On forecasting solar eruptive events by the sunspot dynamics detected at photospheric level

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The magnetic reconnection has
important role in impulsive events!

Are there any other features of dynamic phenomena
that may be a signature of impulsive events?

Flare forecast strategy

The majority of the flare forecast methods use magnetograms.

Present method:

Tracking the dynamics of sunspots input data:

SDD-(SOHO/MDI - Debrecen Data)

HMIDD-(SDO/HMI - Debrecen Data)

The data of positions, areas and mean magnetic fields for all observable sunspots and sunspot groups on a 1-1.5 hourly basis.

Maximum gradient method

We define a **proxy quantity for the weighted horizontal magnetic gradient:**

$$WG_M = \left| \frac{\sum_i B_{p,i} \cdot A_{p,i} - \overbrace{\sum_j B_{n,j} \cdot A_{n,j}}^{\text{Magnetic flux}}}{d_{pn}} \right|$$

We follow the variation of WG_M in the area of highest magnetic gradient.

Korsos et al. ApJ, 802, L21, 2015

Generalized selection criteria of the considered spots

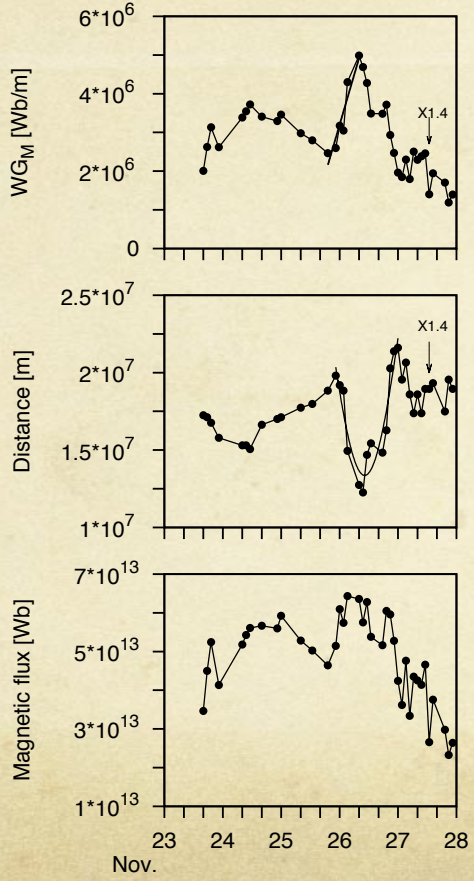
- A new spot (*min. 3 MSH*) emerges close (*within 40 Mm*) to an existing spot of opposite polarity in the region of strongest magnetic gradient. This area will be traced.

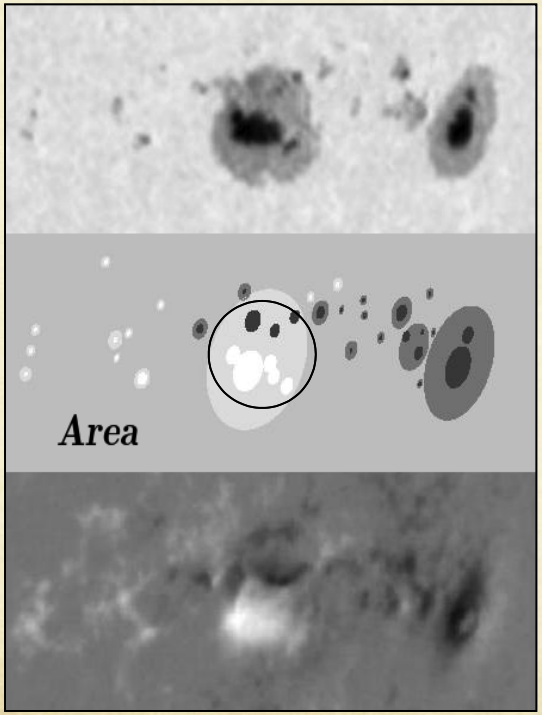
- The center of the studied area is fixed!

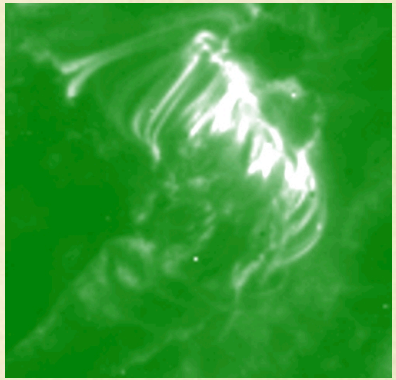
- The diameter of the area under study is 3º. Afterwards, all spots are taken into account within this region and the **weighted horizontal magnetic gradient** (WG_M) is estimated from their summarized data.

Korsos et al. ApJ, 802, L21, 2015

#1: NOAA 8771







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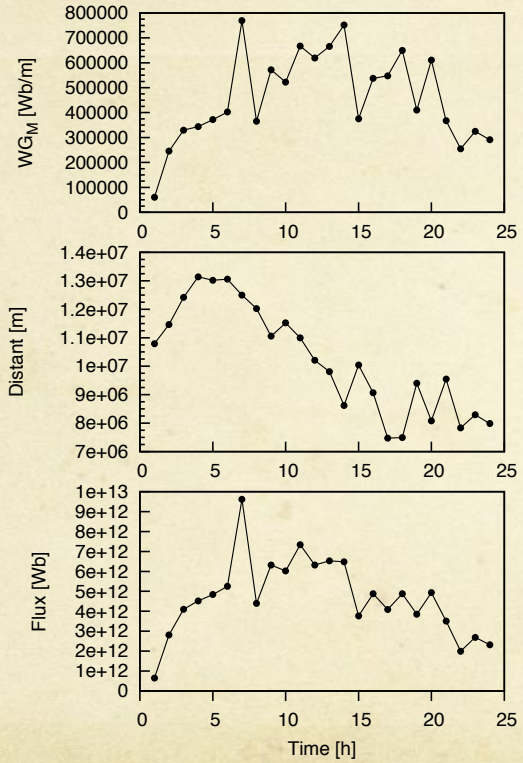
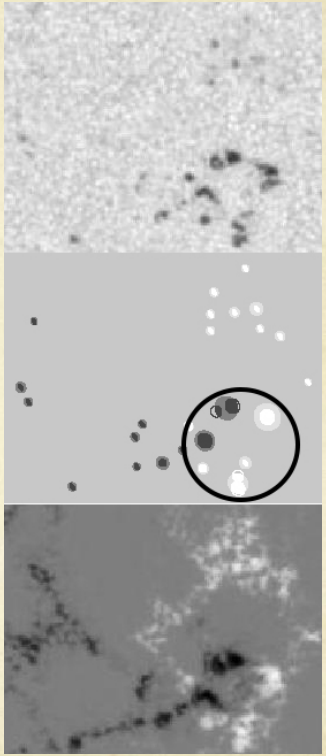
No Flare!

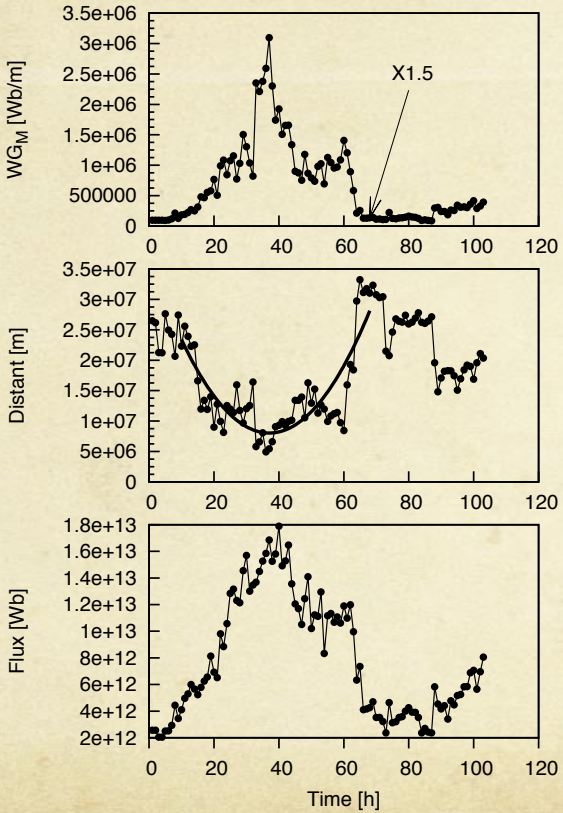
#2: NOAA 11995

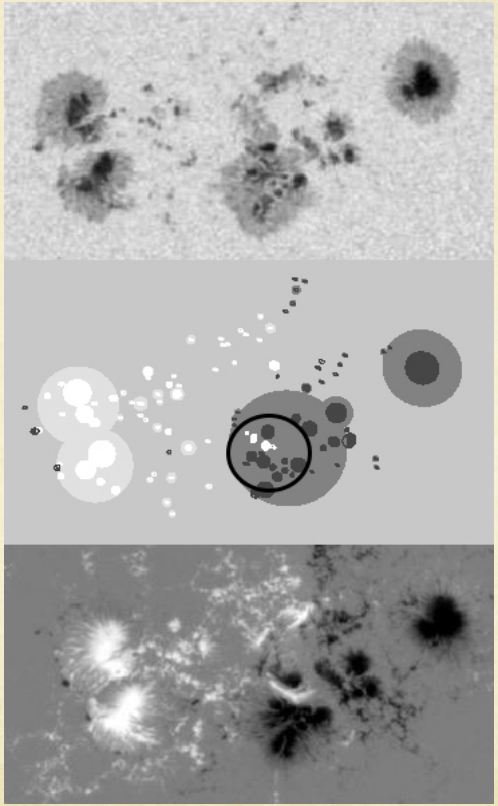


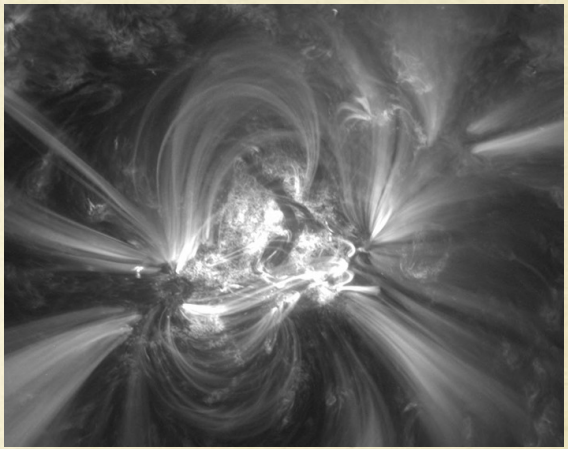


Korsos et al. ApJ, 802, L21, 2015

#3: NOAA 11166







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After the case studies, based on statistics

Features of interest:

- Steep rise of WG_M

- High maximum of WG_M

- Decrease of the WG_M until the flare

- Variation of WG_M consists of the variation of d and flux

What is the predicting value of the WG_M variation? Time? Intensity?

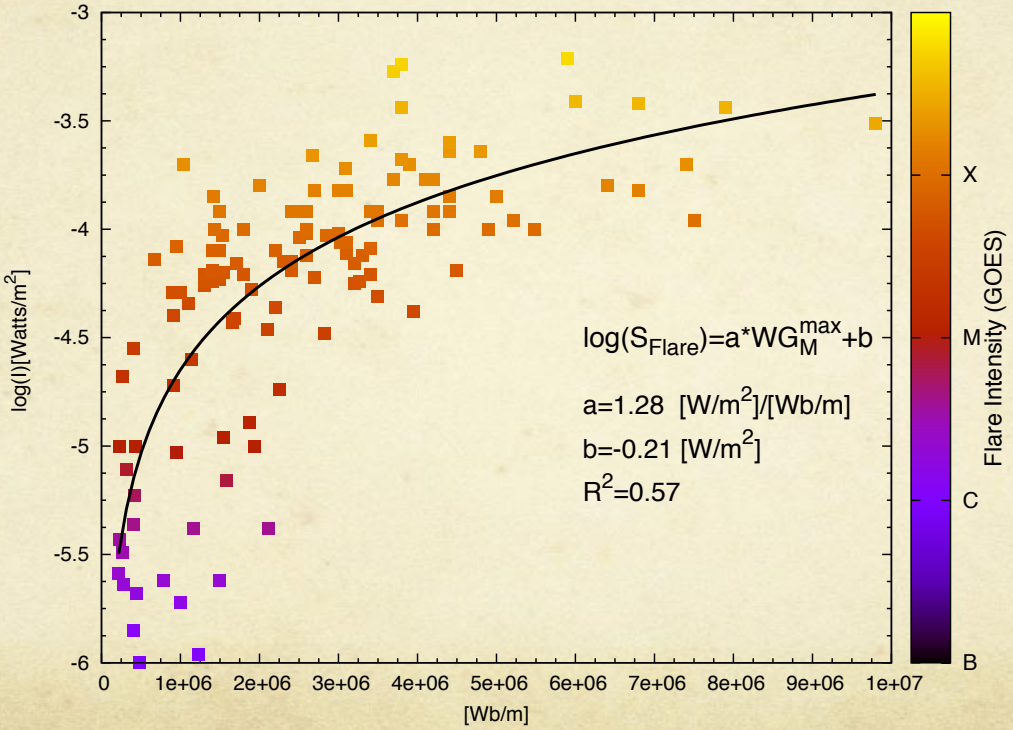
Statistics of **130 ARs** (within ±60º CMD)

Korsos, Baranyi, Ludmany, 2014 ApJ, 789, 107

Inverse relationships to predict the flare intensity

The flare intensity can be estimated from the maximum of WG_M.

Relationship between the proxies of the free energy and the released energy.



Korsos et al. ApJ, 802, L21, 2015

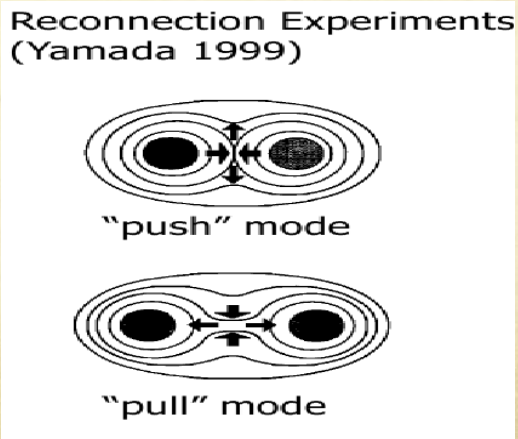
An unexpected phenomenon, two phases prior to the flare onset:

At first approaching and then receding fluxes of opposite polarities prior to flares.

Two similar results:

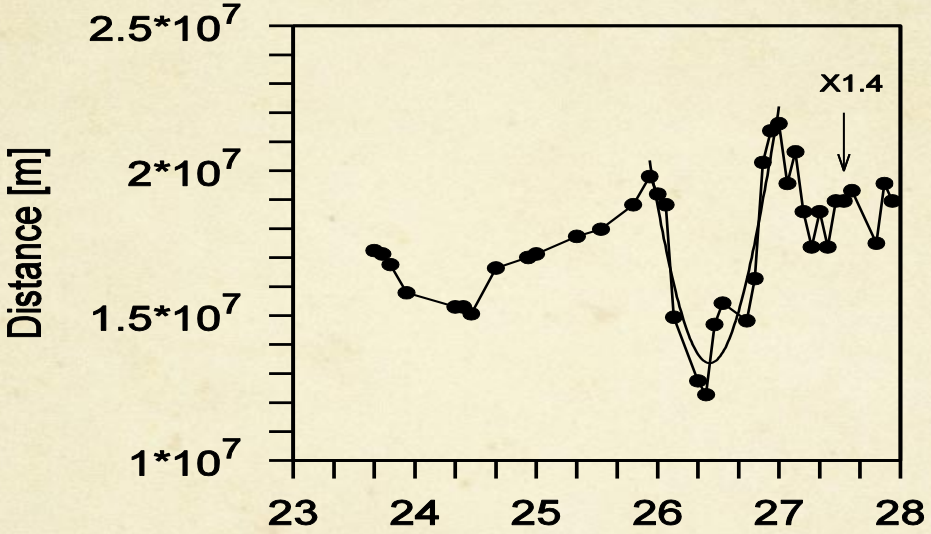
"... flare reconnection on a vertical current sheet is caused by the diverging flows that remove magnetic flux and plasma from the reconnection site. "
A theoretical result of Kusano et al., (2012, ApJ, 760, 31)

Push-Pull mode of reconnection identified in laboratory experiments (Yamada ,1999)



Variation of the distance between the subgroups of opposite polarity

#1:NOAA 8771

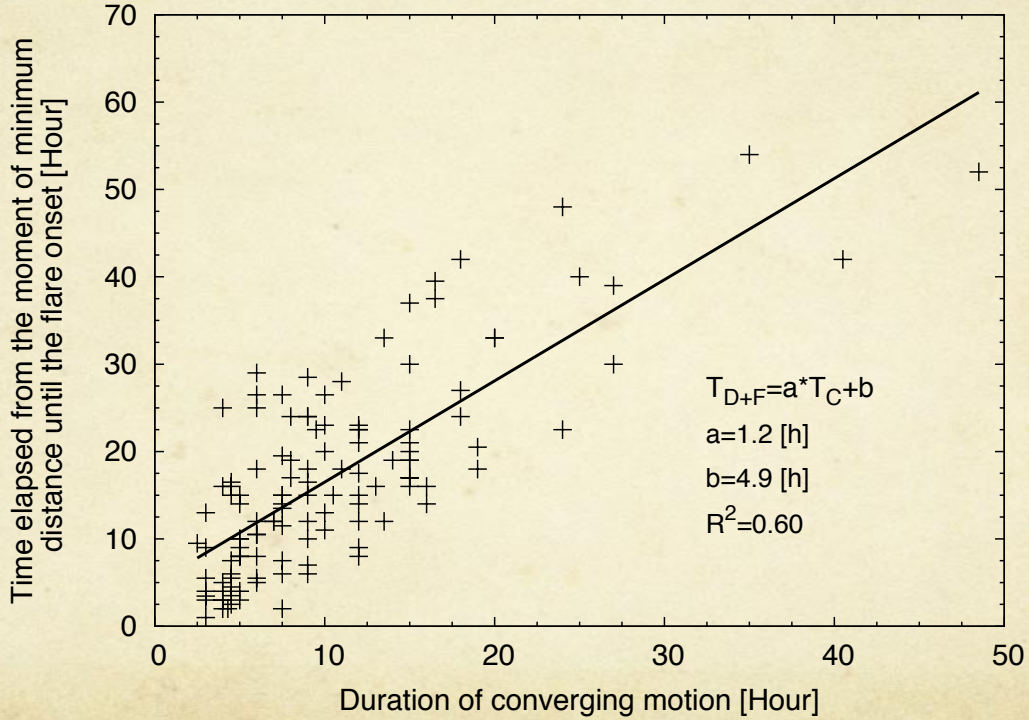


After an approaching motion the subgroups recede until the flare

Korsos et al. ApJ, 802, L21, 2015

The estimate of the expected time of flare onset

Approaching and the time from the closest position until the flare onset.



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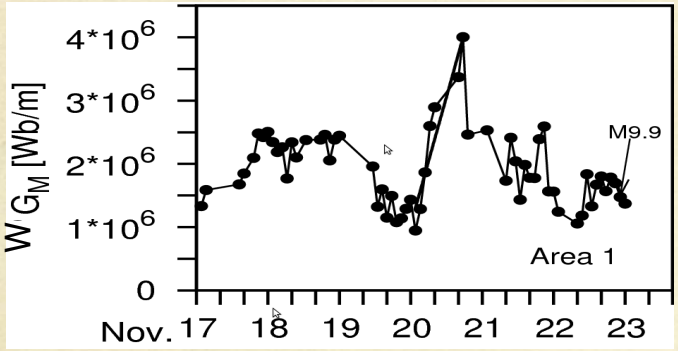
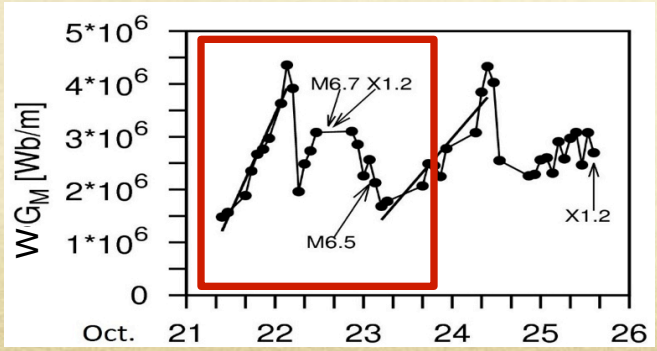
Relationship between previous maximum of WG_M determined and the value of WG_M at flare onset

#4: NOAA 8771



#5: NOAA 9672

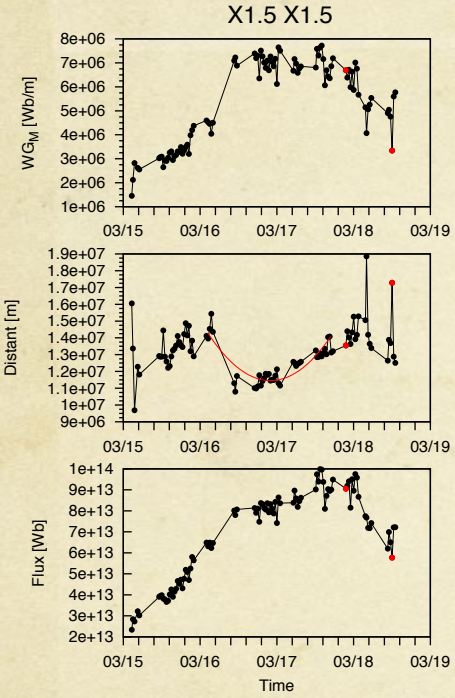


Probability for further flare(s)	
Decrease is *above* 50%	Decrease is *below* 50%
63 %	37 %
20 %	80 %

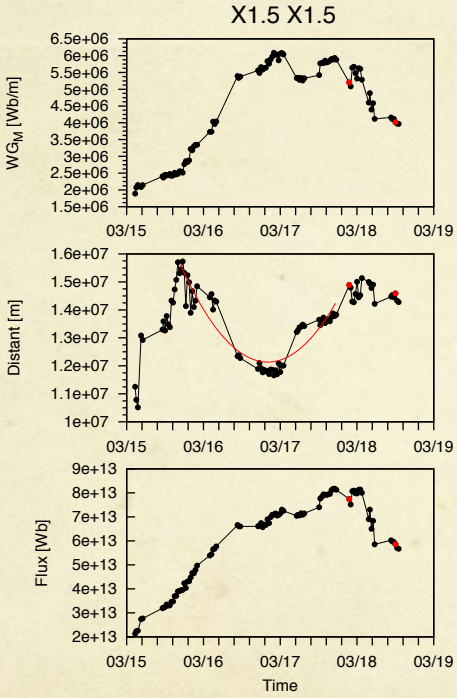
Korsos et al. ApJ, 802, L21, 2015

NOAA 10314 in 3D:

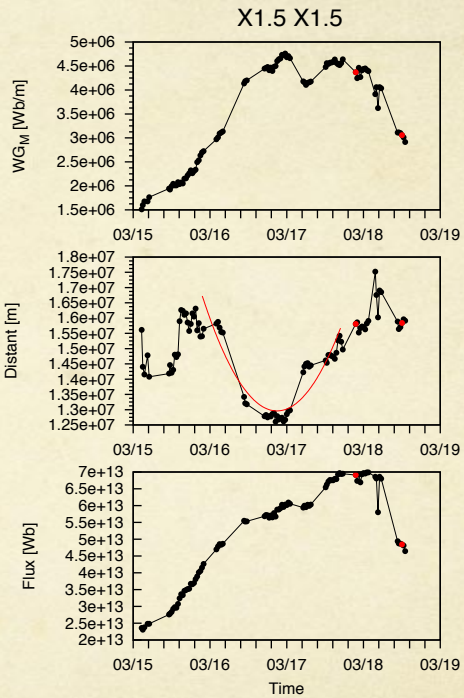
0 Mm level



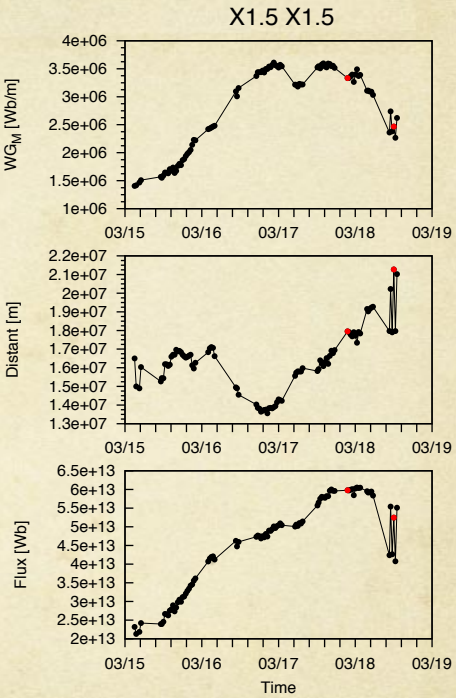
1 Mm level



2 Mm level



3 Mm level



03/16 03:01 -10 h 03/15 17:01 -5 h 03/15 22:01 +1 h 03/16 04:01

Conclusions

Tracking of the following quantities may be promising for flare forecast:

- Weighted horizontal gradient of magnetic field ($\boldsymbol{WG_M}$),
- Steep increase of $\boldsymbol{WG_M}$ → for warning,
- High maximum of $\boldsymbol{WG_M}$ → for the assessment of flare intensity and CME,
- Decrease of $\boldsymbol{WG_M}$ after maximum → for warning,
- Time of Push mode vs. Time of Pull mode → onset time of flare
- Maximum of $\boldsymbol{WG_M}$ vs. the value of $\boldsymbol{WG_M}$ where flare happens. → One or more flare

Thank you for your attention!

Acknowledgement

The authors thank for financial support from STFC UK. This project has also received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 637302 (PROGRESS).