Can there be a metrology for psychometricians?

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Abstract

Metrology -- the “science of measurement and its application” according to the *International Vocabulary of Metrology* (VIM) -- is a body of knowledge traditionally bound to the measurement of physical quantities, sometimes with the further specification that only high quality (in some sense to be agreed) measurement-related activities constitute actual metrology, as those performed in the US by the NIST.

Given the social reputation of measurement, it is not amazing that there is a tension to continue the historical process of expanding such a still strict scope, where in particular under scrutiny is the necessity that the object of measurement is a physical quantity.

Arguing about metrology is then a good opportunity to discuss of the very nature of measurement and its limits, between science, technology, mathematics, and society.

My profile

Luca Mari (MS in physics, University of Milano, Italy, 1987; Ph.D. in measurement science, Polytechnic of Torino, Italy, 1994) since 2006 has been a full professor of measurement science with Università Cattaneo - LIUC, Castellanza, Italy, where he teaches courses on measurement science, statistical data analysis, and system theory.

He is 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). He has been the chairman of the TC7 (Measurement Science) of the International Measurement Confederation (IMEKO).

Some of my recent publications

LM, P.Blattner, F.Pavese, **Improving the understandability of the next edition of the International System of Units (SI) by focusing on its conceptual structure**, *Measurement*, 2017

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

D.Petri, LM, P.Carbone, **A structured methodology for measurement development**, *IEEE Trans. Instr. Meas.*, 2015

A.Mencattini, LM, **A conceptual framework for concept definition in measurement: the case of 'sensitivity'**, *Measurement*, 2015

LM, **Evolution of 30 years of the International Vocabulary of Metrology (VIM)**, *Metrologia*, 2015

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

P.Micheli, LM, **The theory and practice of performance measurement**, *Management Accounting Research*, 2014

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

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. Instr. Meas.*, 2012

A.Giordani, LM, **Measurement, models, uncertainty**, *IEEE Trans. Instr. Meas.*, 2012

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

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Measurement

journal homepage: www.elsevier.com/locate/measurement

An introduction to the Rasch measurement approach for metrologists ☆

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Quantities, Quantification, and the Necessary and Sufficient Conditions for Measurement ☆

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The (meta-)message: metrology is less monolithic
than possibly supposed “from the outside”

Taking a look at the ways it is differently interpreted
may suggest some hypotheses on how
the sciences of physical and non-physical measurement
could learn from each other

The proposal:

a short discussion on four interpretations
of what metrology is,
each from a strict, traditional standpoint
toward a broader, encompassing view

… with a premise,

aimed at providing a context for the discussion

and hopefully at sharing some basic concepts and terms

Joint Committee for Guides in Metrology (JCGM)

(established in 1997)

BIPM	Int.l Bureau of Weights and Measures
OIML	Int.l Organization of Legal Metrology
ISO	Int.l Organization for Standardization
IEC	Int.l Electrotechnical Commission
ILAC	Int.l Laboratory Accreditation Cooperation
IUPAP	Int.l Union of Pure and Applied Physics
IUPAC	Int.l Union of Pure and Applied Chemistry
IFCC	Int.l Federation of Clinical Chemistry and Lab. Medicine

Joint Committee for Guides in Metrology (JCGM)

(established in 1997)

Metrology : BIPM

Legal metrology : OIML

Standardization : ISO IEC

Accreditation : ILAC

Domain-related : IUPAP (physics) IUPAC (chemistry)
IFCC (clinical chemistry and lab medicine)

JCGM “guidance docs”

the VIM

the GUM

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

The scope of JCGM

metrology: «science of measurement and its application» [VIM, def. 2.2]

«In this Vocabulary [the VIM], it is taken for granted that there is no fundamental difference in the basic principles of measurement in physics, chemistry, laboratory medicine, biology, or engineering. Furthermore, an attempt has been made to meet conceptual needs of measurement in fields such as biochemistry, food science, forensic science, and molecular biology.»

A terminological premise

According to the VIM:

measurement: the process of measuring

measurand: the quantity intended to be measured

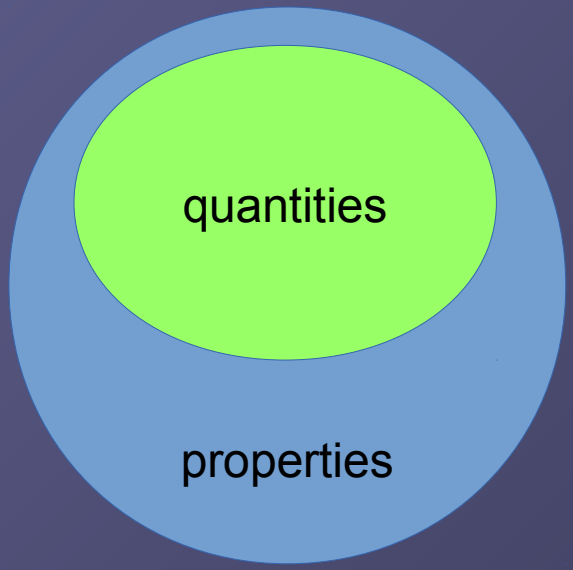
measurement result: the outcome of measurement,
in the form of a **quantity value**
(or an interval of quantity values, a pdf on a set of quantity values, etc)

(the VIM avoids the noun “measure” because too ambiguous)

A conceptual premise

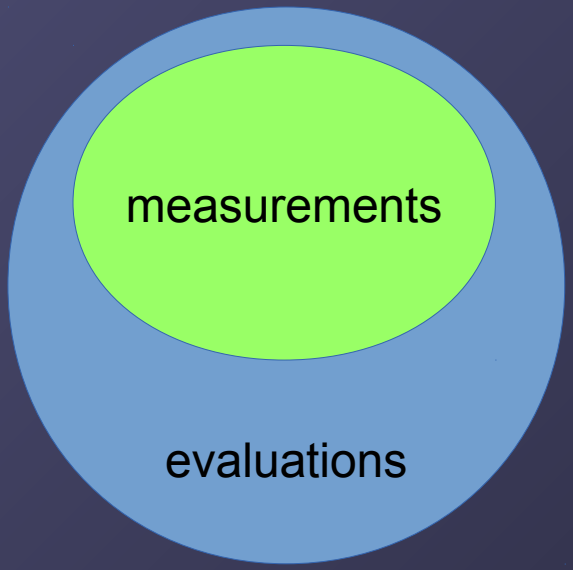
quantities are
specific properties:

{quantities} ⊂ {properties}



measurements are
specific evaluations:

{measurements} ⊂ {evaluations}



Why could the question "what is metrology?" be interesting to psychometricians?

1. Metrology is a socially acknowledged context of measurement

2. The public trust attributed to measurement results
   is not attributed to the outcomes of other forms of evaluation

Hence claims such as "this information comes from a measurement",
and "this information is provided by a metrological institution",
have a societal significance

(*and in a situation of post-truth and alternative facts...*)

Four interpretations:

metrology is...

1. the body of knowledge
   about evaluations of physical properties
2. the body of knowledge about measures
3. what National Metrology Institutes do
4. the body of knowledge
   about evaluations of sufficiently high quality

These interpretations are not alternative…

… and in fact a (very conservative) position might consider metrology as what National Metrology Institutes do relating to sufficiently high quality evaluations of physical quantities

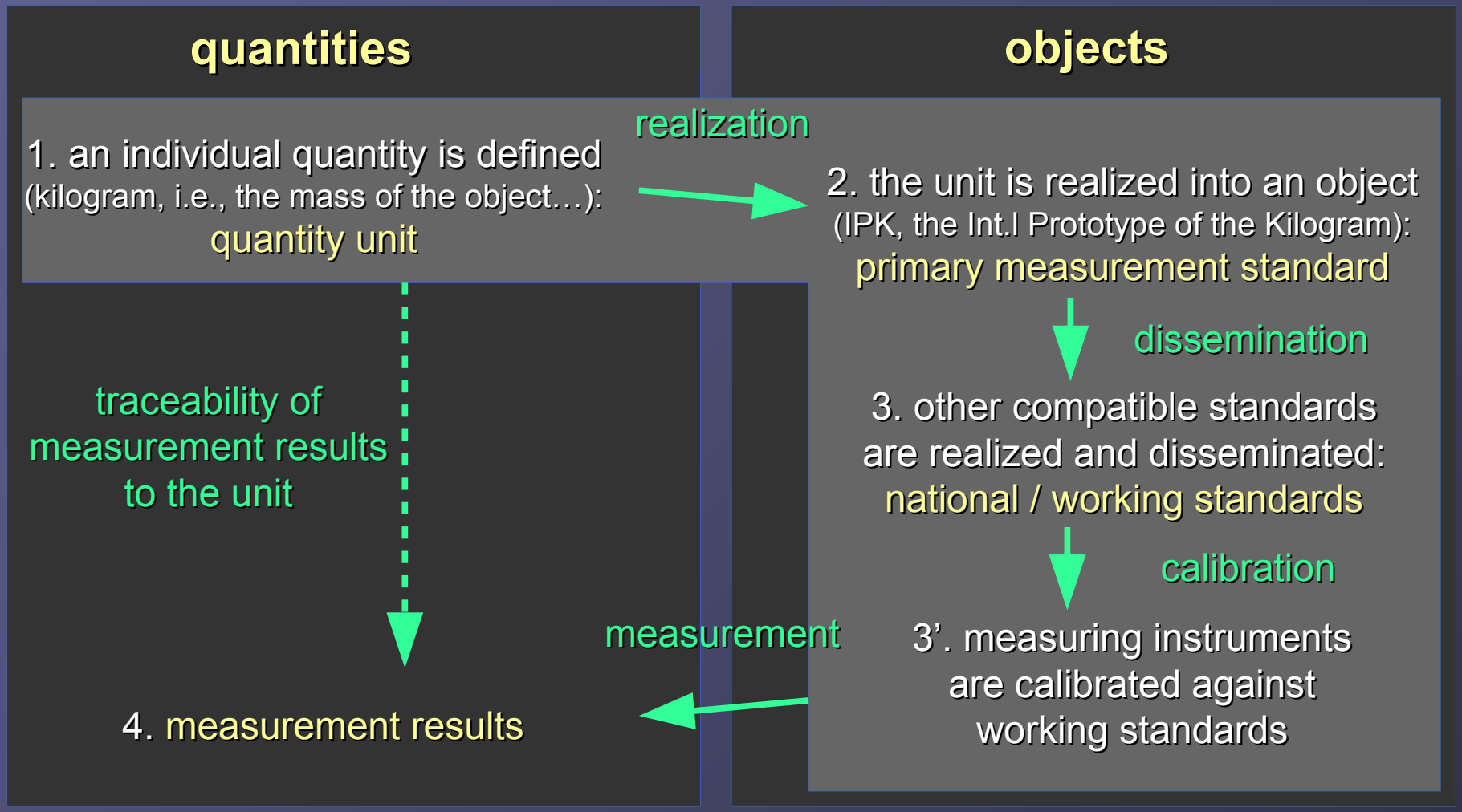
More explicitly:
«Metrology is the science of measurement. It covers three main activities:
1. the definition of internationally accepted units of measurement, e.g. the metre;
2. the realization of units of measurement by scientific methods,
   e.g. the realization of a metre through the use of lasers;
3. the establishment of traceability chains by determining and documenting the value and accuracy of a measurement and disseminating that knowledge, e.g. the documented relationship between the micrometer screw in a precision engineering workshop and a primary laboratory for optical length metrology.»

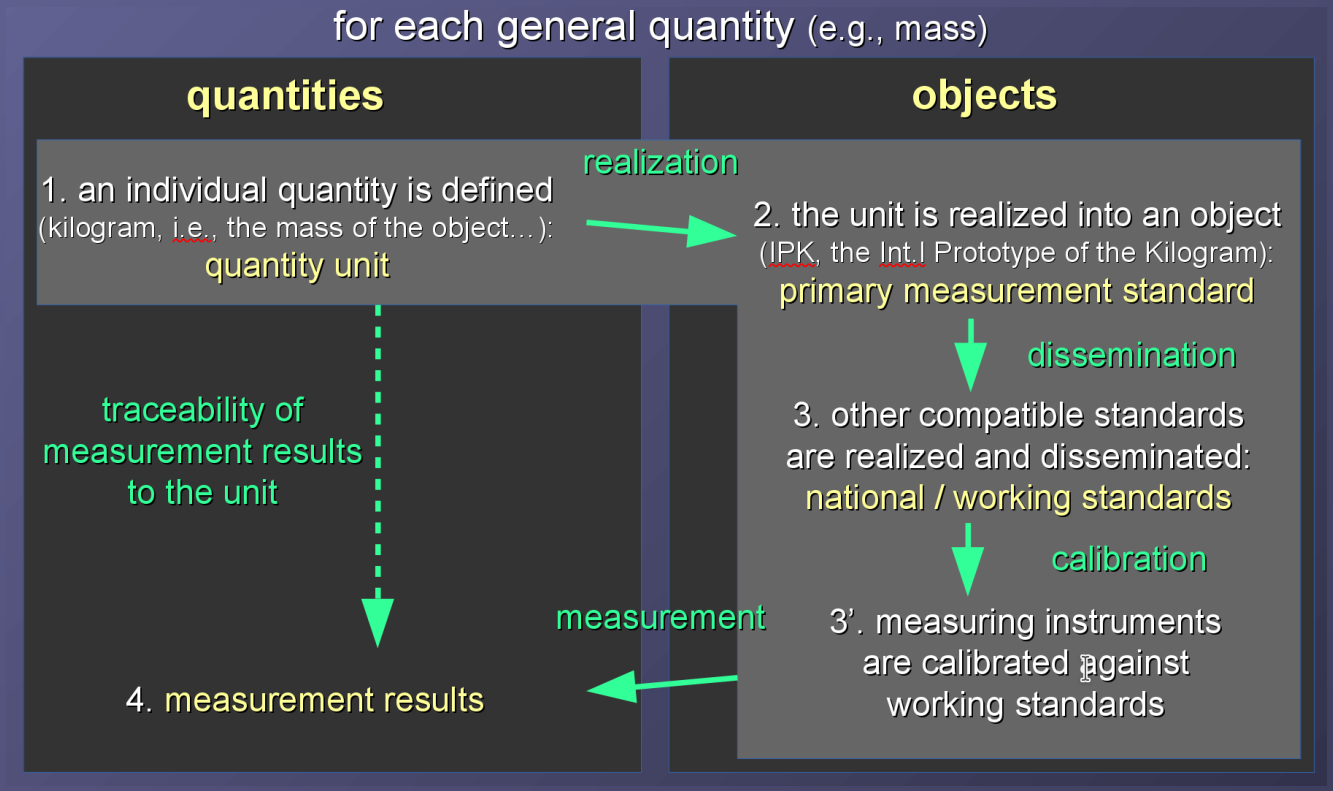
[Metrology in short, 3rd edition, EURAMET project 1011, 2008, http://www.euramet.org/publications-media-centre/documents/metrology-in-short]

A mini-tutorial on metrology...

(simplified version)

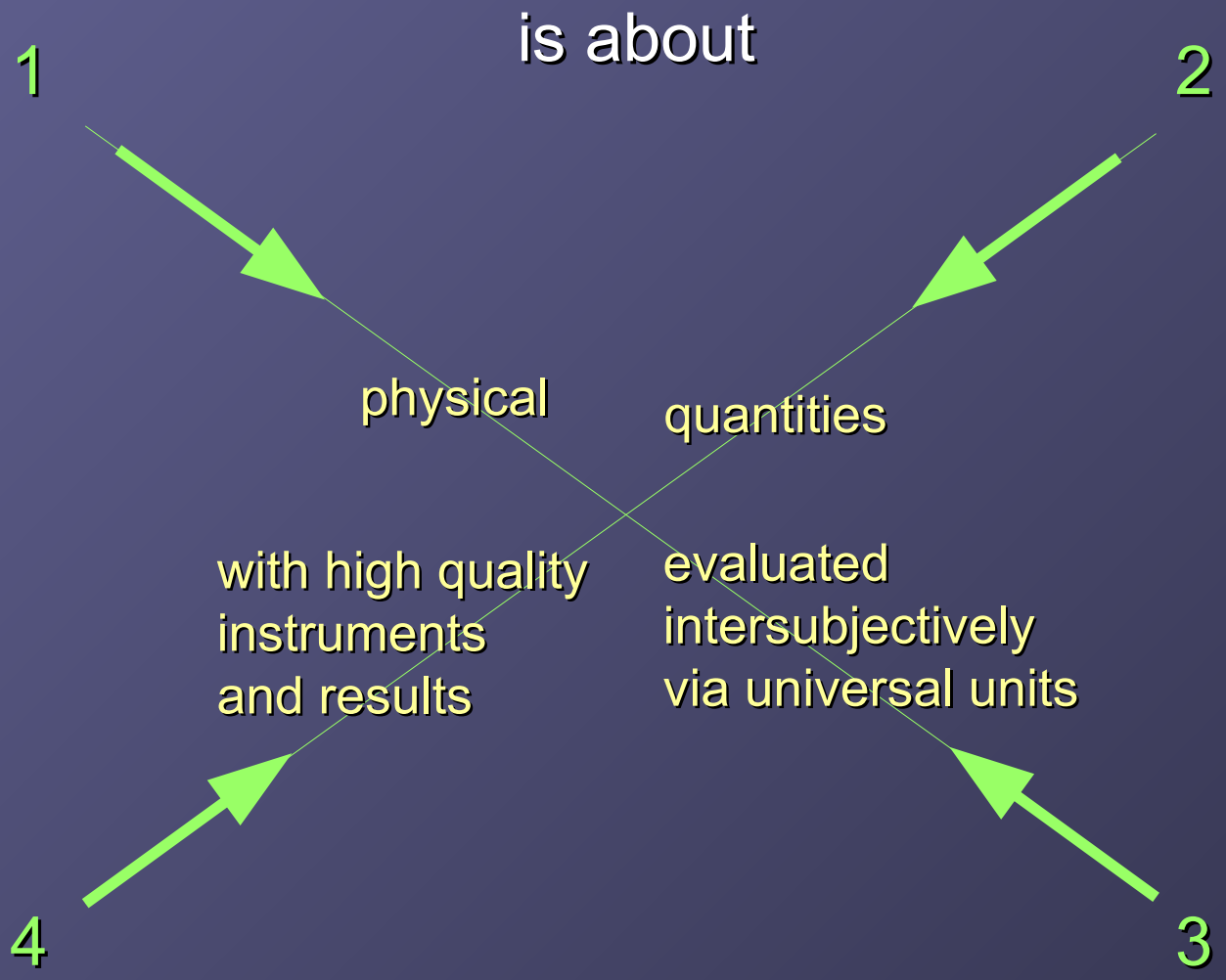
for each general quantity (e.g., mass)



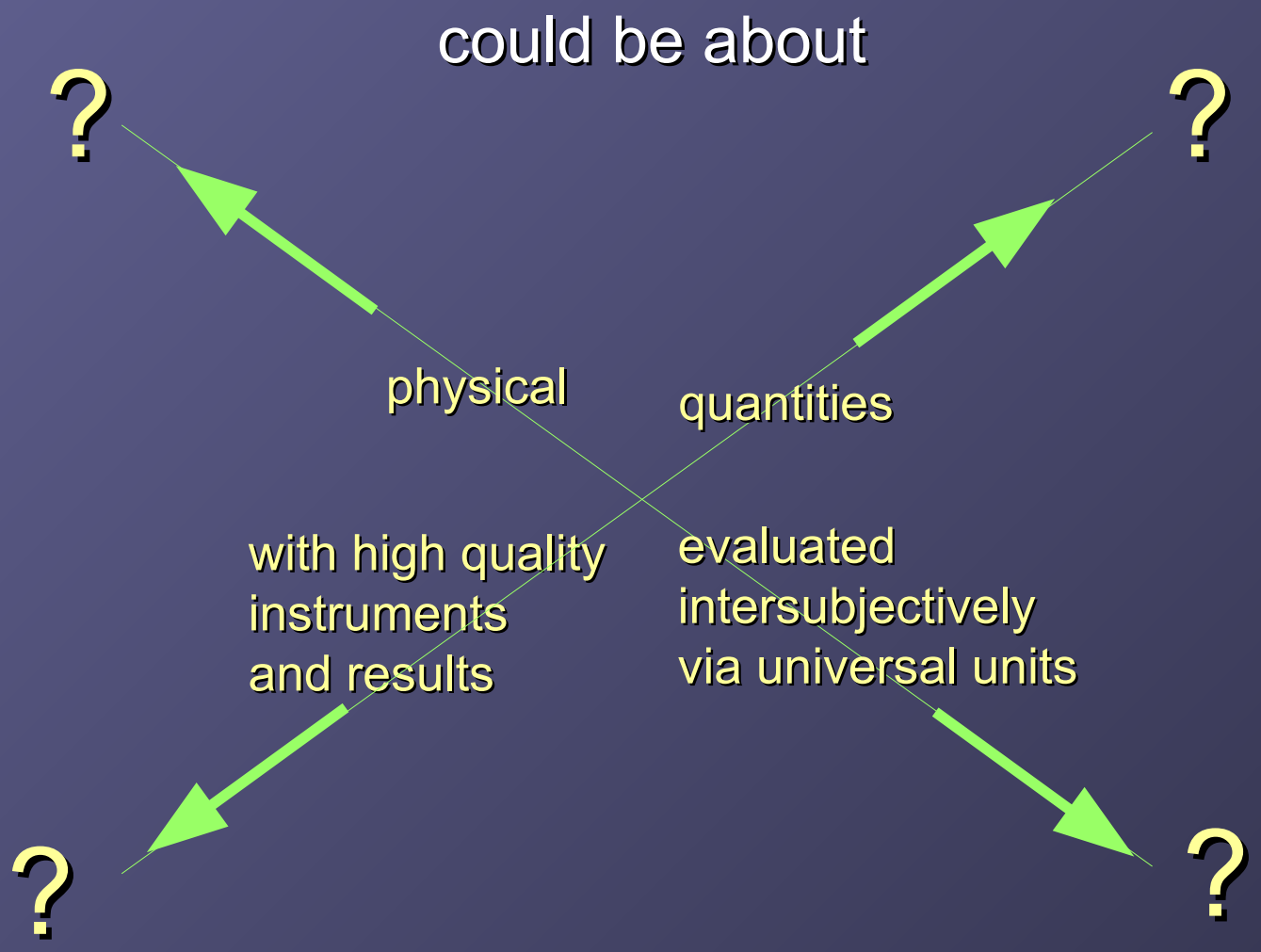


(*such a strict standpoint*
is plausibly not so interesting
to psychometricians...)

“Strict” metrology



“Broad” metrology



Interpretation 1 (***disciplinary*** characterization)

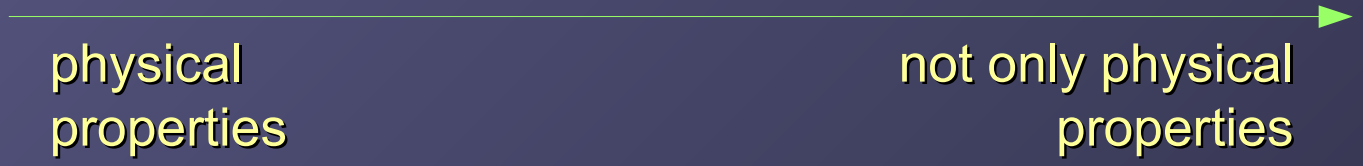
metrology is the body of knowledge
about evaluations of physical properties

Rationale:
measurement historically developed
relating to geometrical quantities

Broadening interpretation 1...

The concept ‘measurable property’ has widened its scope in history (the term “weights and measures” is the trace of a not so far past in which weights were not considered measures...)

Q: can non-physical properties be measured?



Interpretation 2 (***semantic*** characterization)

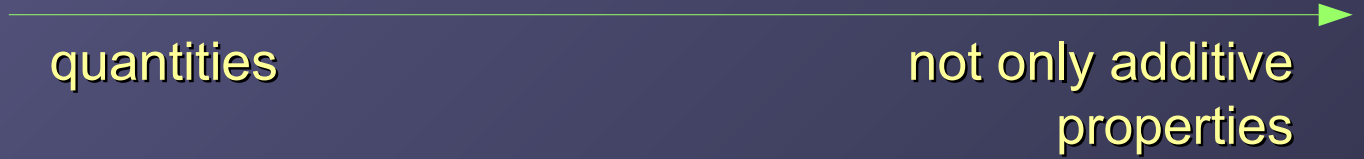
metrology is the body of knowledge about quantities,
i.e., “measures”

Rationale:
‘measurement’ and ‘measure’ belong to
the same concept system

Broadening interpretation 2...

Despite they seem to be coextensive,
the concepts ‘measurement’ and ‘measure’ are different,
and measure theory is a mathematical theory about additive properties
(i.e., Euclidean quantities and their generalizations)

Q: can non-Euclidean / non-additive / non-ratio properties be measured?



Interpretation 3 (***organizational*** characterization)

metrology is what National Metrology Institutes (NMIs) do
to guarantee intersubjectivity of evaluations
via universal units

Rationale:
NMI activity is the foundation of the metrological system

Broadening interpretation 3...

NMIs develop and disseminate measurement standards
as tools for making intersubjectivity in measurement possible

Q: can intersubjectivity of information on empirical properties
be guaranteed without universal units?

intersubjectivity
by universal units

intersubjectivity
by some general strategies

Interpretation 4 (*axiological* characterization)

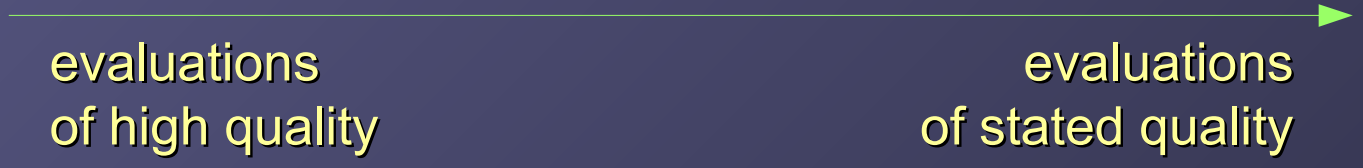
metrology is the body of knowledge
about evaluations of sufficiently high quality

Rationale:
measurement is widespread
and not any measurement is a metrological activity

Broadening interpretation 4...

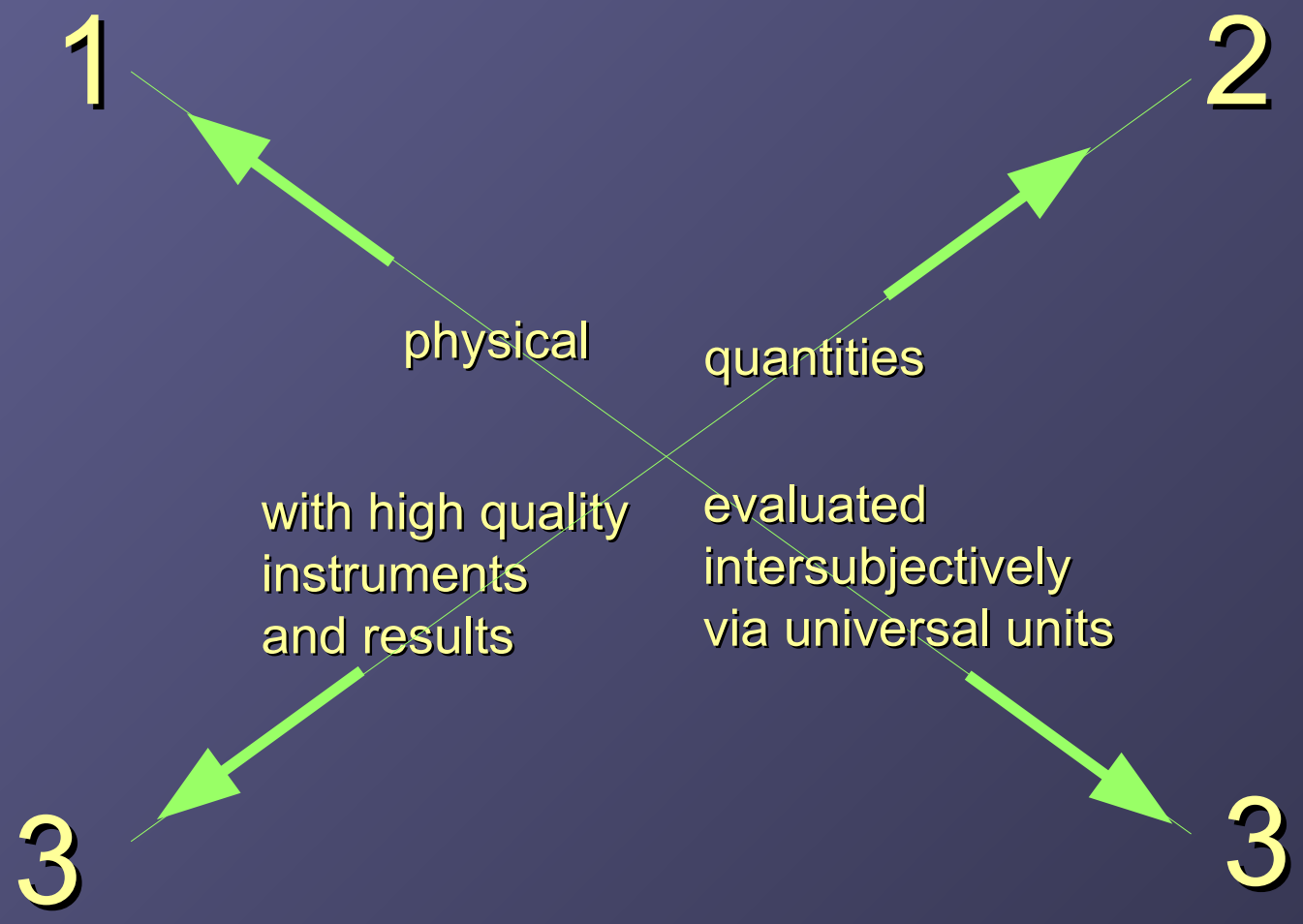
Metrology is sometimes intended (particularly by NMIs) as only covering "scientific" measurement, with "small" measurement uncertainty

What is important here is that measurement results convey information as both quantity / property values and quality of such values

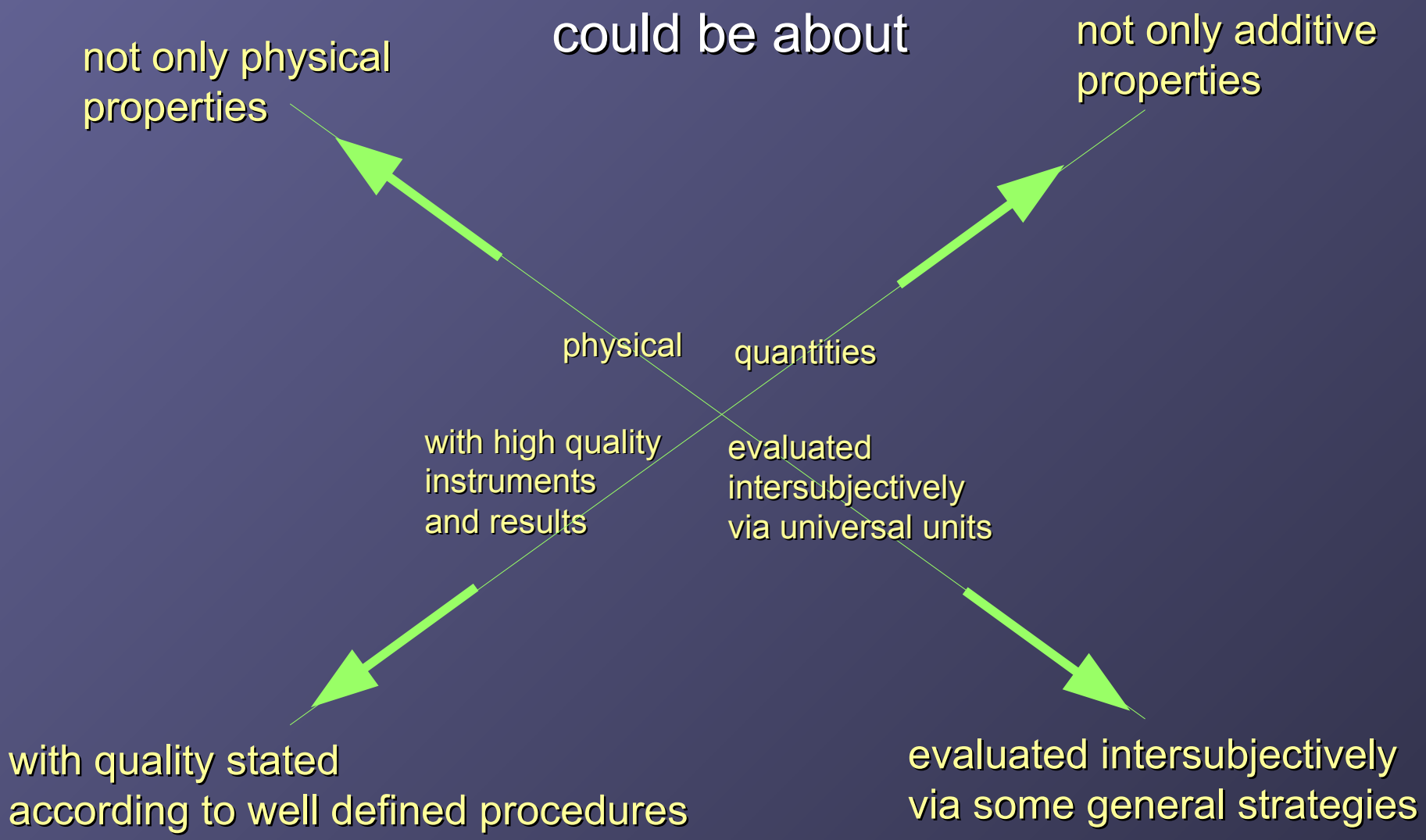


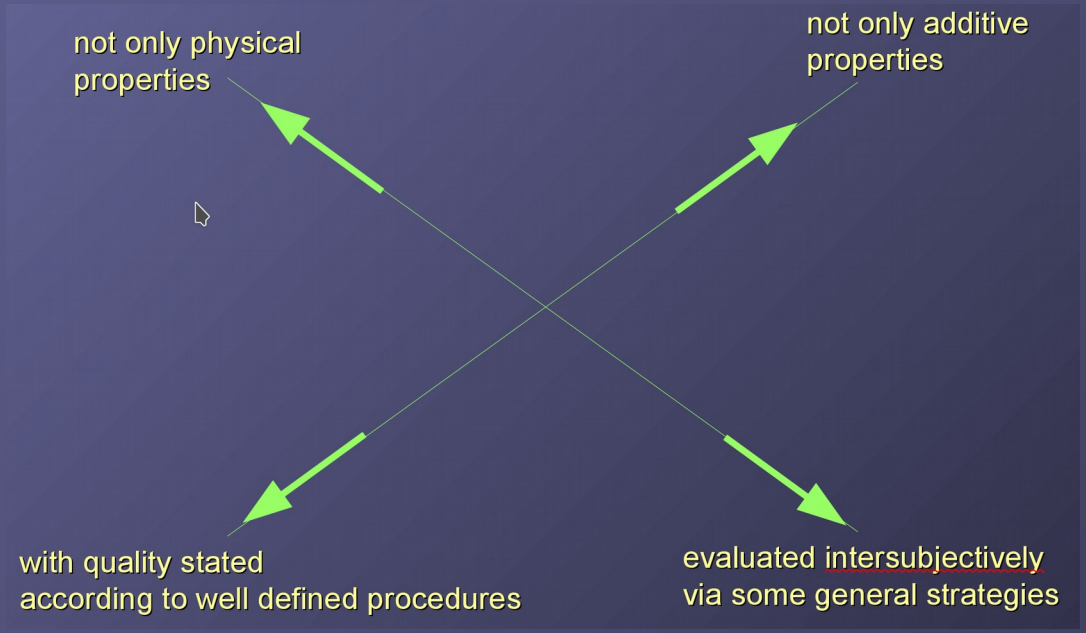
Synthesis

From “strict” to “broad” metrology



“Broad” metrology





(*such a “broad” metrology seems to be a context where psychometricians and engineers can productively work together...*)

Can there be a metrology for psychometricians?

THANK YOU
FOR YOUR KIND ATTENTION

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