Education 274C: The Philosophy of Measurement

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10. Metrology

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from the Course Overview

This course [...] will provide a general introduction to the philosophical foundations of measurement theory, with a special focus on measurement in the social sciences.

[...]

Finally, we will explore the relationship between psychometrics and metrology (i.e., the science of measurement, classically meaning physical measurement).

The VIM, as reference

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

My basic messages are simple:

1. measurement (of physical quantities) is laden with stereotypes: be aware of them

2. at a fundamental level measurement can be characterized independently of the domain

An example

Q1: What is the result of 1 m + 1 nm ?

A1: 1.000000001 m

Q2: What is the length of the segment A+B where:

len(A) = 1 m len(B) = 1 nm

A2: len(A+B) = 1.000000001 m

Q3: What is the length of the physical object A+B where:

len(A) = 1 m len(B) = 1 nm

An example (cont.d)

Q1: What is the result of 1 m + 1 nm ?

Q2: What is the length of the segment A+B, len(A)=1 m, len(B)=1 nm ?

Q3: What is the length of the physical object A+B, len(A)=1 m, len(B)=1 nm ?

Are they the same question?

Q1 → algebra

Q2 → geometry

Q3 → empirical domain (physics, in this case)

A3 (plausibly): len(A+B) = 1 m

Synthesis

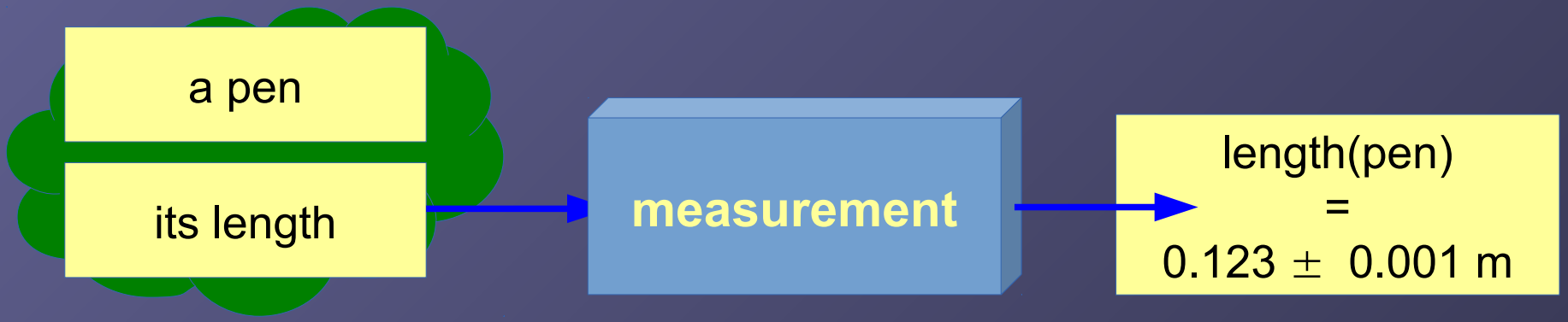
in measurement we exploit models

(e.g., this physical object is a cylinder and as such has a length)

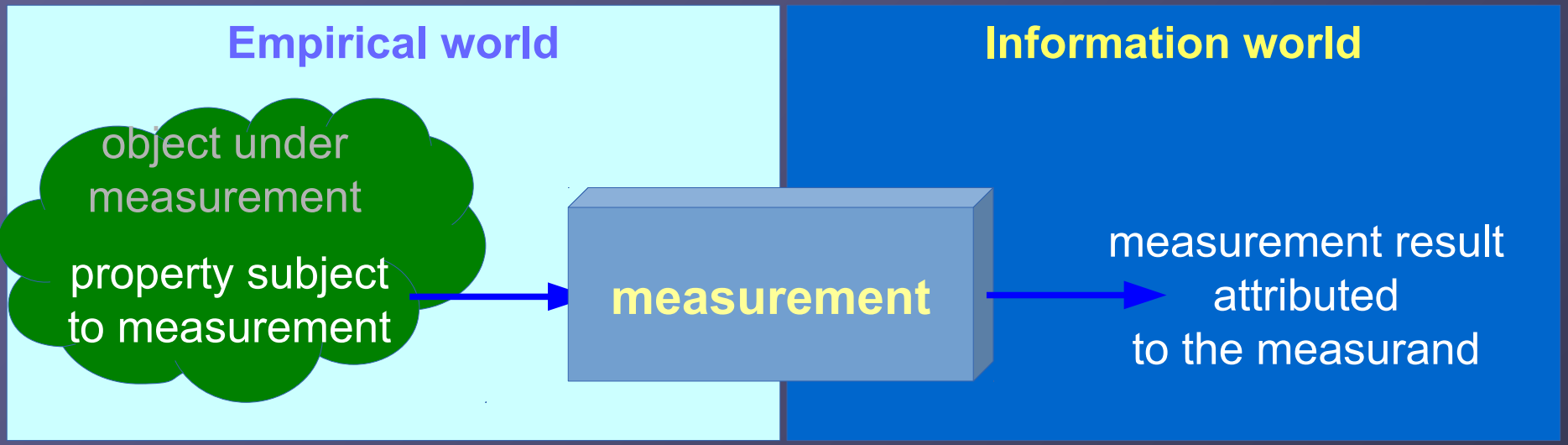
what we report as measurement results

is related to the empirical world through models

Measurement as a black box



Measurement as a black box

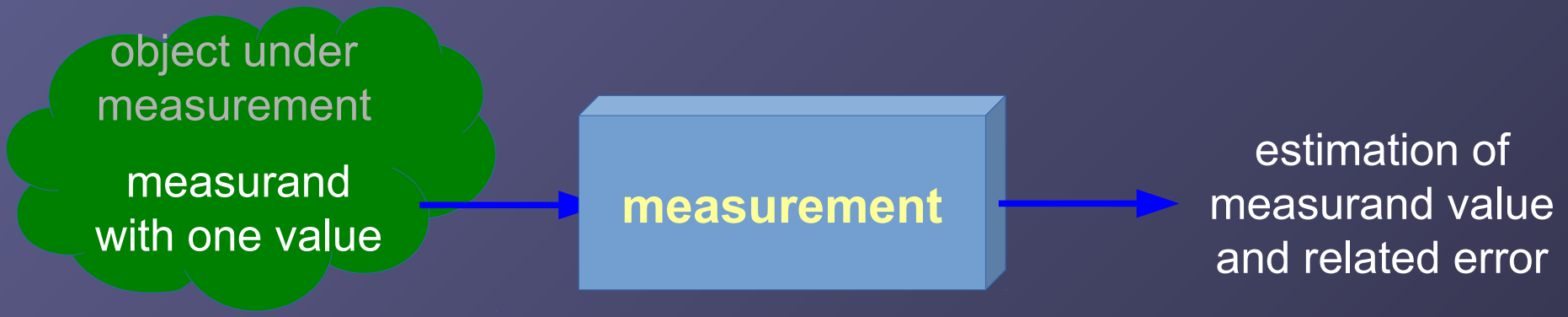


- Measurement is a process, not its result (and “measure” is not used)
- Measurement results are property values (typically numbers with units, together with uncertainty)
- Measurement maps an empirical entity to an informational one

The tradition

The tradition of physical measurement has an strong empiricist connotation:

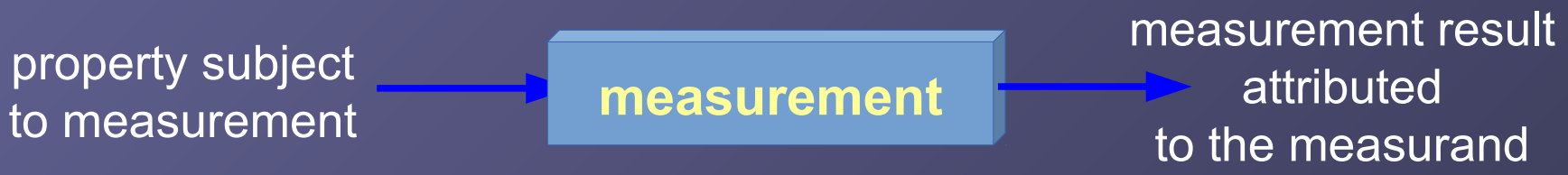
- the measurand is the property subject to measurement,
- and property values “are in” the empirical world,
- so that measurement is aimed at discovering them
- and only errors, to be reported, prevent their “perfect” discovery



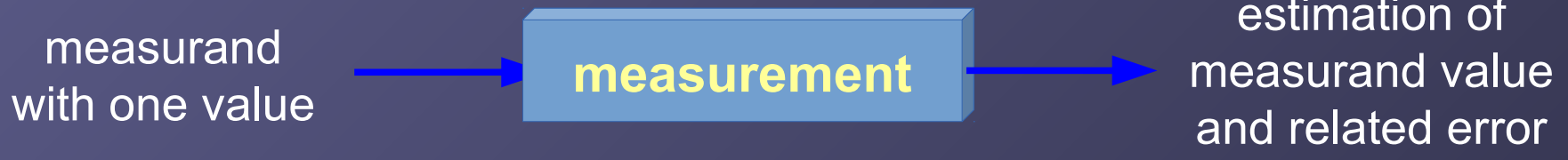
The peculiar (?) consequence is that “perfect” measurement would be an identity process

Challenging the tradition

Compare the generic schema:



and the way it is interpreted according to the tradition:



What is missing in the traditional view?

models

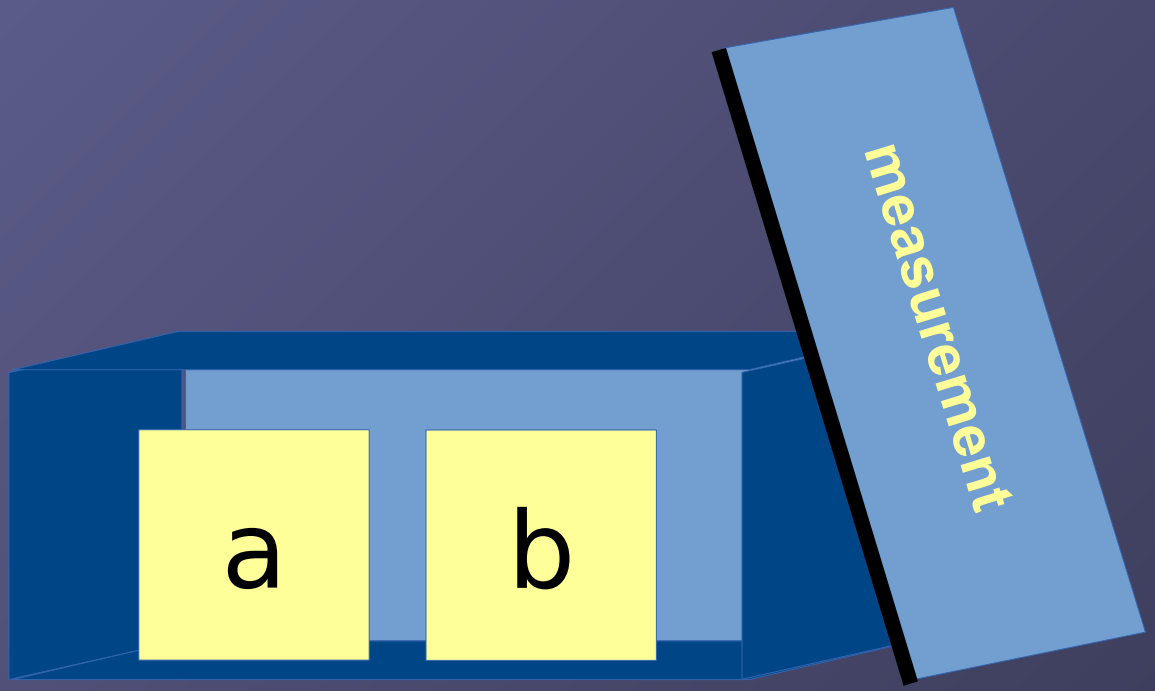
Beyond tradition

Back to the generic schema:

- While the measuring instrument interacts with the property subject to measurement (which is empirical)...
- … the measurand is the property intended to be measured (as in the VIM3 definition) (which is model-dependent)

In designing and performing measurement
we do our best for our intentions to correspond to empirical states,
but this is a matter of quality of models and measuring instruments,
not metaphysical assumptions

Hence, inside the black box...



… there are both experimental and informational elements

A theory of measurement neglecting the role of instruments...

«We are not interested in a measuring apparatus and in the interaction between the apparatus and the objects being measured. Rather, we attempt to describe how to put measurement on a firm, well-defined foundation»

[F. Roberts, Measurement theory, 1979]

… is indeed a generic theory of representation...

… but measurement is more than generic representation

There is nothing physics-dependent in this framework...

… which applies also to non-physical properties

(the interesting specificity is another one)

What is the specificity?

How is measurement characterized
as a specific kind of evaluation / representation?

Hypothesis

The information produced by measuring systems is / should be:

- specific to the measurand, and then independent of any other property of the object or the surrounding environment, including the measuring system and the subject who is measuring;
  → this is a condition of objectivity

- interpretable in the same way by different users in different places and times, because expressed in a form independent of the specific context and only referring to entities which are universally accessible;
  → this is a condition of intersubjectivity

How can you obtain
(sufficiently) objective and intersubjective information
from your evaluation process?
(so that you can rely on it,
and you can consider it a measurement)

Note that this is unrelated to using numbers:
“numerical evaluation” is NOT synonymous of “measurement”

There is nothing physics-dependent in this characterization...

Developing and performing evaluation processes that are (sufficiently) objective and intersubjective is the fundamental task of applied measurement science

Different disciplines exploit different techniques but the basic endeavor is the same

THANK YOU
FOR YOUR KIND ATTENTION

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My profile

[M.Sc. in physics; Ph.D. in measurement science]

I am full professor of measurement science at the Cattaneo University – LIUC, Castellanza (VA), Italy, where I teache courses on measurement science, statistical data analysis, system theory.

I am currently the chairman of the TC1 (Terminology) and the secretary of the TC25 (Quantities and Units) of the International Electrotechnical Commission (IEC), and an IEC expert in the WG2 (VIM) of the Joint Committee for Guides in Metrology (JCGM). I have been the chairman of the TC7 (Measurement Science) of the International Measurement Confederation (IMEKO).

I am the author or coauthor of several scientific papers published in international journals and international conference proceedings. My research interests include measurement science and system theory.

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Some of my recent publications

LM, D.Petri, **Measurement science: constructing bridges between reality and knowledge**, *IEEE Instr. Meas. Mag.* (forthcoming)

P.Micheli, LM, **The theory and practice of performance measurement**, Management Accounting Research (forthcoming)

LM, M.Wilson, **An introduction to the Rasch measurement approach for metrologists**, *Measurement*, 2014

A.Frigerio, A.Giordani, LM, **On representing information: a characterization of the analog/digital distinction**, *Dialectica*, 2013

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LM, A.Giordani, **Quantity and quantity value**, *Metrologia*, 2012

LM, P.Carbone, D.Petri, **Measurement fundamentals: a pragmatic view**, *IEEE Trans. Instr. Meas.*, 2012

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D.Macii, LM, D.Petri, **Comparison of measured quantity value estimators in nonlinear models**, *IEEE Trans. Instr. Meas.*, 2010