Education 274C: Research Seminar in Measurement:

Philosophy of Measurement

2. Metrology

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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 (more philosophically oriented) publications

LM, P.Carbone, A.Giordani, D.Petri, **A structural interpretation of measurement and some related epistemological issues**, *Studies in History and Philosophy of Science*, 2017

LM, **Toward a harmonized treatment of nominal properties in metrology**, *Metrologia*, 2017

LM, D.Petri, **The metrological culture in the context of Big Data: Managing data-driven decision confidence**, *IEEE Instrumentation and Measurement Mag.*, 2017

LM, A.Maul, D.Torres Irribarra, M.Wilson, **Quantities, quantification, and the necessary and sufficient conditions for measurement**, *Measurement*, 2017

LM, D.Petri, **Measurement science: constructing bridges between reality and knowledge**, *IEEE Instrumentation and Measurement Mag.*, 2014

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

LM, **A quest for the definition of measurement**, *Measurement*, 2013

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

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

A.Giordani, LM, **Measurement, models, uncertainty**, *IEEE Trans. Instrumentation and Measurement*, 2012

A.Giordani, LM, **Property evaluation types**, *Measurement*, 2012

A.Frigerio, A.Giordani, LM, **Outline of a general model of measurement**, *Synthese*, 2010

LM, **The problem of foundations of measurement**, *Measurement*, 2005

LM, **Epistemology of measurement**, *Measurement*, 2003

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.

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

One problem, three problems

Q1: What is the result of $1 + 10^{-9}$?

A1: 1.000000001

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

Three problems, three solutions

Q1: What is the result of $1 + 10^{-9}$?

→ An **algebraic** problem, solved by computation

Q2: What is the length of the segment $a+b$, len(a)=1 m, len(b)=1 nm ?

→ A **geometric** problem, solved by computation with units

Q3: What is the length of the physical object $a+b$, len(a)=1 m, len(b)=1 nm ?

→ A **measurement** problem

A3 (plausibly): len($a+b$) = 1 m

Measurement problems: the set up

We acknowledge that in the empirical world there are:

* **objects** (phenomena, processes, events, ...)
* having **properties** (attributes, features, ...)
* by which objects can be **compared**,
  and sometimes prove to be indistinguishable

By some of their properties objects can also be **ordered**

By some of their properties objects can also be **composed additively**

Metrology grew up from additive properties

An example (cont.d)

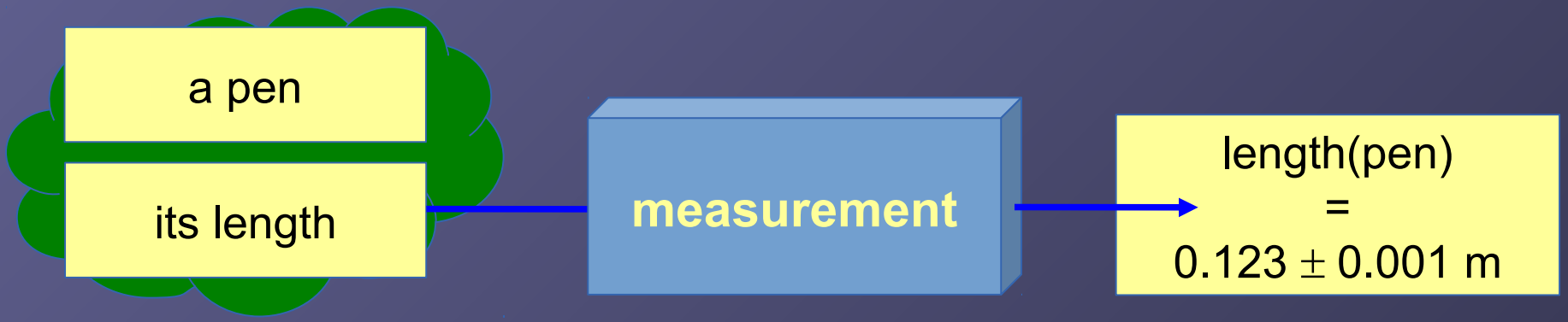
Synthesis:

in measurement we exploit models

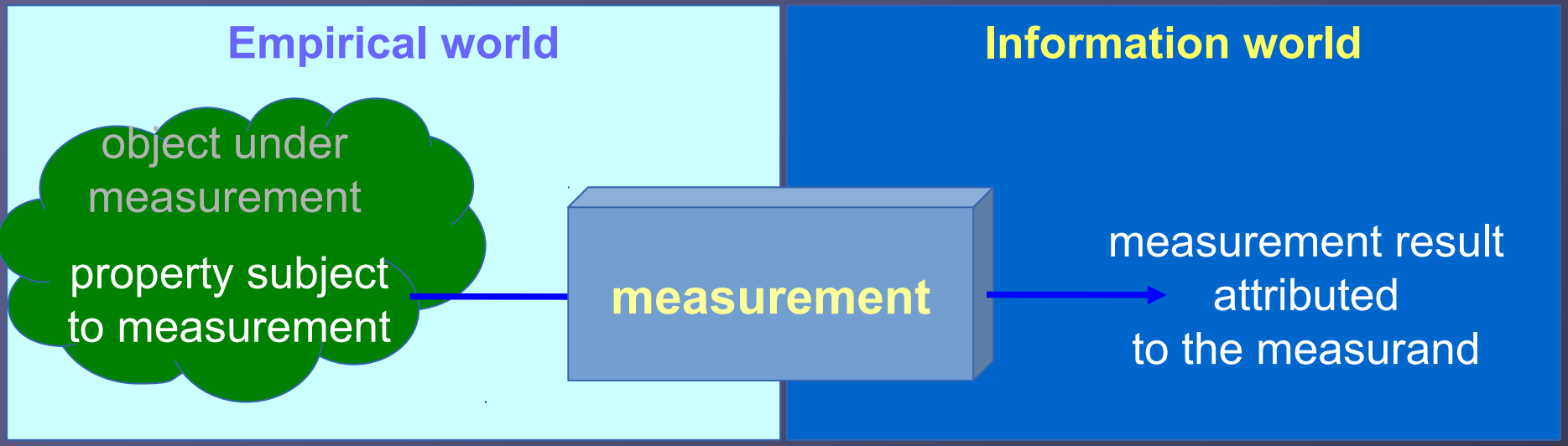
(e.g., this physical object is a cylinder and as such has a length)

and we should remember that what we report
as measurement results
is related to the empirical world through models

Measurement as a black box



Measurement as a black box

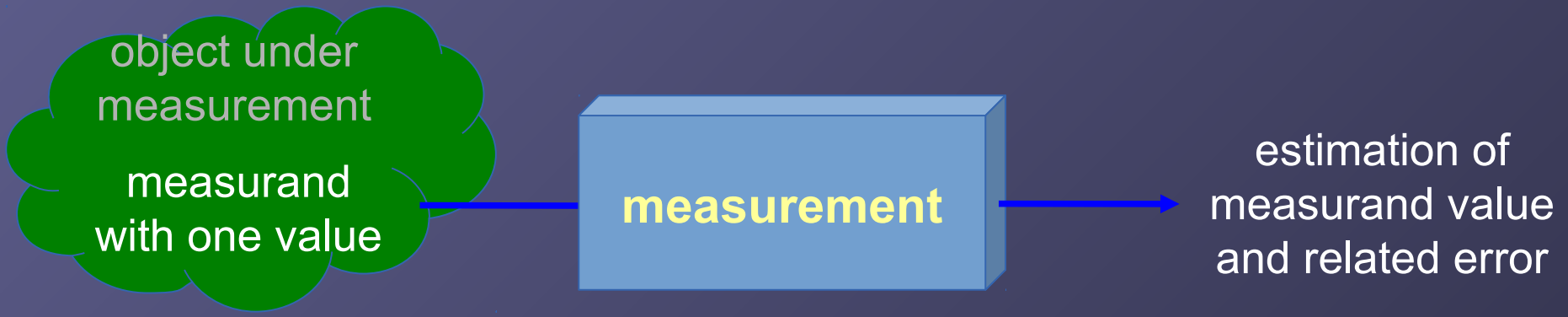


- Measurement is a process, not its result (and “measure” is not used)
- Measurement results are property values (typically numbers with units, together with uncertainty)
- Measurement maps an empirical entity to an informational one and therefore has a meta-physical role (…!)

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

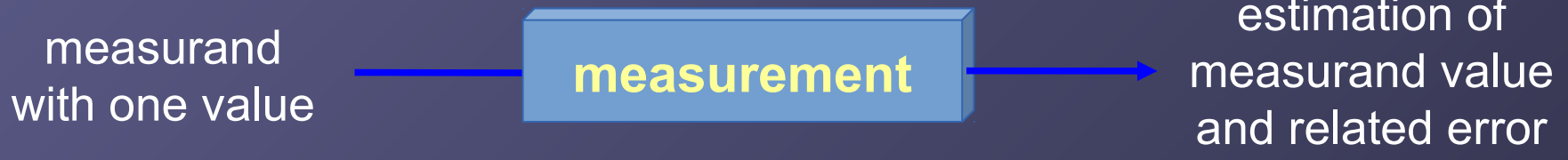


The peculiar (?) consequence is that “perfect” measurement would be an identity process

Challenging the tradition

Compare the generic schema:

and the way it is interpreted according to the tradition:

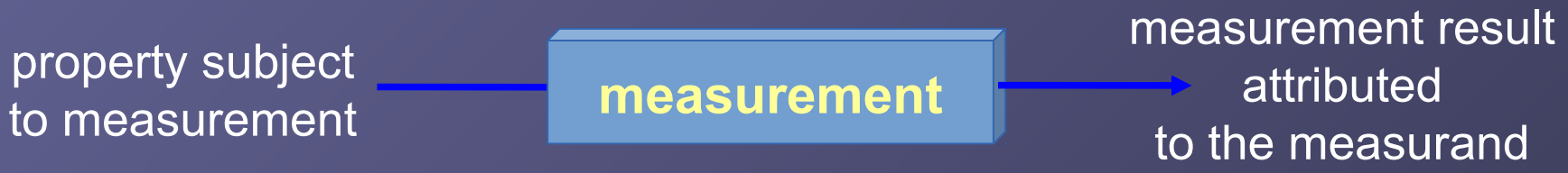


What is missing here?

models

Beyond tradition

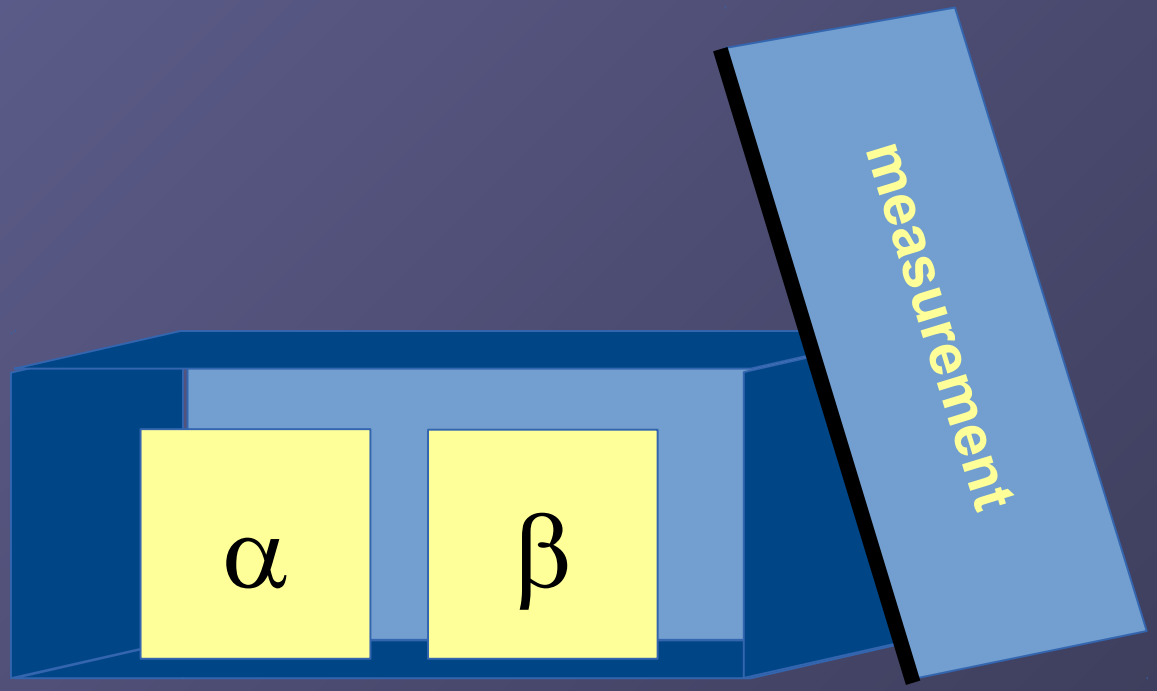
Back to the generic schema:



- 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]

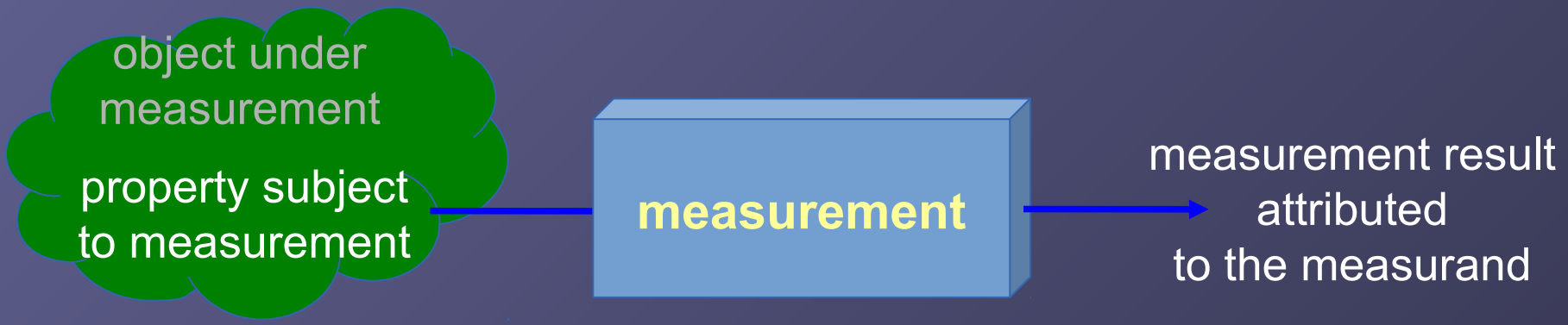
… is indeed a generic theory of representation...

«[there is] a certain deficiency of realism in philosophical discussions of measurement»

[O.D. Duncan, Notes on social measurement, 1984]

… but measuring instruments are empirical information devices

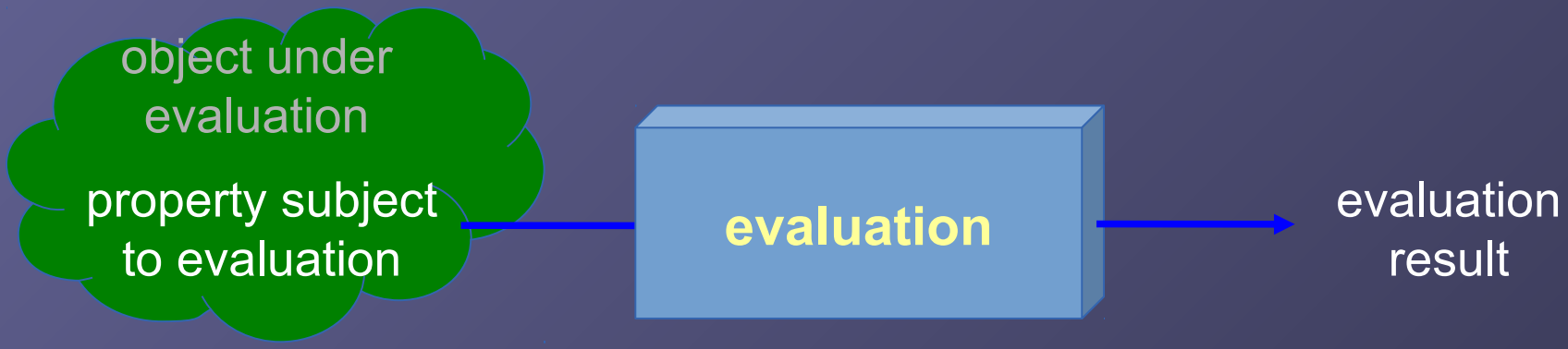
There is nothing physics-dependent in this framework...



… 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?

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

The VIM, as reference

My basic message is simple:

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

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

THANK YOU
FOR YOUR KIND ATTENTION

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