



12th Hellenic Astronomical Conference

Aristotle University Research Dissemination Center (KEDEA)

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ACADEMY



of ATHENS



The **F**orecasting **S**olar **P**article **E**vents and **F**lares (**FORSPEF**) Tool

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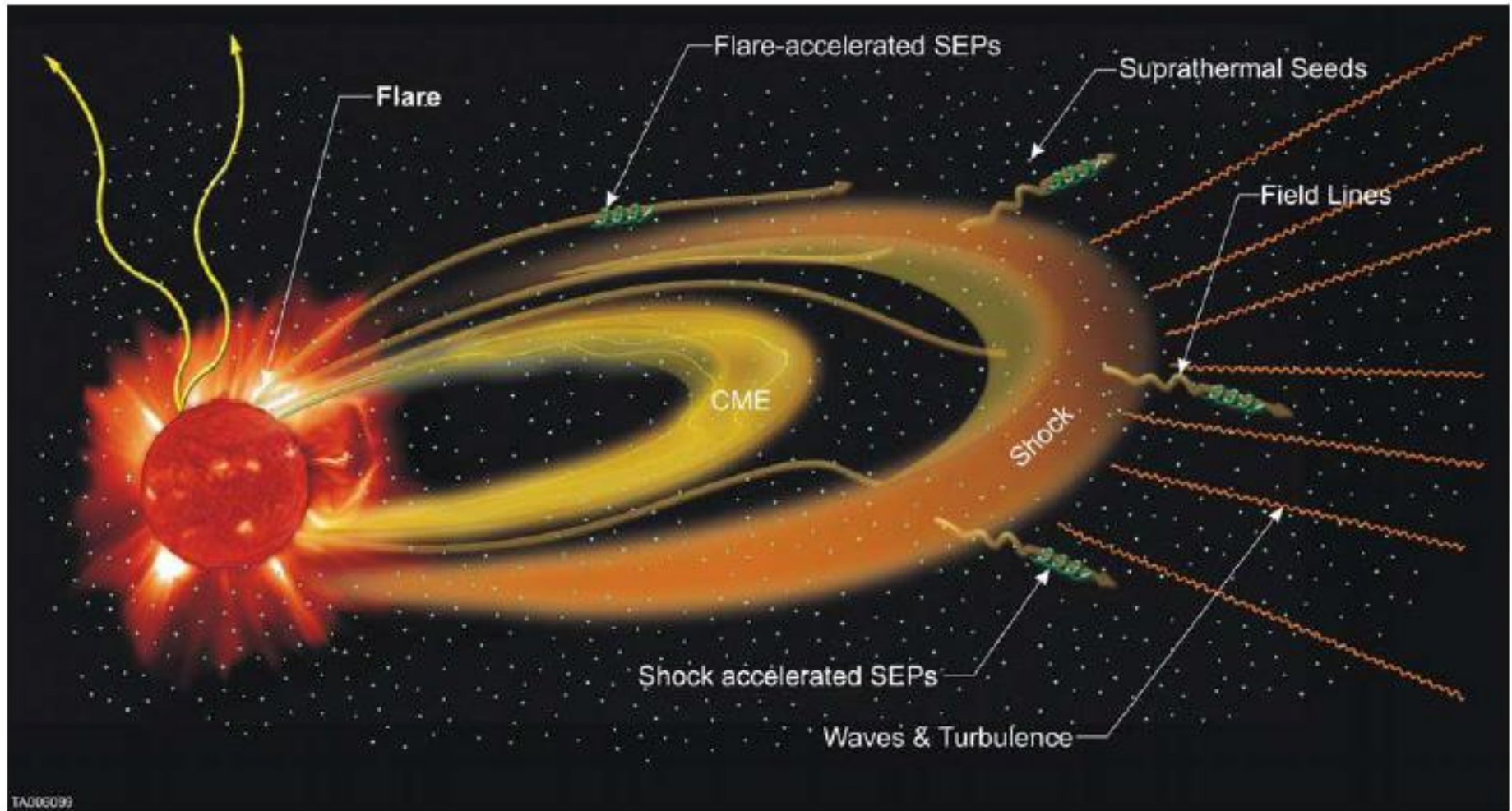
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Mathematics, Greece

³European Space Agency, European Research and Technology Center,
The Netherlands

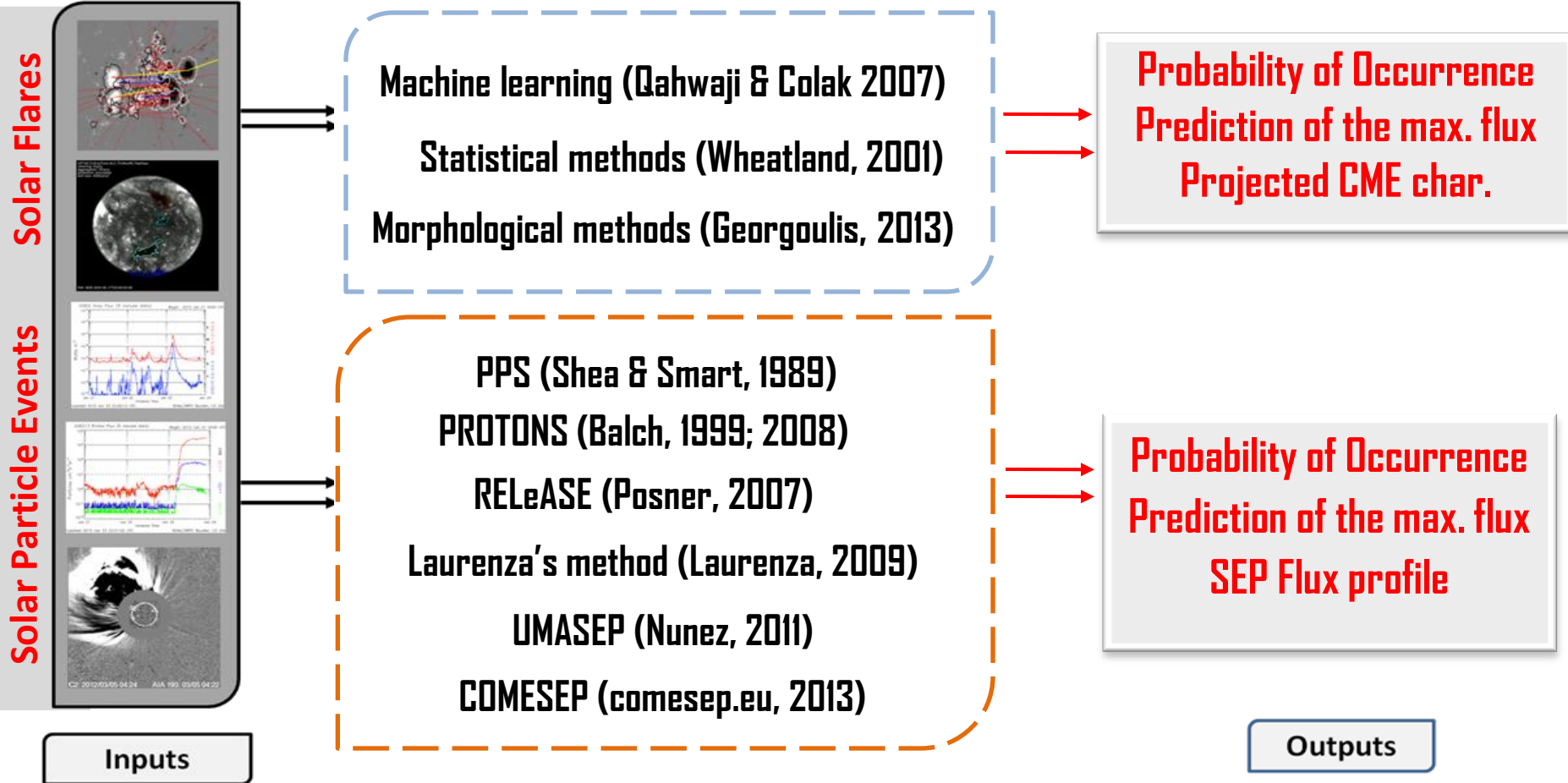
Background

Solar Energetic Particle (SEP) events

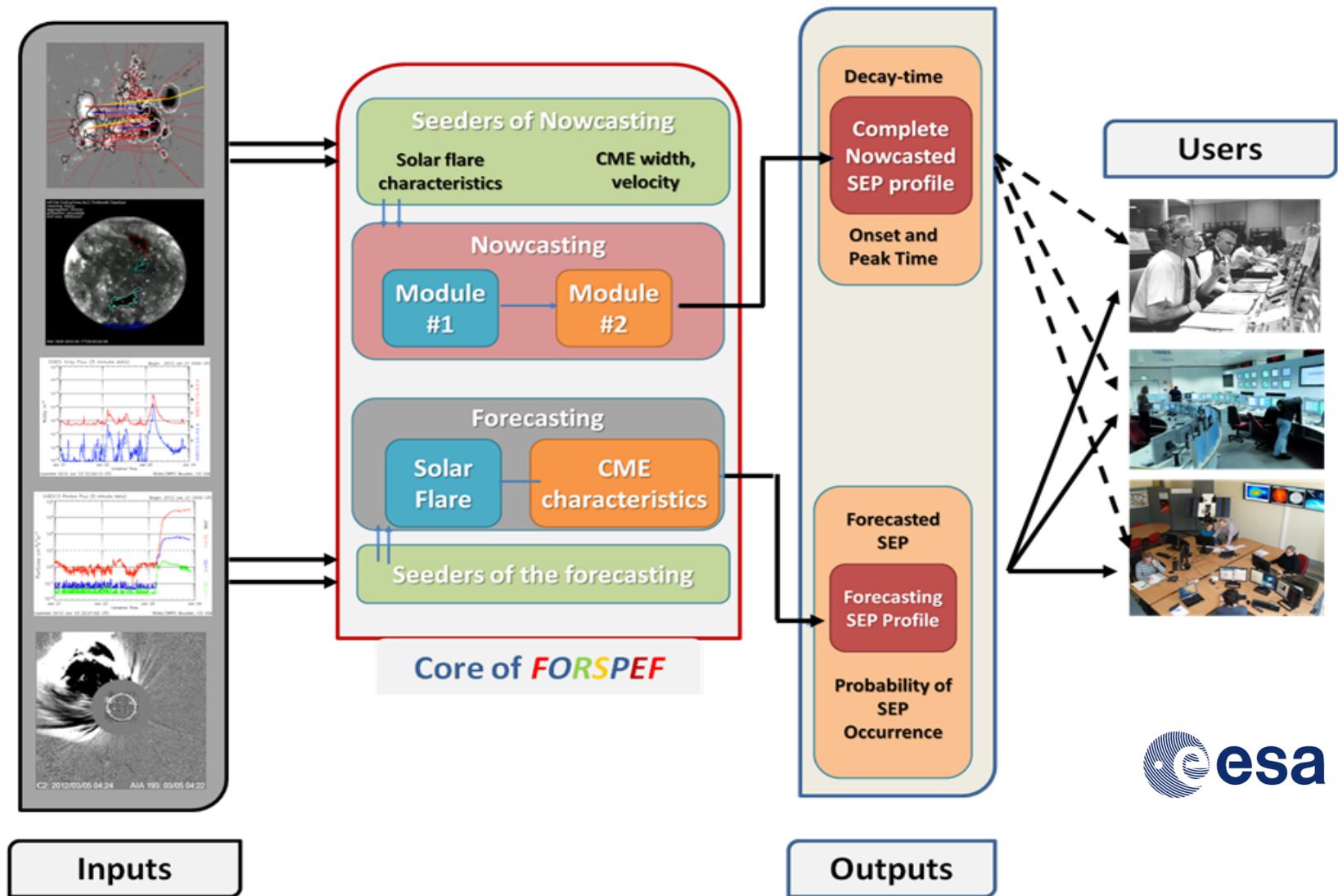


Background

How to forecast Solar flares and SEP events ?



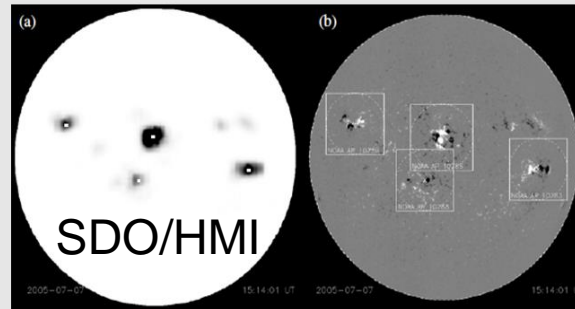
The FORSPEF system



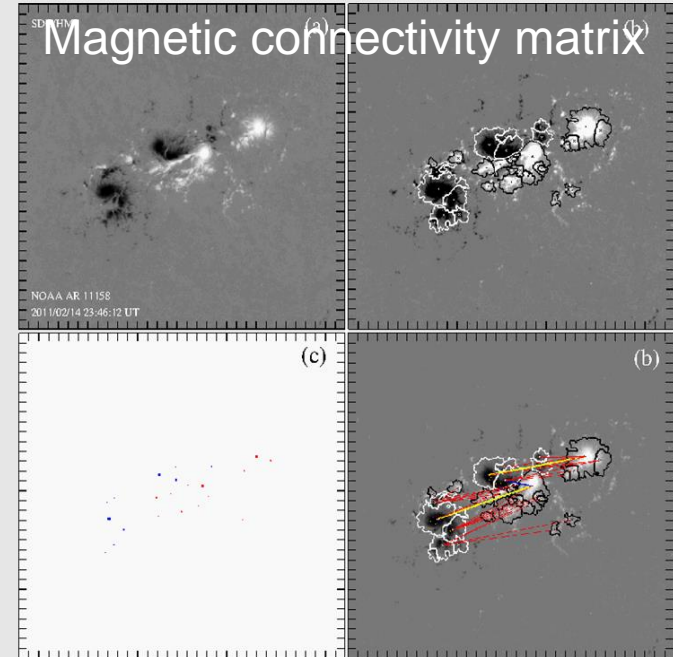
The FORSPEF system

Solar Flares (& Projected CME) Forecasting

> The **Solar Flare Prediction** will rely primarily on the “effective connected magnetic field strength” (B_{eff}) prediction metric



$$B_{eff} = \sum_{i=1}^{N_+} \sum_{j=1}^{N_-} \frac{\Phi_{ij}}{L_{ij}^2}$$

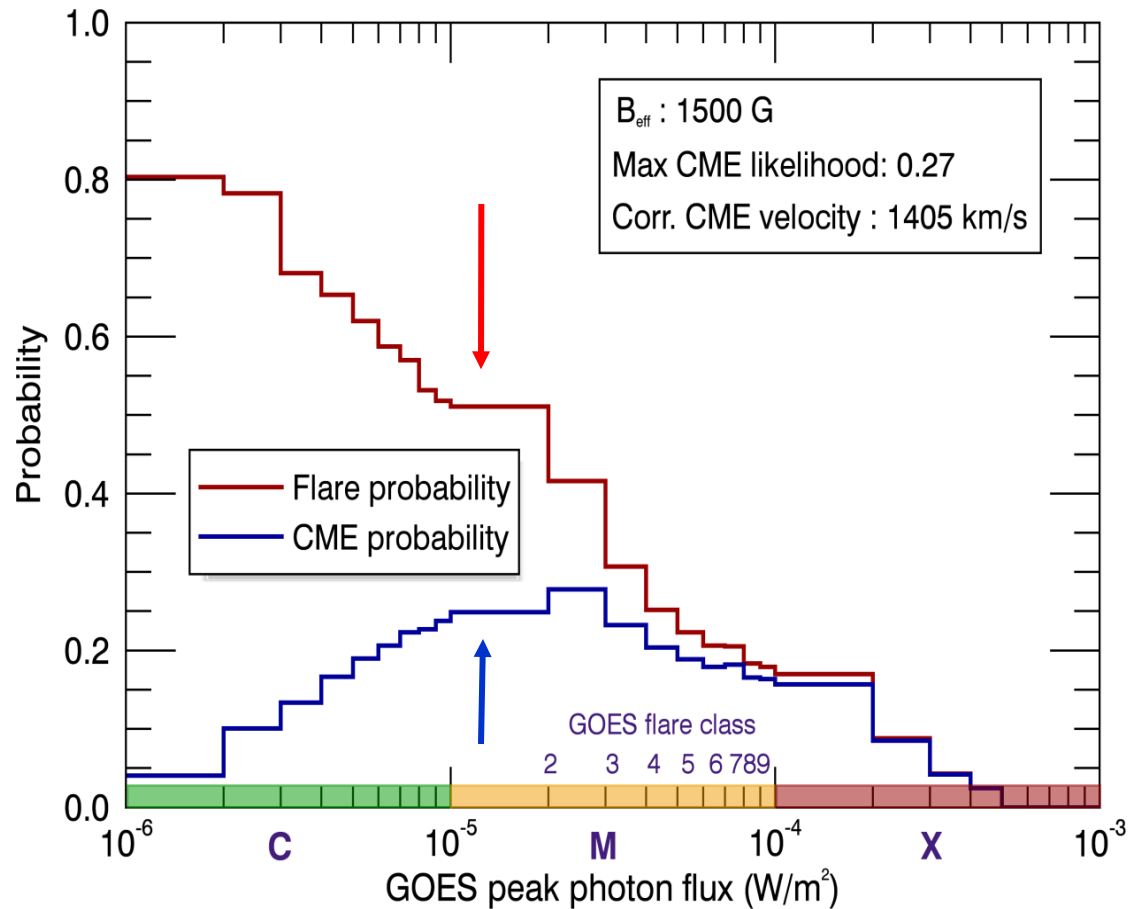


The FORSPEF system

Solar Flares (& Projected CME) Forecasting

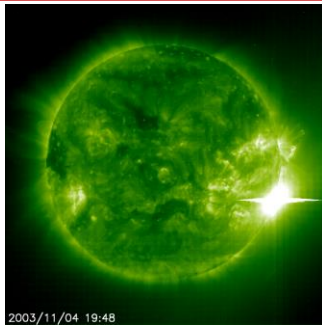
> Flare & (Projected) CME prob.

A pictorial output of the range of probabilities for different flare classes (**red histogram**). Also shown is the respective CME likelihood curve (**blue histogram**).

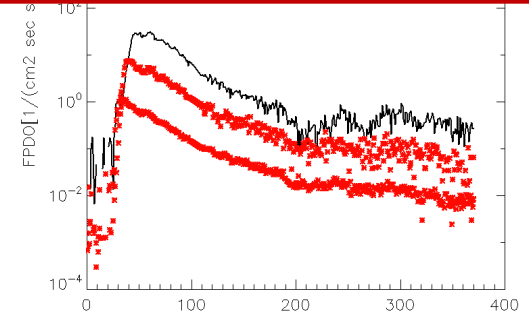
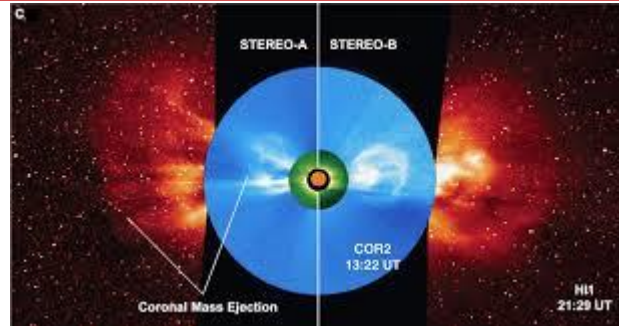


The FORSPEF system

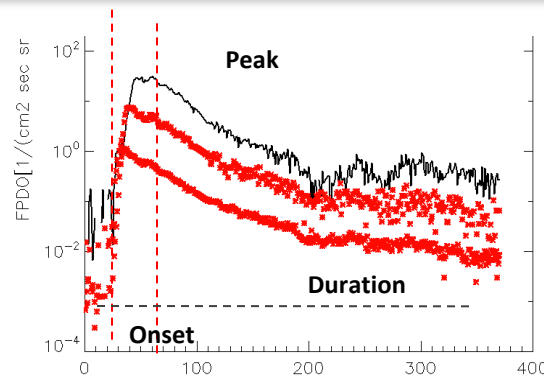
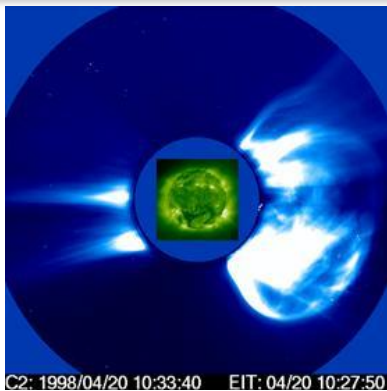
SEP Forecasting & Nowcasting



+



> Given **specific solar parameters** (flare mag, CME width, velocity) identify the probability that an **SEP event** will **occur**



> Given **a subset of flares and CMEs that do produce SEP events**, how do the characteristics of the SEP event relate to those of the parent solar event?

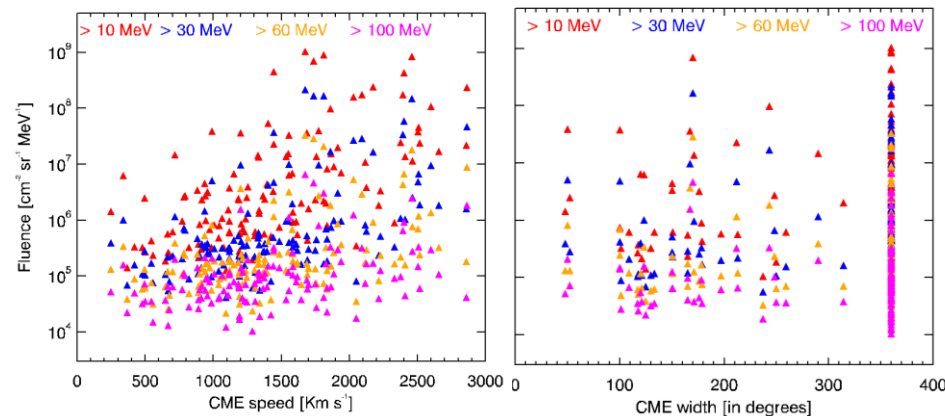
The FORSPEF database

SEP Forecasting & Nowcasting

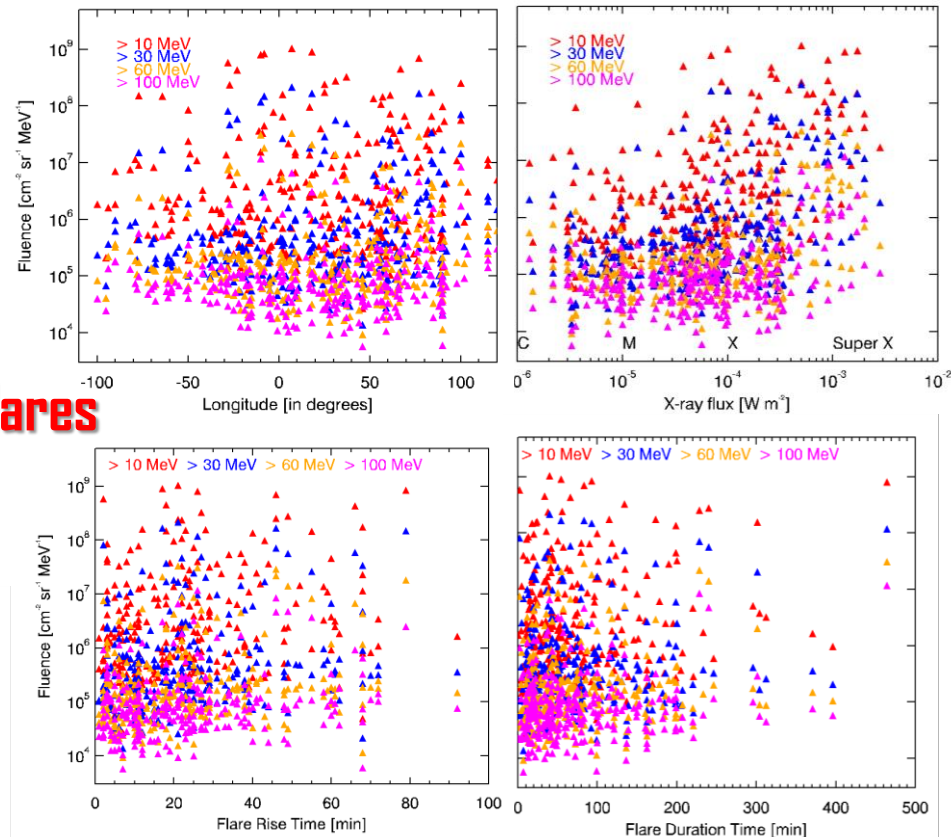
Soft X-Rays Solar Flare Start Time					Solar Flare Peak Time					SEP Start Time				
1985	4	24	9	14	1985	4	24	9	22	1985	4	24	11	1
1985	7	9	1	26	1985	7	9	2	4	1985	7	9	2	2
1986	2	4	7	35	1986	2	4	7	40	1986	2	4	9	2
1986	2	5	12	37	1986	2	5	12	53	1986	2	5	2	3
1986	2	6	6	18	1986	2	6	6	25	1986	2	6	8	3
1986	2	7	10	11	1986	2	7	10	29	1986	2	7	13	1

> **The FORSPEF SEP database** includes **314** SEP events, **20459** SFs (\geq C1.0) (from 1984-2013) and **3680** CMEs (from 1997 to 2013).

CME



Flares

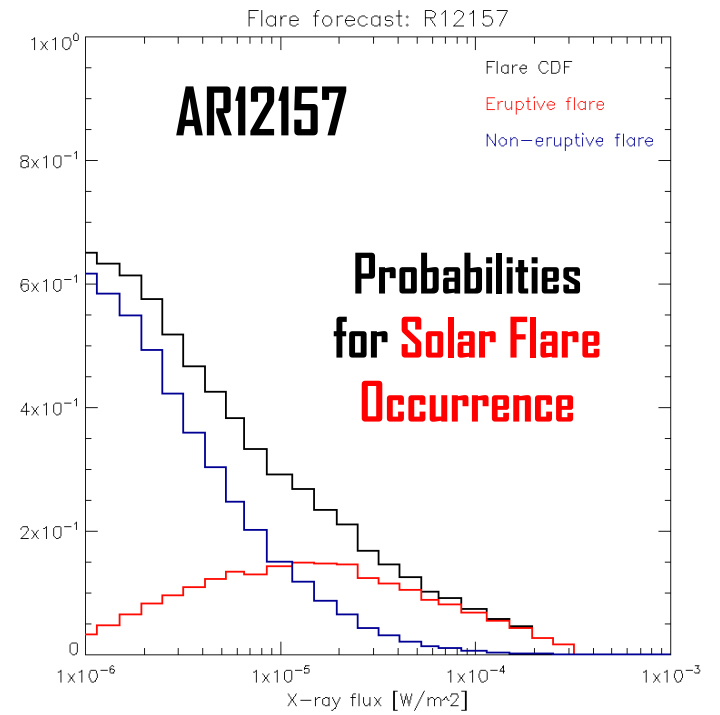
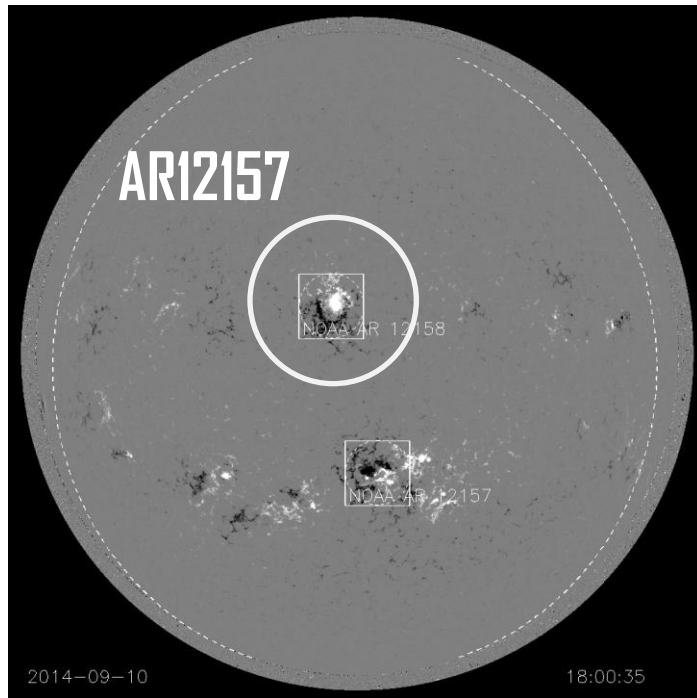


6 Indicators: **Flares:** flux, longitude, rise time, duration / **CMEs:** velocity, width;
2 Physical quantities: peak flux, fluence
4 Energy width ranges: > 10; > 30; > 60; > 100 MeV

The FORSPEF system

Forecasting mode

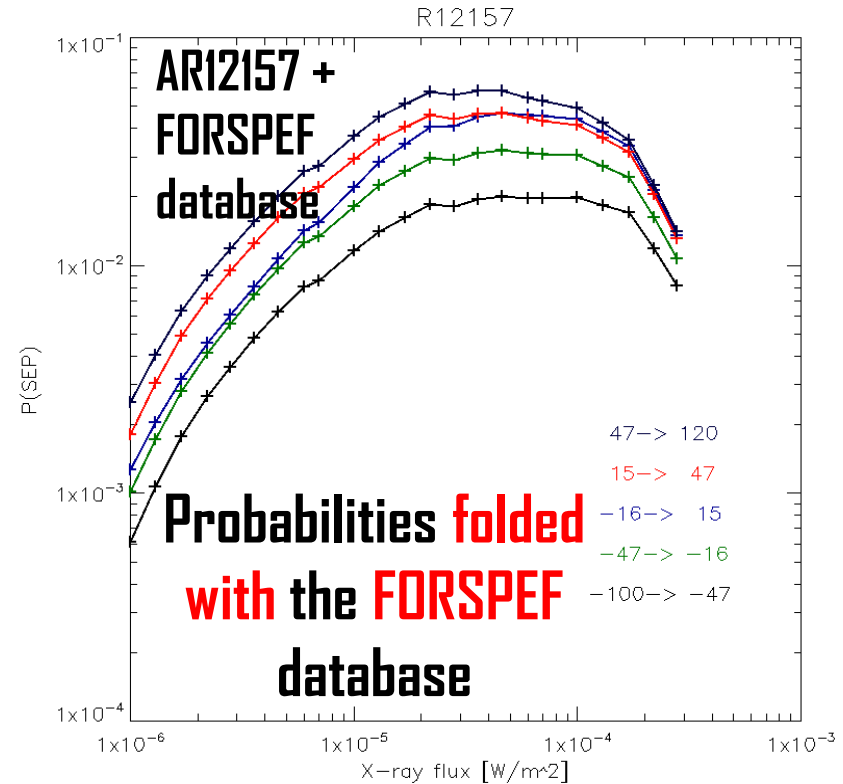
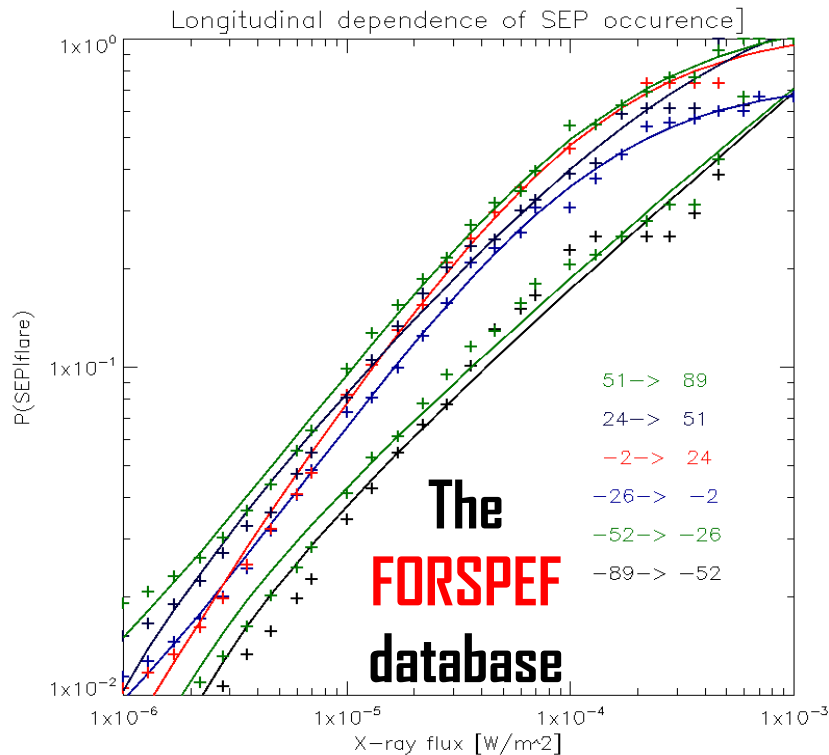
Actual Work Scheme



The FORSPEF system

Forecasting mode

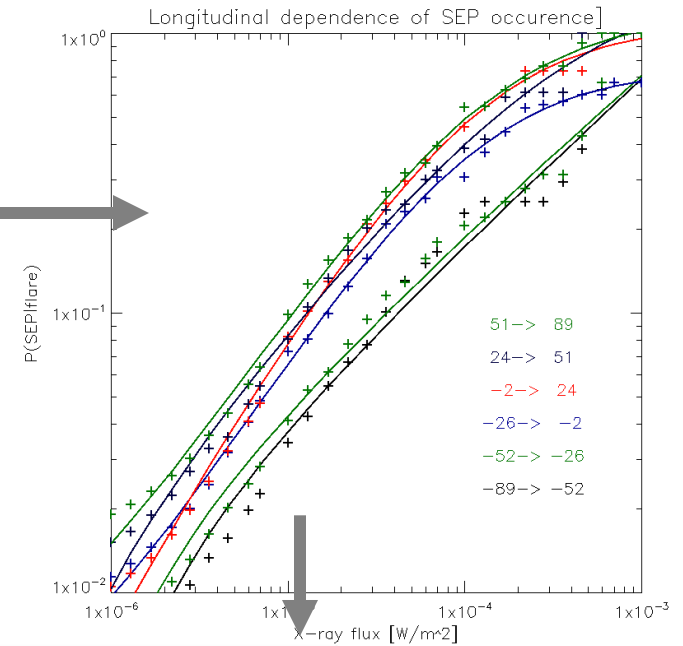
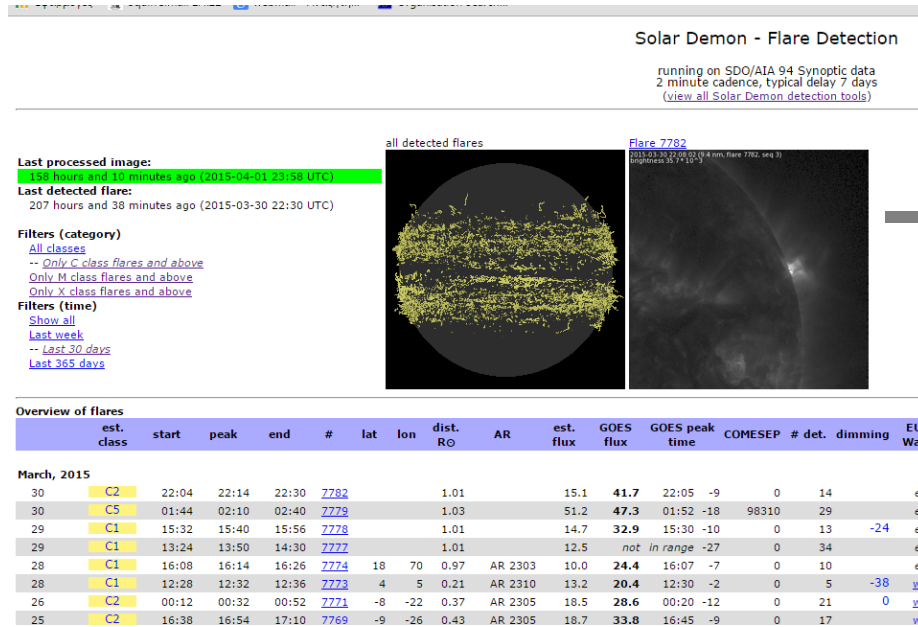
Actual Work Scheme



The FORSPEF system

Nowcasting mode

Actual Work Scheme

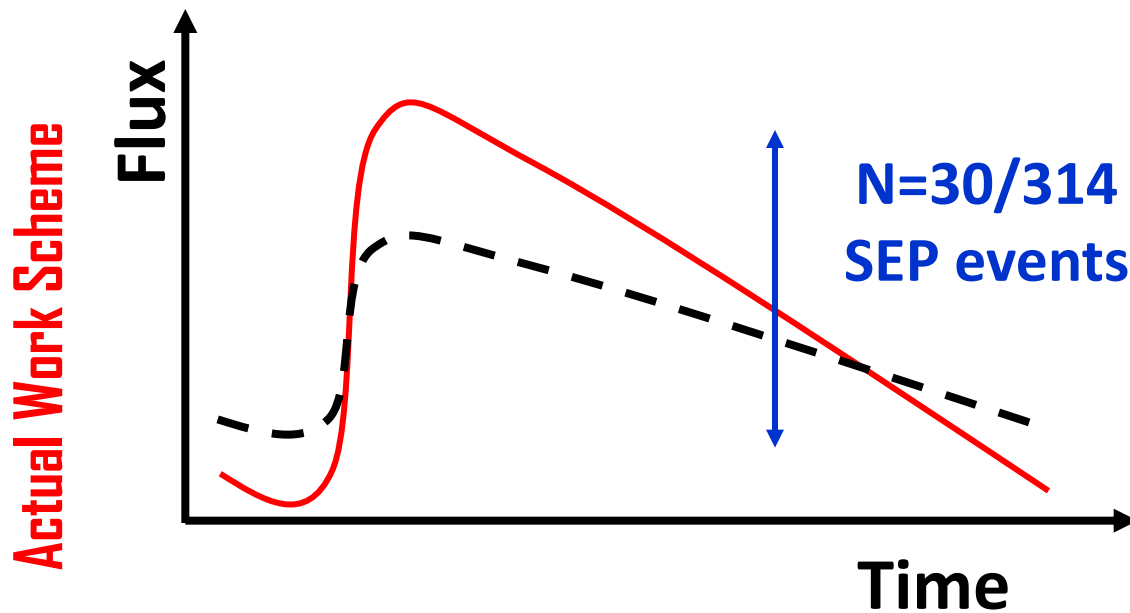


> SEP Nowcasting, offers

- Probability of SEP occurrence for a given SF
- The expected SEP characteristics

The FORSPEF system

Nowcasting mode



> SEP Nowcasting, offers

- For a given SF, **30 historical SEP events** from the FORSPEF database, closest in terms of the **flare longitude** and within *one order of magnitude* in the **flare flux** are chosen.

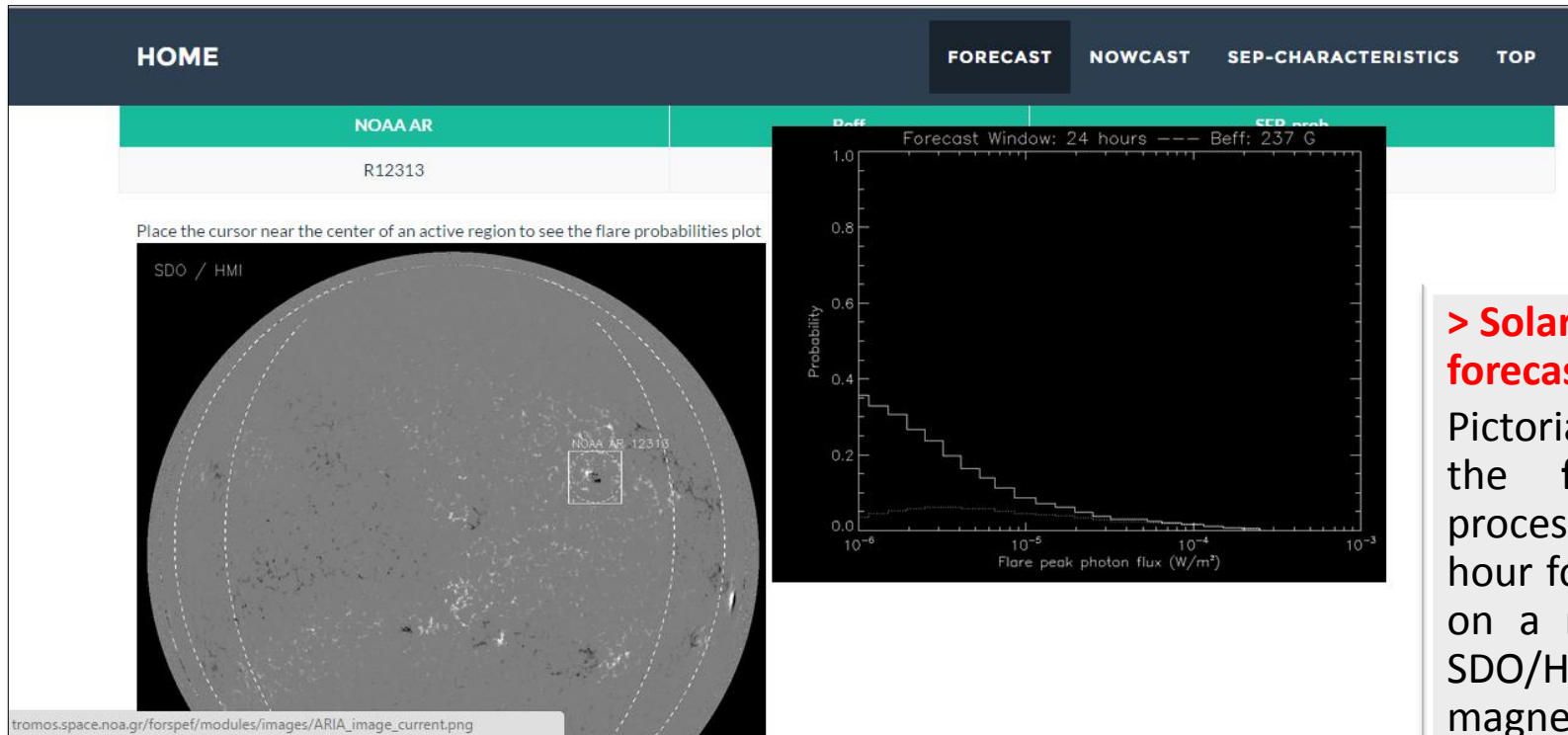
- All SEP characteristics are calculated on the basis of this SEP events sub sample.

> SEP Nowcasting, offers

- Probability of SEP occurrence for a given SF
- The expected SEP characteristics

Results

Outputs of the system

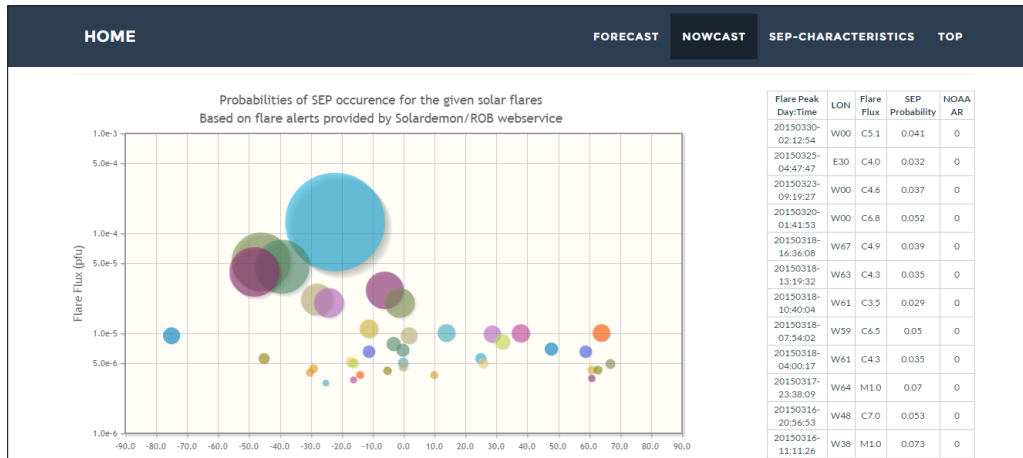


> Solar flare forecasting

Pictorial outputs of the **flare-prediction** process with a 24-hour forecast window on a recent full-disk SDO/HMI magnetogram.

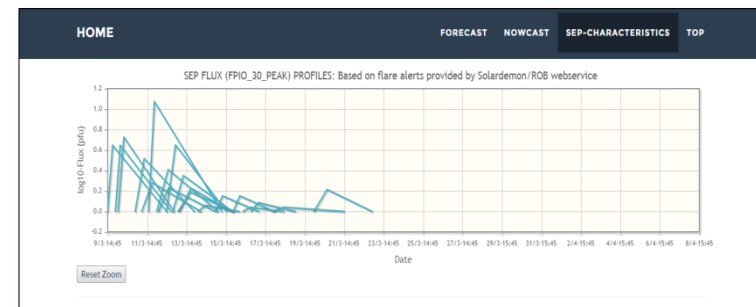
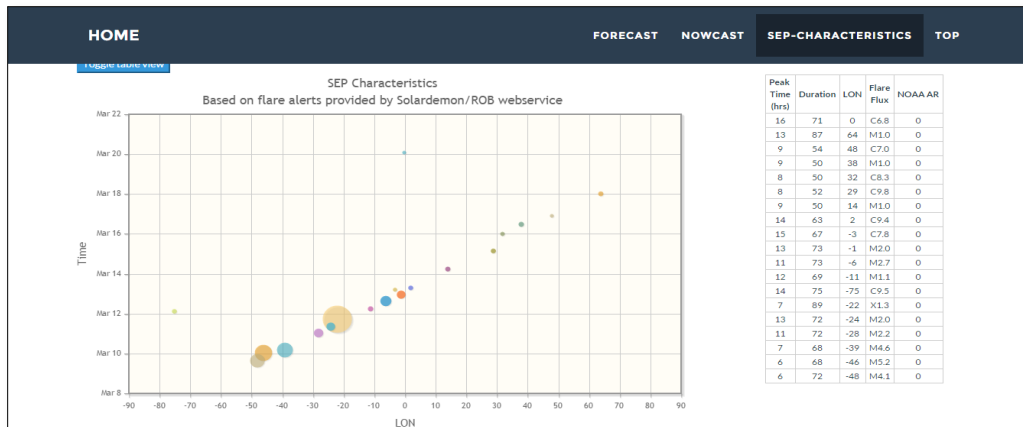
Results

Outputs of the system



>SEP Nowcasting

Illustrations of the derived SEP characteristics for a given flare.



Conclusions

> The FORSPEF system

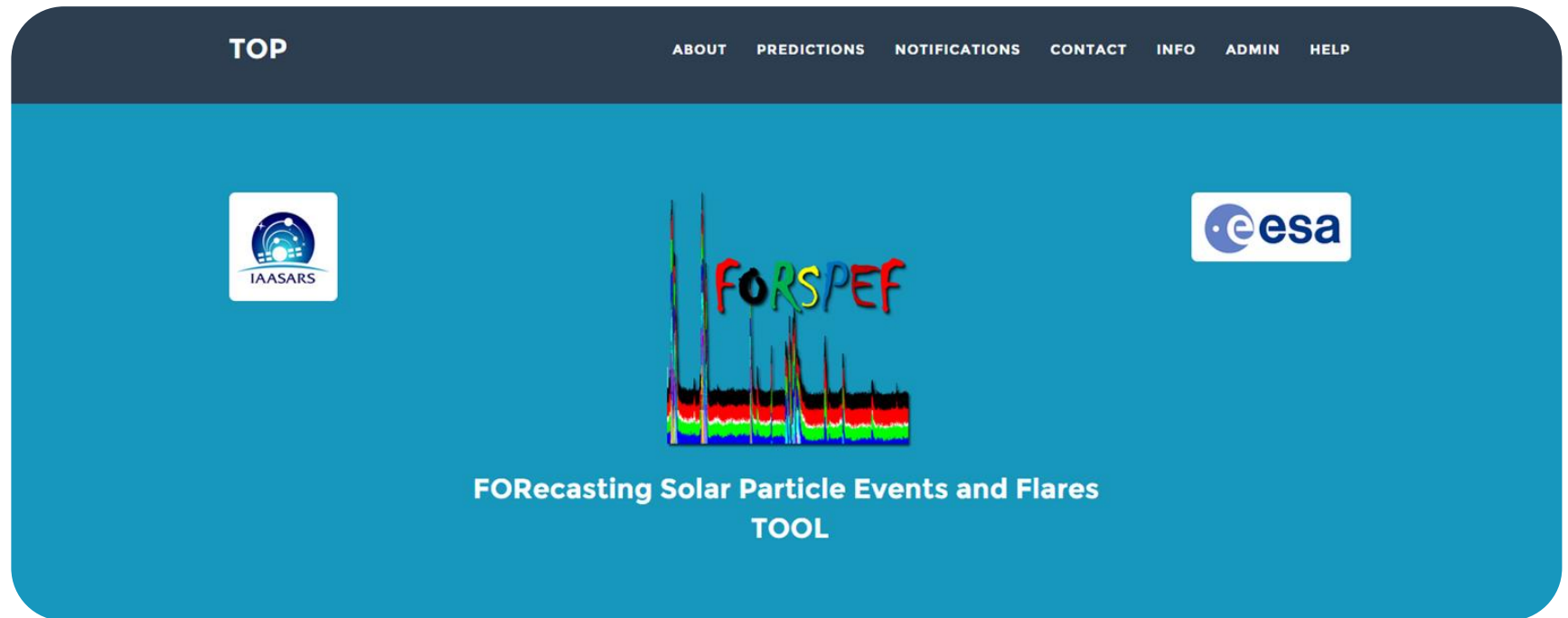
> Incorporates a **novel method** for the **solar flare prediction** and a **new database** of **SEP events, solar flares** and **CMEs**.

> Provides **forecasting of SEPs** based on **solar flare & projected CME** characteristics (e.g. speed)

> Offers a **24-hour** forecast of SEP events, **up to 70° EW** covering practically the entire course of the AR toward the limb (up to $\sim 85^\circ$), under the assumption that the AR does not change significantly over this course.

> **FORSPEF has been released in April 2015 / info @**
<http://tromos.space.noa.gr/forspef>

Thank you



[web] <http://tromos.space.noa.gr/forspef>

FORecasting Solar Particle Events and Flares

Acknowledgments: The research leading to these results has received funding from the European Space Agency, ESA Contract No. 4000109641/13/NL/AK

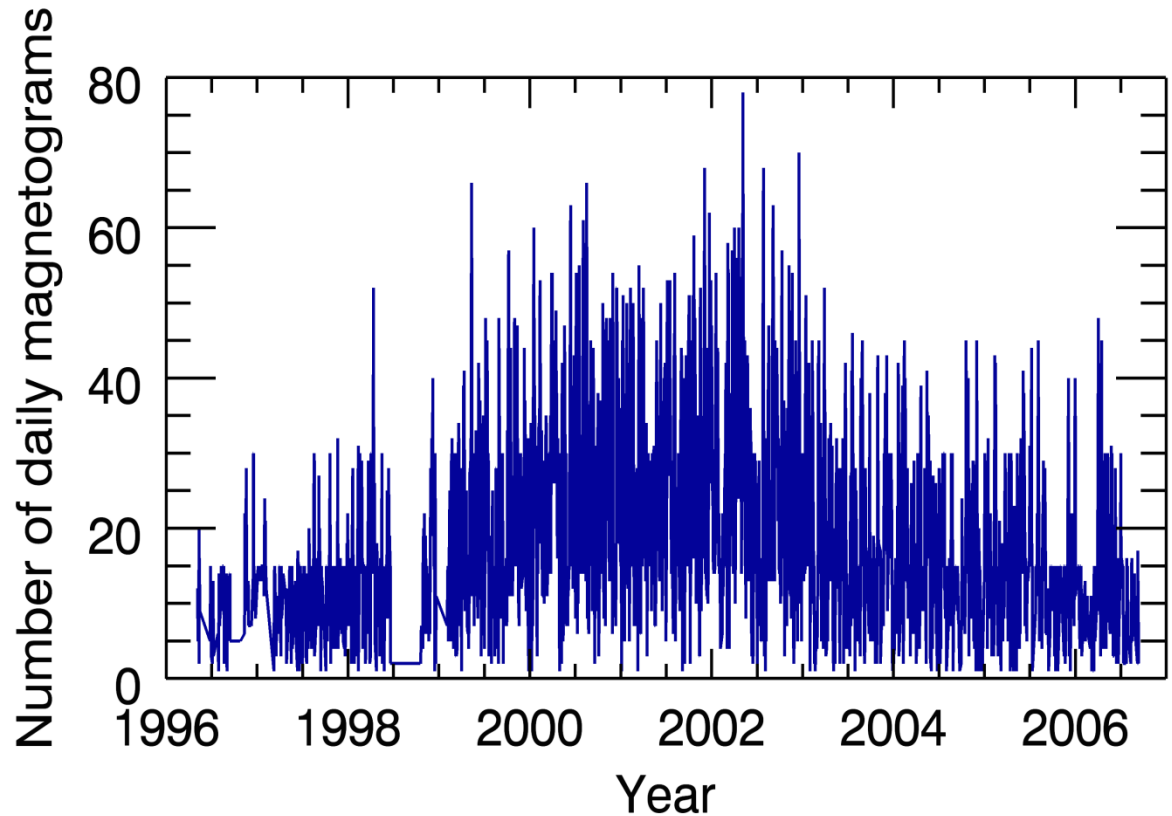
Back-up slides

The SOHO/MDI database

Solar Flares (& Projected CME) Forecasting

> The **SOHO/MDI** magnetogram sample used for the Solar Flare Prediction.

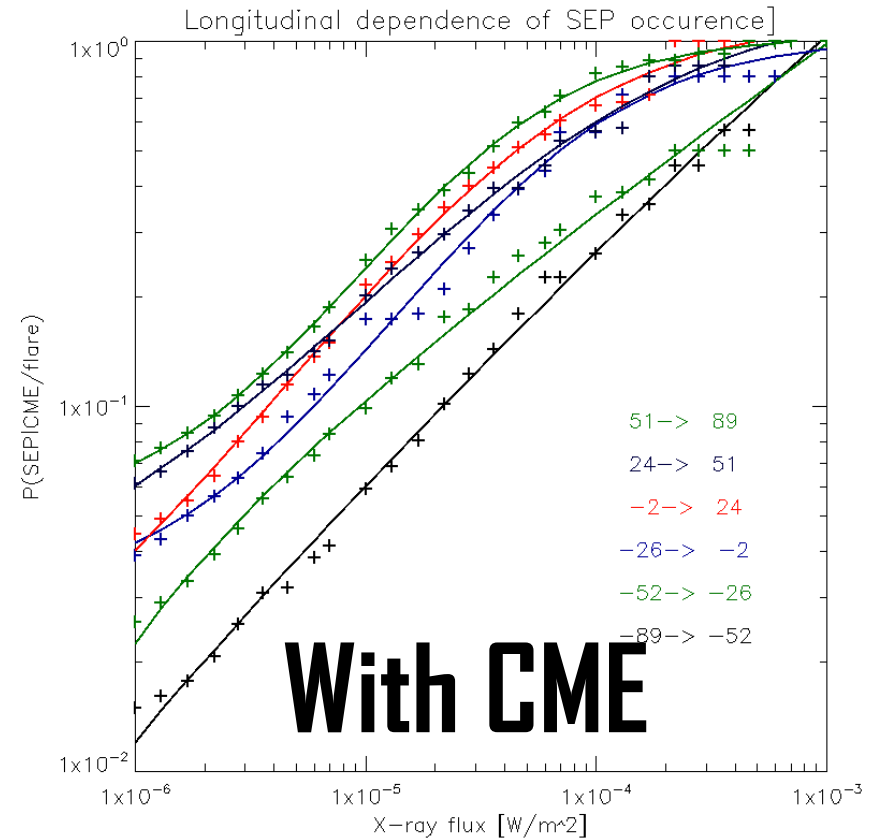
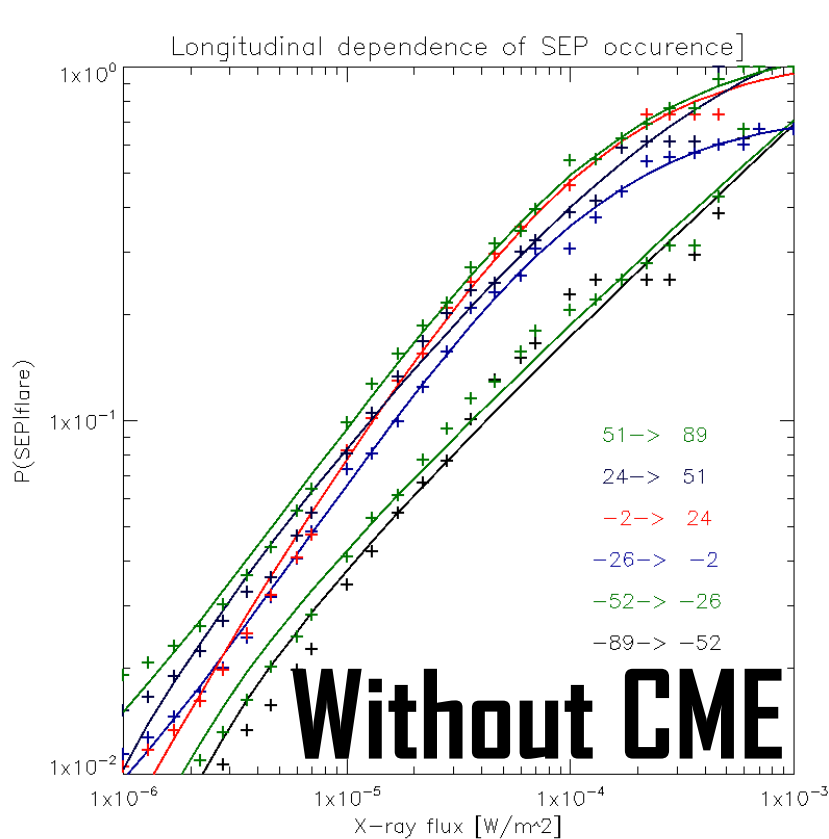
> It covers **Solar Cycle 23** and includes observations of **2736 days**, **1416 ARs** and **55691 individual magnetograms**.



The FORSPEF system I Using CMEs

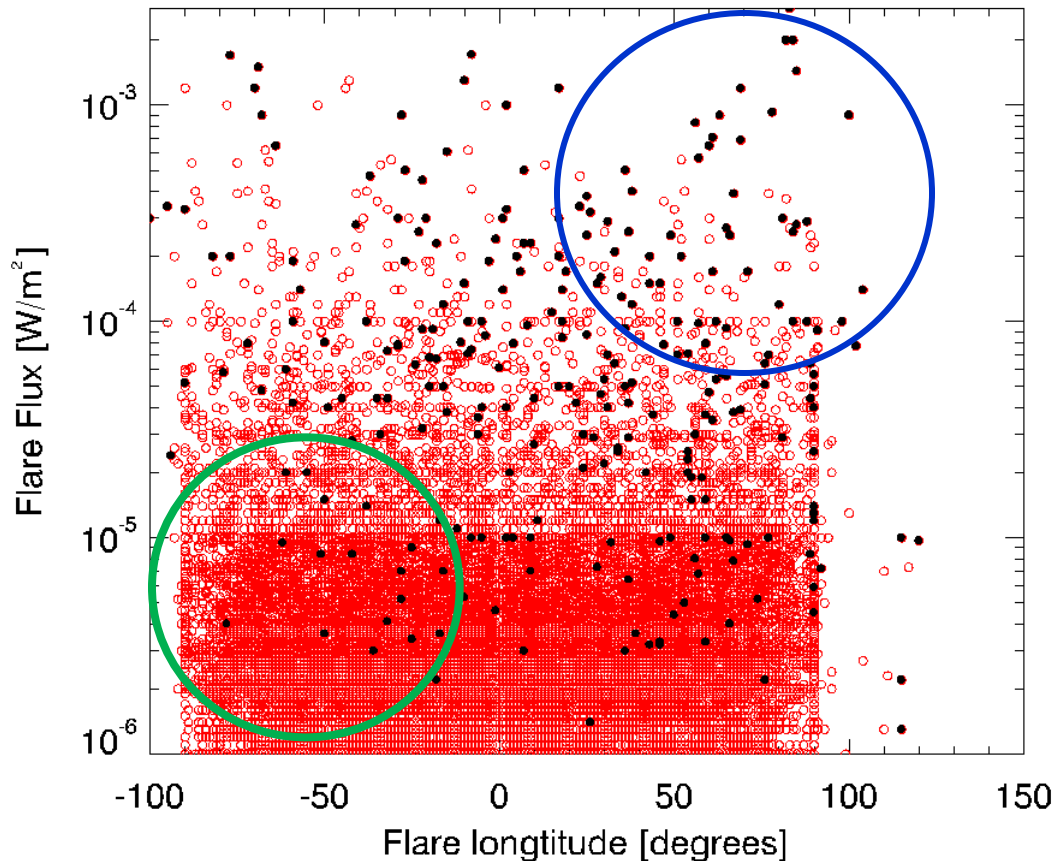
Nowcasting mode

Actual Work Scheme



The FORSPEF database

Statistical analysis I Solar Flares



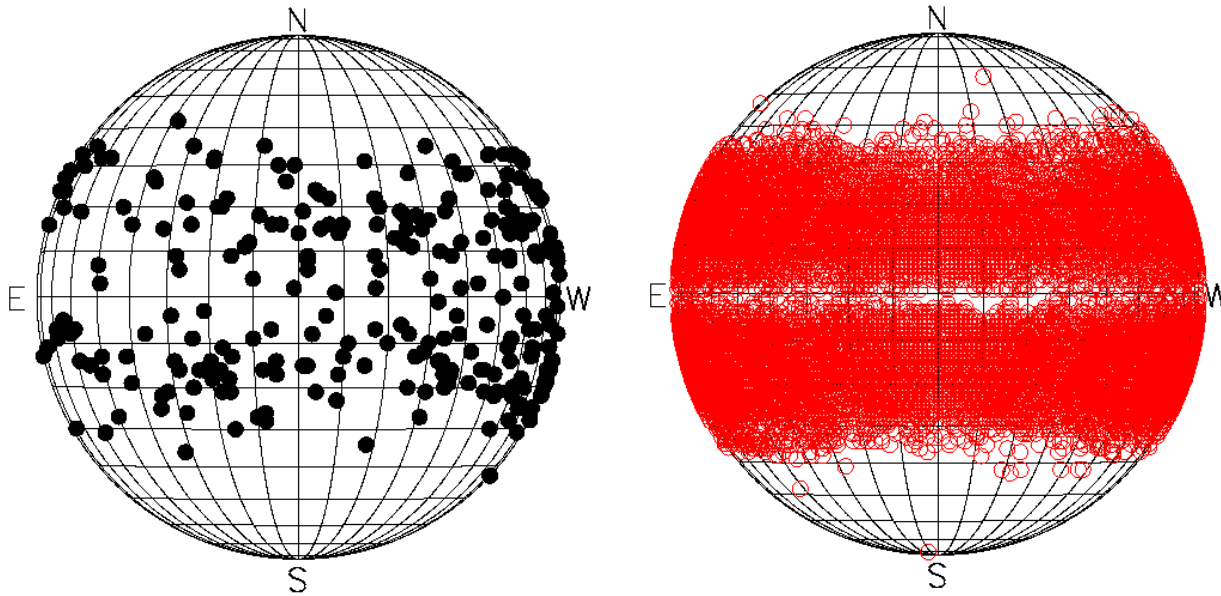
> X-ray flare flux versus flare longitude. The flares associated with **SEP events** are presented by the **filled black circles** and all other (**non SEP flares**) by the **open red circles**

Belov et al., 2005

Papaioannou et al., 2015a

The FORSPEF database

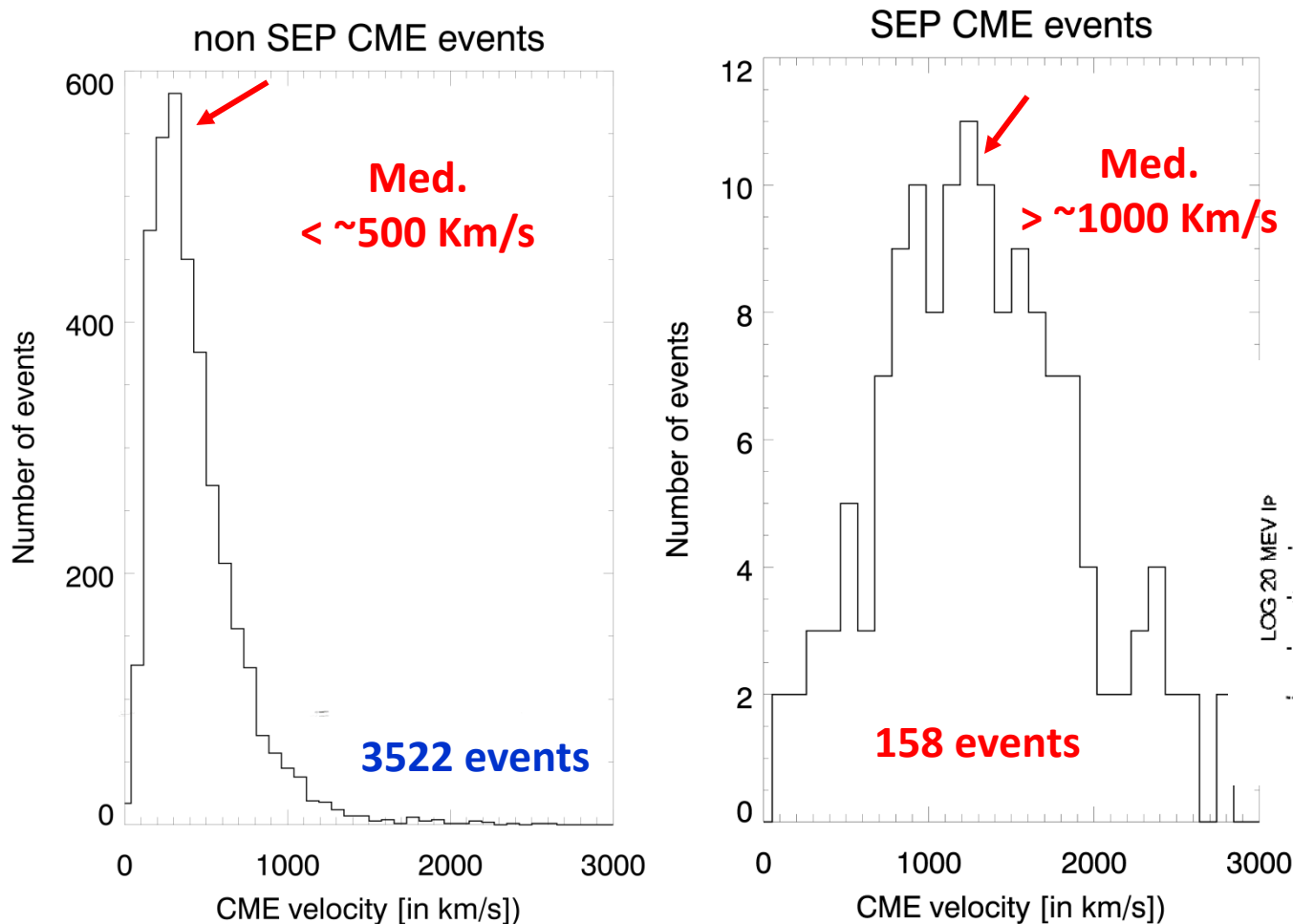
Statistical analysis I Solar Flares



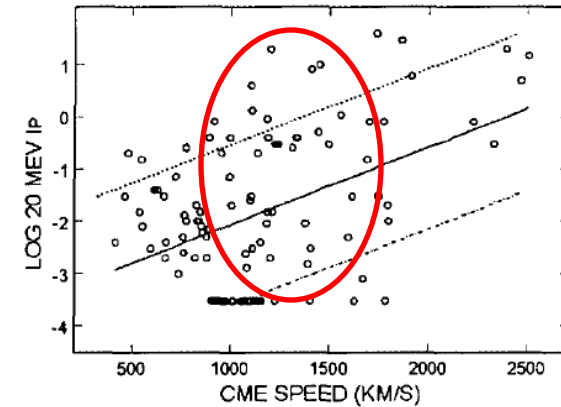
> Distribution of solar flare latitude (in degrees) as a function of the flare longitude (in degrees). The flares associated with **SEP events** are presented by the **filled black circles** and all other (**non SEP flares**) by the **open red circles**

The FORSPEF database

Statistical analysis I CMEs



> Distribution of the events as a function of the CME velocity [km/s].



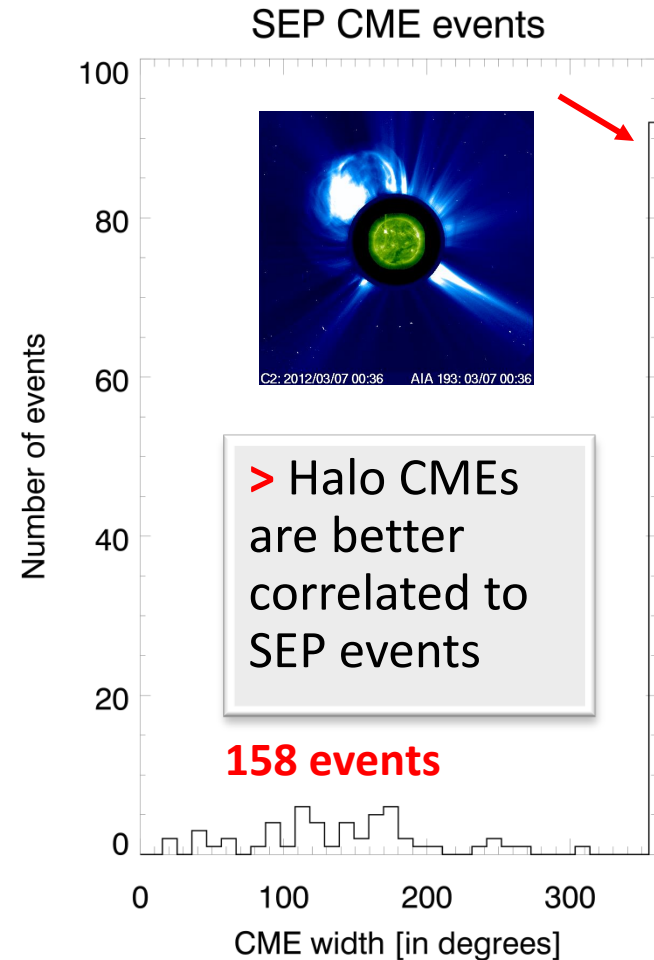
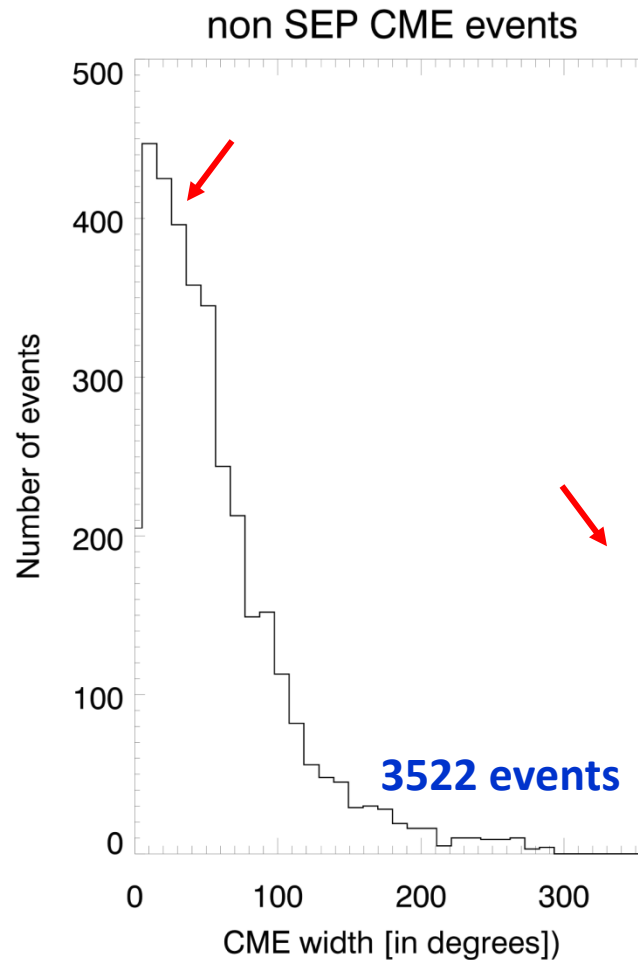
Kahler & Vourlidas, 2004

Gopalswamy et al., 2002

The FORSPEF database

Statistical analysis I CMEs

> Distribution of the events as a function of the CME width [degrees].



Kahler, 2001

Kahler & Vourlidas, 2013