Workshops

- Wednesday, November 20, 12:00 PM to 2:00 PM:
  Models of measurement: the general structure

- Thursday, November 21, 9:00 AM to 11:00 AM:
  Models of measurement: measuring systems and metrological infrastructure

- Thursday, November 21, 2:00 PM to 4:00 PM:
  An overview on measurement uncertainty: from the standpoint of the Guide to the Expression of Uncertainty in Measurement (GUM)

- Friday, November 22, 10:00 AM to noon:
  Is the body of knowledge on measurement worth to be a 'science', and what may be the scope of a measurement science?

Workshop 4

Is the body of knowledge on measurement worth to be a 'science', and what may be the scope of a measurement science?

Luca Mari

Università Cattaneo – LIUC, Italy

University of California, Berkeley
Friday, November 22, 2013

Abstract

Measurement is commonly considered a critical but only instrumental process: the body of knowledge related to measurement appears the juxtaposition of multiple contributions, from physics (or chemistry, biology, psychology, economy, ...), to systems theory and control theory, signal theory and statistics, but also information theory and computer science, philosophy of science and ontology. In perspective, also political science and ethics might be progressively interested in measurement and its social implications. Is there a distinctive, common ground for a science of measurement in the diversity of these topics? The workshop aims at introducing the discussion and proposing some reflections on the actual status of science of such a body of knowledge.

My profile

Luca Mari (M.Sc. in physics; Ph.D. in measurement science) is full professor of measurement science at the Cattaneo University – LIUC, Castellanza (VA), Italy, where he teaches courses on measurement science, statistical data analysis, 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). He is the author or coauthor of several scientific papers published in international journals and international conference proceedings. His research interests include measurement science and system theory.

Some of my recent publications

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

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

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

LM, V.Lazzarotti, R.Manzini, **Measurement in soft systems: epistemological framework and a case study**, *Measurement*, 2009

LM, **A computational system for uncertainty propagation of measurement results**, *Measurement*, 2009

LM, **On (kinds of) quantities**, *Metrologia*, 2009

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

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

LM, **Beyond the representational viewpoint: a new formalization of measurement**, *Measurement*, 2000

«There are two possible outcomes:
if the result confirms the hypothesis,
then you've made a measurement;
if the result is contrary to the hypothesis,
then you've made a discovery.»

attributed to E. Fermi

That measurement is (at least socially) important does not seem under discussion:

«an estimated 80% [of the world trade] is affected by standards and regulations»

where

«the cost to producers and service providers of complying with standards can be 10% of production costs»

[BIPM, Evolving needs for metrology in trade, industry and society and the role of the BIPM (Kaarls Report), Bureau International des Poids et Mesures, 2007, http://www.bipm.org/utils/en/pdf/Kaarls2007.pdf]

measurements being the basis to assess this compliance

According to the VIM,
metrology is the «science of measurement and its application»:

but is there, properly speaking, a science of measurement?

The question is twofold:

- is there a specific body of knowledge about measurement?
- if yes, is it a science?

MBoK = measurement body of knowledge

MS = measurement science

Two hints that MS, if even a MS does exist, has some troubles:

- terminology related to measurement is often idiosyncratic
- the MBoK is often taught as a (small) part of another discipline

(admittedly, physics has a complex relation with measurement: N.R. Campbell even stated that physics «might almost be described as the science of measurement»

[N.R. Campbell, Physics – The elements, 1920])

Two paradoxes of MBoK: 1

From the **historical** point of view:

- in the past, following the (neo-)Platonic tradition numbers were considered “in the world”, and therefore each quantity was assumed having a “true value”, so that measurement was just in charge of acquiring (“discovering”) what is already there
- today the unavoidable role of models is emphasized, and someone concludes that measurement is not so important because everything is the product of an interpretation and in fact “anything goes”, so that measurement is just one more kind of “worldmaking” (and therefore an activity of “invention”)

Two paradoxes of MBoK: 2

From the **disciplinary** point of view:

physical measurement is generally much more effective than social measurement (or assessment: someone questions even about the measurability of non-physical properties and the issue has generated a long lasting debate), but in the recent decades social scientists developed theories on foundations of measurement of which physicists and engineers are mainly unaware

Sometimes measurement science is characterized in reference to another science, X, in particular as

- the quantitative side of X
- the experimental side of X

The underlying idea is that X develops the content and MS adds some methodological component to it

Accordingly, MS would be an ancillary discipline,
and possibly more a technology than a science

And even provided that it is accepted as a science,
how would it be classified in reference to
the Popper's problem of demarcation,
as an experimental (as physics and chemistry)
or a formal (as mathematics and logic) science?

That is, does it generate
experimentally falsifiable statements
or theorems derivable from suitably chosen axioms?

Were measurement science an autonomous science,
it should be possible to exhibit its contents:
what are they?

An option

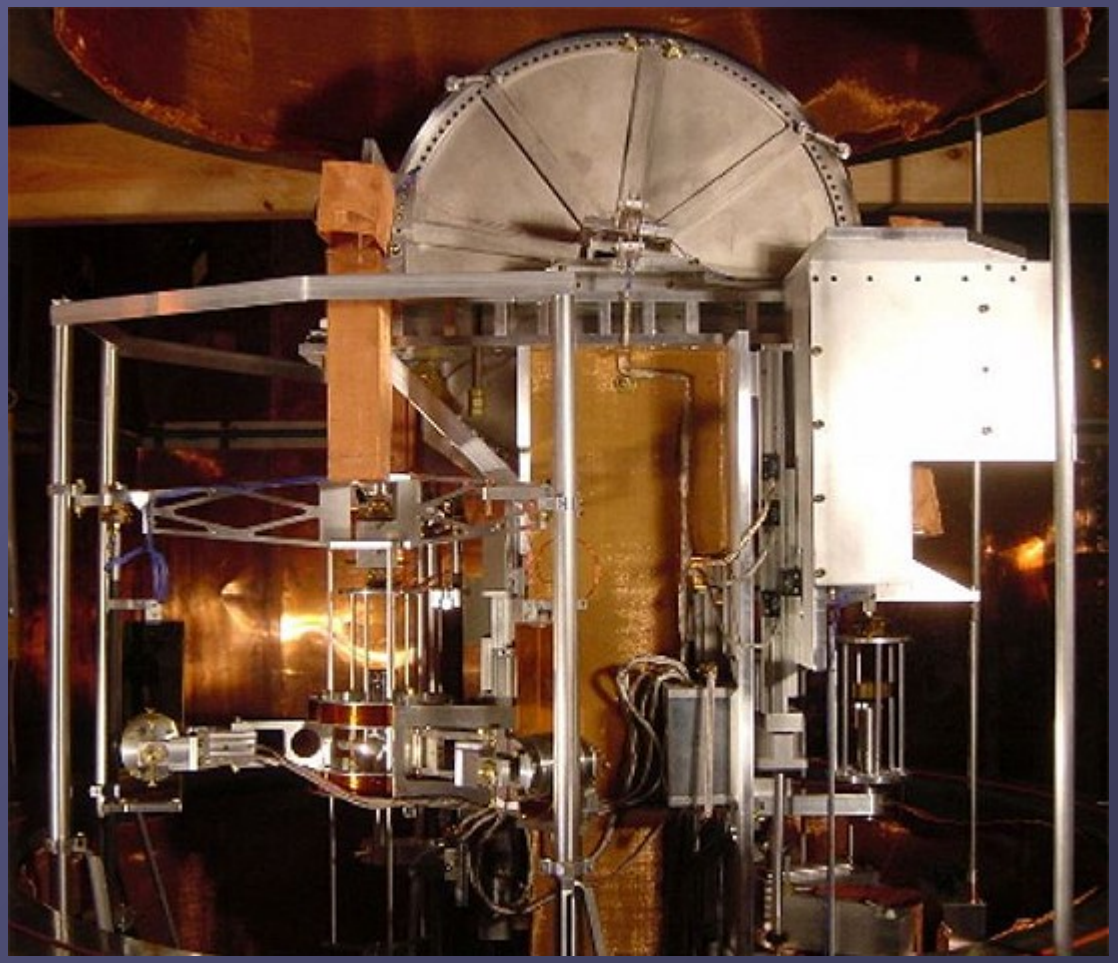
Metrology is the niche area of super-high precision activities related to the definition of quantity units, their realizations in primary standards, and their key comparisons

(see http://kcdb.bipm.org/)

as performed by National Metrology Institutes (NMIs)

(see http://www.bipm.org/en/practical_info/useful_links/nmi.html)

(and in fact in some contexts the VIM definition is reversed, and metrology is considered this specific part of the broader MS / MBoK)



Another option

Metrology is characterized not by content, but by its emphasis on the organizational issues arising from that so peculiar sociotechnical infrastructure that is the metrological system, including measurement standards and traceability chains of calibrations, aimed at guaranteeing the metrological traceability of measurement results and more globally the sustainability and the reliability of the international technical accreditation or certification systems, then more or less superposing metrology and legal metrology

I

(Acts whose publication is obligatory)

DIRECTIVE 2004/22/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 31 March 2004

on measuring instruments

(Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Community, and in particular Article 95 thereof,

Having regard to the proposal from the Commission [1],

(3) Legal metrological control should not lead to barriers to the free movement of measuring instruments. The provisions concerned should be the same in all Member States and proof of conformity accepted throughout the Community.

(4) Legal metrological control requires conformity with specified performance requirements. The performance

These options have
both conceptual and historical justifications,
but they present only a part,
and not the most fundamental one, of the whole picture

Is there a specific body of knowledge about measurement?

Is it a science?

Demarcation

Disciplines like physics:

aim at the knowledge of aspects of the empirical world

aim at producing theories of the empirical world that pass rigorous experimental tests and therefore are considered at least partially and temporarily true

Disciplines like mathematics:

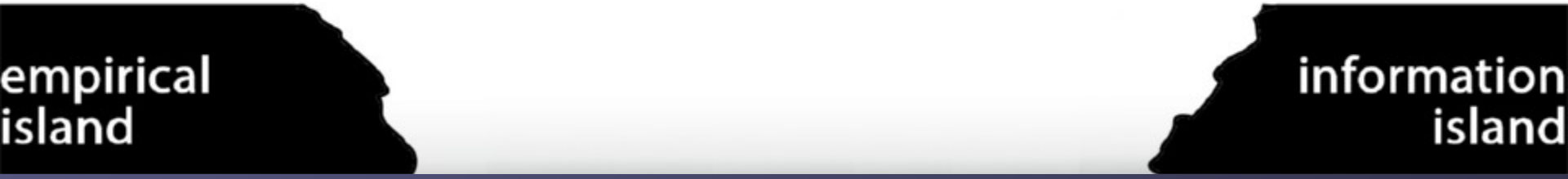
aim at the development of formal structures

aim at producing theories that allow consistent demonstrability of interesting (in some sense of the term) theorems

Islands...

The inhabitants of the **empirical island** are **experimental methods**

The inhabitants of the **information island** are **formal methods**



(What) do they communicate with each other?

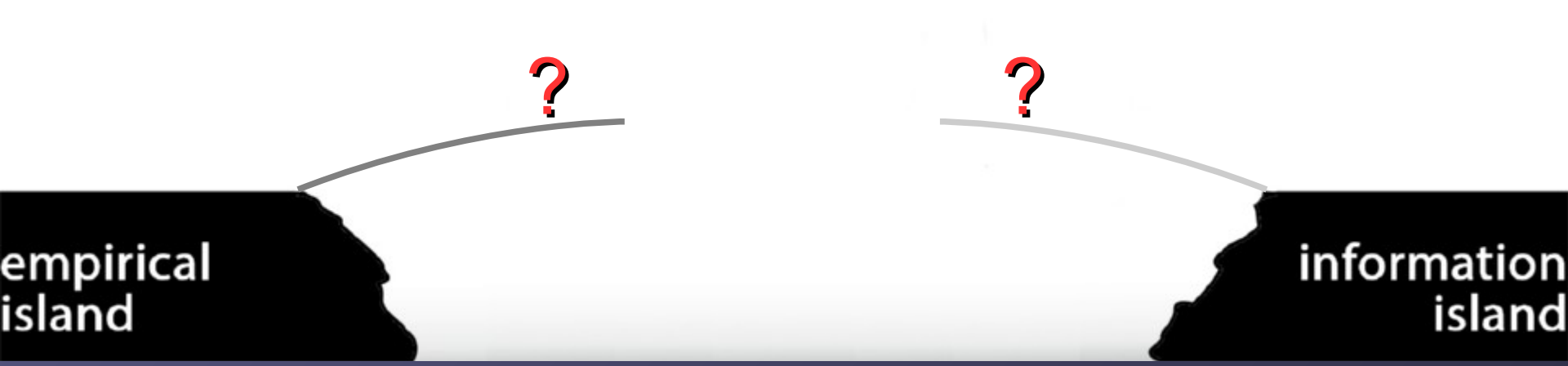
Bridges...

The inhabitants of the **empirical island**

ask the information island for tools to represent information and perform inference from it

The inhabitants of the **information island**

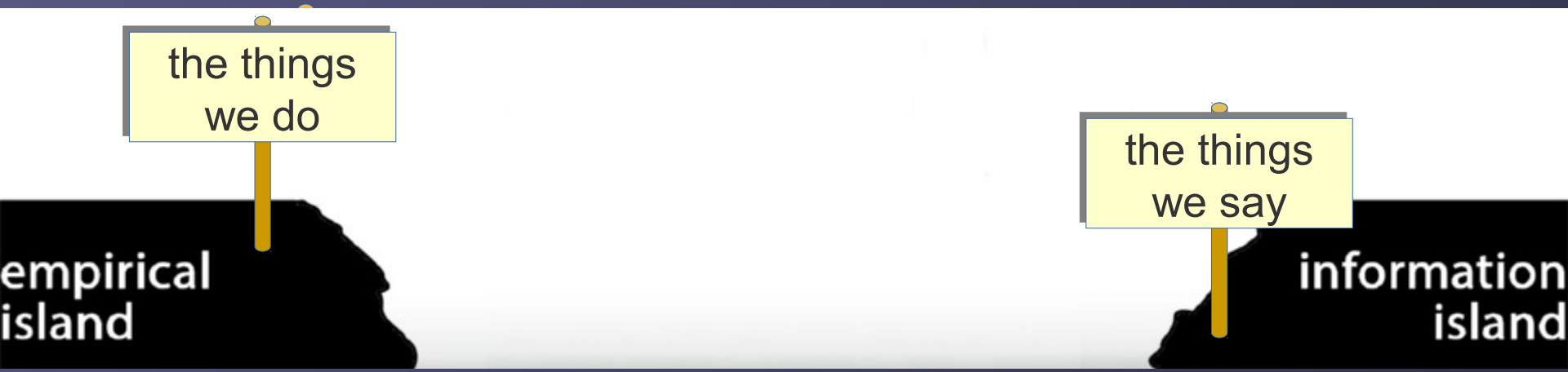
ask the empirical island for inspiration and experimental application



Hence there are bridges...

«... the realm of **things we say**
as distinguished from the realm of **things we do**...»

[P.W. Bridgman, How much rigor is possible in physics?, 1959]



P.W. Bridgman, How much rigor is possible in physics?, in:

THE AXIOMATIC METHOD

WITH SPECIAL REFERENCE TO GEOMETRY AND PHYSICS

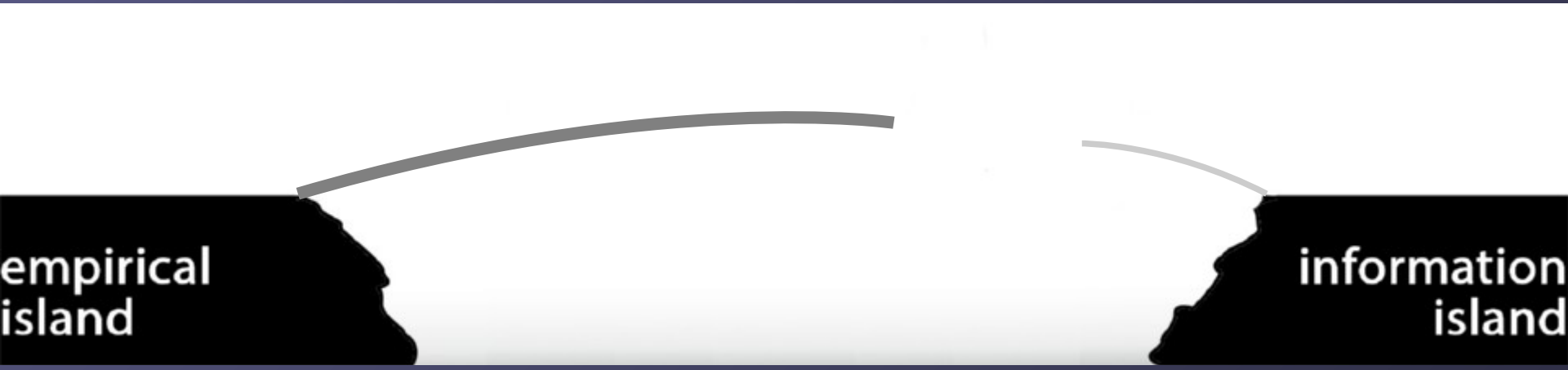
Proceedings of an International Symposium held at the
University of California, Berkeley, December 26, 1957 — January 4, 1958

A critical asymmetry

Islands can be explored and known only by creating maps of them...

... and maps belong to the information island, so that

- the inhabitants of the information island could never cross bridges
- the inhabitants of the empirical island must reach the other island and there learn how to draw maps



Hypothesis /1

Measurement is a privileged tool for building bridges,
and measurement results are high quality maps

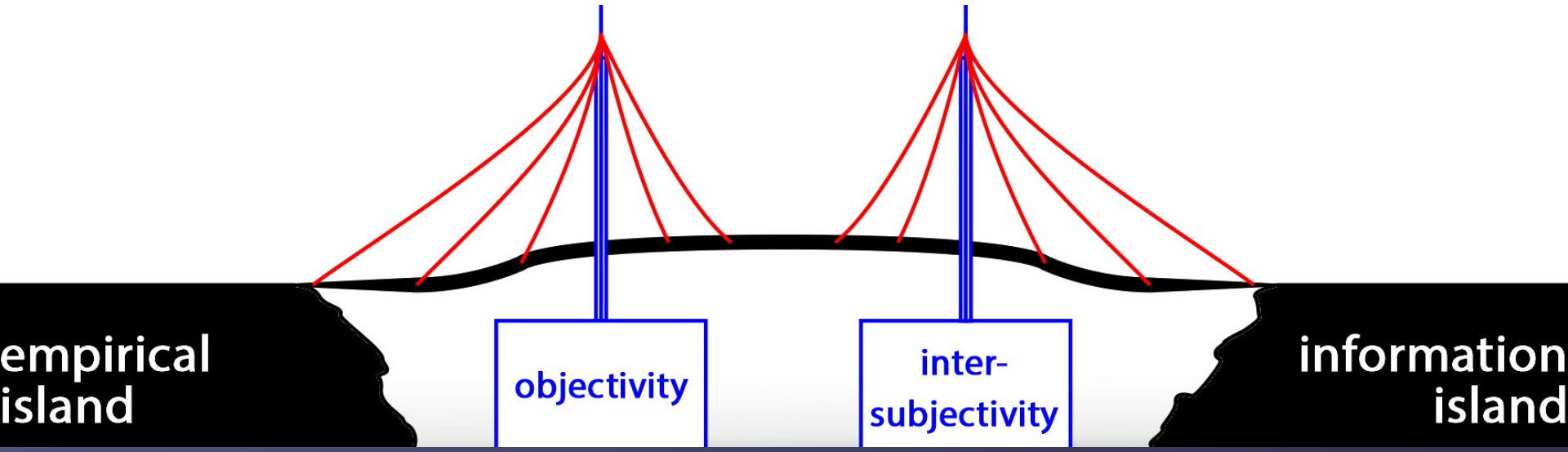
Hence, MS is the architecture of reliable bridges,
that guarantee high quality maps of (portions of) the empirical island

But where do this guarantee come from?

Using numbers as maps
does not give this guarantee

Hypothesis /2

Measurement results are high quality maps because they have **a specified and provable level of objectivity and intersubjectivity**



Yes-no sharpness?

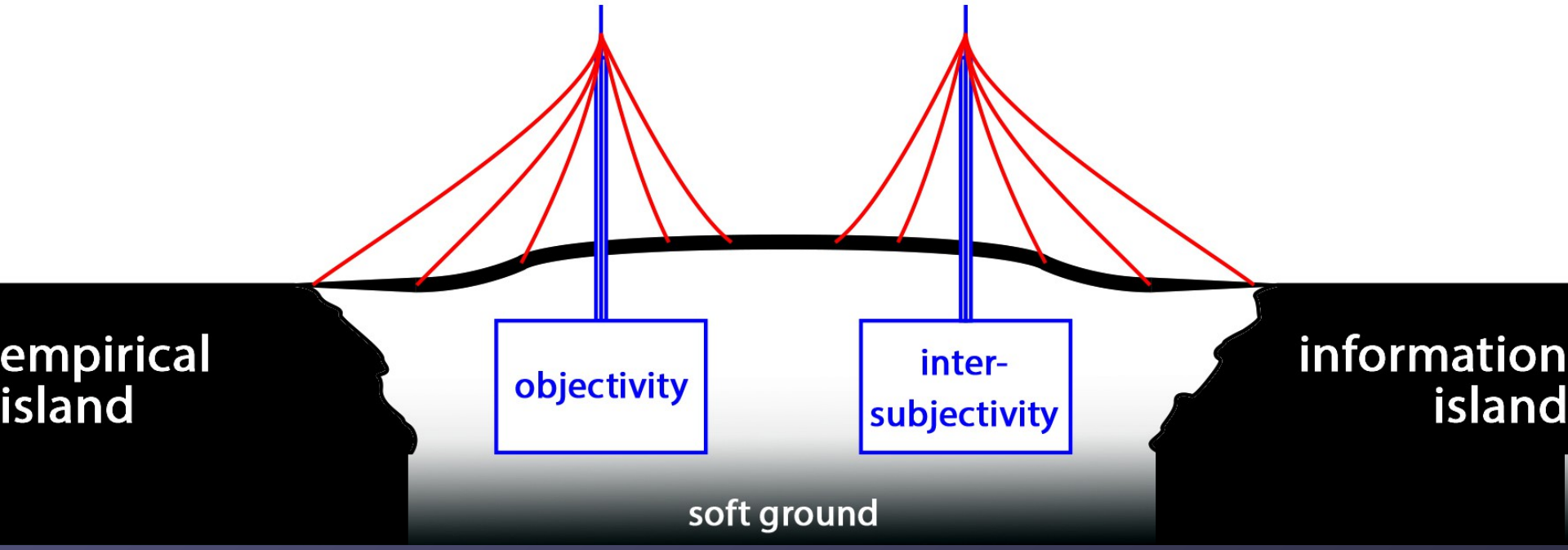
«There are certain human activities which have apparently perfect sharpness. The realm of mathematics and of logic is such a realm, par excellence. Here we have yes-no sharpness – two numbers are either equal to each other or they are not; a certain point either lies on a given line or it does not; there is only one straight line connecting any two points.

Now it is a matter of observation that **this yes-no sharpness is found only in the realm of things we say as distinguished from the realm of things we do**.»

[P.W. Bridgman, How much rigor is possible in physics?, 1959]

Measurements results, that are maps of "things we do", cannot be "yes-no sharp":
they aim at being objective and inter-subjective
but cannot be it completely

The two pillars of objectivity and inter-subjectivity,
by which the bridges built by measurement science are supported,
lean on a soft ground



Until a recent past, the existence of this soft ground was justified with purely experimental reasons: despite their empirical nature, quantities were assumed as having intrinsic true values, that measurement can only estimate due to experimental errors

Accordingly, at least for parts of the empirical island the availability of “true maps” were assumed, generally unknown only because the bridges between the two islands are not stable enough

True maps?

A short tale on “true maps”

«In that Empire, the Art of Cartography attained such Perfection that the map of a single Province occupied the entirety of a City, and the map of the Empire, the entirety of a Province. In time, those Unconscionable Maps no longer satisfied, and the Cartographers Guilds struck a Map of the Empire whose size was that of the Empire, and which coincided point for point with it. The following Generations, who were not so fond of the Study of Cartography as their Forebears had been, saw that that vast Map was Useless, and not without some Pitilessness was it, that they delivered it up to the Inclemencies of Sun and Winters. In the Deserts of the West, still today, there are Tattered Ruins of that Map, inhabited by Animals and Beggars; in all the Land there is no other Relic of the Disciplines of Geography.»

[J.L. Borges, Collected fictions, 1999]

“On Rigor in Science”

“On Rigor in Science”

Maps cannot be the territory

(and if they were, they would be useless)

Is this cultural relativism,
or has this something to do with it?

No!

Acknowledging the pragmatic, knowledge-based nature of measurement does not hinder realism

«An interpretive hypothesis, such as '*e* is the electron charge', involves the assumption that there are certain physical objects, e.g., electrons, that is, certain things out there, independent of the mind.

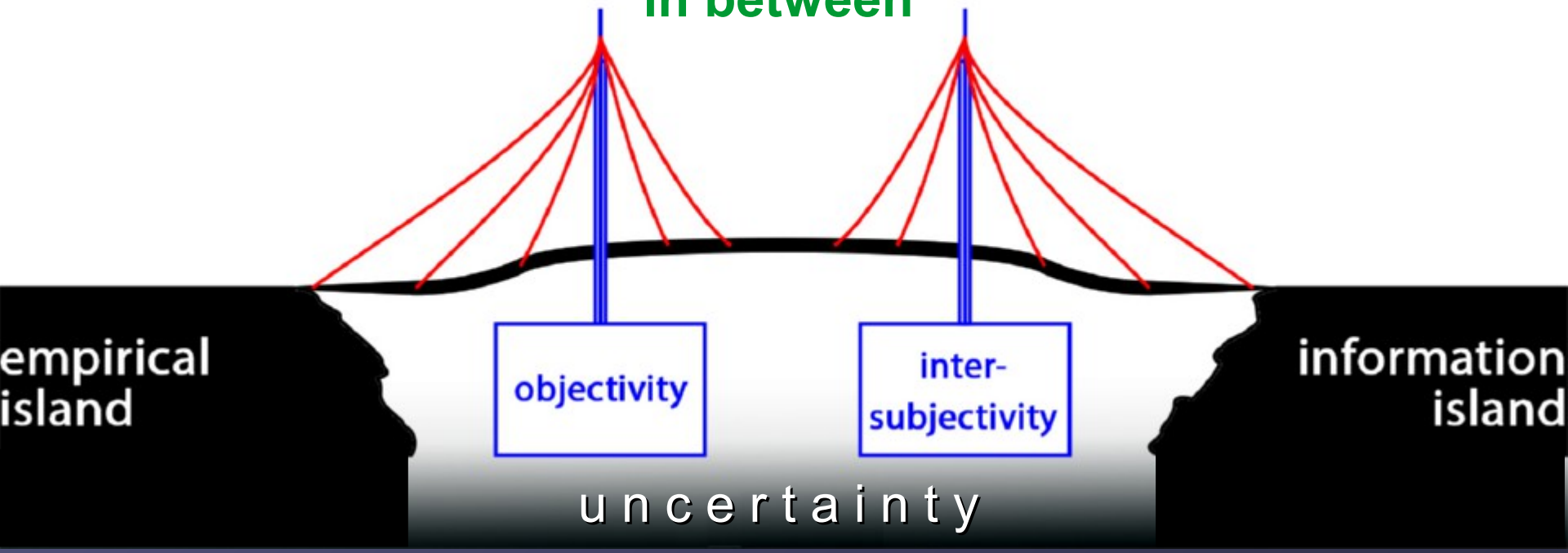
But this is an assumption that may turn to be false. Therefore one speaks of the hypothetical or intended referent of a theory – in the philosophical not the psychological sense of the word. Nonetheless **a physical theory does talk, even though hypothetically, of real entities: total fictions are left to literature**.»

[M. Bunge, Foundations of physics, 1967]

While natural and social sciences
build maps
of the empirical island...

... and mathematics
studies how to build maps ...

... measurement science operates in between



Measurement science operates in between

MS shares features
of both experimental and formal sciences

and therefore

is neither a purely empirical nor a purely formal BoK

Measurement science operates in between

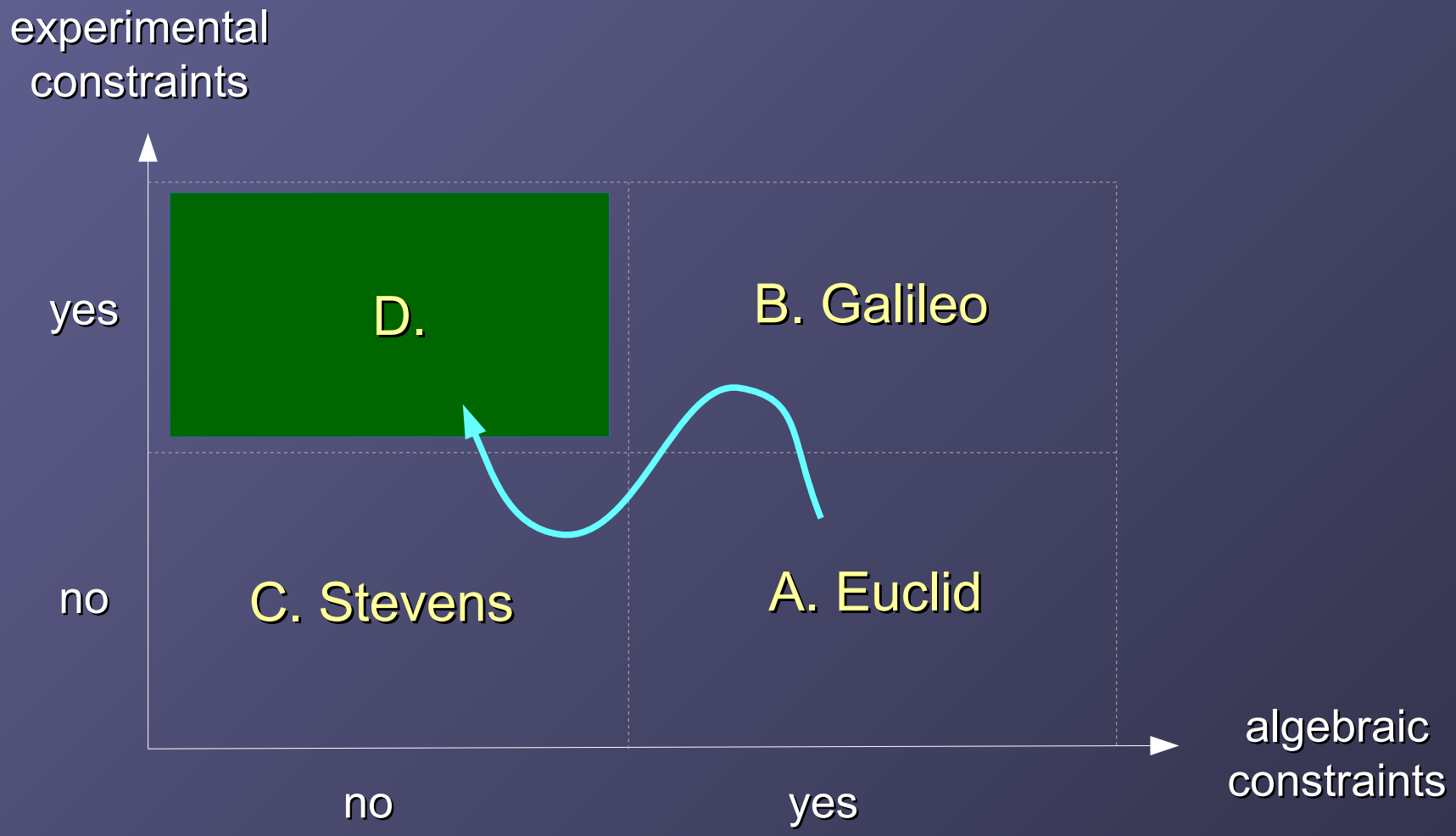
This is its apparent weakness:

bridges might be considered
just as tools to make connections...

... but this is also its strength:

experimental sciences and technology
need such connections

From ‘measure’ to ‘measurement’...



Is MS the science
of valid experimental information processes?

THANK YOU
FOR YOUR KIND ATTENTION AND HOSPITALITY

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