Skoltech

Skolkovo Institute of Science and Technology

“Space Data Processing:
Making Sense of Experimental Data”

Topic 6
"Key parameters to extract the process regularities"

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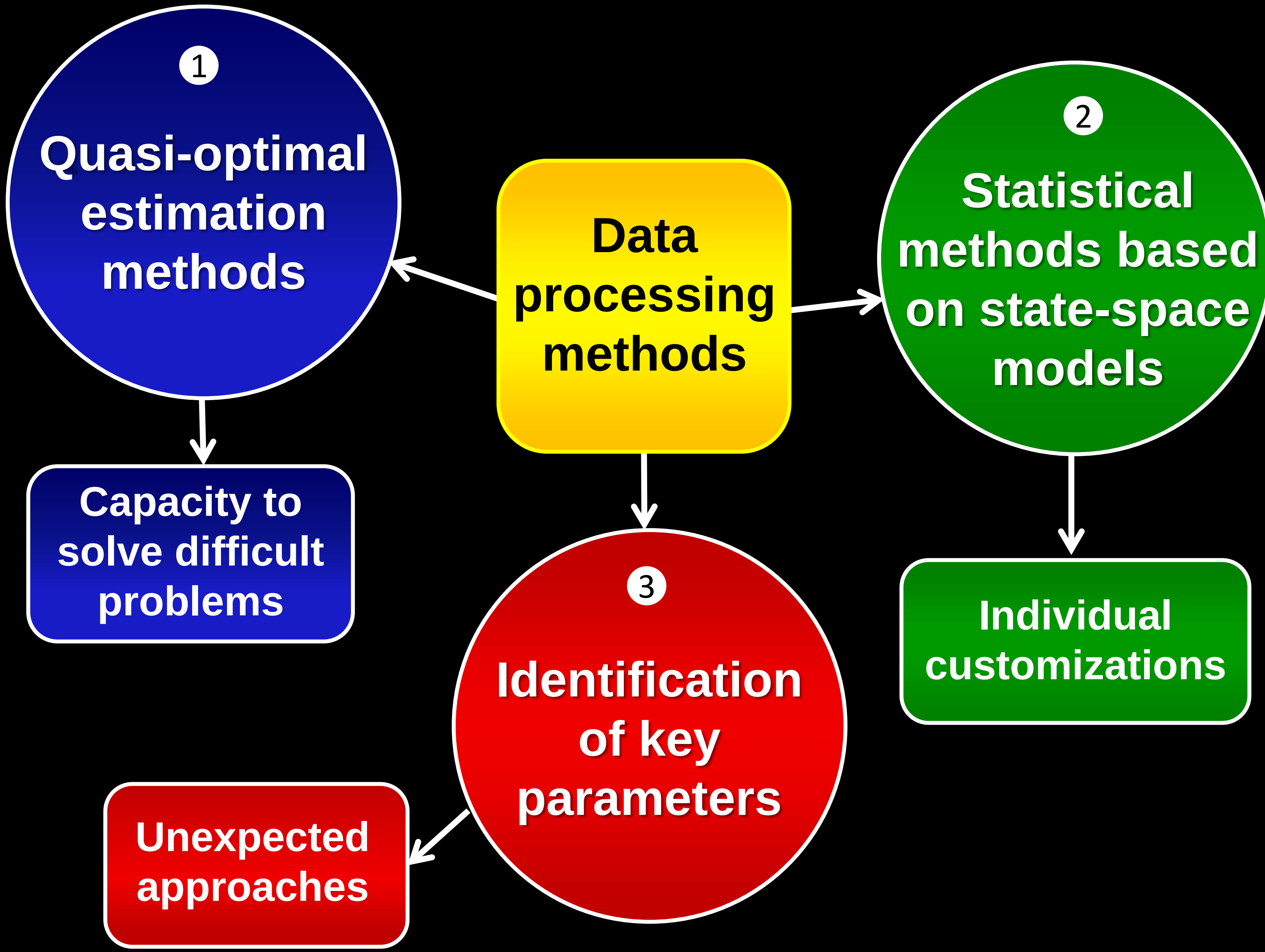
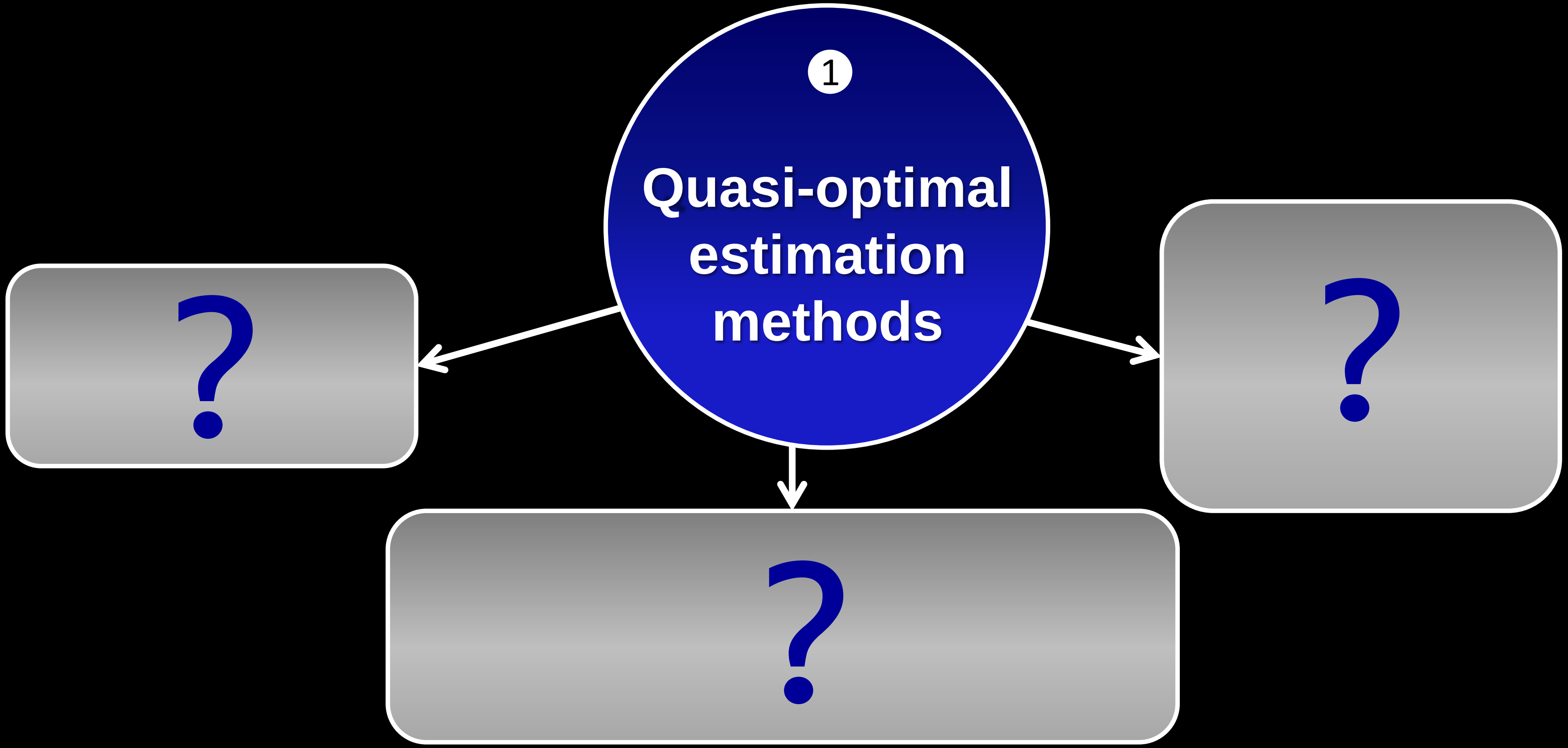

1
Quasi-optimal estimation methods
Data processing methods
2
Statistical methods based on state-space models
Capacity to solve difficult problems
3
Identification of key parameters
Individual customizations
Unexpected approaches


1
Quasi-optimal estimation methods
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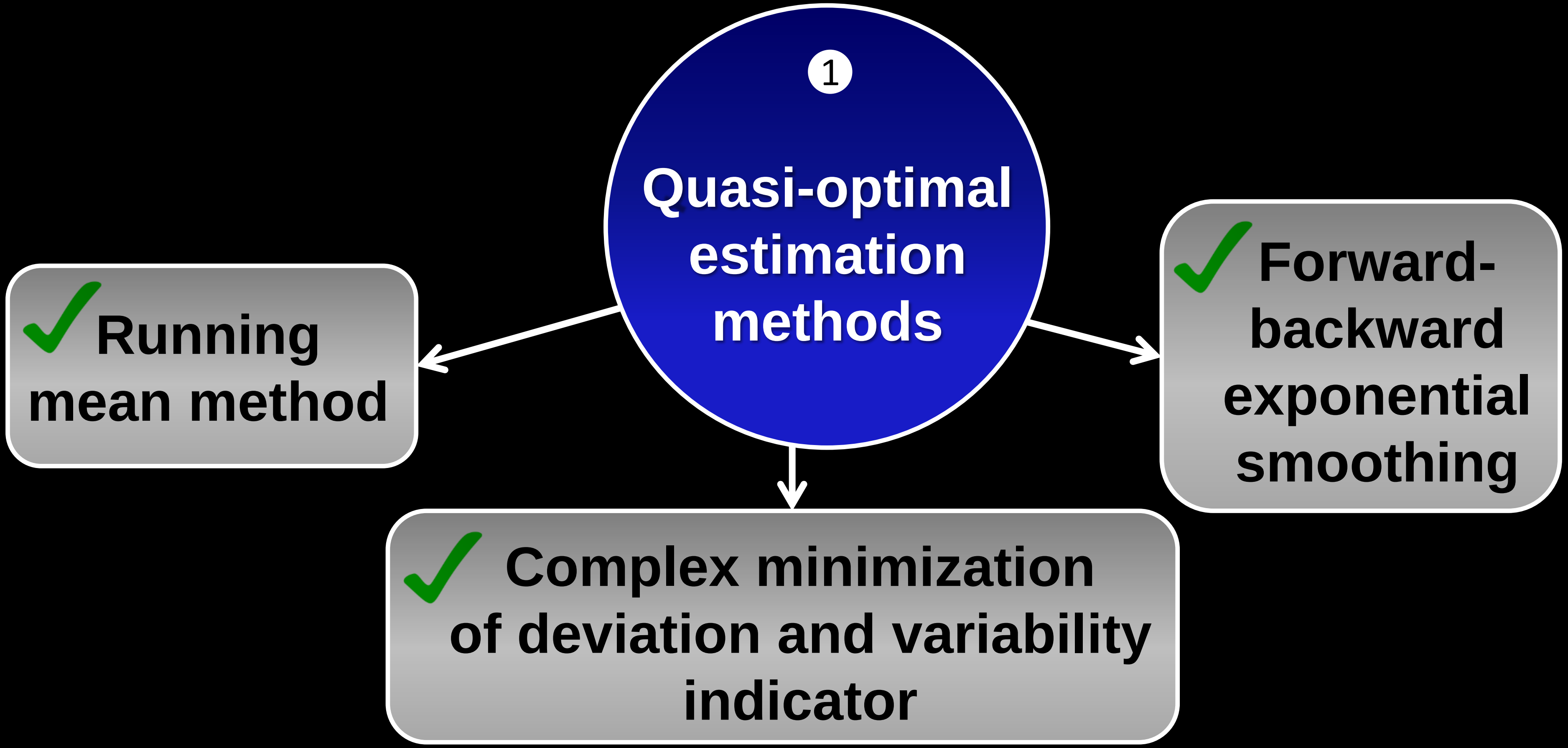
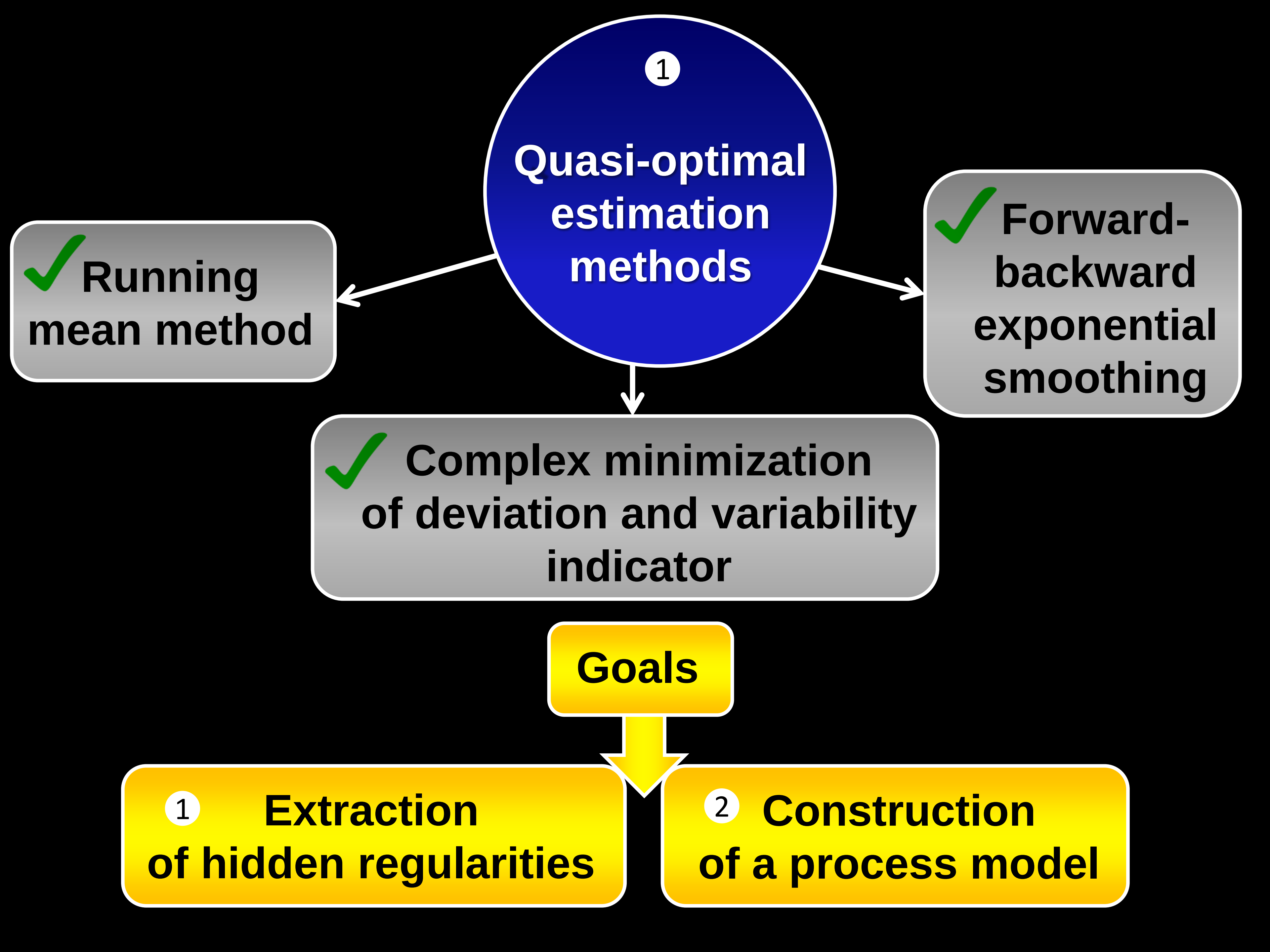
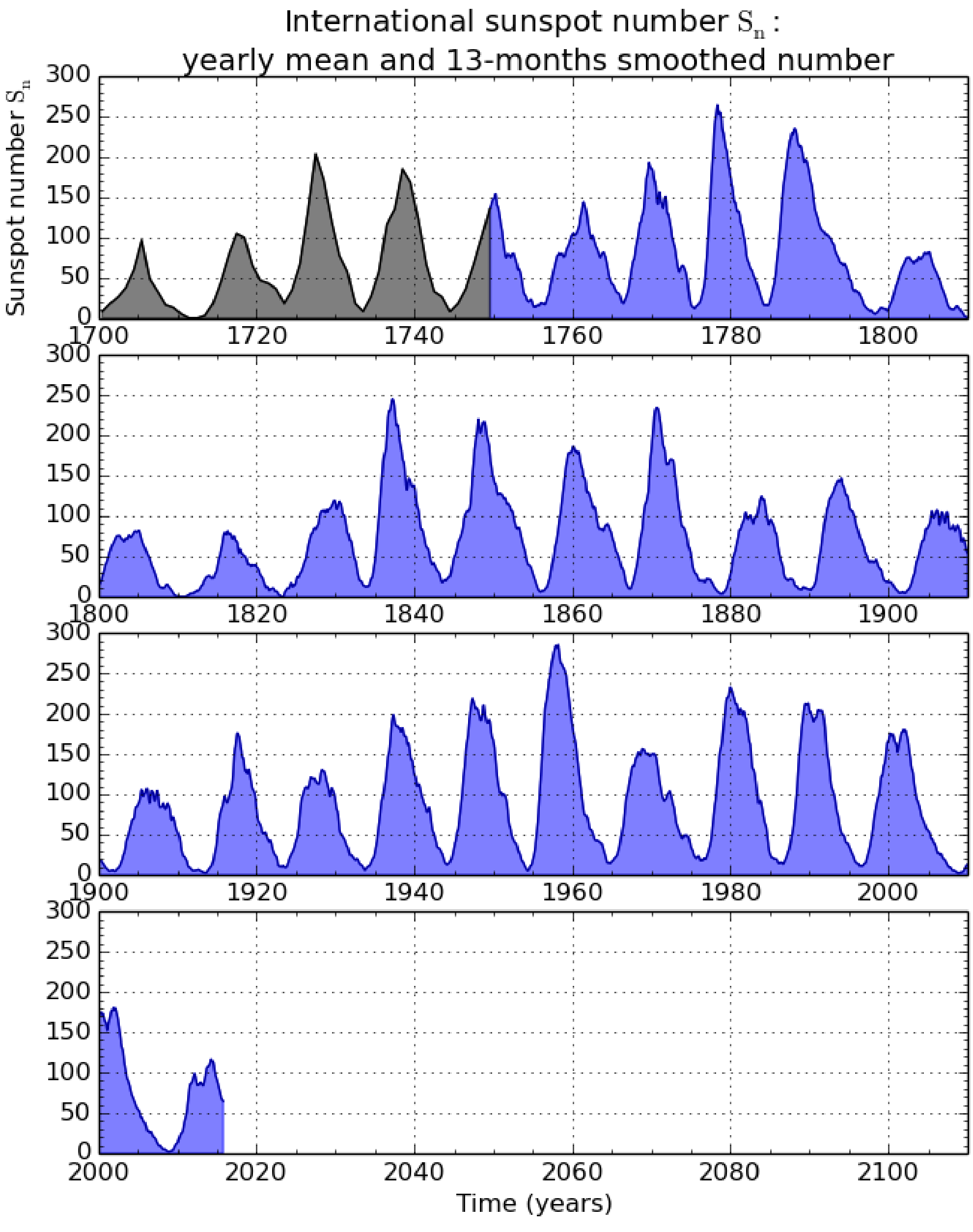
?



1
Quasi-optimal estimation methods
Running mean method
Forward-backward exponential smoothing
Complex minimization of deviation and variability indicator


1
Quasi-optimal estimation methods
Running mean method
Forward-backward exponential smoothing
Complex minimization of deviation and variability indicator
Goals
1 Extraction of hidden regularities
2 Construction of a process model

Sunspot number observations 1700-2016



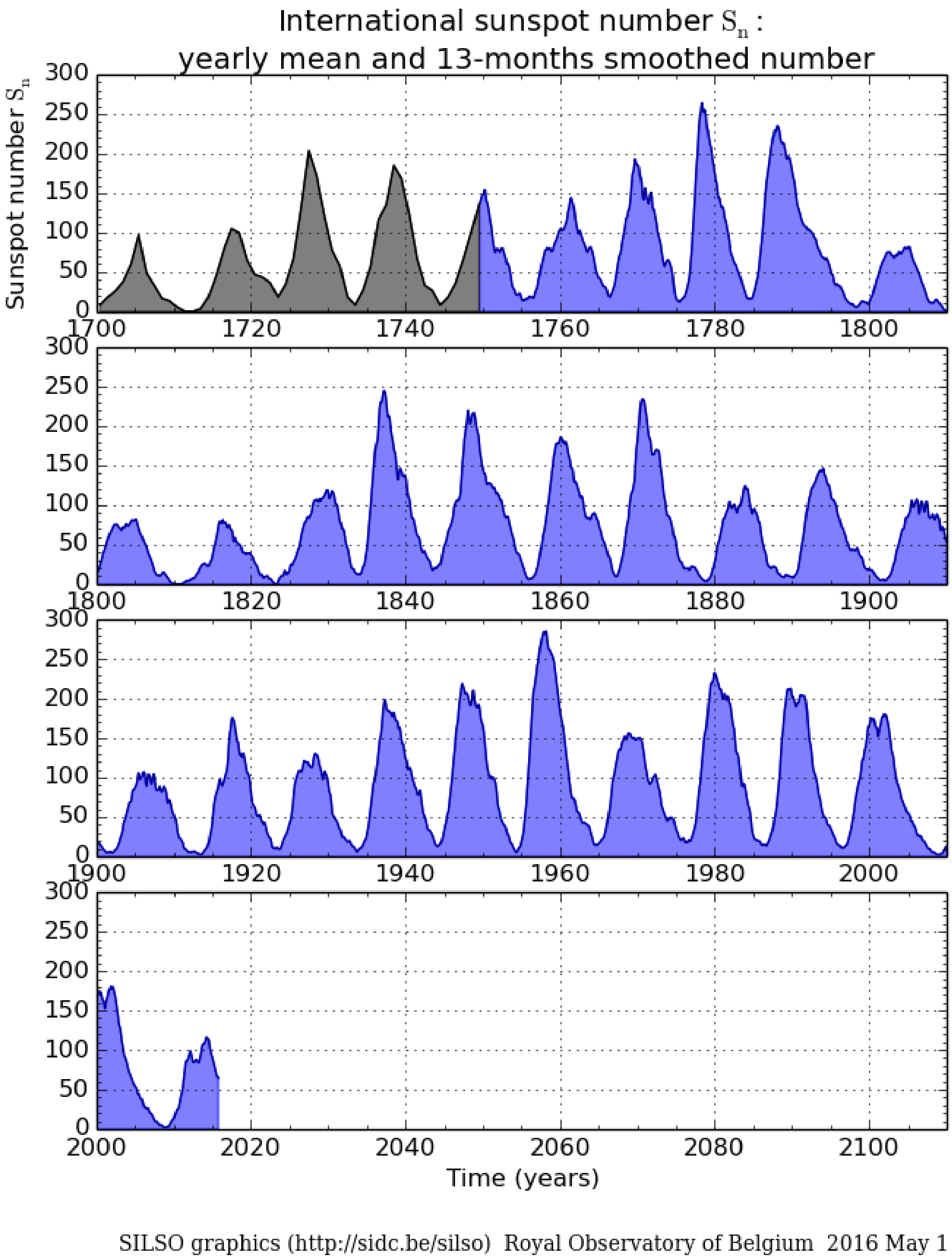
Visible regularities from smoothed curve

11-year sunspot cycle

The ascent phase is shorter than the decent one

Stronger cycles grow faster in the beginning of ascent phase compared to weaker cycles

Sunspot number observations 1700-2016



Construction of a process model

$$f(t) = \frac{a(t-t)^3}{e^{(t-t_0)^2/b^2} - c}$$

a → cycle maximum

b → related with time from maximum to minimum

c → cycle asymmetry

t_o → starting time

Parameters are determined according to LSM

Hathaway et al. : 1994, The shape of the sunspot cycle. *Solar Physics*, 151, 177.

2

Statistical methods based on state-space models

✓ **State space models**

State equation

$$X_{i+1} = f(X_i) + w_i$$

Measurement equation

$$z_i = h(x_i) + \eta_i$$

X_{i+1} → State vector

z_i → Measurement vector

f → Transition function

h → Measurement function

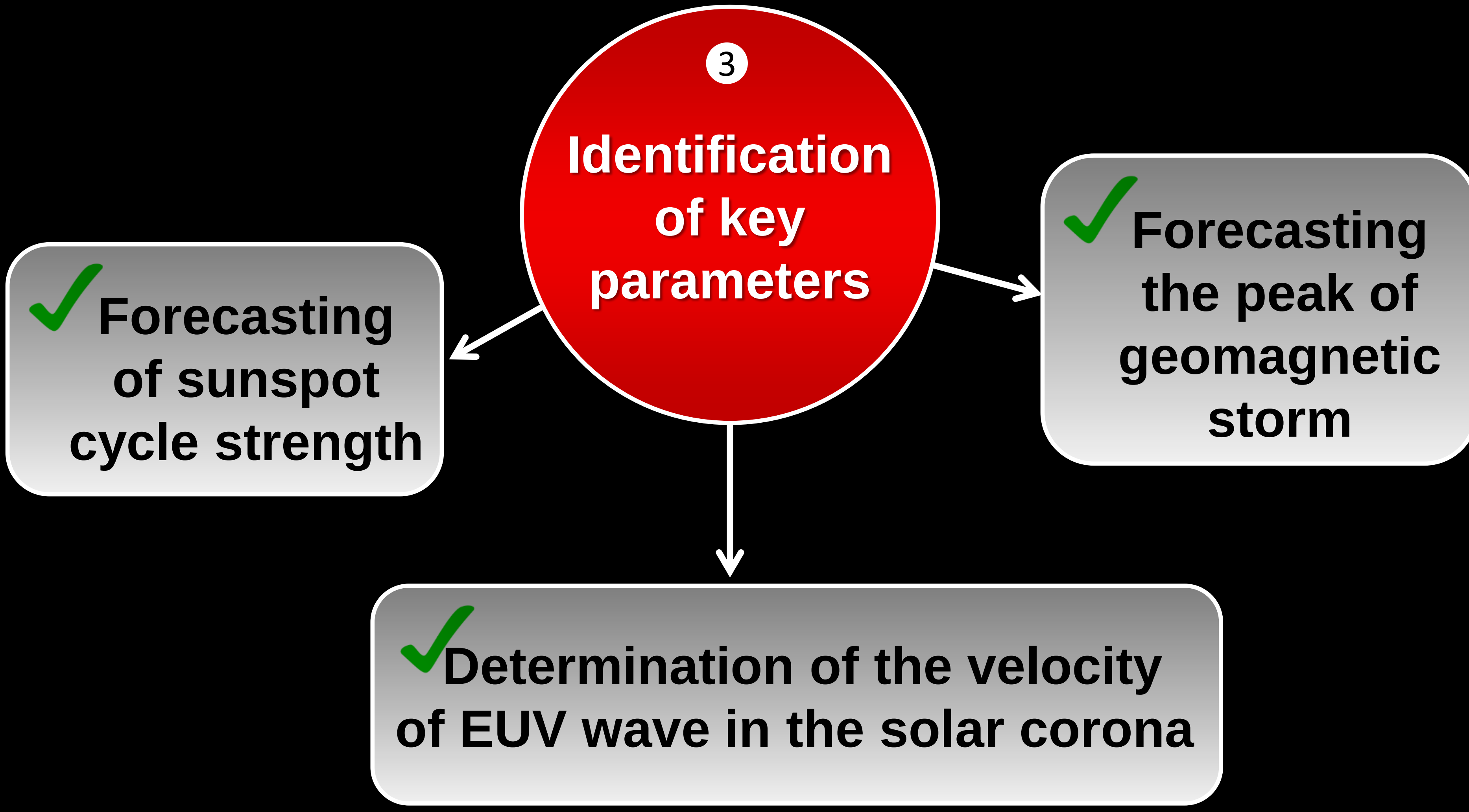
2

Statistical methods based on state-space models

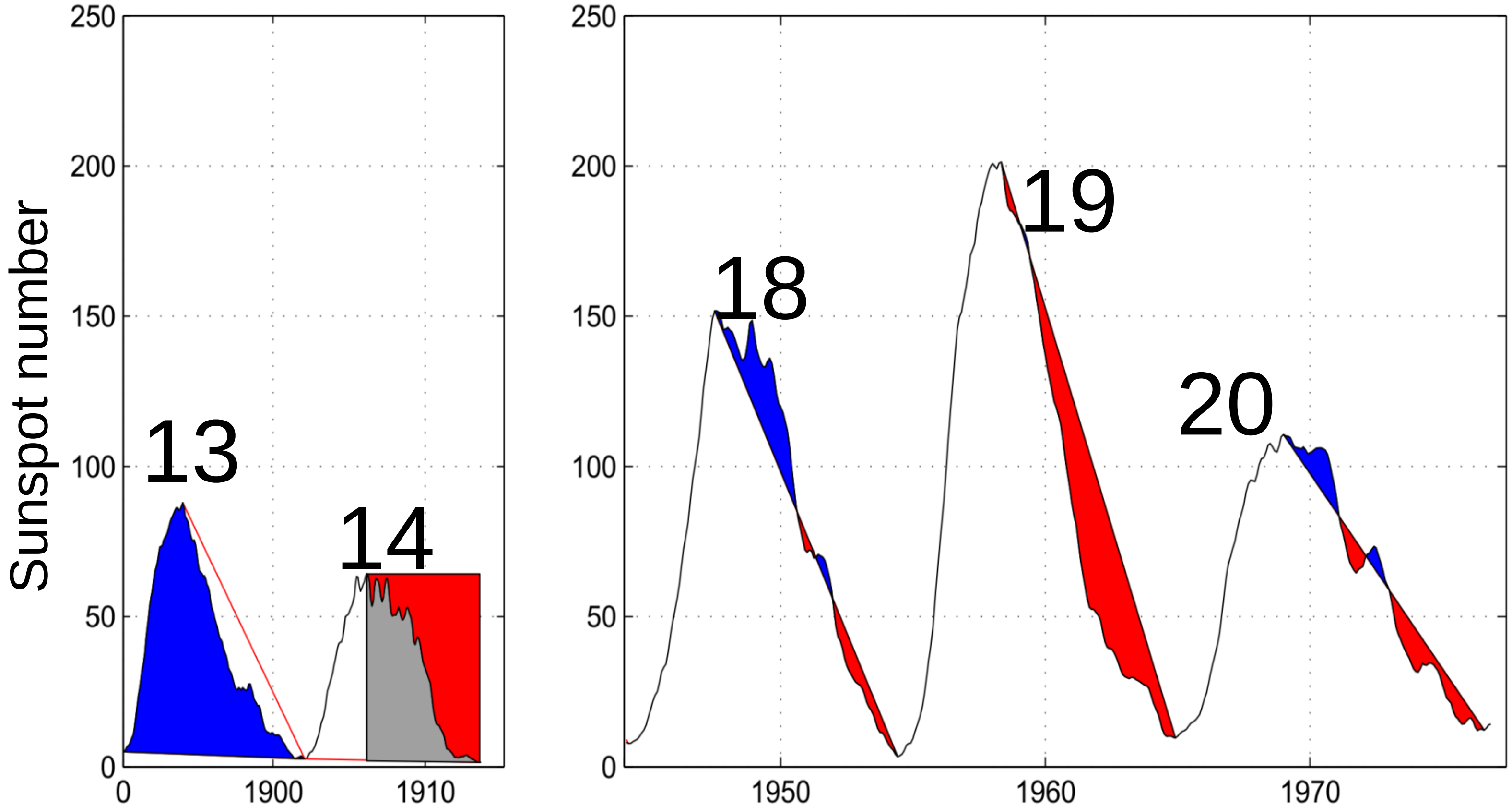
✓ **State space models**

Kalman filter requires the knowledge of noise statistics

Noise statistics identification

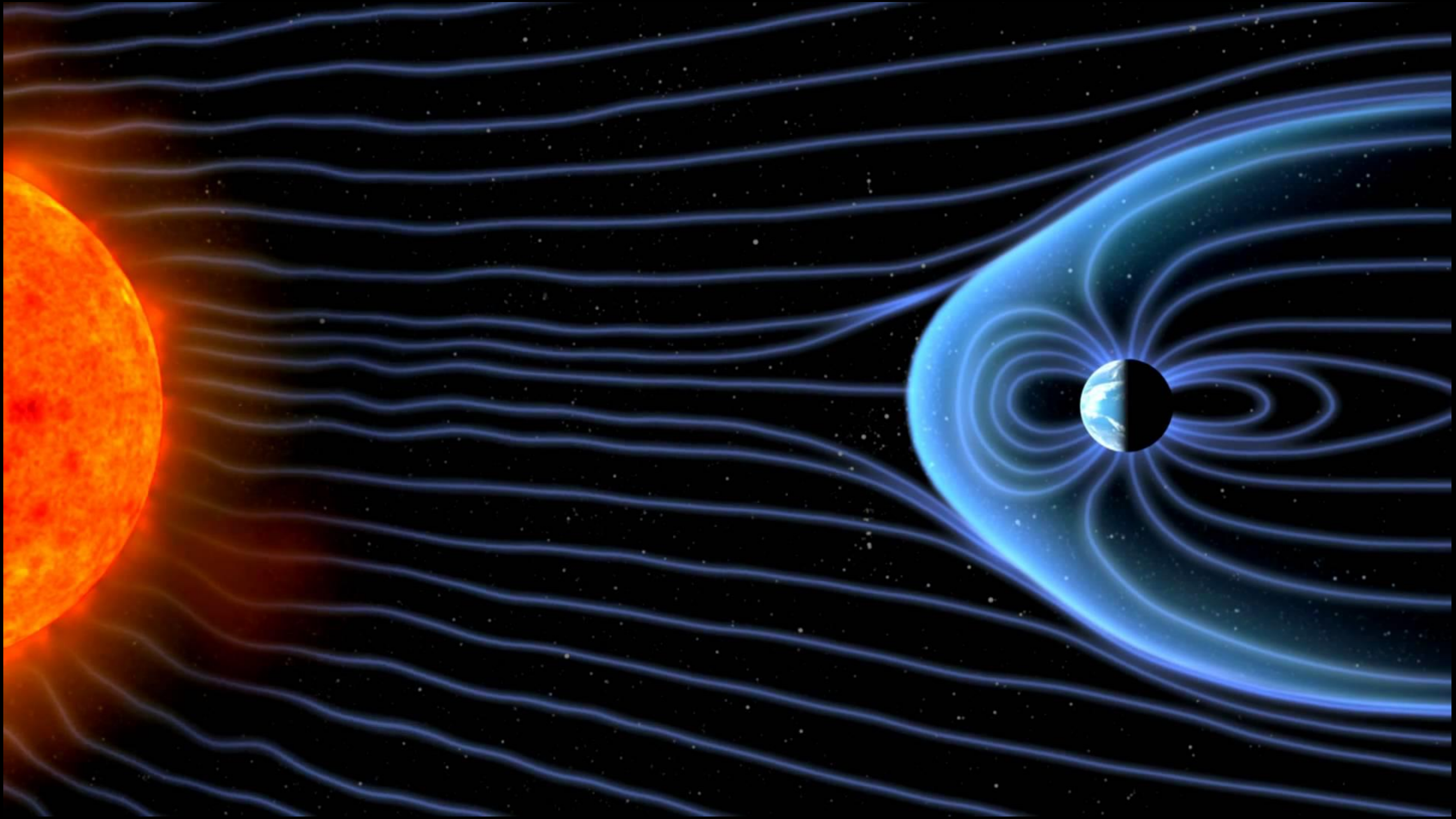

3
Identification of key parameters
Forecasting of sunspot cycle strength
Forecasting the peak of geomagnetic storm
Determination of the velocity of EUV wave in the solar corona

Forecasting the 11-year sunspot cycle strength



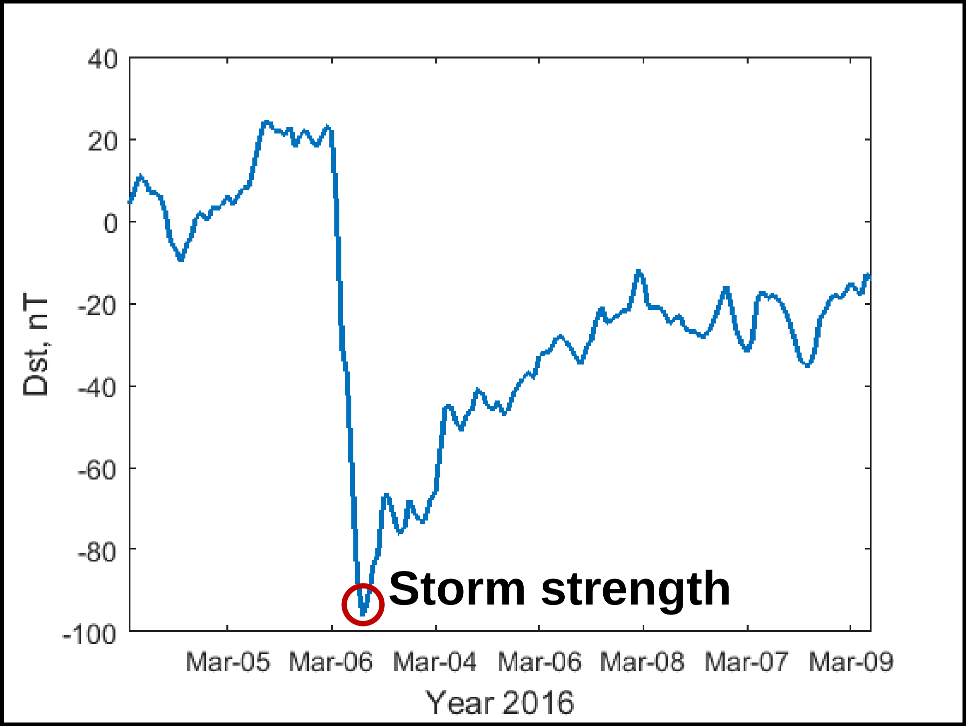
Key parameter → **Relationship between red and blue areas**

Solar – terrestrial relationships



Geomagnetic storm index

Disturbance storm time (Dst) geomagnetic index



Dst dynamics is mainly driven by

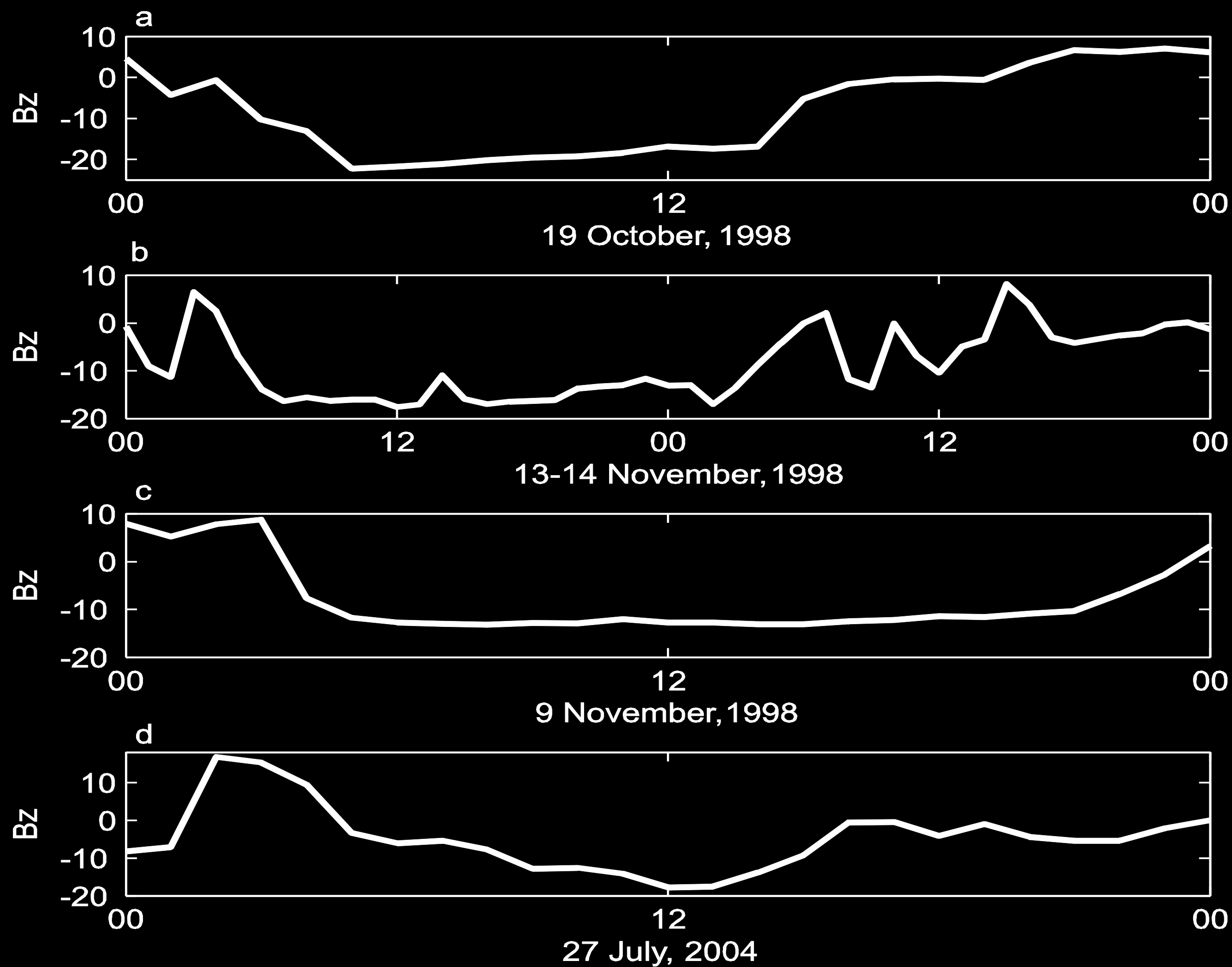
↓

1. **Solar wind speed**

↓

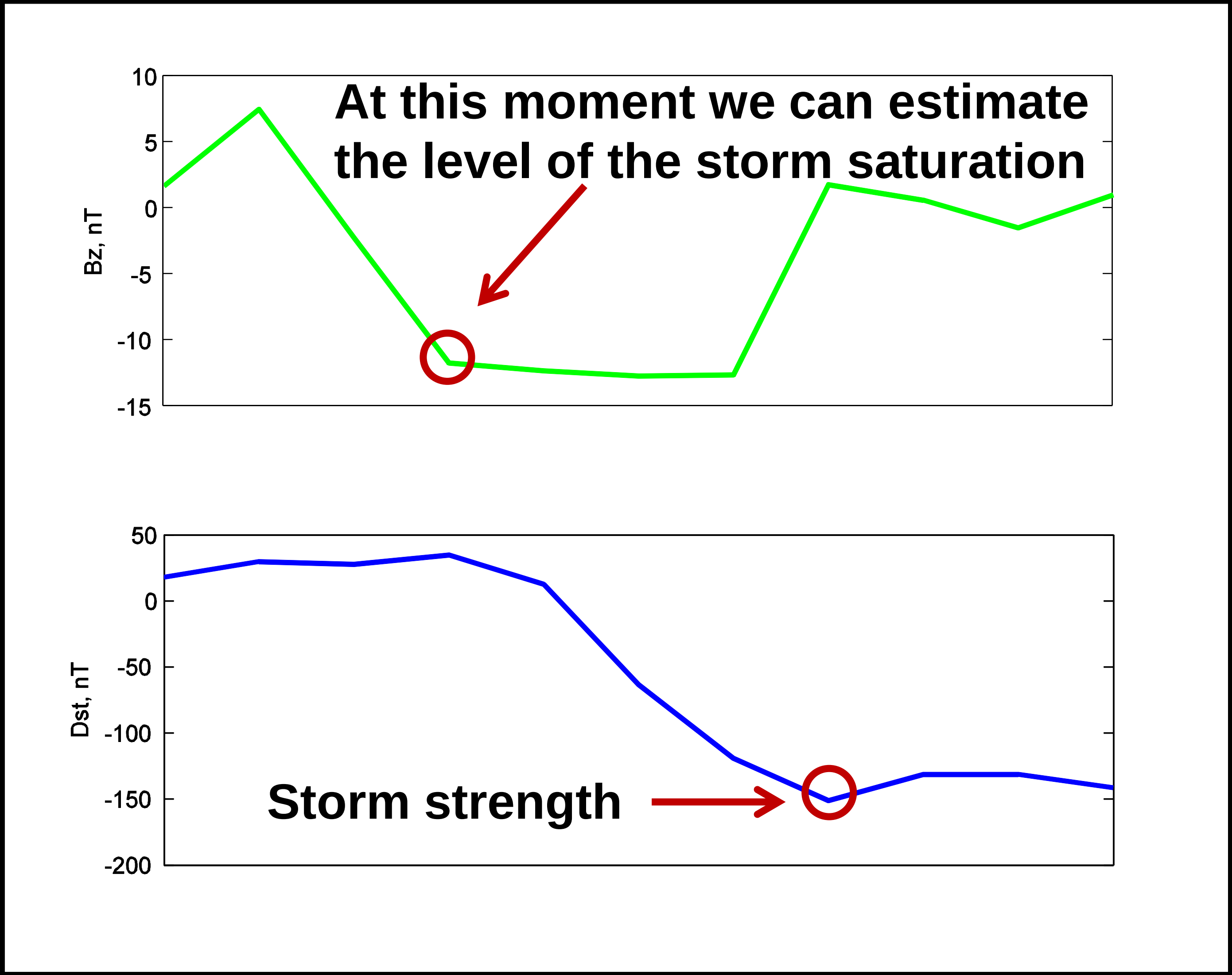
2. **Southward component of Interplanetary magnetic field (IMF)**

Forecasting peak of geomagnetic storm



Dynamics of southward component of interplanetary magnetic field Bz

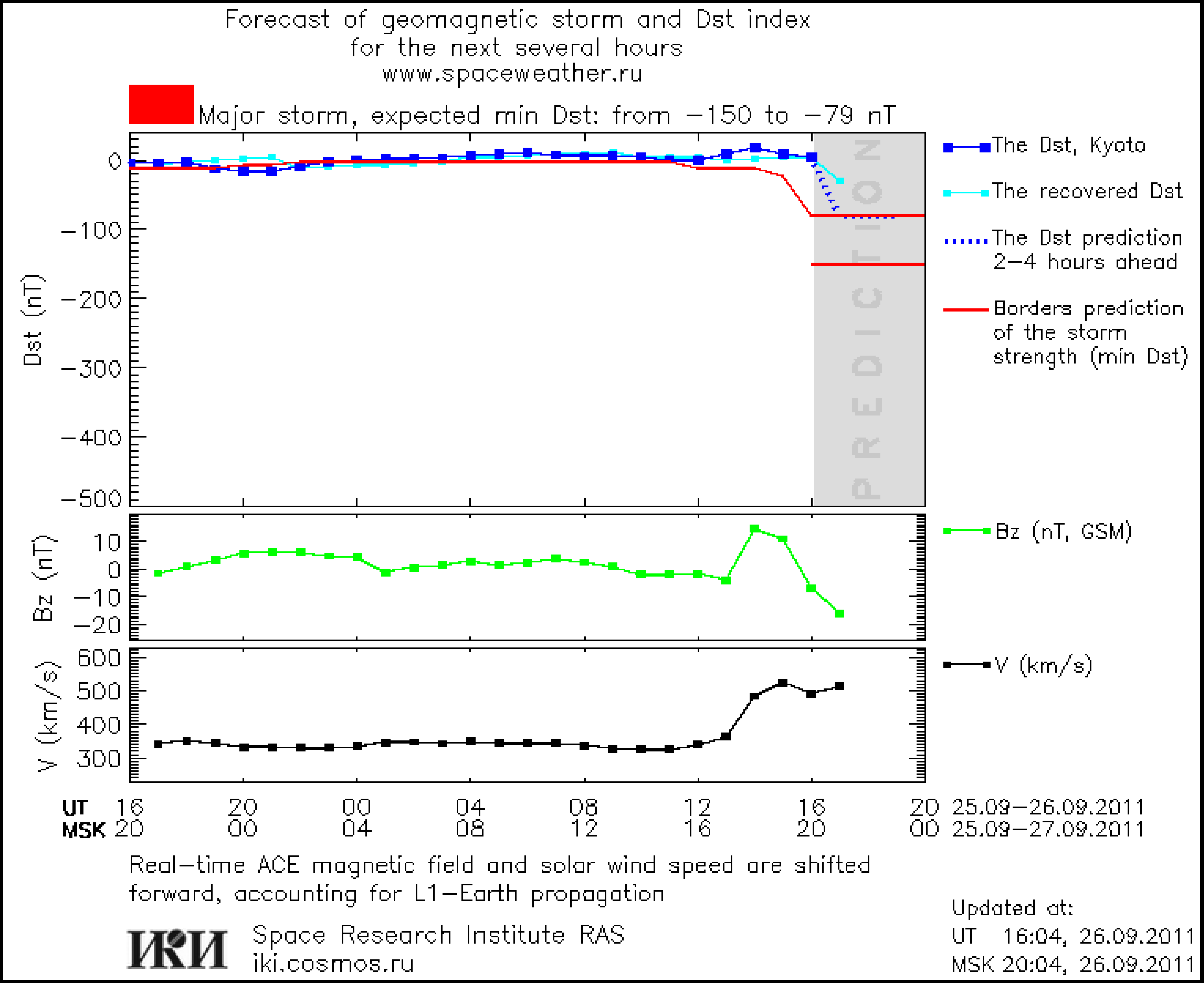
Forecasting peak of geomagnetic storm



Geomagnetic Storm Saturation
24 – 25 October 2011

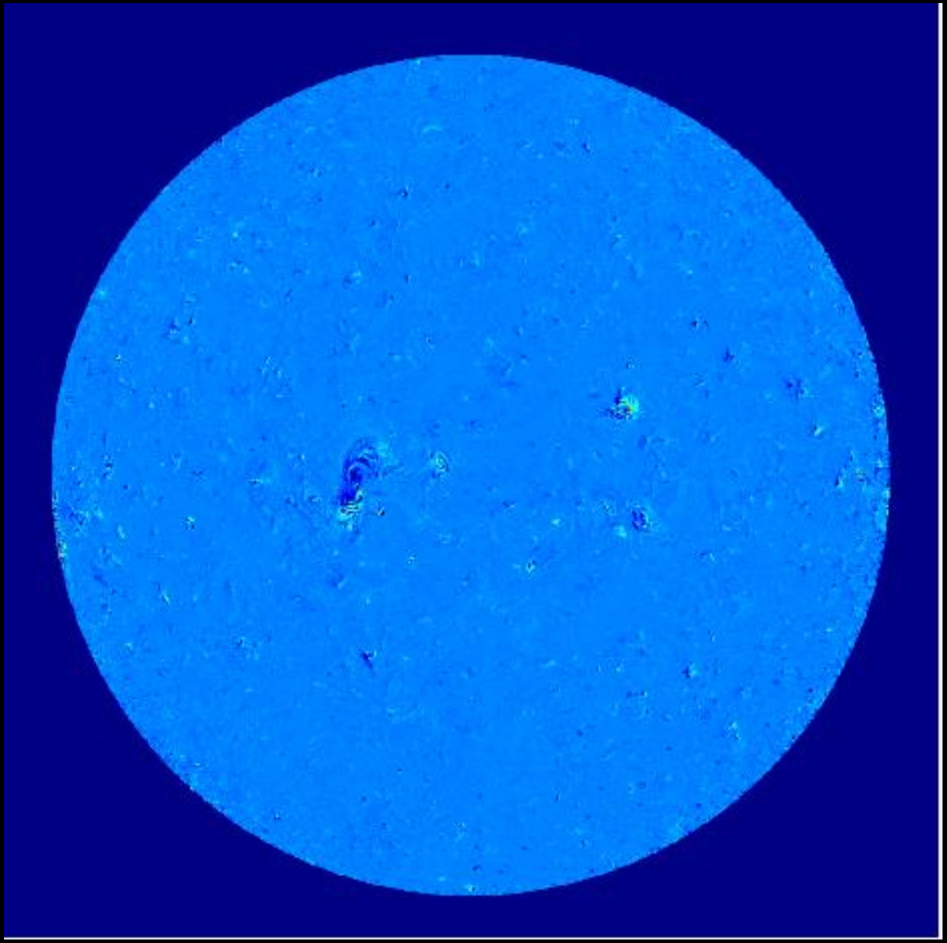
Key parameter → **Saturation point**

Geomagnetic storm forecasting service
www.spaceweather.ru

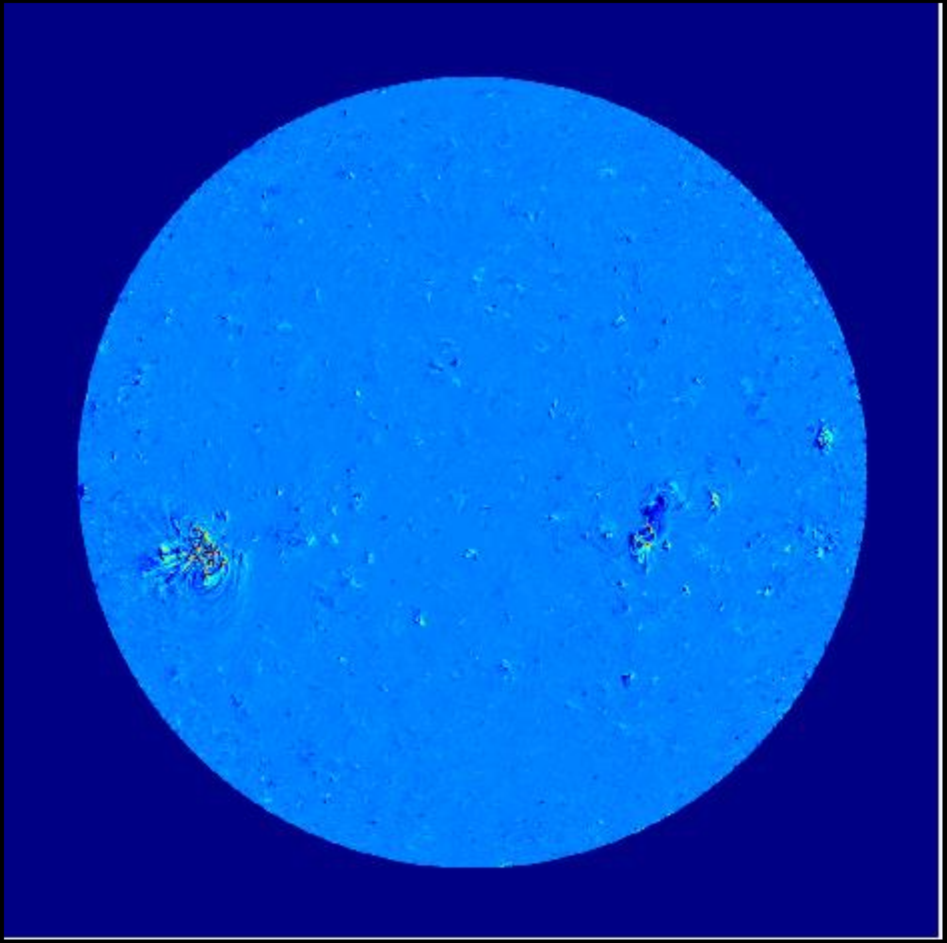


Coronal mass ejections December 7, 2007

STEREO A



STEREO B

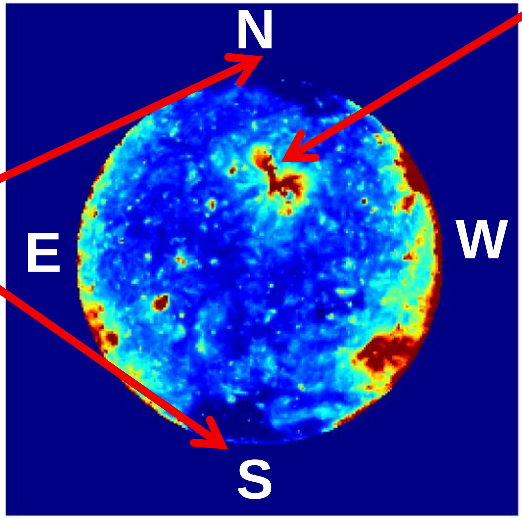


Wave rate: 123 km/s, Wave height: 14 000 – 100 000 km

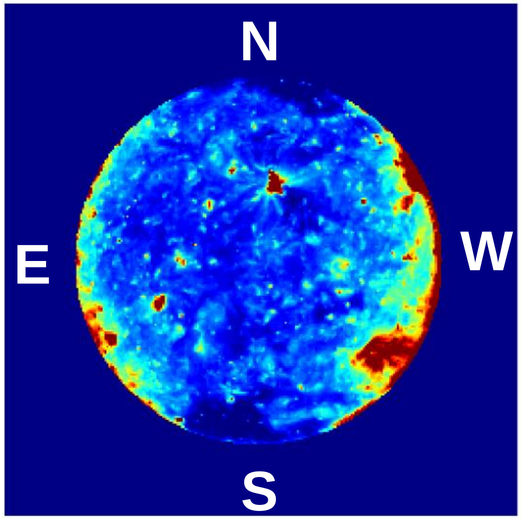
Coronal mass ejections May 12, 1997, SOHO images

Eruptive center

Coronal holes
discharge
fast solar wind



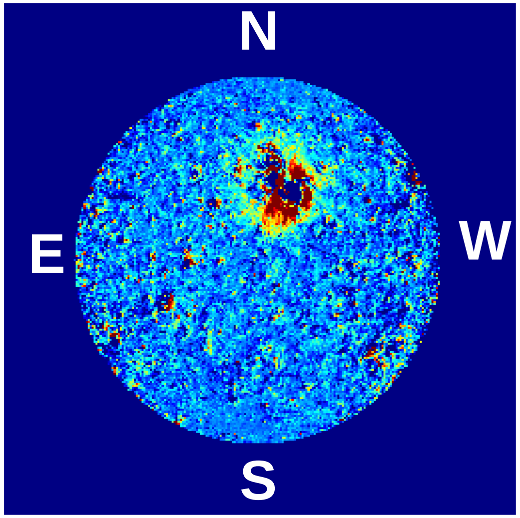
4:50 UTC



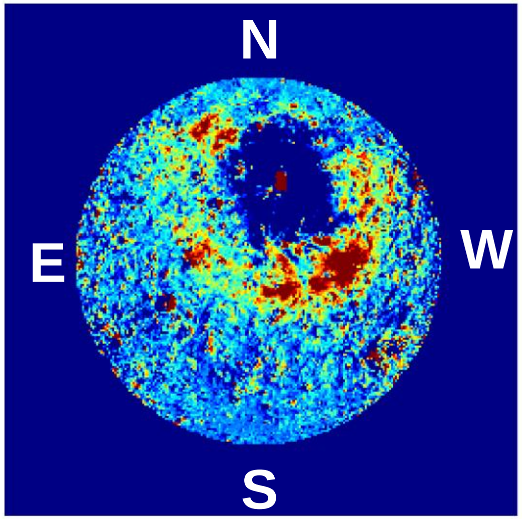
5:07 UTC

EUV wave propagates quasi-circular.
However, propagationof EUV wave
toward northwest is stopped by coronal hole

Coronal mass ejections May 12, 1997, SOHO difference images



4:50 - 4:34 UTC

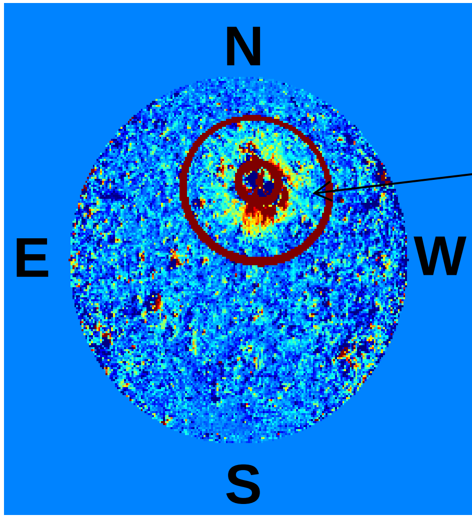


5:07 – 4:34 UTC

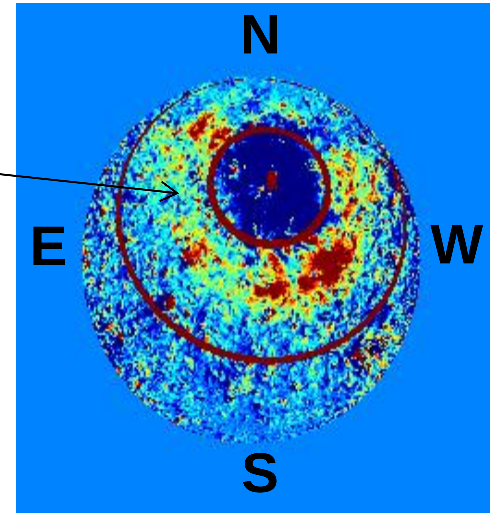
Difference image allows observing the dynamics of EUV wave propagation

Estimation of coronal wave radial rate and front width

SOHO difference images, May 12 1997

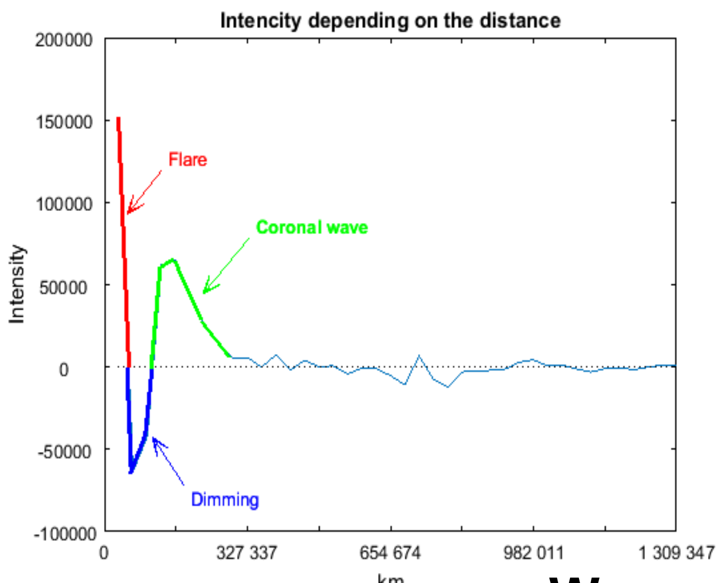


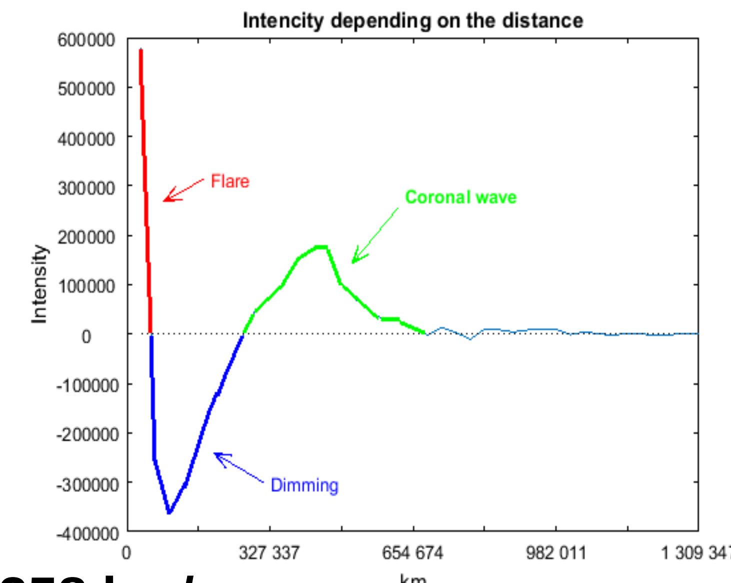
Wave front



4:50 - 4:34 UTC

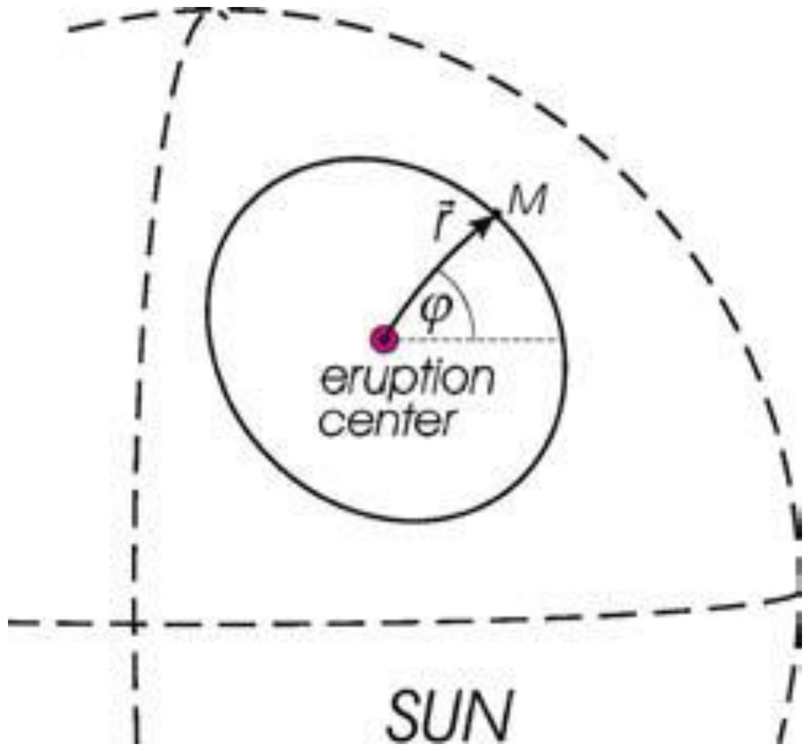
5:07 – 4:34 UTC





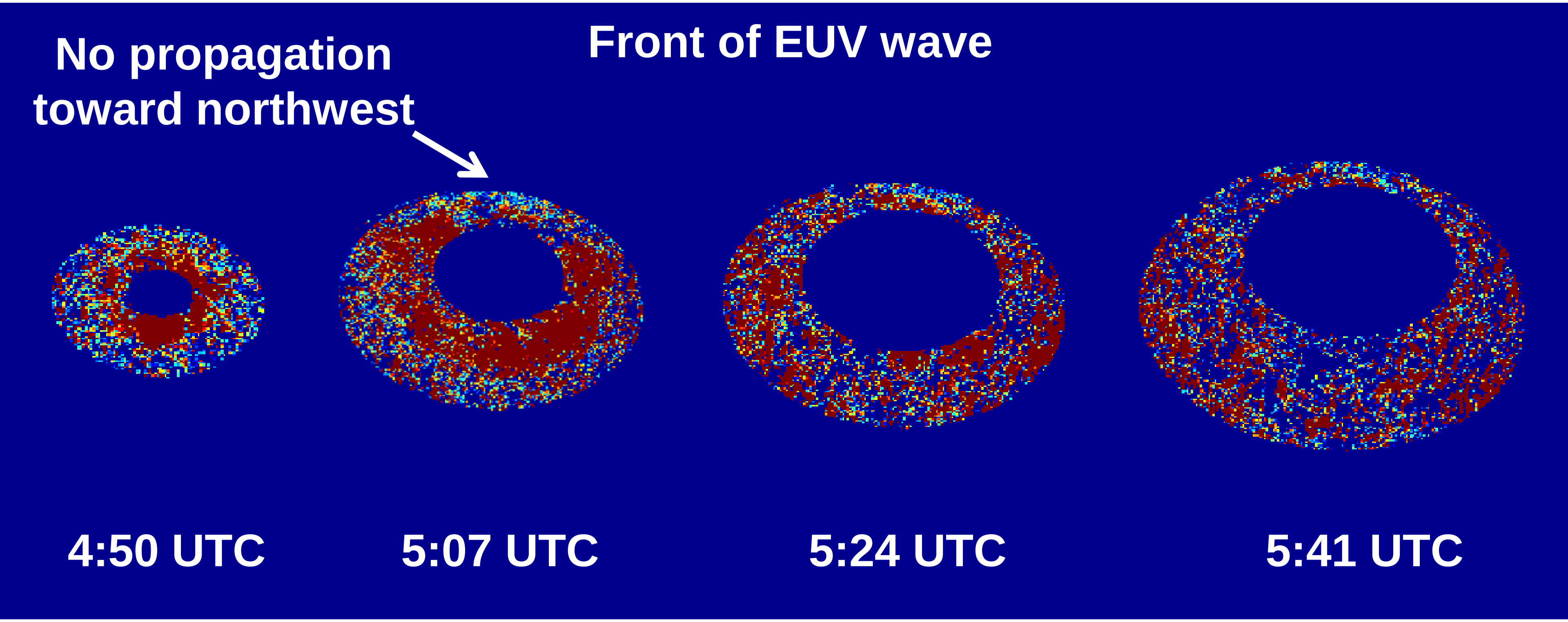
Wave rate: 258 km/s

Determination of the angular velocity of EUV wave in the solar corona



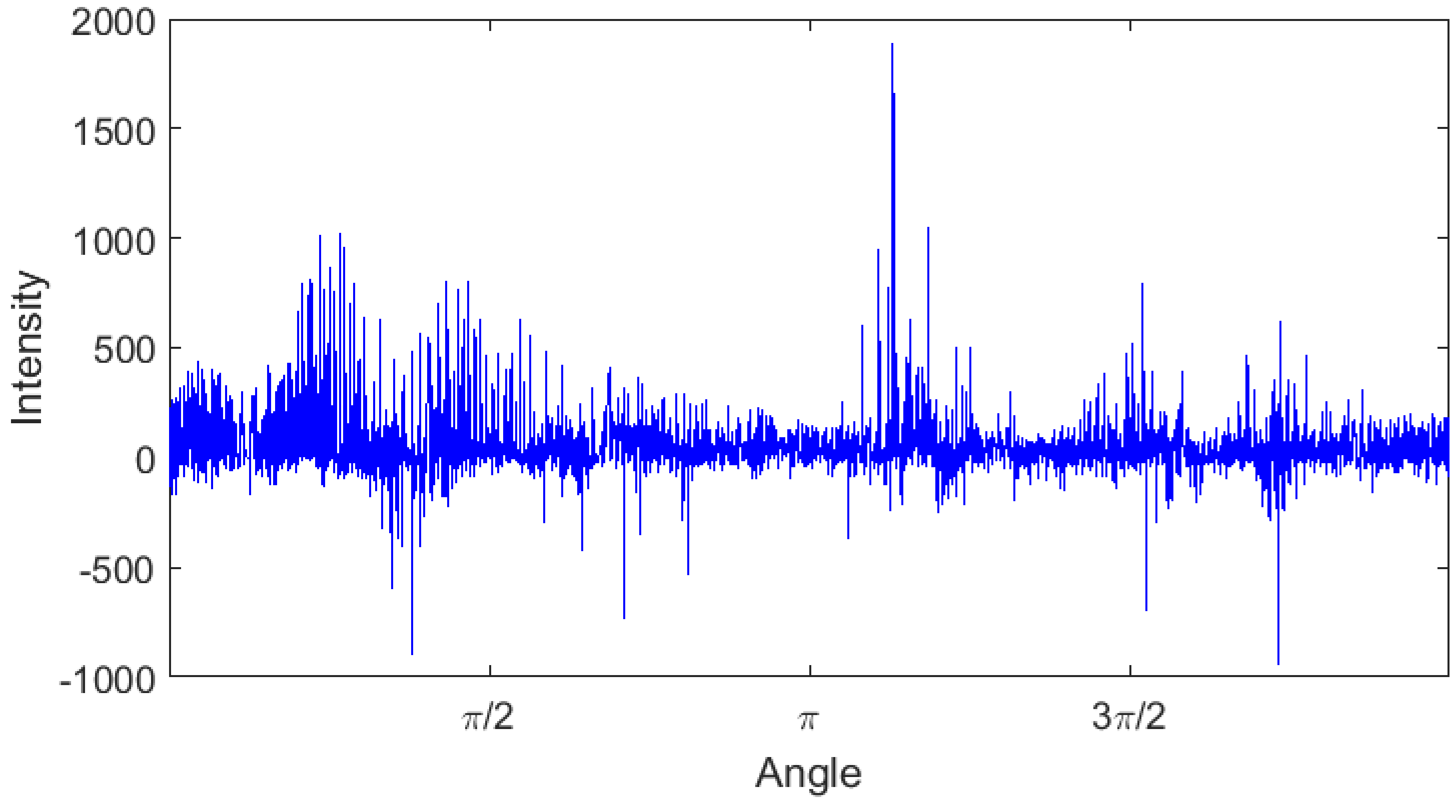
Polar coordinates $\vec{r}, \phi$ of a pixel on the solar disk. The center of a system is at eruptive center.

Determination of the angular velocity of EUV wave in the solar corona



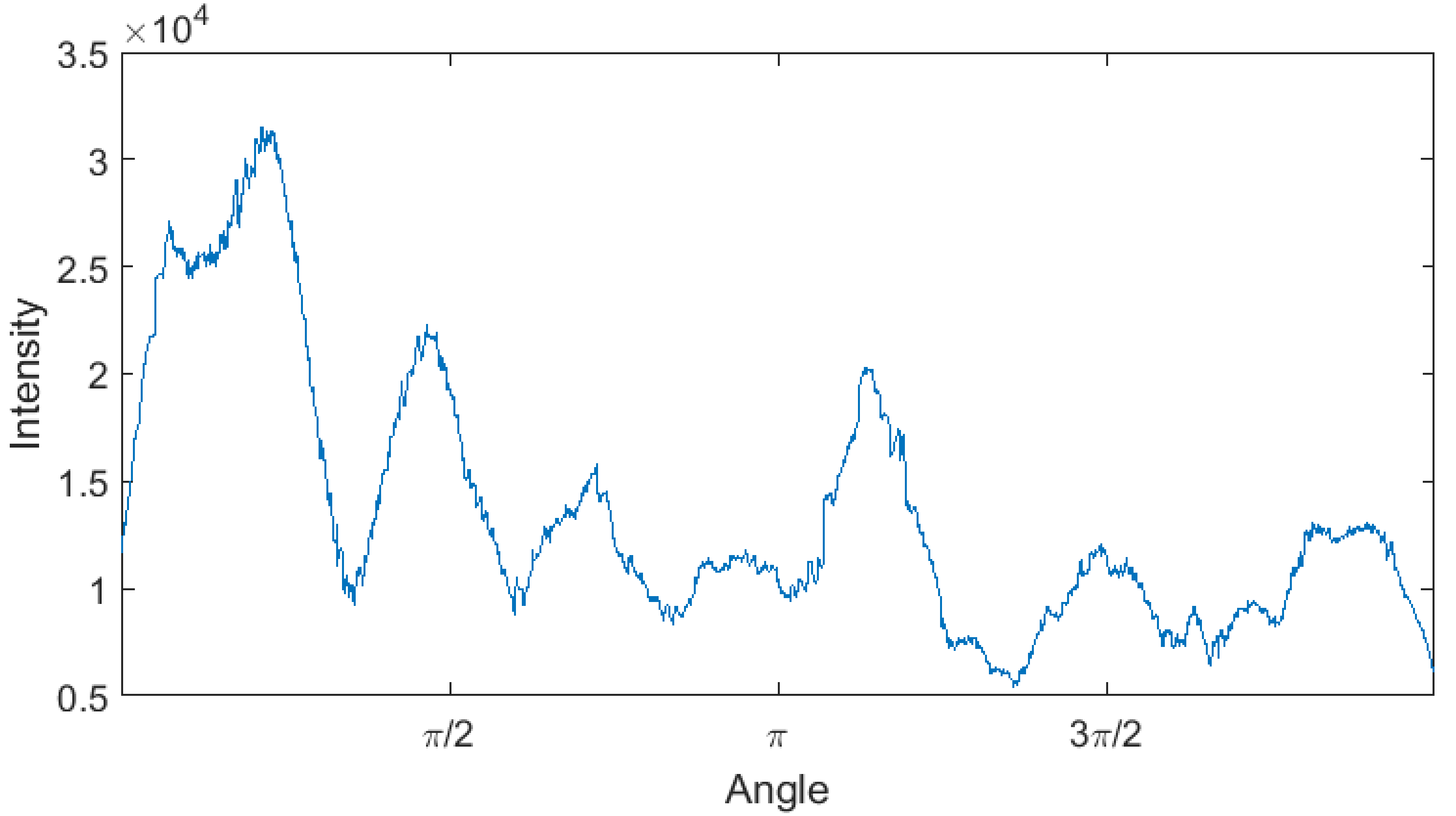
Front of EUV wave propagates over the solar disc

Dependence of intensity of EUV wave front on angle



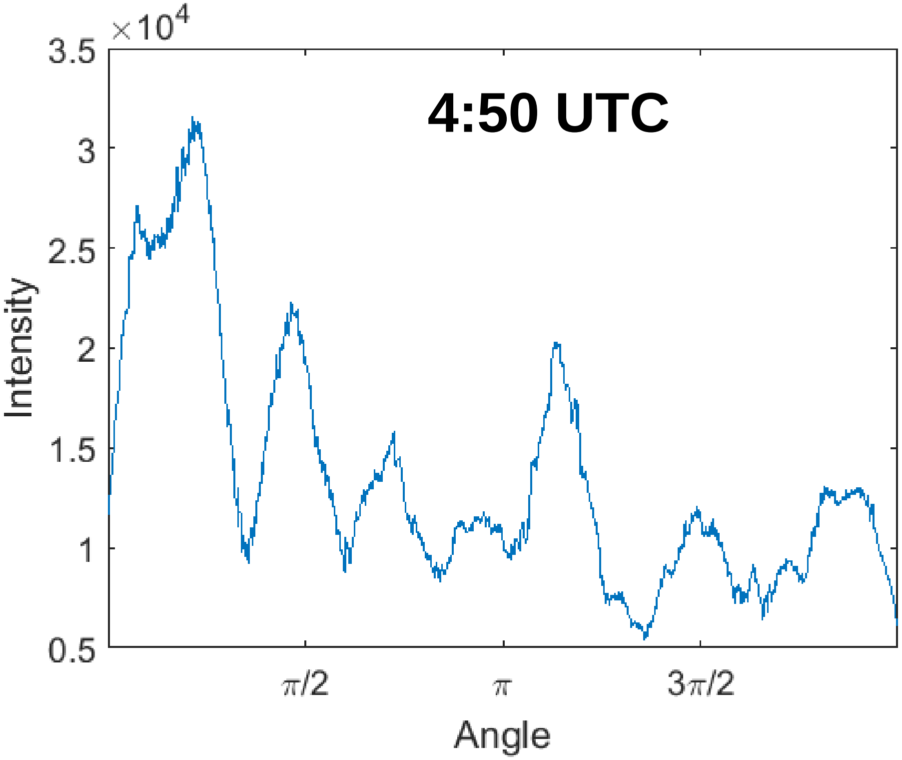
The information about the wave front localization is hidden in the noise. Smoothing is needed.

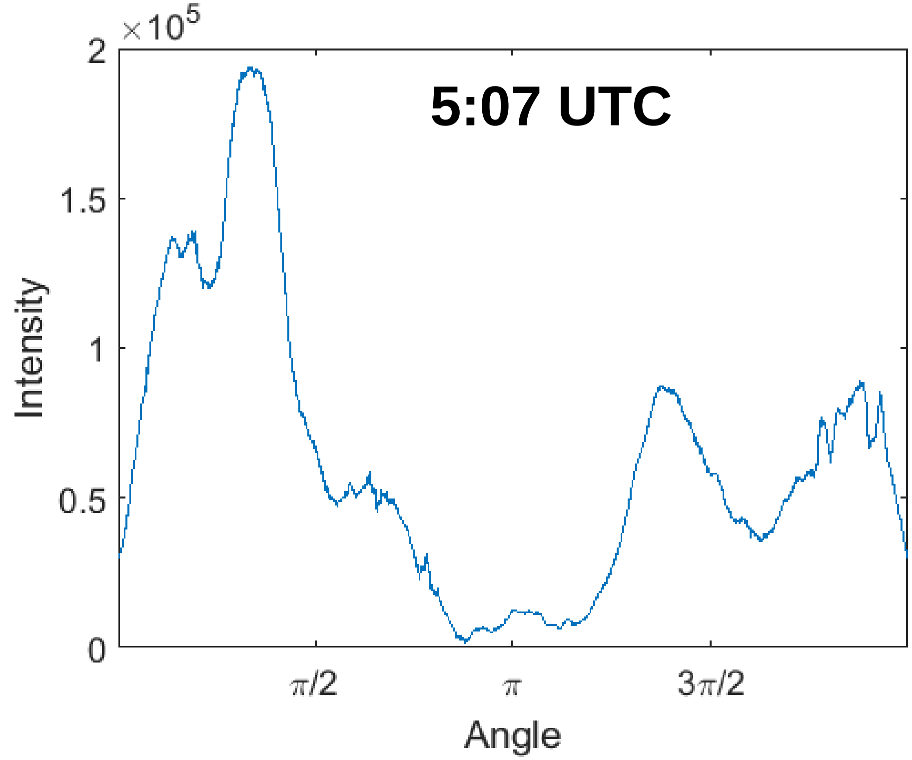
Dependence of smoothed intensity of EUV wave front on angle



Running smoothing → **Each pixel is replaced by the sum of all pixels on the angular interval of length $\pi/8$ centered on the considered point.**

Dependence of smoothed intensity of EUV wave front on angle





Intensity from 2 to 4 radians corresponding to northwest direction is excluded from analysis

Coordinate of intensity center

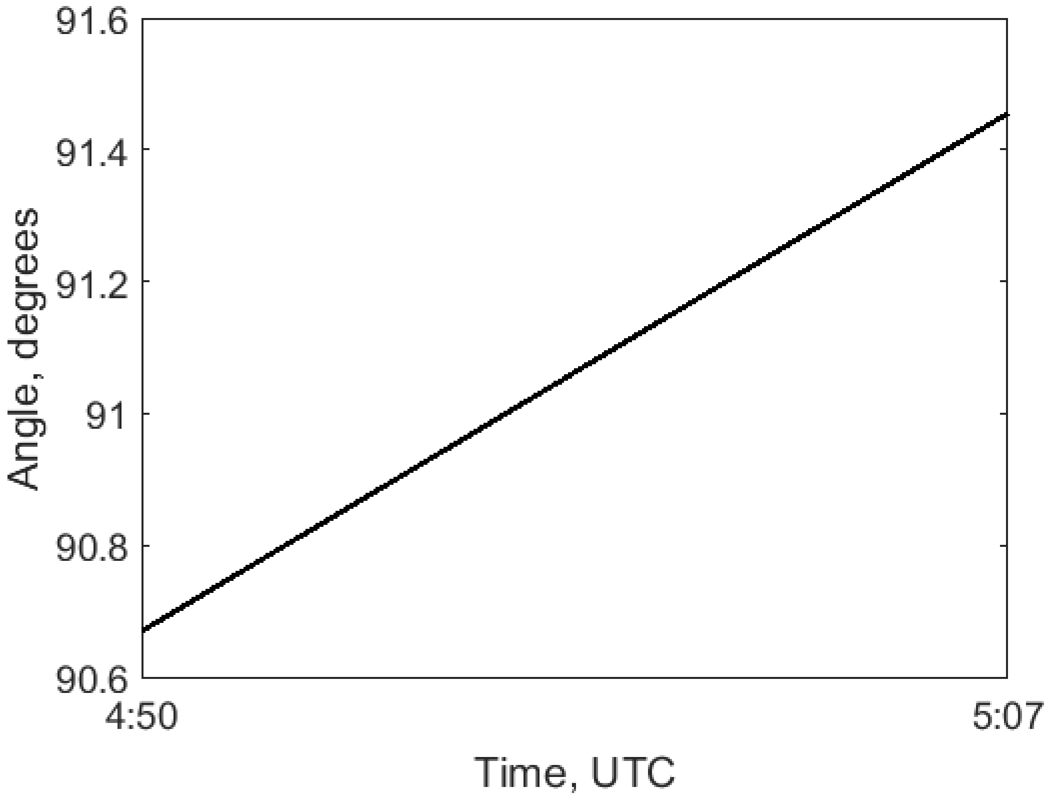
I_j → Intensity of EUV wave front

j^c → Coordinate of intensity center

$$j^c = \sum_{j=1}^{N} j \cdot I_j \Big/ \sum_{j=1}^{N} I_j$$

To determine the angular velocity of EUV coronal wave we need to analyze the dynamics of polar angles for intensity centers $\phi(j^c)$

Determination of the angular velocity of EUV wave in the solar corona



For two sequent images the angle of EUV wave propagation slightly increases