

“Experimental Data Processing”

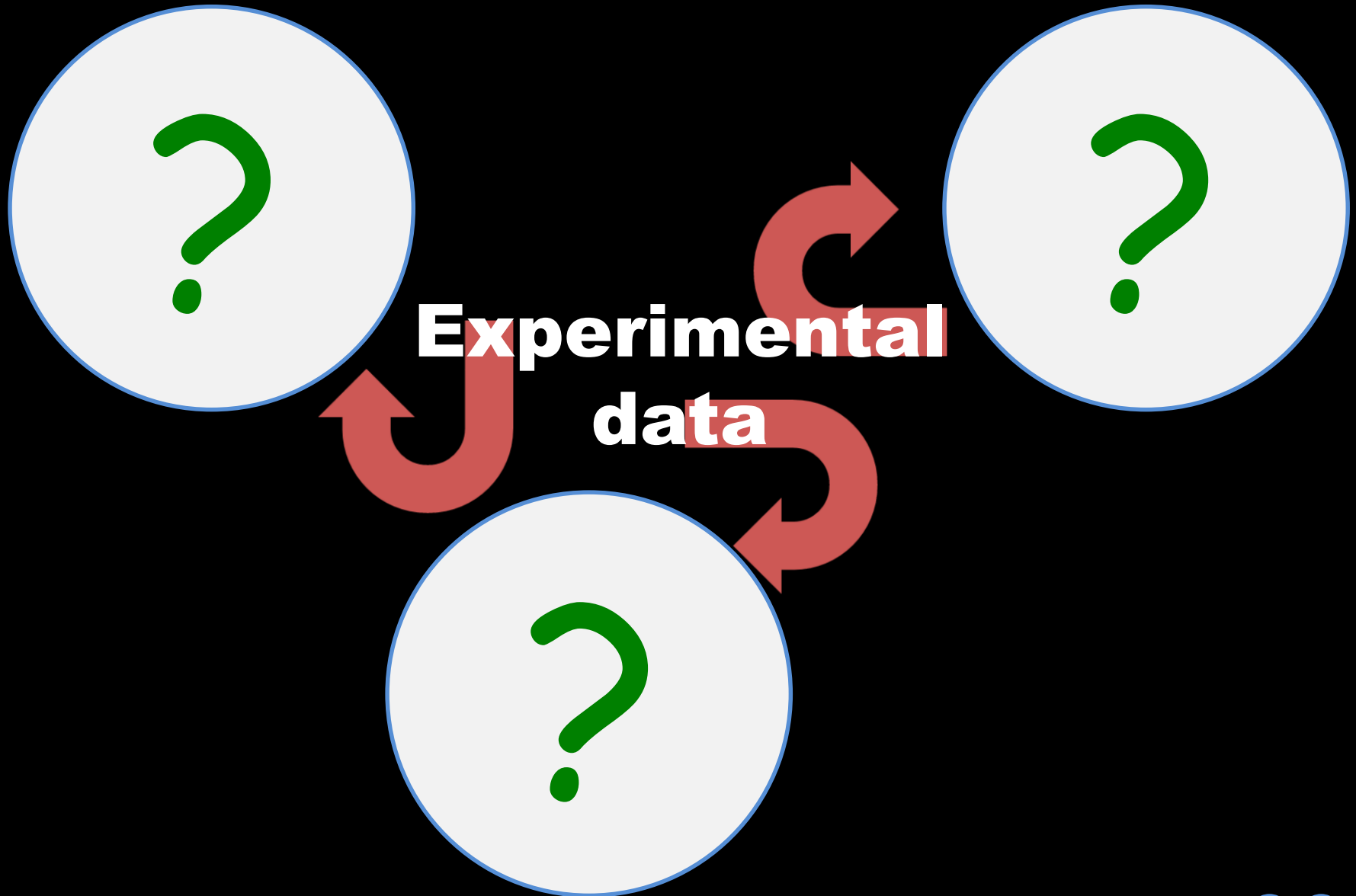
Introduction to the course

Tatiana Podladchikova

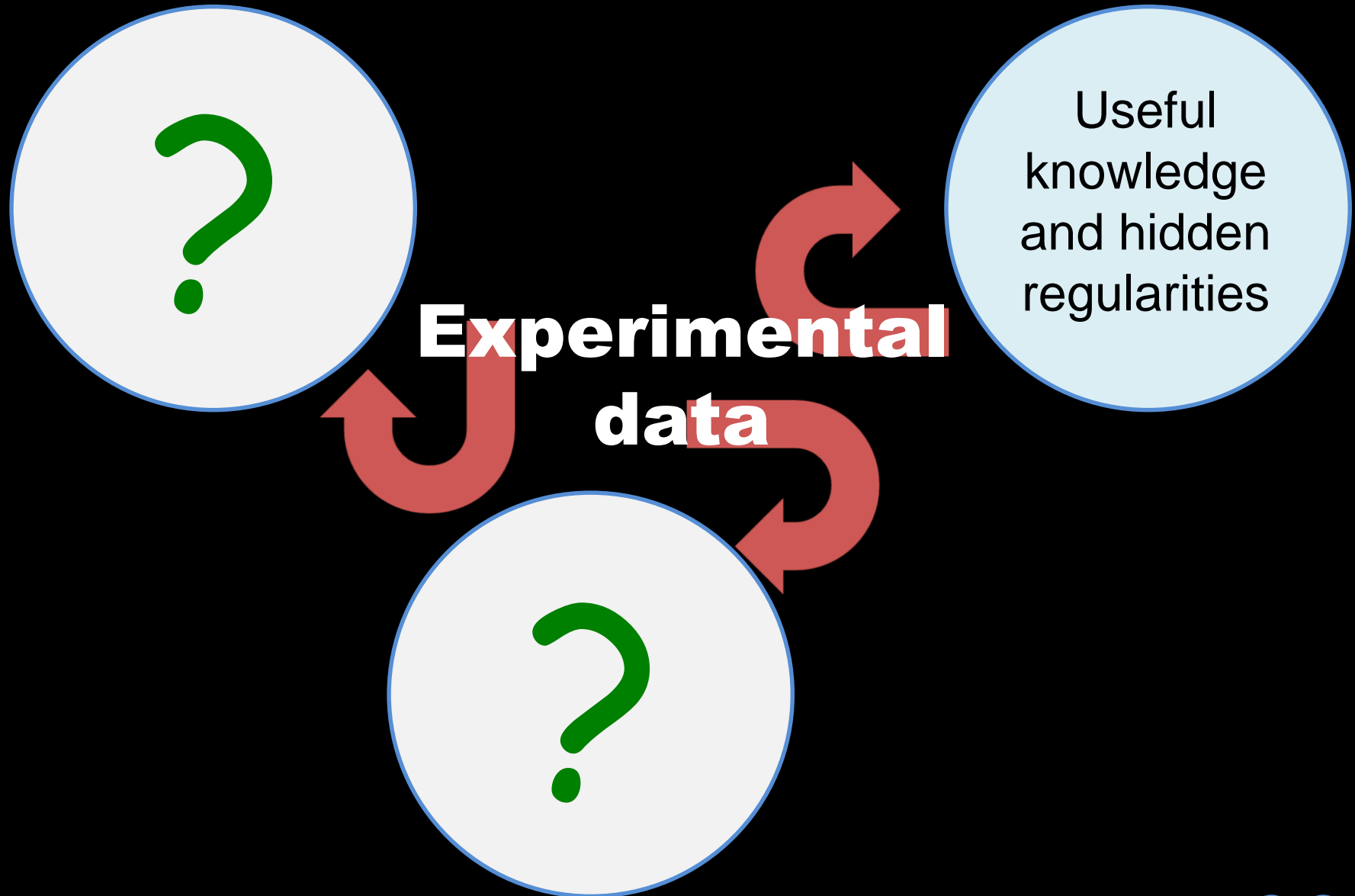
Term 1B, October 2018

t.podladchikova@skoltech.ru

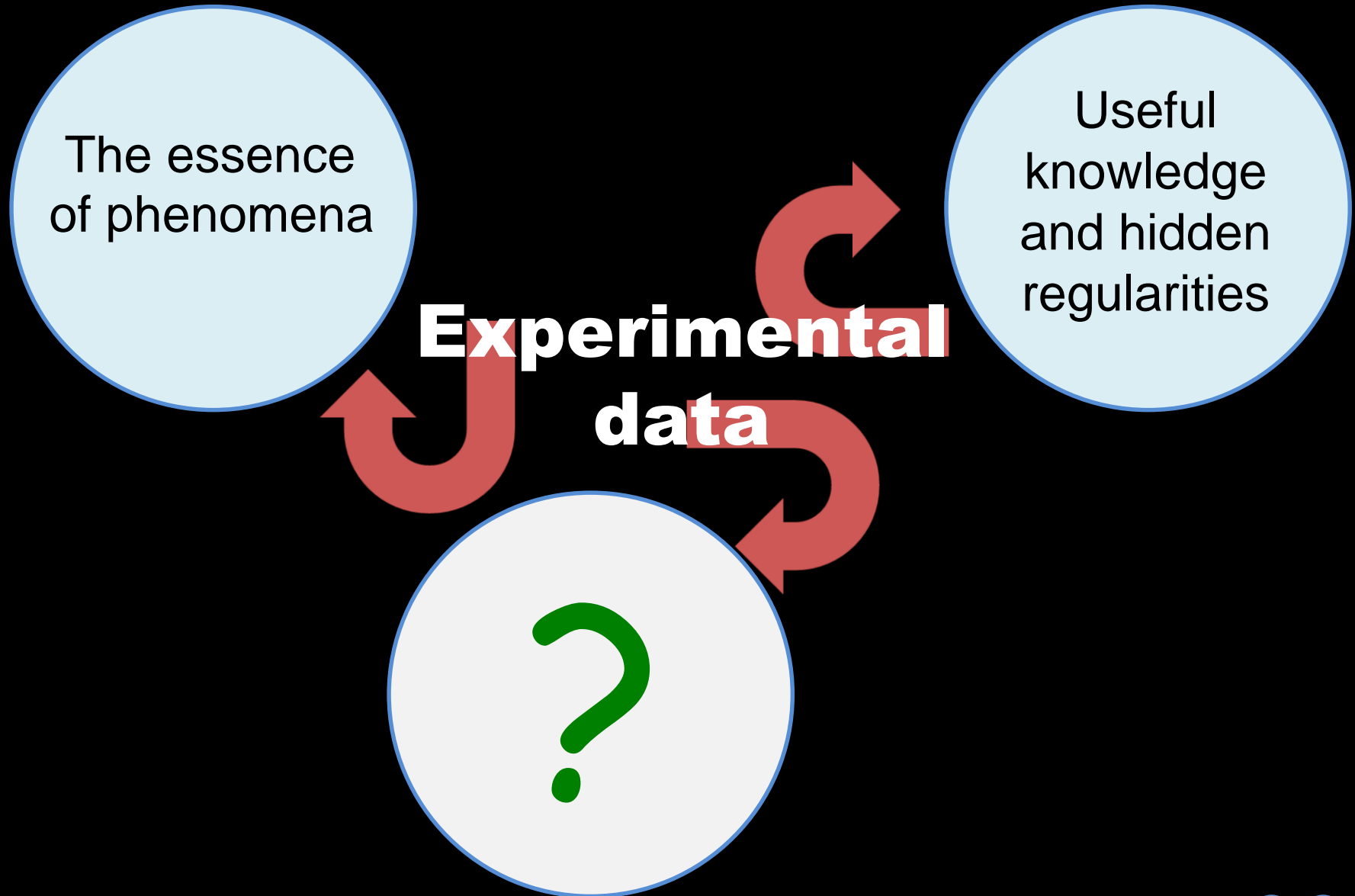
What sense can be made of experimental data?



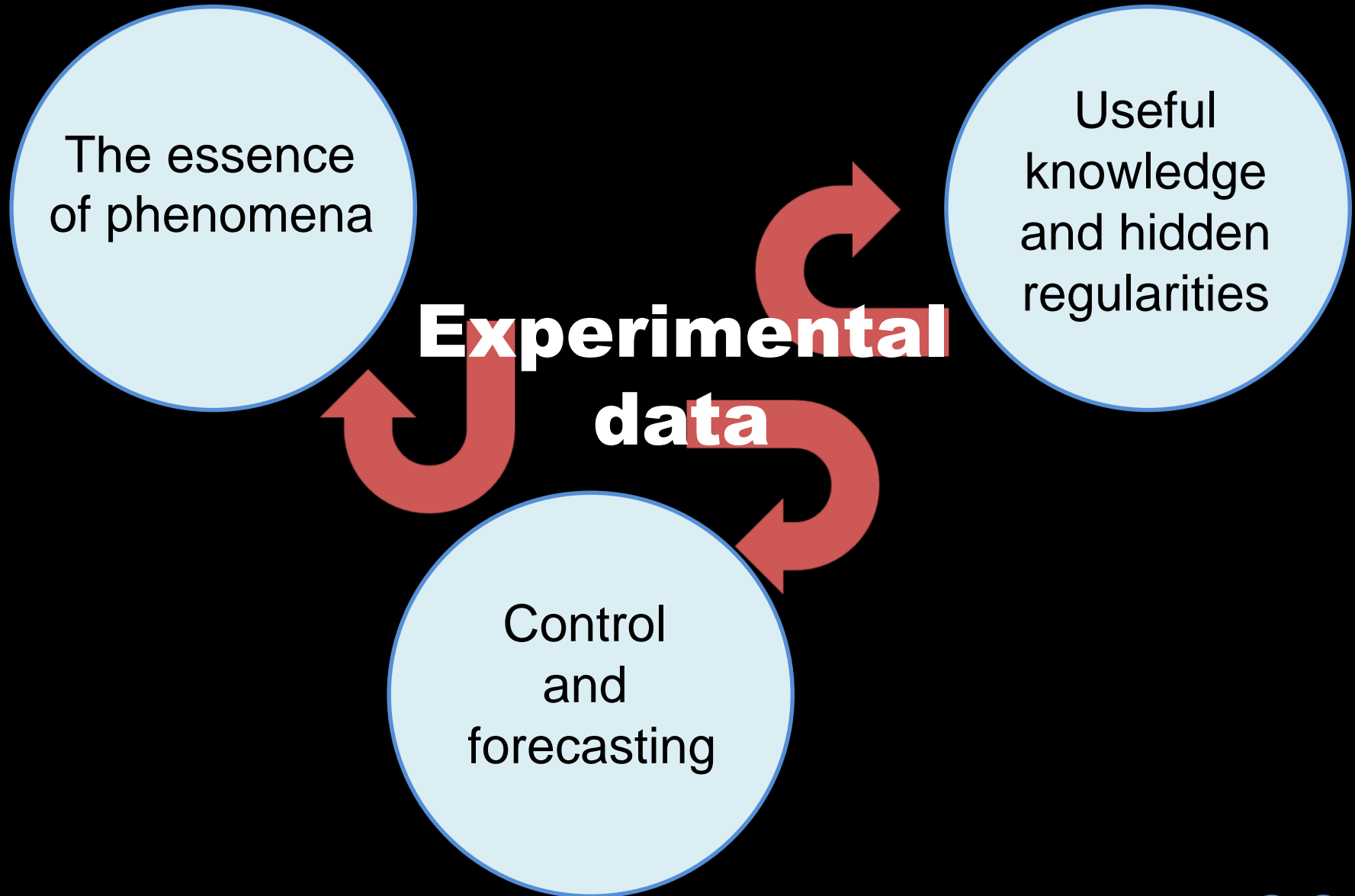
What sense can be made of experimental data?



What sense can be made of experimental data?

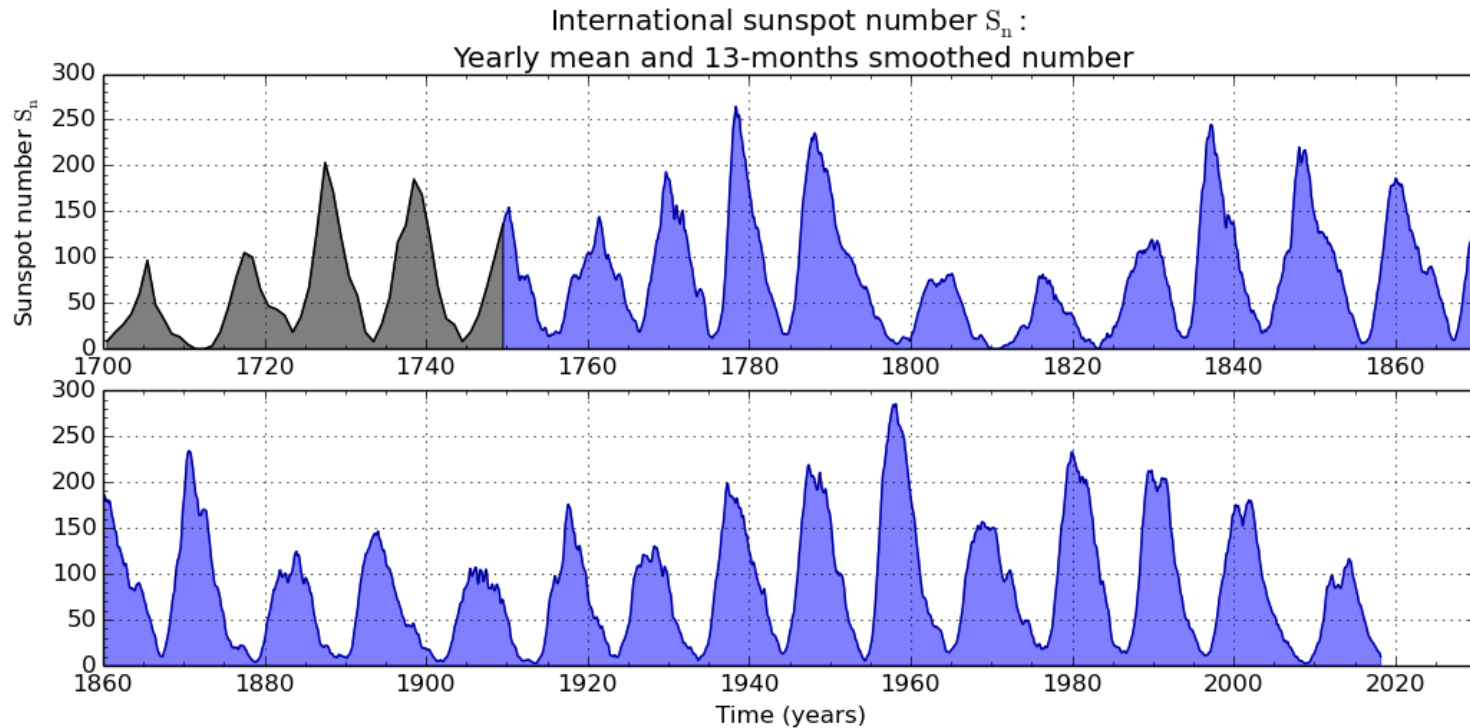


What sense can be made of experimental data?



Sunspot number observations 1700-2016

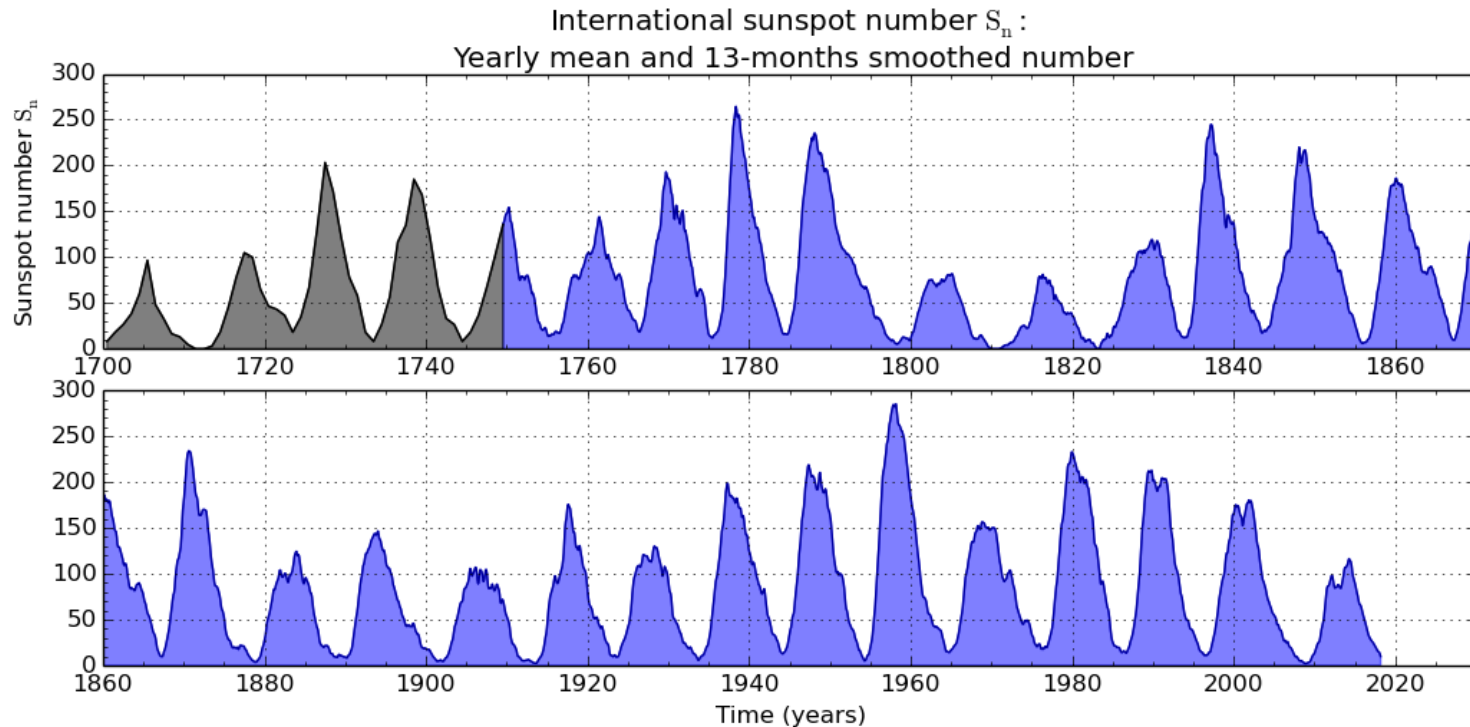
What regularities are visible?



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 October 1

Sunspot number observations 1700-2017

What regularities are visible?

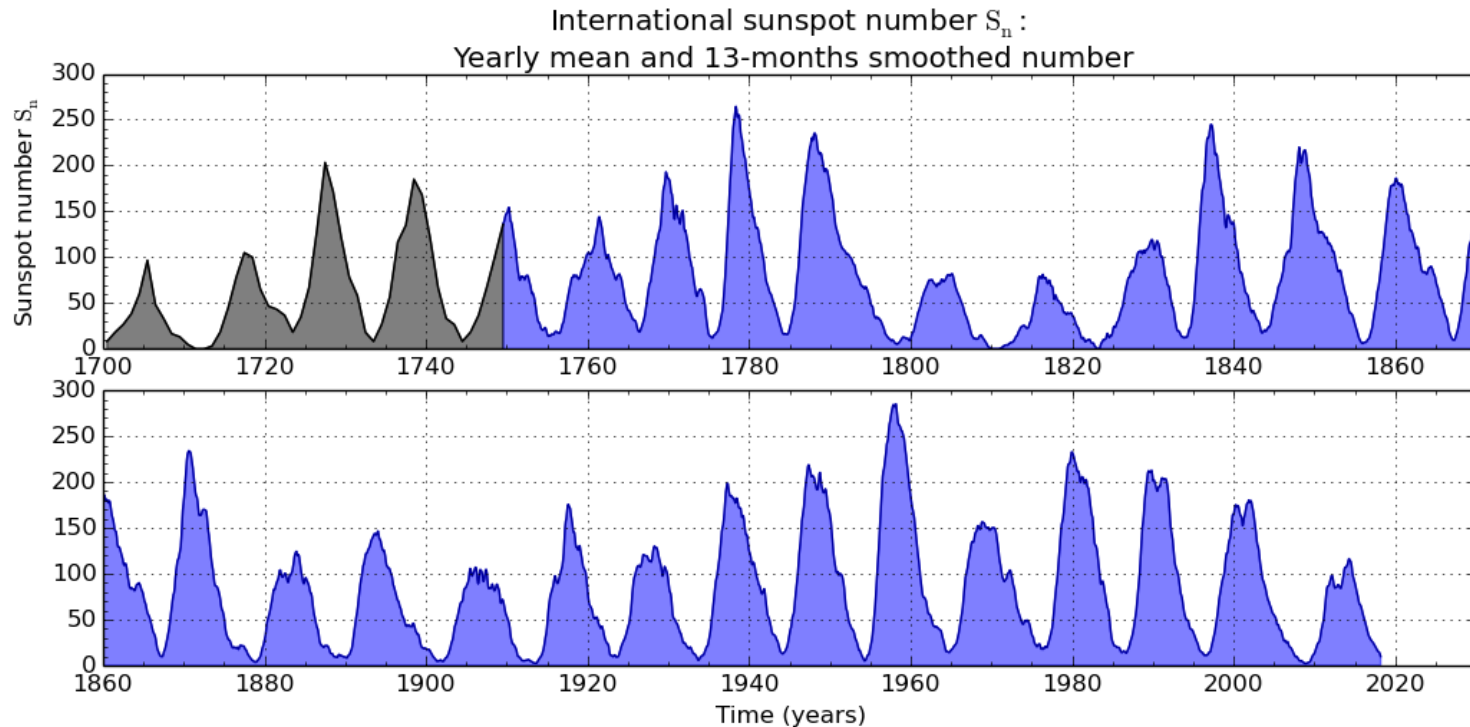


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 October 1

11-year sunspot cycle

Sunspot number observations 1700-2017

What regularities are visible?



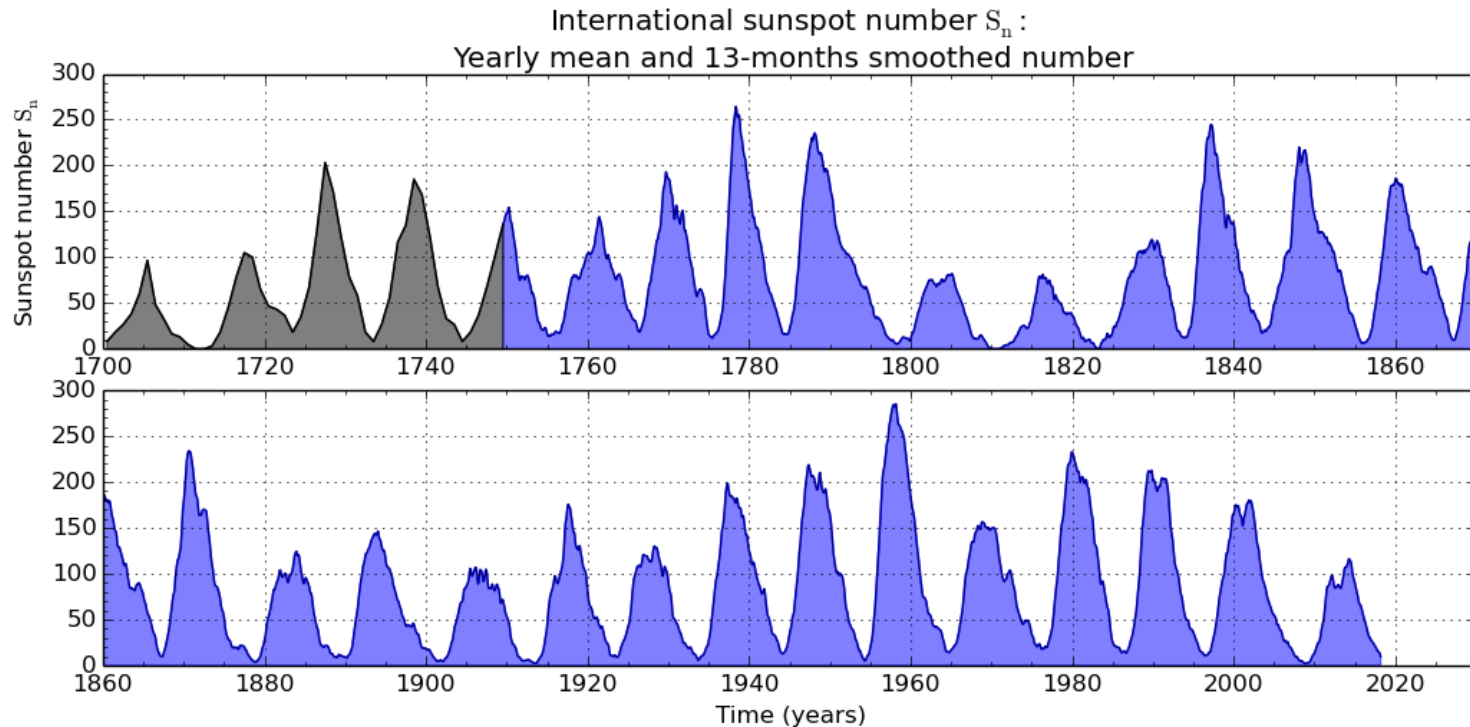
SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 October 1

11-year sunspot cycle

**The ascent phase
is shorter than
the decent one**

Sunspot number observations 1700-2017

What regularities are visible?



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 October 1

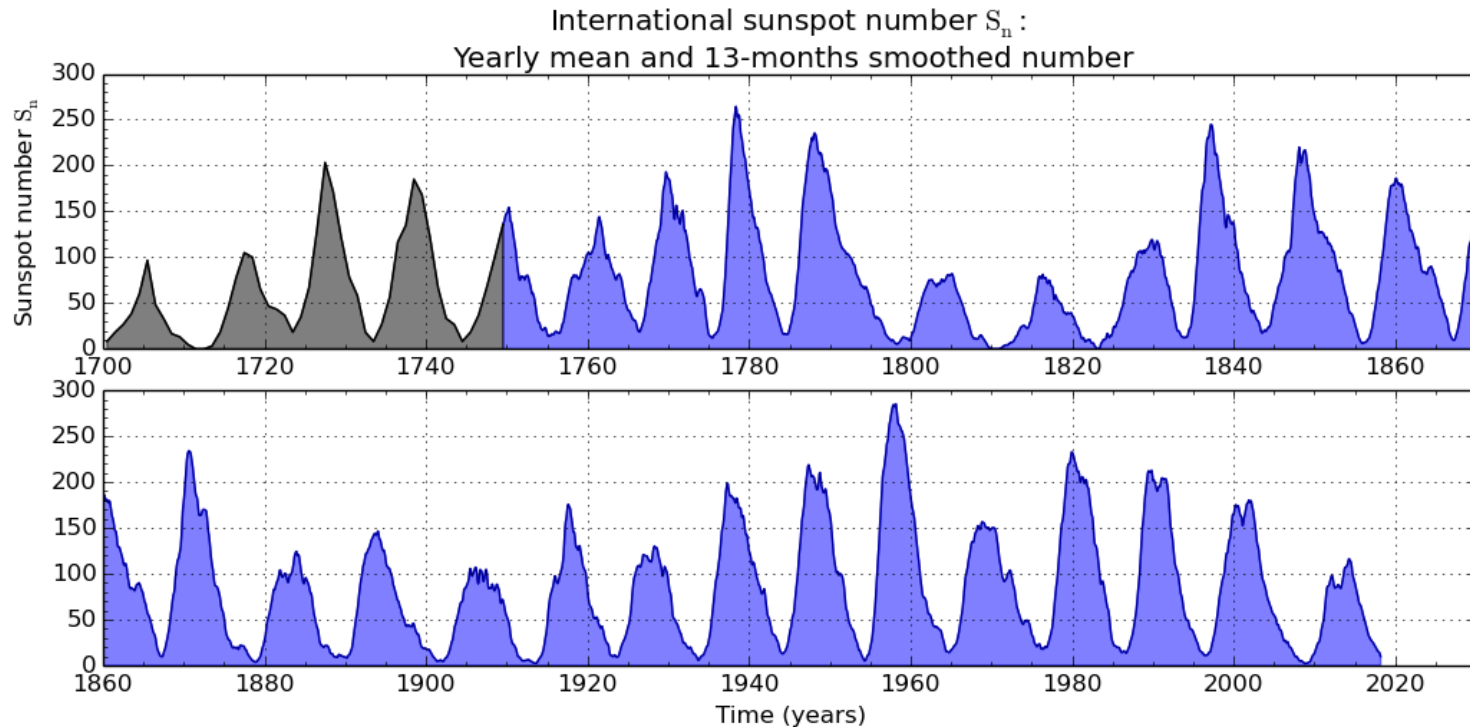
11-year sunspot cycle

**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 1700-2017

What regularities are visible?



SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 October 1

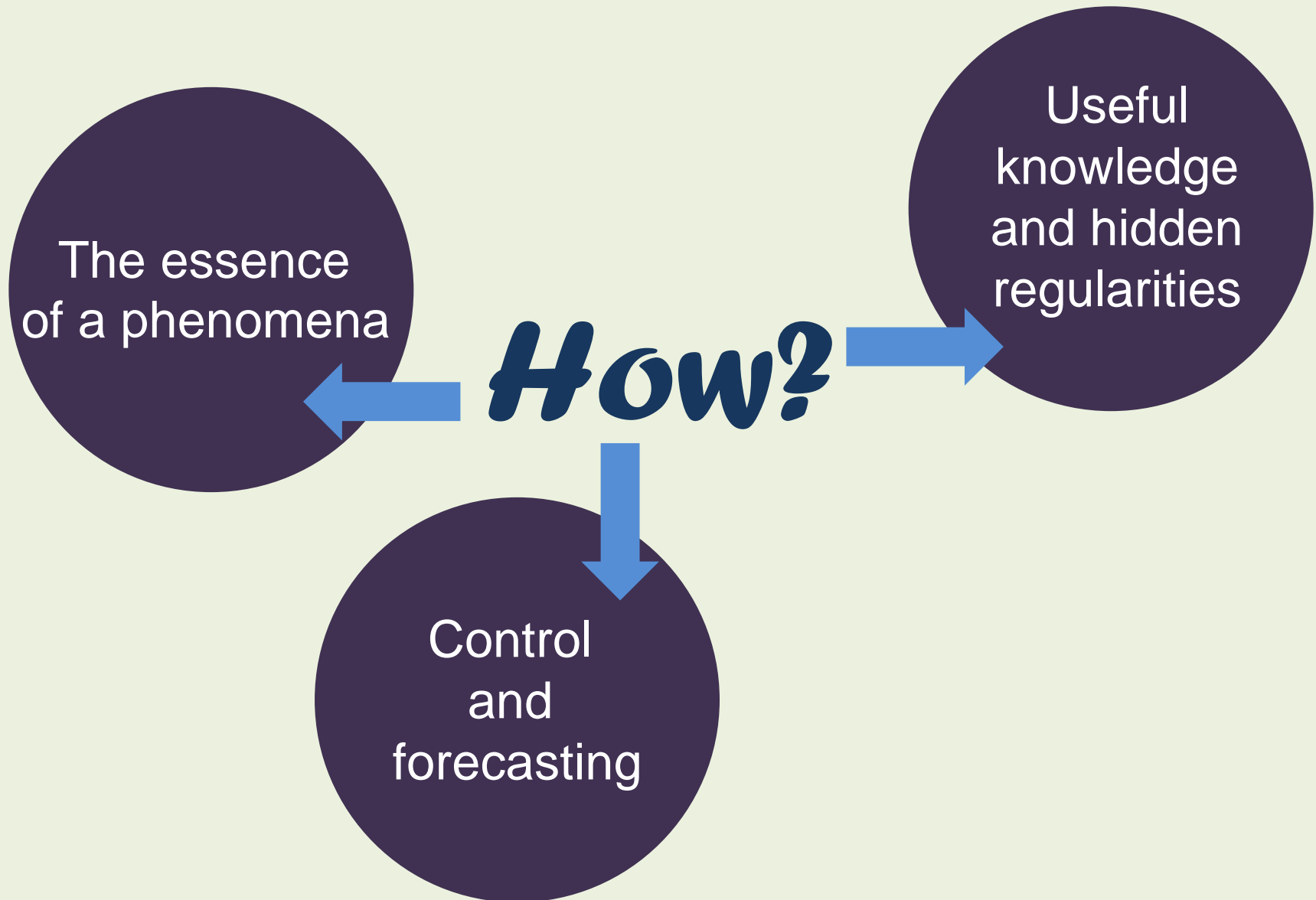
11-year sunspot cycle

**The ascent phase
is shorter than
the decent one**

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

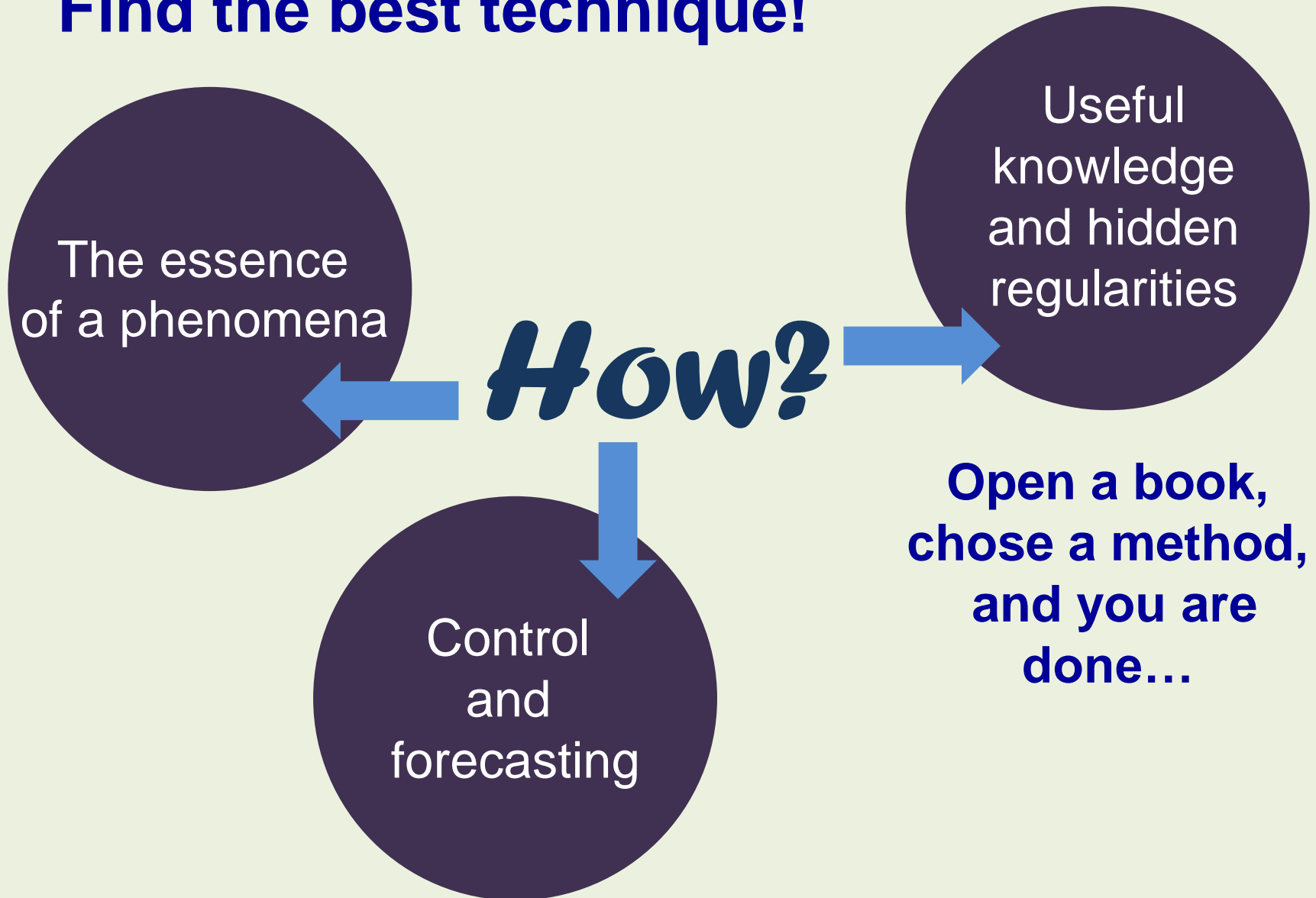
**Any regularities
to forecast the
peak of next
cycle 25?**

What do we need to accomplish these goals?



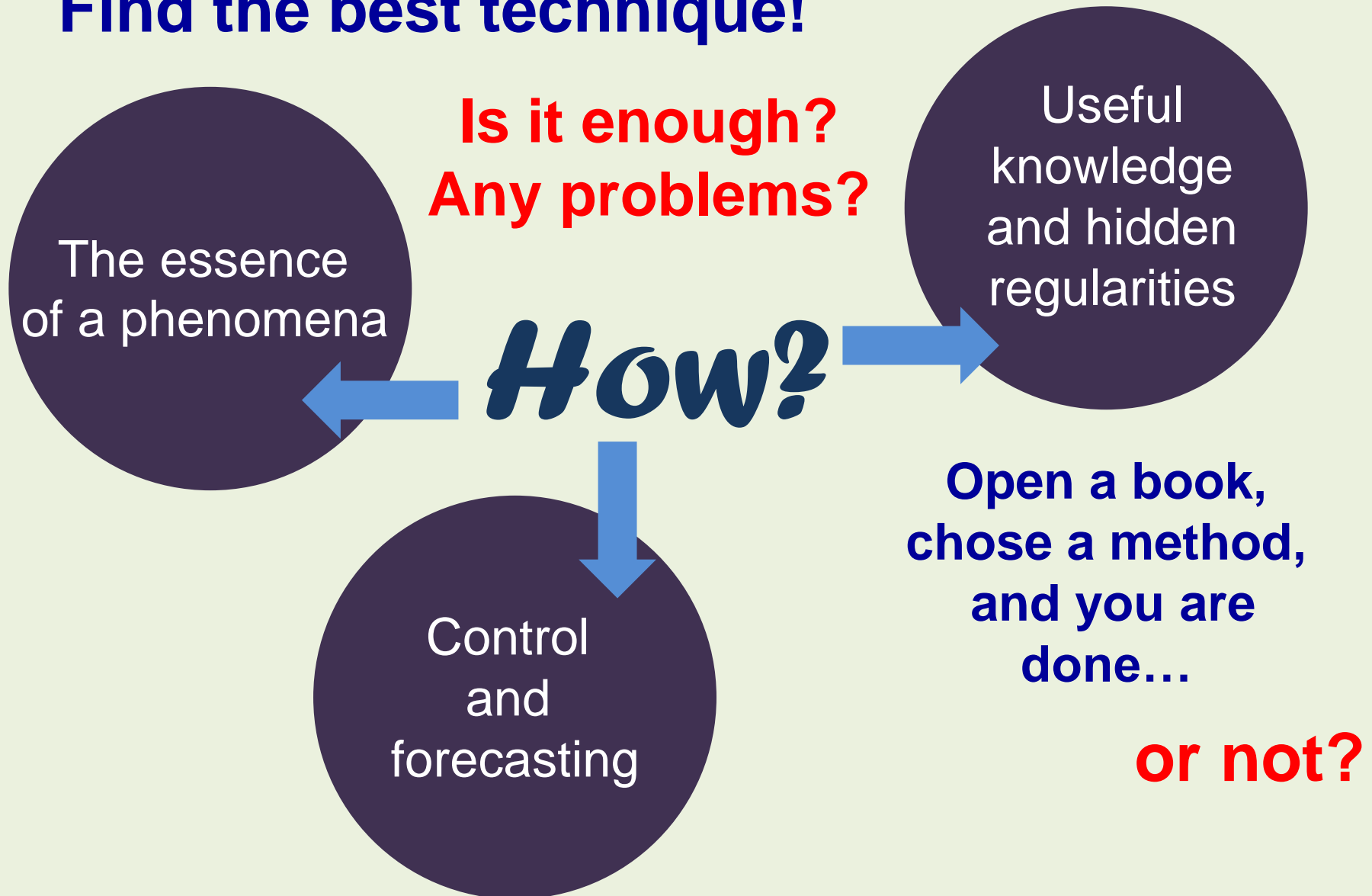
What do we need to accomplish these goals?

Find the best technique!

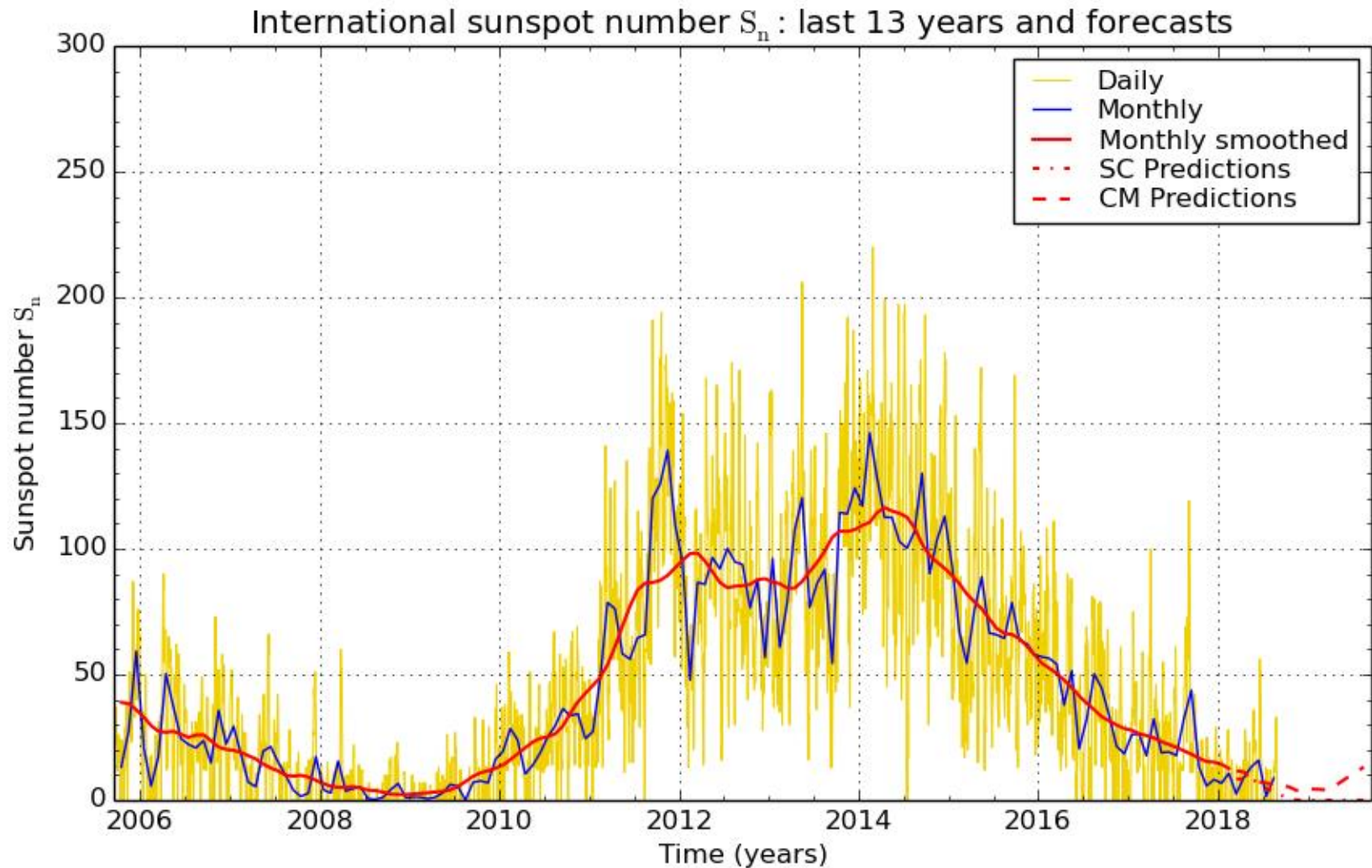


What do we need to accomplish these goals?

Find the best technique!



Trend extraction in conditions of random errors

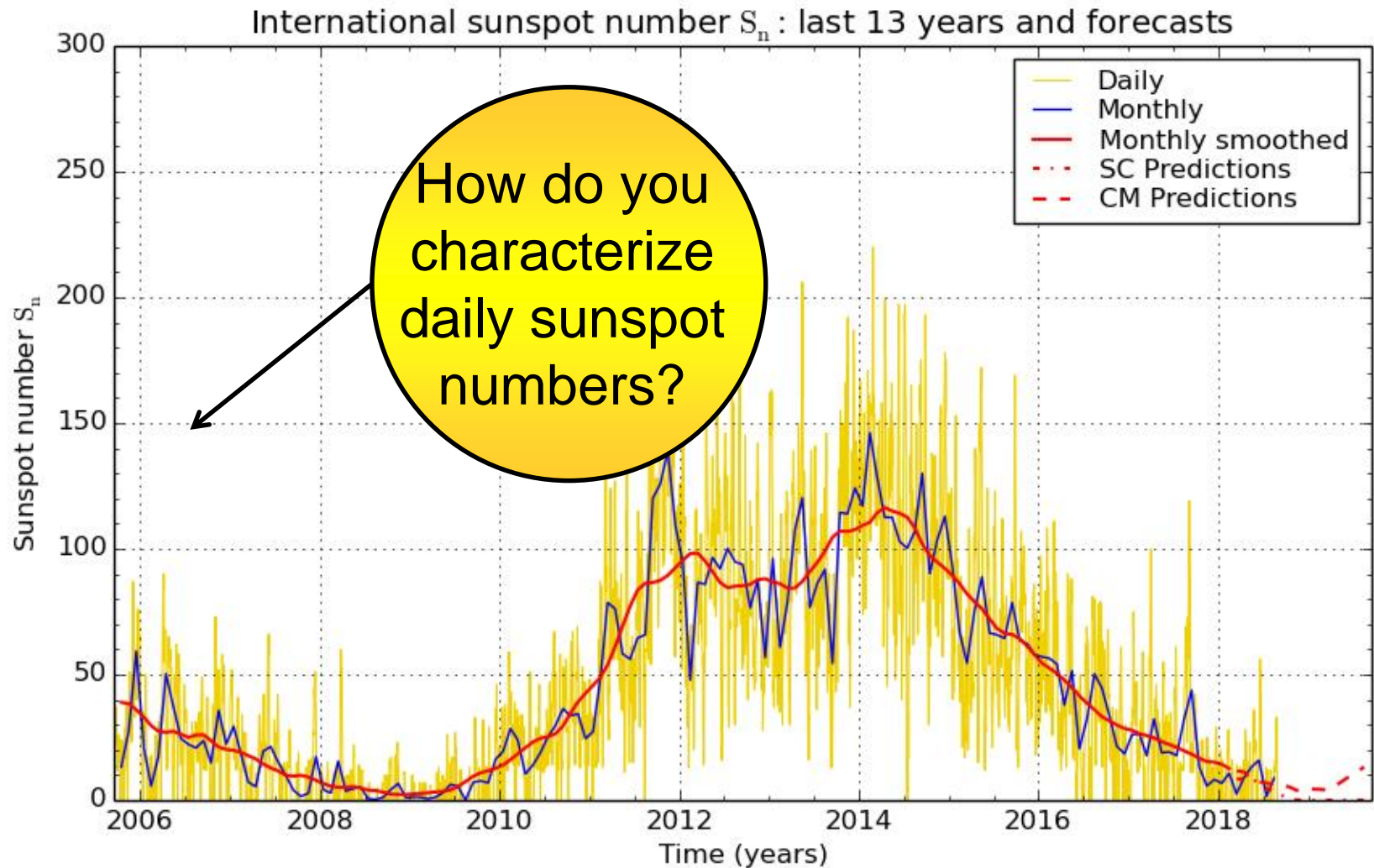


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 September 1

Problem 1: noise



Trend extraction in conditions of random errors

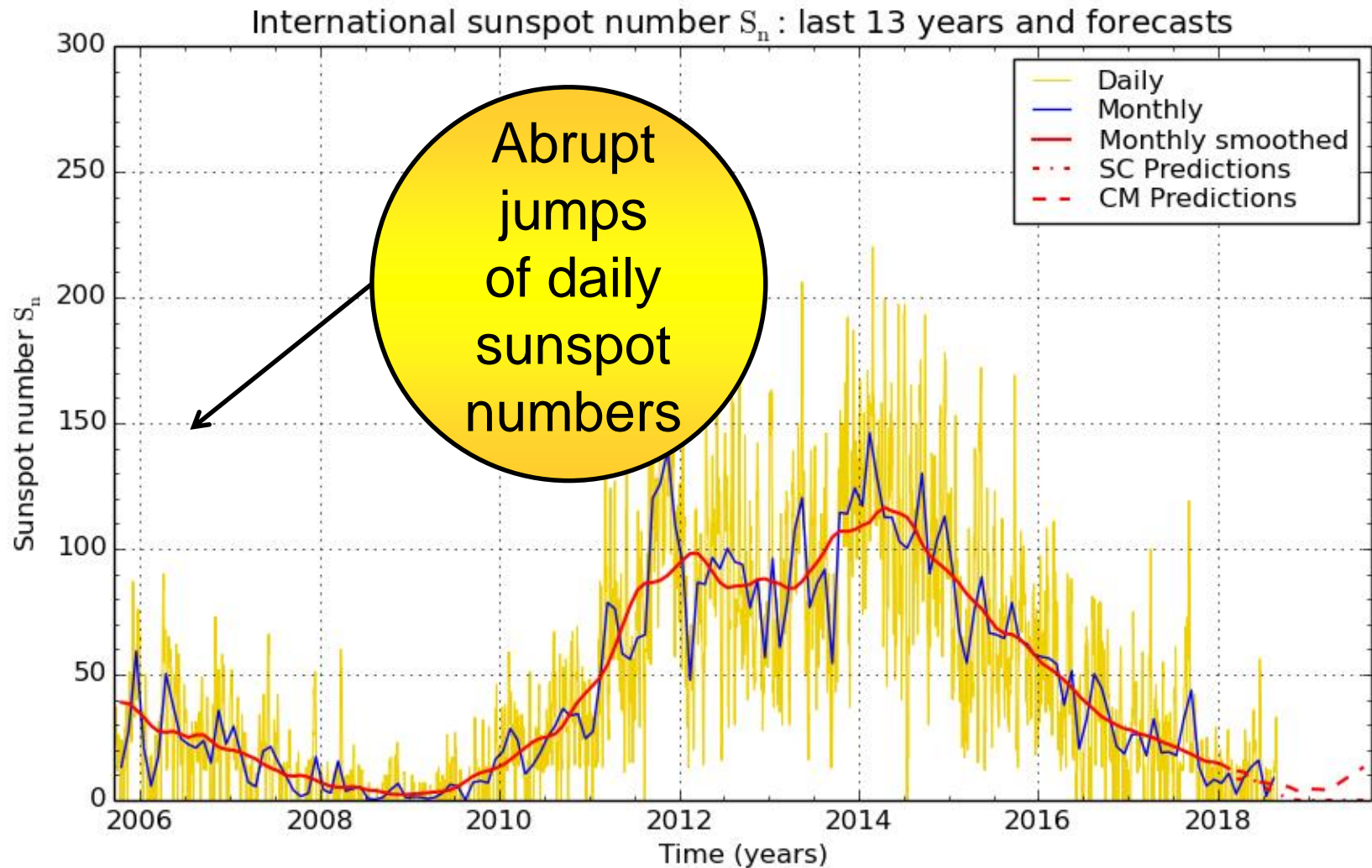


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 September 1

Problem 1: noise



Trend extraction in conditions of random errors

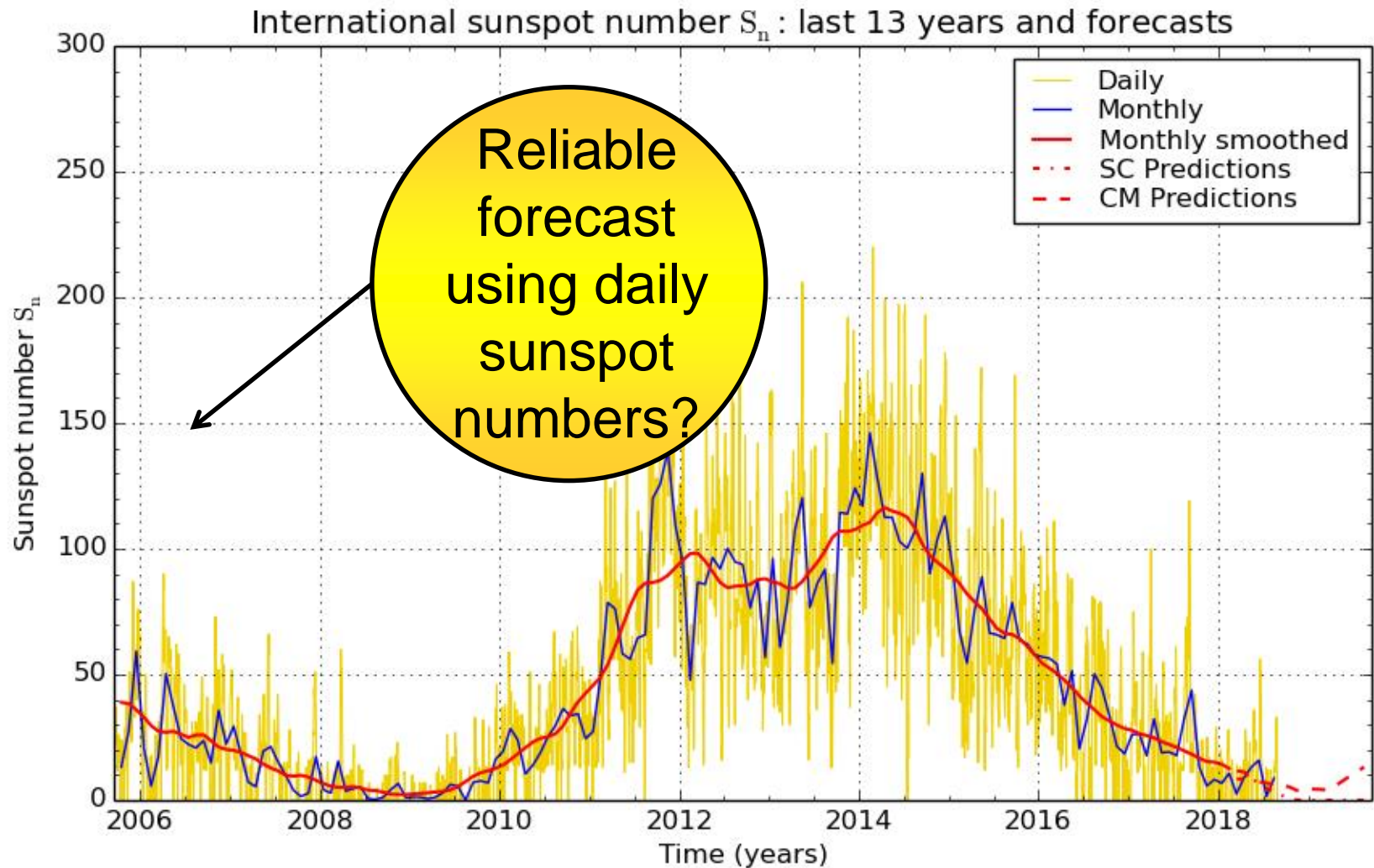


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 September 1

Problem 1: noise



Trend extraction in conditions of random errors

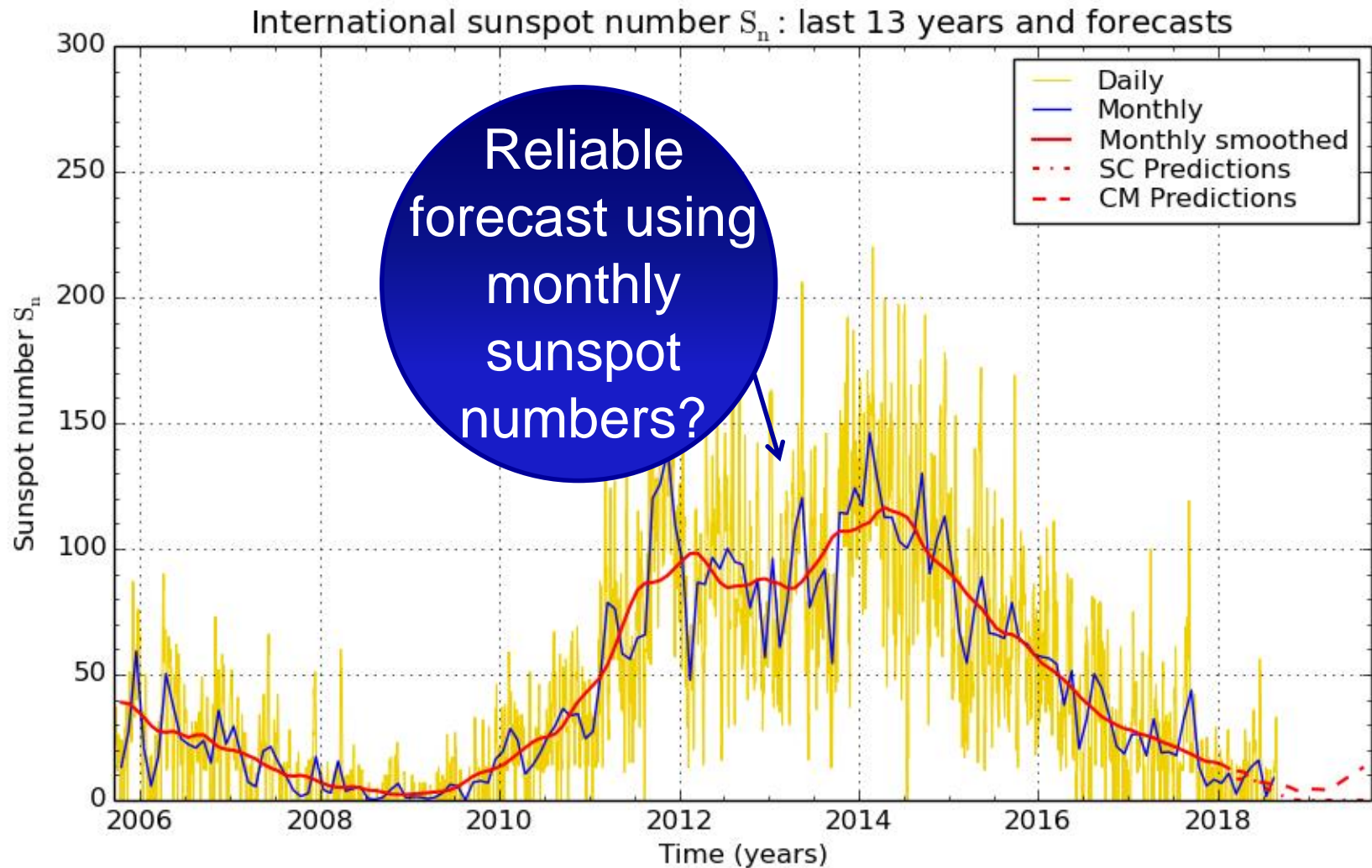


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 September 1

Problem 1: noise



Trend extraction in conditions of random errors

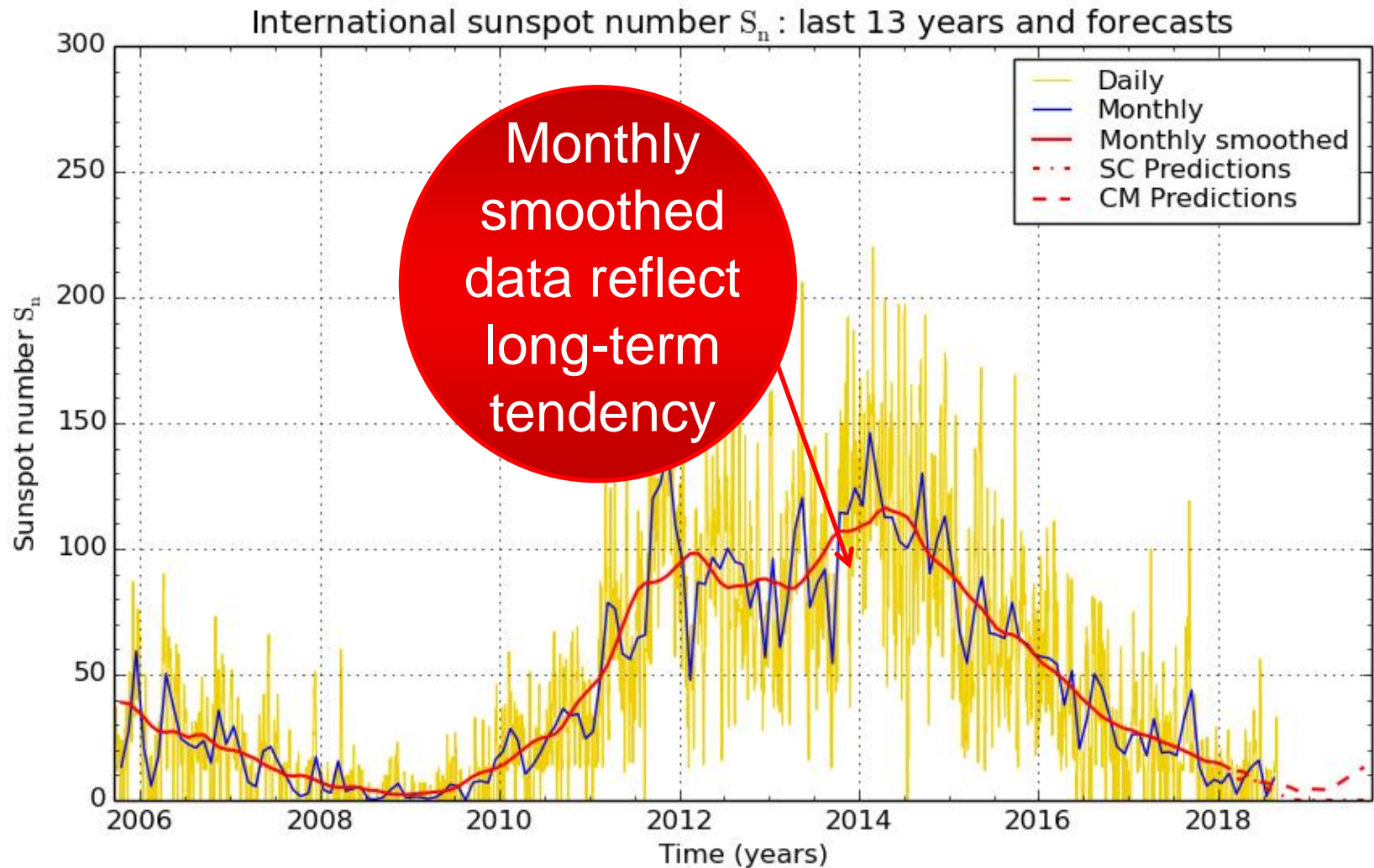


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 September 1

Problem 1: noise



Trend extraction in conditions of random errors

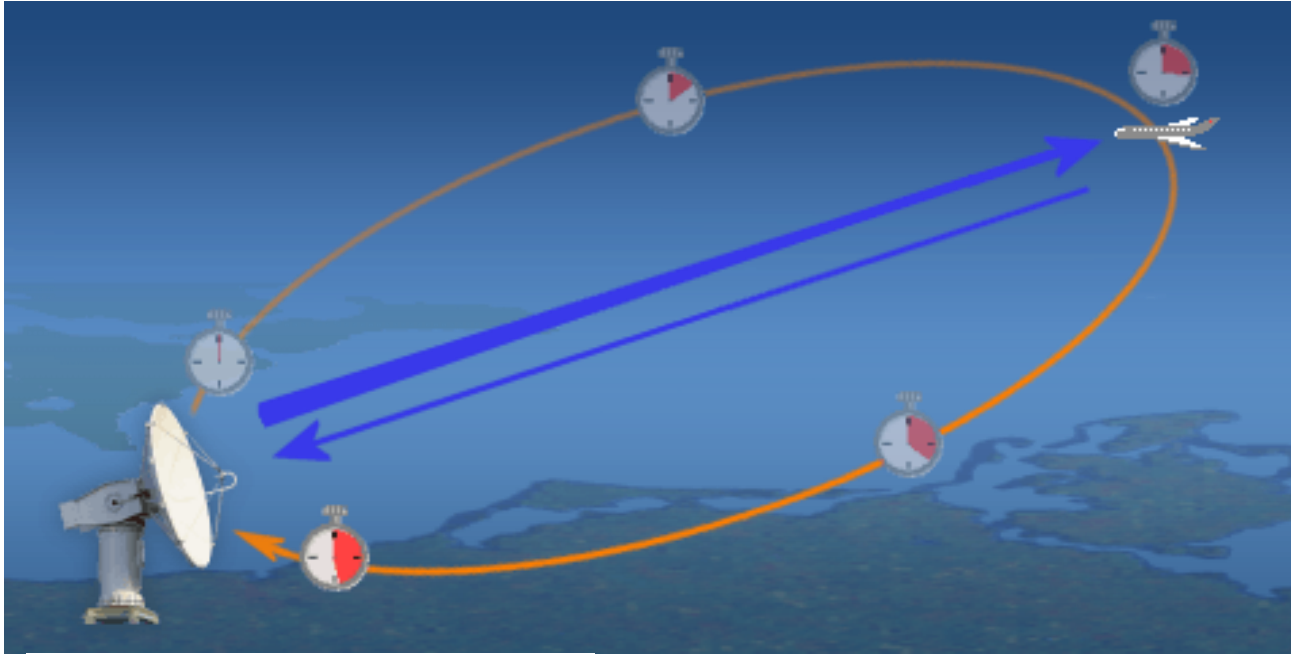


SILSO graphics (<http://sidc.be/silso>) Royal Observatory of Belgium 2018 September 1

Problem 1: noise



Noise reduction for experimental data is needed



Aircraft might disappear from a radar



Doctor might come up with a misdiagnosis



Business default

Problem 1: noise

How to be sure in the reliability of result?

1

**Validity
of applying
a technique**

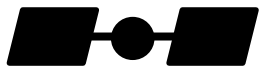
Problem 2: reliability



How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



Man-made satellite

Case 1: **valid**

*How to determine
the satellite position?*

Problem 2: reliability



How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



1



Man-made satellite



Navigation satellite

Case 1: valid

**Navigation satellite 1 measures
the distance to man-made satellite**

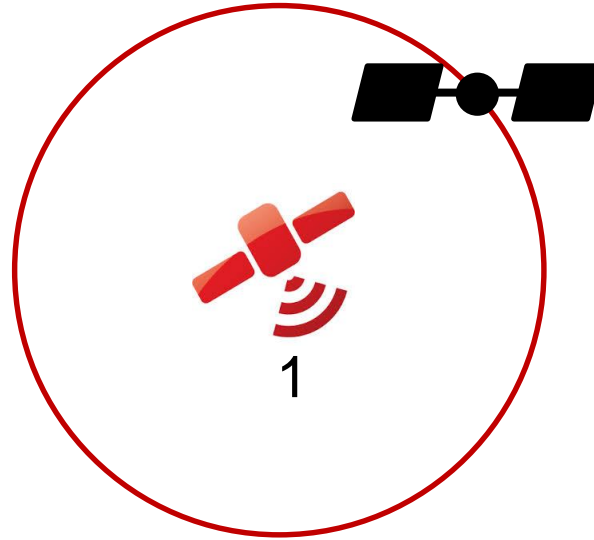
Problem 2: reliability



How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



Man-made satellite



Navigation satellite

Case 1: valid

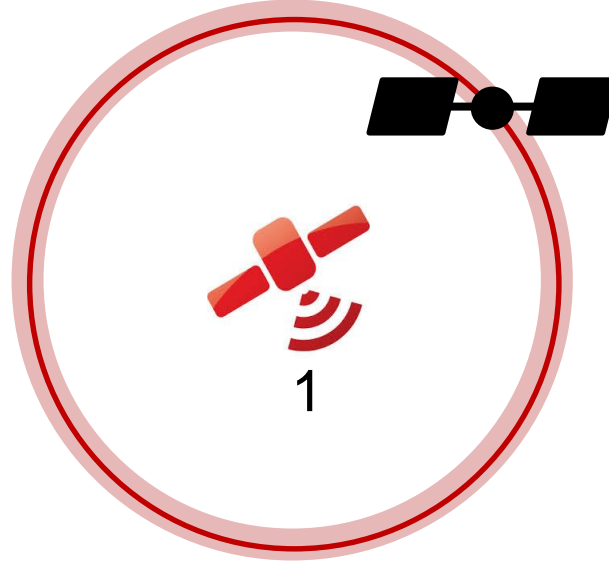
**Man-made satellite
is somewhere on a circle**

Problem 2: reliability

How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



Man-made satellite



Navigation satellite

Case 1: valid

**Measurements of distance to
man made satellite have errors**

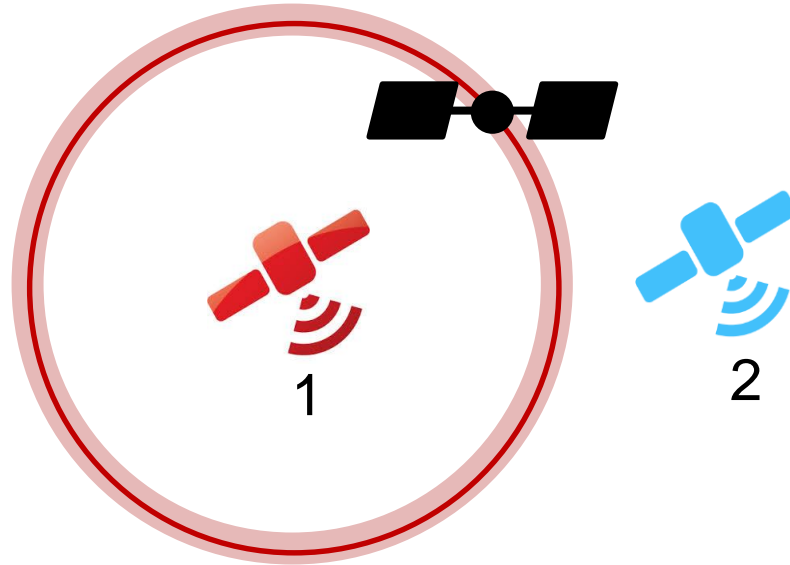
Problem 2: reliability



How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



Man-made satellite



Navigation satellite

Case 1: valid

**Navigation satellite 2 also measures
the distance to man-made satellite**

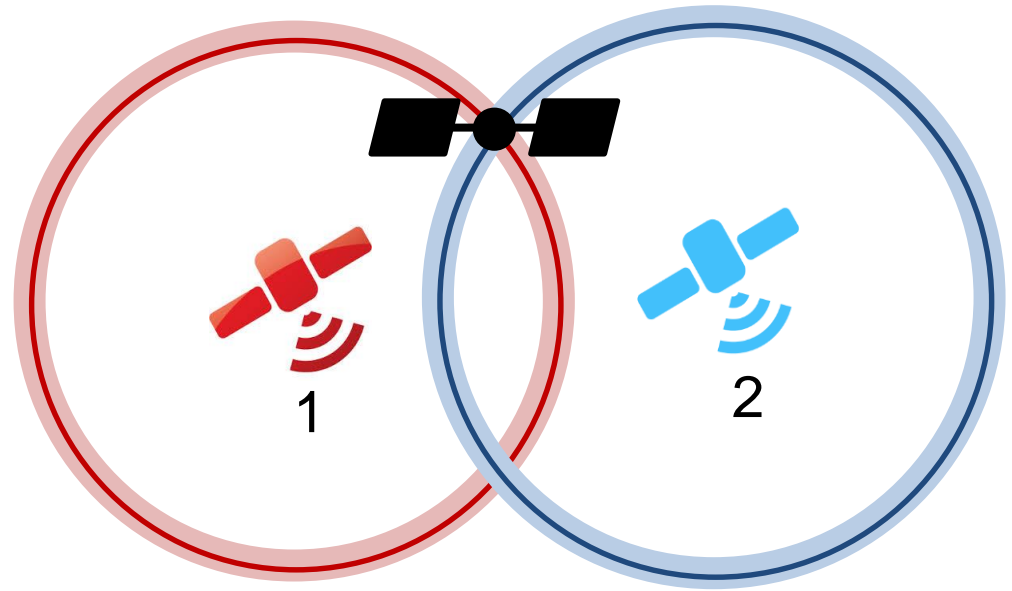
Problem 2: reliability



How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



Man-made satellite



Navigation satellite

Case 1: valid

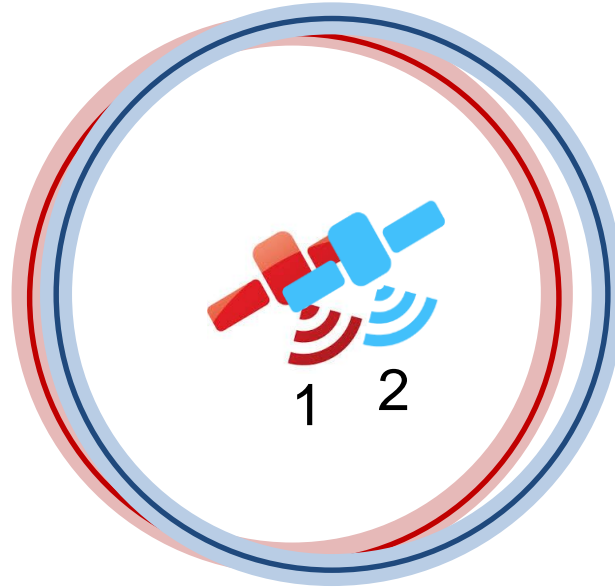
**The position of a satellite is
at the intersecting points of circles**

Problem 2: reliability

How to be sure in the reliability of result?

1

**Validity
of applying
a technique**



-?



Man-made satellite



Navigation satellite

**Case 2: Not valid:
II-conditioned problem**

Satellite position is undefined!

Problem 2: reliability



How to be sure in the reliability of result?

2

**Methods
of accuracy
estimation**

Problem 2: reliability

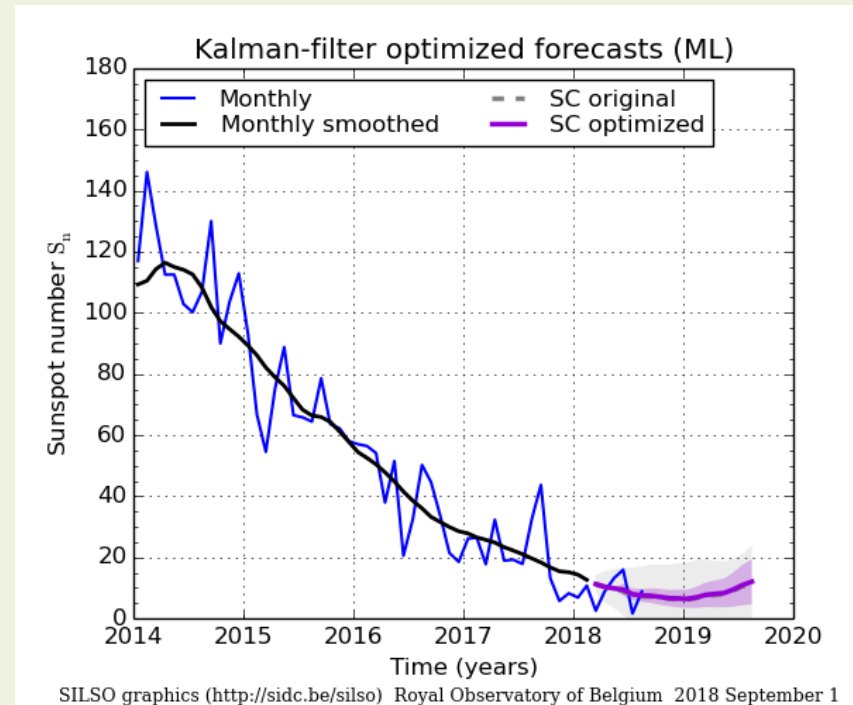


How to be sure in the reliability of result?

2

Methods of accuracy estimation

Problem 2: reliability



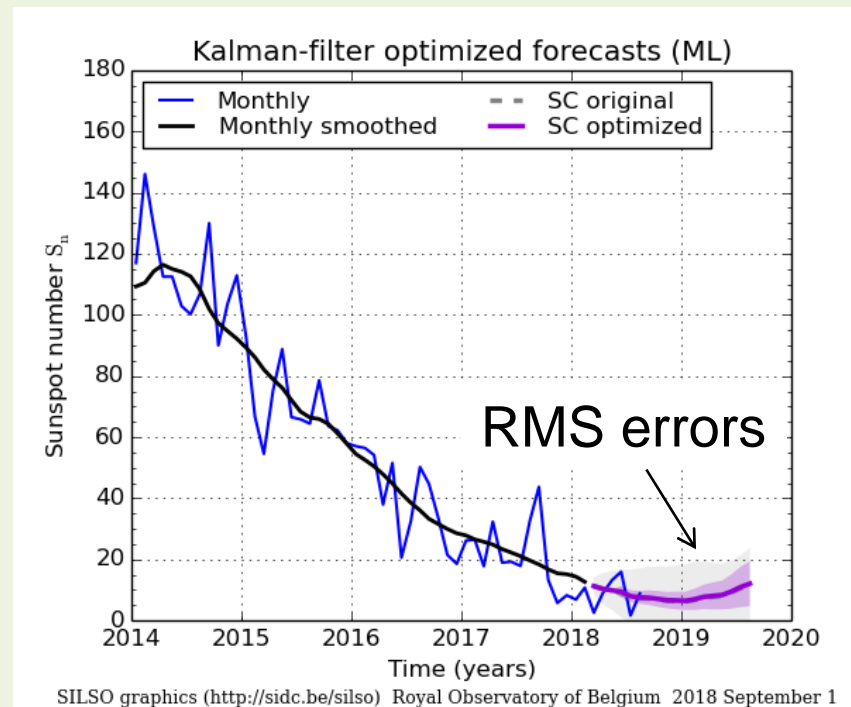
How to be sure in the reliability of result?

2

Methods of accuracy estimation

Optimal methods
usually provide
the accuracy
of estimation

Problem 2: reliability



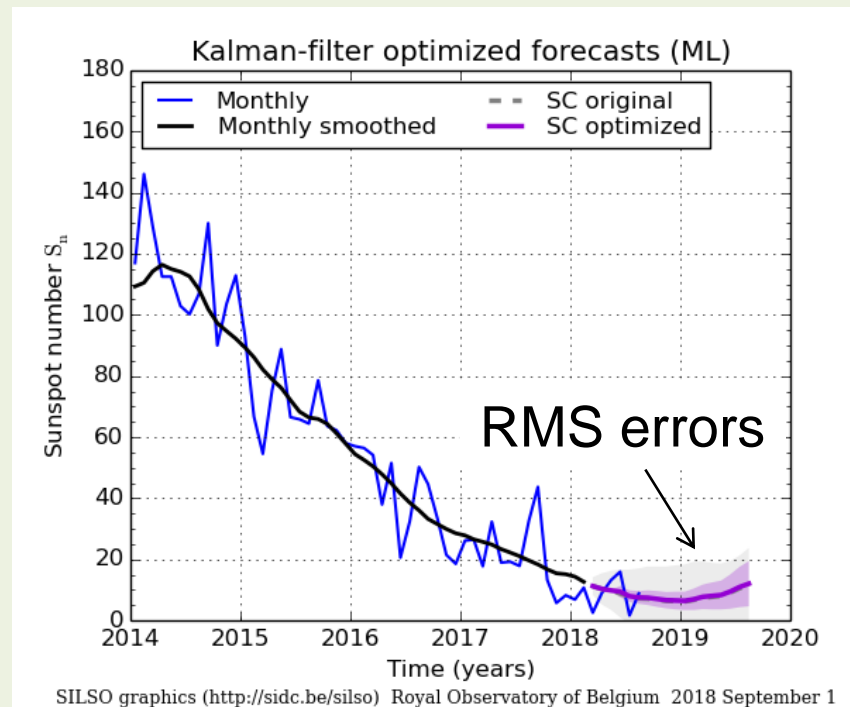
How to be sure in the reliability of result?

2

Methods of accuracy estimation

Optimal methods
usually provide
the accuracy
of estimation

Alternative ways to
estimate the accuracy
are needed due to great
uncertainty and non-
optimal estimation



Problem 2: reliability



How to be sure in the reliability of result?

3

**Practical
confirmation**

Problem 2: reliability



How to be sure in the reliability of result?

3

**Practical
confirmation**



- ✓ High costs
- ✓ Sometimes impossible



Parker Solar Probe Launch, 12 August 2018
A mission to touch the Sun!

“Practice is the criterion of truth”

Problem 2: reliability



**Simple non-optimal methods
can solve difficult problems**

```
graph TD; A[Simple non-optimal methods can solve difficult problems] --> B[Simple non-optimal methods are often used in conditions of high uncertainty]; A --> C[Simple methods are easy to apply]; B --- C; D[Simplicity of use without proper analysis may be a trap leading to false conclusions]
```

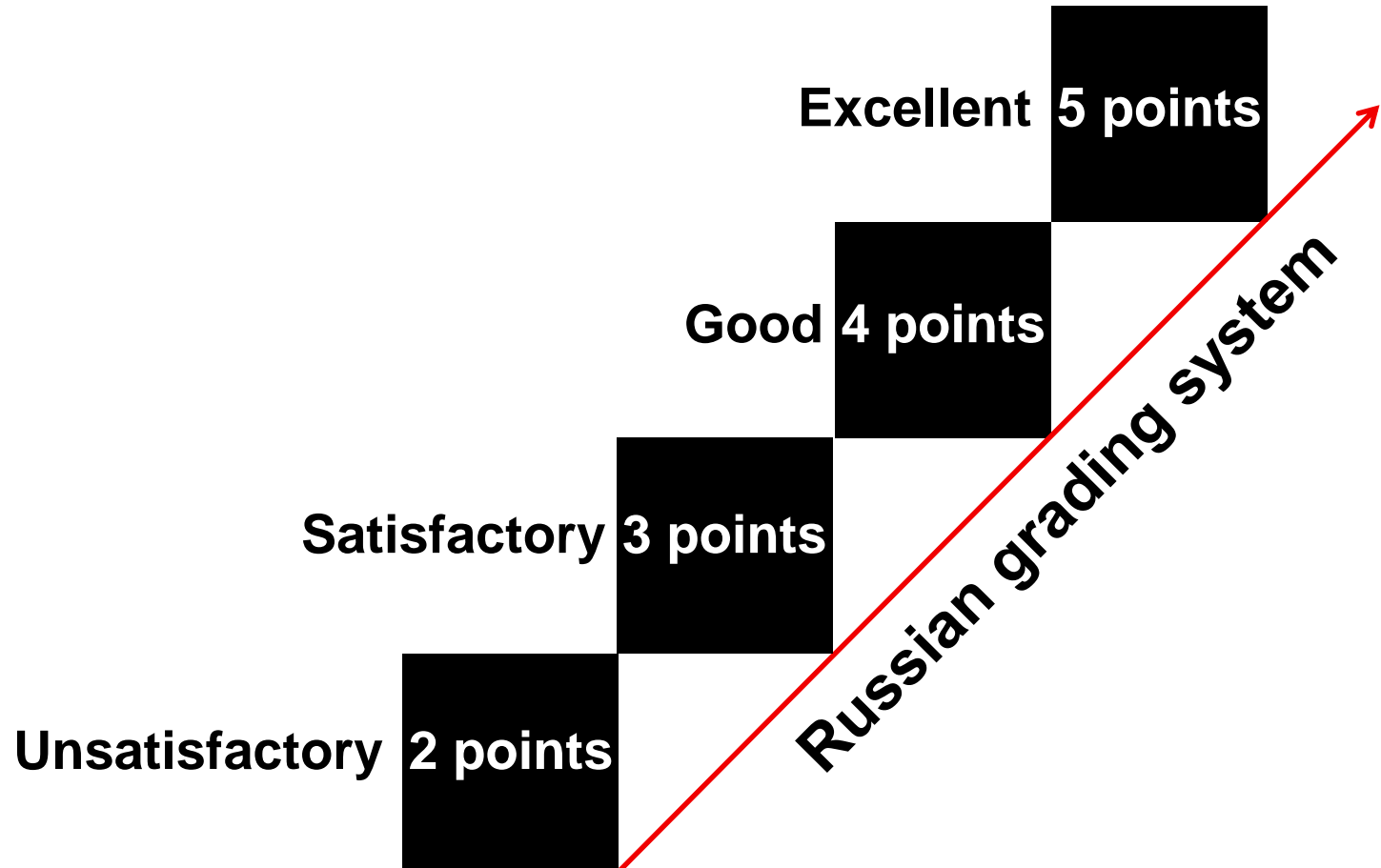
**Simple non-optimal
methods are often
used in conditions
of high uncertainty**

**Simple methods
are easy to apply**

**Simplicity of use without proper
analysis may be a trap leading
to false conclusions**

Problem 3: no proper analysis

Simple method to solve difficult problem



Problem 3: no proper analysis



Simple method to solve difficult problem

Problem

Estimate "Excellent" knowledge using "Satisfactory" and "Unsatisfactory" knowledge

Unsatisfactory 2 points

Satisfactory 3 points

Good 4 points

Excellent 5 points

Russian grading system

Problem 3: no proper analysis

Simple method to solve difficult problem

Solution

$$5=2+3$$

Excellent = Unsatisfactory + Satisfactory

False conclusion

Unsatisfactory 2 points

Satisfactory 3 points

Good 4 points

Excellent 5 points

Russian grading system

Problem 3: no proper analysis

Simple method to solve difficult problem

Solution

$$5=2+3$$

Excellent = Unsatisfactory + Satisfactory

False conclusion

Any method
must be followed
by analysis
of estimation error,
even if it is simple

Unsatisfactory 2 points

Satisfactory 3 points

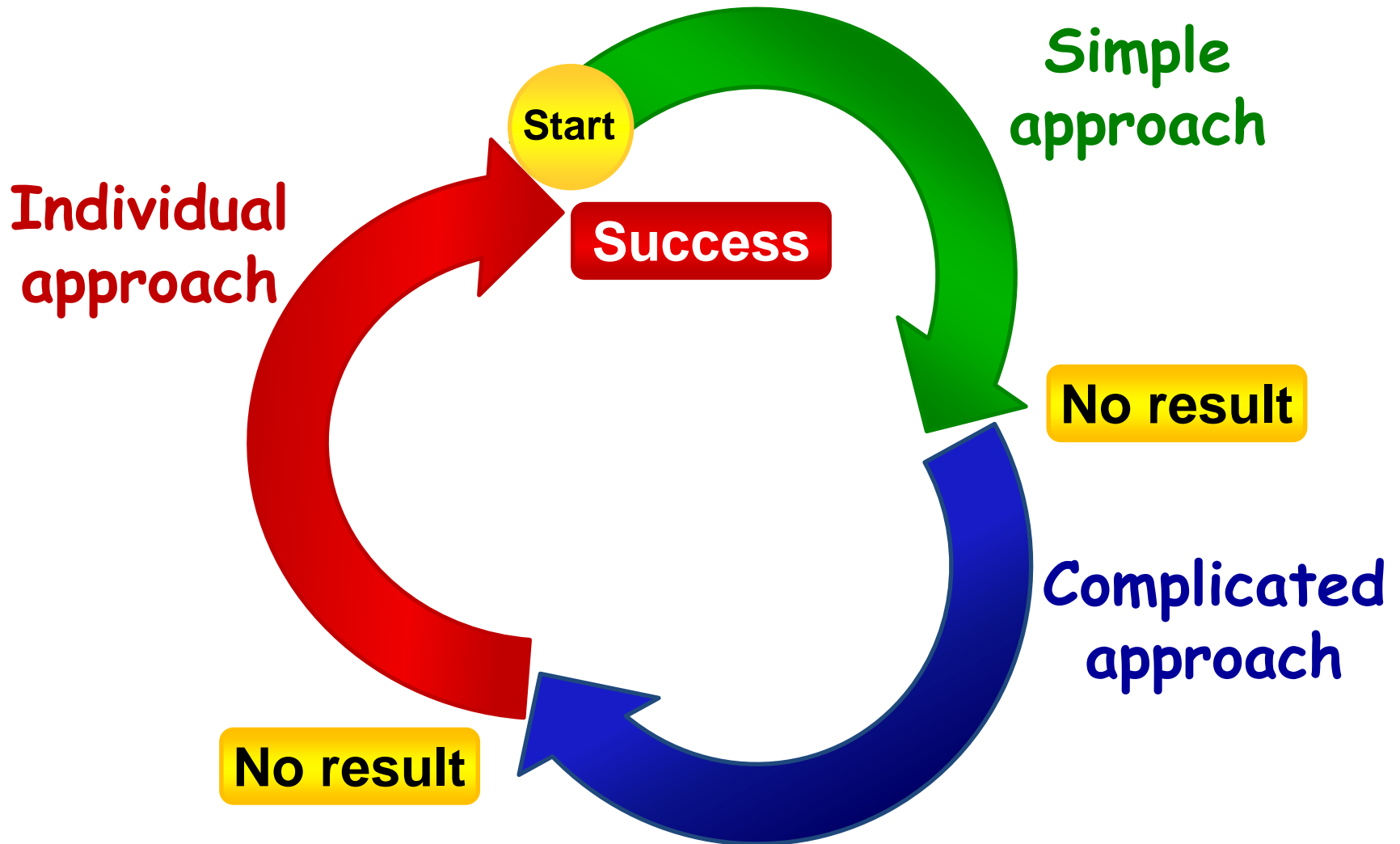
Good 4 points

Excellent 5 points

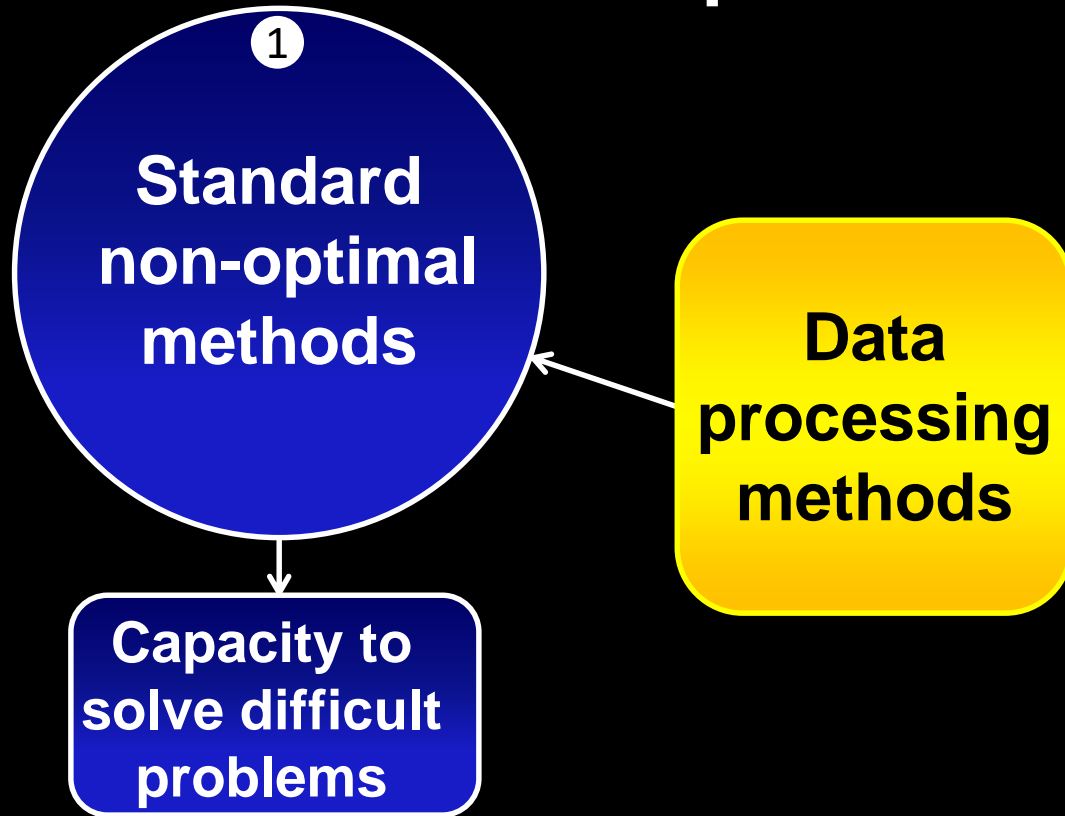
Russian grading system

Problem 3: no proper analysis

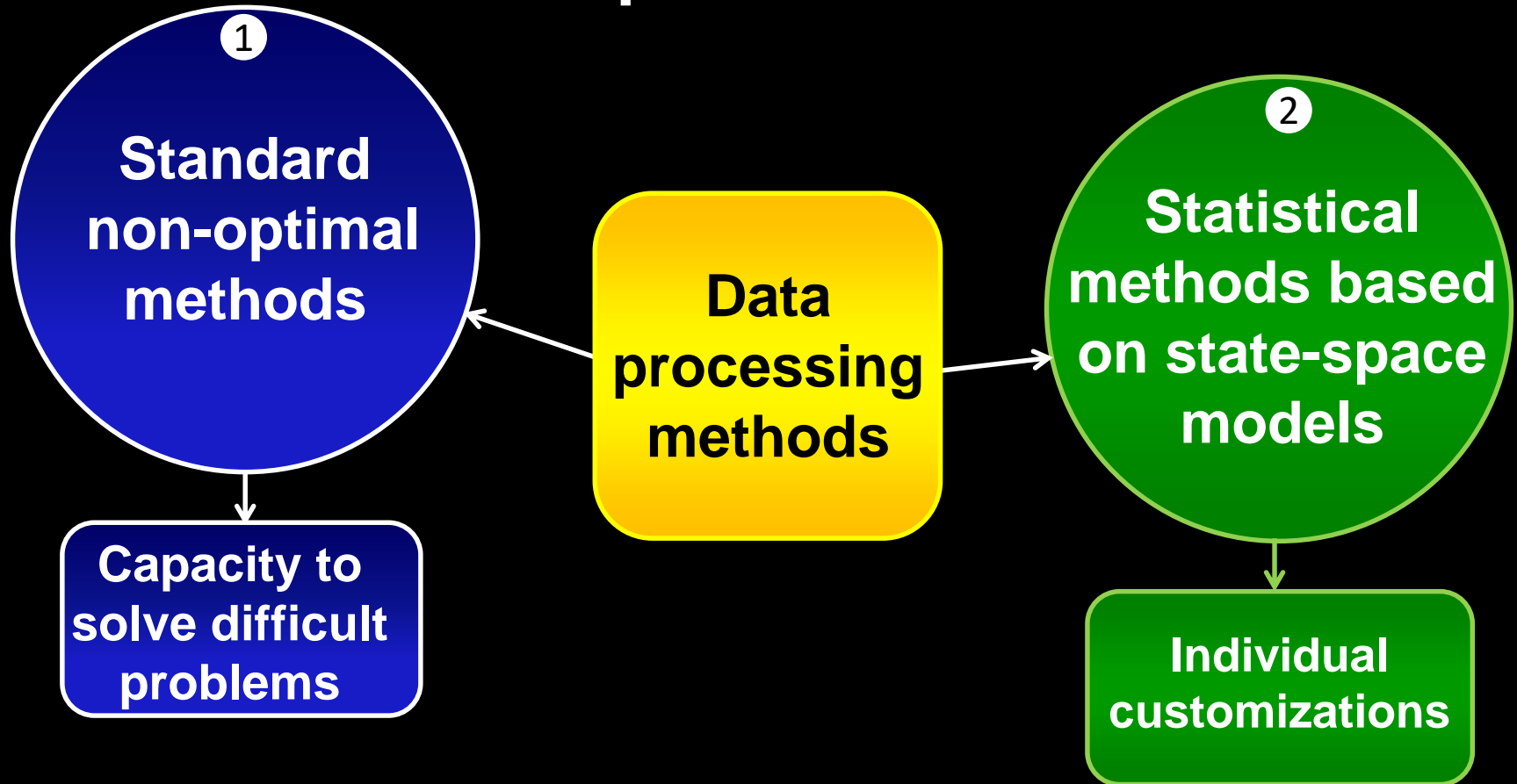
“Experimental data processing course” is dedicated to the solution of problems mentioned above



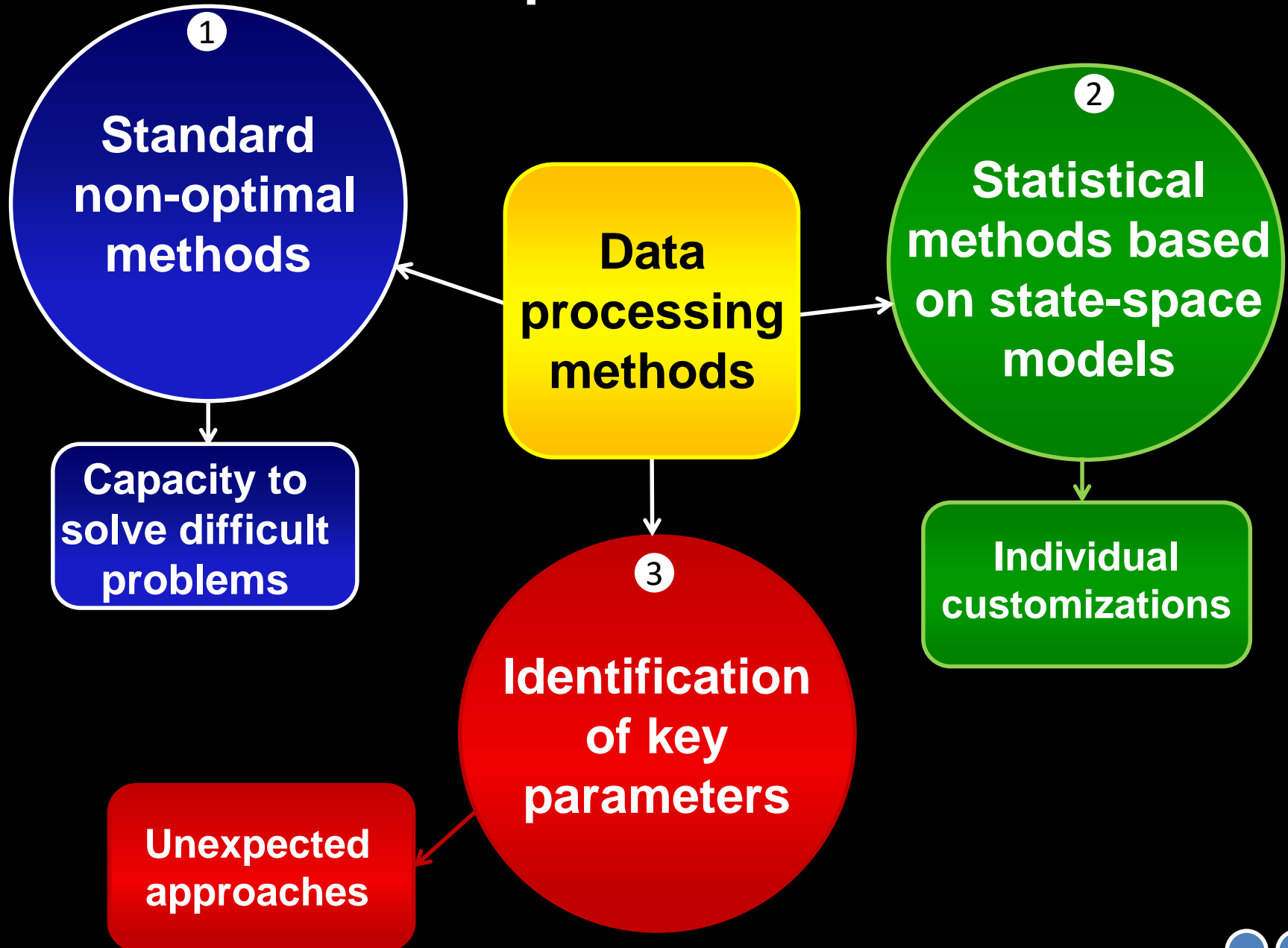
Main topics of the course



Main topics of the course



Main topics of the course



Applications

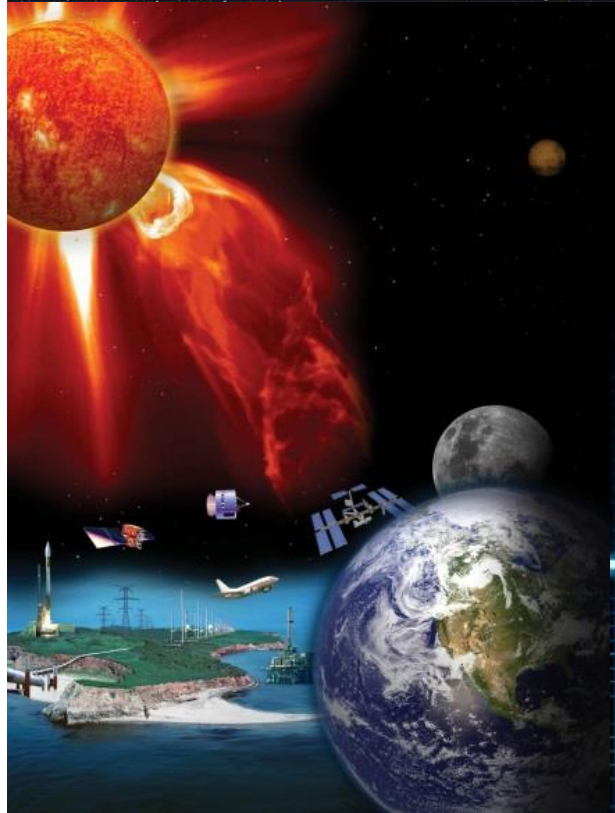
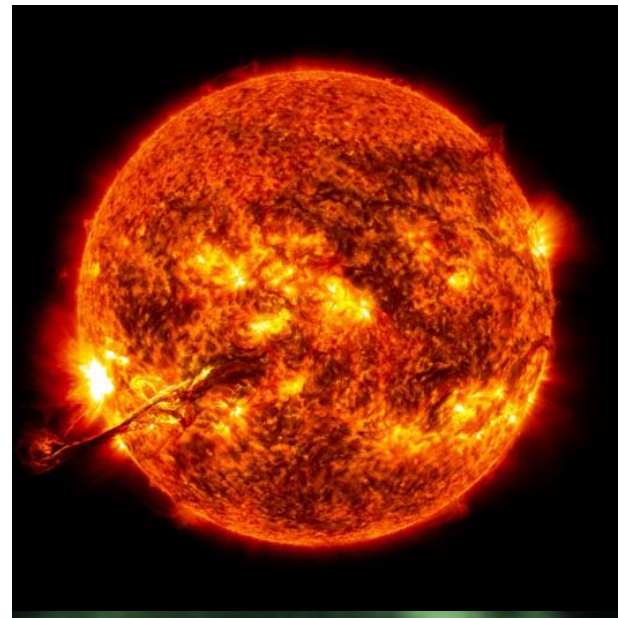
Navigation

Solar physics

Geomagnetism

Space weather

Biomedicine



A Venn diagram illustrating the components of learning. It consists of four overlapping shapes: a yellow oval at the top labeled 'Learning outcomes', a green rounded rectangle on the left labeled 'Knowledge', a blue circle at the bottom labeled 'Skills', and a red rounded rectangle on the right labeled 'Experience'. The 'Learning outcomes' oval overlaps with all three other shapes. 'Knowledge' and 'Skills' overlap each other, as do 'Skills' and 'Experience'. 'Knowledge' and 'Experience' do not overlap.

Learning outcomes

Knowledge

Skills

Experience

Learning outcomes

Knowledge

Skills

Experience



- ① The state-of-the-art methods and their productivity



Learning outcomes

Knowledge

Skills

Experience



① The state-of-the-art methods and their productivity

② Main problems for space applications



Learning outcomes

Knowledge

Skills

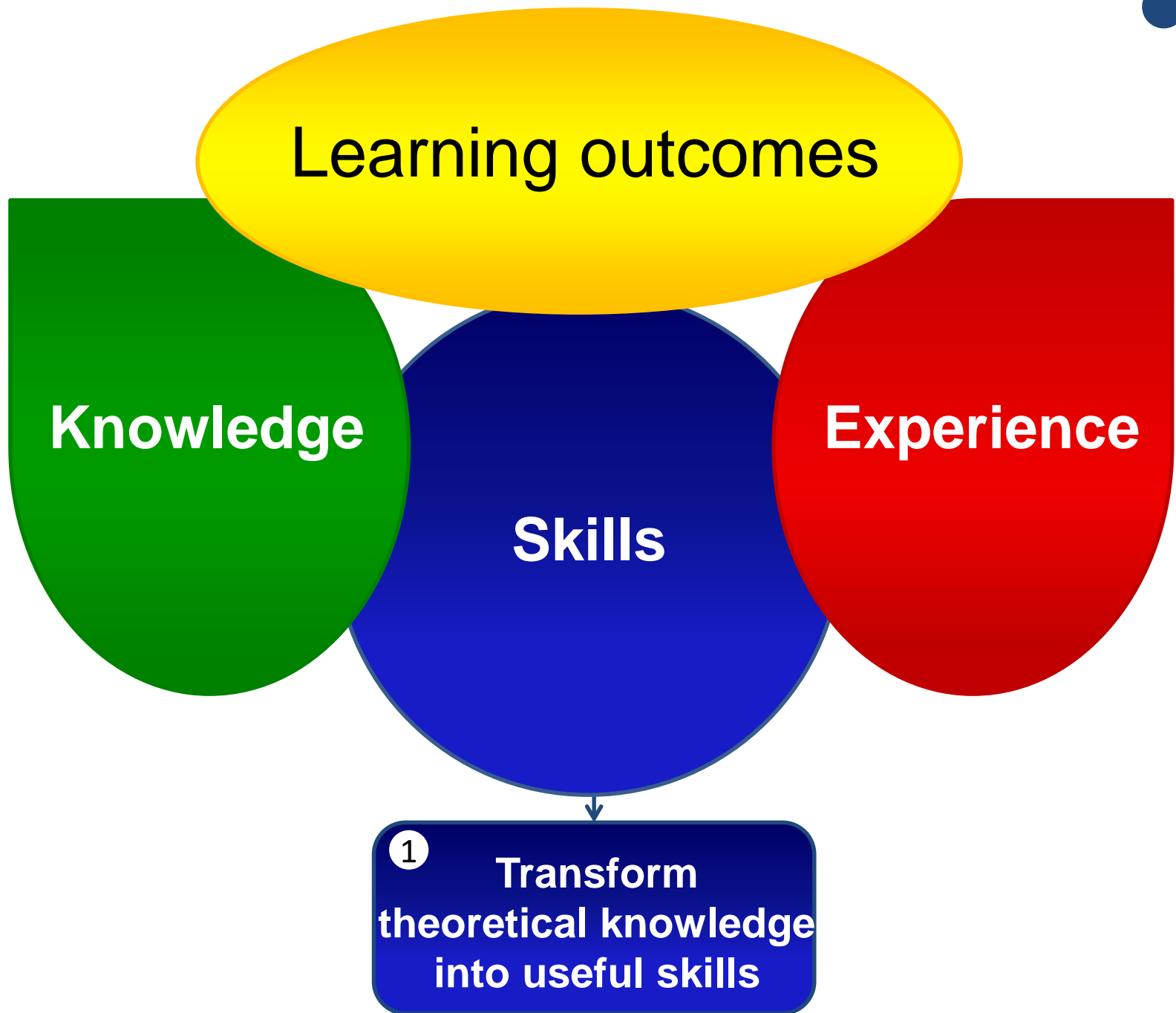
Experience



① The state-of-the-art methods and their productivity

② Main problems for space applications

③ Estimation of accuracy and reliability



Learning outcomes

Knowledge

Skills

Experience

2

**Identify
specific features
of experimental data**

1

**Transform
theoretical knowledge
into useful skills**



Learning outcomes

Knowledge

Skills

Experience

2

**Identify
specific features
of experimental data**

1

**Transform
theoretical knowledge
into useful skills**

3

**Detect and
analyze shortcomings
of methods**



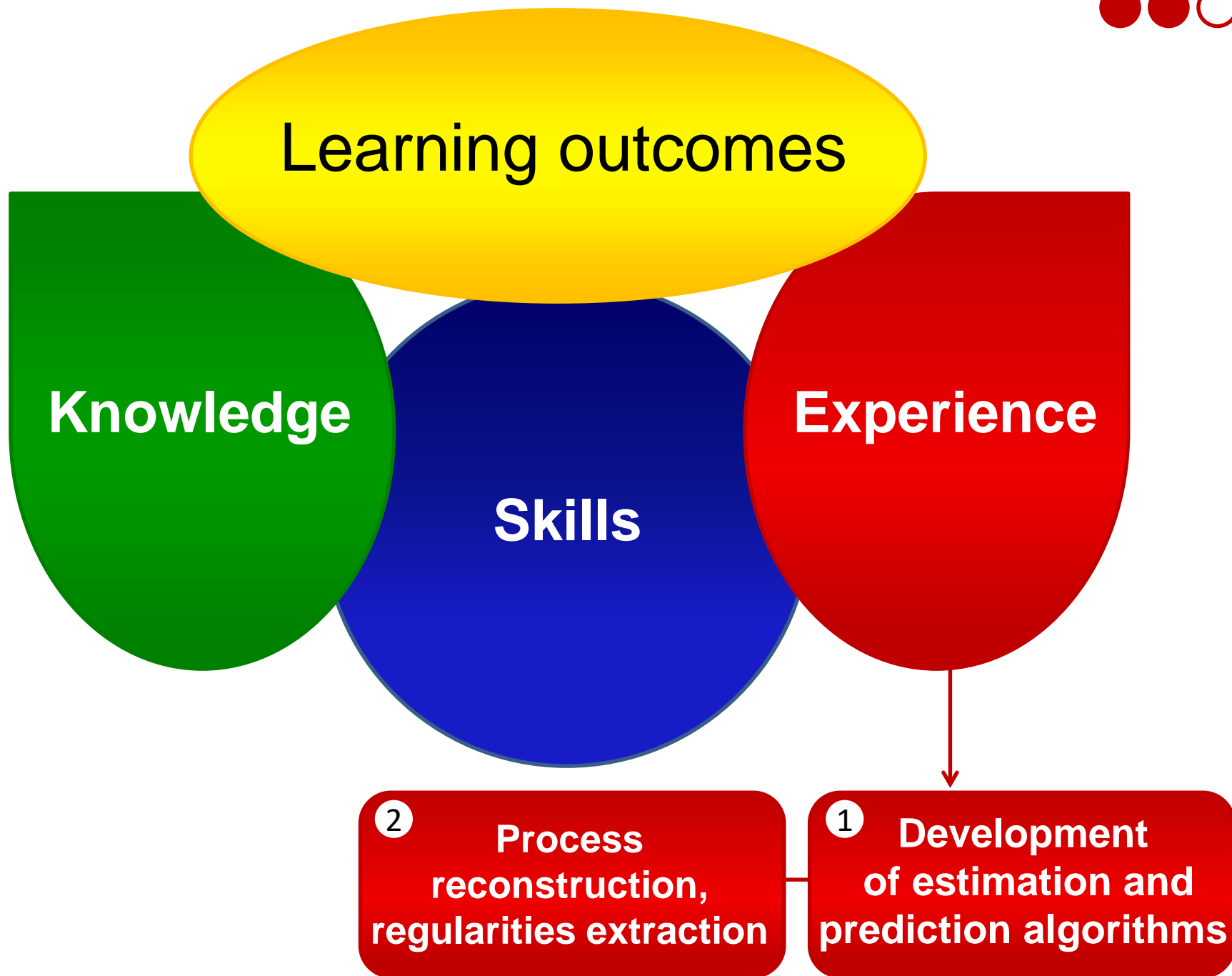
Learning outcomes

Knowledge

Skills

Experience

**1 Development
of estimation and
prediction algorithms**





Learning outcomes

Knowledge

Skills

Experience



3

**Estimation
accuracy, prevention
of false conclusions**

2

**Process
reconstruction,
regularities extraction**

1

**Development
of estimation and
prediction algorithms**

Assignments and laboratory works

Laboratory works in class
Assignments
Final project
Exam

What do you need for laboratory works?

Laptop
Matlab, Python
Inspiration