# Introduction

## Tirana, Albania, 2 to 4 June 2010

**Stephan Mieke**

# Introduction

- Measurement is present in almost every human activity, e.g. industrial, commercial, scientific, healthcare, safety and environmental.
- Measurement uncertainty is associated with any measurement.
- Measurement uncertainty plays a central role in quality assessment and quality standards.
- In conformity assessment the probability of making an incorrect decision based on the measurement and managing the consequential risks can be determined.
- As the tolerances applied in industrial production become more demanding, the role of measurement uncertainty becomes more important when assessing conformity to these tolerances.

# Introduction

- No measurement is exact. When a quantity is measured, the outcome depends on the measuring system, the measurement procedure, the skill of the operator, the environment, and other effects.
- Even if the quantity were to be measured several times, a different indication value would in general be obtained each time.
- The dispersion of the indication values would relate to how well the measurement is made. Their average would provide an estimate of the true quantity value that generally would be more reliable than an individual indication value.
- It is not possible to state how well the true value of the measurand is known, but only how well it is believed to be known. Measurement uncertainty can be described as a measure of how well one believes one knows the true value of the measurand. This uncertainty reflects the incomplete knowledge of the measurand.

# Introduction

## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Introduction

## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

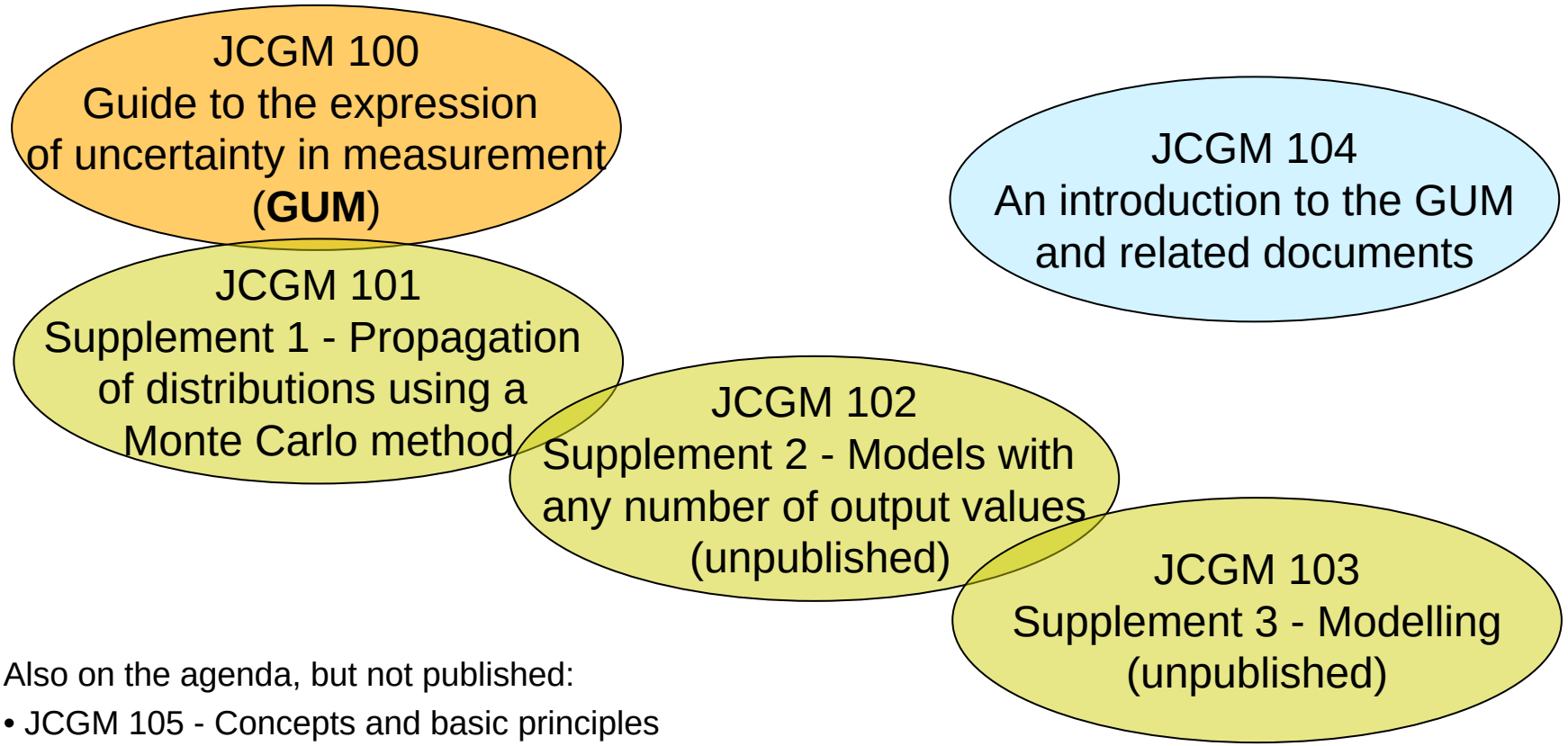
# **Introduction** - JCGM documents and other literature

Joint Committee for Guides in Metrology (JCGM):

- International Bureau of Weights and Measures (BIPM)
- International Electrotechnical Commission (IEC)
- International Federation of Clinical Chemistry and Laboratory Medicine (IFCC)
- International Laboratory Accreditation Cooperation (ILAC)
- International Organization for Standardization (ISO)
- International Union of Pure and Applied Chemistry (IUPAC)
- International Union of Pure and Applied Physics (IUPAP)
- International Organization of Legal Metrology (OIML)

# **Introduction** - JCGM documents and other literature

## Evaluation of measurement data




Also on the agenda, but not published:

- JCGM 105 - Concepts and basic principles
- JCGM 106 - The role of measurement uncertainty in conformity assessment
- JCGM 107 - Applications of the least-squares method

Download from: http://www.bipm.org/en/publications/guides/gum.html

# **Introduction** - JCGM documents and other literature

JCGM 100
Guide to the expression of uncertainty in measurement (**GUM**)

**pros**
- calculation by hand is possible
- in the framework of the Guide exact

**cons**
- linearization of the mathematical model required

JCGM 101
Supplement 1 - Propagation of distributions using a Monte Carlo method

**pros**
- no linearization of the mathematical model required
- shows the dispersion (PDF) of the result

**cons**
- requires software for practical application
- will give slightly different results every time the calculation is started

# **Introduction** - JCGM documents and other literature

Other literature:

- The Expression of Uncertainty and Confidence in Measurement (UKAS M3003)

  http://www.ukas.com/library/Technical-Information/Pubs-Technical-Articles/Pubs-List/M3003.pdf

- International vocabulary of metrology - Basic and general concepts and associated terms (VIM, 3rd ed., JCGM 200:2008)

  http://www.bipm.org/en/publications/guides/vim.html

- Metrology in short, 3rd edition

  http://www.euramet.org/index.php?id=mis

# Introduction

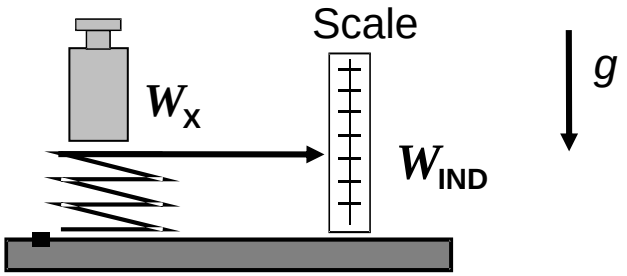
## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Introduction - Traceability chain

## Methods of measurement

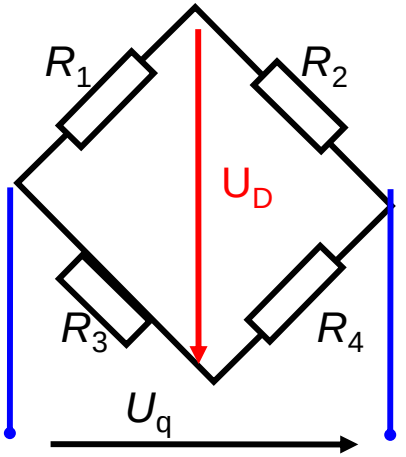
- Indication




The quantity (object) is used itself to generate the indicated reaction.

- Difference

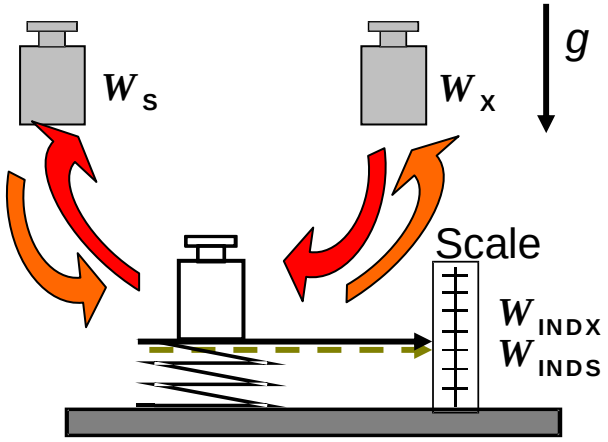
Example:
Wheatstone bridge



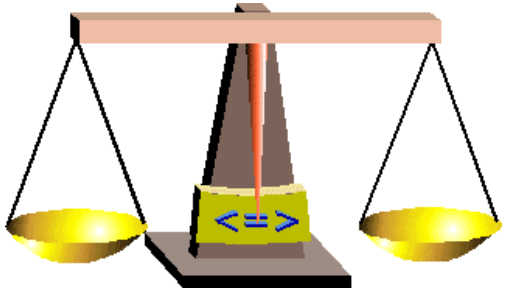

Determination of the difference of a quantity.

- Substitution

The value of quantity is determined using a a standard and by taking alternate readings




- Compensation

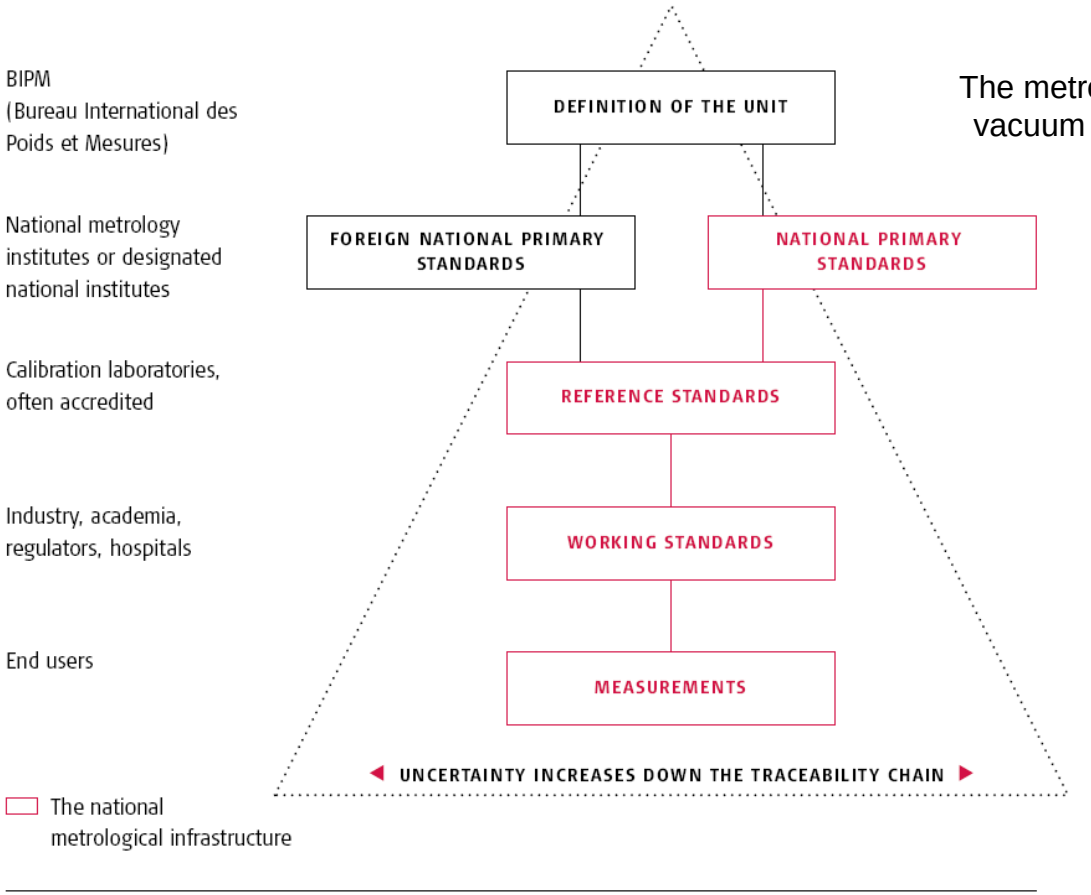




Simultaneous direct comparison (null method)

# Introduction - Traceability chain

**Figure 1: The traceability chain**




taken from Metrology in short, 3rd edition (http://www.euramet.org/index.php?id=mis)

**Example**

The metre is the length of the path travelled by light in vacuum during a time interval of 1 / 299 792 458 of a second.

laser interferometery length measurement

length comparator

measuring rod

height of a table

**Traceability chain - the link to basic quantities**

# Introduction

## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Introduction - Definitions in the VIM

2.26 **measurement uncertainty**

non-negative parameter characterizing the dispersion of the **quantity values** being attributed to a **measurand**, based on the information used

Note: The definition in the GUM refers to the old VIM definition from 1993:

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

# Introduction - Definitions in the VIM

1.1 **quantity**

property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

1.19 **quantity value**

number and reference together expressing magnitude of a **quantity**

2.3 **measurand**

**quantity** intended to be measured

# Introduction - Definitions in the VIM

1.1 **quantity**

property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

| | | |
|---|---|---|
| length, $l$ | radius, $r$ | radius of circle A, $r_{\mathrm{A}}$ or $r(\mathrm{A})$ |
| | wavelength, $\lambda$ | wavelength of sodium D radiation, $\lambda_{\mathrm{D}}$ or $\lambda(\mathrm{D{:}Na})$ |
| energy, $E$ | kinetic energy, $T$ | kinetic energy of particle $i$ in a given system, $T_i$ |
| | Heat, $Q$ | heat of vaporization of sample $i$ of water, $Q_i$ |
| electric charge, $Q$ | | electric charge of the proton, $e$ |
| electric resistance, $R$ | | electric resistance of resistor $i$ in a given circuit, $R_i$ |
| amount-of-substance concentration of entity B, $c_{\mathrm{B}}$ | | amount-of-substance concentration of ethanol in wine sample $i$, $c_i(\mathrm{C_2H_5OH})$ |
| number concentration of entity B, $C_{\mathrm{B}}$ | | number concentration of erythrocytes in blood sample $i$, $C(\mathrm{Erys{:}B}_i)$ |
| Rockwell C hardness (150 kg load), $\mathrm{HRC}(150\ \mathrm{kg})$ | | Rockwell C hardness of steel sample $i$, $\mathrm{HRC}_i(150\ \mathrm{kg})$ |

# **Introduction -** Definitions in the VIM

1.1 **quantity**

property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

1.19 **quantity value**

number and reference together expressing magnitude of a **quantity**

EXAMPLE
Mass of a given body: 0,152 kg or 152 g

2.3 **measurand**

**quantity** intended to be measured

# Introduction

## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Introduction - Bayesian statistic

**Conventional statistic**

The value of the measurand is assumed to be an unknown constant and the measurement data are random variables.

**Bayesian statistic**

The measurement data are constants and the value of the measurand is a random variable. The probability distribution for the value of the measurand describes the degree of belief about all possible values that could be attributed to the value of the measurand.

# Introduction

## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Introduction - Probability density functions (PDF)

**conventional statistic**

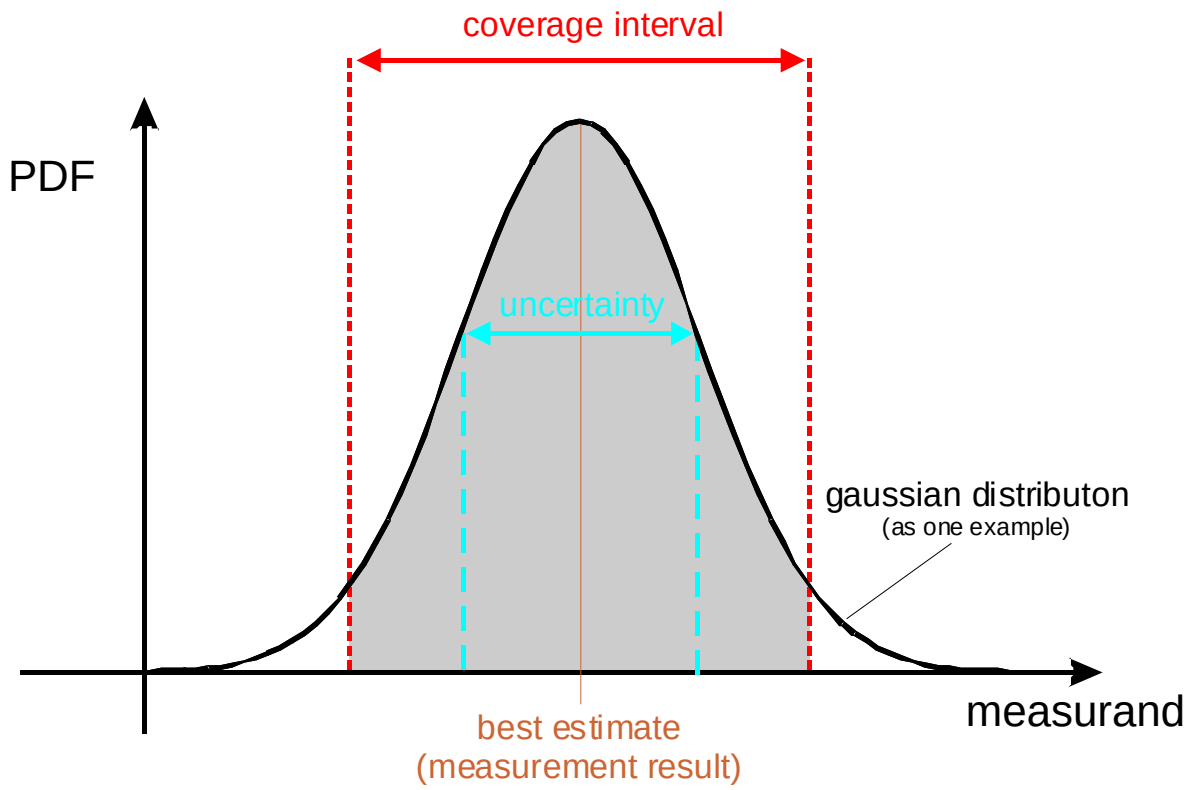
probability is understood to be the relative frequency of the occurrence of an observable random event in an infinite series of trials performed under identical conditions.

**Bayesian statistic**

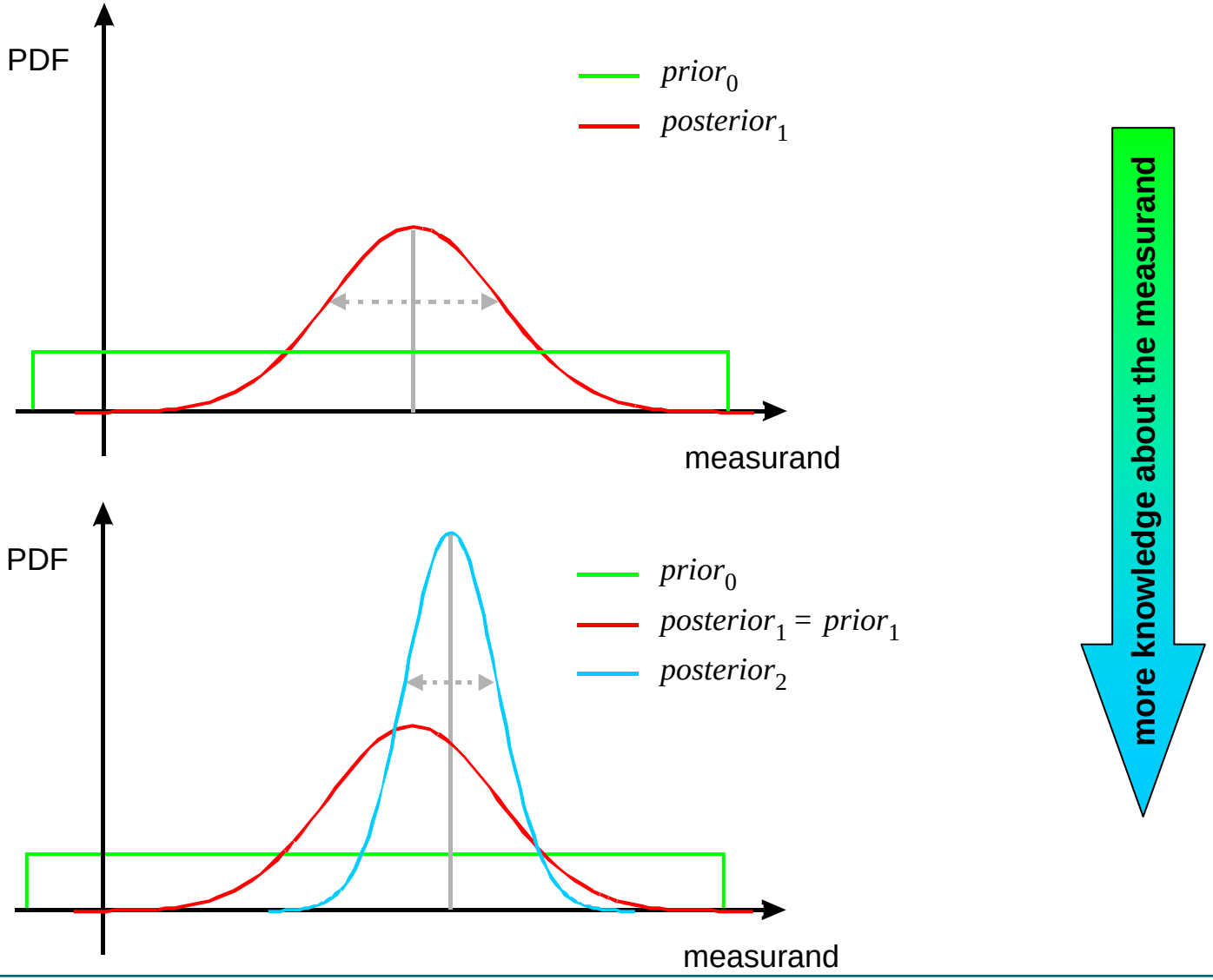
probability is understood to be a degree of belief or of the plausibility of a proposition, conditional on all relevant information that is available about that proposition.

# **Introduction -** Probability density functions (PDF)

The probability density function describes the available knowledge about the quantity.



# Introduction - Probability density functions (PDF)



# Introduction

*Thank you for your attention*

*Questions ???*

*stephan.mieke@ptb.de*