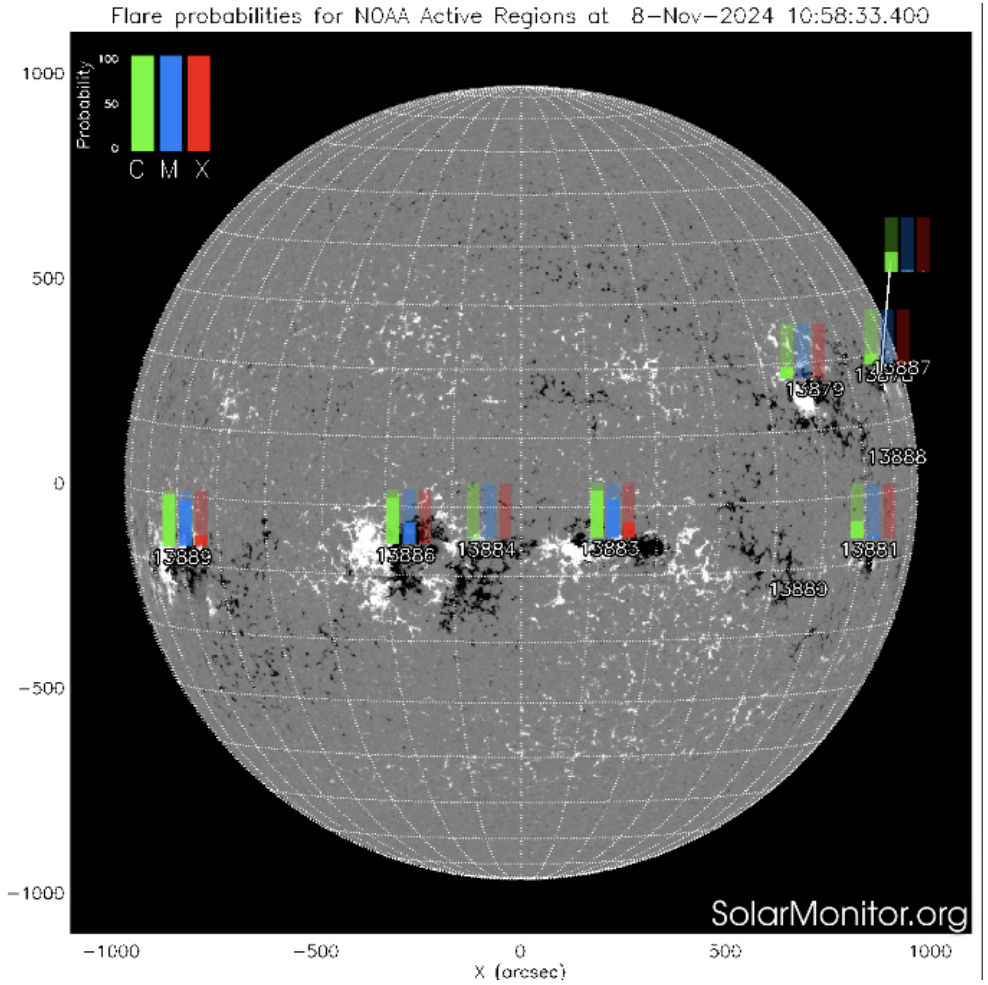
Some of these large solar eruption could eject material directly into Earth



posing potential hazards to our technology

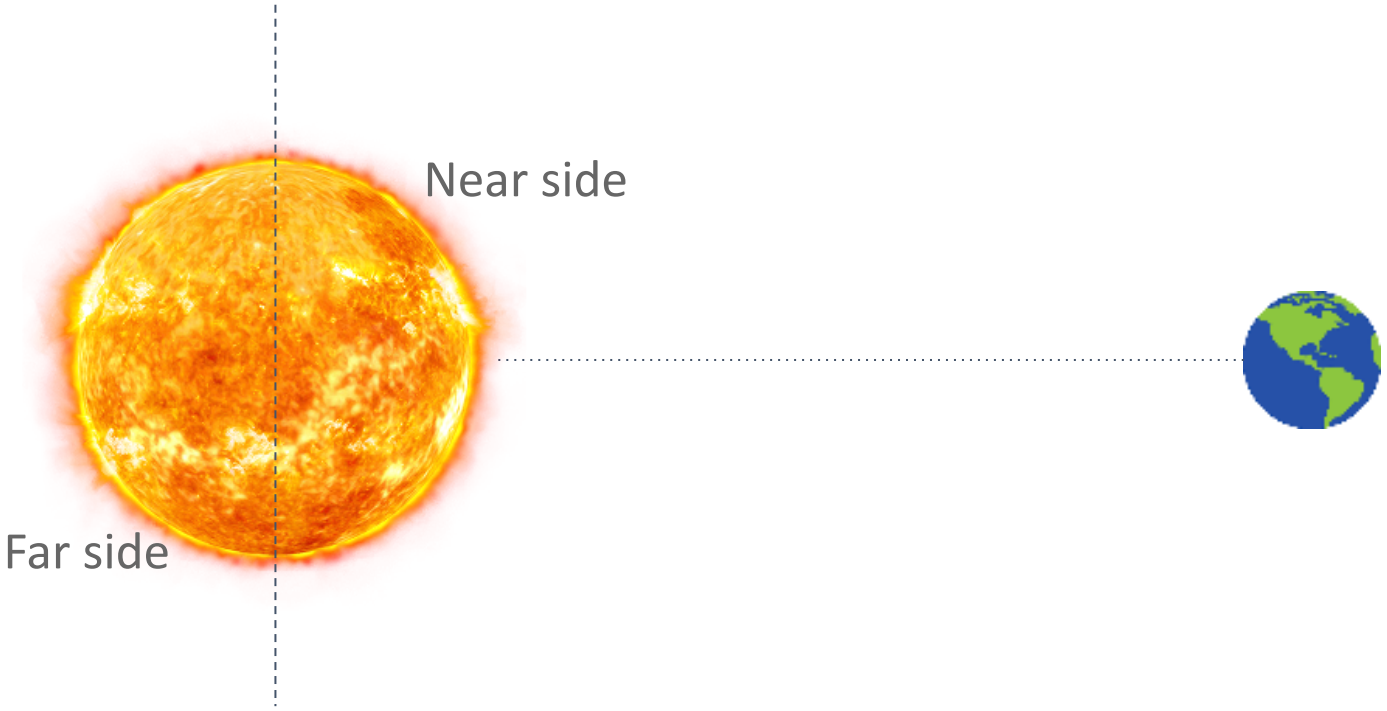
How much in advance can we predict a large solar eruption?

Many science groups run daily flare forecasts to predict flares within 24 hours



Can we get proxies for these probabilities days, or even a couple of weeks, in advance?

Sun’s Far side vs Near side



Nearside: The side of the sun that faces Earth

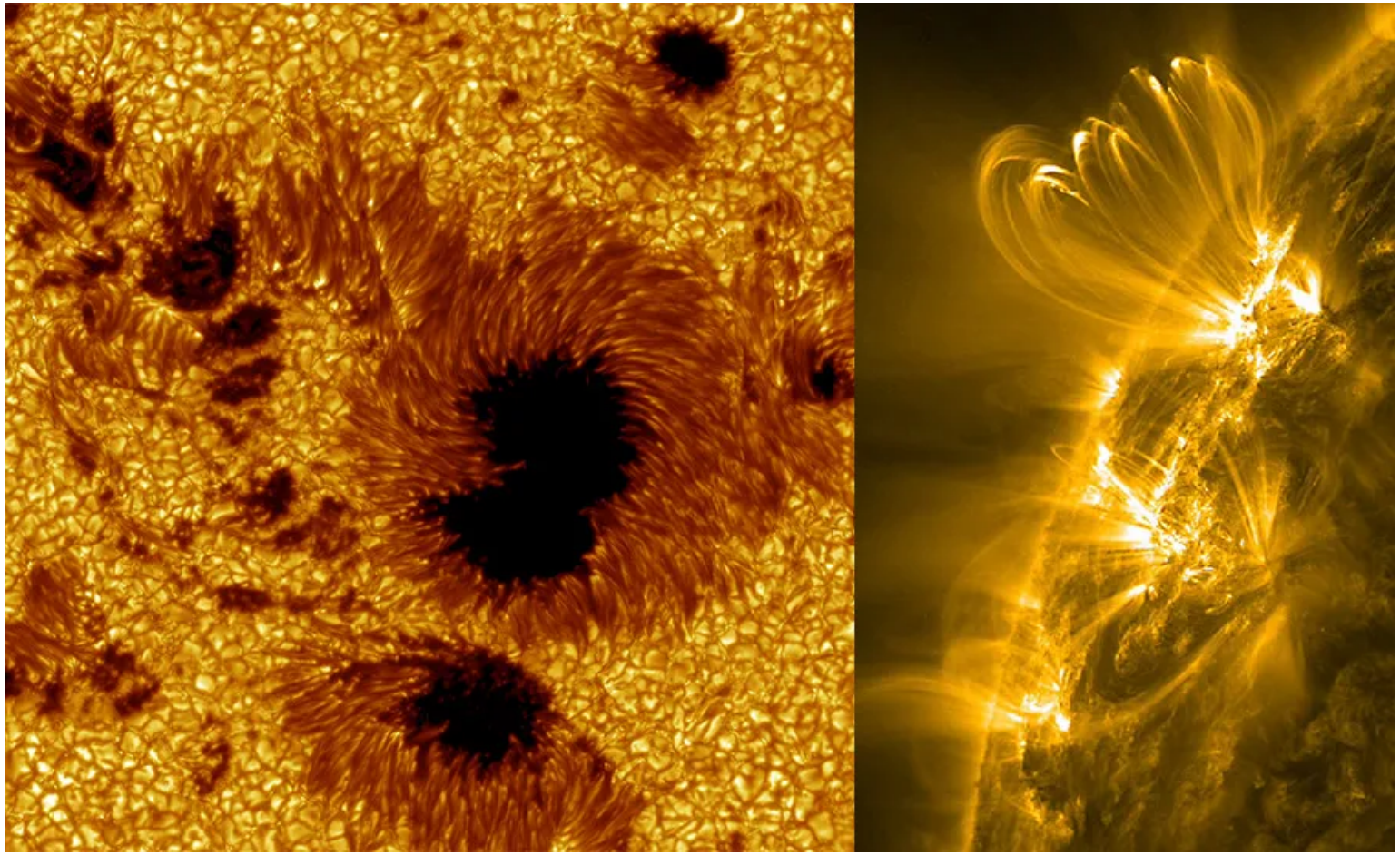
Farside: The side of the Sun that we cannot directly see from Earth

Motivation: Can we guess what is coming up to the nearside?

In this work we assess the helioseismic holography techniques to predict the appearance of solar active regions due to the solar rotation.

What an Active Region (AR) is?

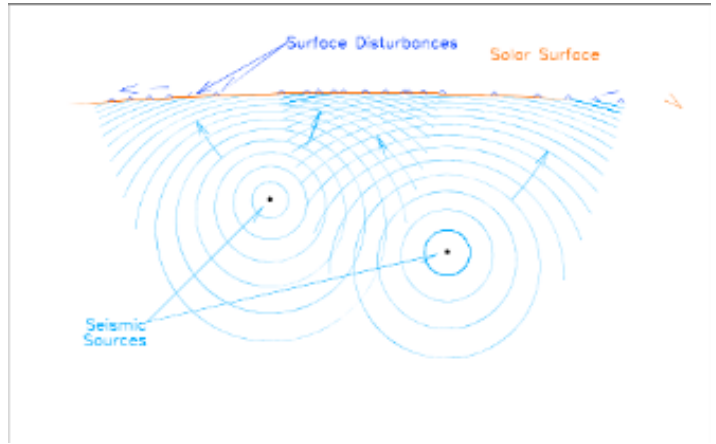
Dark sunspots are visual indicators of active regions

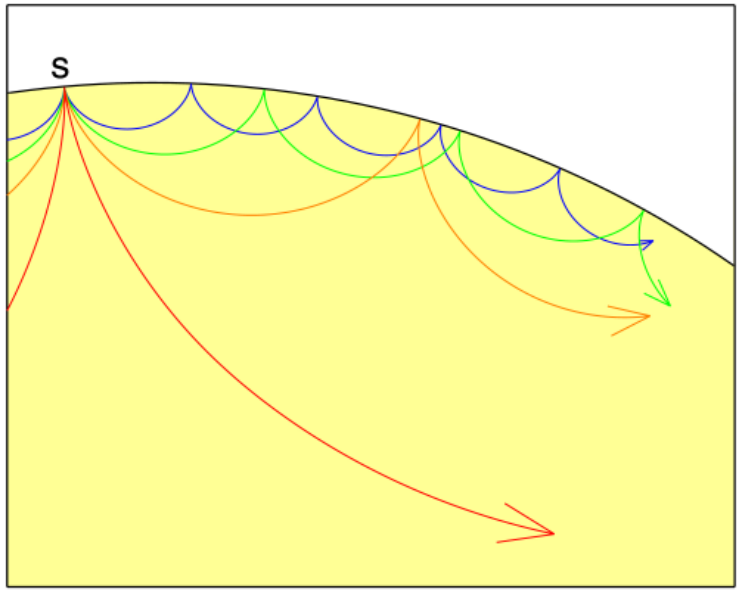


They are places in the solar atmosphere where the magnetic field is relatively more intense. These regions frequently spawn various types of solar activity, including energetic eruptions such as solar flares and coronal mass ejections (CME).

Helioseismic Holography

Is a technique that involves measuring the travel times of the Sun's acoustic waves these waves as they move through the Sun and are reflected back to the surface. Differences in travel times can reveal various features and acoustic anomalies.

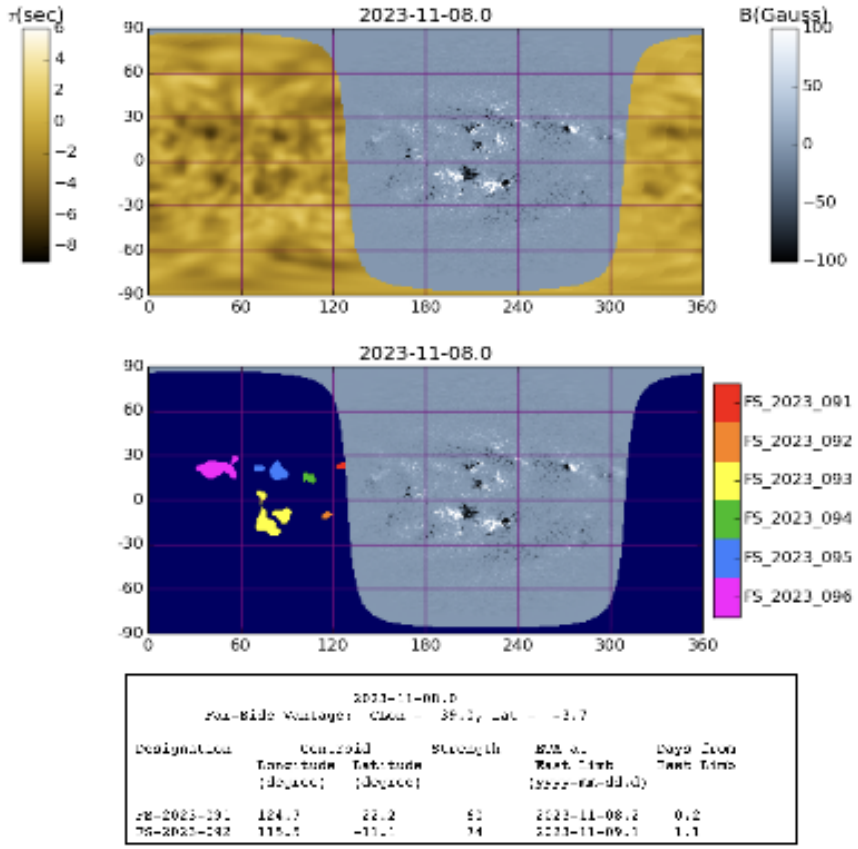




Using this technique, a team at the NorthWest Research Associates routinely construct maps of the far side of the Sun, revealing sunspots, active regions, and other features that affect the acoustic speed of the global solar seismic waves

DATA USED

Stanford Seismic Monitor of the Sun's Far Hemisphere for the Solar Dynamics Observatory



NOAA - Solar Active Region Catalog

```
:Product: 0702SRS.txt
:Issued: 2014 Jul 02 0030 UTC
# Prepared jointly by the U.S. Dept. of Commerce, NOAA,
# Space Weather Prediction Center and the U.S. Air Force.
#
oint USAF/NOAA Solar Region Summary
SRS Number 183 Issued at 0030Z on 02 Jul 2014
Report compiled from data received at SWO on 01 Jul
I.  Regions with Sunspots.  Locations Valid at 01/2400Z
Nmbr Location  Lo  Area  Z   LL   NN Mag Type
2096 N09W51   357  0010 Hsx  01   01 Alpha
2097 N12W44   350  0010 Hsx  01   03 Alpha
2100 N09W02   309  0020 Dai  06   11 Beta
2102 N13E30   277  0050 Dsi  08   08 Beta
2104 S11E39   268  0410 Dkc  07   16 Beta-Gamma-Delta
2105 S06W04   311  0010 Bxo  03   03 Beta
2106 N15E46   261  0050 Dao  07   09 Beta
2107 S20E46   261  0260 Dhc  10   08 Beta-Delta
2108 S08E68   239  0030 Dao  06   05 Beta
IA. H-alpha Plages without Spots.  Locations Valid at 01/2400Z Jul
Nmbr  Location  Lo
2098  S09W77   024
2099  S16W61   008
2101  S07W75   022
2103  S10E10   297
II. Regions Due to Return 02 Jul to 04 Jul
Nmbr Lat    Lo
2089 N17    211
2095 N05    208
```

The National Oceanic and Atmospheric Administration (NOAA) reports daily at 00:30 UTC the observable solar active regions from the previous day through the Solar Region Summary (SRS), which provides a detailed description of the active regions currently visible on the solar disk

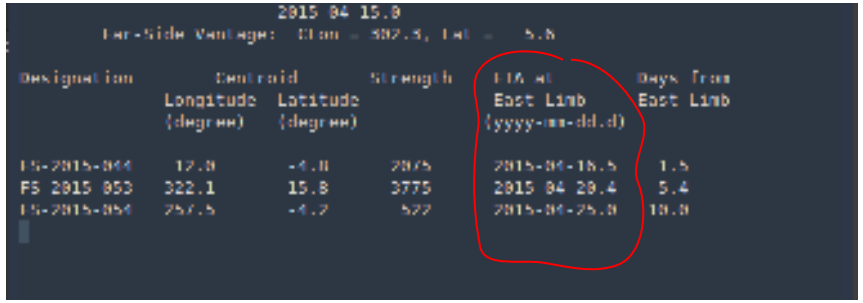
Our Analysis

- Compared the new near side's AR reported in a week by NOAA with the mean strength by week of the AR of the far side giving by holography helioseismic techniques.

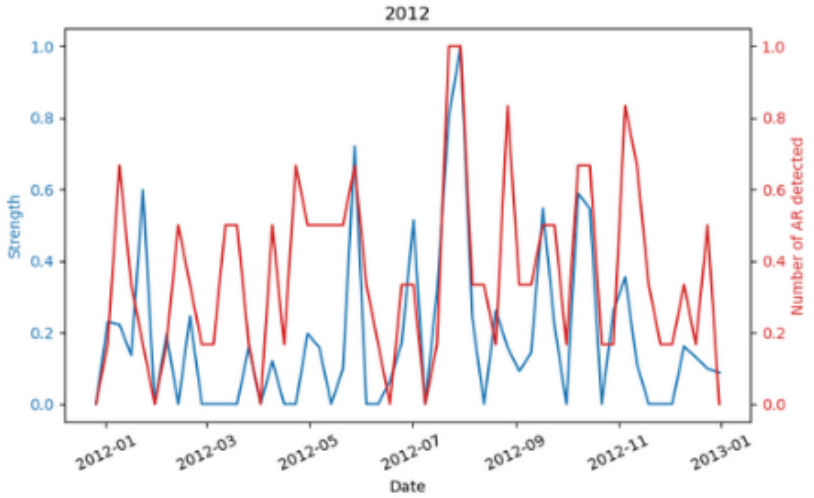
⇒ Using the Stonyhurst heliographic coordinate system we take the new AR at east limb with Longitude:

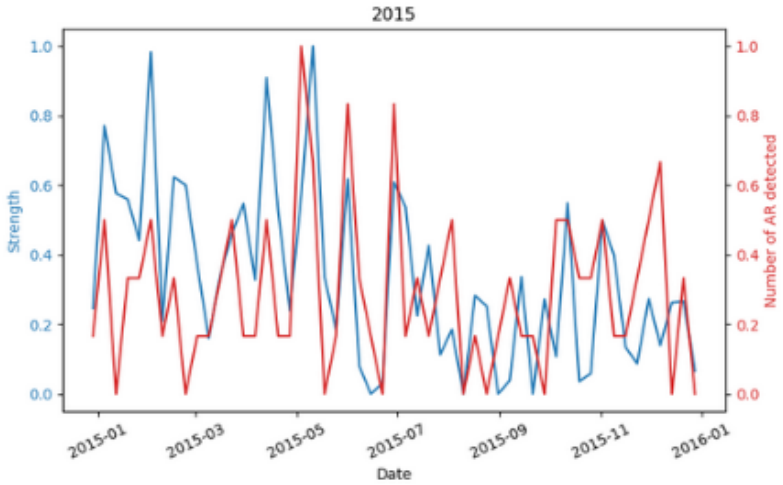
$$-90 < L_0 < -65$$

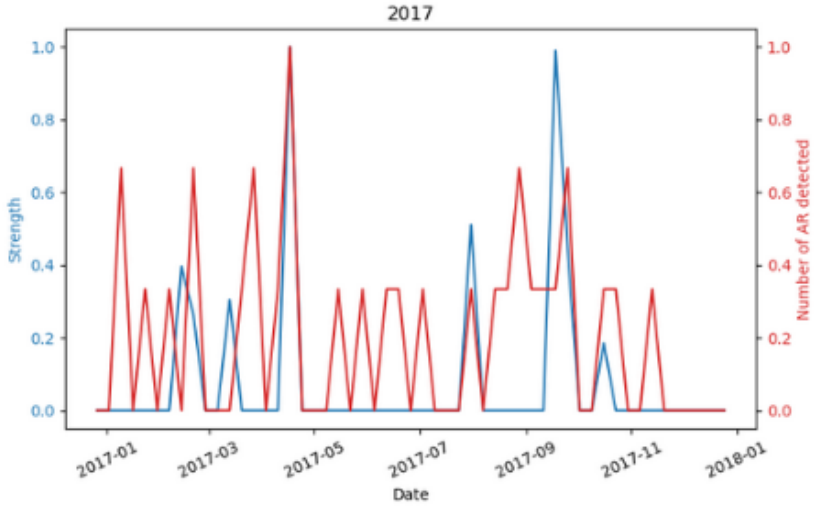
⇒ The AR's prediction date as the lastest reported for that AR

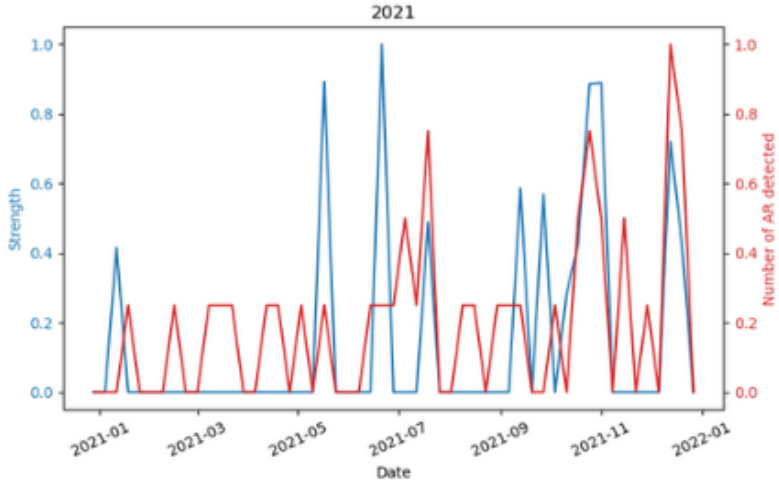


Weekly mean strength vs New AR's number at east limb







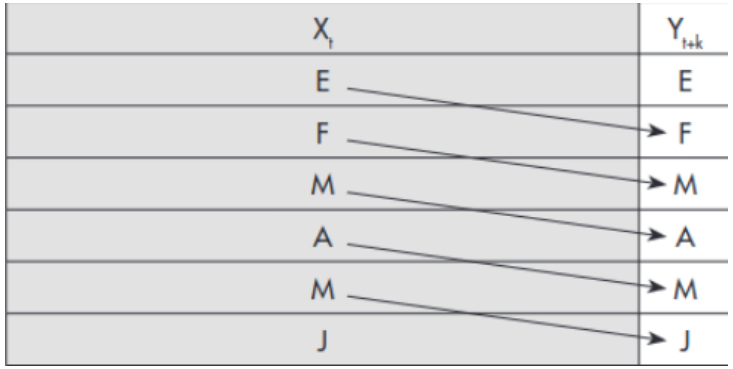


CROSSCORRELATION

Allows to correlate series out of phase in time

$$r_{XY(K)} = \frac{\Sigma[(X_t - \mu_x)*(Y_{t+k} - \mu_Y)]}{N\,S_x\,S_Y} = \frac{1}{N}\sum[(\frac{X_t - \mu_x}{S_x})*(\frac{Y_{t+k} - \mu_Y}{S_Y})] \quad en\ lag +$$

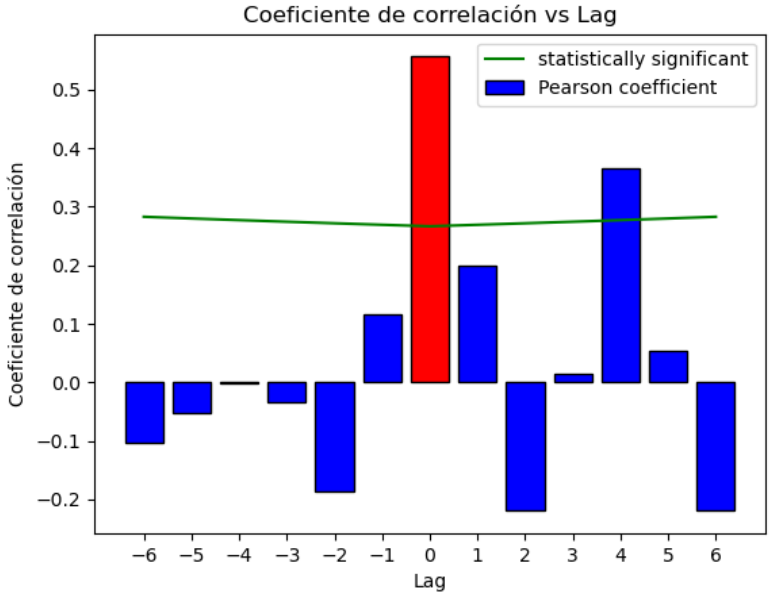
$$r_{YX(-K)} = \frac{\Sigma[(Y_t - \mu_y)*(X_{t+k} - \mu_Y)]}{N\,S_x\,S_Y} = \frac{1}{N}\sum[(\frac{Y_t - \mu_y}{S_y})*(\frac{X_{t+k} - \mu_x}{S_x})] \quad en\ lag -$$

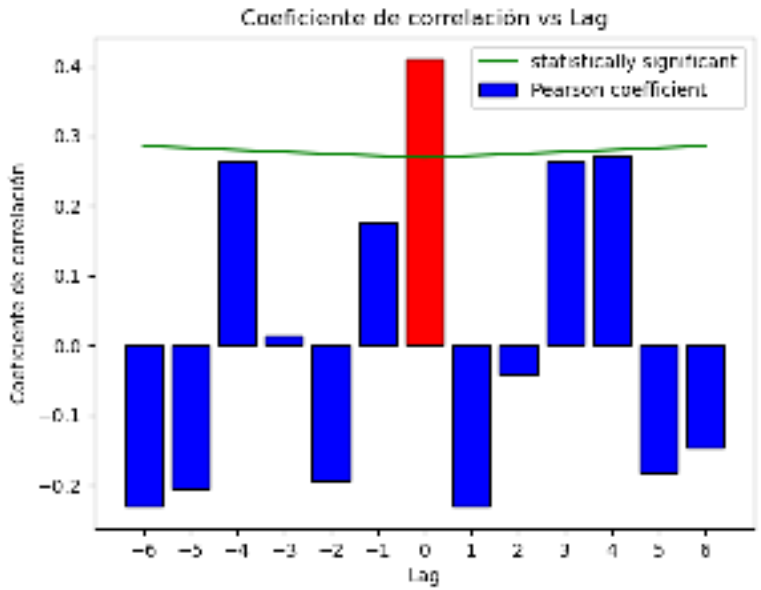


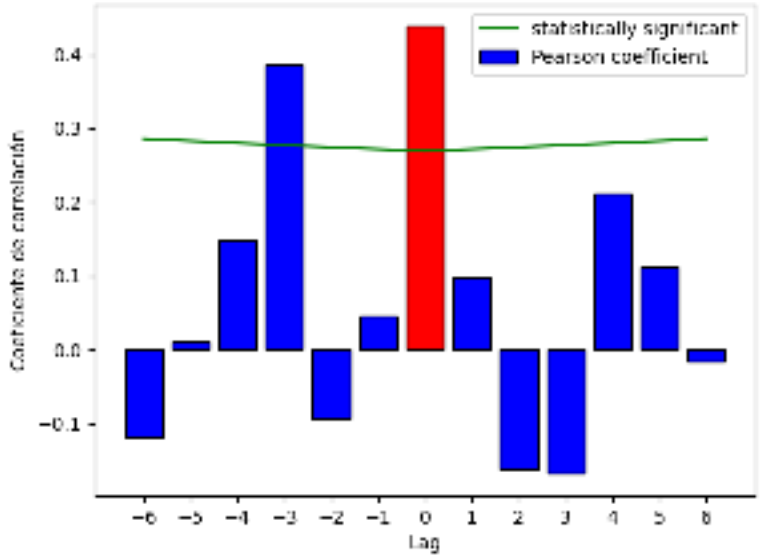
A correlation is considered statistically significant if:

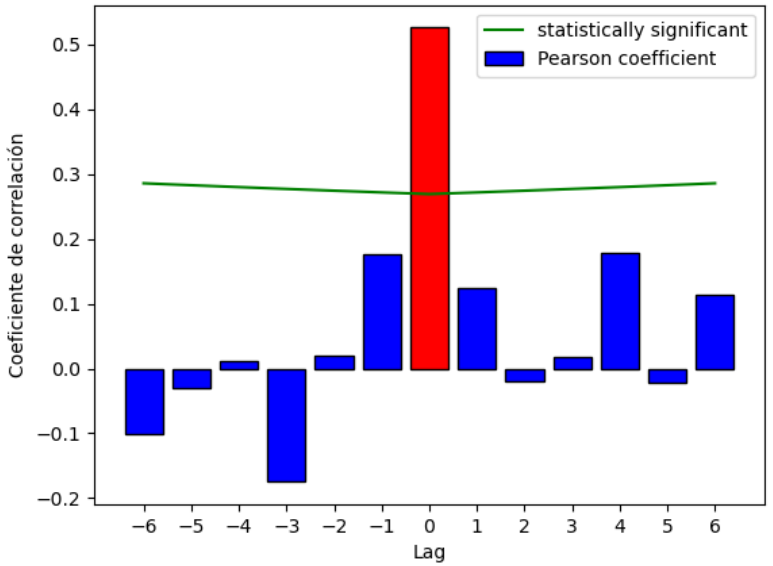
$$r_{xy}(k) > \frac{1{,}96}{\sqrt{(N-k)}}$$

Using the crosscorrelation analysis









Correlations found

year	r (Pearson)	τ (Kendall)	s (Spearman)
2011	0.55	0.34	0.42
2012	**0.53**	0.32	0.41
2013	0.25	0.26	0.35
2014	0.24	0.09	0.14
2015	**0.31**	0.24	0.33
2016	0.45	0.46	0.56
2017	**0.44**	0.3	0.32
2018	-0.11	-0.1	-0.1
2019	0.44	0.19	0.19
2020	0.3	0.3	0.3
2021	**0.52**	0.36	0.42
2022	0.17	0.13	0.16

Some Considerations

- Some of the AR of the Nearside aren’t reported by the NOAA in a timely manner
- Through the solar maps, we observed that some of the ARs expected to appear on the nearside do not emerge exactly at the east limb on the predicted date but instead appear a few days later near it

Conclusions

- We found a weak positive correlation between the strength of far-side ARs and the emergence of new ARs on the near side.
- Our findings suggest far-side ARs potentially useful precursors for predicting solar activity on the near side.
- There is a need for more sophisticated predictive models that incorporate additional parameters from the far side acoustic maps.

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¡Gracias!

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