

Usefulness of useless science

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youtube: Fiore scienza inutile

If the scientific results financed by taxpayer money are “public goods”, is it useful or even ethical to spend billions Euros/\$ to search for an elementary particle? Or to visit a Jupiter satellite and look for water on Mars? Or to observe a galaxy at the edge of the Universe?

Competition has become one of the major driving forces for research. But are we sure that the competition-driven science model is truly the best one to make *useful* science?

More, is the very concept of knowledge changing today? The scientific method introduced by Galileo more than 400 years ago resisted at least three industrial revolutions. Are we sure it is still valid and applicable today, in the midst of the fourth industrial revolution?

Founded during the
'30s the Princeton
Institute for
Advanced Studies

The Usefulness of Useless Knowledge

— Abraham Flexner



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1939: "Scientists without teaching or administrative duties, so that they can concentrate on deep thoughts, as far as possible from contingent problems and practical applications."



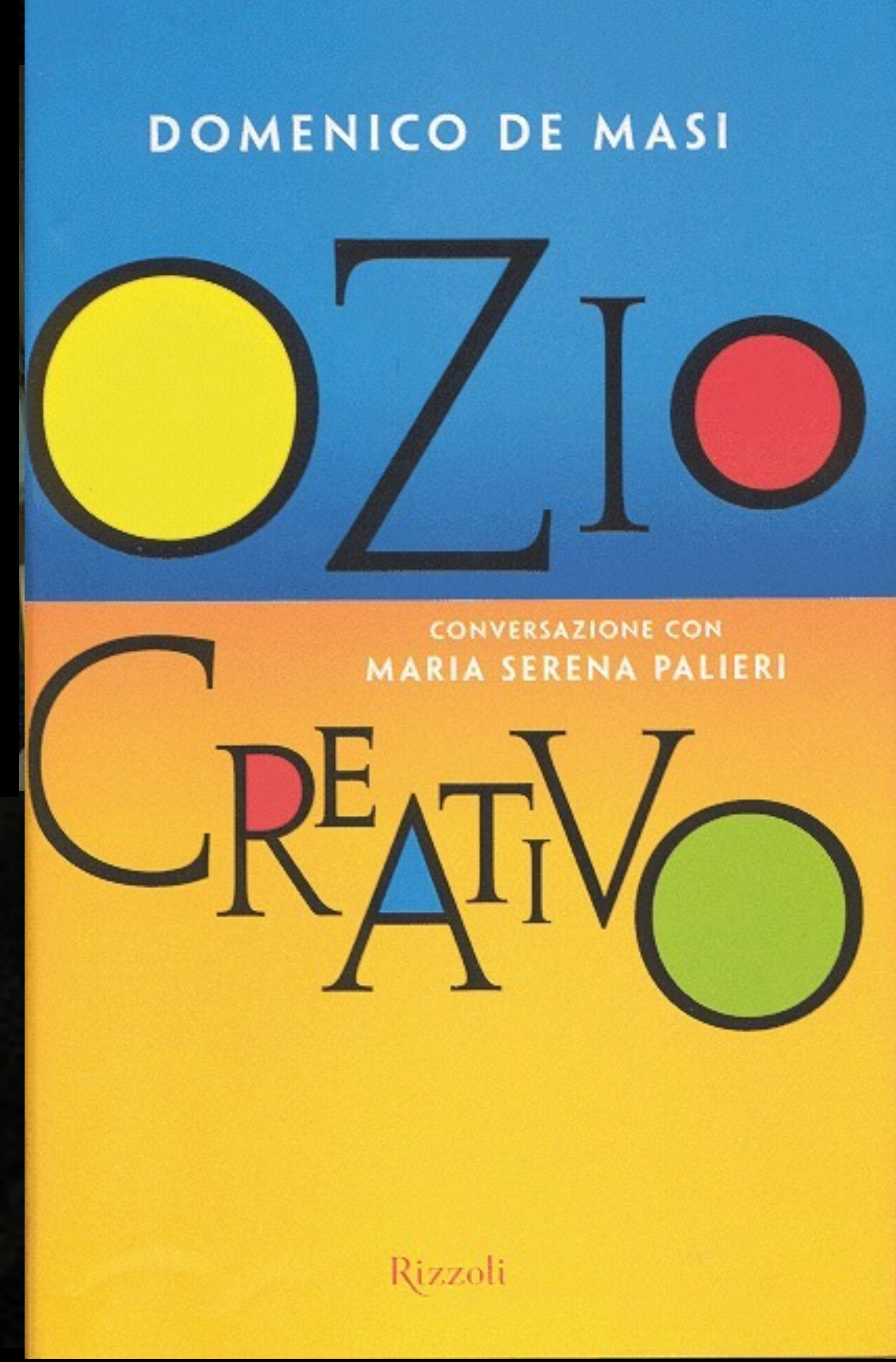


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*“When work to produce wealth,
the study to produce knowledge,
the game to produce well-being
they hybridize and get confused allowing the
creative act”*

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duties, so that they can concentrate on deep
thoughts, as far as possible from contingent
problems and practical applications.”*



Institute of Advanced Studies

Einstein

letter to President Roosevelt

Oppeneimer

Director of the Manhattan project

Godel, Turing, von Neumann:

*I am thinking at something much
more important than bombs:
computers*



Porter: applied research and research not yet applied

It may take decades, if not centuries, to find applications of profound theories. Examples:

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DNA 1953 —> Insuline from genetic engineering 1982

Obvious conclusion

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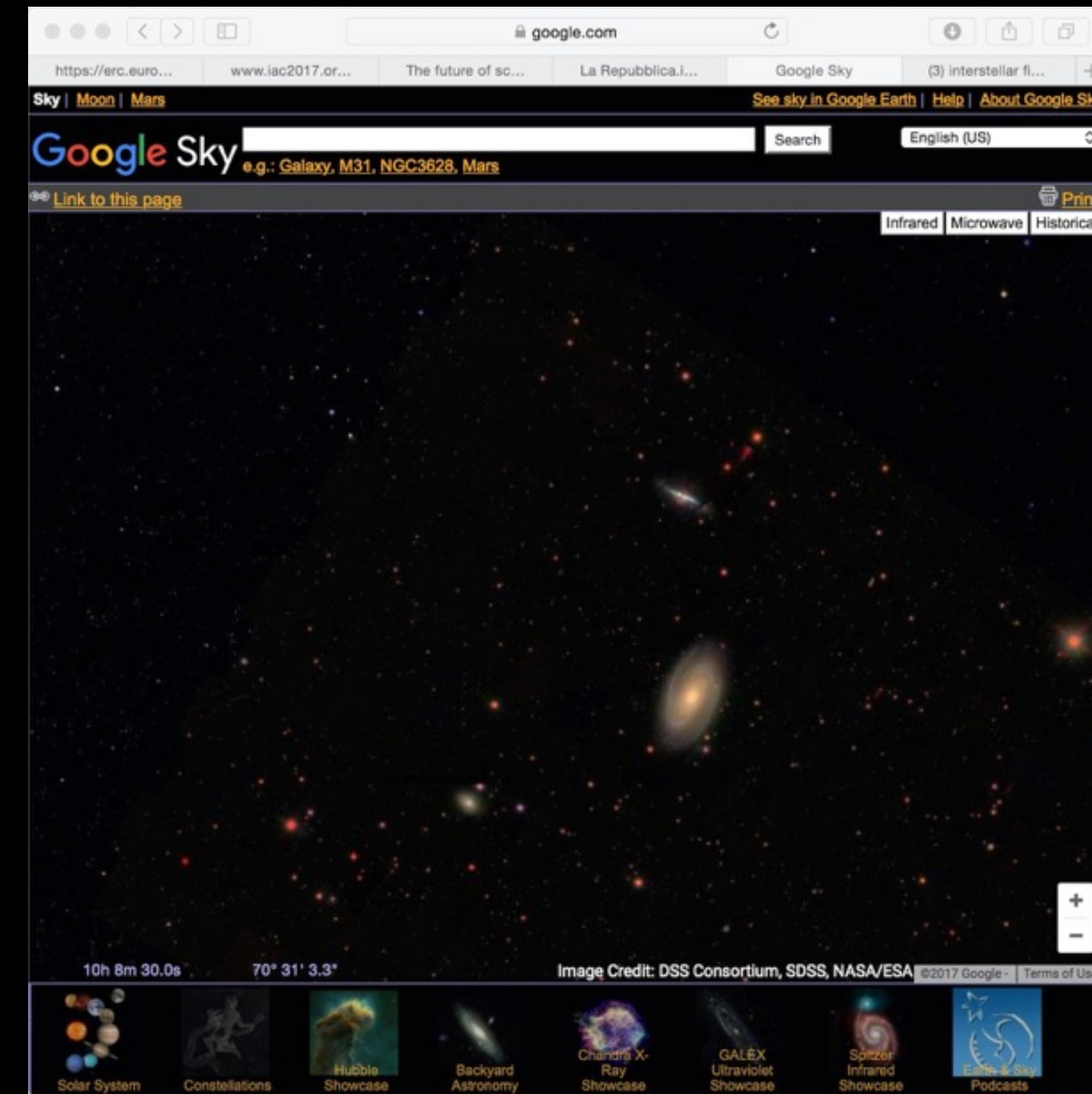


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Observations of Gaia will be at the base of the galactic googlemap ..



So obvious that...

In the world, spending on pure, basic research grew exponentially at the turn of the Second World War, during the Cold War and until the fall of the Berlin Wall.

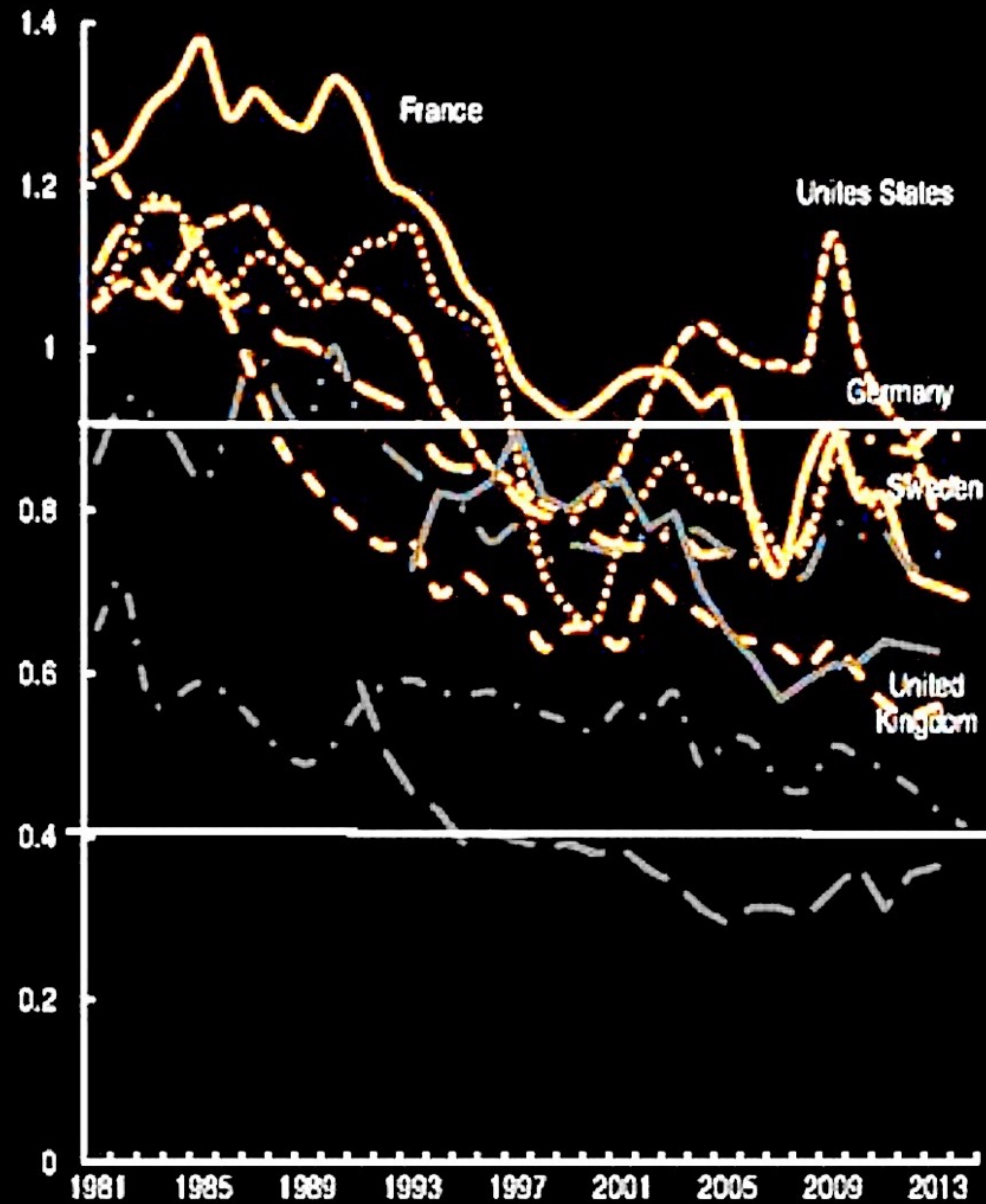
World War II: radio / radar / nuclear / rockets

Cold war: nuclear / rockets

Sputnik/Gagarin: space race, NASA, Apollo project (> 3000 scientific articles, vs. 500 Martian rovers, 1400 ISS, 4000 Cassini)

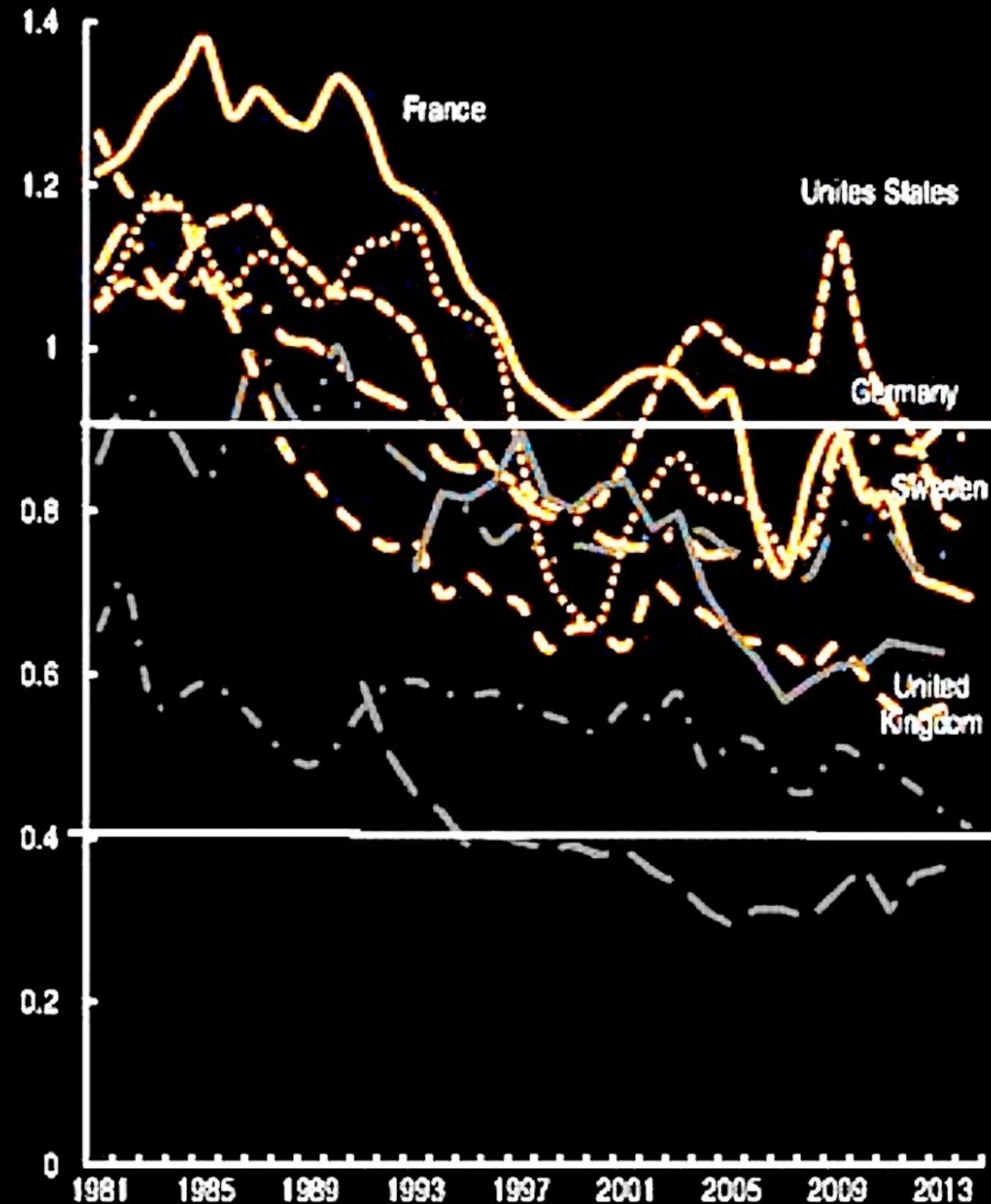
Startup: Silicon Valley (Stanford, Berkeley) , Boston Area (MIT e Harvard)

But...



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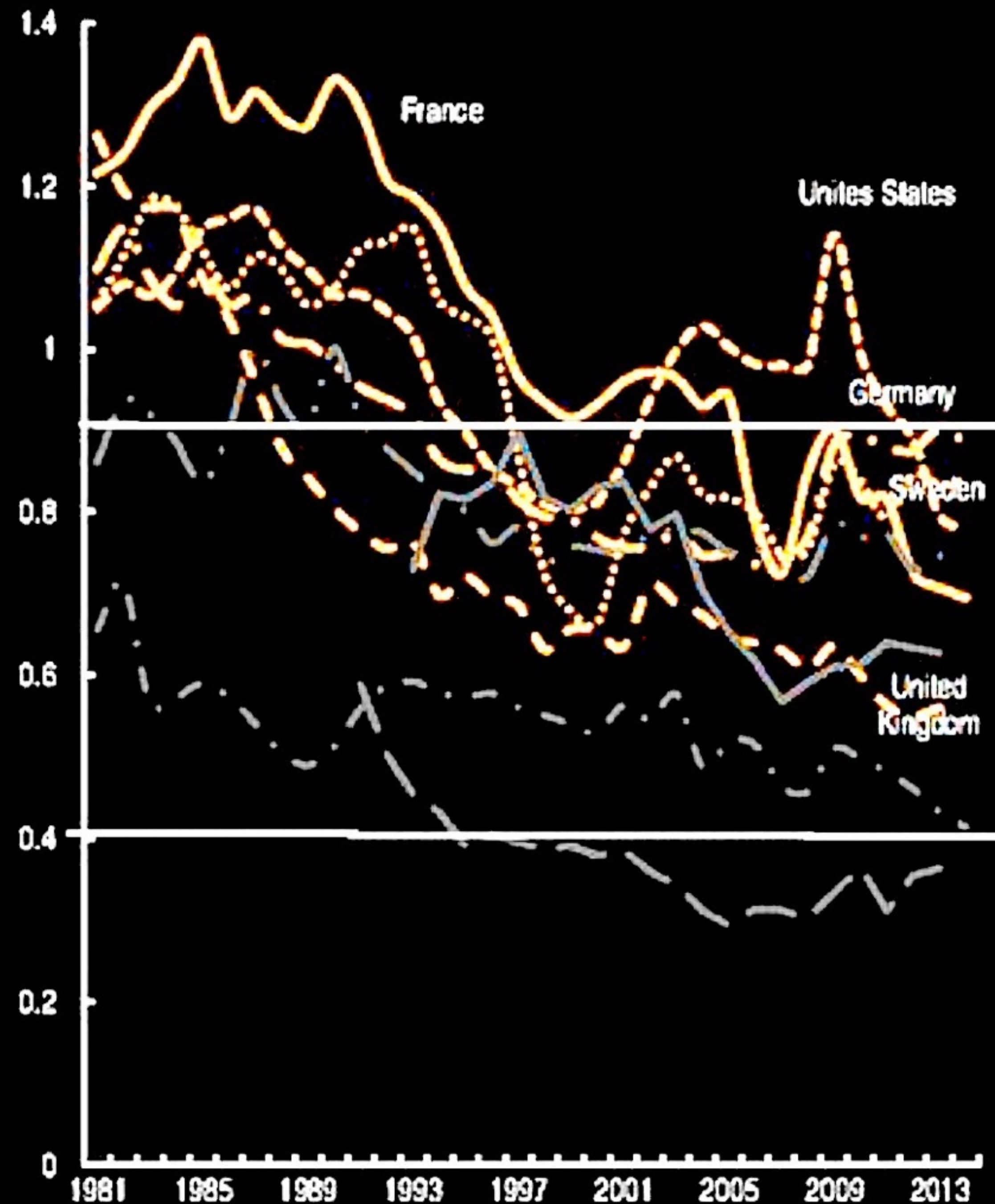
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USA ~ 2% GDP in the 60s, today 0.85% (half for defense research)

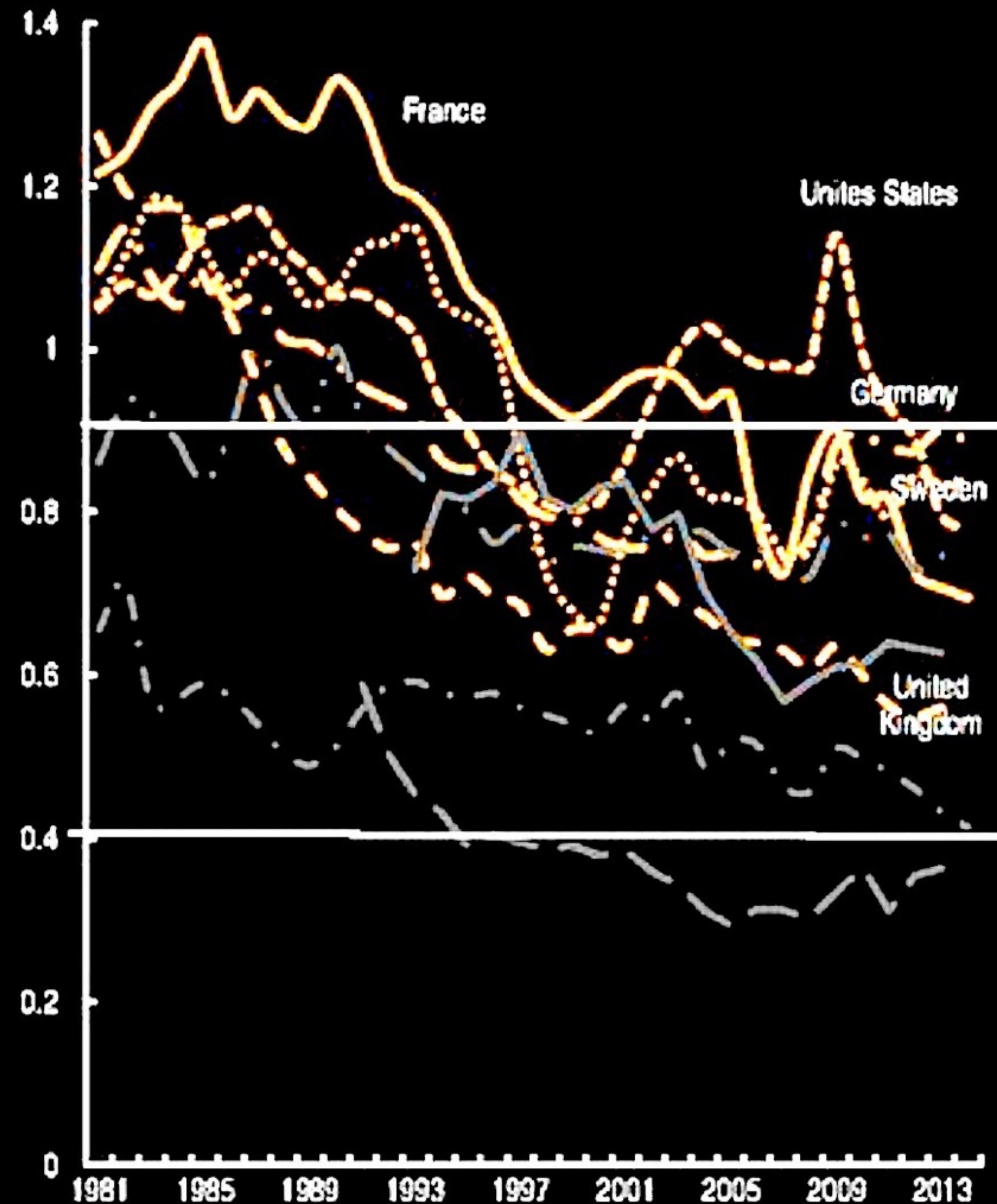


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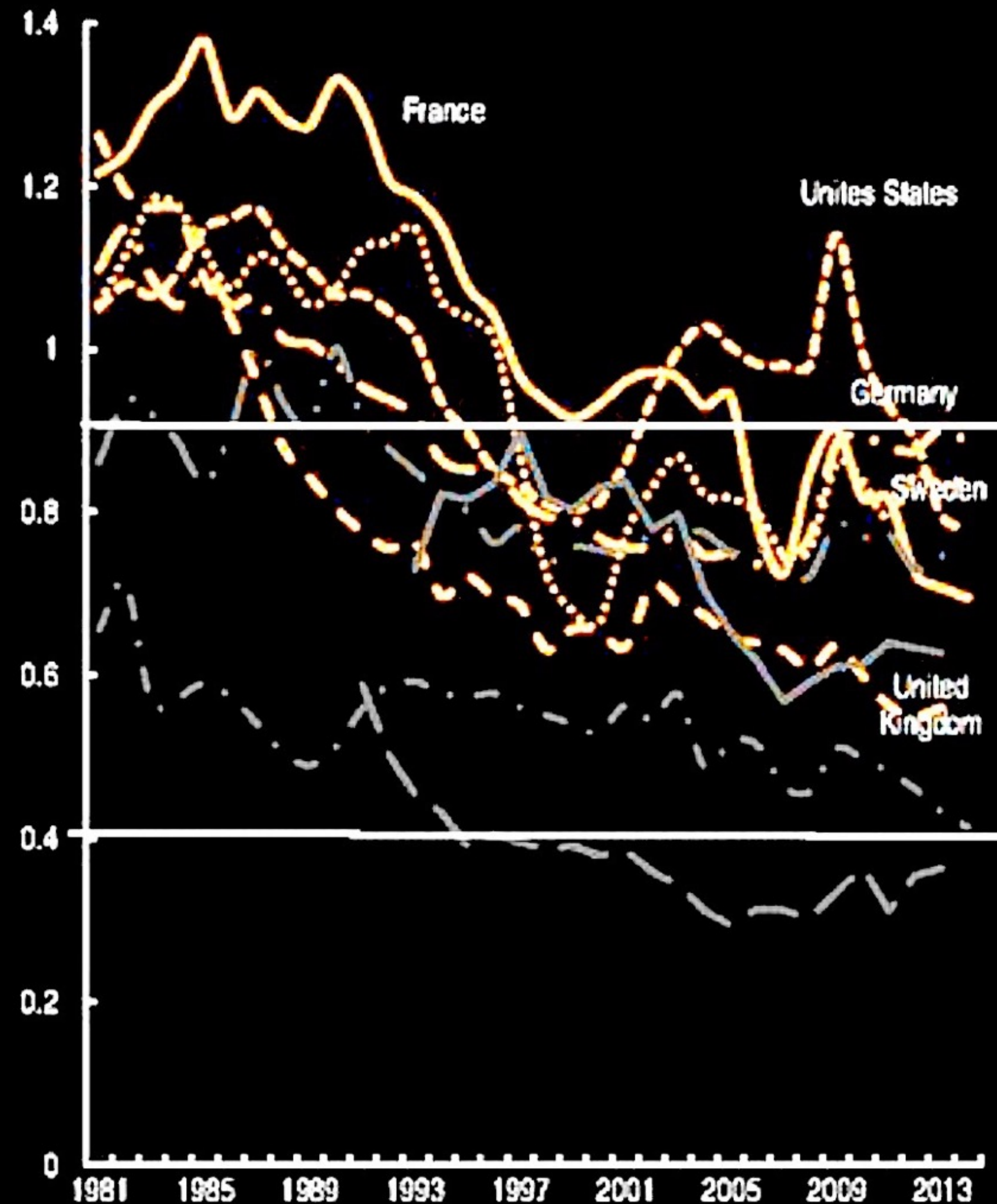
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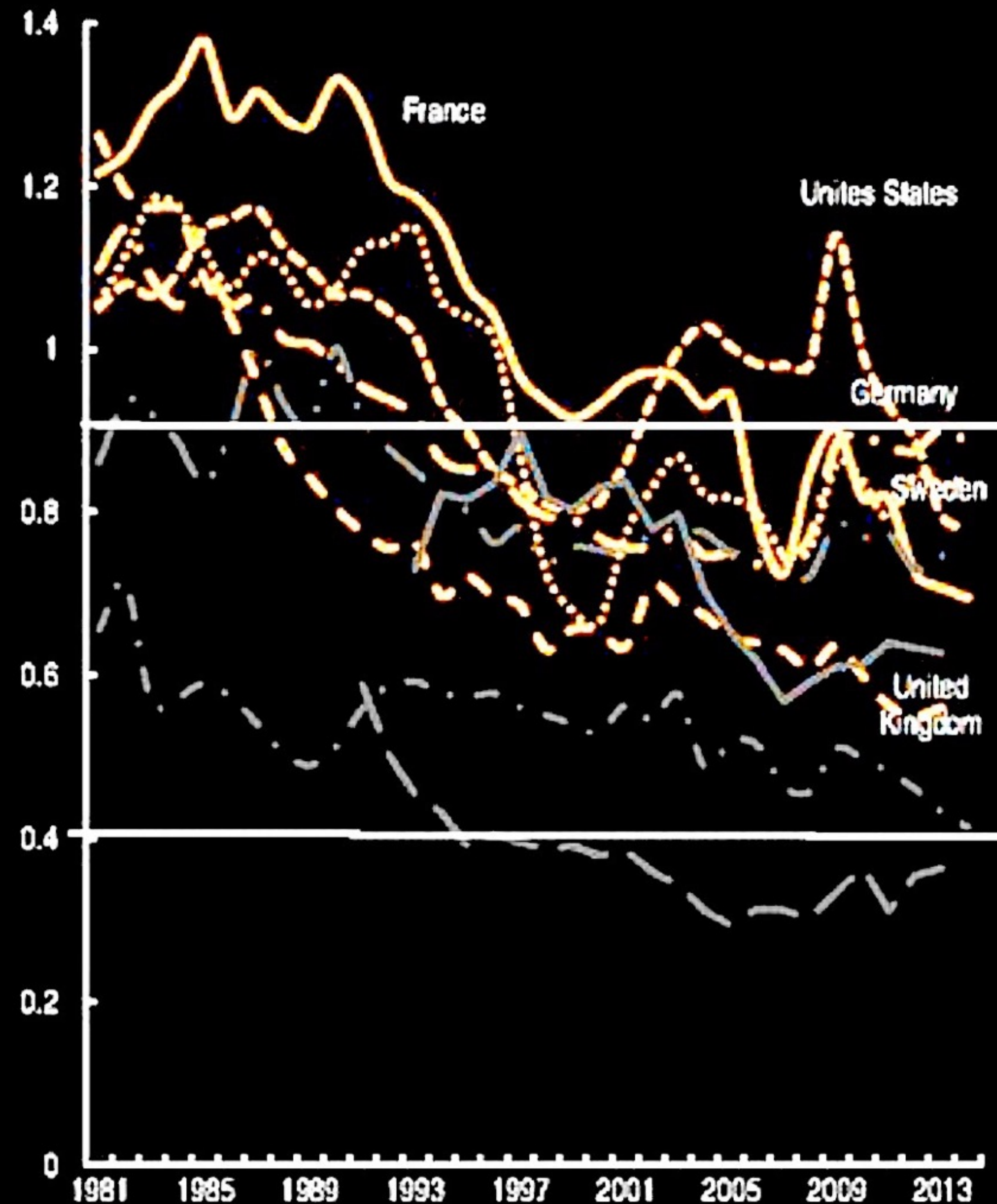
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Private sector invests less and less in basic research: USA 6% of the total. Example of Bell Lab (8 Nobel laureates) today impractical

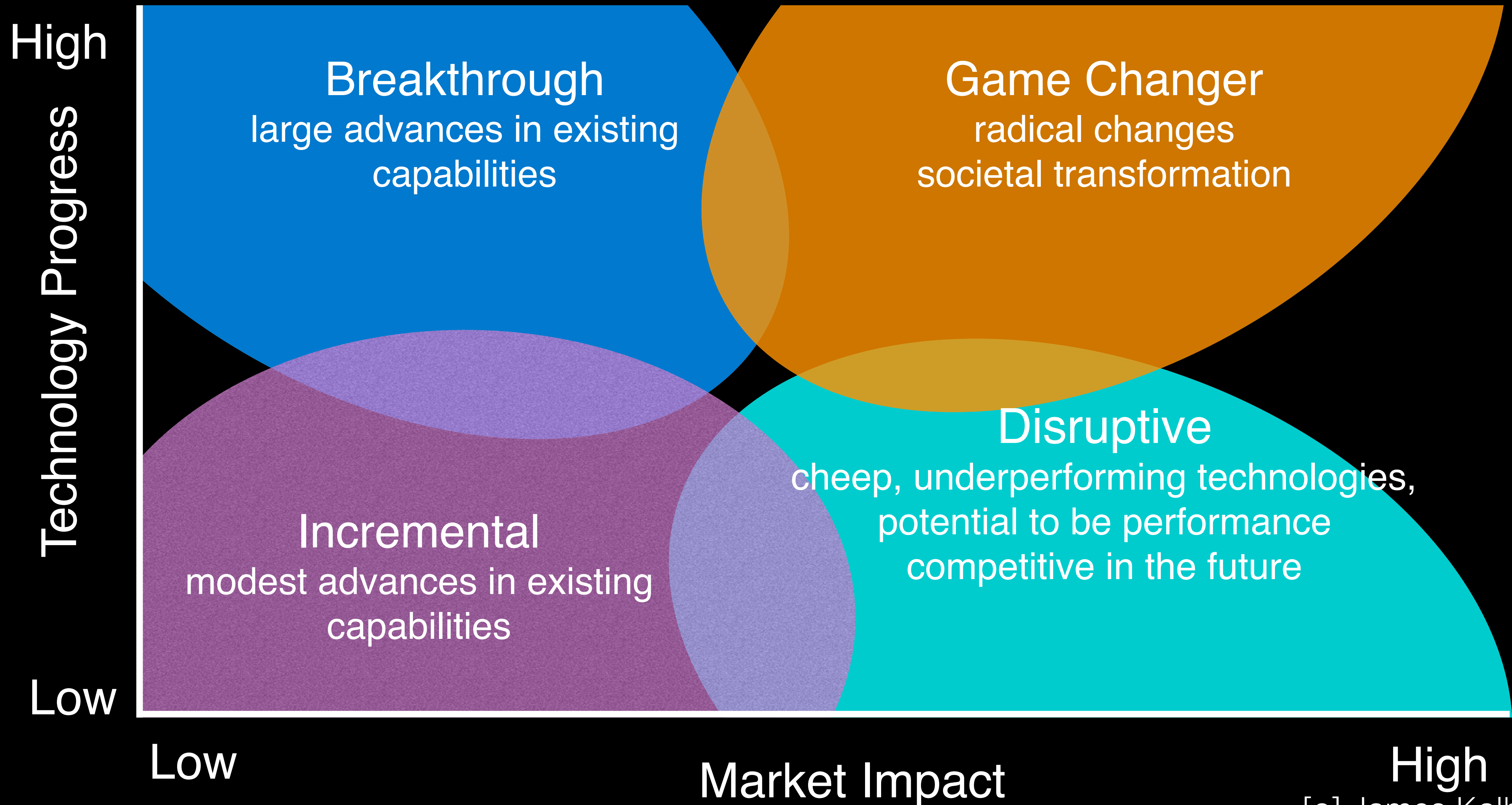


Investments in research 2014

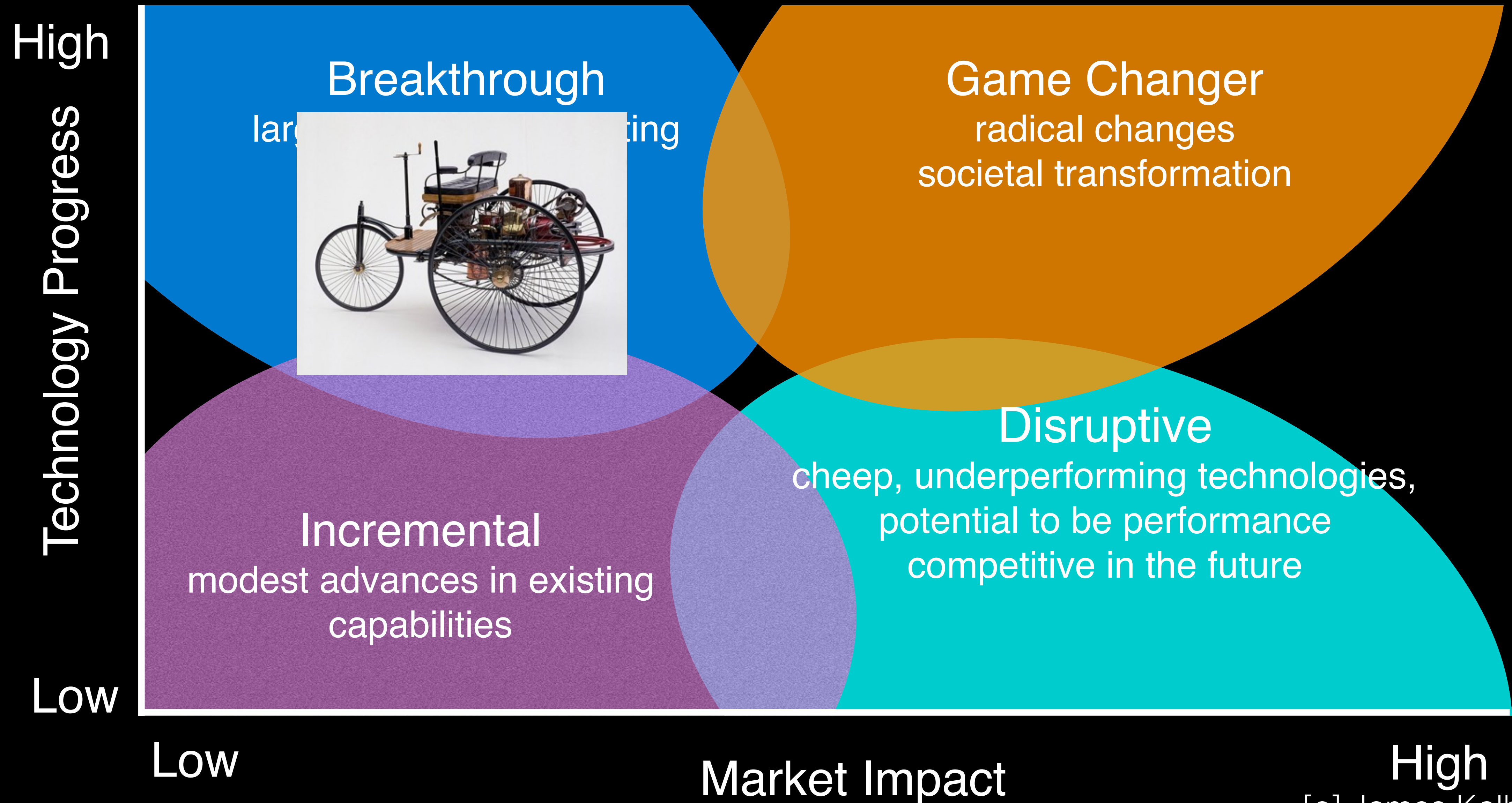
In the world, on average, the public sector invests in research ~ 25% of the total

Country	Public GDP fraction	Total	Abroad	Total G\$	Basic research
Italia	0.56%	1.2%	0.07%	27.7	50%
Francia	0.8%	2.2%	0.26%	58.7	55%
UK	0.5%	1.7%	0.42%	44.2	35%
GER	0.8%	2.0%	0.20%	108.8	
EU	0.67%	2.0%		365.8	
USA	0.85%	2.75%	0.08%	457.0	
China	0.8%	2.0%	-	368.7	25%
Japan	0.8%	3.6%	-	166.9	
Korea	1.0%	4.3%	-	72.3	

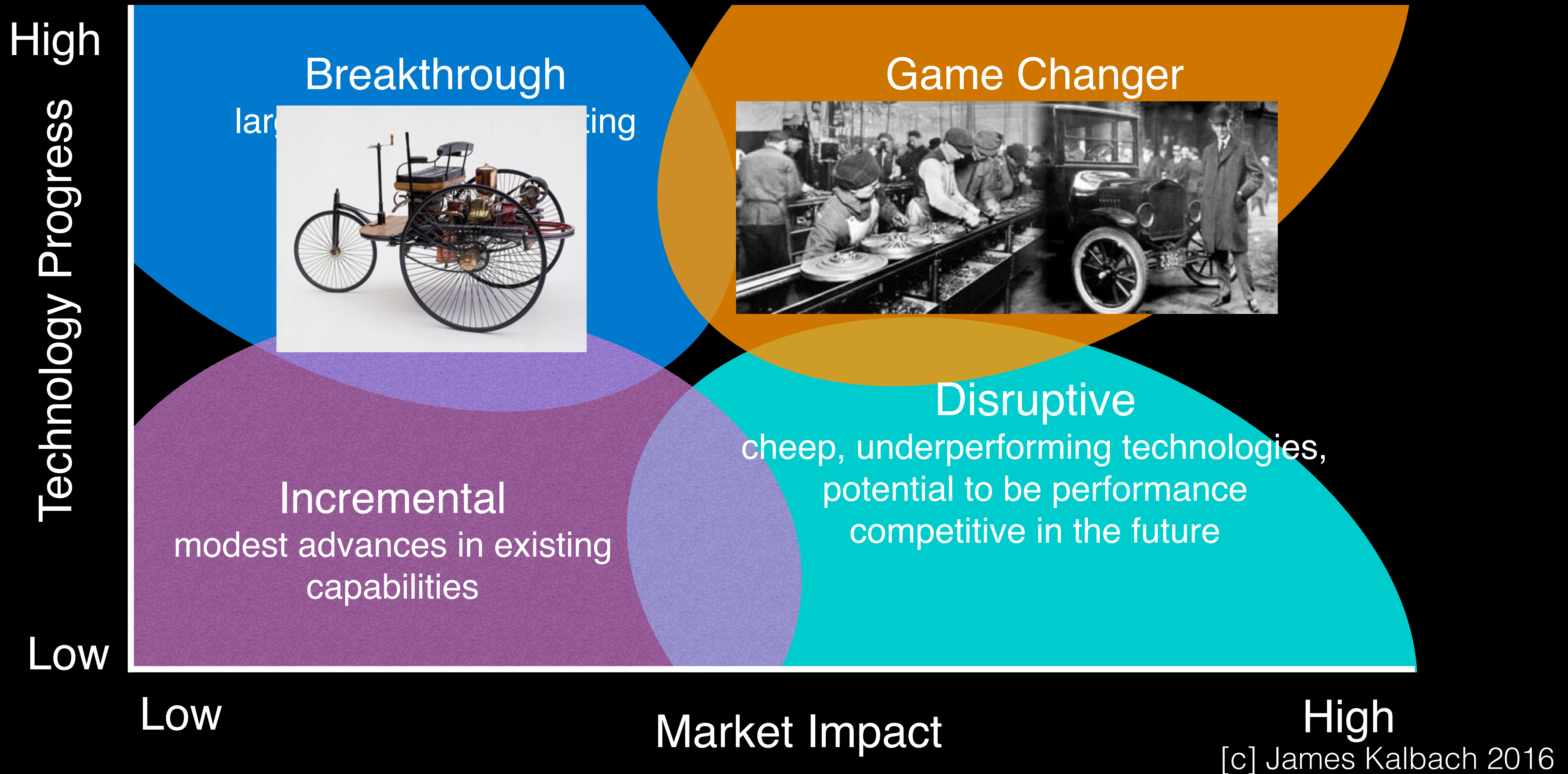
Which research?



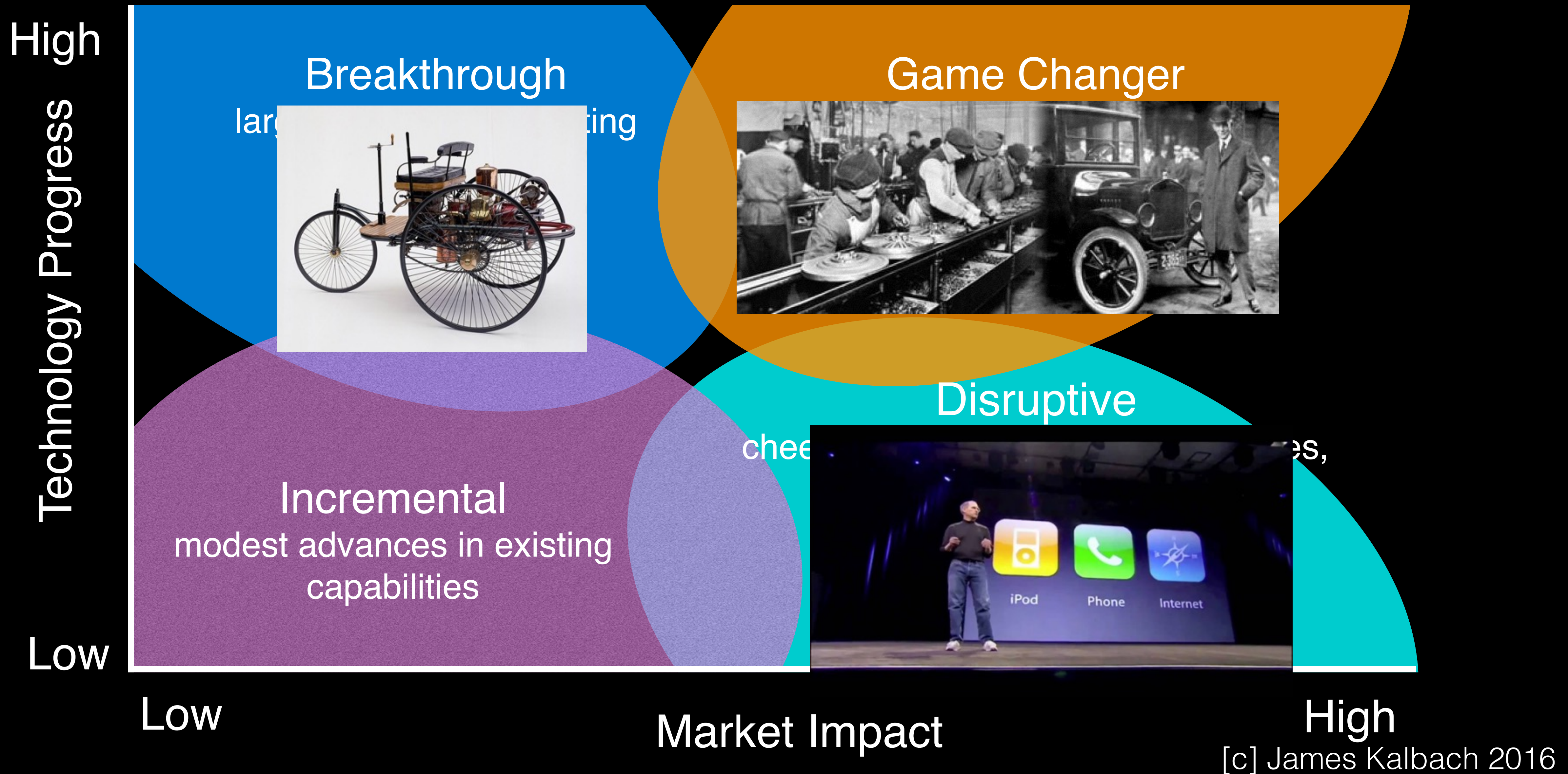
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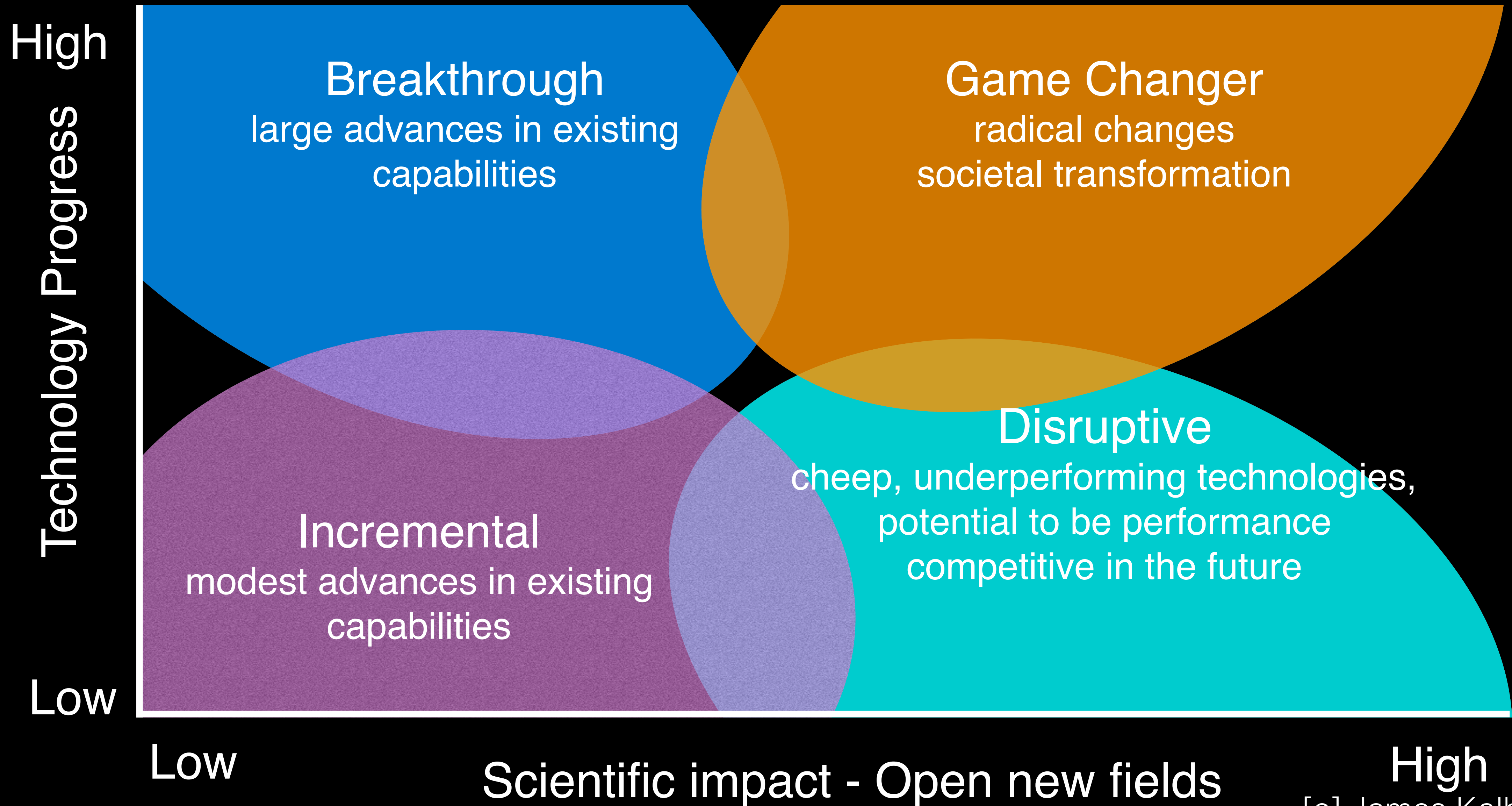
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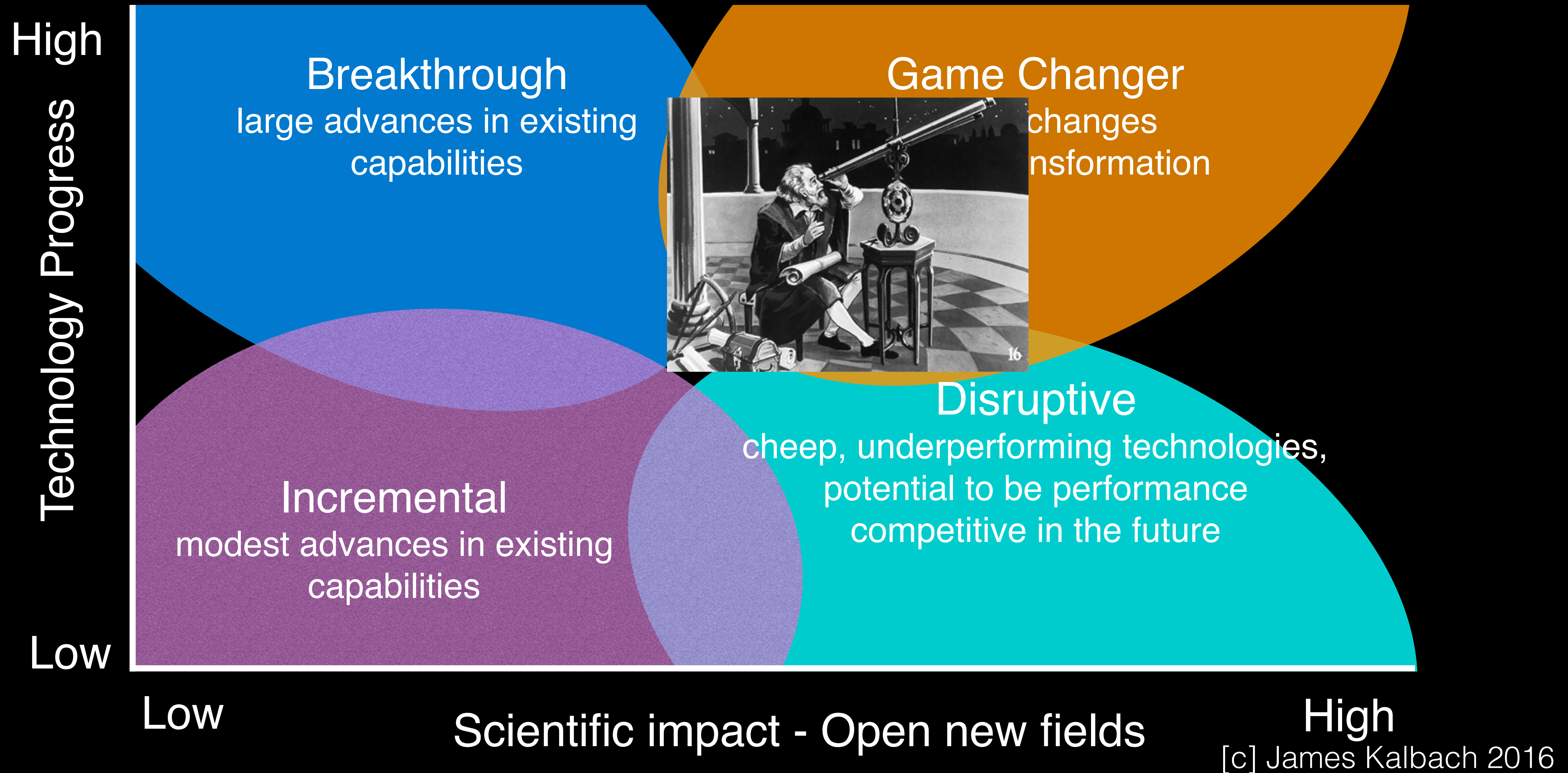
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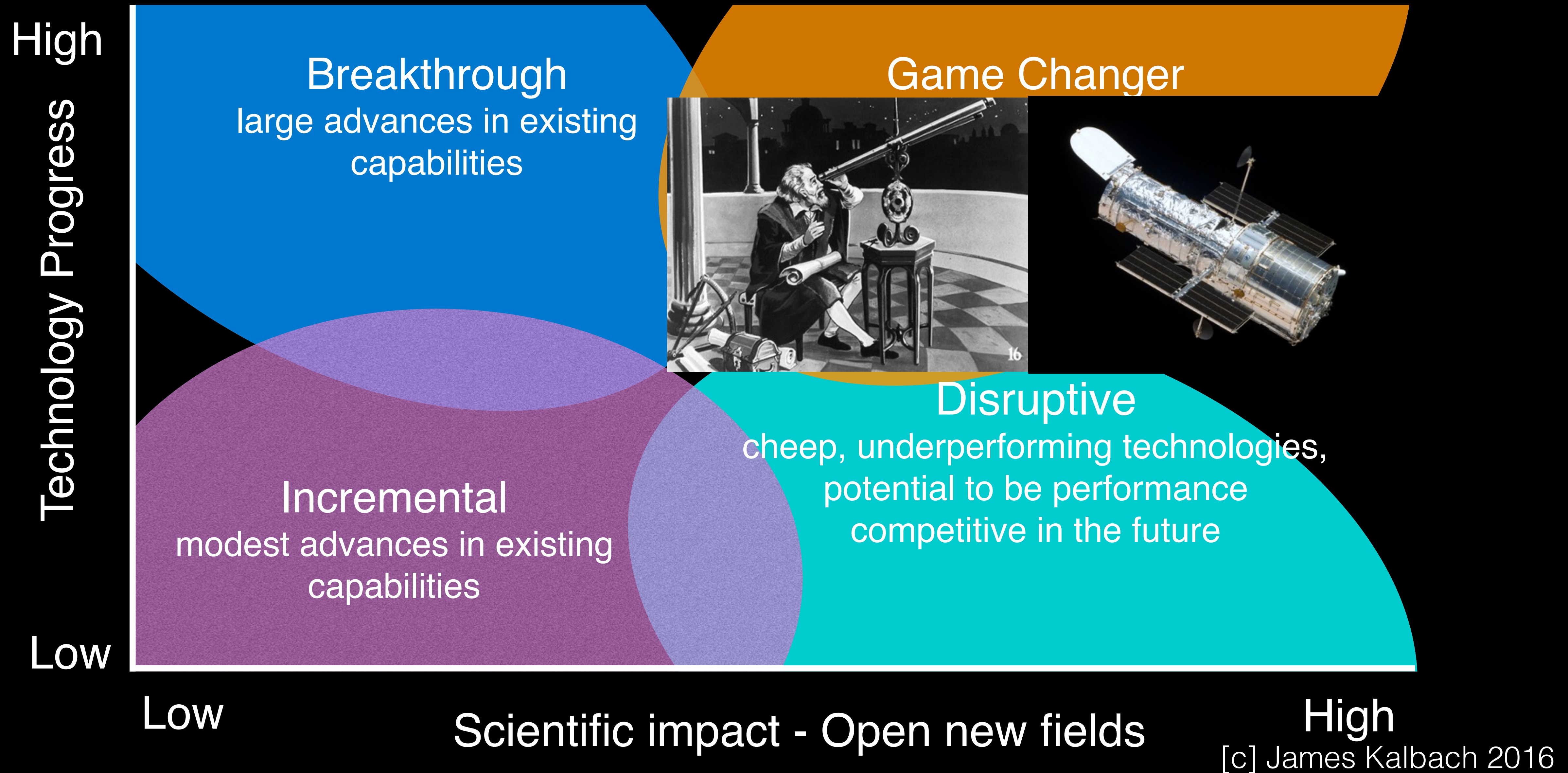
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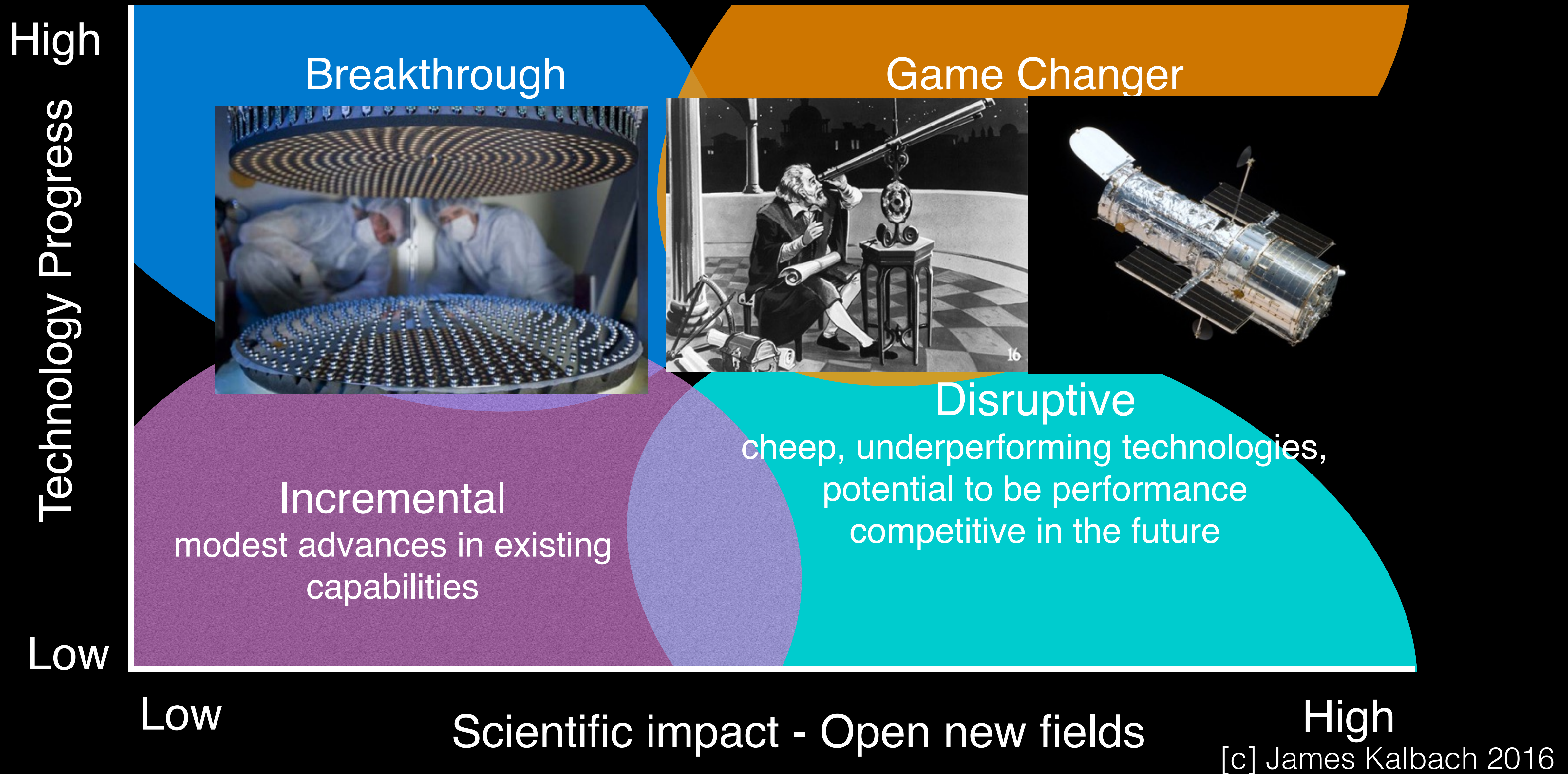
Which research?



Which research?



Which research?



Which research?

High

Technology Progress

Low

Breakthrough



Game Changer



Disruptive

arming technologies,
e performance
in the future



Incremental
modest advances in existing
capabilities

Low

Scientific impact - Open new fields

High

[c] James Kalbach 2016

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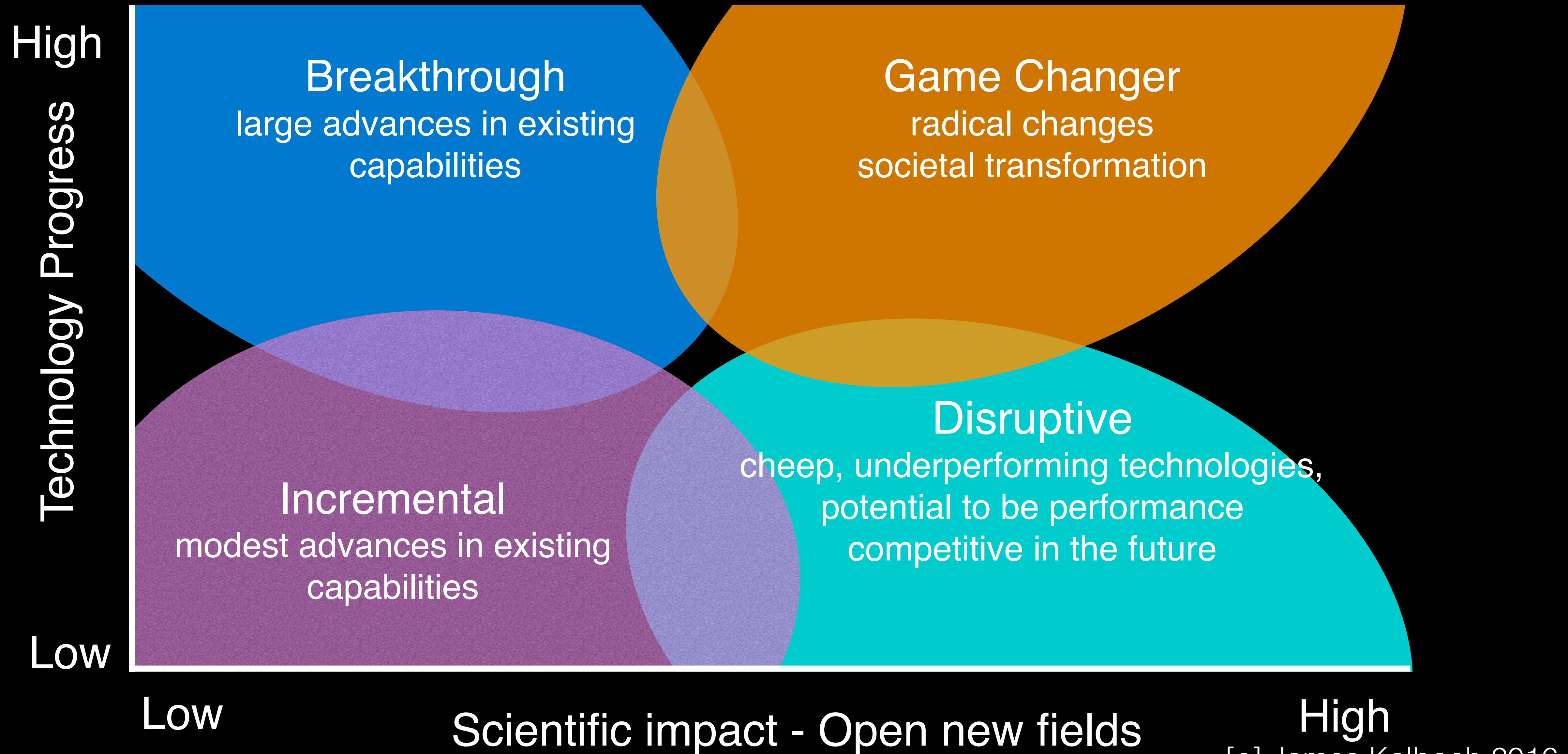
Low

Scientific impact - Open new fields

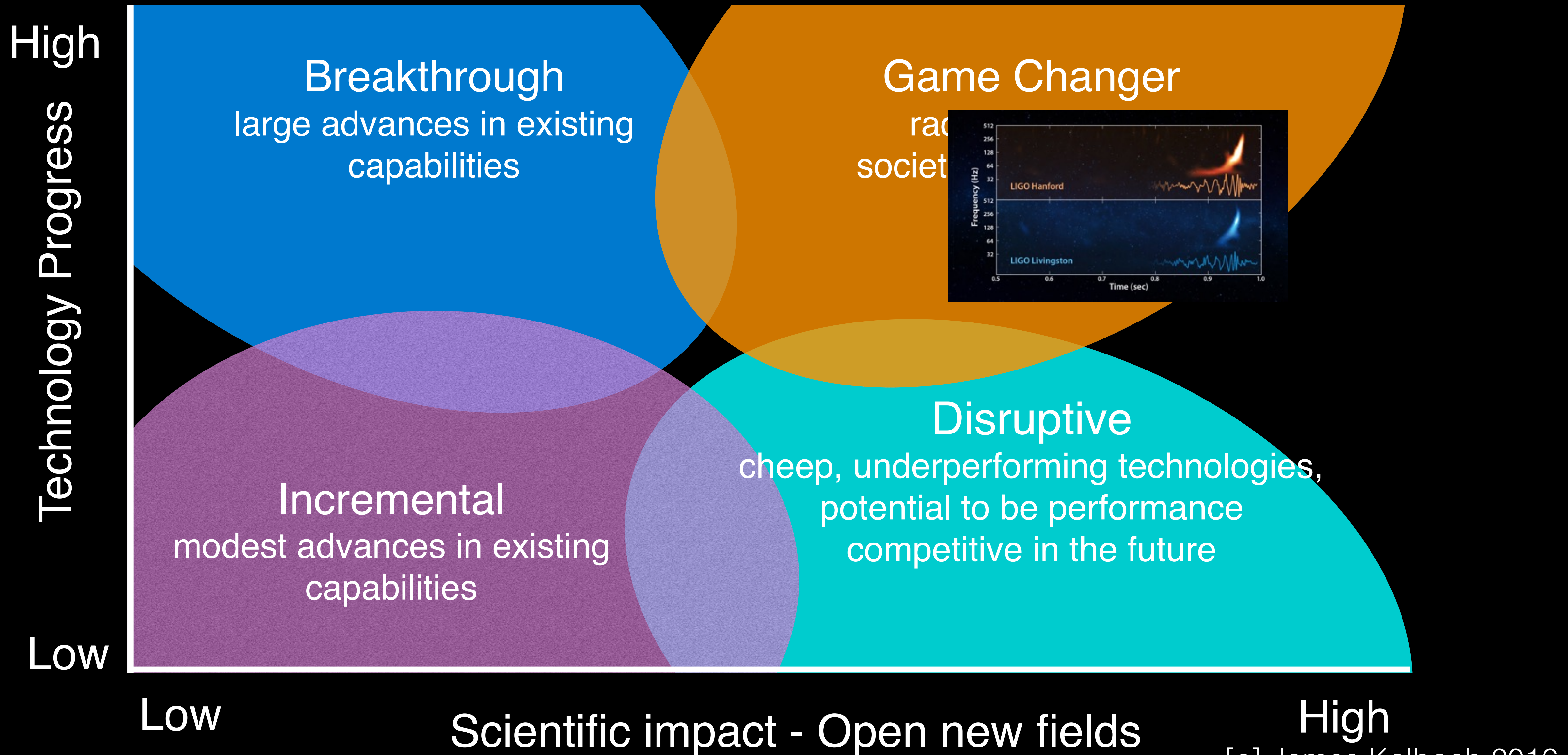
High

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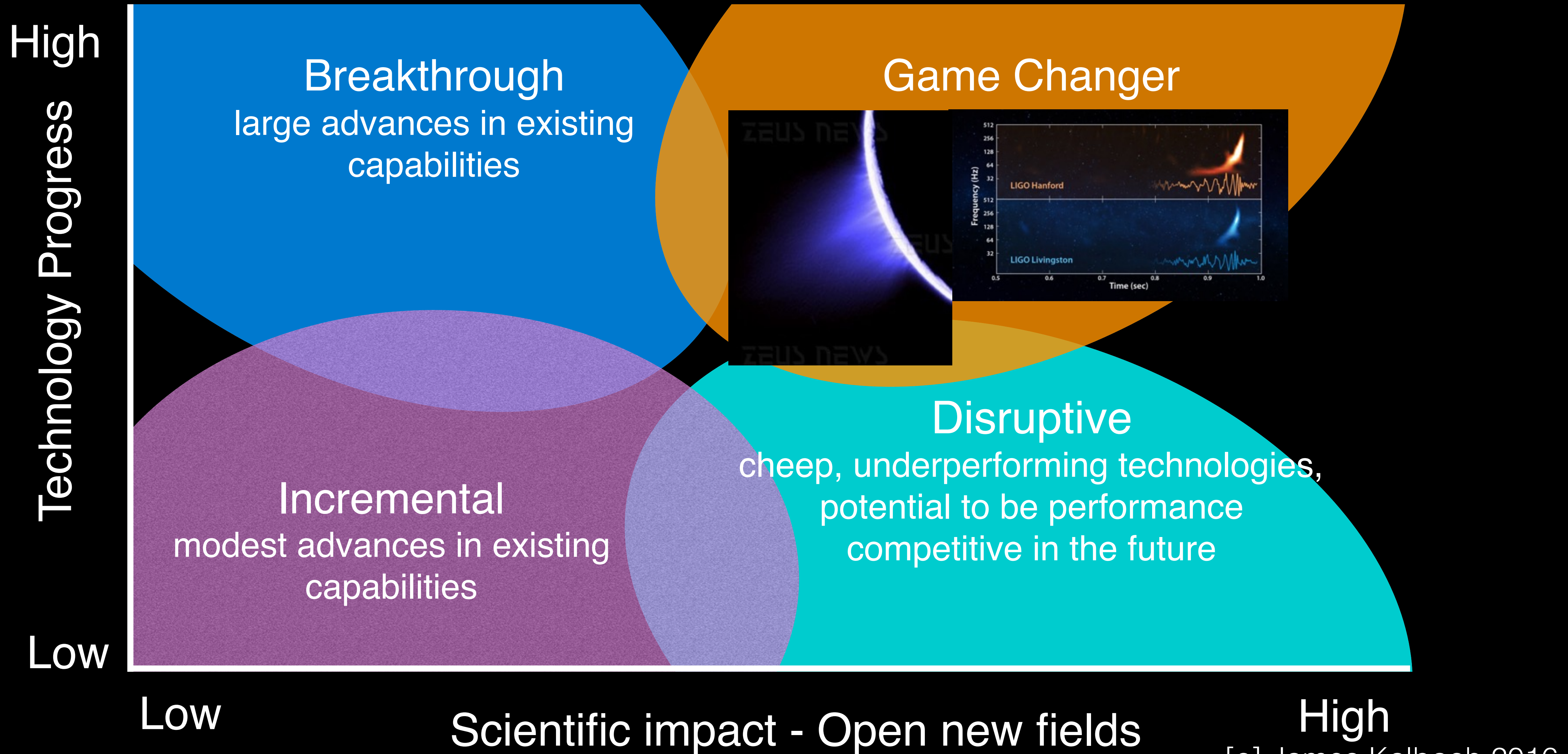
Which research?



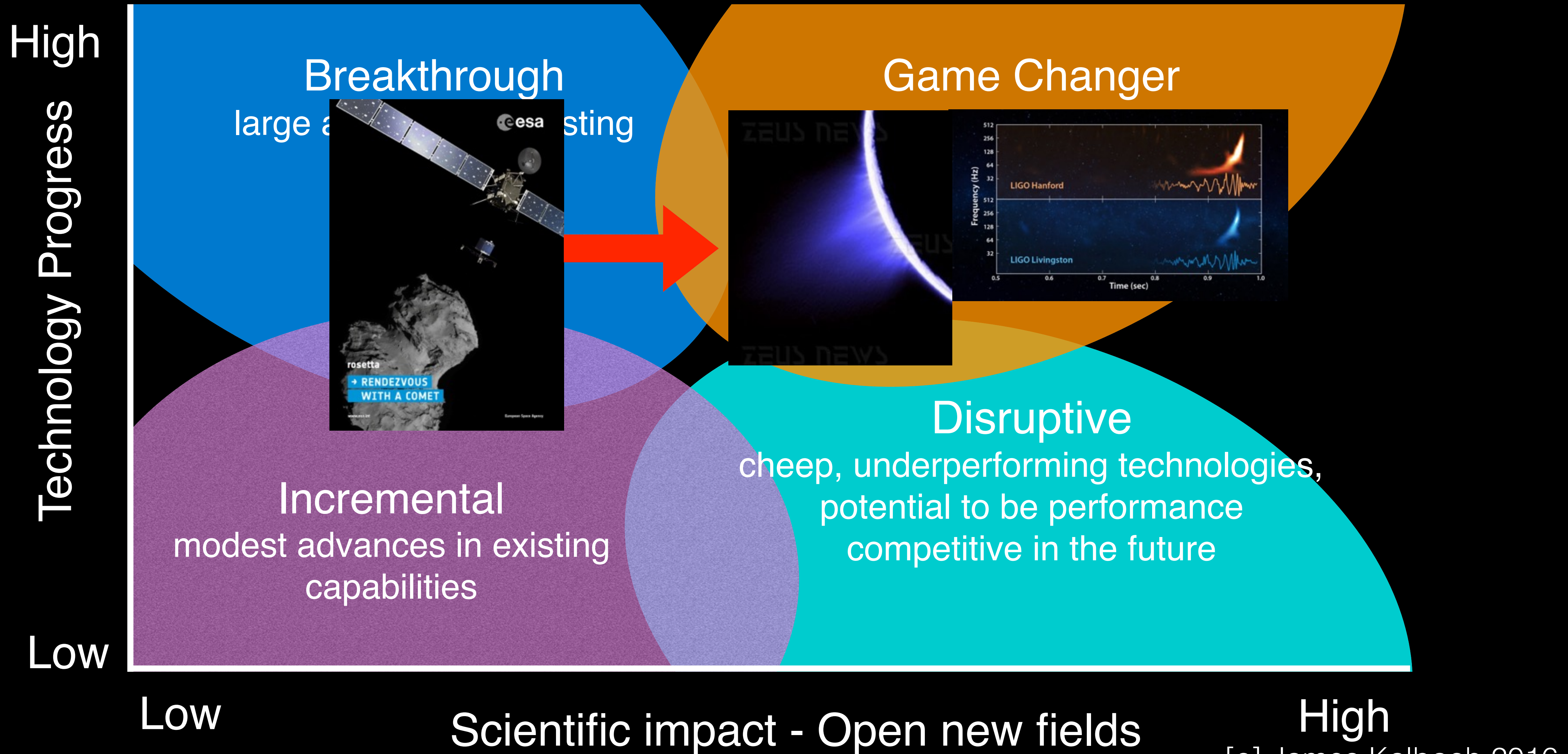
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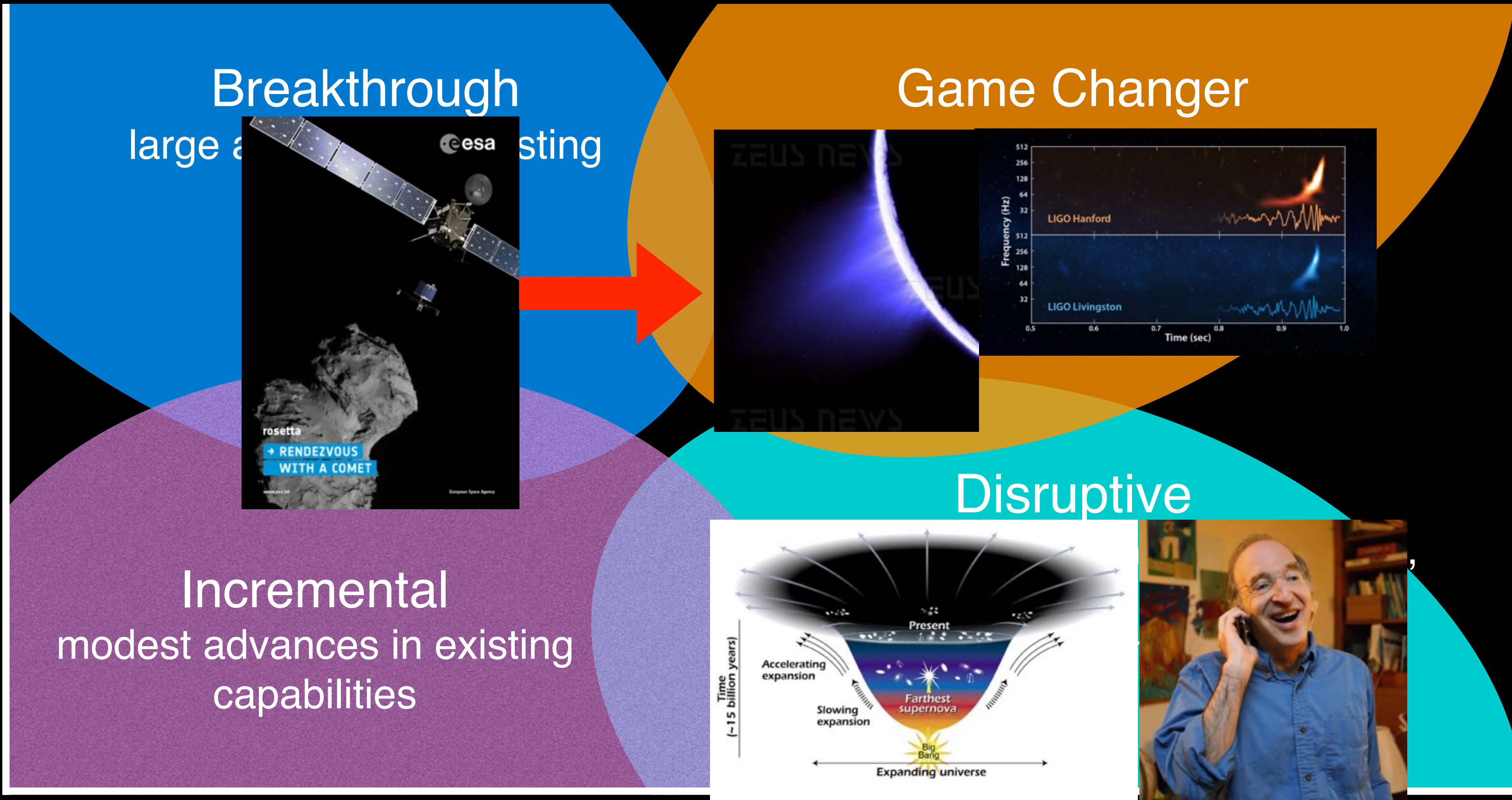


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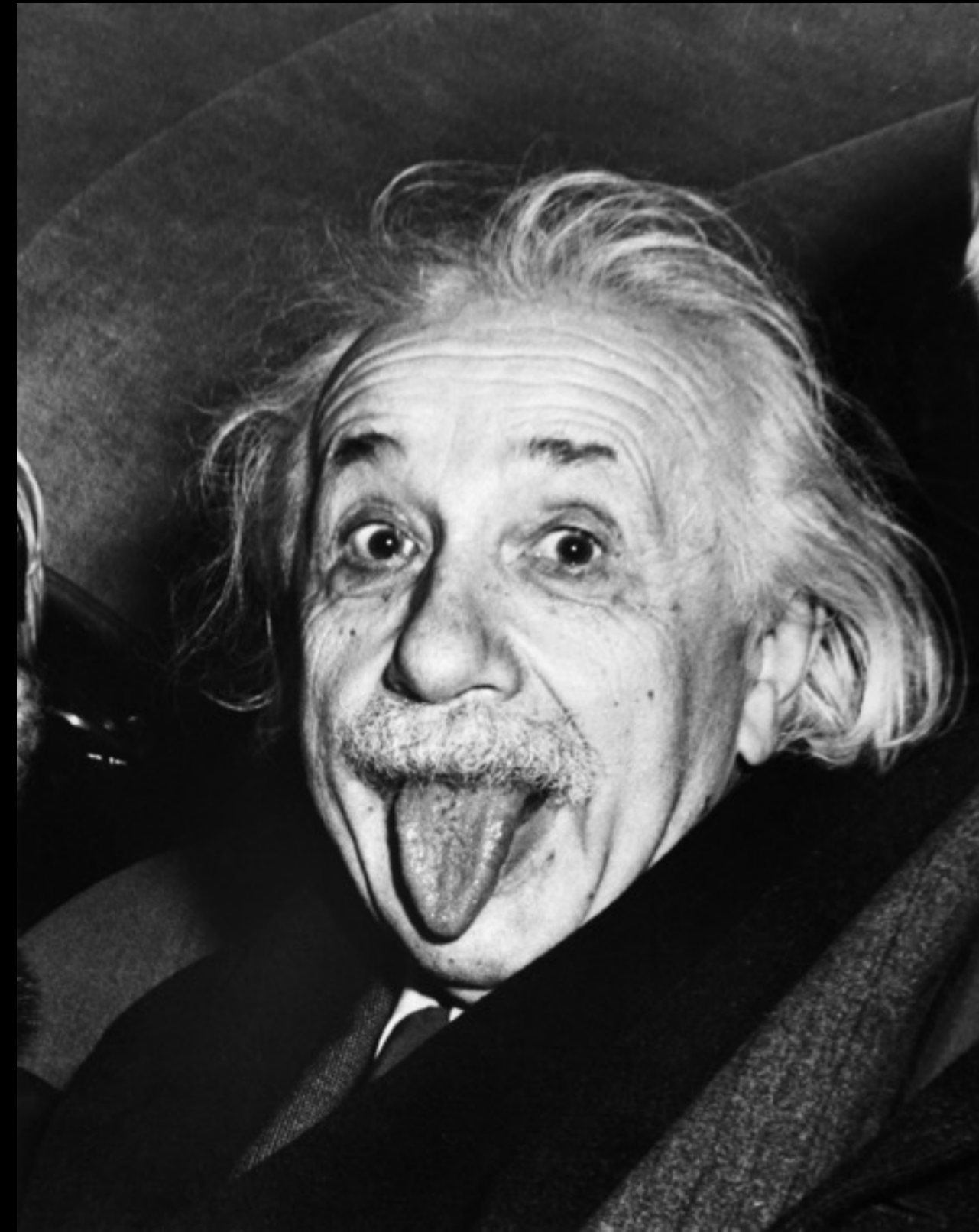
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Propulsive forces for basic research

Propulsive forces for basic research

Imagination is more important than knowledge

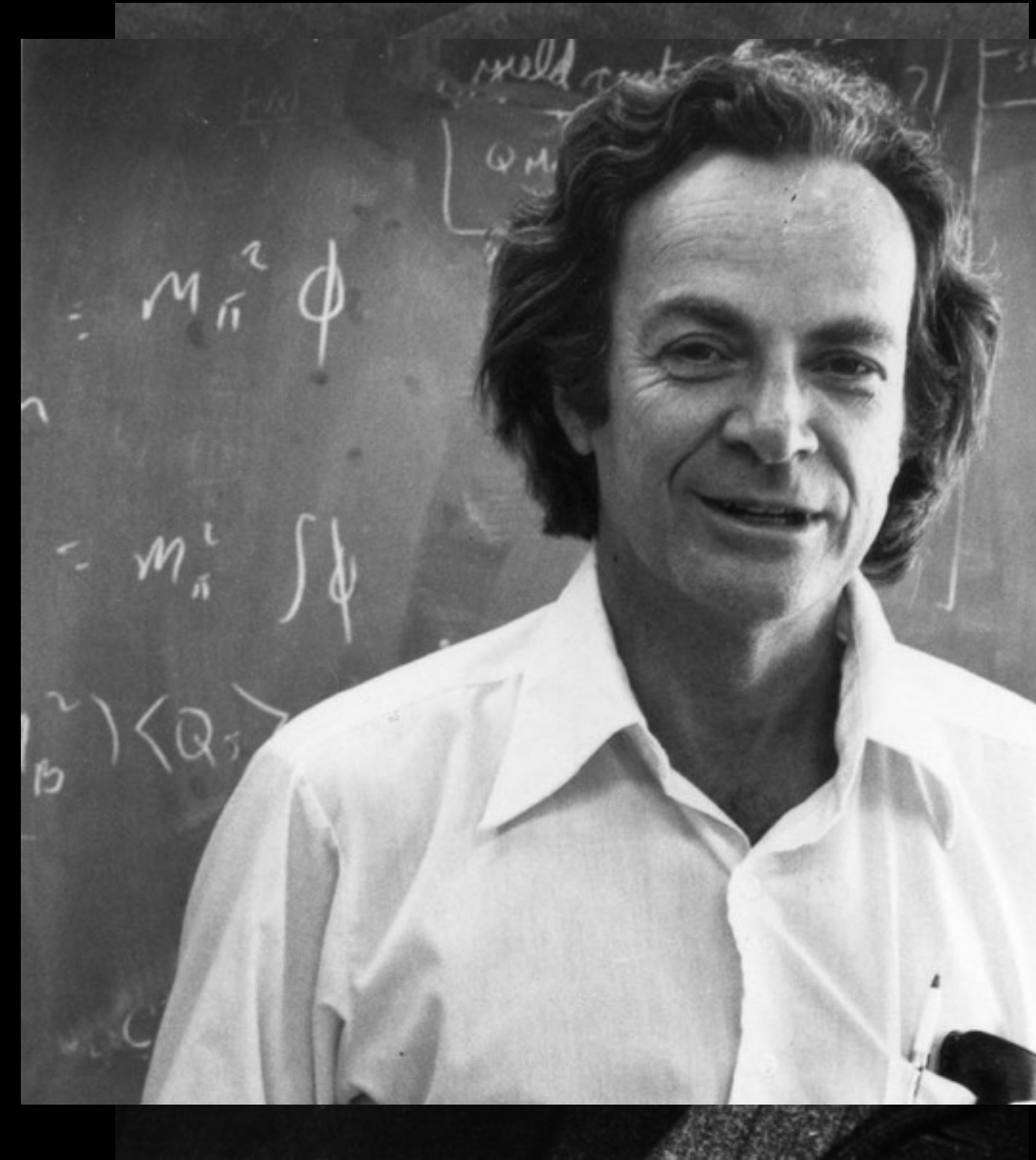


Imagination

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Scientific creativity is *imagination* in a straitjacket



Imagination

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But the fool on the hill

Sees the sun going down

And the eyes in his head

See the world spinning round

Imagination

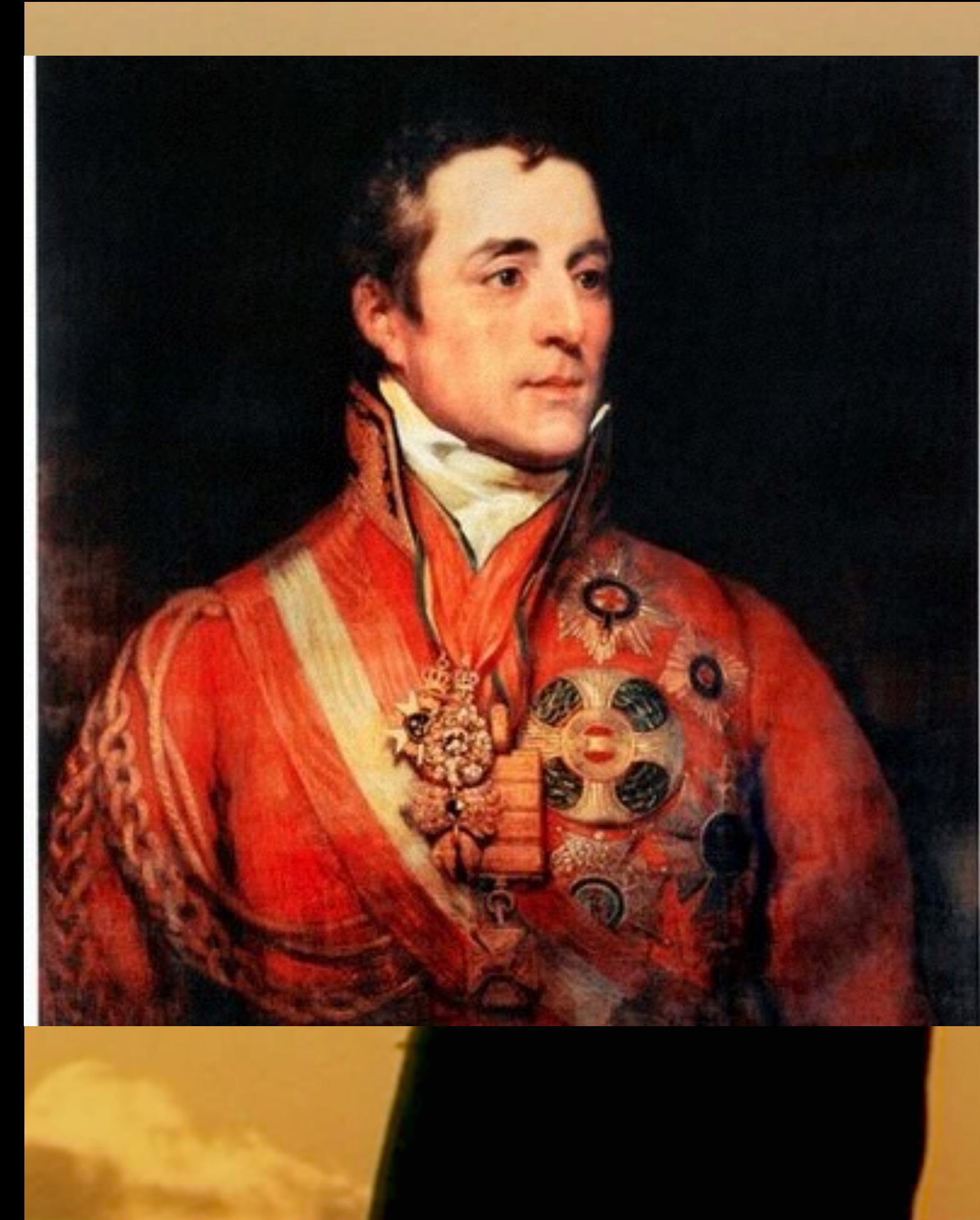


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What is on the other side of the hill



Imagination

Curiosity

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What is on the other side of the hill

Ambition leads me not only farther than any other man has been before me, but as far as I think it possible for man to go.



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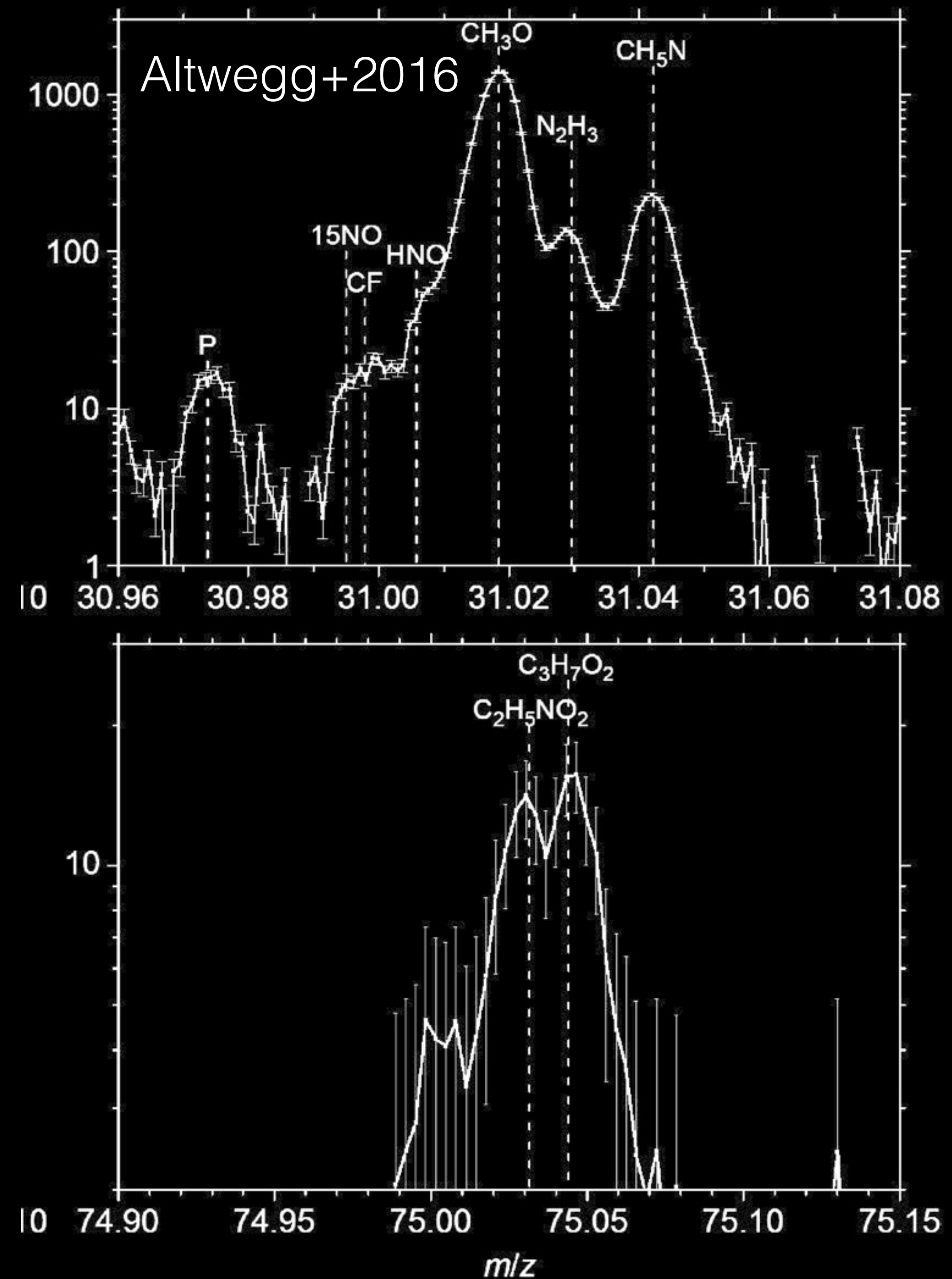
Ambition

The background image shows the Rosetta spacecraft in space, approaching a large, dark, and highly textured comet. The spacecraft is a long, thin structure with a central body and two long arms. The comet's surface is covered in craters and ridges, appearing very rugged. The overall scene is set against a dark, starry background.

Rosetta Human **AMBITION**

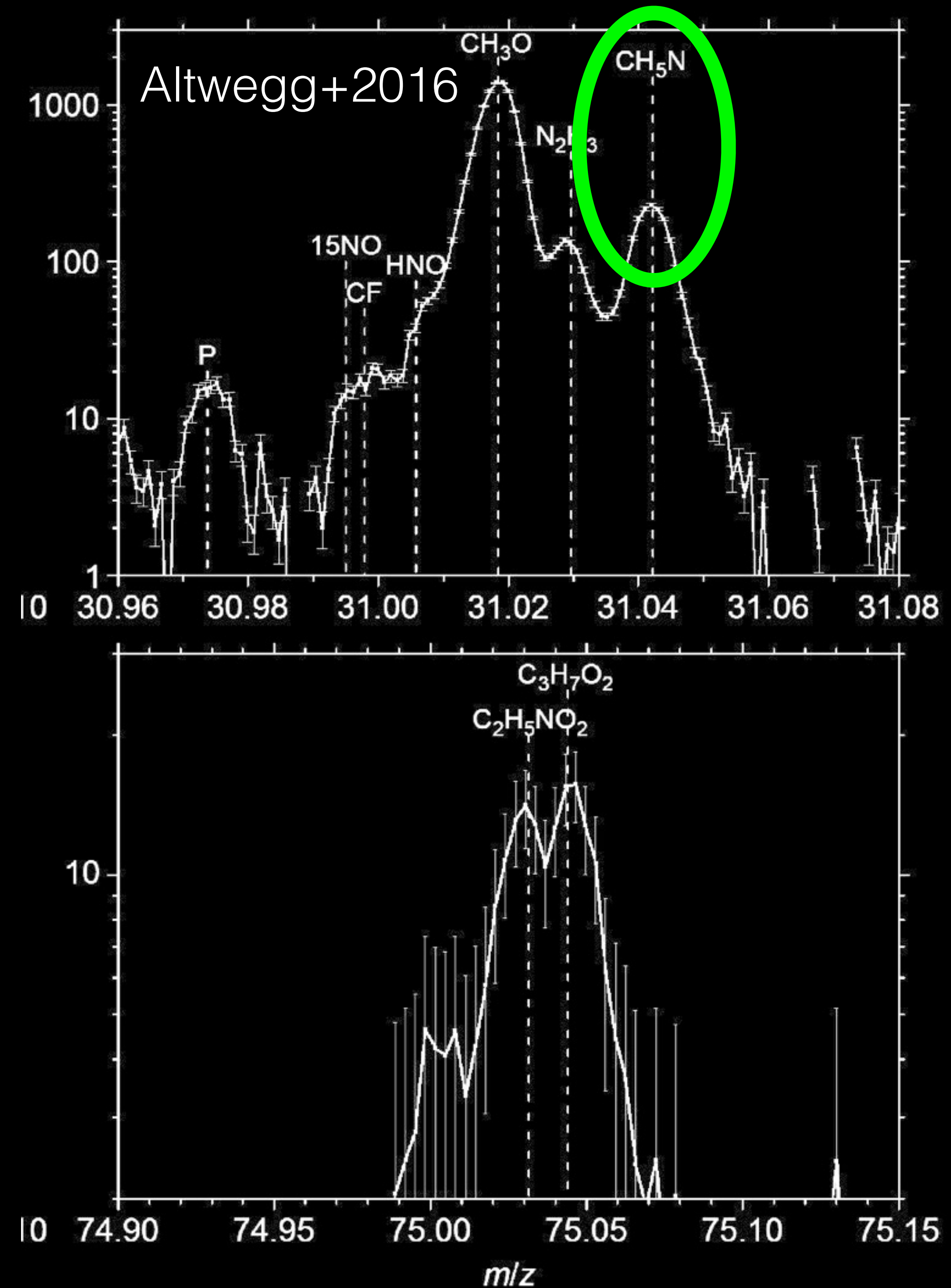


Rosetta: ambition-driven research



Rosetta: ambition-driven research

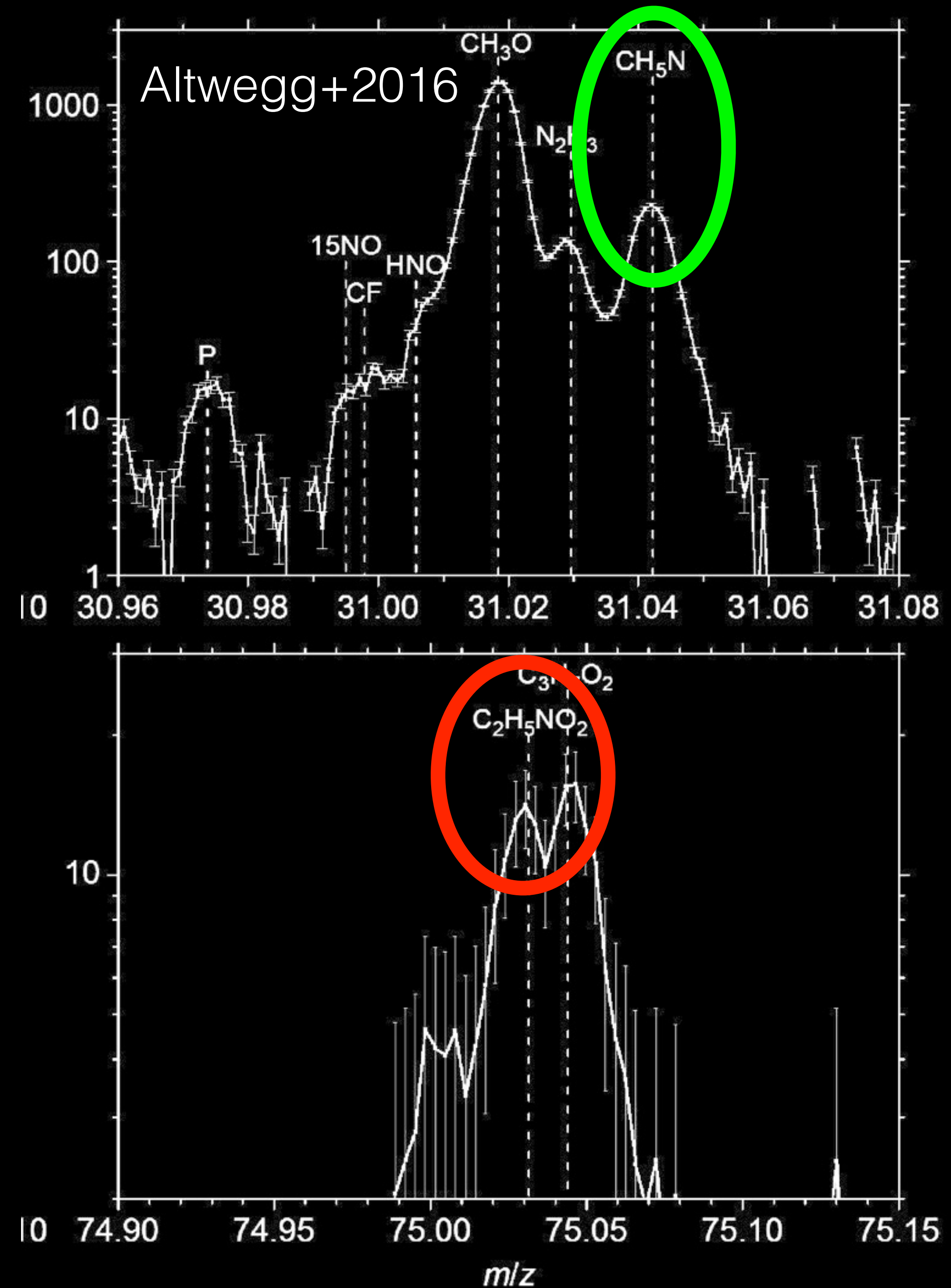
Volatile Methylamine ethylamine



Rosetta: ambition-driven research

Volatile Methylamine ethylamine

Volatile Glycine

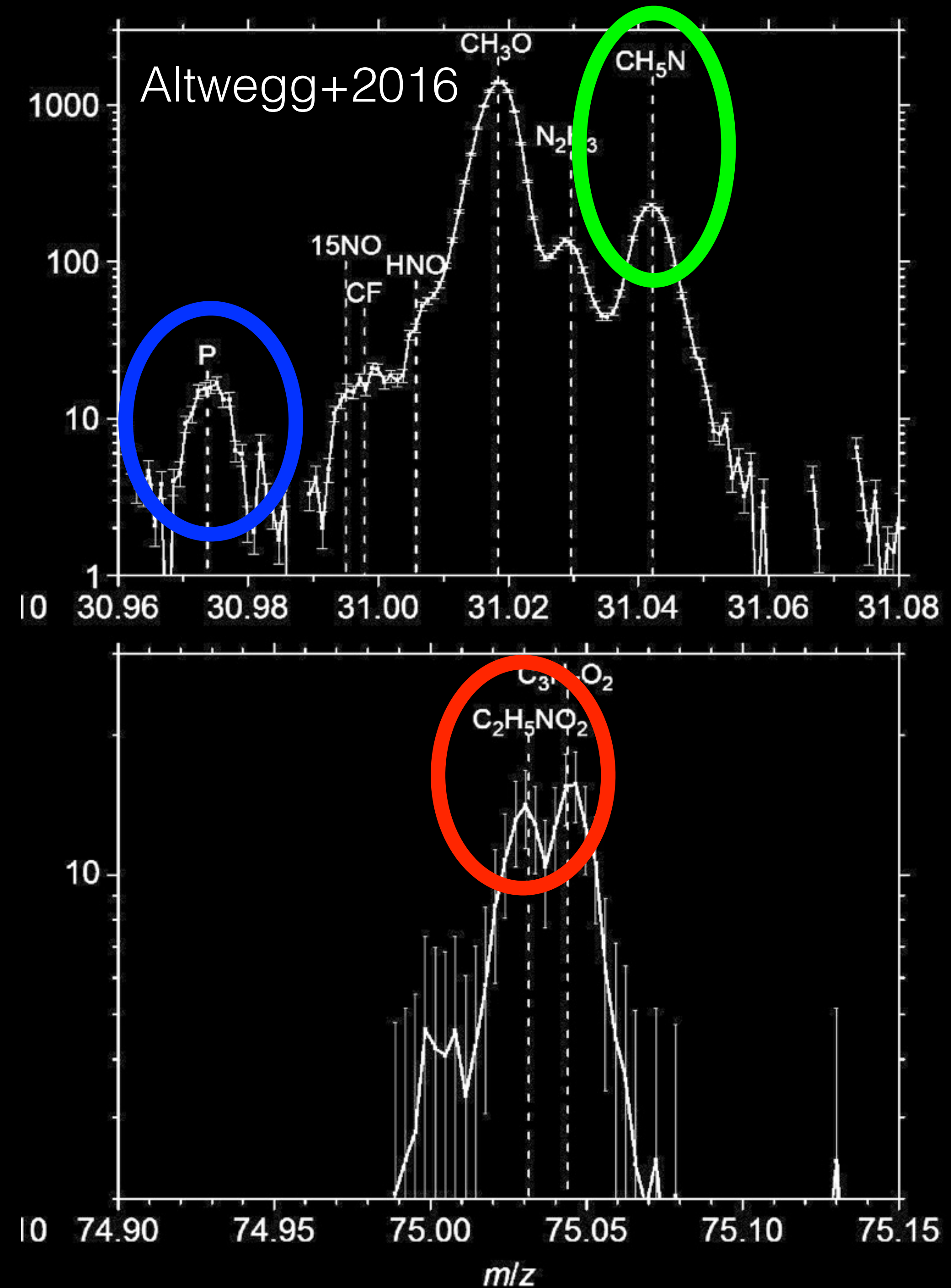


Rosetta: ambition-driven research

Volatile Methylamine ethylamine

Volatile Glycine

Volatile Phosphorus



Rosetta: ambition-driven research

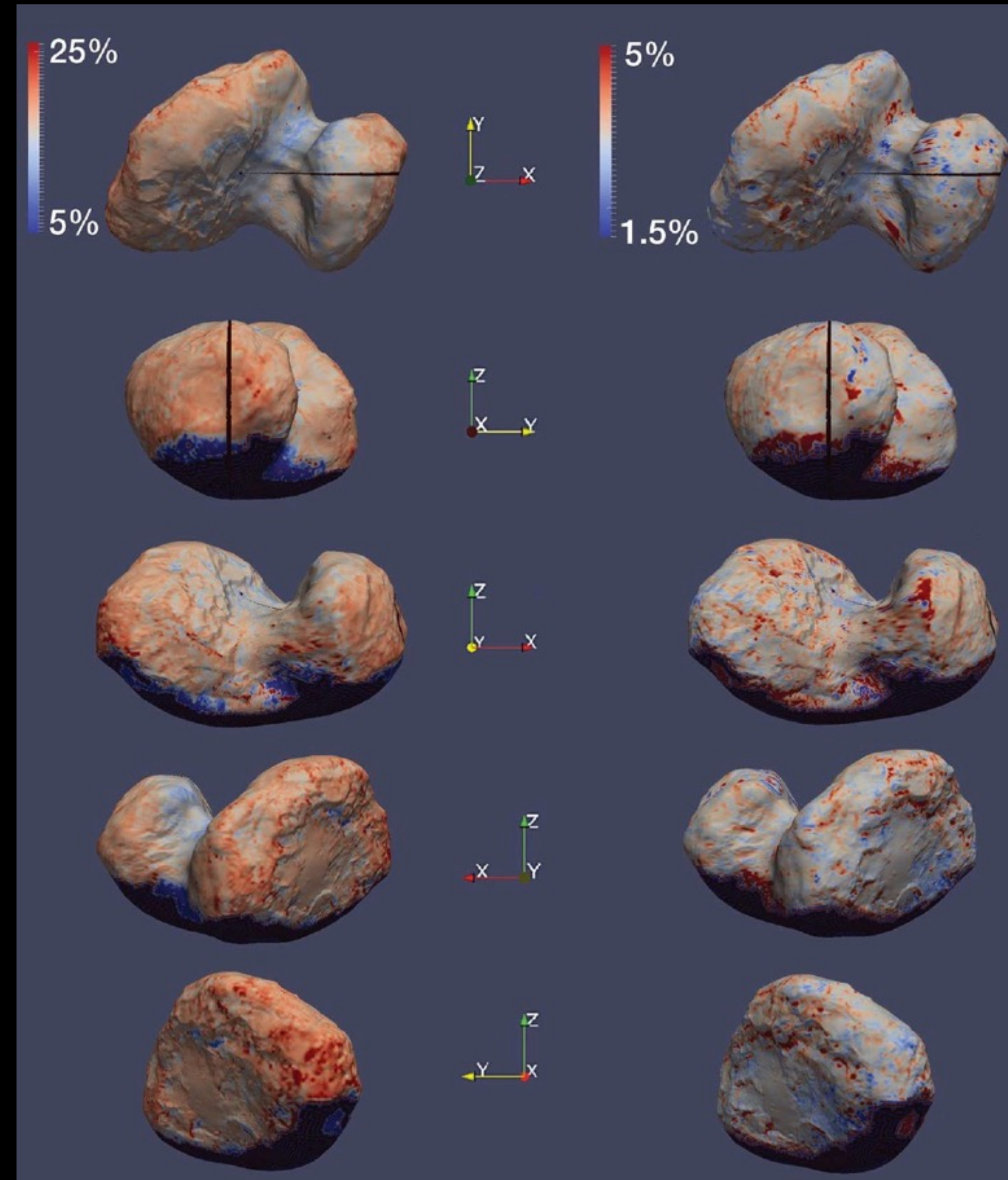
Capaccioni+2015

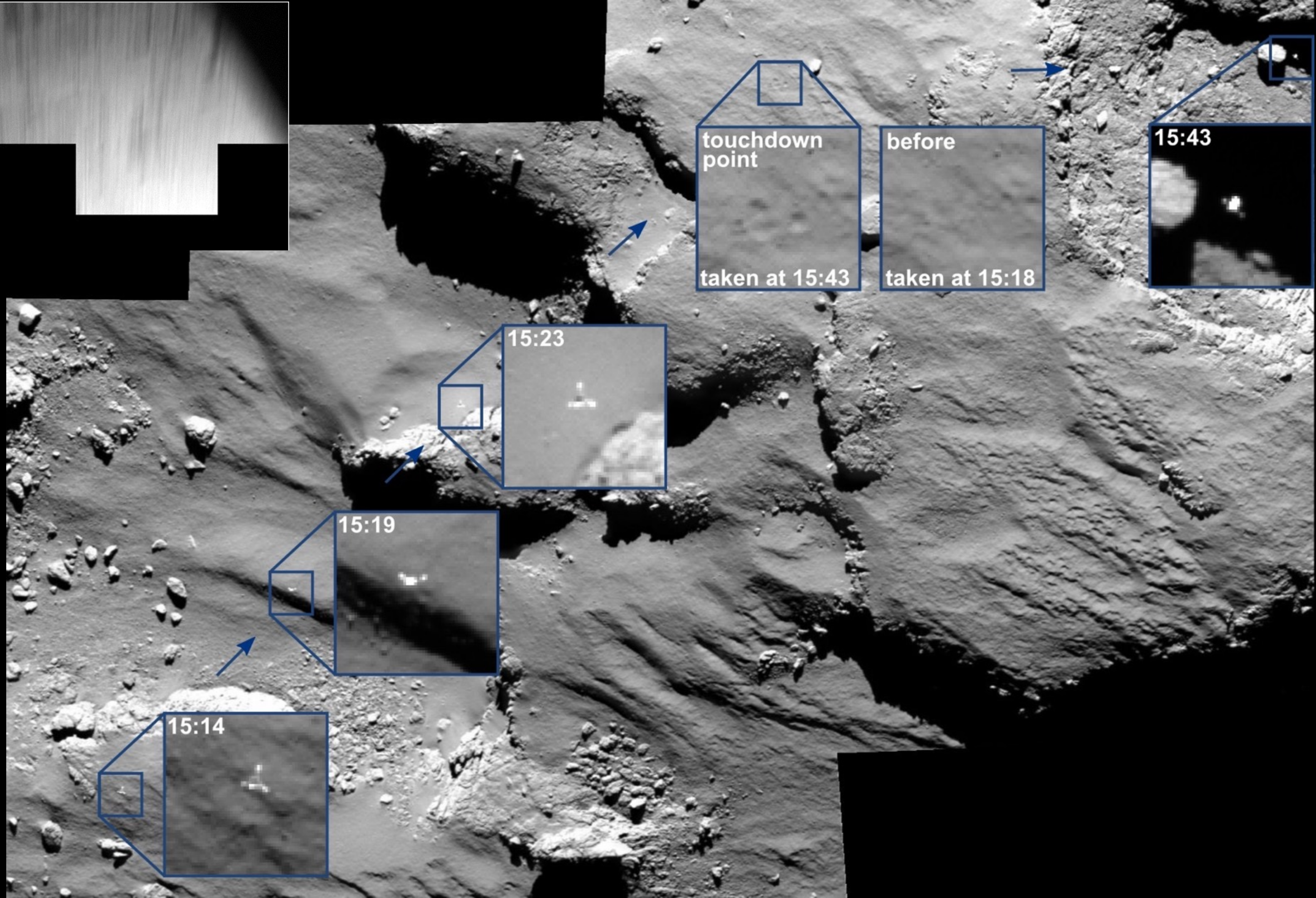
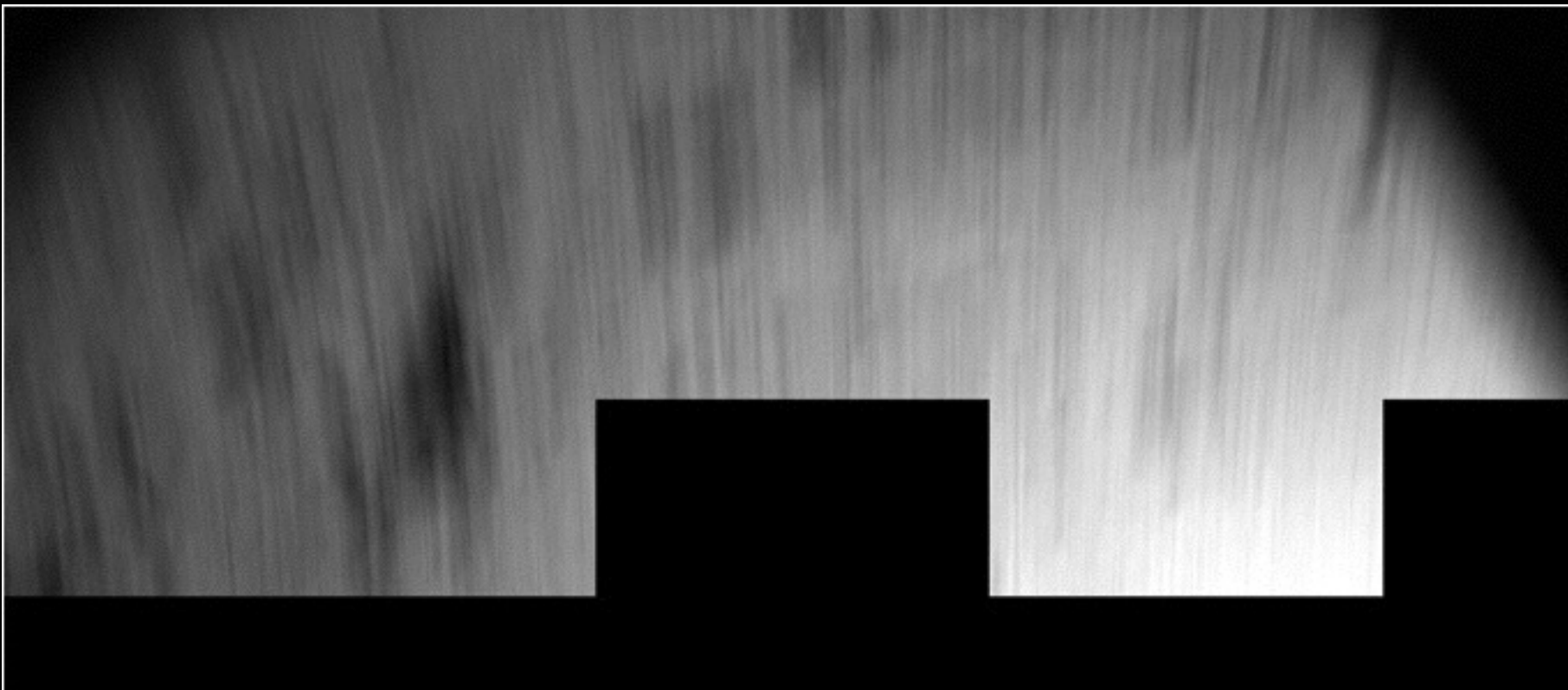
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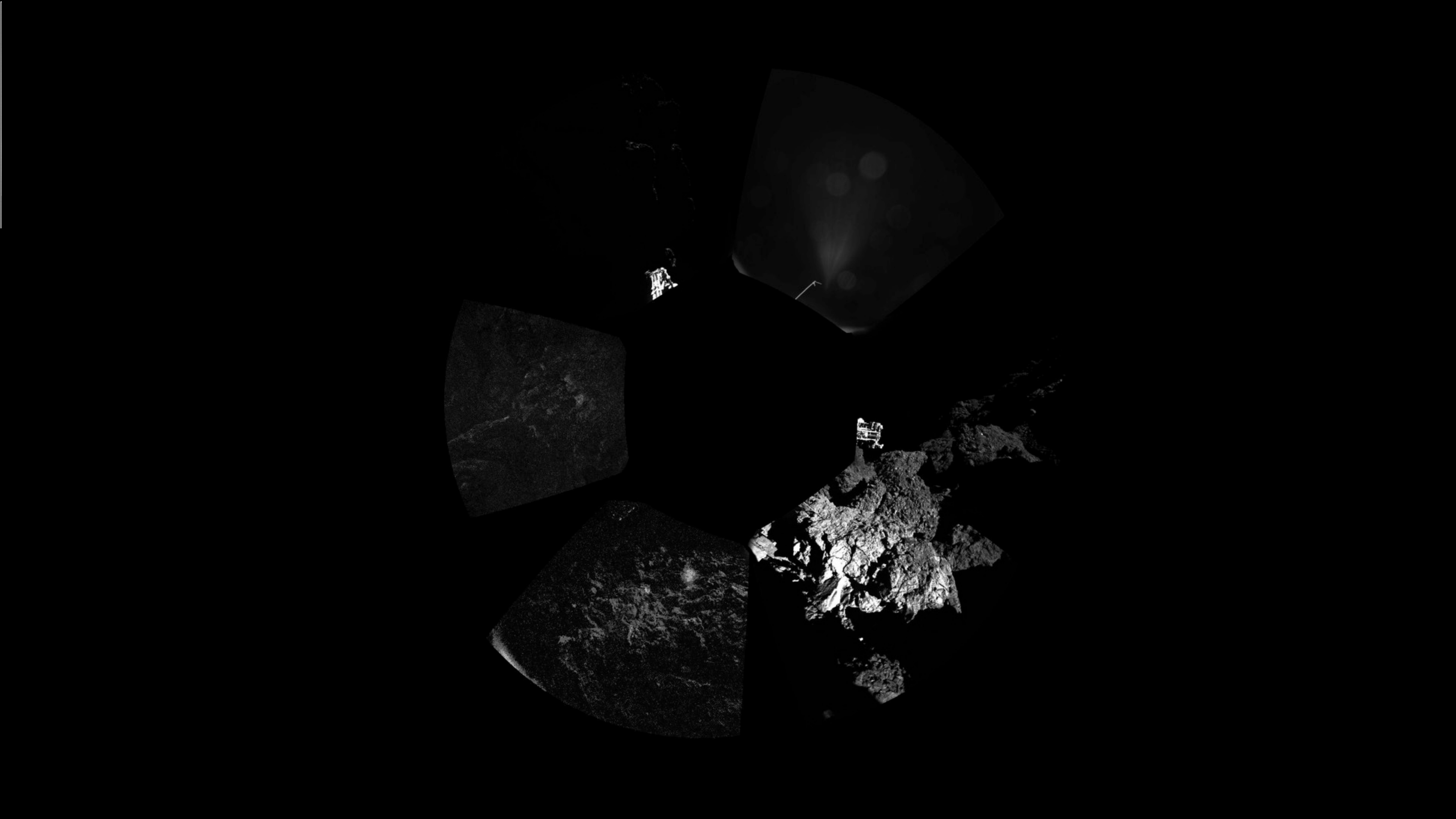
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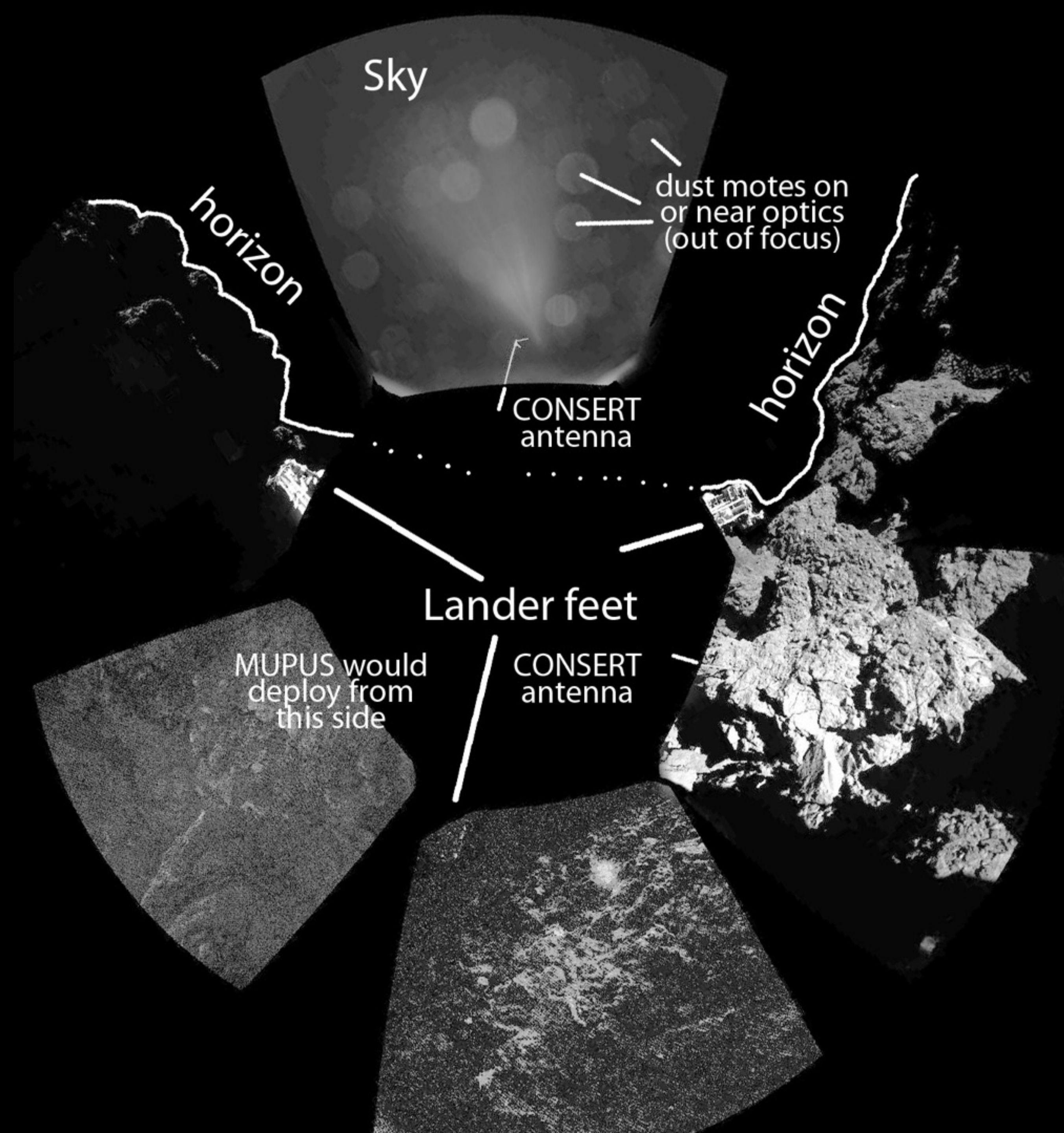
Volatile Phosphorus

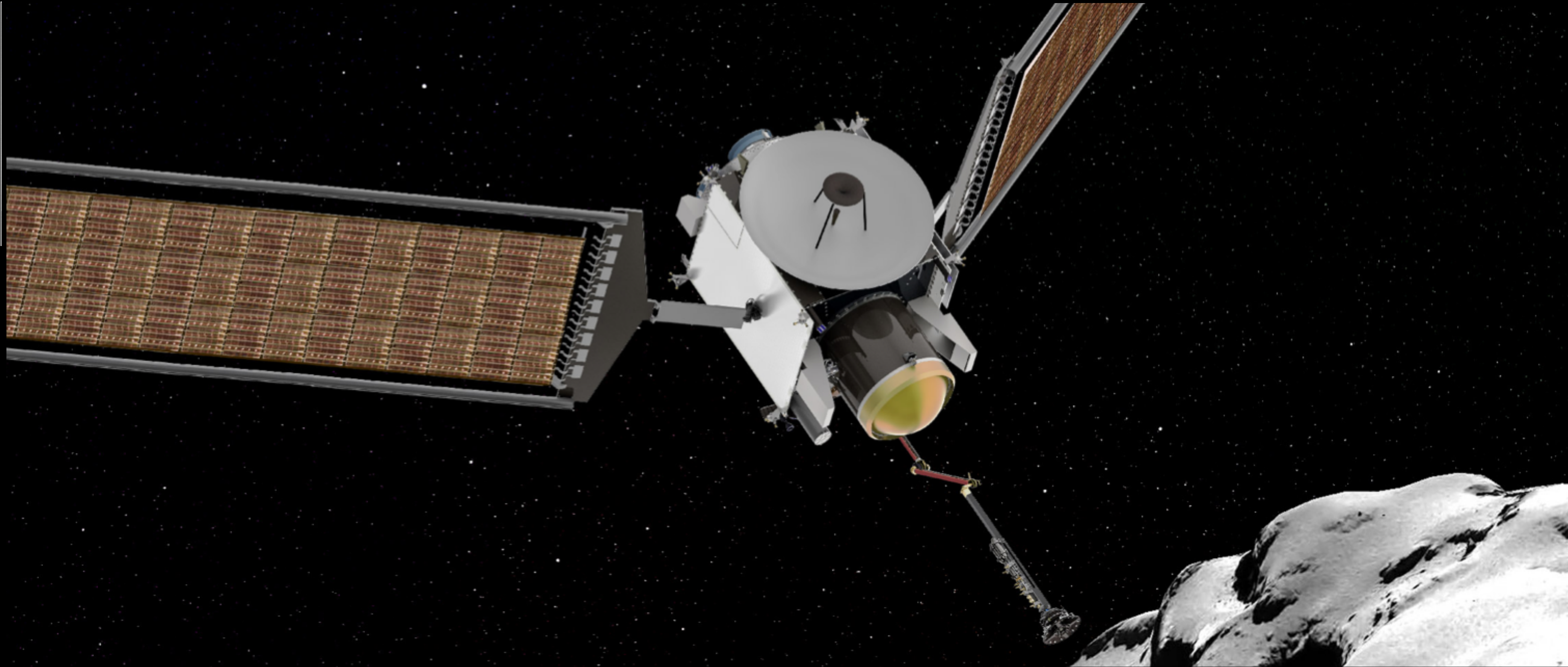
Comet is completely covered by
organic macromolecules
base C-H, O-H





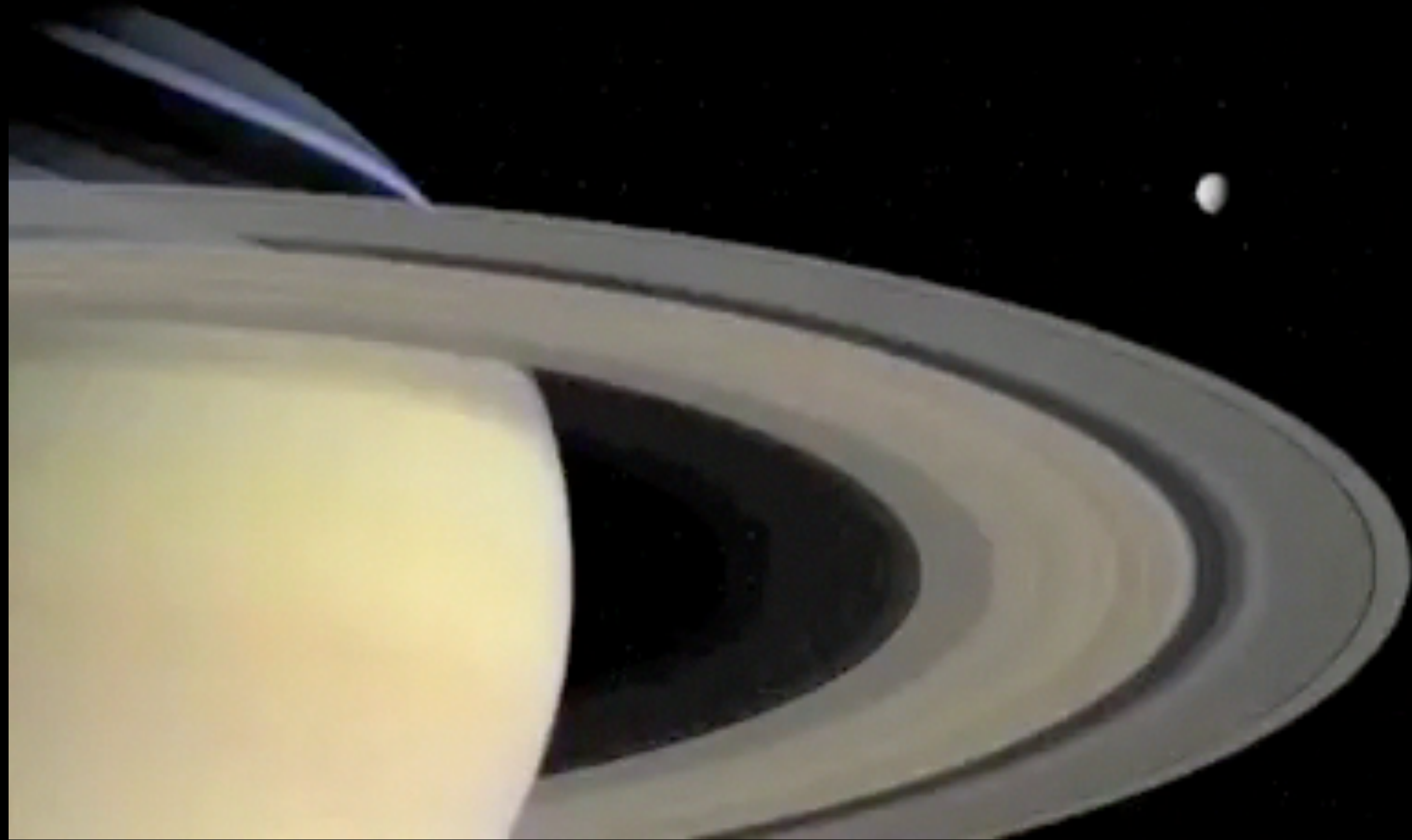




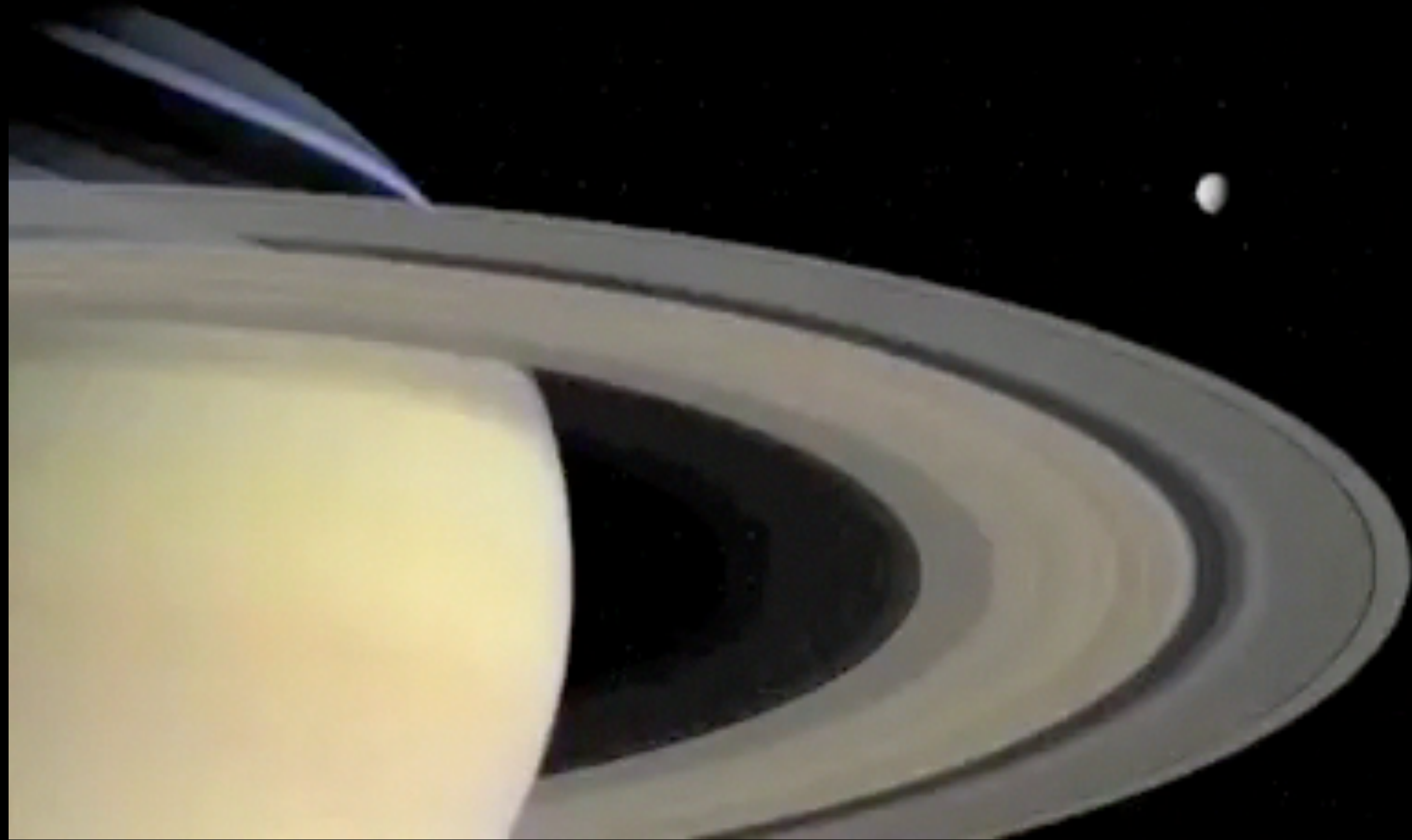


NASA CAESAR mission to Churyumov-Gerasimenko

Icy moons: Encelado

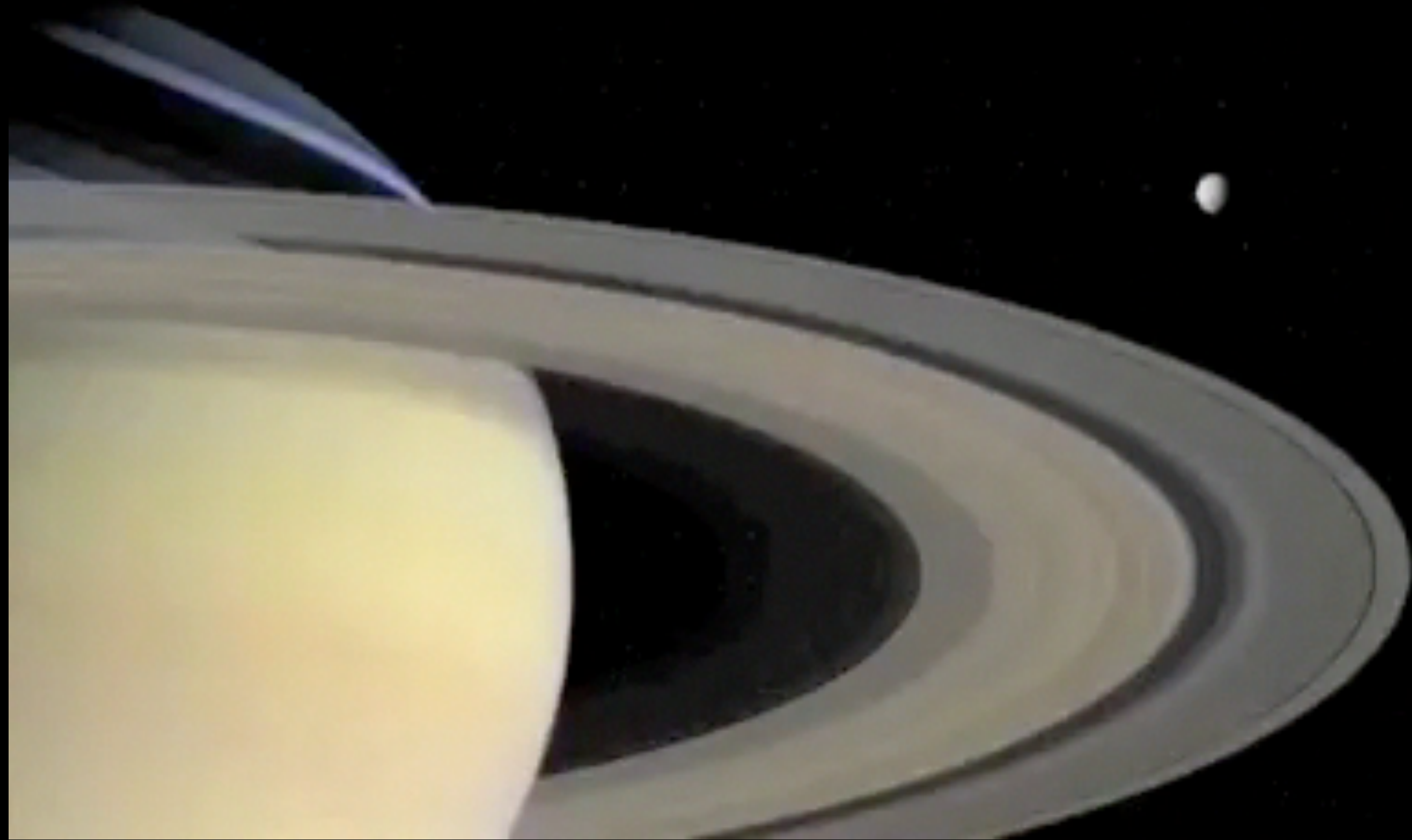


Icy moons: Encelado



Icy moons: Encelado

500km diameter
 $T \sim -200\text{ C}$

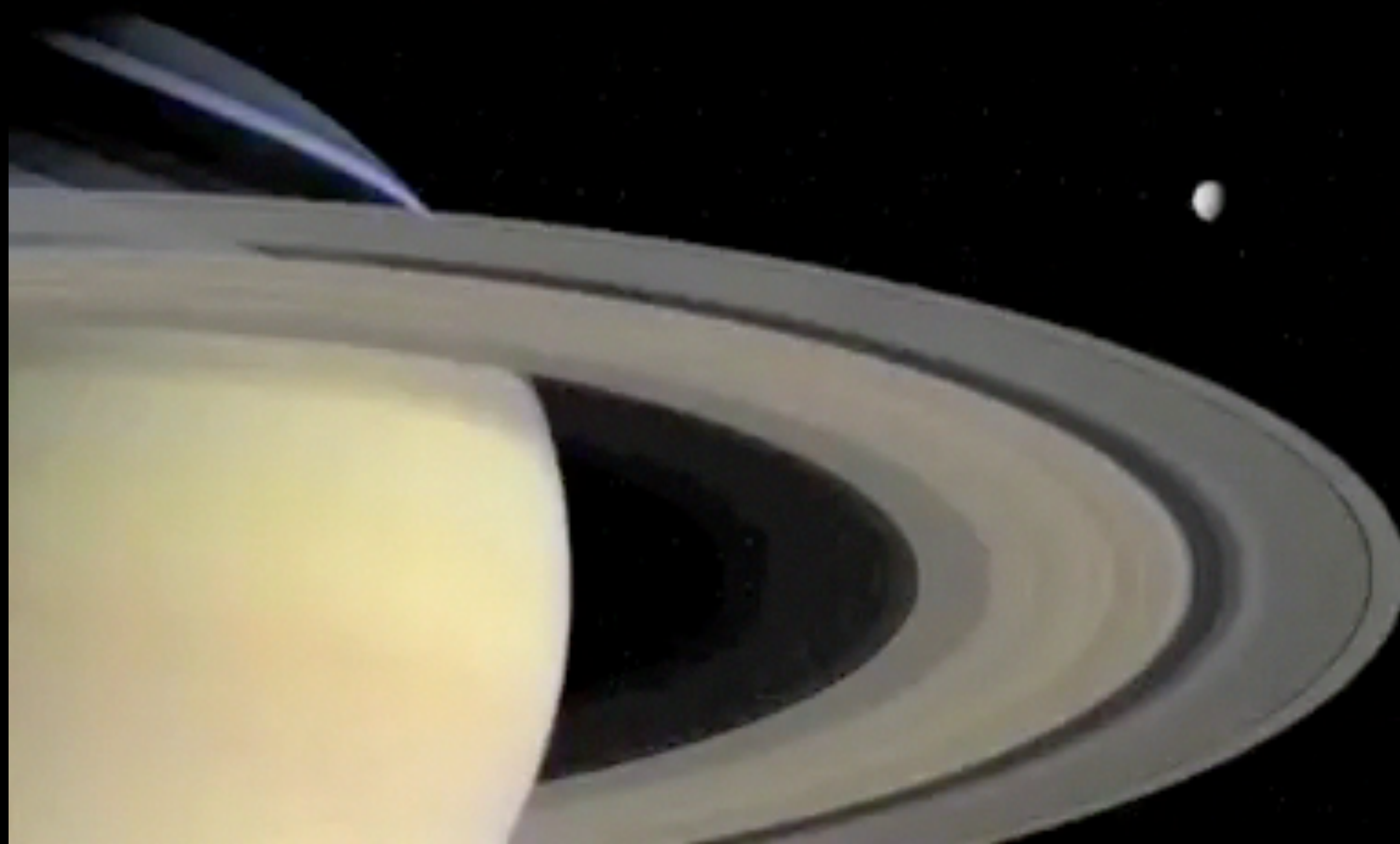


Icy moons: Encelado

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Spectacular
geysers at the
south pole!



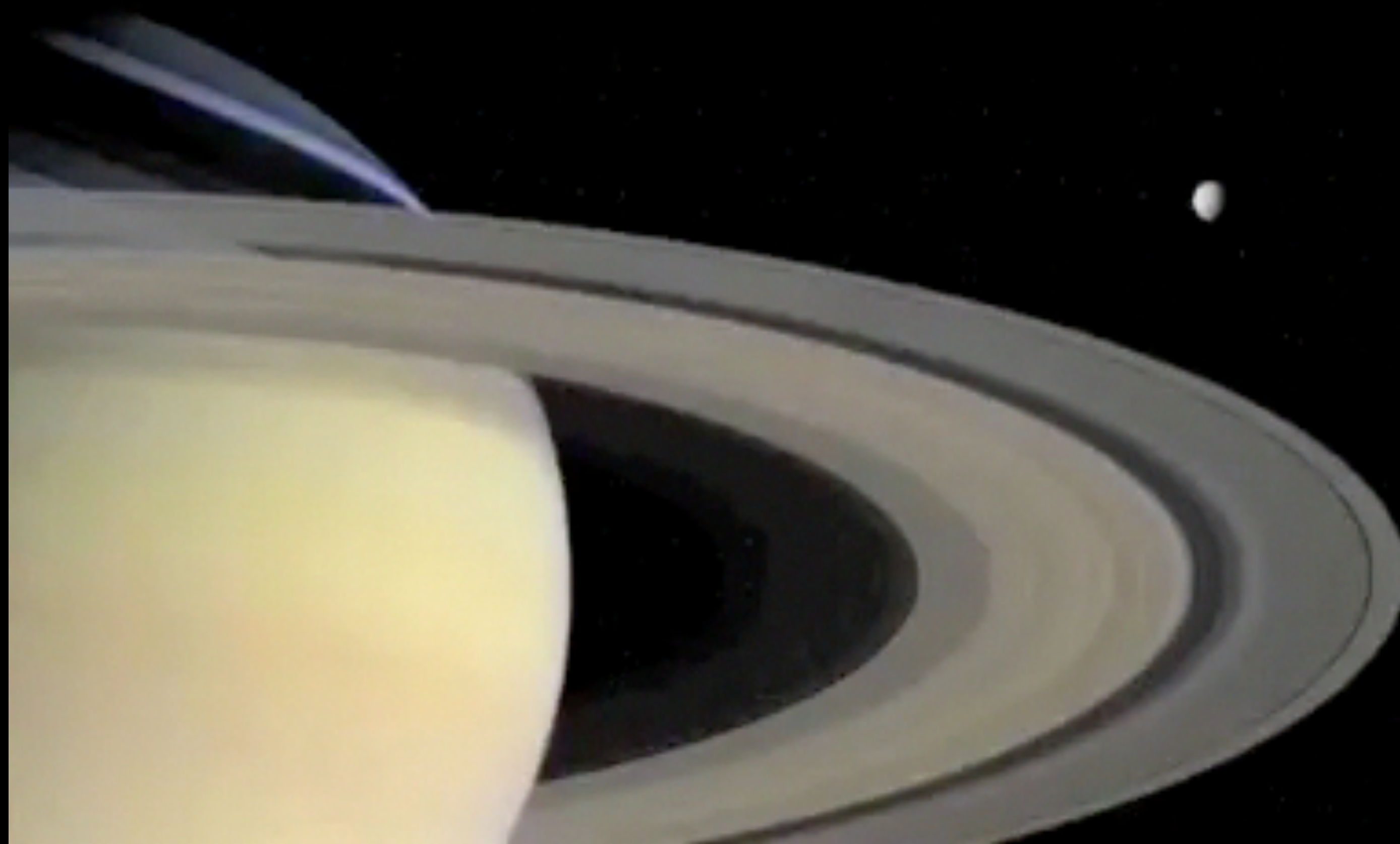
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Icy moons: Encelado

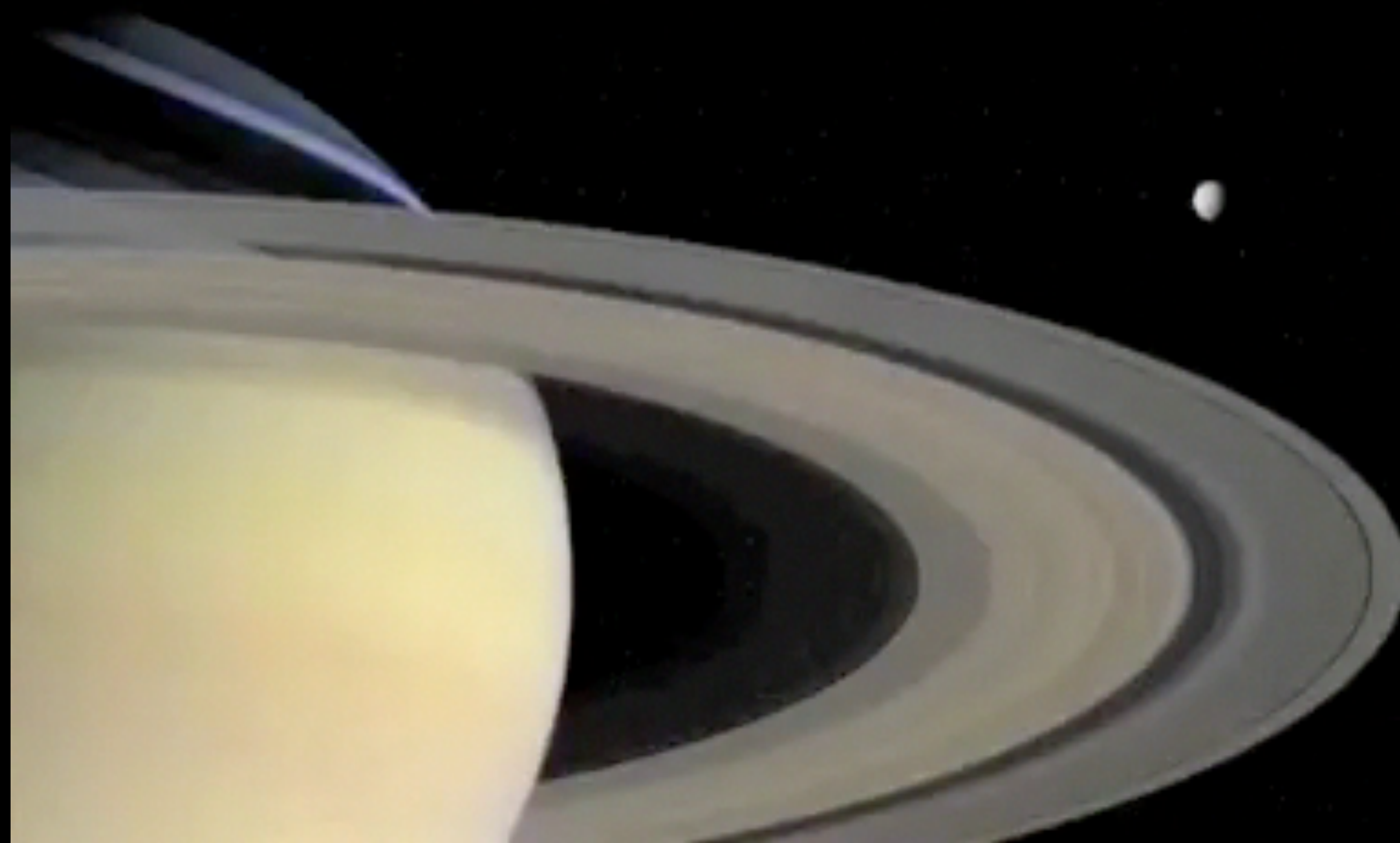
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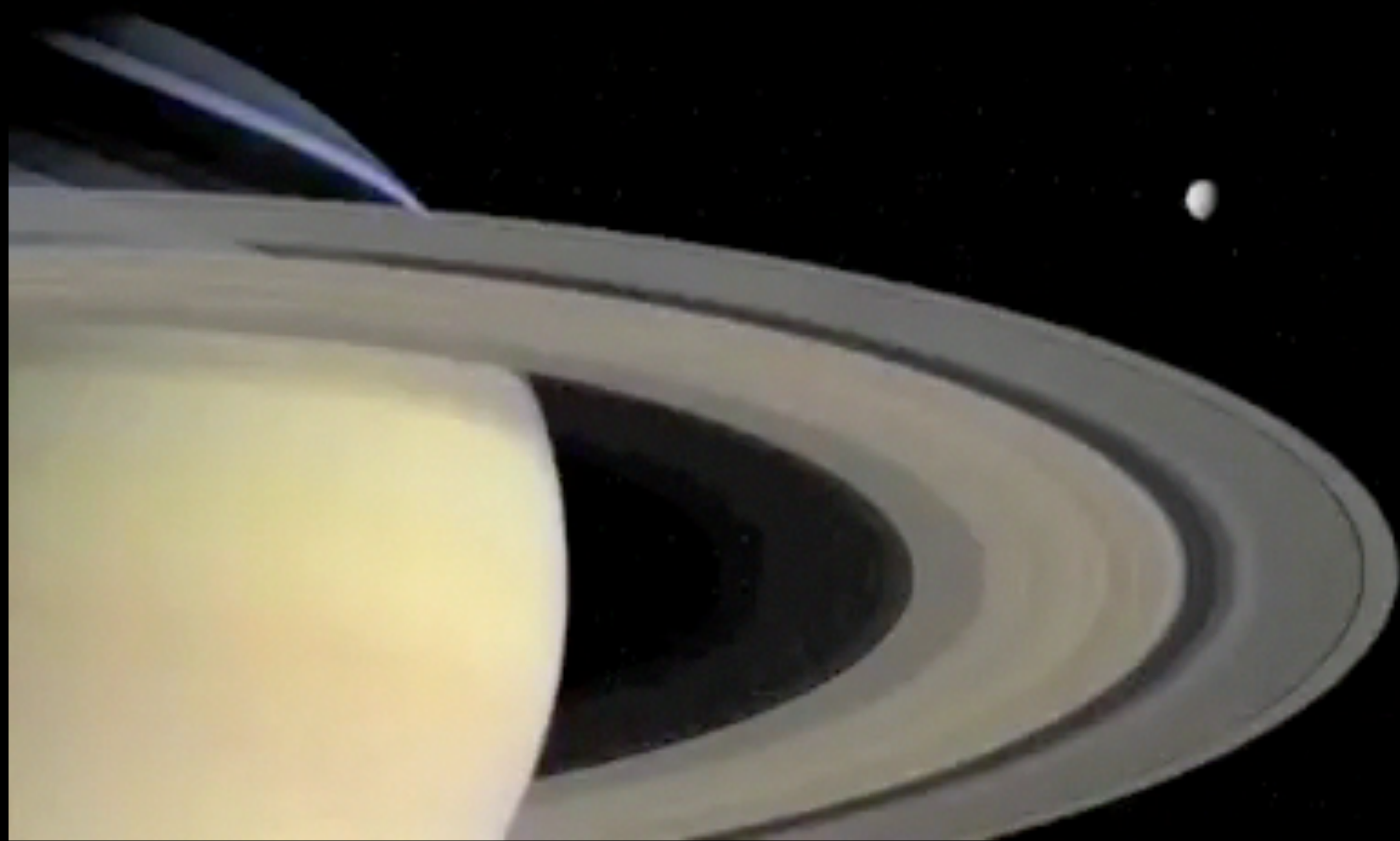
Sprays of ice
and water vapor
thousands of km
high.

Form Saturn
external rings



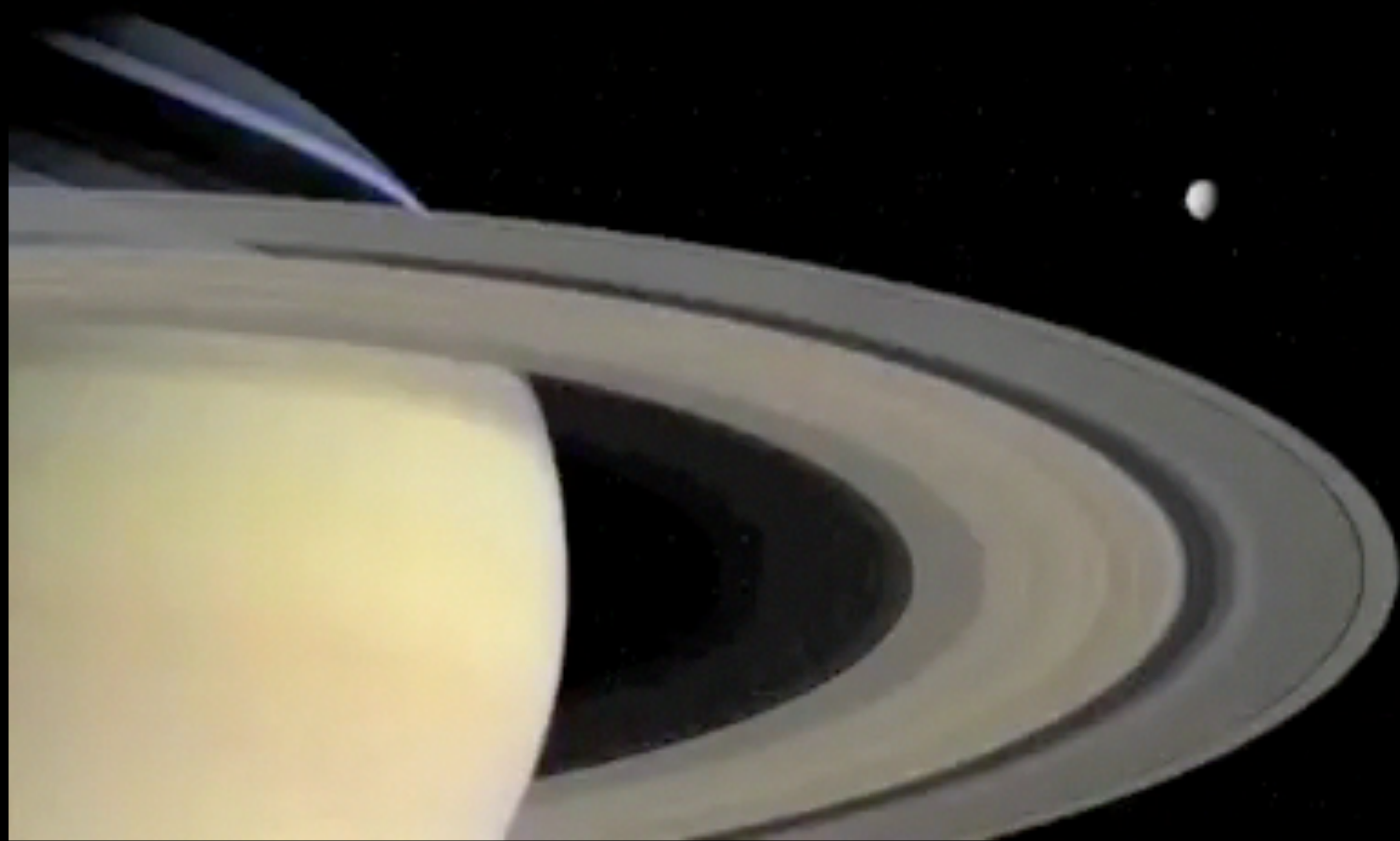
Icy moons: Encelado

Young fractures.
High T near
fractures (-100 C).



Icy moons: Encelado

Young fractures.
High T near
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Organic molecules



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H₂



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Prebiotic conditions



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Prebiotic conditions

Global oceans
(orbital wobble)



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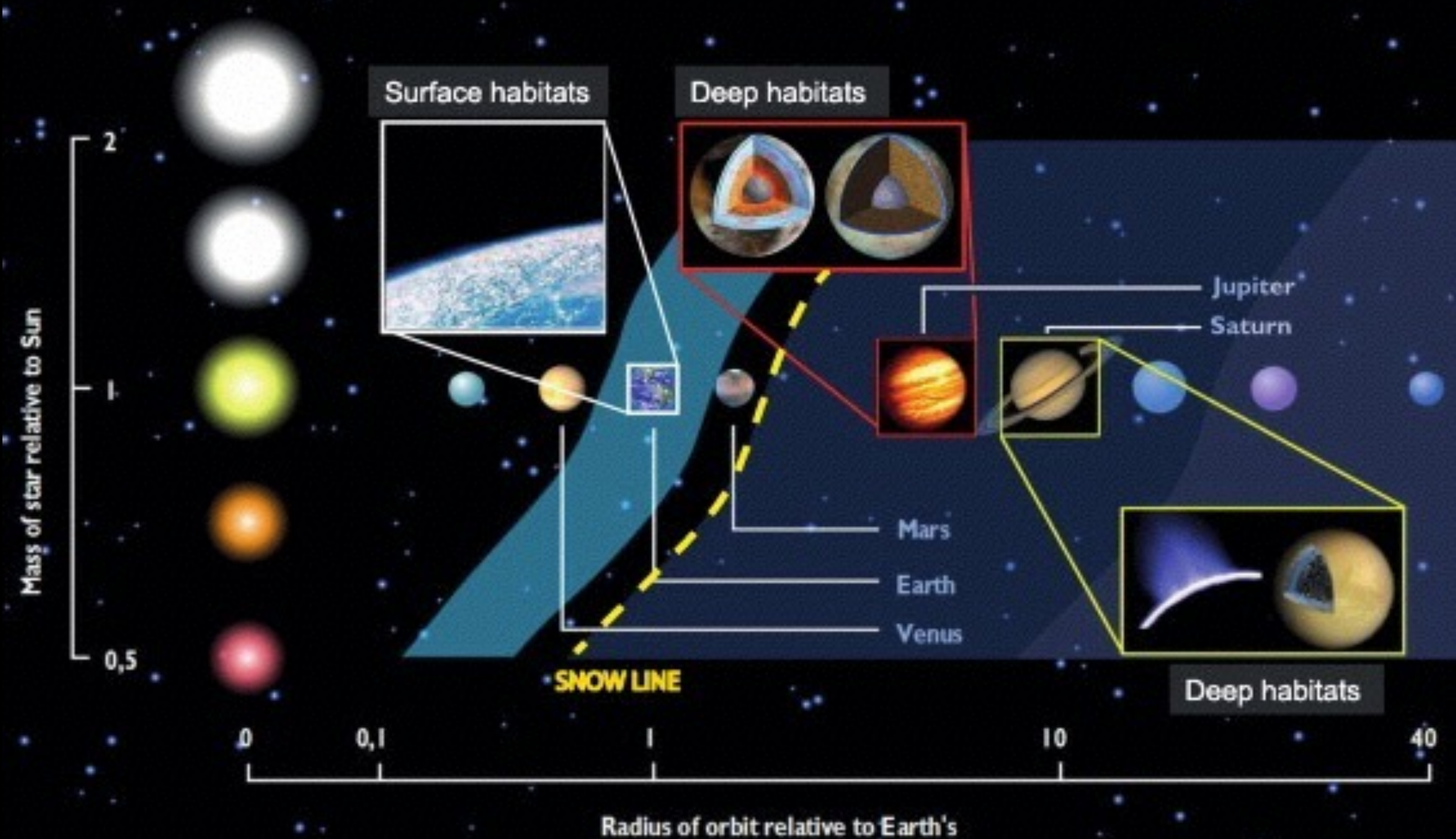
H₂

Prebiotic conditions

Global oceans
(orbital wobble)

Heating caused by
tidal forces

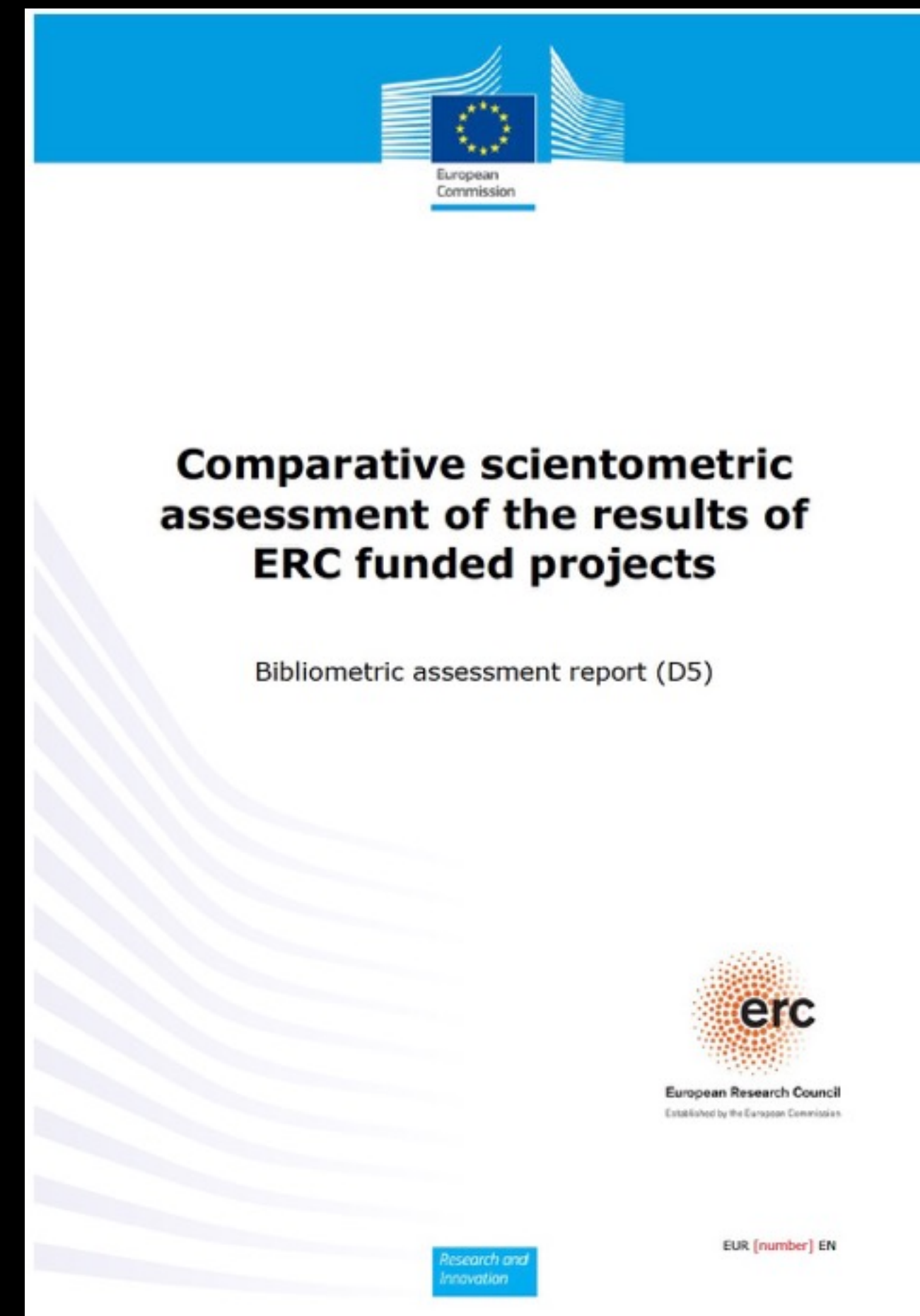




A new driving force for research:
competition

Competition-driven science

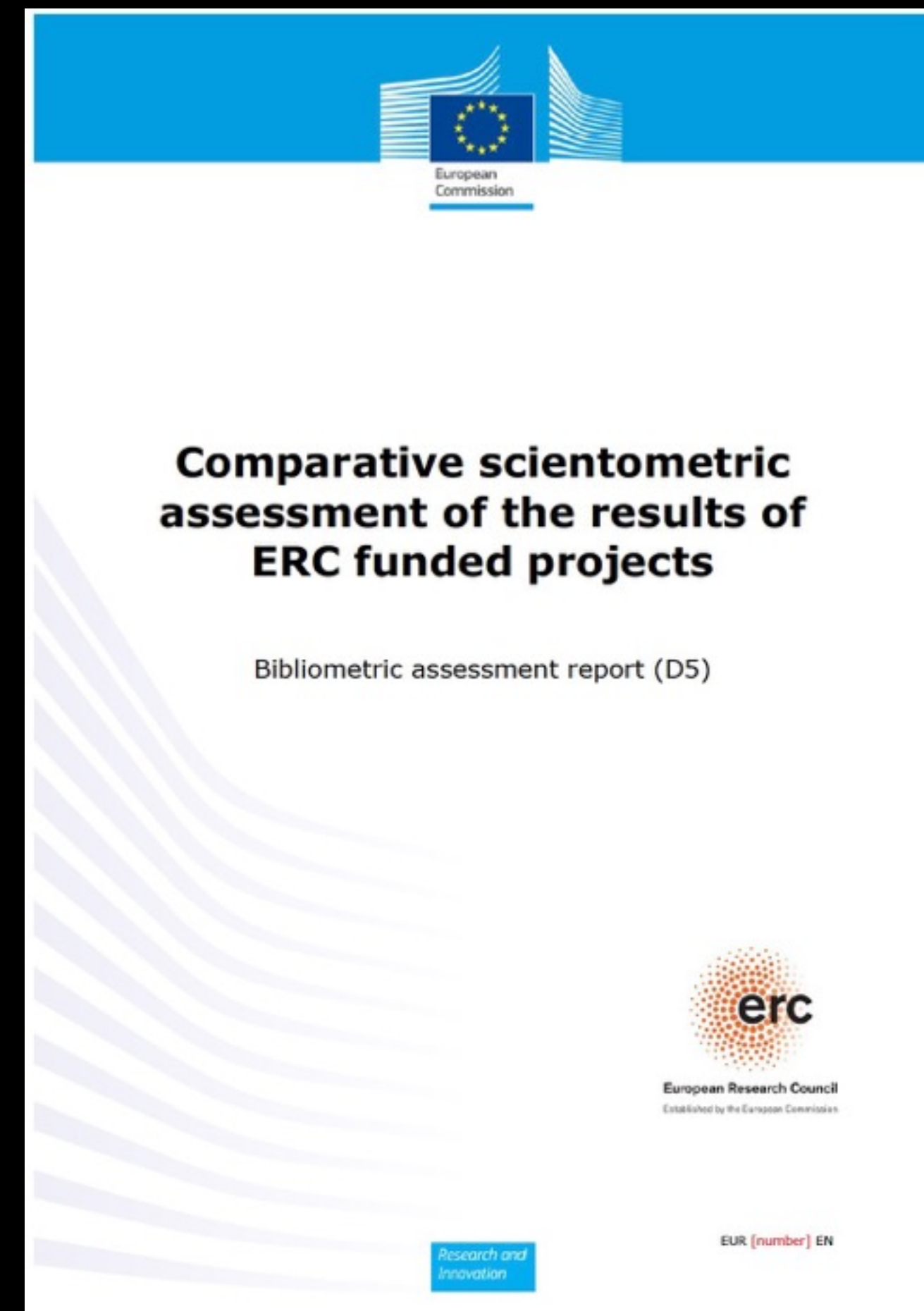
The balance between science driven by competition and science driven by curiosity / ambition has changed in the last 30 years, in favor of the former. Example: the ERC system, 13.1 BEuro 2014-2020



Competition-driven science

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Extremely competitive: 1 proposal out of 10 financed
How many breakthroughs and how much advancement of science does it produce?

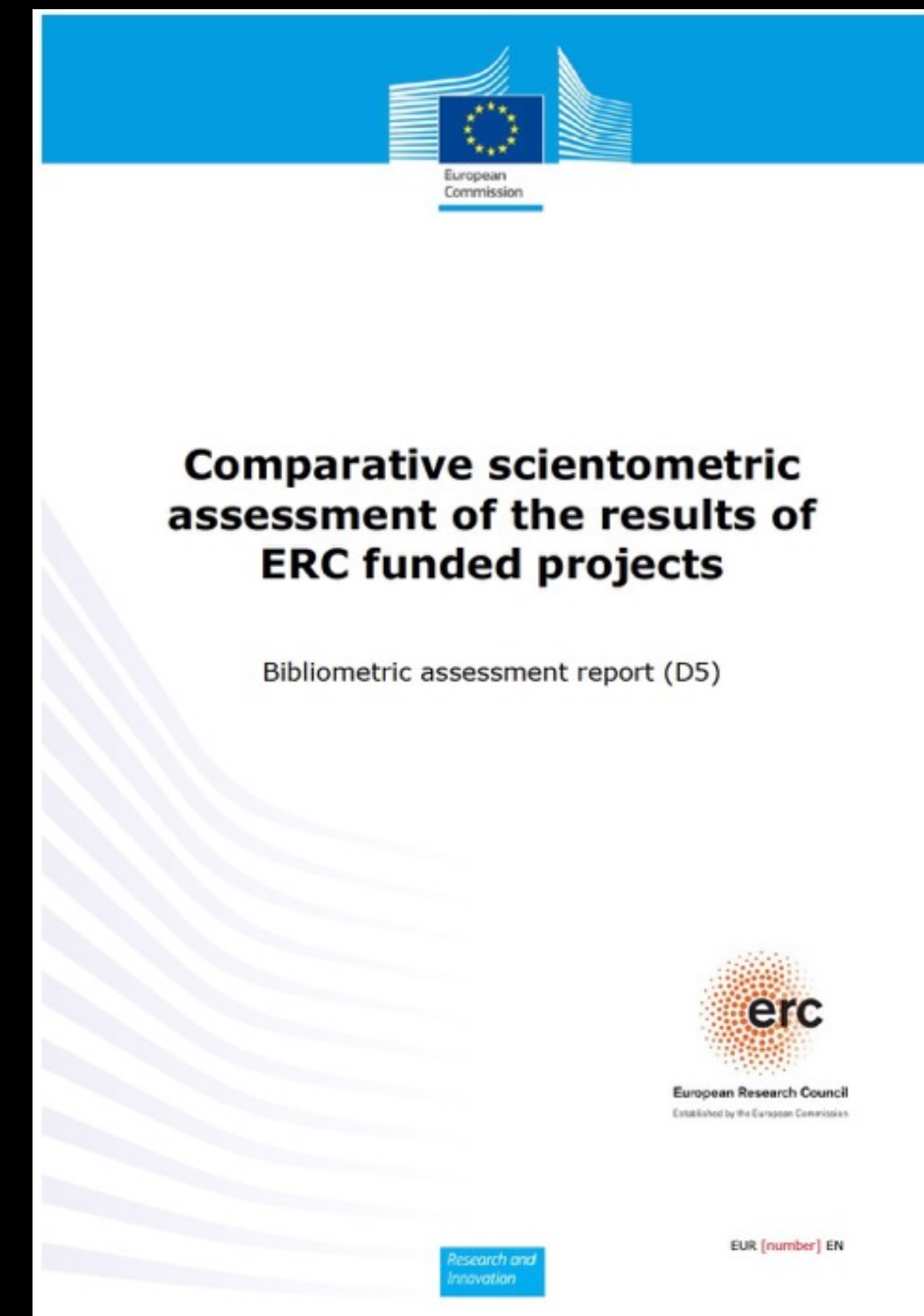


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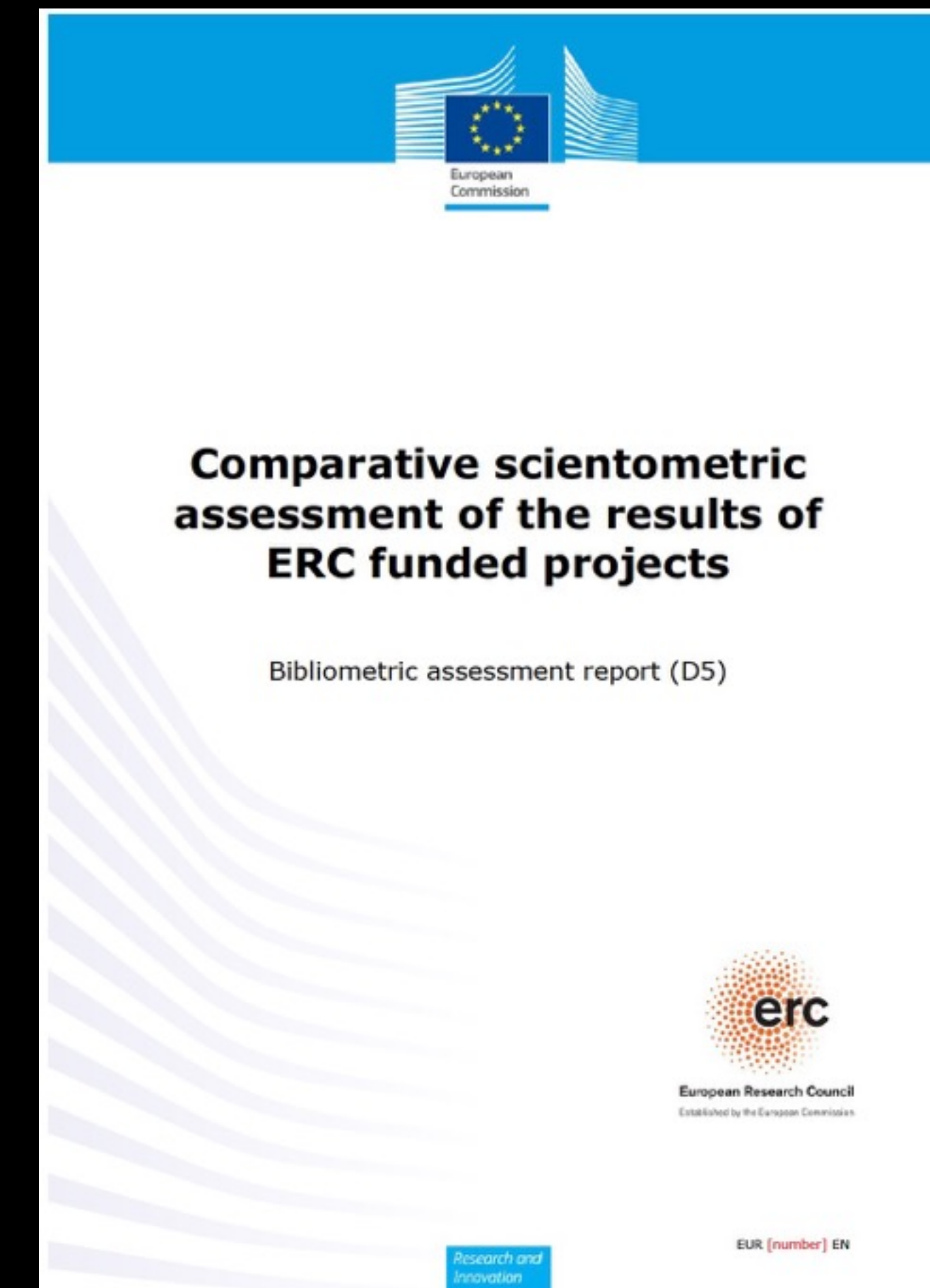
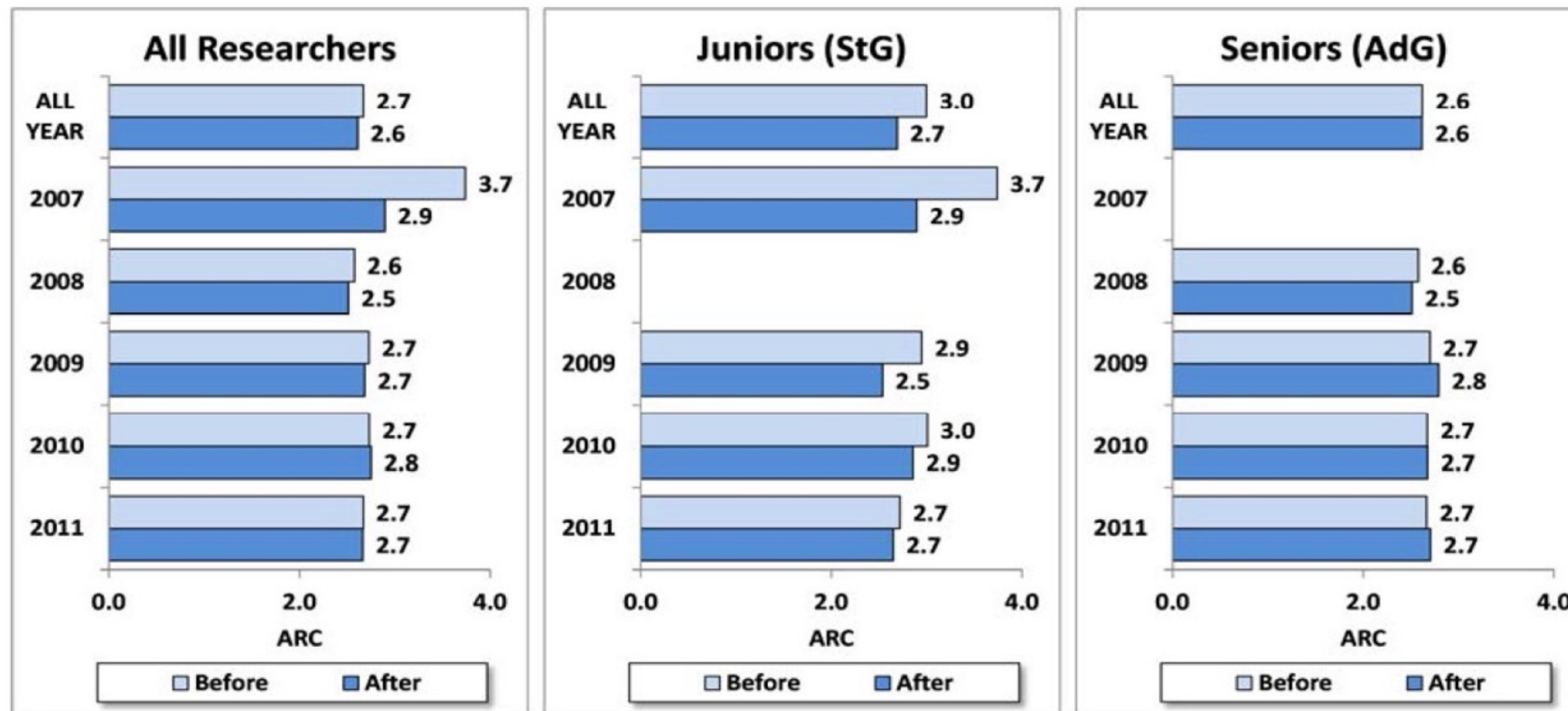
- Does productivity increase with funding?
- Are the winners really the most competitive researchers?



Competition-driven science

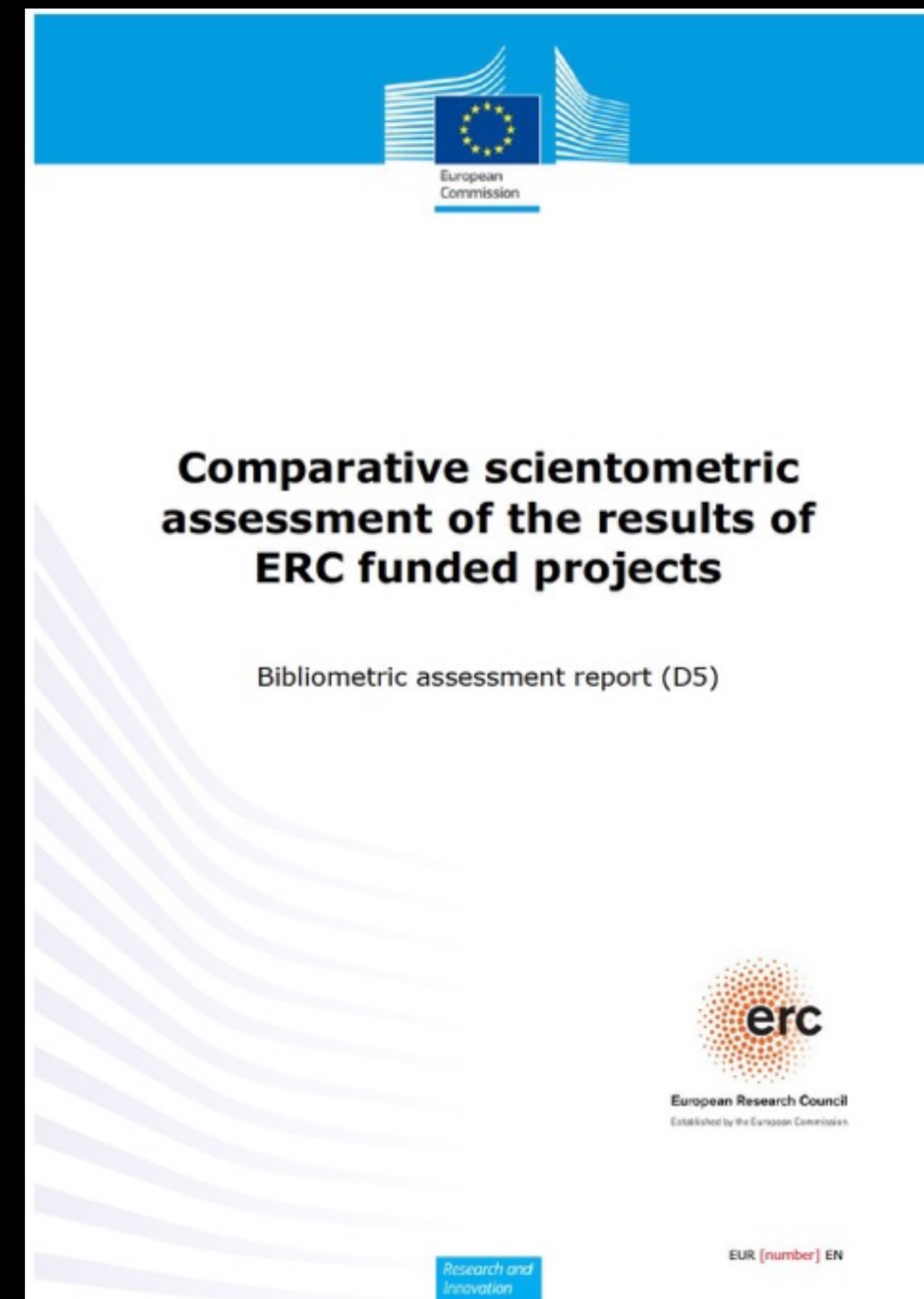
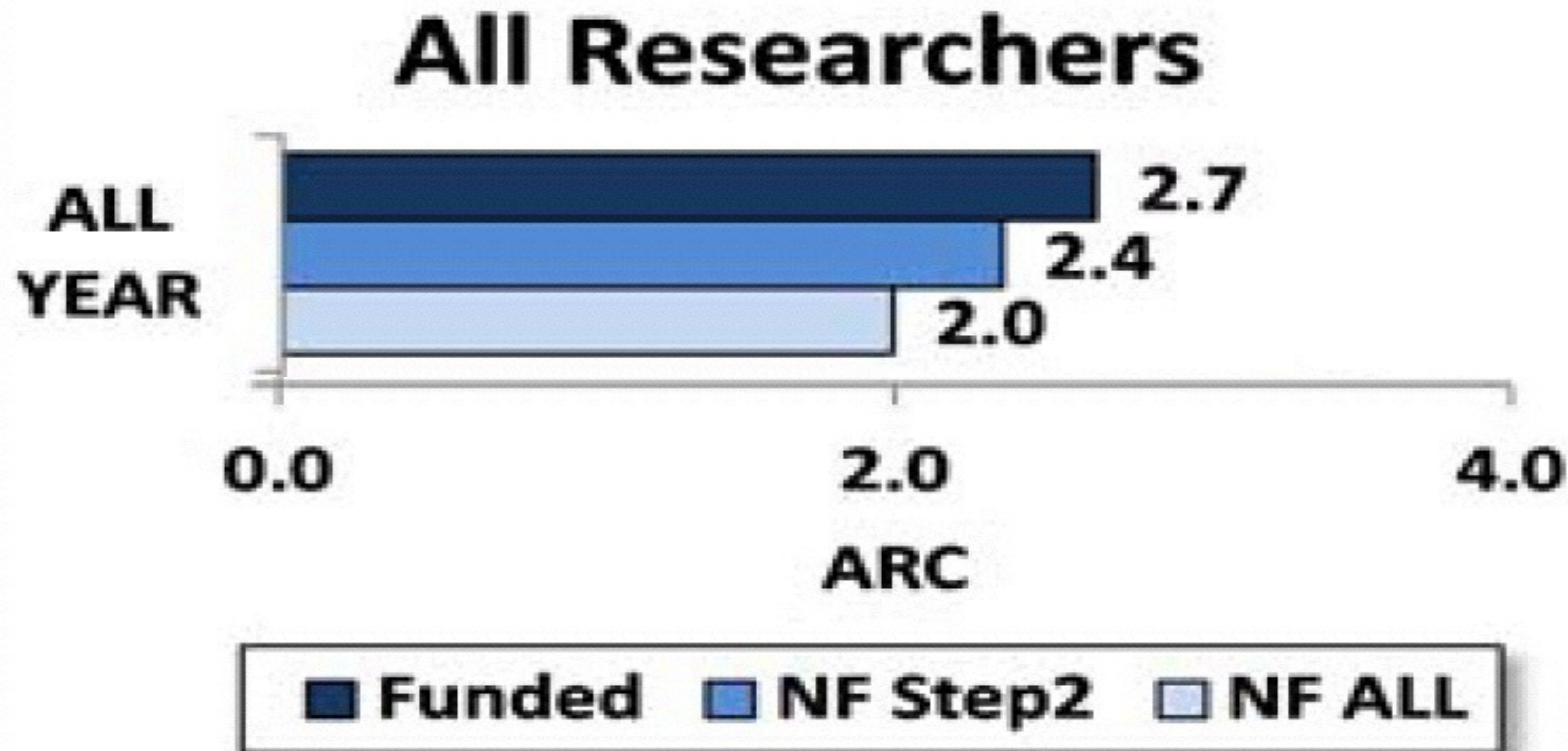
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Figure 3-19. Average of Relative Citations (ARC) of ERC Funded Researcher Before and After the Grant Start Year by Seniority and Competition Year



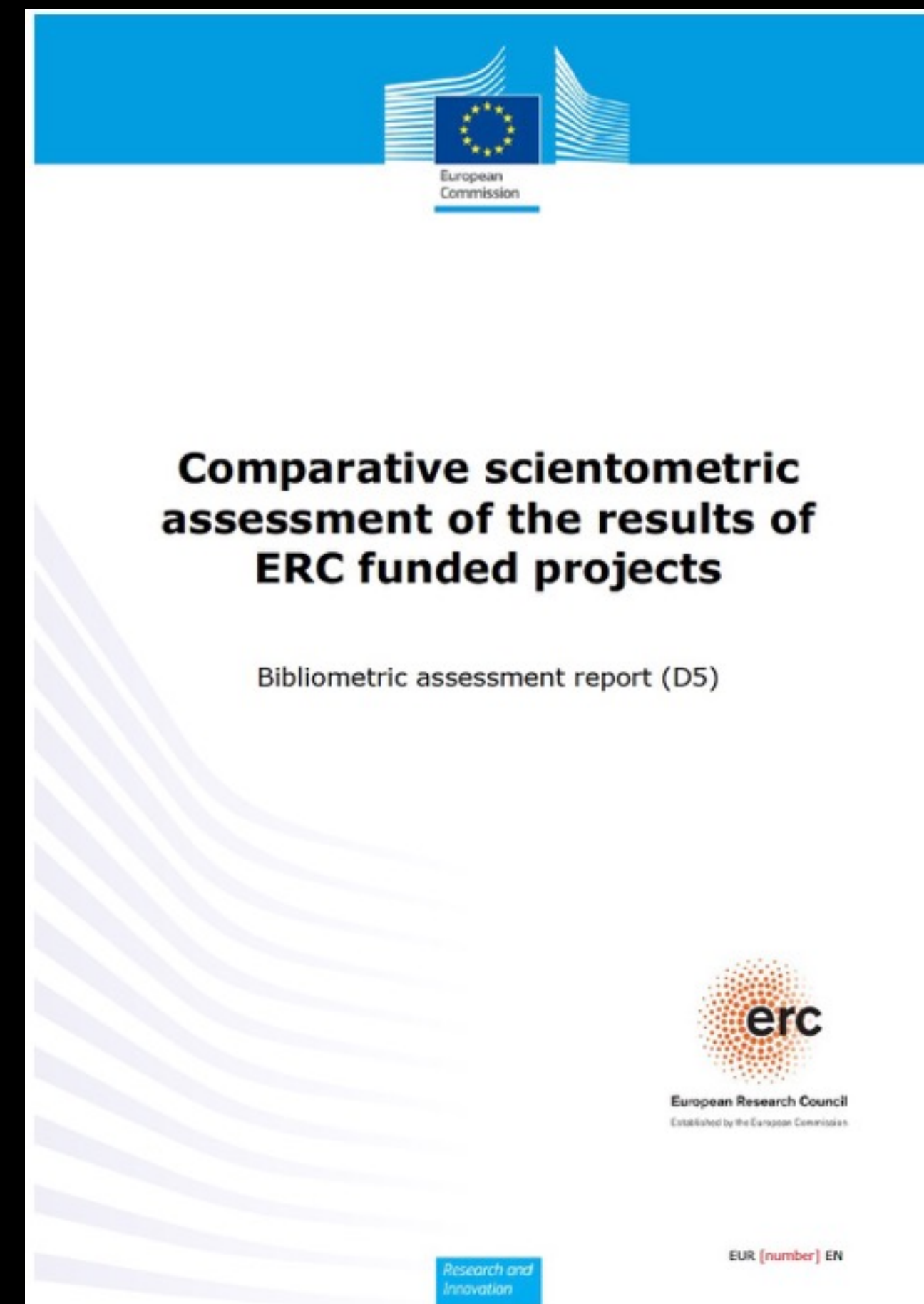
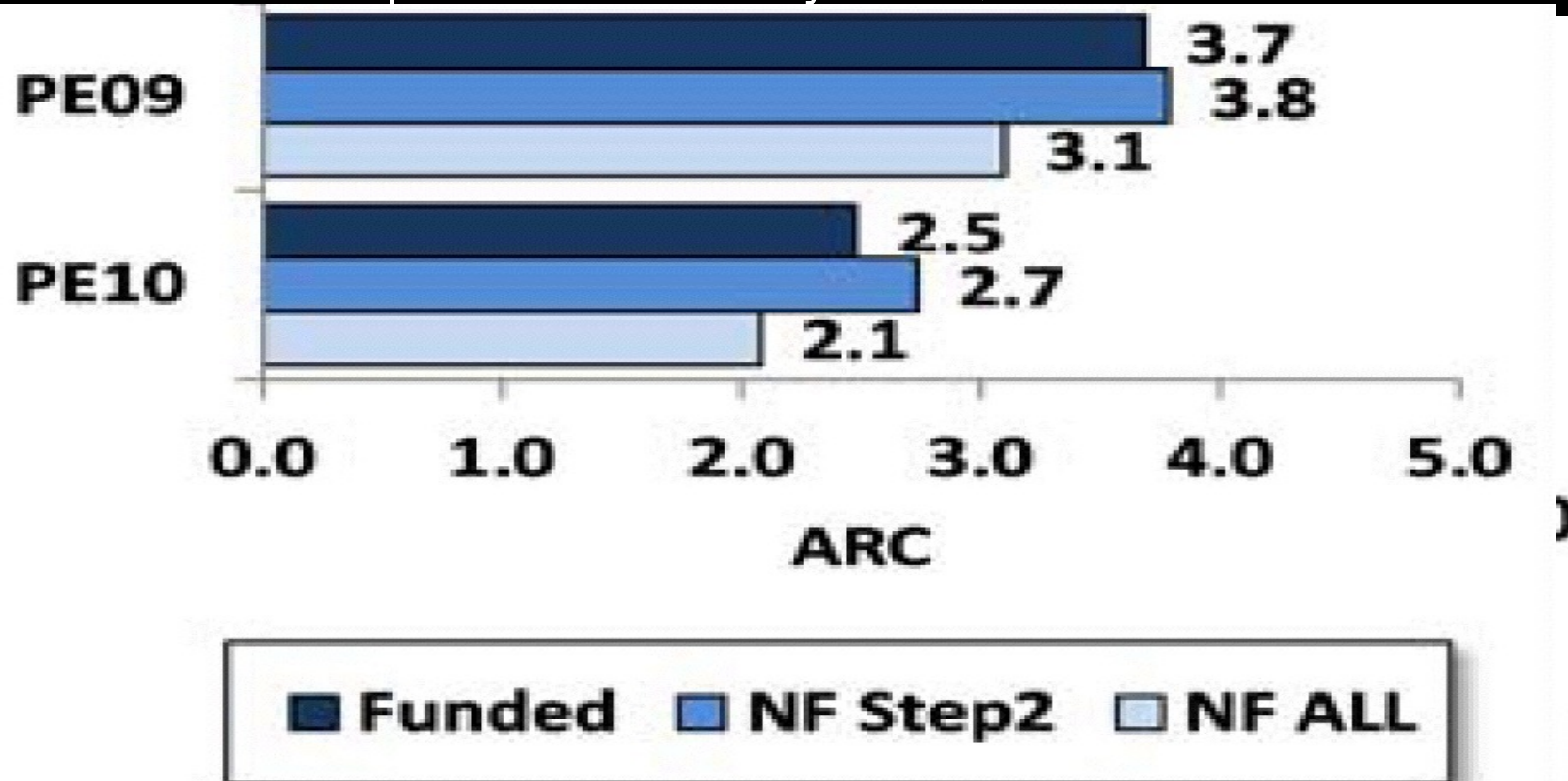
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Competition-driven science

The ERC system

As to the effect of ERC funding, the bibliometric data does not provide any evidence for a major impact on the publication output of grantees, either from a quantitative point of view, or from a qualitative one. While the ERC researchers slightly increase their productivity during the funding period, their scientific impact remains essentially unchanged. Along the same lines, ERC funding does not seem to lead to the adoption of more intense interdisciplinary practices than those observed in the global research landscape. However, one should note that the publication output of ERC grantees is already outstanding at the moment they submit their applications. Improving such performances is therefore not an easy task.

Competition-driven science

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Competition-driven science often produces incremental results

A new driving force for research:
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a) incremental results; b) demand of short term positions cheap and mobile.
Dual labor market.

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Thorne: “Today it would not be easy to convince the government to finance a project like LIGO, politics no longer wants to risk big scientific adventures”

Historical trends: scientific production

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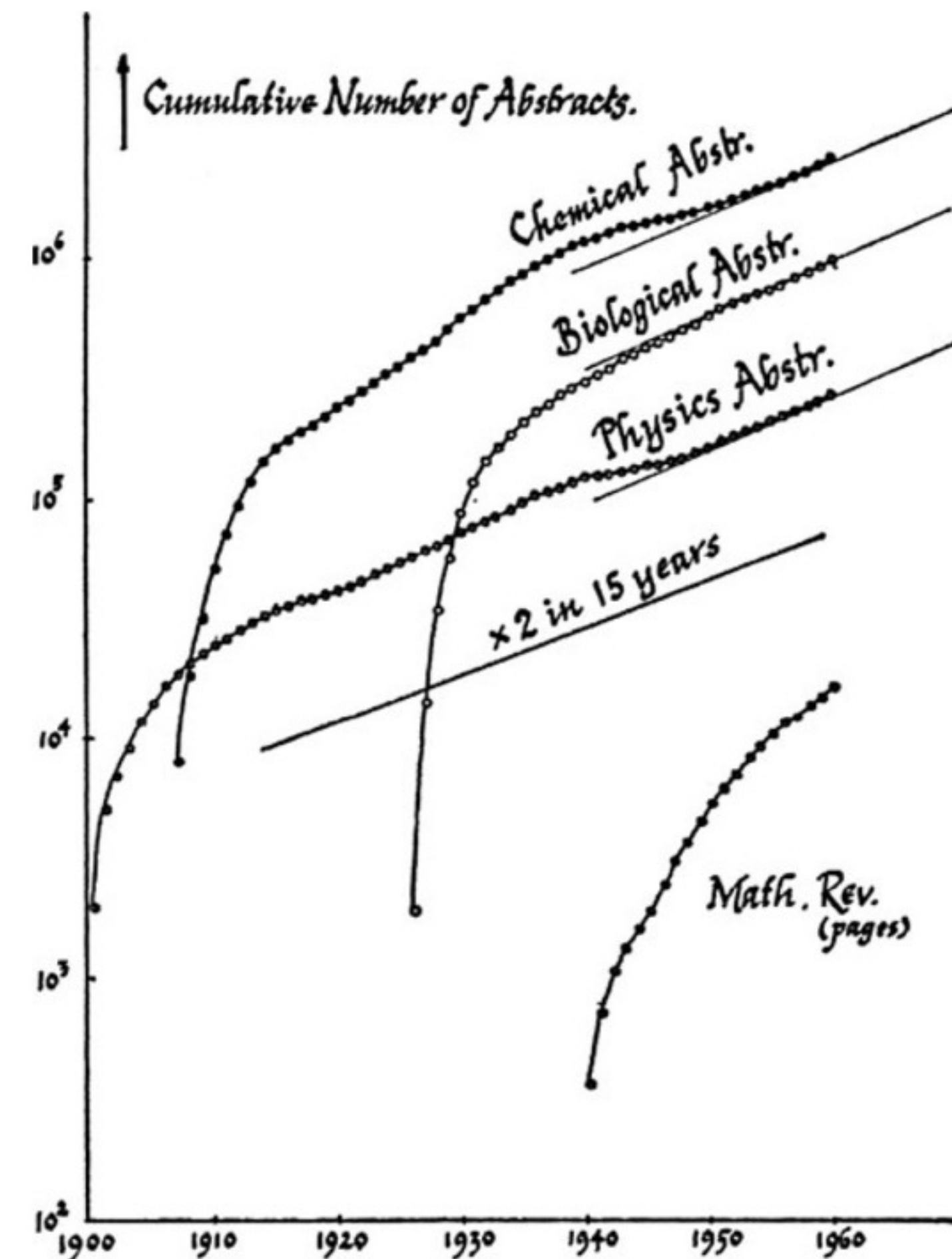


Fig. 2. CUMULATIVE NUMBER OF ABSTRACTS IN VARIOUS SCIENTIFIC FIELDS, FROM THE BEGINNING OF THE ABSTRACT SERVICE TO GIVEN DATE

It will be noted that after an initial period of rapid expansion to a stable growth rate, the number of abstracts increases exponentially, doubling in approximately 15 years.

Historical trends: scientific production

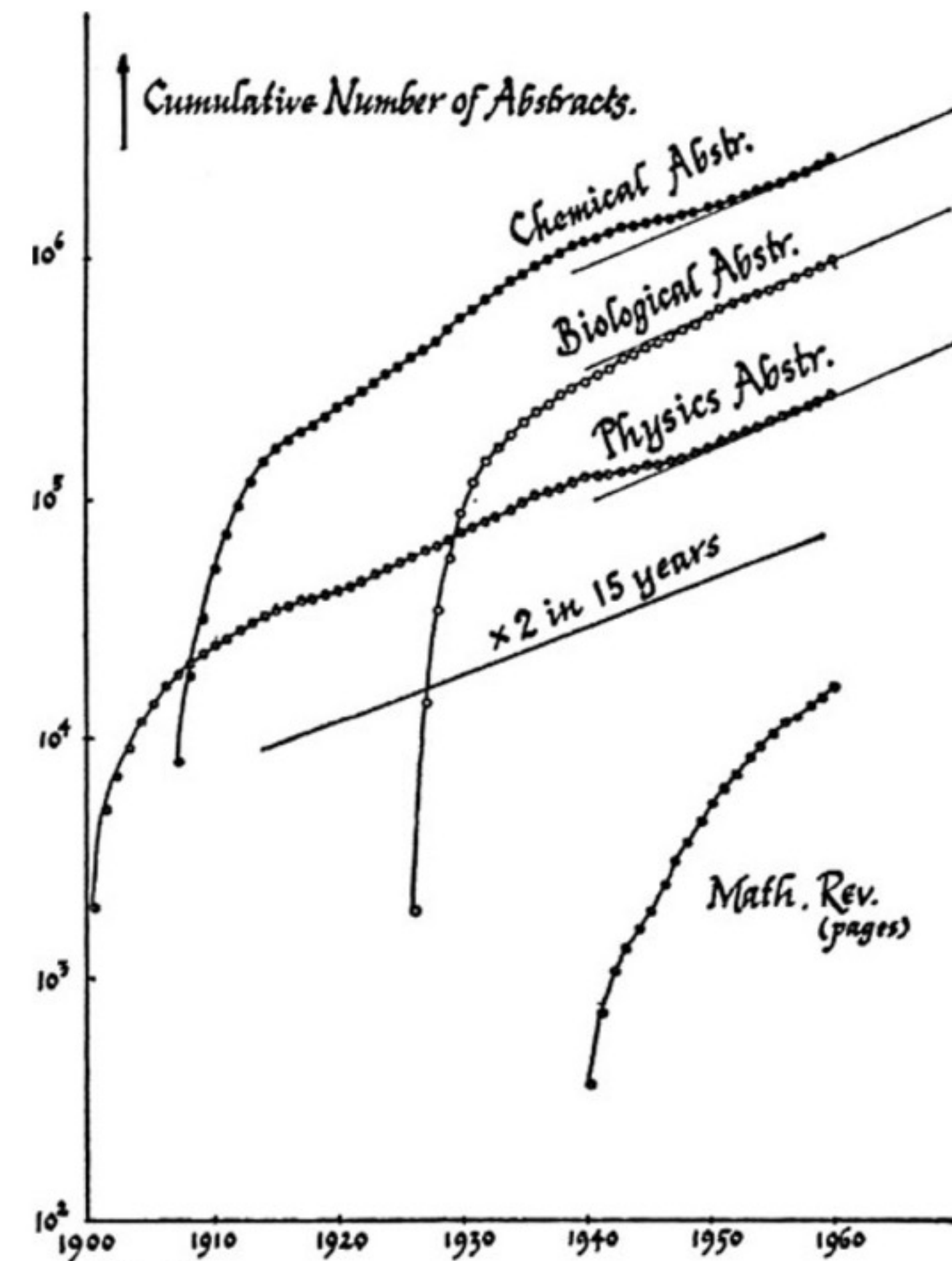
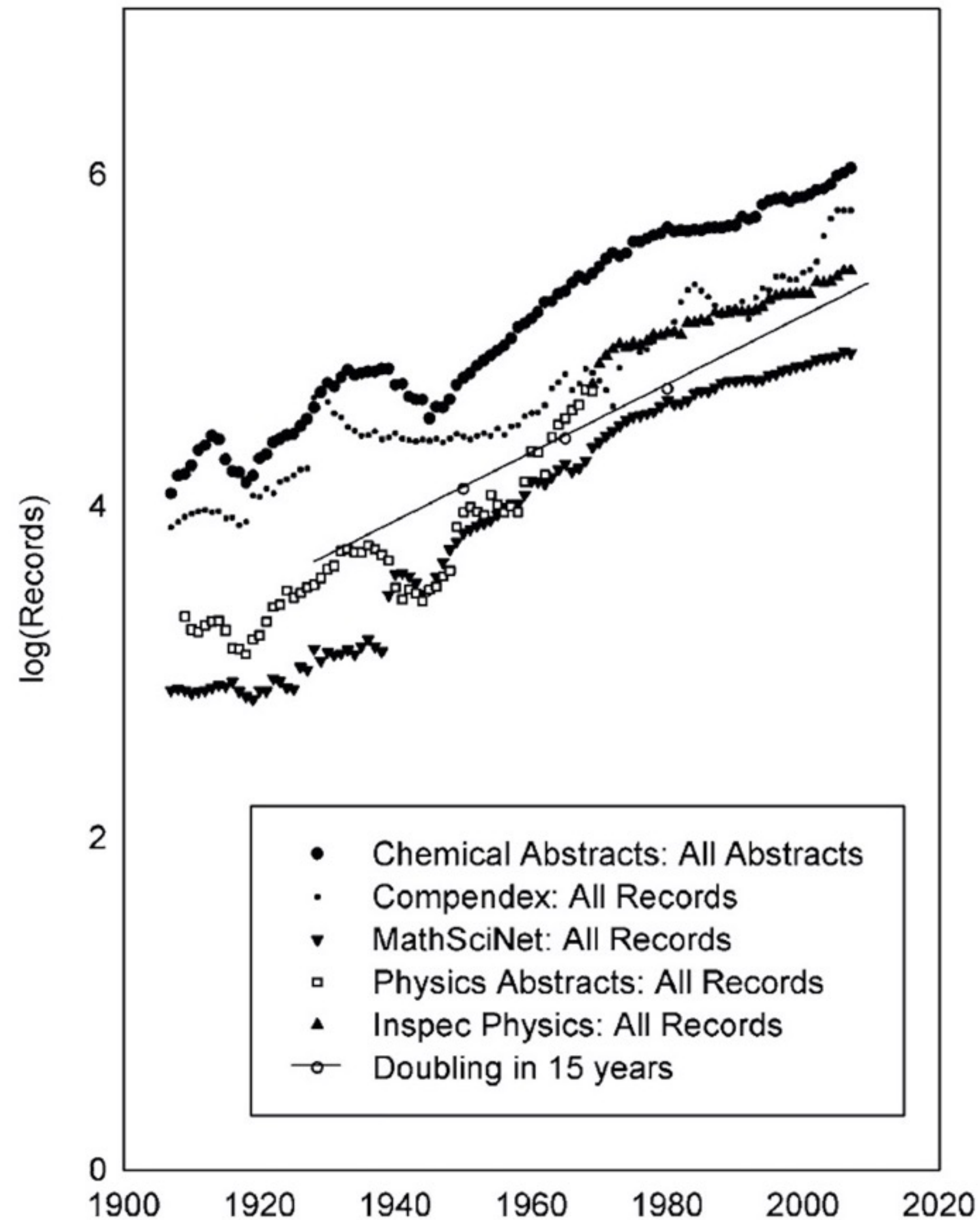
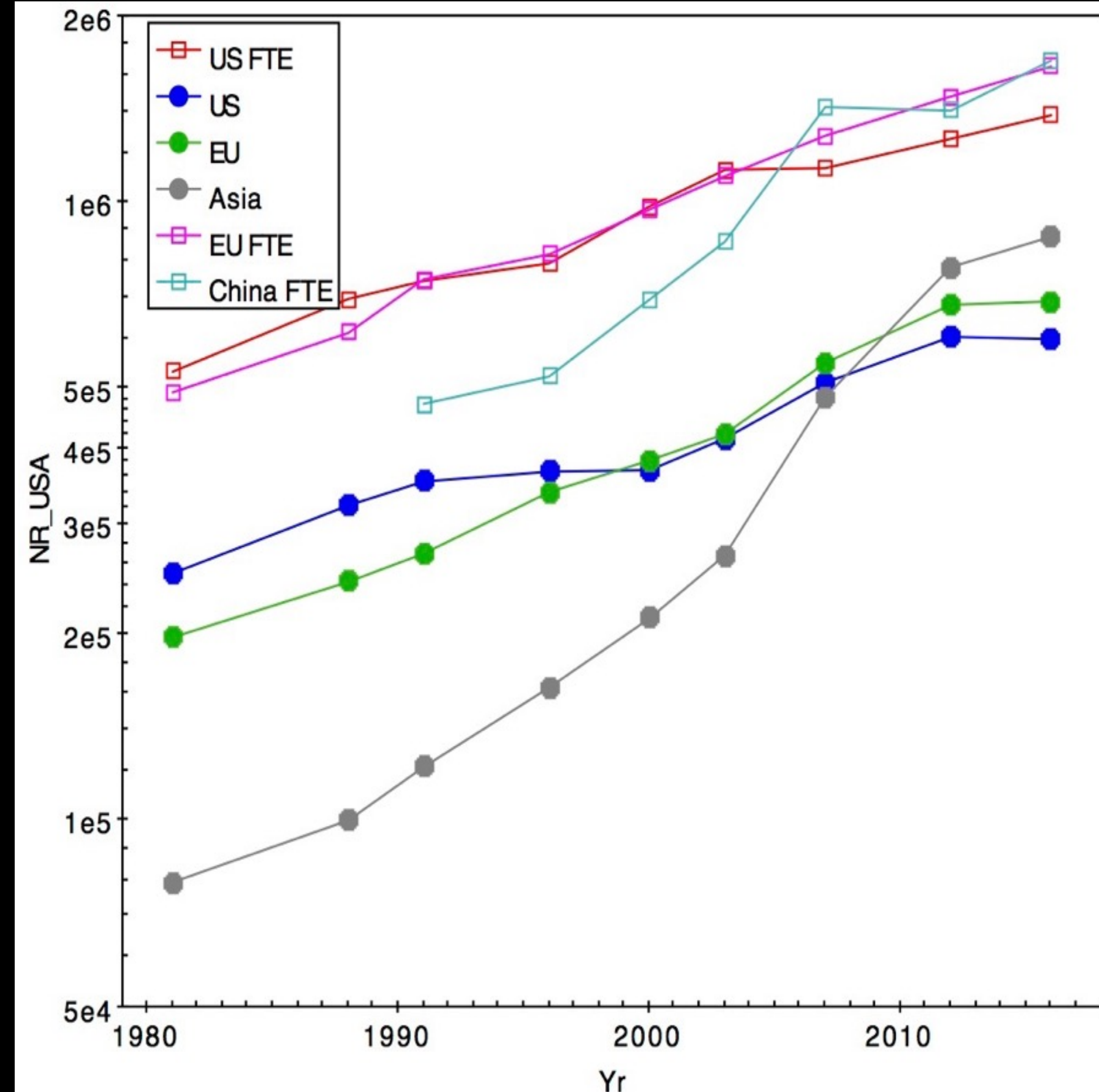
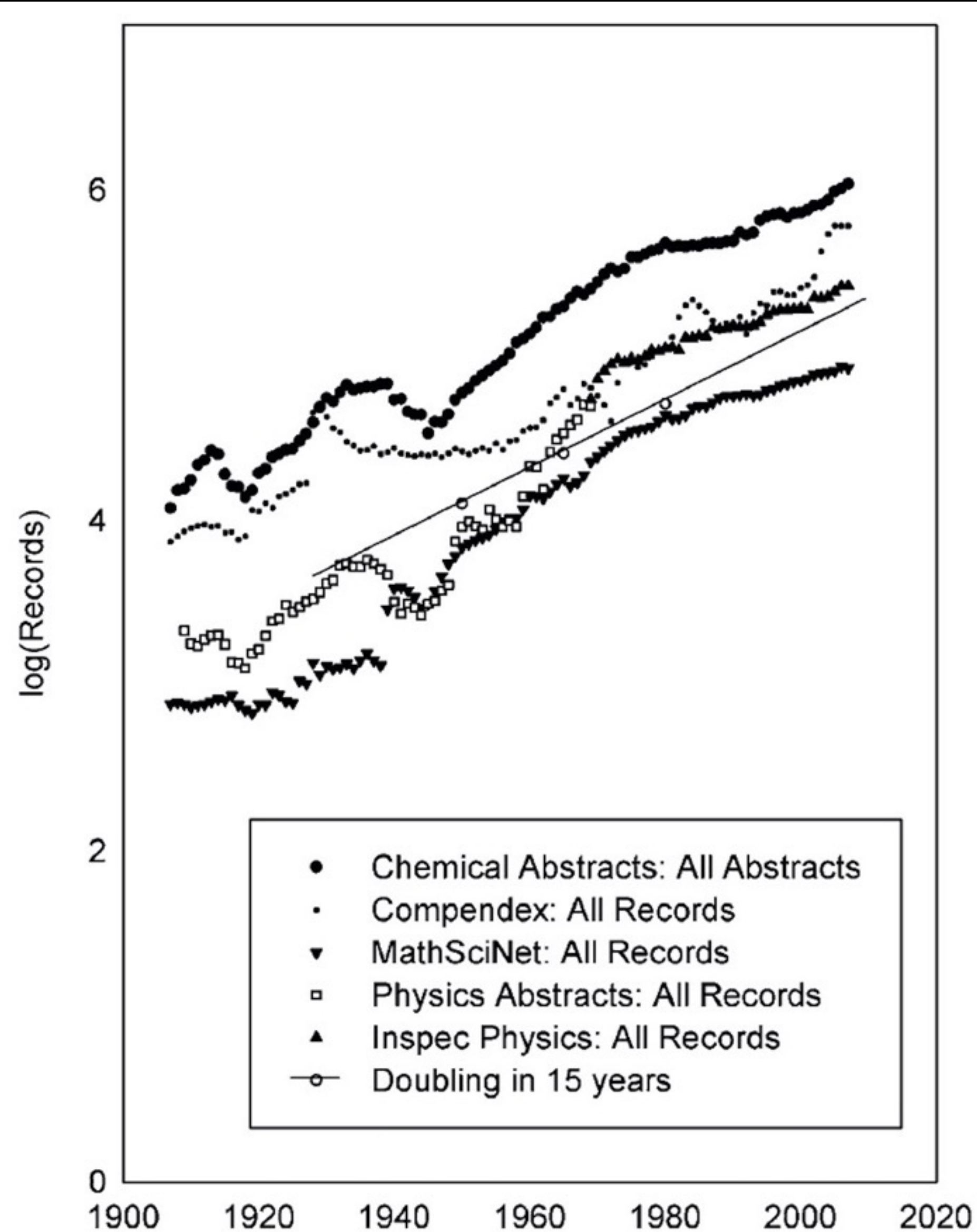


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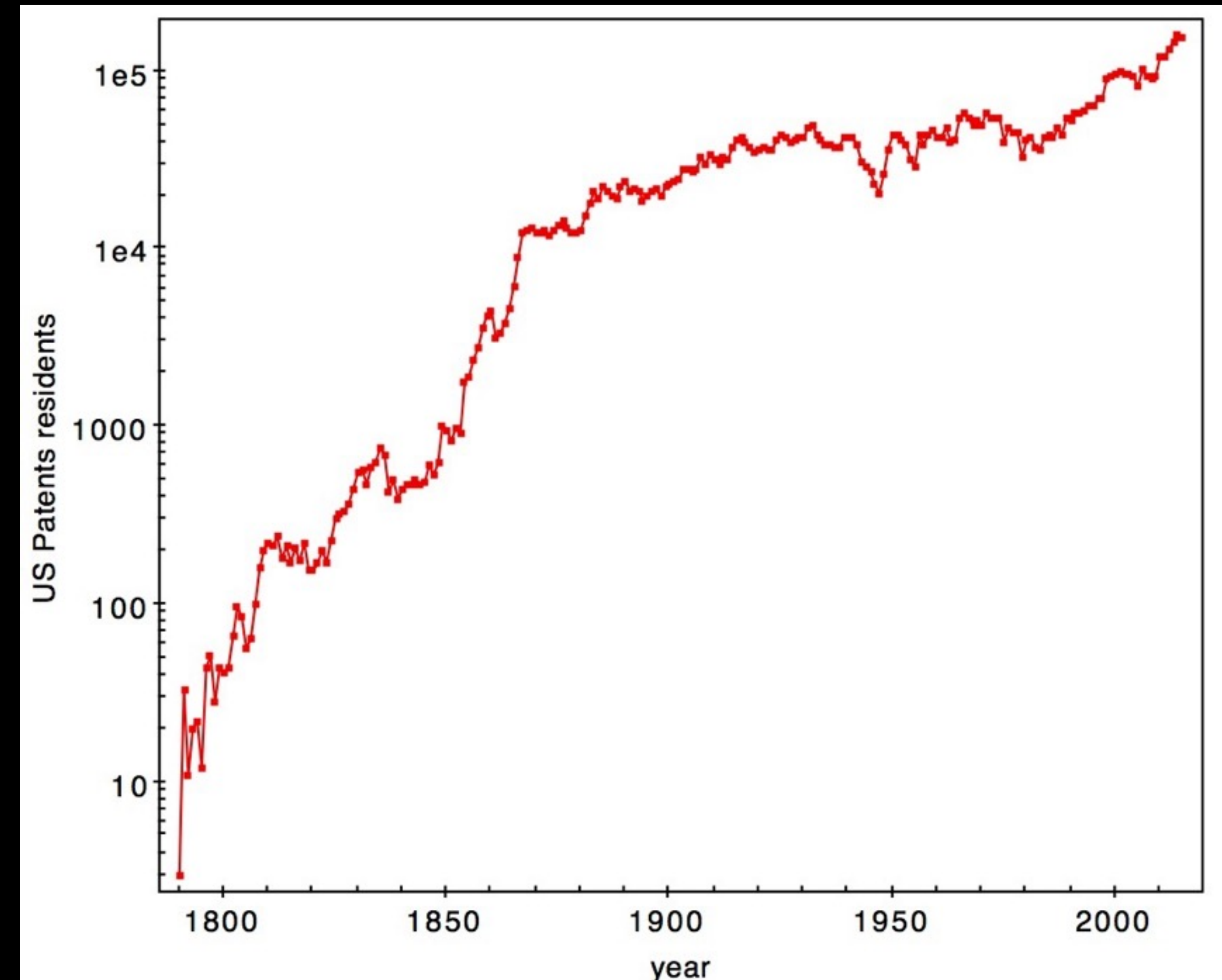
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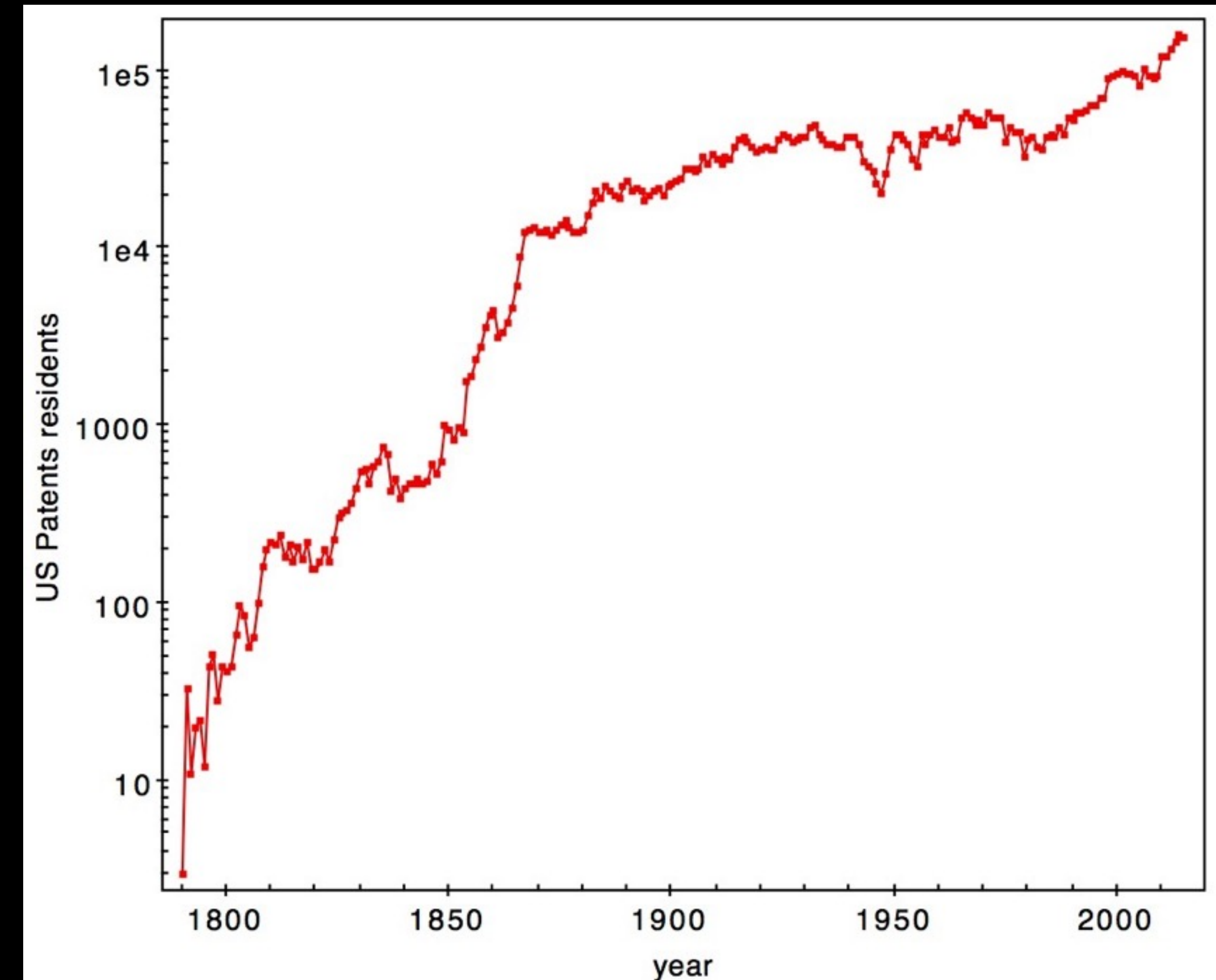
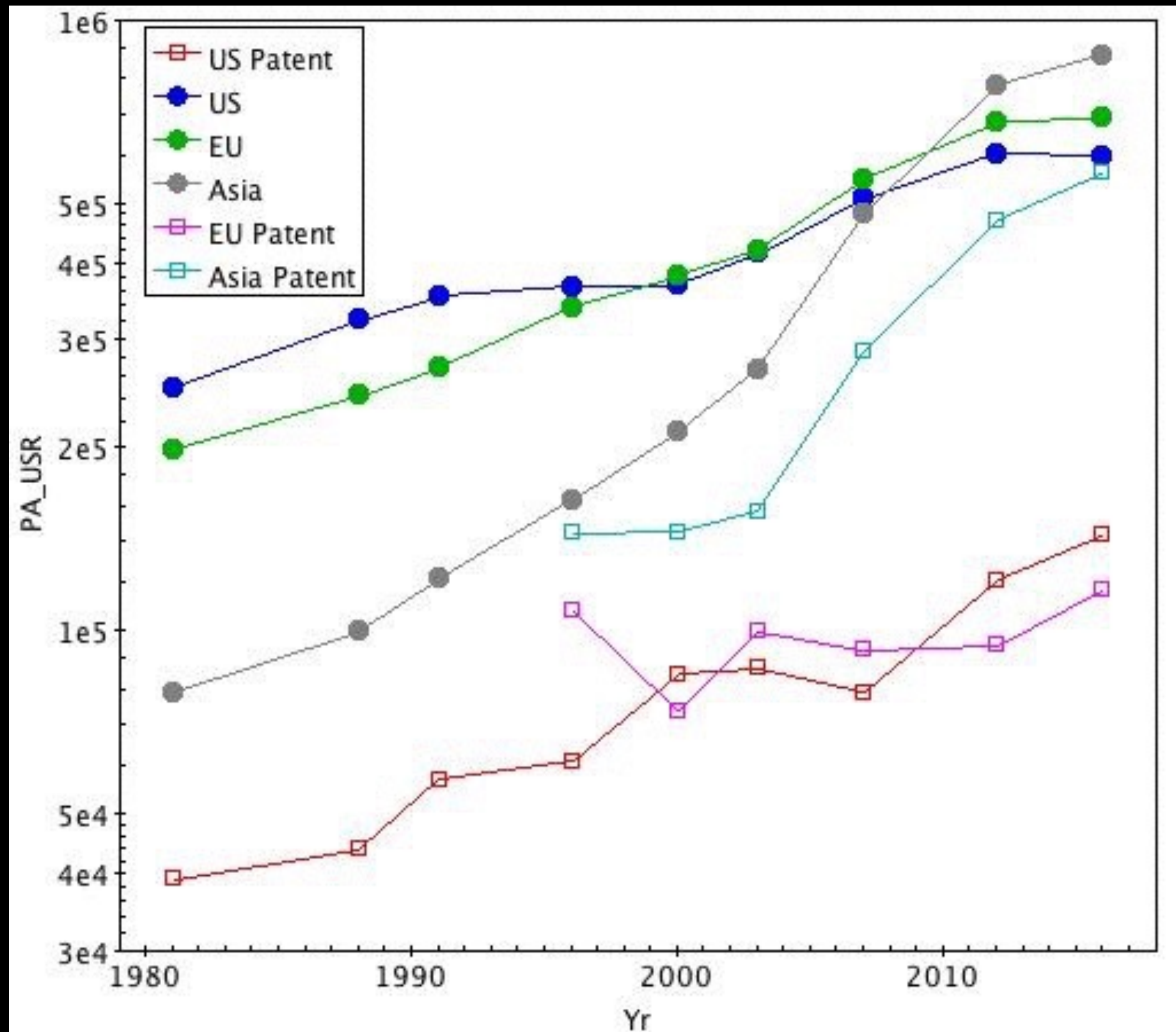


Historical trends: Transfer Knowledge

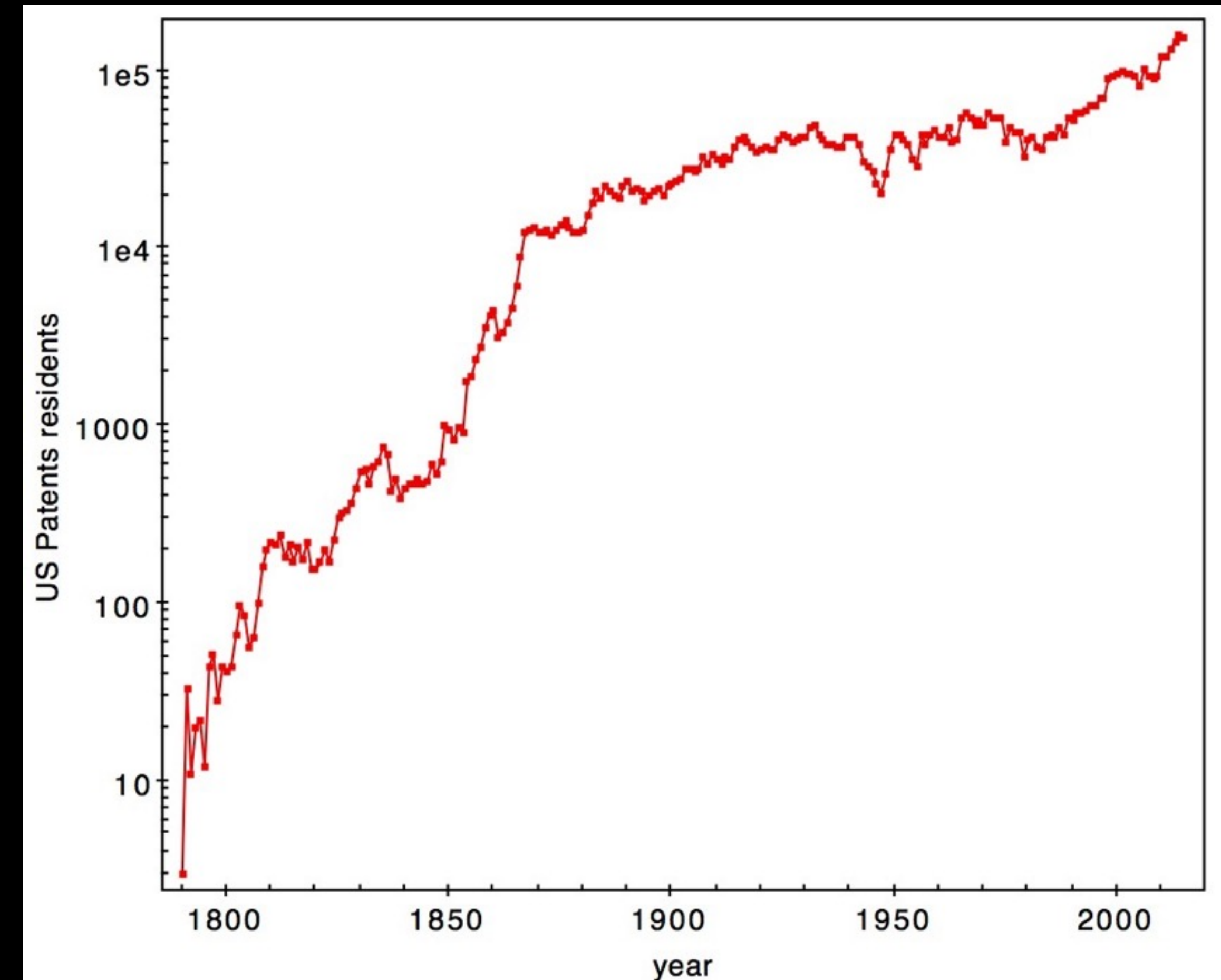
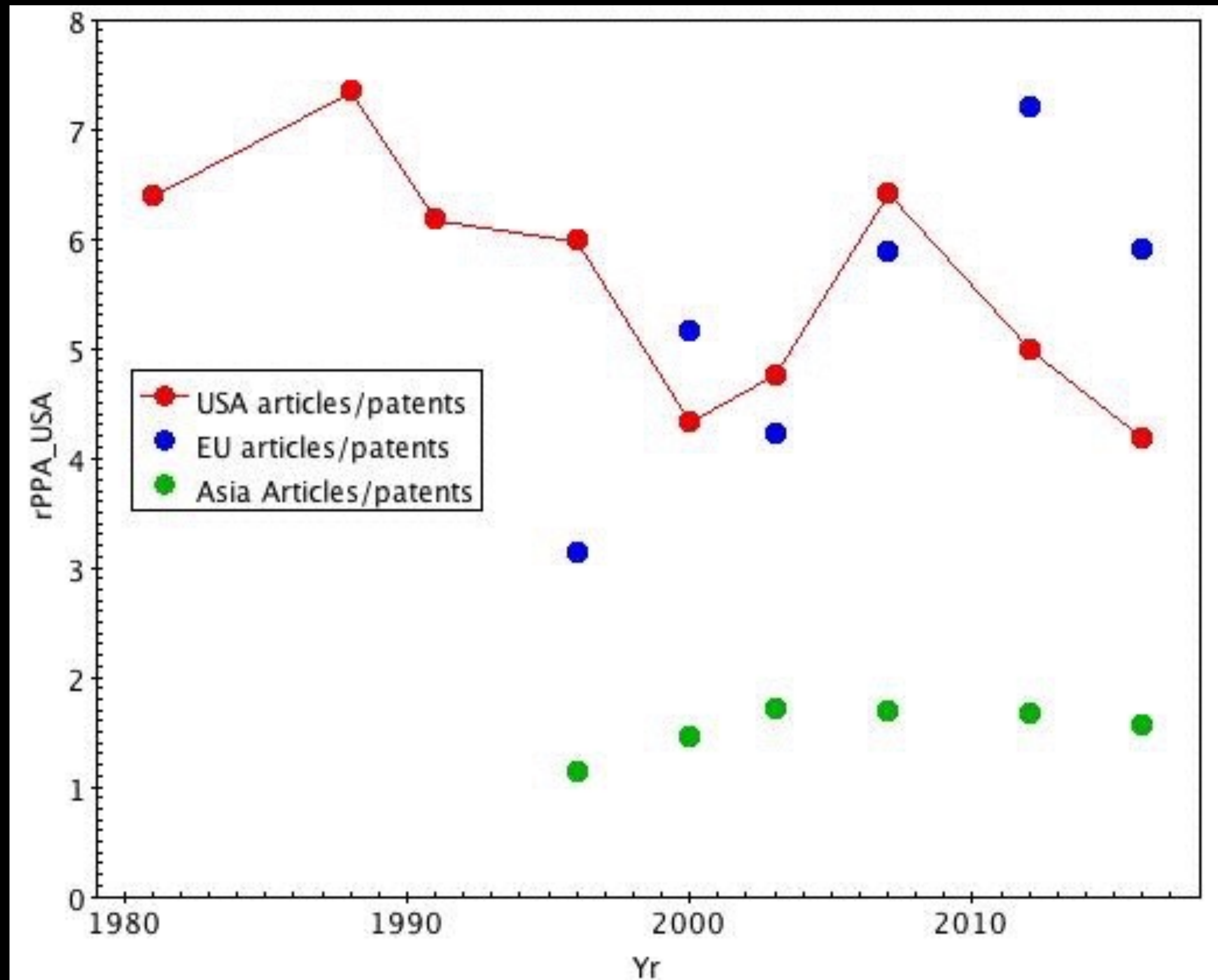
Historical trends: Transfer Knowledge



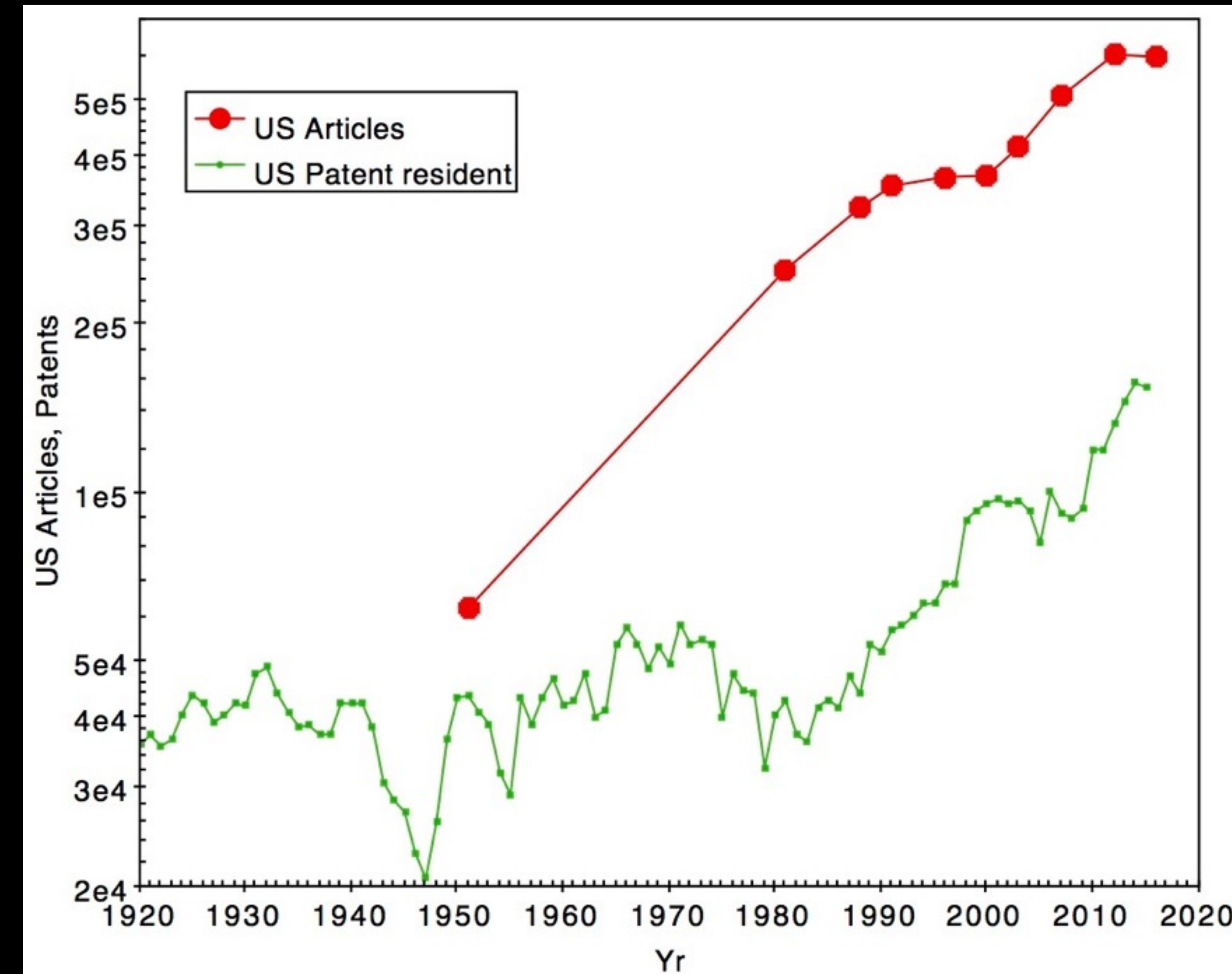
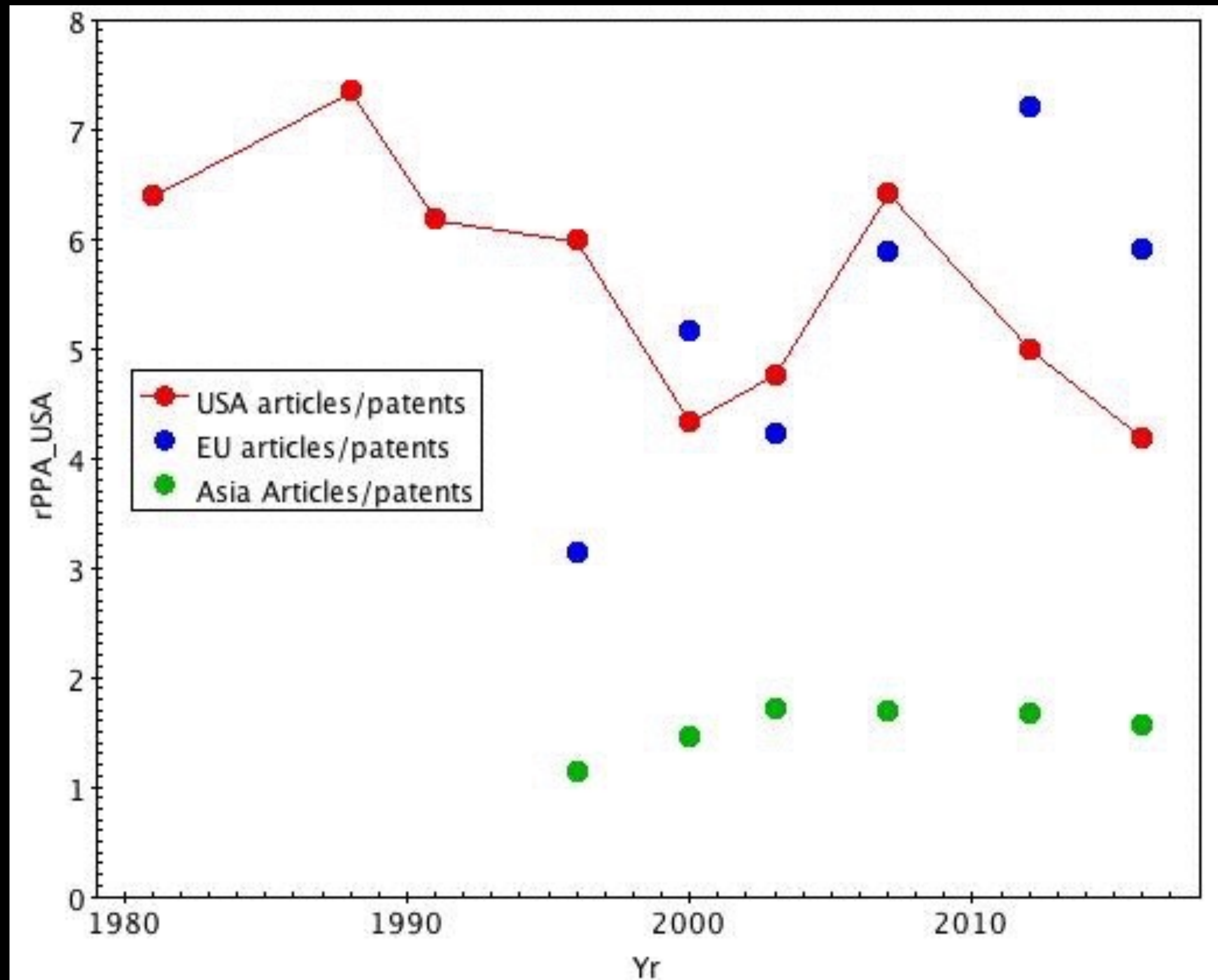
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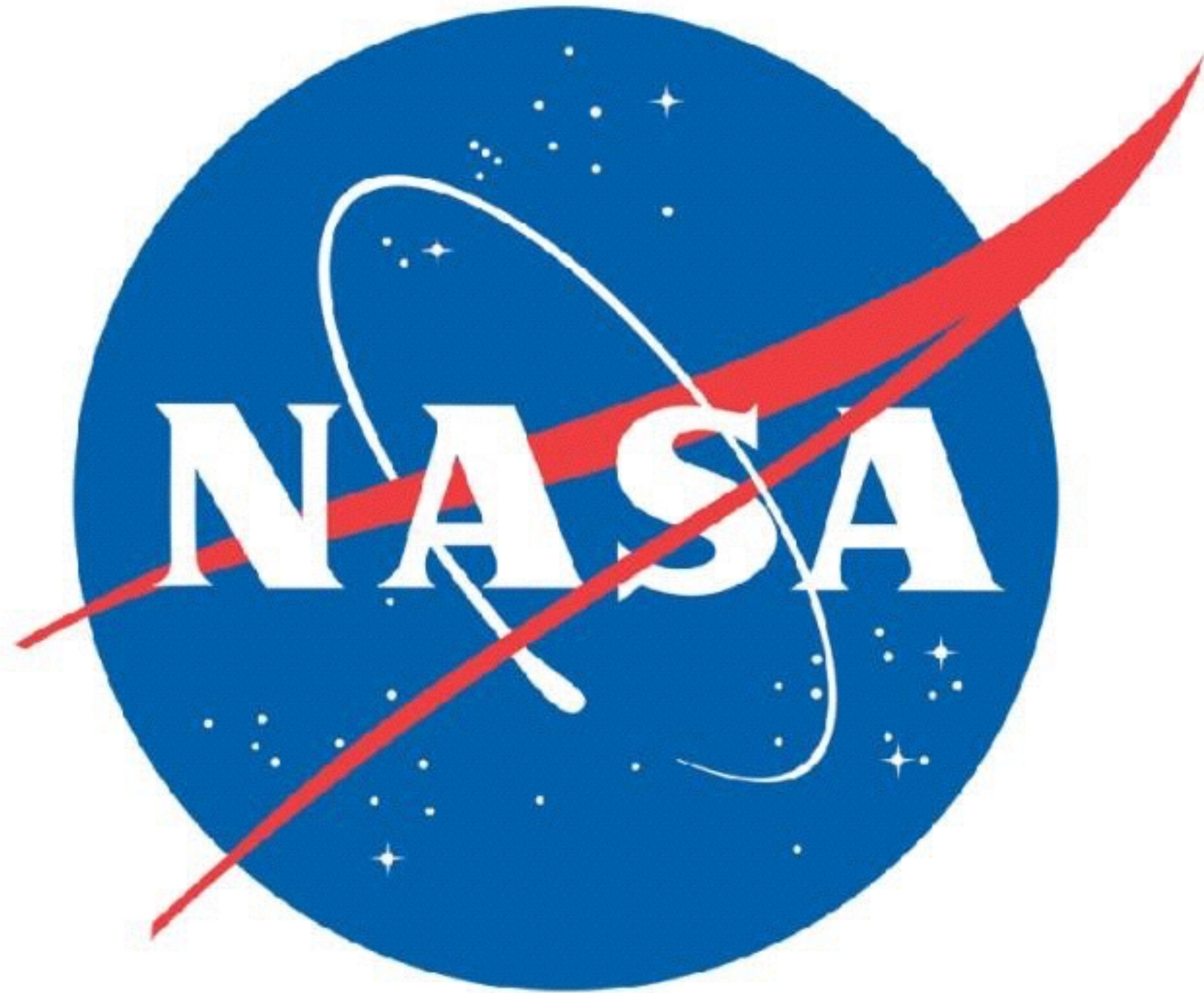


Science is a risky business

Is still Science a risky business?

THE GREATEST TEACHER,

FAILURE IS



Failure is **not** an option

Conclusion

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Return to public institutions the ability 'to make ambitious science and therefore ambitious choices.

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Reduce the short-term, cheap position: drive the recruitment through tenure tracks

Collaborate with private sector who want to invest in ambitious projects

But, how to do science?

The scientific method was invented by Galileo 400 years ago, and has resisted at least three industrial revolutions:

- 1750 - The first industrial revolution in UK

- 1900 - Ford and the assembly line

- 1950 - von Neumann dream: computers

- >2000 - Is resisting to the fourth? (Big data, IoT, AI)

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Model confirmed, model rejected

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However, theoretical ideas influence the choice of the experiment and the interpretation of data ...

Feyerabend: The experiments that may contradict the dominant vision come from rival theories. Scientists should never agree. **No method**, in times of crisis, scientists proceed by violating the rules

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100 methods: the essence of science is to draw conclusions from incomplete information. Great chance of error. Science requires correction mechanisms, a collection of practical activities to unmask errors.

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Feynmann: Science is organized skepticism towards the reliability of experts' opinion

The fourth industrial revolution

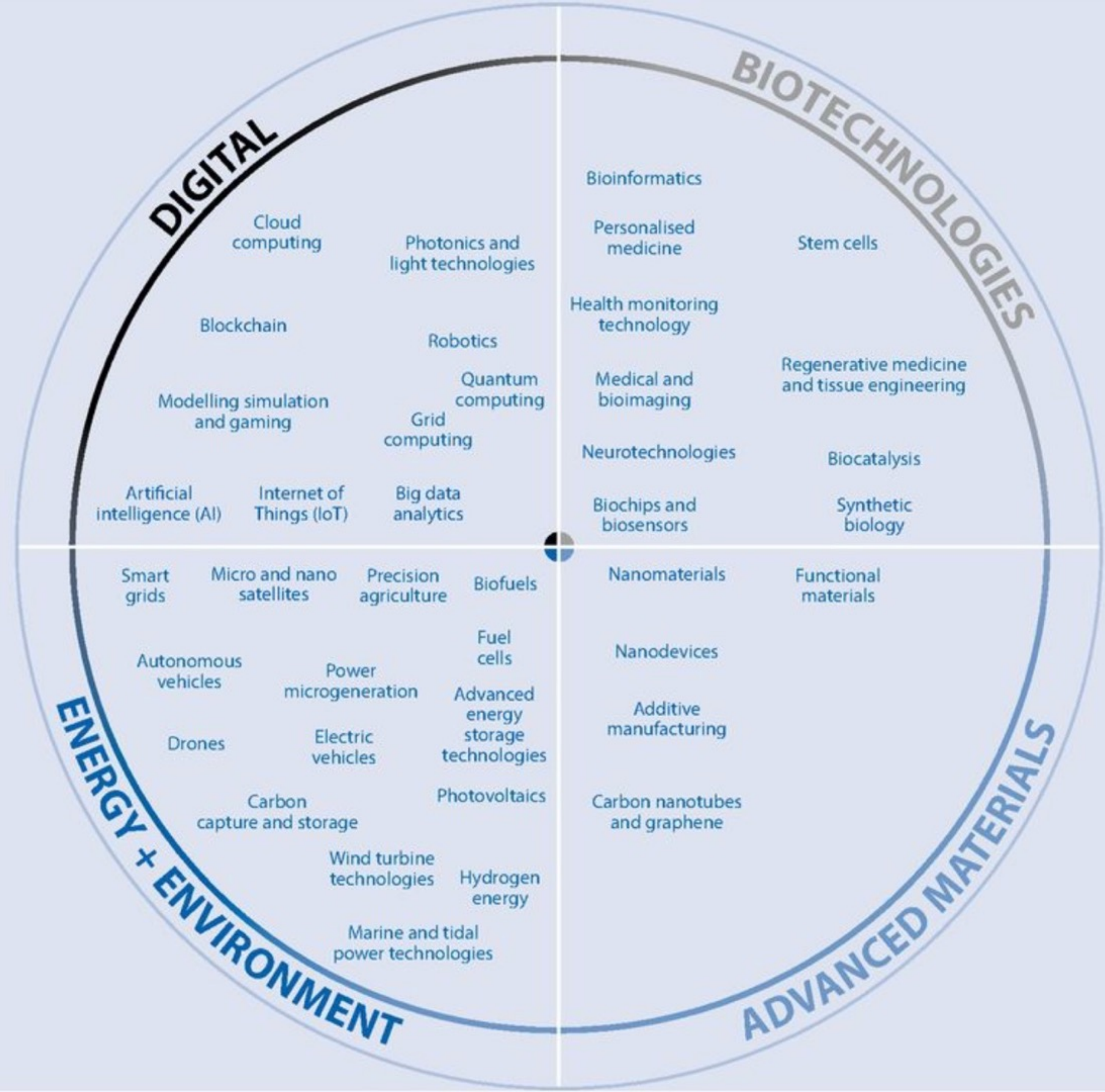
Organisation for Economic Cooperation and Development



OECD Science, Technology
and Innovation Outlook 2016



The fourth industrial revolution



The fourth industrial revolution

Internet of Things

Big data

Artificial Intelligence

Neurotechnologies

Nano/micro satellites

Nanomaterials

Additive manufacturing (3D printing)

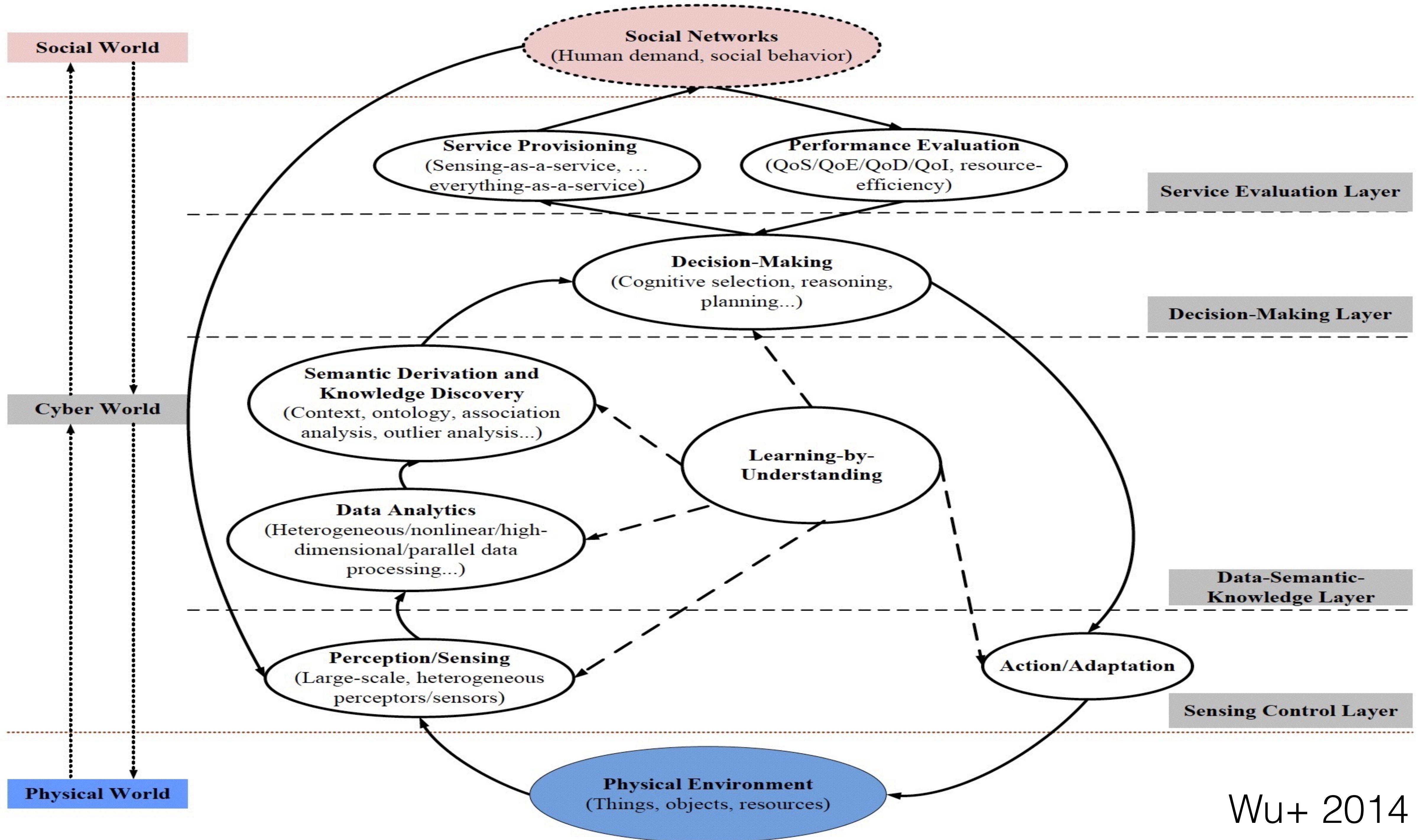
Energy storage

Synthetic biology

Blockchain



IoT+AI+Big data analytics =
Cognitive IoT





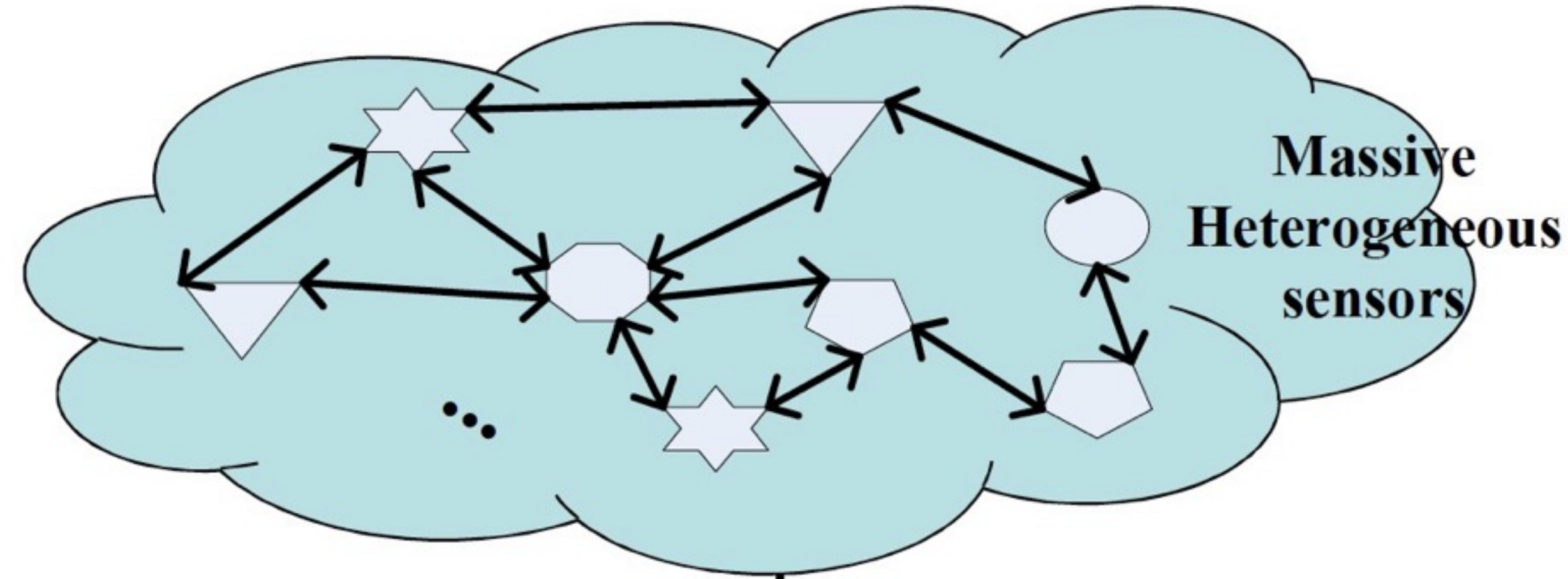




Kyle Reese to Sarah Connor

*Defense network computer, new, powerful, **hooked into everything**, trusted to run it all. They say it got smart, **a new order of intelligence**. Then it saw all people as a threat, not just the ones on the other side. Decided our fate in a microsecond: extermination.*





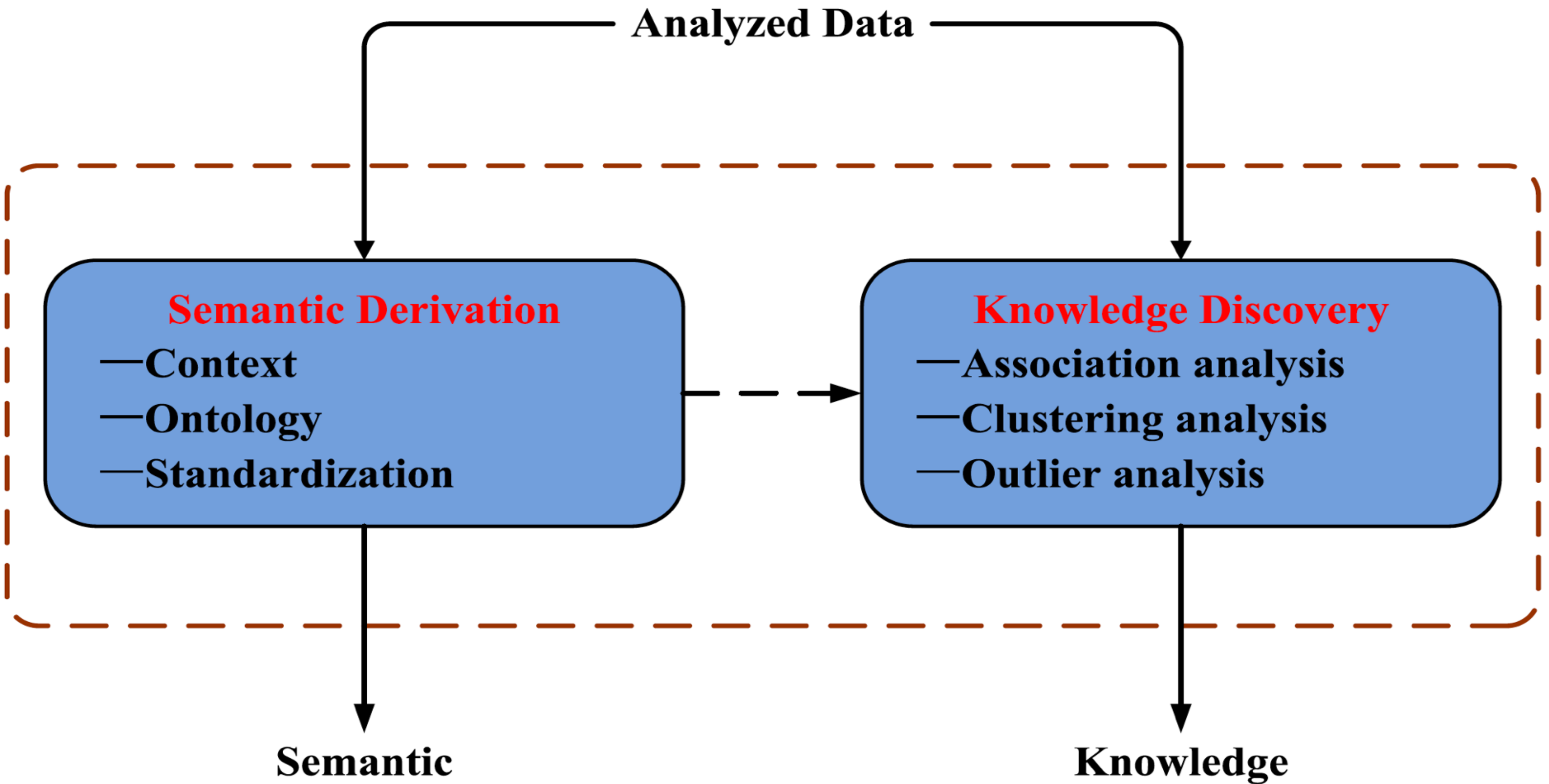
Raw Sensing Data

Massive, noisy, corrupted, heterogeneous, high-dimensional, and nonlinear separable...

Massive Data Analytics

- Heterogeneous data processing
- Nonlinear data processing
- High-dimensional data processing
- Distributed and parallel data processing

Organized Data



Science driven by testing of computer generated hypotheses based on patterns extracted from massive datasets.

Data will increasingly precede the research idea.

The process and utility of model development will change because the data will contain all objects of interest.

Data will be comprehensive, not representative.

Scientific method

First observation

Model/theory

Experiment

Model confirmation/rejection

Prediction



Cognitive IoT

Observations

Data analysis

Extrapolation



Knowledge

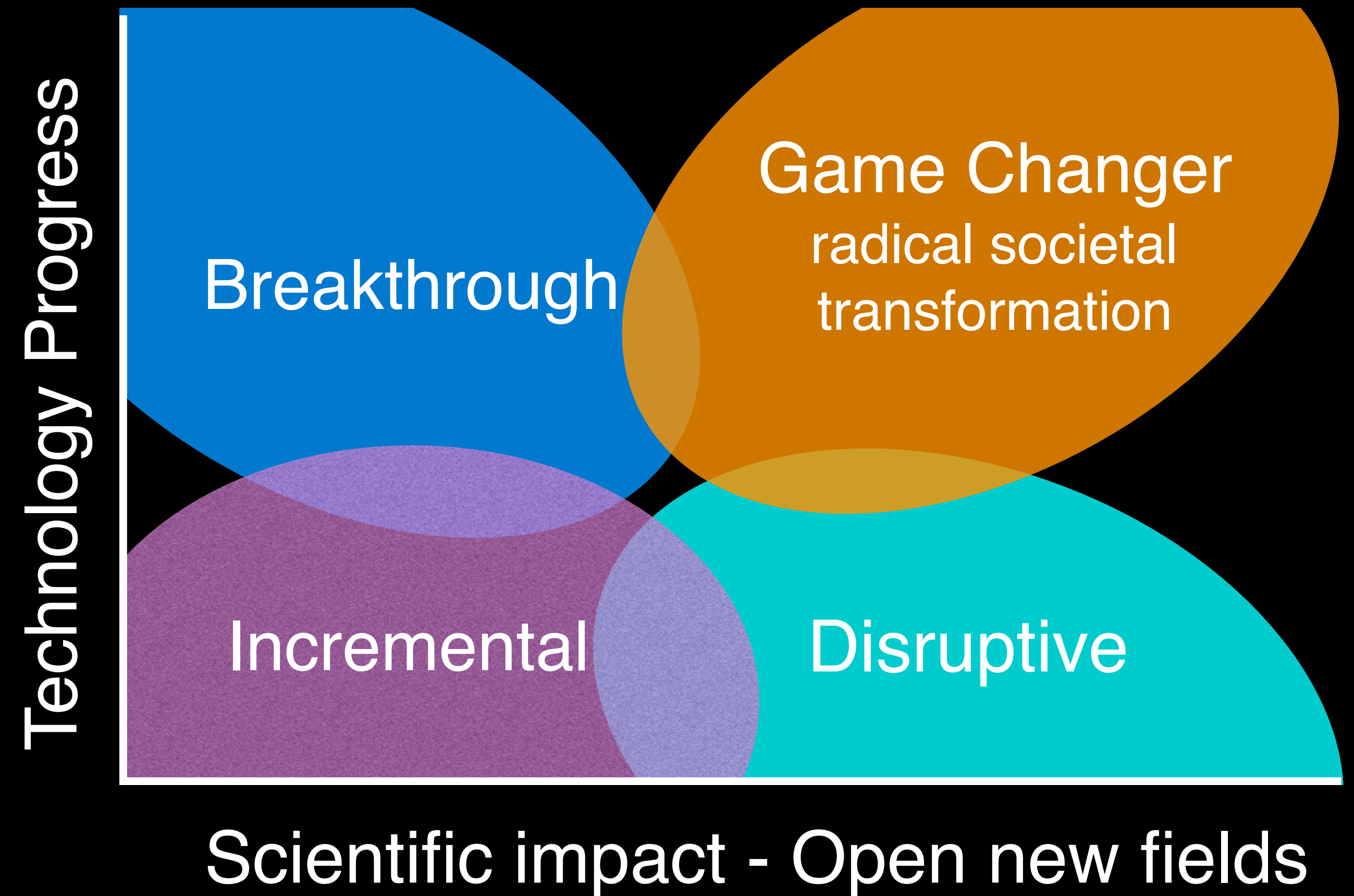
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A (weak) reply

Sensors, computers, robots, software could not exist without strong theories that allowed their development (in particular quantum mechanics and relativity)

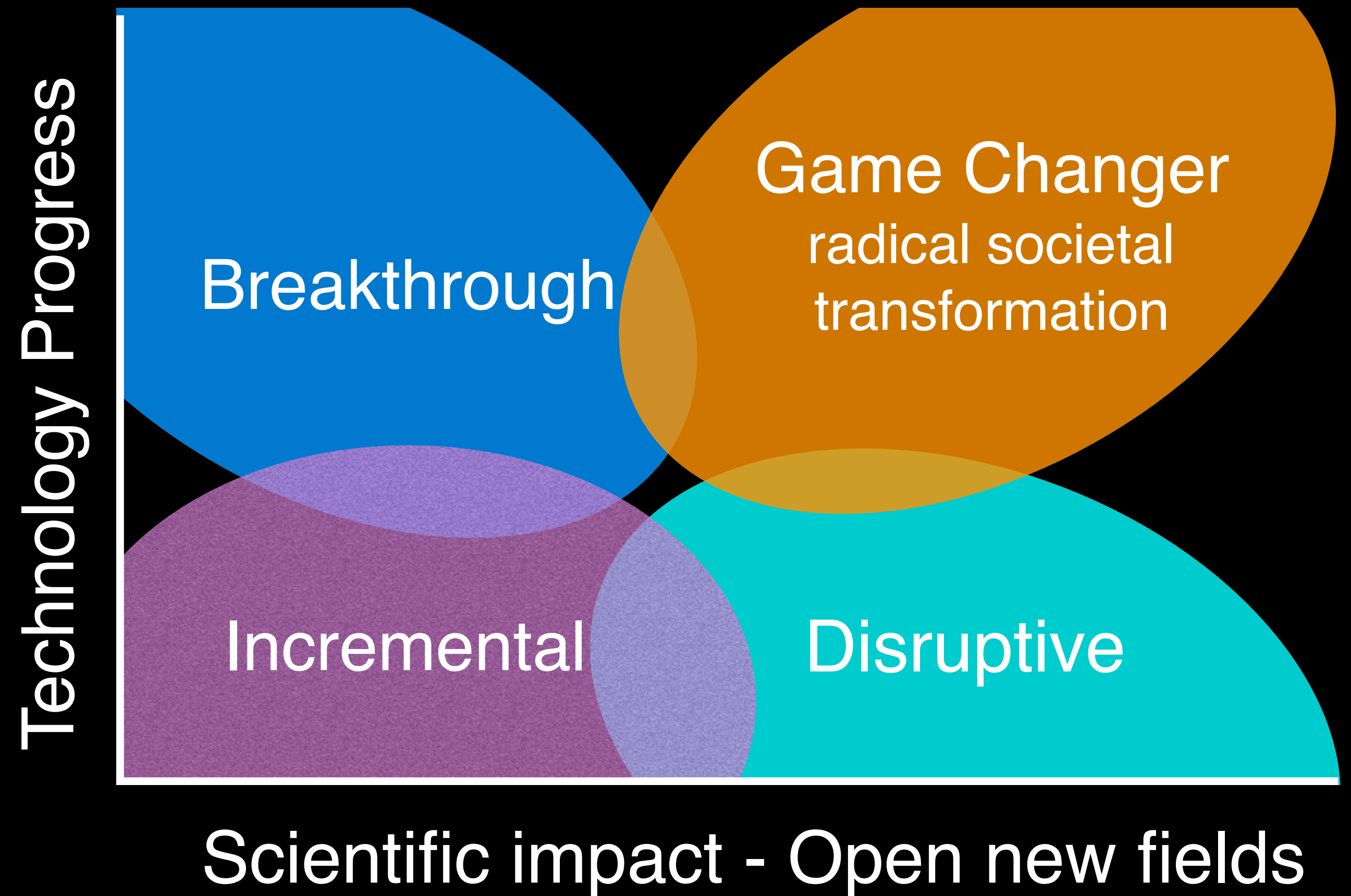
A CloT proto-system already exist: Google

Is there a way out?



Is there a way out?

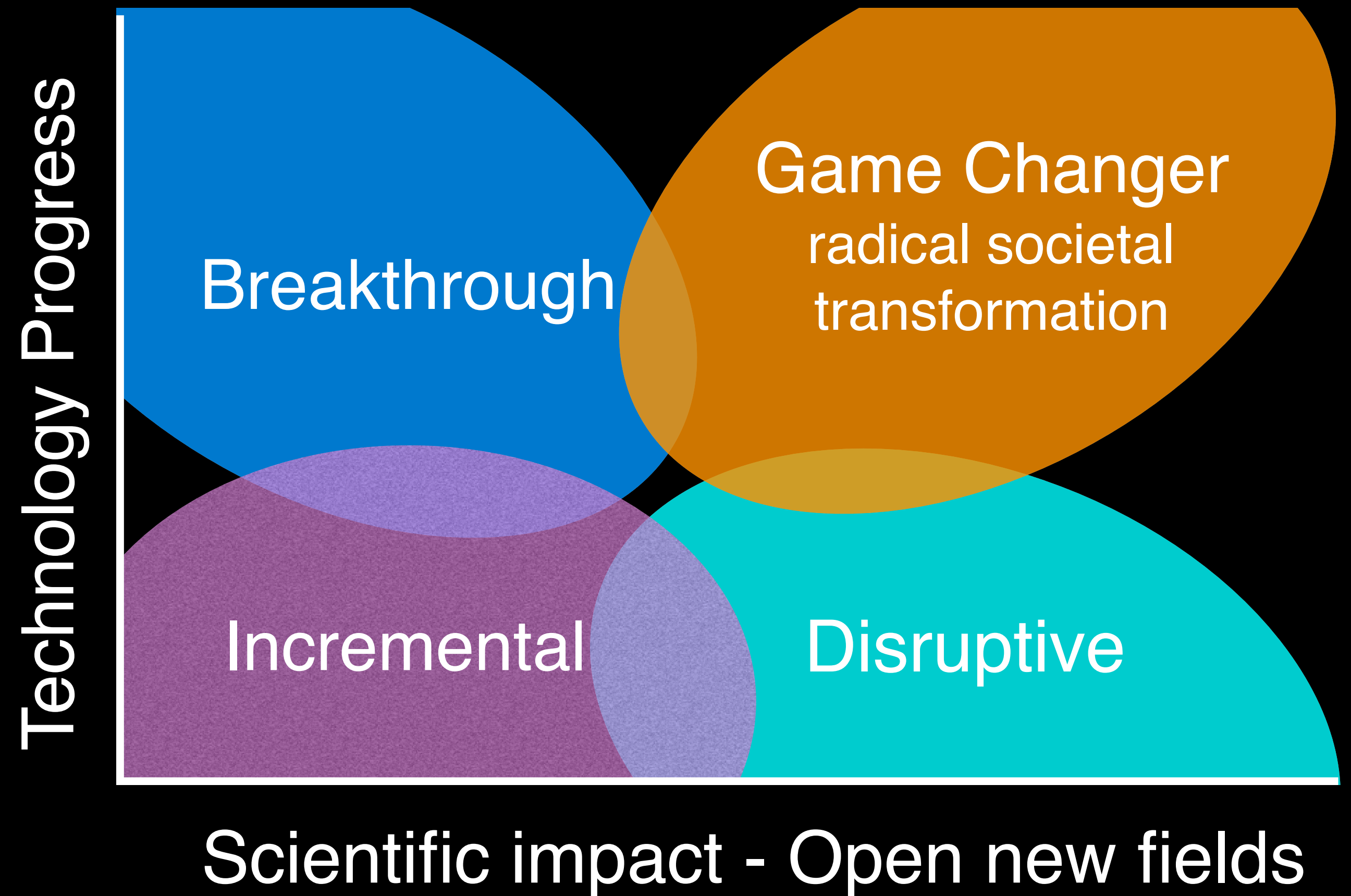
Incremental knowledge: there is no match: CloT (or even google) win easy



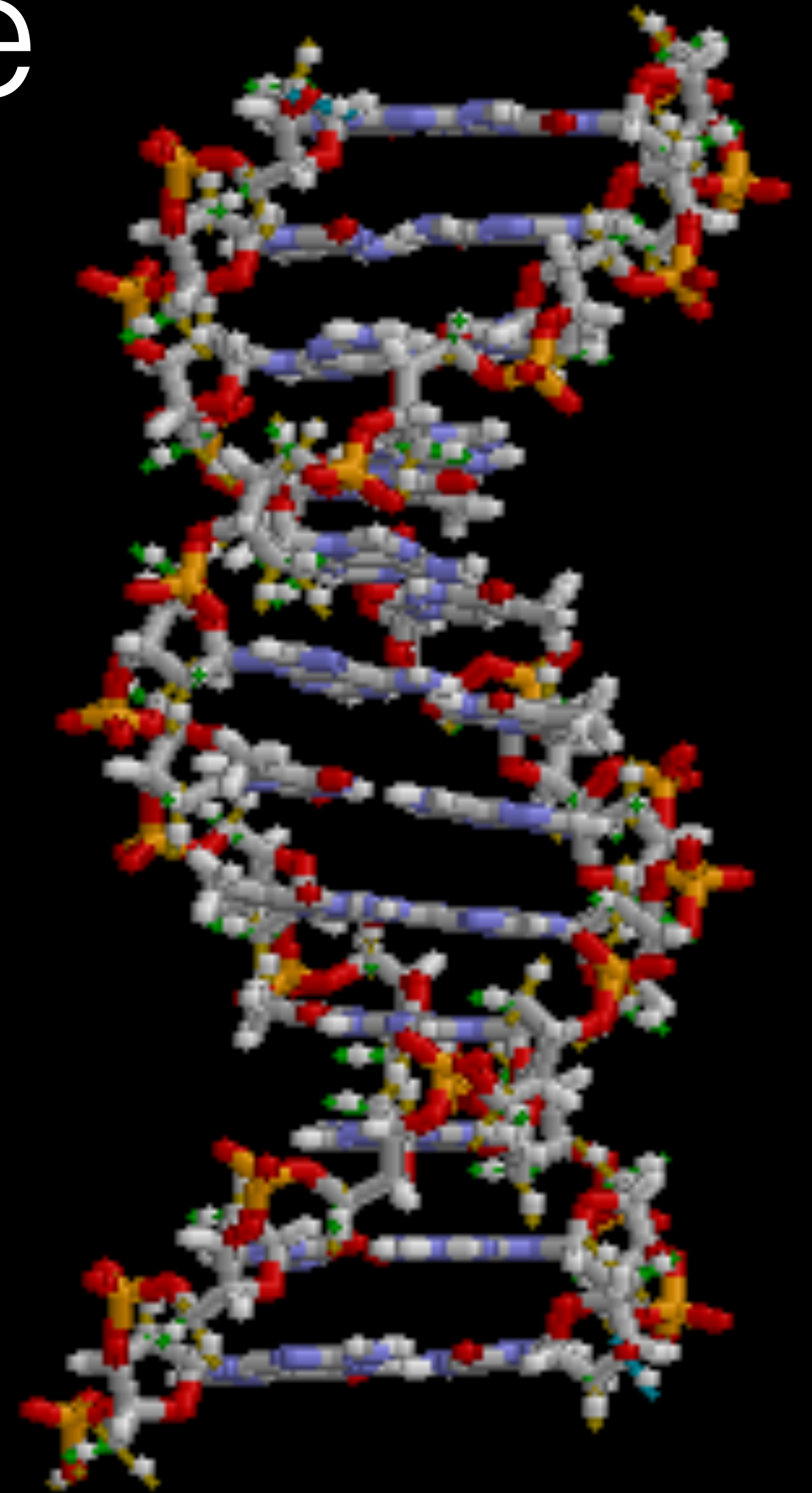
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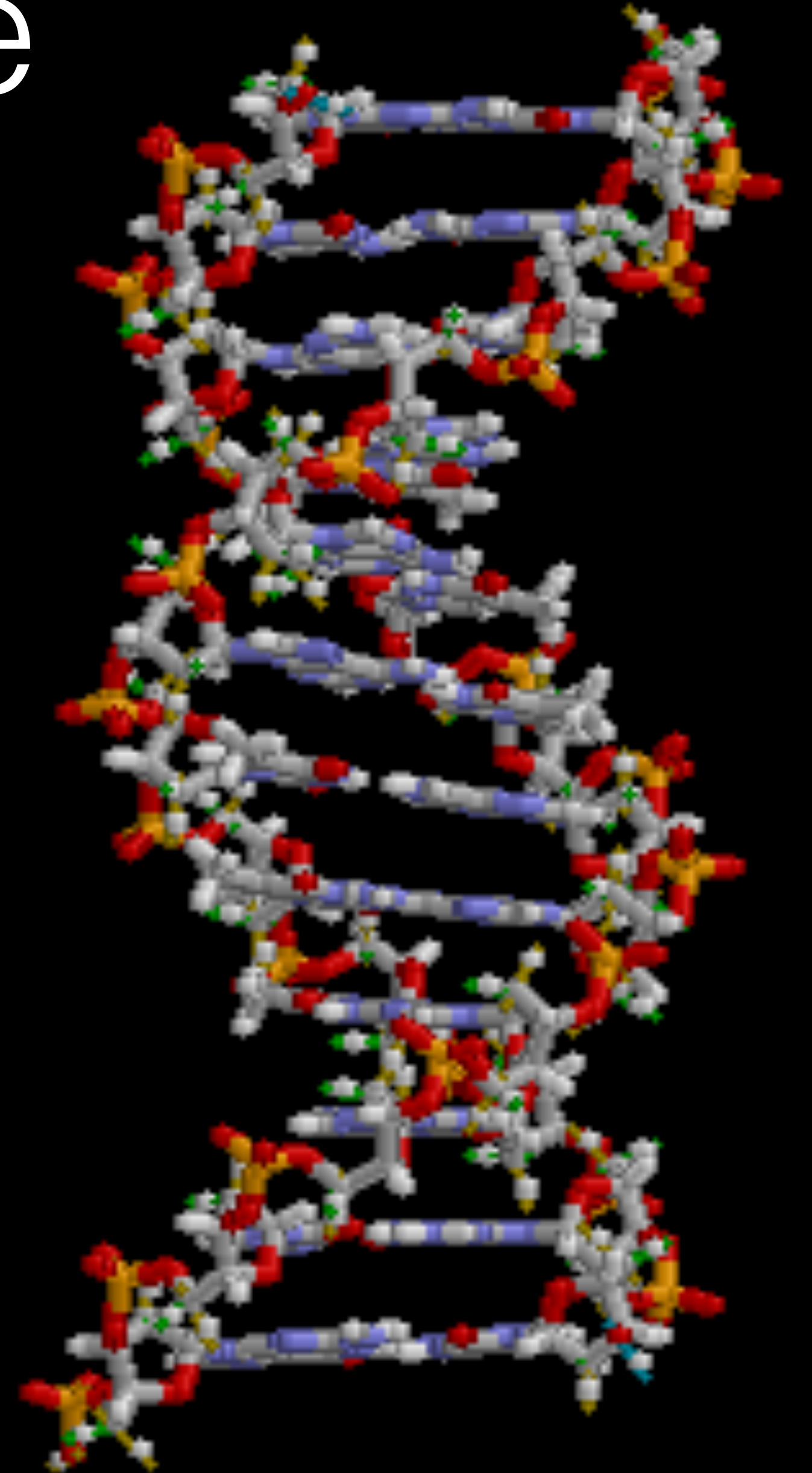
But are CloT and Google able to produce scientific results truly Game Changer? Those causing radical changes in the society?



The origin of Life



The origin of Life

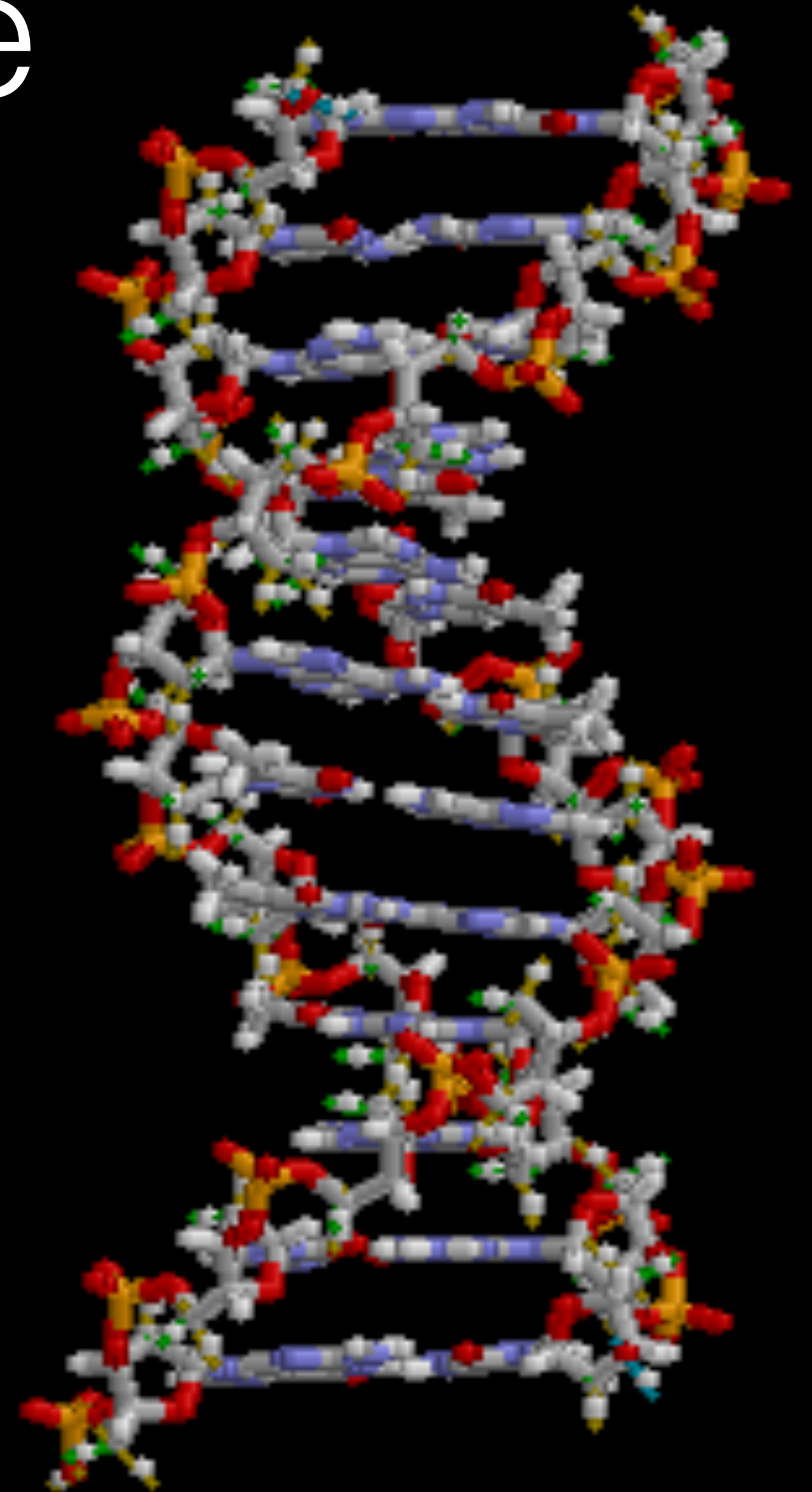


The origin of Life

Origin of Life

The first principles

Research in the laboratory, the lego of life



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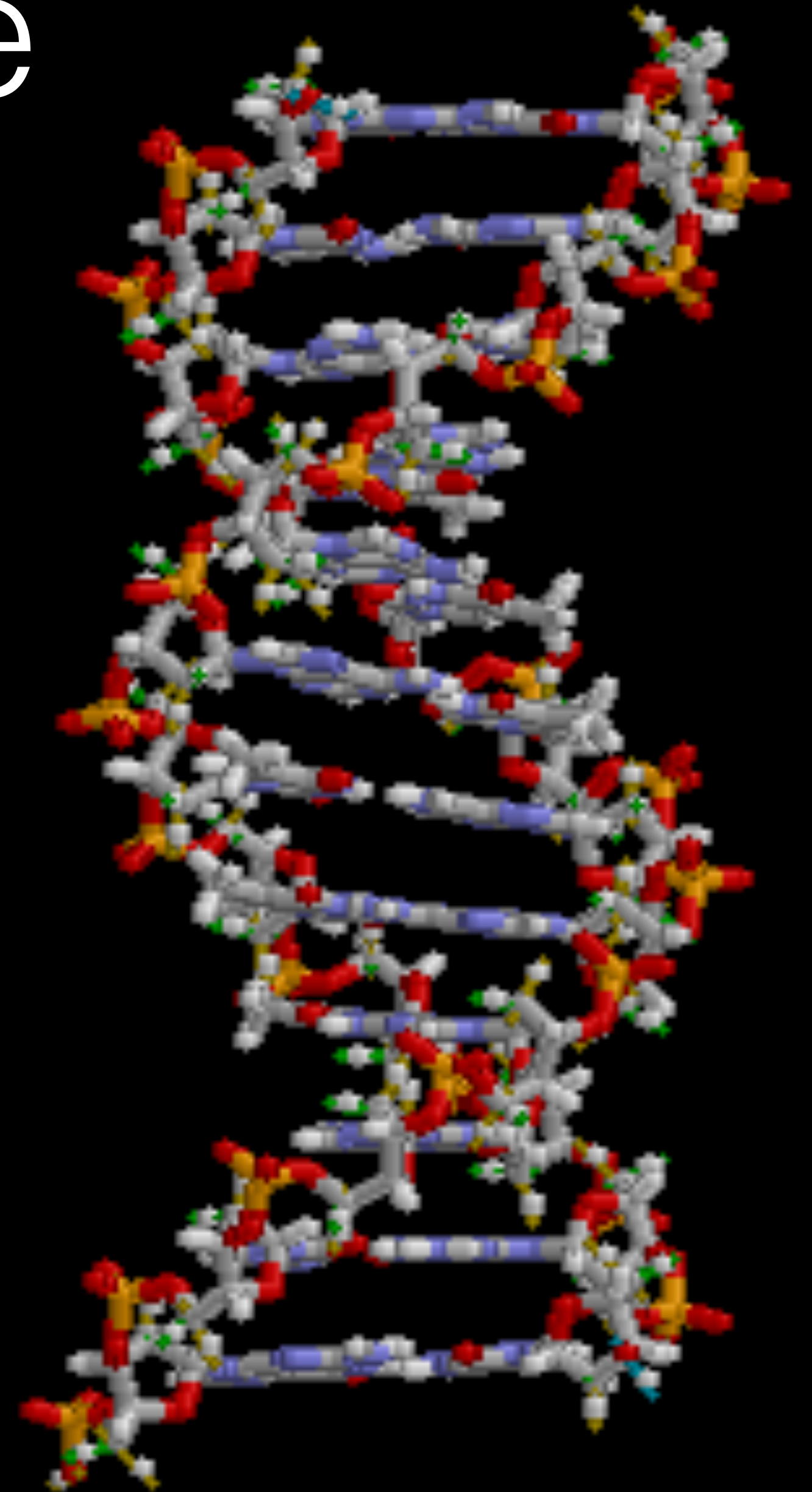
The search for an alien life

Solar system

Mars, comets, frozen moons

Exoplanets

SETI



The origin of Life



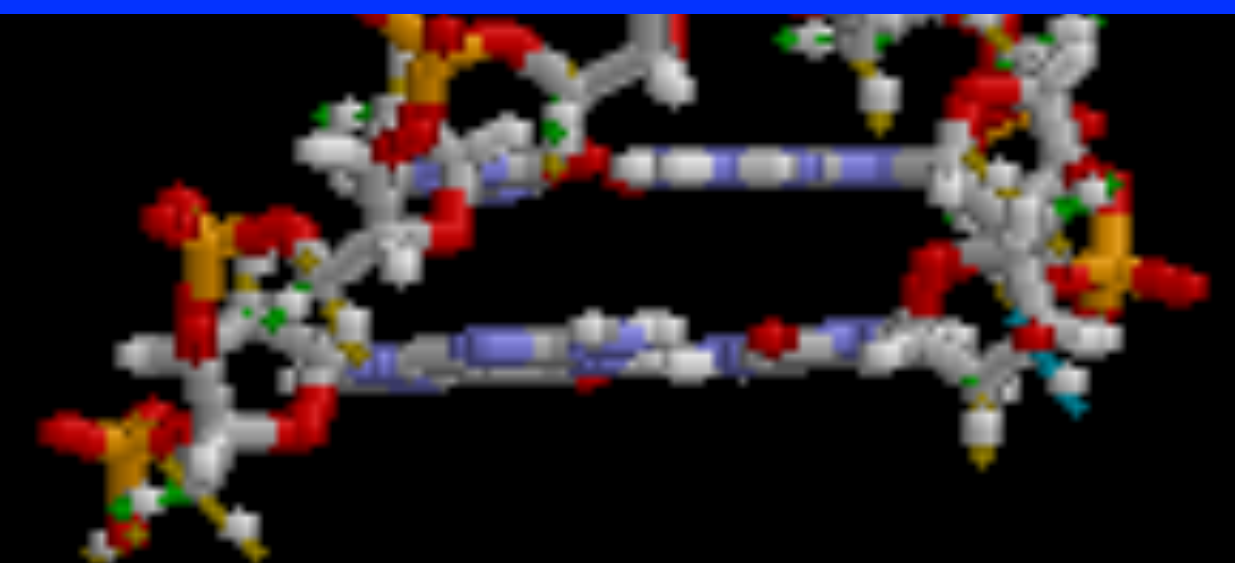
Imagination

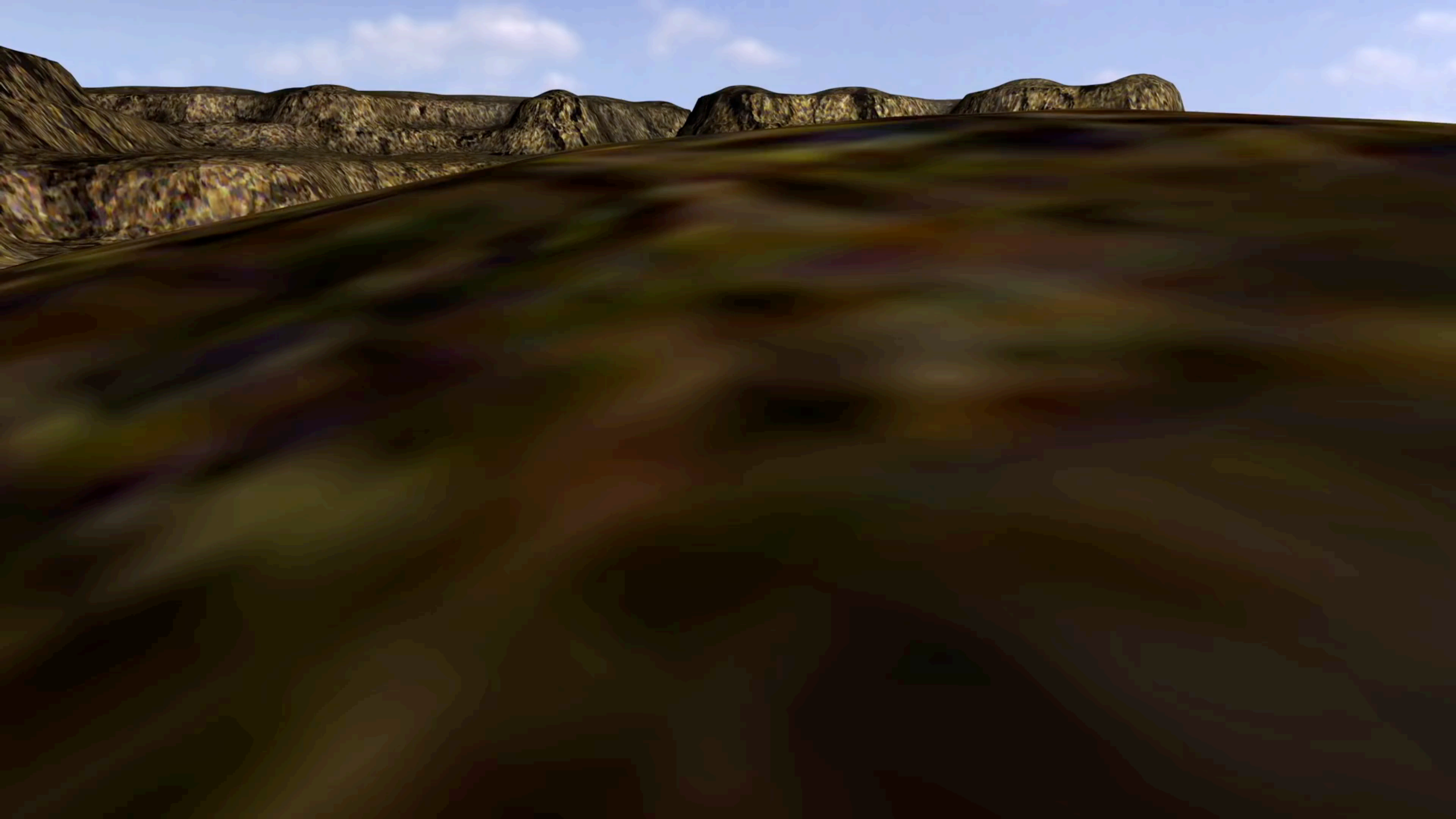
vs

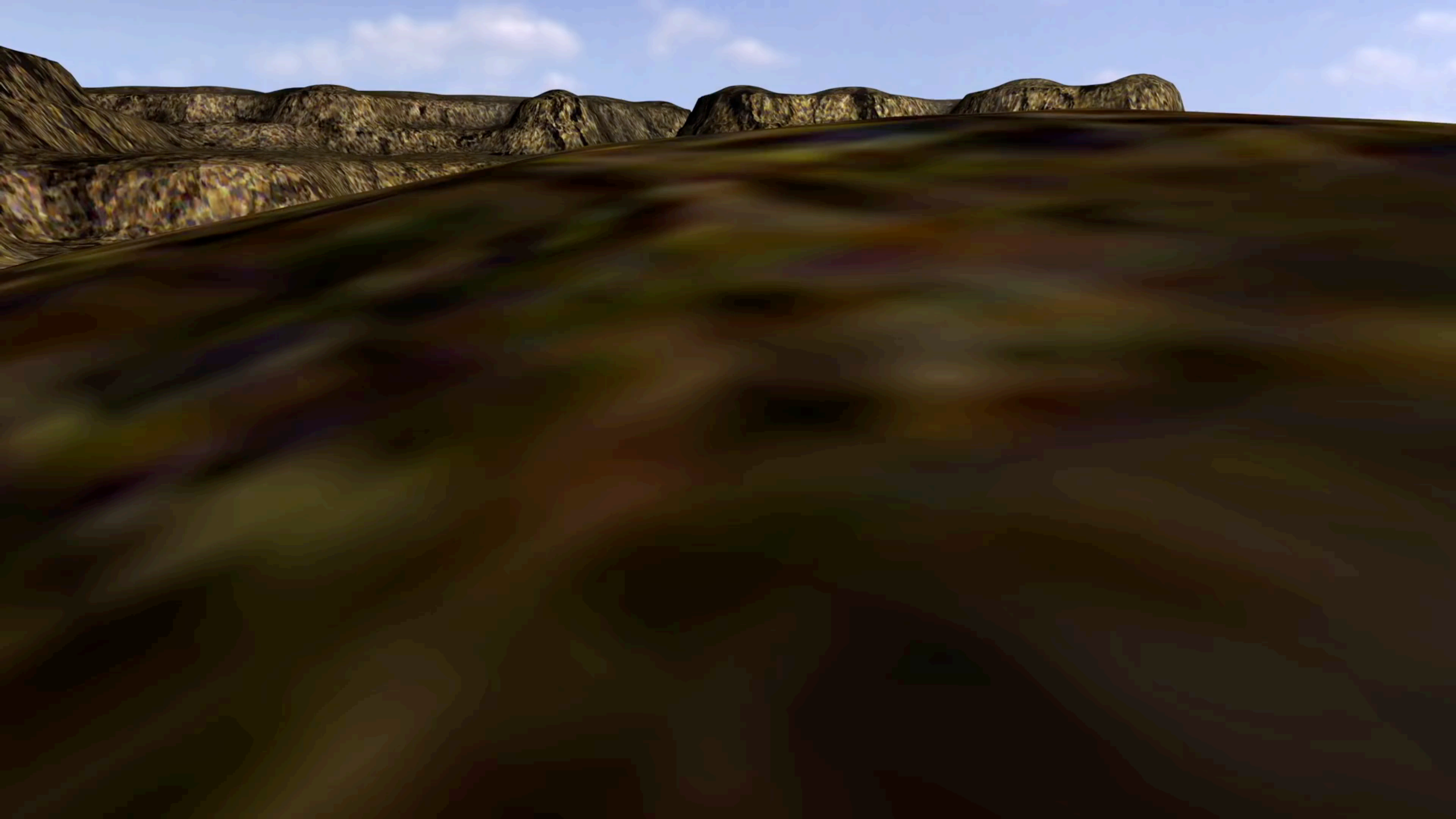
computing

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BREAKTHROUGH STARSHOT

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INITIATIVES BREAKTHROUGH INITIATIVES BREAKTHROUGH INITIATIVES BREAKTHROUGH INITIATIVES



SIX MEMOS
FOR THE NEXT MILLENNIUM

Alb Calvins

- 1 - Lightness
- 2 - Quickness
- 3 - Exactitude
- 4 - Visibility
- 5 - Multiplicity
- 6 - Consistency

Reclutamento

Modello Italiano (Francese)

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Definire aree di ricerca strategiche

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